Chapter X

ENGINEERING

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This Chapter gives engineering studies including cost estimate for the selected optimum route, based on the results of topographic survey and soil and material investigation.

10-1 TOPOGRAPHIC SURVEY

To obtain more detailed information for engineering designs, the following topographic surveys were carried out:

a) Profile survey
b) River cross section survey
c) Road cross section survey

10-1-1 Profile Survey

Profile survey was carried out for the new road sections and undulating existing road sections as shown in Table 10-1. Out of total length surveyed, the length related to the optimum route is 41.4 kilometers in 7 road links. Brief remarks on these links are given below.

a) Road Link 6

The alternate ups and downs are salient along 7.7 kilometers long section as the road formation follows the original rolling terrain.

b) Road Link 11 & 16

The existing road in the town of Wichian Buri is no more expected to be widen, as the resident houses approach close to the road. Therefore, a bypass was planned about 1 kilometer east of the center of Wichian Buri. The bypass section is 3.7 kilometers long and passes mostly paddy fields.

c) Road Link 28

The profile survey was performed for the entire length of 15.5 kilometers of the section from Khok Charoen to Yang Lat, where the new road construction was planned. The topography varies from flat paddy area to hilly terrain. The cross section of water courses which the proposed route crosses were also surveyed.

d) Road Link 35 & 37

As the existing road, which has been constructed by MDU, follows undulating original ground, ups and downs are quite remarkable.

e) Road Link 40

The existing road takes rather curved route in the village of Nam Ron (1) and resident houses cling to it. As the widening and improvement of the alignment were anticipated very difficult, the new construction of a bypass was planned about 500 meters east of the village. The bypass, 2 kilometers long, passes mostly paddy fields and crosses two rivers.

The profile was drawn at a scale of 1/10,000 in horizontal and 1/500 in vertical, and used for alignment design.

10-1-2 River Cross Section Survey

For the bridge design and discharge analysis of flood, river cross section survey was made at five sites shown in Table 10-1, where the constructions of rather long bridges were anticipated. Two sites are related to the construction of the optimum route, one at the crossing of the Leng River and the other at the Tabo River.

10-1-3 Road Cross Section Survey

Road cross sections were taken at 145 sites every one kilometer along the optimum route. They were drawn at a scale of 1/100, and used for the planning of widening and raising up of the existing roads and subsequent estimation of earthwork volumes.

10-2 SOIL AND MATERIAL INVESTIGATION

Soil and material investigation was carried out to obtain more detailed information for designs of earthwork, pavement and bridge foundation.
It included the following items:

a) Machine boring
b) CBR test in situ
c) Laboratory tests

10-2-1 Machine Boring

Sub-surface conditions were investigated by machine boring with Standard Penetration Test at four major bridge sites where the constructions of rather long bridges were anticipated. Their locations are shown in Figure 7A-1 of Appendix 7. The total length of the boring was 73.4 linear meters. Two boring sites out of four, namely, B-3 and B-4 are located on the optimum route. The logs of borings are shown in Figure 7A-2 of Appendix 7.

Bore hole B-3 locates on the left bank of the Leng River crossing the Road Link 16. The soil profile begins with a layer of silty clay top soil, about 1.0 meter thick. Underneath top soil is a layer of stiff silty clay, 14 meters thick with various colours. N-value of this layer increases from 10 to 23 with depth. Under this layer, there exists a layer of hard clayey silt having more than 100 of N-value. This layer is expected to be a satisfactory foundation of the bridge.

Bore hole B-4 locates on the right bank of the Tabo river in the village of Nam Ron (1) on the Road Link 40. The soil profile begins with a layer of silty clay top soil, 1 meter thick, followed by a layer of stiff clay, about 16 meters thick. N-value of this layer increases from 25 to more than 100 with depth. Underneath the layer is a layer of hard clayey silt with more than 100 of N-value.

10-2-2 CBR Test in Situ

CBR tests in situ were carried out at 10 places on the existing road to assess the bearing capacity of subgrade soil, of which 9 are related to the optimum route. The testing locations are shown in Figure 7A-1 of Appendix 7. CBR values were taken after removing the laterite surfacing which is 5 to 10 centimeters thick. The test results are shown in Table 10-2. The CBR values at 1 inch penetration range from 4.5 to 28.4, which are generally higher than those obtained by laboratory test discussed in 10-2-3.

10-2-3 Laboratory Tests

Physical and mechanical tests were carried out for 50 samples of subgrade soils, selected materials (laterite) and crushed stone. They included the following:

- Natural moisture content test
- Consistency test
- Sieve analysis test
- Compaction test
- CBR test

Samples were collected in the entire Project Area, but those related to the construction of the optimum route are 28 samples. The sampling locations are shown in Figure 7A-1 of Appendix 7. Samplings were made by the survey team and testings by the Lom Sak Center of DOH. The test results are summarized in Table 10-3, and the details of CBR test are shown in Figure 7A-3 of Appendix 7.

The test results suggest the following:

- Subgrade soils are classified mainly as silty clay with high plasticity, and correspond to A-6 or A-7 of AASHO classification. CBR value of subgrade ranges from 2 to 5.
- Laterites were found at many palces along the project road. They have sufficient CBR value, more than 10, enough to be used as selected materials. However, they do not satisfy such the conditions for subbase materials as specified in Standard Specification of DOH because of their high plasticity indexes and poor gradings.
- Crushed stone which can be obtained from quarries in and around the Project Area has CBR value of 50 to 80.

In addition to the above tests, cone index tests were carried out for 5 samples in order to determine the compaction degree and to assess the trafficability of construction equipment. The sampling locations are shown in Figure 7A-1 in Appendix 7. The tests were made for three degrees of compaction, 10, 21 and 56 blows by 4.5 kilogram-rammer, at three water contents, natural moisture content and ± about 5 percent to it. The results are compiled in Figure 7A-4 of Appendix 7 and are summarized in Table 10-4. In general, the cone index ranges from 2 to 7, when compacted at natural moisture content. It increases to more than 15 when compacted at about 5 percent below the natural moisture content. On the other hand, it decreases to 0.3-4.1 at about 5 percent above the natural moisture content. The results also indicate the tendency that the cone index decreases as the compaction degree increases. This means that the compaction corresponding to AASHO's T-180 method, which is equivalent to 56 blows by 4.5 kilogram-rammer, results in over-compaction.

10-2-4 Sources of Materials

1) Embankment

As mentioned in 10-2-2, the soils along the optimum route are generally classified into A-6 or A-7 of AASHO's classification. These types of soil are not so excellent material for embankment, but can be used when proper construction method is taken. Therefore, the embankment material can be obtained from every places in the Project Area.

2) Selected Material

As aforementioned, laterite which has sufficient CBR value as selected material, more than 10, can be obtained at many places along the proposed route.

3) Subbase

The requirements of materials as subbase are outlined in the Standard Specification of DOH as follows:

- Liquid limit	less than 25%
- Plasticity Index	less than 6%
- Percentage of contents passing the No. 200 sieve	less than 25% in weight
- CBR at 95% of maximum dry density by AASHO T-180 method	more than 20

Although there are many sources of laterite along the project road, no laterite which satisfied all of the above requirements was found during the investigation made in a rather limited time. It is possible, however, to find the laterite which satisfies the above requirements by more detailed investigation.

According to some reports like "Problems in the Use of Iron-rich Laterites in the Roadway Structure, S.E. Thailand", the plasticity index of laterite can be reduced easily by cement or lime stabilization. Among the samples collected this time, there are some laterite which satisfies all of the above requirements if the plasticity index could be reduced.

The sources of laterites which satisfy the requirements as subbase material in their natural condition were found in the southern part of the Project Area. They are all located along the Route 21 and denoted as L-1, L-2 and L-3 as shown in Figure 7A-5 of Appendix 7. Among them, L-1 is the nearest source and hauling distance is 50 to 60 kilometers when it is utilized in the central sections of the project road. The laterites from these sources have CBR of more than 20 percent. Especially, the laterite from L-1 has very good quality, high CBR value of more than 80 percent, low plasticity index and good grading, and it can be used also as a base course material.

As aforementioned, some laterites from nearby the project road can be improved by the cement or lime stabilization to satisfy the requirements as subbase material. Therefore, it is recommendable in the detailed design stage to make comparative study between stabilization of poor laterite which can be obtained within a short distance and the usage of laterite in good quality from distant sources. Based on the study results, the definite sources of subbase should be determined.

4) Base

Three rock quarries now in operation would be available for the construction of the project road. They are denoted as R-1, R-2 and R-3 and their locations are shown in Figure 7A-5 of Appendix 7.

R-1 and R-3 are located within the reasonable hauling distance, 10 kilometers when R-1 is used for the construction of the southern end section and 30 kilometers when R-3 is used for the construction of the northern end section of the project road. However, in case they are used for the construction of the central sections, the hauling distance exceeds 80 kilometers. Two candidate rock quarries, R-4 and R-5, were found within a reasonable hauling distance to the central sections. R-4 quarry has a plan for exploitation in the near future. If this can be used for the project, the hauling distance of base course material to the central sections would be shortened to around 40 kilometers. The rocks of the above five quarries are limestone of good quality. They have high CBR value of more than 80 percent, except only one sample from R-3 which showed 48 percent, and can be used as aggregates of SBST and cement concrete.

10-3 HYDROLOGICAL STUDY

The optimum route crosses many tributaries of the Pasak River. Due to the insufficient drainage capacity of bridge openings and culverts of the existing road, some low formation sections suffer from overflow in rainy season. For the construction of all-weather road, suitable provision of openings is necessary together with the raising up of road formation level. Hydrological study is, therefore, quite important for the design of the Project Road.

Based on the 1/50,000 scale topographic maps, supplemented with aerial photographs, catchment area of each water course crossing the optimum route was identified as shown in Figure 8A-1 of Appendix 8. Hydrological study was made for the following 8 catchment areas which have rather large areas.

Catchment Area No.	Road Link No.	Number of Water Courses	Catchment Area (km^2)
11	11	1	63
12	11	2	302
15	16	2	197
27	25	3	454
28	28	1	110
34	40	2	209
35	40	1	140
36	40	2	3,900

The following factors were incorporated in the study.

a) Rainfall pattern in the Project Area

b) Discharge analysis considering the time lag between the beginning and the peak of flood

c) Reserving capacity on the upstream side of the opening

1) Rainfall Pattern

The past records of hourly rainfall pattern were available at Lop Buri and Don Muang. They are characterized by squall, concentrating more than 75 percent of daily rainfall in an hour, as shown below.

Rainfall Pattern

(mm)

Location	Hours					
	1	2	3	6	12	24
Lop Buri /1	86.8	104.4	104.4	113.6	113.6	113.6
Don Muang /2	104.3	114.0	117.0	117.2	117.5	124.0

Note: /1 recorded in 1964
/2 recorded in 1962

As described in 7-3-6, the maximum daily rainfall recorded in the Project Area was 153.9 milimeters. Using this record as a control total, the above data were expanded to formulate the rainfall pattern in the Project Area. The effective hourly rainfall was then calculated by subtracting the loss, which was obtained using the following equations:

$$R_L = R \times (1 - 0.00036R^{1.5}) \qquad R \leqq 100$$

$$R_L = 64 \qquad R > 100$$

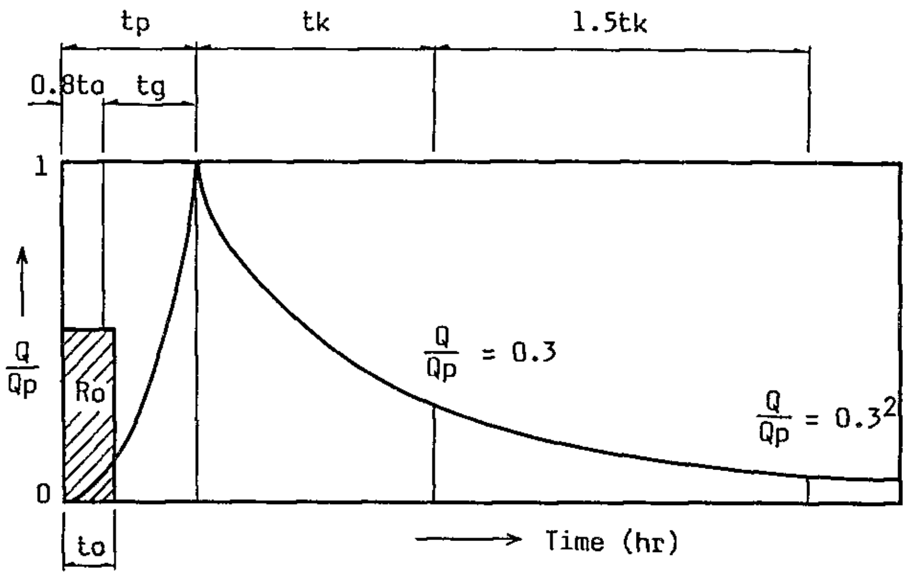
Where, R_L : Cumulative loss rainfall (mm)
R : Cumulative rainfall (mm)

Though two patterns were formulated, the one based on the records at Dong Muang was used in the study as this gave larger discharge. It is tabulated in Table 8A-1 of Appendix 8.

2) Discharge Analysis

For the squall type of rainfall, the Rational Method, which bases on the concept of average rainfall intensity during several hours, can not be reasonably applied in discharge calculation. Moreover, the analysis in consideration of the change of reserved volume with the lapse of time is not possible by this method. Unit hydrograph Method which incorporates the time lag between the beginning and the peak of flood at the subject place was, therefore, used in the study.

The concept of the Unit Hydrograph Method is expressed by the following figure:



This figure shows that the flood discharge (Q) at the subject place caused by the effective rainfall (Ro) occured in an unit duration (t_o) reaches its peak (Q_p) with a time lag (t_p), then gradually decreases. The peak discharge is calculated by the following equation, of which derivation is explained in Appendix 8:

$$Q_p = \frac{0.2778\ A.Ro}{0.3t_p + tk} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$t_p = t_g + 0.8\ t_o$$

$$t_k = 2.0\ t_g$$

where, Qp : Peak discharge (m^3/sec)

A : Catchment area (km^2)

Ro : Effective rainfall (mm)

tp : Time in which the discharge increase from zero to Qp (hr)

t_k : Time in which the discharge decrease from Qp to $0.3\ Qp$ (hr)

tg : Time lag between $0.8\ t_o$ and the peak of flood (hr)

to : Unit duration of rainfall (hr)

a) Time Lag between the Beginning and the Peak of Flood (tp)

Time of concentration was taken as the time lag between the . beginning and the peak of flood. The mean velocity of flood water was calculated by Manning's formula shown below, then the time of concentration was calculated as shown in Table 10-5.

Manning's formula

$$V = \frac{1}{n} R^{2/3} I^{1/2}$$

where, V : Mean velocity of flood water (m/sec)

R : Hydraulic mean depth (m)

I : Mean gradient of river channel

n : Manning's coefficient of roughness, 0.05 was taken

b) Unit Hydrograph

Unit hydrograph, which is the unit discharge curve by the unit effective rainfall of 1 millimeter in unit hour in the catchment area, was established for each catchment area, based on the respective characteristics of catching basin. The main features of unit hydrograph are shown in Table 10-6, together with the peak discharge by unit effective rainfall (qmax).

c) Discharge Curve

Discharge curves of each catchment area were established based on the unit hydrograph and the rainfall pattern formulated from the Don Muang's record. For catchment Area No. 36, as it has long time of concentration of more than 2 days, modified pattern was used. Discharge curves are shown in Figure 10-1.

The discharge thus calculated was used as the inflow volume in the subsequent examination of bridge length for relief open.

3) Relief Open

The water level on the upstream area at the time of flood is calculated according to the reserved volume in the area. The principle applied for the determination of bridge length for relief open was that the water level should not exceed the past highest water level.

The relation between the water level and the reserved volume on the upstream area was formulated for each catchment area based on the topographic maps.

The following is the basic equation used for the calculation of the reserved volume.

$$\frac{1}{2}(I_t+I_{t+1}) = \frac{1}{2}(O_t+O_{t+1}) + (V_{t+1}-V_t)$$

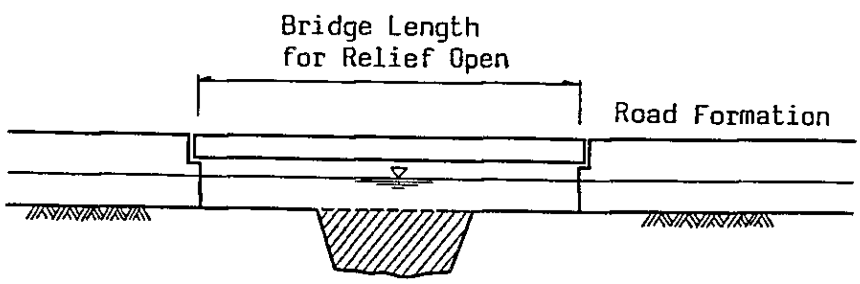
where, I_t, I_{t+1} : Inflow volume at time t and t+1 (m^3)

O_t, O_{t+1} : Outflow volume at time t and t+1 (m^3)

V_t, V_{t+1} : Reserved volume at time t and t+1 (m^3)

a) Inflow Volume

The general view of the river cross section at bridge site is as shown below.



The volume which flows in the hatched area was considered as basic-flow discharge and was subtracted from the inflow volume. The basic-flow discharge calculated based on the results of the river cross section survey, assuming a uniform flow, are summarized in Table 10-7.

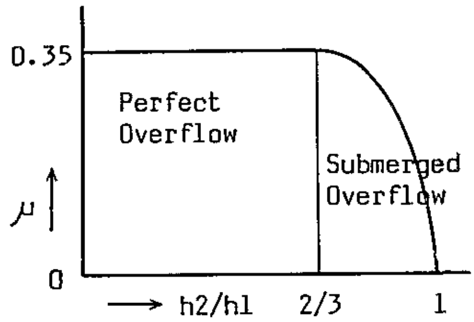
b) Outflow Volume

The outflow volume through the bridge opening was calculated by the following equation.

$$Q = \mu B h_1 \sqrt{2g h_1}$$

where, Q : Discharge through the bridge for relief open (m^3/sec)

μ : Discharge coefficient, $\mu = f(h_2/h_1)$



B : Length of bridge (m)

h_1: Water depth of upstream side (m)

h_2: Water depth of downstream side (m)

g : Acceleration of gravity (9.8 m/sec^2)

Using the equations and inputs mentioned above, the water level on the upstream area can be determined by the convergent calculation. Firstly the water level by flood discharge was calculated for the length of the existing bridges (or proposed bridges in case that replacement or new construction is planned). Then, it was compared with the allowable water level which is the highest water level in the past. If it exceeded the allowable one, the bridge length was prolonged and another calculation was made until the calculated water level becomes below the allowable one. The examination of the Catchment Area No. 12 of Link 11 is compiled in Appendix 8, as an example of the process of determination of the bridge length for relief open.

The following shows the length of bridge required as a relief open:

Length of Bridge for Relief Open

Catchment Area No.	Road Link No.	Bridge Length (m)
11	11	98
12	11	84
36	40	203

Note: For Catchment Areas No.15, 27, 28, 34 and 35, no additional length for relief open is necessary.

10-4 ENGINEERING DESIGN

10-4-1 Geometric Design

The geometric design criteria established in Chapter VII were also applied.

Two major deviations from the existing road were designed at Wichian Buri in Road Link 11 and 16 and Nam Ron (1) in Road Link 40. These two villages have much population and resident houses stick to the both sides of the existing road. There is no room left for raising up and widening the existing road formation. Moreover it is unfavorable to allow high volumes of through traffic to pass the densely populated area from the viewpoint of public health and traffic accidents. Then, bypasses were planned at these places.

The Wichian Buri bypass, new construction of 3.7 kilometers, brings 1 kilometer shortcut to the existing road. It crosses Wichian Buri - Ban Nam Ron (2) road in two places. These connections were designed as intersections. The another bypass of Nam Ron (1) is a detour of 2.0 kilometers, 0.4 kilometers longer than the existing road. The MDU road will be connected to this bypass. Besides the above deviations, minor improvement of sharp curved portions was designed in Road Links 11, 37 and 40, which is 0.9 kilometers in total length.

For the following road connections, regular design criteria were not applied and they were designed as intersections. Their diagrammatic layouts are shown in Drawings of Volume 2.

(1) Link 3 - Route 205
(2) Link 6 - Link 11
(3) Link 18 - Link 22
(4) Link 40 - Route 2271

The total length of the Project Road was finally counted at 151.3 kilometers, of which 21.2 kilometers are new road construction. For the whole length, station numbers were put at 1 kilometer intervals starting from Tha Maduk.

The vertical alignment was designed to follow generally the existing road alignment except for the following submerged sections where raising up was designed.

Raising Up of Formation Level

Station	Length (m)	Height (m)
0+200 - 1+900	1,700	1.0
2+600 - 3+800	1,200	1.0
33+500 - 34+0	500	0.5
34+300 - 35+100	800	0.7
37+0 - 37+500	500	0.5
44+500 - 48+800	4,300	1.0
49+500 - 50+500	1,000	0.5
56+0 - 57+800	1,800	0.5
58+200 - 59+200	1,000	1.0
62+200 - 64+0	1,800	0.5
72+900 - 74+500	1,600	0.5
90+400 - 92+400	2,000	1.0
98+100 - 98+200	100	0.5
141+900 - 148+600	6,700	1.5
148+600 - 150+900	2,300	1.0
Total	27,300	

In addition, minor improvements were designed for the sections of poor vertical alignment in Road Link 3, 6, 35 and 37, 24.1 kilometers in total length, and for poor bridge approaches. The design of vertical alignment for new road was made based on the established design criteria. The maximum gradient of 8 percent occurs at two places in Road Link 28.

The plan and profile of the Project Road are shown in Drawings of Volume 2. For the central part of the Project Road between Sap Bon and Noen Sadao, the plan and profile was also prepared for Route Alternative-II and included in Volume 2.

10-4-2 Earthwork

By soil and material investigation, it was confirmed that soils in the Project Area can be used as embankment material. Therefore, the side borrow method was judged to be applied for both improvement sections and new construction sections. The typical cross sections of F4 and F5 Standard roads are shown in Drawings of Volume 2. Cutting slope was judged to be stable at 1.5:1 in soil and 0.5:1 in rock. On the other hand, embankment slope was designed at 2:1. The cross sectional design was made based on the surveyed cross sections of 1 kilometer intervals.

10-4-3 Pavement Design

1) Kind of Pavement

The DOH's design standard specifies the kind of pavement according to the predicted traffic volume. For the road sections having ADT more than 300 in the 7th year after the opening, low cost pavement (SBST) is to be constructed, while for the sections having ADT of below 300, soil aggregate surfacing be constructed.

According to the traffic forecast made in Chapter IX, the following road links require SBST:

Road Links which Require SBST

Road Link No.	Section	Length (km)	ADT in 7th Year
3	Tha Maduk - Rang Yoi	12.5	442
6	Rang Yoi - Si Thep	18.0	316
11	Si Thep - Wichian Buri	23.3	339
16	Wichian Buri - Sap Bon	20.7	842
18	Sap Bon - Nong Daeng	5.3	488
40	Nam Ron (1) - Phetchabun	11.4	579
	Total	91.2	

In addition to the above length, SBST was also planned for the portions passing through villages in order to alleviate the dust nuisance to the residents. These portions are shown below:

Road Link No.	Name of Village	Length (km)
22	Nong Daeng	0.3
23 & 25	Pak Bot	0.7
25 & 28	Khok Charoen	0.5
28 & 35	Yang Lat	0.2
35	Kham Muat	0.2
35 & 37	Tham Nam Bang	0.6
37	Nam Ron (1)	0.5
	Total	3.0

Consequently, the total length of SBST is counted at 94.2 kilometers out of 151.3 km of the total length of the project road. For the remaining 57.1 kilometers, soil aggregate surfacing was designed.

2) Design CBR

Most of the soils along the project road are classified as A-6 or A-7 of ASSHO's classification, as mentioned in the preceding section.

In the laboratory, the soaked CBR values at 95 percent of maximum dry density by ASSHO's compaction test method T-180 were measured. They were generally less than 3 percent, exclusive of some samples which have high CBR value. Some samples have CBR values of less than 2 percent, but such low values are judged to be unreliable as the test result itself. Moreover, from the experience of the Consultant on the same kind of soils, such low values are not considered to occur. Therefore, these low values were neglected in the pavement design.

Based on the results of labolatory test, 2 percent was taken as the CBR of subgrade soil, conservatively. However, 2 percent of design CBR is still low, and the pavement, if designed based on such low value, requires a greater thickness of pavement resulting in high construction cost. In order to increase the design CBR, a layer of selected material was designed on the subgrade soil. In case a 20 centimeters layer of selected material having CBR of 10 percent are placed on the subgrade soil having CBR of 2 percent, the design CBR increases to about 5 percent, calculated by the following equation.

$$CBR_d = \left[\frac{h_1 CBR_1^{1/3} + h_2 CBR_2^{1/3}}{100} \right]^3$$

where, CBR_d : Design CBR (%)

CBR_1 : CBR of selected material (%)

CBR_2 : CBR of subgrade soil (%)

h_1 : Thickness of selected material (cm)

h_2 : Thickness of subgrade soil (cm), $h_1 + h_2 = 100$

The sources of laterite having CBR of the order of 10 percent can be found at numerous places along the project road. In the pavement design, therefore, a 20 centimeters layer of selected material of laterite was placed on the subgrade soil for new construction sections, raising up sections and the portions of widening, and 5 percent was taken as the design CBR.

If a laterite having higher CBR value can be obtained abundantly in the vicinity of the project road, pavement thickness can be reduced by placing a thicker layer of selected material. It is recommended, therefore, that further investigation be carried out to find the source of better laterite.

In the course of soil and material investigation, CBR in situ was also taken at several places along the existing road links, after the removal of laterite surfacing which is 5 to 10 centimeters thick in general. The CBR in situ ranges from 6 to 30 percent, and is generally higher than the CBR values obtained by the labolatory test, which is considered as the normal characteristics of the soils encountered along the project road, and also considered that this reflects the compaction by the traffic loads accumulated for a long period. In determining the design CBR, it is more usual to base on the labolatory CBR than to base on the CBR in situ. Therefore, the thickness of pavement, in case the pavement would be placed directly on the surface of the existing road, was also designed based on the design CBR of 5 percent. However, a layer of selected material was not designed in this case because the existing road have been already strengthened with a 5 to 10 centimeters thick layer of laterite on the subgrade soil.

3) Pavement Thickness

The pavement design of SBST was made using the method of "Road Note 31, A guide to the structural design of bituminous-surfaced roads in tropical and sub-tropical countries" by Road Research Laboratory, as suggested by DOH. The method of Road Note 31 bases on the design CBR value of subgrade and traffic volume expressed in the number of commercial vehicles.

According to the Road Note 31, it is more appropriate to make pavement design for initial life of 10 years under the condition that an overlay will be carried out when required by traffic increase. In this study, however, traffic volume in 1989, 7th year after the opening of the project road, was used for the pavement design, considering that it is normal design policy in Thailand to design for an initial life of 7 years, at which an overlay of asphaltic concrete is constructed to extend the pavement life to 15 years.

The Road Note 31 presents two design charts to determine the thickness of each layer of pavement according to the traffic volume, Design Chart 1 for up to 150 commercial vehicles per day and Design Chart 2 for 150 to 1,500. According to the traffic forecast, all road links which requires low cost pavement will have more than 150 commercial vehicles per day in 1989. Therefore, the Design Chart 2, shown in Figure 10-2, was applied.

The following gives the thickness of each layer of pavement determined based on the design CBR of 5 percent using the Design Chart 2 of Road Note 31, subject to an overlay of 5 centimeters thick premixed asphaltic concrete in 1989.

- Selected material layer :		20 cm
- Subbase:		23 cm
lower subbase :	13 cm	
upper subbase (minimum CBR 25%) :	10 cm	
- Base (Crushed stone) :		15 cm
- Bituminous prime and Surface Dressing (SBST) :		1.7 cm

The pavement design of soil aggregate surfacing was made with the following thickness, in accordance with the DOH's standard for the typical pavement structures.

- Selected material (CBR more than 6 percent) : 20 cm
- Soil aggregate (CBR more than 15 percent) : 20 cm

The pavement structures of SBST and soil aggregate surfaced roads are illustrated in the Drawing of Volume 2.

10-4-4 Bridge Design

The construction of 38 bridges was planned in the Project, including 6 bridges of new construction, 25 bridges for the replacement of the existing timber bridges and 7 bridges for relief open. The list of the proposed bridges is shown in Table 10-8.

1) Sub-structure

Judging from the boring data at two bridge sites, which show the depth of the firm foundation at 10 and 15 meters below the ground surface, pile foundation should be designed. However, shallow foundation was expected for some bridges as an outcrop of rock was seen especially in hillside area. Therefore, two types of foundation structures, namely spread foundation and pile foundation, were designed according to the site conditions. More detailed investigation is required in the detailed design stage to determine the type of foundation.

2) Super-structure

No long span bridge was necessitated as the rivers are narrow at all sites. All bridges were, therefore, designed with reinforced concrete slab bridges with span ranging from 7 to 10 meters. They have a carriageway width of 7 meters and sidewalk width of 1 meter.

The design of bridges was based on the standard design of DOH for both sub-structure and super-structure. The standard drawings of bridge are shown in Drawings of Volume 2.

10-4-5 Culvert Design

For the water courses having small catchment area, box or pipe culvert was designed. Based on the same procedure discussed in 10-3, the discharge was calculated for each water course. For the culvert design, the maximum discharge was taken considering that the time of concentration is rather short. The size of culvert was determined based on the calculation of drainage capacity by Manning's formula with 20 percent allowance, as shown in Table 8A-9 of Appendix 8. DOH's standard design was also used for the culvert design. The standard drawings of box and pipe culverts are shown in Drawings of Volume 2.

10-5 CONSTRUCTION METHOD AND SCHEDULE

10-5-1 Construction Method

As the Project is mainly composed of the improvement works of the existing road, no special method of construction is required. Only some considerations are presented below.

1) Earthwork

The side borrow method by bulldozer will be applied generally for the construction of embankment. For the new construction sections, side borrow will be made from both sides of road to minimize the earth moving. On the other hand, for the widening sections of the existing road without raising up, side borrow is desirable to be made from one side to keep the existing traffic during construction.

However, for raising up of the existing submerged sections, side borrow method is not applicable, because the soils on roadside are not suitable as embankment material, as described in 7-3-2. Materials should be transported from suitable borrow pits by the shovel and dump method. For these sections, as the existing traffic has also to be kept, the construction will be carried out half by half of road width. During the embankment of first half, the traffic will use the other half, and upon completion of the embankment of first half, the traffic will be led to the completed half and the embankment will proceed to the remaining half.

The trafficability of construction equipment on the soils along the project road was checked based on the results of cone index test. According to the test results, the cone index ranges from 2 to 7, in case the soils are compacted at the natural moisture content, and it decreases to less than 2 when compacted at about 5 percent above the natural moisture content. The required cone index is more than 3 for 15 ton class bulldozer and more than 5 for 21 ton class bulldozer. In rainy season when the water content of soil is anticipated to increase considerably, the construction will become difficult even by 15 ton class bulldozer. Therefore, earthwork was judged to be carried out in dry season only.

The results of cone index test also show the tendency of over-compaction when compacted by AASHO's T-180 compaction test method. Therefore, in constructing embankment, the compaction corresponding to the energy of AASHO's T-99 compaction test method should be employed instead that of T-180.

2) Pavement Works

The pavement works should also be carried out in dry season. Heavy rain will increase the water content of subbase and base course materials which cause difficulty in compaction, and moreover it will decrease the adhesion of bituminons materials which makes poor the workmanship of SBST.

Considerable amount of base course material, about 86,000 cubic meters, will be required in the Project. Therefore, it is preferable to produce crushed stones and stock them in a suitable manner prior to the construction, which can be carried out in rainy season.

3) Bridge Construction

The bridge construction is also recommendable to be carried out in dry season, when no temporary bridge will be required because the traffic can go on the dried up riverbed as a detour, and moreover no coffering or drainage work will be required for the construction of sub-structure. The whole bridge construction will be completed within two and a half years, provided that the construction works will be carried out in dry season mobilizing 6 parties of working force and a 3.5 cubic meters class concrete mixer, and that precast concrete piles will be produced in rainy season.

10-5-2 Construction Schedule

Neigher sophisticated technique nor special type of equipment is required for the construction of the proposed road. It was judged, therefore, reasonable to invite local contractors for all of the construction works.

Judging from the capacity of average local contractors to mobilize equipment and working force, the construction works were assumed to extend two and a half years by two contractors. The whole road length would be divided into two lots at Nong Daeng, the Lot-I from Tha Maduk to Nong Daeng (79.8 km) and the Lot-II from Nong Daeng to Phetchabum (71.5 km).

The tentative construction schedule of both lots together with the implementation schedule were prepared and are shown in Figure 10-3.

10-6 COST ESTIMATE

Cost estimate was made in the same line with that stated in Chapter VII. For the major work items, construction quantities were calculated based on the engineering design made in the preceding section. Quantities by road link are shown in Table 10-9. The financial construction cost was estimated by applying the unit rates established in 7-4-2, dividing into local and foreign currency, as shown in Table 10-10. The summary of financial cost estimate is given in the following table in which price contingency is included.

SUMMARY OF INVESTMENT COST

(Financial Cost)

	In Baht (million)			US$ Equivalent/1 (million)		
	Local	Foreign	Total	Local	Foreign	Total
Direct Construction Cost	121.3	102.1	223.4	6.07	5.11	11.18
Physical Contingency	18.2	15.3	33.5	0.91	0.76	1.67
Engineering & Administration	17.9	-	17.9	0.90	-	0.90
Land Acquisition	2.7	-	2.7	0.13	-	0.13
Sub total	160.1	117.4	277.5	8.01	5.87	13.88
Price Contingency/2	28.5	26.2	54.7	1.42	1.31	2.73
Total	188.6	143.6	332.2	9.43	7.18	16.61

Remarks: /1 At exchange rate of US$1.00 = Baht 20
/2 At assumed annual escalation rates of: 6% (1978), 5.5% (1979) and 5% (1980-81) for local component; and 7% (1978), 6.5% (1979) and 6% (1978-81) for foreign component.

It was assumed that the construction works would start in mid-1980 for a period of two and a half years after the detailed design in 1979. Yearly disbursement was calculated assuming that: half of engineering cost would be expensed for detailed design in 1979, land acquisition cost in 1980, and 20 percent of the remaining costs in 1980 and 40 percent in each year of 1981 and 1982. The estimated yearly fund requirements are as follows:

YEARLY FUND REQUIREMENT

	1979	1980	1981	1982	Total
Local Currency (Baht 1,000)	9,473	36,197	69,700	73,185	188,555
Foreign Currency (US$ 1,000)	-	1,338	2,837	3,008	7,183
Total (Equivalent)					
(Baht 1,000)	9,473	62,963	126,447	133,337	332,220
(US$ 1,000)	474	3,148	6,322	6,667	16,611

Table 10-1 PROFILE AND RIVER CROSS SECTION SURVEY

PROFILE SURVEY

Road Link No.	Location/1 (km)	Length (km)	Remarks
6	0 - 7.7	7.7	Existing road
7/2	0 - 17.0	17.0	New road
11	21.8 - 23.3	1.5	New road (Wichian Buri Bypass)
12/2	0 - 20.5	20.5	New road
16	0 - 2.2	2.2	New road (Wichian Buri Bypass)
28	0 - 15.5	15.5	New road
35 & 37	0 - 12.5/1	12.5	Existing road
40	0 - 2.0	2.0	New road (Nam Ron(1) Bypass)
Total		78.9	

Notes: /1 Indicated in the distances from the beginning point of road link, but in case of Link 35 & 37 the distance from the end point of Link - 37 is given.

/2 Excluded from the optimum route

RIVER CROSS SECTION SURVEY

Road Link No.	Location	Name of River
8/1	4.2 KM from Mai Sarika	Pasak
8/1	5.8 KM from Mai Sarika	Pasak
16	9.0 KM from Wichian Buri	Leng
36/1	6.7 KM from Sam Yaek	Pasak
40	1.2 KM from Nam Ron	Tabo

Note: /1 Excluded from the optimum route

Table 10-2 CBR IN SITU

Location	Penetration	
	0.1"	0.2"
C-1	8.8	11.2
C-2	22.1	26.1
C-3	28.4	22.6
C-4	12.6	16.8
C-5	10.6	14.1
C-6	23.8	22.5
C-7	4.5	5.9
C-8	6.2	7.9
C-9	12.8	16.6

TABLE 10-3 173

LINK NO.	CBR 95% OF AASHO T-180 (%)	CLASSIFICATION	REMARKS
3	2.2	A-6	*
6		A-7-5	*
	3.3	A-6	*
	28.9	A-2-6	**
		A-2-4	**
11	8.2 (100%)	A-6	*
	17.8	A-4	**
		A-2-4	**
	6.2	A-6	*
16		A-7-6	*
	0.55	A-7-6	*
	1.0	A-7-5	*
22		A-2-4	**
	2.7	A-7-5	*
	2.2 (100%)	A-7-5	*
		A-7-5	*
25	10.7	A-6	*
28	0.99	A-6	*
		A-6	*
	11.2		**
	10.7		**
35	8.6	A-6	*
37	3.3	A-7-5	*
		A-7-5	*
	1.38 (100%)	A-6	*
40	0.88	A-7-6	*
	87		***
	48		***

* For Subgrade
** For Selected Material
*** For Crushed Stone

Table 10-3 RESULTS OF THE SOIL TESTS RELATED TO THE OPTIMUM ROUTE

LINK NO.	SAMPLE NO.	NATURAL MOISTURE CONTENT (%)	CONSISTENCY (%)			SIEVE ANALYSIS (No. of Sieve)						COMPACTION TEST		CBR 95% OF AASHO T-180 (%)	CLASSIFICATION	REMARKS
			L.L.	P.L.	P.I.		3/4"	3/8"	10	40	200	O.M.C. (%)	MAXIMUM DRY DENSITY (g/cm³)			
3	Sm-9	14.35	25.3	12.4	12.9		4.5	23.2	19.1	10.4	42.8	8.1	1,891	2.2	A-6	*
6	S -9	9.84	42.8	25.0	17.8		3.6	18.5	18.8	8.2	50.9				A-7-5	*
	Sa-6		35.5	16.3	19.2		5.2	35.4	15.6	11.2	36.4	7.9	2,000	3.3	A-6	*
	Sm-8	15.74	26.3	12.7	13.6		10.4	40.3	14.4	9.7	25.2	7.8	2,256	28.9	A-2-6	**
	S -8	7.61	24.7	15.5	9.2		11.8	27.3	15.2	6.8	18.9				A-2-4	**
11	Sm-7	14.96	25.8	11.1	14.7		0.1	5.1	3.5	12.3	79.0	12.0	1,880	8.2 (100%)	A-6	*
	Sa-5		18.1	10.1	8.0		1.3	7.7	10.3	18.1	68.1	9.4	2,113	17.8	A-4	**
	S -7	6.79	21.7	12.9	8.8		7.5	50.6	10.3	13.2	18.4				A-2-4	**
	Sm-6	19.00	29.6	14.3	15.3		1.4	4.5	2.8	9.4	81.9	12.8	1,957	6.2	A-6	*
16	S -6	42.06	82.3	45.0	37.3		0.6	0.9	1.6	11.1	85.8				A-7-6	*
	Sa-4		79.3	32.5	46.8		6.8	2.1	1.5	2.6	87.0	17.8	1,684	0.55	A-7-6	*
	Sm-5	21.76	44.3	20.0	24.3		0.2	15.7	13.7	12.8	60.7	16.0	1,856	1.0	A-7-5	*
22	S -5	9.64	18.2	10.5	7.7		4.8	12.5	10.7	37.1	34.9				A-2-4	**
	Sa-3		82.3	29.7	52.6			4.1	3.1	32.7	60.1	13.0	1,887	2.7	A-7-5	*
	Sm-4	18.95	48.0	24.0	24.0		0.4	4.1	2.2	3.7	89.6	16.6	1,763	2.2 (100%)	A-7-5	*
	S -4	18.98	44.9	23.7	21.2			2.3	3.6	9.5	84.6				A-7-5	*
25	Sm-3	15.60	22.3	11.0	11.3			3.1	5.2	34.0	57.7	10.4	2,025	10.7	A-6	*
28	Sm-13	43.20	28.1	11.9	16.2			0.1	3.9	8.7	87.3	24.5	1,302	0.99	A-6	*
	S -10	29.60	37.7	18.2	19.5		0.9	0.8	2.9	42.7	52.7				A-6	*
	Sa-2			N.P.				8.0	18.5	46.8	26.7	9.5	2,038	11.2		**
	Sm-12	19.00		N.P.				0.2	9.1	81.2	9.5	13.2	1,701	10.7		**
35	Sm-2	9.90	38.5	20.1	18.4		3.0	32.8	14.6	6.9	45.5	15.4	1,764	8.6	A-6	*
37	Sa-1		50.4	25.3	25.1		0.8	4.5	5.4	16.8	72.5	18.2	1,679	3.3	A-7-5	*
	S -2	19.10	55.3	27.4	27.9			2.3	4.4	13.3	80.0				A-7-5	*
	Sm-1	27.70	53.1	25.4	27.7			3.0	6.4	14.5	76.1	24.0	1,473	1.38 (100%)	A-6	*
40	Sm-11	26.6	71.7	40.9	30.8		1.2	5.6	3.5	7.0	82.7	21.0	1,451	0.88	A-7-6	*
	Sc-1					16.6	28.1	32.2	12.2	4.3	6.6	5.6	2,319	87		***
	Sc-2					20.7	29.3	32.8	10.4	3.5	3.3	6.9	2,297	48		***

* For Subgrade
** For Selected Material
*** For Crushed Stone

Table 10-4 CONE INDEX

Sample No.	Water Content (%)	Numbers of Blows		
		10	21	56
CI-1	14.1	more than 15.5	more than 15.5	more than 15.5
	19.0/1	more than 15.5	more than 15.5	more than 15.5
	25.4	4.11	4.03	4.03
CI-2	13.9	more than 15.5	more than 15.5	more than 15.5
	17.8/1	5.55	5.75	7.10
	23.0	1.06	1.10	0.89
CI-3	15.0	more than 15.5	more than 15.5	more than 15.5
	20.2/1	1.85	1.96	1.75
	23.6	0.93	0.84	0.75
CI-4	32.3	more than 15.5	13.62	more than 15.5
	37.5/1	1.85	1.96	1.75
	42.7	0.93	0.84	0.75
CI-5	6.9	more than 15.5	more than 15.5	more than 15.5
	12.9/1	5.67	4.08	4.18
	17.8	0.27	0.27	0.27

Note: /1 Natural moisture content.

Table 10- 5 TIME OF CONCENTRATION

Catchment Area No.	Features of River Channel				Mean Velocity	Time of Concentration
	Length L (km)	Difference in Elevation dH (m)	Mean Gradient I	Hydraulic Mean Depth R (m)	(m/sec)	tp (hr)
11	7.2	80.0	1/90	1.5	2.763	2.8
	10.8	42.0	1/257	1.3	1.486	
12	14.5	260.0	1/56	1.5	3.500	6.5
	19.5	36.0	1/542	1.3	1.023	
15	16.2	220.0	1/74	2.0	3.500	5.0
	13.0	14.0	1/929	1.8	0.971	
27	20.5	240.0	1/86	1.5	2.826	9.2
	29.5	67.0	1/441	1.3	1.134	
28	6.4	402.0	1/16	0.8	3.500	3.8
	17.4	90.0	1/193	1.0	1.438	
34	25.6	400.0	1/64	1.0	2.500	4.2
	10.6	74.0	1/143	1.5	2.190	
35	27.0	938.0	1/29	1.0	3.500	5.8
	20.6	75.0	1/275	1.5	1.581	
36	147.0	190.0	1/774	1.2	0.812	50.3

Table 10-6 UNIT HYDROGRAPH

Catchment Area No.	Catchment Area (km^2)	Length of River Channel (km)	Grade of River Channel	Time Lag of Flood Peak t_p (hr)	t_g	t_k	Peak Discharge (m^3/hr)
11	63.0	18.0	1/310	2.8	2.0	5.6	2.718
12	302.0	34.0	1/1,500	6.5	5.7	13.0	5.612
15	197.0	29.2	1/910	5.0	4.2	10.0	4.759
27	454.0	50.0	1/1,400	9.2	8.4	18.4	5.960
28	110.0	23.8	1/350	3.8	3.0	7.6	3.490
34	209.0	36.2	1/300	4.2	3.4	8.4	5.996
35	140.0	47.6	1/800	5.8	5.0	11.6	2.905
36	3,900.0	147.0	1/1,100	50.3	49.5	100.6	9.365

Table 10-7 BASIC-FLOW DISCHARGE

Catchment Area No.	Water Course No.	Link	Cross Sectional Area of River (m^2)	Gradient of River	Hydraulic Mean Depth (m)	Basic-Flow Discharge
11	1	No. 11	14.75	1/310	0.873	15.3
12	1	No. 11	25.60	1/1,500	1.506	17.4
	2		28.30	1/1,500	1.546	19.5
15	1	No. 16	55.00	1/910	1.923	56.4
	2		10.00	1/910	0.833	5.9
27	1	No. 25	116.00	1/1,400	3.602	145.7
	2		25.00	1/1,400	0.926	12.7
	3		20.00	1/1,400	0.909	10.0
28	1	No. 28	50.00	1/350	0.962	52.1
34	1	No. 40	80.00	1/300	2.857	186.0
	2		37.50	1/300	1.875	65.8
35	1	No. 40	50.00	1/800	0.962	34.4
36	1	No. 40	525.00	1/1,100	5.899	1,033.6
	2		140.00	1/1,100	2.979	174.8

Table 10-8 LIST OF PROPOSED BRIDGES

ROAD LINK NO.	STATION	BRIDGE LENGTH (M) & SPAN ARRANGEMENT	REMARKS
11	33 + 700	14.0 (2 @7.0)	Bridge for Relief Open
	34 + 700	84.0 (12 @7.0)	Bridge for Relief Open
	45 + 100	21.0 (3 @7.0)	Replacement of Timber Bridge (W = 5.6, L = 15.5)
	46 + 0	42.0 (6 @7.0)	Bridge for Relief Open
	46 + 900	42.0 (6 @7.0)	Bridge for Relief Open
	48 + 350	21.0 (3 @7.0)	Replacement of Timber Bridge (W = 4.2, L = 15.5)
16	62 + 400	63.0 (9 @7.0)	Replacement of Timber Bridge (W = 4.0, L = 63.7)
	62 + 650	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 4.6, L = 6.9)
	69 + 400	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 4.2, L = 11.3)
	72 + 950	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 4.2, L = 11.5)
18	76 + 900	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 4.2, L = 15.0)
22	80 + 600	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 4.2, L = 14.9)
	80 + 850	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 4.2, L = 11.2)
	81 + 150	21.0 (3 @7.0)	Replacement of Timber Bridge (W = 4.2, L = 22.5)
	85 + 700	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 4.3, L = 11.5)
	89 + 50	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 2.7, L = 2.5)
	89 + 900	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 4.2, L = 11.2)
	90 + 850	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 2.7, L = 4.5)
	91 + 650	21.0 (3 @7.0)	Replacement of Timber Bridge (W = 4.2, L = 15.0)
23	94 + 350	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 4.4, L = 15.4)
	96 + 650	21.0 (3 @7.0)	Replacement of Timber Bridge (W = 4.2, L = 18.4)
	97 + 250	24.0 (3 @8.0)	Replacement of Timber Bridge (W = 4.5, L = 24.3)

Table 10-8 LIST OF PROPOSED BRIDGES (Continued)

ROAD LINK NO.	STATION	BRIDGE LENGTH (M) & SPAN ARRANGEMENT	REMARKS
25	98 + 550	30.0 (3 @10.0)	Replacement of Timber Bridge (W = 4.5, L = 23.7)
	100 + 200	24.0 (3 @8.0)	Replacement of Timber Bridge (W = 4.4, L = 23.6)
	100 + 400	21.0 (3 @7.0)	Replacement of Timber Bridge (W = 4.4, L = 18.4)
28	104 + 550	10.0 (1 @10.0)	Bridge on New Construction Road
	104 + 800	14.0 (2 @7.0)	Bridge on New Construction Road
	105 + 880	14.0 (2 @7.0)	Bridge on New Construction Road
	106 + 500	10.0 (1 @10.0)	Bridge on New Construction Road
35	124 + 500	21.0 (3 @7.0)	Replacement of Timber Bridge (W = 3.5, L = 21.5)
40	140 + 50	21.0 (3 @7.0)	Bridge on Nam Ron (1) Bypass
	140 + 700	14.0 (2 @7.0)	Bridge on Nam Ron (1) Bypass
	142 + 80	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 3.5, L = 12.0)
	142 + 200	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 3.3, L = 14.5)
	142 + 820	14.0 (2 @7.0)	Replacement of Timber Bridge (W = 3.6, L = 10.3)
	147 + 500	42.0 (6 @7.0)	Bridge for Relief Open
	149 + 150	63.0 (9 @7.0)	Bridge for Relief Open
	149 + 800	98.0 (14 @7.0)	Bridge for Relief Open
TOTAL		952.0	

Table 10-9 CONSTRUCTION QUANTITIES (OPTIMUM ROUTE)

DESCRIPTION	UNIT OF Q'TY	ROAD LINK NUMBER												TOTAL
		3	6	11	16	18	22	23	25	28	35	37	40	
LINK LENGTH	km	12.5	18.0	23.3	20.7	5.3	14.0	4.4	6.0	15.5	8.5	11.7	11.4	151.3
WORK ITEMS														
Clearing & Grubbing	ha	-	-	5	2	-	-	-	-	50	-	-	1	58
Soil Excavation	m^3	46,100	32,800	110,900	93,500	2,300	52,900	6,300	12,300	73,900	32,000	67,700	152,200	682,900
Rock Excavation	m^3	-	-	-	-	-	-	-	-	14,000	2,900	4,500	-	21,400
Embankment	m^3	56,600	54,700	114,300	97,800	6,500	60,700	12,100	16,400	213,900	37,800	38,200	138,400	847,400
Selected Fill	m^3	13,500	22,200	28,700	25,300	1,800	11,400	2,900	8,900	33,800	16,100	22,500	24,000	211,100
Subbase/1 & Shoulder	m^3	23,600	36,500	46,800	41,300	6,700	16,700	4,700	10,800	36,000	17,500	24,400	30,700	295,700
Base	m^3	11,400	16,500	21,200	18,900	4,900	300	100	800	300	600	800	10,100	85,900
Prime & SBST	m^2	72,100	104,300	133,900	119,500	30,700	1,800	600	5,100	1,800	3,500	4,700	63,800	541,800
Pipe Culvert	m	80	200	850	1,240	-	160	370	160	1,150	240	320	240	5,010
Box Culvert	m	20	40	-	20	-	-	-	-	80	-	-	-	160
Long Span Bridge	m	-	-	-	-	-	-	-	-	-	-	-	-	0
Short Span Bridge	m	-	-	224	105	14	126	59	75	48	21	-	280	952
LAND ACQUISITION	ha	-	-	6	9	-	-	-	-	62	-	-	7	84

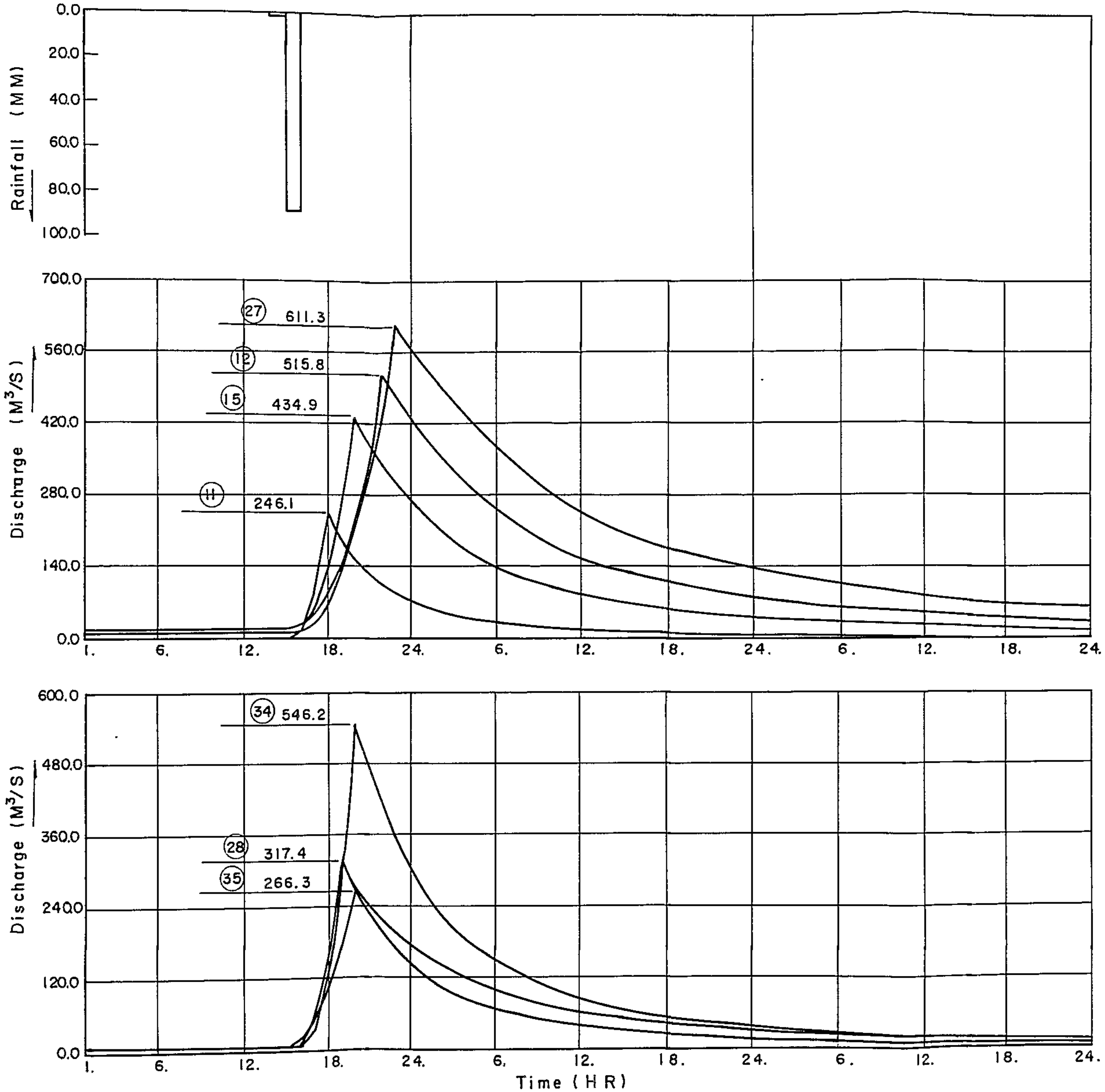
Remarks: /1 To be understood as laterite surfacing in case that F5 Standard is applied.

Table 10-10 TOTAL CONSTRUCTION COST
(OPTIMUM ROUTE)

DESCRIPTION	UNIT OF Q'TY	Q'TY	FINANCIAL UNIT RATE (Baht)	FOREIGN PORTION (%)	TAX (%)	FINANCIAL COST (1,000 Bahts)			ECONOMIC COST (1,000 Bahts)
						TOTAL	LOCAL CURRENCY	FOREIGN CURRENCY	
DIRECT CONSTRUCTION COST									
Clearing & Grubbing	ha	58	7,000	42	9.1	406	235	171	369
Soil Excavation	m^3	682,900	30	46	9.9	20,487	11,063	9,424	18,459
Rock Excavation	m^3	21,400	70	51	13.7	1,498	734	764	1,293
Embankment	m^3	847,400	55	41	9.6	46,607	27,498	19,109	42,133
Selected Fill	m^3	211,100	70	41	9.6	14,777	8,718	6,059	13,358
Subbase/1 & Shoulder	m^3	295,700	130	47	10.8	38,441	20,374	18,067	34,289
Base	m^3	85,900	300	51	6.7	25,770	12,627	13,143	24,043
Prime & SBST	m^2	541,800	35	55	5.5	18,963	8,533	10,430	17,920
Pipe Culvert	m	5,010	1,400	34	8.2	7,014	4,629	2,385	6,439
Box Culvert	m	160	9,200	38	10.8	1,472	913	559	1,313
Long Span Bridge	m	-	50,000	46	11.3	-	-	-	-
Short Span Bridge	m	952	33,000	46	11.3	31,416	16,965	14,451	27,866
Sub total						206,851	112,289	94,562	187,482
Minor Items (8% of the above)						16,548	8,983	7,565	14,999
Total						223,399	121,272	102,127	202,481
PHYSICAL CONTINGENCY/2						33,510	18,191	15,319	30,372
ENGINEERING AND ADMINISTRATION/3						17,872	17,872	-	16,198
SUB TOTAL						274,781	157,335	117,446	249,051
LAND ACQUISITION	ha	84	32,000		-	2,688	2,688	-	2,688
TOTAL						277,469	160,023	117,446	251,739

Remarks: /1 To be understood as laterite surfacing in case that F5 Standard is applied.
/2 15% of direct construction cost
/3 8% of direct construction cost

Figure 10-1 DISCHARGE CURVES



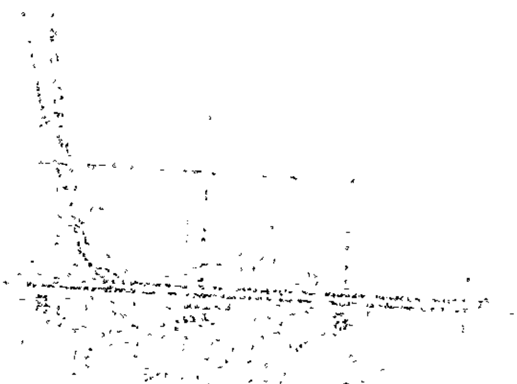


Figure 10-1 DISCHARGE CURVES (Continued)

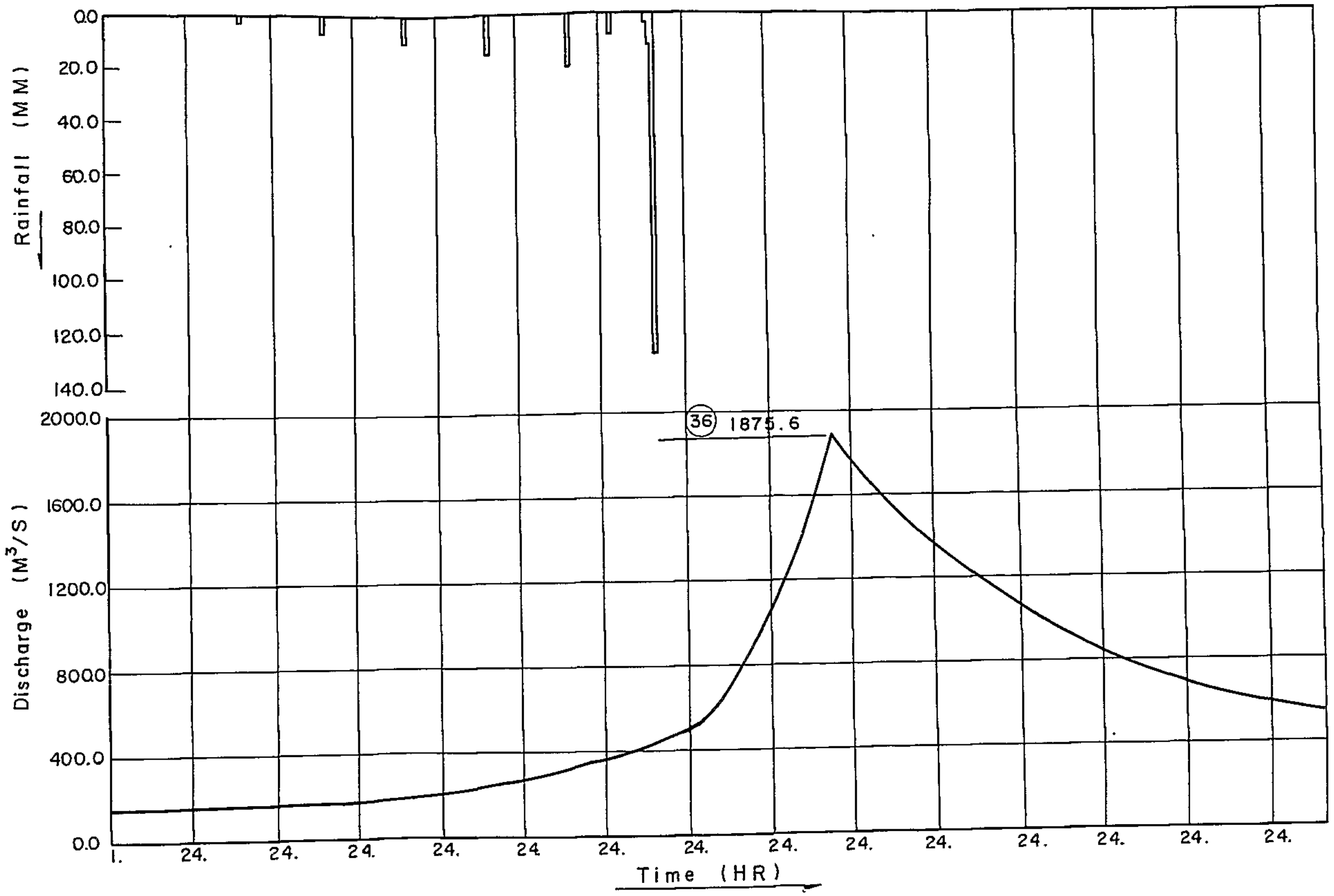
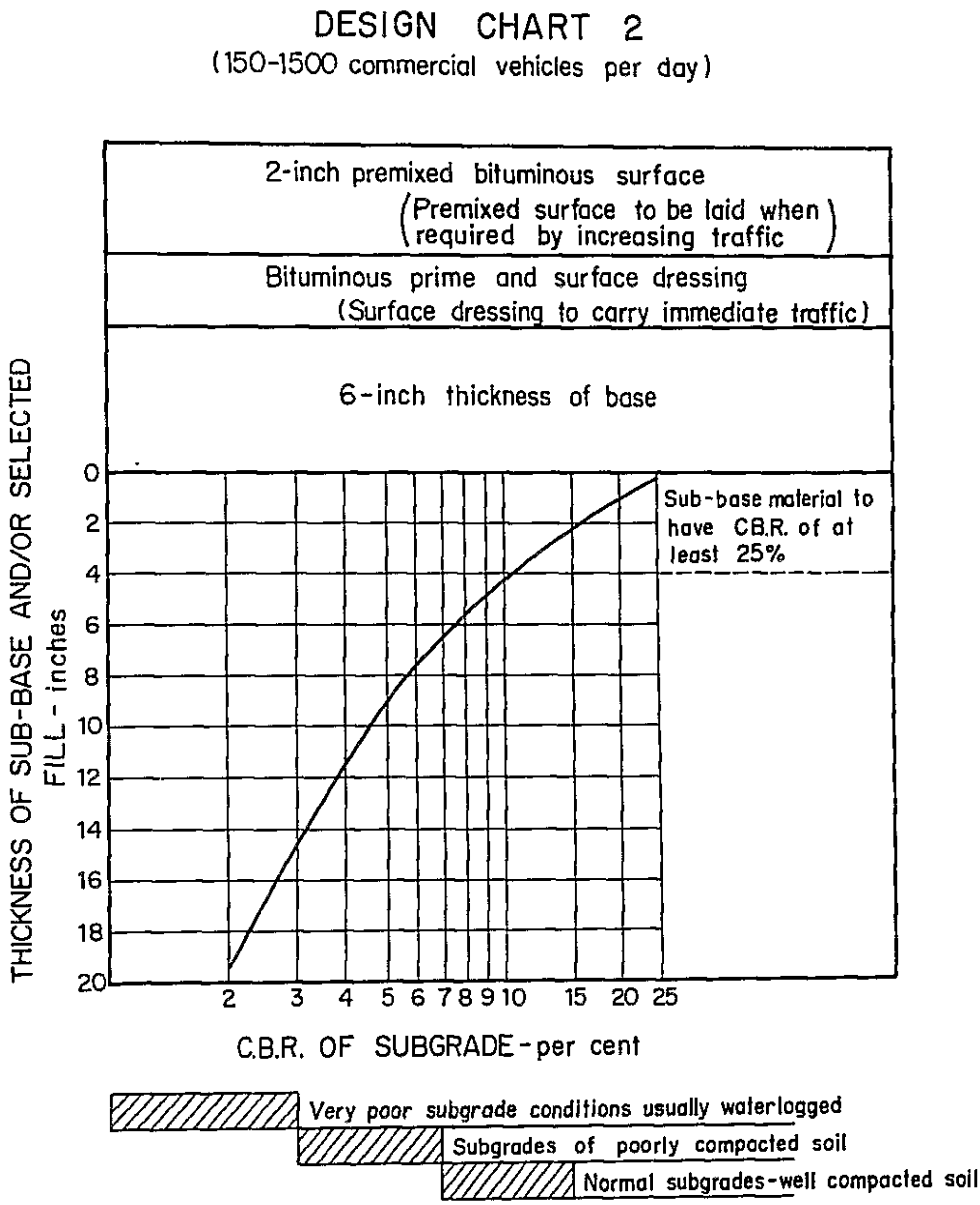


Figure 10-2 PAVEMENT DESIGN CHART



APPROXIMATE GUIDE TO SUBGRADE CONDITIONS

Figure 10-3 IMPLEMENTATION AND WORK SCHEDULE

IMPLEMENTATION SCHEDULE

Item	1978	1979	1980	1981	1982	1983
Feasibility Study						
Detailed Design						
Tendering - Contract Award						
Land Acquisition						
Construction						
Opening						

WORK SCHEDULE (LOT - I) L = 79.8 KM (0 KM - 79.8 KM)

Work Item	Unit	Quantity	1980	1981	1982	1983
Mobilization and Preparatory Works	—					
Clearing and Grubbing	ha	7				
Soil Excavation	m^3	285,600				
Embankment	m^3	329,900				
Selected Fill	m^3	91,500				
Subbase and Shoulder	m^3	154,900				
Base	m^3	72,900				
Prime and SBST	m^2	460,500				
Pipe Culvert	m	2,370				
Box Culvert	m	80				
Short Span Bridge	m	343				

WORK SCHEDULE (LOT - II) L = 71.5 KM (79.8 KM - 151.3 KM)

Work Item	Unit	Quantity	1980	1981	1982	1983
Mobilization and Preparatory Works	—					
Clearing and Grubbing	ha	51				
Soil Excavation	m^3	397,300				
Rock Excavation	m^3	21,400				
Embankment	m^3	517,500				
Selected Fill	m^3	119,600				
Subbase and Shoulder	m^3	140,800				
Base	m^3	13,000				
Prime and SSBT	m^2	81,300				
Pipe Culvert	m	2,640				
Box Culvert	m	80				
Short Span Bridge	m	609				

Chapter XI

EVALUATION

Chapter XI

EVALUATION

11-1 GENERAL

The improvement of road network with the selected optimum route will bring about various benefits. Major quantifiable benefits include road users' savings and net incremental value added in the agricultural production attributable to the Project. In addition, one of the important effects is the impacts of completely linked road network in the region. The complete linking of the Project Area with the major centers of the outer area will grant easy communication to the greater number of the rural people. The proposed route gives the balanced effects of those mentioned above.

11-2 ECONOMIC EVALUATION

11-2-1 Economic Costs

The economic costs of the Project are net of taxes and other transfer items, and include direct construction cost, engineering and administration costs, physical contingency, right-of-way, and road maintenance costs. The eco- nomic costs are estimated on the basis of 1978 constant prices. The initial investment costs of construction and annual routine maintenance cost are summarized as shown below. In addition, an overlay cost in 1989 was estimated at 37.6 million Bahts.

Construction Cost

	(million Baht)
1979	8.1
1980	50.8
1981	96.4
1982	96.4

Annual Routine Maintenance Cost

	(million Baht)
1983	2.8
1989	3.0
1990	2.7
1997	2.8

The costs required for the attainment of projected agricultural benefits are the initial land preparation costs and the annual production costs. However, these costs were not included in the project costs but deducted in the calculation of net agricultural benefits.

11-2-2 Economic Benefits

Benefits considered in calculation of economic internal rate of return are the savings of road users' costs and the net increment in agricultural production attributable to the Project.

The savings of road users' costs which include vehicle operating costs and occupants' time costs were calculated, under the refined traffic forecast described in Chapter IX, and summarized below:

Road Users' Cost Savings

	1983	1989	1997
			(million Baht)
Normal Freight Traffic	0.8	1.0	1.3
Normal Passenger Traffic	44.2	48.8	55.3
Induced Passenger Traffic	2.8	5.5	5.8
Total	47.8	55.3	62.4

Elements of the agricultural benefits are discussed in Chapter V. For the estimation of the net incremental agricultural benefits of the optimum route, annual net value of production and initial land preparation costs were calculated in combination of sectional values of Alternative-I and -II, and summarized below:

Agricultural Benefits

	1983		1989		1997	
	W	$\bar{W}$	W	$\bar{W}$	W	$\bar{W}$
Area (1,000 rai)						
Maize	324	324	380	338	403	354
Paddy	180	180	206	190	211	204
Beans	143	143	182	156	192	172
Net Value of Production (million Baht)	143.4	124.3	190.4	139.6	206.2	159.9
Land Preparation Cost (million Baht)	5.5	1.6	1.4	1.6	1.4	1.6
Increment of Net Added Value (million Baht)	15.2		51.0		46.3	

11-2-3 Economic Internal Rate of Return

Based on the economic costs and benefits, economic internal rate of return (EIRR) was calculated, under the same conditions as described in 8-1, at 20.4 percent, which exceeds the opportunity cost of capital of the country. Streams of costs and benefits are tabulated in Table 11-1. From a viewpoint of national economy, the implementation of the Project is justifiable.

11-2-4 Sensitivity Analysis

The sensitivity of EIRR to the changes of major elements was tested in three cases: i) 10 percent cost increase, ii) 10 percent benefit decrease iii) combination of the above two cases. The EIRR of each case are calculated as below.

EIRR (Sensitivity Analysis)

(%)

Case (i)	Case (ii)	case (iii)
18.8	18.7	17.1

The results show that the economic viability of the Project is relatively less sensitive in all cases, and that the Project continues to be feasibible in any cases.

11-3 SOCIAL IMPACTS

The Project will have social impacts to the rural society, though they are non-quantifiable. The project road completes a trunk network of all-weather road linking with the Route 21 at Phetchabun and through Wichian Buri and with the Route 205 at Tha Maduk. This will provide a basis for the future development of the more dense network. One of the most important effects of the Project will be the complete linkage between the Project Area and the provincial centers, Phetchabun and Lam Narai, where most of the established social institutions exist. Improvement of the network of all-weather road will benefit the rural people to improve their accessibility to the existing social institutions such as major markets, schools, health centers and administrative centers.

Easy connection with the provincial centers will accelerate the raising-up of living standard of the Project Area. The more information on the process of the economic development in urban areas will be brought into the Project Area, the greater the enhancement of the economic activities there will be.

Especially, the increase of the rural income accrued from the agricultural development attributable to the Project will stimulate the consumption and the consequent investment in the Project Area. These multiplying effect will greatly contribute to the reducing of the existing regional income imbalance.

11-4 FEEDER ROAD DEVELOPMENT

The present study aims at the planning of all-weather artery road in the Project Area. To complete the whole road network in the Project Area, the construction of some feeder roads will be required in the next step.

The important feeder roads are those links Amphoe offices to the National Highway Route-21 to strengthen the local administration and social security. Two Amphoe offices are located in the Project Area, one at Si Thep and the other at Wichian Buri. At present, a good access of paved road is serving for Wichian Buri, while, the access to Si Thep is only a poor soil aggregate surfaced road. The improvement of the access to Si Thep (Mai Sarika - Si Thep, Link-8) is, therefore, considered to be the most important feeder road.

The additional construction cost required for the improvement of this link was estimated at 42,232,000 Bahts, excluding price contingency, which is about 12 percent increase of the original Project cost, while the additional benefit was estimated at only 2 percent of the original Project benefits. This means the additional investment itself is not economically justifiable. However, even if the improvement of Link-8 is added, the Project is still feasible judging from the results of the sensitivity test.

11-5 CONCLUSION

It is concluded that the Project is technically sound and economically viable, and has a remarkable social impacts. Hence, it is recommendable for the Royal Government of Thailand to proceed to the further stages for the implementation of the Project so that the proposed road opens to traffic in 1983 as planned. It is also recommendable to carry out the detailed surveys and design works to define the detailed specifications of the construction works as well as to obtain the more precise estimates of the construction costs.

Table 11-1 COSTS AND BENEFITS STATEMENT
(OPTIMUM ROUTE)

(million Baht)

	COSTS			BENEFITS			DISCOUNTED AT 12%	
Year	Const. Cost	RMC	Total	Agricultural Benefit	Road Users' Benefit	Total	Costs	Benefits
1979	8.1		8.1				8.1	
1980	50.8		50.8				45.4	
1981	96.4		96.4				76.8	
1982	96.4		96.4				68.6	
1983		2.8	2.8	15.2	47.8	63.0	1.8	35.7
1984		2.8	2.8	20.5	49.1	69.6	1.6	35.3
1985		2.9	2.9	25.8	50.3	76.1	1.5	34.4
1986		2.9	2.9	31.0	51.6	82.6	1.3	33.4
1987		2.9	2.9	36.3	52.8	81.1	1.2	32.1
1988		3.0	3.0	41.6	54.1	95.7	1.1	30.8
1989		40.6	40.6	51.0	55.3	106.3	13.1	30.6
1990		2.7	2.7	50.4	56.2	106.6	0.8	27.4
1991		2.7	2.7	49.9	57.1	107.0	0.7	24.5
1992		2.7	2.7	49.3	58.0	107.3	0.6	21.9
1993		2.8	2.8	48.8	58.9	107.7	0.6	19.7
1994		2.8	2.8	48.2	59.7	107.9	0.5	17.6
1995		2.8	2.8	47.6	60.6	108.2	0.4	15.8
1996		2.8	2.8	47.1	61.5	108.6	0.4	14.1
1997		2.8	2.8	46.3	62.4	108.7	0.3	12.6
Total	251.7	80.0	331.7	609.0	835.4	1,444.4	224.8	385.9

Discounted Economic Costs (mil. B):

Construction Cost	198.9
RMC	25.9
Total	224.8

Discounted Economic Benefits (mil. B):

Agricultural Benefit	154.0
Road User's Benefit	231.9
Total	385.9

Net Present Value (mil. B): 161.1

Benefit Cost Ratio: 1.72

IRR (%): 20.4

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