UNITED NATIONS

COMMITTEE FOR COORDINATION OF INVESTIGATIONS

OF THE LOWER MEKONG BASIN

NONG KHAI / VIENTIANE BRIDGE PROJECT

LAOS — THAILAND

FEASIBILITY REPORT

PART III

ENGINEERING AND ECONOMIC DATA

OVERSEAS TECHNICAL COOPERATION AGENCY

Japan, September 1969

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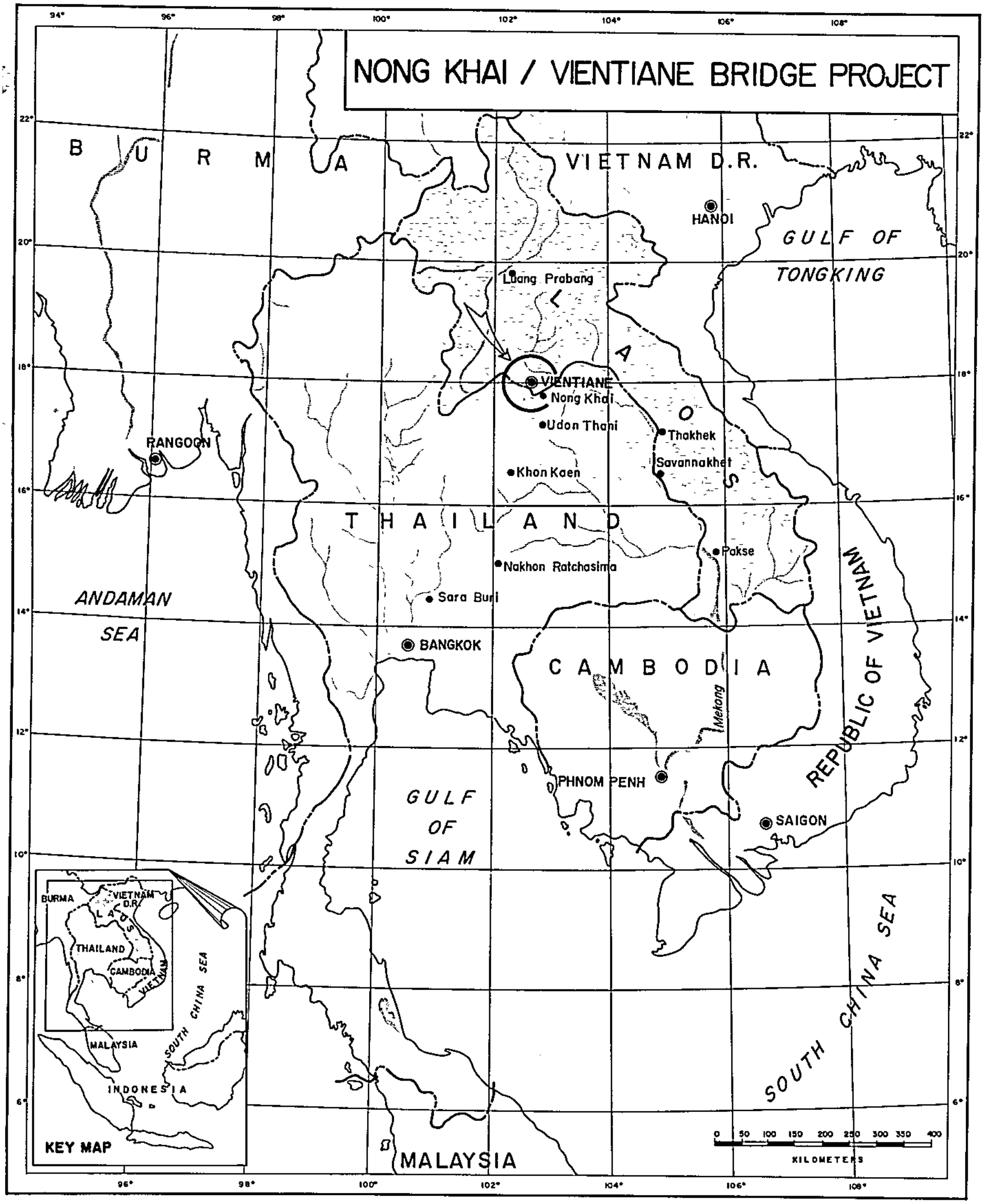
PREFACE

The feasibility investigation on the Nong Khai/Vientiane Bridge Project was carried out at site in two phases in 1967 and 1968, in accordance with the Plan of Operation signed in April 1967 between the Government of Japan and the Mekong Committee.

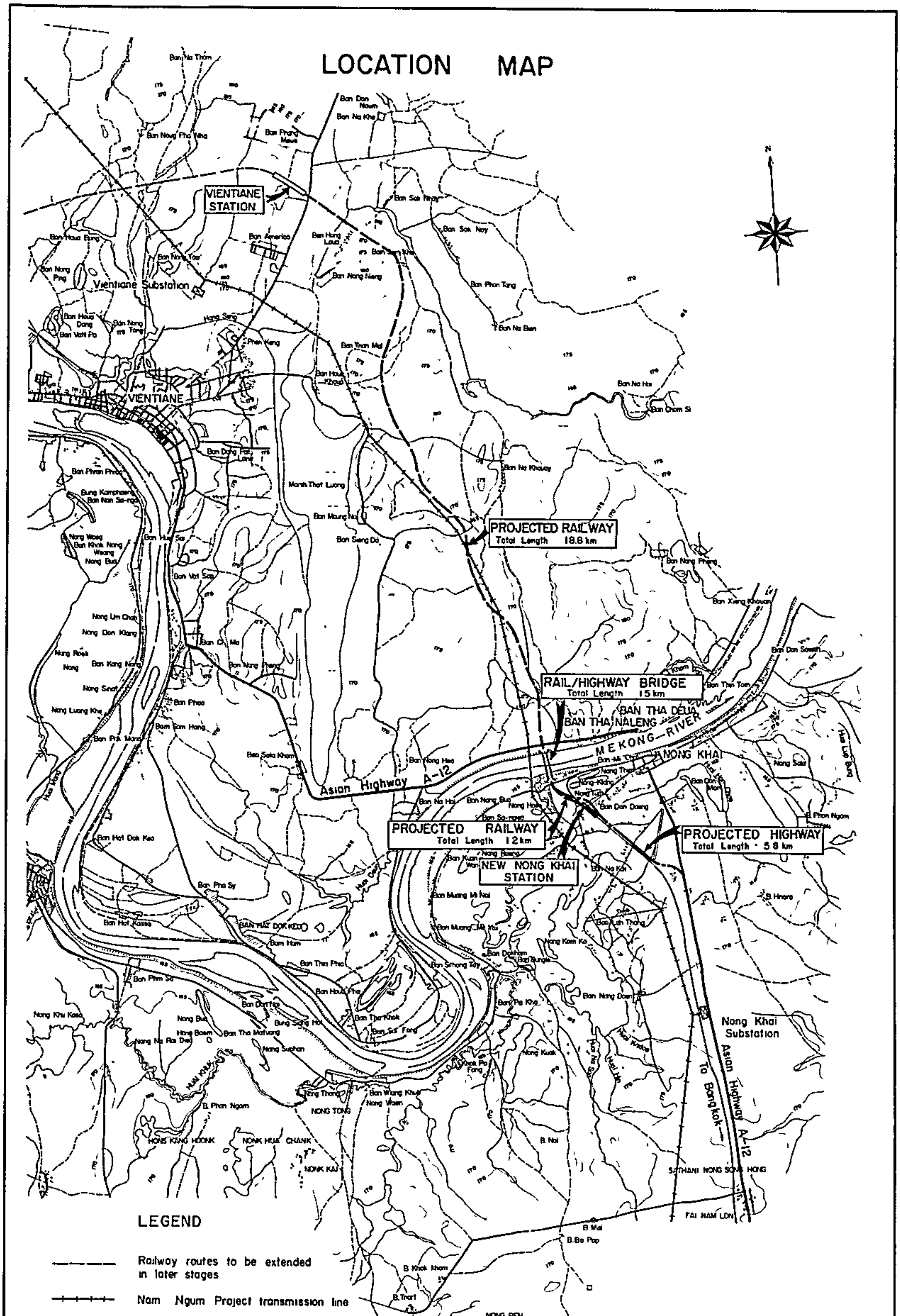
The first phase investigation was undertaken for about two months from August to October 1967 and the second phase investigation for about four months from February to June 1968.

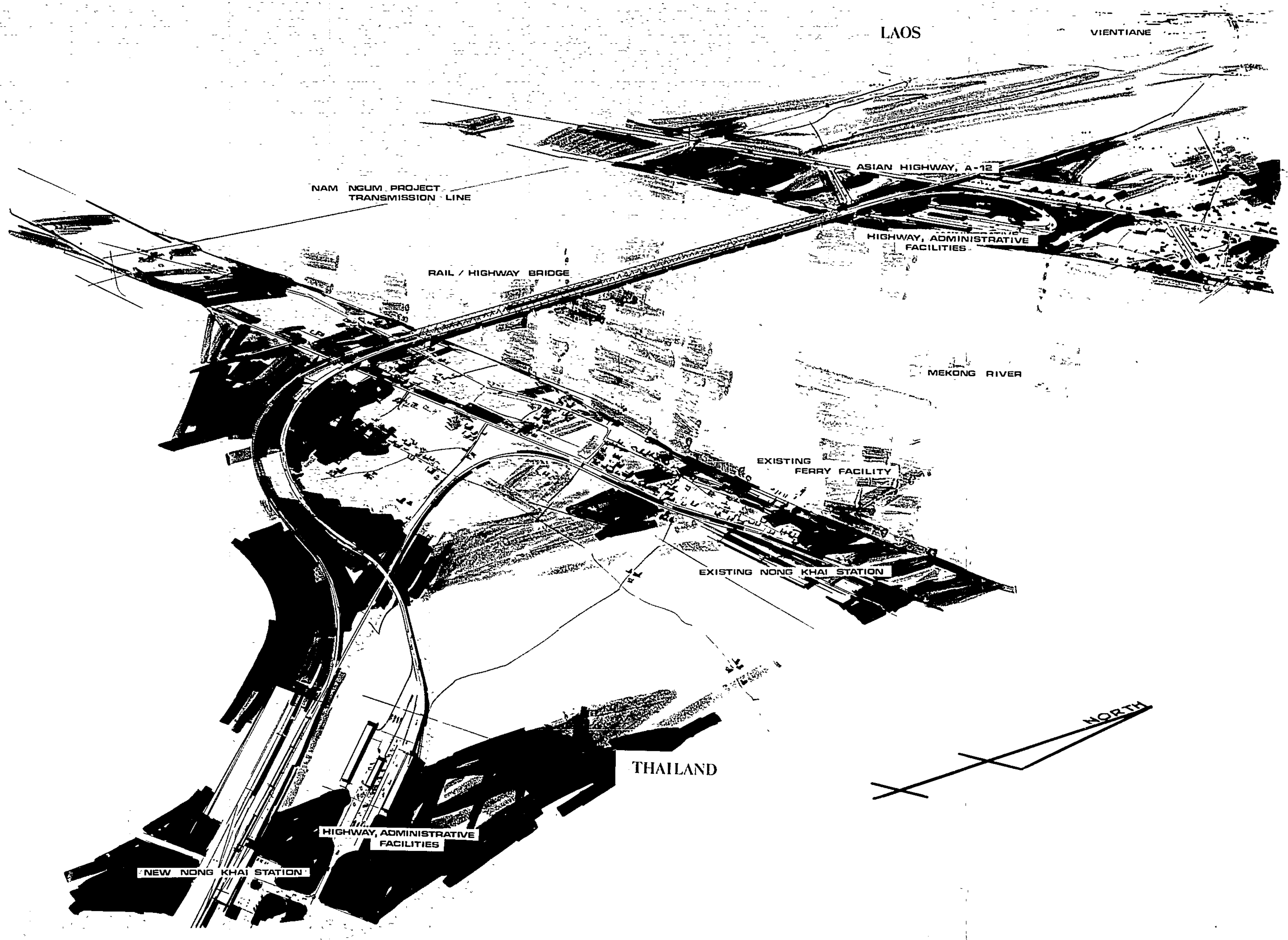
The results of the field investigations such as topographic survey, soil survey, material survey, analyses of meteor- and hydrologic data, and economic survey, are compiled in this report.

This report therefore constitutes an integral part of the Feasibility Reports PART I "SUMMARY AND RECOMMENDATION" and PART II "ENGINEERING, ECONOMIC AND FINANCIAL STUDIES".



NONG KHAI / VIENTIANE BRIDGE PROJECT
BURMA
VIETNAM D.R.
HANOI
GULF OF TONGKING
Luang Prabang
LAOS
VIENTIANE
Nong Khai
Udon Thani
Thakhek
Savannakhet
Khon Kaen
RANGOON
THAILAND
Pakse
Nakhon Ratchasima
Sara Buri
ANDAMAN SEA
BANGKOK
CAMBODIA
Mekong
REPUBLIC OF VIETNAM
PHNOM PENH
GULF OF SIAM
SAIGON
SOUTH CHINA SEA
MALAYSIA
KILOMETERS
0 50 100 150 200 250 300 350 400
KEY MAP
BURMA
VIETNAM D.R.
LAOS
THAILAND
CAMBODIA
VIETNAM
SOUTH CHINA SEA
MALAYSIA
INDONESIA


LOCATION MAP
VIENTIANE STATION
Vientiane Substation
VIENTIANE
PROJECTED RAILWAY
Total Length 18.8 km
RAIL/HIGHWAY BRIDGE
Total Length 1.5 km
BAN THA DEUA
BAN THA NALENG
MEKONG RIVER
NONG KHAI
Asian Highway A-12
PROJECTED RAILWAY
Total Length 1.2 km
NEW NONG KHAI STATION
PROJECTED HIGHWAY
Total Length 5.8 km
Nong Khai Substation
To Bangkok
Asian Highway A-12
N
LEGEND
Railway routes to be extended in later stages
Nam Ngum Project transmission line
SCALE
0
5 km


LAOS
VIENTIANE
ASIAN HIGHWAY, A-12
NAM NGUM PROJECT
TRANSMISSION LINE
HIGHWAY, ADMINISTRATIVE
FACILITIES
RAIL / HIGHWAY BRIDGE
MEKONG RIVER
EXISTING
FERRY FACILITY
EXISTING NONG KHAI STATION
NORTH
THAILAND
HIGHWAY, ADMINISTRATIVE
FACILITIES
NEW NONG KHAI STATION

PROJECT FEATURES

Item			Description
I.	PROJECT		
	1.	Location	670 kilometers northeast of Bangkok, 20 kilometers southeast of Vientiane and 3 kilometers upstream of Nong Khai
	2.	Purpose	To build a rail/highway bridge across the Mekong, a highway, a new railway to be extended from Nong Khai to Vientiane, and two administrative facilities for immigration, customs and plant quarantine.
	3.	Construction cost	U.S.$ 21,500,000
II.	BRIDGE		
	1.	River width	640 m
	2.	Type	
		(i) Main bridge	Steel Warren truss, two 3-span continuous and one 2-span continuous, besides a suspended span
		(ii) Approach viaducts	
		Railway part	Plate girder and reinforced-concrete 3-span-continuous rigid frame construction
		Highway part	Composite girder and reinforced-concrete 3-span-continuous hollow slab construction
	3.	Bridge width	17.8 m
		(i) Railway part	4.0 m
		(ii) Highway part	8.0 m
		(iii) Sidewalk	1.5 m
		(iv) Gangway	1.5 m
	4.	Bridge length	
		(i) Main bridge	650 m
		(ii) Approach viaducts	803.5m
		Railway part	473.5m
		Highway part	330 m
	5.	Max. pier spacing	90 m
	6.	Abutment and pier	2 open caissons on both banks, and 8 pneumatic caissons on the Mekong river-bed
III.	RAILWAY		
	1.	Track	Single
	2.	Track gauge	1.000 m
	3.	Length	20 km
	4.	Station	
		(i) Vientiane station	100,000 m^2
		(ii) New Nong Khai station	55,000 m^2
IV.	HIGHWAY		
	1.	Length	5.8 km
	2.	Width	
		(i) Roadway	7 m (two lanes)
		(ii) Shoulder	2.5 m each
V.	ADMINISTRATIVE FACILITIES		48,000 m^2

BENEFITS AND COSTS

	Item	Discount rate (%)	Unit	Characteristic value △
I.	FUTURE TRAFFIC			
	1. Vehicles			
	A.D. 1973		vehicles/day	1,353
	1990		"	9,025
	2000		"	13,538
	2. Railway freight			
	A.D. 1973		tons/day	606
	1990		"	2,737
	2000		"	3,991
	3. Railway passengers			
	A.D. 1973		persons/day	380
	1990		"	2,045
	2000		"	3,025
II.	ANNUAL BENEFIT	3	U.S.$	7,036,300
		7	"	5,619,100
		10	"	4,794,800
III.	ANNUAL COST	3	U.S.$	1,195,600
		7	"	1,886,900
		10	"	2,478,700
IV.	BENEFIT-COST RATIO	3		5.9
		7		3.0
		10		1.9
V.	INTERNAL RATE OF RETURN		percent	15.9
VI.	INDIRECT BENEFIT			
	1. Lumber industry		Much expedited	
	2. Mining		Much expedited	
	3. Urbanization		Rapid, especially around the Vientiane station	
	4. Rise in land value		Remarkable	
	5. Livestock industry		Self-sustaining expedited	
	6. Saving in stock		Much	

△: These characteristic values are given for the case that no toll is charged on the bridge.

NONG KHAI/VIENTIANE BRIDGE PROJECT

FEASIBILITY REPORT

PART III

ENGINEERING AND ECONOMIC DATA

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CHAPTER I

TOPOGRAPHIC SURVEYS

1.1. Survey Operations

When the feasibility study was started in August 1967, only a 1:20,000 topographic map of the project area was available, which was prepared by enlarging a 1:40,000 aerial photograph taken ten years before. This map was far from sufficient for the study, and consequently necessary surveys were made during the first- and second-phase investigations.

In the first-phase investigation, one aim of which was to select the most desirable bridge site from among the envisaged sites – the Nong Khai, Vientiane, and Pa Mong sites – were carried out spot levelings from Vientiane to each site, echo-soundings of the Mekong's bottom and simple triangulations for measuring the river width at each site.

After the Mekong Committee, based on the First-Phase Report and its Advisory Board's recommendation, had finally selected the Nong Khai site for bridge construction, the second-phase study was started mainly for the purpose of selecting the kind of bridge, i.e., a highway bridge or a rail/highway bridge. And in order to obtain data for this selection, following surveys were carried out: plane-table survey of the bridge site; river-bottom sounding around the bridge site; route surveys of the projected highway and railway; precise leveling across the Mekong to clarify the discrepancy in elevations as adopted in Thailand and in Laos; and precise triangulation for measuring the exact river width at the bridge site.

Based on the Second-Phase Report, the Mekong Committee made choice of the rail/highway-bridge project and requested that a detailed study be made on the rail line to be extended about 20 kilometers from Nong Khai to Vientiane, because the route surveys made during the second-phase investigation covered the projected railway on the Thai side and part of that on the Lao side, totaling only 3 kilometers. The remaining part of the projected railway on the Lao side about 17 kilometers was confined to the extent of a reconnaissance for the purpose of comparing five envisaged routes. Therefore, in compliance with the Mekong Committee's request, detailed route surveys were carried out, as a supplement investigation, on Route C and Route C/D, considered most promising among the envisaged five routes.

The gists of survey operations are shown in Table 1.1 and in Fig. 1.1.

1.2. Leveling and Elevations

In the first- and second-phase investigations, all levelings were based on the third-order bench-mark V-636 in Vientiane, authorized by the Mekong Committee and embodied by a spike driven into a wall of the Ministry of Foreign Affairs' building, registered to lie at an elevation of 170.105 meters above mean sea level at Ko Lak in Thailand.

In the first-phase investigation, spot leveling was carried out along the Asian Highway A-12 starting from the bench-mark V-636 to a bench-mark N-6 set up at Tha Naleng. In the second-phase investigation, leveling was carried out across the Mekong from N-6 to a bench-mark set up on the Thai

Table 1.1. Gists of Survey Operations

	Item	Unit	Work quantity	Specification	Remarks
I.	First-phase investigation				
	1. Spot leveling	km	43	Double-run leveling Diff. in elev.: 1.5 cm and less in a distance of 1 km	From Vientiane to each of the three bridge sites, Pa Mong, Vientiane and Nong Khai
	2. Echo-sounding	km^2	1.2	Accuracy of the machine: 1/100 Sounding depth: 25 m and more	In the Mekong river channel at the three sites
	3. Simple triangulation to measure the width of the Mekong	Place	3		At the three bridge sites
II.	Second-phase investigation				
	1. Spot leveling	km	1	Double-run leveling	Bench-marks B.M.N-6 to B_T via the bench-mark established by N.E.A. in the site of Hydrographic Office to unify the elevation of the topography of the project area extending over both countries
	2. Plane table survey including echo-sounding	km^2	8	Scale: 1/2,000, 1 m contour	Nong Khai bridge site
	3. Route survey	km	8	Transverse survey: 50 m long each on both sides of the route at intervals of 100 meters along the routes	Nong Khai bridge site
	4. Triangulation	Place	1		Nong Khai bridge site, for the purpose of measuring the exact width of the Mekong.
III.	Supplementary investigation				
	1. Route survey	km	27	Transverse survey: 50 m long each on both sides of the route at intervals of 100 m along the routes	Two routes, C and C/D for the projected railway in Laotian territory, and the route of the approach road linking the Vientiane railway station with the Asian Highway A-3.
	2. Spot leveling	km	10	Double-run leveling	Bench-mark V-636 to Bench-mark B.M.T-1 in the route C and also to Bench-mark B.M.T-2 in route C/D for the purpose of establishing the bench-marks at the proposed sites of Vientiane Station, respectively.

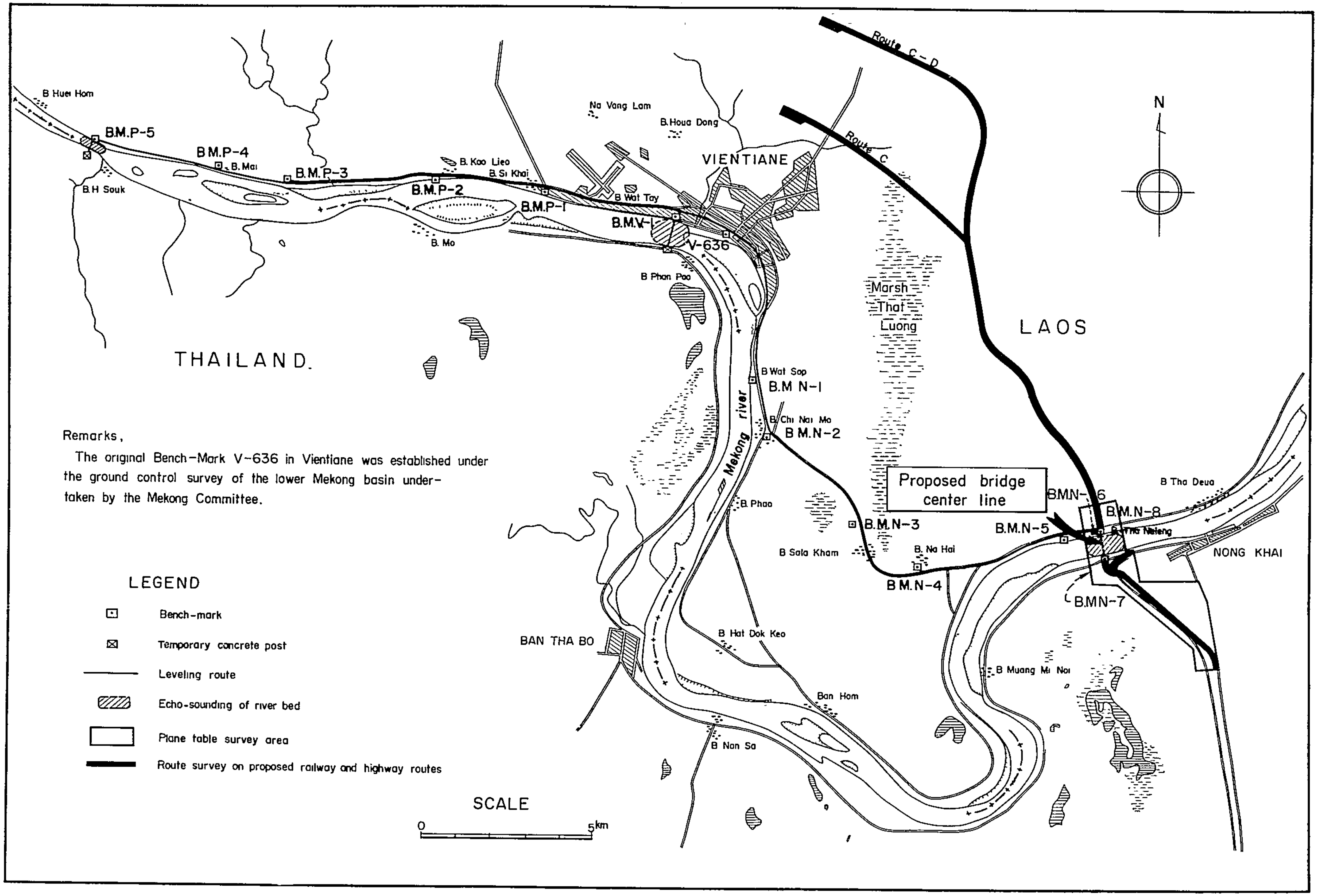
Remarks:-

1) The results of the survey operations executed in the first-phase investigation regarding the Pa Mong and Vientiane bridge sites are not compiled in this report.

2) The results of the transverse survey operations in the route survey are not compiled in this report, too.

3) The map on a scale of 1/2,000 obtained from the plane table survey is not listed in this report. But, reference is made to PLATE 2 titled "GENERAL LAYOUT" scaled down to 1/10,000 from the above map in the Feasibility Report PART II "ENGINEERING, ECONOMIC AND FINANCIAL STUDIES".

Fig. 1.1. SURVEYED ROUTES AND AREA



side. The results of leveling are listed in Data 1.1. (1) and (2), and the locations of bench-marks are shown in Data 1.2. (1) to (3).[/1]

When the leveling was made across the Mekong as above noted, the level line was carried from N-7 to a bench-mark set up by the National Energy Authority (NEA) of Thailand in the compound of the Hydrographic Office at Nong Khai, and the elevation of this bench-mark was leveled at 165.861 meters, as shown in Data 1.1.[/2] as compared with 166.044 meters authorized by the Thai authorities. This means that there is a discrepancy of 0.183 meters in elevations as leveled by the Japanese team and as authorized in Thailand, notwithstanding that both are alike based upon the same mean sea level at Ko Lak.

Therefore, it has become necessary to clarify the cause of the discrepancy and, at the same time, to place on the same basis the elevations of all bench-marks for construction use located in both Laos and Thailand. For this purpose, check levelings of the bench-mark and the staff-gage zero point in the compound of the Hydrographic Office as well as the zero point of the water gage in the Royal Irrigation Department (RID) gaging station at Nong Khai were conducted based upon the third-order bench-mark V-636 in Vientiane and a first-order bench-mark P-396 located in the precinct of the Nong Khai Governor's Office, which is registered to lie at an elevation of 167.7639 meters above mean sea level at Ko Lak, as shown in Data 1.3. The result of the check leveling is given in Data 1.1. (3), and it was found that some errors must be involved in the elevation of either of V-636 and P-396 or in the elevations of both.

At present there are many bench-marks in the project area, especially on the Thai side, which, according to a report entitled "Report of Ground Control Survey November 1959 – June 1960",[/3] are all based on mean sea level at Ko Lak. Whether based on a same datum or not, it is a serious problem that two different elevations shall be assigned to any of the bench-marks lying in a project area. Therefore, it is strongly recommended that the elevations of all bench-marks related to the project execution, beginning with V-636 and P-396, be unified on a consistent basis by the time when the project would be put into execution.

The discrepancy in bench-mark elevations causes a problem in determining the bridge elevation. The bridge is required to provide for navigation a vertical clearance not less than 10 meters above the

---

/1: Bench-marks N-6 and N-7 were set up on the bridge center line at Nong Khai as proposed in the First-Phase Report.

/2: The leveling across the Mekong was made by a long sight of about 400 meters. A double-run leveling was made to cope with the inaccuracy associated with such a long sight. The error in this leveling is estimated at 0.018 meters.
The error in the spot leveling of a stretch of about 20 kilometers from V-636 in Vientiane to N-6 at Tha Naleng is estimated at 0.004 meters, so that the probable total error becomes 0.022 meters.
When the project would be put into execution, a more precise leveling should be carried out. For this, reciprocal leveling is recommendable, which is usually employed with advantage in determining the difference in elevations between two points separated by a river, lake or any other topographic barrier that prevents keeping backsights and foresights balanced.

/3: Prepared by Hunting Survey Corporation Ltd. in December 1960.

design highwater level determined from the water-level records observed at the Hydrographic Office and the RID gaging station, as described in Paragraph 5.2. Therefore, should the water-level gage in use in the Hydrographic Office have been set based on the registered elevation, El.166.044, of the bench-mark in the office's compound, the adopted design high-water level will come out by 0.183 meters higher than what will be estimated based on the elevation of 165.861 meters of the said bench-mark as surveyed from the Vientiane bench-mark V-636. This means that the bridge elevation designed based on the adopted design high-water level would provide a vertical clearance by 0.183 meters greater than what had been envisaged in designing. Consequently, the discrepancy will act, fortunately in the present case, on the safe side in respect of the navigation requirement.

Furthermore, the zero point of the RID gaging station gage staff was found by the check leveling to lie at an elevation of 153.812 meters as shown in Data 1.1. (3). This elevation differs by 0.812 meters from the registered elevation of 153.000 meters. This discrepancy, however, has no much influence on the computation of the design high-water level.

1.3. Echo-Sounding

Echo-soundings were carried out in the first- and second-phase investigations to measure the depths of the river bottom. In the first-phase investigation, soundings were made at the then envisaged three bridge sites, the Pa Mong, Vientiane and Nong Khai sites. After the selection by the Mekong Committee of the Nong Khai site, detailed soundings were made at this site along ten courses shown in Data 1.4. (1).

The results of soundings at the Nong Khai site are shown in Data 1.4. (1) and (2), but those of the Pa Mong and Vientiane sites are not presented in this report.

1.4. Triangulation

1.4.1. General

In the first- and second-phase investigations, triangulation was carried out at the Nong Khai site to measure the river width along the bridge center line as proposed in the First-Phase Report.

The triangulation base line should have been located on either bank of the river. But as it seemed to require much time and cost in jungle clearing, the base line was located on a sand-bar lying the river course. Necessary corrections were made on the measurements to minimize errors that would arise from high temperature and other causes. The distance between the bench-marks N-6 and N-7, denoted by L and T in Fig. 1.2, respectively, was determined by electronic computation of the following equations.

1.4.2. Computation

In Fig. 1.2, $\overline{AB}$ is the base line and $\overline{LT}$ lies on the bridge center line proposed in the First-Phase Report. Measured were the base line length and angles a to ℓ shown in the figure. The measured base line length was 200.000 meters and the angles were measured as follows:

$a = 75°43'15.0"$; $b = 54°19'10.0"$;

$c = 38°15'55.0"$; $d = 37°15'05.0"$;

$e = 49°10'00.0"$; $f = 82°19'50.0"$;

$g = 11°14'47.5"$; $h = 10°42'00.0"$;

$i = 130°02'00.0"$; $j = 76°31'10.0"$;

$k = 131°30'05.0"$; $\ell = 21°56'32.5"$;

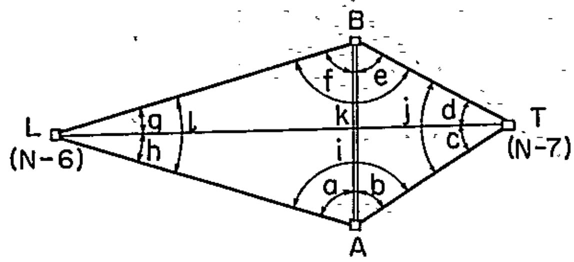


Fig. 1.2. Triangulation Quadrilateral

(1) Base Line Correction

The measured length, D_N, of the base line was corrected for temperature, tape sag and tape pull as expressed by the following equation. Corrections for tape slope and altitude were omitted as they are insignificant.

$$D = D_N + C_t + C_s + C_p \quad \cdots\cdots (1)$$

in which D = corrected length;
C_t = temperature correction;
C_s = sag correction; and
C_p = pull correction.

i) Temperature Correction

$$C_t = \alpha (T_m - T_0) D_N \quad \cdots\cdots (2)$$

in which T_0 = standard temperature (15°C);
T_m = mean temperature during operation (29°C); and
α = coefficient of thermal expansion of tape (0.0000117 m/°C).

Hence $C_t = 0.0000117 (29 - 15) 200 = \underline{0.03276 \text{ m}}$

ii) Sag Correction

$$C_s = -\frac{1}{24}\left(\frac{w\,d}{P}\right)^2 D_N \quad \cdots\cdots (3)$$

in which w = weight of tape per meter (0.02158 kg/m);
d = unsupported length of tape (10 m); and
P = mean applied pull (10 kg).

Hence $C_s = -\frac{1}{24}\left(\frac{0.02158 \times 10}{10}\right)^2 \times 200 = \underline{-0.00388 \text{ m}}$

iii) Pull Correction

$$C_p = \frac{(P - P_0)}{E\,S} D_N \quad \cdots\cdots (4)$$

in which P = mean applied pull (10 kg);
P_0 = standard pull (7 kg);
E = modulus of elasticity of tape (2.1×10^6 kg/cm²); and

S = cross-sectional area of tape ($0.02479\ cm^2$).

Hence $C_p = \dfrac{10 - 7}{2.1\,(10)^6 \times 0.02749}\ 200 = \underline{0.01040\ m}$

Thus, the corrected length of the base line becomes

$$D = 200 + 0.03276 - 0.00388 + 0.01040 = \underline{200.03928\ m}$$

from which the base line length was determined as 200.0393 meters.

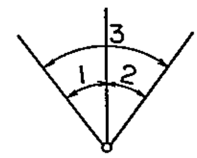


Fig. 1.3. Angles 1, 2 and 3

2) Angle Adjustment

i) Conditions

The measured angles of the quadrilateral BLAT shown in Fig. 1.2 shall be adjusted so that they will satisfy the following conditions:

a) Angle 1 plus angle 2, shown in Fig. 1.3, shall equal angle 3;
b) The sum of interior angles of a triangle shall be 180° exactly; and
c) The side length of a triangle shall be the same irrespective of the course of computation.

The above three conditions are expressed by station, angle and side equations to follow, respectively.

a) Station Equations

$$a_0 + b_0 = i_0\,; \quad c_0 + d_0 = j_0\,; \quad e_0 + f_0 = k_0, \quad g_0 + h_0 = \ell_0 \quad \ldots\ldots \qquad (5)$$

in which $a_0, b_0, \ldots$ denote the most probable values of angles a, b, ...

b) Angle Equations

$$a_0 + b_0 + c_0 + d_0 + e_0 + f_0 + g_0 + h_0 = 360°;$$

$$a_0 + h_0 = d_0 + e_0\,; \text{ and } b_0 + c_0 = g_0 + f_0 \quad \ldots\ldots \qquad (6)$$

c) Side Equations

$$\overline{AB}/\sin(c_0 + d_0) = \overline{TB}/\sin b_0\,; \qquad \overline{TB}/\sin g_0 = \overline{LT}/\sin(e_0 + f_0)\,;$$

$$\overline{AB}/\sin(g_0 + h_0) = \overline{AL}/\sin f_0\,; \qquad \overline{AL}/\sin c_0 = \overline{LT}/\sin(a_0 + b_0)\,,$$

from which

$$\frac{\sin(a_0 + b_0)}{\sin(e_0 + f_0)}\ \frac{\sin(c_0 + d_0)}{\sin(g_0 + h_0)} \cdot \frac{\sin f_0}{\sin b_0}\ \frac{\sin g_0}{\sin c_0} = 1 \quad \ldots\ldots \qquad (i)$$

Similarly,

$$\overline{AB}/\sin(c_0 + d_0) = \overline{AT}/\sin e_0\,; \qquad \overline{AT}/\sin h_0 = \overline{LT}/\sin(a_0 + b_0)\,;$$

$$\overline{AB}/\sin(h_0 + g_0) = \overline{BL}/\sin a_0\,; \qquad \overline{BL}/\sin d_0 = \overline{LT}/\sin(e_0 + f_0)\,,$$

from which

$$\frac{\sin(a_0+b_0)\quad \sin(g_0+h_0)}{\sin(c_0+d_0)\quad \sin(e_0+f_0)} \cdot \frac{\sin d_0 \quad \sin e_0}{\sin a_0 \quad \sin h_0} = 1 \quad \ldots\ldots\ldots\ldots \quad \text{(ii)}$$

Finally, from Eqs. (i) and (ii)

$$\frac{\sin^2(g_0+h_0)\ \sin b_0\ \sin c_0\ \sin d_0\ \sin e_0}{\sin^2(c_0+d_0)\ \sin a_0\ \sin f_0\ \sin g_0\ \sin h_0} = 1 \quad \ldots\ldots\ldots\ldots \quad (7)$$

ii) Computation of Adjustment Values, or Probable Errors

a) Observation Equations

When the observed values are denoted by $a_1, b_1, \ldots$, and the adjustment values or probable errors by $v_a, v_b, \ldots$,

$$\left.\begin{array}{llll} a_0 = a_1 + v_a\ ; & b_0 = b_1 + v_b\ ; & c_0 = c_1 + v_c\ ; & d_0 = d_1 + v_d\ ; \\ e_0 = e_1 + v_e\ ; & f_0 = f_1 + v_f\ ; & g_0 = g_1 + v_g\ ; & h_0 = h_1 + v_h\ ; \\ i_0 = i_1 + v_i\ ; & j_0 = j_1 + v_j\ ; & k_0 = k_1 + v_k\ ; & \ell_0 = \ell_1 + v_\ell \end{array}\right\} \ldots\ldots \quad (8)$$

b) Condition Equations

Substitution of Eq. 8 into the four station equations of Eq. 5 will yield

$$\varphi_1 \equiv v_a + v_b - v_i + w_1 = 0, \quad \text{where } w_1 = a_1 + b_1 - i_1 \quad \ldots\ldots \quad (9.1)$$

$$\varphi_2 \equiv v_c + v_d - v_j + w_2 = 0, \quad \text{where } w_2 = c_1 + d_1 - j_1 \quad \ldots\ldots \quad (9.2)$$

$$\varphi_3 \equiv v_e + v_f - v_k + w_3 = 0, \quad \text{where } w_3 = e_1 + f_1 - k_1 \quad \ldots\ldots \quad (9.3)$$

$$\varphi_4 \equiv v_g + v_h - v_\ell + w_4 = 0, \quad \text{where } w_4 = g_1 + h_1 - \ell_1 \quad \ldots\ldots \quad (9.4)$$

Similarly, from the three angle equations of Eq. 6,

$$\varphi_5 \equiv v_a + v_b + v_c + v_d + v_e + v_f + v_g + v_h + w_5 = 0 \quad \ldots\ldots \quad (9.5)$$

$$\text{where } w_5 = a_1 + b_1 + c_1 + d_1 + e_1 + f_1 + g_1 + h_1 - 360^\circ$$

$$\varphi_6 \equiv v_a + v_h - v_d - v_e + w_6 = 0, \quad \text{where } w_6 = a_1 + h_1 - d_1 - e_1 \quad \ldots\ldots \quad (9.6)$$

$$\varphi_7 \equiv v_b + v_c - v_g - v_f + w_7 = 0, \quad \text{where } w_7 = b_1 + c_1 - g_1 - f_1 \quad \ldots\ldots \quad (9.7)$$

Expressing the side equation, Eq. 7, in terms of the probable errors requires some mathematical operations. When logarithms of both sides of the equation are taken,

$$2 \log \sin(g_0 + h_0) - 2 \log \sin(c_0 + d_0) + \log \sin b_0$$

$$+ \log \sin c_0 + \log \sin d_0 + \log \sin e_0 - \log \sin a_0 - \log \sin f_0 - \log \sin g_0$$

$$- \log \sin h_0 = 0 \quad \ldots\ldots\ldots\ldots \quad \text{(iii)}$$

The logarithmic sine, log sin a_0 that equals log sin $(a_1 + v_a)$, can be expressed, by the Taylor's theorem, in the following form, as v_a is very small as compared with a_1:

$$\log \sin a_0 = \log \sin(a_1 + v_a) = \log \sin a_1 + d_a v_a \quad \ldots\ldots\ldots\ldots \quad \text{(iv)}$$

in which $d_a = 21.055\ (10)^{-7} \cot a_1$. This equation holds for angles other than a_0. Then, after some computation, the following equation can be derived from Eq. (iii).

$$\varphi_8 \equiv d_{gh}(v_g + v_h) - d_{cd}(v_c + v_d) + d_b v_b + d_c v_c + d_d v_d + d_e v_e$$
$$- d_a v_a - d_f v_f - d_g v_g - d_h v_h + w_8 = 0 \quad \ldots\ldots\ldots\ldots \quad (9.8)$$

in which
$$w_8 = 2 \log \sin (g_1 + h_1) - 2 \log \sin (c_1 + d_1) + \log \sin b_1$$
$$+ \log \sin c_1 + \log \sin d_1 + \log \sin e_1 - \log \sin a_1$$
$$- \log \sin f_1 - \log \sin g_1 - \log \sin h_1$$

c) Correlate Equations

When the theorem of least square is followed, the most probable values of adjustment angles, or probable errors, can be determined from the condition that a function Ω as defined by the following Eq. 10 shall become minimum.

$$\Omega = [vv] - 2(\lambda_1\varphi_1 + \lambda_2\varphi_2 + \ldots + \lambda_8\varphi_8) \quad \ldots\ldots\ldots\ldots \quad (10)$$

in which [vv] denotes the sum of the squares of probable errors and $\lambda_1 \lambda_2, \ldots, \lambda_8$ are coefficients to be determined so that Ω becomes minimum.

Therefore, if the expressions of φ given in Eq. 9 are substituted in Eq. 10 and then partial derivatives of Ω with respect to v_a, v_b ,..., v_i are put equal to zero, following equations will be obtained.

$$\left.\begin{aligned}
v_a &= \lambda_1 + \lambda_5 + \lambda_6 - \lambda_8 d_a ; \\
v_b &= \lambda_1 + \lambda_5 + \lambda_7 + \lambda_8 d_b ; \\
v_c &= \lambda_2 + \lambda_5 + \lambda_7 - \lambda_8 (d_{cd} - d_c) ; \\
v_d &= \lambda_2 + \lambda_5 - \lambda_6 - \lambda_8 (d_{cd} - d_d) ; \\
v_e &= \lambda_3 + \lambda_5 - \lambda_6 + \lambda_8 d_e ; \\
v_f &= \lambda_3 + \lambda_5 - \lambda_7 - \lambda_8 d_f ; \\
v_g &= \lambda_4 + \lambda_5 - \lambda_7 + \lambda_8 (d_{gh} - d_g) ; \\
v_h &= \lambda_4 + \lambda_5 + \lambda_6 + \lambda_8 (d_{gh} - d_h) ; \\
v_i &= -\lambda_1 ; \quad v_j = -\lambda_2 ; \quad v_k = -\lambda_3 ; \quad v_\ell = -\lambda_4
\end{aligned}\right\} \ldots\ldots\ldots \quad (11)$$

Substitution of v_a, v_b ..., v_ℓ of Eq. 11 into Eqs. 9.1 to 9.8 will yield eight equations with respect to eight indeterminate coefficients, λ_1 ' λ_2, ..., λ_8, that can be determined by simultaneous solution of these equations. Once these coefficients are known, probable errors can be computed by Eq. 11, and the most probable values of angles by Eq. 8.

(3) Most Probable Length of $\overline{LT}$

The length $\overline{LT}$ on the bridge center line can geometrically be expressed by the following equation, based on the base line $\overline{AB}$.

$$\overline{LT} = \frac{\sin(a_0 + b_0)}{\sin(g_0 + h_0)} \frac{\sin f_0}{\sin c_0} \overline{AB} \quad \text{.......................} \quad (12)$$

The most probable length of $\overline{AB}$ is 200.0393 meters, as noted in (1). Therefore, if the most probable values of angles a_0, b_0, c_0, f_0, g_0 and h_0 will be determined from the computation described in (2), the most probable length of $\overline{LT}$ can be computed from Eq. 12.

In the present study, all computations were made by an electronic computer and $\overline{LT}$ was computed as 641.722 meters.

RESULTS OF LEVELING (1)

ROUTE: Vientiane to Nong Khai bridge site

Unit: m

T. P. No.	DISTANCE	DIFFERENCE OF ELEVATION 1	2	MEAN	ADJUST	ADJUSTED DIFFERENCE	ELEVATION	REMARKS
V.636							170.105	Authorized
TPN-1		+0.084	+0.087	+0.085			170.190	
N-2		+0.751	+0.755	+0.753			170.943	
N-3		+0.558	+0.556	+0.557			171.500	
N-4		-0.855	-0.862	-0.859			170.641	Wat Sop
N-5		+0.230	+0.240	+0.235			170.876	
N-6		+0.088	+0.105	+0.096			170.972	GOV. B.M. 8-S40
N-7		+1.903	+1.902	+1.903			172.875	
N-8		+3.273	+3.272	+3.272			176.147	
N-9		-1.563	-1.565	-1.564			174.583	
N-10		-0.230	-0.235	-0.233			174.350	
N-11		-1.546	-1.549	-1.547			172.803	
N-12		-3.465	-3.464	-3.465			169.338	N.K.K. B.M.43
N-13		-1.770	-1.760	-1.765			167.573	
N-14		+0.309	+0.309	+0.309			167.882	
N-15		-0.446	-0.450	-0.448			167.434	
N-16		-0.088	-0.097	-0.092			167.342	
N-17		+0.080	+0.081	+0.081			167.423	
N-18		+0.235	+0.229	+0.232			167.655	
N-19		+0.402	+0.409	+0.405			168.060	N.E.A. B.M.
BMN-6		+0.164	+0.164	+0.164			168.224	Laotian side
TPT-1		-12.172	-12.171	-12.171			156.053	
T-2		-0.653	-0.645	-0.649			155.404	
T-3		+0.277	+0.277	+0.277			155.681	
T-4		+10.180	+10.181	+10.180			165.861	N.E.A. B.M.
BMN-7		+0.713	+0.713	+0.713			166.574	Thai side
BMN-6							168.224	
BMN-8		-0.008	-0.010	-0.009			168.215	

RESULTS OF LEVELING (2)

Elevation of the bench-marks set on the leveling route

Unit: m

T. P. No.	DISTANCE	DIFFERENCE OF ELEVATION 1	2	MEAN	ADJUST	ADJUSTED DIFFERENCE	ELEVATION	REMARKS
TPN-3		–	–	–			171.500	
BMN-1		+2.878	+2.888	+2.883			174.383	
BMN-2		–	–	–			170.972	TPN-6
TPN-10		–	–	–			174.350	
BMN-3		+0.088	+0.087	+0.087			174.437	
TPN-13		–	–	–			167.573	
BMN-4		+0.218	+0.214	+0.216			167.789	
TPN-18		–	–	–			167.655	
BMN-5		-0.190	-0.191	-0.190			167.465	
Checking midway on the leveling: –								
TPN-4		–	–	–			170.641	
Zero point of staff gage in the Wat Sop G.S.		-12.643	–	-12.643			157.998	

Remarks:

1) This leveling was of single-run.
2) Since the elevation of the zero point of staff gage in the Wat Sop gaging station is EL.158.040 above the mean sea level at Ko Lak datum, the difference of the elevations is 4.2 centimeters.

RESULTS OF LEVELING (3)

Route: River crossing

Unit: m

T. P. No.	DISTANCE	DIFFERENCE OF ELEVATION 1	2	MEAN	ADJUST	ADJUSTED DIFFERENCE	ELEVATION	REMARKS
B.M.I.							167.764	Authorized
TP-1		-1.929	-1.929	-1.929			165.835	
TP-2		+1.865	+1.862	+1.864			167.699	
B.M.II		-1.665	-1.668	-1.667			166.032	Authorized
G.S.I.		+0.167	+0.167	+0.167			166.199	Authorized
B.M.I							167.764	Authorized
G.S.II		-0.953	-0.951	-0.952			166.812	Authorized

1) This leveling was carried out in order to check the elevation of the authorized bench-marks and the zero point of the gage staff.

2) The abbreviations quoted above are explained as follows.

B.M.I	:	Bench-mark in the site of Governers' Office (P-396)
B.M.II	:	Bench-mark in the site of Hydrographic Office
G.S.I	:	12-meter point above zero point of the staff gage of the gaging station in the site of Hydrographic Office
G.S.II	:	13-meter point above zero point of the staff gage in the RID's gaging station

3) Since the elevation of the zero point of staff gage in the RID's gaging station is El.153.000 above the mean sea level at Ko Lak datum, the difference of the elevation is 0.812 meters.

RESULTS OF LEVELING (4)

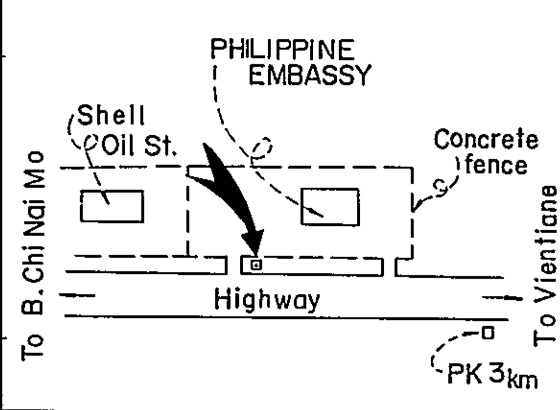
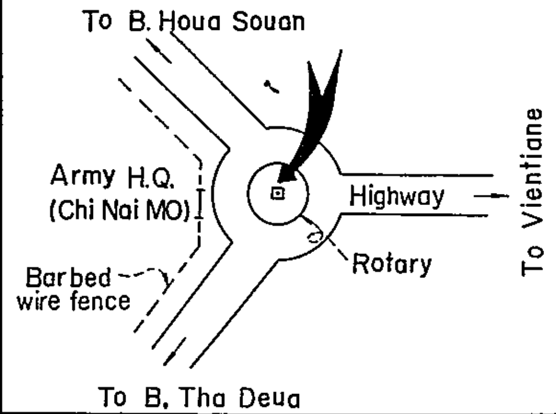
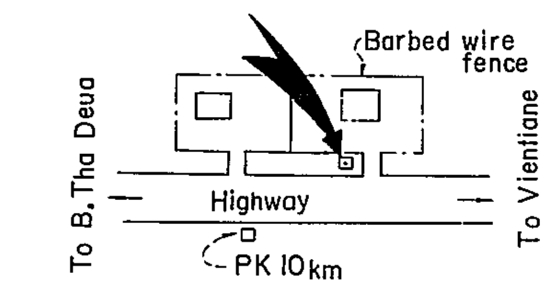
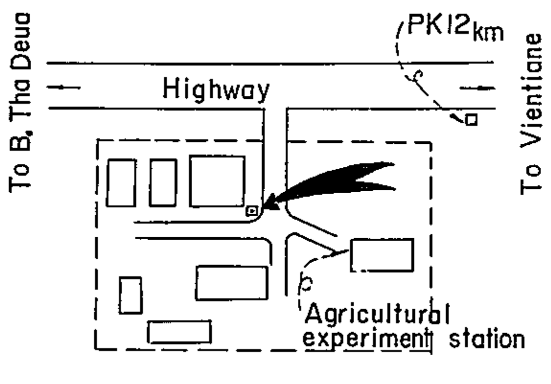
Leveling route: Vientiane to proposed sites of Vientiane railway station

Unit: m

T. P. No.	DISTANCE	DIFFERENCE OF ELEVATION 1	2	MEAN	ADJUST	ADJUSTED DIFFERENCE	ELEVATION	REMARKS
V.636							170.105	Authorized
TPT-1		+2.653	+2.663	+2.658			172.763	
T-2		-2.945	-2.953	-2.949			169.814	
3		-0.675	-0.679	-0.677			169.137	
4		-3.300	-3.302	-3.301			165.836	
BMT-1		+0.096	+0.096	+0.096			165.932	Route C
T-5		+0.662	+0.669	+0.665			166.597	
T-6		-0.185	-0.182	-0.183			166.414	
BMT-2		-0.469	-0.458	-0.463			165.951	Route C/D

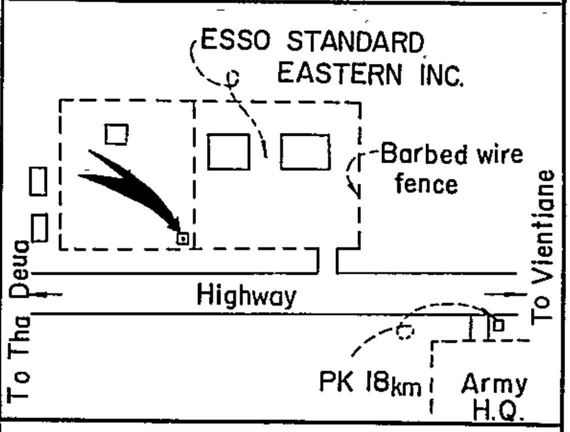
Remarks: This leveling was carried out on the routes from the Bench-mark V 636 set in the Vientiane city to the Bench-marks T-1 of the route C and T-2 of the route C/D provided near the two sites for the proposed Vientiane railway station.

Location of Bench-Marks (1)

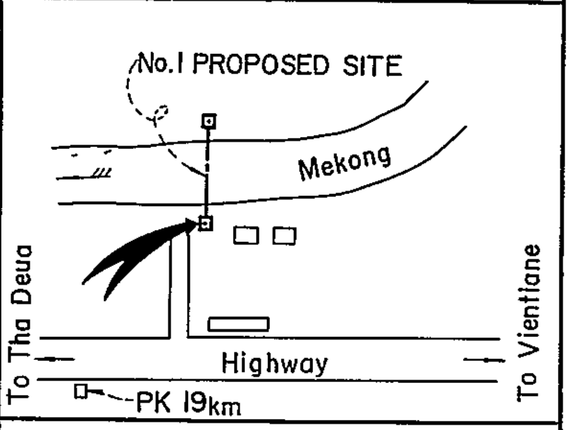
B.M. No.	DESCRIPTIONS		SKETCH
N-1	ELEVATION	174.383	
	LOCATION	Ban Wat Sop	
	ESTABLISHED ON	26 Sep. 1967	
	CARVED ELEVATION		
	Concrete precast post		
N-2	ELEVATION	170.972	
	LOCATION	Ban Chi Nai Mo	
	ESTABLISHED ON	26 Sep. 1967	
	CARVED ELEVATION		
	Concrete precast post		
N-3	ELEVATION	174.437	
	LOCATION	Ban 10 Km	
	ESTABLISHED ON	28 Sep. 1967	
	CARVED ELEVATION		
	Concrete precast post		
N-4	ELEVATION	167.789	
	LOCATION	Ban Na Hai	
	ESTABLISHED ON	28 Sep. 1967	
	CARVED ELEVATION		
	Concrete precast post		

Location of Bench-Marks (2)

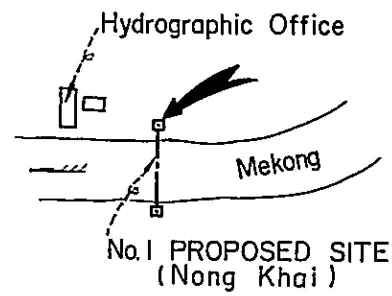
B. M. No.	DESCRIPTIONS		SKETCH
N-5	ELEVATION	167.465	see sketch below
	LOCATION	Ban Tha Naleng	
	ESTABLISHED ON	28 Sep. 1967	
	CARVED ELEVATION		
	Concrete precast post		



B. M. No.	DESCRIPTIONS		SKETCH
N-6	ELEVATION	168.224	see sketch below
	LOCATION	Ban Tha Naleng (No. 1 proposed site)	
	ESTABLISHED ON	28 Sep. 1967	
	CARVED ELEVATION		
	Concrete precast post		

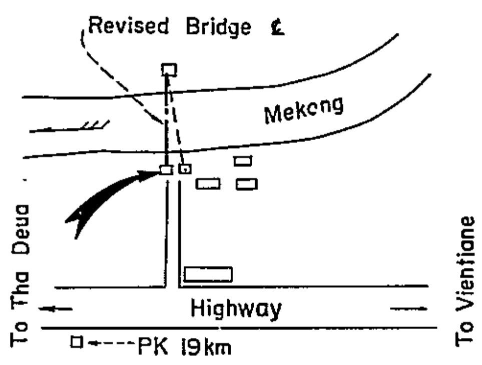
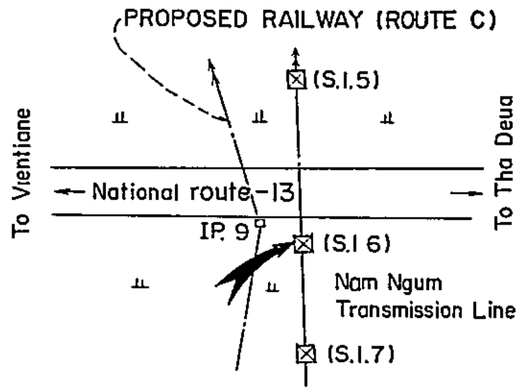
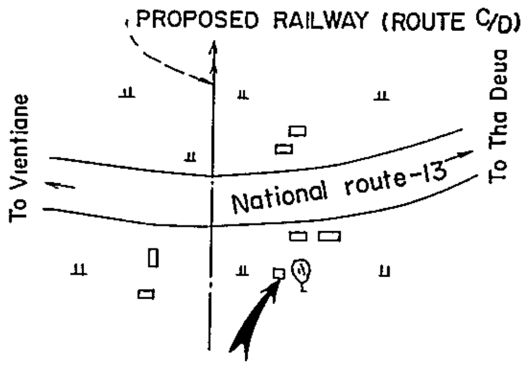


B. M. No.	DESCRIPTIONS		SKETCH
N-7	ELEVATION	166.574	see sketch below
	LOCATION	Wat Chommane (No.1 proposed site)	
	ESTABLISHED ON	9 Mar. 1968	
	CARVED ELEVATION		
	Concrete precast post		



B. M. No.	DESCRIPTIONS		SKETCH
	ELEVATION		
	LOCATION		
	ESTABLISHED ON		
	CARVED ELEVATION		

Location of Bench-Marks (3)

B. M. No.	DESCRIPTIONS		SKETCH
N-8	ELEVATION	168.215	
	LOCATION	Ban Tha Naleng	
	ESTABLISHED ON	23 Dec. 1968	
	CARVED ELEVATION		
	Concrete precast post		
T-1	ELEVATION	165.932	
	LOCATION	Ban Phon Keng	
	ESTABLISHED ON	14 Dec. 1968	
	CARVED ELEVATION		
	Concrete precast post		
T-2	ELEVATION	165.951	
	LOCATION	Ban Pha Khao	
	ESTABLISHED ON	14 Dec. 1968	
	CARVED ELEVATION		
	Concrete precast post		
	ELEVATION		
	LOCATION		
	ESTABLISHED ON		
	CARVED ELEVATION		

HARZA ENGINEERING COMPANY INTERNATIONAL
BANGKOK, THAILAND
MONUMENT RECORD

MONUMENT RECORD — FORM 5003 HAUGHTON

PROJECT Mekong River Survey COUNTRY Thailand DATE 1959/60

MONUMENT P-396 TYPE R.T.S. HOR. ORDER ______ VERT. ORDER 1st

SPHEROID ______ DATUM ______ ELEVATION DATUM M.S.L. KO LAK

LATITUDE ______ LONGITUDE ______ ELEVATION + 167.7639

UTM ZONE ______ NORTHING ______ EASTING ______

UTM ZONE ______ NORTHING ______ EASTING ______

AZIMUTH TO ______ GEODETIC ______ GRID ______

AZIMUTH TO ______ GEODETIC ______ GRID ______

LINE DIAGRAM 3 COMP. FILE E MAP SHEET 197/254

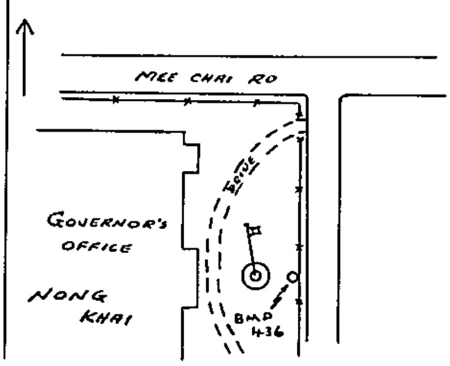
PHOTO IDENTIFICATION: LINE NO. M 59 SW ROLL NO. 1 EXPOSURE NO. 13

DESCRIPTION: Recovered Existing RTS Monument

Mark is a brass peg buried in a square concrete monument located in front of the Governors Office in NongKhai.

Published Elevation

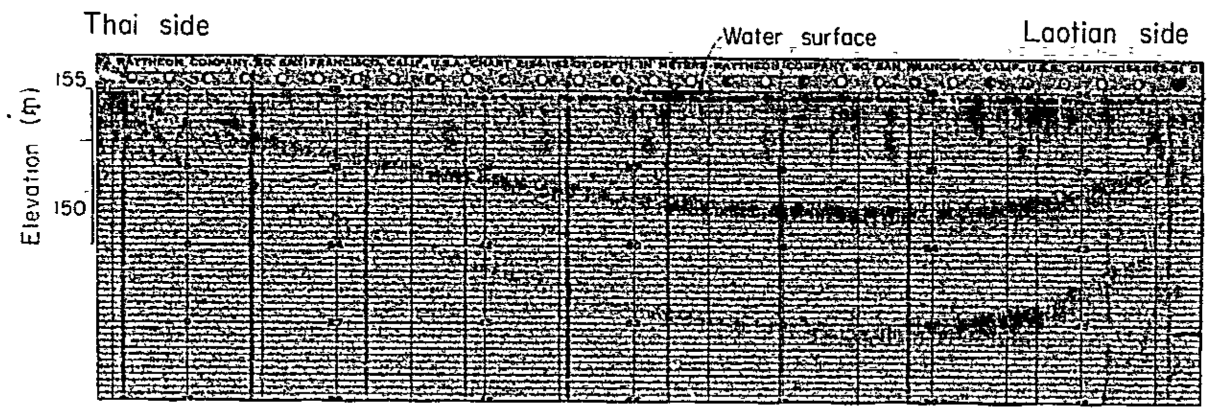
SKETCH:



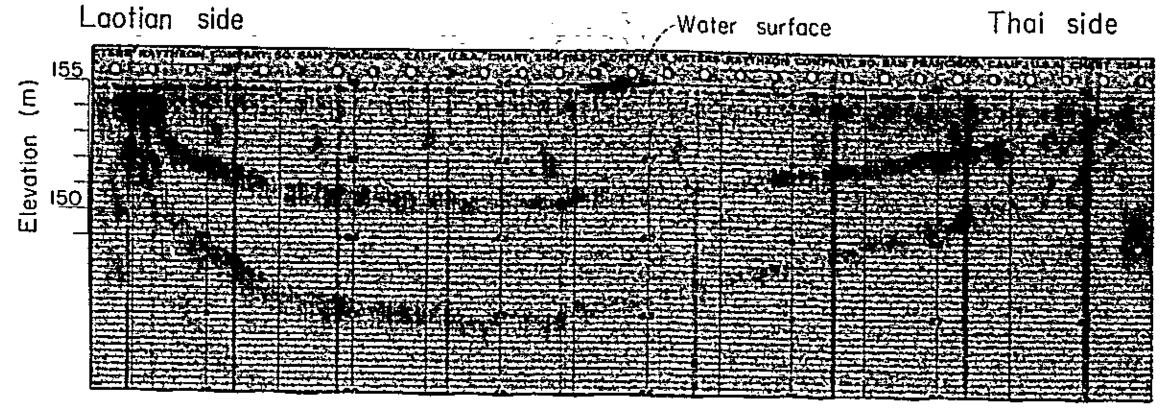
Surveys financed by the GOVERNMENT OF CANADA under the COLOMBO PLAN and the UNITED STATES OF AMERICA under the INTERNATIONAL COOPERATION ADMINISTRATION.

Canadian contractor - Hunting Survey Corp. Ltd., Toronto
U. S. A. contractor - Harza Engineering Company, Chicago

ECHO - SOUNDING RECORDS OF NONG KHAI SITE (I)



COURSE - A



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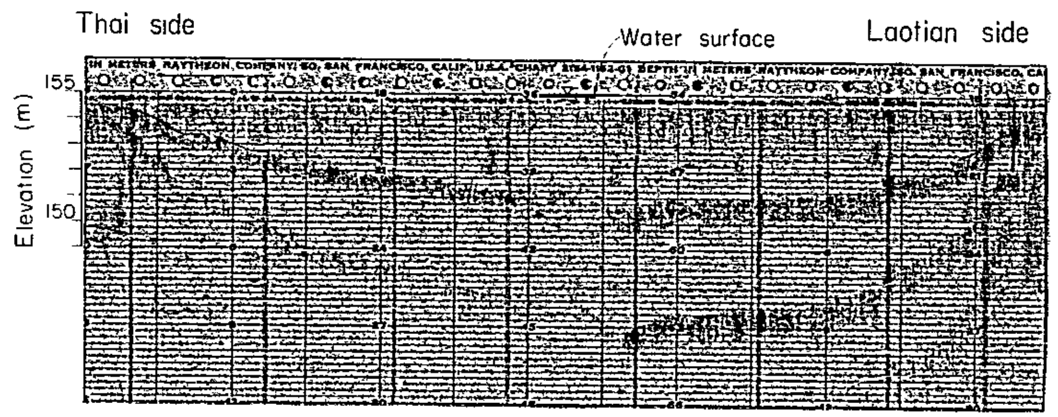

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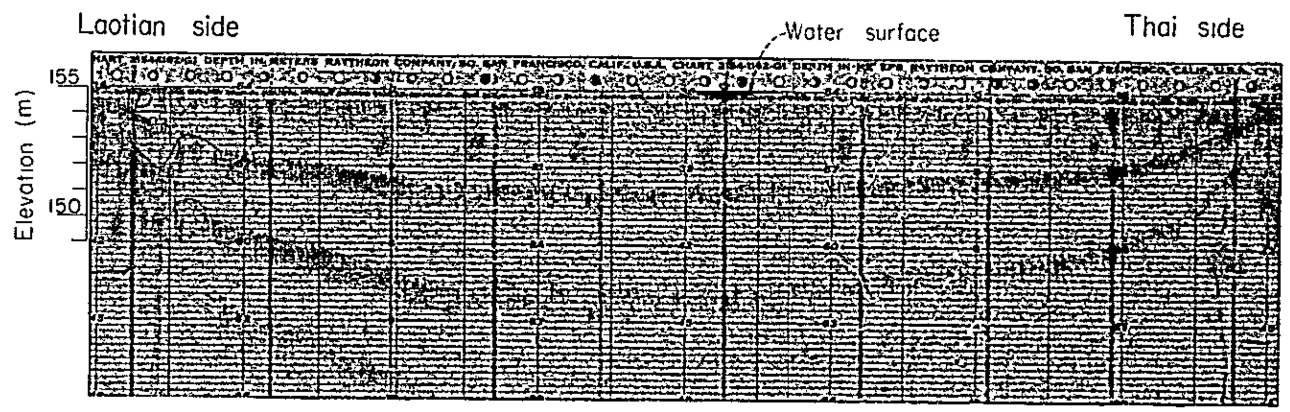

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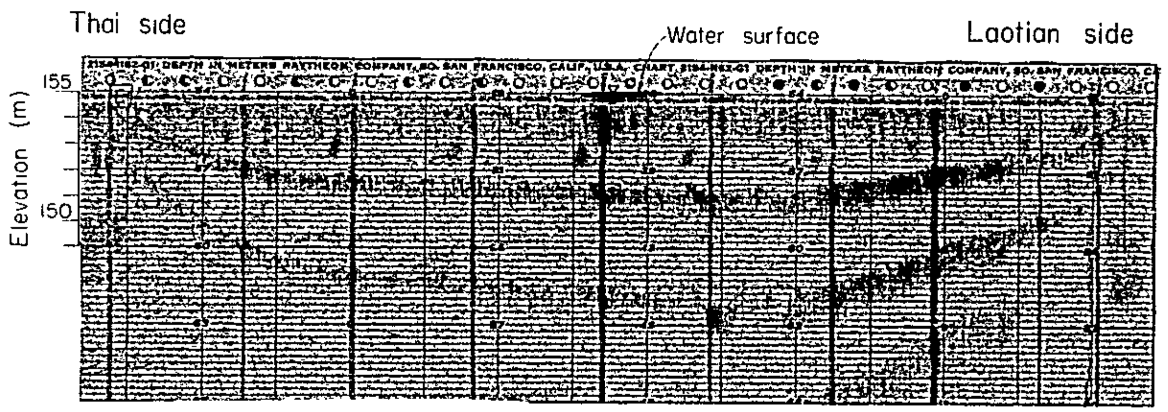
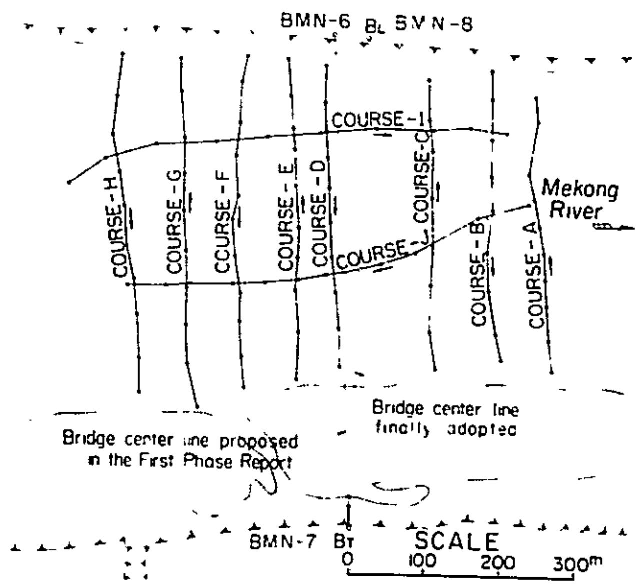


COURSE - E

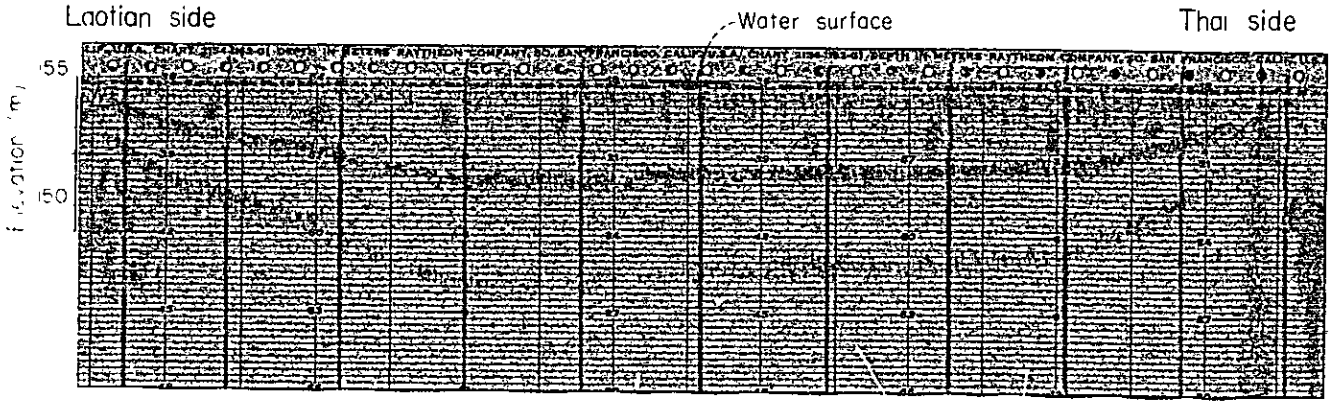
Remarks :

1) These records were taken on April 5 1968 in the second phase investigation
2) Water surface on April 5,1968, EL 155.0^{m}

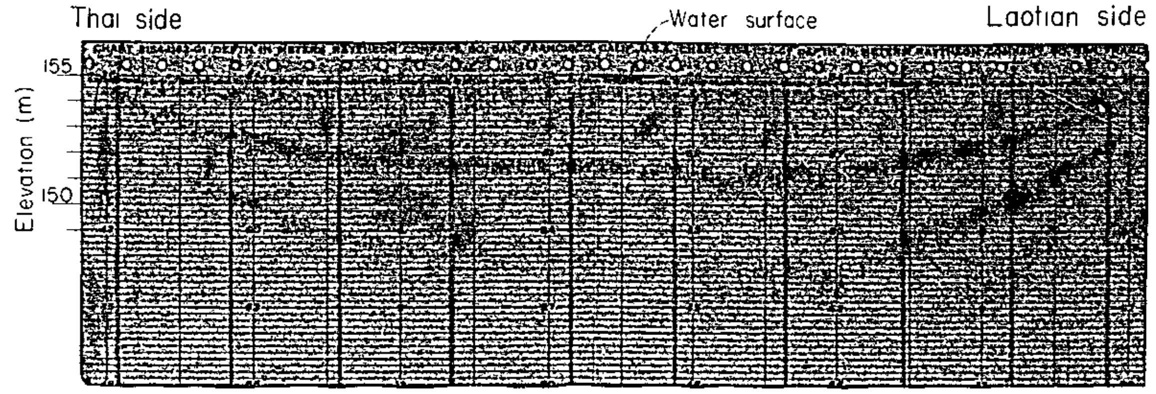


ECHO - SOUNDING RECORDS OF NONG KHAI SITE (2)

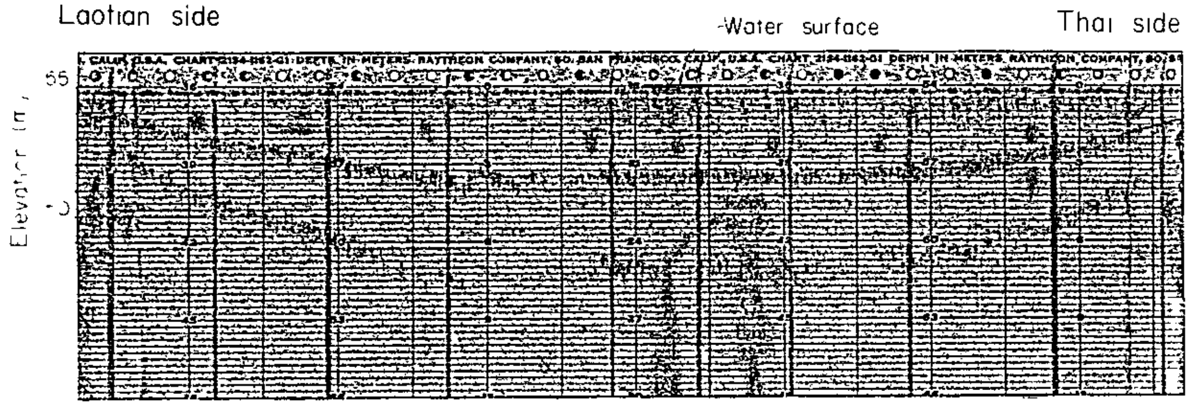
Data 1.4.



COURSE - F



COURSE - G



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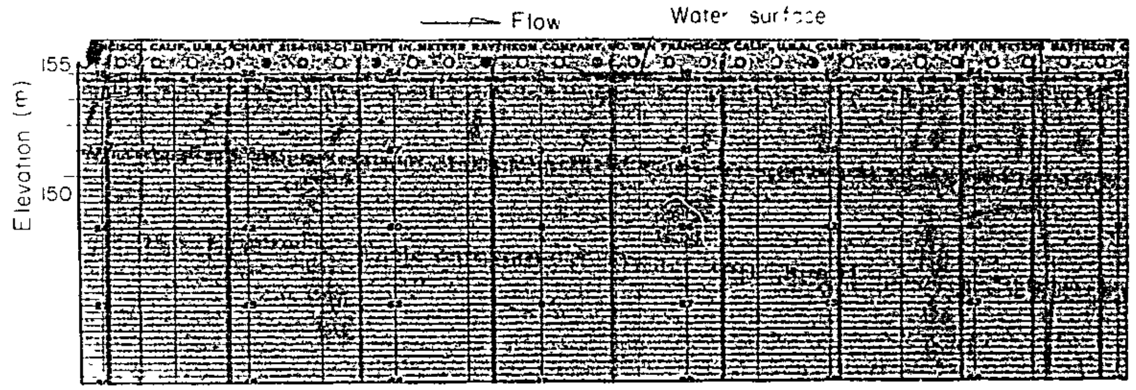
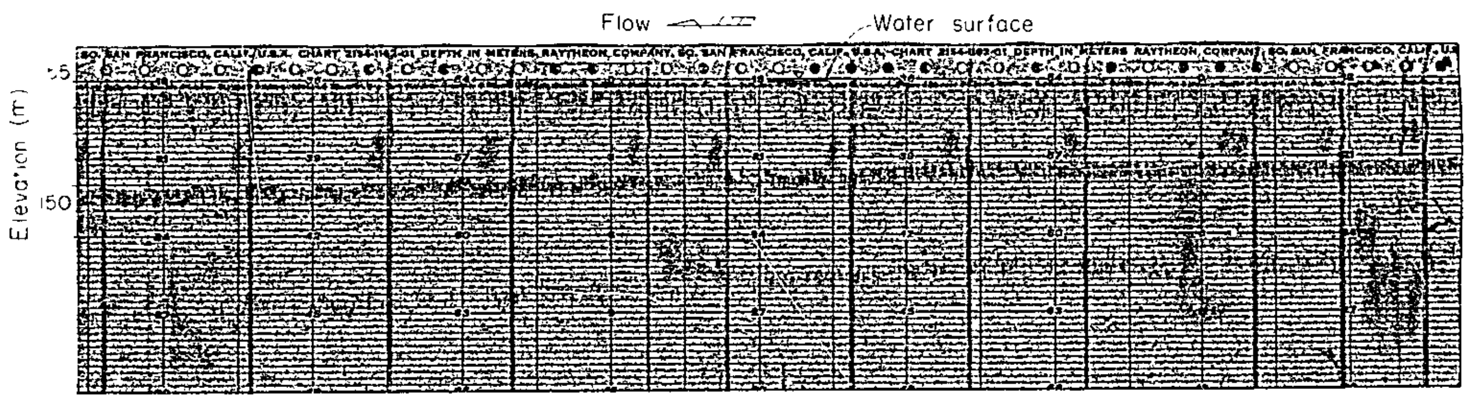


COURSE - I



COURSE - J

Remarks

1) These records were taken on April 5 1968 in the second phase investigation

2) Water surface on April 5 1968 EL 155.0m

CHAPTER II

SOIL SURVEY

2.1. General

In studying the feasibility of the present project, it was indispensable to know the location of bedrock under the Mekong's bottom on which the bridge piers shall be founded as well as to study the characteristics of the ground soil on which the projected highway and railway shall be built.

To survey the bedrock location, test drillings were made into the river-bed and into the grounds on both sides of the river. The ground soil was studied by making reconnaissance along the projected highway and railway routes and by test pits dug at several places. Furthermore, a test drilling was executed at the northern end of the That Luong marsh, where the rail line would pass if it should be located on Route C.

In January 1968, the Mekong Committee finally selected the Nong Khai site for bridge construction. Accordingly, the soil surveys carried out since then were confined to this site.

2.2. Test Drilling

When informed of the Mekong Committee's choice of the Nong Khai site, the Japanese Government immediately dispatched a team of soil-survey experts to the site so as not to miss the then prevailing dry season, because in the rainy season the Mekong flows high and rapid and test drilling through water will be all but impossible.

The drilling was started in mid-February 1968 and was finished in June 1968, just before the onset of the rainy season. Drillings were executed in numerical order as shown in Fig.2.1 and Table 2.1, starting from No.1 hole on the Laotian side located on the bridge center line proposed in the First-Phase Report. The No.1 hole was aimed at grasping the general aspect of the geological formation of the bridge site prior to the execution of the river-bed drilling.

Although the choice had been made of the Nong Khai site, the actual location of the bridge center line was undecided when the second-phase investigation was started. Therefore, at the beginning of the second-phase investigation, the bridge team made a field study on the location of the bridge center line and it was concluded that there can be found on the Thai side no appropriate place except a site between the Hydrographic Office and a small stream that joins the Mekong about 400 meters upstream from the office. In the light of this conclusion, the bridge center line proposed in the First-Phase Report was just right insofar as the location on the Thai side is concerned.

It is desirable to have a comprehensive knowledge of the geological features of the area around the bridge route. Therefore, drillings were executed not only along the bridge center line as proposed in the First-Phase Report but also along three lines located parallel to the center line as shown in Fig.2.1. In total, 19 holes were drilled into the rivber-bed, totaling about 290 meters in length.

On the riverside terrains, three holes each were drilled on the Thai and Laotian sides on the bridge center line. In addition, two holes were drilled at a site on the Thai side where the projected highway will cross the existing railway[1] and one hole on the Laotian side at the northern end of the That Luong marsh where Route C of the projected railway is located. Holes drilled on land number nine, with a total length of 244 meters.

Thus, holes drilled total 28 in number and 534 meters in length. The results are shown hole by hole in "Geological Records" presented in this report. The geological profile along the bridge center line proposed in the First-Phase Report is given in Fig.2.2. This center line, when surveyed during the second-phase investigation, was found not to lie at right angles to the river course. In the Second-Phase Report, therefore, the bridge center line was corrected to fall at right angles to the river course as shown in Fig.2.3. Judged from Fig.2.3 that shows the contour lines of the bedrock surface around the bridge site, it can be said that there will be no conspicuous difference in the geological formation between the original and corrected bridge center lines.

The following are the gists of the geological features of the bridge site as judged from the test drilling.

On both sides of the river, surface soil, loam, sand, gravel and weathered siltstone, lying in this order from the ground surface, overlie bedrock of firm siltstone. The bedrock surface is assumed to lie on the Laotian side 15 to 20 meters deep from the ground surface at an elevation of 149 to 153 meters above mean sea level, and on the Thai side about 20 meters deep from the ground at an elevation of about 144 meters.

The alluvial river-bed that covers the bedrock consists of sand and gravel 3 to 5 meters thick on the Laotian side and of fine sand 7 to 13 meters thick on the Thai side, underlain throughout by a thin layer of weathered siltstone.

The bedrock consists of Jurassic reddish siltstone with thin shale layers intercalated that extends over a vast tract on both sides of the river. The bridge piers are planned to be founded on this bedrock by excavating it about two meters from its surface to guard against an eventual scouring of the river-bed. The bedrock lying under the river-bed has a compressive strength of about 170 kg/cm^2 as shown in Data 2.8.

2.3. Soil Tests

In order to know soil-engineering properties of the subsoil on the riverside terrains, in total twelve undisturbed samples were taken from No.21, No.22, No.24, No.25, No.26 and No.27 holes, as shown in Table 2.2.[2] The samples were almost obtained from alluvial deposits and sent to Japan, where they were tested on various properties as shown in Table 2.4. The test results are shown in Table 2.4 and other tables and graphs presented in this paragraph.

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[1]: A highway overbridge will be built, if the railway would not be extended into Laos. In the rail/highway-bridge project, the crossing will first be made by level crossing and later by grade separation when traffic would increase.

[2]: No samples could be taken in undisturbed condition from the river-bed layers of silt, sand and gravel because of their looseness.

Table 2.1. Features of Test Drilling Holes

	Hole No.	Depth (m)	Elevation of ground surface or river-bed (m)	Hole diameter (mm)	Number of penetration tests	Operation period (year: 1968)
Drilling on riverside terrains	1	24.00	168.33	65 – 56	18	Feb.23–Mar. 1
	21	22.00	166.59	65 – 56	13	Apr.29–May 5
	22	44.30	Unobserved	65 – 56	43	Apr.27–May 28
	23	23.40	163.81	65 – 56	14	May 6–May 11
	24	26.00	165.80	65 – 56	13	May 12–May 16
	25	25.00	164.71	85 – 65	11	May 18–May 26
	26	35.00	165.41	85 – 65	23	May 27–Jun. 7
	27	23.00	168.17	65 – 56	15	May 30–Jun. 4
	28	21.30	167.90	65 – 56	14	Jun. 5–Jun. 8
	Total	244.00			164	
Drilling into river-bed.	2	16.60	155.73	65 – 56	11	Feb.28–Mar. 2
	3	17.15	155.73	65 – 56	7	Mar. 5–Mar. 7
	4	13.00	151.92	65 – 56	3	Mar. 2–Mar. 8
	5	13.00	150.96	65 – 56	4	Mar. 9–Mar.13
	6	13.60	153.58	65 – 56	6	Mar.11–Mar.16
	7	16.21	149.84	65 – 56	3	Mar.14–Mar.18
	8	13.00	150.73	65 – 56	3	Mar.19–Mar.25
	9	12.80	151.61	65 – 56	4	Mar.21–Mar.23
	10	17.10	151.13	65 – 56	3	Mar.26–Mar.30
	11	12.50	152.16	65 – 56	1	Mar.26–Mar.29
	12	12.00	150.95	65 – 56	1	Mar.30–Apr. 1
	13	7.20	149.82	65 – 56	1	Apr. 2–Apr. 3
	14	13.50	151.35	65 – 56	4	Apr. 2–Apr.10
	15	16.30	156.11	65 – 56	5	Apr. 5–Apr. 9
	16	23.80	155.28	65 – 56	3	Apr.11–Apr.18
	17	15.00	152.36	65 – 56	6	Apr.11–Apr.16
	18	16.00	151.20	65 – 56	1	Apr.16–Apr.23
	19	28.00	155.57	65 – 56	5	Apr.19–Apr.26
	20	13.00	150.93	65 – 56	4	Apr.24–Apr.25
	Total	289.76			75	

Drilling machine: UD – 5
Inclination of hole: Vertical

Table 2.2. Sources of Undisturbed Samples

Bore Hole	Sample	Sampling Depth, In Meters
No. 21	No. 1	5.7 - 6.3
	No. 2	7.4 - 7.8
	No. 3	10.3 - 11.25
No. 22	No. 4	0.7 - 1.35
	No. 5	3.0 - 3.4
No. 24	No. 6	6.2 - 6.93
	No. 7	9.6 - 10.35
No. 25	No. 8	6.5 - 7.25
	No. 9	7.3 - 8.2
No. 26	No. 10	8.0 - 8.75
	No. 11	9.0 - 9.95
No. 27	No. 12	1.0 - 1.7

When classified according to the results of grain size analysis and consistency tests, all samples belonged to loam or clay. The samples of No.21, No.22, No.24 and No.27 holes showed that the layers from which they were taken cannot provide a satisfactory foundation for supporting heavy structures like a bridge.

The samples from No.25 and No.26 holes showed an undesirable characteristic that their compressive strengths are lowered by vibration. This fact was proved by the comparison of the unconfined compressive strengths of the samples with the compressive strengths estimated by Terzaghi's experimental formula based on N-values of penetration test.

The N-value means the number of blow required for a specified penetration. In the course of drilling made through the alluvial layers, penetrations were carried out, following the standard method specified by Japanese Industrial Standards[1], at every one-meter depth for the purpose of estimating the bearing capacity or compressive strength and the resistance to pile driving of the soil.

The observed N-values, compressive strengths, q'_u, estimated by Terzaghi's formula and unconfined compressive strengths, q_u, are shown in Table 2.3. As can be seen from this table, the values of q_u of No.1 to No.6 samples, taken from the riverside on the Thai side, coincide well with the lower limits of q'_u. These samples as well as No.27 sample, taken on the Laotian bank, showed low sensitivity ratios. Therefore, the grounds at both ends of the bridge where these samples were taken can be expected to provide a fairly good foundation. Contrary to the above, the values of q_u of No.8, No.9, No.10 and No.11 samples, taken at a site where the projected highway will cross the existing railway on the Thai side, are far less than the lower limits of q'_u. These samples were found to have high sensitivity ratios, meaning that their compressive strengths will decrease when subjected to

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1: A 63.5-kg hammer is let fall 75 centimeters and the number of blow per 30 centimeters of penetration is recorded as the N-value.

Table 2.3. N-Value and Compressive Strength

Borehole	Sample	N-Value	q'_u kg/cm²	q_u kg/cm²
No. 21	No. 1	12	1 - 2	1.2
	No. 2	11	1 - 2	0.88
	No. 3	13	1 - 2	1.05
No. 22	No. 4	6	0.5 - 1	0.51
	No. 5	6	0.5 - 2	0.47
No. 24	No. 6	11	1 - 2	0.86
	No. 7	12	1 - 2	3.92
No. 25	No. 8	17	2 - 4	0.43
	No. 9	17	2 - 4	0.29
No. 26	No. 10	11	1 - 2	0.50
	No. 11	14	1 - 2	0.56
No. 27	No. 12	1-2	less than 0.25	0.66

Note: q'_u is the compressive strength estimated from N-value, and q_u the unconfined compressive strength.

vibration or by remolding.

When tested in regard to consolidation, the samples listed in Table 2.2, excepting No.4 and No.5 samples taken at the northern end of the That Luong marsh, showed considerably low initial void ratios and preconsolidation loads that can be thought well greater than what will be acting due to actual overburdens. Therefore, foundation subsidence due to consolidation would hardly occur at sites where these samples were taken.

Apart from the above, it can be said from the results of penetration tests that foundation piles of structures to be built on both sides of the river shall be driven through surface layers of loam or clay into sand or gravel layers though some difficulties will arise on account of the compactness of the loam or sand layers.

Fig. 2.1. LOCATION OF TEST DRILLING HOLES

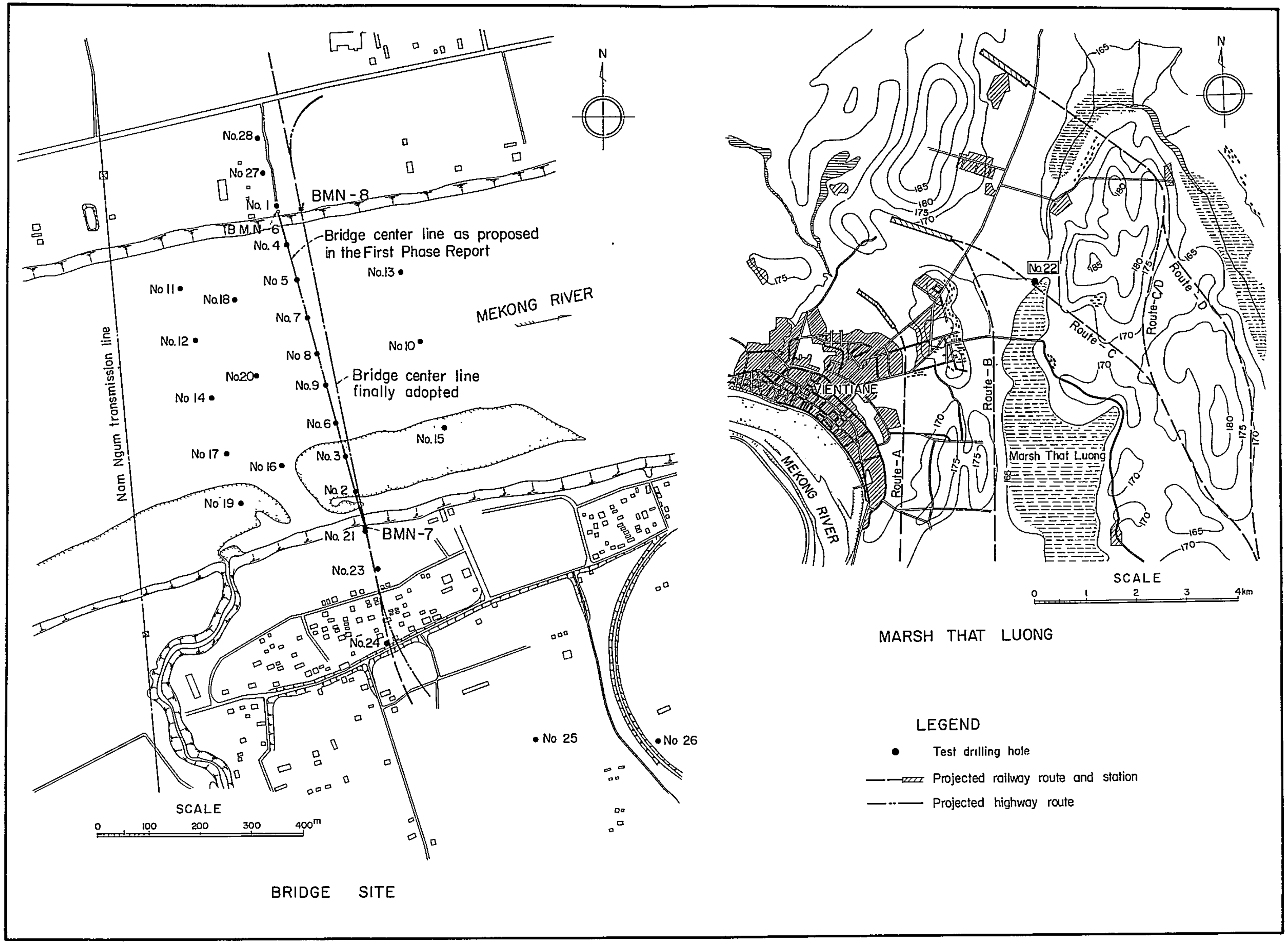


Fig. 2.2 GEOLOGICAL PROFILE OF BRIDGE SITE

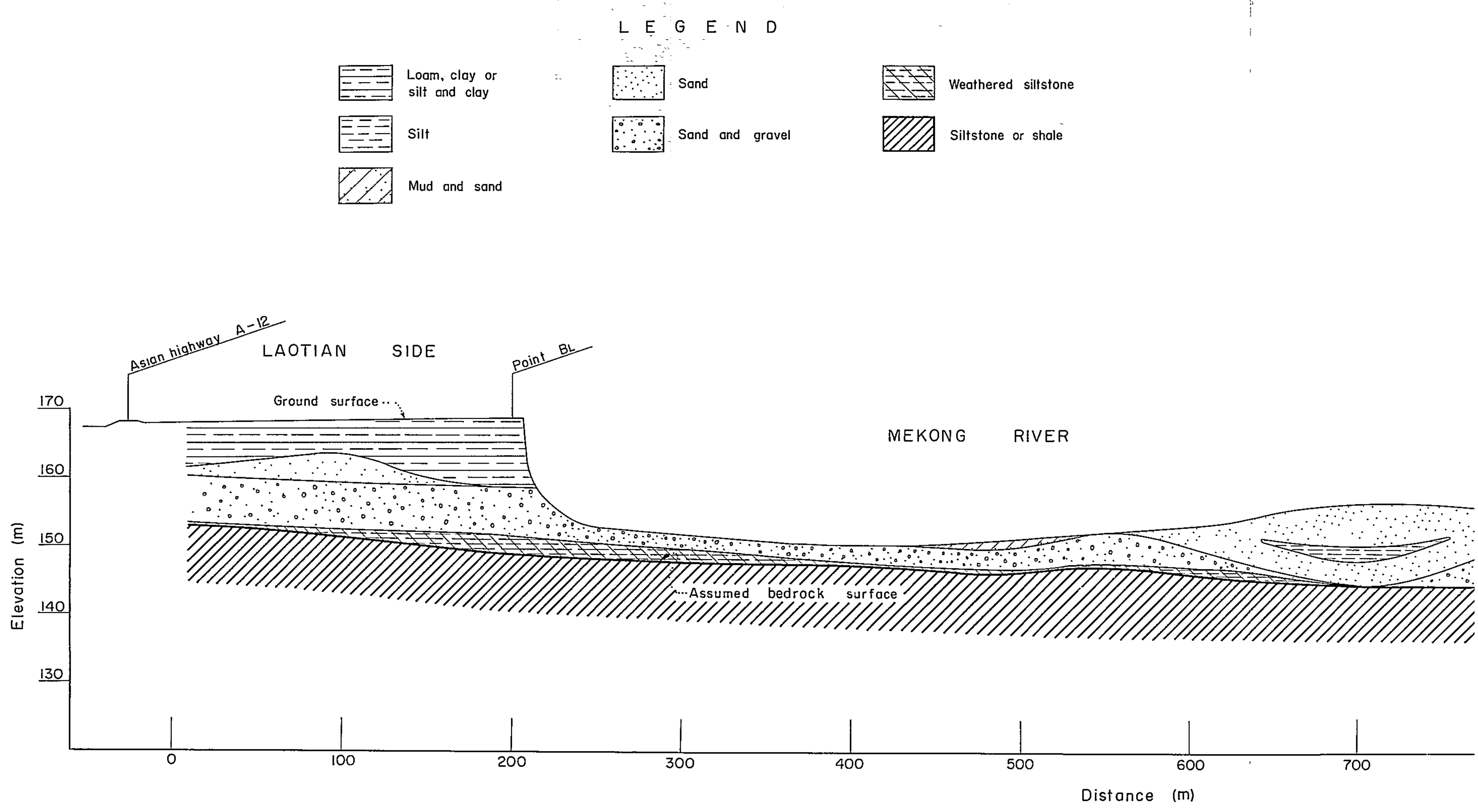


Fig. 2.2 GEOLOGICAL PROFILE OF BRIDGE SITE

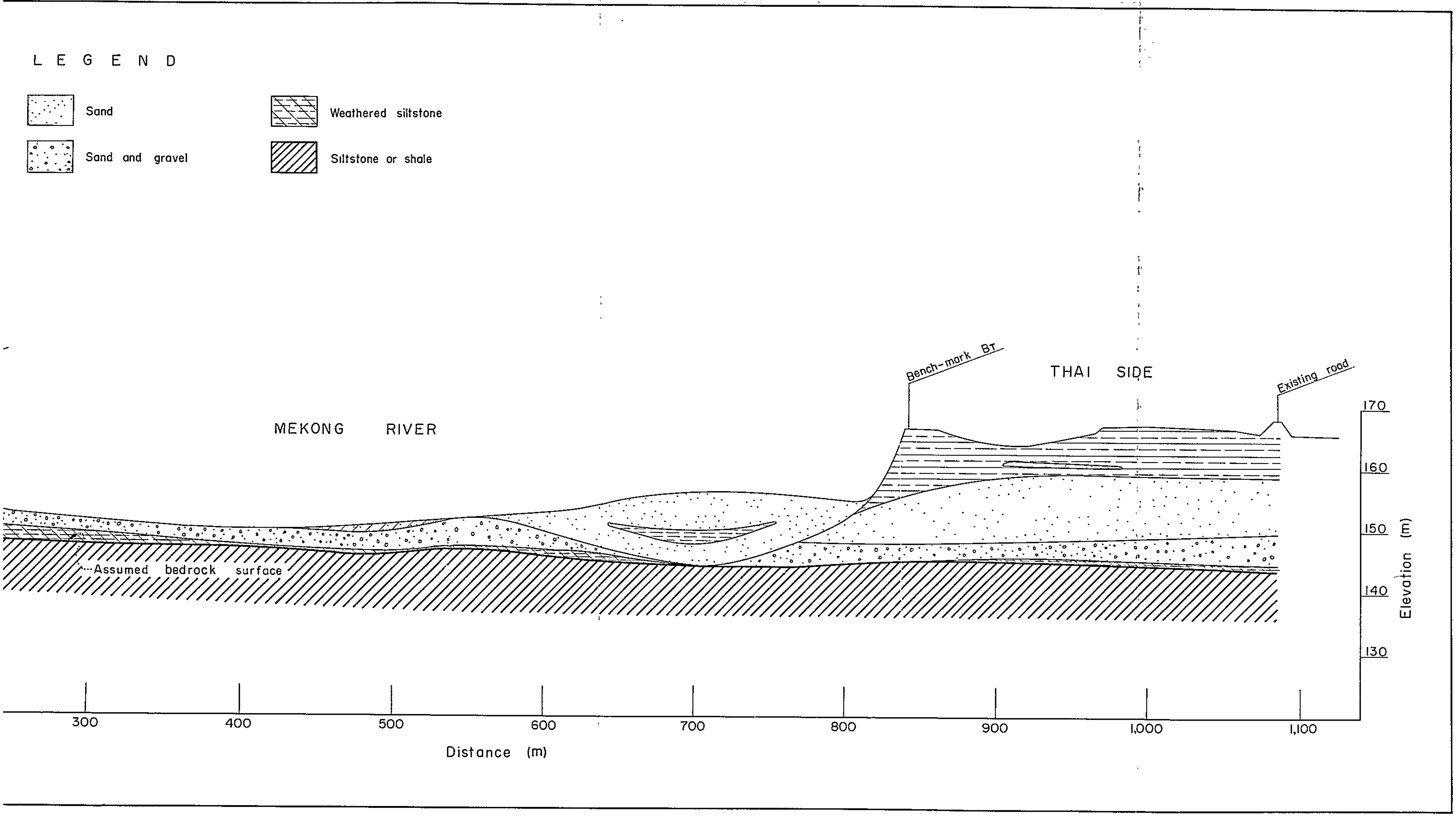
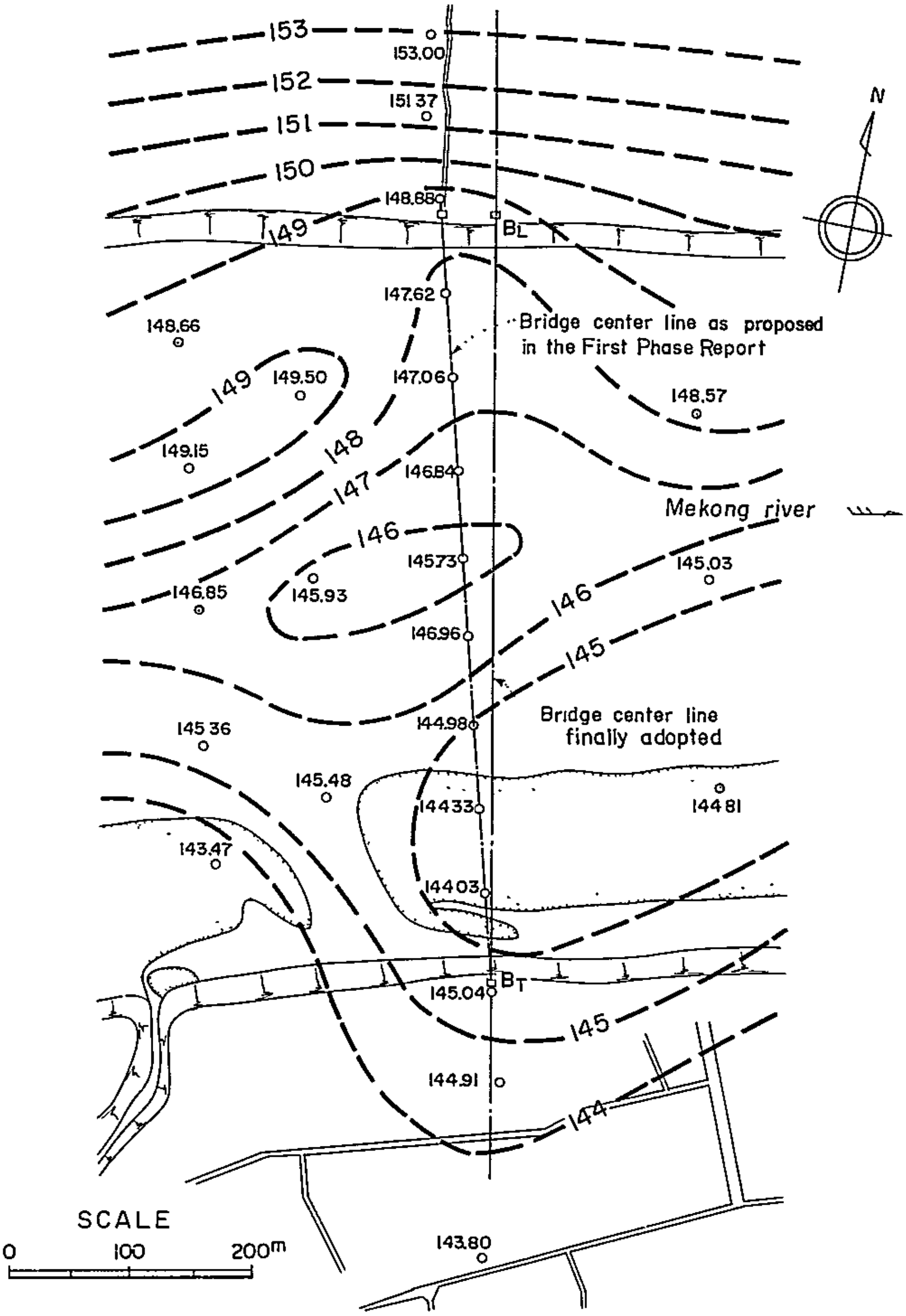


Fig. 2.3. CONTOUR MAP OF ASSUMED BEDROCK SURFACE AT BRIDGE SITE



Remarks

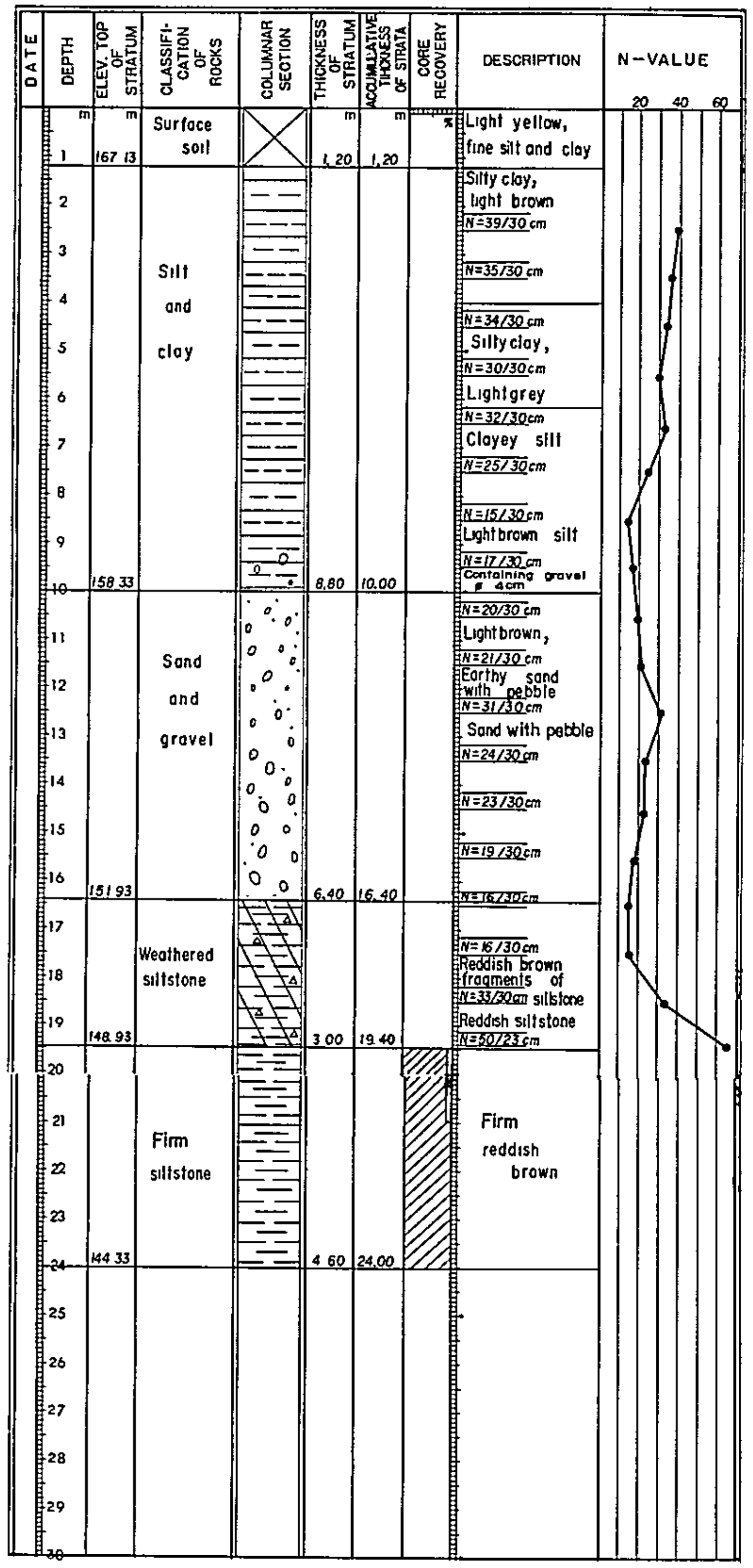
Judged from this contour map, the bedrock profile along the finally adopted bridge center line will be almost the same as that along the bridge center line as proposed in the First-Phase Report, shown in Fig. 2.2.

GEOLOGICAL RECORDS OF TEST DRILLING HOLES (I)

Data 2.1.

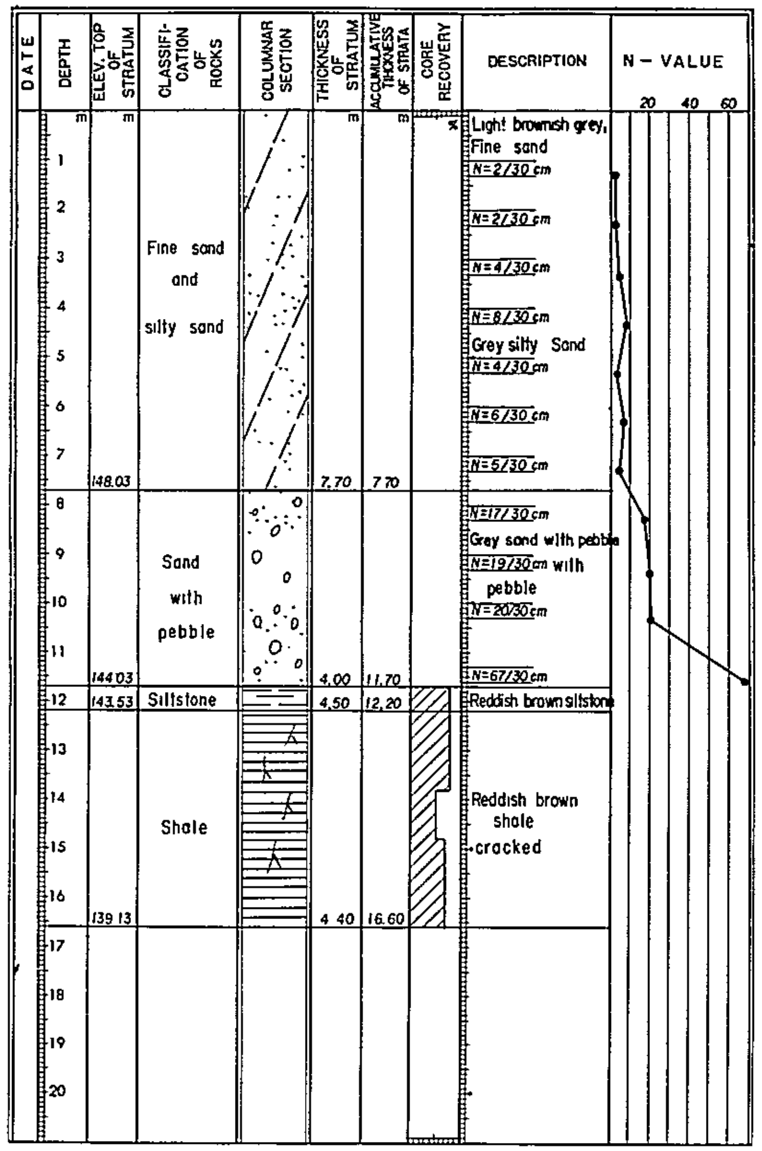
HOLE NO 1

LOCATION : Left Bank (Laos)
ELEVATION OF SURFACE 168.33 M



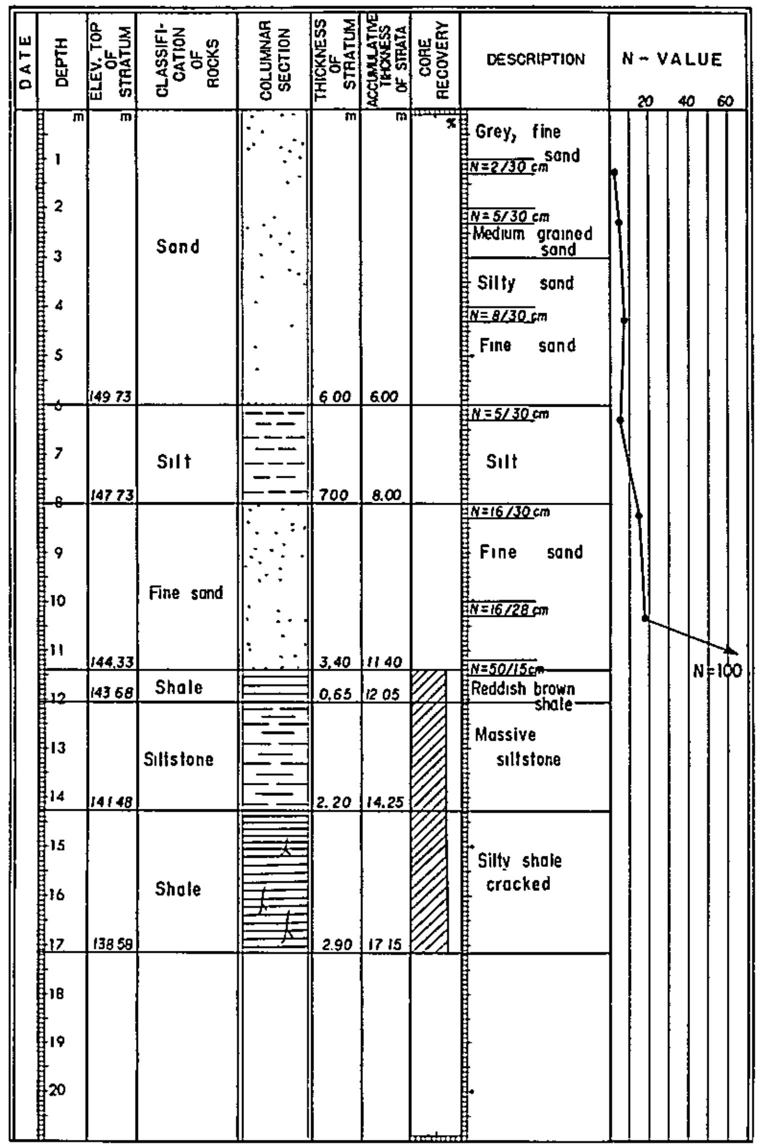
HOLE NO 2

LOCATION : Riverbed
ELEVATION OF SURFACE 155.73 M



HOLE NO 3

LOCATION : Riverbed
ELEVATION OF SURFACE 155.73 M



GEOLOGICAL RECORDS OF TEST DRILLING HOLES (2)

HOLE NO. 4

LOCATION : Riverbed
ELEVATION OF SURFACE 151.92 M

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N - VALUE (20 40 60)
		150.42	Sand and Pebble		1.50	1.50		Light yellow sand and pebble N = 9/30cm	
		149.92	Gravel		0.50	2.00		Gravel	
		147.62	Weathered and fragmental siltstone with gravel		2.30	4.30		N=25/30cm Weathered siltstone with gravel N=32/30cm	
						8.00		Firm shaly siltstone	
			Firm siltstone			9.00		Fine-grained siltstone	
		138.92			8.70	13.00		Firm siltstone	

HOLE NO. 5

LOCATION : Riverbed
ELEVATION OF SURFACE 150.96 M

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N - VALUE (20 40 60)
			Sand and gravel		1.50	1.50		Yellow brown sand and pebble N=16/30cm	
		148.96			0.50	2.00		Gravel and sand	
		147.06	Weathered siltstone with gravel		1.90	3.90		N=23/30cm Weathered siltstone and gravel N=30/30cm	
		146.46	Siltstone		0.60	4.50		N=50/11cm Siltstone	N=136
		145.96	Shale		0.50	5.00		Shale, crushed	
		137.96	Siltstone		8.00	13.00		Siltstone, sound Vertical joint at 7.5m	

HOLE NO. 6

LOCATION : Riverbed
ELEVATION OF SURFACE 153.58 M

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N - VALUE (20 40 60)
		147.58	Grey fine sand		6.00	6.00		Grey, fine sand N=2/30cm N=2/30cm N=7/30cm	
		146.58	Sand with pebble		1.00	7.00		N=24/30cm Fine sand with pebble	
		144.98	Gravel with weathered siltstone		1.60	8.60		N=32/30cm Gravel N=50/25cm with Gravel with fragmental siltstone	
								Siltstone with joints	
		139.98	Siltstone		5.00	13.60		Massive siltstone	

GEOLOGICAL RECORDS OF TEST DRILLING HOLES (3)

HOLE NO 7

LOCATION : Riverbed
ELEVATION OF SURFACE 149.84 m

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE
	0.90	148.94	Gravel with rock fragments	0.90	0.90		Chert gravel and fragments of siltstone	
	3.00	146.84	Gravel, sand and silt	2.10	3.00		N=18/30 cm; Gravel, sand and silt; N=22/30 cm	
	9.00		Siltstone	6.00	9.00		N=50/11 cm; Reddish brown siltstone; Partly shaly; Vertical joint at 8.5m	N=136
	16.21	133.63		7.21	16.21		Shaly siltstone; Sound	

HOLE NO 8

LOCATION : Riverbed
ELEVATION OF SURFACE 150.73 m

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE
	1.50	149.23	Mud and sand	1.50	1.50		Mud and grey sand; N=27/30 cm	
	4.00	146.73	Sand and gravel	2.50	4.00		Mud, sand and gravel; N=25/30 cm; Sand and gravel; N=37/30 cm	
	5.00	145.73	Gravel and rock fragments	1.00	5.00		Gravel and siltstone fragments	
	5.80		Siltstone	0.80	5.80		Shaly siltstone	
	13.00	137.73		7.20	13.00		Siltstone vertical joint between 7m and 8m	

HOLE NO 9

LOCATION : Riverbed
ELEVATION OF SURFACE 151.61 m

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE
	4.30	147.31	Sand with pebble	4.30	4.30		N=4/30 cm; Fine sand with pebbles; N=18/30 cm; N=19/30 cm	
	4.65	146.96	Gravel	0.35	4.65		N=70/30 cm Gravel ϕ 5cm	N=150
	4.95	146.66	Siltstone	0.30	4.95		Siltstone	
	5.55	146.06	Shale	0.60	5.55		Silty shale cracked	
	12.80	138.81	Siltstone	7.25	12.80		Siltstone	

GEOLOGICAL RECORDS OF TEST DRILLING HOLES (4)

HOLE NO 10

LOCATION : Riverbed
ELEVATION OF SURFACE 151.13 M

DATE	DEPTH	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE (20 40 60)
		150.13	Muddy sand		1.00	1.00		Muddy sand	
		148.13	Sand and pebble		2.00	3.00		N=3/30cm Fine sand with pebble N=18/30cm	
		146.03	Gravel and sand		2.10	5.10		N=19/30cm Gravel and sand N=26/30cm	
		145.03	Weathered siltstone		1.00	6.10		Fragmental siltstone	
			Siltstone		2.00	8.10		Reddish brown siltstone	
					1.00	9.10		Ditto, brittle	
		141.03			1.00	10.10		Siltstone	
		140.03	Sandstone		1.00	11.10		Fine grained sandstone	
			Siltstone		1.70	12.80		Shaly siltstone	
					0.30	13.10		Ditto, cracked	
		134.03			4.00	17.10		Massive siltstone	

HOLE NO. 11

LOCATION : Riverbed
ELEVATION OF SURFACE 152.16 M

DATE	DEPTH	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE (20 40 60)
		150.26	Sand and gravel		1.90	1.90		Brown gravel Contents. 40~70%	
		148.66	Clay		1.60	3.50		Hard clay N=50/12cm	N=88
			Siltstone		0.60	4.10		Reddish brown siltstone	
		139.66			8.40	12.50		Reddish brown, clayey siltstone	

HOLE NO 12

LOCATION : Riverbed
ELEVATION OF SURFACE 150.95 M

DATE	DEPTH	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE (20 40 60)
		150.55	Sand		0.40	0.40		Grey med. sand	
		149.15	Sand and gravel		1.40	1.80		Sand, Pebble and gravel with siltstone fragment N=30/30cm	
		138.95	Siltstone and shale (alternated)		10.20	12.00		Fine-grained siltstone and shale (alternated)	

HOLE NO 13

LOCATION : Riverbed
ELEVATION OF SURFACE 149.82 M

DATE	DEPTH	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE (20 40 60)
		148.57	Weathered shale		1.25	1.25		Weathered shale N=50/25cm	
		148.02	Shale		0.65	1.80		Shale, cracked	
		142.62	Siltstone		5.40	7.20		Siltstone	

HOLE NO 14

LOCATION : Riverbed
ELEVATION OF SURFACE 151.35 M

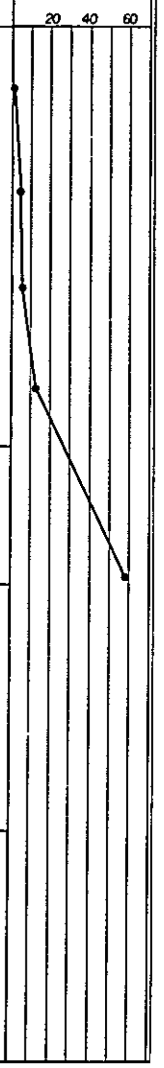
DATE	DEPTH	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE (20 40 60)
		147.35	Sand and gravel		4.00	4.00		Grey sand and gravel N=24/30cm N=28/30cm Containing N=21/30cm siltstone fragments	
		146.85	Weathered siltstone		0.50	4.50		N=23/30cm Weathered siltstone	
		137.85	Siltstone		9.00	13.50		Shaly; Shaly	

GEOLOGICAL RECORDS OF TEST DRILLING HOLES (5)

HOLE NO 15

LOCATION : Riverbed
ELEVATION OF SURFACE 156.11 M

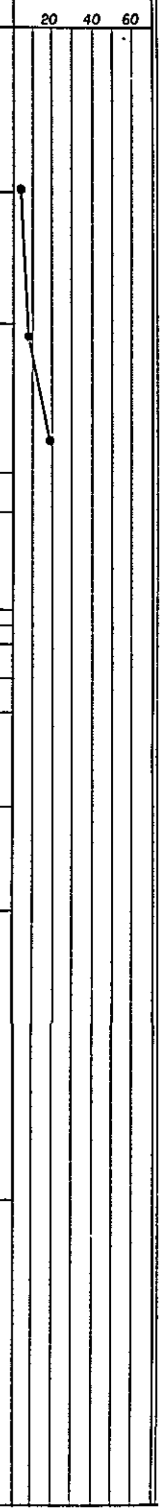
DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	DESCRIPTION
8.50	147.61	Fine sand	8.50	8.50	N=2/32cm; Grey, Fine sand; N=5/30cm; N=6/30cm; N=12/30cm
11.30	144.81	Sand and pebble	2.80	11.30	Sand and pebble; N=58/30cm
16.30	139.81	Siltstone	5.00	16.30	Siltstone



HOLE NO 16

LOCATION : Riverbed
ELEVATION OF SURFACE 155.28 M

DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	DESCRIPTION
3.30	151.98	Sand	3.30	3.30	Grey, fine sand; N=4/30cm
6.00	149.28	Sand with pebble	2.70	6.00	Sand with subangular pebble; N=7/30cm
9.00	146.28	Sand	3.00	9.00	Fine sand; N=18/30cm
9.80	145.48	Weathered siltstone	0.80	9.80	Weathered siltstone
11.80	143.48	Siltstone	2.00	11.80	Clayey siltstone
12.10	143.18	Shale	0.30	12.10	Shale
12.50	142.78	Siltstone	0.40	12.50	Clayey siltstone
13.20	142.08	Shale	0.70	13.20	Shale
13.80	141.48	Siltstone	0.60	13.80	Siltstone
15.80	139.48	Shale	2.00	15.80	Shale
17.90	137.38	Siltstone	2.10	17.90	Sound siltstone
23.80	131.48	Shale	5.90	23.80	Shale



HOLE NO 17

LOCATION : Riverbed
ELEVATION OF SURFACE 152.36 M

DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	DESCRIPTION
6.20	146.16	Sand	6.20	6.20	Grey sand; N=13/30cm; N=15/30cm; N=18/30cm; N=22/30cm; N=15/30cm; Accompanied pebbles; N=25/30cm
7.00	145.36	Weathered siltstone	0.80	7.00	Weathered
15.00	137.36	Siltstone	8.00	15.00	Siltstone partly shale; Siltstone

GEOLOGICAL RECORDS OF TEST DRILLING HOLES (6)

Data 2.1.

HOLE NO 18

LOCATION . Riverbed
ELEVATION OF SURFACE 151.20 M

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE
	0–1.70	149.50	Gravel		1.70	1.70		Subangular or round; N=50/13cm	N=115
	1.70–3.60	147.60	Shale		1.90	3.60		Reddish brown shale, cracky after drying	
	3.60–16.00	135.20	Siltstone		12.40	16.00		Siltstone; Shaly, fine-spotted; Siltstone	

HOLE NO 19

LOCATION : Riverbed
ELEVATION OF SURFACE 155.57 M

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE
	0–6.50	149.07	Sand		6.50	6.50		Fine sand; N=4/30cm; N=5/30cm	
	6.50–7.00	148.57	Silt		0.50	7.00		Loamy silt	
	7.00–10.00	145.57	Sand and pebble		3.00	10.00		N=21/30cm; Fine sand with pebble; N=14/30cm	
	10.00–12.10	143.47	Gravel		2.10	12.10		Gravel ø = 5 ~ 6cm; N=40/10cm	N=135
	12.10–28.00	127.57	Siltstone		15.90	28.00		→(Core lost); →(Core lost); Reddish-brown siltstone; Firm siltstone; → (Core lost); Reddish brown siltstone partly conchoidal	

HOLE NO 20*

LOCATION : Riverbed
ELEVATION OF SURFACE 150.93 M

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE
	0–2.00	148.93	Sand		2.00	2.00		Grey med sand; N=15/30cm	
	2.00–5.00	145.93	Sand and gravel		1.00	5.00		N=21/30cm; Sand & gravel with weathered siltstone; N=27/30cm; N=50/25cm weathered siltstone	
	5.00–13.00	137.93	Siltstone		8.00	13.00		Fine-grained siltstone	

GEOLOGICAL RECORDS OF TEST DRILLING HOLES (7)

HOLE NO 21

LOCATION . Right Bank (Thai)
ELEVATION OF SURFACE 166.59 m

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE (20 40 60)
	0–4	162.59	Loam		4.00	4.00		Light brown loam; N=5/30cm; N=7/30cm; N=7/30cm	
	4–11	155.59	Silt		7.00	11.00		N=8/30cm; Light brown clayey; N=12/30cm; 5.70 TWS. 6.30; N=11/30cm; 7.40 TWS. 7.80; Dark brown; N=13/30cm; Gray brown; 10.30 TWS. 10.85; TWS. 11.25	
	11–19	147.59	Sand		8.00	19.00		Fine-grained; N=17/30cm; Medium-grained; N=23/30cm; N=36/30cm; Coarse-grained	
	19–21.55	145.04	Sand & pebbles		1.50	21.55		N=37/30cm; Sand and pebbles; N=29/30cm; N=45/15cm	N=90
	21.55–22.00	144.59	Siltstone		0.45	22.00		Siltstone	

HOLE NO 22

LOCATION : That Luang
ELEVATION OF SURFACE. Unobserved

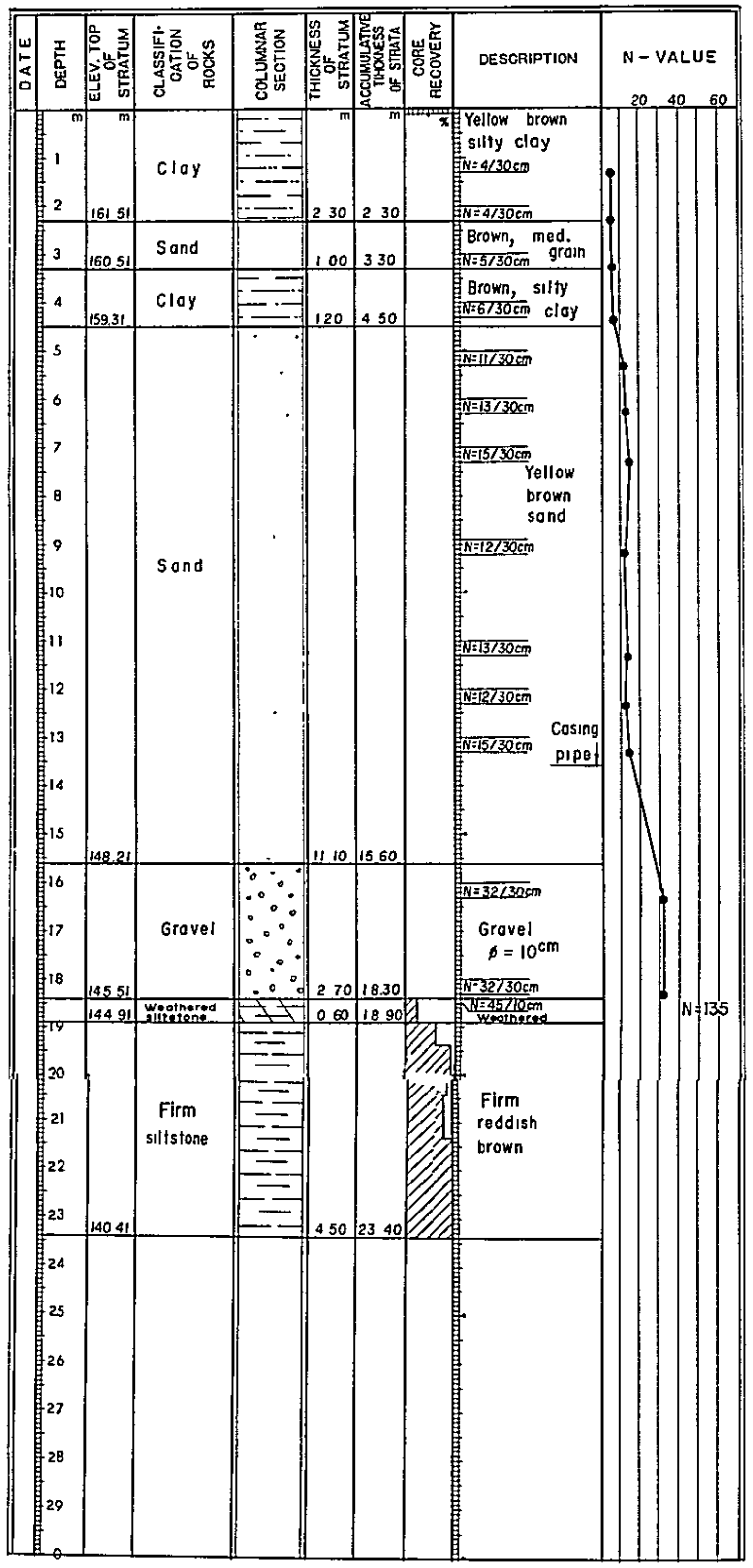
DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE (20 40 60)
	0–0.40		Soil		0.40	0.40		Surface soil	
	0.40–1.60		Clay		1.20	1.60		Dark grey 0.70 TWS 1.35; N=6/30cm	
	1.60–2.90		Sand		1.30	2.90		Grey, brown, coarse; N=7/30cm	
	2.90–9.70		Clay		6.80	9.70		Grey, silty 3.00 TWS 3.40; N=6/30cm; Grey, sandy; N=9/30cm; Gray brown, sandy; N=14/30cm; Light yellow; N=15/30cm; Yellow brown; N=12/30cm; Reddish brown; N=9/30cm	
	9.70–12.80		Sand		3.10	12.80		N=10/30cm; Clayey; N=12/30cm; Grey brown; N=15/30cm	
	12.80–15.90		Clay		3.10	15.90		N=17/30cm; Sandy, Containing pebbles; N=23/30cm; N=26/30cm	
	15.90–16.70		Sand		0.80	16.70		N=17/30cm Clayey	
	16.70–17.80		Clay		1.10	17.80		Sandy; N=13/30cm	
	17.80–25.80		Sand		8.00	25.80		N=17/30cm; Containing gravel; N=19/30cm; N=19/30cm; Light grey, clayey; N=18/30cm; N=28/30cm; Partly with gravels; N=31/30cm; N=34/30cm; N=25/30cm	
	25.80–28.10		Clay		2.30	28.10		Yellow brown; N=32/30cm; Sandy, Partly with gravel; N=39/30cm	
	28.10–30							N=31/30cm; Fine-grained; N=34/30cm	

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N-VALUE (20 40 60)
	30–44.30		Sand with gravel		16.20	44.30		N=35/30cm; Containing gravel φ10~50m/m; N=40/30cm; N=50/25cm; N=50/22cm; N=50/13cm; Grey, Containing gravel φ10~50m/m; N=50/21cm; N=50/27cm; N=50/26cm; N=50/21cm; N=50/25cm; With gravel; N=50/23cm; N=50/21cm; Cave-in; N=50/21cm; N=50/18cm; N=50/17cm	N=115; N=71; N=71; N=71; N=71; N=83; N=88
								Finish	

GEOLOGICAL RECORDS OF TEST DRILLING HOLES (8)

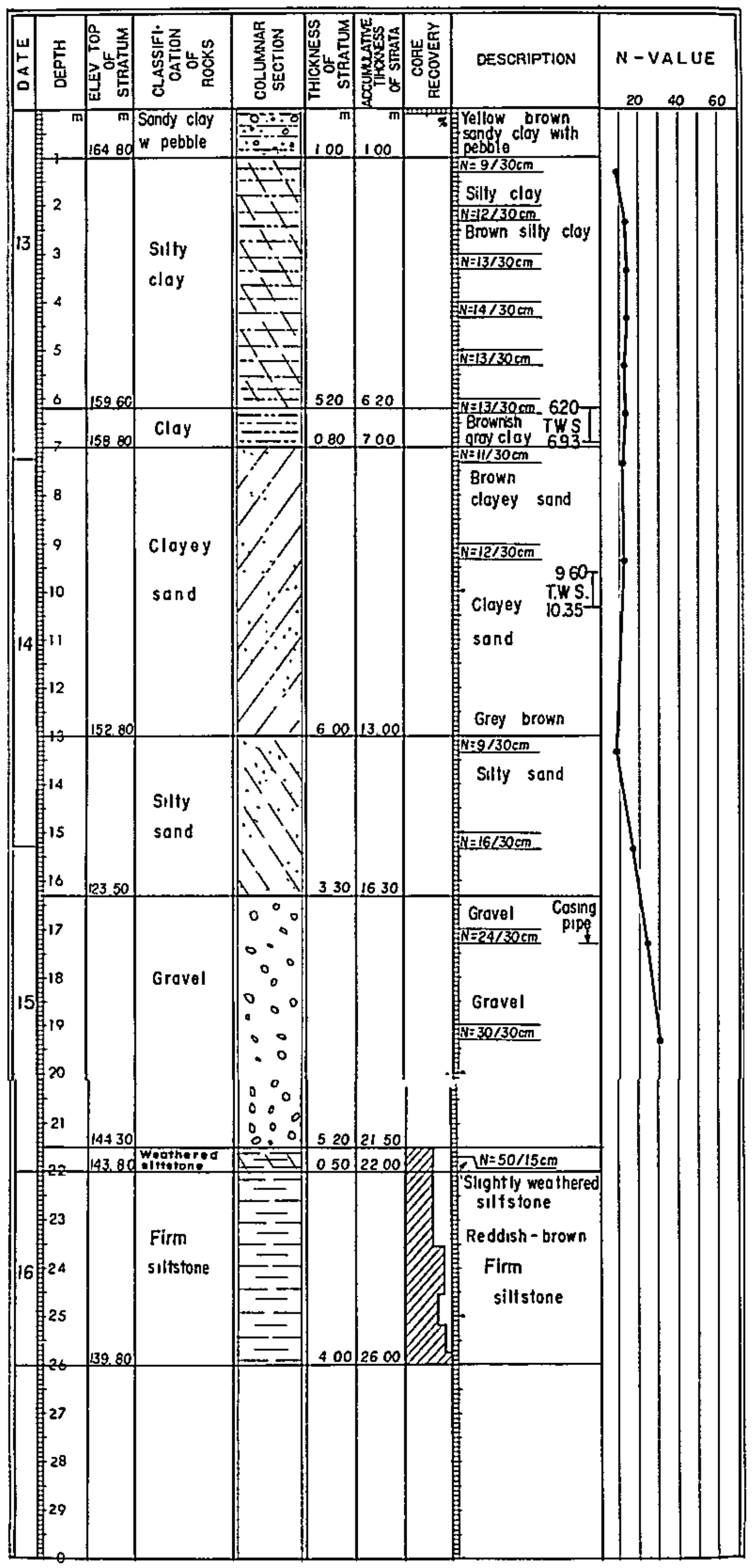
HOLE NO 23

LOCATION . Thai side
ELEVATION OF SURFACE 163.81 M



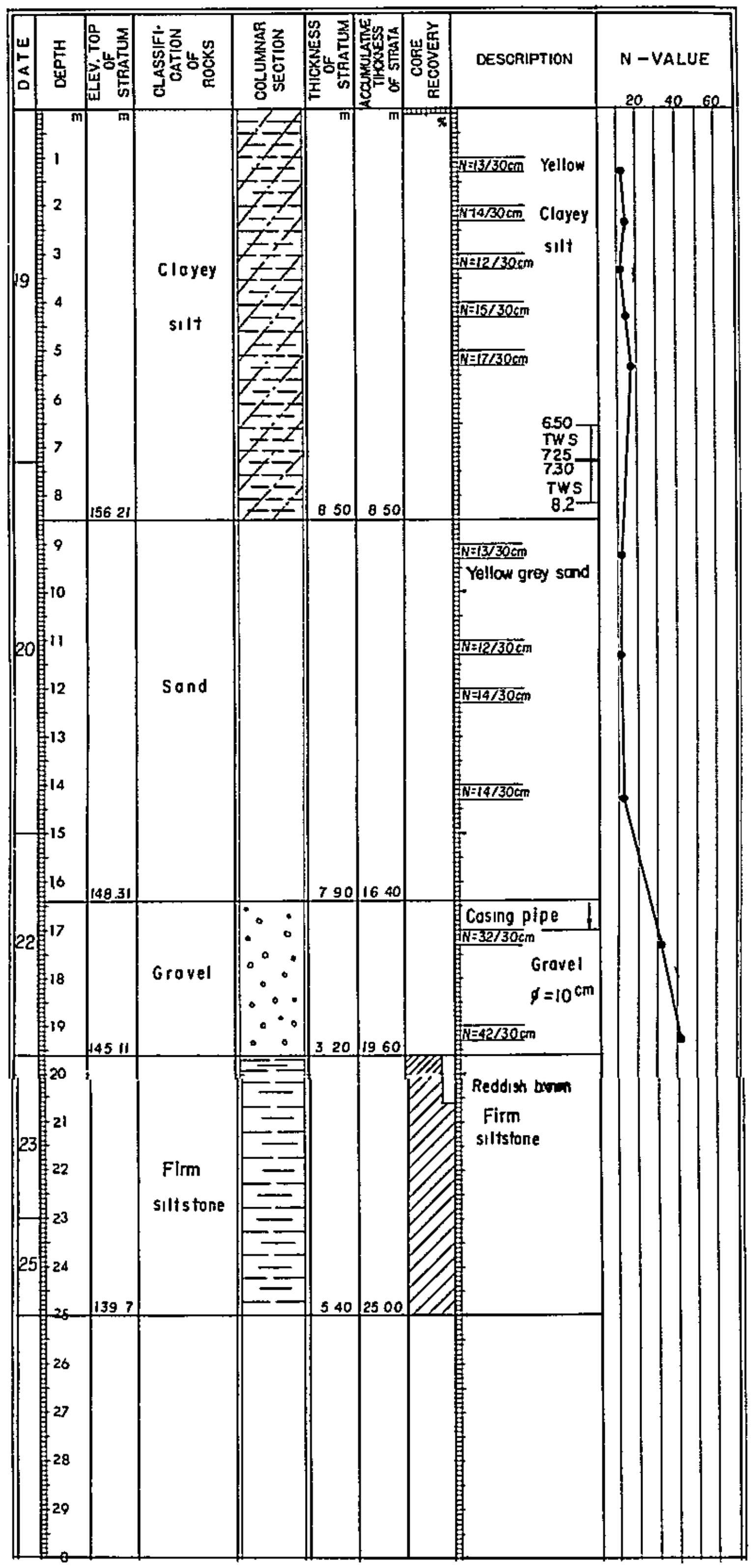
HOLE NO. 24

LOCATION : Thai - side
ELEVATION OF SURFACE 165.80 M



HOLE NO 25

LOCATION : Thai - side
ELEVATION OF SURFACE 164.71 M



GEOLOGICAL RECORDS OF TEST DRILLING HOLES (9)

HOLE NO 26

LOCATION : Thai - side
ELEVATION OF SURFACE 165.41 M

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION
28, 29	0 – 6.50	158.91	Sandy silt	6.50	6.50		Yellow brown sandy silt; N=19/30cm; N=16/30cm; N=15/30cm; N=15/30cm; N=12/30cm
29	6.50 – 11.00	154.41	Silty sand	4.50	11.00		N=11/30cm; Silty sand; 8.0 – TW.S – 8.75; 9.0 – TW.S – 9.75; N=14/30cm; Sand
31	11.00 – 24.00	141.41	Sand and gravel	13.00	24.00		N=18/30cm; N=38/30cm; Sand and gravel; N=39/30cm; ø=5-10cm; N=39/30cm; N=39/30cm; N=40/30cm; N=41/30cm; Yellow brown sand and gravel; N=40/30cm; N=41/30cm; N=42/30cm
1, 3, 5	24.00 – 35.00	130.41	Gravel	11.00	35.00		N=41/30cm; Pebble; N=40/30cm; Pebble and gravel; N=43/30cm; Gravel; N=42/30cm; ø=10cm; Gravel; N=41/30cm; ø=5-15cm; N=43/30cm; ø=1-10cm

HOLE NO 27

LOCATION : Laotian side
ELEVATION OF SURFACE 168.17 M

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION
	0 – 0.40	167.77	Soil	0.40	0.40		Soil
	0.40 – 4.80	163.37	Clayey loam	4.40	4.80		Dark grey Clayey loam; 1.0 – TWS – 1.7; N=1/20cm; Containing humus; N=12/34cm; Containing light grey clay; N=17/30cm
	4.80 – 6.60	161.57	Clayey sand	1.80	6.60		N=13/30cm; Containing mica; N=12/30cm
	6.60 – 9.10	159.07	Sand	2.50	9.10		N=10/30cm; N=10/30cm
	9.10 – 15.90	152.27	Sand with gravel	6.80	15.90		N=22/30cm; N=23/30cm; Accompanied with brown clay; N=31/30cm; N=25/30cm; N=38/30cm; Gravel ø10-30m/m; N=32/30cm; Partly with gravel ø=50m/m; N=30/30cm
	15.90 – 16.80	151.37	Weathered siltstone	0.90	16.80		N=50/22cm; Reddish brown decomposed
	16.80 – 23.00	145.17	Siltstone	6.20	23.00		Firm reddish brown siltstone

GEOLOGICAL RECORD OF TEST DRILLING HOLE (10)

HOLE NO 28

LOCATION . Laotian Side
ELEVATION OF SURFACE 167 M.90

DATE	DEPTH (m)	ELEV. TOP OF STRATUM (m)	CLASSIFICATION OF ROCKS	COLUMNAR SECTION	THICKNESS OF STRATUM (m)	ACCUMULATIVE THICKNESS OF STRATA (m)	CORE RECOVERY (%)	DESCRIPTION	N – VALUE (20 40 60)
		167.10	Soil		0.80	0.80		Containing vegetable fiber	
	1–6	161.70	Loam		5.40	6.20		N=7/30cm Clayey N=11/30cm Accompanying a little humus N=15/30cm N=15/30cm Brown N=20/30cm Sandy	
	6–7	160.00	Sand with clay		1.70	7.90		N=11/30cm Containing N=9/30cm pebbles	
	8–11	156.30	Sand with gravel		3.70	11.60		N=25/30cm Grey brown sand/gravel N=22/30cm Gravel: ø40 m/m 50 m/m N=15/30cm N=12/30cm	
	12–14	153.00	Sand and gravel		3.30	14.90		Grey brown sand/gravel N=35/30cm Sand/Gravel N=50/21cm = 1:1 Accompanyinied with N=50/24cm a little clay	N=71
	15–21	146.60	Siltstone		6.40	21.30		Reddish-brown Slightly weathered	
	22–30								

Table 2.4. Summary of Soil Test

Location: Nong Khai

Items	Unit	Characteristics											
Sample No.		1	2	3	4	5	6	7	8	9	10	11	12
Bore Hole No.		21	21	21	22	22	24	24	25	25	26	26	27
Sampling Depth	m	5.70–6.30	7.40–7.80	10.30–11.25	0.70–1.35	3.00–3.40	6.20–6.93	9.60–10.35	6.50–7.25	7.30–8.20	8.00–8.75	9.00–9.95	1.00–1.70
I. Observation		Reddish brown	Reddish brown	Reddish brown	Grey brown	Reddish brown	Reddish brown	Reddish brown	Reddish brown	Reddish brown	Reddish brown	Reddish brown	Yellow brown
II. Properties													
(1) Natural water content, w	%	20.11	21.23	24.04	26.25	36.70	22.04	28.42	25.41	25.75	25.75	25.40	16.45
(2) Specific gravity of soil, G		2.68	2.65	2.70	2.68	2.70	2.75	2.67	2.73	2 69	2.70	2.65	2.76
(3) Wet density, r_t	g/cm^3	1.875	1.940	1.893	2.044	1.789	2.009	1.792	1.899	1.891	1.948	1.992	2.067
(4) Dry density, r_d	g/cm^3	1.561	1.600	1.526	1.619	1.308	1.646	1.395	1.514	1.503	1.549	1.588	1.775
(5) Void ratio, e		0.717	0.656	0.769	0.655	1.064	0.671	0.914	0.803	0.790	0.743	0.669	0.555
(6) Degree of saturation, S	%	75.17	85.76	84.41	100	93.13	90 33	83.02	86 39	87.68	93.46	100	81.81
III. Grain Size													
(1) Constitution													
i) Gravel part	%	–	–	–	1.0	–	–	–	–	–	–	–	–
ii) Sand part	%	3.5	3.0	5.0	16.5	13.5	2.0	1.5	19.5	51.0	33.0	31.0	25.5
iii) Silt part	%	75.0	74.0	78.0	45.0	62.0	68.5	63.5	38.0	54.0	54.0	54.0	51.0
iv) Clay part	%	21.5	23.0	16.5	48.0	41.5	36.0	30.0	17.0	11.0	13.0	15.0	23.5
(2) Max. diameter	mm	0.105	0.105	0.105	4.8	2.0	0.105	0.105	0.42	0.84	0.42	0.42	2.0
(3) 60 % diameter, D_{60}	mm	0.035	0.033	0.0403	0.016	0.013	0.017	0.018	0.06	0.13	0.07	0.063	0.06
(4) 10 % diameter, D_{10}	mm	–	–	0 0018	–	0.0017	–	–	0.0018	0.004	0.0028	0.002	–
(5) Uniformity coefficient		–	–	22.4	–	7.65	–	–	33.3	32.5	25.0	31.5	–
(6) Grain size classification		Silty clay loam	Silty clay loam	Silty loam	Clay	Clay	Silty clay	Silty loam	Silty loam	Silty loam	Silty loam	Silty loam	Silty clay loam
(7) Unified classification		CL	CL	CL	CL or CH	CL or CH	CL	CL or CH	ML or OL	SC	ML or OL	CL	CL
IV. Consistency													
(1) Liquid limit, L.L.	%	33.25	39.80	35.20	49.80	52.00	37.10	53.10	28.20	24.10	26.40	26.85	36.50
(2) Plastic Limit, P.L.	%	20.45	21.70	22.05	17.37	20.47	20.64	24.33	22.15	18.66	22.49	18.49	11.68
(3) Plasticity index, P.I.		12.80	18.10	13.15	32.43	31.53	16.46	28.77	6.05	5.46	3.91	8.42	24.82
(4) Flow index, F.I.		6.30	8.48	8.25	10.10	10.10	12.80	5.10	5.95	5.10	5.05	5.05	15.70
V. Shearing Strength													
(1) Unconfined compression													
i) Compression strength	kg/cm^2	1.195	0.883	1.051	0.505	0.471	0.861	3.920	0.426	0.290	0.498	0.556	0.664
ii) Sensitivity ratio		2.36	1.56	4.08	1.18	1.64	1.38	5.16	N.G. △1	4.08	N.G. △1	N.G. △1	1.06
(2) Direct compression													
i) Cohesion, c	kg/cm^2	–	–	–	–	–	0 60	–	0.30	–	0.70	0.28	0.60
ii) Internal friction angle, ϕ		–	–	–	–	–	40°02'	–	37°36'	–	15°39'	22°47'	30°58'
(3) Triaxial compression													
i) Cohesion, c	kg/cm^2	0.50	0.80	0.45	0.925	0 20	0.82	1.15	0.21	0.10	0.35	0.24	0.50
ii) Internal friction angle, ϕ		12°25'	19°18'	10°46'	5°43'	8°32'	11°52'	13°30'	15°39'	16°42'	6°17'	8°32'	15°07'
VI. Consolidation													
(1) Initail void ratio, e_o		0.610	0.672	0.670	0.642	1.360	0.689	0.876	0.769	0.657	0.616	0.680	0.682
(2) Preconsolidation Load, p_o	kg/cm^2	3.50	4.50	3.20	1.22	1.17	3.00	4.90	3.00	2.63	3.90	2.48	0.56
(3) Compression index, C_c		0.198	0.186	0.147	0.161	0.361	0.235	0.308	0.251	0.201	0.137	0.146	0.158
(4) Coef. of consolidation, C_v	cm^2/sec	$2.8x10^{-2}$	$1.66x10^{-2}$	$2.1x10^{-3}$	$8.2x10^{-3}$	$8.1x10^{-3}$	$1.22x10^{-2}$	$2.0x10^{-2}$	$2.22x10^{-2}$	$3.1x10^{-2}$	$1.29x10^{-2}$	$1.15x10^{-2}$	$1.7x10^{-2}$
(5) Coef. of volume compressibility, M_v	cm^2/g	$1.3x10^{-5}$	$7.0x10^{-6}$	$8.1x10^{-6}$	$1.95x10^{-5}$	$4.7x10^{-5}$	$1.21x10^{-5}$	$8.6x10^{-6}$	$1.38x10^{-5}$	$1.28x10^{-5}$	$6.3x10^{-6}$	$1.03x10^{-5}$	$5.4x10^{-5}$
(6) Coef. of permeability, K	cm^2/sec	$3.6x10^{-7}$	$1.18x10^{-7}$	$1.74x10^{-8}$	$1.6x10^{-7}$	$3.8x10^{-7}$	$1.5x10^{-7}$	$1.75x10^{-7}$	$3.04x10^{-7}$	$4.0x10^{-7}$	$8.1x10^{-8}$	$1.2x10^{-7}$	$9.2x10^{-7}$

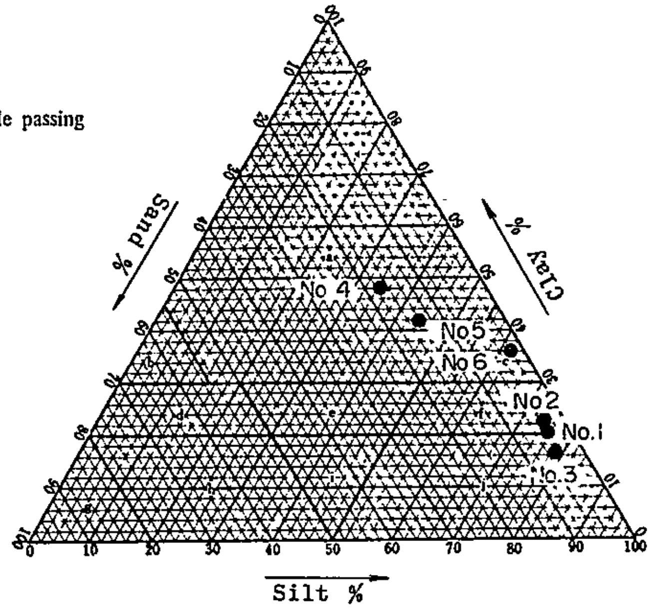
Remarks: △1 Remolding was impossible.

MECHANICAL ANALYSIS (1)

Location Nong Khai

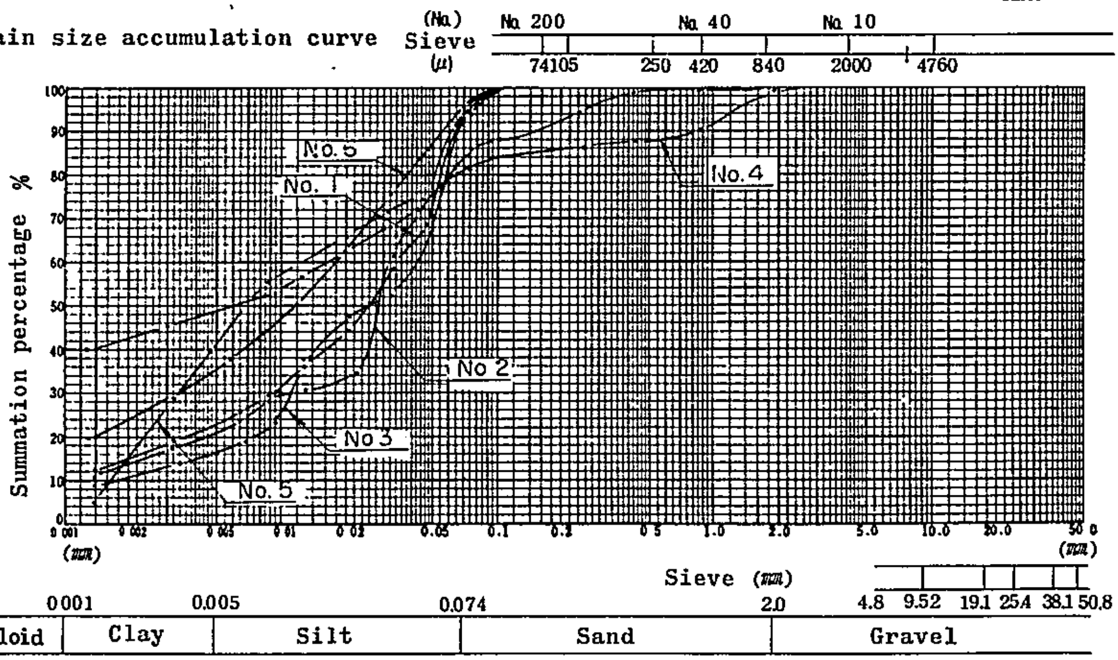
Soil classification of grain size (Sample passing 2000 μ sieve)

- a CLAY
- b SANDY CLAY
- c SILTY CLAY
- d SANDY CLAY LOAM
- e CLAYEY LOAM
- f SILTY CLAY LOAM
- g SAND
- h SANDY LOAM
- i LOAM
- j SILTY LOAM



Sample No.	Gravel %	Sand %	Silt %	Clay %	Max. size mm	D60 mm	D10 mm	Uniformity Coeff.	2000μ sieve Passing sample (%)	420μ sieve Passing sample (%)	74μ sieve Passing sample (%)	Sign of Plotted part on triangular diagram	Classification
No. 1	–	3.5	75.0	21.5	0.105	0.035	–	–	100	100	96.0	f	SILTYCLAY LOAM
No. 2	–	3.0	74.0	23.0	0.105	0.033	–	–	100	100	97.0	f	SILTY CLAY LOAM
No. 3	–	5.0	78.5	16.5	0.105	0.0403	0.0018	22.4	100	100	95.5	j	SILTY LOAM
No. 4	1.0	16.5	34.5	48.0	4.8	0.016	–	–	99.0	87.0	82.0	a	CLAY
No. 5	–	13.5	45.0	41.5	2.0	0.013	0.0017	7.65	100	98.5	86.5	a	CLAY
No. 6	–	2.0	62.0	36.0	0.105	0.0107	–	–	100	100	98.5	c	SILTY CLAY

Grain size accumulation curve

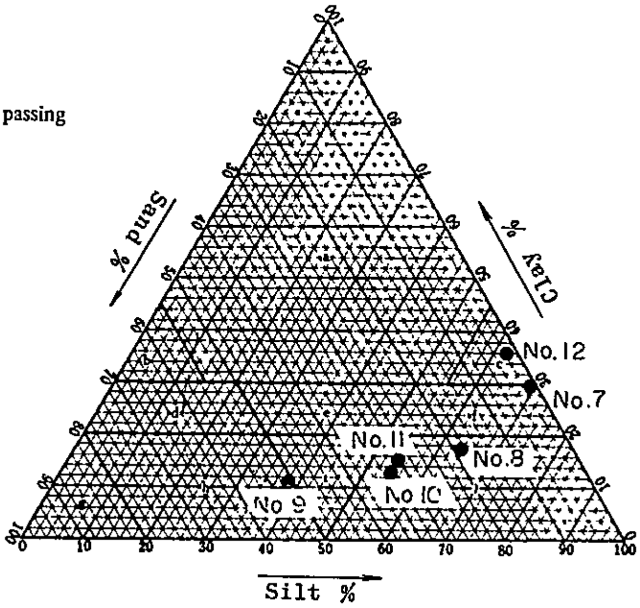


MECHANICAL ANALYSIS (2)

Location Nong Khai

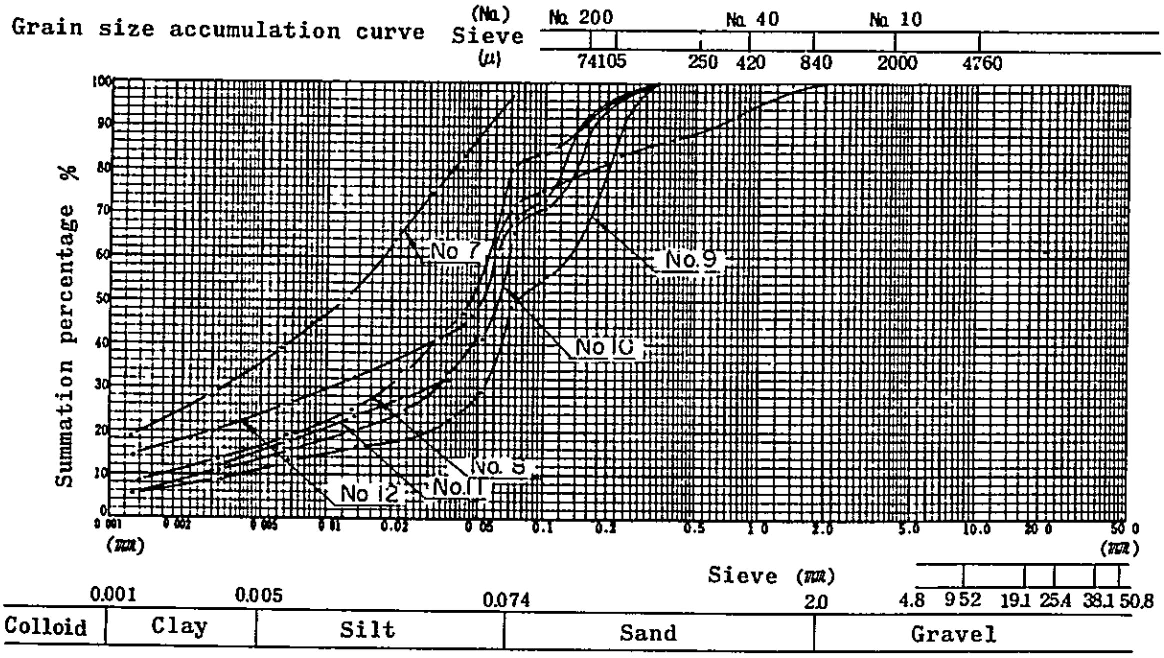
Soil classification of grain size (Sample passing 2000 μ sieve)

a CLAY
b SANDY CLAY
c SILTY CLAY
d SANDY CLAY LOAM
e CLAYEY LOAM
f SILTY CLAY LOAM
g SAND
h SANDY LOAM
i LOAM
j SILTY LOAM



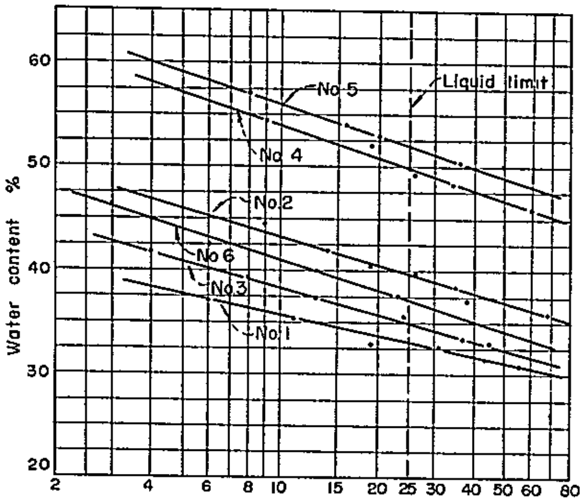
Sample No.	Gravel %	Sand %	Silt %	Clay %	Max. size mm	D60 mm	D10 mm	Uniformity Coeff	2000μ sieve	420μ sieve	74μ sieve	Sign of Plotted part on triangular diagram	Classification
									Passing sample (%)				
No 7		1.5	68.5	30.0	0.105	0.018	–	–	100	100	98.5	c	SILTY CLAY
No. 8		19.5	63.5	17.0	0.420	0.006	0.0018	33.3	100	100	80.5	j	SILTY LOAM
No 9		51.0	38.0	11.0	0.84	0.13	0.004	32.5	100	99.5	49.0	h	SANDY LOAM
No.10		33.0	54.0	13.0	0.42	0.007	0.0028	25.0	100	100	67.0	j	SILTY LOAM
No 11		31.0	54.0	15.0	0.42	0.063	0.002	31.5	100	100	69.0	j	SILTY LOAM
No.12		25.5	51.0	23.5	2.0	0.06	–	–	100	90.5	74.5	c	SILTY CLAY LOAM

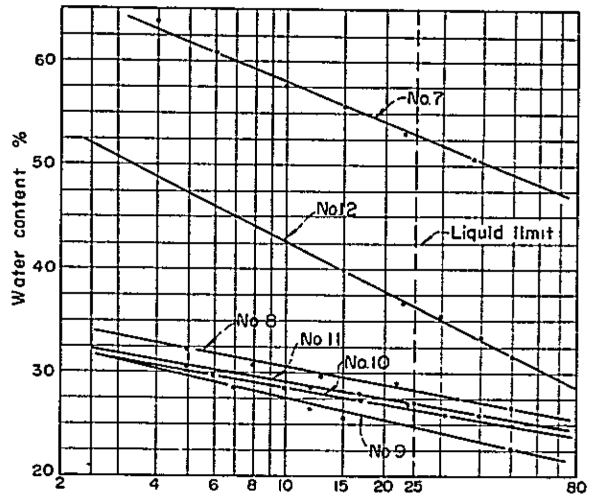
Grain size accumulation curve



Liquid Limit and Plastic Limit Tests

Sample No.	Liquid limit in percent	Plastic limit (1)	Plastic limit (2)	Plastic limit Mean	Plasticity index	Flow index
1	33.25	20.76	20.14	20 45	12.80	6.30
2	39.80	21.67	21.72	21.70	18.10	8.48
3	35.20	22 17	21.92	22 05	13.15	8.25
4	49.80	17.49	17.24	17.37	32.43	10.10
5	52 00	20 62	20.32	20.47	31.53	10 10
6	37.10	20.66	20 62	20.64	16 46	10.00
7	53.10	24.75	23.91	24.33	28.77	12 80
8	28.20	22.27	22.02	22.15	6.05	5.10
9	24.10	18.46	18.85	18 66	5 46	5.95
10	26.40	22.54	22.43	22.49	3.91	5.10
11	26.85	18.50	18 36	18.43	8.42	5.05
12	36.50	11.85	11.50	11 68	24.82	15.70





Number of blows

Remarks: Soils passing 0.4mm sieve were used for deciding the liquid and plastic limits.

Direct Shear Test

Sample No.	Dry density (g/cm³)	Normal stress (kg/cm²)	Maximum shear stress (kg/cm²)	Cohesion c (kg/cm²)	Internal friction angle ϕ
6	1.650	0.6	1.118	0.60	40°02′
	1.618	1.1	1.511		
	1.649	1.6	1.739		
	1.630	2.1	2.400		
8	1.491	0.6	0.758	0.30	37°36′
	1.496	1.1	1.190		
	1.498	1.6	1.373		
	1.501	2.1	1.914		
10	1.480	0.6	0.874	0.70	15°39′
	1.507	1.1	0.963		
	1.499	1.6	1.137		
	1.501	2.1	1.309		
11	1.542	0.6	0.531	0.28	22°47′
	1.520	1.1	0.766		
	1.536	1.6	0.937		
	1.510	2.1	1.163		
12	1.754	0.6	0.973	0.60	30°58′
	1.770	1.1	1.237		
	1.781	1.6	1.560		
	1.783	2.1	1.654		

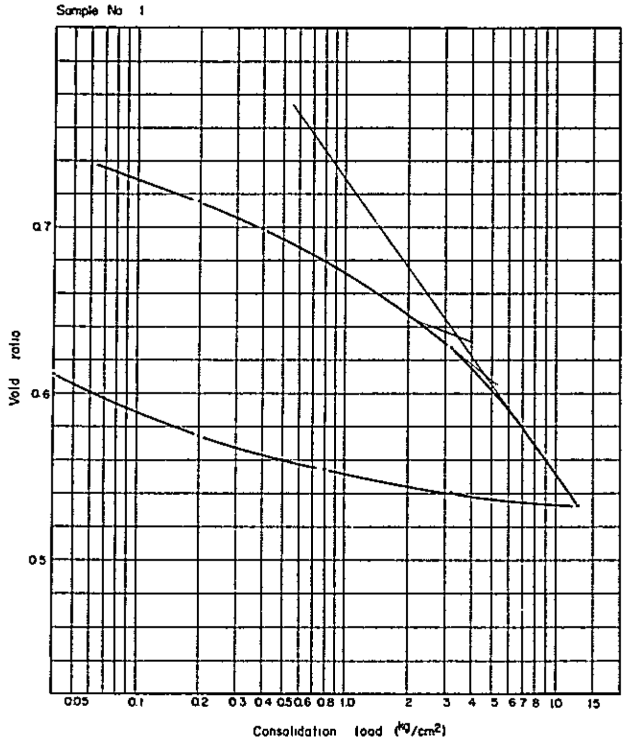
Triaxial Compression Test

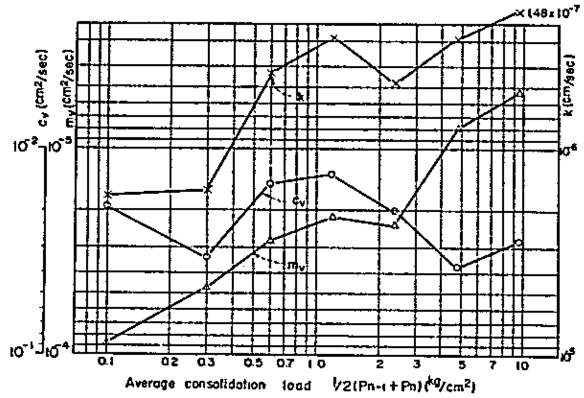
Sample No.	Dry density γ_d (g/cm³)	Lateral pressure σ_3 (kg/cm²)	Max. compression stress σ_1 (kg/cm²)	Cohesion c (kg/cm²)	Internal friction angle ϕ
1	1.600 1.561 1.562	1 2 3	1.803 2.431 2.776	0.50	12°25′
2	1.600 1.615	1 2	3.238 4.250	0.80	19°18′
3	1.543 1.526 1.509	1 2 3	1.569 2.038 2.747	0.45	10°46′
4	1.619 1.605 1.619	1 2 3	0.725 0.921 1.198	0.925	5°43′
5	1.273 1.308 1.329	1 2 3	0.828 1.161 1.804	0.20	8°32′
6	1.622 1.619 1.646	1 2 3	2.547 3.100 3.651	0.82	11°52′
7	1.406 1.400 1.395	1 2 3	3.602 4.182 4.691	1.15	13°30′
8	1.461 1.514 1.551	1 2 3	1.160 1.985 2.583	0.21	15°39′
9	1.503 1.481	1 2	1.031 1.896	0.10	16°42′
10	1.611 1.549 1.549	1 2 3	1.046 1.358 2.100	0.35	6°17′
11	1.595 1.588 1.580	1 2 3	0.961 1.231 1.709	0.24	8°32′
12	1.668 1.742 1.775	1 2 3	2.10 2.78 3.31	0.50	15°07′

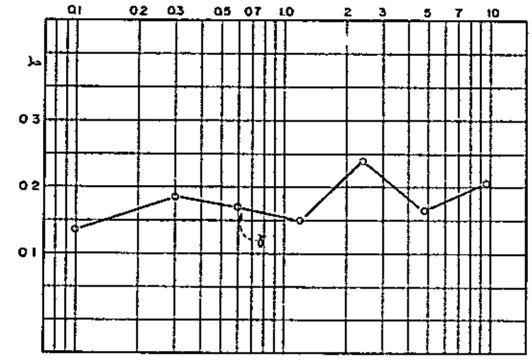
Unconfined Compression Test

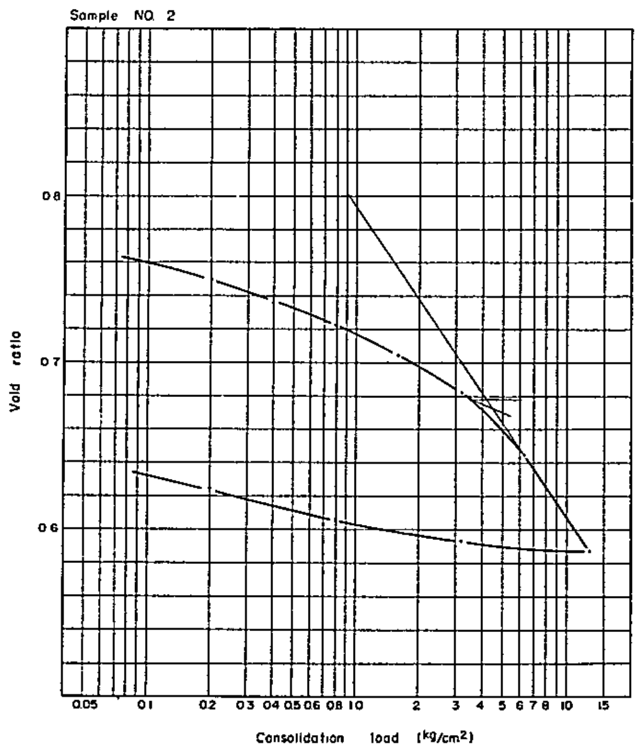
Sample No.	Mean water content (%)	Unit weight (g/cm³)	Unconfined compression strength (kg/cm²) undisturbed sample	disturbed sample	Sensitivity ratio
1	19.06	1.878	1.195	0.508	2.36
2	27.41	1.878	0.883	0.564	1.56
3	22.89	1.858	1.051	0.258	4.08
4	26.77	2.030	0.505	0.427	1.18
5	38.27	1.803	0.471	0.287	1.64
6	24.86	1.965	0.861	0.626	1.38
7	28.70	1.797	3.920	0.760	5.16
8	27.18	1.848	0.426	-	-
9	21.17	1.838	0.290	0.071	4.08
10	25.76	1.934	0.498	-	-
11	25.85	1.950	0.556	-	-
12	16.51	1.992	0.664	0.627	1.06

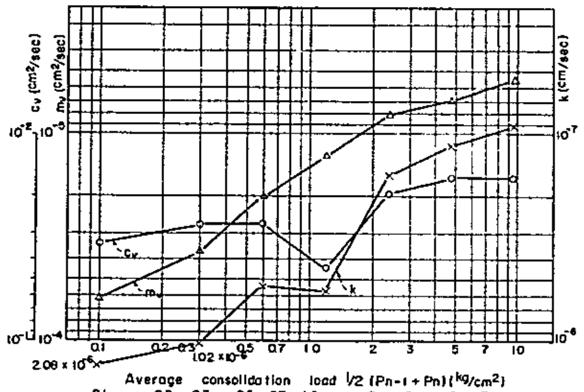
CONSOLIDATION TEST (I)

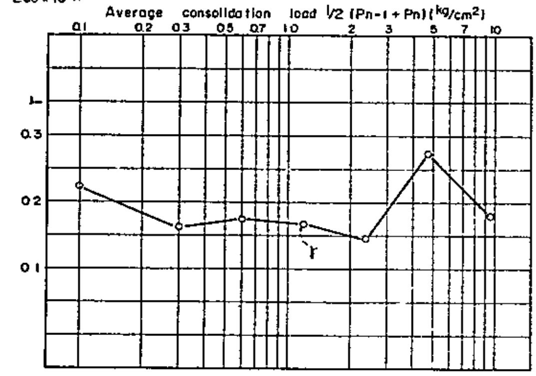








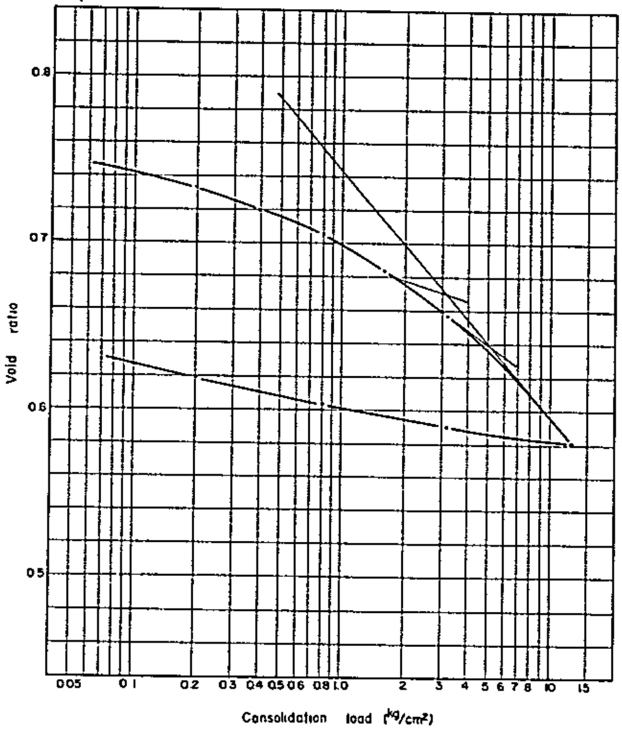


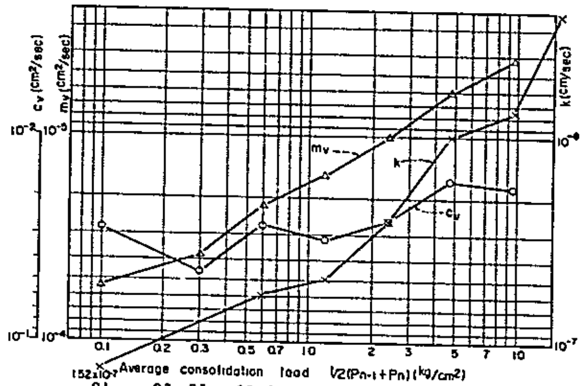


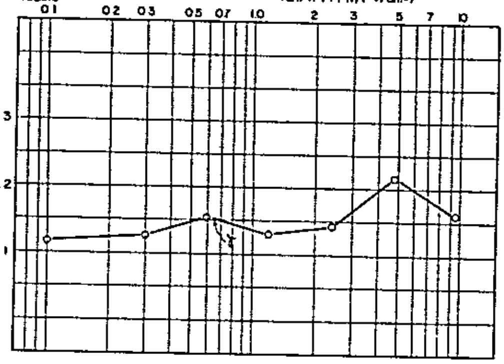
Remarks
c_v Coefficient of consolidation
m_v Coefficient of volume compressibility
k Coefficient of permeability
γ Primary compression ratio

CONSOLIDATION TEST (2)

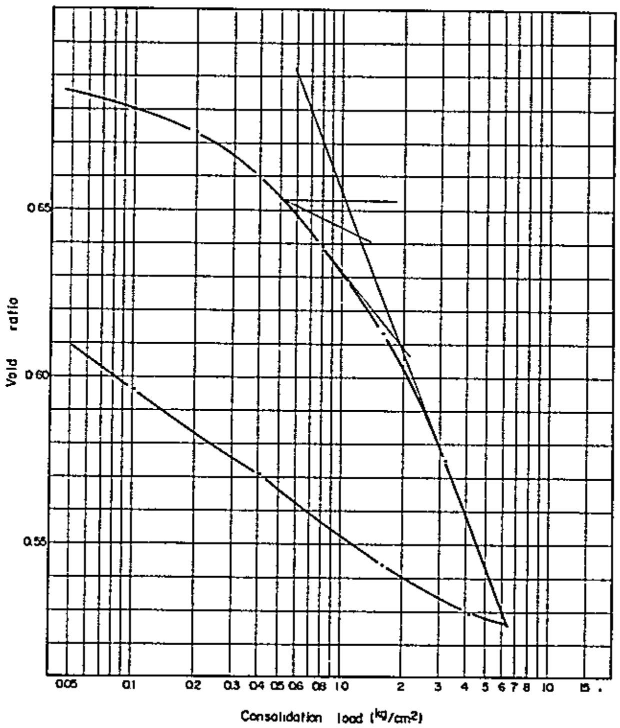
Sample No. 3

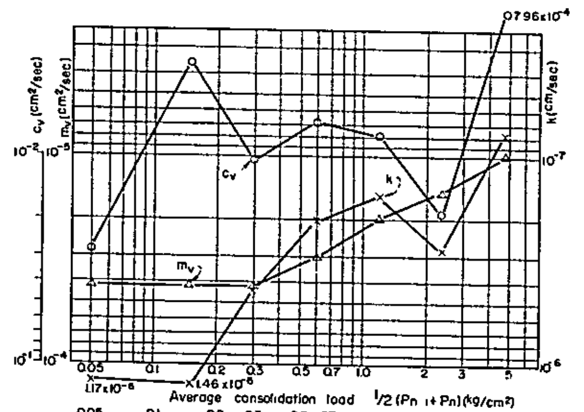


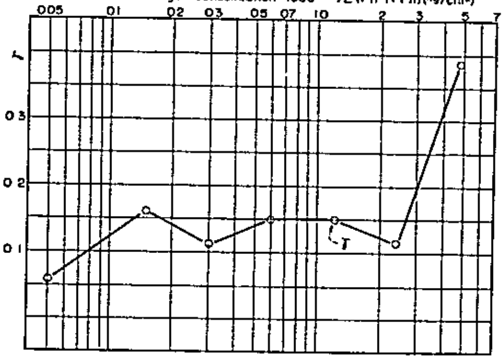




Sample No 4



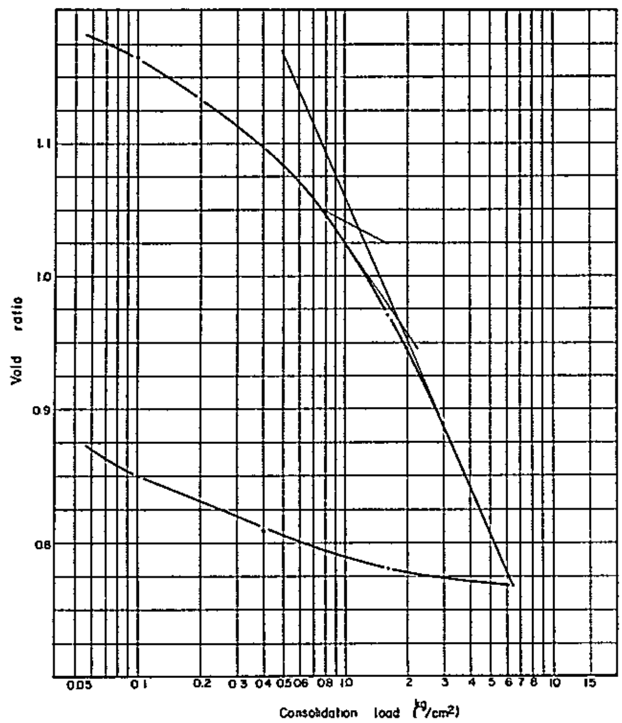


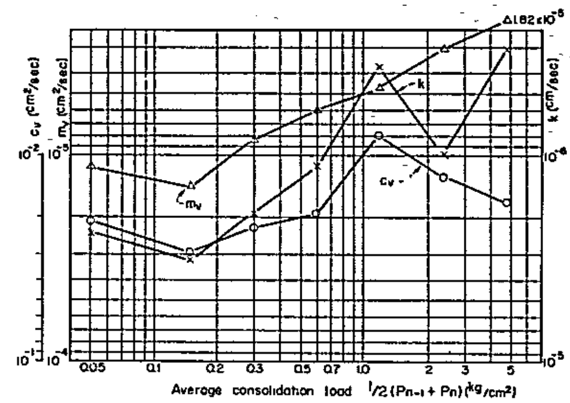


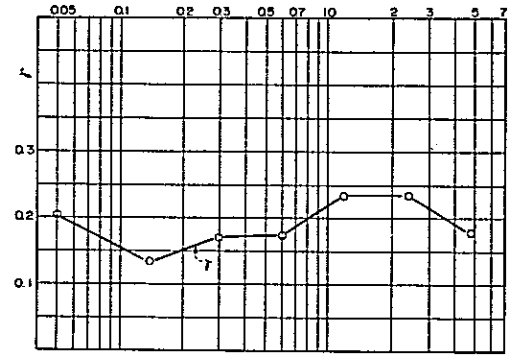
Remarks
- c_v Coefficient of consolidation
- m_v Coefficient of volume compressibility
- k Coefficient of permeability
- γ Primary compression ratio

CONSOLIDATION TEST (3)

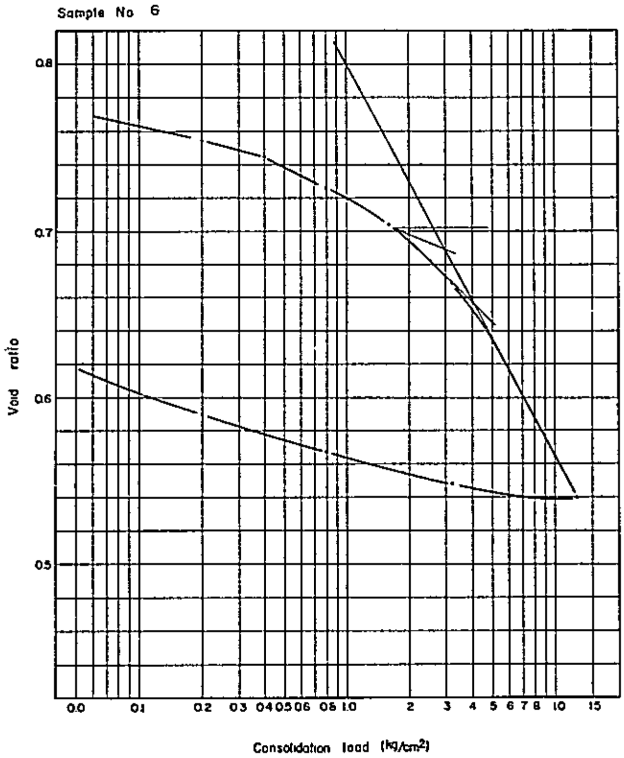
Sample No 5

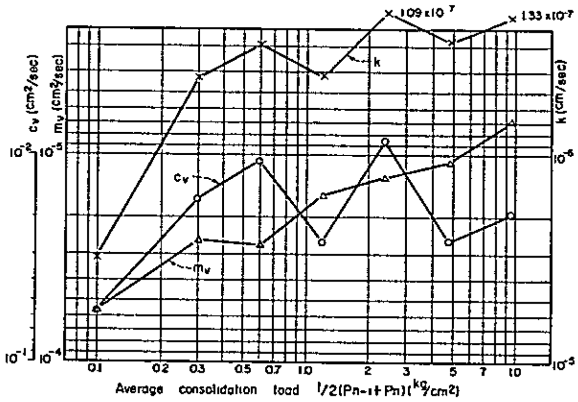


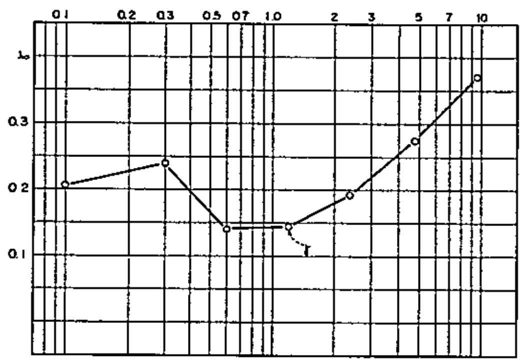




Sample No 6





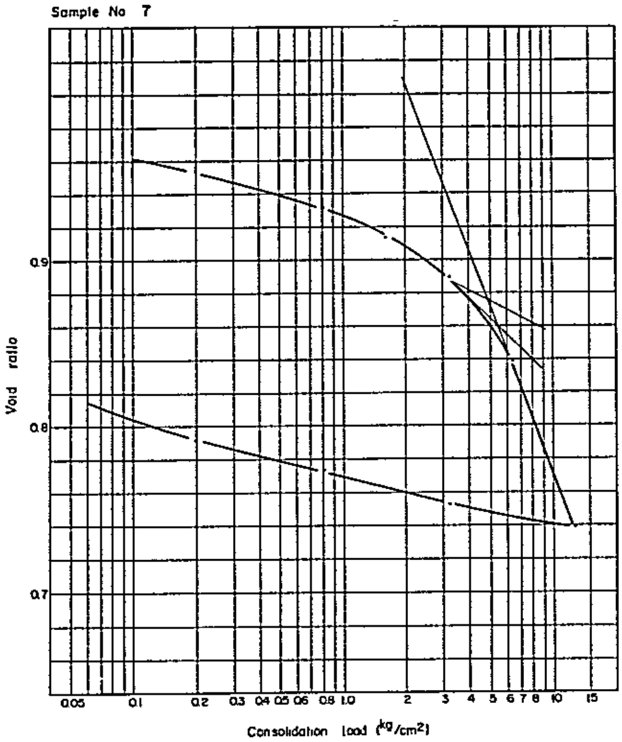


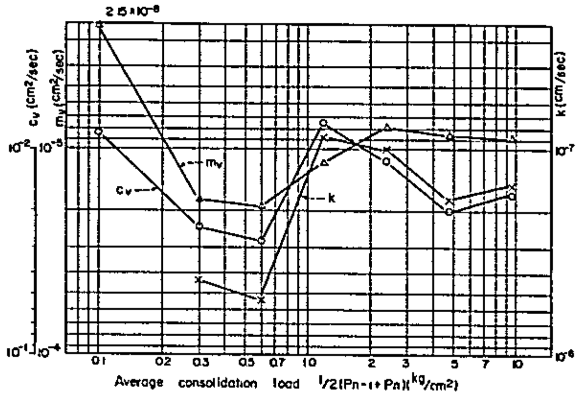
Remarks c_v Coefficient of consolidation
m_v Coefficient of volume compressibility
k Coefficient of permeability
γ Primary compression ratio

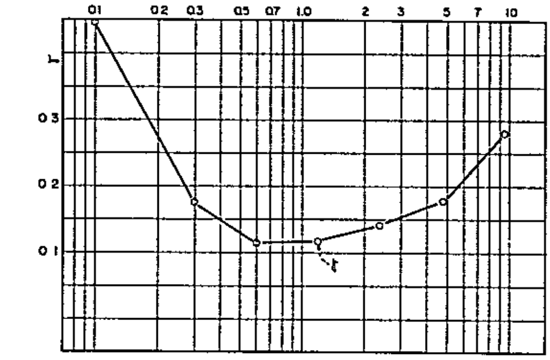
CONSOLIDATION TEST (4)

Data 2.7

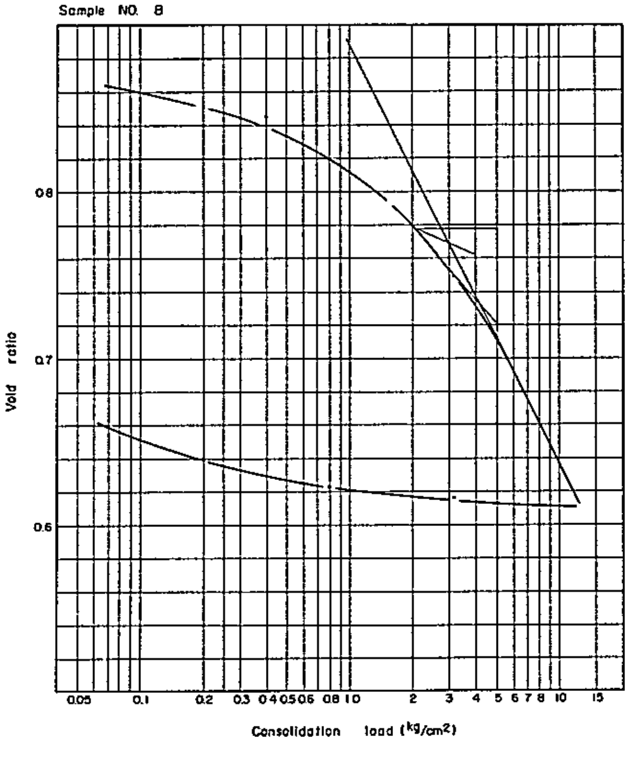
Sample No 7

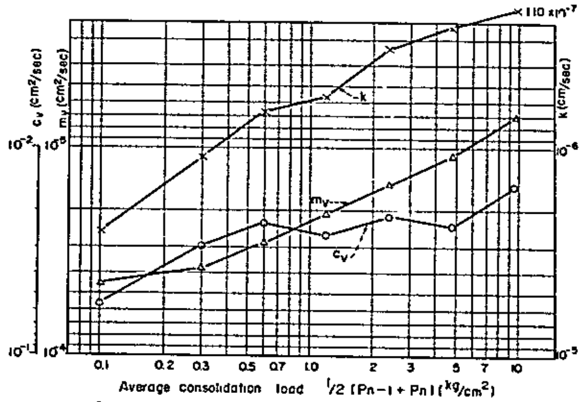


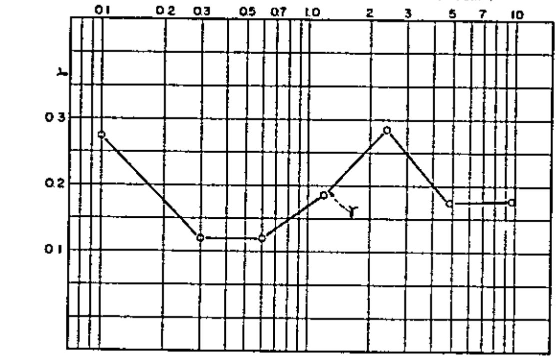




Sample NO. 8



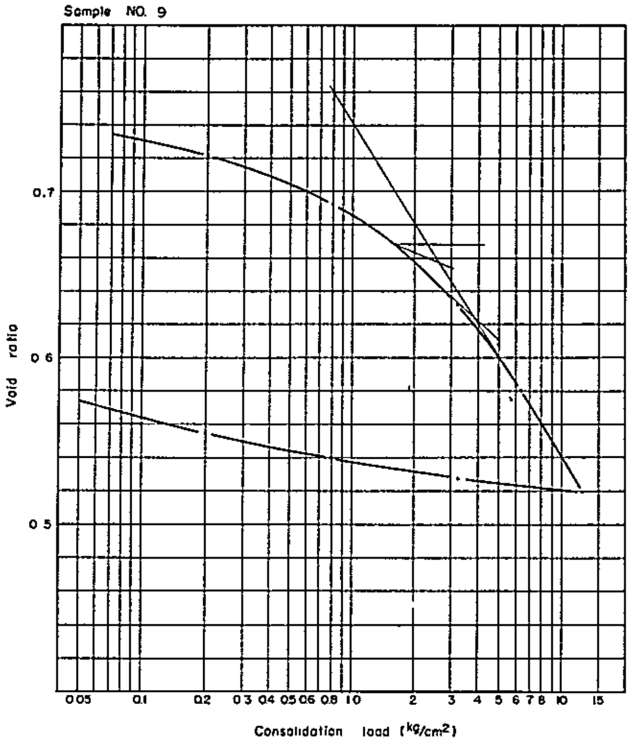


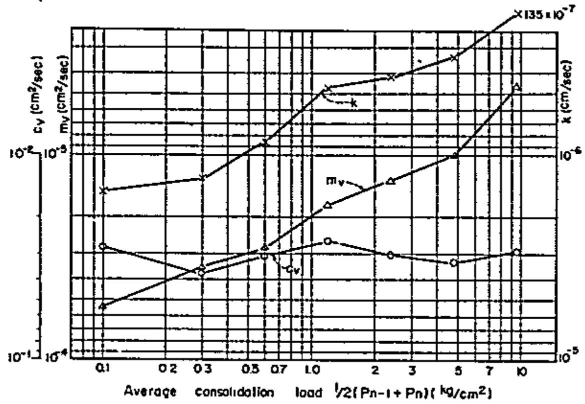


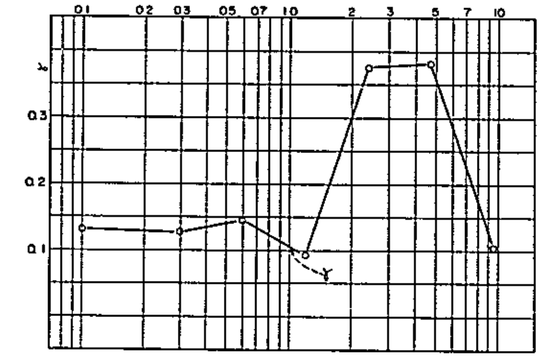
Remarks c_v Coefficient of consolidation
m_v Coefficient of volume compressibility
k Coefficient of permeability
r Primary compression ratio

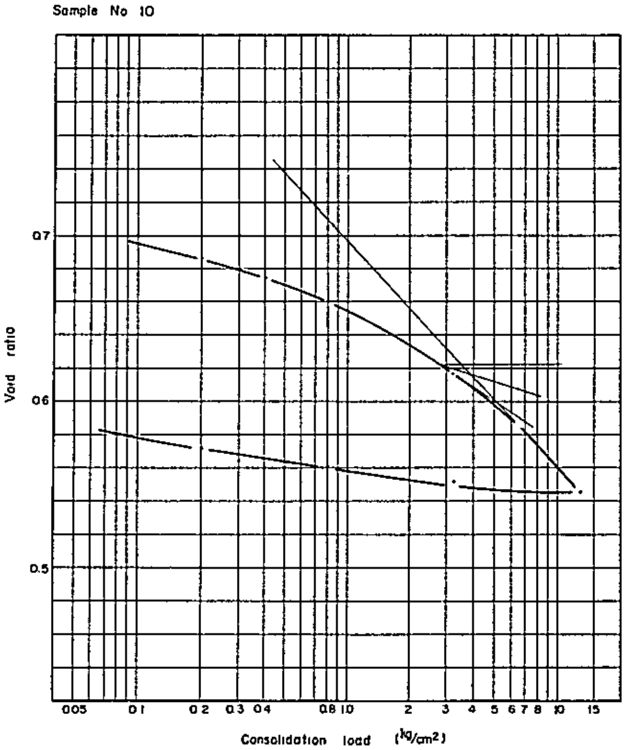
Data 2.7.

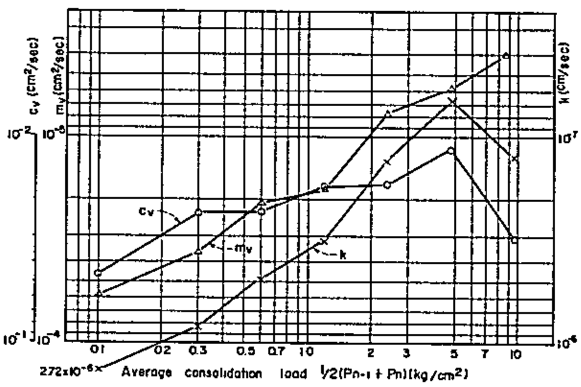
CONSOLIDATION TEST (5)

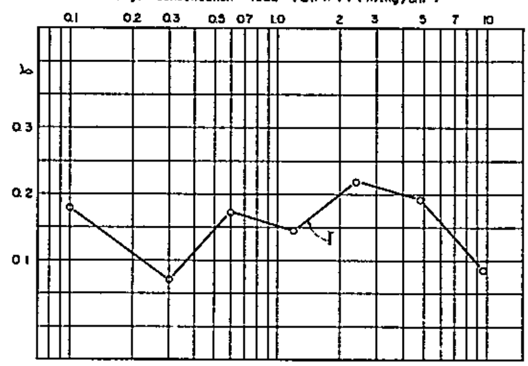






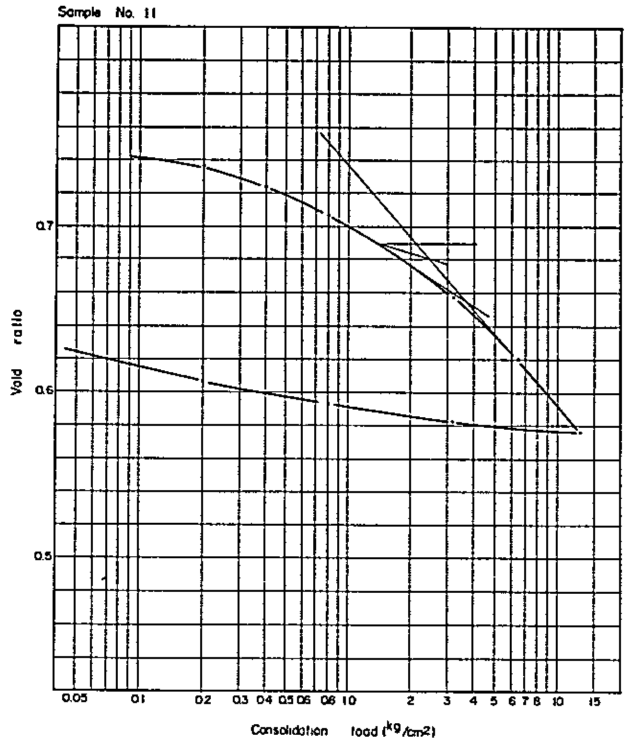


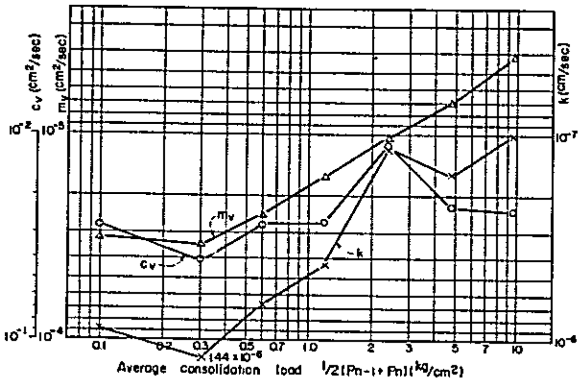


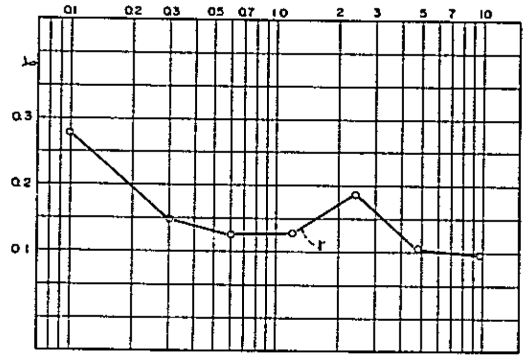


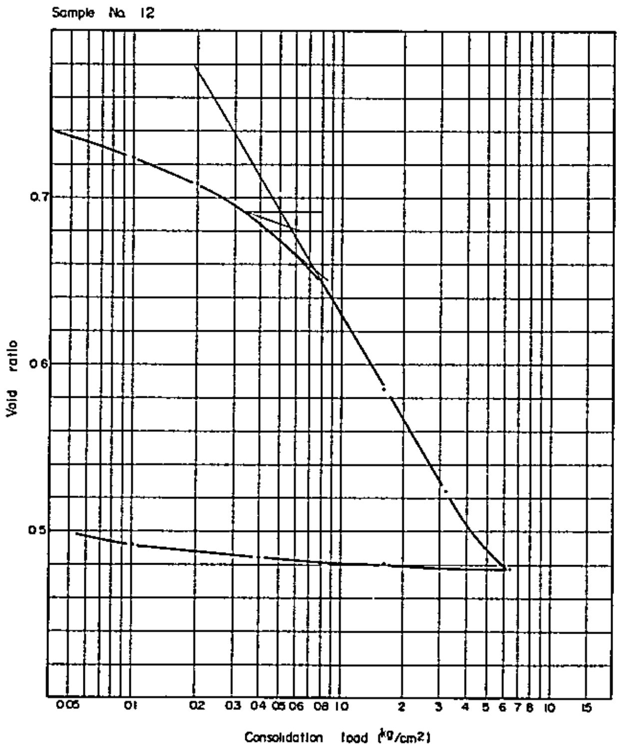
Remarks
- c_v Coefficient of consolidation
- m_v Coefficient of volume compressibility
- k Coefficient of permeability
- γ Primary compression ratio

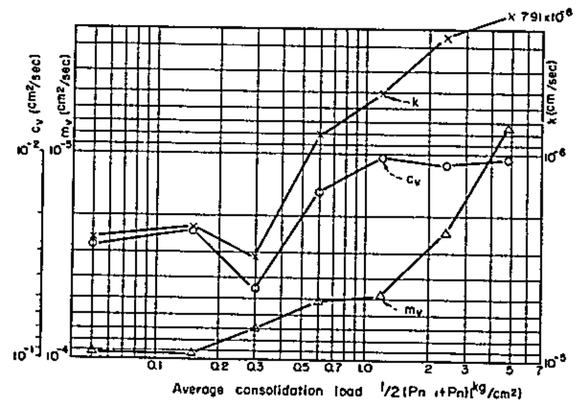
CONSOLIDATION TEST (6)

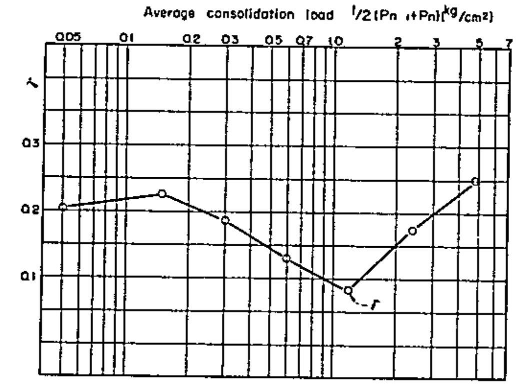












Remarks c_v Coefficient of consolidation
m_v Coefficient of volume compressibility
k Coefficient of permeability
γ Primary compression ratio

Compressive Strength of Core Samples of Silstone
As Tested at the Chuo University Laboratory in Tokyo
on August 17, 1968

Sample	Bore hole	Sampling depth (m)	Compressive strength (kg/cm²)
No. 1	No. 5	7.5 - 7.7	173
No. 2	No. 6	10.45 - 10.60	170
No. 3	NO. 9	7.3 - 7.4	165
Mean			169

Compressive Strength of Core Samples of Siltstone
As Tested at the NEA Laboratory in Bangkok
on April 1, 1968

Bore hole	Sampling depth (m)	Compressive strength (kg/cm²)
No. 1	20	115.3
No. 3	12	126.9

CHAPTER III

MATERIAL SURVEY

3.1. General

There are many kinds of construction materials available in both Laos and Thailand, for instance, cement, timber, brick, laterite, stone, ballast and concrete aggregates.

Common materials such as timber, brick and laterite can be obtained in or around the project area. Cement and ballast, however, cannot be obtained in or around the project area. Cement will probably be supplied from factories in Bangkok, and ballast is available near Sara Buri about 550 kilometers south of the project site. According to the Thai Royal State Railway's information, ballast of good quality will be available in the Boriram and Souren areas about 100 kilometers east of Nakorn Ratchasima, in the Khoa Tham Bhon area located midway between Sara Buri and Boua Yay and in the Loei area about 130 kilometers west of Udon Thani. These sites were not surveyed in the second-phase investigation. It is therefore necessary to select suitable quarries at the next stage/1.

Sandstone outcrops can be found on both banks of the Mekong near Pa Mong. This sandstone is of the late mesozoic era having a medium hardness. It is, however, not suitable for use as railway ballast which generally requires a high hardness against abrasion.

Concrete aggregates and embankment materials can be collected in the vicinity of the bridge site.

3.2. Concrete Aggregates

From a reconnaissance made on the Mekong within a reasonable distance from the bridge site, three promising sand and gravel deposits, shown in Fig.3.1, were found. Site A is located 10.8 kilometers downstream from the bridge site on the Thai side, Site B 6.2 kilometers downstream on the Laotian side, and Site C 6.5 kilometers upstream on the Thai side.

Test samples were taken from these deposits at eleven places shown in Fig.3.1, and fine sand samples were also taken at two sites, indicated as No.12 and No.13 in Fig.3.1, near the bridge end on the Thai side to test their suitability for concrete aggregates.

Tests on grain size, specific gravity, unit weight, water content and organic impurity and decantation tests of the samples as well as compression tests of concrete prepared by mixing the sample sands and gravels were made at the Ministry of Public Works and Transportation laboratory in Vientiane, following the provisions of the Japanese Industrial Standards/2. The test results are summarized in Table 3.1 and are shown in detail in tables and graphs presented in this paragraph.

All samples were found satisfactory in respect of specific gravity, unit weight, water content and

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/1: In estimating the construction cost of the present project, as described in the Feasibility Report Part II, railway ballast was assumed to be supplied by rail from the Sara Buri area.

/2: Abrasion tests were not made because the testing machine was then out of order.

organic impurity. Organic impurity was of so samll a trace as might be totally disregarded. Decantation tests revealed that the percentage of fine particles that passed No.200 screens was less than 3 percent, a practical maximum limit as stipulated in the Japanese Industrial Standards.

In spite of the fact that fine particles that passed No.200 screens accounted for a very small part as noted above, the fineness moduli of most sands were found relatively low, ranging from 2.0 to 2.4. This is because the sands consist more of grains ranging 0.15 to 0.60 millimeter in size than of grains larger than 0.60 millimeters. In some samples, grains between 0.15 and 0.60 millimeters in size amounted to as much as 80 percent.

Therefore, if these sands should be used as fine aggregate of concrete, it is desirable to improve their grading so that the fineness moduli be raised up to 2.6 at the lowest. The sands taken at No.5 and No.11 sites showed fineness moduli of 2.9 and 2.6 to 2.7, respectively, and hence are acceptable. On the contrary, the sands at No.12 and No.13 sites, near the bridge end on the Thai side, showed a fineness modulus of about 0.9.

The maximum grain size was about 60 millimeters in the samples taken at Site A, about 20 millimeters at Site B and about 45 millimeters at Site C. The gravels at Sites A and C are acceptable as coarse aggregate of concrete, but the gravel at Site B is too fine to be used for ordinary concrete structures. The gravels at Sites A and C showed that the grain-size grading curves were within the accepatable limits stipulated by the Japanese Industrial Standards, but the grading curves of the gravel from Site B fell beyond the limits. All the samples of sand except Samples No.10 and No.11 also fell out of the limits.

Such being the results, only Site C especially the area where Samples No.10 and No.11 were taken is regarded as satisfactory. If the sand and gravel deposits at Sites A, and B would be used for the production of concrete, the improvement of grading by means of a screening plant or others would be necessary.

The tentative design of the present project calls for about 85,000 cubic meters of sand and gravel for concrete structures and pavements, of which about 55,000 cubic meters shall be supplied on the Thai side and 30,000 cubic meters on the Laotian side. The 55,000 cubic meters required on the Thai side shall preferably be supplied from Site C, because the sand and gravel at this site seem most acceptable as compared with those at Site A or Site B. The 30,000 cubic meters to be used on the Laotian side had better be supplied, instead of from Site B, rather from a sand-bar near Hat Khoueideng about 15 kilometers downstream from Tha Naleng, where the Laotian Ministry of Public Works and Transportation is now making a large-scale digging of sand and gravel with modern equipments.

The aggregate survey made so far has served for grasping an outlook on the supply of fine and coarse aggregates for concrete as well as pavement. It is recommended, however, that a more detailed survey be made on the supply plan of aggregates.

3.3. Embankment Materials

It is most economical in highway construction if embankment materials of good quality are available in the vicinity of the projected route. With this in view, soil samples were taken at six sites, marked S-1 to S-6 in Fig.3.2, lying along three proposed routes of the highway on the Thai side.

The samples were sent to Japan and were subjected to grading tests, consistency tests, compaction tests, shearing strength tests including direct shear tests and triaxial compression tests, and CBR tests. As it was found in the course of testing that all samples have a nature of swelling, swelling tests were supplemented. The test results are summarized in Table 3.10 and are shown in detail in tables and graphs presented in this paragraph.

It was first found from the grading and consistency tests that the sampled soils undergo a conspicuous volume change with the change in moisture content, a characteristic not desirable for subgrades or embankments in highway construction.

Next, the compaction, triaxial compression and CBR tests, made on samples in the state of optimum water content, revealed the following.

(1) A relatively high maximum density can be expected in all samples.
(2) All samples showed high shearing strengths enough for ensuring the stability of embankments less than two or three meters in height.
(3) Excepting Sample No.5 from Site S-5, all samples showed extremely low CBR values. This is due to the nature of the soils to swell when saturated with water, a characteristic not desirable for highway embankments.

As noted above, the tests revealed that the soils around the projected highway routes, from which the samples were taken, are suitable for embankments as far as they remain in the state of optimum water content, but once they would be saturated with water, their strengths will be reduced remarkably.

Therefore, in order to know more about the swelling, tests were made on the following four kinds of samples: (1) Samples, molded in the state of optimum water content, were saturated with water immediately after the molding and after 1-, 7- and 14-day curing in unloaded condition; (2) Samples, molded in the state of optimum water content, were first loaded with surcharge loads of 0.15, 0.30 and 0.45 kg/cm^2, and were saturated with water when the deformation due to the loading would have almost ended (this took in most cases about 24 hours); (3) Soils were mixed with sand of 0.3-millimeter maximum size, the sand being proportioned to 30 and 60 percent in weight of the soil. The mixed samples were molded in the state of optimum water content and were immediately saturated with water in unloaded condition; and (4) Cement, 5 percent in weight of the soil, was mixed into samples. Soil-cement samples were molded in the state of optimum water content and after 1- and 7-day curing in unloaded condition, were saturated with water.

The swelling tests made as described above revealed the following:

(1) Swelling ratios are much higher in unloaded condition than in loaded condition; and when soils are saturated with water, shearing strengths all but vanish. These features were observed irrespective of the duration of curing.
(2) In the state after the deformation due to surcharge loads has ended, swelling ratios are very low and shearing strengths are hardly affected by the change in water content.
(3) In the case of sand-mix, swelling ratios cannot be lowered but shearing strengths remain considerably high even if saturated with water.
(4) In the case of the tested soil-cement mix, swelling ratios were remarkably low and shearing strengths remained unchanged.

From the tests and studies made so far, the following can be concluded.

(1) The soil at S-5 seems the most suitable for highway embankments, followed by the soils at S-3 and S-4 in this order. If the soil at S-5, S-3 or S-4 would be used in highway embankments without any stabilizing treatment, a soil layer about one meter thick shall be placed as a surcharge load. Soils at S-1, S-2 and S-6 should not be used in highway embankments.

(2) Roadway shoulders on embankments shlall be treated, for stability, with soil-cement mix or other stabilizing materials such as slaked lime with pozzolana or bituminous materials.

The above conclusions were taken into account in the tentative designs not only of highway embankments but also of railway embankments. The highway cross-section shown in the Feasibility Report Part II was designed following the above conclusion (2). It is desired, however, that a detailed investigation be made on whether embankment materials of good quality might be found in areas not far from the projected highway and railway routes.

Fig. 3.1. RECOMMENDABLE SAND AND GRAVEL DEPOSITS

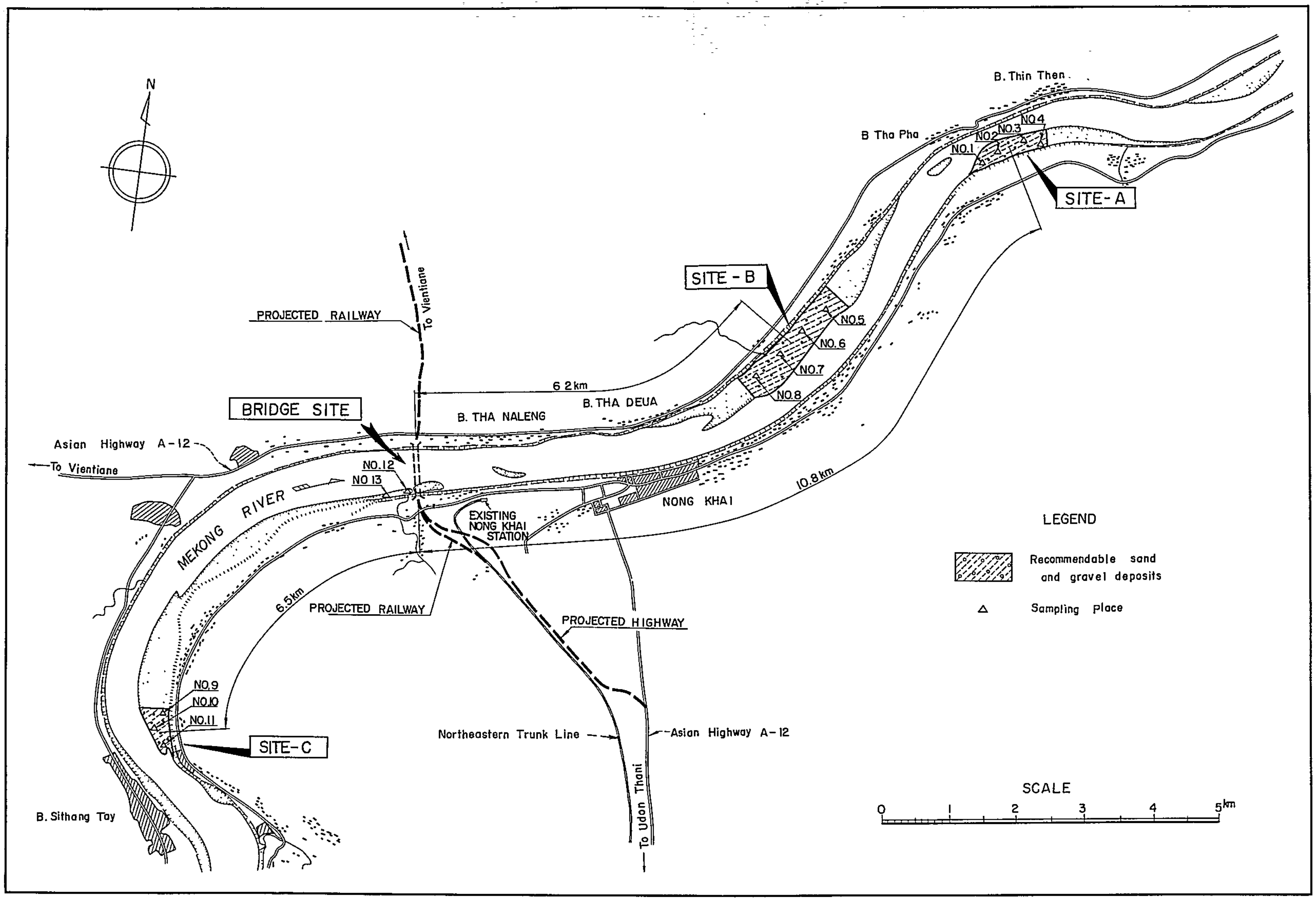


Table 3.1. Concrete Aggregate Tests

Items	Site	A				B				C				Bridge site	
	Sample No.	1	2	3	4	5	6	7	8	9	10	11-1	11-2	12	13
(1) Sand															
	Max. size (mm)	2.7	1.2	1.6	3.0	3.5	2.5	1.3	2.0	1.1	2.2	2.0	2.2	0.3	0.3
	Fineness modulus	2.24	2.05	2.08	2.05	2.90	2.48	2.23	2.45	2.13	2.32	2.60	2.70	0.9	0.9
	Unit weight (kg/m^3)		1610	1660			1560	1660			1710	1720	1710		1630
	Specific gravity		2.63				2.59					2.60	2.60		2.54
	Water content (%)		1.21				1.02					0.81	1.07		2.1
	Particles passing No.200 sieve (%)	0.9			1.0	1.2			0.8	0.6	0.6				
	Organic impurities					Trace				Trace					
(2) Gravel															
	Max. size (mm)	(60)	(60)	(45)	(53)	20	20	20	15	18	40	45	50		
	Fineness modulus	7.73	7.80	7.37	7.82	6.74	6.75	6.70	6.40	6.46	7.49	7.72	7.69		
	Unit weight (kg/m^3)		1730	1850			1740	1740			1820	1870	1870		
	Specific gravity		2.62	2.62			2.58					2.63	2.61		
	Water content (%)		0.48	0.86			1.26					0.62	0.67		
(3) Concrete															
	Slump (cm)	6.5		7.5			7.3				10.5				
	σ_7 (kg/cm^2)	108		–			–				108				
	σ_{28} (kg/cm^2)	–		113			170				176				

Remarks: Design mix for concrete specimen; cement: 250 kg/m^3, water: 150 kg/m^3, gravel: 1380 kg/m^3, sand: 640 kg/m^3, W/C: 60 %

σ_7 : 7-day strength ; σ_{28} : 28-day strength

SAND AT SITE A (1)

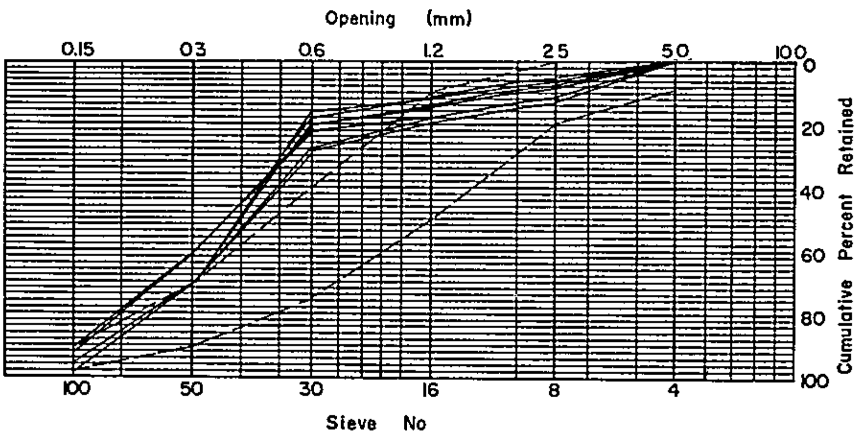
1) SIEVE ANALYSIS

W: Cumulative weight retained (grm)
%: Cumulative percent retained

F.M.: Fineness modulus

Sample No.	1				2			
Weight of sample	516 grms		541.7 grms		516 grms		500 grms	
Sieve No.	W	%	W	%	W	%	W	%
4	0	0	0	0	0	0	0	0
8	71	13.4	63.2	11.7	37	7.2	27	5.4
12	84	15.9	76.4	14.1	43	8.3	34	6.8
16		(19.0)		(18.0)		(11.0)		(10.0)
30	146	27.6	165.2	26.8	79	15.3	86	17.2
50	371	70.1	384.2	71.0	360	69.8	402	80.4
100	499	94.4	513.2	94.9	487	94.5	490	98.0
Passing	529	100.0	541.7	100.0	516	100.0	500	100.0
Max. size	2.7mm		3.0 mm		1.3 mm		1.3 mm	
F.M.	2.25		2.22		1.98		2.11	

Sample No.	3				4			
Weight of sample	504 grms		505 grms		503 grms		495 grms	
Sieve No.	W	%	W	%	W	%	W	%
4	1	0.2	0	0	0	0	0	0
8	42	8.3	44	8.7	66	13.1	67	13.5
12	50	9.9	53	10.5	76	15.1	76	15.4
16		(13.0)		(13.0)		(18.5)		(18.5)
30	98	19.4	96	19.0	110	21.9	113	22.8
50	355	70.5	355	70.4	302	60.0	300	60.6
100	487	96.6	489	96.8	450	89.3	447	90.4
Passing	504	100.0	505	100.0	503	100.0	495	100.0
Max. size	1.8 mm		1.8 mm		2.9 mm		2.9 mm	
F.M.	2.08		2.08		2.03		2.06	



SAND AT SITE A : (2)

2) UNIT WEIGHT

Sample No.		2		3	
Weight of sample	(grm)	3,212	3,226.5	3,319	3,331
Volume of sample	(cm^3)	2,000	2,000	2,000	2,000
Unit weight	(kg/m^3)	1,610	1,610	1,660	1,670

3) SPECIFIC GRAVITY

Sample No.			2	
Weight of sample	(grm)	A =	500	500
Capacity of flask	(cm^3)	B =	500	500
Water added to flask	(cm^3)	C =	311	309
Specific gravity A/(B - C)			2.64	2.62

4) ABSORPTION

Sample No.			2	
Weight, surface dry condition	(grm)	A =	500.0	500.0
Weight, oven dry condition	(grm)	B =	494.2	493.8
Absorption (A - B)/B x 100 (%)			1.17	1.25

5) MATERIAL PASSING No. 200 SIEVE

Sample No.		1		4	
Weight of sample before washing	(grm)	500.0	500.0	500.0	500.0
Weight of sample after washing	(grm)	495.2	496.1	494.3	496.1
Decreased amount	(grm)	4.8	3.9	5.7	3.9
Percentage		0.96	0.78	1.14	0.78

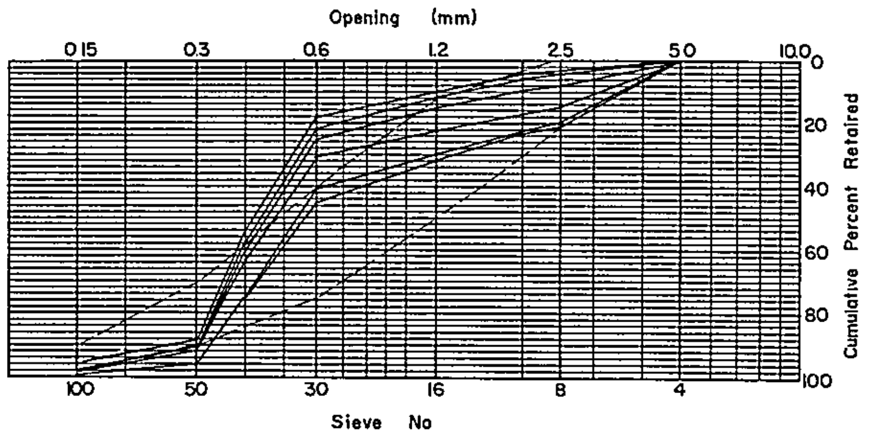
SAND AT SITE B (1)

1) SIEVE ANALYSIS

W: Cumulative weight retained (grm) F.M.: Fineness modulus
%: Cumulative percent retained

Sample No.	5				6			
Weight of sample	500 grms		500 grms		500 grms		500 grms	
Sieve No.	W	%	W	%	W	%	W	%
4	3	0.6	4	0.8	4	0.8	0.5	0.1
8	98	19.6	101	20.2	76	15.2	39.5	7.9
10	112	22.4	113	22.6	84	16.8	46.5	9.3
16		(32.5)		(30.0)		(23.0)		(15.0)
30	226	45.2	203	40.6	152	30.4	117.5	23.5
40	371	74.2	375	75.0	307	61.5	293.5	58.7
50	483	96.6	477	95.5	461	92.2	457.5	91.5
100	499	99.8	495	99.0	491	98.2	487.5	97.5
Passing	500	100.0	500	100.0	500	100.0	500.0	100.0
Max. size	3.5 mm		3.5 mm		1.9 mm		3.2 mm	
F.M.	2.94		2.86		2.60		2.36	

Sample No.	7				8			
Weight of sample	500 grms		500 grms		500 grms		500 grms	
Sieve No.	W	%	W	%	W	%	W	%
4	0	0	1	0.2	0.8	0.2	0	0
8	19	3.8	25	5.0	14.3	2.9	18	3.6
10	22	4.4	30	6.0	109.6	21.9	22	4.4
16		(11.0)		(12.5)		(23.5)		(13.5)
30	91	18.2	105	21.0	127.8	25.6	138	27.6
40	267	53.4	283	56.6	420.8	84.2	437	87.5
50	441	88.2	455	91.0	484.8	97.0	491	98.2
100	479	95.8	492	98.4	488.8	97.8	495	99.0
Passing	500	100.0	500	100.0	500.0	100.0	500	100.0
Max. size	1.2 mm		1.5 mm		2.2 mm		1.5 mm	
F.M.	2.17		2.28		2.47		2.42	



SAND AT SITE B (2)

2) UNIT WEIGHT

Sample No.		6			
Weight of sample	(grm)	3,317.2	3,322.2	3,327.2	3,322.2
Volume of sample	(cm^3)	2,000	2,000	2,000	2,000
Unit weight	(kg/m^3)	1,560	1,560	1,660	1,660

3) SPECIFIC GRAVITY

Sample No.			6	
Weight of sample	(grm)	A =	500	500
Capacity of flask	(cm^3)	B =	500	500
Water added to flask	(cm^3)	C =	306	307
Specific gravity A/(B - C)			2.58	2.59

4) ABSORPTION

Sample No.			6	
Weight, surface dry condition	(grm)	A =	500.0	500.0
Weight, oven dry condition	(grm)	B =	495.2	494.7
Absorption (A - B)/B x 100 (%)			0.97	1.07

5) MATERIAL PASSING NO. 200 SIEVE

Sample No.		5		8	
Weight of sample before washing	(grm)	641.8	570.0	522.6	500.0
Weight of sample after washing	(grm)	634.9	563.0	517.2	497.7
Decreased amount	(grm)	6.9	7.0	5.4	2.3
Percentage		1.1	1.2	1.0	0.5

6) ORGANIC INPURITIES

Sample No.	5
Result	Trace

SAND AT SITE C (1)

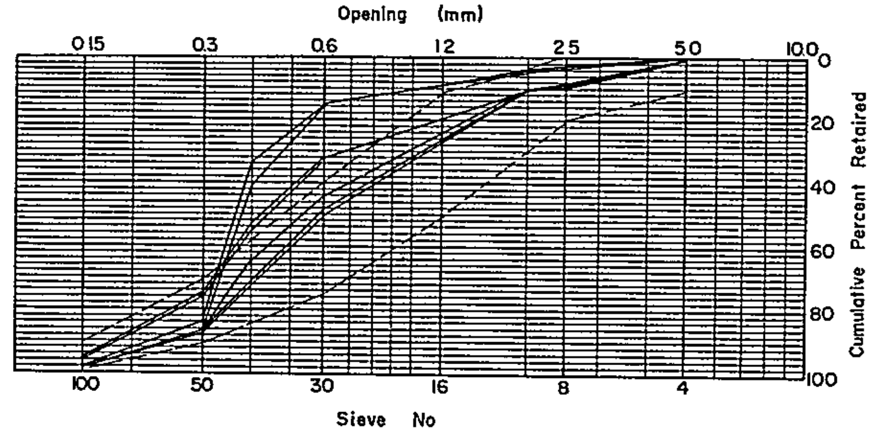
1) SIEVE ANALYSIS

W: Cumulative weight retained (grm)
%: Cumulative percent retained

F.M.: Fineness modulus

Sample No.	9				10			
Weight of sample	500 grms		500 grms		500 grms		500 grms	
Sieve No.	W	%	W	%	W	%	W	%
4	0	0	0	0	0	0	0	0
8	19	3.8	15	3.0	47	9.4	49	9.8
10	23	4.6	20	4.0	55	11.0	58	11.6
16		(9.0)		(9.0)		(20.0)		(20.0)
30	79	15.8	79	15.8	165	33.0	163	32.6
40	164	32.8	200	40.0	272	54.4	263	52.5
50	418.9	83.8	434	86.8	380	76.0	371	74.2
100	498.0	99.6	498	99.6	475	95.0	472	94.4
Passing	500	100.0	500	100.0	500	100.0	500	100.0
Max. size	1.1 mm		1.1 mm		2.3 mm		2.3 mm	
F.M.	2.12		2.14		2.33		2.31	

Sample No.	11 - 1				11 - 2			
Weight of sample	500 grms		500 grms		500 grms		500 grms	
Sieve No.	W	%	W	%	W	%	W	%
4	0	0	0	0	0	0	0	0
8	43	8.6	42.4	8.5	43	8.6	47	9.4
10	51	10.2	50.0	10.0	50	10.0	53	10.6
16		(24.0)		(24.0)		(26.0)		(27.0)
30	217	43.5	217.0	43.4	242	48.4	251	50.2
40	323	64.6	319.0	63.8	354	70.8	356	71.2
50	430	86.0	431.0	86.2	433	86.6	437	87.4
100	490	98.0	489.0	97.8	492	98.4	492	98.4
Passing	500	100.0	500	100.0	500	100.0	500	100.0
Max. size	2.0 mm		2.0 mm		2.0 mm		2.2 mm	
F.M.	2.60		2.60		2.68		2.72	



SAND AT SITE C (2)

2) UNIT WEIGHT

Sample No.	10		11-1		11-2	
Weight of sample (grm)	3,408.2	3,427.3	3,438.2	3,446.2	3,404.2	3,410.2
Volume of sample (cm^3)	2,000	2,000	2,000	2,000	2,000	2,000
Unit weight (kg/m^3)	1,700	1,710	1,720	1,720	1,700	1,710

3) SPECIFIC GRAVITY

Sample No.			11-1		11-2	
Weight of sample	(grm)	A=	500.0	500.0	500.0	500.0
Capacity of flask	(cm^3)	B =	500.0	500.0	500.0	500.0
Water added to flask	(cm^3)	C =	307.5	307.5	308.3	308.3
Specific gravity A/(B - C)			2.60	2.60	2.60	2.60

4) ABSORPTION

Sample No.			11-1		11-2	
Weight, surface dry condition	(grm)	A =	500.0	500.0	500.0	500.0
Weight, oven dry condition	(grm)	B =	496.3	495.7	494.9	494.5
Absorption (A - B)/B x 100 (%)			0.75	0.87	1.03	1.11

5) MATERIAL PASSING NO.200 SIEVE

Sample No.		9 and 10	
Weight of sample before washing	(grm)	502.0	500.7
Weight of sample after washing	(grm)	499.1	497.8
Decreased amount	(grm)	2.9	2.9
Percentage		0.58	0.58

6) ORGANIC INPURITIES

Sample No.	9
Result	Trace

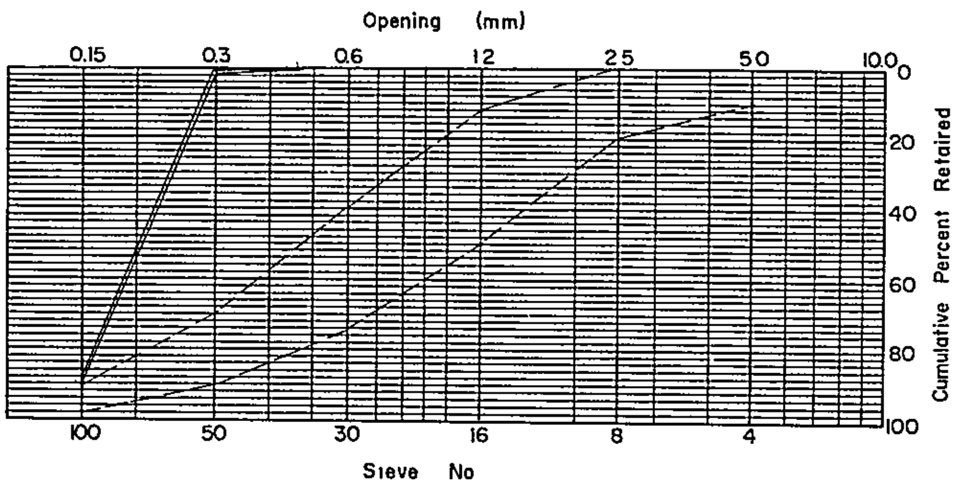
SAND AT BRIDGE SITE (1)

1) SIEVE ANALYSIS

W: Cumulative weight retained (grm)
%: Cumulative percent retained

F. M.: Fineness modulus

Sample No.	12				13			
Weight of sample	494.2 grms		490.5 grms		500.4 grms		500.9 grms	
Sieve No.	W	%	W	%	W	%	W	%
4								
8								
12								
16		(0)		(0)		(0)		
30	0	0	1.7	0.3	0.2	0	0	0
50	2.0	0.4	5.2	1.1	5.7	1.1	5.7	1.1
100	444.4	88.9	439.2	89.6	447.7	89.5	453.7	90.6
Passing	494.2	100.0	490.5	100.0	500.4	100.0	500.9	100.0
Max. size	0.3 mm		0.3 mm		0.3 mm		0.3 mm	
F.M.	0.89		0.91		0.91		0.92	



SAND AT BRIDGE SITE (2)

2) UNIT WEIGHT

Sample No.		12		13	
Weight of sample	(grm)	2,903	2,903	2,925	2,927
Volume of sample	(cm^3)	2,000	2,000	2,000	2,000
Unit weight	(kg/m^3)	1,450	1,450	1,460	1,460

3) SPECIFIC GRAVITY

Sample No.				13	
Weight of sample		(grm)	A =	500.0	500.0
Capacity of flask		(cm^3)	B =	500.0	500.0
Water added to flask		(cm^3)	C =	303.2	302.5
Specific gravity	A/(B - C)			2.54	2.53

4) ABSORPTION

Sample No.				13	
Weight, surface dry condition		(grm)	A =	500.0	500.0
Weight, oven dry condition		(grm)	B =	491.9	492.1
Absorption	(A - B)/B	(%)		1.65	1.61

5) MATERIAL PASSING NO.200 SIEVE

Sample No.		13	
Weight of sample before washing	(grm)	500.0	500.0
Weight of sample after washing	(grm)	491.3	487.7
Decreased amount	(grm)	8.7	12.3
Percentage		1.74	2.46

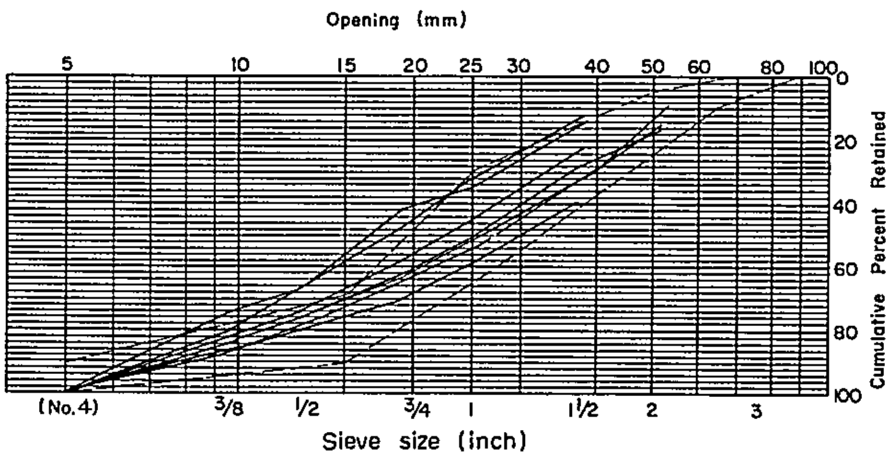
GRAVEL AT SITE A (1)

1) SIEVE ANALYSIS

W: Cumulative weight retained (grm) F.M.: Fineness modulus
%: Cumulative percent retained

Sample No.	1				2			
Weight of sample	21,515 grms		21,464 grms		4,855 grms		6,302 grms	
Sieve size unit	W	%	W	%	W	%	W	%
2	3,680	17.1	3,675	17.1				
1-1/2	6,008	27.9	5,999	27.9	1,114	23.0	2,433	38.6
1	11,150	51.8	11,090	51.6	2,238	46.1	3,762	59.7
3/4	13,437	62.5	13,337	62.1	2,808	57.9	4,449	70.6
1/2			16,067	74.8	3,553	73.2	5,076	80.5
3/8	17,887	83.0	17,874	83.3	3,981	82.1	5,457	86.6
No. 4	21,515	100.0	21,464	100.0	4,855	100.0	6,302	100.0
Max. size	(60 mm)		(60 mm)		(55 mm)		(70 mm)	
F.M.	7.73		7.73		7.63		7.96	

Sample No.	3				4			
Weight of sample	4,125 grms		5,131 grms		11,831 grms		13,884 grms	
Sieve size (inch)	W	%	W	%	W	%	W	%
2					1,747	14.8	1,566	11.3
1-1/2	542	13.1	820	16.0	3,835	32.4	4,521	32.5
1	1,298	31.5	1,800	35.1	5,940	50.2	7,630	55.0
3/4	1,994	48.4	2,194	42.8	7,370	62.3	9,027	65.0
1/2	2,804	68.0	3,498	68.2	9,080	76.8	11,015	79.3
3/8	3,082	74.8	4,088	79.7	10,052	85.0	12,053	86.7
No. 4	4,125	100.0	5,131	100.0	11,831	100.0	13,884	100.0
Max. size	(45 mm)		(50 mm)		(55 mm)		(50 mm)	
F.M.	7.36		7.38		7.80		7.84	



GRAVEL AT SITE A (2)

2) UNIT WEIGHT

Sample No.		2		3	
Weight of sample	(grm)	18,596	18,585	19,944	19,956
Volume of sample	(cm^3)	10,776	10,776	10,776	10,776
Unit weight	(kg/m^3)	1,730	1,720	1,850	1,850

3) SPECIFIC GRAVITY and ABSORPTION

Sample No.				2		3	
Surface dry condition	Weight in air	(grm)	A =	2,000.0	2,000.0	2,000.0	2,000.0
	Weight in water	(grm)	B =	1,237.5	1,235.0	1,233.0	1,242.5
Weight, oven dry condition		(grm)	C =	1,991.0	1,990.0	1,984.0	1,983.2
Specific gravity	A/(A - B)			2.62	2.61	2.61	2.64
Absorption	(A - C)/C x 100 (%)			0.45	0.50	0.86	0.85

GRAVEL AT SITE B (1)

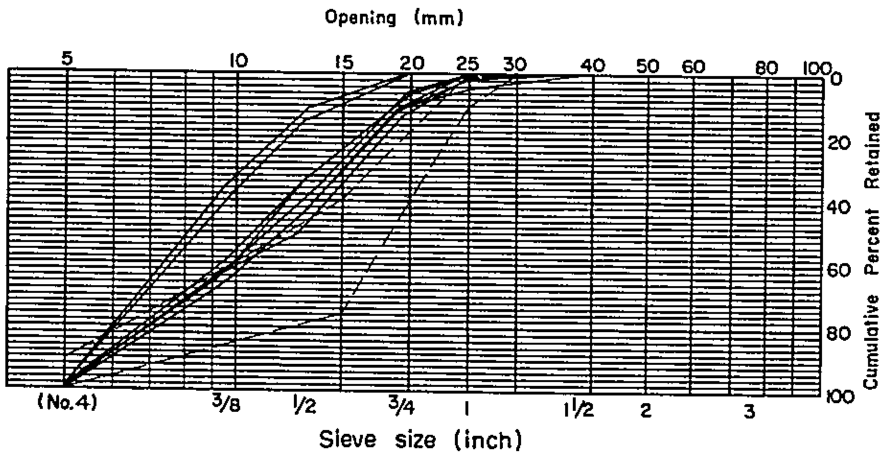
1) SIEVE ANALYSIS

W: Cumulative weight retained (grm)
%: Cumulative percent retained

F.M.: Fineness modulus

Sample No.	5				6			
Weight of sample	5,000 grms		5,000 grms		5,000 grms		5,000 grms	
Sieve size (inch)	W	%	W	%	W	%	W	%
2								
1-1/2	0	0	0	0	0	0	0	0
1	43	0.9	107	2.1	90	1.8	55	1.1
3/4	372	7.4	676	13.5	439	8.8	567	11.4
1/2	2,043	40.8	1,989	39.8	2,259	45.2	2,222	44.5
3/8	3,145	62.9	3,151	63.0	3,152	63.0	3,348	67.0
No. 4	5,000	100.0	5,000	100.0	5,000	100.0	5,000	100.0
Max. size	20 mm		22 mm		20 mm		20 mm	
F.M.	6.70		6.77		6.72		6.78	

Sample No.	7				8			
Weight of sample	4,957 grms		4,912 grms		1,420 grms		1,370 grms	
Sieve size (inch)	W	%	W	%	W	%	W	%
2								
1-1/2	0	0	0	0	0	0	0	0
1	222	4.5	180	3.7	13	0.9	12	0.9
3/4	472	9.5	459	9.3	20	1.4	20	1.5
1/2	1,732	35.0	1,690	34.4	178	12.5	204	14.8
3/8	2,940	59.3	3,041	62.0	527	37.1	559	40.6
No. 4	4,957	100.0	4,912	100.0	1,420	100.0	1,370	100.0
Max. size	20 mm		20 mm		15 mm		15 mm	
F.M.	6.69		6.71		6.38		6.42	



GRAVEL AT SITE B (2)

2) UNIT WEIGHT

Sample No.		6 and 7	
Weight of sample	(grm)	18,726	18,626
Volume of sample	(cm^3)	10,776	10,776
Unit weight	(kg/m^3)	1,740	1,730

3) SPECIFIC GRAVITY and ABSORPTION

Sample No.				6	
Surface dry condition	Weight in air	(grm)	A =	2,106.3	2,052.1
	Weight in water	(grm)	B =	1,288.0	1,256.9
Weight, oven dry condition		(grm)	C =	2,080.6	2,025.9
Specific gravity	A/(A - B)			2.58	2.58
Absorption	(A - C)/C x 100 (%)			1.23	1.28

GRAVEL AT SITE C (1)

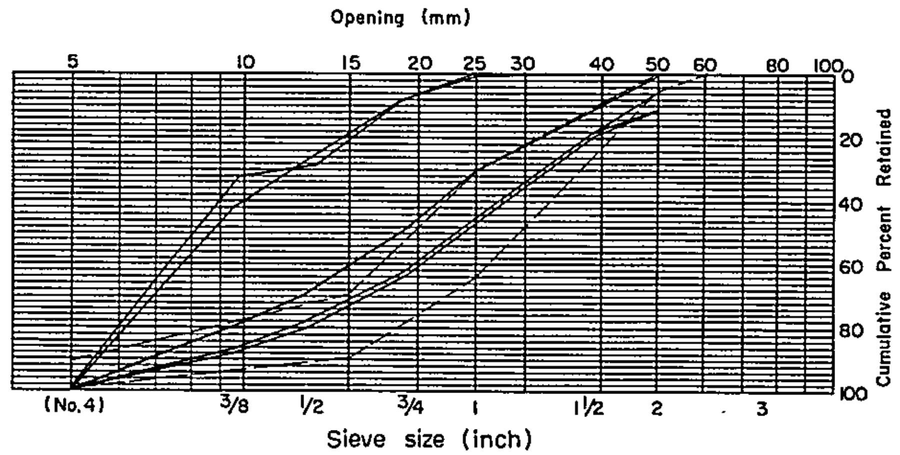
1) SIEVE ANALYSIS

W: Cumulative weight retained (grm)
%: Cumulative percent retained

F.M.: Fineness modulus

Sample No.	9				10			
Weight of sample	2,120 grms		2,120 grms		15,000 grms		15,000 grms	
Sieve size (inch)	W	%	W	%	W	%	W	%
2						(0)		(0)
1-1/2	0	0	0	0	1,645	11.0	1,645	11.0
1	32	1.5	18	0.8	4,570	30.4	4,652	31.0
3/4	166	7.8	173	8.2	7,275	48.5	7,278	48.5
1/2	601	28.3	582	27.5	10,344	69.0	10,338	69.0
3/8	720	34.0	914	43.1	12,088	80.0	12,016	80.1
No. 4	2,120	100.0	2,120	100.0	15,000	100.0	15,000	100.0
Max. size	18 mm		18 mm		40 mm		40 mm	
F.M.	6.42		6.51		7.39		7.40	

Sample No.	11 - 1				11 - 2			
Weight of sample	20,833 grms		20,544 grms		18,841 grms		18,728 grms	
Sieve size (inch)	W	%	W	%	W	%	W	%
2	1,192	5.7	1,192	5.8	2,077	11.0	2,077	11.1
1-1/2	4,250	20.4	4,199	20.4	3,802	20.2	3,632	19.4
1	9,910	47.6	9,647	47.0	8,456	44.9	8,399	44.8
3/4	13,218	63.5	12,996	63.2	11,861	62.9	11,690	62.4
1/2	16,680	80.1	16,458	80.0	14,925	78.2	14.755	78.8
3/8	18,291	87.8	18,160	88.4	16,400	87.0	16,230	86.6
No. 4	20,833	100.0	20,544	100.0	18,841	100.0	18,728	100.0
Max. size	45 mm		45 mm		50 mm		50 mm	
F.M.	7.72		7.72		7.70		7.68	



GRAVEL AT SITE C (2)

2) UNIT WEIGHT

Sample No.		10		11 - 1 and 11 - 2	
Weight of sample	(grm)	19,656	19,656	20,226	20,026
Volume of sample	(grm)	10,776	10,776	10,776	10,776
Unit weight	(kg/m³)	1,820	1,820	1,880	1,860

3) SPECIFIC GRAVITY AND ABSORPTION

Sample No.				11 - 1		11 - 2	
Surface dry condition	Weight in air	(grm)	A =	5,053.5	5,135.0	5,023.3	5,083.9
	Weight in water	(grm)	B =	3,120.4	3,192.5	3,099.1	3,134.5
Weight, oven dry condition		(grm)	C =	5,022.6	5,102.7	4,989.6	5,050.6
Specific gravity	A/(A - B)			2.62	2.64	2.61	2.61
Absorption	(A - C)/C x 100 (%)			0.62	0.63	0.68	0.66

COMPRESSIVE STRENGTH TEST OF CONCRETE

1) DESIGN MIX

Cement:	250 kg/m³	Gravel:	1,380 kg/m³
Water:	150 kg/m³	Sand:	640 kg/m³
W/C:	60 %		

2) RESULTS OF TESTS

Sampling site: Sand	Sampling site: Gravel	Weight (kg)	Apparent density (kg/m³)	Slump (cm)		Compressive strength (kg/cm²)
A	A	13.48	2,550			109
		13.43	2,540	6.5, 6.5	σ_7	104
		13.52	2,550			95
	Mean	13.48	2,550	6.5		103
	A,B,C	13.08	2,470			108
		12.90	2,440			114
		13.05	2,460	7.2, 7.7	σ_{28}	133
		12.91	2,440			107
		12.95	2,440			113
	Mean	12.98	2,450	7.5		113
B	B,C	13.10	2,470			172
		13.14	2,480			169
		12.92	2,440	7.0, 7.5	σ_{28}	172
		12.97	2,450			175
		13.04	2,460			164
	Mean	13.03	2,460	7.3		170
C	C	13.06	2,460			105
		13.45	2,540		σ_7	105
		13.16	2,480			115
					Mean	108
		13.37	2,530	10.1, 10.9		178
		13.34	2,520		σ_{28}	177
		13.40	2,530			176
		13.46	2,540			172
	Mean	13.32	2,510	10.5	Mean	176

Remarks:

1) Specimen size: 15 cm dia. x 30 cm high (V = 5,300 cm³)
2) Cement used: Ordinary Portland cement made in Thailand (Tiger brand)
3) σ_7 : Compressive strength at 7-day age
4) σ_{28} : Compressive strength at 28-day age

Fig.3.2 LOCATION OF SAMPLING PLACES FOR HIGHWAY EMBANKMENT MATERIAL

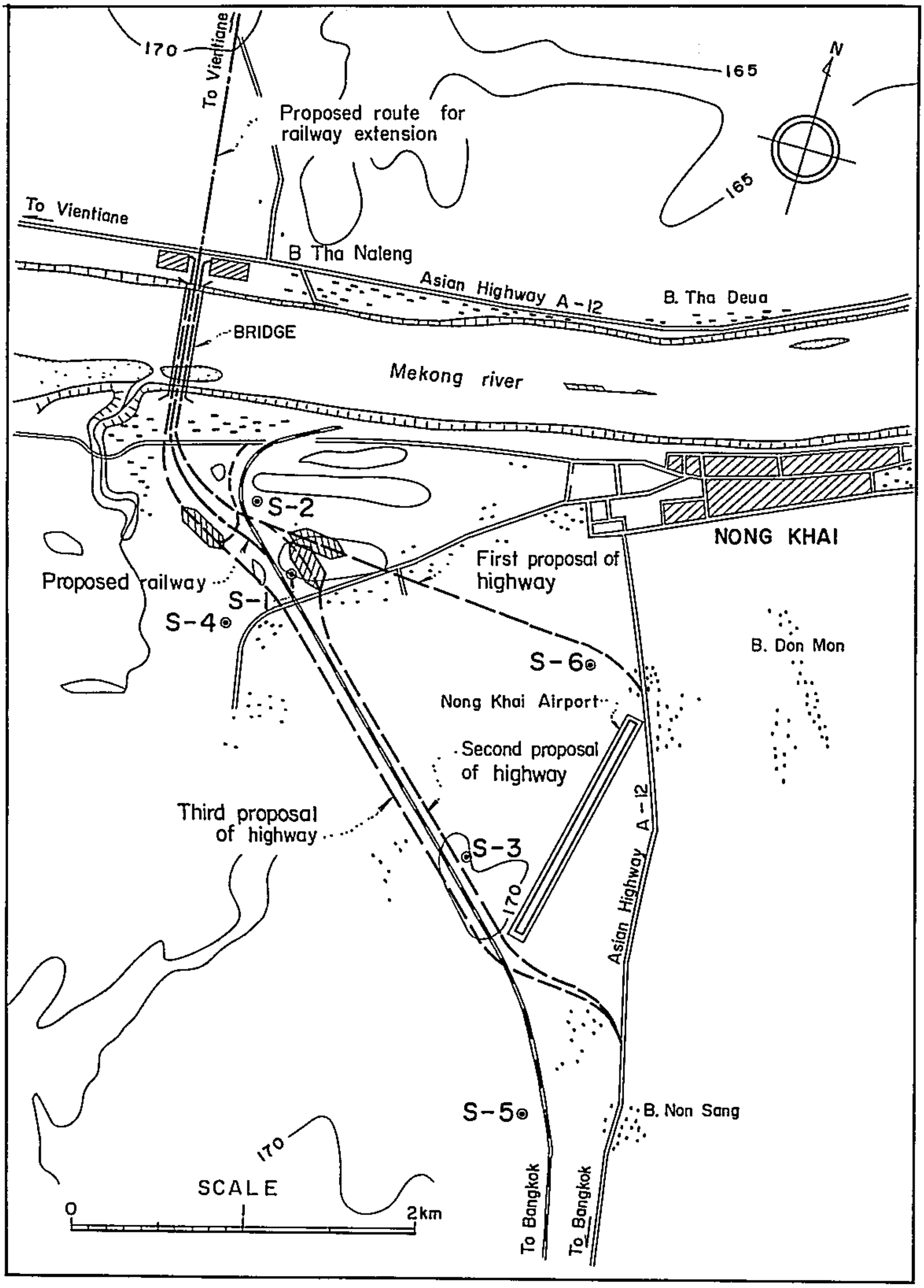


Table 3.2. Summary of Soil Test

Location: Nong Khai

Items	Unit	1	2	3	4	5	6
		Characteristics					
Sample No		1	2	3	4	5	6
I. Observation		Grey brown	Grey brown	Yellow brown	Yellow brown	Yellow brown	Red brown
II Properties							
(1) Natural water contents, W	%	32.20	30.71	9.56	12.41	14.27	14.21
(2) Specific gravity of soil, G		2.73	2.75	2 71	2.70	2.71	2.72
III. Grain size							
(1) Proportion							
i) Gravel part	%	0	0	6.0	0	8.0	0
ii) Sand part	%	0.1	1.0	24.0	5.0	12.0	8.0
iii) Silt part	%	26 9	38.0	38.0	68.0	41.0	58.0
iv) Clay part	%	73.0	61.0	32.0	27.0	39.0	34 0
(2) Maximum diameter	mm	0 105	0.105	4.8	0.42	4.8	0 25
(3) 60% diameter, D_{60}	mm	0 032	0 0049	0.037	0.047	0.04	0.04
(4) Grain size classification		Clay	Clay	Clay	Silty clay loam	Clay	Silty clay
(5) Unified classification		CH	CH	CL	ML or CL	CH	MH or CH
(6) AASHO's classification		A-7	A-7	A-7	A-6	A-7	A-7
IV. Consistency							
(1) Liquid limit, L.L.	%	63.52	56.55	45.20	34.50	50.80	54.70
(2) Plastic limit, P.L.	%	28.32	25.07	16.81	16.04	16.61	16.00
(3) Plasticity index, P.I.		35.20	31.48	28.39	18.46	34.19	38.70
(4) Flow index, F.I.		9.73	13.60	13.12	9.76	13.60	6.80
V. Compaction							
(1) Optimum water contents		17.8	17.7	12.5	13.2	12.0	14.0
(2) Max. density, d_{max}	g/cm^3	1.638	1.750	1.970	1.918	1.896	1.881
VI. Shearing strength							
(1) Triaxial compression							
i) Cohesion, c	kg/cm^2	2.05	1.75	1.10	1.10	1.55 / 2.10	1.75 / 1.75
ii) Internal friction angle, ϕ		33°00′	16°42′	33°01′	19°18′	21°48′ / 33°01′	30°58′ / 16°46′
VII. Consolidation							
(1) Initial void ratio		0.539	0.573	0.383	0.381	0.407 / 0.586	0.335 / 0.398
(2) Preconsolidation load, P_0	kg/cm^2	0.58	0 61	0.35	0.47	0.91 / 0.78	0.69 / 0.60
(3) Compression index, C_c		0.539	0.573	0.383	0.381	0.407 / 0.386	0.335 / 0.398
(4) Coef. of consolidation, C_v	cm^2 /sec	0.58	0.61	0.35	0.47	0.91 / 0.78	0.69 / 0.60
(5) Coef. of volume compressibility, M_v	cm^2/g	0.195	0.196	0.150	0.148	0.086 / 0.083	0.259 / 0.266
(6) Coef. of permeability K	cm/sec	4.4×10^{-3}	1.1×10^{-2}	7.0×10^{-3}	9.8×10^{-3}	1.9×10^{-2} / 1.6×10^{-2}	1.7×10^{-3} / 4.7×10^{-3}
VIII. Modified C.B.R.		1.31		1.14		6.20	0.68
IX. Swelling test							
(1) Case 1							
Curing period							
0 day,							
Swelling ratio	%	22.84		21.34		9.24	58.28
Direct compression, C	kg/cm^2	0.112		0.062		0 17	0 028
ϕ	o	0°55′		2°07′		23°16′	0°24′
τ	kg/cm^2	0.128		0.099		0.60	0.035
1 day,							
Swelling ratio	%	–		12.98		4.31	–
Direct compression, C	kg/cm^2	–		0.26		0.14	–
ϕ	o	–		0°04′		28°49′	–
τ	kg/cm^2	–		0.27		0.69	–
7 days,							
Swelling ratio	%	–		11.10		5.52	–
Direct compression, C	kg/cm^2	–		0.24		0.25	–
ϕ	o	–		3°27′		25°39′	–
τ	kg/cm^2	–		0.30		0.73	–
14 days,							
Swelling ratio	%	–		19.15		11.56	–
Direct compression, C	kg/cm^2	–		0 10		0.24	–
ϕ	o	–		6°17′		20°19′	–
τ	kg/cm^2	–		0.21		0.61	–
(2) Case 2							
Surcharge load							
0.15 kg/cm^2							
Swelling ratio	%	1.50		0.90		-0.79	–
Direct compression, C	kg/cm^2	0.62		0.48		0.20	–
ϕ	o	2°52′		15°39′		31°48′	–
τ	kg/cm^2	0.67		0.76		0.82	–
0.30 kg/cm^2,							
Swelling ratio	%	-0.75		-0 05		-1.39	–
Direct compression, C	kg/cm^2	0.48		0.70		0.57	–
ϕ	o	5°43′		2°52′		18°16′	–
τ	kg/cm^2	0.58		0.75		0.90	–
0.45 kg/cm^2							
Swelling ratio	%	0.76		-0.10		-2.31	–
Direct compression, C	kg/cm^2	0.78		0.52		0.33	–
ϕ	o	7°59′		11°19′		25°11′	–
τ	kg/cm^2	0.92		0.72		0.80	–

VI. Triaxial compression									
i) Cohesion, c	kg/cm²	2.05	1.75	1.10	1.10	1.55	2.10	1.75	1.75
ii) Internal friction angle, ϕ		33°00′	16°42′	33°01′	19°18′	21°48′	33°01′	30°58′	16°46′
VII. Consolidation									
(1) Initial void ratio		0.539	0.573	0.383	0.381	0.407	0.586	0.335	0.398
(2) Preconsolidation load, P_0	kg/cm²	0.58	0.61	0.35	0.47	0.91	0.78	0.69	0.60
(3) Compression index, C_c		0.539	0.573	0.383	0.381	0.407	0.386	0.335	0.398
(4) Coef. of consolidation, C_v	cm² /sec	0.58	0.61	0.35	0.47	0.91	0.78	0.69	0.60
(5) Coef. of volume compressibility, M_v	cm²/g	0.195	0.196	0.150	0.148	0.086	0.083	0.259	0.266
(6) Coef. of permeability K	cm/sec	4.4x10⁻³	1.1x10⁻²	7.0x10⁻³	9.8x10⁻³	1.9x10⁻²	1.6x10⁻²	1.7x10⁻³	4.7x10⁻³

VIII. Modified C.B.R.		1.31	1.14	6.20	0.68
IX. Swelling test					
(1) Case 1					
Curing period					
0 day,					
Swelling ratio	%	22.84	21.34	9.24	58.28
Direct compression, C	kg/cm²	0.112	0.062	0.17	0.028
ϕ	o	0°55′	2°07′	23°16′	0°24′
τ	kg/cm²	0.128	0.099	0.60	0.035
1 day,					
Swelling ratio	%	–	12.98	4.31	–
Direct compression, C	kg/cm²		0.26	0.14	–
ϕ	o	–	0°04′	28°49′	–
τ	kg/cm²	–	0.27	0.69	–
7 days,					
Swelling ratio	%	–	11.10	5.52	–
Direct compression, C	kg/cm²	–	0.24	0.25	–
ϕ	o	–	3°27′	25°39′	–
τ	kg/cm²	–	0.30	0.73	–
14 days,					
Swelling ratio	%	–	19.15	11.56	–
Direct compression, C	kg/cm²	–	0.10	0.24	–
ϕ	o	–	6°17′	20°19′	–
τ	kg/cm²	–	0.21	0.61	–
(2) Case 2					
Surcharge load					
0.15 kg/cm²					
Swelling ratio	%	1.50	0.90	-0.79	–
Direct compression, C	kg/cm²	0.62	0.48	0.20	–
ϕ	o	2°52′	15°39′	31°48′	–
0.30 kg/cm², τ	kg/cm²	0.67	0.76	0.82	–
Swelling ratio	%	-0.75	-0.05	-1.39	–
Direct compression, C	kg/cm²	0.48	0.70	0.57	–
ϕ	o	5°43′	2°52′	18°16′	–
τ	kg/cm²	0.58	0.75	0.90	–
0.45 kg/cm²					
Swelling ratio	%	0.76	-0.10	-2.31	–
Direct compression, C	kg/cm²	0.78	0.52	0.33	–
ϕ	o	7°59′	11°19′	25°11′	–
τ	kg/cm²	0.92	0.72	0.80	–
(3) Case 3					
Mixing ratio					
30 %,					
Swelling ratio	%	–	30.55	16.13	–
Direct compression, C	kg/cm²	–	0.28	0.12	–
ϕ	o	–	21°49′	32°38′	–
τ	kg/cm²	–	0.68	0.76	–
60%,					
Swelling ratio	%	–	27.52	12.34	–
Direct compression, C	kg/cm²	–	0.17	0.15	–
ϕ	o	–	23°17′	31°48′	–
τ	kg/cm²	–	0.60	0.77	–
(4) Case 4					
Curing period					
1 day,					
Swelling ratio	%	–	5.21	0.18	–
Direct compression, C	kg/cm²	–	1.12	3.20	–
ϕ	o	–	33°02′	1°44′	–
τ	kg/cm²	–	1.77	3.23	–
7 days,					
Swelling ratio	%	–	3.55	1.09	–
Direct compression, C	kg/cm²	–	1.60	0.77	–
ϕ	o	–	11°52′	52°49′	–
τ	kg/cm²	–	1.81	2.04	–

Remarks:–

(1) The details of the cases 1,2,3, and 4 in the swelling test are described in Paragraph 2.3, in the Second Phase Report.

(2) In making CBR and swelling tests, the sample No.1 was mixed with the sample No.2, and the sample No.3 with the sample No.4, because of the similar characteristics.

(3) The CBR test was made after the samples were saturated with water for four days.

(4) The specimen that was used for the swelling test was 6 cm in diameter and 2 cm in height.

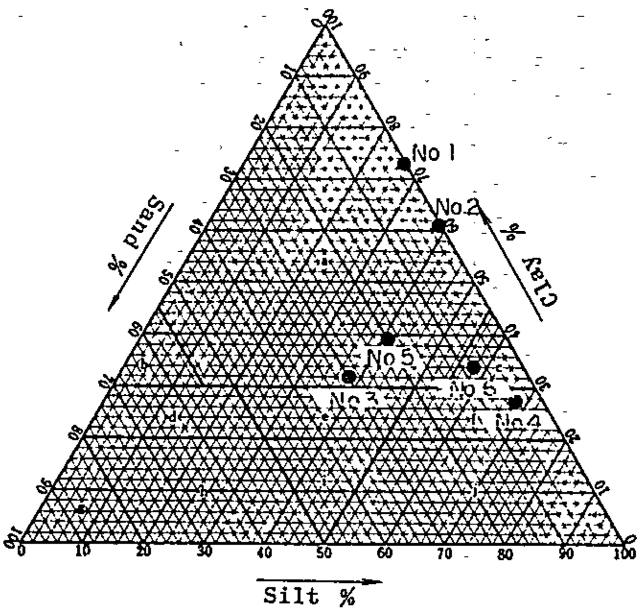
(5) The negative swelling ratio means the compression ratio.

GRAIN SIZE ANALYSIS

Location Nong Khai

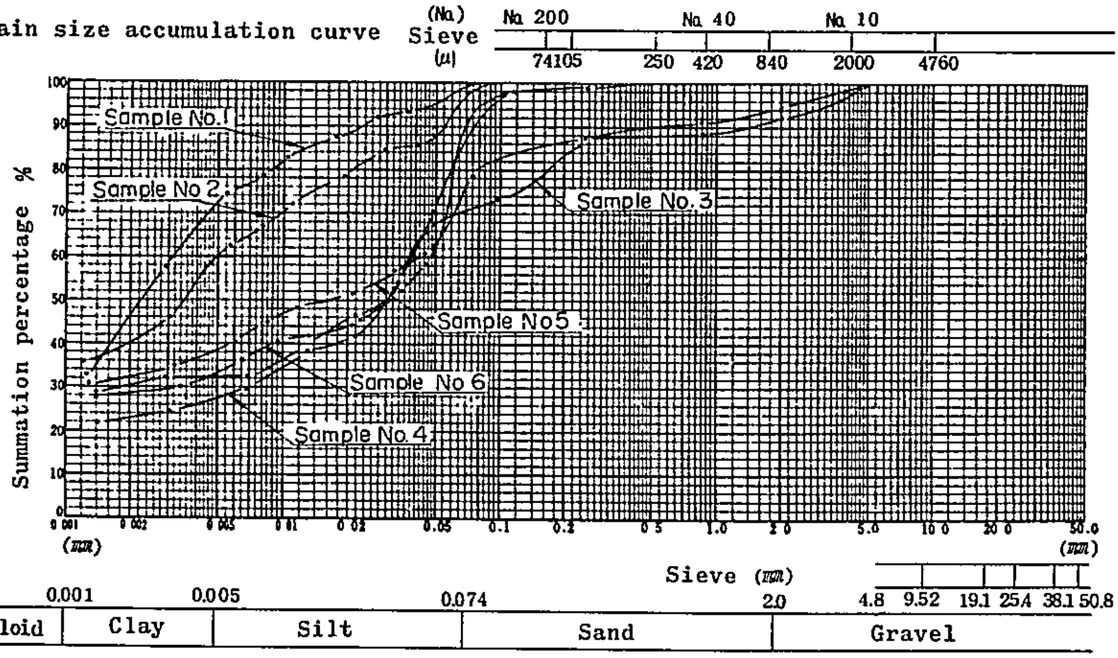
Soil classification by grain size

a CLAY
b SANDY CLAY
c SILTY CLAY
d SANDY CLAY LOAM
e CLAYEY LOAM
f SILTY CLAY LOAM
g SAND
h SANDY LOAM
i LOAM
j SILTY LOAM



Sample No	Gravel %	Sand %	Silt %	Clay %	Max. size mm	D60 mm	D10 mm	Uniformity Coeff	2000μ sieve Passing sample (%)	420μ sieve Passing sample (%)	74μ sieve Passing sample (%)	Sign of Plotted part on triangular diagram	Classification
1	0	0 1	26 9	73	0.105	0.0032	–	–	100	100	99 9	a	CLAY
2	0	1	38	61	0 105	0 0049	–	–	100	100	98 9	a	CLAY
3	6	24	38	32	4 8	0 037	–	–	94 1	90.0	70 2	a	CLAY
4	0	5	68	27	0.42	0.047	–	–	100	100	94 8	f	SILTY CLAY LOAM
5	8	12	41	39	4 8	0.04	–	–	92 2	87 5	79 7	a	CLAY
6	0	8	58	34	0 25	0.04	–	–	100	100	92 1	c	SILTY CLAY

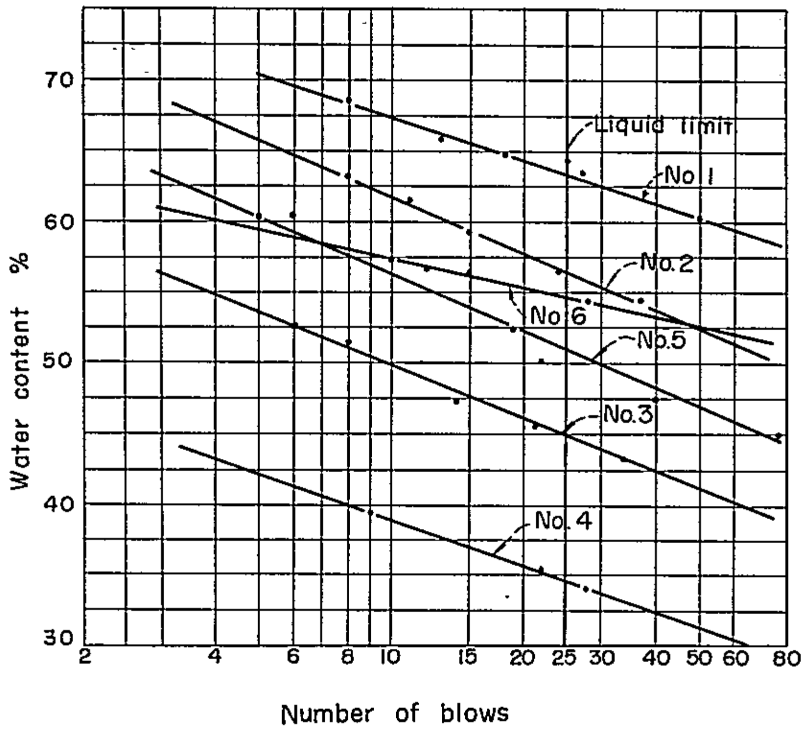
Grain size accumulation curve



Liquid Limit and Plastic Limit Tests

Result of Test

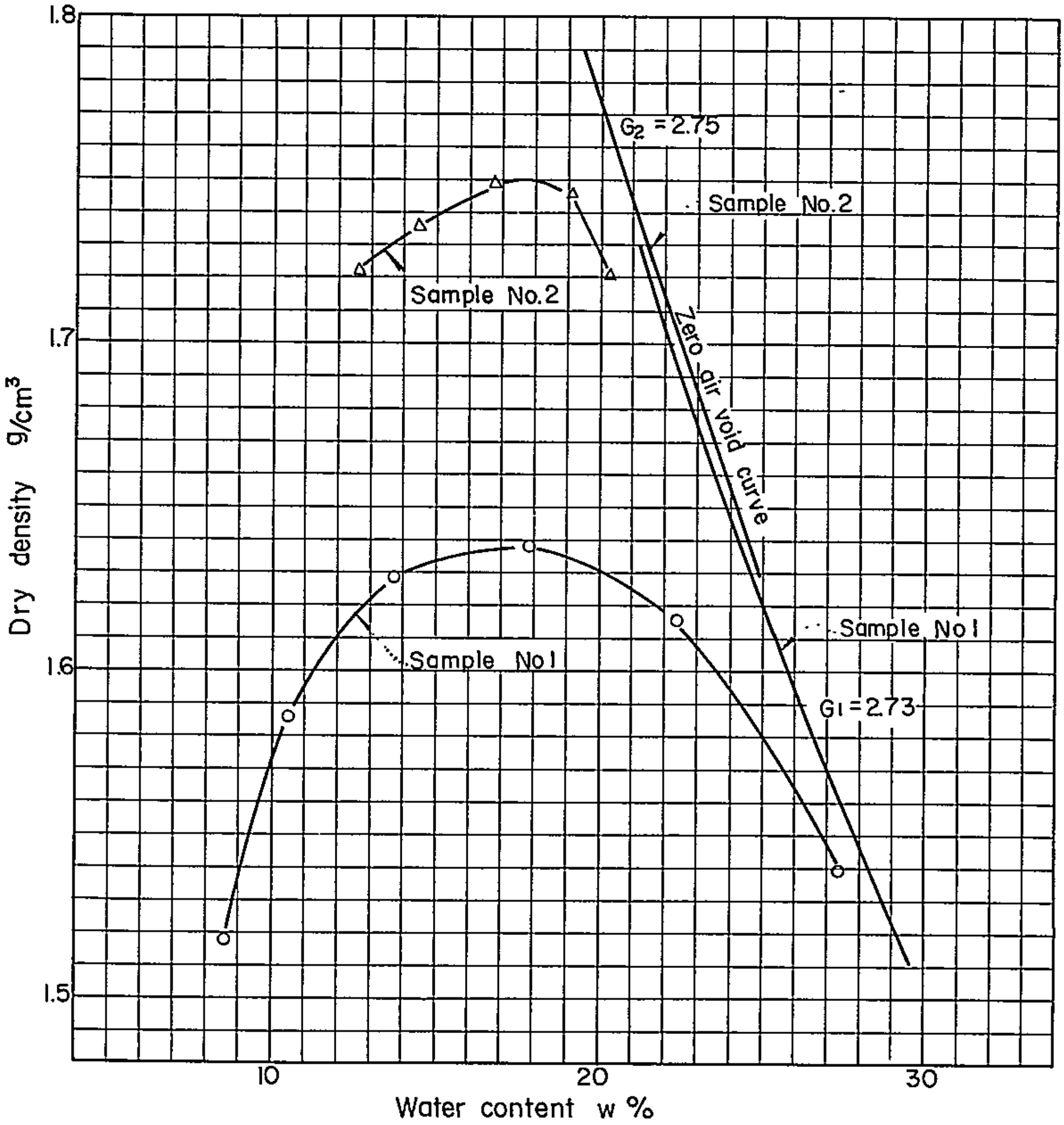
Sample No.	Liquid limit	Plastic limit (1)	Plastic limit (2)	Plastic limit Mean	Plasticity index	Flow index
1	63.52	28.82	27.82	28.32	35.20	9.73
2	56.55	25.08	25.05	25.07	31.48	13.60
3	45.20	16.72	16.90	16.81	28.39	13.12
4	34.50	16.01	16.06	16.04	18.46	9.76
5	50.80	16.71	16.50	16.61	34.19	13.60
6	54.70	16.07	15.93	16.00	38.70	6.80



Remarks: The soil passing 0.4mm sieve was used for the test to decide the liquid and plastic limits.

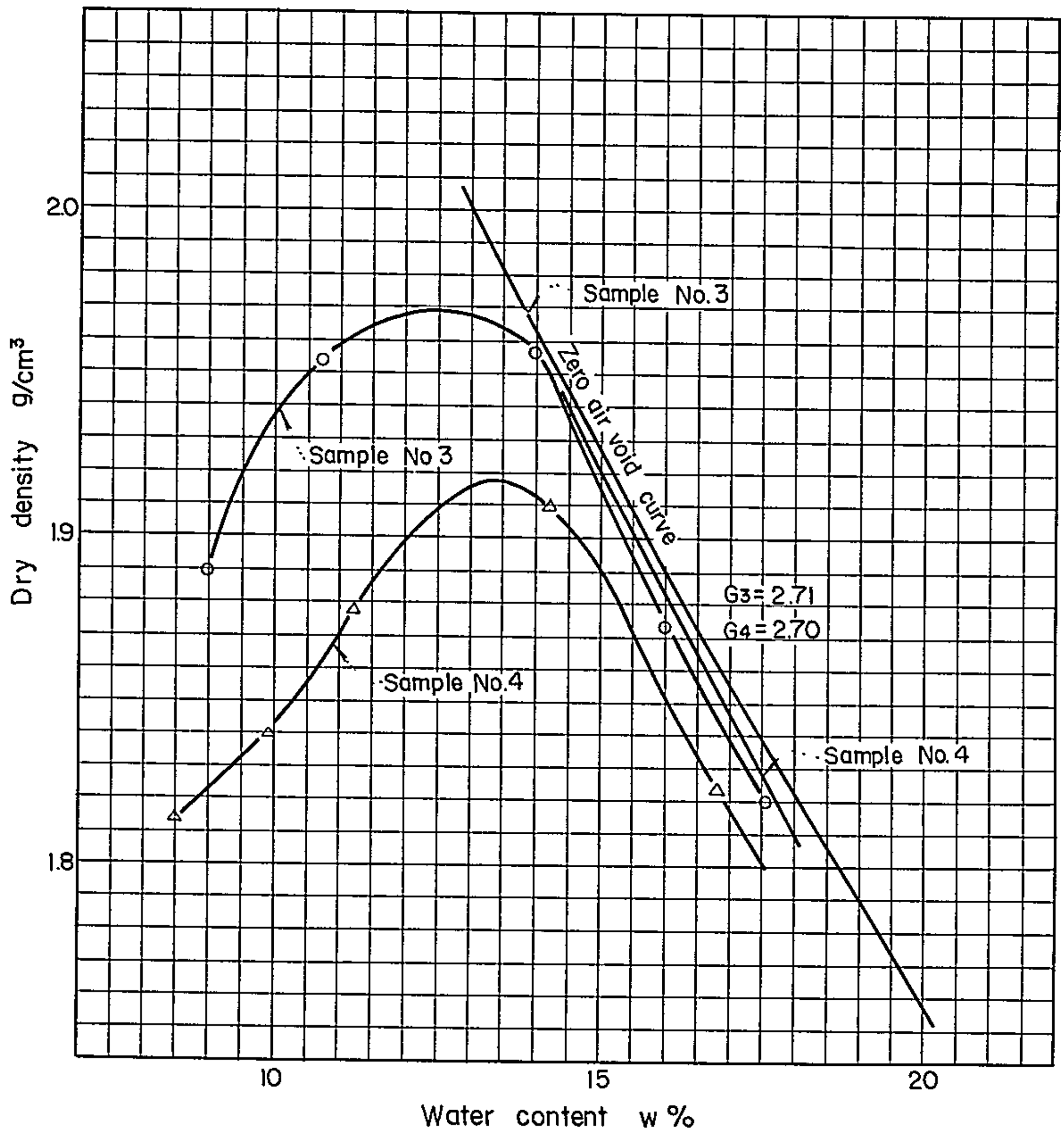
COMPACTION TEST (I)

Sample No.	Optimum water content	Max. dry density
1	17.8 %	1.638 g/cm³
2	17.7	1.750



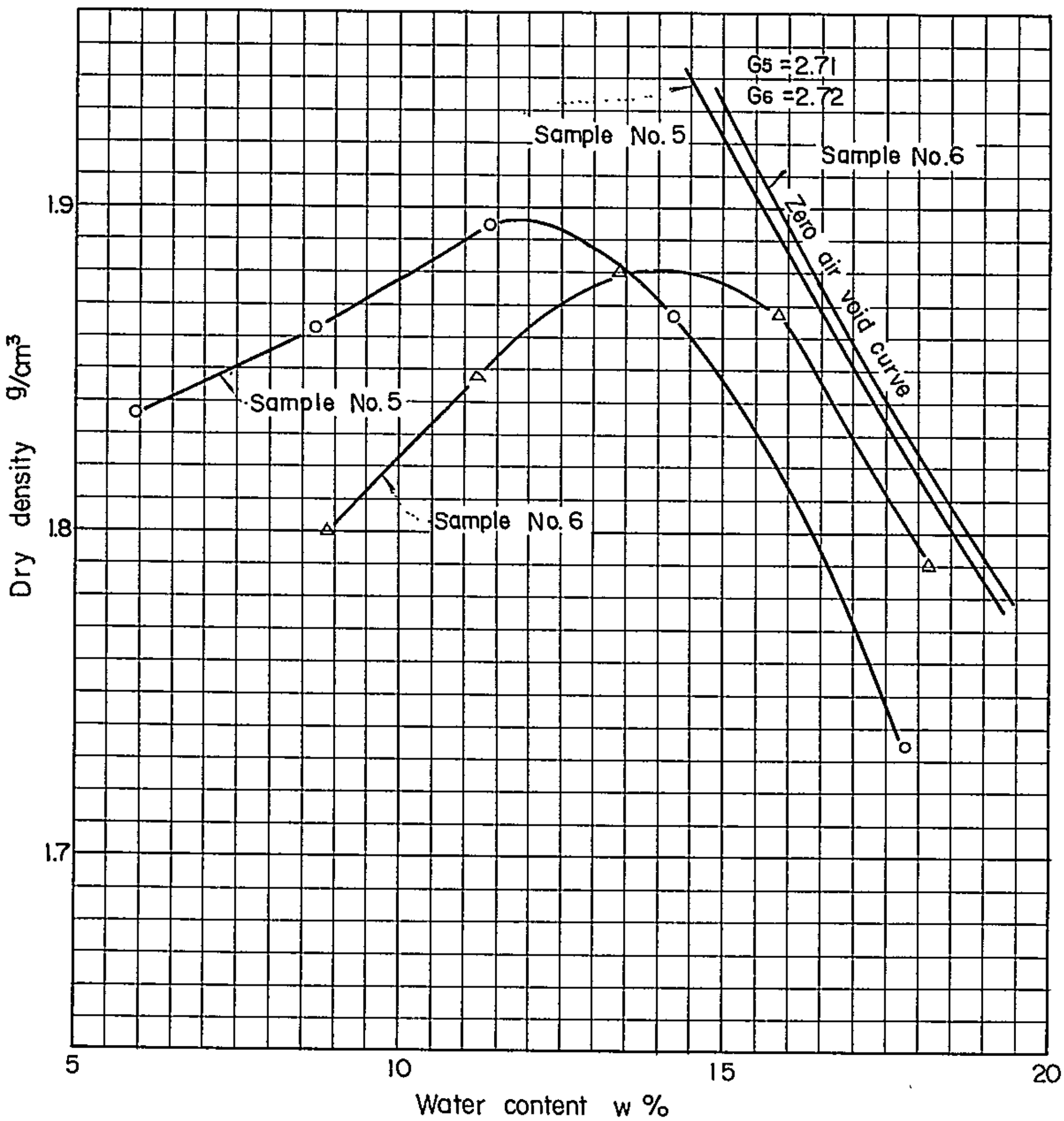
COMPACTION TEST (2)

Sample No.	Optimum water content	Max. dry density
3	12.5 %	1.970 g/cm³
4	13.2	1.918



COMPACTION TEST (3)

Sample No.	Optimum water content	Max. dry density
5	12.0	1.896
6	14.0	1.881



Direct Shear Test

Case No.	Test condition	Sample No.	Dry density (g/cm³)	Normal stress (kg/cm²)	Maximum shear stress (kg/cm²)	Cohesion c (Kg/cm²)	Internal friction angle ϕ	Shearing strength τ (kg/cm²)
(1)	Curring period, 0 day	1 & 2	1.445 1.453 1.428	0.6 1.1 1.1	0.121 0.208 0.129	0.112	0°55′	0.128
		3 & 4	1.559 1.542 1.620	0.6 1.6 2.1	0.0831 0.112 0.140	0.062	2°07′	0.099
		5	1.830 1.725 1.876 1.764	0.6 1.1 1.6 2.1	0.396 0.741 0.869 1.329	0.17	23°16′	0.60
		6	1.222 1.309 1.197	0.1 0.6 1.1	0.0265 0.0542 0.0358	0.028	0°24′	0.035
	Curing period, 1 day	3 & 4	1.734 1.690 1.693	0.6 1.1 1.6	0.269 0.240 0.270	0.26	0°04′	0.27
		5	1.753 1.738 1.817	0.6 1.1 1.6	0.491 0.770 1.039	0.14	28°49′	0.69
	Curing period, 7 days	3 & 4	1.766 1.766 1.648	0.6 1.1 1.6	0.271 0.369 0.332	0.24	3°27′	0.30
		5	1.758 1.776 1.784	0.6 1.1 1.6	0.548 0.782 1.025	0.25	25°39′	0.73
	Curing period, 14 days	3 & 4	1.616 1.587 1.544 1.598	0.6 1.1 1.6 2.1	0.153 0.308 – 0.278	0.1	6°17′	0.21
		5	1.658 1.709 1.691 1.699	0.6 1.1 1.6 2.1	0.494 0.675 1.036 1.217	0.24	20°19′	0.61
(2)	Surcharge load, 0.15 kg/cm²	1 & 2	1.688 1.703 1.722	0.6 1.1 1.6	0.655 0.677 0.960	0.62	2°52′	0.67
		3 & 4	1.958 1.986 1.978	0.6 1.1 1.6	0.634 0.793 1.036	0.48	15°39′	0.76
		5	1.903 1.827 1.922	0.6 1.1 1.6	0.573 0.909 1.216	0.20	31°48′	0.82
	Surcharge load, 0.30 kg/cm²	1 & 2	1.734 1.729 1.713	0.6 1.1 1.6	0.521 0.663 0.633	0.48	5°43′	0.58
		3 & 4	1.992 1.985 1.946	0.6 1.1 1.6	0.729 0.885 0.774	0.70	2°52′	0.75
		5	1.934 1.932 1.928	0.6 1.1 1.6	0.770 0.940 1.104	0.57	18°16′	0.90
	Surcharge load, 0.45 kg/cm²	1 & 2	1.706 1.707 1.741	0.6 1.1 1.6	0.879 0.990 1.020	0.78	7°59′	0.92
		3 & 4	1.965 1.965 1.981	0.6 1.1 1.6	0.659 0.713 0.856	0.52	11°19′	0.72
		5	1.933 1.945 1.971	0.6 1.1 1.6	0.602 0.845 1.121	0.33	25°11′	0.80
(3)	Mixing ratio, 30 %	3 & 4	1.394 1.616 1.600 1.622	0.6 1.1 1.6 2.1	0.480 0.600 1.023 1.140	0.28	21°49′	0.68
		5	1.759 1.800 1.784 1.668	0.6 1.1 1.6 2.1	0.516 0.856 1.157 1.486	0.12	32°38′	0.76
	Mixing ratio, 60 %	3 & 4	1.569 1.581 1.599 1.557	0.6 1.1 1.6 2.1	0.403 0.629 0.891 1.311	0.17	23°17′	0.60
		5	1.687 1.771 1.738 1.710	0.6 1.1 1.6 2.1	0.515 0.847 1.152 1.489	0.15	31°48′	0.77
	Curing period, 1 day	3 & 4	1.900 1.790 1.838	0.6 1.1 2.1	1.526 2.359 2.444	1.12	33°02′	1.77
			[illegible]	[illegible]	[illegible]			

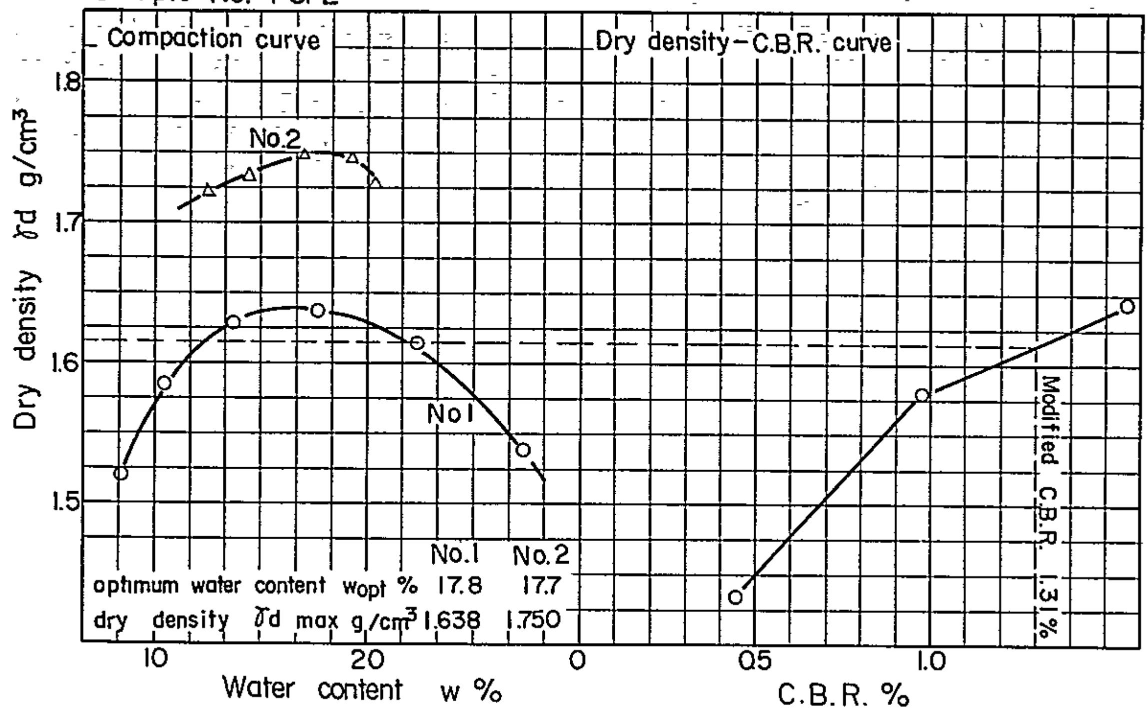
	1 day	5	1.753 1.738 1.817	0.6 1.1 1.6	0.491 0.770 1.039	0.14	28°49′	0.69
	Curing period, 7 days	3 & 4	1.766 1.766 1.648	0.6 1.1 1.6	0.271 0.369 0.332	0.24	3°27′	0.30
		5	1.758 1.776 1.784	0.6 1.1 1.6	0.548 0.782 1.025	0.25	25°39′	0.73
	Curing period, 14 days	3 & 4	1.616 1.587 1.544 1.598	0.6 1.1 1.6 2.1	0.153 0.308 – 0.278	0.1	6°17′	0.21
		5	1.658 1.709 1.691 1.699	0.6 1.1 1.6 2.1	0.494 0.675 1.036 1.217	0.24	20°19′	0.61
(2)	Surcharge load, 0.15 kg/cm²	1 & 2	1.688 1.703 1.722	0.6 1.1 1.6	0.655 0.677 0.960	0.62	2°52′	0.67
		3 & 4	1.958 1.986 1.978	0.6 1.1 1.6	0.634 0.793 1.036	0.48	15°39′	0.76
		5	1.903 1.827 1.922	0.6 1.1 1.6	0.573 0.909 1.216	0.20	31°48′	0.82
	Surcharge load, 0.30 kg/cm²	1 & 2	1.734 1.729 1.713	0.6 1.1 1.6	0.521 0.663 0.633	0.48	5°43′	0.58
		3 & 4	1.992 1.985 1.946	0.6 1.1 1.6	0.729 0.885 0.774	0.70	2°52′	0.75
		5	1.934 1.932 1.928	0.6 1.1 1.6	0.770 0.940 1.104	0.57	18°16′	0.90
	Surcharge load, 0.45 kg/cm²	1 & 2	1.706 1.707 1.741	0.6 1.1 1.6	0.879 0.990 1.020	0.78	7°59′	0.92
		3 & 4	1.965 1.965 1.981	0.6 1.1 1.6	0.659 0.713 0.856	0.52	11°19′	0.72
		5	1.933 1.945 1.971	0.6 1.1 1.6	0.602 0.845 1.121	0.33	25°11′	0.80
(3)	Mixing ratio, 30 %	3 & 4	1.394 1.616 1.600 1.622	0.6 1.1 1.6 2.1	0.480 0.600 1.023 1.140	0.28	21°49′	0.68
		5	1.759 1.800 1.784 1.668	0.6 1.1 1.6 2.1	0.516 0.856 1.157 1.486	0.12	32°38′	0.76
	Mixing ratio, 60 %	3 & 4	1.569 1.581 1.599 1.557	0.6 1.1 1.6 2.1	0.403 0.629 0.891 1.311	0.17	23°17′	0.60
		5	1.687 1.771 1.738 1.710	0.6 1.1 1.6 2.1	0.515 0.847 1.152 1.489	0.15	31°48′	0.77
(4)	Curing period, 1 day	3 & 4	1.900 1.790 1.838	0.6 1.1 2.1	1.526 2.359 2.444	1.12	33°02′	1.77
		5	1.905 1.903 1.900	0.6 1.6 2.1	3.243 3.880 3.268	3.20	1°44′	3.23
	Curing period, 7 days	3 & 4	1.831 1.838 1.977	0.6 1.1 1.6	1.786 1.829 2.753	1.60	11°52′	1.81
		5	1.858 1.838 1.880	0.6 1.1 2.1	1.556 2.210 2 352	0.77	51°49′	2.04

Triaxial Compression Test

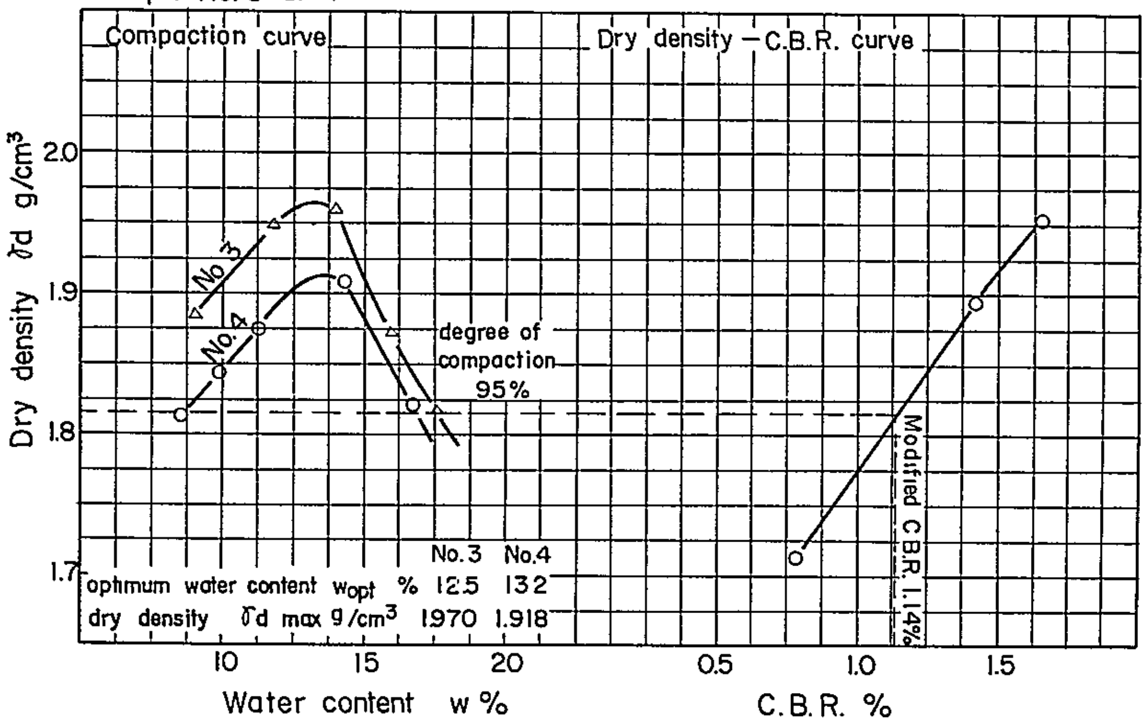
Sample No.	Dry density γ_d (g/cm³)	Lateral pressure σ_3 (kg/cm²)	Max. compression stress σ_1 (kg/cm²)	Cohesion c (kg/cm²)	Internal friction angle ϕ
1 & 2	1.720	0.5	10.48	2.05	35°00'
	1.720	1.0	12.72		
	1.725	1.5	10.88		
	1.715	2.0	14.92		
	1.402	1.0	3.961	1.75	16°42'
	1.398	2.0	6.490		
	1.396	3.0	7.502		
	1.382	4.0	7.734		
3 & 4	1.920	0.5	5.41	1.10	33°01'
	1.927	1.0	10.18		
	1.922	1.5	10.19		
	1.926	2.0	9.17		
	1.600	1.0	4.029	1.10	19°18'
	1.605	2.0	5.226		
	1.603	3.0	6.153		
5	1.903	0.5	9.90	2.10	33°01'
	1.900	1.0	12.19		
	1.901	1.5	11.64		
	1.904	2.0	12.37		
	1.618	1.0	4.703	1.55	21°48'
	1.615	2.0	7.118		
	1.611	3.0	8.263		
6	1.889	0.5	7.64	1.75	30°58'
	1.884	1.0	8.44		
	1.889	1.5	9.83		
	1.881	2.0	14.26		
	1.599	1.0	4.286	1.75	16°42'
	1.606	2.0	6.520		
	1.596	3.0	7.575		
	1.589	4.0	8.444		

C. B. R. TEST

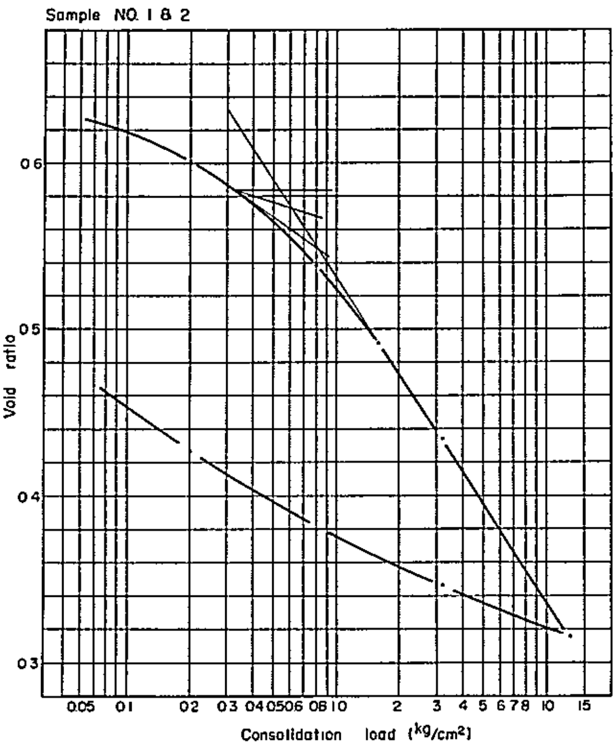
Sample No. 1 & 2

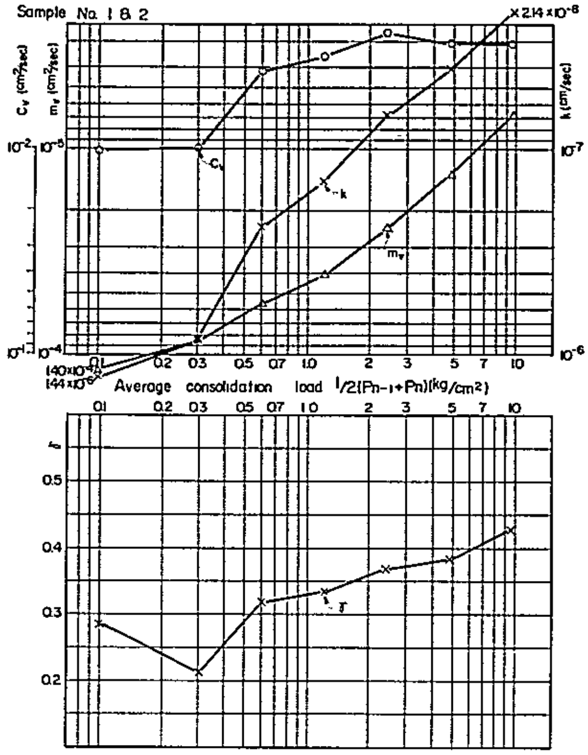


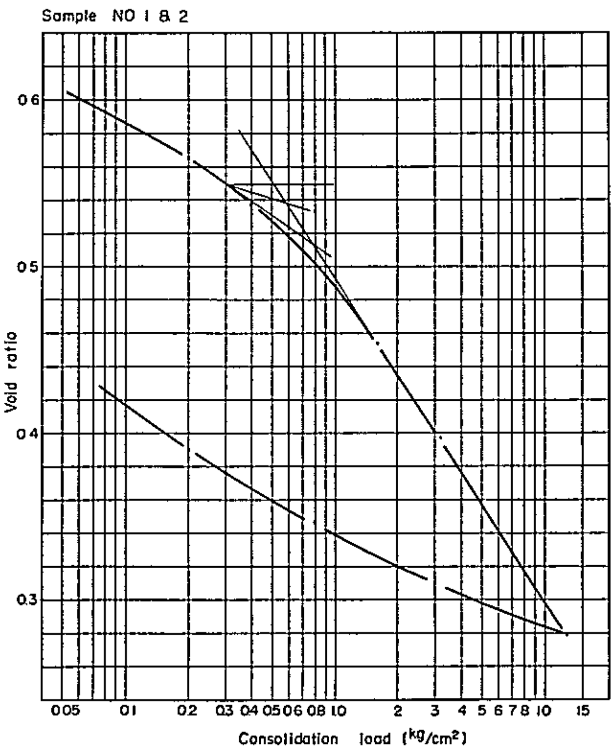
Sample No. 3 & 4

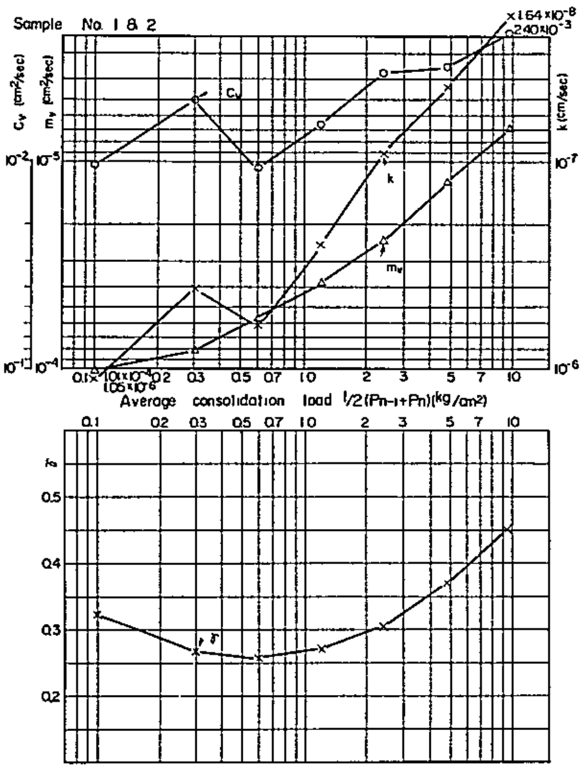


CONSOLIDATION TEST (1)



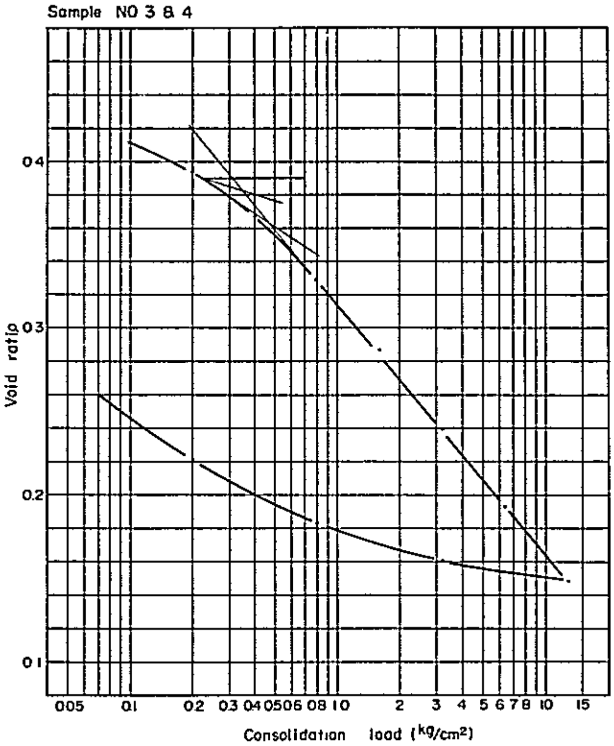


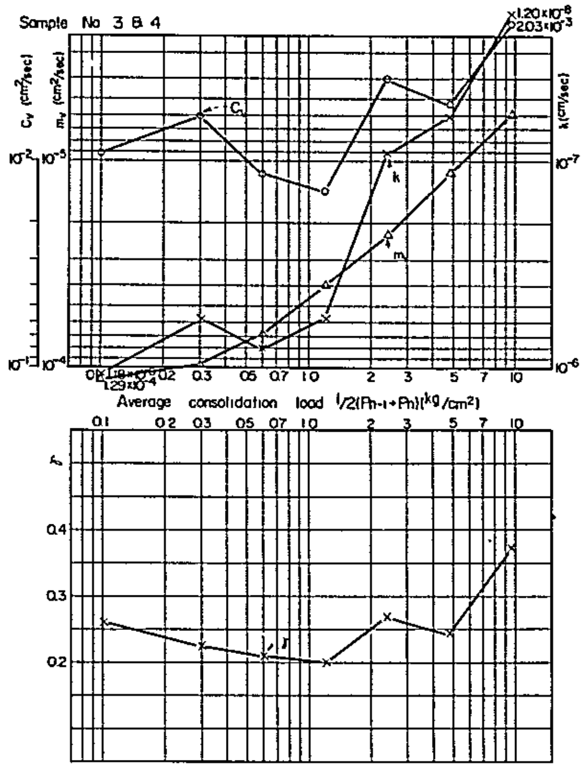


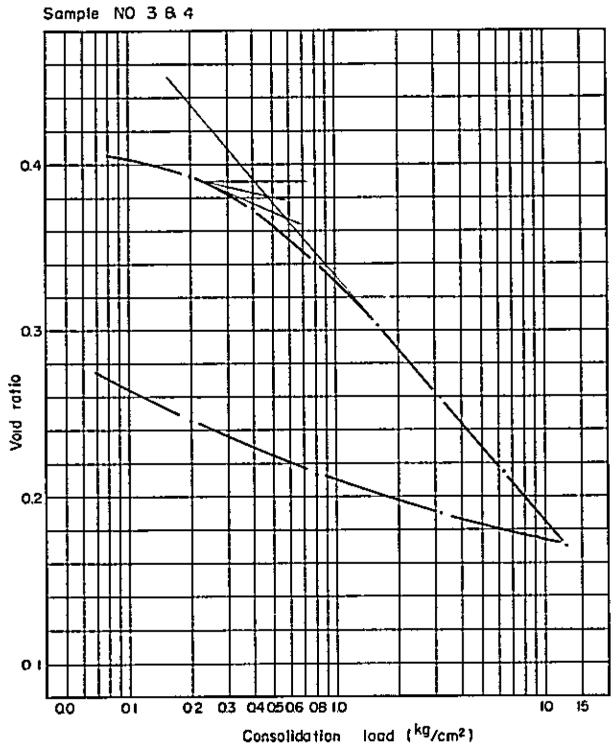


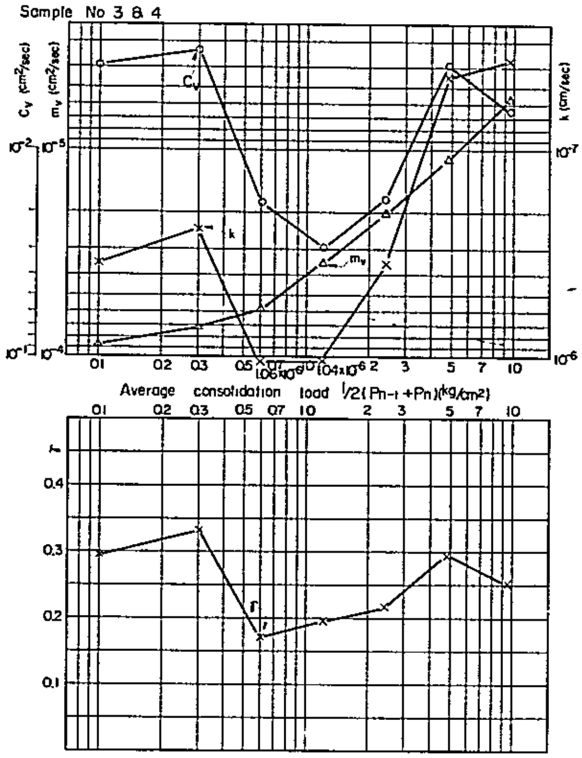
Remarks
- c_v Coefficient of consolidation
- m_v Coefficient of volume compressibility
- k Coefficient of permeability
- r Primary compression ratio

CONSOLIDATION TEST (2)





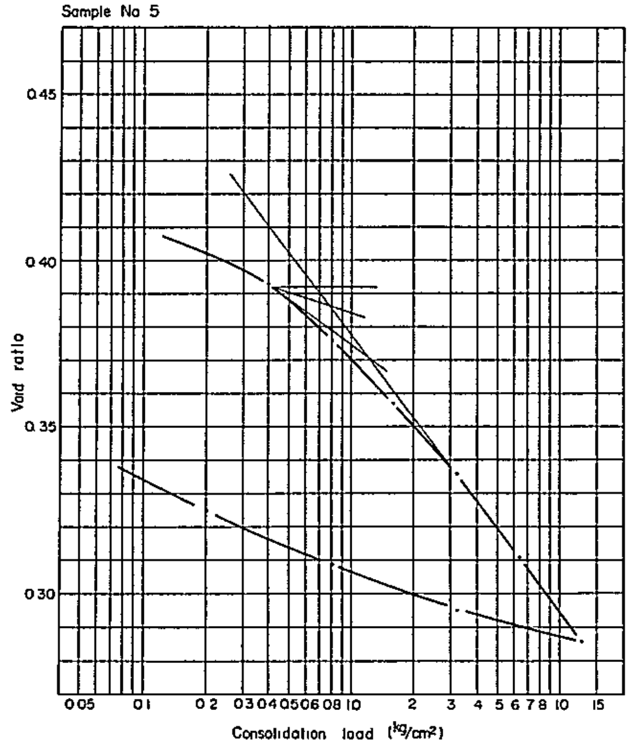




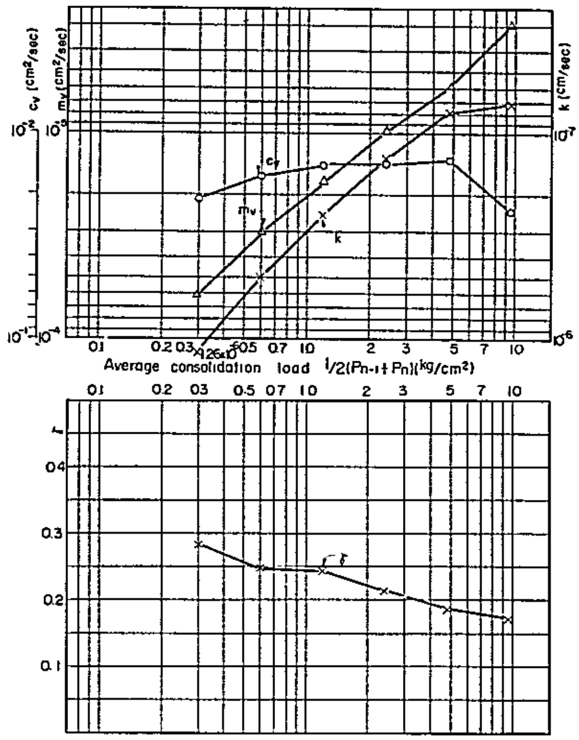
Remarks c_v Coefficient of consolidation
m_v Coefficient of volume compressibility
k Coefficient of permeability
γ Primary compression ratio

CONSOLIDATION TEST (3)

Sample No 5



Sample No 5



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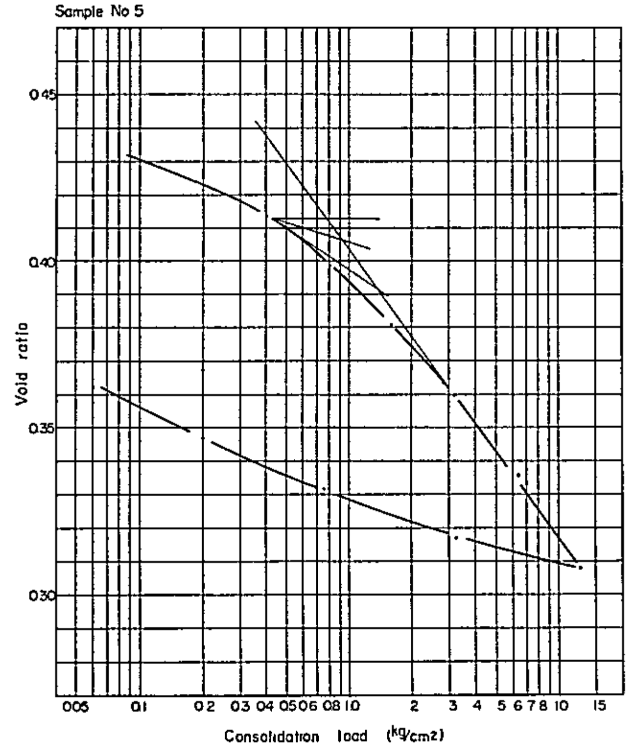
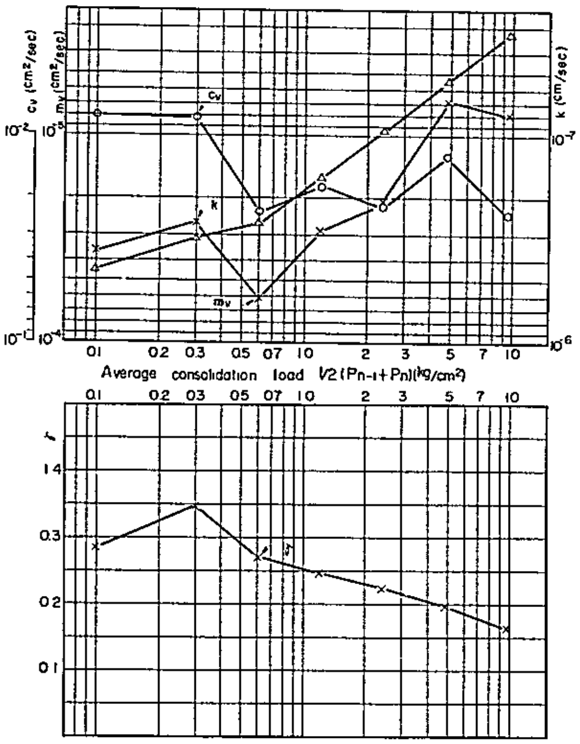


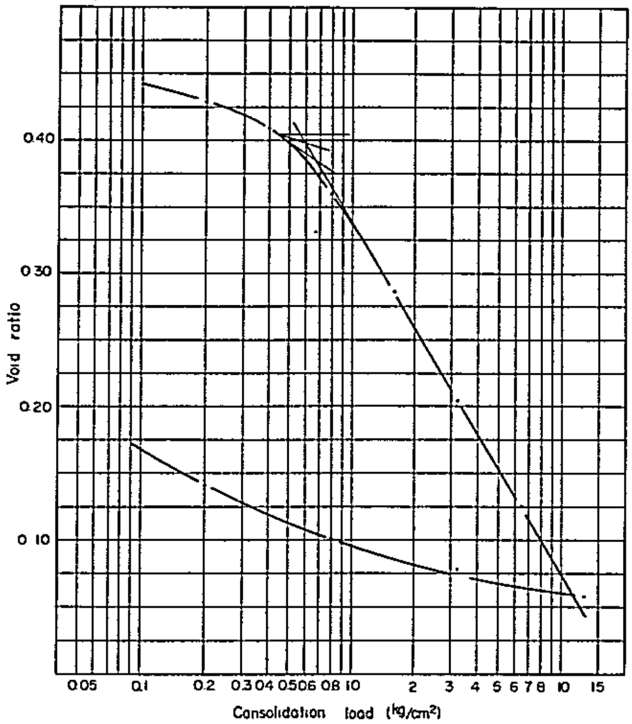
Sample No 5



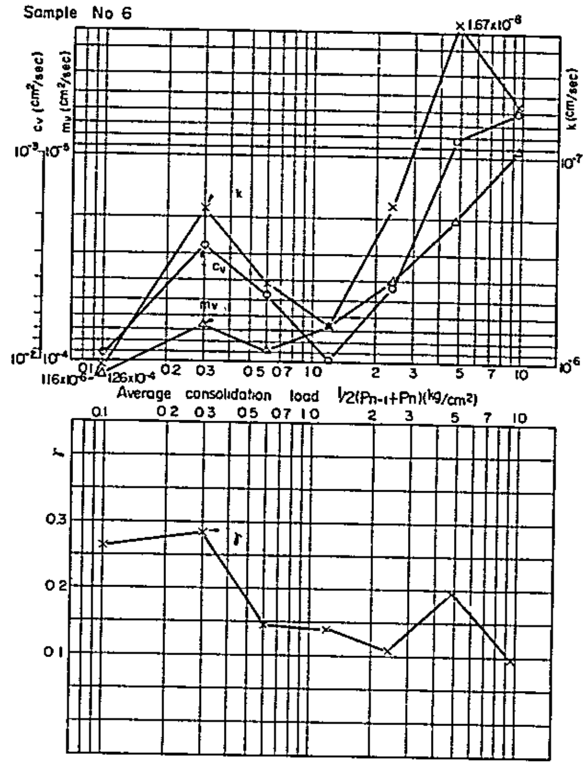
Remarks c_v Coefficient of consolidation
m_v Coefficient of volume compressibility
k Coefficient of permeability
γ Primary compression ratio

CONSOLIDATION TEST (4)

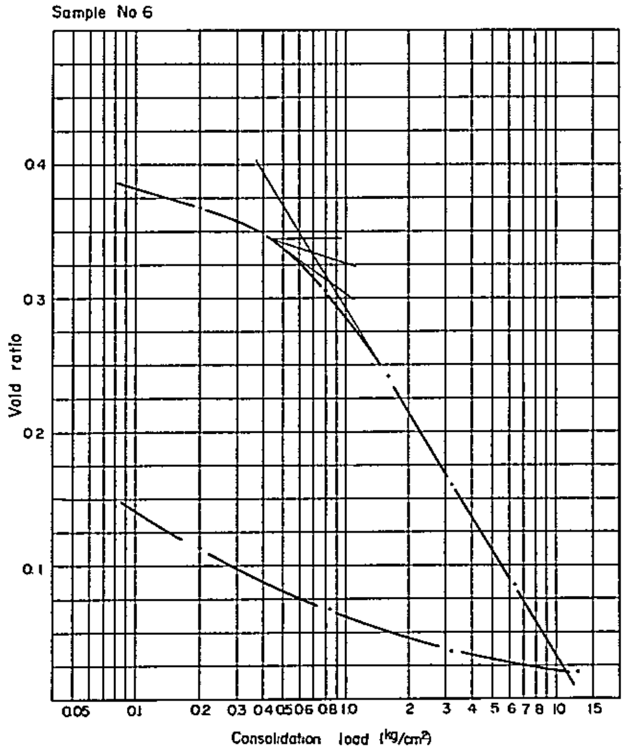
Sample No 6



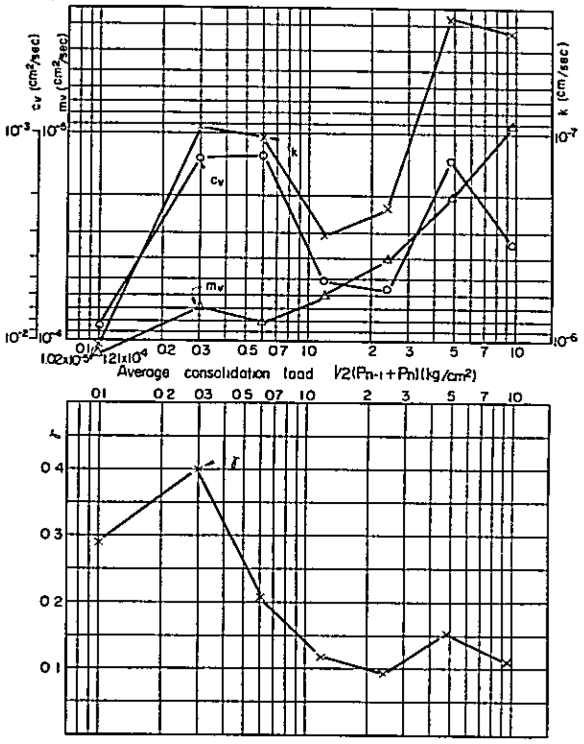
Sample No 6



Sample No 6



Sample No 6



Remarks c_v Coefficient of consolidation
m_v Coefficient of volume compressibility
k Coefficient of permeability
γ Primary compression ratio

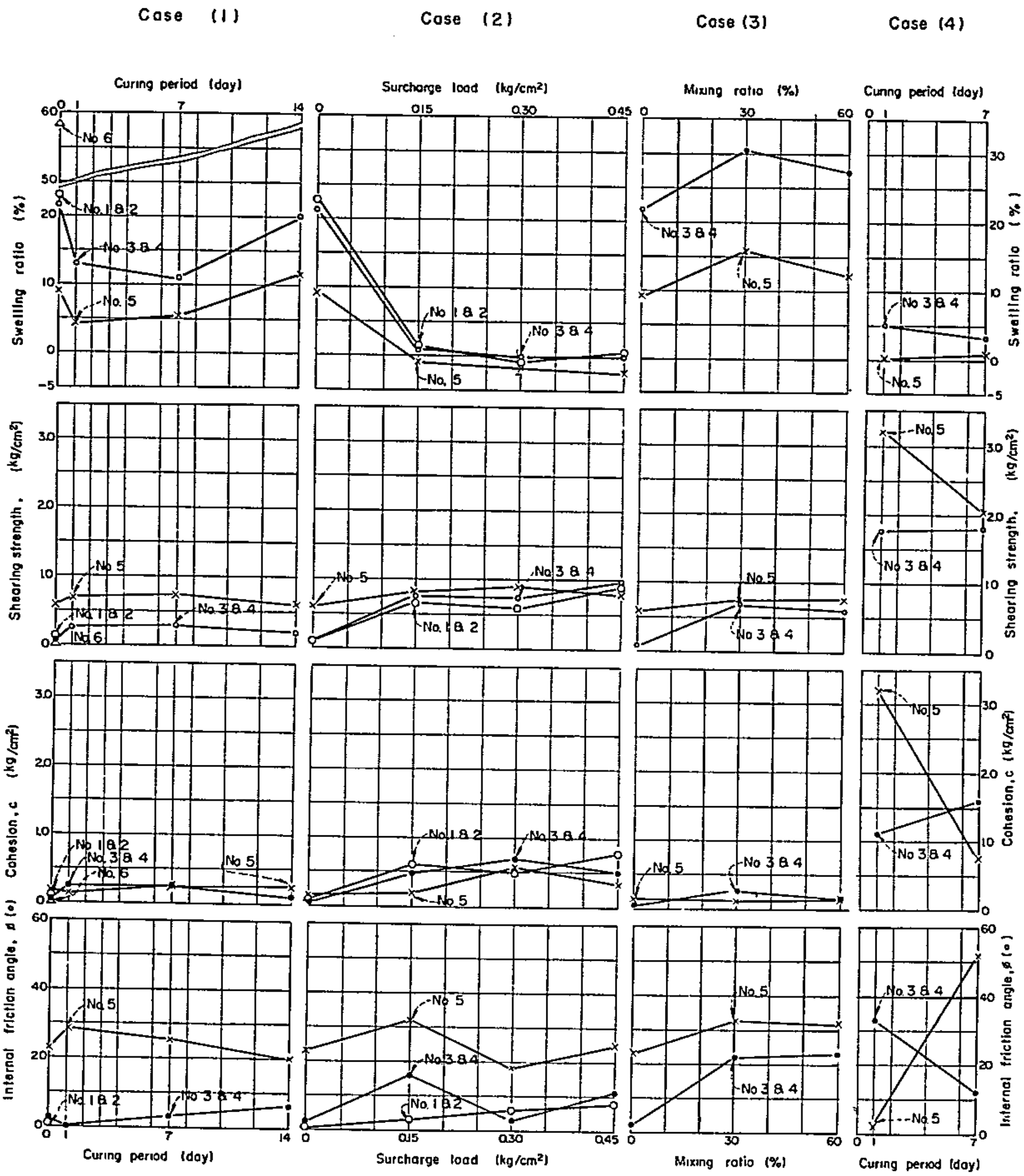
Data 3.16.

Swelling Test (1)

Unit: Percent

		1 & 2				3 & 4					5					6				
		(1)	(2)	(3)	Mean	(1)	(2)	(3)	(4)	Mean	(1)	(2)	(3)	(4)	Mean	(1)	(2)	(3)	(4)	Mean
1. Case (1)																				
Curing period,	0 day	24.26	21.21	23.04	22.84	26 37	24.99	21.43	12.55	21.34	5.05	12.15	6.29	13.45	9.24	47.41	60.27	65.85	59.60	58.28
	1 day	–	–	–	–	11.59	13.29	14.05	–	12.98	4.84	6.33	1.76	–	4.31	–	–	–	–	–
	7 days	–	–	–	–	8.39	9.95	14.97	–	11.10	6.05	5.74	4.77	–	5.52	–	–	–	–	–
	14 days	–	–	–	–	15.56	22.66	21.63	–	19.95	13.09	10.11	11.47	–	11.56	–	–	–	–	–
2. Case (2)																				
Surcharge load,	0.15 kg/cm^2	3.10	1.18	0.16	1.50	2.61	0 13	-0.04	–	0.90	-0.79	-0.77	-0.81	–	-0.79	–	–	–	–	–
	0.30 kg/cm^2	-0.98	-0.91	-0.36	-0 75	-0.03	-0.04	-0 08	–	-0.05	-1.85	-1.38	-0.95	–	-1.39	–	–	–	–	–
	0.45 kg/cm^2	1.31	0.98	-0.02	0.76	-0.07	-0.05	-0.18	–	-0.10	-2.04	-2.36	-2.52	–	-2.31	–	–	–	–	–
3. Case (3)																				
Mixing ratio,	30%	–	–	–	–	33.45	32.90	28.12	27.74	30.55	14.90	16.23	15.89	17.49	16.13	–	–	–	–	–
	60%	–	–	–	–	27.31	27.05	29.61	26.11	27.52	11.12	9.76	13.26	15.22	12.34	–	–	–	–	–
4. Case (4)																				
Curing period,	1 day	–	–	–	–	4.19	10.45	0.14	6 05	5.21	0.11	0.21	0.21	–	0.18	–	–	–	–	–
	7 days	–	–	–	–	4.05	4.19	2 40	–	3.55	0.64	1.19	0.33	1.1	1.09	–	–	–	–	–

SWELLING TEST (2)



Remarks Case (1) The samples were molded in the state of optimum water content and saturated with water after curing for several days at the unloaded condition

Case (2) The samples were molded in the state of optimum water content and saturated with water at the loaded condition after the compressive deformation due to loading was almost completed (generally after 24 hours)

Case (3); The samples were mixed with the sand of 0.3 millimeter in maximum size by 30 percent of the soil sample in weight in the state of optimum water content or by 60 percent of it, and saturated with water at the unloaded condition immediately after molding

Case (4). The samples were mixed with cement by five percent in weight in the state of optimum water content and saturated with water after curing for several days at the unloaded condition

CHAPTER IV

METEOROLOGY

4.1. Meteorological Data of the Project Area

Meteorological data recorded at the Vientiane, Nong Khai and RID meteorological stations, located as shown in Fig. 5.1, were gathered during the first- and second-phase investigations, as listed in Table 4.1. The salient features, analyzed based on the records given in Data 4.1. to 4.5. are summarized in Table 4.2.

Table , 4.1
Meteorological Records Gathered During
the First- and Second-Phase Investigations

Item	Period Covered By the Record		
	Vientiane Station	Nong Khai Station	RID (Nong Khai) Station
Atmospheric Temperature	Jan.'58–Feb. '68*	Mar. '64–Dec. '67	Jan. '65–Apr. '68*
Rainfall	Jan. '58–May '68*	Jan. '64–Dec. '67*	Apr. '55–Apr. '68
Relative Humidity	Jan. '58–Feb. '68*	Mar. '64–Dec. '67	–
Evaporation	Jan. '58–Feb. '68	–	–
Prevailing wind direction and wind velocity	Jan. '59–Apr. '68	Feb. '66–Dec. '67	–

N.B. Records asterisked are not presented in the present report.

Table 4.2 Salient Meteorological Features of the Project Site

(a) Rainfall (At RID Station, Nong Khai, 1958-1967)

Maximum daily rainfall	221.2 mm
Maximum monthly rainfall	727.4 "
Annual rainfall, maximum	1,857.7 "
" mean	1,501.5 "
" minimum	1,157.5 "
Annual rainy days/1, maximum	117 days
" mean	95 "
" minimum	67 "
Annual workable days/2, Maximum	256 "
" mean	235 "
" minimum	205 "

(b) Wind Velocity

Maximum daily-mean wind velocity:

At Nong Khai Station	(1966-1967)	9.5 m/sec
At Vientiane Station	(1959-1968)	26.0 "

(c) Atmospheric Temperature (At Nong Khai Station, 1964 to 1967)

Mean daily-highest	35.0°C
Mean daily-mean	26.6° C
Mean daily-lowest	12.8° C

(d) Relative Humidity (At Nong Khai Station, 1964 to 1967)

Maximum of monthly-maximum	98 %
Mean of monthly-mean	74 %
Minimum of monthly-minimum	45 %

N.B. /1: Excluding rainy days in which the daily rainfall was less than one millimeter.

/2: Excluding the day following a rainy day or the last day of a series of rainy days, a rainy day being defined as noted above.

Data 4.1.

DAILY RAINFALL RECORD (1)

STATION: R.I.D. (Nong Khai)

Unit: mm Annual Total: 1157.5 Year 1958

D \ M	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	M \ D
1									27.6				1
2				3.2	57.6								2
3													3
4					6.9		4.4	19.0					4
5						24.5							5
6					7.4	31.2		16.2	2.8				6
7						3.4	9.0		30.0				7
8							18.0	13.6					8
9							11.5						9
10				10.3				8.1	45.5				10
11					1.4	5.2		17.5	2.6				11
12					4.8	14.6		14.1					12
13					6.7	13.1				4.6			13
14						7.7				14.2			14
15								50.6		6.4			15
16						1.8		2.2					16
17					8.3	52.5			9.5				17
18						8.0		6.4	8.2				18
19						1.5			1.4				19
20							61.2						20
21						10.6	9.0		7.0				21
22					1.5		6.0		2.4				22
23							9.7						23
24					35.3	56.7	11.7						24
25						1.1	2.0	5.5					25
26						40.9							26
27						62.6		34.6					27
28							7.8	70.0					28
29							85.0						29
30					1.8		12.5						30
31								9.1					31
Max				10.3	57.6	62.6	85.0	70.0	45.5	14.2			Max
Days				2	10	16	13	13	10	3			Days
Total				13.5	131.7	335.4	247.8	266.9	137.0	25.2			Total

DAILY RAINFALL RECORD (2)

STATION: R.I.D. (Nong Khai)

Unit: mm Annual total: 1607.2 Year 1959

D \ M	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	M \ D
1						2.9			7.7				1
2						9.3	7.3	12.1	5.9				2
3		4.3					9.0	3.6					3
4								4.6	34.0				4
5		0.7			2.0		2.6		23.1				5
6									116.5				6
7									10.0				7
8							3.0		122.2				8
9								3.7	60.5				9
10			0.5		12.8		82.4		132.3				10
11							19.2						11
12			0.2				20.3		67.2				12
13									26.8				13
14									25.4				14
15					1.0				16.0				15
16				26.3		0.8	11.0	40.0					16
17					46.8	11.8		18.0					17
18							10.1	1.3	6.7				18
19			0.8				7.3	12.6					19
20							2.2	0.9	57.4				20
21					5.0		2.9	40.7					21
22			5.6	27.6	43.5	7.8			3.9				22
23				9.2	10.9	10.0		1.5					23
24					21.5	0.3	13.9	25.6	3.6				24
25							2.2	7.8	8.2				25
26			2.8					3.2					26
27			1.3		20.5	16.6	34.5	11.8					27
28						23.7	9.7	44.5					28
29							1.1	8.1					29
30							59.0						30
31					15.6								31
Max		4.3	5.6	27.6	46.8	23.7	82.4	44.5	132.3				Max
Days		2	6	3	9	9	18	17	18				Days
Total		5.0	11.2	63.1	179.6	83.2	297.7	240.0	727.4				Total

DAILY RAINFALL RECORD (3)

STATION: R.I.D. (Nong Khai)

Unit: mm　　Annual total: 1616.5　　Year 1960

D \ M	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	M / D
1		3.4			3.0		1.7			4.3			1
2								3.2		1.8			2
3					12.5	62.0	53.1	42.1	0.2				3
4						9.0	10.1		8.5				4
5						0.6			4.2				5
6								5.4	11:8				6
7								23.0	54.0				7
8					4.9			34.0	152.8				8
9						12.1		38.7	19.4				9
10					19.1				2.5				10
11		4.6				2.0	18.4	2.0	20.5				11
12		4.4	8.3				20.0	3.5					12
13							4.0	25.1		18.3			13
14								14.5	45.2	8.5			14
15					3.1	1.3	15.2						15
16						0.7	13.5	4.9		3.5			16
17					1.4			8.1					17
18					3.8			52.7					18
19								66.7	13.1				19
20					39.4		17.5	14.1		23.0			20
21					3.7	8.7							21
22			7.0		20.3		26.2	44.6	4.8				22
23					13.3		1.5	2.0	26.3				23
24				4.2	17.0	5.8	16.9	58.2	5.5				24
25		3.0	2.4				27.7	3.2	11.8				25
26		1.0				1.3		3.0	8.9				26
27			34.7						31.6				27
28						8.1		3.8	9.3				28
29				14.3			35.6	0.5	12.6				29
30						1.3		24.9					30
31							23.1	9.7					31
Max		4.6	34.7	14.3	39.4	62.0	53.1	66.7	152.8	23.0			Max
Days		5	4	2	12	12	15	24	19	6			Days
Total		16.4	52.4	18.5	141.5	112.9	284.5	487.9	443.0	59.4			Total

DAILY RAINFALL RECORD (4)

STATION: R.I.D. (Nong Khai)

Unit: mm　　Annual total: 1686.5　　Year: 1961

D \ M	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	M / D
1			11.4				2.2		15.7	43.4			1
2								2.1	19.1	4.6			2
3					24.6								3
4			0.6					20.5	13.1				4
5						7.6		7.5	2.6				5
6			0.3				1.6	9.7	1.1				6
7			11.4			1.2	2.8		20.8				7
8						9.0	2.5		9.4				8
9				20.9		10.7	6.4	7.6	105.7	77.6			9
10						14.7	7.5		1.7				10
11				9.1	26.3	7.6		5.3	3.5				11
12						17.6		4.3					12
13						8.9		26.6	4.2				13
14						8.5		4.8	16.2				14
15						0.5		28.7	5.2				15
16						3.7	1.9		8.5				16
17					33.8	18.4	6.3	1.4	16.4				17
18					38.4		33.3		15.2				18
19				3.8	0.6		16.2	24.1	20.4				19
20					7.6		0.4	6.0	8.2				20
21					60.6		2.2	144.1	44.7				21
22					0.4								22
23						2.1		0.3					23
24					65.2	17.8			11.2				24
25					1.6	38.5			72.0				25
26				5.6		0.8		37.5	3.2				26
27					19.7	0.5	8.6	2.4					27
28					16.0		14.5	2.5					28
29		8.5			2.2	30.4	10.3	14.9	23.9				29
30				13.5	0.2		2.2		5.9				30
31							53.3	9.7					31
Max		8.5	11.4	20.9	65.2	38.5	53.3	144.1	105.7	77.6			Max
Days		1	4	5	14	18	17	20	24	3			Days
Total		8.5	23.7	52.9	297.2	198.5	172.2	360.0	447.9	125.6			Total

DAILY RAINFALL RECORD (5)

STATION: R.I.D. (Nong Khai)

Unit: mm Annual total: 1857.7 Year 1962

D \ M	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	M \ D
1			1.6		4.6	49.7	48.2	21.9	2.6				1
2			0.2				0.8	12.6	5.3				2
3				10.9	4.6	1.6		31.4	33.4				3
4						12.9		11.5	5.8	13.9			4
5				2.4	16.9	4.7			0.7	8.9			5
6			1.0					9.2		79.1			6
7								45.1		11.4			7
8					56.9			13.3		29.6			8
9			0.7			24.4			8.3				9
10			11.1			20.0	11.5	5.5	10.6	1.2			10
11						0.8	6.7	60.0	17.3	0.8			11
12				19.3	14.2	29.5	4.7	35.6				1.3	12
13							48.0	11.5	4.4				13
14							31.8			10.7			14
15						4.2	38.6						15
16		5.2					1.4		0.5				16
17			9.3			68.6	3.0	12.4	21.6				17
18		10.0			73.9	28.7	16.2	3.1	19.2				18
19		1.3				5.7	27.1	29.0	0.1				19
20				0.1			1.6	13.3					20
21					20.0			6.3					21
22				5.5	26.5				74.5				22
23				6.9			0.6	20.0	19.7				23
24				10.0	4.3	1.5	16.3	2.4	21.0				24
25				6.4	2.3		4.3	39.4	0.7				25
26						19.7		28.6					26
27			2.4	2.9					29.8				27
28				1.2					40.8				28
29				26.2					1.2				29
30				22.5	3.2	0.2		6.8					30
31					5.8		5.7	35.4					31
Max		10.0	11.1	26.2	73.9	68.6	48.2	60.0	74.5	79.1		1.3	Max
Days		3	7	12	12	15	17	22	20	8		1	Days
Total		16.5	26.3	114.3	233.2	272.2	266.5	454.3	317.5	155.6		1.3	Total

DAILY RAINFALL RECORD (6)

STATION: R.I.D. (Nong Khai)

Unit: mm Annual total: 1308.0 Year 1963

D \ M	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	M / D
1							0.2	5.3	2.4				1
2						1.0		0.8					2
3					12.6	40.4	1.6		2.8				3
4						38.6	29.8						4
5					11.7		0.2	2.0	13.0	24.0	18.6		5
6					12.4	1.4		21.1		2.3			6
7				75.0				20.6		0.7	4.5	1.1	7
8					1.3	7.7		25.9	4.3			0.8	8
9			0.4			48.2			33.1		41.5		9
10						33.8	0.5		37.4				10
11								6.2					11
12						2.2	3.4	11.4	0.5				12
13							14.9	0.8					13
14													14
15			0.7			27.9	24.3						15
16				1.3	1.1	6.2			6.0				16
17				1.3			1.7		11.7				17
18				4.0	15.8		3.7	6.1	55.9				18
19				2.2	64.8		5.5	12.4	8.3				19
20					5.5	38.5	7.6						20
21							6.8						21
22							2.7	4.1	6.3				22
23							3.0	11.2					23
24		0.7			17.8		16.1	0.5	4.0				24
25					0.8		33.1	0.7					25
26					33.3	42.6	9.7	36.0	3.6	4.4			26
27							6.4	3.9		18.1			27
28				15.9	2.6	6.7		1.5		0.2			28
29							4.9			9 7			29
30					10.7		56.7						30
31							2.4						31
Max		0.7	0.7	75.0	64.8	48.2	56.7	36.0	55.9	24.0	41.5	1.1	Max
Days		1	2	6	13	13	22	18	14	7	3	2	Days
Total		0.7	1.1	99.7	190.4	295.2	235.2	170.5	189.3	59.4	64.6	1.9	Total

DAILY RAINFALL RECORD (7)

STATION: R.I.D. (Nong Khai)

Unit: mm Annual total: 1585.5 Year 1964

D \ M	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	M \ D
1				3.5	29.3				15.0	20.0			1
2					0.7		5.7		1.5	3.4			2
3					59.0	6.3	8.4		25.6	25.7			3
4					25.1		8.7	25.7	13.0	3.4			4
5						8.9			11.0				5
6						23.7		2.5	21.2				6
7			1.7			7.1	34.5	3.1	8.4				7
8				6.0	14.5		2.5			24.9			8
9						3.1		7.2		6.4			9
10				7.7	1.2			3.7		15.6			10
11				15.0	4.3	1.8	65.0						11
12				14.0		4.3			4.0				12
13				21.0		1.3		50.0	27.0	6.3			13
14			3.0				8.4	9.8					14
15					2.0	46.0		2.3	28.8	13.5			15
16					0.7	3.3			5.5				16
17				22.1			3.7		18.3				17
18					21.8	7.5			41.9				18
19									11.2				19
20			8.8			42.0							20
21				4.2	69.7	3.8	37.2	12.0					21
22			6.3			0.4	15.0	0.9	0.7	8.0			22
23					49.2	5.7		16.0	8.9	20.1			23
24				9.8	9.8			1.7		11.2			24
25					23.1	7.4	0.5	42.5					25
26						33.7		4.6					26
27					17.2	0.2		3.7	26.2				27
28				14.5	18.9	2.1		1.2	0.5				28
29					27.1			38.5					29
30				2.6	4.3			0.6					30
31								16.0					31
Max			8.8	22.1	69.7	46.0	65.0	50.0	28.8	25.7			Max
Days			4	11	18	19	11	19	18	12			Days
Total			19.8	120.4	377.9	208.6	189.6	242.0	268.7	158.5			Total

DAILY RAINFALL RECORD (8)

STATION: R.I.D. (Nong Khai)

Unit: mm Annual total: 1339.8 Year 1965

D \ M	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	M / D
1					1.9			6.6					1
2	5.2								26.7				2
3									1.6				3
4						5.2	10.0	4.2	5.0		2.2		4
5				16.6		5.7			0.9	4.0			5
6				2.0		13.1	7.9		63.3				6
7					0.2	2.9		0.6	20.5				7
8				15.1		1.5		1.0	5.6	3.2			8
9						2.2			55.0				9
10						3.7				3.5			10
11				2.8		32.1	21.8		55.5	1.9			11
12						9.8	11.4						12
13					8.7	2.3		65.6	20.3				13
14						10.4			10.8				14
15					1.0	44.2							15
16					118.0	59.1		1.4					16
17								1.5					17
18				33.7		2.3		14.6					18
19						0.3		14.5					19
20					4.2	32.2		29.1	11.5				20
21						9.1	57.8	16.0	1.1				21
22				40.5		8.2		1.8					22
23					0.4	1.4	9.2	56.2					23
24				36.5			8.7		14.3	7.2			24
25				0.8			1.5			0.7			25
26				12.9			6.4	19.2					26
27					2.1	0.4	14.2	0.7		2.5			27
28					16.8	12.1		0.9					28
29					2.6	12.3	12.2	4.5					29
30					4.1	11.8							30
31					14.6								31
Max	5.2			40.5	118.0	59.1	57.8	65.6	63.3	7.2	2.2		Max
Days	1			9	12	23	11	17	14	7	1		Days
Total	5.2			160.9	174.6	282.3	161.1	238.4	292.1	23.0	2.2		Total

DAILY RAINFALL RECORD (9)

STATION: R.I.D. (Nong Khai)

Unit: mm   Annual total: 1529.7   Year 1966

D \ M	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	M / D
1				0.2			2.3	16.6					1
2							12.9	35.6	12.2				2
3			7.6		58.5	3.4	3.4	17.5					3
4					1.7	15.0	2.8	10.8					4
5				2.5		65.0		7.7					5
6					30.0	5.4			10.7				6
7								2.8					7
8						0.6		0.6					8
9					14.3	10.1		2.0	20.5	15.7			9
10								6.0		2.8			10
11								71.6					11
12				1.7				6.4					12
13				14.3			22.7		5.5				13
14					15.1				25.3				14
15					10.9	36.2	30.0	22.5	0.8				15
16				5.0	42.8		3.2	158.5					16
17					7.9		3.1						17
18					21.2		1.1						18
19					21.0	33.3	17.2						19
20				0.6	5.7		10.2	5.4					20
21				81.4			3.5	37.3					21
22						25.5	2.5	30.3					22
23					12.0		18.6	11.2					23
24				12.4	11.5			5.6					24
25					30.1	5.6		4.2		35.4			25
26					15.5	1.8		15.7		14.6			26
27				13.8	21.7	2.5		21.0					27
28							16.9	5.4					28
29						1.2	0.8						29
30								71.8					30
31								2.5					31
Max			7.6	81.4	58.5	65.0	30.0	158.5	25.3	35.4			Max
Days			1	9	16	13	16	24	6	4			Days
Total			7.6	131.9	319.9	205.6	151.2	569.0	75.0	68.5			Total

DAILY RAINFALL RECORD (10)

STATION: R.I.D. (Nong Khai)

Unit: mm Annual total: 1326.4 Year 1967

D \ M	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	M / D
1			1.2		22.3								1
2			19.0			1.9	26.3						2
3						6.0							3
4						0.2	2.6	0.1					4
5						3.2	3.5						5
6				4.0		21.8			3.4				6
7						4.3	2.0	4.5					7
8			7.2		0.2	26.2		12.9					8
9						0.5	20.9	5.2					9
10					9.5		11.0	24.0	16.3				10
11						3.2		5.8			17.3		11
12				3.0		11.0	4.8	2.3			4.5		12
13				22.0	0.5		25.0	3.5					13
14													14
15				18.1			26.2						15
16					13.5		10.0		36.8				16
17			4.5	2.5	14.7				18.8				17
18					21.3								18
19					4.1			49.1	27.0				19
20			16.1			53.5		221.2	8.4				20
21				0.4				7.0	31.8				21
22				52.5			12.3	56.9	2.8				22
23		2.6					2.9	3.4					23
24							13.5	11.7					24
25						0.5	3.8	2.2					25
26				47.5			11.9	2.5	20.8				26
27						0.3		4.7	3.6				27
28					2.8	62.0		21.0					28
29					12.2	3.0		8.4					29
30													30
31			12.2										31
Max		2.6	19.0	52.5	22.3	62.0	26.3	221.2	36.8		17.3		Max
Days		1	6	8	10	15	15	14	10		2		Days
Total		2.6	60.2	150.0	101.1	197.6	176.7	446.4	169.7		21.8		Total

DAILY RAINFALL RECORD (11)

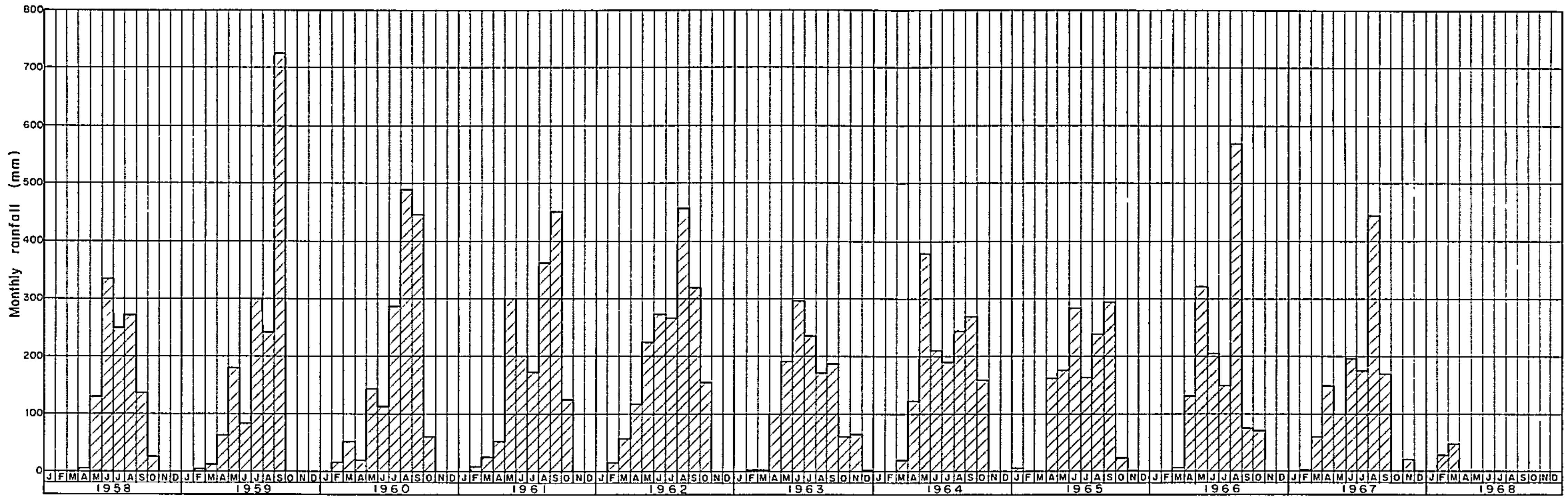
STATION: R.I.D. (Nong Khai)

Unit: mm Annual total: Year 1968

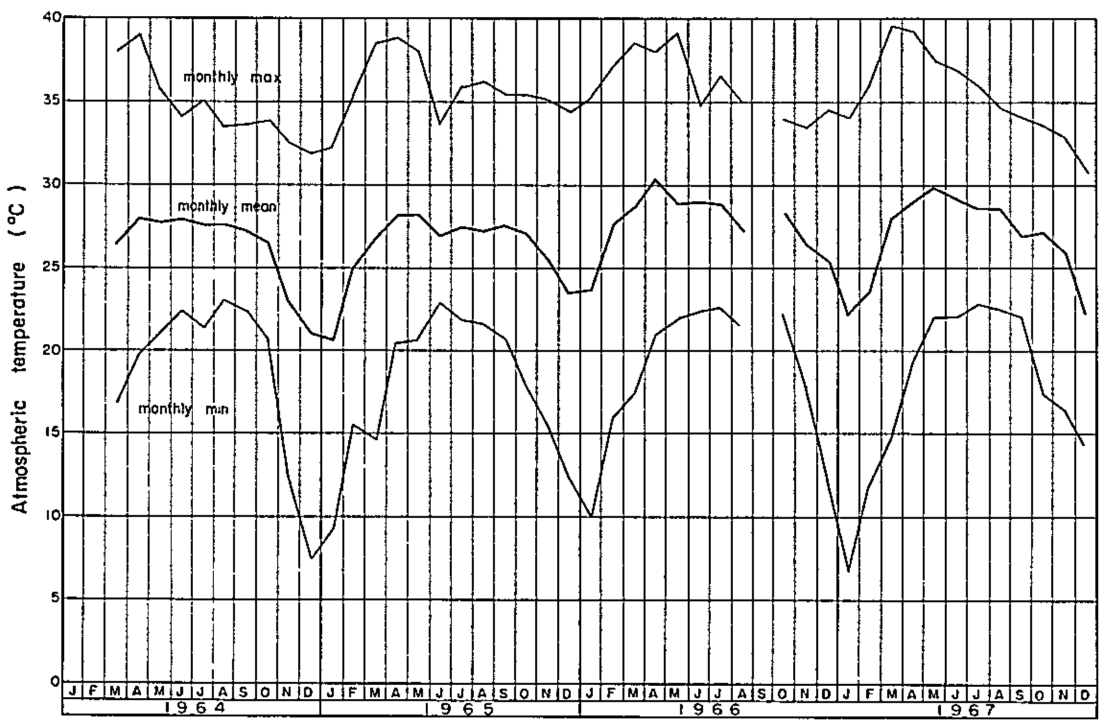
D \ M	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	M / D
1													1
2													2
3													3
4				27									4
5				19.5									5
6													6
7			25.0	2.3									7
8			3.2										8
9													9
10			1.0										10
11													11
12			3.5										12
13													13
14													14
15				25.2									15
16													16
17													17
18													18
19													19
20													20
21													21
22													22
23													23
24													24
25													25
26													26
27													27
28													28
29													29
30													30
31													31
Max			25.0	19.5									Max
Days			4	4									Days
Total			32.7	49.7									Total

RAINFALL , AIR TEMPERATURE AND RELATIVE HUMIDITY

MONTHLY RAINFALL AT RID METEOROLOGICAL STATION

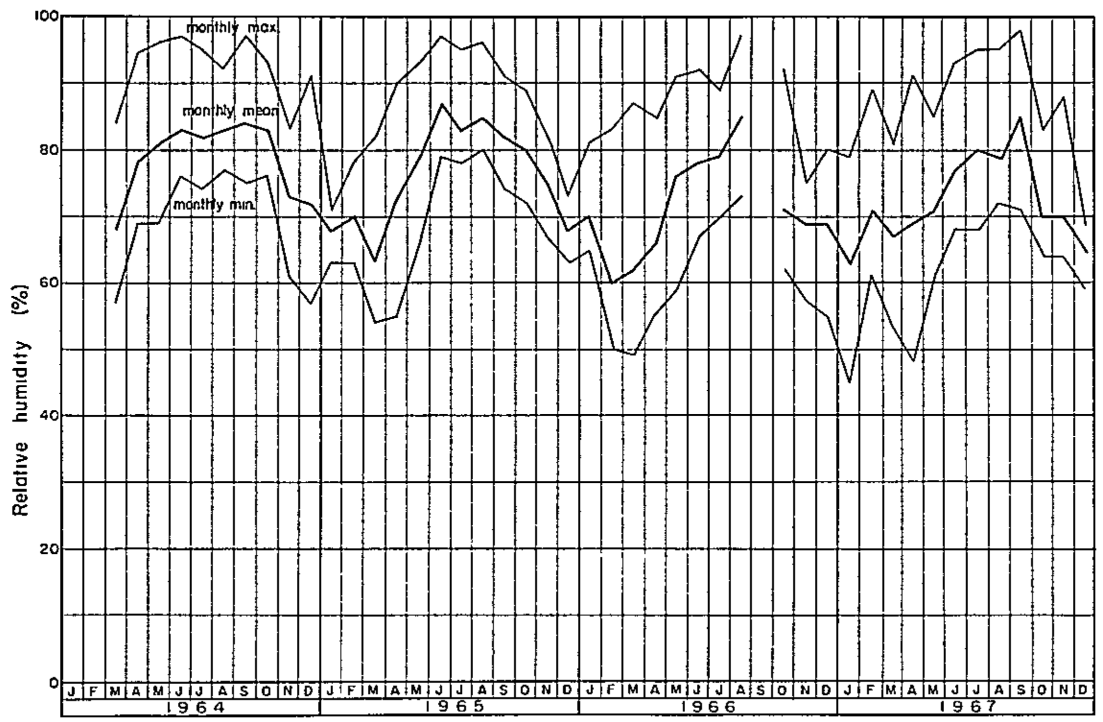


ATMOSPHERIC TEMPERATURE AT NONG KHAI METEOROLOGICAL STATION



Remarks Based on the daily - maximum, daily-mean and daily - minimum of atmospheric temperature
No data were recorded in september 1966 due to flood

RELATIVE HUMIDITY AT NONG KHAI METEOROLOGICAL STATION



Remarks Based on the daily - mean relative humidity
No data were recorded in september 1966 due to flood

Daily Prevailing Wind Direction and Mean Wind Velocity at Nong Khai Meteorological Station (1)

Year: 1966

Date	Jan.∠1		Feb.		Mar.		Apr.		May		Jun		Jul.		Aug.		Sep.∠2		Oct.		Nov.		Dec.	
	Dir.	Vel	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel	Dir.	Vel.	Dir.	Vel.
1			W	0.6	NE	1.4	SE	1.9	SE	2.3	SW	1.2	SW	0.4	E	1.4	–	–	NE	1.3	WE	2.4	NE	3.6
2			W	0.5	NE	2.1	SW	1.6	SE	1.4	SW	2.3	SW	1.0	SW	2.1	–	–	NE	0.4	E	3.5	NE	5.6
3			W	0.6	SE	0.6	SW	1.2	E	3.3	SW	1.2	SW	1.6	NE	0.6	–	–	NE	0.6	NW	1.0	NE,SW	0.5
4			W	0.6	SW	1.0	SE,SW	1.2	NE	1.2	SW	1.2	SW	1.2	SE	1.0	–	–	NE	1.6	NE	1.2	N	0.7
5			E	1.0	W	0.6	SW	1.4	SE	1.2	SW	1.2	SW	1.4	SW	0.6	–	–	NE	0.9	NE	2.1	NE	0.7
6			NE	1.9	N	1.0	E	1.9	SW	1.2	SW	0.6	SW	1.2	W	0.8	–	–	NE	1.8	SW	4.7	E	0.8
7			E	1.0	SW	0.8	SW	1.4	NE	1.2	SW	1.2	SW	1.0	SW	0.8	–	–	NE	1.3	NE	0.6	N	0.5
8			E	0.8	N	2.3	NE	1.6	NE	1.2	SW	1.9	SW	1.6	SW	2.3	–	–	NE	0.9	NE	0.2	NE	0.2
9			E	1.0	NE	0.4	SW	1.2	SW	1.6	SW	1.6	SW	1.6	SW	0.4	–	–	NE	0.8	NE	0.1	NE	0.2
10			W	1.2	S	1.2	NE	1.9	SW	2.0	SW	1.9	SW	1.2	SW	1.2	–	–	E	0.9	NE	0.4	NE	0.4
11			NE	0.6	NE	0.8	N	1.0	SW	1.2	SW	1.2	SW	1.9	SW	1.0	–	–	W	2.1	NE	0.3	E	0.6
12			NE	2.3	NW	1.0	NE	2.1	SW	1.6	SW	2.5	SW	1.4	SW	1.0	–	–	NE	0.7	E	0.4	NE	1.1
13			SE	2.3	W	1.0	SW	1.4	SW	1.0	SW	2.5	SW	1.6	SW	1.0	–	–	SW	0.8	E	0.4	NE	0.7
14			E	1.6	NW	1.2	SW	1.4	SW	2.3	E	1.4	SW	1.4	SW	1.2	–	–	SW,NE	0.6	E	0.9	NE	0.4
15			W	1.0	W	1.4	SW	1.4	E	1.2	SW	1.2	NW	1.2	SW	1.4	–	–	E,W	1.0	NE	1.1	E	0.5
16			W	0.8	W	1.0	SW	1.6	SW	1.2	SW	1.0	SW	0.8	SW	1.0	–	–	E	0.8	NE	0.3	E	0.5
17			W	0.8	E	1.2	S,W	1.9	SW	2.7	SW	1.0	NE,SW	1.4	NE	1.2	–	–	NE	1.5	NE	1.5	ESE	0.2
18			NE	1.0	SW	1.0	NE	3.9	SW	2.5	NE	2.9	S	1.4	SW	1.0	–	–	NE	1.8	NE	0.9	NW	0.4
19			W	1.4	SE	2.4	SW	1.2	SW	1.6	SW	1.6	E	1.4	W	2.5	–	–	NE	2.5	NE	0.4	W	0.2
20			W	0.8	E	1.6	SW	2.7	NE	2.9	SW	1.0	SW	2.1	SW	1.6	–	–	NE	1.9	NE	0.9	E	0.4
21			NE	0.8	SW	1.2	E	3.5	E	3.9	SW	1.9	SE,SW	1.4	SW	1.2	–	–	NE	2.4	NE	5.9	E,S	1.1
22			SW	1.4	SW	2.9	NE	0.8	E	1.0	SW	1.2	SW	1.4	SW	2.9	–	–	NE	1.4	NE	1.8	W	0.8
23			E	3.7	SW	1.0	W	1.0	SW	0.8	SW	2.5	SW	1.4	SW	1.0	–	–	SW	1.2	NE	0.4	N	0.2
24			NE	2.1	SW	1.0	SW	1.4	SW	2.7	SW	1.0	SW	1.6	C	1.0	–	–	SW	0.8	NE	0.5	ENE	0.8
25			W	0.8	SW	1.0	SW	1.0	E	1.2	SW	1.4	SW	2.9	SW	1.0	–	–	SE	0.6	NE	1.1	NE	0.7
26			NE	1.2	E	2.3	SW	2.1	NE,SW	3.5	SW	1.0	NW,SW	3.3	SW	2.3	–	–	E	1.8	NE	2.3	NE	0.7
27			NE	1.6	E	2.5	SW	2.1	SW	1.4	SW	0.6	SW	2.8	SW	2.5	–	–	E	1.0	NE	0.2	NE	1.8
28			E	1.2	SE	1.0	SW	0.8	SW	1.6	NE,SW	1.2	SW	1.0	SW	0.8	–	–	E	1.8	ENE	0.2	NE	1.1
29					SW	1.0	SW	1.2	SW	1.5	SW	1.2	SW	1.9	E	1.0	–	–	NE	1.4	NW	0.6	NE	0.2
30					E	2.0	NE	3.1	SW	1.8	SW	2.1	SW	1.9	SW	2.1	–	–	NE	0.6	NE	2.6	NE	0.4
31					E	1.2			SW	1.2			SW	1.9	SE	1.2	–	–	NE	1.1			NE	0.6

∠1: No available data in January.
∠2. No observation due to flood in September.

Abbreviation : Dir. ..... Prevailing direction.
Vel. ..... Mean wind velocity in m/sec.

Daily Prevailing Wind Direction and Mean Wind Velocity at Nong Khai Meteorological Station (2)

Year : 1967

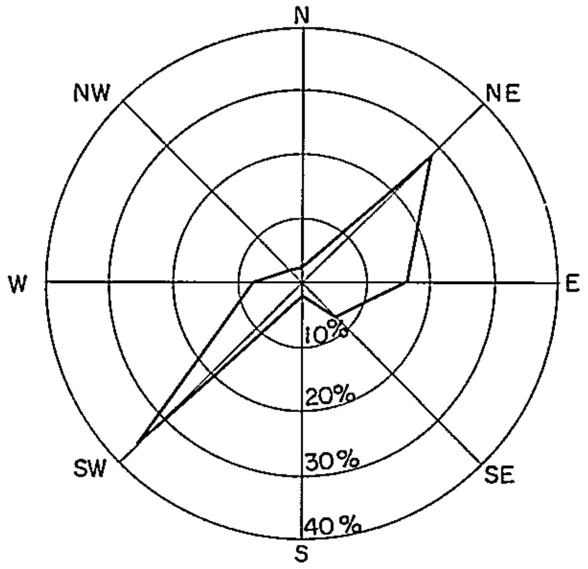
Date	Jan. Dir	Jan. Vel	Feb. Dir.	Feb. Vel.	Mar. Dir.	Mar. Vel.	Apr. Dir.	Apr. Vel.	May Dir.	May Vel.	Jun. Dir.	Jun. Vel.	Jul. Dir.	Jul. Vel.	Aug. Dir.	Aug. Vel.	Sep. Dir.	Sep. Vel.	Oct. Dir.	Oct. Vel.	Nov. Dir.	Nov. Vel.	Dec. Dir.	Dec. Vel.
1	NE	1.2	NW	2.1	NE	1.4	SW	1.0	S	1.1	SE	1.4	SW	1.4	SW	1.9	SW	2.5	NE	1.4	E	2.9	NE	1.2
2	NE	3.1	E	1.4	NE	1.4	SW	1.2	S	1.3	SE,SW	1.2	E	0.8	SW	3.3	SW	1.2	E	1.6	NE	4.3	NE	0.8
3	NE	6.4	E	4.0	W	1.0	SW	1.9	W	1.2	SW	1.0	E	1.0	SW	4.3	SW	2.7	E	2.0	NE	4.0	NE	0.6
4	NE	3.0	NE	0.8	W	1.2	SW	1.0	N	1.4	SW	1.0	C	1.2	SW	3.1	W	2.1	NE	2.0	NE	2.4	NE	0.5
5	NE	1.5	NE	2.7	SE	1.6	SE	2.9	SW	0.8	SE	1.4	SW	2.5	SW	2.5	NE	1.2	E	1.2	NE	4.2	NE	0.3
6	C	0.4	NE	3.5	SE	4.5	SE	1.2	S	1.4	E	1.2	SW	3.1	SW	2.1	SW	1.0	E	1.2	NE	2.9	NE	0.7
7	C	0.7	NE	1.6	SE	3.1	SW	1.4	C	1.3	SW	1.2	SW	1.2	SW	2.3	E	0.6	NE	1.2	NE	3.2	NE	1.0
8	NE	1.4	NE	1.0	SE	1.2	SW	0.8	SE	4.7	W	1.2	SW	1.2	SW	1.0	NE	1.6	NE	0.8	NE	3.3	NE	1.2
9	C	0.5	E	1.2	E	1.9	SW	1.4	SW	1.4	SE	3.5	SE	1.0	E	1.2	NE,SW	1.6	W	1.2	NE	2.1	NE	0.6
10	NE	1.2	NE	1.0	E	2.7	SW	1.2	SE	1.6	SW	1.0	SW	1.2	E	1.2	NE	1.0	SW	0.8	NE	2.9	E	1.4
11	NE	3.7	SE	3.1	E	1.0	SW	1.2	SE	1.9	E	1.4	E	1.0	E,W	1.0	N	0.8	E	1.6	NE	5.2	E	0.6
12	NE	1.2	NE	2.3	E	1.0	SW	1.9	W	0.6	E	1.4	SE,SW	1.6	SW	1.2	NE	0.6	SW	1.0	E	9.5	NE	1.0
13	NE	2.5	SE	1.0	E	1.2	SW	1.2	SW	1.6	SE	0.8	SW	1.6	W	1.6	W	0.6	E	0.8	E	4.6	E	1.6
14	NE	0.7	NE	3.7	E	1.2	SW	1.4	SE	2.5	SW	0.8	SE,SW	1.4	SW	2.0	W	0.6	E	0.8	NE	4.9	NE	0.6
15	NE	1.8	NE	1.9	E	2.1	E	2.1	SE	1.6	W	1.2	E	1.0	W	1.0	NE	1.2	E	1.9	NE	3.2	NE	0.4
16	NE	2.8	NE	1.2	C	0.6	C	0.8	SE	4.1	SW	1.2	E	0.4	SE	1.2	E	1.2	W	1.0	NE	2.8	NE	0.2
17	NE	2.2	NE	2.3	NE	1.2	SE	1.9	E	4.5	SW	2.1	SW	1.0	SW	1.6	NE	1.2	W	1.2	NE	3.2	NE	0.8
18	NE	1.5	NE	3.1	C	0.6	SW	1.0	E	1.6	SW	2.1	SW	1.4	SW	1.4	NE	1.2	E,W	0.8	NE	2.9	NE	0.6
19	SE	0.4	NE	1.2	SE	0.6	SW	1.9	W	2.5	SW	2.1	S,W	1.4	SW	1.2	SW	0.8	NE	1.0	NE	2.9	NE	0.4
20	NE	0.8	NW	1.0	SW	0.8	SE,SW	1.6	SW	1.9	SW	1.9	W	1.6	E	0.8	SW	2.1	E	1.0	NE	2.5	NE	0.3
21	E	1.0	C	0.6	S	0.8	SE	2.4	SE	0.8	SE,SW	1.0	NE	1.6	SW	1.4	SW	1.0	NE	1.2	NE	2.8	NE	0.3
22	E	0.8	NW	0.6	C	0.6	SW	1.8	SW	4.4	SW	1.2	E	1.2	SW	1.2	E	0.6	NE	1.6	NE	2.5	NE	0.3
23	C	2.7	W	1.0	C	0.2	SW	1.2	SW	4.1	W	1.2	W	1.4	SW	2.3	SE	1.4	NE	1.0	NE	2.5	NE	0.5
24	SE	0.6	SE	1.0	E	1.9	SE	1.0	SW	2.3	SW	1.4	SW	1.4	SW	1.4	E	0.6	NE	2.1	W	2.1	NE	0.3
25	SW	0.5	E	1.4	E	1.9	SE	1.4	SW	2.4	E	1.0	SW	1.9	E	1.0	E	0.8	NE	0.8	NE	3.1	NE	0.3
26	SW	2.1	E	5.2	NW	0.8	SE,SW	2.1	SW	2.0	SW	2.5	SW	1.2	W	0.8	E	1.0	NE	1.2	NE	2.8	NE	0.3
27	SW	1.0	SE	4.7	W	0.8	SE	1.9	SW	0.8	SE	2.3	SW	1.4	E	2.3	E	1.4	NE	1.2	NE	0.8	NE	0.3
28	SW	1.0	E	2.1	SW	1.2	S	1.3	SE	3.7	SE	1.9	SW	3.1	SW	1.2	E	0.8	NE	1.2	NE	1.2	NE	0.3
29	SW	1.0			SW	1.2	S	0.6	SW	1.9	SW	2.1	SW	1.4	SW	3.1	C	0.2	NE	0.8	E	3.1	E	0.5
30	E	0.8			SW	0.8	SSW	1.2	SW	1.2	SW	1.4	NE	1.2	W	1.9	W	1.0	W	1.2	E	3.1	NE	0.4
31	NE	5.2			SW	1.2			SW	2.7			SW	1.2	SW	1.6			NE	0.8			NE	0.4

Abbreviation. Dir . . . Prevailing direction
Vel . . .. Mean wind velocity in m/sec

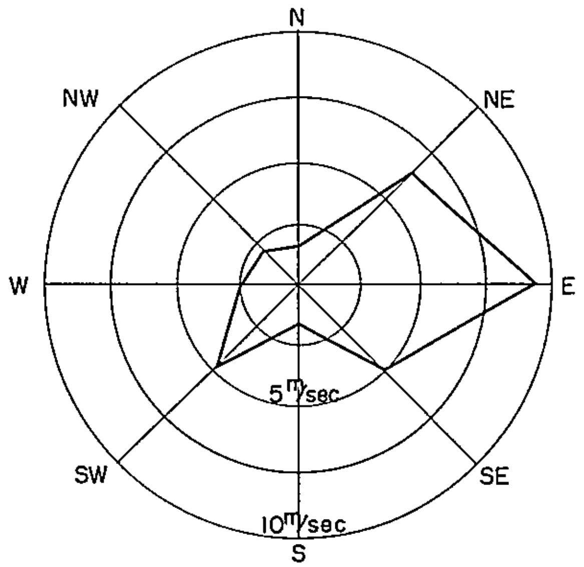
Data 4.4.

WIND DIAGRAM

At Nong Khai Meteorological Station
From Feb. 1966 to Dec. 1967



DAILY PREVAILING DIRECTION



MAX. WIND VELOCITY

Monthly Max. Wind Velocity and Its Direction at Vientiane Meteorological Station, 1959 to 1968

	1959		1960		1961		1962		1963	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Jan.	ENE	5	ENE	4	SSW	4	SSE	3	SW	7
Feb.	NNW	4	E	8	E	3	ENE	3	E	4
Mar.	Var.	–	NW	4	ESE	4	E	3	Var.	–
Apr.	Var.	–	S	10	S	10	SSW	8	Var.	–
May	Var.	–	ENE	5	NNE	8	NW	3	SSE	3
Jun.	Var.	–	E	4	SW	4	N	3	N	3
Jul.	WNW	13	NE	3	ENE	6	W	8	SW	3
Aug.	WNW	5	ESE	4	SSW	3	ENE	8	N	3
Sep.	WSW	6	NE	4	WNW	3	W	4	WSW	4
Oct.	NE	5	SE	5	WNW	5	HE	1	SE	2
Nov.	E	5	ESE	3	NNW	4	N	6	N	2
Dec.	ESE	8	ENE	5	N	2	NNE	5	N	2

	1964		1965		1966		1967		1968	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Jan.	ESE	3	E	3	NNW	4	E	8	SE	3
Feb.	WSW	6	S	3	NE	4	E	4	E	8
Mar.	ESE	3	E	4	W	4	S	9	ESE	27
Apr.	NNW	4	W	4	N	10	SSE	8	SSE	8
May	S	4	W	10	NE	4	N	9		
Jun.	NNW	4	N	3	NNW	4	NNW	7		
Jul.	SSE	3	W	8	SE	5	W	8		
Aug.	S	3	NW	20	N	3	SW	6		
Sep.	S	3	W	4	S	4	SW	7		
Oct.	SW	2	NE	7	ESE	4	ESE	6		
Nov.	W	3	E	4	N	4	E	6		
Dec.	SE	3	–	–	–	–	E	3		

Remarks : Dir. = Wind direction
Vel. = Monthly max. wind velocity in m/sec

CHAPTER V

HYDROLOGY

5.1. Hydrologic Data

During the first- and second-phase investigations, hydrologic data of the Mekong around the projected bridge site were collected from the Vientiane gaging station located at Wat Sop, the Hydrographic Office at the outskirts of Nong Khai, and the RID's gaging stations located at Wat Hai Sok, Ban Dok Kham, Wat Sri Mong Kol and Ampho Tha Bo on the Thai side, shown in Fig. 5.1.

Collected data are listed in Table 5.1. Excepting those asterisked in Table 5.1, the collected data are presented in this report.

Table 5.1. Hydrologic Data Collected During the First- and Second-Phase Investigations

Gaging Station	Item	Period Covered
Vientiane	Water-level	Jan. 1966 - Apr. 1968
	Water-level and Discharge	Jan. 1966 - Mar. 1967
	Water Temperature	Jan. 1960 - Dec. 1961
	Flood Hydrograph*	1923 - 1967
Hydrographic Office	Water-level	Jun. 1964 - Apr. 1968
	Flow Velocity	1966 - 1968
	Flood Flow Velocity	Sept. 1966
RID, Wat Hai Sok	Water-level*	Jun. 1955 - Mar. 1968
	Stage Hydrograph	Jun. 1937 - Mar. 1966
RID, Ban Dok Kham	Water-level*	Jan. 1963 - Dec. 1967
RID, Wat Sri Mong Kol	Water-level*	Jan. 1963 - Dec. 1967
RID, Ampho Tha Bo	Water-level*	Jan. 1963 - Dec. 1967

N.B. The data asterisked are not presented in this report as they were not based upon in the hydrologic analysis presented in this report.

The characteristic water-levels of the Mekong, as analyzed for the period from 1958 to 1967, are given in Table 5.2.

Table 5.2. Elevations of Characteristic Water-Levels of the Mekong, As Analyzed for the Period 1958 - 1967

Water-Level	RID, Wat Hai Sok	Hydrographic Office	Bridge Site
Highest, Ever Recorded	167.6	168.4	—
95-day (Rich)	159	160	161
185-day (Ordinary)	156	157	157
275-day (Low)	155	156	156
355-day (Dry)	154	155	155
Lowest, Ever Recorded	153	154.8	—

Note: Elevations are in meters above mean sea level.

5.2. Design High-Water Level

5.2.1. General

The Plan of Operation stipulates that the Nong Khai/Vientiane bridge shall provide a navigation course having a vertical clearance not less than 10 meters above the preponderant high-water level at the bridge site. Accordingly, the preponderant high-water level of the Mekong at the bridge site is one of important criteria in the bridge planning and hence is hereinafter called the design high-water level.

The design high-water level was decided by probability computation based on the past water-level records of the Mekong.

5.2.2. Bases of Computation

There are two water-level-gaging stations near the bridge site: the Hydrographic Office's gaging station located 135 meters downstream of the bridge site and the RID's Wat Hai Sok gaging station located about 3,000 meters downstream from the bridge site.

While the Hydrographic Office's station was established in June 1964, the RID's Wat Hai Sok station was established in 1937 and is keeping water-level records for many years. From this reason, the estimation of the design high-water level was made in the following sequence.

(1) To calculate the probable high-water levels at the RID's station from the past water-levels recorded there:
(2) To estimate the relationship between the water-levels of the RID's and the Hydrographic Office's stations:
(3) To assume from the above relationship the probable high-water levels at the Hydrographic Office's station; and finally
(4) To estimate the probable high-water levels at he bridge site from the probable high-water levels at the Hydrographic Office's station based on the fact that the water surface slope of the Mekong at this site varies not much according to the season, ranging from 1/10,000 to 1/9,000.

5.2.3. Probability Computation

(1) Probable High-Water Levels at RID's Station

The water-level records at the RID's Wat Hai Sok gaging station are available for the period from 1937 to 1967, except 1943, 1950, 1953 and 1959. The highest high-water levels of each year were picked up, and the computation of the probable high-water levels was made based on the order-statistic method on the assumption that the picked-up high-water levels would show a logarithmic-normal distribution.

The computation was made based on the equations given below.

$$\xi = \alpha(\log x - \log x_0), \text{ or } \log x = \frac{1}{\alpha}\xi + \log x_0 \quad \cdots\cdots \quad (1)$$

in which ξ = normal variable for an arbitrary year;

α = parameter that indicates the degree of dispersion;

x = probable high-water level;

and x_0= geometric mean of the annual highest high-water levels.

The normal variable ξ is to be determined by solving the following equation:

$$\phi_0(\xi) = \frac{1}{\sqrt{\pi}}\int_{-\infty}^{\infty} e^{-\xi} d\xi = 1 - W_0(\xi) \quad \cdots\cdots \quad (2)$$

in which ϕ_0= non-exceeding probability (Gaussian distribution function);

W_0= exceeding probability; and

The value of α is determined from

$$\frac{1}{\alpha} = \frac{\sigma_{\log x}}{\sigma_\xi}, \quad \sigma_{\log x} = \sqrt{\frac{1}{n}\Sigma(\log x_i)^2 - (\log x_0)^2} \quad \cdots\cdots \quad (3)$$

in which x_i = observation values (annual highest high-water levels) ;

n = number of observation (number of years) ; and

σ_ξ = product rate of probability of observation values.

The highest water-level in each year from 1937 to 1967 observed at the RID Wat Hai Sok gaging station were shown in the stage hydrographs given in Data 5.3. Excepting those of 1943, 1950, 1953 and 1961, of which the records are incomplete, the highest water-levels in each of 27 years were taken as x_i, expressing their heights in meters above an elevation of 160.000 meters above mean sea level.

Then $\Sigma \log x_i = 17.96141$ and $\Sigma(\log x_i)^2 = 12.32613$; consequently

$$\log x_0 = \frac{1}{n}\Sigma \log x_i = \frac{1}{27}(17.96141) = 0.66524$$

Substitution of these values in Eq. (3) yields

$$\sigma_{\log x} = \sqrt{\frac{1}{27}(12.3261) - (0.6652)^2} = 0.1182$$

According to the Hazen's method, σ_ξ is 0.6908 in the case of 27 samples. Therefore $1/\alpha$ becomes 0.1182/0.6908 or 0.1711. Therefore, from Eq. 1

$$\log x = 0.66524 + 0.1711\,\xi \quad \cdots\cdots \quad (4)$$

Now, if the normal variables ξ for selected periods of recurrence are computed from Eq. 2 and then are substituted in Eq.4, the probable high-water levels of the selected periods of recurrence at he RID Wat Hai Sok gaging station become as given in Table 5.3.

Table 5.3
Probable High-Water Levels At RID Wat Hai Sok Station

Period of Recurrence In Years	ξ	log x	x In Meters	High-Water Levels Above Mean Sea Level, In Meters[a]
2	0	0.66524	4.63	164.63
5	0.5951	0.76707	5.85	165.85
10	0.9062	0.82030	6.61	166.61
20	1.1630	0.86426	7.32	167.32
40	1.3859	0.90237	7.99	167.99
50	1.4520	0.91372	8.20	168.20
100	1.6450	0.94670	8.85	168.85
200	1.8215	0.97690	9.48	169.48

Note: a: These elevations are based upon the zero point registerered at 153.00 meter above mean sea level at Ko Lak.

(2) Probable High-Water Levels At Hydrographic Office

Comparing the water-levels recorded at the RID Wat Hai Sok gaging station and at the Hydrographic Office's gaging station on same days durng the period from June 1964 to April 1968, the relationship between the recorded water-levels at the two stations can be represented by a straight line shown in Fig. 5.2. Based on this relationship, the probable high-water levels at the Hydrographic Office were computed from those at the RID station given in Table 5.3 and are listed in Table 5.4.

(3) Probable High-Water Levels At Bridge Site

The bridge site is located 135 meters upstream of the Hydrographic Office. If it is assumed that the Mekong's water surface slopes 1/9,000 to 1/10,000 at this site, the water level at the bridge site will be 0.015 meter higher than at the Hydrographic Office and the probable high-water levels at the bridge site become as given in Table 5.4. The relationship between the period of recurrence in years and the high-water levels above mean sea level in meters can be represented by a straight line shown in Fig.5.3.

Table 5.4. Probable High-Water Levels At RID Station, Hydrographic Office and Bridge Site Above Mean Sea Level

Period of Recurrence In Years	RID Gaging Station	Hydrographic Office	Bridge Site
2	164.63	165.49	165.50
5	165.85	166.68	166.69
10	166.61	167.41	167.42
20	167.32	168.10	168.11
40	167.99	168.74	168.75
50	168.20	168.95	168.96
100	168.85	169.60	169.61
200	169.48	170.20	170.21

Note: The figures for the Hydrographic Office and the bridge site are based on the zero-point elevation at the Office, and those for the RID station on the zero-point elevation of the station.

5.2.4. Design High-Water Level

Based on the water-levels recorded at the RID station during the period of 1937 to 1967, the number of days and the maximum duration in days per year in which the water level was above the computed probable high-water levels, given in Table 5.3 or 5.4, are given in Table 5.5.

This table indicates that in the past the water level remained above the 2-year probable high-water level at a rate of one to 50 days, above the 5-year probable high-water level at one to 310 days, and abbove the 10-year probable high-water level at one to 700 days. The table also shows that the 2-year probable high-water level has occurred very frequently as compared with the probable high-water levels of recurrence of five or more years. No water level was recorded above the 50-, 100- and 200-year probable high-water levels.

At the RID station, an extraordinary high-water of El.167.54 occurred in 1966, which corresponds to the 25-year probable high-water level. At this time, the water-level remained 29 days above the 2-year probable high-water level, 20 days over the 5-year probable level and 14 days above the 10-year probable level.

Considering the above-mentioned facts, it was decided to adopt the 5-year probable high-water level as the design high-water level, which is El.166.69 at the bridge site. And making allowance of 0.31 meter, the design high-water level at the bridge site was finally decided at 167.00 meters above mean sea level based on the registered elevation of the zero point at the Hydrographic Office.

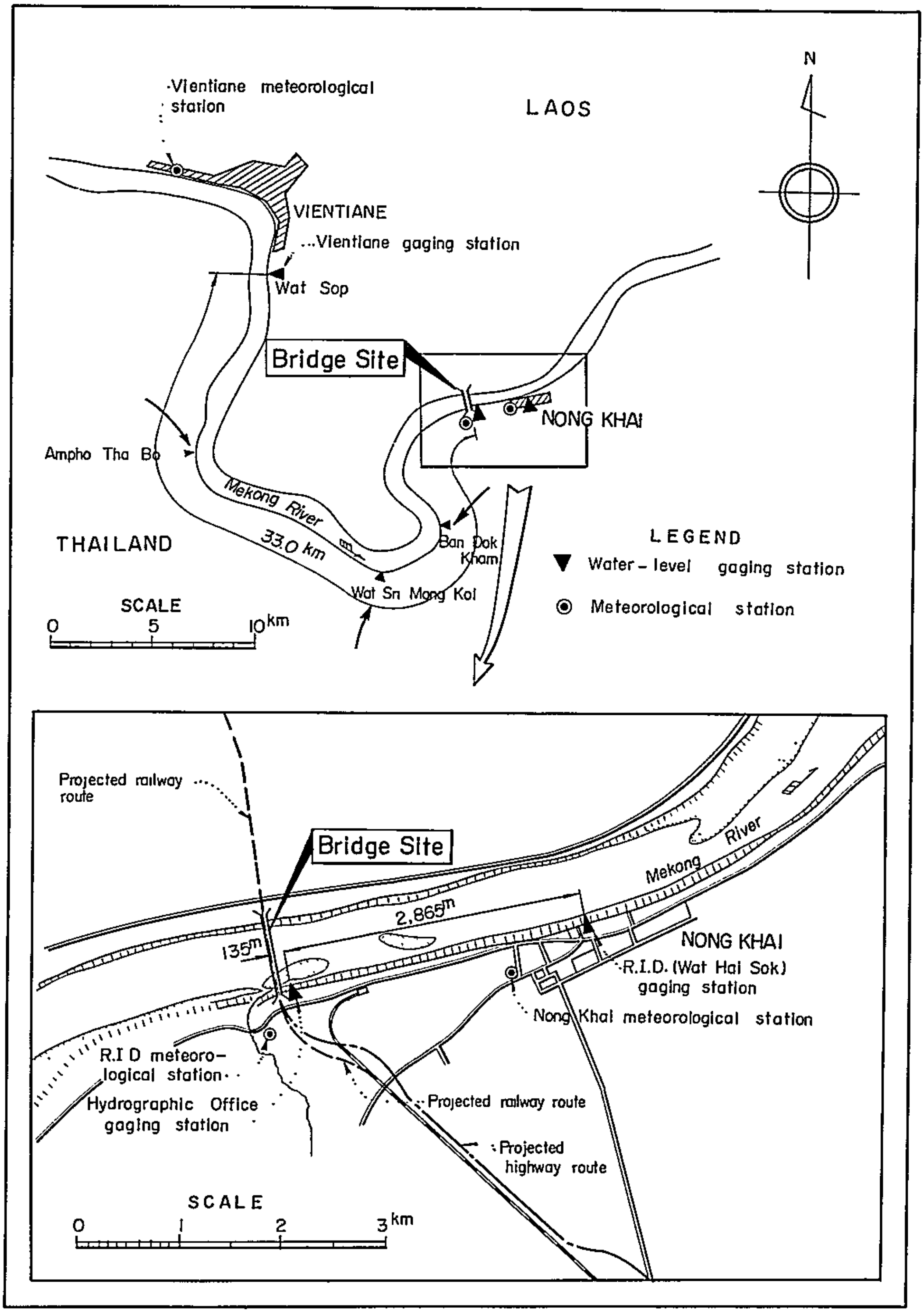
Table 5.5
Number of Days and Longest Duration in Days Per Year,
In Which Actual Water Level At RID Wat Hai Sok Station
Remained Above Probable High-Water Levels, 1937-1967

		Probable High-Water Level			
Elevation, in meters:		164.63	165.85	166.61	167.32
Period of Recurrence:		2 years	5 Years	10 Years	20 Years
Days in	1937	25	0	0	0
	1938	11	0	0	0
	1939	14	0	0	0
	1940	2	0	0	0
	1941	12	0	0	0
	1942	25	3	0	0
	1945	21	4	0	0
	1946	10	5	0	0
	1948	9	0	0	0
	1952	11	0	0	0
	1954	4	0	0	0
	1955	6	0	0	0
	1960	6	0	0	0
	1961	4	0	0	0
	1964	3	0	0	0
	1966	31	20	14	7
Total Days in 27 Years:		194	32	14	7
Ratio:		1/50	1/310	1/700	1/1400
Longest Duration, days:		29	20	14	7

Note:

1) In 1943, 1950, 1953 and 1959, the records were incomplete.
2) In other years not listed above, the water level remained below the 2-year probable high-water level.
3) No water level above the 50-year probable high-water level was recorded.

Fig. 5.1. LOCATION OF WATER-LEVEL GAGING STATIONS AND METEOROLOGICAL STATIONS



WATER LEVELS AT HYDROGRAPHIC OFFICE (1)

River system: Mekong Year: 1964 Unit: El (m)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
1						–	159.45	161.37	164.01	161.91	159.51	158.32	1
2						–	159.32	161.91	163.69	161.71	159.42	158.02	2
3						–	159.08	162.37	163.34	161.60	159.36	157.83	3
4						–	158.83	162.47	163.18	161.85	159.30	157.72	4
5						–	158.72	162.29	163.04	162.15	159.21	157.76	5
6						–	158.93	161.93	163.09	162.20	159.14	157.80	6
7						–	161.45	161.58	163.36	161.85	159.10	157.73	7
8						–	164.38	161.55	164.09	161.52	158.95	157.59	8
9						–	164.56	161.77	164.85	161.33	158.85	157.47	9
10						–	165.32	162.13	165.07	161.33	158.72	157.40	10
11						157.52	165.41	162 31	164.91	162.22	158.60	157.38	11
12						157.54	165.12	162 36	164.73	162.73	158.56	157.37	12
13						157.71	165.84	162.31	164.57	162.74	158.43	157.31	13
14						157.84	164.29	162.19	164.38	162.57	158.35	157.23	14
15						157.78	165.00	162.10	164.02	162.33	158.20	157.15	15
16						157.65	163.62	162.20	163.99	162.05	158.16	157.08	16
17						157.50	163.16	162.72	163.89	161.82	158.08	157.01	17
18						157.37	162.72	163.20	163.82	161.62	158.01	156.96	18
19						157.21	162.38	163.37	163.54	161.37	157.95	156.90	19
20						157.11	162.11	163.31	164.08	161.17	157 88	156.87	20
21						157.18	161.75	163.16	163.93	161.01	157.82	156.82	21
22						157.33	161.63	163.13	163.64	160.84	157.74	156.79	22
23						157.55	161.75	163.68	163.41	160.66	157.72	156.74	23
24						157.73	161.95	164.26	163.39	160.53	157.71	156.71	24
25						157.93	161.80	164.79	163.28	160.48	157.65	156.69	25
26						158.41	161.67	165.18	163.21	160.44	157.63	156.72	26
27						158.61	161.65	165.81	163.06	160.34	157.74	156.72	27
28						158.71	161.61	165.63	163.88	160.10	158.38	156.70	28
29						158.86	161.44	165.18	162.60	159.91	158.64	156.65	29
30						159.21	161.43	164.84	162.28	159.76	158.55	156.63	30
31							161.16	164.38		159.61		156.60	31
Max							165.84	165.81	165.07	162.74	163.64	158.32	Max
Min							158 72	161.37	162.28	159.61	157 63	156.60	Min
Total							5027.53	5055.48	4912.33	5001.75	4753.36	4872.67	Total
Days							31	31	30	31	30	31	Days
Mean							162.18	163.08	163.74	161.35	158.44	157.18	Mean

Zero point of water gauge: El. 154 211 m

WATER LEVELS AT HYDROGRAPHIC OFFICES (2)

River system: Mekong Year: 1965 Unit: El (m)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
1	156.57	155.86	155.34	154.87	154 94	156.10	160.90	162.26	162.90	161.51	163.64	158.40	1
2	156.55	155.84	155.32	154.86	154.90	156.30	160.89	162 29	162.67	161.28	163.29	158 31	2
3	156.53	155.82	155.30	154.84	154.88	156 52	160.77	162.56	162.41	161.01	162.72	158.21	3
4	156.50	155.78	155.30	154.84	154.86	156 61	160.67	162.61	162.35	160.78	162.23	158.15	4
5	156.48	155.79	155.29	154.85	154.87	156.66	160.54	162.72	162.46	160.63	162.15	158.06	5
6	156 46	155.79	155.29	154.87	154.89	156.72	160.49	162.49	162.25	160.53	162.83	158.00	6
7	156.43	155.79	155.25	154.84	154.91	156.82	160.74	162.12	162.01	160.45	163.56	157.95	7
8	156.39	155 80	155 22	154.84	155.01	156.90	160.86	161.75	161.91	160.43	163.65	157.89	8
9	156.36	155.83	155.10	154.84	155.09	156.90	160.78	161.50	162.18	160 44	163.15	157.83	9
10	156.34	155.82	155.16	154.84	155.07	156.92	160.72	161.10	162.56	160.39	162.56	157.79	10
11	156.31	155.81	155.14	154.86	155.07	156.96	161.02	161.07	162.87	160.39	162.00	157.73	11
12	156.27	155.81	155.12	154.86	155.16	157.13	161.74	161.41	162.98	160 32	161.56	157.66	12
13	156.23	155.80	155.09	154 90	155.24	157.39	161.99	161.98	162.91	160.24	161.20	157.62	13
14	156.20	155.79	155.07	154.91	155.34	157.63	161.83	162.61	162.85	160 13	160.88	157.66	14
15	156.17	155.78	155.06	154.91	155.40	157.89	161.60	162.91	162.93	160.01	160.58	157.53	15
16	156.16	155.76	155.04	154.89	155.42	158.62	161.33	162.82	162.94	159.98	160.24	157.54	16
17	156.14	155.75	155.04	154.90	155.39	158.33	161.02	162.82	162.91	159.96	160.02	157.58	17
18	156.13	155.77	155.06	154.89	155 34	158.70	160.84	163.11	162.79	159.95	159.83	157.59	18
19	156.13	155.79	155.06	154.92	155.20	159.13	160.98	163.33	162.76	159.88	159.65	157.53	19
20	156.13	155.78	155.05	154.91	155.16	159.32	161.70	163.53	162.69	159.68	159.50	157.56	20
21	156.12	155.71	155.04	154.98	155.61	159.53	161.65	163.44	162.69	159.58	159.37	157.42	21
22	156.09	155.65	155.02	155.03	155.05	159.47	161.40	163.34	162.63	159.54	159.24	157.72	22
23	156.10	155.59	155.01	155.07	155.07	159.47	161.63	163.07	162.35	159.37	159.13	158.68	23
24	156.13	155.54	155.01	155.10	155.19	159.60	161.78	162.78	162.09	159.20	159.03	159.35	24
25	156.16	155.50	155.01	155.12	155.45	159.89	161.73	162.64	161.89	159.02	158.96	159.41	25
26	156.13	155.45	155.02	155.12	155.52	160.21	161.61	162.73	161.86	158.85	158.86	159.06	26
27	156.08	155.40	155.00	155.08	155.54	160.52	161.63	162.79	161.92	158.70	158.77	158.64	27
28	156.07	155.37	154.98	155.04	155.59	160.66	162.56	162.70	161.88	158.68	158.70	158.29	28
29	155.96		154.95	155.01	155.62	160.56	162.60	162.78	161.82	159.76	158.60	158.02	29
30	155.93		154.92	154.97	155.70	160.71	162.40	162.95	161.75	162.53	158.49	157.78	30
31	155.90		154.89		155.84		162.33	163.04		163.93		157.63	31
Max	156.57	155.86	155.34	155.12	155 84	160.71	162.60	163.53	162.98	163.93	163.65	159.41	Max
Min	155.90	155.37	154.89	154.84	154.86	156.10	160.49	161.07	161.75	160.01	158.49	157.42	Min
Total	4843.15	4360.17	4808.15	4647.96	4812.32	4748.17	5002.73	5039.25	4873.21	4967.15	4824.39	4898.59	Total
Days	31	28	31	30	31	30	31	31	30	31	30	31	Days
Mean	156.23	155.72	155.10	154.93	155.24	158.27	161.38	162.56	162.44	160.23	160.81	158.02	Mean

Zero point of water gauge: El. 154.211 m

WATER LEVELS AT HYDROGRAPHIC OFFICE (3)

River system: Mekong Year: 1966 Unit: El (m)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
1	157.48	156.35	155.73	155.20	155.33	156.77	161.40	162.75	167.43	166.29	160.42	157.85	1
2	157.38	156.37	155.71	155.20	155.30	156.89	160.99	163.37	167.52	162.03	160.25	157.79	2
3	157.29	156.43	155.69	155.19	155.37	157.05	160.60	164.01	167.72	161.79	160.45	157.71	3
4	157.21	156.46	155.67	155.18	155.23	157.13	160.27	164.28	167.97	161.68	160.49	157.65	4
5	157.06	156.45	155.65	155.15	155.20	157.13	160.00	164.42	168.14	161.76	160.33	156.60	5
6	157.11	156.38	155.63	155.12	155.18	157.03	160.26	165.03	168.23	161.82	160.06	157.54	6
7	157.06	156.33	155.61	155.11	155.22	157.13	161.80	165.50	168.29	162.08	159.80	157.48	7
8	157.02	156.26	155.58	155.11	155.19	157.08	162.52	165.46	168.36	162.62	159.61	157.44	8
9	156.98	156.21	155.54	155.17	155.19	157.14	162.60	165.30	168.38	163.20	159.43	157.41	9
10	156.94	156.17	155.51	155.26	155.21	157.24	162.58	165.15	168.39	163.27	159.20	157.42	10
11	156.91	156.13	155.48	155.30	155.23	157.42	162.29	165.08	168.35	162.96	159.15	157.43	11
12	156.86	156.00	155.48	155.33	155.28	157.67	161.97	164.97	168.23	162.54	159.03	157.43	12
13	156.84	156.06	155.48	155.34	155.35	157.81	161.76	164.93	168.07	162.12	158.91	157.37	13
14	156.82	156.04	155.47	155.35	155.43	157.91	161.49	164.97	167.82	161.76	158.81	157.29	14
15	156.79	156.01	155.46	155.34	155.56	158.02	161.20	164.99	167.51	161.46	158.73	157.22	15
16	156.75	155.99	155.44	155.34	155.67	158.15	161.16	165.05	167.13	161.20	158.64	157.13	16
17	156.72	155.96	155.45	155.29	155.76	158.31	161.37	165.26	166.75	161.01	158.57	157.07	17
18	156.67	155.93	155.43	155.27	155.77	158.48	161.86	165.44	166.51	160.91	158.51	157.02	18
19	156.63	155.89	155.42	155.28	155.79	158.74	162.58	165.48	166.26	160.97	158.44	156.97	19
20	156.60	155.86	155.41	155.37	155.81	159.02	163.07	165.34	165.92	161.22	158.38	156.93	20
21	156.60	155.84	155.43	155.41	155.86	159.55	163.13	165.12	165.57	161.51	158.32	156.92	21
22	156.52	155.82	155.43	155.46	156.03	159.93	163.20	165.02	165.19	161.71	158.23	156.91	22
23	156.49	155.81	155.41	155.35	156.47	160.12	163.16	165.24	164.74	161.61	158.16	156.92	23
24	156.46	155.79	155.34	155.32	157.03	160.18	163.01	165.86	164.27	161.34	158.09	156.93	24
25	156.44	155.77	155.30	155.30	157.10	160.36	162.78	166.04	163.90	161.07	158.05	156.89	25
26	156.42	155.76	155.27	155.38	156.98	160.77	162.60	166.16	163.67	160.89	158.01	156.83	26
27	156.38	155.75	155.20	155.33	157.00	161.02	162.31	166.40	163.51	160.65	157.98	156.76	27
28	156.35	155.75	155.19	155.39	157.04	161.31	162.07	166.65	163.23	160.47	157.94	156.69	28
29	156.34		155.20	155.39	157.13	161.64	162.74	166.89	162.90	160.67	157.94	156.64	29
30	156.35		155.19	155.36	157.06	161.63	161.45	167.13	162.55	160.53	157.91	156.59	30
31	156.35		155.17		156.87		161.83	167.33		160.55		156.55	31
Max	157.48	156.46	155.73	155.46	157.13	161.64	163.16	167.33	168.39	163.27	160.49	157.85	Max
Min	156.34	155.75	155.17	155.11	155.18	156.77	161.40	162.75	162.55	160.47	157.91	156.55	Min
Total	4859.82	4369.57	4818.97	4658.59	4832.64	4758.63	5020.05	5124.62	4992.51	5009.69	4767.84	4872.38	Total
Days	31	28	31	30	31	30	31	31	30	31	30	31	Days
Mean	156.77	156.06	155.45	155.28	155.89	158.62	161.94	165.31	166.42	161.60	158.92	157.17	Mean

Zero point of water gauge: El. 154.211m

WATER LEVELS AT HYDROGRAPHIC OFFICE (4)

River system: Mekong   Year: 1967   Unit: El (m)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
1	156.51	155 87	155.31	155.10	155.76	156.01	157.23	162.74	161.08	163.03	158.64	158.32	1
2	156 48	155.83	155.28	155 06	155.76	155.98	157.41	162.53	160.93	162.91	158.68	158.12	2
3	156.44	155.80	155.25	155 02	155.82	155.90	157.52	162.25	160.77	163.03	158 65	157.92	3
4	156.41	155.76	155 23	154.98	155.82	155.84	157.70	161.86	160.62	163.01	158.57	157.78	4
5	156.36	155.74	155 24	154.95	155.78	155.84	157.85	161.45	160.51	162.84	158 45	157.65	5
6	156 32	155.72	155.29	154.94	155.71	155.91	157.78	161.02	160.41	162.57	158 35	157.58	6
7	156.29	155.69	155.33	154.93	155.61	156 00	157.67	160 62	160 40	162.31	158.23	157.52	7
8	156.26	155.66	155.32	154.95	155 54	156.07	157.69	160 25	160.43	162.08	158.18	157.46	8
9	156.24	155.66	155.29	155.00	155.49	156.30	157.69	159.90	160.49	161.84	158.13	157.38	9
10	156.20	155 66	155.24	155.03	155.49	156 67	157.71	159.71	160.72	161.61	158.14	157.39	10
11	156.18	155 65	155.20	154.98	155.61	157.08	157 79	159.74	161.03	161.37	158.10	157.22	11
12	156.18	155 67	155.18	154.95	155.68	157.75	157.79	160.14	161 04	161.12	158.06	157.15	12
13	156.18	155.71	155.17	154.92	155.71	158.38	157.70	160 83	161.33	160.84	157.96	157.08	13
14	156.20	155.70	155.16	154 93	155.77	158.35	157 66	161.50	161.63	160.84	157 84	157.00	14
15	156.23	155.68	155 19	154.96	155.81	158.16	157.66	162.00	161.98	160.30	157.78	156.96	15
16	156.21	155 64	155.25	155.01	155.85	157.94	157.73	161.85	162.72	160.07	157.74	156.92	16
17	156.17	155.60	155.30	155.08	155.87	157.72	158.19	161 60	163.48	159.90	157.69	156.90	17
18	156.18	155.56	155.34	155.12	155.93	157.52	158.73	161.53	163.90	159.78	157.65	156.88	18
19	156.21	155.53	155.38	155.20	155.92	157.35	158.96	161.87	163.88	159.73	157.76	156.88	19
20	156.27	155.40	155.40	155.30	155.86	157.27	158.96	162.33	163.45	159.78	158.34	156.93	20
21	156 29	155.48	155.39	155.39	155 83	157.24	159.35	162.85	163.00	160.01	158.94	157 00	21
22	156 27	155.46	155.32	155.46	155 80	157.26	160.37	163.73	162.75	160.28	159.01	157.00	22
23	156.26	155.43	155.26	155.51	155.70	157.31	160.79	164.05	162.65	160 21	159 89	156.92	23
24	156.23	155.41	155.19	155.57	155.56	157.45	160.63	164.09	162 63	159.85	158.77	156.84	24
25	156.16	155 40	155.16	155.64	155.48	157.28	160 31	165.00	162.99	159.51	158.79	156.77	25
26	156 09	155.38	155.13	155.67	155.45	157.14	159.97	164 65	163 48	159.22	158.73	156.71	26
27	156 05	155.36	155.08	155.70	155 46	157.00	159.74	163 10	163.74	159.60	158.56	156.65	27
28	156.00	155 34	155.06	155.74	155.52	156.97	159.70	162.57	163 68	158.81	158.34	156.61	28
29	155 96		155.07	155.77	155.65	156.99	161.66	162.13	163.69	158.69	158.23	156.57	29
30	155.94		155.08	155.79	155.81	157.06	162 86	161.70	163.38	158.63	158 43	156.52	30
31	155.91		155.10		155 94		162.98	161.31		158.62		156 48	31
Max	156.51	155.87	155 40	155 79	155.94	158 38	162 98	165.00	163 90	163.03	159 01	158.32	Max
Min	155 91	155 34	155.06	154.92	155.45	155 84	157.23	159.71	160 40	158.62	157 65	156.48	Min
Total	4842.68	4356.79	4812.19	4656 65	4826 99	4709.74	4925.78	5020 90	4862.79	4982.39	4750.63	4871.11	Total
Days	31	28	31	30	31	30	31	31	30	31	30	31	Days
Mean	156.22	155.60	155.23	155.27	155.71	156.99	158.90	161.96	162.09	160.72	158.35	157.13	Mean

Zero point of water gauge: El 154.211 m

WATER LEVELS AT HYDROGRAPHIC OFFICE (5)

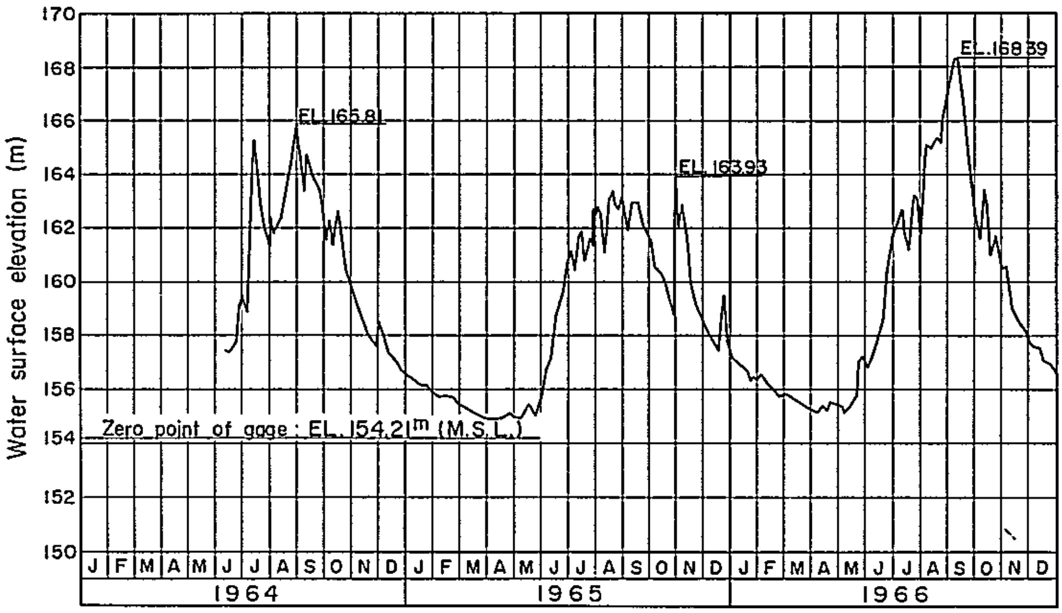
River system: Mekong Year: 1968 Unit: El (m)

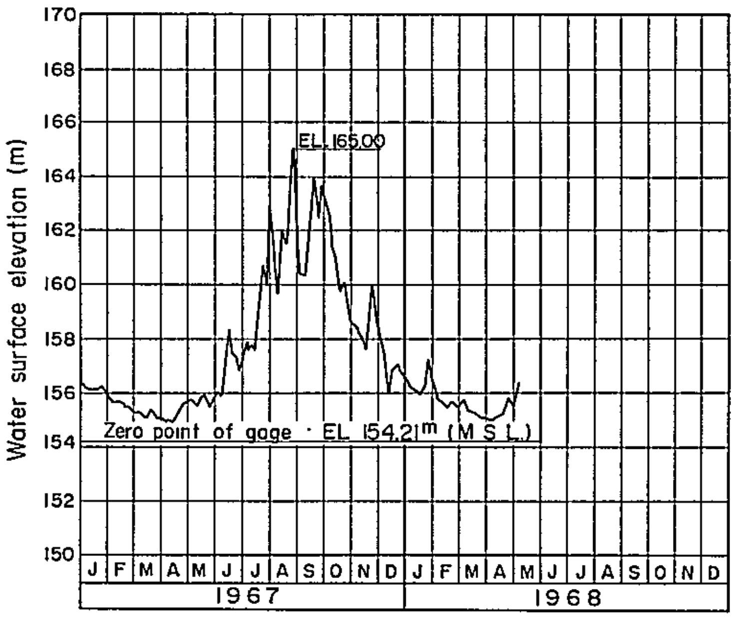
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
1	156 44	156.09	155.49	155.02	155.65								1
2	156.41	155.99	155.55	155.02	155.81								2
3	156.38	155 94	155.65	155 01	156 00								3
4	156.34	155 88	155.72	155.01	156.14								4
5	156.31	155 86	155.75	155.03	156.26								5
6	156.28	155 82	155.70	155.03									6
7	156.25	155.79	155.60	155.01									7
8	156.23	155.75	155.31	155.00									8
9	156.21	155.72	155.42	155.02									9
10	156.20	155.69	155.40	155.06									10
11	156.17	155 65	155.37	155.07									11
12	156.16	155.62	155.38	155.06									12
13	156.13	155.59	155 39	155.07									13
14	156 11	155.56	155 38	155.08									14
15	156 08	155.55	155 33	155 16									15
16	156.07	155.53	155.29	155.22									16
17	156.03	155 52	155.27	155.22									17
18	156 01	155.51	155 28	155.20									18
19	156.00	155.54	155.22	155.23									19
20	156.00	155 66	155.20	155.30									20
21	156.02	155 65	155.17	155.42									21
22	156.08	155.67	155.14	155.56									22
23	156.05	155.70	155.11	155.68									23
24	156.31	155.65	155.05	155.80									24
25	156.58	155.60	155.03	155.81									25
26	157.04	155.53	155.07	155 72									26
27	157.06	154 48	155.04	155 61									27
28	156.79	155.45	155.03	155 55									28
29	156 54	155.45	155 02	155.50									29
30	156.34		155.05	155.57									30
31	156.20		155 04										31
Max	157.06	156 09	155.75	155.81									Max
Min	156.00	155.45	155.02	155.00									Min
Total	4844.82	4513 44	4814.45	4658.04									Total
Days	31	29	31	30									Days
Mean	156.28	155.64	155.31	155.27									Mean

Zero point of water gauge: El. 154.211 m

Data 5.2.

STAGE HYDROGRAPH AT HYDROGRAPHIC OFFICE G.S., 1964-1968

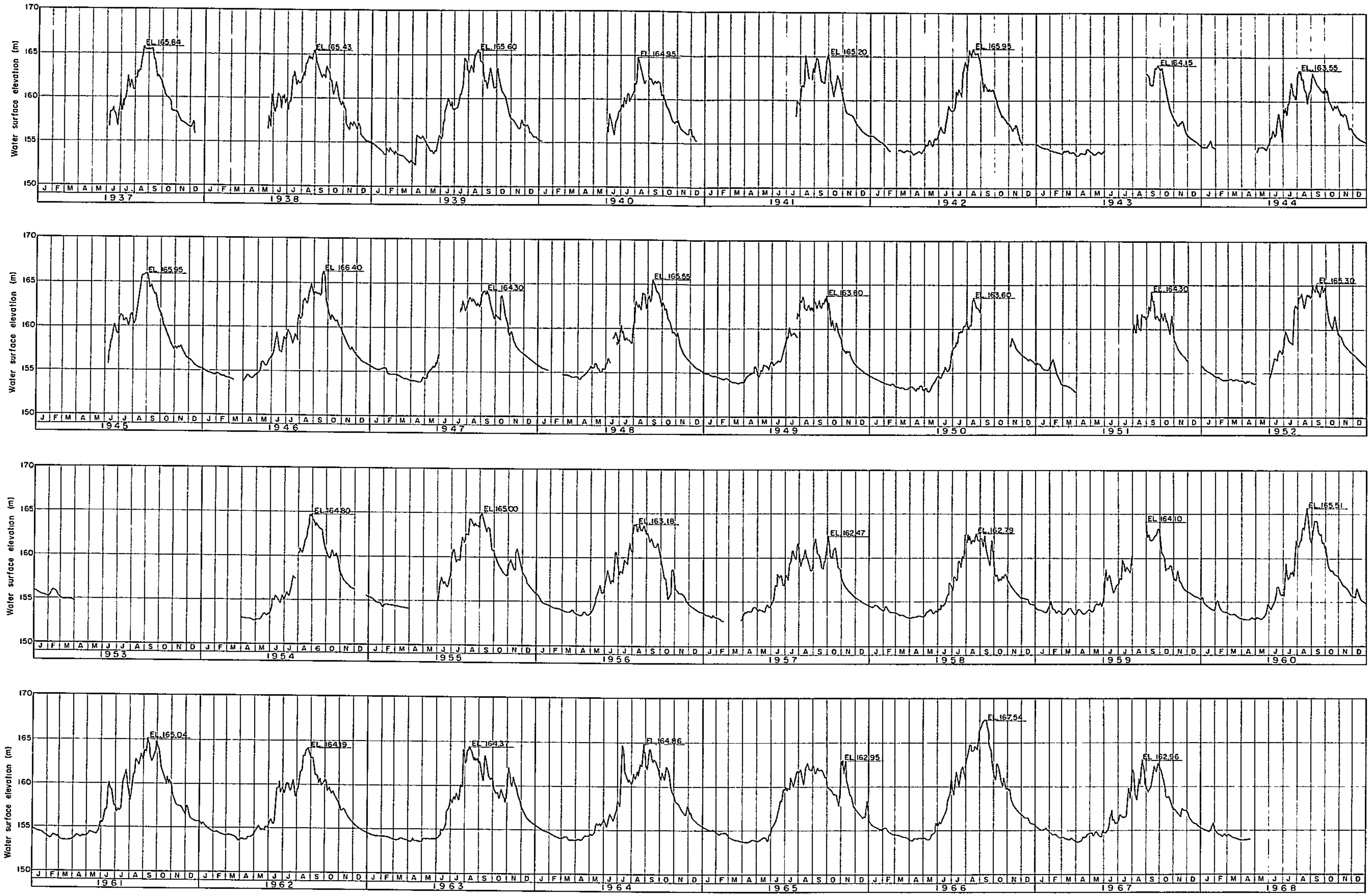




Remarks

1) Gage was installed on June 11,'64 and data were taken ever since.
2) Figures given here show daily mean value of three readings a day taken at 6.00, 12:00 and 18:00.

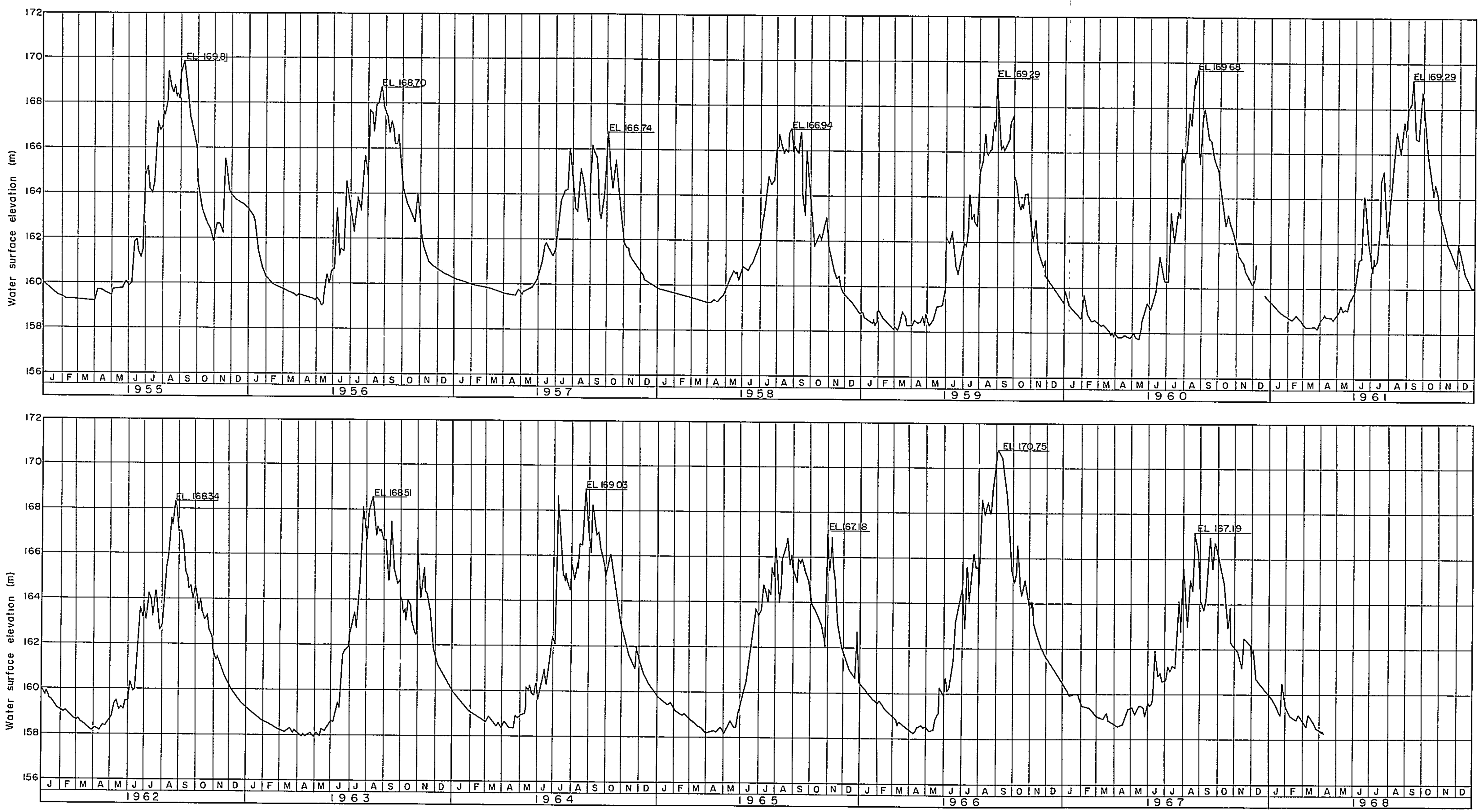
STAGE HYDROGRAPH AT R.I.D. (WAT HAI SOK) GAGING STATION, 1937-1968



Remarks Zero point of present staff gage EL 153.00 m

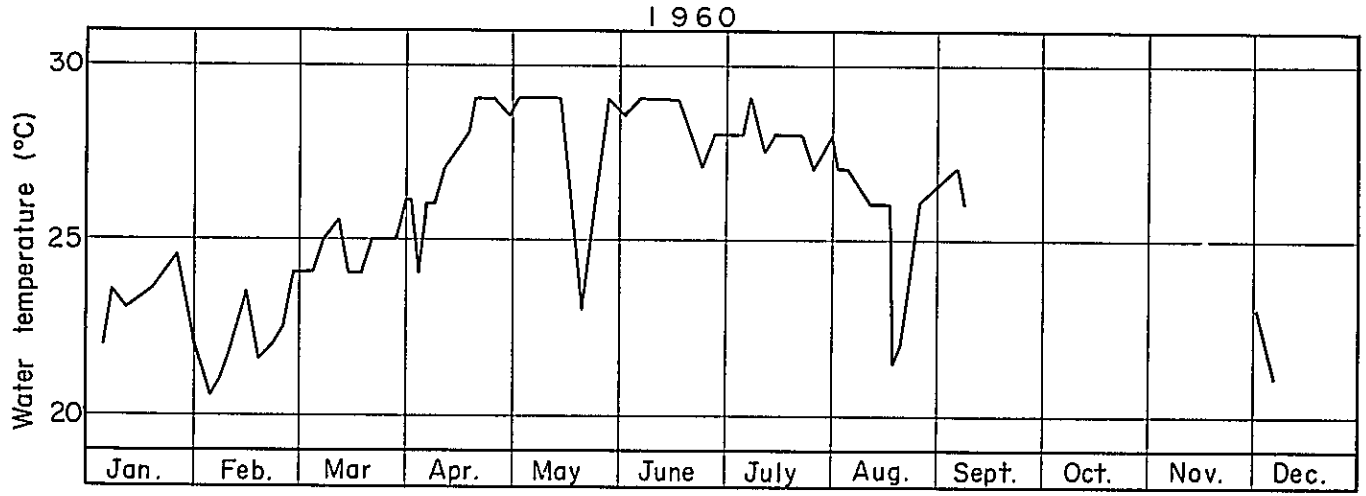
Data 5.4.

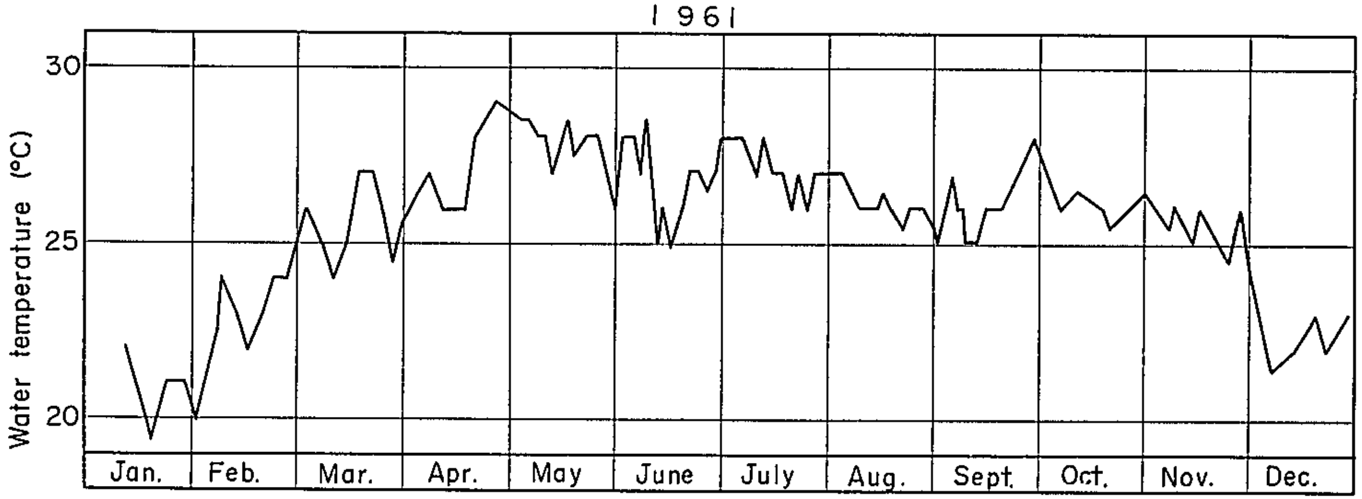
STAGE HYDROGRAPH AT VIENTIANE (WAT SOP) GAGING STATION, 1955 - 1968



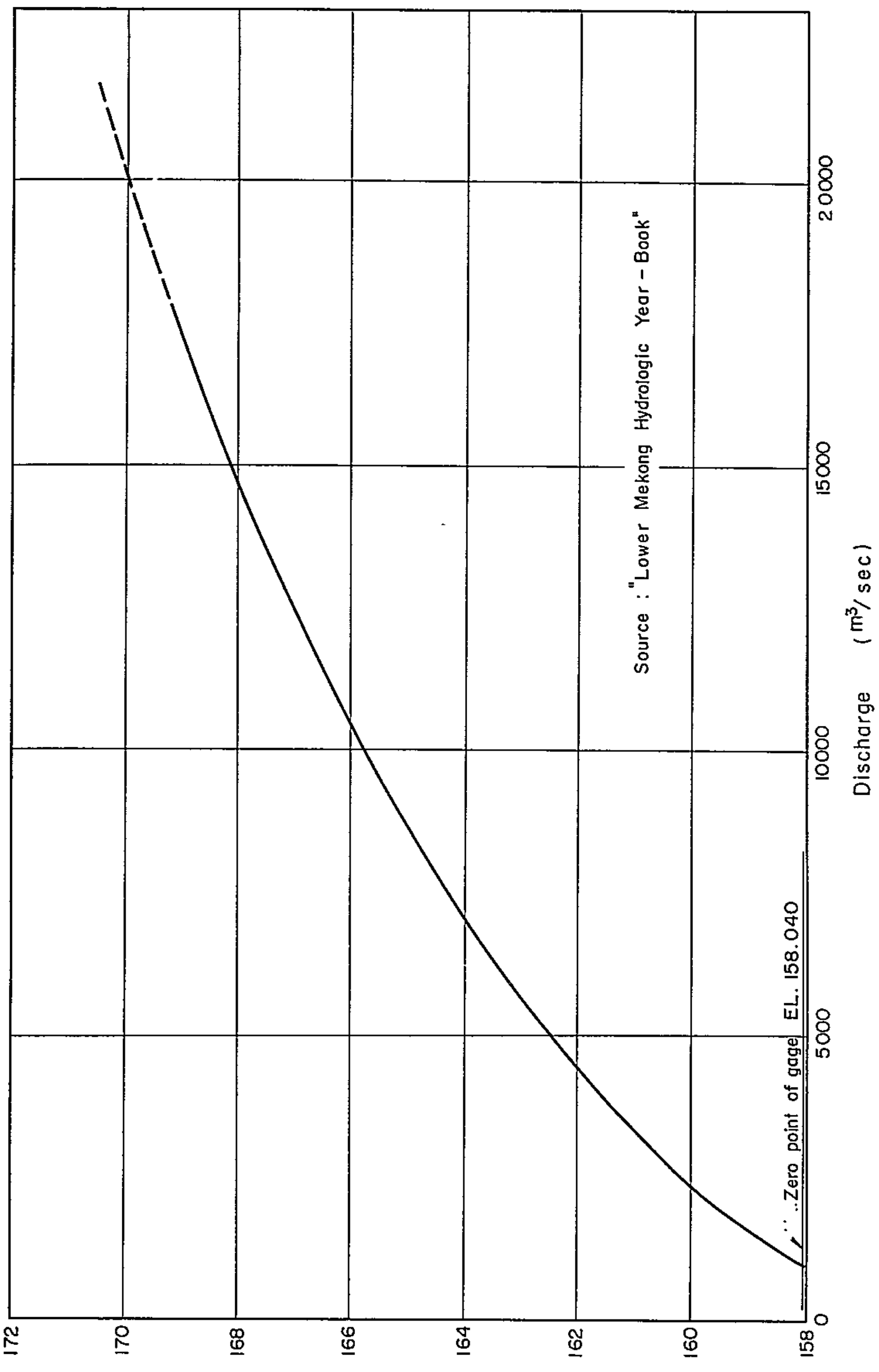
Remarks Zero point of gage EL 158.040 m

WATER TEMPERATURE OF THE MEKONG AT VIENTIANE, 1960 AND 1961

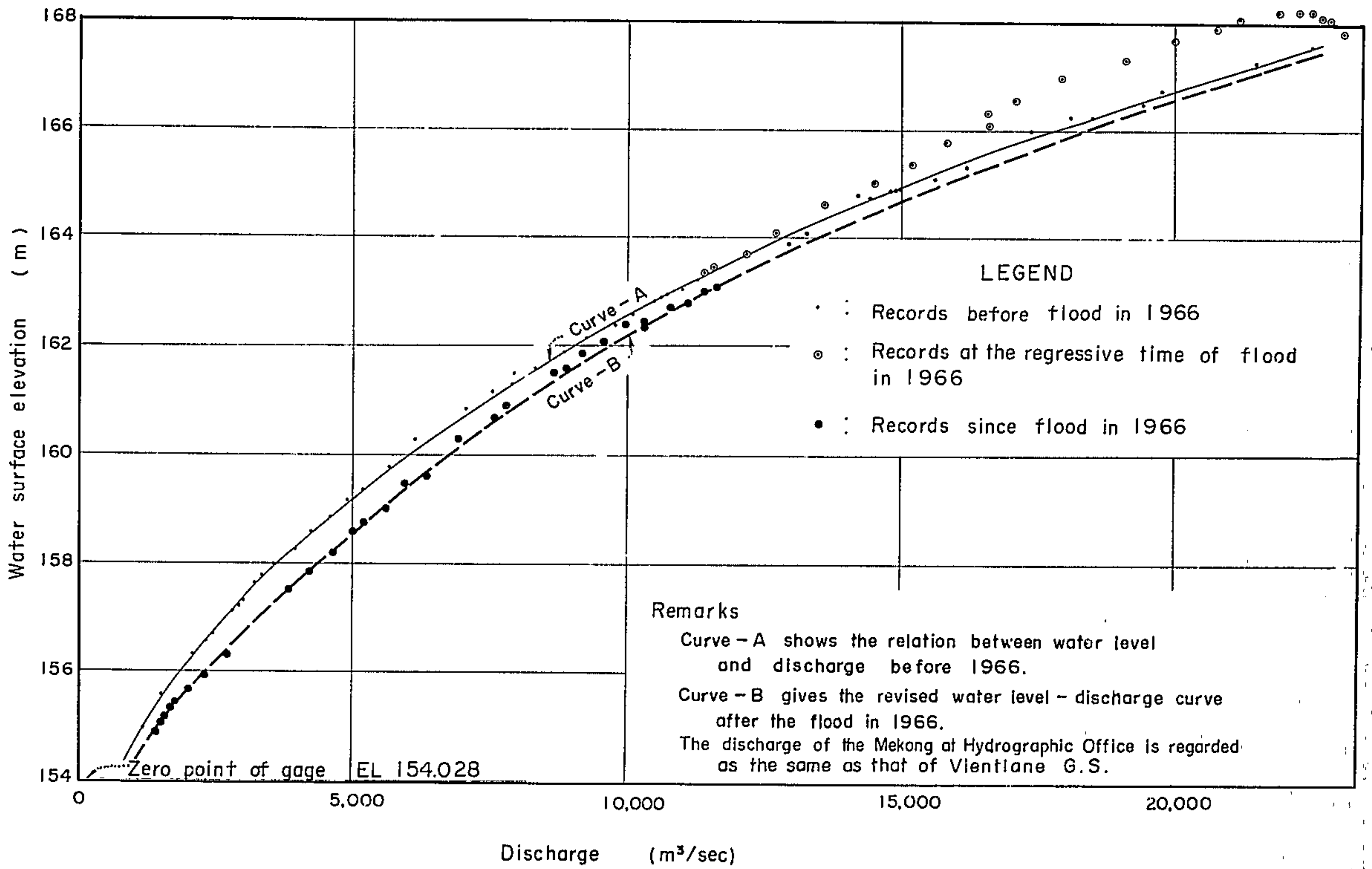




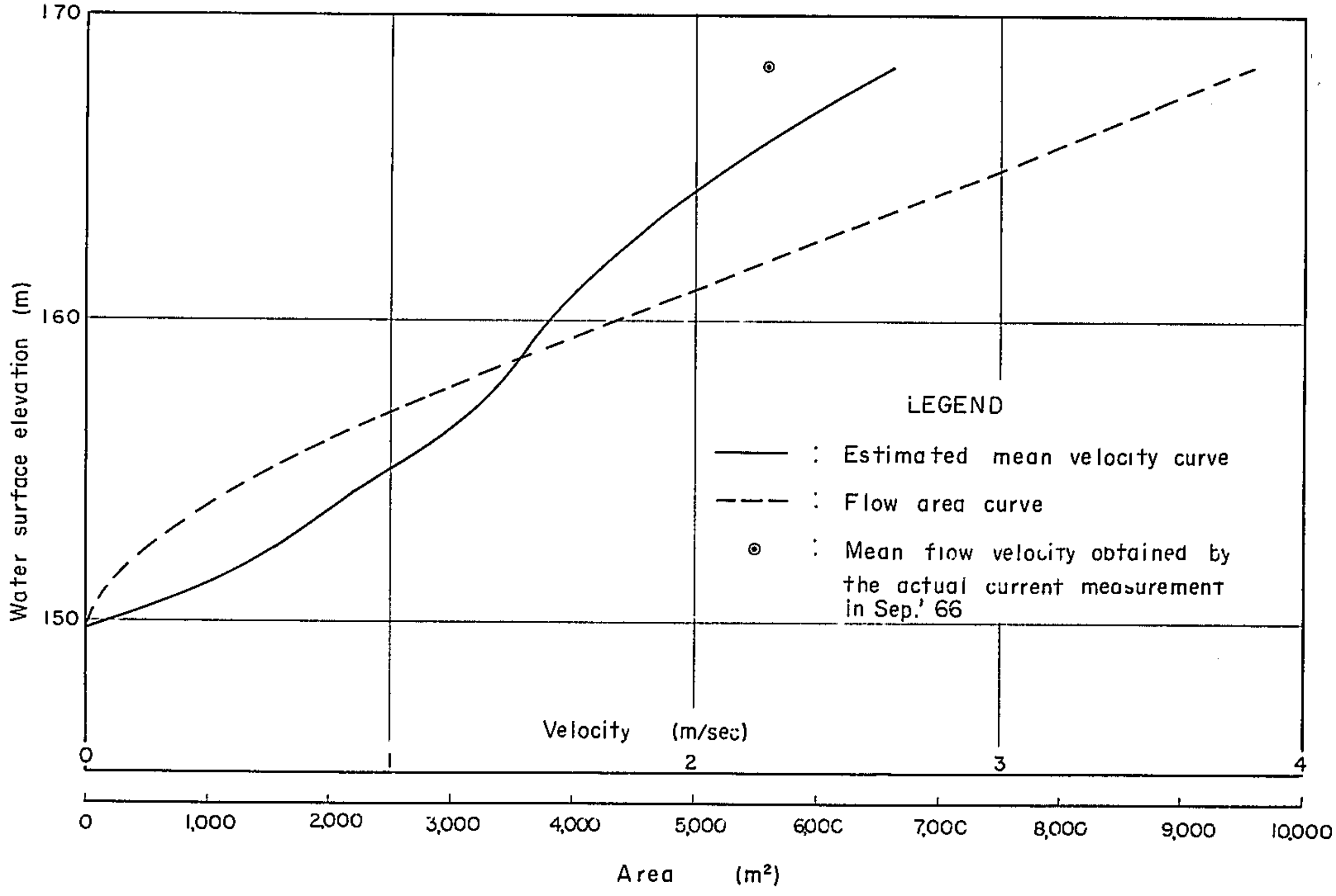
RATING CURVE OF THE MEKONG AT VIENTIANE (WAT SOP) G.S.



RATING CURVES OF THE MEKONG AT HYDROGRAPHIC OFFICE G.S.

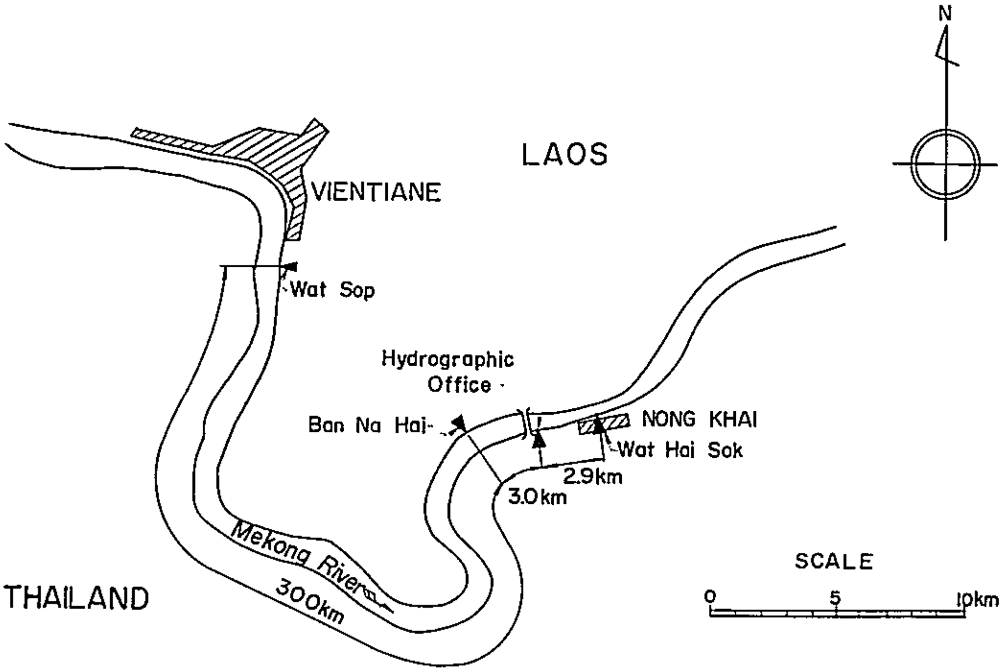


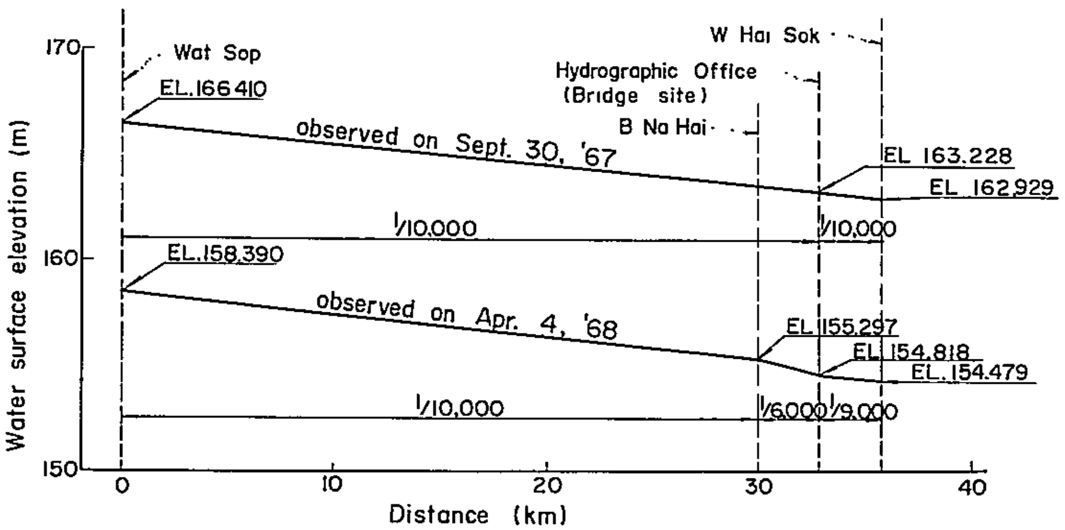
FLOW AREA AND MEAN FLOW VELOCITY OF THE MEKONG AT THE BRIDGE SITE



Data 5.9.

WATER SURFACE SLOPE





Remarks :

In both the first-and second-phase investigations, water levels were observed simultaneously at different places up-and downstream from the bridge site

Based on the results of survey and the Manning's formula, the roughness coefficients "n" of the Mekong at the immediately up-and downstream reaches of the bridge site were estimated at 0.032 and 0.046 in the dry season, and 0.025 and 0.049 in the rainy season, respectively.

Fig.5.2. RELATIONSHIP BETWEEN WATER-LEVELS RECORDED AT RID (WAT HAI SOK) AND HYDROGRAPHIC OFFICE GAGING STATIONS

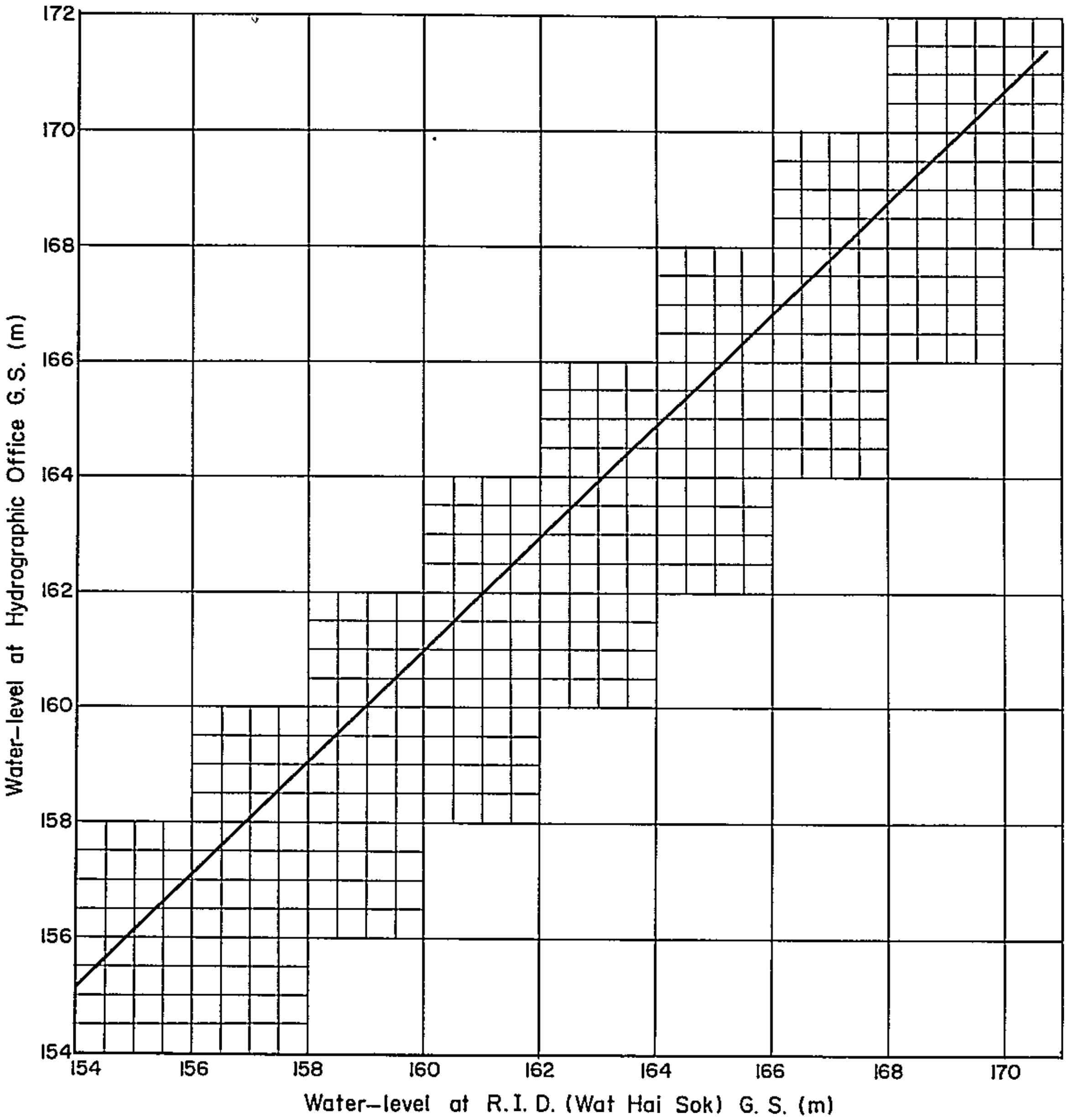
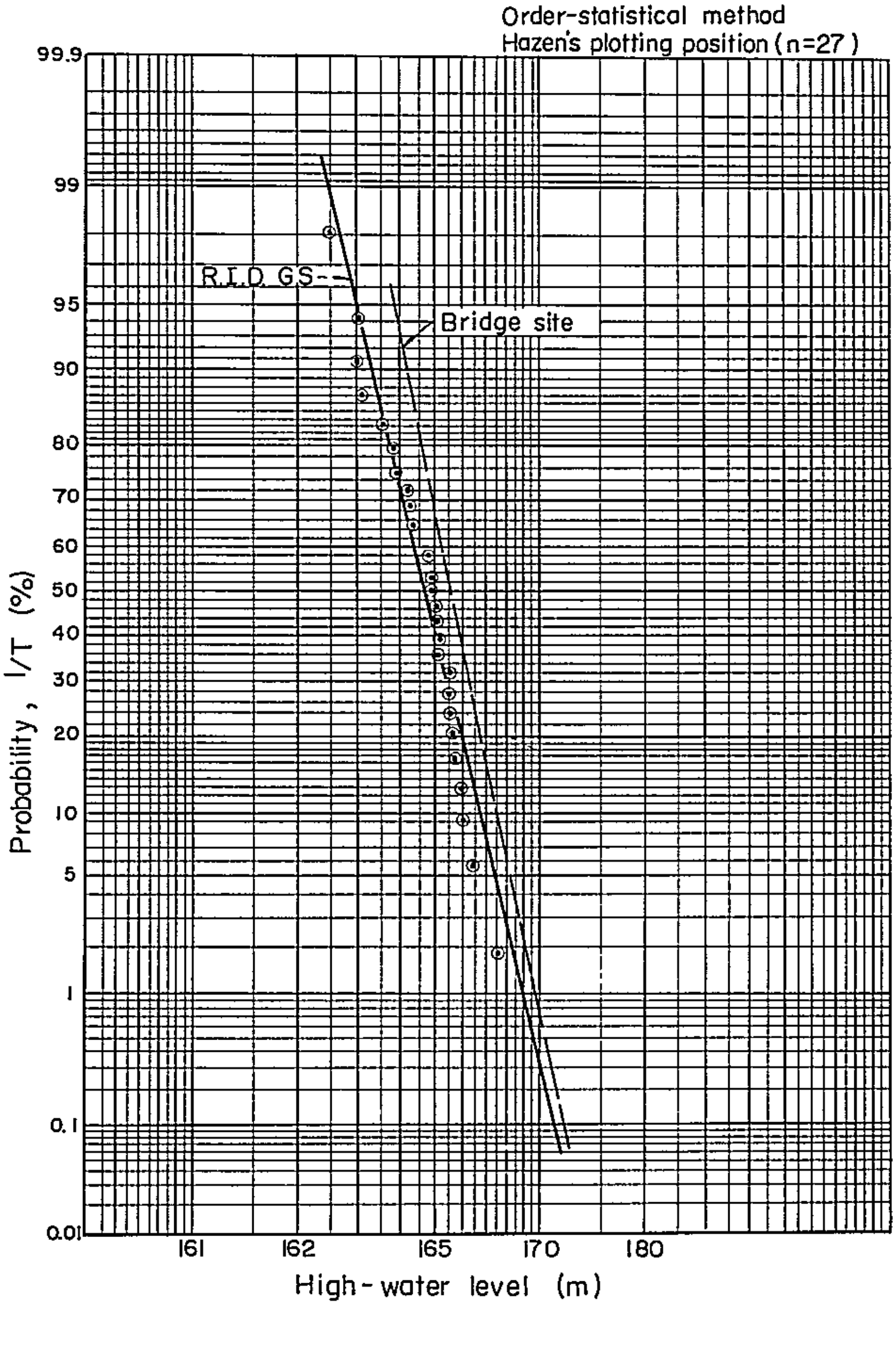


Fig.5.3. PROBABLE HIGH-WATER LEVEL AT R.I.D. (WAT HAI SOK) G.S. AND BRIDGE SITE



CHAPTER VI

ECONOMIC SURVEY

6.1. General

As mentioned in the Feasibility Report Part II, the economic feasibility of the present project was studied by appraising the benefit-cost ratio, capitalized net benefit and the internal rate of return.

The cost estimate, including the construction cost and the annual expense, was made for the tentative design presented in the Feasibility Report Part II. Various benefits, direct and indirect, were estimated based on the data gathered during economic surveys made in the first- and second-phase investigations.

For the purpose of obtaining data for estimating the possible future traffic upon which the direct benefits shall be based, studies on the following items were made in the first-phase investigation.

1) Imaginary traffic that would have been initiated on the new bridge, if the bridge would have been opened to traffic just at the time point when the traffic survey was made;
2) Sudden growth of traffic due to the impact of bridge construction;
3) Natural growth rate of traffic; and
4) Benefit per unit volume of traffic.

In the second-phase investigation, studies were made on indirect benefits that might be brought about by the project and on the relationship between the bridge tolls and the possible future traffic.

Various data gathered or surveyed as well as results of studies concerning the economic feasibility of the project are presented in the following.

6.2. Data on Salient Economic Features of Laos and of Project Area

Various data were supplied from various sections of the Laotian and Thai governments and other authorities concerned. In this paragraph are presented some data on the Laotian national economy and economic features in the project area.

Major Industries in Laos

Item	Number of factory	Unit	Annual production (x 10^3) 1962	1963	1964	1965	1966	1967	Remarks
Match manufactory	1	case	–	–	–	2.5	3.0	3.5	1 case = 7,200 boxes and 1 box = 50 matches
Cigarette manufactory	3	case	–	–	–	40.57	46.0	50.0	1 case = 50 cartoons, 1 cartoon = 10 packages and 1 package = 20 cigarettes
Rubber sandal manufactory	4	dz.	–	–	30	56	72	78	
Fizzy drink manufactory	6	btl.	5,400	5,700	6,300	6,800	7,200	8,000	1 at Saravane, 1 at Savannakhet, 3 in Vientiane and 1 at Luang Prang
Plastic bag manufactory	2	kg.	–	–	–	72.0	72.0	75.0	Polyethylene bags
Mechanical rice-mill	208	ton	–	–	88.2	100	110	110	8 of 1st class capable of annual production of 2,400 tons/year 10 of 2nd class capable of annual production of 1,500 tons/year 190 of 3rd class capable of annual production of 200 tons/year
Textile printing	1	m	–	–	–	–	600	600	
Alcohol distillery	14	liter	–	–	1,200	1,200	1,800	1,800	Small distilleries capable of production from 150 to 200 litres/day
Power sawmill	76	m^3	–	–	150	156	160	200	Sawn wood
Ice manufactory	8	ton	–	–	20	26	30	35	4 in Vientiane, 1 at Luang Prabang, 1 at Savannakhet, 1 at Pakse and 1 at Khammuane
Candle manufactory	3	case	–	36	36	40	40	45	1 case = 100 packages

Laotian Export and Import, 1966

Item	Quantity, In kg	Amount In Kips	Amount In US.$
I. Export	9,509,815	357,725,434	715,451
Foodstuffs (vegetables, fruits, coffee-beans, etc.)	738,197	75,474,520	150,949
Mineral Ores (tin, copper and iron)	601,886	225,831,440	451,663
Timber and Crushed Stone	8,137,597	39,135,000	78,270
Others (resin and rosin, musical instruments)	32,135	17,284,474	34,569
II. Import	170,089,248	10,017,158,506	20,034,317
Rice and Other Cerials	42,150,225	2,492,026,152	4,984,052
Sugar and Other Foodstuffs	2,077,025	266,133,592	532,267
Oil Products (Gasoline, oil and grease)	81,131,828	1,381,481,563	2,762,963
Construction Materials (steels, cement, bolts, nuts, etc.)	19,744,472	587,266,751	1,174,534
Electric Appliances and Apparatuses	2,039,014	833,092,444	1,661,829
Motorcars, Tractors and Cycles	2,465,060	1,271,250,396	2,542,501

Gross National Product of Laos

Estimated gross national product per head (US$)

	Vientiane	Self-supporting economy	Market economy
1962	–	55.43	120.20
1963	–	55.98 (1.01)	126.21 (1.05)
1964	–	56.54 (1.01)	132.52 (1.05)
1965	–	57.11 (1.01)	139.15 (1.05)
1966	132	57.11 (1.00)	139.15 (1.00)
1967	135 (1.025)	57.68 (1.01)	146.11 (1.05)
1973	157 (1.025)	61.23 (1.01)	195.80 (1.05)
1990	241 (1.025)	72.51 (1.01)	448.76 (1.05)

Population (10^3 persons)

	Laos	Self-supporting economy	Market economy
1962	2,450	2,082.5	367.5
1963	2,509 (1.024)	2,133 (1.024)	376 (1.024)
1964	2,569 (1.024)	2,184 (1.024)	385 (1.024)
1965	2,635 (1.026)	2,240 (1.026)	395 (1.026)
1966	2,698 (1.024)	2,293 (1.024)	405 (1.024)
1967	2,765 (1.025)	2,350 (1.025)	415 (1.025)
1973	3,207 (1.025)	2,725 (1.025)	482 (1.025)
1990	4,880 (1.025)	4,146 (1.025)	734 (1.025)

Remarks: Figures in the brackets show index to value of the foregoing year.

Population in Project Area

County		Population
Vientiane Province	(as of 1967)	270,771
Vientiane city		113,168
Pong-Hong		21,747
Thourakhom		16,814
Saythavy		31,106
Phanthaboun		8,955
Xayfong		32,510
Nasaythong		23,116
Vang-Vieng		13,600
Sanakham		9,755
Nong Khai Province	(as of 1966)	297,833
Nong Khai		69,390
Tha Bo		44,850
Sri Chieng Mai		28,967
Phong Visay		69,789
Muang Kan		55,697
Saika		29,140

Remarks:

Collected from the Office of Vientiane Province and from the Nong Khai Province Bureau of Statistics.

Prices in Nong Khai and Vientiane (1)

Items	Unit	Nong Khai (Baht)	Nong Khai (Kip)	Vientiane (Kip)
1. Miscellaneous cereals				
Rice (Laos)	kg	2.35	58.75	76
Rice (ordinary)	"	2.65	66.25	98
Bread	"		25	83
Cassava	"	2.5	62.5	70
Black bean	"	5	125	110
2. Vegetables				
Convalvulus	kg	2	50	80
Tomato	"	0.50	12.5	50
Chilipepper	"	6	150	300
War gourd	"	1	25	65
Chinese cabbage	"	3	75	100
Lettuce	"	2	50	50
Beefsteak plant	"	5	125	60
Cabbage	"	1	25	30
Green piece	"	6	150	200
Japanese onion	"	2	50	100
Garlics	"	6	150	150
Bean sprouts	"	2.5	62.5	50
Cucumber	"	1	25	130, 20
Dry onion	"	6	150	200
Potato	"	6	150	280
Manpao	"	0.75	18.75	25
Wild tomato	"	3	75	150
Long bean	"	4	100	100
3. Fruits				
Apple	kg	5	125	250

Item	Unit	Nong Khai (Baht)	Nong Khai (Kip)	Vientiane (Kip)
Banana	kg	4	100	150–200
Water melon	no.	5	125	300
Shaddock	"	3.5	87.5	120
Orange	kg	4	100	120–200
Pineapple	no.	4	100	180
Coconut	"	1.5	37.5	30
Grape	kg	12	300	400
4. Meat and eggs				
Beef	kg	14	350	450
Pork (with bone)	"	12	300	500
Pork (fat of meat)	"	12	300	500
Pork (high quality)	"	17	425	500
Pork (with hide)	"	10	250	420
Chicken	no.	10	250	800–1000
Duck's egg	"	0.6	15	17
Fish	kg	14–15	350–375	600
		18–20	450–500	
Fish (salted)	"	20–25	550–625	700
5. Dry food and condiments				
Dried onion	kg	2.5	62.5	70
Dry cattle fish	"	17–28	425–700	650–800
Thin threads of beach-jelly	"	16	400	500–700
Salt	"	0.5	6.2	25
6. Other foodstuff				
Condensed milk	can	2.5–3.0	62.5–75	11.0

Prices in Nong Khai and Vientiane (2)

Item	Unit	Nong Khai (Baht)	Nong Khai (Kip)	Vientiane (Kip)
Lard	kg	12	300	300
Soup (Chinese style)	bottle	5–6	125–150	100
Black coffee	cup	0.5	12.5	15
Milk coffee	"	1	25	25
7. Electricity and fuel				
Electricity	kwh	1.30	32.5	40
Petroleum	lit.	50	2	36
Electric bulbs	no.	4–5	100–125	140
8. Daily commodities				
Saucer	no.	3–5	75–125	170
Nail	kg	5	125	150
Aluminum streaming basket	no.	18	450	450–550
Washing soap	box	9	225	200
Toilet soap	no.	3	75	70
Vacuum bottle	"	70	1,750	1,350
		40	1,000	570
Soap	"	0.5	12.5	20
Powder soap	box	8	200	85
Toilet paper	no.	3	75	60
Match	10 boxes	2	50	50
9. Medicals				
Aspirin	tab.	0.10	2.5	7.5
Quinine	"	0.05	1.25	7.5
10.Charges				
Hair dressing (man)	person	5–7	125–175	150
Hair dressing (woman)	"	10–15	250–375	300

Item	Unit	Nong Khai (Baht)	Nong Khai (Kip)	Vientiane (Kip)
City bus	km	0.50	12.5	30
Movie (2nd class)	person	3–5	75–125	100
Play (2nd class)	"	2–3	50–75	100
Drama and sports	"	"	"	100
11. Magazines and smoking				
Daily paper	no.	0.5–1.0	12.5–25	50
Weekly magazine	"	3.0–3.5	75–87.5	140
Tobacco	box	2.5–3.5	62.5–87.5	20
12. Electric instruments				
Refrigerator	no.	3,675	91,875	60,000
Fan	"	604	15,100	16,000
13. Vehicles				
Bicycle (Thailand)	no.	550	13,750	14,500
Bicycle (Japan)	"	850	21,250	18,000
Motorcycle	"	6,200	155,000	135,000
14. Construction material				
Cement	ton	–	14,000	19,000
Steel bar (9 mm dia.)	"	3,080	77,000	78,000
Steel bar (6 mm dia.)	"	3,250	81,250	100,000
Steel plate	"	20.5		380
Veneer	"	50	1,250	1,400
Timber	"	900	22,500	12,800

Level of Monthly Consumption in Nong Khai and Vientiane

(Unit: tons)

	Gasoline	Cement	Rice	Steel bar	Beer	Hog	Refrigerator	Watermelon
Nong Khai	600	-	2,500	150	16	-	2	-
Vientiane city	750	1,650	1,500	200	40	74	10	135

(Unit: tons/1,000 persons)

	Gasoline	Cement	Rice	Steel bar	Beer	Hog	Refrigerator	Watermelon
Nong Khai	8.65	-	36.02	2.16	0.23	-	0.03	-
Vientiane city	6.62	14.57	13.26	1.77	0.35	0.65	0.09	1.19

Remarks: The population of 69,400 as of December 1966 of Nong Khai Province and 113,200 as of July 1966 of Vientiane were used for the estimation of the quantity of consumption per 1,000 persons mentioned above.

6.3. Possible Future Traffic

In general, the traffic volume on a toll bridge is largely influenced by the level of tolls. In the present study, the possible future traffic was estimated first assuming that the same tolls would be collected on the bridge as on the existing car ferry operating between Nong Khai and Tha Naleng, and then the influence on the future traffic of the bridge tolls was studied.

6.3.1. Imaginary Initial Traffic

It is necessary for estimating the future traffic to assume an imaginary traffic that would be initiated on the new bridge, if the bridge would be opened to traffic at the time when the "present traffic" is surveyed or estimated, namely, in 1967 in the present case. This traffic is in no way the actual traffic in 1967, but an imaginary traffic that shall be estimated from the present traffic under the above assumption.

In order to know the present traffic flows, an origin-destination survey of highway and waterway traffic was carried out in 1967 at ten selected sites lying in and around the project area as shown in Fig.6.1. The results are shown in Fig.6.1 by the traffic flows of freight, passengers and vehicles between possible zonal pairs.

Various informations on the traffic in the project area were supplied from the Thai Government's Departments of Highway, Customs, and Immigration, the Royal State Railway of Thailand, the Nong Khai and Udon Thani Stations, the Civil Aviation Department of Laos and other authorities concerned.

As regards the ferry traffic across the Mekong, in addition to the Tha Naleng vehicular ferry surveyed in the course of the origin-destination survey, traffics on the passenger ferry between Nong Khai and Tha Deua and on small-scale ferries between Vientiane and Sri Chieng Mai and between Tha Bo and Hat Dok Keo were also surveyed. Informations on the waterway traffic from Vientiane downstream to Savannakhet and upstream to Luang Prabang were gathered at customs and immigration stations located in Vientiane.

From the data thus obtained, the flows of freight, passengers and vehicles between possible zonal pairs were analyzed and are listed in Tables 6.1 to 6.4.

The imaginary initial traffic that shall be assumed if the bridge would be opened to traffic in 1967 were estimated taking account of the present traffic flows on the following seven stretches based on the origin-destination survey.

(1) From Vientiane to Sri Chieng Mai and Tha Bo;
(2) Between Vientiane and Nong Khai Station;
(3) Between Vientiane and the town of Nong Khai;
(4) Between Vientiane and Udon Thani,
(5) Between Tha Deua and Nong Khai Station;
(6) Between Tha Deua and the town of Nong Khai; and
(7) Between Tha Deua and Udon Thani.

The estimated imaginary initial traffics are given in Table 6.2 in the Feasibility Report Part II, Chapter VI.

Fig. 6.1. ORIGIN-DESTINATION SURVEY POINTS AND TRAFFIC FLOW AS OF 1967

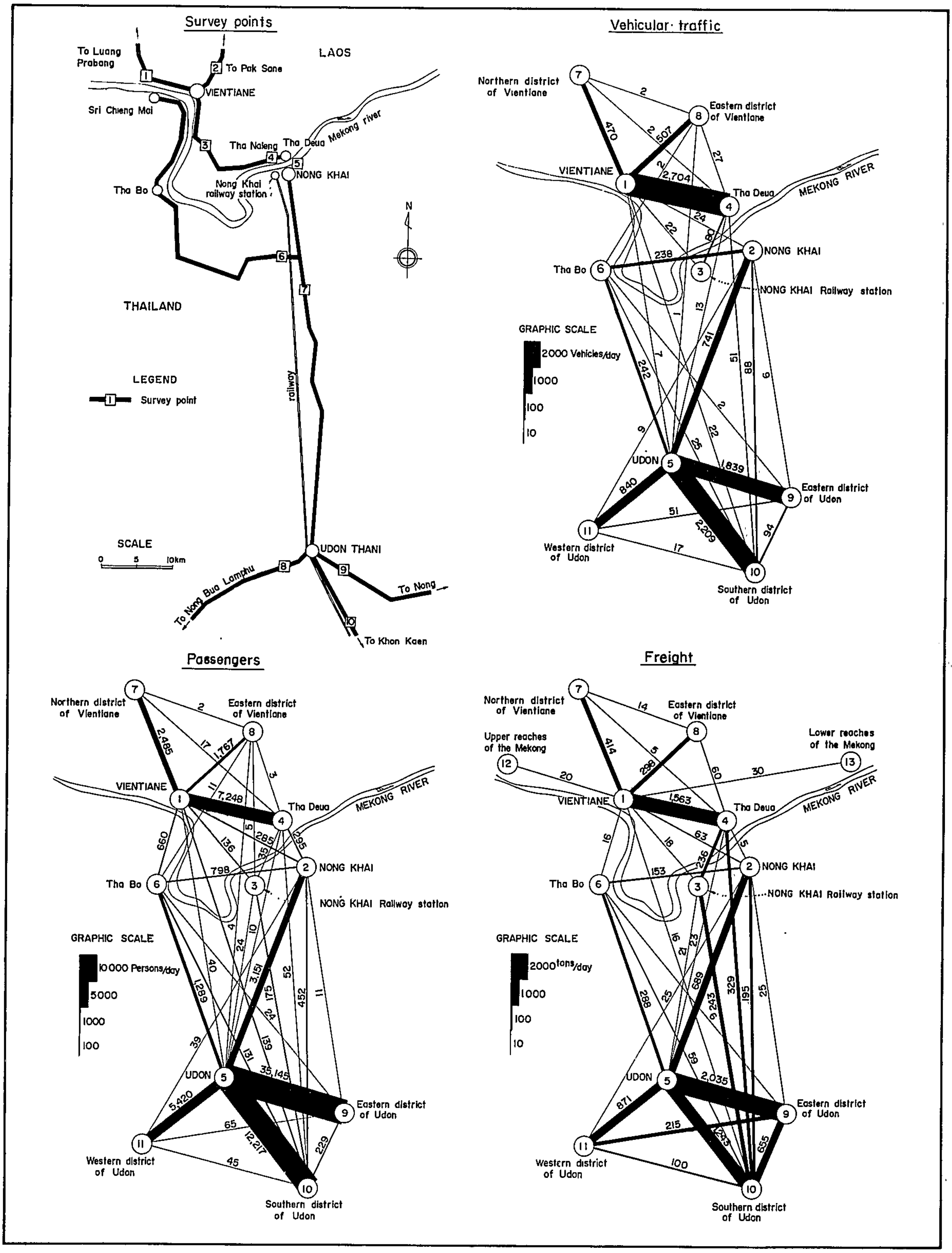


Table 6.1. Interzonal Vehicles
(1967)

Unit: cars/day

No.	Zone	1 Vientiane	2 Nong Khai	3 Nong Khai Sta.	4 Tha Deua	5 Udon	6 Tha Bo	7 North. Dist. Vientiane	8 East. Dist. Vientiane	9 East. Dist. Udon	10 South. Dist. Udon	11 West. Dist. Udon	12 Upper Mekong	13 Lower Mekong	Total
1	Vientiane		24	22	2,704	7		470	507		22				3,756
2	Nong Khai					741	238			6	88	9			1,106
3	Nong Khai Sta.				80										102
4	Tha Deua					13		2	27		51				2,877
5	Udon						242		1	1,839	2,209	840			5,892
6	Tha Bo								2	2	25				509
7	N. Dist. V'tiane								2						474
8	E. Dist. V'tiane														539
9	E. Dist. Udon										94	51			1,992
10	S. Dist. Udon											17			2,506
11	W. Dist. Udon														917
12	Upper Mekong														
13	Lower Mekong														
	Total														20,670

Table 6.2. Interzonal Passengers
(1967)

Unit: persons/day

No.	Zone	1 Vien-tiane	2 Nong Khai	3 Nong Khai Sta.	4 Tha Deua	5 Udon	6 Tha Bo	7 North. Dist. Vien-tiane	8 East. Dist. Vien-tiane	9 East. Dist. Udon	10 South. Dist. Udon	11 West. Dist. Udon	12 Upper Mekong	13 Lower Mekong	Total
1	Vientiane		285	136	7,248	40	660	2,485	1,767		139				12,760
2	Nong Khai				295	3,151	798			11	452	39			5,031
3	Nong Khai Sta.				35	24			5		175				375
4	Tha Deua					10		17	3		52				7,660
5	Udon						1,289		4	35,145	12,217	5,420			57,300
6	Tha Bo								11	24	131				2,913
7	N. Dist. V'tiane								2						2,504
8	E. Dist. V'tiane														1,792
9	E. Dist. Udon										229	65			35,474
10	S. Dist. Udon											45			13,440
11	W. Dist. Udon														5,569
12	Upper Mekong														
13	Lower Mekong														
	Total														144,818

Table 6.3 Interzonal Freight (1)
(1967)

Unit: tons/day

No.	Zone	1 Vien-tiane	2 Nong Khai	3 Nong Khai Sta.	4 Tha Deua	5 Udon	6 Tha Bo	7 North. Dist. Vien-tiane	8 East. Dist. Vien-tiane	9 East. Dist. Udon	10 South. Dist. Udon	11 West. Dist. Udon	12 Upper Mekong	13 Lower Mekong	Total
1	Vientiane		63.0	18.0	1563.0		15.5	414.0	298.0		15.8		20.0	30.0	2,437.6
2	Nong Khai				5.0	689.0	153.0			25.0	195.0	25.0			1,155.0
3	Nong Khai Sta.				236.0	21.0					243.0				518.0
4	Tha Deua					23.0		5.0	60.0		329.0				2,221.0
5	Udon						288.0			2,035.0	1,243.0	871.0			5,170.0
6	Tha Bo									6.0	59.0				521.5
7	N. Dist. V'tiane								14.0						433.0
8	E. Dist. V'tiane														372.0
9	E. Dist. Udon										655.0	215.0			2,936.0
10	S. Dist. Udon											100.0			2,839.8
11	W. Dist. Udon														1,211.0
12	Upper Mekong														20.0
13	Lower Mekong														30.3
	Total														19,865.2

Table 6.4. Interzonal Freight (2)
(1967)

Unit: tons/day

No.	No. / Zone	1 Vien-tiane	2 Nong Khai	3 Nong Khai Sta.	4 Tha Deua	5 Udon	6 Tha Bo	7 North. Dist. Vien-tiane	8 East. Dist. Vien-tiane	9 East. Dist. Udon	10 South. Dist. Udon	11 West. Dist. Udon	12 Upper Mekong	13 Lower Mekong	Total departure freight
1	Vientiane		63 (63)	0 (18)	1,537 (1,563)			276 (414)	175 (298)		0 (15)				2,051 (2,371)
2	Nong Khai					427 (689)	90 (153)			23 (25)	63 (195)	10 (25)			613 (1,150)
3	Nong Khai Sta.	18			236 (236)										254 (254)
4	Tha Deua	26				0 (23)		0 (5)	60 (60)		0 (329)				86 (2,216)
5	Udon		262		23		134 (288)			147 (2,035)	639 (1,041)	73 (871)			1,276 (4,947)
6	Tha Bo		63			154				6 (6)	2 (59)				225 (506)
7	N. Dist. V'tiane	138			5				1 (14)						144 (433)
8	E. Dist. V'tiane	123						13							136 (372)
9	E. Dist. Udon		2			1,888					200 (655)	25 (215)			2,115 (2,394)
10	S. Dist. Udon	15	132		329	404	57			455		0 (100)			1,392 (2,394)
11	W. Dist. Udon		15			798				190	100				1,103 (1,211)
12	Upper Mekong														
13	Lower Mekong														
	Total Arrival Freight	320	537	0	2,130	3,671	281	289	236	821	1,002	108			9,375 (18,790)

Remarks:– The figures in parentheses involve round-trip weights.

6.3.2. Rates and Indices of Future Traffic Growth

The traffic growth in the future may be considered as composed of the natural growth of the present traffic and the sudden increase due to the impact of the bridge opening.

The natural growth of traffic in the project area was estimated in Part II on the assumption that the traffic activity in the area will increase with the production activity in the area which, in turn, will increase with the gross national product of Laos. Accordingly, for the purpose of knowing the relationship between the traffic activity in the project area and the gross national product of Laos, the following data were collected.

(1) The number of ferry passengers and the volume of ferry freight, from the Vientiane customs and the Thai Immigration Department;
(2) The arrival freight at the Nong Khai railway terminal, from the Thai Royal State Railway; and
(3) The gross national product of Laos in the past as well as the estimation for the future, from the USAID.

The collected data are summarized in Table 6.5.

Table 6.5. Gross National Product of Laos and Annual Traffic, 1960 to 1966

Year	Gross National Product of Laos, In US.$ Million (P_L)	Ferry Freight in tons (A_F)	Number of Ferry Passengers (A_P)	Arrival Freight At Nong Khai Station, in tons (A_R)
1960	142.73	42,188.2	891	61,278.9
1961	144.49	83,440.4	21,275	56,964.7
1962	152.11	141,827.4	20,989	102,789.1
1963	159.25	133,348.2	19,643	128,827.4
1964	167.51	131,663.7	25,046	129,397.1
1965	173.26	131,342.7	63,560	116,662.0
1966	175.50	—	74,976	—

The relationship between the above-listed gross national products and the traffic volumes can be expressed roughly by the following linear equations.

$$A_F = 2,324.7 P_L - 253,313.4$$
$$A_P = 1,713.4 P_L - 240,543.7 \quad \ldots\ldots\ldots\ldots (1)$$
$$A_R = 2,255.2 P_L - 253,750.0$$

in which A_F = annual ferry freight in tons;
A_P = annual number of ferry passengers;

A_R = annual freight in tons arriving at the Nong Khai railway terminal; and
P_L = gross national product of Laos, in US.$ million.

To estimate the future traffic volumes from the above equations, it is necessary to appraise the gross national product of Laos, P_L, in the future. The past data given in Table 6.5 shows that it has increased at an average annual rate of about 5 percent from 1961 to 1965. In Burma and Cambodia, there were the times in the past when the annual growth rate of the gross national product was about 6 percent. Therefore, when the future exploitation of undeveloped resources and the promotion of social welfare in Laos would be considered, the gross national product of Laos would be considered to increase in the future at an annual rate of 6 to 7 percent.

Accordingly, if it is assumed that P_L will increase at an average annual rate of 5 percent from 1965 to 1970, at 6 percent from 1970 to 1975, at 6.5 percent from 1975 to 1985, and at 7 percent after 1985, the values of A_F, A_P and A_R, based on the gross national product of Laos in 1966, become as listed in Table 6.6. The figures listed in Table 6.6 are the future traffic volumes due to natural growth. The indices of natural growth of traffic based on the 1967 traffic are shown in Table 6.6. (Table 6.6 is presented in Part II as Table 6.3.).

Table 6.6. Natural Growth of Traffic

Year	Gross National Product (P_L) In US.$ One Million	Annual Growth Rate (%)	Ferry Freight (A_F) In Tons	Growth Rate	Ferry Passenger (A_P) In Persons	Growth Rate	Arrival Freight At Nong Khai (A_R) In Tons	Growth Rate
1966	175.50							
1967	184.28	5	175,080	1.00	75,200	1.00	161,840	1.00
1970	213.32	5	242,590	1.39	124,960	1.66	227.330	1.40
1973	254.07	6	337,320	1.93	194,780	2.59	319,230	1.97
1975	285.47	6	410,320	2.34	248,580	3.31	390,040	2.41
1980	391.12	6.5	655,920	3.75	429,600	5.71	628,300	3.88
1985	535.87	6.5	992,420	5.67	677,620	9.01	954,740	5.90
1990	751.59	7	1,493,910	8.53	1,047,230	13.93	1,441,240	8.91

The sudden increase of traffic that would be touched off by the bridge opening can be estimated by the so-called method of gravity model[1] explained below.

If T_{ij} denotes the volume of traffic between two zones, i and j, it can be expressed by

$$T_{ij} = k \frac{X_i X_j}{(d_{ij})^b} \quad \cdots\cdots (2)$$

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[1]: Walter Isard: "Method of Regional Analysis An Introduction to Regional Science", John Wiley, 1960.

in which X_i and X_j = indices that express the degree of economic activities in zones i and j, respectively;

d_{ij} = economical distance between zones i and j; and

k and b = constant and exponent to be properly determined according to the case.

If the values of T_{ij} and d_{ij} before and after the bridge opening are denoted by $T_{ij}(0)$ and $T_{ij}(1)$, and by $d_{ij}(0)$ and $d_{ij}(1)$, respectively, and the difference of $T_{ij}(1)$ and $T_{ij}(0)$ is computed following the method of finite difference calculus,

$$\Delta T_{ij} = T_{ij}(1) - T_{ij}(0) = \left[\left\{ \frac{d_{ij}(0)}{d_{ij}(1)} \right\}^{b} - 1 \right] T_{ij}(0) \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

ΔT_{ij} is nothing but the sudden increase in the traffic that would be touched off by the completion of the bridge. Therefore, if the rate of this increase is denoted by p, p becomes

$$P = \frac{\Delta T_{ij}}{T_{ij}(0)} = \left\{ \frac{d_{ij}(0)}{d_{ij}(1)} \right\}^{b} - 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

To compute p from the above equation, the exponent b and the economical distances, $d_{ij}(0)$ and $d_{ij}(1)$, must be known. Analyzing the result of the origin-destination survey, b was determined at 1.6229. The economical distances were computed taking account of the time and cost of vehicle operation on condition that the bridge tolls would equal the current ferry charges. Bu substituting b=1.6229 and the estimated economical distances in Eq.4, the increase rate p was estimated at 0.26 for vehicles of passenger use and at 0.13 for trucks.

Accordingly, the indices of the possible future traffic based on the 1967 traffic were computed as shown in Table 6.8, taking into account the assumed average load per vehicle for each vehicle shown in Table 6.7. The future traffic is estimated in terms of the number of vehicles, instead of in terms of passengers or tons of freight, and so it is necessary to assume the average load per vehicle. In the present study, it was assumed as shown in Table 6.7.

Table 6.7. Assumed Average Load Per Vehicle

Vehicle	In 1967 and 1973	In 1990
Personal Car	3 persons	2 persons
Taxi	4 "	2.5 persons
Bus	14 passengers	14 passengers
Heavy Truck	2.69 tons	3 tons
Light Truck	0.25 ton	0.25 ton
Motorcycle	1.2 persons	1.2 persons

The computed indices of the possible future traffic in 1973 and 1990, on the basis of the 1967 traffic, are listed in Table 6.8 being divided according to the means of traffic.

Table 6.8. Growth Indices of Possible Future Traffic[1]

Kind of Traffic	Growth Indices of the Traffic Diverted from Passenger Ferry			Growth Indices of the Traffic Diverted from Car Ferry		
	1967	1973	1990	1967	1973	1990
I. Highway Traffic						
1. Buses	1.00	2.59	13.93	1.00	3.26 (2.59x1.26)	17.55 (13.93x1.26)
2. Personal cars	1.00	2.59	20.90 (13.93x3/2)	1.00	3.26 (2.59x1.26)	26.33 (13.93x1.26 x3/2)
3. Taxis	1.00	2.59	22.29 (13.93x4/2.5)	1.00	3.26 (2.59x1.26)	28.08 (13.93x1.26 x4/2.5)
4. Heavy Trucks	1.00	1.93	7.65 (8.53x2.69/3)	1.00	2.18 (1.93x1.13)	8.64 (8.53x1.13 x2.69/3)
5. Light Trucks	1.00	1.93	8.53	1.00	2.18 (1.93x1.13)	9.64 (8.53x1.13)
6. Motorcycles	1.00	2.59	13.93	1.00	3.26 (2.59x1.26)	17.55 (13.93x1.26)
II. Railway Traffic						
1. Passengers	1.00	2.59	13.93	1.00	3.26 (2.59x1.26)	17.55 (13.93x1.26)
2. Freight	1.00	1.97	8.91	1.00	2.23 (1.97x1.13)	10.07 (8.91x1.13)

Note. [1] : On condition that the bridge tolls would equal the current ferry charges.

6.3.3. Influence of Bridge Tolls

The indices of the possible future traffic listed in Table 6.8 are based on the assumption that tolls of the same level as the current ferry charges would be collected on the bridge. However, as it is natural that the traffic will be affected by the level of the bridge tolls, the influence on the future traffic of the bridge tolls was studies as explained in the following.

Let C_{if} = bridge toll for traffic "i", set equal to the ferry charge;

C_{ij} = bridge toll for traffic "i", set at "j", different from the ferry charge;

Q_{if} = volume of traffic "i" when the bridge toll is set at C_{if}; and

Q_{ij} = volume of traffic "i" when the bridge toll is set at C_{ij} .

Then, the ratio of Q_{ij} to Q_{if} can be considered a function of the ratio of Cij to C_{if}. Therefore, if the former ratio is denoted by Y_i and the latter by X_i, the relationship between Y_i and X_i can in general be expressed by

$$Y_i = F(X_i), \text{ in which } Y_i = \frac{Q_{ij}}{Q_{if}}, \quad X_i = \frac{C_{ij}}{C_{if}} \qquad (5)$$

$F(X_i)$ is a function that must satisfy the following conditions.

a) When C_{ij} equals C_{if}, Q_{ij} necessarily equals Q_{if}. Therefore,

$$Y_i = 1, \text{ when } X_i = 1 \qquad (6a)$$

b) If α_i denotes the value of the ratio of Q_{ij} to Q_{if}, when tolls are not collected on the bridge ($C_{ij} = 0$),

$$Y_i = \alpha_i, \text{ when } X_i = 0 \qquad (6b)$$

c) If tolls will be set infinitely high ($C_{ij} = \infty$), the traffic will vanish ($Q_{ij} = 0$). Therefore,

$$Y_i = 0, \text{ when } X_i = \infty \qquad (6c)$$

Innumerable equations can satisfy the above conditions. However, as is usually used in like problems, an exponential function is assumed for $F(X_i)$, as follows.

$$Y_i = \alpha_i A^{aX_i} \qquad (7)$$

which satisfies the condition (6b) irrespective of the values of A and a.

If logarithms of both sides of Eq.7 are taken,

$$\log Y_i = \log \alpha_i + a X_i \log A \qquad (7a)$$

Then, from the condition (6a),

$$0 = \log \alpha_i + a \log A \qquad (8)$$

from which

$$A^a = \frac{1}{\alpha_i} \qquad (9)$$

And substitution of Eq.9 into Eq.7 yields

$$Y_i = \alpha_i^{1-X_i} \qquad (10)$$

which also satisfies the condition (6c).

When X_i and Y_i are expressed in terms of tolls and traffics, respectively, from Eq.10

$$Q_{ij} = Q_{if}\, \alpha_i^{\,1-(C_{ij}/C_{if})} \qquad (11)$$

As the traffic Q_{if} has already been estimated for each year from 1973 to 2000 as given in Table 6.7 in the Feasibility Report Part II and C_{ij} and C_{if} are given values, the problem is reduced to the estimation of α_i, the ratio of the traffic when tolls are not collected to the traffic when tolls equaling the current ferry charges are collected.

From the study on highway traffic in Japan, it was found that α_i can in general be estimated by

$$\alpha_i = \frac{Q_{in}}{Q_{io}} = \left(1 + \frac{C_{io}}{C_{ir}}\right)^{K_i} \quad \text{.............................} \quad (12)$$

in which Q_{in} = volume of traffic "i" when tolls are not collected;

Q_{io} = volume of traffic "i" when toll "C_{io}" is collected (Q_{io} and C_{io} correspond to Q_{if} and C_{if} of the present case, respectively);

C_{ir} = operating cost of traffic "i"; and

K_i = an exponent pertinent to traffic "i".

From Eq. 12 follows

$$K_i = \frac{\log (Q_{in}/Q_{io})}{\log\left(1 + \frac{C_{io}}{C_{ir}}\right)} \quad \text{.................................} \quad (13)$$

Therefore, if traffic volumes Q_{in} and Q_{io} are surveyed, K_i can be computed from Eq. 13 as C_{io} is the known toll and C_{ir} is the operation cost that can readily be estimated.

The value of K_i was estimated from the traffic data observed before and after the release for free-of-charge traffic of several toll roads in Japan as shown in Table 6.9.

In applying Eq.12 to the present case, C_{io} shall be substituted with the current ferry charges, C_{if}, and the cost of vehicle operation in the project area shall be put into C_{ir}. The operation cost C_{ir} was estimated based on the economic survey of the project area.

Once K_i and C_{ir} are known, α_i can be computed from Eq.12 substituting the current ferry charge C_{if} for C_{io}, and the results are shown in Table 6.10. Now that α_i is known, the possible future traffic Q_{ij} corresponding to the toll C_{ij} can be computed from Eq.11. The relationship between the toll ratio (C_{ij}/C_{if}) and the traffic ratio (Q_{ij}/Q_{if}), and the computed future traffic Q_{ij} are shown in Figs. 6.2 and 6.3 in the Feasibility Report Part II, respectively.

Table 6.9 Computation of Exponent K_i From Eq. 13

Traffic	Traffic, In Cars		Toll C_{io} (Yen)	Operating Cost, C_{ir} (Yen)	$\frac{Q_{in}}{Q_{io}}$	$1+\frac{C_{io}}{C_{ir}}$	K_i (Eq.13)
	Q_{in}	Q_{io}					
Buses	487	464	249	4,980	1.049	1.050	0.98
Personal Cars	4,563	3,470	99	228	1.315	1.434	0.76
Taxis	2,684	1,735	99	108	1.547	1.917	0.67
Heavy Trucks	4,562	4,361	190	3,230	1.046	1.059	0.79
Light Trucks	9,478	3,758	172	74	2.522	3.324	0.77
Motorcycles	5,106	3,275	45	43	1.559	2.047	0.62
Railway Passengers							0.98
Railway Freight							0.79

Remarks: Based on traffic data in Japan.

(1) Q_{in} and Q_{io} denote volumes of traffic after and before release of toll roads for toll-free traffic, respectively.

(2) The values of K_i for railway passengers and freight are assumed to equal those for buses and heavy trucks, respectively.

Table 6.10 Computation of Traffic Ratio α_i From Eq. 12

Traffic	Traffic Between Vientiane and	Distance (km)	Operating Cost, Bahts Per km	C_{ir}	Ferry Charge C_{if} Bahts	$1+\frac{C_{ir}}{C_{if}}$	K_i	α_i (Eq.12)
Buses	Udon Thani	77	0.88	68	57(C)	1.838	0.98	1.82
Personal Cars	Udon Thani	77	0.67	52	40(C)	1.769	0.76	1.54
Taxis	Nong Khai	23	0.67	15	40(C)	3.667	0.67	2.38
Heavy Trucks	Bangkok	647	1.92	1,242	110(C)	1.089	0.79	1.07
Light Trucks	Nong Khai	23	0.88	20	57(C)	3.850	0.77	2.81
Motorcycles	Nong Khai	23	0.10	2	5(P)	3.500	0.62	2.17
Railway Passenger	Bangkok	647	–	120	5(P)	1.042	0.98	1.03
Rail Freight	Bangkok	647	–	460	40(C)	1.087	0.79	1.07

Remarks:

(1) (C) and (P) indicate the car ferry between Nong Khai and Tha Naleng and the passenger ferry between Nong Khai and Tha Deua, respectively.

(2) The ferry charge for buses was assumed 57 Bahts, the same as for light trucks considering that the riding efficiency of buses would in the future drop from the present too high level.

(3) The ferry charge for heavy trucks was estimated as follows:
Charged are 59 Bahts per trip per truck and 17 Bahts per round trip per ton of freight. One-way freight of 6 tons is assumed. Then, average one-way charge = 59 + (6 x 17)/2 = 110 Bahts.

(4) The ferry charge for light trucks was estimated as follows:
Charged are 40 Bahts per trip per truck and 17 Bahts per round trip per ton of freight. One-way freight of 2 tons is assumed. Then, average one-way charge = 40 + (2 x 17)/2 = 57 Bahts.

(5) Rail freight operating cost was estimated as follows:
At present, rail freight from Bangkok to Tha Naleng costs 330 Bahts per ton plus 170 Bahts per ton for handling and others, totaling 500 Bahts per ton. In the future, truck transport on the car ferry across the Mekong will be saved. If it is assumed that on the average 6 tons of freight is carried by a 7-ton truck, the truck transportation costs 17 (7 + 6)/6 = 37 Bahts per ton, roughly 40 Bahts per ton. Therefore, the operation cost in the future becomes 500–37=463 Bahts per ton, roughly 460 Bahts per ton.

6.4. Direct Benefits

6.4.1. General

As mentioned in the Feasibility Report Part II, Chapter VI, the direct benefit of the present project is considered to consist of the time benefit that arises from the saving in the travel time and the operation benefit that accrues from the cost saving in travel.

The benefit of a traffic can be computed by multiplying the volume of the traffic by the average benefit per unit volume of the traffic, called the "unit benefit" of the traffic. The unit benefit, B_i of a traffic can be computed by

$$B_i = \frac{\Sigma f_{mn} B_{mn}}{\Sigma f_{mn}} \quad \cdots\cdots \quad (14)$$

in which f_{mn} = volume of the traffic on a route between m and n ;

B_{mn} = benefit per unit volume of the traffic between m and n ;

and the summation shall extend over all routes on which the traffic is operated.

For the purpose of benefit estimation, data were collected on the following items: (1) distances measured along roads between selected pairs of sites: (2) costs per kilometer of vehicle operation and travel; (3) charges and times required in the Mekong crossing by ferries; (4) average running speeds of vehicles; (5) charges for wait of vehicles for passenger use, trucks and others; (6) average loads of vehicles; and (7) the national income per capita of Thailand. The data on (1) to (4) were obtained from the Thai Government's Highway Department, (5) and (6) from government authorities concerned of Thailand and Laos, and (7) from the Thai Statistics Bureau.

Basic data collected are summarized in Table 6.11. The benefit estimation was made based upon the imaginary initial traffic in 1967 estimated as given in Table 6.11.

6.4.2. Time Benefits

To compute time benefits, it is first necessary to estimate the monetary value of unit time, say an hour. The hourly time values for traffics were computed as follows.

(1) Taxis and Personal Cars
In Laos, the taxi charge for wait is 45.4 Kips, or 1.85 Bahts, per hour. This was taken as the hourly time value per taxi or personal car.

2) Buses
The hourly time value for buses was estimated assuming that bus passengers who average 14 per bus would ride taxis or personal cars that carry four passengers on the average. Thus the hourly time value per bus becomes 1.85(14/4) = 6.50 Bahts.

3) Heavy Trucks
In Thailand, the hourly charge of a heavy truck is 8.3 Bahts. This was taken as the hourly time value per heavy truck.

4) Light Trucks

The hourly time value for light trucks was estimated by multiplying the above 8.3 Bahts by the ratio of average loads, 0.25 ton of light trucks to 2.69 tons of heavy trucks. Thus, the hourly time value becomes 8.30(0.25/2.69) = 0.77 Baht per vehicle.

5) Freight

The hourly time value per ton of freight was derived by dividing the hourly charge, 8.30 Bahts, of a heavy truck by the average load of 2.69 tons. Thus, 8.3/2.69 = 3.10 Bahts per ton of freight.

(6) Passengers

As for the passenger's hourly time value, it was taken as the mean of the hourly taxi charge for wait per passenger on the Laotian side and the hourly per-capita income on the Thai side. The former becomes 1.85/4 = 0.46 Baht per passenger as a taxi carries four passengers on the average. The annual per-capita income in Thailand is reported to amount 2,784 Bahts. Therefore, if a workday of 8 hours will be assumed throughout a year, the hourly per-capita income becomes 2,784/(365 x 8) = 0.95 Bahts. Thus, the hourly time value per passenger becomes (0.46 + 0.95)/2 = 0.71 Baht.

(7) The hourly time value for motorcycles was estimated by multiplying the hourly time value 0.71 Baht for passengers by the riding efficiency 1.2 persons of motorcycles, or at 0.85 Baht per vehicle.

It is next necessary to estimate the time that would be saved by the use of the projected routes. This will be computed by dividing the differences between the distances of the existing and projected routes by the average running speeds of traffics. If the computation will be done based on the distances given in Table 6.11, the results will become negative for all cases because the projected route measure a little longer than the present routes. However, it shall be reckoned that at present vehicles, passengers and freight are all compelled to lose time at the ferry sites and in transshipment. The loss of time of this kind constitute the major part of the time saving and was assumed half an hour per trip for all traffics.

Therefore, when for each traffic the time savings and the traffic volumes on routes on which the traffic is being operated or is expected are known, the average saving in time per unit volume of the traffic can be computed, following Eq. 14, by

Average Time Saving Per Traffic

$$= \frac{\Sigma \begin{pmatrix}\text{Traffic} \\ \text{Volume}\end{pmatrix} \left[\frac{\text{Present Distance} - \text{Projected Distance}}{\text{Running Speed}} + \frac{1}{2} \text{ Hour} \right]}{\Sigma \text{ (Traffic Volume)}} \qquad \cdots\cdots\cdots\cdots \quad (15)$$

If the average time saving will be computed from Eq. 15 in terms of hours, the time benefit per traffic will finally be obtained by multiplying the average time saving by the hourly time value of the traffic. The actural computation was carried out based on the daily imaginary initial traffic given in Table 6.11, and the results are shown in Table 6.12.

Table 6.11.

Basic Data For Estimation of Time and Operation Benefits

I. Route Distances, In Kilometers

	Route	Existing Route	Projected Route	Difference
(1)	Vientiane – Tha Bo and Sri Chieng Mai	80.6	82.0	-1.4
(2)	Vientiane – Nong Khai Railway Station	20.5	22.2	-1.7
(3)	Vientiane – Nong Khai	22.7	24.4	-1.7
(4)	Vientiane – Udon	76.6	78.0	-1.4
(5)	Tha Deua – Nong Khai Railway Station	3.4	6.3	-2.9
(6)	Tha Deua – Nong Khai	5.6	8.4	-2.8
(7)	Tha Deua – Udon	59.5	62.1	-2.6

II. Traffic Cost, Expense and Speed, and Ferry Charge

Traffic	Operation Cost, In Bahts per Km	Speed In Km/Hr	Ferry Charge In Bahts
Small-Size Buses	0.88	72	40 per vehicle
Large-Size Buses	2.49	72	195 〃
Taxis and Personal Cars	0.67	80	40 〃
Heavy Trucks	1.92	72	110 〃
Light Trucks	0.88	72	57 〃
Motorcycle	0.10	40	5 〃
Rail Passengers via Paseenger Ferry	0.15	72	5 per person
Rail Passengers via Car Ferry	0.17	80	13 〃
Rail Freight	0.71	72	17 per ton

III. Daily Imaginary Initial Traffic

Traffic	Route Listed in I. (1)	(2)	(3)	(4)	(5)	(6)	(7)
Small-Size Buses	1	–	–	–	–	–	–
Large-Size Buses	–	–	5	1	1	6	–
Personal Cars	–	–	28	19	5	27	–
Taxis	1	–	27	–	3	27	–
Heavy Trucks	–	–	24	71	–	–	–
Light Trucks	–	–	–	2	–	–	1
Motorcycles	–	–	29	–	3	30	–
Rail Passengers via Passenger Ferry	–	135	–	–	–	–	–
Rail Passengers via Car Ferry	–	6	–	–	–	–	–
Rail Freight (ton)	–	254	–	–	–	–	–

6.4.3. Operation Benefits

The operation benefit of a traffic is considered to consist of the product of the difference between the distances of the present and projected routes and the unit operating cost and the ferry charge. The unit operation costs are given in Table 6.11. The computation was made by Eq. 14 based on the daily imaginary initial traffics given in Table 6.11. The results are shown in Table 6.12.

6.4.4. Total Benefits

The total benefits per traffic are shown in Table 6.12. The annual net benefits and capitalized net benefits of the project were computed for the following three cases: (1) when the same tolls would be collected on the bridge as on the exisitng ferry; (2) the bridge tolls would be set at half the current ferry charges; and (3) no tolls would be collected on the bridge. The results are given in Table 6.10 and Fig. 6.4 in the Feasibility Report Part II.

Table 6.12. Time and Operation Benefits, In Bahts Per Traffic

Traffic	Time Benefit	Operation Benefit	Total Benefit	As Adopted
Small-Size Buses	3.12	38.63	41.75	117.1
Large-Size Buses	3.06	189.33	192.39	
Personal Cars	0.87	38.53	39.40	39.4
Taxis	0.87	38.35	39.22	39.2
Heavy Trucks	3.98	107.03	111.01	111.0
Light Trucks	0.36	55.24	55.60	55.6
Motorcycles	0.48	4.78	5.26	5.3
Railway Freight	1.05	25.58	26.63	26.6
Railway Passengers	0.26	7.17	7.43	7.4

6.5. Annual Cost

The annual cost of the project comprises the annual fixed and movable costs.

The annual fixed cost was estimated based on the construction costs and the useful lives of project structures estimated as shown in Table 6.13, considering three different rates, namely, 3, 7 and 10 percent, of discount.

The annual movable cost means the annual working expense that comprises the costs of operation, maintenance and replacement as well as the expense necessary for toll collection in case tolls would be charged.

The estimated annual working expenses are shown in Table 6.14 and the total annual costs in Table 6.15.

Table 6.13.

Useful Lives and Construction Costs of Project Structures

Item		Useful Life In Years	Construction Cost in U.S.$
I. Bridges			
1. Main bridge; composite-girder and plate-girder bridges		40	8,000,000
2. Rigid-frame and hollow-slab bridges		50	1,010,000
3. Asphalt pavement		10	35,000
4. Railway track		20	75,000
	Mean	41	9,120,000
II. Railway			
1. Earthwork		50	4,305,000
2. Track and accessories		20	2,360,000
3. Concrete Structures		50	1,095,000
4. Buildings		45	705,000
	Mean	41	8,465,000
III. Highway			
1. Earthwork and culverts		50	1,395,000
2. Asphalt pavement		10	140,000
3. Permanent residential buildings		45	155,000
	Mean	46	1,690,000
IV. Administrative Facilities			
1. Earthwork		50	630,000
2. Asphalt pavement		10	125,000
3. Buildings		50	1,470,000
	Mean	48	2,225,000
Total	Mean	42	21,500,000

Table 6. 14. Annual Working Expenses, In U.S. Dollars

Item	Unit Cost	Quantity	Annual Expense
I. Bridges			
1. Painting of steel members	0.2	51,000 sq m	10,200
2. Lighting	0.017	8,400 sq m	140
3. Asphalt Pavement	0.19	8,400 sq m	1,600
4. Sundries (5% of 1 to 3)			660
			12,600
II. Railway			
1. Maintenance of way and structures	2,075	20.1 km	41,700
2. Maintenance of equipments	2,155	"	43,400
3. Traffic operation	3,040	"	61,100
4. Miscellaneous operation	250	"	5,000
5. Personnel expenses	1,000	20 person	20,000
6. General expenses	810	20.1 km	16,300
			169,500
III. Highway			
1. Asphalt pavement	445	4.3 km	1,900
2. Shoulders	55	"	240
			2,140
IV. Administrative Facilities			
1. Asphalt pavement	0.12	140,000 sq m	16,800
2. Lighting	0.015	"	2,100
3. Personnel expenses	1.000	100 person (80 person)	100,000 (80,000)
4. Sundries (5% of 1 to 3)			5,960 (4,960)
			124,860 (103,860)
		Total:	309,100 (288,100)

Note: Parenthesized figures are for the case when tolls would not be collected.

Table 6.15. Annual Costs, In U.S. Dollars

	Discount Rate	Bridge	Railway	Highway and Administrative Facilities	Total
Total Construction Cost		9,120,000	8,465,000	3,915,000	21,500,000
Mean Useful Life		41	41	47	
Capital Recovery Factor	3%	0.0427124	0.0427124	0.0399605	
	7%	0.0746596	0.0746596	0.0730374	
	10%	0.1020498	0.1020498	0.1011468	
Annual Fixed Cost	3%	389,500	361,600	156,400	907,500
	7%	680,900	632,000	285,900	1,598,800
	10%	930,700	863,900	396,000	2,190,600
Annual Working Expense					
(i) Tolls Collected		12,600	169,500	127,000	309,000
(ii) Tolls Not Collected		12,600	169,500	106,000	288,100
Total Annual Cost					
(i) Tolls Collected	3%	402,100	531,100	283,400	1,216,600
	7%	693,500	801,500	412,900	1,907,900
	10%	943,300	1,033,400	523,000	2,499,700
(ii) Tolls Not Collected	3%	402,100	531,100	262,400	1,195,600
	7%	693,500	801,500	391,900	1,886,900
	10%	943,300	1,033,400	502,000	2,478,700

6.6. Indirect Benefits

As the indirect benefits that would result from the implementation of the present project can be considered such benefits as the cost down in manufacturing and price drops accompanied by increased demand, all these chiefly due to the drop in the cost of transportation; and decrease in goods in stock, encouraged export, rises in the land value and in the development values of natural resources, promotion of tourism, economic progress and others that would be brought forth from the improved traffic system.

Fact-finding surveys were made at factories of tobacco, plastic bags, footwears and the like, ironworks, lumbermills, rice mills, hemp-dressing mills, stores and markets that handle rice, clothings, construction materials, cars, oil and so on, all located in and around Vientiane and Nong Khai. Informations were also obtained from customs and imigration stations located at the ferries between Sri Chieng Mai and Vientiane, between Tha Bo and Hat Dok Keo, and between Nong Khai and Tha Deua.

Among the various merits of the project, what accounts most for the indirect benefits is the cost saving in transportation due to the dispensation from the ferry crossing. When the present ferries would be replaced by a bridge as planned, not only the ferry charges will be saved but also troublesome transshipment or cargo handling would be spared.

However, the costs of transshipment and cargo handling at the ferry sites vary so largely according to the kind of traffic, the season and other conditions that they can hardly be dealt with in a general way. Therefore, to furnish a basis for considering the indirect benefits, in Table 6.22 are shown the savings in the transportation costs that would arise from the saving of ferry charges, by items of Laotian imports and exports as of 1966. These ferry charges will constitute one major part of the saving in transportation cost in the case when no tolls would be collected on the bridge.

In Table 6.16 are shown the ratios of unit savings to cost prices in Vientiane. Also are shown the savings in transportation of some items in case they would be carried from Bangkok to Nong Khai by Express Transportation Organization (ETO), because the survey team was informed of that the reduction in the ETO charges could be expected on account of the intensified competition among transportation agencies.

Table 6.16

Savings, In U.S. Dollars, In Transportation Cost Due To Dispensation With Ferry Charges In Laotian Imports and Exports As of 1966

Item	Annual Quantity	Unit Saving	Cost Price[/1]	Annual Saving	Ratio[/2] (%)
Import					
Consumer Goods					
Rice	30,000 t	1.50	189.0	45,000	0.8
Watermelon	1,620 t	2.20[/3]	34.4	3,564	6.4
Pork	888 t	1.00	548.0	888	1.8
Beer	2,250 t	3.50(7.00)[/4]	428.0	7,875(15,750)[/4]	0.8(1.6)[/4]
Juice	300 t	3.50(7.00)	304.2	1,050(2,100)	1.2(2.3)
Refrigerator	5,400 t	1.50(3.00)	100.8	8,100(16,200)	1.5(3.0)
Electric Fan	600 t	0.30(0.60)	30.7	180(360)	1.0(2.0)
Bicycle	3,600	0.14	31.3	504	0.6
Motorcycle	1,000	0.14	134.5	140	0.5
			Sub-Total:	67,301 (84,506)	
Production Goods					
Petroleum	100,000 t	2.50	83.0	250,000	3.0
Passenger Car	400	1.80	1,470.0	720	0.1
Truck	40	1.80	5,520.0	72	0.0
Cement	20,000 t	4.02[/3]	37.5	80,400	10.7
Steel Bar	2,400 t	2.50	150.5	6,000	1.7
Steel Plate	2,400 t	2.50	260.0	6,000	1.0
Veneer	130 t	5.00	450.0	650	1.1
Tobacco Leaves	1,000 t	36.0(36.8)[/3]	1,800.0	36,000(36,800)	2.0(2.0)
Sandal Material	360 t	2.50	350.0	900	0.7
Polyethylene	180 t	74.3(77.8)[/3]	310.0	13,374(14,004)	24(25.1)
			Sub-Total:	394,116(395,546)	
			Total:	461,417(480,052)	
Export					
Timber	32,400 t	1.50	40.0	48,600	3.8
			Grand Total:	510,017(528,652)	

Remarks: An exchange rate of 500 Kips to one dollar was based upon.

/1 : Including customs duties.

/2 : Ratio of unit saving to cost price, in percent.

/3 : Including allowance for pilferage and damage during transportation.

/4 : Parenthesized figures are the values for the case of transportation from Bangkok to Nong Khai by Express Transportation Organization.

CHAPTER VII

MISCELLANEOUS DATA COLLECTED

7.1. General

Many kinds of data relating to the present project were collected during the first- and second-phase investigations. They contributed much to the present study. However, as they are very voluminuous, in the following are mentioned only what were expressly useful or seem noteworthy.

7.2. Notes on Characteristic Data

(1) Thai Highway and Railway Design Standards

Information on the highway design standards was supplied from the Thai Government Highway Department and that on the railway from the Royal State Railway of Thailand. Provisions stipulated in these standards were observed in making tentative designs of the highway, railway and bridges, as presented in the Feasibility Report Part II. The gists of the design standards are listed in Tables 5.3 and 5.4 in Chapter V of the Feasibility Report Part II.

(2) Cost Data in the Project Area

Data on compensation for land, houses and fruite farms as well as current priecs of local materials and daily or monthly wages of workmen and laborers in the project area were collected. Although their particulars are not presented in this report, these data were of much avail in estimating the construction cost of the present project.

(3) Data on Nong Khai-Tha Naleng Car Ferry

In the second-phase investigation, as an alternative to the present bridge project, a comparative study was made on a plan, in which the capacity of the existing vehicular ferry between Nong Khai and Tha Naleng will be augmented step by step conforming to the growth of traffic. Therefore, necessary data were collected. It was found, however, that the bridge project has the undisputable advantage of the alternative plan. The collected data are not presented in this report.

(4) Electric Power Source

At present, a 22-kV distribution line, coming from Udon Thani, runs near the bridge site as shown in Fig. 7.1. In the near future, this line will connect with the projected Nong Khai substation, a 5,000-kVA, 110/22-kV station of the 110-kV transmission line between the Pong Neeb and the projected Nam Ngum power stations. Therefore, at the time when the bridge construction would begin, sufficient power would be available from the Pong Neeb station or possibly from the Nam Ngum station.

(5) Data on River-Bed Scouring

Some informations were supplied from the Laotian authority about the river-bed condition around an intake tower built in the Mekong for supplying water to Vientiane. For the purpose of getting a clue to river-bed scouring, the survey team made an echo-sounding of the river-bed around the intake tower and an about 5-meter deep depression was found extending over an area about 20 meters in diameter located about 20 meters downstream and 10 meters toward the river center from the tower, as shown in Fig. 7.2, (B). This depression is what had already been found by the Laotian authority in 1967, as shown in Fig. 7.2, (A).

It was also found that the river-bed is affected by scouring action to the extent of some 50 meters downstream and that the river bank on the Laotian side, extending about 50 meters upstream and downstream from the tower, is subjected to erosion by turbulent flow.

The above study was aimed at obtaining bases for judging the influence of the bridge piers on the shipyard training center now under construction on the Thai side about 150 meters downstream from the bridge site. Although the bridge team's and the Laotian surveys were both conducted during the dry seasons and hence the river condition in the rainy or high-water season is not yet to be investigated, it can be said from the study made so far that the river-bed scouring due to the bridge piers would not materially influence the shipyard.

It is, however, recommended that surveys be made on the river condition in the high-water season and that a hydraulic model test be carried out, at the stage of the detailed design, to reach a more decisive judgement.

(6) Seismological Data

A note entitled "Some Considerations Relative to Possible Installation of Seismographic Equipments at Lower Mekong Projects (Note By Mekong Secretariat)" was supplied from the Mekong Committee. The following the excerpt of the part relating to the present project.

"According to the data at present available, the site at Pa Mong lies outside the seismic belt. There are traditions of small earthquakes being felt in the region, but it seems probable that there were the marginal effects of large earthquakes originating at quite considerable distance . . . . .

"Some small earthquakes have been reported in Laotian territory from time to time, but it is generally considered that their origins are some considerable distance away."

The Mekong Committee, referring to the above note, recommended that there would be no need of taking account of earthquakes in the structural design of the present project.

(7) Thai Aviation Regulations

The highway on the Thai side is planned to approach the bridge running through a narrow space lying between the existing rail line and the Nong Khai airfield as shown in Fig. 7.1. On inquiry, Thai Civil Aviation Department presented the bridge team necessary data for locating a highway in the vicinity of an airfield. Observing the related regulations, the highway route on the Thai side was studied and located as shown in the Feasibility Report Part II, Chapter V.

(8) Vientiane's City Plan

For the purpose of referring to about the location of the railway station in Vientiane, two maps of Vientiane's city planning were obtained from the Laotian Government. They are based on the present status of the city and no description about the future expansion of the city is given. One map is presented as Fig. 7.3.

(9) Data on Plans of Transportation System

Various data on the present traffic flow as well as on the future plans of transportation systems in Thailand and Laos were collected. Some of them are presented in Figs. 7.4 to 7.6.

(10) Maps of the Project Area

Maps of various scale covering the project area and its environs were obtained from the Geographical Bureau in Vientiane.

Fig. 7.1. SOURCE OF ELECTRICITY FOR CONSTRUCTION USE

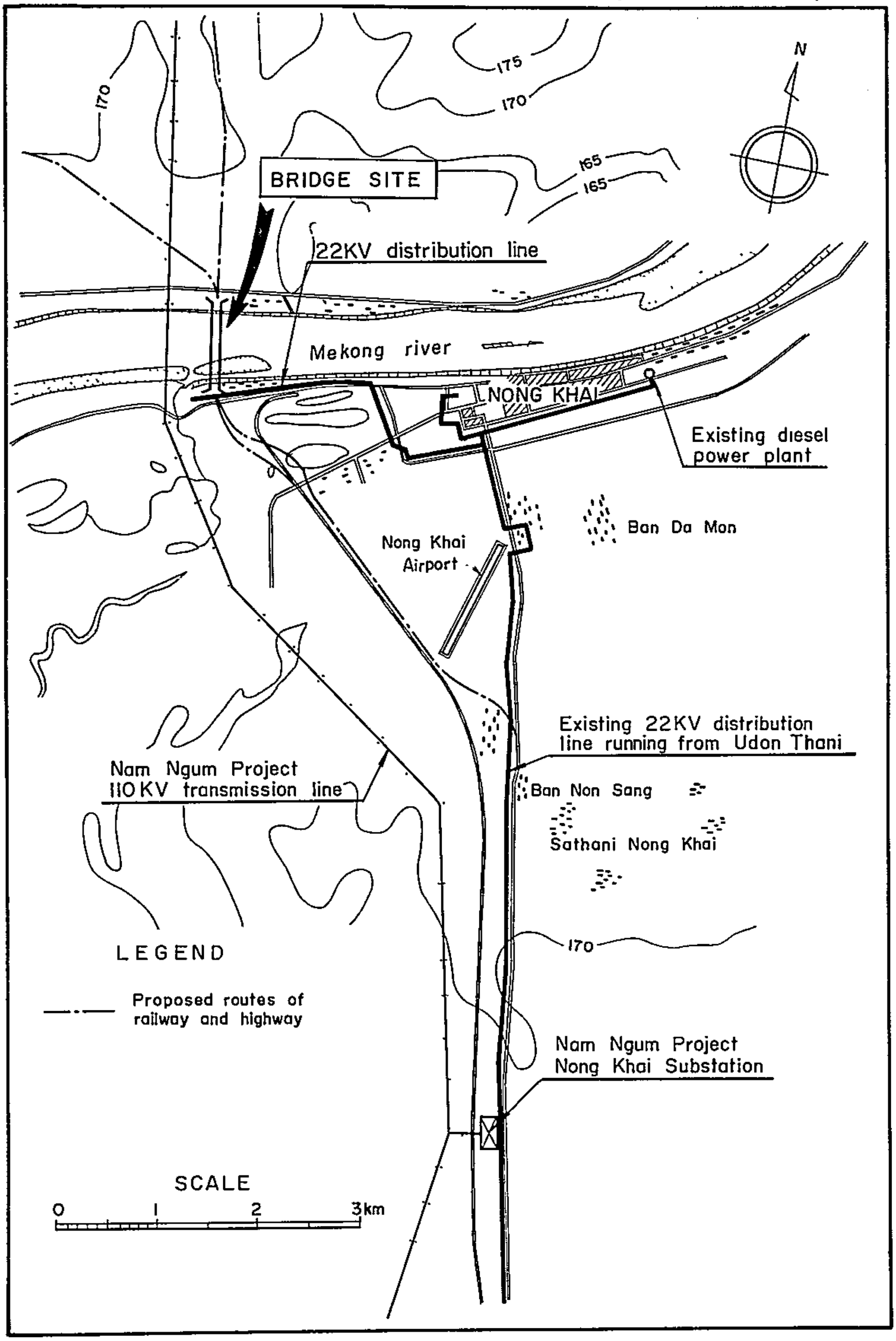
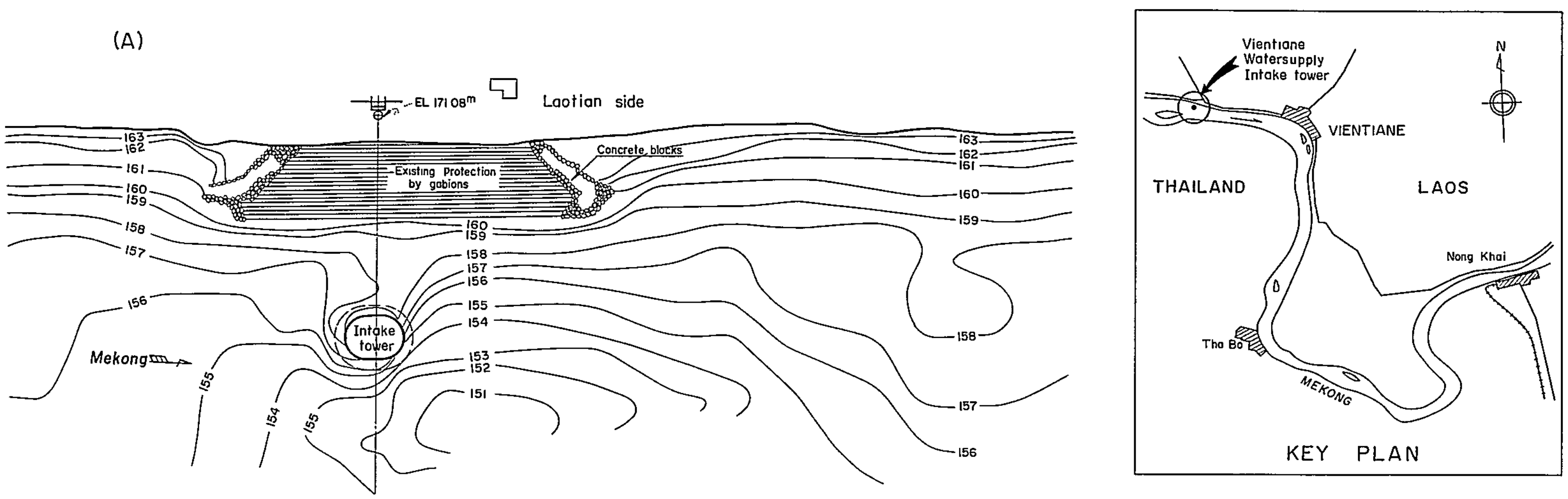
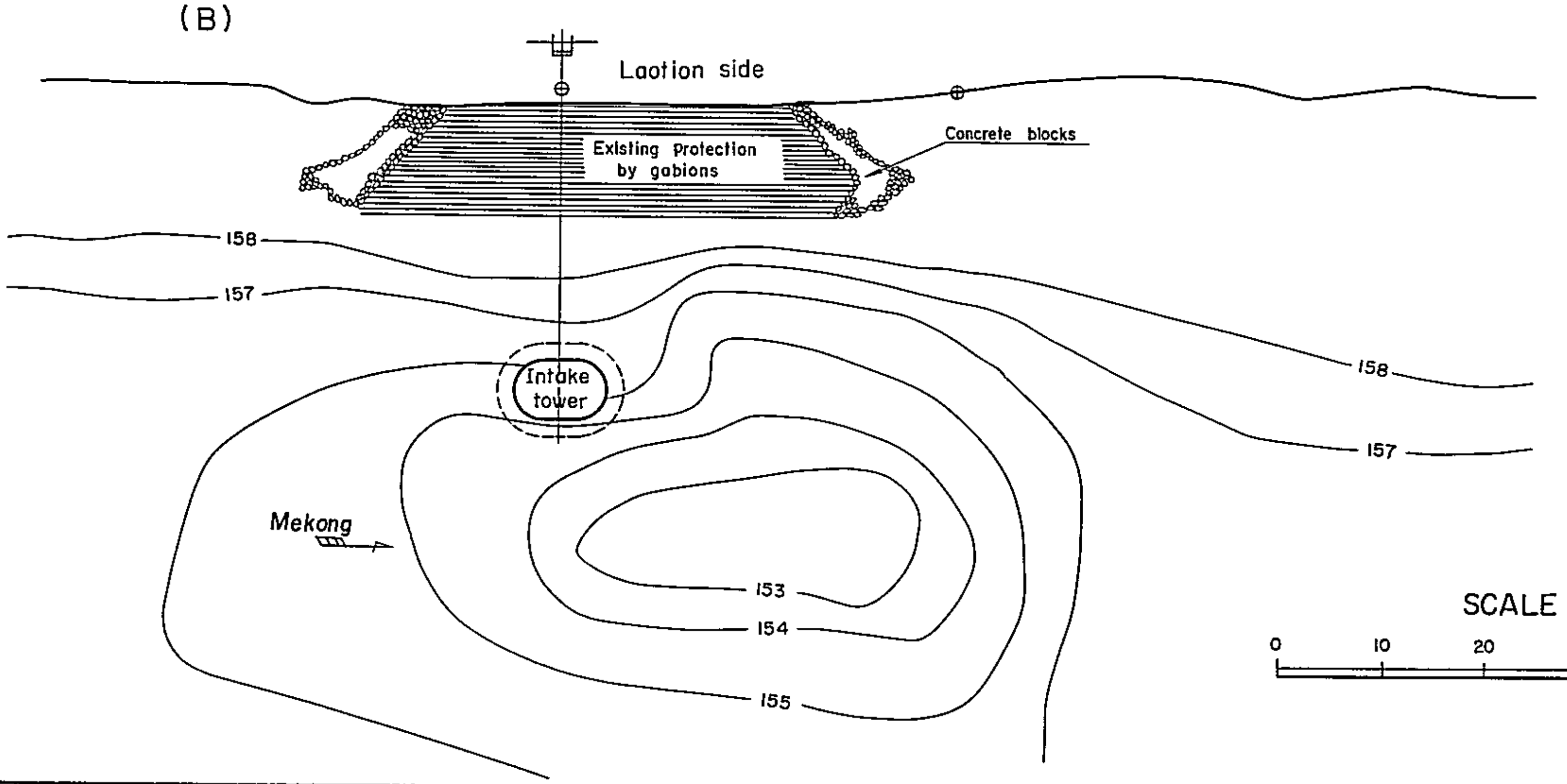


Fig. 7.2. SCOURING EFFECT





Remarks.

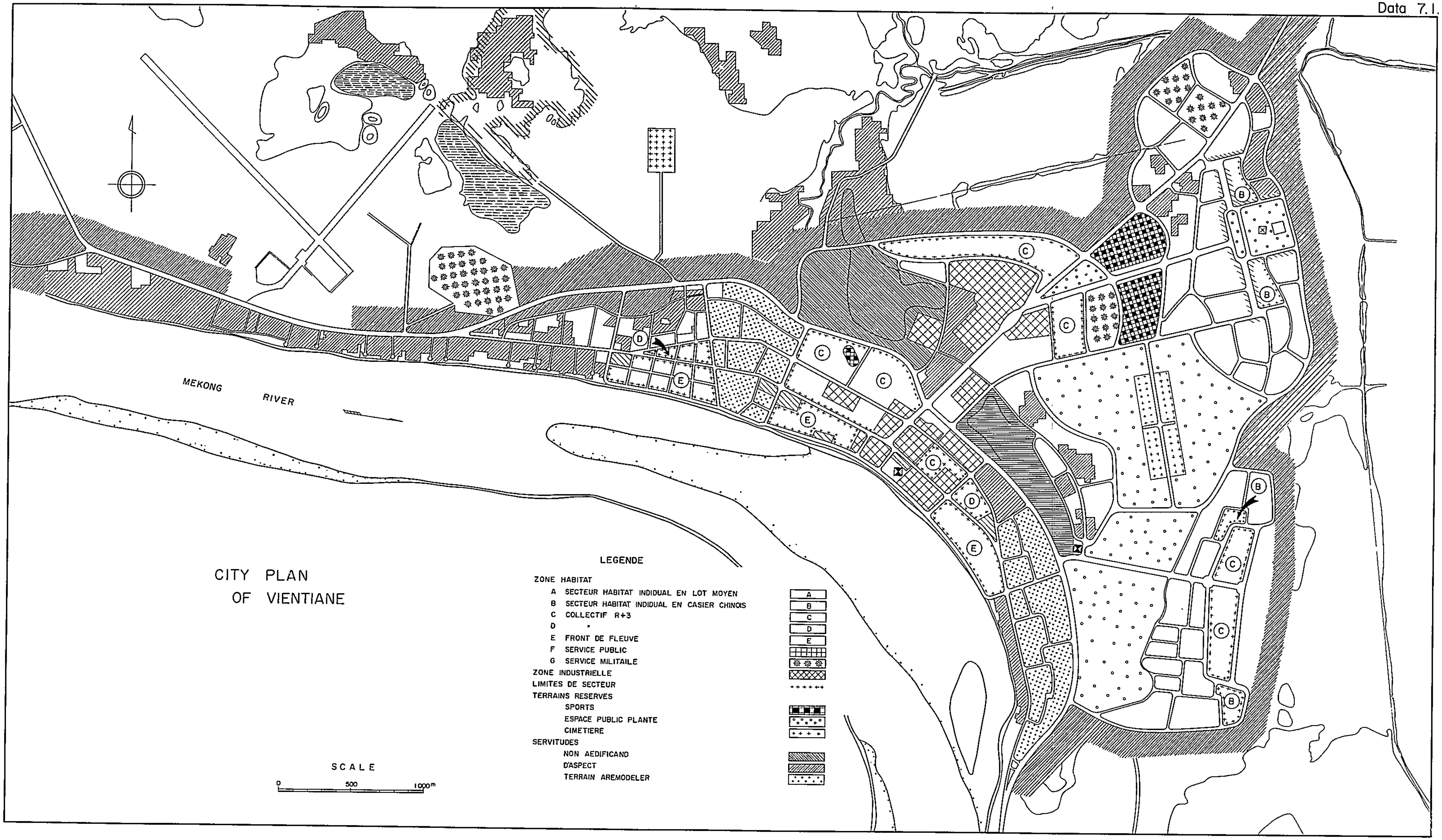
(A)

This topographic map was based on the measurement conducted by the staff of T.P. in Laos on 13 March 1967.

(B)

This is the result of echo-sounding made by Survey Team on 4 April 1968.

Data 7.1.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OF VIENTIANE
MEKONG
RIVER
LEGENDE
ZONE HABITAT
A SECTEUR HABITAT INDIDUAL EN LOT MOYEN
B SECTEUR HABITAT INDIDUAL EN CASIER CHINOIS
C COLLECTIF R+3
D ▪
E FRONT DE FLEUVE
F SERVICE PUBLIC
G SERVICE MILITAILE
ZONE INDUSTRIELLE
LIMITES DE SECTEUR
TERRAINS RESERVES
SPORTS
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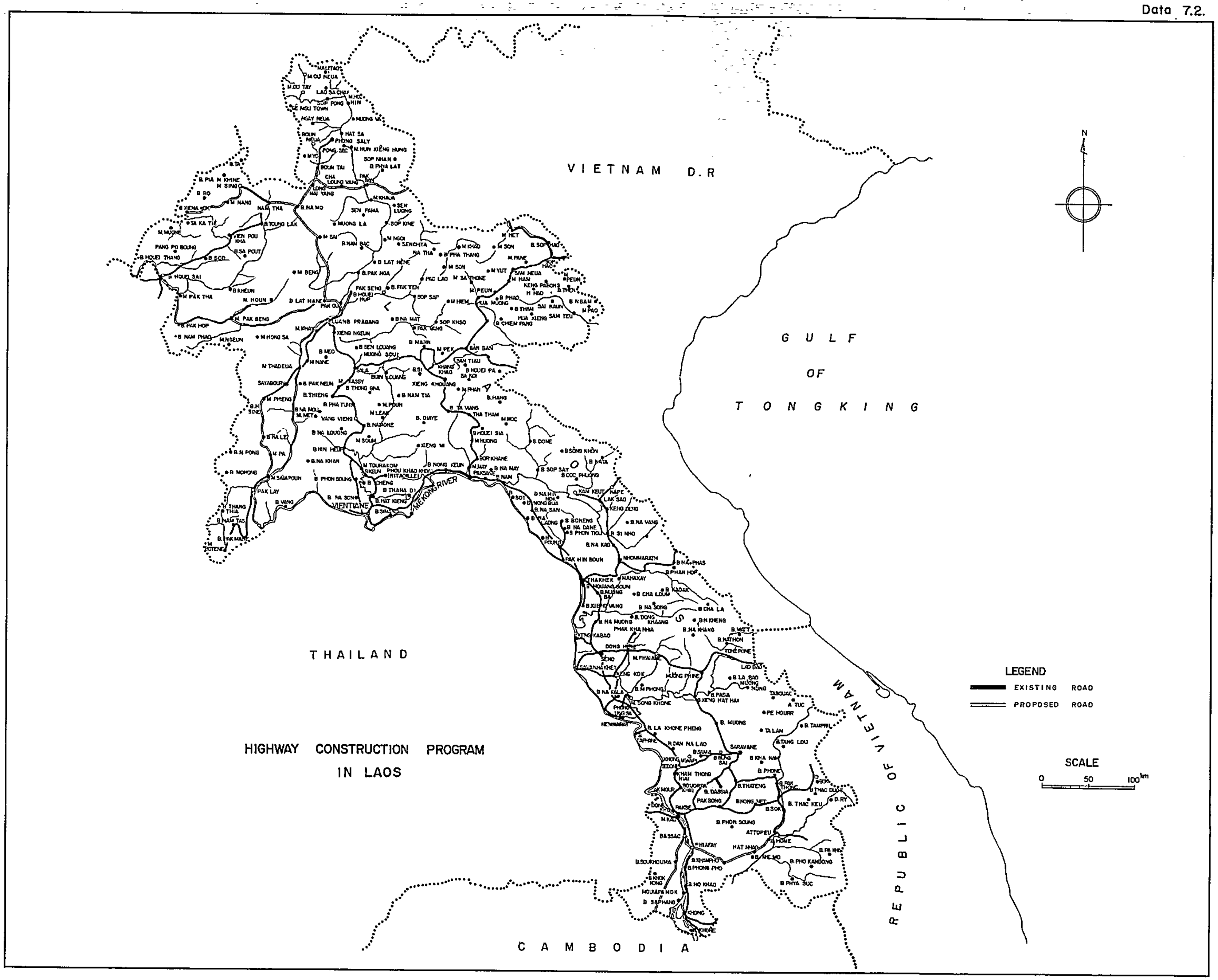
VIETNAM D.R
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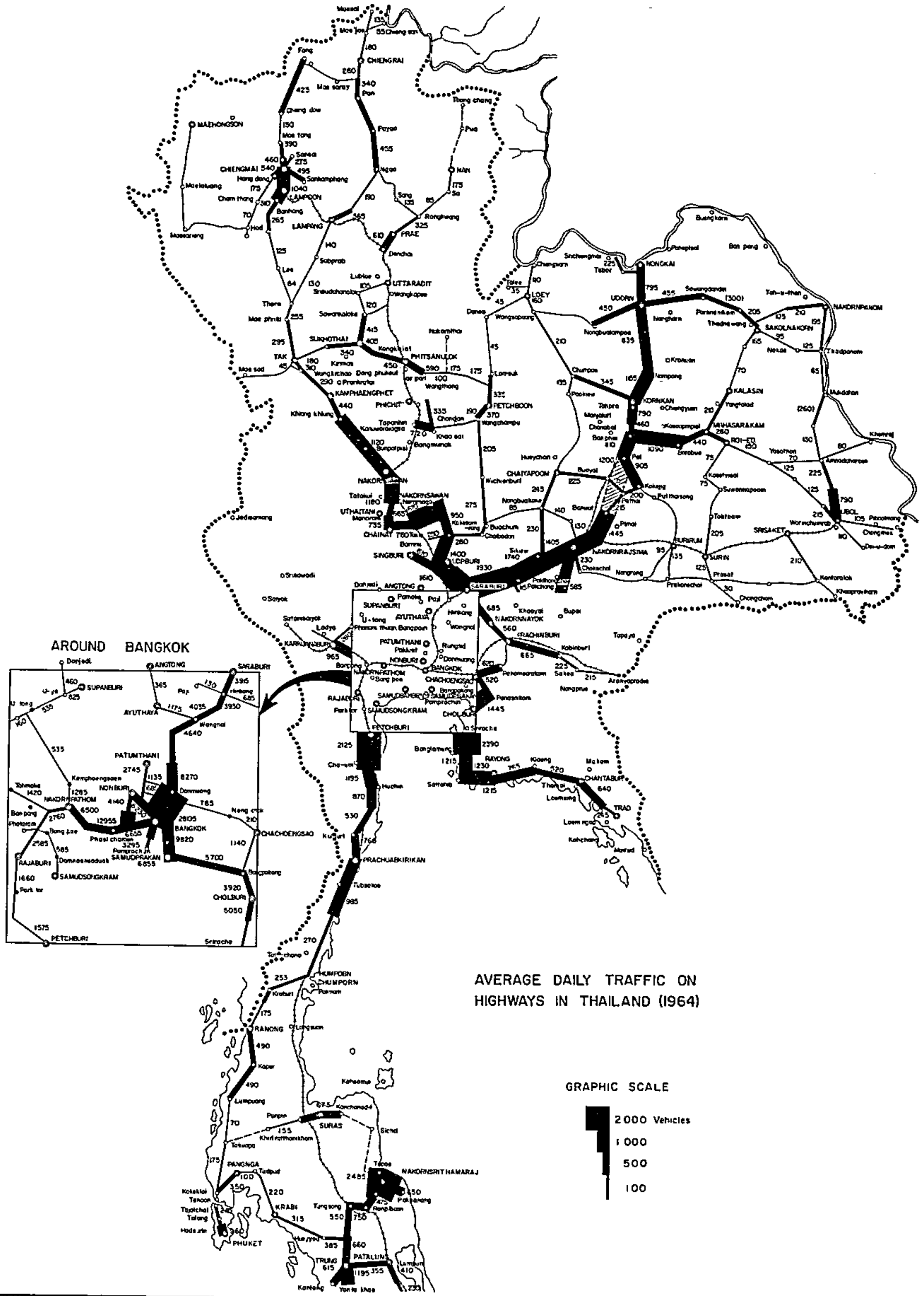
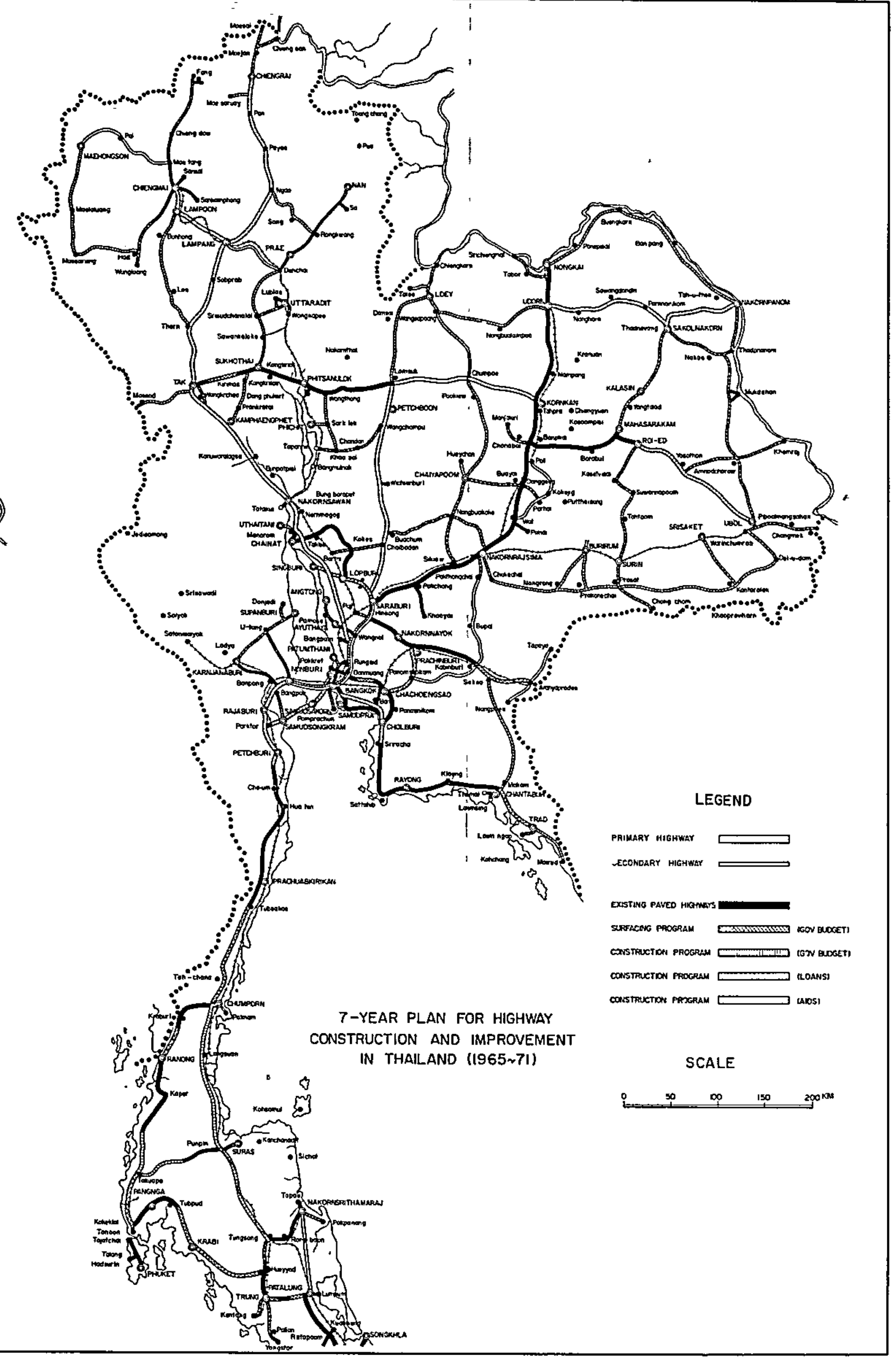
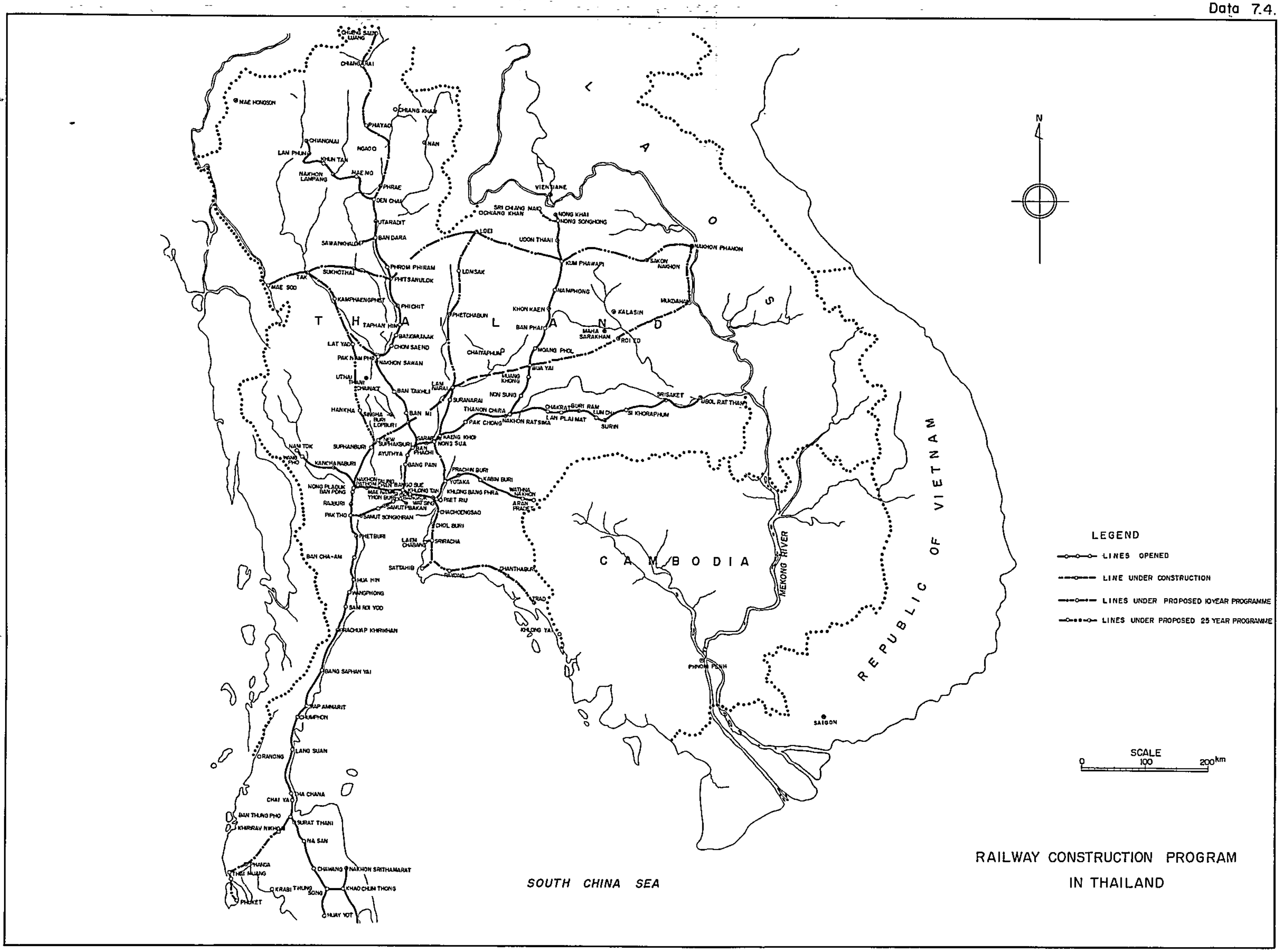


AVERAGE DAILY TRAFFIC ON HIGHWAYS IN THAILAND (1964)



7-YEAR PLAN FOR HIGHWAY CONSTRUCTION AND IMPROVEMENT IN THAILAND (1965~71)



RAILWAY CONSTRUCTION PROGRAM IN THAILAND