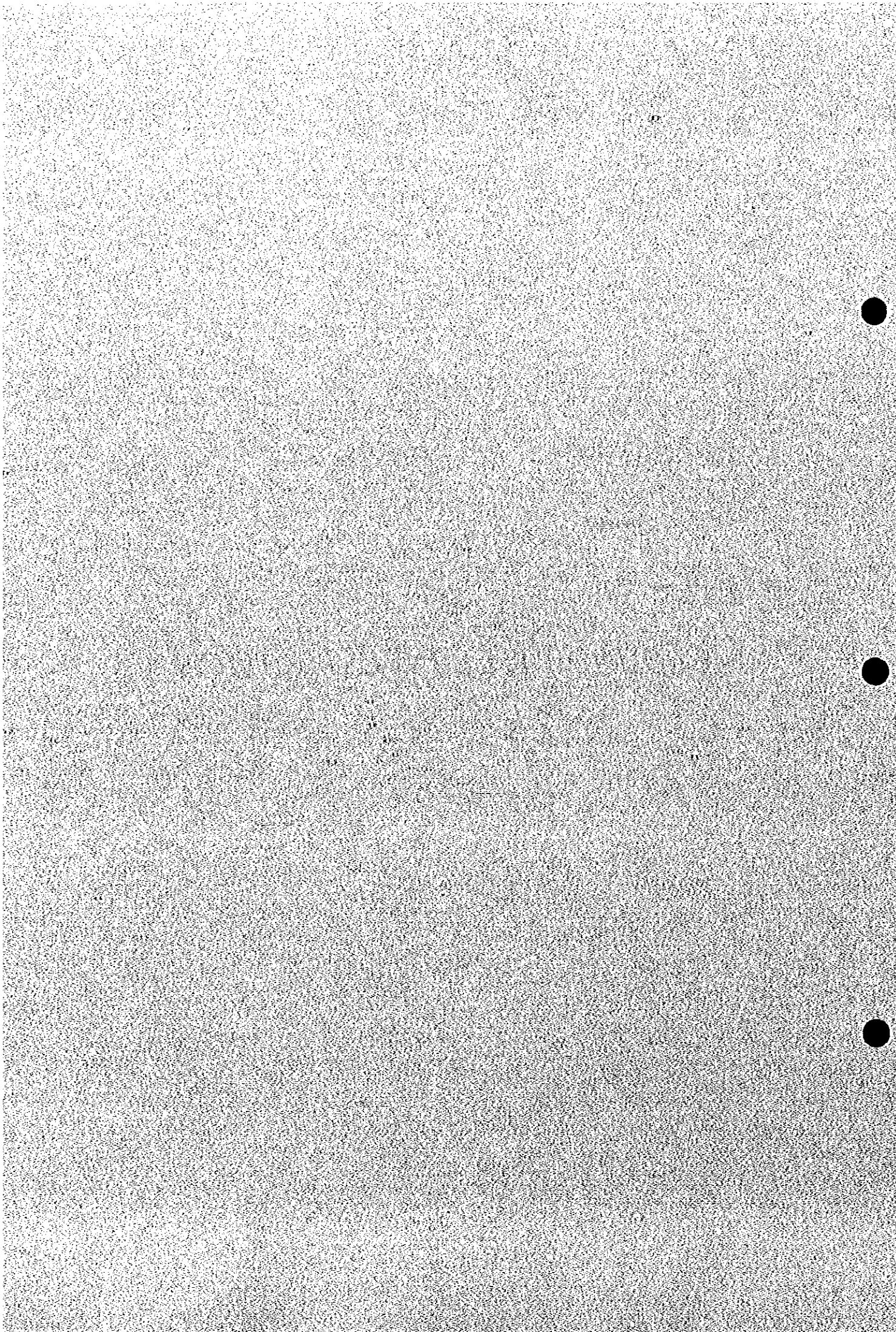


PART II

GROUNDWATER INVESTIGATION



PART II GROUNDWATER INVESTIGATION

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CHAPTER 1

HYDROGEOLOGY

PART II GROUNDWATER INVESTIGATION

CHAPTER 1 HYDROGEOLOGY

1.1 Hydrogeological Settings by Province

The hydrogeological conditions of the study area are different by province. The hydrogeological conditions of the five provinces are mentioned below.

The mountains and hills in the northern section of Thai Nguyen Province are mainly made up of shale from the Cambrian to the Ordovician periods. The southern section consists of sandstone, shale, and limestone rocks from the Triassic to the Jurassic periods. The southernmost end of Thai Nguyen occupies a corner of the Red River Delta, with a geology made up of alluvial and diluvial unconsolidated sediments.

Hanoi is made up of the thick unconsolidated sediments of the Red River Delta. Its alluvial and diluvial layers overlie red Triassic mudstone and sandstone layers that form the basement rock of the region.

Situated at the southernmost end of the Red River Delta, Ninh Binh is in a low-lying zone made up of unconsolidated sediments from the alluvial to diluvial periods. On the other hand, Triassic sandstone, shale, and marl make up the hills, while limestone makes up the mountains in this province.

The coastal plains of Thanh Hoa Province is formed by the alluvial and diluvial unconsolidated sediments in the Ma River Delta. Hills made up of limestone from the Ordovician to the Permian periods mainly dot the interior of the plains like islands. The mountains in the western and southwestern regions geologically consist of Triassic sandstone, shale and conglomerates. The northern section of the mountain, however, consists of granitic magma and tuff.

In the province of Ha Tinh, alluvial and diluvial unconsolidated sediments in the Ca River Delta make up the coastal plains, while the hills and mountains consist of granitic magma, Triassic sandstone, shale, and conglomerates.

1.1.1 Thai Nguyen

The geology of Thai Nguyen Province consists of Ordovician to Cretaceous sedimentary formations, intrusive rocks, and Quaternary sediments. The hydrogeological map of Thai Nguyen Province is shown in Figure 1.1.1. From the hydrogeological points of view, there are seven (7) aquifer units in Thai Nguyen Province as mentioned below.

(1) Quaternary sedimentary aquifer

Quaternary sediments are distributed along two side of the Cau River or in the small depressions between the mountains in Nui Coc (Dai Tu District), Cao Ngan, Duong Lien, Thuong Dinh, Uc Son, Ba Hang (Pho Yen District) and in Phu Binh District. Lithological composition is mainly sand and gravel.

Groundwater potential of this aquifer is medium to small, depending upon facies and thickness.

(2) Terrigenous aquifer

This aquifer consists of Ban Hang stratum (Kbh), Ha Coi stratum (J₁₋₂ hc), Van Lang stratum (T_{3n-r-vl}), Na Khuat stratum (T₂ nk). The Terrigenous sediments are distributed in south-east of Tam Dao mountain, south-east of Thai Nguyen city, south of Phao mountain. Lithological composition is characterized by cobble, sandstone and siltstone.

Groundwater potential of this aquifer is limited.

(3) Terrigenous effusive aquifer

This aquifer consists of Song Hien stratum (T₁ sh), Tam Dao stratum (T₂ td) and Tam Lung stratum (J-Ktl). The aquifer is distributed in Kim Hy, Cuong Loi, Lam Son, Yen Lac, Vo Nhai, La Hien and Binh Long regions. The thickness of the aquifer ranges from 300 to 1,000 m. The terrigenous effusive sediments consist of sandstone, siltstone, tuff, rhyolite, rhyolite pocfia, shale and limeshale.

Groundwater potential changes from place to place, but it is generally limited.

(4) Terrigenous carbonate aquifer

This aquifer consists of Dai Thi stratum (D₁ dt), Bac Bun stratum (D₁ bb), Mia Le stratum (D₁ ml), Lang Dan stratum (D₂ ld), Na Quan stratum (D₃ nq), and Toc Tat stratum (D₃tt). The thickness of the aquifer changes from 180 to 1,000 m. They

distributed in Dai Tu District. Lithological composition of the aquifer is characterized by conglomerate, shale, sericite, limestone.

The groundwater potential of this aquifer changes very much. In some place, groundwater potential is high, but in some place groundwater potential is very limited.

(5) Carbonate deposits aquifer

This aquifer consists of Bac Son stratum (C-P bs) and Dong Dang stratum (P₂ dd). The aquifer is distributed in Vo Nhai, Dinh Ca and Dai Tu Districts. The thickness of the aquifer is 350 m. Lithological composition is characterized by limestone.

Groundwater potential of this aquifer is high. But groundwater potential of Carboniferous-Lower Permian formation changes by place to place.

(6) Old metamorphic aquifer

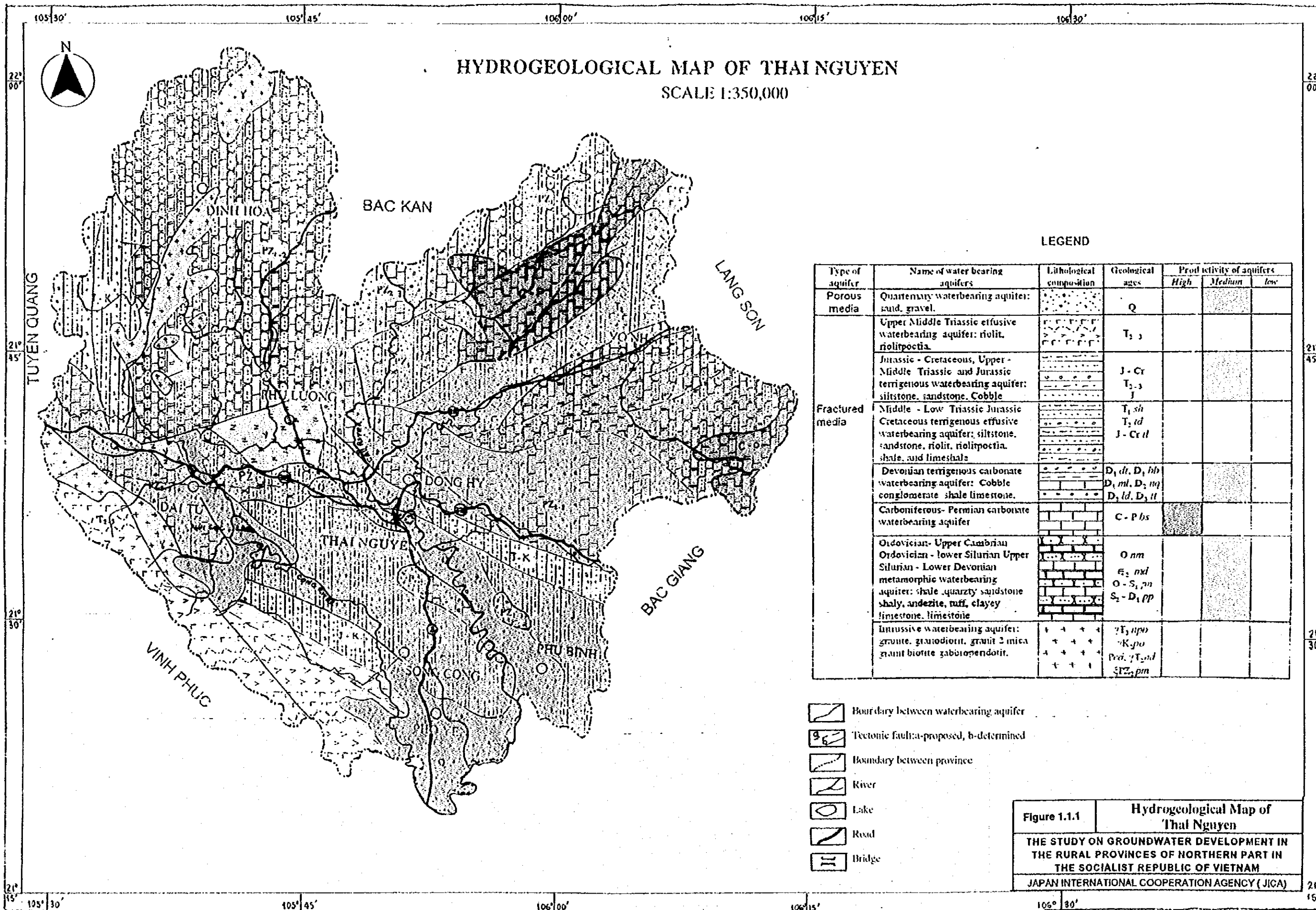
This aquifer consists of Na Mo stratum (Onm), Mo Dong stratum (Є₂md), Than Sa stratum (O-S₁ts) and Phia Phuong stratum (S₂-D₁ pp). They distributed in South-West of Lang Hit mountain, Than Sa depression, north of Cho Mai, west of Na Ri, along the road from Phia Khoa to Ban Thi. Lithological composition of old metamorphic rocks is characterized by shale, quartzose shale-sandstone and limestone. The thickness ranges from 300 to 1,200 m.

The groundwater potential of this aquifer is medium.

(7) Intrusive aquifer

This aquifer consists of intrusive rocks of Phia Bioc stratum (γT₃ npb), Pia Oac stratum (γK₂ po), Cho Don stratum (Pcd), Nui Dieng stratum (γ T₂ nd) and Pia Ma stratum (ΞPZ₂ pm). They are distributed in Cho Chu massive near Cho Chu town, Thien Khe, Da Lien, Nui Chua, Son Dau, Nui Phao, and Pia Ma massives. Lithological composition of intrusive rocks is characterized by granite, granodiorite, two mica granite, biotite granite and gabro-peridotite.

Groundwater potential of this aquifer is very low.



1.1.2 Hanoi

The geology of Hanoi City consists of Permian to Triassic formations in the northern mountainous area and Quaternary sediments in the Red River Delta. The hydrogeological map of Hanoi Province is shown in Figure 1.1.2.

The Red River delta is composed of sediments mainly transported by the Red River in the period of Quaternary, from the Pleistocene to the Holocene epochs. The average thickness of the sediments reach 80 m in the study area, although the thickness is only 30 m in Soc Son District, northern part of Hanoi. The hills and mountains around the delta are mainly composed of Mesozoic (Upper-Middle Triassic) rocks. However, the basement of the delta is mainly composed of Tertiary (Pliocene) sediments.

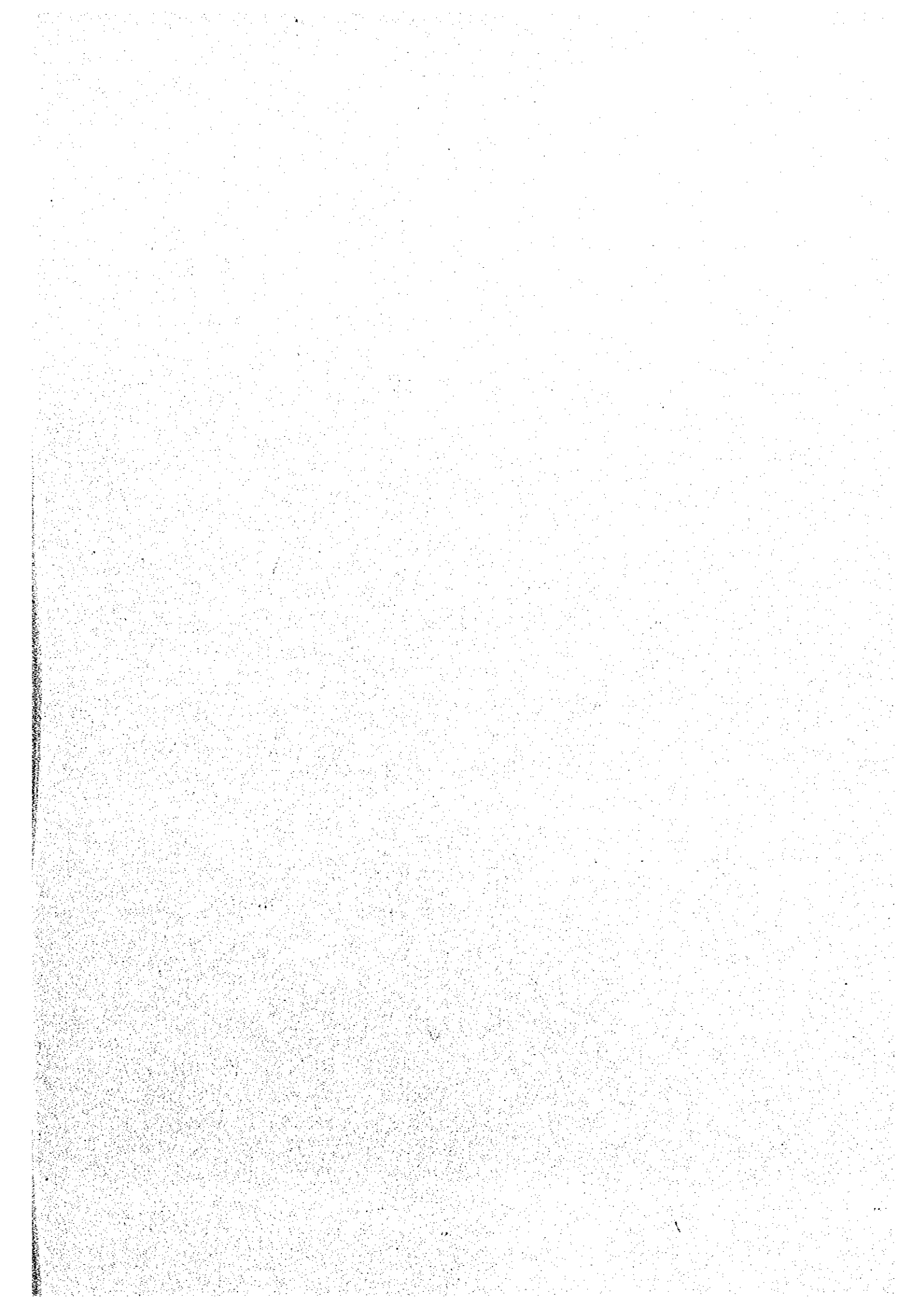
From the hydrogeological points of view, there are two (2) aquifer units in the Quaternary sediments in Hanoi area as mentioned below.

(1) **Confined Pleistocene aquifer (Lower Aquifer)**

This aquifer occurs 40 to 80 m in depth with thickness of 40 m, although it occurs 10 to 30 m in depth thickness of 20 m in Soc Son District. This is a confined Pleistocene aquifer called Lower Aquifer (Qa), which is used for public water supply and industry use by deep wells. The Lower Aquifer (Qa), which belongs to Lechi Formation of Lower Pleistocene and Hanoi Formation of middle Pleistocene, is the main aquifer in Hanoi area. Lechi Formation mainly consists of sand and gravel layers with well-rounded cobbles. At the top of the formation, a thin silty layer is often found, which separates the formation from the above formation. The lower part of Hanoi Formation is composed of sand and gravel layers with cobbles and boulders.

(2) **Unconfined Holocene aquifer (Upper Aquifer)**

This aquifer is distributed near the ground surface having 20 to 30 m in thickness. This is an unconfined Holocene aquifer, called as Upper Aquifer (Qb) in the area. The Upper Aquifer (Qb) is mainly used for domestic purposes by shallow dug wells.



HYDROGEOLOGICAL MAP OF HANOI

SCALE: 1 : 200,000



LEGEND

Type of aquifer	Name of water bearing aquifers	Lithological composition	Geological ages	Productivity of aquifers		
				High	Medium	Low
Porous media	Holocene waterbearing aquifer: sand, clay silt.	[Symbol]	Q _v			
	Pleistocene waterbearing aquifer: gravel, cobble, sand, clay.	[Symbol]	Q ₁₋₃			
Fractured media	Permian - Triassic intrusive waterbearing aquifer: sandstone, siltstone, claystone, rhyolite	[Symbol]	P - T			

Mineralisation of water (g/l)

- [Symbol] Less 0.1 g/l
- [Symbol] 0.1 - 1.0 g/l

Productivity of exploitable pumping station (m³/day)

- [Symbol] Less 10,000
- [Symbol] 10,000 - 20,000
- [Symbol] > 20,000

Other remarks

- [Symbol] River, stream
- [Symbol] Canal
- [Symbol] Lake, pond
- [Symbol] Dike
- [Symbol] Railway
- [Symbol] Road
- [Symbol] Bridge
- [Symbol] Boundary between province
- [Symbol] Boundary between waterbearing aquifer

LEGEND

- [Symbol] Q_b Holocene Upper Aquifer
 - [Symbol] Cf1 First Confining Layer
 - [Symbol] Q_{a-b} Upper Pleistocene Aquifer Third Aquifer
 - [Symbol] Cf2 Second Confining Layer
 - [Symbol] Q_a Middle-Lower Pleistocene Lower Aquifer
 - [Symbol] Br Tertiary-Proterozoic Basement Rocks
- [Symbol] Existing Test Well & its Number

HYDROGEOLOGICAL CROSS-SECTION ALONG LINE I-I

0 1 2 5 km

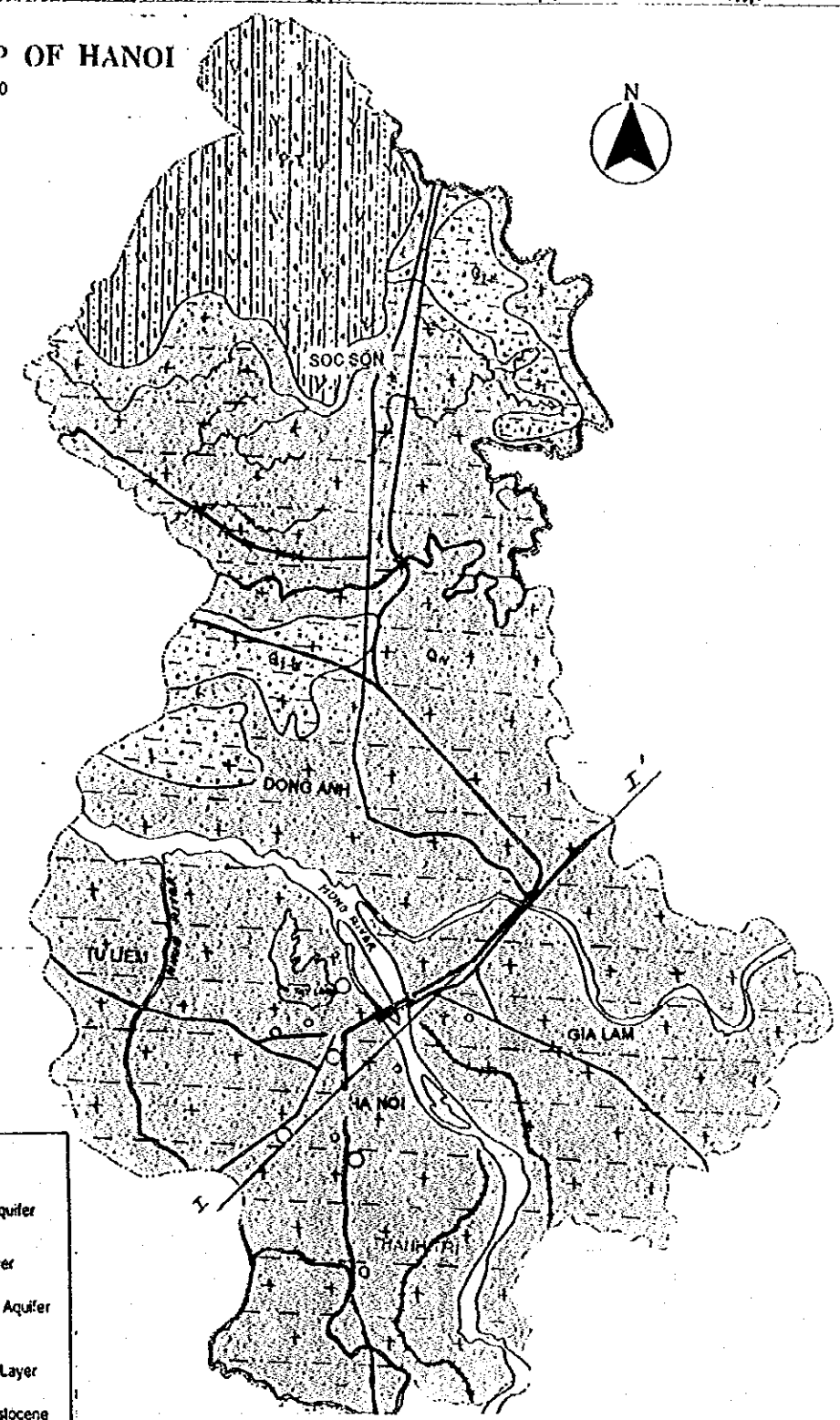
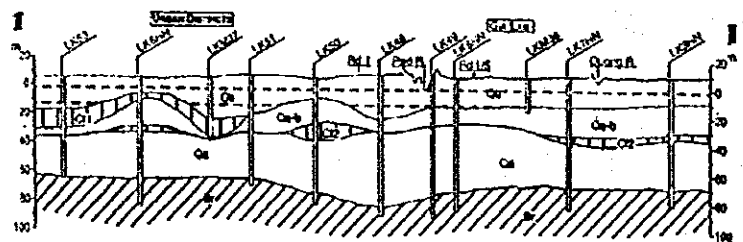
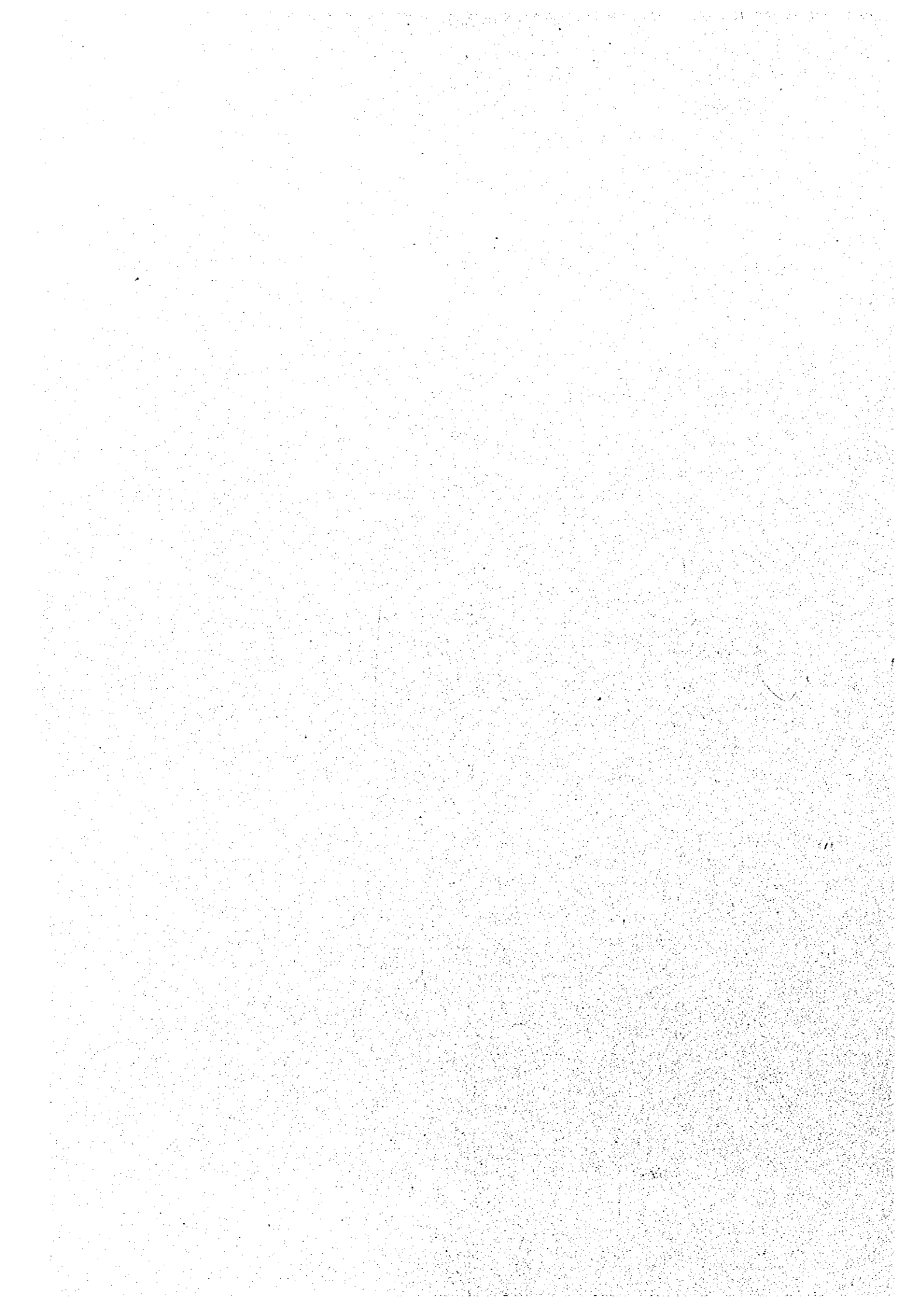


Figure 1.1.2 Hydrogeological Map of Ha Noi
 THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM
 JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



1.1.3 Ninh Binh

The geology of Ninh Binh Province consists of Lower to Upper Triassic, Neogene sediments, and Quaternary sediments. The hydrogeological map of Ninh Binh Province is shown in Figure 1.1.3. From the hydrogeological points of view, there are eight (8) aquifer units in Ninh Binh Province as mentioned below.

(1) Upper Holocene aquifer

This aquifer consists of Thai Binh stratum (Q_{IV}^{3tb}). The aquifer is distributed in the East of Truong Yen mountain, along the Hoang Long River, and in Yen Mo Commune. Lithological composition is characterized by sand and clay. The thickness of this aquifer is limited.

Groundwater potential of the aquifer is limited.

(2) Holocene aquitard

This aquitard consists of upper Hai Hung stratum ($Q_{IV}^{1-2hh_2}$). Lithological composition of the aquitard is characterized by marine sediment (mainly clay and clayey sand). The aquitard is distributed from Gia Hung to Gia Thanh Communes in Gia Vien District. The thickness of clay layer is 2 to 5 m.

(3) Lower-Middle Holocene aquifer

This aquifer consists of lower Hai Hung stratum ($Q_{IV}^{1-2hh_1}$). The aquifer consists of river and marine beds. This aquifer is distributed in the depth from 3 to 27m below ground surface and covered by younger sediments.

This aquifer has less information on productivity and quality.

(4) Upper-Middle Pleistocene aquifer

This aquifer is composed of lower Vinh Phuc stratum ($Q_{III}^{vp^1}$) and Hanoi stratum (Q_{II-III}^{hn}). The aquifer is distributed in Nho Quan and Tam Diep Districts and covered by Holocene sediments. Lithological composition is characterized by sand and gravel.

The groundwater potential is high, but its quality is poor.

(5) Neogene terrigenous aquifer (N)

Neogene terrigenous sediments (N) consists of Vinh Bao stratum (N vb) and Ha Noi stratum (N hn) occurs on the surface only in Phu Oc and south of Tam Diep with an

area about 0.5 to 0.6 km². The thickness of Neogene aquifer varies from 150 to 200 m.

The groundwater potential is small and not satisfied for water supply.

(6) Upper-Middle Triassic terrigenous aquifer

This aquifer consists of Suoi Bang stratum (T₃ n-r sb), Muong Trai stratum (T₂ l mt) and Nam Tham stratum (T₁ l nt). Lithological composition is characterized by terrigenous sediments (calcareous clay, calcareous shale, sandstone, siltstone) of Upper-Middle Triassic terrigenous sediments. The aquifer is distributed in the western Xich Tho (Lien Noi, Thach Binh) and in Bich Son (Gia Vien District and South Tam Diep Town). The thickness of the aquifer varies from 150 to 850 m.

Groundwater potential of the aquifer is generally small.

(7) Middle Triassic carbonate aquifer

This aquifer is composed of Dong Giao stratum (T₂ adg). The carbonate rocks of this aquifer is widely distributed in Nho Quan, Gia Vien and Tam Diep Districts. The aquifer is mainly composed of limestone.

Groundwater potential of the aquifer is very high, but the yield changes by place to place.

(8) Lower Triassic terrigenous aquifer

This aquifer consists of Co Noi stratum (T₁ cn). The terrigenous sediments expose only in Tam Diep and Nho Quan Districts with small area. Lithological composition is characterized by siltstone, sandstone, and some limestone.

Groundwater of this aquifer is important source for water supply in Tam Diep Town and Hoang Long District.

HYDROGEOLOGICAL MAP OF NINH BINH PROVINCE

Scale 1:150,000

I. WATERBEARING AQUIFERS

Index	Water type	Lithological composition	Aquifer name and main rock composition	Geological units	Productivity of aquifer		
					High	Medium	Low
1	Porous media		Upper Holocene porous waterbearing aquifer (Hai Hung strata) Sand, sandy clay	Q _u ¹ ab			
2			Middle lower Holocene porous waterbearing aquifer (lower Hai Hung strata) Sand, sandy clay	Q _u ² ab			
3			Upper-middle Pleistocene porous waterbearing aquifer (Hai Noi strata) Sand, gravel, pebble	Q _u ³ ab			
4			Upper Holocene and Middle Pleistocene aquifer (Hai Hung and Vinh Phuc strata) Clay	Q _u ⁴ ab			
5	Fractured media		Neogene to Tertiary waterbearing aquifer (Ha Noi and Vinh Phuc strata) Sandstone, siltstone, shale	T ₁ ab			
6			Upper middle Tertiary karstic waterbearing aquifer (Sông Bung, Hoàng Tru, Nam Than strata) Sandstone, siltstone, shale	T ₂ ab			
7			Middle Tertiary carbonate waterbearing aquifer (Đông Grai strata) Limestone	T ₃ ab			
8			Lower Tertiary karstic carbonate waterbearing aquifer (Cổ Nho strata) Sandstone, sandstone, limestone	T ₄ ab			

II. WATER SOURCES

Productivity	High	Medium	Low
Open source (Q _u)	>1	0.1 - 1	<0.1
Well (Q _u)	>1	0.2 - 1	0.01 - 0.2
Symbol	○	○	○
Diameter (mm)	3	2	1

- Non water well
- ⊙ Well with mineral water
- △ Water exploitation well
- A — B Hydrogeological cross section line
- 25
110
Well on the section
Above - Index number of the tested interval
The arrow shows the initial and stable water levels
- Hydrogeological boundary
- a — b Fault: a - Determined, b - Proposed
- Other remarks
- ▨ River, stream
- ▨ Rail way
- ▨ Road
- ▨ Bridge
- ▨ Boundary between provinces

HYDROGEOLOGICAL CROSS SECTION ALONG LINE AB
Horizontal scale 1:150,000
Vertical scale 1:3,000

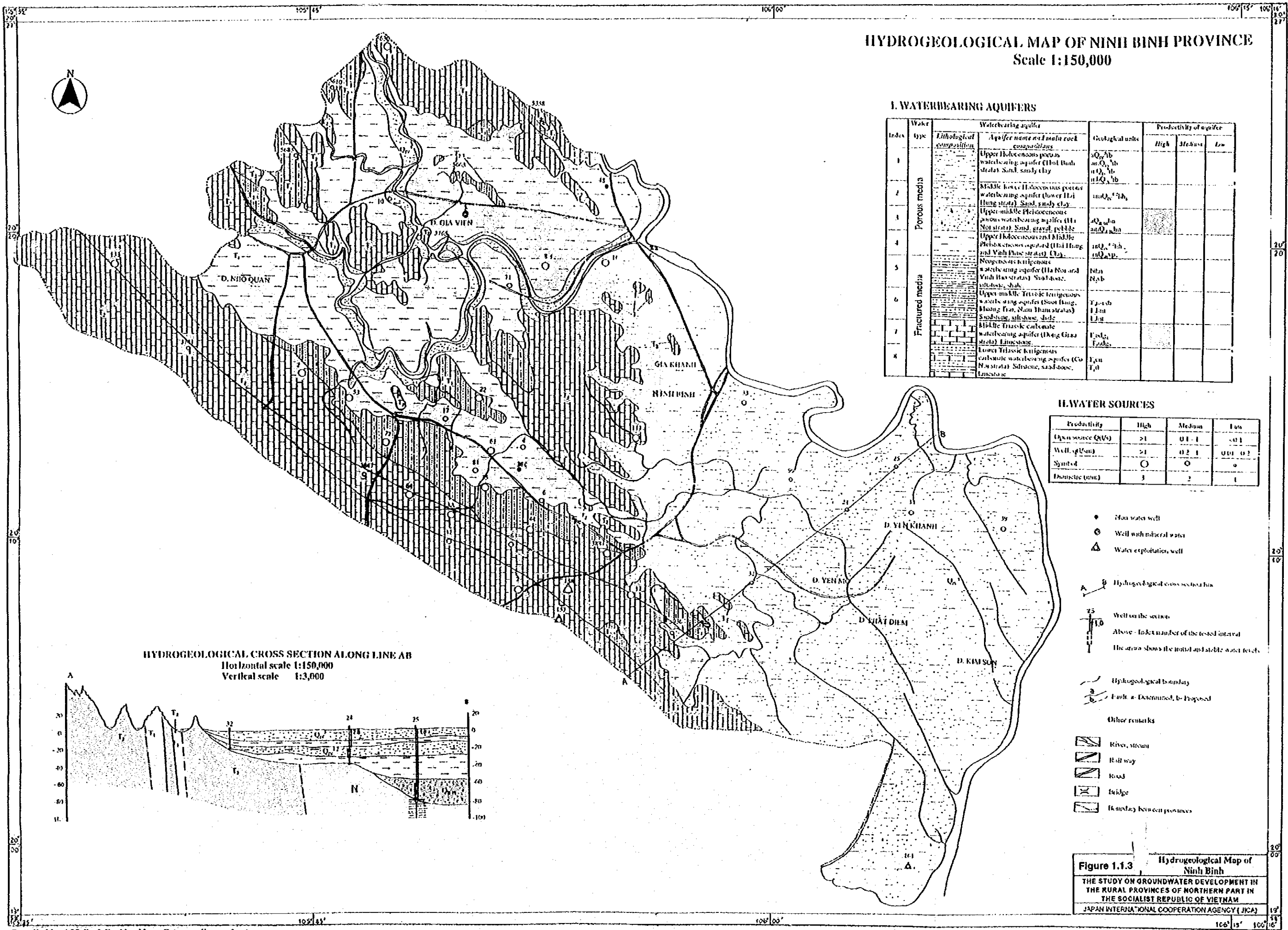
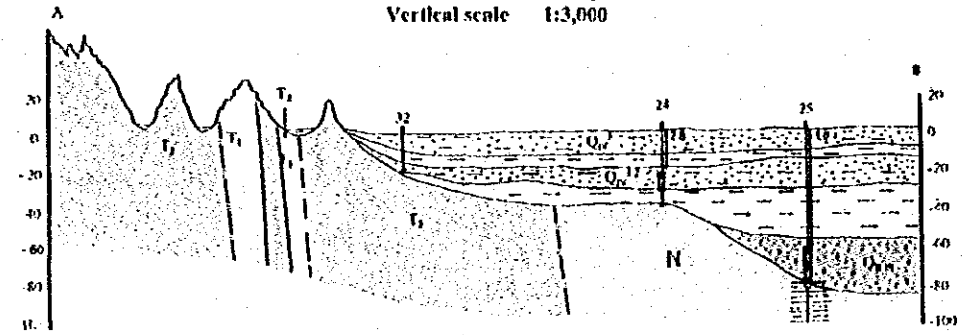
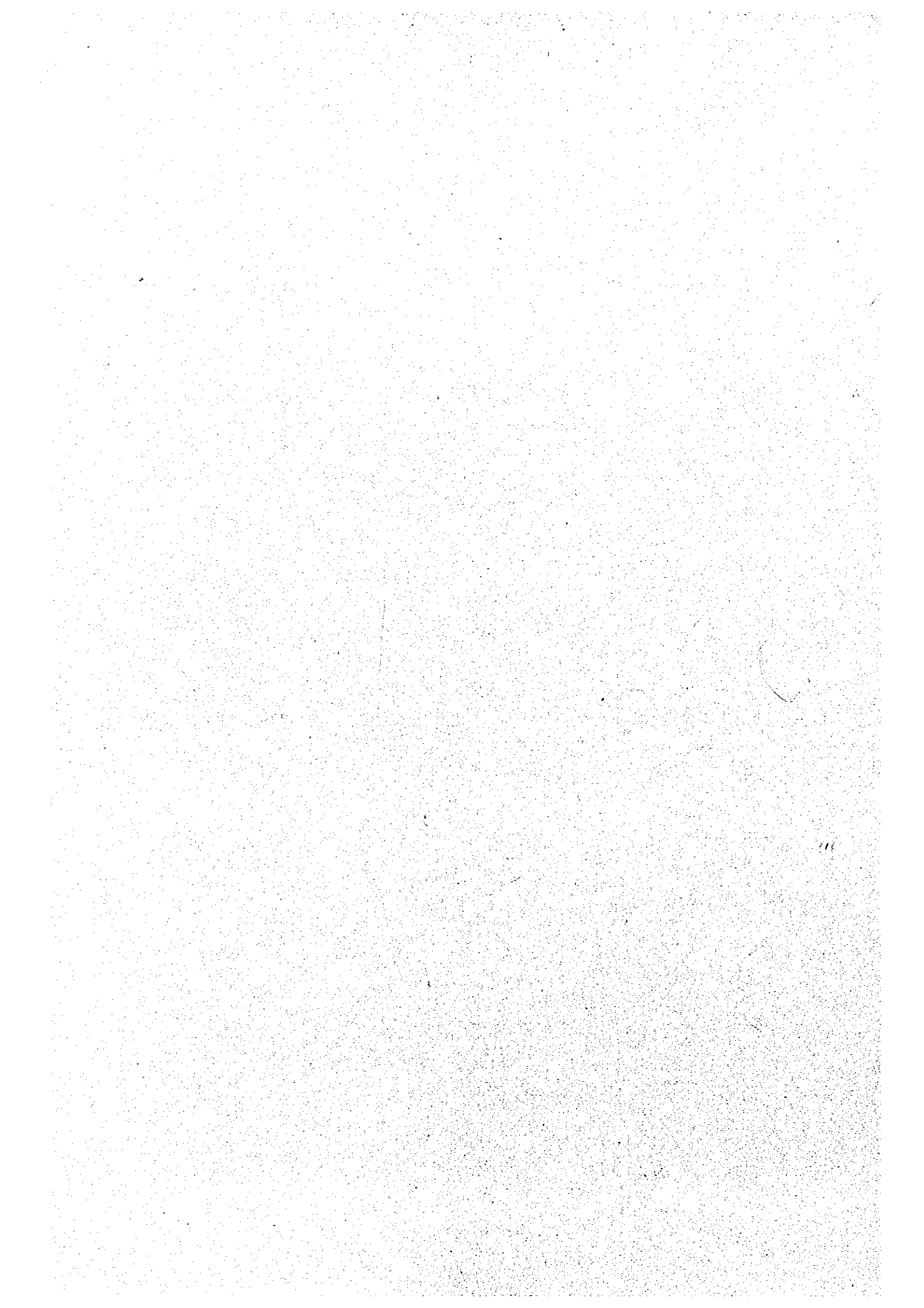


Figure 1.13 Hydrogeological Map of Ninh Binh
THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Compiled by ASS. Prof. Dr. Ngo Ngoc Cat according to the data of Hydrogeological and Engineering Company N^o 2



1.1.4 Thanh Hoa

The geology of Thanh Hoa Province consists of Upper Proterozoic to Upper Cretaceous formations, intrusive rocks, volcanic rocks, and Quaternary sediments. The hydrogeological map of Thanh Hoa Province is shown in Figure 1.1.4. From the hydrogeological points of view, there are twenty (20) aquifer units in Thanh Hoa Province as mentioned below.

(1) Upper Holocene aquifer (Q_{IV}^3)

Upper Holocene aquifer is distributed near Chu River, Ma River, Do Len, Ham Rong railroad station, along the coastal zone from Nga Son to Tinh Gia, and Sam Son beach. Lithological composition is characterized by gravel, cobble, sand, and clay. The aquifer is composed of the sediments of river, river marine, and marine lake origin. The thickness of the aquifer ranges from 1 to 10 m.

Groundwater potential of this aquifer is not high, but groundwater from the aquifer is very important for water supply in the coastal area.

(2) Lower-Middle Holocene aquifer (Q_{IV}^{1-2})

Lower-Middle Holocene sediments are widely distributed in Thanh Hoa plain. Lithological composition of sediments is characterized by clay, silt, sand with gravel of different origin. The thickness of this aquifer ranges from 2 to 40 m.

Groundwater potential of this aquifer is very low.

(3) Upper Pleistocene aquifer (Q_{III})

This sediments mainly consist of fine materials. The formation is underlain by Lower-Middle Pleistocene aquifer.

Groundwater potential of Upper Pleistocene aquifer is very poor. This formation can be treated as an aquitard.

(4) Extrusive aquifer (βQ_{II-IV})

This aquifer is exposed on the surface in the limited area. Lithological composition of extrusive rocks is basalt. The thickness of weathered basalt aquifer ranges from 30 to 50 m.

Groundwater potential of this aquifer is limited.

(5) Upper Cretaceous aquifer (K_{2yc})

Upper Cretaceous sediments are distributed in northwest and southeast of Thanh Hoa City. The area where the sediments are exposed is very small. Lithological composition is conglomerate and siliceous sandstone.

The groundwater potential of this aquifer is very limited.

(6) Upper Triassic-Lower Jurassic aquifer

This aquifer consists of Dong Do stratum (T_{3n-r} dd), Muong Hinh stratum (T_{3-J}₁ mh). Upper Triassic-Lower Jurassic sediments exposed in south and southeast of Thanh Hoa Province. Lithological composition is characterized by extrusive rhyolite, poefia, lime sandstone, sandstone, siltstone, shale with thin lens of coal.

The groundwater potential of this aquifer is very limited.

(7) Middle Triassic aquifer

This aquifer consists of Nam Tham stratum (T₂ lnt), distributed in the form of belt in the northwestern part of Thanh Hoa Province. Lithological composition is lime clay, siltstone, and sandstone.

The groundwater potential of this aquifer is very poor.

(8) Middle Triassic carbonate aquifer (T₂ adg and T₂adt₂)

Middle Triassic aquifer has a typical lithological composition, that is limestone. This aquifer occurs in northwest of Thanh Hoa Province, in the small areas of the western part in Quan Hoa District, and in the southwestern part of Nhu Xuan District. The thickness of this aquifer ranges from 70 to 120 m.

This aquifer has very high groundwater potential and prospective for water supply.

(9) Middle Triassic terrigenous aquifer

This aquifer consists of Lower Dong Trau stratum (T₂ a dt₁), distributed widely in south of Thanh Hoa Province from Quan Hoa District to Nhu Xuan District. Lithological composition is sandstone, siltstone, shale, and conglomerate.

The groundwater potential of this aquifer is limited.

(10) Lower Triassic terrigenous aquifer (T₁)

This aquifer is distributed in the Cam Thuy and Vinh Loc Districts, north and northeast of Thanh Hoa Province. Lithological composition is siltstone, sandstone, shale, and clayey limestone.

The potential of groundwater in this aquifer is limited.

(11) Upper Permian aquifer

This aquifer consists of Yen Duyet and Cam Thuy strata (P₂). The aquifer is distributed in Cam Thuy, Ngoc Lac, Thach Thanh, Vinh Loc and Yen Duyet Districts. The lithological composition is characterized by spilite, diabase-tuff, siltstone, and lens of limestone.

This aquifer has limited potential of groundwater.

(12) Carboniferous- Lower Permian carbonate aquifer (C-P₁)

Carboniferous-Lower Permian sediments occurs in Quan Hoa, Cam Thuy, Ha Trung, Dong Son, and Nong Cong Districts. Lithological composition is limestone.

The groundwater potential of this aquifer is high, and prospective for water supply.

(13) Upper Devonian terrigenous aquifer

This aquifer consists of Ban Cai stratum (D₃ bc) distributed in north and northwest of Thanh Hoa Province. Lithological composition is siliceous shale, sandstone, and lens of limestone.

The groundwater potential of this aquifer is very limited.

(14) Middle Devonian carbonate aquifer

This aquifer consists of Mo Tom stratum (D₂ mt). The aquifer is distributed on the north and northwest of Ban Cai stratum and around the Dien Lu geosyncline. Lithological composition is mainly limestone.

The groundwater potential of this aquifer is high and perspective for water supply.

(15) Lower Devonian terrigenous aquifer

This aquifer consists of Nam Phia stratum (D₁ np). Nam Phia Stratum is distributed in north and northwest of Thanh Hoa Province, and surrounded by Mo Tom stratum. The

lithological composition is shale with siltstone and sandstone.

The potential of groundwater of this aquifer is limited.

(16) Upper Ordovician-Lower Devonian terrigenous-carbonate aquifer

This aquifer consists of Pa Ham stratum ($O_3 - D_1$ ph). Pa Ham stratum occurs in two belts from Quan Hoa to Lang Chanh Districts with NW-SE direction. The length of each belt is 40 to 50 km, and the width is 1 km. The lithological composition is shale, sandstone and limestone.

The ground water potential of this aquifer is limited.

(17) Lower Ordovician metamorphic aquifer

This aquifer consists of Dong Son stratum (O_{1ds}). The Dong Son stratum exposed on southwest of Cam Thuy District, south of Ha Trung and Dong Son Districts, and Hau Loc District. The lithological composition is clayey silt and sandstone.

The potential of groundwater of this aquifer is very limited.

(18) Upper Cambrian terrigenous carbonate aquifer (ϵ_3)

This aquifer is widely distributed in Ba Thuoc, Cam Thuy, Quan Hoa, Hoi Xuan Districts. They consist of three (3) strata, namely Dien Lu stratum (ϵ_3 dl), Lang Vac stratum (ϵ_3 lv) and Ham Rong stratum (ϵ_3 hr). The lithological composition is characterized by clayey shale, siltstone, and limestone.

The potential of groundwater of this aquifer is limited.

(19) Upper Proterozoic-Middle Cambrian metamorphic aquifer ($Pt_2 - \epsilon_2$)

This aquifer exposes on the west of Quan Hoa, Lang Chanh, and Nhu Xuan Districts. The lithological composition is shale, quartz sandstone, and clayey limestone.

The groundwater potential of this aquifer is very limited.

(20) Intrusive aquifer

Intrusive rocks are widely exposed in northwest of Thanh Hoa Province. The lithological composition of intrusive rocks are granite, biotite diabase, granodiabase and pyroxenite.

The groundwater potential of this aquifer is very limited.

HYDROGEOLOGICAL MAP OF THANH HOA

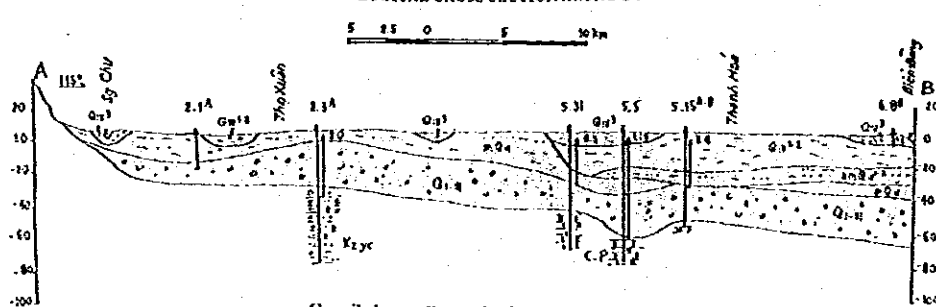
SCALE 1:400,000

Legend

Type of aquifers	Name of water-bearing aquifers	Lithological composition	Geological ages	Productivity of aquifers		
				High	Medium	Low
POROUS MEDIA	Upper Triassic water-bearing aquifer: sand, gravel, siltstone, clay, etc.	[Symbol]	Q ₁			
	Lower Triassic water-bearing aquifer: sand, sandy silt, clay	[Symbol]	Q ₂			
	Upper Permian water-bearing aquifer: clay, silt, clay, etc.	[Symbol]	Q ₃			
FRACTURED MEDIA	Permian water-bearing aquifer: fossil, tuff, weathered basalt	[Symbol]	P ₁			
	Upper Devonian water-bearing aquifer: siltstone, sandstone, shale	[Symbol]	K ₁			
FRACTURED MEDIA	Upper Triassic water-bearing aquifer: siltstone, sandstone, shale, etc.	[Symbol]	T ₁			
	Lower Triassic water-bearing aquifer: siltstone, sandstone, shale, etc.	[Symbol]	T ₂			
	Middle Triassic water-bearing aquifer: siltstone, sandstone, shale, etc.	[Symbol]	T ₃			
	Upper Permian water-bearing aquifer: siltstone, sandstone, shale, etc.	[Symbol]	P ₁			
	Lower Permian water-bearing aquifer: siltstone, sandstone, shale, etc.	[Symbol]	P ₂			
	Upper Devonian water-bearing aquifer: siltstone, sandstone, shale, etc.	[Symbol]	D ₁			
	Lower Devonian water-bearing aquifer: siltstone, sandstone, shale, etc.	[Symbol]	D ₂			
	Upper Carboniferous water-bearing aquifer: siltstone, sandstone, shale, etc.	[Symbol]	C ₁			
	Lower Carboniferous water-bearing aquifer: siltstone, sandstone, shale, etc.	[Symbol]	C ₂			
	Upper Permian water-bearing aquifer: siltstone, sandstone, shale, etc.	[Symbol]	P ₁			

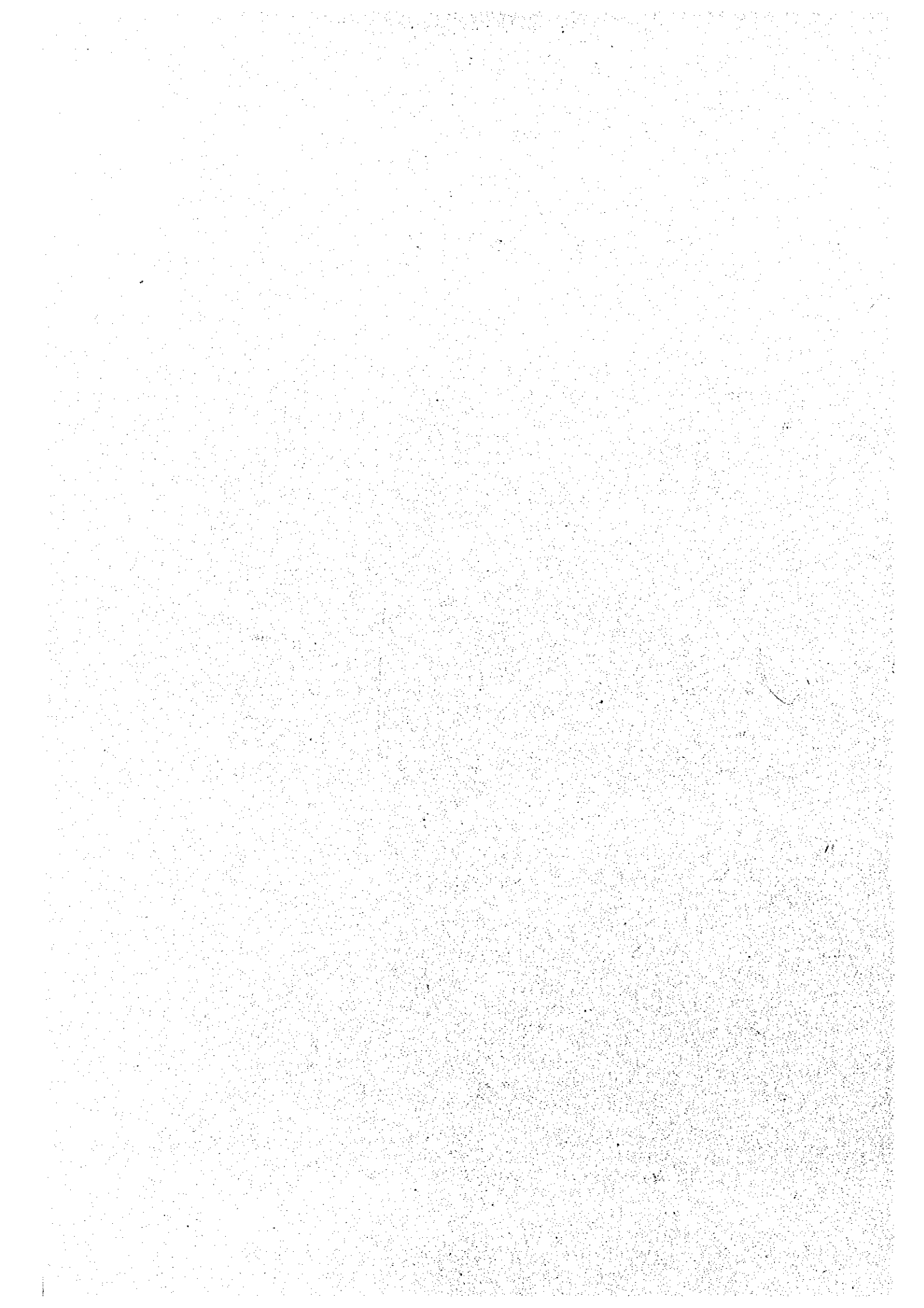
- Other remarks**
- 1. Number
 - 2. Discharge, l/s
 - 3. Total mineralization, g/l
 - 4. Temperature of water, °C
- Spring**
- 1. Number
 - 2. Discharge, l/s
 - 3. Direction, g/l
 - 4. Static level, m
 - 5. Mineralization, g/l
 - 6. Depth, m
- Well**
- 1. Number
 - 2. Discharge, l/s
 - 3. Direction, g/l
 - 4. Static level, m
 - 5. Mineralization, g/l
 - 6. Depth, m
- Hand dug well**
- 1. Number of wells
 - 2. Geological age of strata
 - 3. Discharge, m³/day
 - 4. Mineralization, g/l
 - 5. Depth, m
- Boundary between water-bearing aquifers**
- Tectonic proposed fracture**
- Tectonic fracture**

HYDROGEOLOGICAL CROSS-SECTION ALONG LINE AB



Compiled according to the data of Hydrogeological and Engineering Company No2

Figure 1.1.4 Hydrogeological Map of Thanh Hoa
THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



1.1.5 Ha Tinh

The geology of Ha Tinh Province consists of Ordovician to Upper Triassic formations, intrusive rocks, and Quaternary sediments. The hydrogeological map of Ha Tinh Province is shown in Figure 1.1.5. From the hydrogeological points of view, there are ten (10) aquifer units in Ha Tinh Province as mentioned below.

(1) Quaternary porous aquifer (Q)

Quaternary porous aquifer is exposed on the surface in small plains in the mountainous area of southern part in Huong Son District. They are also distributed as a belt along the river side of the southeastern part of Huong Khe District. The aquifer is mainly composed of alluvial sediments. Lithological composition is sand, pebble, and gravel. The thickness of this aquifer changes from 1.5 to 10 m.

Groundwater potential of this aquifer is very limited.

(2) Holocene aquifer (Q_{IV})

This aquifer is widely distributed in coastal plains. The thickness varies from 10 to 60 m. The Holocene deposits are composed of clayey sand, sand, pebble, and gravel.

Groundwater potential of this aquifer is medium.

(3) The Lower-Upper Pleistocene aquifer (Q_{I-III})

The Lower-Upper Pleistocene deposits are distributed on the surface in the areas between Holocene deposits and Triassic deposits, and in small areas in the southern part of Huong Son District and the eastern to southern parts of Huong Khe District. They are composed of sand, pebble and gravel. The thickness ranges from 5 to 60 m.

This aquifer has high productivity and prospective for water supply.

(4) The Upper Triassic aquifer (T₃)

This aquifer unit is exposed on the surface in the northeastern part of Huong Khe District. They are composed of conglomerate, sandstone, claystone, shale, coal, and clayey limestone.

Groundwater potential of this aquifer is very limited.

(5) Triassic aquifer (T)

This aquifer unit is exposed on the surface with forming of a belt from Phu Loc (Can Loc District) to Thach Xuan and Thach Huong (Thach Ha District). The deposits are composed of siltstone, sandstone, shale, and limestone.

This aquifer has very lower potential

(6) Carboniferous-Lower Permian aquifer (C-P₁)

Carboniferous-Lower Permian deposits are exposed on the surface in the northern part of Huong Khe District with forming a belt from Cam Son to Ky Lam. They are composed of shale, limestone, and tuff.

This aquifer has lower productivity.

(7) Middle Devonian aquifer (D₂)

This aquifer is exposed on the surface in the southeastern part of Ky Anh District. The aquifer is composed of limestone.

This aquifer has higher productivity and prospective for water supply.

(8) Devonian aquifer (D)

This aquifer is distributed on the surface in the southeastern part of Ky Anh District. The Devonian deposits are composed of sandstone siltstone, conglomerate, shale, and limestone.

This aquifer has medium potential of groundwater.

(9) Ordovician-Lower Devonian aquifer (O-D₁)

The Ordovician-Lower Devonian deposits are widely exposed on the surface in the form of a long belt in southeastern part of Ha Tinh Province. They are composed of sandstone, conglomerate, siltstone, shale, andesite, tuff, clayey limestone, and limestone.

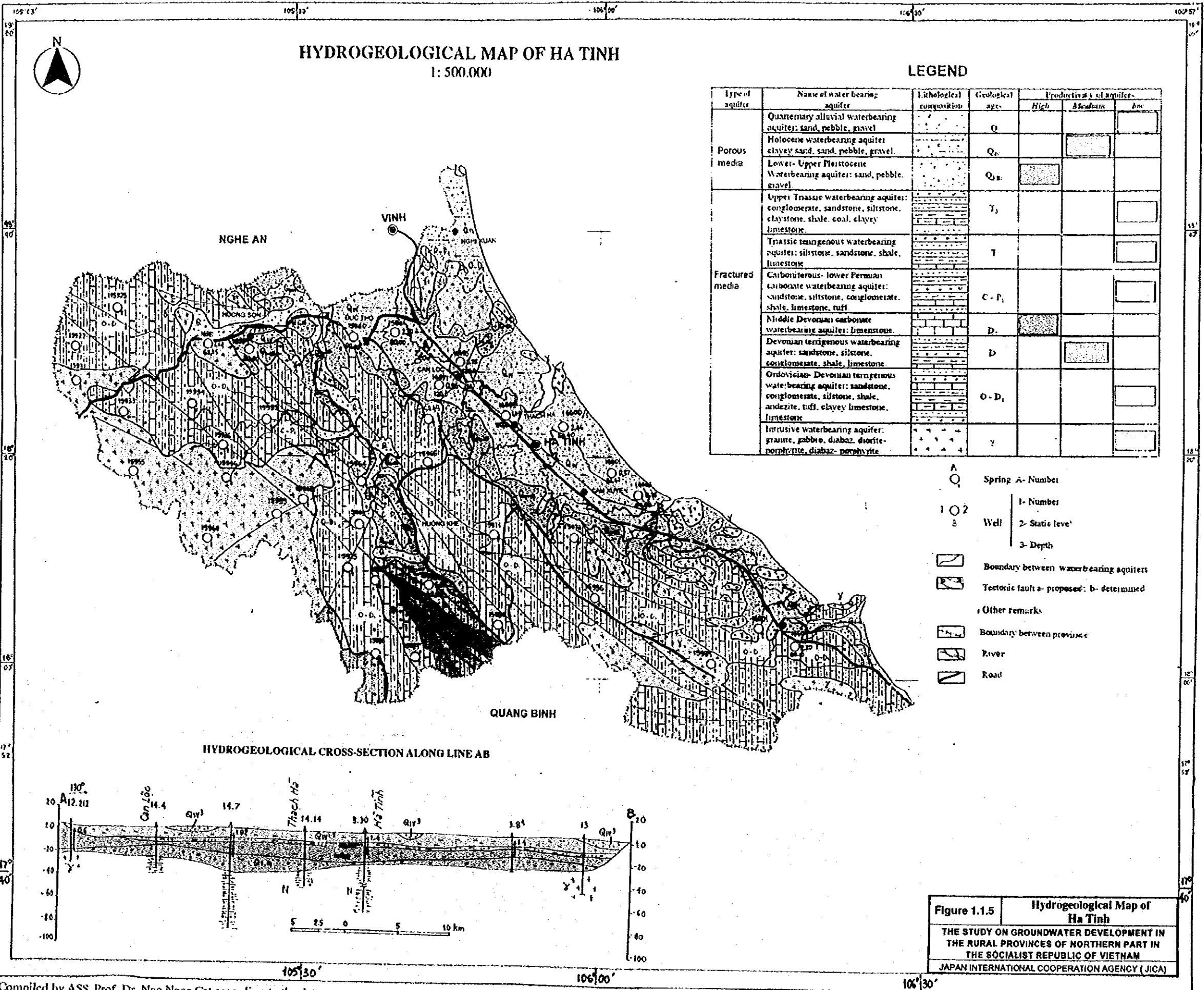
This aquifer has lower productivity.

(10) Intrusive aquifer

The intrusive rocks are distributed in the southeastern part of Huong Khe District and Ky Anh District. They are composed of granite, gabbro, diabase, diorite-porphyrity,

and diabase-porphyrite

This aquifer has lower productivity. But, in some cases such as the zone of tectonic fractures, the yield of a well may be higher.



Compiled by ASS. Prof. Dr. Ngo Ngoc Cat according to the data of Hydrogeological and Engineering Company N 2 &



1.2 Hydrogeological Features in The Target Communes

Groundwater in the target communes occurs in the unconsolidated Quaternary sediments as well as in the basement rocks (mainly in limestone). The Quaternary sediments are distributed in almost all the communes, however, the thickness is small in the communes in Thai Nguyen, some communes in Ninh Binh and Thanh Hoa Provinces. The thickness of the Quaternary sediments at the four (4) drilling sites of the Study in Thai Nguyen ranges from 12.8 to 18.6 m.

The target communes in Hanoi Province are underlain by thick Quaternary sediments. According to the existing data such as the well drilling data by Hydrogeological Company 64 (1993), the thickness of the Quaternary sediments is about 80 m.

In Ninh Binh Province, Yen Thang Commune has thick Quaternary sediments even limestone, sandstone, and shale are exposed on the surface at some locations. The thickness of Quaternary sediments at the test well drilling site is 44.0 m. On the other hand, the thickness of Quaternary sediments in Quang Son and Dong Phong Communes are small.

In Thanh Hoa Province, the target communes in the northern and central part has thick Quaternary sediments, ranging from 23.0 to 48.0 m. The thickness in Van Thang Commune and Nong Cong Town is small. Quaternary sediments in the target communes in Ha Tinh Province is also thick, ranging from 28.0 to 68.4 m at the three (3) test well drilling sites.

The gravely and sandy formations of Quaternary sediments generally form productive aquifer(s). There are at least 2 to 3 aquifer horizons in Hanoi and 1 to 2 aquifer horizons in eastern Ninh Binh, central Thanh Hoa and Ha Tinh Provinces. In Hanoi, gravely layers at depths from 20 to 40 m have been identified as the First Aquifer and gravel layers at depths from 40 to 80 m have been identified as the Second Aquifer (or Main Confined Aquifer). Between the two aquifers, there is a clayey layer forming a confining layer, having 3 to 37 m thick. In Thai Nguyen Province, even the thickness of Quaternary sediments is relatively small in the target communes, sandy layers and gravely layers form an aquifer in some communes.

The basement rocks in the target communes in Thai Nguyen Province are limestone, sandstone, siltstone, and shale in Carboniferous to Permian periods. The basement rocks of the target communes in Ninh Binh Province consist of Triassic limestone, whereas that in Thanh Hoa province consist of Triassic limestone and sandstone. The basement rock of the target communes in Ha Tinh Province consists of Neogene claystone.

Among the basement rocks, fractured limestone and cavernous limestone form good aquifers. If the limestone is solid and massive with less fractures, groundwater yield is very small and the limestone cannot be treated as an aquifer. Similarly, if the porous space in the fractured limestone is filled with clayey materials, the yield from the limestone is limited. Fractured sandstone and shale can be treated as an aquifer, but it is common that the groundwater yield is smaller than fractured limestone. The Neogene claystone in Ha Tinh Province occasionally contains sandy layers, however, it is difficult to extract sufficient groundwater because of its less permeable nature.