

**The Study on Groundwater Development in Central Cambodia  
Final Report**

**Summary Report**

LOCATION MAP

EXCHANGE RATE AND LIST OF ABBREVIATION

EXECUTIVE SUMMARY

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### **4.3 Groundwater Quality**

In the study, detailed investigations on groundwater quality were emphasized and carried out to evaluate the groundwater resources for safe drinking water supply based on the experience of the JICA's groundwater development study in southern Cambodia with considering the problem of groundwater contamination by arsenic and other substances in Cambodia.

#### **(1) Methodology**

Groundwater quality of the newly constructed test wells as well as the selected existing wells was analyzed in a laboratory and measured in the field.

##### **1) Laboratory Analysis**

For the JICA test wells, a total of 31 samples from 30 wells were collected during a period from August to October 2001 after the completion of the well construction. The samples were sent to a laboratory in Bangkok, Thailand. In addition, 10 samples were collected in December 2001 for cross checking purpose and for evaluating the effectiveness of the iron removal device. For the existing wells, a total of 68 samples were collected during the 3rd simultaneous groundwater observation in August 2001.

In the laboratory, following 21 parameters were analyzed for each sample:

Water Temperature, pH, EC, Ca, Mg, Na, K, Fe, Mn, NH<sub>4</sub>, As, CO<sub>3</sub>, HCO<sub>3</sub>, CO<sub>2</sub>, Cl, SO<sub>4</sub>, NO<sub>3</sub>, F, SiO<sub>2</sub>, Hardness, TDS

##### **2) Field Groundwater Quality Measurement**

For the JICA test wells, field groundwater quality measurements were carried out on a monthly basis after the completion of the well construction. For the existing wells, field groundwater quality was measured in the simultaneous groundwater observation (4 times) and the periodic groundwater observation (12 times). The simultaneous observations were carried out in February, May August and November 2001. The numbers of the measured wells were about 250 wells in the simultaneous observation, 26 wells in the periodic observation, and 30 JICA test wells. The field measurements were carried out by the study team members and the counterparts from the DRWS. The methodologies of groundwater sampling, quality measurements, data recording, and data processing were well transferred to the counterparts.

In the field, 11 parameters shown below were measured for each sample:

Water Temperature, pH, ORP, EC, Fe, F, NO<sub>3</sub>, NH<sub>4</sub>, As, coliform, bacteria

## **(2) Results of Laboratory Analysis**

### **1) JICA Test Wells**

#### **a ) Major Dissolved Ions**

The samples from northern Kg. Chhnang province show (Na + K) –HCO<sub>3</sub> type, however, the samples from the central to southern part of the province show Ca – HCO<sub>3</sub> type. In Kg. Cham province, most samples show Mg-HCO<sub>3</sub> type, but there are some samples having Ca-HCO<sub>3</sub> type in Memot district. No. 30 well located in western Kg. Cham province has a strange chemical composition and shows bad water quality. The total amount of major ions in Kg. Chhnang province ranges from 8 to 24 meq/L. The amount in Kg. Cham province is generally lower, having about 5 meq/L. However, there are three (3) wells in Memot district having total major ions of 15 to 20 meq/L. No. 30 well has very high total ions of 45.6 meq/L (Figure 4.3.1 and 4.3.2).

#### **b ) Comparison with WHO Guideline Value**

The results of the laboratory test were compared with the WHO guideline value for drinking water. In the test wells, only No. 7 well has Na concentration of 218 mg/L exceeding the guideline value of 200 mg/L. For Fe, there are 10 wells exceeding the guideline value of 0.3 mg/L. For Mn, there are 19 wells having more than the guideline value of 0.1 mg/L. For As, there are two (2) wells exceeding the guideline value of 0.01 mg/L. For Cl, there is only one (1) well exceeding the guideline value of 250 mg/L. For NO<sub>3</sub>, there is only one (1) well exceeding the guideline value of 50 mg/L. For F, there are three (3) wells having more than the guideline value of 1.5 mg/L. For TDS, there is one (1) well having more than the guideline value of 1,000 mg/L. Out of the 30 test wells, only 11 wells could pass the WHO guideline values of the analyzed parameters. In Kg. Chhnang province, there are two (2) wells out of 10 wells satisfied the guideline values, whereas nine (9) wells out of 20 in Kg. Cham province satisfied the guideline values (Table 4.3.1).

#### **c ) Distribution of Groundwater Quality**

The pH values in the test wells are characterized by more than 7 in Kg. Chhnang province and mostly less than 7 in Kg. Cham province. There are some test wells having 5.6 to 5.85 in pH in Suong and Memot areas in Kg. Cham province. The ORP values in most test wells show positive values, however, negative ORP values ranging from –20 to –60 mV were found from the wells located along the Tonle Sap River and the Mekong River, and from some wells in Suong and Memot areas, indicating the groundwater under reducing conditions. The EC



values in Kg. Chhnang province range from 50 to 100 mS/m. In Kg. Cham province, the EC values range from 4 to 20 mS/m in from the northwestern part to the southeastern part through the central part of the province. The rest of the wells except No.12 and No. 14 wells in Memot and No.30 well in the west have 25 to 50 mS/m in EC, indicating better groundwater quality than Kg. Chhnang province. The maximum value of EC was detected at No. 30 well at a level of 225 mS/m. The higher TDS value more than the WHO guideline value was detected at No. 30 well. The TDS concentrations in Kg. Chhnang province range from 240 to 660 mg/L. In northwestern to southeastern Kg. Cham province has better TDS concentrations ranging from 25 to 200 mg/L. Higher Fe concentrations are found mainly from lowland along the Mekong River and the Tonle Sap River. Fe concentrations along the Mekong River range from 1.9 to 3.6 mg/L. The concentrations along the Tonle Sap River range from 0.4 to 0.7 mg/L. On the other hand, the wells in central to western Kg. Chhnang province and in the northwestern part and the central to eastern parts of Kg. Cham province have less than 0.1 mg/L in Fe concentration (Figure 4.3.3). The Mn concentrations exceed the WHO guideline value in wide areas except southern Kg. Chhnang province and eastern and northwestern Kg. Cham province. The Mn concentrations more than 0.5 mg/L are distributed along the Tonle Sap River and in the upstream area along the Mekong River. Although there is no test well having Na concentration above the WHO guideline value in the study area, it is known in northern Kandal province that the groundwater has higher Na concentrations above the guideline value. In the study area, there are three (3) test wells in Kg. Chhnang province and one (1) well in Kg. Cham province having Na concentrations between 100 and 200 mg/L. No. 30 test well in western Kg. Cham province has Cl concentration of 386 mg/L above the WHO guideline value. No. 8 well in southern Kg. Chhnang province has 170 mg/L. However, the rest of the test wells have less than 50 mg/L.

Arsenic in groundwater exceeds the WHO guideline value at No.10 well (0.098 mg/L) in northern Kg. Chhnang province and at No.23 well (0.027 mg/L) in northern Kg. Cham province along the Mekong River (Figure 4.3.4). Three (3) test wells in northern Kg. Chhnang province have F concentrations ranging from 1.53 to 1.87 mg/L, which exceed the WHO guideline value (Figure 4.3.5). NO<sub>3</sub> values in test well groundwater are lower than 10 mg/L except No. 30 well, which has the level more than the guideline value. There is no test well having NH<sub>4</sub> concentration above the WHO guideline value. Relatively higher NH<sub>4</sub> concentrations ranging from 0.2 to 1.0 mg/L are found at six (6) wells in Kg. Chhnang province and at two (2) wells in Kg. Cham province. No.30 test well in western Kg. Cham has relatively higher value (= 177 mg/L) in SO<sub>4</sub> concentration. However, the rest of the test wells have very low SO<sub>4</sub> concentrations below 20 mg/L.

## 2) Existing Wells

### a ) Major Dissolved Ions

In the dug wells, relatively higher values of the total dissolved ions ranging from 50 to 80 meq/L are found in northeastern Kg. Chhnang province and in the area along the Mekong River in central to western Kg. Cham province. Some wells in the area shows Na–Cl type in groundwater quality. The total amount of major dissolved ions in central to southern Kg. Chhnang ranges from 2 to 10 meq/L. The amount in most of the wells in eastern Kg. Cham province is less than 1 meq/L.

For combined wells, although only three (3) samples from central Kg. Cham province were analyzed, the chemical composition of groundwater varies and the total amount of major ions ranges from 13 to 40 meq/L.

In the borehole wells, most wells have Ca–HCO<sub>3</sub> type of groundwater in Kg. Chhnang province. In Kg. Cham province, more than half of the wells have Mg–HCO<sub>3</sub> type or Ca–HCO<sub>3</sub> type of groundwater. The total amount of major dissolved ions in central Kg. Chhnang province to western Kg. Cham as well as northern Kg. Cham province ranges from 20 to 62 meq/L. The total ions in the rest of Kg. Chhnang province and central Kg. Cham province range from 5 to 15 meq/L. In Memot district, some wells have relatively higher amount of total ions ranging from 4 to 16 meq/L, on the other hand the rest have very small total ions below 1 meq/L (Figure 4.3.6).

#### **b ) Comparison with WHO Guideline Value**

The results of the laboratory test (31 dug wells (DW) and 34 borehole wells(BH)) were compared with the WHO guideline value for drinking water. For Na, there are 3 DW and 2 BH exceeding the guideline value of 200 mg/L. For Fe, there are 9 DW and 19 BH exceeding the guideline value of 0.3 mg/L. For Mn, there are 15 DW and 12 BH exceeding the guideline value of 0.1 mg/L. For As, there are 2 DW and 3 BH exceeding the guideline value of 0.01 mg/L. For Cl, there are 3 DW and 2 BH exceeding the guideline value of 250 mg/L. For NO<sub>3</sub>, there are 3 DW and 1 BH exceeding the guideline value of 50 mg/L. For F, there is no DW and BH exceeding the guideline value of 1.5 mg/L. For NH<sub>4</sub>, there are 4 DW and 2 BH exceeding the guideline value of 1.5 mg/L. For SO<sub>4</sub>, there are 2 DW and 1 BH exceeding the guideline value of 250 mg/L. For TDS, there are 4 DW and 3 BH exceeding the guideline value of 1,000 mg/L. On the other hand, there are 2 DW out of 13 and 3 BH out of 13 in Kg. Chhnang province satisfying all the guideline values of the measured parameters. In Kg. Cham province, 7 DW out of 18 and 5 BH out of 21 satisfied the guideline values (Table 4.3.2).

#### **c ) Distribution of Groundwater Quality**

The pH values in most of the existing dug wells (DW) in the right-bank of the Tonle Sap

River and in the left-bank area of the Mekong River show less than 7 of acidic water. On the other hand, the area between the Tonle Sap River and the Mekong River has alkaline groundwater ranging from 7 to 7.8 in pH. In the existing borehole wells (BH), acidic groundwater having 5.2 to 6.9 in pH occurs in eastern Kg. Cham province, whereas the groundwater in the rest of the areas except two (2) wells in central Kg. Chhnang province show alkaline water with 7 to 7.8 in pH (Figure 4.3.7).

The ORP values in all the DW show more than 0 mV, especially strong acidic water was found in eastern Kg. Cham province with 250 to 500 mV and in central Kg. Chhnang province with 200 to 300 mV. The ORP values of BH in eastern Kg. Cham province range from 250 to 600 mV, showing strong acidic water. However, the groundwater of BH along the Mekong River and in western Kg. Cham province and northern Kg. Chhnang province has 0 to -150 mV in ORP, showing alkaline water.

The EC values of DW in most parts of Kg. Chhnang province and eastern Kg. Cham province have less than 25 mS/m, showing good quality of water. On the other hand, there are wells having more than 100 mS/m in eastern Kg. Chhnang province and central to western Kg. Cham province. In western Kg. Cham, EC values more than 300 mS/m were found. In the BH, smaller values of EC less than 25 mS/m were found in central Kg. Chhnang province and eastern Kg. Cham province. However, EC values ranging from 100 to 300 mS/m were found in northeastern Kg. Chhnang province and western Kg. Cham province (Figure 4.3.8).

The distribution pattern of TDS is similar to that of EC. In DW, the TDS levels exceed the WHO guideline value in the central part of the study area. In BH, higher TDS values more than the WHO guideline values were found from narrower areas in northeastern Kg. Chhnang province and western Kg. Cham province.

The Fe concentrations in DW more than the WHO guideline value are found in northern Memot district, western Kg. Cham province, and northern and central Kg. Chhnang province. The Fe concentrations in BH are generally higher than that in the dug wells in the study area. The area having more than the guideline value is distributed from lowland areas of Kg. Chhnang province to Kg. Cham province except Memot district. Very high Fe levels ranging from 11 to 22 mg/L were found from the wells near the Mekong River (Figure 4.3.9).

The Mn concentrations in DW and BH show a similar distribution pattern. The Mn values exceeding the WHO guideline values are found in eastern and central to western Kg. Cham province and in northern Kg. Chhnang province. The higher Mn levels more than 0.5 mg/L are found in a wide area in the central part of the study area.

The Cl concentrations of both DW and BH are higher than the WHO guideline value in western Kg. Cham province. The area of Cl contaminations in DW is larger than that in BH, and the Cl levels in DW are higher than BH.

The patterns of Na distribution are similar to that of Cl distribution. The Na levels exceed the guideline value in northeastern Kg. Chhnang province and western Kg. Cham province. The

area having more than the guideline value is larger in DW.

The As levels in DW more than 0.01 mg/L are found along the Mekong River in southern Kg. Cham province. In BH, the As levels more than the WHO guideline values are found in northwestern and central Kg. Chhnang province and northern Kg. Cham province.

There is no well having more than the WHO guideline value of F (=1.5 mg/L) in D and BH in the study area. But the F levels in DW are higher than BH. In western Kg. Cham province, some BH has 1.2 to 1.4 mg/L in F concentration.

There are limited wells having NO<sub>3</sub> concentrations above the WHO guideline value in DW and BH. However, the concentrations are higher in DW. The areas having the concentrations above 10 mg/L are widely distributed from the central area to the northeast and the northwest in the study area. In BH, the NO<sub>3</sub> concentrations above 10 mg/L are distributed in western Kg. Cham. In the rest of the area, the higher values are sporadically distributed.

The DW having NH<sub>4</sub> concentrations more than the WHO guideline value are found in northern Kg. Chhnang province, western Kg. Cham province and Memot district. In BH, the levels more than the guideline value are found along the Mekong River in Kg. Cham province.

The SO<sub>4</sub> concentrations in DW exceed the WHO guideline value in central and western Kg. Cham province. The levels higher than 50 mg/L are found in northeastern Kg. Chhnang province to western to central Kg. Cham province. In BH, there is a well having 710 mg/L in SO<sub>4</sub> in northeastern Kg. Chhnang. However, the rest have SO<sub>4</sub> levels within the guideline value even there are some wells having more than the guideline value of SO<sub>4</sub> in Kandal province. The area having more than 50 mg/L is also limited in the study area.

### **(3) Results of Field Measurement**

#### **1) Simultaneous Observation**

The followings are the results of the 4 times of simultaneous groundwater observation.

##### **a ) pH**

It is common in the dug wells (DW) that the eastern Kg. Cham province and most parts in Kg. Chhnang province have pH values less than 7, whereas the central part of the study area has alkaline groundwater. However, the areas of alkaline water and pH values changed over time. In February 2001, the areas having pH values more than 7 were distributed widely from central to western Kg. Cham province. In May 2001, the pH values decreased and the area of alkaline groundwater became smaller. In August 2001, the areas having pH values more than 7 were expanded and the pH values in the area less than 7 in pH slightly increased. In November 2001, the areas more than 7 in pH decreased in central to western Kg. Cham province, however, the areas more than 7 in northeastern Kg. Chhnang province was

expanded.

The pH values in the borehole wells (BH) show less than 7 in eastern Kg. Cham province throughout the simultaneous observation period, however, there are changes in the location of pH=7 contour line and pH values in central Kg. Cham province to Kg. Chhnang province. In February 2001, the area having relatively higher values of pH was widely distributed in the central part of the stud area. In May 2001, the pH values generally decreased and the areas having pH<7 were expanded in western Kg. Cham province and in Kg. Chhnang province. In August 2001, the areas having pH>7 further decreased and the pH values in the area of pH<7 decreased in Kg. Chhnang province. In November 2001, the areas of pH>7 was slightly expanded and the increase of pH values was observed.

#### b ) ORP

In DW, although the ORP values were generally higher in February 2001 with showing more than 200 mV in many places, the values in May 2001 decreased in the whole study area and the values became less than 200 mV except eastern Kg. Cham province. The distribution pattern of ORP values in August 2001 is similar to that of May 2001, however, increase of ORP values was observed in Memot district and he values were decreased in the areas along the Mekong River and the Tonle Sap river. In November 2001, the area of ORP<100 mV appeared in the central part of the study area and the negative values of OPR were found in some wells in western Kg. Cham province and northern Kg. Chhnang province.

In BH, negative values of ORP were found in some areas along the Mekong River and the Tonle Sap River in February 2001. In May 2001, almost all the ORP values in the study area were decreased and the areas of ORP<0 mV were increased. In August 2001, the ORP values slightly increased and the areas of ORP>100 mV were expanded in western Kg. Cham province. The increase of ORP values were also observed in Memot district. In November 2001, the ORP values in Memot district were decreased, and the slight decrease of the value were also observed in the central part of the study area.

#### c ) EC

In DW, there is no significant change in EC distribution pattern and EC values in Kg. Cham province, but there are some changes in EC values in northern Kg. Chhnang province. In the northwestern part of the province, increase of EC values was observed in some wells. The increase of EC values was also observed in northern Kg. Chhnang from August to November 2001.

In BH, The distribution pattern of EC remained almost the same through the simultaneous observation period. More than 150 mS/m of EC values are always found in northeastern Kg. Chhnang province and western Kg. Cham province.

d ) F

In DW, significant changes in F distribution and F values were not found by the simultaneous observation. The higher values of F more than 1.5 mg/L were found in northern and southern Kg. Chhnang province and western Kg. Cham province.

Similarly in BH, significant changes in F distribution and F values were not found by the simultaneous observation. The higher values of F more than 1.5 mg/L were found in northern and southern Kg. Chhnang province and western and central Kg. Cham province along the Mekong River.

e ) NO<sub>3</sub>

In DW, there is no significant seasonal change in NO<sub>3</sub> concentrations and their distributions by the simultaneous observation. There is no well having NO<sub>3</sub> concentration more than the WHO guideline value by the pack test measurement. Relatively higher values more than 10 mg/L were found sporadically in eastern to central and western Kg. Cham province and northern and southern Kg. Cham province.

In BH, F concentrations increased from February to August 2001, but the concentrations decreased in November 2001 in southern Kg. Chhnang province. In the rest of the area, there was no significant seasonal change in NO<sub>3</sub> concentrations and their distributions by the simultaneous observation. There is no well having NO<sub>3</sub> concentration more than the WHO guideline value by the pack test measurement. Relatively higher values more than 10 mg/L were found sporadically in western Kg. Cham province and northern and southern Kg. Cham province. The NO<sub>3</sub> concentrations in eastern Kg. Cham province in borehole wells are lower than that of dug wells.

f ) NH<sub>4</sub>

In DW, there are a few wells in central Kg. Cham and central Kg. Chhnang provinces having NH<sub>4</sub> concentrations more than the WHO guideline value by the pack test measurement. In central Kg. Chhnang province, there was an area having NH<sub>4</sub>>0.5 mg/L in February 2001, but the area disappeared from May 2001. Except this, there was no significant change in NH<sub>4</sub> distribution.

In BH, relatively higher values of NH<sub>4</sub> were detected in some wells in Kg. Chhnang province in February 2001, however, the values decreased from May 2001. In southern Kg. Cham province along the Mekong River, NH<sub>4</sub> concentrations in a few wells show a increasing trend from February to November 2001. In November 2001, three (3) borehole wells in northern Kg. Cham province along the Mekong River had NH<sub>4</sub> concentrations ranging from 2 to 5 mg/L. Except these events, there is no significant variations in NH<sub>4</sub> distribution.

g ) Fe

In DW, the Fe concentrations tended to increase along the Tonle Sap River in Kg. Chhnang province from the period from February to May 2001. Except this, there is no significant change in Fe concentrations. The areas having Fe concentrations above the WHO guideline value are sporadically distributed in the study area.

In BH, the distribution patterns of Fe concentrations are almost the same throughout the simultaneous observations. Along the Mekong River, a zone of higher Fe concentrations was well traced in May and November 2001 because a number of wells near the river could be measured without the flooding. In the rest of the study area, elevated Fe concentrations above the WHO guideline value were found in eastern and western Kg. Cham province and in the area along the Tonle Sap River in Kg. Chhnang province.

#### h ) As

From DW, As concentrations more than 0.05 mg/L were not found throughout the simultaneous observation. There are some wells having As concentration ranging from 0.001 to 0.01 mg/L by the field kit, however, it should be considered that the values are almost below the detection level of the field kit. In the dug wells, there is only one suspect well of actual As contamination, which is located in northwestern Kg. Chhnang province with As level of 0.02 mg/L by field kit.

In BH, the As levels more than 0.05 mg/L were detected in northern Kg. Chhnang province and central to northern Kg. Cham province along the Mekong River. The results of the observations in May and November 2001 show that the highly contaminated zone by As is located along the Mekong River.

## 2) Periodic Observation

Based on the results of the periodic groundwater observation, changes of each groundwater quality parameter are mentioned below.

#### a ) pH

In DW, the pH values at some wells in Kg. Chhnang province and in northwestern Kg. Cham province show a slight increasing trend of pH values from August 2001. The pH values in Suong and Memot areas in Kg. Cham province were fluctuated within a certain range

BH in Kg. Chhnang province and in northwestern Kg. Cham province shows a slight increasing trend of pH values from August 2001.

#### b ) ORP

In DW, although some wells show irregular fluctuations of ORP values over time, the ORP values in Kg. Chhnang province and northwestern Kg. Cham province decreased from January to April 2001. These ORP values once rose in June but again decreased gradually

from July to December 2001. The ORP values Suong and Memot areas also show a decreasing trend of ORP values from January to December 2001.

In BH, the changes in ORP values show a wider range of irregular fluctuations over time. However, the wells in Kg. Chhnang province and in the northwestern part and Memot of Kg. Cham province area have a decreasing trend of ORP values.

#### c ) EC

In DW, the EC values having relatively lower values of EC in Kg. Chhnang province tend to increase slightly from May to December 2001. On the other hand, the EC values in the wells having relatively higher values of EC fluctuated within a certain range. In northwest Kg. Cham province, the changes in EC values are small in the wells with relatively smaller EC values, but the greater EC values irregularly fluctuated over time. In Suong area, the EC values in the wells having smaller values of EC tend to decrease from January to June 2001 then increase from August. In the wells having greater values of EC, one well has a gradual decrease of EC values over time, whereas another has decrease of EC values from January to October 2001 then sharp increase of EC values. In Memot area, the EC values are generally lower than 15 mS/m. Most of the wells have a slight decreasing trend of EC values from February to July 2001 then show a clear increasing trend from August.

In BH, R189G well in Kg. Chhnang province shows higher EC values in the rainy season. But the rest of the wells show that the EC values fluctuated within a limited range of variation. In northwestern Kg. Cham province, the EC values have slight increasing trend over time. The EC values at R321M well in Suong area clearly decreased over time.

#### d ) Fe

In DW, significant changing trend of Fe concentrations cannot be found from the results considering the accuracy of the pack test measurement.

In BH, the range of variation in Fe concentrations is greater when the wells have relatively greater concentrations of Fe. However, some of the wells show irregular patterns of fluctuation. There are three (3) wells having higher Fe concentrations in May to July 2001. In northwestern Kg. Cham province, some wells have increasing trend of Fe levels coinciding the changes in groundwater levels.

#### e ) F

In DW, significant changing trend of F concentrations cannot be found from the results considering the accuracy of the pack test measurement.

In BH, there is one (1) well in Kg. Chhnang province having an increasing of F concentrations. In the rest, there is no significant change of F concentrations over time considering the accuracy of the pack test.



#### f ) NO<sub>3</sub>

In DW, some wells in northwestern Kg. Cham province seem to have a decreasing trend of NO<sub>3</sub> concentrations from July to September 2001. However, considering the accuracy of the pack test measurement, significant changing trend of NO<sub>3</sub> concentrations cannot be found in other areas.

In BH, some wells in northwestern Kg. Cham province tend to increase the NO<sub>3</sub> concentrations from June to September 2001. However, there is no significant change of NO<sub>3</sub> concentrations over time considering the accuracy of the pack test.

#### g ) NH<sub>4</sub>

In DW, although the NH<sub>4</sub> levels in the wells having greater NH<sub>4</sub> values fluctuated with a wide range, there is no clear correlation with the seasonal change. Some wells have higher concentrations in the rainy season but the other has higher values in the dry season.

In BH, the NH<sub>4</sub> concentrations in the borehole wells are generally low so that any significant changing trends of the concentrations cannot be found.

#### h ) As

In DW, there is no significant trend in changes of arsenic levels considering the accuracy and detection limit of As by the filed kit.

In BH, R197G borehole well has increasing trend of As level with oscillation. By March 2001 the As level was below 0.05 mg/L, however, it went up from April and reached 0.2 mg/L in August, September and December 2001. In other wells, no significant trends in As level changes were found considering the field kit limitations.

### **3) JICA Test Well Monitoring**

Based on the results of the groundwater monitoring of the JICA test wells, changes of each groundwater quality parameter were examined.

The pH values in most test wells show a decreasing trend. Particularly the decreasing trend is clear in Suong and Memot areas in Kg. Cham province from August to October 2001. Very high ORP values were found at some wells in September. This is due to the disinfection of the wells by bleaching powder. Except this event, most test wells show decreasing trends of ORP values. About a half of the test wells show increasing trends of EC levels. However, slight drops of EC values were observed in some wells in Kg. Cham province. Fe concentrations at No.23 well in northwestern Kg. Cham province show a decreasing trend. The concentration decreased from 8 mg/L in August to 4 mg/L in December 2001. On the other hand, No.20 test well in Memot area shows an increasing trend of Fe level. No. 23 well and No. 27 well have a

peak of Fe concentration in October 2001. No.4 well in Kg. Chhnang province has an increasing trend of F concentration, starting from 1.5 mg/L in August and reaching 4.5 mg/L in December 2001. The rest of the wells do not show any significant trends in changes of F concentrations. The NO<sub>3</sub> concentrations in No.10 and No.11 wells show a wide range of variations with irregular fluctuations. No.30 test well has more than 50 mg/L in NO<sub>3</sub> concentration from September to December 2001. The NH<sub>4</sub> concentration in No.23 well increased from 0.1 mg/L in July 2001 to 2.0 mg/L in December 2001. The rest of the tests well have NH<sub>4</sub> concentrations below 0.2 mg/L with no significant changing trends. The As concentration of No.10 well in Kg. Chhnang province exceeded 0.05 mg/L in September and December 2001. In No.23 well in Kg. Cham province, 0.3 mg/L of As concentration was detected in November 2001.

#### **4) Coliform and Bacteria**

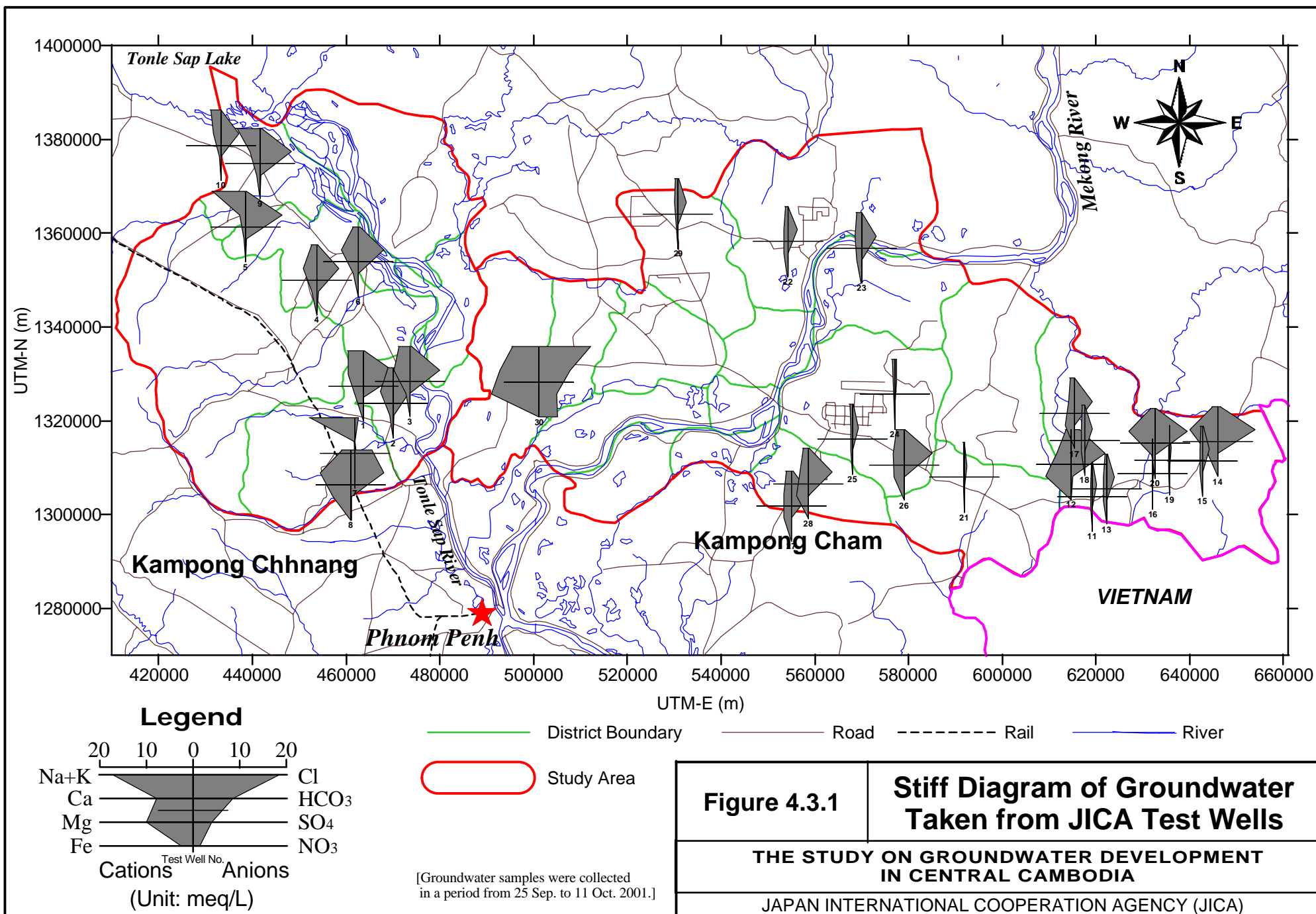
##### **a ) Existing Wells**

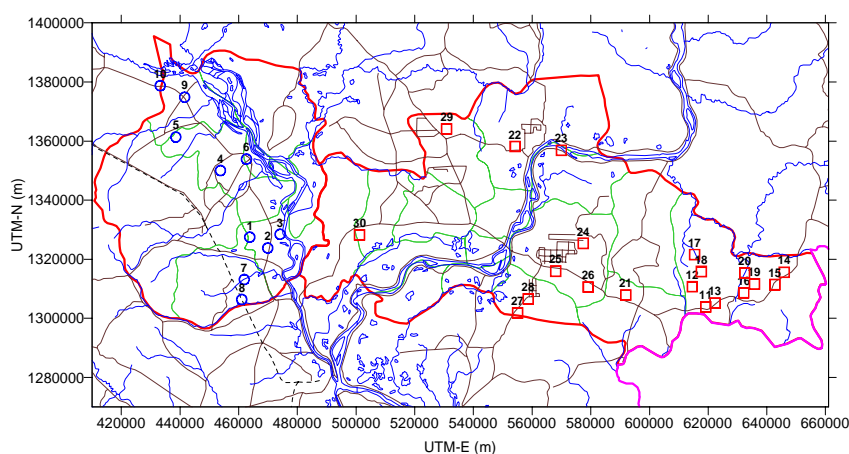
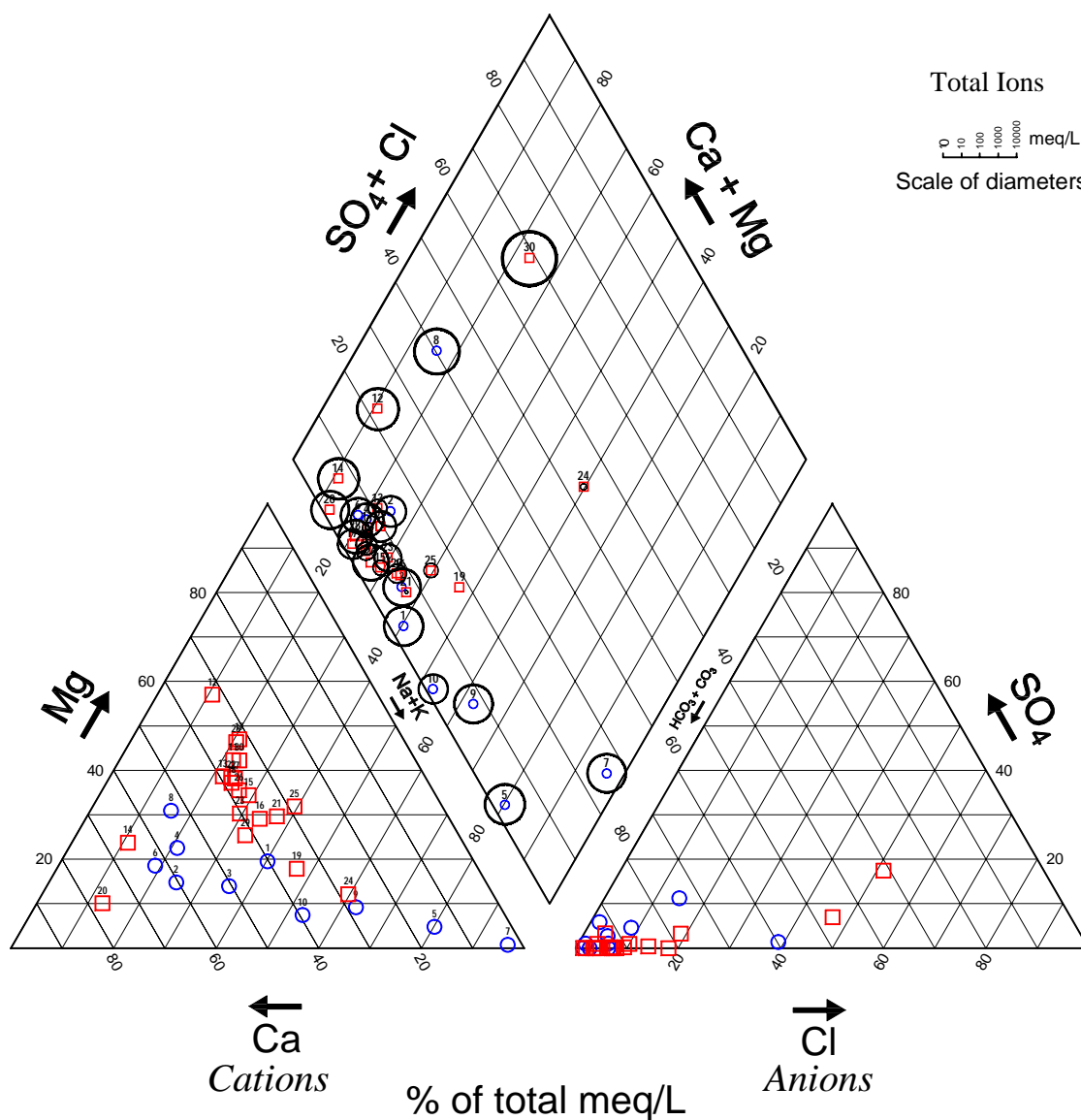
Almost all the dug wells and combined wells were polluted by coliform and bacteria. On the other hand, borehole wells were polluted from 23% to 85% by bacteria in Kg. Chhnang province, and were polluted from 19% to 50% by coliform. In Kg. Cham province, borehole wells were polluted from 40% to 88% by bacteria and from 15% to 46% by coliform. Pollution levels of existing wells on the 3rd simultaneous observations are lower than the 1st and 2nd simultaneous observations.

##### **b ) JICA Test Wells**

In October 2001, coliform and bacteria contamination was found at No.8 well in Kg. Chhnang province. In Kg. Cham province, No.11 and No.18 wells were contaminated by bacteria. Moderate contamination by coliform and bacteria was found at No. 5 well in Kg. Chhnang province. In November 2001, moderate contamination by coliform and bacteria was found at No.2 well in Kg. Chhnang province. In December 2001, only slight contamination by coliform and bacteria was found at five (5) wells. However, the filtered sample at No.6 well was contaminated by bacteria and coliform. Moderate contamination by bacteria was also found from the filtered samples No.23 and No.30 wells in Kg. Cham province.

References: WHO (1996): Guidelines for drinking-water quality, 2nd edition. Volume 2, Health criteria and other supporting information, WHO, Geneva.





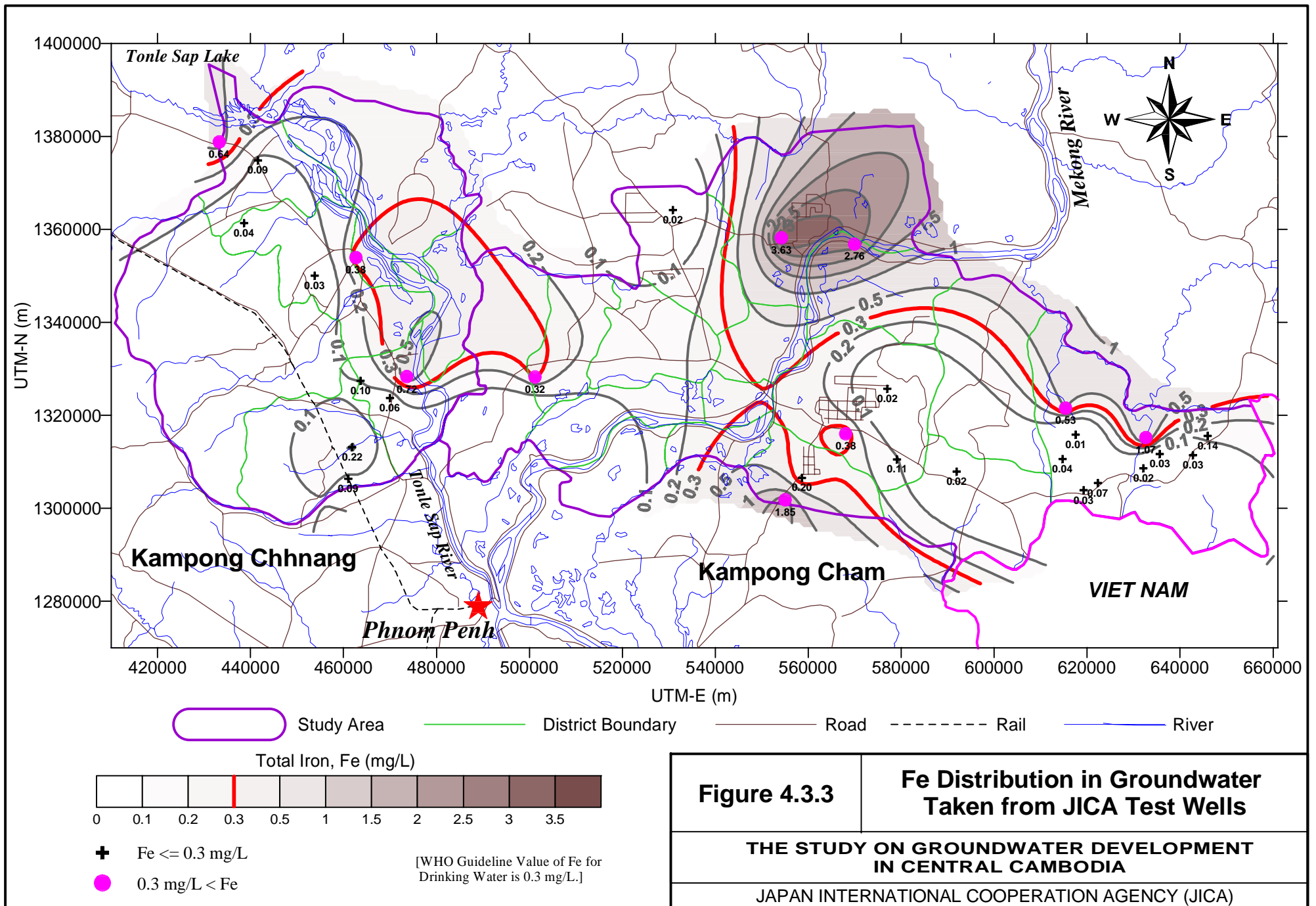
- 1  
○ JICA Test Well  
in Kampong Chhnang
- 11  
□ JICA Test Well  
in Kampong Cham
- (Number indicates JICA Test Well Number.)

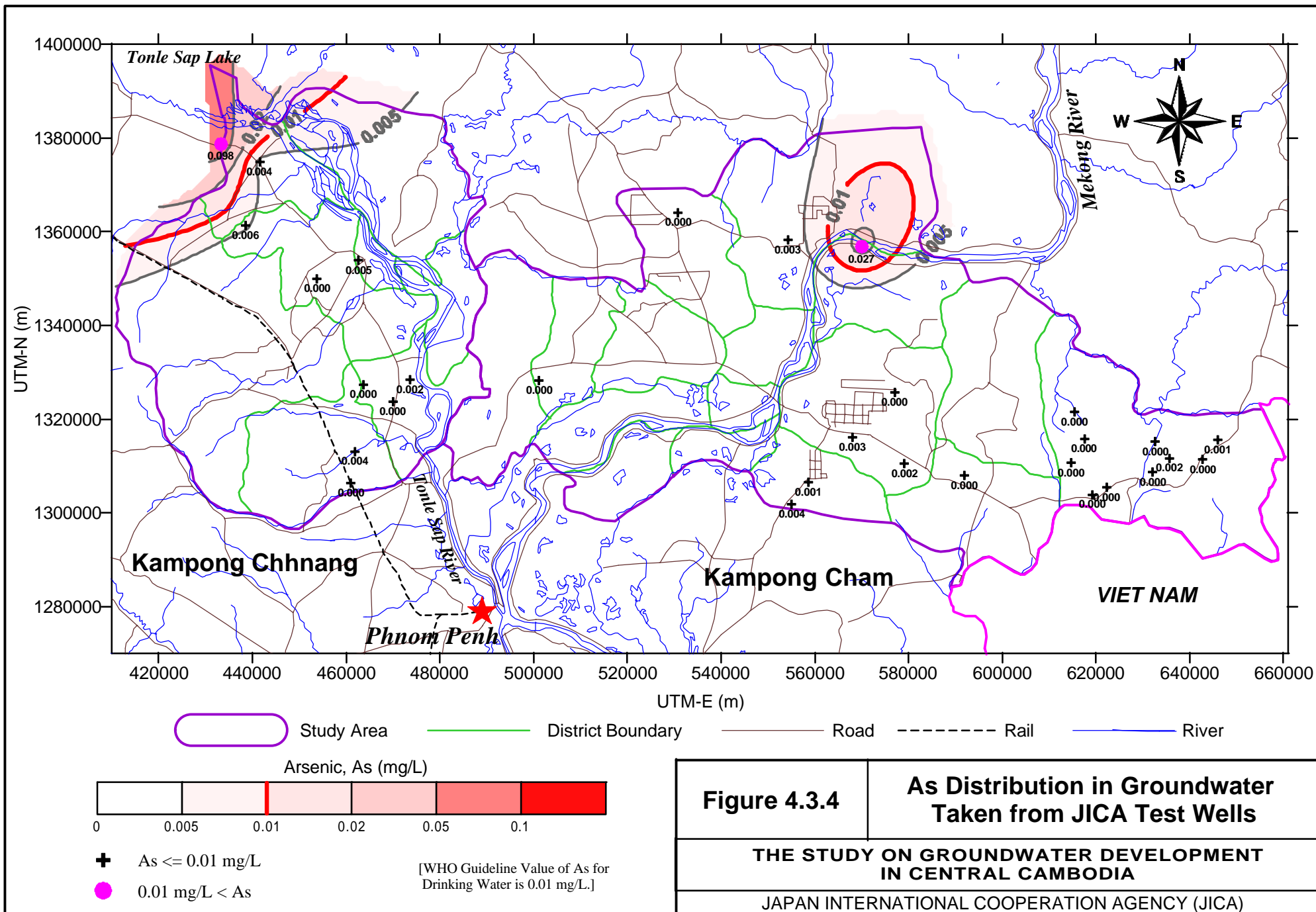
**Figure 4.3.2**

## Trilinear Diagram of Groundwater at JICA Test Wells

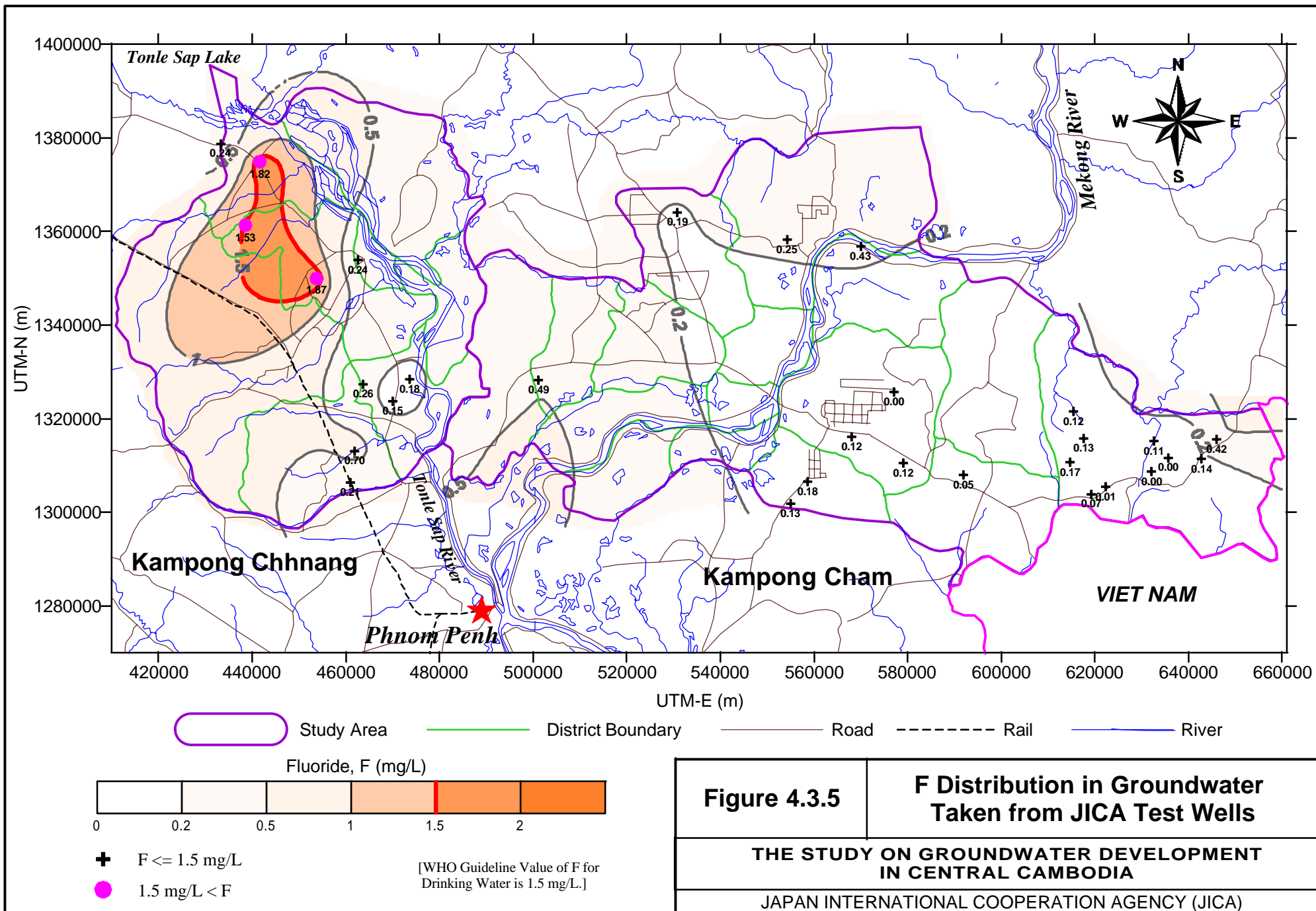
**THE STUDY ON GROUNDWATER DEVELOPMENT  
IN CENTRAL CAMBODIA**

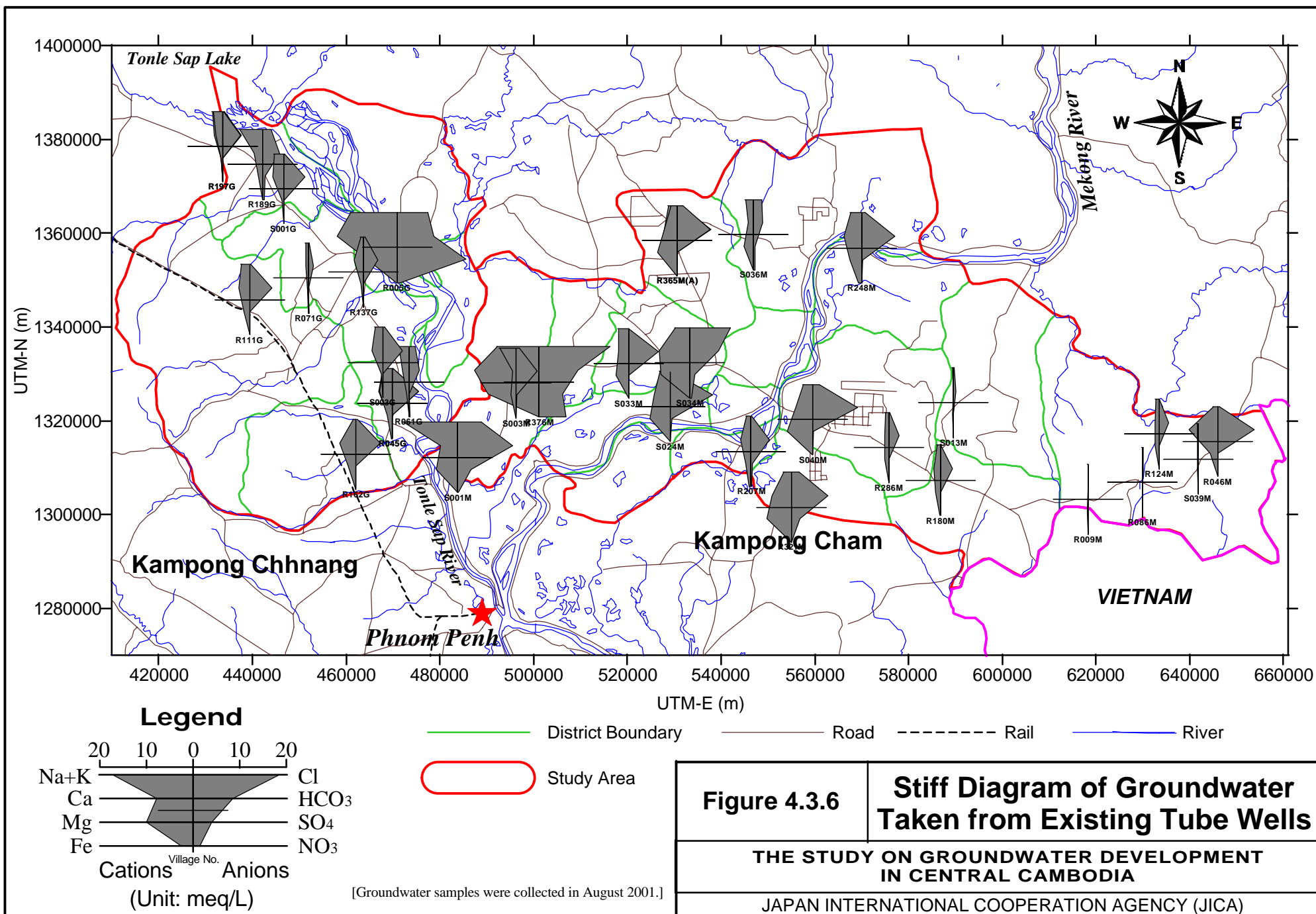
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



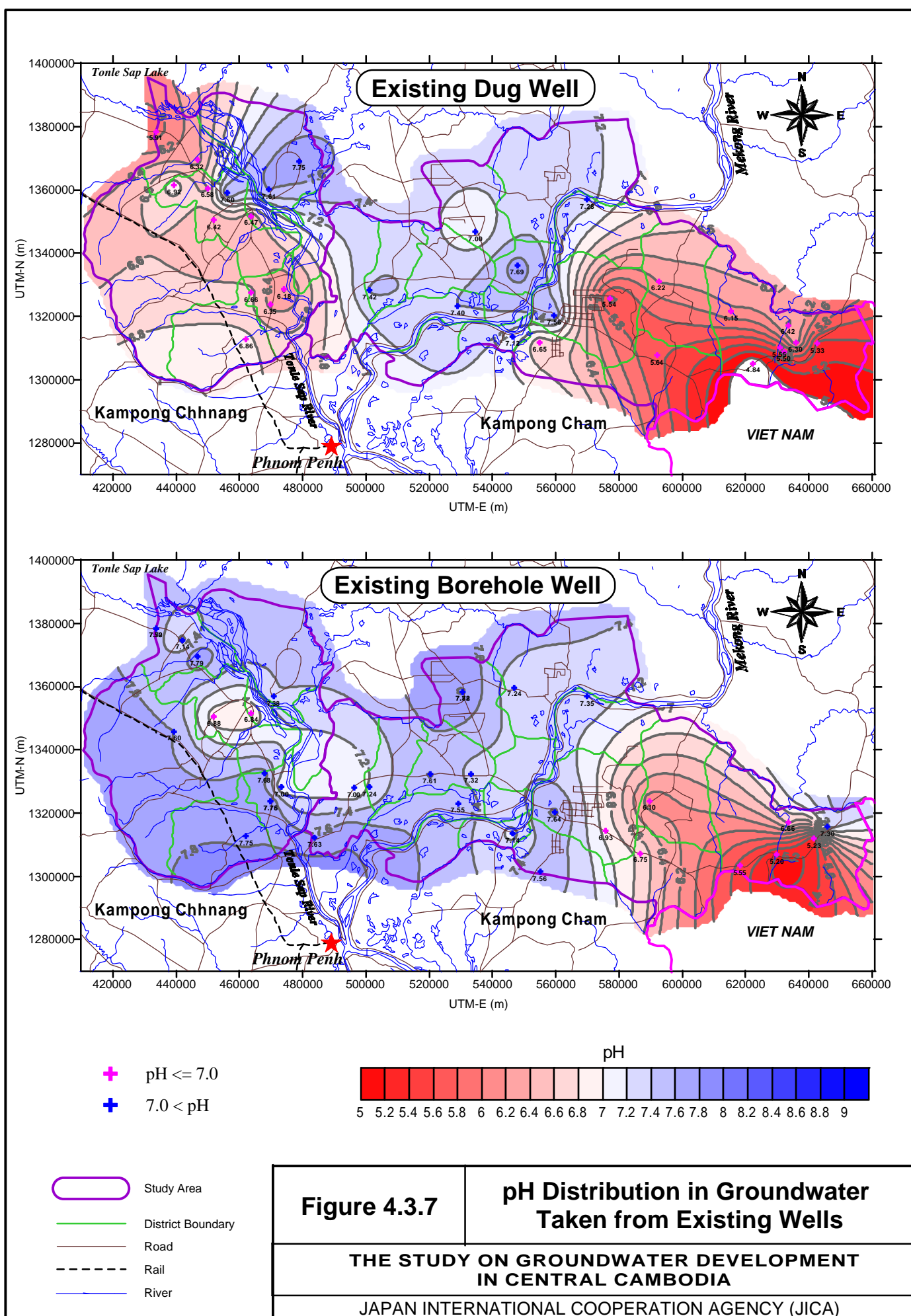


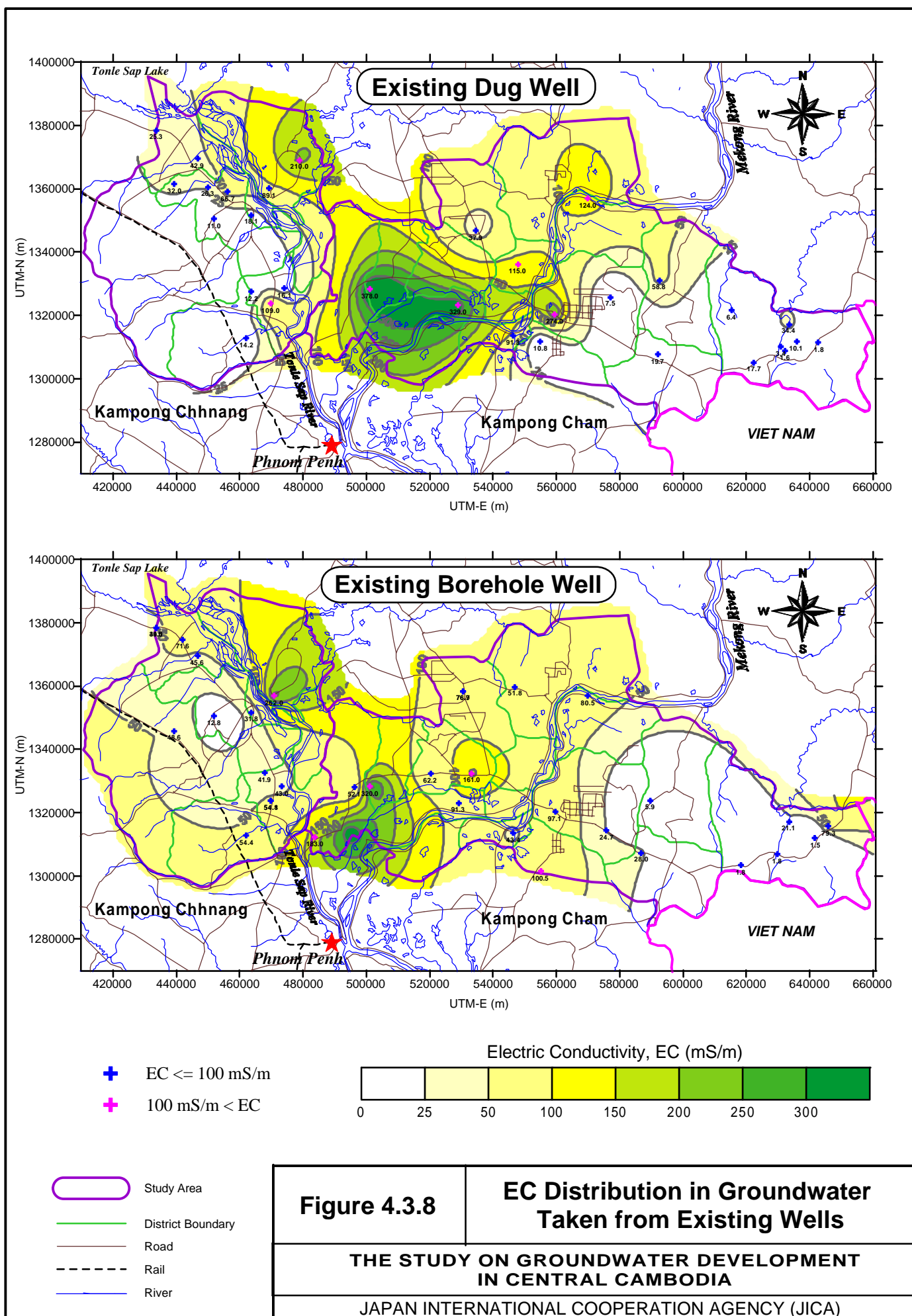












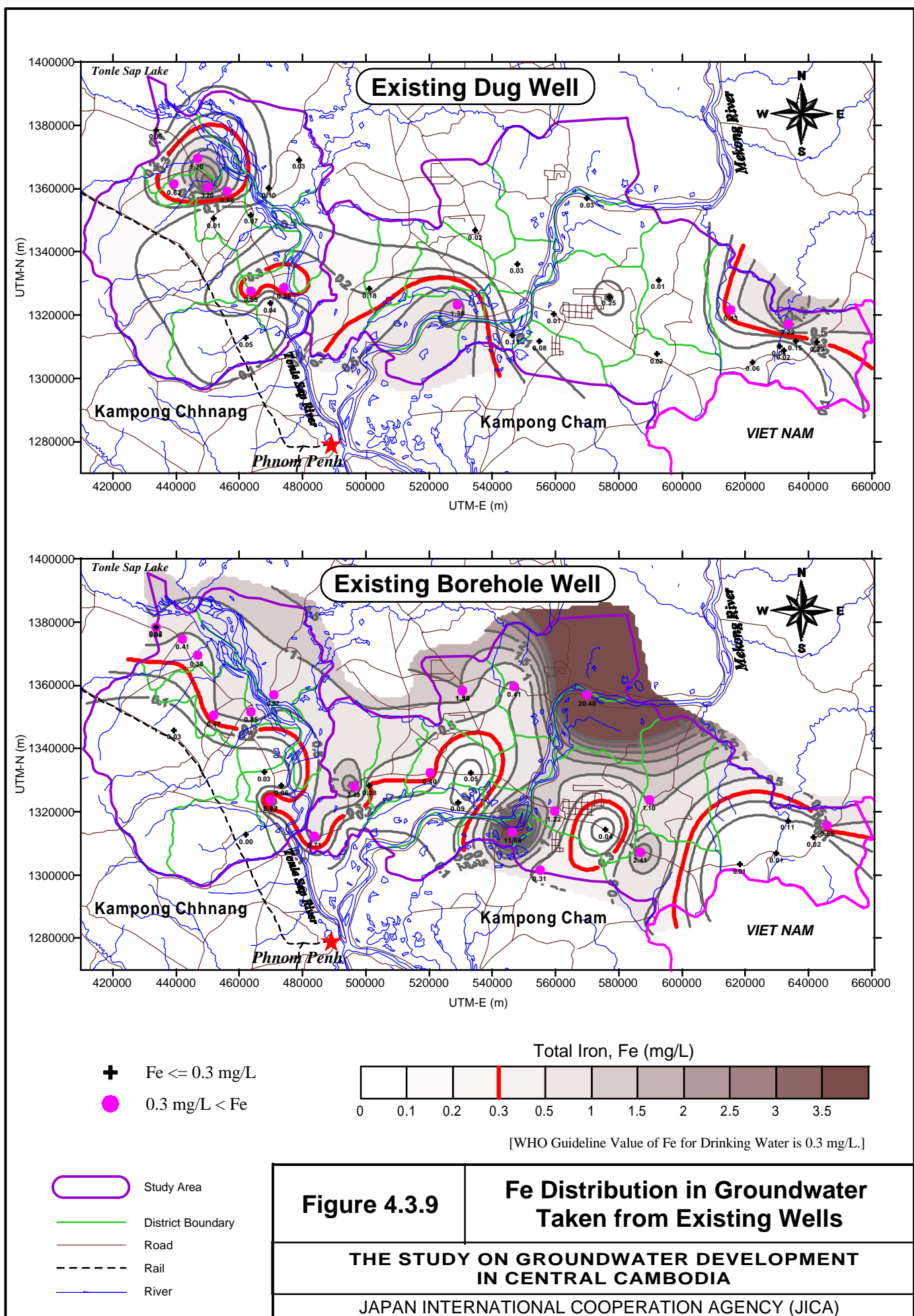




Figure 4.3.1 (1/2) Results of Laboratory Chemical Analysis of Groundwater Taken from JICA Test Wells

												WHO Guideline Value for Drinking Water (mg/L)																								
												300		0.5		0.1		1.5		0.01				250		250		50		1.5				1000		
Well No.	Test No.	Lat No.	Wdgt No.	Sample Type	Sampling Date	Water Temp (°C)	pH	EC (µS/cm)	Ca (mg/L)	Mg (mg/L)	Sulfate (SO <sub>4</sub> ) (mg/L)	Nitrate (NO <sub>3</sub> ) (mg/L)	Total Iron (Fe) (mg/L)	Manganese (Mn) (mg/L)	Arsenic (As) (mg/L)	Zinc (Zn) (mg/L)	Copper (Cu) (mg/L)	Fluoride (F) (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Apparent color at 10m						
1	1	44844	0010	Flow water	25-Sep-01	30.4	7.8	74.3	65.26	18.25	35.57	2.30	0.04	0.75	0.00	0	0.0	457.64	14	1.31	0.00	0.00	35.57	242.0	0	327	Insoluble matter									
2	1	45005	0201	Flow water	13-Dec-04	28.7	7.48	48.3	62.40	18.32	38.30	2.30	0.12	0.20	0.20	0	0.0	421.24	24	0.32	0.00	0.21	24.20	228.0	0	608	Clear									
3	2	44946	0010	Flow water	25-Sep-01	30.8	7.69	45.0	53.44	1.94	24.43	1.30	0.05	0.44	0.05	0	0.0	228.52	8	15.05	0.50	0.33	31.84	198.0	0	258	Insoluble matter									
4	2	45040	0010	Flow water	13-Dec-04	30.4	7.24	37.8	47.70	1.30	24.83	0.00	0.06	0.75	0.00	0	0.0	227.81	14	7.52	4.54	0.00	33.84	148.0	0	222	Small amount of insoluble matter									
5	2	44947	0010	Flow water	25-Sep-01	28.8	7.88	43.8	10.80	11.70	32.80	4.80	0.12	1.80	0.21	0.00	0.0	280.00	12	14.24	2.25	0.23	40.30	272.0	0	284	Small amount of precipitated iron									
6	4	44946	0010	Flow water	28-Sep-01	28.7	7.61	35.2	58.20	14.30	24.83	1.10	0.00	0.05	0.00	0	0.0	281.71	19	0.14	15.88	0.00	33.44	208.0	0	314	Small amount of insoluble matter									
7	3	44846	0010	Flow water	28-Sep-01	30.8	7.88	74.8	28.56	9.10	108.00	8.60	0.06	1.80	0.18	0.00	0.0	470.83	10	0.94	0.07	0.00	36.14	314.0	0	674	Small amount of insoluble matter									
8	8	44930	0010	Flow water	28-Sep-01	30.2	7.88	58.2	12.36	12.11	24.83	1.10	0.06	0.75	0.00	0.00	0.0	220.84	12	13.00	0.00	0.23	41.84	228.0	0	321	Small amount of insoluble matter									
9	1	44930	1010	Flow water	25-Sep-01	30.0	7.10	11.38	140.0	5.60	0.80	0.10	0.00	0.00	0.00	0.00	0.00	118.0	0	25.71	28.81	0.01	32.34	114.0	0	364	Small amount of insoluble matter									
10	1	45002	1010	Flow water	13-Dec-04	29.8	7.10	84.3	8.80	0.91	108.84	2.30	0.27	0.04	0.40	0.00	0.00	38.8	421.42	0	16.27	1.04	0.10	10.00	28.0	0	318	Small amount of insoluble matter								
11	8	44930	1010	Flow water	25-Sep-01	28.4	7.50	122.0	130.40	40.84	42.30	2.50	0.07	0.00	0.00	0.00	0.00	425.52	19	180.37	7.32	11.00	42.30	214.0	100.20	403	Small amount of insoluble matter									
12	8	45004	1010	Flow water	13-Dec-04	28.8	7.28	100.0	132.00	51.10	37.40	2.50	0.00	0.00	0.00	0	0.0	429.48	30	170.48	4.00	0.94	44.30	240.0	180	582	Clear									
13	8	44940	1010	Flow water	28-Sep-01	28.7	7.88	72.8	12.32	8.81	108.80	7.10	0.00	0.04	0.02	0.00	0.00	412.33	14	12.84	0.07	0.17	32.00	144.0	0	408	Small amount of insoluble matter									
14	10	44940	1010	Flow water	28-Sep-01	28.8	7.30	40.0	20.80	0.80	47.80	1.30	0.10	0.04	0.00	0.00	0.00	222.40	1	1.30	0.00	0.14	40.54	34.0	0	252	Small amount of insoluble matter									
15	10	45000	1010	Flow water	14-Dec-04	28.7	7.34	64.4	38.50	8.00	51.80	2.50	0.04	0.14	1.00	0.00	0.0	283.80	10	0.54	0.00	0.04	40.80	110.0	0	284	Small amount of insoluble matter									
16	10	45000	1010	Flow water	14-Dec-04	28.2	7.30	30.3	34.40	4.80	42.80	4.50	0.14	0.01	0.42	0.00	0.0	224.80	11	11.80	0.00	0.20	44.80	108.0	0	327	Clear									
17	11	44930	0010	Flow water	03-Oct-01	28.3	7.20	14.0	7.84	5.80	4.80	1.30	0.00	0.04	0.00	0	0.0	212.3	49	2.37	0.00	0.00	40.12	40.0	0	89	Clear									
18	12	44940	0010	Flow water	10-Oct-01	28.8	7.10	30.1	68.80	40.20	37.30	0.00	0.00	0.00	0.00	0	0.0	490.00	14	47.84	14.84	0.23	40.80	870.0	10.14	300	Clear									
19	13	44940	0010	Flow water	03-Oct-01	28.2	7.00	10.0	14.80	8.80	8.51	1.30	0.00	0.00	0.00	0	0.0	36.33	24	8.23	0.18	1.80	30.37	70.0	0	120	Small amount of precipitated iron									
20	14	44944	0010	Flow water	03-Oct-01	28.8	7.32	35.8	118.20	36.10	32.50	0.50	0.14	0.00	0.05	0.00	0.00	480.55	24	80.17	0.18	0.00	37.84	400.0	3.08	468	Clear									

Figure 4.3.1 (2/2) Results of Laboratory Chemical Analysis of Groundwater Taken from JICA Test Wells

												WHO Guideline Value for Drinking Water (mg/L)																							
												200		3.0		10		1.5		0.01				250		250		30		1.5				1000	
Well No.	Test Well No.	Lab No.	Volum No.	Sample Type	Sampling date	Water Temp (°C)	ORP (mV)	pH	DO	Calcium (Ca)	Magnesium (Mg)	Chloride (Cl)	Perchlorate (ClO <sub>4</sub> )	Total Iron (Fe)	Manganese (Mn)	Arsenic (As)	Nitrate (NO <sub>3</sub> )	Acetate (CH <sub>3</sub> CO <sub>2</sub> )	Fluoride (F)	Dissolved phosphate (PO <sub>4</sub> )	Sulfate (SO <sub>4</sub> )	Chloride (Cl)	Sulfate (SO <sub>4</sub> )	Nitrate (NO <sub>3</sub> )	Fluoride (F)	Chloride (Cl)	Sulfate (SO <sub>4</sub> )	Hardness as CaCO <sub>3</sub>	Permanganate Hardness as CaCO <sub>3</sub>	Total Dissolved Solids (TDS)	Appearance of water at this analysis				
21	15	44955	000M	Flow water	03-Oct-01	28.8	172	8.83	14.5	18.22	8.14	1.82	0.49	0.00	0.00	0.00	0	0.0	20.17	34	2.23	0.00	0.00	0.04	32.89	32.0	0	143	Clear						
22	16	44956	000M	Flow water	04-Oct-01	28.4	226	9.88	3.0	2.24	1.27	2.39	0.19	0.00	0.00	0.00	0	0.0	15.78	49	0.19	0.00	0.00	0.00	9.49	16.0	0	24	Clear						
23	17	44957	020M	Flow water	04-Oct-01	28.2	88	7.28	26.1	24.24	22.36	11.34	4.73	0.53	0.28	0.00	0	0.0	22.46	24	2.17	0.00	0.00	0.12	24.24	180.8	0	214	Clear						
24	18	44958	010M	Flow water	04-Oct-01	21.5	524	8.18	18.8	14.24	8.80	8.51	2.03	0.01	0.00	0.00	0	0.0	18.44	28	2.23	0.00	0.00	0.13	30.66	70.0	0	158	Clear						
25	19	44959	110M	Flow water	04-Oct-01	26.1	210	9.88	3.0	2.88	0.80	5.94	0.83	0.00	0.00	0.00	0.000	0.0	18.53	14	2.37	0.00	1.27	0.00	14.85	16.0	0	38	Clear						
26	20	44961	120M	Flow water	04-Oct-01	27.8	-40	7.27	87.8	112.30	9.80	25.88	1.80	1.37	0.20	0.03	0	0.0	41.84	29	2.28	0.18	0.00	0.11	24.45	218.8	0	288	Insoluble matter						
27	21	44960	170M	Flow water	28-Aug-01	26.3	287	8.00	8.5	4.18	2.80	2.70	4.10	0.00	0.00	0.00	0	0.0	34.82	59	2.27	0.00	0.00	0.18	44.88	22.0	0	19	Clear						
28	21	44958	170M	Flow water	02-Oct-01	26.5	288	8.18	8.5	4.18	2.24	2.96	2.84	0.00	0.00	0.00	0	0.0	36.46	37	1.88	0.00	0.00	0.06	31.44	18.8	0	14	Clear						
29	22	44970	214M	Flow water	22-Sep-01	26.3	-2	8.83	22.8	18.36	10.42	9.84	4.20	0.84	0.47	0.00	0.000	0.0	122.14	28	2.17	0.27	0.00	0.25	12.24	18.2	0	182	Insoluble matter						
30	23	44954	140M	Flow water	28-Sep-01	26.4	-31	8.84	35.5	18.18	15.86	21.59	2.39	0.84	1.84	0.00	0.000	0.0	181.55	34	4.35	5.38	0.00	0.47	54.34	112.2	0	227	Small amount of precipitated iron						
31	23	45007	140M	Flow water	19-Dec-03	26.8	-38	8.88	34.1	18.40	12.18	22.27	2.94	0.74	1.84	0.84	0.007	0.0	191.04	64	5.18	5.24	0.28	0.43	86.84	118.8	0	231	Small amount of precipitated iron						
32	23	45008	140M	Filtered water	19-Dec-03	26.7	23	9.88	34.2	18.40	12.84	22.20	2.80	0.27	1.80	0.80	0.004	0.0	180.87	44	5.14	2.24	2.14	0.41	46.24	122.0	0	229	Small amount of insoluble matter						
33	24	44972	184M	Flow water	07-Oct-01	26.3	0.88	8.85	9.1	4.48	1.17	1.50	8.80	0.00	0.17	0.00	0	0.0	21.87	49	12.84	2.54	0.00	0.00	36.89	18.8	0	50	Small amount of insoluble matter						
34	25	44973	180M	Flow water	08-Oct-01	26.7	0.28	8.43	11.1	8.08	8.20	11.04	2.50	0.88	0.23	0.01	0.000	0.0	39.87	40	6.17	0.24	0.00	0.12	86.28	42.8	0	126	Small amount of insoluble matter						
35	26	44971	170M	Flow water	03-Oct-01	26.2	8	7.65	30.3	48.30	21.20	38.80	1.50	0.11	0.20	0.00	0.000	0.0	380.51	13	7.51	0.18	0.00	0.12	59.28	228.8	0	382	Small amount of insoluble matter						
36	27	44951	100M	Flow water	08-Oct-01	30.9	10.0	8.83	44.8	18.30	20.00	21.53	5.03	0.17	0.00	0.00	0.000	0.0	236.44	46	14.24	0.25	0.00	0.00	22.83	142.2	0	244	Small amount of precipitated iron						
37	27	45009	120M	Flow water	19-Dec-03	26.8	-21	8.84	40.8	18.40	22.21	22.40	2.80	1.80	0.13	0.48	0.004	0.0	225.83	51	5.23	1.23	0.00	0.13	41.83	180.0	0	268	Small amount of precipitated iron						
38	28	45010	120M	Filtered water	19-Dec-03	26.1	24	7.12	42.8	18.30	22.21	22.40	2.20	0.17	0.11	0.52	0	0.0	225.83	33	5.54	0.24	0.00	0.14	41.83	104.0	0	268	Clear						
39	30	44968	121M	Flow water	07-Oct-01	26.4	-32	7.38	32.8	34.38	18.28	21.28	4.10	0.01	0.24	0.00	0.000	0.0	381.57	25	6.23	0.00	0.00	0.14	84.54	208.8	0	325	Clear						
40	29	44954	200M	Flow water	11-Oct-01	26.8	0.28	8.15	18.7	18.34	8.14	11.80	5.40	0.02	0.02	0.02	0	0.0	129.44	29	4.15	0.00	0.12	0.18	87.83	98.8	0	118	Clear						
41	30	44956	170M	Flow water	28-Sep-01	26.4	0.81	7.09	125.0	198.80	125.11	118.35	18.50	0.32	1.30	0.00	0	0.0	480.85	34	380.81	117.35	239.89	0.48	80.08	824.8	682.84	~500	Small amount of insoluble matter						

Figure 4.3.2 (1/4) Results of Laboratory Chemical Analysis of Groundwater Taken from Existing Wells

Well No.	Lab. No.	Village No.	Province	Well Type	Sampling date	Water Temp (10m) (deg-C)	DO (deg-C)	pH	EC (uS/cm)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Total Diss. Sol. (mg/L)	Manganese (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Carbonate (mg/L)	Bicarbonate (mg/L)	Dissolved gas (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrite (mg/L)	Fluoride (mg/L)	Silica (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Total Dissolved Solids (mg/L)	Appearance of water at time analysis
1	44014	0050	Kg	Drilling	08-Aug-01	28.1	10.7	7.90	28.1	64.90	40.01	36.20	1.30	0.10	0.00	0.00	0.004	0.0	256.18	22	11.04	10.84	0.20	0.00	40.50	200.8	0	02	Small amount of insoluble matters
2	44015	0050	Kg	Drilling	09-Aug-01	27.3	10.5	8.88	12.2	5.80	0.80	14.71	4.30	0.05	0.00	0.00	0	0.0	17.48	6	25.31	0.00	0.20	0.00	12.50	10.0	0	15	Small amount of insoluble matters
3	44013	0050	Kg	Drilling	09-Aug-01	28.2	10.1	8.30	108.0	27.30	3.30	171.80	14.80	0.04	0.00	0.00	0	0.0	38.80	20	22.87	30.80	0.00	0.20	18.20	87.0	0.5	04	Small amount of insoluble matters
4	44000	00010	Kg	Drilling	09-Aug-01	28.2	10.0	8.18	18.1	0.00	0.00	11.80	0.00	0.00	0.10	0.10	0	0.0	21.34	20	24.80	0.00	0.20	0.04	15.20	22.4	0	04	Small amount of insoluble matters
5	44002	00002	Kg	Drilling	09-Aug-01	27.7	10.0	8.08	28.3	20.18	1.81	21.80	12.80	0.00	0.04	0.04	0.000	0.0	72.88	30	39.88	0.04	0.20	0.10	17.10	30.4	0	103	Preconditioned iron
6	44017	00110	Kg	Drilling	09-Aug-01	28.3	10.0	8.40	11.4	1.20	1.00	13.20	0.40	0.01	0.00	0.00	0	0.0	18.48	10	18.18	0.00	0.20	0.00	11.20	22.8	0	18	Clear
7	44025	00130	Kg	Drilling	09-Aug-01	28.3	10.0	8.18	210.0	71.20	13.80	327.00	38.00	0.00	0.00	0.00	0.000	0.0	300.10	18	210.24	106.80	30.40	0.00	10.00	236.0	0	1000	Insoluble matters
8	44022	00020	Kg	Drilling	09-Aug-01	27.8	10.0	8.30	22.0	20.00	1.80	18.00	20.00	0.00	0.11	0.12	0	0.0	80.24	17	81.10	1.20	0.20	0.11	18.00	32.0	0.01	100	Small amount of insoluble matters
9	44012	00330	Kg	Drilling	09-Aug-01	28.0	10.0	8.41	18.1	10.50	0.80	10.54	0.20	0.01	0.01	0.11	0	0.0	40.58	20	20.50	0.00	0.20	0.00	14.20	30.4	0.1	100	Small amount of insoluble matters
10	44000	00000	Kg	Drilling	09-Aug-01	28.1	10.0	8.08	14.0	10.40	2.34	6.35	0.00	0.00	0.01	0.00	0	0.0	30.20	10	1.00	0.00	0.20	0.00	12.30	07.2	0.0	08	Small amount of insoluble matters
11	44021	00030	Kg	Drilling	09-Aug-01	28.0	10.0	8.30	25.0	15.80	0.10	16.90	10.00	0.00	0.01	0.00	0	0.0	0.18	10	07.10	4.50	0.20	0.00	07.50	07.0	0.0	100	Insoluble matters
12	44018	00010	Kg	Drilling	09-Aug-01	28.1	10.0	8.30	42.0	0.40	0.00	00.87	00.80	0.20	0.00	0.00	0.000	0.0	40.14	31	87.80	00.00	0.20	0.01	00.80	00.8	0.01	300	Small amount of precipitated iron
13	44001	00000	Kg	Drilling	09-Aug-01	28.0	10.0	7.60	46.7	30.24	1.40	51.07	0.00	0.00	0.10	0.00	0.000	0.0	400.46	14	1.10	1.04	0.00	0.40	08.80	100.0	0	800	Insoluble matters
14	44008	00000	Kg	Clear	09-Aug-01	27.2	10.1	8.04	17.7	1.00	0.20	8.80	10.20	0.00	0.14	0.48	0	0.0	2.00	80	10.70	0.00	0.20	0.10	0.80	20.8	20	100	Clear
15	44003	00000	Kg	Clear	09-Aug-01	28.0	10.1	8.22	1.8	1.80	0.70	1.10	0.20	0.00	0.00	0.00	0	0.0	7.18	50	2.37	0.00	0.00	0.10	0.20	7.0	1	18	Clear
16	44006	00000	Kg	Clear	09-Aug-01	27.8	10.0	8.20	0.8	1.10	0.70	0.80	0.10	0.00	0.01	0.00	0	0.0	0.00	20	1.80	0.00	0.10	0.00	0.00	0.0	1	11	Clear
17	44017	00000	Kg	Clear	09-Aug-01	27.9	10.0	8.20	0.8	1.44	0.80	0.80	0.50	0.04	0.04	0.18	0	0.0	0.18	40	0.80	0.00	0.01	0.00	0.80	7.0	0	25	Clear
18	44005	01010	Kg	Clear	09-Aug-01	27.3	10.1	8.10	6.4	4.10	0.80	2.30	0.00	0.00	0.00	0.00	0	0.0	22.88	37	2.37	0.00	0.00	0.10	04.80	00.8	0	55	Small amount of insoluble matters
19	44005	01000	Kg	Clear	09-Aug-01	27.5	10.0	8.40	34.8	10.44	1.14	20.30	20.80	0.00	0.14	0.01	0.000	0.0	30.48	40	47.80	7.30	1.40	0.10	04.80	02.8	1	08	Small amount of precipitated iron
20	44004	01000	Kg	Clear	09-Aug-01	27.0	10.0	8.30	10.1	1.07	0.10	8.67	2.20	0.10	0.00	0.00	0	0.0	03.62	57	0.40	1.21	0.00	0.10	10.30	27.8	0.0	18	Large amount of insoluble matters



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												WHO Guidelines Value for Drinking Water (mg/L)																						
												200.00		0.30		0.10		1.50		0.05		0.05 to 0.10		0.005		0.005		0.005				1000		
Sl. No.	Sub No.	Village No.	Province	Well Type	Sampling date	Water Temp (Temp)	Dissolved Oxygen	pH	EC	Calcium (Ca)	Magnesium (Mg)	Iron (mg/L)	Perchlorate (mg/L)	Total Diss. (mg/L)	Manganese (mg/L)	Ammonia (mg/L)	Arsenic (mg/L)	Cadmium (mg/L)	Cyanide (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate (mg/L)	Fluoride (mg/L)	Iron (mg/L)	Total Hardness as CaCO <sub>3</sub>	Fluoride as F (ppm)	Total Dissolved Solids (TDS)	Appearance of water at time of analysis						
01	44001	01100	Ag. Cham	DW	20-Aug-01	27.0	28.0	8.04	18.0	0.10	0.05	10.10	10.00	0.00	0.04	0.00	0	0.0	0.0	10.40	40	30.00	4.00	14.10	0.14	10.00	20.0	10	110	Clear				
02	44002	00000	Ag. Cham	DW	01-Aug-01	28.0	10.0	8.10	00.0	20.00	20.40	20.20	10.00	0.10	0.10	0.00	0.00	0	0.0	20.00	30	40.00	0.00	0.00	0.00	20.00	00	000	Clear					
03	44003	00400	Ag. Cham	DW	17-Aug-01	27.0	30	7.00	100.0	100.00	00.00	00.00	0.00	0.00	0.00	0.00	0	0.0	0.0	100.00	40	20.00	20.00	0.00	0.00	00.00	00.00	100	300	Clear				
04	44004	00000	Ag. Cham	DW	01-Aug-01	28.0	20.0	0.04	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.0	0.00	00	0.00	0.00	0.00	0.00	00.00	10.0	0	00	Clear					
05	44005	000000	Ag. Cham	DW	17-Aug-01	28.0	100	0.00	10.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.0	00.00	00	0.00	0.00	0.00	0.00	00.00	00.00	00	0	100	Clear				
06	44006	00000	Ag. Cham	DW	10-Aug-01	27.0	100	0.00	00.0	00.00	10.10	10.00	0.00	0.00	0.00	0.00	0	0.0	00.00	00	00.00	10.00	0.00	0.00	0.00	00.00	100.0	00	000	Clear				
07	44007	00000	Ag. Cham	DW	04-Aug-01	28.0	100	0.00	20.0	20.00	00.00	00.00	0.00	0.00	0.00	0.00	0	0.0	00.00	30	00.00	00.00	0.00	0.00	00.00	00.00	000	000	Small amount of insoluble matter					
08	44008	00000	Ag. Cham	DW	00-Aug-01	27.0	20.0	0.00	00.0	00.00	0.00	00.00	0.00	0.00	0.00	0.00	0	0.0	00.00	20	00.00	0.00	0.00	0.00	0.00	00.00	100.0	00	000	Clear				
09	44009	00000	Ag. Cham	DW	00-Aug-01	28.0	100	0.00	100.0	00.00	00.00	0.00	0.00	0.00	0.00	0.00	0	0.0	00.00	00	00.00	0.00	0.00	0.00	0.00	00.00	000	0	000	Small amount of precipitated matter				
10	44010	00000	Ag. Cham	DW	21-Aug-01	27.0	00	0.00	20.0	20.00	00.00	00.00	0.00	0.00	0.00	0.00	0	0.0	00.00	00	00.00	00.00	0.00	0.00	00.00	000	000	000	Clear					
11	44011	000000	Ag. Cham	DW	01-Aug-01	27.0	00	0.10	00.0	00.00	00.00	00.00	0.00	0.00	0.00	0.00	0	0.0	00.00	40	00.00	0.00	0.00	0.00	00.00	000	0	000	Small amount of precipitated matter					
12	44012	00000	Ag. Cham	DW	00-Aug-01	28.0	100	0.00	100.0	00.00	00.00	0.00	0.00	0.00	0.00	0.00	0	0.0	00.00	00	00.00	0.00	0.00	0.00	0.00	00.00	100.0	00	000	Small amount of insoluble matter				
13	44013	00000	Ag. Cham	DW	10-Aug-01	28.0	30	0.00	00.0	00.00	00.00	00.00	0.00	0.00	0.00	0.00	0	0.0	00.00	0	0.00	0.00	0.00	0.00	0.00	00.00	100.0	0	000	Clear				
14	44014	00000	Ag. Cham	DW	00-Aug-01	28.0	100	0.00	00.0	00.00	00.00	0.00	0.00	0.00	0.00	0.00	0	0.0	00.00	0	0.00	0.00	0.00	0.00	0.00	00.00	100.0	0	000	Clear				
15	44015	00450	Ag. Cham	DW	25-Sep-01	28.0	01	0.00	00.0	00.00	10.00	00.00	0.00	0.00	0.00	0.00	0	0.0	00.00	00	0.00	0.00	0.00	0.00	00.00	100.0	0	000	Small amount of insoluble matter					
16	44016	00450	Ag. Cham	DW	11-Aug-01	28.0	110	0.00	00.0	00.00	10.00	00.00	0.00	0.00	0.00	0.00	0	0.0	00.00	00	0.00	0.00	0.00	0.00	00.00	100.0	0	000	Small amount of precipitated matter					
17	44017	00000	Ag. Cham	DW	11-Aug-01	28.0	100	0.00	00.0	00.00	0.00	00.00	0.00	0.00	0.00	0.00	0	0.0	00.00	20	00.00	0.00	0.00	0.00	00.00	100.0	0	000	Clear					
18	44018	00000	Ag. Cham	DW	00-Aug-01	28.0	00	0.00	00.0	00.00	0.00	00.00	0.00	0.00	0.00	0.00	0	0.0	00.00	00	0.00	0.00	0.00	0.00	00.00	100.0	0	000	Clear					

Figure 4.3.2 (3/4) Results of Laboratory Chemical Analysis of Groundwater Taken from Existing Wells

														MRO Guidelines Value For Drinking Water (mg/L)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
														200.00	0.30		0.10	1.00	0.05			0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.



Figure 4.3.2 (4/4) Results of Laboratory Chemical Analysis of Groundwater Taken from Existing Wells

															MSD Guideline Value For Drinking Water (mg/L)																
															0.050	0.00	0.10	1.00	0.05			0.005	0.005	0.005	0.005	0.50			0.00	0.00	0.00
Sam- No.	Lab- No.	Well No.	Priority	Well Type	Sampling date	Water Temp (F/°C)	DOP (F/°C)	pH	EC (µS/cm)	Calcium SO <sub>4</sub> (mg/L)	Magnesium (mg/L)	Sulfate SO <sub>4</sub> (mg/L)	Potassium K <sup>+</sup> (mg/L)	Total Iron Fe <sup>2+</sup> (mg/L)	Manganese Mn <sup>2+</sup> (mg/L)	Ammonia (NH <sub>4</sub> ) (mg/L)	Nitrate NO <sub>3</sub> (mg/L)	Dissolved Silica SiO <sub>2</sub> (mg/L)	Dissolved phosphate PO <sub>4</sub> (mg/L)	Cadmium Cd (mg/L)	Sulfate SO <sub>4</sub> (mg/L)	Nitrate NO <sub>3</sub> (mg/L)	Fluoride F <sup>-</sup> (mg/L)	Silica SiO <sub>2</sub> (mg/L)	Total Hardness as CaCO <sub>3</sub> (mg/L)	Formic acid Hardness as CaCO <sub>3</sub> (mg/L)	Total Dissolved Solids (TDS) (mg/L)	Appearance of water at time Analysis			
60	44408	50098	Ag Chem	SW	14-Aug-01	58.5	-71	7.00	52.1	13.38	13.88	90.37	0.80	0.00	0.01	0.08	0.008	0.0	0.0048	48	20.88	1.38	0.00	0.41	43.70	88.0	0	374	Small amount of precipitated iron		
62	44409	50098	Ag Chem	SW	20-Aug-01	58.5	21.0	8.10	6.8	0.32	0.32	0.37	0.10	0.10	0.18	0.00	0	0.0	28.18	37	0.77	0.00	0.00	0.00	85.30	17.3	0	75	Clear		
63	44410	50098	Ag Chem	SW	15-Aug-01	59.0	88	7.20	85.2	87.89	31.21	91.30	0.80	0.00	0.71	0.00	0	0.0	106.18	20	0.88	16.40	2.00	0.00	48.20	280.0	0	520	Clear		
64	44413	50098	Ag Chem	SW	15-Aug-01	58.5	-80	1.00	92.2	63.08	30.28	46.90	0.10	0.00	0.00	0.00	0	0.0	288.94	0	0.70	0.00	0.00	0.10	18.30	244.4	0	328	Small amount of insoluble material		
65	44415	50098	Ag Chem	SW	15-Aug-01	21.8	110	3.00	181.0	130.90	75.88	88.57	0.60	0.00	0.00	0.00	0.008	0.0	312.48	28	0.00	50.40	18.80	0.30	63.60	640.0	30.0	810	Clear		
66	44418	50098	Ag Chem	SW	10-Aug-01	59.7	80	3.24	51.0	21.00	20.00	38.00	4.70	0.00	0.00	0.00	0	0.0	120.28	01	84.88	10.80	16.51	0.10	40.10	140.2	51	204	Clear		
67	44419	50098	Ag Chem	SW	30-Aug-01	58.2	280	3.25	4.5	1.80	0.80	0.80	0.10	0.00	0.00	0.18	0	0.0	5.60	50	1.80	0.00	0.00	0.00	8.70	0.0	1	15	Clear		
68	44422	50098	Ag Chem	SW	21-Aug-01	59.7	-87	7.64	51.1	78.40	67.88	44.60	0.10	0.00	0.00	0.00	0	0.0	58.708	21	50.70	5.60	0.00	0.41	75.00	484.0	0	400	Small amount of insoluble material		