CHAPTER 5

TEST WELL DRILLING

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It was initially planned that thirteen (13) test wells would be drilled during Phase I and II of the Study. The exact drilling sites were selected based on the analysis of geophysical prospecting data and hydrogeological interpretations. Finally, each drilling site at thirteen (13) target communes were determined through discussion among the Study Team, the CERWASS, and the commune authorities.

In the course of drilling work in Phase I, two (2) more test wells were drilled in Thanh Hoa and Ha Tinh, because it was needed from the results of test well drilling at initially selected communes. As a result, twelve (12) test wells were drilled in Phase I and three (3) test wells were drilled in Phase II.

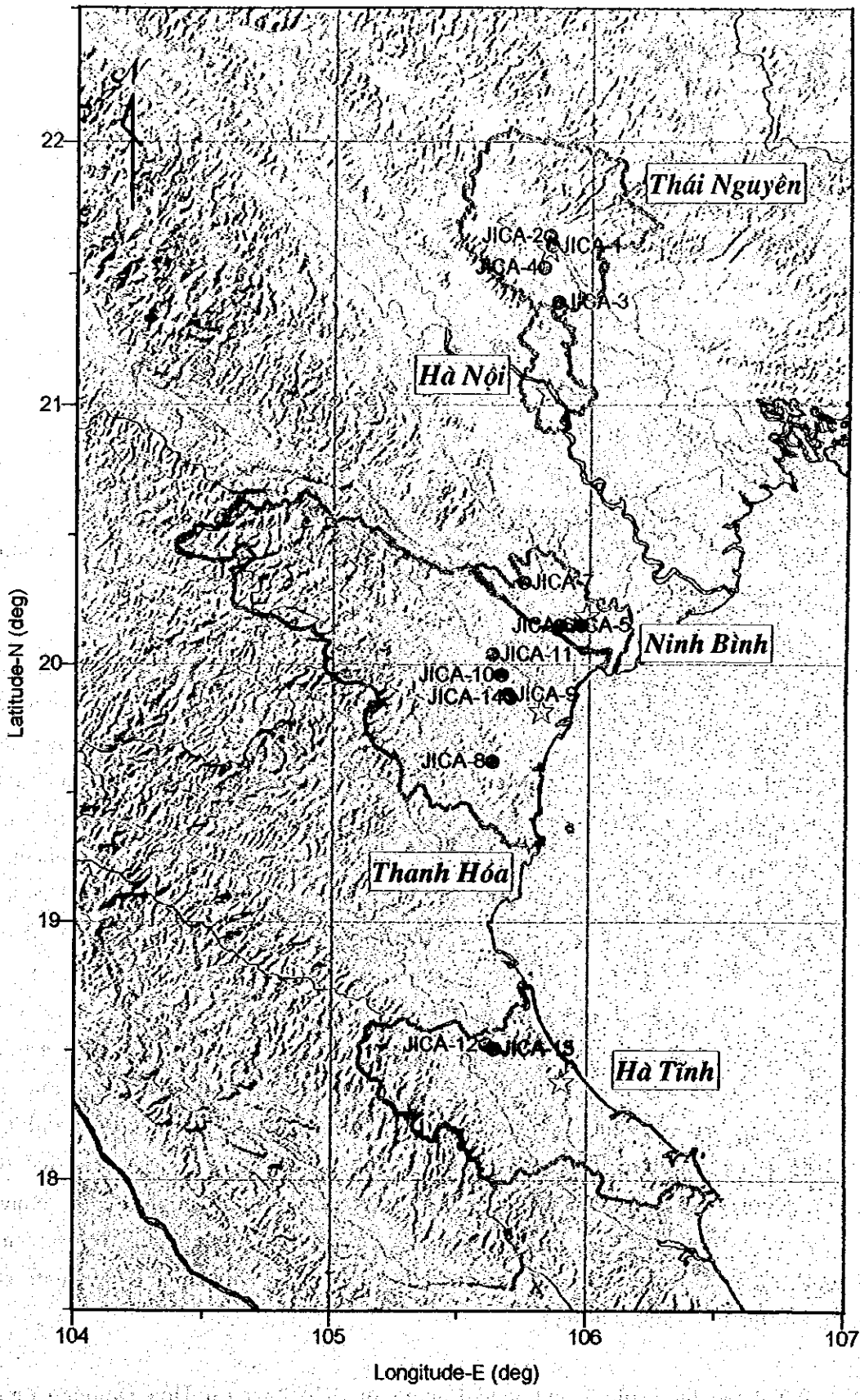
5.1 Drilling Locations

Table 5.1.1 shows the list of the test wells drilled by the Study. In Thai Nguyen Province, four (4) test wells were drilled in the four (4) target communes. Similarly, three (3) test wells were drilled in the three (3) target communes in Ninh Binh Province. In Thanh Hoa Province, five (5) test wells were drilled in five (5) communes out of seven (7) target communes. In Ha Tinh Province, two (2) wells were drilled in Trung Le Commune and one (1) test well was drilled in Duc Yen Commune.

The exact location of the drilling site was determined based on the results of geophysical prospecting, hydrogeological analysis, and discussion among the Study Team, the CERWASS, and the commune authorities. The geographical conditions and land use were also taken into account for selecting the drilling sites. The UTM coordinates of each test well site was measured by a GPS receiver, which are shown in Table 5.1.1. The locations of the test wells are shown in Figure 5.1.1. In Figures 4.2.1 to 4.2.12, the exact locations of the test wells are shown with the locations of the geophysical prospecting and the investigated existing wells.

Table 5.1.1 List of Test Wells Drilled by The Study

Test Well No.	Commune District Province	UTM-E (m)	UTM-N (m)	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)
JICA-1	Đồng Bẩm Đồng Hỷ Thái Nguyên	587420	2389687	100	76	40 to 72	32.0
JICA-2	Hoá Thượng Đồng Hỷ Thái Nguyên	586578	2393846	150	92	24 to 32 56 to 64 76 to 88	28.0
JICA-3	Nam Tiến Phổ Yên Thái Nguyên	590257	2366017	100	21.5	5.5 to 17.5	12.0
JICA-4	Thịnh Đức Thị trấn Thái Nguyên Thái Nguyên	584201	2380475	100	88	8 to 16 52 to 60 68 to 84	32.0
JICA-5	Quang Sơn Thị trấn Tam Điệp Ninh Bình	592553	2228660	150	120	72 to 116	44.0
JICA-6	Yên Thắng Yên Mô Ninh Bình	600941	2228665	150	136	76 to 84 92 to 104 124 to 132	28.0
JICA-7	Đồng Phong Nho Quan Ninh Bình	577617	2246929	150	130	92 to 126	34.0
JICA-8	Vạn Thắng Nông Cống Thanh Hoá	565030	2170050	150	150	99 to 119	20.0
JICA-9	Thiệu Hưng Thiệu Hoá Thanh Hoá	571655	2199306	80	52	32 to 48	16.0
JICA-10	Định Tường Yên Định Thanh Hoá	568421	2207260	91.2	91.2	23.2 to 39.2 47.2 to 63.2	32.0
JICA-11	Vĩnh Thành Vĩnh Lộc Thanh Hoá	564793	2216162	148	80	32 to 48 60 to 76	32.0
JICA-12	Đức Yên Đức Thọ Hà Tĩnh	563705	2048152	106	104	20 to 28 84 to 100	24.0
JICA-13	Trung Lễ Đức Thọ Hà Tĩnh	566783	2046329	100	100	58 to 82	24.0
JICA-14	Thiệu Đô Thiệu Hoá Thanh Hoá	572185	2197515	70	68	18 to 50 58 to 64	38.0
JICA-15	Trung Lễ Đức Thọ Hà Tĩnh	567186	2046557	70	40	16 to 36	20.0



JICA Test Well

Figure 5.1.1 Location of JICA Test Wells

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5.2 Aquifers

The main purpose of drilling test wells in the Study is to evaluate aquifer characteristics for future groundwater development, particularly of deep aquifers. It was expected by the geophysical prospecting that the bedrock occurs at relatively shallow depths in the Study Area except Hanoi. At present, most existing wells in the Study Area are shallow, extracting groundwater from shallow aquifers. Because of this situation, there are almost no data in the Study Area for evaluating deep aquifer characteristics, particularly of basement rock aquifers.

5.2.1 Geology and well structure

During the drilling work, core samples and cutting samples were carefully observed by the hydrogeologists of the Study Team. Figures 5.2.1 and 5.2.15 show the geology and well structure of the test wells.

In Dong Bam (JICA-1 Test Well), the Study Team drilled up to 100 m in depth as shown in Figure 5.2.1. The drilling site is underlain by Quaternary sediments and Carboniferous-Permian limestone. The Quaternary sediments have 18.6 m in thick, consisting of yellowish brown clay from ground surface to 5.0 m in depth, yellow fine sand with clay from 5.0 to 7.5 m, yellowish brown sandy gravel from 7.5 to 11.0 m, gray clay from 11.5 to 14.5 m, and loose sand from 14.5 to 18.6 m. The bedrock of the site is limestone, which was encountered at 18.6 m depth. The limestone from 18.6 to 34.0 m is hard and massive so that the core samples show a stick-type shape. However, the limestone below 34.0 m depth is fractured, and a cave was found at 43.1 to 43.6 m in depth. The fractured limestone continues up to 62.0 m, then very hard crystallized limestone occurs at depths from 62.0 to 64.0 m. This limestone has calcareous breccia, and both breccia and matrix are crystallized and well consolidated. Therefore, the drilling machine could drill only one (1) meter per day at that portion. Below the hard limestone, the fractured limestone again occurs at depths between 64.0 and 72.0 m. From 72.0 m, consolidated hard and massive limestone occurs up to the depth of 100 m. Based on the observation of core samples and interpretation of the geophysical logging data, the Study Team decided to install casing and screen pipes up to 76 m depth. The screen pipes (ϕ56 inches FRP screen) had been installed from 40 to 72 m depth to evaluate aquifer properties of the limestone aquifer.

Figure 5.2.2 shows the geology and well structure of JICA-2 well in Hoa Thuong Commune, Thai Nguyen Province. Quaternary sediments occur from ground surface up to a depth of 12.8 m. Limestone is encountered at a depth of 12.8, it continues up to 96.0 m in depth. The limestone from 12.8 to 36.0 m is fractured, in which cave was found from 32.5 to 33.5m.

Another cave was found at depths from 82.5 to 83.5 m in fractured limestone. From 96.0 to 109.5 m, limestone is mixed with sandstone. Hard sandstone was found from 109.5 to 150.0 m. The bore hole resistivity values indicate that the portions of cave have low resistivity. Based on the geologic conditions, screen pipes were installed at three portions; from 24 to 32 m, from 56 to 64 m, and from 76 to 88 m. The well depth was decided to be 92 m.

Figure 5.2.3 shows the geology and well structure of JICA-3 well in Nam Tien. Quaternary sediments are found up to a depth of 15.4 m. From 15.4 m, hard sandstone with siltstone was encountered. The basement rock from 33.0 to 80.0 m consists of alternations of sandstone and siltstone, in which the ratio of siltstone increases with depth. Hard siltstone with claystone were continuously found from 80.0 to 100.0 m. According to the core observation and the geophysical logging in the bore hole, no fractured zone was found in the basement rock. Therefore, it was evaluated that the basement rock would not yield groundwater. The well depth was decided as 21.5 m and screen pipes were installed for depths from 5.5 to 17.5m to extract groundwater from the gravel layer of the Quaternary sediments.

Figure 5.2.4 shows the geology and well structure of JICA-4 well in Thinh Duc. Quaternary sediments occur up to a depth of 16.5 m. The basement rock is very hard claystone up to 53.0 m, then sandstone and siltstone from 53.0 to 66.1 m. From 66.1 to 100.0 m the basement rock becomes sandstone. Fractured zones having lower resistivity were found from sandstone portions. Screen pipes were installed at sand and gravel layers of Quaternary sediments as well as fractured sandstone.

Figure 5.2.5 shows the geology and well structure of JICA-5 well in Quang Son, Ninh Binh Province. Quaternary sediments consist of clay with gravel, distributed up to a depth of 9.5 m. The basement rock is composed of Triassic limestone. Strongly fractured limestone was encountered from 72.0 to 103.0 m, having a cave from 92.0 to 93.0 m. Screen pipes were installed at depths from 72 to 118 m.

Figure 5.2.6 shows the geology and well structure of JICA-6 well in Yen Thang. Here Quaternary sediments occur until a depth of 44.0 m. The upper part consists of clay and sandy clay, while the lower part consists of clay and gravel. The basement rock consists of limestone. A large cave was found from 45.5 to 51.0 m. There are three horizons of fractured limestone up to a depth of 150.0 m. The screen pipes were not installed at the cave, because the groundwater quality is presumed to be saline at the portion. The screen pipes were set at 76 to 84 m, 92 to 104 m, and 124 to 132 m.

Figure 5.2.7 shows the geology and well structure of JICA-7 well in Dong Phong. Quaternary

sediment is very thin, only 2.4 m from the surface. The basement rock consists of limestone. The limestone is very hard in nature, however, strongly fractured limestone was found at depths from 63.0 to 72.0 m. Screen pipes were installed from 92 to 126 m.

Figure 5.2.8 shows the geology and well structure of JICA-8 well in Van Thang, Thanh Hoa Province. Quaternary sediment is clay and sand, having 6 m thick. The basement rock is composed of sandstone, sandy siltstone, and siltstone with claystone. Fractured sandstone with siltstone occurs at depths from 99.5 to 122.0 m. Screen pipes were installed at 99 to 119 m in depth.

Figure 5.2.9 shows the geology and well structure of JICA-9 well in Thieu Hung. Quaternary sediments have a thickness of 48 m, composed of clay and sand in the upper portion and sand and gravel in the lower portion. The basement rock consists of sandstone. The upper part is weathered sandstone having 3 m in thickness, however, the rest consists of hard sandstone. It was evaluated that the sandstone cannot be treated as aquifer so that screen pipes were installed at depths from 32 to 48 m where Quaternary gravely layers occur.

Figure 5.2.10 shows the geology and well structure of JICA-10 well in Dinh Tuong. Quaternary sediments consist of clay to fine sand in the upper part, and gravel in the lower part. From 34 m in depth basement rocks consisting of claystone and sandstone with conglomerate were encountered. The claystone and sandstone show alternating layers. Screen pipes were set at 23.2 to 39.2 m in the Quaternary gravel layer and at 47.2 to 63.2 m in the fractured claystone and sandstone of the basement rock.

Figure 5.2.11 shows the geology and well structure of JICA-11 well in Vinh Thanh. Quaternary sediment has 23.0 m thick, consisting of sandy clay. The basement rock is composed of limestone. Large caves were encountered at depths from 33.5 to 36.6m and from 50.0 to 54.8 m. Limestone below 73.0 m in depth is hard and massive. Screen pipes were installed at depths from 32 to 48 m and 60 to 76 m, where fissured limestone and cavernous limestone occurs.

Figure 5.2.12 shows the geology and well structure of JICA-12 well in Duc Yen, Ha Tinh Province. Quaternary sediments occur up to a depth of 28.8 m. It is underlain by Neogene sediments. A gravel layer was found in the Quaternary sediments from 22.8 to 28.0 m. The Neogene sediments consist of siltstone and claystone, that are weakly consolidated. The siltstone from 90.8 to 94.2 m contains gravel, and its resistivity is higher in the basement rock. Screen pipes were set at depths from 20 to 28 m in the Quaternary gravel layer and from 84 to 100 m in the Neogene sediments with the gravel-bearing siltstone.

Figure 5.2.13 shows the geology and well structure of JICA-13 well in Trung Le. Quaternary sediments are thick, distributed up to a depth of 68.4 m. The basement rock consists of claystone with siltstone and sandstone. There are two (2) gravel layers in the Quaternary sediments; in between there is a clayey layer separating the gravel layers. It was presumed that the upper part of the gravel layers have saline groundwater so that screen pipes were set at depths from 58 to 82 m to obtain groundwater from the lower part of Quaternary sediments as well as the upper part of Neogene sediments.

Figure 5.2.14 shows the geology and well structure of JICA-14 well in Thieu Do Commune, Thanh Hoa Province. Quaternary sediments have 33.5 m in thickness, consisting of clay and sand in the upper to middle part and gravel with sand in the lower part. The basement rock consists of limestone. The limestone just below the Quaternary sediments is weathered. Tow (2) caves were encountered at depths from 59.0 to 60.0 m and 63.0 to 64.0 m. Screen pipes were installed at depths from 18 to 50 m and 58 to 64 m.

Figure 5.2.15 shows the geology and well structure of JICA-15 well in Trung Le Commune, Ha Tinh Province. This well is drilled about 300 m northeast of JICA-13 well. Quaternary sediments have 35.4 m in thickness, consisting of clay and fine sand in the upper part and gravel with sand in the lower part. The gravel layers were separated by a sandy clay layer having a thickness of 1.5 m.

5.2.2 Bedrock depth

The depth to the basement rock at each drilling site is shown in Table 5.2.1.

The depth to basement rock from ground surface ranges from 12.8 to 18.6 m at four (4) drilling sites in Thai Nguyen.

In Ninh Binh, the basement rock depth is deeper towards east. At JICA-6 well in Yen Thang, the bedrock depth is 44.0 m. The bedrock depths at Quang Son (JICA-5) and Dong Phong (JICA-7) are 9.4 and 2.0 m, respectively.

The depth to basement rock in Thanh Hoa ranges from 6.0 to 48.0 m at the drilling sites. The depth in Van Thanh (JICA-8) is the shallowest, because the well is located near a bedrock mountain. The depths in Thieu Hung (JICA-9) and Thieu Do (JICA-14), both of them are located along Cho River, are 48.0 and 33.5 m, respectively. In the northern part of the province, the basement rock depth at Vinh Thanh (JICA-11) is 23.0 m and the depth at Dinh

Tuong (JICA-10) is 34.8 m.

In Ha Tinh, the test wells did not encounter Mesozoic basement rocks. In the target communes, it is revealed that Quaternary sediments are underlain by Neogene sediments, that mostly consists of clay. The depth to Neogene clay or the bottom of the Quaternary sediments ranges from 28.0 to 68.4 m.

5.2.3 Aquifer Geology

At each test well site, target aquifer(s) was carefully identified based on the results of core sample observation, geophysical logging data, drilling records, and hydrogeological interpretation of existing wells. For instance, if several aquifers are identified from the test well drilling, the target aquifer(s) is carefully selected considering shallow water quality, thickness of aquifer and aquitard, etc. If it is evaluated that the bedrock cannot become an aquifer(s), the Quaternary gravel layer is selected as a target aquifer.

Table 5.2.1 shows the geology, aquifer geology and screen depths of each test well. In Dong Bam (JICA-1), fractured limestone with cave was selected as a target aquifer. In Hoa Thuong (JICA-2), three (3) aquifer layers were identified in limestone. The sandstone and siltstone are very hard and massive at Nam Tien site (JICA-3), screen pipes were set at Quaternary gravel layers and weathered siltstone. At JICA-4 well in Thinh Duc, two (2) possible aquifer zones were identified in sandstone and one aquifer zone was identified in Quaternary sediments.

In Ninh Binh, target aquifers of test wells are limestone. At JICA-6 well in Yen Thang, there is an aquifer zone in Quaternary sediments and another aquifer horizon in shallow portion of the limestone, but those horizons were not selected as target aquifers due to poor water quality of shallow aquifer. The screen pipes were set at zones from 76 to 84 m, 92 to 104 m, and 124 to 132 m. In Dong Phong (JICA-7), shallow portion of the limestone is very hard, so that a target aquifer was found from deeper fractured limestone.

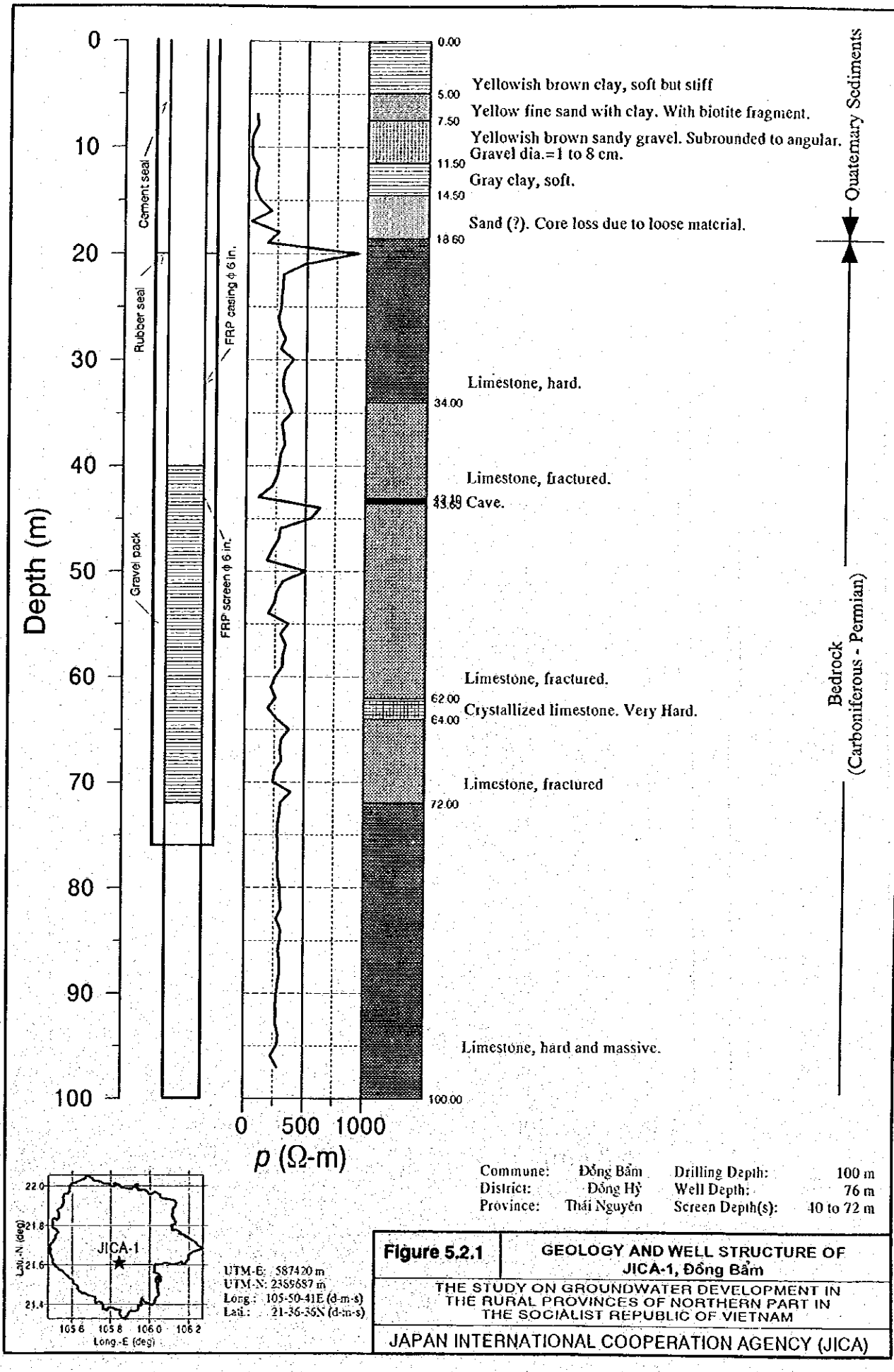
At JICA-8 well in Van Thang, Thanh Hoa, a deep fractured sandstone was selected as a target aquifer. The aquifer geology of JICA-9 well (Thieu Hung) was Quaternary gravel layer, because it was revealed that the bedrock sandstone had no possibility to yield groundwater. At Dinh Tuong (JICA-10), the screen pipes were set at both Quaternary gravel layer and sandstone. Good fractured limestone zones were found at JICA-11 well (Vinh Thanh), the screen pipes were installed from 32 to 48 m and 60 to 76 m. The aquifer geology of JICA-14 well (Thieu Do) is Quaternary gravel layer and limestone.

In Ha Tinh, JICA-13 well was drilled in Trung Le. The screen pipes were set from 58 to 82 m in depth, that were located at Quaternary gravel layer and Neogene clay. However, due to small yield from the well, the target aquifer of the second well (JICA-15) was decided to select Quaternary gravel layer. At JICA-12 well in Duc Yen, Quaternary gravel layer and Neogene clay were selected as target aquifers.

Table 5.2.1 List of Test Wells Drilled by the Study

Test Well No.	Commune District Province	UTM-E (m)	UTM-N (m)	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)	Geology	Bedrock Depth (m)	Aquifer Geology
JICA-1	Đồng Bẩm Đồng Hỷ Thái Nguyên	587420	2389687	100	76	40 to 72	32.0	Quaternary/ Limestone	18.6	Limestone
JICA-2	Hoá Thượng Đồng Hỷ Thái Nguyên	586578	2393846	150	92	24 to 32 56 to 64 76 to 88	28.0	Quaternary/ Limestone/ Sandstone	12.8	Limestone
JICA-3	Nam Tiến Phổ Yên Thái Nguyên	590257	2366017	100	21.5	5.5 to 17.5	12.0	Quaternary/ Sandstone/ Siltstone	15.4	Quaternary gravel & Sandstone
JICA-4	Thịnh Đức Thị trấn Thái Nguyên Thái Nguyên	584201	2380475	100	88	8 to 16 52 to 60 68 to 84	32.0	Quaternaly/ Claystone/ Sandstone	16.5	Quaternary gravel & Sandstone
JICA-5	Quang Sơn Thị trấn Tam Điệp Ninh Bình	592553	2228660	150	120	72 to 116	44.0	Quaternary/ Limestone	9.4	Limestone
JICA-6	Yên Thắng Yên Mô Ninh Bình	600941	2228665	150	136	76 to 84 92 to 104 124 to 132	28.0	Quaternary/ Limestone	44.0	Limestone
JICA-7	Đồng Phong Nho Quan Ninh Bình	577617	2246929	150	130	92 to 126	34.0	Top Soil/ Limestone	2.0	Limestone
JICA-8	Vạn Thắng Nông Cống Thanh Hoá	565030	2170050	150	150	99 to 119	20.0	Quaternary/ Sandstone with Siltstone	6.0	Sandstone
JICA-9	Thiệu Hưng Thiệu Hoá Thanh Hoá	571655	2199306	80	52	32 to 48	16.0	Quaternary/ Sandstone	48.0	Quaternary gravel
JICA-10	Định Tường Yên Định Thanh Hoá	568421	2207260	91.2	91.2	23.2 to 39.2 47.2 to 63.2	32.0	Quaternary/ Sandstone and Claystone	34.8	Quaternary gravel & Sandstone
JICA-11	Vĩnh Thành Vĩnh Lộc Thanh Hoá	564793	2216162	148	80	32 to 48 60 to 76	32.0	Quaternary/ Limestone	23.0	Limestone
JICA-12	Đức Yên Đức Thọ Hà Tĩnh	563705	2048152	106	104	20 to 28 84 to 100	24.0	Quaternary/ Neogene clay	28.0 *	Quaternary gravel & Neogene clay
JICA-13	Trung Lễ Đức Thọ Hà Tĩnh	566783	2046329	100	100	58 to 82	24.0	Quaternary/ Neogene clay	68.4 *	Quaternary gravel & Neogene clay
JICA-14	Thiệu Đô Thiệu Hoá Thanh Hoá	572185	2197515	70	68	18 to 50 58 to 64	38.0	Quaternary/ Limestone	33.5	Quaternary gravel & Limestone
JICA-15	Trung Lễ Đức Thọ Hà Tĩnh	567186	2046557	70	40	16 to 36	20.0	Quaternary/ Neogene clay	35.4	Quaternary gravel

* Depth to Neogene clay



UTM-E: 587420 m
UTM-N: 2359687 m
Long.: 105-50-41E (d-m-s)
Lati.: 21-36-35N (d-m-s)

Commune:	Đồng Bẩm	Drilling Depth:	100 m
District:	Đồng Hỷ	Well Depth:	76 m
Province:	Thái Nguyên	Screen Depth(s):	40 to 72 m

Figure 5.2.1 GEOLOGY AND WELL STRUCTURE OF JICA-1, Đồng Bẩm

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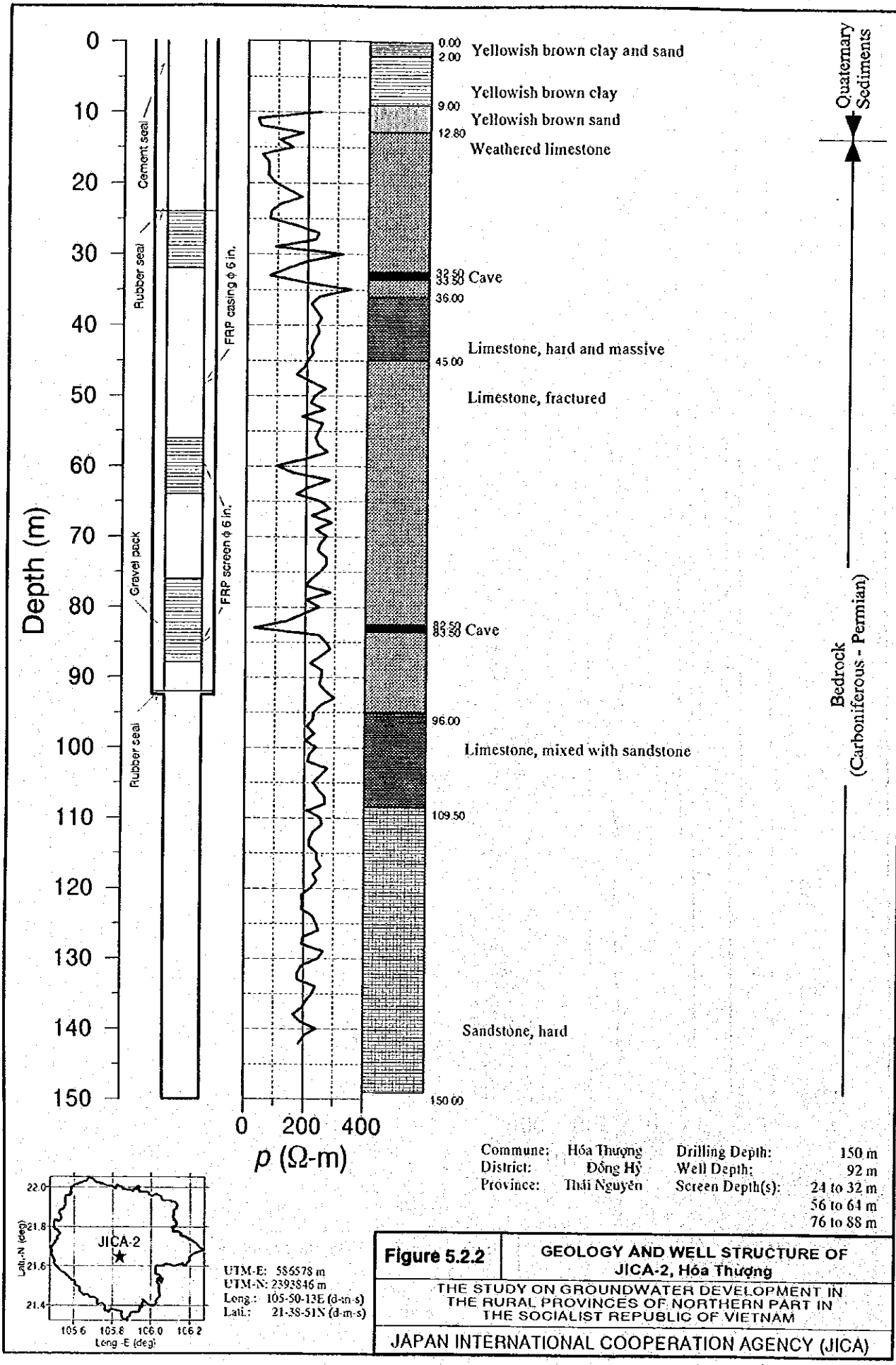

Figure 5.2.2 GEOLOGY AND WELL STRUCTURE OF JICA-2, Hóa Thượng

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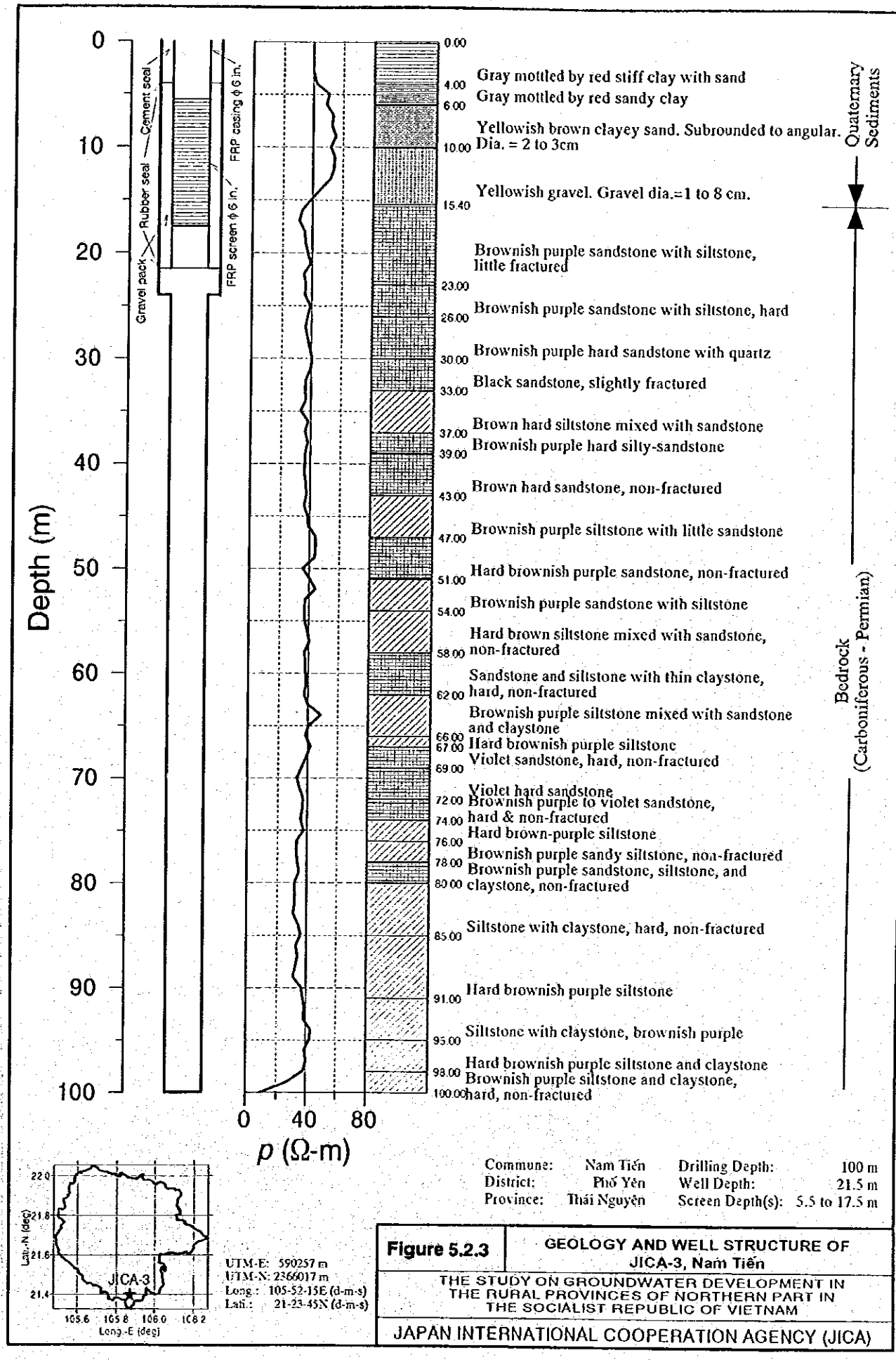

Figure 5.2.3 GEOLOGY AND WELL STRUCTURE OF JICA-3, Nam Tiến

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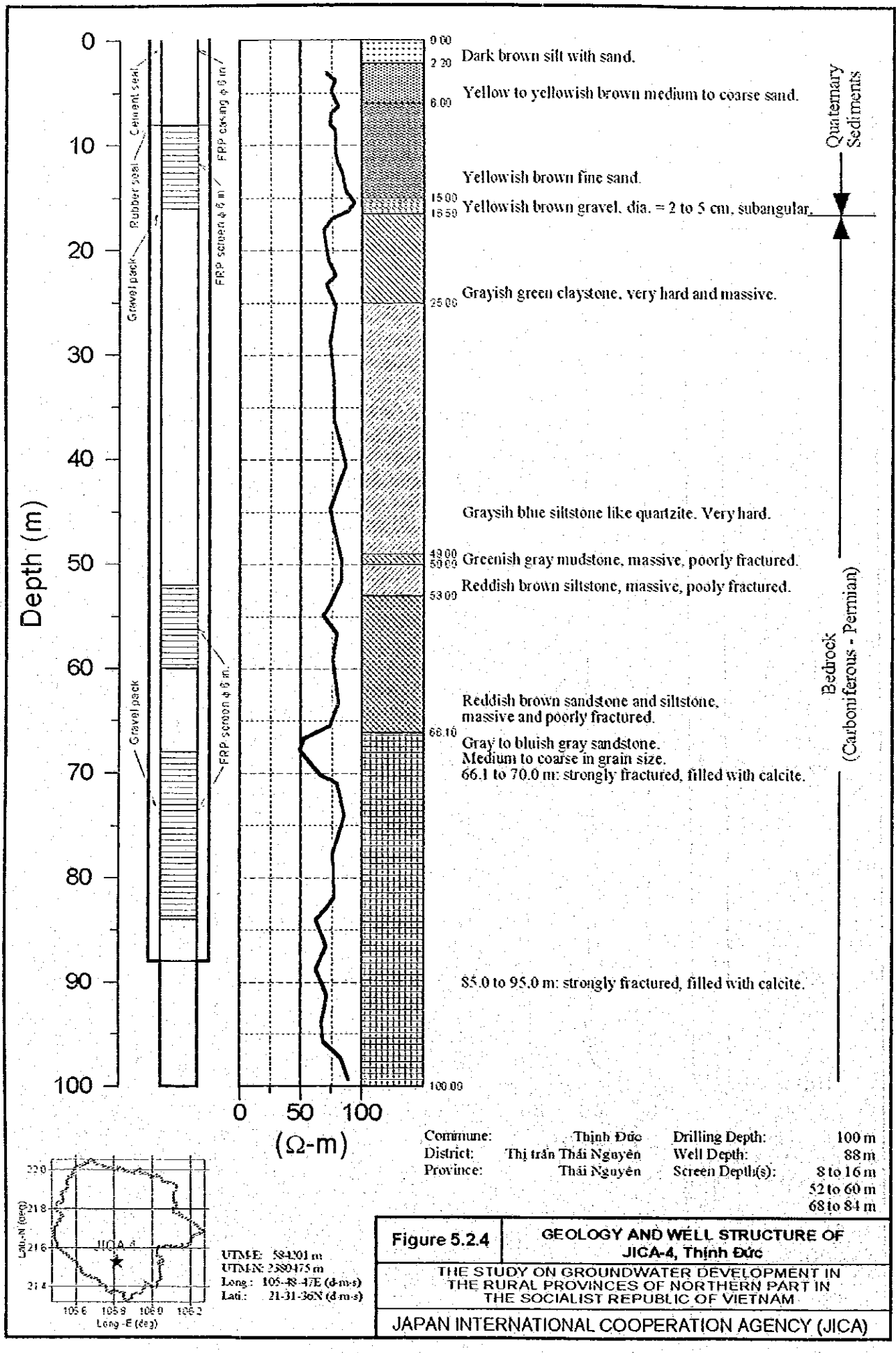

Figure 5.2.4 GEOLOGY AND WELL STRUCTURE OF JICA-4, Thịnh Đức

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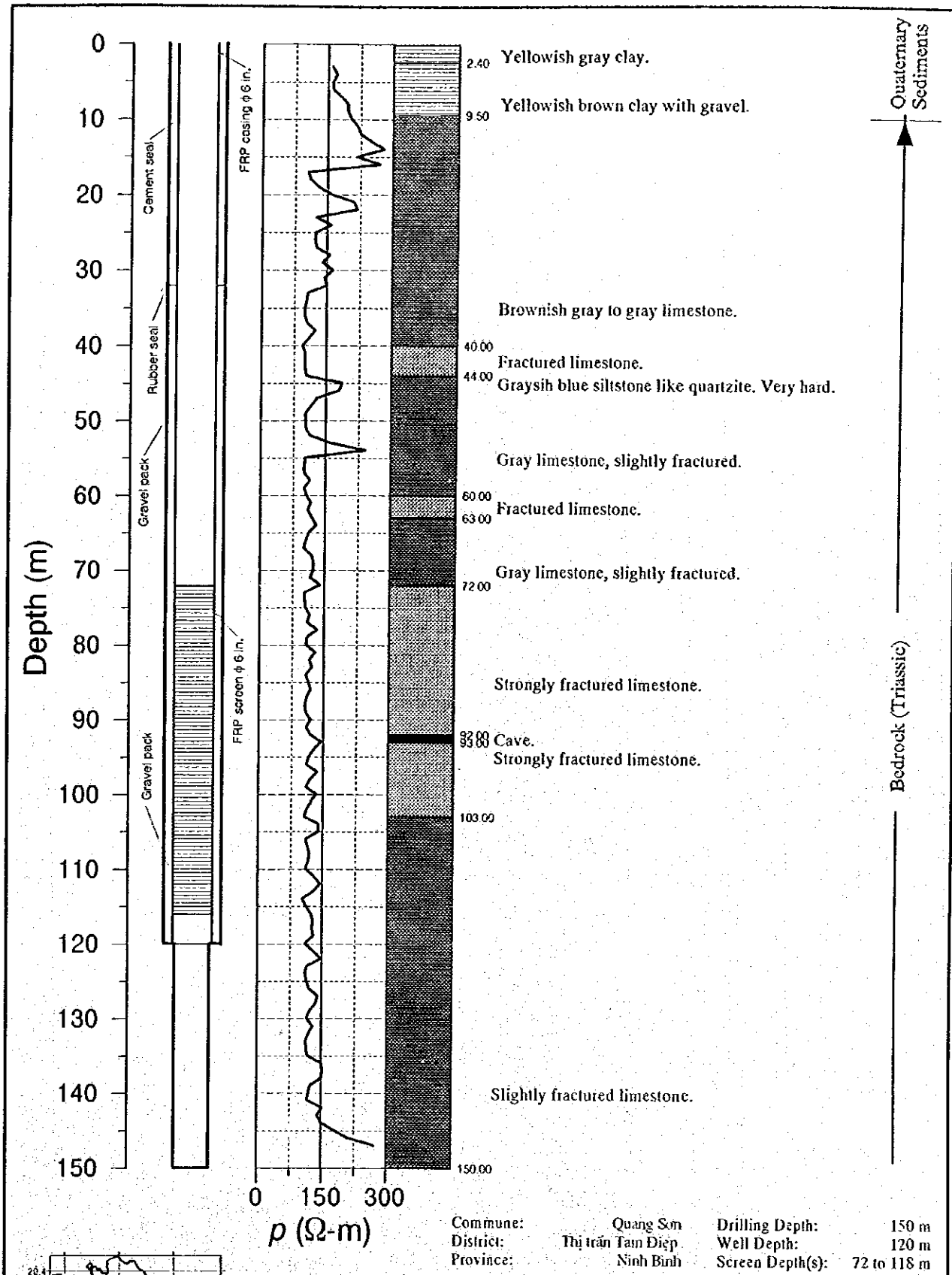

Figure 5.2.5 GEOLOGY AND WELL STRUCTURE OF JICA-5, Quang Sơn

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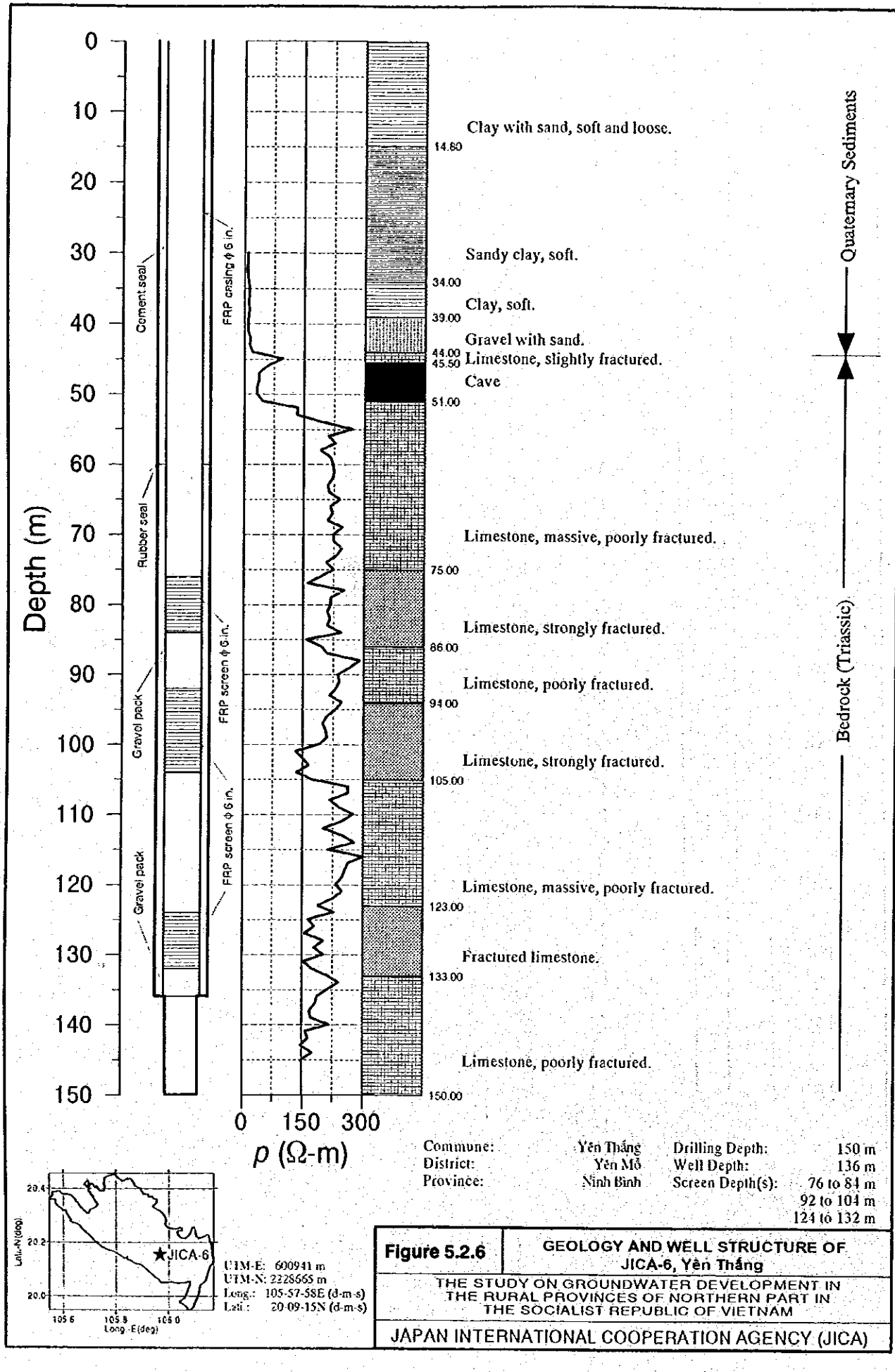

Figure 5.2.6 GEOLOGY AND WELL STRUCTURE OF JICA-6, Yên Thắng

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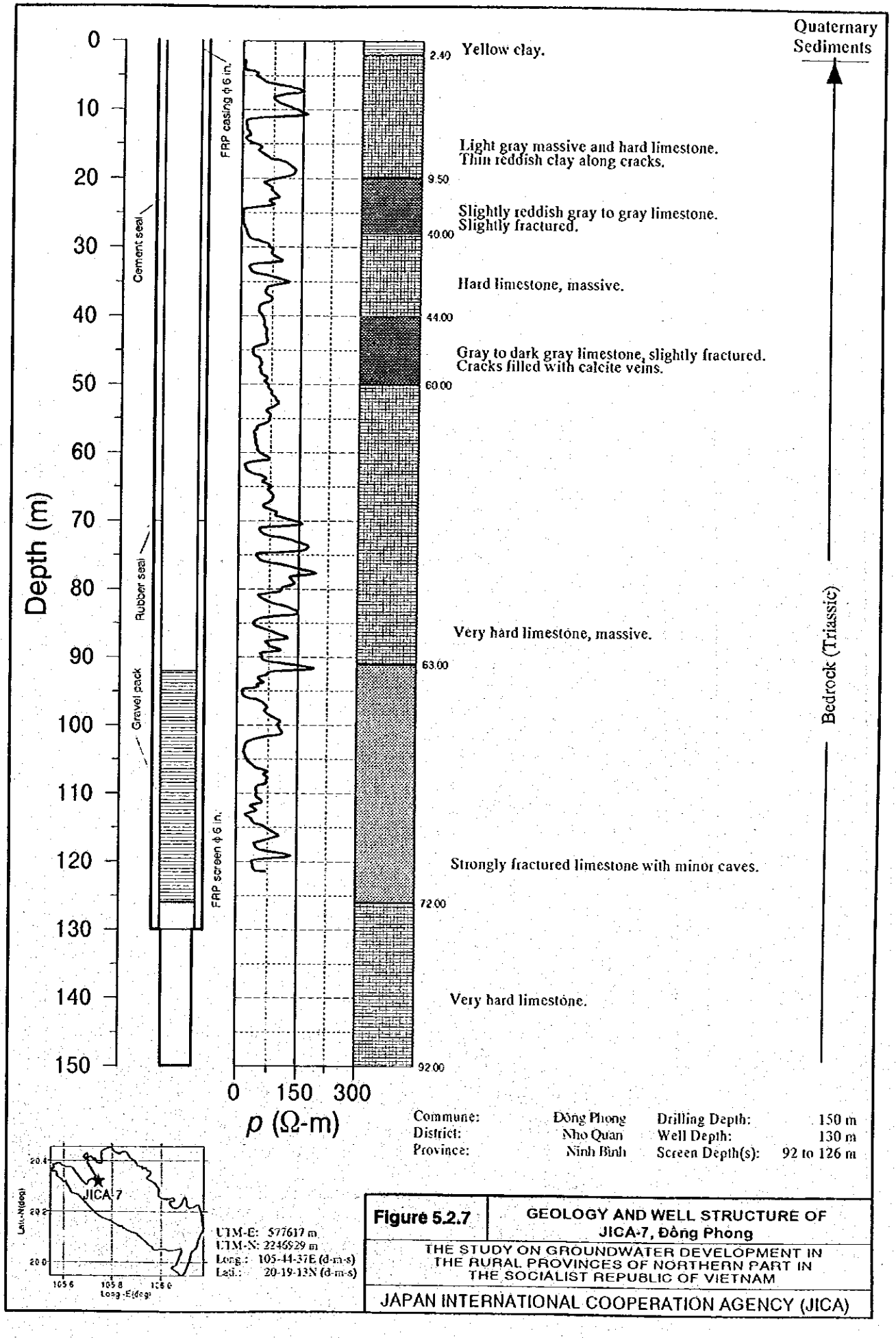

Figure 5.2.7 GEOLOGY AND WELL STRUCTURE OF JICA-7, Đông Phong

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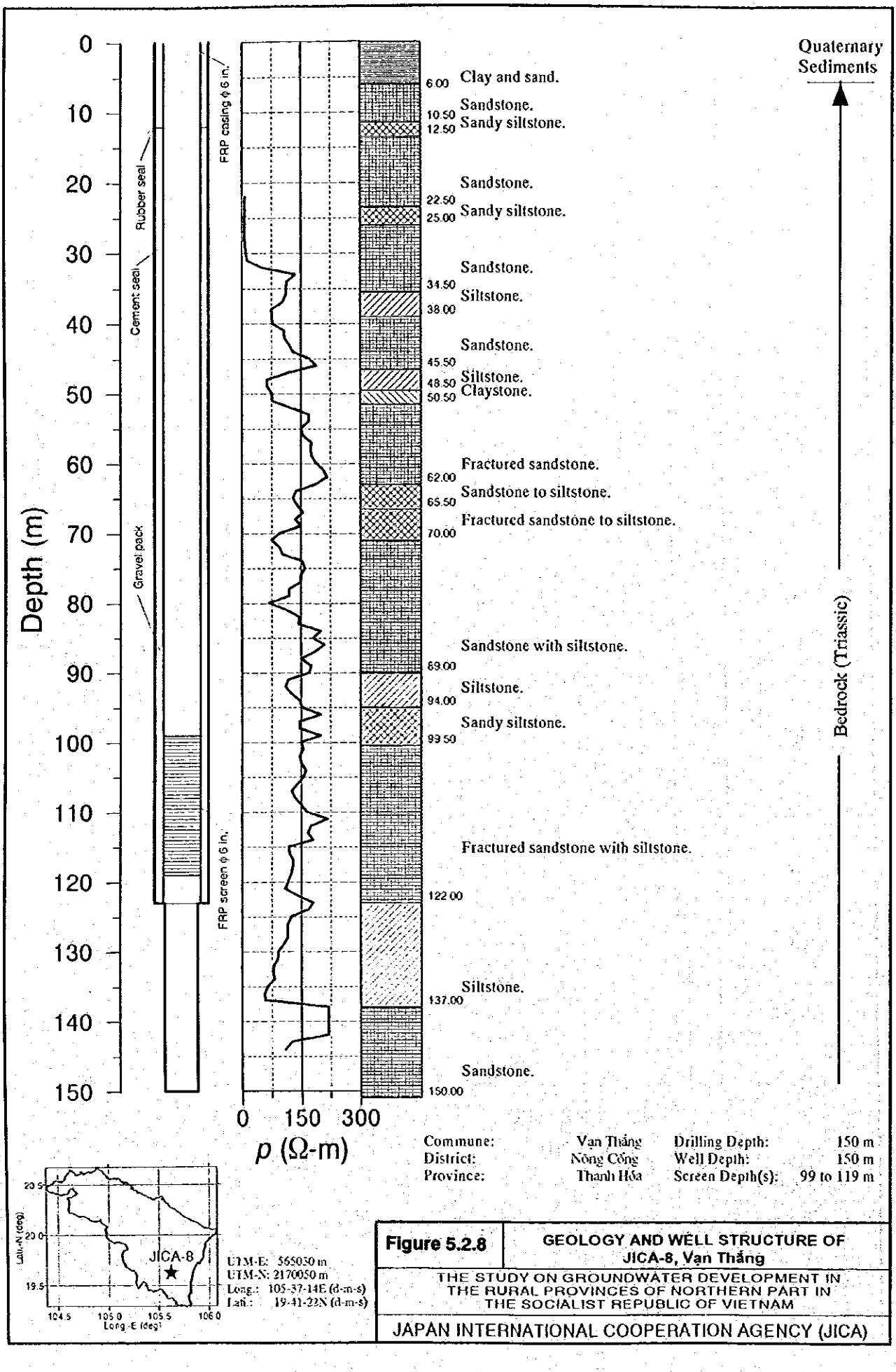

Figure 5.2.8 GEOLOGY AND WELL STRUCTURE OF JICA-8, Vạn Thắng

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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

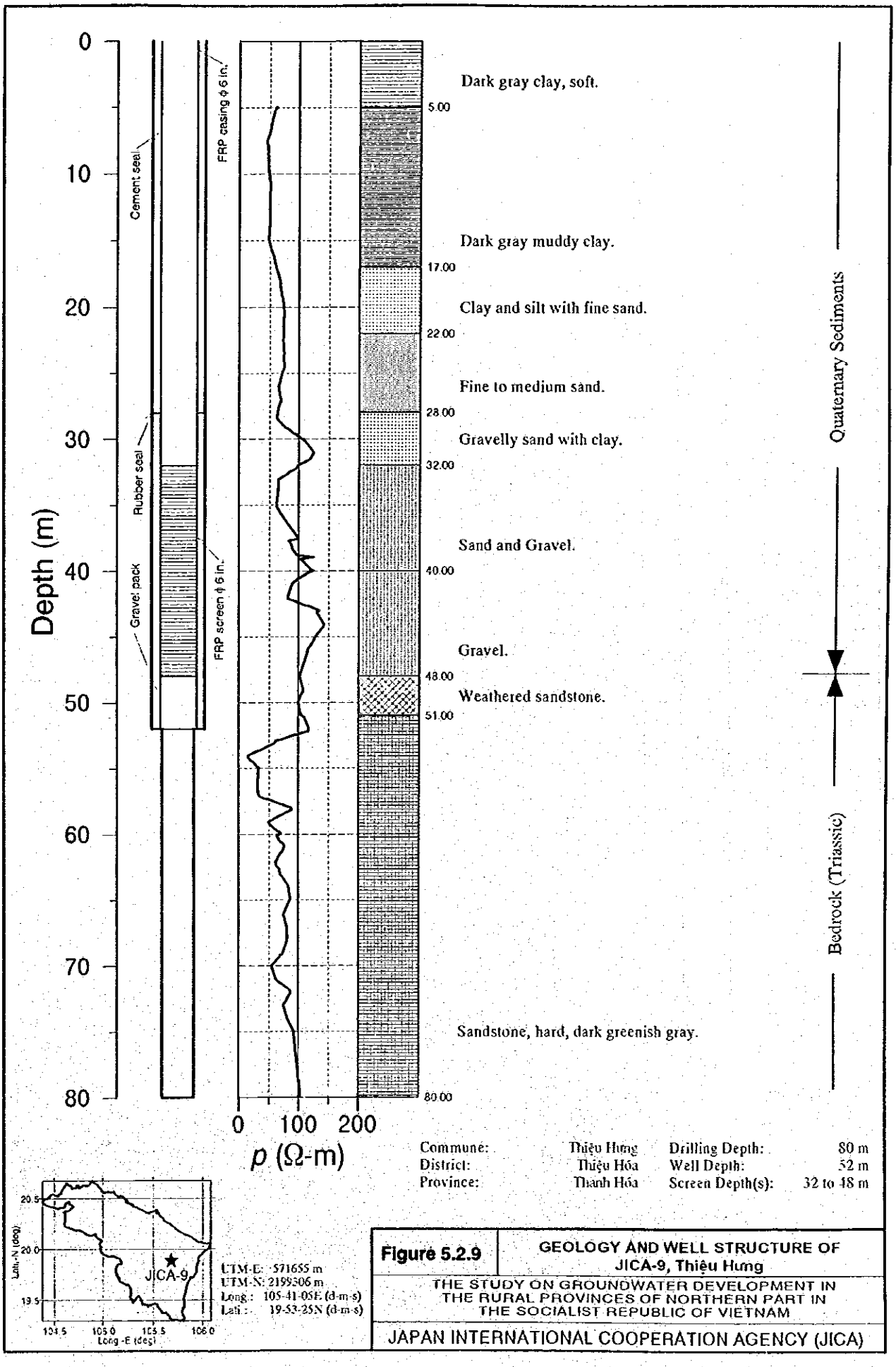
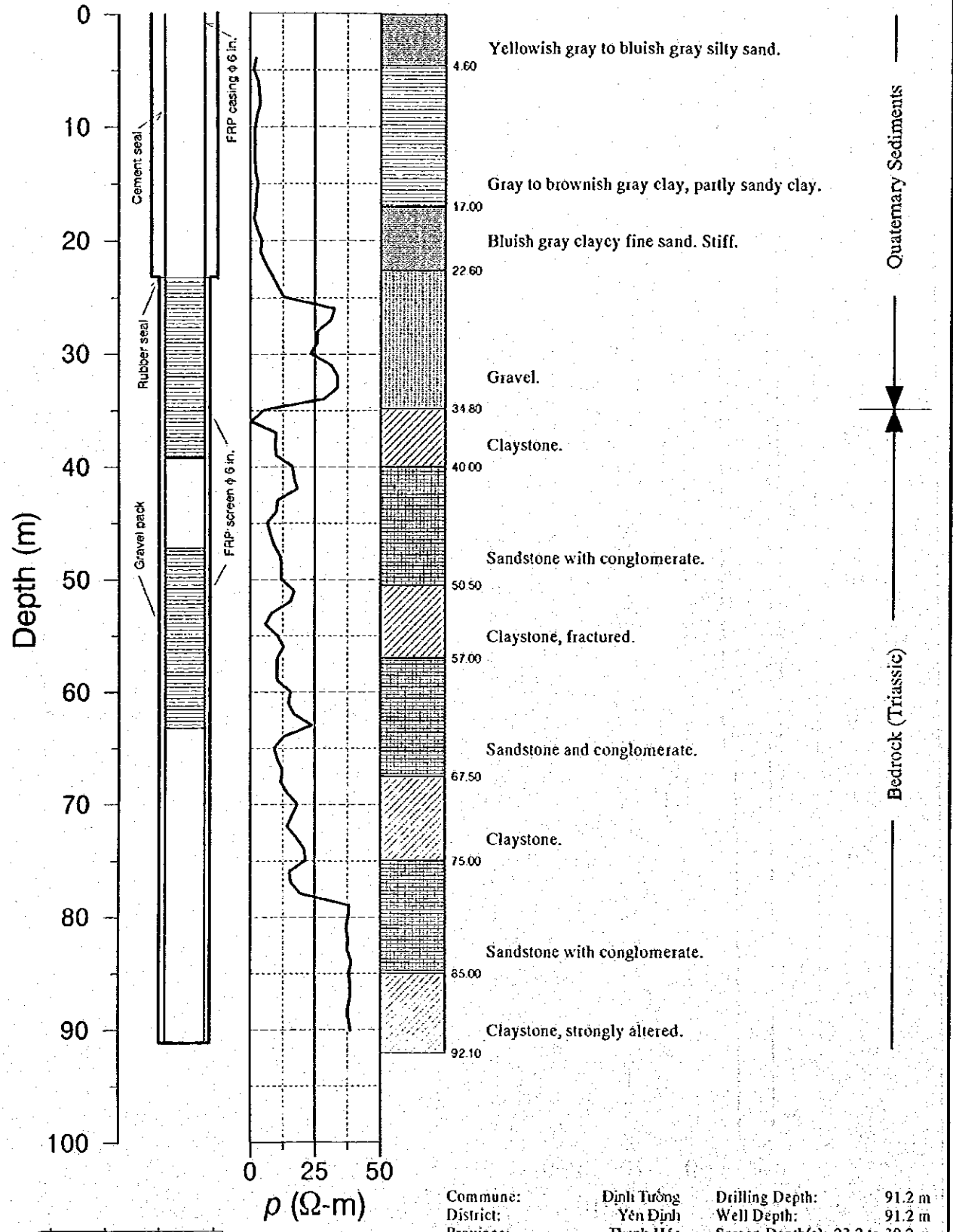
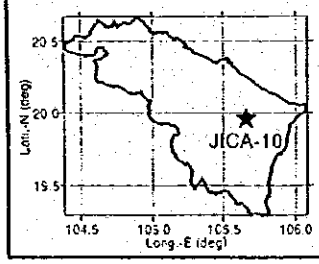


Figure 5.2.9 GEOLOGY AND WELL STRUCTURE OF JICA-9, Thiệu Hưng

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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)





UTM-E: 568421 m
UTM-N: 2207260 m
Long.: 105-39-14E (d-m-s)
Lati.: 19-57-44N (d-m-s)

Commune: Đinh Tường
District: Yên Định
Province: Thanh Hóa

Drilling Depth: 91.2 m
Well Depth: 91.2 m
Screen Depth(s): 23.2 to 39.2 m
47.2 to 63.2 m

Figure 5.2.10 GEOLOGY AND WELL STRUCTURE OF JICA-10, Đinh Tường

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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

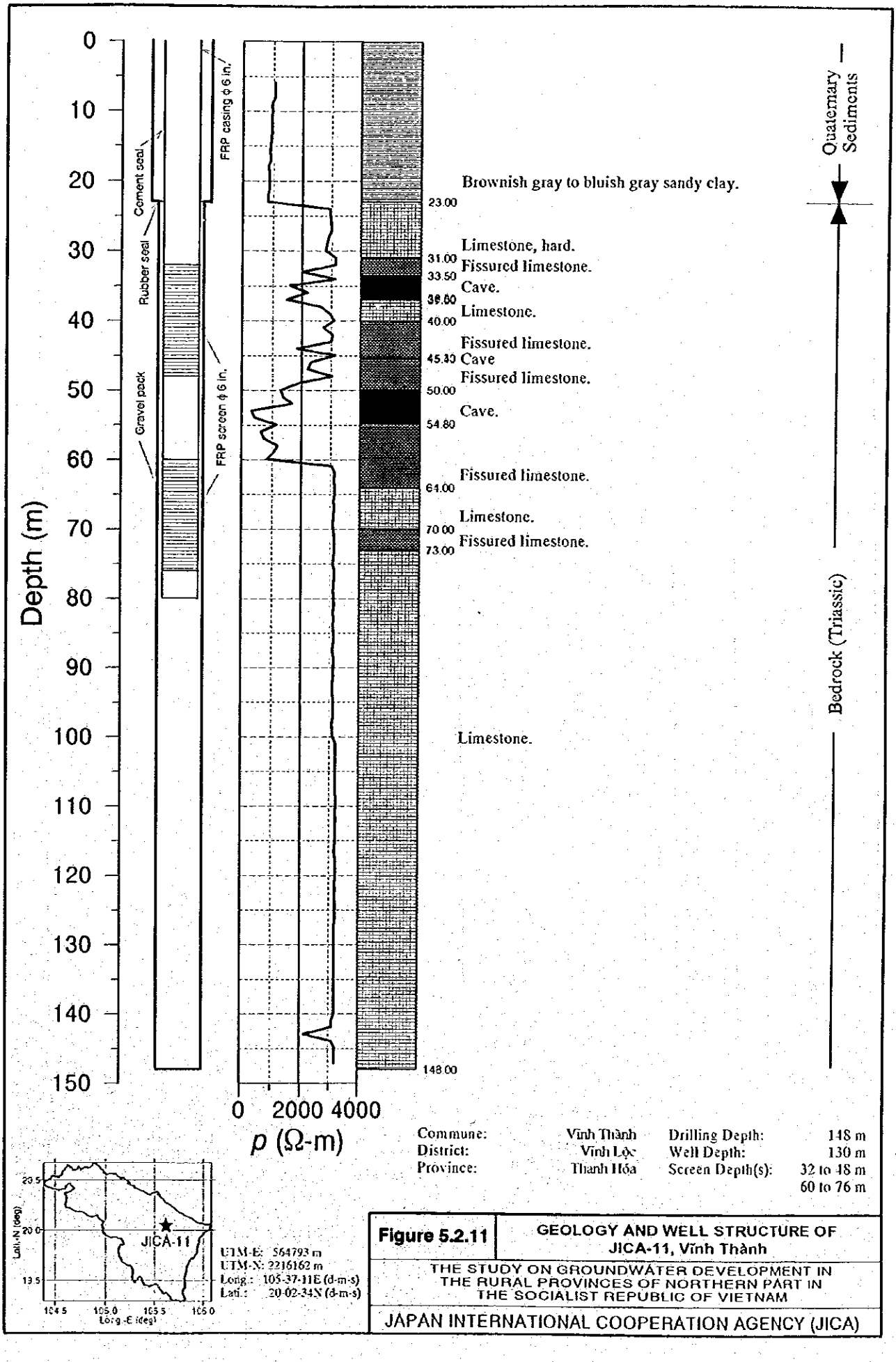


Figure 5.2.11 GEOLOGY AND WELL STRUCTURE OF JICA-11, Vĩnh Thành

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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

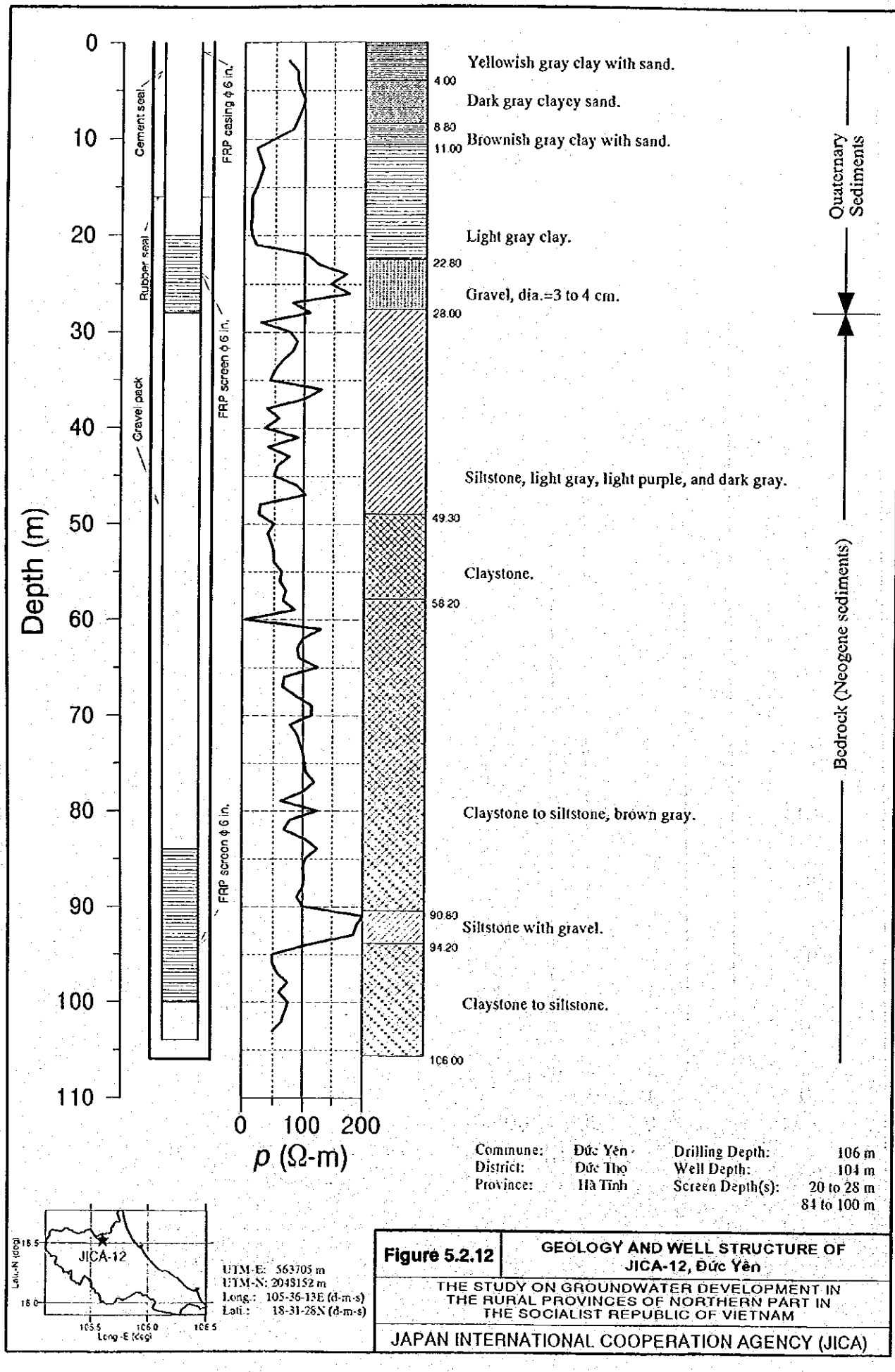
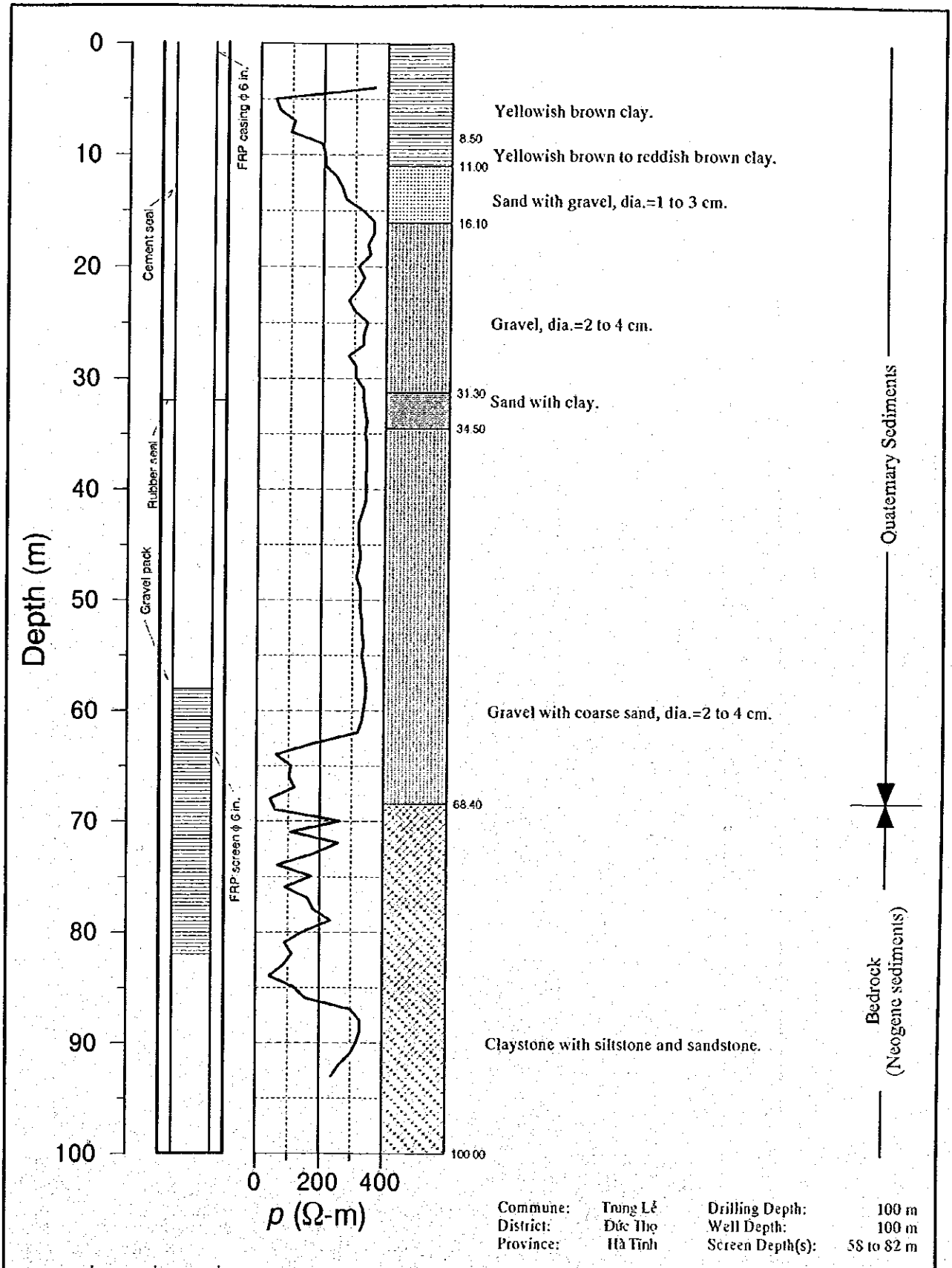


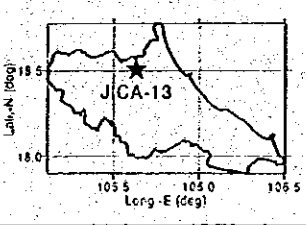
Figure 5.2.12 GEOLOGY AND WELL STRUCTURE OF JICA-12, Đức Yên

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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



Commune:	Trung Lễ	Drilling Depth:	100 m
District:	Đức Thọ	Well Depth:	100 m
Province:	Hà Tĩnh	Screen Depth(s):	58 to 82 m



UTM-E: 565783 m
UTM-N: 2046329 m
Long.: 105-37-58E (d-m-s)
Lati.: 18-30-28N (d-m-s)

Figure 5.2.13 GEOLOGY AND WELL STRUCTURE OF JICA-13, Trung Lễ

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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

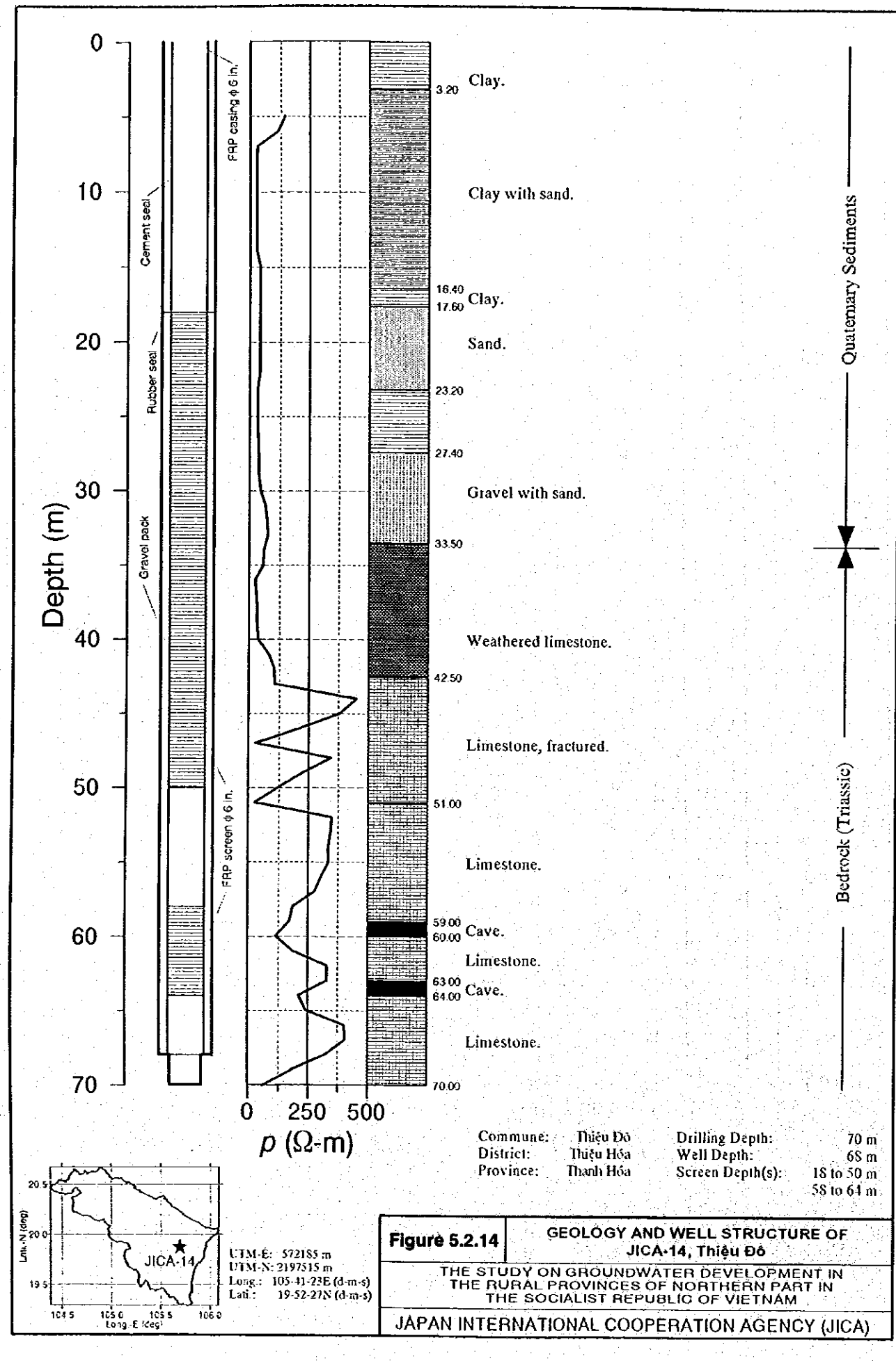


Figure 5.2.14 GEOLOGY AND WELL STRUCTURE OF JICA-14, Thiệu Đô

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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

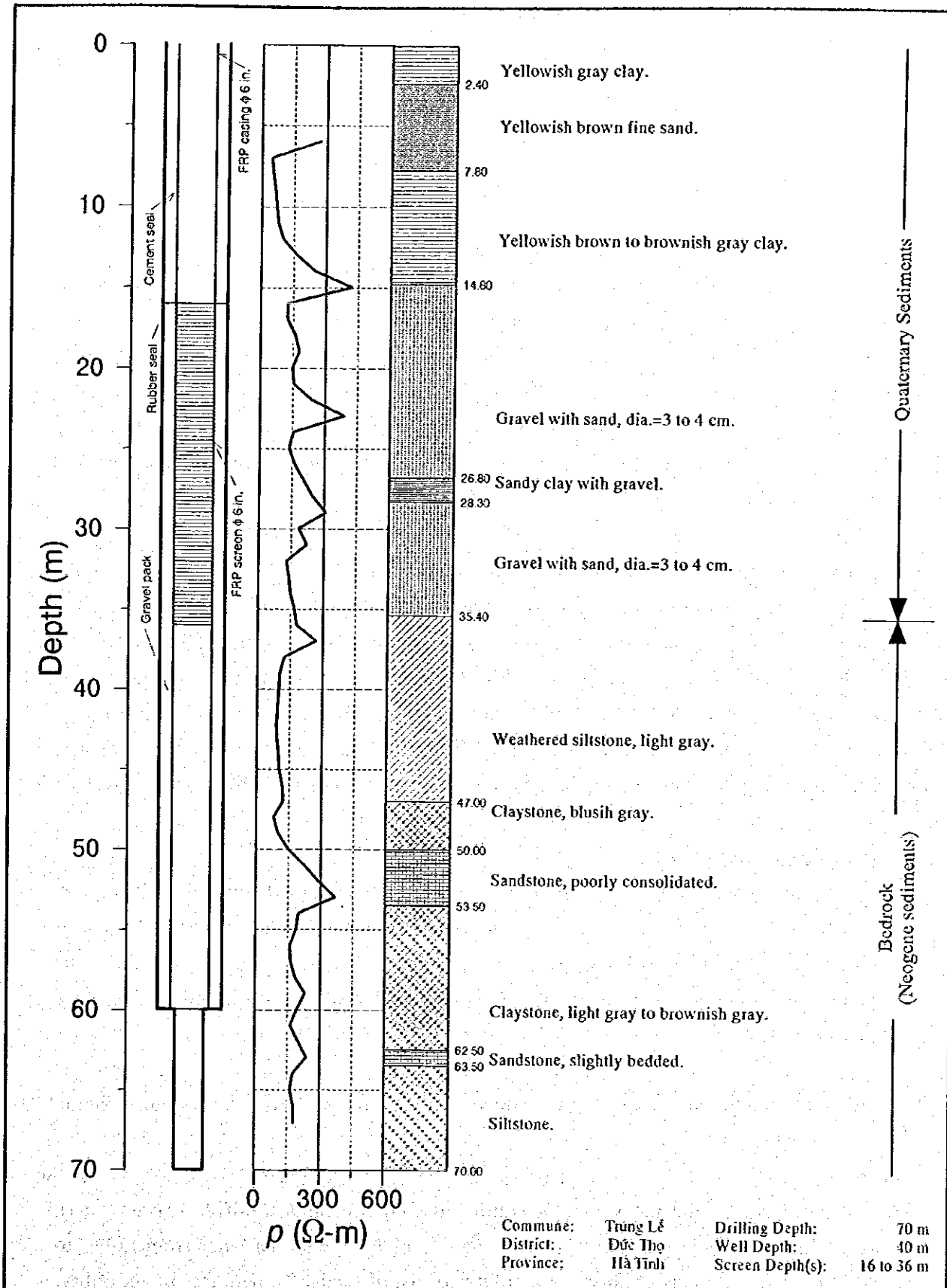


Figure 5.2.15 GEOLOGY AND WELL STRUCTURE OF JICA-15, Trung Lễ

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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

5.3 Yield and Constants

5.3.1 Pumping test

Pumping tests were carried out at the test wells to obtain aquifer constants. The tests were performed after installation of casing/screen pipes and well development. The pumping test is comprised of three (3) types of test; viz. step-drawdown test, continuous drawdown test, and recovery test. The step-drawdown test was conducted prior to the continuous pumping test. Four (4) steps with pumping duration of four (4) hours for each step were conducted in each step-drawdown test. The duration of continuous pumping test was 2,880 minutes (48 hours). The recovery test was started just after the continuous pumping test for a duration of 720 minutes (12 hours).

During a well development work at JICA-1 in Dong Bam, Thai Nguyen, the land near the well sank and the neighboring houses were slightly damaged. The Study Team investigated immediately after the incident, then supervised the contractor to stop the well development work. The incident happened after two (2) days from the starting of well development. The discharge rate was about 900 ℓ/min. The Study Team decided not to perform further well development and pumping test at JICA-1 well to prevent expansion of the damages. Therefore, detailed aquifer evaluation based on pumping test is not available at JICA-1 well.

(1) Step-drawdown test

The results of step-drawdown test at test wells are tabulated in Table 5.3.1. It is noted that the four (4) steps of step-drawdown test could not be carried out at JICA-3 well (Nam Tien, Thai Nguyen) and JICA-13 well (Trung Le, Ha Tinh), because the wells yielded small amount of water so that only two (2) steps' drawdowns were able to be measured.

Graphical interpretation of step-drawdown test at each test well is presented in the Supporting Report.

The results show that the values of aquifer loss coefficient B at JICA-3 (Nam Tien), JICA-4 (Thinh Duc), and JICA-8 (Van Thang) are higher, within a range from 1.0E-2 to 1.0E-1 day/m^2. This is because the aquifers consist of sandstone with less permeability. The B values of JICA-5 (Quang Son) and JICA-6 (Yen Thang) wells are also higher even the aquifer consists of limestone. This can be explained that the porous space in fractured limestone is filled with clayey materials, that may reduce permeability of the aquifer.

The values of well loss coefficient C take a wider range of distribution. Small values of C in a range between 1.0E-7 and 1.0E-8 day^2/m^5, indicating smaller drawdown caused by the well structure, were obtained from JICA-2 (Hoa Thuong), JICA-7 (Dong Phong), JICA-9 (Thieu Hung), and JICA-10 (Dinh Tuong) wells. The C values of JICA-5 (Quang Son) and JICA-6 (Yen Thang) wells are greater, showing the drawdown caused by unit discharge is greater due to the well structure.

The performance of a well can be evaluated from the well efficiency value. If the total drawdown is equal to the drawdown caused by aquifer loss, the well efficiency is 100 %. The test wells of JICA-4 (Thinh Duc) and JICA-7 (Dong Phong) have more than 90 % in well efficiency. Lower well efficiency values below 60 % were obtained from JICA-2 (Hoa Thuong), JICA-11 (Vinh Thanh), JICA-12 (Duc Yen), JICA-14 (Thieu Do), and JICA-15 (Trung Le).

The relationship between discharge rate Q and drawdown s is plotted on a log-log graph. If the Q-s curve is vended upward, the Q value at the turning point is called "critical discharge rate" of the well. It can be said that the discharge rate above the turning point may not suitable for continuous pumping. For example at JICA-2 well (Hoa Thuong), the drawdown curve of the step-drawdown test became almost stable in each step until step-3 ($Q_3$51,080 m^3/day), however, the curve in step-4 ($Q_4$51,440 m^3/day) was not stabilize within the duration of 240 minutes. Therefore, the Q-s curve is vended at step-3 and the Q-s plot at step-4 is plotted above the extended portion of the linear line between step-1 and step-3. Such critical discharge rates are found at wells of JICA-5 (Quang Son, Q5259.2 m^3/day), JICA-6 (Yen Thang, Q5172.8 m^3/day), JICA-14 (Thieu Do, Q51,425.6 m^3/day), and JICA-15 (Trung Le, Q5259.2 m^3/day).

(2) Continuous pumping test and recovery test

The results of continuous pumping test and recovery test are summarized in Table 5.3.2. The values of transmissivity are obtained by Cooper-Jacob method, Theis method, and Recovery method. The values of storativity are obtained by Cooper-Jacob method and Theis method.

The results of continuous pumping test and recovery test by Cooper-Jacob method and Recovery method at each test well is presented in the Supporting Report. The results of continuous pumping test analysis by Theis method are also presented in the Supporting Report. It is noted that the time-drawdown curves of JICA-5 (Quang Son), JICA-9 (Thieu Hung), and JICA-14 (Thieu Do) wells show a leaky type confined aquifer, so

that Hantush method was applied to obtain aquifer parameters.

5.3.2 Aquifer Constants

(1) Transmissivity

The coefficient of transmissivity is one of the most important parameters in groundwater hydrology. The parameter is closely related to geologic conditions. Transmissivity describes the ability of the aquifer to transmit water because it is defined as the flow in volume per unit time through an aquifer section of unit width under a unit hydraulic gradient. Therefore transmissivity values are used as essential data for analyzing both local and regional groundwater flow.

Figure 5.3.1 shows the distribution of transmissivity (T) by analyzing method and by province. It is understood that the distribution patterns of T by province are almost same by the analyzing method. Figure 5.3.2 shows a result of statistical analysis of T distribution by province. It is assumed that the T values have a logarithmic normal distribution. T values obtained from Recovery method, Cooper-Jacob method, and Theis method were used for the statistical analysis. A logarithmic average value (AVG) and a logarithmic standard deviation (STD) were obtained. A range between (AVG2STD) and (AVG1STD) could be treated as a reliable range of T distribution.

The logarithmic average of T in Thanh Hoa is 201.53 m^2/day, which is the highest among the four (4) provinces in the Study Area. Binh has the second highest average T value of 69.70 m^2/day. The average of T values in Thai Nguyen and Ha Tinh are 44.76 and 11.14 m^2/day, respectively.

The reliable range of T distribution in Thai Nguyen is from 18.13 to 110.52 m^2/day. In Ninh Binh, the T values are distributed widely, the reliable T ranges from 8.46 to 574.30 m^2/day. The reliable range of T in Thanh Hoa is limited, ranging from 77.07 to 526.96 m^2/day. The reliable range of T distribution in Ha Tinh is lower than that of other provinces; ranging 1.10 to 112.39 m^2/day.

(2) Hydraulic conductivity

Hydraulic conductivity can be obtained if thickness of the aquifer is known. In the Study, it was assumed that thickness of the aquifer is a total length of the screen pipes, then apparent hydraulic conductivity (k) values were computed by the following equation:

$k5T / b$ (2.1.2)

where b is a total length of screen pipes. The apparent hydraulic conductivity describes average hydraulic conductivity of the aquifer materials of the screen portions. The apparent hydraulic conductivity values are useful for evaluating aquifer permeability as well as designing well structure. The k values were computed by using T values obtained from Recovery method, Cooper-Jacob method, and Theis method. A logarithmic average value (AVG) and a logarithmic standard deviation (STD) were obtained. A range between (AVG2STD) and (AVG1STD) could be treated as a reliable range of k distribution.

Figure 5.3.3 shows the distributions and reliable ranges of k by province. The average k is the highest in Thanh Hoa, having 7.68 m/day in logarithmic average with a reliable range from 2.66 to 22.13 m/day. The average k values of Thai Nguyen and Ninh Binh are almost same, 2.23 and 2.01 m/day, respectively. However, the reliable range of k distribution in Ninh Binh is wider than that in Thai Nguyen. The k values of Ha Tinh are very low; having an average value of 0.49 m/day with a reliable range from 0.05 to 5.20 m/day.

(3) Storativity

Storativity (or storage coefficient, S) values were obtained from Cooper-Jacob method and Theis method. The obtained values are presented in Table 5.3.2. It can be seen that S values are very small when T values are higher. However, it is known that large changes in S cause comparatively small changes in T.

(4) Relationship between transmissivity and specific capacity

Values of specific capacity (Sc) can be easily obtained from pumping rate and final drawdown of the continuous pumping test. Sc values are used not only for evaluating well performance but also for evaluating aquifer productivity.

The relationship between T and Sc of the test wells is shown in Figure 5.3.4. Generally for confined aquifers, the relation between T and Sc is proportional. Logan (1964) presented a relationship $T51.22\ Sc$, which was obtained from the equilibrium equation for confined aquifers with empirically estimated radius of influence of pumped wells. The $T51.22\ Sc$ relation is also shown in the graph.

From the graph, the T-Sc plots by province take different areas. The plots of Thanh Hoa located above the $T51.22\ Sc$ line, having Sc values from 9.6 to 244.4 m^2/day. The plots

of Ninh Binh are also located above the line, having *Sc* values from 4.21 to 197.0 m^2/day. The plots of Thai Nguyen seem to be not parallel to the line. The plots of higher values are located below the line, but the plots of lower values are located above the line. The *Sc* values of Thai Nguyen range from 10.1 to 259.5 m^2/day. The test wells of Ha Tinh are plotted just above the line except JICA-13 well (Trung Le), which has the lowest *T* and *Sc* values among the test wells.

(5) *T* and *Sc* by aquifer geology

Figure 5.3.5 shows *T*-*Sc* plots of the test wells by aquifer geology. The distribution zones of plots by aquifer geology are identified by target aquifer(s) with its permeability. For instance, when the well screens are set at Quaternary sediments and sandstone, but if the sandstone is regarded as less permeable aquifer, the *T* and *Sc* values are thought to represent the Quaternary aquifer.

Although the number of test wells is limited, the Quaternary aquifers have higher *T* values, ranging from 30 to 1,000 m^2/day. The *T* values of limestone aquifers range from 30 to 200 m^2/day with *Sc* values from 5 to 300 m^2/day. Sandstone and claystone have *T* values from 20 to 200 m^2/day, however, the *Sc* values range from 5 to 50 m^2/day.

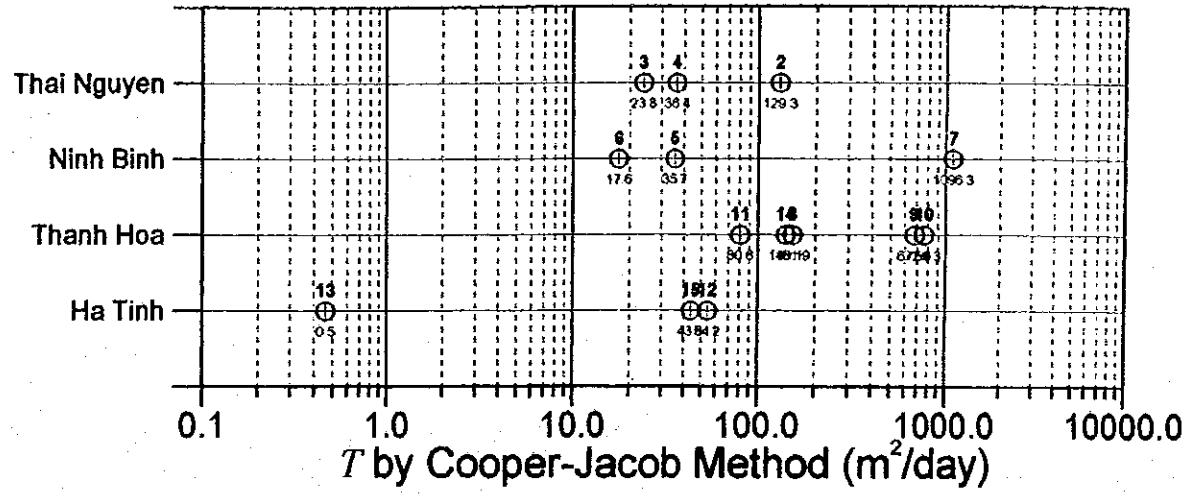
Table 5.3.1 Results of Step-Drawdown Test at JICA Test Wells

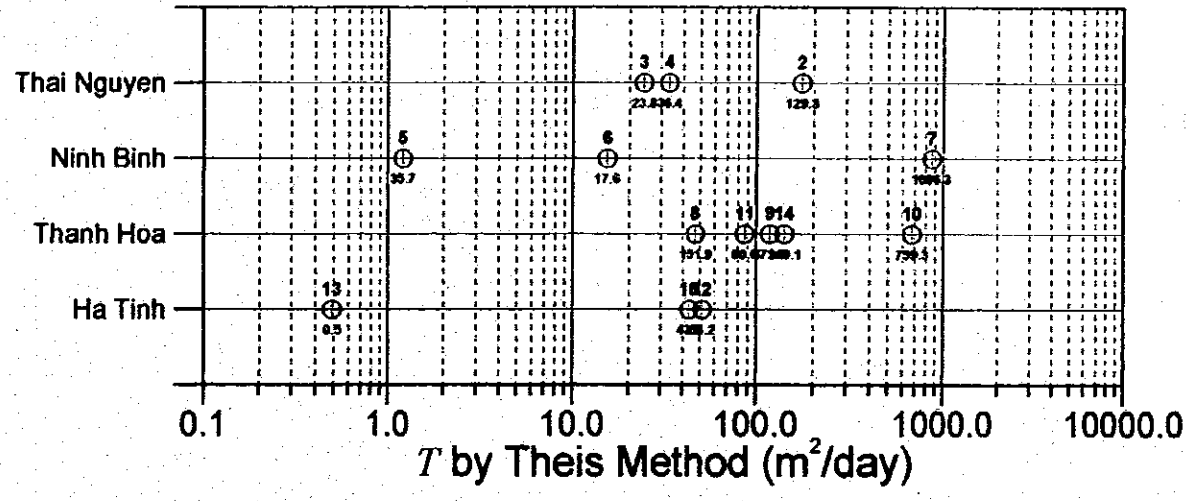
Test Well No.	Commune District Province	UTM-E (m)	UTM-N (m)	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Step-drawdown Test Date(dd/mm/yy) Static Water Level (m below G.L.)	Q1(m^3/day) s1(m) So1(m^2/day)	Q2(m^3/day) s2(m) So2(m^2/day)	Q3(m^3/day) s3(m) So3(m^2/day)	Q4(m^3/day) s4(m) So4(m^2/day)	Aquifer Loss Coefficient B (d/m^2)	Well Loss Coefficient C (d^2/m^5)	Average Well Efficiency (%)
JICA-1	Đồng Bẩm Đồng Hỷ Thái Nguyên	587420	2389687	100	76	40 to 72	-	-	-	-	-	-	-	-
JICA-2	Hoá Thượng Đồng Hỷ Thái Nguyên	586578	2393846	150	92	24 to 32 56 to 64 76 to 88	03/06/1999 3.10	360.00 0.55 654.55	720.00 1.80 400.00	1080.00 2.21 488.69	1440.00 3.76 382.98	1.14E-03	9.62E-07	54.90
JICA-3	Nam Tiến Phổ Yên Thái Nguyên	590257	2366017	100	21.5	5.5 to 17.5	15/04/1999 1.50	69.12 1.75 39.50	138.24 3.66 37.77	- - -	- - -	2.42E-02	1.67E-05	93.49
JICA-4	Thịnh Đức Thị trấn Thái Nguyên Thái Nguyên	584201	2380475	100	88	8 to 16 52 to 60 68 to 84	27/05/1999 2.00	43.20 4.37 9.89	94.18 9.50 9.91	146.88 14.72 9.98	188.35 18.80 10.02	1.02E-01	-9.59E-06	101.48
JICA-5	Quang Sơn Thị trấn Tam Điệp Ninh Bình	592553	2228660	150	120	72 to 116	05/03/1999 10.80	86.40 8.00 10.80	172.80 15.20 11.37	259.20 21.90 11.84	345.60 43.00 8.04	7.44E-02	1.06E-04	78.20
JICA-6	Yên Thắng Yên Mô Ninh Bình	600941	2228665	150	136	76 to 84 92 to 104 124 to 132	17/03/1999 1.23	57.60 10.87 5.30	115.20 22.89 5.03	172.80 35.77 4.83	230.40 54.97 4.19	1.69E-01	2.74E-04	81.77
JICA-7	Đồng Phong Nho Quan Ninh Bình	577617	2246929	150	130	92 to 126	23/03/1999 0.60	432.00 2.07 208.70	864.00 4.56 189.47	1296.00 6.48 200.00	1728.00 8.54 202.34	4.96E-03	4.01E-08	99.26
JICA-8	Vạn Thắng Nông Cống Thanh Hoá	565030	2170050	150	150	99 to 119	05/02/1999 5.70	158.40 9.83 16.11	271.54 20.98 12.94	475.20 41.60 11.42	633.60 56.53 11.21	5.80E-02	5.48E-05	74.95
JICA-9	Thiệu Hưng Thiệu Hoá Thanh Hoá	571655	2199306	80	52	32 to 48	10/02/1999 4.00	352.80 2.40 147.00	705.60 4.55 155.08	1058.40 7.12 148.65	1411.20 10.01 140.98	5.79E-03	9.14E-07	85.65
JICA-10	Định Tường Yên Định Thanh Hoá	568421	2207260	91.2	91.2	23.2 to 39.2 47.2 to 63.2	10/04/1999 4.90	432.00 1.26 342.86	864.00 3.02 286.09	1296.00 4.92 263.41	1728.00 7.04 245.45	2.63E-03	8.73E-07	74.81
JICA-11	Vĩnh Thành Vĩnh Lộc Thanh Hoá	564793	2216162	148	80	32 to 48 60 to 76	24/04/1999 7.55	362.00 1.86 194.62	734.40 4.90 149.88	1123.20 9.80 114.61	1512.00 14.27 105.96	3.85E-03	3.00E-06	54.39
JICA-12	Đức Yên Đức Thọ Hà Tĩnh	563705	2048152	106	104	20 to 28 84 to 100	05/03/1999 2.90	100.00 1.36 79.41	216.00 3.24 66.67	324.00 6.11 53.03	432.00 9.27 46.60	9.36E-03	2.82E-05	57.50
JICA-13	Trung Lễ Đức Thọ Hà Tĩnh	566783	2046329	100	100	58 to 82	08/04/1999 2.60	12.96 2.56 5.06	25.92 14.60 1.78	- - -	- - -	-	-	-
JICA-14	Thiệu Đô Thiệu Hoá Thanh Hoá	572185	2197515	70	68	18 to 50 58 to 64	29/03/1999 2.85	475.20 2.08 228.46	950.40 4.21 225.75	1425.60 7.01 203.37	1900.80 13.67 139.05	3.00E-03	1.88E-06	59.75
JICA-15	Trung Lễ Đức Thọ Hà Tĩnh	567186	2046557	70	40	10 to 36	01/04/1999 2.48	64.80 0.05 76.24	129.60 1.80 72.00	259.20 3.09 83.88	345.60 6.93 49.87	6.69E-03	6.61E-05	47.16

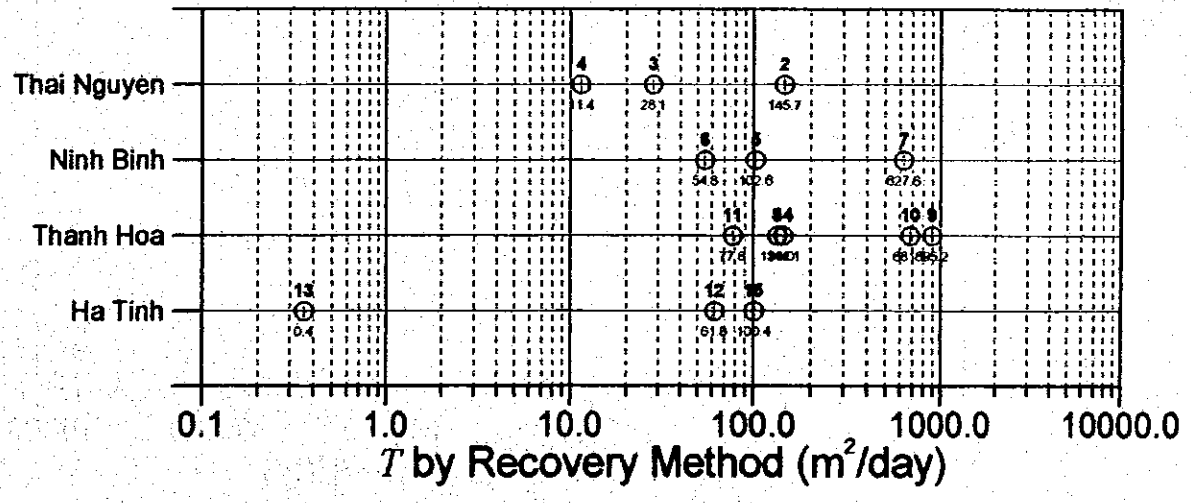
Table 5.3.2 Results of Continuous Pumping Test at JICA Test Wells

Test Well No.	Commune District Province	UTM-E (m)	UTM-N (m)	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)	Continuous Pumping Test										Recovery Test	
												Theis Method			Cooper-Jacob Method			Recovery Method	
								Date (dd-mm-yy)	Static Water Level (m below G.L.)	Pumping Rate, Q (m^3/day)	Final Drawdown, s (m)	Specific Capacity, Sc (m^3/day)	T (m^2/day)	k_{ex} (m/day)	S	T (m^2/day)	k_{ex} (m/day)	S	T (m^2/day)	k_{ex} (m/day)
JICA-1	Đồng Bẩm Đồng Hỷ Thái Nguyên	587420	2389687	100	76	40 to 72	32.0	-	-	-	-	-	-	-	-	-	-	-	-	-
JICA-2	Hoá Thượng Đồng Hỷ Thái Nguyên	586578	2393846	150	92	24 to 32 56 to 64 76 to 88	28.0	04/06/1999	3.10	1440.00	5.55	259.46	173.00	6.18E+00	3.01E-01	129.04	4.62E+00	1.37E+02	145.66	5.20E+00
JICA-3	Nam Tiến Phổ Yên Thái Nguyên	590257	2386017	100	21.5	5.5 to 17.5	12.0	16/04/1999	1.50	138.24	4.75	29.10	24.00	2.00E+00	7.09E-01	23.8	1.98E+00	8.49E-01	28.12	2.34E+00
JICA-4	Thịnh Đức Thị trấn Thái Nguyên Thái Nguyên	584201	2380475	100	88	8 to 16 52 to 60 68 to 84	32.0	28/05/1999	2.00	188.35	18.58	10.14	33.20	1.04E+00	3.71E-15	36.4	1.14E+00	1.93E-16	11.4	3.56E-01
JICA-5	Quang Sơn Thị trấn Tam Điệp Ninh Bình	592553	2228660	150	120	72 to 116	44.0	07/03/1999	10.80	345.60	42.60	8.11	Hantush's method 1.21	2.75E-02 σ = 1.84E+00 (day)	2.15E-01	35.69	8.11E-01	7.73E-22	102.6	2.33E+00
JICA-6	Yên Thắng Yên Mô Ninh Bình	600941	2228665	150	136	76 to 84 92 to 104 124 to 132	28.0	18/03/1999	1.23	230.40	54.79	4.21	16.30	5.46E-01	5.42E-18	17.59	6.28E-01	1.01E-20	54.85	1.96E+00
JICA-7	Đồng Phong Nho Quan Ninh Bình	577617	2246920	150	130	92 to 126	34.0	24/05/1999	0.80	1728.00	8.77	197.04	662.00	2.54E+01	6.82E-19	1096.3	3.22E+01	2.51E-25	627.8	1.85E+01
JICA-8	Vạn Thắng Nông Cống Thanh Hoá	565030	2170050	150	150	99 to 119	20.0	06/02/1999	5.00	813.16	63.58	9.64	47.00	2.35E+00	1.66E-24	151.93	7.60E+00	2.78E-81	134.03	6.70E+00
JICA-9	Thiệu Hưng Thiệu Hoá Thanh Hoá	571655	2199306	80	52	32 to 48	16.0	12/02/1999	4.00	1411.20	10.02	140.84	Hantush's method 118.00	7.38E+00 σ = 4.73E-01 (day)	1.07E-03	572.57	4.20E+01	1.93E-22	895.18	5.59E+01
JICA-10	Đình Tường Yên Định Thanh Hoá	568421	2207260	91.2	91.2	23.2 to 39.2 47.2 to 63.2	32.0	11/04/1999	4.90	1728.00	7.07	244.41	674.00	2.11E+01	1.34E-10	759.31	2.37E+01	3.48E-12	681.7	2.13E+01
JICA-11	Vĩnh Thành Vĩnh Lộc Thanh Hoá	564793	2216162	148	80	32 to 48 60 to 76	32.0	27/04/1999	7.55	1512.00	16.29	92.82	86.30	2.72E+00	2.52E-01	80.56	2.52E+00	4.78E-01	77.76	2.43E+00
JICA-12	Đức Yên Đức Thọ Hà Tĩnh	563705	2048152	106	104	20 to 28 84 to 100	24.0	06/03/1999	3.20	432.00	14.43	29.94	51.30	2.14E+00	5.41E-02	54.18	2.26E+00	3.53E-02	61.75	2.57E+00
JICA-13	Trung Lễ Đức Thọ Hà Tĩnh	566783	2046329	100	100	58 to 82	24.0	09/04/1999	2.80	25.92	22.76	1.14	0.49	2.05E-02	1.59E+00	0.461	1.92E-02	1.89E+00	0.356	1.48E-02
JICA-14	Thiệu Đô Thiệu Hoá Thanh Hoá	572186	2197615	70	68	18 to 50 58 to 64	38.0	30/03/1999	2.85	1900.80	14.19	133.95	Hantush's method 141.00	3.71E+00 σ = 3.98E-01 (day)	1.98E-02	140.07	3.69E+00	2.90E-02	144.07	3.79E+00
JICA-15	Trung Lễ Đức Thọ Hà Tĩnh	567186	2046557	70	40	16 to 36	20.0	02/04/1999	2.48	259.20	6.75	38.40	43.50	2.18E+00	2.07E-02	43.79	2.19E+00	2.46E-02	100.45	5.02E+00

σ: Hydraulic Resistance







406 ← JICA Test Well No.
⊕
30.4 ← Value

Figure 5.3.1	DISTRIBUTION OF T BY PUMPING TESTS AT TEST WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

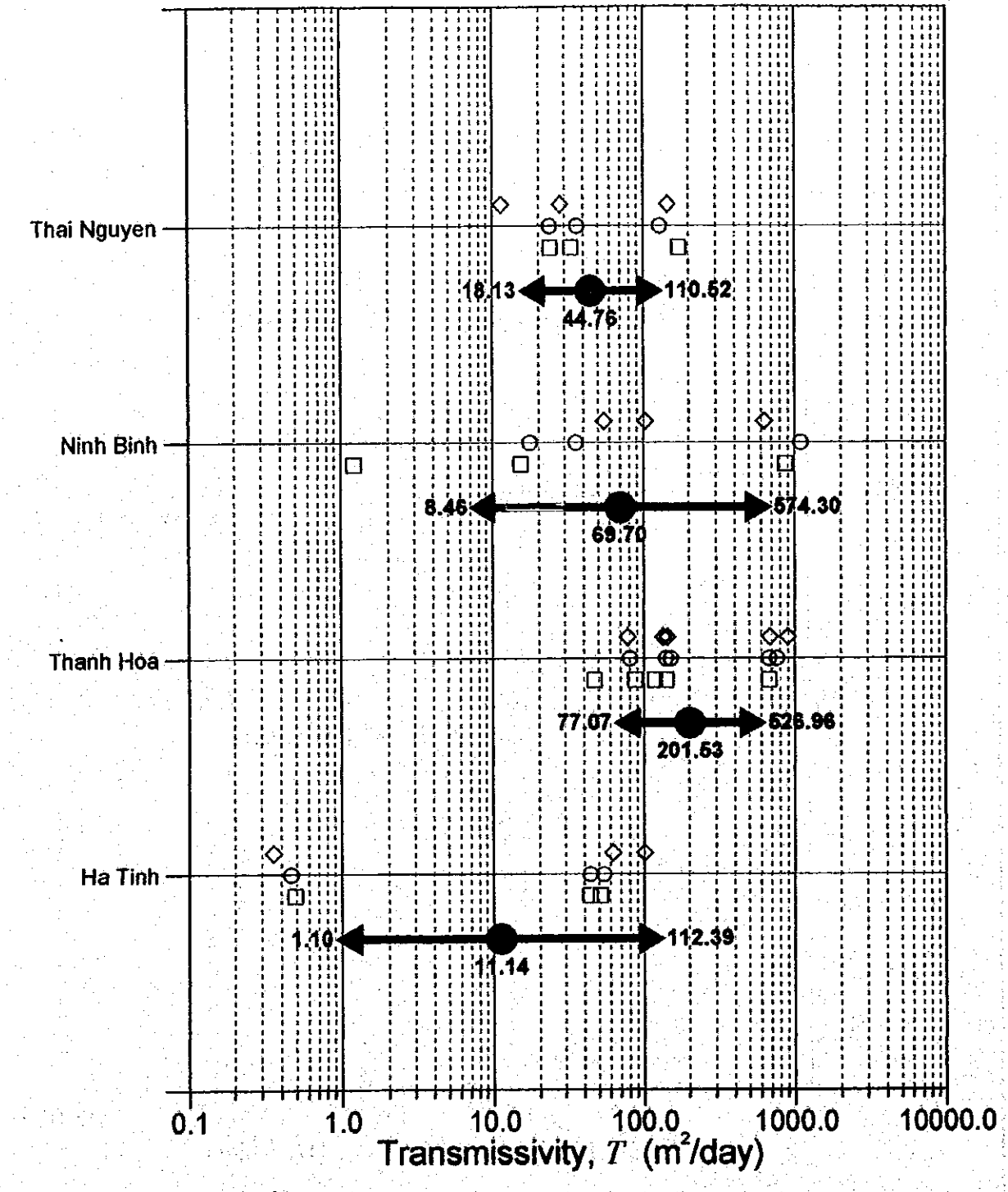


Figure 5.3.2	STATISTICAL ANALYSIS OF *T* DISTRIBUTION BY PROVINCE
THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

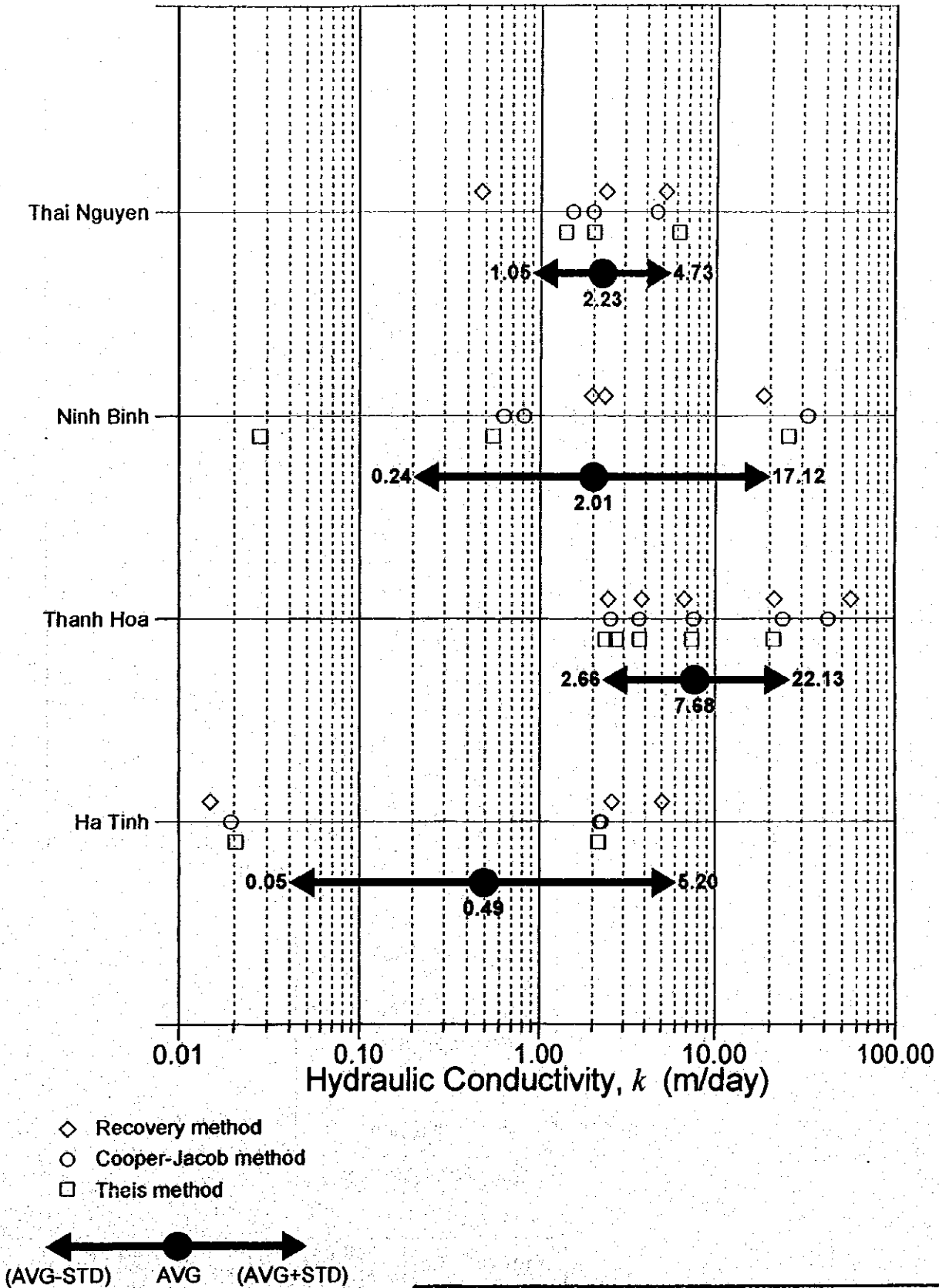
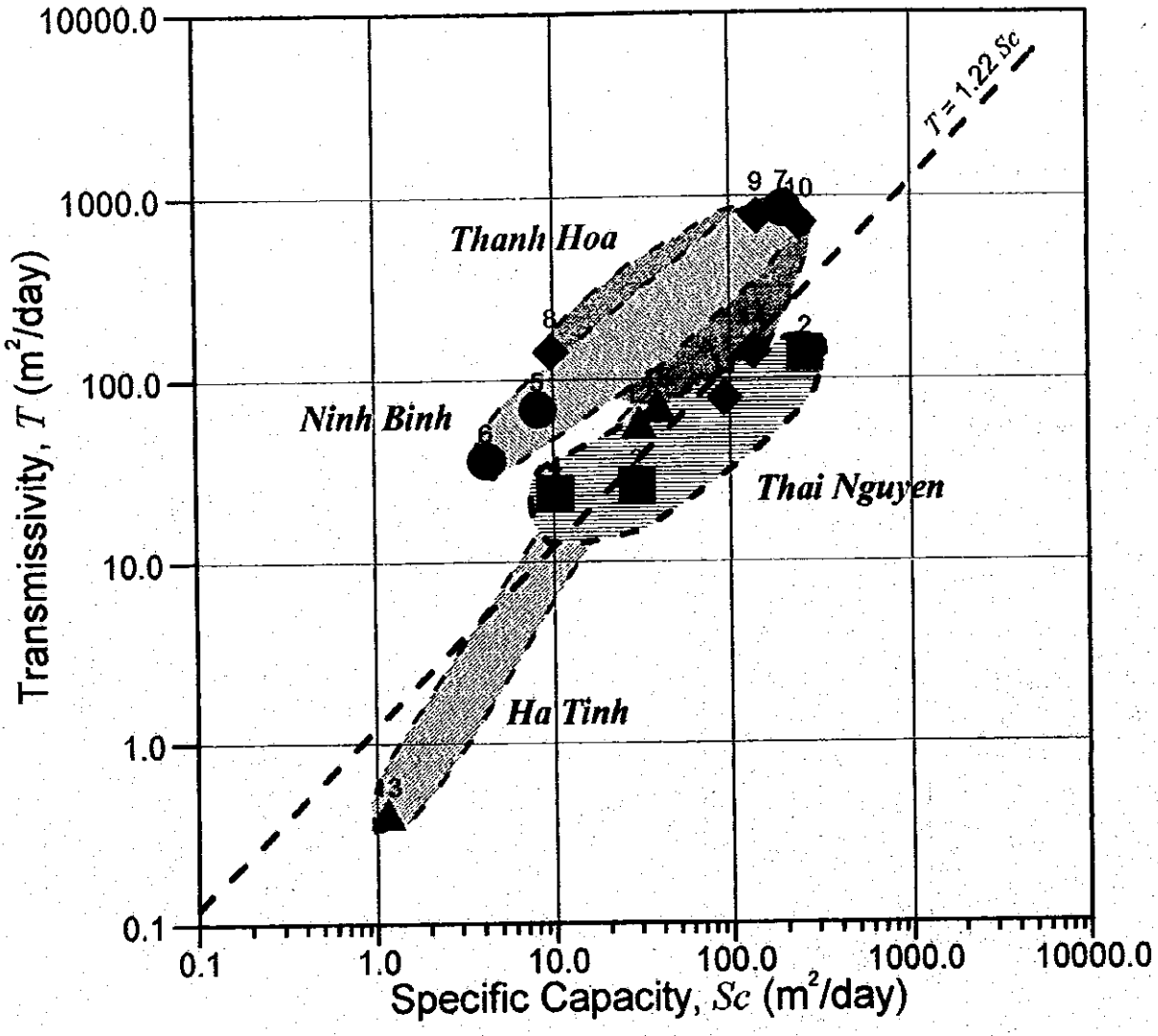


Figure 5.3.3	STATISTICAL ANALYSIS OF *k* DISTRIBUTION BY PROVINCE
THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



Legend of Test Wells

- Thai Nguyen
- Ninh Binh
- Thanh Hoa
- Ha Tinh

(with JICA Test Well No.)

Figure 5.3.4	RELATIONSHIP BETWEEN T AND Sc FROM PUMPING TEST OF TEST WELLS
THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

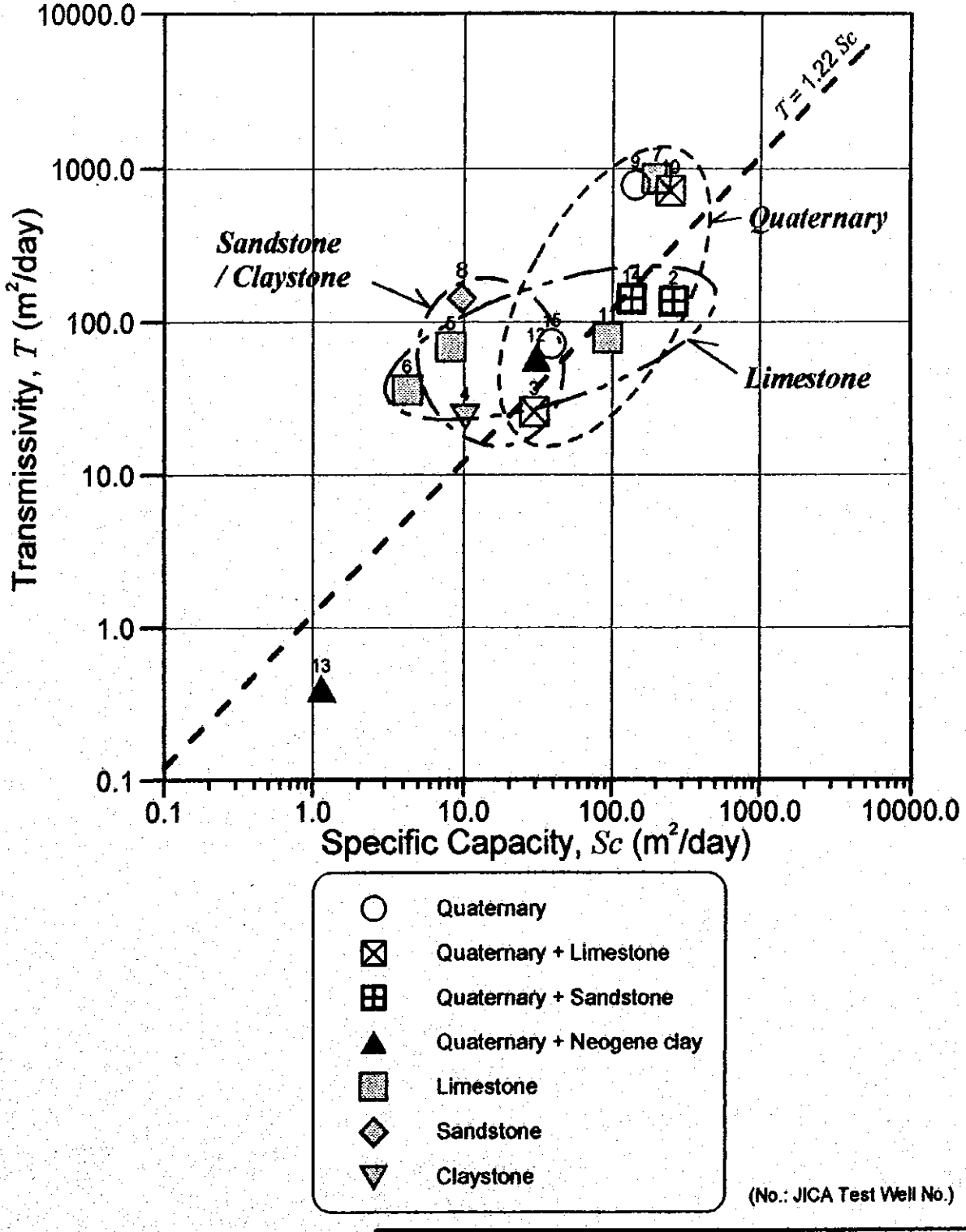


Figure 5.3.5	RELATIONSHIP BETWEEN T AND Sc BY AQUIFER GEOLOGY
THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	