Chapter 6 Water Quality

6.1 Sample Number and Analysis Items

6.1.1 Sample Number

During the field hydrogeological survey, 446 locations were investigated and 42 water samples (7 samples for laboratory analysis and 35 samples for simple water quality test) were collected. The sample for dioxin analysis is taken from D-6 exploratory well and analyzed at Hanoi National University. The sampling locations are shown in Data Book.

6.1.2 Analysis Items

A) The following items are analyzed during field survey.

(1) pH

(2) Electric Conductivity (EC) (μS/cm)

(3) Dissolved Oxygen (DO) (mg/l) (at water sample location)

(4) Water Temperature (℃)

(5) Color and smell

B) The following 18 items are analyzed at the laboratory.

The samples of approx. 2.3 liters by volume for laboratory test were collected during the field survey. The laboratory is the Institute Hygiene and Epidemiology Center in Buon Ma Thuot city under the Ministry of Health. The analysis methods and instruments are shown in Table 6..1.

(1) Total Dissolved Solids (TDS) (mg/l)

(2) Calcium (Ca^{2+}) (mg/l)

(3) Magnesium (Mg^{2+}) (mg/l)

(4) Sodium (Na^{+}) (mg/l)

(5) Potassium (K^{+}) (mg/l)

(6) Bicarbonate (HCO_3^{-}) (mg/l)

(7) Chloride (Cl^{-}) (mg/l)

(8) Sulfate (SO_4^{2-}) (mg/l)

(9) Iron (Σ Fe) (mg/l)

(10) Nitrite (NO_2^{-}) (mg/l)

(11) Nitrate (NO_3^{-}) (mg/l)

(12) Ammonium (NH_4^{+}) (mg/l)

(13) Phosphate (PO_4^{3-}) (mg/l)

(14) Chemical oxygen demand (COD) (mg/l)

(15) Fluoride (F) (mg/l)

(16) Arsenic (As) (mg/l)

(17) Manganese (Mn^{2+}) (mg/l)

(18) Coliform (MPN/100ml)

Table 6.1 Analysis Methods and Instruments of IHE Laboratory

Item	ethod	strument Name, No.	Measuring Limit
TDS (mg/l)	Total Cation +Anion		0.001 mg/l
Ca^{2+} (mg/l)	Titration by Manual	Automatic Buret	0.01 mg/l
Mg^{2+} (mg/l)	Titration by Manual	Automatic Buret	0.001 mg/l
Na^{+} (mg/l)	Flame photometer	Jenway flame photometer (ENGLAND) Model PEP7 - Serial No.6721	0.01 mg/l
K^{+} (mg/l)	Flame photometer	Jenway flame photometer (ENGLAND) Model PEP7 - Serial No.6721	0.001 mg/l
HCO_3^{-} (mg/l)	Titration by Manual	Automatic Buret	0.001 mg/l
Cl^{-} (mg/l)	Ion chromatography	Automatic Buret	0.01 mg/l
SO_4^{2-} (mg/l)	Ion chromatography	Automatic Buret	0.01 mg/l
Total Fe (mg/l)	Color meric	Shimazu vis spectro photometer (JAPAN) Serial No.206-69739-93 Shimazu UV1201V	0.01 mg/l
NO_2-N (mg/l)	Color meric	Shimazu vis spectro photometer (JAPAN) Serial No.206-69739-93 Shimazu UV1201V	0.001 mg/l
NO_3-N (mg/l)	Color meric	Shimazu vis spectro photometer (JAPAN) Serial No.206-69739-93 Shimazu UV1201V	0.01 mg/l
NH_4^{+} (mg/l)	Color meric	Shimazu vis spectro photometer (JAPAN) Serial No.206-69739-93 Shimazu UV1201V	0.001 mg/l
PO_4^{3-} (mg/l)	Color meric	Shimazu vis spectro photometer (JAPAN) Serial No.206-69739-93 Shimazu UV1201V	0.01mg/l
COD/$KmnO_4$ (mg/l)	Titration by Manual	Automatic Buret	0.001 mg/l
F (mg/l)	utron activation alyse method	The Gamma Spectrometer System with Detector Ge(Li), HP	0.0001 mg/l
As (mg/l)	utron activation alyse method	The Gamma Spectrometer System with Detector Ge(Li), HP	0.0001 mg/l
Mn^{2+} (mg/l)	utron activation alyse method	The Gamma Spectrometer System with Detector Ge(Li), HP	0.0001 mg/l
Coliform (MPN/100ml)	PN	Mac conky medium	-

C) Dioxin Analysis by Hanoi National University

Water volume of approximately 20 liters from K-1, G-3 and D-6 exploratory wells are transported and analyzed at the Hanoi National University.

D) Simple Water Quality Test

Simple water quality tests were carried out by the pack test, coliform paper test and Hironaka's arsenic field kit, in order to make a preliminary check on the water quality. The following 11 items were tested.

(1) Magnesium (Mg^{2+}) (mg/l)
(2) Iron (Fe^{2+}, Fe^{3+}) (mg/l)
(3) Nitrite (NO_2^-) (mg/l)
(4) Nitrate (NO_3^-) (mg/l)
(5) Ammonium (NH_4^+) (mg/l)
(6) Phosphate (PO_4^{3-}) (mg/l)
(7) Chemical oxygen demand (COD) (mg/l)
(8) Fluoride (F) (mg/l)
(9) Arsenic (As) (mg/l)
(10) Manganese (Mn^{2+}) (mg/l)
(11) Coliform (MPN/100ml)

6.1.3 Water Quality Standards

The Vietnamese water quality standards of groundwater source are shown in Table 6.2 and for surface water resource in Table 6.3. The sources are classified into the following 3 classes for water supply according to the regulation of TCXD233 (1999), which was regulated by the Ministry of Health.

- Class A: water source with good quality, requiring only simple treatment prior to supply for domestic use.
- Class B: water with normal quality, which should be extracted and treated for domestic use.
- Class C: water with bad quality, which should be treated with special technology for domestic use and its quality must be strictly and regularly monitored.

Table 6.2 Vietnamese Water Quality Standards of Groundwater Source

No.	Parameter		Unit	Water Class		
				Class A*	Class B*	Class C*
1	pH value			6.8 to 7.5	6.0 to 8.0	4.5 to 8.5
2	Dissoleved Oxygen		mg/l O_2	<0.5	0.5 - 2.0	<10
3	Total Hardness		°dH	4 to 8	<4, or 8 to 13	<28
4	Hydrogen Sulfide	H_2S	mg/l	0	0	<0.5
5	Chloride	Cl^-	mg/l	<25	<200	<400
6	Sulphate	SO_4^{2-}	mg/l	<25	<250	<400
7	Nitrite	NO_2^-	mg/l	<0	<0.1	<2
8	Nitrate	NO_3^-	mg/l	0	<6	<10
9	Phosphate	PO_4^{3-}	mg/l	0	<1.5	<2
10	Total Iron	Fe	mg/l	<0.3	<10	<50
11	Manganese	Mn	mg/l	<0.05	<2	<3
12	Ammonium	NH_4^+	mg/l	<0	<3	<30
13	Fluoride	F^-	mg/l	0.5 to 1.0	0 to 0.5, or 1.0 to 1.5	<2
14	Cyanide	CN^-	µg/l	0	<50	<100
15	Phenol		µg/l	0	0.5	<100
16	Arsenic	As	µg/l	0	50	<100
17	Cadmium	Cd	µg/l	0	<1	<5
18	Total Chromium	Cr	µg/l	0	<10	<50
19	Selenium	Se	µg/l	0	<5	<10
20	Mercury	Hg	µg/l	0	0	<1
21	Copper	Cu	µg/l	<50	<1,000	<3,000
22	Lead	Pb	µg/l	0	<10	<50
23	Zinc	Zn	µg/l	<50	<1,000	<5,000
24	E. Coli		MPN/100ml	0	<20	<100

Table 6.3 Vietnamese Water Quality Standards of Surface Water Source

No.	rameter		Unit	Water Class		
				Class A*	Class B*	Class C*
1	pH value			6.5 to 8.5	6.0 to 9.0	pH>9 or pH<6
2	Turbidity		NTU	<20	<500	<1,000
3	Color		mg/l Pt	<10	<100	<200
4	Dissoleved Oxygen		mg/l O_2	<2.0	2 - 5	<10
5	Total Hardness		°dH	4 to 8	<4, or 8 to 13	<28
6	Hydrogen Sulfide	H_2S	mg/l	0	0	<0.5
7	Chloride	Cl^-	mg/l	<25	<200	<400
8	Sulphate	SO_4^{2-}	mg/l	<25	<250	<400
9	Nitrite	NO_2^-	mg/l	<0.1	<1	<2
10	Nitrate	NO_3^-	mg/l	0	<6	<10
11	Phosphate	PO_4^{3-}	mg/l	0	<1.5	<2
12	Total Iron	Fe	mg/l	<0.3	<1	<2
13	Manganese	Mn	mg/l	<0.2	<0.5	<1
14	Ammonium	NH_4^+	mg/l	<0.2	<0.5	<1
15	Fluoride	F^-	mg/l	0.5 to 1.0	<1.5	<2
16	Cyanide	CN^-	µg/l	0	<50	<100
17	Phenol		µg/l	0	0.5	<100
18	Arsenic	As	µg/l	0	50	<100
19	Cadmium	Cd	µg/l	0	<1	<5
20	Total Chromium	Cr	µg/l	0	<10	<50
21	Selenium	Se	µg/l	0	<5	<10
22	Mercury	Hg	µg/l	0	0	<1
23	Copper	Cu	µg/l	<50	<1,000	<3,000
24	Lead	Pb	µg/l	0	<10	<50
25	Zinc	Zn	µg/l	<50	<1,000	<5,000
26	E. Coli		MPN/100 ml	<20	<100	<200
27	Total pesticides (except DDT)		mg/l	0	<0.15	<0.15
28	DDT		mg/l	0	<0.01	<0.01
29	Gross alpha activity		Bq/l	<0.1	<0.1	<0.1
30	Gross beta activity		Bq/l	<1	<1	<1

6.1.4 Main Findings from Water Quality of Existing Water Sources

(1) pH Value

The values range from 4.71 to 8.20, with an average value of 6.25. Ea Drong and Ea Wer commune are in the range from 6.5 to 7.0.

Table 6.4 pH of Existing Water Sources

Type		G-1	G-2	G-3	G-4	G-5	G-6	G-7	Gia Lai
Surface Water	nos.	3	2	5	1	-	-	3	14
	Max	7.19	6.52	7.00	6.53	-	-	7.81	7.81
	Min	6.06	6.34	5.54	6.53	-	-	6.62	5.54
	Average	6.71	6.43	6.34	6.53	-	-	7.21	6.63
Spring Water	nos.	2	1	2	2	3	-	1	11
	Max	5.98	5.75	6.60	5.45	5.34	-	5.68	6.60
	Min	5.55	5.75	5.97	5.29	5.13	-	5.68	5.13
	Average	5.77	5.75	6.29	5.37	5.21	-	5.68	5.63
Shallow Well (Dug Well)	nos.	25	25	19	87	24	49	47	276
	Max	6.24	5.94	5.85	6.97	6.26	8.40	7.81	8.40
	Min	4.86	4.76	4.87	4.89	4.87	5.31	5.80	4.76
	Average	5.43	5.43	5.43	5.31	5.22	6.48	6.57	5.76
Shallow Well (Unicef Hand Pump Well)	nos.	-	-	-	-	-	29	4	33
	Max	-	-	-	-	-	6.75	7.03	7.03
	Min	-	-	-	-	-	6.32	6.44	6.32
	Average	-	-	-	-	-	6.54	6.74	6.57
Deep Well (Dug Well + Drilling Well)	nos.	-	-	-	-	-	-	-	-
	Max	-	-	-	-	-	-	-	-
	Min	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Deep Well (Drilling Well)	nos.	-	-	2	1	4		1	8
	Max	-	-	6.52	5.00	10.61		7.29	10.61
	Min	-	-	6.08	5.00	7.59		7.29	5.00
	Average	-	-	6.30	5.00	9.19		7.29	7.71
Existing Water Supply System	nos.	-	-	-	-	-	-	-	-
	Max	-	-	-	-	-	-	-	-
	Min	-	-	-	-	-	-	-	-
	Average	-	-	-	-	-	-	-	-
Total	nos.	30	28	28	91	31	78	56	342
	Max	7.19	6.52	7.00	6.97	10.61	8.40	7.81	10.61
	Min	4.86	4.76	4.87	4.89	4.87	5.31	5.68	4.76
	Average	5.58	5.52	5.71	5.32	5.73	6.50	6.61	5.91

<pH values of water samples from existing water sources>

There is a trend forward higher pH values in order of shallow well (dug well), spring water, shallow well (UNICEF hand pump well), deep well (dug well + drilling well), surface water, deep well (drilling well), and water supply systems as shown in Figures 6.1 to 6.4.

<Comparison with drinking water standards>

According to the standard “The parameters using for selection of the surface and ground water sources in water supply system” (TCXD 233: 1999), it is mentioned that pH value of class A should be in the range from 6.8 to 7.5 (groundwater) and 6.5 to 8.5 (surface water).

(2) Electric Conductivity (EC)

The values become higher in order of surface water, spring water, shallow well (dug well), deep well (drilling well), water supply systems, shallow well (UNICEF hand pump well), and deep well (dug well + drilling well) as shown in Figures 6.5 to 6.8.

Table 6.5 Electric Conductivity of Existing Water Sources

Type		D-1	D-2	D-3	D-4	D-5	D-6	D-7	Dac Lac
Surface Water	nos.	3	1	3	3	4		1	15
	Max	7.75	7.89	8.15	7.89	7.66		7.05	8.15
	Min	6.88	7.89	7.44	7.22	7.16		7.05	6.88
	Average	7.26	7.89	7.72	7.52	7.40		7.05	7.47
Spring Water	nos.	2			6				8
	Max	6.59			7.08				7.08
	Min	6.44			6.19				6.19
	Average	6.52			6.55				6.54
Shallow Well (Dug Well)	nos.	61	60	72	55	55	26	44	373
	Max	6.91	6.58	7.45	7.15	7.89	6.12	6.99	7.89
	Min	5.66	5.05	5.53	5.54	5.38	4.77	4.71	4.71
	Average	6.25	5.76	6.26	6.49	6.63	5.31	5.45	6.11
Shallow Well (Unicef Hand Pump Well)	nos.					2			2
	Max					7.08			7.08
	Min					7.01			7.01
	Average					7.05			7.05
Deep Well (Dug Well + Drilling Well)	nos.		2	2		8			12
	Max		6.89	6.42		7.08			7.08
	Min		6.82	6.10		6.35			6.10
	Average		6.86	6.26		6.86			6.76
Deep Well (Drilling Well)	nos.	1	4	2		8	14	2	31
	Max	6.98	7.40	7.41		7.00	7.97	6.32	7.97
	Min	6.98	5.61	6.18		6.69	5.34	6.14	5.34
	Average	6.98	6.78	6.80		6.88	7.02	6.23	6.89
Existing Water Supply System	nos.					5			5
	Max					8.20			8.20
	Min					7.04			7.04
	Average					7.38			7.38
Total	nos.	88	29	97	38	36	34		322
	Max	427	162.5	345	135.9	480	424		480
	Min	13.39	11.16	13.00	6.53	21.4	29.9		6.53
	Average	59.4	47.5	73.5	35.9	108.1	129.8		72.7

(3) Total Dissolved Solids (TDS)

The values in Dac Lac province are in the range from 9.529 - 695.098 mg/l with an average of 184.6 mg/l. The dominant values are in the range of 100 - 150 mg/l as shown in Figures 6.9 to 6.10.

(4) Total Iron (Fe)

The values in Dac Lac province ranged from 0.01 to 4.50 mg/l and 0.92 mg/l on average. The dominant values are in the range of 0 - 0.3 mg/l as shown in Figure 6.11. The values in Ea Wer commune (D-5) and Krong Kmar town (D-7) are higher than that of the other communes.

<Relationship between total Fe contents and existing water sources>

The values of the samples from each water source are about average for UNICEF hand pump wells and slightly higher for deep drilling wells than other water sources.

Table 6.6 Iron of Existing Water Sources

Type	Total Fe (mg/l)	Average (mg/l)
Surface water	0.16 - 1.05	**0.49**
Spring water	0.15 - 0.28	**0.24**
Shallow well (dug well)	0.06 - 7.10	**0.78**
Shallow well (UNICEF hand pump well)	0.92 - 1.90	**1.41**
Deep well (Dug + drilling well)	0.09 - 0.39	**0.26**
Deep well (drilling well)	0.01 - 3.50	**1.02**

<Comparison with drinking water standards>

According to the Vietnamese standard (TCXD 233: 1999), it is mentioned that the total iron value of class A should be less than 0.3 mg/l for groundwater and surface water.

All other measured values are classified as either class A or B.

(5) Manganese (Mn^{2+})

The values in Dac Lac province ranged from 0.0010 to 3.2851 mg/l, with an average of 0.1642 mg/l as shown in Figures 6.12 and 6.13. The dominant values are in the range of 0 - 0.1 mg/l. The average value is higher than that of the other two provinces. The values in Krong Kmar commune (D-7) are higher than that of the other communes.

<Relationship between Mn^{2+} and Water Sources>

The average value of shallow well (dug well) is higher than that of the other water sources.

Table 6.7 Manganese of Existing Water Sources

Type	Mn^{2+} (mg/l)	Average (mg/l)
Surface water	0.0302 - 0.1411	**0.0589**
Spring water	0.0375 - 0.0877	**0.0636**
Shallow well (dug well)	0.0010 - 3.2851	**0.1396**
Shallow well (UNICEF hand pump well)	0.0457 - 0.0785	**0.0632**
Deep well (dug + drilling well)	0.0230 - 0.0370	**0.0230**
Deep well (drilling well)	0.0020 - 0.1716	**0.0401**

<Comparison with Drinking Water Standards>

According to the Vietnamese standard (TCXD 233: 1999), it is mentioned that

Manganese value of class A should be less than 0.05 mg/l for groundwater and less than 0.2 mg/l for surface water. One value was classified into exceeding class C (>3mg/l), and this value is measured at the dug well in Krong Kmar town (D-7, 3.2851 mg/l). All of other measured values are classified as either class A or B.

(6) Arsenic (As)

<Comparison with Drinking Water Standards>

According to the Vietnamese standard (TCXD 233: 1999), it is mentioned that Arsenic value of class A should be 0 mg/l, and class B should be less than 0.05 mg/l. All of the measured values are classified into class B, and highest As (0.0097 mg/l) was measured at deep well (dug well + drilling well) in Ea Wer commune (D-5) as shown in Figures 6.14.

(7) Fluoride (F)

<Comparison with Drinking Water Standards>

According to the Vietnamese standard (TCXD 233: 1999), it is mentioned that fluoride value of class A should be 0 mg/l, and class B should be less than 0.05 mg/l. All of the measured values are classified into class B, and the highest value of 0.4215 mg/l was from the drilled well in Krong Kmar commune (D-7) as shown in Figures 6.15 and 6.16.

(8) Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, NO_3^{-}

Table 6.8 shows the laboratory result of water quality analysis of existing water sources. According to the trilinear diagrams and stiff diagrams as shown in Figures 6.17 to 6.20, geo-chemical types are summarized as shown Table 6.9;

Table 6.8 Result of Water Quality Analysis of Existing Water Sources

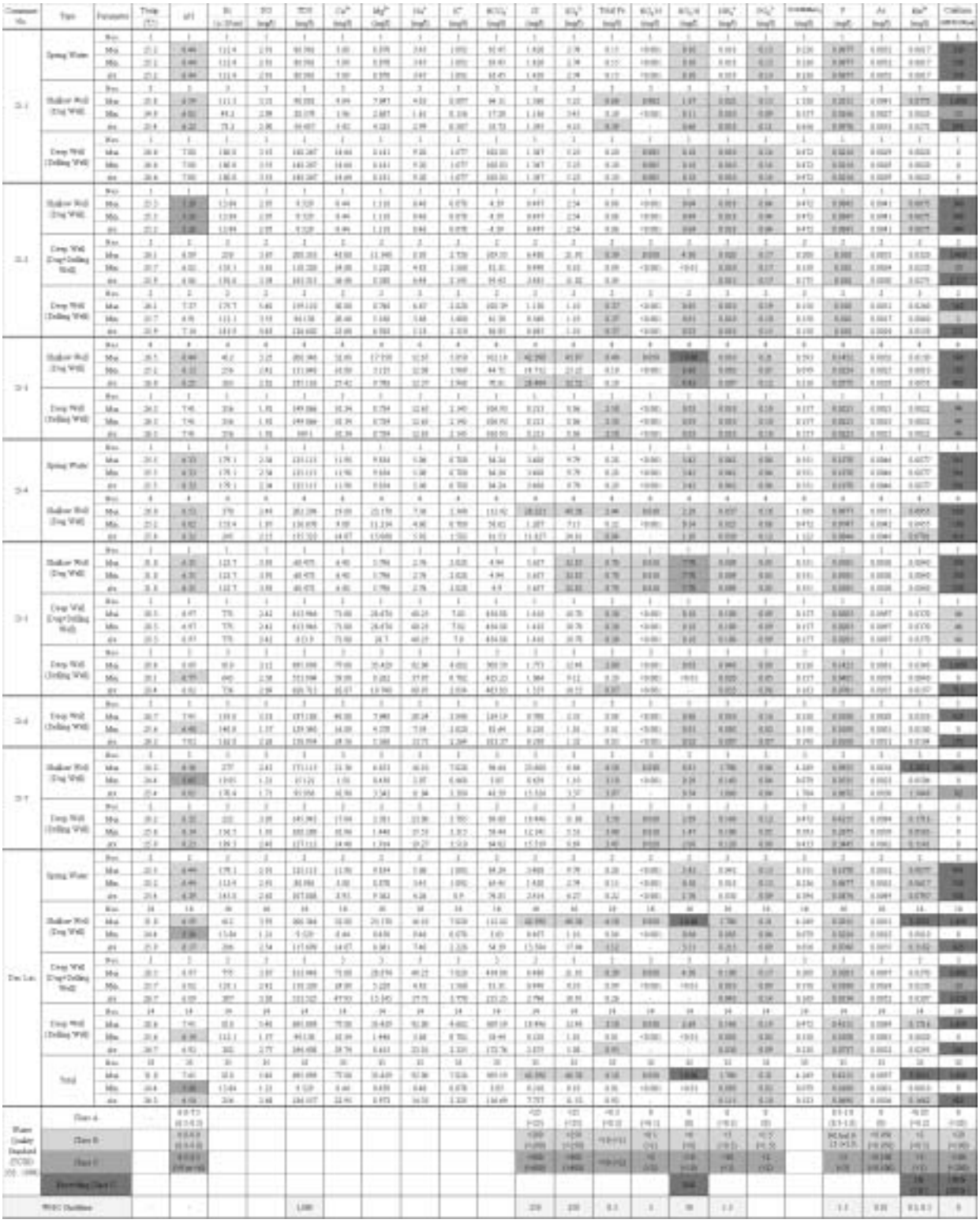


Table 6.9 Geo-chemical Types of Existing Water Sources

Type	Water Type	Nos.
Surface water	$Mg\text{-}Ca\text{-}HCO_3$	4
	$Ca\text{-}Mg\text{-}HCO_3$	1
Spring water	$Mg\text{-}Ca\text{-}HCO_3$	2
	$Mg\text{-}SO_4\text{-}HCO_3$	1
	$FMg\text{-}Ca\text{-}SO_4$	1
Shallow well (dug well)	$Mg\text{-}Ca\text{-}HCO_3$	8
	$Mg\text{-}Ca\text{-}SO_4$	6
	$Ca\text{-}Mg\text{-}HCO_3$	5
	Ca-HCO3	4
	Ca-Na-Mg	4
Sallow well (Dug well)	$Ca\text{-}Na\text{-}SO4\text{-}HCO_3$	1
	$Ca\text{-}Mg\text{-}Na\text{-}SO_4\text{-}HCO_3$	1
	Ca-Mg-HCO3-Cl	1
Deep well (dug + drilling wells)	$Ca\text{-}Mg\text{-}HCO_3$	2
	$Ca\text{-}Mg\text{-}Na\text{-}HCO_3$	1
Deep well (drilling well)	$Ca\text{-}Mg\text{-}HCO_3$	5
	$Na\text{-}Ca\text{-}HCO_3$	4
	$Ca\text{-}Mg\text{-}Na\text{-}HCO_3$	2

<Comparison with Drinking Water Standards>

The standard value of chloride for class A is less than 25 mg/l and class B is less than 200 mg/l by the Vietnamese standard. All data of chloride show less than 200 mg/l and classified as either class A or B.

The standard value of sulphate for class A is less than 25 mg/l and class B is less than 250 mg/l by the Vietnamese standard. All data of sulphate show less than 250 mg/l and classified as either class A or B.

The standard value of nitrate for class A is 0 mg/l and class B is less than 6 mg/l by the Vietnamese standard. The data in Krong Buk commune (D-3, 10.00 mg/l) exceeded class C.

(9) Nitrite (NO_2^-), Ammonium (NH_4^-)

<Comparison with Drinking Water Standards>

The standard value of nitrite for class A is 0 mg/l (groundwater) and less than 0.1 mg/l (surface water). The value for class B is less than 0.1 mg/l (groundwater) and less than 1 mg/l (surface water) by the Vietnamese standard. All data of nitrite show less than 0.1 mg/l and classified as either class A or B.

Table 6.10 Nitrite of Existing Water Sources

Type	Class A	Class B	Class C
Surface water	100.0%	0%	0%
Spring water	75.0%	25.0%	0%
Shallow well (dug well)	76.9%	23.1%	0%
Shallow well (UNICEF hand pump well)	100.0%	0%	0%
Deep well (dug + drilling well)	66.7%	33.3%	0%
Deep well (drilling well)	85.0%	15.0%	0%
Total	80.0%	20.0%	0%

The standard value of ammonium for class A is 0 mg/l (groundwater) and less than 0.2 mg/l (surface water). The value for class B is less than 3 mg/l (groundwater) and less than 0.5 mg/l (surface water) by the Vietnamese standard. All data of Ammonium show less than 3 mg/l and is classified into class A and B. The highest value was from the shallow well in Krong Kmar town (D-7, 1.700 mg/l). The ammonium values of each water source are classified as follows;

Table 6.11 Ammonium of Existing Water Sources

Type	Class A	Class B	Class C
Surface water	100.0%	0%	0%
Spring water	100.0%	0%	0%
Shallow well (dug well)	0%	100.0%	0%
Shallow well (UNICEF hand pump well)	0%	100.0%	0%
Deep well (dug + drilling well)	0%	100.0%	0%
Deep well (drilling well)	0%	100.0%	0%
Total	9.0%	91.0%	0%

(10) Coliform

<Comparison with drinking water standards>

The standard value of coliform for class A is 0 MPN/100ml (groundwater) and less than 20 MPN/100ml (surface water). The value for class B is less than 20 MPN/100ml (groundwater) and less than 100 mg/l (surface water) by the Vietnamese standard. More than 82% of all data exceeded class C, and even for deep wells, 33% and 45% of data exceeded class C. The coliform values of each water source are classified as follows;

Table 6.12 Coliform of Existing Water Sources

Type	Class A	Class B	Class C	Exceeding Class C
Surface water	0%	0%	0%	100.0%
Spring water	0%	0%	0%	100.0%
Sallow well (dug well)	1.5%	1.5%	4.6%	92.3%
Shallow well (UNICEF hand pump well)	0%	0%	0%	100.0%
Deep well (dug + drilling well)	0%	0%	66.7%	33.3%
Deep well (drilling well)	30.0%	15.0%	10.0%	45.0%
Total	7.0%	4.0%	7.0%	82.0%

6.1.5 Water Quality of Test Wells

Groundwater samples from the test wells were collected at the pumping test. The samples were brought to the laboratory as soon as possible. The analysis results are shown in Table 6.13.

(1) pH

The 17 data show that, pH values ranged from 6.23 to 8.85,with an average of 7.15. The dominant values range from 7.0 to 7.5 (Figure 6.21). There were no definite differences with existing deep well water.

Table 6.13 Result of Water Quality Analysis of Test Wells and Alternative Water Sources

Sampl. No.	Type	Temp.	pH	EC	DO	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	Total Fe	$NO_2^{-}N$	$NO_3^{-}N$	NH_4^{+}	PO_4^{3-}	COD/K MnO_4	F	As	Mn^{2+}	Coliform*
		(℃)		μS/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	MPN/100m
K-1-0	Well	26.8	7.25	183.6	2.23	151.457	16.20	7.557	9.89	2.028	111.75	0.142	3.897	3.55	<0.001	0.01	0.028	0.09	0.315	0.0300	0.0010	0.1000	11
K-2-0	Well	24.1	7.23	178.7	1.75	151.873	16.28	8.432	9.66	1.950	112.61	1.985	0.96	2.64	<0.001	0.01	0.031	0.07	0.157	0.0100	0.0010	0.0650	17
K-3-0	Well	24.7	7.19	864	1.17	597.608	151.38	10.753	6.44	0.663	184.71	0.496	243.18	3.49	0.005	0.03	0.046	0.04	0.630	1.3200	0.0050	0.1211	33
K-4-0	River	26.7	7.13	66.6	3.15	50.979	5.12	3.074	2.30	1.833	36.66	0.071	1.92	1.88	0.002	0.11	0.035	<0.01	3.226	0.2100	0.0010	0.0050	130
K-5-0	River	25.6	7.15	68.8	3.64	51.037	4.62	2.151	3.45	4.095	33.49	0.496	2.75	4.58	0.005	0.12	0.059	<0.01	7.082	0.1900	0.0010	0.0150	180
K-6-0	River	33.2	7.60	89.4	3.04	68.223	2.46	5.346	5.06	3.822	48.25	0.351	2.94	3.02	0.005	0.06	0.073	<0.01	2.518	0.0800	0.0010	0.0210	2800
G-1-0	Well	27.5	7.32	198.7	1.16	170.062	4.34	2.807	31.97	2.535	124.32	0.915	3.19	0.82	0.030	0.06	0.052	0.03	0.157	0.6600	0.0010	0.0130	33
G-2-0	Well	28.1	7.00	338	3.04	211.444	24.72	12.758	12.65	4.062	142.62	0.993	13.10	0.21	0.002	0.19	0.074	0.10	0.157	0.2900	0.0032	0.1950	0
G-3-0	Well	27.0	7.20	61.7	2.56	166.645	14.38	11.900	7.13	2.964	126.88	0.213	3.89	0.40	<0.001	0.05	0.029	0.14	0.236	0.1007	0.0040	0.0975	34
G-4-0	Well	29.2	7.59	273	5.55	225.997	10.80	13.171	22.43	4.095	155.18	0.355	19.97	0.36	0.010	0.01	0.179	0.07	0.079	0.8000	0.0022	0.1740	5
G-5-0	Well	28.6	7.29	656	2.28	568.373	24.20	20.679	94.30	17.550	410.47	0.071	1.10	0.47	0.001	0.01	0.147	0.06	0.079	0.2900	0.0026	0.0630	23
G-6-0	Well	27.3	6.98	775	1.25	195.322	40.40	13.940	34.96	1.521	57.26	158.350	7.28	3.10	<0.001	9.09	0.138	0.04	0.779	0.0870	0.0034	0.0672	46
G-7-0	Well	27.0	7.18	501	1.42	426.749	42.12	23.219	28.75	1.989	311.34	15.775	3.55	2.07	0.002	0.01	0.098	0.05	0.866	0.2200	0.0010	0.2860	43
D-1-0	Well	25.3	6.43	153.0	2.63	125.028	8.80	7.946	9.66	1.833	93.88	1.407	1.50	0.11	0.001	0.06	0.035	0.06	0.079	0.1300	0.0010	0.0111	31
D-2-0	Well	26.4	6.42	100.6	2.56	64.614	4.92	3.900	5.29	1.599	39.10	0.780	9.02	0.39	0.002	0.02	0.049	0.12	0.157	<0.0001	0.0010	0.0410	11
D-3-0	Well	26.5	7.99	553	1.77	495.166	3.98	3.159	126.50	1.443	309.88	0.284	13.92	0.12	<0.001	0.60	0.103	0.08	0.551	0.2800	0.0060	0.0120	22
D-4-0	Well	25.9	7.85	401	1.59	335.710	2.52	0.620	94.30	3.354	215.70	3.332	15.90	3.76	0.080	0.12	0.071	0.14	0.630	0.6700	0.0010	0.0390	33
D-5-0	Well	27.7	6.93	558	2.35	340.127	70.96	6.051	12.88	1.356	240.65	0.355	7.87	0.82	0.020	0.06	0.233	0.06	0.236	<0.0001	0.0040	1.1110	8
D-6-0	Well	28.0	6.23	145.6	1.92	208.916	21.60	11.676	9.20	2.652	155.37	0.213	8.21	0.65	0.010	0.02	0.072	<0.01	0.630	0.0857	0.0046	0.0755	0
D-7-0	Well	28.1	6.54	186.0	2.02	126.073	9.04	6.282	11.96	3.042	86.56	0.071	9.12	4.09	0.011	0.01	0.293	0.03	0.236	0.0500	0.0010	0.3590	43
Total	nos.	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	max	33.2	7.99	864	5.55	597.608	151.38	23.219	126.50	17.550	410.47	158.350	243.18	4.58	0.080	9.09	0.293	0.14	7.082	1.3200	0.0060	1.1110	2800
	min	24.1	6.23	61.7	1.16	50.979	2.46	0.620	2.30	0.663	33.49	0.071	0.96	0.11	<0.001	0.01	0.028	<0.01	0.079	<0.0001	0.0010	0.0050	0
	average	27.2	7.13	318	2.35	236.570	23.94	8.771	26.94	3.219	149.83	9.333	18.66	1.83	0.009	0.53	0.092	0.059	0.940	0.2752	0.0023	0.1436	175
Standard of MOH	505	-	-			1,000						250	400	0.5	0	10	3.0			1.5	0.05	0.1	

*tests were conducted in the first field survey and F/S. Source: Study Team

<Comparison with Drinking Water Standards>
According to the Vietnamese standard (TCXD 233: 1999), it is mentioned that pH value of groundwater for class A should be in the range from 6.8 to 7.5 and class B should be in the range from 6.0 to 8.0. The pH values of test well water are classified as follows;

Table 6.14 pH of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	10nos.	7nos.	0nos.
	58.8%	41.2%	0%

All of the measured values are classified as either class A or B. The highest value was measured at JICA D-3 test well (Krong Buk commune, 7.99) and the lowest value was measured at JICA D-6 test well (Kien Duc town, 6.23).

(2) EC

The EC values ranged from 61.7 to 864 μS/cm, with an average of 360 μS/cm. The dominant values are in the two groups of 100 - 200 μS/cm and 400 to 800 μS/cm (Figure 6.21). The EC values are slightly higher than that of the existing deep well samples (Table 6.13).

(3) Total Dissolved Solids (TDS)

The values ranged from 64.614 to 597.608 mg/l, with an average of 268.304 mg/l. The dominant values are in the range of 150 to 200 mg/l (Figure 6.21). They are slightly higher than that of the existing deep well samples (Table 6.13).

(4) Total Iron (Fe)

The values ranged from 0.11 to 4.09 mg/l, with average of 1.59 mg/l. Two dominant groups are detected as 0.3 to 1 mg/l and 2 to 4 mg/l (Figure 6.21). These results are slightly higher than that of existing deep well samples (Table 6.13).

<Comparison with drinking water standards>
The standard value of total iron for class A is less than 0.3 mg/l and for class B is less than 10 mg/l. The total Iron values of test well water are classified as follows;

Table 6.15 Iron of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	3nos.	14nos.	0nos.
	17.6%	82.4%	0%

All of the measured values are classified as either class A or B. The highest value was from the JICA D-7 (Krong Kmar, 4.09 mg/l). JICA D-4 (Ea Drong, 3.76 mg/l) was the second highest value.

(5) Manganese (Mn^{2+})

The values ranged from 0.0111 to 1.1110 mg/l, with an average of 0.1665 mg/l. The dominant values ranged from 0 to 0.1 mg/l (Figure 6.21). They are higher than that of existing deep well samples (Table 6.13).

<Comparison with drinking water standards>

The standard value of manganese for class A is less than 0.05 mg/l, for class B is less than 2 mg/l, and for class C is less than 3 mg/l. The manganese values of test well water are classified as follows;

Table 6.16 Manganese of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	5nos.	12nos.	0nos.
	29.4%	70.6%	0%

All of the measured values are classified as either class A or B. The highest value was from the JICA D-5 (Ea Wer, 1.1110 mg/l). The other data exceeding 0.1 mg/l is JICA D-7 (Krong Kmar, 0.3590 mg/l) well.

(6) Arsenic (As)

The values ranged from 0.0010 to 0.0060 mg/l, with an average of 0.0025 mg/l. The dominant values range from 0 to 0.002 mg/l (Figure 6.21). There is no definite difference in the values with the existing deep well samples (Table 6.13).

<Comparison with drinking water standards>

The standard value of arsenic for class A is 0 mg/l, for class B is less than 0.05 mg/l, and for class C is less than 0.1 mg/l. The arsenic values of test well water are classified as follows;

Table 6.17 Arsenic of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	0nos.	17nos.	0nos.
	0%	100.0%	0%

All of the measured values are classified into class B. The highest value was from JICA D-3 (Krong Buk, 0.0060 mg/l) well.

(7) Fluoride (F)

The values ranged from <0.0001 to 1.3200 mg/l. The dominant values ranged from 0 to 0.2 mg/l (Figure 6.21). There is no definite difference in the values with the existing deep well data (Table 6.13).

<Comparison with drinking water standards>

The standard value of Fluoride for class A is should be in the range from 0.5 mg/l to 1.0 mg/l, for class B is range from 0 to 0.5 mg/l and range from 1.0 to 1.5 mg/l. The fluoride values of test well water are classified as follows;

Table 6.18 Fluoride of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	3nos.	14nos.	0nos.
	17.6%	82.4%	0%

All of the measured values are classified as either class A or B.

(8) Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, NO_3^{-} of the JICA Wells

According to the trilinear diagrams as shown in Figures 6.22, most results plotted in the lower left field of the diamond-shape diagram, and $SO_4^{2+} + NO_3^{-} + Cl^{-}$ is less than 20 % in total meq/l. The values of Cl^{-} are less than 20 % in total meq/l. Sodium, chloride, sulphate, and nitrate from the test wells are higher than that of existing deep well data (Table 6.13). The geo-chemical types of the test wells are summarized as follows;

Table 6.19 Geo-chemical Types of Test Wells

Water Type	Nos.
$Na\text{-}HCO_3$	4
$Ca\text{-}Mg\text{-}Na\text{-}HCO_3$	3
$Ca\text{-}Mg\text{-}HCO_3$	2

<Comparison with drinking water standards>
The standard value of chloride for class A is less than 25 mg/l and for class B is less than 200 mg/l (Table 5.13). The chloride values of test well water are classified as follows;

Table 6.20 Chloride of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	16nos.	1nos.	0nos.
	94.1%	5.9%	0%

Only one value classified into class B and this value was from JICA G-6 (Ia Rsiom, 158.350 mg/l). Except this value, the others classified into class A.
The standard value of Sulphate for class A is less than 25 mg/l and for class B is less than 250 mg/l. The Sulphate values of test well water are classified as follows;

Table 6.21 Sulphate of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	16nos.	1nos.	0nos.
	94.1%	5.9%	0%

Only one (1) value classified into class B and this value is from JICA K-3 (Dak Ui, 243.18 mg/l). Except this value, the others classified into class A.
The standard value of nitrate for class A is 0 mg/l, for class B is less than 6 mg/l, and for class C is less than 10 mg/l. The nitrate values of test well water are classified as follows;

Table 6.22 Nitrate of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	0nos.	16nos.	1nos.
	0%	94.1%	5.9%

The contents are classified into class B.

(9) Nitrite (NO_2^-), Ammonium (NH_4^-)

<Comparison with drinking water standards>
The standard value of nitrite for class A is 0 mg/l, for class B is less than 0.1 mg/l, and for class C is less than 2 mg/l. The nitrite values of test well water are classified as follows;

Table 6.23 Nitrite of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	5nos.	12nos.	0nos.
	29.4%	70.6%	0%

All of the measured values are classified as either class A or B. The highest value was from JICA D-4 (Thang Hung, 0.080 mg/l).

The standard value of ammonium for class A is 0 mg/l, for class B is less than 3 mg/l, and for class C is less than 30 mg/l. The ammonium values of test well water are classified as follows;

Table 6.24 Ammonium of Test Wells

Type	Class A	Class B	Class C
JICA Test Well	0nos.	17nos.	0nos.
	0%	100.0%	0%

All of the measured values are classified into class B. The highest value was from JICA D-7 (Krong Kmar, 0.293 mg/l).

(10) Coliform

<Comparison with Drinking Water Standards>

The standard value of coliform for class A is 0 MPN/100ml, for class B is less than 20 MPN/100ml, and for class C is less than 100 MPN/100ml. Detailed measurement of coliform was carried out at the F/S phase. The coliform contents were classified into class B and C of the Vietnamese water quality standards of groundwater source.

(11) Dioxin Analysis

Dioxin analysis was made at Hanoi National University. The 3 samples were taken from JICA K-1, JICA G-3 and JICA D-6 exploratory wells in the time for pumping test or preliminary pumping test. The total 20 liters of each sample were transported to the laboratory.

The appearance of dioxin is inferred that it is by chemical reaction from artificial materials such as agricultural chemical, burning of poly-vinyl chemical materials under low temperature, and deforestation chemicals. The most probable area of serious deforestation by Vietnam War is located near the border of Cambodia. Therefore, the samples were selected as K1, G3 and D6 communes. No dioxin was detected by the laboratory test (Data Book).

6.1.6 Evaluate of the Water Quality

(1) Existing Water Sources

Except for the parameter of coliform levels, these existing water sources are mostly classified into class B to C. Because of low pH and high contents of nitrate contents, many water samples were classified into class C.

The following points are of the importance for future improvement of water quality.

- High values of coliform
- Low pH
- High contents of nitrate
- High contents of manganese
- High contents of iron

(2) JICA Test Wells

Except the water samples which show a high coliform value, these test well water are mostly classified into class A and B. Because of low coliform value by the re-test at F/S stage, many water samples were classified into class B.

The following points are the most important considerations for using these water sources for a water supply.

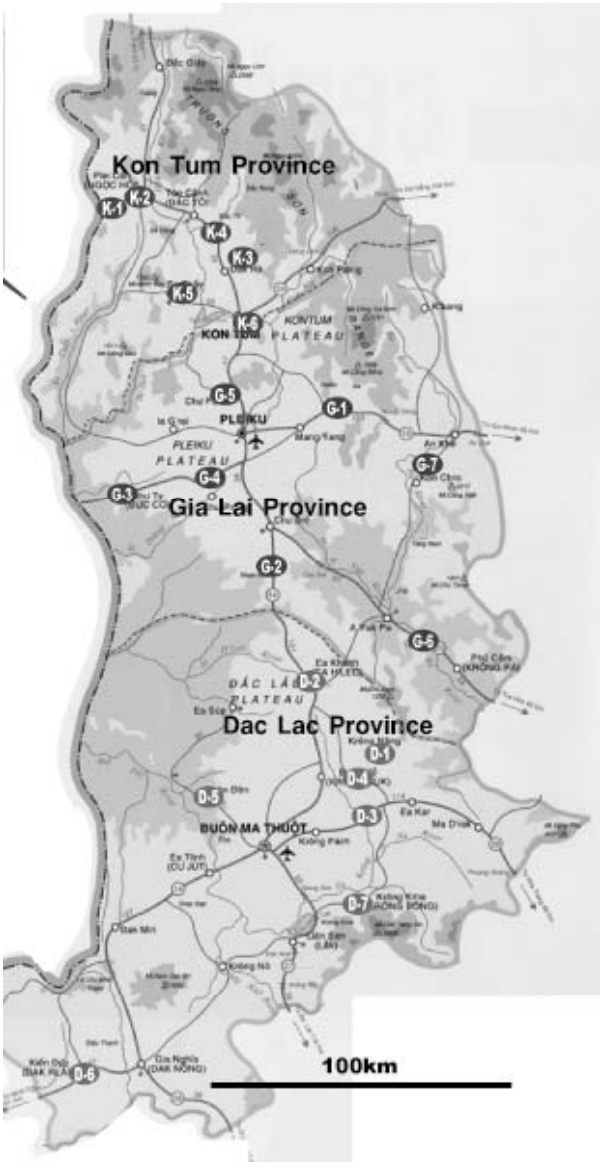
- High contents of iron

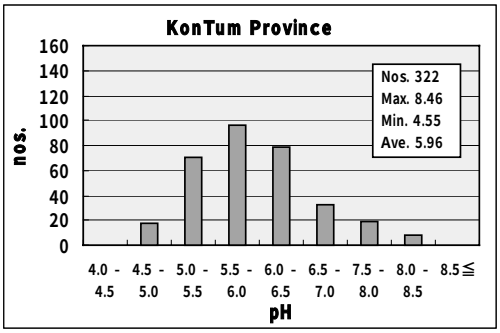
(3) Alternative Water Sources

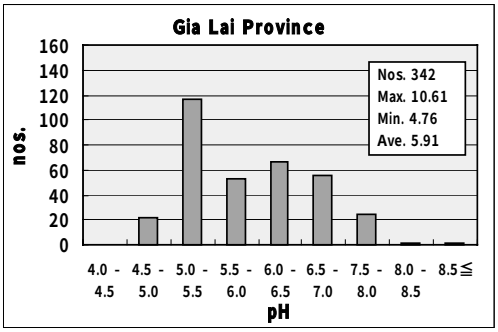
The analyzed surface water samples are mostly classified into class B.

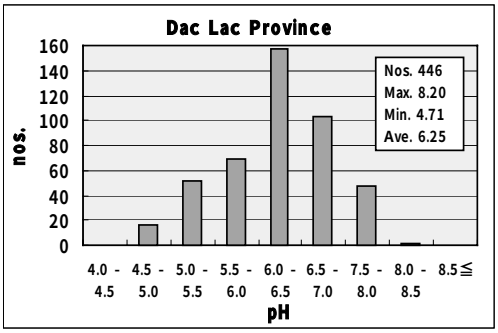
The following points are the most important considerations for using these water sources for water supply.

- High values of Coliform
- High contents of Iron









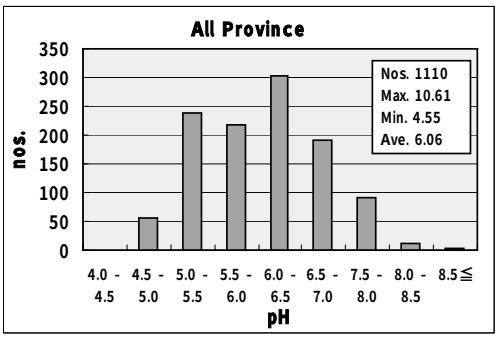
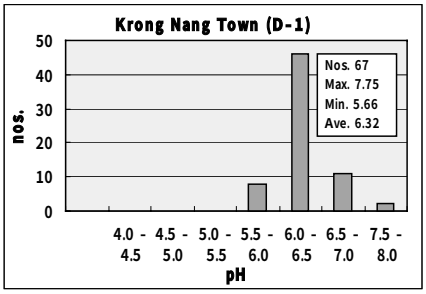
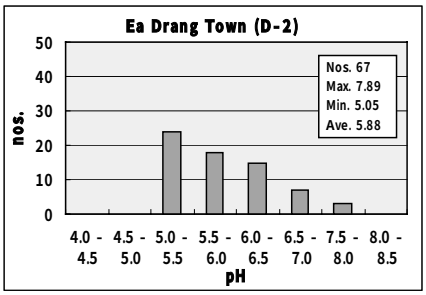
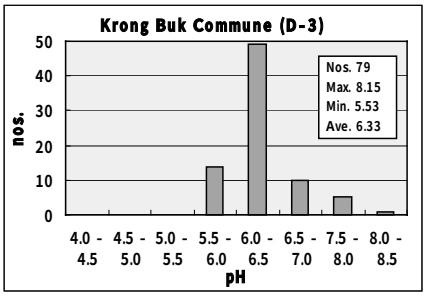
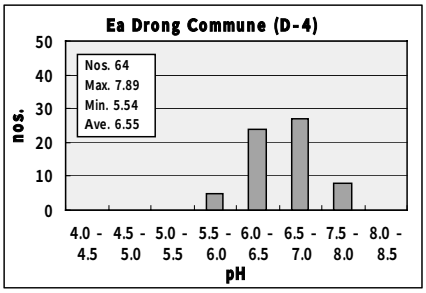


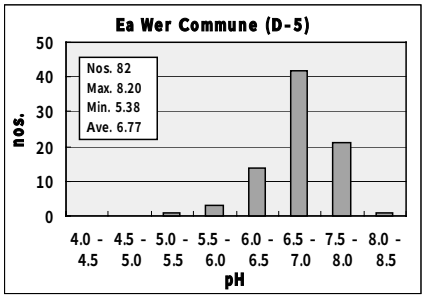
Figure 6.1 pH Value of Existing Water Sources in Three Provinces

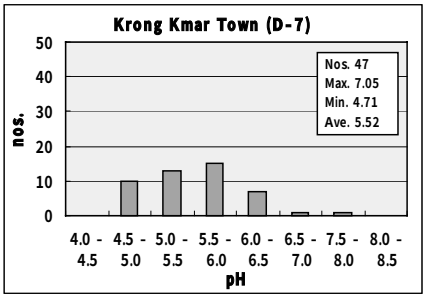












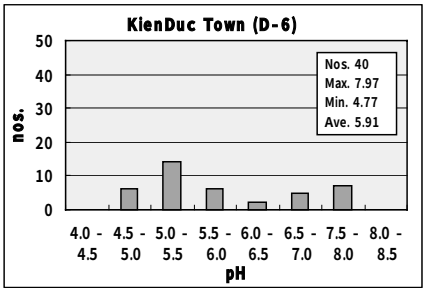
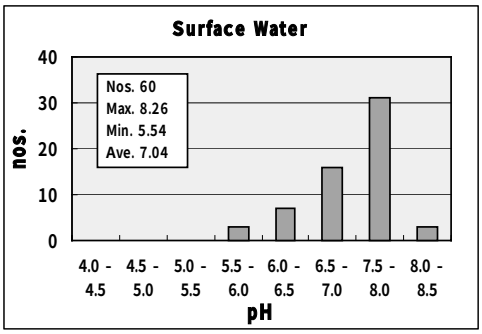
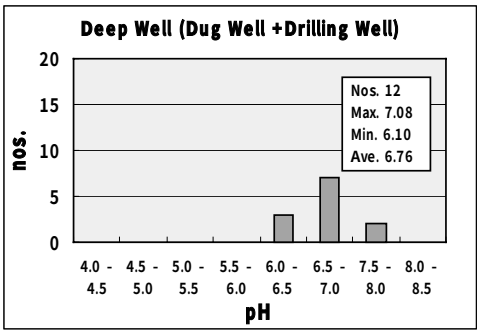
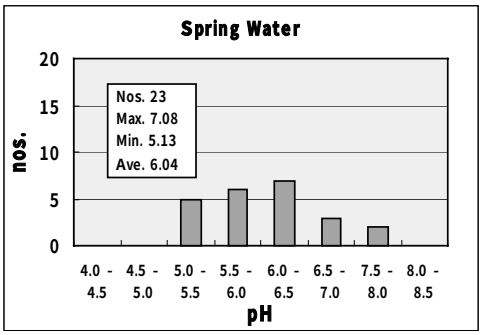
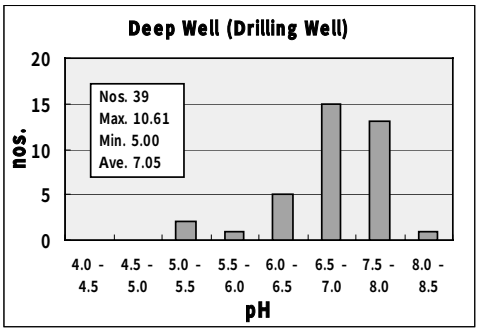


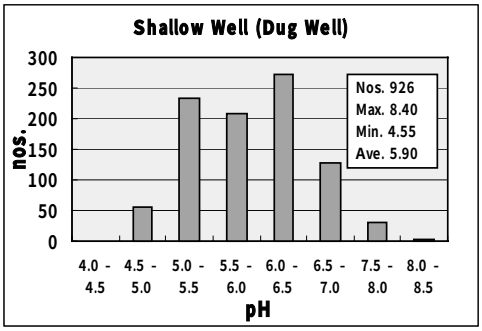
Figure 6.2 pH Value of Existing Water Sources in Dac Lac Province

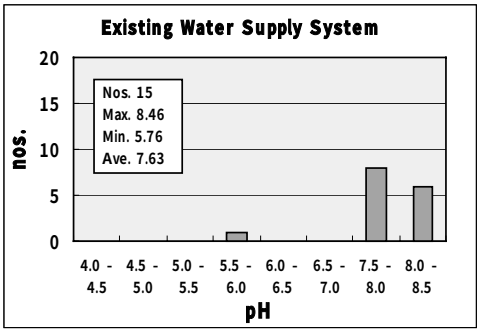


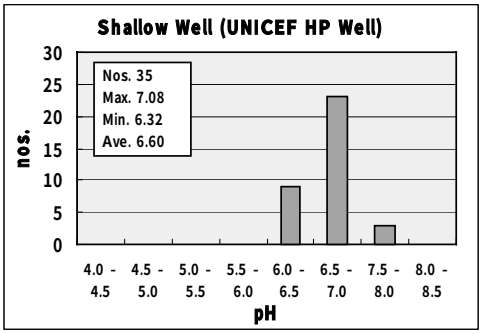












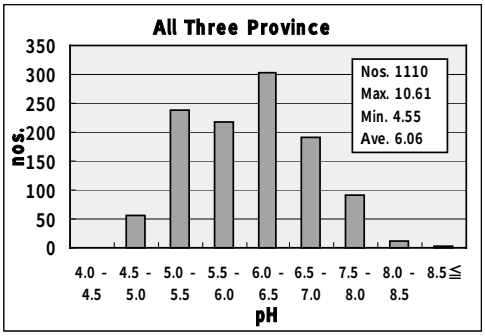
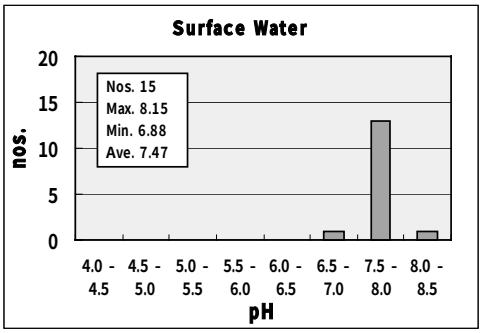
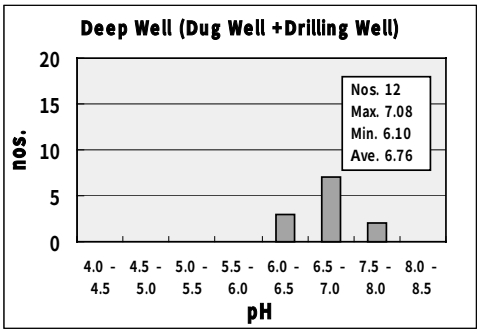
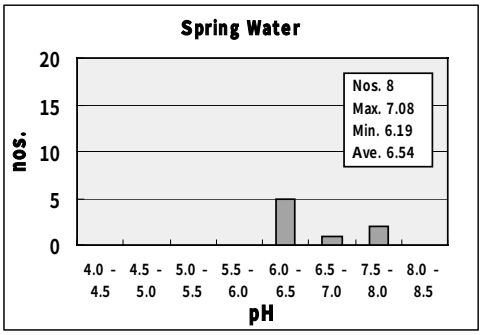
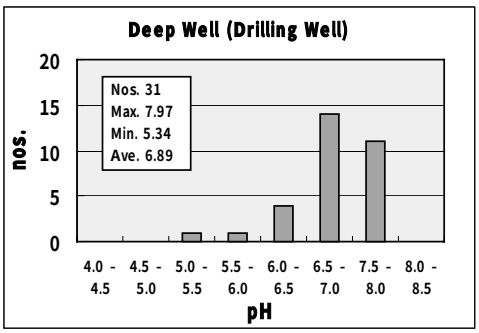


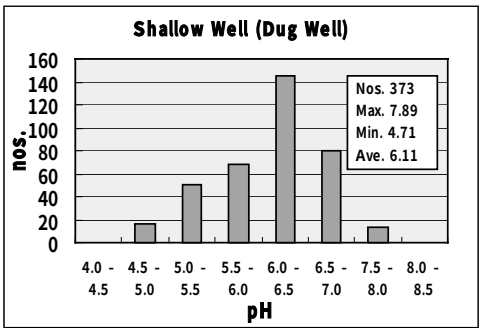
Figure 6.3 pH Value of Existing Water Sources in Three Provinces

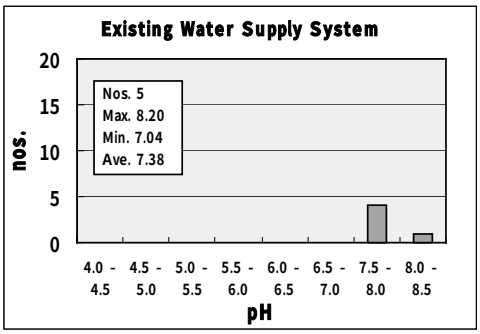


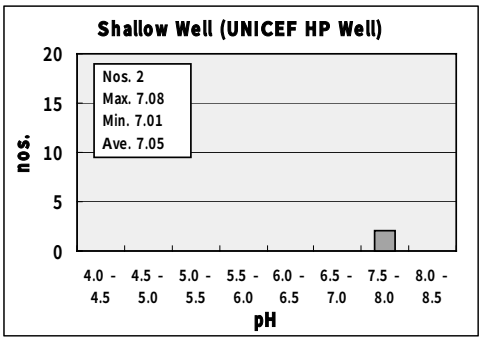












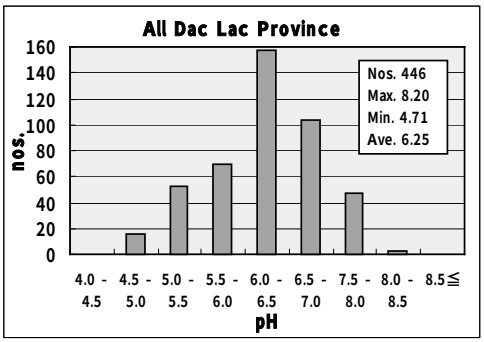


Figure 6.4 pH Value of Existing Water Sources in Dac Lac Province

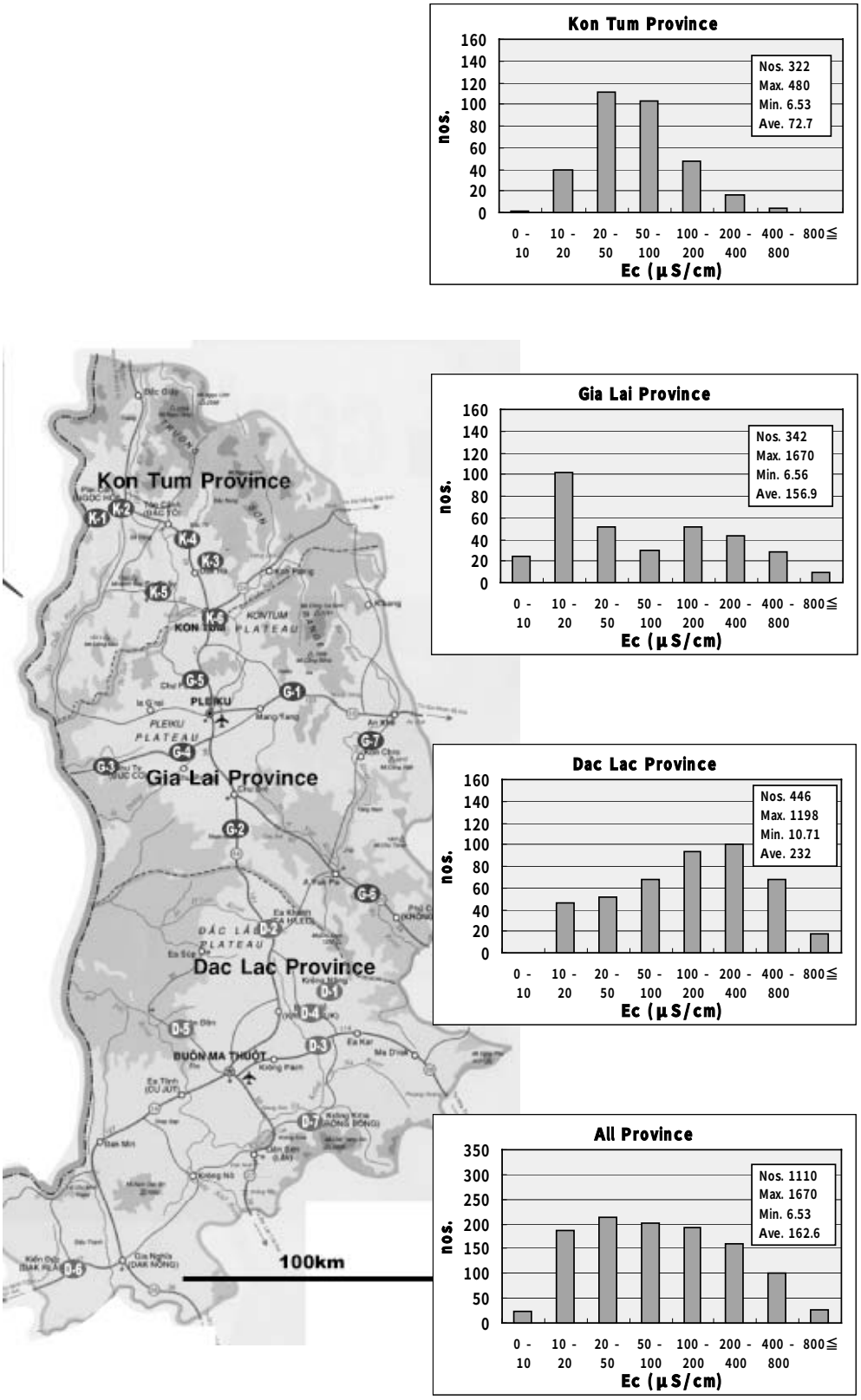


Figure 6.5 EC Value of Existing Water Sources in Three Provinces

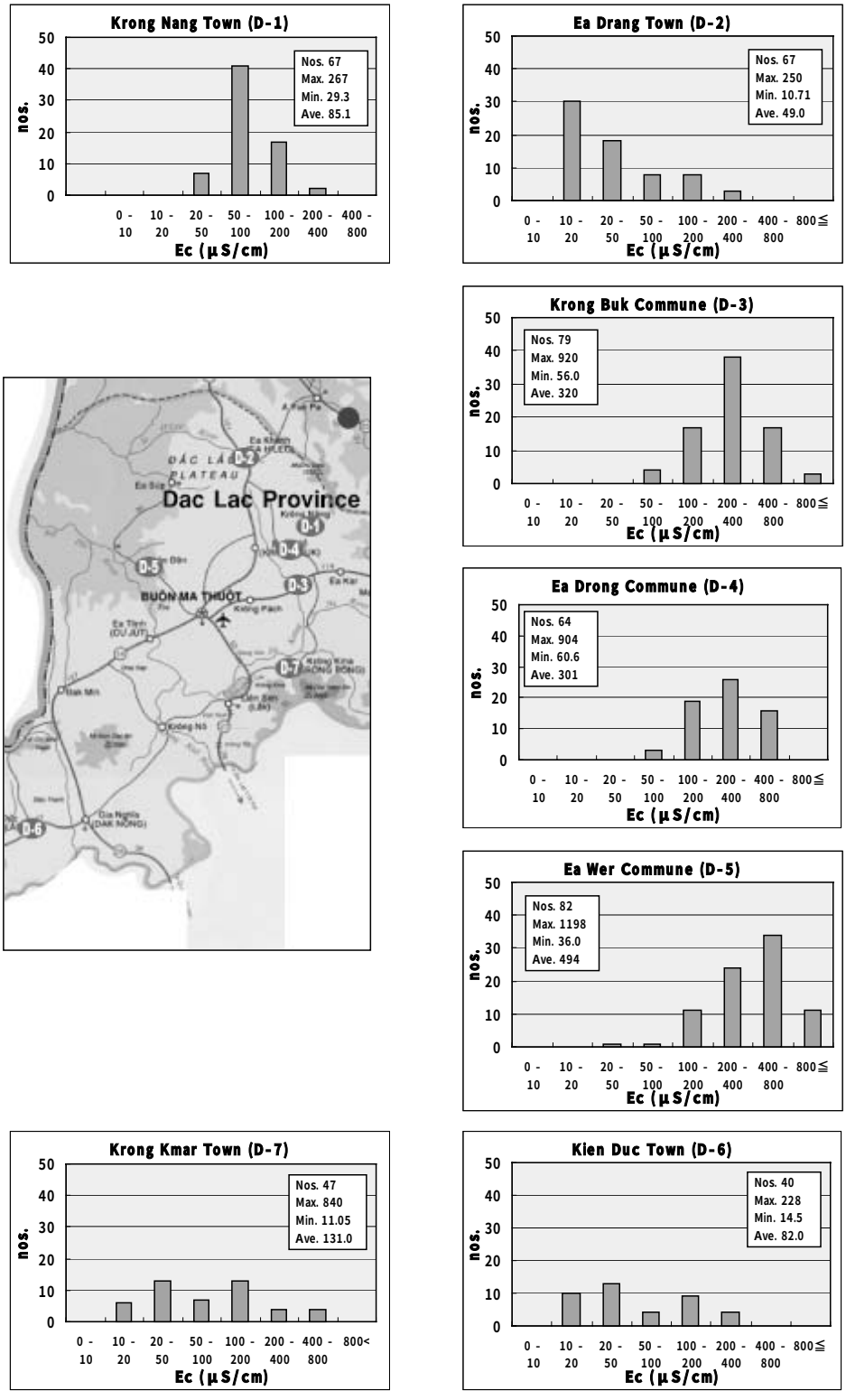
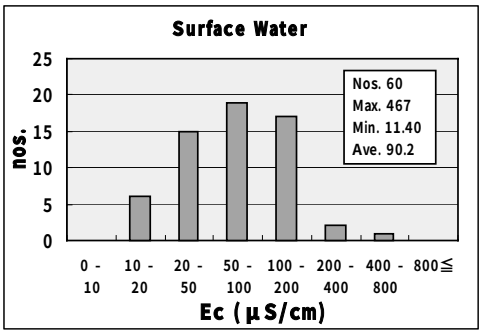
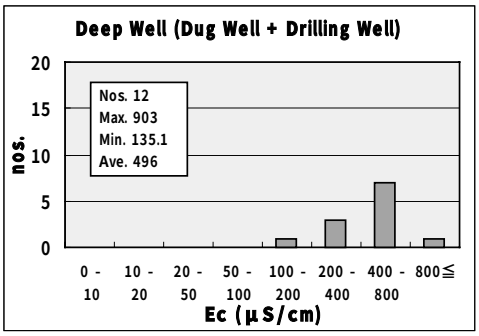
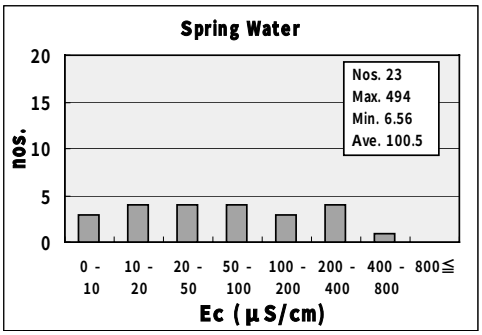
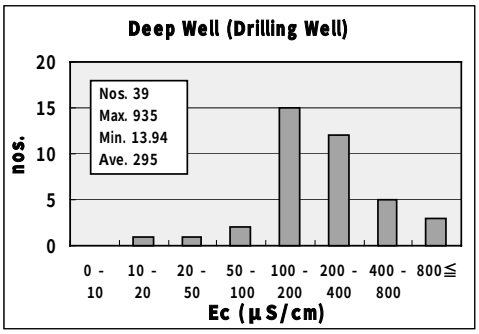


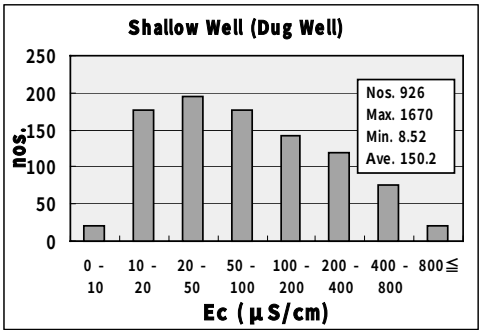
Figure 6.6 EC Value of Existing Water Sources in Dac Lac Provinces

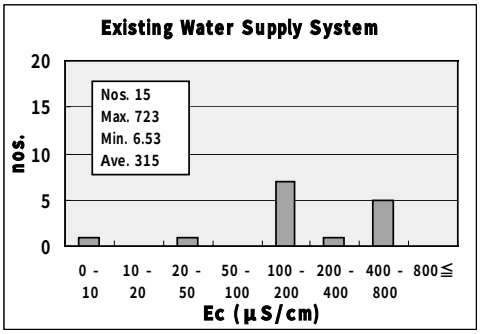


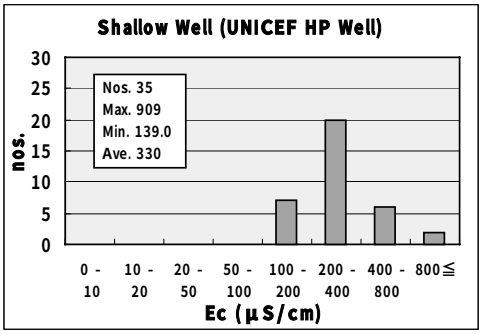












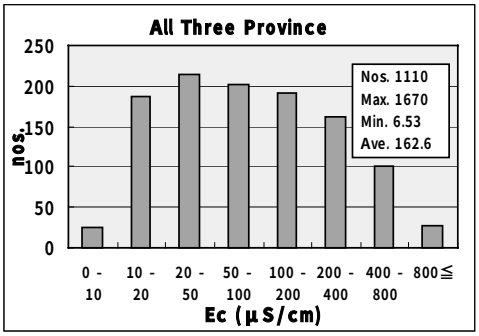
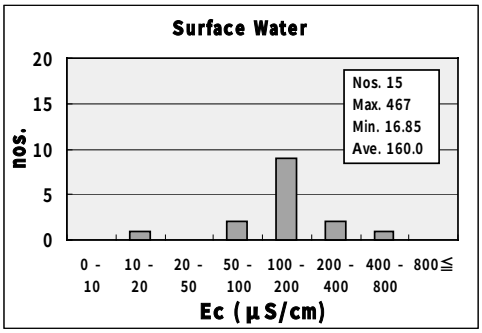
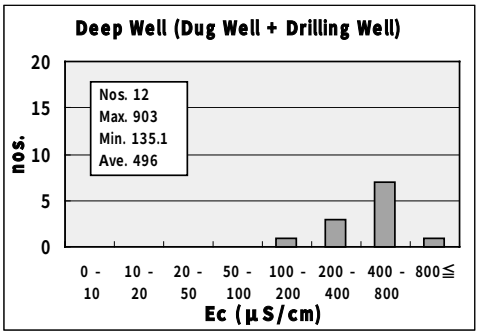
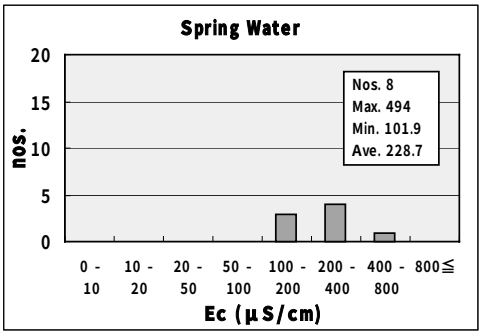
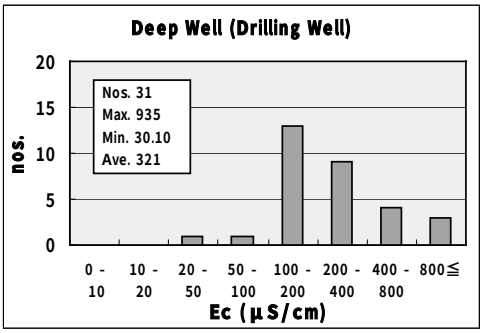


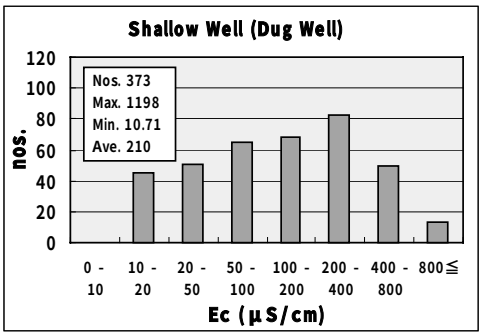
Figure 6.7 EC Value of Existing Water Sources in Three Provinces

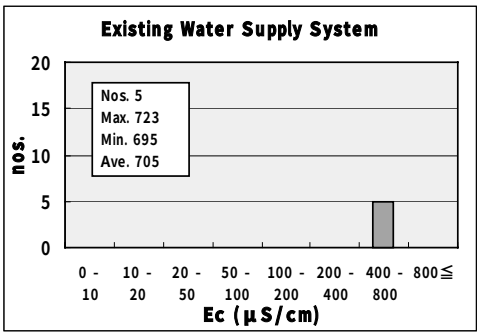


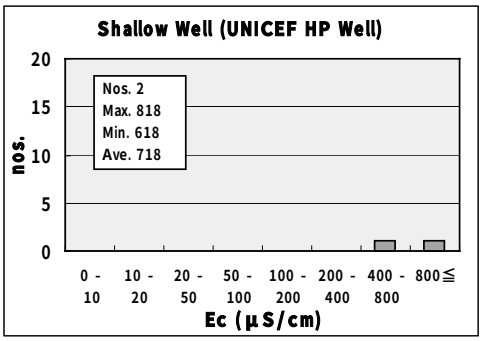












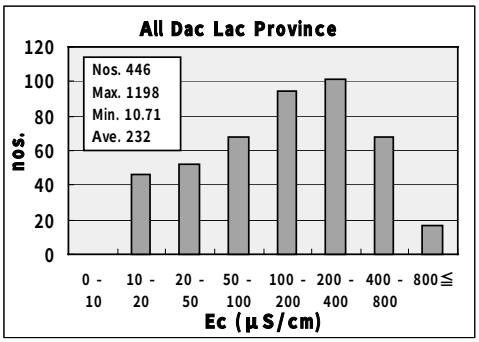
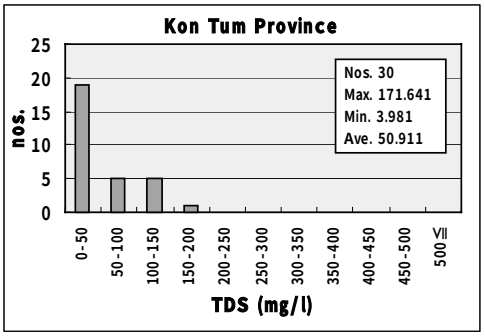
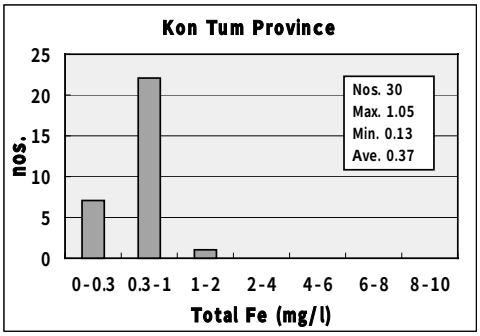
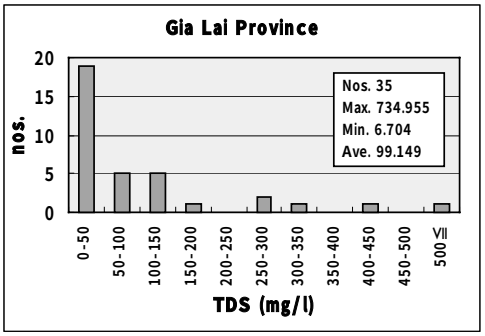
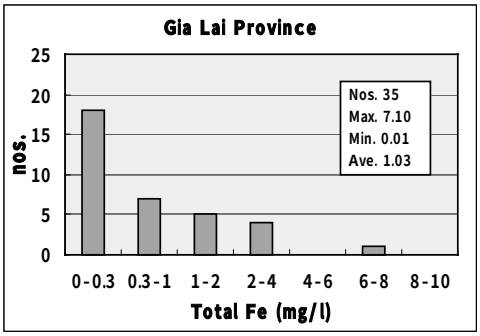


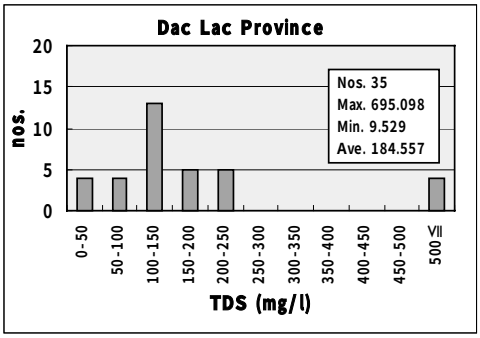
Figure 6.8 EC Value of Existing Water Sources in Dac Lac Province

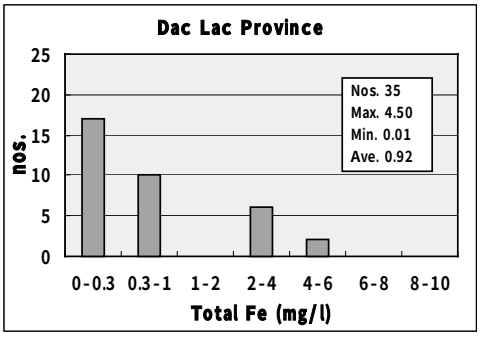


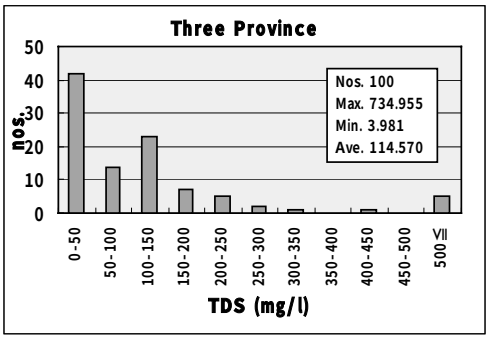












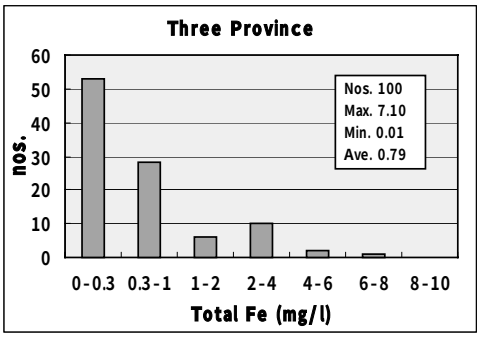
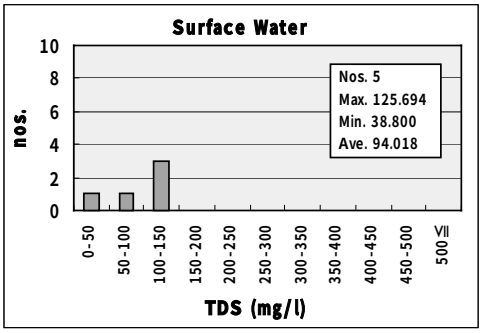
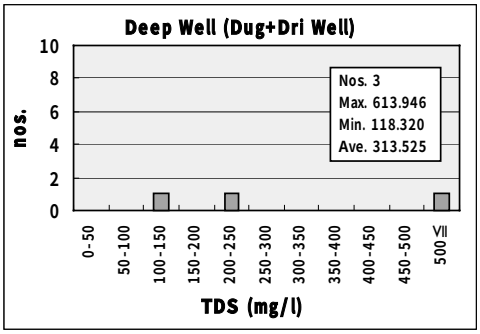
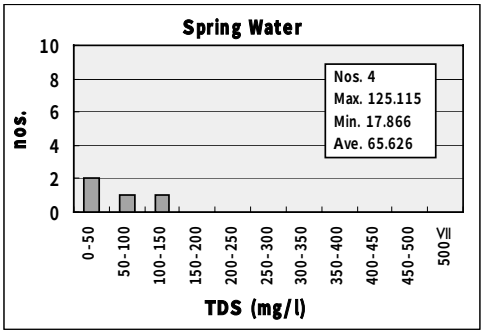
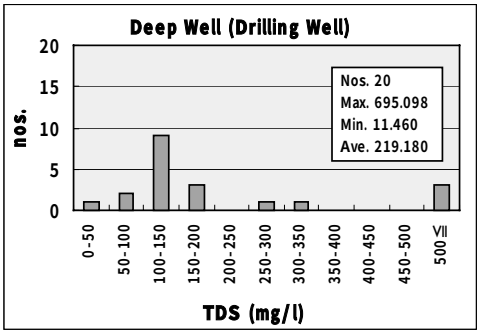


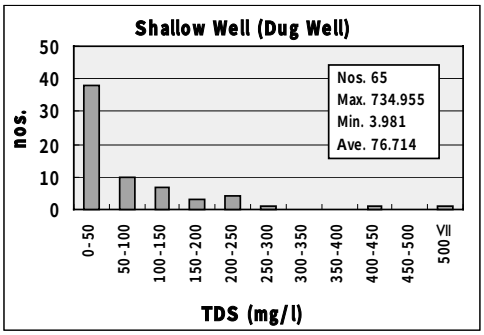
Figure 6.9 Measured TDS and Total Fe-Province

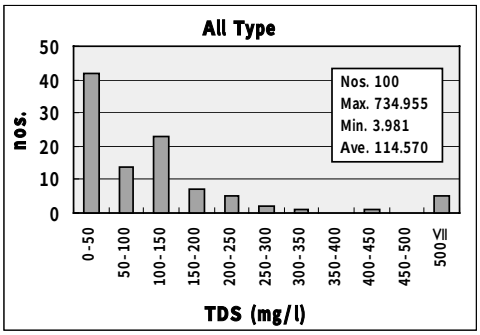












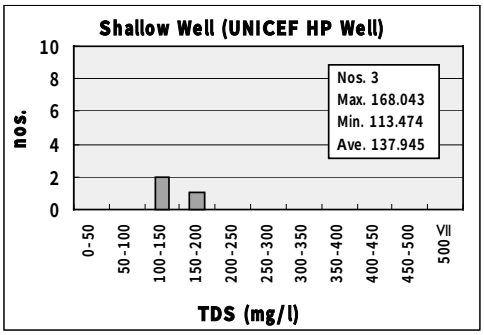
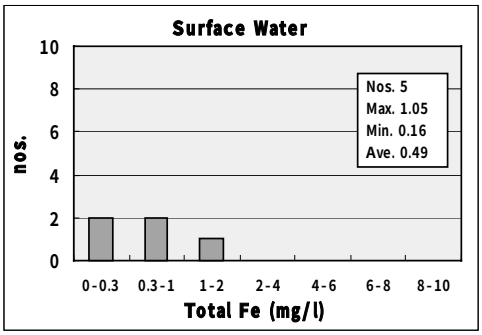
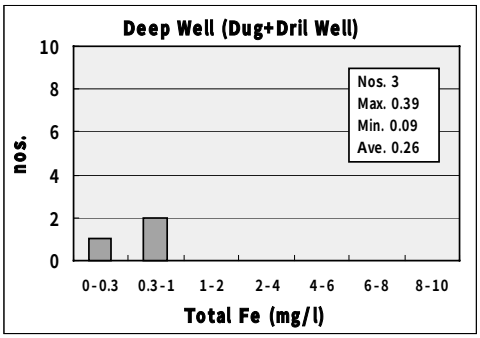
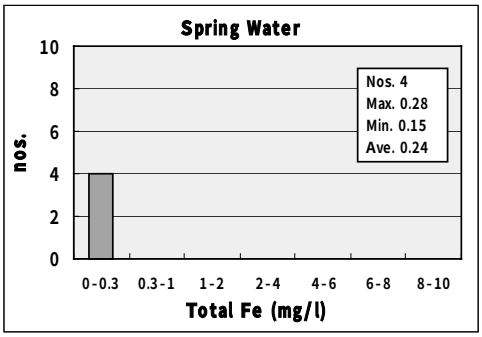
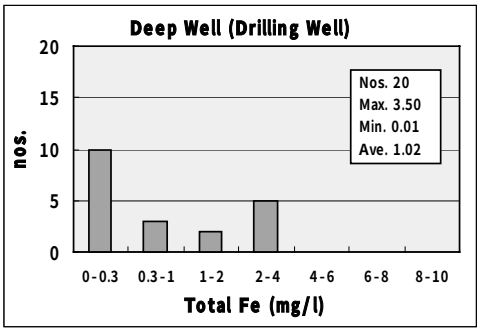


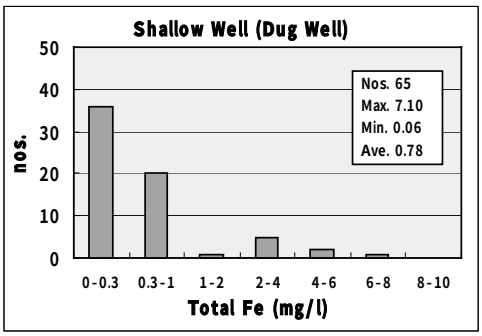
Figure 6.10 Measured TDS Concentration - Each Water Source

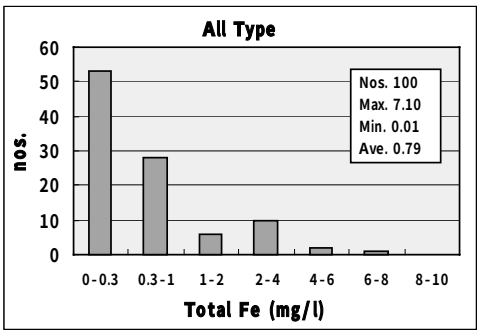












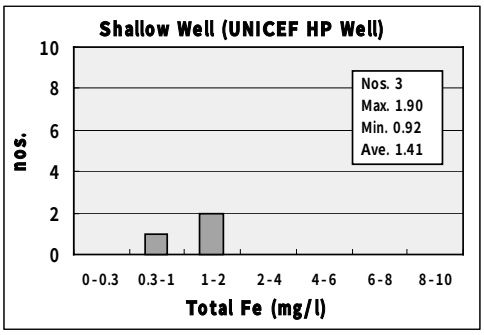
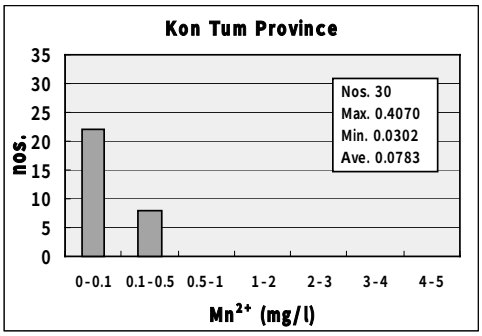
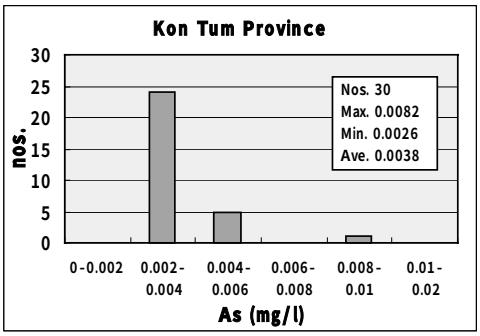
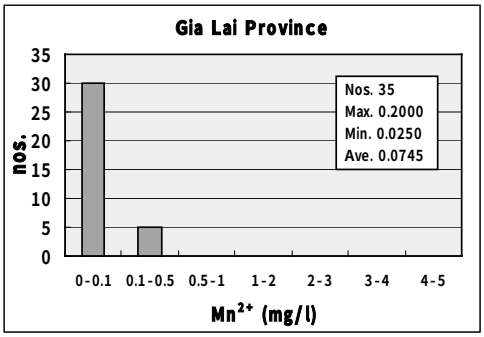
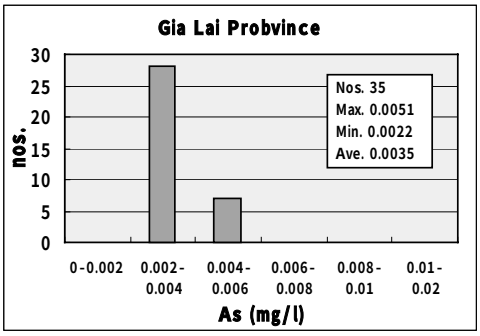


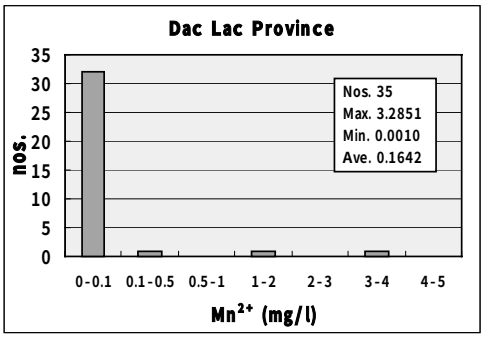
Figure 6.11 Measured Total Iron Concentration - Each Water Source

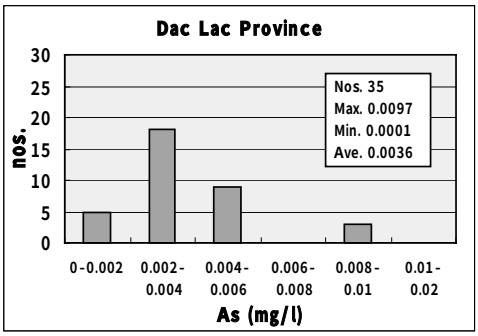


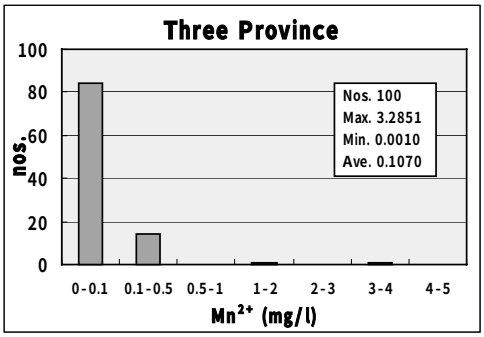












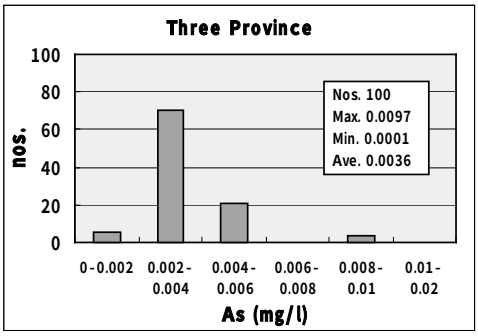
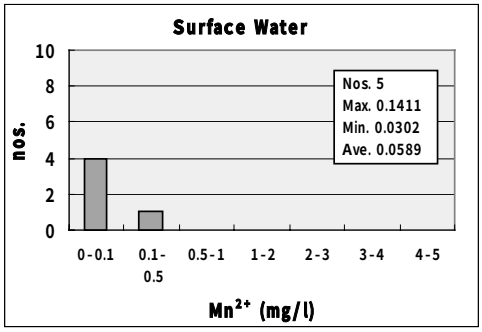
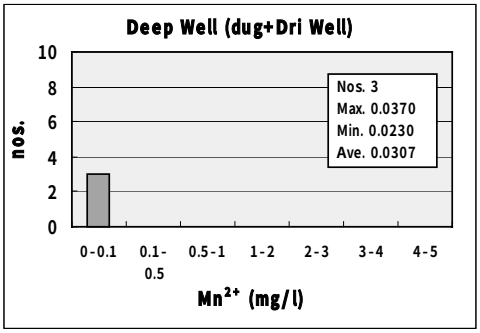
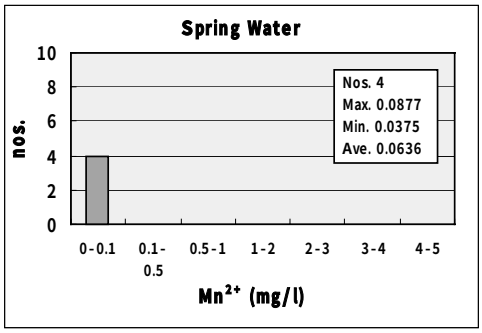
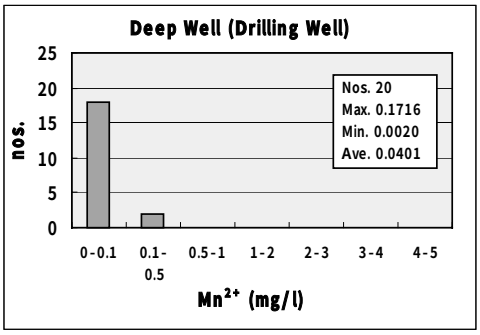


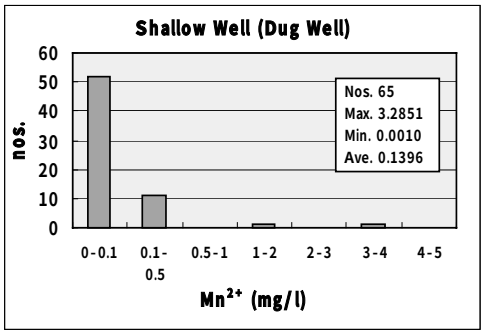
Figure 6.12 Measured Mn2+ and As – Province

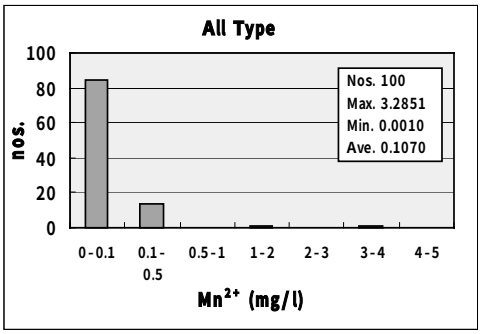












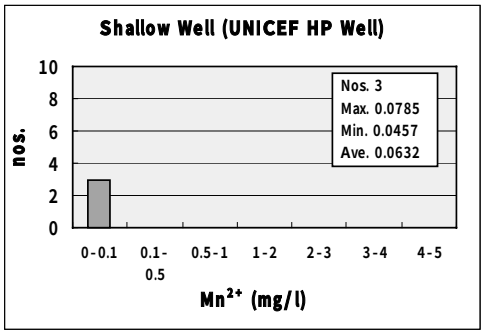
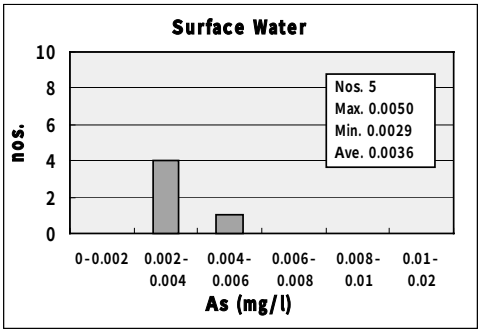
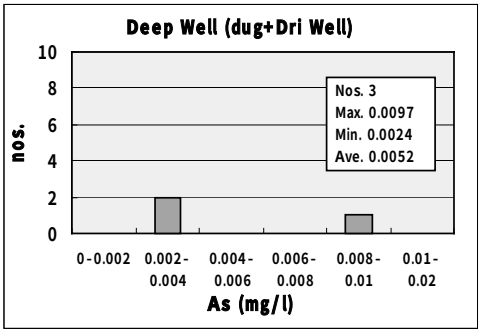
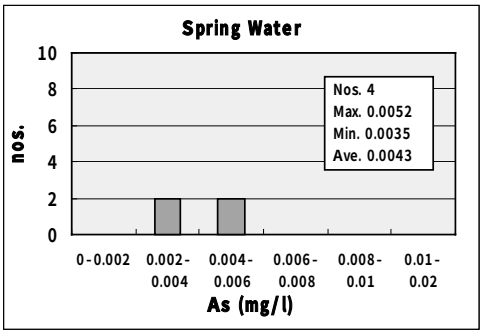
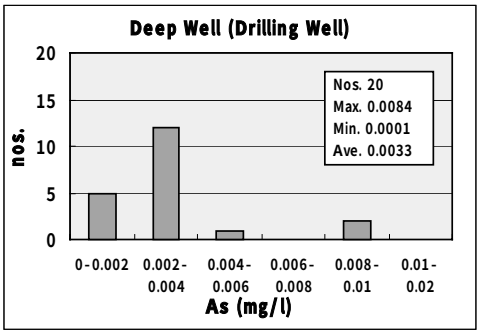


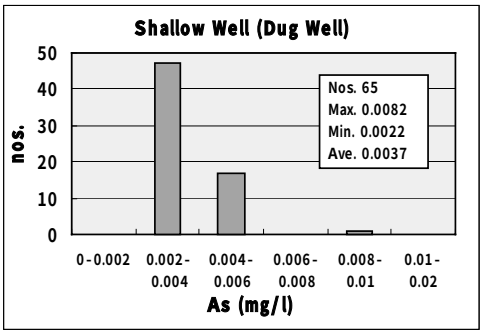
Figure 6.13 Measured Mn2+ Concentration-Each Water Source

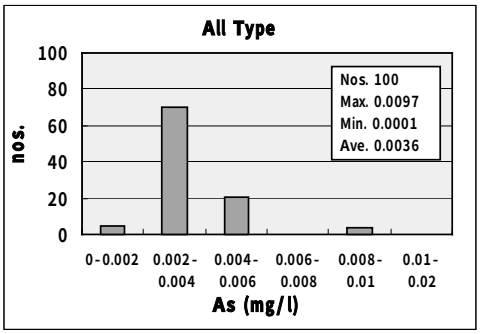












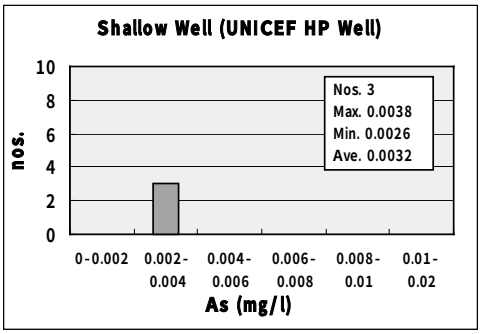
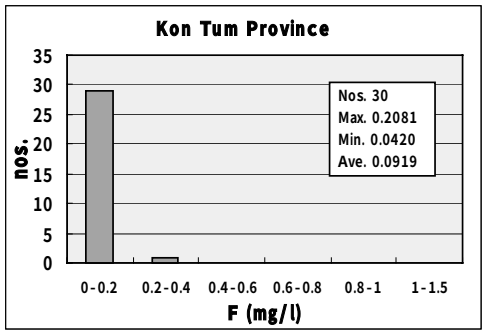
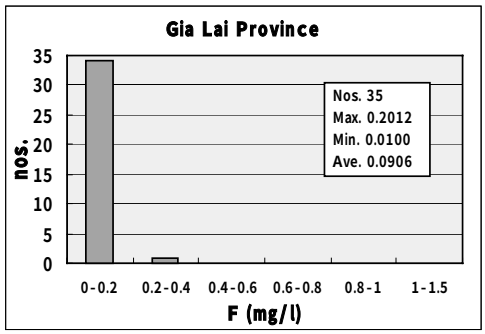
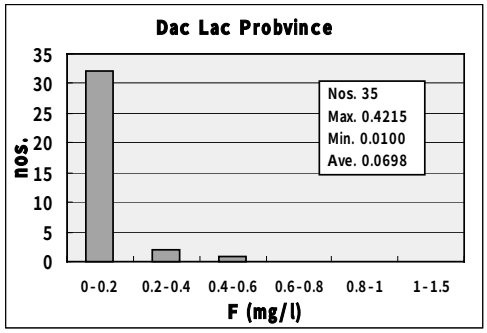


Figure 6.14 Measured As Concentration - Each Water Source







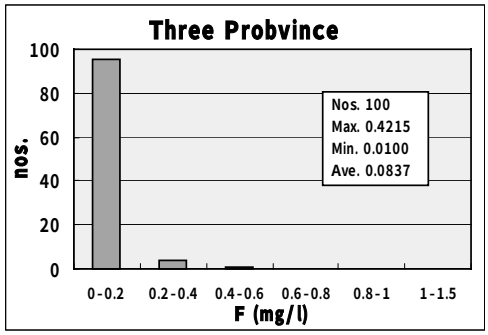
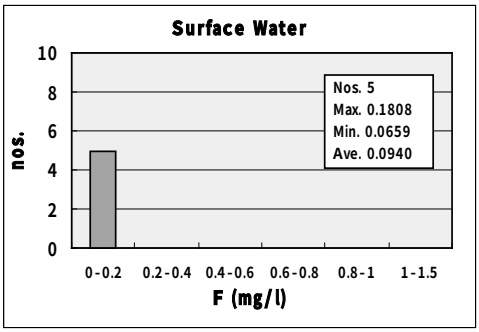
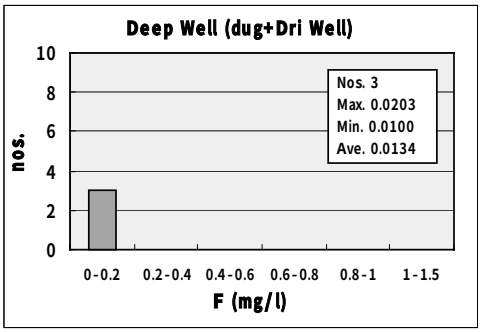
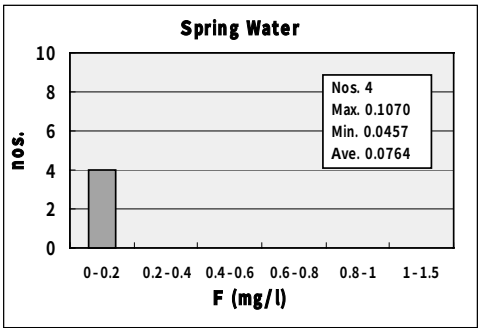
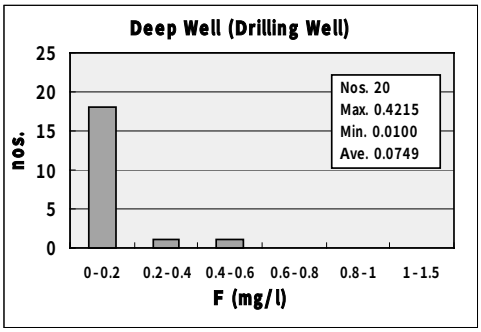


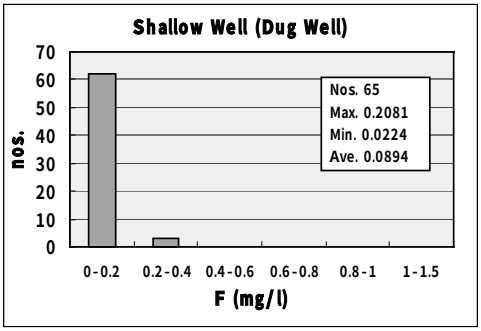
Figure 6.15 Measured F – Province

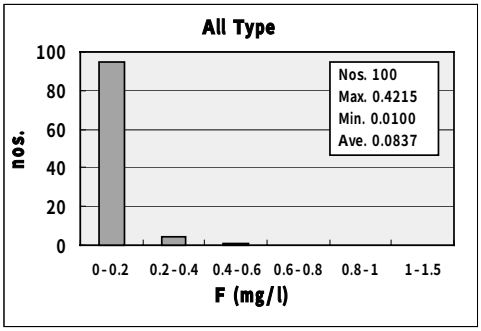












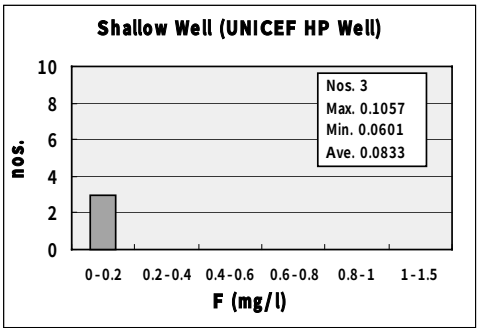


Figure 6.16 Measured Fluoride Concentration - Each Water Source

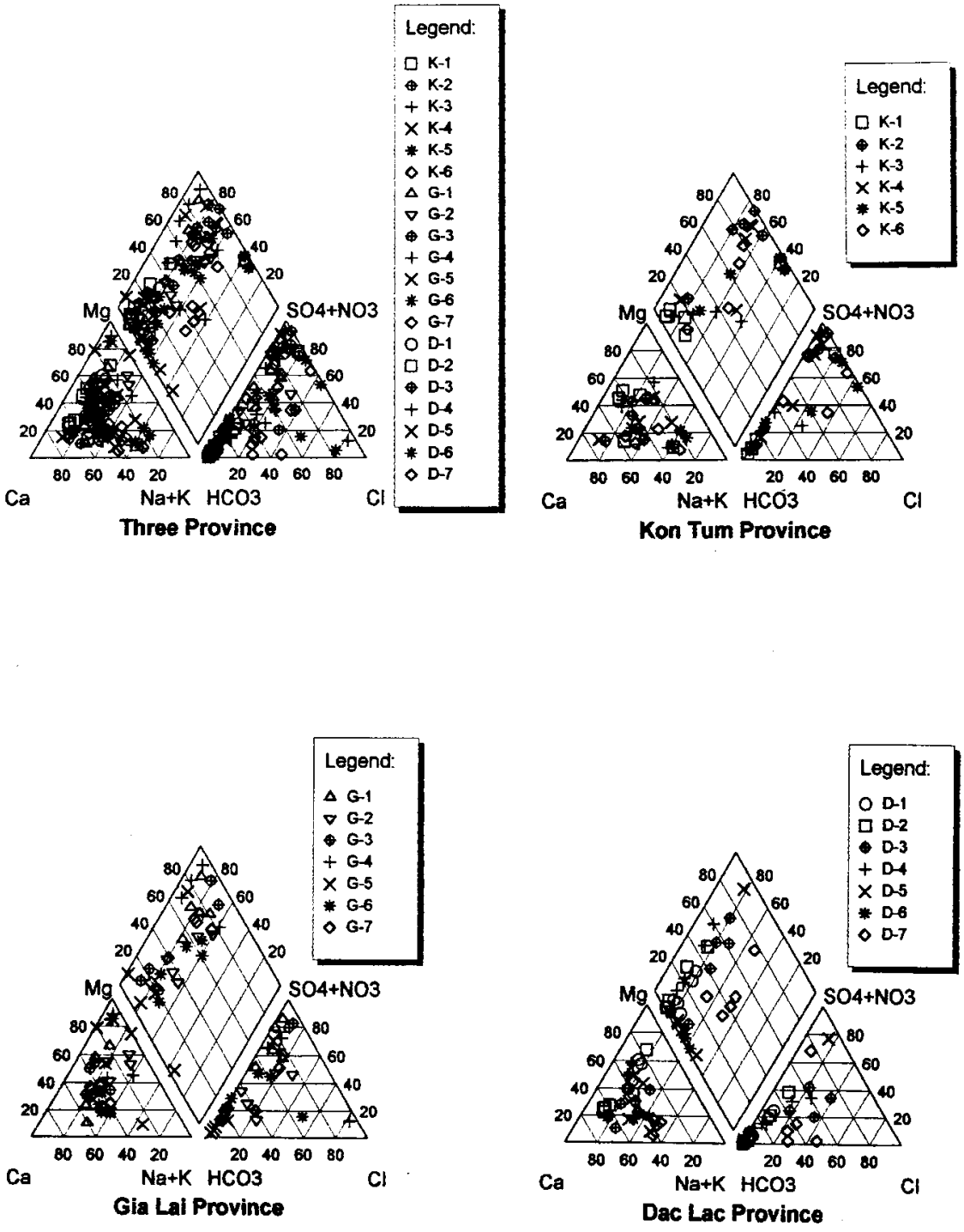


Figure 6.17 Trilinear Diagram of Water Samples from Each Province

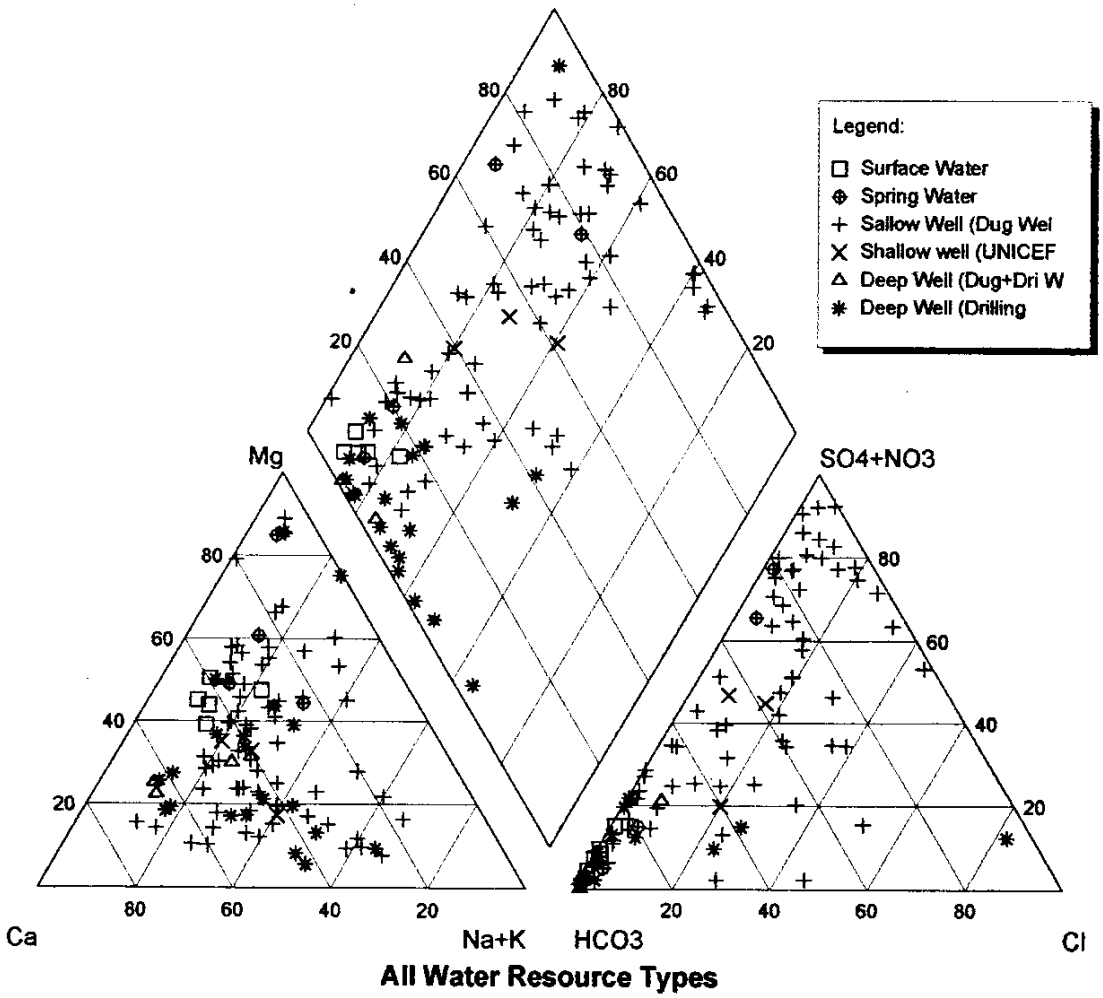
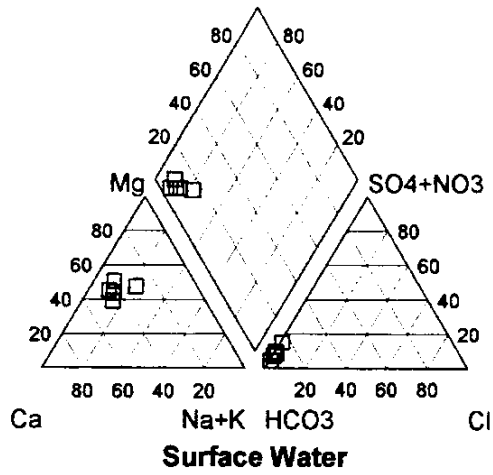
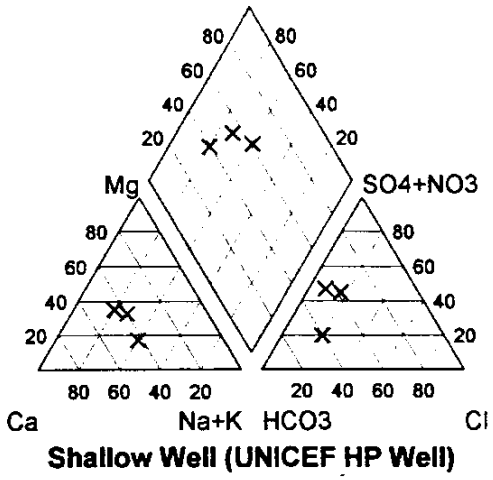


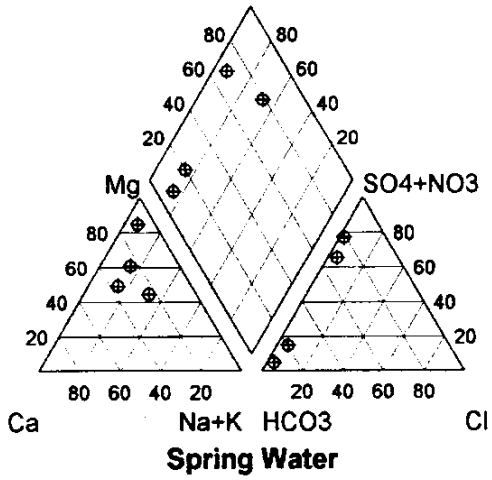
Figure 6.18 Trilinear Diagram of Water Samples from All Water Sources



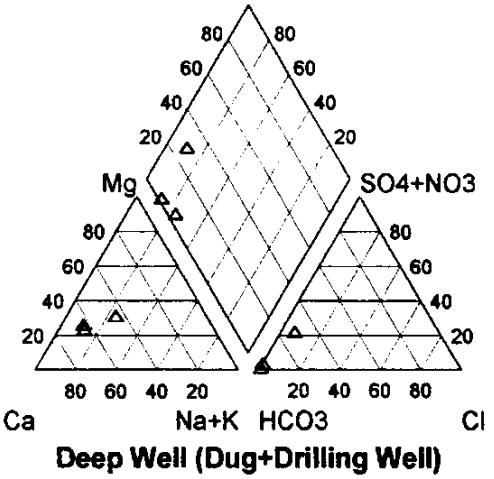
Surface Water



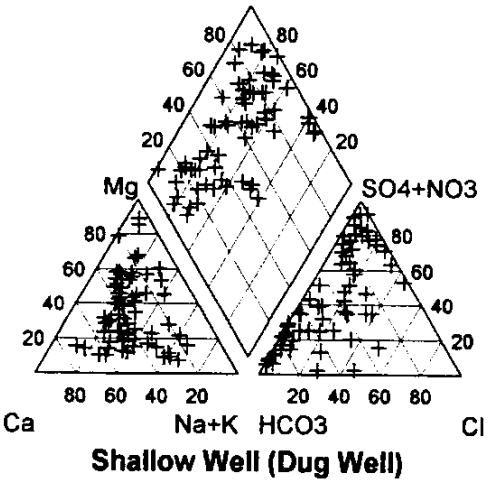
Shallow Well (UNICEF HP Well)



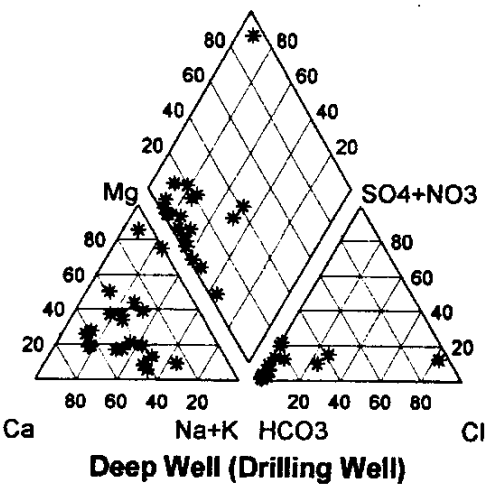
Spring Water



Deep Well (Dug+Drilling Well)



Shallow Well (Dug Well)



Deep Well (Drilling Well)

Figure 6.19 Trilinear Diagram of Water Samples from Each Water Source

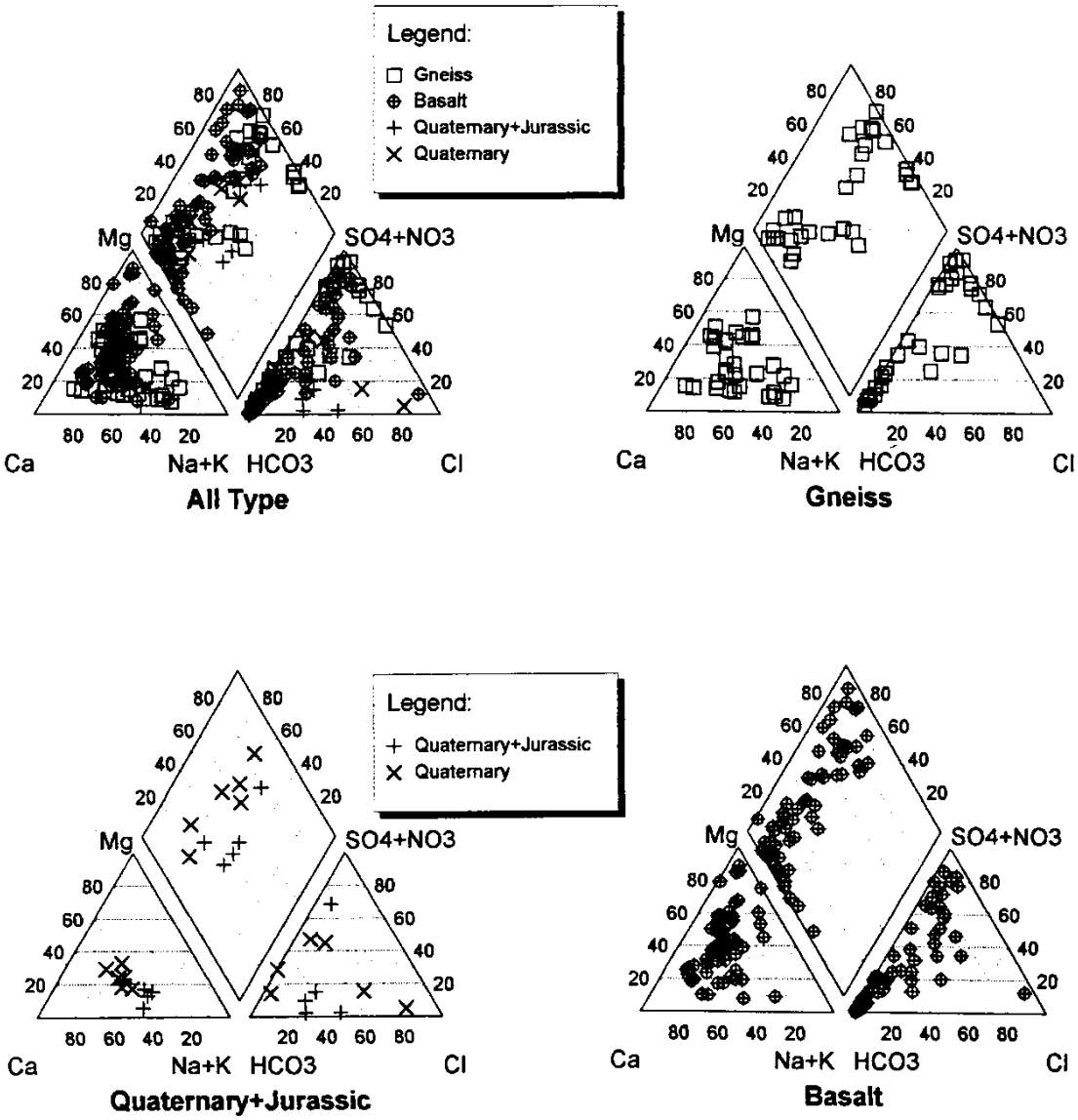
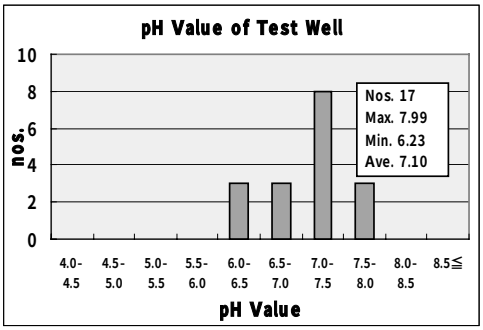
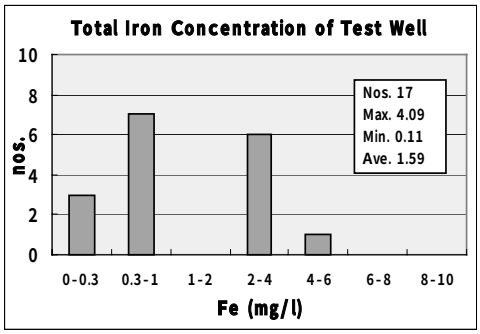
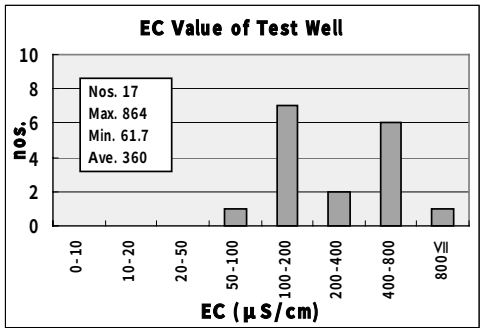
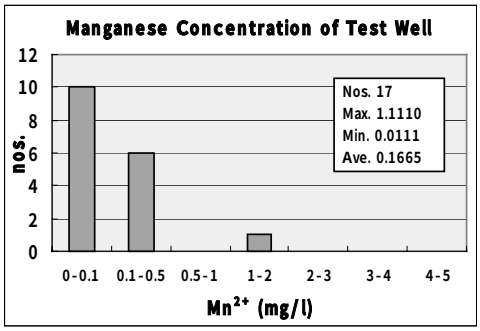


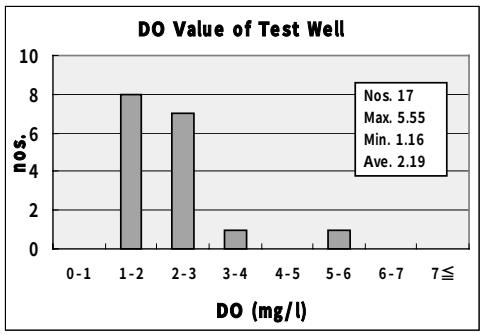
Figure 6.20 Trilinear Diagram of Water Samples from Each Geology Area

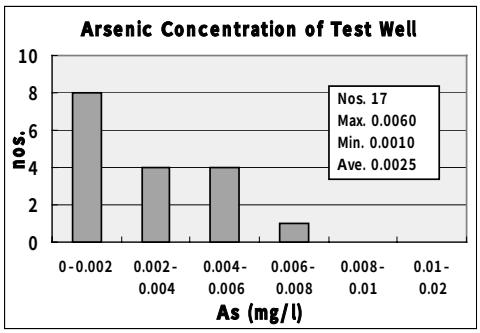


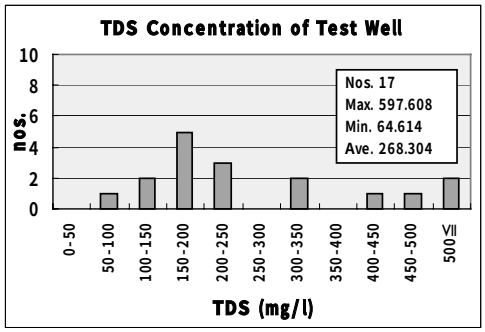












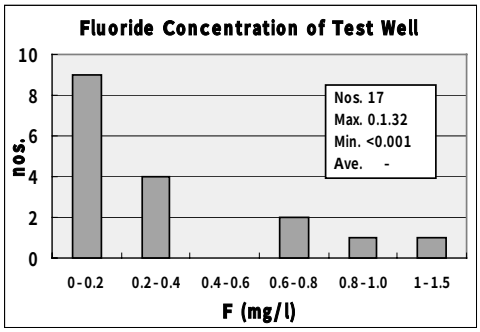


Figure 6.21 Measured Values and Concentrations of Test Well

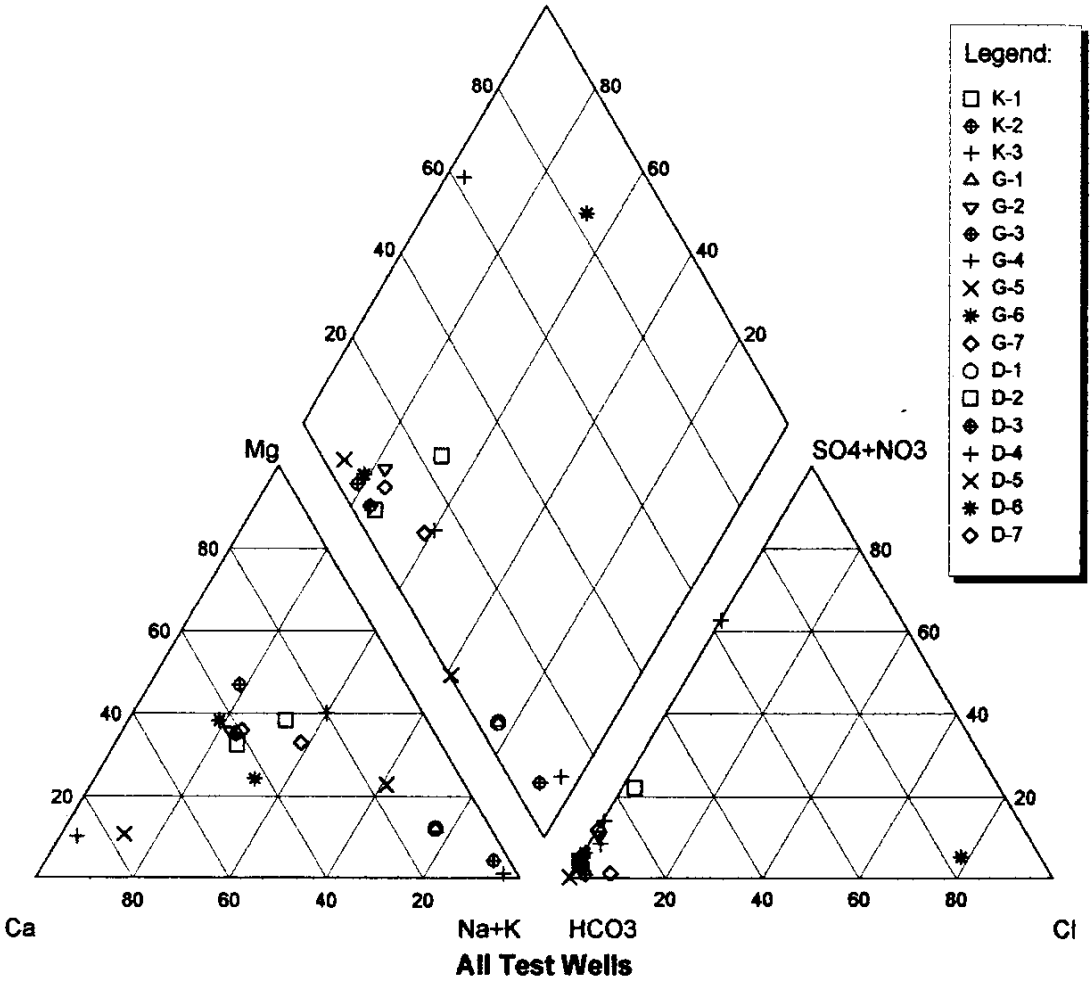
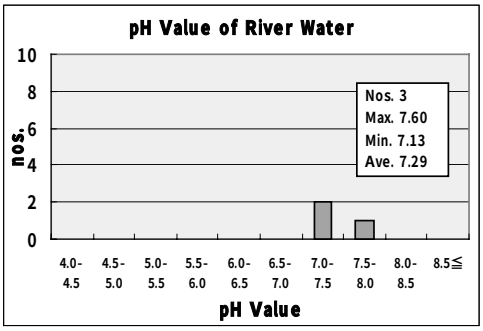
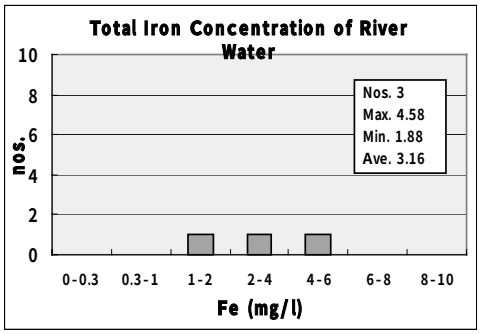
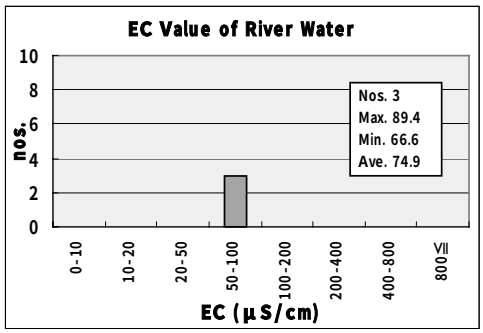
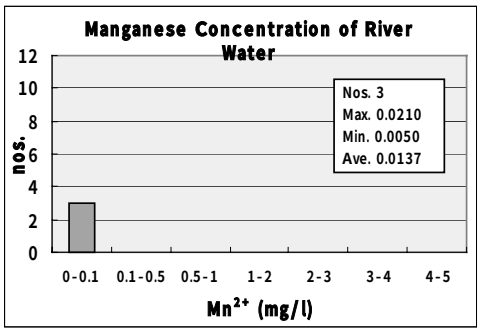


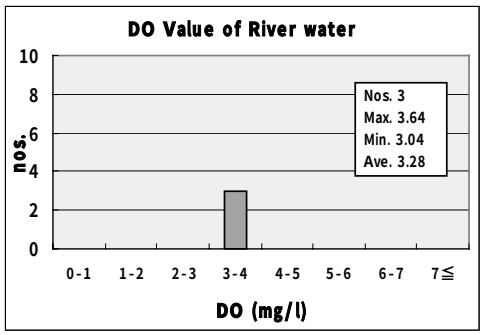
Figure 6.22 Trilinear Diagram of Water Samples from Test Well

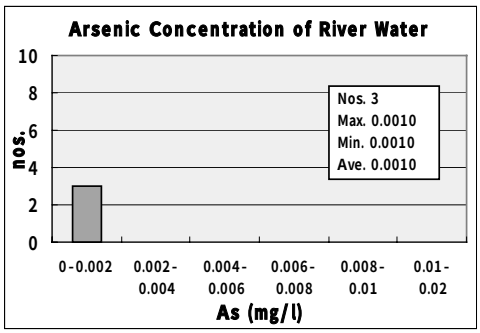


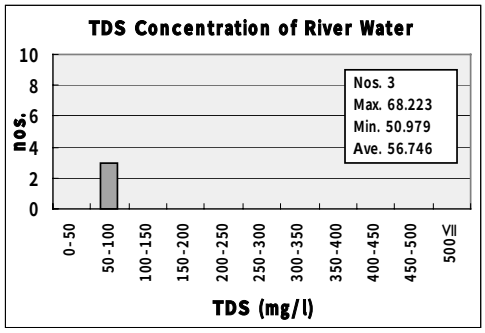












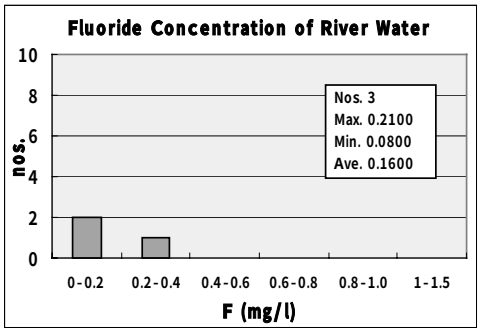


Figure 6.23 Measured Values and Concentrations of Alternative Water Sources

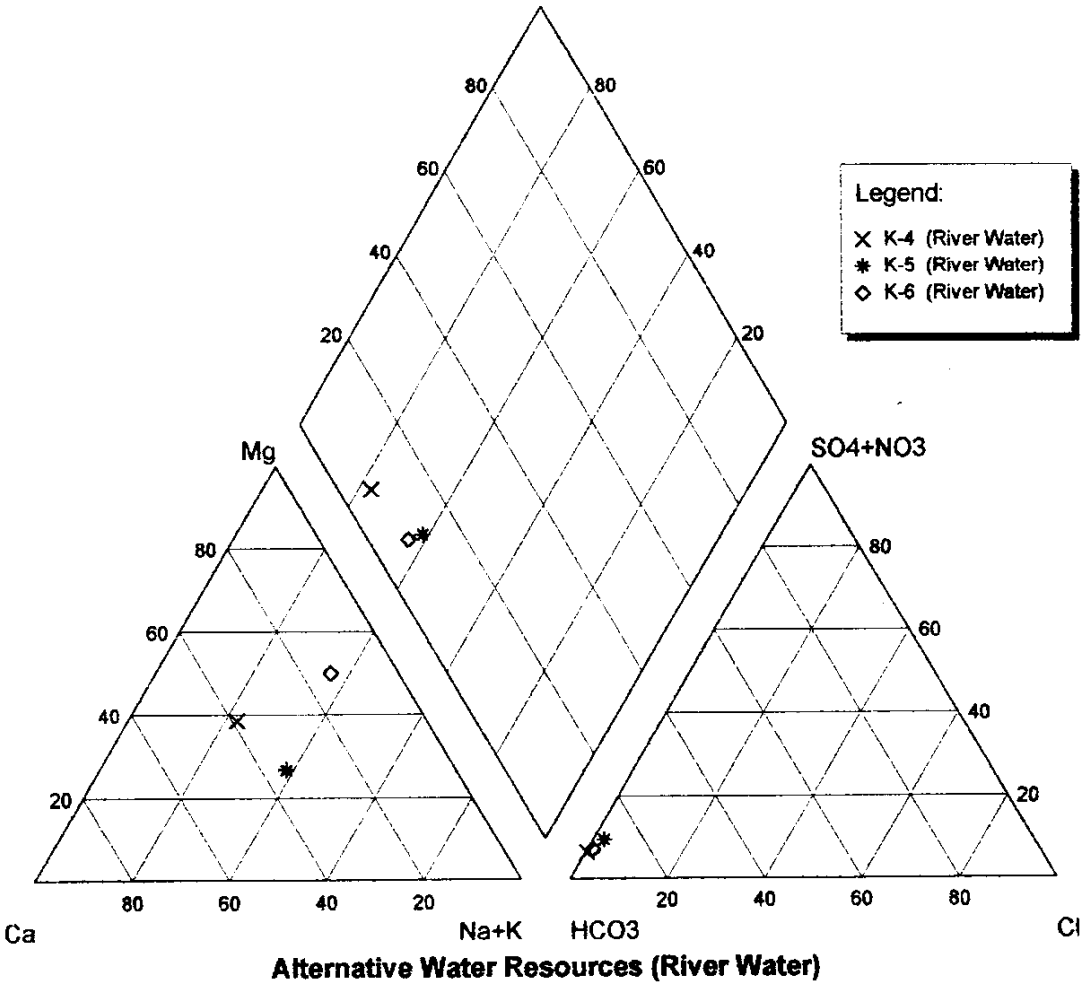


Figure 6.24 Trilinear Diagram of Water Samples from Alternative Water Sources