CHAPTER 5
ENGINEERING SURVEYS FOR DETAILED DESIGN

5.1 Topographic Survey

Following topographic surveys were undertaken (see Table 5.1-1):

- Topographic survey along the bypass alignment including centerline stake-out, profile survey and cross-section survey
- Bridge site topographic survey
- River profile and cross-section survey
- Interchange / intersection topographic survey
- Access road topographic survey
- Box culvert sites topographic survey

JICA specification for the interval of cross-section survey along the bypass alignment was 50m, whereas, that of DPWH Standard is 20m. It was agreed between DPWH and the JICA Study Team on this matter as follows:

Terrain	Interval of Cross-Section Survey
Flat area	50 m
Rolling area	20 m
Montainous area	20 m

As a result of above agreement, the following interval was adopted:

<u>Plaridel Bypass</u>
- Beginning point to Angat River 50 m
- Angat River to End point 20 m

<u>Cabanatuan Bypass</u>
- All sections 50 m

<u>San Jose Bypass</u>
- All sections 20 m

TABLE 5.1-1 TOPOGRAPHIC SURVEY UNDERTAKEN

			PLARIDEL BYPASS		CABANATUAN BYPASS		SAN JOSE BYPASS	
			Specification	Quantity	Specification	Quantity	Specification	Quantity
A) Bypass Route Survey	Topographic Survey		L=21.09 km, W=100m Scale 1:1000, Contour Interval: 1.00m	210.90 ha.	L=33.851 km, W=100m Scale 1:1000, Contour Interval: 1.00m	338.51 ha	L=7.7 km, W=100m, Scale 1:1000, Contour Interval: 1.0m	77 ha
	Profile Survey		L=21.09 km, 590 Stakes, Centerline Stakes Interval : 50m & 20m, 50m: Sta. 0+600-14+600(beg of Angat), 20m: Sta. 15+700(end of Angat)-21+871,590	21.09 km	L=33.851 km, Centerline Stakes Interval : 50m, 677 Stakes, Scale H = 1:1000, V=1:100	33.851 km	L=7.700 km, Centerline Stakes Interval: 20m, 385 Stakes, Scale H=1:1000, V=1:100	7.7 km
	Cross Section Survey		Interval: 50m, Width : 100m, 281 Sections Interval: 20m, Width : 100m, 309 Sections Scale 1:100	590 sections	Interval: 50m, W=100m, 677 Sections Scale 1:100	677 sections	Interval: 20m, W=100m, 385 Sections Scale 1:100	385 sections
B) Bridge Site Topographic Survey	Topographic Survey		Location : 10 Bridges, length : 1.38 km Width : 200m, Area : 27.6 ha. Scale 1:500	27.6 ha.	Location : 15 Bridges, L=2.158 km, W=200m, Area: 43.158 ha, Scale 1:500	43.158 ha	Location : 2 Bridges, L=0.102 km, W=200m, Area: 2.04ha, Scale 1:500	2.04 ha
C) River Profile and Cross Section Survey	Long Bridge	Profile Survey	Location : 1 Bridge, length : 1.0km each up/ downstream, Scale H=1:1000, V=1:100	2.0 km	Location : 2 Bridge, L = 1.0km each up/ downstream, Scale H=1:1000, V=1:100	4.0 km	N/A	-
		Cross Section Survey	W=1.20km, Interval : 200m, L : 11 sections x 1.20km = 13.20km Scale 1:100	11 sections	W=1.20km, Interval : 200m, L : 11 sections x(1.34+0.36)= 18.70km Scale 1:100	22 sections	N/A	-
	Medium / Short Bridge	Profile Survey	Location : 9 Bridges, Length : 0.4km each up/downstream, L : 0.8x9 = 7.2 km Scale 1: 100	7.2 km	Location : 13 Bridges, Length : 0.4km each up/downstream, L : 0.8x13 = 10.4 km Scale 1: 1000, V = 1:100	10.4 km	Location : 4 Bridges, Length : 0.4km each up/downstream, L : 0.8x4 = 3.2 km Scale 1: 1000	3.2 km
		Cross Section Survey	Width = 60m, Interval : 20m, Total length : 0.06x11 sections x 9 = 5.94 km Scale 1:100	99 sections	Width = 60m, Interval : 20m, Total length : 0.06x11 sections x13=8.58 km Scale 1:100	143 sections	Width = 60m, Interval : 20m, Total length : 0.06x11 sections x4=2.64 km Scale 1:100	44 sections
D) Interchange / Intersection Topography Survey	Interchange		1 Location, L=1.19 km, W=100m, 11.9 has. Scale 1:500	11.9 ha.	N/A	-	N/A	-
	Intersection		Bypass : 12 locations, 1 ha/location (Type A: 9 locations, Type C: 3 locations) New Access int.: 2 locs., Scale 1:500	14 ha.	Bypass : 21 locations, 1 ha/location (Type A: 16 locations, Type C: 5 locations) New Access int.: 1 loc., Scale 1:500	22 ha	Bypass : 8 locations, 1 ha/location (Type A: 7 locations, Type C: 1 location) New Access int.: 2 locs., Scale 1:500	8 ha
	Underpass		11 locations (Type B: 11 locations) Scale 1:500	11 ha.	15 locations, Scale 1:1000 (Type B: 15 locations) Scale 1:500	15 ha	1 location, Scale 1:1000 (Type B 1 location) Scale 1:500	1 ha
E) Access Road Topographic Survey	Topographic Survey		7 Locations (2 new, 5 improvement) Length : 3.28 + 5.0 = 8.28km Improvement: 500m each leg, Width = 40m	33.12 ha.	10 Locations (1 new, 9 improvement) Length : 2.394 + 9.0 = 11.394km Improvement: 500m each leg, Width = 40m	48.58 ha	2 Locations (0 new, 2 improvement) Length : 0 + 2.0 = 2.0 km Width = 40m	8 ha
	Profile Survey		Centerline Stakes Interval : 50m Length : 8.28 km Scale H = 1:1000, V=1:100	8.28 km	Centerline Stakes Interval : 50m Length : 11.394 km Scale H = 1:1000, V=1:100	11.394 km	Centerline Stakes Interval : 50m Length : 2.0 km Scale H = 1:1000, V=1:100	2.0 km
	Cross Section Survey		Interval : 50m, Width : 40m Scale 1:100	166 sections	Interval : 50m, Width : 40m Scale 1:100	228 sections	Interval: 50m, W=40m Scale 1:100	40 sections
F) Culvert Site Topographic Survey	Box Culvert		9 Locations, Area : 1 ha/location Scale 1:500	9 ha.	6 Locations, Area : 1 ha/location Scale 1:500	6 ha	6 Locations, Area : 1 ha/location Scale 1:500	6 ha

5.2 Geo-technical, Soils and Material Sources Survey

1) Geo-technical Survey at Bridge Sites

Geo-technical survey which includes borings, the Standard Penetration Tests (SPT) and corresponding laboratory tests for disturbed and undisturbed samples was undertaken at the proposed bridge sites.

Although DPWH's standard is to undertake the geo-technical survey at every substructure location, JICA specified a total number of borings as 68. Therefore, DPWH standard could not be followed. It was agreed between DPWH and the JICA Study Team that the confirmation borings shall be undertaken by the selected Contractor prior to the start of bridge construction.

Number of borings and drilling length undertaken by this Study are shown in Table 5.2-1.

Characteristics of soil layers along the bypasses are as follows:

- At the depth of 5 to 10 meters from the ground surface, gravel layers which contains cobbles are encountered.
- The gravel layer shows high value of N-value (over 50), which is considered due to the result of hitting cobbles. Therefore, N-value of this layer was judged to show rather higher value than the actual.
- For the design of foundation, above condition was taken into account, i.e., N-value was adjusted.
- For the long span bridge site, additional survey which is the Dynamic Cone Penetration Tests was undertaken to check the depth of bearing layer.

2) Soil Tests along the Bypass Alignment

The cone penetration test (CPT) was undertaken at an average interval of 200m along the bypass alignment. Number fo CPT undertaken was as follows:

	No. of CPT
Plaridel Bypass ----------------	90
Cabanatuan Bypass -------------	158
San Jose Bypass ---------------	39
Total	**287**

3) Material Sources Survey

The borrow material sources were identified and one test pitting per bypass and corresponding laboratory tests were undertaken.

TABLE 5.2-1 NO. OF BOREHOLES AND BOREHOLE DEPTH OF EACH BYPASS

Plaridel Bypass

	Bridge No.	Bridge Length (m)	Borehole No.	Borehole Depth (m)
	Interchange	48.5(2 spans)	BH-25	31.0
			BH-26	32.9
	No.1	48.5(2 spans)	BH-8	12.0
			BH-9	10.9
	No. 2	48.5(2 spans)	BH-10	11.9
			BH-11	10.9
	No. 3	48.5(2 spans)	BH-13	11.8
			BH-12	11.8
	No. 4	48.5(2 spans)	BH-14	14.0
			BH-15	14.9
	No. 5	22.7(1 span)	BH-24	16.7
	No. 6	32.8(3 spans)	BH-16	18.9
			BH-17	12.8
			BH-18	16.8
	No. 7	30.2(1 span)	BH-19	14.7
			BH-20	15.7
	No. 8	1090.7(31 spans)	BH-1	10.7
			BH-2	10.9
			BH-3	12.8
			BH-4	10.9
			BH-5	12.8
			BH-6	13.8
			BH-7	21.7
	No. 9	32.8(3 spans)	BH-21	19.8
	No. 10	39.7(3spans)	BH-22	26.0
			BH-23	26.9
Total	11 Bridges	1,399.2 m	26 holes	424.0 m

Cabanatuan Bypass

Bridge No.	Bridge Length (m)	Borehole No.	Borehole Depth (m)
No.1	38.2(3 spans)	BH-33	15.7
		BH-34	14.5
No. 2	69.7(3 spans)	BH-31	12.7
		BH-32	15.7
No. 3	25.7(1 span)	BH-7	19.9
		BH-35	18.0
No. 4	25.7(1 span)	BH-8	9.9
		BH-9	8.9
No. 5	27.7(1 span)	BH-10	9.0
No. 6	38.2(3 spans)	BH-11	11.9
		BH-36	11.0
No. 7	20.7(1 span)	BH-12	12.9
No. 8	20.7(1 span)	BH-13	10.0
		BH-14	10.9
No. 9	60.7(3 spans)	BH-15	12.8
		BH-16	10.8
		BH-17	15.8
No. 10	1120.7(28 spans)	BH-1	10.5
		BH-2	18.7
		BH-3	13.9
		BH-4	8.9
		BH-5	15.6
		BH-6	10.8
No. 11	38.7(2 spans)	BH-18	14.0
		BH-19	14.0
No. 12	150.7(6 spans)	BH-20	13.7
		BH-21	12.0
		BH-22	10.0
		BH-23	11.9
No. 13	19.7(1 span)	BH-29	25.9
No. 14	20.7(1 span)	BH-28	9.9
		BH-30	8.9
No. 15	360.7(9 spans)	BH-24	32.9
		BH-25	22.9
		BH-26	29.8
		BH-27	25.8
15 Bridges	2,038.5 m	36 holes	530.5 m

San Jose Bypass

Bridge No.	Bridge Length (m)	Borehole No.	Borehole Depth (m)
No. 1	36.7(2 spans)	BH-6	11.9
No. 2	25.7(1 span)	BH-5	14.9
No. 3	66.7(3 spans)	BH-1	5.5
		BH-2	10.6
No. 4	60.7(3 spans)	BH-3	24.8
		BH-4	23.6
4 Bridges	189.8 m	6 holes	91.3 m

CHAPTER 6
HYDROLOGICAL SURVEY AND ANALYSIS

6.1 Procedure of Analysis

The procedure of analysis is shown in Figure 6.1-1.

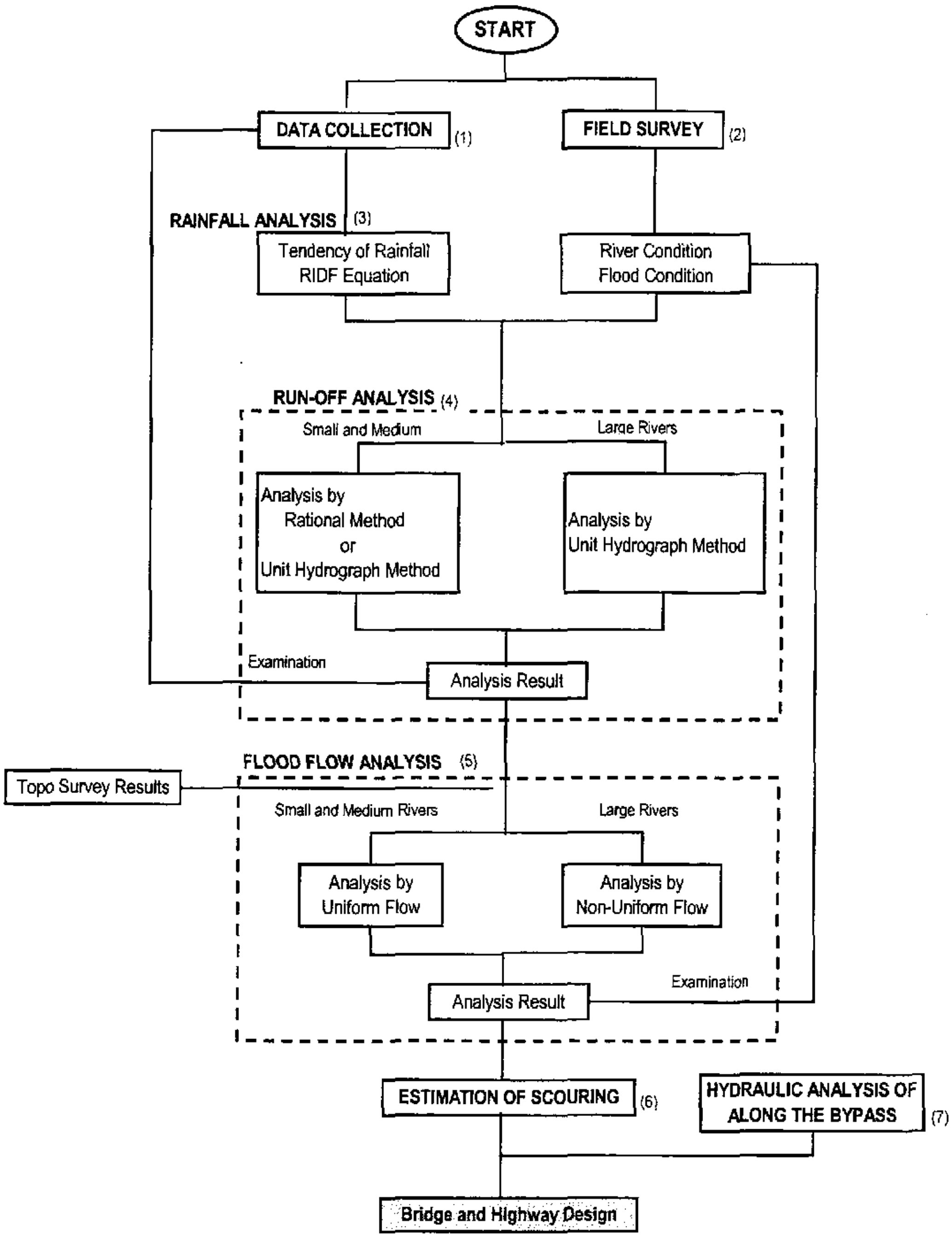


FIGURE 6.1-1 FLOW CHART OF HYDRAULIC AND HYDROLOGICAL ANALYSIS

(1) Data Collection

The data required for the Hydrological and Hydraulic analysis were collected. The collected data were as follows;

Rainfall data in the river basins and vicinity

- Daily rainfall and RIDF data in plain area : 1961-2000
- Annual maximum daily rainfall in mountainous area : 1991-2000
- Summary of typhoons:1971-2000

Data Source: Philippine Atmospheric Geophysical and Astronomical Service Administration (PAGASA).

Data of flow quantity of rivers

- Angat River:1971-1979
- Pampanga River:1971-1979
- Talavera River:1971-1976

Data Source: Philippine Atmospheric Geophysical and Astronomical Service Administration (PAGASA).

Topographical maps

- 1:50,000 map
- 1:250,000 map

Data Source: National Mapping and Resource Information Authority (NAMRIA).

Data on the Dam

- Design flood flow volume of dams
- Capacity curve of water level of dams
- Spillway gate operation rules
- Rainfall data of major typhoons

Data Source: National Irrigation Administration (NIA).

Data on irrigation plan

- Planned waterway location plan
- Parameters of planned waterways

Data Source: National Irrigation Administration (NIA).

Report concerning river planning of Pampanga River

PAMPANGA DELTA DEVELOPMENT PROJECT (1982) by the Japan International Cooperation Agency.

(2) Field Survey

To comprehend the situation of the river and the bridge location and to understand the flood situation along the planed bypasses, the site reconnaissance and field survey was carried out.

The survey items are shown below;

- Survey concerning present condition of rivers (small and medium river)
- Survey concerning river forms in the vicinity of planned bridges (large river)
- Hearing survey concerning past flood condition along each bypass

(3) Rainfall Analysis

The rainfall characteristics was analyzed by using the collected rainfall data. The RIDF (Rainfall Intensity Duration Frequency) equations were prepared by the analysis using the rainfall data in the flat plain area which the data accumulation period is long. The rainfall data of San Jose was so limited in numbers that it was not able to make RIDF equation from the data. As the tendency and the correlation of rainfall in San Jose and Cabanatuan resemble, the RIDF equation of Cabanatuan was adopted for San Jose as well. These RIDF equations were applied to small and medium rivers of which catchment area is within the flat plain area along the bypass.

The rainfalls for the large rivers were analyzed considering the rainfall data in the mountainous area in the eastern part of Central Luzon which belongs to their catchment areas. As the rainfall data compilation work by PAGASA is on the way, the rainfall data of this mountainous area are not yet opened to public. Therefore, rainfall data available were limited. Thus, a high correlation cannot be confirmed for the rainfall in the flat plain area and mountainous area for the reasons that the numbers of rainfall data for mountainous area are significantly few. However, it was able to confirm that the rainfall intensity in mountainous area is higher than that in the flat plain area.

According to the rainfall data of "TYPHOON DITANG in 1992" included in the obtained materials of Pantabangan Dam Plan (Pampanga River) by NIA, rain in the mountainous area is generated on the same day as in the plain area. In addition, it was confirmed that the rainfall in the mountainous area tends to indicate higher values than those in the flat plain area.

Based on above backgrounds, it was decided to reflect the rainfall data of the mountainous area in the RIDF equation for the large rivers of which catchment area includes the mountainous area.

As a reflection technique, the RIDF equation made from the rainfall data in the flat plain area, which has enough numbers of data, was taken as the basic equation and adjustment was made by using the generation ratio of the rainfalls in the plain area and in the mountainous area.

Conclusion of Methodology

RIDF Equation for Small and Medium Rivers	developed from the rainfall data in the flat plain area.
RIDF Equation for Large Rivers	developed from RIDF in the flat plain area with adjustment to reflect the rainfall in the mountainous area.

(4) Run-off Analysis

The run-off analysis of each river was carried out by using the prepared RIDF equation. The following methods for run-off analysis were adopted in accordance with the design standard of DPWH.

RUN-OFF CALCULATION METHOD

CATCHMENT AREA	CALCULATION METHOD
Less than $20km^2$	Rational Method
More than $20km^2$	Unit Hydrograph Method

The run-off analysis was conducted by Unit Hydrograph Method for large rivers of which catchment areas extend over hundreds of square km. Rational Method was applied to other small and medium rivers excluding two medium-scale rivers of which catchment area exceeds $20km^2$.

In the run-off analysis for the large rivers, the flood discharge was calculated by dividing the catchment area into those of branch rivers in order to reflect the flood control function by the dams and to improve the analytical accuracy. The flood discharges at the planned bridge sites were calculated by reflecting the flood discharges of each divided catchment area. In the process, the delay of the flow due to the flowing time required from each divided catchment area to the destination through the river channel was taken into account.

The flood control function was simulated based on the materials of flood control plan of multipurpose dams in Angat River and Pampanga River which has been collected from NIA.

The adequacy of the methodology and the results was verified by comparing the design flood discharge given in the materials of the dam plans.

(5) Flood Flow Analysis

The analysis of the flood flow was carried out based on the flood discharge obtained from the run-off analysis and the results of the topographic survey in order to confirm the flood water level, flow velocity and the range of the flooded area.

Considering the channel conditions of large rivers and other small and medium rivers, the following methodology was used for the flood flow analysis.

Flood Flow Analysis Methodology

Small and Medium Rivers	As the river section shape and the riverbed slope in upstream and downstream are mostly constant, it can be assumed that the flood flow will be generated uniformly in upstream and downstream. Therefore, "Uniform Flow Analysis" which is appropriate for such flow analysis was applied for small and medium rivers.
Large Rivers	As the river cross-sectional shape and riverbed slope are not constant in both upstream and downstream, the flood flow can be assumed to be discontinuous. Moreover, it is necessary to consider the detail flood condition such as influence of back water due to road embankment in the river channel, generating condition of flow velocity at each distinguished location of low waterway and flood plain, etc. Therefore, "Non-uniform Flow Analysis" appropriate for such flow condition was applied for large rivers.

The adequacy of the methodology and the results of the analysis were verified by comparing with flood water levels of 5 to 25 years return period obtained by the hearing survey.

The design water levels for the planned bridges were finally determined by comparing the calculated maximum flood water level and the flood water level in the past obtained by hearing survey. The greater of the two was selected for safety.

(6) Estimation of Scouring

Depth of the maximum scouring of riverbed caused by both normal and flooded stream, and the depth of the local scouring caused by the disorder of local flow in the vicinity of the bridge piers after construction were calculated.

Methodology of the analysis was selected referring technical documents as mentioned below for the computation.

Calculation Method

General Scour : Lacey's Theory
Local Scour : Laursen's Theory, Laursen's Relation

Calculation Method	Descriptions
Lacey's Theory	Method of presuming maximum scouring depth from flood discharge, width of river, and riverbed inclination based on proved data obtained from past experience.
Laursen's Theory	Method of presuming local scouring depth from width, shape, and direction of bridge pier based on proved data obtained from past experience.
Laursen's Relation	Method of presuming maximum scouring depth from shape and angle of pier, flow energy inclination and riverbed material based on proved data obtained from past experience and physical theory.

The depth of the local scouring was determined from both Laursen's Theory and Laursen's Relation, whichever is greater.

(7) Hydraulic analysis along the bypass

The flood analysis for the flood generated in the bypass was carried out to provide the basic materials for the road design.

The analysis was carried out for such places where flood oftenly occurs and hydraulic analysis is required for the bypass road embankment.

- Flood condition in the vicinity of beginning point of Cabanatuan bypass
- Flood condition in the vicinity of San Jose bypass at 157+900

The range of the flooded area, the flood water level and the flood flow velocity obtained from the analysis are used to confirm the adequacy of the bypass road design.

6.2 Number of River Crossings

The main purpose of this study is to examine the flood discharge and water level of each river along the planned bypasses in order to decide the locations of abutments and the span length of the required bridge and the scale of the cross drain facilities.

The numbers of major rivers and waterways crossing the bypasses to be analyzed in the study are shown in Table 6.2-1.

The waterways with comparatively small width not included in the Table are studied separately in the Drainage Design as box or pipe culverts.

TABLE 6.2-1 NUMBER OF RIVERS CROSSING

Bypass Name	Total No. of Rivers	Small and Medium Rivers	Large Rivers
Plaridel Bypass	14	13	1 (Angat River)
Cabanatuan Bypass	16	14	2 (Pampanga/ Talavera Rivers
San Jose Bypass	4	4	0 -

6.3 Analysis Results

6.3.1 RIDF Equation

The rainfall intensity is generally expressed by the equation (1) below. The equation shows the relation between generation intensity and the frequency of the rainfall. Each constant in the equation is obtained by regression analysis using the RIDF data.

RIDF Formula

$$I = A (t + C)^{m} \quad \text{..(1)}$$

where:

I = Rainfall Intensity (mm or mm/hr)
A = Regression Intercept
t = Time of concentration (min)
C = Adjustment factor for best curve fit
m = Slope

(1) Small and Medium Rivers

The rainfall intensity equations adopted for the small and medium river in each bypass are shown in Table 6.3-1.

TABLE 6.3-1 RIDF EQUATION

Return Period (Year)	Plaridel Bypass	Cabanatuan and San Jose Bypasses
100	$2137.6 * (t + 10.0)^{-0.642}$	$2871.7 * (t + 13.61)^{-0.713}$
50	$1908.2 * (t + 10.0)^{-0.643}$	$2595.5 * (t + 13.61)^{-0.715}$
25	$1679.2 * (t + 10.0)^{-0.644}$	$2315.8 * (t + 13.61)^{-0.717}$
10	$1365.4 * (t + 10.0)^{-0.646}$	$1946.2 * (t + 13.61)^{-0.721}$
5	$1117.2 * (t + 10.0)^{-0.647}$	$1644.6 * (t + 13.61)^{-0.725}$
2	$747.7 * (t + 10.0)^{-0.654}$	$1206.1 * (t + 13.61)^{-0.739}$

(2) Large Rivers

RIDF equation for large river is shown in Table 6.3-2. The RIDF equation in the table was prepared by adjusting the basic RIDF equation based on a large numbers of available data of rainfall in the flat plain area by magnifying it with the ratio of rainfall generation in the mountainous area and flat plain area in order to reflect the rainfall effect in the mountainous area.

TABLE 6.3-2 RIDF EQUATION FOR LARGE RIVERS

RIDF Equation Formula

$= M \times A / (t + C)^{m}$

I = Rainfall Intensity (mm/hr)
A = Regression Intercept
t = Time of Concentration (min)
C = Adjustment Factor for Best Curve Fit
m = Slope
M = Magnification Factor

(A, t, C, m: Under B/D)

Item / River Name	Catchment Area	Return Period (year)	Based on B/D RIDF Equation Coefficients A	C	m	Magnification Factor M	Based on D/D RIDF Equation Coefficients M×A	C	m
Angat River	①Dam Area	100	2137.6	10.0	0.642	1.550	3313.4	10.0	0.642
		50	1908.2	10.0	0.643		2957.7	10.0	0.643
		25	1679.2	10.0	0.644		2602.8	10.0	0.644
		10	1365.4	10.0	0.646		2116.4	10.0	0.646
		5	1117.2	10.0	0.647		1731.6	10.0	0.647
		2	747.7	10.0	0.654		1158.9	10.0	0.654
	②Downstream Area	100	2137.6	10.0	0.642	1.200	2565.2	10.0	0.642
		50	1908.2	10.0	0.643		2289.9	10.0	0.643
		25	1679.2	10.0	0.644		2015.0	10.0	0.644
		10	1365.4	10.0	0.646		1638.5	10.0	0.646
		5	1117.2	10.0	0.647		1340.6	10.0	0.647
		2	747.7	10.0	0.654		897.2	10.0	0.654
Pampanga River	①Dam Area	100	2871.7	13.6	0.713	1.000	2871.7	13.6	0.713
		50	2595.5	13.6	0.715		2595.5	13.6	0.715
		25	2315.8	13.6	0.717		2315.8	13.6	0.717
		10	1946.2	13.6	0.721		1946.2	13.6	0.721
		5	1644.6	13.6	0.725		1644.6	13.6	0.725
		2	1206.1	13.6	0.739		1206.1	13.6	0.739
	②Downstream Area of Dam	100	2871.7	13.6	0.713	1.050	3015.3	13.6	0.713
		50	2595.5	13.6	0.715		2725.3	13.6	0.715
		25	2315.8	13.6	0.717		2431.6	13.6	0.717
		10	1946.2	13.6	0.721		2043.5	13.6	0.721
		5	1644.6	13.6	0.725		1726.8	13.6	0.725
		2	1206.1	13.6	0.739		1266.4	13.6	0.739
	③Coronel River Area	100	2871.7	13.6	0.713	1.200	3446.0	13.6	0.713
		50	2595.5	13.6	0.715		3114.6	13.6	0.715
		25	2315.8	13.6	0.717		2779.0	13.6	0.717
		10	1946.2	13.6	0.721		2335.4	13.6	0.721
		5	1644.6	13.6	0.725		1973.5	13.6	0.725
		2	1206.1	13.6	0.739		1447.3	13.6	0.739
	④Downstream Area	100	2871.7	13.6	0.713	1.000	2871.7	13.6	0.713
		50	2595.5	13.6	0.715		2595.5	13.6	0.715
		25	2315.8	13.6	0.717		2315.8	13.6	0.717
		10	1946.2	13.6	0.721		1946.2	13.6	0.721
		5	1644.6	13.6	0.725		1644.6	13.6	0.725
		2	1206.1	13.6	0.739		1206.1	13.6	0.739
Talavera River		100	2871.7	13.6	0.713	1.000	2871.7	13.6	0.713
		50	2595.5	13.6	0.715		2595.5	13.6	0.715
		25	2315.8	13.6	0.717		2315.8	13.6	0.717
		10	1946.2	13.6	0.721		1946.2	13.6	0.721
		5	1644.6	13.6	0.725		1644.6	13.6	0.725
		2	1206.1	13.6	0.739		1206.1	13.6	0.739

6.3.2 Flood Discharge and Design Water Level

(1) Large Rivers

Obtained flood discharges, flood conditions and water levels of each large river for the bridge design are shown in Table 6.3-3. Cross-sections of long bridge sites are shown in Figure 6.3-1.

TABLE 6.3-3 RESULTS OF HYDRAULIC AND HYDROLOGICAL ANALYSIS

River Name	Return Period	Discharge (m^3/sec)	At Proposed Bridge Section		Maximum Flood Water Level By Observation	Recommended Bridge Design Water Level
			Water Level (E.L.+m)	Velocity (m/sec.)	(E.L.+m)	(E.L.+m)
Angat River	100 years	5,460	14.712	0.591	15.3	15.3
	50 years	5,020	14.298	0.573		
	25 years	4,620	13.902	0.555		
	10 years	3,950	13.210	0.523		
	5 years	3,130	12.302	0.478		
Pampanga River	100 years	8,000	31.708	1.500	32.3	32.3
	50 years	6,990	31.306	1.446		
	25 years	6,060	30.954	1.379		
	10 years	4,610	30.318	1.281		
	5 years	3,580	29.797	1.211		
Talavera River	100 years	1,790	44.739	1.901	44.9	44.9
	50 years	1,570	44.499	1.834		
	25 years	1,340	44.239	1.756		
	10 years	1,050	43.857	1.672		
	5 years	810	43.430	1.598		

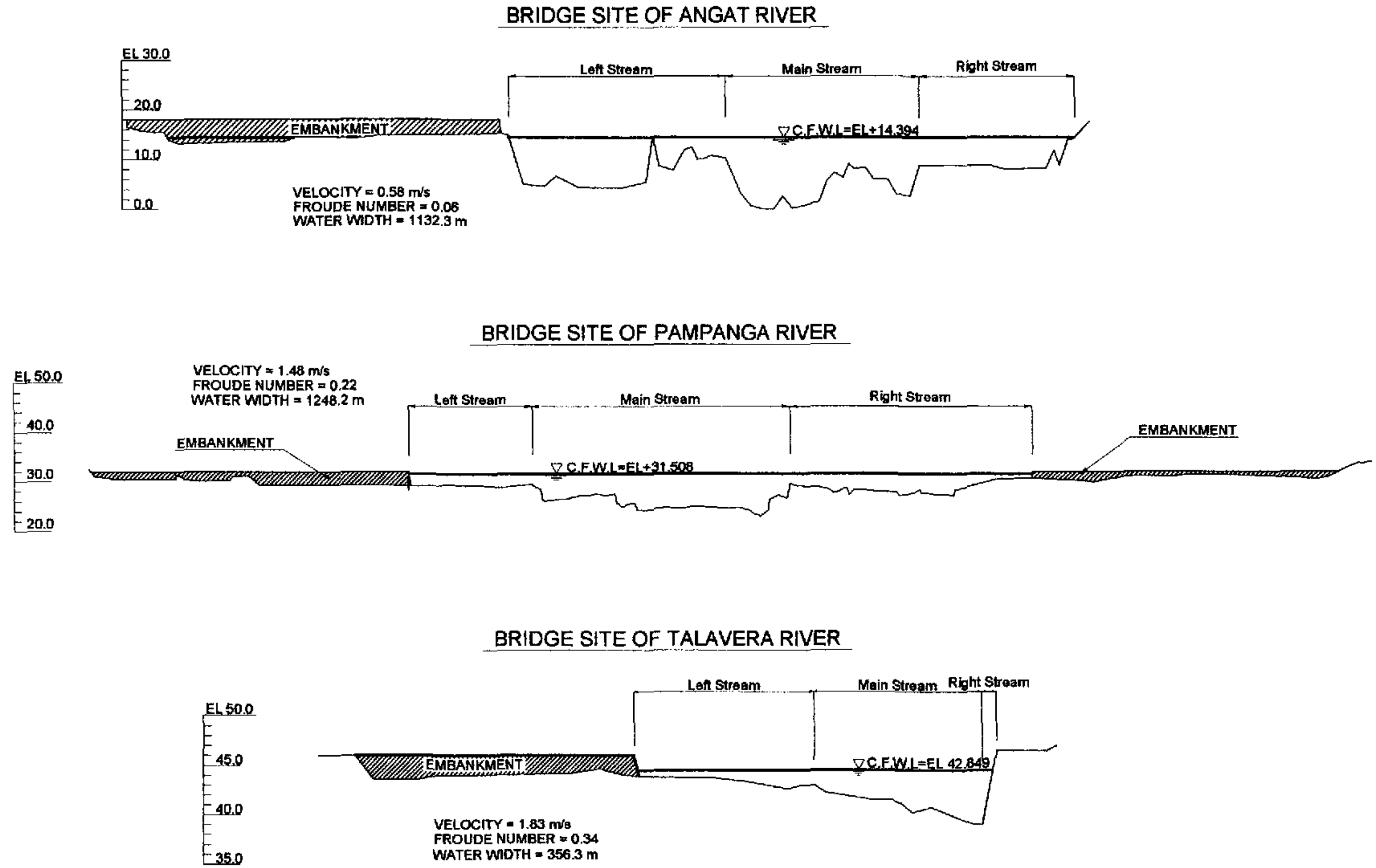


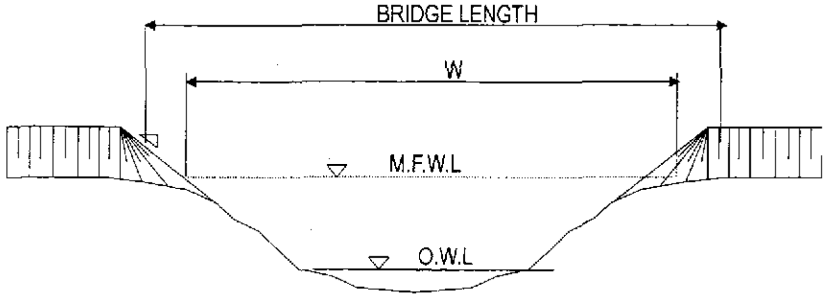
FIGURE 6.3-1 CROSS-SECTION OF BRIDGE SITE

(2) Small and Medium Rivers

The flood discharge and flood water level obtained for each bypass are shown in Table 6.3-4.

TABLE 6.3-4 HYDRAULIC AND HYDROLOGICAL RESULT OF SMALL AND MEDIUM RIVERS

	Bridge Number	Beginning Station	50 - Year Design Hydraulics					River Width, W (m)
			M.F.W.L. from Field Survey	Calculated Flood Elevation	Designed Flood Elevation	Discharge Q (m^3/s)	Velocity V (m/s)	
PLARIDEL	1	40+355.300	9.200	8.857	9.200	125.40	2.700	28.70
	2	41+323.369	10.800	10.728	10.800	124.90	2.800	19.20
	3	41+635.069	11.400	10.500	11.400	IRRIGATION		11.70
	4	41+968.103	11.400	11.041	11.400	109.20	3.620	17.20
	5	45+316.742	14.100	14.658	14.100	85.60	1.300	11.70
	6	45+824.690	15.000	12.700	15.000	IRRIGATION		28.20
	7	46+706.109	17.200	16.477	17.200	14.70	1.160	36.70
	8	48+124.650	15.300	ANGAT RIVER BRIDGE				
	9	49+347.898	16.800	16.329	16.800	119.80	1.920	29.00
	10	50+224.207	16.800	17.058	17.058	101.40	2.130	27.20
CABANATUAN	1	102+925.552	22.800	22.922	22.922	92.70	1.578	41.90
	2	104+998.328	23.700	22.154	23.700	512.80	3.046	44.60
	3	110+672.232	27.400	27.470	27.470	40.60	2.235	30.40
	4	113+177.170	30.700	30.845	30.845	99.70	2.726	16.40
	5	114+076.990	30.900	31.177	31.177	63.40	1.937	12.50
	6	115+304.626	31.100	31.231	31.231	69.00	2.900	17.90
	7	115+790.758	33.700	-	33.700	IRRIGATION		24.40
	8	116+448.026	33.700	33.610	33.700	32.30	2.677	11.40
	9	118+582.028	36.000	33.857	36.000	65.00	2.097	54.90
	10	119+534.178	32.300	PAMPANGA RIVER BRIDGE				
	11	122+359.060	38.400	-	38.400	IRRIGATION		28.60
	12	122+581.666	34.300	34.422	34.422	735.50	4.353	50.30
	13	125+614.096	40.200	39.530	40.200	IRRIGATION		13.00
	14	132+632.444	43.25	TALAVERA RIVER				
SAN JOSE	1	157+454.000	94.800	94.824	94.824	101.80	1.945	26.20
	2	161+374.000	114.800	114.959	114.959	148.10	3.147	27.10
	3	162+222.710	121.700	118.800	118.800	IRRIGATION		21.80
	4	162+782.020	122.700	123.000	123.000	165.00	3.448	35.80



6.3.3 Scouring Depth

The examination of the scouring depth is carried out for large rivers that flood flow will be large and scouring will be critical.

The examination of the scouring in small and medium rivers is reported in the Bridge Design.

Methodology of the analysis was selected referring technical documents as mentioned below and calculated.

General Scouring : Lacey 's Theory
Local Scouring : Laursen 'S Theory and Laursen' s Relation

The river sections with divided segments used for the calculation for large rivers are shown in Figure 6.3-1, and the obtained depths of the scouring are shown in Table 6.3-5.

TABLE 6.3-5 CALCULATED SCOURING DEPTH OF MAJOR RIVERS

Item				River	ANGAT RIVER			PAMPANGA RIVER			TALAVERA RIVER		
					Left Stream	Main Stream	Right Stream	Left Stream	Main Stream	Right Stream	Left Stream	Main Stream	Right Stream
Calculation Parameter	Discharge		Q	(cm/s)	1269.3	3164.3	586.4	464.7	5509.5	1015.8	193.6	1325.4	51
	C.F.W.L.			(E.L.+m)	14.298	14.298	14.298	31.508	31.508	31.508	42.849	42.849	42.849
	Roughness		N		0.06	0.035	0.06	0.055	0.035	0.055	0.05	0.035	0.035
	Water width		W	(m)	432.7	388.3	309.9	320.1	515.7	412.4	177	169	10.3
	Cross Sectional Area		A	(m2)	3113.2	4027.1	1628.5	678.5	2926.8	1227.5	191.8	635.9	28.2
	Slope		S		0.0003	0.0003	0.0003	0.0013	0.0013	0.0013	0.0010	0.0010	0.0010
	Pier Number				14	7	9	3	6	13	5	3	0
	Pier Width				1.5	1.8	1.5	1.5	1.8	1.5	1.5	1.8	1.5
	Clear Bridge Length		L	(m)	401.2	369.4	289.7	313.4	499.5	383.2	165.8	160.9	10.3
	D60		(cm)	(cm)	0.04	0.04	0.04	0.07	1.00	0.07	0.07	1.00	1.00
Calculation Results	General Scour												
		Lacey's Theory		(m)	8.54	11.24	6.53	3.26	8.30	4.63	2.89	7.54	5.55
				(E.L.+m)	5.76	3.06	7.76	28.24	23.21	26.88	39.959	35.309	37.299
	Local Scour												
		Laursen's Theory		(m)	2.25	2.70	2.25	2.25	2.70	2.25	2.25	2.70	2.25
		Laursen's Relation		*(m)*	2.30	2.63	2.09	1.55	2.09	1.69	1.08	1.89	1.76
		Recommended Depth		(m)	2.50	3.00	2.50	2.50	3.00	2.50	2.50	3.00	2.50

6.3.4 Flood Conditions at Beginning Point of Cabanatuan Bypass

(1) Present Flood Conditions

Traffic on the existing Pan-Philippine Highway near the beginning section of Cabanatuan Bypass has been suffering floods from swollen Pampanga River with about five (5) years period.

Discharge of Pampanga River is 7,200 m^3/s, and that of overflow from Pampanga River is 470 and that of Tambo Creek is 81.7 with a return period of 25 years.

(2) Phenomena of Floods

The Barangay Road between Pampanga River and the Pan-Philippine Highway has functioned as a dam or weir as shown in Figure 6.3-2 below. The depth of overflow water at the Barangay Road is about 1.35m. After overflowing the Barangay Road, the rate of overflow water is decreasing rapidly because of the configuration features of inland. The elevation of inland area is becoming higher toward eastside.

Inflow from Pampanga River goes on until the flood level balances with the water level of Pampanga River or the level of Pampanga River dike at elevation of about 23.9m. This elevation is almost equal to that of the existing ground surface along the beginning section of the bypass, excluding the section close to the beginning point. The depth of floods along the bypass beginning section is roughly 50cm. This explains that the bypass alignment almost avoids the deep flood area and that flood area between the existing Pan-Philippine Highway and the bypass becomes a kind of pond because flood water is intercepted by the Barangay Road. After balancing with the water level of Pampanga River, flood water of the pond returns to Pampanga River through Tambo Creek little by little.

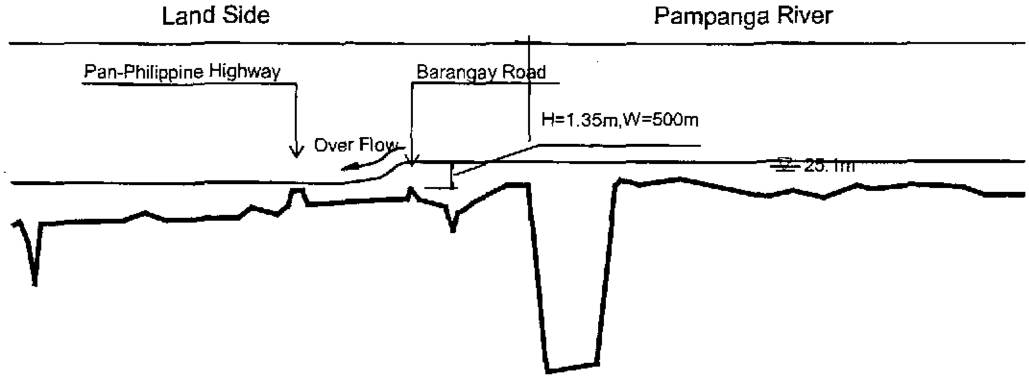


FIGURE 6.3-2 PAMPANGA RIVER OVERFLOW

(3) Conclusion

Based on the phenomena mentioned above cross drainage plan against floods shall be done; namely:

- To consider in the cross drainage design floods from Tambo Creek and other small streams.
- the existing Pan-Philippine Highway at the beginning point has not been covered with floodwater. This explains that the bypass can be connected with Maharlika Highway without raising the existing highway surface.
- the flood area only becomes a pond. This requires no slope protection works against floods because they don't have water flow rate.

PART IV

DETAILED DESIGN

CHAPTER 7

PROJECT OBJECTIVES AND DESIGN POLICY

7.1 Objectives of the Project

Problems of the existing Pan-Philippine Highway are discussed in Chapter 2. This bypass construction project basically aims at elimination of such problems and to provide better transport facility for the sound development of the project area and the country as a whole.

Objectives of the Project are as follows:

1) To restore the road function of the Pan-Philippine Highway which is the most important arterial road in the country,
2) To provide fast, safe, comfortable and reliable means of transportation,
3). To mitigate serious traffic congestion of existing urban sections,
4) To improve urban environment and amenity of the project areas,
5) To guide sound urbanization of the project areas, and
6) To support socio-economic development of the influence areas.

7.2 Design Policies

In order to achieve above project objectives, the following design polices are established:

- Mobility oriented highway design
- Provisions for future urbanization along the bypass
- Optimum utilization of the bypass (or to attract enough traffic to the bypass)
- Appropriate measures for local traffic and its convenience
- Appropriate measures for divided communities and agricultural lands by the bypass
- Preservation of the environment
- Traffic safety
- Minimal adverse social impacts

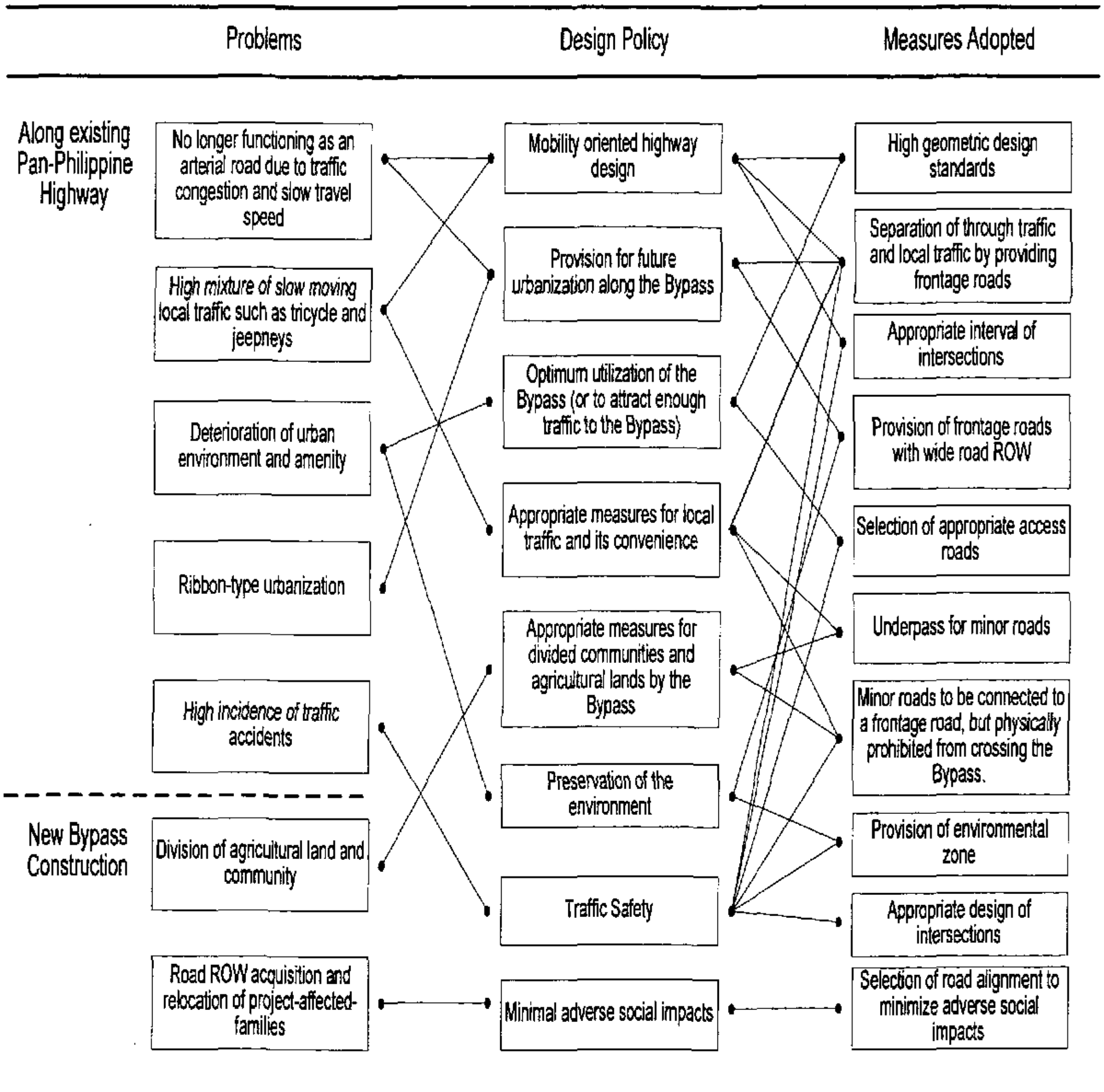
Design policies are achieved by adopting the following measures:

- To adopt high geometric design standards
- To separate through traffic from local traffic by providing frontage roads.
- To provide appropriate interval (distance) between intersections
- To provide frontage roads with wide road ROW
- To select appropriate access roads, and when necessary provide new access roads
- To provide underpass for minor roads
- To prohibit local traffic to cross the bypass by connecting minor roads with only the frontage road, but not with the bypass main carriageway

- To provide environmental zone between the bypass main carriageway and frontage roads
- To design intersections focusing on traffic safety
- To select road alignment which realizes the minimal adverse social impacts

Table 7.1-1 shows inter-relation between problems and design policy as well as measures adopted in the design.

TABLE 7.1-1 HIGHWAY DESIGN POLICY



7.3 Stage Construction

7.3.1 Construction Stages

In view of the scale of the Project, traffic demand forecast and the budgetary framework of DPWH, the Project was recommended to be implemented by stages in the Feasibility Study as follows:

Initial Stage : Construction of a 2-lane bypass

Ultimate Stage : Widening of a 2-lane bypass to a 4-lane bypass

Road right-of-way was recommended to be acquired for the width of 4-lane at the initial stage to prohibit any development within the road right-of-way required for the ultimate stage.

7.3.2 Initial Stage Construction

1) Alternative Schemes

The alternative scheme study was undertaken to determine what portion of the Ultimate Stage in terms of cross-section component be constructed at the Initial Stage in due consideration of the following:

a) Minimization of demolition of Initial Stage works during Ultimate Stage construction
b) Safe and easy construction during Ultimate Stage construction
c) Traffic mobility and safety during the operation period from Initial Stage to Ultimate Stage
d) Avoidance of squatters sheltering in the acquired road ROW which remains unutilized until Ultimate Stage construction starts.

Four alternatives were prepared as follows (see Figure 7.3-1):

Alternative-1 : To construct one direction of Ultimate Stage to achieve a), b) and c) above.

Alternative-2 : To construct outer one lane of each direction of Ultimate Stage to mainly achieve d) above.

Alternative-3 : To construct 2-lane at the middle of road ROW to mainly achieve c) above.

Alternative-4 : To construct frontage roads for the section with frontage roads and outer one lane of each direction of Ultimate Stage to mainly achieve d) above.

A plan of each alternative is shown in Figure 7.3-2 to 5.

Type of Cross-Section by Alternative (Cabanatuan Bypass)

Alternative	Type of Cross-Section (km)					Total
	Type-1	Type-2	Type-3	Type-4	Transition	
1	28.20	-	-	-	-	28.20
2	12.00	11.72	-	-	4.48	28.20
3	12.70	-	11.30	-	4.20	28.20
4	6.60	-	4.07	14.73	2.80	28.20

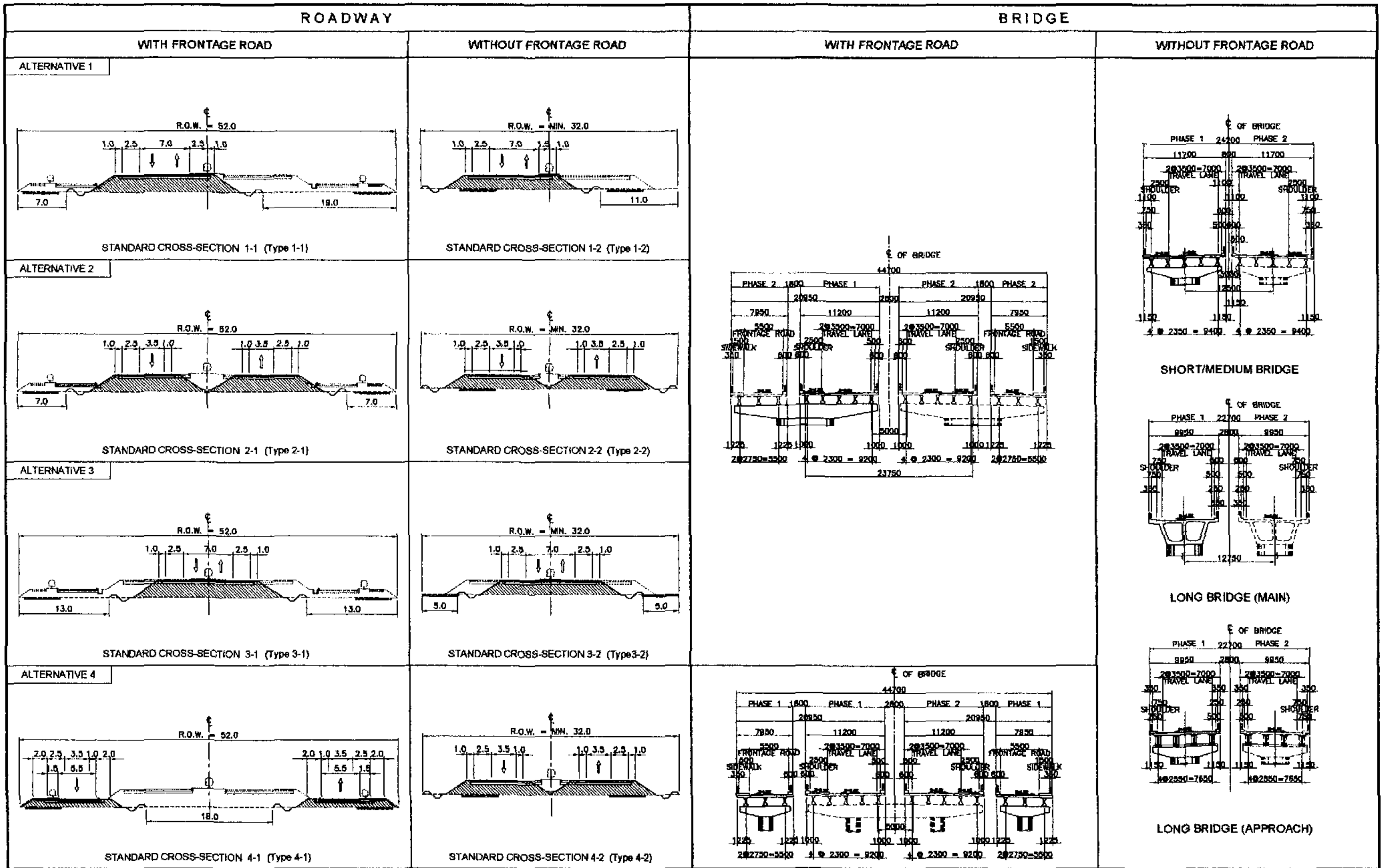


FIGURE 7.3-1 ALTERNATIVE STANDARD CROSS-SECTIONS FOR STAGE 1 (CABANATUAN BYPASS)

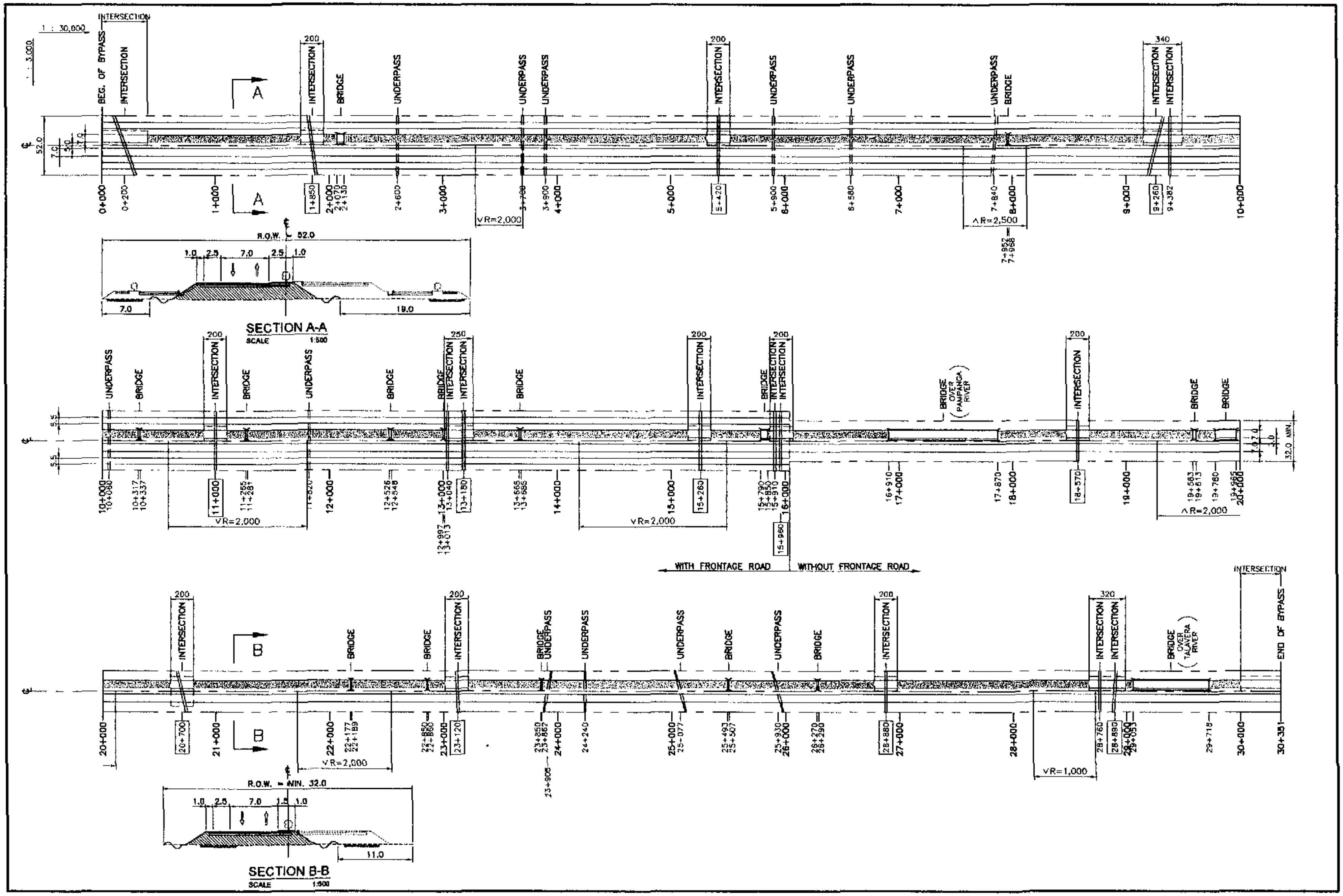


FIGURE 7.3-2 ALTERNATIVE 1 (CABANATUAN BYPASS)

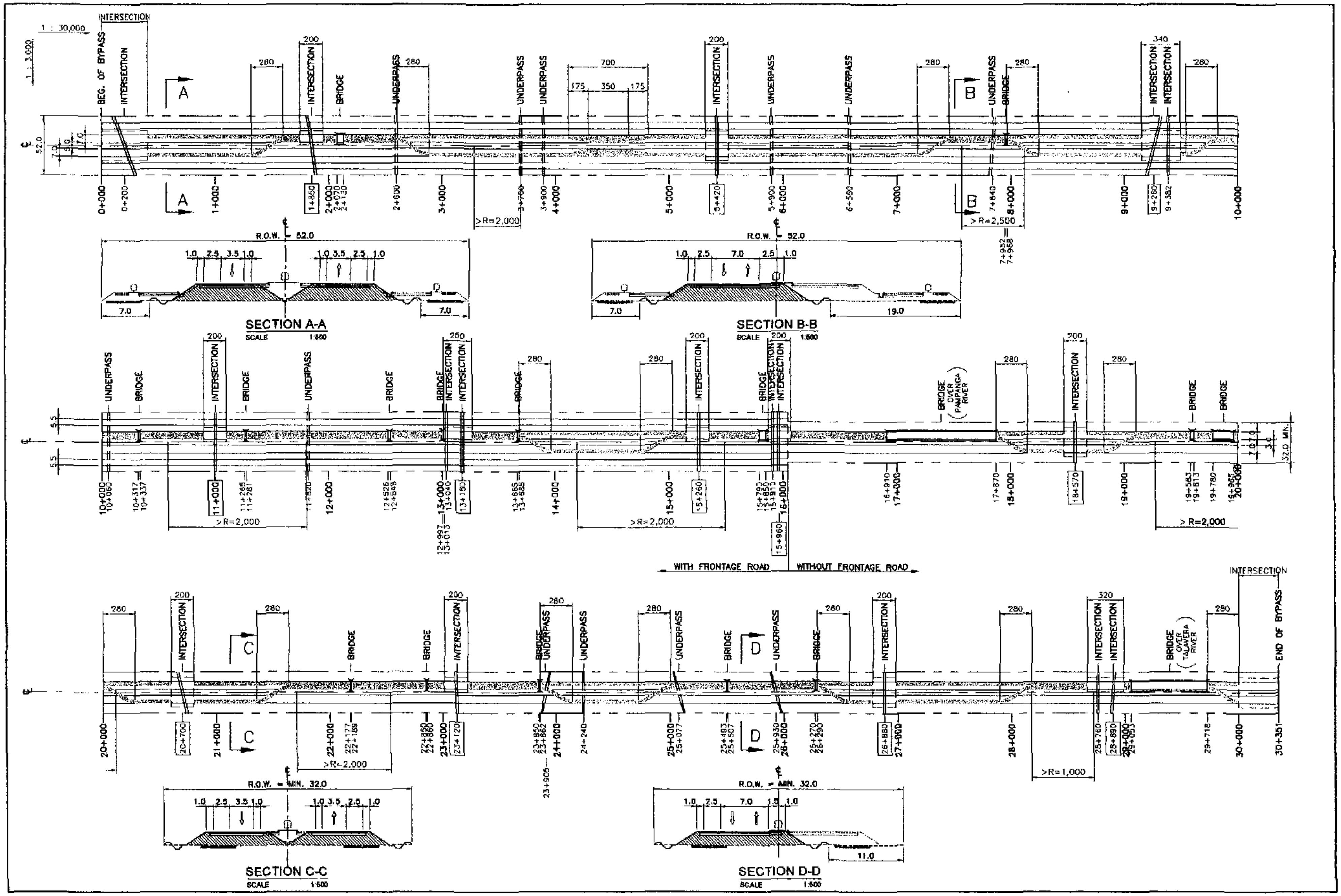


FIGURE 7.3-3 ALTERNATIVE 2 (CABANATUAN BYPASS)

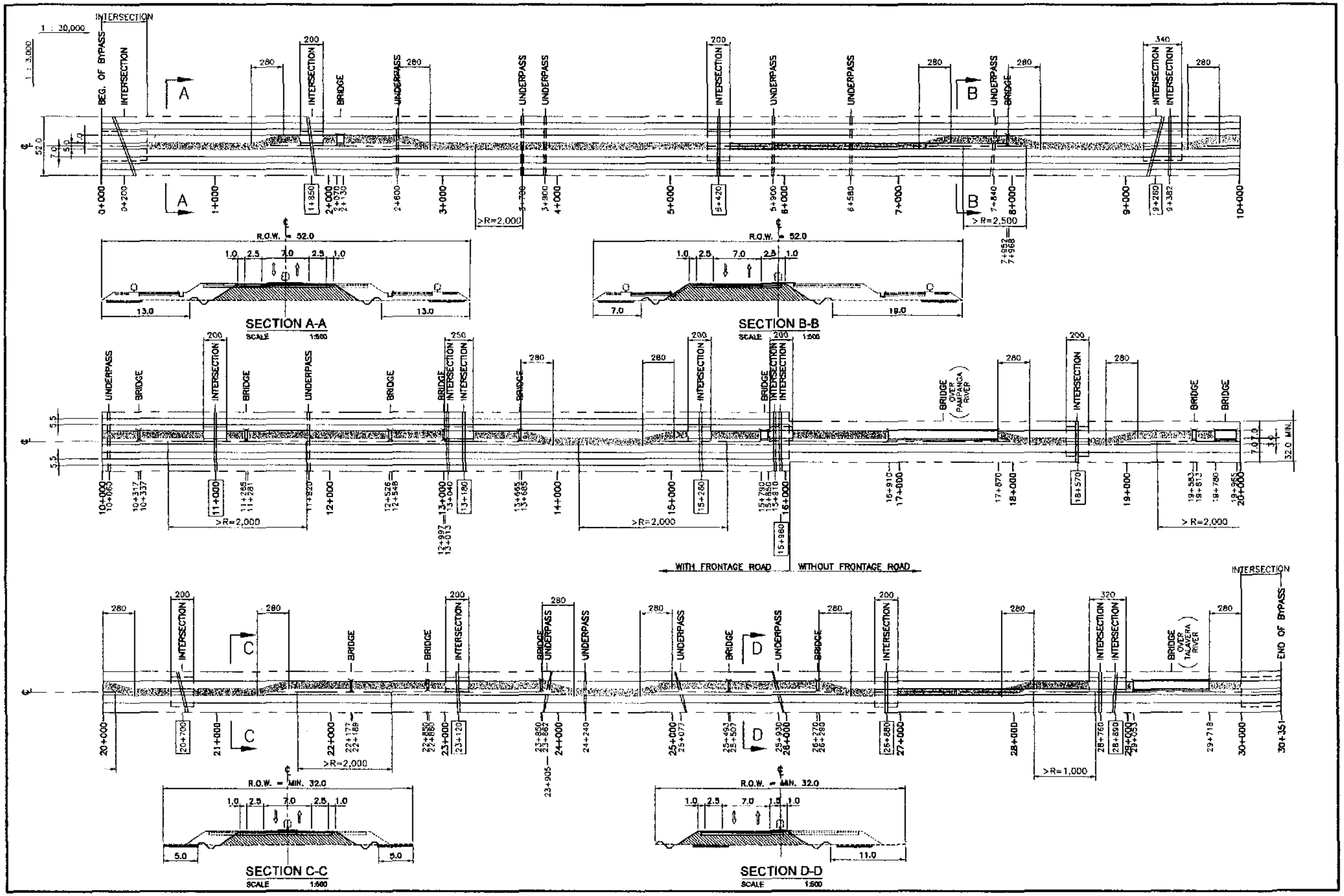


FIGURE 7.3-4 ALTERNATIVE 3 (CABANATUAN BYPASS)

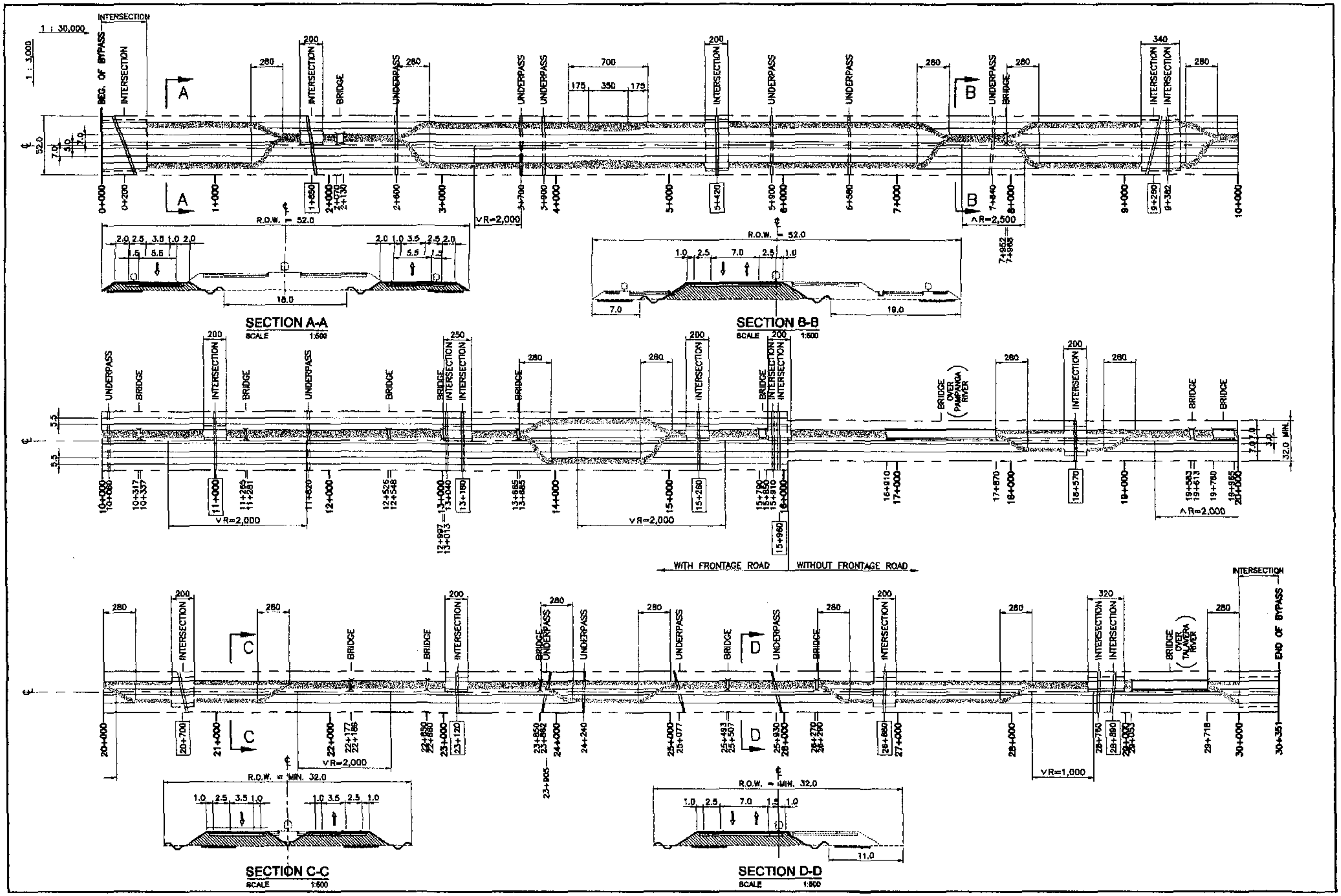


FIGURE 7.3-5 ALTERNATIVE 4 (CABANATUAN BYPASS)

2) Countermeasures against Squatters Sheltering in the Acquired Road ROW

The Study Team obtained various ways of avoiding squatters from DPWH Regional / District Offices, DPWH counterparts, LGU's staff and local consultants as shown below:

a) To provide a fence along the ROW perimeters

b) To provide warning / information signs such as "RESTRICTED AREA, GOVERNMENT PROPERTY", etc.

c) To plant shrubs in a vacant area

d) To allow farmers to continue cultivation. Compensation cost shall be paid only when construction starts

e) To provide watchman to patrol the area

f) To avail a vacant area for public use such as playground, part, etc.

g) To provide backfill to delineate ROW limits

h) To plant fast growing trees (such as Gemulina) with an agreement with barangay associations and/or NGO's

i) To involve DPWH District Office staff during construction supervision so that they can monitor the area after construction

j) To utilize the area as drainage canal

k) Strict monitoring and enforcement by LGU's

l) Strict enforcement of the Anti-squatting law

m) Adoption of City / Municipal Ordinances that ensure non-intrusion of persons and animals within ROW except on properly designated areas

n) Concerned City / Municipalities to adopt resolution citing classification of lands within ROW as non-residential. DPWH should officially request concerned City / Municipality to create and pass such ordinance

3) Evaluation of Alternatives

All alternatives were evaluated based on the following criteria:

Factors Adopted	Weight
• Construction difficulty and safety	5
• Stage I facilities not utilized in Stage II	5
• Traffic function	5
• Construction Cost	5
• Roadside development opportunity	5
• Possibility of illegal occupancy	5
	30

Evaluation Criteria

a) Construction difficulty and safety

Overall evaluation is rated as follows:

Easy	5 points
Medium	3 points
Difficult	1 point

b) Stage I facilities not utilized in Stage II

Evaluated by waste cost of Stage I work

Waste Cost (Million P)	Points
0 – 25	5
26 – 50	4
51 – 75	3
76 – 100	2
over 100	1

c) Traffic Function

Evaluated by overall evaluation

Good	5 points
Fair	4 points
Bad	3 points

d) Construction Cost

Evaluated by total cost (Stage I & Stage II)

Additional Cost Compared to the Lowest	Points
0 – 25 MP	5
26 – 50 MP	4
51 – 75 MP	3
76 – 100 MP	2
over 100 MP	1

e) Roadside Development Opportunity

High	:	5 points
Medium	:	4 points
Low	:	3 points

f) Possibility of Illegal Occupancy

Low	:	5 points
Medium	:	3 points
High	:	1 point

Evaluation result is shown in Table 7.3-1.

TABLE 7.3-1 EVALUATION OF SCHEMES FOR STAGE CONSTRUCTION (CABANATUAN BYPASS)

Evaluation Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
1. Construction Difficulty / Safety	.			
a) Working space	➢ W = 13 m, 25 m, one side free.	➢ W = 2 @ 14 m, one side free. W = 8 m, both sides restricted.	➢ W = 2 @ 19 m, one side free. W = 9 m, one side free.	➢ W = 28 m, both sides restricted. W = 8 m, both sides restricted.
b) Material and Equipment Handling / Accessibility to Working Area.	➢ Easy. Can access from all roads.	➢ Difficult. Cannot access from all roads. Access is via bypass.	➢ Easy. Can access from all roads.	➢ Difficult. Cannot access from all roads. Access is via bypass.
c) Necessity of barrier.	➢ Set barrier along working area.	➢ Needs more stable barrier along working area.	➢ Needs more stable barrier along working area.	➢ Needs stronger barrier to protect against spillage of materials.
- Height between Carriageway and Working Area.	➢ Same or lower	➢ Same or lower.	➢ Same or lower.	➢ Working area is higher than Carriageway.
d) Necessity for a narrower paved carriageway.	➢ No need to narrow.	➢ D = 1.5 m to be narrowed	➢ D = 1.5 m to be narrowed.	➢ No need to narrow, but overtaking lane cannot be used.
Overall evaluation.	➢ Easy.	➢ Difficult.	➢ Difficult.	➢ Medium.
Relative Weight = 5	5	1	1	4
2. Stage 1 Facilities not utilized in Stage 2.				
a) Carriageway, Shoulder and Median.	➢ Sub-base in shoulder.	➢ Sub-base in shoulder. Pavement and Sub-base in transition section (4.48 km).	➢ Sub-base in shoulder. Pavement and Sub-base in median and transition section (4.20km).	➢ Sub-base in shoulder. Pavement and Sub-base in transition section (2.80km) and overtaking lane.
b) Drainage	—	➢ Temporary drainage at the middle.	—	➢ Temporary drainage at the middle.
c) Embankment Slope Protection (Sodding)	➢ Sodding on one side.	➢ Sodding on two sides.	➢ Sodding on two sides.	➢ Sodding on two sides.
d) Waste Cost of Stage 1 Works (Million PhP)	➢ P15M.	➢ P31M.	➢ P82M	➢ P35M.
Relative Weight = 5	5	4	2	4
3. Traffic Function				
a) Overtaking	➢ Any section, OK.	➢ Limited section only.	➢ Any section, OK.	➢ Limited section only.
b) Friction with Local Traffic (Tricycle, Jeepney, etc.)	➢ Low.	➢ Medium.	➢ Low.	➢ High (Local traffic will enter in a carriageway).
c) Safety (Divided or Not)	➢ Not divided.	➢ Not divided sections (43%), Divided sections (57%).	➢ Not divided.	➢ Not divided sections (23%), Divided sections (77%).
d) Traffic Movement at Intersections.	➢ One (1) intersection/intersection.	➢ One (1) intersection/intersection.	➢ One (1) intersection/intersection.	➢ Two (2) intersections/intersection.
e) Driving Comfort.	➢ Provides continuity and sufficient sight distance.	➢ Limited continuity. Minimum passing sight distance.	➢ Provides continuity and sufficient sight distance.	➢ Limited continuity. Minimum passing sight distance.
Overall Evaluation	➢ Good.	➢ Fair.	➢ Good.	➢ Bad.
Relative Weight = 5	5	4	5	3
4. Construction Cost (Million PhP)				
Total Cost	4,131 (0)	4,156 (25	4,230 (99)	4,223 (92)
a) Construction Cost for Stage 1.	1,747 (0)	1,840 (93)	1,747 (0)	1,936 (189)
b) Construction Cost for Stage 2.	2,384 (0)	2,316 (-68)	2,483 (99)	2,287 (-97
Relative Weight = 5	5	4	2	2
5. Roadside Development Opportunity	➢ Low	➢ Medium	➢ Low	➢ High
Relative Weight = 5	3	4	3	5
6. Possibility of Illegal Occupancy	➢ High	➢ Medium	➢ High	➢ Low
Relative Weight = 5	1	3	1	5
Total Evaluation Criteria = 30	24	20	14	23
Rank	1	3	4	2

Evaluation

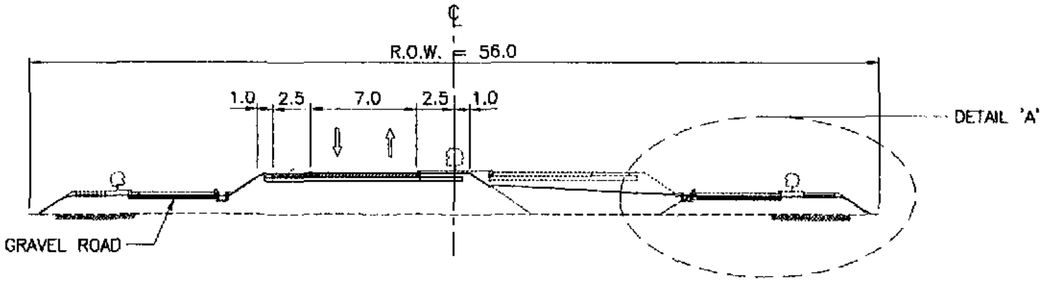
Alternative 1 obtained the highest score followed by Alternative 4. Alternative 4 is superior to Alternative 1 on the following factors:

- Roadside development opportunity
- Possibility of illegal occupancy

One solution to improve Alternative 1 on these factors is to construct low standard gravel surface frontage road for agricultural and local traffic use along the Bypass as shown in Figure 7.3-6.

It was recommended that Alternative 1 with gravel surface frontage road be adopted for the Project.

It was also recommended that DPWH with close coordination with concerned LGUs takes all possible measures to avoid squatting within the acquired road right-of-way.



SECTION WITH FRONTAGE ROAD
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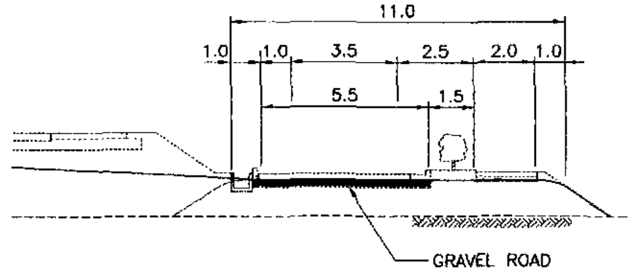

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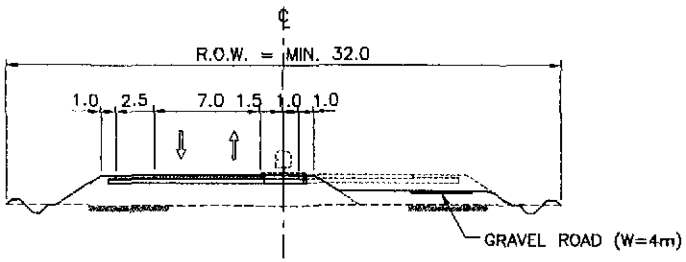

SECTION WITHOUT FRONTAGE ROAD
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FIGURE 7.3-6 ALTERNATIVE-1 WITH GRAVEL ROAD

CHAPTER 8
DESIGN CRITERIA AND STANDARDS

8.1 Highway Design

The highway design was carried out based on the following criteria and standards:

- DESIGN Guidelines Criteria and Standards for Public Works and Highways, VOLUME – II
- A Policy on Geometric Design of Highways and Streets, 1996 (AASHTO)
- Highway Capacity Manual, Special Report, Transportation Research Board 1997 (TRB)
- Road Structure Ordinance, Japan Road Association, 1983 (JRA)

This study basically followed the standards of the Philippines, however, in case that there were some lacking items or, from the standpoint of economic considerations, the appropriate standards were established by referring to other provisions.

Table 8.1-1 and 8.1-2 gives the geometric design criteria for the bypasses and new access roads, respectively. The points of the design are as follows:

- All the bypasses have a design speed of 80 km/h, new access roads and frontage roads have 60 and 50 km/h, respectively.
- The width of a through lane of the bypasses is 3.5m. Frontage roads of Plaridel, Cabanatuan and San Jose Bypasses have 6.5m, 6.5m and 4.0m in width respectively with one-way traffic.
- Center median of Plaridel Bypass and Cabanatuan Bypass has 3.0m in width throughout the bypass.
- Frontage roads of Plaridel and Cabanatuan Bypasses are exclusive for local traffic and to avoid them to utilize the main bypass carriageways. Frontage roads of San Jose Bypass are exclusive roads for small/slow vehicles such as tricycles and bikes.
- The design will be carried out giving priority to through traffic and avoiding local traffic to enter onto main carriageways of the bypass.
- Underpass boxes are to be provided for the sections where the bypass disconnects communities and agricultural activities over 0.5 km in length.

TABLE 8.1-1 GEOMETRIC DESIGN CRITERIA FOR BYPASSES

DESIGN ELEMENTS/PARAMETERS			UNIT	BYPASS ROAD						REMARKS
				Plaridel Bypass		Cabanatuan Bypass		San Jose Bypass		
				Main Bypass	Frontage Road	Main Bypass	Frontage Road	Main Bypass	Bike/Tricycle Road	
DESIGN SPEED			kph	80	50	80	50	80	50	Phil. Standard
ALIGNMENT ELEMENTS										
HORIZONTAL ALIGNMENT	Minimum Radius	Alignment	m	360	80	360	80	360	80	AASHTO
	Minimum Sight Distance	Stopping	m	100	60	100	60	100	60	Phil. Standard
		Passing	m	560	340	560	340	560	340	Phil. Standard
	Maximum Superelevation Rate		%	8	8	8	8	8	8	AASHTO
	Sharpest Curve without Superelevation		m	3,500	1,110	3,500	1,110	3,500	1,110	AASHTO, JRA (Japan Road Association)
VERTICAL ALIGNMENT	Maximum Grade		%	4	6	4	6	4	6	AASHTO
	Minimum Grade		%	0.50 (0.20)	0.35	0.50	0.35	0.50	0.35	Phil. Standard
	Vertical Curve	Min. Crest Radius	m	4800	1000	4800	1000	4800	1000	AASHTO (Upper Range)
		Min. Sag Radius	m	3200	1200	3200	1200	3200	1200	AASHTO (Upper Range)
CROSS SECTION ELEMENTS:										
Lane	Width		m	3.50	6.00	3.50	6.00	3.50	3.50	Phil. Standard
	Cross Slope		%	2.0	1.5	2.0	1.5	2.0	1.5	AASHTO, Phil. Standard
Median	Width		m	3.00	-	3.00 & 5.00	-	0.5*	-	AASHTO, JRA
	Offset/Side Clearance		m	0.50	-	0.50	-	0	-	AASHTO, JRA
Shoulder	Width		m	2.50	-	2.50	-	2.50	-	AASHTO, JRA
	Cross Slope		%	2.5	-	2.5	-	2.5	-	AASHTO, JRA
Sidewalk	Width		m	-	2.00	-	2.00	-	2.00	AASHTO, JRA
	Cross Slope		%	-	1.5	-	1.5	-	1.5	AASHTO, JRA
VERTICAL ELEVATION CONTROLS:										
Vertical Clearance	Bypass		m	5.0	-	5.0	-	5.0	-	Phil. Standard
	Underpass** (Box)		m	4.4	-	4.4	-	4.4	-	for Irrigation Maintenance Road**
			m	2.5	-	2.5	-	2.5	-	for Farm Access
DESIGN TRAFFIC VOLUME:										
Design Year			Year	2020	-	2020	-	2020	-	
DesignTraffic Volume			pcupd	42,999	-	36,531	-	22,457	-	
Number of Lanes & Target Years	Y2005		N	2	-	2	-	2	-	
	Y2020		N	4	-	4	-	2	-	

Notes:

* To provide pavement markings in parallel with a distance of 0.5m.

** To provide basically at-grade intersection for Crossing only.

Figure in ( ) shows absolute minimum value to be used only when the condition necessitate.

TABLE 8.1-2 GEOMETRIC DESIGN CRITERIA FOR NEW ACCESS ROADS

DESIGN ELEMENTS/PARAMETERS			UNIT	Plaridel New Access Road	Cabanatuan New Access Road	San Jose New Access Road	REMARKS
DESIGN SPEED			kph	60	60	60	Phil. Standard
ALIGNMENT ELEMENTS							
HORIZONTAL ALIGNMENT	Minimum Radius	Alignment	m	125	125	125	AASHTO Table III-6
	Minimum Sight Distance	Stopping	m	80	80	80	AASHTO Table III-1
		Passing	m	407	407	407	AASHTO Table III-5
	Maximum Superelevation Rate		%	8	8	8	AASHTO
	Sharpest Curve without Superelevation		m	1520	1520	1520	AASHTO Table III-12
VERTICAL ALIGNMENT	Maximum Grade		%	6	6	6	AASHTO
	Minimum Grade		%	0.50 (0.35)	0.50 (0.35)	0.50 (0.35)	Phil Standard
	Vertical Curve	Min. Crest Radius	m	1400	1400	1400	AASHTO (Lower Range)
		Min. Sag Radius	m	1500	1500	1500	AASHTO (Lower Range)
CROSS SECTION ELEMENTS:							
Lane	Width		m	3.35	3.35	3.05	Phil. Standard, JRA
	Cross Slope		%	1.5	1.5	1.5	Phil. Standard, JRA
Median	Width		m	1.00	1.00	1.00	Phil. Standard, JRA
	Offset/Side Clearance		m	0.30	0.30	0.30	Phil. Standard, JRA
Shoulder	Width		m	1.50	1.50	1.50	Phil. Standard, JRA
	Cross Slope		%	3.0	3.0	3.0	Phil. Standard, JRA
Sidewalk	Width		m	2.00	2.00	2.00	Phil. Standard, JRA
	Cross Slope		%	1.5	1.5	1.5	Phil. Standard, JRA

Note:

Figure in ( ) shows absolute minimum value to be used only when the condition necessitate

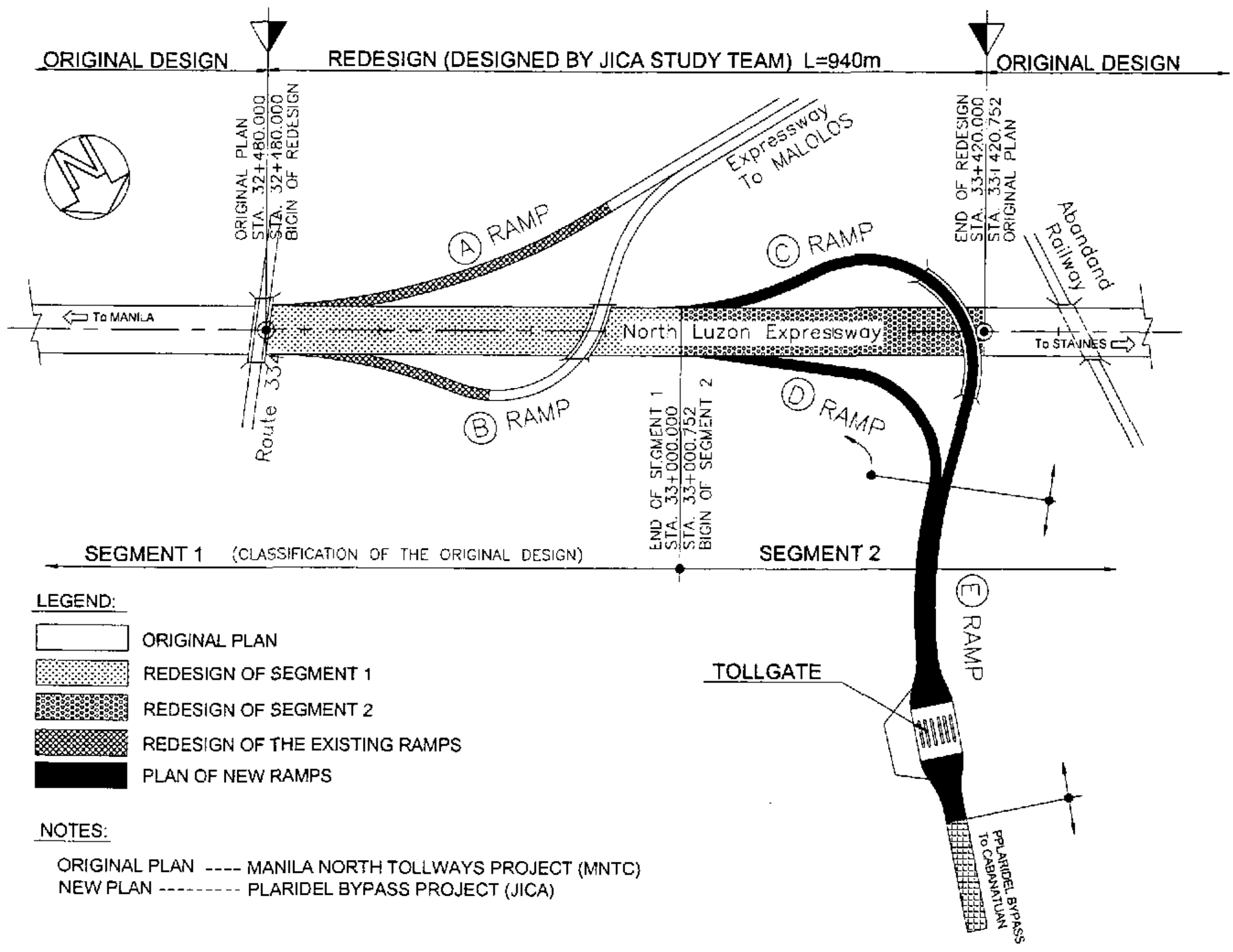
8.2 Interchange Design

8.2.1 General

The Plaridel Bypass diverts from the North Luzon Expressway (NLE), which is being maintained and operated by PNCC and MNTC (Manila North Tollways Corporation).

The NLE is planned to be widened from the existing 4 lanes to 8 lanes in the section between Manila and Burol Interchange and to 6 lanes in the Northern section from the Burol Interchange. In order to connect the ramps of the Plaridel Bypass to NLE, future widening of NLE must be taken into account. As shown in the Figure 8.2-1 below, the interchange design consists of the design of new ramps C and D and the redesign of the NLE including the ramps A and B.

Design and geometrical criteria of PNCC/MNTC was basically adopted. Design standard, for ramp terminal and toll gate were based on AASHTO and JHPC (Japan Highway Public Corp.).



KEY PLAN

FIGURE 8.2-1 PLAN OF BUROL INTERCHANGE

8.2.2 Geometric Design Standard

Geometric Design Standard for NLE and ramps are shown in Tables 8.2-1 and 8.2-2

TABLE 8.2-1 GEOMETRIC DESIGN STANDARD FOR THROUGHWAY NEARBY THE INTERCHANGE ON NLE

Item	Unit	Standard for Throughway on NLE	Adopted Value for Burol Interchange		Remarks
			NLE/Expressway to Malolos	NLE/Plaridel Bypass	
Design Speed	km/h	100	100	100	
Number of Lane	-	8-lane (6-lane)	8-Lane	8-Lane (6-Lane)	
Lane Width	m	3.50 (3.60)	3.50	3.50	( ): Existing
Outer Shoulder	m	2.40	0.60	0.60, 3.00	
Median Width	m	6.00 (13.20)	3.00	3.00 ~ 6.00	( ): Existing
(Medial Strip)	m	4.80 (12.00)	0.67	0.67 ~ 4.80	( ): Existing
(Inner Shoulder)	m	0.60	1.165	1.165 ~ 0.60	
Crossfall of Pavement	%	2.50	2.50	2.50	
Crossfall of Outer Shoulder	%	2.50	2.50	2.50	
Type of Pavement	-	PCCP	PCCP	PCCP	
Maximum Superelevation Rate	%	6.0	2.5	2.5	
Minimum Radius	m	1500 (1000)	∞	10,000	( ): absolute value
Maximum Gradient	%	2.0 (3.0)	0.599	2.360	( ): absolute value
Stopping Sight Distance	m	160	-	-	
Minimum Vertical Curve Length	m	85	80		
Minimum Horizontal Curve Length	m	1200/θ (170)	-	-	( ): absolute value
Minimum Transition Curve Length	m	85	-	-	
Minimum Radius for Curves not Requiring Transition Curves	m	3,000	-	-	
Minimum Radius for Curves not Requiring Superelevation	m	6,000	-	-	
Minimum Relative Slopes					
· between Profile of Edge of Multi Lane Pavement & Center Line	-	1/150			
Value of Superelevation on Curvature		4%			
Combined Gradient	%	10.0	2.6	3.4	
Vertical Clearance Limit	m	4.47 (4.90)	4.47	* 5.10	*: 4.9+0.2 0.2(Overlay)

TABLE 8.2-2 GEOMETRIC DESIGN STANDARD FOR RAMPS

Item		Unit	Standard for Ramps	Adopted for Ramps of Burol Interchange		Remarks
				A and B Ramps	C and D Ramps	
Design Speed		km/h	40	40	40	
1- way, 2-lane	Lane Width	m	3.50	3.50	3.50	
	Outer Shoulder	m	2.00	2.00	2.00	
	Inner Shoulder	m	1.00	1.00	1.00	
2- way, 2-lane	Lane Width	m	3.50	3.50	3.50	
	Outer Shoulder	m	2.50 (1.50)	2.00	2.00	
	Median Width	m	2.50 (2.00)	2.00	2.50	
	(Medial Strip)	m	1.50 (1.0)	0.670	1.50	
	(Inner Shoulder)	m	0.50	0.665	0.50	
Crossfall of Pavement		%	2.00	2.00	2.00	
Crossfall of Outer Shoulder		%	2.00	2.00	2.00	
Type of Pavement		-	PCC Pavement	PCC Pavement	PCC Pavement	
Maximum Superelevation Rate		%	10.0	6.0	7.0	
Minimum Radius		m	50 (40)	150	100	( ): absolute value
Maximum Gradient		%	6.0 (8.0)	6.0	6.0	( ): absolute value
Stopping Sight Distance		m	40	-	40	
Minimum Vertical Curve Length		m	35	-	80	
Minimum Horizontal Curve Length		m	$500/\theta$ (70)	-		( ): absolute value
Minimum Transition Curve Length		m	35	-		
Minimum Radius for Curves not Requiring Transition Curves		m	140	-		
Minimum Radius for Curves not Requiring Superelevation		m	800	-		
Minimum Relative Slopes						
· between Profile of Edge of Multi Lane Pavement & Center Line		-	1/100			
Value of Superelevation on Curvature			4%			
Combined Gradient		%	11.5			
Vertical Clearance Limit		m	4.47 (4.90)	4.47	* 5.10	*: 4.9+0.2 0.2(Overlay)

8.3 Intersection Design

The intersection design was carried out based on the following criteria and standards:

- DESIGN Guidelines Criteria and Standards for Public Works and Highways VOLUME – II
- A Policy on Geometric Design of Highways and Streets, AASHTO, 1996
- Highway Capacity Manual, Special Report, Transportation Research Board (TRB), 1997
- Road Structure Ordinance, Japan Road Association (JRA), 1983
- The Planning and Design of At-Grade Intersections, Japan Society of Traffic Engineers (JSTE), 1988

Geometric design criteria for intersections are given in Table 8.3-1 by the class of crossing roads. For maintenance roads along irrigation canals, appropriate openings will be provided for maintenance/agricultural vehicles crossing the bypasses, which was accepted by the National Irrigation Administration (NIA).

The bypasses have three (3) intersecting types as shown in Figure 8.3-1 and 8.3-2; Type-A, Type-B and Type-C. The features of each intersection type are as follows:

Type-A: At-Grade Intersection

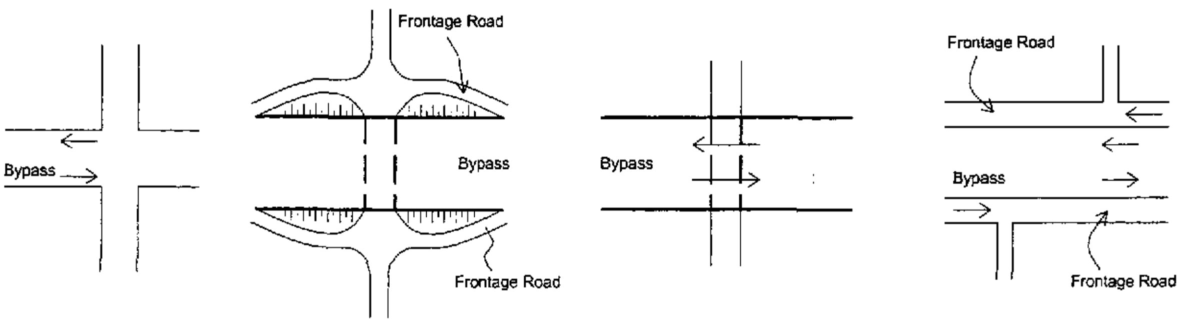
- Major at-grade intersection for the bypass with national/provincial road.
- Minor at-grade intersection for the bypass with barangay road.
- Medium opening for NIA irrigation maintenance roads.

Type-B: Underpass

- To provide this type for the sections where the bypass disconnects community/agricultural activities for over 0.5km.

Type-C: Access to only Frontage Roads

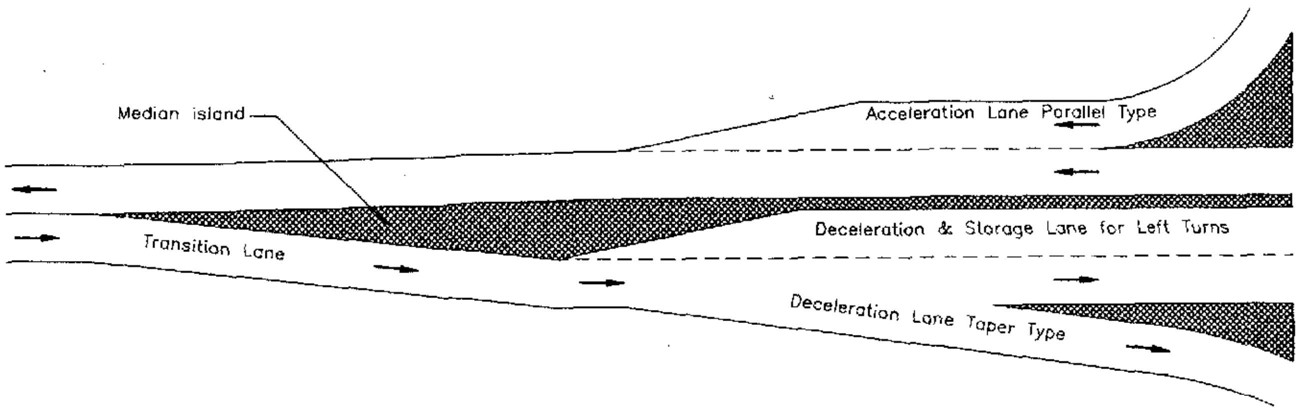
- Direct access to the bypasses is not allowed.
- To be provided for minor roads intersecting the bypasses in consideration of the existing local road network.



Type - A (At Grade) Type - B : Underpass (with Frontage Road) Type - B : Underpass (without Frontage Road) Type - C (Only Access to Frontage Road)

FIGURE 8.3-1 INTERSECTING TYPES

TABLE 8.3-1 GEOMETRIC DESIGN CRITERIA FOR INTERSECTIONS



DESIGN ELEMENTS/PARAMETERS		UNIT	INTERSECTION			REMARKS
			Bypasses	National / Prov'l Roads	Minor Roads	
MAIN ROAD ELEMENTS	Design Speed	kph	80 (60)	60 (50)	40	Values in parentheses are reduced speed approaching inter-section
	Minimum Radius	m	150	100	60	for reduced speed
	Maximum Superelevation Rate	%	4	4	4	AASHTO (Table III-7)
	Minimum Visibility Distance for Traffic Signal	m	170	130	100	for reduced speed ; (JSTE)
	Minimum Length of level section at the Intersection approach	m	40	35	15	(JSTE)
	Maximum Vertical Grade at Intersection Approach	%	2.5	2.5	2.5	(JSTE)
	Storage Length	m	60	60	-	30m. minimum storage length, Phil Std.
	Minimum Storage Lane Width	m	3.00	3.00	-	Phil. Standard
	Minimum Transition Length	m	60	60	-	(JSTE)
	Minimum Taper Length	m	45	30	-	for auxillary lane-storage
	Deceleration Length (including taper)	m	105	70	-	Phil. Standard
	Acceleration Length (including taper)	m	145	85	-	Phil. Standard
TURNING ELEMENTS	Design Vehicle		WB - 15	WB - 15	SU	AASHTO; WB - 15 (Semi-Trailer) ; SU (Single-Unit Truck)
	Design (Turning) Speed	kph	15	15	15	AASHTO
	Minimum Turning Radius (inner edge)	m	15	15	8.5	AASHTO (Table III-20)
	Width of Turning Lane	m	6.00	6.00	-	AASHTO (Table III-20) no provision of passing stalled vehicles

Note : JSTE - Japan Society of Traffic Engineers

- Type of Intersection
  - Type A: At-grade Intersection
    - Major At-grade Intersection
      - Intersecting roads are national and provincial roads and important barangay roads from the viewpoints of road network
      - Left / right turn lanes and divisional islands are to be provided *for intersecting roads*
    - Minor At-grade Intersection
      - Intersecting roads are barangay roads for community and agricultural land access
      - Shared lane without divisional island for intersecting road
    - Opening for crossing only
      - Only for farmers crossing or NIA irrigation canal maintenance road
      - Provide center-median opening
  - Type B: Underpass Box
    - For Vehicular traffic
      - Vertical clearance = 4.4m
    - For Pedestrian / farmers crossing
      - Vertical clearance = 2.5m
  - Type C: Access to the frontage road only.
    - Access to main carriageway of the bypass not allowed. Intersecting roads are minor community roads.

FIGURE 8.3-2 TYPE OF INTERSECTION

8.4 Pavement Design

The design of pavement structure was carried out based on the following guidelines:

- AASHTO GUIDE For Design of Pavement Structure, 1993 (AASHTO Guide)
- DESIGN Guidelines Criteria and Standards for Public Works and Highways, Volume II, BOD

The best pavement structures for the bypasses were selected through the Life-Cycle-Cost Analysis (LCCA). Design requirements used in LCCA for rigid (PCC) and flexible (AC) pavements are summarized in Table 8.4-1.

Major design requirements are as follows:

(1) Equivalent Single Axle Loads (ESAL)

The design procedure for all highways is based on cumulative expected 18-kip equivalent single axle loads (ESAL) during the analysis period (W18), which procedures converts mixed traffic into these 18-kip ESAL units.

The following equation was used to determine the Design ESAL (W_{18}) in the design lane which is for the outer lane of 4-lane carriageway.

$$W_{18} = D_D \times D_l \times \widehat{W}_{18}$$

Where:

D_D = a directional distribution factor (=0.5)
D_L = a lane distribution factor (=0.70; outer lane)

$\widehat{W}_{18}$ = the predicted cumulative two-directional 18-kip ESAL units
= $AADT \times 365 \times T_f \times ESALF$
AADT = an annual average daily traffic
T_f = a traffic growth factor
= $\dfrac{(1 + i/100)^n - 1}{i/100}$
i = a traffic growth rate (%)
n = analysis period (years)
ESALF = an equivalent single axle load factor
Bus load factor = 1.0
Truck load factor = 3.2
(The above load factors are from the F/S)

Design ESAL

Figure 8.4-1 shows the design ESAL for the design lane. The Plaridel and Cabanatuan Bypasses were divided into two sections based on the traffic volume projected under the F/S, namely, before and after the Angat River and the Pampanga River.

TABLE 8.4-1 DESIGN REQUIREMENTS

Category	Description
a. Design Variable	
a.1 Time Constraints	
• Performance Period	Life of Initial Pavement Structure
• Analysis Period	Planned Stage Construction; 25 years
a.2 Traffic Loading	W_{18} = 18-kip Equivalent Single Axle Load (ESAL) Application Traffic Loading Classes; 6 classes (A to E)
a.3 Reliability	Z_R = 50% So = 0.3~0.4 for Standard Error, not considered
a.4 Environmental Impact	
• Roadbed Swelling	PSIsw = Loss of PSI; not considered
b. Performance Criteria	
b.1 Time Constraints	PSI = Po - Pt = P0 - Δ PSIw - Δ PSIsw (Δ PSIsw ; not considered)
c. Material Properties for Structural Design	
c.1 Effective Roadbed Soil Resilient Modulus (Flexible)	MR (pci); estimated based on CBR = 5%
c.2 Effective Modulus of Subgrade Reaction (Rigid)	K-Value(pci); estimated based on CBR and subbase thickness
c.3 Pavement Layer Materials Characterization	E_{SB} = Modulus of Subbase (13,000 psi) E_{BS} = Modulus of Base (23,000 psi) E_{AC} = Modulus of Asphalt Concrete (350,000 psi) Ec = Modulus of Elasticity of PCC (3.28×10^6 psi)
c.4 PCC Modulus of Rupture (Rigid) (Flexural Strength)	S'c = Estimated Mean Value for PCC Modulus of Rupture (psi); 580 psi
c.5 Structural Layer Coefficient (Flexible)	Asphalt Concrete Layer Coefficient ; 0.39 Bitumen Stabilized ; 0.2 Crushed Gravel Base ; 0.105 Subbase ; 0.095
d. Pavement Structural Characteristics	
d.1 Drainage	Flexible m = Layer Coefficient Modifying Factor; 1.0 Rigid CD = Drainage Coefficient; 1.0
d.2 Load Transfer (Rigid)	
• Jointed Pavement	
• Tied Shoulder or Widened Outside Lane	J = Load Transfer Coefficient; 3.8 (United Shoulder)
d.3 Loss of Support (Rigid)	LS = Loss of Support 1.0~3.0 for unbounded granular materials 2.0~3.0 for fine granular or natural subgrade materials 0~1.0 for cement Treated Granular Base

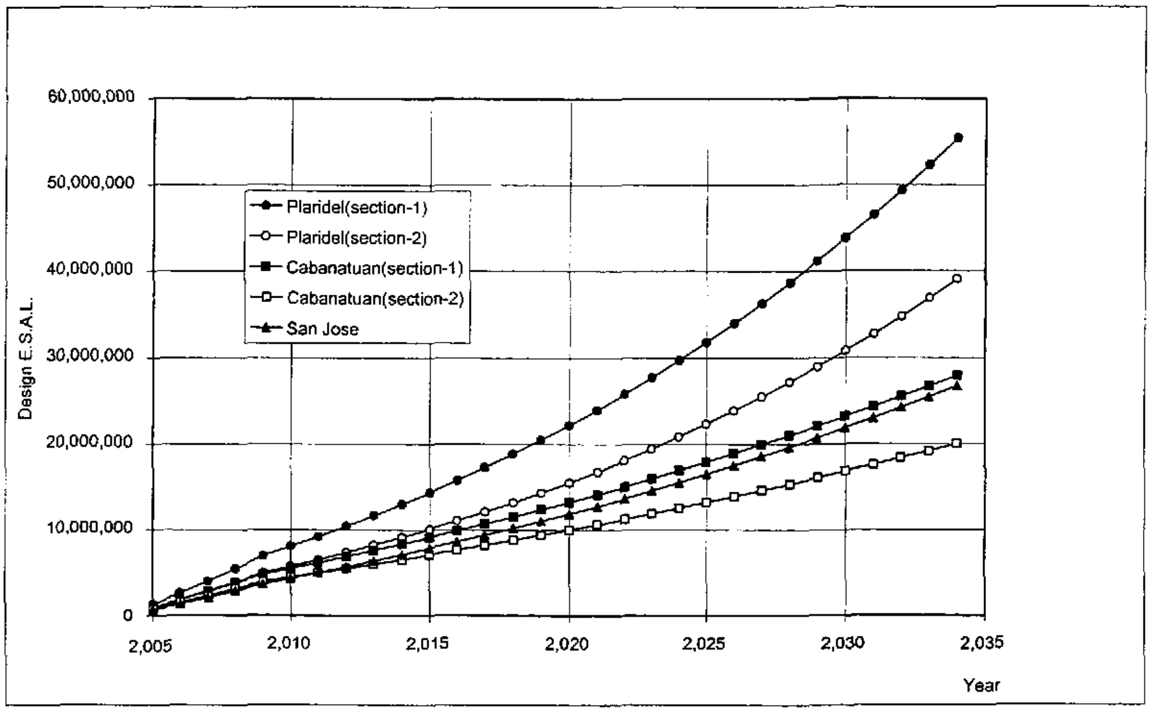


FIGURE 8.4-1 DESIGN ESAL BY YEAR FOR EACH BYPASS

(2) Performance Criteria (ΔPSI)

The initial serviceability indexes (Po) were observed at the AASHTO Road Test:

Po	=	4.5 for rigid pavement	(PCC)
Po	=	4.2 for flexible pavement	(AC)

AASHTO Guide (1993) suggests the terminal serviceability indexes (Pt) as follows:

Pt	=	2.5 for design of major highway
Pt	=	2.0 for design of highway

In this study, the following ΔPSI was adopted because of the arterial road.

$\Delta PSI = 4.5 - 2.5 = 2.0$ (for PCC) $\Delta PSI = 4.2 - 2.5 = 1.7$ (for AC)

(3) Material Properties for Structural Design

(i) Effective Roadbed Soil Resilient Modulus, (Flexible Pavement)

To determine effective roadbed soil resilient modulus (MR) exclusively for the design of flexible pavements based on serviceability criteria, laboratory resilient modulus test (AASHTO T274) should be performed on representative sample in stress and moisture conditions. Seasonal resilient modulus should also be determined based on conditions of primary moisture seasons, dry and wet seasons.

In this Study, effective roadbed soil resilient modulus (MR) were estimated as shown in Table 8.4-2.

(ii) Effective Modulus of Subgrade Reaction (Rigid Pavement)

An effective modulus of subgrade reaction (k-value) will be developed for rigid pavement design, accounting for seasonal modulus value, effects of subbase characteristics, effects of rigid foundation, relative damage of slab thickness due to 18-kip ESAL, loss of support etc.

In this Study, effective modulus of subgrade reaction (k-value) were estimated, taking into account the effect of subbase, as shown in Table 8.4-2.

TABLE 8.4-2 STRENGTH OF ROADBED/SUBGRADE

CBR	K (pci)	MR (pci)	
of Subgrade	of Subgrade	of Subgrade	K (pci)
2	50	2,500	80
3	100	4,000	130
4	120	5,000	170
6	160	6,000	210
8	180	7,000	230
10	200	8,000	250
15	230	12,000	280
20	250	15,000	300

SOURCE: Feasibility Study of the Road Improvement Project on the Pan-Philippine Highway (Philippine-Japan Friendship Highway), 1987 (JICA)

NOTE: K; estimated based on the suggestion by Portland Cement Association.

(4) Time Scale

Initial Performance and the analysis periods are factors of time scales for the discussion on the pavement design.

According to the 1993 AASHTO Guide, the analysis period is recommended as follows based on the highway conditions:

Highway Conditions	Analysis Period (years)
High-volume urban	30 – 50
High-volume rural	20 – 50
Low-volume paved	15 – 25
Low-volume aggregate surface	10 – 20

In accordance with AASHTO Guide, 30 years of the analysis period was applied to the bypasses, which were regarded as a High-volume rural.

(5) Life-Cycle Cost Analysis

(i) Alternatives of Pavement Types

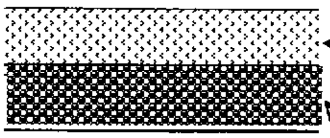
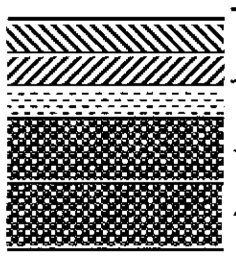
Three kinds of pavement composition as shown in Table 8.4-3 were prepared for the PCC and AC pavements, respectively based on the following considerations.

- Initial performance period
- Minimum thickness in the Philippines
- Traffic volume scale

- Sensitiviy to the pavement design
- Construction difficulty and cost

TABLE 8.4-3 ALTERNATIVES OF PAVEMENT TYPES

Unit: cm

PCC Pavement				AC Pavement			
	Case-1	Case-2	Case-3		Case-1	Case-2	Case-3
Slab	23	25	28	AC thickness	8	10	12
Subbase	25	25	25	Cement Treated Base Course	10	10	10
				Base Course	25	25	25
				Subbase Course	30	30	30
				SN	4.30	4.61	4.91
After Performance Period: AC Overlay Thickness 5.0cm				After Performance Period: AC Overlay Thickness 5.0cm			
							

(ii) Maintenance Costs

Table 8.4-4 gives the list of routine maintenance activities and unit costs widely adopted in DPWH for PCC and AC pavements. The unit costs in the Table were used for the LCCA to estimate the maintenance cost.

TABLE 8.4-4 ROUTINE MAINTENANCE ACTIVITIES AND ITS UNIT COSTS

Maintenance Activities	Maintenance Level	PCC Quantity	PCC Unit Cost**	AC Quantity	AC Unit Cost**
1. Crack and Joint Sealing	Good	63.2 l/km		602.7 l/km	
	Fair	120.6 l/km	84.42	160.7 l/km	95.0
	Bad	140.7 l/km	P/liter	200.9 l/km	P/ltr.
2. Temporary Patching	Good	0 cu.m/km		0 cu.m/km	
	Far	0 cu.m/km	5,267.95	0 cu.m/km	5,267.95
	Bad	20.0 cu.m/km	P/cu.m	23.0 cu.m/km	P/ltr.
3. Patching	Good	0 cu.m/km		cu.m/km	
	Fair	6.0 cu.m/km	7,532.95	6.3 cu.m/km	7,532.95
	Bad	8.3 cu.m/km	P/cu.m	7.8 cu.m/km	P/cu.m.
4. Replacement of Pavement	Good	0 sq.m/km		0 sq.m/km	
	Fair	0 sq.m/km	2,515.80	0 sq.m/km	424.07
	Bad	25.9 sq.m/km	P/sq.m	57.4 sq.m/km	P/sq.m

Source: * *DPWH, Pan-Philippine Highway Mindanao Section Rehabilitation Project Road Maintenance Sustainability Study, March 1998*
** *DPWH, Region XI Maintenance Division, April 2001*

To determine level of maintenance requirement in accordance with serviceability index, (PSI) the following values were adopted in this analysis.

PCC Pavement	Serviceability Index
Good	4.5 ≥ PSI ≥ 4.0
Fair	4.0 > PSI ≥ 3.2
Bad	3.2 > PSI ≥ 2.5
Very Bad	2.5 > PSI

AC Pavement	Serviceability Index
Good	4.2 ≥ PSI ≥ 3.8
Fair	3.8 > PSI ≥ 3.1
Bad	3.1 > PSI ≥ 2.5
Very Bad	2.5 > PSI

Based on the computed PSI and maintenance level required, an annual maintenance cost of each pavement type was calculated.

5cm AC overlay is proposed to be carried out when PSI reaches 2.5.

(6) Recommendation

For each bypass, the following pavement structure was recommended, which was resulted from the Life-Cycle Cost Analysis of pavement.

- Pavement Type : PCC Pavement
- Slab Thickness :
    - Plaridel Bypass
        - Section before the Angat River = 28cm
        - Section after the Angat River = 25cm
    - Cabanatuan Bypass = 25cm
    - San Jose Bypass = 25 cm
- Subbase Thickness :
    - All bypasses = 25 cm

8.5 River Opening Design Criteria for Bridge Planning

1) Design Criteria

The design criteria on river opening for bridge planning refers to the following standards and guidelines:

[1] Design Guidelines for Criteria and Standards for Public Works and Highways, Volumes I & II, Department of Public Works and Highways (DPWH).

[2] Highway Drainage Guidelines, American Association of State Highway and Transportation Officials (AASHTO), 1999 Metric Ed.

[3] Guidelines for River Control and Management, Ministry of Construction, Japan

2) Bridge Location Considerations

Selecting favorable stream crossings should be considered in the preliminary route determination to minimize construction, maintenance and replacement costs. Natural stream meanders should be studied and, if necessary, channel changes, river training works and other construction that would reduce erosion problems and prevent possible loss of the structure should be considered.

Foundations of bridges placed across channel changes should be designed for possible deepening and widening of the relocated channel due to natural causes. On wide flood plains, the lowering of approach fills to provide overflow sections designed to pass unusual floods over the highway is a means of preventing loss of structures. Where relief bridges are needed to maintain the natural flow distribution and reduce backwater, caution must be exercised in proportioning the size and in locating such structures to avoid undue scour or changes in the course of the main river channel.

Some important conditions to be considered in the selection of bridge location includes:

- Stability of river course – changes in river course for braided, straight and meandering streams requires spanning the entire channel, stabilizing banks around abutment and designing for anticipated scour,
- Condition of river bank both upstream and down stream – condition of river bank stability may require bank protection to control erosion and meandering,
- Aggradation and Degradation – locations with possible aggradation and degradation should be avoided,
- Islands, Delta Formations and Alluvial Fans – formed by deposition of materials, these formations are undesirable since these are not permanent and may lead to bridges being built in the wrong place, and
- Confluences – this should be avoided as confluences of stream presents complex hydrologic and hydraulic behavior.

3) Design Flood Frequency

The design flood frequency to be adopted for bridge design is one (1) in fifty (50) years.

4) Bridge Length

The total bridge length is decided based on the Maximum Flood Water Level (MFWL) with a 50-year return period. Figure 8.5-1 shows the definition of the bridge length.

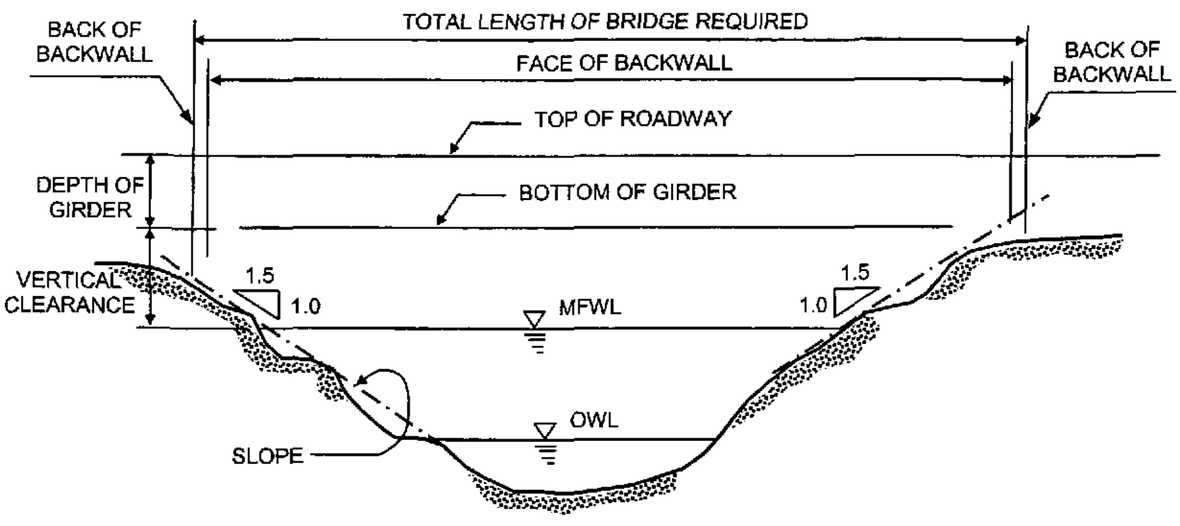


FIGURE 8.5-1 DEFINITION OF BRIDGE LENGTH

5) Bridge Spans

Minimum Span Length for River Discharge Greater than 500 m^3/sec. The span length of bridge should be longer than the calculated length using the following equation in accordance with the design flood discharge of the river (Guidelines for River Control and Management, Ministry of Construction, Japan).

$$L \geq 20 + 0.005Q \quad \text{for } 500 < Q < 2000$$

$$L \geq 30 + 0.005Q \quad \text{for } Q > 2000$$

where: L = minimum span length (m)
Q = design discharge (m^3/sec)

Existing Bridge Span Lengths. Reference will be given to the existing structures such as bridges in the upstream or downstream of the proposed bridge location. The proposed bridge should at least have a similar span as the existing bridge structure.

Sizes of Drifting Logs, Debris, Etc. Careful assessment should be done to determine the maximum probable size of debris including logs expected to pass in the bridge location. The span lengths should allow passage of such debris without imposing risk on the bridge or clogging the passageway of water.

6) Pier Width on River Section

Bridge piers located on river section should not impose obstruction to the flow of water in the river. Therefore, the dimensions of the bridge piers in the river should not take more than 5% of the river section.

7) Clearances

The general clearance between the Maximum Flood Water Level (MFWL) and the bottom of the lowest member of the superstructure shall be as follows:

Condition	**Minimum Vertical Clearance or Freeboard (m)**	**Remarks**
Streams/River carrying debris	1.50	DPWH Design Guidelines, Vol. II
Streams/Rivers without debris	1.00	DPWH Design Guidelines, Vol. II

8.6 Bridge Design

8.6.1 Design Standards and Specifications

The design of bridges for stream or river crossings is based on the recommendations of the following standards and specifications:

[1] Design Guidelines for Criteria and Standards for Public Works and Highways, Volumes I & II, Department of Public Works and Highways (DPWH).

[2] Standard Specifications for Highway Bridges and Airports, Department of Public Works and Highways (DPWH), 1995.

[3] National Structural Code of the Philippines, Association of Structural Engineers of the Philippines (ASEP) Volume II A & B – Bridges, 2^{nd} Ed., 1997.

[4] DPWH Department Order

a. No. 75 "DPWH Advisory for Seismic Design of Bridges", 17 July 1992.

b. No. 229 "Guidelines on Soil Survey and Sampling for Highway Design and Subsurface Exploration for Design of and Construction of Foundation of Bridges", July 1993.

c. No. 56 "Quality of Plans", 22 March 1995.

[5] Standard Specifications for Highway Bridges, American Association of State Highway and Transportation Officials (AASHTO), 16^{th} Ed., 1996.

[6] Highway Drainage Guidelines, American Association of State Highway and Transportation Officials (AASHTO), 1999 Metric Ed.

[7] Guide Specifications for Design and Construction of Segmental Concrete Bridges, American Association of State Highway and Transportation Officials (AASHTO), 1999.

[8] ACI-343R-95 Analysis and Design of Reinforced Concrete Bridge Structures, Reported by ACI Committee 343, American Concrete Institute (ACI).

[9] Specifications for Highway Bridges, Japan Road Association (JRA), 1992.

8.6.2 Live Load (*LL*)

The carriageway live loading shall be the AASHTO MS 18 (HS20-44) Standard Truck or Lane Loading as shown in Figure 8.6-1. Military Loading and Permit Design Live Load is also shown in Figure 8.6-1.

Sidewalk Live Loading (until bridge length L = 30.5m) …….. 4.07 kPa

Other sidewalk loading shall be based on AASHTO Sec. 3.14

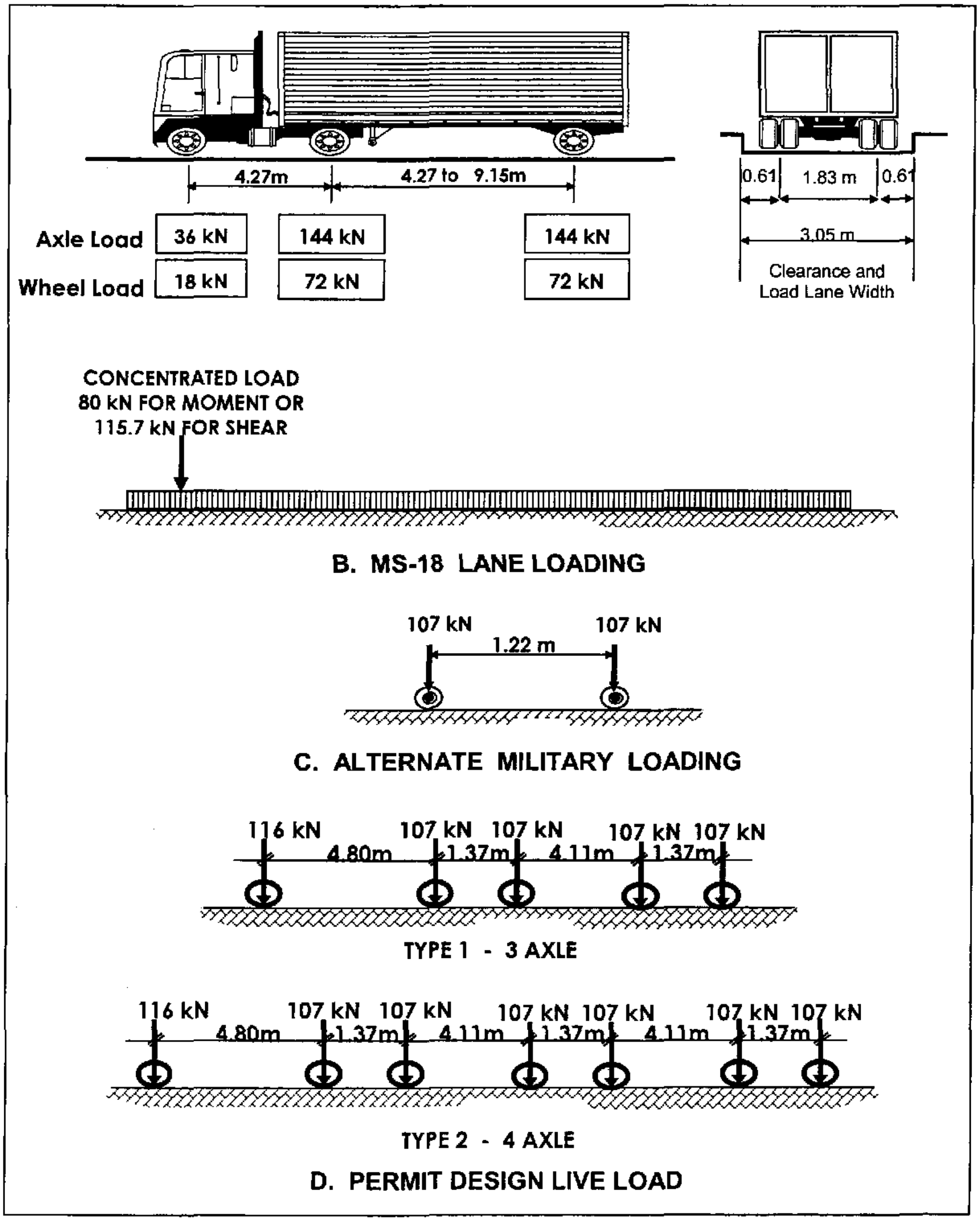


FIGURE 8.6-1 AASHTO LIVE LOADING

8.6.3 Seismic Forces

Seismic design coefficients adopted are shown in Table 8.6-1.

TABLE 8.6-1 DESIGN COEFFICIENTS

Seismic Design Item	Bypass Location		
	Plaridel	Cabanatuan	San Jose
Acceleration Coefficient, A	0.40	0.40	0.55
Importance Classification, IC	I (Essential)	I (Essential)	I (Essential)
Seismic Performance Category, SPC	D	D	D
Soil Type	II	II	II
Site Coefficient	1.2	1.2	1.2

The Soil Type and Site Coefficient given in the above Table are based on soil characteristics in general, each bridge site will be evaluated based on the local soil data.

8.6.4 Load Combination

The Group Loading combinations for Service Load Design and Load Factor Design, as recommended by AASHTO is taken as:

$$\text{Group (N)} = \gamma\{\beta_D DL + \beta_L (L + I) + \beta_C CF + \beta_E E + \beta_B B + \beta_S SF + \beta_W W + \beta_{WL} WL + \beta_L LF + \beta_R (R + S + T) + \beta_{EQ} EQ\}$$

where γ and β are coefficients taken from Table 3.22.1A of AASHTO.

TABLE 8.6-2 AASHTO LOAD COMBINATION

	Grp	γ	D	$(L+I)_n$	$(L+I)_p$	CF	E	B	W	WL	L	R+S +T	EQ	Stress Factor %
SERVICE	I	1.00	1	1	0	1	β_E	1	0	0	0	0	0	100
	II	1.00	1	0	0	0	1	1	1	0	0	0	0	125
	III	1.00	1	1	0	1	β_E	1	0.3	1	1	0	0	125
	IV	1.00	1	1	0	1	β_E	1	0	0	0	1	0	125
	V	1.00	1	0	0	0	1	1	1	0	0	1	0	140
	VI	1.00	1	1	0	1	β_E	1	0.3	1	1	1	0	140
	VII	1.00	1	0	0	0	1	1	0	0	0	0	1	133
LOAD FACTOR	I	1.30	β_D	1.67	0	1	β_E	1	0	0	0	0	0	Not Applicable
	IB	1.30	β_D	0	1	1	β_E	1	1	0	0	0	0	
	II	1.30	β_D	0	0	0	β_E	1	1	0	0	0	0	
	III	1.30	β_D	1	0	1	β_E	1	0.3	1	1	0	0	
	IV	1.30	β_D	1	0	1	β_E	1	0	0	0	1	0	
	V	1.25	β_D	0	0	0	β_E	1	1	0	0	1	0	
	VI	1.25	β_D	1	0	1	β_E	1	0.3	1	1	1	0	
	VII	1.30	β_D	0	0	0	β_E	1	0	0	0	0	1	

*** Permit Live Loading shall be used to check the member capacity under Load Factor Design using Group Loading Combination IB.*

β_E : 1.00 for vertical and lateral loads

For Load Factor Design

β_E : 1.3 for lateral earth pressure for retaining wall
β_E : 1.0 for vertical earth pressure
β_D : 0.75 for minimum axial & max. moment (column)
β_D : 1.0 for maximum axial & min. moment (column)
β_D : 1.0 for flexural and tension member

8.6.5 Vertical Clearances

The vertical clearances shown in Table 8.6-3 for structures shall be maintained for all bridges crossing major roads, access roads and streams or rivers:

TABLE 8.6-3 VERTICAL CLEARANCE

Location	Min. Vertical Clearance (m)	Remarks
Major Road Crossing	4.87 (16 ft.)	5.0 m vertical clearance will be adopted
Access Road Crossing	4.27 (14 ft.)	
River/Stream Crossing Freeboard Considering Debris Passage Below Bridge	1.50	Max. Flood Water Level to Lowest Structure Member
River/Stream Crossing Freeboard Without Considering Debris Passage Below Bridge	1.00	Max. Flood Water Level to Lowest Structure Member. To be applied to irrigation canals.

8.7 Drainage Design

8.7.1 Design Standards and Guidelines

Drainage design is carried out in accordance to the related Chapters of "Part-3 Highway Design, in Volume-II of "Design Guidelines, Criteria and Standards for Public Works and Highways"; (DPWH Guidelines). Where there is no relevant provision in DPWH Guidelines, applicable provisions of "A Policy on Highway Drainage", June- 1987, Japan Road Association; (JRA) and "Highway Drainage Guidelines", Metric- Edition, American Association of State Highway and Transportation Official; (AASHTO), 1999" are applied.

In Design, approved "Standard Drawings" by DPWH, which are prepared by the Bureau of Design (BOD) have been also considered.

8.7.2 Design Frequency (Return Period)

The design frequencies adopted in this project are adhering to the recommendation found in the DPWH Design Guidelines as shown in Table 8.7-1.

TABLE 8.7-1 DESIGN FREQUENCIES

Type of Structure	Return Periods
Bridge	1 in 50 years
Box Culverts	1 in 25 years
Road Embankment	1 in 10 years
Drain Pipes and Pipe Culverts	1 in 10 years
Side ditches	1 in 2 years
Surface drainage	1 in 2 years

8.7.3 Cross-Drainage

(1) Type and Size of Cross-Drainage Structure

The pipe diameters are determined based on the calculated discharge but 910 mm diameter is considered as the minimum size. This 910 mm size allows carrying out the pipe maintenance easily since the size can allows working inside it.

Figure 8.7-1 shows the adopted methodology to choose the most reasonable drainage structure among pipe culverts, box culverts and bridges based on the capacity of the drainage of these different structures and the maximum runoff discharge value of the each defined catchment area. The selections started by using a single pipe culvert having 910 mm diameter. The larger diameters 1070 mm, 1220 mm and up to 1520 mm are used as far as the rate of flow will require. If the rate of flow becomes greater than the capacity of 1520 mm single pipe, then the capacity of double 910 mm to 1520 mm pipes is checked. When the rate of flow becomes greater than the capacity of double 1520 mm diameter pipes, then the box culvert is used to drain the water. Different standard size of box culverts are used to accommodate the drained water as long as the rate of flow is not more than 40 m^3/sec including single, double and up to triple vents. When the rate of flow becomes greater than 40 m^3/sec, a bridge is basically selected.

During the above analysis, the Rational Method of analysis is adopted when the catchment area is not more than 20 Km^2. For the areas more than 20 Km^2, the Unit Hydrograph Method is used.

(2) Height of Embankment

Based on the DPWH Design Guideline Vol.-II, Item 500.3.6 "Backfilling", the minimum backfilling elevation is 0.3 m. Base on the requirements of structural design; the minimum height is 0.6 m. The finished grade of the bypass has been checked adhering to the required invert elevation levels of inlets and outlets of cross drainages. The invert elevations were modified as far as the standard requirements can be maintained. Otherwise, the finished bypass grade was modified to coincide with the cross drainage inlets and outlets invert elevations requirements.

(3) Live Load

The carriageway live load is the one defined by AASHTO MS 18 (HS20-44) Standard Truck that means the wheel load design value is 72 KN. The Impact factor is taken equal to 1.3.

(4) Structural Design

Reinforced Concrete Pipe Culverts (RCPC)

The supporting strength of the pipe can be defined as the vertical load per meter run on the laid pipe that will cause its failure. The Standard Three-Edge Bearing Method of Loading gives this strength.

Considering that loads on a pipe culvert depend on the height of earth fill, in all cases, top level of sub-base course is kept at least 0.60 m above top level of the cross pipe. Under H-20 Loading, the equivalent force (D-Load) in KN/m of pipe to cause 0.3 mm crack for the various embankment heights are shown in Table 8.7-2 in case of concrete bedding.

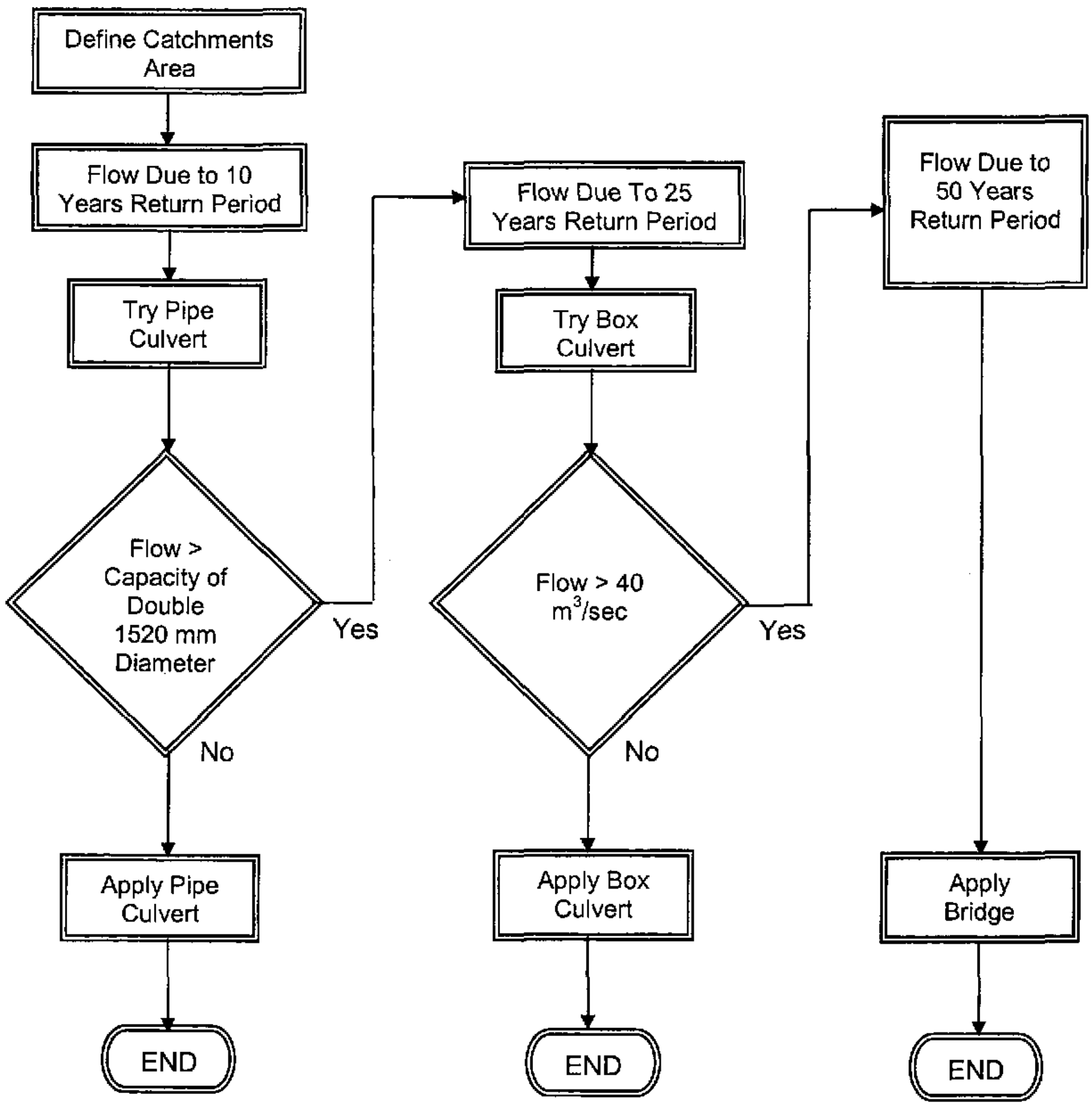


FIGURE 8.7-1 SELECTION OF TYPE OF CROSS DRAINAGE STRUCTURE

TABLE 8.7-2 EQUIVALENT D-LOAD IN KN/M TO CAUSE 0.3 MM CRACK

Fill Height (m)	Pipe Diameter (mm)				
	610	910	1070	1220	1520
0.6	24.42	36.63	42.73	48.84	61.04
0.9	19.00	28.51	33.27	38.01	47.51
1.2	16.96	25.44	29.68	33.92	42.41
1.5	16.96	24.57	28.66	32.76	40.93
1.8	17.01	24.57	28.66	32.76	40.93
2.1	17.10	25.66	29.94	34.22	42.77
2.4	17.99	26.98	31.47	35.97	44.96
2.7	20.03	30.05	35.05	40.06	50.07
3.0	22.22	33.33	38.89	44.45	55.56

The structural design follows the BOD Standard Drawing Design Set-No.1 Sheet- No.-01. Depending on the design live loading, pipes selection is done within Standard Strength Concrete and Extra Strength Concrete 317 Kg/cm^2 Culvert Pipes having two lines of circular reinforcement. These two categories are corresponding to Class II and Class IV, respectively, on ASTM C76M – 97, that having concrete strength equal to 27.6 MPa. The minimum pipe covering is taken 0.6 m from the lower face of the concrete pavement base course as recommended by the DPWH Guidelines.

All reinforcement steel should be intermediate (Grade 40) ASTM A-615 with deformation conforming to ASTM A-305.

Reinforced Concrete Box Culverts (RCBC)

Reinforced concrete box culverts are rigid frame structures with square or rectangular opening. The height of the box and also the box span vary from 1.0m to 3.0m. It is recommended for economy of design to keep the span to the height ratio from 1:1 to 1:1.5.

Reinforced concrete box culverts are suitable for the sites with small waterway requirements up to about 15m with low to medium height from the deck level to the bed level. Provision of monolithic construction of the whole structure and continuity of the walls and slabs give an economical solution.

Box culvert consists of the main box/boxes and wingwalls. Main box/boxes will have the required length to pass the carriageway width. The wingwalls are provided to retain the earth of the embankment on both sides. Some time additional works against erosion are required on upstream and downstream of the culvert.

All concrete shall have a minimum compression strength in 28 days of f'_c = 20.7 Mpa (3000 psi). All exposed concrete should be chamfered by minimum of 30 mm. No construction joint is to be made except where specified in drawings. When bottom slab will be subjected to abrasion additional thickness of 20 mm should be added to increase steel coverage.

All reinforcing steel should be intermediate (Grade 40) ASTM A-615 with deformation confirming to ASTM A-305.

When the height of fill will equal zero, upper slab will follow the crown of the finished roadway.

The box culvert shall be constructed on a layer of lean concrete of 50 mm minimum thickness.

When there is less than 0.6 m of fill above top slab of culvert additional reinforcement transverse to the main reinforcement should be add at the bottom of the top slab in accordance with AASHTO 1.3.2.E.

(5) Hydraulic Design

The size and number of pipes/vents required for a given location depend on the volume of water to be discharged through the RCPC/RCBC, condition of entry at the inlet, frictional resistance of inside surface, length of the culvert, hydraulic mean radius and operating head of water. For design of culvert size, culverts are assumed to flow full. The diameter of pipe and number of vents are so selected that for a given discharge, the heading up of water does not go higher than the predetermined safe level, and the criteria for safety set as the road embankment is not overtopped, nor any property will be damaged by submergence. The high level of water on the outfall side near the exit of culvert is also predetermined. The difference of the levels of water at inlet and exit is the operating head. This head is used to overcome the frictional resistance of the wetted surface of the culvert, supply the energy required to generate velocity of flow and force water through the inlet of the culvert.

Culverts are dimensioned in accordance with the method and procedure experienced in DPWH Guidelines that incorporates the method of U.S. Bureau of Public Roads. In the design, the discharge is increased by 20% as a measure in opposition to siltation effect on reducing discharge efficiency.

(6) Locations of Cross-Drainage

The locations of cross drainage facilities were decided taking into consideration the main following characteristics:

1) Locations defined by the catchment areas analysis,
2) Locations of existing irrigation channels,
3) Locations in flat terrain where water flow direction cannot be certainly defined. Flat cross-pipe is provided to avoid bypass acting as a dam at this location.

After the required pipes are provided at the abovementioned locations, the spacing between the successive pipes is checked. If the spacing is greater than 250 m an additional pipe is located in between. This maximum spacing is considered in order to create the facilities to drain the surface water runoff discharge within a reasonable length.

(7) Headwalls

Head walls are provided at the distance coinciding with the pipe length and reasonably far from the toe of embankment on both ends of a pipe. Flared type headwall was selected to provide the required safety against scouring at inlet and outlet of the pipe.

(8) Bedding

Bedding that consist of Type A continuous concrete cradle conforming to the plan detail was selected to distribute the vertical reaction around the lower exterior surface of the pipe and reduce stress concentrations within the pipe wall.

(9) Joint of Pipes

Pipe sections are cast in short lengths of 1.0 m for ease of construction, transportation and placement. The culvert overall length is adjusted to be a multiple of this normal pipe length. When laid end to end on prepared bedding at the site the section need to be jointed together. The popular methods of jointing are:

- Concrete collar joint;
- Spigot and socket joint; and
- Tongue and groove joint.

Tongue and groove joint is selected since it is the common method in the project area. Pipe joints will be cement grouted and concrete collar will be cast to ensure that no water seepage can be occurred at joint locations. The collar shall have a minimum width of 150 mm and a thickness equal to the thickness of the pipe itself.

8.7.4 Surface Drainage

(1) Inlet Interception Capacity

Two types of inlet are used to drain storm water; namely the Curb Inlet Manhole (CIM) and scupper inlets. CIM is vertical opening in the curb covered by a top slab. Scupper inlet is usually small circular hole to drain surface storm water in the bridge deck. Based on Vol. IX of AASHTO Guidelines for Storm Drain Systems (1999), the following equations have been used to estimate the inlet interception capacity:

Curb Inlet Manhole (CIM):

$$L_T = 0.076\ Q^{0.42}\ S^{0.3}\ (1 / n\ S_x)^{0.6}$$

where,

- L_T = curb opening length to intercept 100% of the gutter flow (m),
- Q = flow (m^3/sec),
- S = longitudinal slope,
- n = Manning roughness coefficient (0.013 for concrete pavement), and
- S_x = cross slope.

Scupper Inlet:

$$Q = A\ K \sqrt{2gh}$$

where,

- h = operating head in meters,
- g = acceleration due to gravity in m/sec^2 = 9.81 m/sec^2,
- K = conveyance factor, and it is a function of length (L), mean hydraulic radius (R) and the coefficient of roughness (n) of the pipe surface, and
- A = area of the pipe cross-section.

The factor K is determined by:

$$K = 1 / \sqrt{1 + K_e + K_f}$$

where,

- K_e = head lost at entry; K_e = 0.08 for bell mouthed entry and 0.51 for sharp edged entry,
- K_f = head lost due to friction of pipe = $0.0033\ L / R^{1.3}$ for concrete pipe,
- L = pipe length in meters and R = hydraulic mean radius in meters.

The capacity of a curb-opening inlet in sag depends on water depth at the curb, the curb opening length, and the height of the curb opening. Spread on the pavement is the usual criterion for judging the adequacy of pavement drainage inlet design. The weir location for a curb-opening inlet is at the lip of the curb opening. The weir equation for this inlet is:

$$Q_i = C_w\, L\, d^{1.5}$$

where,

- Q = flow rate (m^3/sec)
- C_w = coefficient = 2.3 (1.25 for SI)
- L = length of curb-opening (m)
- D = depth at curb measured from the normal cross slope, i.e. $d = TS_x$

(2) Flow in Gutter

Based on Vol. IX of AASHTO Guidelines for Storm Drain Systems (1999), the following equations have been used to estimate the flow in gutter and spread length:

$$Q = (0.376/n)\, S_x^{1.67}\, S^{0.5}\, T^{2.67}$$
$$T = 1.443\, [(Q\, n) / (S_x^{1.67}\, S^{0.5})]^{0.375}$$
$$d = T\, S_x$$

where,

- Q = rate of discharge (m^3/sec),
- n = Manning's roughness coefficient,
- S = longitudinal slope,
- S_x = cross slope,
- T = top width of water surface (m), and
- d = depth of flow at deepest point (m).

(3) Storm Drain Pipes

Concerning to pipe maintenance requirements, minimum 610 mm diameter is applied for the longitudinal pipelines under the outer sidewalk and 460 mm diameter is applied for the cross pipes in order to avoid the silting problem.

Table 8.7-3 shows the calculated speeds of flow for the abovementioned-selected diameters under different longitudinal slopes conditions. The minimum pipe longitudinal slope is selected as 0.5% while 1% is recommended to acquire a reasonable speed of flow that will minimize the silting inside the pipes. Vol. IX of AASHTO Guidelines for Storm Drain Systems (1999) also recommends same values.

The pipes are designed for 10 years return period while the curb opening length is designed for 2 years return period as specified by the DPWH Design Guidelines.

In the structural design, the cross pipes are designed to sustain the live loads defined by H-20. The longitudinal pipes under the sidewalk are not subjected to this live load.

Areas around the bypass are expected to develop and urbanize in future. Therefore, in the design of the drainpipes, this future urbanization was taken into consideration. The pipes will not only drain water due to rainfall runoff discharges but also will drain water due to existing of residential areas. In the estimation of runoff from this future urbanization, an additional 50 m width along each side of the bypass is considered.

The drop from the inlet flow line to outlet line should be between 0.65 to 1.6 m. The minimum invert slope is 0.005.

TABLE 8.7-3 EFFECTS OF PIPE SLOPES ON VELOCITY AND CAPACITY OF FLOWS

Slope %	Pipe Diameter			
	460 mm		610 mm	
	Capacity (m^3/sec)	Velocity (m/sec)	Capacity (m^3/sec)	Velocity (m/sec)
0.30	0.1793	1.0794	0.3806	1.3029
0.40	0.2070	1.2464	0.4395	1.504
0.50	0.2315	1.3935	0.4913	1.6820
0.60	0.2536	1.5265	0.5382	1.8425
0.70	0.2739	1.6488	0.5814	1.9901
0.80	0.2928	1.7626	0.6215	2.1275
0.90	0.3106	1.8696	0.6592	2.2566
1.00	0.3274	1.9707	0.6949	2.3787
1.10	0.3433	2.0669	0.7288	2.4948
1.20	0.3586	2.1588	0.7612	2.6057
1.30	0.3733	2.2469	0.7923	2.7121
1.40	0.3873	2.3318	0.8222	2.8145
1.50	0.4009	2.4136	0.8510	2.9133
1.60	0.4141	0.4454	0.8789	3.0088
1.70	0.4268	2.5695	0.9060	3.1014
1.80	0.4392	2.644	0.9322	3.1913
1.90	0.4512	2.7164	0.9578	3.2788
2.00	0.4630	2.7870	0.9827	3.3640

Note: 0.5% is the minimum slope.

(4) Selection of Design Spread

The objective in the design of a drainage system for a curbed highway pavement sections is to collect runoff in gutter and convey it to pavement inlets in a manner that provides reasonable safety for traffic and pedestrians at a reasonable cost. The process of selecting the spread for design involves decisions regarding acceptable risk of accidents and traffic delays and acceptable costs for the drainage system. Risks associated with spread of water on traffic lanes are higher with greater traffic volume and high speeds. At speeds higher than 70 km/hr., water on the pavement can cause hydroplaning. Therefore, the classification of the highway is guiding the selection of the design-spread length.

Following the U.S. Bureau of Public Roads practices, the design criteria for the main carriageway is selected to keep the spread length of water less than the shoulder width that means the maximum spread length for the main carriageway should be less than or maximum equal to 2.5 m. This design criteria ensure to keep the through traffic lanes of the main carriageway free of water.

For tricycle-lane/frontage road where traffic volume will be light and running speeds recognizably low, the design criteria is taken to keep the maximum water spread length less than one-half of the traffic lane or one-half of the traffic lane plus the gutter width that means less than 2 to 2.25 m. The Standard in case of low running speeds and traffic volume is recommended the abovementioned criteria or more.

For bridges, the design criterion is selected to maintain as far as possible the spread width within the shoulder width. However, due to the narrow width of shoulder in case of long span bridges, the spread can be extended as long as the minimum standard requirements of traffic lane width can be maintained.

(5) Curb Inlet Locations And Spacing

Geometric design almost governs the locations of drainage inlets. Therefore, inlets are placed at:

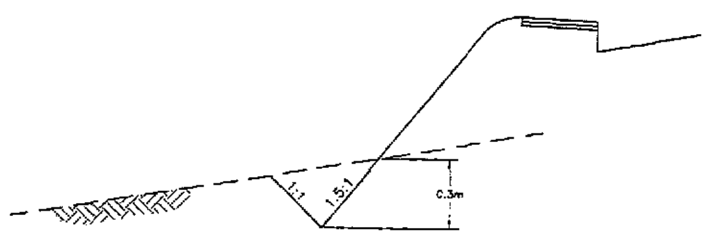
- All low points in the grade (sag),
- At median breaks,
- At intersections,
- Where drainage would flow onto the bypass pavement,
- Where pavement surface are warped, and
- At entrance and exit of bridges.

On continuous slopes, the spacing among inlet locations is governed by two main criteria, which are the inlet interception capacity and the spread of water from edge of the curb. By DPWH Design Guidelines Vol.II, "Urban Drainage Structure", the maximum spacing is 50 m.

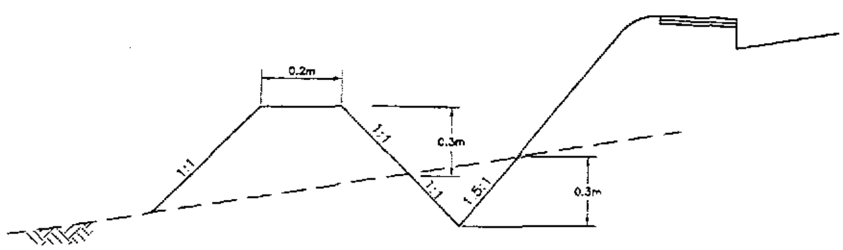
8.7.5 Side Ditches

Side ditches are designed for 2 years return period. The maximum longitudinal slope is 4% while the minimum is 0.5%. All side ditches are extended to the cross drainage RCPC/RCBC or to existing natural waterways to avoid scouring problem at outlets.

Figure 8.7-2 shows the minimum proposed sections of side ditches. Type (a) will be constructed to convey water in the areas without a rice field while Type (b) will be constructed within rice field areas.



TYPE (A)



TYPE (B)

FIGURE 8.7-2 CROSS SECTIONS OF SIDE DITCHES

8.8 Miscellaneous Highway Facilities Design

Miscellaneous highway facilities to be designed for the bypass include the followings:

1) Monuments, Markers, Guide Posts (602)
2) Guardrails (603)
3) Road Signs (605)
4) Pavement Markings (606, 612)
5) Reflective Pavement Stud (607)
6) Delineators
7) Traffic Signals
8) Street Lightings

Notes: The figures in ( ) are the item numbers in the "Standard Specifications, Volume II" of DPWH.

The following Design Standards, Design Manual, Design Guidelines and Specification are referred for the design.

- "Design Guidelines, Criteria and Standards for Public Works and Highways, Volume II": Bureau of Design (BOD)
- "Course Notes on Transportation and Traffic Technology, Road Facilities": National Center for Transportation Studies (NCTS) and JICA.
- "Manual for the Design and Layout of Traffic Signals in the Philippines": DPWH (Jan. 1983)
- "Manual on Pavement Markings": Ministry of Public Highways (1980)
- "Standard Specifications, Volume II Highway, Bridges and Airports": DPWH (1995)
- "Guard Rail Installation Standard and manual" Japan Road Association (1998)
- "Road Sign Installation Standard and manual" Japan Road Association (1987)
- "Delineator Installation Standard and manual" Japan Road Association (1984)
- "Road Lighting Installation Standard and manual" Japan Road Association (1981)
- "Design Standard for Road Works" Bureau of Construction, Tokyo Metropolitan Government, Japan (Jun.1999)

8.9 Revetment Design

8.9.1 Design Guidelines

Revetment design is carried out in accordance with the relevant Chapters of "Part 2 – Hydraulic Design, in Volume II of Design Guidelines, Criteria and Standards for Public Works and Highways" (DPWH Guidelines).

8.9.2 Proposed Design Criteria

The design criteria in Chapter 4 "Design Procedure", Section 4.14 "Revetments" of DPWH Guidelines are summarized in Table 8.9-1 and the design procedures detailed in this section will be applied.

TABLE 8.9-1 DESIGN CRITERIA FOR REVETMENTS

<table>
<tr><th>Item</th><th>Criteria</th></tr>
<tr><td>General</td><td>Revetments are flood control structures constructed along riverbanks subjected to direct attack of the river flow and along second dike slopes for protection against scouring and wave wash.</td></tr>
<tr><td>a) Location and Alignment</td><td>1. Along meander bends of the river.
2. At downstream and upstream of hydraulic structures where turbulent flow usually occurs, it should be smoothed to prevent formulation of vortices and dead water zones.
3. Along side slopes of main irrigation canals to prevent loss of water due to percolations.</td></tr>
<tr><td>b) Freeboard</td><td>Generally, a minimum free board allowance of 0.60 m above the maximum experienced flood level or design flood level, as the case may be, provided for revetments confining flood flows.</td></tr>
<tr><td>c) Slope</td><td>Slope of revetment will depend on the kind of materials used and protection works required for the structure. The table below shows the recommended slopes of revetment with respect to the kind of materials to be used in the construction of said structures.

Recommended Slope of Revetments
<table>
<tr><th>Kind of Materials</th><th>Condition</th><th>Height in Meter</th><th>Slope</th></tr>
<tr><td>Stone Masonry</td><td>Wet masonry</td><td>3 or more but less than 5</td><td>1:2</td></tr>
<tr><td>Concrete Block Masonry</td><td>Dry masonry</td><td>Less than 3</td><td>1:3</td></tr>
<tr><td>Stone Pitching</td><td>Dry masonry</td><td>Less than 3</td><td>1.5:1</td></tr>
<tr><td>Concrete Block Pitching</td><td></td><td>3 or more</td><td>2:1</td></tr>
<tr><td>Wire cylinder pitching</td><td></td><td>3 or more</td><td>2:1</td></tr>
<tr><td>Connected Concrete Block Pitching</td><td></td><td>Less than 3</td><td>1.5:1</td></tr>
</table></td></tr>
<tr><td>d) Height</td><td>Heights of revetments will depend on the maximum experienced flood level or design flood level. For other cases when combined with flood control works such as levee/embankment, the height of the revetment is up to the required height of the structures.</td></tr>
</table>

8.10 Slope Protection Design

8.10.1 Design Guidelines and References

Based on the following guidelines and references, design criteria for slope protection are developed.

- References
  - *Slope Stability* Engineering, Institute of Civil Engineering
  - Disaster Assistance Manual, Federal - Aid and Design Division

- Japanese Guidelines
  - A policy for Slope Protection and Stabilization, March 1999, Japan Road Association
  - Manual for Road Earthworks, August 1990, Japan Road Association

8.10.2 Proposed Design Criteria

The proposed basic design criteria are stated hereafter:

a) Standard Gradients of Cut Slope

Gradients of cut slope vary with types and condition of soil and height of cut. Table 8.10-1 shows the standard cut slope gradients without treatment or provision of slight protection work such as sodding.

b) Standard Gradients of Embankment Slope

Gradients of embankment slopes have been designed in accordance with the kind of embankment materials, geological condition of embankment foundation, height of embankment and other conditions.

Standard gradient of embankment slope shown in Table 8.10-2 is generally adopted in accordance with the type and height of embankment materials used.

TABLE 8.10-1 STANDARD GRADIENTS OF CUT SLOPES

Soil or Rock		Height of Cut	Gradient
Hard Rock			0.3:1 to 0.8:1
Soft Rock			0.5:1 to 1.2:1
Sand	Not dense, and Poorly graded		1.5:1 or above
Sandy Soil	Dense	Less than 5m	0.8:1 to 1.0:1
		5 to 10m	1.0:1 to 1.2:1
	Not dense	Less than 5m	1.0:1 to 1.2:1
		5 to 10m	1.2:1 to 1.5:1
Sandy soil with gravel or rock masses	Dense, or well graded	Less than 10m	0.8:1 to 1.0:1
		10 to 15m	1.0:1 to 1.2:1
	Not dense, or poorly graded	Less than 10m	1.0:1 to 1.2:1
		10 to 15m	1.2:1 to 1.5:1
Cohesive Soil		0 to 10m	0.8:1 to 1.2:1
Cohesive soil with rock masses or cobble stones		Less than 5m	1.0:1 to 1.2:1
		5 to 10m	1.2:1 to 1.5:1

TABLE 8.10-2 STANDARD GRADIENTS OF EMBANKMENT SLOPES

Filling Materials	Height of Fill (m)	Gradient
Sand with well grading, gravel and sand mixed with gravel.	Less than 5 m.	1.5:1 to 1.8:1
	5 to 15 m.	1.8:1 to 2.0:1
Sand with poor grading	Less than 10 m.	1.8:1 to 2.0:1
Rock masses (including Muck)	Less than 10 m.	1.5:1 to 1.8:1
	10 to 20 m.	1.8:1 to 2.0:1
Sandy soil, hard clayey soil, hard clay (hard Clayey soil and clay of alluvium)	Less than 5 m.	1.5:1 to 1.8:1
	5 to 10 m.	1.8:1 to 2.0:1
Soft clayey soil	Less than 5 m.	1.8:1 to 2.0:1

8.11 Tree Planting

The following standards are applied to the design of tree planting:

- Department of Public Works and Highways (DPWH)

1) DPWH SPECIFICATIONS 1995 (VOLUME □)
   - ➢ ITEM 100 – CLEARING AND GRUBBING
     - □100.2.3 Individual Removal of Trees or Stamps
     - □100.3 Method of Measurement
   - ➢ ITEM 608 – TOPSOIL
   - ➢ ITEM 609 – SPRIGGING
   - ➢ ITEM 610 – SODDING
   - ➢ ITEM 611 – TREE PLANTING
2) DEPARTMENT ORDER
   - ➢ Tree planting along National Road (NO.15, Series of 2000 dated 1/24/2000)

- Department of Environment and Natural Resources (DENR)

1) TREE PLANNING & PLANTING
   - ➢ PLANTING INFORMATION
   - ➢ PROPER PLACES FOR AROUND HOMES (Planning for the Future)
2) INDIGENOUS SPECIES FOR REFORESTATION

- Japan Highway Public Corporation

1) DESIGN STANDARD 1999 (VOLUME□)
   - ➢ LANDSCAPE PLANTATION

- Bureau of Construction, Tokyo Metropolitan Government, Japan

1) DESIGN STANDARD FOR ROAD WORKS, Jun.1999
   - ➢ PLANTING FOR URBAN ROADS