The Study on Groundwater Development in Central Cambodia
Final Report

Summary Report

LOCATION MAP
EXCHANGE RATE AND LIST OF ABBREVIATION
EXECUTIVE SUMMARY

CONTENTS

CHAPTER 4

GROUNDWATER INVESTIGATION

CHAPTER 4 GROUNDWATER INVESTIGATION

4.1 Hydrogeology

4.1.1 Hydrogeologic Conditions

Basement rocks, Plio-Pleistocene sediments, basalt and alluvial deposits characterize the hydrogeology of the Study area. The alluvial deposits can be found in the lowland along the Mekong and the Tonle Sap Rivers, and the Plio-Pleistocene sediments in the gentle slope, hill and plateau which are distributed in the western and eastern part of the Study area, respectively. Basalt covers the plateau and the hill, which are distributed in the central and eastern part of the Study area. The basement rocks composes the western mountains and covered by the Quaternary sediments in the slope and in the lowland. It sporadically forms isolated mountains in the lowland（Figure 2.1）.

(1) Western Section of the Study Area (Kg. Chhnang Province)

Basement rocks composed of sand stone, granite and rhyolite are extensively distributed in the western mountainous section of Kampong Chhnang. The gentle slope contiguous to the western mountains is covered by Pleistocene sediments consisting of sand and clay. Alluvial deposits is distributed along the Tonle Sap River. Groundwater exists in the sand and gravel layers in Quaternary sediments and the fissure and the weathered zone of the basement rocks.

(2) Central Section of the Study Area（western Kg. Cham Province）

The area is composed of the alluvial lowland along the Mekong River and the plateau of Plio-Pleistocene. The alluvial deposits consist of sand and clay and the sandy layer constitute an aquifer but the quantity and quality is not so good. Plio-Pleistocene sediments are composed of sand, gravel and clay and sand-gravel layer forms an aquifer of good quantity and quality. Basalt also forms an aquifer in the fissure zone. Plio-Plestocene aquifer is artesian and the flowing well can be seen in some area.

(3) Eastern Section of the Study Area

The area is located in the left bank of the Mekong River and composed of the plateau and hill. They consist of Plio-Pleistocene sediments and basalt. Plio-Pleistocene sediments are sand, gravel and clay. The aquifer yields good quantity and quality of groundwater. The well in this

area often becomes flowing well. Basalt forms an aquifer in the fissure zone. The basement rocks mainly composed of sand stone underlies beneath Plio-Pleistocene sediments. They form an aquifer in the fissure and the weathered zone.

4.1.2 Hydrogeologic Unit

Based on the geological investigations of the Study and some related literatures, hydrogeologic units in the Study area are summarized as shown in Table 4.1.

Table 4.1 Hdrogeologic Unit of the Study Area

Geologic Age		Geology	Symbol	Hydrogeologic Unit	Remark
Quaternary	Holocene	Alluvial deposit	Q4	Mainly Aquitard	
		Old River Deposit		Mainly Aquitard	
	Pleistocene	Plateau Deposit	Q2-3	Aquifer・Aquitard	
		Plateau Basalt	QB, N2-Q1	Aquifer	Fissure Zone
		Terrace-Plateau deposit	N2-Q	Aquifer・Aquitard	Flowing
Tertiary	Pliocene				
Pre-Tertiary		sand stone rhyolite granite	D-C γ	Aquifer	Weathered zone Fissure zone
				Impermeable basement	Fresh・compact zone

4.1.3 Test Well Drilling

The test wells were drilled at the 30 priority villages. The locations and the results of the drilling are presented in Figure 4.1.1 and Table 4.2, respectively. The representative well logs are also presented in Figure 4.1.2 (Western section of the Study Area), Figure 4.1.3 (Central Section) and Figure 4.1.4 (Eastern Section).

Based on the test well drilling and geophysical survey, an iso-depth contour map of the basement rocks was produced (Refer to the Hydrogeological Map). It is difficult to interpret the depth of the basement rocks in Kg. Cham Province because of high resisitivity of basalt as it is nearly same value as the basement rocks. According to the test drilling, the depth of the basement rocks ranges from 10m to 30m in Kg. Chhnang Province. In the central section and eastern section of the Study area, the depth is estimated to be more than several hundred

meters because thick Plio-Pleistocene sediments cover the area. On the other hand, in Memot district of the eastern section of the Study area, it is distributed at the depth from 10m to 70m.

4.1.4 Aquifer Constant

Pumping tests were conducted at the 30 test wells in order to obtain aquifer constants, such as permeability, storativity and specific capacity. Figure 4.1.5 shows a relation between the drawdown and the pumping rate by province and by aquifer geology. The specific capacity of the basement rocks ranges from 0.2m^3/day to 200m^3/day. It is depending on the scale and intensity of the fissure zone. Plio-Pleistocene aquifers are excellent in quantity as it ranges from several ten m^3/day to 670m^3/day in maximum. Basaltic aquifer ranges from 5.5m^3/day to 27.9m^3/day in the eastern section and the basement rock aquifer from 6.7m^3/day to 114.6m^3/day in Memot district.

Table 4.2 Screen Installed Horizon of Test Wells

Test Drilling Site			Main Screen Position		Yield (Q) (L/min)
Village No.	Basin No.	Elev. (m)	Depth (GL-m)	Horizon	
Kg. Chhnang					
R035G	G-2D	22	22～42	**BR** (fissure zone in rhyolite)	100
R045G	G-2D	12	20～32	**BR** (fissure zone in sandstone)	19
R061G	G-1	5	11～24	**P** (coarse sand)	19
R072G	G-2B	21	11～20	**BR** (fissure zone in sandstone)	120
R082G	G-2B	23	45～58	**BR** (fissure zone in sandstone)	8
R083G	G-2B	40	----	----	0
R085G	G-2B	20	12～20	**BR** (weathered zone in sandstone)	44
R162G	G-2D	18	44～60	**BR** (fissure zone in sandstone)	23
R168G	G-2E	22	15～30	**BR** (weathered zone in sandstone)	66
R189G	G-2A	14	24～36	**BR** (fissure zone in rhyolite)	65
R197G	G-2A	12	16～24	**P** (medium to coarse sand)	12
Kg. Cham					
R008M	M-5D	55	19～36	**BR**	250
R015M	M-5C	88	17～25	**B** (fissure zone)	280
R019M	M-5D	73	14～25	**BR** (weathered zone)	50
R046M	M-6A	60	5～25	**BR** (fissure zone in sandstone)	240
R055M	M-6A	152	33～48	**B**	17
R092M	M-6B	82	15～21	**B** (weathered zone)	330
R101M	M-6E	142	18～35	**BR** (weathered zone in sandstone)	280
R106M	M-6D	85	24～28	**L**	2
R115M	M-6C	115	34～45	**B** (fissured zone)	115
R126M	M-6B	79	10～15	**P** (coarse sand & fine sand)	49
R127M	M-6B	40	33～46	**BR** (fissure zone in sandstone)	110
R171M	M-5A	27	24～36	**P** (medium sand)	60*
R214M	M-2B	17	61～81	**P** (fine to medium sand)	30*
R248M	M-1	17	43～59	**P** (fine to medium sand))	250
R264M	M-6F	25	24～36	**P** (fine sand)	514
R269M	M-5A	18	25～37	**P** (coarse sand)	250
R273M	M-5A	17	12～19	**B**	100
R321M	M-4B	16	49～61	**P** (fine to coarse sand)	900
R337M	M-4B	50	18～36	**B** (weathered zone)	133
R363M	M-3B	43	26～42	**P** (fine to medium sand)	483
R376M	M-2D	12	13～23	**P** (fine to medium sand)	150

<Abbreviation>

L : Laterite, **B** : Basalt lava, **P** : Pliocene/Pleistocene unconsolidated sediments, **BR** : Basement rocks

* : Artesian

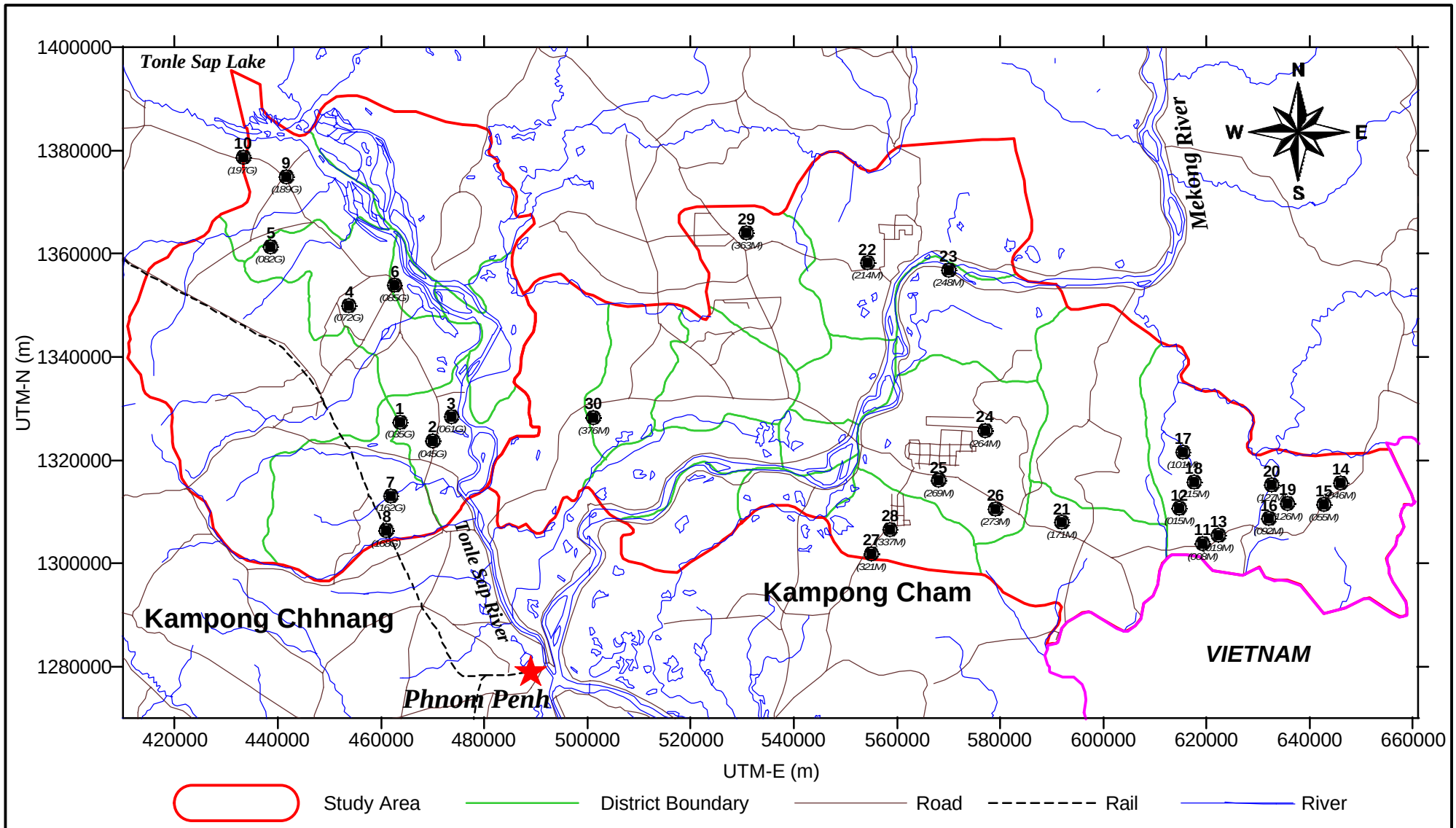
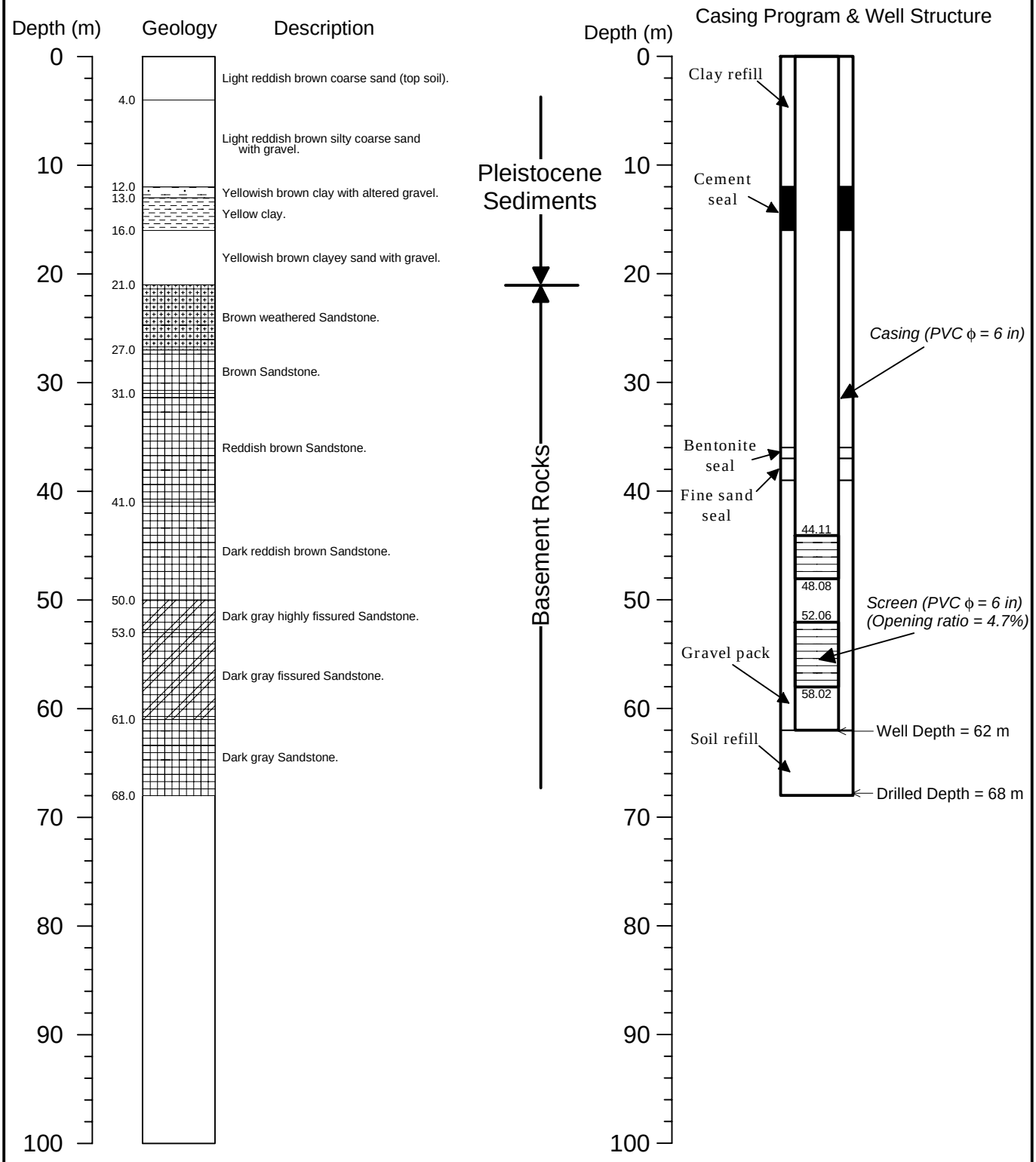


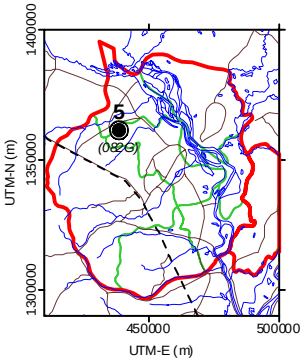
Figure 4.1 **Location of JICA Test Wells**

THE STUDY ON THE GROUNDWATER DEVELOPMENT IN CENTRAL CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



LOCATION MAP



WELL LOCATION

Province:	Kg. Chhnang	Long.-E(deg):	104.4351
District:	Rorea Bier	Lati.-N(deg):	12.3142
Commune:	Prasneb	UTM-E(m):	438577
Village:	Prasneb	UTM-N(m):	1361365
Village No.:	082G		

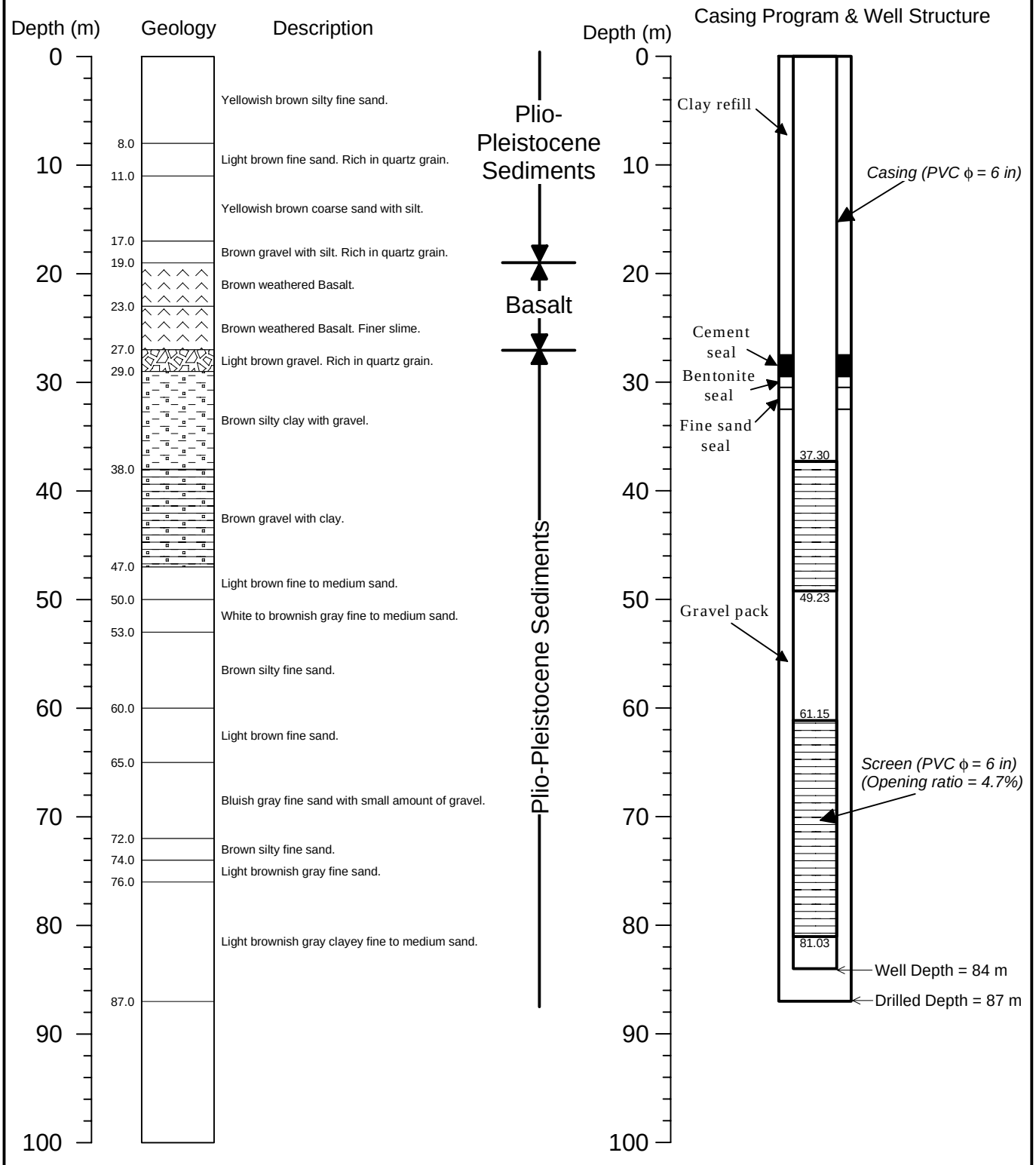
WELL SPECIFICATION

Drilled Depth:	68.0 m
Well Depth:	62.0 m
Screen Depth(s):	44.11 - 58.025 m
Screen Length:	9.94 m
Ground Elevation:	23 m

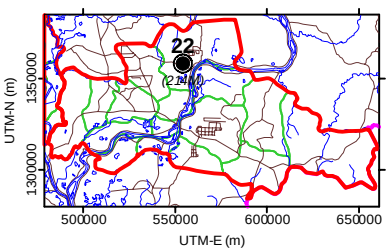
Figure 4.2 — **Columnar Section and Well Structure of No. 5 Test Well (Vil. No. 082G)**

THE STUDY ON GROUNDWATER DEVELOPMENT IN CENTRAL CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



LOCATION MAP



WELL LOCATION

Province:	Kg. Cham	Long.-E(deg):	105.4987
District:	Steung Trang	Lati.-N(deg):	12.2858
Commune:	Preak Kak	UTM-E(m):	554231
Village:	Tuol Pou	UTM-N(m):	1358213
Village No.:	214M		

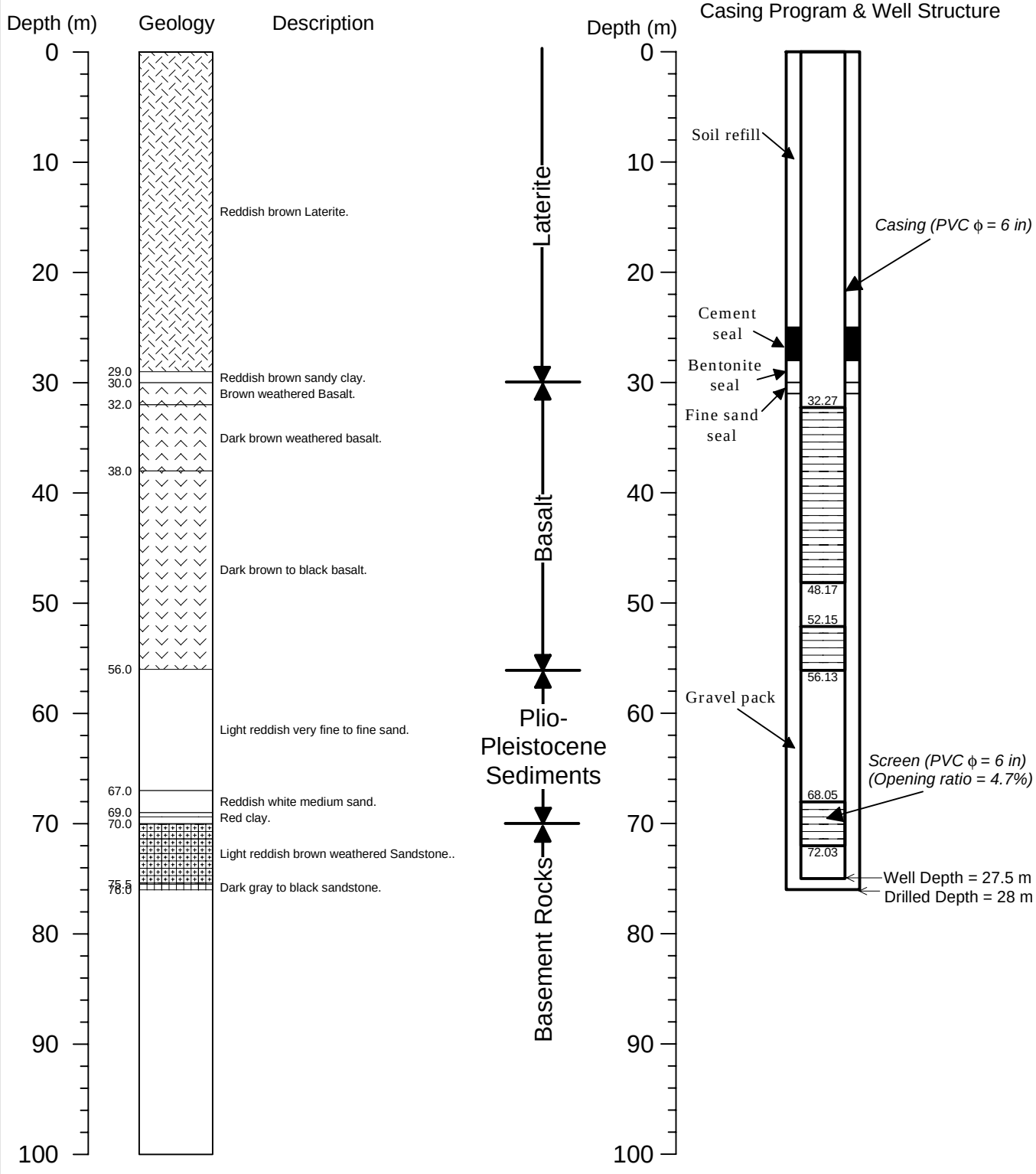
WELL SPECIFICATION

Drilled Depth:	87.0 m
Well Depth:	84.0 m
Screen Depth(s):	37.30 - 81.03 m
Screen Length:	31.80 m
Ground Elevation:	17 m

Figure 4.3 — **Columnar Section and Well Structure of No. 22 Test Well (Vil. No. 214M)**

THE STUDY ON GROUNDWATER DEVELOPMENT IN CENTRAL CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



WELL LOCATION

Province:	Kg. Cham
District:	Memot
Commune:	Ton Lung
Village:	Sla Phnum
Village No.:	055M

Long.-E(deg):	106.3110
Lati.-N(deg):	11.8599
UTM-E(m):	642783
UTM-N(m):	1311401

WELL SPECIFICATION

Drilled Depth:	76.0 m
Well Depth:	75.0 m
Screen Depth(s):	32.28 - 72.03 m
Screen Length:	23.85 m
Ground Elevation:	152 m

LOCATION MAP

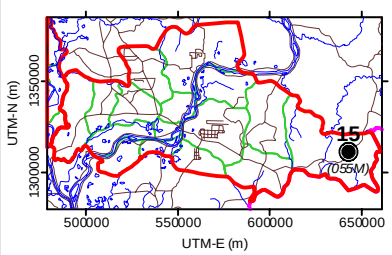
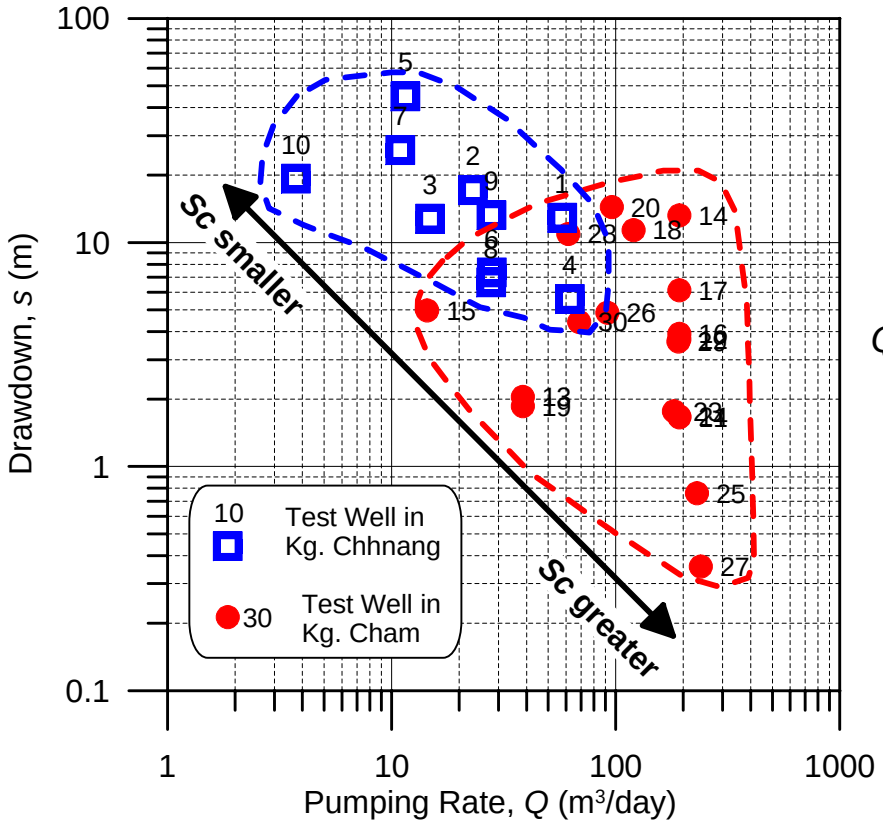


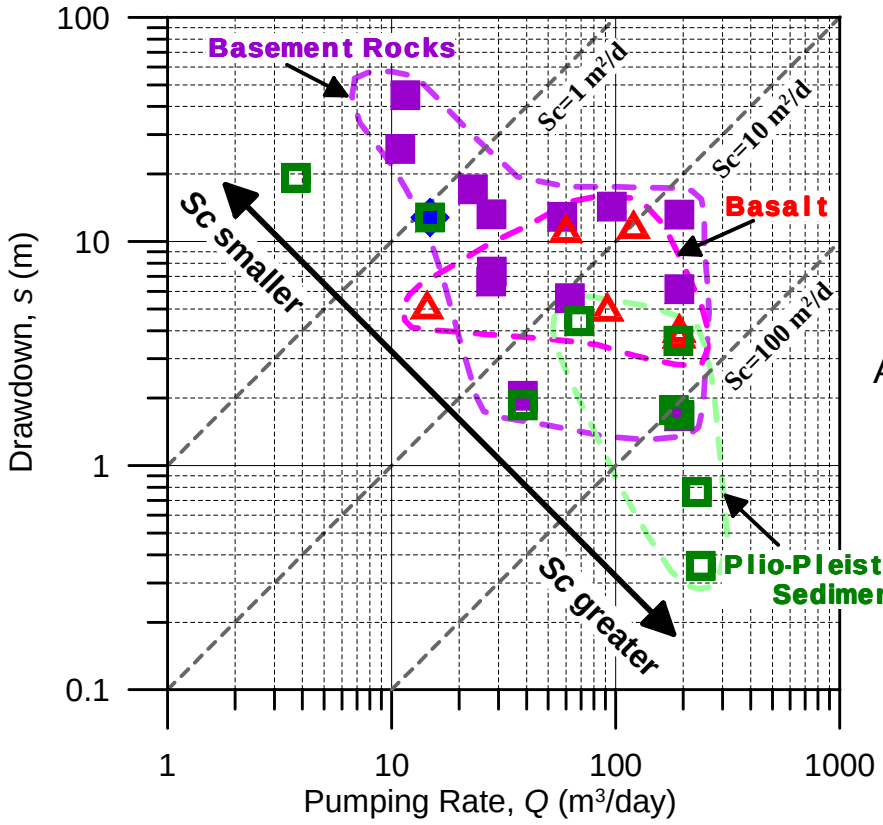
Figure 4.4 — **Columnar Section and Well Structure of No. 15 Test Well (Vil. No. 055M)**

THE STUDY ON GROUNDWATER DEVELOPMENT IN CENTRAL CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



Q-s Plots by Province



Q-s Plots by Aquifer Geology

Sc : Specific Capacity (= *Q* / *s*)

Figure 4.5	***Q-s* Plots of Test Wells by Province and Aquifer Geology**

THE STUDY ON GROUNDWATER DEVELOPMENT IN CENTRAL CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

4.2 Groundwater Levels

For the existing wells, the groundwater levels were measured in the dug wells and combined wells in the 4 times of simultaneous observations and the 12 times of monthly periodic observations(Figure 4.2.1). The simultaneous observations were carried out in February, May, August and November 2001. The groundwater levels of the newly constructed JICA Test Wells were monitored by monthly basis after their constructions. The numbers of surveyed wells are about 150 wells in the simultaneous observation, 26 wells in the periodic observation, and 30 wells in the JICA test well monitoring. These surveys were carried out by the study team members and the counterparts of DRWS. The measuring method using a portable groundwater level meter and the data recording/processing method were well transferred to the counterparts.

(1) Simultaneous Observation

1) Distribution of Depth to Groundwater Level

The distribution maps of the groundwater levels at dug wells were prepared based on the simultaneous observation. The maps show the distributions of depth to the groundwater level from the ground surface (DTW). From the 4 times observation, it is common that the DTW in some wells in Memot district in Kg. Cham exceeds 20 m, while the DTW ranges from 5 to 10 m near the areas of Kg. Chhnang city and Kg. Cham city, and in northwestern and northeastern Kg. Cham province. The DTW in the rest of the area shows within 5 m.

In February 2001, shallow DTW within 2 m was widely distributed in Kg. Chhnang province, whereas the DTW in Kg. Cham province ranges from 2 to 4 m in most areas. In May 2001, groundwater levels declined in the most parts of the study area and only a few small areas have DTW smaller than 2 m. In August 2001, groundwater levels rose in the study area except Memot district. Wide areas in Kg. Chhnang had DTW smaller than 2 m and the groundwater levels in the northwest and south of Kg. Cham province also rose. In November 2001, the groundwater levels became further shallower in the study area. Most of Kg. Chhnang province and western to southern Kg. Cham province had DTW less than 2 m (Figure 4.2.2).

2) Distribution of Changes in Groundwater Level

The distribution maps of groundwater level changes show that, for a period from February to May 2001, groundwater levels declined wide areas in the study area. The declined areas are located in most parts in Kg. Chhnang province and the areas along the Mekong River, western

part and eastern part of Memot area in Kg. Cham province. Declined groundwater level ranges from 3 to 7 m in western to southern parts of Kg. Chhnang province and the area near Kg. Chhnang town. In Kg. Cham province, the groundwater level declined 1 to 3 m in the area along the Mekong River and 1 to 4 m in some parts in Memot district. On the other hand, the groundwater levels in the western part of Kg. Cham province and in the area between the Mekong River and Memot district rose for the period. For a period from May to August 2001, the groundwater levels in the most parts of the study area went up. Groundwater level rise ranges from 3 to 8 m in central and southern Kg. Chhnang province and central to southern Kg. Cham province(Figure 4.2.3)For a period from August to November 2001, the groundwater levels still rose at 2 to 4 m in central to southern Kg. Chhnang province and western, northeastern and eastern Kg. Cham province. On the other hand, slight declines of groundwater levels were observed in the northwestern part of Kg. Chhnang province and in the southern and southeastern parts of Kg. Cham province.

3) Distribution of Groundwater Level Elevation

The groundwater level elevation at each well site was computed by the DTW and the elevation of ground surface read from the topographical maps. Then the elevation maps of the groundwater table were prepared for the surveyed months. The elevation of groundwater level (GWL) shows a good agreement with the general distribution pattern of the ground elevation. Although there are minor seasonal differences in GWL, the general distribution patterns of GWL show almost same over time. The lower GWL values smaller than 6 m above sea level (masl) are distributed in the areas along the Tonle Sap River in Kg. Chhnang province and the southwestern part of Kg. Cham province. On the other hand, the areas having more than 30 masl are distributed in western part of Kg. Chhnang province, northwest and eastern parts of Kg. Cham province(Figure 4.2.4).

Based on the distribution of the elevations of groundwater levels, the dominant groundwater flow direction is from western mountainous areas to eastern low land along the Tonle Sap River in Kg. Chhnang province. In Kg. Cham province, groundwater flow directions are broadly divided into two (2) parts by a ridge of groundwater table having WNW-ESE orientation located along the basalt plateau distributed in northern, central and eastern parts of Kg. Cham province. It is estimated that the groundwater in the south of the ridge flows toward south or southwest. On the contrary, the groundwater in the north of the ridge is presumed to flow toward north or northeast.

(2) Periodic Observation

The groundwater levels at 26 existing wells (24 dug wells and 2 combined wells) were

monitored on monthly basis from January to December 2001. In Kg. Chhnang province, the groundwater levels in most wells declined from January to May then start to rise from June and reached the highest water level in October to November 2001. The groundwater levels in some wells suddenly rose from July to August the higher water levels continued until November. In December 2001 the groundwater levels in all the wells started to decline.

In northwestern Kg. Cham province (= on the right bank of the Mekong River), most of the wells show the lowest groundwater levels in February. The water levels once rose in March then again dropped in April. From May the water levels gradually rose until October. From November the water levels sharply dropped. In Suong area of Kg. Cham province, there are two (2) types in groundwater level change. The water levels in some wells show the lowest levels in February to March then they gradually went up until October. The water levels in the other wells gradually declined from January to July then rose sharply from September to October. The highest water levels appeared in September to October in most wells. Then the water levels of all the wells sharply dropped from November to December. In Memot district of Kg. Cham province, the groundwater levels in most of the wells declined from February to June or July. Only a few wells show the lowest water level in April. Then the water levels of most wells rose from August to October. It is noted that the dug well having deeper groundwater level has the highest groundwater level in November and December (Figure 4.2.5).

(3) JICA Test Well Monitoring

The groundwater levels of the JICA test wells had been monitored since May 2001 at earlier completed wells and all the 30 wells were monitored for a period from August to December 2001.

In the test wells in Kg. Chhnang province, the groundwater levels fluctuated at depths between 0.5 and 6 m. The water levels in most wells went up from May to September and their highest values appeared in September to November. The groundwater level at No. 3 test well, which is located near the Tonle Sap River, clearly dropped from October, indicating that the groundwater level fluctuation coincides with the movement of the river water level. However, there are some wells having irregular fluctuations of groundwater levels, which are presumably caused by the groundwater pumping just before the measurements due to the poor aquifer productivity.

In northwestern Kg. Cham province, No. 22 test well had been an artesian flowing well from May to December 2001. The other three (3) wells have groundwater levels at depths from 1 to

9 m. No. 29 and No. 30 test wells, those are located far from the Mekong River, had the highest groundwater levels in November. The groundwater level of No. 23 well coincides the water level of the Mekong River, showing the highest water level in September then sharp drop of water level at 6 m by December.

In Suong area in Kg. Cham province, No. 21 well had artesian flow from July to December 2001. The other five (5) wells have groundwater levels fluctuating at depths between 1 to 8 m. No. 25 and No. 26 test wells have shallow groundwater levels at depths between 1 and 2 m. The water levels gradually rose from June to October then dropped in November to December. On the other hand, the groundwater levels at No. 24, No. 27, and No. 28 test wells fluctuated at depths between 4 and 8 m. Among the three (3) wells, the water levels at No. 24 and No. 28 wells are relatively shallower and suddenly went up in September to October.

In Memot district in Kg. Cham province, the groundwater levels of the test wells except No. 15 well ranged from 0 to 13 m in depth. The water levels of No. 14 well are shallow, showed 0.22 m above ground elevation in August 2001. The rest of the wells show rise of groundwater level from July to October. The water levels started to decline from November, however, the amount of decline is relatively small compared with the test wells in other areas. The groundwater level of No. 15 well is deep, ranging from 23 to 30 m in depth. The well had the lowest water level in July then the water level rose in September and dropped in October. The highest water level is recorded in December 2001.

(4) Characteristics of Groundwater Level Change

From the investigations of the groundwater levels, the characteristics of the changes in groundwater level in the study area differ from place to place. The groundwater levels near the Mekong River and the Tonle Sap River change with the river water levels. The patterns of groundwater level change in Memot district vary by the well location and its ground elevation. However, the changes in groundwater level of the area show a delayed seasonal cycle from the rainy season – dry season cycle, showing the lowest levels in the beginning of the rainy season (June to July) and the highest levels in the beginning of dry season (November to December). The rest of the study area has lowest groundwater levels in April to May and the highest values in September to October.

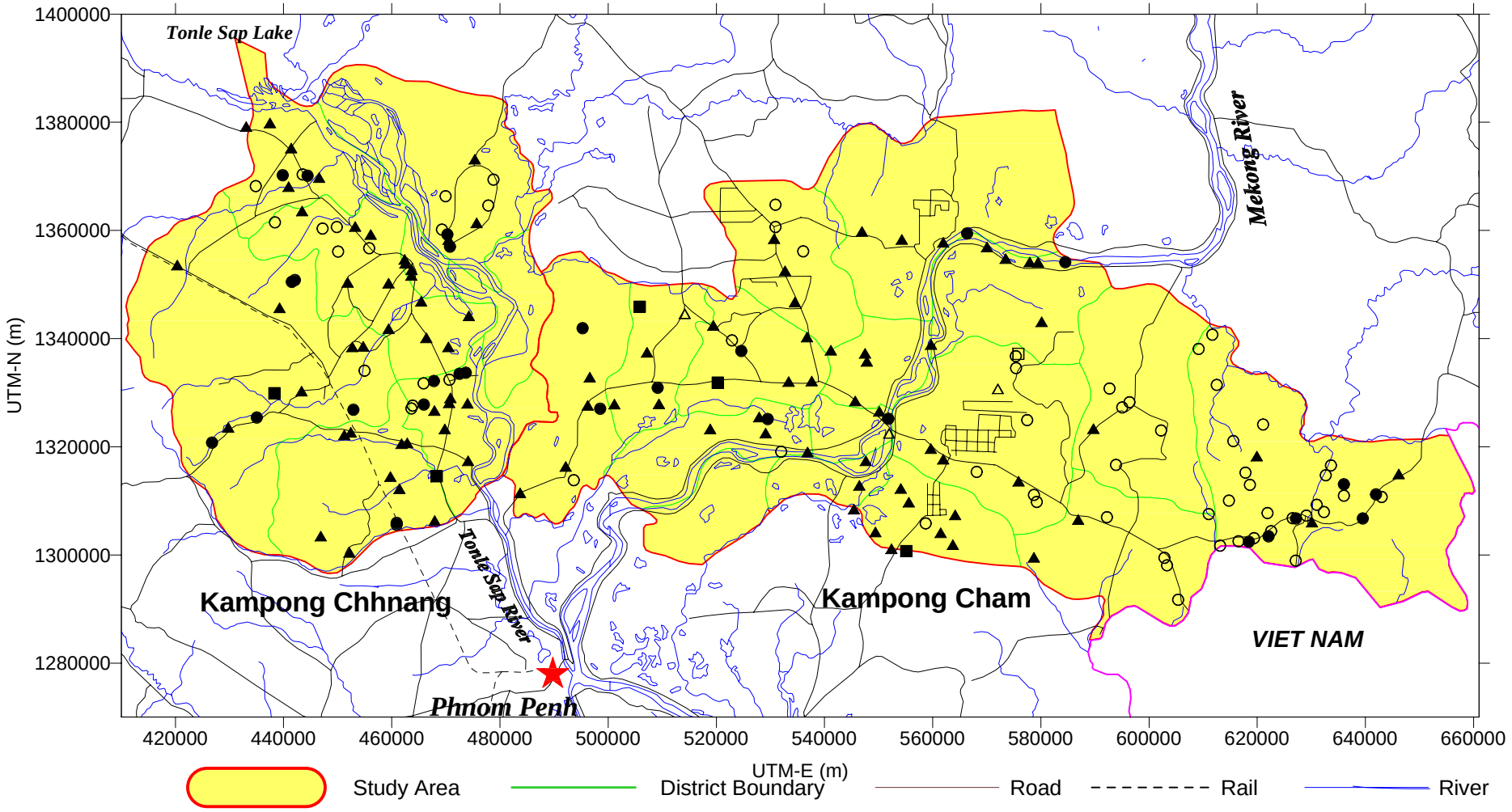
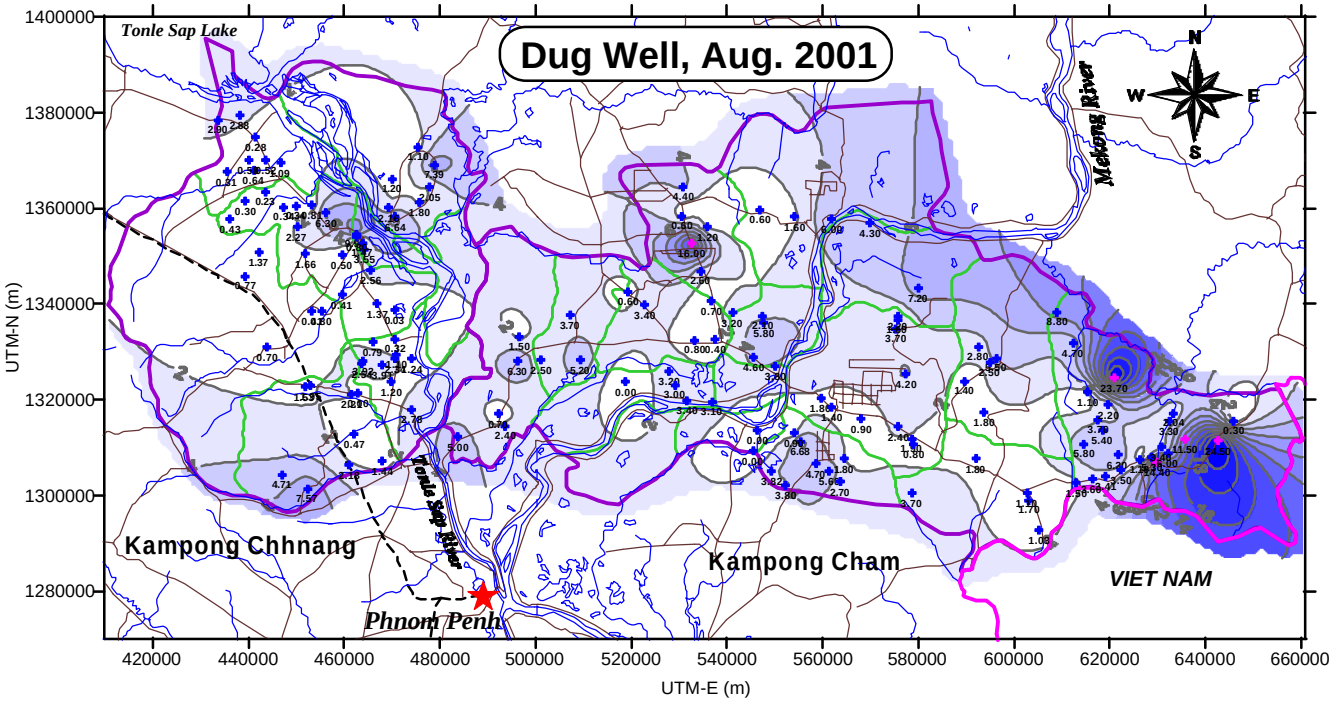
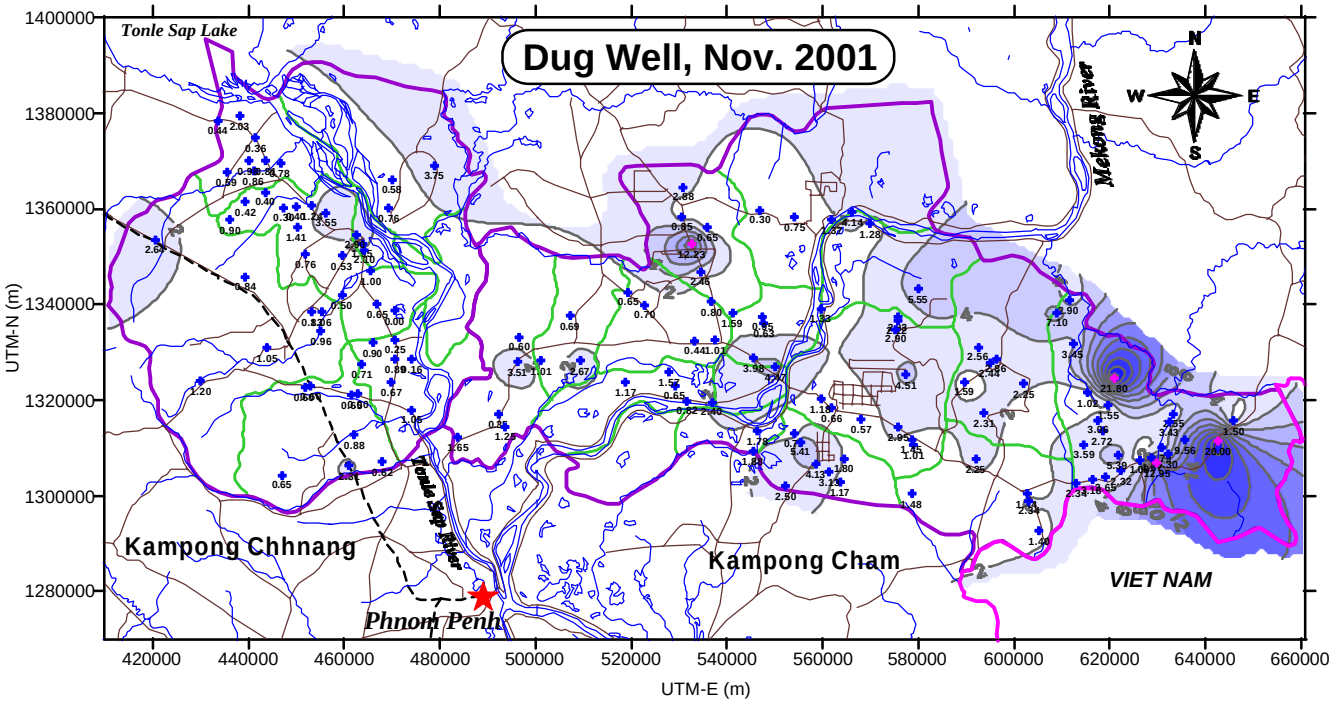


Figure 4.2.1 **Location of Surveyed Wells in Simultaneous Obsevation**

THE STUDY ON GROUNDWATER DEVELOPMENT IN CENTRAL CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)





DTW < 10 m

10 m =< DTW

Depth to Groundwater Table from Ground Surface, DTW (m)

0 2 4 6 8 10 12 14 16 18 20

Study Area

District Boundary

Road

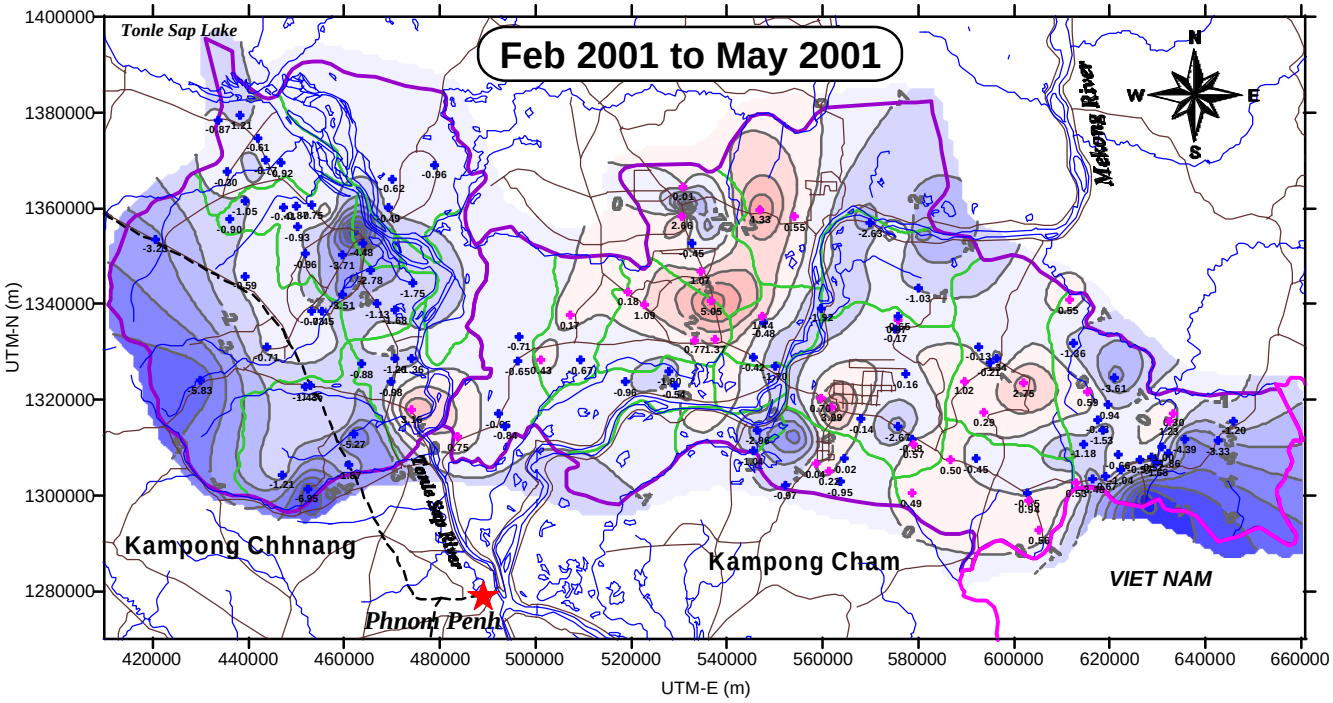
Rail

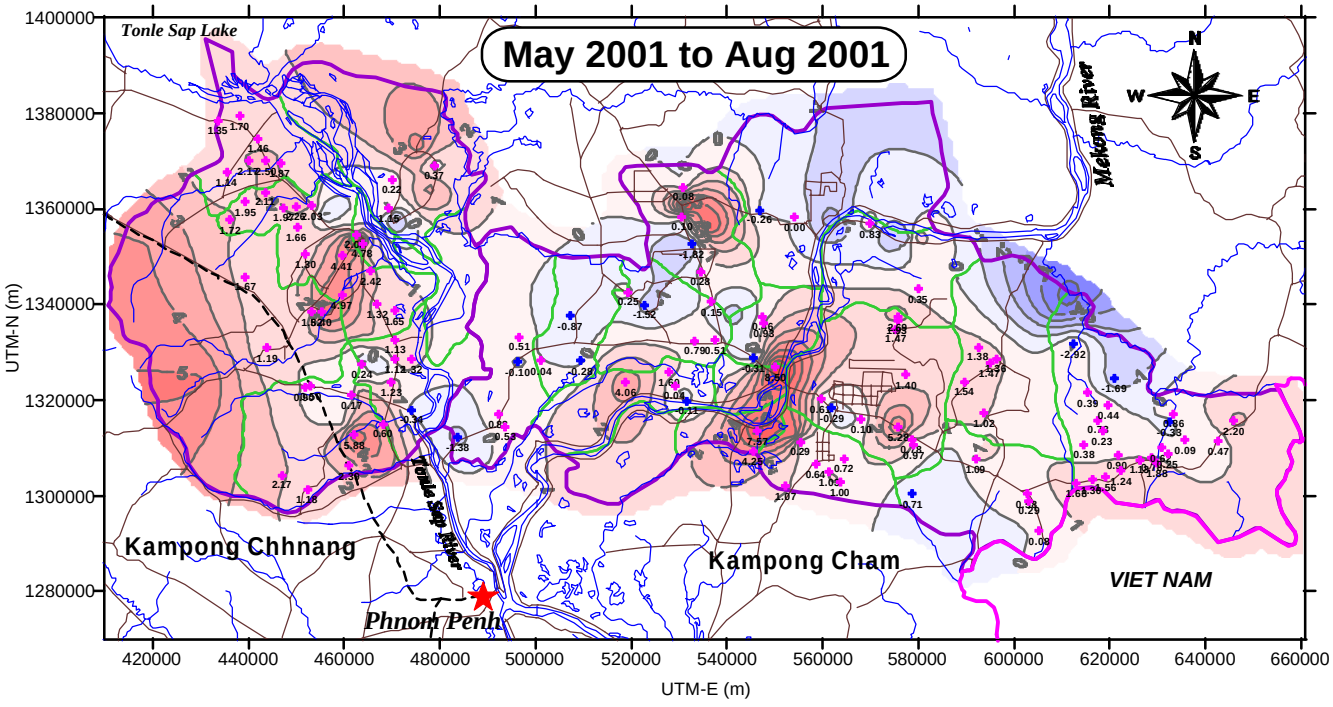
River

Figure 4.2.2 **Distribution of Depth to Groundwater Level at Existing Dug Wells (Aug 2001, Nov 2001)**

THE STUDY ON GROUNDWATER DEVELOPMENT IN CENTRAL CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)





GWL Decreased

GWL Increased

Changes in Groundwater Level [GWL] (m)

-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10

Study Area

District Boundary

Road

Rail

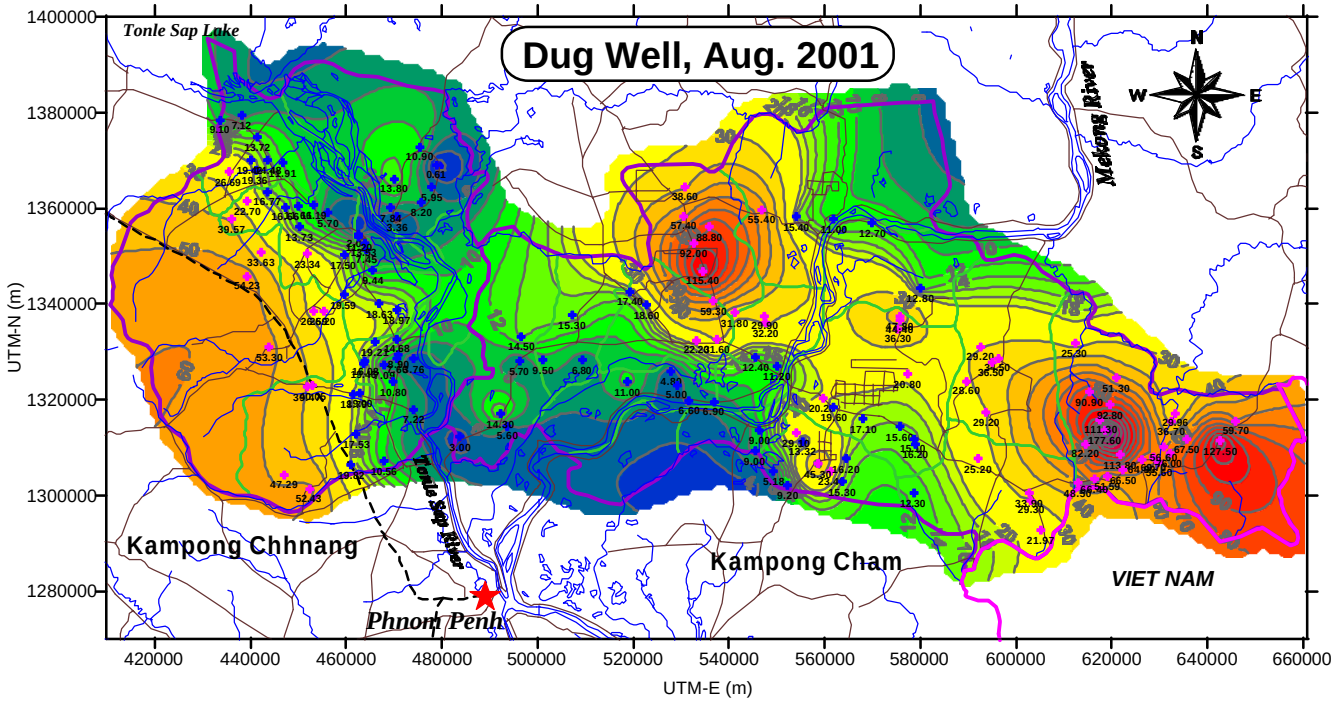
River

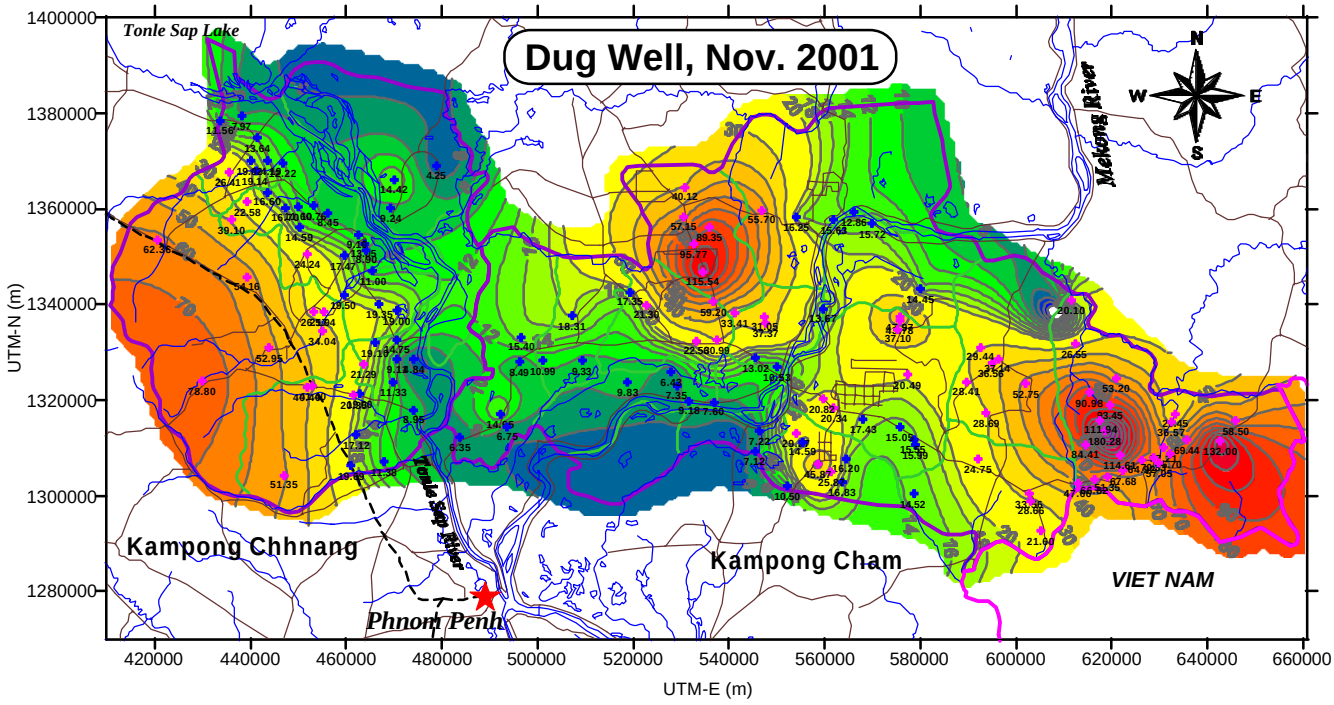
Figure 4.2.3

Changes in Groundwater Level at Existing Dug Wells (Feb to May 2001 and May to Aug 2001)

THE STUDY ON GROUNDWATER DEVELOPMENT IN CENTRAL CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)





GWL < 20 m

20 m =< GWL

Groundwater Level, GWL (m above sea level)

0 2 4 6 8 10 12 14 16 18 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

Study Area

District Boundary

Road

Rail

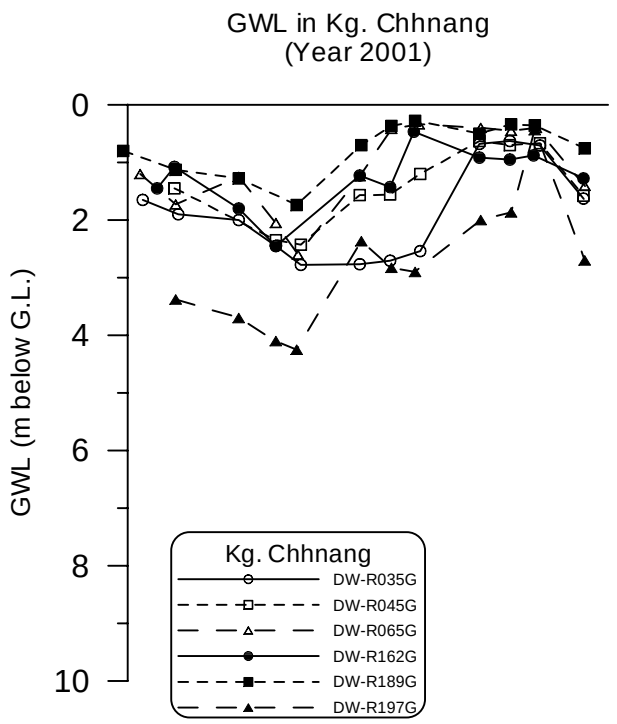
River

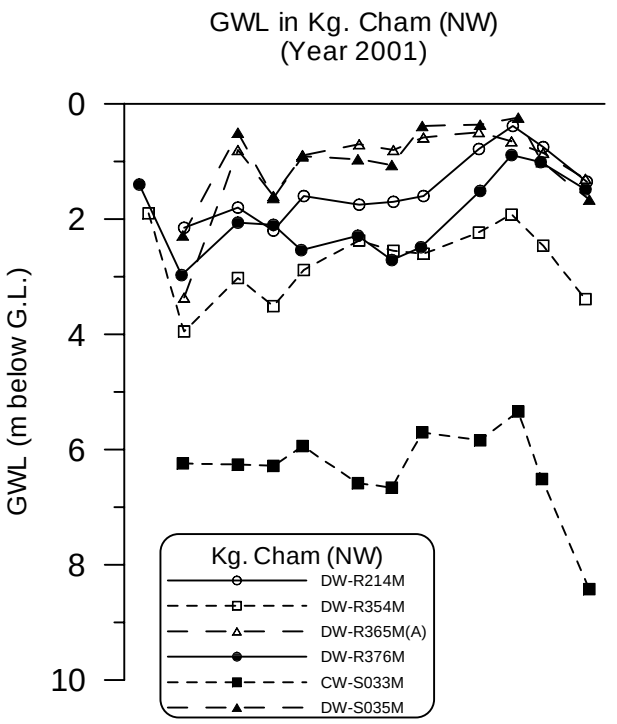
Figure 4.2.4

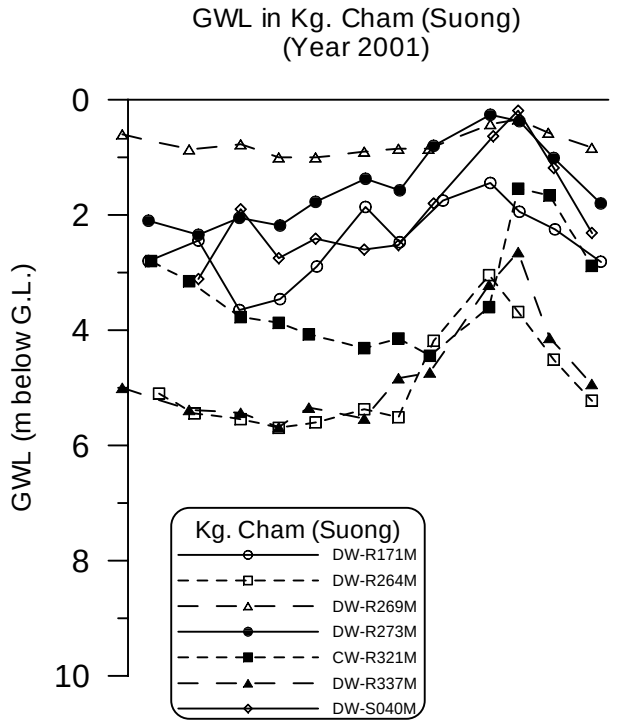
Distribution of Groundwater Level at Existing Dug Wells (Aug 2001, Nov 2001)

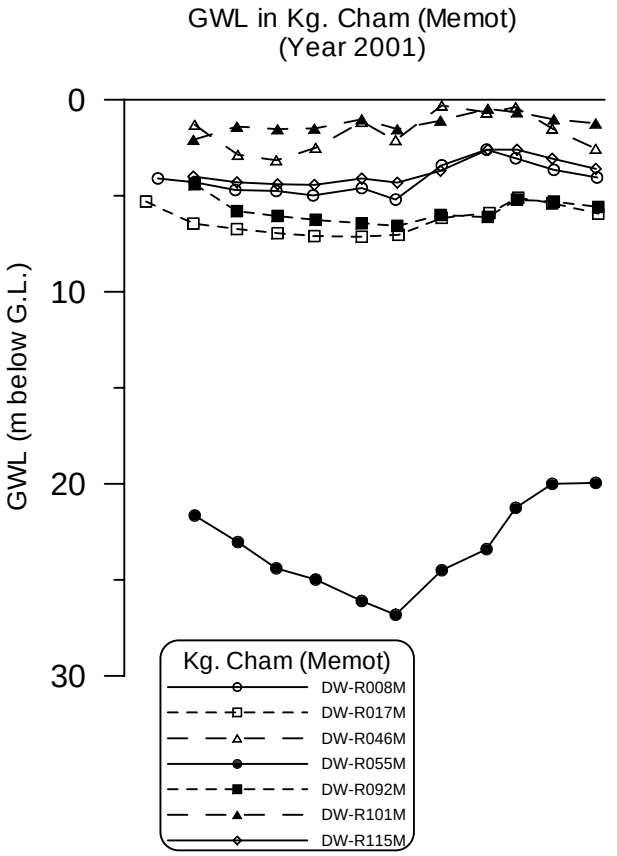
THE STUDY ON GROUNDWATER DEVELOPMENT IN CENTRAL CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)









DW: Dug Well
CW: Combined Well

Figure 4.2.5 **Changes in Groundwater Levels at Existing Dug Wells and Combined Wells**

THE STUDY ON GROUNDWATER DEVELOPMENT IN CENTRAL CAMBODIA

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)