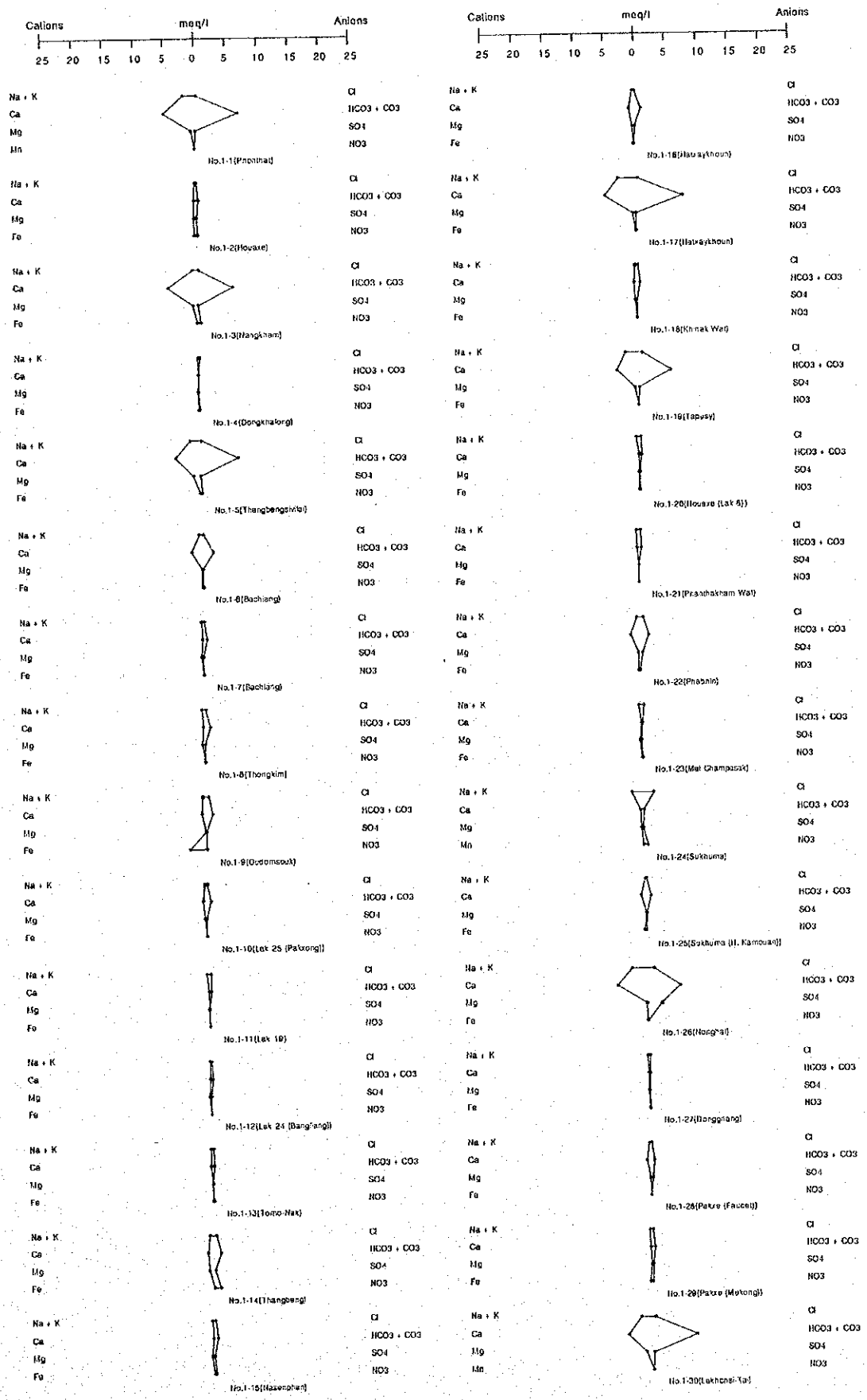

Figure 6.3.2 (1/2) Stiff Diagram of Water Quality in the Wet Season, June in 1994

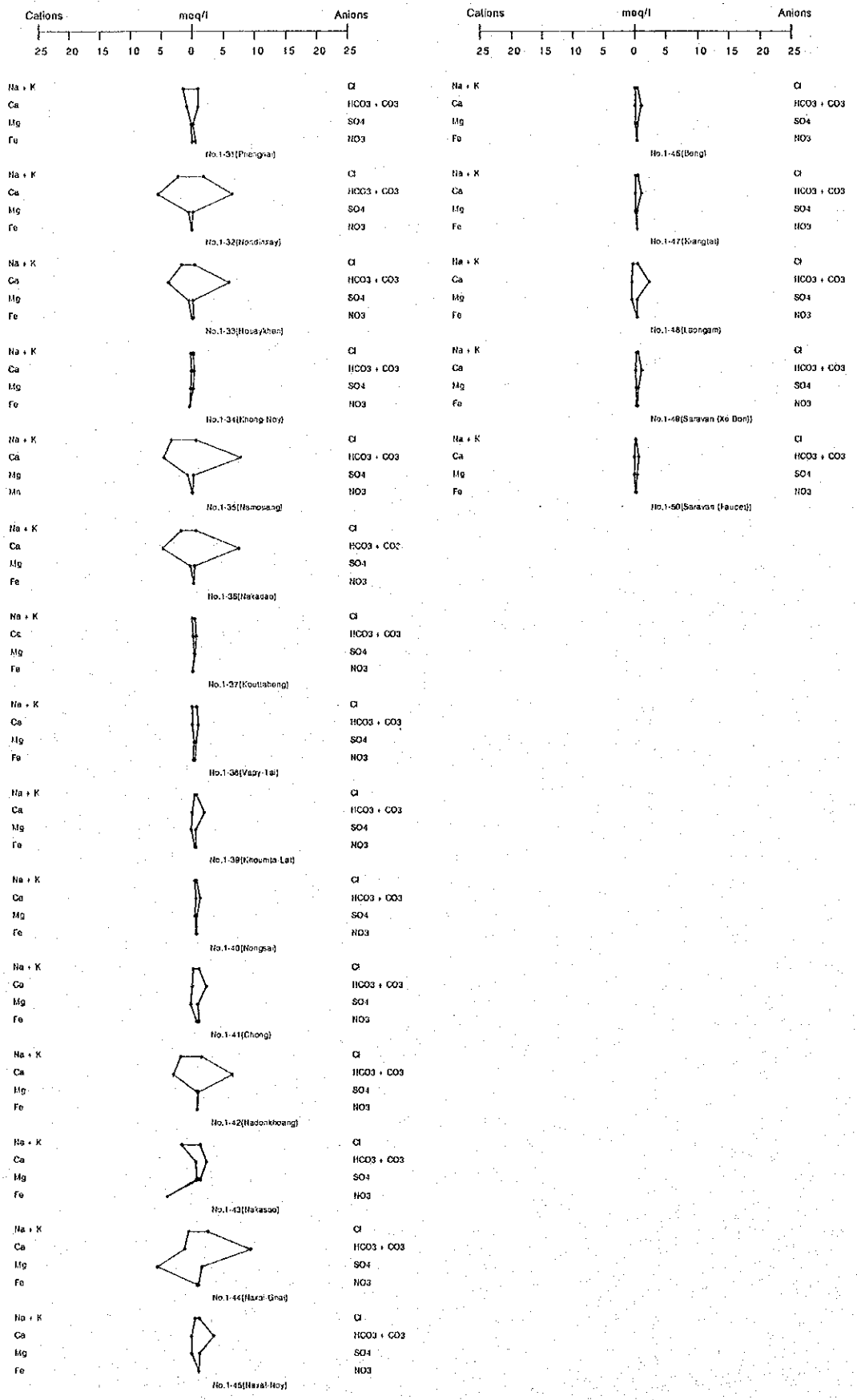

Figure 6.3.2 (2/2) Stiff Diagram of Water Quality in the Wet Season, June in 1994

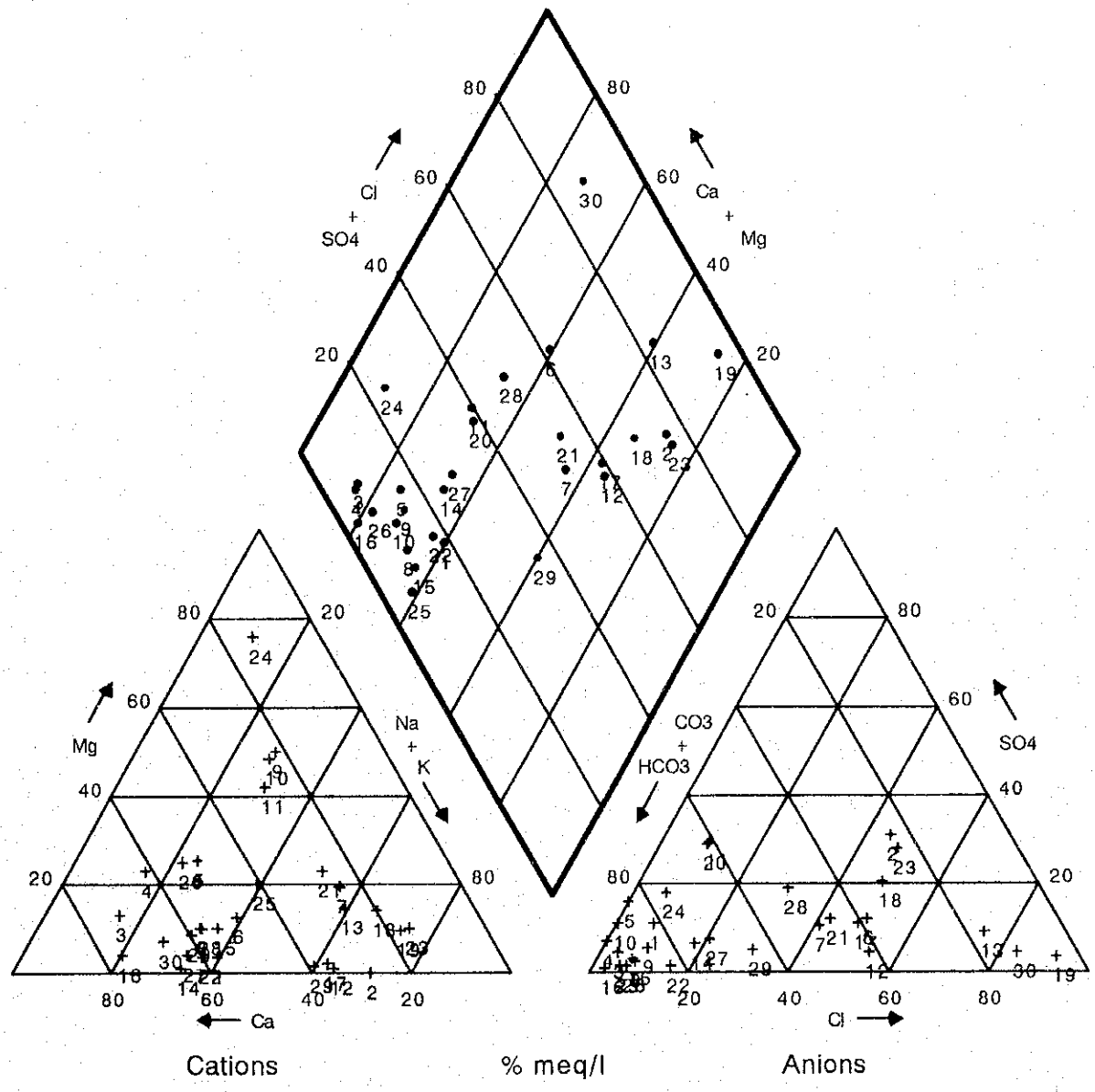

Figure 6.3.3 Tri-linear Diagram of Water Quality in the Dry Season, Nov. to Dec. in 1994

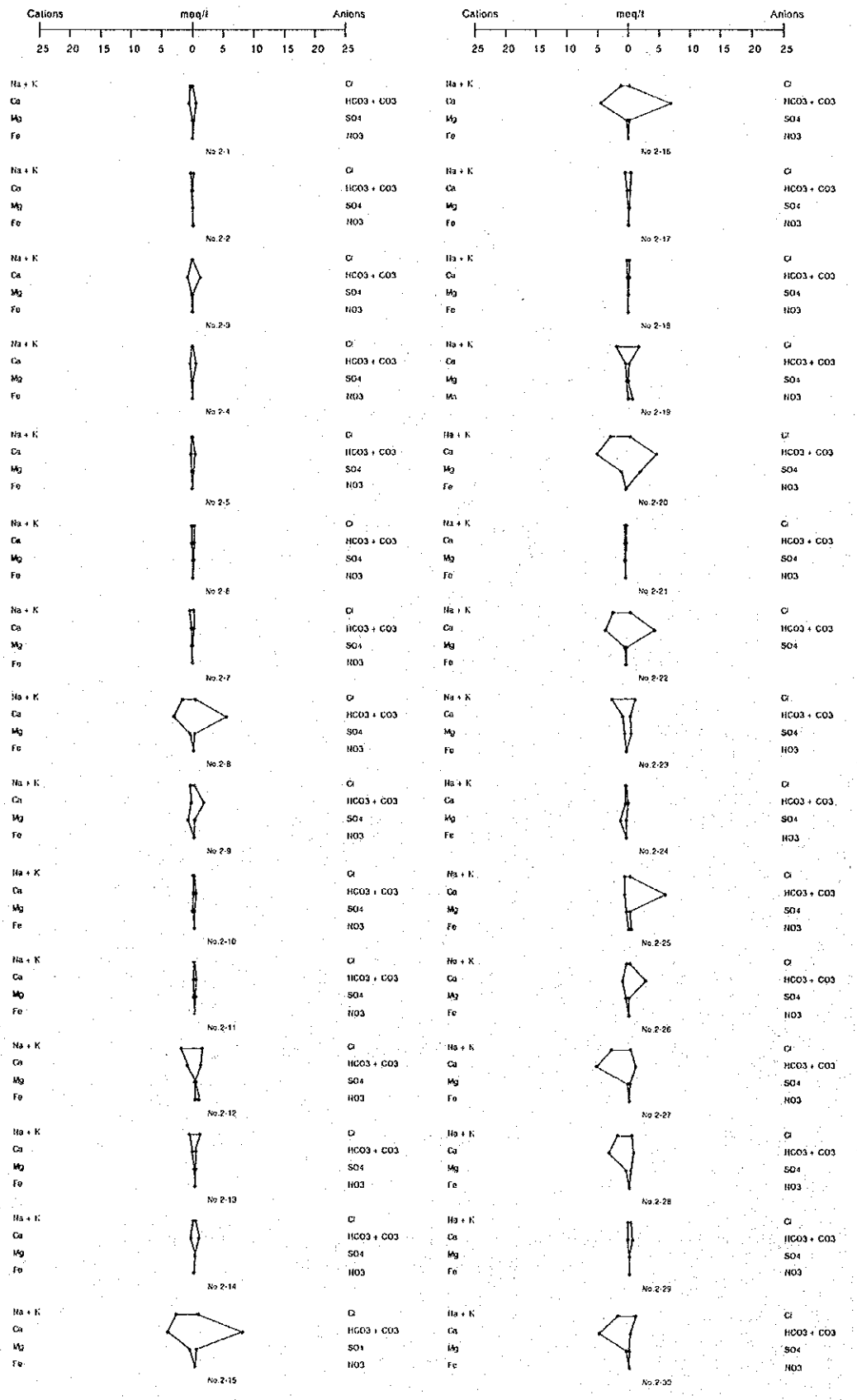

Figure 6.3.4 Stiff Diagram of Water Quality in the Dry Season, Nov. to Dec. in 1994

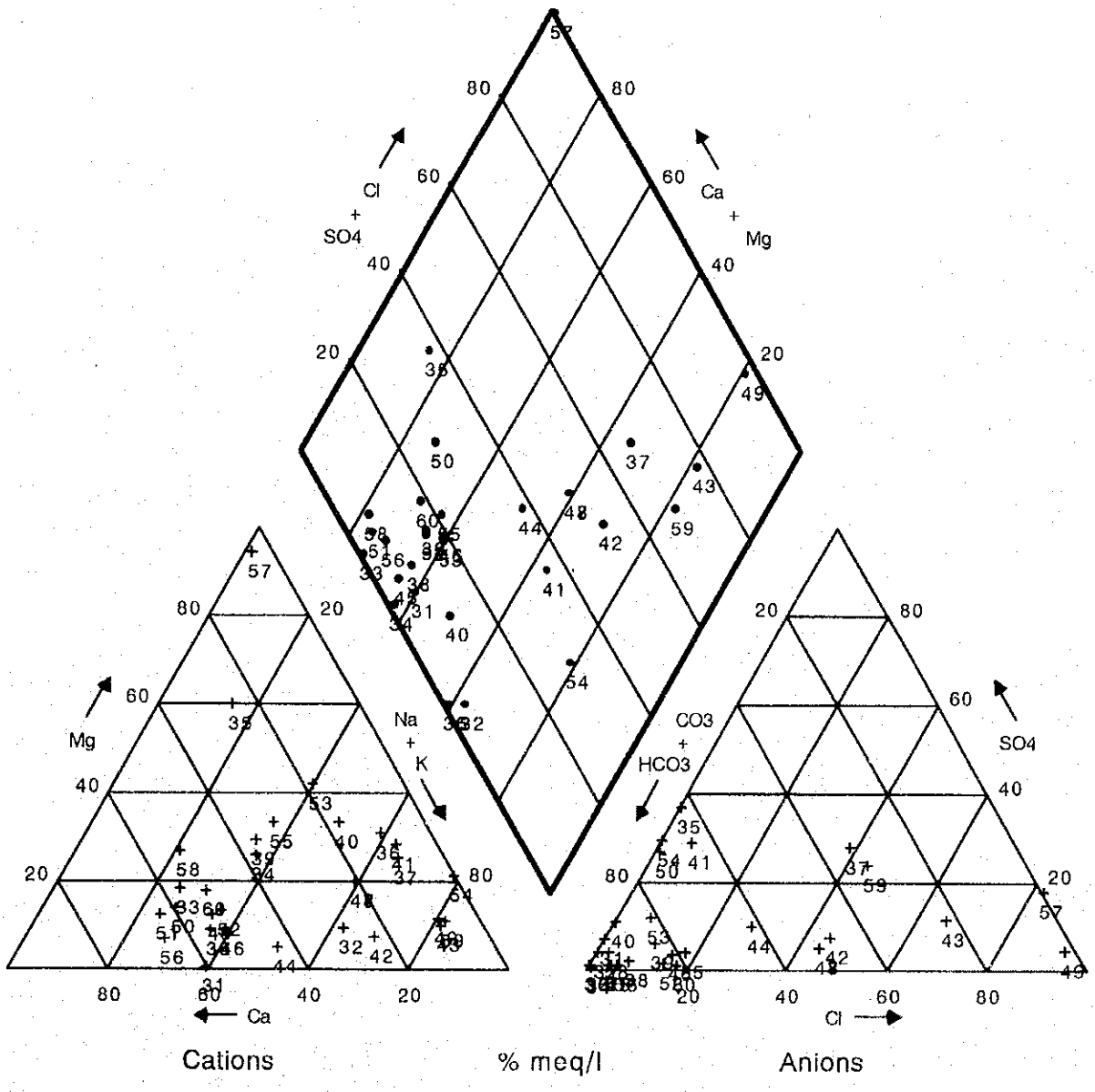

Figure 6.3.5 Tri-linear Diagram of Water Quality in the Dry Season, Jan. to Feb. in 1995

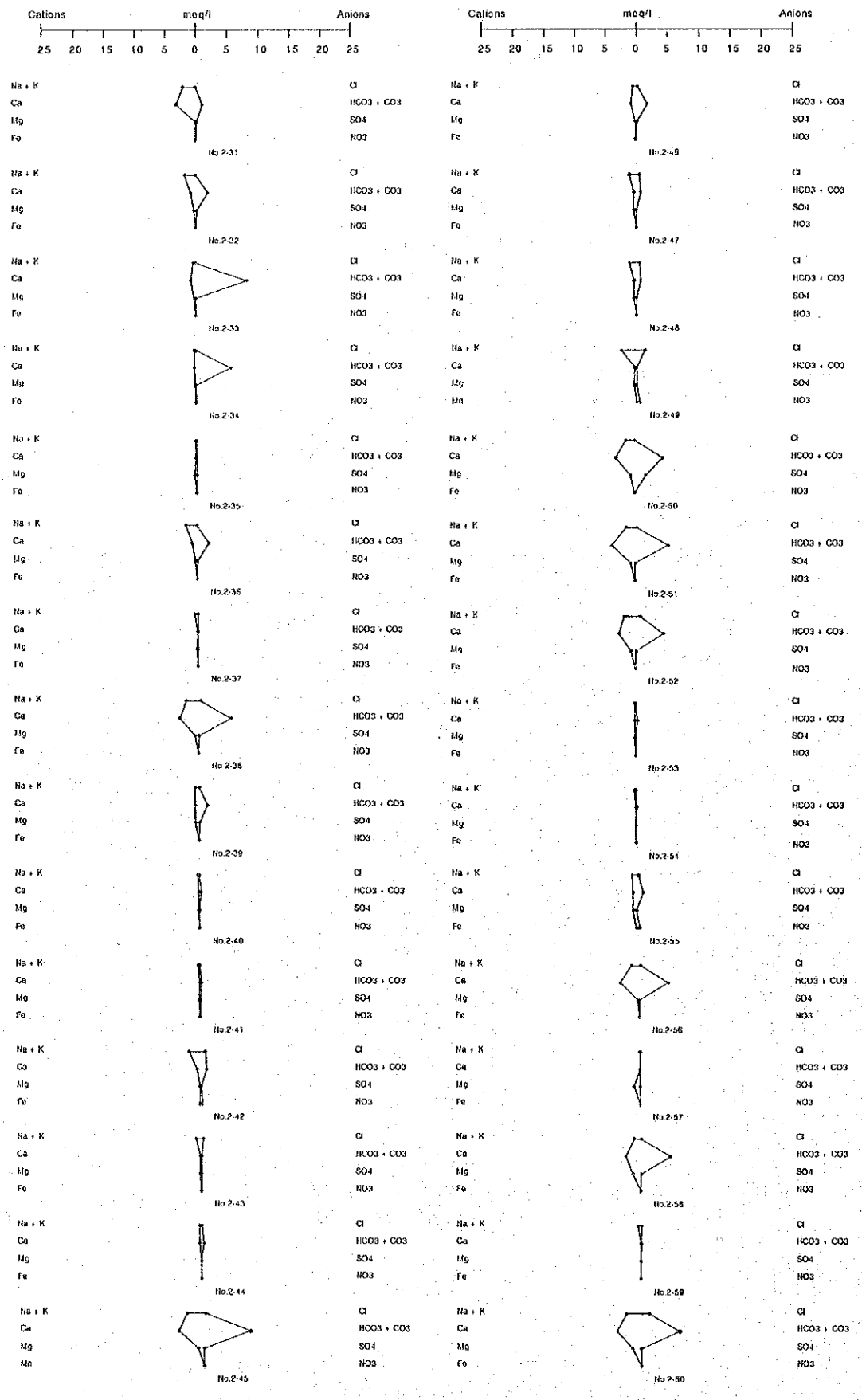

Figure 6.3.6 Stiff Diagram of Water Quality in the Dry Season, Jan. to Feb. in 1995

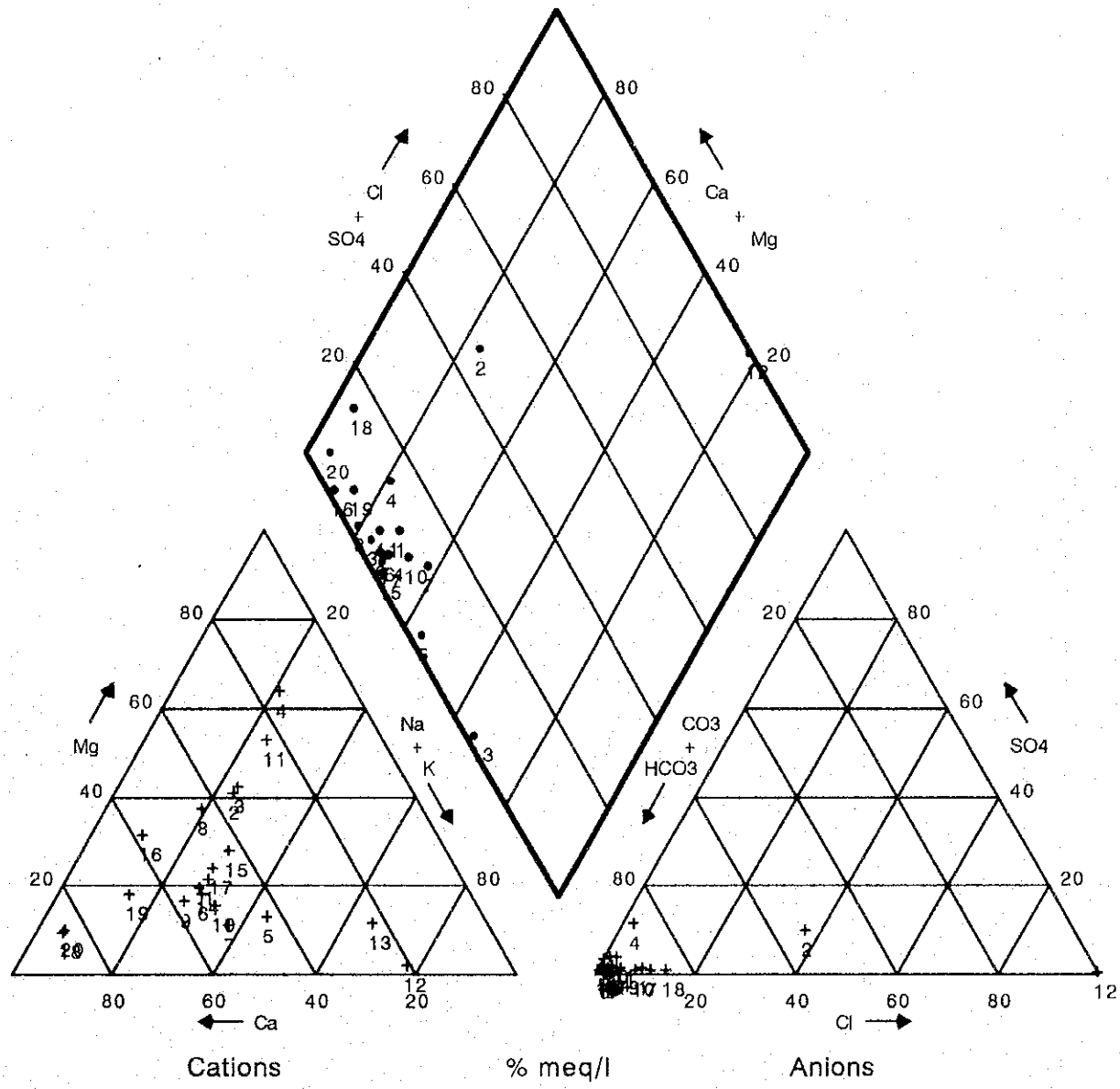

Figure 6.3.7 Tri-linear Diagram of Water Quality for New Boreholes in the Dry Season, Feb. in 1995

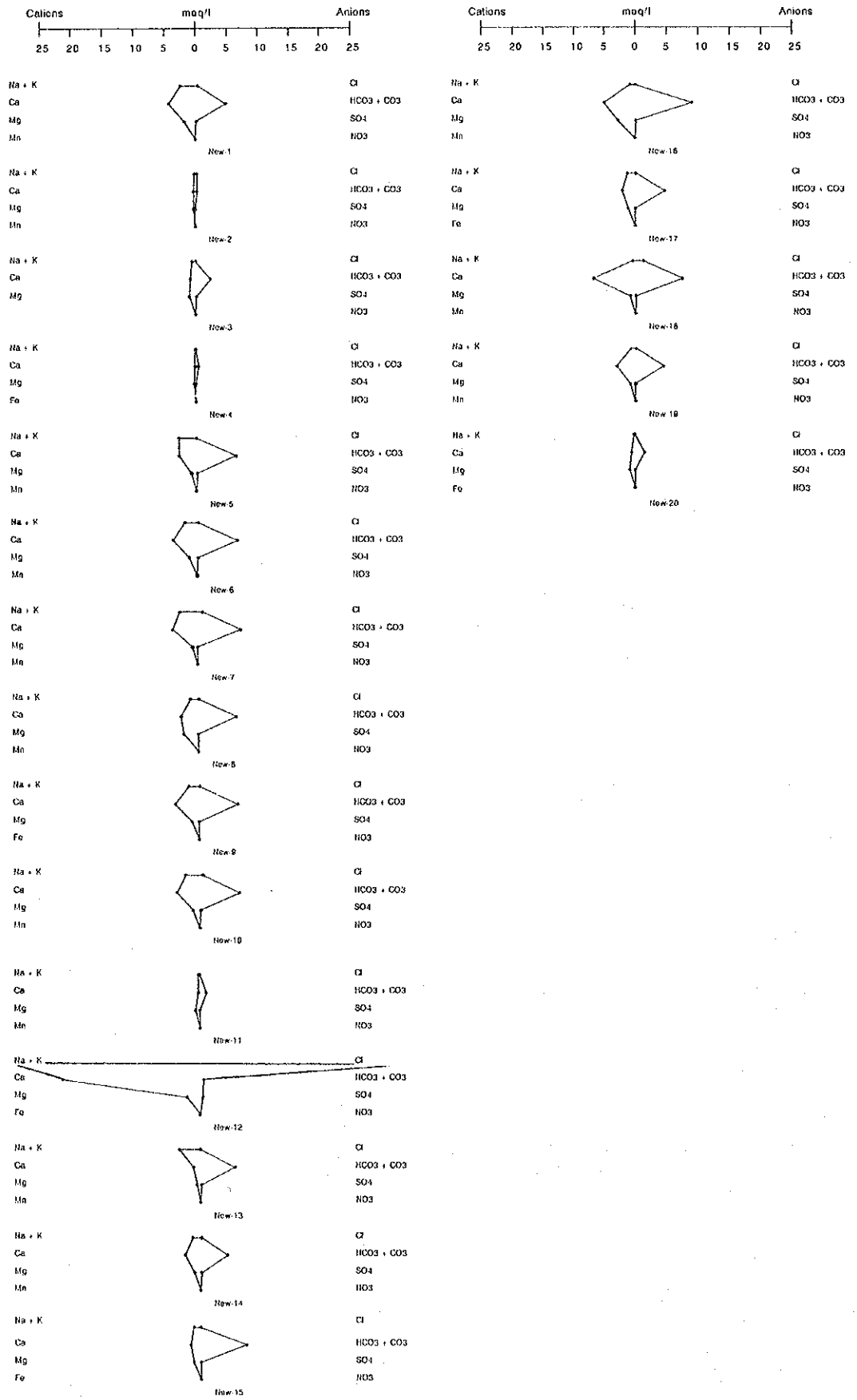

Figure 6.3.8 Stiff Diagram of Water Quality for New Boreholes in the Dry Season, Feb. in 1995

CHAPTER 7 PILOT WATER SUPPLY SYSTEMS

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CHAPTER 7 PILOT WATER SUPPLY SYSTEMS

7.1 Pilot Water Supply Facilities

To obtain a design standard of the water supply system, test wells were constructed and hand-pumps or motor-pumps were installed. The reinforced concrete cover slab (platform) was constructed around the well for its sanitary protection. The well, hand-pump and faucet were covered with roof supported by wooden pole. An elevated water tank was constructed at the motor-pump well. The system was operated by the village people and monitored by the Study Team for six months from February to July, 1995.

7.1.1 Location and depth of the well

Twenty (20) test wells were drilled at the selected villages in Champasak and Saravan Provinces. Well depth and casing length are detailed in the table below. (Refer also to Chapter 4.6).

In B. Houaxe (C-8) and B. Beng (S-84), the wells were drilled up to 182 m and 66 m, respectively. The motor-pumps were installed and the elevated water tanks were constructed in these two villages. The hand-pumps were installed in the other 18 wells.

7.1.2 Well completion

After drilling, well was completed by placing casings and screens, cementing, and gravel packing (**Figure 7.1.1**).

(1) Casing and screen

The casing for the motor-pump well was 6" diameter steel pipe (ASTM A-120), and that for the hand-pump well 4" diameter PVC pipe.

The standard screen used for the motor-pump well was the perforated casing with an opening ratio of 19% and a slot size of 3.17 mm to 8.89 mm (**Figure 7.1.2**). The total screen length was designed at 20 m, and the screen positions were set at different layers.

The standard screen used for the hand-pump well was a slit type PVC screen, with an opening ratio of 5% and a slot size of 3.2 mm (**Figure 7.1.3**). The total screen length was designed at 20 m, and screen positions were set at different layers.

(2) Gravel packing

The well in hard rock formation can be left open. The test drilling revealed that the formation is mostly composed of hard rock such as basalt and Jurassic sandstone and shale. However, it is partly unconsolidated or weathered and contains sand or mud in the fracture. Therefore, the well screen was gravel-packed in order to stabilize the aquifer, minimize sand pumping, and increase well yields. The grain size of the gravel was 4 mm to 5 mm.

(3) Backfilling and cementing

After completing the gravel-packing, the annular space outside the casing was backfilled by drill cuttings. In addition, within 5 m from the surface of the ground, cement grout is placed to avoid the entrance of surface water.

7.1.3 Pumping equipment

For the 18 test wells, the India MK III hand-pump were installed. This pump is being used not only in Laos but worldwide. The India MK III uses an open-top cylinder and a 2.5 inch galvanized pipe for the riser main, so that the piston can be withdrawn for maintenance without pulling out the riser main. Applicable range of static water level is from 5 m to 40 m. The cylinder setting ranges from 20 m to 50 m (**Figure 7.1.4-7.1.5**). The pumping rate depends on the static water level and aquifer transmissivity. However, as observed in the field, existing well equipped with India MK III in Champasak shows that 15 to 20 liters/min of discharge is generally possible.

For the other two test wells, the GRUNDFOS submersible motor pumps were installed. The capacity of the pump is as follows.

B. Houaxe	: Model SP5A-21, 3.0 Hp, 2.2 kw
	: Pumping capacity: 5 m^3/h
	: Head: 82 m
B. Beng	: Model SP14A-10, 5.0 Hp, 3.7 kw
	: Pumping capacity: 14 m^3/h
	: Head: 48 m

7.1.4 Other facilities

A reinforced concrete platform, a drain and a roof were constructed at each hand-pump well. The platform is 3 m x 3 m wide and 0.15 m thick. The drain is 10 m long with an inlet at the end for feeding livestock and watering garden. The hand-pump well is covered with roof to protect it from direct sunlight. The roof also symbolizes the well as the center of the community (**Figures 7.1.6** to **7.1.7**).

The elevated water tank and communal faucet were constructed at the motor-pump well. The tank system is composed of 6 fiber board water tanks and elevated to 3 m above the ground surface. The total storage capacity is 9 m^3. The communal faucet was built with two hydrants. It has a corrugated asbestos roof supported by wooden poles (**Figure 7.1.8-7.1.9**).

7.2 Operation and Maintenance

A survey was conducted to obtain data on operation and maintenance, and on community participation in the pilot water supply systems. **Table 7.2.1** summarizes the results of the survey. The survey sheets are included in the data report.

7.2.1 Pump operation

Almost all hand pumps are functioning normally and operated well, however, a hand pump in Ban Houn Tai stopped in May, 1995 because of clogging in the pump cylinder. The riser pipes were pulled out and the pump cylinder was cleaned up. The hydroxide sludge had accumulated and plugged the bottom of the cylinder. The sludge was formed by the oxidation of iron and manganese dissolved in groundwater. The same phenomenon was found at Ban Lak 21, however, there was no clogging of hand pump. Instead, reddish brown muddy water came out in May, 1995. The details of this phenomenon will be explained later.

The submersible pump installed in Ban Houaxe and Ban Beng were functioning well. However, in Ban Houaxe, the pump stopped due to a pipe valve damage caused by children. The pipe valve was repaired, and the water supply system resumed operation shortly. Another breakdown of the pump happened at Ban Beng in June, 1995. The riser pipe was disconnected at the coupling joint near the top and fell down to the bottom of the borehole. This may be caused by defects in the pipe materials used in the construction. After reinstallation of the riser pipes and submersible pump, the water supply system resumed operation.

Daily checking of the hand pump and cleaning of its environ were recommended by the Study Team, and a trial education of the village people on maintenance of the water supply system was conducted. However, village people are generally indifferent to those matters until the pump breakdown happens. When breakdown occurs, the village people just notify the district office. However, the pump is neither checked nor repaired because of lack of staff, knowledge, skills, materials and equipment.

7.2.2 Water quantity and quality

The test wells are being used mainly for drinking, cooking and washing except for those wells of inferior water quality. All test wells did not dry up, and except for the reduction of pumping rate at Ban Nongphai, Ban Lak 21 and Ban Hountai, most of them maintained a constant pumping rate even in the driest months of April and May.

The wells are being operated 13 to 18 hours a day intermittently from early morning to evening. Except for the said three villages, the pumping rate of the hand pump was 15 to 20 liters per minute. The pumping rate was 40 to 50 liters per minute in Ban Houaxe and Ban Beng, where the submersible pumps were installed.

Except for Ban Houaxe, Ban Lak 21 and Ban Houn Tai, the water quality is almost satisfactory and drinkable for all the villages. In Ban Houaxe, water is used for washing only because of its high salinity. However, the groundwater is effectively used for flushing toilet in the Houaxe Hospital, washing of clothes and bathing. In Ban Lak 21 and Ban Houn Tai, the groundwater

was not used for drinking, cooking and washing of clothes because of high iron and manganese contents.

7.2.3 Collection of water rates

In all villages, 200 kips per month is collected from families using the water supply system except for Ban Houaxe. Water charge or payment is collected by the village head every month. From March to May, 1995, the collection was normal, though several villages did not finish the collection in May. However, in Ban Nongkhe, which is located in the southern part of Champasak Province, no collection was made. People of this village refused to pay because they said that they can use existing wells free of charge.

In Ban Houaxe, the water rate is 40 kips/person/month, the number of users is 630, and 25,200 kips/month is being collected, although groundwater is salinized and can not be used for drinking. In addition, the Houaxe Hospital pays 2,000 kips/month because groundwater is now being used effectively to maintain sanitary condition. Before the supply of groundwater, the hospital's bathrooms and toilets were terribly dirty, but now they are much improved.

The power bills for the water supply system of Ban Houaxe were as follows:

February, 1995	36 kwh	680 kips
March	48 kwh	2,800 kips
April	370 kwh	6,860 kips

The power rates are as follows:

1 to 100 kwh	8 kips/kwh
100 to 300 kwh	15 kips/kwh
>300 kwh	25 kips/kwh

The power payments made by the village were higher than those calculated by the tariff because of the inclusion of some fees for the installation and/or miscellaneous items.

In Ban Beng, the number of users is 600. The water rate is 200 kips/family/month. The power consumptions and the power bills were as follows:

February, 1995	32 kwh	810 kips
March	94 kwh	1,300 kips
April	97 kwh	1,330 kips

Ban Beng's electricity consumption is less than that of Houaxe because of the difference in pump lifts or groundwater level drawdowns.

7.3 Water Collection and Use

7.3.1 Survey at five pilot facilities

An operation and maintenance survey was conducted after completion of the pilot water supply systems in five (5) selected villages. The five villages were selected considering the location, population, tribe, agricultural products, etc. as shown in **Table 7.3.1**.

Table 7.3.1 Selected Villages for Trial Operation and Maintenance Survey

Village Name Description	1 B. Phonphai	2 B. Houn-Tai	3 B. Beng	4 B. Samkhanaboua	5 B Lak-21
Province	Saravan	Saravan	Saravan	Champasak	Champasak
No. of Population	more than 1,000	500 - 1,000	500 - 1,000	500 - 1,000	less than 500
Tribe	Lao Lum	Lao Theung	Lao Theung	Lao Lum	Mix
Water Supply System	Hand-pump	Hand pump	Motor-pump	Hand-pump	Hand-pump
Hydrogeologic Unit	Ep	Ba1	Ba2	Ep	Ba1
Main Products	Paddy	Coffee, Upland Rice	Upland Rice	Paddy	Orchard, Upland Rice

B. Phonphai was chosen because of its large population. B. Houn-Tai and B. Beng were selected because most villagers are Lao Theung (Middle Lao) which have custom, way of living, culture different from Lao Lum in the other villages. B. Beng has a motor-pump well with an elevated water tank and a communal faucet while the other four villages have hand-pump wells.

The survey was conducted from 7 to 12 March, 1995. The detailed survey sheet is included in the data report. The survey results are summarized as follows.

After the completion of the water supply system, it seems to be operated smoothly without any serious problem. The village people pays little attention to the maintenance of the facility, such as daily cleaning of the surrounding area or the drain, daily checking of the hand-pump, etc. As long as the pump works well, people do not pay any attention to maintenance.

The hand-pump systems are being operated from early morning to late night in every villages. The number of water carriers is more twice a day: in the morning from 6 a.m. to 9 a.m. and in the early evening from 4 p.m. to 7 p.m. From 10 a.m. to 2 p.m., the number of water carriers is less. Usually the village people fetch water before and after going to work in the field, and they take a rest in the afternoon.

Most of the carriers are females, about 31% of the total in B. Beng and 74% in B. Phonphai. The percentage of water carrier by sex and age is shown in **Figures 7.3.1 - 7.3.5**. In B. Phonphai, B. Lak 21 and B. Samkhanaboua, the number of female carriers is twice that of male, while in B. Beng and B. Houn-Tai, the numbers of the female and male carriers are almost equal. Because in the latter two villages, the male takes shower at the pump site, then carries water to his home, while taking shower near the pump is prohibited in the former three villages.

In the case of B. Beng with a motor-pump well, it was observed that more water is lost than in the case of a village with a hand-pump well, because almost all villagers take their shower at the motor-pump site.

7.3.2 Comparison of water collection and use

(1) Surveyed villages

Essential informations such as the number of water collection trips, volume of water, etc. are important factors for planning of the water supply program. Ten (10) villages were surveyed for these informations (**Table 7.3.2**). To compare the water use of with and without the water supply system, six villages where the pilot water supply systems were constructed and four villages where water is taken from traditional water sources were selected.

Table 7.3.2 Ten selected villages and type of water source

No.	Village Name	Water Source
	Champasak Province	
1	Nongkhamkhao	River, shallow well, pond
2	Lak 24*	River, hand pump
3	Houakhoua	Hand pump, shallow well
4	Louy*	Hand pump, shallow well
5	Nongphai	Hand pump
	Saravan Province	
1	Chong*	River, Hand pump
2	Donmuang*	River, Hand pump
3	Beng*	Motor pump
4	Senvang-noy	River
5	That-noy	River

*Pilot water supply system.

(2) Method of survey

The survey was conducted as follows:

a) Prepare location maps of 10 selected villages and choose 10 families from each village as samples.

b) Record census data of each family, travel time for water collection, volume of water and its use.

c) Measure the distance from the family's house to the main water source.

A survey sheet is shown in **Table7.3.3,** and an example of the village map is shown in **Figure 7.3.6.**

(3) Results of survey

Most of the families think that the groundwater is more clean than other waters. They use it for domestic purposes, particularly for drinking, cooking, washing utensils and watering garden. Bathing and washing clothes are usually done in river or pond if such is a traditional water source. However, babies are cleaned and their clothes are washed usually at the hand-pump well site because water is more clean. The survey results are summarized as follows:

a) Cooking and drinking will consume about 30 liters of clean water/day/family.
b) Washing utensils will consume about 10 liters of clean water/day/family.
c) Each family stores about 10 liters of clean water/day in the house.
d) Watering garden of about 25 m^2 will consume about 80 litersof clean water/day.
e) Bathing babies will consume about 10 liters of clean water/day.
f) Washing clothes for babies will use about 20 liters of clean water/day.
g) In the 10 selected villages, very few families seem to use clean water for feeding their livestock.
h) For brewing and local whisky-making house industries, many families in B. Chong will use about 150 liters of clean water/week/family.

7.4 Water Quality Problems

7.4.1 Saline water in Ban Houaxe

The electric conductivity (EC) taken from Houaxe test well showed 5,850 μS/cm on June 8,1995. It has decreased from 10,000 μS/cm during well completion in February, 1995. However, it is still not drinkable and used only for bathing, washing clothes and utensils, etc. It is effectively used in the Houaxe Hospital for washing toilets and clothes, etc. The toilets before were very dirty, however, they are much improved now.

The water rate of 40 kips/person/month is being collected by the village head every month for the payment of electricity. The number of water users is 630. The hospital is also paying 2,000 kips/month. The electric charge in April, 1995 was 6,860 kips (370 kwh). It is therefore understood that the village people can afford to pay for the electricity, and that the well is being used effectively and maintained adequately.

In order to supply drinking water, the Study Team rehabilitated an existing well located some 500 m away from the hospital. The depth of the well is estimated to be 32 m. An India MKII hand pump which was installed in the well before had been broken, and the riser pipes and the pump cylinder had fell down to the bottom of the well. Also, the well had been plugged by bamboos and stones. These obstacles were removed and the riser pipes were pulled out. The well was developed by air lifting. A new India MK III, which was provided by the WES of

Champasak Province, was then installed. This well is now being used for drinking water the village people.

7.4.2 Turbid water in Ban Lak 21

When the Study Team visited Ban Lak 21 (C-49), the groundwater of the test well had reddish-brown turbid colour. Therefore, the hand-pump was dismantled, and the riser pipes were pulled out. Thick reddish brown hydroxide sludge adhered to the pump rods and riser pipes in which the water level fluctuates. The sludge was removed by washing. The pump rods and pipes were then reinstalled. The reddish brown colour had lightened just after the reinstallation. However, water became brownish after pumping for sometime.

The same phenomenon occurred in the test well at Ban Houn Tai (S-100). Water could not be pumped out because the cylinder valve was clogged with sludge. The pump rods and riser pipes were pulled out and reinstalled after cleaning.

The cause of the turbid water might be oxidization of iron (Fe) and manganese (Mn) dissolved in the groundwater. During the pumping test conducted in February, 1995, the groundwater was more clear although metallic in taste. A potential contaminant source of Fe and Mn is the red clay overlaying this area widely.

These two villages are located on the Basalt Slope of Bal, where the basaltic lava flows of Neogene to Quaternary age forms a productive aquifer. The basaltic lava flow is widely covered by a thick red clay as mentioned above. On the other hand, another three test wells drilled in the Basalt Slope of Ba2 and Ba3, i.e., Ban Beng (S-84), Ban Thongsala (C-44) and Ban Chong (S-56), have no problem in water quality at present. In Ba2 and Ba3, the aquifer is also composed of lava flow, however, the overlying red soil is thin or lacking. The water quality of these three test wells are clean and drinkable.

However, water quality analysis of water samples from B. Lak 21 and B. Houn-Tai revealed the presence of iron bacteria in groundwater. The Study Team made a simple sand filter using drums. A treated sample was collected and analyzed together with untreated water samples from B. Lak 21 and B. Houn-Tai. The results of laboratory analysis are as follows:

Sample Name	Iron (mg/l)	Manganese (mg/l)	Iron bacteria (MPN/mg)*
B. Hountai	33	0.05	1,100
B. Lak 21 - untreated	21	0.21	790
B. Lak 21 - after filter	0.18	0.05	49

*MPN: Most Probable Number

Based on the water quality analysis conducted during well completion, iron concentrations were 0.07 mg/l in B. Houn-Tai and 0.02 mg/l B. Lak 21. (Refer to Chapter 6). The result indicates that in the process of oxidation, ferrous ions have changed to ferric ions by iron bacteria, accumulating ferric hydroxide.

The original source of iron bacteria is generally not known. In some cases, the bacteria are already in the groundwater before the wells are drilled. Also, bacteria may be introduced to the wells by drilling operations.

On the basis of the above observations, the following suggestions were made:

(1) Take great care to avoid introducing iron bacteria into the well during drilling works. All drilling fluid mix water and equipment should be chlorinated.

(2) Seal the red soil by cementing the annular space outside the casing to protect from intrusion of possible contaminant source of Fe and Mn.

(3) Set the screen position as deep as possible in weakly weathered or fresh basaltic lava.

(4) Use of aeration and sand filter.

(5) Periodic cleaning of the pump, riser pipes and screens using chlorinated water. Jetting or air-lift pumping should be conducted to agitate the well (every six months may be required).

7.5 Trial Education at the Village

The success of village water supply system depends on proper attention to the six key elements of the whole system: the community, the aquifer, the well, the maintenance system, the pump and the finance. Among these elements, the maintenance system and the pump are particularly important after the hand pump installation. The present Study formulates a groundwater-based rural water supply program. For the safety and sustainability of water supply system, an education program reflecting the concept of Village Level Operation and Maintenance (VLOM) was prepared for the villagers.

7.5.1 VLOM concept

According to UNDP/WORLD BANK (1987), experience of people engaged in rural water supply programmes all over the world showed that a central maintenance system, requiring a motor vehicle and crew to move out from a base camp, is unable to keep pumps in satisfactory condition. However, a village-level maintenance is feasible if the pump is specifically designed.

- Easily maintained by a villager-caretaker, requiring minimal skills and few tools
- Manufactured in-country, primarily to ensure the availability of spare parts
- Robust and reliable under field conditions
- Cost effective

The pump introduced in the program is India Mark III (VLOM) since this pump is used in Laos as well as in other countries. Villagers to be educated were village caretakers or candidates. Women were involved in the program.

7.5.2 Scope of trial education

The trial education program for the maintenance of the water supply system is prepared for the villagers. Construction of water supply system, particularly initial pump installation, was not explained in the program. General maintenance, overhaul and repairs due to breakdown were also excluded from the program. These activities are to be conducted by the maintenance team belonging to the PHD.

The Study Team carried out a trial education at five villages using a text book. The text book was presented in Lao version in a separate volume. The contents of the book are as follows:

a) Maintenance Policy and Organization
b) Keep Pump Environs Clean
c) Daily Checking of Pump
d) Replacing Spares for Pump Head
e) Replacing Spares for Valve Unit
f) Method of Valve and Riser Pipe Test
g) Village Mechanic Tool

7.5.3 Result of trial education

During the Trial Education Program, villagers seem to understand daily maintenance, such as cleaning of well environs and greasing of pump head. They may understand the methods of dismantling the pump head, extracting pump rods in case of minor trouble, and repairing them. The India MK III hand-pump is designed as VLOM. However, some experience and skills are still needed for the caretakers to repair the hand pump by themselves. Village mechanic tool is also necessary and must always be stored in the village.

In case of serious damage, villagers are requested to inform the District Water Supply Section (DWSS) for the repair of the hand pump. Presently, DWSS does not have any staff, equipment or materials. They have to ask assistance from the Provincial Water Supply Service which is more capable in terms of qualified staff and equipment.

Aside from the education, almost all villagers requested the following matters:

1) More hand-pump well for their use.
2) The surrounding area should be lined with concrete not only the platform.
3) Bathing and washing place with drain should be provided near the pump.

7.6 Considerations for WID

In consideration of the WID, a survey on women's activities in the rural community was conducted to obtain basic data on their role in the rural water supply program. A total of 10 villages was selected from the 20 villages where the test wells and the pilot water supply systems were constructed in Champasak and Saravan Provinces (**Table 7.6.1**). A total of 100 women were interviewed using a questionnaire.

Most of the families in the Study Area are engaged in agriculture such as rice cultivation. In general, women in rural areas are actively involved in every stage of agricultural production. In addition, domestic activities, such as collecting water, washing, cooking and taking care of children, etc., constitute essential parts of the work of women. These activities of women are unproductive in the Study Area, and their working conditions have to be improved in order to achieve a better life and to raise their status.

Table 7.6.2 summarizes the results of the survey. It shows that farming is performed by both men and women. The most heavy and dangerous tasks such as clearing grass and trees in the forest and preparing ricefields are traditionally done by men. Weeding of the ricefields is usually done by women.

Other productive activities such as gardening, planting fruit trees and raising pigs and poultry are performed by female members of the family. Also the daily tasks of cooking, collecting water, cleaning the house and washing clothes and utensils, are the responsibilities of women.

The survey showed that the average number of women's working hours for farm and domestic activities is 11.48 hours/day in Champasak and 11.38 hours/day in Saravan.

After the installation of water supply systems, the burden of woman to arrange clean water for her family has been alleviated rapidly in both provinces.

In Champasak, the average distance to water source before the installation of JICA's water supply system is 494 m. But after installation, distance is reduced to only 72 m. In Saravan, the distance is reduced from 1,025 m to 114 m, which is quite satisfactory.

Before the installation, women in Champasak have to spend an average of about 4.29 hours/day to collect enough water for their family. But after the installation, the average is remarkably reduced to only 1.01 hours/day. Meanwhile, this average has been reduced from 3.37 hours/day to 1.09 hours/day in Saravan.

Almost all women are using the time savings provided by the new water supply system to productive activities such as farming and handicraft.

Ninety two (92) women think that the water rate (220 kips/month) has no effect on their household expense, but the rest feel that it is expensive and should be reduced to about 50 kips/month.

On the question about their request for a JICA's water supply system, almost all women were satisfied with every aspect of the system such as the design, pump house, water quality and quantity, etc. Only four women recommended that the roof of the pump house be built more bigger to keep the platform clean during the rainy season and also to protect them from sun and rain.

Almost all women are willing to participate in the operation and maintenance works of the water supply system. However, the participation is limited only to the cleaning of well environs, etc. Nobody volunteers as a technical caretaker of the water supply system or as an accountant. Since the accountant has to collect money every month, she has to visit all the families in the village. Some of the families may refuse or delay the payment, and such matters are too troublesome for the women.

Table 7.1.1 Location and Depth of the Well

Village No.	Village Name	Well Depth (Planning)	Wel Depth (Casing length)	Drill. Depth
1. C-4	B.Nongphai	50 m	49 m	50 m
2. C-8	B.Houaxe	100 m	180 m	182 m
3. C-16	B.Louy	50 m	48 m	48 m
4. C-44	B.Thongsala	50 m	25 m	43 m
5. C-49	B.Lak-21	50 m	45 m	60 m
6. C-65	B.Lak-24	50 m	49 m	50 m
7. C-75	B.Nongkhe	50 m	50 m	50 m
8. C-79	B.Samkhanaboua	50 m	43 m	45 m
9. C-88	B.Maisivilai	50 m	50 m	50 m
10. C-89	B.Nasenphan	50 m	50 m	50 m
11. S-4	B.Houaykapho	50 m	42 m	45 m
12. S-12	B.Nongsano	50 m	50 m	50 m
13. S-24	B.Donmuang	50 m	50 m	50 m
14. S-39	B.Nongngog	50 m	49 m	50 m
15. S-50	B.Samia	50 m	49.5 m	50 m
16. S-56	B.Chong	50 m	49 m	50 m
17. S-64	B.Phonphai	50 m	50 m	50 m
18. S-75	B.Nakasao	50 m	50 m	53 m
19. S-84	B.Beng	100 m	60 m	66 m
20. S-100	B.Houn-Tai	50 m	52 m	54 m
Total	1100 m	1090.5 m	1146 m	

Table 7.2.1 **Status of Operation and Maintenance in the Test Wells**

Survey on June,1995

No.	Name of Village	Number of Users	Depth of Well (m)	Type of Pump	Water Quality	Time of Operation (hours)	Water Rates (kip/family/month)	Status of Collection (Mar.-May)	Well Environs
C-4	Nongphai	557	50	India.MK3	Good	15	200	Collected	clean
C-8	Houaxe	630	180	Submersible	Salty	15	40*	May, not yet	clean
C-16	Louy	150	48	India MK3	Good	16	200	Collected	clean
C-44	Thongsala	383	43	India MK3	Good	15	200	Collected	clean
C-49	Lak 21	562	45	India MK3	Bad (Fe,Mn)	15	200	Apr. not yet	clean
C-65	Lak 24	445	49	India MK3	Good	17	200	Collected	clean
C-75	Nongkhe	54	50	India MK3	Good	13	not collected	-	clean
C-79	Samkhanabua	631	43	India MK3	Good	15	200	May, not yet	clean
C-88	Maisivilai	300	50	India MK3	Good	16	200	May, not yet	clean
C-89	Nasenphan	176	50	India MK3	Good	16	200	Collected	clean
S-4	Houaykapho	613	42	India MK3	Good	18	200	Collected	clean
S-12	Nongsano	235	50	India MK3	Good	16	200	Collected	clean
S-24	Donmuang	410	50	India MK3	Good	13	200	May, not yet	clean
S-39	Nongnong	478	49	India MK3	Good	15	200	May,not yet	clean
S-50	Samia	308	49.5	India MK3	Good	14	200	Collected	clean
S-56	Chong	191	49	India MK3	Good	14	200	Collected	clean
S-64	Phonphai	1071	50	India MK3	Good	15	200	Collected	clean
S-75	Nakasao	725	50	India MK3	Good	15	200	Collected	clean
S-84	Beng	600	60	Submersible	Good	14	100	May,not yet	clean
S-100	Houn Tai	450	52	India MK3	Bad (Fe,Mn)	15	200	Collected	clean

*kip/person/month

Table 7.3.3.(1) Result of Water Use Survey Selection 5 Villages in Saravan Province

Village BENG (P)
Enumerator VILAI
Weather CLEAR

Source Observed Mr. VILAI (Village Chief)
Date. 23. June. 1995.

HOUSEHOLD CENSUS

NO	Name of Household head	No in Household	HOUSEHOLD COMPOSITION 0 tol2 Years	13 to60 Years	Over to60	Water Source	DISTANCE TO WATER SOURCE Old (m)	New (m)	INDICES OF Wealth's Paddy(ha)	Livestock's	Up-Land	Remarks
1	VILAI	6	4	2	0	H. Soun	1,100	12	0.2	B-0. C-4	Rice 0.7ha	Farming
2	SAOSOK	4	0	4	0	H. Soun	1,000	160	0	B-0. C-2	Rice 2ha	Farming
3	NHOU	5	3	2	0	H. Soun	700	350	0.2	B-0. C-3	Rice 1ha	Farming
4	TAO TEAN	6	0	6	0	H. Soun	800	120	0	B-0. C-2	Rice 0.5ha	Farming
5	TAO CHIT	4	2	2	0	H. Soun	900	85	0	B-0. C-0	Rice 1ha	Farming
6	TAO SAVAN	4	2	2	0	H. Thong	350	280	0	B-0. C-7	0	Teacher
7	DOM	5	3	2	0	H. Thong	300	550	0	B-0. C-0	Rice 0.5ha	Farming
8	KO	7	4	3	0	H. Thong	500	350	0	B-0. C-5	Rice 2ha	Farming
9	BOULEUT	3	1	2	0	H. Thong	450	440	0	B-1. C-5	Rice 1ha	Farming
10	POUI	6	3	3	0	H. Soun	900	560	0.3	B-0. C-0	Rice 1ha	Farming

C : Number of Cattle

B : Number of Water Buffalo

Table 7.3.3.(2) Result of Water Use Survey Selection 10 Families in Village

Interview for each 10 Users

Survey date 27. June. 1995.

Village Name BENG (P)	1	2	3	4	5	6	7	8	9	10	
Name of Selected House head	VILAI	SAOSOK	NHOU	TAO TEAN	TAO CHIT	TAO SAVAN	DOM	KO	BOULEUT	POUI	subtotal
Water stored last night (A)	10	10	25	10	10	15	15	15	15	20	145
Drinking unboiled (yes or no)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	
[MORNING]											
1) Cooking and Tea	15	10	15	10	15	10	15	10	15	15	130
2) Washing food and utensils	10	10	10	10	10	10	10	10	10	5	95
3) Personal Washing	40	40	40	60	40	40	40	40	40	60	440
4) Washing clothes	20	20	0	0	20	0	0	20	20	40	140
5) Garden watering	0	40	80	80	60	40	80	20	60	0	460
6) Livestock	0	0	0	0	0	0	0	0	0	0	0
7) Brewing and industry	0	0	0	0	0	150	0	0	0	60	210
Sub TOTAL (B)	85	120	145	160	145	250	145	100	145	180	1475
Water collected in morning	40	80	170	170	20	20	20	40	40	20	620
Water stored in morning (C)	10	10	25	10	10	15	15	15	15	20	145
CHECK: (A + B) - C = TOTAL	85	120	145	160	145	250	145	100	145	180	1475
[AFTERNOON]											
1) Cooking and Tea	15	10	15	10	15	10	15	10	15	15	130
2) Washing food and utensils	10	10	10	10	10	5	10	10	10	10	95
3) Personal Washing	60	40	50	60	40	40	50	70	30	60	500
4) Washing clothes	0	0	0	0	0	0	0	20	20	0	40
5) Garden watering	0	40	80	80	60	40	80	20	60	0	460
6) Livestock	0	0	0	0	0	0	0	0	0	0	0
7) Brewing and industry	0	0	0	0	0	0	0	0	0	0	0
Sub Total (D)	85	100	155	160	125	95	155	130	135	85	1225
Water collected during day	80	160	320	320	50	60	50	100	100	80	1320
Water stared in evening (E)	20	20	30	20	20	20	20	20	20	20	210
CHECK: (C + D) - E = TOTAL	75	90	150	150	115	90	150	125	130	85	1160
Clothes washed at source ?	PUMP	PUMP	PUMP	PUMP	PUMP	PUMP	PUMP	PUMP	PUMP	PUMP	
Personal washing at source ?	PUMP	PUMP	PUMP	PUMP	PUMP	PUMP	PUMP	PUMP	PUMP	PUMP	

Table 7.3.3.(3) Result of Water Collection Survey in Selected Each 10 Families

Village Name BENG
Name of Source observed VILAY
Kind of Water Source (Electrical PUMP)

Times between which observed
Survey Date . 27. June. 1995

Pumping Volume and Time

Name of House	VILAY	SAOSOK	NHOU	TAO TEAN	TAO CHIT	TAO SAVAN	DOM	KO	BOULEUT	POUI	Remark's
1) Collect time	5.00	6.20	5.50	5.40	5.00	5.10	5.30	5.30	6.20	5.50	* Pumping
Collector	WOMAN	GIRL	GIRL	GIRL	WOMAN	WOMAN	WOMAN	GIRL	GIRL	WOMAN	Volume
Amount (Liter)	20	20	20	20	20	20	20	20	20	20	(Liter/time)
2) Collect time	7.10	7.30	9.30	7.30	0.00	0.00	0.00	9.30	8.30	0.00	** PM
Collector	WOMAN	GIRL	GIRL	GIRL				GIRL	GIRL		After
Amount (Liter)	20	60	150	150				20	20		Midday
	PM	PM	PM	PM	PM	PM	PM	PM	PM	PM	
3) Collect time	4.00	5.00	5.00	5.30	5.45	4.30	5.10	5.45	5.50	6.20	
Collector	WOMAN	GIRL	GIRL	GIRL	GIRL	GIRL	GIRL	GIRL	GIRL	GIRL	
Amount (Liter)	40	80	150	150	30	40	30	60	60	60	
4) Collect time	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Collector											
Amount (Liter)											
5) Collect time											
Collector											
Amount (Liter)											
6) Collect time											
Collector											
Amount (Liter)											
AMOUNT (Liter/day)	80	160	320	320	50	60	50	100	100	80	

Table 7.3.3.(4) Result of Water Collection Survey in Selected 10 Families

Village Name BENG
Name of Source observed Mr. VILAY
Kind of Water Source (Electrical PUMP)

Times between which observed
Survey Date 28. June. 1995.

Pumping Volume and Time

Name of House	VILAY	SAOSOK	NHOU	TAO TEAN	TAO CHIT	TAO SAVAN	DOM	KO	BOULEUT	POUI	Remarks
AM											
1) Collect time	5.30	6.20	6.20	5.40	5.00	6.30	6.10	6.20	6.20	6.30	
Collector	WOMAN	GIRL	GIRL	GIRL	WOMEN	GIRL	GIRL	GIRL	MEN	GIRL	
Amount (Liter)	20	30	30	20	20	20	20	20	20	20	
2) Collect time		9.00	10.00	8.00		9.00	9.10	8.10			
Collector		WOMEN	GIRL	GIRL		MEN	GIRL	MEN			
Amount (Liter)		60	150	150		20	20	20			
	PM	PM	PM	PM	PM	PM	PM	PM	PM	PM	
3) Collect time	5.00	5.10	4.30	5.30	5.45	4.30	5.10	5.45	5.50	6.10	
Collector	GIRL	GIRL	GIRL	GIRL	GIRL	GIRL	GIRL	GIRL	GIRL	GIRL	
Amount (Liter)	40	80	150	150	30	40	30	60	60	60	
4) Collect time	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Collector											
Amount (Liter)											
5) Collect time											
Collector											
Amount (Liter)											
6) Collect time											
Collector											
Amount (Liter)											
AMOUNT (Liter/day)	60	170	330	320	50	80	70	100	80	80	

Table 7.6.2 Results of Woman in Development in Champasak Province

No.	Name of Interviewee	Village Name	Working Hours	Water Collect Trip		Distance (m)		Time (Hours)	
				Before	After	Before	After	Before	After
1	Mrs.Toey	Thongsala	9.5	2	3	1,000	100	2.0	0.5
2	Mrs.Tim	Thongsala	12.5	2	2	1,000	100	2.0	0.5
3	Mrs.Suk	Thongsala	11.0	3	3	1,000	150	2.5	1.0
4	Mrs.Bai	Thongsala	11.0	3	3	1,000	150	2.5	1.0
5	Mrs.Champa	Thongsala	7.5	4	3	1,000	100	3.0	0.5
6	Mrs.Chiwai	Thongsala	12.5	2	2	1,000	50	3.0	0.5
7	Mrs.Som	Thongsala	11.5	2	2	1,000	100	2.0	0.5
8	Mrs.Bualean	Thongsala	9.5	2	3	1,000	100	2.0	0.5
9	Mrs.Von	Thongsala	11.5	2	3	1,000	100	3.0	0.5
10	Mrs.Phom	Thongsala	10.5	3	3	1,000	150	3.0	1.0
11	Mrs.Na	Louy	11.5	10	5	1,000	100	6.0	1.0
12	Mrs.Kai	Louy	10.0	4	3	600	100	4.0	1.0
13	Mrs.Sudjai	Louy	12.5	5	3	800	100	5.0	1.5
14	Mrs.Thongmee	Louy	11.5	10	5	1,000	100	10.0	1.0
15	Mrs.Tum	Louy	10.0	6	4	1,000	100	4.0	1.0
16	Miss Udorn	Louy	12.5	10	5	1,000	100	6.0	1.0
17	Mrs.Boonkong	Louy	12.0	10	5	800	50	10.0	1.0
18	Mrs.Chantha	Louy	11.0	10	5	1,000	100	10.0	1.0
19	Mrs.Sai	Louy	7.5	2	2	1,000	100	10.0	1.0
20	Mrs.Si	Louy	11.0	3	2	1,000	100	3.0	1.0
21	Mrs.Korn	Lak 24	10.5	2	2	150	50	1.0	0.5
22	Mrs.Suk	Lak 24	10.0	6	6	150	50	3.0	1.0
23	Mrs.Khon	Lak 24	11.0	3	3	150	50	1.5	1.0
24	Mrs.Ma	Lak 24	11.0	3	3	100	50	1.5	1.0
25	Mrs.Ta	Lak 24	11.5	4	4	130	80	2.0	2.0
26	Mrs.Sumontha	Lak 24	11.5	3	3	80	50	1.5	1.0
27	Mrs.Na	Lak 24	11.0	3	3	130	50	1.5	1.0
28	Mrs.Khai	Lak 24	11.0	3	3	70	50	1.5	1.0
29	Mrs.Mai	Lak 24	11.0	3	3	80	50	1.5	1.0
30	Mrs.Ron	Lak 24	11.0	3	3	130	50	1.5	1.0
31	Mrs.Srivon	Samkhanaboua	12.5	4	3	150	50	4.0	1.5
32	Mrs.Tui	Samkhanaboua	12.0	5	3	150	50	3.0	1.0
33	Mrs.Vandee	Samkhanaboua	13.5	3	3	150	50	3.0	1.5
34	Mrs.Nang	Samkhanaboua	12.0	4	3	150	50	2.0	1.0
35	Mrs.Pae	Samkhanaboua	12.0	4	3	150	50	2.0	1.0
36	Mrs.Sangvon	Samkhanaboua	12.0	4	3	200	70	2.0	1.0
37	Mrs.Chanpeng	Samkhanaboua	10.0	3	3	200	50	3.0	1.5
38	Miss Khan	Samkhanaboua	14.0	3	3	150	50	3.0	1.5
39	Mrs.Thongvian	Samkhanaboua	12.5	4	3	250	50	4.0	1.5
40	Miss Touy	Samkhanaboua	12.5	4	3	150	50	4.0	1.5
41	Mrs.Tee	Nasenphan	12.0	7	10	300	50	8.0	1.0
42	Mrs.Sue	Nasenphan	13.0	3	3	200	50	6.0	1.0
43	Mrs.Luang	Nasenphan	12.5	3	3	250	50	7.0	1.0
44	Mrs.Nang	Nasenphan	13.5	4	6	200	50	8.0	1.0
45	Mrs.Phone	Nasenphan	13.0	4	3	200	50	8.0	1.0
46	Mrs.Pui	Nasenphan	13.0	3	4	200	50	6.0	1.0
47	Mrs.Kan	Nasenphan	14.5	6	10	200	50	8.0	1.0
48	Mrs.phan	Nasenphan	12.5	3	4	250	50	6.0	1.0
49	Mrs.Vong	Nasenphan	11.0	4	3	200	50	8.0	1.0
50	Mrs.Yueng	Nasenphan	10.0	4	3	200	50	10.0	1.0
	Total		574.0	207	178	24,270	3,600	214.5	50.5
	Average		11.48	4.14	3.56	494	72	4.29	1.01

Table 7.6.3 Results of Woman in Development in Saravan Province

No.	Name of Interviewee	Village Name	Working Hours	Water Collect Trip		Distance (m)		Time (Hours)	
				Before	After	Before	After	Before	After
1	Mrs.Moem	Nongngo	14.0	3	5	2,000	300	6.00	2.50
2	Mrs.Pai	Nongngo	11.5	5	3	2,000	250	6.00	1.50
3	Mrs.Dou	Nongngo	13.0	3	4	2,000	250	6.00	2.00
4	Mrs.Boun	Nongngo	11.0	8	5	2,000	200	8.00	2.50
5	Mrs.Tou	Nongngo	12.0	6	4	2,000	200	6.00	2.50
6	Mrs.Buakham	Nongngo	11.5	6	3	1,500	150	5.00	1.50
7	Mrs.Kang	Nongngo	13.5	5	3	2,000	150	5.00	1.50
8	Mrs.Thongwon	Nongngo	13.5	6	3	2,000	250	6.00	1.50
9	Mrs.Khaew	Nongngo	11.5	5	3	2,000	200	7.00	1.50
10	Mrs.Toui	Nongngo	14.0	6	4	2,000	250	10.00	2.00
11	Mrs.Kaew	Chong	10.0	3	2	500	100	2.00	1.00
12	Mrs.Don	Chong	10.5	3	4	500	100	3.00	1.00
13	Mrs.Noy	Chong	10.0	3	4	500	100	2.00	1.00
14	Mrs.Thong	Chong	5.0	3	2	1,000	70	6.00	1.00
15	Mrs.Bounmi	Chong	10.0	3	2	800	100	4.00	1.00
16	Mrs.Won	Chong	10.0	3	2	1,000	100	4.00	1.00
17	Mrs.Kham	Chong	10.0	3	2	800	100	3.00	1.00
18	Mrs.Sa	Chong	10.0	3	2	1,000	100	3.00	1.00
19	Mrs.Tum	Chong	10.0	3	2	1,000	100	3.00	1.00
20	Mrs.Ni	Chong	12.0	3	2	500	100	2.00	1.00
21	Mrs.Ta	Nongsano	12.0	2	2	80	50	1.00	1.00
22	Mrs.Sudjai	Nongsano	12.5	2	2	50	50	1.00	1.00
23	Mrs.Sripai	Nongsano	13.0	3	3	200	50	1.00	0.50
24	Mrs.Pae	Nongsano	12.5	3	3	200	50	1.00	0.50
25	Mrs.Aui	Nongsano	12.5	3	3	250	50	1.50	1.00
26	Mrs.Air	Nongsano	12.5	3	3	300	50	1.50	0.50
27	Mrs.Noi	Nongsano	12.0	2	2	150	50	1.00	1.00
28	Miss Tun	Nongsano	12.0	2	2	150	50	1.00	1.00
29	Mrs. Van	Nongsano	12.0	2	2	100	50	1.00	1.00
30	Mrs.Thoum	Nongsano	12.0	2	2	100	50	1.00	1.00
31	Mrs.Khan	Beng	10.5	3	2	1,000	50	2.50	0.50
32	Mrs.Khambai	Beng	11.5	1	1	1,000	70	2.00	0.50
33	Mrs.Sabai	Beng	10.0	3	3	1,500	150	5.00	1.00
34	Mrs.Van	Beng	11.0	3	1	1,500	150	3.00	1.00
35	Mrs.Knai	Beng	13.5	2	1	1,500	50	1.50	0.50
36	Mrs.Ta	Beng	10.5	3	2	1,500	50	2.00	0.50
37	Mrs.Lok	Beng	10.5	3	3	1,500	150	6.00	1.00
38	Mrs.Saosuen	Beng	9.5	2	1	1,000	50	2.00	1.00
39	Mrs.Tim	Beng	10.5	2	3	1,500	100	5.00	1.00
40	Mrs.Sai	Beng	10.5	3	2	1,200	150	4.00	1.00
41	Mrs.Aue	Hountai	11.0	2	1	500	100	2.00	0.50
42	Mrs.Van	Hountai	9.5	3	2	1,000	100	3.00	1.00
43	Mrs.Manee	Hountai	12.0	3	2	1,000	100	3.00	1.00
44	Mrs.Maneeon	Hountai	11.0	3	3	1,000	100	3.00	1.00
45	Mrs.Miang	Hountai	11.0	3	3	1,000	100	3.00	1.00
46	Miss Phom	Hountai	11.0	3	3	800	100	2.50	1.00
47	Mrs.Mue	Hountai	12.0	2	3	1,000	70	3.00	1.00
48	Mrs.Thongpan	Hountai	12.0	3	2	1,000	150	3.00	1.00
49	Mrs.Song	Hountai	13.0	2	2	1,500	150	3.00	1.00
50	Mrs.Tim	Hountai	12.5	3	2	600	100	2.00	0.50
	Total		569.0	159	127	51,280	5,710	168.50	54.50
	Average		11.38	3.18	2.54	1,026	114	3.37	1.09

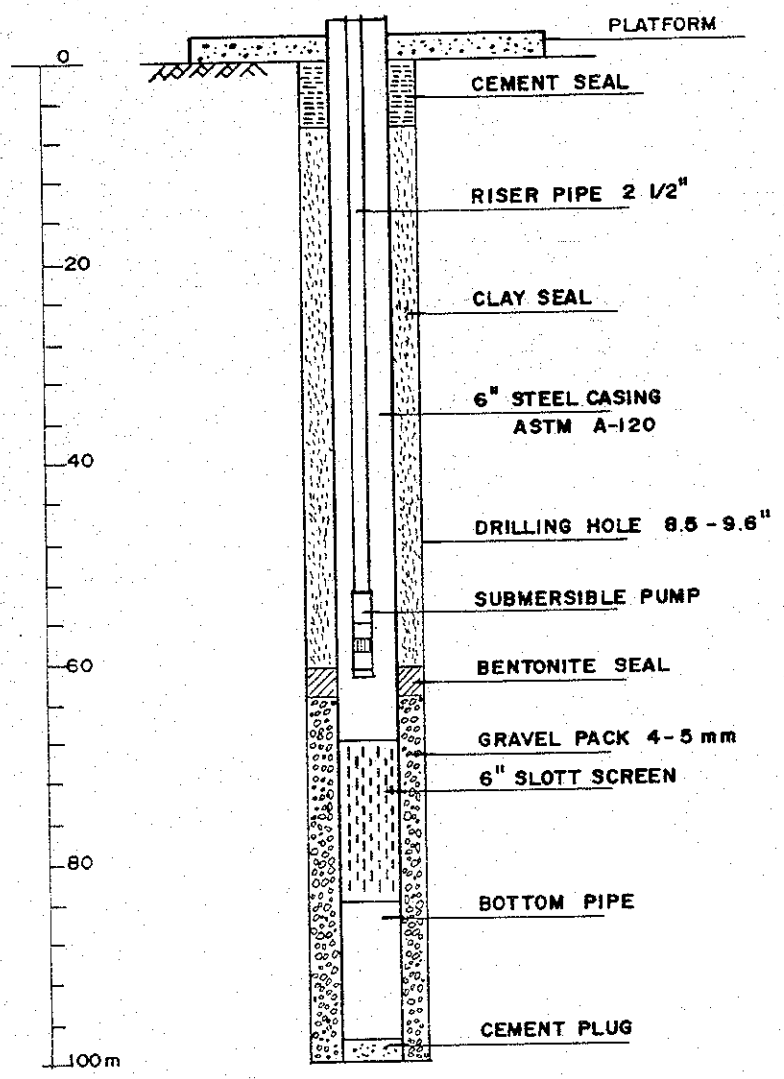
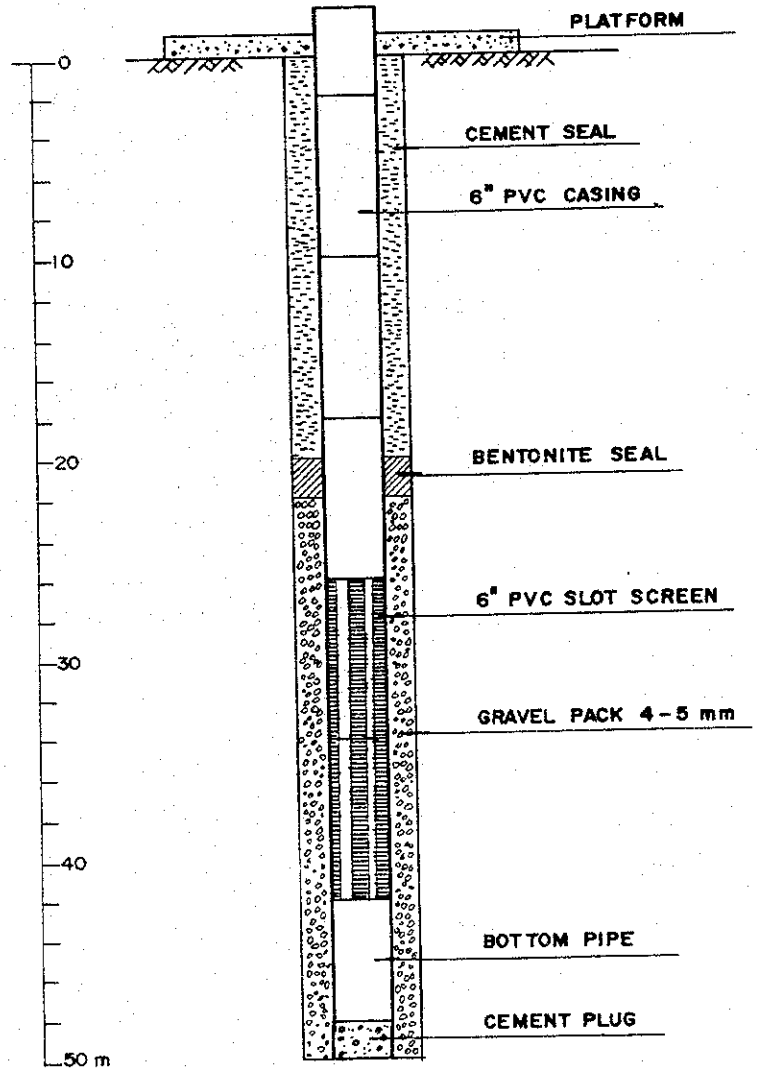
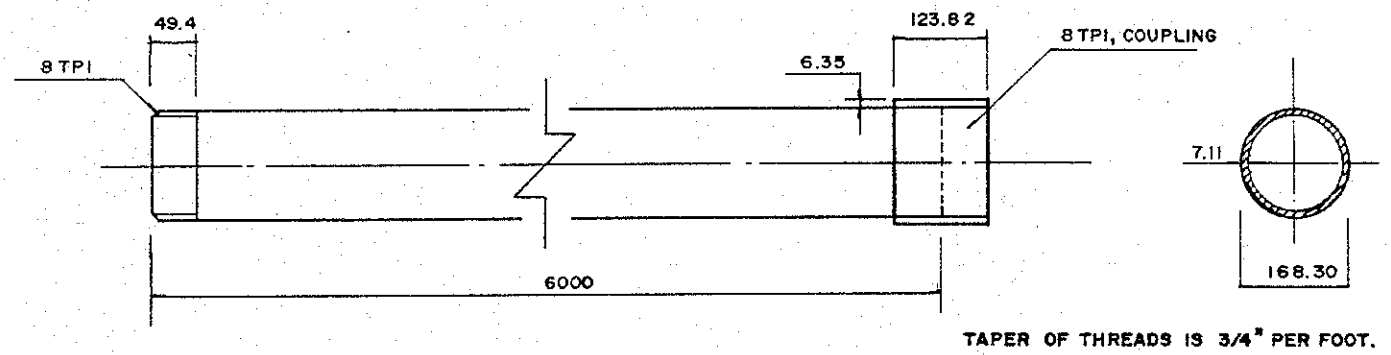


Figure 7.1.1 **TYPICAL SUBMERSIBLE PUMP WELL**

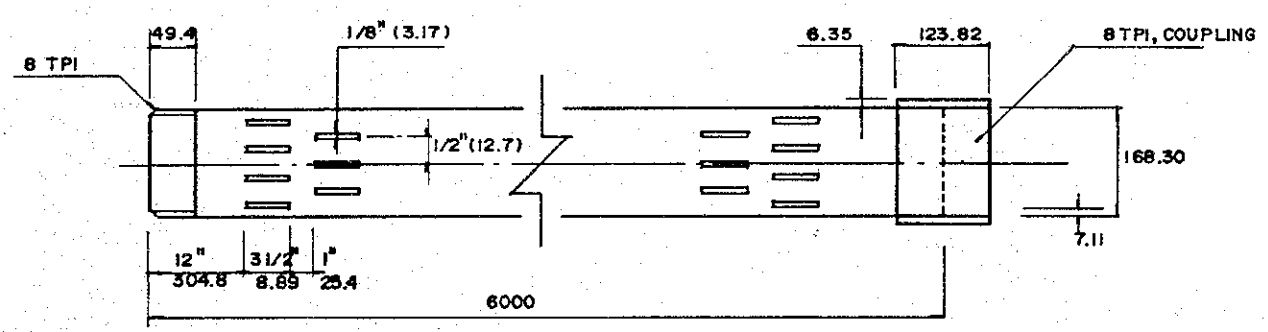


TYPICAL HAND PUMP WELL



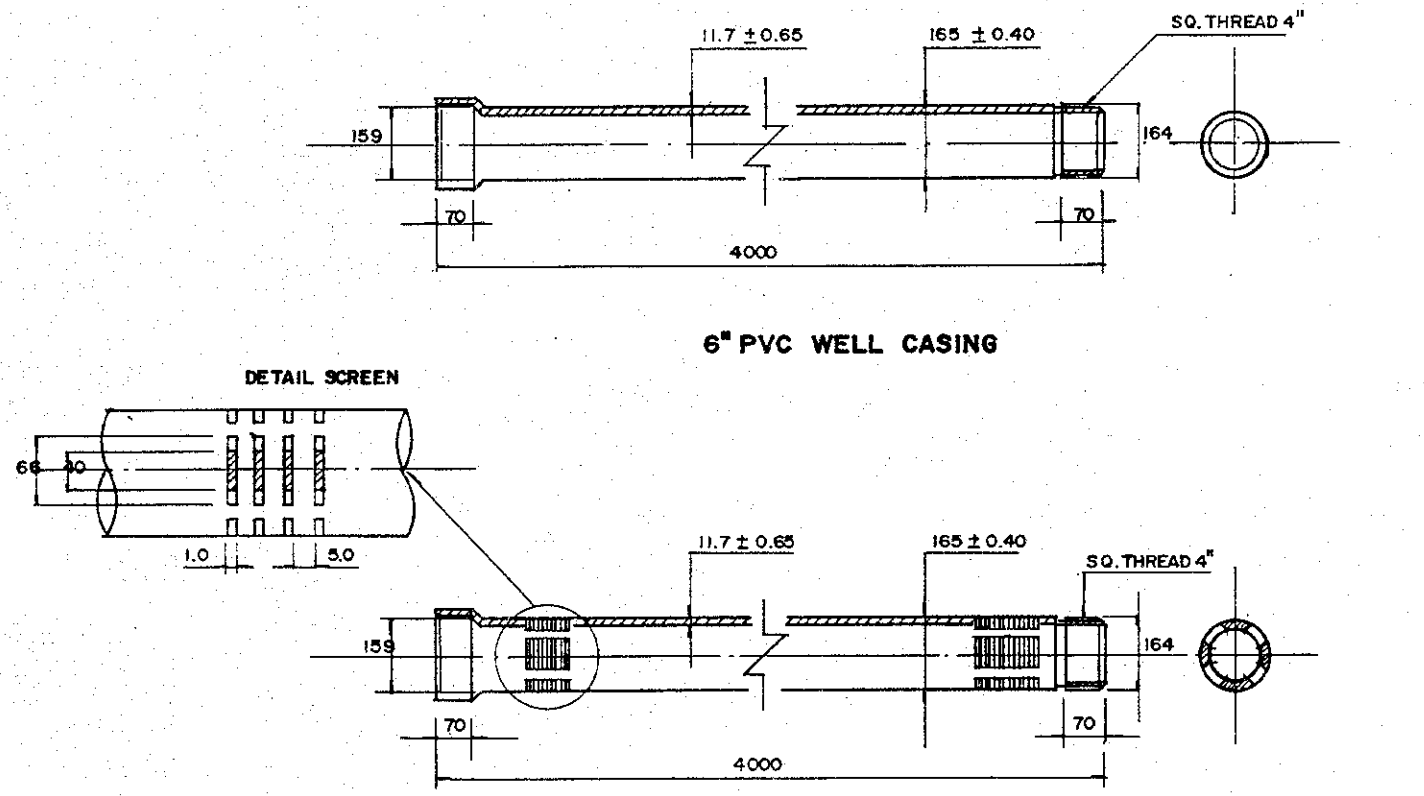
TAPER OF THREADS IS 3/4" PER FOOT.

6" STEEL CASING ASTM A-120



OPENING AREA IS 19% OF SURFACE AREA.
TAPER OF THREADS IS 3/4" PER FOOT.

Figure 7.1.2 6" Slott Screen ASTM A-120



OPENING AREA ON INTERNAL SURFACE : 5 %

Figure 7.1.3 6" PVC Well Screen

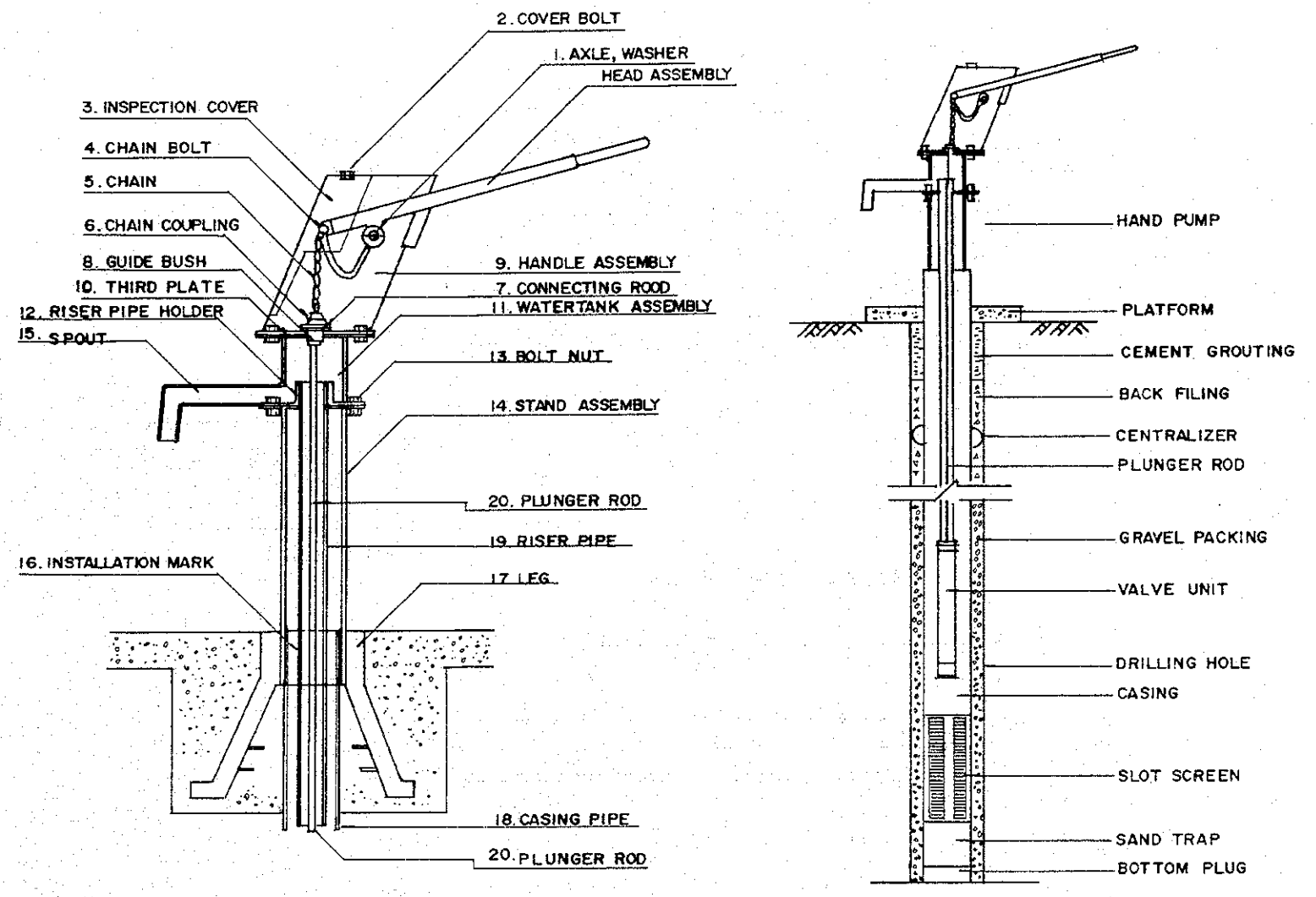


Figure 7.1.4

INDIA MARK III HANDPUMP

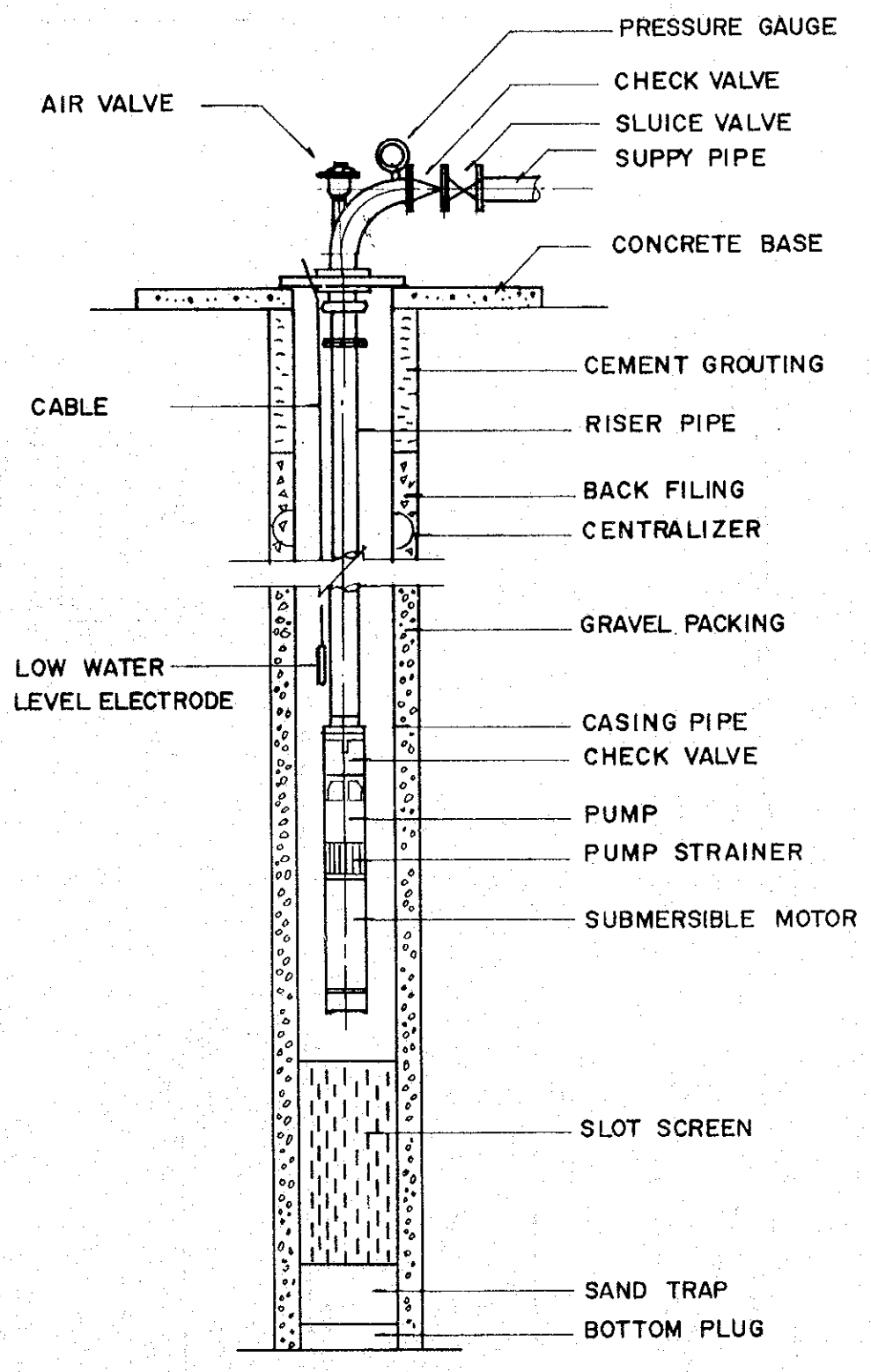


Figure 7.1.5

SUBMERSIBLE PUMP WELL

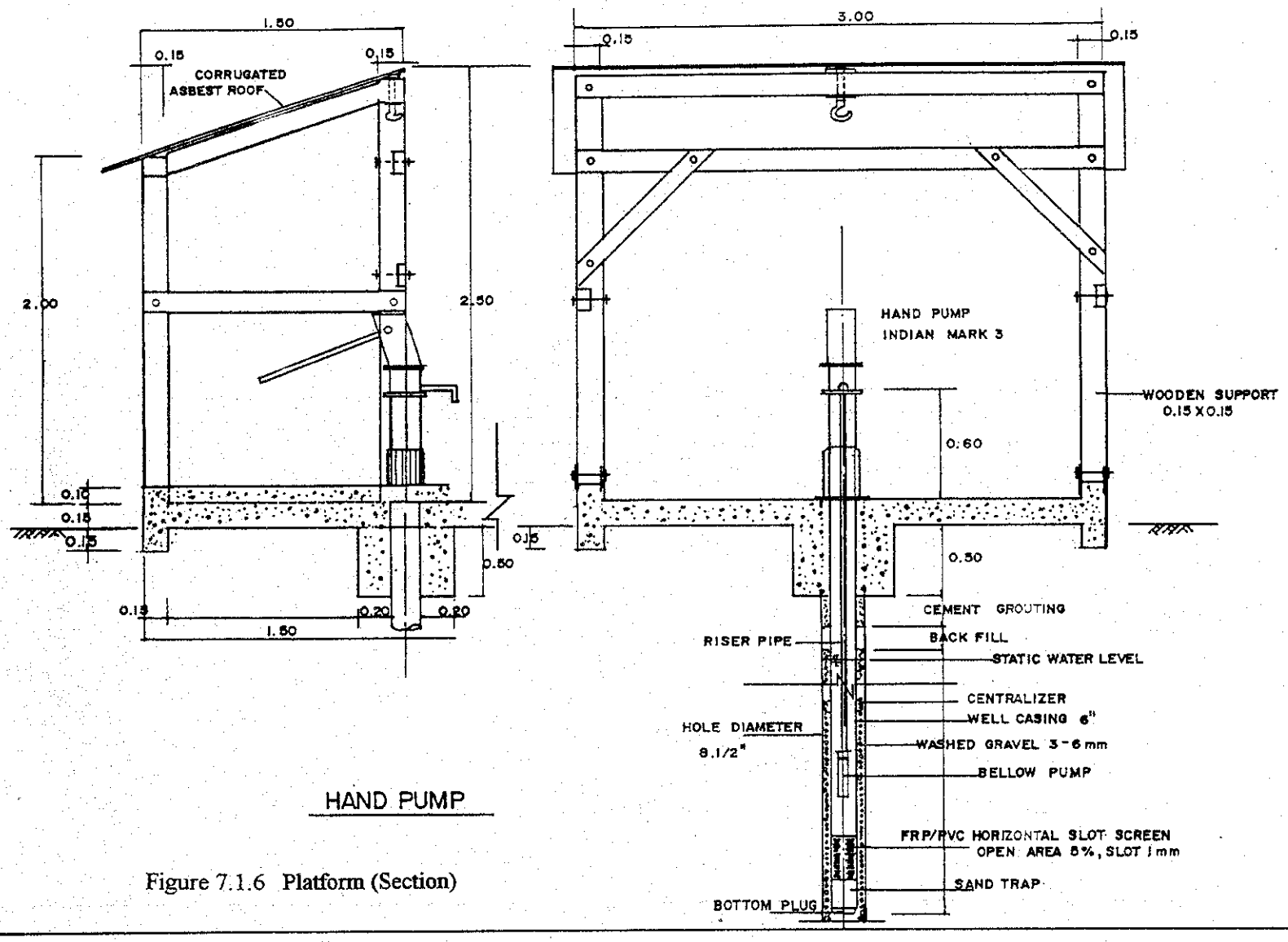


Figure 7.1.6 Platform (Section)

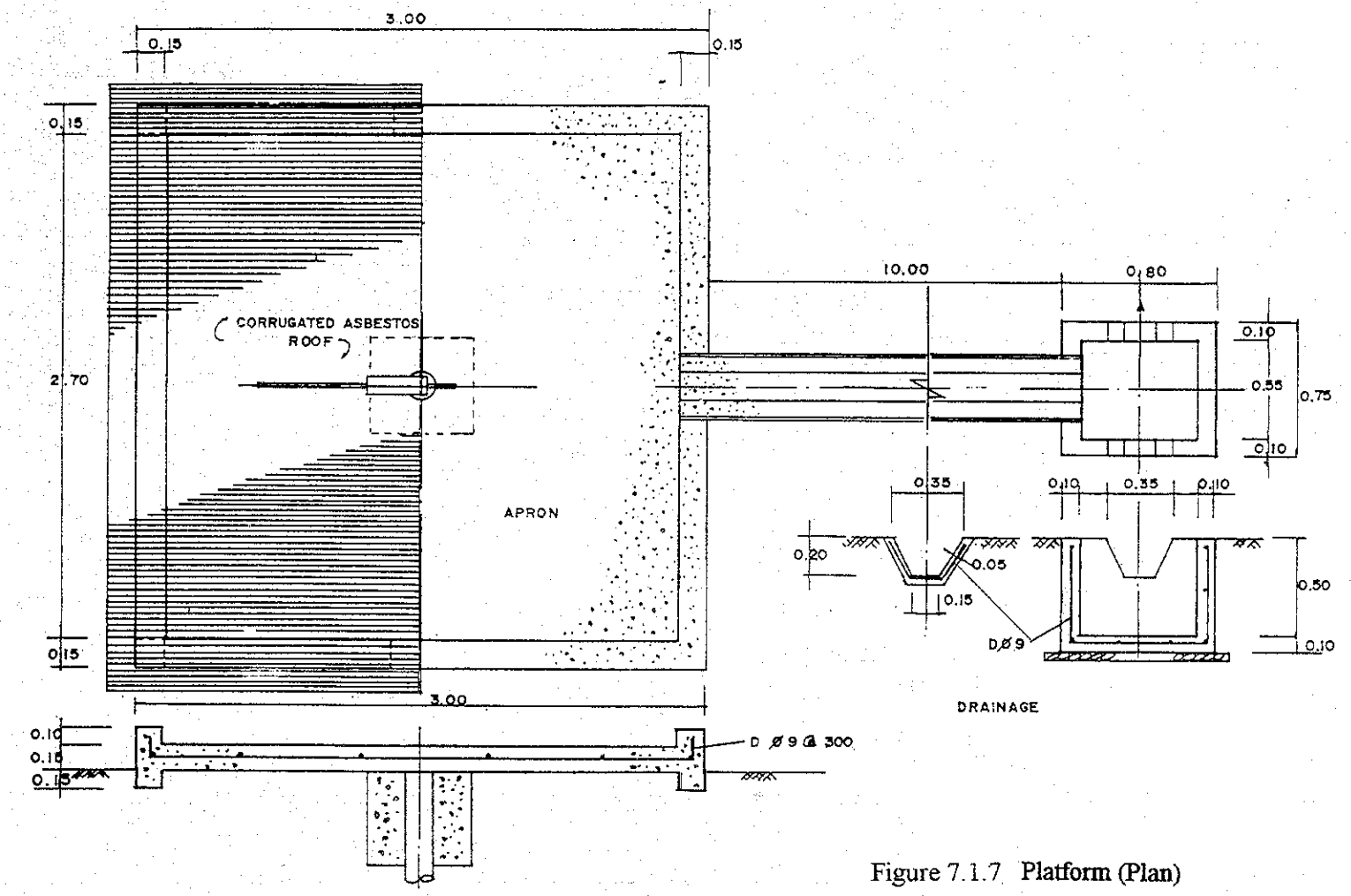


Figure 7.1.7 Platform (Plan)

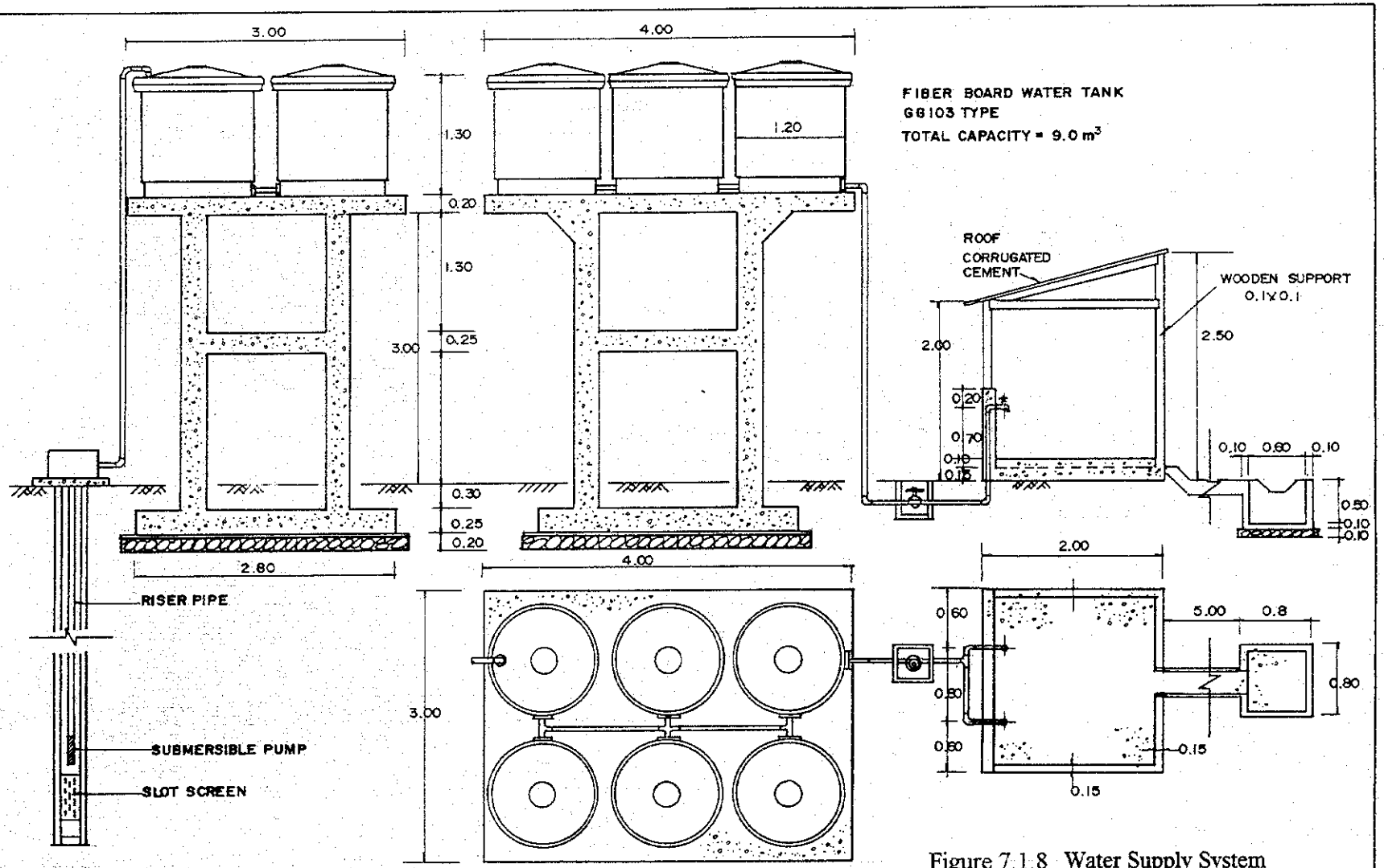


Figure 7.1.8 Water Supply System

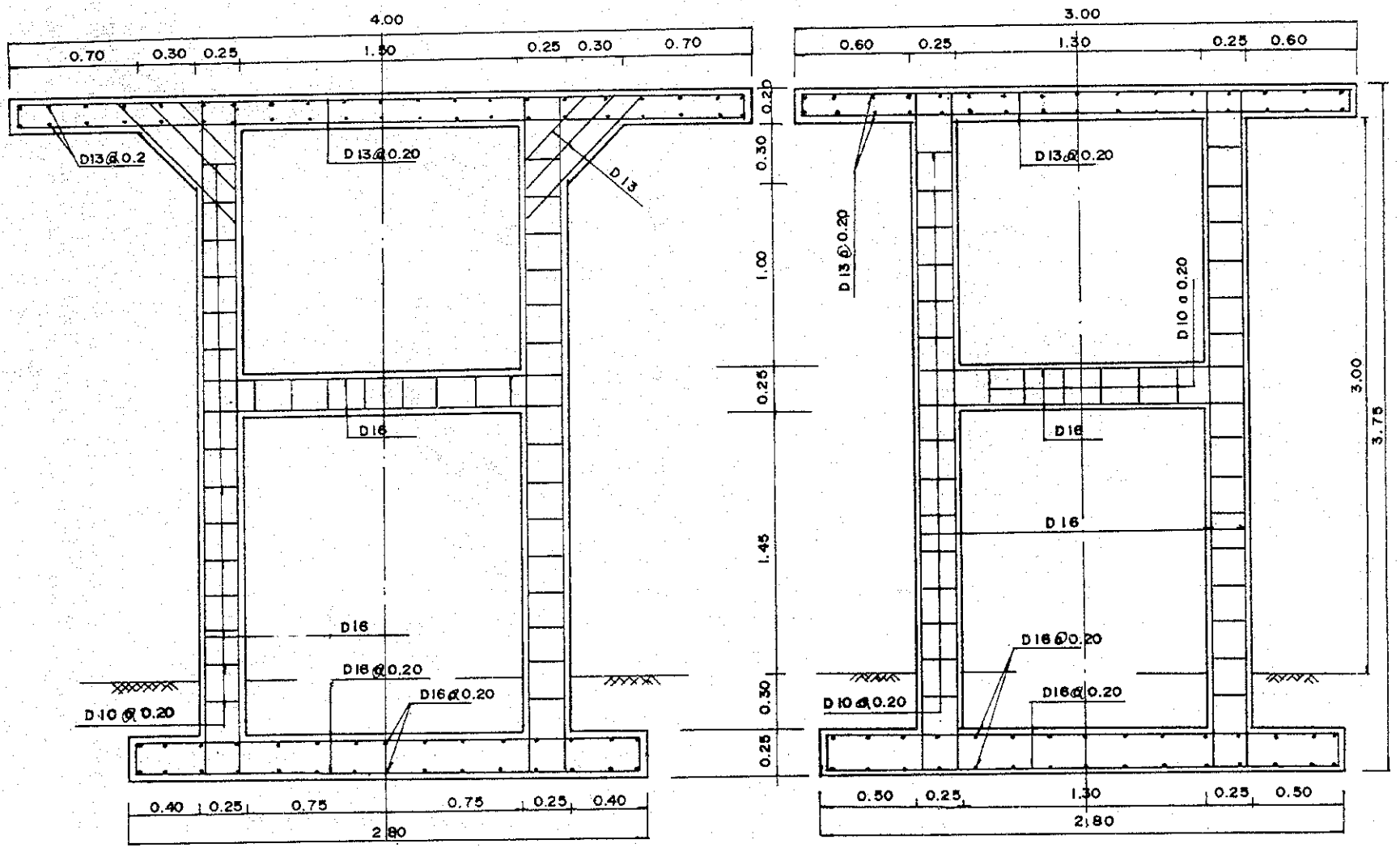
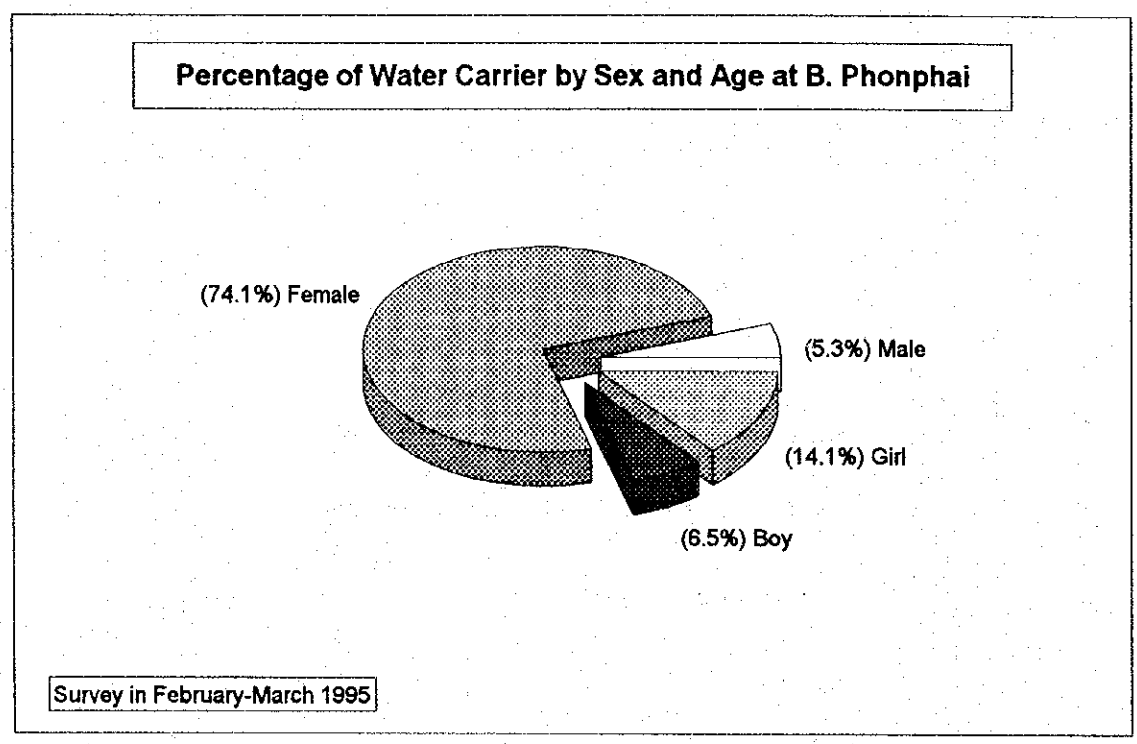


Figure 7.1.9 Water Tank Support

Figure 7.3.1 Result of Trial Operation and Maintenance at B. Phonphai, Saravan



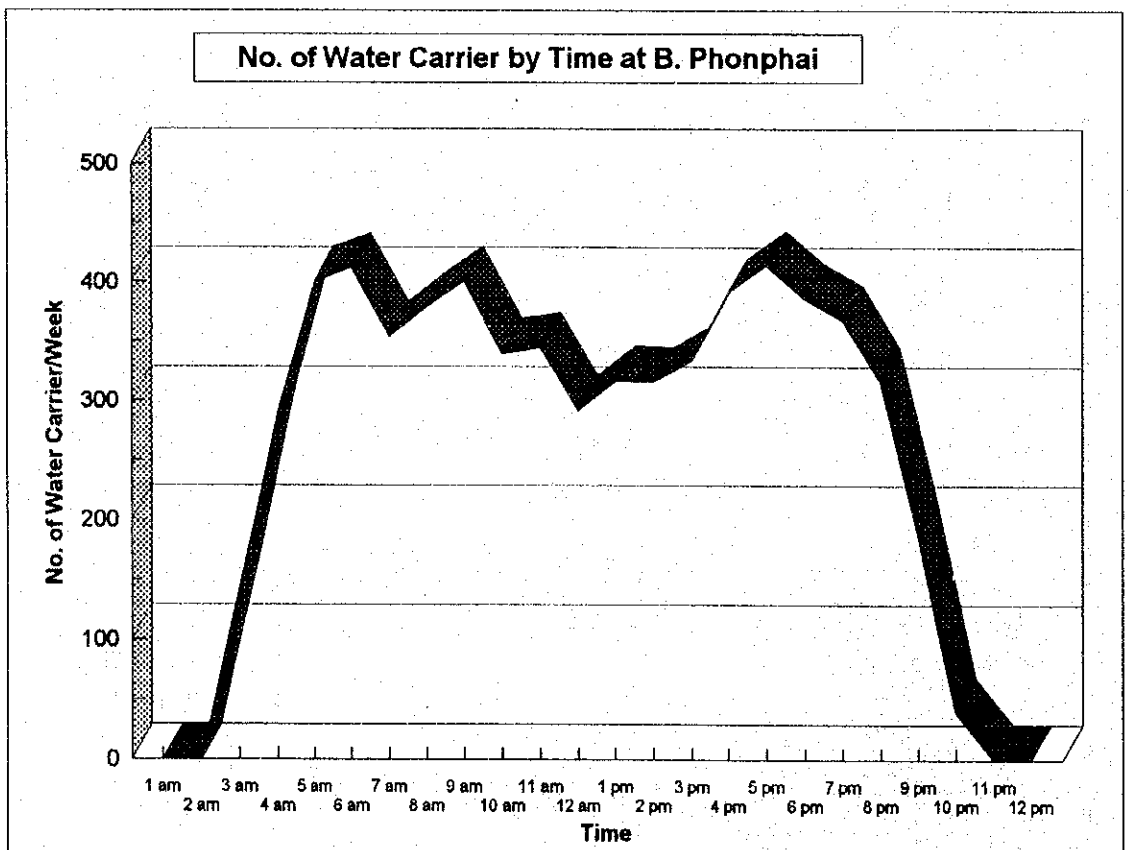
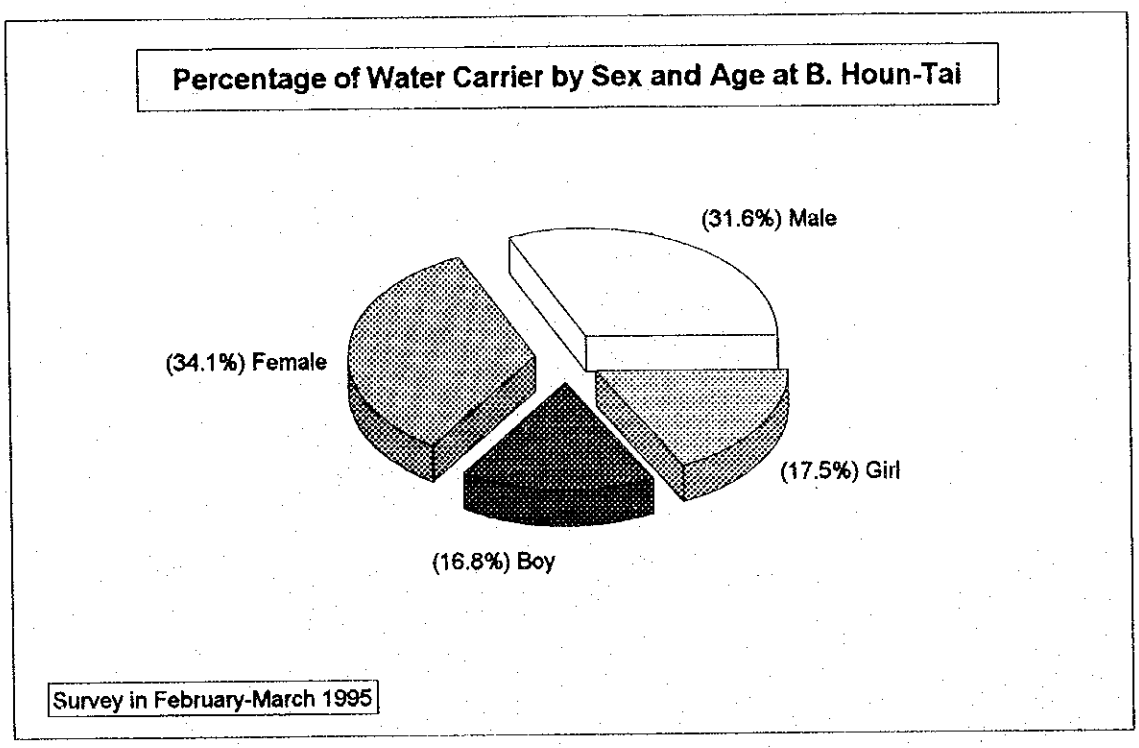


Figure 7.3.1. Result of Trial Operation and Maintenance at B. Phonphai, Saravan

Figure 7.3.2 Result of Trial Operation and Maintenance at B. Houn-Tai, Saravan



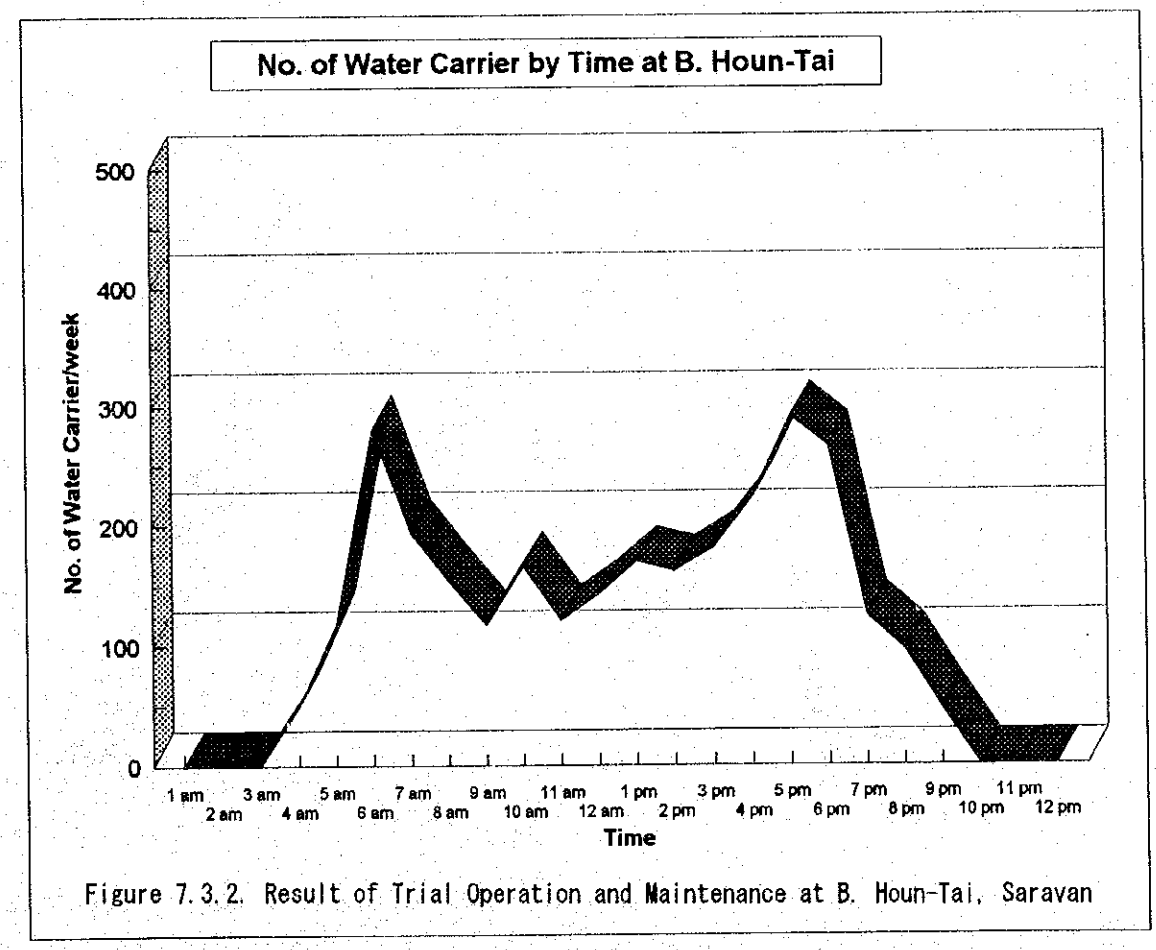
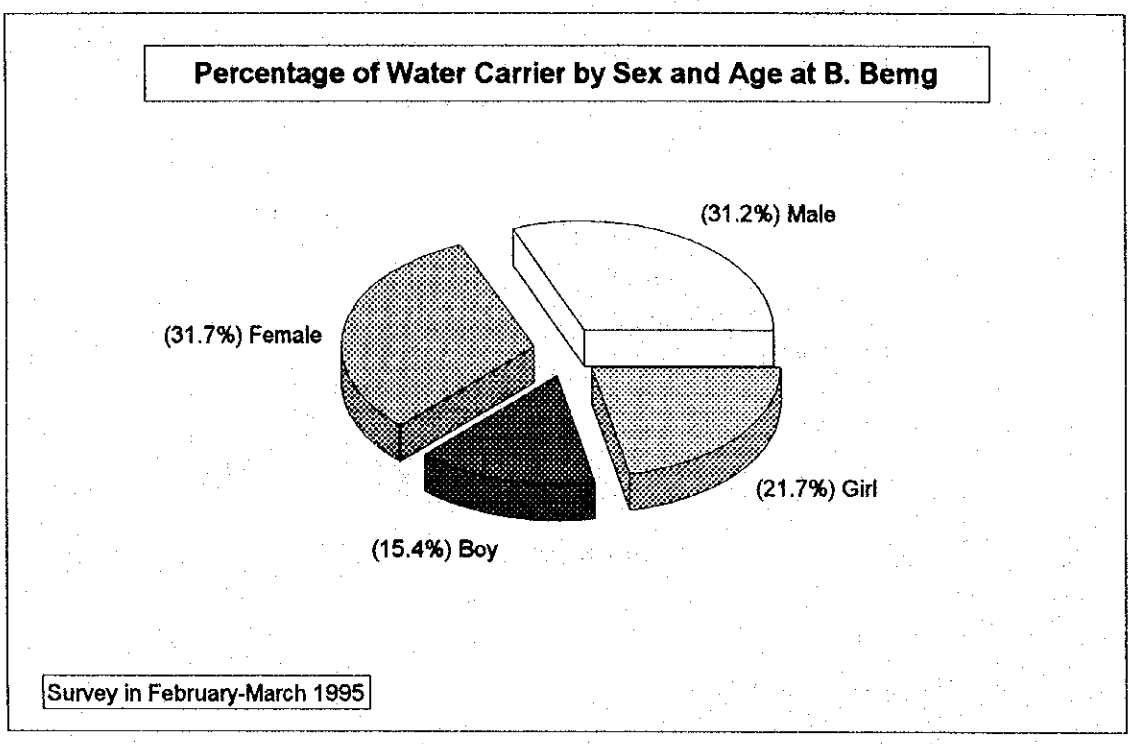


Figure 7.3.2. Result of Trial Operation and Maintenance at B. Houn-Tai, Saravan

Figure 7.3.3 Result of Trial Operation and Maintenance at B. Beng, Saravan



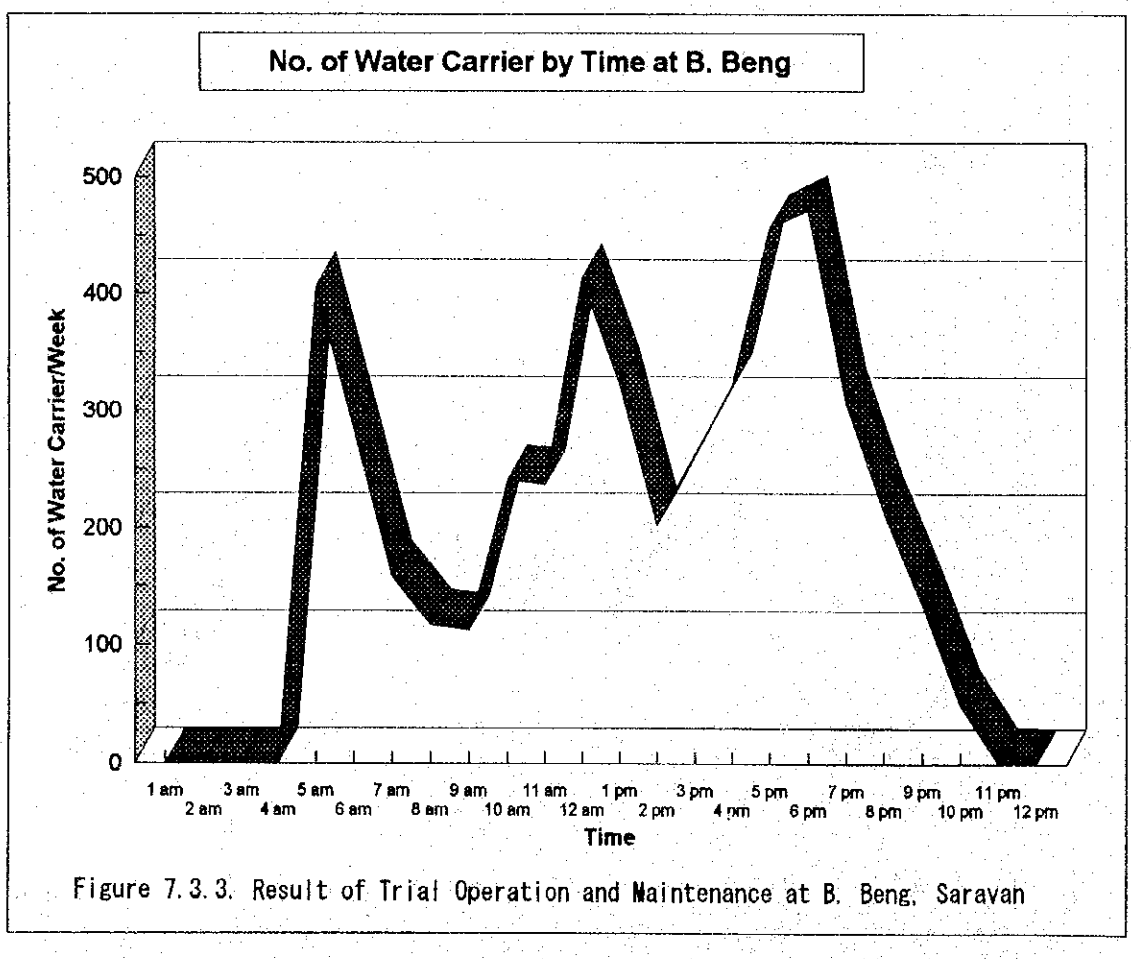
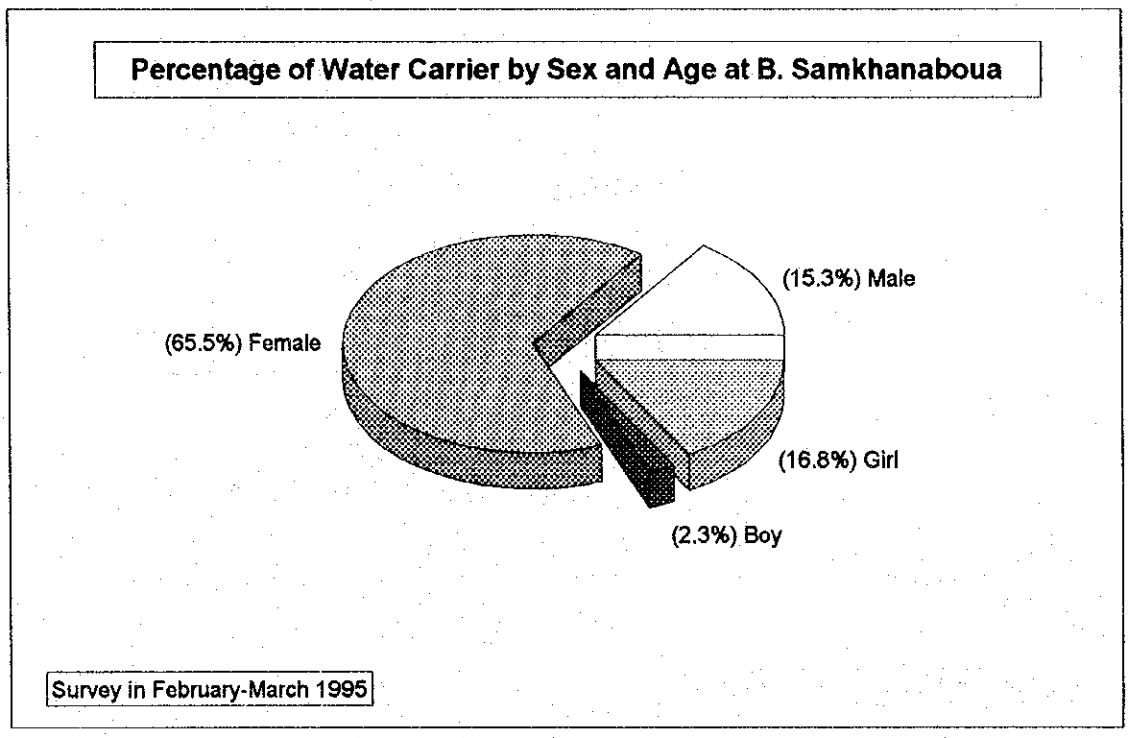


Figure 7.3.3. Result of Trial Operation and Maintenance at B. Beng, Saravan

Figure 7.3.4 Result of Trial Operation and Maintenance at B. Samkhanaboua, Champasak



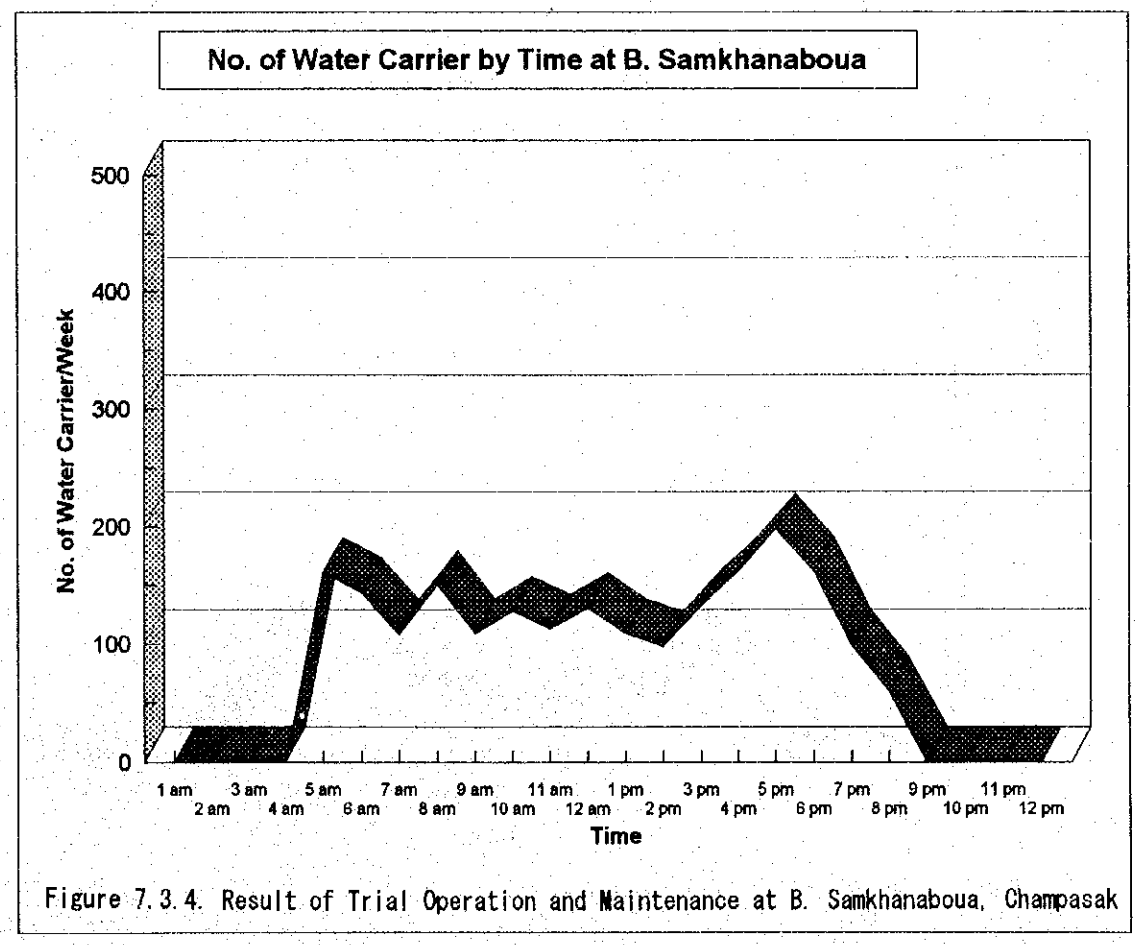
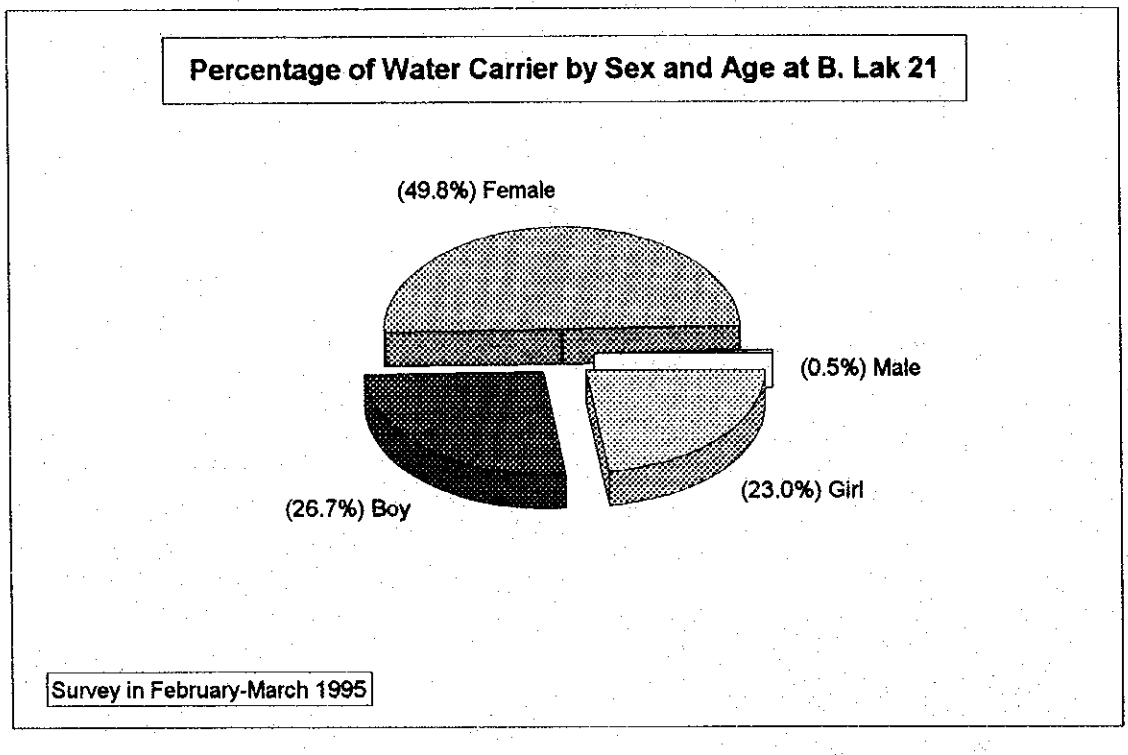


Figure 7.3.4. Result of Trial Operation and Maintenance at B. Samkhanaboua, Champasak

Figure 7.3.5 Result of Trial Operation and Maintenance at B. Lak 21, Champasak



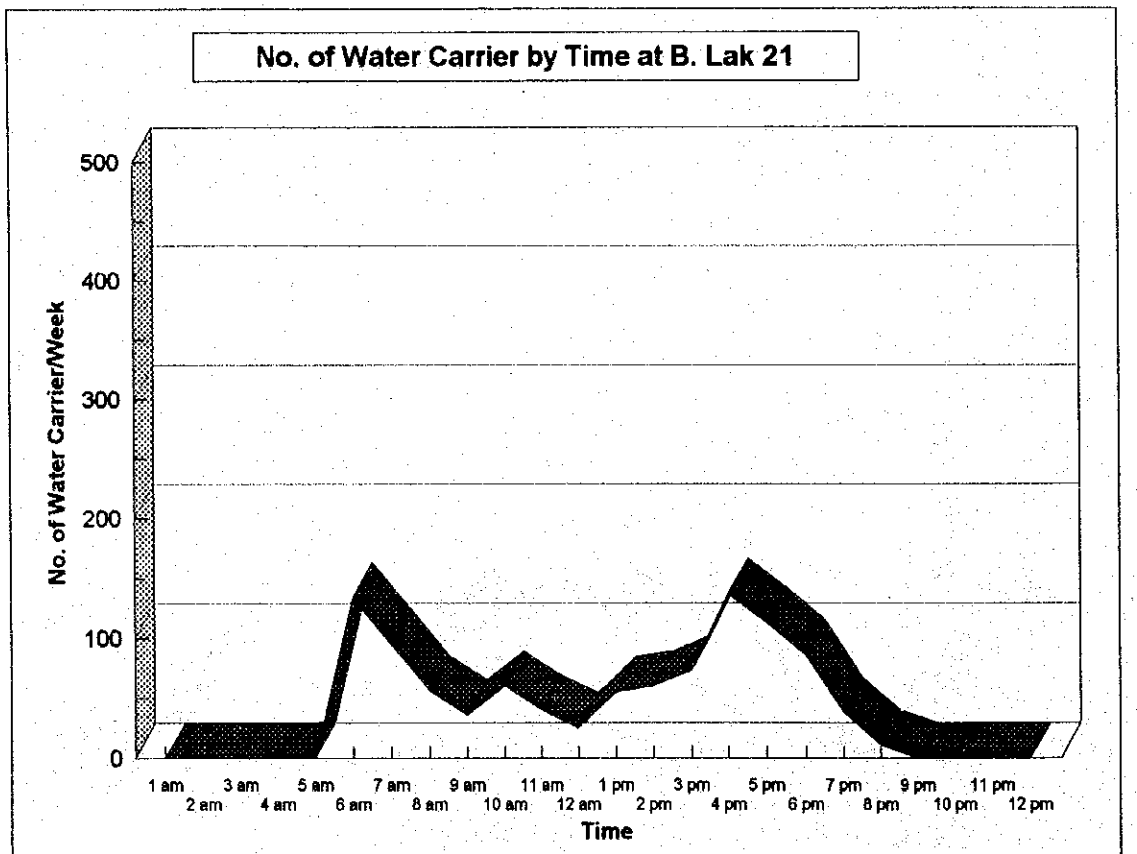
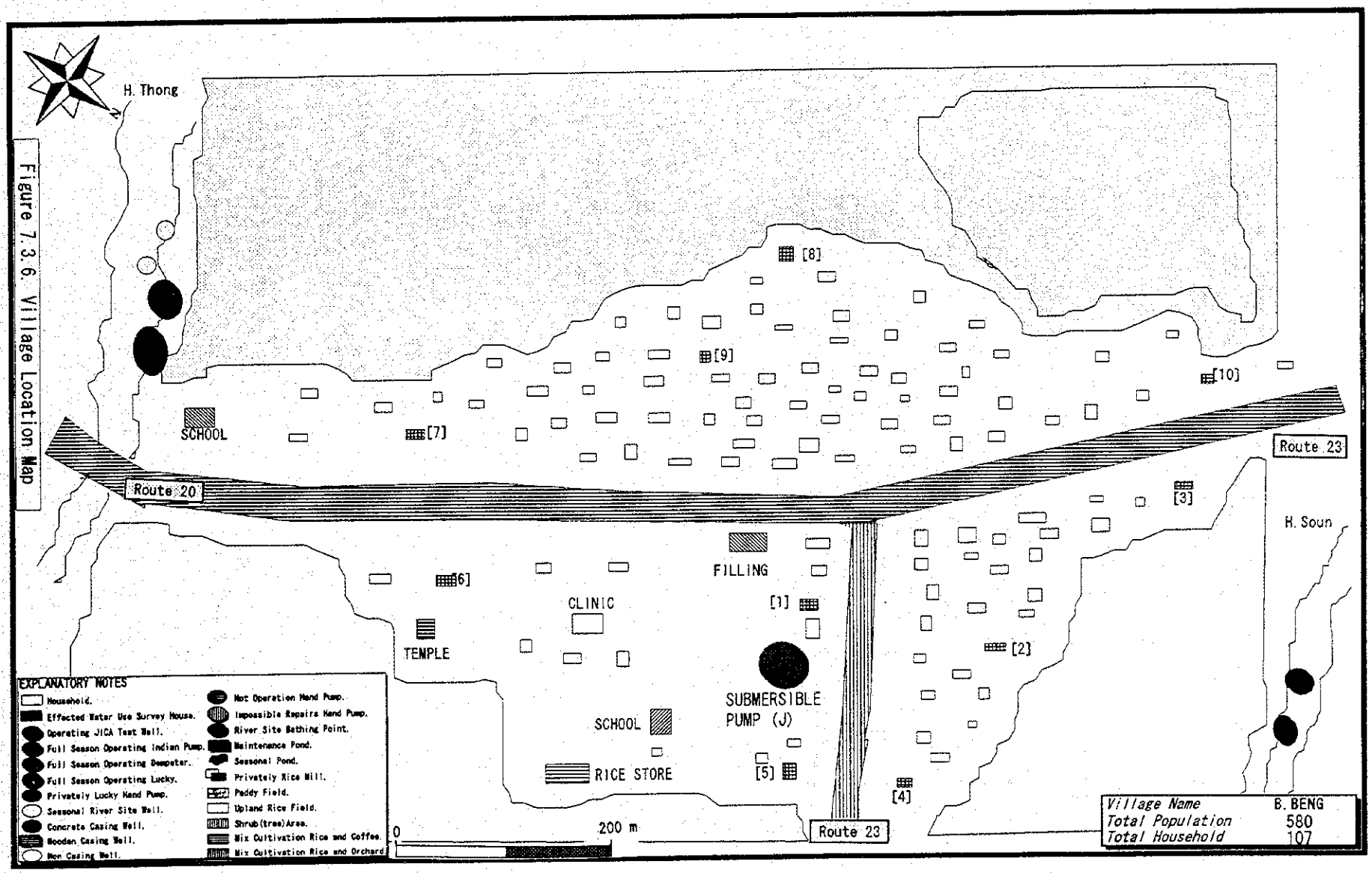


Figure 7.3.5. Result of Trial Operation and Maintenance at B. Lak 21, Champasak

Figure 7.3.6. Village Location Map



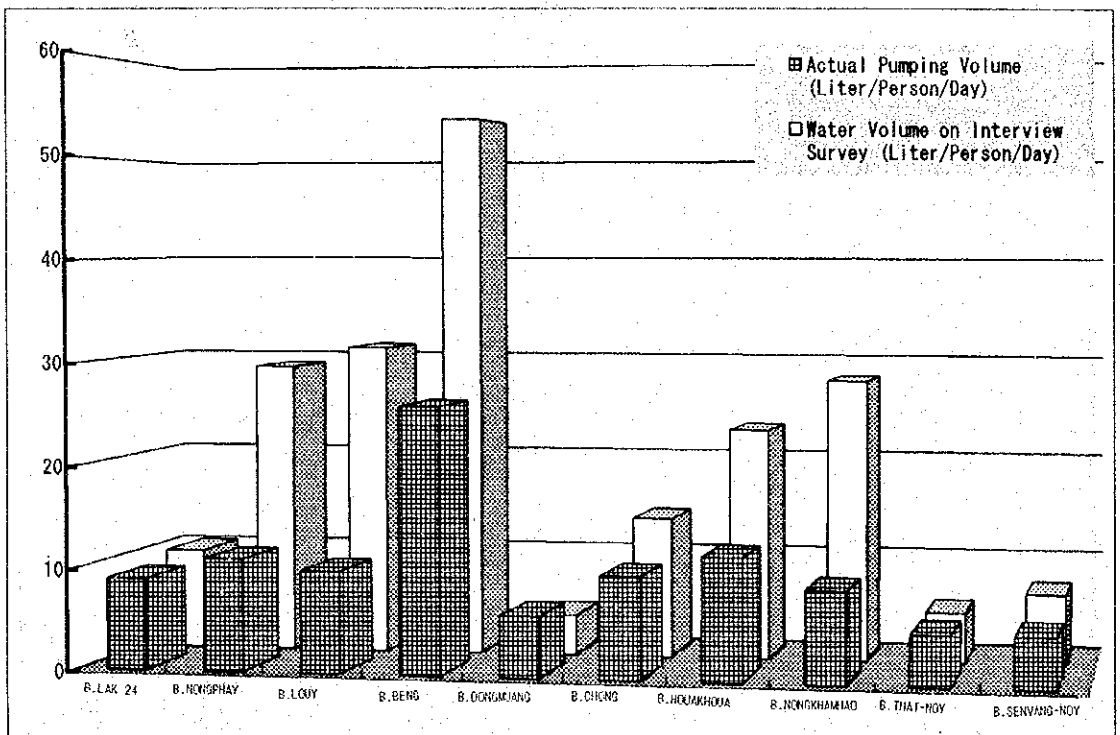


Figure 7.3.7. Compare for Actual Pumping Volume with Declare Water Volume

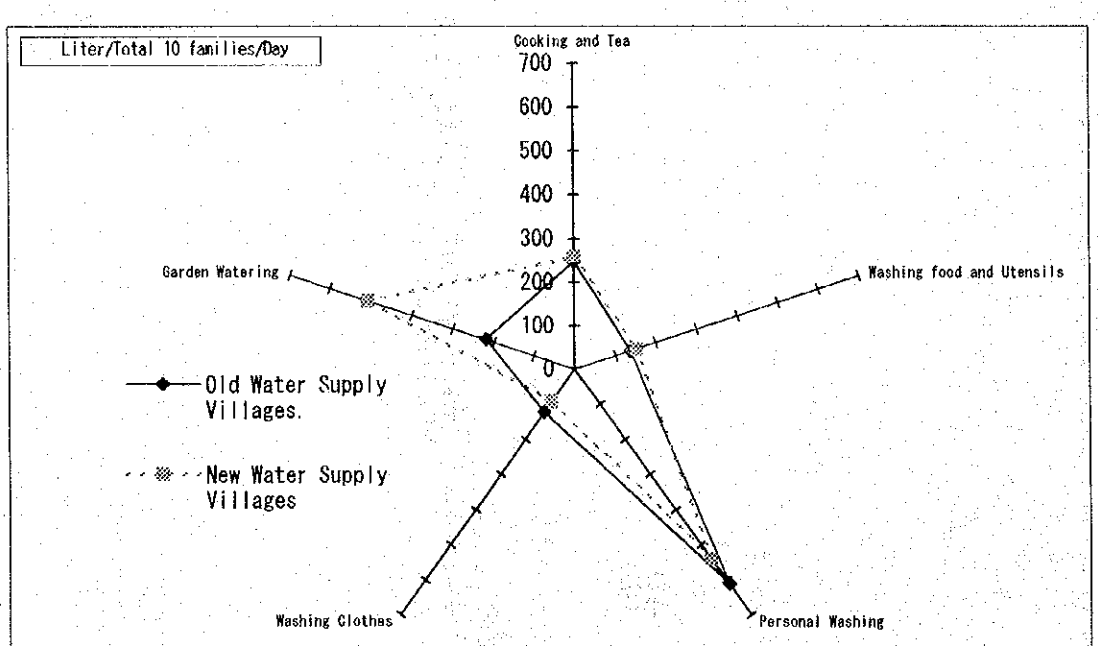


Figure 7.3.8 Comparison of Water Use in New Water Source and Old Water Source

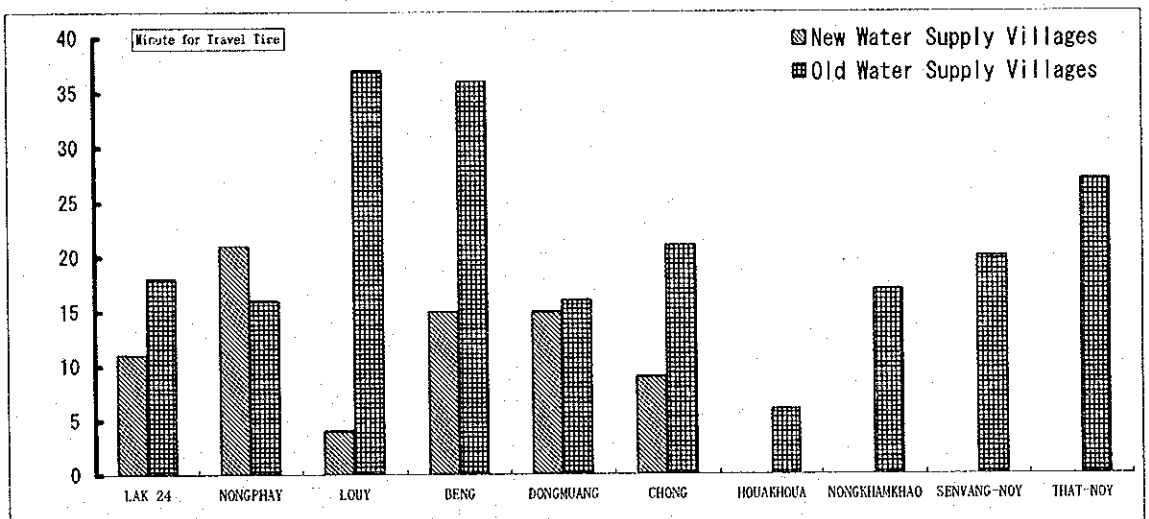


Figure 7.3.9. Round Trip Travel Time to Source in Minute

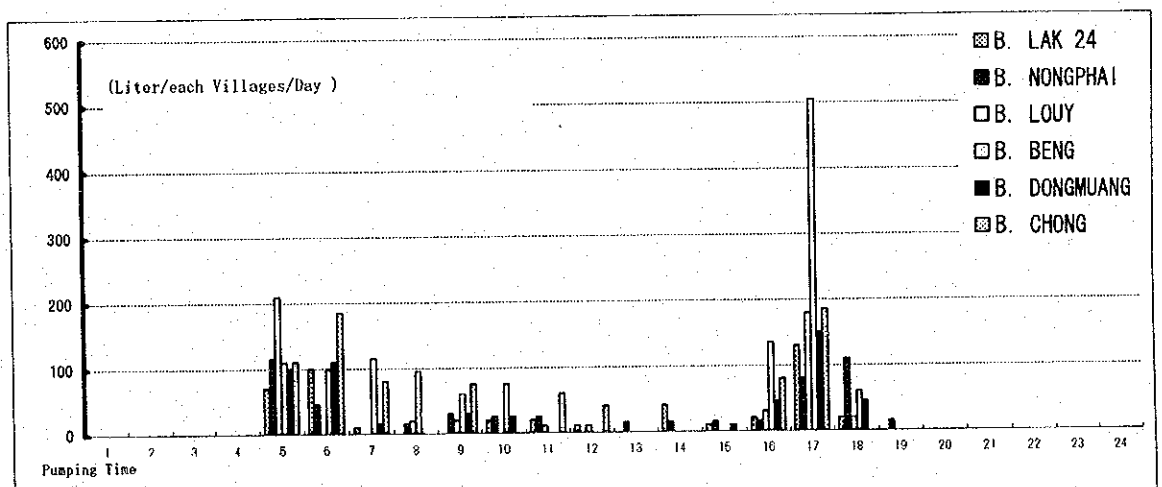


Figure 7.3.10. Pumping Time at New Water Source

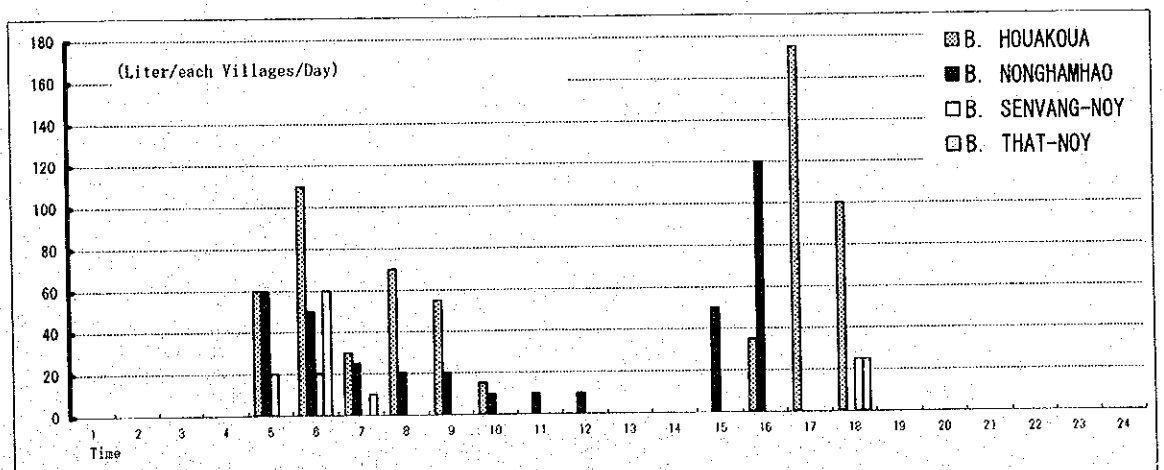


Figure 7.3.11. Pumping Time at Old Water Source

CHAPTER 8 GROUNDWATER DEVELOPMENT PLANNING

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CHAPTER 8 GROUNDWATER DEVELOPMENT PLANNING

8.1 Groundwater Resources Evaluation

8.1.1 Basic Concept on Quantitative Evaluation

The terms used in groundwater quantitative analysis are "storage capacity" and "yield". The storage capacity generally refers to the total capacity of groundwater which can be held in an aquifer or in a groundwater basin. The yield refers to the amount of groundwater which can be taken from an aquifer or from a groundwater basin by human activities.

In general, in relation to the qualitative evaluation of the groundwater resources, the yield which responds to the decline in groundwater level creates a problem, while the absolute value of the storage capacity is not such a problem.

Yield is generally classified into three categories, i.e., "sustained yield ","mining yield" and 'permissible yield". The concept of the sustained yield can be applicable in the evaluation of the basin-wide groundwater resource.

The sustained yield is defined as the "groundwater amount which can be withdrawn from a groundwater basin continuously, without any undesired results" (Todd,1959). In general, the term "safe yiled" is used in place of this. "Undesired results" refers to an increase in pumping costs due to decline in the groundwater level, the occurrence of land subsidence and seawater intrusion.

This definition includes 2 criteria:
(a) the water balance can be maintained perennially
(b) there are no economic nor groundwater accident risks.
With importance placed on the criteria pointed out in a), the term "perennial yield" can also be employed (Todd,1980).

8.1.2 Evaluation of the Sustained Yield

The potential yield of groundwater in the study area is large. However, the condition of the groundwater is rather variable, ranging from unconfined groundwater found in alluvium and semi-confined to confined groundwater found in Jurassic shale and sandstone, and Quaternary basalt.

In the Jurassic to Cretaceous Plain, discharge into the small rivers occurs in the rainy season intermittently, though the Mekong River and Xe Don River are effluent. On the other hand, in the basalt slope, the tributaries of the Xe Don River is effluent and the storage in the basin is high. Considering the above conditions, the sustained yield can be assessed from the water balance of the basin.

Water balance calculations revealed that the recharge volume of the Study Area is estimated as 210 mm/year in the Jurassic plain and 500 mm/year in the basaltic slope. The recharge volume

per unit area ranges from 575 m^3/day/km^2 (210 mm/year) to 1,370 m^3/day/km^2 (500 mm/year). This volume multiplied by the groundwater basin gives the recharge volume of the entire groundwater basin. The sustained yield could not exceed this volume.

8.1.3 Groundwater Potential of Each Hydrogeologic Unit

A groundwater potential map is prepared and presented in Figure 8.1.1. Schematic hydrogeology of each unit and the number of candidate village are also presented in Table 8.1.1 Groundwater potential are qualitatively evaluated and divided into four ranks, i.e., A, B, C and D.

A : High potential
B : Medium potential
C : Low Potential
D : No Potential

Qf: Groundwater level ranges from one meter to 11m and fluctuates with respect to the river water level. Specific capacity shows 5 to 36 m3/hour/m, the highest in the Study Area, indicating high groundwater potential (rank A). However, groundwater potential is low in the areas where groundwater level is deep since groundwater exists in Jurassic shale.

Qt: This unit is ranked C. Groundwater table ranges 7m to 8m. Aquifer is thin and groundwater may exist in Jurassic shale. Specific capacity is low.

Ep: Groundwater level ranges 4m to 11m. Unconsolidated surface bed is less than 2m thick. Aquifer
is the weathered zone of Jurassic shale. Specific capacity shows rather high values, and this unit is
ranked B.

Eh: Groundwater level is lower than Ep because of surface undulation. This unit is ranked B to C.

Ba1: This unit is ranked A to C because the distribution of basalt lava changes from place to place and because the surface sediments are not homogeneous. Groundwater level and specific capacity vary from place to place.

Ba2: This unit is ranked B to C. Groundwater level is shallow, but the aquifer is thin, and varies from place to place. Confined groundwater is expected in the deep strata.

Ba3: This unit is composed of hard rock, therefore it is ranked B to C. However, groundwater can be developed from underlying Jurassic shale.

Et: This unit is ranked C to D consists mainly of thin deposit overlying hard rock. Groundwater may be developed along the river, but low specific capacity is expected

P: Few groundwater is replenished in this area and ranked C to D.

M: Groundwater cannot be expected except in the mountain valleys (ranked C to D)

8.1.4 Optimum Well Yield

The optimum well yield was estimated from the step draw down data of the test wells and grouped by hydrogeologic unit as follows.

Qf,Qt:	133-380 m^3/day (average 219 m^3/day)
Ep,Eh:	9-111(average 55 m^3/day)
Ba1,Ba3:	20-267 m^3/day (average 138m^3/day)
Ba2:	1700-3800 m^3/day
Et:	32-129 m^3/day

8.2 Target Aquifers

8.2.1 Drilling Location

The hydrogeological map and groundwater potential map prepared in the Study will be helpful in obtaining the hydrogeologic information , such as hydrogeologic unit, groundwater level, and groundwater potential of the candidate village. However, exact drilling location must be determined by using geophysical exploration methods. The vertical electric sounding (VES) and Very Low Frequency (VLF) method shall be conducted in order to obtain resistivity profile of the village and to detect anomaly, which may indicate groundwater.

The VES should be conducted at least 5 points per village. The VLF should run along with the VES survey line at least 300 m. Table 8.2.1 shows the range of resistivity obtained in the Study Area. Figure 8.2.1 also indicates the anomaly due to geologic structure, such as fault or fractured zone. These geophysical data will be interpreted together with surface geological information and the drilling site will finally be determined.

8.2.2 Aquifer Characteristics of Each Hydrogeologic Unit

Based on the correlation of aquifers and lithological and geophysical well logs, the aquifer of each hydrogeologic unit is summerized as follows (Table 8.2.2)

Qt and Qf have water table aqufers in the shallow sand and gravel beds , however, groundwater mostly dries up in the dry season. Groundwater can be developped from underlying Jurassic sandstone and shale. Resistivity log of the sandstone and shale ranges from 40 to 80 Ω-m and natural gamma log ranges from 20 to 40 cps.

Ep and Eh constitute unconfined or semiconfined intergranular or fissured aquifer of Jurassic shale,mudstone and sand stone. The sand stone aquifer of Ep and Eh generally shows 80-160 Ω-m in resistivity, while shale shows less than 20 Ω-m. Natural gamma ranges from 5 to 20 cps in Eh and 30 to 40 cps in Ep.

Et have unconfined or semiconfined fissured aquifers of Triassic acidic tuff and Paleozoic slate. Resistivity log of the acidic tuff and Paleozoic slate show 50 Ω-m. Natural gamma is 10-20 and 20-30 respectively.

Ba1,Ba2 and Ba3 have confined aquifers of Paleogene to Pleistocene Boloven basalts. Weathered basalt shows low resistivity of 20 to 40 Ω-m, while fresh or weakly wethered basalt shows 200 to 1000 Ω-m in resistivity. Natural gamma shows 4 to 8 cps in wethered basalt and around 20 in weakly weathered basalt. However, groundwater quality is rather inferior due to rich manganese and iron contents, particularly in Ba1 area.

8.2.3 Development Scale

Table 8.2.3 shows the number of candidate village of two province by each hydrogeologic unit. In the village water supply plan, groundwater could meet water demand of these villages in all of the hydrogeologic units. Particularly, in Ba2, Ba3 and Qf areas, where high groundwater potential can be expected, a single well equipped with a submersible pump can supply large population more than 1500. However, in Ep,Eh and Et areas, where groundwater potential is ranked to B or C, it is suitable for construction of hand pump well.

Table8.2.3 Number of Candidate Village in Each Hydrogeologic Unit

Unit	Potential Evaluation	Qmax (l/min)	Saravan	Champasak	Total
Qf	A	90-260	22	23	45
Qt	C	(-117)	2	1	3
Ep	B	12-115	29	9	38
Eh	B-C	6- 50	15	20	35
Ba1	B-C	14-88	4	21	25
Ba2	A	1200-2600	13	13	26
Ba3	B	185	15	3	18
Et	B-C	22-90		10	10
Total			100	100	200

Qmax: Optimum well discharge estimated by the pumping test of this study
( ) estimation from existing data

8.3 Standard Well Design

8.3.1 Target depth

The depth of the well varies place to place depending on the aquifer conditions. However, the test well depth was 48 m in average and all the test well encountered productive aquifers within a depth of 50m except B.Houaxe. Therefore, an average target depth is set to 50m for the handpump and the motor pump wells. Groundwater shall not be taken from the lower Jurrasic formation deeper than 50m, particularly in the hydrogeologic unit Ep and Eh. In the Ba1 area, however, the screen should be placed at the lower basaltic layer as deep as possible in order to

avoid contamination from overlying surface red soil and to take groundwater from fresh fissured basalt.

Figure 8.3.1 shows hydrogeological cross section along Route 13 in the western Basaltic slope. According to the geophysical exploration, the thickness of the basaltic layer exceeds 100 m in most of the section except from B.Bachian (C38) to B.Thongsala (C44) . In Ba1 area, the thickness of the surface red soil ranges from 20 to 30 m which is about 1/3 of the basaltic layer. Underlying the basalt is the Jurassic formations and productivity of this aquifer is poor compared with the basaltic aquifer.

8.3.2 Drilling Method

(1) Drilling operation

Down-the-Hole (DTH) drilling method shall be used in order to drill hard formations , such as Jurassic sandstone and basalt.The drilled hole diameter must be 8.5 to 9.6 inch.

Particularly in Ba1 area, drilling works must be performed carefully in order to avoid introducing iron bacteria into a well. All drilling fluid mix water should be chlorinated initially to a 50 mg/l free chlorine concentration. More chlorine must be added periodically to maintain a 10 mg/l free chlorine residual. The drill rods, bits, and tools should be chlorinated thoroughly.
A temporary casing should be placed in unconsolidated formation such as the surface red soil in the Ba1 area. This casing will be withdrawn as cement grout is placed (Figure 8.3.2).

(2) Logging and screen position

In order to identify the aquifer and decide on the screen position and length, spontaneous logging, resistivity and natural gamma ray logging are carried out after the drilling. Resistivity curves indicates the lithology of rock strata penetrated by the borehole and enable fresh and salt water to be distinguished in the surrounding material. The sign of the spontaneous potential (SP) depends on the ratio of salinity of the drilling mud to the formation water. These logs often inidicate same subsurface conditions. Natural gamma log also indicate the presence of groundwater.

In most of the Study Area, groundwater exists in the intergranular space or fissure of Jurrasic sand stone and shale. In the basaltic slope of the Boloven Plateau, groundwater occurs in the fissures of hard rock. Purpose of geophysical logging is to detect permeable fresh groundwater zone in the hard rock. Thefore, the geophysical logs must bes carefully interpreted together with observation of drill cuttings. The resistivity, SP and natural gamma obtained in the test wells can be used as an index of the formation (Table 8.2.2).

8.3.3 Well Completion

(1) Casing

Considering the corrosive groundwater quality in the Study Area, Fiber Reinforced Pipe (FRP) should be used to prolong well life and efficient operation, particularly, in the Ba1 area. For the

submersible pump borehole, the diameter of the casing is 6" (150 mm) and that of the hand pump borehole is 5" (125 mm) with wall thickness of more than 4 mm. The length of screen should be 4 m.

(2) Screen

Since aquifer consists of hard rock, the open area of the screen can be large. In order to avoid groundwater of inferior water quality, the screen must be placed in single aquifer. In the hand pump well, the standard screen should be a diagonal slot type with an opening ratio of more than 12 % and a slot size of 1 mm width . For the motor pump well, a ring type (or a pipe base) screen of more than 20 % of the opening ratio should be placed (Figure 8.3.3). A total screen length is designed as 8 m . The screen should be placed in those zones having the highest hydraulic conductivity.

(3) Gravel packing

The well can be left as open hole since the aquifer is composed of hard rock. However, the sand and mud are often contained in the fissure,crack or weathered portion of the rock. Therefore, the well screen is filter packed in order to minimize sand pumping and increase the effective radius and yield of the well. The grain size of the gravel should be 4-5 mm . The gravel should also be chlorinated.

(4) Well completion

In the completion of the filter-packed well, except for the screen area, the annular space surrounding the casing must be grouted to prevent entrance of water of inferior quality and to stabilize caving rock formations. Particularly, the grouting must be carefully performed to ensure that the water from the surface red soil is completely sealed.

(5) Well development

Following completion, the well is developed to increase its specific capacity, prevent sand pumping, and obtain maximum econimic well life. The air lift pumping method should be used to clean up the well and remove the finer material from the natural formations and gravels surrounding the screen.

(6) Pumping test

Following development of the well, the pumping test should be conducted to determine its yield and drawdown. A constant-discharge, a step drawdown and a recovery tests should be conducted.

(7) Installation of pump

The pump should placed in the well considering natural water level and its fluctuation, pumping water level and the screen position.

Table 8.1.1(1) Groundwater Potencial Based on Hydrogeologic Features.

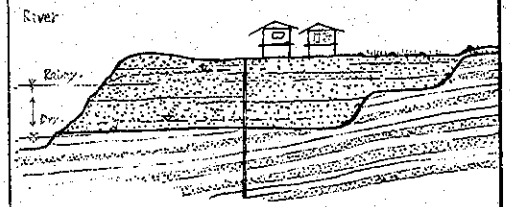
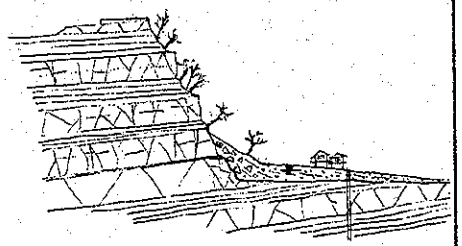
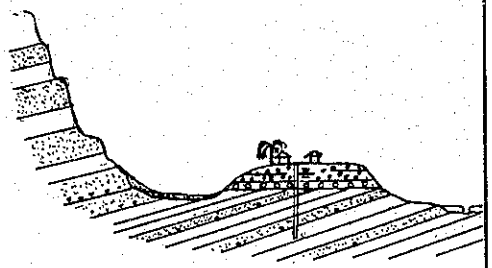
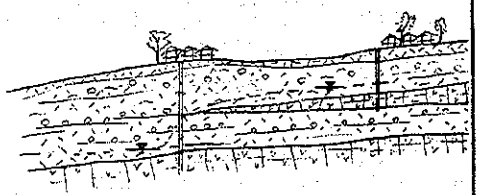
Types of Hydrogeologic Features		Province, district	Village Number ○ Test well Point
Qf Topography: Flood plain, Accumulation Terrace. Lithology: Sand, silt, clay, gravel. Geologic Time: Quaternary Aquifer: Sand, gravel Water Depth (Dry season, G.L.-m): 6-13m Well yield: (Test well) Sc=14-128m³/day/m; Qmax=133-380+m³/day (Existing well) Qmax=120-864m³/day Water Quality (Test well) PH=7.1-7.4, EC=376-767 μs/cm (Existing well) PH=7-8, EC=400-600 μs/cm Groundwater potential: A		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 18, 20, 22, 23, (24), 25, 26, 29, 30, 31, 32, 33, 34, 35. 42, 43, 44, 46, 47, 48, 49, (50) 1, 5, 17, 18, 22, 23, 24, 25, 33, 34, 35, 36. (75) 76. 80, 82, 83. 84, 85, 91, 93, 95, 97.
Qt Topography: Alluvial fan, Talus slope. Lithology: Sand, silt, clay, Sandstone, shale. Geologic Time: Quaternary, Jurassic Aquifer: Unconsolidated sand, Jurassic sandstone. Water Depth (Dry season, G.L.-m): 7-8m Well yield: (Test well) (Existing well) Qmax=0-168m³/day Water Quality (Test well) PH= — , EC= — (Existing well) PH=7-8, EC=460-800 μs/cm Groundwater potential: C		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 21, 28. 100.
Qte Topography: Accumulation terrace Lithology: Gravel, shale, sandstone Geologic Time: Tertiary, Jura-Creta Aquifer: Gravel, Sandstone Water Depth (Dry season, G.L.-m): 7-9m Well yield: (Test well) Sc=16m³/day/m; Qmax=73m³/day (Existing well) Sc= — ; Qmax= — Water Quality (Test well) PH=5.6, EC=96 μs/cm (Existing well) PH= — , EC= — Groundwater potential: B		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 7, 9, 10, 11, 12, 13, 14, 15, (16)
Bal Topography: Basalt slope. Lithology: Mudflow deposits, loam, ash, lava flows. Geologic Time: Neogene-Quaternary Aquifer: Lava flows Water Depth (Dry season, G.L.-m): 20-35m Well yield: (Test well) Sc=3-20m³/day/m; Qmax=20-127m³/day (Existing well) Qmax=96-2000?m³/day Water Quality (Test well) PH=5.6-5.9, EC=55-115 μs/cm (Existing well) PH=6-7, EC=10-100 μs/cm Groundwater potential: B-C		Saravan (S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak (C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 97, 98, 99, (100) 38, 39, 40, 41, 42, 45, 46, 47, 48, (49), 50, 51, 52, 53, 54, 55, 56, 57, 58, 59. 64.

Table 8.1.1(2) Groundwater Potencial Based on Hydrogeologic Features.

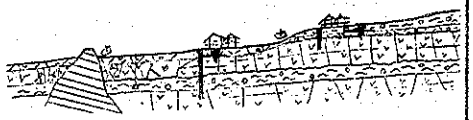
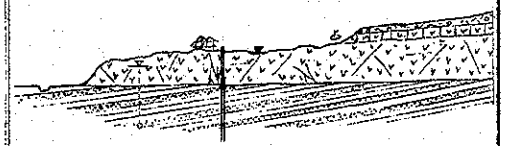
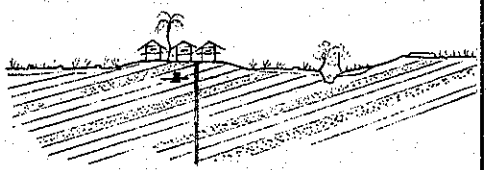
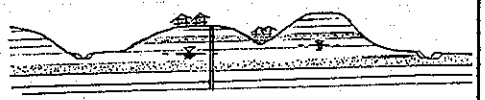
Types of Hydrogeologic Features		Province, district	Village Number
Ba2 Topography: Basalt slope. Lithology: Basalt lava flows. Geologic Time: Neogene-Quaternary Aquifer: Lava flows, autobrecciated lava. Water Depth(Dry season, G.L.-m):13-24m Well yield: (Test well)Sc=1700-1900m³/day/m;Qmax=1728-3800+m³/day (Existing well)Qmax=—m³/day Water Quality (Test well)PH=6.4, EC=165-230 μs/cm (Existing well)PH=5-7, EC=15-200 μs/cm Groundwater potential: A		Saravan(S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak(C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 84, 85, 86, 87, 88, 89. 90, 91, 92, 93, 94, 95, 96. 43, 44, 60, 61. 62, 63, 67, 68, 69, 70, 71, 72, 73.
Ba3 Topography: Basalt slope. Lithology: Basalt lava flow, sandstone, shale. Geologic Time: Pg-Ng basalt lava, J. sandstone. Aquifer: Basalt lava, Jurassic sandstone. Water Depth(Dry season, G.L.-m):4-12m Well yield: (Test well)Sc=19.1m³/day/m;Qmax=267m³/day (Existing well)Qmax=144-216m³/day Water Quality (Test well)PH=7.0, EC=569 μs/cm (Existing well)PH=6-7, EC=41-250 μs/cm Groundwater potential: B		Saravan(S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak(C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 51, 52, 53, 56, 57, 58, 59. 61, 76, 77, 79, 80, 81, 83. 37. 66, 74.
Ep Topography: Erosional plain Lithology: Red shale, fine to medium sandstone. Geologic Time: Jurassic Aquifer: Sandstone, sandy shale. Water Depth(Dry season, G.L.-m):7-12m Well yield: (Test well)Sc=3-166m³/day/m;Qmax=17-166+m³/day (Existing well)Qmax=0-672m³/day Water Quality (Test well)PH=7.0-7.3, EC=447-627 μs/cm (Existing well)PH=6.5-8, EC=300-700 μs/cm Groundwater potential: B		Saravan(S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak(C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 15, 16. 17, 27, 36, 37, 38. 39, 40, 41, 45, 54, 55. 60, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 82. 26, 28, 29, 31. 65. 77, 78, 79, 81.
Eh Topography: Erosional hill Lithology: Red shale, sandstone, conglomerate. Geologic Time: Jurassic-Cretaceous Aquifer: Sandstone, conglomerate. Water Depth(Dry season, G.L.-m):9-20m Well yield: (Test well)Sc=1-17.3m³/day/m;Qmax=9-73m³/day (Existing well)Qmax=144-408m³/day Water Quality (Test well)PH=6.7-7.1, EC=790-4000 μs/cm (GL-60-180m) (Existing well)PH=5-7, EC=600-1000 μs/cm Groundwater potential: B-C		Saravan(S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak(C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14. 19 2, 3, 4, 6, 8, 19, 20, 21, 27, 30, 32.

Table 8.1.1(3) Groundwater Potencial Based on Hydrogeologic Features.

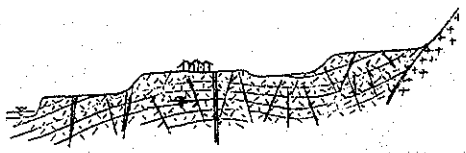
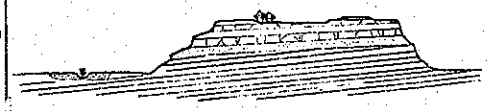
Types of Hydrogeologic Features		Province, district	Village Number
Et1, Et2 Topography: Erosional terrace Lithology: Slate, sandstone, Acidic tuff, dacite. Geologic Time: Permian-Triassic Aquifer: Fissured aquifer Water Depth(Dry season, G.L.-m): 8-17m Well yield: (Test well)Sc=4.6-36.9m²/day/m; Qmax=32-129m²/day (Existing well)Qmax=--m²/day Water Quality (Test well)PH=6.8-7.3, EC=430-763μs/cm (Existing well)PH=7.2-7.7, EC=300-600μs/cm Groundwater potential: B-C		Saravan(S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak(C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	 86, 87, 88, 89, 90, 92, 94, 96, 98, 99.
P Topography: Platcau, High plain Lithology: Medium-coarse sandstone, mudstone. Geologic Time: Jurassic-Cretaceous Aquifer: Sandstone, Fissured. Water Depth(Dry season, G.L.-m): Deep, Shallow(perched) Well yield: Low Groundwater potential: C		Saravan(S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak(C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	
M Topography: Mountains Lithology: Metasediments, plutonic rocks. Geologic Time: Precambrian-Paleozoic Aquifer: Fissured aquifer, Sand in valley. Water Depth(Dry season, G.L.-m): Deep shallow Well yield: Low Groundwater potential: C-D		Saravan(S) Lakhonepheng Khongxedon Vapy Saravan Laongam Champasak(C) Sanasomboon Bachiang Pathoomphone Sukhuma Khong	

Table 8.1.2 Types of Hydrogeologic Features Based on Topography and Geology

Symbol	Topography and Geology	Aquifer	Groundwater level	Specific Capacity	Q(max)	Q(max)	Groundwater Potential	Water Quality(Borehole)			
			(Dryseason)	Sc	This Study	Existing(USAID)		Testwell		Existing Well(30-60m)	
			G.L.-m	m^3/day/m	m^3/day	m^3/day	A(High)-D(Low)	PH	EC(us/cm)	PH	EC(us/cm)
Qf	Flood plain,Accumulation terrace. Sand,Silt and Clay,Jurassic shales	Quaternary Sand,Gravel. Jurassic Sandstone.	6-13	14-128	133-380-	120-864	A	7.1-7.4	376-767	7-8	400-600
Qt	Alluvial fan,Talus slope. Sand,Silt,Jurassic shales.	Sand. Jurassic Sandstone.	7-8	- -	- -	0-168	C	-	-	7-8	460-800
Qte	Accumulation terrace. Gravel,Jura-Creta,sandstone,shale.	Gravel. Jura-creta,Sandstone.	7-9	16	73	408	B	5.6	96	-	-
Ba1	Basalt slope. Mudflow Deposits,Ash,Loam,Lava flow.	N-Q Basalt Lava. Basalt lava flow.	20-35	3-20	20-127	96-2000?	B-C	5.6-5.9	55-115	6-7	10-100
Ba2	Basalt slope. Basalt lava flows.	N-Q Basalt Lava. Autobrecciated lava.	13-24	- 1700-1900	- 1728-3800+	-	A	6.4	165-230	5-7	15-200
Ba3	Basalt slope. Basalt lava flows,Jurassic shales.	Pg Basalt Lava. Jurassic sandstone.	4-12	- 19.1	267	144-216	B	7	569	6-7	41-250
Ep	Erosional plain. Jurassic red shale,sandstone.	Jurassic sandstone, sandyshale.	7-12	3-166	17-166+	0-672	B	7.0-7.3	447-627	6.5-8	300-700
Eh	Erosional Hill. Jurassic red shale,sandstone.	Jurassic sandstone, conglomerate.	9-20	1-17.3	9-34	144-200	B-C	6.7-7.1	790-4000	5-7	600-1000
Et1	Erosional terrace. Triassic Acidic welded tuff,Dacite.	Fissured aquifer.	8-15	4.6 -	32	-	B-C	6.8-7.3	197-430	7.2-7.7	300-600
Et2	Erosional terrace. Paleozoic slate,sandstone.	Fissured aquifer.	8-17	36.9	129	-	B	6.8	763	-	-
P	Plateau,High Plain. Jura.-Creta,sandstone,shale.	Sandstone. Locally Fissured aquifer.	Low	-	-	-	C	-	-	-	-
M	Mountains. Metasediments,Plutonic rocks.	Fissured aquifer. Sand,silt in Valley.	Low-high	-	-	-	C-D	-	-	-	-
Es	Escarpment,Ridge.	-	-	-	-	-	-	-	-	-	-

Table 8.2.1 Resistivities of Rocks and sediments in The Study Area (ohm-m)

Geologic time	Rocks and Sediments	ohm-m	Aquifer
Quaternary	Clay	6---23	
	Sand	70---150	*
Paleogene to	Basalt lava	800--2000	
Quaternary	Basalt Breccia	100--500	*
	Weathered Ba(dry).	100--700	*
	Weathered Ba.	10---100	
Jurassic	Sandstone	50---350	*
	Sandstone(hard)	200--600	
	Mudstone	15---70	
	Sandy Shale	20---90	*
	Hard Shale	12---50	
	Conglomerate	30---40	*
	Weathered.	10---100	
Triassic	Acidic Tuff	300--450	*
	Weathered.	4----20	
Permian	Slate	900--1500	*
	Weathered.	20---30	

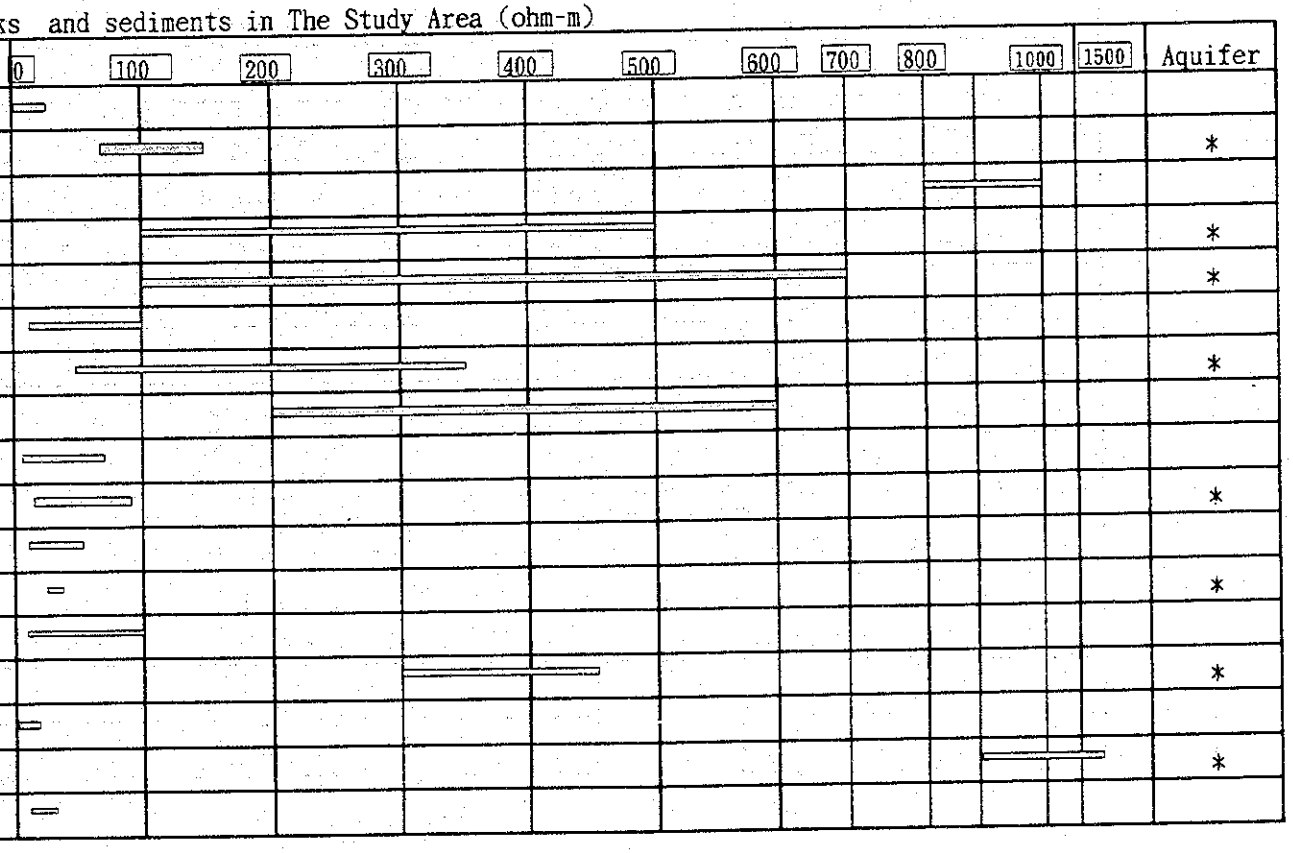
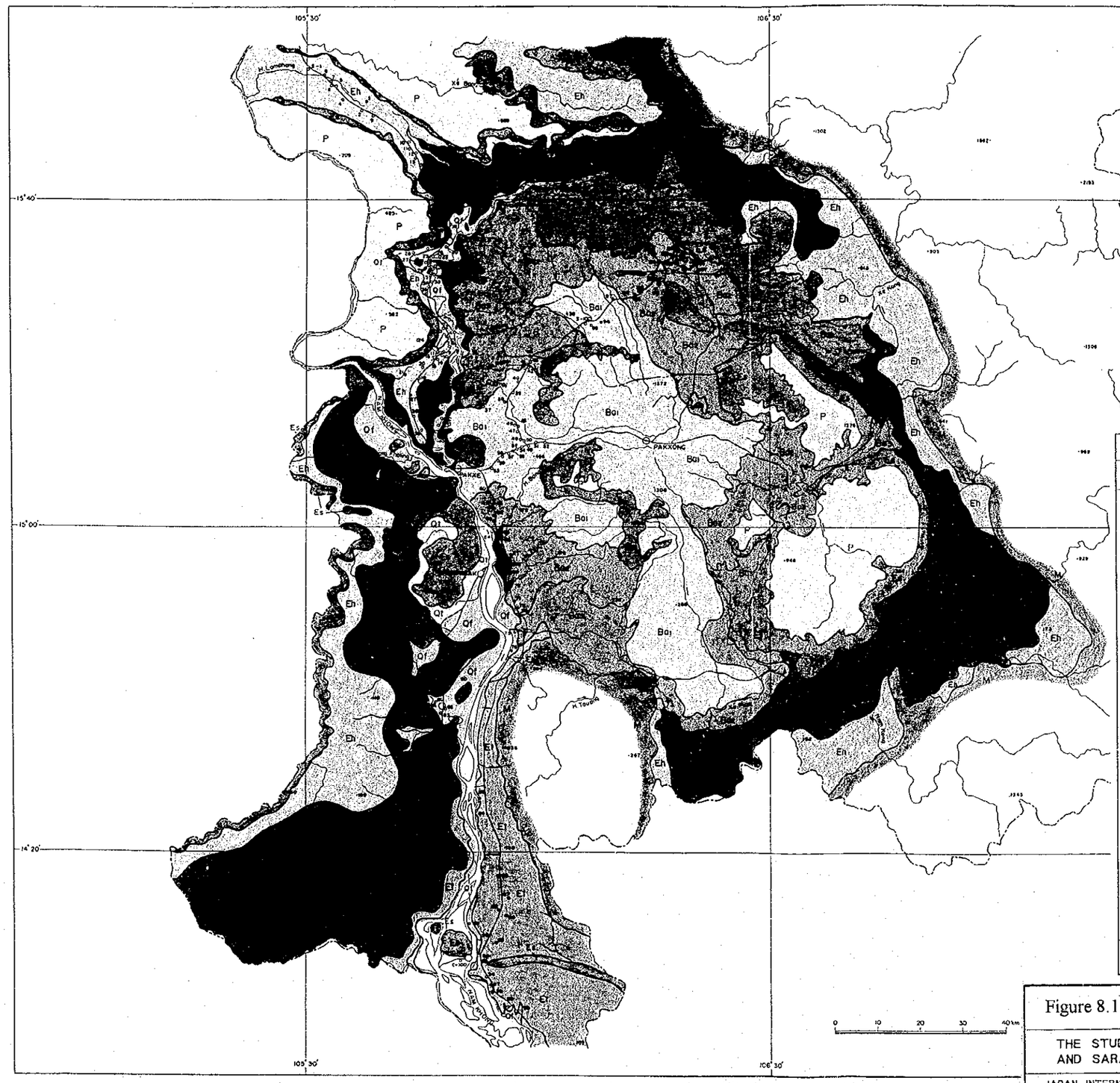


Table 8.2.2 **Correlation of Aquifers and Geophysical Well Logs**

No.	Village Name	Depth of Well (m)	Screen Length (m)	Aquifer	Resistivity Short (Ω-m)	Spontaneous Potential (mV)	Natural Gamma (cps)	Hydrogeologic Unit
C4	Nongphai	49	20	sandstone	50	200+	5-20	Eh
C8	Houaxe	180	60	sandstone	80-100	100+	20±	Eh
C16	Louy	48	24	conglomerate sandstone	40-100 40>	unknown		Eh
C44	Thongsala	25	12	basalt	200-1000	500-	20±	Ba2
C49	Lak 21	45	12	weathered basalt	80-100	200-	8-12	Ba1
C65	Lak 24	49	12	sandstone	80-160	100+	20-40	Ep
C75	Nongkhe	50	20	sandy shale	50	500-	20-40	Qf
C79	Samkhanaboua	43	20	shale	10-20	*	10-30	Ep
C88	Máisivilai	50	28	slate	50	*	20-30	Et
C89	Nasenphan	50	24	acidic tuff	50	200+	10-20	Et
S4	Houaykapho	42	20	sandstone	120-180	*	20-30	Eh
S12	Nongsano	50	28	mudstone	10-40	*	30-40	Eh
S24	Donmuang	50	16	sandstone	80	50-	30-40	Qf
S39	Nongong	49	16	sandstone	60-80	50-	30-40	Ep
S50	Samia	50	21	mudstone sandstone	40-60 60-80	100- 100+	30-40 20-30	Qf
S56	Chong	49	20	mudstone sandstone	40 80+	100+ 100+	10-30 30±	Ba3
S64	Phonphai	50	16	sandstone	60-80	200-	20±	Ep
S75	Nakasao	50	24	sandstone	120-160	200-	30-40	Ep
S84	Beng	60	30	weathered basalt	100-200	500+	4-8	Ba2
S100	Houantai	52	24	weathered basalt	20-40	1000+	4-8	Ba1



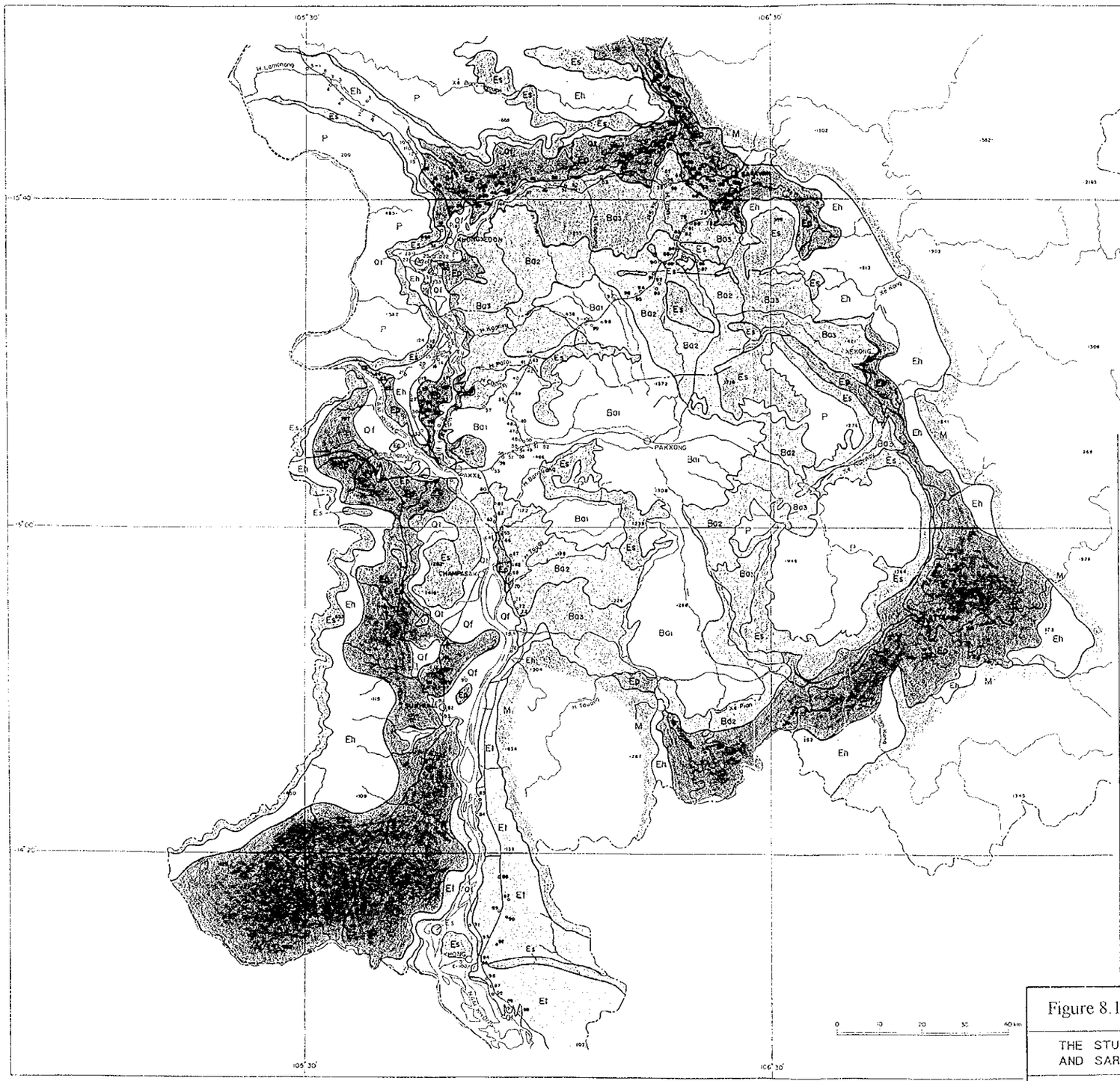
LEGEND

Symbol	Geomorphology and Geology	Groundwater Potential
Qf	Flood Plain, Accumulation Terrace Unconsolidated sand, silt and clay.	A-B
Qt	Alluvial Fan, Talus slope. Unconsolidated sand, silt.	C
Ba1	Basalt Slope. Mudflow Deposits with Boulder, Ash, Basaltic Lava Flows.	A-C
Ba2	Basalt Slope. Basaltic Lava Flows, Mudflow Deposits.	B-C
Ba3	Basalt Slope. Basaltic Lava Flows	B-C
Eh	Erosional Plain. Redshale, Fine to Medium Sandstone	B
Eh	Erosional Hill Red Shale, Fine to Medium Sandstone	B-C
Ei	Erosional Terrace. Dacitic Tuff, Rhyolite, Slate,Sandstone.	C-D
P	Plateau, High Plain. Sandstone, Shale	C-D
M	Mountains. Metasediments, Plutonic rocks: Hydrogeologic Basement	C-D
Es	Escarpment, Ridge	---
○	Candidate Villages	A - D High-Low

Figure 8.1.1 Groundwater Potential Map Based on Hydrogeology

THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC

JAPAN INTERNATIONAL COOPERATION AGENCY(JICA) | KOKUSAI KOGYO CO.,LTD. CONSTRUCTION PROJECT CONSULTANTS.INC



LEGEND

Symbol	Geomorphology and Geology	Groundwater Potential
Qf	Flood Plain, Accumulation Terrace Unconsolidated sand, silt and clay.	A–B
Qt	Alluvial Fan, Talus slope. Unconsolidated sand, silt.	C
Ba1	Basalt Slope. Mudflow Deposits with Boulder, Ash, Basaltic Lava Flows.	A–C
Ba2	Basalt Slope. Basaltic Lava Flows, Mudflow Deposits.	B–C
Ba3	Basalt Slope. Basaltic Lava Flows	B–C
Ep	Erosional Plain. Redshale, Fine to Medium Sandstone	B
Eh	Erosional Hill Red Shale, Fine to Medium Sandstone	B–C
Et	Erosional Terrace Dacitic Tuff, Rhyolite, Slate,Sandstone.	C–D
P	Plateau, High Plain. Sandstone, Shale	C–D
M	Mountains. Metasediments, Plutonic rocks; Hydrogeologic Basement	C–D
Es	Escarpment, Ridge	—
○	Candidate Villages	A – D High-Low

Figure 8.1.1 Groundwater Potential Map Based on Hydrogeology

THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC

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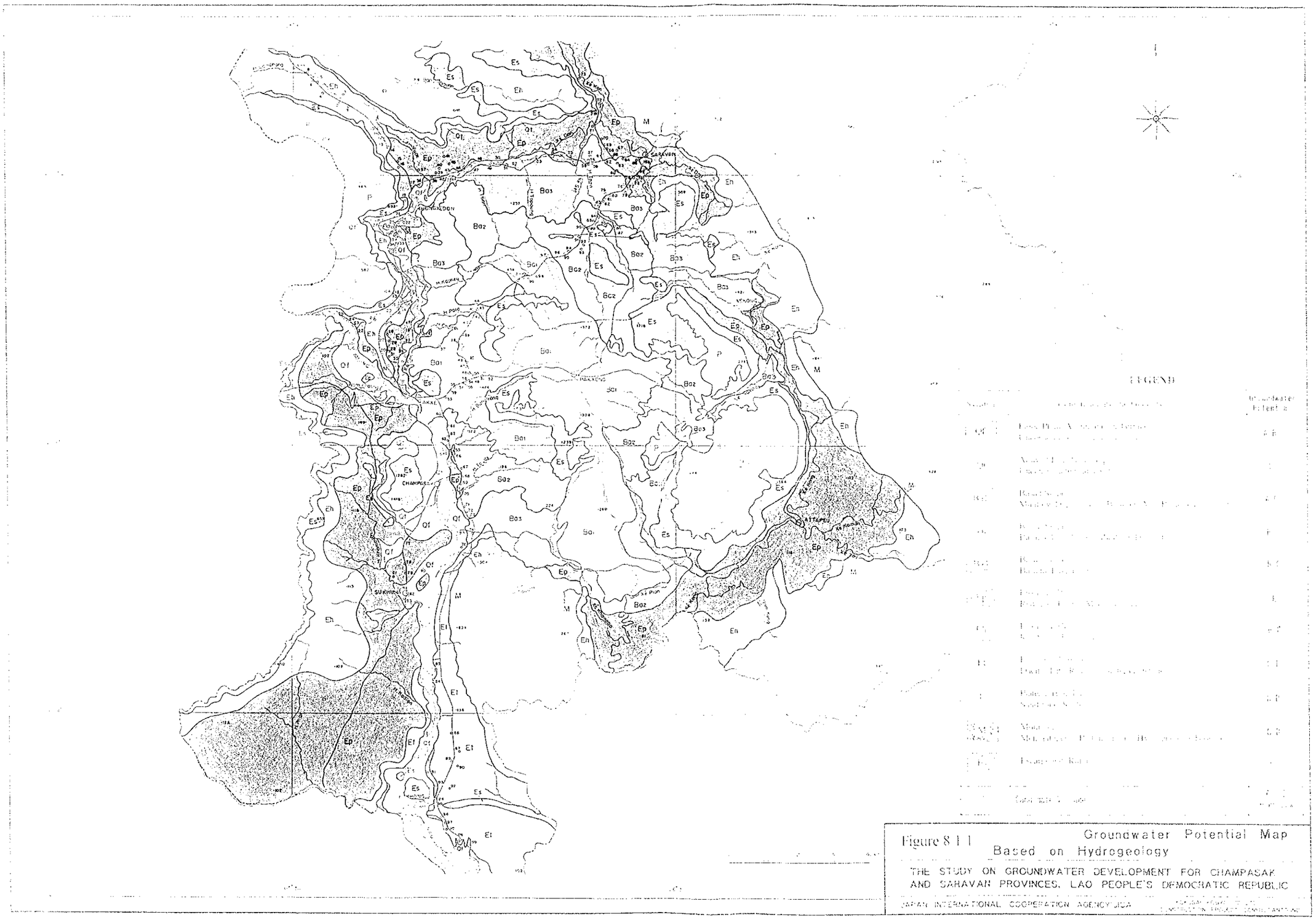
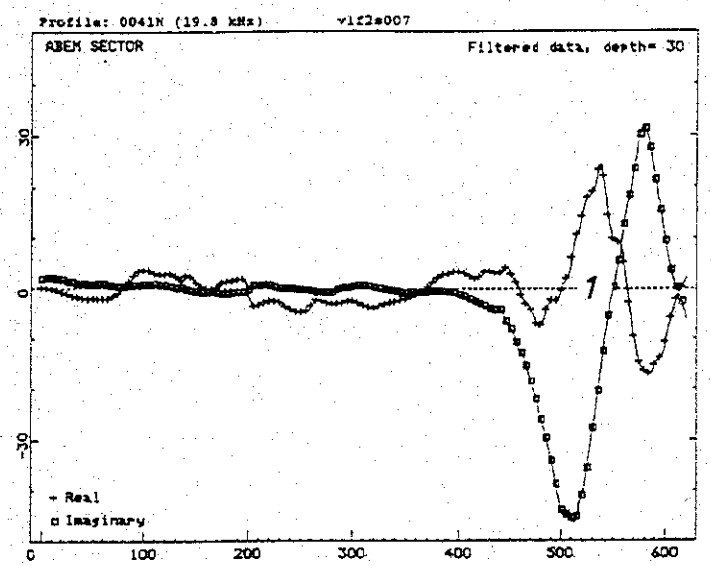
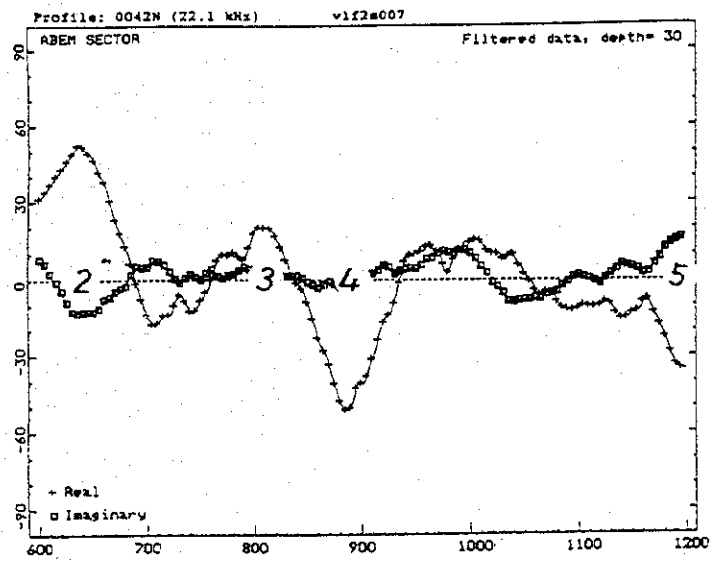


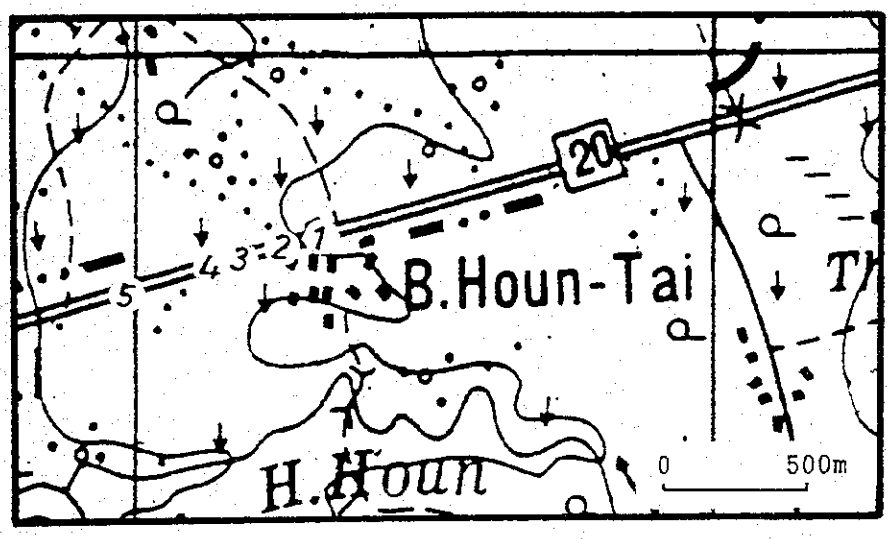
Figure 8.1.1 Groundwater Potential Map Based on Hydrogeology

THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC

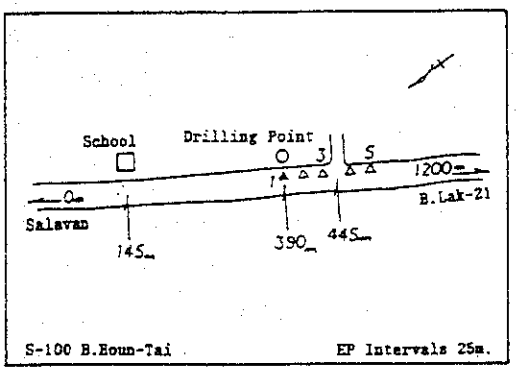
JAPAN INTERNATIONAL COOPERATION AGENCY JICA







N



△ E.P.Centre

Figure 8.2.1 Filtered Data and Anomaly Indication on VLF method (S 100 B.Houn-Tai)

THE STUDY ON GROUNDWATER DEVELOPMENT FOR CHAMPASAK AND SARAVAN PROVINCES, LAO PEOPLE'S DEMOCRATIC REPUBLIC

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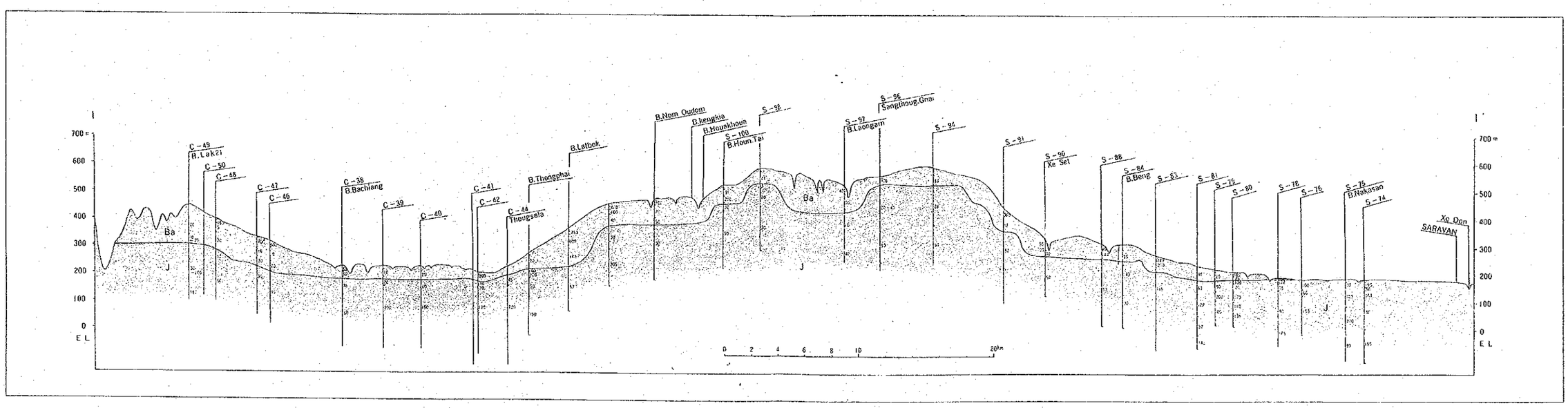
Figure 8.3.1 Geological Profile of Basalt Slope



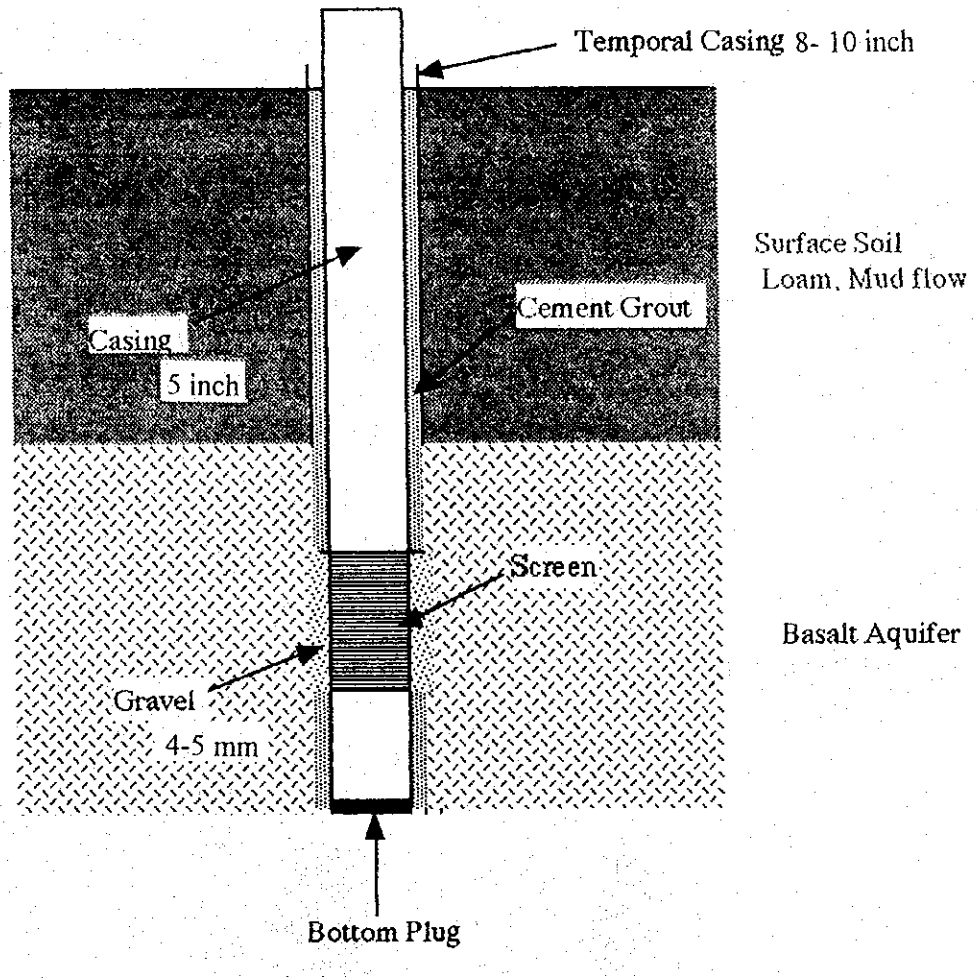


Figure 8.3.2 Well Construction in Ba1 Area