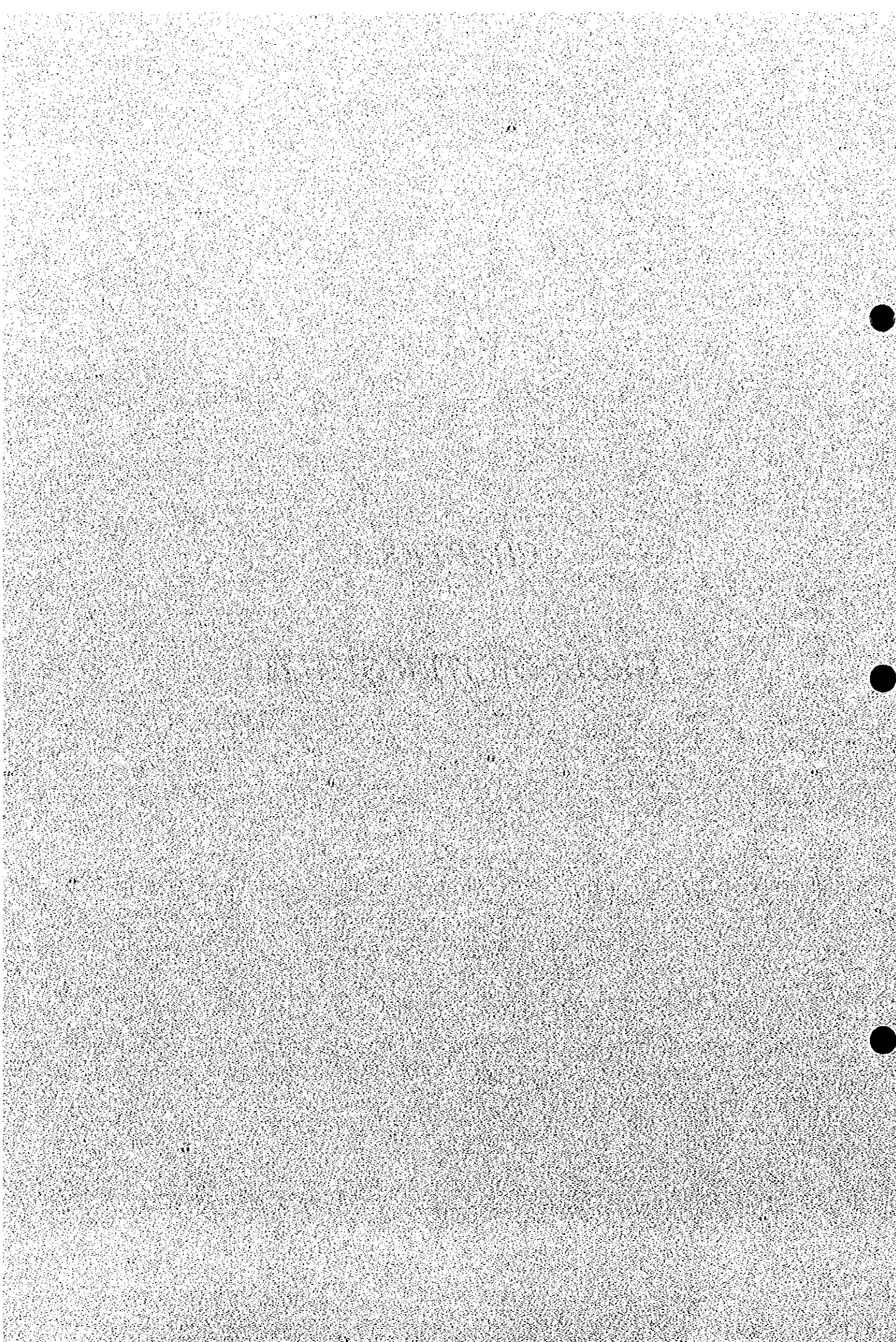


**CHAPTER 3**

**GROUNDWATER QUALITY**



## CHAPTER 3 GROUNDWATER QUALITY

### 3.1 Water Quality of Existing Shallow Wells

#### 3.1.1 Methodology of Field Measurement, Sampling and Laboratory Analysis

Groundwater quality of existing wells in the study area was investigated by the field measurement and laboratory analysis. During the field hydrogeological survey, 241 existing wells were investigated and 213 water samples were collected. At least 10 existing wells were investigated and 10 water samples were collected at each target commune. The locations of measured existing wells are shown in Figures 4.2.1 to 4.2.12 together with the locations of the geophysical prospecting and the test wells.

During the field survey, the following water quality parameters were measured:

- pH
- Electric Conductivity (EC) (mS/m)
- Oxidation-Reduction Potential (ORP) (mV)
- Dissolved Oxygen (DO) (mg/l)
- Water Temperature (°C)
- Coliform (pcs./ml)

The portable pH meter, EC meter, ORP meter, DO meter and coliform test paper were used for the measurement. The color and smell of the water was also noted during the field survey.

The groundwater samples for laboratory analysis were collected during the field survey. The sampling volume of water is 1.5 liters. The water was kept in a plastic sampling bottle without air. The water samples were brought into a laboratory in Hanoi as soon as possible after sampling.

The laboratory analysis was carried out by the Institute of Chemistry, Department for Analytical Science under the Vietnam National Center for National Science and Technology. The following twenty one (21) parameters were analyzed in the laboratory:

- (1) PH
- (2) Temperature (°C)
- (3) Electric Conductivity (EC) (mS/m)

- (4) Hardness (meq/l)
- (5) Total Dissolved Solids (TDS) (mg/l)
- (6) Oxidation-Reduction Potential (ORP) (mV)
- (7) Dissolved Oxygen (DO) (mg/l)
- (8) Nitrate ( $\text{NO}_3^-$ ) (mg/l)
- (9) Nitrite ( $\text{NO}_2^-$ ) (mg/l)
- (10) Ammonium ( $\text{NH}_4^+$ ) (mg/l)
- (11) Manganese ( $\text{Mn}^{2+}$ ) (mg/l)
- (12) Sulfate ( $\text{SO}_4^{2-}$ ) (mg/l)
- (13) Iron ( $\Sigma \text{Fe}$ ) (mg/l)
- (14) Chloride ( $\text{Cl}^-$ ) (mg/l)
- (15) Bicarbonate ( $\text{HCO}_3^-$ ) (mg/l)
- (16) Calcium ( $\text{Ca}^{2+}$ ) (mg/l)
- (17) Magnesium ( $\text{Mg}^{2+}$ ) (mg/l)
- (18) Sodium ( $\text{Na}^+$ ) (mg/l)
- (19) Potassium ( $\text{K}^+$ ) (mg/l)
- (20) Fluoride (F) (mg/l)
- (21) Arsenic (As) (mg/l)

At each site, the UTM coordinate was measured by a portable GPS receiver. Then the groundwater level from the measuring point (MP) and the height of the MP from the ground surface was measured to calculate the depth to groundwater level from the ground surface. In most dug wells, the actual well depths were measured by sinking a measuring scale.

### **3.1.2 Groundwater Quality by Province**

Figure 3.1.1 shows the trilinear diagram of groundwater collected from existing wells in the Study area. Most samples of both dug wells and tube wells are plotted in the upper area of the central diamond-shape diagram, indicating that the groundwater of the study area is originated from shallow aquifer and partly influenced by saline water.

#### **(1) Thai Nguyen Province**

The groundwater samples from Thai Nguyen Province are plotted on the trilinear diagram in Figure 3.1.2. In cations, all samples show the Mg percentage of the total cations is less than 30 %. In the diamond-shape diagram, most samples of Hoa Tuong Commune are plotted in the left side. On the other hand, most dug well samples of Nam Tien and Think Duc are plotted in the right side of the diagram, indicating ( $\text{Cl}^-$   $\text{ISO}_4^{2-}$ ) is rich in anions.

**(2) Hanoi Province**

The groundwater samples taken from Hanoi Province are plotted on the trilinear diagram as shown in Figure 3.1.3. Most of tube well samples are plotted in the central and upper left side of the diamond-shape diagram. Two (2) samples taken from dug wells of Xuan Dinh Commune are plotted in the right side of the central diagram, showing that the chemical composition is similar to saline water.

**(3) Ninh Binh Province**

Figure 3.1.4 shows the trilinear diagram of Ninh Binh Province. All samples are plotted in the upper central to upper left side of the diamond-shape diagram. Most samples show that the  $\text{Ca}^{2+}$  content in cations is more than 30 % of the total meq/l. In anions,  $\text{Cl}^-$  is less than 50 % and  $\text{HCO}_3^-$  is more than 30 % to the total anions.

**(4) Thanh Hoa Province**

Groundwater samples obtained from Thanh Hoa Province are plotted on the trilinear diagram as shown in Figure 3.1.5. Most dug well samples are plotted in the upper central part of the diamond-shape diagram. The plots of tube well samples are briefly divided into two (2) groups. The one is consist of tube wells of Nong Cong town that plotted on the right side of the diamond-shape diagram. The other one is consist of the rest of the tube wells of different communes plotted on the left side of the diagram.

**(5) Ha Tinh Province**

Figure 3.1.6 shows the trilinear diagram of Ha Tinh Province. The plots on the diamond-shape diagram are relatively concentrated from the upper central to the upper right fields of the diagram. The composition of cations is characterized by that the  $\text{Mg}^{2+}$  content ranges between 10 to 40 % and the  $\text{Ca}^{2+}$  content takes a range from 20 to 50 % in meq/l.

**3.1.3 Range of Groundwater Quality Parameters by Province**

From the results of field measurements and laboratory analysis of groundwater quality, the ranges of water quality parameters are analyzed by province. The characteristics of the quality parameters distribution are mentioned below.

**(1) pH (see Figure 3.1.7)**

The pH values measured during the field survey were used for the analysis. The distribution pattern of pH values in Thai Nguyen Province is unique compared with

those of other provinces. There are two (2) peaks of the pH values distribution; one is 5.0~5.5 and the other is 7.0~7.5. It is characteristic that the relatively strong acidic groundwater ranging from 4.5 to 5.5 in pH occurs in Thai Nguyen. These acidic groundwater is mainly found in the red soil areas where weathered shale and sandstone exist. The pH values more than 7.0 are found mainly in limestone area.

In Hanoi Province the pH values range from 5.0 to 7.5. The range of pH values in Ninh Binh is relatively narrow and located in mainly alkaline side. The range of 7.0~7.5 is dominant in the province.

The pH distribution pattern of Thanh Hoa is similar to that of Ha Tinh Province. The major range in both provinces is 6.5 to 7.5. However, the pH values in Ha Tinh Province take more wider range, from 4.5 to 8.0.

**(2) EC (see Figure 3.1.8)**

The EC values measured during the field survey were used for the analysis. In Thai Nguyen Province the EC values are distributed in a range between <5 and 100~200 mS/m. The peak range is 20~50 mS/m and the major range is from 10~20 to 50~100 mS/m.

The EC values of Hanoi groundwater range from 5~10 to 100~200 mS/m. There are two (2) peaks of EC distribution; one is 5~10 mS/m and the other is 50~100 mS/m. The latter is the main peak in the investigated communes.

The groundwater in Ninh Binh Province shows a range of EC values from <5 to 200~400 mS/m. The ranges of 20~50 and 50~100 mS/m form a peak. The number of wells having ranges of 100~200 and 200~400 mS/m is greater than that of between <5 and 10~20 mS/m.

The main range of EC distribution in Thanh Hoa Province is 50~100 mS/m. The pattern shows a normal distribution. The EC values take a wide range from 5~10 to 400<= mS/m, however, most samples fall into a range from 20~50 to 100~200 mS/m.

In Ha Tinh Province, the main EC range is located higher portion of 100~200 mS/m. Most samples fall into a range between 20~50 and 100~200 mS/m. But there are five (5) samples in a range from 200~400 mS/m.

As a result, it can be said that the groundwater in Thai Nguyen is good and that of Ha

Tinh is poor among the five (5) provinces from the view point of EC distribution.

**(3) TDS (see Figure 3.1.9)**

The values of TDS were measured by the laboratory analysis. In Thai Nguyen Province TDS values range from 10~50 to 1,000~2,000 mg/l. A protruding distribution peak can be seen at a range of 100~500 mg/l.

Most TDS values of Hanoi Province take a range from 50~100 to 1,000~2,000 mg/l. The distribution peak is located at 500~1,000 mg/l. There is one sample in a TDS range of <10 mg/l, however, 4 samples fall into a range of 1,000~2,000 mg/l.

The main peak of TDS in Ninh Binh Province stands at 50~100 mg/l. However, the distribution pattern is not symmetric and more than half of the samples fall into a range from 500~1,000 and 2,000~5,000 mg/l.

The distribution pattern of TDS in Thanh Hoa groundwater shows almost symmetric. A main distribution peak is located at 500~1,000 mg/l. The TDS values takes a wide range from 50~100 to 5,000<= mg/l, however, most of the samples fall into a range from 100~500 to 1,000~2,000 mg/l.

The TDS values in Ha Tinh Province distributed in a range from 100~500 to 2,000~5,000 mg/l. The main peak is located at 500~1,000 mg/l, but about half of the samples fall into a range from 1,000~2,000 to 2,000~5,000 mg/l.

As a result, it is concluded that the groundwater quality of Thai Nguyen is better and that of Ha Tinh is worse among the five (5) provinces based on the TDS distribution analysis.

**(4) Fe (see Figure 3.1.10)**

The total Fe ( $\Sigma$ Fe) values analyzed by laboratory test were used for the analysis. The Fe concentration is distributed in a range from <0.1 to 0.5~1.0 mg/l. The number of samples decreases with increasing of Fe concentration.

In Hanoi province the range of Fe concentration is limited between 0.1~0.2 and 1.0~2.0 mg/l. The distribution pattern shows a normal distribution. The major distribution range is 0.2~0.5 mg/l and 0.5~1.0 mg/l.

The range of Fe concentration of the Ninh Binh groundwater is from <0.1 to 1.0~2.0

mg/l. There are two (2) peaks of the distribution pattern; one is the range of 0.1~0.2 mg/l and the other is 0.5~1.0 mg/l.

The main range of Fe concentration in Thanh Hoa Province is 0.5~1.0 mg/l. The samples are distributed between 0.1~0.2 mg/l and 5.0<= mg/l. About half of the samples fall into a range from 1.0~2.0 and 5.0<= mg/l.

The distribution pattern of Fe concentration in Ha Tinh Province is similar to that of Thanh Hoa Province. The main bar stands at the range of 0.5~1.0 mg/l and the second bar stands at the range of 0.2~0.5 mg/l.

As a result, it is concluded that the Fe concentration in groundwater is higher in Thanh Hoa and Ha Tinh Provinces.

**(5) Mn (see Figure 3.1.11)**

The concentrations of Manganese (Mn) were measured by the laboratory analysis. In Thai Nguyen Province Mn concentration ranges mainly from >0.05 to 0.05~0.1 mg/l. There is a sample falling into a range of 0.5~1.0 mg/l.

The Mn concentration in Hanoi Province takes a wide range from 0.05~1.0 to 10.0<= mg/l. Although the main peak stands at 0.05~1.0 mg/l, the second small peak is located at 1.0~5.0 mg/l.

In Nin Binh Province the Mn concentration takes a range from <0.05 to 0.5~1.0 mg/l. The main peak stands at 0.05~0.1 mg/l. The number of samples at the ranges of 0.1~0.3, 0.3~0.5 and 0.5~1.0 mg/l is only one.

The Mn concentration in Thanh Hoa Province takes a range from <0.05 to 1.0~5.0 mg/l. Although 50 samples fall into a range of 0.05~0.1 mg/l, 3 to 5 samples fall into the ranges of <0.05, 0.1~0.3, 0.3~0.5, 0.5~1.0, and 1.0~5.0 mg/l.

The distribution peak of Mn concentration in Ha Tinh Province is also located at 0.05~0.1 mg/l. However, the ratio of samples falling into the ranges of 0.3~0.5, 0.5~1.0, and 1.0~5.0 mg/l is greater than that of other provinces.

As a result, it can be stated that the groundwater in Ha Tinh Province and Hanoi Province has higher concentration of Manganese.



**(6) Cl (see Figure 3.1.12)**

The concentrations of Chloride (Cl) were measured by the laboratory analysis. In Thai Nguyen Province Cl concentration ranges from <10 to 100~250 mg/l. Most of the samples fall into a range of 10~50 mg/l.

The Cl concentration in Hanoi Province ranges from <10 to 250~500 mg/l. Only one sample exceeds a concentration of 250 mg/l.

The groundwater in Ninh Binh Province has Cl concentration between a range from <10 to 250~500 mg/l. Although the tallest bar stands at 10~50 mg/l, the second tallest bar stands at 100~250 mg/l.

The Cl concentration of Thanh Hoa groundwater takes two ranges; one is from 10~50 to 100~250 mg/l and the other is from 500~1,000 and 1,000~2,000 mg/l. Three (3) samples fall into a range from 500 to 2,000 mg/l.

The Ha Tinh groundwater takes a distribution range of Cl concentration from 10~50 to 250~500 mg/l. Among 41 samples, 8 samples fall into a range of 250~500 mg/l.

As a result, it is found that the part of Thanh Hoa groundwater has higher concentration of Cl. Some part of Ha Tinh groundwater has also relatively high concentration of Cl. The Cl concentration of Thai Nguyen groundwater is less than that of other provinces.

**(7) SO<sub>4</sub> (see Figure 3.1.13)**

The concentrations of Sulfate (SO<sub>4</sub>) were measured by the laboratory analysis. In Thai Nguyen Province SO<sub>4</sub> concentration ranges from <10 to 250~400 mg/l. Out of 45 samples, 24 samples fall into the ranges of 50~100 mg/l and 100~250 mg/l.

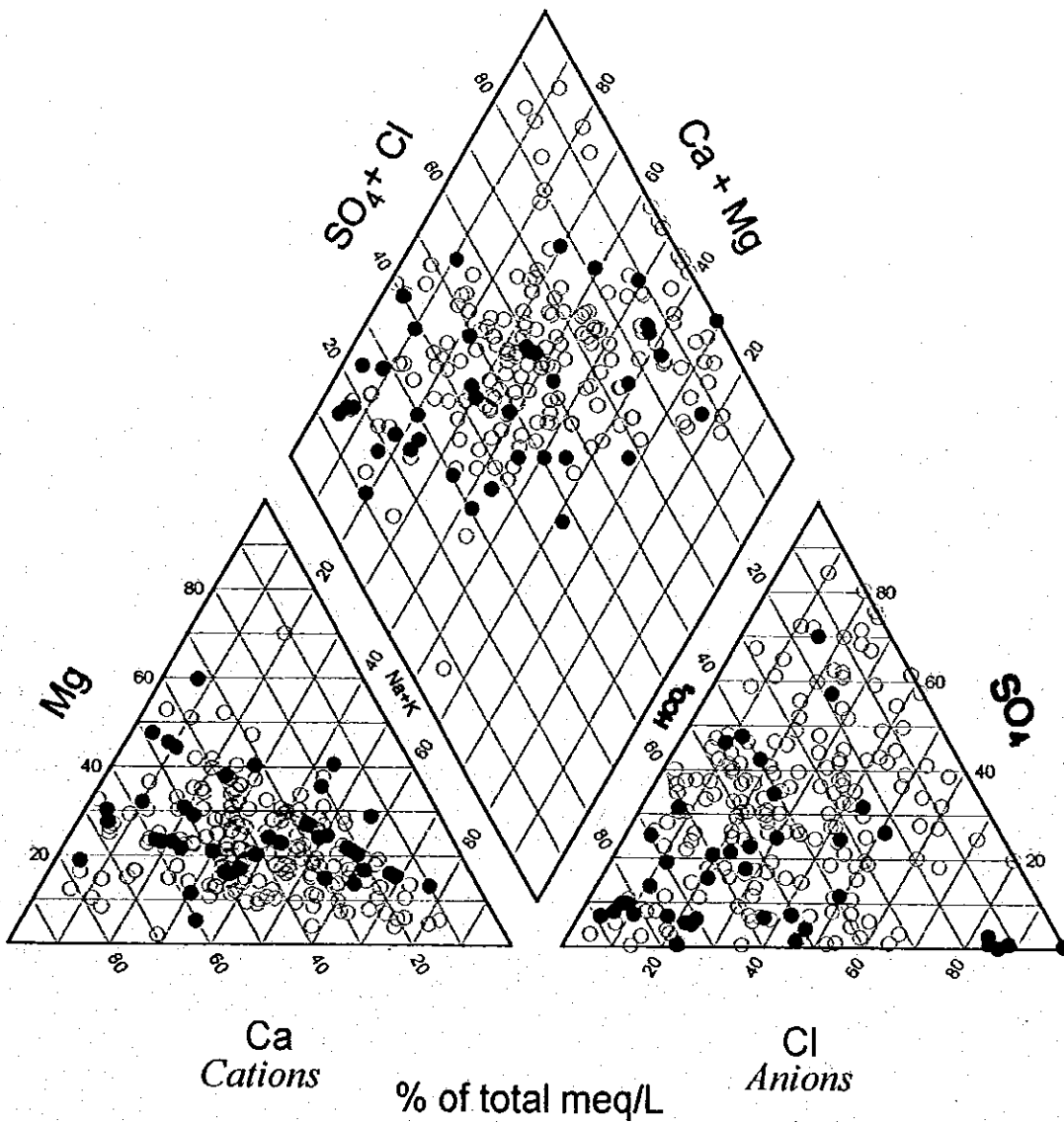
The distribution range of SO<sub>4</sub> concentration in Hanoi Province is the same as Thai Nguyen Province. However, the distribution peak is located at lower concentration between 10~25 and 25~50 mg/l.

In Ninh Binh a steep peak can be seen at 100~250 mg/l. Two (2) samples out of 37 samples fall into a range of 400~1,000 mg/l.

There are two (2) distribution peaks of SO<sub>4</sub> concentration in Thanh Hoa Province; one is 10~25 mg/l and the other is 100~250 mg/l. Two (2) samples fall into the range of 400~1,000 mg/l.

The distribution peak of Ha Tinh groundwater is located at 100~250 mg/l. More than half samples fall into a SO<sub>4</sub> range from 100~400 mg/l. There are two (2) samples falling into a range of 400~1,000 mg/l.

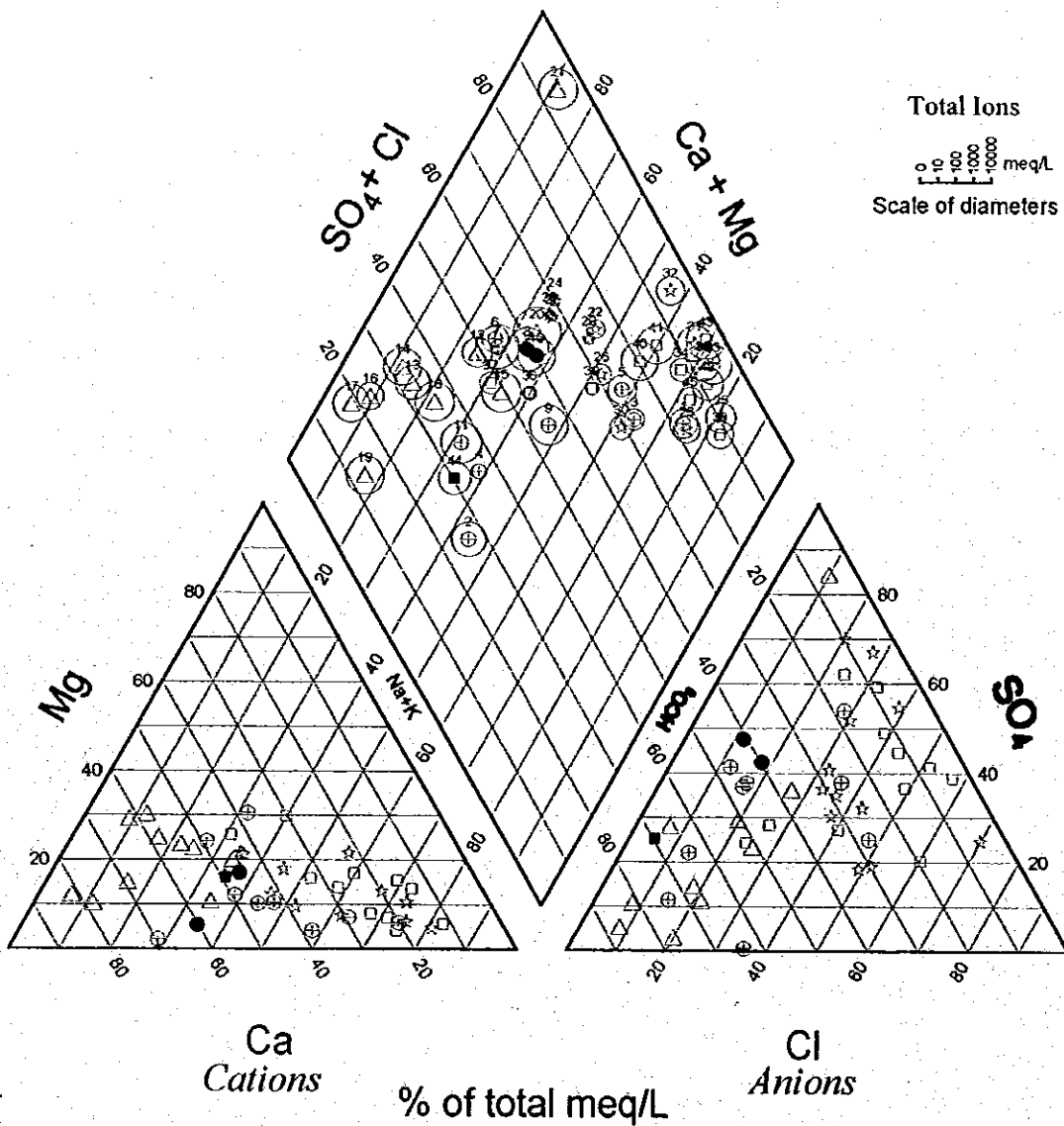
As a result, it can be said that the SO<sub>4</sub> concentration is higher in Ha Tinh and Thanh Hoa Provinces.



○ Existing Dug Well

● Existing Tube Well

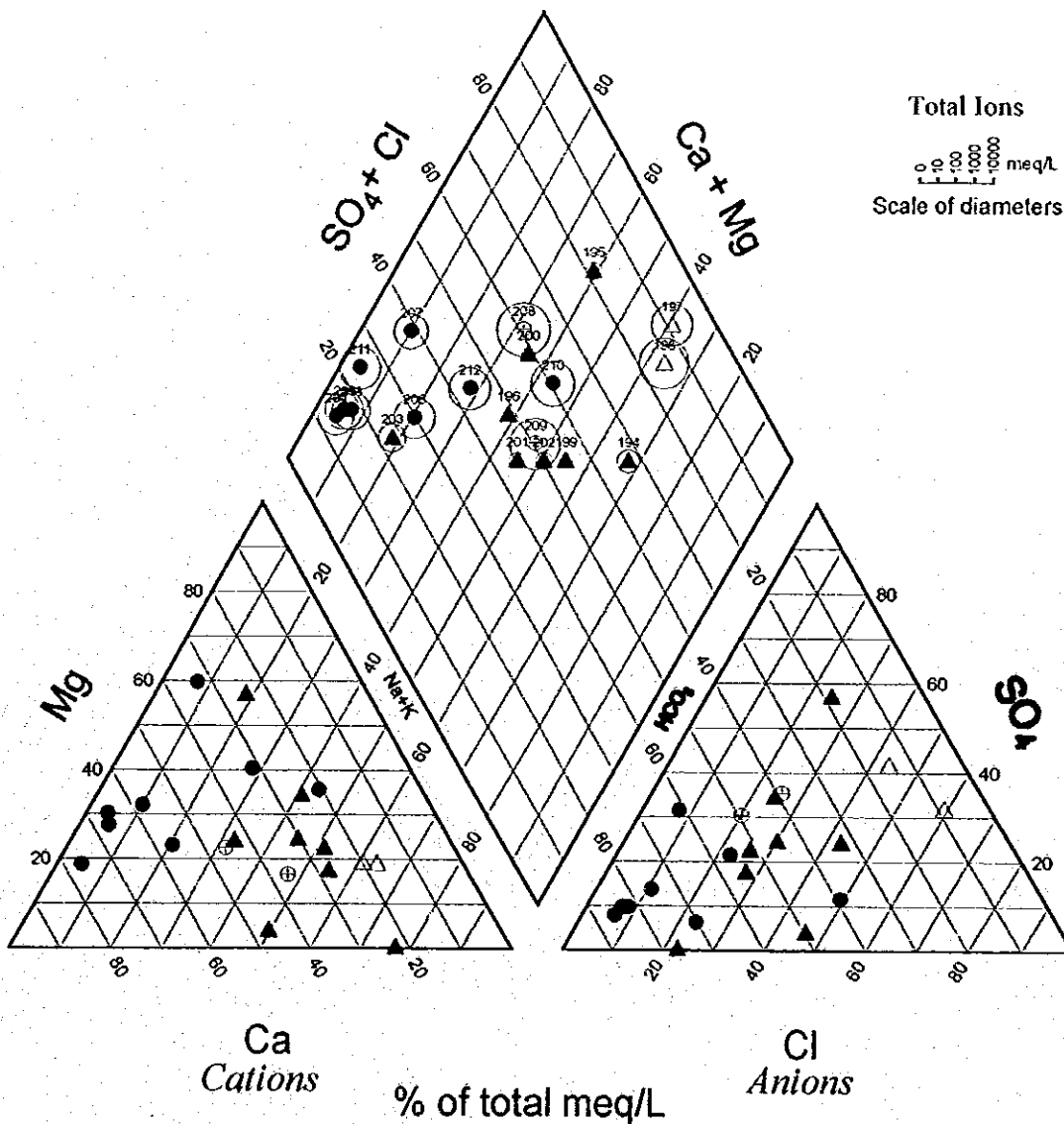
<b>Figure 3.1.1</b>	<b>TRILINEAR DIAGRAM OF GROUNDWATER FROM EXISTING WELLS IN THE STUDY AREA</b>
<b>THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM</b>	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



Existing Dug Well      Dong Bam      Hoa Thuong      Nam Tien      Tinh Duc  
 ⊕      △      □      ☆

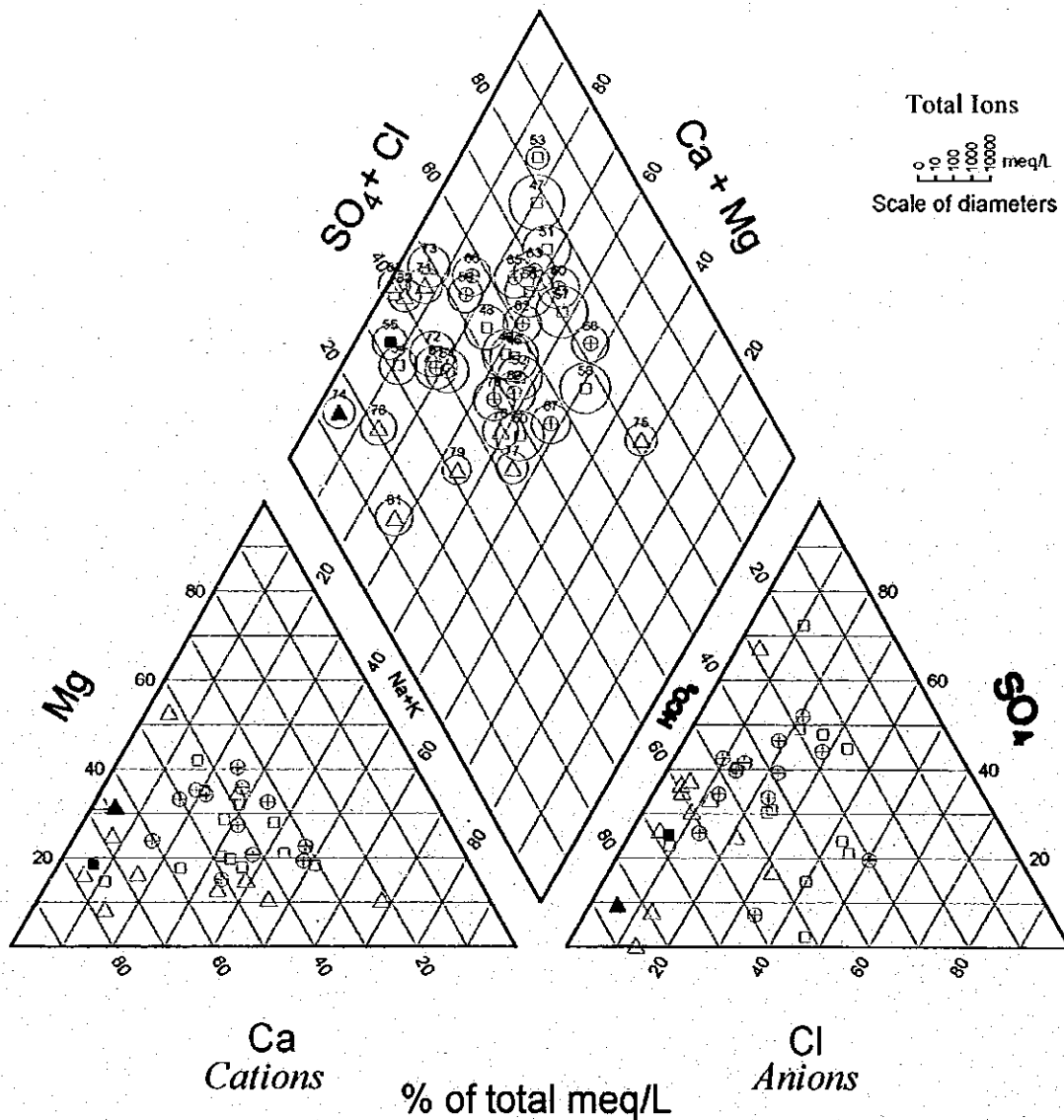
Existing Tube Well      ●      ■

Figure 3.1.2	<b>TRILINEAR DIAGRAM OF GROUNDWATER FROM EXISTING WELLS IN THAI NGUYEN PROVINCE</b>
	<b>THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM</b>
	<b>JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)</b>



	Dong Ngac	Xuan Dinh
Existing Dug Well	⊕	△
Existing Tube Well	●	▲

Figure 3.1.3	TRILINEAR DIAGRAM OF GROUNDWATER FROM EXISTING WELLS IN HANOI PROVINCE
	THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM
	JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

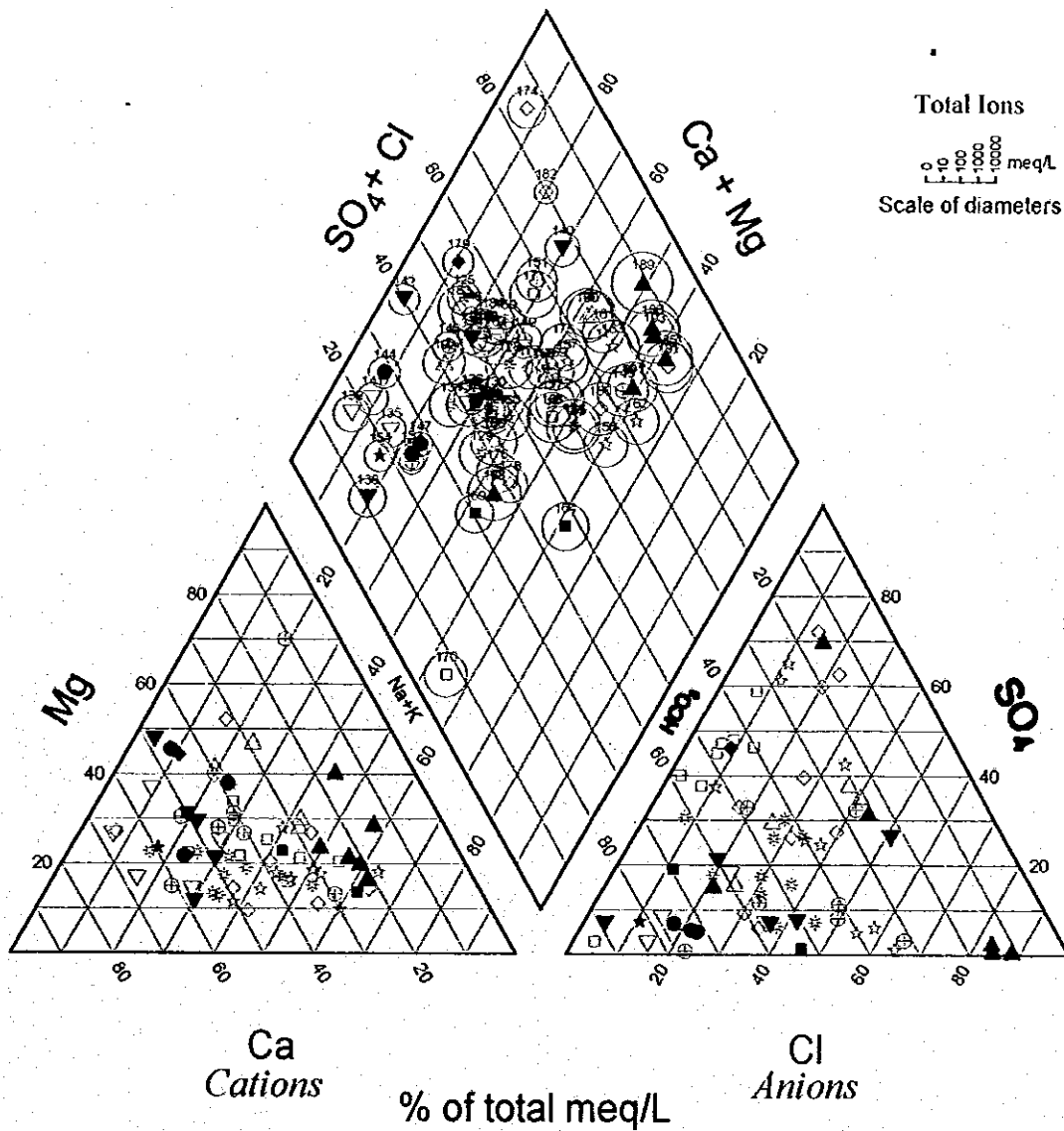


Dông Phong    Quang Son    Yen Thang

Existing Dug Well    ⊕    △    □

Cave/Spring Water    ▲    ■

Figure 3.1.4	TRILINEAR DIAGRAM OF GROUNDWATER FROM EXISTING WELLS IN NINH BINH PROVINCE
	THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM
	JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

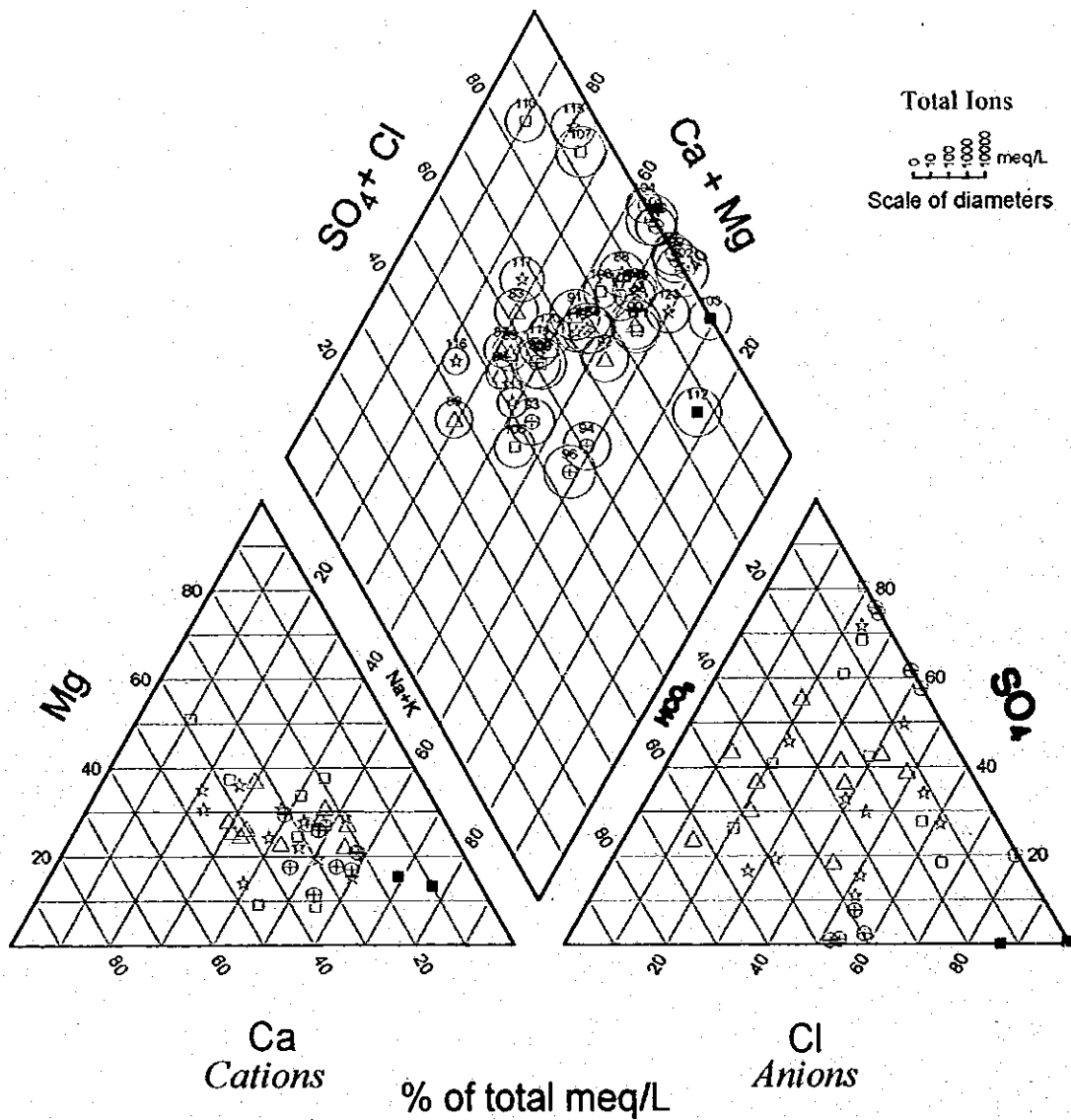


	Dinh Tuong	Nong Cong T.	Thieu Do	Thieu Hung	Van Thanh	Vinh Loc T.	Vinh Than
Dug Well	⊕	△	□	☆	◇	▽	*
Tube Well	●	▲	■	★	◆	▼	

**Figure 3.1.5** TRILINEAR DIAGRAM OF GROUNDWATER FROM EXISTING WELLS IN THANH HOA PROVINCE

THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

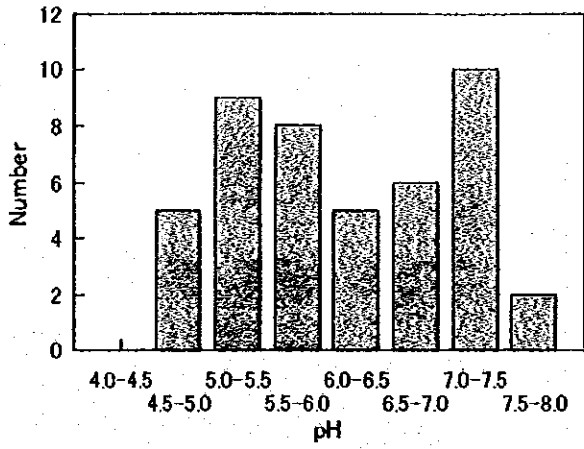


Existing Dug Well      Bui Xa ⊕      Duc Yen △      Trung Le □      Yen Ho ☆

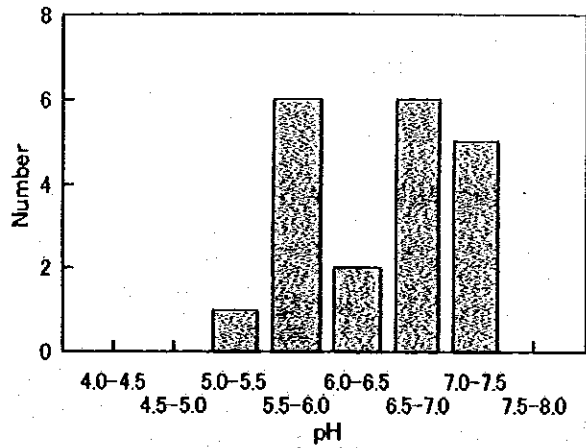
Existing Tube Well                                                             ☆      \*

Figure 3.1.6	TRILINEAR DIAGRAM OF GROUNDWATER FROM EXISTING WELLS IN HA TINH PROVINCE
	THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

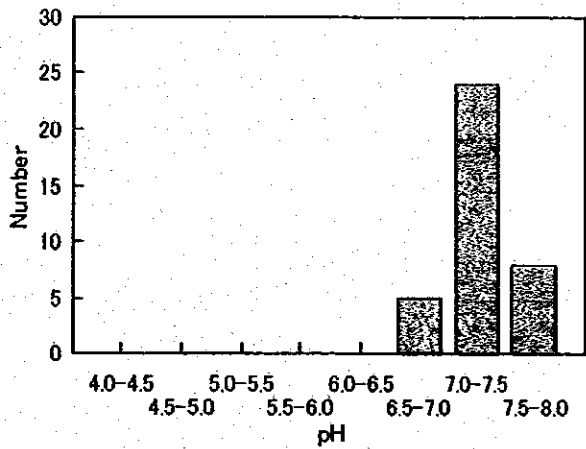
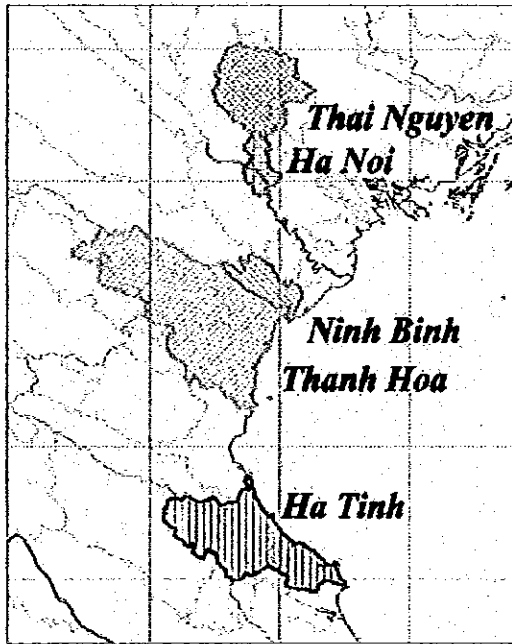




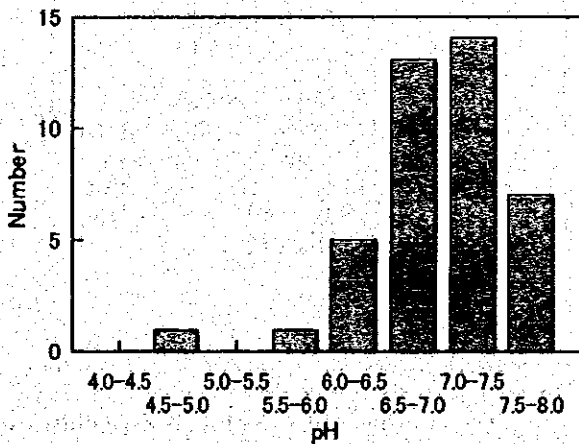
Thai Nguyen



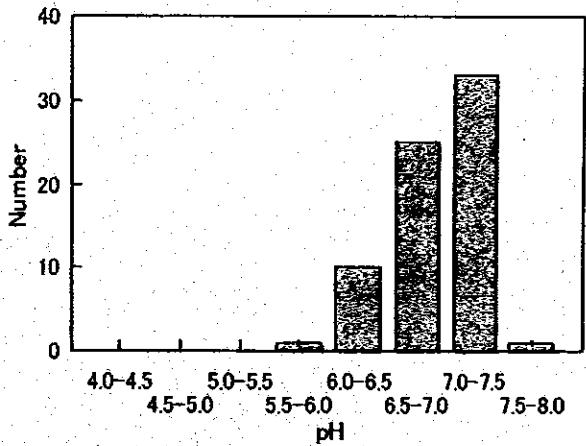
Ha Noi



Ninh Binh



Ha Tinh



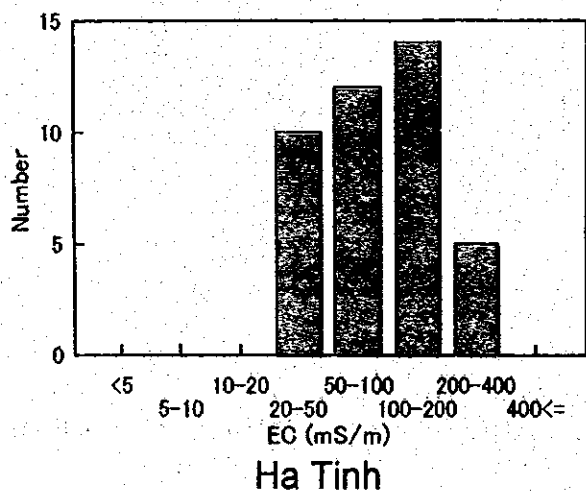
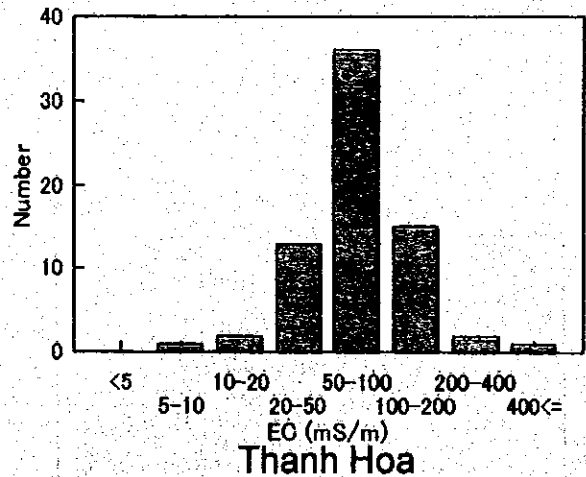
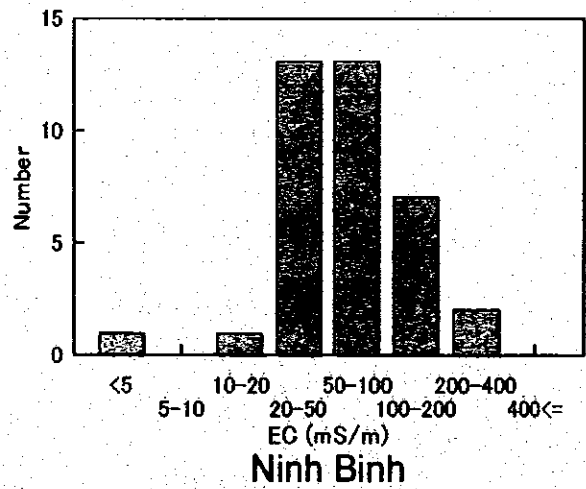
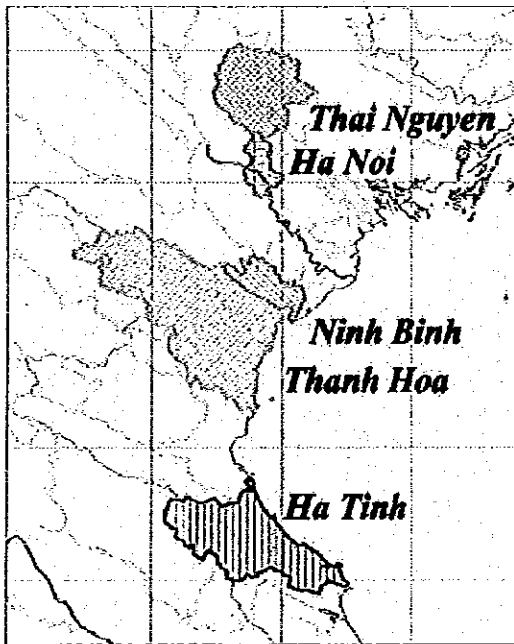
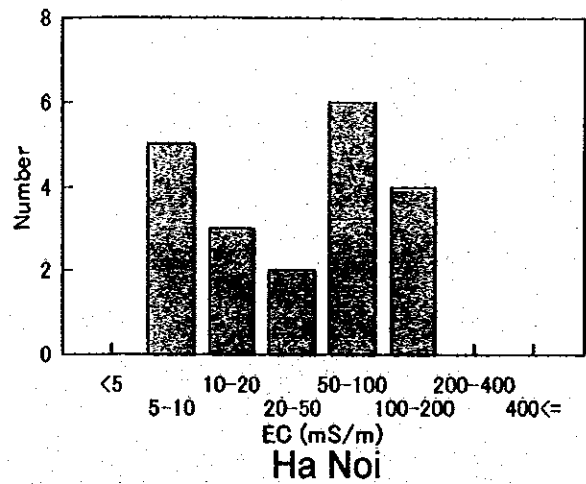
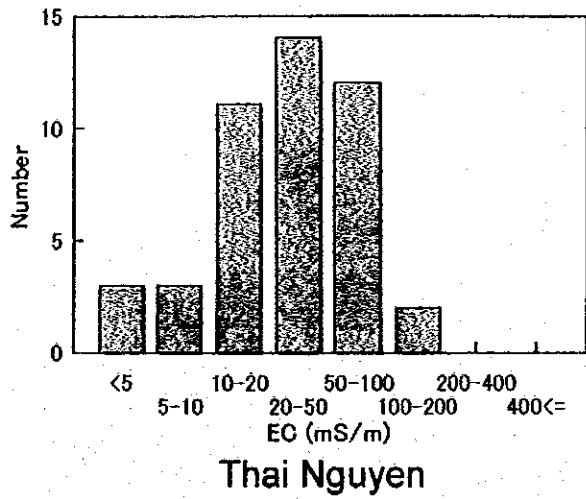
Thanh Hoa

**Figure 3.1.7** Distribution of pH Values of Groundwater by Province

THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

(Groundwater samples were collected from existing wells.)

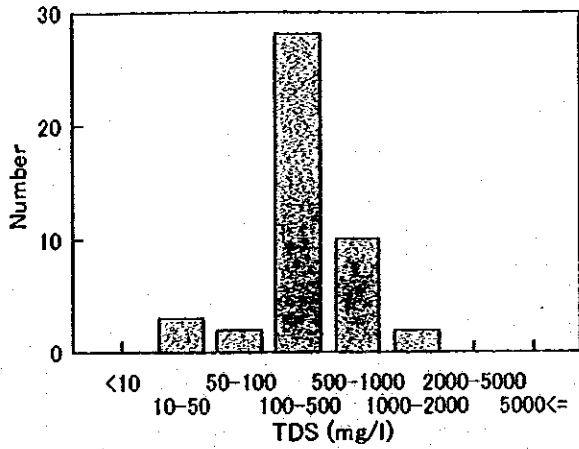


**Figure 3.1.8** Distribution of EC Values of Groundwater by Province

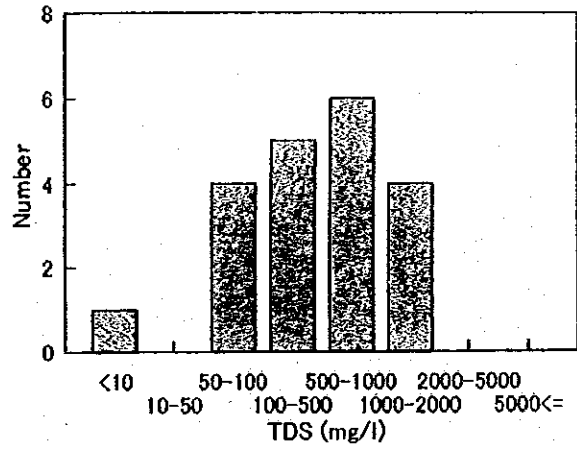
THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

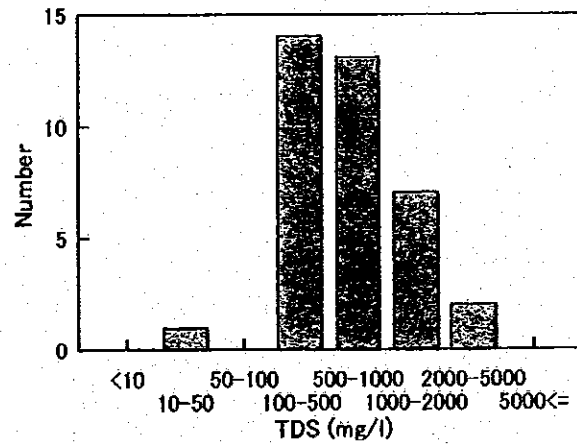
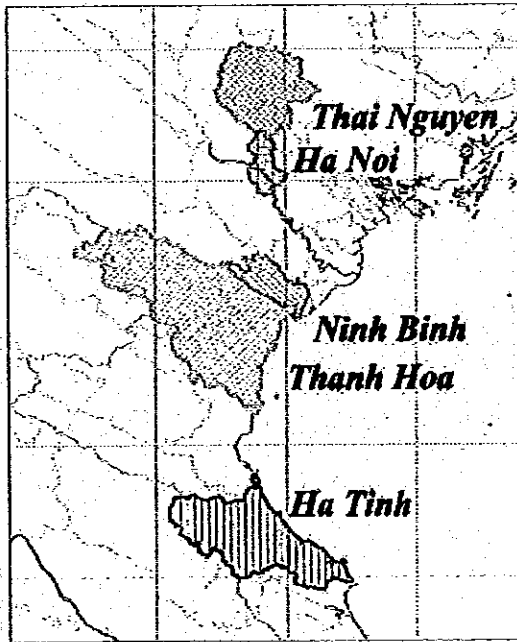
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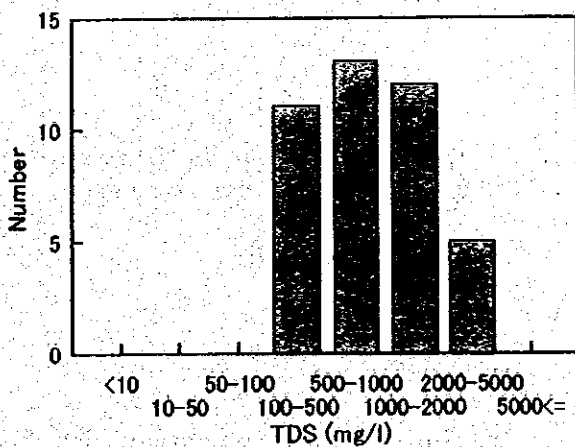
Thai Nguyen



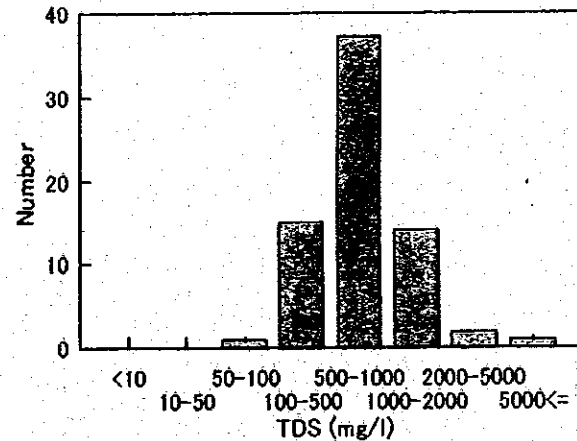
Ha Noi



Ninh Binh



Ha Tinh



Thanh Hoa

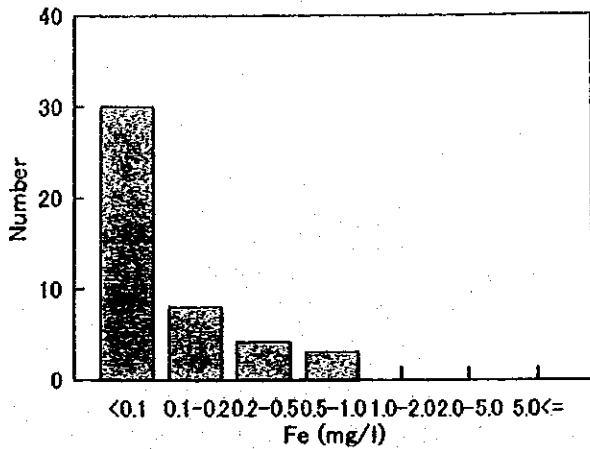
Figure 3.1.9

Distribution of TDS Values of Groundwater by Province

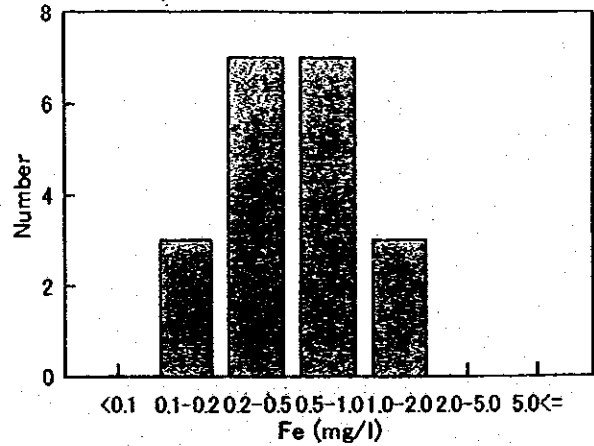
THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

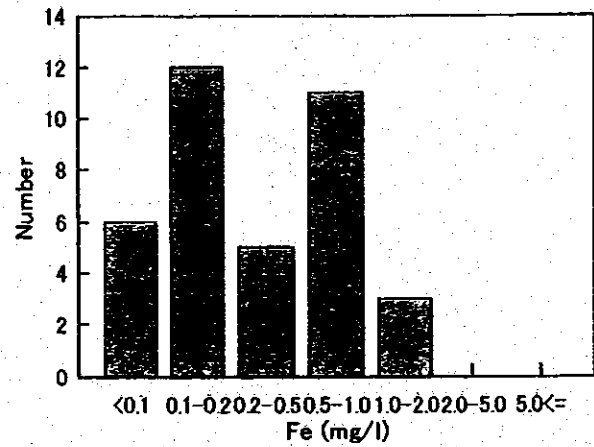
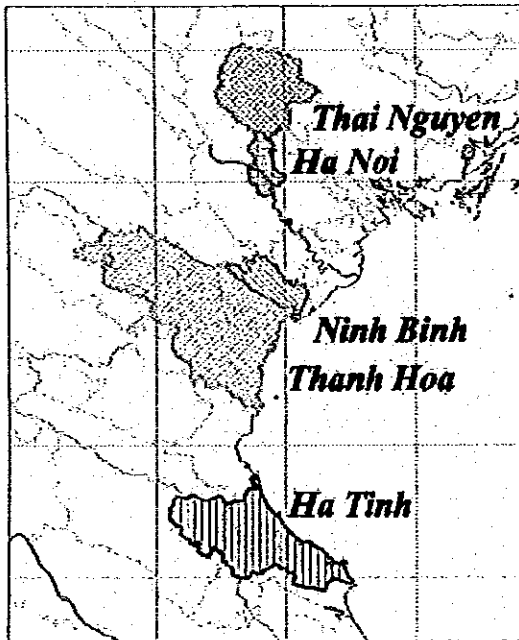
(Groundwater samples were collected from existing wells.)



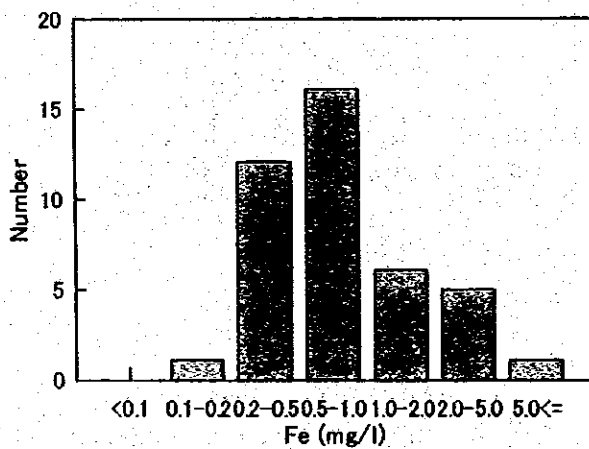
Thai Nguyen



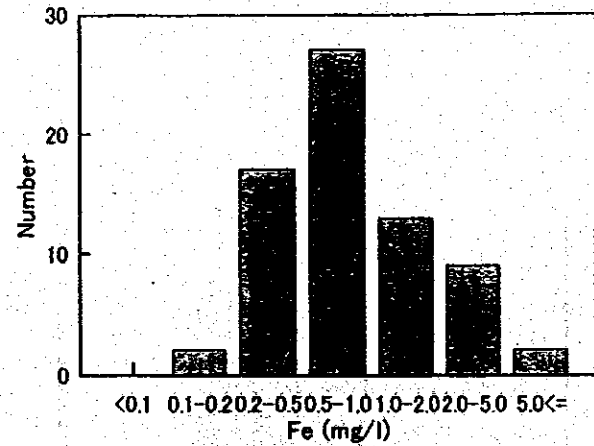
Ha Noi



Ninh Binh



Ha Tinh



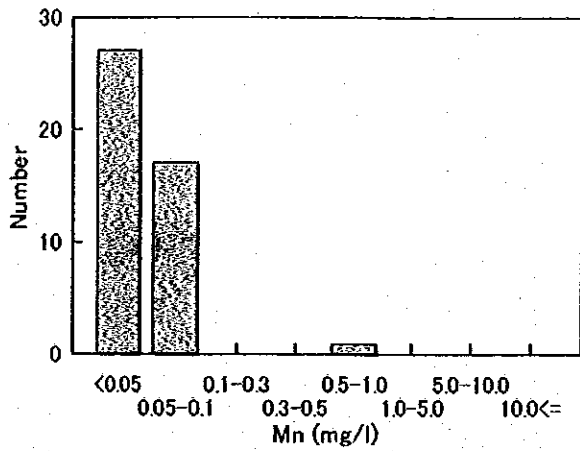
Thanh Hoa

Figure 3.1.10 Distribution of Fe Concentration of Groundwater by Province

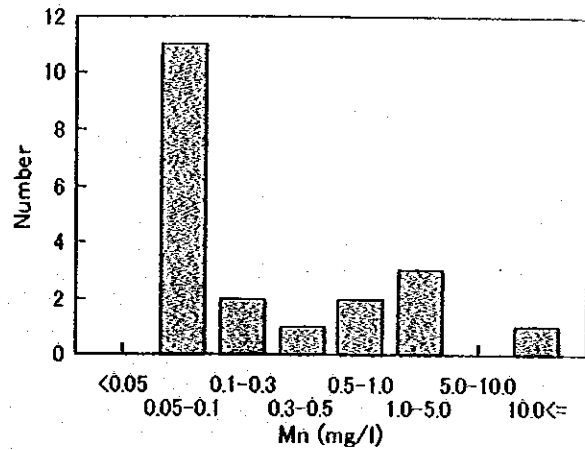
THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

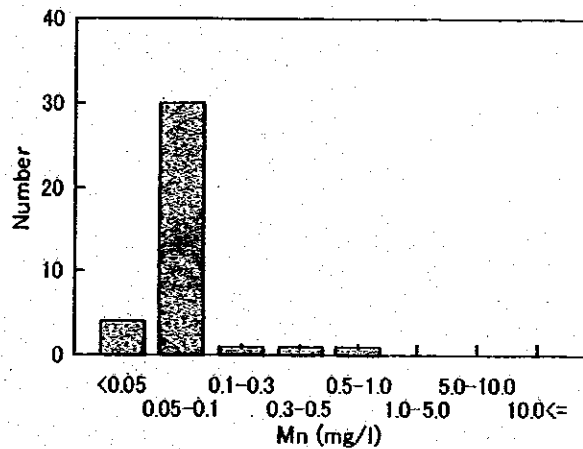
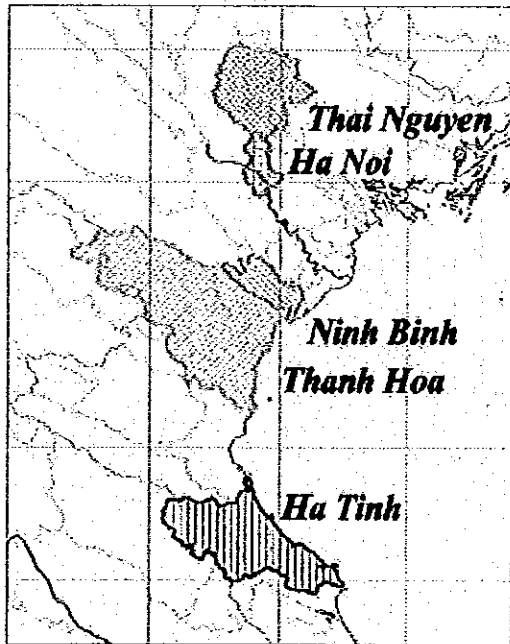
(Groundwater samples were collected from existing wells.)



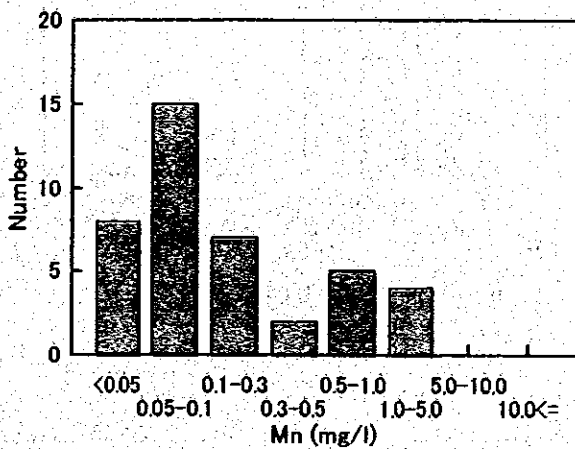
Thai Nguyen



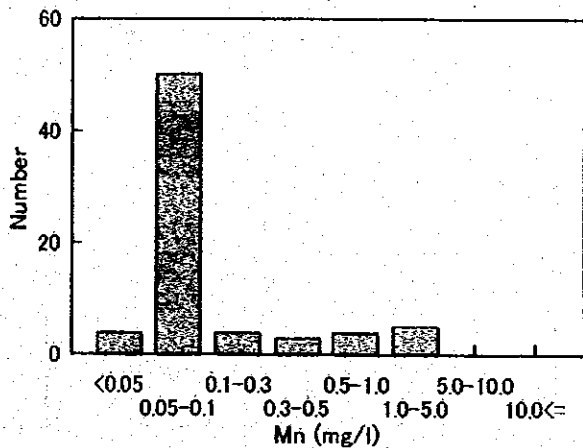
Ha Noi



Ninh Binh



Ha Tinh



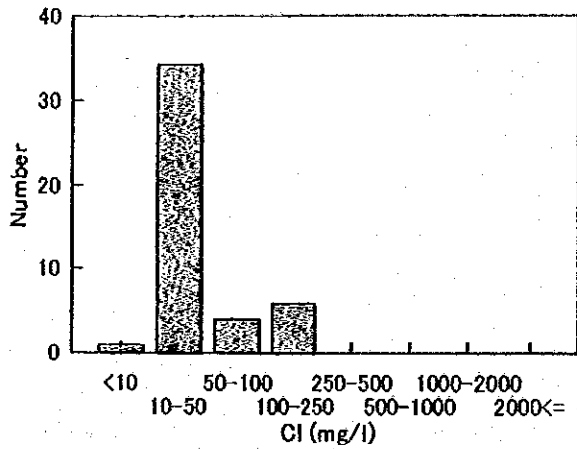
Thanh Hoa

(Groundwater samples were collected from existing wells.)

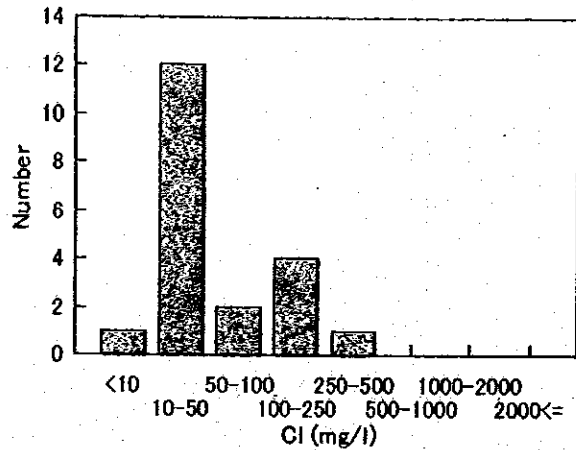
**Figure 3.1.11** Distribution of Mn Concentration of Groundwater by Province

THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM

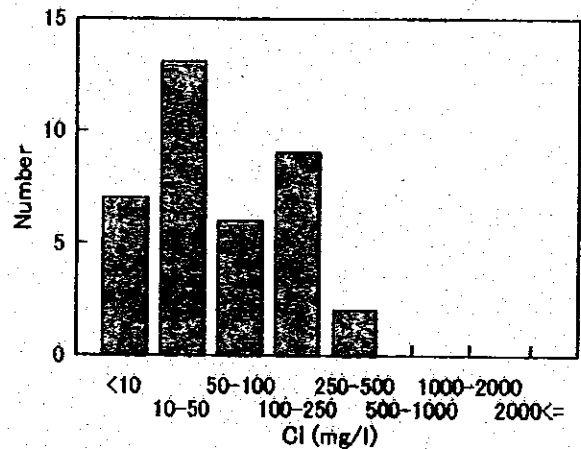
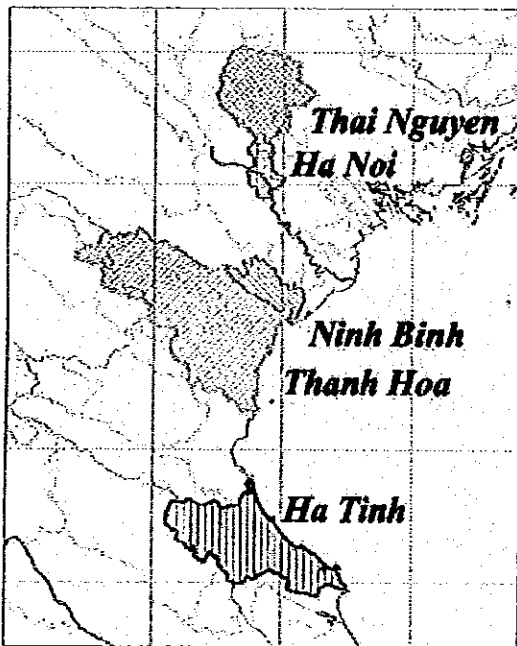
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



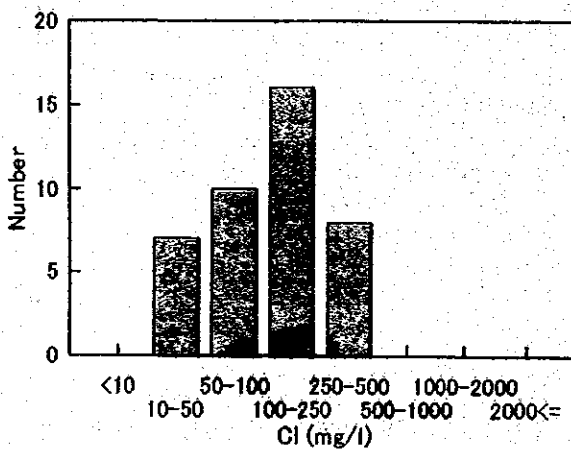
Thai Nguyen



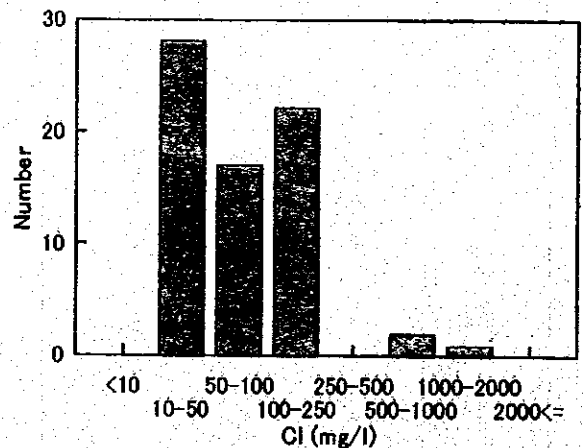
Ha Noi



Ninh Binh



Ha Tinh



Thanh Hoa

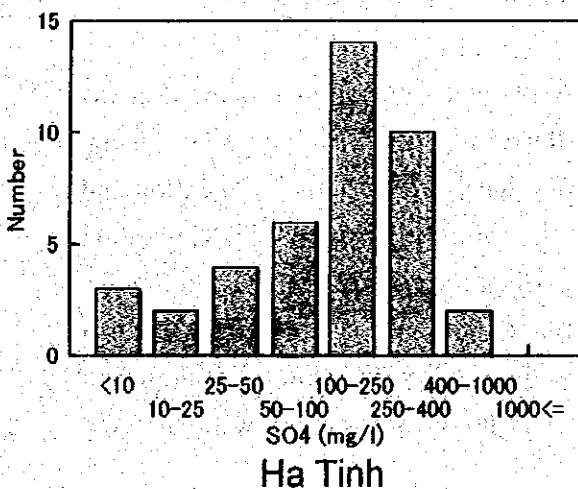
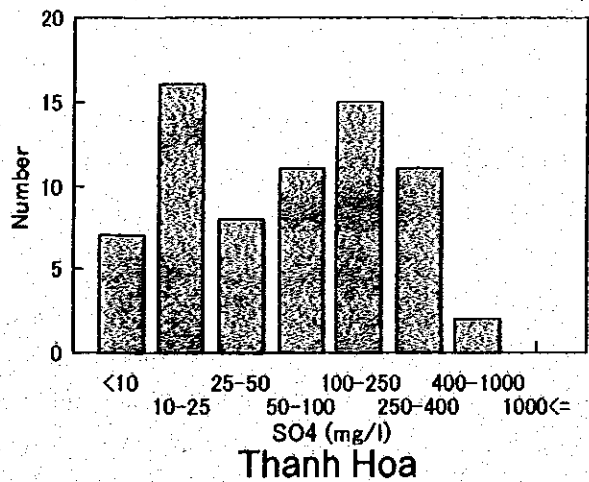
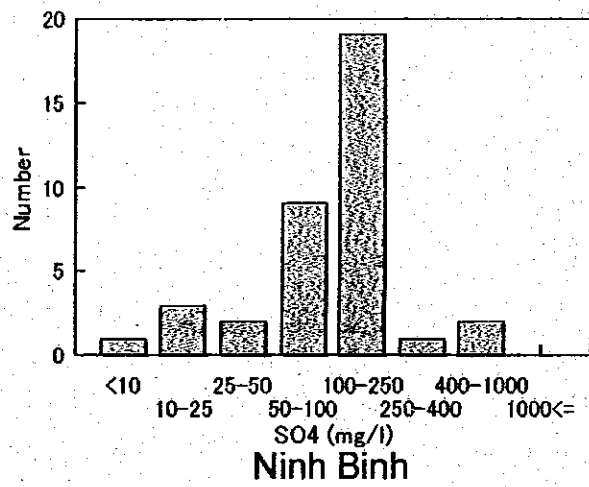
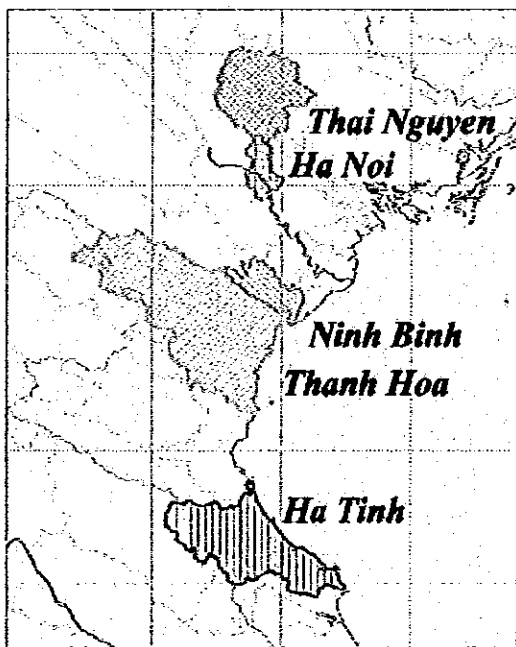
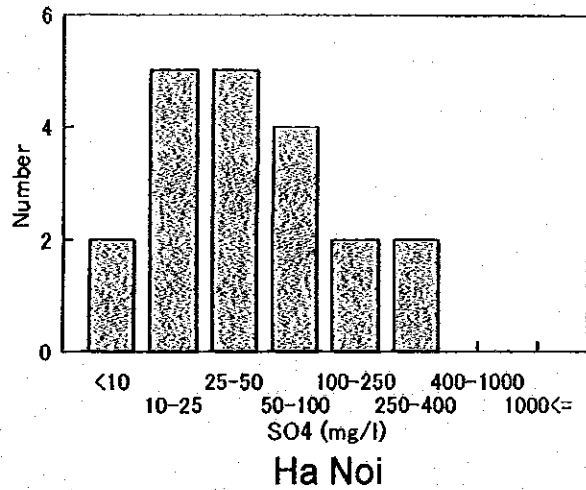
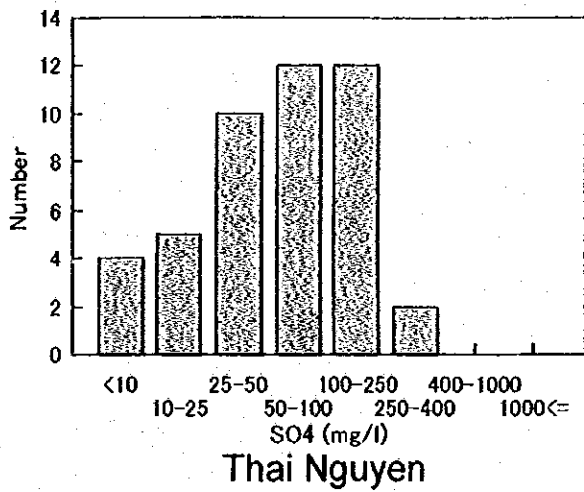
Figure 3.1.12

Distribution of Cl Concentration of Groundwater by Province

THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

(Groundwater samples were collected from existing wells.)



**Figure 3.1.13** Distribution of SO<sub>4</sub> Concentration of Groundwater by Province

THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

(Groundwater samples were collected from existing wells.)

## **3.2 Water Quality of Test Wells**

Groundwater samples from the test wells were collected during the continuous pumping test. The samples were brought to a laboratory as soon as possible after sampling. The results of laboratory chemical analysis are shown in Table 3.2.1. It is noted that water sample of JICA-1 well (Dong Bam) was not collected because the well development and pumping test were not done. The measured chemical parameters in the laboratory test are the same as mentioned in Chapter 3.1.1.

### **3.2.1 Trilinear Diagram analysis**

Based on the results of chemical analysis, a trilinear diagram was prepared to understand the chemical properties of groundwater in the test wells. Figures 3.2.1 shows the trilinear diagram of test well water.

The test well water in Thai Nguyen shows Ca-HCO<sub>3</sub> type. Two (2) wells in Ninh Binh (JICA-5 and JICA-7) and two (2) wells in Thanh Hoa (JICA-10 and JICA-11) also show Ca-HCO<sub>3</sub> type. These wells are plotted on the left side of the diamond-shape graph. Three (3) wells' water in Thanh Hoa (JICA-8, 9, 14) are plotted in the central part of the diamond-shape graph. The three (3) wells of Ha Tinh (JICA-12, 13, 15) and one (1) well in Ninh Binh (JICA-6) show Na-Cl type. This Na-Cl type water has higher concentration of total ions as indicated by circles on the diamond-shape graph.

### **3.2.2 Stiff Diagram**

Figure 3.2 2 shows the Stiff diagrams of the test well water. It is clearly shown that three (3) test wells in Ha Tinh and one (1) well at Yen Thang, Ninh Binh show high concentration of Na and Cl. The chemical composition of the wells is similar to the sea water.

In Thanh Hoa, the patterns of JICA-10 well and JICA-11 well show similar shape, but the other three (3) wells show different shapes. Particularly at JICA-8 well at Van Thang, although the concentration is not higher, the water shows that Na and Cl are main cation and anion, indicating that the water may be influenced by the saline river water. In Ninh Binh, JICA-6 well at Yen Thang has the largest pattern in the diagrams. Cl is dominant in anions, however, not only Na but also Mg concentrations are higher in cations. The pattern of JICA-5 well is similar to that of JICA-7 well. In Thai Nguyen, the size of Stiff pattern is smaller in JICA-3 and JICA-4 wells, but JICA-2 well has a relatively larger Stiff pattern with showing Ca-HCO<sub>3</sub> rich in water.



Table 3.2.1 Results of Laboratory Chemical Analysis of Groundwater Samples Taken from JICA Test Wells

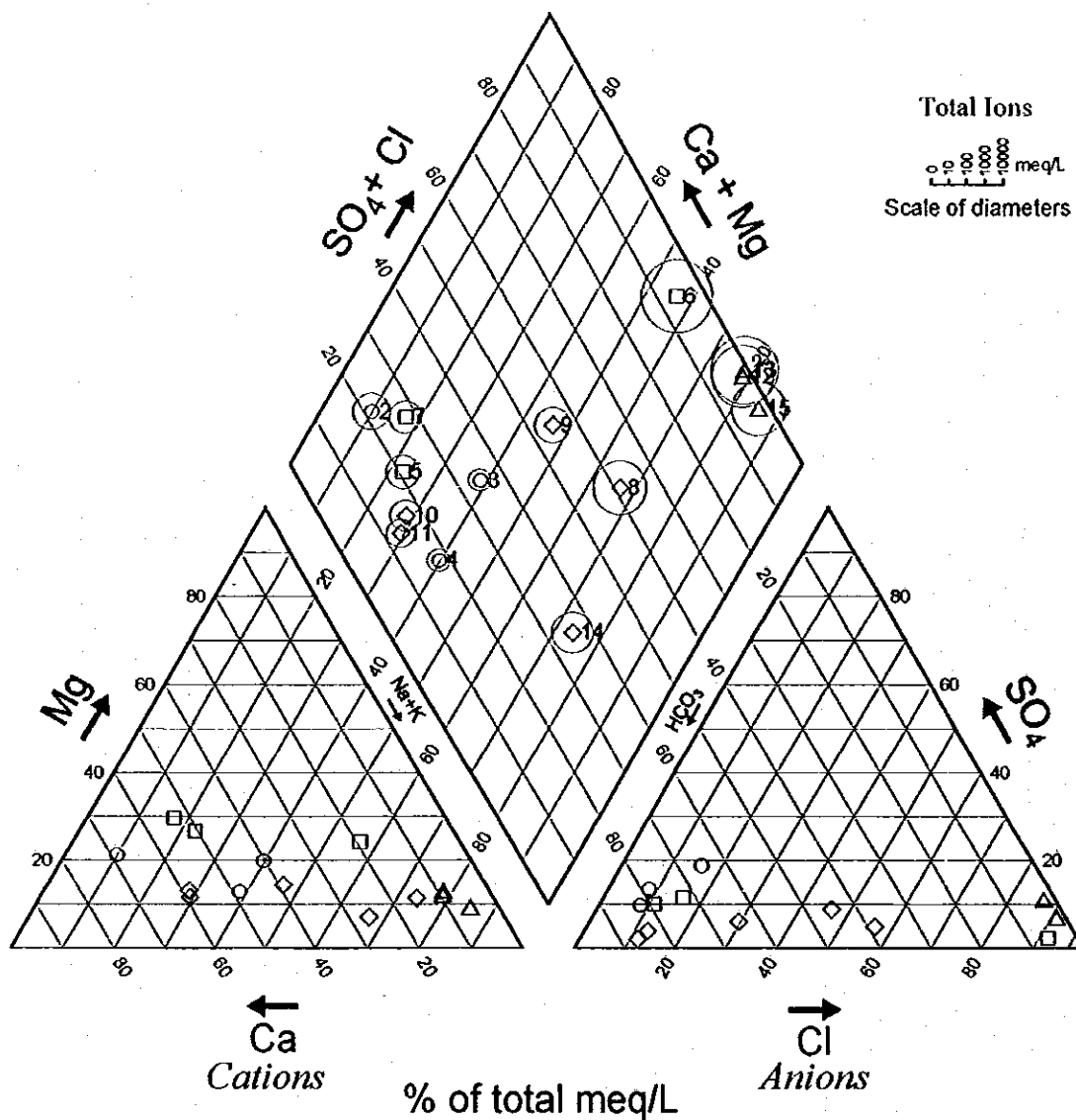
Test Well No.	Commune	Geology	Temp. (°C)	EC (mS/m)	Hardness (mg/l)	TDS (mg/l)	Redox potential (mV)	DO (mg/l)	WHO Guideline Values for Drinking Water											
									Vietnamese Drinking and Domestic Water Quality Standard for Ground Water (Bảng Số 1)						WHO Guideline Values for Drinking Water					
									8.5-8.5	10.00	50.00	1.000	1.500	0.100	250.00	0.300	250.00	200.00	1.500	10.00
pH	Nitrate (NO <sub>3</sub> <sup>-</sup> ) (mg/l)	Nitrite (NO <sub>2</sub> <sup>-</sup> ) (mg/l)	Ammonium (NH <sub>4</sub> <sup>+</sup> ) (mg/l)	Manganese (Mn <sup>2+</sup> ) (mg/l)	Sulfate (SO <sub>4</sub> <sup>2-</sup> ) (mg/l)	Iron (Fe) (mg/l)	Chloride (Cl <sup>-</sup> ) (mg/l)	Bicarbonate (HCO <sub>3</sub> <sup>-</sup> ) (mg/l)	Calcium (Ca <sup>2+</sup> ) (mg/l)	Magnesium (Mg <sup>2+</sup> ) (mg/l)	Sodium (Na <sup>+</sup> ) (mg/l)	Potassium (K <sup>+</sup> ) (mg/l)	Fluoride (F <sup>-</sup> ) (mg/l)	Arsenic (As) (µg/l)						
JICA-1	Dong Bam	Quaternary/Limestones	-	-	-	-	-	-	-	-	-	-	-	-	-					
JICA-2	Hoa Thong	Quaternary/Limestones/Sandstone	25.4	46.8	5.440	466	140	5.88	1.120	0.080	0.195	40.22	17.75	295.20	83.20	15.61	12.20	2.52	0.058	1.89
JICA-3	Nam Tien	Quaternary/Sandstone/Siltstone	25.9	15.8	1.300	145	148	8.15	0.405	0.014	0.058	20.08	12.88	90.80	22.20	3.60	18.40	3.07	0.052	2.03
JICA-4	Thinh Duc	Quaternary/Claystone	25.1	18.8	1.436	160	165	8.12	0.680	0.090	0.112	11.40	7.12	122.20	19.20	5.76	20.92	1.26	0.049	1.74
JICA-5	Quang Son	Quaternary/Limestones	24.1	4.1	3.790	408	285	6.15	0.684	0.025	0.178	23.68	19.20	238.50	48.80	15.60	18.30	11.70	0.055	1.66
JICA-6	Yen Thang	Quaternary/Limestones	22.6	225.0	31.000	408	208	5.95	0.412	0.015	0.088	90.10	280.60	280.60	275.50	210.50	17.90	1.51	0.060	1.88
JICA-7	Dong Phong	Top Soil/Limestones	25	46.5	3.980	402	204	6.18	0.750	0.042	0.172	26.12	26.63	207.40	51.20	17.28	17.90	1.51	0.060	1.96
JICA-8	Yen Thang	Quaternary/Sandstone	22.8	75.5	7.120	782	148	5.75	0.305	0.022	0.088	48.20	22.90	486.50	110.50	18.20	10.90	10.90	0.060	1.69
JICA-9	Thieu Hung	Quaternary/Sandstone	23.8	64.0	3.170	628	198	6.15	0.341	0.100	0.073	24.20	93.43	156.50	46.50	10.40	62.10	1.70	0.043	1.60
JICA-10	Dinh Tuong	Quaternary/Sandstone	26.3	41.6	3.108	409	208	6.02	0.321	0.024	0.088	3.40	19.53	222.80	50.50	6.90	25.88	3.92	0.052	1.74
JICA-11	Vinh Thanh	Quaternary/Limestones	25.4	38.5	2.410	382	235	6.05	0.250	0.010	0.078	3.42	14.22	183.40	40.20	4.80	21.78	1.68	0.059	1.62
JICA-12	Duc Yen	Quaternary/Neogene clay	24.1	183.5	7.380	408	195	6.10	0.238	0.009	0.064	118.50	40.50	40.50	64.20	50.20	44.60	44.60	0.049	2.02
JICA-13	Trung Le	Quaternary/Neogene clay	25.8	517.5	12.820	408	158	5.81	0.425	0.026	0.081	36.78	27.40	27.40	90.80	82.20	36.80	0.084	1.89	
JICA-14	Thieu Do	Quaternary/Limestones	28.5	110.2	2.297	408	195	6.10	0.412	0.019	0.057	23.56	92.30	345.80	26.05	12.08	118.40	51.26	0.052	1.86
JICA-15	Trung Le	Quaternary/Neogene clay	26.1	218.5	3.000	408	174	5.90	0.329	0.018	0.071	105.21	29.40	29.40	22.80	22.80	11.32	0.056	1.76	

More than WHO Guideline Value

**Table 3.2.1 Results of Laboratory Chemical Analysis of Groundwater Samples Taken from JICA Test Wells**

		WHO Guideline Values for Drinking Water																						
Test Well No.	Commune	Geology	pH (6.5-8.5)	Temp. (°C)	EC (mS/m)	Hardness (mg/l)	TDS (mg/l)	Redox potential (mV)	DO (mg/l)	Vietnamese Drinking and Domestic Water Quality Standard for Ground Water (Rural Supply)		WHO Guideline Values for Drinking Water												
										Nitrate (NO <sub>3</sub> <sup>-</sup> ) (mg/l)	Nitrite (NO <sub>2</sub> <sup>-</sup> ) (mg/l)	Ammonium (NH <sub>4</sub> <sup>+</sup> ) (mg/l)	Manganese (Mn <sup>2+</sup> ) (mg/l)	Sulfate (SO <sub>4</sub> <sup>2-</sup> ) (mg/l)	Iron (Fe) (mg/l)	Chloride (Cl <sup>-</sup> ) (mg/l)	Bicarbonate (HCO <sub>3</sub> <sup>-</sup> ) (mg/l)	Calcium (Ca <sup>2+</sup> ) (mg/l)	Magnesium (Mg <sup>2+</sup> ) (mg/l)	Sodium (Na <sup>+</sup> ) (mg/l)	Potassium (K <sup>+</sup> ) (mg/l)	Fluoride (F <sup>-</sup> ) (mg/l)	Arsenic (As) (µg/l)	
JICA-1	Dong Bam	Quaternary/Limestone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
JICA-2	Hoa Thuong	Quaternary/Limestone/Sandstone	7.22	25.4	46.8	5,440	466	140	5.88	0.090	0.195	0.302	40.22	17.75	295.20	83.20	15.61	12.20	2.52	0.056	1.89			
JICA-3	Nam Tien	Quaternary/Sandstone/Siltstone	6.50	25.0	15.8	1,300	145	146	6.15	0.405	0.058	0.032	20.68	12.88	90.80	22.20	3.60	18.40	3.07	0.052	2.03			
JICA-4	Thinh Duc	Quaternary/Claystone	7.51	25.1	15.0	1,435	160	165	6.12	0.680	0.112	0.084	11.40	7.12	122.20	19.20	5.76	20.92	1.26	0.049	1.74			
JICA-5	Quang Son	Quaternary/Limestone	7.42	24.1	4.1	3,790	408	205	6.15	0.694	0.025	0.178	23.59	19.20	238.50	48.60	15.60	18.30	11.70	0.055	1.56			
JICA-6	Yen Thang	Quaternary/Limestone	7.05	23.6	293.0	31,000	2,072	208	5.95	0.412	0.015	0.088	80.10	20.50	290.60	275.50	210.50	307.00	78.60	0.053	1.88			
JICA-7	Dong Phong	Top Soil/Limestone	7.82	25	40.5	3,980	402	204	6.18	0.750	0.172	0.026	25.12	26.63	207.40	51.20	17.28	17.90	1.51	0.060	1.56			
JICA-8	Van Thang	Quaternary/Sandstone	6.75	23.8	72.5	7,120	782	148	5.75	0.305	0.022	0.088	48.20	412.80	486.90	110.50	18.20	91.70	10.90	0.060	1.69			
JICA-9	Thieu Hung	Quaternary/Sandstone	6.80	22.8	84.0	3,170	628	198	6.15	0.341	0.100	0.073	24.20	93.43	156.50	46.50	10.40	62.10	1.70	0.043	1.80			
JICA-10	Dinh Tuong	Quaternary/Sandstone	7.30	26.3	41.6	3,108	409	206	6.02	0.321	0.024	0.088	8.40	19.53	222.80	50.80	8.90	25.88	3.92	0.032	1.74			
JICA-11	Vinh Thanh	Quaternary/Limestone	7.78	25.4	38.5	2,410	382	205	6.05	0.250	0.010	0.078	3.42	14.22	183.40	40.20	4.80	21.72	1.88	0.059	1.82			
JICA-12	Duc Yen	Quaternary/Neogene clay	6.80	24.1	183.5	7,380	3,510	195	6.10	0.238	0.009	0.084	116.59	1120.60	40.30	64.20	50.20	302.60	44.60	0.049	2.02			
JICA-13	Trung Lu	Quaternary/Neogene clay	6.80	25.8	517.5	12,620	2,620	156	5.81	0.425	0.081	0.030	36.78	172.70	27.40	90.80	82.20	306.60	36.80	0.084	1.89			
JICA-14	Thieu Do	Quaternary/Limestone	7.65	26.5	110.2	2,297	1,050	195	6.10	0.412	0.019	0.057	25.56	92.30	343.80	25.05	12.08	118.40	51.26	0.052	1.85			
JICA-15	Trung Lu	Quaternary/Neogene clay	6.80	26.1	216.5	3,000	2,180	174	5.90	0.325	0.018	0.071	105.21	105.80	29.40	22.60	22.80	11.32	0.056	1.75				

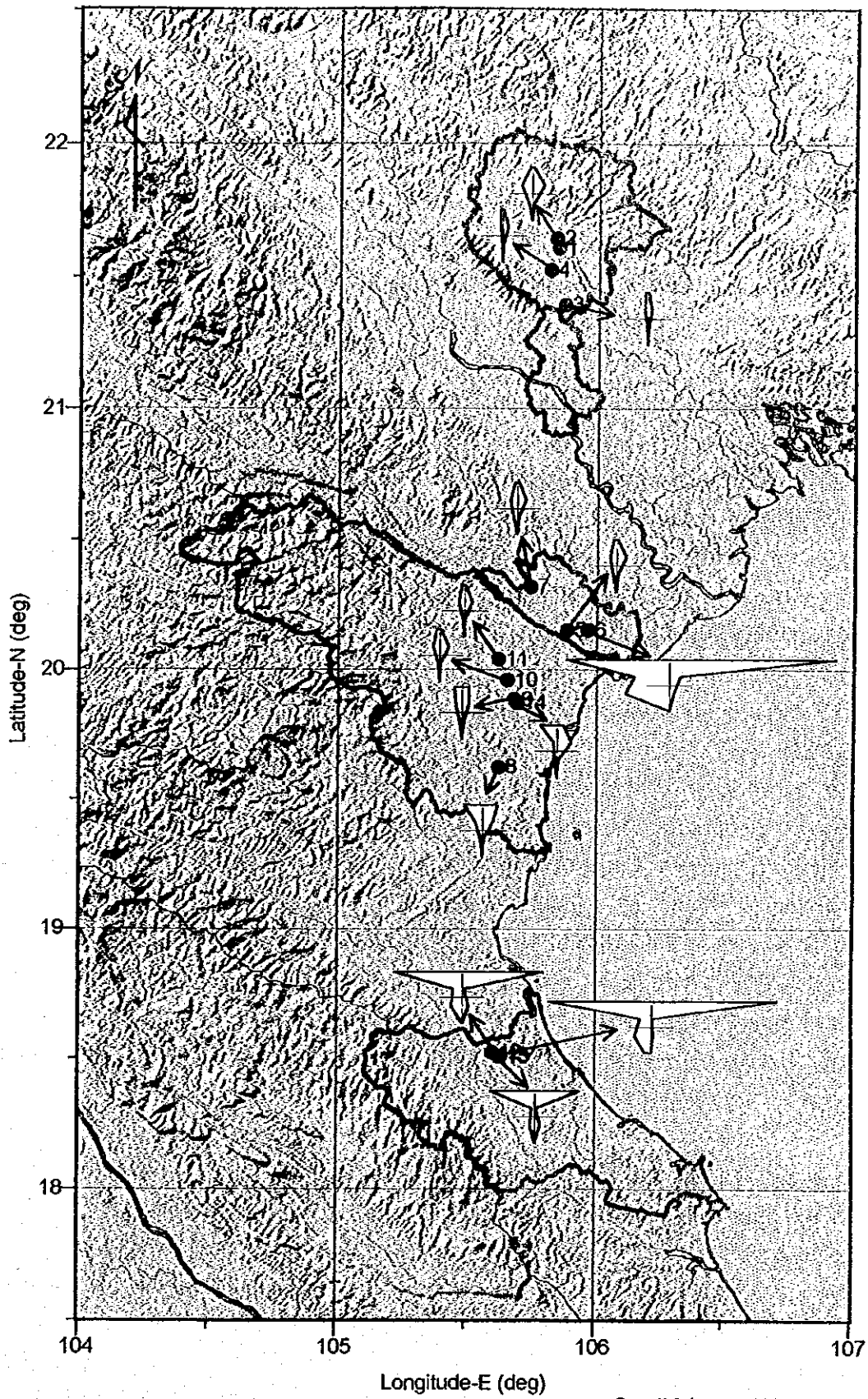
More than WHO Guideline Value      More than Vietnamese Guideline Value



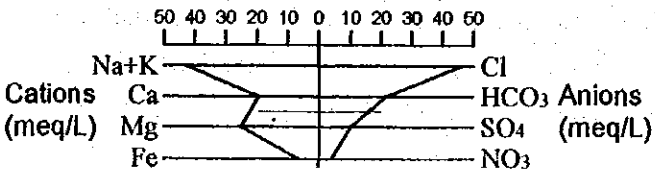
**JICA Test Wells**

- Thái Nguyên
- Ninh Bình
- ◇ Thanh Hóa
- △ Hà Tĩnh

<b>Figure 3.2.1:</b>	<b>TRILINEAR DIAGRAM OF GROUNDWATER TAKEN FROM TEST WELLS</b>
<b>THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM</b>	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



● JICA Test Well



**Figure 3.2.2 Stiff Diagram of JICA Test Wells**  
 THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM  
 JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

### **3.3 Water Quality of Existing Wells in Hanoi Area**

The groundwater quality in Hanoi area were monitored by DGM (1988) for a period from 1988 to 1997 by measuring groundwater samples of the monitoring wells twice a year (in the rainy season and the dry season). JICA (1997) also presented the groundwater quality measured at the productions of the Hanoi Water Supply System from 1990 to 1995.

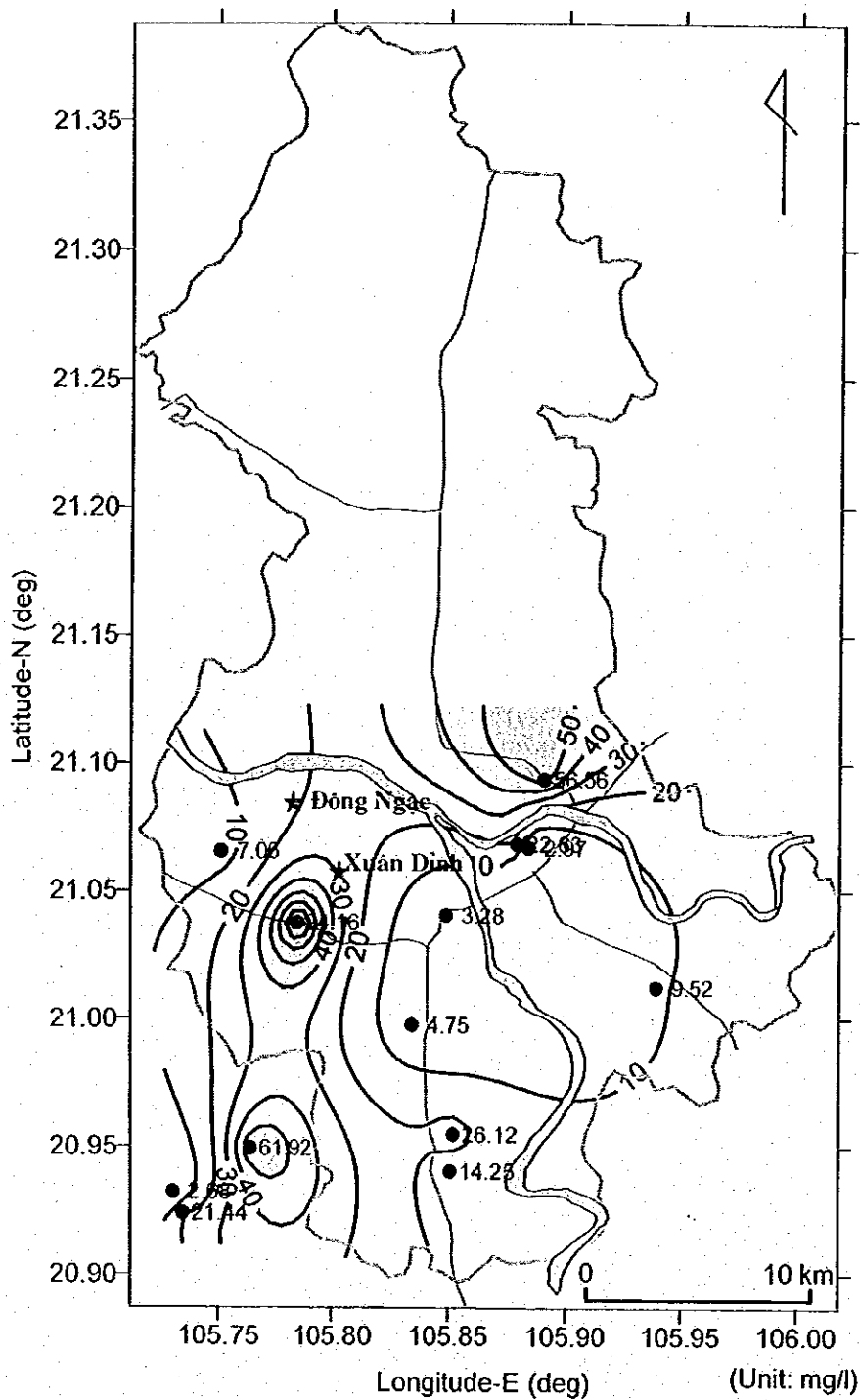
According to the data of DGM (1998), higher Iron concentrations were found in the southwestern to southern parts of Hanoi area as shown in Figure 3.3.1. The figure is prepared by the data measured in the second half of 1997 (rainy season) from the Second Aquifer. From this, the Iron concentration is estimated as 3 to 10 mg/l in the eastern part of Hanoi city and 10 to 30 mg/l in the target communes of Dong Ngac and Xuan Dinh. However, it is noted that the results of Iron concentration by DGM (1998) are different from the actual concentrations of the pumped water from the production wells, because the DGM (1988) might collect and analyzed "stagnant water" in the monitoring wells.

Figure 3.3.2 summarizes the groundwater quality of the existing well fields of the Hanoi Water Supply System. According to the data, Mai Dich well field, which is located about 4 km southwest of Xuan Dinh Commune and having 17 production wells, has the maximum and average Fe concentrations of 3.3 and 0.7 mg/l, respectively. Similarly, Ngoc Ha well field, which is located about 2 km south of Xuan Dinh Commune and having 11 production wells, has the maximum and average Fe values of 4.7 and 1.6 mg/l. The maximum Fe concentrations of Yen Phu, Ngo Si Lien, and Ha Dinh well fields are 11.6, 16.7, and 19.7 mg/l, respectively. These Fe concentrations indicate that the Second Aquifer of Hanoi area is Fe rich in groundwater, particularly in south and southeast of Hanoi City. The data suggest that the Fe concentration in the target communes is more than 0.5 mg/l, exceeding the Vietnamese drinking water standard.

Manganese concentrations are also high in the existing well fields, showing the maximum values of 2.4 mg/l at the nearest well field from the target communes. The average values are also above the standard value (50.1 mg/l) in Ngoc Ha, Mai Dich, Ngo Si Lien, Yen Phi, Luong Yen, and Tuong Mai well fields. From this it is predicted that the Manganese concentration in the target communes is more than the standard value.

Very high NH<sub>4</sub> concentrations more than 10 mg/l are detected in Yen Phu, Ngo Si Lien, Ha Dinh, Tuong Mai, and Phap Van well fields. The standard value of NH<sub>4</sub> is 3.0 mg/l so that it is possible that the NH<sub>4</sub> concentration in the target communes is more than the standard value. However, it would be possible that the Second Aquifer is locally contaminated by dirty

surface water due to some problems of the well structure. JICA (1997) employs 1.2 mg/l of NH<sub>4</sub> concentration as the design value of the Hanoi Water Supply System.

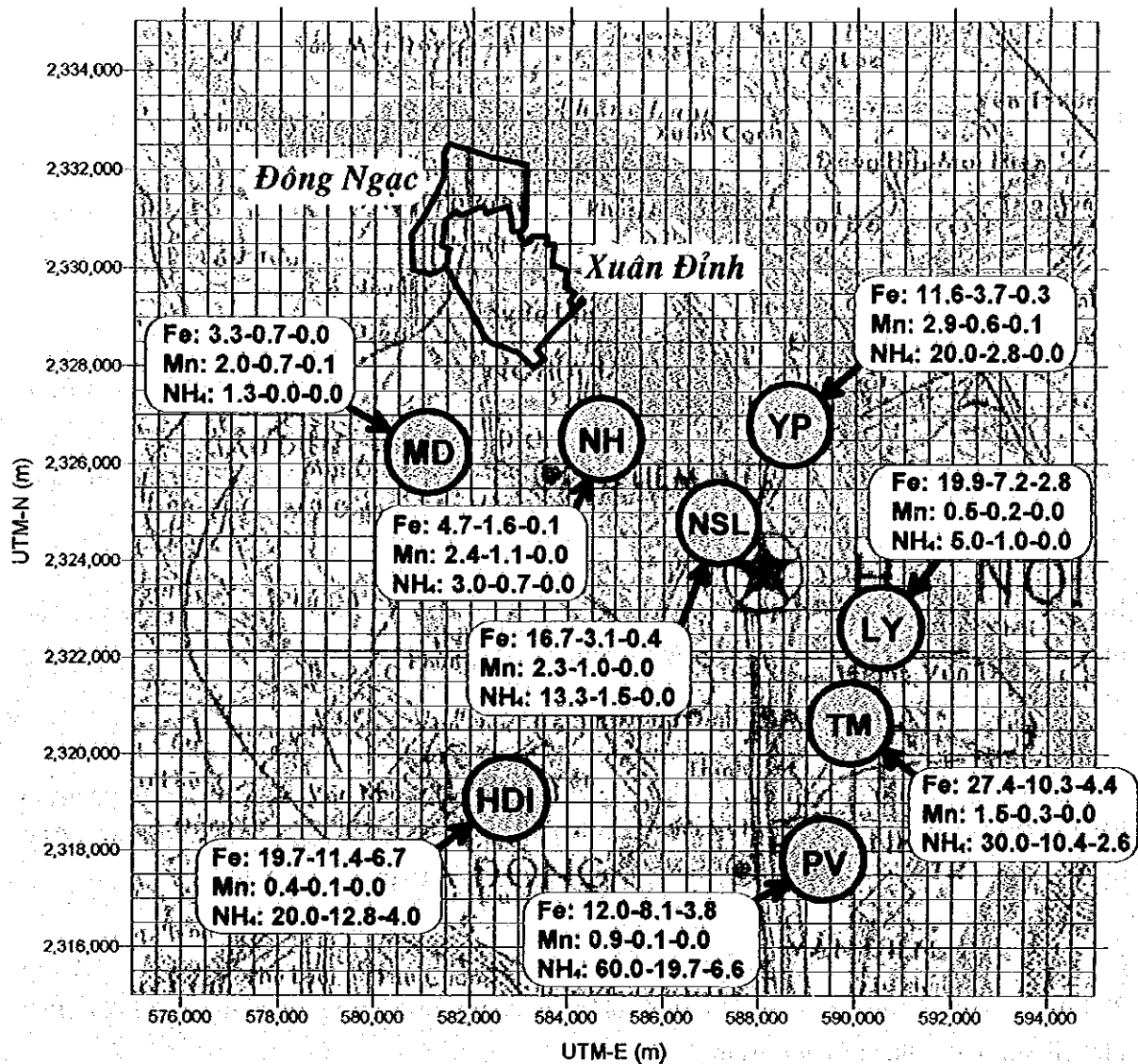


● 4.75 Monitoring Well with Fe Concentration (mg/l)  
(in the second half of 1997)

[Data Source: ĐẶC TRUNG / ĐỘNG THÁI NƯỚC DƯỚI ĐẤT VÙNG ĐỒNG BẰNG BẮC BỘ (1988-1997)]

<b>Figure 3.3.1</b>	<b>Fe Concentrations Measured at Monitoring Wells in Hà Nội Area (in the second half of 1997)</b>
<b>THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM</b>	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

## Groundwater Quality of Well Fields in Hà Nội Area



Water Quality of Production Wells by Well Field

**Fe: Max-Avg-Min**  
**Mn: Max-Avg-Min**  
**NH: Max-Avg-Min**

(Unit: mg/l)

**Name of Well Field**

- MD: Mai Dich
- NH: Ngoc Ha
- YP: Yen Phu
- NSL: Ngo Si Lien
- LY: Luong Yen
- TM: Tuong Mai
- HDI: Ha Dinh
- PV: Phap Van

[Data source: JICA (1997)]

<b>Figure 3.3.2</b>	<b>Groundwater Quality of Well Fields in Hà Nội Area</b>
THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



## **3.4 Hydrochemical Analysis**

### **3.4.1 pH-ORP Relations of Groundwater by Province**

Figure 3.4.1 shows pH-ORP plots of groundwater measured at existing wells during the field investigation by province. In Thai Nguyen province, the relationship between pH values and ORP values shows almost linear; the ORP values decrease with increasing pH values. This is a typical relationship between pH and ORP.

In Hanoi province, it seems that the ORP values increase with pH values. But the plots are divided into two (2) groups; one has pH values ranging from 5.0 to 6.0 with ORP values from 100 to 200 mV, and the other has pH values ranging from 6.4 to 7.2 with ORP values from 200 to 300 mV. In each group, it can be seen that the ORP values decrease with increasing pH values.

In Ninh Binh, there are many samples plotted around pH = 7.0 and ORP = 200 mV. The plotted area shows a triangle shape, with corners of (pH = 5.8, ORP = 250 mV), (7.8, 200 mV), and (6.7, -100 mV).

The groundwater of Thanh Hoa province has higher values of ORP. About half of the samples have ORP values more than 300 mV. The plotted area is wider than that of Ninh Binh. And the triangle-shape plotted area stretches from the upper left to the lower right.

In Ha Tinh, most of the plots are located within an area of pH = 5.0 to 7.7 and ORP = -100 to 200 mV. Except some plots having low pH values, the distribution pattern of the pH-ORP plots is similar to that of Ninh Binh.

As a result, it is understood that the pattern of pH-ORP plots is different by province. It is noted that the plots may change by season due to the occurrence of groundwater recharge from the rain water and river water.

### **3.4.2 Relationships among ORP, Fe and Mn**

Figure 3.4.2 shows the relationships among ORP, Fe and Mn concentration of groundwater from the existing wells in the Study area. The upper left graph presents the relationship between Fe concentration and ORP. It is hard to find any significant correlation. Higher concentration of Fe more than 1.0 mg/l occurs at an ORP range from -100 to 500 mV.

The upper right graph shows the relationship between Mn concentration and ORP. Although there is no significant correlation between Mn concentration and ORP, the Mn concentrations more than 0.5 mg/l seem to increase with ORP. The higher Mn concentrations more than 1.0 mg/l take an ORP range from 100 to 400 mV.

The lower graph shows the relationship between Fe concentration and Mn concentration. There is no significant correlation between the Fe and Mn concentrations. However, it can be seen that the samples having more than 5.0 mg/l in Fe concentration have less Mn concentration below 0.5 mg/l. On the other hand, most of the samples having Mn concentration more than 0.5 mg/l have less Fe concentration below 2.0 mg/l.

### 3.5 Comparison with Drinking Water Standards

#### 3.5.1 Groundwater of Test Wells

The WHO guideline values for drinking water and the Vietnamese drinking and domestic water quality standard for drinking water (rural supply) are shown in Table 3.2.1 together with the results of test well water analysis. In the table, values exceeding the standards are shown with shaded color. It is noted that the Vietnamese standard value of Nitrite ( $\text{NO}_2^-$ ) is 0.000 mg/l, but the standard value was not applied to this interpretation.

From this table, it is understood that groundwater within the standards values obtained only from four (4) wells; namely JICA-3 (Nam Tien), JICA-4 (Thinh Duc), JICA-7 (Dong Phong), and JICA-10 (Dinh Tuong) wells. The groundwater from other test wells has at least one chemical parameter exceeding the guideline value. In addition, there is no wells exceeding the guideline values of Nitrate ( $\text{NO}_3$ ), Ammonium ( $\text{NH}_4^+$ ), Sulfate ( $\text{SO}_4^{2-}$ ), Fluoride (F), and Arsenic (As). The parameters exceeded by the test well water are as follows:

(1) pH

According to the Vietnamese standard, pH values should be in the range from 6.5 to 8.5. The pH values of three (3) test wells are out of the range. Those are JICA-5 (Quang Son, pH = 6.25), JICA-13 (Trung Le, pH = 4.65), and JICA-15 (Trung Le, pH = 5.15) wells.

(2) TDS

The guideline value of TDS (Total Dissolved Solids) is 1,000 mg/l by WHO and the Vietnamese standards. There are five (5) wells exceeding this value; JICA-6 (Yen

Thang, TDS = 2,372 mg/l), JICA-12 (Duc Yen, TDS = 1,815 mg/l), JICA-13 (Trung Le, TDS = 5,269 mg/l), JICA-14 (Thieu Do, TDS = 1,096 mg/l), and JICA-15 (Trung Le, TDS = 2,149 mg/l).

**(3) Mn<sup>2+</sup>**

The guideline value of Manganese is 0.100 mg/l by WHO and the Vietnamese standard. There are seven (7) wells exceeding this value. The highest value was measured at JICA-13 (Trung Le, 7.310 mg/l). JICA-12 (Duc Yen) has the second highest value of 2.050 mg/l. In Thanh Hoa, JICA-8 (Van Thang) and JICA-9 (Thieu Hung) have higher Manganese concentrations of 0.270 and 0.480 mg/l, respectively. Two (2) wells in Ninh Binh also have Manganese concentrations more than the guideline value; JICA-5 (Quang Son, 0.250 mg/l) and JICA-6 (Yen Thang, 0.420 mg/l). In Thai Nguyen, only JICA-2 well (Hoa Thuong) has a higher value of 0.392 mg/l.

**(4) Fe**

The guideline value of Iron is 0.300 mg/l by WHO and 0.500 mg/l by the Vietnamese standard. There are seven (7) test wells exceeding 0.500 mg/l and one (1) well between 0.300 and 0.500 mg/l. The highest Fe concentration was measured at JICA-13 well (Trung Le, 72.640 mg/l). JICA-2 well (Hoa Thuong) has the second highest value of Iron, that is 5.150 mg/l. Other test wells exceeding 0.500 mg/l are JICA-6 (Yen Thang, 1.800 mg/l), JICA-8 (Van Thang, 0.950 mg/l), JICA-9 (Thieu Hung, 1.420 mg/l), JICA-11 (Vinh Thanh, 1.820 mg/l), and JICA-12 (Duc Yen, 0.820 mg/l). JICA-5 well in Quang Son has 0.420 mg/l in Iron concentration, which is above the WHO guideline value but is below the Vietnamese standard value.

**(5) Cl<sup>-</sup>**

The guideline value of Chloride is 250.0 mg/l by WHO whereas it is 500.0 mg/l by the Vietnamese standard. There are four (4) test wells having more than 500.0 mg/l, and one (1) has a concentration between 250.0 and 500.0 mg/l. The highest Cl concentration was measured at JICA-6 (Yen Thang, 2,343.0 mg/l). In Ha Tinh, all the test wells have Cl concentrations more than 500.0 mg/l; JICA-12 (Duc Yen, 1,126.0 mg/l), JICA-13 (Trung Le, 1,775.2 mg/l), and JICA-15 (Trung Le, 609.8 mg/l). In Thanh Hoa, JICA-8 well (Van Thang) has a Cl concentration of 412.8 mg/l, which is above the WHO guideline value, but it is below the Vietnamese standard.

**(6) Na<sup>+</sup>**

The guideline value of Sodium is 200.00 mg/l both by the WHO and the Vietnamese standards. There are five (5) test wells exceeding the guideline value. The highest Na

concentration of 906.80 mg/l was measured at JICA-13 well (Frung Le). The second highest value was observed at JICA-6 well (Yen Thang). Other wells having more than the standard value are JICA-8 (Van Thang, 317.00 mg/l), JICA-12 (Duc Yen, 588.40 mg/l), and JICA-15 (Trung Le, 391.23 mg/l).

### 3.5.2 Groundwater of Existing Wells

The results of chemical analysis of the groundwater taken from existing wells were compared with the Vietnamese drinking and domestic water quality standard for drinking water (rural supply).

#### (1) pH

According to the Vietnamese standard, pH values should be in the range from 6.5 to 8.5. Very low pH values ranging from 4.5 to 5.5 were found from Thinh Duc and Nam Tien communes in Thai Nguyen province where red soils derived from weathered sandstone and shale are distributed. In other areas, the groundwater occurs in limestone tends to show neutral to slightly alkaline water, whereas the groundwater occurs in sandstone and shale tends to show acidic water.

#### (2) TDS

The guideline value of TDS (Total Dissolved Solids) is 1,000 mg/l by the Vietnamese standards. In Thai Nguyen province only two (2) wells have more than the standard value. In Hanoi province four (4) samples show TDS concentrations of 1,000 to 2,000 mg/l. More than half of the samples in Ninh Binh have more than the standard value. In Thanh Hoa province about 1/3 of samples have more than the standard value. In Ha Tinh province, about half of the samples show TDS concentrations of 1,000 to 5,000 mg/l.

#### (3) Mn<sup>2+</sup>

The guideline value of Manganese is 0.100 mg/l by the Vietnamese standard. In Thai Nguyen almost all samples have Manganese concentrations below the standard value. In Ninh Binh province, only three (3) samples in Yen Thang commune exceed the guideline value. However, some samples from Hanoi, Thanh Hoa, and Ha Tinh provinces have Mn concentrations more than the standard. Particularly in Ha Tinh province, more than half of the samples have Mn concentrations more than the standard.

#### (4) Fe

The guideline value of Iron concentration is 0.500 mg/l by the Vietnamese standard. In

Thai Nguyen province only three (3) samples exceed the standard value. Some areas in Hanoi and Ninh Binh province have higher Fe concentrations than the standard. Most samples in Thanh Hoa and Ha Tinh provinces have Fe concentrations more than the standard. In the both provinces, Fe concentrations more than 2.0 mg/l were found from the wells of 20 to 30 % of the total.

**(5) Cl<sup>-</sup>**

The guideline value of Chloride is 500.0 mg/l by the Vietnamese standard. Only three (3) tube wells in Nong Cong town in Thanh Hoa province have Cl concentrations more than the standard value.

**(6) Na<sup>+</sup>**

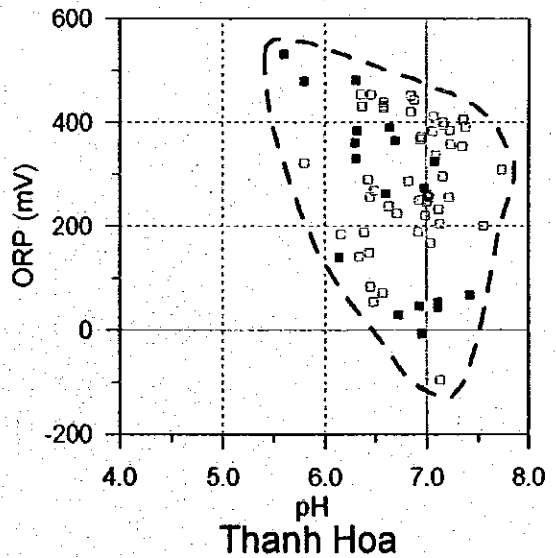
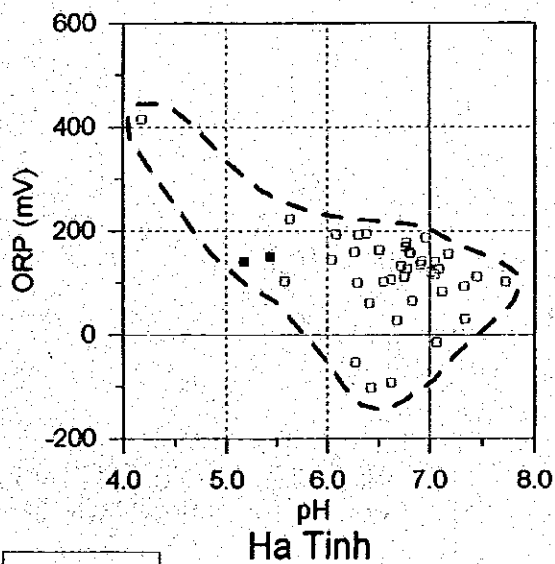
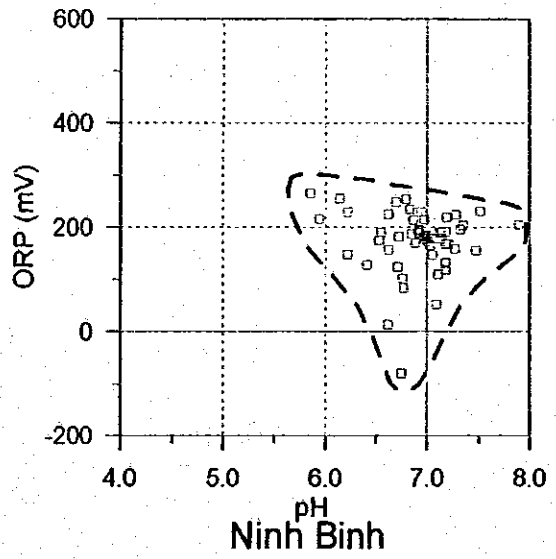
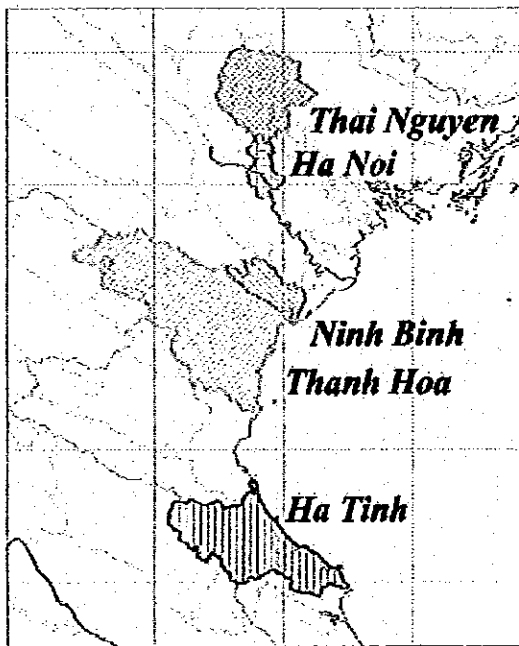
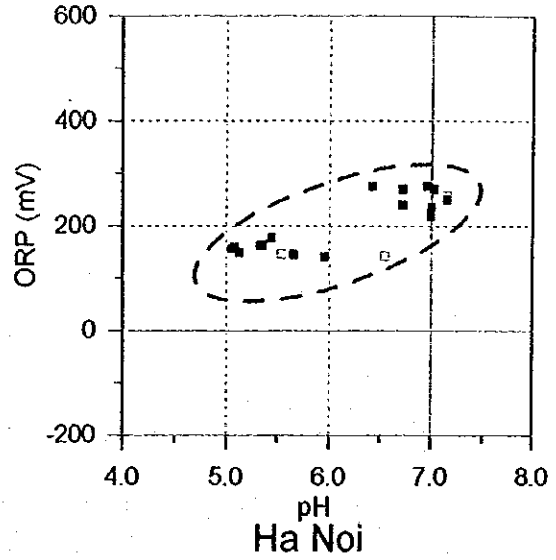
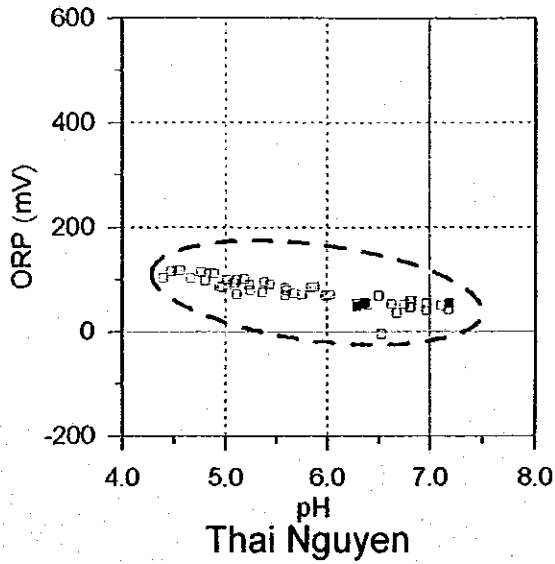
The guideline value of Sodium is 200.00 mg/l by the Vietnamese standards. Wells having Sodium concentrations more than the standard value are found from Xuan Dinh commune in Hanoi, Van Thanh commune and Nong Cong town in Thanh Hoa, and Bui Xa commune in Ha Tinh.

**(7) SO<sub>4</sub><sup>2-</sup>**

The guideline value of Sulfate is 400.00 mg/l by the Vietnamese standards. All the wells in Thai Nguyen, Hanoi, and Ninh Binh provinces show lower Sulfate concentrations than the standard value. The wells having Sulfate concentrations more than the standard value are found in Thanh Hoa and Ha Tinh provinces.

**(8) Coliform**

According to the Vietnamese drinking water standard, total coliform bacteria should not be detected from drinking water. The existing well investigation of the Study show that the groundwater of almost all existing dug wells is contaminated by coliform. The color of the potable coliform test paper totally changed into reddish to brownish color by numerous coliform bacteria.



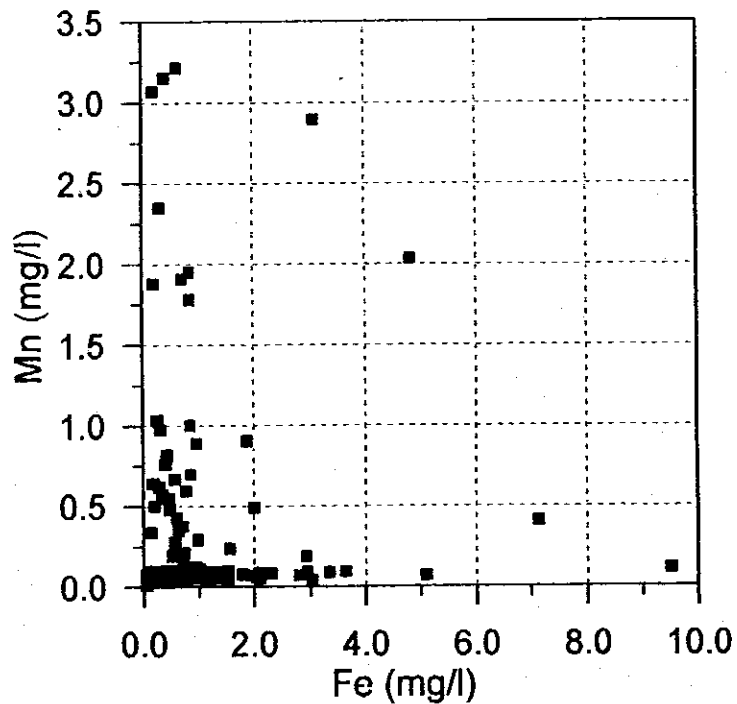
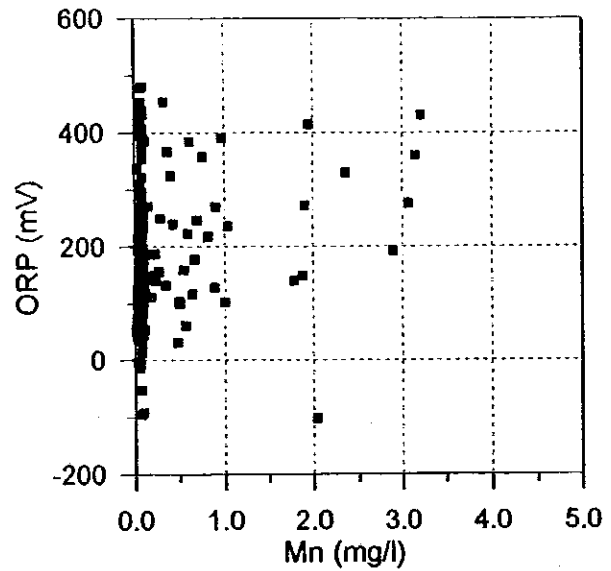
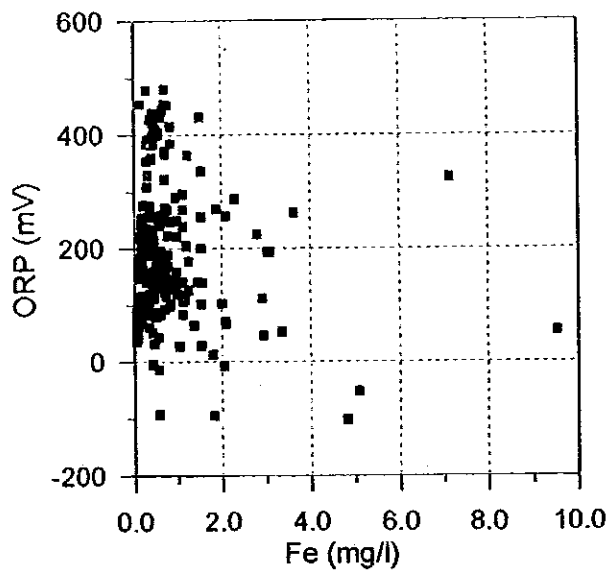
(Groundwater samples were collected from existing wells.)



Figure 3.4.1      pH - ORP Plots of Groundwater by Province

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(Groundwater samples were taken from existing wells. A high Mn concentration of 19.374 mg/l was neglected from these plots.)

Figure 3.4.2	Relationships among ORP, Fe and Mn Concentrations of Groundwater from Existing Wells
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