CHAPTER A-4 CONSTRUCTION PLAN, COST ESTIMATE AND IMPLEMENTATION PROGRAM

4.1 Construction Plan

4.1.1 Construction Policy

The construction plan has been prepared based on the following policies:

1) Proper consideration shall be given to local regulations required in Cambodia for construction work to proceed.

2) The construction method and schedule shall be agreeable with local conditions and local practice.

3) Local construction equipment and materials shall be utilized as much as possible. When necessary these can be imported from Thailand or other countries, based on the most economical within the range of specified quality.

4.1.2 Considerations on Construction Planning

The following are considered in planning the construction schedule, taking into account the local conditions:

1) The clearance of landmines and UXOs is indispensable prior to the commencement of the detailed design, due to the fact that NR.57 is notorious for serious landmine contamination.

2) The project is divided into two stages, based upon the progress of landmine clearance. Stage-1 includes the improvement of the road and facilities from Km3 to Km50, where landmines have already been cleared and it is safe within 15m on each side of the road. Stage-2 comprises of the rest of NR.57, where landmines are yet to be cleared and it is recommended that the clearing be carried out during the detailed design period for Stage-1.

3) Commencement of the construction work is scheduled to start in November, in order to avoid interference by high water levels during the rainy season, which in Cambodia, starts in May and ends in October.

4) To ensure on-going traffic is not disturbed during construction work, a detour is provided for each bridge site adjacent to the existing bridge.

4.1.3 Landmines and UXO

As stated in the preceding section, NR.57 is notorious for landmine and UXO contamination. **Figure 4.1.1** shows the progress of clearing landmines in the vicinity of NR.57. Landmines have already been cleared up to approximately 50 km from Battambang along NR.57. The clearance is limited to 15 m on each side from the road centre. Landmine and UXO clearance is indispensable prior to the commencement of the detailed design.

From the information provided by CMAC, it will take about four months with a cost of three hundred thousand (300,000) US$ to clear the remaining area.

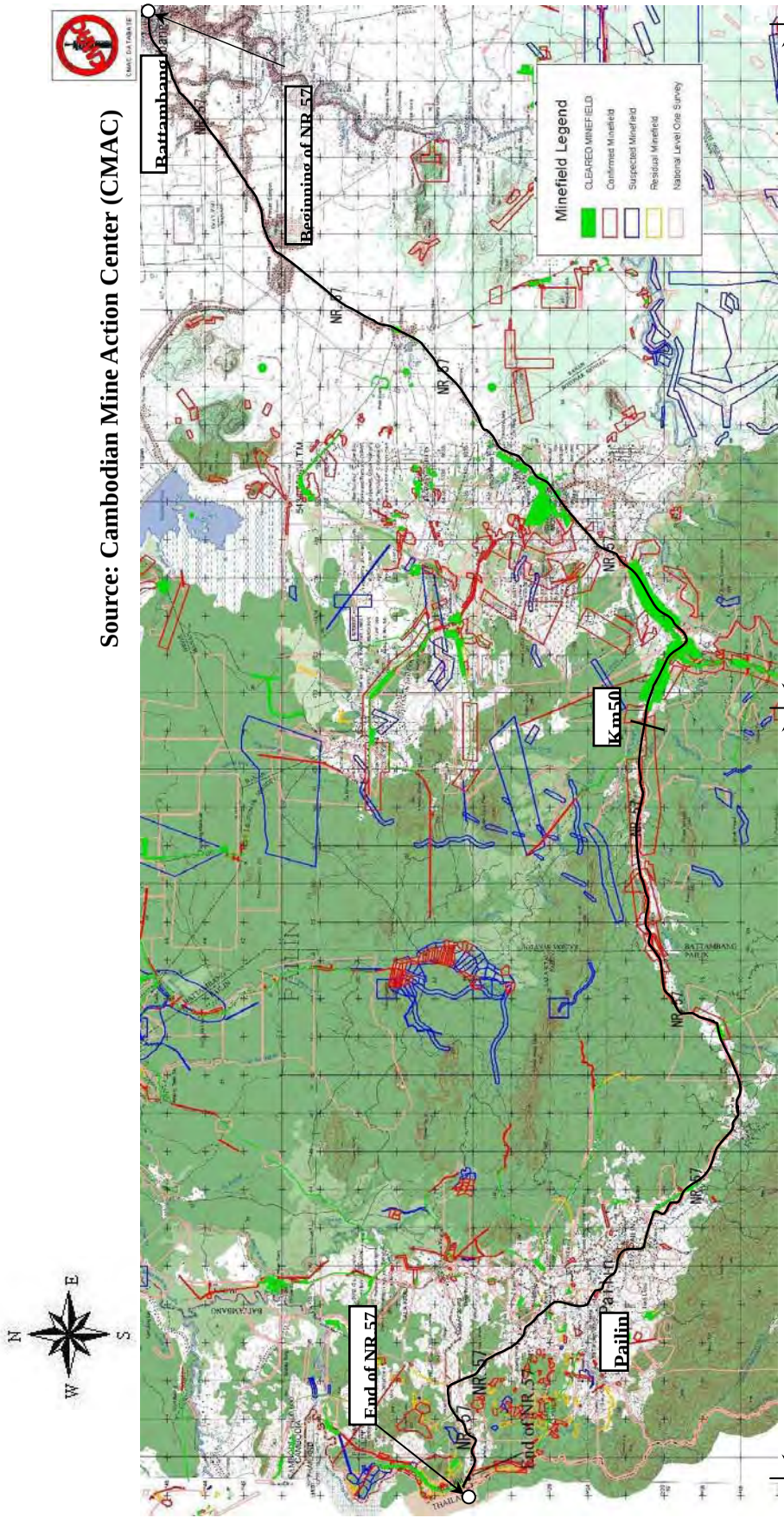


Figure 4.1.1 Landmine Contamination Map Along NR.57

4.1.4 Major Project Components

The project includes the whole length of NR.57, including the town sections. The section up to about Km3 from the start is inside the urban area of Battambang and is excluded from the scope of the improvement under the present project.

Major components of the project are the road rehabilitation of 101 km(from Km3 to Km104), replacement of 12 bridges amounting to a total length of 340m and replacement of culverts with a total length of 2,500m. Major components of the project are listed in **Table 4.1.1**.

Table 4.1.1 Project Components

Road Component	**Total Road length = 101 km**			
	Culverts			
	S.N.	**Total No.**	**Total Length**	**Type**
	1	22	418	RCBC-1
	2	11	2098	RCBC-2
	3	22	418	RCBC-3
	4	63	1197	RCPC-1
	5	10	190	RCPC-2
	6	2	38	RCPC-3
	Total	**130**	**2470**	
Bridge Component	**Bridge No.**	**Length**	**Bridge Type**	**Foundation Type**
	1	15.0	RCS	RC Pile
	2	24.6	RCS	RC Pile
	3	24.6	RCS	RC Pile
	4	18.6	RCDG	RC Pile
	5	48.6	PCDG	RC Pile/Spread
	6	33.6	RCDG	RC Pile/Spread
	7	14.0	RCS	RC Pile
	8	24.0	RCS	RC Pile/Spread
	9	18.6	RCDG	RC Pile
	10	33.0	RCS	RC Pile/Spread
	11	13.0	RCS	RC Pile
	12	72.6	RCDG	Spread Footing
	Total	**340.2**		

Note: RCPC – Reinforced Concrete Pipe Culvert, RCBC – Reinforced Concrete Box Culvert, 1,2,3 stand for no. of cell
RCS – Reinforced Concrete Slab, RCDG-Reinforced Concrete Deck Girder, PCDG-Precast Prestressed Deck Girder and RC Pile – Precast Reinforced Concrete Pile (400x400)

4.1.5 Procurement and Transportation Plans

The area along NR.57 is not well developed, due to the contamination by landmines and UXOs. Accidents from landmine explosions still occur in the daily life of the residents along the road. Because of this security issue, the development of material sources has not progressed well except for some existing ones. There are, however, potential areas for crushed stone and aggregate. Local material sources for road and bridge structure are listed in **Table 4.1.2**.

Table 4.1.2 Material Souces for Road and Bridge Structures

Type of Materials	Material Sources
Laterite (for Road Body & Sub-Grade)	Sala Kroa, Banon, Moung Ruessei
Sand (for Sub-Base)	Banon
Crushed Stone (Sub-Base, Base and Agrregate)	Dei Kraham and hills of Pailin
Bitumen (for Pavement)	Asphalt Plant near Banon for Stage-1 and Pailin for Stage-2
Embankment material (Road Body & Sub-grade)	Borrow Pit along NR.57

For Stage-1 road construction the material is predominantly for filling. Filling material for the roadbed and sub-base can be supplied from Banon, which is located 20km from Battambang. For Stage-2, Sala Troa might have an advantage for the supply of material. So far other potential areas, near Pailin, for the supply of road structure materials have not been so well explored.

The locations of the local material sources are given in **Figure 4.1.2**.

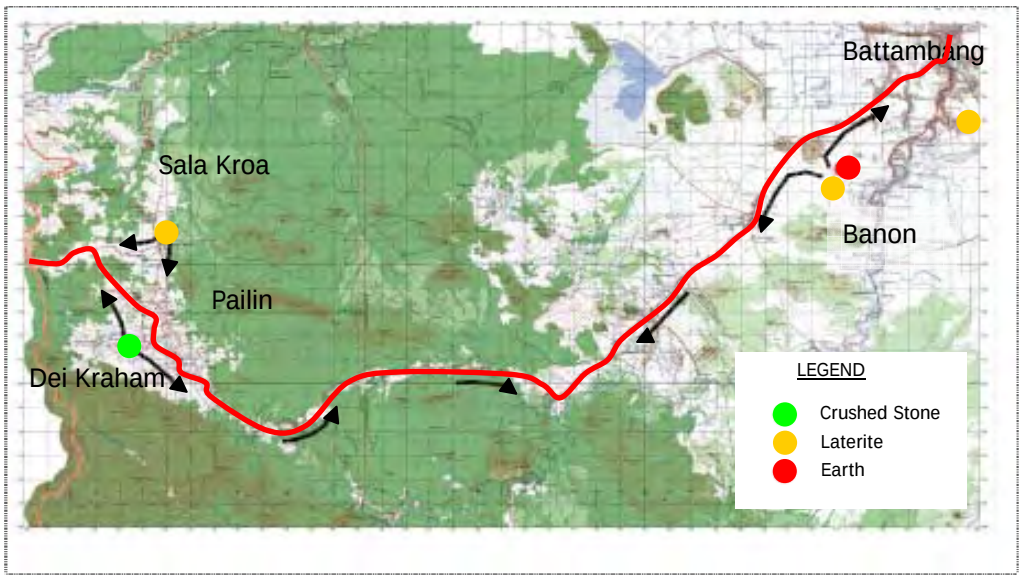


Figure 4.1.2 Location Map of Quarry and Borrow Pit Along NR.57

4.1.6 Share of the Work

The project is considered to be financed by External Resources. The share of work responsibility between the External Resources and the Government of Cambodia is shown in **Table 4.1.3.**

Table 4.1.3 Share of Work between External Resources and the Government of Cambodia

Item	Content	Share		Remarks
		Other Countries	Cambodia	
Procurement of Equipment and Materials	Purchase and transport of equipment and material	○		
	Custom clearance of the above		○	
	Improvement of road for inland transport		○	
Survey and evacuation of landmine and UXO			○	Before the work commencement
Project Preparation	Land acquisition & conpensation etc. needed for the construction works		○	Site office, stock and work yards,
	Preparation works other than the above	○		
	Shift of Public Utilites such as Water supply line, Power supply line, communication cable		○	Before the work commencement
	Removal of existing bridges		○	
Project components	Construction of bridges and roads, other related works	○		

4.2 Cost Estimate

4.2.1 Construction Cost

For the purpose of cost estimates, the costs of temporary and indirect works have been estimated based on similar projects in Cambodia and are given in **Table 4.2.1**.

Table 4.2.1 Share of Temporary and Indirect Works

For NR.57 (Road: 101km, 12 Bridges: 340m)

Construction Works				
	Direct Cost		A	(a+b)
		Direct Construction Work	a	
		Site Temporary Work	b	a*10%
	Temporary Works in Common		B	a*5%
	Site Management		C	a*7%
	General Management		D	(A+B+C)*6%
Detailed Design and Supervision				
	Detailed Design & Construction Supervision			10%

Site temporary works include:

1. Temporary work on Site,
2. Machine use and depreciation
3. Engineer's dispatching
4. Others

Temporary works in common include:

1. Preparation works, including leasing fees for detours and other purposes.
2. Plant installation
3. Import, transportation and other costs for imported materials and equipment
4. Security cost
5. Quality control
6. Building and maintenance of project offices and consumable goods

Site Management includes:

1. Labor management cost
2. Safety precaution costs for sanitary and others
3. Insurance cost
4. Wages and other allowances of project staff and workers
5. Welfare cost
6. Transportation and communication cost
7. Others

General Management includes:

1. Management cost of head office
2. Profit

The summary of estimated construction costs is given in **Table 4.2.2**.

Table 4.2.2 Estimated Construction Cost

Construction Cost of NR.57		Amount (x 1,000 US$)
	Km3 - Km104	35,529
	12 Bridges on NR.57	3,888
	Pipe and Box Culverts on NR.57	3,378
Total of Construction Works		42,795
Engineering Works		
	Detailed Design & Construction SV	4,280
TOTAL CONSTRUCTION COST		**47,075**

(1) Shared cost by External Resources

Components	**Preliminary Cost Estimate（x 1,000 US$）**	
	Stage-1 (~50km)	**Stage-2 (50km~)**
Road &Bridge Construction	29,573	22,222
Detailed Design, Construction Supervision	2,057	2,222
Sub-Total	22,631	24,444
Grand Total	**47,075**	

(2) Shared cost by the Government of Cambodia

Items	**(Equivalent in x1,000 US$)**	**Remarks**
Land Acquisition	28.4	
Clearing of Land Mines and UXOs	300.0	(0.57US$/$m^2$)
Relocation of Public Utilities (Electricity, Water & Communication)	10.0	
Total	338.4	

(3) Total Project Cost

The Total Project Cost is estimated as the total of the cost shared by external resources and by the Government of Cambodia and is estimated to be US$ 47,413,400.

Table 4.2.3 Total Project Cost

Unit:1,000US$

	External Resources	Cambodia Government
Construction Cost	42,795.0	
Detailed Design & Construction Supervision	4,280.0	
Land Acquisition		28.4
Landmine and UXO Clearance		300.0
Relocation of Public Utilities		10.0
Total	47,075.0	338.4
Grand Total	47,413.4	

4.2.2 Conditions

Cost estimation has been done with the conditions mentioned below:

1. Time of cost estimation: June 2006
2. Exchange rate: 1 US Dollar = 4,113.5 Riels
3. Construction period: The project is to have 2 Stages as mentioned in the implementation schedule.

4.2.3 Unit Rates

Major unit rates used for the cost estimation are as given in **Table 4.2.4**.

Table 4.2.4 Unit Price of Major Materials and Workers (1/2)

CODE	Title	Spec.	Unit	Local (US$)
Worker				
R01	Supervisor		day	23.00
R02	Bridge Worker		day	11.00
R05	Rigger		day	9.50
R06	Labor		day	7.20
R07	Carpenter		day	11.20
R08	Steel Worker		day	10.50
R09	Welder		day	11.50
R10	Painter		day	9.50
R11	Traffic Controller		day	8.50
R12	Simple Labor		day	4.80
R13	Equipment Operator		day	19.00
Aggregate				
B01	Rubble	500~800mm	m^3	5.80
B02	Cobble	200~400mm	m^3	5.80
B03	Crushed Stone	0~50mm	m^3	7.30
B04	Fine Aggregate		m^3	1.80
B05	Coarse Aggregate	5~40mm	m^3	10.00
B06	A/C course Aggregate	0~20mm	m^3	11.70
B07	Filler for A/C		m^3	6.50
B08	Sub-Base Material	C-30	m^3	8.90
B11	Base Course Material	M-40	m^3	9.80
B12	Laterite		m^3	1.60
B13	A/C(Asphalt Concrete)		t	57.60
Construction Equipment				
M03	Backhoe	Bucket 0.8m^3	day	143.00
M06	Bulldozer	21ton	day	170.00
M07	Road roller	10~12ton	day	108.00
M08	Motor Grader	L=3.1m	day	161.00
M09	Tire Roller	8~10ton	day	107.00
M11	Vibro-Roller	3~5ton	day	91.00
M12	Dump Truck	10ton	day	95.00
M17	Truck Crane	40t	day	223.00
M18	Crawler Crane	40t	day	234.00
M19	Trailer	20t	day	163.00
M22	Road Sprinkler	6m^3	day	69.00
M23	Asphalt Finisher	2.4~4.5m	day	288.00
M27	Power Generator	50KVA	day	48.00
M28	Power Generator	100KVA	day	60.00
M36	Pile Driver		day	433.00
M39	Concrete Mixer	0.5m^3	day	60.00
M40	Portable Concrete Mixer	5m^3	day	133.00
Steel Material				
S01	H-Steel		ton	760.00
S02	I-Steel		ton	760.00
S05	Steel Panel t=9mm		ton	630.00
S06	Steel Panel t=12mm		ton	640.00
S09	Round Steel Bar		ton	655.00
S10	Deformed Steel Bar	D10~D32	ton	610.00
S13	PC Tendon		ton	1,050.00

Table 4.2.4 Unit Price of Major Materials and Workers (2/2)

CODE	Title	Spec.	Unit	Local (US$)
C02	Cement		ton	72.00
C03	Ready Mixed Concrete	18N/mm^2	m^3	48.00
C04	Ready Mixed Concrete	21N/mm^2	m^3	51.08
C05	Ready Mixed Concrete	24N/mm^2	m^3	52.86
C06	Ready Mixed Concrete	30N/mm^2	m^3	54.64
C07	Ready Mixed Concrete	40N/mm^2	m^3	62.50
Worker				
E01	Civil Engineer	20 years	month	1,595.00
E02	Civil Engineer	10 years	month	920.00
E03	Civil Engineer	5 years	month	570.00
E04	Surveyor	10 years	month	920.00
E05	Surveyor's assistant		month	388.00
E06	Power Engineer	10 years	month	920.00
E07	Power Engineer's Assistant		month	570.00
E08	Chief Auditor	10 years	month	820.00
E09	Chief Clark	10 years	month	618.00
E10	Typist		month	313.00
E11	Driver		month	288.00
E12	Security Guard		month	200.00
Fuel				
F01	Diesel		L	0.790
F02	Gasoline		L	1.000
F03	Prime Cost	CSS-1	ton	287.00
F04	Tack Coat	MC70	ton	355.00
F05	Straight Asphalt	Grade 60/70	ton	277.00
Others				
K01	PC Concrete Pile	400*400, 6m	m	86.00
K02	Concrete Pile	400*400、10.9m	No.	970.00
K03	Bailey Bridge		Month	4,800.00
K05	Wooden Peg	φ150, L=1500	No.	2.40
K06	Wooden Peg	φ150, L=2000	No.	3.20
Construction Equipment（RCC）				
RC01	Backhoe (RCC)	0.6m^3	Day	195.00
RC02	Vibro-Roller(RCC)		Day	27.00
RC03	Motor Grader (RCC)	3.1m	Day	164.00
RC04	Road Roller (RCC)	10～12t	Day	111.00
RC05	Truck Crane 2.9t (RCC)		Day	68.00
RC06	Crawler Crane (RCC)		Day	460.00

Ref. RCC “the Road Construction Center”

Unit costs of work items used for the construction cost estimation are given in **Table 4.2.5**.

Table 4.2.5 Unit Costs of Work Items

Work Item		Unit	Unit Price (US$)
Earth Work			
	Stripping	m^2	0.21
	Removal of top soil	m^3	1.92
	Embankment	m^3	2.57
	Sub-Grade	m^3	2.76
	Shoulder Filling	m^3	3.82
	Shoulder Preparation	m^2	0.94
	Sodding	m^2	1.67
Slope Protection			
	Gabion Mat	m	40.60
	Wet Masonry	m^2	58.28
Pavement			
	Sub-Base (t=16cm)	m^2	2.81
	Base (t=15cm)	m^2	4.31
	Binder (t=5cm)	m^2	7.92
	Surface (t=4cm)	m^2	7.17
Bridge Structure			
	Precast RC Pile (400x400mm)	m	103.11
	Bored Pile (φ=1,000mm),CIP Pile	m	152.40
	Leveling Concrete (18N/mm)	m^3	52.21
	Rebar	ton	707.00
	Form Work	m^2	8.63
	Concrete (24N/mm2)	m^3	55.63
	PC Girder Casting	m	388.28
	PC Girder Installation	m	118.81
	Shoe	Set	510.91
	Expansion Joint	m	579.57
	Bridge Plate	No.	280.00
Drainage			
	Surface Drainage	Set	183.00
	Pipe Installation φ＝1,000mm	No.	46.00
Road Facilities			
	Guide Post	No.	17.81
	Guide Rail	m	56.82
	Road Marking (Yellow Center Line)	m^2	10.00
	White Side Line	m^2	9.50
	Cross Line	m^2	9.50
	Traffic Signal	No.	195.00
	Hamper	m^2	7.34

4.3 Maintenance Plan

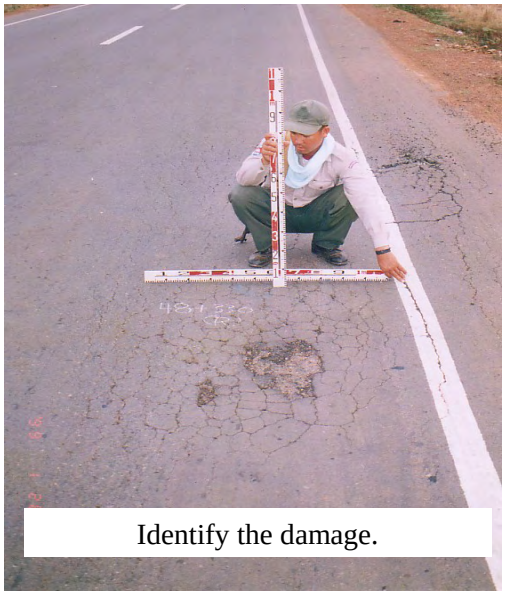
4.3.1 Preparation of Maintenance Plan

NR.57 is 104 km long from the Rong Vong, Moul Preah intersection of NR.5 to the Thailand border. The jurisdiction of 66 km long belongs to the DPWT in Battambang and the remaining 38 km long belongs to the DPWT in Pailin. The project road is being maintained in accordance with the following classifications:

(1) Routine maintenance

Based on the result of the meeting held between the MPWT and MEF in 2006, this activity will be performed by Force Account. The details of the activity are as follows:

1) Preparation of the road inventory based on a daily patrol
2) Cleaning of road surface, side ditches, culverts, patching pot-holes, sealing of cracks
3) Trimming and cutting trees/grass and minor repair other than the ones carried out during periodic maintenance



Identify the damage.

Trim the branch of tree.

Figure 4.3.1 Routine Maintenance Activity

(2) Periodic maintenance

This activity will be carried out on a Contract-Out basis. The details of the activity are as follows:

1) Replacement of damaged culverts

2) Patching and overlay of the defective road surface requiring a medium/large scale repair

Figure 4.3.2 Circulation of Periodical Maintenance Activity.

(3) Typical organization of maintenance activity

In comparison the maintenance capability of the DPWT in Pailin is less than that of the DPWT in Battambang**.** However, under the present organization, the DPWT in Battambang is obliged to support the DPWT in Pailin in terms of personnel and equipment. Present organization charts of both DPWTs are shown in **Figure 4.3.3**.

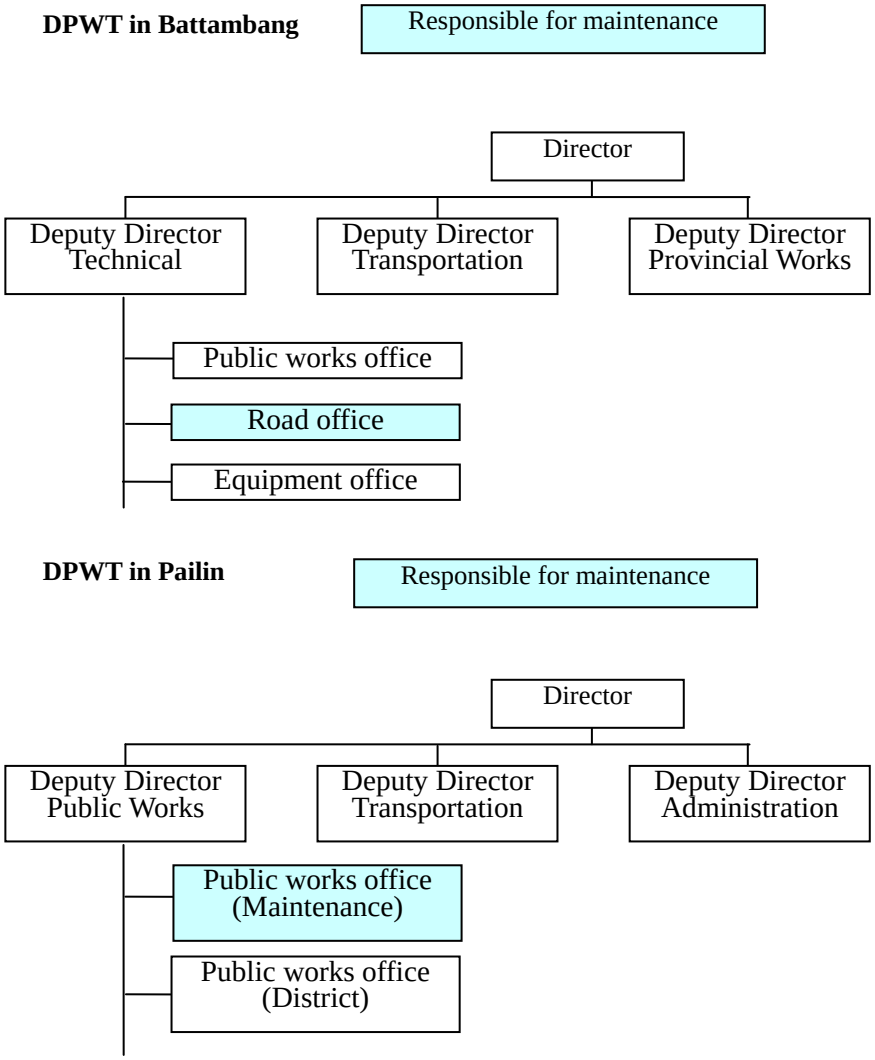


Figure 4.3.3 Organization Charts of the DPWTs Concerned

4.3.2 Maintenance Operation Plan

(1) Organization and Operation

As road authorities where this project is located, the MPWTs and DPWTs of Battambang and Pailin will undertake the maintenance of the proposed improvement of national road No.57.

These provinces belong to the west region where the study team presented the proposal requesting considerations to perform training, personnel exchange and equipment supply. The DPWT in Battambang is the group leader in the region. The DPWT in Battambang will maintain NR.57 in good road condition and, at the same time, support the DPWT in Pailin in terms of personnel and equipment.

(a) Implementation and Arrangement of the Maintenance Activities

A critical issue is the upgrade the service capacity of the maintenance system, to cope with the demand of the country's economic development. Without appropriate maintenance works the

road is deterioring with increasing speed. Under such conditions and with limited technical and financial resources, the road authorities still have to take full responsibility for maintaining this asset.

Demarcation of maintenance works between the MPWT and the DPWT is shown in **Table 4.3.1**.

Table 4.3.1 Demarcation of Maintenance Management

Activity	MPWT	DPWT
Daily and Monthly Patrol	1. Evaluation of monthly inspection record by Public Works Research Center (PWRC).	1. Patrol to be conducted to check road condition, structure, facilities, obstacles, illegal occupancy and so on. 2. Visual inspection and road serviceability check are conducted. 3. Inspection sheet to be recorded.
Routine Maintenance Works	1. Assessment of DPWT's budget request by DOR. 2. Preparation of project estimation by DOR. 3. Bidding and preparation of contract, force account or contract-out to be determined by a bidding committee. 4. Supervising of project by DOR. 5. Inspection of project by DOR.	1. Preparation of routine maintenance plan based on daily and monthly patrol record for the request of budget to MPWT. 2. Implementation or supervising of project. 3. Preparation of routine progress & final report
Periodic Maintenance Works	1. Preparation of project estimations, bill of quantities, designs & spec. by PWRC. 2. Bidding and preparation of contract by a bidding committee. 3. Supervising and reporting of project by PWRC. 4. Hand over of management to DOR.	1. Inspection sheet shall be recorded conducting regular patrol. 2. Transfer of management from PWRC.
Emergency Works	1. Conducting inspection by PWRC & DPWT 2. Preparation of project estimations, designs & spec. by PWRC. 3. Bidding and preparation of contract by PWRC 4. Supervision and reporting of project by PWRC. 5. Hand over of management to DOR.	1. Conducting inspection by PWRC & DPWT 2. Transfer of management from PWRC.

(b) Operation of Maintenance Works

The operation of the maintenance program will follow the Maintenance Guideline and project management cycle so that maintenance of NR 57 will contribute greatly in strengthening the present efforts of the government to implement the Road Maintenance Policy at a provincial level.

The proposed organization for routine maintenance is shown in **Figure 4.3.4**.

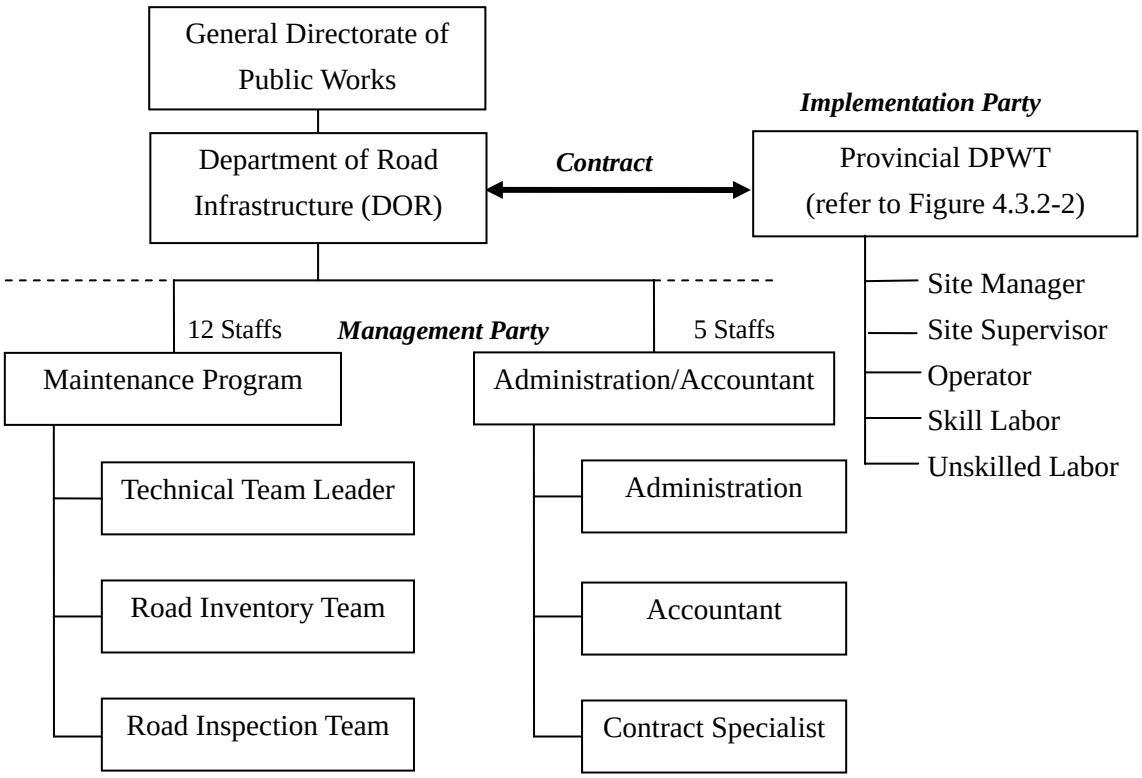


Figure 4.3.4 Routine Maintenance Management in Short Term

(2) Financial Program

(a) Required Maintenance Cost

Total maintenance cost for NR.57 is estimated to be about $0.131million per annum, as shown in **Table 4.3.2,** by applying a unit maintenance cost per km, which consists of a routine patrol cost, cleaning-up cost and patching work to the subject length of the NR.57.

Table 4.3.2 Estimation of Annual Maintenance Cost for NR. 57

NR.57	Dist.(km)	Unit Maintenance Cost ($/km)		Maintenance Cost ($ mil/year)		
		Patrol	Patching	Patrol	Patching	Total
Battambang - Pailin	104.0	32	866	0.0401	0.0904	0.131

Frequency of Patrol: 1 time a month
Frequency of Patching : 1 time a year

(b) Financial Plan

With regard to the future financing plan for urgent projects, there are two alternatives as described below:

Alt. 1; Financing by Road Maintenance Added Tax

On the basis of the expected amount of gasoline the expected revenue from added tax or road maintenance special fund in 2010 is forecasted to be about $30 million, of which about $22.0 million is scheduled for the maintenance of the existing roads in the nation. The required maintenance cost of $0.13 million is far below the $8 million balance between the expected revenue and expenditure of the fund.

Alt. 2; Financing by charging a maintenance charge on road users

This is a method to cater for the maintenance cost by charging a fee on the road users. This type of charge has already been introduced on the sections on NR.4 nearby Phnom Penh where a certain amount of fee is being charged on vehicles passing on the route.

If the level of charge is equivalent to that presently charged on NR.4 a simple analysis suggests that the fund achieved from fees levied by this method would be about $ 0.154 million in 2010, which is a sufficient amount of revenue to cover the maintenance cost; refer **Table 4.3.3 and Table 4.3.4**.

It can be concluded that one of these methods can be used to procure road maintenance funds from road users, therefore reducing the burden of extra expenses on the MPWT.

Table 4.3.3 Comparison of Maintenance Expenditure and Revenue from Road-user Charge Project NR.57

Year 2010	Required Maintenance Cost ($ mil./year)	Expected Revenue from Road User Charge ($ mil./year)
Cost & Revenue	0.131	0.154

Table 4.3.4 Expected Revenue from the Project

		Total Vehicle		Vehicle with 4 Wheel		Revenue from M/C($ Per day)		Revenue from 4 – wheel($ Per day)		Expected Revenue ($ mil. Per year)		Expected Revenue ($ mil. /year)
Project	Section	YR 2005	YR 2010	YR 2005	YR 2010	YR 2005	YR 2010	YR 2005	YR 2010	YR 2005	YR 2010	YR 2010
NR57	FS1	1,733	2,163	520	649							
	FS2	476	543	143	163							
	FS3	1,052	1,363	316	409							
	FS4	569	834	171	250							
NR57 Average		958	1,226	287	368	121	156	208	267	0.120	0.154	0.154

Ref. Road User Charge (1) M/C:$0.181/one time, (2) 4 Wheel and over :$0.725/one time M/C percentage 70% is assumed.
Assumption has been made on the above result as follow:
1. Charge on M/C is 1/4 of 4 wheel vehicles

(3) Allocation Plan

(a) Routine Maintenance

In accordance with the demarcation agreement between the MPWT and MEF, the typical allocation of labor and equipment required for routine maintenance is as follows:

Table 4.3.5 Allocation Plan for Routine Maintenance

Road Patrol and Inventory		
Classification	Number	Remarks
Engineer	1	
Skilled Worker	2	
Transportation	1	Pick up

Trimming & Cutting Trees and Grass		
Classification	Number	Remarks
Site Manager	1	
Skilled Worker	3	
Flagman	2	
Grass Cutter	3	Engine Type
Dump Truck	2	4t

Patching Pothole		
Classification	Number	Remarks
Site Manager	1	
Site Supervisor	1	
Skilled Worker	15	
Flagman	2	
Air Compressor	1	5.0m^3/min.
Vibration Roller	2	3-4t, Tandem
Vibration Roller	2	0.8-1.0t, Hand Guide
Dump Truck	1	4t
Dump Truck	1	2t
Concrete Cutter	1	Dia.25cm
Tired Backhoe	1	0.3m^3
Asphalt Sprayer	1	25l./min.
Truck with crane	1	175PS

(b) Periodic Maintenance

The typical allocation of labor and equipment expected from contractors is as follows:

Table 4.3.6 Allocation Plan for Periodical Maintenance

Patching Pothole		
Classification	Number	Remarks
Site Manager	1	
Site Supervisor	1	
Skilled Worker	20	
Flagman	2	
Wheel Roller	1	1.2m^3
Macadam Roller	1	6t
Rammer	1	80kg
Tandem Roller	1	1t
Dump truck	2	10t
Concrete Cutter	1	Dia.25cm
Tired Backhoe	1	0.4m^3
Asphalt Distributor	1	6m3
Truck with crane	1	175PS
Trailer	1	

Asphalt Concrete Overlay		
Classification	Number	Remarks
Site Manager	1	
Site Supervisor	1	
Skilled Worker	15	
Flagman	2	
Macadam Roller	1	6t
Tandem Roller	1	1t
Pneumatic Roller	3-5	8-20t
Dump Truck	3-5	10t
Tractor Bloomer	1	
Asphalt Finisher	1	
Asphalt Distributor	1	6m^3
Water Tank	1	6m^3
Trailer	1	

(c) Frequency

The pavement structure of NR.57 is expected to be designed with asphalt concrete and the following maintenance frequency is recommended:

Table 4.3.7 Frequency of Maintenance

Activity	Frequency	Remarks
Road Patrol	At least once a month	
Inventory	Once a year	Information shall be transmitted to Technical Research Center
Routine Maintenance	Based on Road Patrol Result	
Periodic Maintenance	Based on Inventory Result	Standard life of asphalt concrete is 10 years and medium scale of damage is considered to occur five years after completion of the improvement

4.4 Implementation Plan

4.4.1 Project Components

The construction of NR.57 consists of a total of 101 km of road component including a total of 2470m of culverts and a bridge component of 12 bridges with a total length of 340m as detailed previously in **Table 4.1.1**.

4.4.2 Procurement Source

The material procurement sources for bridges and pavement are given in **Table 4.4.1**.

Table 4.4.1 Material Procurement Sources

Material Source	Source Country		Sources
	Cambodia	Others	
Structural Materials			
Crushed stone (foundation, sub-base)	○		Domestically
Cement	○		Domestically
Sand	○		Domestically
Crushed stone (Aggregate)	○		Domestically
Rebar：D 6 ～D32	○		Domestically
Admixture for Concrete		○	Thailand
Pre-stressing tendon		○	Thailand
Shoe		○	Thailand
Non-shrink cement	○		Domestically
Pre-stressing device for PC		○	Thailand
Crushed stone for masonry	○		Domestically
Steel Concrete Tube	○		Domestically
Bitumen	○		Phnom Penh
Gabion		○	Thailand,
Corner Stone	○		Domestically
Concrete Peg	○		Domestically
Wooden Peg	○		Domestically
Steel sheet pile	○		Domestically
Sealing strip	○		Domestically
Timber	○		Domestically
Expansion Joint		○	Thailand
Guard Rail		○	Thailand

Table 4.4.2 Sources of Major Construction Equipment

Equipment	Spec.	Phnom Penh	RCC	Third Country
Backhoe	0.2m^2	○		
Backhoe	0.6m^2	○	○	
Bulldozer	21t	○	○	
Bulldozer	15t	○		
Motor Grader	3.1m	○	○	
Road roller	8t	○	○	
Tyreroller	8-20t	○		
Concrete Mixer	0.1m^3	○		
Concrete Mixer	0.5m^3	○		
Concrete Plant	Weigh Mix			○
Road Sprinkler	4.kl	○	○	
Dumptruck	6t		○	
Dumptruck	10t	○		
Truckcrane	11t	○		
Crawler Crane	40t	○		
Crawler Crane	50t		○	
Crawler Crane	100t			○
Crawler Crane	150t			○
Diesel Hammer	2.5t	○		
Vibro-Hammer	40kw			○
Reverse Driller				○
Water Tank	50m^3			○
Girder Erection Facilities				○
Power Generator	250KVA	○		
Power Generator	100KVA	○		
Power Generator	45KVA			
Power Generator	15KVA	○		
Submersible Pump	150mm			○
Submersible Pump	100mm			○
Compressor	5m^3	○		
Truck	2t	○		
Truck	4t	○		

Large cranes, reverse circulation drills, vibration hammers etc. are not locally available. If required, these can be procured from Thailand. The procurement plan for major equipment is shown in the **Table 4.4.2**.

4.4.3 Implementation Schedule

The schedule below has been prepared with the following considerations:

(1) Preparation Work

Clearance of landmines and UXOs is essential before the commencement of the detailed design of Stage-2. Four (4) months is considered necessary to carry out the work in parallel to the

detailed design of Stage-1.

(2) Detailed design

The main scope of works for the detailed design includes the review of the preliminary design including preliminary design drawings, construction planning, procurement planning and cost estimation. The period required for the detailed design is estimated to be 6 months.

(3) Preparation of Tender Documents

Main tasks scheduled from public announcement to the establishment of the construction contract are as follows:

- Preparation of tender documents
- Public announcement
- Pre-qualification of bidders
- Tendering
- Tender evaluation
- Promotion of contract establishment

The period required for the above is estimated to be 3 months.

(4) Construction supervision

The followings are the major items:

- Collation and approval of survey data and construction planning
- Quality control
- Schedule control
- Progress quantity check
- Safety management
- Handover

It is estimated that a total time of 5 years will be required for both the stages; 2 years for Stage-1 and 3 years for Stage-2.

(5) Construction Equipment

All construction equipment, which is not already available, will have to be imported as there is no local leasing company. For some equipment such as backhoe, bulldozer and tire roller, large size crane, reverse circulation drill and vibration-hammer, it is believed that there is enough in Cambodia at present to cope with the demand. If required equipment may be sourced from Thailand.

(6) Construction Schedule

The construction schedule has been prepared based upon the quantities involved in the major construction work and construction method. The quantities are as shown in **Table 4.4.3**.

Table 4.4.3 Quantities of Major Construction Work Items

Title of Work		Major Item	Unit	Quantity
Road (101 km)				
	Earth Work	Embankment	m^3	313,000
		Sub-Grade	m^3	313,000
	Pavement	Sub-Base	m^2	1,393,600
		Base Course	m^2	1,372,800
		Binder	m^2	1,369,000
		Surface Course	m^2	780,000
Bridge(12 Bridge)				
	Total Length of 12 bridges		m	340.2
Culvert (130 Culverts) 1 Cell			m	2,470

(7) Implementation Schedule

The Project Implementation Schedule has been prepared based on the above considerations and is as shown in **Figure 4.4.1**.

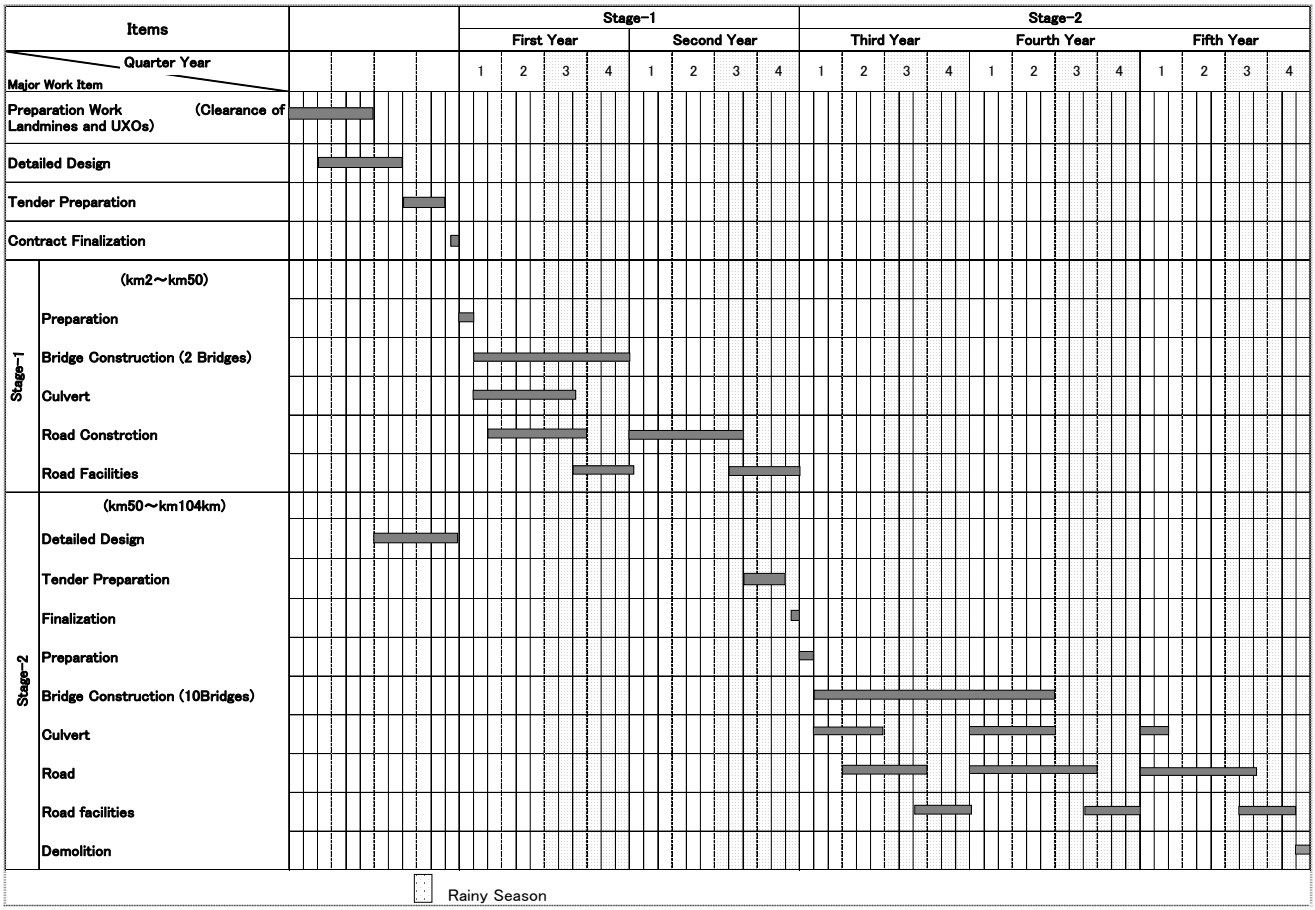


Figure 4.4.1 Project Implementation Schedule

CHAPTER A-5 PROJECT EVALUATION

5.1 Study Approach

The purpose of this chapter is to evaluate the project for National Road No.57 from the traffic, economic, financial, and regional development points of view.

In order to achieve the purpose of the study, the following steps are carried out:

Step 1: Forecast traffic demand "with" and "without" the project,

Step 2: Estimation of economic benefits based on the traffic demand on the project road and unit vehicle operating costs,

Step 3: Estimation of economic costs based on the estimated financial costs mentioned in the previous section,

Step 4: Economic evaluation using economic benefits and economic costs

Step 5: Sensitivity analysis by varying factors of influence on the economic indicators

Step 6: Evaluation from a financial viewpoint

Step 7: Identification of impacts on regional development

Step 8: Overall evaluation

Figure 5.1.1 shows the procedure for the project evaluation.

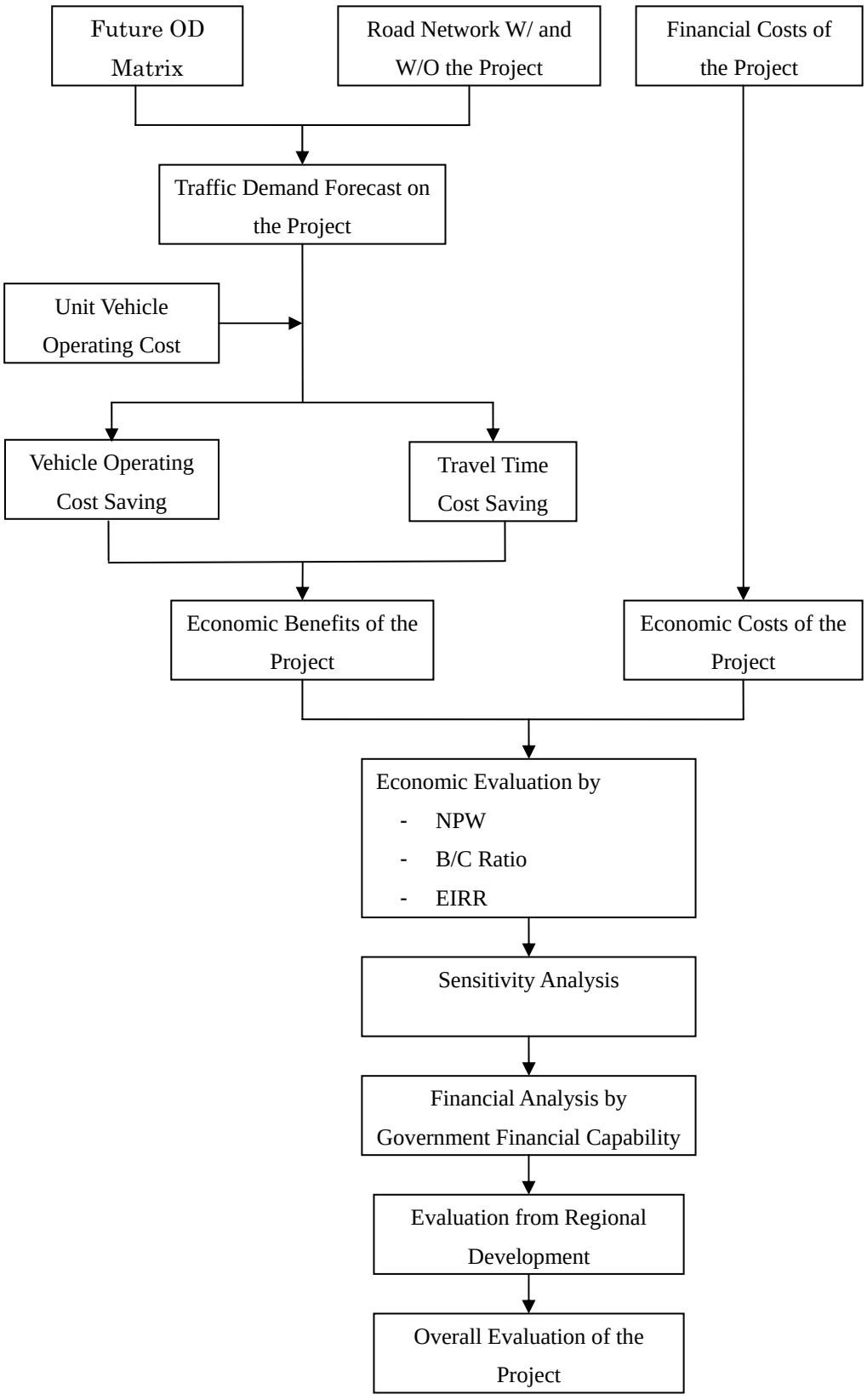


Figure 5.1.1 Procedure for Project Evaluation

5.2 Traffic Demand Forecast

In the Master Plan Study there was a forecast for the future traffic demand, in a form of an OD matrix, for the years 2010, 2015 and 2020. In this section, there is a forecast of traffic demand on National Road No 57 using a traffic assignment method to the road network integrated with National Road No.57. The forecast of traffic volume on NR.57 for the scenario "with" the project is summarized in **Table 5.2.1**.

Table 5.2.1 Assigned Traffic Volume on NR.57

Vehicle/Day

Section	Year	MC	LV	HV	Total
Section 1 Battambang - Potanak Mondol	2005	2,360	798	344	3,502
	2010	2,540	1,032	496	4,068
	2015	2,848	1,269	613	4,730
	2020	3,128	1,553	738	5,419
Section 2 Potanak Mondol – Pailin Town	2005	404	301	74	779
	2010	408	350	91	849
	2015	416	404	103	923
	2020	476	491	123	1,090
Section 3 Pailin Town - Intersecting Point of PR.160	2005	1,516	464	31	2,011
	2010	1,984	600	39	2,623
	2015	2,792	821	51	3,664
	2020	4,060	1,055	69	5,184
Section 4 Pailin Town - Thailand Boarder)	2005	1,004	230	10	1,244
	2010	1,476	338	14	1,828
	2015	2,276	522	22	2,820
	2020	3,200	700	34	3,934

Note: In 2011, all improvement project will be opened to the traffic

The estimated vehicle kilometers and vehicle hours on NR.57 are shown in **Tables 5.2.2** and **5.2.3**, respectively. These tables are based on the benefit calculation.

Table 5.2.2 Total Vehicle Kilometers with and without on NR 57 Improvement Project

Unit: PCU Km / day

	2005	2010	2015	2020
Section 1 (Battambang – Potanak Mondol)	63,255	78,950	94,645	112,165
Section 2 (Potanak Mondol – Pailin Town)	22,372	25,521	28,717	34,451
Section 3 (Pailin Town- Intersecting Point of PR.160)	6,838	8,860	12,201	14,079
Section 4 (Pailin Town – Thailand Boarder)	8,059	11,813	18,243	25,169
Total	100,524	125,143	153,805	185,864

Table 5.2.3 (1) Total Vehicle Hours in NR.57 with and without NR.57 Improvement Project During Dry Season

Unit: PCU Hour/day

	W/O or W/	2005	2010	2015	2020
Section 1 Battambang - Potanak Mondol	W/O	2,108	2,632	3,155	3,739
	W/	1,054	1,316	1,577	1,869
	W/O-W/	1,054	1,316	1,577	1,869
Section 2 Potanak Mondol – Pailin Town	W/O	746	851	957	1,148
	W/	373	425	479	574
	W/O-W/	373	425	479	574
Section 3 Pailin Town - Intersecting Point of PR.160	W/O	228	295	407	469
	W/	137	177	244	282
	W/O-W/	91	118	163	188
Section 4: Pailin Town – Thailand Boarder)	W/O	269	394	608	839
	W/	134	197	304	419
	W/O-W/	134	197	304	419
Total	W/O	3,351	4,171	5,127	6,195
	W/	1,698	2,115	2,604	3,145
	W/O-W/	1,653	2,056	2,523	3,051

Table 5.2.3 (2) Total Vehicle Hours in NR.57 with and without NR.57 Improvement Project During Rainy Season

Unit: PCU Hour / day

	W/O or W/	2005	2010	2015	2020
Section 1 Battambang - Potanak Mondol	W/O	3,163	3,947	4,732	5,608
	W/	1,054	1,316	1,577	1,869
	W/O-W/	2,108	2,632	3,155	3,739
Section 2 Potanak Mondol – Pailin Town	W/O	1,119	1,276	1,436	1,723
	W/	373	425	479	574
	W/O-W/	746	851	957	1,148
Section 3 Pailin Town - Intersecting Point of PR.160	W/O	342	443	610	704
	W/	114	148	203	235
	W/O-W/	228	295	407	469
Section 4: Pailin Town – Thailand Boarder)	W/O	403	591	912	1,258
	W/	134	197	304	419
	W/O-W/	269	394	608	839
Total	W/O	5,026	6,257	7,690	9,293
	W/	1,675	2,086	2,563	3,098
	W/O-W/	3,351	4,171	5,127	6,195

5.3 Economic Evaluation

5.3.1 Assumptions for the Economic Evaluation

(1) Evaluation Period

The evaluation period is assumed to be 25 years from 2011 to 2035 taking into account the service life of the National Road No.57 Project.

(2) Implementation Schedule

The implementation schedule is assumed as follows:

- 2007 Detailed design
- 2007 Land acquisition
- 2008 - 2010 Construction
- 2011 Open to the public

(3) "With" and "Without" the Project

Economic benefits are calculated as differences between "With" and "Without" the Project. For the calculation of economic benefits, the situation of "Without" the Project is defined as "Do Nothing" on the existing NR.57, while "With" the Project is defined as the NR.57 with the proposed improvement project implemented.

(4) Economic Benefits

Economic benefits in the economic analysis are assumed to be the following two(2): a) Saving in vehicle operating cost (SVOC) and b) Saving in travel time cost (STTC). In the benefit calculation, special considerations on SVOC and STTC during dry and rainy seasons are taken into account. The economic benefit can be calculated from the following formula:

$$AB = ((SVOC^{Dry} + STTC^{Dry}) + (SVOC^{Rainy} + STTC^{Rainy}))$$

Where: AB: Annual benefits
$SVOC^{Dry}$: Saving in vehicle operating cost during dry season
$STTC^{Dry}$: Saving in travel time cost during dry season
$SVOC^{Rainy}$: Saving in vehicle operating cost during rainy season
$STTC^{Rainy}$: Saving in travel time cost during rainy season

These SVOC and STTC benefits are computed from total vehicle kilometers and hour time units. Yearly benefits during the evaluation period are calculated using interpolated and extrapolated methods for the projected years, 2010, 2015 and 2020.

(5) Economic Costs

For the economic analysis, costs in terms of financial prices are converted to be in terms of economic prices.

In this economic analysis, all the costs are classified into items of a) trade goods, b) non-trade goods and c) transfer items. It is assumed that trade goods are equivalent to the foreign currency portion, and the aggregation of non-trade goods is the local currency portion. Transfer items are the portions for taxes.

The economic prices for all non-trade goods are obtained by applying the standard conversion factor (SCF).

The SCF is estimated to be 0.893 according to the statistical data regarding foreign trade and government revenues in Cambodia,.

(6) Price Indices and Project Life

For the economic and financial evaluation, the following assumptions are made:

- Pricing date: As of March 2006
- Foreign Exchange Rate 1US Dollar = 4,000 Riel

(7) Economic Indicators

The economic evaluation method principally employed is the benefit cost analysis. The economic indicators used in this study are as follows:

- Net Present Value (NPV)
- Benefit Cost Ratio, (BCR), and
- Economic Internal Rate of Return (EIRR)

5.3.2 Estimation of Benefit

(1) Basic Vehicle Operating Cost

The basic vehicle operating cost (BVOC) as shown in **Table 5.3.1** was estimated in the master plan stage. In the pre-feasibility study, the same BVOC is used for the benefit calculation.

Table 5.3.1 Basic Vehicle Operating Cost (Excluding Tax)

Type	Item	Motor Cycle	Car	Pick-up	Mini Bus	Large Bus	Light Truck	Medium Truck	Heavy Truck
Distance related VOC	Fuel cost	145.3	2,543.5	3,052.1	3,270.2	11,973.8	3,877.2	14,710.6	14,710.6
	Lubricant cost	8.0	19.9	29.9	39.8	348.3	123.8	359.4	359.4
	Tire cost	6.9	63.1	75.7	97.8	1006.1	174.7	706.4	2060.2
	Maintenance cost	6.7	136.4	131.5	296.6	623.5	199.6	306.1	579.6
	Depreciation cost	0.4	8.5	9.8	18.3	38.5	10.3	16.3	30.8
	S-total	167.3	2,771.3	3,299.0	3,722.7	13,990.2	4,385.6	16,098.8	17,740.7
	Overhead cost	0.0	0.0	329.9	372.3	1,399.0	438.6	1,609.9	1,774.1
	Total	167.3	2,771.3	3,628.9	4,095.0	15,389.2	4,824.2	17,708.7	19,514.7
Time related VOC	Crew cost	75.0	275.0	412.5	1,344.0	2,170.0	1,488.0	2,542.0	2,542.0
	Maintenance cost	2.3	5.1	5.1	18.1	21.9	18.1	21.9	25.6
	Insurance cost	20.0	493.1	475.4	296.6	623.5	199.6	368.8	698.4
	Depreciation cost	0.2	4.6	5.3	9.9	20.7	5.5	8.8	16.6
	S-total	97.6	777.7	898.2	1,668.6	2,836.1	1,711.2	2,941.4	3,282.5
	Overhead cost	0.0	0.0	89.8	166.9	283.6	171.1	294.1	328.3
	Total	97.6	777.7	988.0	1,835.4	3,119.8	1,882.3	3,235.6	3,610.8
Total		264.9	3,549.0	4,616.9	5,930.4	18,509.0	6,706.5	20,944.3	23,125.5
VOC /1000 km		26.5	142.0	153.9	197.7	264.4	167.7	243.5	268.9

(2) "With" and "Without" Improvement

Using the basic VOC set up above, the unit VOCs in cases of "with" and "without" improvement are estimated in **Table 5.3.2**.

Table 5.3.2 VOC on NR.57 in cases of "With" and "Without" Improvement

US $/1,000 km

	Laterite Road	
	Dry Season	Rainy Season
W/O Improvement	192.4	217.6
	Asphalt Concrete (AC)	
W/ Improvement	155.5	

Table 5.3.3 Travel Speed on NR.57 in cases of "With" and "Without" Improvement

	Laterite Road	
	Dry Season	Rainy Season
W/O Improvement	25.0 km/h	15.0 km/h
	Asphalt Concrete (AC)	
W/ Improvement	60.0 km/h	

Table 5.3.4 Forecast of Time Value per Vehicle, by Vehicle Type

US $/hour

	2005	2010	2015	2020
Motor Cycle	0.321	0.388	0.491	0.648
LV	2.394	2.897	3.663	4.836
Bus	3.166	3.831	4.844	6.395

(3) Estimation of Benefits

The saving in vehicle operating costs and travel time cost were estimated and are shown in **Table 5.3.5.**

Table 5.3.5 Estimation of Annual Benefits

Unit: US $ 1000/Year

Year	Saving in VOC	Saving in TTC	Total Saving
2010	2,110	2,359	4,470
2015	2,594	3,667	6,261
2020	3,134	5,850	8,985

5.3.3 Estimation of Economic Costs

(1) Economic Costs

The project cost, which was already calculated in the previous chapter, is expressed as the financial costs. It is therefore necessary to convert from financial costs to economic costs. In this study, the economic costs are estimated by deducting from financial costs the government taxes and duties and applying the SCF for non-trade goods. The results of the estimation are shown in **Table 5.3.6**.

Table 5.3.6 Estimation of Economic Costs

Unit: US $ 1000/Year

Description		**Economic Cost**	**Financial Cost**
1	Construction Cost	38,606	43,172
2	Row Acquisition/ Resettlement	309	340
3	Consultancy	3,861	4,317
3-1	Detailed Design	1,544	1,727
3-2	Construction Supervision	2,317	2,590
4	Environmental Monitoring	64	71
	Total	42,840	47,900

(2) Maintenance Cost

The maintenance cost, which consists of routine maintenance and periodic maintenance, was estimated in 4.3.2. The maintenance cost is converted to the economic cost as follows:

Table 5.3.7 Annual Maintenance Cost Estimate

Unit: US $ 1000/Year

	Economic Cost	Financial Cost
Routine maintenance Cost	193	216
Periodic Maintenance Cost	193	216

5.3.4 Economic Evaluation

(1) Cost Benefit Analysis

The economic analysis of the Project is based on the above-mentioned estimates of costs and benefits. **Table 5.3.8** shows the cost-benefit analysis of the NR.57 Improvement Project during the project life period of 25 years and **Table 5.3.8** shows the cost-benefit stream. The results of the economic analysis show that a Net Present Value (NPV) of US $ 9.81 million and B/C Ratio of 1.26 over the 25 year life of the road using a discount rate of 12.0 %, which is designated by the Ministry of Economic and Finance. The Economic Internal Rate of Return (EIRR) was compiled at 14.34 %.

Table 5.3.8 Economic Indications of Cost Benefit Analysis

NPV (US $ '000)	9,814.0
Benefit Cost Ratio (B/C Ratio)	1.26
EIRR (%)	14.34

Notes: 1) Project life is assumed to be 25 years
2) Discount rate is 12 %

(2) Sensitivity Analysis

The sensitivity analysis is conducted under a worse case scenario incorporating increases and/or decreases of the estimation of costs and benefits. **Table 5.3.9** shows the results of the sensitivity analysis.

Table 5.3.9 Sensitivity Analysis regarding Costs and Benefits for NR.57 Improvement Project

		Indicator	Benefits		
			10% down	Base Case	10% up
Costs	10% down	NPV (US '000)	8,617	13,361	18,104
		B/C Ratio	1.25	1.39	1.53
		EIRR (%)	14.3	15.4	16.5
	Base Case	NPV (US '000)	5,071	9814	14,557
		B/C Ratio	1.13	1.26	1.39
		EIRR (%)	13.3	14.3	15.4
	10% up	NPV (US '000)	1,524	6,267	11,011
		B/C Ratio	1.04	1.15	1.27
		EIRR (%)	12.4	13.4	14.3

Note: The life of the project is assumed to be 25 years

(3) Summary of Economic Analysis

Since the economic indicators in most cases are over the cut-off level, which is considered to be 12 % of EIRR in Cambodia, the implementation of the National Road No. 57 Improvement Project is justified from a national economic point of view.

Table 5.3.10 Cost- Benefit Stream for NR.57 Improvement Project

SQ	Year	Construction	Maintenance	Cost Total	Benefit	Net Benefit	Discount Cash Flow(at 12%)		
							Cost	Benefit	Net Benefit
1	2007	4,278		4,277.6		-4,277.6	4,277.6	0.0	-4,277.6
2	2008	12,833		12,832.8		-12,832.8	11,457.9	0.0	-11,457.9
3	2009	17,110		17,110.4		-17,110.4	13,640.3	0.0	-13,640.3
4	2010	8,555		8,555.2		-8,555.2	6,089.4	0.0	-6,089.4
5	2011	0.0	386.0	386.0	4,793.2	4,407.2	245.3	3,046.1	2,800.8
6	2012	0	386.0	386.0	5,139.8	4,753.8	219.0	2,916.4	2,697.4
7	2013	0	386.0	386.0	5,511.4	5,125.4	195.6	2,792.3	2,596.7
8	2014	0	386.0	386.0	5,909.9	5,523.9	174.6	2,673.4	2,498.8
9	2015	0	386.0	386.0	6,337.3	5,951.3	155.9	2,559.5	2,403.6
10	2016	0	386.0	386.0	6,795.5	6,409.5	139.2	2,450.5	2,311.3
11	2017	0	386.0	386.0	7,286.9	6,900.9	124.3	2,346.2	2,221.9
12	2018	0	386.0	386.0	7,813.8	7,427.8	111.0	2,246.3	2,135.3
13	2019	0	386.0	386.0	8,378.9	7,992.9	99.1	2,150.6	2,051.6
14	2020	0	386.0	386.0	8,984.7	8,598.7	88.5	2,059.1	1,970.6
15	2021	0	386.0	386.0	9,634.4	9,248.4	79.0	1,971.4	1,892.4
16	2022	0	386.0	386.0	10,331.1	9,945.1	70.5	1,887.4	1,816.9
17	2023	0	386.0	386.0	11,078.1	10,692.1	63.0	1,807.1	1,744.1
18	2024	0	386.0	386.0	11,879.2	11,493.2	56.2	1,730.1	1,673.9
19	2025	0	386.0	386.0	12,738.1	12,352.1	50.2	1,656.5	1,606.3
20	2026	0	386.0	386.0	13,659.2	13,273.2	44.8	1,585.9	1,541.1
21	2027	0	386.0	386.0	14,646.9	14,260.9	40.0	1,518.4	1,478.4
22	2028	0	386.0	386.0	15,706.0	15,320.0	35.7	1,453.7	1,418.0
23	2029	0	386.0	386.0	16,841.7	16,455.7	31.9	1,391.8	1,359.9
24	2030	0	386.0	386.0	18,059.5	17,673.5	28.5	1,332.6	1,304.1
25	2031	0	386.0	386.0	19,365.4	18,979.4	25.4	1,275.8	1,250.4
26	2032	0	386.0	386.0	20,765.7	20,379.7	22.7	1,221.5	1,198.8
27	2033	0	386.0	386.0	22,267.3	21,881.3	20.3	1,169.5	1,149.2
28	2034	0	386.0	386.0	23,877.4	23,491.4	18.1	1,119.7	1,101.6
29	2035	0	386.0	386.0	25,604.0	25,218.0	16.2	1,072.0	1,055.9
Total		42,776.0	9,650.0	48,148.4	313,405.7	265,257.3	37,620.1	47,434.0	9,814.0

5.4 Financial Appraisal

In the Master Plan Study, the overall financial analysis of the implementation program for the improvement and rehabilitation projects proposed has been examined. As a result, the implementation program as shown in **Table 5.4.1** of the Master Plan Study was recommended. This project is principally in accordance with the recommended implementation program and there are no problems for the implementation of the project from a financial point of view.

Table 5.4.1 Financial Analysis of the Project

(US Dollar Million)

Description	Short Term (2006-2010)
A.. Fund to be Procured	
(1) International fund	428
(2) Domestic fund	135
Total	563
B. Proposed Implementation Program in M/P	
(1) Improvement / Rehabilitation	403
・ NR.57 Improvement Project	47
(2) Maintenance	157.7
(3) Urgent Rehabilitation Program	(20)
Total	516
C. Amount of Balance	47

5.5 Impacts on Regional Development

(1) Reduction of Transport Cost

Table 5.5.1 shows the transport cost for medium and heavy trucks. Battambang traders exporting agricultural products such as rice to Thailand will receive reductions in transport costs per truck of about 8 dollars during the dry season and 10 dollars during the rainy season. Such reduction in the transport cost will promote a) an increase in export of agricultural products in Pailin and Battambang Provinces, and b) a reduction of consumer prices for consumer's goods.

Table 5.5.1 Transportation Cost by Truck between Battambang and Thailand Border

US $

	Dry Season		Rainy Season	
	Medium Truck	Heavy Truck	Medium Truck	Heavy Truck
W/O Improvement	32.9	36.3	34.9	38.5
W/ Improvement	25.1	27.8	25.1	27.8
W/O – W/ Improvement	7.8	8.5	9.8	10.7

(2) Regional Development

The project will provide a practicable and efficient transport facility within the area influenced by NR.57. As a result the following benefits are expected on the development of the region:

a) Since economic activities within the area influenced by NR.57 will be stimulated, the project will contribute to economic growth of Batambang and Pailin Provinces,
b) Foreign and local investments in the area are expected to increase in the agricultural sector and also the service sector. As a result an increase in household income can be expected.
c) Population in the direct influence area of NR.57 as shown **Table 5.5.2** will receive the benefits such as increased household income and job opportunities.

Table 5.5.2 Future Population in Direct Influence Area of NR.57

Province/District		2005	2010	2015	2020
Battambang	Svay Pao	18,246	20,344	22,582	24,840
	Baran	92,909	103,594	114,989	126,488
	Rattonak Mondol	37,443	41,749	46,341	50,975
	S-Total	148,598	165,687	183,912	202,303
Pailin	Pailin	29,372	36,098	43,642	52,022
Total		177,970	201,785	227,554	254,325

CHAPTER A-6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The Pre-Feasibility Study for NR.57 has shown that this project is technically and economically viable with a high economic internal rate of return as discussed in Chapter FS-A-5.

This project should be implemented as early as possible due to its importance as indicated in the implementation schedule proposed in Chapter FS-A-4.

6.2 Recommendations

It is recommended that the Royal Government of Cambodia take the following actions to ensure that this project is implemented successfully.

6.2.1 Preparation Aspects

(1) Allocation of Budget for Project Preparation

The project costs do not include the cost of the resettlement of residents or the relocation of houses and public property from the construction areas, camp yards, stock yards, borrow pits and spoil areas.

For the smooth implementation of this project the Royal Government of Cambodia needs to allocate a budget for the above preparatory works.

(2) Clearing of Landmines and UXOs

As a consequence of the history of the region, the area from Km50 to the end of the project is still contaminated with landmines and UXOs.

For the safety of the people involved in the project, as well as the local inhabitants, this contaminated area must be cleared before field investigations such as topographic and geotechnical surveys are undertaken.

6.2.2 Management Aspects

(1) Operation and Maintenance

This project is for the construction of a road consisting of asphalt concrete pavements and concrete bridges. These structures will deteriorate on a daily basis if maintenance is neglected.

Therefore, maintenance activities shall be conducted in accordance with Chapter FS-A-4 in order to ensure that the road facilities are kept safe, to prolong the life of the road to and preserve this important asset.

(2) Recycling of the Existing Temporary Superstructure

The existing temporary superstructures and Bailey bridge structures that are in a good condition

should be recycled for use as bridges on provincial roads or rural roads in the future.

(3) Education on Traffic Safety, Rules and User Behavior

After the completion of the project, it is predicted that the volume of traffic and vehicle speeds will increase. It is therefore recommended that steps should be taken to organize traffic safety education and improve traffic rules and user behavior, and that traffic regulations should be strictly observed in order to decrease the number of traffic accidents.

6.2.3 Environmental Aspects

The annex of the sub-decree on the environmental impact assessment process No.72.ANRK.BK, 11 August, 1999 stipulates which projects are required to have an environmental impact assessment (EIA). According to the sub-decree, the construction of national roads exceeding 100 km in length requires a full scale EIA. The project length of NR.57 is 104 km, which is more than 100 km. Therefore a full scale EIA is required for the NR.57 project.

However, the necessary survey could not be conducted during the preparation of this Pre-Feasibility Study for NR.57, as this study is still at a preliminary level.

Therefore, it is recommended that the EIA should be conducted as soon as possible once it has been decided to proceed with the project. When conducting the EIA, the following should be considered and included in the EIA by the MPWT, as the project owner.

(1) Samlaut Multiple Use Area

Part of NR.57 is on the border-line of the protected Samlaut multiple use area, which is stipulated in declaration (Parkas) No.1033 on Protected Areas, June 3, 1944. The unique characteristics of the protected area are described in annex E of the declaration as follows:

It is an evergreen forest area within the watershed of the Battambang River. It has been denuded by mining operations causing severe erosion and increased sedimentation of the river which flows into the Tonle Sap Lake.

Investigations and necessary mitigation measures should be considered, together with MOE, in order to protect the environment in the area.

(2) Resettlement

There is a possibility that a certain amount of resettlement will be required due to the project. The social impacts should be examined and necessary measures should be considered. A Resettlement Action Plan (RAP) should also be formulated.

To ensure the appropriate resettlement of residents there should be adequate public consultation, a public awareness survey and a clear cut-off date.

(3) Other items

In addition to the usual items that are required for an EIA, the following items in particular should be considered and included in the EIA:

- Local economy, land use and local resources:
  Disordered development and land speculation may occur along the road. An environmental and social impact survey should be conducted, including a baseline survey, before the project is implemented. If some impacts are expected, the necessary measures should be undertaken in cooperation with the relevant governmental agencies.

- Infectious diseases:
  A large numbers of construction workers will travel to the site from other areas. Measures against infectious diseases, such as HIV/AIDS, should be considered.

- Air pollution, noise and vibrations, especially in the urban areas of Battambang and Pailin:
  Detours and earthworks during the construction period may cause air pollution, and construction machines and equipment may cause noise and vibrations. Air pollution, noise and vibrations may also occur with the increased traffic volumes after the project completion. Monitoring, including a baseline survey, should be considered. The necessary mitigation measures, especially in the urban area, should be considered.

- Environmental management plan (EMP):
  An EMP, including the monitoring of resettlement activities, should be included in the EIA.

- Landmines and UXOs:
  There are a large number of landmines and UXOs in the project area. The clearance of these landmines and UXOs is crucial before the project implementation.

- Other Items:
  There may be UXOs and landmines around the construction areas, including in the borrow pit camp yard, and stock yard. Clearance of these items should be undertaken in cooperation with the Cambodian Mine Action Center (CMAC).

In addition to the above points, there should be an information disclosure to not only the PAPs, but also all stakeholders, such as other people along NR.57 and the NGOs.

PACKAGE B

THE URGENT BRIDGE REHABILITATION PROGRAM

CHAPTER B-1 INTRODUCTION

1.1 General

In the Road Network Development Master Plan Study, the JICA Study Team has proposed a road network development plan up to 2020 and an implementation plan for road development including prioritization of the projects and improvement measures.

The Urgent Bridge Rehabilitation Program was identified as one of the highest priority projects and therefore a pre-feasibility was conducted.

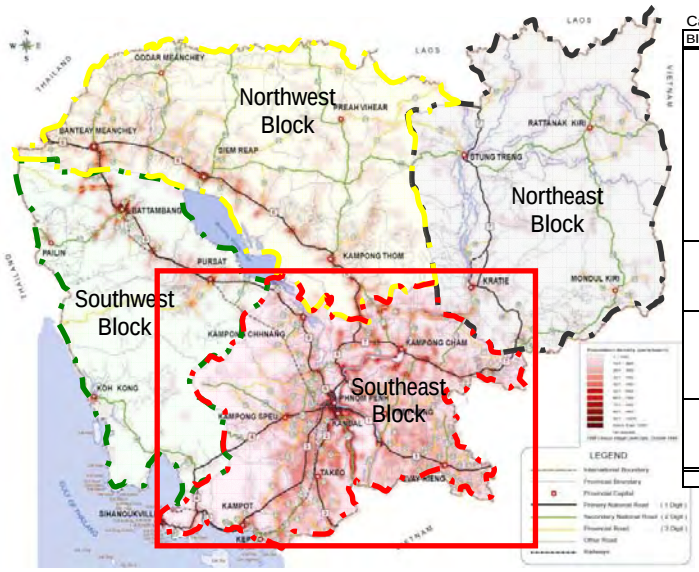
1.2 Purpose of Pre-feasibility Study

The purpose of this Pre-feasibility Study is to comprehensively evaluate the feasibility of this program based on the following aspects:

(1) Estimation of the project cost based on the preliminary design and the implementation plan based on the optimum construction method and schedule
(2) Economic and financial analysis
(3) Estimation of the maintenance cost
(4) Initial Environmental Impact Analysis

1.3 Project Description for the Urgent Bridge Rehabilitation Program

The Southeast block, as shown in **Figure 1.3.1**, was selected as the highest priority block in the Master Plan. There are still many heavily damaged temporary/permanent bridges that were not restored during the urgent rehabilitation of sections of 1- and 2-Digit national roads.. The list of urgent bridge rehabilitation requirements in the southeast block prepared by the MPWT is shown in **Table 1.3.1**.



Cambodia Population Source:Seila 2004

Block	No.	Province Name	Population	
Southeast	3	Kampong Cham	1,746,612	
	4	Kampong Chhnang	444,475	
	5	Kampong Speu	690,963	
	7	Kampot	575,013	
	8	Kandal	1,185,791	
	12	Phnom Penh	1,001,951	
	14	Prey Veng	1,065,550	
	18	Krong Preah Sihanouk	173,904	
	20	Svay Rieng	529,531	
	21	Takeo	881,940	
	23	Krong Kep	34,065	8,329,795
Northeast	10	Kracheh	285,251	
	11	Mondul Kiri	47,391	
	16	Ratanak Kiri	124,403	
	19	Stung Treng	92,870	549,915
Northwest	1	Banteay Meanchey	675,463	
	6	Kampong Thom	624,846	
	13	Preah Vihear	141,749	
	17	Siem Reap	776,978	
	22	Otdar Meanchey	144,371	2,363,407
Southwest	2	Battambang	948,706	
	9	Koh Kong	130,562	
	15	Pursat	385,301	
	24	Krong Pailin	54,203	1,518,772
		Total		12,761,889

Figure 1.3.1 Block Map and Population

Table 1.3.1 List of Urgent Bridge Rehabilitation (Southeast Block) prepared by MPWT

Code No.	Rd. No.	STA.	Prov.	Type	W (m)	L (m)	Con-dition	Others
1	3	105+985	Kampot	Bailey	4.20	48.00	Poor	
2		107+000		Bailey	4.20	18.00	Poor	
3		148+600		Steel+Concrete	4.50	277.60	-	Under construction on the new route
4	31	120+000		Concrete	4.20	55.00	Poor	
5	33	005+050		Compact 200	4.50	87.00	-	Collapsed on Jan. 27, 2006
6		036+540		Bailey	4.20	30.00	Poor	
7	33	160+250	Kep	Concrete	7.00	11.00	Poor	
8	11	083+811	Prey Veng	I-Steel	5.40	42.20	Poor	New concrete substructure by ADB
9		084+900		I-Steel	5.40	42.20	Poor	
10		088+094		I-Steel	5.40	84.20	Poor	
11		089+060		I-Steel	4.90	54.00	Poor	
12		103+475		I-Steel	4.85	48.00	Poor	
13		127+100		I-Steel	4.85	24.10	Poor	
14	7 (Old)	340+200	Kratie	I-Steel+Wooden	4.50	36.00	Poor	
15	7	277+200		Bailey+Concrete	4.50	130.00	Poor	
16	7 (Old)	355+300		Bailey+Wooden	4.50	92.00	Poor	
17	2	022+608	Kandal	Compact	7.00	15.00	Poor	
18		028+180		Compact	7.00	18.00	Poor	
19	3	025+927		Bailey	4.50	37.00	Poor	
20	21	024+414		Compact 100	4.10	18.00	Poor	
21		031+684		Concrete	3.50	7.50	Poor	Khmer Rouge Regime
22		036+671		Concrete	5.10	24.00	Poor	Khmer Rouge Regime
23		039+812		I-Steel	4.10	24.00	Poor	Khmer Rouge Regime
24		040+554		I-Steel	4.10	24.00	Poor	Khmer Rouge Regime
25		045+801		Concrete	3.60	11.80	Poor	Khmer Rouge Regime
26		052+436		Concrete	3.50	14.20	Poor	Khmer Rouge Regime
27		054+477		Compact 100	4.10	54.00	Poor	Khmer Rouge Regime
28		056+430		Concrete	3.80	8.50	Poor	Khmer Rouge Regime
29		060+051		Compact 100	4.10	27.00	Poor	
30		061+407		Compact 100	4.10	48.00	Poor	
31		068+042		Compact 100	4.10	27.00	Poor	
32		074+875		Compact 100	4.10	48.00	Poor	
33	2	034+190	Takeo	Steel	4.00	8.20	Poor	
34		046+700		Steel	4.00	8.00	Poor	
35	3	091+552		Bailey	4.20	12.00	Poor	
36		094+002		Concrete	7.00	16.00	Poor	

There are many beneficiaries around these bridges and as such there will be very high socio-economic benefits. However bridges are not very long, if may not be financially feasible. Hence, basically this program shall be conducted by grant aid.

In the list provided by the MPWT, there are many bridges that are still comparatively good structurally and also some bridges that are already under re-construction.

Therefore, it was decided to short-list the high priority bridges.

1.3.1 Screening of the Urgent Bridge Rehabilitation in Southeast Block

The above list was evaluated and screened by the JICA Study for including in a proposal to the donors for aid, taking into consideration the following criteria:

1) The bridge length should be more than 30 meters, which may need the technological assistance of the donors. The Cambodian Government can improve shorter bridges.
2) The basic human needs of a large number of people in and around the project area should be improved.

The urgent bridges to be rehabilitated are screened as the 1st screening by the following criteria:

1st Screening

(1) The lengths of No.2, 7, 13, 17, 18, 20, 21, 22, 23, 24, 25, 26, 28, 29, 31, 33, 34, 35 and 36 bridges are less than 30m and hence are screened out.

(2) The following bridges have also been screened out for the indicated reasons. A new bridge is under construction in an alternative route in parallel to No.3 bridge in NR.3. No.5 bridge in NR.33 is under construction urgently by the MPWT after it collapsed. The concrete substructure of No.8 bridge in NR.11 has already been constructed by ADB.

(3) No.14 and No.16 bridges are located in old NR.7 alignment, and hence are screened out.

The list of bridges after 1st screening is given in **Table 1.3.2**, which also show their conditions.

Table 1.3.2 Existing Condition of Urgent Bridge Rehabilitation (1st Screening)

Code No.	Rd. No.	STA.	Prov.	Width (m)	Length (m)	Span	Bri. Capa (ton)	Structural Condition			AADT : PCU Y2005	Remarks
								Super -structure	Sub -structure	Evalua -tion		
1	3	105+985	Kam Pot	4.20	48.0	4	15	Bailey	Conc. Pier +Steel Pile (Old)	Poor	3,090	Near Wat
4	31	120+000	Kam Pot	4.20	55.0	3	15	Concrete Truss	Conc. Pier +Steel Bent	Poor	386	Installation of supporting pier
6	33 (AH123)	036+540	Kam Pot	4.20	30.0	1	5	Bailey	Conc. Abutment	Very poor	713	
9	11	084+900	Prey Veng	5.40	42.2	3	15	I-Steel +Timber Deck	Timber (Old)	Very poor	2,087	Heavy damaged timber Pier
10	11	088+094	Prey Veng	5.40	84.2	6	15	I-Steel +Timber Deck	Timber (Old)	Very poor	2,087	Heavy damaged timber Pier
11	11	089+060	Prey Veng	4.90	45.2	5	15	I-Steel +Timber Deck	RC wall Pier +Timber (Very old)	Very poor	2,087	Heavy damaged timber Pier
12	11	103+475	Prey Veng	4.85	48.0	4	15	I-Steel +Timber Deck	Timber (Very old)	Very poor	1.765	Heavy damaged timber Pier
15	7 (AH11)	277+200	Kratie	4.50	130.0	6	15	Bailey +Timber Deck	Concrete (Old)	Poor	2,099	Poor pier condition Collapsed by overloaded vehicle
19	3	025+927	Kandal	4.50	37.0	1	15	Bailey +Steel Deck	Conc. Abutment (Old)	Poor	5,169	Old abutment / poor condition
27	21	054+477	Kandal	4.10	54.0	4	15	Bailey +Steel Deck	Steel Bent Pier	Poor	177	Corroded piers / river constricted
30	21	061+407	Kandal	4.10	48.0	2	15	Bailey +Steel Deck	Conc. Pile Bent	Poor	177	River constricted
32	21	074+875	Kandal	4.10	48.0	2	15	Bailey +Steel Deck	Conc. Wall Pier	Poor	177	Relatively new pier

The existing structural conditions were confirmed for the above 12 bridges by field investigation, and the importance for these bridges was checked.

2nd Screening

The poor structural condition, insufficient existing bridge capacity and their importance rated on current traffic volume, lead to the following bridges being selected:

(1) Bridges No.4, 9, 10, 11, 12 and 19 were selected due to their poor structural conditions and insufficient bridge capacity.

(2) Bridges No.1, 15 and 19 were selected from their importance and high traffic volume.

As the result, 8 bridges were selected as priority bridges to be rehabilitated under the Program as shown below.

- 3 bridges on NR.3 and NR.33 in Kampot Province
- 1 bridge on NR.7 in Kratie Province
- 4 bridges on NR.11 in Prey Province.

1.3.2 Project Description for the Urgent Bridge Rehabilitation Program

The 8 bridges, with a total existing bridge length of 464m, selected for the urgent bridge rehabilitation program are all temporary and located on 1- and 2-Digit national roads in the flat terrain of the southeast region in Cambodia.

The improvement target for these bridges is to provide permanent structures with sufficient bridge capacity and standard of construction.

Br. No.	Rd. No.	STA.	Width (m)	Length (m)	Bri. Capa. (ton)	Y2005 AADT (PCU)	Structural Condition		
							Superstructure	Substructure	Evaluation
1	3	025+927	4.50	37.00	15	5,169	Bailey +Steel Deck	Conc. Abutment	Poor
2	3	105+985	4.20	48.00	15	3,090	Bailey	Conc. Pier +Steel Pile	Poor
3	7	277+200	4.50	130.00	15	2,099	Bailey +Timber Deck	Concrete	Poor
4	11	084+900	5.40	42.20	15	2,087	I-Steel +Timber Deck	Timber	Very poor
5	11	088+094	5.40	84.20	15	2,087	I-Steel +Timber Deck	Timber	Very poor
6	11	089+060	4.90	45.20	15	2,087	I-Steel +Timber Deck	RC wall Pier +Timber	Very poor
7	11	103+475	4.85	48.00	15	1,765	I-Steel +Timber Deck	Timber	Very poor
8	33	036+540	4.20	30.00	5	713	Bailey	Conc. Abutment	Very poor

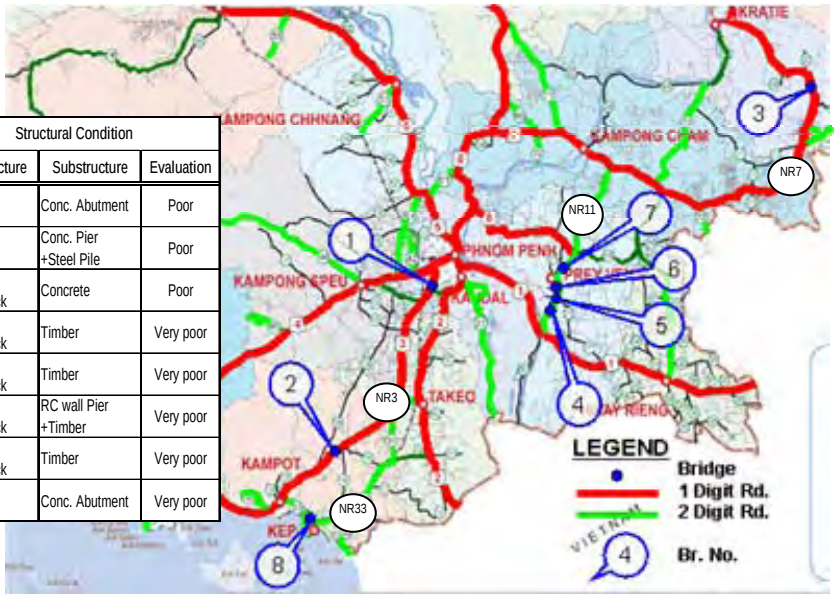


Figure 1.3.2 Location of Bridges to be Rehabilitated

CHAPTER B-2 GENERAL CONDITION AND ENGINEERING SURVEY

2.1 Natural Condition

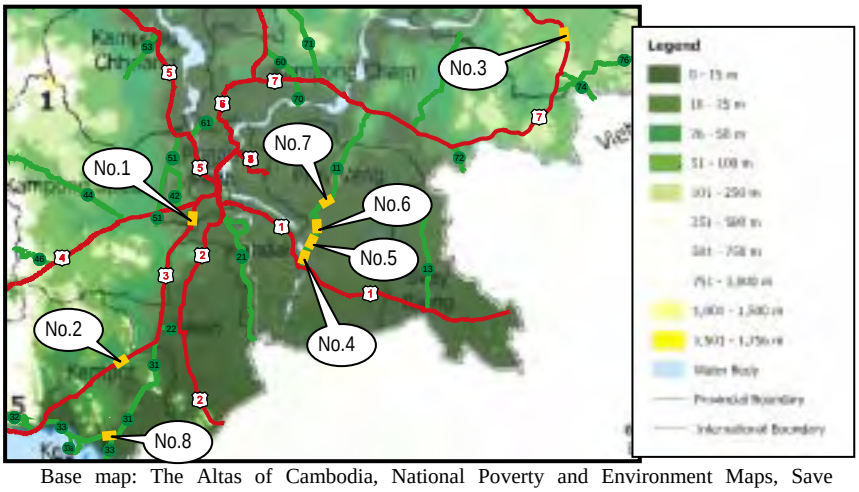
2.1.1 Geography and Geology on the Project Site

The bridge sites are in relatively flat geographic areas except for the Bridge No.3 site on NR.7. Notably, Bridges No.4 to No.7 are located in the Mekong river floodplain area. The site conditons of each bridge are classified as follows:

(1) Flat and Low Elevation and also Flood Area: Bridge No.4, No.5, No.6 and No.7 on NR.11

(2) Flat and Low Elevation Area: Bridge No.1 and No.2 on NR.3, and No.8 on NR.33

(3) Mountanious Area: Bridge No.3 on NR.7



Base map: The Altas of Cambodia, National Poverty and Environment Maps, Save Cambodia's Wildlife with Support from Danida

Figure 2.1.1 Elevations of the Project Site

The existing road elevations around each bridge and the Y2000 flood level at MOWRAM stations near the project sites are shown in **Figure 2.1.2**.

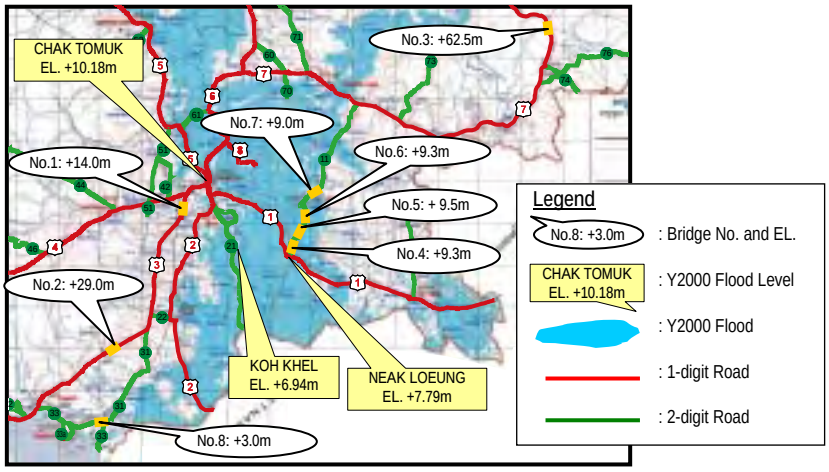


Figure 2.1.2 Year 2000 Flood in Cambodia with Flood Levels at MOWRAM Stations

2.1.2 Hydrology and Geology on the Project Site

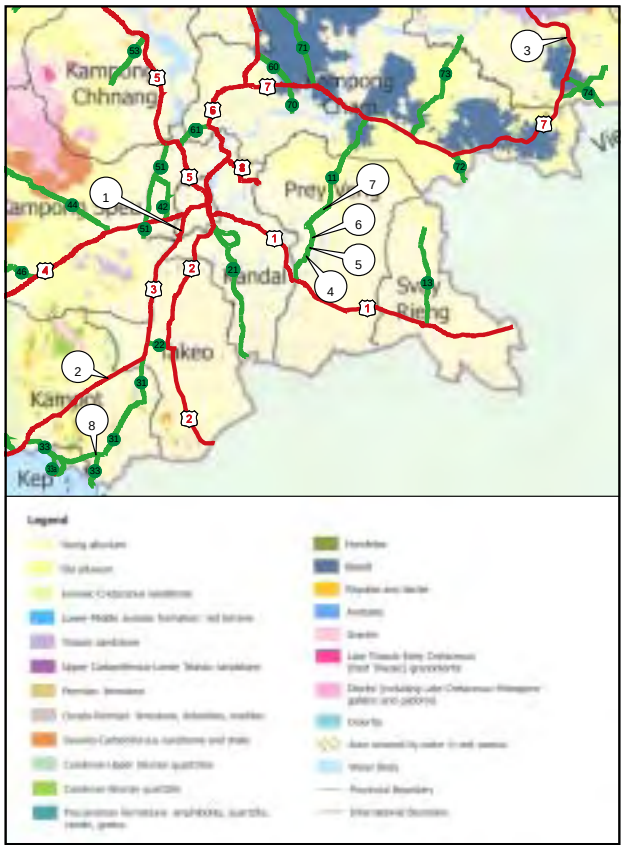
The general geological conditions in the vicinity of the Project sites are shown in **Figure 2.1.3**.

The bridge sites except Bridge No.3 on NR.7 are covered by young alluvium deposited by the Mekong River and the Bassac River, and Bridge No.3 site is located in an old alluvium area.

Annual rainfall around the Project sites is shown in **Figure 2.1.4**.

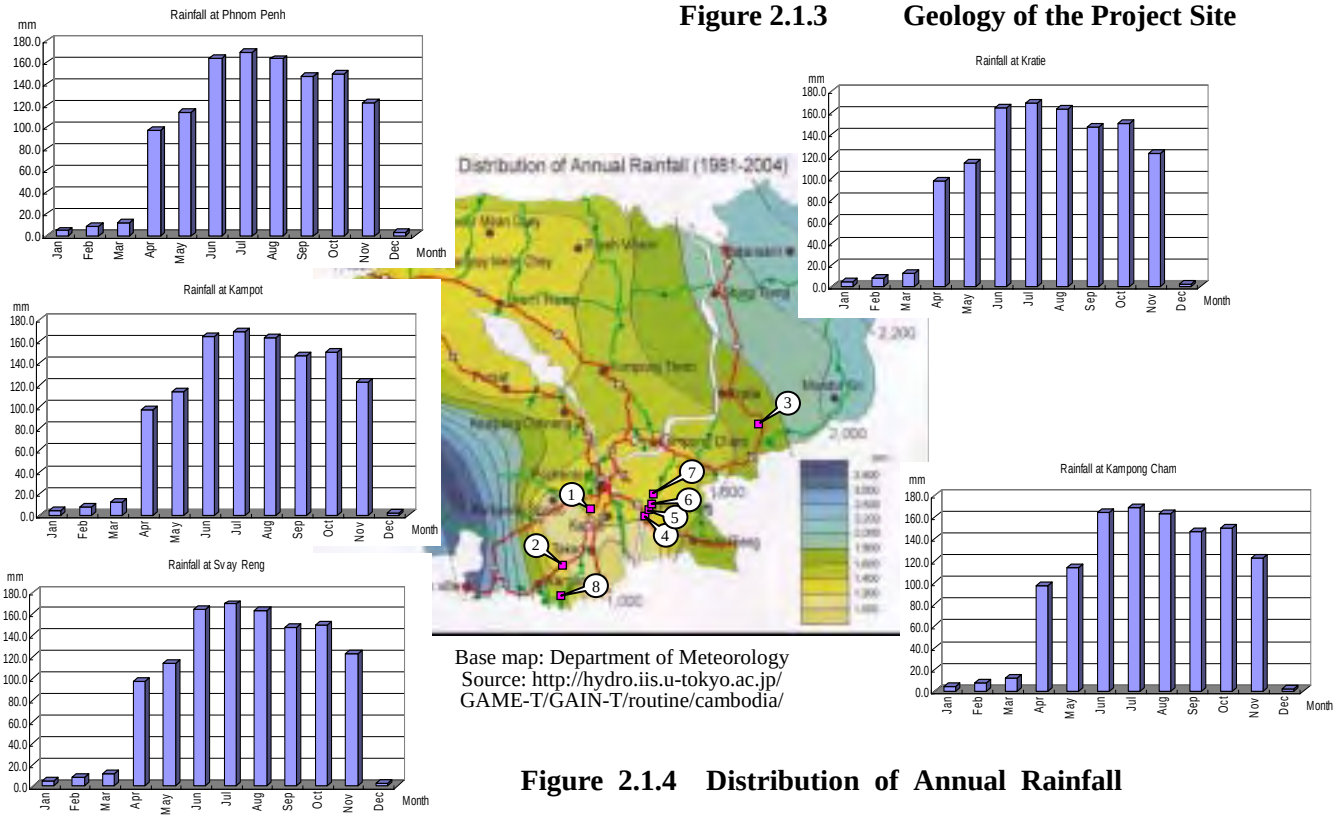
The annual rainfall of the bridge sites is as follows: (a) Bridge No.2 site is approximately 1,200 mm, (b) Bridge No.1, No.3, No.4, No.5, No.6 and No.7 sites are in the range of 1,200-1,400mm and (c) Bridge No.8 site is in the range of 1,400-1,600mm.

This region has a tropical monsoon climate.



Base map: The Altas of Cambodia, National Poverty and Environment Maps, Save Cambodia's Wildlife with Support from Danida

Figure 2.1.3 Geology of the Project Site



Base map: Department of Meteorology
Source: http://hydro.iis.u-tokyo.ac.jp/GAME-T/GAIN-T/routine/cambodia/

Figure 2.1.4 Distribution of Annual Rainfall

2.2 Socio-Economic Condition

2.2.1 Bridge No.1 on NR.3

(1) Population

Bridge No.1 site is located at 25.927 km on National Road No. 3 (NR.3) towards the southern part of Phnom Penh, which is at the boundaries of Phnom Penh, Kandal and Kampong Speu Provinces.

The population of the area directly influenced by Bridge No.1 on NR.3 is estimated at approximately 338,160 in 2005 of which, that in Dangkao district is 127,315 persons, that in Kandal Stueng district is 94,712 persons and that in Kong Pisei is about 116,136 persons. It is expected to increase to 384,500 persons in 2010, 434,160 person in 2015, and 486,330 persons in 2020 as shown in **Table 2.2.1**.

Table 2.2.1 Existing and Future Population in the Bridge No.1 Area, 2005-2020

Province/District		2005	2010	2015	2020	AAGR (%)
Phnom Penh	Dangkao	127,315	148,704	172,497	198,544	1.030
Kandal	Kandal Stueng	94,712	104,562	114,286	123,315	1.018
Pampong Speu	Kong Pisei	116,136	131,234	147,376	164,472	1.023
Total		338,163	384,500	434,159	486,331	1.025

Notes: 2005: Estimated on the basis of 2004 village data

2010, 2015, 2020: forecasted based on the growth rate in the Master Plan

(2) Land use

Land use around Bridge No.1 on NR.3 consists of rich irrigated paddy fields. However, since the site is within the Phnom Penh Metropolitan area light industries, such as the garment industry and vehicle repair industry, are being developed in the area influenced by this bridge site as shown in **Figure 2.2.1**.

2.2.2 Bridge No. 2 on NR.3

(1) Population

Bridge No.2 site, which is located at 105.985 km on National Road No. 3 (NR.3) from Phnom Penh, belongs to Chhuk and Dang Tong Districts of Kampot Province.

The population around the Bridge No.2 site on NR.3 is estimated at approximately 145,520 in 2005, which is lower than that at Bridge No.1 site. Of this population, that in Chhuk district is 91,830 persons and that in Dang Tong is about 53,690 persons. It is expected to increase to 158,900 in 2010, 172,730 in 2015, and 185,850 in 2020 as shown in **Table 2.2.2**.

Table 2.2.2 Existing and Future Population in the Bridge No. 2 Area, 2005-2020

Province/District		2005	2010	2015	2020	AAGR (%)
Kampot	Chhuk	91,827	100,275	108,999	117,283	1.016
	Dang Tong	53,688	58,627	63,728	68,571	1.016
Total		145,515	158,902	172,727	185,854	1.016

Notes: 2005: Estimated on the basis of 2004 village data

2010, 2015, 2020: forecasted based on the growth rate in the Master Plan

(2) Land use

Land use around Bridge No.2 on NR.3 consists of paddy and flooded paddy fields as well as marshland. However, since the site is far from the Phnom Penh and Sihanoukville, there is no industrial development or commercial activity found in the area influenced by this bridge site as shown in **Figure 2.2.1**.

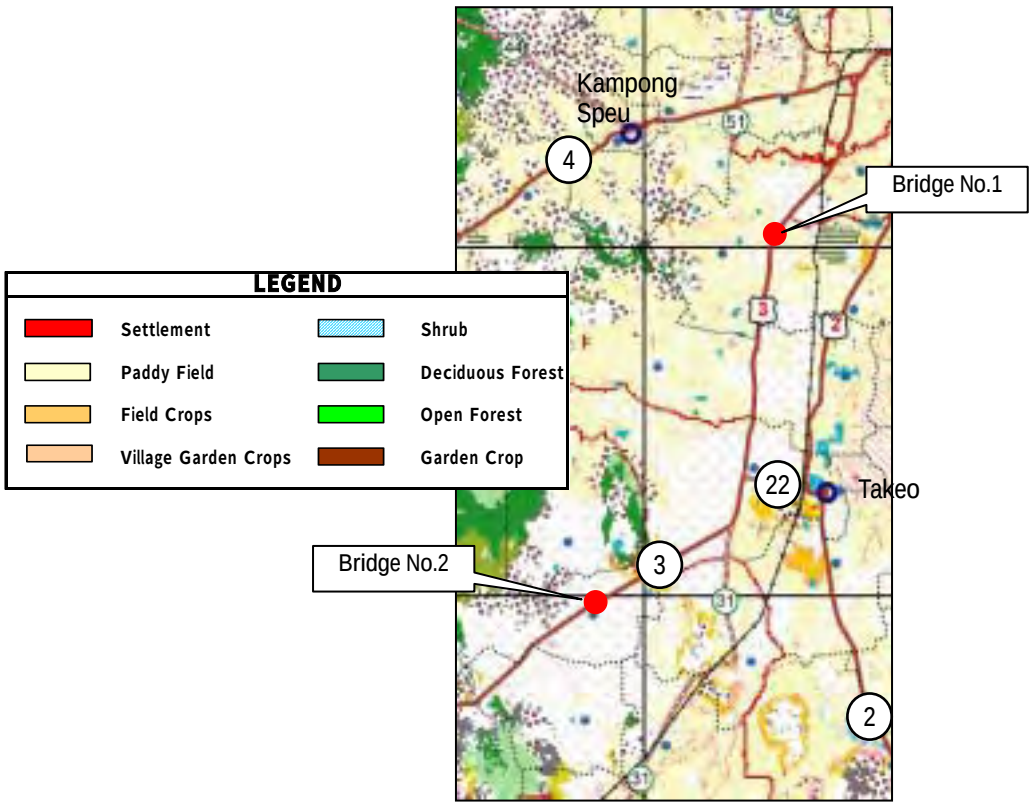


Figure 2.2.1 Land Use around Bridge No.1 and 2 Sites

2.2.3 Bridge No.3 on NR.7

(1) Population

The Bridge No.3 site, which is located at 277.200 km on National Road No.7 (NR.7) north east of Phnom Penh, belongs in the Snuol district of Kratie Province.

The population around the Bridge No.3 site on NR.7, which can be said to be an unpopulated area,

is estimated at approximately 42,970 persons in 2005. It is expected to increase to 48,800 persons in 2010, 54,800 persons in 2015 and 60,800 persons in 2020 as shown in **Table 2.2.3**.

Table 2.2.3 Existing and Future Population in the Bridge No. 3 Area, 2005-2020

Province/District		2005	2010	2015	2020	AAGR (%)
Kratie	Chhuk	42,972	48,816	54,820	60,795	1.023

Notes: 2005: Estimated on the basis of 2004 village data

2010, 2015, 2020: forecasted based on the growth rate in the Master Plan

(2) Land use

Land use around Bridge No.3 on NR.7 consists of dense forest with some grassland as shown in **Figure 2.2.2**.

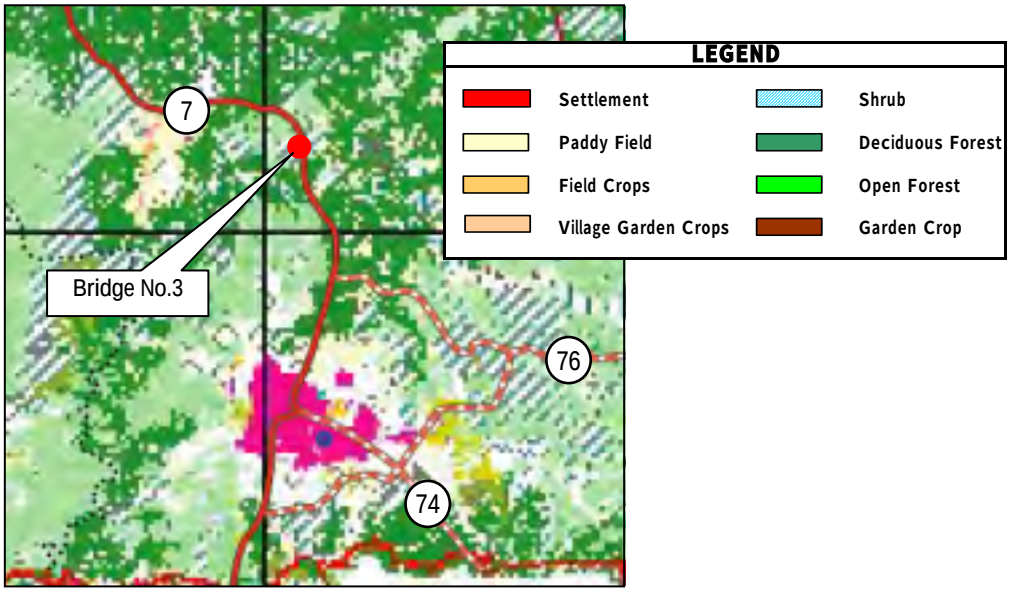


Figure 2.2.2 Land Use around Bridge No.3 Site

2.2.4 Bridges No.4, 5, 6 and 7 on NR.11

(1) Population

Bridge No.4, 5, 6 and 7 sites are located at 84.900, 88.094, 89.060 and 103.475 km respectively on National Road No.11 (NR.11) towards the east direction from Phnom Penh. These bridges belong to the Peam Ro, Kampong Leav and Prey Veang districts of Prey Veang Province.

The population around Bridge No.4, 5, 6 and 7 sites on NR.11 is estimated at approximately 225,000 in 2005, of which that in Peam Po district is 64,290 persons, that in Dang Tong is about 58,790 persons and that in Prey Veang is about 101,930 persons. It is expected to increase from 225,000 in 2005 to 241,660 in 2010, 256,160 in 2015 and 269,220 in 2020 as shown in **Table 2.2.4**.

Table 2.2.4 Existing and Future Population in the Bridge No. 4, 5, 6 & 7 Areas, 2005-2020

Province/District		2005	2010	2015	2020	AAGR (%)
Prey Veang	Peam Ro	64,291	69,049	73,192	76,925	1.012
	Kampong Leav	58,788	63,138	66,926	70,339	1.012
	Prey Veang	101,930	109,473	116,041	121,959	1.012
Total		225,009	241,660	256,159	269,223	1.012

Notes: 2005: Estimated on the basis of 2004 village data

2010, 2015,2020: forecasted based on the growth rate in the Master Plan

(2) Land Use

Land use around Bridges No.4, 5, 6 and 7 on NR.11 consists of rich flooded and irrigated paddy fields. The land use in the areas influenced by these bridge sites is shown in **Figure 2.2.3**.

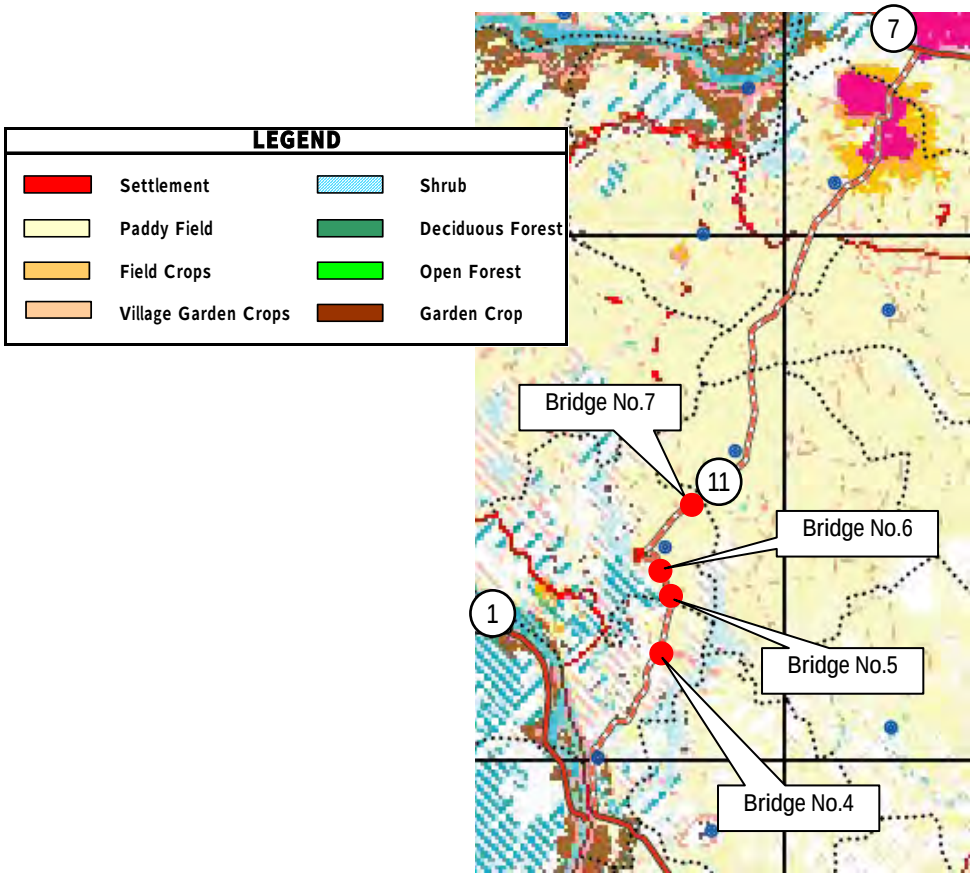


Figure 2.2.3 Land use around Bridges 4, 5, 6 and 7 Sites

2.2.5 Bridge No.8 on NR.33

(1) Population

The Bridge No.8 site is located at 36.540 km on National Road No.33 (NR.33) to the east of Sihanoukville. This bridge belongs to Kampong Trach district of Kampot Province.

The population around Bridge No.8 on NR.33 is estimated at approximately 90,000 in 2005. It is expected to increase from 90,000 in 2005 to 98,200 in 2010, 106,790 in 2015 and 114,900 in 2020 as shown in **Table 2.2.5**.

Table 2.2.5 Existing and Future Population in the Bridge No. 8 Area, 2005-2020

Province/District		2005	2010	2015	2020	AAGR (%)
Kampot	Kampong Trach	89,965	98,242	106,789	114,905	1.016

Notes: 2005: Estimated on the basis of 2004 village data

2010, 2015, 2020: forecasted based on the growth rate in the Master Plan

(2) Land Use

Land use around Bridge 8 on NR.33 consists of paddy and flooded paddy fields. However due to being near the coastal area of the Gulf of Thailand, the tourist industry is being developed in the area influenced by this bridge site as shown in **Figure 2.2.4**.

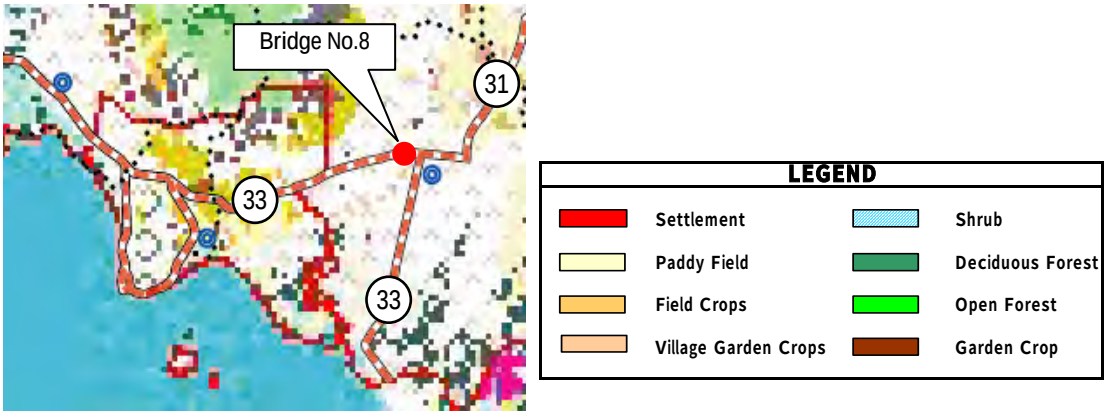


Figure 2.2.4 Land use around Bridge No.8 Site

2.3 Engineering Survey

2.3.1 Topographic Survey

The topographic survey for the preliminary design of the urgent bridge rehabilitation program has been carried out based on National Benchmarks established by a geographic survey in 1993-97.

(1) Temporary benchmark setting

Temporary benchmarks, made of concrete pile with a metal rivet on the head, have been installed at each bridge site. The locations have been selected in open areas to provide a good reception of signals from the GPS satellites.

The list of temporary benchmark data is shown in **Table 2.3.1**.

Table 2.3.1 List of Temporary Benchmark Data

BM No.	Br. No.	Location	Coordinates		Elevation	Remarks
			North	East		
1	1	NR.3, Km025+927	1,262,419.202	477,393.452	14.205	Datum: WGS84 System, MSL(Mean sea level 1996 - 1997) Projection: UTM Zone 48N Ellipsoid GRS-80
2	2	NR.3, Km105+985	1,198,615.336	441,537.799	28.759	
3	3	NR.7, Km277+200	1,354,121.976	654,995.165	62.247	
4	4	NR.11, Km084+900	1,265,466.522	538,652.654	9.148	
5	5	NR.11, Km088+094	1,268,279.347	537,635.535	9.040	
6	6	NR.11, Km089+060	1,269,154.236	537,207.061	9.108	
7	7	NR.11, Km103+475	1,277,771.833	544,400.905	8.764	
8	8	NR.33, Km036+540	1,167,111.989	442,321.532	2.546	

(2) Road centerline profile survey

The exiting road centerline profile was surveyed in the area of every bridge including approach roads, 100m in length, on both sides from the existing abutments. Elevations of beginning points, ending points, 20m interval points, intersection and major points were measured from the temporary benchmarks.

(3) Topographic survey

A topographic survey was carried out for the area around every bridge including approach roads, 100m in length, on both sides from the existing abutments and with a 30m width on both sides from the existing road centerline.

(4) River cross-section survey

A river cross-section survey was carried out at the centerline of every bridge and 100m upstream and downstream from the exiting bridge centerline. High water levels for each bridge sites were noted in the drawings based on observations or interviews during the survey period.

2.3.2 Geotechnical Investigation

A geotechnical investigation was carried out for the preliminary bridge design as follows:

(1) Mechanical boring:

Eight (8) mechanical borings (boreholes) were conducted at seven (7) sites, two (2) positions near Bridge No.1 and 2 on NR.3, two (2) positions near Bridge No.3 on NR.7, three (3) positions near Bridges No.4 to No.7 on NR.11, and one (1) position near Bridge No.8 on NR.33.

(2) Standard penetration test

The standard penetration tests to find the N-value and sampling were carried out at 1.00 m intervals at each borehole.

(3) Laboratory tests

Laboratory tests on the selected samples were conducted for the following tests:

1) Specific Gravity

2) Density
3) Moisture Content
4) Grain Size Analysis
5) Atterberg Limits

The borehole logs and locations are shown in **Table 2.3.2** and **Figure 2.3.1**.

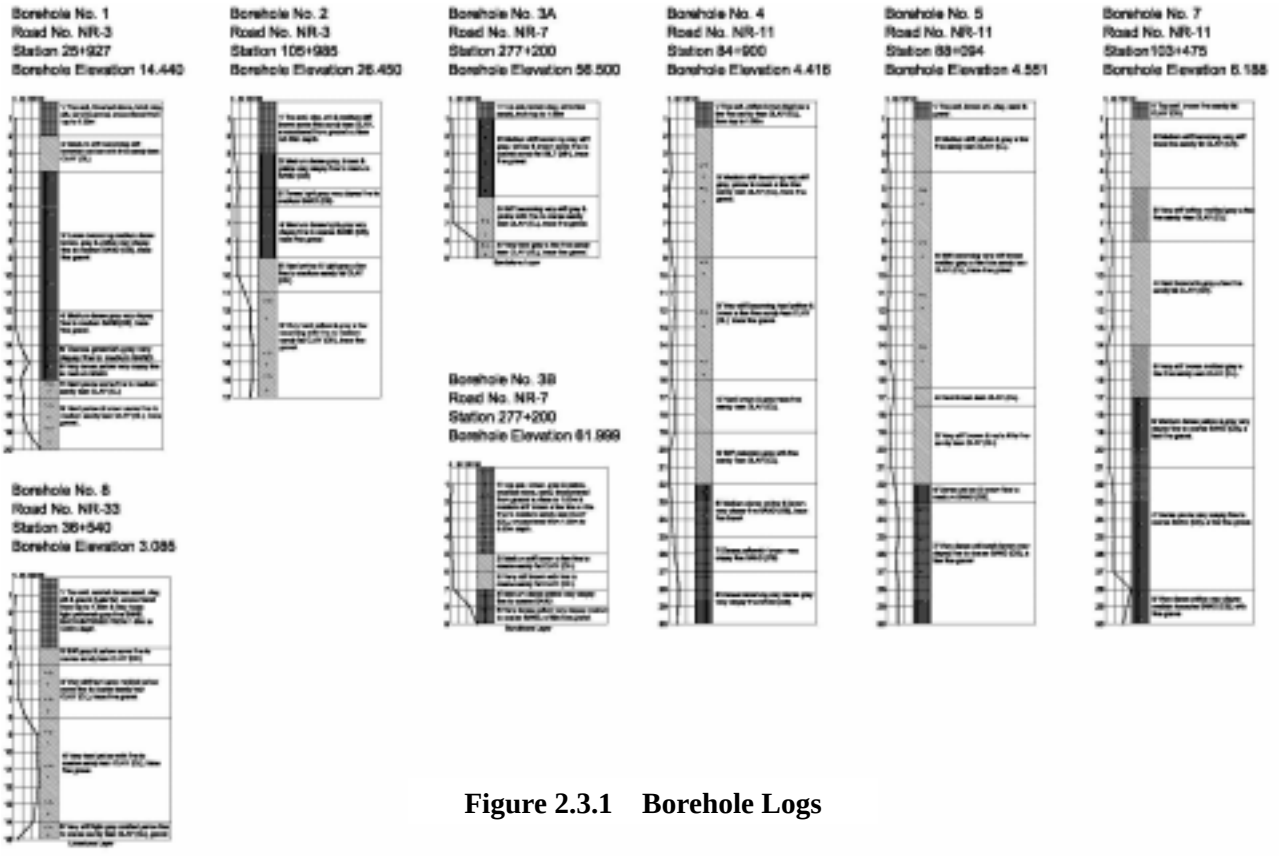


Figure 2.3.1 Borehole Logs

Table 2.3.2 Coordinates and Elevation of Boreholes

Bridge No.	North	East	Elevation	Remarks
1	1262444.321	477422.719	14.440	BH1
2	1198637.519	441579.206	26.450	BH2
3	1354251.966	654930.928	56.500	BH3A
3	1354120.700	654996.355	61.999	BH3B
4	1265441.234	538625.128	4.416	BH4
5	1268404.434	537595.436	4.551	BH5
6	---	---	---	No Borehole
7	1277836.087	544464.090	6.188	BH7
8	1167121.943	442302.351	3.085	BH8

2.3.3 Hydrologic Survey

Hydrologic and hydraulic analyses were also conducted for the Urgent Bridge Rehabilitation. **Table 2.3.3** shows the hydraulic design data for the bridges.

Table 2.3.3 Hydraulic Design Data for Urgent Rehabilitation Bridges

Road No.	Bridge			Catchment Area (km^2)	Design Flood Discharge (m^3/s)	Approaching Velocity (m/s)	Design Flood Level (Elev. m)	Recommended Waterway Opening Width W_S (m)
	No.	Station (km+m)	Location					
NR.3	1	025+927	Kandal	114.6	284	3.05	12.74	53.93
NR.3	2	105+985	Kampot	256.8	238	3.2	27.50	49.37
NR.7	3	277+200	Kratie	1,000.0	1,775	3.17	58.41	134.82
NR.11	4	084+900	Prey Veng	64.2	150	1.84	7.50	39.19
NR.11	5	088+094		237.9	573	2.26	8.77	76.62
NR.11	6	089+060		184.6	454	2.84	8.15	68.15
NR.11	7	103+475		74.8	177	1.93	8.20	42.55
NR.33	8	036+540	Kampot	176.5	62	1.88	1.81	25.20

Note : 1) Based on Road Design Standard, Part 3. Drainage, CAM PW.03.103.99

2) Estimated by HEC-HMS method (C.A. > 25 km2) and verified by flood mark.

3) $W_s = CQ^{1/2}$ where C = 3.2 and Q = Design Flood Discharge (m^3/s)

CHAPTER B-3 PRELIMINARY DESIGN

3.1 Design Concept and Criteria

3.1.1 Design Concept and Criteria for Road

(1) Design Concept

The following design concepts have been considered in the access road design:

- The existing road alignment shall be maintained as much as possible to minimize the construction cost and to minimize the negative socio-environmental impacts during construction.
- The road profile shall be adjusted accordingly to meet the minimum requirements of bridge design flood freeboard.
- The road geometric and cross-section shall comply with the Cambodian Highway road classification requirements. However, since the total road improvement at bridge locations will be carried-out at a later stage, the R4/U4 geometric road class standard (CRDS) with 80 km/hr design speed is adopted for the access road design.

(2) Design Criteria

1) Applicable Design Standards

The design standard used for the design of access roads is basically

- The Cambodia ROAD DESIGN STANDARD (CRDS), Department of Public Works and Transport (MPWT), 2003
  - ⇒ Part-1 Geometry (CAM PW.03.101.99),
  - ⇒ Part-2 Pavement (CAM PW.03.102.99) and,
  - ⇒ Part-3 Drainage (CAM PW.03.103.99).

When no provision exists in the Road Design Standard of Cambodia, AASHTO (A Policy on Geometric Design of Highways and Streets, 2001), JRSO (Japan Road Structure Ordinance), AASHTO Guide for Design of Pavement Structures, 1993) etc. have been applied.

2) Geometric Design Criteria

The summary of geometric design criteria applied in the design is given in **Table 3.1.1**. The roads where the bridges were selected are National Roads NR.3, NR.7, NR.11 and NR33. Although the roads NR.3 and NR.7 are 1-Digit National Highway eligible to be classified as R5, the design speed for all the approach roads were taken as 80 km/hr because the access roads may be temporary and may need adjustment when the whole length of road is rehabilitated.

3) Typical Cross Section

The typical cross section applied in the design of access roads is given in **Figure 3.1.1**, which is based on the total formation width of 14m for road class of R5.

Table 3.1.1 Summary of Geometric Design Criteria

Design Elements			Type/Value	Remarks
1	Road Classification		R4/U4	
2	Terrain		Plain	
3	Design Vehicles (L x W x H)		16.7 x 2.6 x 4.1	WB- equivalent
4	Design Speed (km/hr)		80	
5	Cross-Sectional Elements	Formation Width (m)	14.0	
		Carriageway Width (m)	13.0	
		Traffic Lane Width (m)	3.5	
		Paved Shoulder Width (m)	1.5	
		Granular Shoulder Width (m)	1.5	
		Unpaved Verge Width (m)	0.5	
		Crossfall of Roadway (%)	3.0	6% for unpaved shoulder
		Slope of Earthworks		
		Fill	V : H = 1:2.0	1:1.5 for shallow fill
		Cut	Varies	Varies with soil condition
6	Horizontal Alignment	Horizontal Curve		
		Minimum Radius (m)	335 (135)	() for exceptional
		Superelevation		
		Maximum Superelevation (%)	6.0	
		Minimum Radii without Se (m)	1500	
7	Vertical Alignment	Maximum Grade (%)	6	
		Vertical Curve		
		Minimum K-value		
		Crest Curve	30	
		Sag Curve	28	

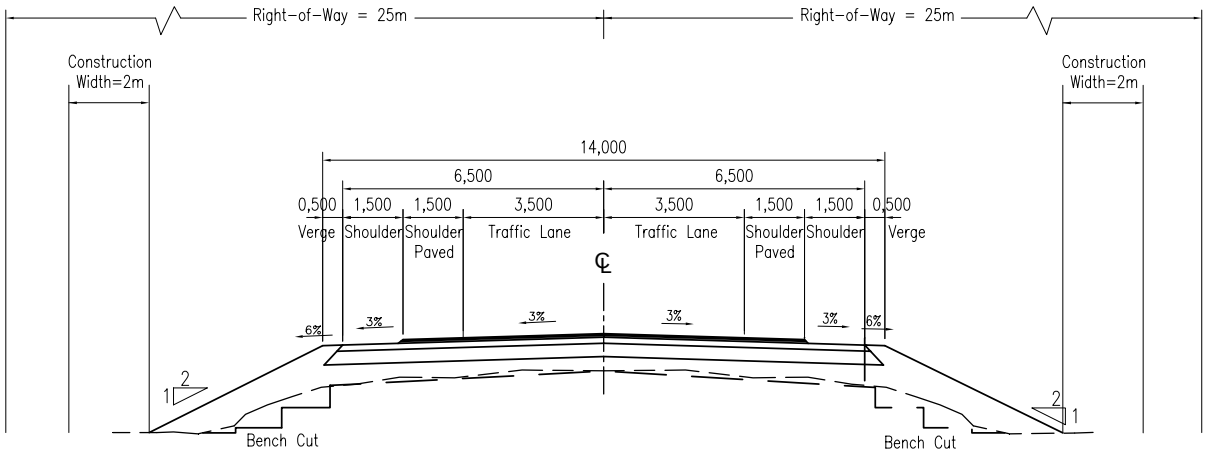


Figure 3.1.1 Typical Cross Section

4) Pavement Design Criteria

Road Design Standard of Cambodia presents the typed design for pavement structures and does not include detailed procedure. So the AASHTO Guide for Design of Pavement Structure has been applied for the pavement design.

The AASHTO method of pavement design requires basically the following four types of design input requirements:

1) Design variables; the design variables include the performance and analysis period, traffic and the selection of parameters like reliability and overall standard deviations. The traffic data includes the estimation of total application of traffic load during pavement life (as obtained from the performance and analysis period) in terms of Equivalent Single Axle Load of 8.2 tones. The directional distribution factor and lane distribution factors are also required as the input design data.

2) Performance criteria; it is based on the concept of serviceability index. The initial serviceability index (p_0) is the serviceability of pavement immediately after construction and the terminal serviceability index (p_t) is the least acceptable serviceability of the pavement near the end of the pavement life before rehabilitation is required. The difference in these two parameters gives the design serviceability loss (ΔPSI).

3) Material properties; the material properties of various layers of the pavement structures from subgrade to subbase, base and surface courses are required in terms of resilient modulus. The resilient modulus of subgrade, subbase and base courses can be derived from the widely used CBR values of the material for these layers.

4) Pavement characteristics; it includes mainly the drainage coefficients for the subbase and base course layers.

For a set of the design input data, the required Structural Number (SN) is estimated from the AASHTO Nomograph or by solving the equation of the Nomograph as shown in **Figure 3.1.2**.

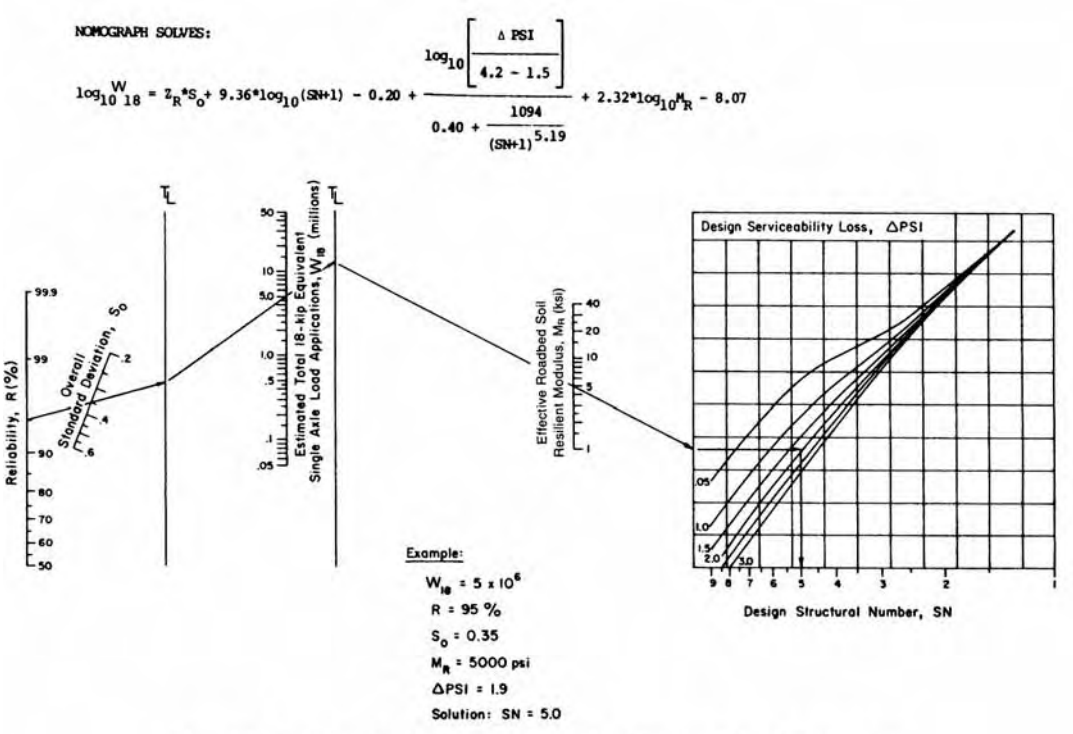
A set of the pavement layer thicknesses is then identified which, when combined, will provide the load-carrying capacity corresponding to the design SN. The following equation provides the basis for converting SN into actual thicknesses of surface, base and subbase layers:

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

Where, a_1, a_2, a_3 = layer coefficients representative of surface, base, and subbase courses, respectively

D_1, D_2, D_3 = actual thickness (in inches) of surface, base, and subbase courses, respectively

m_2, m_3 = drainage coefficients for base and subbase layers, respectively



Note: The values of R, S_0 and ΔPSI shown in Figure are examples given in figure of AASHTO and are not the values used in this Study.

Figure 3.1.2 AASHTO Design Equation, Nomograph

The design criteria that will be applied in the pavement design based on the AASHTO method is given in **Table 3.1.2**.

The Cambodian Standard does not clearly stipulate the design period for improvement projects with Asphalt Concrete, although a period of 20-25 years is mentioned for new granular pavement and 10-15 years for Asphalt overlays. AASHTO recommends a performance period of 10-15 years for asphalt concrete pavements and hence a period of 10 years has been used for design. Other input variables are based on the typical values for major arterial road.

Table 3.1.2 Summary of Design Criteria for Pavement Design

Design Input Requirements			Value	Reference
1	Design Variables	Performance Period (years)	10	General
		Analysis Period (years)	10	General
		Traffic		
		Equivalent Single Axle Load (ton)	8.2	AASHTO
		Directional Distribution Factor, D_D	0.6	AASHTO
		Lane Distribution Factor, D_L	1.0	AASHTO
		Reliability (%)	85	AASHTO
		Overall Standard Deviation	0.45	AASHTO
2	Performance Criteria	Initial Serviceability Index, p_0	4.2	AASHTO
		Terminal Serviceability Index, p_t	2.2	AASHTO
		Design Serviceability Loss, ΔPSI	2.0	AASHTO
3	Material Properties	Effective Roadbed Soil Resilient Modulus, M_R (psi)	1500 × CBR	General
		Layer Coefficient for Subbase Course, a_3	from CBR	AASHTO chart
		Layer Coefficient for Base Course, a_2	from CBR	AASHTO chart
		Layer Coefficient for Asphalt Concrete, a_1	Resilient Mod.	AASHTO chart
4	Pavement Characteristics	Drainage Coefficients for Base and Subbase Course, m_2, m_3	1.0	AASHTO

3.1.2 Design Concept and Criteria for Bridge

(1) Design Concept

In order to meet the project objectives, the following design concepts are adopted to establish the design criteria:

- The bridge shall have the same functional standard as the road – its geometric and cross-sectional elements shall comply with the requirements of the road functional class or category;
- The existing bridge alignment/location (where geometric elements comply with the road standard) shall be maintained as much as possible to minimize additional right-of-way;
- The bridge shall be designed to have minimum adverse social impact through proper selection of route alignment, proper construction method in urban areas, and minimum disturbance to population and encroachment to private properties;
- Environmental preservation shall be a primary concern through (a) selection of design and construction methodology that will minimize impact and damage to environment, (b) minimum encroachment to rivers and waterways, (d) sufficient clearance to design water level, and (d) provision of proper river protection;

- The bridge shall incorporate appropriate traffic safety facilities in design and construction.
- The scale and type of bridge shall be determined based on:
  - Bridge Length and Superstructure – river width, river discharge, design flood level, freeboard, design loads and durability,
  - Substructure and Foundation – pier height, foundation embedment depth, bearing layer and capacity, design loads, and river protection, and
  - Structure Type – economy/cost-effectiveness, durability, vertical alignment, environmental impacts, constructability, and maintainability.

(2) Design Criteria

1) Applicable Design Standards

- Australian Bridge Design Code, CAM PW.04.101.99, AUSTROADS, 1996
- Cambodian Bridge Design Standard (CBDS),CAM PW.04.102.99, MPWT, 2003
- Cambodian Road Design Standard, Part 3. Drainage (CRDS), CAM PW.03.103.99, MPWT, 2003
- Standard Specifications for Highway Bridges, AASHTO, 1996
- Specifications for Highway Bridges, Japan Road Association, 1996, 2002
- Specification for River Facilities, Japan River Association, 1998.

The basic design requirements will be referred to the Cambodian Bridge Design Standard. However, when the said guidelines do not cover other aspects of design or when a safer, more efficient requirement is needed, the design of bridges shall refer to other standards.

2) Bridge Location Considerations

The bridges for the proposed Urgent Bridge Rehabilitation are all located in the existing national road alignment. However, some important conditions to be considered in the selection of bridge location include:

- Stability of river course – changes in river course for braided, straight and meandering streams require spanning the entire channel, stabilizing banks around abutment and designing for anticipated scour, and
- Condition of river bank both upstream and down stream – condition of river bank stability may require bank protection to control erosion and meandering.

3) Design Flood Frequency and Minimum Freeboard

The design flood frequency to be adopted for bridge design is one (1) in fifty (50) years as specified in the CRDS Part 3 for R5 and R4/U4 Category roads. The design maximum flood water level (DFL) shall be determined based on this return flood frequency.

The minimum freeboard from the DFL to the soffit of girders/slabs is recommended to be:

- 1.0m for river discharge >500 - 2,000 m^3/s
- 0.80m for river discharge >200 - 500 m^3/s, and
- 0.60m for river discharge < 200 m^3/s in accordance with the Japan River Facilities.

The above minimum freeboard shall be applied unless the requirements of water navigation clearance prevail. In all cases, bridges under this study have no requirements for water navigation clearance.

4) Bridge Length

The total bridge length is decided based on:

- the maximum design flood water level (DFL) and discharge with a 50-year return period,
- bridge opening that will not constrict river discharge flow, and
- existing topographic and natural condition requiring bridge to span the obstruction.

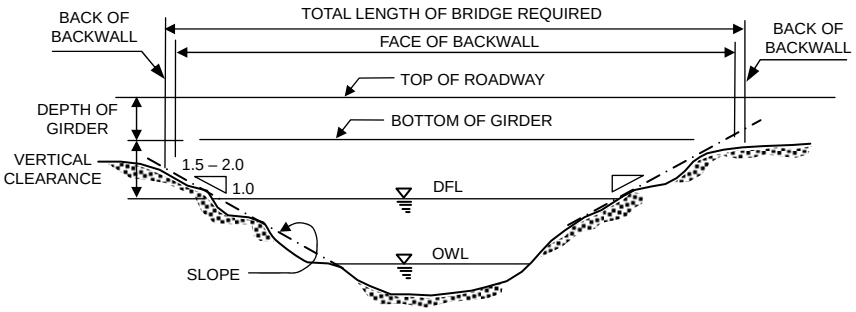


Figure 3.1.3 Planning for Bridge Crossings

5) Typical Cross-Section for Bridges

To provide a consistent level of service as required by the CBDS, the traffic lane widths on bridges shall have the same width as that provided on the approach roadway. Moreover, the code requires a minimum of 500mm edge clearance from the adjacent traffic lanes for bridges with or without footways.

Recently constructed bridges along 1-Digit national roads are provided with 1.0m to 1.5m of shoulders which functions as motorcycle/bike lanes to segregate slow-moving from fast-moving vehicles. Moreover, on-going bridge projects under different funding institutions (including

ADB, Japan, Thailand, Korea, China, etc.) provide 1.50m shoulder on bridges (see **Table 3.1.3**).

Table 3.1.3 (a) Typical Bridge Cross-Section Dimensions for On-going Projects

Route No.		NR.1	NR.2	NR.3	NR.3	NR.3	NR.2	NR.5
Bridges		C1 Section, 2 Bridges	C2,5 Bridges	Kampong Bay Br.	13 bridges	Slakou Br.	Ta Khmau II, Prek Ho Br.	1 bridge
Funding		Japan	Japan	Korea	Korea	Japan	Japan	ADB
Design Speed (km/hr)		80	-	-	-	60	60	80
Cross-Section	Carriageway (m)	3.5 x 2	3.5 x 2	3.5 x 2	3.5 x 2	3.5 x 2	3.5 x 2	3.5 x 2
	Shoulder/Motorcycle Lane (m)	2.5 x 2	1.0 x 2	1.0 x 2	1.55 x 2	1.5 x 2	1.5 x 2	1.5 x 2
	Sidewalk (m)	1.0 x 2	-	1.2 x 2	-	1.0 x 2	1.5 x 2	-
	Total (m)	14.0	9.0	11.4	10.1	12.0	13.0	10.0

Table 3.1.3 (b) Typical Bridge Cross-Section Dimensions for On-going Projects

Route No.		NR.6	NR.7	NR.7	NR.48	NR.56	NR.68
Bridges		46 Bridges	12 Bridges	Sekong Br.	4 Bridges	19 Bridges	20 Bridges
Funding		ADB	China	China	Thai	ADB	ADB
Design Speed (km/hr)		80	80	80	-	80	80
Cross-Section	Carriageway (m)	3.5 x 2	3.5 x 2	3.5 x 2	3.5 x 2	3.5 x 2	3.5 x 2
	Shoulder/Motorcycle Lane (m)	1.5 x 2	1.5 x 2	0.75 x 2	1.5 x 2	1.5 x 2	1.5 x 2
	Sidewalk (m)	-	-	0.75 x 2	-	-	-
	Total (m)	10.0	10.0	10.0	10.0	10.0	10.0

Sidewalks or footways are also being provided on bridges in urban areas and near residential areas.

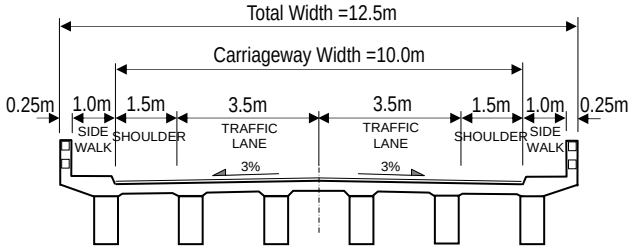
Based on the CBDS and the recent bridge construction trends, the following cross-section dimensions presented in **Table 3.1.4** below and shown in **Figure 3.1.4** are proposed for the bridges:

Table 3.1.4 Proposed Basic Cross-Section Dimensions

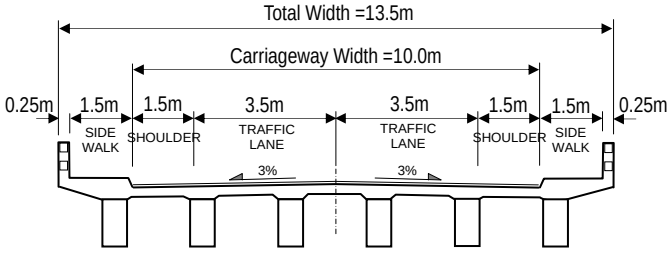
Road Name	No. of Lanes	Bridge Width (m) - **URBAN**				Bridge Width (m) - **RURAL**			
		Traffic Lane	Shoulder/ Motorbike Lane	Side-walk	Total	Traffic Lane	Shoulder/ Motorbike Lane	Side-walk	Total
Urgent Bridges (NR.3, NR.7, NR.11, NR.33)	2	2 @ 3.5	2 @ 1.5	2 @ 1.5	13.0	2 @ 3.5	2 @ 1.5	2 @ 1.0	12.0

Basically, two traffic lanes are provided on the bridge with the same width as the road section. However, the shoulder is narrowed down to 1.5m for motorcycles similar to the newly constructed and on-going bridge projects (although the CBDS requires only 0.5m - 1.0m edge clearance for bridges more than 30m long). This will provide safe and smooth traffic flow on

the bridge. Moreover, sidewalk is provided for bridges in urban areas to protect pedestrians while only the 1-Digit road bridges are provided with 1.0m wide sidewalks in rural areas.



(a) Urgent Bridge Rehab in Rural Areas



(b) Urgent Bridge Rehab in Urban Areas

Figure 3.1.4 Typical Bridge Cross-Sections

6) Design Loads

The design loads shall be based on the CBDS with reference to AASHTO and Japanese Specifications. The design loads for bridges are classified as presented in **Table 3.1.5**.

Table 3.1.5 Design Load Classification

Permanent Load		Transient Load	
1	Structure Dead Load	9	Live Load
2	Superimposed Dead Load	10	Pedestrian Traffic Load
3	Earth Pressure Loads	11	Wind Load
4	Normal Water Flow and Buoyancy	12	Earthquake Load
5	Shrinkage and Creep Effects	13	Flood and Debris Impact Load
6	Prestress Effects	14	Differential Temperature Effects
7	Bearing Friction or Stiffness	15	Bridge Temperature Variation Effects
8	Differential Settlement		

i. Dead Load

The dead load intensities for the different materials are shown in **Table 3.1.6** below.

Table 3.1.6 Dead Load Intensity

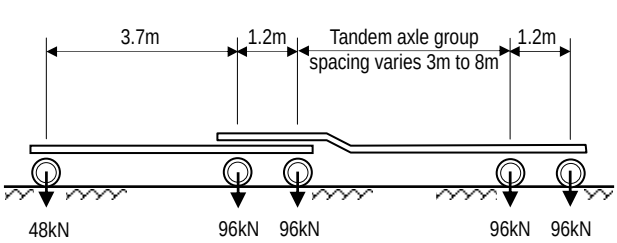
Classification	Item	Unit	Intensity
Dead Load	Aluminum Alloy	kN/m^3	26.7
	Bituminous Wearing Surface, Asphalt	kN/m^3	22.0
	Compacted Earth Filling	kN/m^3	16.0 – 19.0
	Compacted Gravel, Road Material	kN/m^3	19.0 – 23.0
	Concrete (Light Weight)	kN/m^3	12.3 – 19.6
	Concrete	kN/m^3	22.5 – 26.0
	Masonry	kN/m^3	23.5
	Sand – Fine (Dry)	kN/m^3	15.5 – 17.5
	Sand – Coarse (Dry)	kN/m^3	18.0 – 19.5
	Sand (Saturated)	kN/m^3	22.5
	Steel and Other Ferrous Metals	kN/m^3	77.0
	Water, Fresh	kN/m^3	9.8
	Water, Salt	kN/m^3	10.0
Superimposed Dead Load	Wearing Surface, (50 mm thick)	kN/m^2	1.1
	Bridge Parapet	kN/m^3	22.5 – 26.0
	Handrail	kN/m^3	22.5 – 26.0
	Public Utilities	kN/m	None
	Others	kN/m	None

ii. Live Load

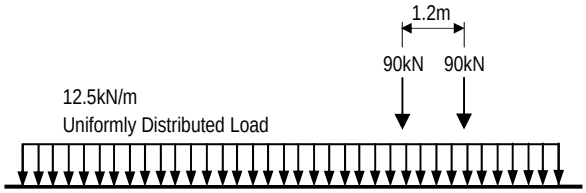
Previous design of bridges in Cambodia utilized different specifications for the design live load (including AASHTO, JRA, AUSTROADS, China, Thailand and other specifications). However, with the issuance of the CBDS in 1999, bridges are required to be designed for the effects of the T44 Truck Loading, the L44 Lane Loading and the Heavy Load Platform (HLP240) loading which are heavier than the previous design live loads.

On the other hand, the Asian Highway Standard stipulates for the design of bridges for the effects of AASHTO HS20-44 loading, which is comparatively lighter than the CBDS requirements.

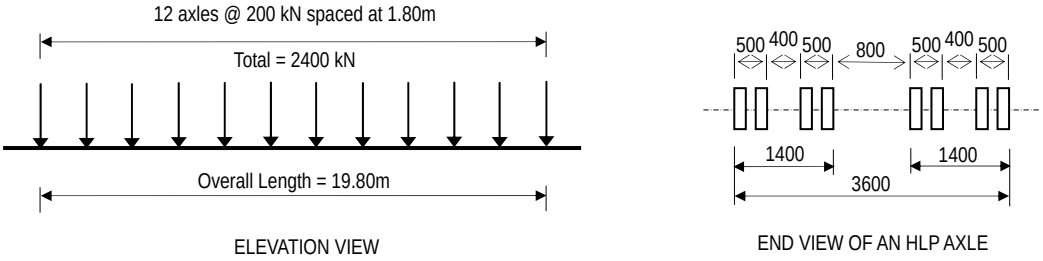
The T44 Truck Loading, the L44 Lane Loading and the Heavy Load Platform (as shown in **Figure 3.1.5**) shall be applied as the design live load in this Study.



(a) T44 Truck Loading



(b) L44 Lane Loading



NOTE: The HLP240 loading shall be assumed to centrally occupy two Standard Design Lanes

(c) Heavy Load Platform Loading (HLP 240)

Figure 3.1.5 Design Live Load

iii. Earthquake Forces

There are no records of seismographs inside Cambodia in the World Earthquake database. Moreover, information gathered in neighboring countries indicates there are no recorder epicenters in Cambodia.

The equivalent quasi-static horizontal earthquake force H (kN) is determined as:

$$H = \alpha IKCS\, W$$

W (kN) is the total gravitational force of the nominal dead load subjected to the acceleration and $\alpha = 0.13$, while the other coefficients *IKCS* are set in the code.

A uniform acceleration coefficient of a = 0.05 is considered appropriate throughout Cambodia.

"As a minimum requirement for conditions prevailing in Cambodia, the ends of the deck at abutments and at piers of simply supported structures shall allow for a minimum 200mm of horizontal displacement additional to displacements calculated for loadings without falling off the edge of the support" (CBDS).

iv. Wind Forces

Design for wind loading is to be based on a static analysis (quasi-static approach) using a design gust wind speed in conjunction with a mean loading coefficient. The methodology of

determining the wind loading is based on the 1992 AUSTROADS Bridge Design Code and the Australian Standard for Wind Loading (AS 1170.2).

v. Thermal Effects

Daily and seasonal fluctuations in air temperature and solar radiation cause both variations in average bridge temperature and differential temperature gradient across structural members. Forces generated from these thermal effects should be considered in the design.

7) Design Properties of Materials

The strengths of material for concrete, reinforcing bars, structural steel and other shall be determined in consideration of the Cambodian standard for materials and strengths and the available materials that have been previously applied to other bridge projects.

A summary of the materials and strengths used in previous projects including ADB, WB, JICA and Japan Grant Aid is presented in **Table 3.1.7** and **Table 3.1.8** which will also be referred to during the basic design in this Study.

Table 3.1.7 List of Materials and Strengths for Concrete used in Bridge Projects

PC Girder	f'_c = 35~42 MPa	Abutment, Piers	f'_c = 24~32 MPa
RC Girder	f'_c = 24~42 MPa	RC Pile (Cast-in Place)	f'_c = 30~32 MPa
RC Slab	f'_c = 24~42 MPa	RC Pile (Precast)	f'_c = 30~32 MPa
Approach Slab	f'_c = 21~24 MPa	Box Culvert	f'_c = 21~32 MPa
RC Hand Rail	f'_c = 21~24 MPa		

Table 3.1.8 Reinforcing Bars and Prestressing Strands used in Bridge Projects

Reinforcing Bars, Deformed	f_y = 400~420 MPa
Reinforcing Bars, Plain	f_y = 240~300 MPa
Prestressing Steel, 7-wire	f_p = 1860 MPa

The Cambodian Bridge Design Code specifies the following strengths:

- Concrete : f'_c = 25, 32, 40 and 50 MPa
- Reinforcing Bars : Plain, f_y = 250 MPa
  Deformed, f_y = 400 MPa
- Prestressing Steel : 7-wire AS1311, f_p = 1750~1860 MPa

To simplify the basic design, reinforced concrete structures shall be designed using concrete compressive strength of f'c = 32MPa while 42MPa shall be used for prestressed concrete members. Reinforcing bars shall have tensile strength of 400MPa.

8) Geotechnical Consideration

Basically, substructure foundations shall be embedded to soil layers with sufficient bearing resistance to support the contemplated loads. Considering the common forms of foundation used in bridge projects in Cambodia, the following bearing capacities shall be used:

- Allowable Bearing Capacity of 400mm x 400mm RC Driven Pile : 500 kN
- Allowable Bearing Capacity of ϕ1000mm RC Cast-in-Place Pile : 2000 kN
- Allowable Bearing Capacity of Spread Footing in Sandstone : *800 - 1000 kPa

*This capacity is assumed since no tests for sandstone was conducted

3.2 Road Design

3.2.1 Existing Road Conditions

Bridges selected for urgent bridge rehabilitation belong to National Roads NR.3, NR.7, NR.11 and NR.33. The existing surface conditions of these roads are generally Double Bituminous Surface Treatment (DBST). The existing conditions of approach roads are given in **Table 3.2.1** and **Figure 3.2.1**.

Table 3.2.1 Existing Conditions of Approach Roads for Bridges

Bridge No.	Road No.	Station	Exsiting Bridge	Existing Conditions of Approach Roads				Remarks
				Cross-Section			Surface Type	
				Traffic Lane (m)	Shoulder (m)	Total Width (m)		
1	3	25+900	Bailey Bridge with Steel Deck	7.0	2@1.5	10.0	DBST	Fair
2	3	105+958	Bailey Bridge with Steel Deck	6.5	2@1.5	9.5	DBST	Fair
3	7	277+130	Bailey Bridge with Timber Deck	7.0	2@1.5	10.0	DBST	Fair
4	11	84+878	Steel I-Girder with Timber Deck	7.0	2@1.0	9.0	DBST	Fair. Dragon/scour holes observed.
5	11	88+048	Steel I-Girder with Timber Deck	7.0	2@1.0	9.0	DBST	Fair. Dragon/scour holes observed.
6	11	89+025	Steel I-Girder with Timber Deck	7.0	2@1.0	9.0	DBST	Fair. Dragon/scour holes observed.
7	11	103+448	Steel I-Girder with Timber Deck	7.0	2@1.0	9.0	DBST	Fair. Dragon/scour holes observed.
8	33	36+524	Bailey Bridge with Steel Deck	7.0	2@1.5	10.0	DBST	Fair


BR1, NR.3 Km 25+900


BR2, NR.3 Km105+958


BR3, NR.7 Km 277+130


BR4, NR.11 Km 84+878


BR5, NR.11 Km 88+048


BR6, NR.11 Km 89+025


BR7, NR.11 Km 103+448


BR8, NR.33 Km 36+524

Figure 3.2.1 Approach Roads for Bridges

3.2.2 Geometric Design

(1) Design of Horizontal Alignment

- As stated in the design concept, the road will generally follow the existing alignment to avoid any adverse socio-environmental effects. As enough space was available for detour during construction, the existing alignments of bridges were retained.
- The alignment design is based on the detailed topographic survey of the area by using total station. Digital Terrain Models (DTM) were prepared for each bridge site from the survey data and were used for the design.
- Generally, the alignments for the approach roads for all the bridges are straight, except for Bridge No.3 on NR.7 where a curve is located near the end.

(2) Design of Vertical Alignment

- Design of profile was based on the profile of existing road created from the prepared Digital Terrain Models.
- Increase in profile grade was done to meet the requirement of free board for the bridge. Vertical curves were designed with the minimum K value of 30 for crest. However, the sag curves at the end of the approach road connecting to the existing road is designed with K value of 15, which corresponds to the design speed of 60 km/hr on existing road.

(3) Design of Cross Sections

- The cross section of approach road has a formation width of 14 m, as required by R5 standard of the Cambodian Road Design Standard. The bridge section has a total paved

width of 10m (3.5m lane width plus 1.5m paved shoulder). Since the approach road is for a short section, it is recommended to provide same 10m paved width as the bridge for traffic safety purposes and additional 1.5m shoulder with granular base/subbase, as shown in the typical cross sections.

- The total length of road improvement is taken as 100m on both sides from the abutment of the bridge, which includes 40m of standard cross section and 60m of taper to match to the existing road, as shown in **Figure 3.2.2**.

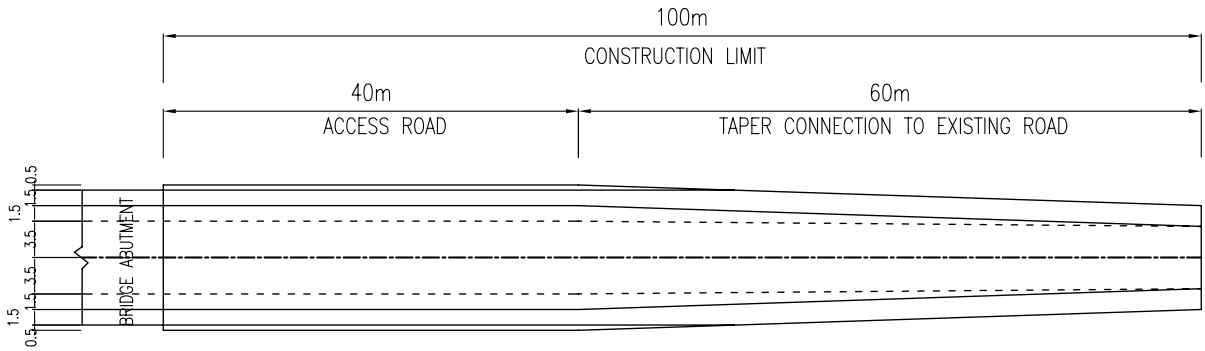


Figure 3.2.2 Construction Limit of Approach Roads

3.2.3 Pavement Design

(1) Traffic Volume and Design Equivalent Single Axle Load (ESAL)

Traffic survey was conducted at each highway of bridge locations.

The performance and analysis periods are taken as 10 years as mentioned in the design criteria. The opening year of improvement is taken as the beginning of year 2011. Traffic forecasts show the results for the years 2010, 2015 and 2020. The growth factors for intermediate years have been calculated from these results. The cumulative total Equivalent Single Axle Load (ESAL) values for 10 years are shown in **Table 3.2.2** for each bridge site. The total values include the total for light and heavy vehicles.

As there was no compiled standard data for axle load for Cambodia, the equivalent single axle factors for light and heavy vehicles are taken as 0.00356 and 1.89 respectively, which are the values applied in the improvement of National Road No.1.

The motorcycle volumes virtually do not contribute to the total design ESAL values and hence are not considered for pavement design.

The Design ESAL values for each bridge site are also shown in **Table 3.2.2**.

(2) Thickness Design

Based on the field survey and laboratory tests at each bridge site, design CBR values were estimated as given in **Table 3.2.3**.

Where the field CBR values are less than or equal 4, replacement of subgrade is necessary to obtain the required Design CBR values. Possibility of using subgrade material of higher CBR shall also be investigated in detail along with more detailed investigation of existing road bed material during detailed design stages.

Table 3.2.2 Cumulative ESAL Values for Each Bridge Site

	Cumulative Total ESAL Values							
	BR1	**BR2**	**BR3**	**BR4**	**BR5**	**BR6**	**BR7**	**BR8**
2011	494874	402950	129128	434465	434465	434465	419854	20331
2012	551623	423218	133284	539869	539869	539869	523891	22562
2013	614883	444505	137574	670845	670845	670845	653710	25039
2014	685400	466862	142002	833600	833600	833600	815699	27790
2015	764008	490345	146573	1035844	1035844	1035844	1017832	30845
2016	858589	551752	150296	1098988	1098988	1098988	1079978	34131
2017	964878	620853	154115	1165985	1165985	1165985	1145922	37768
2018	1084326	698611	158031	1237071	1237071	1237071	1215897	41792
2019	1218560	786111	162047	1312496	1312496	1312496	1290149	46245
2020	1369413	884573	166166	1392525	1392525	1392525	1368942	51172
Both Directions	8606553	5769779	1479216	9721688	9721688	9721688	9531874	337675
Per Lane	5163932	3461867	887530	5833013	5833013	5833013	5719125	202605
Design ESAL	**5.2 million**	**3.5 million**	**0.9 million**	**5.8 million**	**5.8 million**	**5.8 million**	**5.7 million**	**0.2 million**

Table 3.2.3 Estimated CBR for Each Bridge Site

Bridge No.	**Soil Description**	**Field CBR**	**Design CBR**
No.1	Sandy lean clay with N-value of 12. Gravel/Sand content of about 30%.	7	6
No.2	Medium stiff brown and fine sandy lean clay with N-Value of 4 to 7. Sieving size of #200 passed is 73%.	7	6
No.3	Brown, clay, silt & fine sandy lean clay with N-value of 7 to 14, which is part of embankment. Sieving size of #200 passed is 73%.	7	6
No.4	Yellow, brown, and a few fine sandy clay, silt & fine sandy lean clay with N-value of 3, which is part ofembankment. Sieving size of #200 passed is 92%.	4	4 with replacement
No.5	Brown silt, clay & gravel with N-value of 5 to 7, which is part of embankment. Sieving size of #200 passed is 94%.	5	4
No.6	Ditto	5	4
No.7	Brown fine sand fat clay with N-value of 8, which is part of embankment. Sieving size of #200 passed is 98%.	6	4
No.8	Redish brown sand, clay, silt &gravel (laterite) with N-value of 1 to 9, which is part of embankment. Sieving size of #200 passed is 98%.	2	4 with replacement

The material properties of the pavement structures used in the design are given in **Table 3.2.4** based on the Design Criteria and AASHTO charts/equations.

Table 3.2.4 Material Properties of Pavement Layer Materials

Material	CBR	Elastic Modulus (MR)
Subgrade	CBR 4 or 6	6000 or 9000 psi
Aggregate Subbase	CBR≥30	15000 psi
Aggregate Base	CBR≥80	28400 psi
Asphalt Concrete Binder/Surface	--	300000 psi

The required Structural Numbers (SN) and the designed pavement thicknesses for the respective bridge sites are then calculated as given in **Table 3.2.5**.

Table 3.2.5 Designed Pavement Thicknesses for Each Bridge Site

Bridge	Design ESAL (million)	Design CBR (%)	SN	Asphalt Concrete		Base	Subbase
				Surface	Binder		
1	5.2	6	3.91	4 cm	5 cm	25 cm	30 cm
2	3.5	6	3.69	4 cm	5 cm	20 cm	30 cm
3	0.9	6	2.99	4 cm	5 cm	15 cm	20 cm
4	5.8	4	4.56	4 cm	5 cm	30 cm	40 cm
5	5.8	4	4.56	4 cm	5 cm	30 cm	40 cm
6	5.8	4	4.56	4 cm	5 cm	30 cm	40 cm
7	5.7	4	4.55	4 cm	5 cm	30 cm	40 cm
8	0.2	4	2.73	4 cm	5 cm	15 cm	15 cm