CHAPTER 1

GIS DATABASE

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This study involves all kinds of data on natural conditions (groundwater resources, geology, topography, meteorology, etc.); socio-economic conditions (population, administrative division, land use; etc.); water use (wells distribution, water demand, existing water services etc.); and groundwater contamination, especially arsenic contamination. These data were collected from various sources with different formats, however, most of the data has the feature of geographic information.

Characteristics of the geographic information are usually presented as maps, and the interrelation between different data has to be clarified by spatial distribution-based integration and analysis.

To perform this kind of integration and analysis efficiently, the Geographic Information System (GIS) has been developing in recent years as an independent technique. Many GIS software was developed so that spatial information analysis involving display, query, transformation, extraction and integration, can be performed promptly by computer.

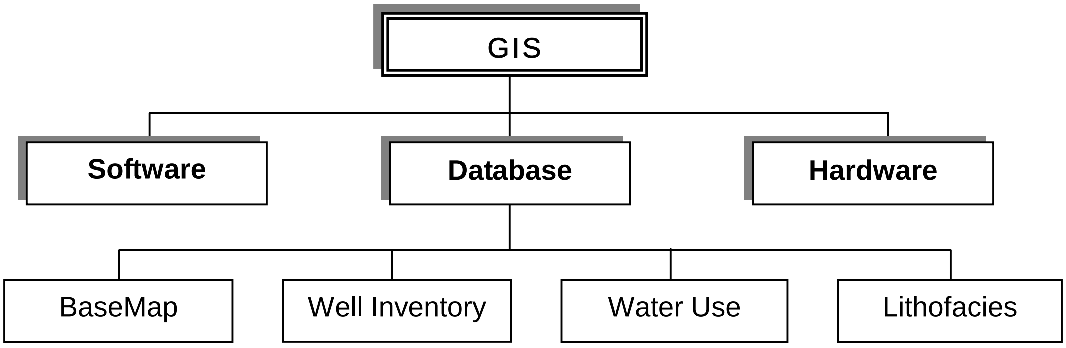
The GIS has been built in this study for the following purposes:

- Analysis of existing geographic information and creation of Base Map
- Analysis of arsenic contamination situation
- Support for other components in the study

The GIS in this study is also expected to improve the ability of DPHE, the counterpart agency, in management of groundwater resources.

1.1 Components of GIS

The following concept chart shows the outline of the GIS constructed in this study. The GIS consists of 3 main portions: a GIS database, GIS software and hardware.



Compared with software and hardware, the specifications of which are attached in the appendix, the database is the most important portion in the GIS, and the database in this study consists of four (4) sub-databases:

1.1.1 Base Map Database

The database is used for management and maintenance of fundamental information on natural and socio-economic conditions relevant to this study. The database contains the following location and shape information: administrative boundaries, topography, geology, rivers and lakes, roads, urban areas, land use, location of meteorological observation stations, location of JICA test wells, and so on.

The attribute data attached to these location and shape files included the area for administrative unit up to Mouza level, population data from the previous census and predication, rainfall and evaporation records, land use patterns, soil classification, lithofacies, and so on.

1.1.2 Well Inventory

Well inventory is mainly created on the basis of the DPHE Well Register (WR). The results of the 300 well survey in Phase I and II of this study, and the result of the well screening survey in the supplementary survey were also contained in the well inventory. Moreover, well log data and the water quality analysis results from previous surveys were also included in the database.

1.1.3 Simulation Data Base１

The database contains data relevant to the estimation of groundwater withdrawal for irrigation and domestic water use, such as the paddy field ratio, population density and infiltration index for each soil type in each mesh of the groundwater simulation model domain.

1.1.4 Simulation Data Base 2

The database contains lithofacies data for each mesh of the same model domain as simulation database 1.

1.2 Materials for GIS Database

1.2.1 Source Data for Base Map

The map that is referred to as the "Base Map" contains fundamental information relevant to natural and socio-economic information such as administration boundaries, roads, and rivers, lakes, etc. Most kinds of thematic maps were created by overlaying the survey result onto the Base Map. Therefore, the accuracy of thematic maps is restrained by the Base Map.

The accuracy of the Base Map depends on two factors: the source map and processing process. The accuracy of the processing process can be ensured by a proper digitizing procedure and strict quality control. However, nothing can be done to increase the accuracy of the source data.

The 1:50,000 scale Thana map created by LGED, is used as the source data. The Thana map was published in 1994, as the result of an UNDP project (project number: ILO PROJECT BGD and 89/041), and is believed as the most accurate map in Bangladesh now. The main data sources and production process of the Thana map are as follows:

- 1989 to 1990 spot images
- 1983 to 1984 aerial photographs
- Topographic maps
- Thana maps
- BBS
- Field checking.

Since most data for the Thana map were collected about 10 years ago, it is beyond the capacity of the Thana map to contain the change of the features within the past 10 years, such as the change in administration boundary as the result of the re-division of administrative units, land development, roads construction, and so on.

By comparing the Mouza names on the Thana map and the latest list from the Land Use Office, more than a 10% difference was revealed. And actually the agreement between the Thana map and BBS population census is also not so good as expected. Therefore, this Thana map has to be considered a little out of date for the Base Map in this study.

However, no new map in Bangladesh has been published with a scale larger than that of the Thana map. Although a newer map, which can respond to change of subsequent administration classification reorganization etc. is in progress in Mouza unit, several more years are believed necessary for its completion.

Nevertheless, by comparison of the Thana map with the land satellite image of 2000, it was confirmed that the main roads, swamps and rivers in the LGED Thana map are fundamentally in agreement with the satellite image.

Therefore, the Thana map was used for creating files of the Base Map, such as administrative boundaries, main urban areas, roads, rivers, lakes and ponds.

1.2.2 Data for Well Inventory

In 18 DPHE Thana offices of the three districts, there is a Well Registers (WR) involving all DPHE wells in the study area. The data in the WR was taken as the main portion of the well inventory.

1) History and Characteristic of WR

The creation of WR was in the beginning of 1970’s in most Thanas. The data of wells created far before the creation of WR is also included, and the date of well construction were as detail as day.

WR is supposed just for the registration of a new well, but not for well and groundwater management, because no data could found concerning the water level and quality monitoring. Even the data about use conditions is absent from the WR, that is, there is no information in WR for identifying if the well is still in use not. WR mainly consists of items on location, depth, construction date, cost sharing, shape or size of platform, and so on.

2) Identification of Well Location

The only address in WR is for indicating well location. Therefore, it is impossible to plot accurately the wells onto the Base Map. The address for most wells in WR is as accurate as the unit of village.

A big problem was encountered in the creation of the well inventory while matching WR data into the Base Map, because the address system used in WR is quite different from the address system of the LGED Thana map.

Mouzas were used as the minimum administration unit in previously published maps, and are being used in current map preparation in Bangladesh. However, a Mouza is not common unit for address identifying at least in the study area. Instead, villages or Paras (colony of the residence contained in village) are used as convenient address units by local people and DPHE staff.

For more than half of the total wells in WR, there is no difficulty in matching villages or Paras into Mouzas because the pronunciation or spelling of them is quite similar. On the hand, for the rest of the wells, the precise matching is actually impossible because of the completely different pronunciation or spelling between WR and Thana map.

As a result, the accuracy of well location identification for the well inventory database could not be perfectly ensured, although all possible methods have been tried, such as to collect and make use of the village list from the Assistance Land Office, or to check the villages one by one with the help of DPHE Thana office staff.

3) Renewal of the Data

There is only one copy of the WR kept in the DPHE Thana office, and the data was written in by hand. This situation impedes the renewal of data. It is not clear how or how many times the WR has been updated within the approximately 30 years since WR was created. However, it is believed that WR has not been renewed for a long time, and the renewal is very hard work in the present situation.

Consequently, any changes carried out in the administrative units would render well locations undeterminable. It is obvious that the data in WR are losing their availability unless the inspiration was carried out on the basis of the well inventory created in this study.

Although, the renewal and/or restructure of WR are necessary to make it meet the needs of well and groundwater management, WR played a great role as the basic data for the well inventory. In spite of the problem of the minimum address unit, it is believed that the well location identification at union level is accurate enough for groundwater use analysis, and analysis at this level is believed as the most detailed one in the study area up to this study.

1.2.3 Data for Land Use Map

The latest land use map is created using land satellite images taken by landsat No.5 in February 2000. The 1/50,000 scale SOB topography map was used for geometric compensation, and the 1992 to 1994 LGED land use map was used for the sample extraction of land use patterns.

1.2.4 Data for Geological Map

The geological section and other figures for deep stratum were created on the basis of the survey results such as core boring and geographical prospecting in this study. DPHE and BWDB well log data also were used in lithofacies analysis.

On the other hand, the surface geological map is created using the data of the 1/1,000,000 scale geology map from BGS.

1.2.5 Data for Soil Type Classification

Soil can be classified by suing various criteria like the type of original rocks, the color of soils, the climate and topography zoning, and so on. In this study, however, the soil classification was carried out for the calculation of the recharge rate from rainfall to aquifer, and the infiltration rate from farmland; therefore, soil grain size is taken as the main criteria for the classification. 1/125,000 SRDI soil distribution map was used as the source data.

1.2.6 Demographic-statistics Data

Demographic-statistics data is based on the population census of BBS (Bangladesh Bureau of Statistics). The BBS population census was performed 3 times before this study in 1974, 1981 and 1991. The latest census was carried out during the study period in 2001, however, the result has not published even at the Thana level. Therefore, the reliable population data in administrative unit smaller than district is the census of 1991. For the 2001's census, BBS has published the preliminary report, in which the 2001 population at the district level is available.

Similar to WR, the problem was encountered when matching the population data to the Base Map. Although the administrative unit for the population census in BBS agrees with the LGED Thana map at the Thana level, more than 10% of union and Mouza are expressed in different ways between these two kinds of data sources.

For the data with different address expression between the two sources, the matching was carried out under the principle that the total population for each Thana has to be the same as it is in BBS, and for those administrative units that were divided in different ways or presented by different address, the population data were matched by taking the spelling and area of the address as the judgment factors. As a result, all the population data was linked to the Base Map, and the deviation was reduced to less than 10% in union level.

1.2.7 Meteorological Data

Two kinds of meteorological data, rainfall and evapotranspiration, are essentially important for hydrological analysis and groundwater simulation. BMD (Bangladesh Meteorology Department) and BWDB (Bangladesh Water Development Board) carry out meteorological observation respectively in the study area.

Besides the three Thanas, where the district offices are located, there are 5 more meteorological observation stations in the Thanas of Sailkupa and Kaliganj in Jhenaidah District, and Chuagachha, Sharsha and Keshabpur in Jessore District. Data covering a period of 11-years (1988 to 1999) were collected, and the details of the data quality are as mentioned in the Main Report.

1.2.8 Urban Area Water Service

Out of the nine (9) Pourashavas in the study area, 7 have developed urban water services. The sketch maps of water supply pipeline and other relevant facilities were collected from all the Pourashavas. Georeferencing was carried out using control points selected from main roads and rivers, for lack of direction indicator, scale and other necessary features in several sketch maps.

1.3 Thematic Map

1.3.1 Location of the Study Area

Figure 1.3.1 shows the location of the Study Area. The Study Area is located in southwestern Bangladesh, covering 18 Thanas in the 3 districts of Chuadanga, Jhenaidah and Jessore.

1.3.2 Thematic Map on Natural Condition

1) Topography Map

Topography around the study area is shown in Figure 1.3.2. Although the study area is basically a flat plain, the elevation gently goes down from northwest to southwest with an average gradient of about 1.6m against 10km^2.

2) Geology map

Figure 1.3.3 shows the geology map. There are 3 main sediments in the study area. Deltaic silt is the most popular one covering about 82% in area. Next to deltaic silt are fine grain sediments of clay and peat, covering about 16%. The remaining 12% is deltaic sand, which is distributed in the northern part of the study area along rivers.

3) Surface Water System

Figure 1.3.4 shows rivers, lakes and ponds in the Study Area.

4) Rainfall Distribution

Figure 1.3.5 shows the average monthly rainfall distribution pattern in the study area. The rainfall changes largely according to the seasons. In the dry season, which continues about half a year from November to next April, the total rainfall is only about 10% of the yearly rainfall. In contrast, the monthly rainfall in the rainy season from May to October is equivalent to and/or more than the total rainfall during the whole dry season.

Table 1.3.1 shows the average monthly rainfall at each meteorological observation station.

Table 1.3.1 Average Monthly Rainfall

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sept	Oct	Nov	Dec
Jessore	17	35	55	61	158	313	294	265	241	115	40	11
Keshabpur	9	43	57	37	199	361	372	364	238	181	26	7
Benapole	9	43	57	37	199	361	372	364	238	181	26	7
Chuadanga	16	27	23	40	131	255	329	257	313	106	24	13
Jhenaidah	15	55	72	60	266	305	345	196	262	120	30	16
Kaliganj	9	43	57	37	199	361	372	364	238	181	26	7
Chuagachha	16	27	23	40	131	255	329	257	313	106	24	13
Sailkupa	8	30	28	60	221	287	342	264	285	102	39	18
Average	**12**	**38**	**47**	**47**	**188**	**312**	**344**	**291**	**266**	**137**	**29**	**12**

5) Soil Classification

Figure 1.3.6 shows the soil classification map. Silty clay loam is the most popular soil type all over the study area. The second one is clayey soil distributed in the area from the southern to northwest part. The roughest soil type is sandy loam, covering little area at the southern and the southwest part of the study area.

Table 1.3.2 shows the area and percentage of each soil type. The permeability of soil changes with the soil type, and then has an influence on the irrigation amount and groundwater recharge.

Table 1.3.2 Soil Classification by Grain Size

Soil Type	Area (km^2)	Percentage
Clay	670.3	11.8%
Silty clay	957.7	16.9%
Silt loam and silty clay	103.9	1.8%
Silty clay loam	2542.5	44.9%
Silt loam and Silty clay loam	50.9	0.9%
Silt loam	1007.6	17.8%
Silty loam	102.4	1.8%
Sandy loam	231.2	4.1%
Total	**5666.6**	**100%**

1.3.3 Thematic Maps on Social Economy Condition

1) Administrative Boundary

Figure1.3.7 shows the administrative boundary to union level.

Table 1.3.3 shows the fundamental information of each Thana.

Table 1.3.3 Basic Information of the Study Area

Thana	Area (km^2)	Union #	Mouza #	Pop_{1991}	Pop_{2001}
Chuadanga District					
Alamdanga	366.2	14	127	245,497	298,477
Chuadanga	305.97	8	141	223,247	273,157
Damurhuda	305.79	7	77	213,291	262,357
Jibannagar	196.35	4	70	125,102	153,391
Jhenaidah District					
Harinakunda	230.11	8	78	163,172	181,316
Jhenaidah	456.91	18	268	346,982	385,565
Kaliganj	312.32	12	194	219,950	244,408
Kotchandpur	164.24	6	81	108,769	120,864
Moheshpur	417.82	13	156	265,274	294,772
Sailkupa	375.92	15	182	294,808	327,590
Jessore District					
Abhoynagar	238.84	8	89	205,588	238,229
Bagherpara	267.4	9	156	170,707	197,810
Chuagachha	265.63	11	101	198,412	229,914
Jessore	425.26	16	242	503,208	583,102
Jhikargachha	298.87	11	162	238,478	276,341
Keshabpur	254.94	9	143	201,709	233,734
Manirampur	453.08	17	246	330,914	383,453
Sharsha	330.93	11	135	257,266	298,112
Total	**5666.58**	**197**	**2648**	**4,312,748**	**4,982,593**

2) Road Map

Figure 1.3.8 shows the road map.

3) Population Distribution

Figure 1.3.9 shows the population density of each Thana in 2001, as well as a graph of population change for each district in each census year.

Because the result of the 2001 population census has not been published, the population of each Thana in 2001 was estimated using the following formula:

Pop2001＝Pop1991×Population increase ratio of the district with the estimated Thana in it

In the above formula, Pop1991 was obtained from BBS data, and the population increase ratio of district was calculated from the 1991 census and 2001 population census preliminary report.

Table 1.3.4 shows the population of each census year in the 3 districts, and the average yearly population increase ratio between 1991 and 2001.

Table 1.3.4 Population in Each Census Year

District	1974	1981	1991	2001	$Ratio_{91-01}$
Chuadanga	56.2	67.7	80.8	98.7	2.0%
Jhenaidah	117.5	130.8	139.9	155.5	1.1%
Jessore	140	170.6	210.6	244.1	1.5%

Unit: 10,000 persons

In the study area, Jessore Thana has the biggest population (583 thousands) and the highest population density (more than 1,300 person/km^2), where the biggest city Jessore is located. A small population density appears in Bagherpara Thana of Jessore District and Moheshpur Thana of Jhenaidah District. However, the small population density is also over 700 persons/km^2.

In total, the population density in the northern part is relatively small, less than 900 perssons/km^2. However, most Thanas in the southern part have a population density larger than 900 persons/km^2, except Manirampur Thana in Jessore District.

Figures 1.3.10 to 1.3.12 shows the graphs of population change for each Thana, and 2001's population density of each union in Chuadanga, Jhenaidah and Jessore Districts, respectively.

4) Land Use

Figure 1.3.13 shows the land use map.

According to the resolution of the landsat image, the pixel size of the land use map was set as 25m in both X (easting) and Y (nothing) directions.

Based on the characteristics of the land use in the study area, 7 kinds of land use patterns were classified. The area and ratio of each land use pattern in the study area are shown in Table 1.3.5.

Table 1.3.5 Land Use Classification

Code	Item	Area(ha)	Area Ratio(%)
1	River, lake and other water bodies	16,798	3
2	Paddy field	178,558	31.5
3	Dry farm land	144,069	25.4
4	Humidity farm land	151,462	26.7
5	Forest	47,651	8.4
6	Uncultivated land	23,270	4.1
7	Urban Area	4,849	0.9
Total		**566,657**	**100**

5) Urban Area Water Service System

Out of 9 Pourashavas in the study area, seven (7) have urban water services. Figure 1.3.14 shows the locations of the water supply systems in the study area, and Figure 1.3.15 to 1.3.21 show the sketches of them.

The main proportions of the water services in the study area are complied in Table 1.3.6.

Table 1.3.6 Outline of Water Services in the Study Area

Thana	S_Pop*	Pump#**	L_Pipe***
Jessore	96.2	17+2****	101.7
Chuadanga	37.1	6+2	53.1
Jhenaidah	38.8	7+2	51.9
Kotchandpur	11.4	3	30.1
Sailkupa	12.7	3	24.1
Kaliganj	17	3	19.7
Moheshpur	4.9	2	11.7
Total	**218.1**	**41+6**	**292.3**

* : Service population X 1000 persons.

** : Number of pumps.

*** : Total length of pipeline in 1000 meters.

**** : 2 JICA test wells are going to be added into water services.

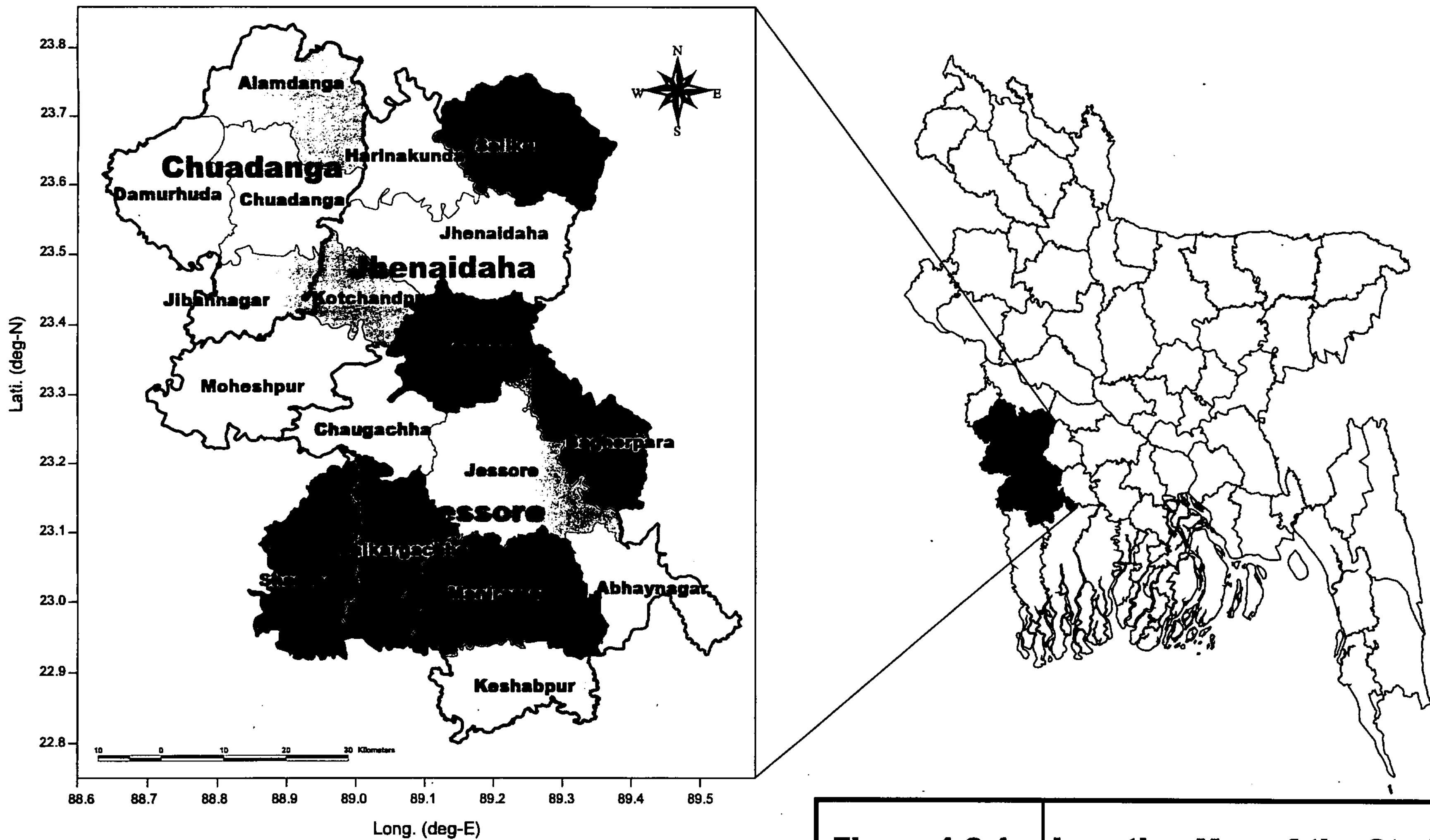
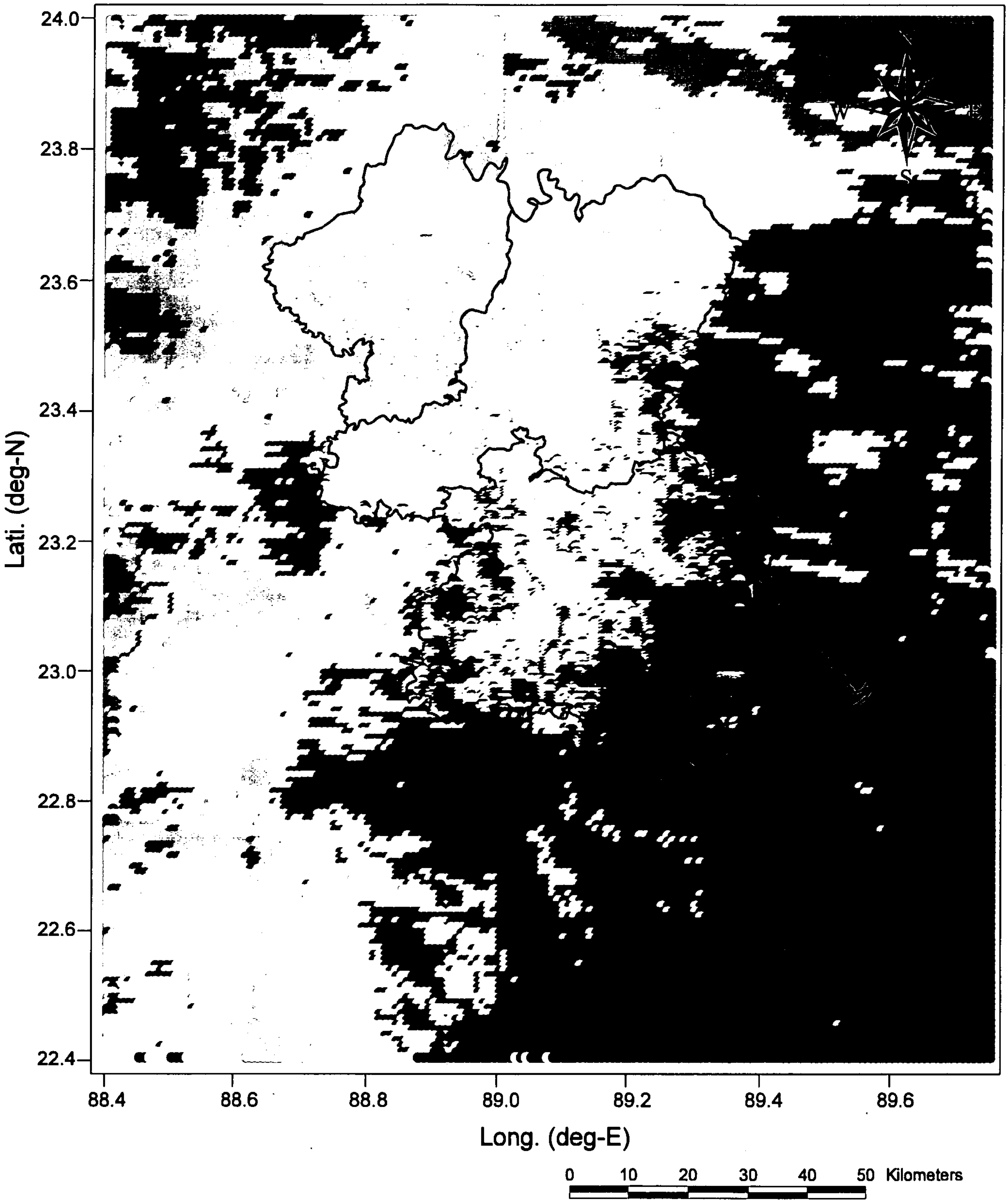


Figure 1.3.1	Location Map of the Study Area

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



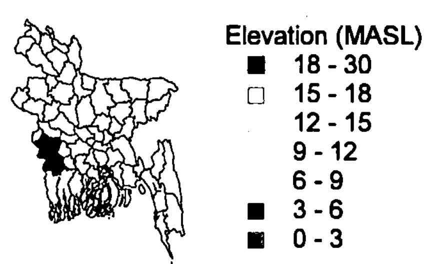
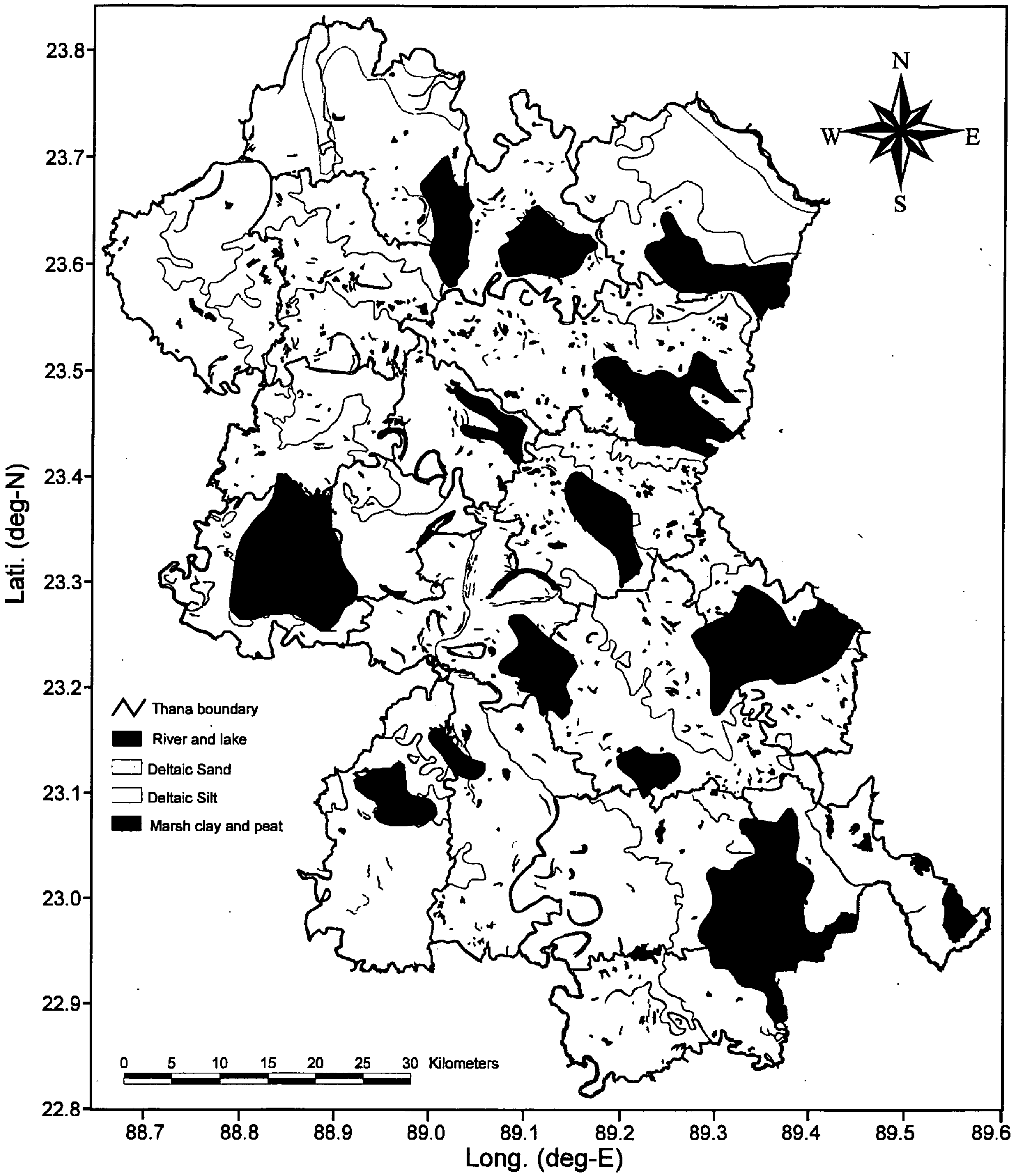


Figure 1.3.2	**Topography Map**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



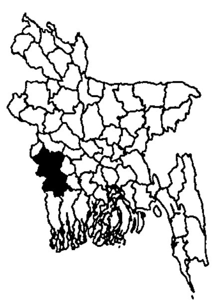


Figure 1.3.3	Simplified Geological Map of the Study Area
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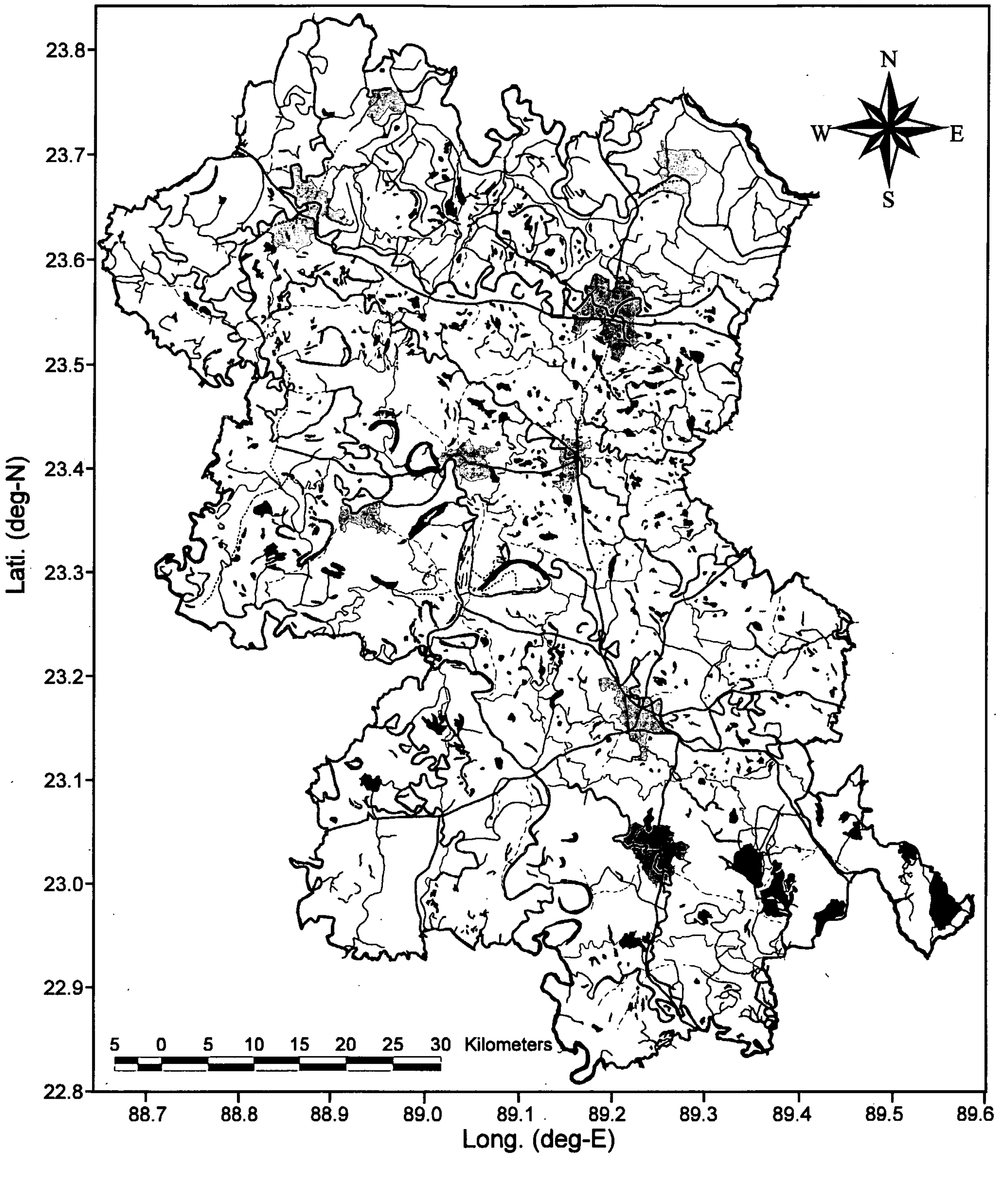

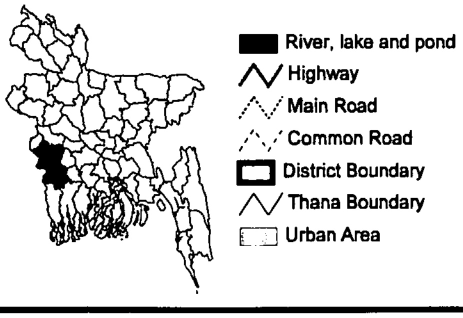

Figure 1.3.4	**Rivers and Water Bodies in the Study Area**
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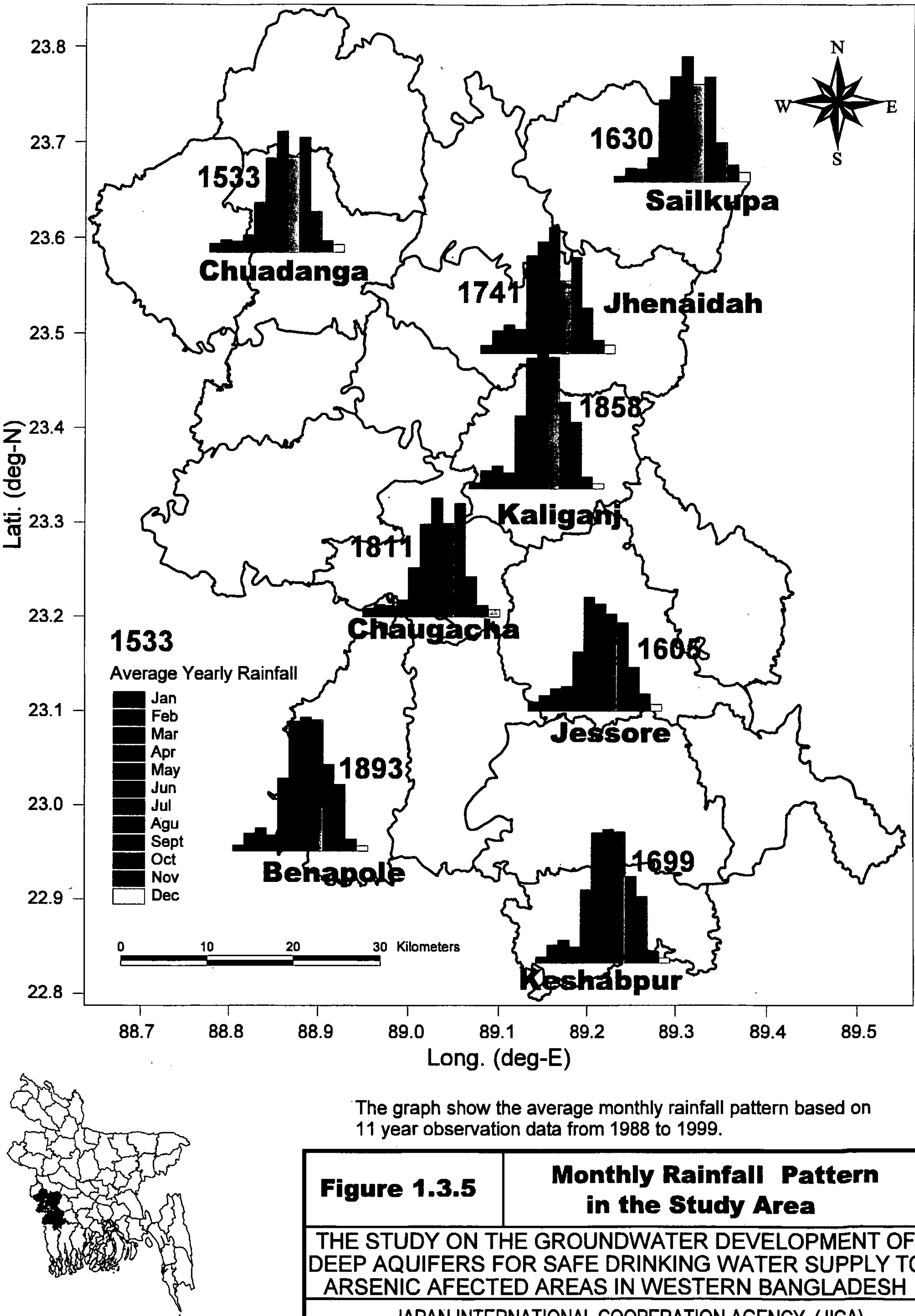

The graph show the average monthly rainfall pattern based on 11 year observation data from 1988 to 1999.

Figure 1.3.5	Monthly Rainfall Pattern in the Study Area

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

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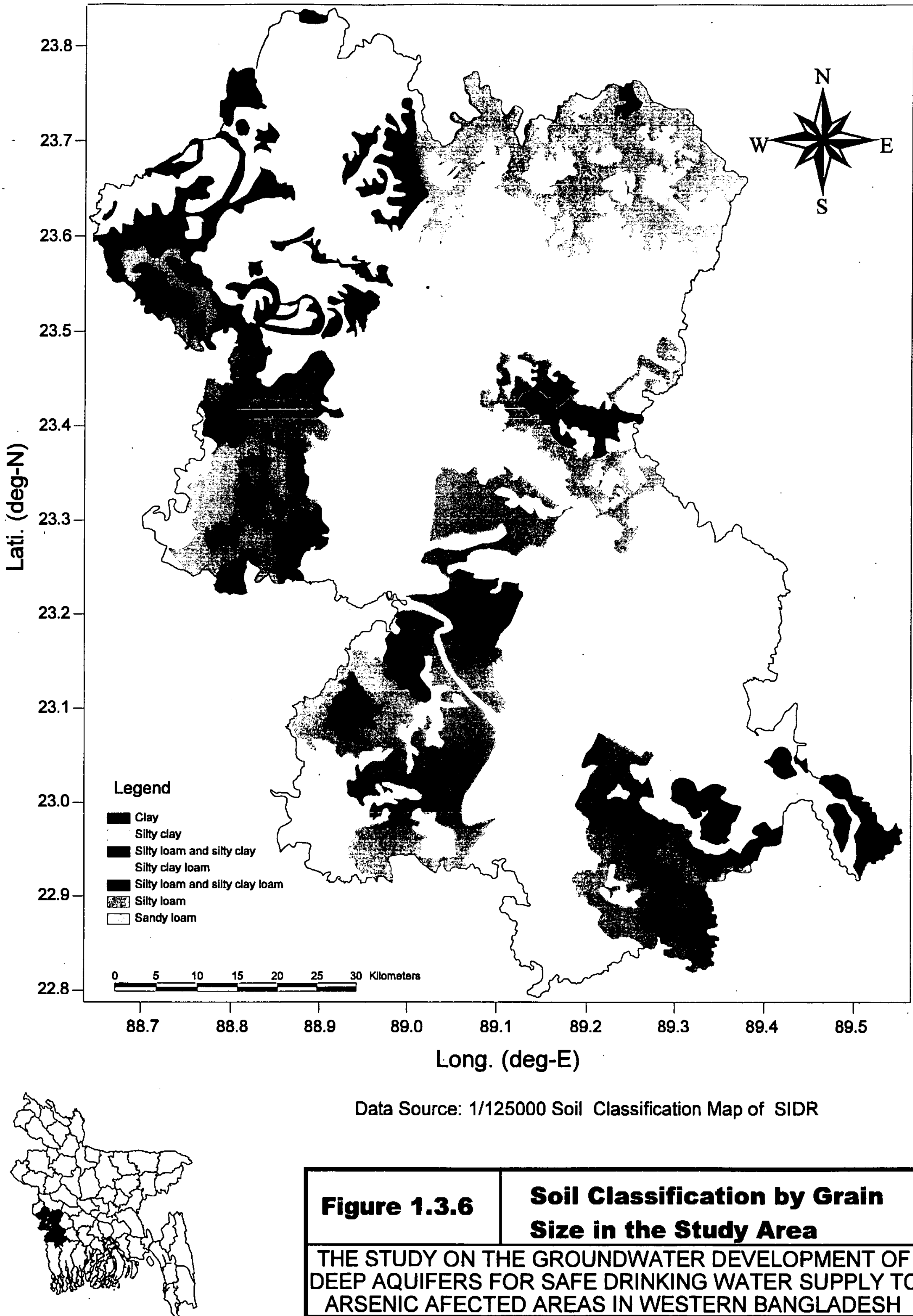

Data Source: 1/125000 Soil Classification Map of SIDR

Figure 1.3.6	Soil Classification by Grain Size in the Study Area
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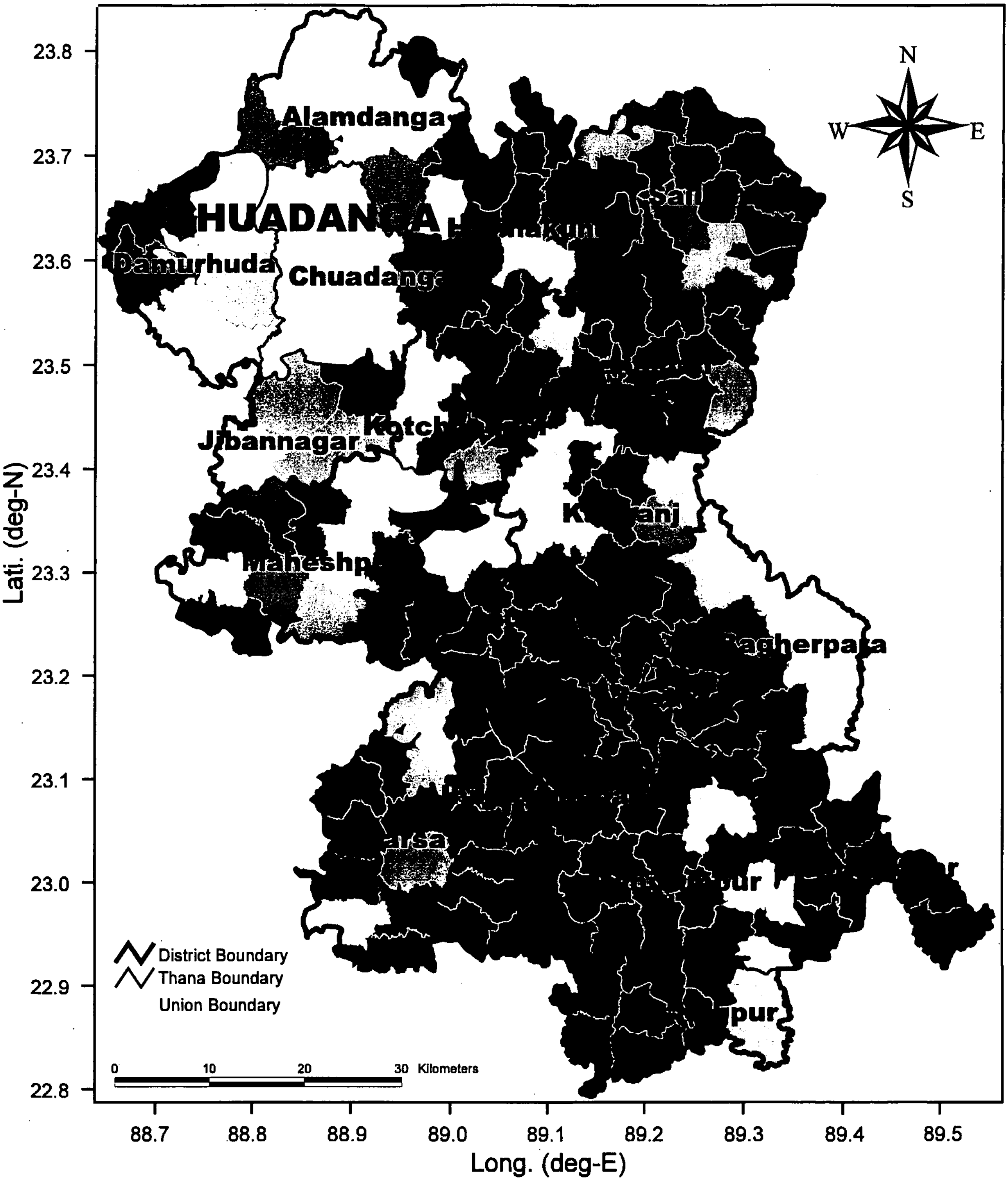

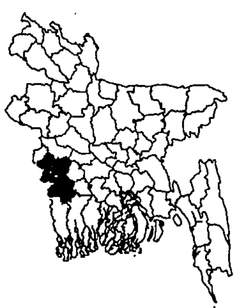

Figure 1.3.7	**Adiministrative Boundary Map**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

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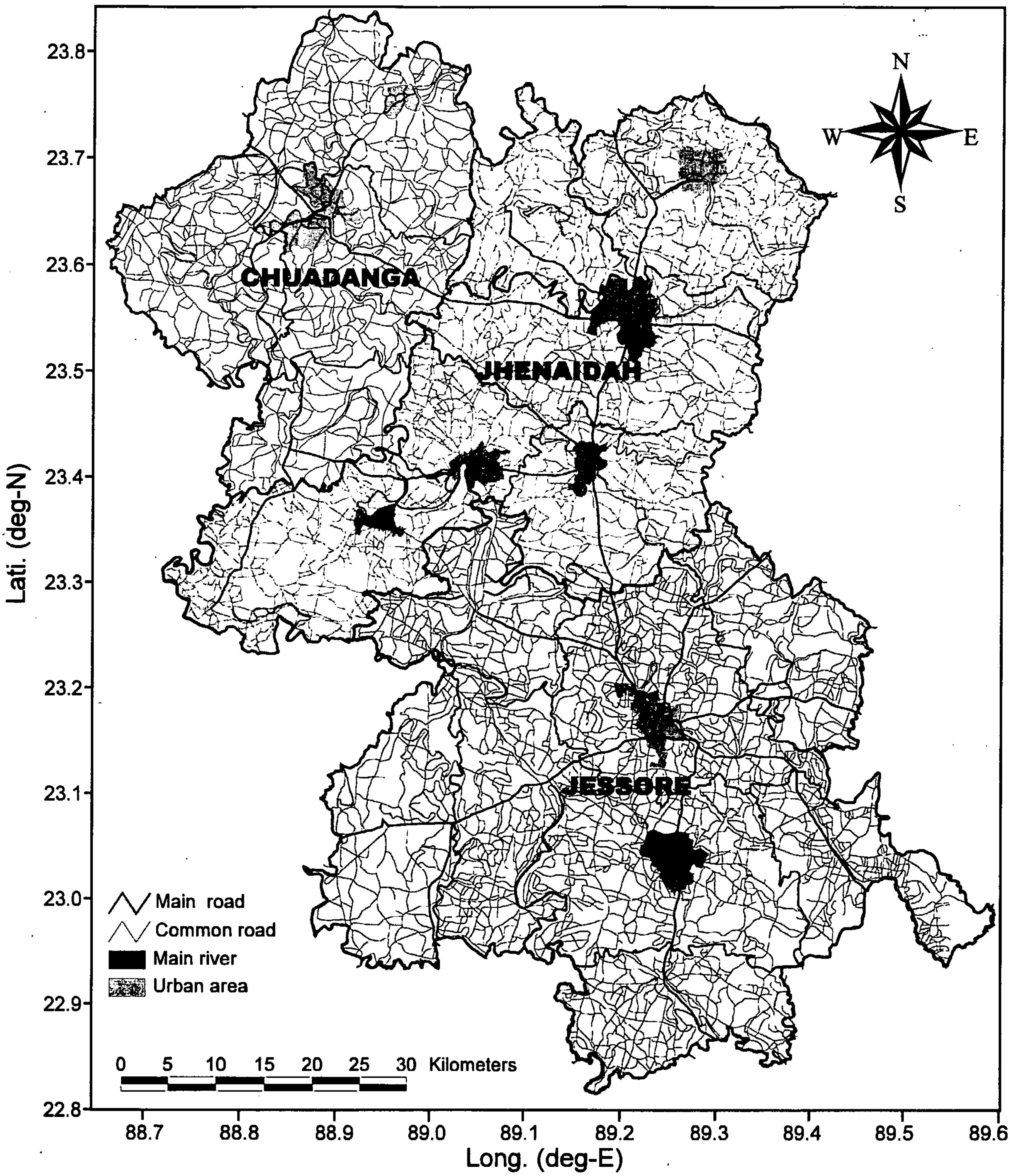

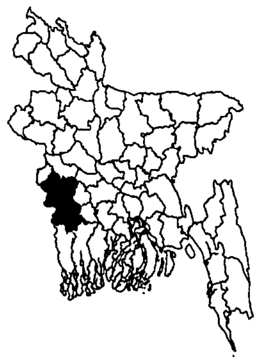

Figure 1.3.8	**Road Map of the Study Area**

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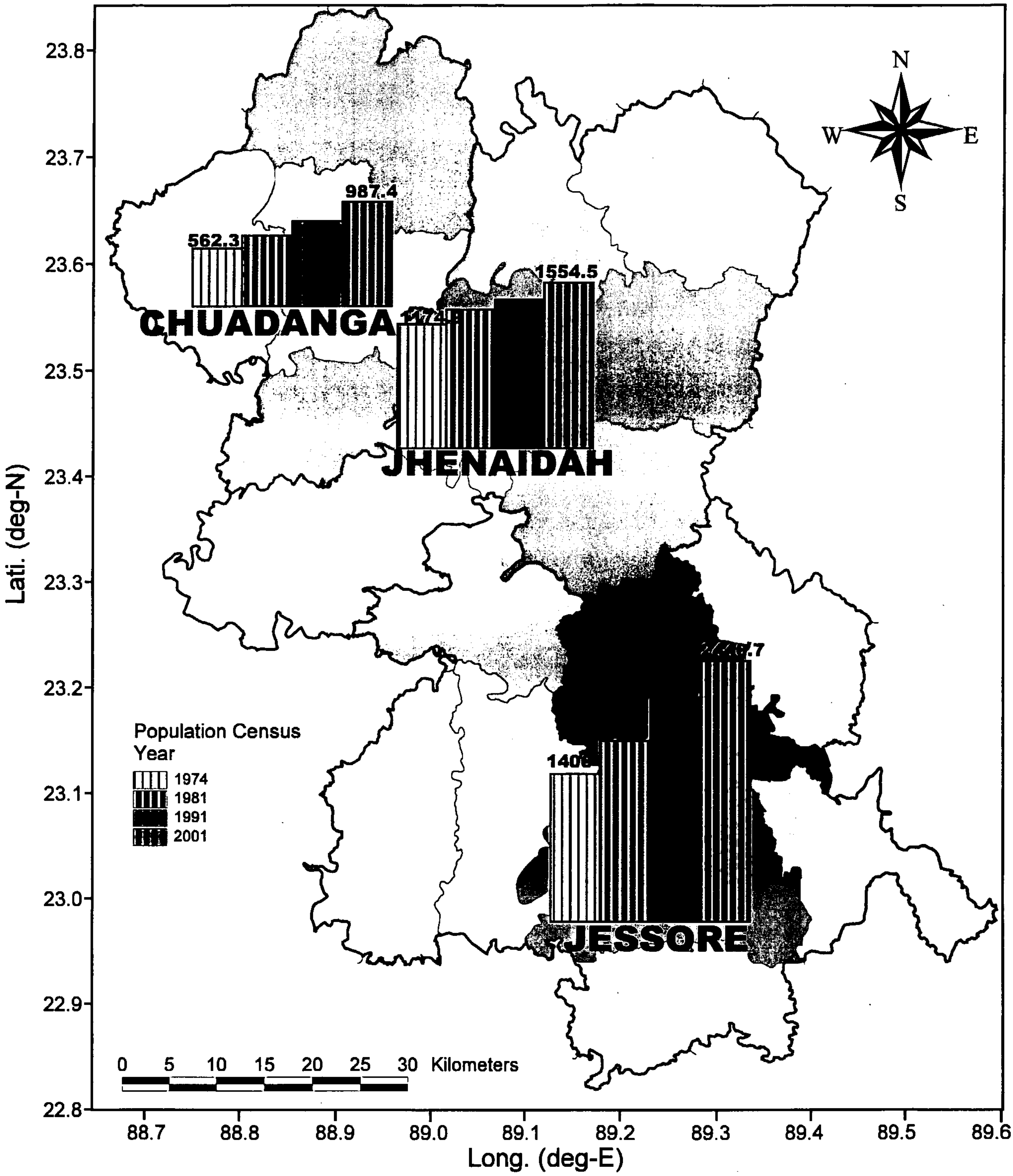

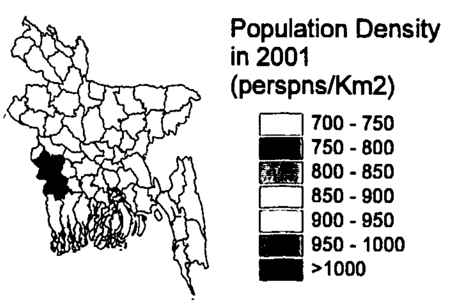

Figure 1.3.9	Population Distribution in the Study Area

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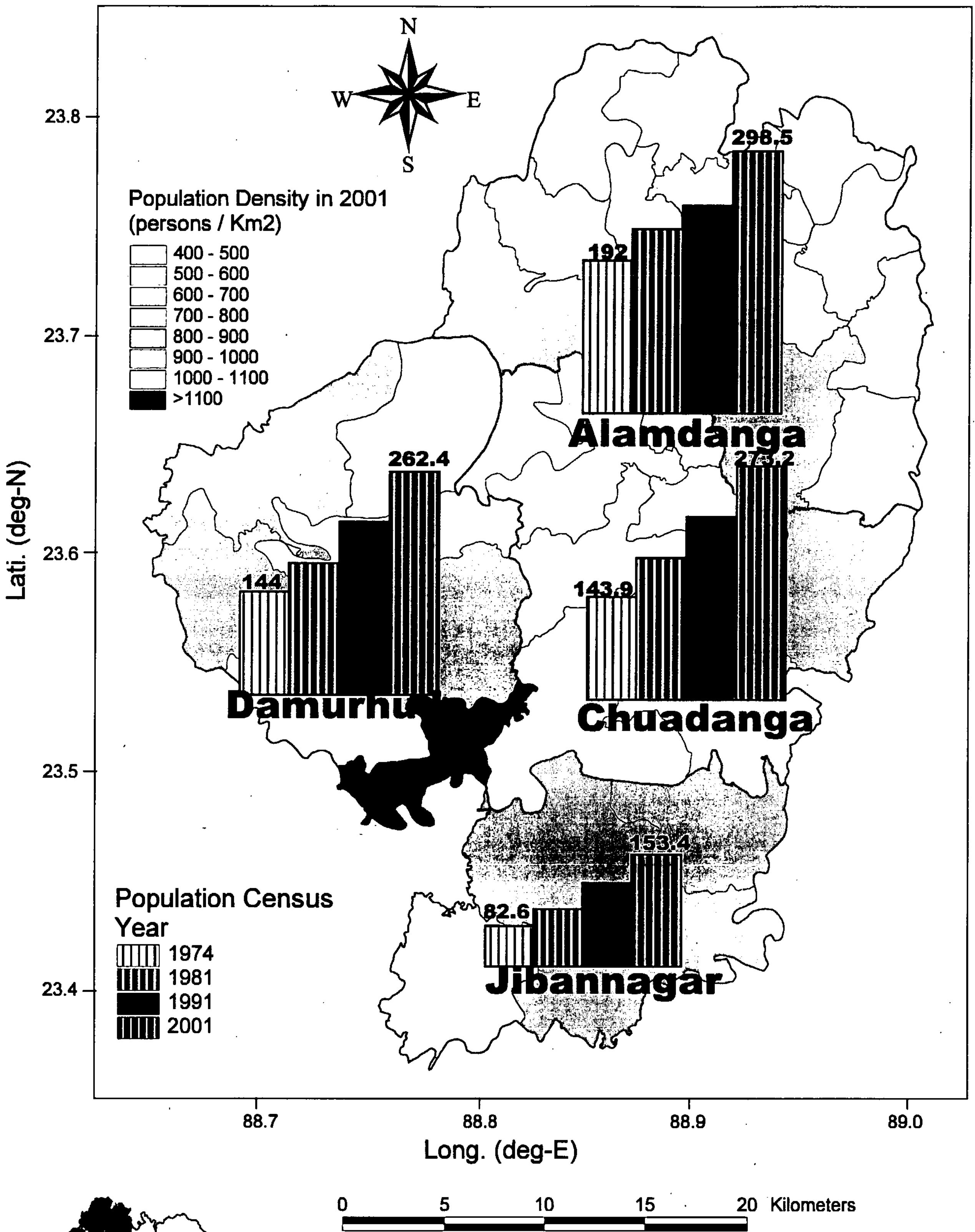

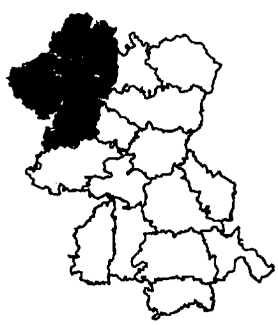

Figure 1.3.10	**Population Density Distribution in Chuadanga District**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

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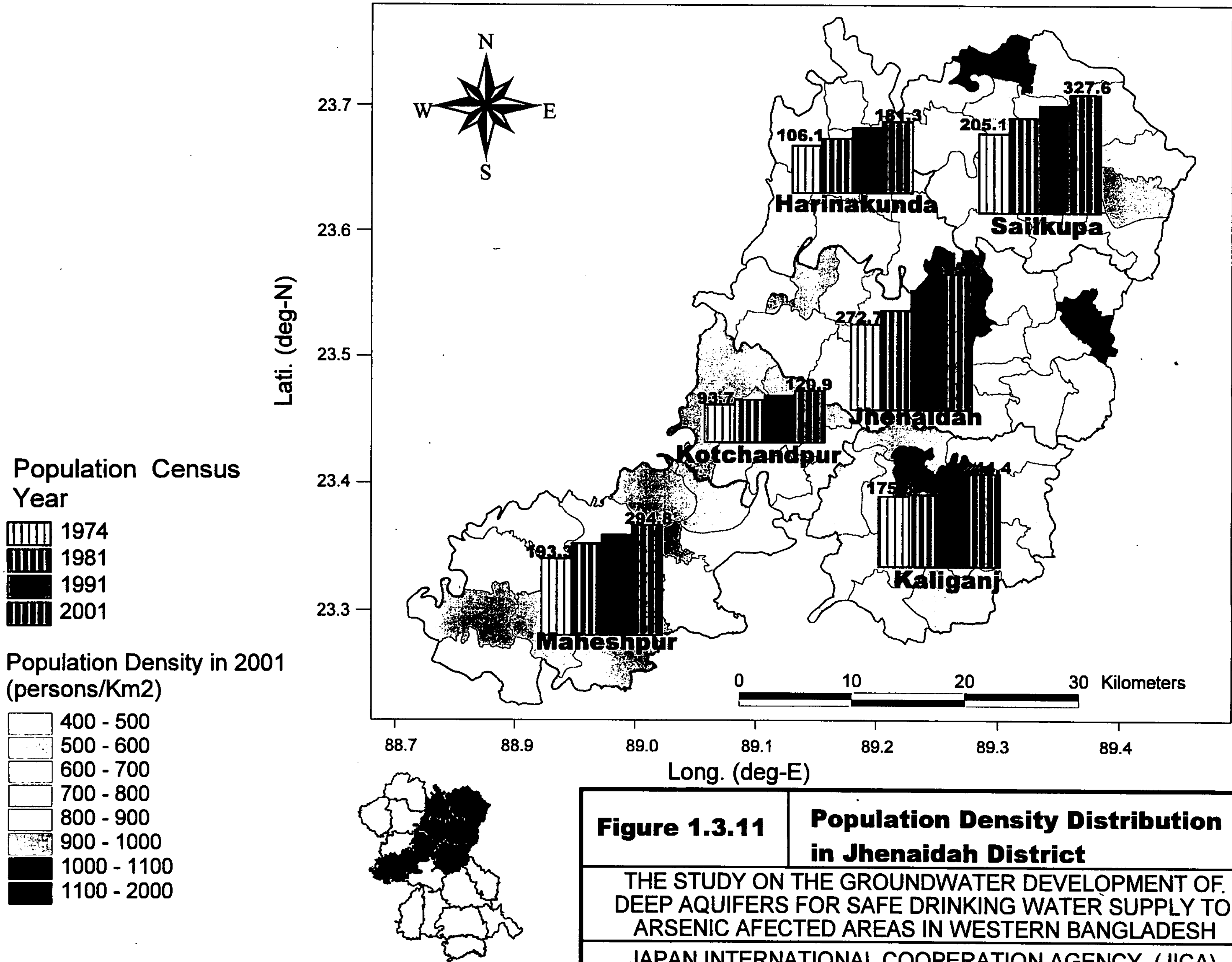


Figure 1.3.11 **Population Density Distribution in Jhenaidah District**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

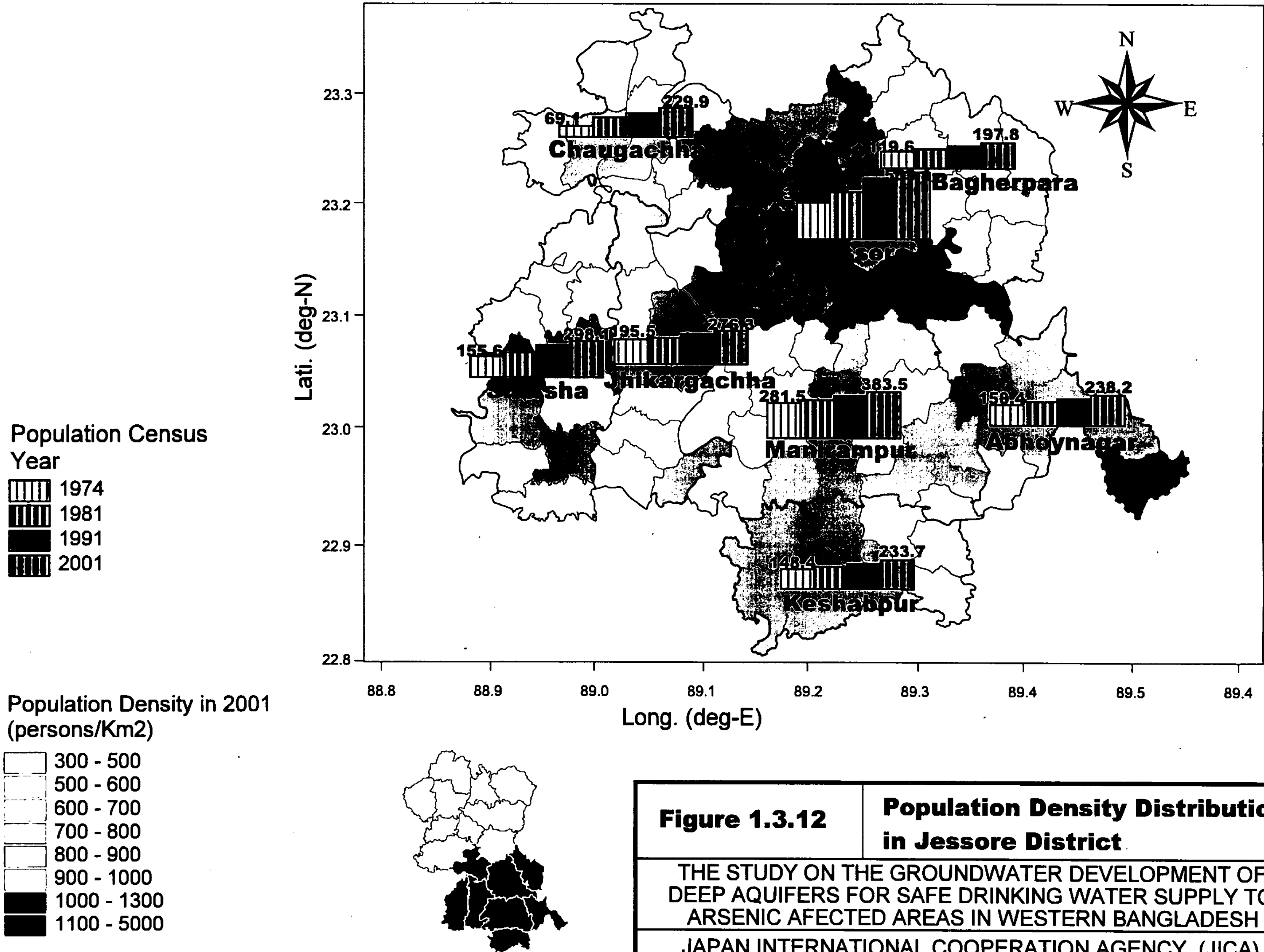


Figure 1.3.12	Population Density Distribution in Jessore District
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

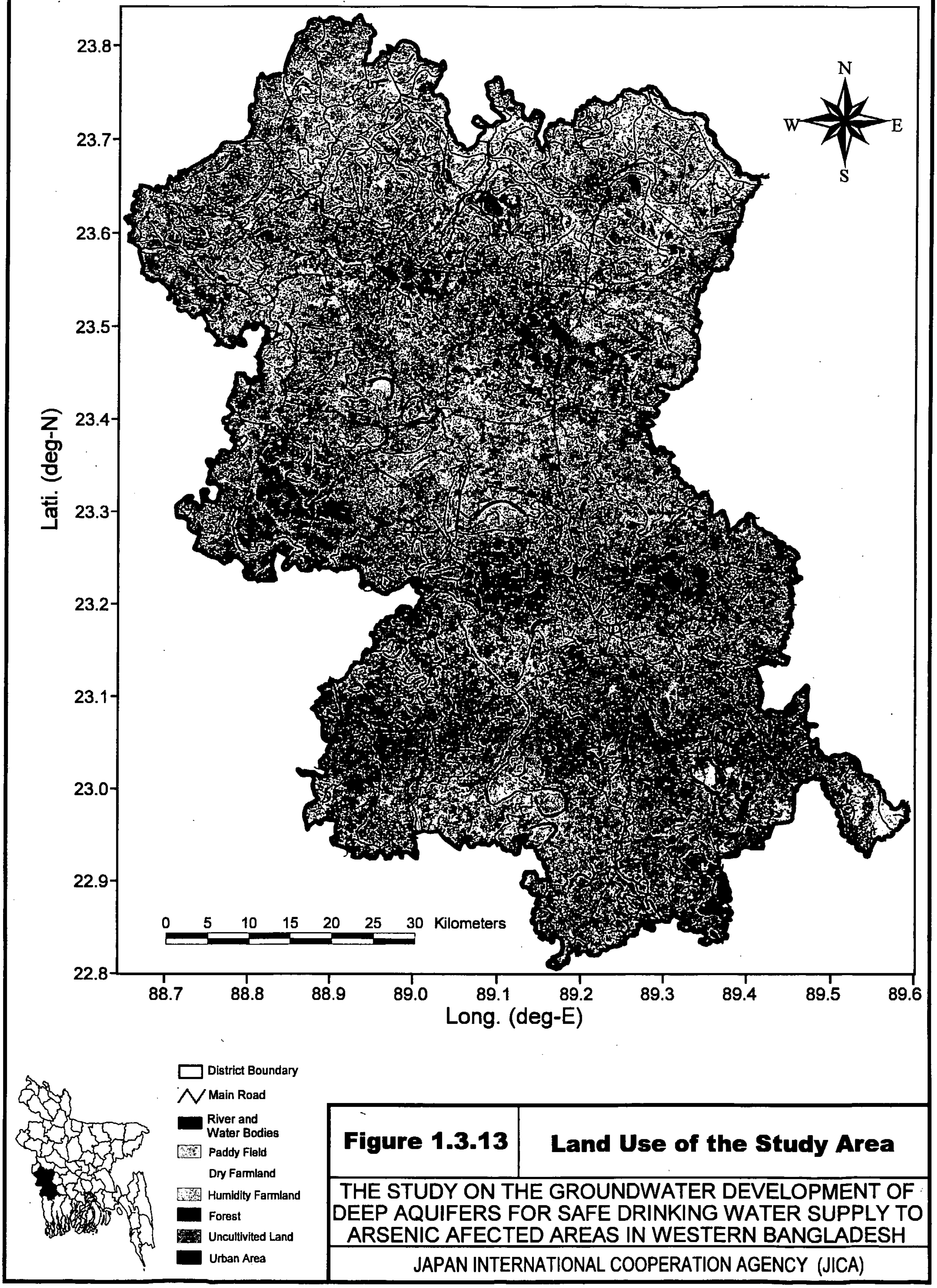
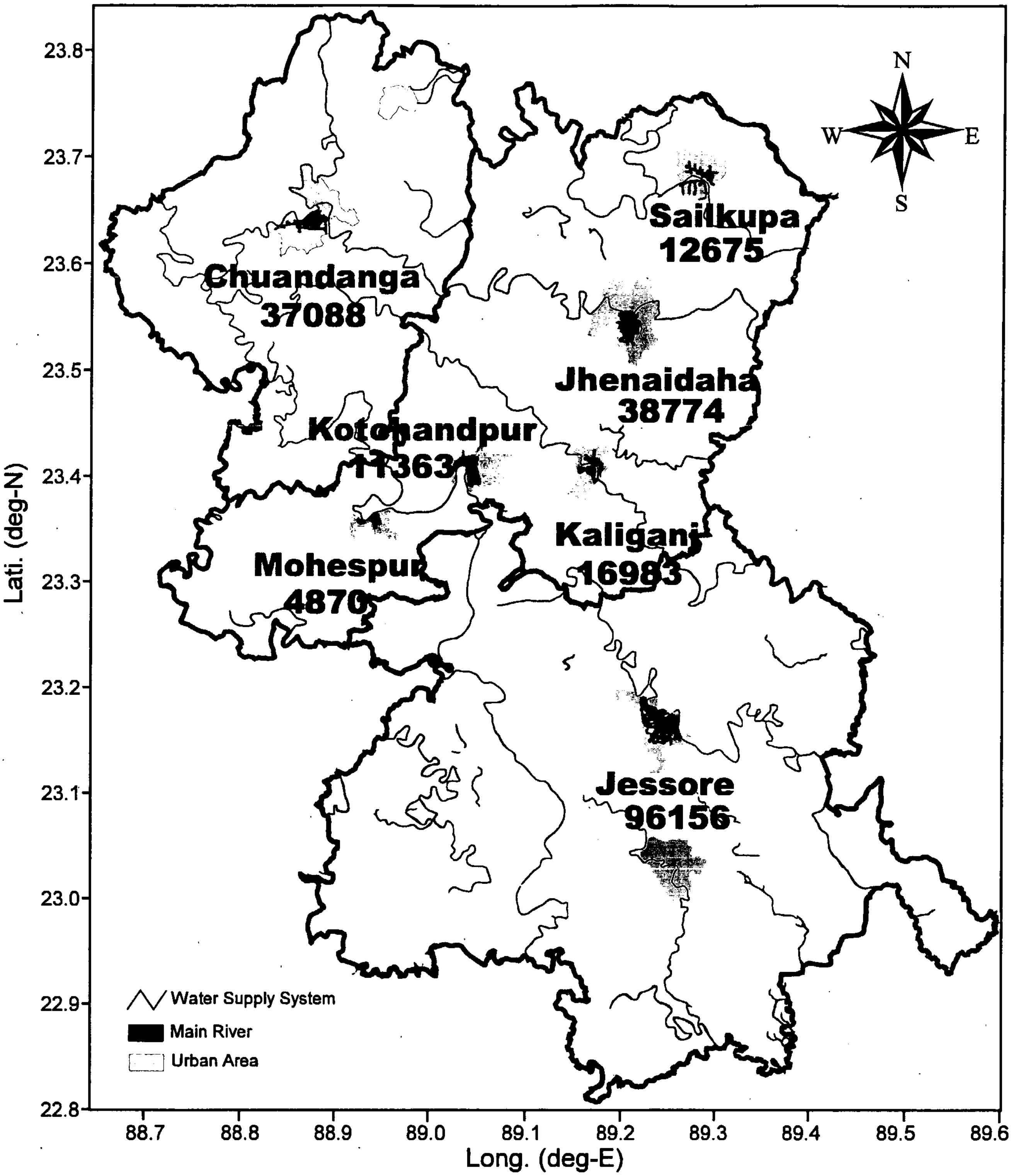
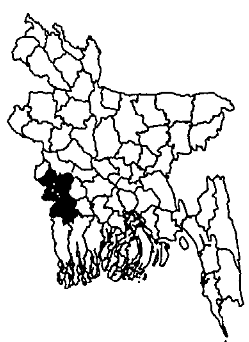


Figure 1.3.13	**Land Use of the Study Area**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	





The blue color figures in the map show the estimated water service population

Figure 1.3.14	**Location of Pourashava Water Supply Systems in the Study Area**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

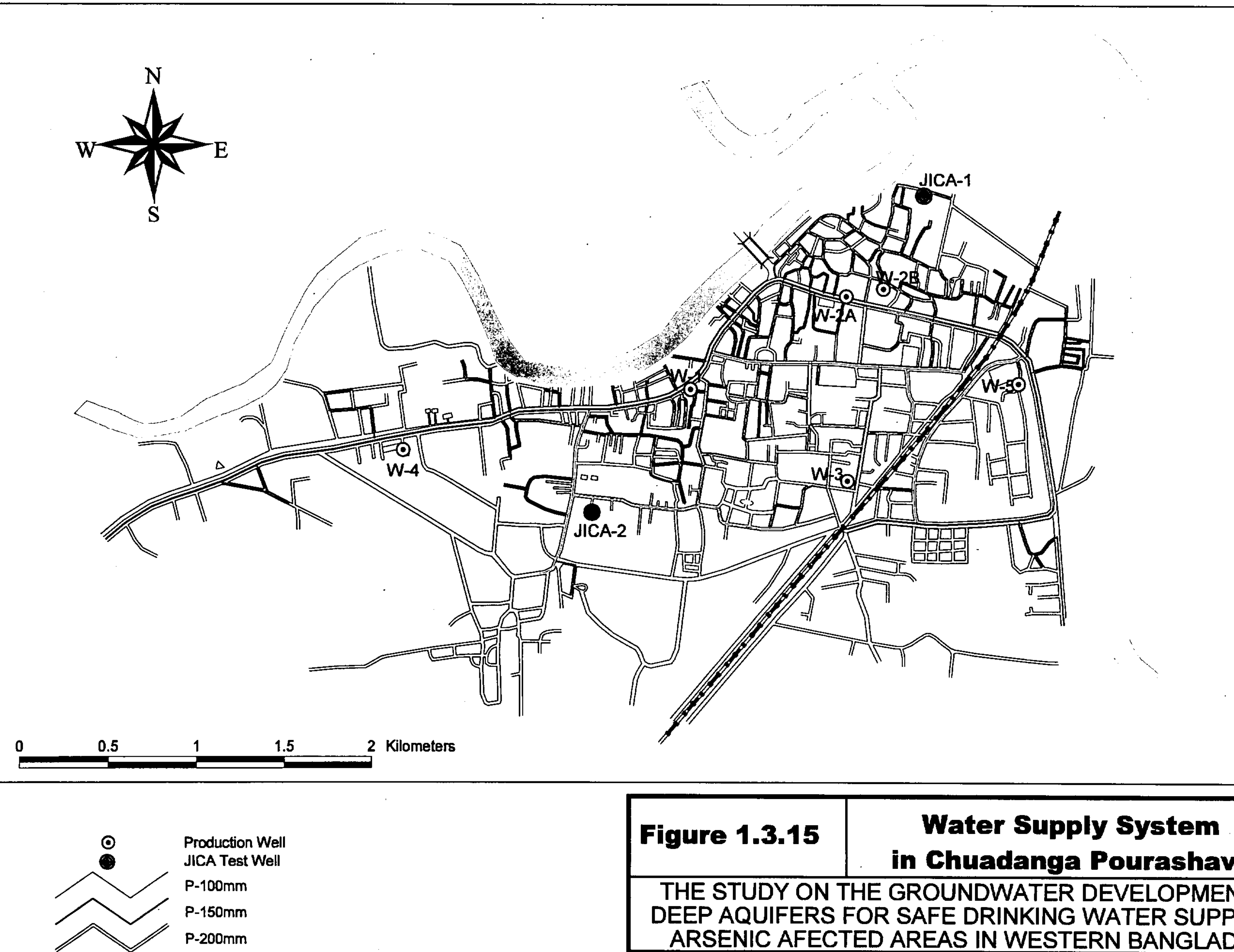


Figure 1.3.15	Water Supply System in Chuadanga Pourashava

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Figure 1.3.16	**Water Supply System in Jessore Pourashava**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

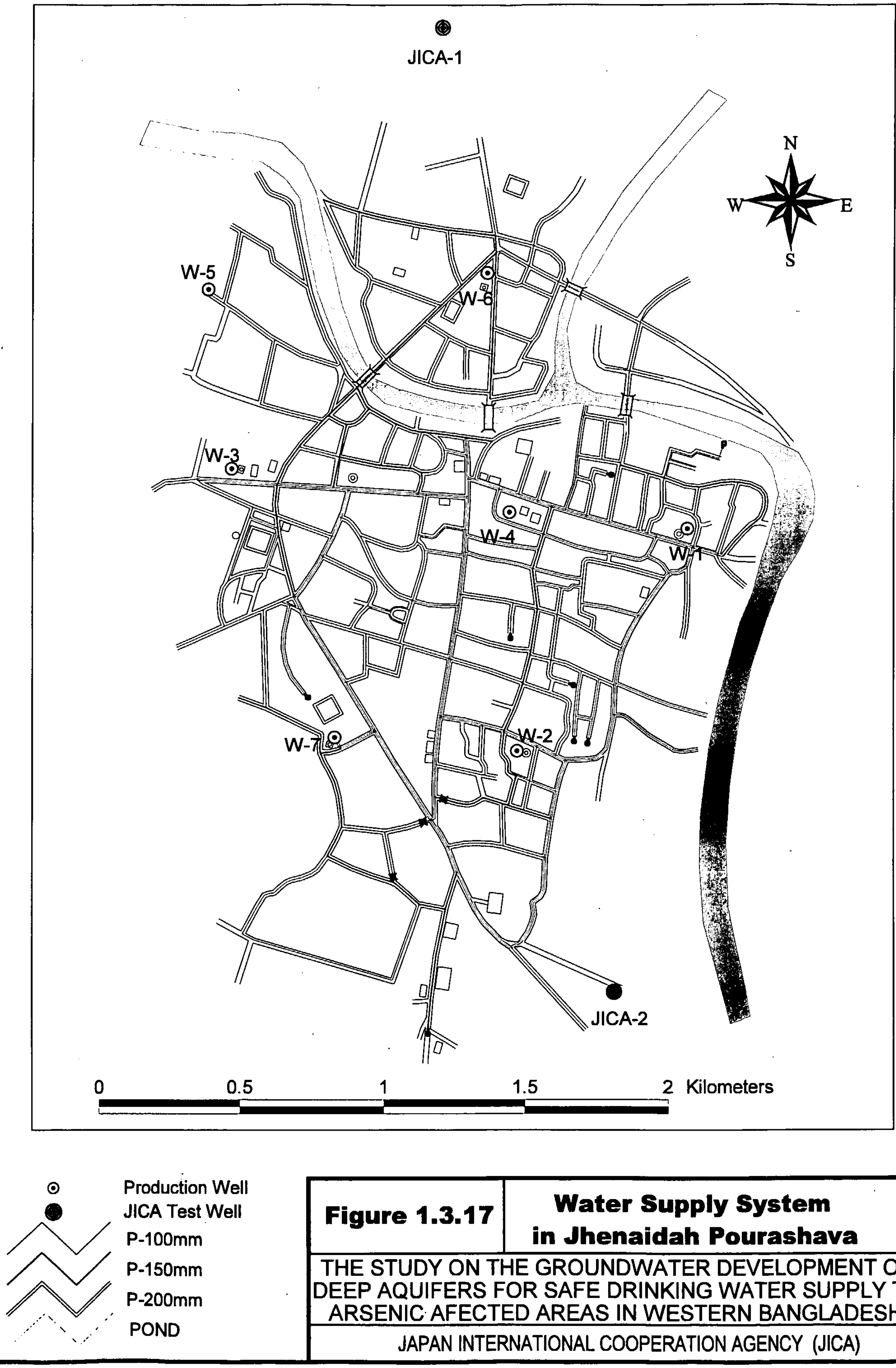


Figure 1.3.17	Water Supply System in Jhenaidah Pourashava

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

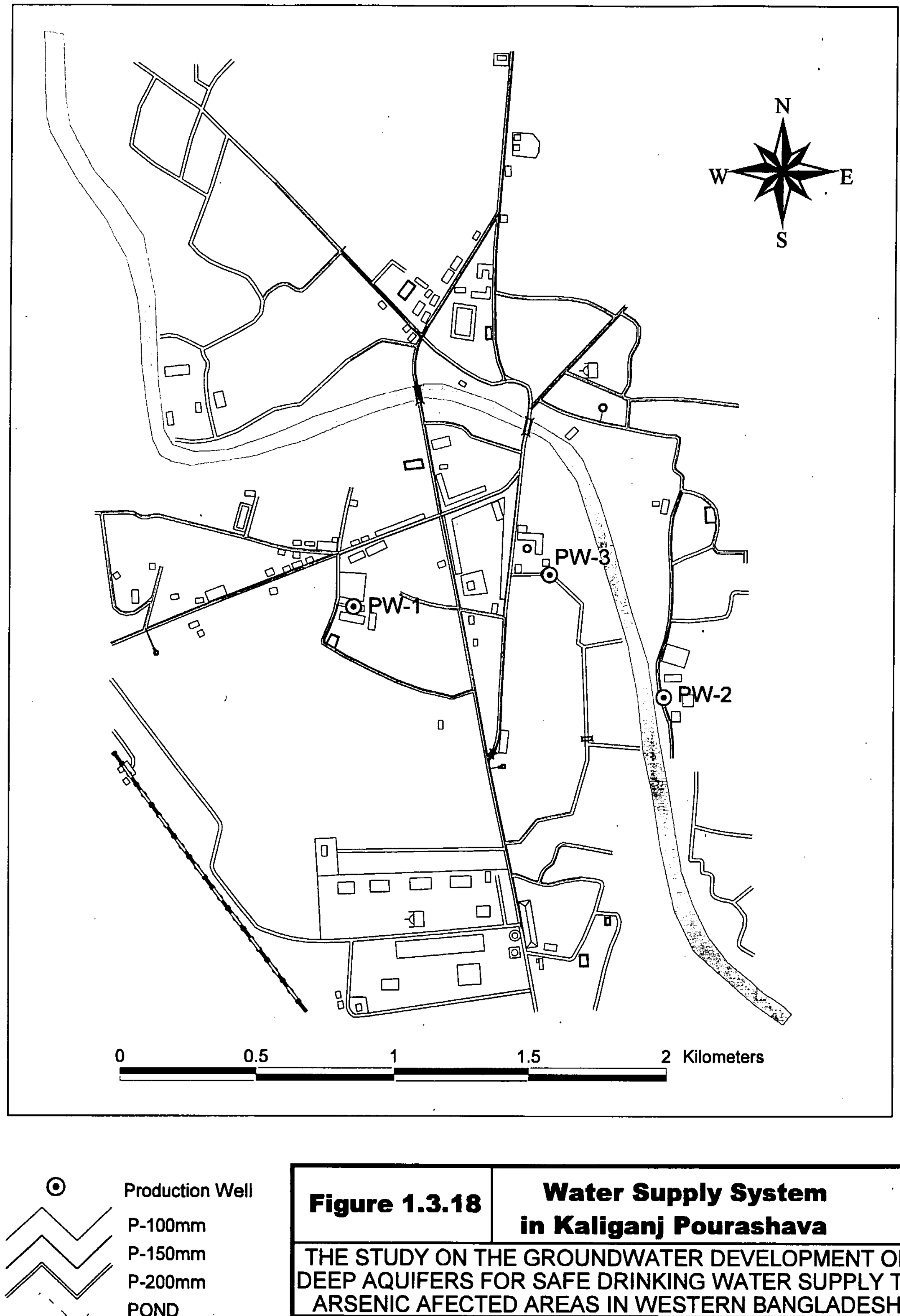
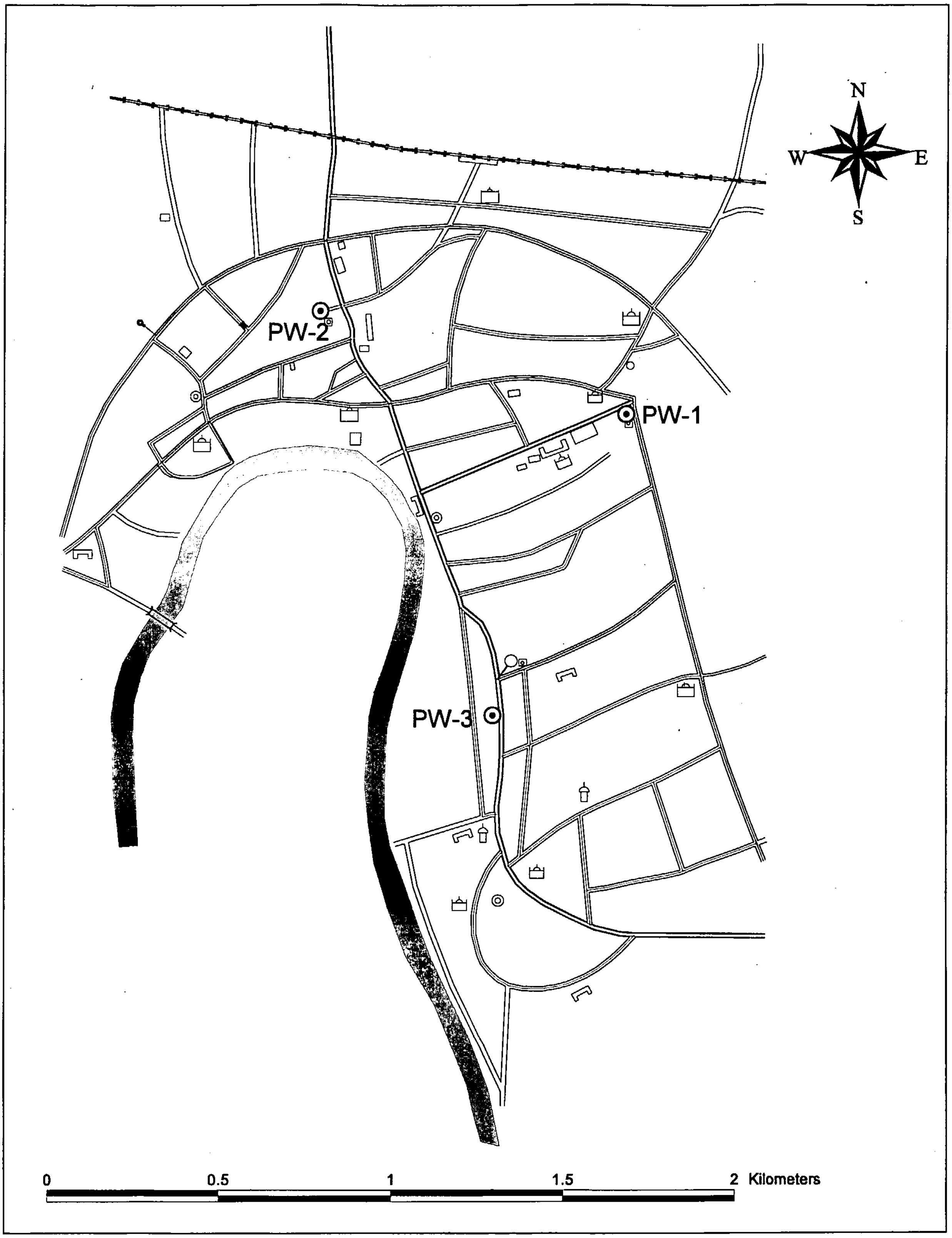


Figure 1.3.18	**Water Supply System in Kaliganj Pourashava**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



Production Well
P-100mm
P-150mm
P-200mm

Figure 1.3.19	Water Supply System in Kotchandpur Pourashava

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

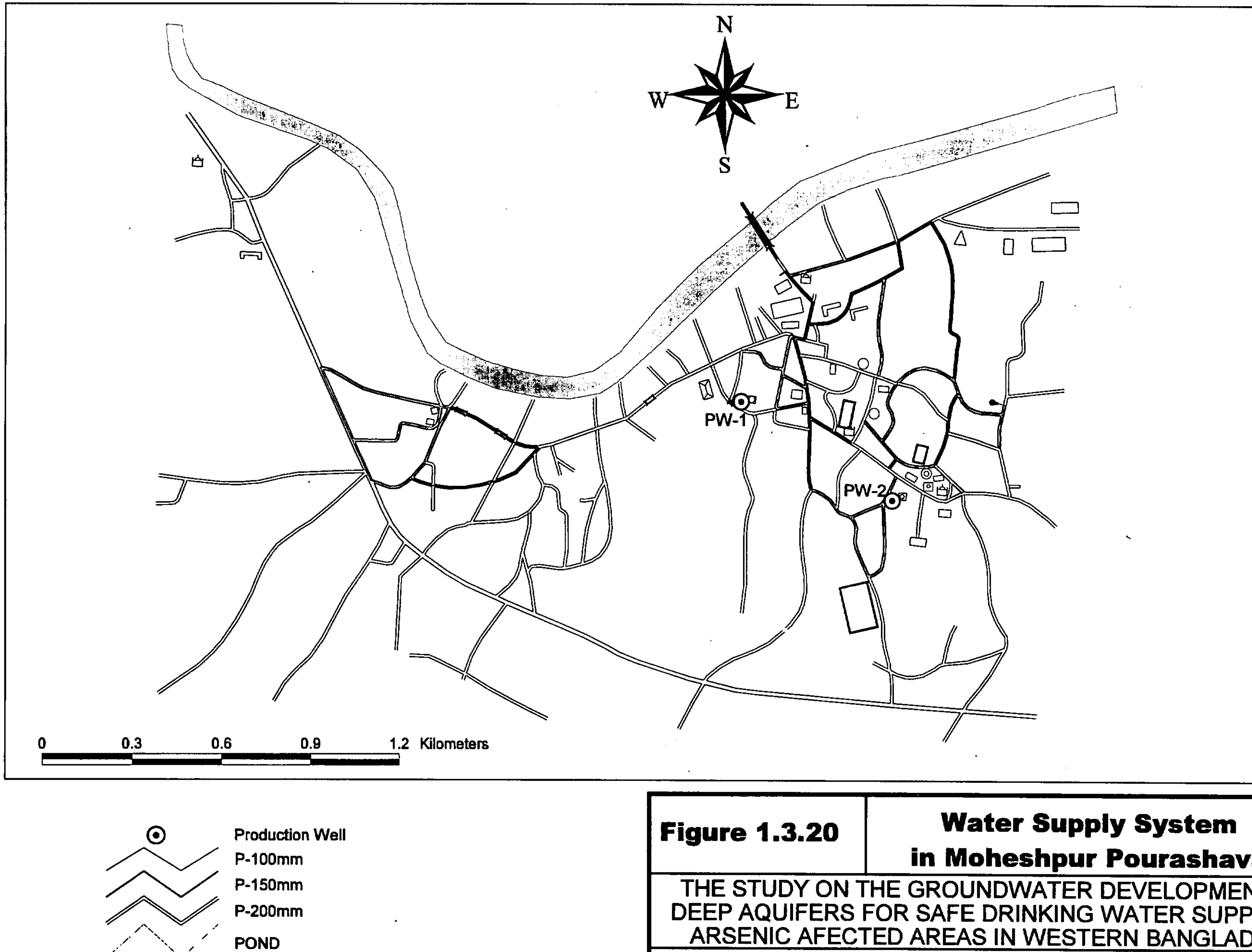


Figure 1.3.20	Water Supply System in Moheshpur Pourashava
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

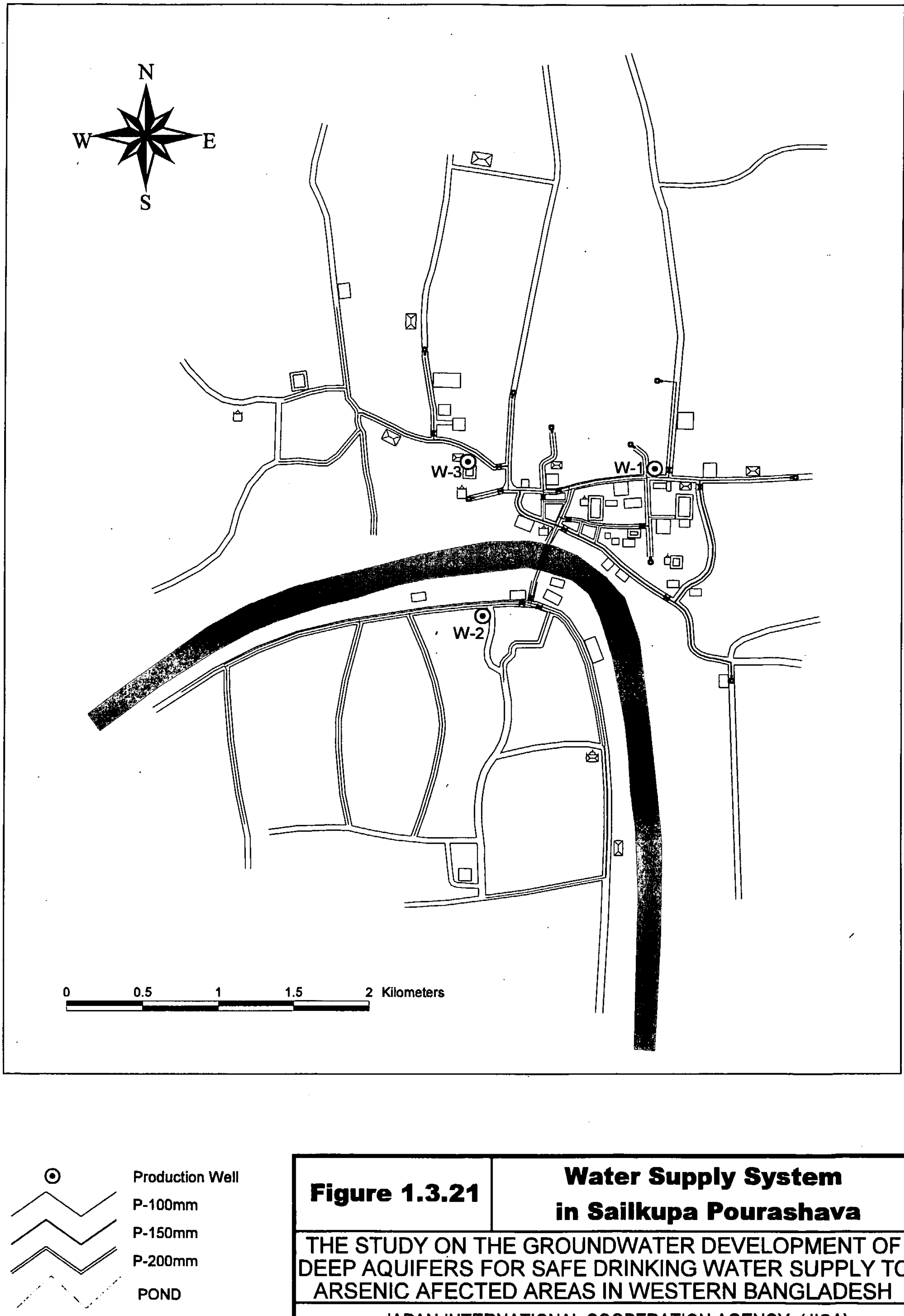


Figure 1.3.21 **Water Supply System in Sailkupa Pourashava**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

1.4 Well Inventory

1.4.1 Structure of Well Inventory

The well inventory was created on the basis of DPHE WR. Taking the convenience of utility and management into consideration, the common database program ACCESS included in MS Office was selected as the engine to set up the well inventory database.

The following tables are contained in the well inventory.

1) Main Table

The main table on the well inventory contains about 20 items that indicate well address, type, depth, filter type, date of construction, source of project involved, expense system and so on.

For lack of valid data, null value exists in the table. The items and the number of valid data in the main table are as follows:

Structure for Main Table

Field Name	Content	Number of Data
WELL_ID	Well ID based on administrative unit	43,771
Former_ID	Well ID in DPHE well register	43,770
District	District name	43,771
Thana	Thana name	43,771
Union	Union name	43,771
Mouza	Mouza name	43,771
Village	Village name	43,771
Care Taker	Name of care taker	43,769
Date	Construction date (up to Dec. 1999)	39,151
Depth	Well depth in feet	43,079
Type	Well Type	43,104
Und_Proj	Under project	8,387
Exp_syst	Expense system	20,782
Sink_TBWL	Whether a tube well was sunk	41,346
Flt_Type	Filter type	7,922
Flt_lngt	Filter Length	7,922
Cement	# of packs of cement used for platform	11,036
Lng_plt	Length of platform	17,512
Wdt_plt	Width of platform	17,512
Iron	Iron measurement result	27,787
Chloride	Chloride measurement result	13,668
Discharge	Discharge data	9,650

2) Log Data Table

Log data from 286 DPHE wells in the study area are contained in this table.

3) Water Quality Data Table

This table contains the arsenic analysis result from 779 wells in the study area. All of these data were taken before this study.

4) 300 well Table 1 (Rain season)

The table contains the results of a 300 well survey in the rainy season. The items in this table include well code, groundwater level observation result, and water quality measurement result. For general parameters of water quality there are water temperature, electricity conductivity, pH and ORP. For special parameter, iron and arsenic are shown. The results of two kinds of analysis for arsenic, field kit and AAS, are shown.

5) 300 well Table 2 (Base Information and Dry Season Survey Result)

The table contains the results of a 300 well survey in the dry season. In addition to the items contained in the 300 well table1, address, coordination, type of pump, depth and other fundamental information about the surveyed wells were also included.

6) Result in Supplementary Survey

In the supplementary survey, all the wells from 16 Mouzas in Keshabpur Thana were surveyed for well screening. In total, data for more than 3,000 wells were collected, including address, coordination, construction year, well depth, name of owner, and water quality measurement results. Although the data were input into the well inventory, the majority of the wells in this table are not DPHE wells.

1.4.2 General Characteristics of DPHE Wells

1) Well Density

Figure 1.4.1 shows the Thana level DPHE well density. The DPHE well density changes largely in the study area. The minimum density appears in Alamdanga Thana of Chuadanga District, being only 2 well/km^2. The maximum value is located in Sailkupa Thana of Jhenaidah, more than 15 wells/km^2.

In the southern part, DPHE wells density has a relatively uniform distribution, varying from 6 to 10 wells/km^2. In the northern part, however, the density changes largely with each Thana.

2) Density of DPHE Well Against Population

Figure 1.4.2 shows the Thana level DPHE well density to population.

The number of DPHE wells per 1,000 persons changes from 2 to about 20 in the study area. This density distribution can be used to examine the reliance of residents on DPHE wells.

Most DPHE wells are shallow tube wells with a hand pump, considered suitable as a water supply for several dozen residents. Therefore, in Thanas with high well density to population, such as Sailkupa and Kaliganj, the water supply can be considered as largely depending on DPHE wells; on the other hand, in several other Thanas like Alamdanga, where the DPHE well density is relatively small, the water supply can be considered as depending on wells or water sources other than DPHE facilities.

The DPHE well density distribution at the union level is shown in Table 1.4.1.

3) Change of DPHE Wells in Each Period

Figure.1.4.3 shows the number of the DPHE wells constructed in each period. In most Thanas, the first record of well construction is around the beginning of the1950's. However, the number of wells constructed by the 1970's occupies only less than 20% of the total DPHE wells. DPHE wells increased abruptly from the 1970's, and the tendency of this rapid increase in well number continued until the first half of the 1990s. In the late half of the 1990's, the speed of increase became low again.

The union level changes of DPHE well number in each period are shown in Table 1.4.2.

4) Well Type

Five (5) well types were recorded in WR: deep tube, shallow tube, Tara, PVC and others. However, it is difficult to understand what kind of criteria was used for distinguishing tube wells into deep and shallow tube wells, because for both types the total depth range is the same. The total depth of the wells classified into deep tubes varies from 14 to 251m, while the total depth of the shallow tube wells varies from 14 to 257m. The average depth of wells in the category of deep tube is 41.84m, while the average depth for shallow wells is 41.85m.

If the classification of well type has a proper standard, the data could be compiled as shown in Figure 1.4.4.

5) Classification by Well Depth

Figure 1.4.5 shows the Thana level classification of DPHE wells by depth. Most of the DPHE wells have a depth less than 60m. As to the difference in well depth throughout the study area, it can be found that most wells in the western part have a depth between 30 to 40m, while the most common depth in the eastern part is between 40 to 50m, a little deeper than that in the western part.

The union level well classification by depth is shown in Table 1.4.3.

Table 1.4.1 DPHE Well Density in the Study Area (by 1999)

(35/6)

Union	T-well	POP01	Density (well/1000p)	Area (km^2)	Density (well/Km^2)
CHUADANGA DISTRICT					
Alamdanga					
Alamdanga	2	15461	0.2	19	0.1
Alamdanga Pourashava	55	9027	7.5	10	5.3
Baradi	72	19560	4.5	22	3.3
Bhangabaria	53	25743	2.5	28	1.9
Dauki	53	19891	3.3	25	2.1
Gangni	67	22809	3.6	26	2.6
Hardi	61	26903	2.8	27	2.3
Jamjami	46	14737	3.8	22	2.1
Jehala	77	20197	4.7	20	3.8
Kalidaspur	91	8460	13.2	21	4.4
Khadimpur	37	38738	1.2	51	0.7
Khaskara	59	22697	3.2	28	2.1
Kumari	50	18459	3.3	20	2.5
Nagdaha	125	35795	4.3	48	2.6
Sub Total	**848**	**298,477**	**2.8**	**366**	**2.3**
Chuadanga					
Alokdia	86	21,286	4.0	20	4.4
Begampur	260	54,741	4.7	59	4.4
Chuadanga Pourashava	51	34,054	1.5	37	1.4
Kutubpur	322	30,404	10.6	43	7.5
Mominpur	222	16,389	13.5	18	12.2
Paddabilla	83	21,356	3.9	23	3.6
Shankarchandra	329	44,851	7.3	55	6
Titudaha	350	50,076	7.0	52	6.7
Sub Total	**1,703**	**273,157**	**6.2**	**306**	**5.6**
Damurhuda					
Damurhuda	427	35,362	12.1	37	11.6
Darshana	306	31,413	9.7	27	11.1
Howli	459	36,597	12.5	47	9.7
Juranpur	390	41,162	9.5	49	8
Kapasdanga	372	31,407	11.8	43	8.6
Kuralgachhi	489	48,877	10.0	49	9.9
Natipota	448	37,539	11.9	53	8.5
Sub Total	**2,891**	**262,357**	**11.0**	**306**	**9.5**
Jibannagar					
Andulabaria	226	26,563	8.5	37	6.1
Banka	348	47,361	7.3	60	5.8
Jibannagar	302	36,965	8.2	44	6.9
Uthali	346	42,502	8.1	55	6.3
Sub Total	**1,222**	**153,391**	**8.0**	**196**	**6.2**
Chuadanga District Total	**6,664**	**987,382**	**6.7**	**1,174**	**7.1**

Table 1.4.1 DPHE Well Density in the Study Area (by 1999) (36/6)

Union	T-well	POP01	Density (well/1000p)	Area (km^2)	Density (well/Km^2)
JHENAIDAH DISTRICT					
Harinakunda					
Bhayna	159	21,566	7.4	25	6.4
Chandpur	238	25,294	9.4	36	6.7
Daulatpur	283	30,031	9.4	36	7.9
Harinakunda	255	23,165	11.0	24	10.6
Joradaha	181	11,921	15.2	15	12.1
Kapashati	242	23,995	10.1	36	6.7
Raghunathpur	191	22,143	8.6	30	6.4
Taherhuda	220	23,201	9.5	29	7.6
Sub Total	**1,769**	**181,316**	**9.8**	**230**	**7.7**
Jhenaidah					
Dogachhi	551	14,394	38.3	18	30.5
Fursandi	233	19,349	12.0	29	8.1
Ganna	385	27,602	13.9	34	11.4
Ghorsal	228	19,113	11.9	27	8.4
Haldhani	160	18,125	8.8	20	8.2
Harishankar	187	19,964	9.4	25	7.6
Jhenaidah Paurashava	265	44,809	5.9	40	6.6
Kalicharanpur	157	14,992	10.5	17	9.4
Kumarbaria	156	14,682	10.6	22	7
Madhuhati	311	27,165	11.4	36	8.7
Maharajpur	342	26,292	13.0	36	9.6
Naldanga	253	25,534	9.9	34	7.5
Padmakar	171	22,301	7.7	18	9.7
Paglakanai	89	8,627	10.3	11	8.4
Porahati	268	27,425	9.8	32	8.3
Sadhuhati	116	20,619	5.6	25	4.7
Sagenna	190	20,513	9.3	19	10.1
Surat	199	14,058	14.2	17	11.9
Sub Total	**4,261**	**385,564**	**11.1**	**457**	**9.3**
Kaliganj					
Barobazar	354	31,985	11.1	34	10.3
Jamal	195	21,341	9.1	25	7.7
Kaliganj Paurashava	225	23,897	9.4	15	15
Kashtabhanga	219	19,595	11.2	24	9.2
Kola	228	21,079	10.8	33	7
Maliat	107	15,672	6.8	23	4.6
Niamatpur	254	26,549	9.6	24	10.7
Raigram	255	21,751	11.7	29	8.9
Rakhalgachhi	259	22,044	11.7	36	7.1
Simla Rokanpur	52	10,496	5.0	16	3.2
Sundarpur Durgapur	111	12,983	8.5	22	5
Trilochanpur	304	17,016	17.9	31	9.9
Sub Total	**2,563**	**244,408**	**10.5**	**312**	**8.2**

Table 1.4.1 DPHE Well Density in the Study Area (by 1999)

(37/6)

Union	T-well	POP01	Density (well/1000p)	Area (km^2)	Density (well/Km^2)
Kotchandpur					
Baluhar	168	19,810	8.5	26	6.4
Dora	182	19,245	9.5	33	5.5
Elengi	191	21,865	8.7	25	7.5
Kotchandpur Paurashava	59	12,175	4.8	18	3.3
Kushna	207	31,782	6.5	32	6.4
Sabdalpur	168	15,986	10.5	29	5.8
Sub Total	**975**	**120,863**	**8.1**	**164**	**5.9**
Moheshpur					
Azampur	245	26,393	9.3	30	8.2
Bansbaria	218	24,321	9.0	36	6
Fatehpur	263	18,874	13.9	30	8.6
Jadabpur	275	24,095	11.4	37	7.5
Kazirber	239	27,643	8.6	35	6.8
Manderbari	227	26,573	8.5	36	6.4
Moheshppur Paurashava	51	5,706	8.9	11	4.5
Natima	219	22,726	9.6	37	5.9
Nepa	200	23,300	8.6	38	5.3
Pantapara	228	28,533	8.0	35	6.5
Sundarpur	41	13,778	3.0	23	1.8
Swaruppur	155	25,022	6.2	35	4.5
Syamkur	237	27,808	8.5	35	6.7
Sub Total	**2,598**	**294,772**	**8.8**	**418**	**6.2**
Sailkupa					
Abaipur	242	19,800	12.2	21	11.4
Bagura	262	26,149	10.0	25	10.6
Dhalhara	286	25,244	11.3	26	10.9
Dignagar	183	18,049	10.1	18	10.1
Dudhsar	242	25,615	9.4	29	8.4
Fazilpur	243	17,286	14.1	19	12.6
Fulhari	212	18,377	11.5	20	10.4
Hakimpur	243	24,101	10.1	26	9.4
Kancherkol	314	23,721	13.2	21	14.9
Mirjapur	335	27,944	12.0	35	9.5
Nityanandapur	289	21,764	13.3	32	8.9
Sailkupa Paurashava	199	18,418	10.8	21	9.3
Sarutia	89	22,737	3.9	27	3.3
Tribeni	336	14,732	22.8	21	15.7
Umedpur	326	23,652	13.8	33	10
Sub Total	**3,801**	**327,589**	**11.6**	**376**	**10.1**
Jhenaidah District Total	**15,967**	**1,554,514**	**10.3**	**1,957**	**8.2**

Table 1.4.1 DPHE Well Density in the Study Area (by 1999)

(38/6)

Union	T-well	POP01	Density (well/1000p)	Area (km^2)	Density (well/Km^2)
JESSORE DISTRICT					
Abhaynagar					
Baghutia	177	24,588	7.2	27	6.7
Mahakal	283	48,141	5.9	57	4.9
Noapara	399	46,161	8.6	39	10.2
Payra	198	22,217	8.9	27	7.3
Rajghat	303	23,479	12.9	25	12.3
Siddhipasa	422	33,884	12.5	36	11.9
Sridharpur	95	18,582	5.1	12	8.1
Subharara	266	21,177	12.6	17	16
Sub Total	**2,143**	**238,229**	**9.0**	**239**	**9**
Bagherpara					
Bandabilla	184	25,430	7.2	34	5.5
Basuari	168	19,208	8.7	22	7.5
Darajhat	204	20,809	9.8	26	8
Dhalgram	159	19,090	8.3	28	5.7
Dohakula	198	23,000	8.6	33	6
Jaharpur	186	19,868	9.4	27	6.8
Jamdia	206	21,835	9.4	32	6.5
Narikelbaria	217	24,791	8.8	36	6.1
Raipur	166	23,779	7.0	31	5.4
Sub Total	**1,688**	**197,810**	**8.5**	**267**	**6.3**
Chaugachha					
Chaugachha	153	19,656	7.8	21	7.4
Dhuliani	134	12,456	10.8	14	9.3
Hakimpur	288	20,091	14.3	29	9.8
Jaradishpur	131	17,041	7.7	20	6.5
Narayanpur	149	20,427	7.3	29	5.1
Pashapole	251	18,115	13.9	23	11
Patibila	218	17,904	12.2	20	10.8
Paulsara	144	30,954	4.7	27	5.4
Singhajhuli	181	12,071	15.0	14	12.8
Sukpukhuria	304	29,925	10.2	35	8.8
Swarupdaha	298	31,274	9.5	34	8.8
Sub Total	**2,251**	**229,914**	**9.8**	**266**	**8.5**
Jhikargachha					
Bankra	197	20,705	9.5	22	8.8
Gadkhali	229	26,528	8.6	26	8.8
Ganganandapur	199	28,587	7.0	30	6.5
Hazirbag	245	24,077	10.2	29	8.6
Jhikargacha	337	33,152	10.2	30	11.2
Magura	266	26,202	10.2	31	8.7
Nabharan	270	26,524	10.2	26	10.3
Nibaskhola	240	20,336	11.8	25	9.6
Panisara	242	23,666	10.2	25	9.8
Shankarpur	254	23,426	10.8	27	9.5
Simulia	273	23,138	11.8	29	9.5
Sub Total	**2,752**	**276,341**	**10.0**	**299**	**9.2**

Table 1.4.1 DPHE Well Density in the Study Area (by 1999)

Union	T-well	POP01	Density (well/1000p)	Area (km^2)	Density (well/Km^2)
Jessore					
Arabpur	169	43,212	3.9	24	7.1
Basundia	192	36,169	5.3	27	7.2
Chanchra	218	34,191	6.4	27	8.1
Churamankati	210	39,017	5.4	33	6.4
Diara	249	39,922	6.2	35	7.2
Fatepur	256	34,661	7.4	28	9.2
Haibatpur	223	40,012	5.6	40	5.6
Ichhali	224	31,829	7.0	30	7.4
Jessore Paurashava	133	65,443	2.0	27	4.9
Kachua	169	33,411	5.1	25	6.9
Kasimpur	295	41,441	7.1	30	9.7
Lebutala	226	32,123	7.0	24	9.5
Naopara	363	36,267	10.0	24	15.1
Narendrapur	262	30,670	8.5	23	11.6
Ramnagar	369	40,346	9.1	27	13.8
Seikhhati	122	4,388	27.8	3	39.1
Sub Total	**3,680**	**583,102**	**6.3**	**425**	**8.7**
Keshabpur		233,734	1		
Bidyanandakati	238	32,242	7.4	33	7.2
Gaurighona	240	19,304	12.4	26	9.2
Keshabpur	277	35,463	7.8	33	8.3
Majitpur	175	24,083	7.3	23	7.5
Mangalkot	239	21,380	11.2	23	10.6
Panjia	240	23,642	10.2	28	8.6
Sagardari	287	28,107	10.2	29	9.8
Sufalakati	239	19,021	12.6	26	9.3
Trimohini	368	30,492	12.1	34	10.9
Sub Total	**2,303**	**233,734**	**9.9**	**255**	**9**
Mamirampur					
Bhojgati	95	11,931	8.0	13	7.2
Chaluahati	218	24,332	9.0	27	8.2
Dhakuria	160	23,744	6.7	37	4.3
Durbadanga	143	23,194	6.2	24	6
Haridaskati	154	24,073	6.4	29	5.3
Hariharnagar	169	27,824	6.1	34	4.9
Jhanpa	138	24,675	5.6	28	5
Kasimnagar	312	14,087	22.1	18	17.6
Khanpur	168	20,332	8.3	24	7
Khedapar	261	25,342	10.3	31	8.4
Kultia	208	19,754	10.5	34	6.1
Manirampur	193	31,490	6.1	28	6.8
Maswimnagar	282	28,866	9.8	32	8.7
Monoharpur	240	11,628	20.6	16	15.3
Nehalpur	431	12,618	34.2	14	31.2
Pohita	229	28,798	8.0	35	6.6
Shyamkur	413	30,765	13.4	29	14.3
Sub Total	**3,814**	**383,453**	**9.9**	**453**	**8.4**

Table 1.4.1 DPHE Well Density in the Study Area (by 1999)

(40/6)

Union	T-well	POP01	Density (well/1000p)	Area (km²)	Density (well/Km²)
Sharsha		298,111	1		
Bagachra	200	28,910	6.9	29	7
Bahadurpur	193	25,265	7.6	32	6
Benapole	156	41,216	3.8	29	5.4
Dihi	222	25,601	8.7	35	6.4
Goga	249	21,252	11.7	29	8.6
Kayba	247	23,443	10.5	29	8.7
Lakshmanpur	229	22,219	10.3	25	9.2
Nizampur	164	19,116	8.6	26	6.3
Putkhali	288	27,722	10.4	30	9.5
Sharsha	338	35,871	9.4	31	11
Ulashi	223	27,496	8.1	37	6
Sub Total	**2,509**	**298,111**	**8.4**	**331**	**7.6**
Jessore District Total	**21,140**	**2,440,693**	**8.7**	**2,535**	**8.3**
STUDY AREA TOTAL	43,771	4,982,589	8.8	5,667	7.7
			38	5,667	39

Table1.4.2 Number of DPHE Wells Constructed in Each Year from 1970 to 1999.

(1/5)

Union	By1970	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	-89	90	91	92	93	94	95	96	97	98	99	Unkown	Total
Chuadanga District																																	
Alamdanga Thana																																	
Alamdanga																1	1																2
Pourashava																5	4	3	2	2	6		2	5	3	1	1	1	3	8	9		55
Baradi																1	3	1	3	3	7		1	4	1	3	1	6	11	17	7	3	72
Bhangabaria																5	4	3	3	6	4		1	4	3	1	2		3	6	8		53
Dauki																2	2	3	3	5	5		2	4	5		1	1	3	10	7		53
Gangni																	2	4	6	3	5		3	7	7	8	1	1	4	5	6	5	67
Hardi																7	4	3	4	4	3		3	4	5	2	1	1	3	8	9		61
Jamjami														1			4	2	4	3	1			4	6	1	1	1	3	7	8		46
Jehala										1						2	3	3	4	2	5		4	4	4		1	3	5	15	16	5	77
Kalidaspur																2	5	6	3	1	5		6	8	13	8	2	6	12	5	9		91
Khadimpur																2	3	2	1	4	1		1		4	4	2		1	2	9	1	37
Khaskara																1	5	4	4	2	4		2	3	7	2	2		3	9	9	2	59
Kumari																	4		5		3			3	4	3	2	3	6	8	9		50
Nagdaha																1	15	13	7	6	14		4	7	8	8	5	6	1	8	5	17	125
Chuadanga Thana																																	
Alokdia						3	1			1			1	3	3	2		6	3	2	14		3	7	8	7	5	1	5	5		6	86
Begampur			2		9	13	4		2	34	10		14	13	2	7	5	12	21	4	13		5	4	11		4	3	6	7	14	41	260
Pourashava	1				1	1			4	5	8		3	2		1	3	2	7		2			1	1				1		1	7	51
Kutubpur	3				8	16	1		3	22	10		8	13	6	9	8	31	26	4	13		4	10	19	18	22	3	7	23	6	29	322
Mominpur	1				6	2	7		31	23	1		12	5	17	11	9	17	15	4	2		9	2	14	3	1	1	5	5	10	9	222
Paddabilla	1						1		4	1			3			1	1	8	5		3			2	11	7	9	2	5	10		9	83
Shankarchandra	1					5	2	1	25	8	19		28	1	3	10	10	28	27	5	13		4	4	21	11	13	1	3	14	10	62	329
Titudaha							6		5	1			1				2	7	55	5	22		3	4	18	13	33	1	7	13	1	153	350
Damurhuda Thana																																	
Damurhuda	12			8	6		3	6	54	13	2		25		12	17	16	9	10	3	12		13	6	7	11	17	27	25	27	10	76	427
Darshana	2				3	18	4		6	40			12	4		23	4	7	10	2	12		10	6	12	3	3	1	3	7	4	110	306
Howli				2	1		3		8	38	1		23	2	13	17	4	8	10	1	19		12	4	11	11	7	13	25	35	12	179	459
Juranpur	3			2	3	11	1	3	73	14			4	8	20	15	7	7	13	2	16		4	16	8	4	2	6	15	6	22	105	390
Kapasdanga	7						3	2	29		11		3	7	8	16	6	6	11	2	22			3	25	26	29	5	16	10	18	107	372
Kuralgachhi							4		1		9		13		6	10	5	4	24	3	15		15	7	19	37	38	9	17	37	18	198	489
Natipota	4			1			2	1	35	19	6		15	6	31	10	2	5	13	3	8		9	8	13	4	8	6	17	51	17	154	448
Jibannagar Thana																																	
Andulabaria						1	5	1	48		18				19	4	7	7	11	4	10		4	4	19	4	3	2	5	3	19	28	226
Banka							2		2	71	5			16	20	11	14	9	27	8	17		4	5	18	9	6	4	12	10	15	63	348
Jibannagar	2				3	2	3		31		9		11		9	19	18	10	15	3	7		4	5	14	10	3	5	7	5	26	81	302
Uthali						1	4		2	36			24	1		12	7	13	43	5	25		3	5	8	10	3	3	14	4	23	100	346
Jhenaidah District																																	
Harinakunda Thana																																	
Bhayna							3		9	19										2	2	4	8	3	9	4	6	2	3	5	3	77	159
Chandpur					4	20	3	7	21	28		3	3	12		8				4	3	16	10	8	8	9	6	3	9	8	1	44	238
Daulatpur	5				1	17	2		26	28	5	1	10	3	12	6	8			6	7		14	12	10	17	15	15	16	15	6	26	283
Harinakunda					6	11			26			3	22		2	19	11	5	5	5	5	14	9	6	11	19	12	7	16	16	5	20	255
Joradaha						2	2		7	10			1		1					5	2	24	12	12	10	19	6	2	12	4	2	48	181

Table1.4.2 Number of DPHE Wells Constructed in Each Year from 1970 to 1999.

(2/5)

Union	By1970	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	Unkown	Total
Kapashati	1						2		5	37			1	1	6	8	6	5	5	5	3	11	9	9	8	14	12	5	8	23	9	49	242
Raghunathpur					5	1	9		6	8			6	1	9	8	5	8	5	3	4	5	10	11	15	12	10	2	8	3	4	33	191
Taherhuda							8		6	8			5	1	7	1	3	3	2	8	4	8	23	11	15	33	11	6	8	5	5	39	220
Jhenaidah Thana																																	
Dogachhi	7			1	4	3	25	2	62	21	4	11	5	12	16	13	15	14	17	15	13	10	25	26	22	48	26	30	16	20	4	64	551
Fursandi	13				4		16		2	23	3	15		9	1	8	11	6	1	6	3	5	6	13	5	13	20	12	6	8		24	233
Ganna	8			1	5	1	25		45	4		23	8	6	18	18	24	9	23	25	10	4	10	16	18	23	16	13	9	12	1	10	385
Ghorsal						1	12		8	9	3		4	1	5	9	11	7	11	9	7	2	8	14	10	16	10	9	3	5		54	228
Haldhani	1				2		11	6	11	1	2	13	3	1	7	7	14	6	10	4	4	1	6	11	4	7	3	10	3	3	1	8	160
Harishankar	3				1		11		8	8		7		8			8	5	12	5	2	4	9	12	6	16	28	12	4	6	3	9	187
Paurashava	11	4			4	4	8	1	37	13		15	7	4	8	8	9	3	9	5	6	10	6	13	13	23	10	9	4	5	1	15	265
Kalicharanpur	7	2			1		11		15	6	3	4	3		3	6	4	2	4	2	8	5	11	4	5	11	15	10	3	7		5	157
Kumarbaria	2				3		5		12	7	1		3		6	4	12	8	9	7	5	1	10	3	2	11	5	5	4	8	2	21	156
Madhuhati	5	1		1	4		8		15	13	2	1	11	10	3	12	15	8	15	17	6	2	11	21	15	18	15	10	8	17		47	311
Maharajpur	3						16	1	20	4	3	1	3	8	1	4	30	40	30	26	11	7	8	18	8	13	16	13	28	11		19	342
Naldanga	1	1		3	4	3	12		4	26	1	17	1	10	10	9	19	12	10	16	8	8	8	15	6	21	8	8	3	6		3	253
Padmakar	6	1			1		8		20	1		6	1	14	1	2	9	13	10	9	1	4	8	6	5	12	12	3	6	8	2	2	171
Paglakanai					3		2		12			4		3	5	7	6	1	2	3	1	1	4	5	2	5	4	7	3	1	2	6	89
Porahati					1		35	1	32	4	1	1	4	2	6	16	13	16	11	10	7	11	6	13	5	14	14	4	3	9		29	268
Sadhuhati					1		6		6	13						1	3	3	4	4	4	3	1	5	6	6	3	9	3	2	1	32	116
Sagenna	3				5	6	15		23	12	1	1	6		4	6	7	5	8	5	6	7	9	13	8	11	7	1	7	4		10	190
Surat				1		1	10		9	16			1			2	6	3	10	9	3	5	6	11	5	13	11	8		4	4	61	199
Kaliganj Thana																																	
Barobazar					7		27		5	33	9		12	14	16	17	19	7	7	8	3	10	8	9	5	10	9	9	31	19	17	43	354
Jamal				5	1	12	11		17	3	4		5	13	10	7	11	6	7	6	6	5	7	10	6	5	7	4	4	3		20	195
Paurashava					3		21		20	7	5		5	5	15	29	2	1	11	8	4	16	6	10	7	6	3	1	4	3		33	225
Kashtabhanga					6	1	21			12	12		6	5	19	24	7	11	8	2	8	8	10	11	11	12	8	5	3	2	1	6	219
Kola	6				5		16		12	20	13		2	8	10	10	8	5	10	6	2	7	7	11	8	5	7	5	3	5	3	34	228
Maliat							3		3	7	2			3	3	8	5	1	4	3	3	2	5	11	9	6	6	2	3	3		15	107
Niamatpur					4		23	1	9	27	5		17	9	13	16	22	7	9	6	5	12	9	9	7	7	9	3	3	2		20	254
Raigram	1						8		11	37	4	4	9	1	9	9	13	6	4	4	6	8	8	15	7	12	11	5	8	6	1	48	255
Rakhalgachhi	38	1			1	9	24		1	7	9		14	18	14	13	9	3	9	9	6	1	5	12	17	9	17	1	6	4	1	1	259
Simla Rokanpur																					9	1	6	2	12	1	7	5	3	4	1	1	52
Sundarpur	1				1		10		5	2	2		1	2	5	4	2	5	3	4	3	5	2	12	8	4	4	2	3	3		18	111
Trilochanpur					2	1	29		31	15	18		6	9	24	18	23	6	11	7	3	14	10	14	7	8	13	11	5	5	1	13	304
Kotchandpur Thana																																	
Baluhar							13		11	17						1	2	1		1	6	1	2	7	5	5	6	3	5	6		76	168
Dora	7					3	2		21			1	1	9	7	8	30	9	5	8	11	5	2	14	9	6	7	5	4	2	4	2	182
Elengi	19				6		4		23	5			7	7	7	8	10	1	2	6	19	2	4	9	7	5	5	3	8	4	1	19	191
Paurashava	2				1				14					1	2	2	6	3	2	1	2	1	4	3	5	2		1	4	3			59
Kushna	8			1	1	6	3		28	15		7	7	1	9	7	19	4	4	4	6	9	2	6	11	7	8	3	7	3		21	207
Sabdalpur	3				5				42	7	6		3	9	1	5	10	3	3	4	5	2	2	8	10	7	5	2	5	3		18	168
Moheshpur Thana																																	
Azampur	2					1	2	1	37	11	2	3	12	6	13	11	6	6	6	7	6	9	9	2	5	17	21	3	9	6	1	31	245

Table1.4.2 Number of DPHE Wells Constructed in Each Year from 1970 to 1999. (3/5)

Union	By1970	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	Unkown	Total
Bansbaria	1					1	21		29	11	11		6	6	11	7	3	1			1		9	3	2	6	3	1	4	1		80	218
Fatehpur	5				1		4		24	15	11		5	4	15	12	10	8	8	6	7	9	16	7	15	7	19	14	12	14		15	263
Jadabpur							4		22	25	9	2	11	8	13	11	16	9	7	7	6	6	9	11	9	18	13	12	9	9	2	27	275
Kazirber	1			4			5		27	9	11		6	6	16	14	17	9	10	3	7	8	9	5	8	13	8	7	3	5	1	27	239
Manderbari							5		28	5	2	3	12	3	12	14	12	9	13	6	4	10	6	13	3	9	5	8	11	4		30	227
Paurashava																1			1	2						15	26	4	1	1			51
Natima	1						7		11	16	6	2	8	6	12	8	9	8	11	2	1		5	9	9	9	8	4		1		66	219
Nepa							10		7	12	4	2	9	7	14	10	13	7	6	10	3	7	6	3	7	6	7	6	3	3		38	200
Pantapara	4					1	3		35	7	8		8	4	10	13	11	5	10	5	7	6	8	9	6	19	10	4	5	6		24	228
Sundarpur							1		6	1	1		1		1	1	3	2	2	3		3	2		6	4	1	1	2				41
Swaruppur	3					1	2		21	1	9	2		4	11	7	10	5	5	4	2	4	7	11	9	5	11	3	4	5		9	155
Syamkur	1						3	1	17	15	5	4	11	4	14	15	11	7	9	5	8	8	10	11	7	10	7	3	7	5		39	237
Sailkupa Thana																																	
Abaipur	1						1		43	5	5	4			9	11	3	6	8	6	8	13	14	14	9	20	17	5	7	3	1	29	242
Bagura							3		7	32	1	12		1	8	7	4	8	11	6	5	18	12	13	10	13	18	9	9	2		53	262
Dhalhara							1		39	5	7	4	4	5	8	3	2	18	16		17	15	5	10	14	19	17	12	7	23	1	34	286
Dignagar	26		1	1	9	4	1	3	4	18		8	6	4	2	5	1	6	3	4	7	7	4	10	13	9	6	12	7		1	1	183
Dudhsar	4						3		13	4	1	1	3		7	2	2	1	8	1	12	13	10	8	9	20	12	1	15	4	2	86	242
Fazilpur							1		39	8	10	1		7	7	7	10	4	6	5	6	7	9	12	17	20	9	14	4	3	5	32	243
Fulhari							3		15	15				7	5	5	7	3			5	4	6	8	6	5	8	1	5	3	1	100	212
Hakimpur							1		36	8	1	11	2	3	9	6		13	18		8	20	9	5	7	8	6	9	5	8	1	49	243
Kancherkol	2								24	1		6		2	15	13	10	12	7	12	15	24	13	19	15	18	22	18	4	8	1	53	314
Mirjapur	49	2		3	2	1	2	2	3	18	35	20			15	10	10	13	11	9	9	26	12	13	10	10	6	4	7	5	2	26	335
Nityanandapur							2		40	8	6	7	1	4	9	11	4	7	12	7	10	3	7	10	13	24	18	2	15	4	3	62	289
Paurashava	1			1			3		5	4		1									3	7	6	7	17	55	18	6	4	1	8	52	199
Sarutia							2		4	11											2		4		3	10	4		1			48	89
Tribeni	58						1		38		10	15	13	8	16	20	19	12	18	9	4	20	11	14	9	5	4	1	4	3	1	23	336
Umedpur							3		22	17				4	10	1		2	13	7	8	14	11	10	10	11	10	5	11	7	1	149	326
Jessore District																																	
Abhaynagar Thana																																	
Baghutia	28				2		17		38	2	10		4	7	8	5	8	4	6	1	4		4	3	5	6	1	8	1	2		3	177
Mahakal	43				4	1	29		69		14		9	7	17	18	4	9	7	8	3		4		1	9	4	11	2	3	7		283
Noapara	23		4		2	1	24		81	2	19		2	16	7	28	22	17	29	14	10		4	4	2	17	4	17	14	15	8	13	399
Payra	9				2		24		13	18	6		2	10	9	4	3	6	13		3		4	4	7	12	3	13	8	8	6	11	198
Rajghat	43				5		13		58	3	17		10	11	13	15	10	9	11	12	9		4	5	3	12	6	13	14	4	3		303
Siddhipasa	61		3		4		44		83		17		1	21	14	14	9	4	19	10	13		5	5	8	15	14	20	17	14	6	1	422
Sridharpur	11						8		18	7	3		1	5	5			4	3	2	6		1	1		6	2	5	4		1	2	95
Subharara	36		1				12			45	10		1	10	7	6	6	4	16	6	14		4	3	11	21	2	8	22	18	3		266
Bagherpara Thana																																	
Bandabilla	28				4	15	3			34	1		1	6	11	14	18	2		2	5		6		6	4	3	4	6	4	7		184
Basuari	8				7	14	1		29	1	4		8	1	2	3	22	7	12	2	5		4	4		8	2	4	12	7		1	168
Darajhat	6			2	13	15			28	9	8		8	6	2	23	18	13	4	1	9		3	4	2	6	2	3	10	6	1	2	204
Dhalgram	13				5	21			1	9	20		7	6	6	2	10	8	17	1	1		3	2	6	3	1	5	4	6	2		159
Dohakula	26		1	1	4	17			51	6			7	6	5	13	8	2	3	2	6		3	3	5	8	3	1	9	6		2	198
Jaharpur	9				2	14	4		48	7	3		8		1	1	14	3	4	1	4		3	4	5	5	2	8	6	10	1	19	186

Table1.4.2 Number of DPHE Wells Constructed in Each Year from 1970 to 1999.

(4/5)

Union	By1970	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	Unkown	Total
Jamdia	17				3	22	1			41			7	2	11	2	19	14	20	3	4		1	8	5	5	3	3	9	5	1		206
Narikelbaria	31				8	20			1	61	3		3	5	8	5	8	3	1	6	6		5	3	8	4	4	2	18	3	1		217
Raipur	23				8	24	3	1	1	48	2		2	3	5	5	16	10	6		1					1		3		3	.	1	166
Chaugachha Thana																																	
Chaugachha	18				1		9		9	2							4		3	3	2		6	7	2	1		16	8	1	11	50	153
Dhuliani	15			7	2	9	5	2	1	1			1	5	3	10	6	5	4	2	3		1	2	7	4	2	4	14	6	9	4	134
Hakimpur	24			2	1	1	7	1	6	8	2				3		9	5	7	3	19		30	10	8	14	13	10	35	21	19	30	288
Jaradishpur	8			1	3	5	4	5	4	1			3	3	6	4	3	4	5	3	3		2	4	1	3	2	4	16	22	12		131
Narayanpur	2						11		8	1			4			1	3	4	5	1	5		5	3	2	14	2	2	3	4	7	62	149
Pashapole	6		1	5	3	2	6	3	11	7	3		6	5	9	5	7	6	7	3	7		14	11	2	11	5	9	14	20	25	38	251
Patibila	14		2	4	10	2	7	5	9	4	3		3	3	9	8	4	3	3	1	5		9	7	5	6	4	16	19	12	18	23	218
Paulsara	2		1	1	2		10	1	5										1		3		6	4	4	5	3	5	7	12	8	64	144
Singhajhuli							4		3	10			5	2		7	6	2	3	3	3		4	14	9	20	7	2	15	15	23	24	181
Sukpukhuria	3					1	16		14	5			7	5	4	1	7	3	10	5	6		13	19	3	5	4	7	21	15	21	109	304
Swarupdaha	34			6	2		16	2	16	8	2		4	1	4	2	6	1	7	6	7		5	14	9	3	9	18	17	14	16	69	298
Jessore Thana																																	
Arabpur	17			1	1		15		3	19	3		5	1	6	11	5	10	1	2	3		11	8	13	3	4	6	9	6	6		169
Basundia	21			8	4		9		42		11		8	1	5	10	6	7	4	1	4		6	12	2	10	4	9	4	2	1	1	192
Chanchra	23			2	2		17		41		10		4	4	13	3	13	4	4	5	2		6	8	3	4	5	21	5	10	9		218
Churamankati	26		3	2	4		12		43		10		22	4	8	8	5	5	6	5	8		4	10	3	3	4	3	4	3		5	210
Diara	13		1		1		27		41	11	11		11	1	4	16	14	6	7	5	6		7	13	9	8	6	11	3	3	13	1	249
Fatepur	13				20				2	46	1		10	6	8	16	7	11	7	2			13	9	5	11	13	22	14	7	13		256
Haibatpur	15		5		5		12		42	1	11		9	2	10	10	6	11	5	2	8		8	10	5	11	4	7	9	12	3		223
Ichhali	6				2		9		10	40	11		7	2	8	6	6	12	6	3	4		6	10	4	10	9	18		7	4	24	224
Paurashava	12				2	1	7		14	3	6		9	2	4	9	12	7	7	4	3		3	4	4	5	2	4		8	1		133
Kachua	11			5	1		2		34		5		7		7	6	3	7	4	1	4		5	12	3	16	10	15	3	4	4		169
Kasimpur	30			1	3		13		63		8		13	5	16	13	10	7	9	8	5		9	16	9	10	8	19	4	11	4	1	295
Lebutala	18			14	3		12		34	1	11		8	7	6	5	5	8	4	4	7		6	10	5	10	10	11	3	7	14	3	226
Naopara	24		4	5	10		10		63	3	16		9	6	11	9	12	20	12	5	12		15	17	14	21	12	22	8	12	11		363
Narendrapur	7				3		17		7	48	12		10	4	17	15	9	28	5	2	5		8	8	3	19	8	14	5	6	1	1	262
Ramnagar	22			2	4		17		63	6	16		9	12	15	18	6	15	7	3	2		10	21	12	14	25	7	8	36	19		369
Seikhhati	17		1	7	3	1	7		15		6		4		3	2	6	6	3	1	3		2	10	1	2	7	6	7	1	1		122
Jhikargachha Thana																																	
Bankra	7				5	9			24		9		6	10	17	13	8	8	10	6	4		8	4	5	9		2	9	4	17	3	197
Gadkhali	35					15			33	7	1		18	8	15	10	10	11	13	10	10		7	1		8			8	3	6		229
Ganganandapur	19				6	11			49		6		7	2	14	3	11	8	10	6	9		8	1	2	8	1	6	4	3	4	1	199
Hazirbag	14				9	14	1		2	27	17		10	11	17	26	5	11	14	8	8		8	4	4	7		5	11	3	9		245
Jhikargacha	69		1		1	17			33	1	8		7	7	33	29	27	19	15	19	11		8			4	1		9	6	12		337
Magura	41			2	4	11				36	9		8	9	15	5	19	16	22	13	9		6	5	1	10	2	2	10	7	4		266
Nabharan	48			1	5	24	1		2	28	11		16	7	28	4	8	12	10	9	6		7	5	4	7		4	6	5	12		270
Nibaskhola	25				4	11	1		5	38	9		7	13	17	14	9	12	14	7	9		10	2	1	7	2	2	8	5	8		240
Panisara	40				2	10	1		32	2	10		15	5	11	12	15	11	10	8	11		8	3	5	10	1	3	7	4	6		242
Shankarpur	23				9	16			6	1	5		10	6	15	20	9	9	20	8	5		7	3	1	8	2	6	9	42	14		254
Simulia	32				5	17			48		14		14	12	19	6	16	12	13	6	7		9		2	6			12	12	11		273
Keshabpur Thana																																	

Table1.4.2 Number of DPHE Wells Constructed in Each Year from 1970 to 1999. (5/5)

Union	By1970	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	Unkown	Total
Bidyanandakati	40			1	1	1	16	1	52	2	10		5	3	11	13	16	4	8	7	7		3				1	6	19	4	6	1	238
Gaurighona	19		2	3		4	1	4	40		3		10	1	6	15	23	6	7	8	4		4	7	2	10	2	29	20	4	5	1	240
Keshabpur	25					1	1	2	66		14			5	14	35	28	7	4	3	10		3	14		12	1	6	15	5	4	2	277
Majitpur	14		3	8		4	1		19	11			6		13	8	22	10	5	4	9		1	7	6	4	1	4	10	2	3		175
Mangalkot	37		3	6	2	5	8	1	38	1	11		5	9	5	12	23	5	4	4	4		4	9	7	2	1	2	21	3	6	1	239
Panjia	39								46		16		3	5	5	7	29	5	11	5	11		4	11	7	3	3	5	19	3	1	2	240
Sagardari	33			1	1	5	21		1	38	16		2	10	14	16	33	8	8	7	5		4	10	9	5	2	3	18	3	11	3	287
Sufalakati	27					1	1		4	28	20		18		3	8	37	9	8	7	8		3	11	7	4	1	3	24	3	1	3	239
Trimohini	20		1	15	14	6	19		29	27	14		12	11	14	17	27	9	8	12	18		5	14	2	14	2	7	17	7	3	24	368
Mamirampur Thana																																	
Bhojgati	21			6	3	2			7		2		4	5	3	3	2	3	3	2	6		6	1	5	1	1	3	1	4	1		95
Chaluahati	49			11	2		1		42		10		2	1		5	4	3	3	2	4		4	3	4	14		2	2	48	1	1	218
Dhakuria	34			3	4	1				22	11		1	6	1	4	5	1	4	3	6		5	4	7	7	9	4	3	8	7		160
Durbadanga	17				9	4	4	1	1	26	4		7	2	8	14	5	5	1		4		3	2	4	2	5	5	4	1	3	2	143
Haridaskati	23			7	6	2			10	8	3	1	8		5	5	8	1	2	4	6	1	7	5	11	11	10	4	4	2			154
Hariharnagar	19			7	6				1	49	4	7	1	4	4	7	8	4	3	1	2	4	4	5	3	7	10	1	1	6	1		169
Jhanpa	17				2	2	1				13	3		3	2	7	20	5	4	5	12	3	4	2	4	7	8	3	5	2	4		138
Kasimnagar	54			11	13	3	1	1	35	24	7	35	8	5	10	14	8	7	9	3	4	10	15	7	4	1	1	2	18	1	1		312
Khanpur	25	1		2	6	7	1		21	4	2	7	4	8	3	8	3	5	6	4	9	5	5	3	8	12	6	1		1		1	168
Khedapar	29	1		5	12	11		1	17	39	9	7	9	5	13	9	10	14	4	6	14	2	8	4	2	10	6	3	6	3	2		261
Kultia	23				8	3			3	26	8	6	9	1	9	24	8	3	4	4	11	1	3	5	9	15	11	6	6	1		1	208
Manirampur	29			3	4	3			13	31	5	6	8	6	5	6	9	5	6	2	4	8	8	5	3	9	2	3	3	7			193
Maswimnagar	45			17	5	8	2		14	53	8	6		12	10	12	8	15	2	5	8	4	5	6	4	8	12	8	4	1			282
Monoharpur	32	1		1	12	7	2		20	4	11	3	6	11	9	24	12	5	19	3	13	4	7	4	7	8	2	9	3	1			240
Nehalpur	42			11	17	5	3	1	36	15	11	11	12	14	23	36	25	14	8	5	20	9	11	6	17	8	7	7	19	36	2		431
Pohita	23				7	1	1		49	15	6	11	6	8	11	5	6	7	9	1	8	4	5	4	4	6	16	8	3	5			229
Shyamkur	43			7	9	12	2	1	69	20	13	17	26	15	7	33	16	9	7	6	11	11	10	6	7	18	13	6	7	12			413
Sharsha Thana																																	
Bagachra	12				3	3	11		1	49	8		3	1	4	5	7	5	2		5	3	7	4	10	9	15	6	3	10	2	12	200
Bahadurpur	26				2	4	9		1	38	9	2	5	6	3	11	9	1	3	1	4	2	9	7	10	6	4	7	2	10	2		193
Benapole	13				3	5	9			12	8	20		4	2	6	6	4	3	3	1	7	7	8	4	8	3	6	3	7	3	1	156
Dihi	25				2	5	18		35	4	13		7	7	6	3	2	2	3	4	5	5	6	3	14	6	11	7	1	8		20	222
Goga	7	1			6	7	11		46	2	19	2		6	5	7	12	3	4	2	5	10	19	5	2	13	12	16	4	7	4	12	249
Kayba	9	1			8	4	14		48	2	9		8	6	2	4	6	4	3	3	1	10	6	4	1	16	23	4	3	11	3	34	247
Lakshmanpur	44			1	6	7	8		28	4	5	1	9	5	8	6	9	5	1	4	9	5	11	5	13	5	10	4	2	9	2	3	229
Nizampur	36			1	3	5	9		25		8		6	5	1	5	8	3	2	1	4	1	7	6	5	1	4	5	2	8	3		164
Putkhali	35				2	6	14		3	63	17	1	10	7	9	6	13	3	4	1	7	9	14	11	13	5	7	9	4	7	2	6	288
Sharsha	27				4	9	23	1	30	2	13	5	9	8	6	33	15	7	2	1	7	12	13	6	11	15	16	9	5	10	4	35	338
Ulashi	12				10	6	14		47	1	14		7	4	6	7	8	5	3	2	6	2	10	3	6	9	5	11	3	6	5	11	223

Table1.4.3 Distribution of DPHE Well in Each Depth(m). (1/6)

Union	<10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	>100	Unkown	Total
Chuadanga District													
Alamdanga Thana													
Alamdanga				2									2
Pourashava	4	4	2	41	4								55
Baradi	2	4	2	46	12							6	72
Bhangabaria	3	1	2	41	6								53
Dauki	3	1	1	40	8								53
Gangni	7	7	2	42	8	1							67
Hardi	4	1	1	44	11								61
Jamjami	2		3	33	8								46
Jehala	3	1	1	55	15	1						1	77
Kalidaspur	6	4	2	69	10								91
Khadimpur	3	4		29								1	37
Khaskara	4	6	1	41	5							2	59
Kumari	3	1	1	40	5								50
Nagdaha	15	2	2	61	24	1		1				19	125
Chuadanga Thana													
Alokdia	8	4	4	46	20	4							86
Begampur	54	13	28	128	26	10					1		260
Pourashava	11	1	4	23	11	1							51
Kutubpur	34	12	22	118	115	20	1						322
Mominpur	31	6	16	107	49	13							222
Paddabilla	3	2	9	47	21	1							83
Shankarchandra	47	22	51	153	50	6							329
Titudaha	59	21	31	175	52	12							350
Damurhuda Thana													
Damurhuda	95	18	29	160	21	13	2					89	427
Darshana	74	20	50	84	20	10						48	306
Howli	71	10	50	143	49	28						108	459
Juranpur	85	15	40	154	21	1					1	73	390
Kapasdanga	130	25	45	97	13	16						46	372
Kuralgachhi	51	16	19	264	25	14						100	489
Natipota	82	12	49	118	35	18	1					133	448
Jibannagar Thana													
Andulabaria	18	8	23	119	50	7	1						226
Banka	29	23	36	155	84	19	1					1	348
Jibannagar	37	15	27	140	59	9	1					14	302
Uthali	31	22	38	190	45	17			2		1		346
Jhenaidah District													
Harinakunda Thana													

Table1.4.3 Distribution of DPHE Well in Each Depth(m).

(2/6)

Union	<10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	>100	Unkown	Total
Bhayna	7			65	78	9							159
Chandpur	7	5	2	85	127	12							238
Daulatpur	6	2	4	125	129	15		1			1		283
Harinakunda	7	3		87	155	3							255
Joradaha	5	1	2	83	83	7							181
Kapashati	10	1		89	131	11							242
Raghunathpur	8	2	3	73	101	4							191
Taherhuda	11	5	3	119	78	4							220
Jhenaidah Thana													
Dogachhi	29	10	16	89	356	46		3				2	551
Fursandi	7	3	20	17	148	21						17	233
Ganna	29	2	16	62	244	32							385
Ghorsal	23	1	3	39	149	13							228
Haldhani	13	1	11	7	112	15						1	160
Harishankar	8	6	1	15	143	14							187
Paurashava	10	2	17	50	170	16							265
Kalicharanpur	8	2	3	21	118	4					1		157
Kumarbaria	14		2	18	93	10	2					17	156
Madhuhati	24		2	41	222	20		1				1	311
Maharajpur	42	6	16	38	212	28							342
Naldanga	18		3	20	189	23							253
Padmakar	8	1	10	15	124	13							171
Paglakanai	3		1	3	75	7							89
Porahati	17	2	4	33	190	21	1						268
Sadhuhati	11		2	13	82	8							116
Sagenna	22	1	7	17	126	17							190
Surat	8	3	3	19	149	17							199
Kaliganj Thana													
Barobazar	22		15	8	244	60	5						354
Jamal	11	5	3	7	155	14							195
Paurashava	11	2	3	3	196	10							225
Kashtabhanga	12	3	4	6	182	11	1						219
Kola	14		3	9	183	18	1						228
Maliat	5	2	1	9	80	10							107
Niamatpur	13	1	5	14	203	18							254
Raigram	12	1	2	13	211	16							255
Rakhalgachhi	10		6	5	220	18							259
Simla Rokanpur					52								52
Sundarpur Durgapur	3	4		3	97	4							111
Trilochanpur	7		4	12	251	30							304

Table1.4.3 Distribution of DPHE Well in Each Depth(m).

(3/6)

Union	<10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	>100	Unkown	Total
Kotchandpur Thana													
Baluhar	6	16	9	13	120	4							168
Dora	13	13	4	20	121	10	1						182
Elengi	8	2	7	20	143	11							191
Paurashava	6	8	3	3	38	1							59
Kushna	12	16	8	19	146	6							207
Sabdalpur	7	4	13	12	124	8							168
Moheshpur Thana													
Azampur	13			24	194	14							245
Bansbaria	8	1	2	15	169	23							218
Fatehpur	7	3	2	26	218	7							263
Jadabpur	13		6	34	214	7	1						275
Kazirber	19	3	6	28	175	8							239
Manderbari	15			13	184	15							227
Paurashava	2			4	41				2		2		51
Natima	12		3	20	182	2							219
Nepa	16		1	12	164	7							200
Pantapara	8	1	3	23	177	16							228
Sundarpur	1		1	4	33	2							41
Swaruppur	8		1	6	134	6							155
Syamkur	24		3	15	173	10						12	237
Sailkupa Thana													
Abaipur	18	2		22	199	1							242
Bagura	18		1	26	206	11							262
Dhalhara	26	1		24	222	13							286
Dignagar	13	2		20	136	12							183
Dudhsar	15	4	2	25	179	17							242
Fazilpur	16	1		28	195	3							243
Fulhari	12	1	4	15	164	15		1					212
Hakimpur	23			12	200	8							243
Kancherkol	12	2	3	33	248	16							314
Mirjapur	41	2	3	17	251	21							335
Nityanandapur	17	3	1	23	233	12							289
Paurashava	2			16	180	1							199
Sarutia	1			1	83	4							89
Tribeni	28	3	9	42	232	20	2						336
Umedpur	18	8		35	250	14					1		326
Jessore District													
Abhaynagar Thana													
Baghutia	13	2	1	9	140	12							177

Table1.4.3 Distribution of DPHE Well in Each Depth(m). (4/6)

Union	<10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	>100	Unkown	Total
Mahakal	17		1	6	220	39							283
Noapara	11		6	8	354	13	3	4					399
Payra	5	3		13	161	11		2			3		198
Rajghat	7	1	3	6	267	19							303
Siddhipasa	27	14	4	11	310	39	1	9	5	1	1		422
Sridharpur	3			2	83	7							95
Subharara	21	1	4	4	196	27	2	2	9				266
Bagherpara Thana													
Bandabilla	14	3	7	7	99	54							184
Basuari	9		2	5	142	10							168
Darajhat	27	6	3	18	132	17	1						204
Dhalgram	8	2	2	7	123	16	1						159
Dohakula	9		5	9	172	3							198
Jaharpur	9	12	4	2	90	69							186
Jamdia	10	7	2	9	167	11							206
Narikelbaria	6	4	1	2	191	13							217
Raipur	4			2	153	7							166
Chaugachha Thana													
Chaugachha	7	3	14	92	34	3							153
Dhuliani	5	2	9	77	40	1							134
Hakimpur	4	44	6	32	174	27			1				288
Jaradishpur	6		1	35	82	7							131
Narayanpur	3	4	2	27	101	12							149
Pashapole	6	7	3	115	110	10							251
Patibila	7	3	7	53	136	11	1						218
Paulsara	8	2	1	70	61	2							144
Singhajhuli	8	8	3	85	76	1							181
Sukpukhuria	10	5	7	54	195	32					1		304
Swarupdaha	15	6	22	66	158	30					1		298
Jessore Thana													
Arabpur	11	2	1	1	135	19							169
Basundia	5		1	3	164	17	2						192
Chanchra	15			2	178	23							218
Churamankati	8	1	3		191	7							210
Diara	10		7	6	217	9							249
Fatepur	6		1		232	16	1						256
Haibatpur	13	1	4	7	184	14							223
Ichhali	9	1	3	1	191	19							224
Paurashava	12	2	1		111	7							133
Kachua	4		2	1	155	7							169

Table1.4.3 Distribution of DPHE Well in Each Depth(m). (5/6)

Union	<10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	>100	Unkown	Total
Kasimpur	10		4	5	267	9							295
Lebutala	7	1	6	3	200	9							226
Naopara	17	3	2	3	330	8							363
Narendrapur	10	6		2	215	27	1	1					262
Ramnagar	35	12	1	4	298	19							369
Seikhhati	2	1	3		106	10							122
Jhikargachha Thana													
Bankra	16	2	3	108	62	5	1						197
Gadkhali	24	15	25	126	34	5							229
Ganganandapur	9	8	17	83	66	15						1	199
Hazirbag	21	9	16	136	50	13							245
Jhikargacha	21	32	93	137	44	10							337
Magura	15	18	45	112	64	12							266
Nabharan	19	17	47	113	56	18							270
Nibaskhola	21	11	22	138	44	4							240
Panisara	21	12	19	126	58	6							242
Shankarpur	19	5	15	129	80	6							254
Simulia	16	6	21	151	63	16							273
Keshabpur Thana													
Bidyanandakati	27		16	24	156	15							238
Gaurighona	15		4	22	159	35	5						240
Keshabpur	27	1		22	213	14							277
Majitpur	10	5	4	35	113	7		1					175
Mangalkot	18	4	7	48	154	8							239
Panjia	10	1	3	17	202	6	1						240
Sagardari	18	2	11	44	183	29							287
Sufalakati	16	8	1	10	186	17				1			239
Trimohini	26	9	13	48	265	7							368
Mamirampur Thana													
Bhojgati	15	1	4	12	49	14							95
Chaluahati	16		14	16	114	57	1						218
Dhakuria	11		1	18	88	42							160
Durbadanga	7	1	3	6	77	48	1						143
Haridaskati	9	2	5	13	74	50	1						154
Hariharnagar	9		13	14	94	39							169
Jhanpa	3	4	12	21	87	11							138
Kasimnagar	22	1	25	35	110	117	2						312
Khanpur	6	1	3	14	90	54							168
Khedapar	25	4	4	17	153	58							261
Kultia	11	2	2	17	98	74	3	1					208

Table1.4.3 Distribution of DPHE Well in Each Depth(m).

(6/6)

Union	<10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	>100	Unkown	Total
Manirampur	16		6	29	113	28	1						193
Maswimnagar	9	8	25	55	153	32							282
Monoharpur	16	7	10	20	124	59					4		240
Nehalpur	52	6	7	27	175	145	17	2					431
Pohita	11	2	11	15	123	67							229
Shyamkur	18	1	11	36	222	119	3	3					413
Sharsha Thana													
Bagachra	7	5	21	103	46	16					2		200
Bahadurpur	10	4	28	118	23	10							193
Benapole	8	5	13	99	21	10							156
Dihi	11	6	39	112	45	9							222
Goga	12	9	27	108	79	13	1						249
Kayba	13	8	44	116	50	14	2						247
Lakshmanpur	11	5	45	124	35	9							229
Nizampur	6	2	30	80	35	10	1						164
Putkhali	15	6	42	156	50	18	1						288
Sharsha	23	10	69	150	68	17	1						338
Ulashi	14	5	27	113	51	11	2						223
Total	**3,150**	**913**	**1,965**	**9,124**	**24,508**	**3,268**	**78**	**32**	**19**	**2**	**20**	**692**	**43,771**

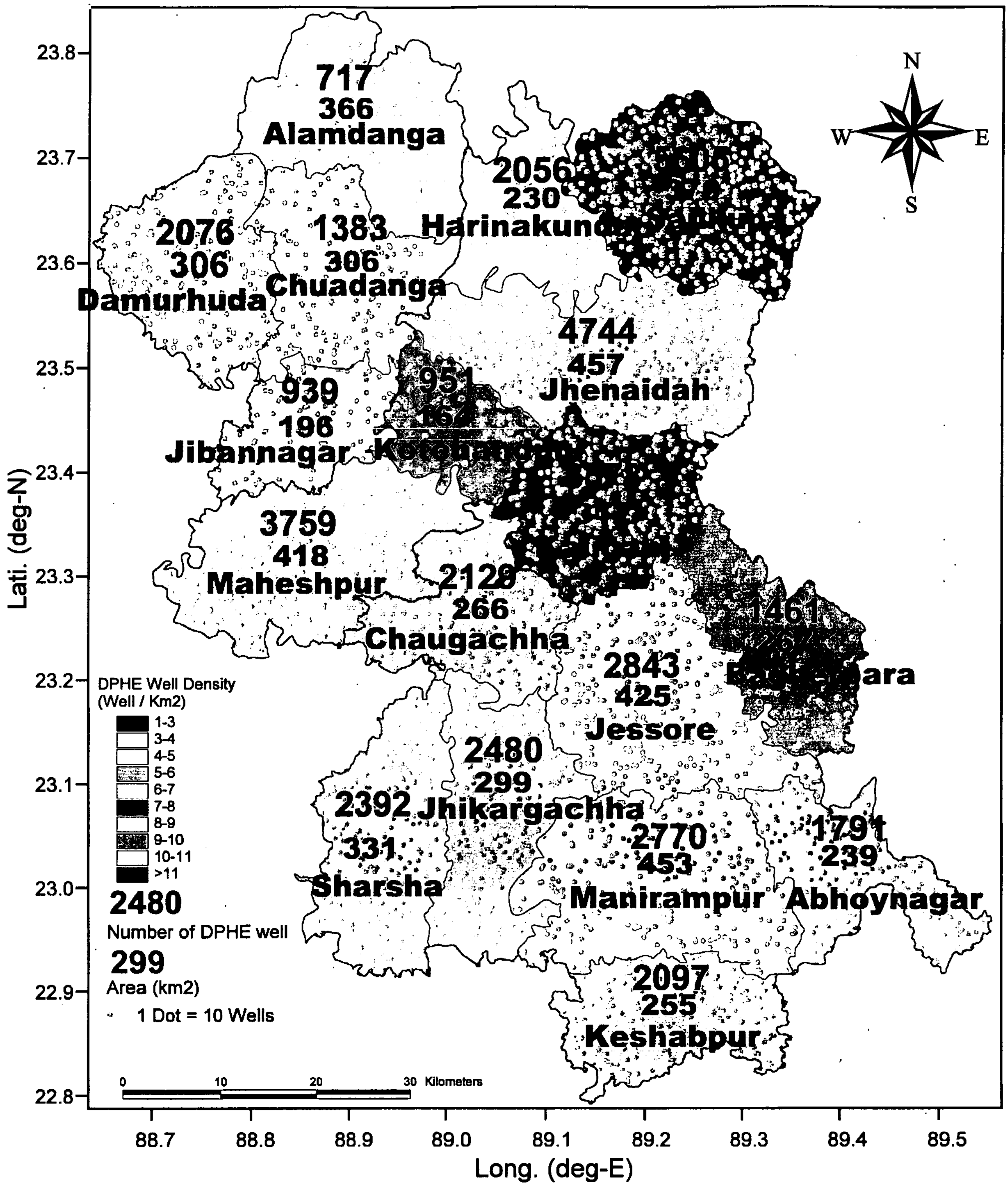
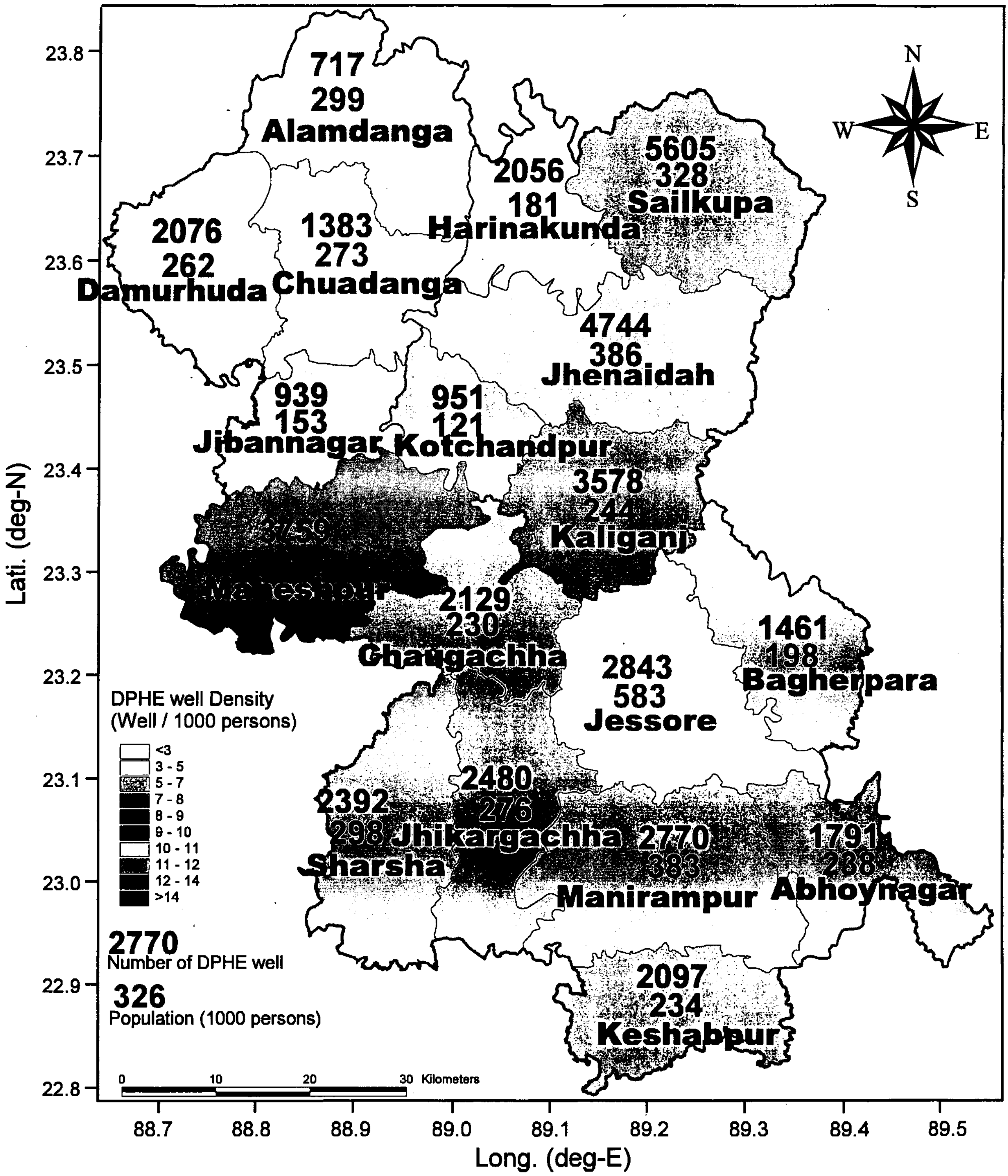


Figure 1.4.1	**DPHE Well Density in the Study Area**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



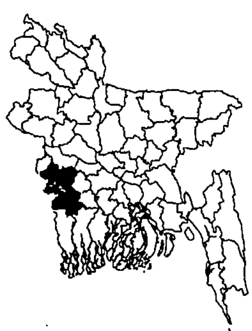


Figure 1.4.2	**DPHE Well Density in the Study Area**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

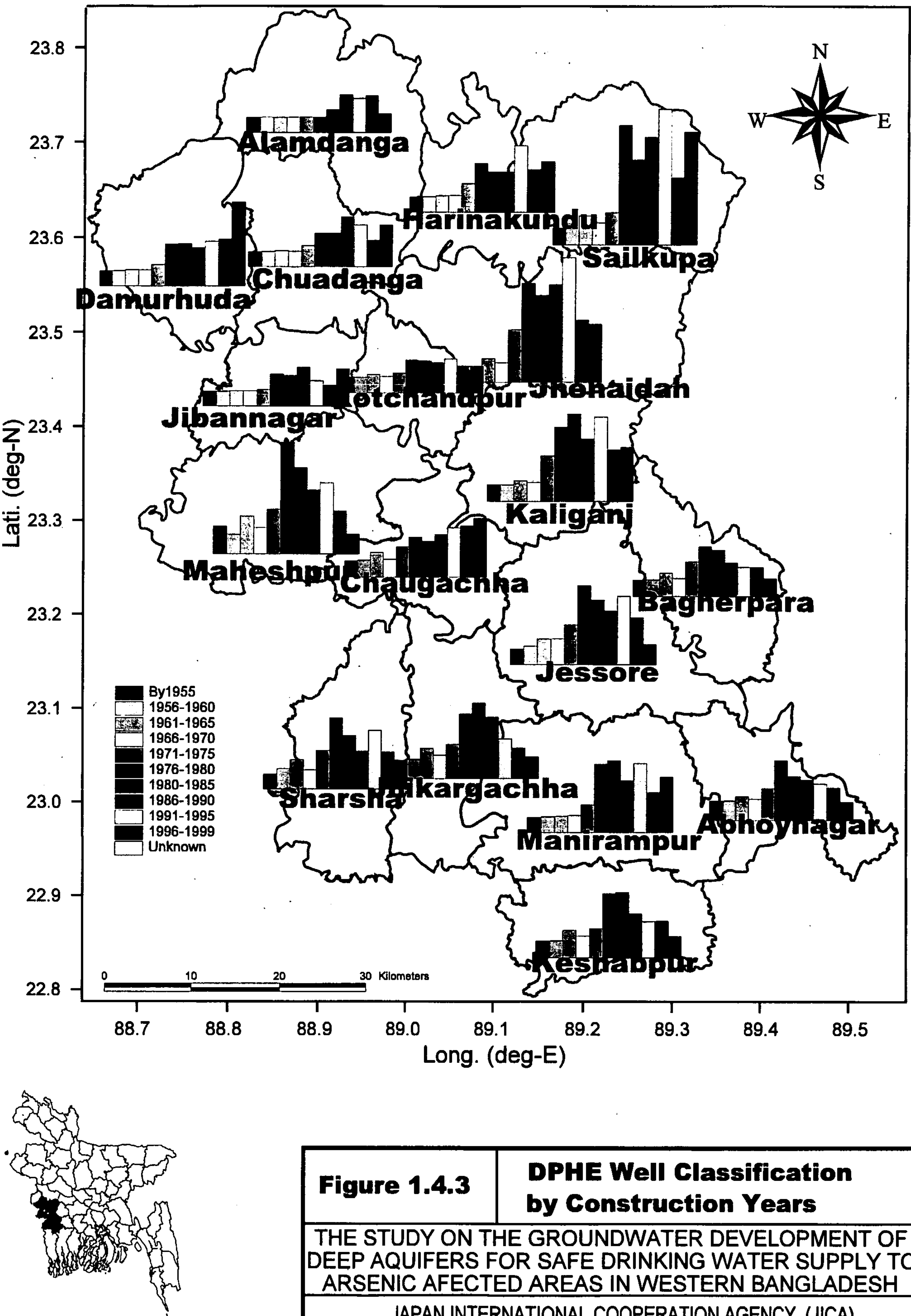


Figure 1.4.3	DPHE Well Classification by Construction Years
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

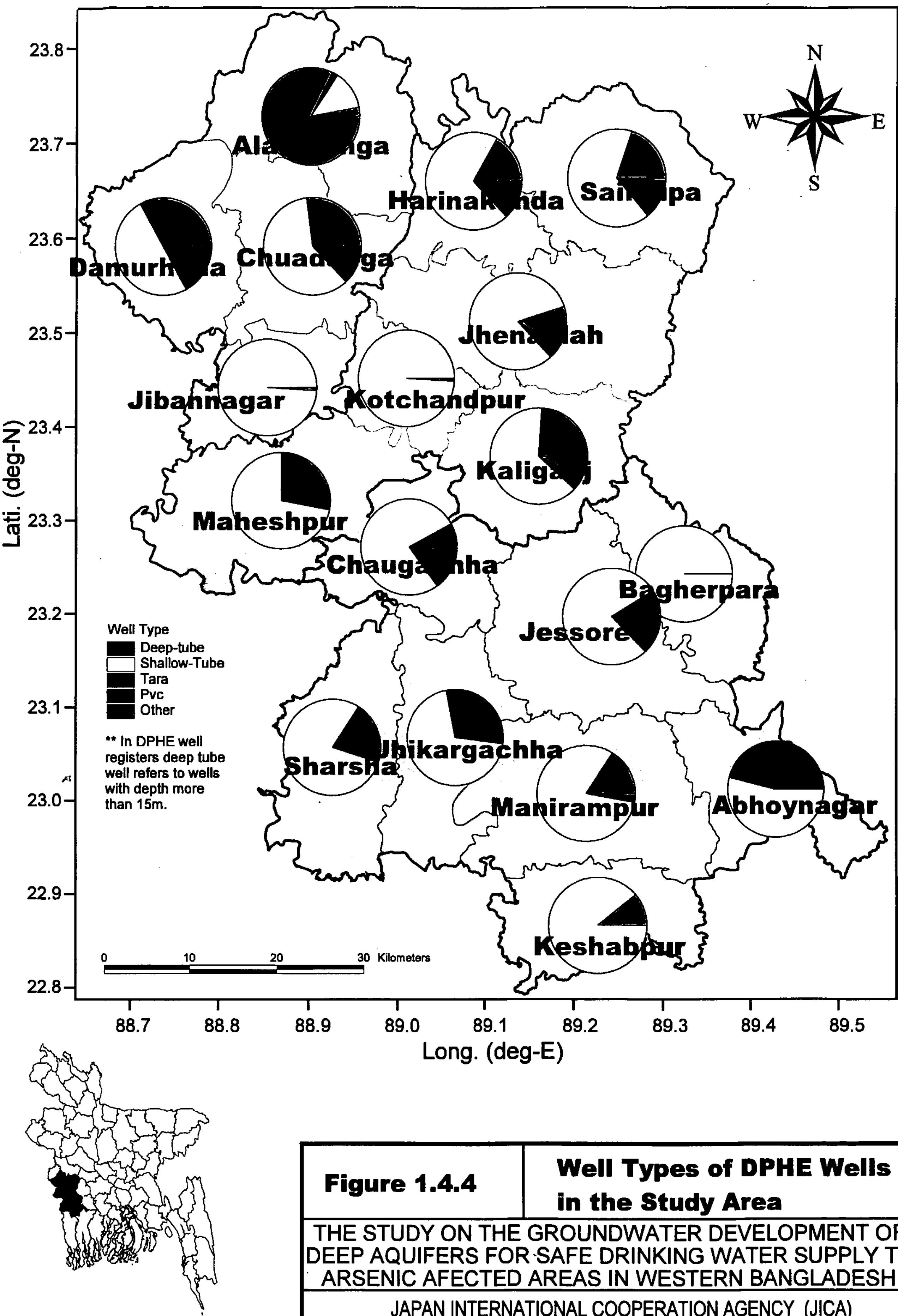
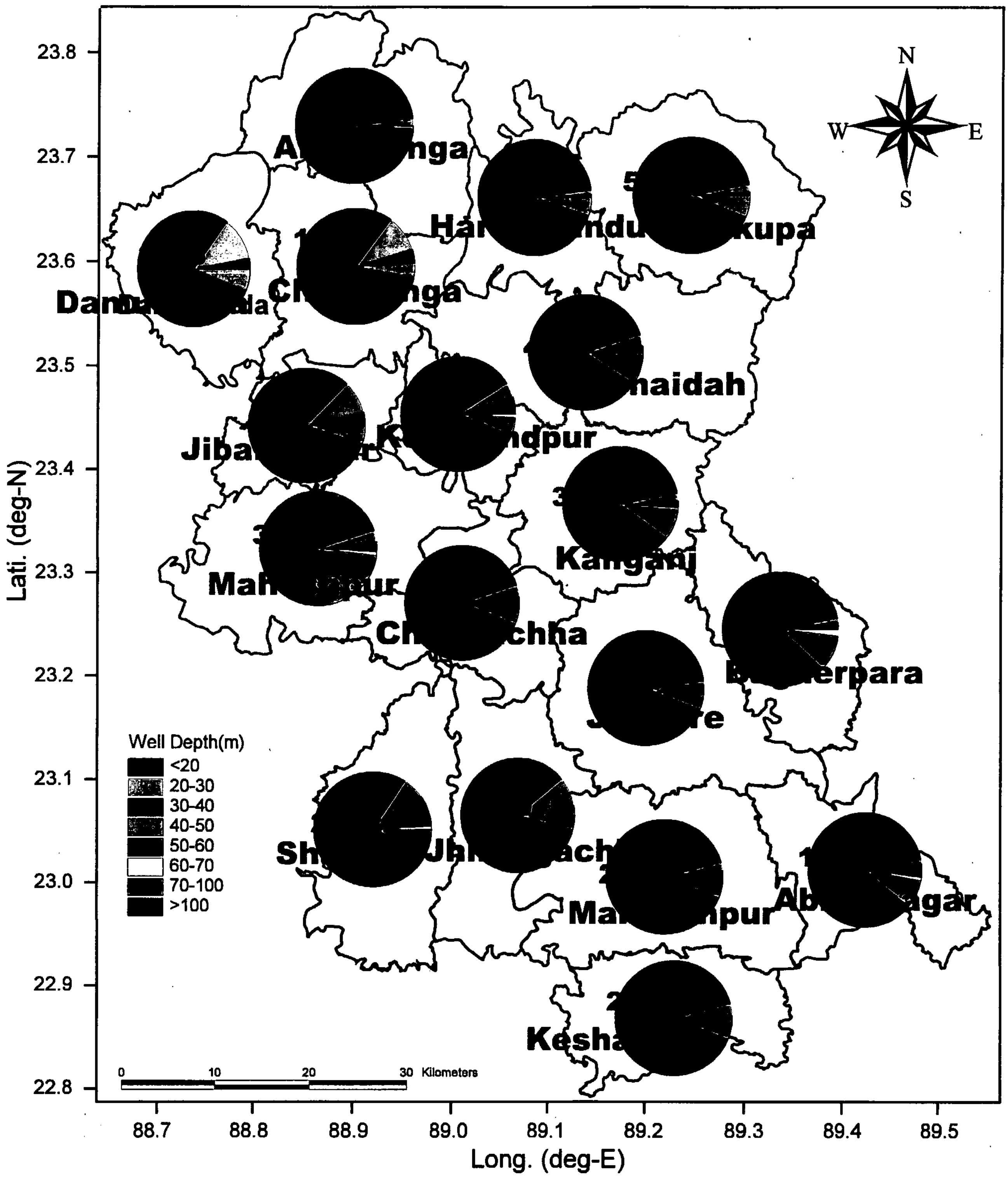


Figure 1.4.4	Well Types of DPHE Wells in the Study Area
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



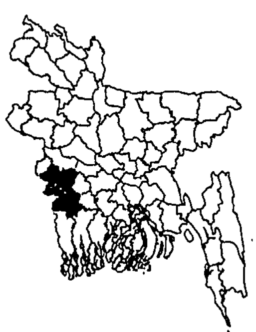


Figure 1.4.5	**DPHE Well Classification by Depth in the Study Area**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

1.5 Analysis by GIS Database

1.5.1 Analysis of Arsenic Contamination Situation

300 DPHE wells were selected all over the study area for water sampling and arsenic analysis to make clear the distribution of arsenic in groundwater. Sampling and water quality analysis were carried out twice in both the rainy and dry season. Based on the analysis results, arsenic contour maps for each season have been created and shown in the main report.

In this study, GIS was used for supplementary analysis to examine the arsenic contamination situation in geographic units.

1) Seasonal Change of Arsenic Level

Figure 1.5.1 shows the seasonal change of arsenic, using the result of analysis by AAS. Arsenic analysis results can be classified into 4 groups on the basis of Bangladesh drinking water standard value, 0.05mg/l:

Group 1: The arsenic level was less than 0.05mg/l in both the rainy and dry seasons. Wells within this group can be identified as meeting the Bangladesh water quality standard, and were colored blue in the map.

Group 2: The arsenic level was over 0.05mg/l in both seasons. Wells within this group can be ascertained as facing an arsenic problem, and were colored red.

Group 3: The arsenic level was over 0.05mg/l only in the rainy season, but less than the standard value in the dry season. Wells in this group were colored green.

Group 4: The arsenic level was over 0.05 mg/l only in the dry season, but less than the standard value in the rainy season. Wells in this group were colored purple.

The majority of wells on the map were indicated in blue or red to give a relatively clear indication of whether the water can be used for a drinking water supply or not.

On the hand, some wells were represented in green or purple, to indicate that the arsenic level goes over the Bangladesh water standard value only in certain seasons. Although it still remains necessary to confirm why this change occurred, the following reasons could be taken into consideration.

- The arsenic level in those wells is closely approaching the value of the Bangladesh water quality standard. Therefore, the change could be caused by very small or permissible analysis deviation, which exists in all kinds of chemical analysis because of the limitation of the analysis equipment and other unavoidable reasons.
- The arsenic level in those wells actually did change with seasons resulting from the change of water quality caused by groundwater recharge, discharge and flow.

Further monitoring and investigation are necessary to make sure where and which one mentioned above would be the main reason for this kind of seasonal change in arsenic levels. However, it could be suggested that the suitability of water from those wells is quite dubious, because at the least the arsenic level there is as high as or near the Bangladesh water quality standard value, even though the value might not be exceeded at times.

The following table gives the frequency of the 4 groups.

Group	**1(Blue)**	**2(Red)**	**3(Green)**	**4(Purple)**
Frequency	186	94	10	8

Wells in groups 2 to 4 can be considered as having an arsenic problem. And the proportion of dubious wells out of them is about 20%.

Generally, water quality standards are used for distinguishing whether the water could be used for drinking purposes or not. For arsenic, however, WHO set a guideline value of 0.01mg/l, which is stricter than the Bangladesh water quality standard value. These two standard values were used for classification of surveyed wells to provide a reference for examining the suitability of water there. The result of the classification is shown in Figure 1.5.2.

From all the Thanas in the study area, arsenic contaminated wells were ascertained, and arsenic contamination is more serious in the western part than in the eastern part. If judging the suitability of water quality by the present Bangladesh standard, 6 Thanas from Chuadanga、Jibannagar, Chuagachha, Jhikargachha, Sharsha and Keshabpur can be identified as facing a serious problem because more than 50% of the wells there are in excess of the standard value of 0.05mg/l in both the rainy and dry seasons. In contrast, the proportion of the same kind of wells in 4 northeastern Thanas, Harinakunda, Jhenaidah, Kaliganj and Bagherpara, is less than 25%. However, this proportion changes to over 50% if the applied standard is shifted to the WHO guideline value.

2) Arsenic Affected Population

Rather than the number of arsenic contaminated wells, the arsenic affected population is a more important issue to heed. Based on the ratio of contaminated wells, the affected population was estimated in each Thana, and the result is shown in Figure 1.5.3.

Two (2) numbers were expressed in each Thana to show the estimation results using different contamination ratios. One of the numbers, Pop1, gives the population estimated by the ratio of wells with arsenic level over 0.05mg/l in both seasons. The other number, Pop2, gives the population estimated by the ratio of wells with an arsenic level over 0.05mg/l at least once in either the rainy or dry season.

There is no question that Pop2 is equal to or larger than Pop1, however, what needs to be made clear about the difference between Pop1 and Pop2 is that this difference gives us an idea of the population who uses groundwater with an arsenic level as high as or near the water quality standard value, but possibly less than the value with the change of seasons.

Therefore, if Pop1 could be classified as facing a serious arsenic contamination problem, the population corresponding to the difference between Pop1 and Pop2 could be considered as under the risk of arsenic contamination, but the problem is not as serious as with Pop1.

The estimation result of arsenic affected population in 2001 is shown in Table 1.5.1.

Table 1.5.1 Estimated Population Affected by Arsenic Contamination

Unit: Thousand persons

District	Thana	Affected Pop1*	Affected Pop2**
Chuadanga	Alamdanga	47	110
	Chuadanga	164	191
	Damurhuda	87	109
	Jibannagar	96	96
Jhenaidah	Harinakunda	45	45
	Jhenaidah	62	99
	Kaliganj	26	26
	Kotchandpur	33	33
	Moheshpur	173	173
	Sailkupa	16	16
Jessore	Bagherpara	46	46
	Chuagachha	131	181
	Jessore	81	81
	Jhikargachha	149	170
	Keshabpur	162	162
	Manirampur	133	167
	Sharsha	149	199
	Bagherpara	46	46
Total		**1,626**	**1,930**

Affected Pop1*: Estimated by the percentage of wells with arsenic level over 0.05mg/l in both rainy and dry seasons.

Affected Pop2**: Estimated by the percentage of wells with arsenic level over 0.05mg/l at least once in rainy or dry season.

As a result of this estimation, 1,626 thousand people in the study area can be ascertained as suffering from arsenic contamination. The total arsenic affected population increases to 1,930 thousand, including those who might be affected, or at least using water with arsenic levels near 0.05mg/l.

3) Arsenic Affected Population Density

It seems difficult to solve at once the arsenic contamination problem for the entire affected population and in the whole contaminated area. Countermeasures for the arsenic problem would be formulated and implemented step by step in consideration of all related factors.

Therefore, it is necessary to make clear the priority of formulating and implementing countermeasures. From various factors, the arsenic affected population density is a factor relevant to the efficiency of countermeasures; therefore, the density was calculated and shown in Figure 1.5.4. Similar to the estimation of the affected population, two numbers are expressed in the map.

Within the two densities given on the map, the one related to Pop1 would be taken into high consideration because it is an index concerning the seriously affected population. By this index, Keshabpur Thana has the highest priority, because the density of seriously affected people there is the largest, over 600 persons/km^2.

4) Arsenic Contamination Map

An arsenic contour map has been created and shown in the main report to express the distribution of arsenic concentration, and Figures 1.5.1 to 1.5.4 in above section were created to show the arsenic distribution when examined by water quality standard.

A water quality standard is usually set on the basis of many factors, but not only on the subject substance itself. Therefore, safety is not always ensured, even if the water quality standard is met. Especially with arsenic, since it is not only unnecessary, but also harmful to human health, the ingestion of arsenic should be reduced to as little as possible. On the one hand, because of the restrictions of removal technology, cost of treatment, and so on, the standard value for arsenic could not be set as low as “no detected”, even though this grade standard value has been applied to many subjects such as pesticides.

Therefore, it is necessary to evaluate arsenic not only by water quality standard, but also by the arsenic level itself.

Figure 1.5.5 shows one result of this kind of approach. The arsenic contamination situation was classified by arsenic level, and shown in the pie graph for each Thana. Cool colors (blue and green) give the ratio of the water samples with arsenic levels less than the Bangladesh water quality standard value, and warm color (orange and red) show the ratio of samples over 0.05mg/l.

Obviously, those Thanas can be identified as facing a serious arsenic contamination problem, if the ratio of warm color is large there showing that many samples have exceeded Bangladesh water quality standard value. On the other hand, even if the ratio of warm colors is the same, the arsenic contamination situation could be different.

The ratio of the warm colored portion is near 70% in 2 Thanas, Chuadanga and Keshabpur, indicating a similar result of evaluation by the Bangladesh water quality standard. However, the ratio of the red colored portion is quite different between the two Thanas, about 15% in Chuadanga and 30% in Keshabpur. That is, the ratio of people in Keshabpur who are using water with arsenic more than double the Bangladesh water quality standard value is about twice the ratio in Chuadanga.

The same case can also be found in Jibannagar and its adjacent Thana, Moheshpur. A similar result would be obtained in evaluation by the Bangladesh water quality standard value in these two Thanas, however, the ratio of people in Jibannagar using water with arsenic levels over 0.1mg/l is far larger than the ratio in Moheshpur. Therefore, from the viewpoint of the amount of arsenic ingested, Jibannagar Thana should be considered as facing a more serious arsenic contamination problem than Moheshpur.

5) Relationship between Arsenic and Lithofacies

The result of 300 well survey was also overlain on the geology map (see Figure 1.3.3) to examine the relationship between arsenic and lithofacies. The result of the examination is shown in Figure 1.5.6 and Table 1.5.2. No significant correlation could be found between arsenic level and lithofacies.

Table 1.5.2 Relation between Arsenic Level and Lithofacies

Lithofacies	Now	05T	Pct	01T	Pct	05O	Pct	01O	Pct
Deltaic Sand	3	0	0.0	3	100	1	33.3	3	100
Deltaic Silt	264	84	31.8	169	64	141	53.4	217	82.2
Marsh Clay and Peat	31	8	25.8	17	54.8	16	51.6	26	83.9

Now : Number of surveyed wells
05T : Number of wells with arsenic level over 0.05 mg/l in both rainy and dry seasons
01T: Number of wells with arsenic level over 0.01 mg/l in both rainy and dry seasons
05O : Number of wells with arsenic level over 0.05 mg/l at least once in rainy or dry seasons.
01O: Number of wells with arsenic level over 0.01 mg/l at least once in rainy or dry seasons.

6) Relation between Arsenic and Soil Type

The well survey results were also overlain on the soil type classification map (see Figure 1.3.6) to examine the relation between arsenic and soil type. The result of the examination is shown in Figure 1.5.7 and Table 1.5.3. Like lithofacies, the significant relation between soil type and arsenic could not be identified.

Table 1.5.3 Relation between Arsenic Level and Soil Type

Soil Type	Now	05T	Pct	01T	Pct	05O	Pct	01O	Pct
Clay	16	5	31.3	8	50	8	50	13	81.3
Silty clay	47	9	19.1	26	55.3	27	57.4	39	83
Silty loam and silty clay	10	6	60	8	80	7	70	9	90
Silty clay loam	145	50	34.5	96	66.2	79	54.5	121	83.4
Silty loam & silty clay loam	5	1	20	2	40	3	60	4	80
Silty loam and silty clay	65	17	26.2	39	60	29	44.6	50	76.9
Sandy loam	10	4	40	10	100	5	50	10	100

Now: Number of surveyed wells
05T: Number of wells with arsenic level over 0.05 mg/l in both rainy and dry seasons
01T: Number of wells with arsenic level over 0.01 mg/l in both rainy and dry seasons
05O: Number of wells with arsenic level over 0.05 mg/l at least once in rainy or dry

seasons.

01O: Number of wells with arsenic level over 0.01 mg/l at least once in rainy or dry seasons.

1.5.2 Basic Data for Groundwater Simulation

1) Groundwater Use for Irrigation

The irrigation amount is basic data for groundwater simulation. And the data has to be prepared according to the simulation period and simulation span. In this study, as mentioned in the main report, the groundwater simulation period was specified as the 19 years from 1983 to 2001, and the simulation span was set as one month.

There is no irrigation amount data in the study area; therefore, the irrigation amount was estimated by using GIS.

For the irrigation amount estimation, 5 factors need to be taken into consideration. Each of the factors was set as a layer. All layers were overlain in GIS. The outline of layer construction and analysis flow is shown in Figure 1.6.1.

Basically, the irrigation amount *QI* can be calculated by the following formula:

$$Q_I = (E + I - R) * R_p$$

E : Evaporation

I: Infiltration

R: Rainfall

Rp: Ratio of paddy field

a. Layer 1: Ratio of Paddy Field

Ratio of paddy field is the basic factor for irrigation, meaning the proportion of paddy field to the whole calculated area. The ratio in the year of 2000 is shown in Figure 1.6.2, which was obtained by overlaying the land use map (see Figure 3.1.3) into the simulation domain.

b. Layer 2: Irrigation Pattern by Soil Type

b.1. Irrigation Index

The irrigation amount depends on the consumption of water in paddy fields, which mainly consists of evaporation and infiltration. Evaporation is a meteorological factor, which changes little in plain areas such as the study area. On the other hand, the amount of infiltration depends on soil type and changes largely for different soil.

Therefore, the soil classification map (see Figure 1.3.6) was overlain onto the simulation grid to specify a representative soil type to each mesh of model mush. Figure 1.6.3 shows the resulting soil type specification.

Another important issue is permeability for each soil type. The data from a previous study[4)] was compiled for reference and shown in the following table.

Irrigation Depth for Land Preparation and Land Soaking in mm

Soil type	# of samples	Maximum	Minimum	Average
Sandy loam	7	250	197	218
Loamy1	5	214	186	201
Loamy2	8	204	165	184
Clay loam	2	168	156	162
Clay	1	--	--	120

Referring to the previous study, the irrigation index for all soil types in the study area was specified as follows:

Soil Type in the Study Area	Irrigation Index
Sandy Loam	1.08
Silty loam	1
Silty loam and silty clay loam	0.94
Silty loam and silty clay	0.87
Silty clay loam	0.81
Silty Clay	0.7
Clay	0.6

b.2. Irrigation Unit

Because silty loam is the exact same soil type within the Base Map database and tested during the previous study, it was taken as the basic soil type having an irrigation index value of one (1). The irrigation amount for silty loam was then taken as the irrigation unit *I* and calculated as follows:

$$I = D \times H/A$$

D: Average pump Discharge (lps) ＝43.71 (lps)

H: Average operating hours (Hours) =1074 (Hr)

A: Irrigation area (ha) =18.07 (ha)

Therefore,

I ＝ 9352.5 (m^3/ha) 935.25 mm

b.3. Yearly Infiltration Unit (Qy)

Yearly infiltration unit *Qy* means the infiltration amount of basic type soil for one irrigation period, and was calculated as follows:

$$Qy = R + I - E$$

R: Rainfall = 315mm

I: Irrigation = 935mm

E: Evaporation = 498mm

Therefore,

Qy = 315 + 935－498 = 752 mm

b.4. Daily Infiltration Unit (Qd)

The daily infiltration unit *Qd* means average the daily infiltration amount of basic type soil, and was calculated as follows:

$$Q_d = \text{Qy / (Irrigation days)} = 752 / 212 = 3.547 \text{ (mm/day)}$$

c. Layer 3: Monthly Irrigation Amount

It is well known that irrigation is carried out only in months when the recharge (rainfall) is less than consumption (evaporation and infiltration). Based on the rainfall distribution data from Figure 1.3.5, the irrigation period in the study area was ascertained as 7 months from October to next April. The average irrigation amount for each month in the irrigation period is estimated as follows:

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Evaporation	71.1	62.8	51.4	48.6	59.3	92.9	112
Infiltration	110	106.4	110	110	99.3	110	106.4
Rainfall	134.8	28.5	11.2	12.3	36.8	46.2	45.7
Irrigation	46.3	140.7	150.2	146.2	121.8	156.8	172.7

d. Layer 4: Irrigation Area and its Change

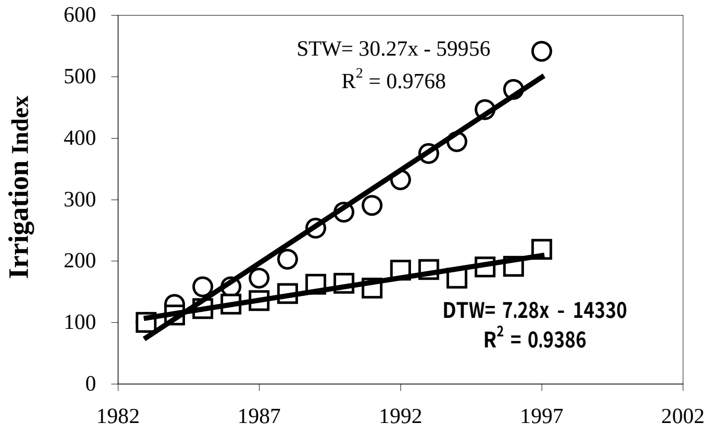
The paddy field ratio in the study area for 2000 was obtained on the basis of land use map; however, the ratio in other years has to be estimated using agricultural statistics and previous studies.

d.1. Farm Land Increase Ratio

Based on the data of GOB[1), 2)], the farmland area has increased since the 1970's, and the average yearly increase ratio is 0.56 %.

d.2. Irrigation Ratio

Irrigation is not carried out for all farmland, including paddy fields. To analyze and arrange the data from GOB[1)-3)], an index of the irrigation ratio was specified and the change of the index is shown in the following graph. The correlation formulas in the graph were used to estimate the irrigation ratio in years later than 1997.



DTW and STW here refer to Deep Tube Well and Shallow Tube Well, respectively.

Based on the data and processing procedures mentioned above, the farmland index and irrigation ratio for DTW and STW in the study area were estimated as follows:

Year	Ratio $_{DTW}$	Ratio $_{STW}$	Farmland Index
1983	3.2	13.3	235
1984	3.6	16.6	236
1985	3.9	19.9	237
1986	4.2	20.1	238
1987	4.3	21.8	240
1988	4.7	25.3	241
1989	5.2	30.9	243
1990	5.2	33.5	244
1991	5	34.3	245
1992	5.9	39.6	247
1993	6	43.9	248
1994	5.5	45.4	249
1995	6.1	51.3	251
1996	6.1	54.6	252
1997	7	61.9	254
1998	6.9	60.5	255
1999	7.1	63.7	256
2000	7.4	67.2	258
2001	7.6	70.3	259

e. Layer 5: Grid Division of Simulation Model

Figure 1.6.4 shows the specification of grid division used for groundwater simulation.

The specification of the groundwater simulation model domain is as follows:

Boundary: BTM Easting 359000 to 456000
Northing 520000 to 638000
WGS84 Longitude 88.61 to 89.6
Latitude 22.7 to 23.84

Number of column = (BTM Easting 456000 – 359000) / 1000 = 97

Number of row = (BTM Northing 638000 – 520000) / 1000＝118

Number of mesh = 97 x 118 = 11,446

Number of mesh to cover the study area 6,018

f. Result of Irrigation Amount Estimation

All 5 layers mentioned above including relative parameters were overlain into GIS to estimate the monthly irrigation amount for each simulation model mesh. The result of the estimation was shown in Table 1.5.4 and Figure 1.6.5.

In the past 19 years, from 1983 to 2001, groundwater consumption in the study area increased about 5 times from 666 to 3,148 million tons. Out of the total amount, irrigation by DTW increased a little less than 3 times, from 129 to 306 million tons, whereas more than 5 times from 537 to 2,842 million tons by STW.

Figure 1.6.6 shows the estimated monthly irrigation amount. Within an irrigation period from October to the following April, the irrigation amount changes with rainfall and evaporation. The largest irrigation amount appears in April, just before the rainy season, and the smallest one is in October, just after the rainy season.

Figure 1.6.7 shows the distribution of the irrigation amount in 2001 all over the study area. The irrigation amount by STW is as large as about 10 times the amount by DTW.

Figure 1.6.8 gives the irrigation amount by STW in April and October 2001, respectively. The amount in April is as large as nearly twice the irrigation amount in October.

2) Groundwater Use for Domestic Water Supply

Similar to groundwater use for irrigation, it is necessary to make clear groundwater withdrawal for domestic use not only for groundwater simulation, but also for groundwater management.

In a certain period, groundwater use for domestic water supply can be estimated by the following formula:

$$Q_{D} = Pop \times Unit \times Rario\_{GW}$$

Pop : Service population

Unit : Amount of water use per day per capita

$Rario\_{GW}$: Ratio of groundwater use in domestic water supply

Since no previous data on this issue could be collected in the study area, the domestic use of groundwater was estimated on the basis of the data obtained in this study. The estimation was carried out by the procedure shown in Figure 1.6.9.

a. Layer 1: Population

The most important factor for domestic use estimation is population. Within all collected population data, that is the 1974, 1981, and 1991 population censuses and the 2001 census preliminary report, the 1991 census was selected as base data from the criteria of particularity and accuracy.

The population in each year except 1991 was estimated on the basis of the 1991 census and the average yearly population increase ratio calculated using the 1981 and 1991 censuses.

As mentioned in the previous section, the population data from BBS could not be perfectly matched at the Mouza level because the difference of the minimum administrative unit used in the two data sources. Therefore, the population estimation was carried out at the union level, which is a minimum administration unit with reliable population data.

The yearly population increase ratio was calculated at the Thana level because of the lack of unity between the 1981 and 1991censuses at the union level.

b. Layer 2: Land Use

Land use pattern is important for domestic water use estimation, because the water use unit, that is, the water use amount per capita per day is largely different between urban and rural areas.

b1. Urban Area

As with the calculation of farmland distribution, the urban area was obtained by overlaying the land use map (see Figure 1.3.13) on the simulation grid layer (see Figure 1.6.4)

b2. Water Use Unit in Rural Area

No previous survey could be referred to get the water use unit in the rural area. Therefore, the unit was calculated on the basis of the data in the village survey in this study.

Three (3) model villages were selected from each district in the study area. And the water use data from the survey was compiled as follows:

District	Chuadanga	Jhenaidah	Jessore
Unit(l/day/capita)	11.0	13.3	13.8

b.3 Water Use Unit in Urban Area

Different from the rural area, in some urban areas there exist a water service system as well as private wells with an electricity power pump, therefore, the water use unit is larger than the rural area. The water use unit in the urban area was specified as 30 liters per day per capita, which is about 2.5 times that in the rural area.

c. Layer 3: Ratio of Groundwater Use

Domestic water use can be calculated just by overlaying layer 1 and layer 2. However, as groundwater is not the unique source for domestic water supply, the ratio of groundwater withdrawal in the whole domestic use is requested for this estimation.

The present ratio of groundwater withdrawal was set as 90% to be a base ratio of the estimation;

the ratio for other years was estimated using the ratio of wells by the calculation year multiplying to the base ratio.

For the same reason mentioned in the section on the well inventory data, although all wells in DPHE well registers have been matched into Mouza unit, actually union is the minimum administration unit in the well inventory with relatively reliable well location information.

Therefore, the ratio of wells of each calculation year to all present wells was calculated in union unit, and the number of wells in union unit in each year were as shown in Figure 1.4.3 and Table 1.4.2.

d. Layer 4: Grid Division of Simulation Model

Grid division of simulation model is the same as layer 5 for irrigation use estimation.

e. Yearly Groundwater Withdrawal for Domestic Use

Figure 1.6.10 and Table 1.5.5 show yearly groundwater withdrawal for domestic use in the study area during the simulation period.

From 1983 to 2001, domestic water use increased with the increase in population in the study area. On the other hand, contrasting to the average yearly increase ratio of population in this 19 year period, which is about 2%, the average yearly increase ratio of groundwater withdrawal for domestic use is as large as 3 times, being about 6%, as a result of the rapid progress of groundwater development from the second half of the 1970s to the first half of the 1990s.

Another tendency indicated by the estimation result is that the increase of groundwater withdrawal for domestic use changed to a little slowly from the second half of the 1990s, in comparison with former years.

f. Distribution of Groundwater Withdrawal for Domestic Use

Figure 1.6.11 shows the distribution of yearly groundwater withdrawal for domestic use throughout the study area in 2001. For the majority of mesh, where the rural area is distributed, yearly groundwater withdrawal for domestic use changes from 1,000 to 8,000 tons/km^2/year. On the other hand, yearly groundwater withdrawal for domestic use in the urban area changes from 15,000 to 58,000 tons/km^2/year, far larger than that in the rural area.

g. Total Groundwater Use

Figure 1.6.12 shows the total groundwater use in the study area in years of 1983, 1991 and 2001. In the study area, groundwater use can be generally classified into irrigation by shallow tube well (STW) and deep tube well (DTW), and domestic use.

Out of these 3 groundwater use portions, STW holds the largest proportion and the most rapid rate of increase. In contrast, domestic use holds the highest priority in water development;

however, the proportion of it is the smallest, less than 1%.

3) Arrangement of Lithofacies Data

The specification of aquifers is the basic requirement of groundwater simulation as mentioned in the main report. The specification was performed on the basis of the result of the core boring survey with reference to existing log data as mentioned in the main report. GIS was used in this specification to assign the lithofacies data into each mesh of the simulation model.

Five (5) layers were specified in the model, however, several layers are combined into Figure 1.6.13 to 1.6.15 to show depth of top, thickness of combined layer, and thickness of accumulated clay layer within the upper layer (layer A+B), middle layer (layer C) and lower layer (layer C+D).

1.6 Basic Data for Priority Project Area

Based on all the results in this study, a master plan was formulated for solving the problem of arsenic contamination, as well as improving the condition of domestic water supply. According to the seriousness of the arsenic problem, the arsenic affected area was classified into urgent area and semi-urgent area, and the implementation of countermeasures was suggested step by step according to the priority of urgent situation (refer to the main report).

Basic information about the area and population are compiled in Mouza unit for each urgent situation group and shown in Tables 1.6.1 and 1.6.2.

The population in year 2001 was estimated by the same procedure and parameters as the population estimation for domestic water use calculation. Populations for the 16 Mouzas within the supplementary survey are obtained from the result of the socio-economic survey.

Reference

Strategies and program framework for Agricultural Development in Bangladesh, GOB, 1996.

Agricultural Year Book. 1998.

Evolution of Irrigation Technology and Its Impact on the Development of Farming Systems and Environment in Bangladesh, M.S.U Talukder and M.S.Alam, 1993.

Irrigation management for crop diversification in Bangladesh. M.R.Biswas, M.A.S.Mandal, 1993.

Table.1.5.4 Groundwater Withdral for Irrigation in the Study Area (1983 to 2001)

Unit : Million Ton

Year	Jan		Feb		Mar		Apr		Oct		Nov		Dec		Yearly		
	DTW	STW	DTW	STW	DTW	STW	DTW	STW	DTW	STW	DTW	STW	DTW	STW	DTW	STW	Total
1983	20.2	83.9	16.7	70.0	21.5	90.1	23.8	99.3	6.4	26.6	19.3	80.9	20.7	86.3	129	537	666
1984	22.5	105.1	18.7	87.6	24.1	112.8	26.7	124.3	7.1	33.3	21.7	101.2	23.1	108.1	144	673	817
1985	24.6	125.7	20.6	104.6	26.5	134.8	29.1	148.4	7.8	39.8	23.7	121.0	25.3	129.1	158	804	961
1986	26.2	127.0	21.9	105.8	28.2	136.2	31.0	150.0	8.3	40.2	25.2	122.2	27.0	130.5	168	813	980
1987	27.3	137.8	22.8	114.8	29.3	147.8	32.3	162.8	8.6	43.7	26.3	132.7	28.1	141.6	175	882	1,056
1988	29.8	159.6	24.8	132.9	32.0	171.2	35.2	188.5	9.5	50.6	28.7	153.6	30.6	164.0	191	1,021	1,212
1989	32.7	195.2	27.2	162.6	35.1	209.3	38.6	230.5	10.3	61.8	31.5	187.8	33.6	200.5	209	1,248	1,458
1990	33.2	211.8	27.7	176.5	35.6	227.2	39.1	250.2	10.5	67.1	31.9	203.8	34.1	217.6	212	1,355	1,567
1991	31.5	216.9	26.2	180.7	33.7	232.6	37.2	256.1	10.0	68.7	30.3	208.7	32.4	222.8	201	1,387	1,589
1992	37.5	250.3	31.3	208.6	40.2	268.5	44.3	295.7	11.8	79.3	36.1	241.0	38.5	257.2	240	1,602	1,842
1993	37.7	277.5	31.4	231.2	40.4	297.6	44.4	327.9	11.9	87.9	36.2	267.1	38.8	285.0	241	1,775	2,016
1994	34.7	286.5	28.9	238.7	37.3	307.3	41.1	338.5	11.0	90.7	33.4	275.8	35.7	294.4	222	1,833	2,055
1995	38.4	324.2	32.0	270.1	41.2	347.7	45.4	382.9	12.2	102.6	36.9	312.0	39.5	333.0	246	2,074	2,320
1996	38.5	344.6	32.1	287.1	41.4	369.6	45.5	407.0	12.2	109.2	37.2	331.7	39.6	354.1	247	2,204	2,451
1997	44.2	391.1	36.8	325.9	47.4	419.5	52.2	462.1	13.9	123.9	42.5	376.5	45.4	401.8	283	2,502	2,785
1998	43.3	382.4	36.2	318.5	46.5	410.1	51.3	451.7	13.8	121.1	41.7	368.0	44.6	392.9	278	2,446	2,724
1999	44.8	402.1	37.3	335.0	48.1	431.2	52.9	474.9	14.2	127.4	43.2	386.9	46.0	413.1	287	2,572	2,859
2000	46.4	424.2	38.8	353.4	49.8	455.0	54.9	501.1	14.7	134.4	44.7	408.2	47.6	435.8	297	2,714	3,011
2001	47.9	444.2	39.9	370.1	51.3	476.4	56.6	524.7	15.1	140.7	46.1	427.5	49.2	456.4	306	2,842	3,148

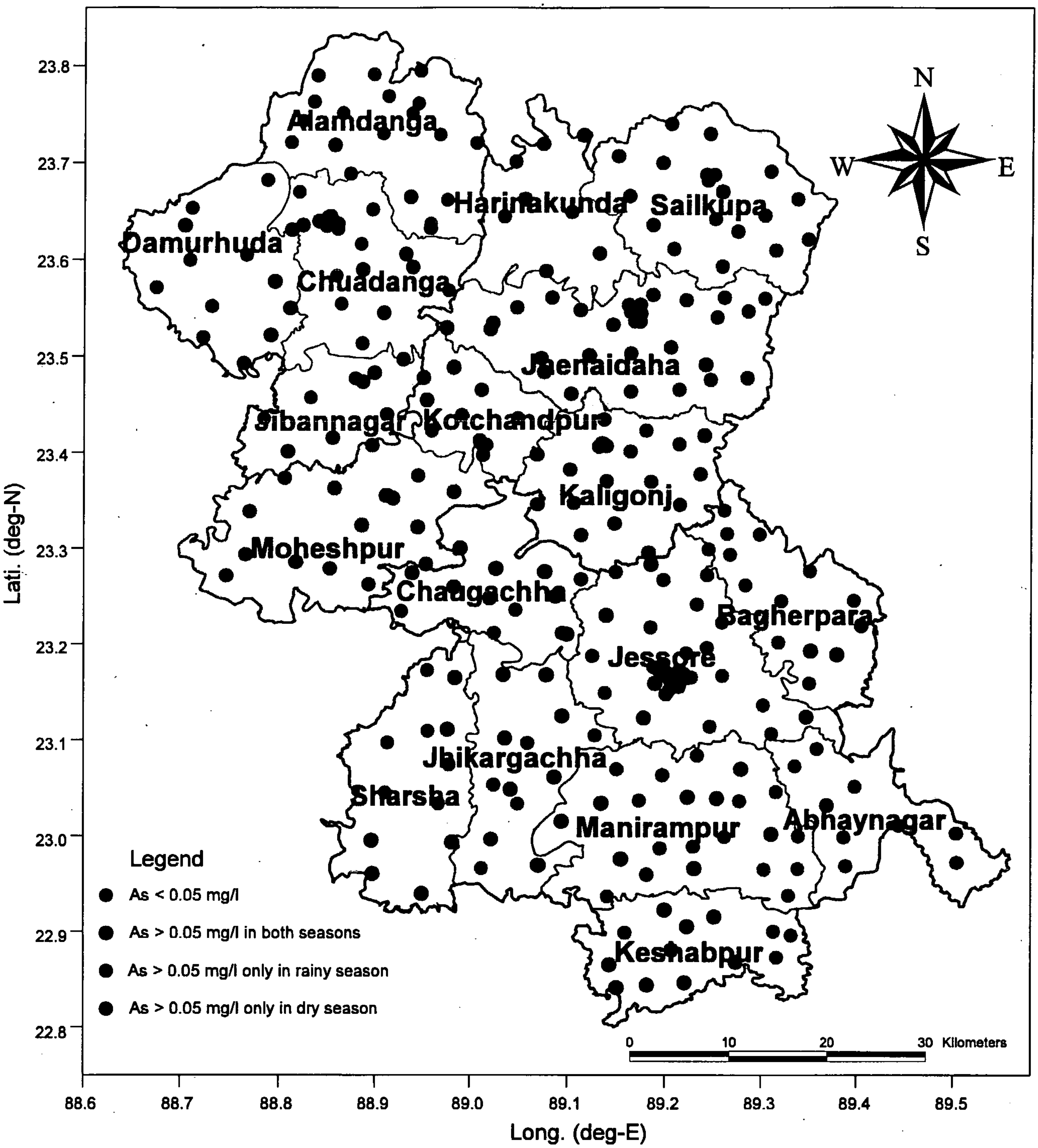
DTW : Deep Tube Well STW : Shallow Tube Well

Table1.5.5 Groundwater Withdral for Domestic Use from 1983 to 2001

Unit: 1,000 ton

Year	Chuadanga		Jhenaidah		Jessore		Whole Study Area		
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Pct*
1983	62	960	322	2,273	386	4,429	770	7,662	9.1
1984	90	1,055	371	2,498	429	4,895	890	8,449	9.5
1985	122	1,167	405	2,755	502	5,388	1,030	9,309	10.0
1986	141	1,284	427	2,970	552	5,778	1,119	10,032	10.0
1987	174	1,466	451	3,212	603	6,184	1,227	10,862	10.2
1988	188	1,561	484	3,415	626	6,472	1,297	11,447	10.2
1989	208	1,730	535	3,643	666	6,875	1,410	12,248	10.3
1990	250	1,866	582	3,904	697	7,208	1,530	12,978	10.5
1991	267	1,963	620	4,194	731	7,632	1,617	13,789	10.5
1992	295	2,091	676	4,520	768	8,080	1,739	14,691	10.6
1993	321	2,290	741	4,850	804	8,496	1,867	15,636	10.7
1994	339	2,444	837	5,285	844	9,052	2,020	16,781	10.7
1995	346	2,582	904	5,681	869	9,504	2,119	17,767	10.7
1996	366	2,687	948	5,995	906	10,015	2,220	18,697	10.6
1997	390	2,856	1,001	6,354	935	10,582	2,327	19,792	10.5
1998	434	3,123	1,057	6,689	995	11,120	2,486	20,932	10.6
1999	466	3,255	1,088	6,902	1,014	11,447	2,569	21,604	10.6
2000	475	3,314	1,111	7,064	1,035	11,693	2,620	22,071	10.6
2001	483	3,374	1,134	7,230	1,055	11,945	2,673	22,550	10.6

Pct : Percentage of Domestic Water Use in Urban Arae



Rainy Season: June - July ,2000
Dry season: December 2000 - January 2001

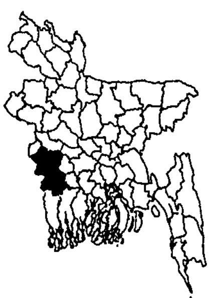


Figure 1.5.1	**Seasonal Change of Arsenic Level in Surveyed Wells.**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

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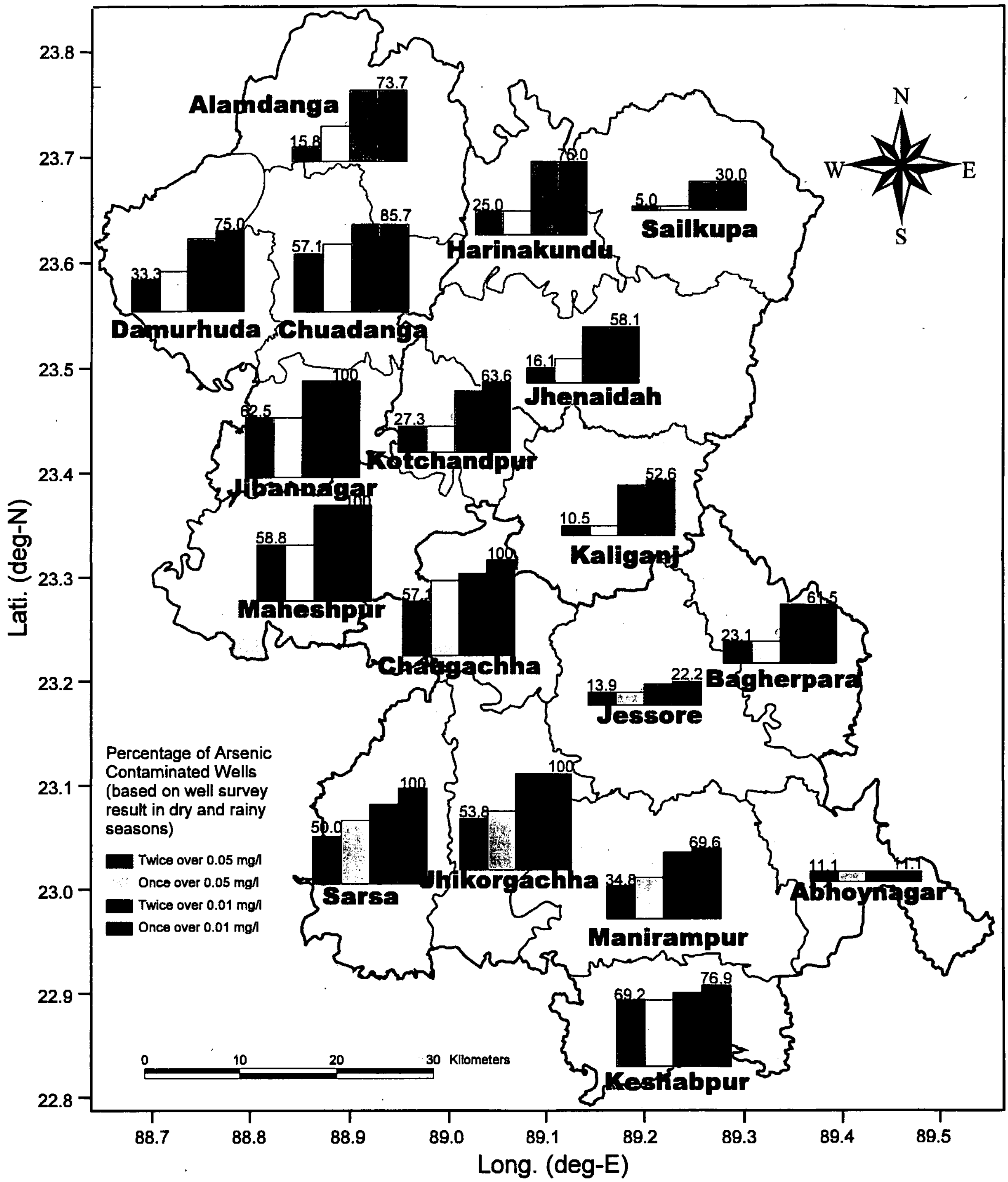

Rainy Season: June - July ,2000
Dry season: December 2000 - January 2001

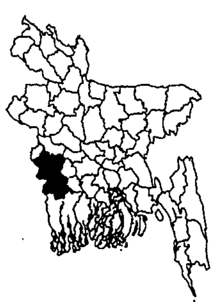

Figure 1.5.2	Distribution of Arsenic Contaminated Wells in the Study Area .
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
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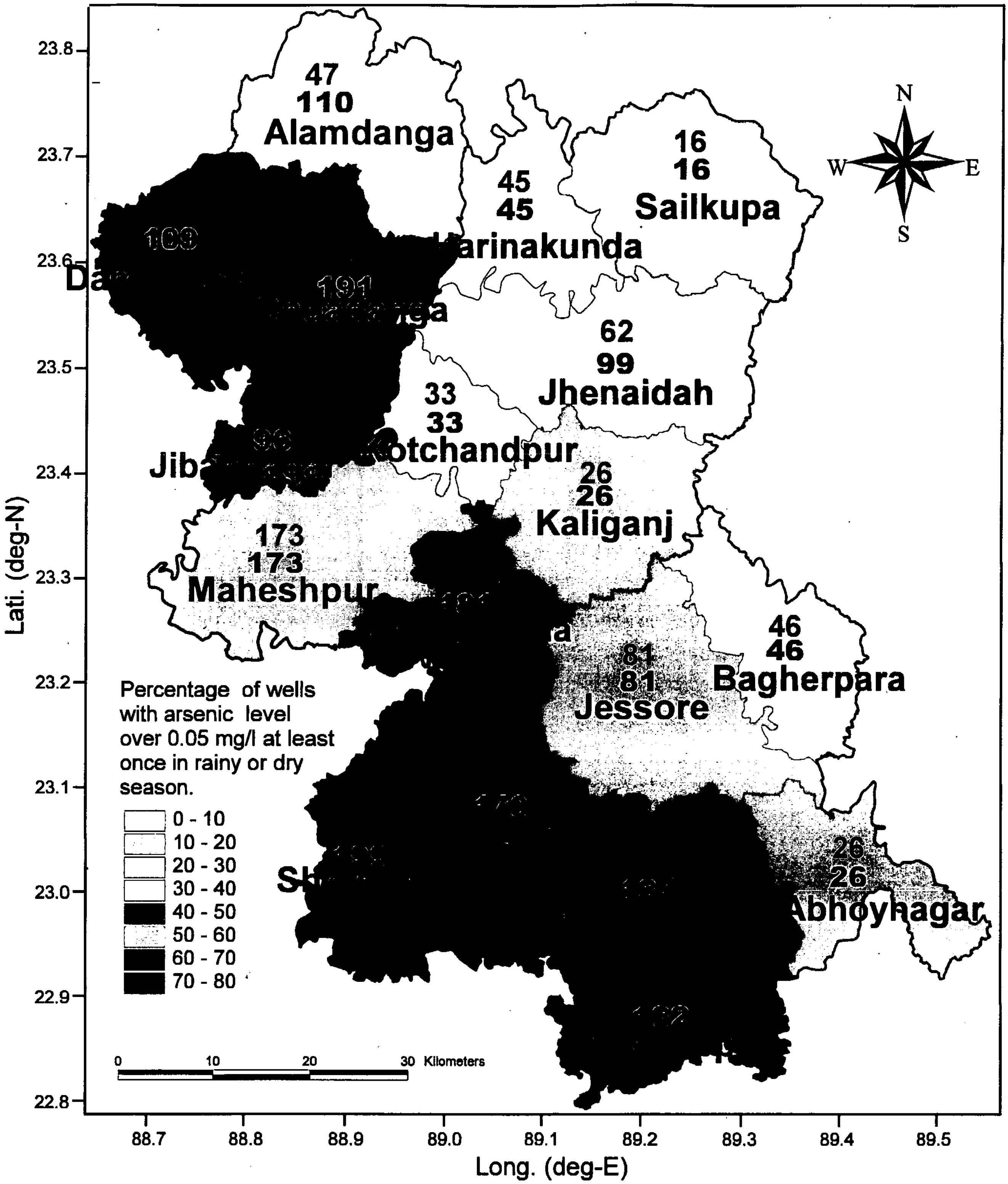

149: Arsenic affected population (X1000 persons) estimatd by the percentage of wells with arsenic level over 0.05 mg/l in both seasons.

170: Arsnic affected population (X1000 persons) estimated by the percentage of wells with arsenic level over 0.05 mg/l at least once in rainy or dry season.

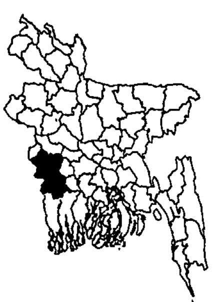

Figure 1.5.3	**Estimated Population affected by arsenic in the Study Area (2001)**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
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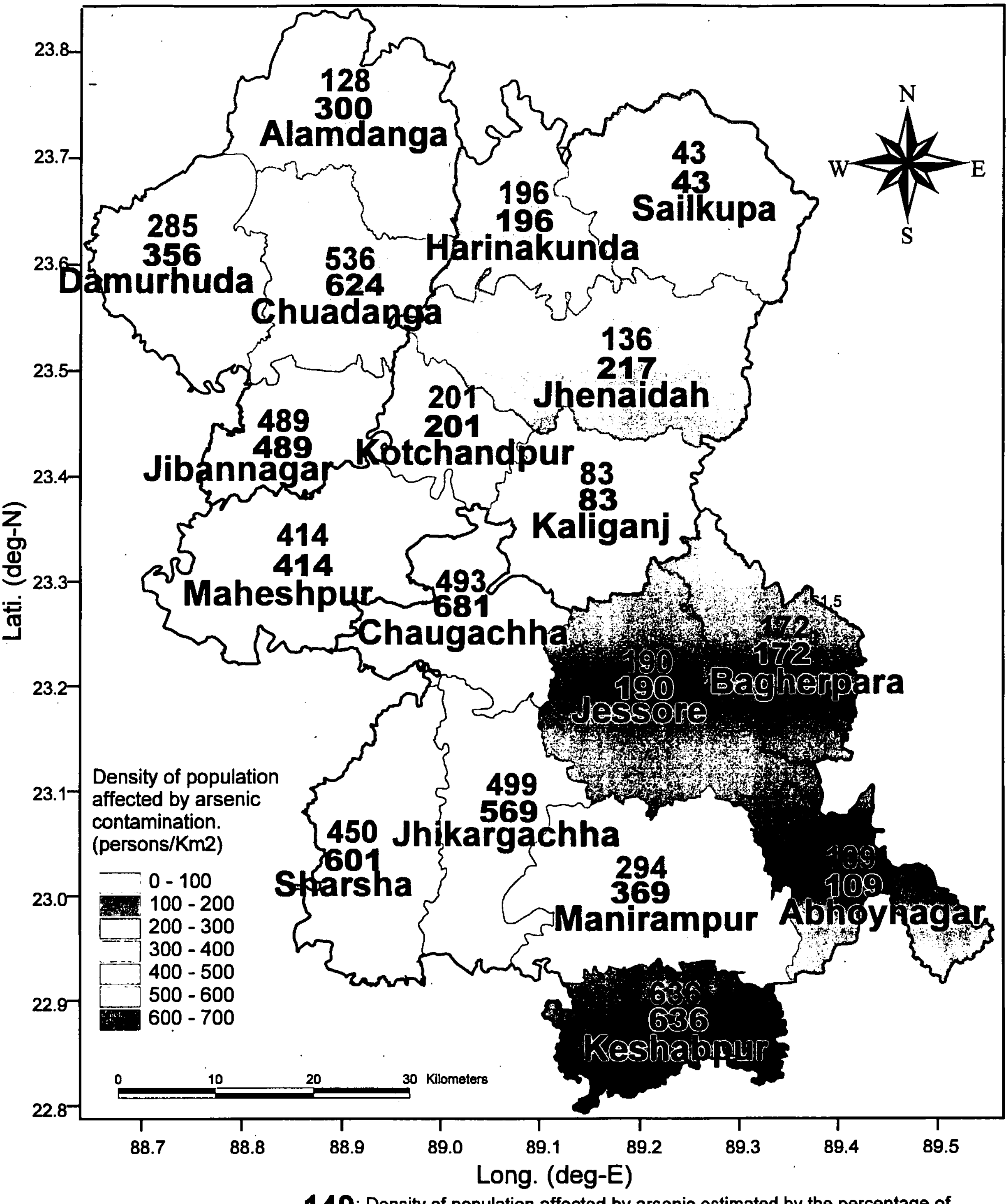

149: Density of population affected by arsenic estimated by the percentage of wells with arsenic level over 0.05 mg/l in both seasons.

170: Density of population affected by arsnic estimated by the percentage of wells with arsenic level over 0.05 mg/l at least once in rainy or dry season.

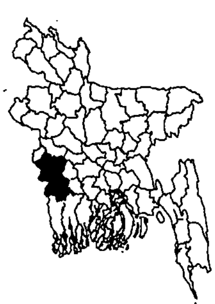

Figure 1.5.4	**Density of Population Affected by Arsenic Contamination**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
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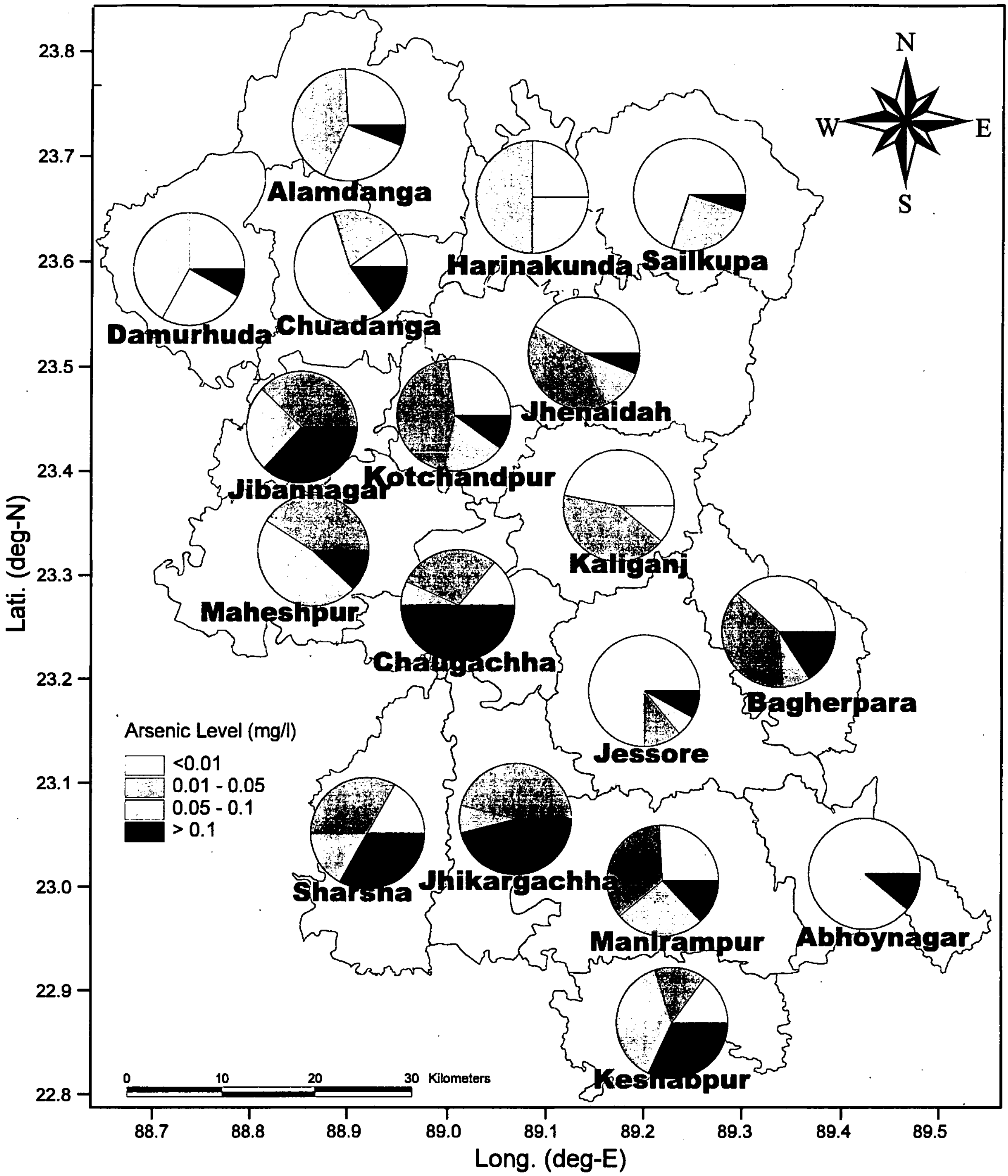

Dry season: December 2000 - January 2001

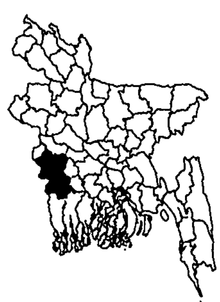

Figure 1.5.5	**Distribution of Arsenic Level in the Study Area**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
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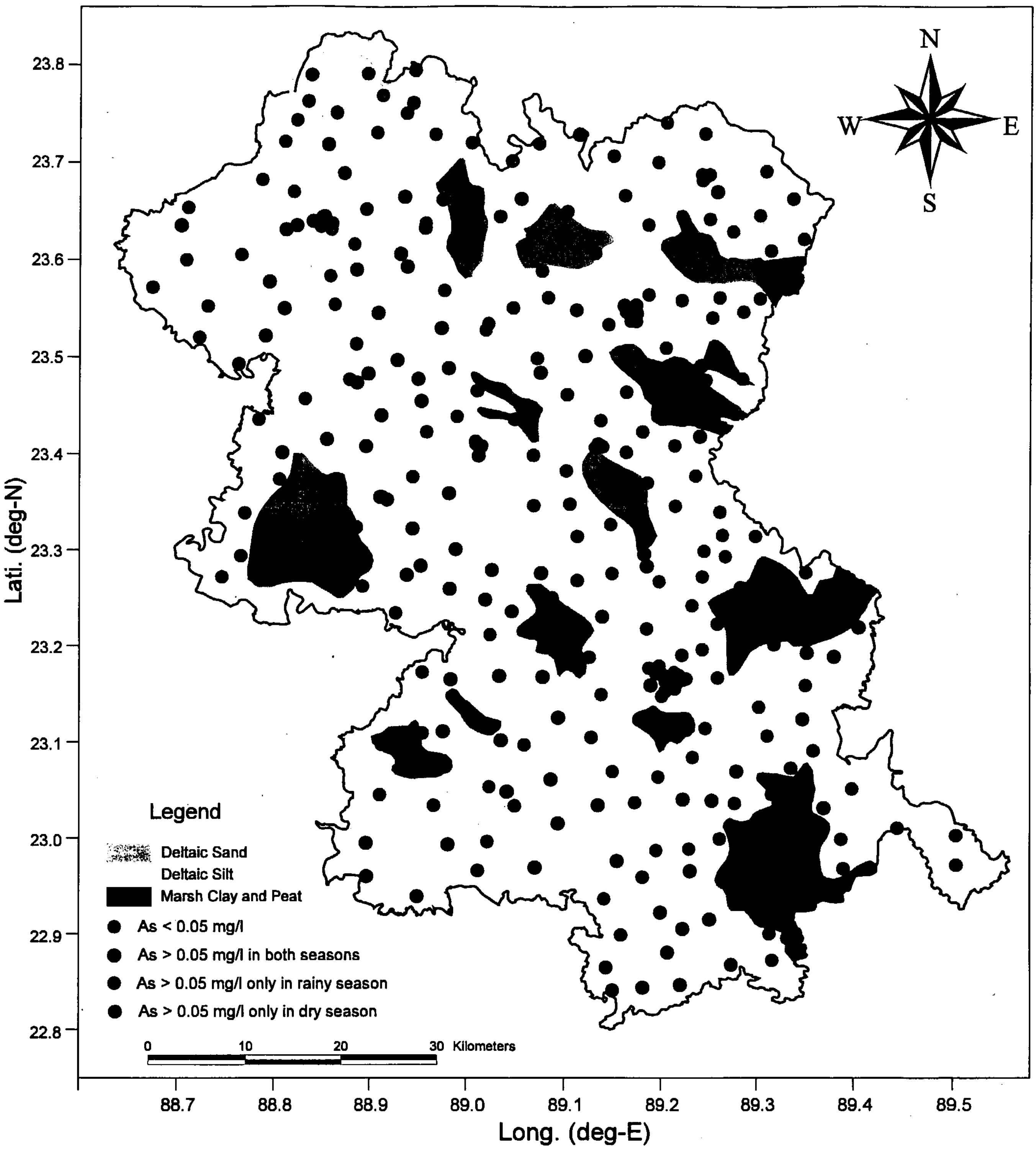

Rainy Season: June - July ,2000
Dry season: December 2000 - January 2001

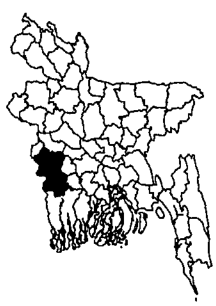

Figure 1.5.6	**Relationship between Arsenic and Lithofacies**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
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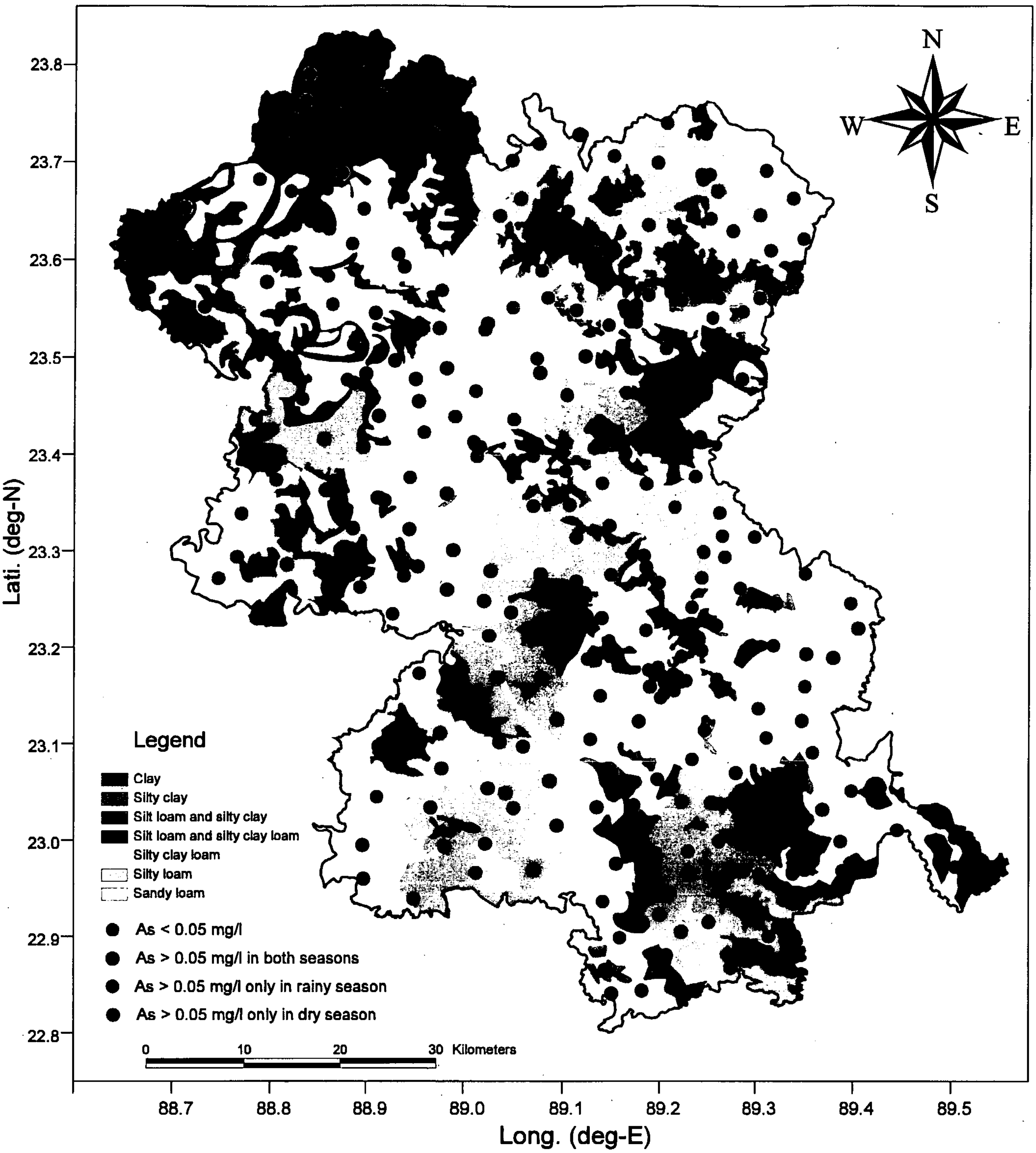

Rainy Season: June - July ,2000
Dry season: December 2000 - January 2001

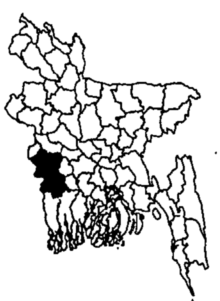

Figure 1.5.7	**Relationship between Arsenic and Soil Type**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

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Table 1.6.1 Basic Information for Urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
Chuadanga						
	Alamdanga	Nagdha	Baleswarpur	3.79	1,471	1,609
		Nagdha	Balierpur	4.48	1,744	1,907
		Nagdha	Chhagharia	2.72	1,027	1,123
		Nagdha	Santa	0.84	632	691
		subtotal	**4**	**11.83**	**4,874**	**5,331**
	Chuadanga	Kutuabpur	Sahapur	1.51	1,095	1,335
		Paddabila	Burapara	1.71	1,407	1,715
		Paddabila	Subdi	4.05	2,365	2,883
		Shankar Chandra	Bahalgashi	2.29	1,538	1,875
		Shankar Chandra	Basu Bandhard	1.65	1,235	1,505
		Shankar Chandra	Bhandardaha	3.63	2,544	3,101
		Shankar Chandra	Chhaygharia	5.63	3,599	4,387
		Shankar Chandra	Jugihuda	1.68	1,247	1,520
		Titudaha	Aria	2.15	1,547	1,886
		Titudaha	Bara Aria	2.37	1,933	2,356
		Titudaha	Bara aria Cha	0.41	582	709
		Titudaha	Bara Salua	4.30	3,080	3,755
		Titudaha	Batkedanga	2.19	1,584	1,931
		Titudaha	Gaherpur	2.46	1,742	2,123
		Titudaha	Garuitupi	2.05	1,423	1,735
		Titudaha	Girishnagore	1.18	1,267	1,544
		Titudaha	Gobargara	2.88	1,943	2,369
		Titudaha	Godhtha Bihar	0.67	729	889
		Titudaha	Kalupol	2.96	2,457	2,995
		Titudaha	Sarabaria	3.66	2,716	3,311
		Titudaha	Sujatpur	1.97	1,387	1,691
		Titudaha	Tegharia	5.25	3,333	4,063
		Titudaha	Titudaha	4.24	2,921	3,561
		subtotal	**23**	**60.89**	**43,674**	**53,238**
	Damurhuda	Darshana	Dakhin Chanad	4.14	2,925	3,566
		Darshana	Sayampur	2.74	2,550	3,170
		Howli	Dudpathlia	4.90	2,760	3,431
		subtotal	**3**	**11.78**	**8,235**	**10,166**
	Jibannagar	Andolbaria	Anantapur	0.86	521	654
		Andolbaria	Andolbaria	6.75	4,079	5,120
		Andolbaria	Bajdia	3.29	1,825	2,291
		Andolbaria	Bidyaharpur	0.85	472	593
		Andolbaria	Ghugagachhi	1.07	603	757
		Andolbaria	Harda	1.99	534	670
		Andolbaria	Karchadanga	2.91	1,573	1,975
		Andolbaria	Kultala	3.57	1,911	2,399
		Andolbaria	Nidhikunda	2.06	1,172	1,471
		Andolbaria	Nischintapur	3.28	1,833	2,301
		Andolbaria	Panka	3.91	2,309	2,899
		Andolbaria	Sahapur	2.61	1,338	1,680
		Banka	Barodi	1.7	1,031	1,294
		Banka	Madhabpur	1.76	1,037	1,302
		Banka	Puranderpur	2.05	1,219	1,530
		Banka	Raypur	10.17	5,656	7,100
		subtotal	**16**	**48.83**	**27,113**	**34,036**
Total in Chuadanga District			**46**	**133.33**	**83,896**	**102,771**

Table 1.6.1 Basic Information for Urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
Jhenaidaha						
	Jhenaidaha	Maduhati	Oaira	1.01	755	957
		Sadhati	Hazra	0.56	227	288
		subtotal	**2**	**1.57**	**982**	**1,245**
	Kotchandpur	Dora	Bagabanpur	0.73	354	411
		Dora	Bhamradanga	3.22	1,216	1,411
		Dora	Chhay Khada	3.77	2,153	2,499
		Dora	Chuadanga	1.65	621	721
		Dora	Dhopabila	2.72	1,686	1,957
		Dora	Dyamampur	1.15	1,056	1,226
		Dora	Lakshmipur	1.53	1,208	1,402
		Dora	Malikpur	1.76	928	1,077
		Dora	Sibnagore Ban	2.03	917	1,064
		Dora	Suadi	3.32	2,009	2,332
		subtotal	**10**	**21.88**	**12,148**	**14,098**
	Moheshpur	Manderbari	Alisa	0.48	511	714
		Manderbari	Babla Mathbha	1.43	801	1,119
		Manderbari	Bathangachai	2.90	2,769	3,868
		Manderbari	Biswanathpur	0.94	913	1,275
		Manderbari	Habaspur	1.94	1,701	2,376
		Manderbari	Joka	1.07	801	1,119
		Manderbari	Kamalpur	1.34	1,350	1,886
		Manderbari	Maheskhola Bh	3.20	1,703	2,379
		Manderbari	Manderbaria	2.83	1,936	2,705
		Manderbari	Sohapur	1.85	1,406	1,964
		Manderbari	Syamanagore	0.73	696	972
		Natma	Idrakpur	5.90	6,105	8,529
		Natma	Jagusa	3.21	697	974
		Natma	Kuripol	1.08	1,045	1,460
		Natma	Narayanpur N	5.92	1,735	2,424
		Natma	Nasti	1.83	1,554	2,171
		Natma	Shibnandapur	4.12	634	886
		Natma	Surjydia	2.07	1,997	2,790
		Natma	Ujjawalpur	2.95	781	1,091
		Pantapara	Boalia	0.77	730	1,020
		subtotal	**20**	**46.56**	**29,865**	**41,722**
Total in Jhenaidah District			**32**	**70.1**	**42,995**	**57,065**
Jessore						
	Chaugachha	Phulsara	Afra	2.27	2,104	2,911
		Swarupdaha	Andarkota	4.07	3,207	4,437
		Phulsara	Aradaha	1.53	1,292	1,788
		Phulsara	Balidapara	1.90	1,523	2,107
		Phulsara	Barulia	1.43	1,112	1,539
		Patibaria	Bhabanipur	0.49	441	610
		Phulsara	Chanda	0.68	4,561	6,310
		Chaugachha	Chandpur	0.70	721	998
		Phulsara	Charabari	1.75	1,424	1,970
		Chaugachha	Chaugachha	4.49	4,786	6,622
		Swarupdaha	Chotar huda	1.43	1,238	1,713
		Jagadispur	Dakhin sagore	0.91	875	1,211
		Chaugachha	Deghalsinga	2.41	2,413	3,339
		Phulsara	Durbarkathi	1.29	1,079	1,493

Table 1.6.1 Basic Information for Urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Sukpujuria	Durgapur	0.82	776	1,074
		Patibaria	Ichhapur	1.73	1,579	2,185
		Phulsara	Jamiar	1.54	1,353	1,872
		Jagadispur	Jhihnakunda	0.82	738	1,021
		Jagadispur	Kandi	2.95	2,426	3,357
		Swarupdaha	Kanysanpur	1.31	1,216	1,682
		Chaugachha	Kayarpara	3.22	2,863	3,961
		Swarupdaha	Kharincha	3.37	3,233	4,473
		Singhajhuli	Khorda Singha	0.94	879	1,216
		Swarupdaha	Madhabpur	3.93	3,199	4,426
		Phulsara	Mahamadpur	0.55	449	621
		Singhajhuli	Majali	0.80	752	1,040
		Sukpujuria	Makapur	1.60	1,189	1,645
		Chaugachha	Manmathapur	0.73	671	928
		Jagadispur	Marua	2.50	2,285	3,161
		Patibaria	Muktadaha	1.86	1,564	2,164
		Sukpujuria	Nagor barani	2.36	2,040	2,822
		Patibaria	Panchnamia	1.45	1,315	1,819
		Phulsara	Phulsara	2.94	2,662	3,683
		Sukpujuria	Purbapara	5.04	4,103	5,677
		Patibaria	Purhuda	1.25	1,142	1,580
		Phulsara	Rainagore	0.98	916	1,267
		Patibaria	Rostampur	1.47	1,282	1,774
		Patibaria	Sadipur	0.81	724	1,002
		Jagadispur	Safarajpur	1.61	1,398	1,934
		Phulsara	Salua	3.51	3,163	4,376
		Swarupdaha	Sanchadanga	1.92	1,733	2,398
		Phulsara	Sibnagore	0.85	732	1,013
		Singhajhuli	Singhajhuli	1.79	1,834	2,537
		Sukpujuria	Sukpujuria	4.51	3,635	5,029
		Swarupdaha	Swarupdaha	3.15	2,771	3,834
		Patibaria	Teghari	2.18	1,695	2,345
		Swarupdaha	Tengurpur	1.15	1,077	1,490
		Phulsara	Tentulbaria	1.19	1,043	1,443
		Swarupdaha	Trinibus	2.15	1,644	2,275
		subtotal	**49**	**94.4**	**86,857**	**120,173**
	Jessore	Arabpur	Amanganti	1.38	2,253	2,801
		Churamankati	Jaghatia	2.96	2,271	2,796
		Jessore Paura	Kholadanga	1.64	3,833	4,718
		Arabpur	Krishnabati	0.80	1,108	1,364
		Chanchra	Madia	4.42	5,292	6,514
		Arabpur	Media	0.16	963	1,185
		Chanchra	Tapaswidarga	1.46	2,467	3,037
		subtotal	**7**	**12.8**	**18,187**	**22,415**
	Jhikargachha	Simulia	Ajmatpur	1.69	1,142	1,420
		Bankra	Alipur	0.56	939	1,167
		Magura	Angardaha	0.92	754	937
		Magura	Arblngti	0.62	433	538
		Magura	Bahairampur	0.65	553	687
		Bankra	Bankra	3.15	2,528	3,143
		Panisara	Barini	2.98	2,067	2,570
		Nabharan	Baysa	2.63	2,062	2,563
		Panisara	Bejatala	0.1	336	418
		Bankra	Bilkachua	0.58	431	536
		Nabharan	Chandpur	1.61	1,038	1,290
		Magura	Chaveda	1.4	1,156	1,437

Table 1.6.1 Basic Information for Urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Magura	Daharamagura	3.02	2,208	2,745
		Simulia	Dasatina	1.7	1,350	1,678
		Bankra	Digdana	2.11	1,857	2,308
		Simulia	Ganadharpur	1.73	1,262	1,569
		Ganganandapur	Ganganandapur	4.11	2,983	3,708
		Nabharan	Haria	1.81	1,377	1,712
		Jhikargachha	Hariadiara	2.68	1,902	2,364
		Simulia	Jamalour	0.3	277	344
		Ganganandapur	Jiulgachha	1.12	696	865
		Ganganandapur	Kagmari	3.22	2,069	2,572
		Simulia	Khaskoli	2.48	1,584	1,969
		Simulia	Khorda Matio	1.43	906	1,126
		Panisara	Kriahna Chand	1.22	840	1,044
		Ganganandapur	Krishana chan	0.96	557	692
		Simulia	Madukhali	2.54	1,705	2,119
		Magura	Magura	6.27	4,024	5,002
		Nabharan	Manikali	1.27	855	1,063
		Bankra	Matsia	3.11	2,619	3,256
		Magura	Misridiara	3.08	2,043	2,540
		Magura	Mohammad pur	0.94	700	870
		Panisara	Mohinihati	2.82	1,853	2,303
		Bankra	Mukundapur	1.27	818	1,017
		Ganganandapur	Nabagram	0.97	686	853
		Nibaskhola	Naoali	1.2	1,095	1,361
		Panisara	Narangall	2.25	1,421	1,766
		Simulia	Palla	1.71	1,175	1,461
		Simulia	Radhanagar	2.64	1,505	1,871
		Panisara	Ragunathpur	0.81	788	980
		Hazirbag	Raipatan	2.82	1,771	2,202
		Nibaskhola	Sadipur	3.38	1,892	2,352
		Jhikargachha	Sagarpur	0.78	663	824
		Simulia	Sagarpur	0.54	367	456
		Magura	Santoshnagore	2.23	1,579	1,963
		Simulia	Simulia Gopinathp	3.69	2,560	3,182
		Simulia	Sriramkathi	1.37	1,015	1,262
		Jhikargachha	Srirampur	5.29	3,828	4,759
		Bankra	Ujjalpur	4.11	2,776	3,451
		Simulia	Uttar Rajpur	0.93	786	977
		subtotal	**50**	**100.8**	**71,831**	**89,294**
	Keshabpur	**Keshabpur**	**Altapol**	**5.05**	**6,022**	**8,702**
		Keshabpur	**B.Narendrapur**	**3.17**	**3,096**	**4,153**
		Keshabpur	**Bajitpur**	**0.73**	**809**	**1,142**
		Keshabpur	**Baliadanga**	**1.82**	**1,925**	**2,907**
		Keshabpur	**Brahmakati**	**1.5**	**1,231**	**1,448**
		Keshabpur	**Byasdanga**	**1.23**	**992**	**1,118**
		Keshabpur	**Habaspol**	**0.82**	**799**	**1,107**
		Keshabpur	**Keshabpur**	**0.42**	**1,000**	**1,512**
		Keshabpur	**Khatiakhali**	**0.7**	**648**	**895**
		Keshabpur	**Madhyakul**	**3.04**	**2,702**	**3,485**
		Keshabpur	**Magradanga**	**1.34**	**1,142**	**1,303**
		Keshabpur	**Ramlhandrapur**	**1.96**	**1,303**	**1,359**
		Keshabpur	**Sabdia**	**1.17**	**1,013**	**1,720**
		Keshabpur	**Sarfabad**	**0.8**	**549**	**519**
		Keshabpur	**Sujapur**	**1.48**	**1,117**	**1,373**
		Panjia	**R. Bankabarsi**	**2.43**	**1,769**	**1,941**
		Bidyanandakati	Bidyanandakat	1.12	786	921

Table 1.6.1 Basic Information for Urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Bidyanandakati	Kaliari	1.54	1,075	1,260
		Bidyanandakati	NA	0.58	2,085	2,444
		Bidyanandakati	NA	2.97	1,583	1,855
		Majitpur	Kusaldia	0.52	606	710
		Majitpur	Majitpur	2.3	2,093	2,453
		Majitpur	Mirzapur	1.84	1,144	1,341
		Mangalkot	Baradoathra	1.43	949	1,112
		Mangalkot	Barenga	2.59	2,041	2,392
		Mangalkot	Basudia	2.33	1,544	1,810
		Mangalkot	Chhato pather	2.28	1,755	2,057
		Mangalkot	Chuadanga	1.52	1,354	1,587
		Mangalkot	Ghagha	0.92	546	640
		Mangalkot	Kandarpara	3.02	1,291	1,513
		Mangalkot	Kedarpur	0.89	1,532	1,796
		Mangalkot	MAgurKali	1.16	1,255	1,471
		Mangalkot	Mangalkot	2.51	2,442	2,862
		Mangalkot	NA	0.57	547	641
		Mangalkot	Panchpot	0.37	960	1,125
		Mangalkot	Panchril	1.49	1,228	1,439
		Mangalkot	Ramdrishanpur	1.56	1,007	1,180
		Panjia	Belakati	2.33	1,934	2,267
		Panjia	Brahmandanga	1.98	1,378	1,615
		Panjia	Harbhanga	2.95	2,019	2,366
		Panjia	Imamnagore	0.41	401	470
		Panjia	Itad	1.65	634	743
		Panjia	Lepakati	0.37	429	503
		Panjia	Madardanga	1.68	1,831	2,146
		Panjia	Mandradanga	1.48	989	1,159
		Panjia	P. Bankabarsi	1.15	873	1,023
		Panjia	Panjia	2.95	1,893	2,219
		Panjia	Sataiskati	0.73	346	406
		Sagardari	Bishnupur	1.86	1,354	1,587
		Sagardari	Dharamapur	1.28	1,355	1,588
		Sagardari	Fathpur	0.5	557	653
		Sagardari	Gibindapur	0.85	875	1,026
		Sagardari	Gopsona	2.31	1,986	2,328
		Sagardari	Kasta	1.97	1,789	2,097
		Sagardari	Mansbaria	1.73	881	1,033
		Sagardari	Meherpur	3.01	2,146	2,515
		Sagardari	Mirzapur	1.41	1,116	1,308
		Sagardari	Ragurampur	0.51	472	553
		Trimohini	Barandali	4.77	3,634	4,259
		Trimohini	Sahapur	0.94	744	872
		Trimohini	Saraskathi	0.7	423	496
		subtotal	**61**	**100.7**	**83,999**	**102,523**
	Manirampur	Durbadanga	Bantbila	1.62	1,386	1,640
		Durbadanga	Durbadanga	5.03	3,461	4,096
		Hariharnagore	Barachetta	0.99	853	1,010
		Hariharnagore	Binodkati	0.58	353	418
		Hariharnagore	Boarkhatara	0.16	296	350
		Hariharnagore	Damurkhali	2.53	1,823	2,158
		Hariharnagore	Enayetpur	1.46	1,540	1,823
		Hariharnagore	Gopunahal	0.99	617	730
		Hariharnagore	Hariahrpur	1.42	1,277	1,511
		Hariharnagore	Khatura	1.82	1,330	1,574
		Hariharnagore	Knemkoin	1.66	1,182	1,399

Table 1.6.1 Basic Information for Urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Hariharnagore	Kola	0.85	546	646
		Hariharnagore	Madampur	2.23	1,957	2,316
		Hariharnagore	Madhupur	2.19	1,174	1,390
		Hariharnagore	Mahatabpur	2.19	1,118	1,323
		Hariharnagore	Mohadevpur	0.97	727	860
		Hariharnagore	Pachpota	1.59	1,244	1,472
		Hariharnagore	Rupaspur	2.14	1,263	1,495
		Hariharnagore	Salli	1.51	1,068	1,264
		Hariharnagore	Tajpur	1.80	1,245	1,474
		Hariharnagore	Tentulia	2.30	1,178	1,394
		Jhanpa	Dodria	0.81	578	684
		Jhanpa	Joka	1.69	1,034	1,224
		Jhanpa	Kamalpur	0.80	719	851
		Jhanpa	Lmallikpur	0.42	637	754
		Jhanpa	Shalakdaha	2.03	1,397	1,654
		Khenderpar	Baro Khender	0.66	403	477
		Khenderpar	Basantapur	0.86	543	643
		Khenderpar	Dighipara	0.85	1,082	1,281
		Maswimnagore	Kismat Chakla	1.03	837	991
		Rothia	Gangali	1.67	1,322	1,565
		Rothia	Maraghacha	1.55	1,239	1,466
		Rothia	Setamatpur	2.09	1,733	2,051
		Shyamkur	Aminpur	1.58	1,607	1,902
		Shyamkur	Bangalipur	0.79	882	1,044
		Shyamkur	Chinadula	1.06	927	1,097
		Shyamkur	Durgapur	0.27	280	331
		Shyamkur	Hasandanga	1.80	1,780	2,107
		Shyamkur	Jamla	1.92	1,406	1,664
		Shyamkur	Mujgunni	2.59	2,227	2,636
		Shyamkur	Nagarghop	0.15	220	260
		Shyamkur	Ramnagore	0.80	792	937
		Shyamkur	Saiyad Mamuud	0.44	1,625	1,923
		Shyamkur	Shyamkur	6.61	4,859	5,751
		Shyamkur	Teghar	0.78	436	516
		subtotal	**45**	**69.3**	**54,203**	**64,155**
	Sharsha	Bagachra	Bagdanga	0.82	785	1,045
		Bagachra	Basatpur	9.60	7,541	10,037
		Bagachra	Mahishakut	3.45	1,089	1,449
		Bagachra	Samta	3.06	3,269	4,351
		Bagachra	Tengra	3.44	2,847	3,789
		Goga	Amali	2.62	2,096	2,790
		Goga	Bhulat	7.62	5,027	6,691
		Goga	Goga	5.91	4,807	6,398
		Goga	Gopalpur	0.68	602	801
		Goga	Harishchandra	1.24	1,174	1,563
		Goga	Ichhapur	4.32	1,874	2,494
		Goga	Khhapur	2.26	1,358	1,807
		Goga	Setal	4.35	1,402	1,866
		Kayba	Baikali	2.31	1,195	1,590
		Kayba	Bhabanipur	1.77	1,601	2,131
		Kayba	Dadkhali	0.42	774	1,030
		Kayba	Dhentara	1.27	797	1,061
		Kayba	Digha	2.95	1,583	2,107
		Kayba	Kayba	4.18	4,042	5,380
		Kayba	Mahisha	1.84	1,834	2,441
		Kayba	Raghabpur	1.29	965	1,284

Table 1.6.1 Basic Information for Urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Kayba	Rudrapur	3.82	2,925	3,893
		Nazimpur	Kanainagore	0.75	286	381
		Putkhali	Balanda	6.58	5,509	7,332
		Putkhali	Barapota	0.80	1,740	2,316
		Putkhali	Kadamtala	2.54	1,682	2,239
		Putkhali	Putkhali	4.68	3,995	5,317
		Putkhali	Rajgonj	1.20	279	371
		Putkhali	Sibnathpur	3.19	4,924	6,553
		subtotal	**29**	**89.0**	**68,002**	**90,506**
Total in Jessore District			**241**	**467**	**383,079**	**489,067**
Total			**319**	**670.4**	**509,970**	**648,903**

Table 1.6.2 Basic Information for Semi-urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
Chuadanga						
	Alamdanga	Bhangabaria	Bagadi	3.64	2,356	2,577
		Bhangabaria	Bhogali	3.11	3,445	3,768
		Bhangabaria	Gaurihard	5.26	2,035	2,226
		Gangni	Sahebpur	3.11	1,041	1,139
		Khadimpur	Batiapara	3.33	2,988	3,268
		Khadimpur	Jugirhuda	2.24	456	499
		Khadimpur	Lakhmipur	2.36	652	713
		Khadimpur	Majhad	3.16	2,239	2,449
		Khadimpur	Ramchandrapur	0.91	420	459
		Khadimpur	Rangpur	1.36	1,127	1,233
		Nagdha	Burapara	1.41	1,092	1,194
		Nagdha	Ghorldi	3.28	1,467	1,605
		Nagdha	Harkandi	2.40	2,175	2,379
		Nagdha	Jahanpur	13.11	8,769	9,591
		Nagdha	Khasbagunda	1.24	1,155	1,263
		Nagdha	Nagdha	4.90	4,015	4,391
		Nagdha	Paik para	3.70	2,115	2,313
		Nagdha	Polbagunda	1.08	780	853
		subtotal	**18**	**59.6**	**38,327**	**41,920**
	Chuadanga	Alokdia	Manirampur	8.66	7,293	8,890
		Alokdia	Pirpur	3:57	2,636	3,213
		Begampur	Akandabaria	5.55	4,016	4,895
		Begampur	Begampur	7.13	5,279	6,435
		Begampur	Bhabanipur	2.36	2,491	3,037
		Begampur	Dosta	2.62	2,085	2,542
		Begampur	Fursetpur	4.34	3,501	4,268
		Begampur	Jadupur	1.97	2,471	3,012
		Begampur	Jhajri	4.02	2,759	3,363
		Begampur	Krishanapur	4.95	3,485	4,248
		Begampur	Rangirpota	3.21	2,232	2,721
		Begampur	Sailmari	1.59	1,349	1,644
		Begampur	Ujalpur	3.67	2,646	3,225
		Chuadanga Pour	Bazruk	5.46	4,106	5,005
		Chuadanga Pour	Bhingrulla	1.92	1,319	1,608
		Chuadanga Pour	Chudanga	4.75	3,327	4,056
		Chuadanga Pour	Digri	2.66	2,107	2,568
		Chuadanga Pour	Hat Kaligonj	0.50	685	835
		Chuadanga Pour	Hazhati	1.79	2,308	2,813
		Chuadanga Pour	Kulchara	3.67	2,497	3,044
		Chuadanga Pour	Nurnagore	2.34	1,694	2,065
		Chuadanga Pour	Sumurdia	4.02	2,920	3,559
		Chuadanga Pour	Taltolla	5.95	4,300	5,242
		Kutuabpur	Boalia	5.83	5,023	6,123
		Kutuabpur	Dattail	2.12	1,569	1,913
		Kutuabpur	Sahebnagore	1.17	865	1,054
		Kutuabpur	Sambhunagore	2.59	1,852	2,258
		Mominpur	Boalmari	1.39	1,512	1,843
		Mominpur	Chandpur	4.33	2,781	3,390
		Mominpur	Kathuli	4.84	3,467	4,226
		Mominpur	Sarishadanga	4.61	3,279	3,997
		Mominpur	Sirajkandi	3.10	2,364	2,882
		Paddabila	Aliar nagore	4.27	2,965	3,614
		Paddabila	Chandipur	1.02	881	1,074
		Paddabila	Dhuturhat	2.69	1,745	2,127

Table 1.6.2 Basic Information for Semi-urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Paddabila	Gopalnagore	0.20	784	956
		Paddabila	Gopinatrhpur	0.57	1,335	1,627
		Paddabila	Hogladanga	3.60	2,846	3,469
		Paddabila	Khejura	1.81	1,345	1,640
		Paddabila	Nafardihi	1.07	542	661
		Shankar Chandra	Fulbari	3.64	2,541	3,097
		Shankar Chandra	Jalsukha	3.42	2,365	2,883
		Shankar Chandra	Manikdihie	2.14	1,740	2,121
		Shankar Chandra	Shakechandra	2.22	2,157	2,629
		Titudaha	Baldia	1.35	1,089	1,327
		Titudaha	Chandpur	1.24	1,370	1,670
		Titudaha	Chhato Salua	5.89	4,430	5,400
		Titudaha	Hurullah pur	1.34	2,466	3,006
		Titudaha	Kharagoda	1.58	1,439	1,754
		Titudaha	Khejurtala	1.79	1,514	1,846
		subtotal	**50**	**156.5**	**123,772**	**150,877**
	Damurhuda	Damurhuda	Ujirpur	4.12	4,469	5,555
		Darshana	Dakhin Ramnag	2.49	5,295	6,582
		Darshana	Jaynagar	2.63	725	901
		Darshana	Krishanapur	1.31	1,654	2,056
		Darshana	Sultsnpur	2.05	1,482	1,842
		Darshana	Zirat	1.27	1,127	1,401
		Howli	Bstupur	4.87	3,712	4,614
		Howli	Howli	4.75	1,749	2,174
		Howli	Joyrampur	17.72	12,383	15,393
		Howli	Loknathpur	13.11	8,055	10,013
		subtotal	**10**	**54.3**	**40,651**	**50,534**
	Jibannagar	Andolbaria	Chak Silinda	0.22	630	791
		Andolbaria	Dumuria	2.66	1,841	2,311
		Andolbaria	Silinda	0.25	251	315
		Banka	Baidyanathpur	2.30	1,428	1,792
		Banka	Balarampur	1.94	1,152	1,446
		Banka	Bankunda	1.55	1,105	1,387
		Banka	Gangadaspur	5.98	3,637	4,565
		Banka	Ghosnagore	0.70	445	558
		Banka	Hansadaha	6.04	4,053	5,088
		Banka	Kandarpara	1.81	1,207	1,515
		Banka	Katapol	1.56	1,188	1,491
		Banka	Kishnapur	1.97	1,397	1,754
		Banka	Maruppur	2.82	1,815	2,279
		Banka	Minajpur	6.23	3,719	4,669
		Banka	Moktarpur	2.15	1,353	1,698
		Banka	Paransati	0.90	637	799
		Banka	Pathla	1.28	918	1,152
		Banka	Pratappur	1.69	1,245	1,563
		Banka	Raghnathpur	0.15	132	166
		Banka	Sonda	1.23	769	965
		Banka	Srirampur	1.69	1,046	1,314
		Banka	Tentulia	1.91	1,258	1,579
		Jibannagore	Gangadapur	2.42	1,603	2,012
		Jibannagore	Haripur	0.82	612	769
		Jibannagore	Jadabpur	0.83	654	821
		Jibannagore	Jibannagore	5.44	4,463	5,602
		Jibannagore	Narayanpur	2.67	1,920	2,410
		Jibannagore	Sankari	2.89	1,796	2,255
		Jibannagore	Subalpur	1.96	1,283	1,611
		Uthli	Dehati	3.20	2,228	2,797

Table 1.6.2 Basic Information for Semi-urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Uthli	Kasipur	7.00	4,816	6,046
		Uthli	Singnagar	1.04	784	984
		subtotal	**32**	**75.3**	**51,384**	**64,503**
Total in Chuadanga District			**110**	**345.7**	**254,134**	**307,834**
Jhenaidah						
	Harinakunda	Chandipur	Hakimpur	2.53	1,227	1,571
		Chandipur	Hamirhati	2.08	1,675	2,144
		Chandipur	Kalaphaula	0.45	95	122
		Chandipur	Jadabpur	1.17	823	1,054
		Chandipur	Parmathurapur	2.61	1,052	1,347
		subtotal	**5**	**8.8**	**4,872**	**6,237**
	Jhenaidaha	Ganna	Betai	1.44	1,105	1,401
		Ganna	Ganna	5.81	2,970	3,765
		Ganna	Khal kula	0.48	377	478
		Ganna	Mahadevpur	2.32	1,174	1,488
		Ganna	Paschim Jhin	0.64	350	444
		Ganna	Paschim Nara	0.79	324	411
		Ganna	Pura bati	0.49	510	647
		Jhenaidaha Paur:	Gilabara	0.85	540	685
		Jhenaidaha Paur:	Gopinath pur	1.92	1,011	1,282
		Jhenaidaha Paur:	Lakshmikol	0.87	552	700
		Jhenaidaha Paur:	Mahihakura	0.96	616	781
		Jhenaidaha Paur:	Mathurapur	2.29	4,598	5,829
		Jhenaidaha Paur:	Panchtikri	0.34	220	279
		Kumarbaria	Dephalbaria	3.81	1,787	2,265
		Kumarbaria	Goalbari	1.21	619	785
		Kumarbaria	Jargram	0.77	765	970
		Kumarbaria	Kumarbaria	3.32	395	501
		Kumarbaria	Nagore Bathan	1.96	1,687	2,139
		Kumarbaria	Ramnagore	1.90	1,151	1,459
		Kumarbaria	Rautal	1.19	619	785
		Maduhati	Chorkol	2.72	3,296	4,178
		Maduhati	Mamunsia	2.52	1,512	1,917
		Maduhati	Sripur	1.31	794	1,007
		Maharajpur	Bhabanipur	1.02	358	454
		Maharajpur	Maharajpur	2.55	1,025	1,299
		Maharajpur	Uttar Bhabani	0.89	544	690
		Sadhati	Bankira	5.07	1,412	1,790
		Sadhati	Gobindapur	0.89	371	470
		Sadhati	Mamudpur	1.40	718	910
		subtotal	**29**	**51.7**	**31,400**	**39,804**
	Kaliganj	Barobazar	Grammajdia	2.87	1,706	2,080
		Barobazar	Jaganathpur	2.03	905	1,103
		Barobazar	Jalkarmajdia	1.74	361	440
		Barobazar	Sonalidanga	1.14	963	1,174
		Rakhalgachhi	Bara dhapadi	4.54	1,267	1,544
		subtotal	**5**	**12.3**	**5,202**	**6,341**
	Kotchandpur	Dora	Dora	2.97	808	938
		Dora	Garsuti	0.81	331	384
		Dora	Panchila	2.67	1,197	1,389

Table 1.6.2 Basic Information for Semi-urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Dora	Rudrapur	1.07	317	368
		Dora	Srirampur	2.42	1,514	1,757
		Sabdalpur	Bahirgachhi	2.90	908	1,054
		Sabdalpur	Baliadanga	2.14	536	622
		Sabdalpur	Datiar Kahi	1.32	927	1,076
		Sabdalpur	Jydia	8.70	1,576	1,829
		Sabdalpur	Kanyangar	0.71	488	566
		Sabdalpur	Mandarbaria	1.86	627	728
		Sabdalpur	Manikdihie	0.83	541	628
		Sabdalpur	Sabdalpur	1.98	2,474	2,871
		subtotal	**13**	**30.4**	**12,244**	**14,210**
	Moheshpur	Azampur	Adampur	1.50	1,312	1,833
		Azampur	Azampur	3.36	1,053	1,471
		Azampur	BaliBhadrapur	1.76	1,725	2,410
		Azampur	Huda Azampur	1.88	1,790	2,501
		Azampur	Naodagram	0.94	622	869
		Azampur	Ramchandrapur	3.41	3,262	4,557
		Azampur	Saiyadpur	1.25	425	594
		Bansbaria	Bansbaria	4.31	2,083	2,910
		Bansbaria	Bhabaria	5.00	3,219	4,497
		Bansbaria	Bhairaba	5.07	3,618	5,054
		Bansbaria	Dumurtala	6.33	3,042	4,250
		Bansbaria	Ruli	1.56	1,231	1,720
		Bansbaria	Satpota	1.31	884	1,235
		Bansbaria	Sripur	2.04	1,110	1,551
		Bansbaria	Sripur Bangal	2.54	1,287	1,798
		Fatopur	Chandpur	6.23	2,541	3,550
		Fatopur	Ekterpur	0.98	935	1,306
		Fatopur	Jagihuda	3.84	2,005	2,801
		Fatopur	Kanaidanga	1.28	1,225	1,711
		Fatopur	Nimtala Fat	4.41	3,813	5,327
		Fatopur	Puranderpur	7.90	4,082	5,703
		Jadabpur	Chak Durgapur	1.71	744	1,039
		Jadabpur	Poradaha	2.46	1,016	1,419
		Manderbari	Bamangachi	0.77	774	1,081
		Manderbari	Hudahankar	3.58	1,617	2,259
		Manderbari	Jadunathpur	1.28	1,216	1,699
		Manderbari	Mirzapur	5.70	2,015	2,815
		Manderbari	Pachbaria	1.78	1,733	2,421
		Manderbari	Raripara	0.40	443	619
		Manderbari	Srirampur	3.50	1,529	2,136
		Moheshpur	Hamidpur	5.57	1,595	2,228
		Moheshpur	Jalilpur	4.13	2,571	3,592
		Moheshpur	Moheshpur	1.60	969	1,354
		Natma	Bamangachha	0.65	634	886
		Natma	Dariarpur	5.11	1,034	1,445
		Natma	Madartala	1.63	1,588	2,218
		Natma	NA	1.19	1,394	1,947
		Natma	Sastarbaor	1.31	1,254	1,752
		Pantapara	Baichitala	3.37	2,015	2,815
		Pantapara	Bautira tarin	1.45	1,394	1,947
		Pantapara	Bazipota	0.82	476	665
		Pantapara	Begampur	3.25	2,308	3,224
		Pantapara	Bhogerdari	0.82	490	685

Table 1.6.2 Basic Information for Semi-urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Pantapara	Durgapur	1.24	334	467
		Pantapara	Ghugorikagmar	5.11	4,994	6,977
		Pantapara	Kakildanga	1.00	979	1,368
		Pantapara	Manikdihi	2.57	2,463	3,441
		Pantapara	Maturanagore	4.08	1,023	1,429
		Pantapara	Padmarajpur	0.86	845	1,180
		Pantapara	Pantapara	5.48	4,028	5,627
		Pantapara	Pirgachha	3.44	2,967	4,145
		Pantapara	Ragunathpur	0.62	632	883
		Sundarpur	Sundarpur	4.83	3,176	4,437
		Swaruppur	Gokulnagal	6.00	1,729	2,415
		Swaruppur	Irsaldanga	2.94	1,150	1,607
		Swaruppur	Porapara	4.34	2,222	3,104
		Swaruppur	Sankarpur	0.52	548	766
		Syamkur	Jelepota	2.01	1,814	2,534
		subtotal	**58**	**164.0**	**98,977**	**138,274**
Total in Jhenaidah District			**110**	**267.3**	**152,695**	**204,865**
Jessore						
	Chaugachha	Chaugachha	Ber Gabindapu	5.63	3,284	4,544
		Chaugachha	Dighal Singa	1.23	879	1,216
		Chaugachha	Lakshar pur	2.24	1,346	1,862
		Dhuliani	Sahazadpur	2.70	1,549	2,143
		Hakimpur	Bakshi pur	1.88	1,076	1,489
		Jagadispur	Arpara	2.25	1,387	1,919
		Jagadispur	Erukandi	2.63	1,617	2,237
		Jagadispur	Jagadispur	3.91	2,319	3,209
		Narayan Pur	Barakhanpur	2.60	1,604	2,219
		Narayan Pur	Batikamari	1.96	1,062	1,469
		Narayan Pur	Bundalitoala	1.87	1,102	1,525
		Narayan Pur	Gautuli	13.40	7,413	10,256
		Narayan Pur	Harakanda	1.63	1,108	1,533
		Narayan Pur	Hogal Danga	1.30	840	1,162
		Narayan Pur	Manginpara	0.77	460	636
		Narayan Pur	Narayan pur	2.54	1,655	2,290
		Narayan Pur	Petbaria	1.69	1,098	1,519
		Pashapole	Bil eral	2.76	1,560	2,158
		Pashapole	Burnia	1.34	1,074	1,486
		Pashapole	Durali	0.27	187	259
		Pashapole	Hauli	1.60	960	1,328
		Pashapole	Maligati	0.79	468	648
		Pashapole	Palua	3.00	1,912	2,645
		Pashapole	Ragunathpur	1.75	1,132	1,566
		Pashapole	Rangiali	1.69	1,060	1,467
		Pashapole	Sureswarkati	0.23	176	244
		Patibaria	Bishwanathpur	0.28	434	600
		Patibaria	Halyapur	1.03	699	967
		Patibaria	Niamathpur	3.72	2,276	3,149
		Patibaria	Patibaria	3.86	2,300	3,182
		Phulsara	Ariazi Kotali	0.33	556	769
		Phulsara	Kotalipar	0.77	561	776
		Singhajhuli	Jaganathpur	3.62	2,220	3,072
		Singhajhuli	Jamalta	0.90	571	790
		Singhajhuli	Patambarapur	1.38	802	1,110
		Sukpujuria	Ballabpur	3.30	2,044	2,828

Table 1.6.2 Basic Information for Semi-urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Sukpujuria	barani	3.26	1,935	2,677
		Sukpujuria	Rajapur	0.53	528	731
		Sukpujuria	Ramkrishnapur	2.58	1,809	2,503
		Swarupdaha	Digri	2.62	1,597	2,210
		Swarupdaha	Godadaharpur	0.86	538	744
		Swarupdaha	Hazuli	1.10	661	915
		Swarupdaha	Kukuria	4.43	2,680	3,708
		Swarupdaha	Maslia	1.34	871	1,205
		Swarupdaha	Surbananada H	0.68	465	643
		subtotal	**45**	**99.4**	**61,875**	**85,609**
	Jessore	Arabpur	Brhamattar	0.56	1,995	2,456
		Arabpur	Durgaour	2.01	2,607	3,209
		Arabpur	Malanchi	1.31	2,195	2,702
		Arabpur	NA	1.50	3,442	4,237
		Arabpur	Ragurampur	0.60	710	874
		Arabpur	Swjalpur	0.96	1,839	2,264
		Chanchra	Banibaha	0.39	631	777
		Chanchra	Berbari	0.77	721	888
		Chanchra	Bhaturia	3.11	2,626	3,233
		Chanchra	Rudrapur	0.64	2,098	2,583
		Chanchra	Rupdia	4.08	3,895	4,795
		Chanchra	Taricha	1.75	1,584	1,950
		Chanchra	Tentulia	0.83	1,021	1,257
		Churamankati	Bhagalpur	0.70	2,201	2,709
		Churamankati	Dogachhia	4.92	4,143	5,100
		Churamankati	Gobila	1.20	1,469	1,808
		Churamankati	Kamalpur	2.00	1,597	1,966
		Churamankati	Shajali	2.91	3,093	3,807
		Habitpur	Kaudia	1.27	819	1,008
		Habitpur	Natuagara	2.19	1,757	2,163
		subtotal	**45**	**33.7**	**40,443**	**49,785**
	Jhikargachha	Bankra	Khalsi	3.60	2,884	3,586
		Bankra	Khosal nagore	1.97	1,647	2,048
		Bankra	Simulia	1.10	878	1,092
		Bankra	Sukurkola	0.70	491	610
		Gadkhali	Bamanali	1.37	1,741	2,164
		Gadkhali	Barapur	3.19	3,108	3,864
		Gadkhali	Beniali	3.48	2,816	3,501
		Gadkhali	Bodhkna	4.52	3,676	4,569
		Gadkhali	Fatepur	1.73	1,445	1,797
		Gadkhali	Gadkhali	5.42	4,546	5,652
		Gadkhali	Hajirali	1.15	1,037	1,288
		Gadkhali	Jsfarnagore	2.36	1,765	2,194
		Gadkhali	Kamarpara	0.80	816	1,014
		Gadkhali	Putuapara	1.59	1,559	1,938
		Gadkhali	Sadirail	0.34	384	478
		Ganganandapur	Balia	0.86	809	1,006
		Ganganandapur	Blshahari	2.47	2,022	2,514
		Ganganandapur	Chhutipur	0.59	1,676	2,083
		Ganganandapur	Coalhati	2.82	2,119	2,634
		Ganganandapur	Dattapara	1.61	1,337	1,662
		Ganganandapur	Garursuti	3.18	2,135	2,654
		Hazirbag	Bishanupur	2.71	2,042	2,539
		Hazirbag	Deuli Khorda	4.96	3,560	4,425
		Hazirbag	Havikhali panchpa	1.28	1,046	1,300
		Hazirbag	Hazirbag	0.08	242	301

Table 1.6.2 Basic Information for Semi-urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Hazirbag	Ista	1.06	961	1,195
		Hazirbag	Jugihuda	1.05	698	867
		Hazirbag	Komar Chanda	1.33	922	1,146
		Hazirbag	Moshespara	2.28	1,786	2,221
		Hazirbag	Sonakur	2.39	2,145	2,667
		Jhikargachha	Jhaudia	0.55	446	554
		Jhikargachha	Jhikargachha	1.66	1,926	2,395
		Jhikargachha	Kiranpur	1.79	1,755	2,182
		Jhikargachha	Krinhunagore	1.42	3,444	4,281
		Jhikargachha	Mobaraklpur	0.74	1,304	1,621
		Jhikargachha	Payadanga	1.35	1,568	1,949
		Magura	Chandura	1.23	1,055	1,311
		Magura	Joyrampur	0.79	684	850
		Magura	Kacmela	3.68	3,011	3,743
		Magura	Monahatpur	2.05	1,634	2,032
		Magura	Phulbari	2.77	2,202	2,737
		Nabharan	Amini	0.90	649	807
		Nabharan	Kalagachhi	1.15	1,076	1,337
		Nabharan	Kaliani	0.97	799	993
		Nabharan	Nittyanaandak	0.80	656	816
		Nabharan	Panchpola	0.96	749	931
		Nabharan	Ramchandrapur	1.16	1,024	1,273
		Nabharan	Sharifpur	1.27	1,183	1,471
		Nabharan	Uttare Deuli	1.48	1,304	1,621
		Nibaskhola	Kanairali	2.91	2,359	2,932
		Nibaskhola	Nischintapur	1.28	1,043	1,296
		Nibaskhola	Sadipur	0.28	238	296
		Panisara	Chandupatila	0.60	651	809
		Panisara	Gobrapur	0.88	612	760
		Panisara	Kaurla	1.55	1,363	1,694
		Panisara	Kutia	1.06	944	1,174
		Panisara	Nilkanthanago	0.46	481	598
		Panisara	Panisara	1.71	1,472	1,830
		Panisara	Puranderpur	3.31	3,566	4,433
		Panisara	Rajpur	1.67	1,325	1,648
		Panisara	Sadipara	1.21	1,040	1,292
		Panisara	Taora	2.08	1,664	2,069
		Shankarpur	Bakulia	2.59	1,782	2,215
		Shankarpur	Khatbaria	1.54	1,297	1,612
		Simulia	Andolpara	2.63	1,890	2,350
		Simulia	Sialghona	3.24	2,444	3,038
		subtotal	**66**	**117.7**	**102,932**	**127,956**
	Keshabpur	Bidyanandakati	Aulganti	0.64	935	1,096
		Bidyanandakati	Baga	1.50	1,140	1,336
		Bidyanandakati	Bhabanipur	0.39	270	316
		Bidyanandakati	Bhandakhola	1.68	1,438	1,685
		Bidyanandakati	Burihati	2.94	2,735	3,205
		Bidyanandakati	Fathpur	0.75	767	899
		Bidyanandakati	Hariagoap	3.72	2,012	2,358
		Bidyanandakati	Hasnapur	1.68	1,399	1,640
		Bidyanandakati	Hizaldanga	0.43	488	572
		Bidyanandakati	Kabilpur	1.67	957	1,122
		Bidyanandakati	Kakilkhali	0.95	846	992
		Bidyanandakati	Khapdahi	1.02	680	797
		Bidyanandakati	Mahadevpur	0.94	742	870
		Bidyanandakati	Mominpur	1.90	1,677	1,965
		Bidyanandakati	Nehalpur	0.53	722	846

Table 1.6.2 Basic Information for Semi-urgent Area

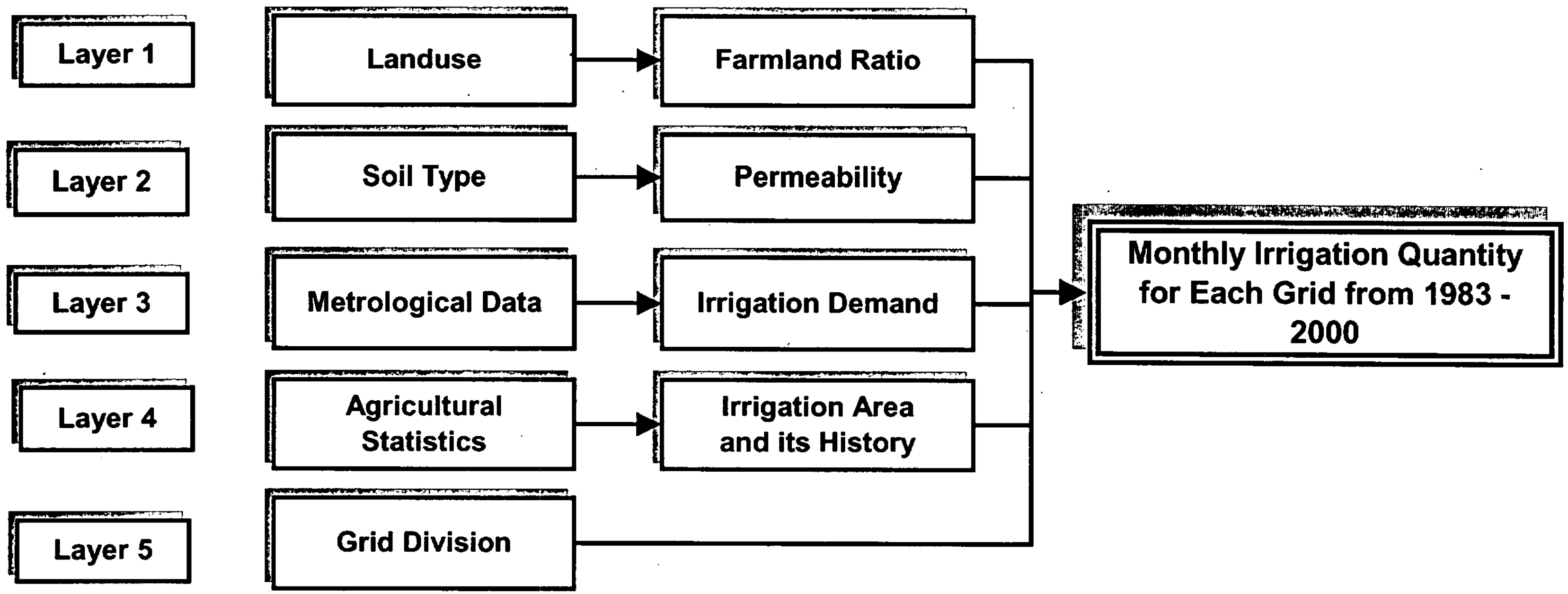
District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Bidyanandakati	Parchakra	1.25	1,653	1,937
		Bidyanandakati	Rejakati	1.11	604	708
		Bidyanandakati	Saksekanpur	0.39	464	544
		Bidyanandakati	Teghari	1.42	1,316	1,542
		Bidyanandakati	Tita bazidpur	1.82	1,450	1,699
		Gaurighona	Burali	3.97	2,028	2,377
		Keshabpur	Durmutia	1.95	1,851	2,169
		Keshabpur	Mulgram	6.05	4,405	5,163
		Majitpur	Atenda	0.38	625	733
		Majitpur	Bacsa	3.12	2,732	3,202
		Majitpur	Deuli	1.55	1,456	1,706
		Majitpur	G.Bagdaha	1.16	2,320	2,719
		Majitpur	Hizlatola	0.59	597	700
		Majitpur	Lakshminatbka	1.64	1,166	1,367
		Majitpur	Patrapar	0.39	526	616
		Majitpur	Pratapur	2.96	2,160	2,532
		Majitpur	Sikarpur	1.60	1,659	1,944
		Majitpur	Sridfala	2.51	1,850	2,168
		Majitpur	Srirampur	2.87	1,849	2,167
		Panjia	Dongaghata	0.58	320	375
		Panjia	Manharnagore	5.37	4,236	4,965
		Panjia	Sagar Dattaka	1.92	1,351	1,583
		Sagardari	Barahati	2.12	1,763	2,066
		Sagardari	Chingra	3.12	3,028	3,549
		Sagardari	Jahihra	1.60	1,119	1,311
		Sagardari	Komarpur	1.91	1,473	1,726
		Sagardari	Sagardari	3.46	2,768	3,244
		Sagardari	Shekpur	1.34	1,229	1,440
		Sagardari	Sripur	0.26	345	404
		Sufalakati	Haria ghop	0.94	764	895
		Sufalakati	Krishanagore	0.28	396	464
		Sufalakati	Narayanpur	5.41	3,133	3,672
		Sufalakati	Sarutia	1.92	1,462	1,714
		Trimohini	Baormasina	0.69	491	575
		Trimohini	Begampur	1.35	1,396	1,636
		Trimohini	Bhalukghar	2.75	2,461	2,884
		Trimohini	Chalitabaria	1.17	740	867
		Trimohini	Chandura	3.01	2,789	3,269
		Trimohini	Dattanagar	0.68	367	430
		Trimohini	Janpur	2.74	2,203	2,582
		Trimohini	Kariakhali	2.00	1,227	1,438
		Trimohini	Komarpol	2.21	1,879	2,202
		Trimohini	Mrizanagar	4.32	3,150	3,692
		Trimohini	Sarappur	1.52	707	829
		Trimohini	Satbaria	3.98	3,672	4,304
		Trimohini	Srirampur	0.92	431	505
		subtotal	**61**	**115.0**	**92,419**	**108,317**
	Manirampur	Bhojgati	Chalkidanga	2.24	1,692	2,003
		Bhojgati	Deiabati	0.66	451	534
		Chaluahati	Atfghara	1.67	1,502	1,778
		Chaluahati	Base Chaluaha	1.10	883	1,045
		Chaluahati	Bil Pantdahar	0.38	413	489
		Chaluahati	Chaluahti	2.35	1,853	2,193
		Chaluahati	Gauripur	1.94	1,554	1,839
		Chaluahati	Gopikantapur	0.81	438	518
		Chaluahati	Gopikantapur	0.55	703	832
		Chaluahati	Harispur	0.71	575	681

Table 1.6.2 Basic Information for Semi-urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Chaluahati	Hayat pur	1.58	1,237	1,464
		Chaluahati	Lakshmanpur	1.74	1,191	1,410
		Chaluahati	Lhani	0.62	438	518
		Chaluahati	Moharakpur	5.17	3,299	3,905
		Chaluahati	Pamchhatha	0.68	445	527
		Chaluahati	Ralneswarpur	1.82	1,388	1,643
		Chaluahati	Ramnath pur	1.14	1,029	1,218
		Chaluahati	Rasulpur	0.61	879	1,040
		Chaluahati	Ratandia	1.75	1,460	1,728
		Chaluahati	Singher khaza	0.80	627	742
		Chaluahati	Tripuropur	1.26	1,084	1,283
		Dhakuria	Joypur	6.51	4,132	4,891
		Durbadanga	Harina	1.06	998	1,181
		Hariharnagore	Goalbari	1.90	1,112	1,316
		Hariharnagore	Mokterpur	3.15	2,109	2,496
		Jhanpa	Chandipur	2.07	1,867	2,210
		Jhanpa	Hanuar	6.11	5,164	6,112
		Jhanpa	Jampa	11.25	7,640	9,043
		Jhanpa	Khalia	1.84	1,334	1,579
		Jhanpa	Manaharpur	0.69	924	1,094
		Kasimnagore	G.Acaazi Gaye	0.64	330	391
		Khanpur	Baliadanga	0.62	1,065	1,261
		Khanpur	Bharatpur	3.13	2,973	3,519
		Khanpur	Khanpur	9.39	6,755	7,995
		Khanpur	Tentulia	0.53	571	676
		Khenderpar	Galdhra	4.65	3,162	3,743
		Khenderpar	Khenderpara	3.94	2,893	3,424
		Manirampur	Bijayrampur	3.95	1,825	2,160
		Manirampur	Debidespur	2.39	1,681	1,990
		Manirampur	Durgapur	1.45	2,048	2,424
		Manirampur	Durgapur	0.61	1,764	2,088
		Manirampur	Hokaba	2.17	1,356	1,605
		Manirampur	Jaljhara	3.78	2,993	3,543
		Manirampur	Juranpur	1.52	1,229	1,455
		Manirampur	Manirampur	0.32	832	985
		Manirampur	Mohadevpur	2.84	1,895	2,243
		Manirampur	Mohanpur	1.14	1,160	1,373
		Manirampur	NA	0.97	1,545	1,829
		Manirampur	NA	0.93	2,619	3,100
		Manirampur	Solapur	0.56	450	533
		Manirampur	Taherpur	1.19	1,225	1,450
		Manirampur	Thte Kamalpur	1.19	1,094	1,295
		Maswimnagore	Bampur	1.30	994	1,177
		Maswimnagore	Baro Khajura	2.42	1,440	1,704
		Maswimnagore	Bharatpur	1.09	678	802
		Maswimnagore	Hakimpur	1.11	1,289	1,526
		Maswimnagore	Hazrakati	3.39	2,798	3,312
		Maswimnagore	Hazrakati So	0.91	859	1,017
		Maswimnagore	Kamutahlatala	0.82	746	883
		Maswimnagore	Lakshmikantap	0.98	643	761
		Maswimnagore	Maswimnagore	3.66	2,794	3,307
		Maswimnagore	NA	5.89	3,474	4,112
		Maswimnagore	Noali	2.96	2,358	2,791
		Maswimnagore	Parkhajura	6.11	5,387	6,376
		Maswimnagore	Samserbeg	0.74	614	727
		Rothia	Bagdob	1.98	1,385	1,639
		Rothia	Ereda	4.53	2,823	3,341
		Rothia	Kasimpur	1.59	1,200	1,420

Table 1.6.2 Basic Information for Semi-urgent Area

District	Thana	Union	Mouza	Area(Km2)	Pop1991	Pop2001
		Rothia	Kodiapara	2.24	1,873	2,217
		Rothia	Nachpara	0.73	607	718
		Rothia	Sarapur	1.77	1,184	1,401
		Rothia	Saraskathi	2.71	1,888	2,235
		Shyamkur	Agarhati	0.83	943	1,116
		Shyamkur	Dhaligati	0.94	715	846
		Shyamkur	Lauri	4.08	3,390	4,012
		Shyamkur	Pardia	1.62	1,255	1,485
		Shyamkur	Sundalpur	0.74	754	892
		subtotal	**77**	**167.2**	**131,977**	**156,210**
	Sharsha	Bagachra	Bagachra	6.77	8,821	11,740
		Bagachra	Pipragashhi	1.40	597	795
		Dihi	Daridurgapur	0.75	314	418
		Dihi	Gokrana	3.14	1,176	1,565
		Dihi	Jaikaesabdalc	0.84	1,709	2,275
		Dihi	Khalishakhakl	0.82	409	544
		Dihi	Panditpur	1.67	1,082	1,440
		Kayba	Baguri	2.98	997	1,327
		Kayba	Raripukria	5.68	3,518	4,682
		Nazimpur	Amtala	0.78	588	783
		Nazimpur	Basantapur	5.32	4,189	5,575
		Nazimpur	Chandurlargho	1.40	887	1,181
		Nazimpur	Ekjhala	0.97	577	768
		Nazimpur	Ganitpara	0.39	477	635
		Nazimpur	Gorpara	5.89	3,310	4,405
		Nazimpur	Kandarpara	2.62	1,751	2,330
		Nazimpur	Keralkali	2.05	1,190	1,584
		Nazimpur	Nazimpur	3.06	1,803	2,400
		Putkhali	Baritti Achra	1.45	1,024	1,363
		Putkhali	Daulatpur	3.02	1,444	1,922
		Putkhali	Rajapur	2.83	1,427	1,899
		Putkhali	Sikri	3.91	1,900	2,529
		Ulashi	Babarbari	4.27	992	1,320
		Ulashi	Barabaria	4.35	2,932	3,902
		Ulashi	Jadunathpur	1.59	1,030	1,371
		Ulashi	Kayandaha	3.89	3,296	4,387
		Ulashi	Khtnira	1.25	1,176	1,565
		Ulashi	Rampur	1.79	1,956	2,603
		subtotal	**28**	**74.9**	**50,572**	**67,308**
Total in Jessore District			**297**	**607.9**	**480,218**	**595,184**
Total				**1,220.9**	**887,047**	**1,107,883**



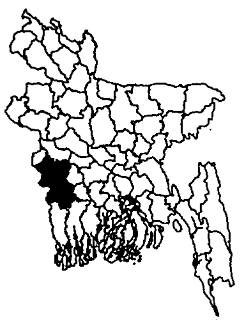
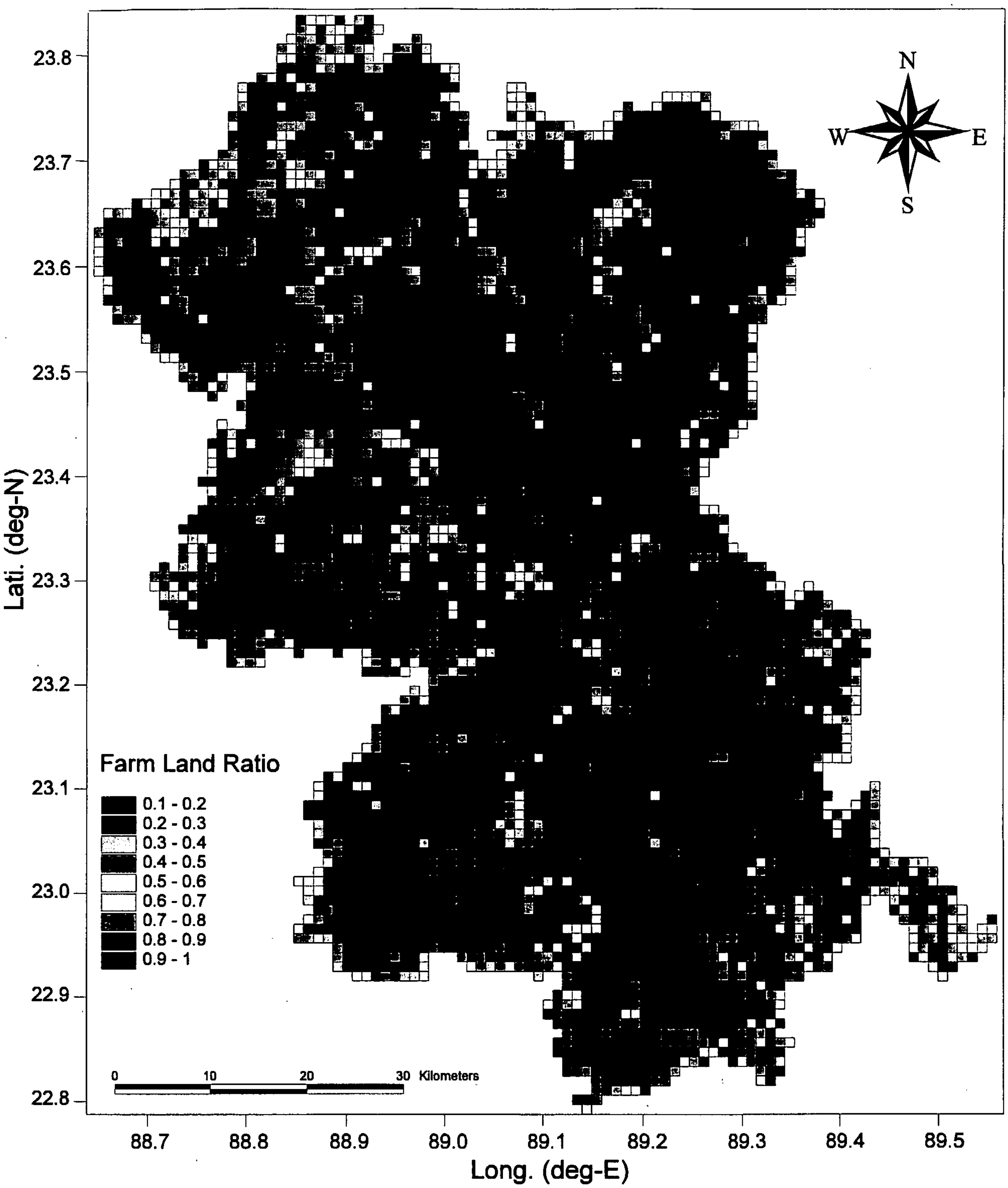


Figure 1.6.1	Flow Chart for Irrigation Quantity Estimation
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



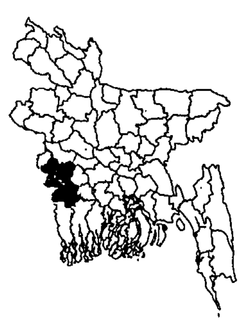
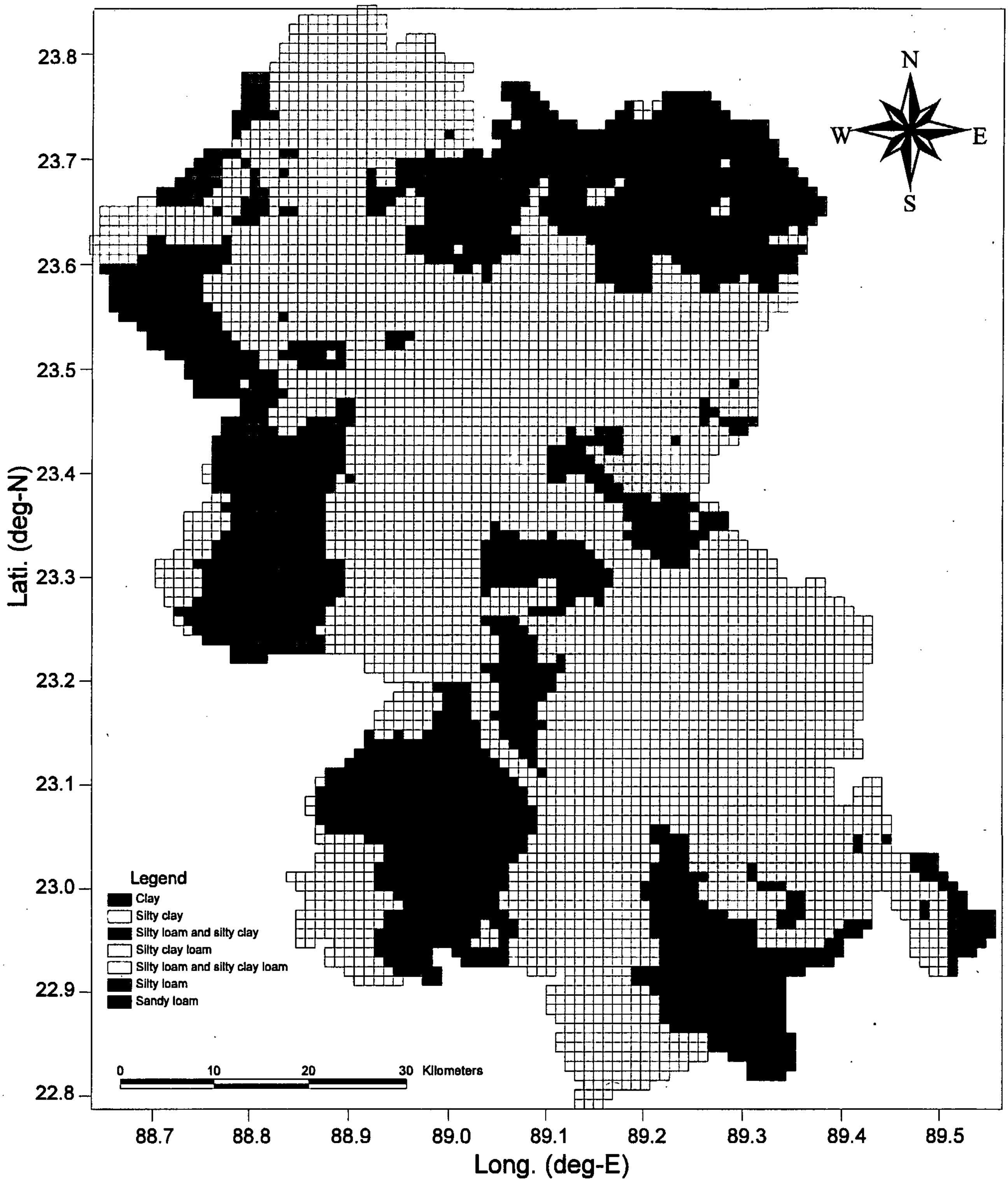


Figure 1.6.2	Ratio of Culltivated Area in the Study Area in 2000
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



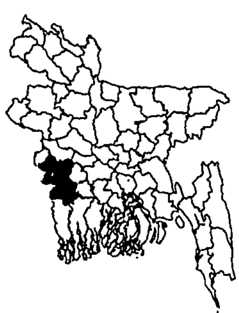


Figure 1.6.3	Soil Type Distribution
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

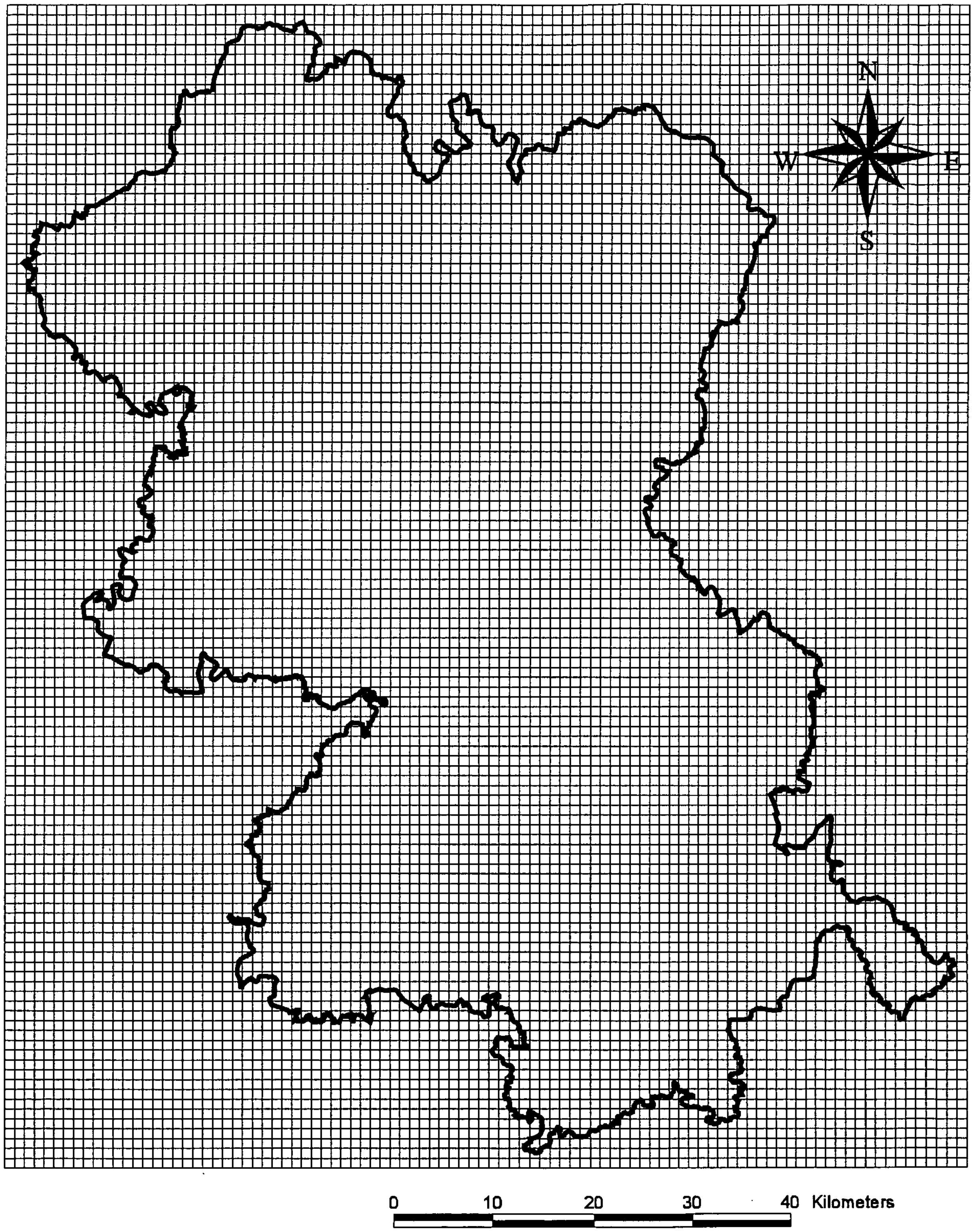
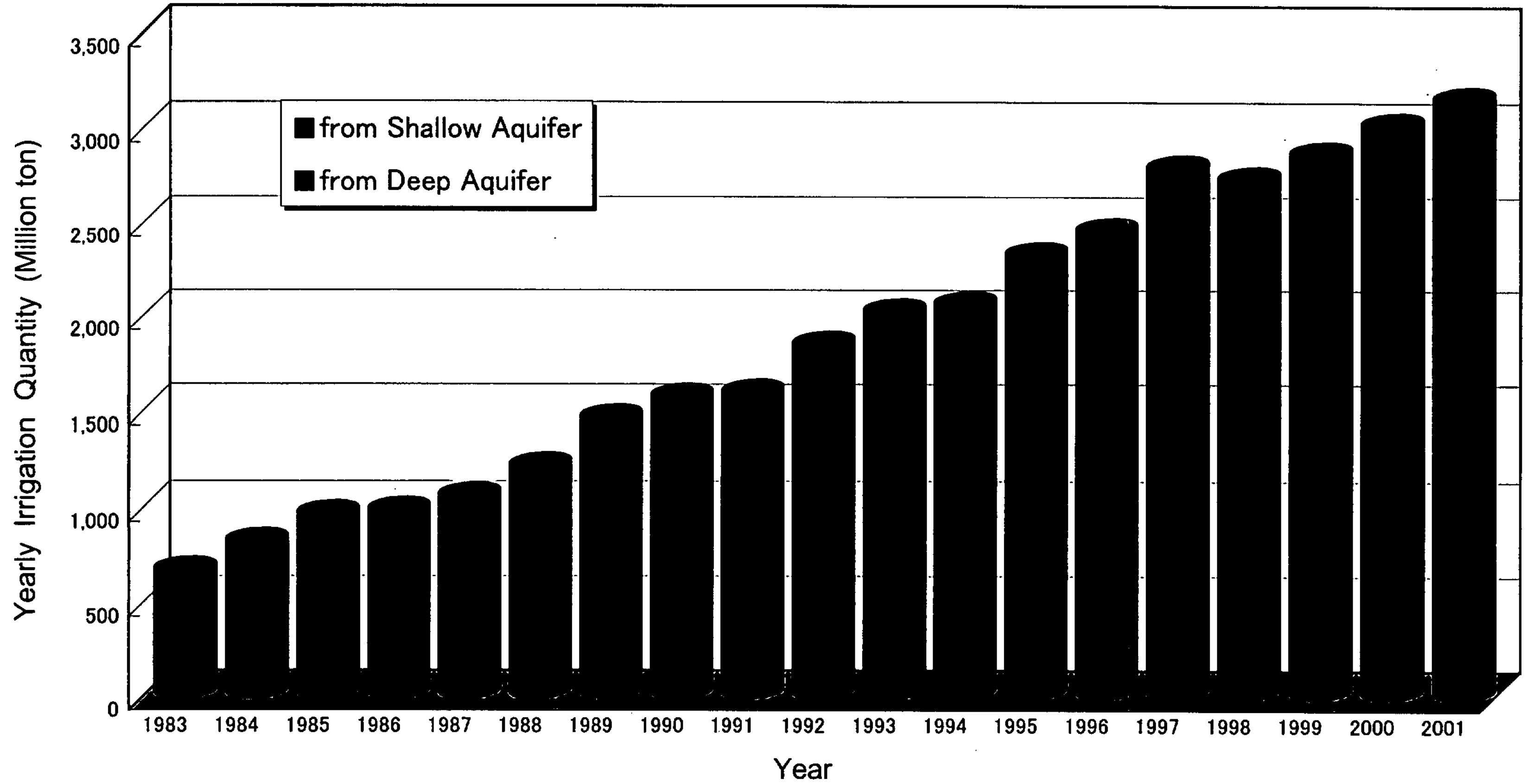


Figure 1.6.4	**Specification of Grid for Groundwater Simulation**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



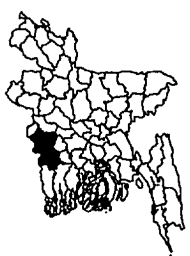
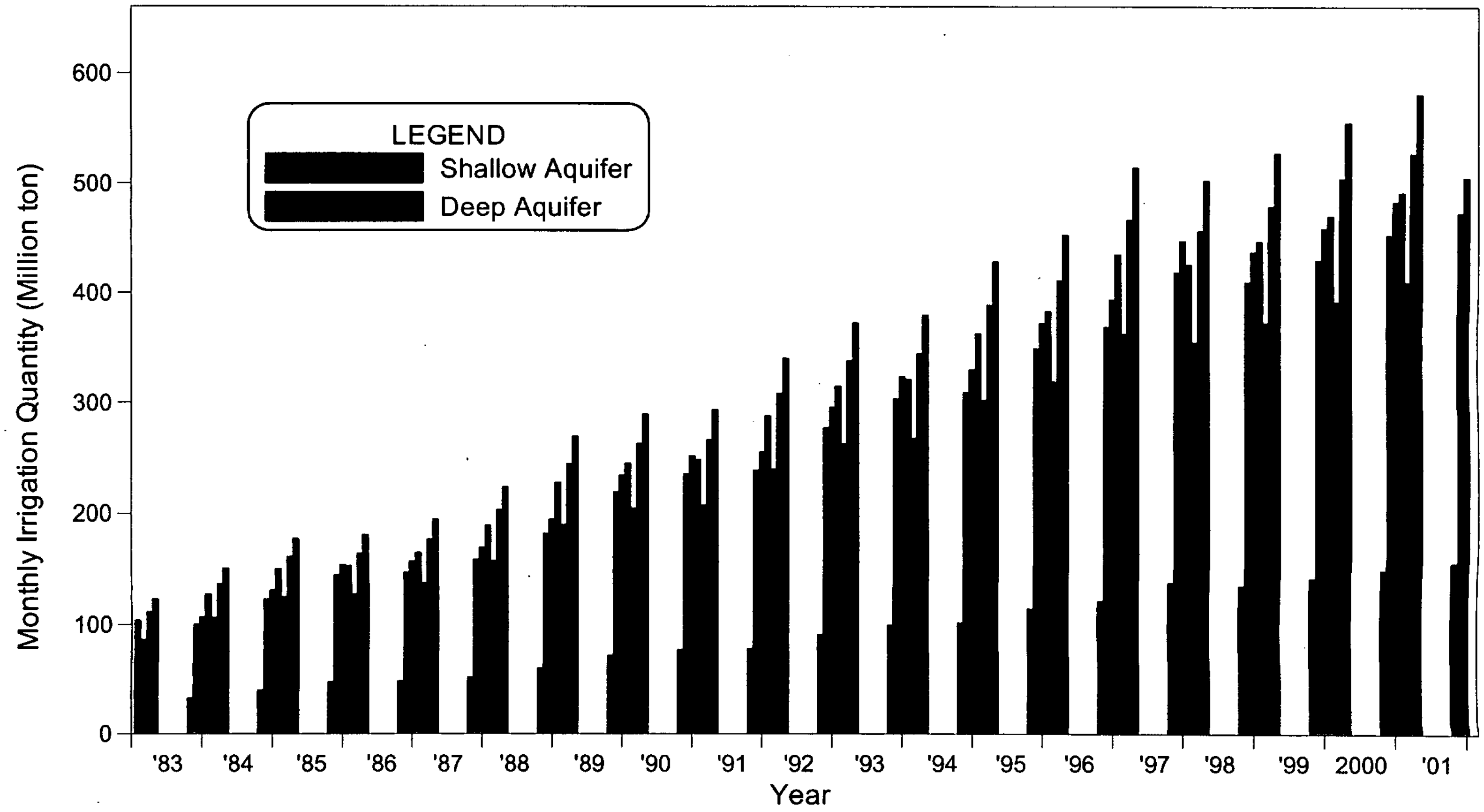


Figure 1.6.5	Estimated Yearly Ground Water Use for Irrigation
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



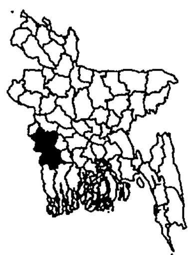


Figure 1.6.6	Estimated Monthly Ground Water Use for Irrigation

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

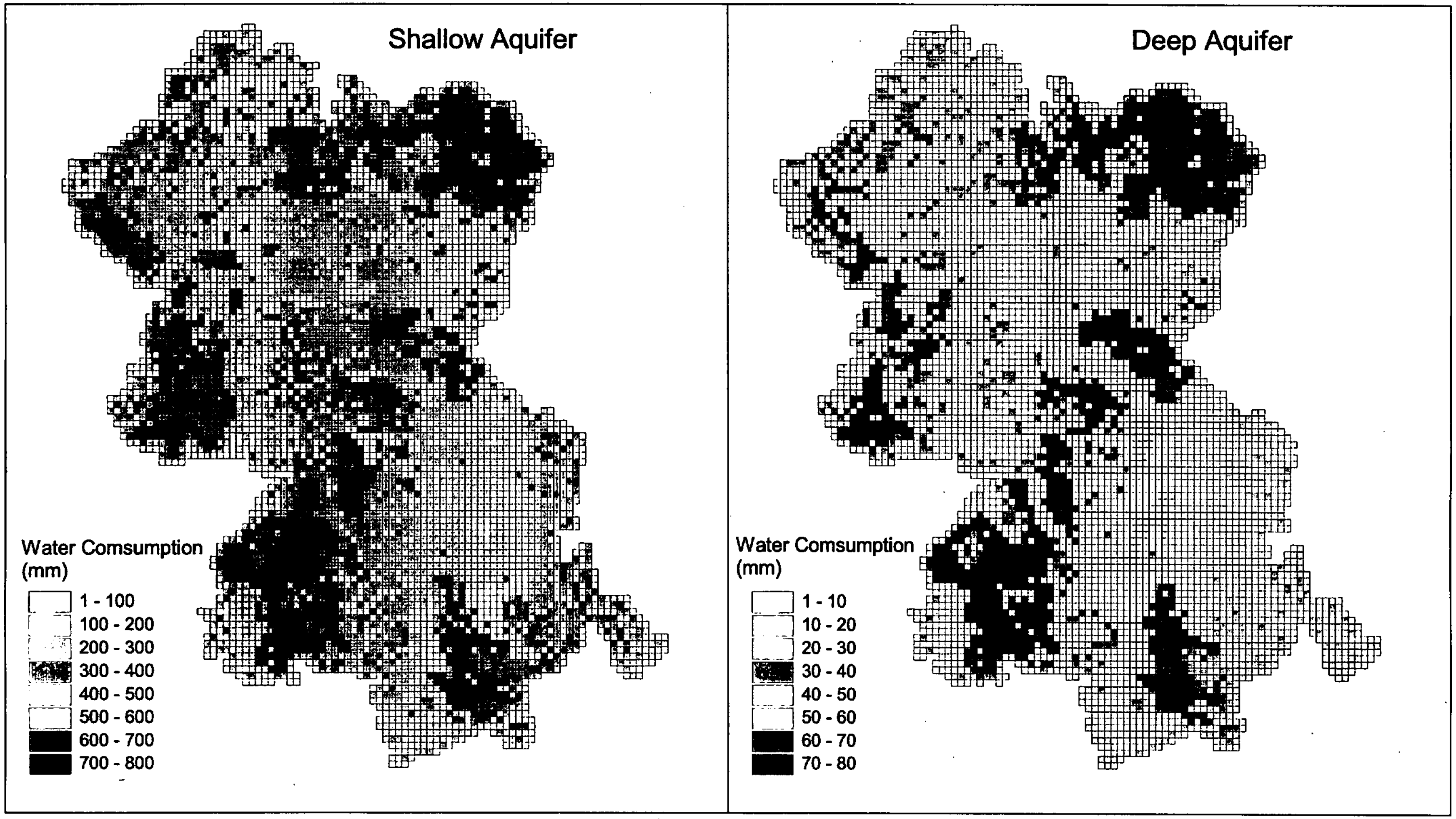


Figure 1.6.7 **Groundwater Consumption for Irrigation from Different Aquifers in 2001**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

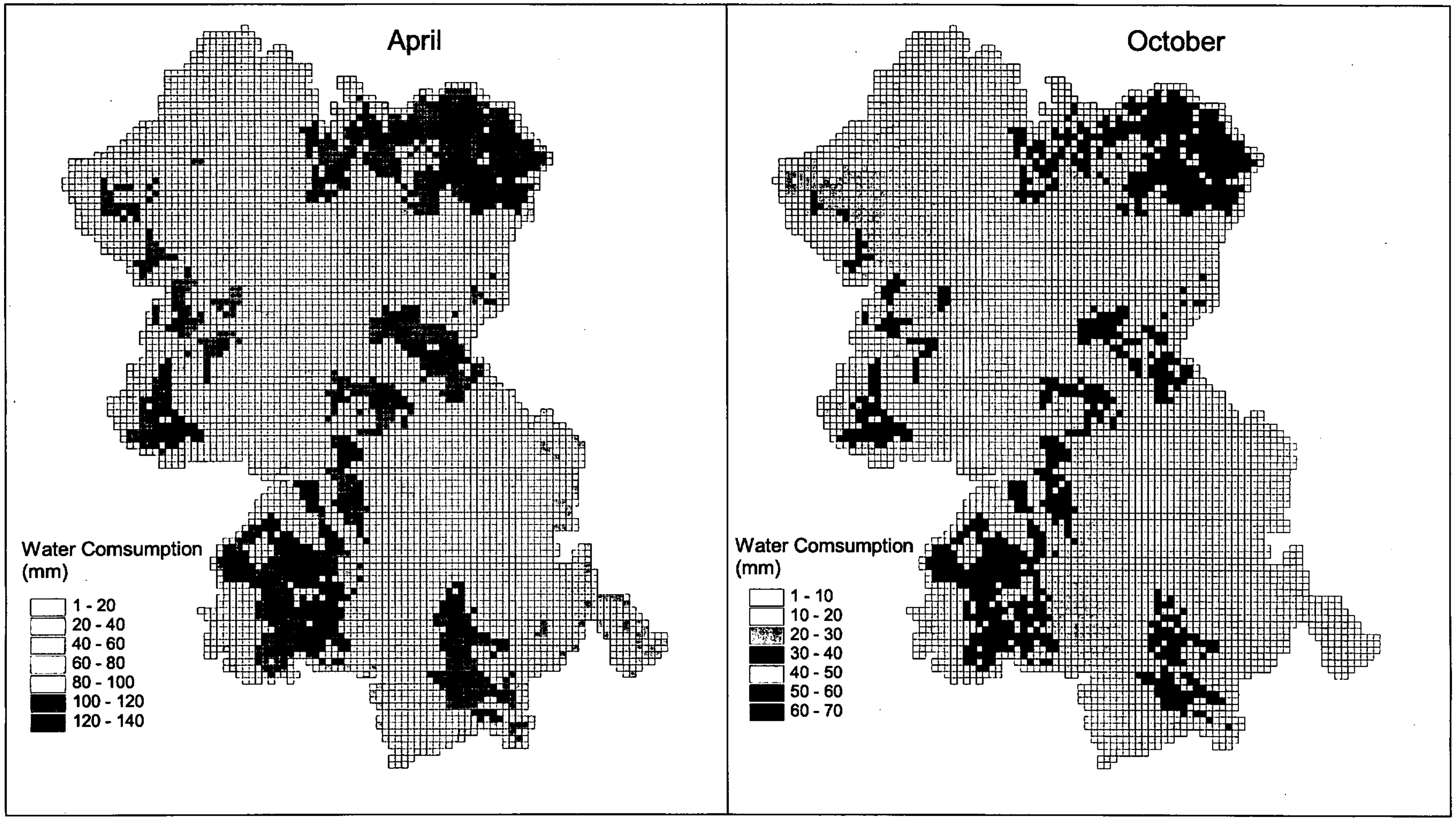
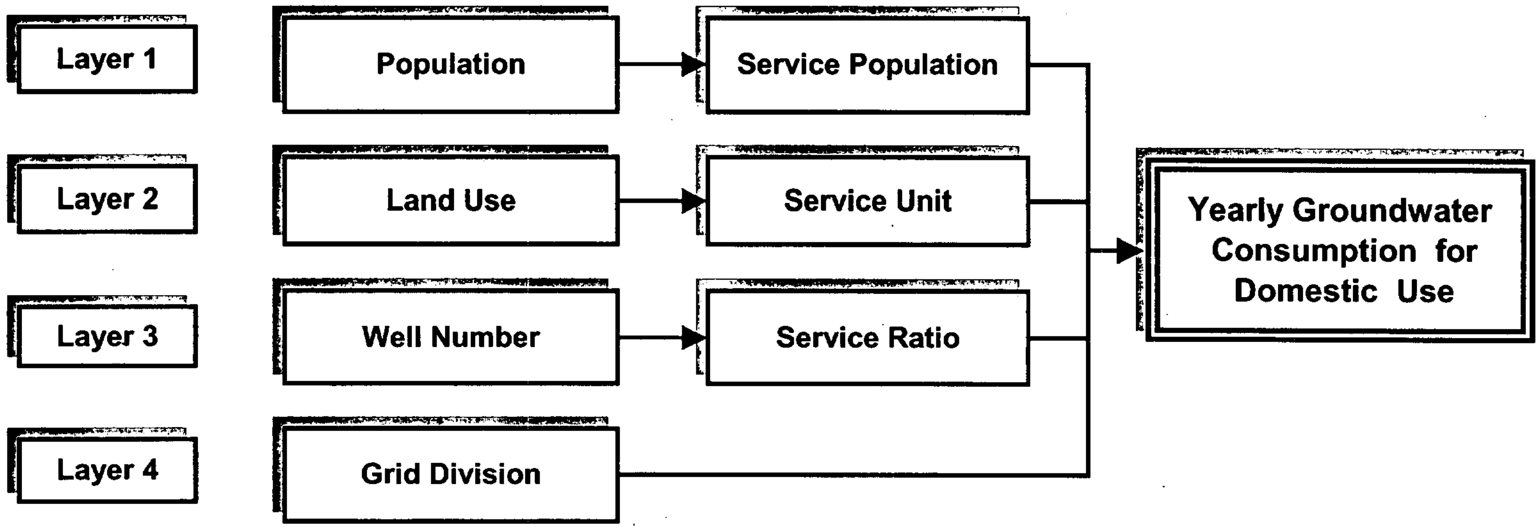


Figure 1.6.8 **Groundwater Consumption for Irrigation from Shallow Aquifer Apr. and Oct in 2001**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



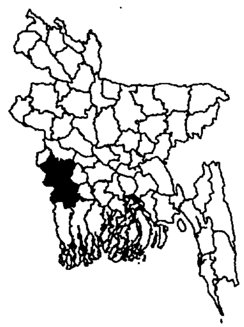
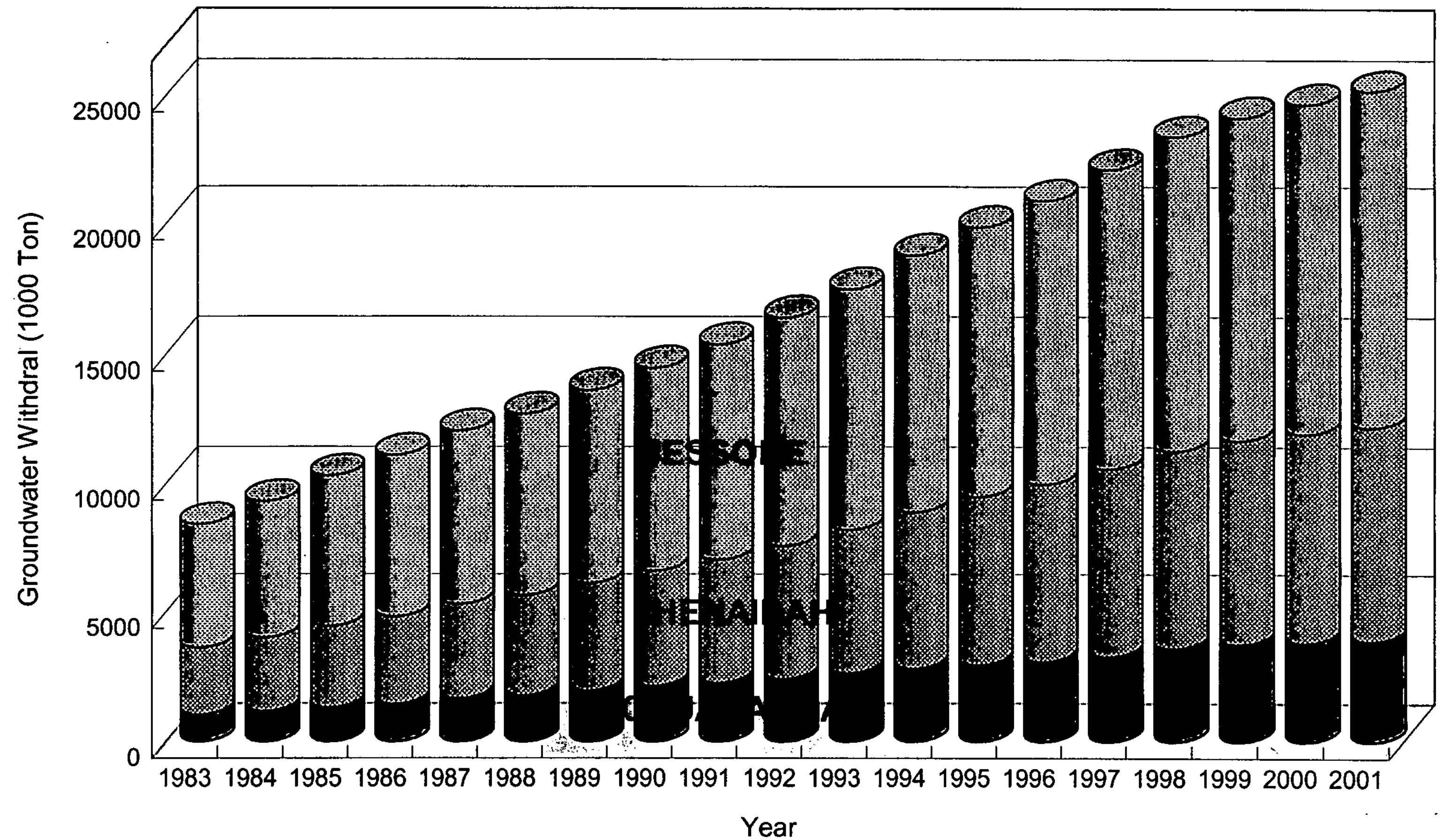


Figure 1.6.9	**Flow Chart for Estimation of Groundwater Consumption for Domestic Use**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



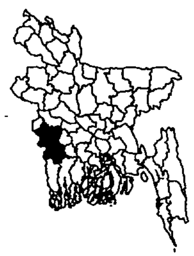
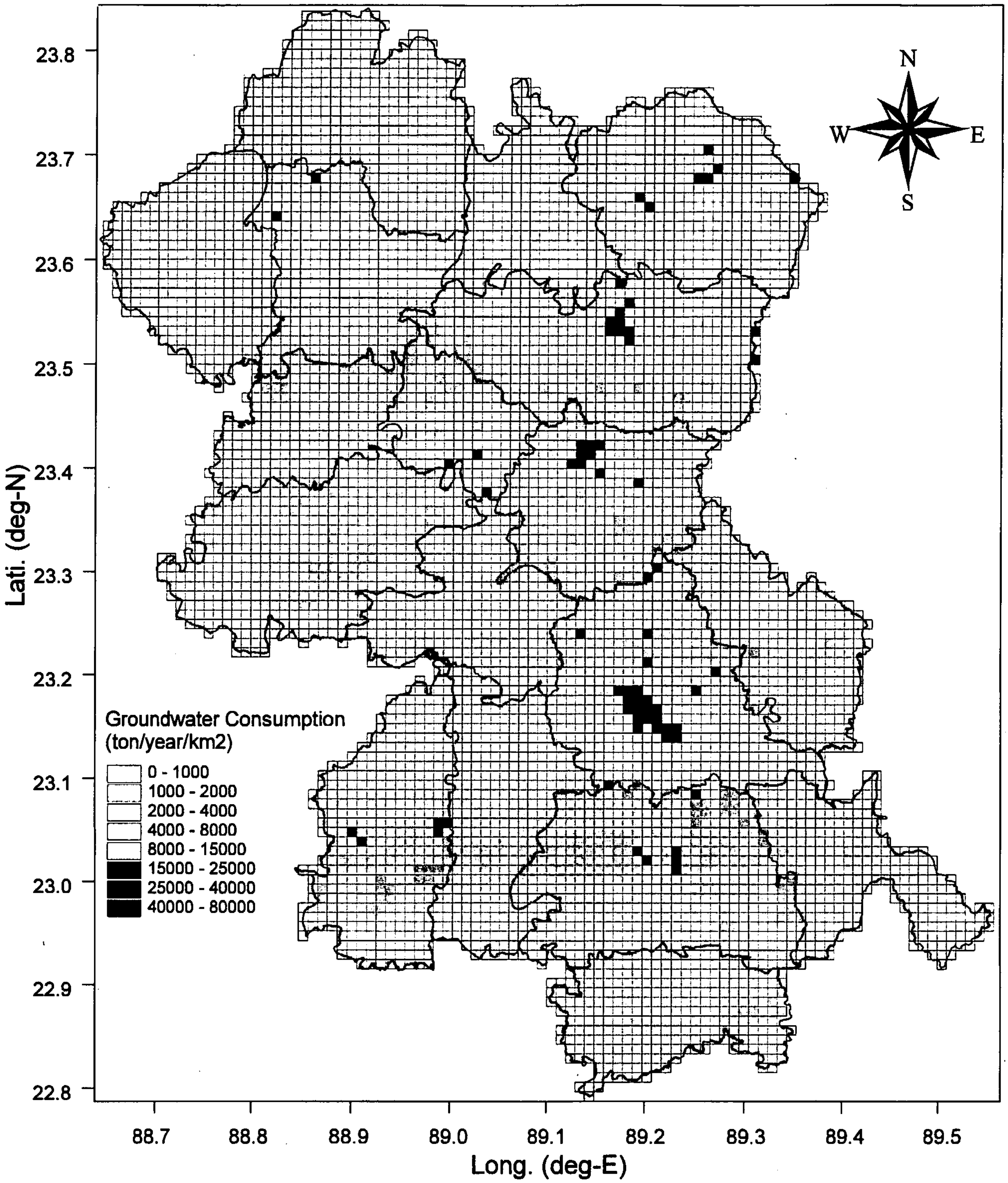


Figure 1.6.10	Estimated Yearly Ground Water Consumption for Domestic Use

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



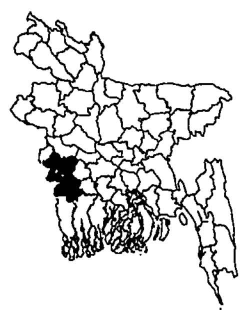
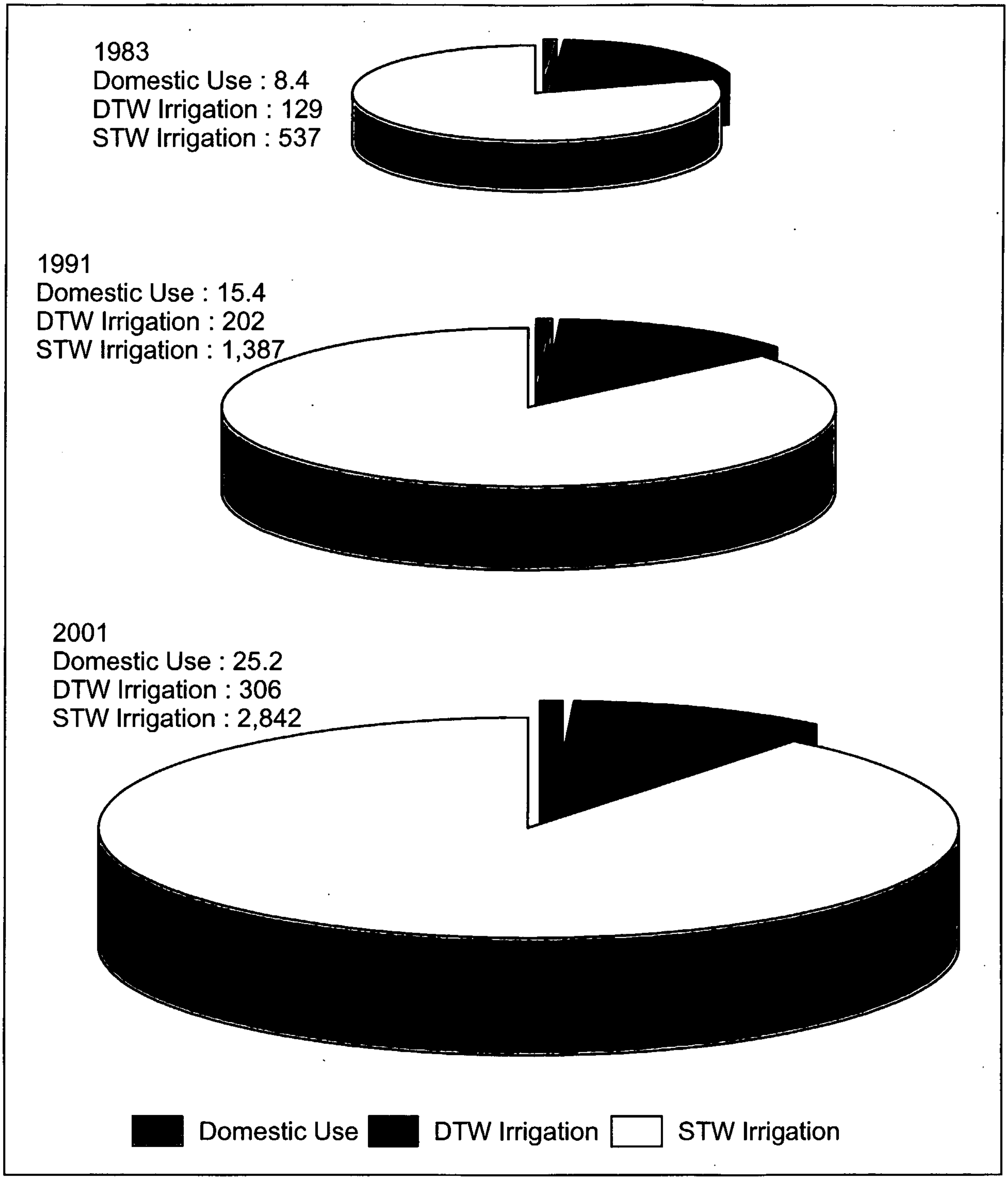
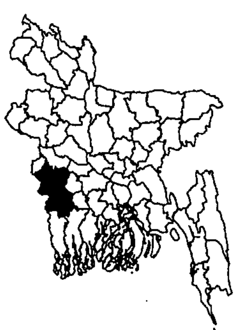


Figure 1.6.11	**Groundwater Consumption for Domestic Water Supply in 2001**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



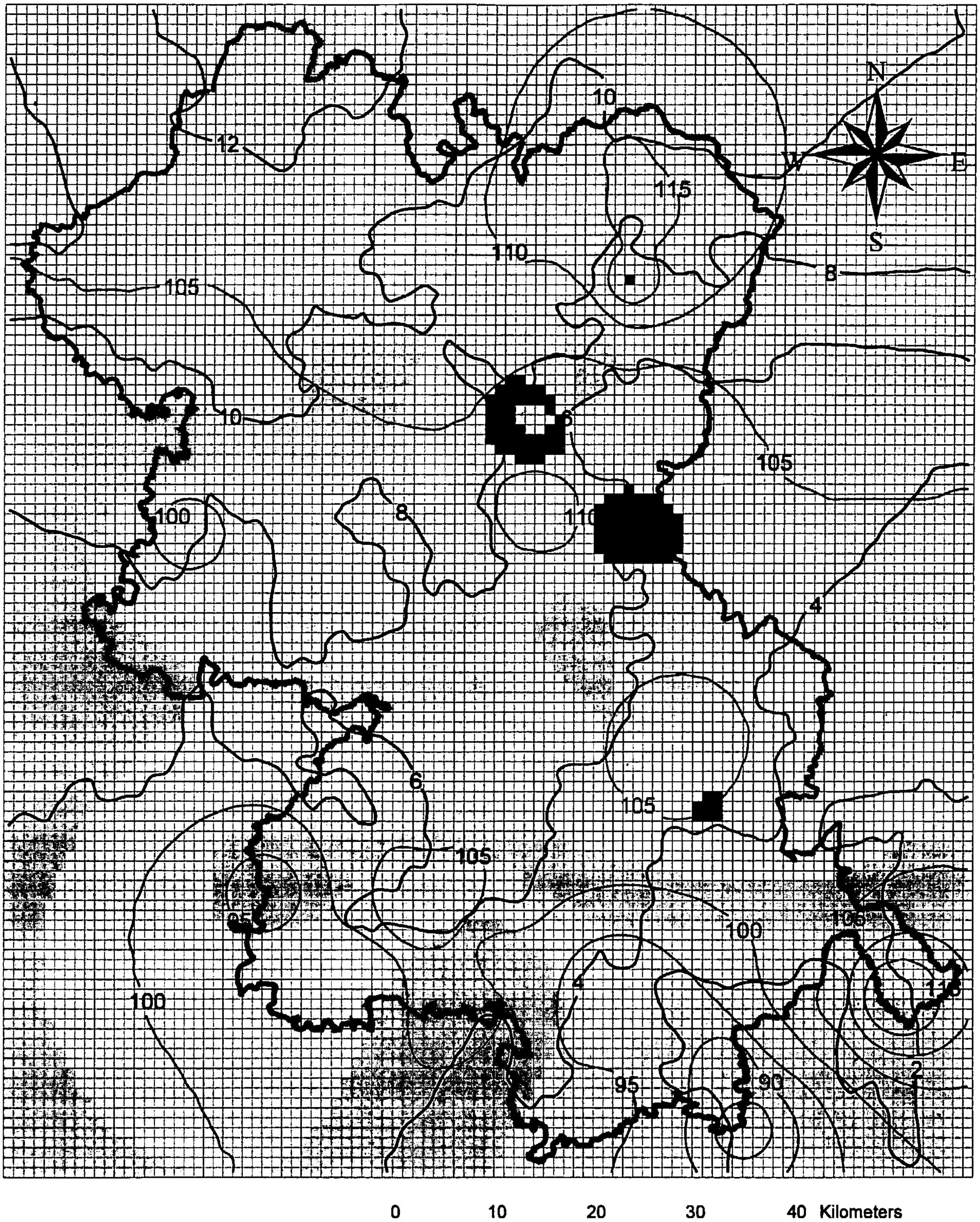


Unit : Million Ton

Figure 1.6.12	**Ratio of Groundwater Use in the Study Area**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



Legend

Elevation of Ground Surface

Thickness of Layers A+B

Thickness of Clay Layer(m)

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- >35

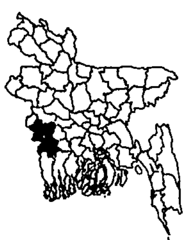


Figure 1.6.13	**Accumulated Thickness of Clay Layer in Layers A + B (Shallow Aquifer).**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

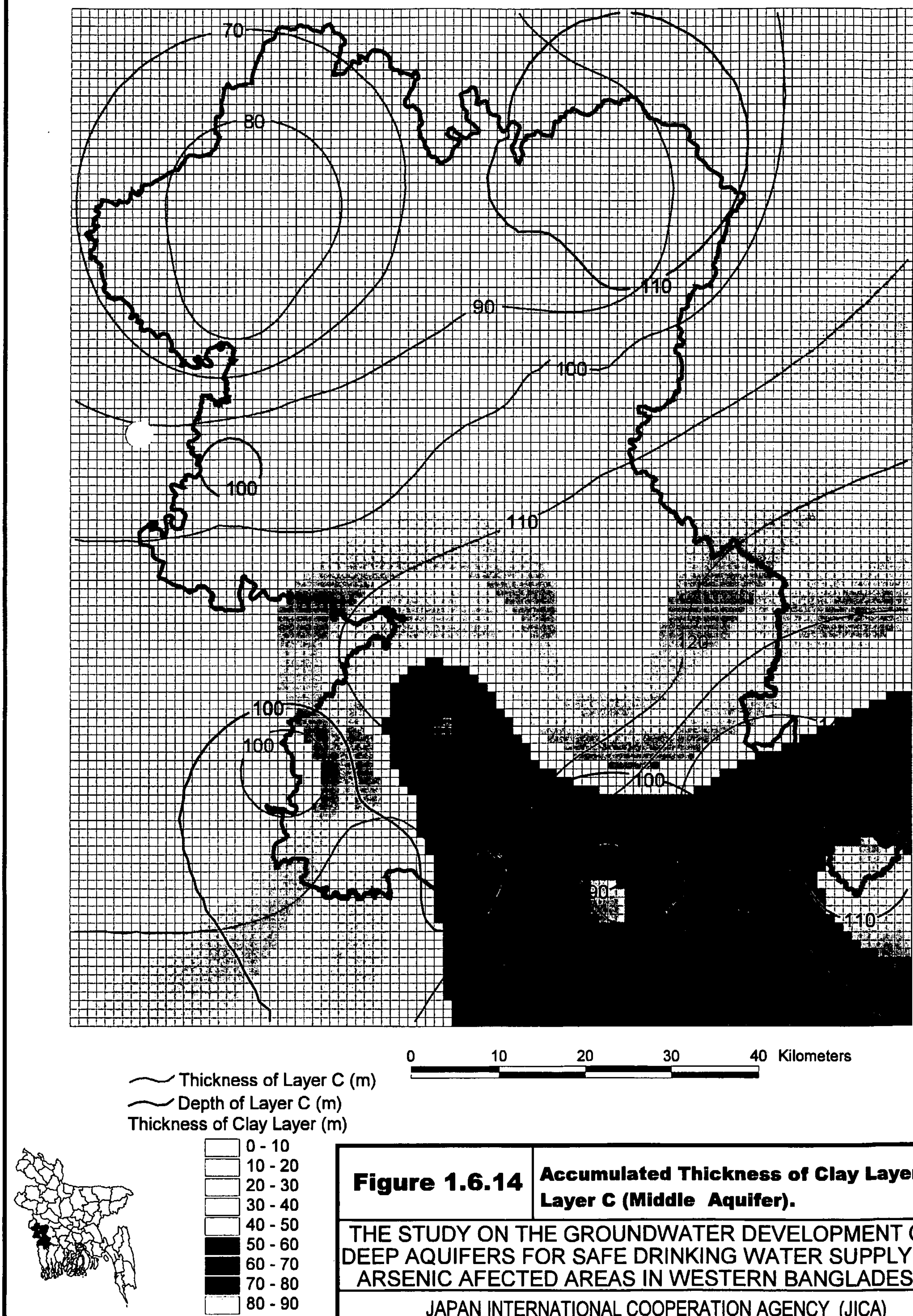


Figure 1.6.14	**Accumulated Thickness of Clay Layer in Layer C (Middle Aquifer).**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

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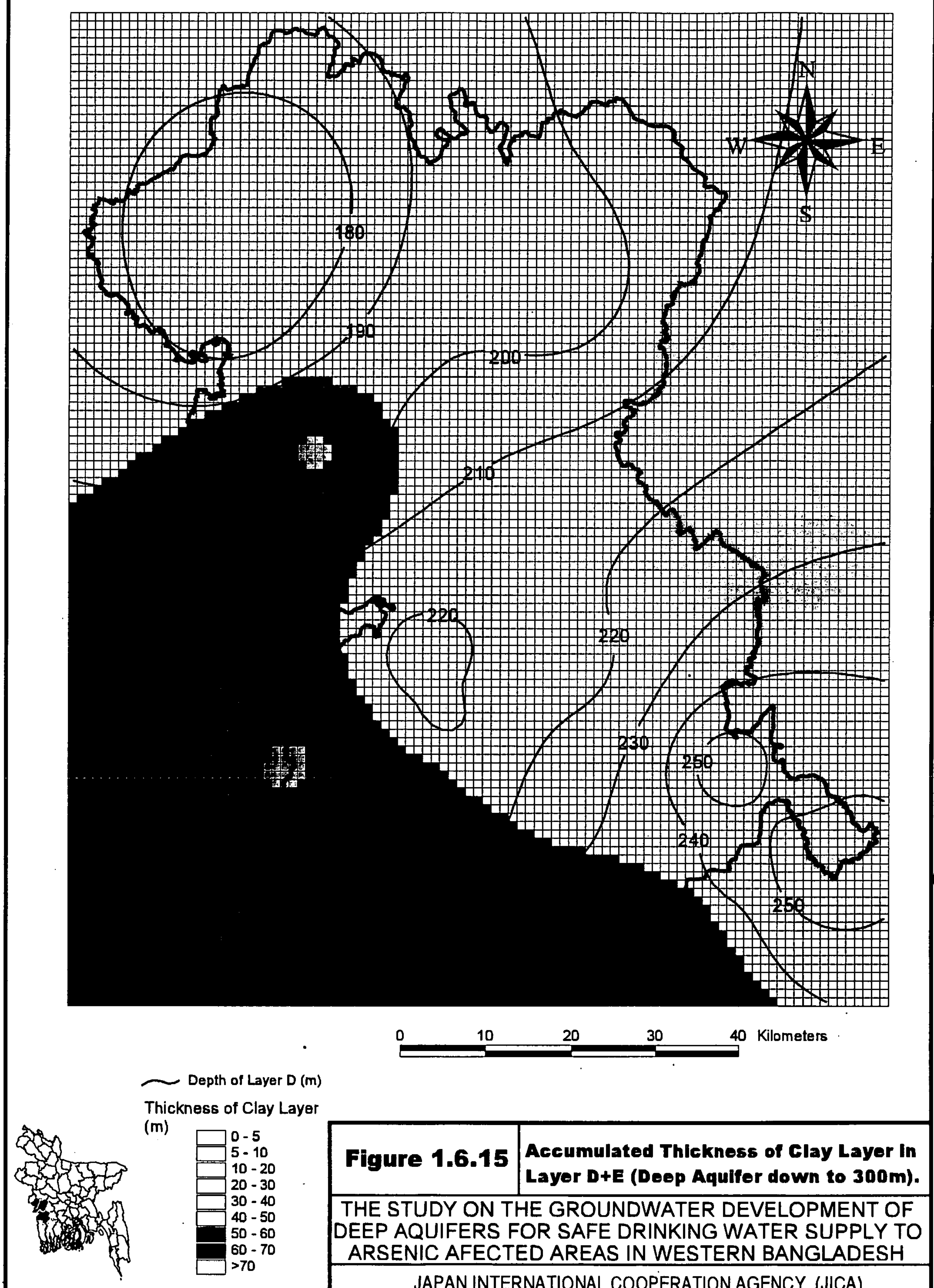


Figure 1.6.15 **Accumulated Thickness of Clay Layer in Layer D+E (Deep Aquifer down to 300m).**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CHAPTER 2

SUBSURFACE HYDROGEOLOGICAL STRUCTURE

CHAPTER 2 SUBSURFACE HYDROGEOLOGICAL STRUCTURE

2.1 Geophysical Prospecting

2.1.1 Purpose of the survey

A geophysical prospecting was carried out in the study area, which covers 3 districts (Chuadanga District, Jhenaidah District and Jessore District), and is shown in Figure 2.1.1.

The primary objective of this survey was to determine the composition and distribution of aquifers in the study area. The selection of the survey station was judged from the geographical features, comparison of log data of wells, the precise site for a measurement and road condition, etc.

On the basis of the general survey results, Electromagnetic Prospecting was decided by survey areas. In this report we describe the outline of the transient electromagnetic (TEM) survey and interpreted results of the data.

2.1.2 Outline of the survey

1) The TEM method

a) Physical principles

TEM is a transient electromagnetic method, often referred to as time-domain electromagnetic method, in which the ground is energized by a man-made magnetic field and its response is measured as a function of time to determine the resistivity of the earth beneath observation point as a function of depth. In this method, a steady current is passed through a loop of wire usually situated on or above the surface of the earth, which is inductively linked to the earth.

The fact that loop sources, which have no direct contact with the earth, can be used makes this method suitable in areas where high surface resistivity prohibits the use of conventional direct current methods. This would include regions covered by desert, sand dunes or extrusive volcanic.

This direct current is abruptly interrupted and the secondary fields due to induced eddy currents can be measured in the absence of the primary field. The currents migrate from the transmitter into the earth and the pattern resembles a “smoke ring”. The rate of change of the magnetic field depends upon the underground resistivity structure. For poor conductive medium, the receiver coil output voltage, which is proportional to the time rate of change of the secondary magnetic field, is initially large but decays rapidly. The response of a good conductor is initially lower but the voltage decays more slowly. The time derivative of the transient magnetic field, which results from these currents can be measured by a coil sensor (see Figure 2.1.2).

The decay of the secondary field measured at the surface can be analyzed to determine the resistivity of the earth at a depth. The resistivity of geological materials is highly dependent upon porosity, saturation, and pore fluid resistivity information about water content and its quality, and TEM resistivity measurements are a valuable structural mapping tool for groundwater studies.

The TEM method was selected for this survey for the following reasons; (1) stability of the transmitter signal, (2) lack of static shift, (3) no near field phenomena, (4) uniqueness of the results, and (5) suitability of ungrounded source.

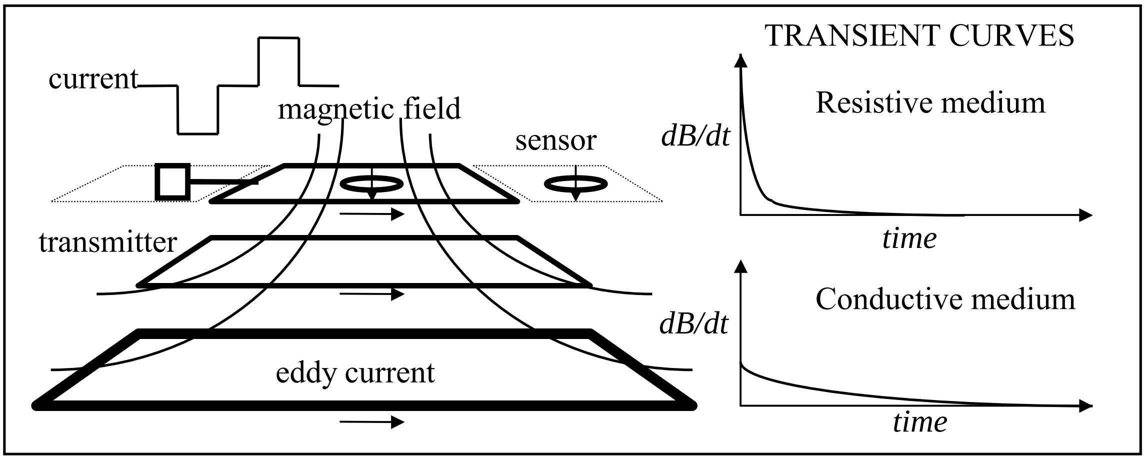


Figure 2.1.2 TEM survey configurations and transient curves

b) Equipment

The specifications of the TEM measurement system manufactured by Geonics Corp., which was used in this survey, are shown in Table 2.1.1.

The receiver console, a PROTEM 57 (D) unit, samples the coil response to the induced magnetic field in the ground at a series of time intervals that are displayed by a prescribed amount from each turn-off of the loop current. Through the use of two transmitter-waveform base frequencies, namely 262.5 and 25 Hz, the decay voltage was recorded in two overlapping time ranges of 0.00613-0.06959 ms and 0.08813-6.978 ms, respectively, after the current was turned off. There are 20 gates in each time range. The channel positions, or gate times, of 20 geometrically spaced time gates are shown in Table 2.1.2.

The TEM Measurement system is shown in the photo below.

TEM47 Coil **TEM57 Coil**
TEM47 Transmitter **Receiver Protem57(D)** **TEM57 Transmitter**

The TEM47 is an internal 12-volt rechargeable battery powered transmitter that can supply a 3A at the maximum. The TEM57 is a 24 volt car-battery powered transmitter that can supply up to 20A at the maximum.

A reference cable is used to establish precise timing between transmitter and receiver. These systems were applied to make high resolution sounding to the depths of a few 100m.

Table 2.1.1 Specifications of TEM survey equipment

MODEL	SPECIFICATIONS	NUMBER
Receiver PROTEM57 (D)	Measured Quantity: Rate of decay of induced magnetic field in nV/m^2 Base Frequencies: 0.3, 0.75, 3, 7.5, 30, 75 and 285 Hz or 0.25, 0.625, 2.5, 6.25, 25, 62.5 and 262.5 Hz Time Gates: 20 geometrically spaced time for each base frequency (6 ms to 800 ms) Dynamic Range: 23 bits (132 dB) Integration Time: 2, 4, 8, 15, 30, 60, 120, 240 sec Synchronization: Reference cable or high stability quartz crystal	1
Coil	Air-cored Coil Effective Area: 31.4 square meters Effective Area: 100 square meters	2

<u>Transmitter</u>	Current waveform: Bipolar rectangular current	2
TEM47	with 50% duty cycle	
	Frequencies: 30, 75, 285 Hz or 25, 62.5, 262.5 Hz	
	Maximum Current: 3 A	
	Output voltage: 0 to 9 V, continuously variable	
	Turn-off Time: 2.5 msec at 3 A into 40 × 40 m loop	
	Faster into smaller loop	
TEM57	with 50% duty cycle	
	Frequencies: 3, 7.5, 30 Hz or 2.5, 6.25, 25 Hz	
	Maximum Current: 20 A	
	Output voltage: 20 and 40 V, continuously variable	
	Turn-off Time: 115μs at 20 A into 5 × 5 m 8 turn loop	

Table 2.1.2 Sampling gate times

GATE	BASE FREQUENCY				
NO	262.5 Hz	62.5 Hz	25 Hz	6.25 Hz	2.5 Hz
1	6.813	35.25	88.13	352.5	881.3
2	8.688	42.75	106.9	427.5	1069
3	11.13	52.50	131.3	525.0	1313
4	14.19	64.75	161.9	647.5	1619
5	18.07	80.25	200.6	802.5	2006
6	23.06	100.3	250.6	1003	2506
7	29.44	125.8	314.4	1258	3144
8	37.56	158.3	395.6	1583	3956
9	47.94	199.8	499.4	1998	4994
10	61.13	252.5	631.3	2525	6313
11	77.94	319.8	799.4	3198	7994
12	99.38	405.5	1014	4055	10140
13	126.7	514.8	1287	5148	12870
14	166.4	654.3	1636	6543	16360
15	206.0	832.3	2081	8323	20810
16	262.8	1059	2648	10590	26480
17	335.2	1349	3373	13490	33730
18	427.7	1719	4297	17190	42970
19	545.6	2190	5475	21900	54750
20	695.9	2792	6978	27920	69780

UNIT: μsec

c) Data processing

The following map shows a flow chart of data analysis used in this study.

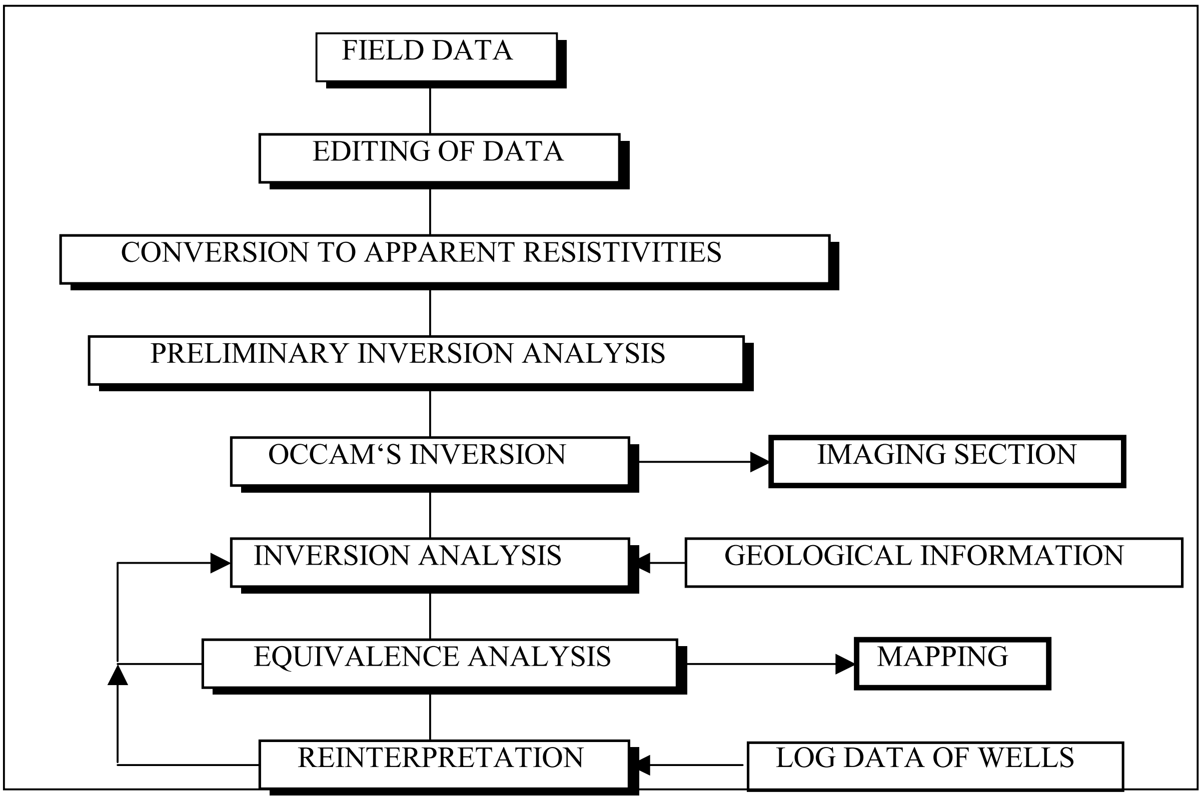


Figure 2.1.3 Flow chart of data analysis

In the first phase of data processing, the decay voltages are transformed into late-time apparent resistivity values at each gate, after checking the measurement parameters (e.g. loop dimensions, gains of receiver, current, station locations and so forth) of field data.

The voltages, V_0 (in unit of mV), which are measured by the PROTEM57 (D) system are converted to the magnetic field decay rate, *dB/dt* (nV/m^2), by the following formula (Geonics, 1992).

$$\frac{dB}{dt} = \frac{V_0 \cdot 19200}{E \cdot 2^n}$$

where *E* is the receiver coil moment (m^2), and *n* is the amplitude gain setting. Apparent resistivity $\rho_a(t)$ (ohm-m) as a function of time are then given by,

$$\rho_a(t) \cong \frac{\mu}{4 p t_c}\left(\frac{2 \mu M}{5 t_c \, dB/dt}\right)^{2/3}$$

where m is magnetic permeability (*4p*10^{-7} in unit of H/m), t_c is the measurement time or the gate center time in s, and *M* is the transmitter moment, which is the product of loop area (m^2)

and current (A).

Occam's inversion technique, named smooth inversion, was used to generate resistivity imaging sections with models up to 15 layers. In this process, a candidate model is iteratively changed to estimate the best fitting model to the observed data under restricted conditions in which the resistivity of each layer changes smoothly. Imaging sections obtained by this technique can visualize underground structures without artificial parameterization. The imaging results were also used to estimate initial model parameters for the following one-dimensional inversion.

The one-dimensional inverse processing is used to obtain one-dimensional resistivity structures where the layered model can be assumed to be from a geological point of view. In this process we can estimate structural parameters (e.g., resistivities and thickness) of best fitting models with up to 8 layers using the least squares method called automatic ridge regression.

Finally, equivalence analysis was done to estimate a set of equivalent models, that is, alternative models that fit the data nearly as well as the best-fit model, but different from this model. The forward calculations for each model are used; these are selected to determine the extent to which modifications to the model can be made according to these guidelines without exceeding a user-specified error. Equivalence analysis also indicates the allowable range of each of the model parameters.

The program that we have used in this study is "TEMIX-GL" developed by Interpex Ltd.

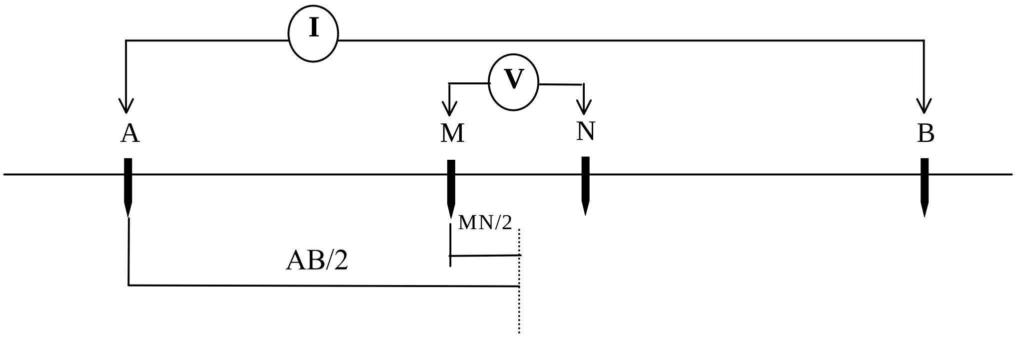
2) Electric Prospecting

a) Physical principles

The electric prospecting method is used in the study of horizontal and vertical discontinuities in the electrical properties of the ground. It is routinely used in hydrogeological investigations to investigate the shallow subsurface geology.

In the electric method, artificially generated electric currents are introduced into the ground and the resulting potential differences are measured at the surface. By knowing that current flowing through the ground and the resulting potential differences of voltage between two potential electrodes, it is possible to compute the resistivity of the earth materials.

In this study area, the Schlumberger method was used. This method throws the current into the current electrode in two places set up on the measurement line, and measuring the potential difference with a couple of potential electrodes installed inside (see Figure 2.1.4).



$\rho a=\pi/4\times((AB^2-MN^2)/MN)\times(V/I)$

V: Measurement voltage between MN(V) I: Transmission current between AB(A)
AB: Current electrode MN: Potential electrode ρa: Apparent resistivity (Ωm)

Figure 2.1.4 Electrode configuration

The combination of the current electrode interval and the potential electrode interval is shown in Table 2.1.3.

Table 2.1.3 Electrode Spaced

(AB/2)	1	2	4	6	8	10	15	20	25	30	35
(MN/2)	0.2	0.2	0.2	0.2/1	1	1	1	1	1/5	5	5
(AB/2)	40	50	60	70	80	90	100	130	160	200	250
(MN/2)	5	5/10	10	10	10	10	10/20	20	20	20	20/50
(AB/2)	300	350	400	450	500	550	600	650	700		
(MN/2)	50	50	50	50	50/100	100	100	100	100		

AB/2: Electrode interval (m), MN/2: Potential interval (m)

b) Equipment

The equipment used in this survey, the Electric measurement system manufactured by BRGM Corp. in France, is shown in the photo below and described in Table 2.1.4.

Syscal R2 **DC-DC Converter** **Battery**

Table 2.1.4 Specifications of Electric survey equipment

MODEL	SPECIFICATIONS	NUMBER
Receiver and Transmitter	Syscal system R2	1
DC-DC 100W Converte		1
	Input voltage: 24 V	
	Output voltage: 110 to 330 V, continuously variable	

2.1.3 Investigation of the geophysical survey method

The geophysical survey method is the Electromagnetic and Electric Prospecting. Though the investigation uses one of these techniques, the techniques had been examined in several districts before the investigation began to determine which one was more suitable. Measurements were made at a total of 6 stations in the 3 districts, as show in Figure 2.1.5.

The measurement place was the same. Figure 2.1.6 shows a comparison of measured TEM data and electric data. As a result, the major difference is the resistivity boundary.

But, the results of the resistivity inversion model are similar.

2.1.4 Measurements

The total number of measurement stations is 200 stations by TEM prospecting, 38 stations in Chuadanga, 67 stations in Jhenaidah, and 95 stations in Jessore. These measurements were made at stations at random with a spacing of approximately less than ten kilometers (see Figure 2.1.7). And a drilling program was conducted at sites identified by TEM as strategic. This program included core observations and geophysical logging.

Measurements were then made at 14 stations (Chuadanga: TEM record numbers are CHU0071, CHU0421 and CHU0731. Jhenaidah: JHE1931, JHE1531 and JHE1041. Jessore: JES0771 and JES1021 to JES1027) on nearby drilling program sites. Table 5.1.6 shows the list of 200 stations surveyed by TEM prospecting.

1) Positioning and station spacing

The stations were plotted on the topographic maps on a scale of 1:50,000 and then located by GPS (Global Positioning System).

2) Measurement configurations

The square transmitter loop 100m on a side was energized with a typical current of 2.5A for high production rates by the TEM47 transmitter. The secondary transmitter, the TEM57, is a typical current of about 12 A for low production rates. At each station, the receiver coil was located inside the square transmitter loop 50m from one side. This configuration was used instead of a central loop sounding to minimize the possibility of instrumental noise produced by currents induced in the instrument case. By keeping the receiver coil close to the transmitter loop, the sounding resembles a central induction measurement at all but the earliest times for the earth resistivity encountered in the study area.

The TEM measurement system is shown in the photo below.

Transmitter side

Receiver side (TEM47)

Receiver side (TEM57)

3) Noise

Several stacks of measured voltages were averaged and noise statistics determined. However, data with reversed polarity during transient were measured at several points where there were transmission line or the other conductive materials. These stations were moved a few hundred meters and usable data was obtained.

4) Result of Geophysical Prospecting

Most of the sounding data are interpreted with from five to six layers in most cases, In general the estimated resistivity ranges from more than 10 to less than 70 ohm-m. At almost all stations, resistivity structures consist of four to five layered models of LHML or LHLML (low, high, middle and low, or LHML type) at about 80% of the stations. In Chuadanga and Jessore Districts, LHLML type is at about 60% of the stations. The estimated resistivity structures are listed in Table 2.1.6.

Table 2.1.5(1) List of Geophysical Prospecting

(CHUADANGA district : 38 stations)

Thana	Union	Mauza	J.L No.	Geo-Code No.	TEM Record No.	Latitude	Longitude
ALAMDANGA	ALAMDANGA	Faridpur	80	339	CHU0801	E23° 43′ 29″	N88° 55′ 29″
ALAMDANGA	BARADI	Baradi	53	091	CHU0531	E23° 44′ 55″	N88° 52′ 47″
ALAMDANGA	BHANGABARIA	Hatubhanga	1	472	CHU0011	E23° 49′ 43″	N88° 51′ 06″
ALAMDANGA	BHANGABARIA	Bagadi	8	033	CHU0081	E23° 46′ 27″	N88° 50′ 20″
ALAMDANGA	DAUKI	Dauki	78	298	CHU0781	E23° 44′ 12″	N88° 58′ 53″
ALAMDANGA	GANGNI	Gangni	17	364	CHU0171	E23° 44′ 19″	N88° 49′ 04″
ALAMDANGA	HARDI	Hardi	68	447	CHU0681	E23° 48′ 12″	N88° 54′ 17″
ALAMDANGA	KALIDASPUR	Parkula	95	815	CHU0951	E23° 47′ 11″	N88° 56′ 34″
ALAMDANGA	JAMJAMI	Beguarkhal	99	107	CHU0991	E23° 40′ 41″	N88° 58′ 02″
ALAMDANGA	KHADIMPUR	Batiapara	28	099	CHU0282	E23° 41′ 28″	N88° 51′ 44″
ALAMDANGA	KHASKARA	Dakshin Lakshmipur	120	281	CHU1201	E23° 38′ 18″	N88° 58′ 05″
ALAMDANGA	NAGDAHA	Chhagharia	90	240	CHU0901	E23° 40′ 28″	N88° 55′ 55″
DAMURHUDA	DAMURHUDA	Muktarpur	32	765	CHU0321	E23° 36′ 02″	N88° 43′ 55″
DAMURHUDA	DARSHANA	Kamarpara	20	612	CHU0201	E23° 29′ 29″	N88° 45′ 04″
DAMURHUDA	HOWLI	Howli	61	510	CHU0611	E23° 35′ 36″	N88° 46′ 25″
DAMURHUDA	HOWLI	Joyrampur	68	510	CHU0682	E23° 34′ 51″	N88° 47′ 55″
DAMURHUDA	HOWLI	Dudhpatila	73	344	CHU0731	E23° 33′ 07″	N88° 48′ 38″
DAMURHUDA	JURANPUR	Ramnagar	51	867	CHU0511	E23° 40′ 58″	N88° 47′ 47″
DAMURHUDA	JURANPUR	Bishnupur	55	114	CHU0551	E23° 38′ 03″	N88° 46′ 47″
DAMURHUDA	KAPASDANGA	Munshibpur	6	778	CHU0061	E23° 34′ 59″	N88° 39′ 39″
DAMURHUDA	KURALGACHHI	Thakurpur	10	956	CHU0101	E23° 33′ 06″	N88° 41′ 15″
DAMURHUDA	KURALGACHHI	Chandipur	28	191	CHU0281	E23° 32′ 02″	N88° 44′ 39″
DAMURHUDA	NATIPOTA	Natipota	41	790	CHU0411	E23° 40′ 25″	N88° 43′ 33″
DAMURHUDA	NATIPOTA	Hemayetpur	43	484	CHU0431	E23° 37′ 49″	N88° 42′ 42″
CHUADANGA	ALOKDIA	Manirampur	3	743	CHU0031	E23° 39′ 14″	N88° 48′ 29″
CHUADANGA	BEGAMPUR	Akandabaria	23	010	CHU0231	E23° 30′ 58″	N88° 49′ 31″
CHUADANGA	BEGAMPUR	Kotali	29	653	CHU0291	E23° 32′ 30″	N88° 51′ 40″
CHUADANGA	KUTUBPUR	Boalia	78	204	CHU0782	E23° 35′ 16″	N88° 56′ 51″
CHUADANGA	MOMINPUR	Kathuli	47	613	CHU0471	E23° 39′ 15″	N88° 53′ 54″
CHUADANGA	CHUADANGA POURASHAVA	Bazruk Gargari	7	-	CHU0071	E23° 37′ 32″	N88° 50′ 12″
CHUADANGA	CHUADANGA POURASHAVA	Chuadanga	42	-	CHU0421	E23° 39′ 39″	N88° 51′ 11″
CHUADANGA	SHANKARCHANDRA	Jalsukha	34	572	CHU0341	E23° 35′ 58″	N88° 52′ 47″
CHUADANGA	TITUDAHA	Titudaha	72	974	CHU0721	E23° 33′ 07″	N88° 55′ 10″

Table 2.1.5(2) List of Geophysical Prospecting

Thana	Union	Mauza	J.L No.	Geo-Code No.	TEM Record No.	Latitude	Longitude
JIBANNAGAR	UTHALI	Khayerhuda	30	454	CHU0301	E23° 27′ 02″	N88° 50′ 28″
JIBANNAGAR	JIBANNAGAR	Umapur	10	980	CHU0102	E23° 25′ 31″	N88° 46′ 53″
JIBANNAGAR	BANKA	Pathla	41	724	CHU0412	E23° 23′ 31″	N88° 49′ 39″
JIBANNAGAR	BANKA	Raypur	69	810	CHU0691	E23° 26′ 05″	N88° 54′ 19″
JIBANNAGAR	ANDULABARIA	Andulbaria	55	028	CHU0552	E23° 29′ 03″	N88° 54′ 11″

(JHENAIDAHA district : 67 stations)

Thana	Union	Mauza	J.L No.	Geo-Code No.	TEM Record No.	Latitude	Longitude
JHENAIDAHA SADAR	SURAT	Ratanpur	152	883	JHE1521	E23° 29′ 43″	N89° 10′ 45″
JHENAIDAHA SADAR	HALDHANI	Haldhani	45	371	JHE0453	E23° 33′ 03″	N89° 04′ 58″
JHENAIDAHA SADAR	GANNA	Kaluhati	69	467	JHE0691	E23° 30′ 33″	N89° 05′ 05″
JHENAIDAHA SADAR	GHORSAL	Munuria	205	701	JHE2051	E23° 27′ 46″	N89° 15′ 16″
JHENAIDAHA SADAR	FURSANDI	Dhananjaypur	260	289	JHE2601	E23° 28′ 40″	N89° 16′ 49″
JHENAIDAHA SADAR	MADHUHATI	Basipur	20	118	JHE0201	E23° 30′ 07″	N89° 01′ 34″
JHENAIDAHA SADAR	JHENAIDAHA PAURASHAVA	Khajura	121	-	JHE1211	E23° 34′ 01″	N89° 09′ 43″
JHENAIDAHA SADAR	JHENAIDAHA PAURASHAVA	Kamarkunda	153	-	JHE1531	E23° 30′ 44″	N89° 10′ 23″
JHENAIDAHA SADAR	KALICHARANPUR	Uttar Kashiasagara	193	907	JHE1931	E23° 32′ 04″	N89° 13′ 06″
JHENAIDAHA SADAR	SAGENNA	Badpukuria	30	048	JHE0301	E23° 32′ 31″	N89° 01′ 42″
JHENAIDAHA SADAR	SAGENNA	Baldanga	34	055	JHE0341	E23° 34′ 18″	N89° 02′ 35″
JHENAIDAHA SADAR	PADMAKAR	Achintyanagar	225	033	JHE2251	E23° 32′ 54″	N89° 17′ 12″
JHENAIDAHA SADAR	SADHUHATI	Bankira	3	089	JHE0031	E23° 31′ 29″	N88° 58′ 22″
JHENAIDAHA SADAR	MAHARAJPUR	Dakshin Ramnaga	88	274	JHE0882	E23° 27′ 04″	N89° 05′ 57″
JHENAIDAHA SADAR	MAHARAJPUR	Kesabpur	111	530	JHE1111	E23° 29′ 31″	N89° 08′ 02″
JHENAIDAHA SADAR	PORAHATI	Basudebpur	184	122	JHE1841	E23° 34′ 29″	N89° 12′ 37″
JHENAIDAHA SADAR	PORAHATI	Bijoypur	217	174	JHE2171	E23° 33′ 06″	N89° 14′ 36″
JHENAIDAHA SADAR	KUMARBARIA	Kumarbaria	61	594	JHE0611	E23° 32′ 26″	N89° 06′ 33″
KALIGANJ	RAIGRAM	Bhatghara	127	168	JHE1271	E23° 21′ 02″	N89° 09′ 20″
KALIGANJ	RAKHALGACHHI	Hasanhati	64	390	JHE0641	E23° 20′ 01″	N89° 04′ 05″
KALIGANJ	JAMAL	Gutiani	89	377	JHE0891	E23° 25′ 33″	N89° 10′ 37″
KALIGANJ	JAMAL	Dauti	100	266	JHE1001	E23° 25′ 29″	N89° 13′ 27″
KALIGANJ	KOLA	Tenghari Huda	173	977	JHE1731	E23° 23′ 22″	N89° 14′ 08″
KALIGANJ	TRILOCHANPUR	Sahapur	45	866	JHE0451	E23° 23′ 57″	N89° 04′ 08″
KALIGANJ	SIMUR ROKANPUR	Chhota Simla	39	235	JHE0391	E23° 23′ 04″	N89° 06′ 28″

Table 2.1.5(3) List of Geophysical Prospecting

Thana	Union	Mauza	J.L No.	Geo-Code No.	TEM Record No.	Latitude	Longitude
KALIGANJ	MALIAT	Maliat	180	635	JHE1801	E23° 20′ 44″	N89° 13′ 00″
KALIGANJ	BAROBAZAR	Sadikpur	161	857	JHE1611	E23° 18′ 28″	N89° 07′ 44″
KALIGANJ	BAROBAZAR	Gram Majdia	195	368	JHE1951	E23° 17′ 43″	N89° 10′ 48″
KALIGANJ	NIAMATPUR	Nagar Chaprail	123	226	JHE1231	E23° 22′ 23″	N89° 11′ 11″
KALIGANJ	SUNDARPUR DURGAPUR	Alaipur	19	008	JHE0191	E23° 25′ 28″	N89° 06′ 43″
KOTCHANDPUR	ELENGI	Gurpara	75	429	JHE0751	E23° 26′ 20″	N89° 02′ 59″
KOTCHANDPUR	KOTCHANDPUR PAURASHAVA	Dudsara	45	-	JHE0452	E23° 25′ 09″	N88° 59′ 55″
KOTCHANDPUR	DORA	Dyarampur	6	294	JHE0061	E23° 29′ 27″	N88° 58′ 08″
KOTCHANDPUR	SABDALPUR	Baliadanga	24	147	JHE0241	E23° 27′ 06″	N88° 57′ 50″
MOHESHPPUR	KAZIRBER	Palianpur	15	736	JHE0151	E23° 15′ 44″	N88° 44′ 26″
MOHESHPPUR	FATEHPUR	Chandpur	104	213	JHE1041	E23° 23′ 15″	N88° 54′ 25″
MOHESHPPUR	MANDERBARI	Hudauhankar	139	407	JHE1391	E23° 19′ 35″	N88° 56′ 44″
MOHESHPPUR	SYAMKUR	Padmapukhuria	28	726	JHE0281	E23° 19′ 25″	N88° 46′ 55″
MOHESHPPUR	BANSBARIA	Bhairaba	48	159	JHE0481	E23° 16′ 45″	N88° 48′ 45″
MOHESHPPUR	MOHESHPPUR PAURASHAVA	Hamidpur	108	-	JHE1081	E23° 20′ 37″	N88° 55′ 37″
MOHESHPPUR	PANTAPARA	Manikdihi	74	646	JHE0741	E23° 21′ 56″	N88° 51′ 36″
MOHESHPPUR	SUNDARPUR	Sundarpur	151	940	JHE1511	E23° 22′ 15″	N88° 57′ 25″
MOHESHPPUR	SWARUPPUR	Huda Kusadanga	34	402	JHE0342	E23° 21′ 52″	N88° 47′ 46″
MOHESHPPUR	NATIMA	Shibanandapur	95	895	JHE0951	E23° 19′ 04″	N88° 52′ 35″
MOHESHPPUR	JADABPUR	Huda Andarkota	85	388	JHE0851	E23° 14′ 48″	N88° 52′ 11″
MOHESHPPUR	JADABPUR	Poradaha	120	776	JHE1201	E23° 16′ 40″	N88° 54′ 02″
HARINAKUNDA	TAHERHUDA	Sripur	11	930	JHE0111	E23° 41′ 26″	N89° 01′ 31″
HARINAKUNDA	TAHERHUDA	Taherhuda	14	956	JHE0141	E23° 41′ 18″	N89° 03′ 18″
HARINAKUNDA	RAGHUNATHPUR	Bhabitpur	18	116	JHE0181	E23° 41′ 29″	N89° 06′ 32″
HARINAKUNDA	HARINAKUNDA	Balarampur	25	077	JHE0251	E23° 40′ 04″	N89° 03′ 42″
HARINAKUNDA	BHAINA	Tailtupi	1	909	JHE0011	E23° 44′ 44″	N89° 03′ 53″
HARINAKUNDA	CHANDPUR	Bashudebpur	72	090	JHE0721	E23° 35′ 54″	N89° 08′ 01″
HARINAKUNDA	DAULATPUR	Parbatipur	33	123	JHE0331	E23° 37′ 51″	N89° 01′ 27″
HARINAKUNDA	KAPASHATI	Ghoragachha	56	335	JHE0561	E23° 36′ 09″	N89° 04′ 57″
SAILKUPA	SARUTIA	Bakharba	55	093	JHE0551	E23° 45′ 05″	N89° 14′ 00″
SAILKUPA	FAZILPUR	Hazramina	68	428	JHE0682	E23° 40′ 30″	N89° 16′ 12″
SAILKUPA	FAZILPUR	Madhabpur	118	610	JHE1181	E23° 38′ 46″	N89° 16′ 59″
SAILKUPA	DHALHARA	Dautia Chakirgati	96	269	JHE0961	E23° 40′ 17″	N89° 20′ 36″
SAILKUPA	DIGNAGAR	Dahakula	47	241	JHE0471	E23° 41′ 08″	N89° 11′ 58″
SAILKUPA	UMEDPUR	Taraf Imedpur	122	956	JHE1221	E23° 37′ 37″	N89° 14′ 23″

Table 2.1.5(4) List of Geophysical Prospecting

Thana	Union	Mauza	J.L No.	Geo-Code No.	TEM Record No.	Latitude	Longitude
SAILKUPA	UMEDPUR	Shashtipur	126	896	JHE1261	E23° 39′ 23″	N89° 14′ 14″
SAILKUPA	FULHARI	Chandpur	133	236	JHE1331	E23° 38′ 22″	N89° 10′ 53″
SAILKUPA	NITYANANDAPUR	Shakhra	155	890	JHE1551	E23° 35′ 26″	N89° 15′ 37″
SAILKUPA	HAKIMPUR	Kaupara	88	527	JHE0881	E23° 41′ 19″	N89° 18′ 18″
SAILKUPA	ABAIPUR	Kumiradaha	177	593	JHE1771	E23° 36′ 31″	N89° 18′ 49″
SAILKUPA	TRIBENI	Padamdi	16	747	JHE0161	E23° 42′ 12″	N89° 09′ 05″
SAILKUPA	MIRJAPUR	Hudamailmari	7	439	JHE0071	E23° 39′ 04″	N89° 08′ 18″

(JESSORE district : 95 stations)

Thana	Union	Mauza	J.L No.	Geo-Code No.	TEM Record No.	Latitude	Longitude
JHIKARGACHHA	MAGURA	Magura	41	604	JES0411	E23° 09′ 09″	N89° 03′ 06″
JHIKARGACHHA	HAZIRBAG	Sonakur	131	946	JES1311	E22° 59′ 54″	N89° 03′ 37″
JHIKARGACHHA	SHANKARPUR	Ulakol	146	986	JES1461	E22° 57′ 44″	N89° 01′ 15″
JHIKARGACHHA	BANKRA	Simulia	162	928	JES1621	E22° 56′ 20″	N89° 03′ 25″
JHIKARGACHHA	PANISARA	Rajapur	71	840	JES0711	E23° 04′ 33″	N89° 06′ 11″
JHIKARGACHHA	PANISARA	Taora	92	968	JES0922	E23° 03′ 18″	N89° 04′ 10″
JHIKARGACHHA	NABHARAN	Krimali	109	497	JES1091	E23° 02′ 36″	N89° 01′ 16″
JHIKARGACHHA	GANGANANDAPUR	Atolia	4	048	JES0041	E23° 11′ 20″	N89° 01′ 38″
JHIKARGACHHA	GADKHALI	Fatepur	30	310	JES0301	E23° 05′ 47″	N89° 03′ 02″
JHIKARGACHHA	JHIKARGACHA	Sagarpur	35	875	JES0351	E23° 07′ 15″	N89° 05′ 25″
SHARSHA	LAKSHMANPUR	Khamarpara	32	538	JES0321	E23° 06′ 51″	N88° 57′ 33″
SHARSHA	PUTKHALI	Sibnathpur	108	906	JES1081	E22° 59′ 09″	N88° 53′ 21″
SHARSHA	BAHADURPUR	Dhanyakhola	38	272	JES0381	E23° 05′ 58″	N88° 53′ 55″
SHARSHA	BAGACHRA	Pipragchhi	127	700	JES1271	E22° 58′ 39″	N88° 58′ 54″
SHARSHA	BENAPOLE	Dighirpar	87	287	JES0871	E23° 02′ 37″	N88° 55′ 27″
SHARSHA	BENAPOLE	Bara Achra	90	073	JES0901	E23° 01′ 27″	N88° 53′ 28″
SHARSHA	KAYBA	Baguri	135	036	JES1351	E22° 56′ 05″	N88° 58′ 57″
SHARSHA	GOGA	Setal	123	891	JES1231	E22° 57′ 35″	N88° 56′ 05″
SHARSHA	SHARSHA	Kulpara	67	560	JES0671	E23° 04′ 28″	N88° 59′ 15″
SHARSHA	DIHI	Tengrali	2	987	JES0021	E23° 11′ 33″	N88° 58′ 23″
SHARSHA	ULASHI	Rampur	98	788	JES0981	E23° 00′ 45″	N88° 57′ 03″
KESHABPUR	KESHABPUR	Mulgram	26	728	JES0261	E22° 55′ 25″	N89° 11′ 27″
KESHABPUR	KESHABPUR	Bhagati Narendrapur	28	154	JES0281	E22° 54′ 50″	N89° 12′ 42″
KESHABPUR	KESHABPUR	Khatiakhali	79	553	JES0791	E22° 54′ 57″	N89° 14′ 41″
KESHABPUR	SUFALAKATI	Kismatsantala	124	567	JES1242	E22° 55′ 05″	N89° 20′ 34″

Table 2.1.5(5) List of Geophysical Prospecting

Thana	Union	Mauza	J.L No.	Geo-Code No.	TEM Record No.	Latitude	Longitude
KESHABPUR	PANJIA	Rajnagar Bankabarsi	102	805	JES1021	E22° 54′ 28″	N89° 15′ 24″
KESHABPUR	PANJIA	Rajnagar Bankabarsi	102	805	JES1022	E22° 54′ 38″	N89° 15′ 23″
KESHABPUR	PANJIA	Rajnagar Bankabarsi	102	805	JES1023	E22° 54′ 48″	N89° 15′ 23″
KESHABPUR	PANJIA	Rajnagar Bankabarsi	102	805	JES1024	E22° 54′ 20″	N89° 15′ 20″
KESHABPUR	PANJIA	Rajnagar Bankabarsi	102	805	JES1025	E22° 54′ 48″	N89° 15′ 10″
KESHABPUR	PANJIA	Rajnagar Bankabarsi	102	805	JES1026	E22° 54′ 49″	N89° 15′ 37″
KESHABPUR	PANJIA	Rajnagar Bankabarsi	102	805	JES1027	E22° 55′ 07″	N89° 15′ 25″
KESHABPUR	PANJIA	Mandardanga	104	672	JES1041	E22° 55′ 55″	N89° 15′ 10″
KESHABPUR	PANJIA	Belakati	108	140	JES1083	E22° 55′ 07″	N89° 16′ 14″
KESHABPUR	PANJIA	Manoharnagar	110	686	JES1101	E22° 55′ 04″	N89° 17′ 20″
KESHABPUR	MANGALKOT	Barenga	83	112	JES0831	E22° 52′ 50″	N89° 15′ 50″
KESHABPUR	MANGALKOT	Ramdrishnpur	94	819	JES0941	E22° 51′ 13″	N89° 15′ 46″
KESHABPUR	GAURIGHONA	Bharchi	135	182	JES1353	E22° 51′ 25″	N89° 18′ 49″
KESHABPUR	TRIMOHINI	Mrizanagar	11	707	JES0111	E22° 53′ 39″	N89° 08′ 42″
KESHABPUR	SAGARDARI	Dharmapur	35	308	JES0352	E22° 50′ 41″	N89° 08′ 46″
KESHABPUR	MAJITPUR	Pratappur	31	791	JES0311	E22° 52′ 09″	N89° 11′ 58″
KESHABPUR	BIDYANANDAKATI	Mominpur	53	665	JES0531	E22° 49′ 31″	N89° 12′ 04″
JESSORE SADAR	CHURAMANKATI	Jaghati	11	402	JES0112	E23° 14′ 51″	N89° 06′ 22″
JESSORE SADAR	CHURAMANKATI	Bagdanga	15	056	JES0151	E23° 12′ 31″	N89° 09′ 21″
JESSORE SADAR	JESSORE PAURASHAVA	Chanchra	77	-	JES0771	E23° 07′ 38″	N89° 12′ 43″
JESSORE SADAR	KACHUA	Munsefpur	223	714	JES2231	E23° 08′ 15″	N89° 18′ 23″
JESSORE SADAR	LEBUTALA	Agrail	158	008	JES1581	E23° 17′ 04″	N89° 14′ 01″
JESSORE SADAR	CHANCHRA	Maidia	59	649	JES0591	E23° 07′ 44″	N89° 11′ 12″
JESSORE SADAR	RAMNAGAR	Bhatpara	213	178	JES2131	E23° 06′ 43″	N89° 15′ 10″
JESSORE SADAR	KASIMPUR	Kifaitnagar	135	596	JES1352	E23° 14′ 23″	N89° 11′ 58″
JESSORE SADAR	DIARA	Faridpur	26	361	JES0262	E23° 10′ 26″	N89° 08′ 42″
JESSORE SADAR	BASUNDIA	Jagannathpur	245	458	JES2451	E23° 06′ 26″	N89° 22′ 29″
JESSORE SADAR	ICHHALI	Rajapur	167	828	JES1671	E23° 14′ 54″	N89° 14′ 32″
JESSORE SADAR	ICHHALI	Kayetkhali	184	560	JES1841	E23° 12′ 36″	N89° 15′ 07″
JESSORE SADAR	HAIBATPUR	Rahamatpur	124	820	JES1241	E23° 16′ 02″	N89° 10′ 06″
JESSORE SADAR	FATEPUR	Baolia	205	125	JES2051	E23° 09′ 42″	N89° 15′ 59″
MANIRAMPUR	KHANPUR	Khanpur	157	527	JES1571	E22° 57′ 57″	N89° 14′ 52″
MANIRAMPUR	JHANPA	Joka	46	454	JES0461	E23° 00′ 32″	N89° 07′ 48″
MANIRAMPUR	JHANPA	Januar	173	357	JES1731	E22° 59′ 34″	N89° 10′ 22″
MANIRAMPUR	CHALUAHATI	Lakshmanpur	200	605	JES2001	E22° 57′ 45″	N89° 11′ 03″
MANIRAMPUR	KULTIA	Amrojhuta	152	016	JES1521	E22° 59′ 17″	N89° 18′ 06″

Table 2.1.5(6) List of Geophysical Prospecting

Thana	Union	Mauza	J.L No.	Geo-Code No.	TEM Record No.	Latitude	Longitude
MANIRAMPUR	MASWIMNAGAR	Hazrakati	186	393	JES1861	E22° 55′ 26″	N89° 08′ 29″
MANIRAMPUR	HARIDASKATI	Haridaskati	131	365	JES1312	E23° 02′ 25″	N89° 18′ 35″
MANIRAMPUR	MANIRAMPUR	Durgapur	100	255	JES1002	E23° 00′ 55″	N89° 14′ 46″
MANIRAMPUR	ROHITA	Saraskati	14	885	JES0141	E23° 04′ 00″	N89° 07′ 29″
MANIRAMPUR	KHEDAPAR	Raghunathpur	52	816	JES0521	E23° 02′ 12″	N89° 10′ 41″
MANIRAMPUR	DHAKURIA	Brahmapur	124	166	JES1243	E23° 04′ 35″	N89° 16′ 54″
MANIRAMPUR	NEHALPUR	Nehalpur	241	739	JES2411	E22° 57′ 44″	N89° 20′ 10″
MANIRAMPUR	BHOJGATI	Molladanga	79	698	JES0792	E23° 04′ 43″	N89° 13′ 31″
CHAUGACHHA	PASHAPOLE	Raghunathpur	218	811	JES2181	E23° 11′ 38″	N89° 03′ 32″
CHAUGACHHA	HAKIMPUR	Chakla	50	211	JES0501	E23° 22′ 08″	N89° 01′ 56″
CHAUGACHHA	PATIBILA	Teghari	208	966	JES2081	E23° 16′ 41″	N89° 02′ 40″
CHAUGACHHA	CHAUGACHHA	Deghal Singa	168	296	JES1681	E23° 14′ 13″	N89° 00′ 39″
CHAUGACHHA	NARAYANPUR	Guatuli	175	381	JES1751	E23° 18′ 08″	N88° 59′ 02″
CHAUGACHHA	NARAYANPUR	Barakhanpur	176	112	JES1761	E23° 20′ 18″	N88° 59′ 23″
CHAUGACHHA	JAGADISHPUR	Jagadispur	212	465	JES2121	E23° 18′ 20″	N89° 04′ 07″
CHAUGACHHA	JAGADISHPUR	Marua	218	656	JES2182	E23° 16′ 30″	N89° 04′ 37″
CHAUGACHHA	SUKPUKHURIA	Suukpukhuria	132	917	JES1321	E23° 15′ 06″	N88° 56′ 12″
CHAUGACHHA	SINGHAJHULI	Jagannathpur	208	472	JES2082	E23° 13′ 40″	N89° 03′ 33″
BAGHERPARA	NARIKELBARIA	Dyarampur	72	376	JES0721	E23° 16′ 26″	N89° 21′ 04″
BAGHERPARA	JAMDIA	Bhitaballa	148	235	JES1481	E23° 09′ 31″	N89° 22′ 05″
BAGHERPARA	RAIPUR	Bhaturia	62	229	JES0621	E23° 14′ 40″	N89° 18′ 54″
BAGHERPARA	JAHARPUR	Betalpara	21	204	JES0211	E23° 19′ 42″	N89° 15′ 34″
BAGHERPARA	BANDABILLA	Chanpatala	47	274	JES0471	E23° 16′ 50″	N89° 17′ 24″
BAGHERPARA	DARAJHAT	Gar	89	452	JES0891	E23° 11′ 29″	N89° 18′ 11″
BAGHERPARA	DOHAKULA	Mamudanipur	108	669	JES1082	E23° 13′ 33″	N89° 24′ 59″
BAGHERPARA	DOHAKULA	Dohakula	116	427	JES1161	E23° 12′ 48″	N89° 22′ 09″
ABHAYNAGAR	SRIDHARPUR	Mathurapur	3	707	JES0031	E23° 04′ 32″	N89° 24′ 28″
ABHAYNAGAR	BAGHUTIA	Paikpara Bhuglihat	25	740	JES0251	E23° 01′ 18″	N89° 27′ 27″
ABHAYNAGAR	MAHAKAL	Banagram	50	099	JES0502	E23° 04′ 56″	N89° 20′ 34″
ABHAYNAGAR	NOAPARA	Saradanga	69	928	JES0691	E23° 01′ 37″	N89° 21′ 26″
ABHAYNAGAR	RAJGHAT	Chalisa	81	276	JES0811	E23° 00′ 24″	N89° 23′ 48″
ABHAYNAGAR	RAJGHAT	Bhulapata	90	232	JES0902	E22° 58′ 48″	N89° 25′ 45″
ABHAYNAGAR	PAYRA	Payra	92	795	JES0921	E22° 57′ 27″	N89° 23′ 43″
ABHAYNAGAR	SIDDHIPASA	Dhulgram	41	386	JES0412	E22° 58′ 27″	N89° 29′ 09″

Table2.1.6(1) List of Resistivity structures obtained by 1D inversion

(CHUADANGA district : 38 stations)

Thana	J.L No.	TEM Record No.	Resistivity(ohm-m) R1	R2	R3	R4	R5	R6	R7	Elevation of boundary(m) D1	D2	D3	D4	D5	D6
ALAMDANGA	80	CHU0801	18.9	118.2	23.1	54.3	37.3	26.7	-	-9.9	-30.0	-50.8	-161.0	-338.2	-
ALAMDANGA	53	CHU0531	16.0	73.3	16.6	59.5	42.8	-	-	-7.1	-25.4	-49.4	-181.2	-	-
ALAMDANGA	1	CHU0011	15.8	97.3	21.7	85.0	31.5	19.5	-	-9.3	-31.2	-55.4	-120.7	-190.1	-
ALAMDANGA	8	CHU0081	19.9	73.1	16.9	58.8	25.0	-	-	-8.5	-27.5	-46.3	-176.9	-	-
ALAMDANGA	78	CHU0781	16.1	39.8	19.4	57.5	29.7	39.4	24.3	-8.2	-22.7	-39.3	-117.1	-189.8	-392.5
ALAMDANGA	17	CHU0171	37.6	100.6	44.9	78.9	33.4	50.5	17.8	-14.5	-35.7	-62.5	-160.0	-226.2	-427.5
ALAMDANGA	68	CHU0681	16.5	45.7	23.4	93.0	29.4	41.5	21.4	-7.3	-26.0	-45.1	-158.6	-290.0	-414.7
ALAMDANGA	95	CHU0951	12.2	39.7	28.9	75.7	40.5	18.4	-	-7.7	-28.2	-51.9	-128.6	-374.2	-
ALAMDANGA	99	CHU0991	13.9	86.6	18.3	55.1	35.1	31.4	-	-7.4	-21.6	-42.5	-126.5	-303.1	-
ALAMDANGA	28	CHU0282	11.6	86.2	14.3	47.5	27.8	9.6	-	-6.1	-25.0	-40.9	-152.7	-330.7	-
ALAMDANGA	120	CHU1201	19.0	60.1	24.3	52.8	31.3	54.5	21.6	-10.3	-32.8	-55.1	-132.8	-230.7	-420.9
ALAMDANGA	90	CHU0901	13.0	27.1	85.3	29.1	70.8	-	-	-10.2	-47.7	-122.3	-228.7	-	-
DAMURHUDA	32	CHU0321	21.8	66.5	46.5	80.8	25.9	3.6	-	-10.1	-36.6	-56.5	-151.5	-413.4	-
DAMURHUDA	20	CHU0201	29.5	85.0	31.4	59.1	13.3	18.6	3.5	-11.2	-27.2	-65.9	-180.8	-275.0	-425.2
DAMURHUDA	61	CHU0611	17.1	36.1	26.5	54.5	35.9	63.4	14.2	-14.9	-30.9	-51.9	-121.7	-207.9	-403.6
DAMURHUDA	68	CHU0682	11.5	25.4	73.0	31.8	95.2	20.6	-	-6.8	-44.9	-101.9	-195.6	-346.1	-
DAMURHUDA	73	CHU0731	27.4	53.4	40.1	69.4	39.5	52.5	19.8	-13.6	-33.4	-65.6	-116.9	-205.6	-342.3
DAMURHUDA	51	CHU0511	26.5	127.5	35.2	74.3	33.1	41.2	-	-10.2	-32.8	-62.6	-139.2	-232.1	-
DAMURHUDA	55	CHU0551	12.3	99.9	23.5	95.0	31.9	20.6	-	-7.7	-25.2	-47.0	-135.2	-375.4	-
DAMURHUDA	6	CHU0061	11.9	61.7	29.1	83.0	21.6	-	-	-8.4	-21.8	-51.3	-140.4	-	-
DAMURHUDA	10	CHU0101	9.7	87.6	24.8	62.0	13.0	5.1	-	-6.5	-29.1	-56.1	-177.8	-359.9	-
DAMURHUDA	28	CHU0281	12.7	60.1	27.0	52.5	22.3	28.9	7.2	-7.7	-23.8	-48.0	-151.2	-243.0	-361.2
DAMURHUDA	41	CHU0411	18.4	60.6	27.0	54.4	30.7	73.9	10.4	-8.1	-26.2	-54.8	-152.5	-210.3	-335.8
DAMURHUDA	43	CHU0431	23.7	90.8	31.1	69.1	32.5	15.3	2.3	-10.2	-27.9	-58.3	-165.8	-295.7	-423.3
CHUADANGA	3	CHU0031	23.7	77.3	27.9	78.1	38.9	19.6	-	-9.5	-35.1	-61.3	-135.0	-460.6	-
CHUADANGA	23	CHU0231	29.6	105.6	33.7	93.3	24.2	5.3	-	-13.0	-35.6	-72.5	-163.0	-405.0	-
CHUADANGA	29	CHU0291	20.0	62.8	33.6	70.3	28.4	16.1	-	-10.3	-32.3	-61.5	-143.7	-361.7	-
CHUADANGA	78	CHU0782	19.7	61.5	23.5	73.0	30.8	50.6	13.4	-10.6	-22.2	-53.1	-131.0	-239.6	-469.3
CHUADANGA	47	CHU0471	14.7	52.9	19.3	59.3	29.0	55.4	34.4	-6.4	-24.0	-48.2	-125.9	-210.4	-313.6
CHUADANGA	7	CHU0071	20.5	65.0	28.5	63.2	35.6	52.9	14.6	-10.3	-28.7	-58.4	-136.2	-219.2	-360.7
CHUADANGA	42	CHU0421	23.2	87.0	15.4	119.4	37.6	27.6	-	-10.2	-31.6	-50.4	-147.3	-370.3	-
CHUADANGA	34	CHU0341	13.8	48.8	21.0	46.9	30.3	37.1	15.1	-6.4	-28.3	-51.9	-122.2	-216.7	-386.1
CHUADANGA	72	CHU0721	27.3	56.7	21.7	52.2	36.0	50.4	14.6	-10.9	-28.3	-50.9	-121.1	-203.7	-391.4
JIBANNAGAR	30	CHU0301	15.7	79.4	29.4	72.4	17.8	18.9	4.6	-4.9	-21.1	-67.2	-163.1	-296.7	-411.3
JIBANNAGAR	10	CHU0102	10.8	90.7	34.4	55.5	19.8	29.5	9.6	-7.3	-20.4	-61.1	-144.1	-258.7	-406.6
JIBANNAGAR	41	CHU0412	18.0	63.0	23.9	51.4	12.9	21.3	6.5	-8.3	-29.0	-59.0	-169.4	-288.7	-391.3

Table2.1.6(2) List of Resistivity structures obtained by 1D inversion

Thana	J.L No.	TEM Record No.	Resistivity(ohm-m) R1	R2	R3	R4	R5	R6	R7	Elevation of boundary(m) D1	D2	D3	D4	D5	D6
JIBANNAGAR	69	CHU0691	21.5	125.4	34.4	49.8	18.1	30.7	9.4	-9.2	-27.7	-74.6	-167.6	-301.3	-448.8
JIBANNAGAR	55	CHU0552	18.0	55.9	20.8	54.8	37.2	21.5	-	-9.9	-25.5	-53.4	-117.9	-279.7	-

(JHENAIDAH district : 67 stations)

Thana	J.L No.	TEM Record No.	Resistivity(ohm-m) R1	R2	R3	R4	R5	R6	R7	Elevation of boundary(m) D1	D2	D3	D4	D5	D6
JHENAIDAHA SADAR	152	JHE1521	42.1	77.6	19.0	67.1	35.0	29.4	-	-11.4	-22.9	-49.8	-142.8	-305.4	-
JHENAIDAHA SADAR	45	JHE0453	15.9	60.7	20.5	60.6	36.4	19.0	-	-10.4	-23.5	-54.7	-131.0	-335.3	-
JHENAIDAHA SADAR	69	JHE0691	19.6	59.6	24.7	63.9	37.5	17.0	-	-10.3	-28.2	-54.1	-129.4	-293.0	-
JHENAIDAHA SADAR	205	JHE2051	16.5	106.8	23.6	41.8	9.3	98.6	-	-10.9	-31.1	-68.0	-136.5	-215.3	-
JHENAIDAHA SADAR	260	JHE2601	28.3	142.8	48.0	77.2	20.9	-	-	-10.0	-32.8	-89.8	-173.1	-	-
JHENAIDAHA SADAR	20	JHE0201	12.6	71.5	24.9	81.0	25.5	4.2	-	-7.2	-19.4	-48.4	-135.1	-311.8	-
JHENAIDAHA SADAR	121	JHE1211	13.2	109.5	27.6	88.3	27.0	-	-	-6.7	-27.0	-56.1	-167.4	-	-
JHENAIDAHA SADAR	153	JHE1531	34.0	69.9	17.0	74.0	36.4	28.5	-	-12.8	-22.1	-47.7	-115.2	-230.4	-
JHENAIDAHA SADAR	193	JHE1931	22.9	139.3	29.1	40.9	38.4	24.7	-	-7.4	-29.8	-56.0	-114.2	-231.0	-
JHENAIDAHA SADAR	30	JHE0301	15.2	39.6	22.4	40.2	36.9	28.3	-	-10.8	-20.8	-45.1	-122.7	-317.6	-
JHENAIDAHA SADAR	34	JHE0341	13.0	64.5	30.3	64.7	33.6	30.6	-	-5.8	-15.3	-51.0	-115.6	-233.5	-
JHENAIDAHA SADAR	225	JHE2251	13.3	79.7	19.6	81.2	32.4	25.8	-	-7.5	-22.9	-45.8	-128.7	-226.1	-
JHENAIDAHA SADAR	3	JHE0031	12.4	23.5	55.7	30.6	85.7	29.1	-	-19.2	-57.7	-127.3	-210.5	-401.4	-
JHENAIDAHA SADAR	88	JHE0882	14.4	102.3	24.0	60.5	35.1	19.5	-	-10.2	-26.4	-50.6	-128.6	-372.6	-
JHENAIDAHA SADAR	111	JHE1111	12.3	29.1	12.8	95.2	44.3	37.3	-	-21.7	-28.1	-44.5	-97.0	-228.8	-
JHENAIDAHA SADAR	184	JHE1841	26.8	111.2	28.2	86.8	32.0	21.8	-	-9.6	-27.4	-59.4	-139.5	-414.0	-
JHENAIDAHA SADAR	217	JHE2171	13.9	65.9	32.1	71.1	38.2	25.4	-	-8.2	-24.4	-57.3	-115.2	-226.9	-
JHENAIDAHA SADAR	61	JHE0611	15.8	71.8	22.6	108.6	27.3	12.0	-	-9.8	-24.8	-49.1	-129.5	-368.4	-
KALIGANJ	127	JHE1271	25.4	76.1	23.6	65.9	41.6	60.0	35.6	-10.4	-23.9	-60.8	-122.4	-183.9	-349.8
KALIGANJ	64	JHE0641	12.6	28.3	14.5	74.4	43.5	63.6	28.3	-17.4	-24.5	-37.2	-114.7	-199.7	-317.7
KALIGANJ	89	JHE0891	9.2	51.8	14.0	52.5	37.1	26.6	-	-5.1	-24.1	-43.0	-175.3	-345.4	-
KALIGANJ	100	JHE1001	14.7	70.4	29.8	45.2	27.8	15.0	-	-8.4	-33.9	-68.4	-140.2	-396.6	-
KALIGANJ	173	JHE1731	14.2	110.9	28.8	47.6	12.6	69.6	-	-7.2	-34.0	-63.5	-151.8	-291.4	-
KALIGANJ	45	JHE0451	13.6	57.3	28.9	88.7	42.1	20.0	-	-9.9	-22.5	-46.2	-143.0	-353.4	-
KALIGANJ	39	JHE0391	15.4	104.7	17.4	49.7	40.3	28.6	-	-9.0	-32.1	-53.5	-148.4	-278.6	-
KALIGANJ	180	JHE1801	12.6	62.7	20.4	69.5	33.1	12.7	-	-7.3	-25.5	-48.0	-140.0	-416.1	-
KALIGANJ	161	JHE1611	13.4	72.0	17.5	53.3	47.2	24.6	-	-7.5	-23.8	-51.0	-103.6	-340.3	-
KALIGANJ	195	JHE1951	21.2	116.4	29.2	45.5	28.7	14.8	-	-9.4	-27.3	-55.0	-165.2	-332.0	-
KALIGANJ	123	JHE1231	20.5	46.3	35.4	52.0	31.8	-	-	-10.3	-30.8	-72.3	-179.3	-	-
KALIGANJ	19	JHE0191	11.9	72.7	18.1	66.3	36.9	17.3	-	-11.4	-27.9	-44.7	-115.5	-322.1	-
KOTCHANDPUR	75	JHE0751	12.0	72.2	28.3	66.3	34.4	19.4	-	-8.6	-17.7	-43.6	-166.6	-360.5	-
KOTCHANDPUR	45	JHE0452	14.8	149.3	25.0	105.3	36.7	6.7	-	-7.7	-30.1	-58.4	-124.4	-384.9	-

Table2.1.6(3) List of Resistivity structures obtained by 1D inversion

Thana	J.L No.	TEM Record No.	Resistivity(ohm-m) R1	R2	R3	R4	R5	R6	R7	Elevation of boundary(m) D1	D2	D3	D4	D5	D6
KOTCHANDPUR	6	JHE0061	21.8	99.5	24.7	82.6	29.4	-	-	-10.4	-29.9	-58.1	-142.6	-	-
KOTCHANDPUR	24	JHE0241	30.4	47.0	29.1	101.0	27.1	13.0	-	-17.7	-27.5	-63.6	-138.6	-491.2	-
MOHESHPPUR	15	JHE0151	10.3	72.9	18.6	98.3	10.8	2.4	-	-5.8	-22.4	-46.3	-144.3	-223.4	-
MOHESHPPUR	104	JHE1041	15.3	69.1	22.6	48.1	19.4	3.0	-	-6.3	-14.9	-47.7	-143.5	-398.1	-
MOHESHPPUR	139	JHE1391	16.0	23.9	18.2	134.0	37.1	59.6	15.5	-18.4	-24.2	-36.0	-137.3	-256.7	-343.7
MOHESHPPUR	28	JHE0281	14.8	93.6	33.0	68.1	33.9	25.4	-	-8.7	-29.1	-57.7	-131.2	-252.6	-
MOHESHPPUR	48	JHE0481	13.0	80.4	23.1	70.9	24.2	6.1	-	-8.2	-24.5	-55.0	-130.8	-244.6	-
MOHESHPPUR	108	JHE1081	14.4	39.2	107.0	25.0	14.7	-	-	-16.9	-40.3	-166.0	-335.0	-	-
MOHESHPPUR	74	JHE0741	14.0	100.4	28.5	54.0	13.3	14.9	6.2	-6.8	-27.3	-57.3	-185.3	-348.6	-486.2
MOHESHPPUR	151	JHE1511	28.3	88.9	28.9	136.7	28.0	32.7	9.1	-11.6	-33.6	-65.4	-159.0	-260.5	-396.6
MOHESHPPUR	34	JHE0342	23.0	73.5	32.0	96.0	23.9	26.3	10.3	-7.8	-31.5	-58.9	-139.4	-216.9	-403.6
MOHESHPPUR	95	JHE0951	12.1	117.0	19.2	61.3	25.0	7.4	-	-7.0	-27.2	-49.7	-151.9	-274.0	-
MOHESHPPUR	85	JHE0851	14.0	66.5	35.4	69.7	19.4	5.1	-	-7.0	-25.4	-70.6	-167.5	-300.9	-
MOHESHPPUR	120	JHE1201	11.0	75.9	17.7	80.1	37.5	17.5	-	-8.6	-28.9	-49.8	-133.5	-206.0	-
HARINAKUNDA	11	JHE0111	27.1	88.0	53.0	97.1	32.1	26.0	-	-9.0	-31.0	-67.2	-147.4	-273.8	-
HARINAKUNDA	14	JHE0141	15.5	80.0	20.0	210.8	78.0	15.2	25.7	-8.0	-20.6	-40.9	-122.5	-177.1	-269.2
HARINAKUNDA	18	JHE0181	26.0	134.6	26.3	58.2	26.0	31.5	13.2	-10.4	-37.4	-65.2	-129.7	-179.8	-362.8
HARINAKUNDA	25	JHE0251	16.8	91.9	20.8	64.8	31.1	25.7	-	-8.7	-27.5	-47.4	-155.0	-237.5	-
HARINAKUNDA	1	JHE0011	17.5	58.4	24.2	58.6	29.2	35.5	13.2	-8.5	-24.0	-51.5	-144.0	-221.2	-397.4
HARINAKUNDA	72	JHE0721	17.8	60.9	35.9	61.6	31.2	45.2	24.2	-10.4	-28.5	-55.4	-160.5	-241.7	-381.7
HARINAKUNDA	33	JHE0331	11.8	39.4	12.6	79.7	37.0	28.2	-	-10.2	-20.2	-35.7	-115.7	-256.9	-
HARINAKUNDA	56	JHE0561	14.2	136.8	26.1	72.0	36.2	24.5	-	-9.5	-34.8	-67.8	-126.6	-279.5	-
SAILKUPA	55	JHE0551	12.2	19.4	9.2	102.5	33.4	12.8	-	-10.9	-16.3	-32.5	-145.0	-371.5	-
SAILKUPA	68	JHE0682	10.5	49.7	7.8	48.9	30.0	34.5	-	-6.5	-15.5	-28.5	-100.7	-245.0	-
SAILKUPA	118	JHE1181	10.5	13.4	58.3	29.8	39.4	-	-	-16.2	-35.7	-99.8	-246.4	-	-
SAILKUPA	96	JHE0961	11.6	14.8	9.5	53.4	25.0	32.7	-	-13.9	-18.2	-31.2	-131.2	-313.0	-
SAILKUPA	47	JHE0471	11.5	48.1	10.3	75.1	26.0	5.4	-	-9.6	-16.4	-31.7	-138.0	-415.9	-
SAILKUPA	122	JHE1221	11.7	8.0	88.7	37.6	24.9	-	-	-19.0	-30.5	-107.4	-367.1	-	-
SAILKUPA	126	JHE1261	9.2	47.5	11.0	60.3	35.0	25.4	-	-7.1	-16.1	-31.9	-109.2	-300.1	-
SAILKUPA	133	JHE1331	13.9	130.6	19.0	83.7	23.9	44.8	26.7	-8.5	-33.6	-54.3	-154.7	-228.3	-380.3
SAILKUPA	155	JHE1551	12.4	82.8	13.4	82.4	32.2	24.7	-	-7.0	-25.9	-43.9	-114.7	-251.9	-
SAILKUPA	88	JHE0881	10.9	61.1	14.3	52.6	22.4	48.1	25.1	-7.3	-19.5	-39.3	-132.7	-196.0	-327.9
SAILKUPA	177	JHE1771	11.6	28.5	10.4	64.4	29.2	23.5	-	-9.6	-17.8	-32.6	-87.0	-336.3	-
SAILKUPA	16	JHE0161	14.5	70.4	18.4	82.5	24.5	32.0	-	-6.7	-23.9	-42.6	-154.5	-224.6	-
SAILKUPA	7	JHE0071	21.5	65.3	25.1	56.2	27.6	40.3	28.4	-10.4	-29.8	-57.4	-150.2	-225.0	-405.1

Table2.1.6(4) List of Resistivity structures obtained by 1D inversion

(JESSORE district : 95 stations)

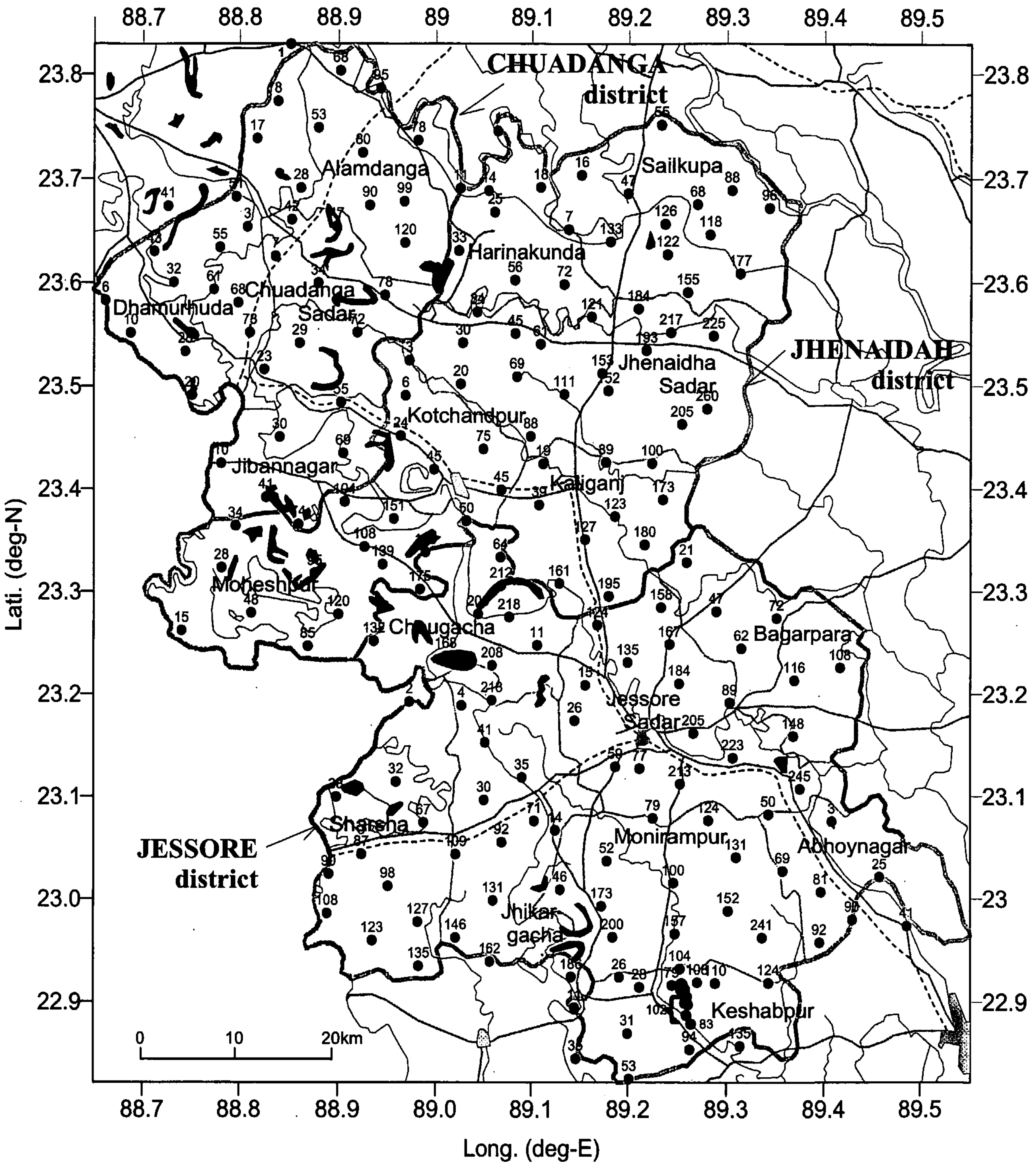
Thana	J.L	TEM			Resistivity(ohm-m)							Elevation of boundary(m)			
	No.	Record No.	R1	R2	R3	R4	R5	R6	R7	D1	D2	D3	D4	D5	D6
JHIKARGACHHA	41	JES0411	11.5	30.2	72.6	23.7	47.8	15.1	-	-24.6	-34.9	-117.7	-222.1	-354.0	-
JHIKARGACHHA	131	JES1311	12.1	102.1	32.7	69.8	21.6	23.8	1.6	-8.7	-20.2	-46.9	-89.8	153.9	404.5
JHIKARGACHHA	146	JES1461	10.9	56.1	21.1	69.2	26.3	34.0	4.8	-7.0	-28.8	-51.9	-127.6	-214.0	-392.1
JHIKARGACHHA	162	JES1621	11.2	112.9	19.9	48.3	14.6	31.0	9.4	-7.5	-30.0	-50.6	-101.9	-187.0	-319.2
JHIKARGACHHA	71	JES0711	18.4	146.3	25.4	64.1	20.1	24.7	16.8	-9.2	-28.3	-53.1	-107.3	-191.2	-368.5
JHIKARGACHHA	92	JES0922	15.4	94.6	26.2	69.6	23.2	46.5	9.8	-9.4	-30.3	-63.6	-119.3	-219.1	-404.8
JHIKARGACHHA	109	JES1091	11.0	70.8	27.1	47.5	25.6	8.7	-	-6.1	-21.7	-45.4	-111.2	-248.4	-
JHIKARGACHHA	4	JES0041	22.1	62.3	14.8	51.8	39.3	17.8	-	-8.6	-17.1	-38.6	-128.8	-332.3	-
JHIKARGACHHA	30	JES0301	10.8	59.6	17.2	68.3	22.1	38.4	7.9	-7.5	-22.5	-37.6	-106.0	-187.2	-339.3
JHIKARGACHHA	35	JES0351	16.2	57.1	20.2	57.1	25.2	35.9	6.7	-10.0	-25.4	-45.2	-109.6	-201.1	-332.0
SHARSHA	32	JES0321	15.1	119.2	22.6	75.0	22.5	52.6	10.1	-8.0	-33.8	-55.2	-117.3	-186.4	-296.7
SHARSHA	108	JES1081	10.8	22.3	10.3	68.5	16.0	2.5	-	-6.1	-13.8	-26.4	-103.9	-166.1	-
SHARSHA	38	JES0381	18.8	102.6	31.1	60.6	22.2	24.9	2.5	-7.5	-29.3	-52.8	-99.0	-172.3	-318.5
SHARSHA	127	JES1271	12.6	57.1	17.9	49.7	26.5	47.6	8.6	-11.1	-24.5	-45.0	-121.6	-198.6	-318.5
SHARSHA	87	JES0871	16.7	68.4	16.5	80.9	14.3	3.3	-	-10.3	-27.1	-42.5	-105.5	-234.0	-
SHARSHA	90	JES0901	17.7	95.4	26.4	122.6	9.1	3.1	-	-7.3	-25.5	-58.2	-131.1	-191.8	-
SHARSHA	135	JES1351	15.3	51.9	25.6	54.7	19.3	7.4	-	-7.1	-25.4	-44.2	-102.9	-224.7	-
SHARSHA	123	JES1231	12.4	86.8	20.5	51.6	9.6	16.0	2.9	-6.7	-27.8	-50.0	-102.3	-183.3	-245.6
SHARSHA	67	JES0671	13.2	121.8	24.3	62.7	17.1	31.7	2.5	-6.8	-31.7	-62.9	-108.1	-208.1	-325.4
SHARSHA	2	JES0021	23.5	95.1	38.0	82.8	17.7	22.0	2.1	-8.2	-34.4	-67.6	-150.6	-257.3	-411.1
SHARSHA	98	JES0981	10.7	114.8	27.4	84.8	19.0	2.9	-	-6.8	-30.8	-66.7	-132.8	-299.0	-
KESHABPUR	26	JES0261	16.6	97.6	24.7	52.3	18.0	34.8	14.0	-8.1	-28.0	-47.7	-88.4	-194.0	-324.8
KESHABPUR	28	JES0281	10.2	15.7	51.0	12.2	18.8	37.8	-	-9.7	-28.3	-98.5	-170.0	-287.8	-
KESHABPUR	79	JES0791	10.3	14.9	5.0	23.8	9.7	21.1	37.4	-9.2	-14.8	-25.9	-68.2	-133.2	-219.5
KESHABPUR	124	JES1242	5.8	23.9	5.8	19.6	9.2	55.6	21.2	-16.2	-11.9	-26.4	-50.2	-95.2	-252.5
KESHABPUR	102	JES1021	7.6	30.4	8.0	13.2	8.9	19.6	41.3	-6.4	-13.0	-23.8	-74.5	-118.1	-197.9
KESHABPUR	102	JES1022	6.0	25.9	5.8	19.4	6.4	22.2	63.4	-4.2	-16.6	-26.7	-72.6	-110.8	-190.5
KESHABPUR	102	JES1023	7.7	19.9	7.7	16.4	7.5	16.9	154.9	-6.7	-14.0	-28.4	-74.0	-109.0	-196.5
KESHABPUR	102	JES1024	6.3	20.4	5.8	17.6	10.1	22.3	43.4	-4.9	-13.1	-26.6	-72.2	-117.2	-198.6
KESHABPUR	102	JES1025	5.3	26.2	5.4	17.3	8.9	21.0	54.7	-3.9	-12.9	-23.1	-57.7	-106.4	-210.5
KESHABPUR	102	JES1026	8.4	26.6	9.4	16.3	9.5	20.8	52.4	-7.6	-17.3	-31.8	-60.3	-113.4	-182.3
KESHABPUR	102	JES1027	9.7	31.9	8.3	13.0	9.7	24.4	106.2	-6.9	-15.0	-29.4	-61.5	-126.9	-197.3
KESHABPUR	104	JES1041	9.4	25.5	9.2	17.7	14.5	56.5	32.2	-7.0	-14.3	-33.0	-91.4	-181.8	-311.3
KESHABPUR	108	JES1083	7.7	34.4	7.8	44.7	7.5	63.5	37.0	-6.6	-16.6	-28.8	-68.0	-110.3	-251.4
KESHABPUR	110	JES1101	8.9	13.6	8.0	40.2	20.6	74.1	37.4	-12.4	-16.8	-28.7	-64.1	-125.8	-251.2
KESHABPUR	83	JES0831	7.1	19.5	6.8	22.9	10.4	41.0	1.3	-6.3	-13.9	-25.6	-62.5	-190.7	-318.4
KESHABPUR	94	JES0941	17.4	73.5	20.8	32.6	10.3	19.3	16.5	-6.0	-26.9	-42.9	-87.5	-224.2	-361.5
KESHABPUR	135	JES1353	23.8	44.8	18.2	40.8	15.6	16.3	-	-16.0	-64.1	-111.8	-208.0	-320.0	-

Table2.1.6(5) List of Resistivity structures obtained by 1D inversion

Thana	J.L	TEM	Resistivity(ohm-m)							Elevation of boundary(m)					
	No.	Record No.	R1	R2	R3	R4	R5	R6	R7	D1	D2	D3	D4	D5	D6
KESHABPUR	11	JES0111	12.2	58.4	15.3	58.0	13.4	18.7	2.8	-7.3	-14.6	-35.6	-118.2	-194.5	-379.3
KESHABPUR	35	JES0352	9.7	75.5	24.2	65.7	13.3	20.8	2.9	-6.5	-21.9	-46.3	-108.2	-173.0	-280.0
KESHABPUR	31	JES0311	18.4	40.1	15.8	36.3	19.5	59.1	19.4	-7.0	-23.6	-39.4	-108.5	-201.3	-365.5
KESHABPUR	53	JES0531	20.7	75.7	22.1	46.7	22.3	37.7	22.6	-9.4	-37.5	-50.0	-119.5	-234.6	-374.8
JESSORE SADAR	11	JES0112	14.4	35.4	24.8	73.8	26.9	44.1	5.3	-11.3	-15.2	-40.3	-114.3	-230.0	-407.0
JESSORE SADAR	15	JES0151	18.8	71.3	22.8	98.4	27.6	14.0	-	-8.0	-28.1	-54.5	-147.0	-307.2	-
JESSORE SADAR	77	JES0771	8.6	24.0	4.9	109.2	14.2	2.0	-	-8.5	-13.6	-23.9	-160.7	-350.2	-
JESSORE SADAR	223	JES2231	8.4	28.5	12.6	29.5	23.2	32.8	13.5	-4.8	-19.2	-36.6	-84.7	-151.2	-236.4
JESSORE SADAR	158	JES1581	16.3	53.8	28.5	51.7	31.9	10.0	-	-8.9	-26.6	-54.8	-114.6	-340.5	-
JESSORE SADAR	59	JES0591	9.7	21.0	42.8	27.2	20.2	-	-	-11.5	-36.6	-117.5	-228.6	-	-
JESSORE SADAR	213	JES2131	10.9	36.9	16.6	31.5	16.0	17.8	-	-7.8	-18.1	-36.5	-122.0	-334.9	-
JESSORE SADAR	135	JES1352	19.0	97.9	16.1	56.6	25.0	11.6	-	-8.7	-25.5	-45.8	-159.7	-330.4	-
JESSORE SADAR	26	JES0262	23.2	62.9	19.2	59.2	21.2	2.9	-	-9.0	-24.0	-47.9	-122.5	-341.0	-
JESSORE SADAR	245	JES2451	23.3	93.5	25.5	33.2	18.6	7.9	-	-7.6	-28.6	-50.5	-92.1	-237.3	-
JESSORE SADAR	167	JES1671	14.1	93.8	18.0	69.3	33.9	14.3	-	-7.0	-25.1	-50.0	-128.9	-336.2	-
JESSORE SADAR	184	JES1841	9.2	45.7	11.9	49.8	34.7	17.5	-	-7.3	-15.2	-31.2	-102.4	-254.3	-
JESSORE SADAR	124	JES1241	22.5	77.0	32.3	76.9	30.7	9.8	-	-7.9	-20.3	-61.6	-136.5	-347.1	-
JESSORE SADAR	205	JES2051	19.3	78.4	15.0	42.7	23.9	29.9	-	-7.1	-23.9	-43.2	-113.0	-256.8	-
MANIRAMPUR	157	JES1571	7.7	79.8	16.2	50.3	11.9	15.4	8.5	-6.8	-18.1	-42.6	-125.1	-222.7	-353.5
MANIRAMPUR	46	JES0461	17.7	87.7	29.1	63.5	15.4	32.7	25.3	-10.8	-22.0	-42.8	-127.9	-232.9	-383.0
MANIRAMPUR	173	JES1731	13.4	45.6	18.8	45.4	9.9	23.8	9.7	-9.9	-22.5	-37.0	-107.7	-174.2	-301.0
MANIRAMPUR	200	JES2001	13.3	62.3	16.3	79.8	21.1	55.0	4.8	-7.1	-20.4	-38.1	-108.5	-183.0	-304.7
MANIRAMPUR	152	JES1521	6.7	59.4	9.8	22.9	11.4	18.3	12.4	-4.3	-19.3	-33.9	-73.1	-160.4	-231.8
MANIRAMPUR	186	JES1861	12.6	113.1	19.8	73.0	17.3	40.1	13.9	-6.4	-32.3	-54.1	-95.8	-186.2	-318.6
MANIRAMPUR	131	JES1312	6.2	16.7	6.4	17.1	12.4	18.0	-	-7.2	-14.2	-23.4	-64.4	-136.9	-
MANIRAMPUR	100	JES1002	16.7	91.2	24.3	47.8	20.2	22.3	13.8	-7.5	-31.6	-55.0	-92.4	-137.4	-184.4
MANIRAMPUR	14	JES0141	20.7	58.3	25.3	48.5	28.6	40.5	10.1	-9.6	-37.9	-59.6	-140.8	-277.6	-392.6
MANIRAMPUR	52	JES0521	13.2	36.9	75.0	22.0	17.9	25.0	-	-11.2	-46.0	-98.7	-149.5	-243.1	-
MANIRAMPUR	124	JES1243	9.0	12.0	29.6	13.1	20.4	8.6	-	-8.2	-27.2	-77.8	-181.5	-334.8	-
MANIRAMPUR	241	JES2411	8.2	23.4	5.3	16.0	9.4	18.0	11.1	-6.1	-12.1	-28.0	-65.6	-124.2	-230.7
MANIRAMPUR	79	JES0792	14.3	83.7	22.0	82.8	22.7	15.1	-	-8.7	-22.1	-55.3	-129.5	-341.4	-
CHAUGACHHA	218	JES2181	12.5	51.0	29.6	79.1	21.1	55.6	40.1	-13.1	-29.7	-54.6	-111.5	-166.2	-236.3
CHAUGACHHA	50	JES0501	11.9	48.1	19.0	56.1	41.7	22.2	-	-6.4	-26.1	-54.5	-118.3	-336.3	-
CHAUGACHHA	208	JES2081	18.3	82.4	16.9	108.0	45.6	28.3	-	-8.2	-30.4	-58.3	-150.5	-294.6	-
CHAUGACHHA	168	JES1681	20.2	103.6	24.3	60.9	35.0	10.0	-	-8.6	-30.7	-60.0	-123.3	-391.8	-
CHAUGACHHA	175	JES1751	17.1	77.4	32.7	69.5	33.5	56.0	12.6	-9.0	-25.1	-57.3	-137.3	-230.6	-419.5
CHAUGACHHA	176	JES1761	12.0	83.3	26.0	117.1	34.0	41.4	6.7	-5.6	-24.1	-57.3	-133.4	-214.5	-406.5
CHAUGACHHA	212	JES2121	26.6	60.4	21.3	68.7	43.2	65.6	17.5	-7.4	-23.7	-50.0	-104.4	-179.7	-323.2

Table2.1.6(6) List of Resistivity structures obtained by 1D inversion

Thana	J.L	TEM			Resistivity(ohm-m)							Elevation of boundary(m)			
	No.	Record No.	R1	R2	R3	R4	R5	R6	R7	D1	D2	D3	D4	D5	D6
CHAUGACHHA	218	JES2182	14.1	45.5	17.7	76.9	61.7	13.4	-	-7.7	-18.5	-44.7	-208.1	-439.3	-
CHAUGACHHA	132	JES1321	10.9	71.8	20.9	61.5	23.1	5.9	-	-6.8	-22.0	-48.5	-152.0	-329.2	-
CHAUGACHHA	208	JES2082	10.4	57.7	13.5	49.0	23.4	57.2	16.4	-7.6	-24.0	-37.3	-137.1	-204.4	-379.7
BAGHERPARA	72	JES0721	13.7	81.5	22.1	61.6	41.8	7.0	-	-7.1	-30.2	-54.9	-125.9	-245.4	-
BAGHERPARA	148	JES1481	9.8	57.1	15.8	49.8	29.7	10.0	-	-6.8	-15.8	-37.5	-101.8	-233.7	-
BAGHERPARA	62	JES0621	10.2	16.1	5.5	64.7	27.7	13.0	-	-11.3	-15.7	-29.2	-103.3	-206.1	-
BAGHERPARA	21	JES0211	14.8	79.9	16.5	50.9	30.3	13.4	-	-5.9	-23.7	-44.5	-142.8	-269.9	-
BAGHERPARA	47	JES0471	11.5	47.5	10.4	95.9	43.4	20.7	-	-14.5	-18.8	-32.1	-108.4	-255.5	-
BAGHERPARA	89	JES0891	14.2	87.1	9.9	34.3	23.0	28.2	15.4	-6.0	-23.5	-40.7	-101.2	-154.4	-235.9
BAGHERPARA	108	JES1082	21.4	67.3	25.4	45.2	19.8	10.7	-	-11.5	-33.2	-60.0	-142.9	-254.1	-
BAGHERPARA	116	JES1161	14.0	133.2	24.5	61.5	36.4	7.6	-	-7.7	-34.3	-63.0	-122.8	-226.9	-
ABHAYNAGAR	3	JES0031	9.7	25.8	6.8	36.5	6.4	22.6	-	-8.8	-16.3	-28.0	-87.1	-145.3	-
ABHAYNAGAR	25	JES0251	11.1	21.1	6.7	29.5	5.6	24.0	14.8	-9.3	-14.7	-29.3	-69.9	-111.3	-169.7
ABHAYNAGAR	50	JES0502	6.0	20.8	6.6	25.2	10.9	47.8	9.1	-7.1	-15.6	-25.8	-64.5	-125.4	-309.5
ABHAYNAGAR	69	JES0691	5.6	33.1	6.4	18.0	14.5	42.0	12.7	-3.3	-10.5	-33.5	-81.2	-171.0	-335.7
ABHAYNAGAR	81	JES0811	8.6	18.3	6.7	13.9	6.0	23.9	5.3	-6.8	-15.2	-24.9	-87.2	-142.2	-313.8
ABHAYNAGAR	90	JES0902	6.4	14.0	4.0	9.6	5.1	23.6	-	-5.8	-11.3	-28.6	-77.4	-122.4	-
ABHAYNAGAR	92	JES0921	5.0	13.8	3.4	10.2	5.2	19.8	-	-5.2	-10.1	-21.0	-54.8	-120.9	-
ABHAYNAGAR	41	JES0412	7.2	70.8	14.9	3.7	17.7	11.2	-	-4.7	-20.4	-71.7	-115.7	-177.6	-



TEM Survey Station
JL No.

Figure 2.1.1	**Location map of TEM survey station**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

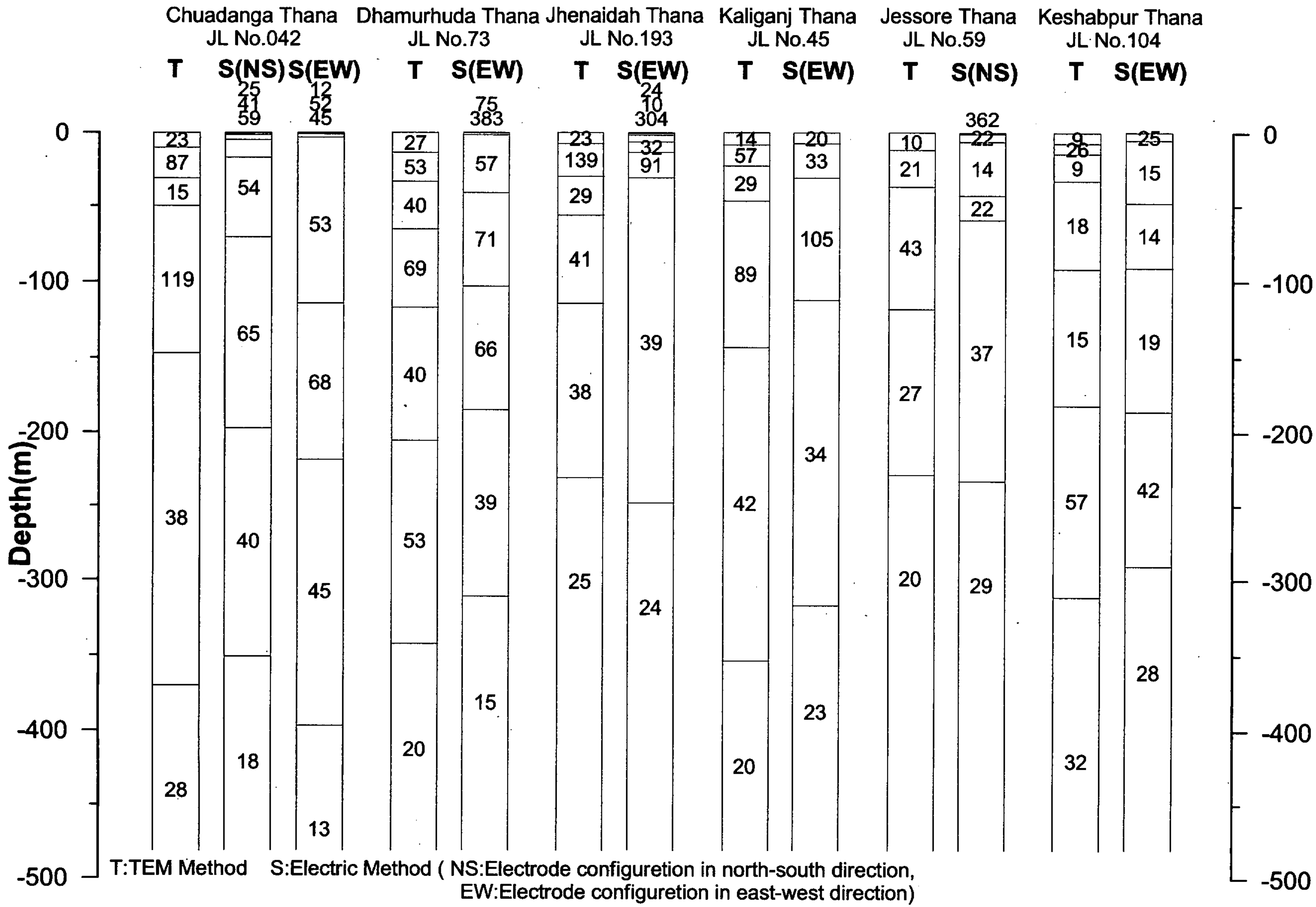


Figure 2.1.5 Comparison of TEM Prospecting and Electric Prospecting

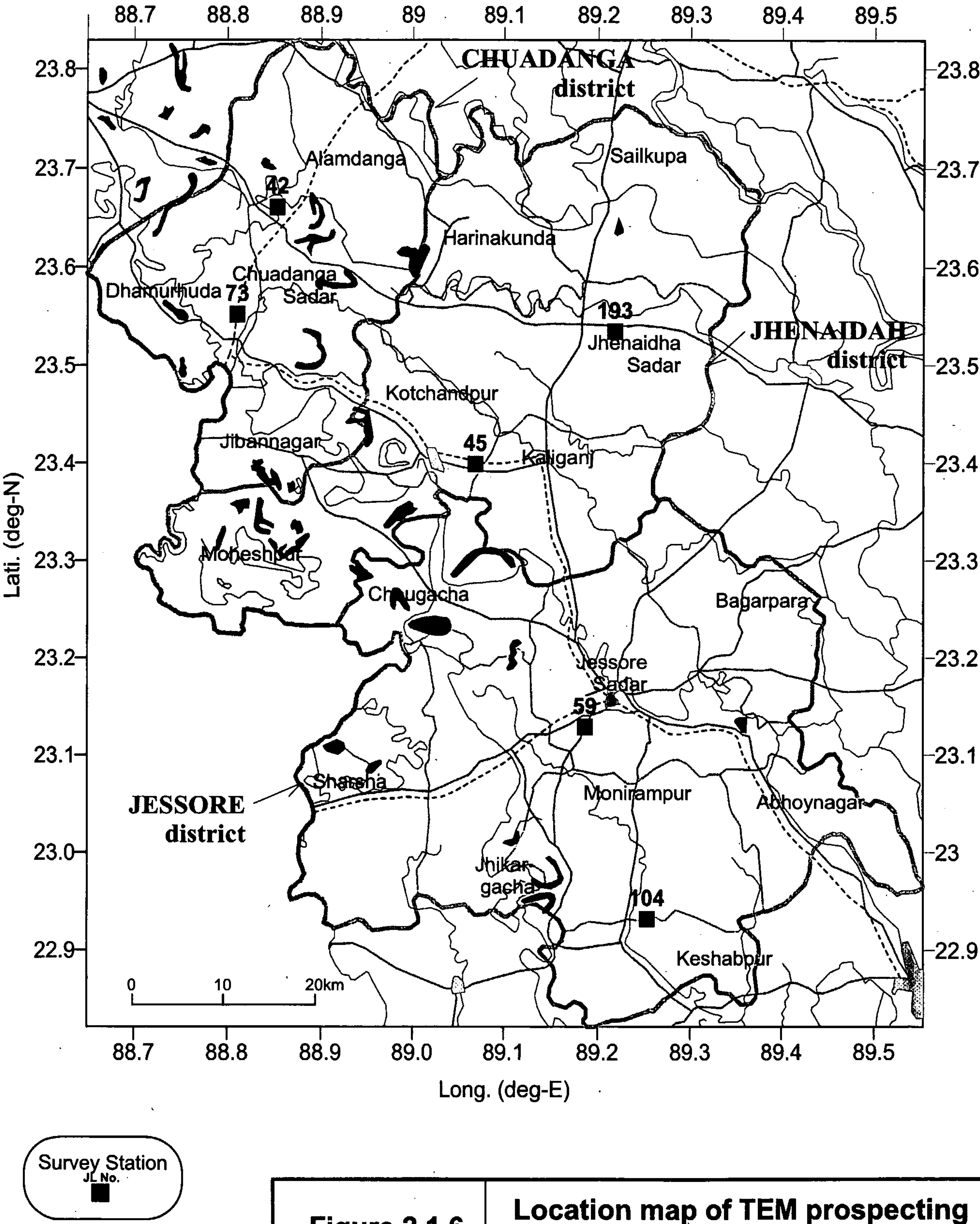


Figure 2.1.6	Location map of TEM prospecting and Electric prospecting

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

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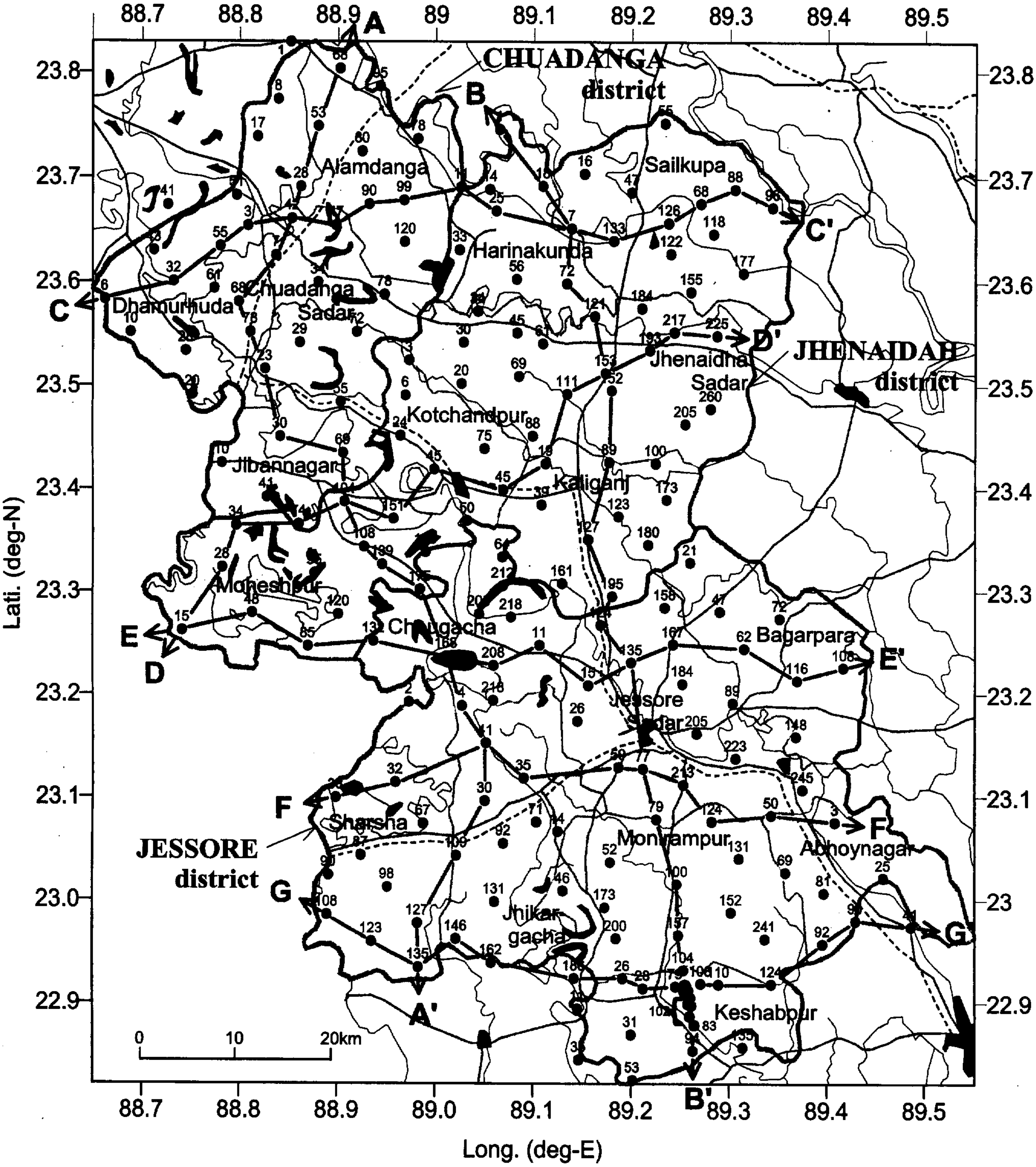


TEM Survey Station
JL No.

Section Line
A ⟷ A'

Figure 2.1.7	Location map of section line

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

2.2 Analysis of Hydrogeological structure

2.2.1 Results of Geophysical Prospecting

Most of the sounding data are interpreted with from five to six layers in most cases. In general, estimated resistivity ranges from more than 10 to less than 70 ohm-m. At almost all stations, resistivity structures consist of four to five layered models of LHML or LHLML (low, high, middle and low, or low, high, low, middle and low resistivity from the surface) type. In Jhenaidah District, the LHML type is at about 80 % of the stations, In Chuadanga and Jessore District, the LHLML type is at about 60 % of the stations. The estimated resistivity structures are listed in Table 2.1.6.

1) Resistivity image sections

Resistivity image sections consist of seven profiles, A-A’, B-B’, C-C’, D-D’, E-E’, F-F’ and G-G’, and are presented in Figures 2.2.1 to 5.2.7. The locations of these profiles are shown in Figure 2.1.7.

1-1) Profile A-A’

This profile, which is composed of 21 stations, begins in the north of Alamdanga Thana, goes through Moheshupur Thana and ends in the south of Sharsha Thana.

In Figure 2.2.1, low resistivity values are represented by reddish colors and high resistivity values are shown in bluish colors.

Subsurface resistivity in the vicinities to the north of Chougacha Thana are high (more than 50 ohm-m), and high resistivity can be seen at depths of 100 and 300m, with a thickness commonly of less than 100m.

The low resistivities of less than 20 ohm-m are deeply distributed in this image.

1-2) Profile B-B’

Profile B-B’ runs from north to south and is composed of 24 stations, as shown Figure 2.2.2. It runs through Harinakunda Thana, Kaliganj Thana and Keshabupur Thana.

The high resistivity values are also in northern parts of the profile and at a depth of about 100m. In Keshabprur Thana, it can be seen at 250m in depth with a thickness of less than 100m.

The low resistivity values are widely distributed from surface to depth in Keshabpur Thana.

1-3) Profile C-C’

This profile runs from west to east, crossing profile A-A’ and B-B’ as shown in Figure 2.2.3 This image was derived from data collected at 16 stations.

The high resistivity can be seen at 100m in depth in the western part of Sailkupa Thana, and middle resistivity values of more than 20 to less than 50 ohm-m are widely distributed.

1-4) Profile D-D'

The section of this profile, which runs from Moheshupur Thana, Kochandpur Thana and Jhenaidah Thana, is composed of 14 stations (see Figure 2.2.4).

High resistivity in Kotchandpur Thana is also at 100m in depth and with thickness. The low to middle resistivity values ranging from 20 to 50 ohm-m can be seen at a depth of more 150m.

1-5) Profile E-E'

As shown in Figure 2.2.5, this section of the profile runs from Mheshpur Thana to Bagarpara Thana and is composed of 13 stations. This profile is the central part of the study area.

High resistivity can be seen slightly. Low to middle resistivity can be seen at a depth of more than 150m.

1-6) Profile F-F'

This profile, composed of 10 stations, runs from Sharsha Thana to Abhaynagar Thana, as shown in Figure 2.2.6. Profile F-F' is similar to profile D-D'.

1-7) Profile G-G'

This profile runs through Sharsha Thana, Manirampur Thana and Abhaynagar Thana in the southern part of the study area, as shown in the Figure 2.2.7.

High resistivity can be seen at the surface in Manirampur Thana. Middle resistivity can be seen at a depth of 100m in the vicinities of Maniranpur Thana and at 300m in depth eastward from Keshabpur Thana to Abhaynagar Thana.

Low resistivity can be seen at the surface in Abhaynagar Thana.

2) Resistivity sections

Resistivity sections along the seven profiles, from A-A' to G-G', are presented in Figures 2.2.8 to 2.2.14. The locations of these profiles are shown in Figure 2.1.7. The final inversion results have been used as existing well data and geologic log data.

Resistivity is one of the most variable of physical properties. The resistivity range of rocks is as follows (source in "Handbook of Physical Constants").

Table 2.2.1 Resistivity range of rocks

Geologic age	Marine sand, Shale, Greywacke	Terrestrial sand, Claystone, Arkose	Volcanic rocks	Granite Gabbro, etc	Limestone, Dolomite, Anhydrite, Salt
Quaternary,Tertiary	1-10	15-50	10-200	500-2000	50-5000
Mesozoic	5-20	25-100	20-500	500-2000	100-10,000
Carboniferous	10-40	50-300	50-1,000	1000-2000	200-100,000
Pre- Carboniferous Paleozoic	40-200	100-500	100-2,000	1000-5000	10,000-100,000
Precambrian	100-2000	300-5,000	200-5,000	5,000-20,000	10,000-100,000

Table 2.2.2 Summary of Lithological Interfaces in borehole

Borehole	Lithology	Depth(m)	Thickness(m)
Dudhpatila	Silt	0.00-7.00	7.00
	FS consists of clay	7.00-60.00	53.00
	FS/MS	60.00-126.50	66.50
	FS/MS(with little gravel)	126.50-166.00	39.50
	FS/MS(with big gravel)	166.00-228.30	62.30
	Silt/FS	228.30-241.00	12.70
	FS/MS	241.00-276.78	35.78
	Silt/FS	276.78-300.00	23.22
Chuadang / Hat Kaluganj	Silt	0.00-7.60	7.60
	FS consists of clay	7.60-42.62	35.20
	FS/MS	42.62-121.00	78.38
	FS/MS(with little gravel)	121.00-164.00	43.00
	FS/MS(with big gravel)	164.00-232.20	68.20
	Silt/FS	232.20-237.50	5.30
	FS/MS	237.50-300.00	62.50
Krishna Chandpur	Silt	0.00-6.00	6.00
	VF/MS	6.00-60.00	54.00
	FS/MS	60.00-102.00	42.00
	CS	102.00-145.00	43.00
Arappur Chandpara	Silt	0.00-4.62	4.62
	VF/MS	4.62-23.35	18.73
	FS	23.35-47.00	23.65
	MS/CS/MS	47.00-70.50	23.50

VF:Very Fine Sand, FS:Fine Sand, MS:Medium Sand, CS:Coarse Sand

The subsurface geology is not fully understood in the study. In particular, there is no existing deep tube well data for the Chuadanga District area. According to the existing geological data, clay or silt is commonly found. The thickness is from a few meters to 30m. In Keshabpur Thana, the clayey layer occurs below depths of 60 to 120m. Its thickness is about 200m. In the western part of Jessore District, the existing wells often encounter a deep clayey layer at depths of 150 to 270m.

The objective of core boring was to obtain hydrogeological information on the study area. The core boring is carried out at 4 locations of Dudpatila Mouza (near TEM record no.CHU0731 station) of Dhamurhuda Thana, Chuadanga Mouza (CHU0421) and Hat Kaluganj Mouza

(CHU0071) of Chuadanga Thana, Krishna Chandpur Mouza (JHE1041) of Moheshupur Thana and Arappur Chandpara (JHE1211) of Jhenaidah Thana.

A summary of the depth and thickness of lithology observed in boreholes is given in Table 2.2.2 on the basis of the above result, when interpreted in the context of the geological setting.

2-1) Profile A-A'

The layer models of this profile, shown in Figure 2.2.8, are almost of the LHML type. Subsurface resistivity is low, and the overburden thickness is about 70m in the Jibannagare Thana and about 50m in the other Thana. The high resistivity of the second layer is from 50m in the south to 100m in the north. The middle of the third layer is thick, with a thickness of about 200m. The lowest resistivity values are found at from 200m in depth in the south to 400m in depth in the north.

This profile is carried out core boring at 4 stations, TEM record no.CHU0421, CHU0071, CHU0731 at a depth of 300m, and JHE1041 at a depth of 145m. Each station of TEM survey was located more than 500m from core boring, for unfavorable survey location include noise statistics determined by transmission line and the other conductive materials.

According to the lithological descriptions of core boring data, the silt and/or clay layer is composed with a thickness of 40 to 60m from the ground surface. The layer below the silt and/or clay layer, the thickness of the fine sand or medium sand layers.

The existing well data of Jikargacha Thana is as follows: TEM record no. JES0411, JES0301, JES1091 and JES1271.

The existing wells were drilled to a depth of 190 to 250m close to JES0411, JES0301, JES1097, JES1271 and JES1351. The clay layer exists at depths from the ground surface to 30m, and at depths of 100 to 250m.

From this, it may be inferred that the sand layer contains gravel from 120 to 230m. The Low resistivity zone (L) of this profile is regarded as silt and/or clay layer. The sand layer contains gravel indicating that the high resistivity zone (H) is regarded as gravel. Most of the deepest layer is regarded as the silt and/or clay layer.

2-2) Profile B-B'

The layer models of this profile are the LHML type in the Kaliganj and Jessore Thana area, and the LHLML type is in the northern part and in the southern part (see Figure 2.2.9).

Subsurface resistivity is low, and the overburden thickness is about 30m in the southern part and about 50m in the northern part. The thickness of the high resistivity layer is from 30m in the south to 100m in the north. The middle layer is thick, with a thickness of about 200m. Low resistivity is found at from 300 to 400 m in depth.

The existing well data of Kheshabpur Thana is characterized by a thick clayey layer of more

than 40m, and the clay of the second layer occurs between 100 to 200m (near JES1024 station). In Manirampur Thana, the clayey layer ranges in depth from 70 to 120m (near the JES1002). In Kaliganj Thana, the clay exists at a depth of 30m from the ground surface (near the JHE0891).
Comparing the existing wells of this profile, the thickness of subsurface low resistivitiy (L) is regarded as the clay layer and its clay layer has an approximate depth of more than 50m. And moreover, in the Keshabupur area it is regarded as the sand with silt and/or clay layer from 80 to 200m in depth.

2-3) Profile C-C'

The layer models of this profile are the LHML type in the western part of the Chuadanga Thana area, and the LHLML type in the southern part (see Figure 2.2.10).
A core boring was conducted in Chuadanga Thana (near CHU0421). According to the existing well data of Sailkupa Thana, most of the sand layer is more than about 150m in depth (near the JES0071).
From the viewpoint, resistivity is regarded as a clay/silt layer occurring at a depth less than 50m. The sand layer containing gravel is regarded as in the high resistivity zone (H) to the middle resistivity zone (M). The (M) is thin in the eastern part and thick in the western part.

2-4) Profile D-D'

The layer models of this profile are almost of the LHML type as show in Figure 2.2.11.
Subsurface resistivity values are overburden thin, about 50m. The high resistivity layer is from 50 to 100m. The middle layer is thick in Kochandpur Thana (more than 200m) and thin in Moheshupur and Jhenaida Thana (about 100m). Low resistivity is found at a depth of 200m in Jhenaidah Thana, and it is deeper in the Moheshupur area.
The existing well data shows an existing sand layer at a depth of more than about 150m (near the JHE0151, JHE0281, JHE1041, JHE1511, JHE0452, JHE1111, JHE1531 and JHE2251). At JHE1041 and JHE1111 there is a clay/silt layer occurring at a depth within 40m from the ground surface.
Regarding the layers of this profile, the high resistivity layer is regarded as the sand layer containing gravel. The middle resistivity layer is regarded as the sand layer, and the low resistivity layer is regarded as the lower layer consisting of sand and silt.

2-5) Profile E-E'

The layer models of this profile are almost all of the LHML type, and in the middle part is the LHLML type (see Figure 2.2.12).
The existing wells were drilled to a depth of 130m close to the JHE0151 and JHE0851. The clay layer is about 10m from the ground surface. The layers below the clay layer are fine sand or

medium sand and coarse sand. The existing wells near JES1352 are mainly in the sand layer, drilled to a depth of 220m, and the clay layers are found sporadically in the sand layer.

The layer of this profile is regarded as depth less than 50m of probable clay layer. The other layers are composed of the sand. The deepest layer is regard as the sand with silt and/or clay layer.

2-6) Profile F-F'

The layer models of this profile are the LHLML type (see Figure 2.2.13).

The existing wells were drilled to depths ranging from 210 to 250m. The wells are JES0411, JES0591, JES0771, JES2131 and JES0502.

This well data is characterized by the thickness of the clay layer. The clay exists at a depth of 35m from the ground surface, existing that the clay layer at a depth between 65 and 140m (at JES0502 station). The well data from near the JES0411 station shows a clayer layer at 150 and 250m.

Comparing the existing wells of this profile, the thickness of the clay layer is regarded as less than about 50m from the subsurface, and between 50 to 150m at the Abhaynagar Thana. In Sharsha Thana, it is regarded as between 100 to 220m. Some other layer is composed of sand.

2-7) Profile G-G'

The layer model of this profile is almost of the LHLML type (Figure 2.2.14).

The existing 12 wells were drilled to depths ranging from 160 to 310m. The thickness of the clay layer is from few 10 to 50m. The clay of the second layer occurs below depths of 70 to 200m. The TEM no JES0281 in Keshabpur Thana is particularly thick at more than 210m.

This profile of inversion models is similar to that of the existing well data.

3) Mapping of Resistivity layer depth

3-1) First layer depth (Low resistivity zone)

The map in Figure 2.2.15 shows the first layer depth generated from the inversion results.

In this figure, blue indicates low resistivity is shallow and yellow indicates its deep.

In general, the depth of the low resistivity increases from southeast to northwest, in the eastern and western part of the study area where low resistivity is deep. The first layer depth is shallow (less than 30m) around Keshabpur Thana and Sailkupa Thana. On the other hand, the layer is deeper (more than 60m in depth) around Jibannagar Thana and Jhenaida Thana.

As mentioned before, these features of the first low resistivity depth probably result from the clayey layer or sand layer.

3-2) Second layer depth (High resistivity zone)

This map indicates the second layer depth of the high resistivity zone (see Figure 2.2.16).

The red on this map indicates it is deep and the blue indicates it is shallow.

The depths of the low resistivity increase from southeast to northwest. The depth to the low boundary of the second layer in the area varies greatly from 30 to 200m below the ground surface. The central part of the study area is deep at the north-south direction.

4) Summary

Transient electromagnetic (TEM) prospecting was successful in acquiring geology data for the groundwater development in the study area. This survey was implemented to define the distribution of layers composed of silt, clay and sand formations.

Since it may, however, be difficult to determine uniquely the contact of each layer from the inversion results, calibration against test-well drilling and core-boring will be required to obtain the most reliable and best results. Furthermore, based upon the calibration, extrapolation to the other stations by a detail survey is necessary.

Reference

Geonics limited, 1992, PROTEM 47 Operating Manual 2.1.

Geonics limited, 1993, PROTEM 57D (C) Operating Manual.

Geol.Soc.Am.Mem.97, 1966, Handbook of Physical Constants.

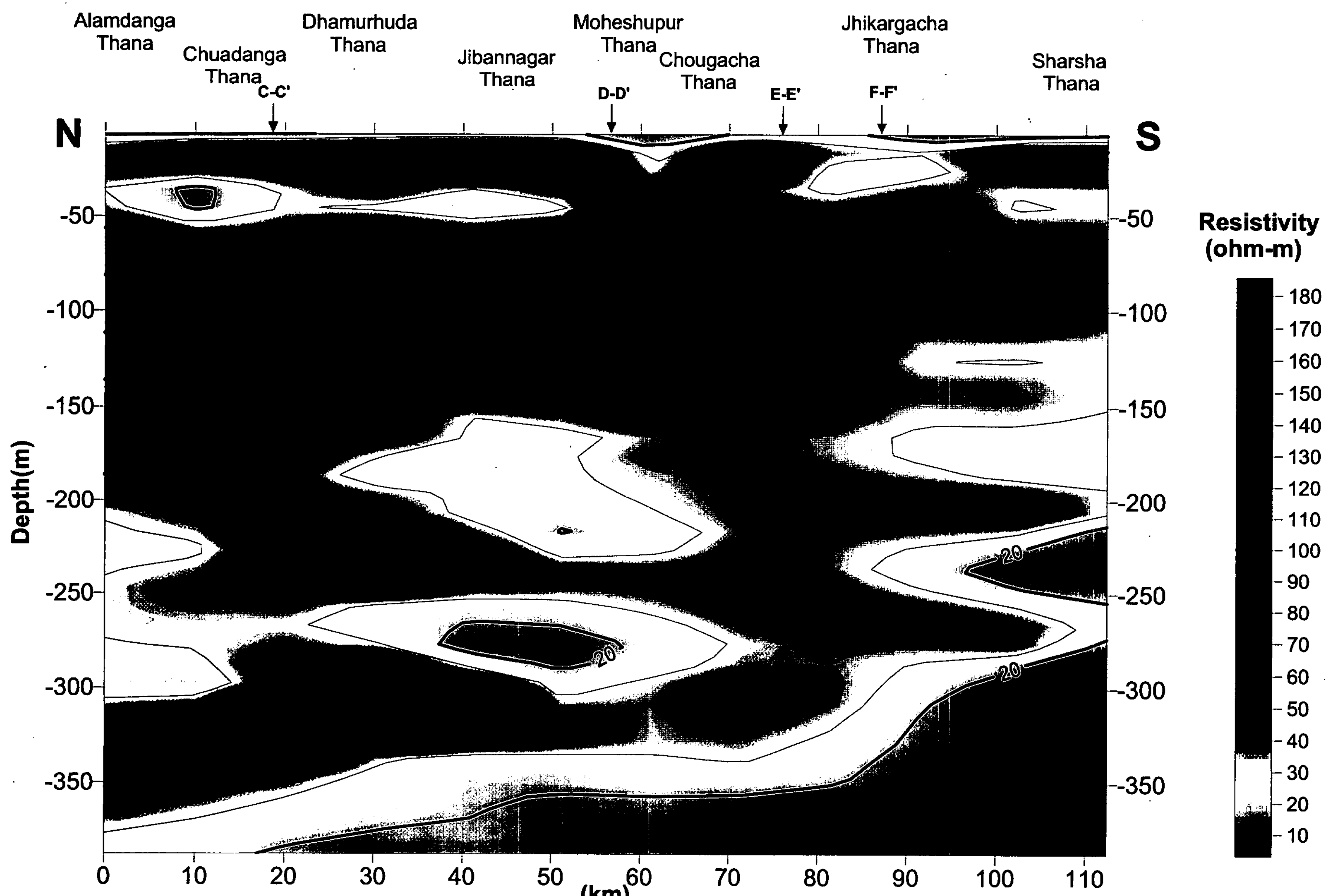


Figure 2.2.1 Resistivity imaging section (A-A')

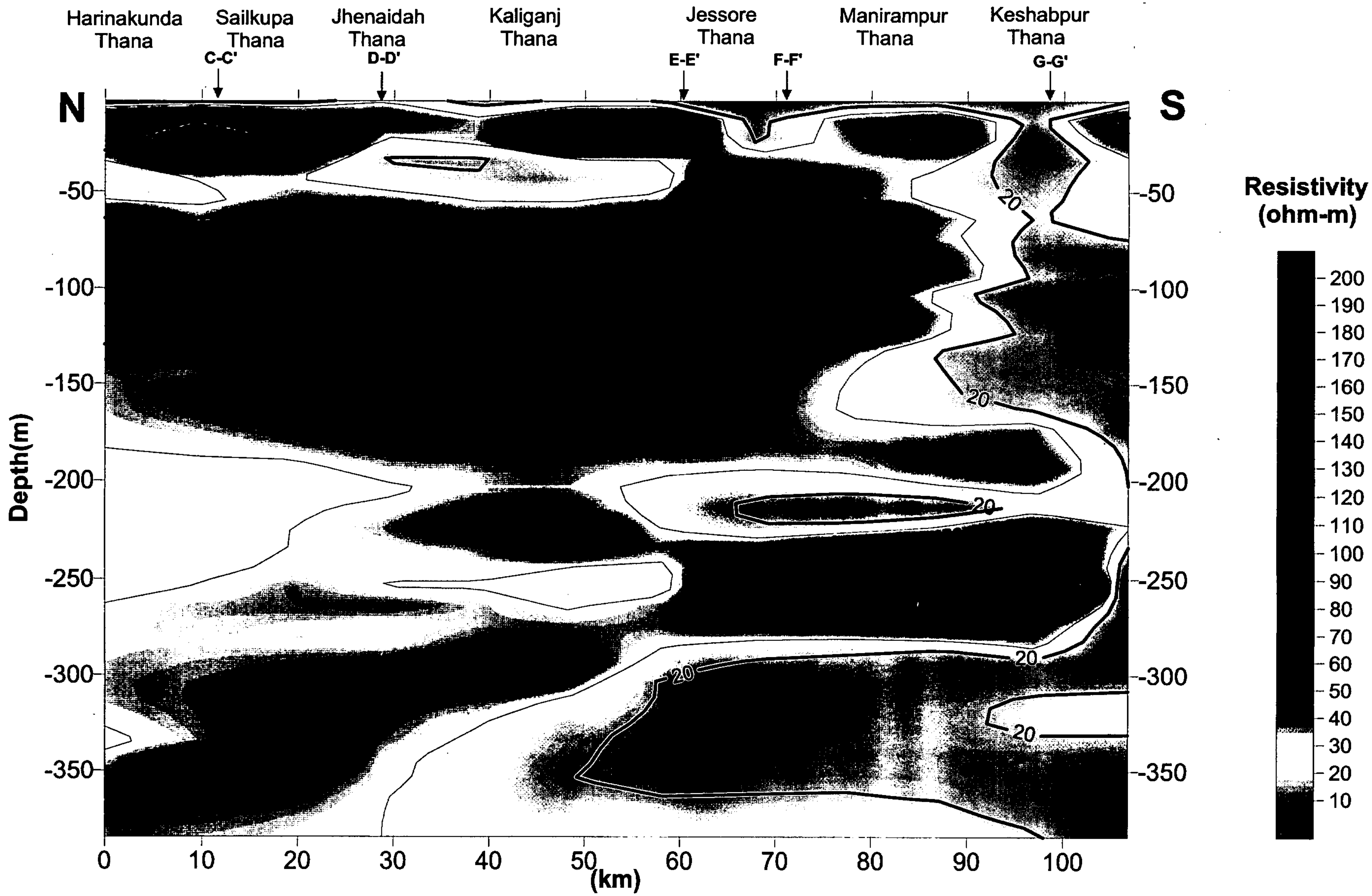


Figure 2.2.2 Resistivity imaging section (B-B')

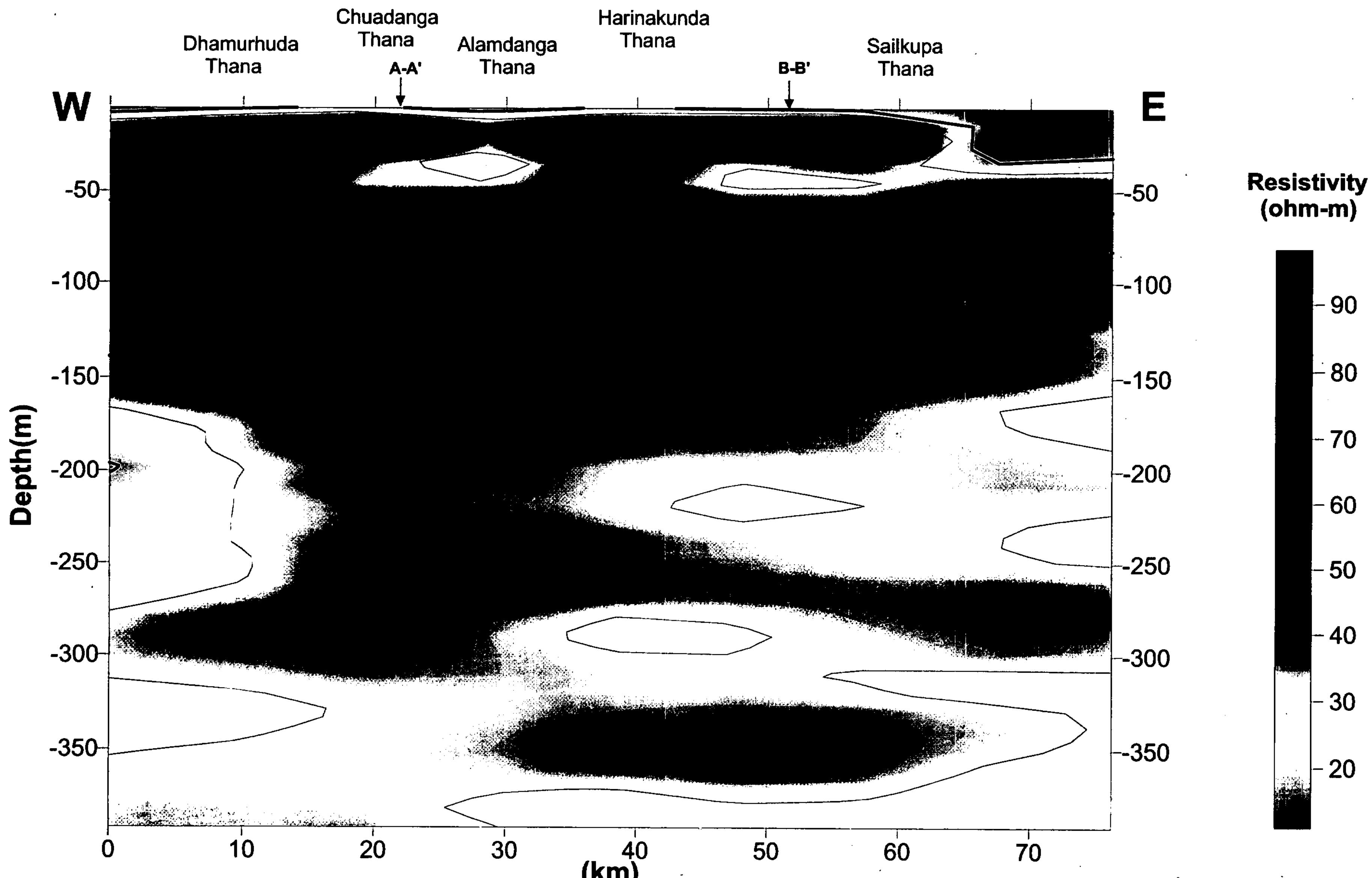


Figure 2.2.3 Resistivity imaging section (C-C')

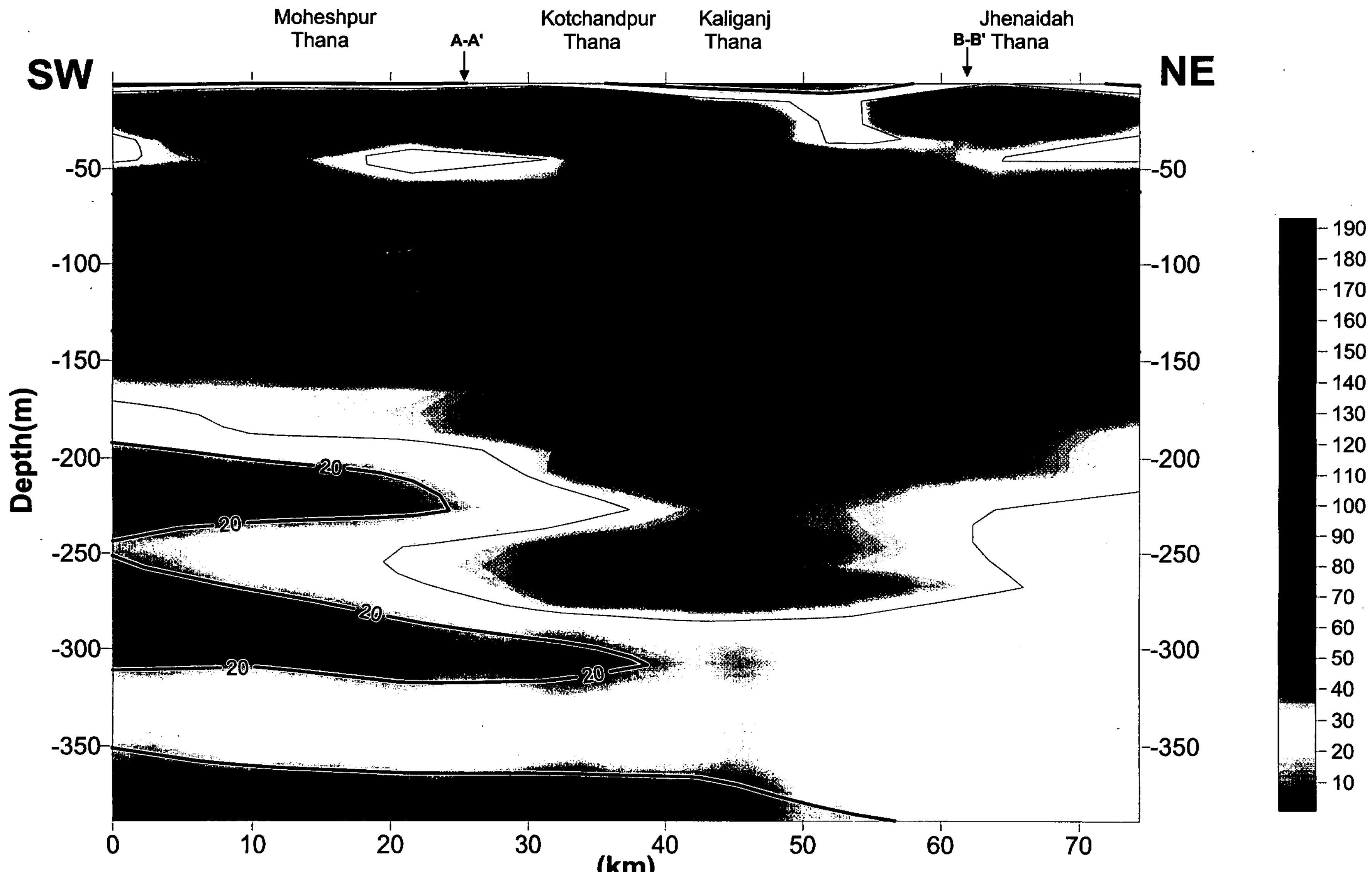


Figure 2.2.4 Resistivity imaging section (D-D')

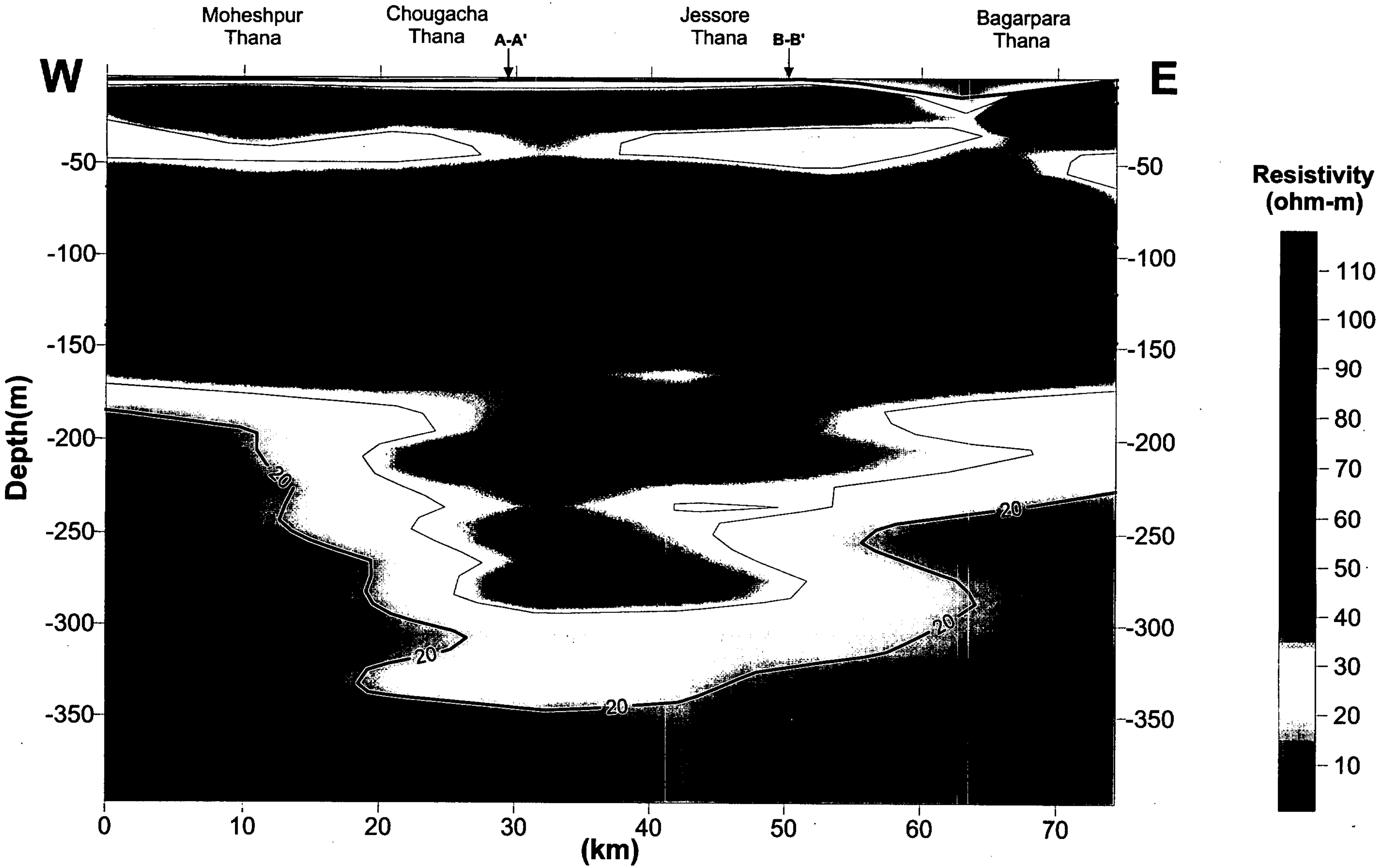


Figure 2.2.5 Resistivity imaging section (E-E')

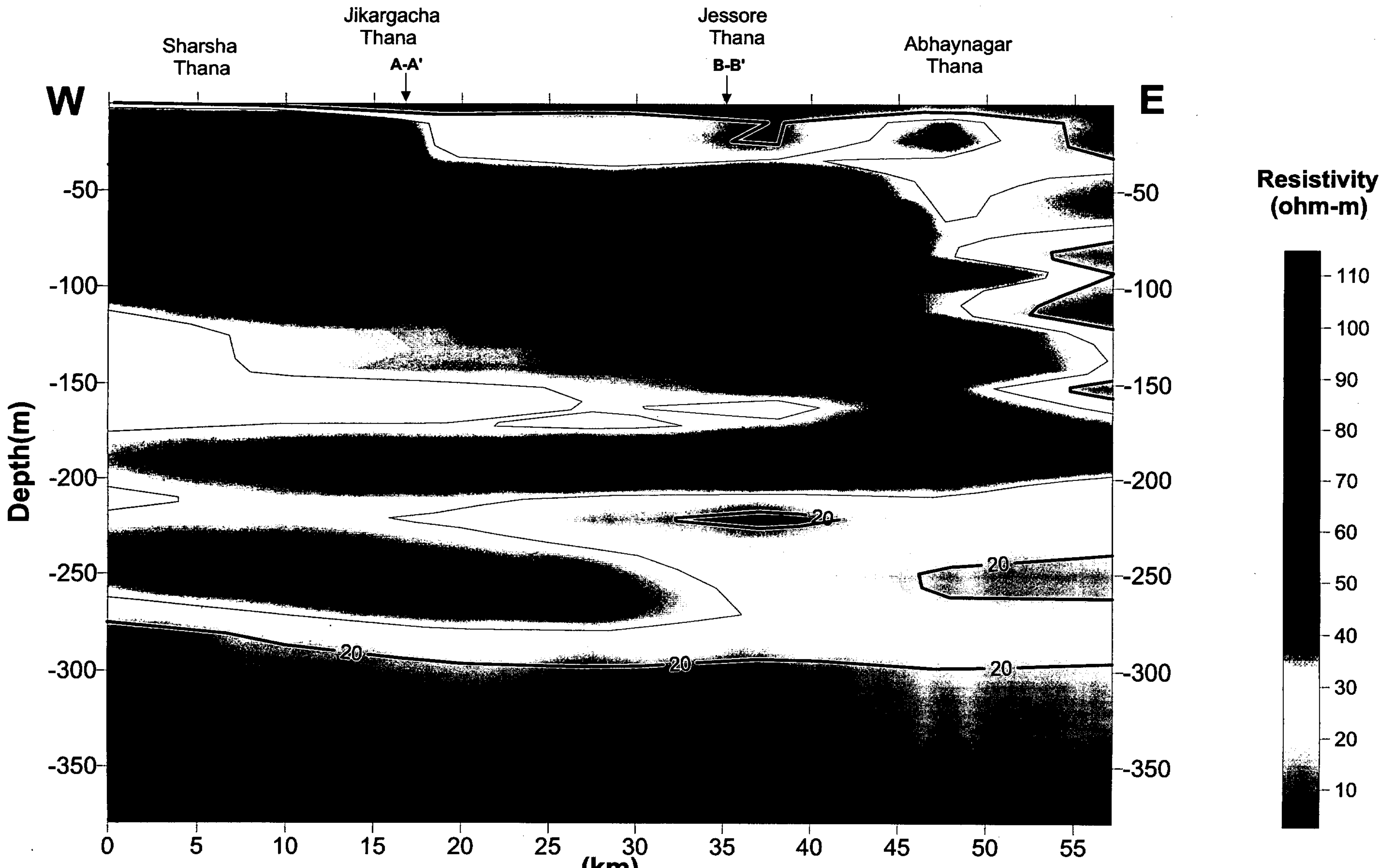


Figure 2.2.6 Resistivity imaging section (F-F')

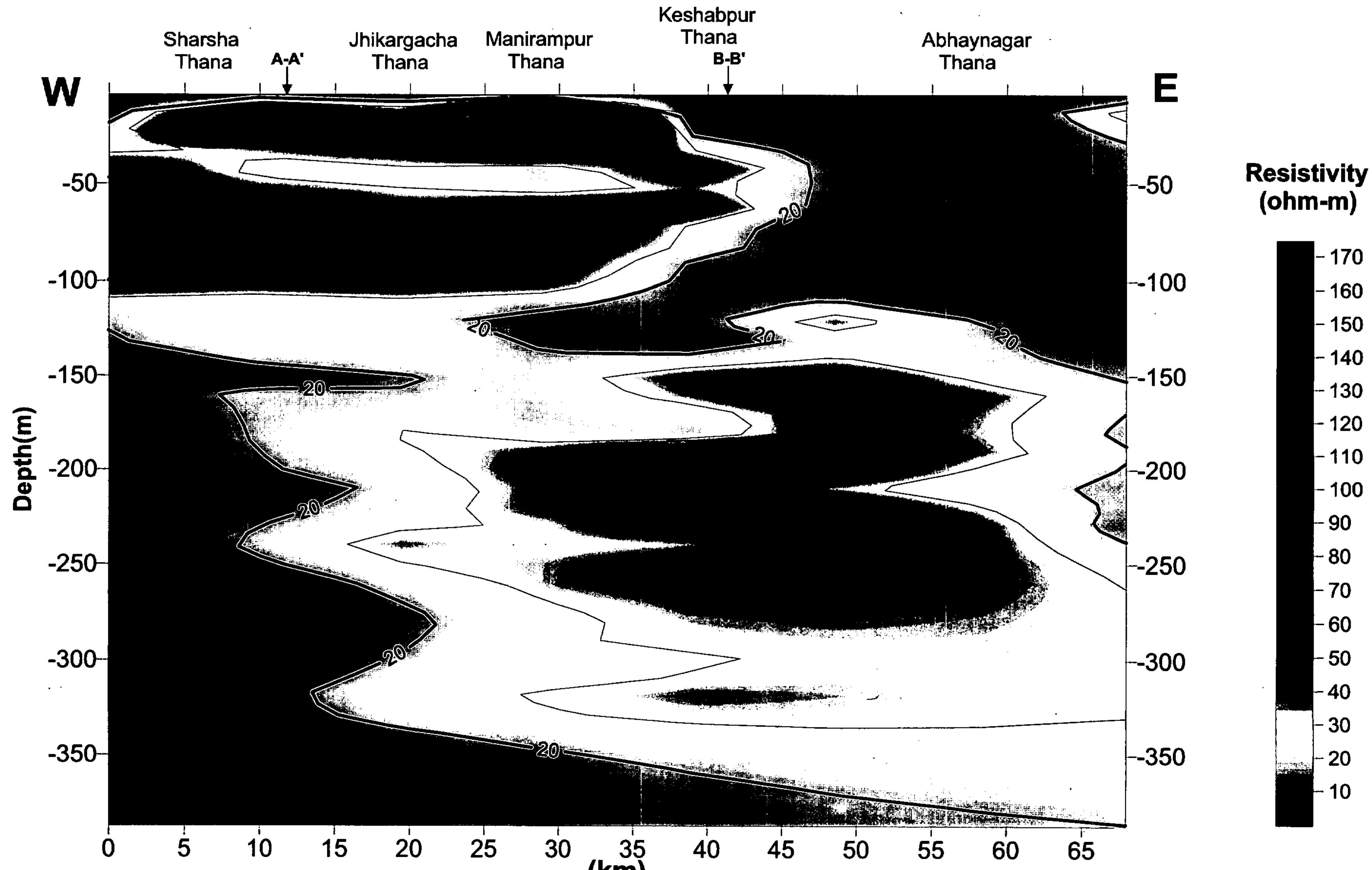


Figure 2.2.7 Resistivity imaging section (G-G')

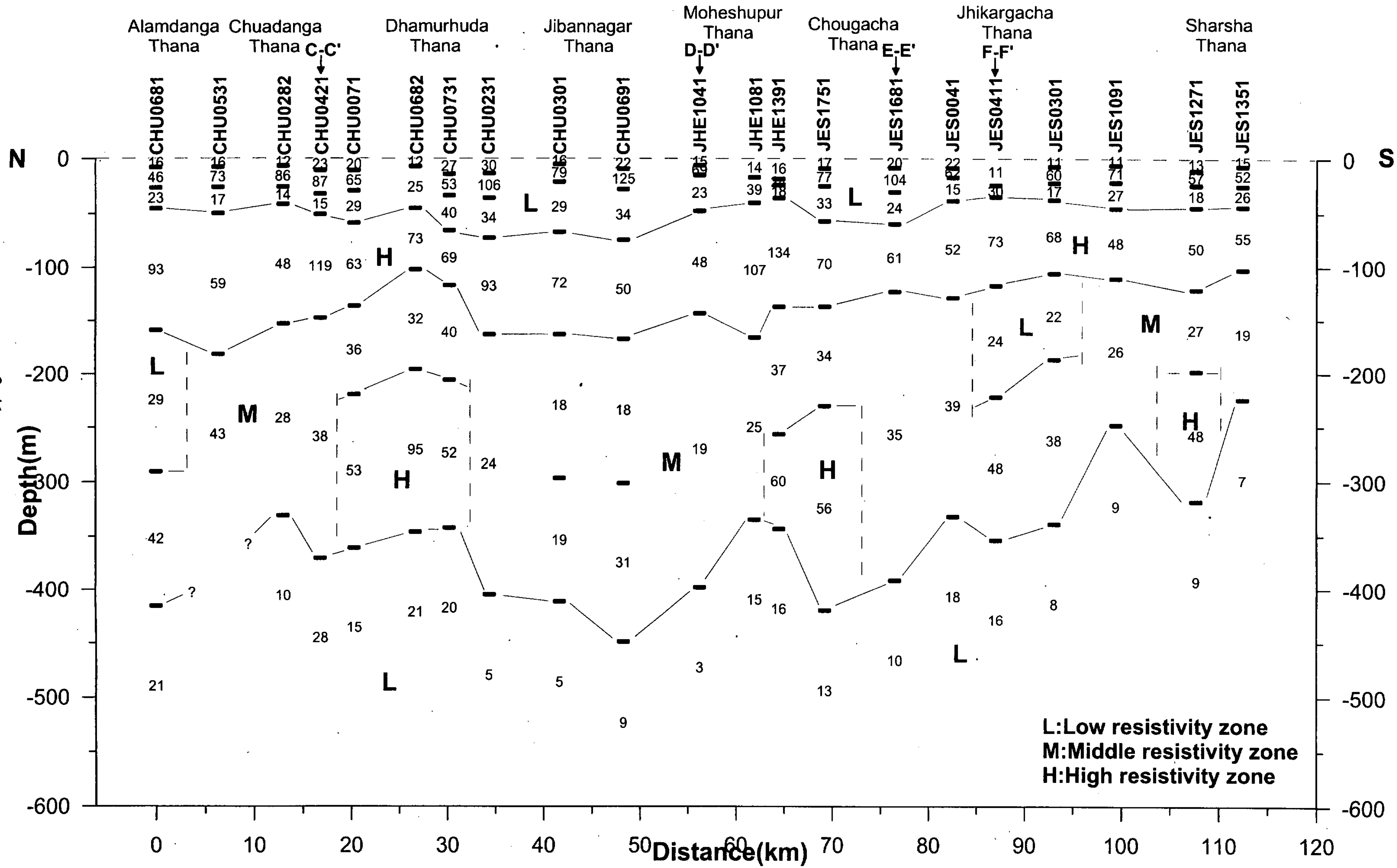


Figure 2.2.8 Resistivity section (A-A')

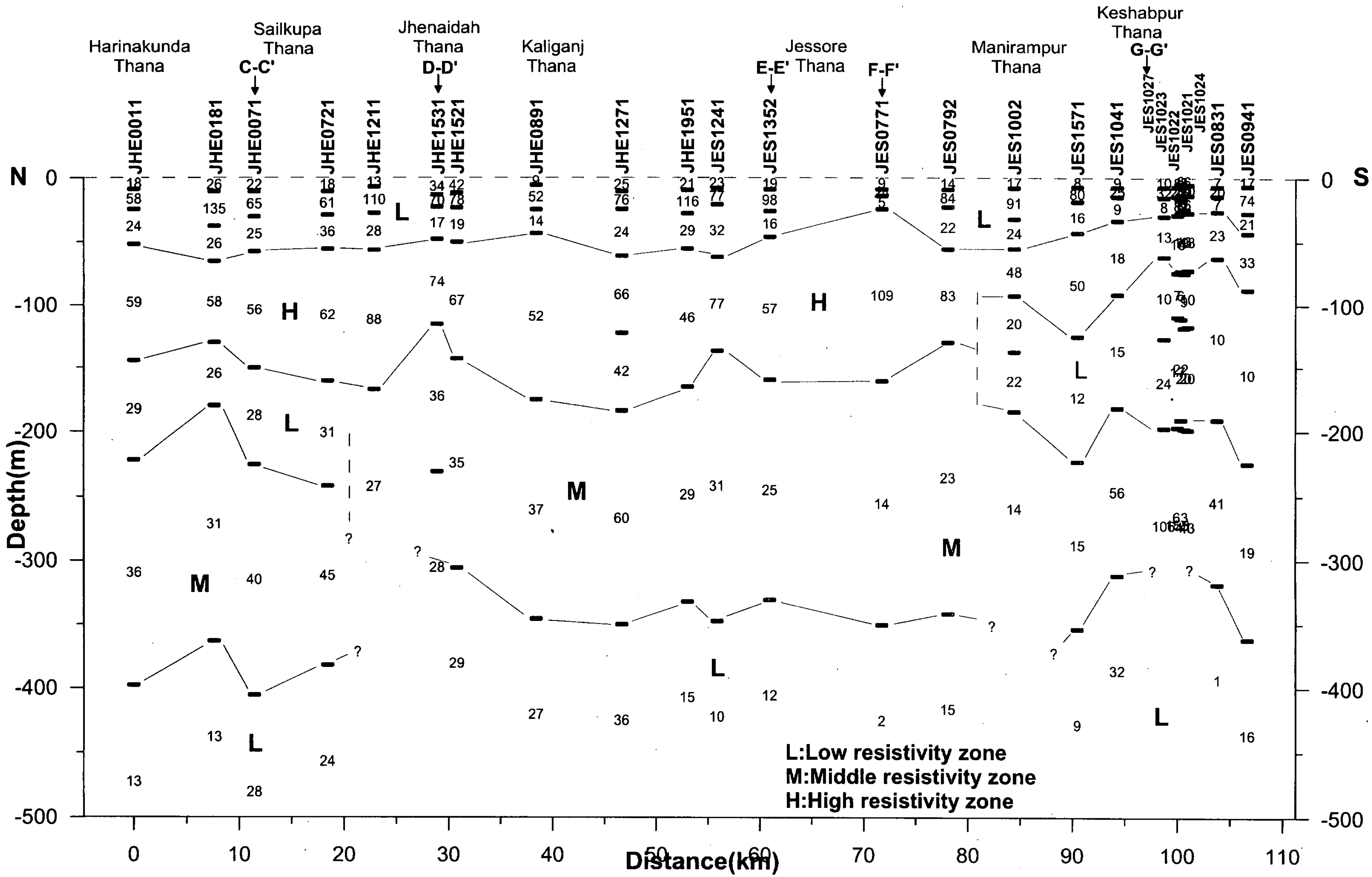


Figure 2.2.9 Resistivity section (B-B')

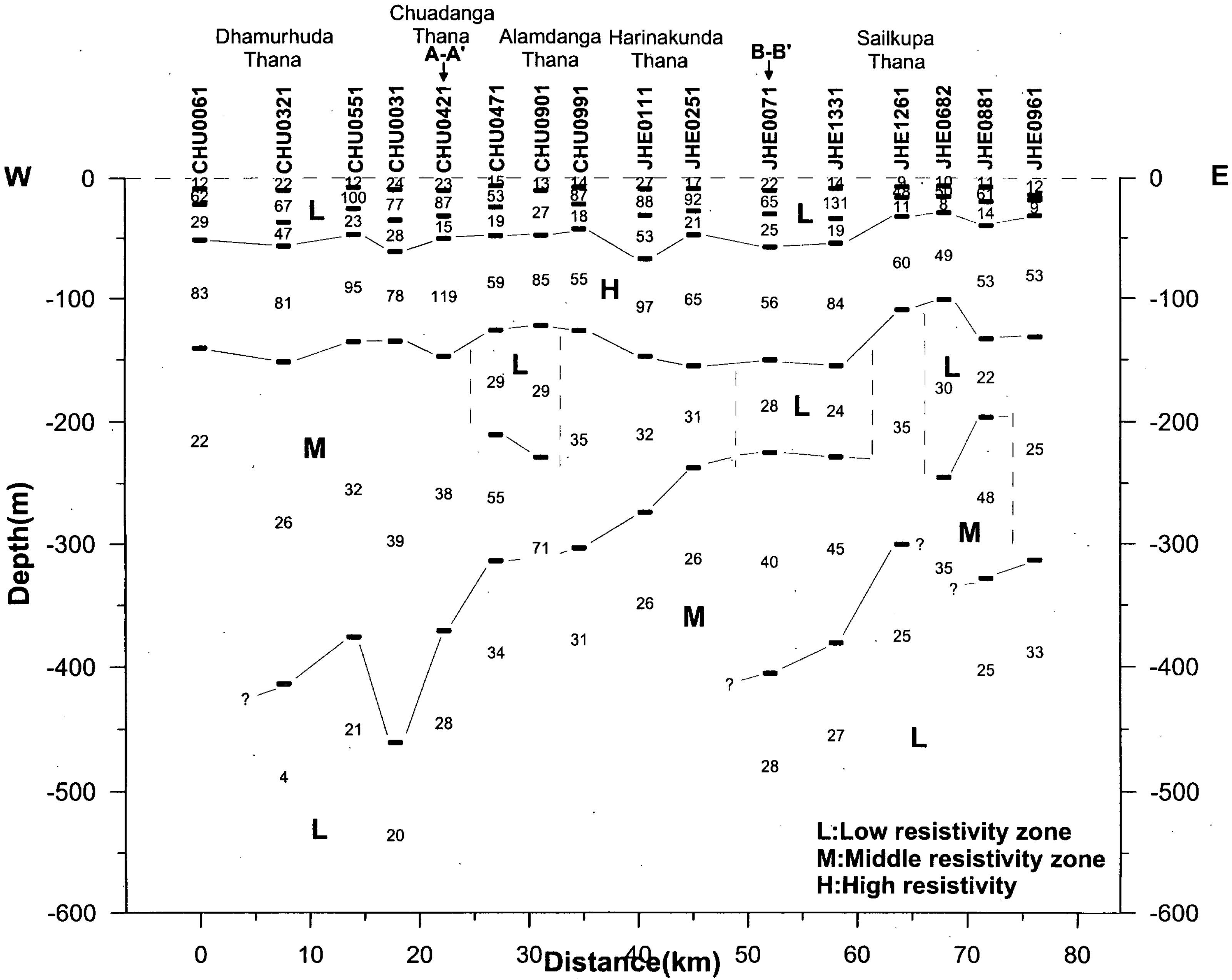


Figure 2.2.10 Resistivity section (C-C')

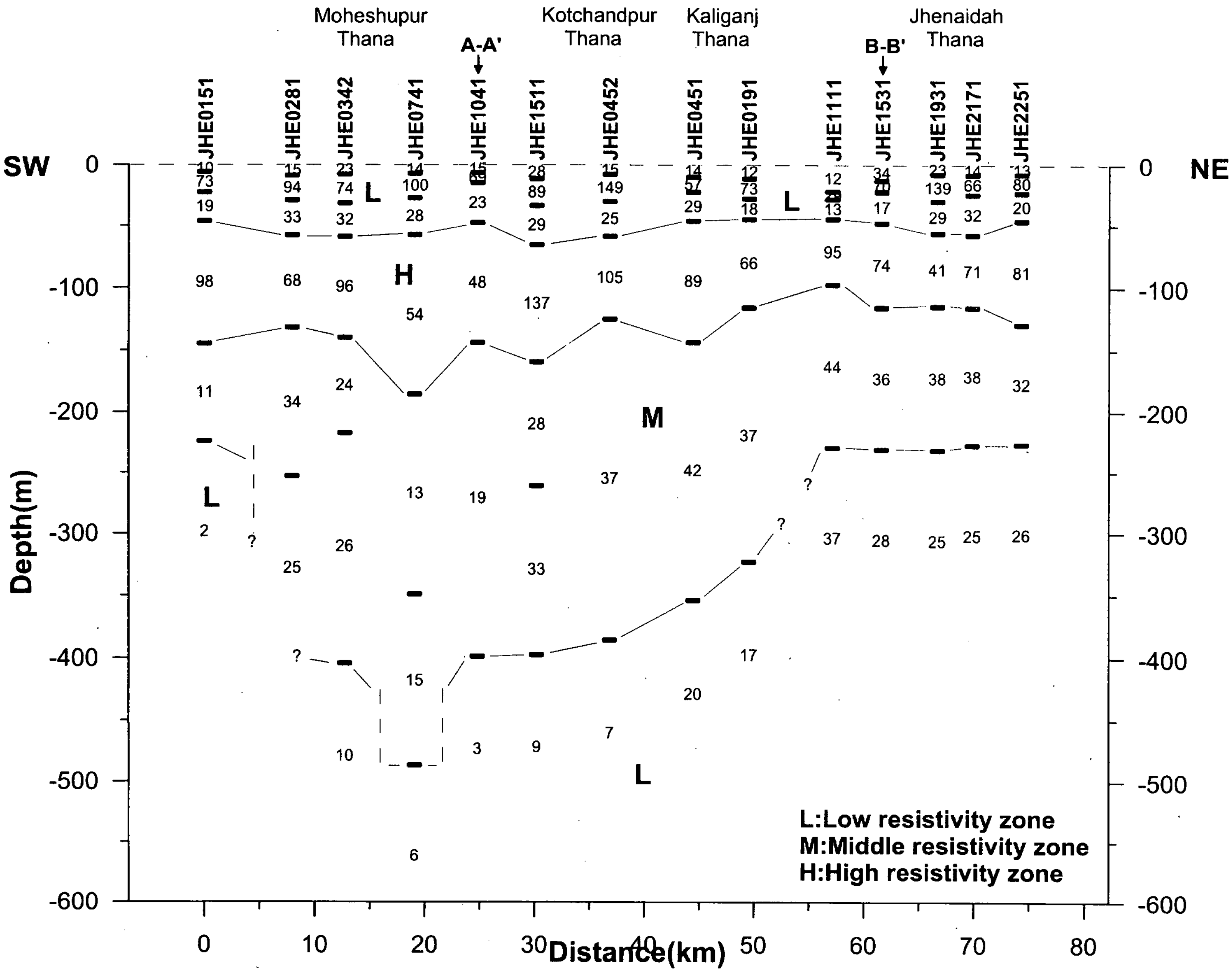


Figure 2.2.11 Resistivity section (D-D')

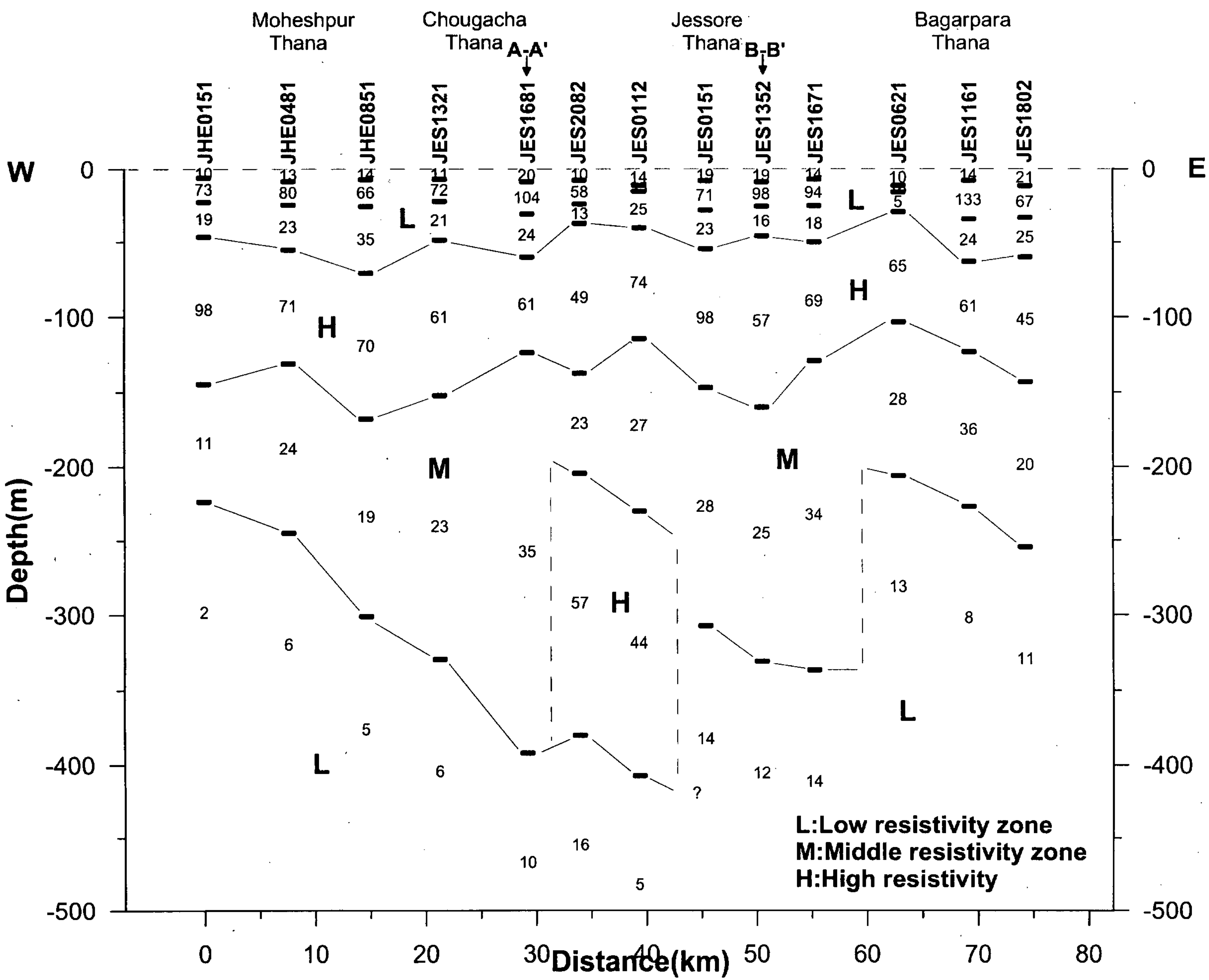


Figure 2.2.12 Resistivity section (E-E')

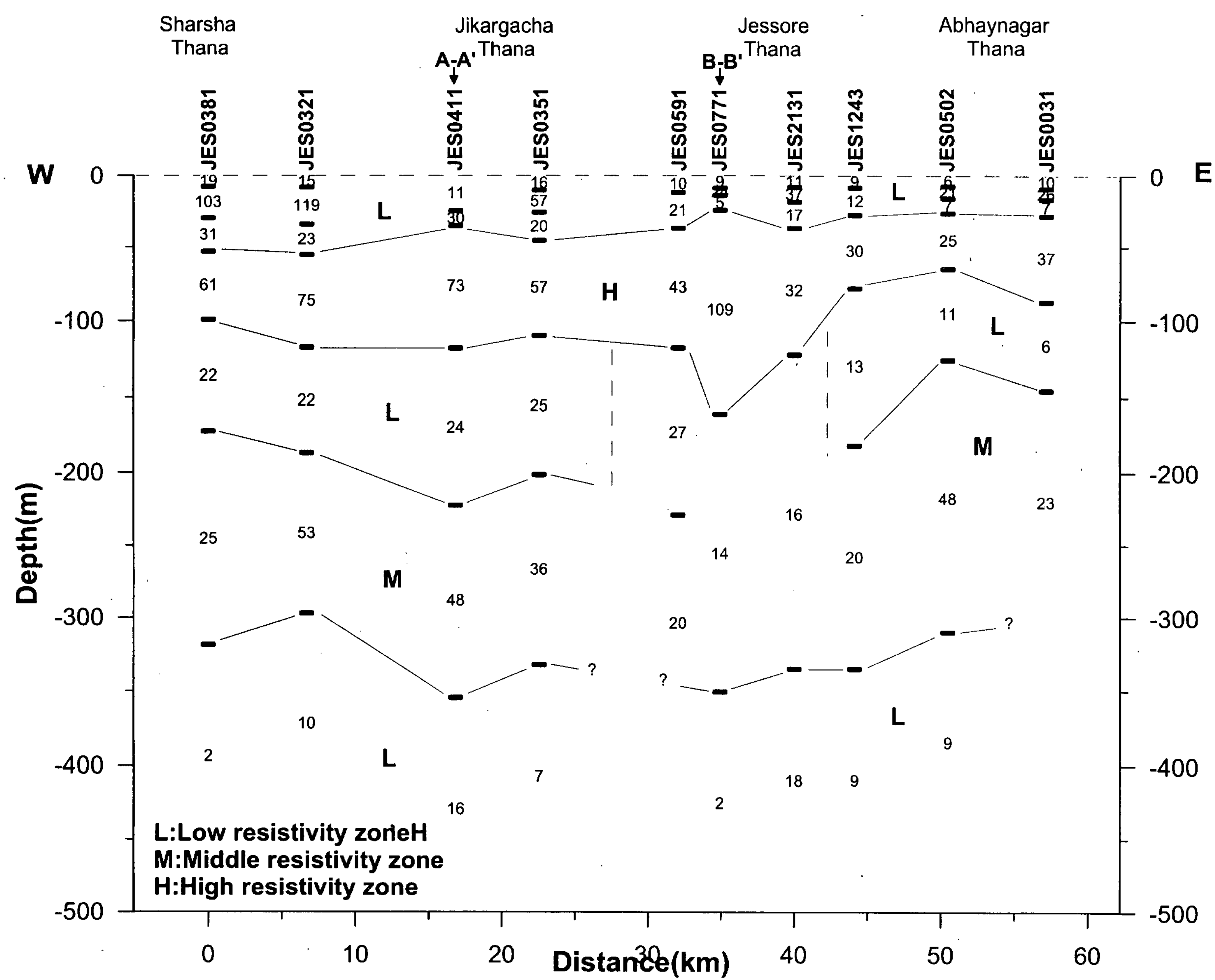


Figure 2.2.13 Resistivity section (F-F')

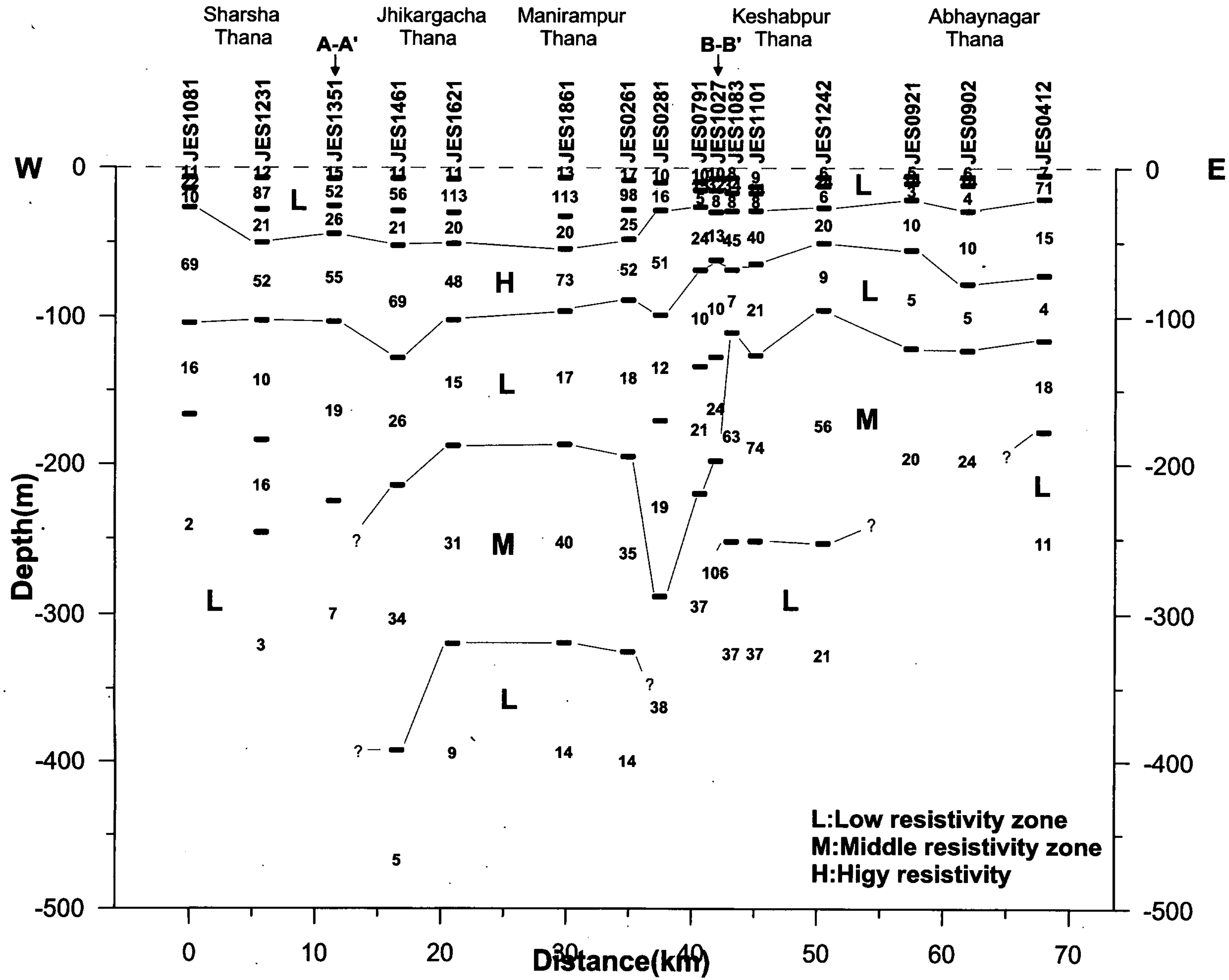


Figure 2.2.14 Resistivity section (G-G')

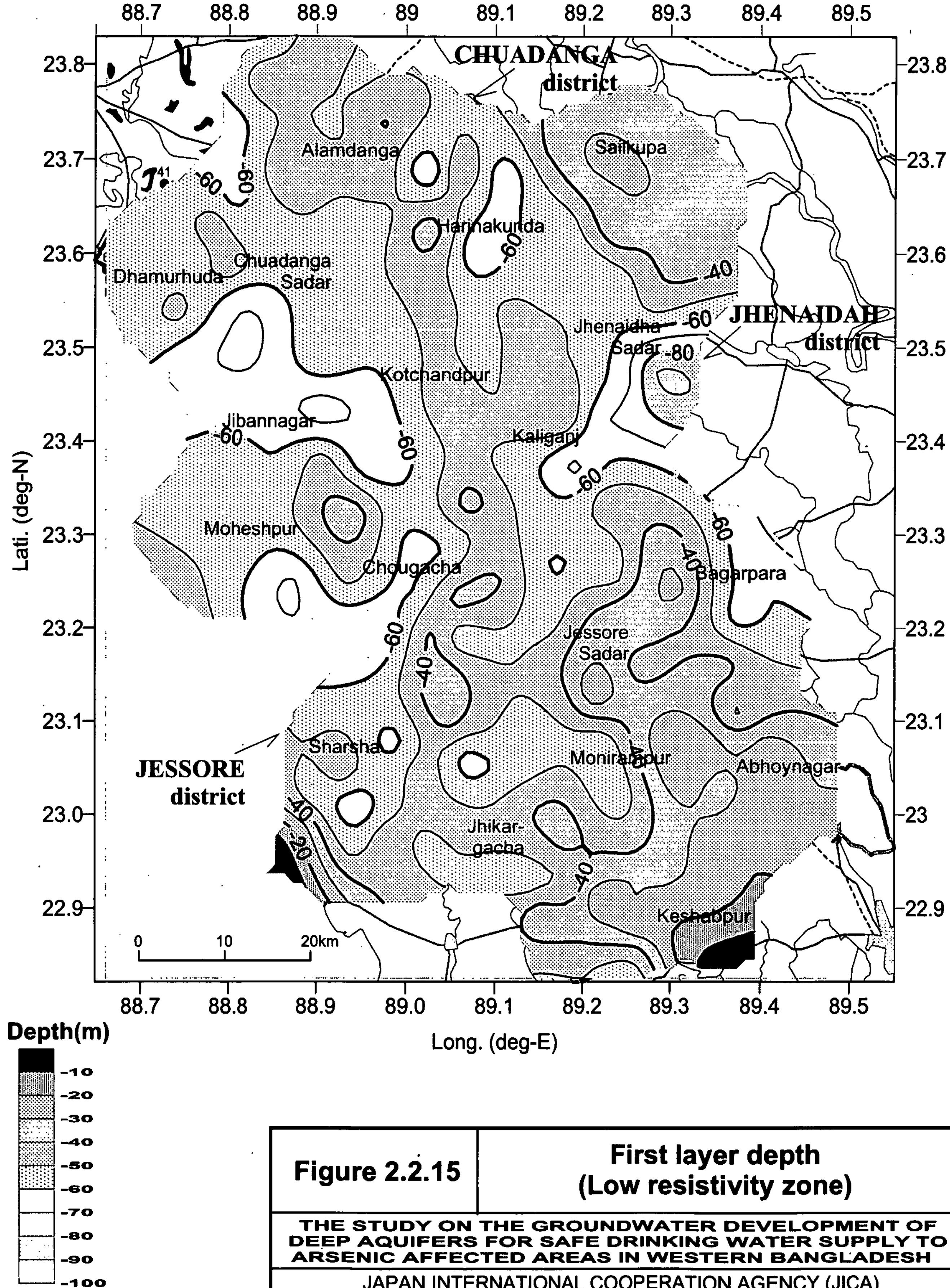


Figure 2.2.15	First layer depth (Low resistivity zone)

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

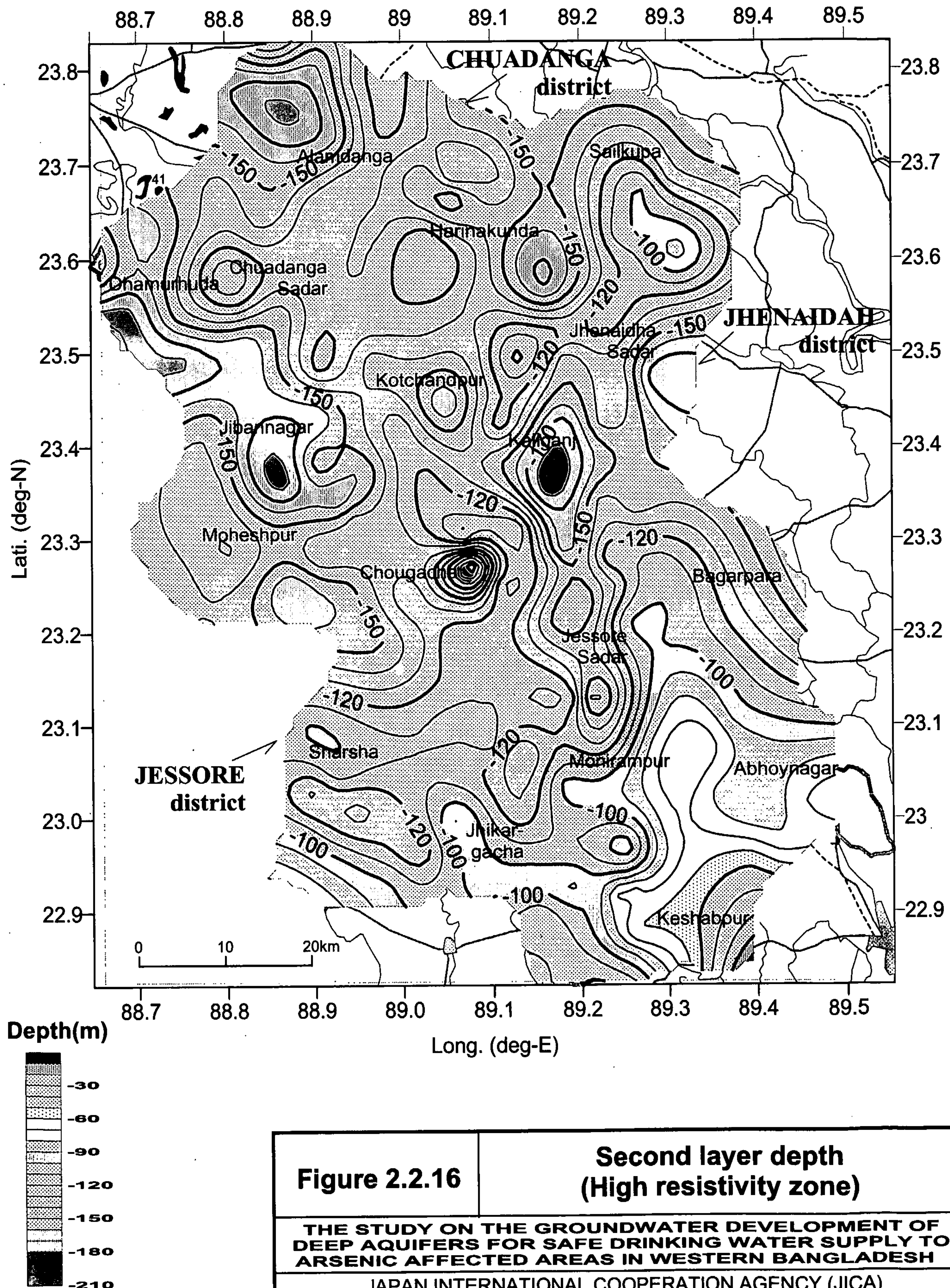


Figure 2.2.16	**Second layer depth (High resistivity zone)**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CHAPTER 3

DETAIL INFORMATION OF ARSENIC TESTING LABORATORY

Supporting Report 1

CHAPTER 3 DETAIL INFORMATION OF ARSENIC TESTING LABORATORY

3.1 Objective of the laboratory

In order to provide accurate data on the arsenic content in a sample, atomic absorption spectrometer was installed in laboratory established within study area. The technical specification of this equipment is determined considering technical aspects such as detection limit, sample handling capacity as well as after-service availability in Bangladesh. To elaborate on the above, a better detection limit can be provided by attaching a Hydride Vapor Generation (HG) unit prior to AAS injection. Also to increase the capacity for the number of sample analyses per day, a continuous flow-injection type HG unit was selected instead of a batch type system.

3.2 Utility and infrastructure

In order to install a testing laboratory in a rural area such as Jhenaidah, which includes site selection, the following are required.

Site requirement for laboratory installation.

<u>Power requirements</u>

Generally, testing equipment such as AAS requires stabilized voltage and a continual power supply though these are fluctuant in developing countries. Therefore, a stabilizer, uninterruptible power supply (UPS) and power generator are set in this laboratory.

UPS (including stabilizer function)

Power generator

Water supply requirements

Laboratory requires suitable water works, water outlet and return water drain to supply tap water continuously for preparing laboratory water, rinsing glass wares, etc. However, the provision time of tap water is limited at the laboratory site. So a reservoir tank is set to keep the required water.

Sink

Gas requirements

In testing, only Argon, a carrier gas, is set for analysis according to the specifications as follows:

Supply pressure 0.35MP

Purity ≧99.9%

Max. consumption 70ml/min

For safety, the gas cylinder is located and set according to the following conditions:

- Not exposed to heat sources such as direct sunlight, a maffle furnace, or a water distillation device
- Sufficiently ventilated
- Place upright and chained tightly to prevent it from tumbling

Argon gas cylinder

Ventilation system

A ventilation duct with a hood is located above the atomizer of AAS to keep the exhaust duct working during the measurement to remove poisonous arsine gas emitted from the device. The hood, duct, and ventilation fans are all made of metal to prevent them from being softened by heat.

Ventilator

Free from dust

Since AAS is sensitive to dust, the laboratory requires a tiled floor and is always to be cleaned with a vacuum cleaner. Cleaning with a broom is not desirable.

Vacuum cleaner

Light intensity

The luminous intensity of the laboratory is set below 1300Lx (in case of fluorescent lamp) in order to prevent influence by strong light in the laboratory.

Installation of air conditioner

Room temperature and humidity

The ambient temperature range is 10 to 35℃ and the humidity is 45 to 80%. Absorbance varies 0.005abs as the temperature changes 1℃, therefore installation of an air conditioner is necessary.

Safety equipment

Safety equipment such as a safety shower, disposable gloves, goggles, and foot protection are set in laboratory.

Facility design of laboratory

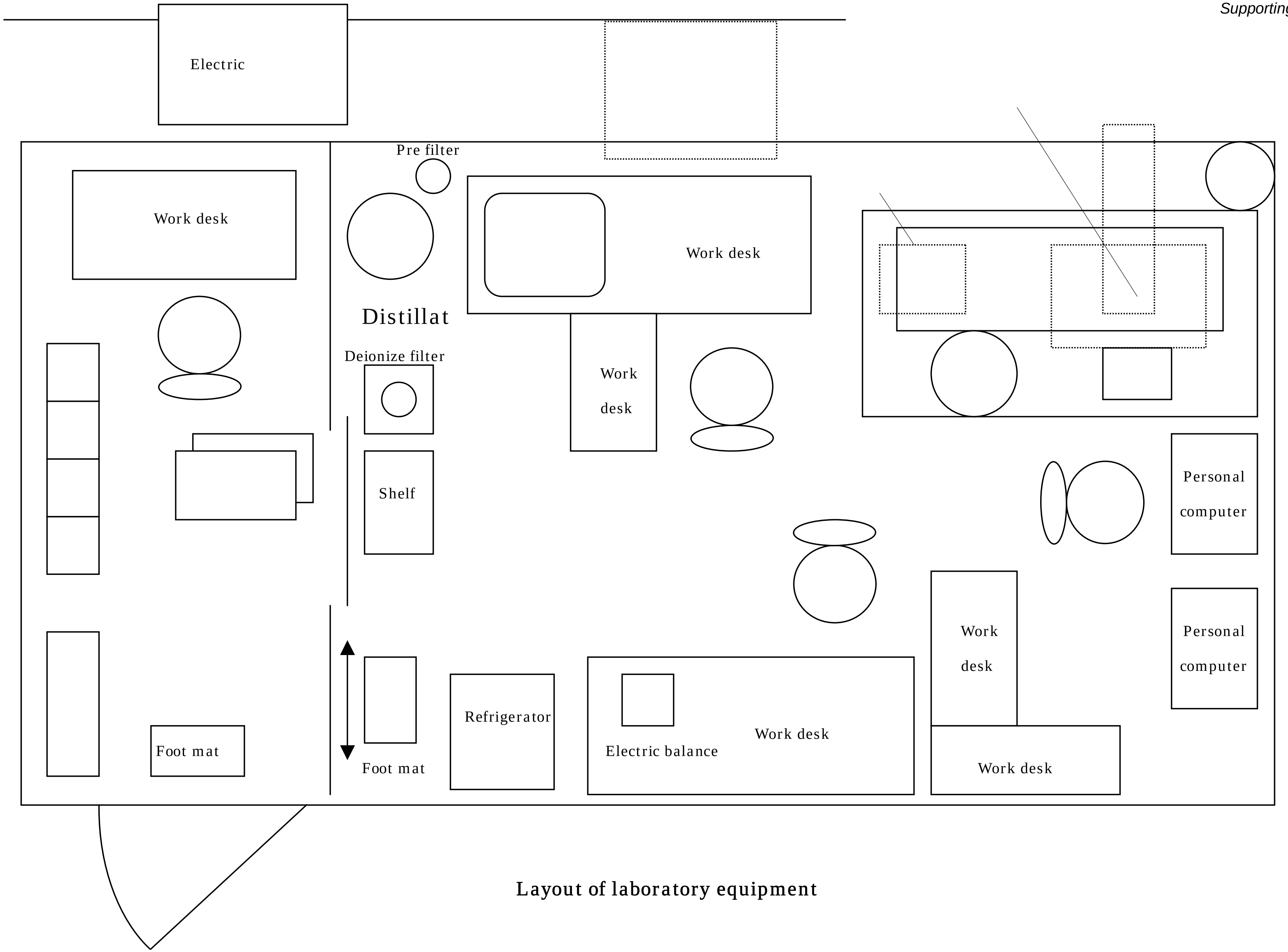
The laboratory facility design for testing arsenic takes workability and safety into consideration. From this view point, the layout should be as shown in the following figure.

Sample store room

In order to safely keep a lot of samples cool and shaded, installation of a sample storeroom is essential and all samples should be arranged in order in this room so that they can be taken out immediately when required.

Samples to be individually numbered

Shelves in the storeroom



Layout of laboratory equipment

3.3 Guideline for quality control of field sampling and testing

In order to avoid problems such as mistakes in sample records, pretreatment, sample mismanagement, and unreliable testing, a guideline was prepared (Annex 2). The guideline is attached for reference and will be revised after discussion and the technical transfer to DPHE, the counterpart of the project.

3.4 Training

Sustaining the installed laboratory is one major task of this project. To do to this, technology transfer and training for the DPHE chemists are essential. A series of technical transfer activities is going on now.

(1) Preliminary training

A preliminary training program for the AAS system was provided in the form of a short training course from August 2 to 3, 2000. Participants from DPHE for the course are as follows.

Mr. Fakhar Uddin	Senior Chemist	DPHE Mymensingh
Mr. Abdus Saltar Miah	Senior Chemist	DPHE Khulna
Mr. Siddique Amin	Senior Chemist	DPHE Rajshahi
Mr. Panna Lal	Senior Chemist	DPHE Comilla
Mr. Anisur Rahman Khan	Junior Chemist	DPHE Mymensingh
Mr. Mohammad Mustaque	Junior Chemsit	DPHE Comilla

Detail of the short course is given below.

2nd August 2000

Time	Topics	Resource	Venue
9:00 am	Reporting		DPHE
9:15 am	Introduction of JICA study	M. Fukuda JICA expert	DPHE
9:30 am	Introduction to Atomic Adsorption Spectroscopy for Arsenic Analysis	T. Higo JICA expert	DPHE
10:45 am	Break		
11:00 am	Introduction to QC in laboratory	M. Fukuda JICA expert	DPHE
12:00 am	Lunch		
2:30 pm	Overview of SHIMSDZU AAS for trace metal analysis	Engr. Nuruzzaman Chief Engineer AQC KC Poddar Application Manager Plasma Plus	Plasma Plus
5:00 pm	Close of day 1		

3rd August 2000

Time	Topics	Resource	Venue
9:00 am	Arsenic Analysis using AAS	KC Poddar Hand on practice	Plasma Plus
10:30 am	Break		
11:45 am	Hand on practice (continue)	KC Poddar	Plasma Plus
12:00 am	Lunch		
1:30 pm	Hand on practice (continue)	KC Poddar	Plasma Plus
3:00 pm	Evaluation	M. Fukuda	Plasma Plus
3:30 pm	Closing		

(2) On the job training

The short training course is considered as an introduction to the subject. Following the course, on the job training at the Khulna laboratory for pre-treatment and at the Jhenaidah JICA Study Team laboratory using the AAS system was conducted. The participants and contents were as follows:

14th February 2000

Participant

Mr. Pawna lal Chowdhury	Senior Chemist	DPHE Khulna
Mr. Sirajurl Haque	Junior Chemist	DPHE Khulna

Date	Topics	Resource	Venue
14th	JICA Study Team Lab opening ceremony	M. Fukuda JICA expert	Jhenaidah JICA Study Team Lab
12th	Guidance for the laboratory	T. Higo JICA expert	Jhenaidah Lab JICA Study Team Lab

21-23 November 2000

Participant

Mr. Abdus Saltar Miah	Senior Chemist	DPHE Khulna
Mr. Sirajurl Haque	Junior Chemist	DPHE Khulna

Date	Topics	Resource	Venue
21st	Guidance for pre-treatment of testing arsenic (digestion)	T. Higo JICA expert	Khulna DPHE Lab
22nd	Demonstration of pre-treatment	T. Higo JICA expert	Khulna Lab DPHE Lab
23rd	Demonstration of pre-treatment (continuation)	T. Higo JICA expert	Khulna DPHE Lab

7th, 12th February 2000

Participant
Mr. Sirajurl Haque Junior Chemist DPHE Khulna

Date	Topics	Resource	Venue
7th	Guidance for AAS system of testing arsenic	T. Higo JICA expert	Jhenaidah JICA Study Team Lab
12th	Arsenic Analysis using AAS "Preparation of standard solution and construction of calibration curve (Hand on practice)	T. Higo JICA expert T. Higo	Jhenaidah Lab JICA Study Team Lab Jhenaidah Lab

3.5 Laboratory Business Plan

In order to run the laboratory after the project finishes and to aim at effective use for arsenic mitigation, a Laboratory Business Plan (Annex 1) was planned in May 2001 and samples from NGOs have been already tested on demand.

Fifty samples have already been collected and tested at the Jhenaidah laboratory. However, 500 Tk/sample, the fixed price of DPHE, seems to be expensive for the villagers. If the price can be decreased, more external samples will be collected from outside and will help the laboratory business.

3.6 Recommendation for sustainable operation

As for technical transfer of arsenic analysis and laboratory management, there are some recommendations.

1. In this laboratory, not only data processing, but also analysis operation of AAS are computerized. Basic computer operation and use of "WizAArd", the operation software of the AAS system, must be learned by all laboratory staff.
2. In addition to 1., the use of database software such as "Excel" will be desirable. It will reduce calculation errors and speed up data processing.
3. In order to keep analysis quality, not only the QC systems for this laboratory, but also some intercomparison test with all DPHE laboratories should be carried out. In this case, this laboratory will be able to manage this system since it has some advantages over the other DPHE laboratory such as the latest production devices of distilled water and so on.

Annex 1

Jhenaidah lab business plan

May 16, 2001

DPHE－JICA Study Team

Introduction

The JICA Study Team first started the survey of groundwater arsenic contamination and its measure in Bangladesh from May, 2000. The JICA Study Team installed the laboratory for arsenic analysis in Jheanaidah in November of the same year, and over 1800 groundwater samples have been analyzed until now. Although the survey activities of the JICA Study Team will continue, in order to transfer this laboratory to DPHE smoothly from now on and to aim at effective use for arsenic mitigation, a business plan for future groundwater arsenic testing at the laboratory has been prepared.

1. Capacity of the Lab

The number of samples in the lab is about 50 samples per day including a certain amount of margin. It follows:

50 sample x 22 day x 12 month =13200 sample / year

If the present organization and condition are maintained, arsenic analysis of at least 10,000 samples per year can be analyzed. On the other hand, DPHE collects external arsenic analysis samples for 500Tk/sample. Therefore, if this lab can collect about 3,000 samples from outside, this lab can recover the cost required for one year of operation as shown in next page.

2. Expenditure Cost Concerning Lab Management

Although the JICA Study Team has outlaid all the costs concerning management of a lab now, after this project ends, the lab should be cared for under the management of DPHE. DPHE needs to be lectured on a budget measure for future lab management. The cost concerning management of this lab is shown in table-1 based on the actual result in 2000 (JICA Study Team's actual expenditure result).

Table-1 Annual cost for running AAS
(In case of measuring 50samples/day) (TK)

Item		unit price	unit	amount/year	cost/year
Electricity					120,000
Reagent	HCl	1,400	L	37	51,100
	KI	7	g	9,600	67,200
	NaOH	15	g	960	14,400
	NaBH4	150	g	1,200	180,000
Others					24,000
Absorption cell		24,600	pcs	12	295,200
Hollow cathode lamp		34,700	pcs	10	347,000
Deuterium lamp		36,000	pcs	5	180,000
Pump tube(for sample)		8,900	packet	5	44,500
Pump tube(for reagent)		8,900	packet	5	44,500
Argon Gas		28,000	cylinder	2	56,000
Filter cartridge for deionization		6,500	pcs	3	19,500
		Total/year(10,000samples)			1,443,400

3. <u>Required man power</u>

The staff required to manage the lab are as follows.

- Senior chemist 1 person
  - General manager of the lab
  - A chemist who has full knowledge not only about arsenic testing but also about general water quality analysis.
  - Someone who has received sufficient operation training of AAS with the JICA Study Team or other training organizations.
  - Part-time job.

- Junior chemist 1 person
  - Manager of the lab
  - A chemist who has full knowledge not only about arsenic testing but also about general water quality analysis.
  - Someone who has received sufficient operation training of AAS with the JICA Study Team or other training organizations.
  - Full-time job.

- Analyst 1 person
  - Assistant to Junior chemist.
  - A chemist with basic knowledge not only about arsenic testing but also a certain amount of general water quality analysis.
  - Someone who has actually experienced arsenic analysis by AAS using an auto-sampler with the JICA Study Team or other analysis organizations.
  - Should not only be sufficiently experienced in analysis but also fieldwork such as sampling.
  - Should be able to arrange analysis results with spreadsheet software, such as Excel.

- Sample collector 1 person
  - Assistant to junior chemist.
  - Someone who has conducted arsenic contaminated groundwater sampling with the JICA Study Team or other analysis organizations etc., should have sufficient fieldwork experience.
  - Should also have experience in lab work, adjustment of a reagent, etc.; should be a man with sufficient experience in auxiliary work.

- Security guard 1 person
- Messenger

4. <u>Training and a lab taking over schedule</u>

Training in this lab started from December of last year, and the chemist of Khulna is expected to further the plan based on the previous training as follows from now on.

✓ 1st phase (May to June, 2001)

-OJT by JICA Study Team-

Technical instruction of lab analysis and sampling by the JICA Study Team is being done. DPHE chemist masters the method of arsenic analysis using AAS through on the job training. DPHE chemists shall participate in the OJT about 2 days a week continuously. Assistants are provided from the JICA Study Team.

✓ 2nd phase (July to August, 2001)

-DPHE and JICA Study Team in cooperation-

In this stage, not only lab analysis and sampling but technology transfers other than analysis, such as data arrangement, sample management, etc., are performed. Moreover, an external sample acceptance organization is prepared. DPHE chemists shall work in the lab about 4 days in a week continuously. Assistants are provided from the JICA Study Team.

✓ 3rd phase (October to December, 2001)

-Launching lab work by DPHE-

DPHE performs lab analysis and a sampling. Although the JICA Study Team performs technical instruction if needed, the management of business is transferred to DPHE. In this stage, technology is transferred about lab management enterprises at large, such as the start of external sample acceptance, and preparing a training program for other DPHE chemists. DPHE appoints DPHE chemists to this lab as a full-time job. Assistants are also provided by DPHE.

5. <u>Time schedule</u>

Time	DPHE	JICA Study Team
1st phase (May to June, 2001)	• **Send DPHE chemist as a trainee about 2 days in a week** • **Start budget measure for lab** • **Start man power planning (stuff up assistants, arrange chemist)**	• Run OJT for AAS etc. • Provide lab assistants
2nd phase (July to August, 2001)	• **Send DPHE chemist as a co-worker about 4 days in a week** • Start planning for external sample acceptance organization	• Run OJT for other than analysis • Provide lab assistants
3rd phase (October to December, 2001)	• **Arrange DPHE chemist as a full-time lab manager.** • Start lab management by DPHE • Start an external sample acceptance • Prepare training program to other DPHE chemist • **Provide lab assistants**	• Support lab management for DPHE

Bold letters show Chief Engineer's matter

6. Recommendation

✓ **Man power**

While the lab work requires staff with special knowledge, availability of such staff with experience of the AAS installed in this lab is very limited in Bangladesh. In such a situation, it is considered to be most suitable for DPHE to re-employ two assistants of the lab currently hired by the JICA Study Team.

✓ **Budget measure**

In order to manage the lab fully operational, a large budget is required. However, if the contract unit price of an external acceptance for 3000 samples is set for example, at 500TK / sample, all costs required for this lab will be covered. Moreover, in order to operate this lab in a good state, it is desirable to analyze a fixed quantity of the sample regularly.

✓ **The management income and outgo in the 2001 fiscal year**

Since this fiscal year, the lab is still under the care of the JICA Study Team, it is expected that a certain amount of consumables for analysis, such as existing reagents, will remains (Table-2) although arsenic analysis is continuously performed. These items will help to launch this lab management enterprise by DPHE to some extent.

Table-2 Stock of consumables for AAS

(as of May, 2001)

Item		present amount
Reagent	HCl	75 L
	KI	1960 g
	NaOH	600 g
	NaBH4	380 g
Absorption cell		4 pcs
Hollow cathode lamp		0 pcs
Pump tube(for sample)		3 packet
Pump tube(for reagent)		3 packet

Annex 2

JICA Study Team Arsenic testing laboratory

Guideline for quality control of field sampling and laboratory testing

Documented February 2001

JICA Study Team

Introduction

This guideline is for field sampling and laboratory operation to get reliable data.

This guideline consists of summaries of testing, standard operation procedures (SOP), quality control (QC) systems, and records.

QC programs include QC samples such as field blank, duplicate sample, spike sample, calibration, as well as the procedure for determination of quantification limits. QC is essential for laboratory operation.

Summaries of testing include associated documents such as testing method, procedures for handling and receiving samples, major equipment, and maintenances of equipments, waste treatment and disposal management, organizing laboratory for safety.

SOP describe the analytical methods to be used the laboratory.

Records include logbooks for testing, including preparation and analysis of each sample serial No., associated standards and QC samples, date of preparation and analysis, analyst, volumes of used, remarks.

1. Summaries of testing

In this laboratory, the testing method of arsenic concentration is based on the Japanese Industrial Standard: “Methods for the examination of water for industrial use (JIS-K-0101)” and American Water Works Association: “Standard method for the examination of water and waste water, 20th edition”.

In this laboratory, the arsenic concentration in groundwater is measured as total arsenic, the concentration of arsenic tested on unfiltered samples, by atomic absorption photometry.

Digestion pre-treatment

Some pond water samples are also tested to determined arsenic. In this case digestion pretreatment is essential to reduce interference by organic matter

Apparatus

- Hot plate
- Conical beakers, 300ml

- Watch glasses
- Volumetric flasks, 25ml

Chemicals

- Nitric acid, conc.
- Sulfuric acid, conc.

Procedure

Transfer 25ml of sample to a conical beaker. Add 2ml of conc HNO3 and a few boiling chips. Boil slowly on hot plate and evaporate to 10ml. Add 2ml of conc HNO3 again and 5ml of H2SO4. Evaporate on a hot plate until dense white fumes of SO3 just appear. If solution doesn't clear, add 2ml of HNO3 and repeat evaporation to fumes of SO3. Heat to remove all HNO3 before continuing treatment. Cool and wash down beaker walls with a little laboratory water and then filter if necessary. Transfer filtrate to a 25ml of volumetric flask with rinsing water to the volumetric flask. Cool and dilute to mark, and mix thoroughly (see SOP).

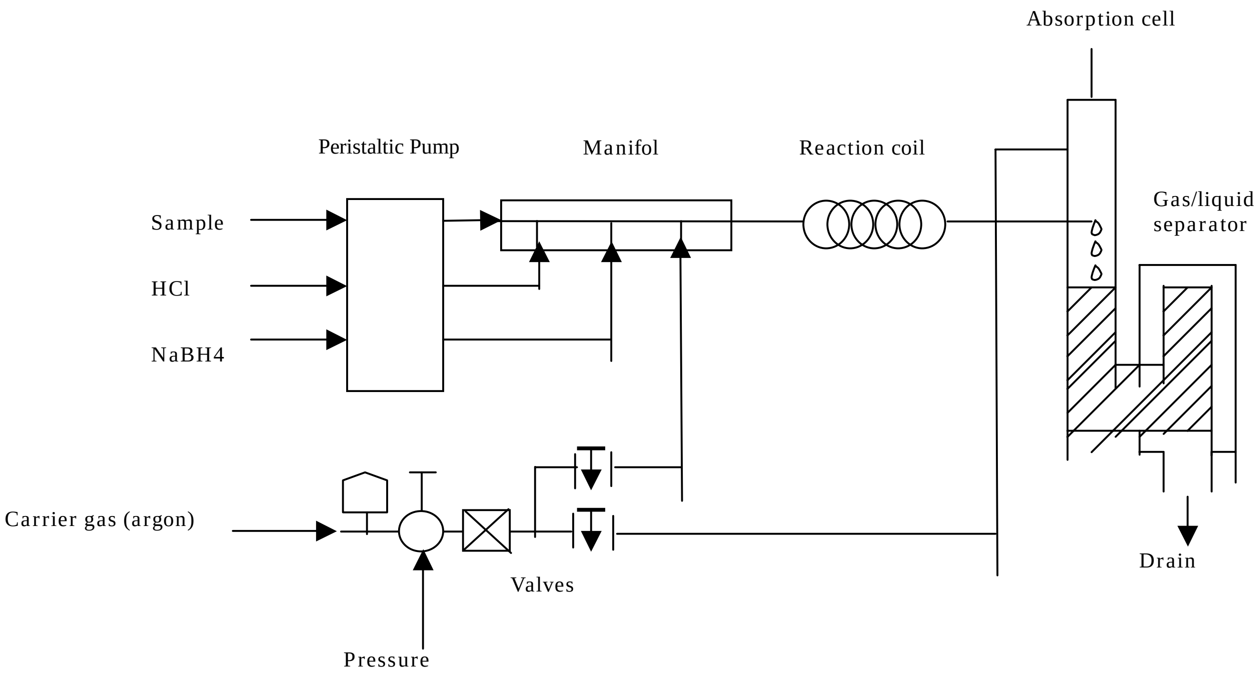
Atomic absorption spectrometry

In order to provide accurate data on the arsenic content in the sample, the atomic absorption spectrometer is installed in laboratory to be established within study area. Technical specification of this equipment is determined considering technical aspects such as detection limit, sample handling capacity as well as after-service availability in Bangladesh. To elaborate the above, a better detection limit can be provided by attaching a Hydride Vapor Generation (HG) unit prior to AAS injection. Also to increase the capacity for the number of sample analyses per day, a continuous flow-injection type HG unit was selected instead of a batch type system.

Principle

This equipment is applicable to the determination of arsenic through conversion to its hydrides by sodium borohydride and aspiration into an atomic absorption atomizer.

As(III) is instantaneously converted by a sodium borohydride reagent in an acid solution to its volatile hydrides. The hydrides are purged continuously by argon into an atomizer of an atomic absorption spectrometer and converted to gas-phase atoms. The sodium borohydride reducing agent by rapid generation of the hydrides in a reaction coil, minimizes dilution of the hydrides by the carrier gas and provides rapid, sensitive determinations of arsenic.



Flow diagram of continuous hydride generation system

At room temperature and solution pH values of 1 or less, the As(V) state of arsenic is reduced relatively slowly by sodium borohydride to As(III), which is then instantaneously converted to arsine, The arsine atomic absorption peaks commonly are decreased by one fourth to one third for As(v) when compared to As(III). Determination of total arsenic requires that all inorganic arsenic compounds be in the As(III) state. Therefore, it is necessary to reduce the sample previously to As(III).

Apparatus

- Atomic absorption spectrometer
- Hydride vapor generation unit
- Muffle heater.
- Absorption cell of cylindrical quartz cell

Reagent

Hydrochloric acid, HCl(1+1)

Sodium borohydride reagent: Dissolve 2.5gr sodium hydroxide and 2.0gr sodium borohydride in laboratory water in this order and add water to 500ml.

20% W/V potassium iodide solution

Commercial standard solution of arsenic (1000ppm As)

Intermediate arsenic solution (100ppb As): Dilute 1ml of commercial standard solution to 100ml with laboratory water

Standard arsenic solution: Dilute 1, 2, 5ml of intermediate solution to 100ml with laboratory water.

Certified reference material (CRM)TMDA-53.2: produced from the National Water Research Institute,

Procedure

(a) Samples are required to be inorganic. Organic samples such as pond water are to be digested as mentioned above.

(b) To get an As(III) sample, add 1ml of 20%W/V potassium iodide solution and 1ml of hydrochloric acid to 10ml of the standard solution or the sample solution , and leave it for about 15min. at room temperature(see SOP).

(c) Load reagents, set the aspiration rate of sample and reagents, then run the hydride vapor generation unit for at least 15 min before instrument calibration.

(d) Start-up atomic absorption spectrometer

(e) Set the samples, blanks, CRM and standard solution to auto sampler unit

(f) Start-up personal computer for measuring operation and data processing

Calculation

In this AAS system, construction of a calibration curve by plotting peak areas of standards versus concentration of standards, measuring peak areas of samples and reading concentrations from curve are computerized. Therefore, reported concentrations can be read directly after standard calibration and actual concentrations are calculated by diluted factors.

Where:

Arsenic mg/L = reported concentration × dilution factor

Major equipment

In this laboratory, major equipment of AAS system consist of

1. Optical bench
2. MS-Windows based PC hardware and software
3. RS-232C cable
4. Installation kit
5. Hollow Cathode lamps for Arsenic
6. HVG-1 Hydride Vapor Generator
7. SARF-16C Atomic Muffle Electric Cell Heater
8. ASC-6100 Auto Sampler with Table Assembly

Including necessary spare parts and accessories and the specification is as follows:

Technical specification of SHIMADZU AA-6800G, HVG-1 system

Spectrophotometer	Measurement wavelength	193.7 nm
	Slit width	1.0 nm
Lamp	Lamp mode	BGC-D2
Data processing	Software environment in laboratory	Windows98
	Concentration conversion mode	Calibration curve
	Loading parameter	Template function
	Result	Print out or file export of summary report
Power requirement		AC100V (transformer is necessary)
	Ambient temperature range	10-35℃
	Ambient humidity range	45-80%
Continuous hydride generator	Measurement mode	Continuous hydride generation method
	Reducing reagent	Sodium borohydride
	Sample aspiration	6ml/min
	Reagent aspiration	1ml/min
	Atomizer	Thermoelectric heated absorption cell
	Carrier gas	Argon gas, supply pressure o.32Pa, consumption 70ml/min.

Procedures for handling and receiving samples

These procedures are based on American Water Works Association: “Standard method for the examination of water and waste water, 20th edition”

1.Sample container and field treatment

The type of sample container used is important when sampling and testing a very low analyte level. In this testing, the sample containers are made of polyethylene with a polyethylene cap. Use only containers that have been acid rinsed. Samples are acidifyed immediately after sampling by concentrated hydrochloric acid (HCl) to pH <2. Commercially available high-purity HCl (As ≦ %) in Bangladesh is used for acidify.

After acidify, samples are stored in a cool-shady place. Laboratory water is used not only in laboratory but also on sampling site for rinsing sampling equipment.

2.Field survey sheet and sample record format

All information of field survey is recorded in the field survey sheets such as location of sampling point, name and address of field and collector's name. Sample code, sampling procedure, collector's name, sample shipper's name, receive and identifier's name, date of all procedures mentioned above are all recorded in the sample record format. All sheets and formats are kept in a safe place.(see attached sheet)

3.Sample delivery to the laboratory

Samples to the laboratory are delivered as soon as possible. The field sampler completes the field work including sampling and notes required information in the field survey sheet and sample record format. Laboratory personnel notes required information in the sample record format when the samples are delivered to the laboratory (see attached format).

4.Receipt and logging of sample

In the laboratory, the laboratory personnel check the condition, label information, and seal of the samples before the samples are accepted. After acceptance, the laboratory personnel assigns a serial No., logs the samples in the computerized laboratory information system, and stores the samples in the sample store room until they are tested .

5.Assignment of samples for analysis

The analyst assigns the samples for analysis. Once the samples are put in the laboratory, the analyst is responsible for their care until they are returned to the storeroom.

6.Disposal of samples

Samples are held for the period of this project or until the data is reviewed and accepted. The disposal is done in accordance with the Bangladesh approved method.

Maintenances of equipments

1.Lamp history

The lifetime of the hollow cathode lamp and deuterium lamp is essential for measuring arsenic.

Check the lifetime of them frequently. This AAS system can count used time of these lamp automatically by selecting this menu from the personal computer connected to AAS.

2.Pump tube replacement

As the pump tube is aged, the aspiration rate declines slowly with time. Therefore, the aspiration rate is monitored by using a measuring cylinder once two weeks, and when the rate drops to about 80% of the initial level, replace the tube with new one.

3.Absorption cell maintenance

The contamination of the absorption cell, made of transparent quartz glass is unavoidable even when it is cleaned every day. If contaminated heavily, the surface of the absorption cell may be activated to reduce the sensitivity. Soak the cell in about 25% acid solution for 1 night and rinse with distilled water thoroughly at least once two weeks.

4.Gas/liquid separator maintenance

As in case of the absorption cell, heavy contamination may result in reduced sensitivity and elevated noises. Soak the cell in about 25% acid solution for 1 night and rinse with distilled water thoroughly at least once two weeks.

Waist treatment and disposal management

Treatment is essential to reduce toxicity of hazardous waste of laboratory. Even on a small scale, treatment is required. Regulation in Bangladesh must be observed severely. In this laboratory, mainly wastewater is required for treatment.

1.Chemical treatment

Drain water from AAS is acidic by hydrochloric acid. Therefore, in this laboratory, neutralization of it using chemicals such as calcium hydroxide is regulated.

2.Ultimate disposal

After wastewater treatment, only nonhazardous drain water can be discharged as wastewater.

2. Standard operating procedures

Standard operating procedures (SOP) describe the analytical methods to be used the laboratory operation. SOP includes as follows:(see attached references)

- Title of test method
- Date of documentation
- Details on the actual test procedure
- Sample preparation procedure
- Calculations
- Trouble shooting

3. Records

Sample code and labels

Sample codes are set to prevent sample misidentification and include following information: sample type, place of sampling, timing of sampling. Sample codes are labeled on the each sample containers.

Sample record format and Log book

In this testing, trace ability is essential for sample identify from collection to data reporting. Sample record format includes the ability to trace possession and handling of the sample from the date of collection through testing. This process is required to demonstrate sample control when the data are used for other purposes and also is useful for routine control of samples. A sample is considered to be under a person's custody or secured in sample storeroom restricted to authorized personnel.

Data confirmation

Sometimes simple mistake such as miscalculation has occurred since a large number of samples are measured in analyses. In order to prevent this, data confirmation sheet is installed (see attached sheet). Laboratory staff except the analyst of the measuring must check the sheet to confirm the result and sign it.

4. Quality control

Chemicals

All chemicals should be reasonable quality but some are critical in particular because AAS has very high sensitivity. In case of using low-quality chemicals, it will result in unacceptable testing data. In general, imported ones such as Wako, Kantou kagaku, Merck, Aldrich are to be used.

1.Hydro chloric acid

It is very critical. HCl is used for acidify of samples and for the testing arsenic by Atomic

Absorption Spectrophotometer (AAS). It is always running in the flow tube and easy to generate contaminated arsenic. So maximum contains of arsenic is below 0.000001% for testing by AAS.

2.Potassium Iodide

Potassium iodide is used for pre-reduction of samples, standards, CRM and blank as a pre-treatment of testing arsenic. It is used relatively high, so that laboratory grade is essential. For preservation, it is kept in refrigerator.

3.Sodium Borohydride

Sodium borohydride is used for reduction of samples, standards, CRM and blank as a reduction reagent of testing arsenic. Its sensitivity is directly affected, so that laboratory grade is required. For preservation, it is kept in refrigerator.

Reagent

1.Laboratory water

Laboratory water is water with no detective concentration of arsenic to be analyzed by the analytical method. To prepare high quality laboratory water is one of the most important factors of analysis. Laboratory water is used for dilution of reagents, samples, and blank analysis. The quality of Laboratory water is related directly to the analysis result. Therefore, the laboratory water used our laboratory is produced by three steps procedures as, pre-filtration, distillation, deionization and the water quality is set very high-class level ($EC \leq 0.1mS/m$).

2.Laboratory blank

Laboratory blank consists of laboratory water and all reagents (HCl and $NaBH_4$) that normally are in contact with samples during the analytical procedure. The laboratory blank is used to calculate the actual concentration of arsenic contained samples. Therefore, one laboratory blank is tested with 20% basis of samples and if the concentration of it is higher than Quantitation limit, take collective action.

QC program

QC program consists of following parameters and is essential factor for generating good data.

1.Calibration

Perform initial calibration with a minimum of three concentrations of standards, and choose a highest concentration at the upper end of the calibration range. Be sure that the calibration range covers the analytical concentration values. In this testing arsenic by AAS, the calibration curve includes some nonlinear portion of curve so that linear curve range is very narrow.

The minimum correlation of coefficient for the calibration curve must be specified. In this testing, a minimum value for the correlation of coefficient is set 0.995. Compare each calibration point to the curve and if any point is not within this criteria, identify the unsuitable sources and correct before sample testing.

Calibration verification is also necessary, but initial and suitable interval confirmation is enough because calibration curve has not change so significantly. Therefore, a verification of calibration by analyzing a standard at a concentration near the midpoint of the calibration range is set, and in this testing, Certified Reference Material (CRM) is used for this verification. In this testing, the calibration verification is set by % recovery ($75\% \leqq R \leqq 125\%$). If %recovery is out of control, identify the unsuitable sources and correct before sample testing.

Where:

$$\% \text{Recovery} = \frac{\text{found value}}{\text{true value}} \times 100\%$$

Calibration curve, itself, is not change so significantly, but sensitivity has changed continuously, so the sensitivity correction of calibration curve is essential for testing sample. In this method, reslope is set every 10samples by using the standard of highest concentration of calibration curve.

2.Duplicate samples

Duplicates are the two samples taken at the same time from one location. In this testing, the maximum range is set within 20% of relative standard deviation (%RSD).

Where:

$$\%\mathrm{RSD} = \frac{\mathrm{s}}{\overline{\mathrm{x}}} \times 100\%$$

$$\mathrm{S} = \sqrt{\sum_{i=1}^{n} \frac{(x_i - \overline{x})2}{(n-1)}}$$

n = total number of values,

3.Spike samples

Spike samples are used to evaluate measurement recovery in a sample matrix , As a minimum , one spike sample are set in one testing day. Spike samples are prepared from the known sample and the standard solution that used for making calibration curve. Prepare different concentrations of spike samples against one known sample, plot these concentration on the graph, draw fitting linier line to y-axis, then read y-intercept of this fitting line and evaluate the results obtained from these one set of spike samples. The standard of result for spike test is set 75%≦the original concentration of the sample≦125% in this laboratory.

4.Quantitation limit

Quantitation limit (QL) is one of the boundary values that can be quantified and all quantitative measurement result must lie within this interval. Especially, minimum quantitation limit is significant because different laboratories will produce different minimum quantitation limit even though using the same analytical procedures. instruments, and sample matrices.

QL is set tentatively by Measuring laboratory blanks at least 20 times.

Where:

$$QL = 10s + \overline{x}$$

s = standard deviation of laboratory blanks

$$s = \sqrt{\sum_{i=1}^{n} \frac{(x_i - \overline{x})2}{(n-1)}}$$

$\overline{x}$ = average of laboratory blanks

When tentative QL is set, measure the tentative QL concentration of laboratory standard at least 20 times. Compute %RSD and QL is finalized if the %RSD is within 10%. By this calculation, the minimum QL is set 0.0005mg/l As in this laboratory and the maximum QL is set 0.005mg/l that is the highest standard point of the calibration curve.

Result of tentative minimum QL (by Measuring laboratory blanks)

No.	As mg/l	No.	As mg/l
1	0.0000548	13	0.0000576
2	0.0000772	14	0.0000636
3	0.0000722	15	0.0000796
4	0.0000847	16	0.0000736
5	0.0000647	17	0.0000357
6	0.0000922	18	0.0000357
7	0.0000124	19	0.0000716
8	0.0000224	20	0.0000716
9	0.0000377	21	0.0000457
10	0.0000218	22	0.0000537
11	0.0000537	23	0.0000676
12	0.0000616	24	0.0000636

Where:
$\overline{x}$ = 0.000057292
s = 0.00020847

Tentative QL is
0.00020847×10+0.000057292
=0.000265762<**0.0005mg/l**

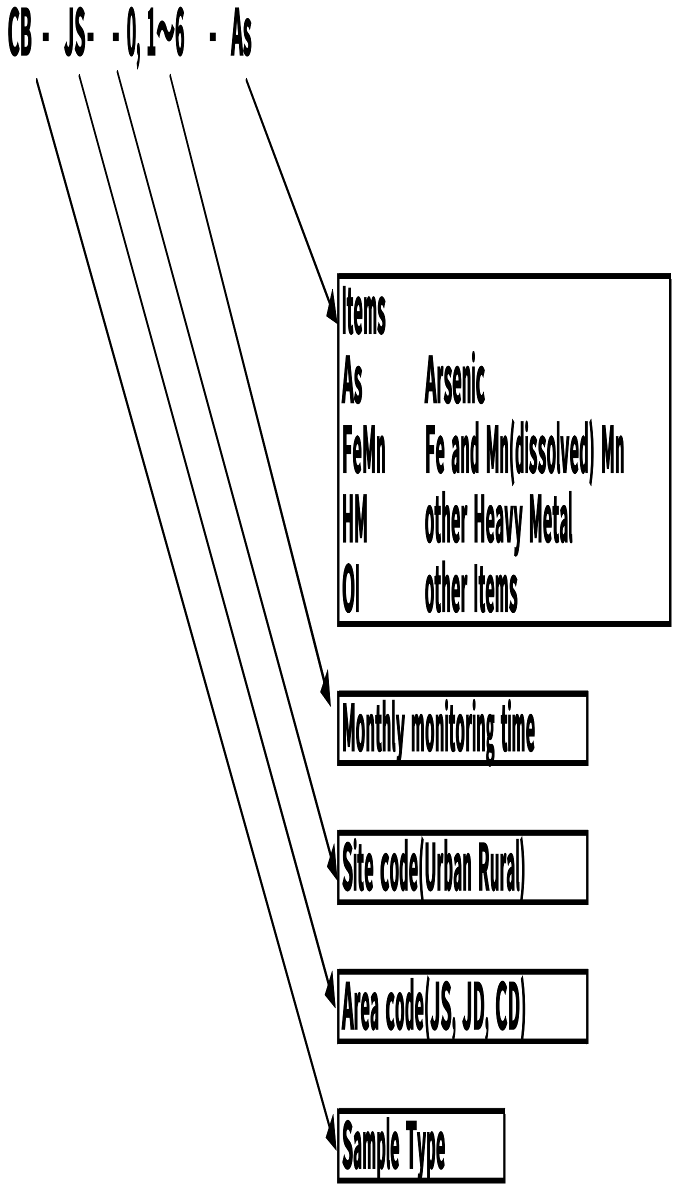
Result of minimum QL (by Measuring 0.0005mg/l of laboratory standard)

No.	As mg/l	No.	As mg/l
1	0.0007173	11	0.0005795
2	0.0007303	12	0.0006194
3	0.0005817	13	0.0006394
4	0.0006617	14	0.0006794
5	0.0005862	15	0.0006305
6	0.0007288	16	0.0007154
7	0.0006216	17	0.0005544
8	0.0005945	18	0.0005686
9	0.0006016	19	0.0005565
10	0.0005442	20	0.0006193

Where:
%RSD=9.6945<10%

Therefore, minimum QL is set
0.0005mg/l

Core Boring


CB - JS- - 0, 1~6 - As
Items
As Arsenic
FeMn Fe and Mn(dissolved) Mn
HM other Heavy Metal
OI other Items
Monthly monitoring time
Site code(Urban Rural)
Area code(JS, JD, CD)
Sample Type

JICA Arsenic project

Sample recording format between field and laboratory

		Arsenic (total)			Arsenic (dissolved)			Fe and Mn (dissolved)			Heavy Metals			Other Items	
	Sample Code	Bottle cleaned	Sample	Acidify by HCl	Bottle clenaed	Sample	Filter and HCl	Bottle clenaed	Sample	Filter and HNO3	Bottel Clenaed	Sample	Acidify by HNO3	Bottle clenaed	Sample
1		〇			〇			〇			〇			〇	
2		〇			〇			〇			〇			〇	
3		〇			〇			〇			〇			〇	
4		〇			〇			〇			〇			〇	
5		〇			〇			〇			〇			〇	
6		〇			〇			〇			〇			〇	
7		〇			〇			〇			〇			〇	
8		〇			〇			〇			〇			〇	
9		〇			〇			〇			〇			〇	
10		〇			〇			〇			〇			〇	
11		〇			〇			〇			〇			〇	
12		〇			〇			〇			〇			〇	
13		〇			〇			〇			〇			〇	
14		〇			〇			〇			〇			〇	
15		〇			〇			〇			〇			〇	
16		〇			〇			〇			〇			〇	
17		〇			〇			〇			〇			〇	
18		〇			〇			〇			〇			〇	
		〇			〇			〇			〇			〇	
29		〇			〇			〇			〇			〇	
30		〇			〇			〇			〇			〇	

Field to JICA study office

Sample packed by ______________________

date ______________

Sample shipped by ______________________

Sample received and confimed by ______________________

JICA study office to laboratory (except for Aresenic)

Sample shipped by ______________________

date ______________

Sample received and confimed by ______________________

Data confirmation sheet

Title
Date 03-Feb-01
Summary

Sample	Report Conc.	As:HVG	dillution	Actual Conc(ppb)	Actual Conc(mg/l)
CRM	3.7218		10	37.218	0.037218
sample001	0.205			0	0
sample002	1.7745		10	17.745	0.017745
sample003	1.2606		100	126.06	0.12606
sample004	0.5502		10	5.502	0.005502
sample005	6.6473		10	66.473	0.066473
sample006	2.0092		100	200.92	0.20092
sample007	4.1984		10	41.984	0.041984
sample008	4.3314		10	43.314	0.043314
sample009	0.4479			0	0
sample010	1.2932		100	129.32	0.12932
sample011	*****			#VALUE!	#VALUE!
sample012	0.937		1.25	1.17125	0.00117125
sample013	4.2665		10	42.665	0.042665
sample014	*****		10	#VALUE!	#VALUE!
sample015	0.5782		2.5	1.4455	0.0014455
sample016	0.1448			0	0
sample017	1.9659		100	196.59	0.19659
sample018	2.079		100	207.9	0.2079
sample019	0.8595		100	85.95	0.08595
sample020	0.2697			0	0
sample021	4.0559		100	405.59	0.40559
sample022	1.7197		100	171.97	0.17197
sample023	2.1325		100	213.25	0.21325
sample024	1.1144		100	111.44	0.11144
sample025	1.3611		100	136.11	0.13611
sample026	0.7532		100	75.32	0.07532
sample027			100	0	0
sample028			100	0	0
sample029	0.1502		1.25	0.18775	0.00018775
sample030	0.1414		1.25	0.17675	0.00017675
sample031	5.0451			0	0
sample032	1.8207		20	36.414	0.036414
sample033	3.1358		10	31.358	0.031358
sample034	3.9094		100	390.94	0.39094
sample035	2.6942		100	269.42	0.26942
sample036	3.7923		20	75.846	0.075846
sample037	3.8524		20	77.048	0.077048
sample038	1.9516		20	39.032	0.039032
sample039	0.3794			0	0
sample040	0.4209			0	0
sample041	1.1817		1.25	1.477125	0.00147713
sample042	2.0278		50	101.39	0.10139
sample043	2.2322		20	44.644	0.044644
				0	0
				0	0
				0	0
				0	0
				0	0
				0	0
				0	0
				0	0
				0	0
				0	0

Sample No. and Dillution are confirmed by ________________

SOP for starting AAS (Usual operation)

SOP written by ______________

Dated ______________

1. Open argon gas cylinder

2. Switch on UPS, AAS main device, hydride vapor generator, atomic muffle, personal computer.

3. Open "WizAArd", software for operation of AAS, on the computer, then "WizAArd Selection window" will be opened. Click "cancel".

4. Fluorinated rubber tube (black rubber tube connected between absorption cell & the gas/liquid separator) must be disconnected from the gas/liquid separator since absorption cell will move for setting up the position automatically.

5. Open "instrument parameter" menu, then click. Connect & wait for few minuets in order to conform the connection between computer and AAS device. When the connection complete, click "OK".

6. Open the file "Standard Operation for 60 samples", already arranged file for operation, MRT table for As analysis will be opened.

7. Open "Edit Parameters" and turn on hollow cathod lamp on it. After that do "Line Search"

8. Connect fluorinated rubber tube to gas outlet of Manifold to the gas/liquid separator

9. Start arsenic analysis and observe if it is working well.

SOP Digestion pre-treatment for As measuring

SOP written by ______________

Dated ______________

300ml conical beaker

← 25ml of sample by 25ml volumetric pipette

← 2ml of Conc. HNO3 by 2-10ml variable digital pipette

△ Heat by hot plate until solution becomes about 10 ml

← 2ml of Conc. HNO3 by 2-10ml variable digital pipette
If necessary, repeat for 2-3 times

← 5ml of H2SO4 (1+1) by 2-10ml variable digital pipette

← Be sure generation of white fume by H2SO4

Filter if necessary

← Fill up pure water to mark with rinsing filter paper

↓

25ml volumetric flask

↓

To pre-reduction

SOP pre-reduction for As

SOP written by ______________

Dated ______________

20ml test tube

1ml* of sample by 1ml fixed pipette

1ml of Conc. HCl by 1ml fixed pipette

1ml of 20w/v% KI by 1ml fixed pipette

Dilute to 10ml by 2-10ml variable digital pipette

Mixing by glass bar

R.T. in 15min.

AAS measuring

＊ ・・・Depends on the As concentration

SOP Shut down process of AAS

SOP written by ______________

Dated ______________

1. When analysis has been completed, save analysis data file on computer. Open “Instrument” menu and “disconnect” on WizAArd to disconnect between computer and AAS. About 20 seconds will be taken to finish it.

2. Turn off computer

3. Before switch off HVG, 3 aspiration tubes (two for reagents and one for sample) must be rinsed thoroughly by distilled water at least 10 minuets. Remove the 3 tubes from water and push “Flush” to keep dry in the tubes.

4. Power off HVG.

5. Power off Muffle Heater

6. Finally turn off AAS and ASC

7. Power off UPS

8. Close argon gas cylinder

SOP plan for starting AAS (in case of changing condition)

SOP written by

Dated ____________

Setting

1: Power on UPS. Then turn on the table tap that is connected with a transformer and computers.

2: When UPS is running exactly, put on computer power.

3: Open the valve of argon gas cylinder and get its pressure with 0.32MPa.

4: Set up 3 delivery tubes* and 2 chemical reagents, that are 5M HCl and $NaBH_4$. Next get tubes tensioned with being revolved around a rotor in HGV. Then turn on HVG. If it does not work, give more pressure by adjusting an argon gas regulator or an adjuster screws suitably, not so tightly, behind a rotor.

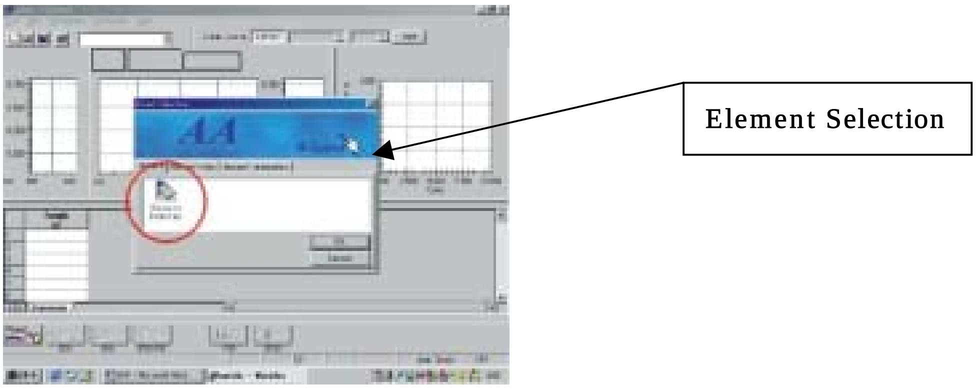
* Yellow marked tube is for $NaBH_4$. Blue marked tube is for HCl. No marked tube is for sample.

5: Fill up the rinse bottle with distilled-deionized water and place it under the arm of ASC. Then turn on ASC.

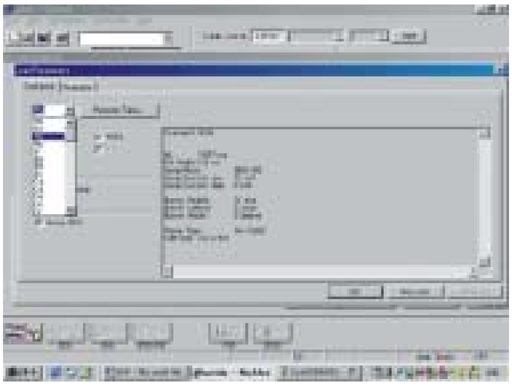
6: At this moment AAS itself can be turned on. After 3 minutes warming run, AAS will give beep sound. This proves that AAS is ready to go.

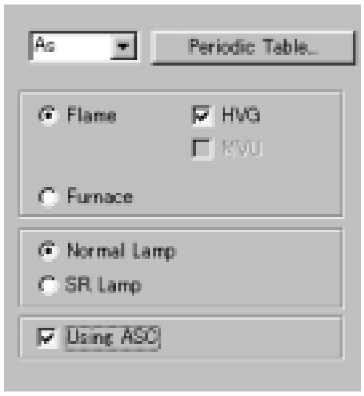
Parameters

7: Click “WizAArd” then you can see the window shown below. And click “element selection”, that is circled in red.

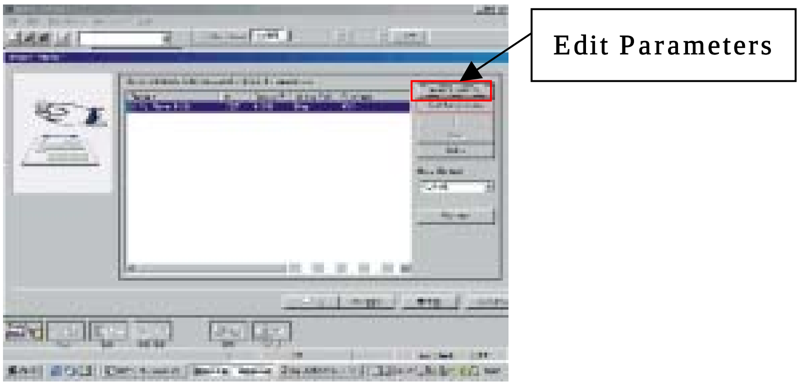


8: Select a target element and give checks in “flame” and “Using ASC”. Then choose “OK”.

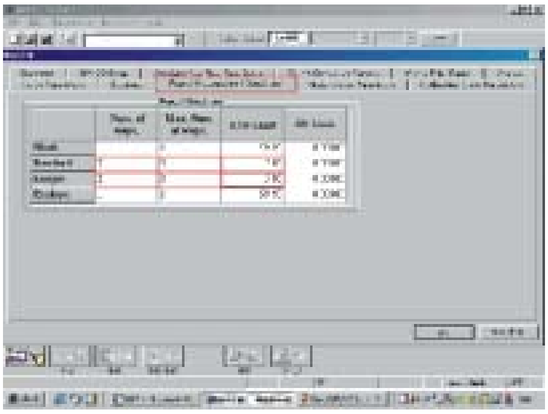



As
Periodic Table...
Flame
HVG
Furnace
Normal Lamp
SR Lamp
Using ASC

9: Go to “Edit parameters”.



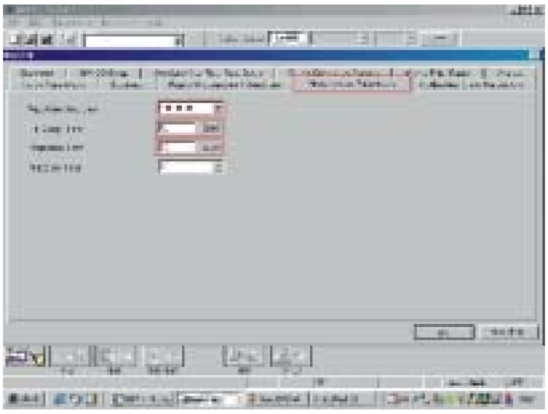
10: Open the window of “Repeat Measurement Conditions” and change some conditions shown in the table below.

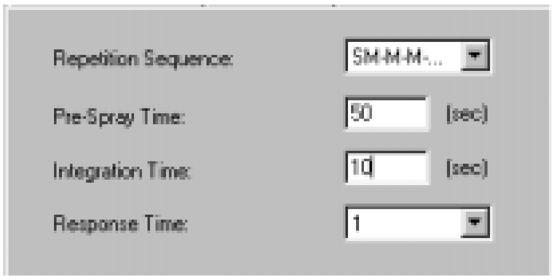


Repeat Conditions

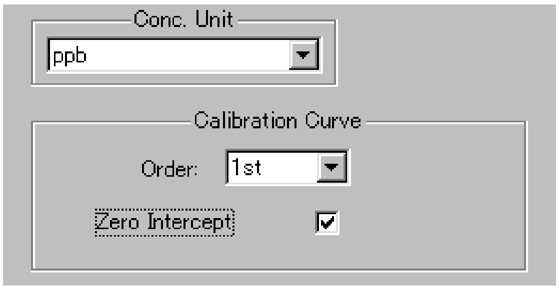
	Num. of Reps.	Max. Num. of Reps.	RSD Limit	SD Limit
Blank	1	1	99.90	0.00000
Standard	2	3	5.00	0.00000
Sample	2	3	5.00	0.00000
Reslope	1	1	99.90	0.00000

11: Open the window of “Measurement parameters” and change parameters shown blow.

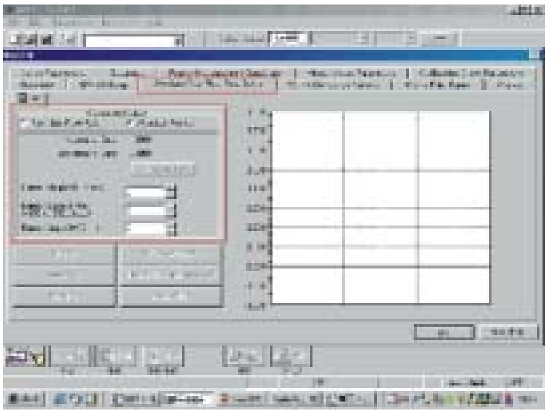


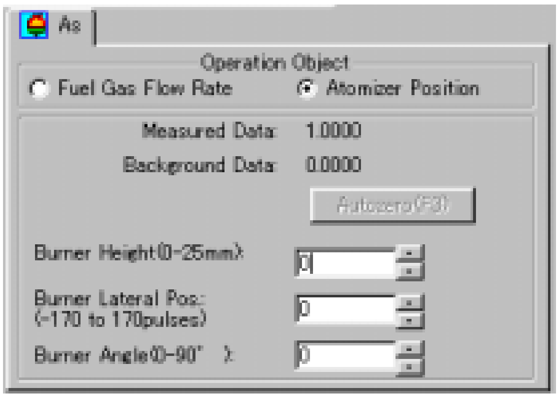

Repetition Sequence:
SM-M-M-...
Pre-Spray Time:
50
(sec)
Integration Time:
10
(sec)
Response Time:
1

12: Open the window of "Calibration Curve Parameters". Then choose "ppb" or ug/l as a concentration unit and 1st order of calibration curve. Eventually click "Zero Intercept" in order to let calibration curve start from zero.



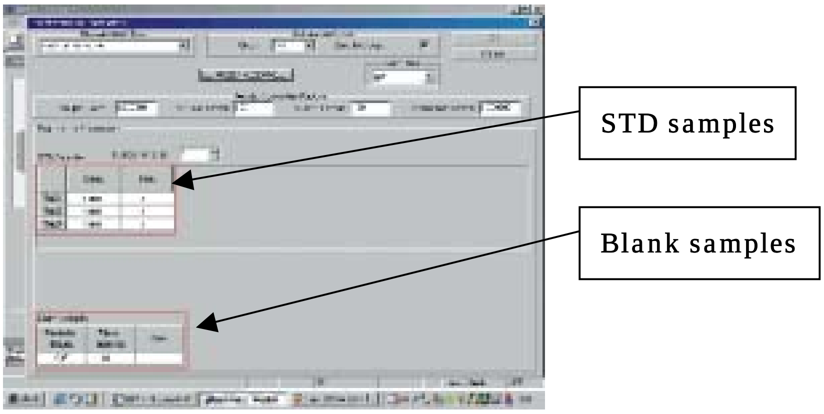
13: Open the window of " Atomizer/Gas Flow Rate Setup" and select "Atomizer Position" then set up the position like in images below. Click "OK" after every operation is done. Then Click "NEXT"



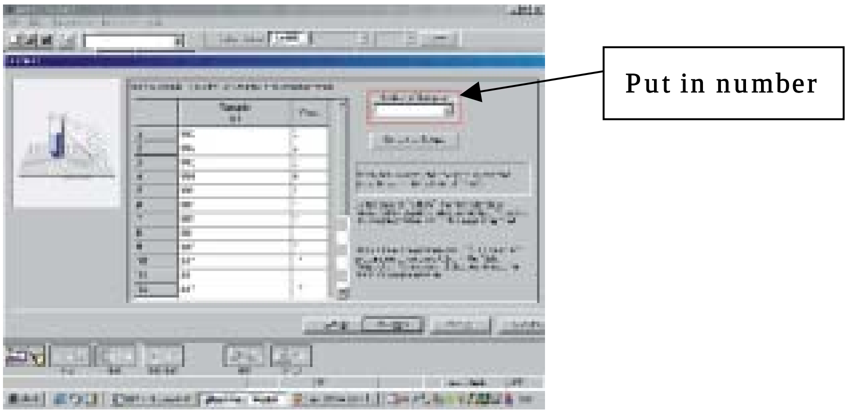


14: Click “Edit” in the window of “Preparation Parameters”.

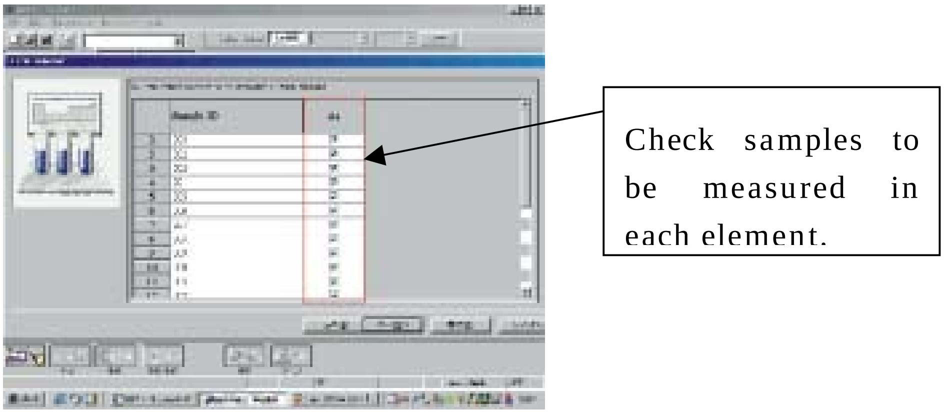
15: Put in appropriate numbers to your STD solution and sequential analysis for blank samples. Then click “OK”.



16: Go to "Next" window. So far put in the number of samples, which you are going to analyze

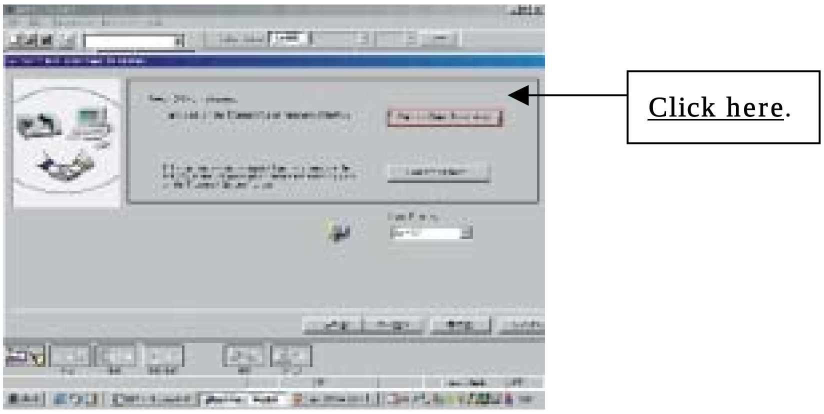


17: Go to "Next" window. If there are some elements to be analyzed, you can select samples to be measured in each element*

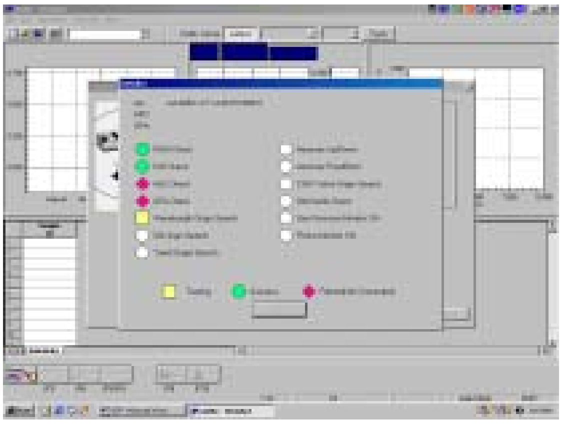


* In case of this AAS all functions are specialized to analyze arsenic. So you cannot measure other elements. This means you have nothing to do in this window.

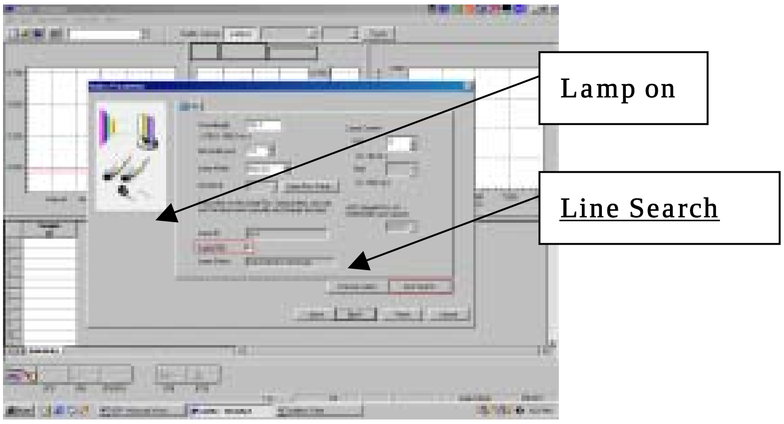
18: Go to "Next" window. When all parameters are determined, Click "Connect/Send Parameters".



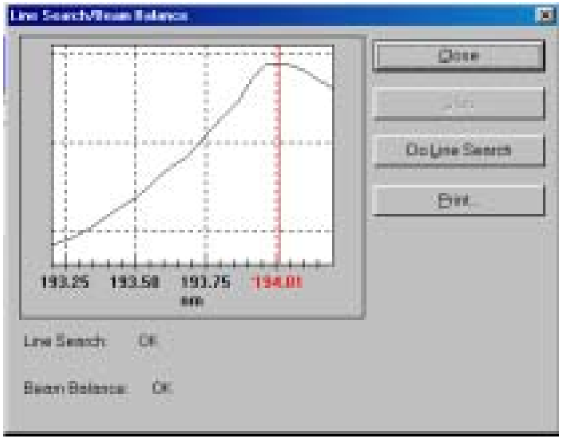
19: When "Connect/Send Parameters" is clicked, the diagram shown below appears in order to confirm each connection between your computer and devices.



20: When connections are confirmed, hollow cathode lamp is turned on. Then line search should be done.



21: If Beam intension is weak, mafful heater should be adjusted in its direction and line search should be done again. When line search and beam balance are OK, click "Close".



22: When everything is ready, click "finish" and start AAS measurement.

CHAPTER 4

ARSENIC REMOVAL EQUIPMENT

CHAPTER 4 ARSENIC REMOVAL EQUIPMENT

4.1 Objective

The objective of the arsenic removal experiment in this project is to provide the information necessary to draw a master plan of arsenic mitigation, in case deep aquifer development cannot be a solution for all the area. Such information shall be backed by hands-on field experience. Therefore, instead of comparing and/or evaluating existing individual technologies of arsenic removal, a more research and development oriented approach was taken. Verification/authorization or rejection of any individual technology option is not expected.

The experiment was designed in such a way that problems and issues associated with arsenic removal equipment and operation are identified and become clear.

The following issues will be studied, though it may be too ambitious to expect answers to all under the project

- Arsenic removal efficiency
- Operation and maintenance
- Cost
- Waste management
- Monitoring requirement
- Operational risk
- Household vs. community based system
- Immediate-emergency vs. long-term option
- Removal of other pollutants

4.2 Basic Approach for Arsenic removal experiment

4.2.1 Systematic categorization of the technologies

When developing arsenic removal technologies, a systematical approach was employed. Theoretical evaluation of each category of technology was done prior to evaluating independent technology options. The approach will eliminate much of the confusion caused by the evaluation of various independent technologies in one step. Here, all technology can be categorized into four groups, namely co-precipitation, adsorption, membrane separation and solar distillation.

A summary of the four categories is shown in the table below.

Table 4.1 Four categories of arsenic removal technologies

Principle	Individual Technology	Advantage	Disadvantage
Co-precipitation	• Alum • Iron • Lime Softening • Passive sedimentation	• Cost of equipment and consumable is relatively inexpensive	• Difficult to remove As (III). • Required oxidation agent. • Required chemical to add. • Complication in operation. • Sludge generation.
Adsorption	• Activated alumina • Oxidized iron • Charcoal	• Cost of equipment and consumable is relatively inexpensive. • Less waste generated compared to precipitation • Simple operation.	• Difficult to remove As (III). • Required oxidation agent. • Need to replace adsorbent→ Waste generation. • Required periodical monitoring. • Influenced by other dissolved ion.
	• Ion exchanged resin	• Some resin capable to remove As (III). • Regeneration process is possible for some resin • Simple operation.	• Expensive consumable (resin) • Need to replace adsorbent→ Waste generation. • Required periodical monitoring. • Influenced by other dissolved ion.
Membrane separation	• Reverse osmosis • Electrodialysis	• Capable to treat large volume.	• Difficult to remove As (III). • Required power for pressurized pump. • Expensive consumable
Solar distillation	• Basin -type	• Capable to. Remove As (III). • Simple operation and maintenance. • No chemical and consumable. • No influence of other dissolved ions.	• Capacity is small.
	• Vacuum type, multi effect type		• Efficiency is not yet demonstrated.

4.2.2 Analysis of technical issues

Based on the categorization of arsenic removal technologies as noted, the following technical issues were considered prior to planning the field experiment.

<u>Arsenic species and pre-oxidation requirement</u>

Arsenic is present in water in two different states of valence, namely As (III) and As (V). In the case of groundwater under reducing - oxygen absent conditions, most, or nearly all arsenic is in the form of As (III). As (III) is electrochemically near neutral while As (V) is a more charged form. This makes As (III) more difficult to remove from water than As (V) by most of the removal methods. In such a case, the pre-oxidation of As (III) to As (V) is required for effective removal of arsenic from water.

The oxidation of As (III) to As (V) by oxygen or aeration takes place at a very slow rate. Therefore, oxidation by oxygen only is not adequate for a removal process requiring quick oxidation. A common oxidizing agent used is Potassium Permanganate or Chlorine. Use of such chemicals may not be any problem in industrial nations but imposes operational problems in the rural village conditions in Bangladesh. Problems include too little or over dosing which may cause water quality deterioration and harmful by-product generation in the case of Chlorine.

It is clear that any removal technology that does not require the pre-oxidation of As (III) to As (V) has an advantage in this aspect.

Based on the category discussed, the pre-oxidation requirement is summarized as follows.

Co-precipitation	-	Required
Adsorption	-	Required (Not required for some Ion exchange resin)
Membrane	-	Required (Membrane cannot stand with an oxidizing agent)
Distillation	-	Not required

<u>Waste management</u>

All arsenic removal technology generates some sort of concentrated waste as a result of the removal operation. How such waste shall be handled to avoid secondary environmental problems is a difficult but important question when considering the nation-wide extension of the technologies. To further discuss the issues the following may be considered.

1) What environmental problems are caused by arsenic concentrated waste? There is arsenic already in the ground. What are the additional problems?

Since arsenic contamination of groundwater is already widespread, secondary environmental problems shall be assessed in view of the additional risk it may impose on current conditions. If the waste imposed only a similar level of risk comparable to the drainage of washing or the use of contaminated tube wells for bathing and/or the use of contaminated groundwater for irrigation, it is probably not worth considering the additional care and cost to handle such waste. On the other hand, if the waste imposes a much higher risk by releasing higher levels of arsenic to groundwater than at present, it should be handled with care. Therefore, the focus of the problem is if certain waste can cause more serious groundwater contamination than at present so that any arsenic removal equipment capable of reducing arsenic down to an acceptable limit will fail once inlet concentrations of arsenic significantly increase because of the waste.

*2) **Do leaching test results provide a guarantee for safe disposal of the waste?***

The answer to this question is probably “NO” because of two considerations. Firstly, a leaching test is a test done under oxidative conditions while underground conditions in Bangladesh are mostly reducing. This is especially important as most waste is in the form of oxide or hydroxide, which is stable in oxidative conditions but unstable in reducing conditions. Secondly, once waste is dumped somewhere it is subject to weathering by heavy rain, sunshine and biological activities. Stable results at the laboratory at limited duration do not guarantee safe disposal.

3) What technologies generate what type / level of waste?

In general, all arsenic removal technologies generate the same amount of arsenic waste when computing “volume of waste x concentration of arsenic in waste” per treated volume of water. Therefore, now we are faced with the dilemma where a technology generating the minimum volume of waste, thus the most efficient process, also generates waste of highest concentration, thus the riskiest waste, while a technology generating waste of less concentration generates a larger volume of waste.

Some generalizations on the type of waste for each category of technology are as follows.

<u>Concentration of waste (in the order of high to low)</u>

Adsorbent > Co-precipitation >> Membrane and distillation

<u>Volume of waste (in the order of largest to smallest)</u>

Distillation and membrane >> Co-precipitation > Adsorbent

<u>Type of waste</u>

Adsorbent	-	spent adsorbent
Co-precipitation	-	precipitated sludge
Membrane	-	concentrated water
Distillation	-	concentrated water

<u>Control of waste concentration and volume</u>

Adsorbent	-	by replacement period
Co-precipitation	-	by raw water concentration
Membrane	-	can be controlled by operation
Distillation	-	can be controlled by operation

To go one step further, it is necessary to consider the threshold concentration of waste. If the concentration of waste is lower than such a threshold value, it will not present an additional risk to the current environment and therefore waste management is not required. If somewhere in the vicinity of such a threshold value, an effort shall be placed on lowering the concentration of waste so that the total operation cost will be minimum. On the other hand, if the concentration of waste is higher than the threshold value, an effort shall be placed on maximizing the efficiency and minimizing the volume of waste to lower the waste management cost.

Determination of such a threshold value shall be based on a baseline study of current arsenic contamination conditions such as the content of arsenic in soil and the fluctuation of arsenic concentrations in tube well water. For example, if the soil content of arsenic in some baseline study indicates an average of 50 mg/kg of arsenic, waste of a similar level does not give any additional risk to that area. In the same way, if arsenic in tube well water fluctuates from 0.5 to 1.0 mg/l in some area, draining wastewater of 1.0 mg/l concentration does not provide any additional risk.

Probably the most feasible strategy for waste management is not to generate waste higher than such a threshold value. In this view, membrane and distillation technologies have a clear advantage because they can control the concentration of wastewater.

Monitoring requirement

Arsenic removal efficiency may be changed during the continuous use of the equipment depending on the nature of the technology. Therefore, periodical monitoring of the treated water is necessary to ensure the good removal of arsenic. It is simple and easy to say so, however from a practical viewpoint, it will be a very difficult task, if not impossible, considering the large number of such monitoring locations. We have to take into account that initial screening of tube wells by field test kits is still far from completion after many years of combined efforts of various organizations. On the other hand, here we are talking about the periodical monitoring (not one time measurement) by laboratory method (not by field test kit). By the nature of treated water monitoring to accurately measure the water at 0.05mg/l of arsenic, a field test kit may not be a reasonable option.

Now the focus of the problem is how to integrate such a monitoring requirement of the technology into the overall evaluation process. A general summary and issues for each category of technology are discussed below.

1) Co-precipitation

Co-precipitation based technology such as the double bucket system using alum is basically a batch process. This means the efficiency of a removal process is independent from previous operation. The only factor that influences the removal efficiency is change in the raw water quality. As tube well water may not change significantly in a short time interval, the monitoring requirement for this purpose is minimal.

On the other hand, the arsenic removal efficiency of the technology highly depends on the operating condition of the process, such as accurate dosing, mixing, reaction time and proper filtration. In this aspect, monitoring of the system is required.

2) Adsorption

Contrary to co-precipitation based technology, an adsorption-based process is a continuous process. Arsenic removal efficiency is influenced by the cumulated operation record as well as water quality. The key issue for adsorption-based technology is the breakthrough bed volume. The breakthrough bed volume is defined as the volume of treatable water per unit volume of adsorbent. For example, if the breakthrough volume of adsorbent A is 10,000, 1 liter of adsorbent A can treat 10,000 liters of water before replacement. From an operational point of view, the breakthrough volume directly relates to the replacement frequency.

There are two complicating factors. First, most adsorbent breakthrough volumes for As (III) and As (V) significantly vary, i.e. low volume for As (III) and large volume for As (V). Only one kind of adsorbent (READ-F) has a larger breakthrough volume for As (III) than As (V). Depending on the composition of arsenic species As (III) and As (V), the breakthrough volume fluctuates. To overcome this problem, most adsorbent processes employ a pre-oxidation process prior to adsorption. Second, other ionic species in the groundwater often compete with arsenic for the adsorption site. Such competition also influences the breakthrough bed volume.

As a result of the above noted complication, the breakthrough volume or replacement period significantly varies depending on the local condition of the tube well water as well as the operating condition of the adsorbent equipment. Therefore, a generalization of the replacement period is difficult to determine. In such a case, periodical monitoring of the treated water is an essential requirement.

3) Membrane

Membrane-based technology has a better removal efficiency for As (V) than As (III). However, use of an oxidizing chemical as some of the adsorbent process is not feasible because, in general, a membrane cannot stand with such an oxidizing agent. Therefore, the arsenic removal efficiency of the membrane-based technology depends highly on the composition of As (III) and As (V). In such a case, it may require more monitoring as such composition may vary by some conditions.

4) Distillation

The distillation process removes arsenic almost completely, regardless of its compositional ratio of As (III) and As (V). Further, its removal does not depend on other factors such as other dissolved species in water nor the previous operating record of the equipment. Therefore, from a theoretical viewpoint, the distillation process requires no monitoring.

In summary, the monitoring requirement for each category of technology can be summarized as follows.

Co-precipitation	-	modest requirement
Adsorption	-	highest requirement
Membrane	-	modest requirement
Distillation	-	lowest requirement

<u>Operational risk</u>

Operational risk includes followings.

1) Misoperation resulting in inadequate removal of arsenic

2) Misoperation resulting in excessive chemical in water

3) Misoperation resulting in breakdown of equipment

4) Misoperation resulting in immediate health problems caused by chemical

Here we can list the possibility of such misoperations for each category of technology.

1) Co-precipitation

Underdosing of chemical	-	Inadequate removal of arsenic
Inadequate mixing or settlement	-	Inadequate removal of arsenic
Overdosing of chemical	-	Excessive chemical or immediate health problems

2) Adsorption

Inadequate pre-oxidation	-	Inadequate removal of arsenic
No replacement of adsorbent	-	Inadequate removal of arsenic

3) Membrane

Lack of maintenance of pump	-	Breakdown of equipment
No replacement of membrane	-	Breakdown of equipment

4) Distillation

Inadequate operation	-	Low volume of treated water

From the above analysis, co-precipitation technology imposes the largest operational risk. However, a more detailed analysis based on field observation is necessary to characterize the risk of each technology.

<u>Household vs. Community based system</u>

Various arsenic removal systems can be grouped by their size/scale of operation. Some systems were designed for household use only while others can produce larger volumes of treated water and thus must be shared by the community. Hereunder, the advantages and disadvantages of both systems will be discussed.

<u>Household-based system</u>

- Advantages:

Easy to introduce socially as community consensus is not required.

Community cooperation is not required as each house takes own responsibility.

Easy to introduce physically as system is small and relatively inexpensive.

- Disadvantages:

Waste management is difficult, if collection and management become necessary.

Monitoring of each system is almost impossible.

<u>Community-based system</u>

- Advantages

Monitoring is relatively easy, compared with household-based system.

Waste management is relatively easy, compared with household-based system.

- Disadvantages:

Community consensus is required for introduction.

Community cooperation and cost sharing is required.

The disadvantages of a community-based system as listed above are probably not real disadvantages. In any case, community consensus and cooperation are desired and required for mitigation work. Through the experiment, this community cooperation issue will be examined.

<u>Immediate-emergency option vs. long-term option</u>

The development and/or selection of arsenic removal technologies that can fulfill all the technical as well as operational requirements, especially the waste management problem, will be a very difficult task. Considering the potential scale of the problem of introducing inadequate technology nationwide, it is rational to examine the technologies very carefully. Such examination may take some time, as field level verification is mandatory.

On the other hand, there are people drinking arsenic contaminated water on a day-to-day basis. Even before the complete examination of the technology options as noted above, some countermeasures, for the time being, are desired. Such countermeasures shall not necessarily eliminate but at least reduce the risk of drinking arsenic contaminated water. At the same time, such immediate countermeasures shall not prevent the introduction of a long-term solution, which may come at a later time. It also shall prevent and/or minimize duplicate expenditure and investment. During the experiment, this issue will also be examined.

<u>Removal of other pollutants</u>

Pollutants other than arsenic are found to be present in some groundwater. Groundwater in coastal areas is often contaminated by saline water. Now, the focus of the problem is on arsenic;

however, in future it may become necessary to consider the removal of other pollutants. For this reason, we will briefly evaluate the capability of the technology for the removal of other pollutants.

1) Co-precipitation

The technology may be able to remove some heavy metal pollutants. It is not possible to remove nitrogen and organic pollutants or salinity either.

2) Adsorption

The capability to remove other pollutants depends on each adsorbent type. For example, activated alumina can remove various ionic species in water.

3) Membrane

The technology can remove most the pollutants including salinity but excluding electrochemically neutral species such as As (III).

4) Distillation

The technology can remove all other pollutants as well as salinity.

4.2.3 Evaluation criteria

Establishing common evaluation criteria is important to avoid confusion, especially when various agencies do their own testing and evaluation of arsenic removal technology. For this purpose, activities were coordinated with other programs. Various discussions with BAMAWSP to avoid duplication were held. In-depth discussions with CIDA-OCETA for ETV-AM were also held to exchange ideas on evaluation criteria. A presentation of the evaluation criteria to be applied under the study was made at the workshop of CIDA-OCETA on July 26 and 27, 2000 in Dhaka.

The following is the evaluation criteria at this stage, taking the technical issues discussed above into consideration. The final evaluation of arsenic removal equipment will be done after completion of the field testing program as well as the survey of the technology testing program done by other organizations.

In addition to the field testing program, other separate issues such as waste management and the possible construction of a waste disposal site, monitoring cost, etc, shall be studied.

Table 4.2 Evaluation criteria of Arsenic Removal Equipment

Aspect	No.	Criteria/Question	Evaluation
Arsenic removal efficiency	1.1	Different removal efficiency for As(III) and As(V)?	
	1.2	Oxidation process required for removal of As(III)?	
	1.3	Removal efficiency depending on the initial raw water concentration?	
	1.4	Removal efficiency changed by continued use?	
	1.5	Removal efficiency influenced by the other dissolved ions?	
	1.6	Field test data (initial and treated concentration, ORP, pH, EC, other ions). Removal rate.	
Operation and maintenance	2.1	Household or community based? What is the capacity per unit?	
	2.2	What is daily operational procedure? Number of steps? Labor time required?	
	2.3	What is maintenance procedure? Weekly, monthly? Number of steps?	
	2.4	Consumable required? What? How often? Is that potentially hazardous?	
	2.5	Chemicals required? What? How often? Is that potentially hazardous?	
	2.6	Waste generated? How much /day, month	
	2.7	Monitoring requirement	
	2.7.1	1.3, 1.4, 1.5 is yes, monitoring required. How often ?	
	2.7.2	Monitoring parameters? Arsenic? Other ions?	
	2.8	Operational risk?	
Cost	3.1	Equipment cost	
	3.1.1	cost/unit	
	3.1.2	cost/l of treated water over expected life time Expected life time of the equipment	
	3.2	Operating cost	
	3.2.1	Manpower cost/day, month, cost/l of treated water	
	3.2.2	Consumable cost/replacement cost/l of treated water. If regenerated, cost/ regeneration	
	3.2.3	Chemical cost/day, month, cost/l of treated water	
	3.2.4	Power or any other utility cost/day, month cost/ l of treated water	
	3.2.5	Monitoring cost/month	
	3.2.6	Waste treatment disposal site construction, collection, transportation	
	3.3	Use of locally available material	
	3.3.1	Equipment	
	3.3.2	Consumable	
	3.3.3	Chemical	

4.3 Design of Arsenic Removal Equipment

4.3.1 Basic plan for experiment

The currently tested technologies in Bangladesh were evaluated briefly as follows. A more detailed description of the technology can be found in other reports such as the Rapid Assessment Program by DfID. Special attention was given to the technologies being tested by BAMWASP to avoid duplication of field testing.

- **Double Bucket System** Oxidation by potassium permanganate and co-precipitation by Alum followed by sand filter.
- **Steven Tech** Field tested at BAMWASP. Developed at Stevens Inst. of Tech. Co-precipitation by oxidized iron.
- **Activated Alumina (BUET)** Developed by DPHE-BUET-UNICEF. Laboratory test completed. Filed test under planning.
- **Activated Alumina (Alcan)** Promoted activatde alumina combined with pre-sand filtration unit.
- **SAFI filter** Candle type filter made of aluminum hydroxide, Mn oxide, Fe oxide. Developed at a university.
- **Kalshi filter** Filtration by coarse sand and iron chip at first tank followed by charcoal and fine sand at second tank.
- **AdsorbAs** Field tested at BAMWSP. German technology. Adsorption by granular oxidized iron.
- **Hybrid** Field tested at BAMWSP. Three types of activated charcoal and alum adsorption.
- **Arsen-X** Field tested at BAMWSP. Adsorption by ion exchanged resin form US.
- **TETRAHEDRON** Field tested at BAMWSP. Adsorption by ion exchanged resin form US.
- **READ-F** Field tested at BAMWSP. Adsorption by ion exchanged resin form Japan.

Double Bucket

Activated Alumina (BUET)

Kolshi Filter

Tetrahedron

Steven Tech

AdsorbAs

Activated Alumina (ALCAN)

READ-F

Photo presented here were taken by courtesy of BETS, SIDKO, MAGC Technology and Shin Nihon Salt Co., Ltd.

Based on the above, the experimental plan for the study was considered. The following points were considered to be important conditions.

① To avoid duplication for technology under field test by BAMWSP. However, common evaluation criteria shall be shared.

② Membrane technology is not appropriate for application in rural conditions in Bangladesh because of its high operation and maintenance requirement.

③ Lime Softening does not have many technical advantages.

④ Technology will be considered for household and community based systems.

⑤ Technology will be considered for emergency-immediate options and long-term options.

After all consideration, it was decided in consultation with DPHE that the following five technologies will be field tested.

- Improvement of Double Bucket System
- Aeration and passive sedimentation
- Adsorption by activated alumina
- Solar distillation （Basin-type）
- Solar distillation （Vacuum-type）

The table below summarizes the five technologies and their category/scale/timing option.

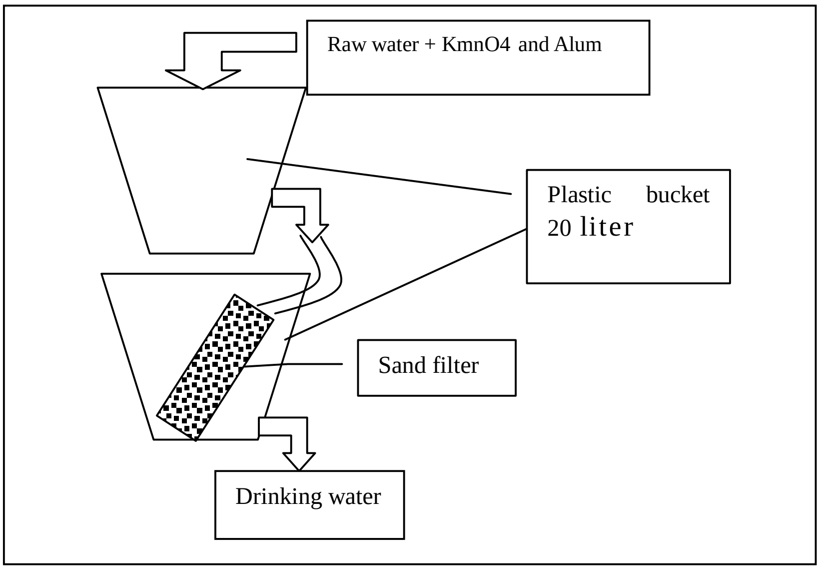
Table 4.3 Summary of Arsenic Removal Experiment Plan

	Category	Scale	Timing
Double bucket	Co-precipitation	Household	Immediate-emergency option
Aeration and passive sedimentation	Co-precipitation	Community	Immediate-emergency option
Adsorption by Activated Alumina	Adsorption	Community	Long-term option
Solar distillation (Basin)	Distillation	Household	Long-term option
Solar distillation (Vacuum)	Distillation	Household (or community)	Long-term option

Multiple units will be installed for the technologies that are influenced by variation of water chemistry. The household-based units will also be tested at multiple locations to check operation and maintenance conditions.

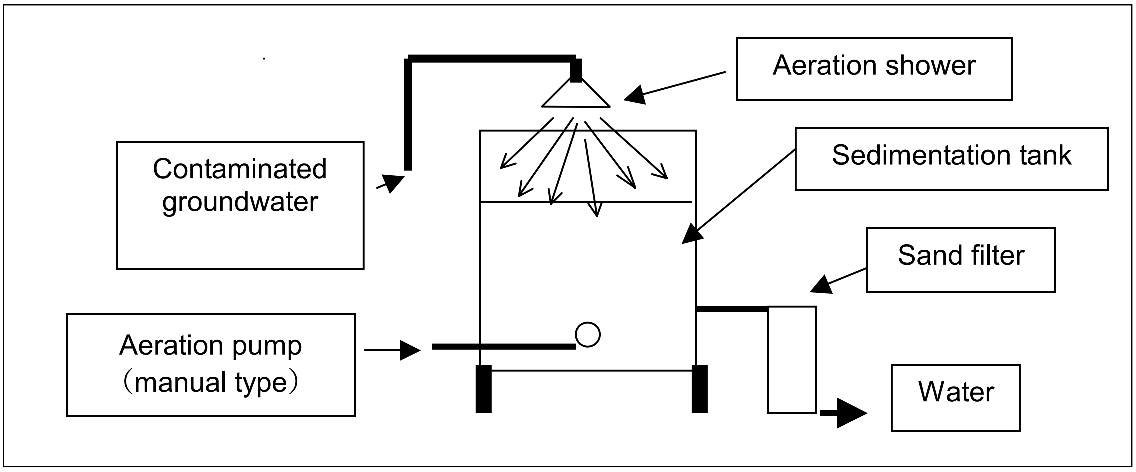
4.3.2 Double bucket system

The system was developed under the DPHE/DANIDA project. The system applies arsenic removal by co-precipitation with alum followed by sand filtration. The first bucket colored red is used to mix arsenic contaminated water with an added oxidizing agent, i.e. potassium permanganate (KMnO4), and alum. After precipitation, the treated water is fed to the second bucket colored green for filtration by fine sand to provide drinking water. The system will produce approx. 20 liters of drinking water per process. The system is designed for households. Under the study, tablet-type chemicals were provided to observe the operational advantage. The system is considered as an immediate option because the sludge problem is not yet solved.



4.3.3 Passive sedimentation system

In Bangladesh, it is said that groundwater kept for a while or overnight is less toxic than groundwater just pumped up. In many cases, arsenic contaminated groundwater contains high concentrations of dissolved iron.



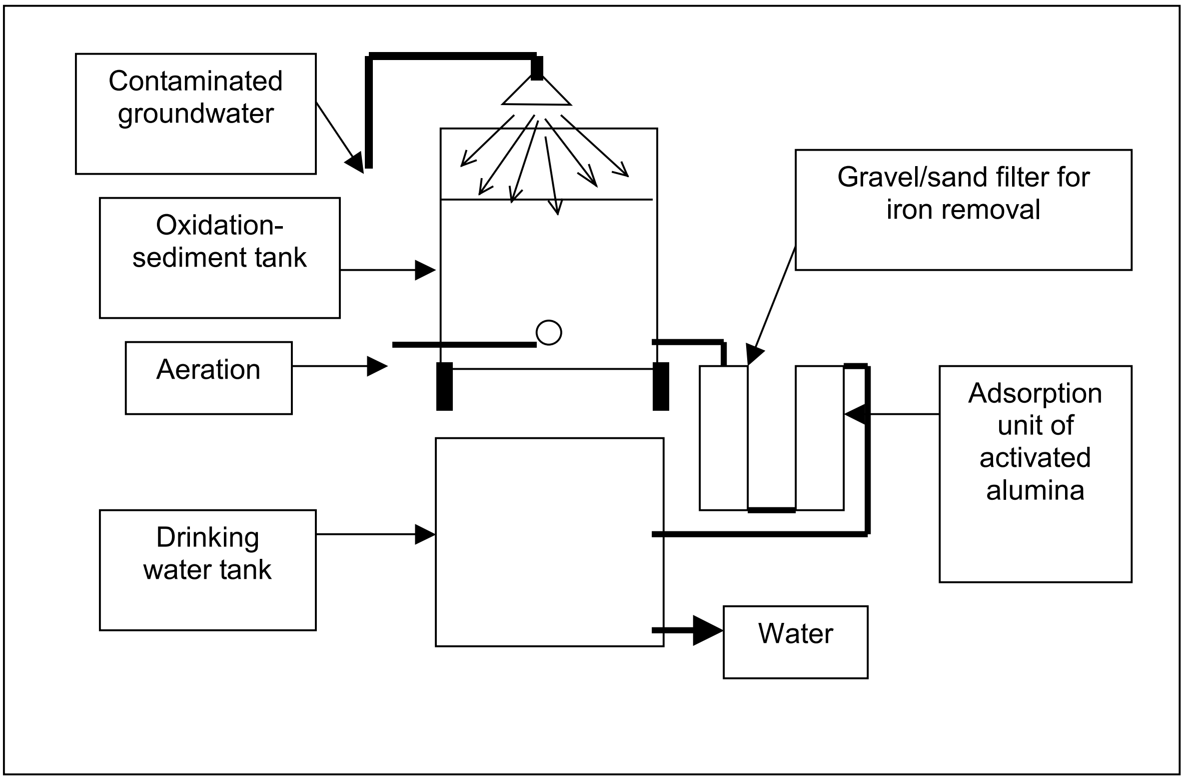
Dissolved iron when in contact with air, is oxidized and precipitated as iron oxide. Iron oxide is known to co-precipitate with arsenic and also to adsorb arsenic at the surface. Furthermore, arsenic itself is also oxidized from a more toxic trivalent species As (III) to a less toxic pentavalent As (V), though the reaction is slow. It is considered that the arsenic concentration as well as toxicity in the water kept for a while is reduced because of the reason noted above. The system is a combination of active aeration and oxidation unit and filtration unit to remove suspended particles of oxidized iron. The system can treat approx. 200l of water per process and is expected to provide a water supply for few families.

The system is considered as immediate option because its removal efficiency is not yet determined.

4.3.4 Activated alumina system

Activated alumina is known to adsorb arsenic and other substances. The adsorption capacity of activated alumina for arsenic is highly effective for pentavalent As (V) while it is less effective for trivalent As (III). Therefore, the system is a combination of pre-treatment by aeration/oxidation and an iron removal filter and adsorption unit of activated alumina. The system is designed for treatment of approx. 1,000l/day for drinking water. Community-based use is expected.

The system is considered as a long-term option.



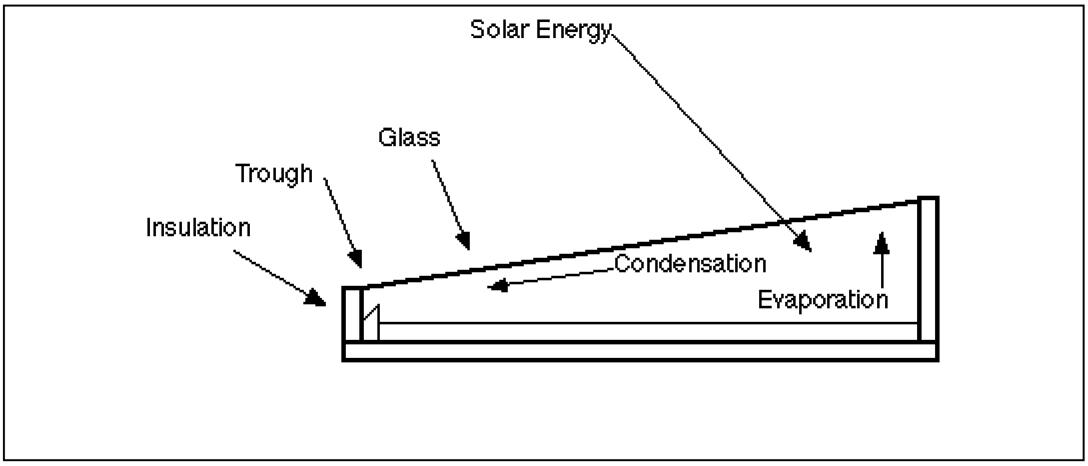
4.3.5 Basin type solar still

A basin-type solar still utilizes solar energy to heat water to produce distilled water. The basic design of the system is shown in the figure below.

Solar distillation technology has perfect arsenic removal efficiency regardless of the original arsenic content with no use of chemicals or consumables. Further, it will not generate waste sludge. The only drawback is its small capacity. However, as shown in the table below, a number of large-scale systems can be found elsewhere in the world, though their application is focused on desalinization. Therefore, the test is focused on its capacity under climatic conditions in Bangladesh. The system is considered as a long-term option.

Table 4.4 Large-scale solar distillation units

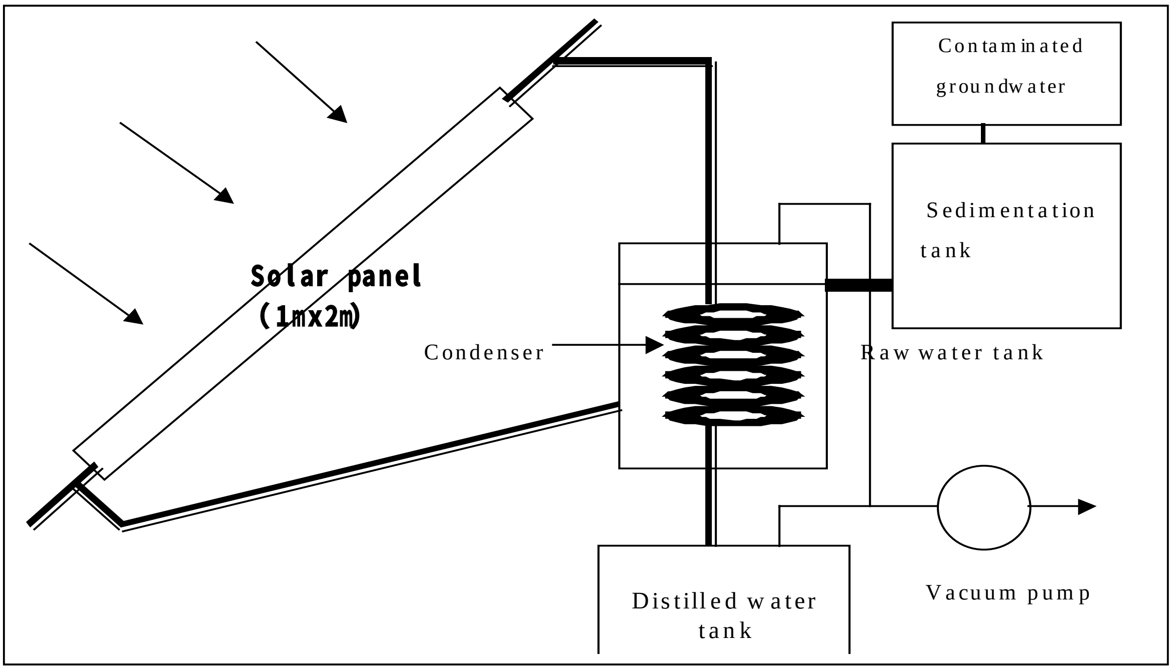
Country	Site	Construction year	Efficiency (kg/m2d)	Total capacity (kg/d)
Australia	Muresk	1963	**2.26**	**833**
	Muresk	1966	**2.26**	**833**
	Cooper Pedy	1966	**2.03**	**6,359**
	Gaiguna	1966	**2.11**	**776**
	Hamelin Pool	1966	**2.19**	**1,211**
	Griffith	1967	**2.22**	**908**
Chili	Quillagua	1968	**4.05**	**401**
Greece	Symi	1964	**2.85**	**7,570**
	Aegina	1964	**2.87**	**4,239**
	Salamis	1965	**2.85**	**1,098**
	Patmos	1967	**3.05**	**26,117**
	Kimolos	1968	**3.05**	**7,570**
	Nisiros	1969	**2.99**	**6,056**
India	Bhavnagar	1965	**2.23**	**833**
Mexico	Natividad Island	1969	**4.02**	**379**
Spain	Las Marinas	1966	**2.99**	**2,574**
Tunisia	Chakmou	1967	**1.22**	**530**
	Mahdia	1968	**3.23**	**4,164**
USA	Daytona Beach	1959	**2.51**	**2,082**



4.3.6 Vacuum-type solar still

A vacuum-type solar still can produce distilled water with much higher efficiency than a basin-type, as the boiling point of water is lower in vacuum. The basic design of the system is shown in the figure below. The system is considered as a long-term option.

The arsenic removal efficiency of vacuum distillation was laboratory tested using tube well water from Bangladesh. No arsenic was detected after the process for water with an original arsenic concentration of 0.15mg/l.



4.3.7 Manufacturing of arsenic removal equipment

Based on the basic design of the arsenic removal equipment discussed above, equipment was manufactured for field experiment. The following equipment was manufactured.

Double bucket system	18 units (chemical in powder and tablet form)
Passive sedimentation system	9 units
Activated alumina system	3 units
Basin-type solar still system	3 units
Vacuum-type Solar still system	1 unit

Priority was given to the use of locally available, off-the-shelf components such as tanks, filter housing and valves as much as possible.

1) <u>Double bucket system</u>

The components of the double bucket system are as follows.

- Two 20-liter plastic buckets (one red and one green)
- Two plastic taps
- One plastic pipe
- 10” of 1/2” PVC pipe
- 5 kg of coarse sand
- One stirring rod

All materials are locally available and the total cost per unit is approximately 300 Taka.

The chemical required is a mixed reagent of alum and potassium permanganate. The dosage per

20-liter treatment is 4g of alum and 0.03g of potassium permanganate. The tablets were fabricated with the same chemical composition in such a way that three tablets are equivalent to one dosage per 20-liter treatment.

2) <u>Passive sedimentation system</u>

The passive sedimentation system is basically the same as or similar to any iron removal unit based on an aeration mechanism. As discussed before, iron removal and pre-oxidation of the water before arsenic removal treatment is common. Therefore, the system is designed in such a way that use of the system as a pre-process unit is easy, if it becomes necessary in future.

The design of the unit is shown in Figure 4.1.

The components of the passive sedimentation system are as follows.

- One 500-liter plastic tank

500-liter plastic water tank available in market. Cost = 2,700 Tk/unit

- One 60-liter ceramic filter housing

60-liter ceramic filter housing available in market. Cost = 2,500 Tk/unit

- One bicycle air pump
- Pipe, fitting, four valves and frame

All materials are locally available.

3) Activated alumina adsorption system

The activated alumina used for the experiment is ALCAN promoted activated alumina AAFS-50. The system is composed of the following.

- Pre-oxidation tank with aeration. Stainless steel 1,000-liter capacity.

1,000-liter stainless steel tank available in market. Cost = 10,200 Tk/unit

- Sand filter using plastic airtight tank

Airtight plastic tank (approx.50-liters) used for chemical storage.
Not sold as product in market, but easily available.

- Activated alumina adsorption unit. (Filter housing is the same as the one used or sand filter of passive sedimentation unit.)
- Reservoir tank, stainless steel 1,000-liter capacity. (same as pre-oxidation tank)
- Pumping system to lift up water to pre-oxidation tank.

One H.P. suction pump for water lift up.
Cost = 5,500Tk/unit

Solar cell powered pump unit for site without electricity Not available in local market.

- Pipe, fitting, five valves and frame.

Details of the unit are shown in Figure 4.2. The unit was designed for universal application to any adsorbent technology. In place of activated alumina, any adsorbent can be used for ceramic filter housing.

4) Basin-type solar distillation system

Basin-type solar distillation can be made of locally available goods. It components are as follows.

- 1 m x 2 m tray.
- Glass cover 1 m x 2 m for the tray
- Black silicon to cover the bottom of tray.

Black silicon to cover the bottom of tray.
Cost = 200 / tube.

- Styrofoam for insulation
- Pipe, fitting, one valves and frame.

Details of the unit are shown in Figure 4.3.

5) Vacuum-type solar distillation system

The vacuum-type solar distillation system is still in an experimental stage. Therefore, the unit used for the experiment is still pre-mature to consider its design detail for costing and local goods availability. Figures 4.4 and 4.5 show the design of the vacuum solar distillation unit for the experiment. It has a solar panel 1 m x 2 m in size but can be up-scaled easily by adding solar panels at a fraction of the total cost.

The table below summarizes the cost information used for the manufacturing of the unit in the experiment.

Table 4.5 Cost information of material and goods

No.	Description	Unit	Cost
1	Plastic water tank 500 litter	each	Tk 2,700
2	Stainless steel water tank 1,000 litter (sheet t=0.5mm)	each	Tk 10,200
3	Filter (60 litter) housing ceramic	each	Tk 2,500
4	Activated alumina ALCAN AAFS-50	per kg	US$ 12.0
5	Electric pump 1 H.P.	each	Tk 5,500
6	G.P. sheet tray (basin type solar distillation unit) t = 1mm	each	Tk 4,000
7	Glass t = 6mm (2,130mm x 1,220 mm)	each	Tk 1,700
8	Black silicone	per tube	Tk 200
9	Styrofoam t = 12mm (2m x 1m)	each	Tk 210
10	M.S. Angle, flat bar	per ton	Tk 20,000
11	Colored C.I. sheet	each	Tk 426
12	Bicycle air pump	each	Tk 400

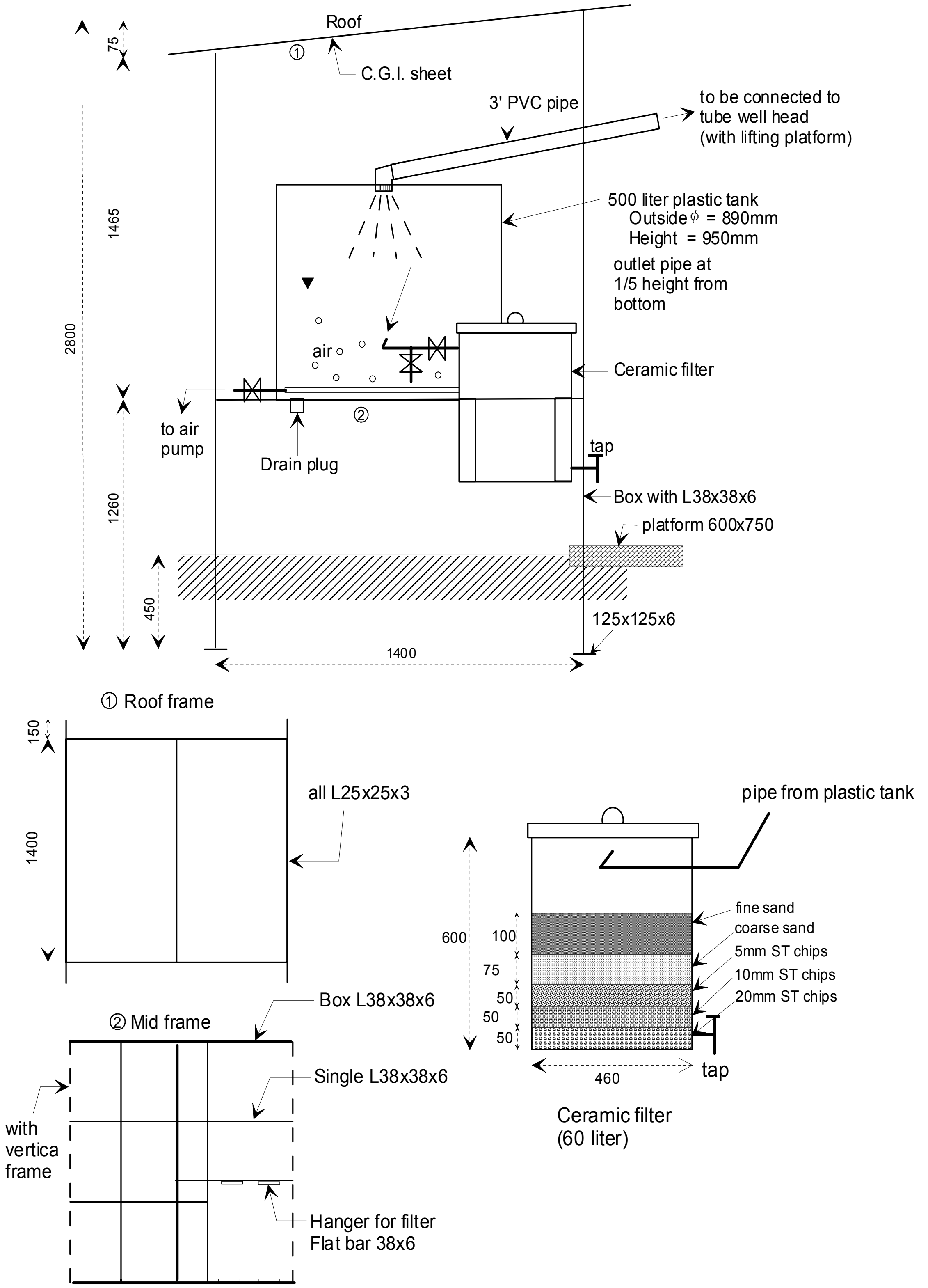


Figure 4.1 Passive Sedimentation Unit

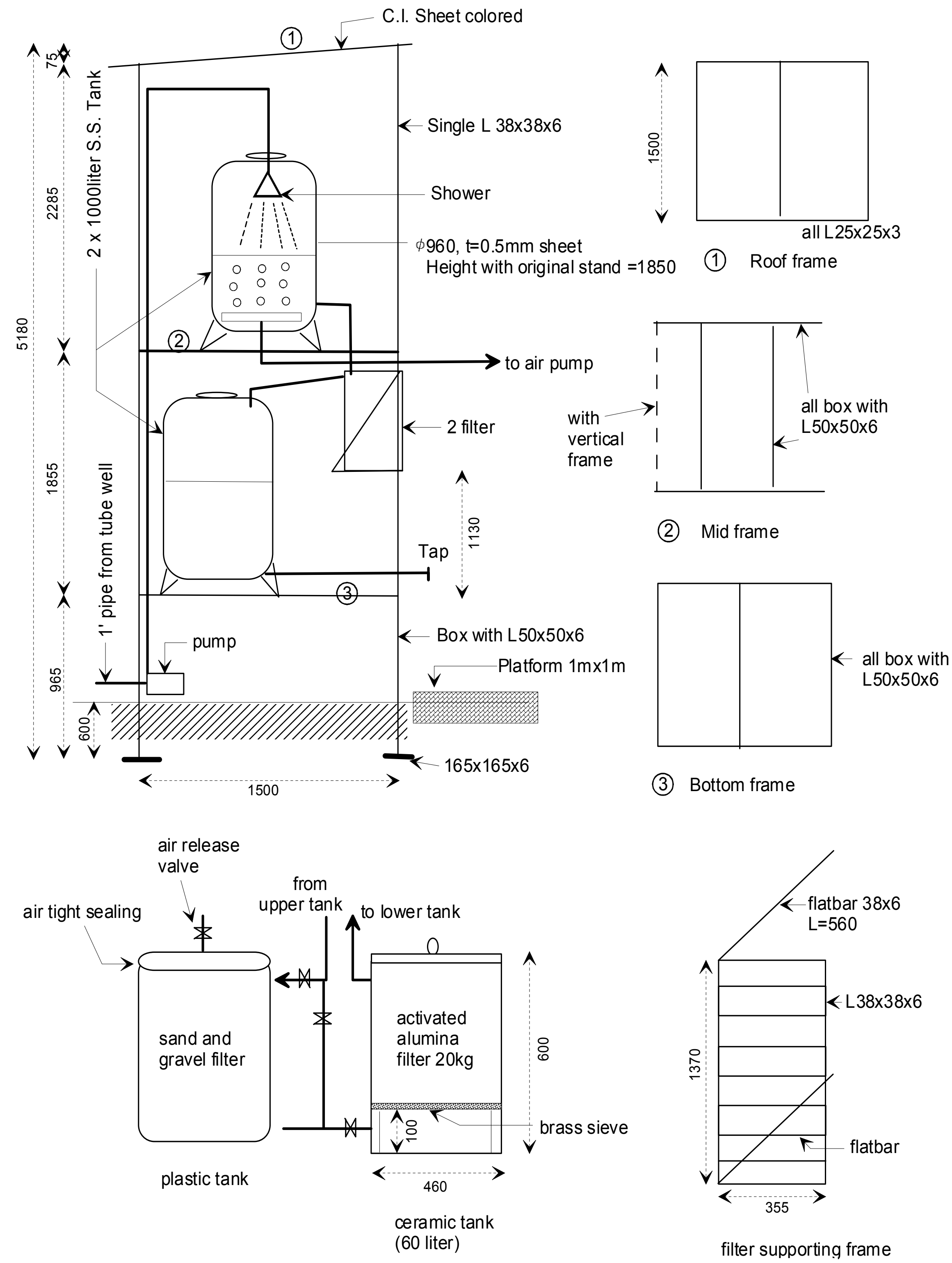


Figure 4.2 Activated Alumina Adsorption Unit

Figure 7.2.2 Activated alumina adsorption unit

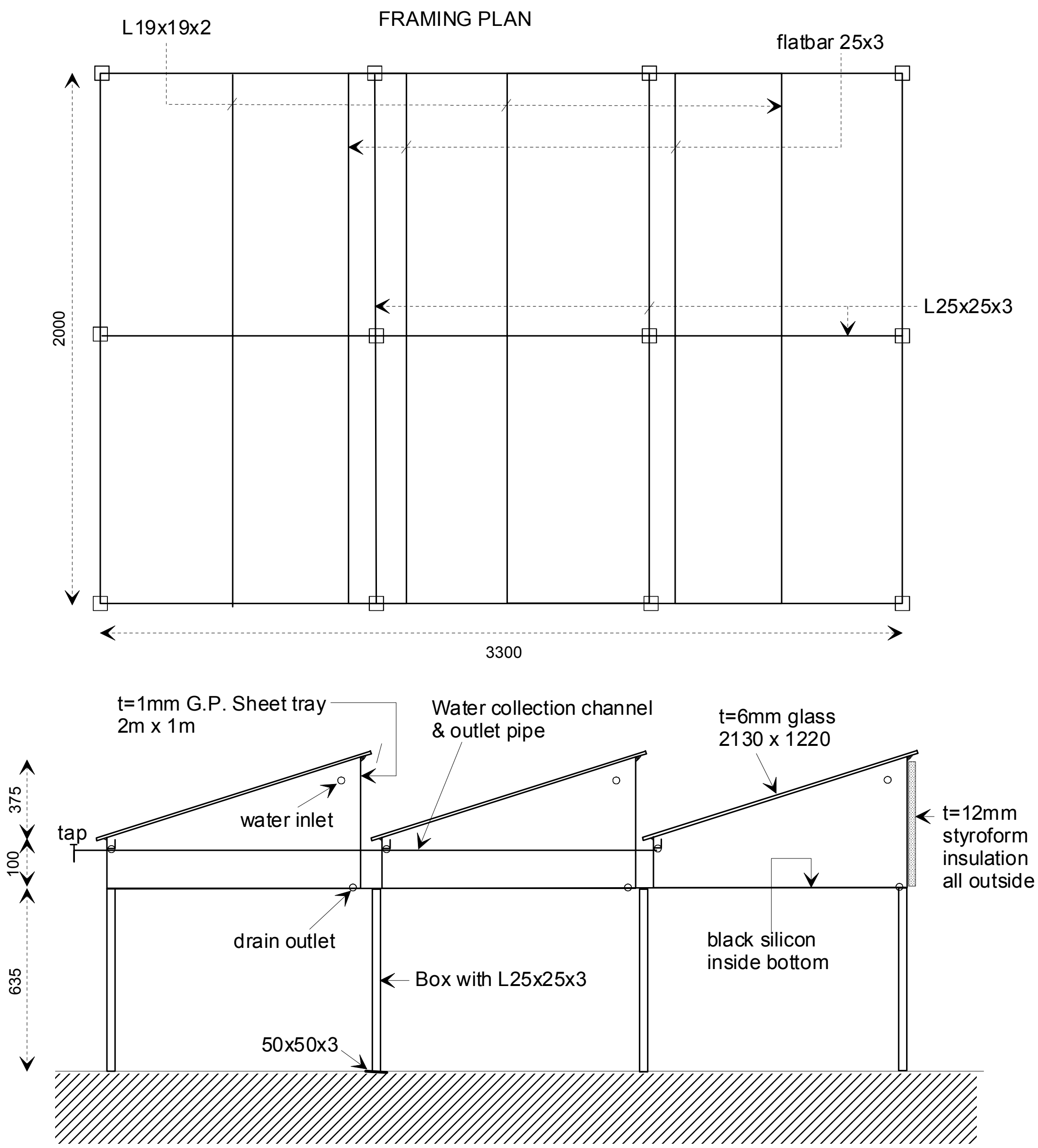


Figure 4.3 Basin Type Solar Distillation Unit

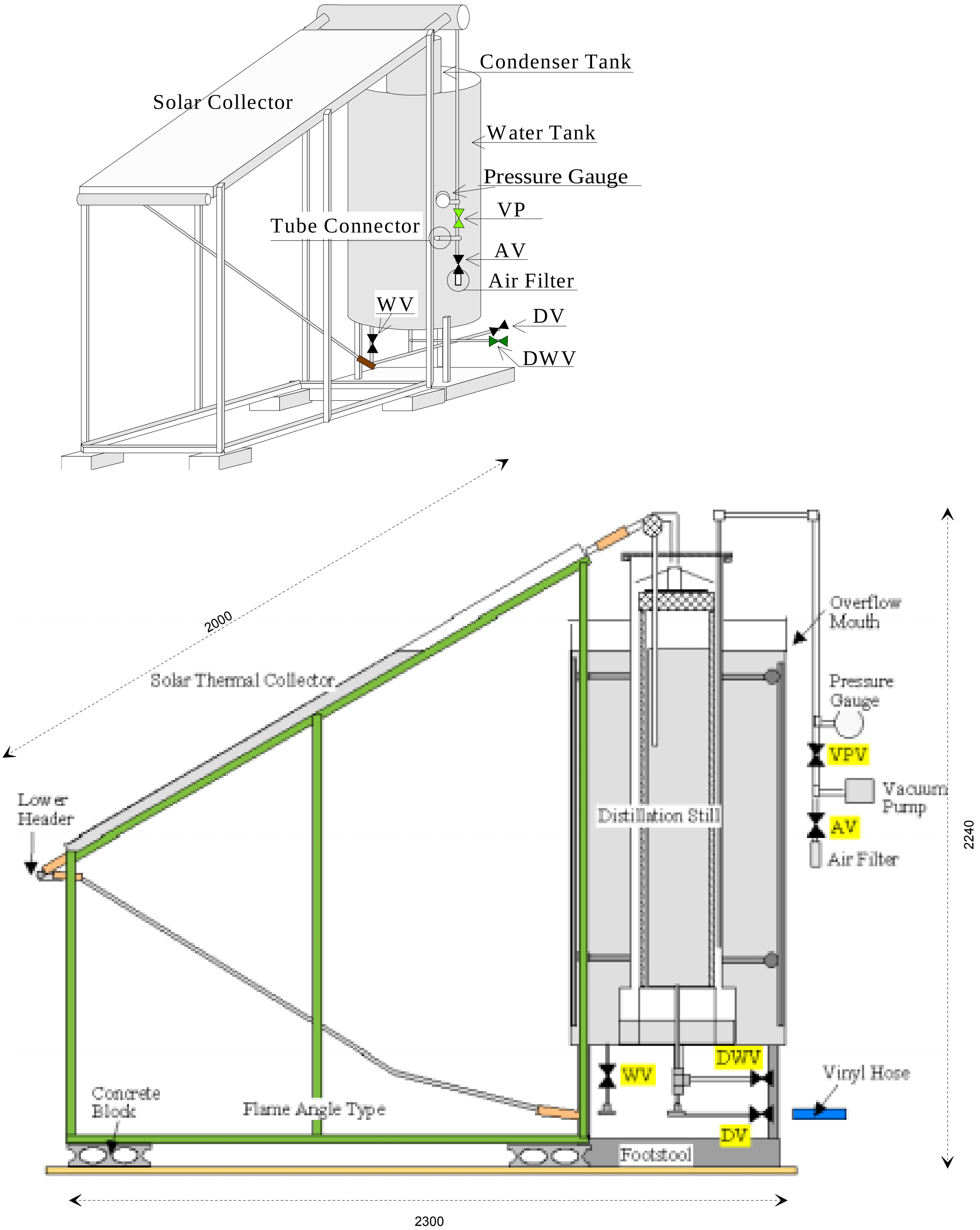


Figure 4.4 Vacuum type solar distillation unit

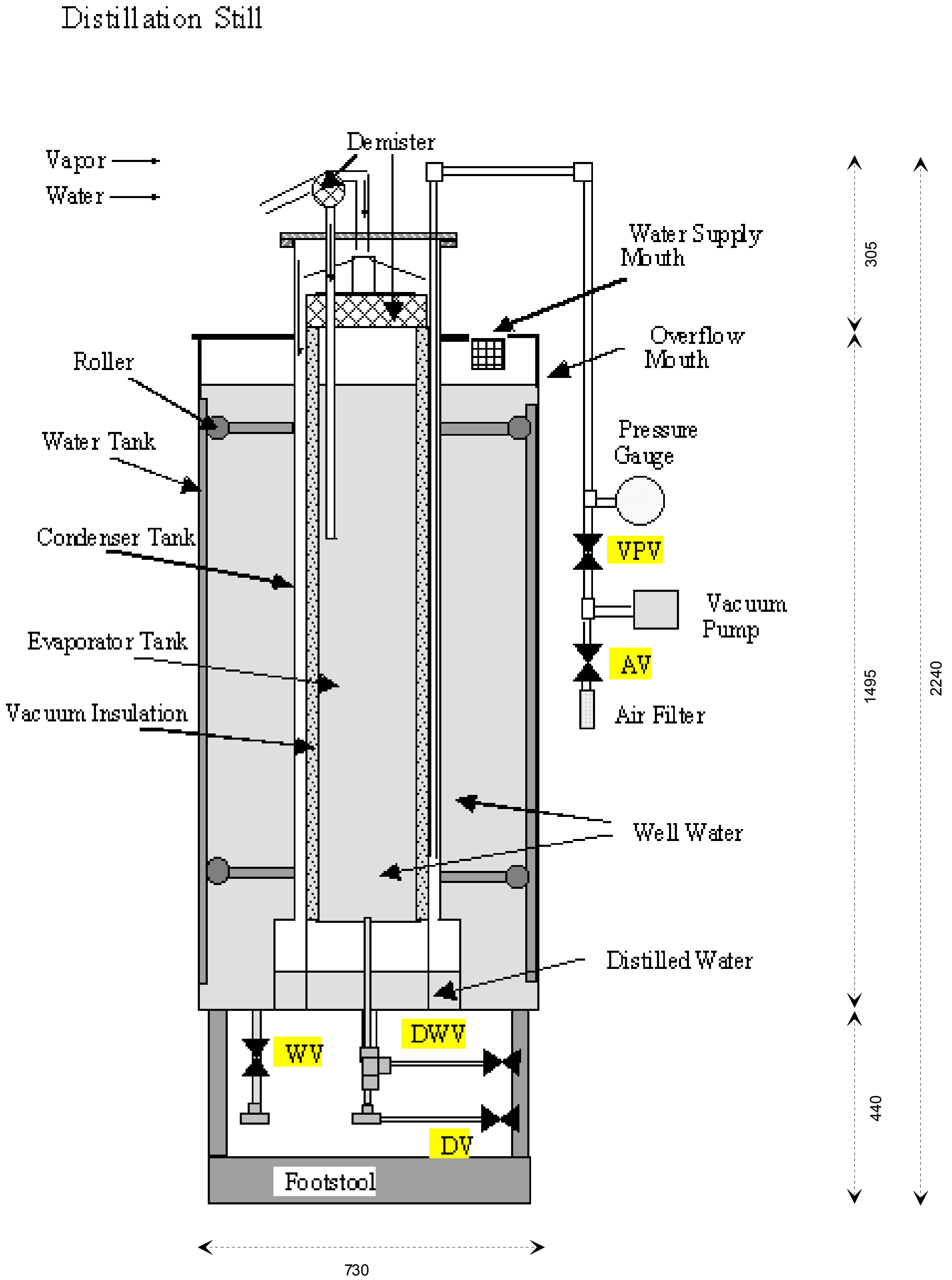


Figure 4.5 Vacuum type solar distillation unit - details of still

4.4 Site selection and installation

4.4.1 Site selection process

Site selection for the arsenic removal equipment was done according to the following process.

Selection of model villages based on 300 existing well survey — Aug. to Sept. 2000

↓

Screening survey of all tube wells at the villages by field test kit — Oct. 2000

↓

Preliminary site consideration based on screening survey — Oct. 2000

↓

Discussion with DPHE district and thana offices
Discussion with local NGO — Oct. 2000

↓

Workshop at Jessore inviting NGO and village committee member
Explanation of arsenic removal technology and experiment
Discussion of the proposed sites for experiment — Nov. 2000

↓

Joint site visits with DPHE, NGO and village committee member
Final selection of the experimental sites and caretakers — Nov. 2000

↓

Negotiation with the caretakers for agreement — Nov. 2000

Site selection process for arsenic removal experiment

When selecting the sites, the following conditions were considered.

<u>General conditions</u>

- Distribution of arsenic contaminated tube wells and concentration of arsenic.
- Location of deep tube wells (existing and planned). Areas not covered by deep tube well or areas far from deep tube well were given priority for arsenic removal experiment.

<u>Technology-wise conditions</u>

1) Double bucket system

- Priority given to families with contaminated tube well that is isolated from others.

2) Passive sedimentation system
   - High iron concentration for precipitation purposes.
   - Approx. 10 families nearby to share the equipment.

3) Activated alumina system
   - Availability of electricity for pumping
   - Approx. 30 to 50 families nearby to share the equipment.
   - Willingness to provide replacement cost of activated alumina by the community.
   - Leadership of the caretaker in the community

4) Solar still (basin and vacuum type)
   - Good sunlight conditions (little shade in the site)

Because of the tight schedule for the experiment, site selection was done using field test kit data only without laboratory analytical data. Some discrepancy between field data and laboratory data was expected, but it was accepted as a reasonable risk.

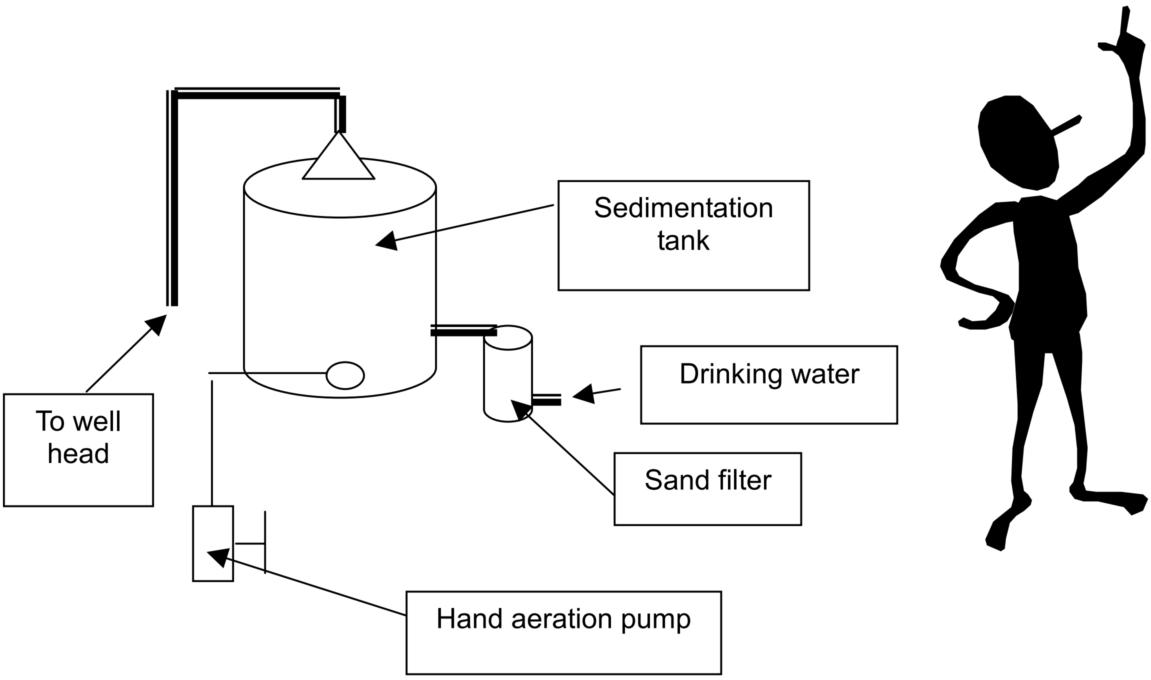
Effort was spent to obtain consensus among all parties concerned for site selection. A series of discussions were held with DPHE district offices, thana offices, NGO in charge and village committee members. On November 5, a workshop for NGOs and village committee members from three model villages was held. In the workshop, the basics of arsenic removal technology, details of the field experimental plan as well as preliminary site selection were discussed. The advantages and disadvantages of each type of arsenic removal equipment were explained carefully, especially the operational and maintenance aspects including future cost bearing by caretakers, to avoid any unnecessary confusion. For this purpose, a table to compare the five types of arsenic removal equipment as well as a brief information sheet for each technology, as shown in the following pages, were prepared. The same information was later translated into Bengali and distributed to the participating NGOs and village members. The proposed care taking agreement for arsenic removal experiment was presented and agreed on by concerned DPHE, NGO and village committee members. An example of the agreement is also attached in the following page.

Workshop of Nov. 5th , 2000 in Jessore

Joint visit to Rajnagar Bankabarsi for site selection with village committee members and NGO (KMMS)

Joint visit to Krishuna Chandrapur for site selection with village committee members and NGO (AID)

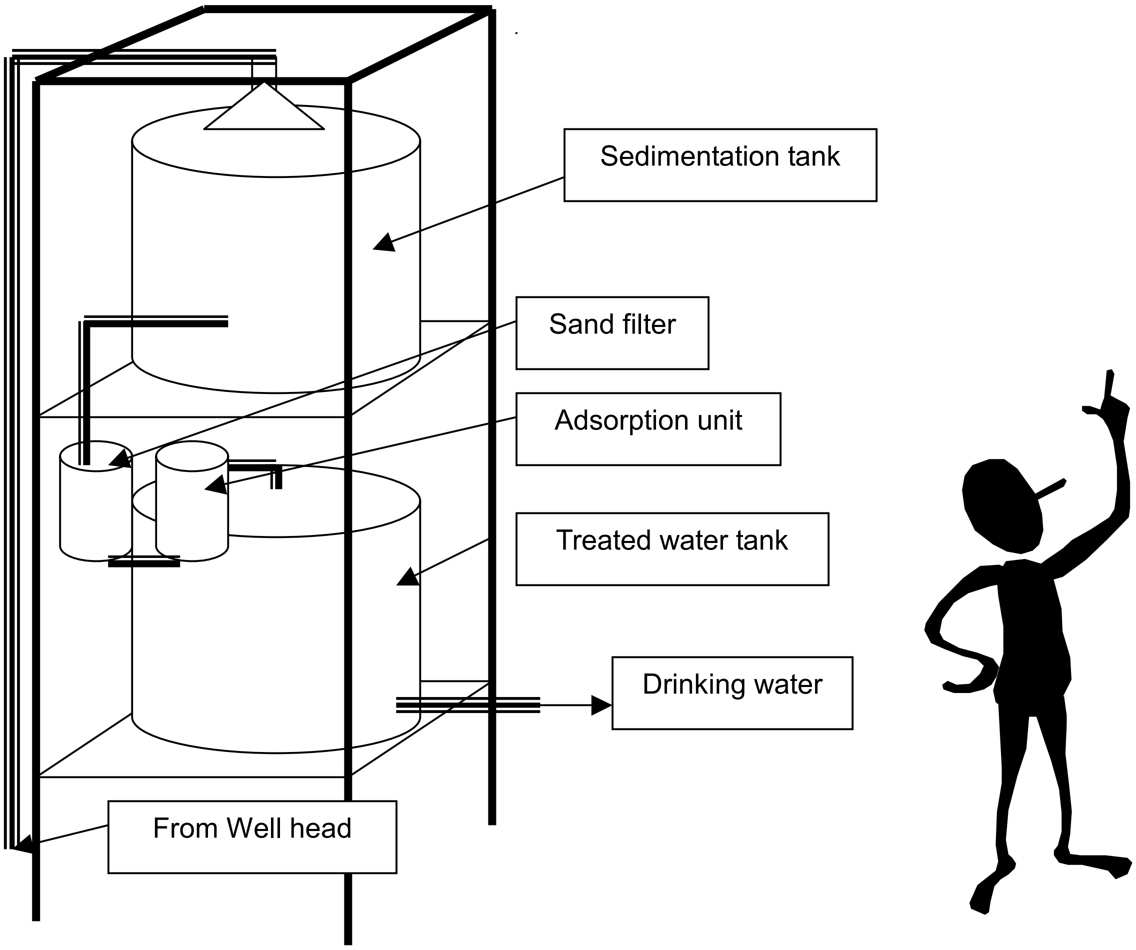
Joint visit to Bara Dudpatila for site selection with village committee members and NGO (ATMABISWAS)



Aeration/ Passive sedimentation/ Filter unit

General:	Remove arsenic by iron in water by co-precipitation.
Operation:	Pump water into the unit in the morning. Aerate water by hand pump some time. Collect water next day and drain the remaining water.
Chemical:	Not required.
Consumable:	Not required.
Maintenance:	Flush water in the unit dairy when draining water. Back flush sand filter once per few days
Running cost:	Zero.
Removal:	Removal depends on water quality. Yet to be studied
Waste:	No sludge
Capacity:	200 to 300l/day

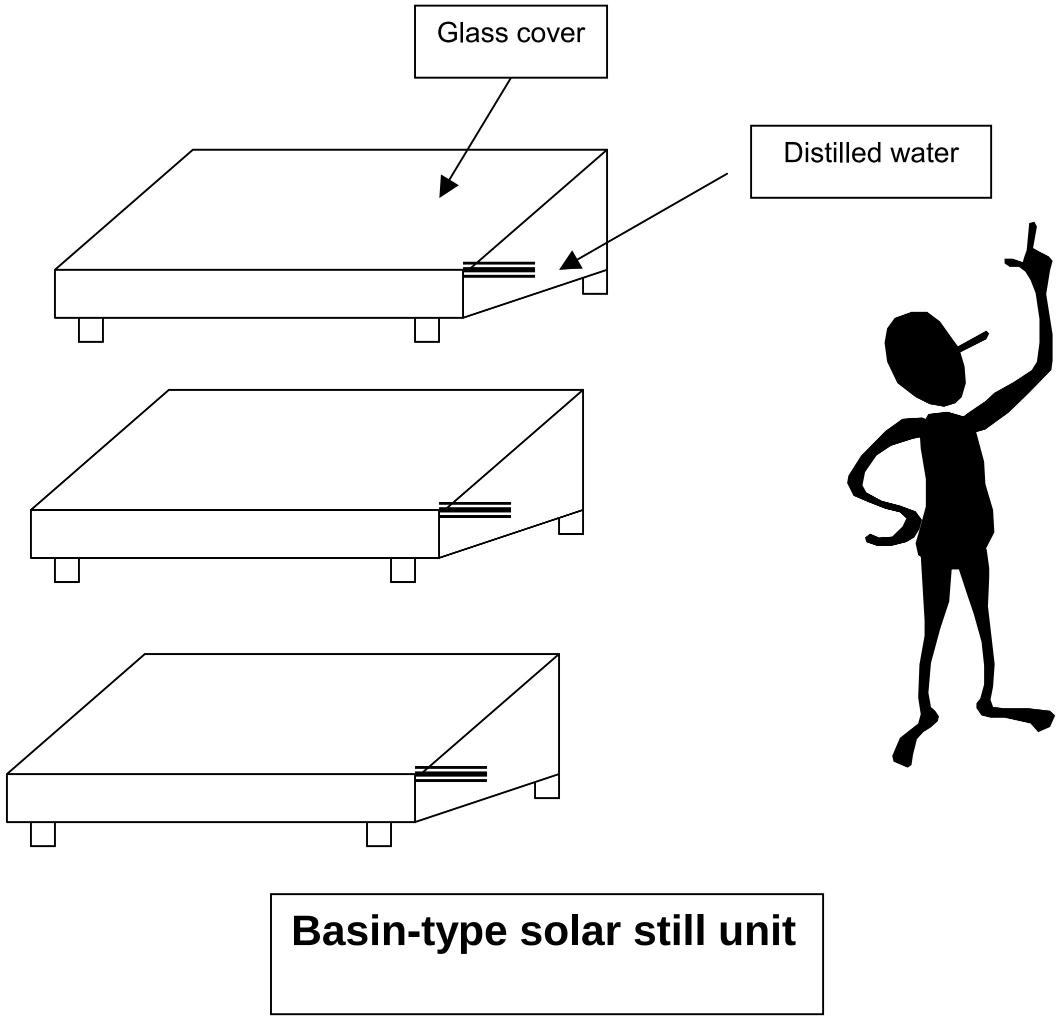
Figure 4.6 Information on passive sedimentation unit



Adsorption unit by Activated Alumina

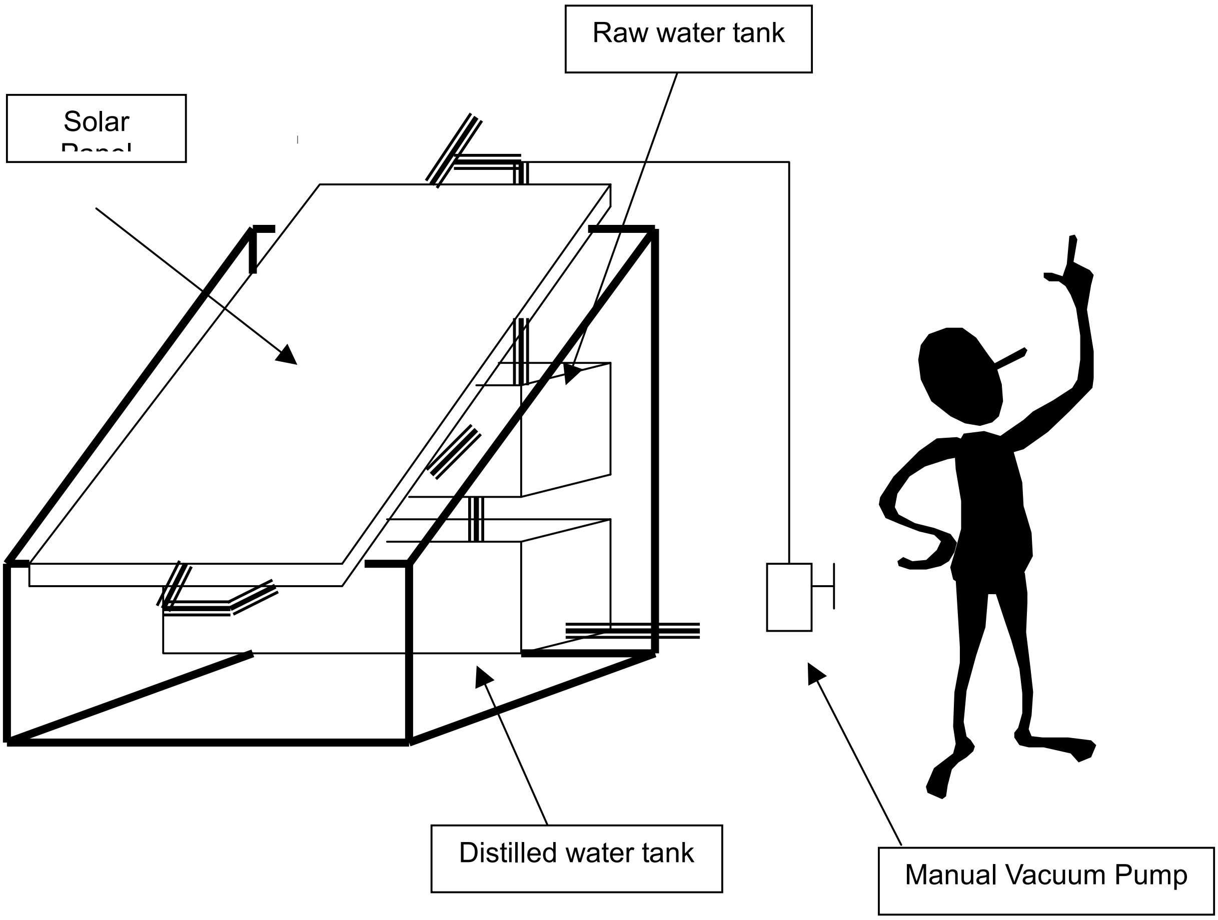
General:	Adsorb arsenic by activated alumina
Operation:	Pump up water to sedimentation tank. Leave for one day.. Some aeration by pump may be required. Open valve at adsorption bed and keep clean water in tank.
Chemical:	Not required.
Consumable:	Activated alumina to be replaced after some time.
Maintenance:	Back flush the sand filter every day. Replace activated alumina few times/year.
Running cost:	Cost of activated alumina approx. 20,000Tk/year
Removal :	Down to below 0.05mg/l. If activated alumina is not replaced at proper timing, arsenic will not be removed.
Waste:	Spent activated alumina should be properly disposed off.
Capacity:	1000l/day

Figure 4.7 Information on activated alumina adsorption unit



General:	Using solar heat to distill water.
Operation:	Pour water into the unit in the morning. Collect water in the evening and drain the remaining water.
Chemical:	Not required.
Consumable:	Not required.
Maintenance:	Flush water in the unit dairy when draining water. Keep glass cover clean and protect from breakage.
Running cost:	Zero.
Removal:	100% removal of arsenic.
Waste:	No sludge
Capacity:	3 to 10l/unit/day x 3 units Output depends on sunlight condition.

Figure 4.8 Information on basin-type solar distillation unit



Vacuum-type solar still unit

General:	Using solar heat to distill water under vacuum.
Operation:	Pour water into the unit in the morning. Operate vacuum hand pump 10 min. twice a day. Collect water in the evening and drain the remaining water.
Chemical:	Not required.
Consumable:	Not required.
Maintenance:	Flush water in the unit dairy when draining water. Keep glass cover clean and protect from breakage.
Running cost:	Zero.
Removal:	100% removal of arsenic.
Waste:	No sludge
Capacity:	10 to 20l/unit/day Output depends on sunlight condition.

Figure 4.9 Vacuum-type solar distillation unit

Table 4.6 Sites Selected for Arsenic Removal Equipment, Krishna Chandrapur

Type	Unit	House.No.	Tube well No.	Arsenic (AAS) mg/l	Note
Double Bucket	7 units	209,210 211.212 213,214	TW-80 TW-81 TW-82 TW-83	0.57 0.63 0.64 0.46	Isolated six Muslim families in northern edge of the village.
Passive sedimentation	1 unit (PS1)	119,120 121,122 123,124 125,126	TW-79	0.52 Fe 5ppm	Small Hindu community in the eastern edge of the village along highway. New tube well was drilled for experiment
Passive sedimentation	1 unit (PS2)	198, 199 200, 201 202, 203 204,205 206,207 208	TW-84	0.16 Fe 10ppm	Small Hindu community in the northern edge of the village. New tube well was drilled for experiment
Passive sedimentation	1 unit (PS3)	23 ID no.120	TW-114	0.20 Fe 5ppm	Southern part of the village. New tube well was drilled for experiment
Activated alumina	1 unit	62A-E ID no.84	TW-94	0.74	Central part of the village. New tube well was drilled for experiment
Solar still vacuum type	1 unit	24 ID no. 119	TW-109	0.19	Southern part of the village. New tube well was drilled for experiment
Solar still basin type	1 unit				

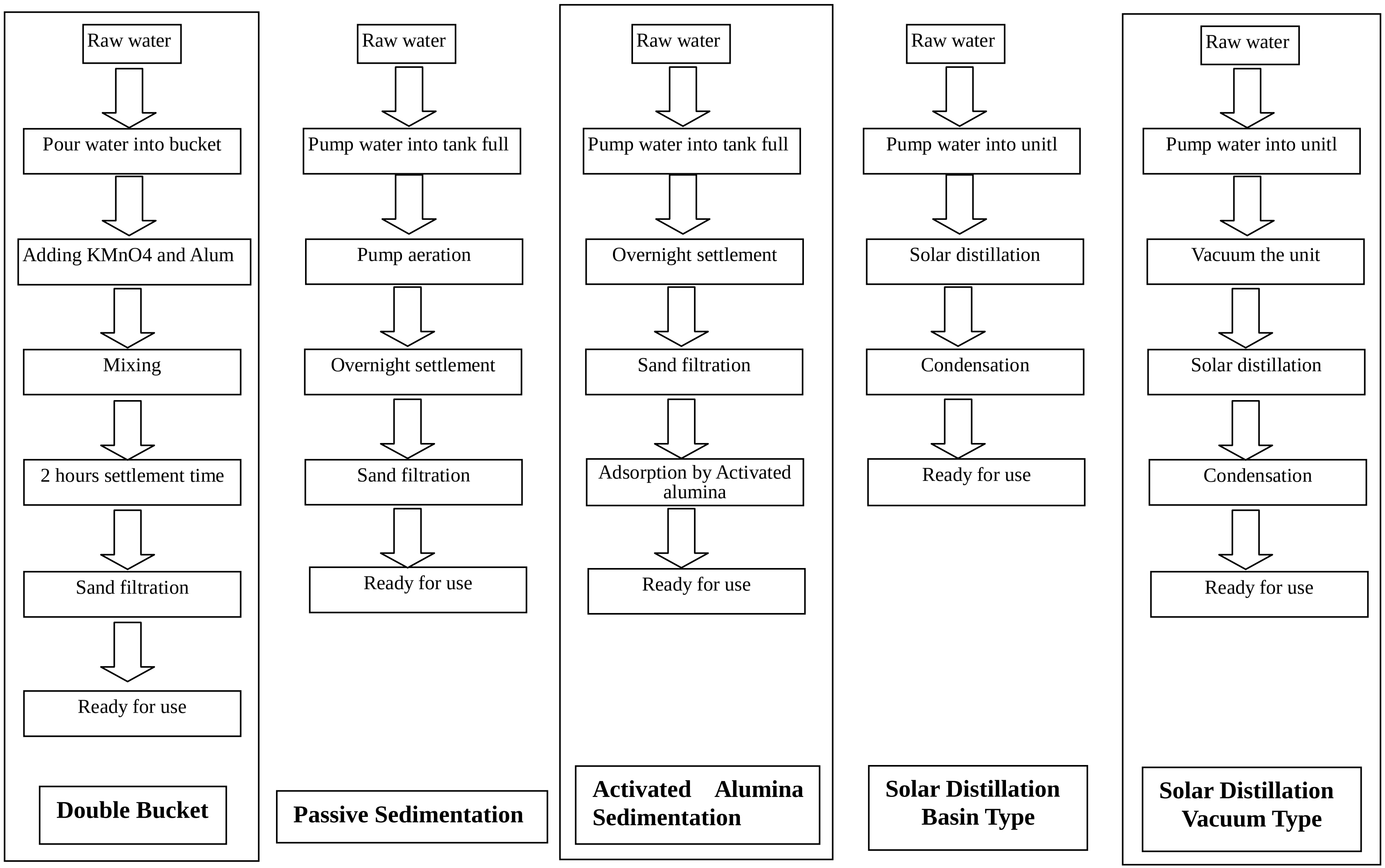


Figure 4.10 Operational flow of five arsenic removal equipment

4.4.2 Bara Dudpatila, Damurhuda, Chuadanga

Situation of arsenic contamination

As shown by the laboratory analytical data in Figure 6.3.5 (Main Report), arsenic contamination of shallow tube wells is limited to the central part of the village. The eastern part and western part of the village does not show arsenic contamination though some isolated tube wells are contaminated. The southern edge of the village is also free from arsenic contamination.

Location of existing and planned deep tube wells

There was no deep tube well provided by DPHE. Improved deep tube wells under the JICA project are planned at the central part of the village.

Site selection

Based on the above situation, the central part of the village was considered the priority area for the arsenic removal experiment. Following the workshop on November 5th, 2000, a joint site visit with DPHE engineer, NGO and village committee members was done on November 8th and 9th, 2000. The final sites for the experiment were determined as follows.

Table 4.7 Sites selected for arsenic removal equipment, Bara Dudpatila

Type	Unit	I.D.No.	Tube well No.	Arsenic (AAS) mg/l	Note
Double bucket	4 units	4,5	TW-168	0.19	Western edge of the village. Isolated contamination.
Double bucket	1 units	8	TW-166	0.14	Western edge of the village. Isolated contamination.
Double bucket	2 units	25	TW-43	0.12	Mid-western part of the village. Isolated contamination. Solar still system to be placed on roof.
Solar still basin type	1 unit				
Passive sedimentation	1 unit (PS1)	45	TW-08	0.27 (Fe 1ppm)	Central part of the village.
Passive sedimentation	1 unit (PS2)	135	TW-158	0.089 (Fe 2ppm)	North-central part o the village.
Passive sedimentation	1 unit (PS3)	124	TW-155	0.23 (Fe 5ppm)	North-central part of the village. New tube well drilled for experiment.
Activated alumina	1 unit	144	TW-108	0.22	East-central part of the village. New tube well drilled for experiment.

Installation of the equipment

After the final selection of installation sites of the equipment, it was found that preliminary work of constructing a lift-up platform for tube wells for the passive sedimentation units as well as drilling a new tube well for the passive sedimentation units and activated alumina unit were required. The lift-up platform was designed to provide easy filling of the water to the sedimentation tank. The design of the platform is shown in the figure below.

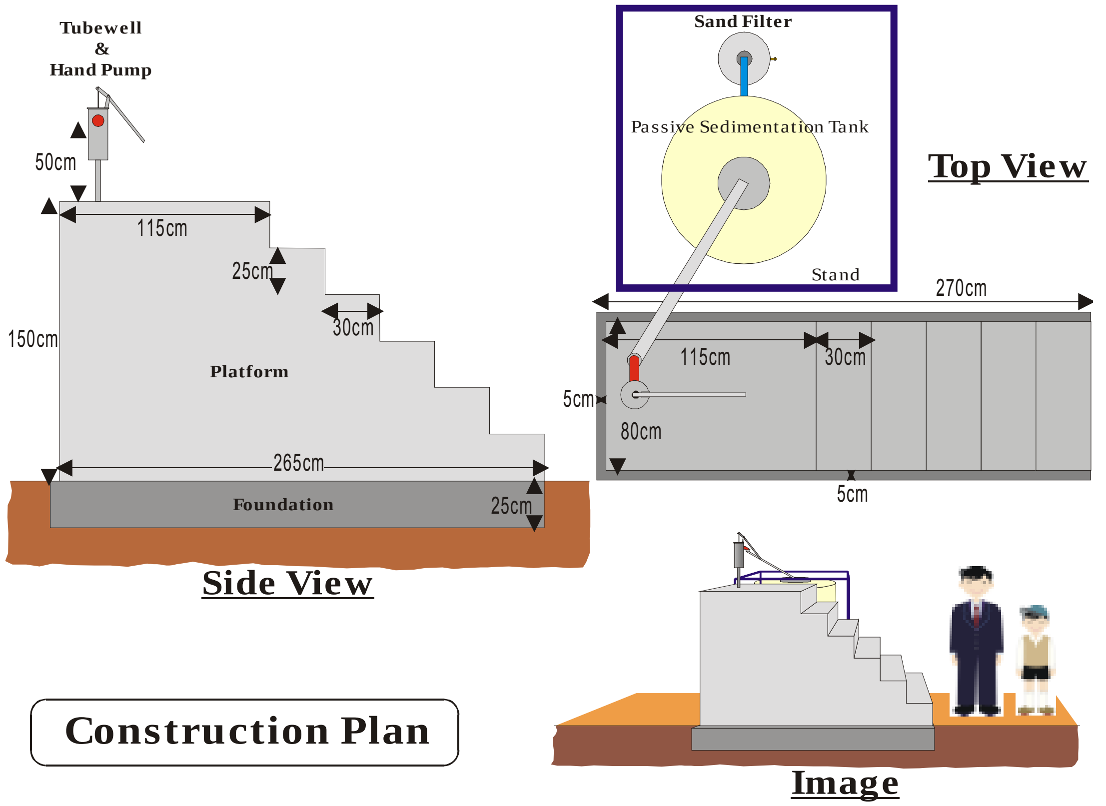


Figure 4.11 Tube well platform for passive sedimentation unit

An electricity connection required to pump up water for activated alumina was also arranged through the Rural Electrification Board.

Installation of the arsenic removal equipment was done as shown in the below table.

Table 4.8 Installation of arsenic removal equipment, Bara Dudpatila

Date	Work done
Nov.10- 21, 2000	Construction of three lift-up platforms for three passive sedimentation units. Drilling of two new tube wells for a passive sedimentation unit and an activated alumina unit.
Nov.25- 27, 2000	Installation of three passive sedimentation units Installation of activated alumina unit. Delivery of seven double bucket units
Dec. 2-4, 2000	Preparation of experiment
Dec. 12-14, 2000	Experiment of arsenic removal by passive sedimentation.
Dec.9 , 2000	Village training for arsenic removal units
Dec.15, 2000	Start routine operation of passive sedimentation and double bucket units .
Jan. 20 -31, 2001	Modification of passive sedimentation units (Inlet system and drainage improvement) Modification of activated alumina unit.(New inlet pipe system with 2 non-return valves. Upgrade of electric pump unit.) Experiment of arsenic removal for activated alumina and passive sedimentation units.
Feb. 1, 2001	Start routine operation of activated alumina unit
Feb.13-15, 2001	Installation of basin type solar still unit. Experiment of basin type solar still unit.

Figure 4.12 shows the map of arsenic removal equipment in Bara Dudpatila, Damurhuda, Chuadanga.

Water quality by field measurement

Based on the field measurement, there was no indication showing any special feature of groundwater quality. As seen in other areas, high iron was observed in most high arsenic water.

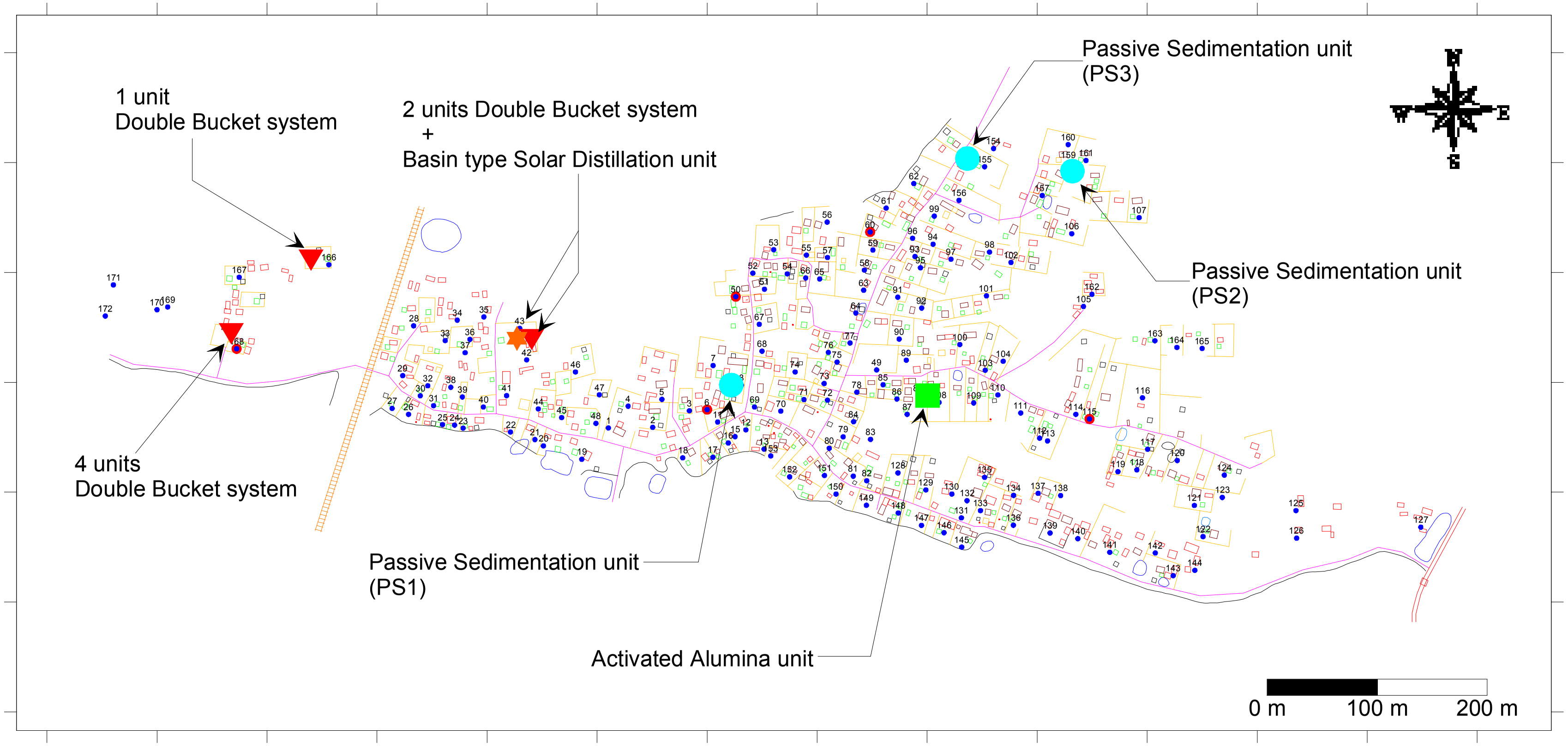


Figure 4.12

Location Map of Arsenic Removal Equipment in Bara Dudpatila Village

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Md. Nawsar Ali

Md. Siddik

Md. Khalis Hossin

Caretakers of double bucket units

User training of double bucket system by JICA team

Care taker - Md. Asraful Alam

Site for passive sedimentation unit (PS1)
Tube well no.08
Before installation (upper)
Installed unit and initial experimental operation (right).

Caretaker - Md. Vasarul Islam

Site for passive sedimentation unit (PS2)
Tube well no.158
Before installation (upper)
Installed unit (right).

Caretaker - Md. Akbar Ali Malita

Site for passive sedimentation unit (PS3)
Tube well no.155
Before installation (upper)
Installed unit and initial experimental operation (right).

Caretaker - Md. Abudus Sattar

Site for activated alumina unit
Near tube well no.108
Before installation (upper)
Newly drilled tube well and installed unit (left).

Caretaker - Md. Khalis Hossin

Site for basin type solar still unit. Roof top of the house. Near tube well no.43
Before installation (upper)
Installed unit (right).
Initial test distillation (lower)

4.4.3 Krishna Chandrapur, Mohespur, Jhenaidah

Situation of arsenic contamination

As shown by the laboratory analytical data in Figure 6.3.9 (Main Report), arsenic contamination of shallow tube well is widespread in most of the area. A fairly large area west of the school and some wells at the southern edge of the village are not contaminated.

Location of existing and planned deep tube wells

The deep tube well currently installed by DPHE is situated in the central part of the village. However, the well was contaminated by arsenic though the concentration is not so high. Improved deep tube wells under the JICA project are planned at the school in the central part of the village.

Site selection

Based on the above situation, the central and the northern parts of the village were considered as the priority area for the arsenic removal experiment. Following the workshop on November 5th, 2000, joint site visits with NGO and village committee members were done on November 6th and 7th, 2000. The final sites for the experiment were determined as follows.

Table 4.9 Sites selected for arsenic removal equipment, Krishna Chandrapur

Type	Unit	House.No.	Tube well No.	Arsenic (AAS) mg/l	Note
Double Bucket	7 units	209,210 211.212 213,214	TW-80 TW-81 TW-82 TW-83	0.57 0.63 0.64 0.46	Isolated six Muslim families in northern edge of the village.
Passive sedimentation	1 unit (PS1)	119,120 121,122 123,124 125,126	TW-79	0.52 Fe 5ppm	Small Hindu community in the eastern edge of the village along highway. New tube well was drilled for experiment
Passive sedimentation	1 unit (PS2)	198, 199 200, 201 202, 203 204,205 206,207 208	TW-84	0.16 Fe 10ppm	Small Hindu community in the northern edge of the village. New tube well was drilled for experiment
Passive sedimentation	1 unit (PS3)	23 ID no.120	TW-114	0.20 Fe 5ppm	Southern part of the village. New tube well was drilled for experiment
Activated alumina	1 unit	62A-E ID no.84	TW-94	0.74	Central part of the village. New tube well was drilled for experiment
Solar still vacuum type	1 unit	24 ID no. 119	TW-109	0.19	Southern part of the village. New tube well was drilled for experiment
Solar still basin type	1 unit				

Installation of the equipment

After the final selection of installation sites of the equipment, it was found that preliminary work of constructing a lift-up platform for tube wells for the passive sedimentation units as well as drilling a new tube well for all passive sedimentation units, activated alumina unit and solar distillation units were required. The electricity supply required to pump up water for activated alumina was not available at the site. Therefore, it is decided to provide a solar cell powered system for the unit. Installation of the arsenic removal equipment was done as shown in the below table.

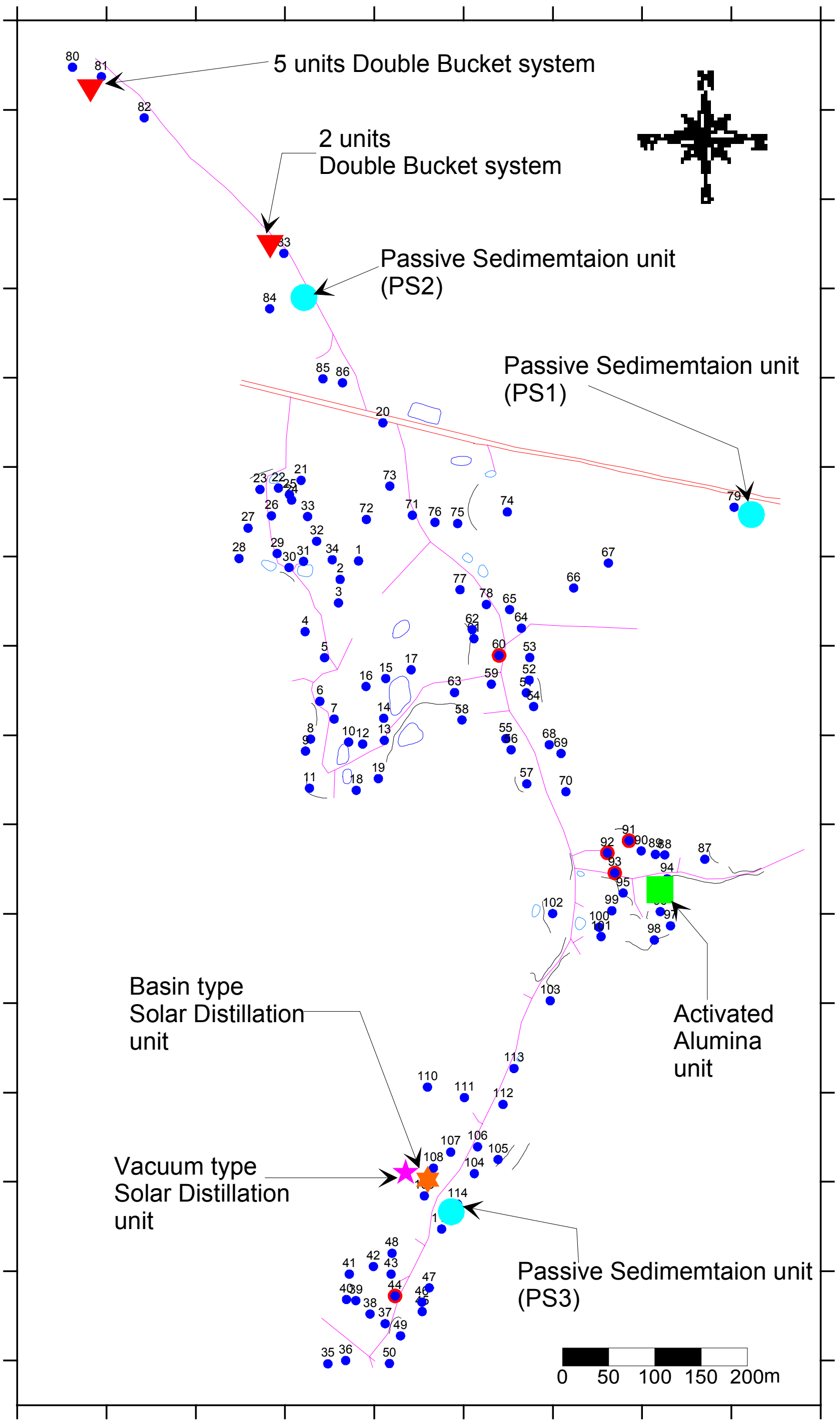
Table 4.10 Installation of arsenic removal equipment, Krishna Chandrapur

Date	Work done
Nov.10- 21, 2000	Construction of four lift-up platforms for three passive sedimentation units and a solar distillation unit. Drilling of five new tube wells for passive sedimentation units, activated alumina unit and solar distillation units.
Nov.22- 24, 2000	Installation of three passive sedimentation units Installation of activated alumina unit. Delivery of seven double bucket units
Dec. 1, 2000	Preparation of experiment
Dec. 3 - 4, 2000	Experiment of arsenic removal by passive sedimentation.
Dec.9 -10, 2000	Village training for arsenic removal units
Dec.10, 2000	Start routine operation of passive sedimentation and double bucket units .
Jan. 28 -30, 2001	Modification of passive sedimentation units (Inlet system and drainage improvement) Installation of solar cell powered pump for activated alumina unit.
Feb. 2-3, 2001	Experiment of arsenic removal for activated alumina and passive sedimentation units. Start routine operation of activated alumina unit
Feb.16-17, 2001	Installation of basin type solar still unit. Experiment of basin type solar still unit.
Late Feb.	Installation and experiment of vacuum type solar still unit (planned)

Figure 4.13 shows the map of arsenic removal equipment in Krishna Chandrapur, Mohespur, Jhenaidah

<u>Water quality by field measurement</u>

Based on the field measurement, there was no indication showing any special feature of groundwater quality. As seen in other areas, high iron was observed in most high arsenic water.



115 Existing Well with TW No.

Existing Well where General Water Quality Sample Collected

Figure 4.13	Location Map of Arsenic Removal Equipment in Krishna Chandrapur Village
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

Md. Abul Hossain

Md. Kutubuddin

Saine,
wife of Md. Nizamuddin

Caretakers of double bucket system in Krishna Chandrapur

Sobi, wife of Md. Abul Kalam

Papila, wife of Md. Azizur Rahman

User training of double bucket units by JICA team

User training of double bucket units by village committee member

Caretaker- Sree Sonzit Kuner

Site for passive sedimentation unit (PS1).
Tube well No. 79
Before installation (upper).
Units installed. New tube well drilled and platform under construction (right)

Caretaker - Jorina

Site for passive sedimentation unit (PS2)
East of tube well no.84
Before installation (upper)
Installation work of the unit and platform construction (right).

Caretaker - Md. Shaha Jamal

Site for passive sedimentation unit (PS3)
South of tube well no.114
Before installation (upper)
Installed unit and initial experimental operation (right).

Caretaker - Mizan Rahman

Site for activated alumina unit
tube well no.94
Before installation (upper)
Installed unit with solar cell powered pump system (right).

Caretaker - Md. Tokkel Doptary

Site for solar distillation units (both basin and vacuum type)
House no.24, ID 119 near tube well no.109
Site before installation (upper)
New tube well and platform constructed (left)
Basin type solar distillation unit installed (lower)

Vacuum type solar distillation unit to be installed by the late February (right)

4.4.4 Rajnagar Bankabarsi, Keshabpur, Jessore

Situation of arsenic contamination

As shown by the laboratory analytical data in the Figure 6.3.9 (Main Report), arsenic contamination of shallow tube well is widespread in all areas of the village except the eastern edge of the village along the main highway.

Location of deep tube wells

The deep tube well currently installed by DPHE is situated at the eastern edge of the village along the main highway. The improved deep tube wells installed under the JICA project are located at the school in the southern part of the village. None of the deep tube wells are contaminated by arsenic.

Site selection

Based on the above situation, the western and the northern parts of the village were considered as priority areas for the arsenic removal experiment. Following the workshop on November 5th, 2000, joint site visits with NGO and village committee members were done on November 11th and 12th, 2000. The final sites for the experiment were determined as follows.

Table 4.11 Sites selected for arsenic removal equipment, Rajnagar Bankabarsi

Type	Unit	I.D.No.	Tube well No.	Arsenic (AAS) mg/l	Note
Double Bucket	4 units	122	TW-01 02	0.33 0.32	Isolated families in northern edge of the village. Hindu families.
Passive sedimentation	1 unit (PS1)	135	TW-24	0.37 Fe 2.0ppm	Western side of the village along the highway
Passive sedimentation	1 unit (PS2)	145	TW-21	0.91 Fe 5.0ppm	Western side of the village along the highway
Passive sedimentation	1 unit (PS3)	NA	TW-23	0.50 Fe 5.0ppm	Western side of the village along the highway
Activated alumina	1 unit	131	No	0.42	New tube well was drilled for experiment
Solar still basin type	1 unit	NA	TW-20	0.71	

Installation of the equipment

After the final selection of installation sites of the equipment, it was found that preliminary work of constructing a lift-up platform for tube wells for the passive sedimentation units as well as drilling a new tube well for the activated alumina unit were required. As for activated alumina, the electricity supply necessary to operate pump was limited to a small area inside the village. Therefore, the site selected with an electricity supply has no existing tube well for this purpose. A new tube well was drilled for the experiment. Installation of the arsenic removal equipment was done as shown in the below table.

Table 4.12 Installation of arsenic removal equipment, Rajangar Bankabarsi

Date	Work done
Nov.18- 27, 2000	Construction of lift-up platform for three passive sedimentation units. Drilling of new tube well for activated alumina unit.
Nov.28- 30, 2000	Installation of three passive sedimentation units Installation of activated alumina unit. Delivery of four double bucket units
Dec. 6, 2000	Preparation of experiment
Dec. 8 - 10, 2000	Experiment of arsenic removal by passive sedimentation. Village training for arsenic removal units
Dec.10 -17, 2000	Test operation for passive sedimentation. Start routine operation of double bucket units .
Jan. 24 -27, 2001	Modification of passive sedimentation units (Inlet system and drainage improvement) Modification of activated alumina unit. (New inlet pipe system with 2 non-return valves. Upgrade of electric pump unit.) Experiment of arsenic removal for activated alumina and passive sedimentation units. Start routine operation of activated alumina unit.
Feb. 4 - 6, 2001	Experiment of passive sedimentation units. (Use of KmnO4)
Feb.17-18 , 2001	Installation of basin type solar still unit. Experiment of basin type solar still unit.

Figure 4.14 shows the map of arsenic removal equipment in Rajnagar Bankabarsi, Keshabpur, Jessore.

Water quality by field measurement

According to the field measurement data, shallow tube well water in Rajnagar Bankabarsi is characterized by its high EC value, over 200 ms/m. This is approximately three times higher than the other model villages. From its geographical location, an influence of saline water intrusion is expected. The taste of water itself is also slightly salty, though the strong smell and taste of dissolved iron dominates. Its water quality will be discussed in more detail in the next section.

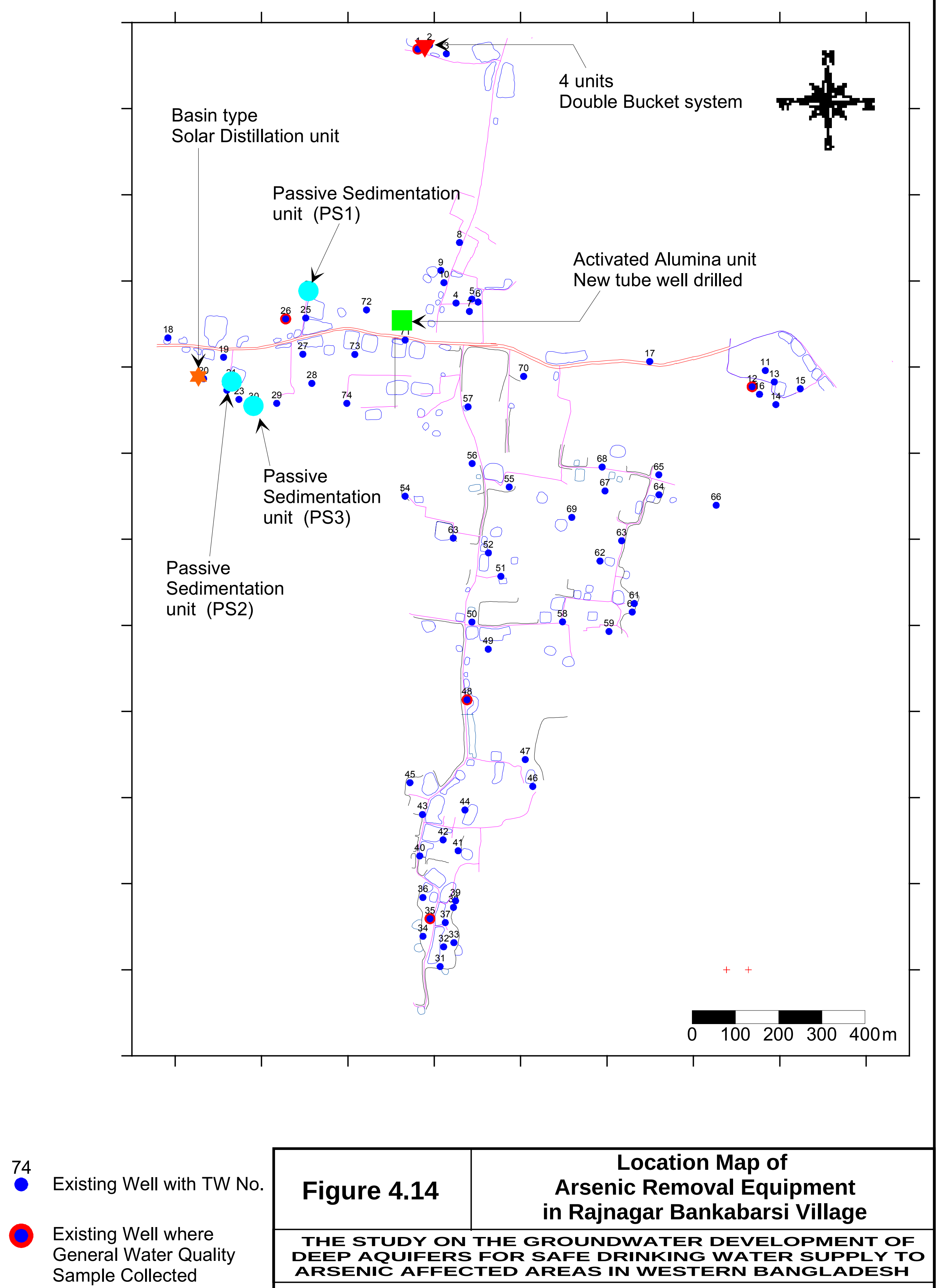


Figure 4.14	Location Map of Arsenic Removal Equipment in Rajnagar Bankabarsi Village
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

Double bucket system 4 units
Caretaker - Barum Kumar Debnath
ID No. 122
Tube well No. TW-01 and 02

Site before installation of passive sedimentation unit
Care Taker - Abudul Latit Daffadan
ID. No.135
Tube well No. TW-24

After construction of platform and installation of passive sedimentation unit (PS1)

Caretaker- Moslam Uddin

Before and after installation.
Site for passive sedimentaion unit (PS2)
I.D. No. 145
Tube well no. TW-21

Caretaker - Mokam Kha

Before and after installation.
Site for passive sedimentaion unit (PS3)
I.D. No. ?
Tube well no. TW-23

Caretaker - Ershadali Moral

Before and after installation.
Site for activated alumina unit
I.D. No. 131
New tube well drilled for experiment.

Before and after installation.
Site for basin type solar distillation unit
Near tube well no. 20

4.5 Field Test

4.5.1 Methodology

After installation of the arsenic removal equipment, the performance was measured during the duration of the project. For this purpose, raw tube well water before the treatment and the treated water from the equipment were measured and sampled.

Field measurement parameters were as follows.

EC, ORP, pH, Temp. As (by AAN field kit) and Fe2+ (by pack test)

Two types of sampling programs were done. Comprehensive sampling was for 27 analytical parameters. Arsenic sampling was for only arsenic testing by AAS. Detail of the parameters, sampling procedure as well as quality control measures were the same as for tube well sampling as discussed in Chapters 4 and 5 in Main Report.

During the test, operational and maintenance issues were also examined through communication with NGO and the village caretakers. Data on the 27 parameters at the laboratory to investigate the influence of water quality on arsenic removal will be discussed in detail in the supporting report. The discussion in the main report will be focused on arsenic data. The table below summarizes the water quality character of the three villages. The data consists of the statistics of all raw water measurement during the arsenic removal experiment

Table. 4.13 Water quality of three villages

Village		Arsenic mg/l	EC mS/m	pH	ORP mV	Fe^{2+} mg/l
Bara Dudpatila	Average	0.26	68	7.3	190	3.1
	min.	0.045	39	7.1	81	0.5
	Max	0.47	100	7.5	340	10
	Standard deviation	0.14	21	0.11	77	2.4
Krishna Chandrapur	Average	0.22	83	7.2	130	4.1
	min.	0.041	40	7	-20	0.2
	Max	0.43	130	7.5	270	10
	Standard deviation	0.13	21	0.15	71	2.7
Rajnagar Bankabarsi	Average	0.49	260	7.2	110	3.3
	min.	0.29	230	7.1	89	1
	Max	1.4	280	7.3	140	5
	Standard deviation	0.28	12	0.072	16	1.7

The results of the test will be discussed in the following section for each type of arsenic removal equipment.

4.5.2 Double bucket system

The double bucket system is one of the most extensively used systems in the field, mainly under the DPHE/DANIDA project at Noakhali district. Good removal of arsenic was reported. Therefore, the operational aspect of the system was focused on in the experiment. Due to the nature of household systems, complete monitoring of the whole unit is, from a practical viewpoint, impossible. How to secure adequate operation by each household, especially the handling of chemicals, may be a key issue for the system. Taking that into consideration, two types of chemical forms, i.e. conventional powder form and tablet form, were prepared for testing.

In the field test, samples from 2 units from each village were measured. In spite of the initial idea as noted above to test the operational aspect of the system, the results from the field experiment look quite confusing with regard to their arsenic removal efficiency.

The first testing was done immediately after the delivery and user training at each village in December, 2000. Initially, only the powder form of the chemical was delivered. The results of the field measurement as well as the laboratory data for arsenic are shown in the following table.

Table 4.14 Initial field test of Double Bucket System

Village	Unit	Chemical	Water	Date	As (field) Mg/l	As (AAS) mg/l	PH	ORP (mv)	EC MS/m	Fe2+ mg/l	As removal
Bara Dudpatila	DB1		Raw	12/13/00	0.07	0.13	7.29	126	39.2	5	93%
		Powder	Treated	12/13/00	0	0.0094	7.04	255	49.8	0	
	DB2		Raw	12/13/00	0.6	0.18	7.13	157	53.5	5	22%
		Powder	Treated	12/13/00	0.02	0.14	7.28	225	60.1	0	
Krishna Chandrapur	DB1		Raw	12/10/00	1	0.29	7.13	164	89.2	5	55%
		Powder	Treated	12/10/00	0.2	0.13	7.04	167	93.3	0	
	DB2		Raw	12/10/00	1	0.43	7.14	93	100	5	42%
		Powder	Treated	12/10/00	0.3	0.25	7.21	156	101	0	
Rajanangar Bankabarsi	DB1		Raw	12/15/00	0.1	0.4	7.15	122	266	2	10%
		Powder	Treated	12/15/00	0	0.36	7.25	321	266	0	
	DB2		Raw	12/15/00	0.8	0.42	7.14	120	265	2	2%
		Powder	Treated	12/15/00	0.03	0.41	7.14	319	268	0	

All units, except DB1 (Double Bucket No.1) unit in Bara Dudpatila, failed to reduce the concentration of arsenic to below 0.05 mg/l. It seems that the EC value has a reverse correlation with arsenic removal efficiency as shown in Figure 4.15, if excluding DB2 unit in Bara Dudpatila.

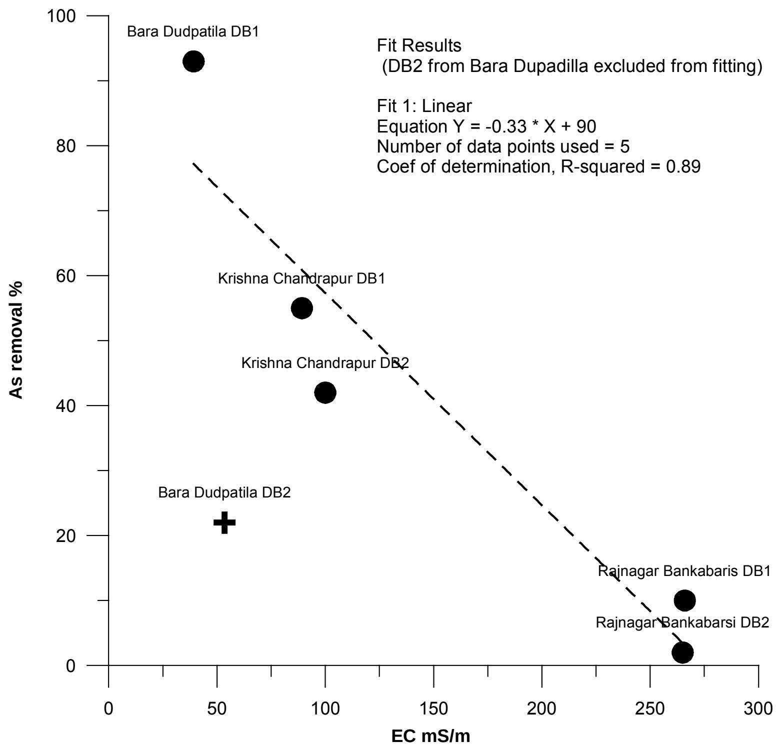


Figure 4.15 Correlation of EC and As removal %

If such a correlation exists, the DB2 data of Bara Dudpatila might reflect some sort of misoperation during the initial testing.

The high EC value implies that there are more competing ion species in the water, which may prevent the oxidation of arsenic and/or co-precipitation with alum. Keeping this possibility in mind, the second round testing was done in January 2001 at Rajanargar Bankbarsi where arsenic removal rates were lowest and EC values were highest. This time, the amount of chemical to be added was increased 2 and 3 times from the original recommendation by DPHE/DANIDA.

Table 4.15 Test data of increased chemical dosing

Village	Unit	Chemical	Water	Date	As (field) mg/l	As (AAS) mg/l	PH	ORP (mv)	EC MS/m	Fe2+ mg/l	As removal
Rajnargar Bankbarsi	DB1		Raw	1/26/01	0.9	0.43	7.14	137	272	5	
		Powder Normal	Treated	1/26/01	0.2	0.19	7.18	118	270	0.2	56%
		Powder 3 times	Treated	1/26/01	0.06	0.042	6.69	307	290	0	90%
	DB2		Raw	1/26/01	0.3	0.36	7.11	131	273	5	
		Powder 2 times	Treated	1/26/01	0.05	0.018	6.73	273	280	0	95%

From the data, two findings were observed. Firstly, arsenic removal of DB1 using a nominal amount of chemical was improved from 10 to 56%. This may be due to the adequate operation this time. The initial test was done under the operation by the caretakers while the test this time was done by the project staff because of unusual the dosing of chemicals. The exact nature of the misoperation in the initial test is not clear at this time, but may be one of the followings: underdosing of chemical, inadequate mixing, inadequate settling time, and/or inadequate filtration. Secondly, arsenic removal by increased dosing of chemical was greatly improved so that the final concentration of arsenic was below 0.05 mg/l. The effect of the high dosages of potassium permanganate on water quality was a concern. However, the resulting pH and ORP were in the range of 6.69 to 6.73 and 273 to 307mV respectively, and the dose not seems to impose an immediate health effect. However, a detailed chemical analysis of the water is now underway to investigate the water quality issue of higher dosing of chemicals. In conclusion, the data supported the hypothesis of the problem noted above as competing ion species prevent arsenic removal either by preventing oxidation or co-precipitation.

In the next step, the tablet-form of the chemicals was introduced to two villages, i.e. Bara Dudpatila and Krishna Chandrapur. The operation using tablets was done by the caretakers and the project staff sampled water from the bucket. At first, there were complaints from the caretakers that the tablet did not easily dissolve in the water and the caretakers had to mix the contents of the bucket for long time. The analytical data also showed less arsenic removal than the initial test with the powder form.

Table 4.16 Test data of tablet form

Village	Unit	Chemical	Water	Date	As (field) mg/l	As (AAS) mg/l	pH	ORP (mv)	EC MS/m	Fe2+ mg/l	As removal
Bara Dudpatila	DB1		Raw	1/31/01	0.02	0.14	7.45	262	41.6	2	46%
		Tablet	Treated	1/31/01	0.03	0.075	6.99	177	44.3	0	
	DB2		Raw	1/31/01	0.2	0.21	7.27	340	67	1	48%
		Tablet	Treated	1/31/01	0.01	0.11	7.08	263	66.8	0	
Krishna Chandrapur	DB1		Raw	2/3/01	0.2	0.21	7.08	NA	92.8	5	29%
		Tablet	Treated	2/3/01	0	0.15	6.98	NA	91	1	
	DB2		Raw	2/3/01	0.3	0.34	7.04	NA	98.9	2	21%
		Tablet	Treated	2/3/01	0	0.27	7.11	NA	100.4	0	

During the test period, neither the arsenic concentration nor total water quality represented by EC value varied significantly as shown in Figure 4.16. Therefore, the lower removal rate cannot be related to the change in the original water quality. Probably, the tablets were not completely dissolved during the operation.

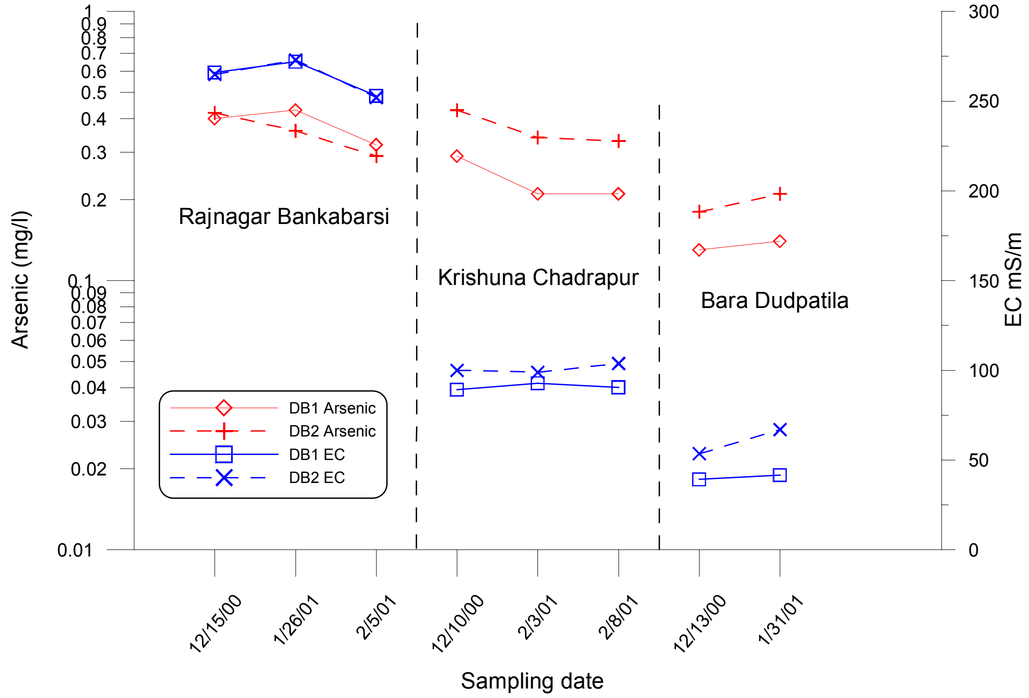


Figure 4.16 Variation of Arsenic and EC by sampling date

Some of the caretakers, at the moment, have started to refuse to use the tablet form of the chemical. In spite of the initial aim for easier operation, the tablet form prepared for the experiment failed to achieve its target.

Because of the successful result of increased chemical dosing at Rajnagar Bankabarsi, the tests with increased dosing were continued at both Krishna Chandrapur and Rajnagar Bnakabarsi.

Table 4.17 Test data of increased chemical dosing -2-

Village	Unit	Chemical	Water	Date	As (field) mg/l	As (AAS) mg/l	PH	ORP (mv)	EC MS/m	Fe2+ mg/l	As removal
Rajnagar Bankabarsi	DB1		Raw	2/5/01	0.8	0.32	7.22	107	253	2	76%
		Powder 2 times	Treated	2/5/01	0.03	0.078	6.8	295	283	0	
	DB2		Raw	2/5/01	1	0.29	7.25	130	252	2	86%
		Powder 2 times	Treated	2/5/01	0	0.04	6.73	296	291	0	
Krishna Chandrapur	DB1		Raw	2/8/01	0.4	0.21	7.1	103	90.5	10	66%
		Powder 2 times	Treated	2/8/01	0.08	0.072	6.91	280	93.5	0.5	
	DB2		Raw	2/8/01	0.4	0.33	7.08	110	103.8	5	39%
		Powder 2 times	Treated	2/8/01	0.1	0.2	6.97	282	97	0.2	

At Rajnagar Bankabarsi, the result was not as good as the previous test. However, removal was accomplished to below 0.05 mg/l for DB2. DB1 was at 0.078 mg/l, but it was not so far from the target of 0.05 mg/l. In contrast, at Krishna Chandrapur, removal was not good at all. This was surprising because the EC value, considered as an indicator of the arsenic removal difficulty of the raw water quality, was much lower in Krishna Chandrapur than in Rajnagar Bankabarsi. This result suggests that EC cannot be a universal indicator and also the increased dosing of chemical cannot be a solution for all cases.

Some of the sample water from the treated bucket was found to be not so clear. In one case, the inside of the bucket (green) was observed and leakage of alum sediment through sand filter was found. It was probably because of a lack of washing of the sand filter. Such alum sediment contains high arsenic, thus the treated water will also show a high arsenic value.

In order to evaluate the leakage problem, a filtration experiment was planned. Samples taken from the treated bucket were further filtered by 0.45μm pore paper, so that any leaked alum particles larger than 0.45μm would be removed from the samples. Then the samples were compared with non-filtered samples. The test was done at Bara Dudpatila and Krishan Chandrapur as shown in Table 4.18. The test of increased dosing was also combined.

Table 4.18 Test data of increased dosing of chemical and additional filtration

Village	Unit	Chemical	Water	Date	As (field) Mg/l	As (AAS) mg/l	PH	ORP (mv)	EC MS/m	Fe2+ Mg/l	As removal
Bara Dudpatila	DB2		Raw	2/15/01	0.6	0.24	7.51	122	51.9	2	
		Powder normal	Treated	2/15/01	0.5	0.14	7.23	230	66.2	0	42%
		Powder normal	Treated + filtered	2/15/01	NA	0.12	NA	NA	NA	NA	50%
		Powder 2 times	Treated	2/15/01	0.05	0.072	7.15	218	68	0	70%
		Powder 2 times	Treated + filtered	2/15/01	NA	0.063	NA	NA	NA	NA	74%
Krishna Chandrapur	DB1		Raw	2/17/01	0.5	0.26	7.2	126	90.5	5	
		Powder 2 times	Treated	2/17/01	0.05	0.13	7.01	269	93.2	0.5	50%
		Powder 2 times	Treated + filtered	2/17/01	0.1	0.089	7.11	256	41(?)	0.2	66%
	DB2		Raw	2/17/01	0.8	0.42	7.25	138	101.3	2	
		Powder 2 times	Treated	2/17/01	0.6	0.29	7.02	297	49(?)	1	31%
		Powder 2 times	Treated + filtered	2/17/01	0.6	0.26	7.24	273	29(?)	0.2	38%

The result showed slight but consistent improvement of arsenic removal by additional filtration. At this stage, it is difficult to determine if the arsenic detected in the samples was a completely dissolved species or particles smaller than 0.45μm. However, from an operational viewpoint, the sand filter probably cannot remove particles smaller than 0.45μm. Therefore, the low arsenic removal rate is due to a technical problem rather than misoperation by the caretakers.

As a hardware problem, several village caretakers reported leakage from cracking in the bucket. Out of the 18 units delivered (36 buckets), 12 buckets has been replaced for this reason. Most of the cracking was at the top/bottom of the valve connection area. Some improvement is required for this problem.

Due to the problem of arsenic removal, use of the system was suspended after April, 2001.

In summary, the findings from the field test of the double bucket system are as follows.

- Removal of arsenic is not consistent and varies by water quality.
- Water quality varies not only between villages but also within villages.
- One indicator of water quality preventing good removal is high EC.
- Increased dosing of chemical improved the removal rate from high EC water at Rajnagar Bankabarsi, but not from water at Krishna Chanrapur.
- Tablet form of the chemical does not dissolve easily.
- Possibility of leakage from sand filter exists.
- Arsenic remained as a dissolved species or as particles smaller than 0.45μm.
- Buckets are vulnerable to cracking.

4.5.3 Passive sedimentation system

The passive sedimentation system can be the most economical arsenic removal technology. Some reported on effectiveness of the method, but there is no solid technical information regarding its effectiveness, limitations or pre-requisites for application. Therefore, the purpose of the experiment is to define the effectiveness and limitations under given conditions. For this purpose, three units per village were installed to observe various raw water quality conditions.

The major factors considered as control for arsenic removal was ORP (oxidation-reduction potential), competing ion species, iron concentration and filtration. During the first testing immediately after installation of the units, the continuous monitoring of ORP and pH in the oxidation/sedimentation tank was conducted. Figure 4.17 shows the change of pH and ORP of the units in Krishna Chandrapur and in Rajnagar Bankabarsi.

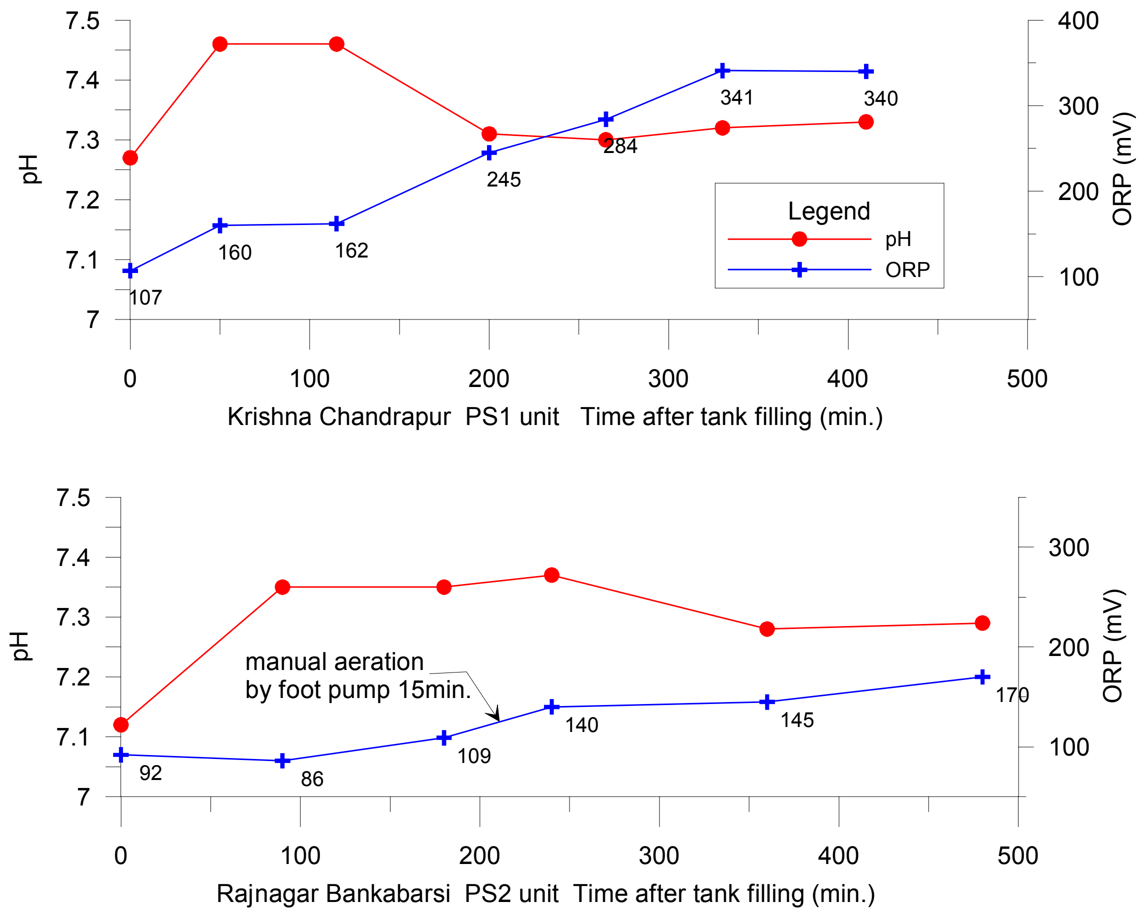


Figure 4.17 pH and ORP monitoring of passive sedimentation units

It was found that changes in pH were similar in the two villages, but changes in ORP were not. The increase in pH at the initial stage may be due to the release of carbon dioxide and subsequent change in the carbonate equilibrium in water. Approximately 8 hours after tank filling, ORP of Krishna Chanrdapur village was as high as 340mV while that of Rajnagar Bankabarsi was 170mV. The original (at time zero) ORP was almost the same for the two cases (92 and 107mV). The slow oxidation in Rajnagar Bankabarsi may be due to its water quality characterized by high EC values.

The ceramic housing for sand filtration has a diameter of 40cm. The thickness of the sand layer in the filter housing was 175 mm. The initial flow rate with the tap valve fully opened was 6 liters per minute from the filter. This flow rate is equivalent to 92m/day speed in the sand layer, which is within the normal rate for sand filtration.

Based on the data, the operating procedure for the test was set as follows.

1) Fill up the tank in the late afternoon near sunset with pumping aeration.
2) Leave water overnight.
3) Start using water after sand filtration in the morning.

This procedure will provide oxidation/sedimentation time longer that 12 hours.

Table 4.20 and Figure 4.18 show the test data of three villages. Figure 4.18 shows the arsenic concentration of treated water in the bar chart with the scale in the right axis and removal % in the line graph with the scale in the left axis. Concentrations of arsenic in treated water were lower than standard for all units in Krishna Chandrapur and PS2 unit in Bara Dudpatila in most of the testing. However, other units shows considerably high arsenic in treated water. Raw inlet water from the tube wells for those units in Krishna Chandrapur and PS2 unit in Bara Dudpatila were relatively low in arsenic compared with the others.

Arsenic removal efficiency varied considerably by village, by units within the same village and by the date of sampling for the same unit. As discussed before for the variation in the removal rate of the double bucket system, fluctuation of inlet water quality is not the reason. One of the major reasons for such variation may be the different operating conditions of the units by the caretakers as well as the project staff. Some of the possible misoperations are as follows:

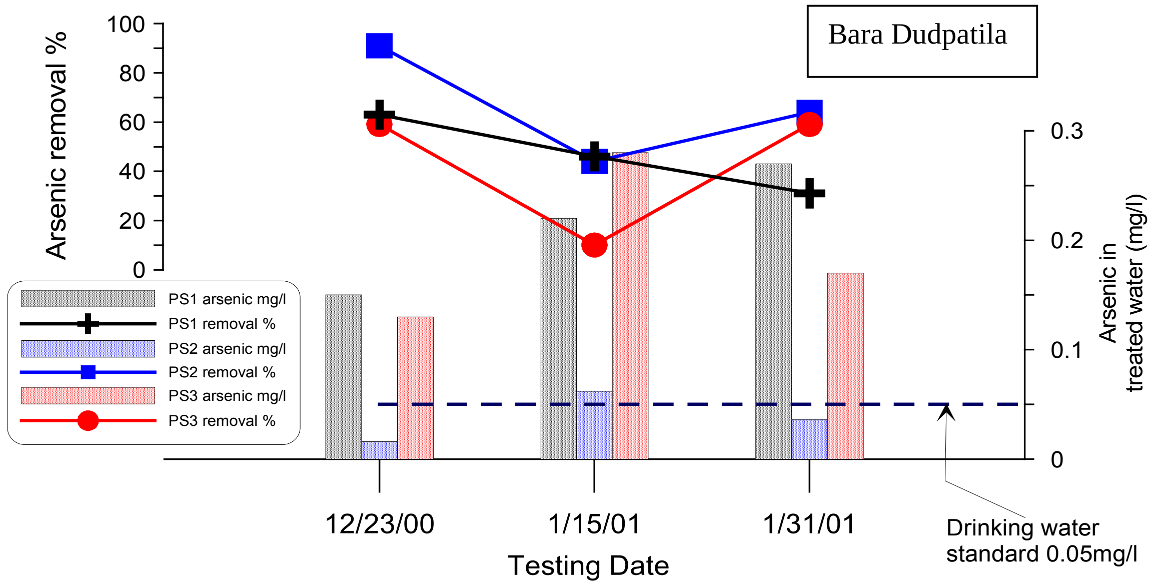
- Constant feeding of water into tank during daytime use. (refer to photo)
- Water feeding from the top of the sand filter and disturbance of sand layer. Possible short-cut in filtration. (refer to photo)
- Lack of cleaning of sand filter and tank.

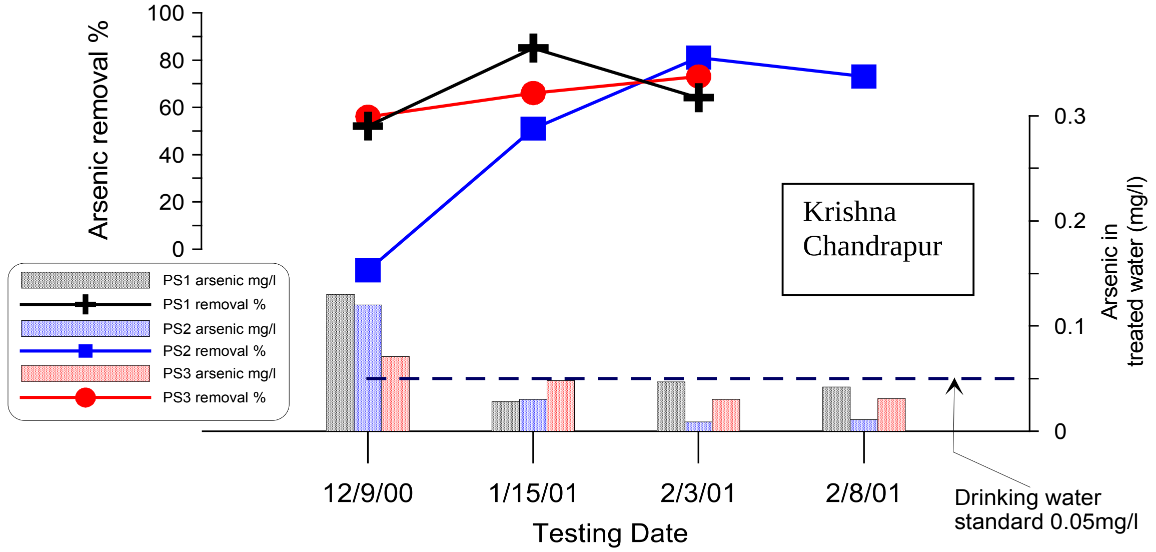
Operation of the units was left to the caretakers at the initial period. Then at a later period, care was taken to assure the proper condition of the units at the time of sampling by the project staff. A relatively stable and better removal rate (> 60%) of the test done after late January, except that of Rajnagar Bankabarsi, supports the assumption. In such a case, the technical capability of the system shall be evaluated using some of the better results when operation was adequate, while variation in the results shall be considered as operational issues of the system.

Table 4.19 Test Data of Passive Sedimentation in Three Villages

Table 7.2.20 Test data of passive sedimentation in three villages

Village	Unit	Water	Date	As (field) mg/l	As (AAS) mg/l	pH	ORP (mV)	EC (mS/m)	Fe^{2+} mg/l	As removal
	PS1	Raw	12/13/00	1	0.4	7.21	98	97.1	1	
		Treated	12/13/00	0.03	0.15	7.38	273	102.8	0	63%
	PS2	Raw	12/13/00	0.03	0.17	7.46	81	66.1	1	
		Treated	12/13/00	0	0.016	7.65	147	55	0	91%
	PS3	Raw	12/13/00	1	0.32	7.24	107	71.1	5	
		Treated	12/13/00	0	0.13	7.43	264	55.9	0	59%
	PS1	Raw	1/15/01	0.1	0.41	7.13	174	100.9	2	
		Treated	1/15/01	0	0.22	7.46	125	61.4	0	46%
Bara Dudpatila	PS2	Raw	1/15/01	0.2	0.11	7.18	234	49.5	5	
		Treated	1/15/01	0	0.062	7.64	119	50.2	0	44%
	PS3	Raw	1/15/01	0.03	0.31	7.37	190	44.8	5	
		Treated	1/15/01	0	0.28	7.53	108	44.8	0	10%
	PS1	Raw	1/31/01	NA	0.39	7.22	291	97.9	0.5	
		Treated	1/31/01	0	0.27	7.44	175	95.6	0	31%
	PS2	Raw	1/31/01	NA	0.1	7.28	181	65.3	2	
		Treated	1/31/01	0	0.036	7.39	335	65.8	0	64%
	PS3	Raw	1/31/01	NA	0.41	7.2	259	73.1	2	
		Treated	1/31/01	0	0.17	7.27	329	80.5	0	59%
	PS1	Raw	12/9/00	0.01	0.27	7.27	107	65.4	2	
		Treated	12/9/00	0	0.13	7.37	341	64.2	0	52%
	PS2	Raw	12/9/00	0.01	0.11	7.27	110	89.9	0.2	
		Treated	12/9/00	0	0.12	7.33	373	80.2	0	-9%
	PS3	Raw	12/9/00	0.2	0.16	7.16	110	86.2	5	
		Treated	12/9/00	0	0.071	7.33	324	82.2	0	56%
	PS1	Raw	1/15/01	0	0.19	7.5	266	51.2	2	
		Treated	1/15/01	0	0.028	7.67	426	49.6	0	85%
	PS2	Raw	1/15/01	0	0.061	7.5	-20	91.2	2	
		Treated	1/15/01	0	0.03	8.02	232	88.2	0	51%
Krishna Chandrapur	PS3	Raw	1/15/01	0	0.14	7.36	227	60	5	
		Treated	1/15/01	0	0.048	8.38	270	60.8	0	66%
	PS1	Raw	2/3/01	0	0.13	7.14	NA	66.3	2	
		Treated	2/3/01	0	0.047	7.35	NA	58	0	64%
	PS2	Raw	2/3/01	0.1	0.046	7.16	NA	90.7	2	
		Treated	2/3/01	0	0.0087	7.38	NA	88.8	0	81%
	PS3	Raw	2/3/01	0.2	0.11	7.28	NA	80.5	2	
		Treated	2/3/01	0	0.03	7.46	NA	79.9	0	73%
	PS1	Treated	2/8/01	0	0.042	7.62	379.967	54.3	0	
	PS2	Raw	2/8/01	NA	0.041	7.16	132.967	40.2	5	
		Treated	2/8/01	0	0.011	7.64	374.967	64.6	0	73%
	PS3	Treated	2/8/01	0	0.031	7.3	141.967	79.2	0	
	PS1	Raw	12/14/00	NA	1.2	NA	NA	NA	NA	
		Treated	12/14/00	NA	0.29	NA	NA	NA	NA	76%
	PS2	Raw	12/14/00	1	1.4	7.12	92	272	5	
		Treated	12/14/00	0.3	0.39	7.3	220	250	0	72%
	PS3	Raw	12/14/00	0.8	0.5	7.1	89	271	5	
Rajnagar Bankabarsi		Treated	12/14/00	0.5	0.38	7.45	190	269	0	24%
	PS1	Raw	1/27/01	0.9	0.4	7.09	91	261	5	
		Treated	1/27/01	0	0.21	7.51	211	259	0	48%
	PS2	Raw	1/27/01	0.5	0.45	7.17	122	273	2	
		Treated	1/27/01	0.03	0.29	7.45	85	271	0	36%
	PS3	Raw	1/27/01	1	0.4	7.15	98	279	5	
		Treated	1/27/01	0.2	0.34	7.52	307	272	0	15%





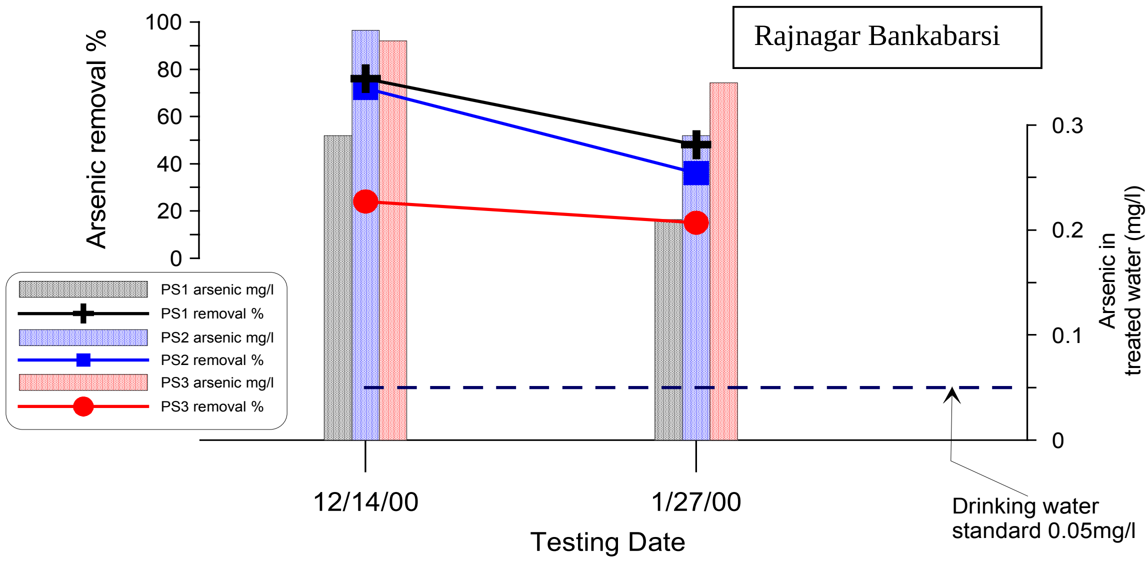


Figure 4.18 Result of passive sedimentation units

Figure 4.19 shown below is the histogram of the removal efficiency by the passive sedimentation system. Distribution is almost normal with an average of 53% and standard deviation of 24%. Considering the fact that most of the lower removal rate were caused by misoperation, it is reasonable to expect (average + 1 standard deviation), that is approx. 75%, as the removal rate for a properly operated unit for inlet water with suitable quality. If we tentatively set the expected rate for the system at 75%, then the highest arsenic concentration applicable is 0.2 mg/l to get 0.05 mg/l in the treated water. In fact, raw inlet water for all units in Krishna Chandrapur and PS2 unit in Bara Dudpatila fell within these limits.

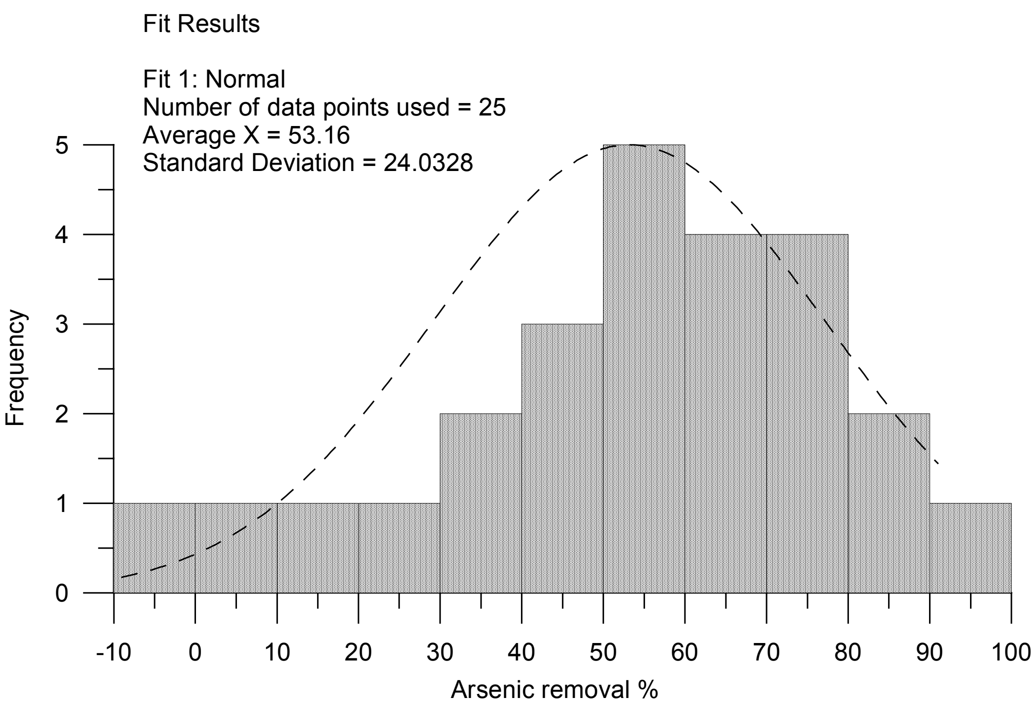


Figure 4.19 Histogram of removal rate by passive sedimentation units

Still, some of the units, such as PS3 unit in Rajnagar Bankabarsi, have very low removal rates, even though operation was done properly. Water quality parameters that make removal difficult were investigated and will be discussed later in the chapter. However, to improve the removal rate from such difficult inlet water, testing of chemical oxidation in addition to the simple aeration/passive sedimentation process was planned.

The test was conducted at PS1 and PS3 units in Bara Dudpatila and all units in Rajnagar Bankabarsi. To enhance the oxidation of arsenic, potassium permanganate was added to the tank when filled up (refer to photo re water in tank). Other operating conditions were the same as usual. The amount of dosing was 1.0 mg/l at Bara Dudpatila, and 1.0 mg/l and 1.5 mg/l at Rajnagar Bankabarsi. At Bara Dudpatila, additional filtration by 0.45μm pore filter was done to examine the possibility of a filtration problem.

The results of test are shown in Table 4.20 below. PS3 unit in Bara Dudpatila showed a clear improvement of over 80% removal. The other units did not show much improvement except PS2 unit of Rajnagar Bankabarsi on the day of 2/4/01. ORP measurements for all cases are above 300mV. We can assume that oxidation was completed for all cases. One factor making PS2 unit in Bara Dudpatila different from the others is its high Fe^{2+} concentration (= 10mg/l). From this point, the Fe^{2+} concentration in inlet water is the key factor for improvement by added chemical oxidation. On the other hand, the reason for the excellent result of PS2 unit in Rajnagar Bankabarsi on the day of 2/4/01 is not clear at this stage.

Added filtration does not provide significant improvement. This is the same case as the double bucket experiment discussed before. Further discussion will not be repeated.

Table 4.20 Test data of passive sedimentation by chemical oxidation

Village	Unit	Water	Date	As (field) mg/l	As (AAS) mg/l	pH	ORP (mV)	EC (mS/m)	Fe2+ mg/l	As removal
Bara Dudpatila	KMnO4 1mg/l added									
	PS1	Raw	2/10/01	0.9	0.47	7.2	270	99.4	2	
		Treated	2/10/01	0.2	0.28	7.48	320	97	0	40%
		Filtered	2/10/01	NA	0.27	NA	NA	NA	NA	43%
	PS3	Raw	2/10/01	0.7	0.43	7.19	121	72.9	10	
		Treated	2/10/01	0.02	0.078	7.49	322	74.9	0	82%
		Filtered	2/10/01	NA	0.075	NA	NA	NA	NA	83%
Rajnagar Bankabarsi	KMnO4 1mg/l added									
	PS1	Raw	2/4/01	0.6	0.41	7.2	121	255	5	37%
		Treated	2/4/01	0	0.26	7.53	331	261	0	
	PS2	Raw	2/4/01	0.4	0.49	7.15	101	276	2	97%
		Treated	2/4/01	0.01	0.013	7.64	328	270	0	
	PS3	Raw	2/4/01	0.5	0.43	7.24	102	272	5	40%
		Treated	2/4/01	0.01	0.26	7.6	332	265	0	
	KMnO4 1.5mg/l added									
	PS1	Raw	2/4/01	0.5	0.35	7.12	125	262	2	40%
		Treated	2/4/01	0.02	0.21	7.52	328	256	0	
	PS2	Raw	2/4/01	0.2	0.41	7.19	94	272	2	39%
		Treated	2/4/01	0.06	0.25	7.62	332	275	0	
	PS3	Raw	2/4/01	0.6	0.44	7.31	99	271	1	45%
		Treated	2/4/01	0.05	0.24	7.51	336	267	0	

Water quality that controls the removal efficiency by the process was considered. In this process, a raw water quality chemistry that can separate the PS1, 2 and 3 units in Krishna Chadrapur and PS2 in Bara Dudpatila from others was searched for. A special effort was taken to find the difference within the raw water quality of Bara Dudpatila. The graph below shows the result of such a study. A combination of the Fe/As ratio and Cl concentration can separate Treatable - Untreatable quality fairly well. The meaning of the Fe/As ratio is straightforward: an excess of

Fe ions is essential in the co-precipitation of arsenic. The Cl concentration may be a general representative of the total dissolved ions. However a graph using Cl ions can separate the samples better than the EC value. Considering the fact that three units in Bara Dudpatila village are located only within a short distance, the factor shall be related to the localized water quality issue. In this regard, the meaning of Cl may be human input by domestic waste to groundwater quality.

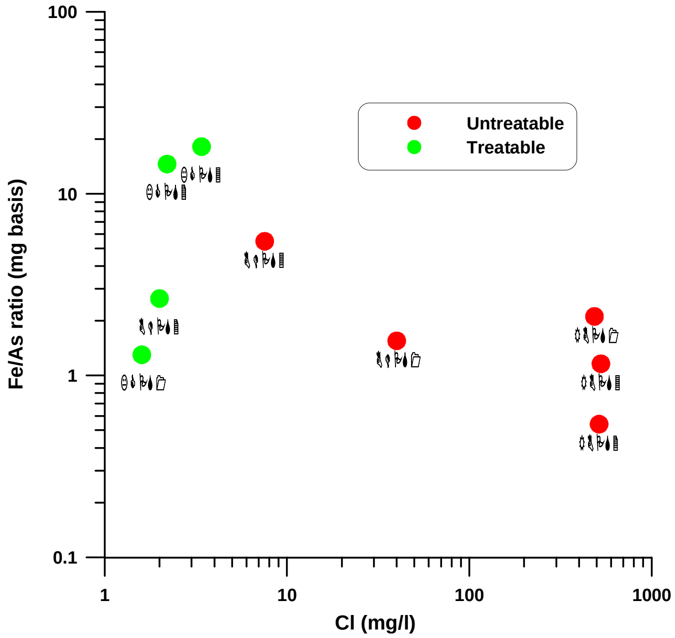


Figure 4.20 Water quality parameter for passive sedimentation

Based on the results, all passive sedimentation units in Rajanagar Bankabarsi and PS1 and PS2 units in Bara Dudpatila were suspended and caretakers were recommended not to use treated water for drinking purposes after March, 2001.

Four units of passive sedimentation were monitored for their removal efficiency.

Table 4.21 Monitoring of Passive Sedimentation units

		Arsenic content in treated water (mg/l) and removal %				
		Jan.2001	Feb. 2001	March 2001	April 2001	June 2001
Krishna Chandrapur	PS 1	*0.064(66%)*	0.042(68%)	*0.052(81%)*	*0.061(70%)*	0.043(83%)
	PS 2	0.030(51%)	0.0087(81%)	0.0057(98%)	0.01(93%)	0.04(70%)
	PS 3	0.048(66%)	0.030(73%)	0.025(84%)	0.030(47%)	*0.18(-)*
Bara Dudpatila	PS 2	0.036(64%)	-	0.029(74%)	*0.067(-)*	*0.13(61%)*

Some samples showed arsenic concentrations above 0.05 mg/l. However, there is no general trend of increasing concentrations over time. Therefore, it is assumed that the removal of arsenic may be affected by some operational problem. Possible causes of the problem are shown in the photos below.

Typical pump and use situation. This makes no oxidation /sedimentation time.

View from top of sand filter. At right side, sand layer was disturbed by bubbling causing short cut pass.

A summary of the findings is as follows.

- Removal of arsenic by passive sedimentation varied considerably by operating condition.
- If properly operated for suitable water quality, 75% removal can be expected. Therefore 0.2 mg/l is the limiting concentration for inlet water.
- High Fe^{2+} /As ratio and low Cl ion concentration are indications of suitable water quality.
- Chemical oxidation by potassium permanganate is effective in improving the removal rate only for water with high Fe^{2+} concentrations.

4.5.4 Activated alumina system

Activated alumina adsorption is used widely for water treatment. Various technical reports were also available regarding arsenic removal by activated alumina. Therefore, the focus of the experiment was not just its removal efficiency, but the effect of water quality on the breakthrough volume and the operational aspect as a community-based system.

Initially, each 20kg of promoted activated alumina was packed in the filter housing. As the bulk density of the activated alumina used is 0.91g/cm^3, 20 kg is equivalent to approx. 22 liters. The breakthrough volume of normal activated alumina for As (V), reported in literature, is over 10,000. The manufacturer of promoted activated alumina (ALCAN) claims that the product is five times more capable than normal activated alumina. Assuming the breakthrough volume as 10,000 for 22 liters of adsorbent, the unit can treat up to 220,000 liters of water. This is equivalent to 220 days use at 1,000 liters per day. In the same way, if the breakthrough volume is 20,000, the unit can be used for 440 days without replacement in theory.

The operating procedure is as follows.

1) Fill up the upper tank in the afternoon.
2) Leave water overnight.
3) Start filtration and adsorption in the morning. Keep water in the lower tank.

The procedure is similar to that of passive sedimentation. The water in the upper tank thus has at least more than 12 hours of oxidation/sedimentation time. Sand filtration before activated alumina shall remove all iron as well as some arsenic. The removal of iron is essential to ensure the longer life of activated alumina as iron may plug the pores of the adsorbent. The filtration rate is approximately 3 to 4 liters per minute from the upper tank to the lower tank. This will provide 5 to 7 minutes contact time with the activated alumina bed. It will take over 4 hours to complete the treatment of 1,000 liters in the upper tank. If filtration is started, all the water will flow from the upper tank to the lower tank. Then, the upper tank is ready to receive new inlet water for the next cycle.

Table 4.22 shows the results of the test in the three villages. The new tube well drilled for the unit in Bara Dudpatila had an arsenic concentration lower than 0.05 mg/l before treatment. This was not expected because the nearby tube well showed higher arsenic contamination. However, the concentration in the new tube well may increase by continued use. The removal of arsenic from the water in this unit was excellent so that the final concentration was 0.0015 mg/l. The unit in Krishna Chandrapur also showed good removal of arsenic, but the final concentration of the treated water was 0.083 mg/l for the first test and 0.051 mg/l for the second test. This is slightly above the target of 0.05 mg/l. For this reason, 30 kg of activated alumina was added to the unit instead of the original 20 kg. This will provide 50% more contact time for the water. After this arrangement, the arsenic in the treated water was 0.035 mg/l.

Table 4.22 Test data of activated alumina

Village	Unit	Water	Date	As (field) mg/l	As (AAS) mg/l	pH	ORP (mV)	EC (mS/m)	Fe2+ mg/l	As removal
Bara Dudpatila	AA	Raw	1/31/01	0.01	0.045	7.28	241	67	2	
		Treated	1/31/01	0	0.0015	7.05	235	58	0	97%
Krishna Chandrapur	AA	Raw	2/3/01	0.3	0.38	6.98	NA	127	5	
		Treated	2/3/01	0	0.083	7.39	283	117	0	78%
		Raw	2/8/01	NA	0.43	6.99	112	65(?)	10	
		Treated	2/8/01	0	0.051	7.27	152	127	0	88%
		Treated	2/17/01	0	0.035	6.72	326	126	0	92%
Rajnagar Bankabarsi	AA	Raw	1/27/01	0.9	0.42	7.19	132	262	2	
		Treated	1/27/01	0	0.088	7.45	293	128	0	79%
		Raw	2/5/01	0.7	0.36	7.32	125	226	5	
		Treated	2/5/01	0.02	0.11	7.64	330	233	0	69%
		Raw	2/6/01	0.6	0.42	7.32	100	255	1	
		Treated	2/6/01	0.01	0.18	7.57	329	255	0	57%

In spite of the good results in Bara Dudpatila and Krishna Chandrapur, the unit in Rajnagar Bnakabarsi had problems. As discussed, the raw water in Rajnagar Bankabarsi is characterized by its high EC value. This means, in general, the water contains more competing ion species than the others. In the first test, arsenic was reduced from 0.42 to 0.088 mg/l. However, the EC value also was reduced from 262 to 128 mS/m after treatment. This suggests that activated alumina had adsorbed various ion species. If so, such adsorbed ion species might occupy many adsorption sites of the activated alumina. Obviously such occupation of the adsorption sites by other ions will reduce the breakthrough volume for arsenic. As expected, the results from the second and third tests show a gradual decrease in arsenic removal. This decrease in removal efficiency had taken place in less than a two-week period. As a countermeasure, 40kg of activated alumina was added to the unit instead of the original 20 kg on March 4, 2001. This will provide 100% more contact time for the water. However, the effect of the improved arsenic removal started to diminish within a month, as shown in Table 4.23.

Table 4.23 Effect of Increased Activated Alumina at Rajanagar Bankabarsi

	3/4/01	3/27/01	4/30/01	5/9/01	5/22/01	6/1/01	7/1/01
Arsenic (mg/kg) in treated water	0.02	0.062	0.23	0.27	0.3	0.4	0.25
Removal %	96%	87%	55%	13%	47%	40%	45%

The result indicated the extreme variation of the breakthrough volume of the system depending on the quality of raw water. It is concluded that replacement of activated alumina every one or two months at Rajanagara Bankabarsi is not economically acceptable to the community. Therefore, use of the system was suspended after July 2001. The table below showed the monitoring data of activated alumina units at Krishna Chanrapur and Bara Dupatila. The arsenic concentration of the treated water at Krishna Chanrapur increased up to 0.14 mg/kg in April. It was not clear whether this is due to the breakthrough or inadequate maintenance of the unit (back flushing) and subsequent iron plugging of the activated alumina. The caretaker of the unit never back flushes the sand filter for iron removal. Also, the solar cell powered pumping system at Krishna Chanrapur broke down in June, 2001. Replacement of activated alumina after repair of the pump was done and operation started again in October 2001. The unit at Bara Dupatila produced treated water with arsenic lower than 0.05 mg/kg. Here, the problem is the stability of the electricity supply for running of the lift up pump. Due to a storm and other reasons, the electricity supply was suspended from time to time. Therefore, an exact estimate of the breakthrough volume of activated alumina has not been done, at this moment.

Table 4.24 Monitoring of Activated Alumina units

		2/8/01	3/2/01	3/25/01	4/27/01	6/1/01	10/6/01
Krishna Chanrapur	Arsenic (mg/kg) in treated water	0.051	0.068	0.073	0.14	-	0.0017
	Removal %	88%	85%	81%	22%	-	99%
Bara Dupatila	Arsenic (mg/kg) in treated water	-	-	0.0059	0.0024	0.0054	-
	Removal %	-	-	85%	94%	92%	-

Overall, the activated alumina unit is functioning as expected. However, the real challenge of the technology is when the breakthrough takes place. Variation of the breakthrough volume depending on the raw water quality is expected as seen at Rajanagar Bankabarsi. This indicates the requirement for extensive monitoring of treated water is high.

A summary of the findings is as follows.

- Activated alumina removes arsenic as expected from normal water (not saline and high EC).
- Saline water and water with high EC value reduce the performance.
- Breakthrough volume varies depending on the raw water quality. Extensive monitoring is required.
- Operation was interrupted because of electricity problems.

4.5.5 Basin-type solar distillation system

As for solar distillation, the arsenic removal efficiency is not an issue. Theoretically, it will remove all dissolved species, except some of the volatile components. Table 4.25 shows the result of testing of the unit in Bara Dudpatila. Arsenic was reduced to 0.001 mg/l, which is near the detection limit of the analytical system. It is also noted that the EC value was reduced from 71.3 to 4.38 mS/m. This demonstrates the removal of all dissolved species. The common problem found in other arsenic removal technologies, i.e. the influence of other dissolved ions, is not a problem for the solar distillation technology.

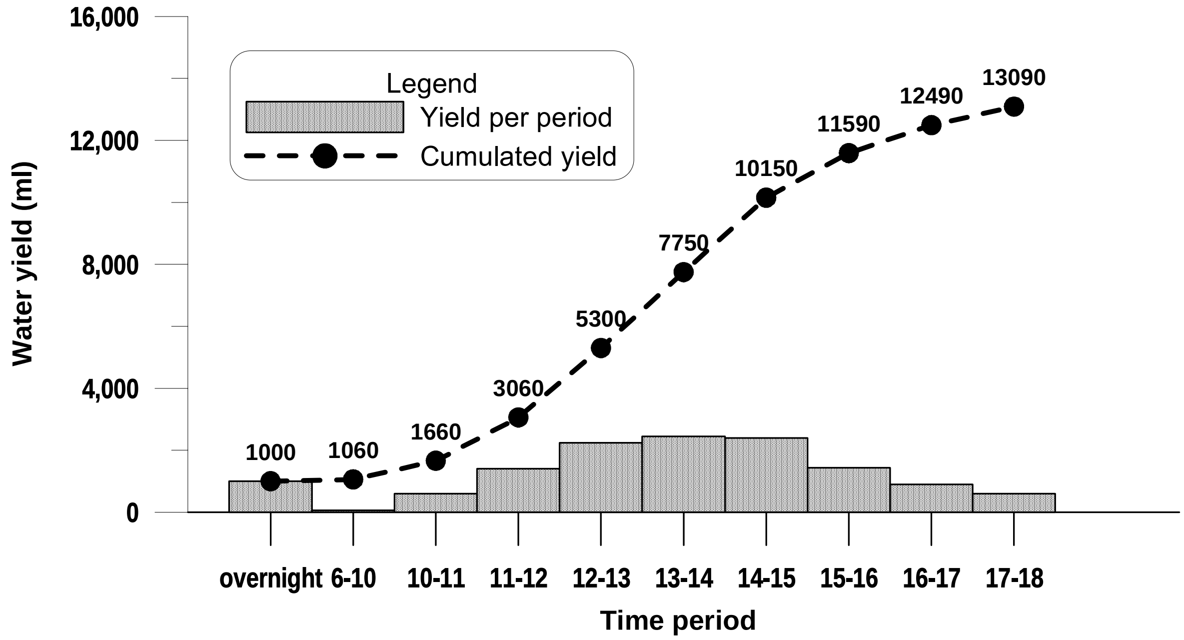
Table 4.25 Test data of basin-type solar distillation

Unit	Water	Date	As (field) mg/l	As (AAS) mg/l	PH	ORP (mV)	EC (mS/m)	Fe2+ mg/l	As removal
SSB	Raw	2/15/01	0.6	0.099	7.32	286	71.3	2	99%
	Treated	2/15/01	0	0.0011	7	409	4.38	0	

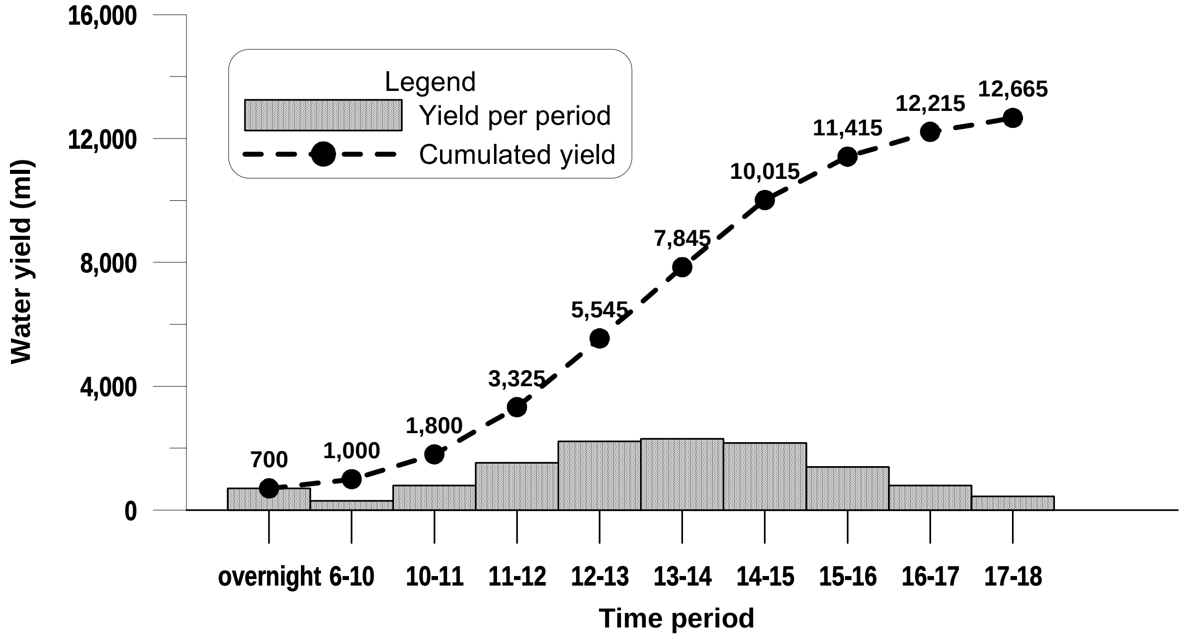
Instead, a major challenge of the unit is its yield. For this reason, a detailed experiment was done to measure its distillation yield. The test was done at the unit in Bara Dudpatila on February 14^{th} and 15^{th} and in Krishna Chandrapur on February 17^{th}. Figures 4.20 and 4.21 show the results of the tests at Bara Dudpatila and Krishna Chadrapur, respectively.

In the figure, the bar chart shows the water yield per sampled time period and the symbol and line graph shows the cumulated water yield. At Bara Dudpatila, approx.12 to 13 liters of water were produced in a day. Since the unit has a basin size of 6 m^2 (1 m x 2 m basin x 3), the efficiency can be calculated as 2.0 to 2.2 liter / m^2. This is in the same range as reported for the efficiency of the basin type unit. It shall be noted that 0.7 to 1 liter of water was also produced during the nighttime. The water vapor produced and condensed in the glass cover on the previous day is the reason for such production. At Krishna Chandrapur, approx. 11 liters of water were produced. As nighttime production was missing at Krishna Chnadrapur test, the overall yield at the two villages is almost the same.

It is expected, with the increased temperature and stronger sunshine toward summer, that the yield will further increase in the coming months.

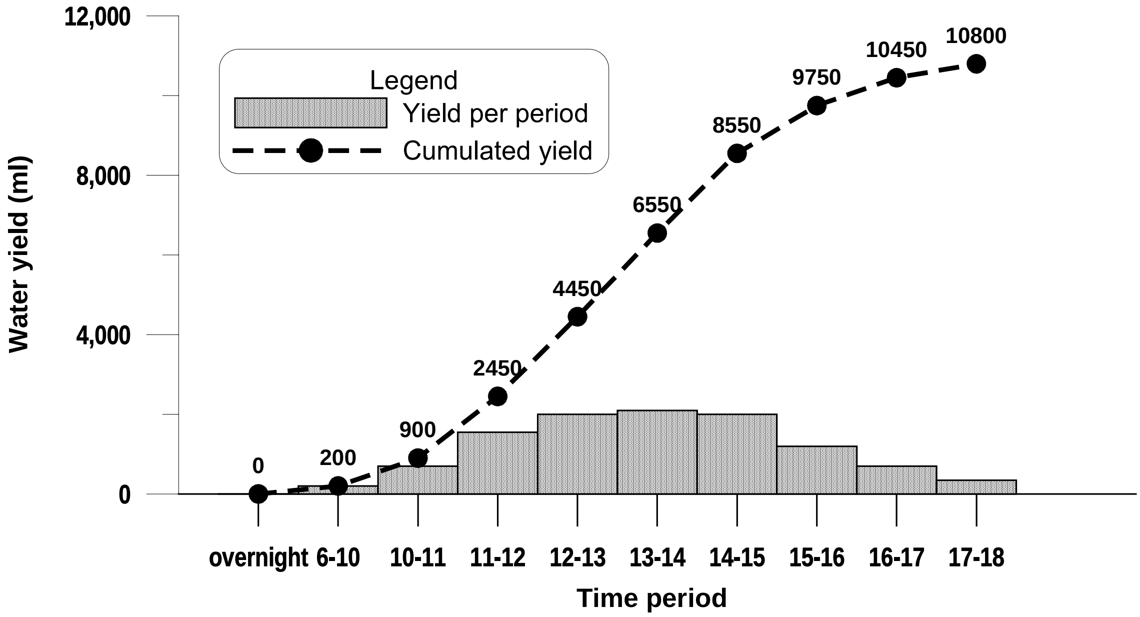


Basin type solar distillation unit experimental data of Feb. 14, 2001



Basin type solar distillation unit experimental data of Feb. 15, 2001

Figure 4.21 Yield of basin-type solar distillation at Bara Dudpatila



Basin type solar distillation unit experimental data of Feb. 17, 2001

Figure 4.22 Yield of basin-type solar distillation at Krishna Chandrapur

Table 4.26 shows the monitoring data of basin type solar distillation units. As expected, arsenic removal is very consistent and nearly 100% all the time. At Rajanagar Bankabarsi, pond water was used for treatment instead of arsenic contaminated groundwater. This demonstrates the all-round flexibility of the distillation process for any type of raw water.

Table 4.26 Monitoring of Basin-type Solar Distillation units

	Arsenic in treated water (mg/l) and removal %			
	Feb. 2001	March 2001	May 2001	June 2001
Rajanagar Bankabarsi	-	0.00058 (100%)	0.00074 (*)	0.0027 (*)
Krishna Chandrapur	-	<0.0005 (100%)	0.0056 (99%)	0.0021 (99%)
Bara Dupatila	0.001 (99%)	-	-	-

(*) pond water was used for treatment. Arsenic removal % not applicable.

There were various engineering problems found during the test. The glass cover of the units at Rajanagar Bankabarsi and Bara Dupatila broke for unknown reasons. It may be due to the stress of the glass from the slight distortion of the frame of the unit. Another possibility is hail. In spite of the sub-tropical climate, Bangladesh often has hail. Therefore, a fish net was installed over the entire unit for protection of the glass cover. Secondly, there was more sediment and precipitation in the bottom of the distillation chamber. Slow flushing of the water was not adequate to remove the precipitation. A glass opening mechanism may be necessary. Fortunately, the problems encountered could be solved by engineering improvements in the manufacturing and do not impose a critical drawback on the system.

A summary of the findings is as follows.

- Solar distillation completely removes arsenic as well as other potential pollutants dissolved in water.
- Basin-type solar distillation can produce approx. 2.0 to 2.2 liter/m^2/day in Bangladesh climate.
- The unit shall be improved for glass protection and bottom cleaning feature.

4.5.6 Vacuum-type solar distillation system

The vacuum-type solar distillation unit was installed at Krishna Chandrapur in late February. The unit applies a solar cell powered vacuum to the water kept in the conventional solar panel to enhance its distillation. Details of the structure of the unit and its function can be found in the supporting report. The solar panel itself has a sunlight receiving area of approx. 1.8m^2. This is approximately 30% of the area of the basin-type unit, which is 6m^2.

A test for its water distillation capacity was conducted from March 3 to 6, 2001. As a result, the following quantities of water were obtained during each test.

March 3 8.30 liters (4.6 liters/m^2/day)
March 4 8.07 liters (4.5 liters/m^2/day)
March 5 9.45 liters (5.25 liters/m^2/day)

Observation on the solar panel by hand touch indicated active boiling inside the panel. The above noted yield seems far too low if active boiling took place in the panel. The temperature of the cooling water for condensation was monitored. The temperature of the water increased fairly quickly and reached a stable condition after a few hours of operation. This suggests that bottlenecking to produce more water is not at the boiling process but at the condensation process. The unit designed as a single effect (heat of evaporation was used only once in the cycle) was not effective in the climatic conditions in Bangladesh. Nevertheless, the experiment provided solid data for single effect units. The potential yield of a multiple effect system can be estimated theoretically based on the data. K. Uda et al. (1994) reported approx. 4 times the yield for a multiple effect system simulation. If we apply this case, a vacuum- multiple effect system can produce approx. 20 liters /m^2/day.

Table 4.27 Test data of Vacuum type Solar Distillation unit

Water	Date	As (field) mg/l	As (AAS) mg/l	pH	ORP (mV)	EC (mS/m)	Fe2+ mg/l	As removal
Raw	3/26/01	0.5	0.13	7.08	129	79.9	5.0	100%
Treated	3/26/01	0.0	<0.0005	7.82	184	0.90	0.0	
Raw	5/21/01	0.3	0.12	7.08	109	81.3	4.0	100%
Treated	5/21/01	0.0	<0.0005	7.56	397	1.25	0.0	

Table 4.27 shows the results for water quality and arsenic removal. Arsenic removal was almost perfect at 100%.

A summary of the findings is as follows.

- Solar distillation completely removes arsenic as well as other potential pollutants dissolved in water.
- Vacuum-type solar distillation can produce approx. 4.5 to 5.0 liters/m^2/day in the Bangladesh climate.
- If improved to a multiple effect system, theoretically, the unit can produce 4 times the water or 18 to 20 liters/m^2/day.

4.6 Evaluation and conclusion

The original plan of evaluating arsenic removal technology was to compile the results of the study with that of BAMWASP to provide a more comprehensive evaluation of the technology. Therefore, the experiment of the study was designed to avoid any duplicate with the BAMWASP project.

In spite of the original plan, BAMWASP renewed its original evaluation project of arsenic removal technology. The OCETA/CIDA initiated ETV-AM (Environmental Technology Verification - Arsenic Mitigation) project took the replacement role. However, the project implemented at almost the same time as this study has not yet started any field experiments and hence there is no official report available.

The DfID funded Rapid Assessment Program selected five arsenic removal technologies as relevant, namely activated alumina by ALCAN, activated alumina by BUET, Stevens technology, Tetrahedran, and Three Kolshi filter. BAMWASP recognized the report but still considers the technologies to be used on an experimental and research basis only.

Under the circumstances, the report will summarize the evaluation of the technologies tested only in this study. The evaluations of the arsenic removal devices were compiled using the criteria as shown in Table 4.28. Criteria was categorized into 1) arsenic removal, 2) operation and maintenance and 3) cost.

As far as arsenic removal efficiency is concerned, distillation technologies show almost complete removal data. Activated alumina and aeration/passive sedimentation show acceptable removal under the appropriate conditions.

The operation and maintenance aspect is more complicated. It is difficult to conclude any one of the technologies has a clear advantage over the others. Solar distillation has an advantage in all aspects except for the small quantities of produced water. The double bucket has more problems in terms of operation and monitoring than the others.

Regarding the cost, some explanation of the figures in the table is necessary. The unit cost of the system as well as the expected life time of the unit are approximate at this stage. Obviously solar distillation has the highest cost/l as a small capacity. For operational cost, the manpower cost was not quantified in this table as we assume all operation to be done by the users. The consumable cost for activated alumina is based on 20,000 Tk/year and 1,000l/day capacity. For monitoring, monthly monitoring is conducted at the cost of 500 Tk/analysis, which is standard DPHE charge.

Table 4.28 Evaluation of five technologies

Aspect	No.	Criteria/Question	Double bucket system	Aeration / Passive sedimentation	Activated alumina	Basin solar distillation	Vacuum solar distillation
Arsenic removal efficiency	1.1	Different removal efficiency for As(III) and As(V)?	Yes	Yes	Yes	No	No
	1.2	Oxidation process required for removal of As(III)?	Yes	Yes	No	No	No
	1.3	Removal efficiency changed by continued use?	No	No	Yes	No	No
	1.4	Removal efficiency influenced by the other dissolved ions?	Yes	Yes	Yes	No	No
	1.6	Field test data. Removal rate.	Not satisfactory	70-90% for adequate quality of raw water	85-95% before breakthrough	99-100%	100%
Operation and maintenance	2.1	Household or community based? What is capacity per unit?	Household 20l/day	Community 400l/day	Community 1000l/day	Household 12l/day	Household 9l/day
	2.2	What is dairy operational procedure? Number of step? Labor time required?	3 step 10-20 min.	2 step 40min.	2 step 10-20min.	1 step 20min.	4 step 30 min
			Refer to flow sheet.				
	2.4	What is maintenance procedure? weekly, monthly? Number of step?	Cleaning bucket and sand filter daily	cleaning tank and sand filter weekly	back flushing every few days	flush bottom water daily	maintenance of vacuum pump once a year
	2.5	Consumable required? What? How often? Is that potentially hazardous?	Yes, KMnO4 and alum, Hazardous	No	Activated alumina 1-2 time/year	No	No
	2.6	Chemicals required? What? How often? Is that potentially hazardous?	Yes, Daily, KMnO4 and alum, Hazardous	No	No	No	No
	2.7	Waste generated? How much /day, month	Yes. Few gram/day	Yes, few gram/day	Yes, 20-80kg/year	No	No
	2.8	Monitoring requirement	Modest	Modest	High	No	No
	2.8-1	1.3, 1.4, 1.5 is yes, monitoring required. How often ?	Minimum monthly	minimum monthly	minimum monthly		
	2.8-2	Monitoring parameters? Arsenic? Other ions?	Arsenic	Arsenic and Iron	Arsenic	not required	not required
	2.9	Operational risk?	Handling of chemical, miss operation, no arsenic removal, excess	No removal of arsenic if miss operated	No removal of arsenic if breakthrough occur	Less production of arsenic free water	Less production of arsenic free water

			chemical				
Cost	3.1	Equipment cost					
	3.1-1	cost/unit	500TK	15,000TK	100,000TK	100,000TK	500,000TK
		Expected life time of the equipment	3 years	10 years	10 years	10 years	20 years
	3.1-2	unit cost/l of treated water over expected life time (TK/l)	0.034	0.014	0.027	2.854	1.712
	3.2	Operating cost (TK/l)					
	3.2-1	Manpower	NA	NA	NA	NA	NA
	3.2-2	Consumable	0	0	0.055	0	0
	3.2-3	Chemical (TK/l)	0.002	0	0	0	0
	3.2-4	Power or any other utility	0	0	0.003	0	0
	3.2-5	Monitoring (500TK/analysis)	0.822	0.055	0.016	0	0
	3.2-6	Waste treatment disposal site construction, collection, transportation	Required	Required	Required	not required	not required
	3.3	Use of locally available material					
	3.3-1	Equipment	Yes	Yes	Yes	Yes	No
	3.3-2	Consumable	Yes	NA	No	not required	NA
	3.3-3	Chemical	Yes	NA	NA	NA	NA

Ideally, the device shall be very easy to use and maintain, treat a sufficient quantity of water, have less risk of misoperation or secondary hazardous accidents, have a consistent arsenic removal efficiency down to 0.05 mg/l, require less monitoring, have less problem in waste disposal, be economically feasible in both the initial and running cost, and be socially acceptable.

Unfortunately, the study could not identify a single arsenic removal device or technology that fulfills all of the requirements necessary to be used in the rural conditions of Bangladesh. Every technology has an advantage in one aspect but a disadvantage in another aspect. Therefore, at this stage, the choice of the device depends on the condition given to a specific site and situation.

As a result, the following three technologies are recommended for the different conditions assumed:

1. Aeration/passive sedimentation
2. Solar distillation combined with rainwater harvesting
3. Adsorption based arsenic removal device

1. Aeration / passive sedimentation

   Technology description: As most of the arsenic contaminated tube well water also contains high iron, aerated oxidation of water causes the precipitation of iron. Arsenic can be removed together with iron once precipitated, by sand filtration.

   Advantage: No chemical or consumable, capable of producing a sufficient volume of water, easy operation and maintenance, low initial cost and negligible running cost, socially acceptable.

   Disadvantage: Arsenic removal efficiency depends on the raw water quality, not applicable to water with high EC or Cl ion concentration, not applicable to water with a small Fe/As ratio, not applicable to high arsenic concentrations above 0.2 mg/l.

   Recommended situation: If raw water quality meets the applicable standard, removal testing shall be conducted before installation of the device.

2. Solar distillation combined with rainwater harvesting

   Technology description: Solar distillation utilizes solar heat to distill the water to remove not only arsenic but also other pollutants completely. Solar distillation can work most efficiently in the dry season while rainwater harvesting can collect the rain in other seasons. A combination of the two technologies can be the most ideal and environmentally friendly solution.

   Advantage: Complete removal of arsenic and other pollutants, no effect by initial raw water quality, no monitoring requirement, no chemical or consumable, easy operation and maintenance, negligible running cost, socially acceptable.

   Disadvantage: Requires a relatively large area, sunshine condition critical, high initial cost

   Recommended situation: Recommended for hospitals or schools where the building roof is available for rainwater collection as well as installation of a solar distillation unit. Donor contribution for initial cost bearing is required.

3. Adsorption based arsenic removal device

   Technology description: Removal of arsenic by adsorption media such as activated alumina, ion exchange resin, cerium hydroxide, granular Fe oxide, etc.

   Advantage: Stable arsenic removal in most cases, easy operation and maintenance, relatively low initial cost, socially acceptable.

   Disadvantage: Monitoring required for breakthrough, costly media for replacement, replacement cycle depends on raw water quality, spent media as hazardous waste,

   Recommended situation: Recommended for area where no other solution is available. Community or users shall be aware of the periodical cost bearing for replacement of media.