CHAPTER 9
PLARIDEL BYPASS DESIGN

9.1 Highway Design

9.1.1 Design Policy

The design policy for Plaridel Bypass is as follows:

- To put importance on traffic mobility.
- Through traffic and local traffic are segregated as much as possible by introducing frontage roads along the section where the adjacent areas are already urbanized or planned to be urbanized by the future city/municipality land use plan.
- To provide at-grade intersections (Type-A) at selected locations only, or more specifically at intersections with national and provincial roads and important Barangay roads in terms of road network configuration.
- The Type-B or Type-C intersections are selectively provided for local traffic convenience where the bypass has frontage roads.
- The at-grade intersection has three (3) types; major intersection, minor intersection and opening for crossing only. Major at-grade intersections were identified not only based on forecasted directional traffic volume at intersections but also considering class of the crossing road, the interval of major intersections and road networks.
  - *Major At-grade Intersection*: to basically provide through, exclusive left/right turn lanes and a divisional island for the approach of a crossing road.
  - *Minor At-grade Intersection*: to basically provide a shared lane for the approach of a crossing road.
  - *Opening for crossing only*: not to allow making left/right turn from both the bypass and a crossing road.
- To provide the underpass (Type-B) in the form of two (2) types; for vehicular traffic, and the other is for pedestrians and farmers.
  - For Vehicular Traffic: to provide vertical clearance of 4.4m.
  - For Pedestrians and Farmers: to providevertical clearance of 2.5 m.
- Openings for crossing only or Type-B intersection are provided for agricultural works and to avoid disconnection of communities, considering road networks in the vicinity of the bypass and the characteristics of their movements.
- Intersections including all types are provided at an interval of about 500 m.
- Such small/slow vehicles as tricycle and bikes entering the carriageway shall be strictly prohibited.
- To avoid an intersection with more than four (4) legs.
- To design the angle of intersection in the range of approximately 60 to 120 degrees in compliance with AASHTO Guide.
- To keep the intersection area to a minimum to the extent possible. Wide

intersection area will pose traffic safety and confusion problems, and high costs.

Figure 9.1-1(1) and 9.1-1(2) show the standard highway cross-sections with frontage roads and without frontage roads, respectively.

9.1.2 Alignment of the Bypass

Figure 9.1-2 shows the alignment of the bypass and the locations of intersections and bridge locations.

- The total length of the bypass is about 22.65 km. Sections with a frontage road have a length of 7.36 km.
- The bypass has two (2) new access roads; one is connected to provincial road No. 334 immediately after the tollgate of the interchange, and the other is for accessing to Plaridel Town Proper.
- There are seven (7) major at-grade intersections, eighteen (18) minor intersections, and nine (9) under-boxes.
- Five (5) out of 18 minor intersections are openings for crossing only, including maintenance roads along irrigation canals.
- Six (6) out of 9 under-boxes are for farmers or pedestrians.
- Transition curves for the horizontal alignment were not employed because the minimum radius is 2,500 m.

9.1.3 Intersection Layout

Plaridel Bypass has thirty three (33) intersections. The features and roles of intersecting roads are explained in Table 9.1-1. Figure 9.1-3 shows the traffic movements in relation to the layout of intersections.

9.1.4 Directional Traffic Flow at Major Intersection

Figure 9.1-4(1) and (2) show the forecasted directional traffic flow at the major intersections in year 2020. Its unit is vehicles per day and per peak-hour.

9.1.5 Intersection Layout of Major Intersection

Intersection layout of major intersections are shown in Figure 9.1-5.

9.1.6 Intersection Layout of Typical Minor Intersections

Typical intersection layout of minor intersection are shown in Figure 9.1-6.

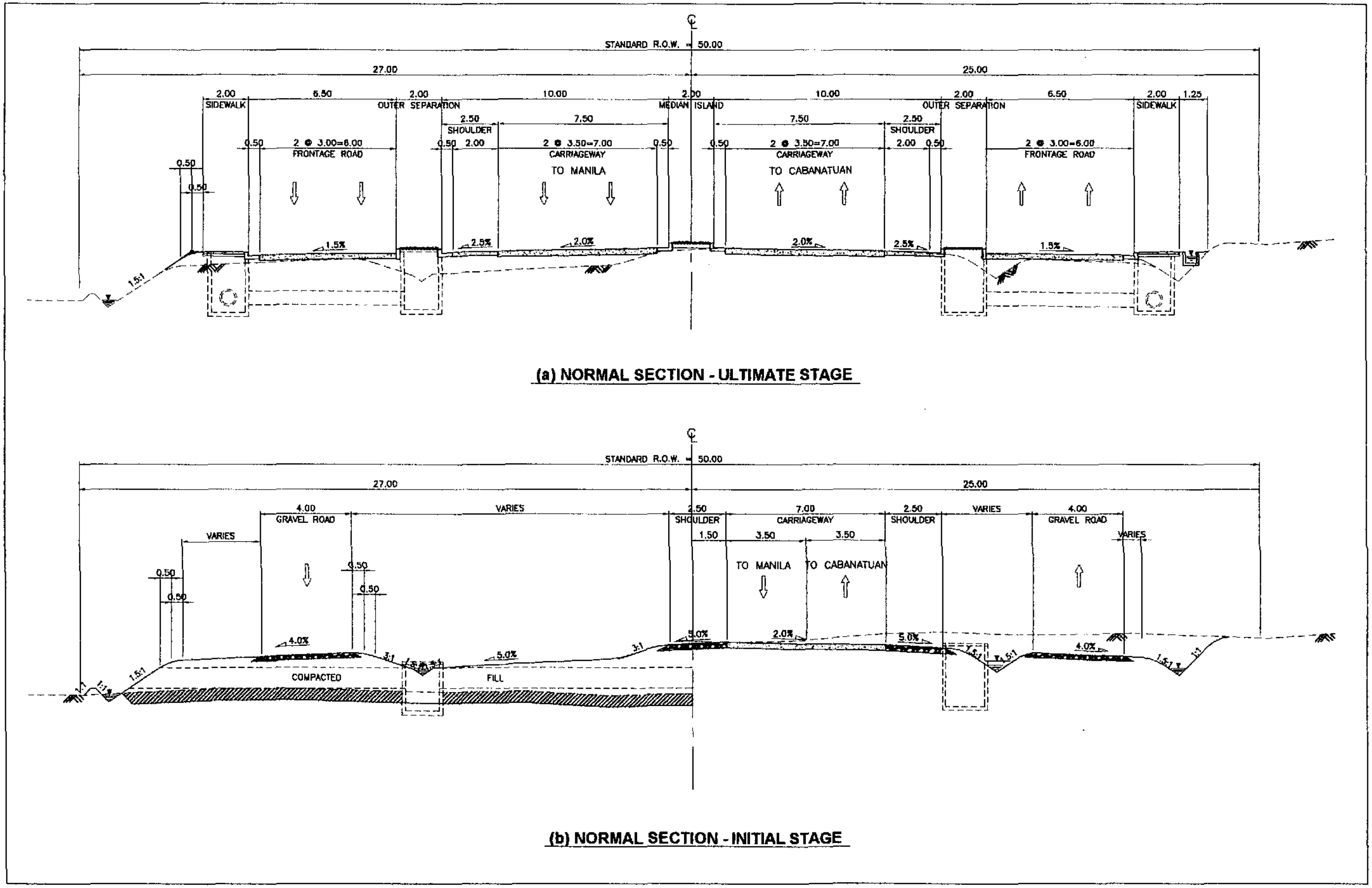
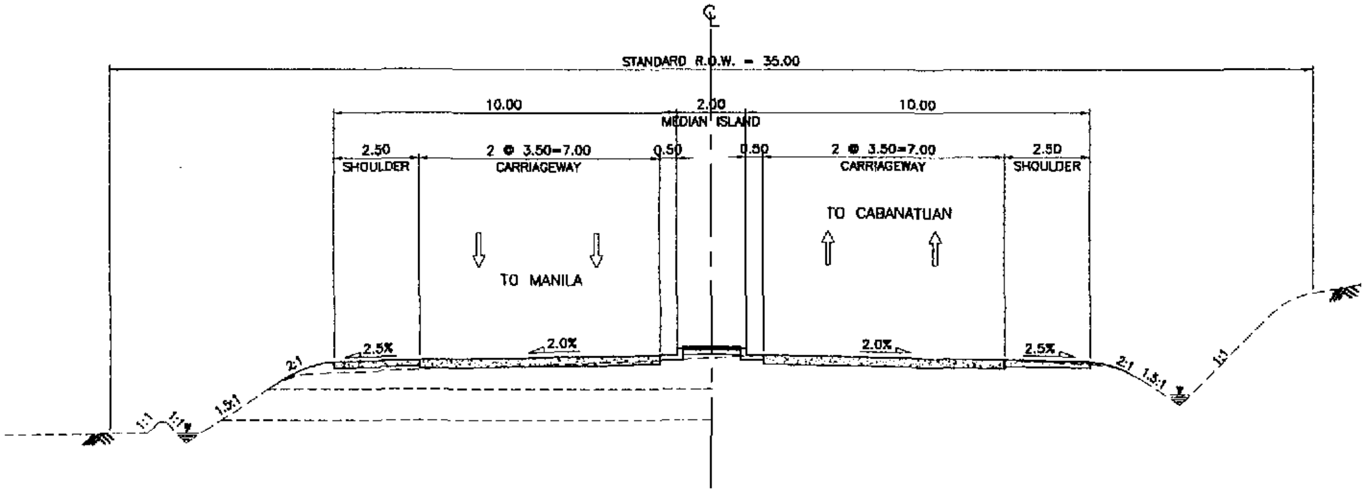
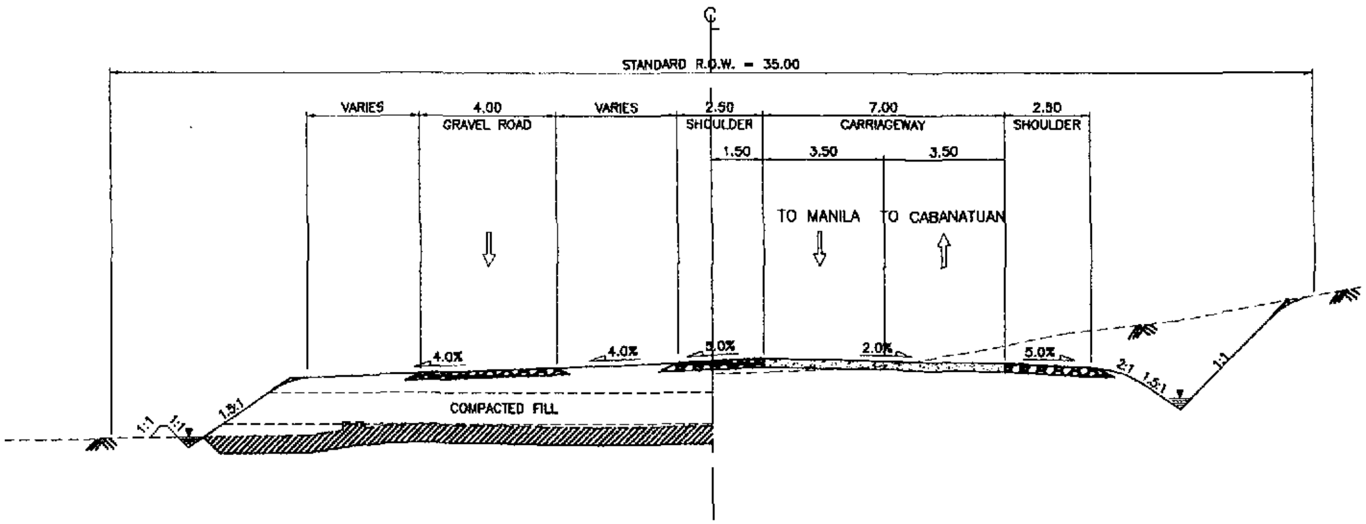


FIGURE 9.1-1(1) TYPICAL CROSS SECTIONS - WITH FRONTAGE ROAD (PLARIDEL BYPASS)



(a) NORMAL SECTION - ULTIMATE STAGE



(b) NORMAL SECTION - INITIAL STAGE

FIGURE 9.1-1(2) TYPICAL CROSS SECTIONS - WITHOUT FRONTAGE ROAD (PLARIDEL BYPASS)

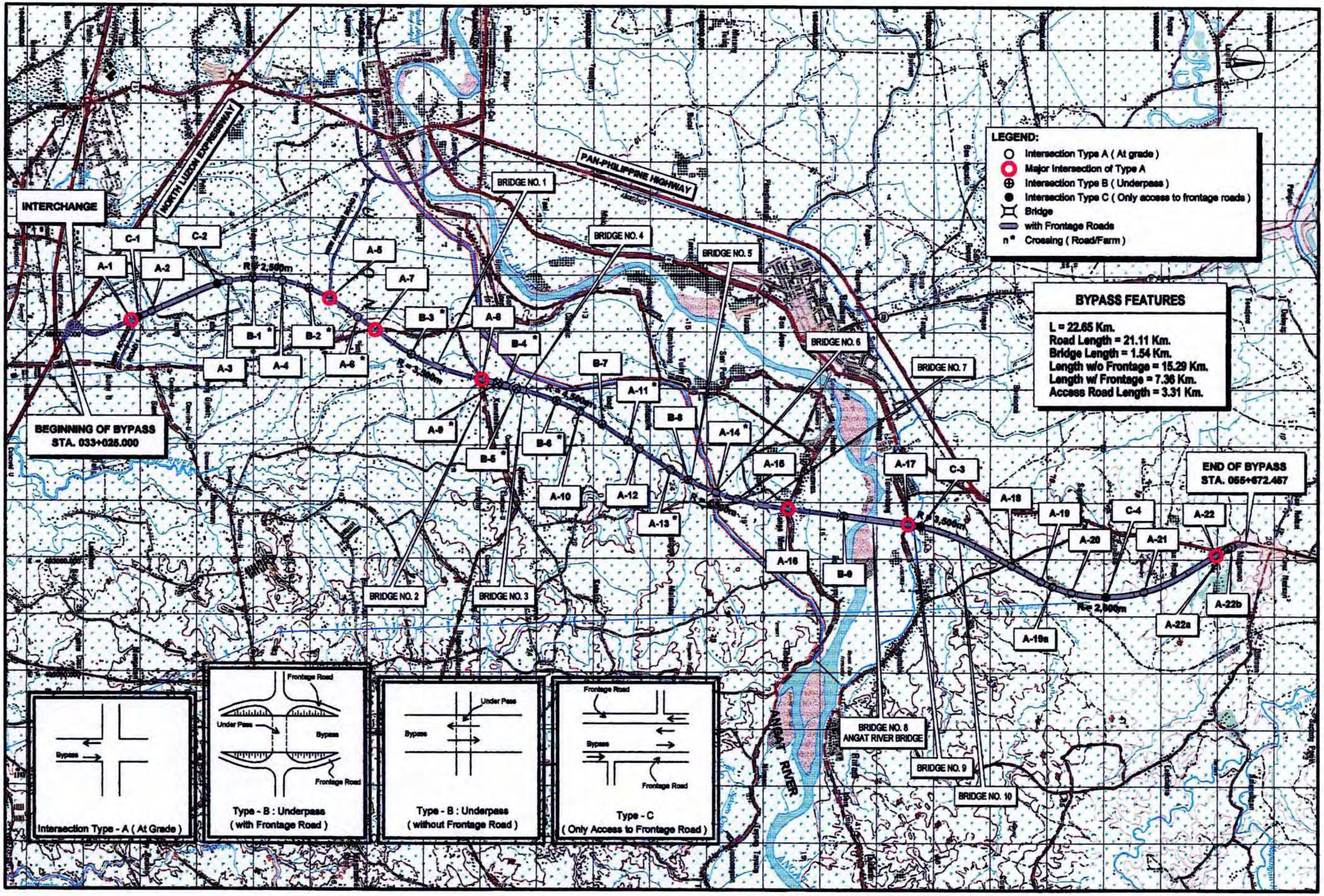


FIGURE 9.1-2 ALIGNMENT OF PLARIDEL BYPASS

TABLE 9.1-1 FEATURES AND ROLES OF INTERSECTING ROADS
(PLARIDEL BYPASS)

Type of Intersections	Descriptions
A-1 (Major Intersection)	The starting point of bypass after proposed interchange area and toll plaza. A new access road to connect to the bypass road from existing provincial road. A traffic signal shall be installed.
C-1	An existing 4.0m PCCP barangay road. This road will access to the frontage road from residential areas on both side of bypass.
A-2	An existing 4.0m PCCP municipal road, a minor road. A developing subdivision is along this road, thus access to bypass is convenient.
C-2	An existing 3.5m earth road. This road connects to the frontage road from residential houses. Minor at-grade intersection A-2 is 150m away.
A-3	An existing minor barangay road with 4.0 m wide PCCP. This road connects to another barangay road.
B-1*	A farm crossing only. This access is a 2.5m clearance underpass crossing for farmers to cross the bypass towards other rice field areas.
A-4	An existing minor barangay 2.50m wide PCCP road. This road access to several scattered surrounding houses. This intersection is 550m away from intersection A-2.
B-2*	A 2.5m clearance farm underpass crossing for farmers to cross the bypass. This location is approximately 500m away from intersection A-3 or 400m away from intersection A-4.
A-5 (Major Intersection)	An existing barangay earth road 2.5m wide. This intersection is planned to be a major intersection because of proposed new access road to Plaridel town proper. A traffic signal shall be installed.
A-6*	An existing irrigation maintenance gravel road, 4.0m wide, an irrigation canal is at one side of the road. This intersection will be design as crossing only for irrigation maintenance vehicles.
A-7 (Major Intersection)	An existing provincial road 5.0m wide PCCP. This is a major road intersection of the bypass. This road is a primary route from Balagtas to Plaridel and vice versa. A traffic signal shall be installed.
B-3*	*A farm underpass crossing*, 2.5m clearance
B-4*	A farm underpass crossing, 2.5m clearance
A-8 (Major Intersection)	An existing provincial road 5.0m wide PCCP. This intersection provides access to the bypass from town of Pandi and vice versa. A major road. A traffic signal shall be installed.
A-9*	An existing irrigation maintenance gravel road 4.0m wide. This road is only at-grade crossing same as intersection A-5
B-5*	A farm underpass crossing, 2.5m clearance
A-10	Existing 3.5m gravel barangay road. This road will serve as an access from agro-industrial farms located near the bypass. A minor road.
B-6*	A farm underpass crossing, 2.5m clearance
A-11*	Existing earth road 3.0m wide. This is a dead end road towards few communities. This road will be to cross only the bypass.
A-12	An existing gravel barangay road 3.0m wide. This road connects to provincial road, same as A-9, access to agro-industrial farm. A minor road.
A-13*	A dead end road existing 3.5m wide earth road access of few communities. This is side road crossing only.
B-7	An existing 3.0m wide gravel irrigation road which connects at a barangay road. An underpass 4.4m is provided *for maintenance crossing only.*
A-14*	An existing irrigation maintenance road. Main irrigation canal. This road will be at-grade crossing only for maintenance vehicle.
A-15	An existing PCCP municipal road 4.5m wide. This road provides the main access towards agro-industrial farm and several communities. A minor road.
A-16 (Major Intersection)	A major road of densely populated area. Existing road is PCCP 6.10m wide, a major route of the town of Bustos and Angat . A traffic signal shall be installed.
B-8	An existing 2.5m wide gravel road near the Angat river. This will be an underpass 4.4m clearance crossing just before proposed bridge abutment. This will also serve as farm road due to agricultural area before the river.
A-17 (Major Intersection)	A major road of densely populated area. Existing road is PCCP 6.10m wide, a major route of the town of Baliuag and San Rafael. A traffic signal shall be installed.
A-18	An existing municipal road 6.10m wide PCCP. This road connects to Pan-Philippine highway coming from San Rafael. A minor road.
A-19	This is the old PNR line paved with PCCP 6.10m wide, an immediate access going in and out of the golf course. Other existing old PNR line is 4.0m gravel road, portion of this road will be used as service frontage road from A-17 to A-19 intersections. A minor road.
A-20	This road will provide access to bypass from old PNR line 4.0m gravel. A minor road.
C-3	An existing dead end earth road, 2.5m wide. This road *connects to the frontage road. Intersection* A-19 and/ or A-20 are approximately 600m away.
A-21	An existing 4.0m gravel barangay road. This road connects to the old PNR line and Pan-Philippine highway at the other side. A minor road.
A-22 (Major Intersection)	An existing 4.0m gravel road which connects to Pan-Philippine highway. A densely populated areas and business centers are near to this intersection. A traffic signal shall be installed.

Note: *Shown intersection "Type A" with asterisk (*) are just at-grade crossing only. Not designed with left turning movements to and from the bypass. Intersection "Type B" with asterisk (*) are farm underpass crossing only located along rice field or other agro-industrial farm areas.*

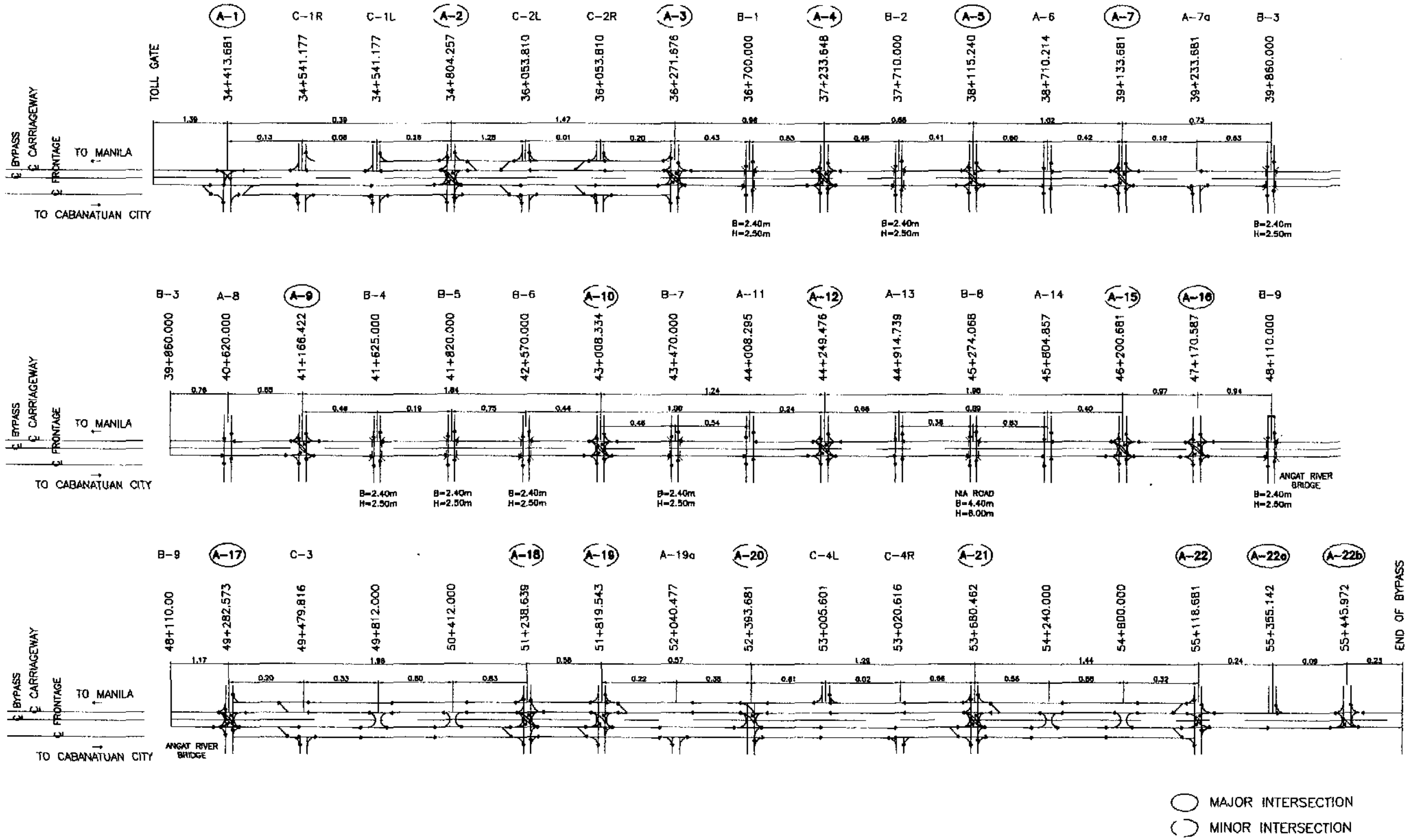


FIGURE 9.1-3 TRAFFIC MOVEMENTS AT INTERSECTIONS OF PLARIDEL BYPASS

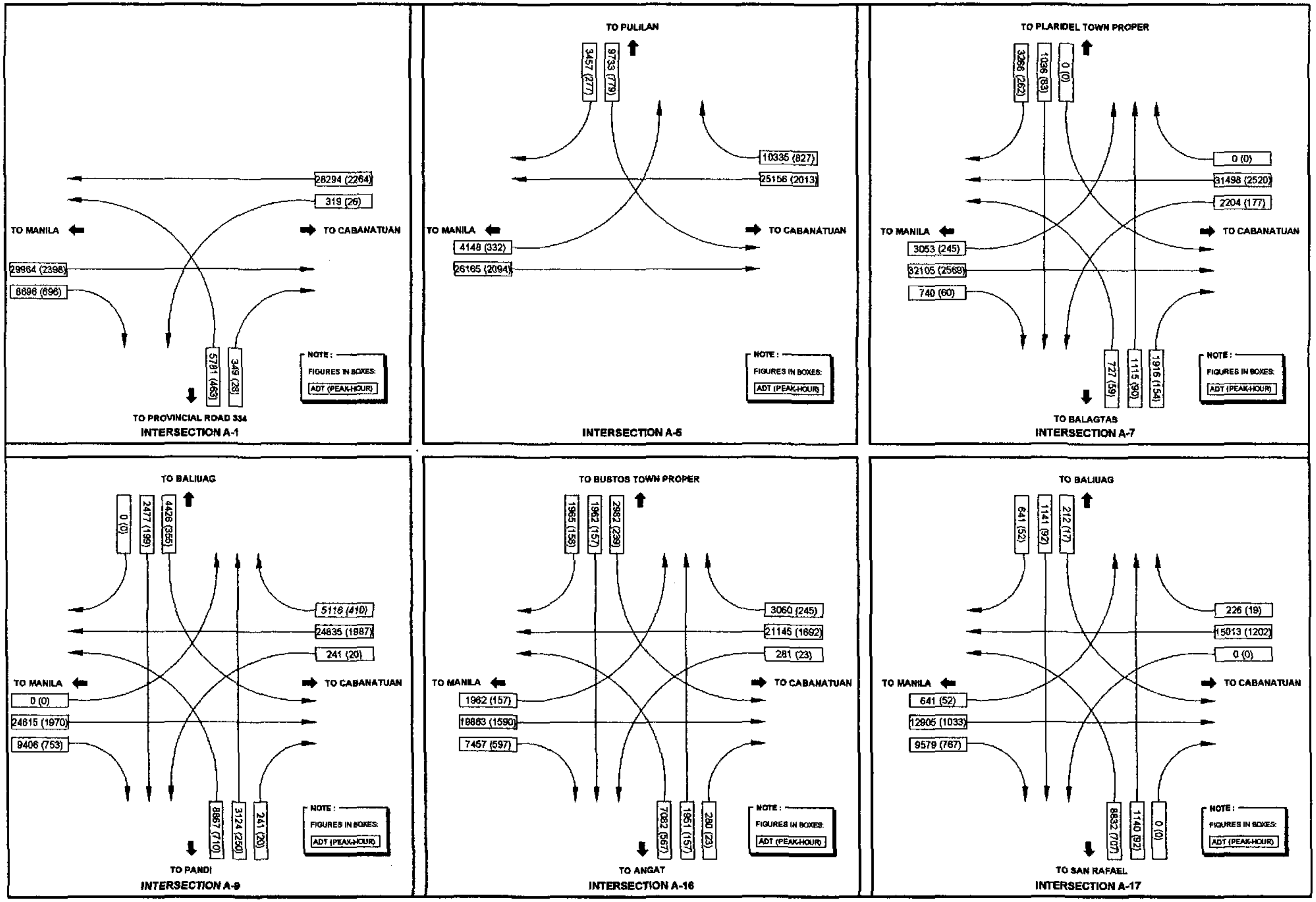


FIGURE 9.1-4 (1) DIRECTIONAL PEAK-HOUR TRAFFIC FLOW AT INTERSECTIONS (PLARIDEL BYPASS)

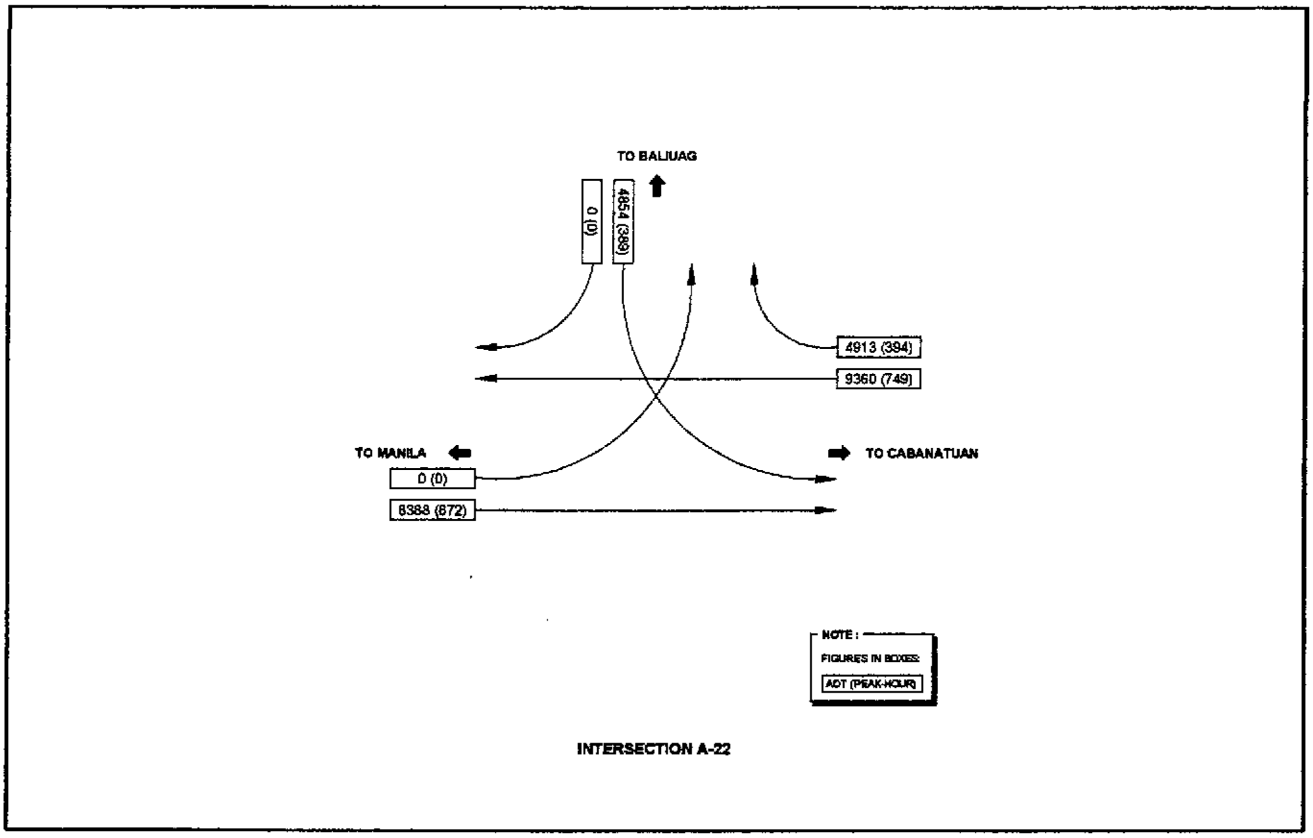


FIGURE 9.1-4 (2)

DIRECTIONAL PEAK-HOUR TRAFFIC FLOW AT INTERSECTIONS (PLARIDEL BYPASS)

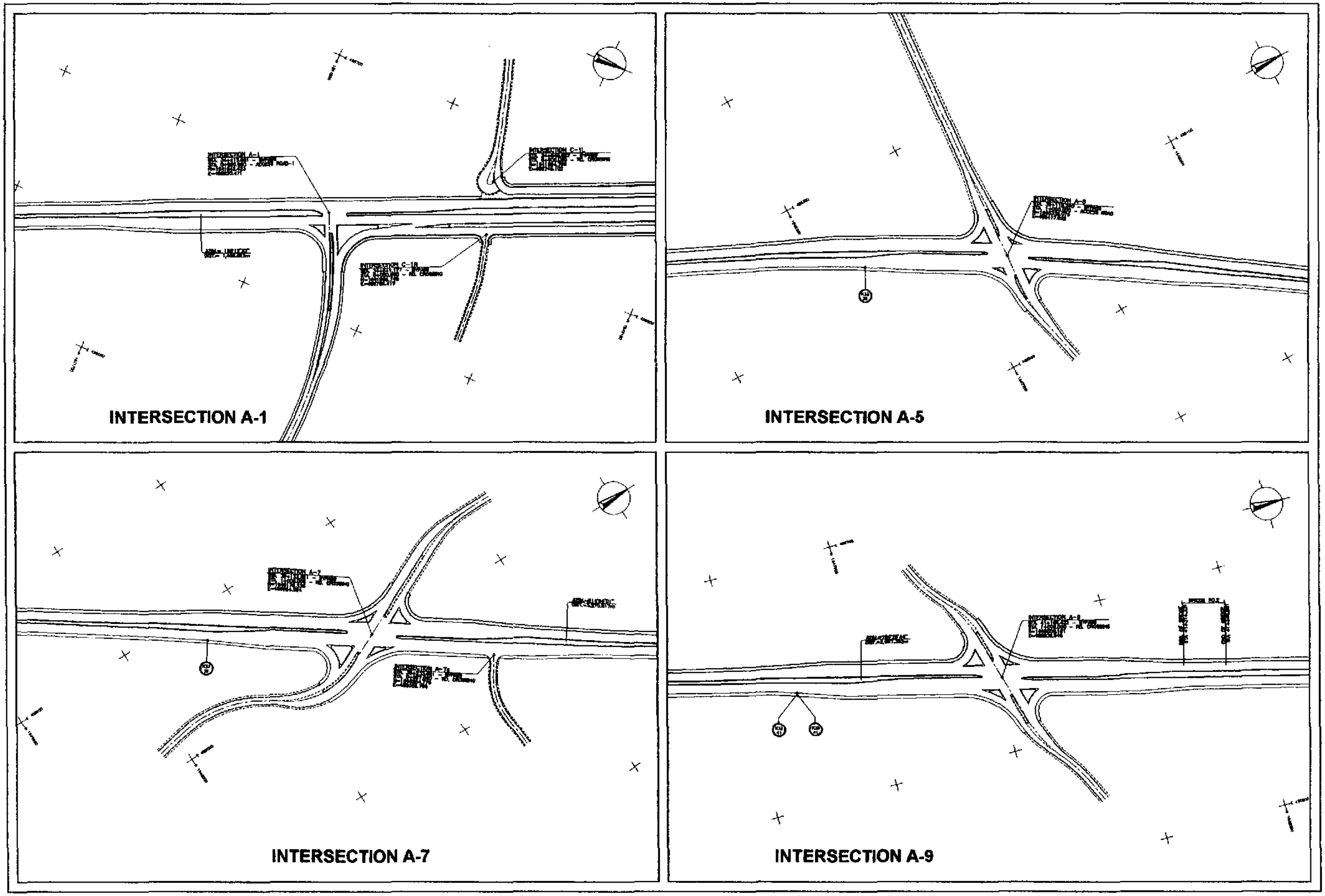


FIGURE 9.1-5(1) MAJOR INTERSECTIONS OF PLARIDEL BYPASS

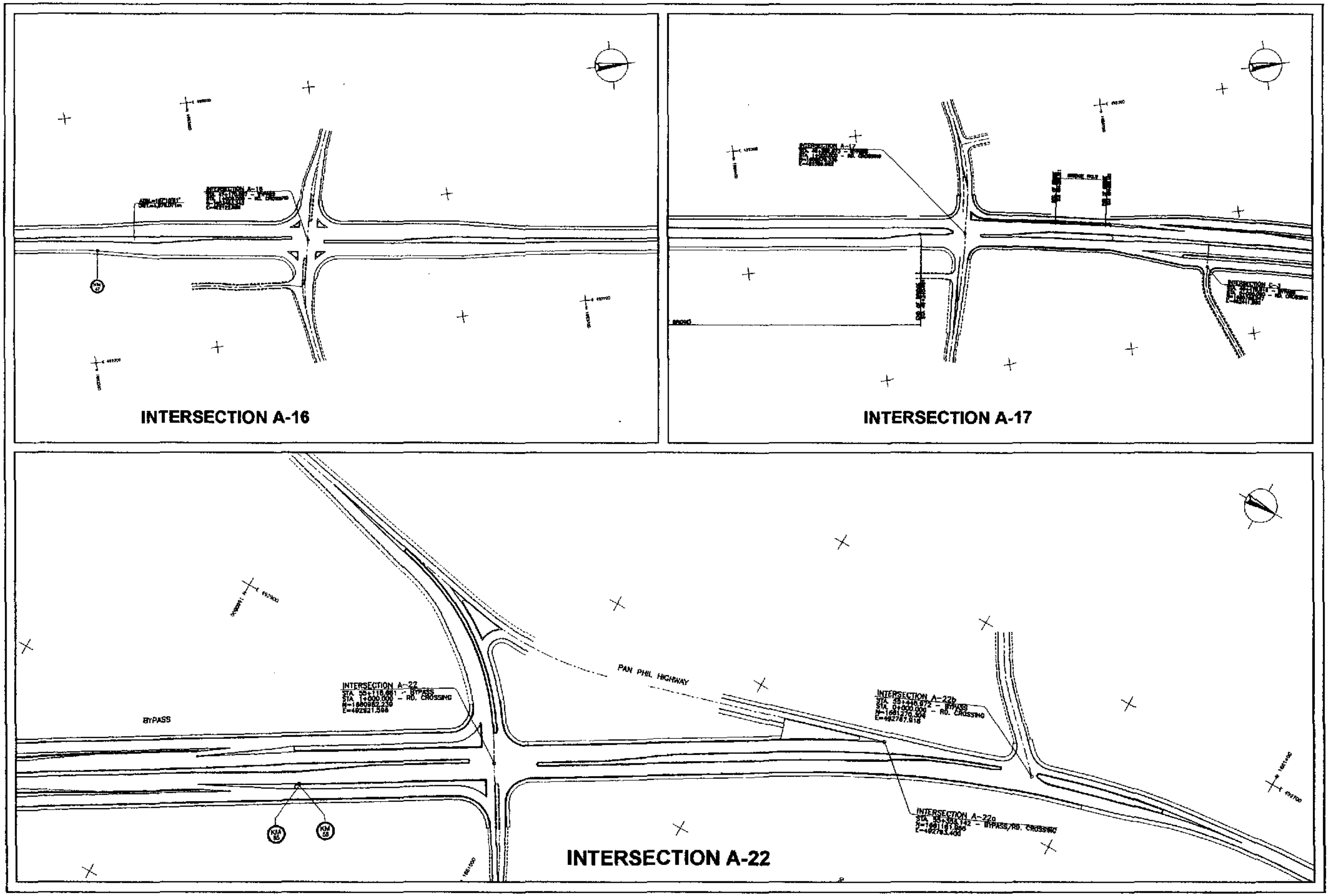


FIGURE 9.1-5(2) MAJOR INTERSECTIONS OF PLARIDEL BYPASS

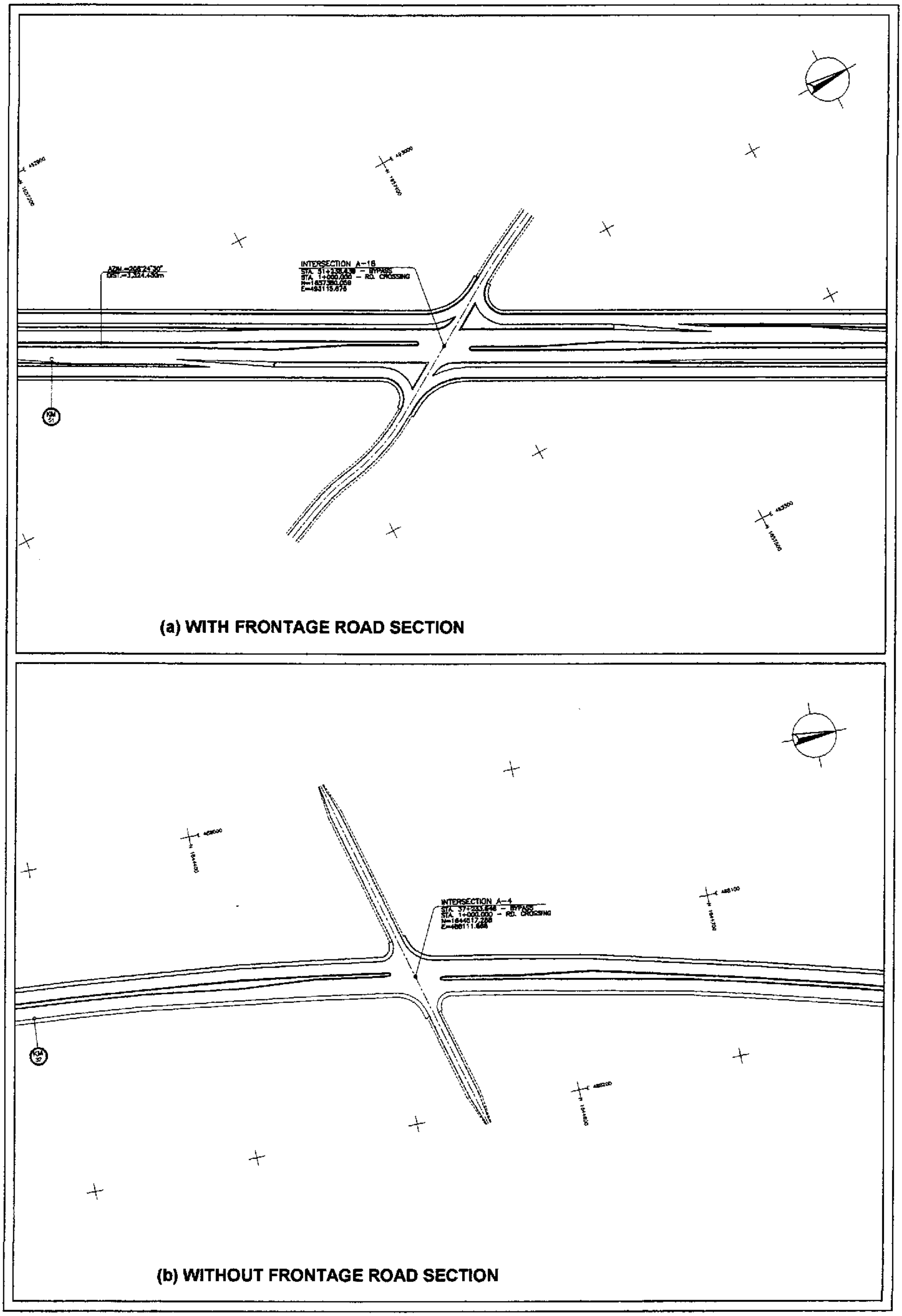


FIGURE 9.1-6 TYPICAL MINOR INTERSECTIONS OF PLARIDEL BYPASS

9.2 Interchange Design

9.2.1 Control Points

The Plaridel Bypass starts at about 500m north of the existing Burol Interchange along the North Luzon Expressway (NLE). The existing Burol Interchange is the facility to branch off another expressway going to Malolos from NLE and the location is shown in Fig.9.2-1. 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. The design for the widening is ongoing and some design data are collected from Manila North Tollways Corporation (MNTC).

The control points to be considered in the design are as follows (see Fig. 9.2-1);

- CP1: Service area along the north bound of NLE
- CP2: Temporary exit from NLE to provincial road no. 334 which will be closed after the completion of the interchange for Plaridel Byapss.
- CP3: Flyover bridge over NLE for provincial road no. 334.
- CP4: Flyover bridge over NLE for existing B ramp
- CP5: Drainage box culvert crossing under NLE
- CP6: Underpass along abandoned railway which is currently used as road.
- CP7: Bridge along the expressway to Malolos.
- CP8: Bridge along the expressway to Malolos for abandoned railway.
- CP9: Poultry farm.

The interchange design consists of realignment of existing Burol Interchange A and B ramps, design of new C, D and E ramps for the Plaridel Bypass, and the design of a toll plaza.

New interchange for the Plaridel Byapss is designed as imperfect direct Y type interchange. The ramps are planned as embankment structures, and bridge structure is required only for C ramp to cross over NLE. The bridge length is determined from the minimum height clearance of 5.10m and the maximum embankment height of 12m. The road levels are kept higher than the existing road level of NLE to prevent from flooding.

Acceleration and deceleration lengths are determined from the design standard of Japan Road Association (JRA) and parallel type was adopted for acceleration lane, while taper type was adopted for deceleration lane.

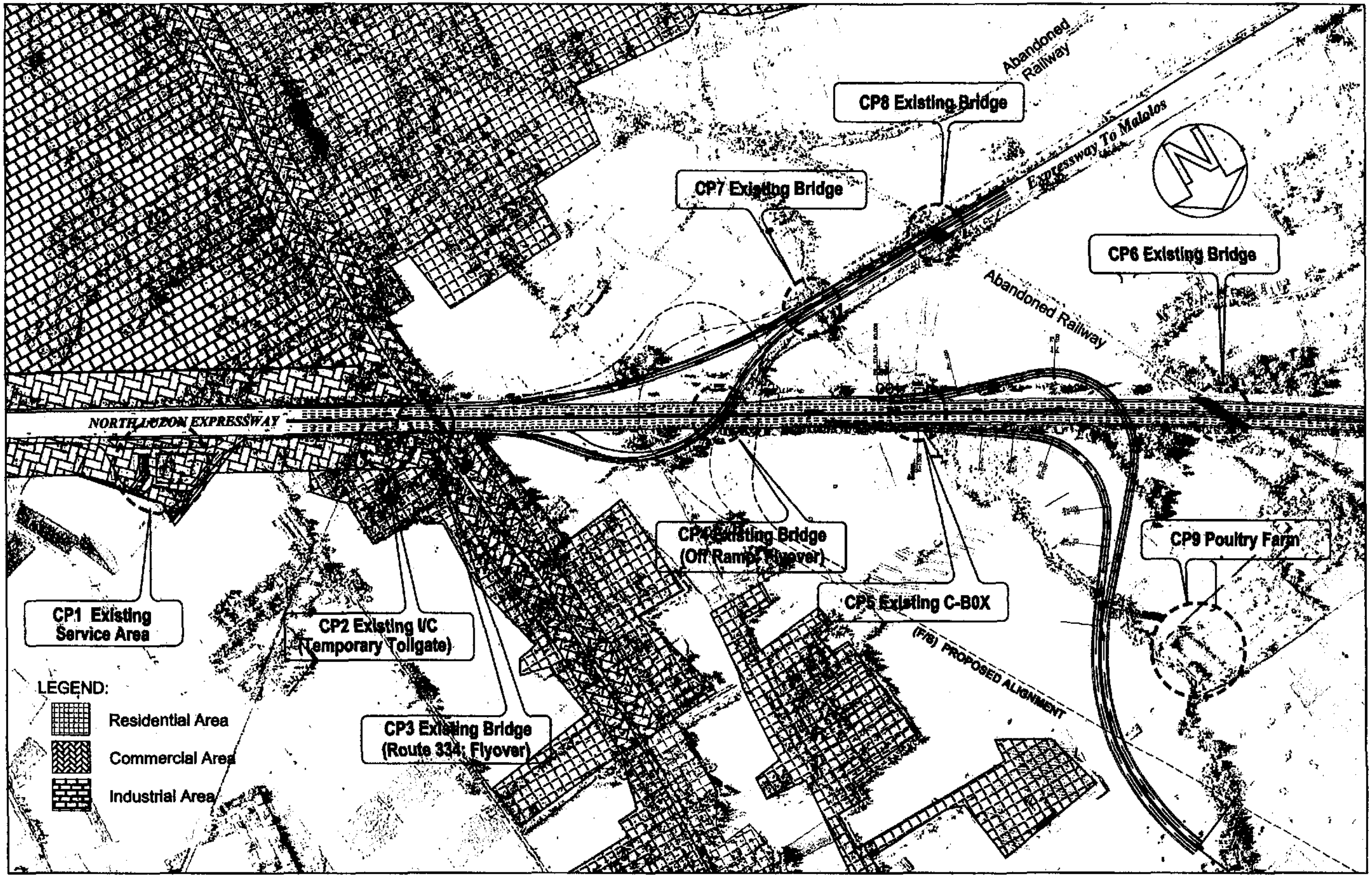


FIGURE 9.2-1 CONTROL POINTS AT BUROL INTERCHANGE AREA

9.2.2 Ramp Terminal Alternatives

Ramp terminals need to be carefully designed in due consideration of successive entrances along the south-bound lanes and successive exits along the north-bound lanes of NLE.

PNCC / MNEC's Plan

- NLE is to be widened from a 4-lane divided expressway to a 8-lane divided expressway up to Burol I/C, and to a 6-lane divided expressway for the northern section from Burol I/C.
- Ramp A is planned to be one-lane and is directly connected to the 4th lane (or outer-most lane) of NLE.
- Ramp B is planned to be one-lane. The 4th plane (outer-most lane) of NLE is directly connected to this ramp.

In due consideration of above, three alternatives were prepared as shown in Table 9.2-1 and illustrated in Figure 9.2-2.

Alternative – 1

- Ramps A and B design by PNCC / MNEC is adopted.
- NLE between Ramps A/B and Ramps C/D is to be a 6-lane divided expressway.
- Ramps C and D are planned to be 2 lanes.
- Ramp C is designed to allow 2-lane merging and Ramp D to allow 2-lane diverging.

Alternative – 2

- Ramps A and B design by PNCC / MNEC is adopted.
- NLE between Ramps A/B and Ramps C/D is to be a 8-lane divided expressway, however, 4th lane (or outer-most lane) is designed as an auxiliary lane.
- The auxiliary lane is to be directly connected to Ramp C or D, thus, Ramp C is designed to allow 1-lane merging and Ramp D to allow 1-lane diverging.

Alternative – 3

- NLE is designed to be a 8-lane divided expressway up to Ramps C and D.
- Ramps A and B is designed to allow 1-lane merging or diverging.
- Fourth lane of NLE is directly connected to Ramps C or D.

TABLE 9.2-1 ALTERNATIVES OF RAMP TERMINAL

Item	No. of Lane of NLE per Direction			Ramp Terminal of Expressway to Malolos						Ramp Terminal of Plaridel Bypass						Remarks
	South of Ramps A&B (Manila Side)	Between Ramps A,B and Ramps C,D	North of Ramps C&D (Angeles Side)	Ramp A (Entrance)			Ramp B (Exit)			Ramp C (Entrance)			Ramp D (Exit)			
				No. of Lane	Type of Terminal	Acceleration Length (m)	No. of Lane	Type of Terminal	Deceleration Length (m)	No. of Lane	Type of Terminal	Acceleration Length (m)	No. of Lane	Type of Terminal	Deceleration Length (m)	
Original Plan of PNCC/MNEC (without Bypass ramps)	4	3	3	1	Directly connected to 4th (outer-most) lane of NLE	—	1	Directly connected to 4th (outer-most) lane of NLE	—	—	—	—	—	—	—	—
Alternative 1	4	3	3	1	Directly connected to 4th (outer-most) lane of NLE	—	1	Directly connected to 4th (outer-most) lane of NLE	—	2	Parallel Type (2-lane merging)	330 (including taper length of 80m)	2	Taper Type (2-lane diverging)	180 (including taper length of 70m)	Ramps A&B follow design of PNCC.
Alternative 2	4	4 (4th lane is planed to be an auxiliary lane, but not as through traffic lane)	3	1	Directly connected to 4th (outer-most) lane of NLE	—	1	Directly connected to 4th (outer-most) lane of NLE	—	2	Parallel Type (1-lane to be directly connected to an auxiliary lane. 1-lane merging)	240 (including taper length of 60m)	2	Taper Type (4th lane of NLE to be directly connected to ramp. 1-lane diverging)	155 (including taper length of 65m)	For the section between ramp A and ramp C, an auxiliary lane is added to NLE. Ramps A and B follow design of PNCC
Alternative 3	4	4	3	1	Parallel Type	240 (including taper length of 60m)	1	Taper Type	155 (including taper length of 65m)	2	Parallel Type (1-lane to be directly connected to 4th lane. 1-lane merging)	240 (including taper length of 60m)	2	Taper Type (4th lane of NLE to be directly connected to ramp. 1-lane diverging)	155 (including taper length of 65m)	4-lane for through traffic is provided along NLE. Ramp A and B design of PNCC to be revised.

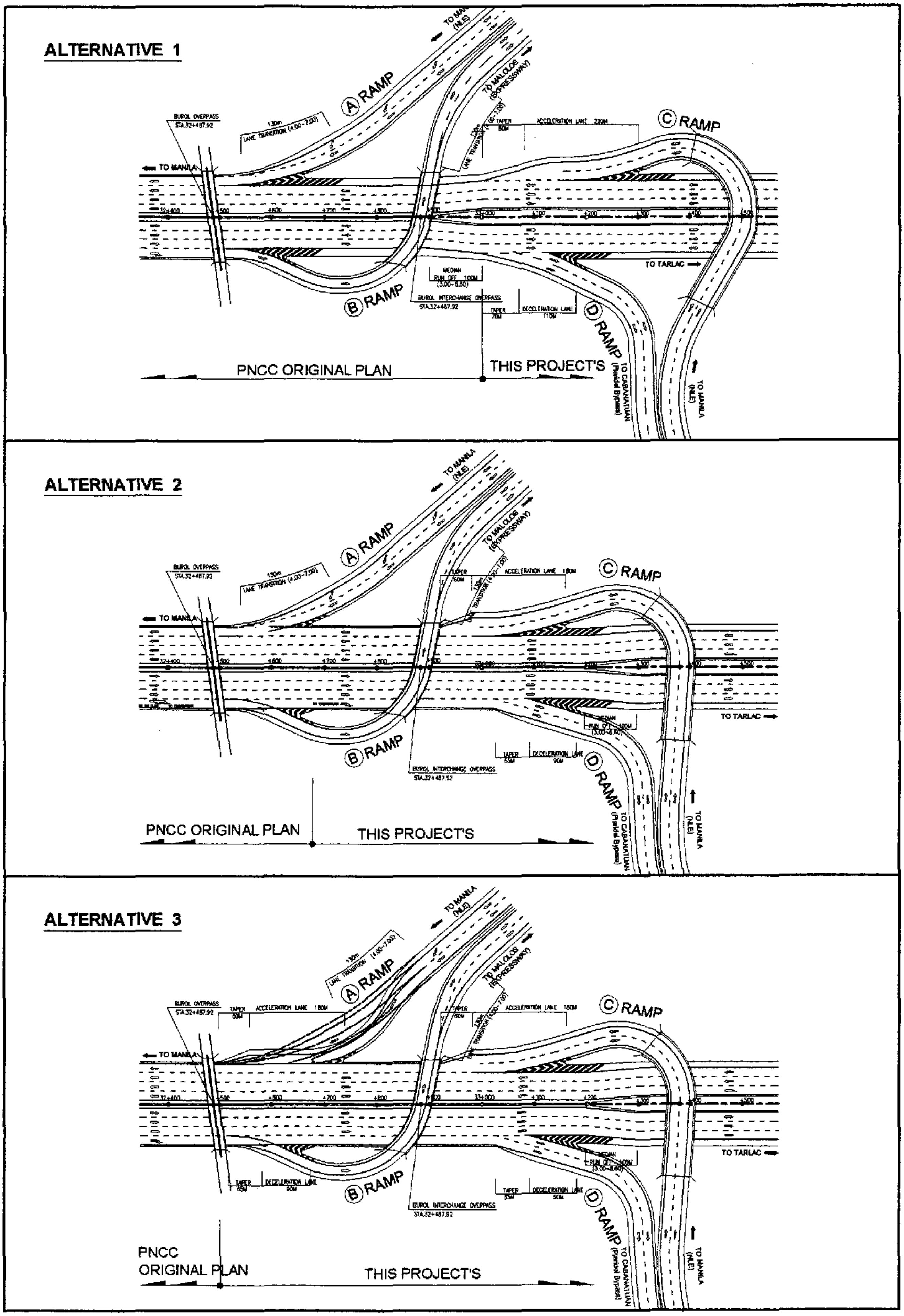


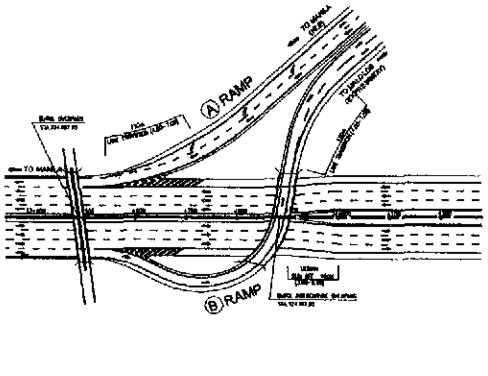
FIGURE 9.2-2 PLAN OF ALTERNATIVES

- Ramp C and D is designed to allow 1-lane merging or diverging.

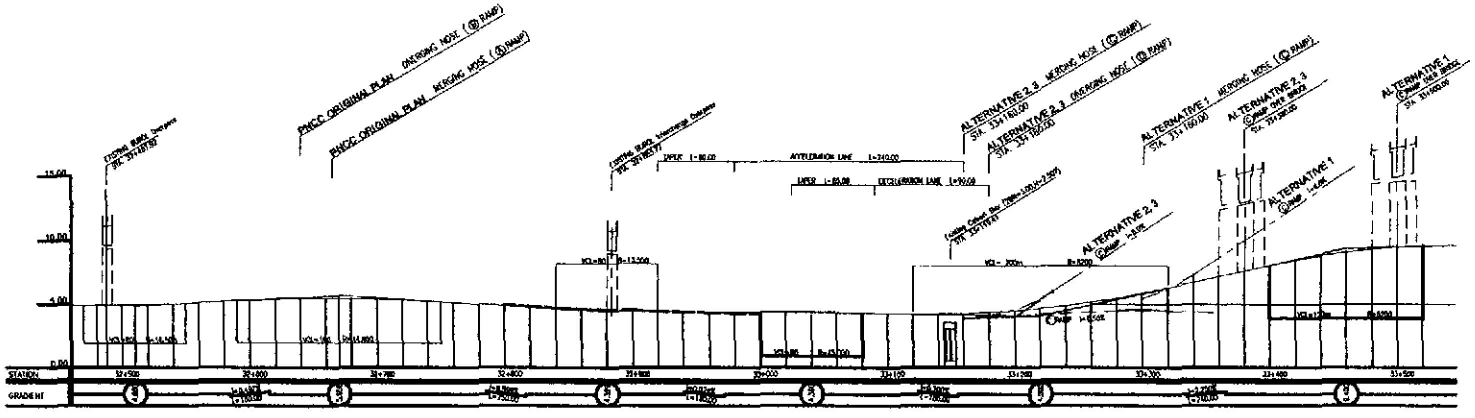
Evaluation of Alternatives is shown in Figure 9.2-3. Alternative-3 is recommended for this interchange.

- Alternative-3 achieves the highest safety in traffic operation.
- Whereas Alternative-1 requires 2-lane merging at Ramp C, therefore, Ramp C viaduct needs to be shifted towards north where NLE elevation is high. Longer viaduct length than other alternatives is required, resulting in the most expensive construction cost.
- Alternative-2 will have traffic operation problem at the NLE section between Ramp A and Ramp C.

Interchange plan based on Alternative-3 is shown in Figure 9.2-4.

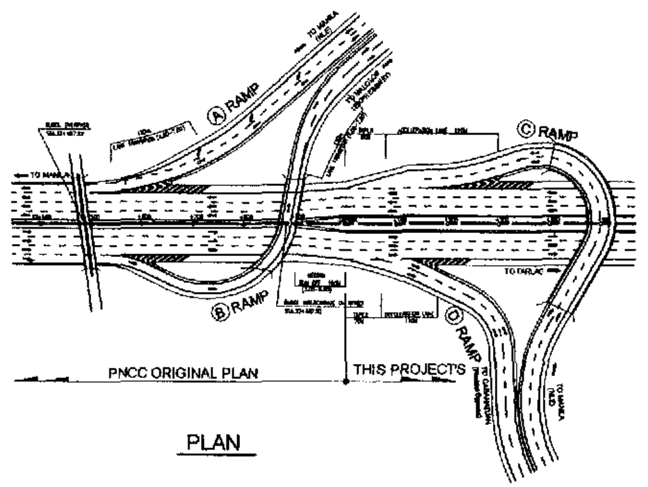


PNCC ORIGINAL PLAN



PROFILE OF BUROL INTERCHANGE ON NLE H=1:4,000 V=1:400

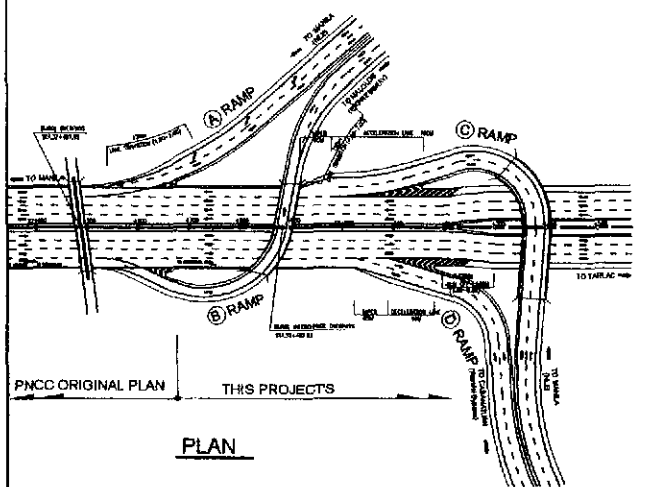
ALTERNATIVE 1



PLAN

GEOMETRY FOR BUROL IC.	NLE	Min.R=10,000	C RAMP MERGING NOSE i=2.25%		△
	C RAMP	Min.R=100 Max. i=6.000 %			○
	D RAMP	Min.R=100 Max. i=2.250 %			○
RUNNING CONDITION	NLE	Good			○
	RAMPS	Grudient i=6.0 % Section L=250m			○
STRUCTURE	C RAMP Bridge	L=180m	3-Level Structure		△
CONSTRUCTION COST	Highest	EVALUATION		3	

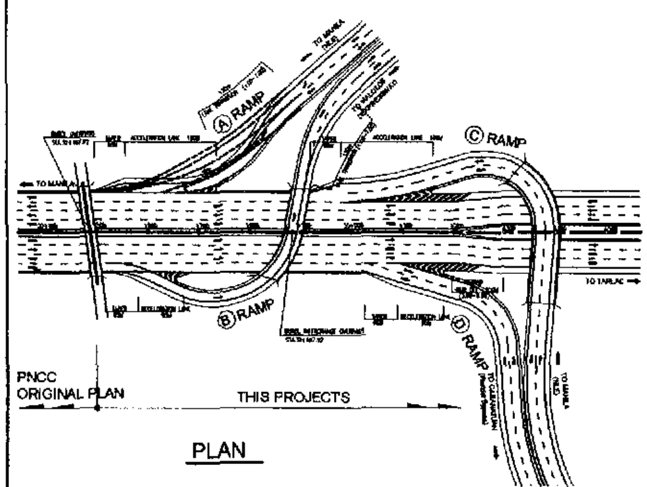
ALTERNATIVE 2



PLAN

GEOMETRY FOR BUROL IC.	NLE	Min.R=10,000	C RAMP MERGING NOSE i=0.29%		○
	C RAMP	Min.R=100 Max. i=6.000 %			○
	D RAMP	Min.R=100 Max. i=0.535 %			○
RUNNING CONDITION	NLE	Good			○
	RAMPS	Grudient i=6.0 % Section L=200m			○
STRUCTURE	C RAMP Bridge	L=120m	2.5-Level Structure		○
CONSTRUCTION COST	Cheapest	EVALUATION		1	

ALTERNATIVE 3



PLAN

GEOMETRY FOR BUROL IC.	NLE	Min.R=10,000	C RAMP MERGING NOSE i=0.29%		○
	C RAMP	Min.R=100 Max. i=6.000 %			○
	D RAMP	Min.R=100 Max. i=0.535 %			○
RUNNING CONDITION	NLE	Good			◎
	RAMPS	Grudient i=6.0 % Section L=200m			○
STRUCTURE	C RAMP Bridge	L=120m	2.5-Level Structure		○
CONSTRUCTION COST	Second	EVALUATION		2	

FIGURE 9.2-3 EVALUATION OF BUROL INTERCHANGE SYSTEM ALTERNATIVES

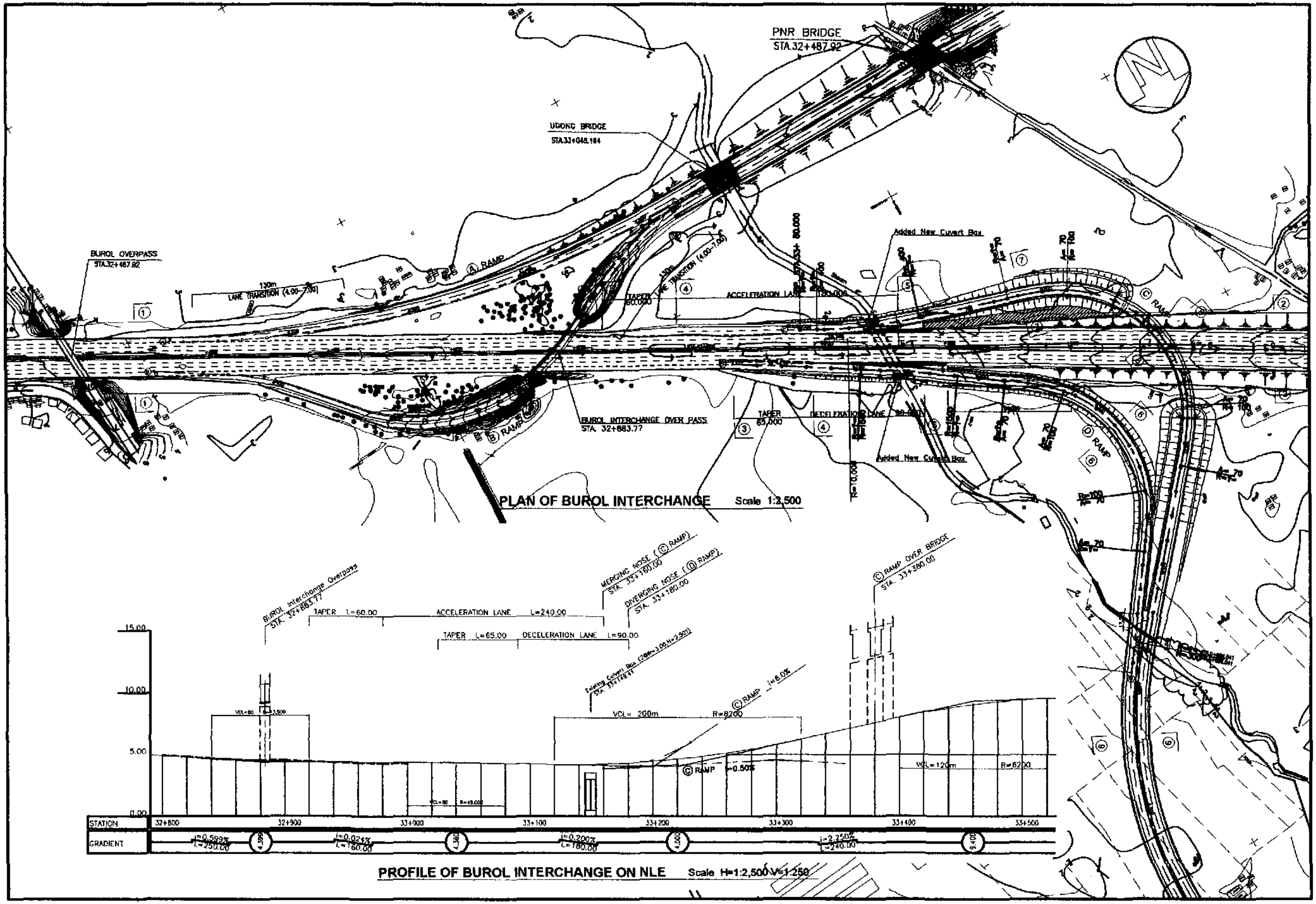


FIGURE 9.2-4 BUROL INTERCHANGE DESIGN OF ALTERNATIVE 3

9.2.3 Required Number of Lane for Toll Gate

The required number of lanes in toll gate, according to the standard of Japan Highway Corporation (JH), will be determined from the □: Traffic Volume (Average interval of passing vehicles), □: Average Service Time and □: Serviceability (Average numbers of waiting vehicles).

(1) Standard Hourly Traffic Volume

As the index for traffic volume, the 30^{th} Hourly Traffic Volume of annual data will be used for the Design Hourly Volume (DHV). The 30^{th} Hourly Traffic Volume can be obtained from the Annual Average Daily Traffic volume (ADT) by the following equation.

$$DHV = ADT \times K \times D$$

K : The rate of 30^{th} hourly traffic volume to ADT

D : The rate of traffic volume in a direction which is larger to the total traffic volume in both direction based on 30^{th} hourly traffic volume.

TABLE 9.2.2 VALUE OF K, D

	Rural	Urban
K	0.12~0.14	0.09~0.12
D	0.60~0.70	0.50~0.60

Source: JH STANDARD

(2) Service Time

The service time used for the estimation of required lane numbers for a toll gate operated in the manner of Open System (non-uniform fare related to the section of the highway) will be, in principle, taken as 6 seconds and 14 seconds for entrance and exit respectively. Other service time may be adopted if it is predicted that the service time will be obviously different from the prescribed values.

(3) Serviceability

Serviceability can be expressed with the average number of waiting vehicles at the toll gate and 1.0 is principally adopted. The value may be altered if it is not applicable for the case depending on geological condition, traffic volume, etc.

The calculation results based on the above equation is summarized in Table 9.2-3. As the design target year for initial stage and ultimate stage is not clear, the required numbers of lanes for both stages were determined referring to the design target year specified in JH Standard shown in Table 9.2-4.

The plan and cross-section is shown in Fig.9.2-5 and 6, respectively.

		Entrance	Exit
Initial Stage	--------------------	3-Lane	6-Lane
Ultimate Stage	----------------------	4-Lane	8-Lane

TABLE 9.2-3 AADT AND NUMBER OF LANE IN THE TOLLGATE

ITEM		2005		2010		2020	
		ENTRANCE	EXIT	ENTRANCE	EXIT	ENTRANCE	EXIT
AADT		10775	17900	12549	19304	22547	23468
K		0.12	0.12	0.12	0.12	0.12	0.12
D		0.6	0.6	0.6	0.6	0.6	0.6
DVH		776	1289	904	1390	1623	1690
b :	Service Time	6	14	6	14	6	14
s :	Number of Lane	3	6	3	6	4	8
a :	Average interval of insertion car	4.640	2.793	3.984	2.590	2.218	2.131
ρ:	Traffic intensity	1.293	5.012	1.506	5.405	2.706	6.571
μ:	Traffic intensity par a lane	0.431	0.835	0.502	0.901	0.676	0.821
k :	Probability of no car in the tollgate	0.26581	0.00443	0.20910	0.00212	0.07010	0.00105
w :	Average waiting time	0.6	8.4	1.0	17.5	2.2	4.9
q :	Number of average waiting	0.3	3.6	0.5	7.5	1.5	2.8
q /s :	Number of average waiting car per one lane	0.1	0.6	0.2	1.2	0.4	0.4

TABLE 9.2-4 DESIGN TARGET YEAR FOR EACH FACILITY

Tollgate Facilities	Target Year
Required land area for Toll Gate	15 years after open
Earthwork for Toll Gate area	10 〃
Walkway	10 〃
Toll island and Carriageway Pavement	10 〃
Tollgate roof	10 〃
Tollbooth and Toll Collecting System	5 〃

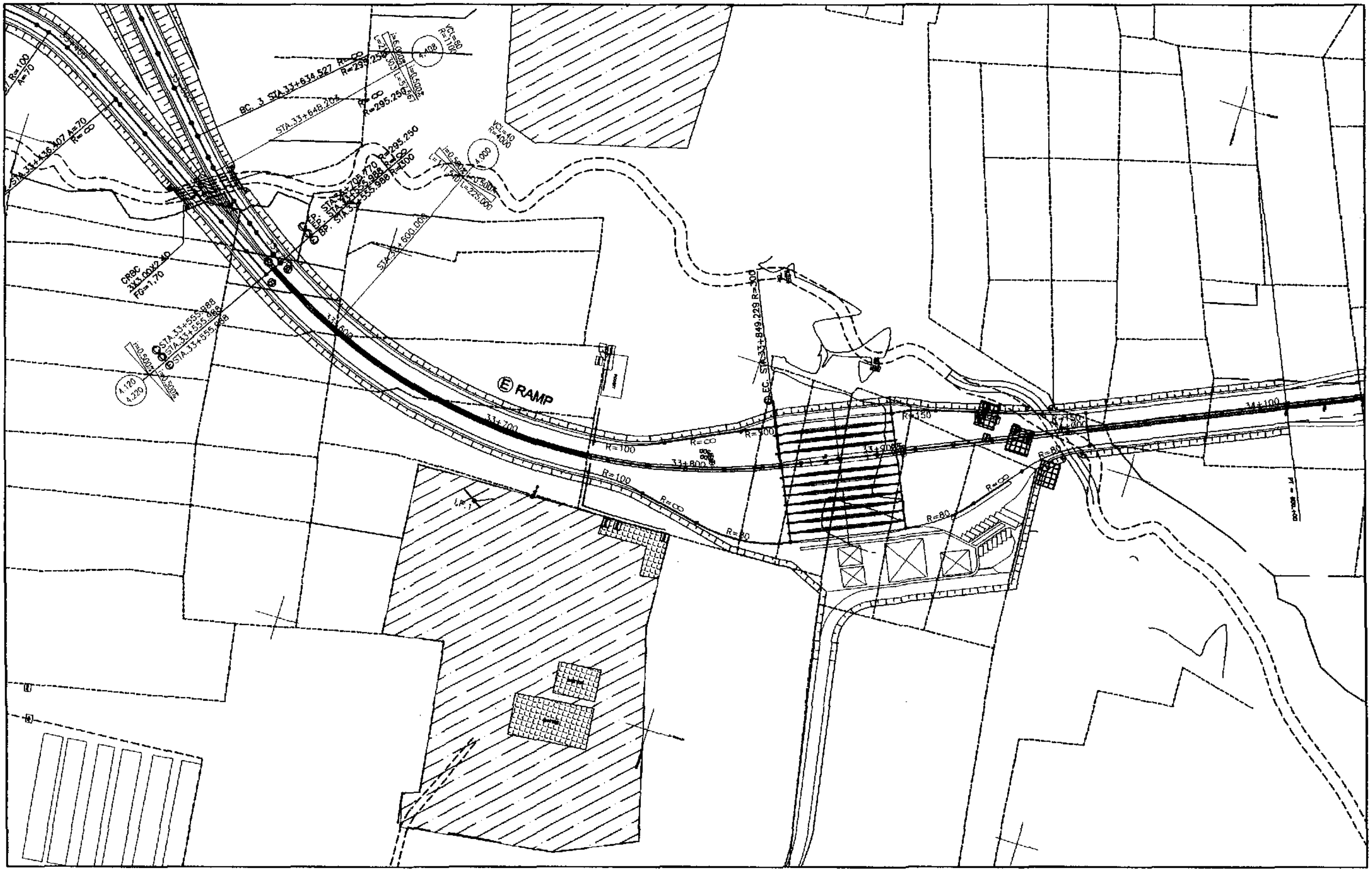
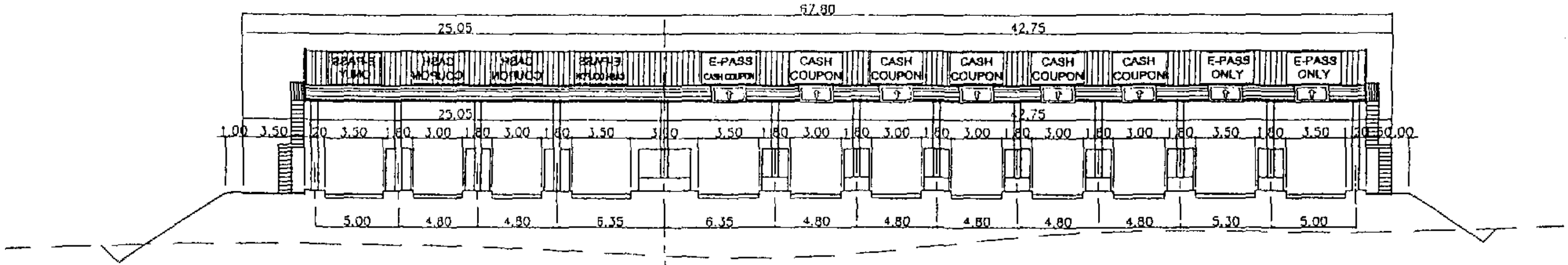
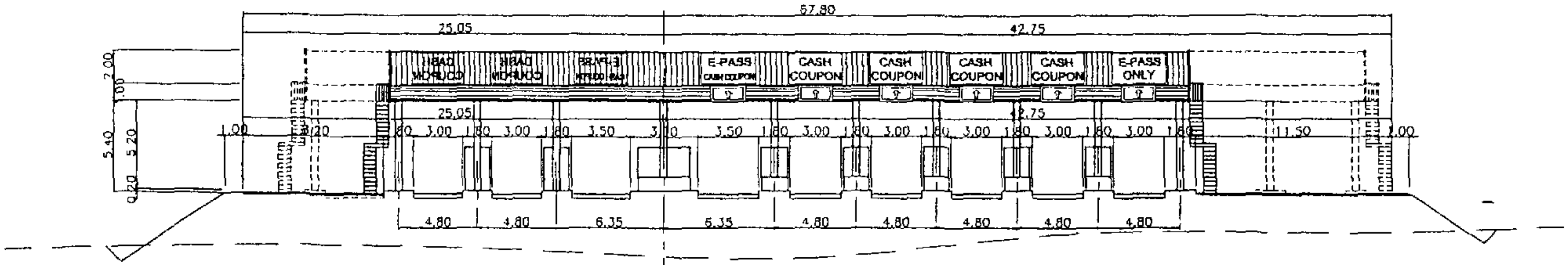


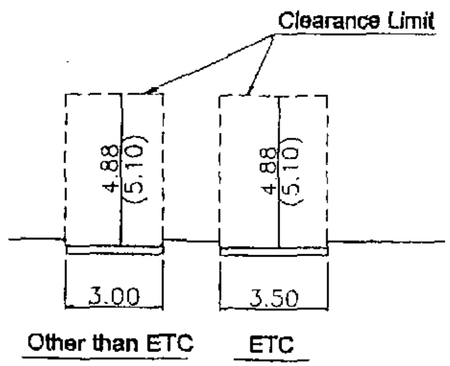
FIGURE 9.2-5 PLAN OF BUROL INTERCHANGE (4)



ULTIMATE STAGE



INITIAL STAGE



ITEM		2005		2010		2020	
		ENTRANCE	EXIT	ENTRANCE	EXIT	ENTRANCE	EXIT
AADT		10775	17900	12549	19304	22547	23468
K		0.12	0.12	0.12	0.12	0.12	0.12
D		0.8	0.8	0.6	0.6	0.6	0.6
DVH		776	1289	904	1390	1623	1690
b :	Service Time	6	14	6	14	6	14
s :	Number of Lane	3	6	3	6	4	8
a :	Average interval of insertion car	4.640	2.793	3.984	2.590	2.218	2.131
ρ :	Traffic intensity	1.293	5.012	1.506	5.405	2.706	6.571
μ :	Traffic intensity per a lane	0.431	0.835	0.502	0.901	0.676	0.821
k :	Probability of no car in the	0.26581	0.00443	0.20910	0.00212	0.07010	0.00105
w :	Average waiting time	0.6	8.4	1.0	17.5	2.2	4.9
q :	Number of average waiting	0.3	3.6	0.5	7.5	1.5	2.8
q / s :	Number of average waiting car per one lane	0.1	0.6	0.2	1.2	0.4	0.4

FIGURE 9.2-6 CROSS-SECTION OF TOLL BARRIER

9.3 Drainage Design

9.3.1 Cross Drainage

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

- Locations defined by the catchment areas analysis,
- Locations of existing irrigation channels,
- 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.

The cross drainage structures are consisting of pipe and box culverts. The dimensions of the drainage structures were designed using the hydraulic monographs prepared by the United State's. Bureau of Public Roads (US BPR) and were also verified mathematically.

The size of pipe and box culverts was selected from the sizes listed in the DPWH Standard Drawing prepared by BOD.

The finished grade of the bypass was checked based on the required invert elevation levels of inlets and outlets of cross drainages. Minimum 0.6 m cover height over cross pipe was considered in design of bypass profile to achieve the requirements of DPWH Guidelines.

1) Catchment Areas and Discharges

Figure 9.3-1 shows the catchment areas. There are sixty-seven (67) areas specified including ten locations where bridges are constructed. The hydrological characteristics of these watersheds, their estimated discharges for the different return periods and capacity of proposed drainage structures are presented in Appendix 9.3-1. Ten (10) years return period is considered for design of RCPC while twenty-five (25) years return period is considered for design of RCBC.

Drainage system of the Plaridel Bypass is shown in Figure 9.3-2.

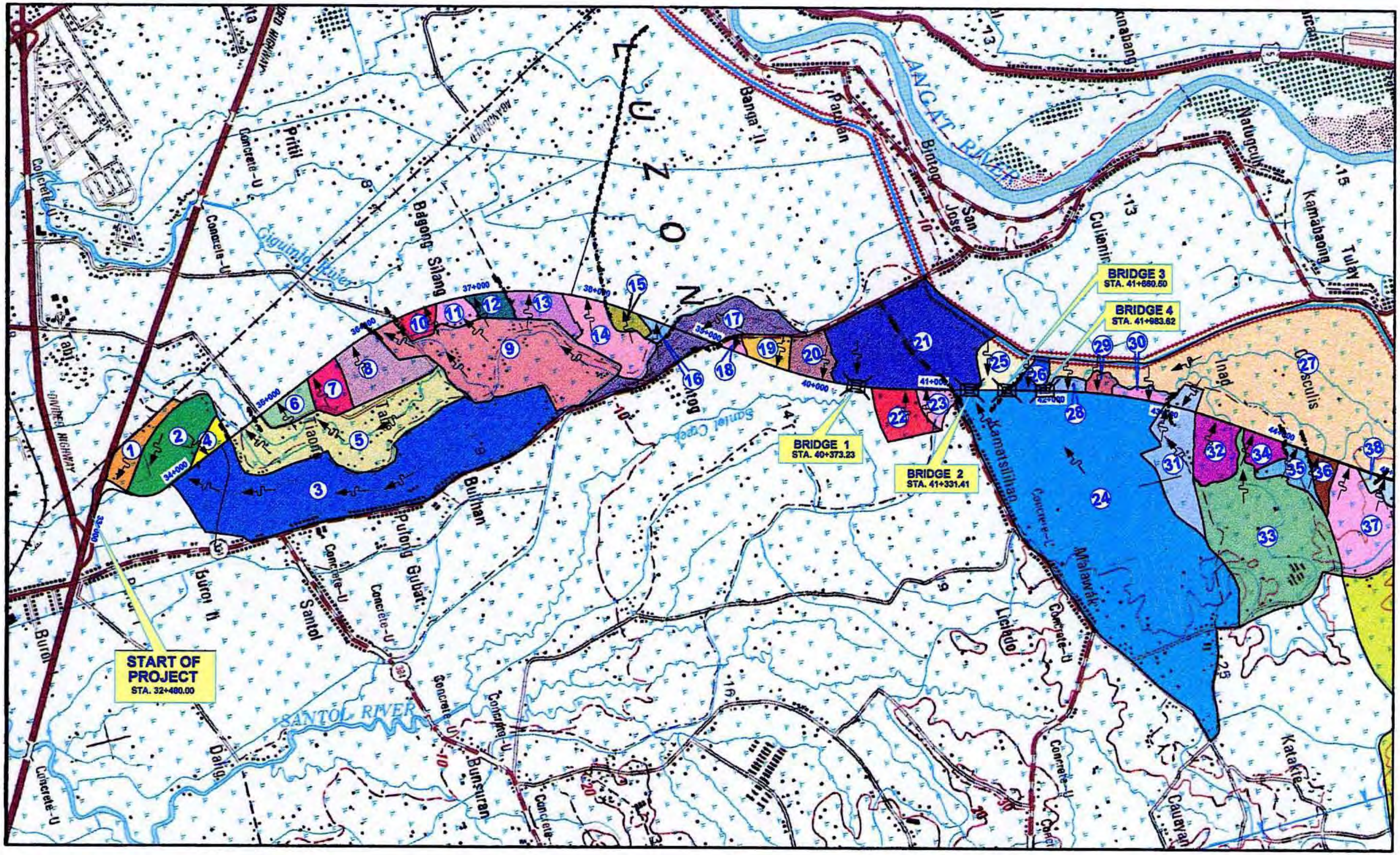


FIGURE 9.3-1 PLARIDEL BYPASS CATCHMENT AREAS (1/2)

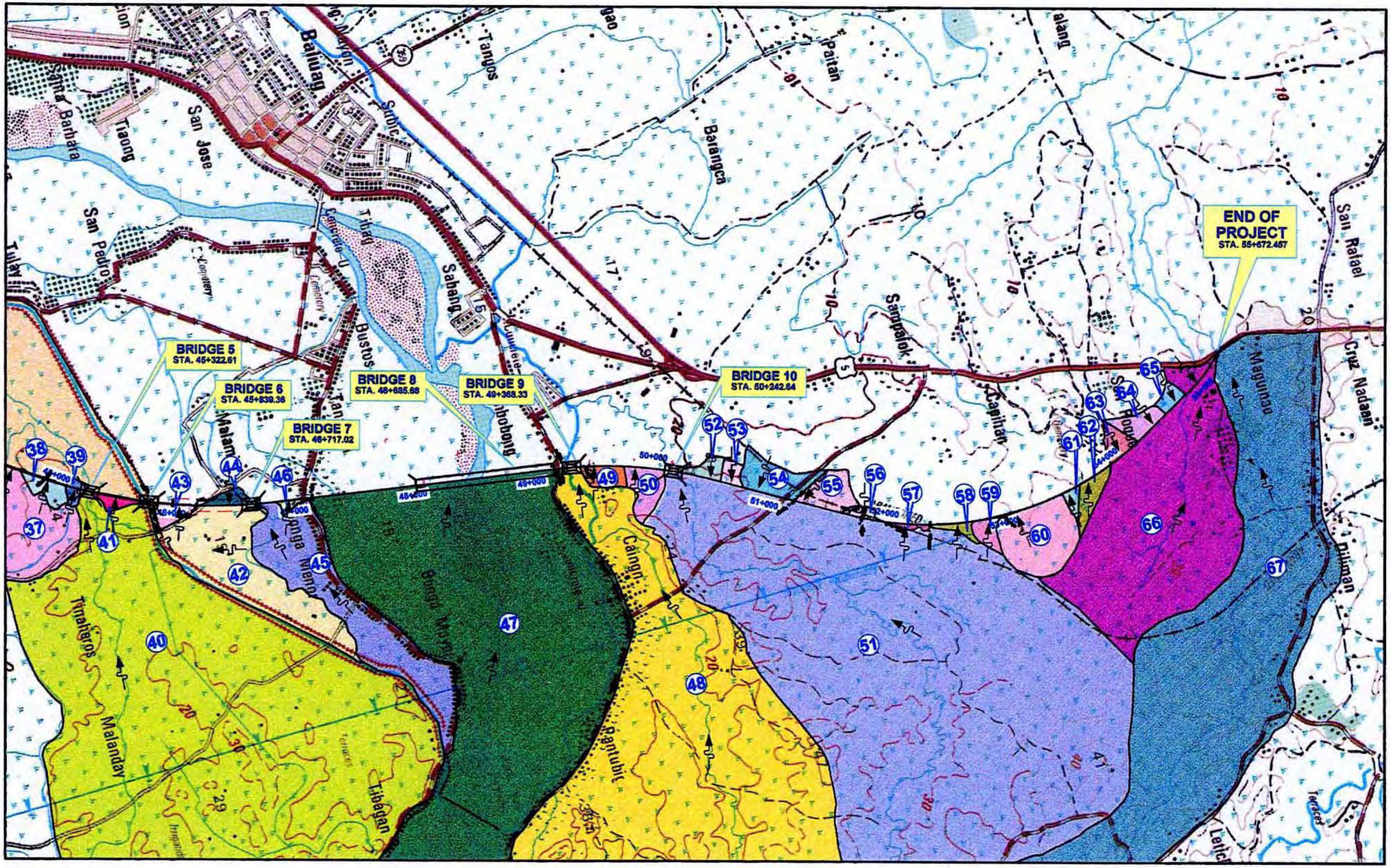


FIGURE 9.3-1 PLARIDEL BYPASS CATCHMENT AREAS (2/2)

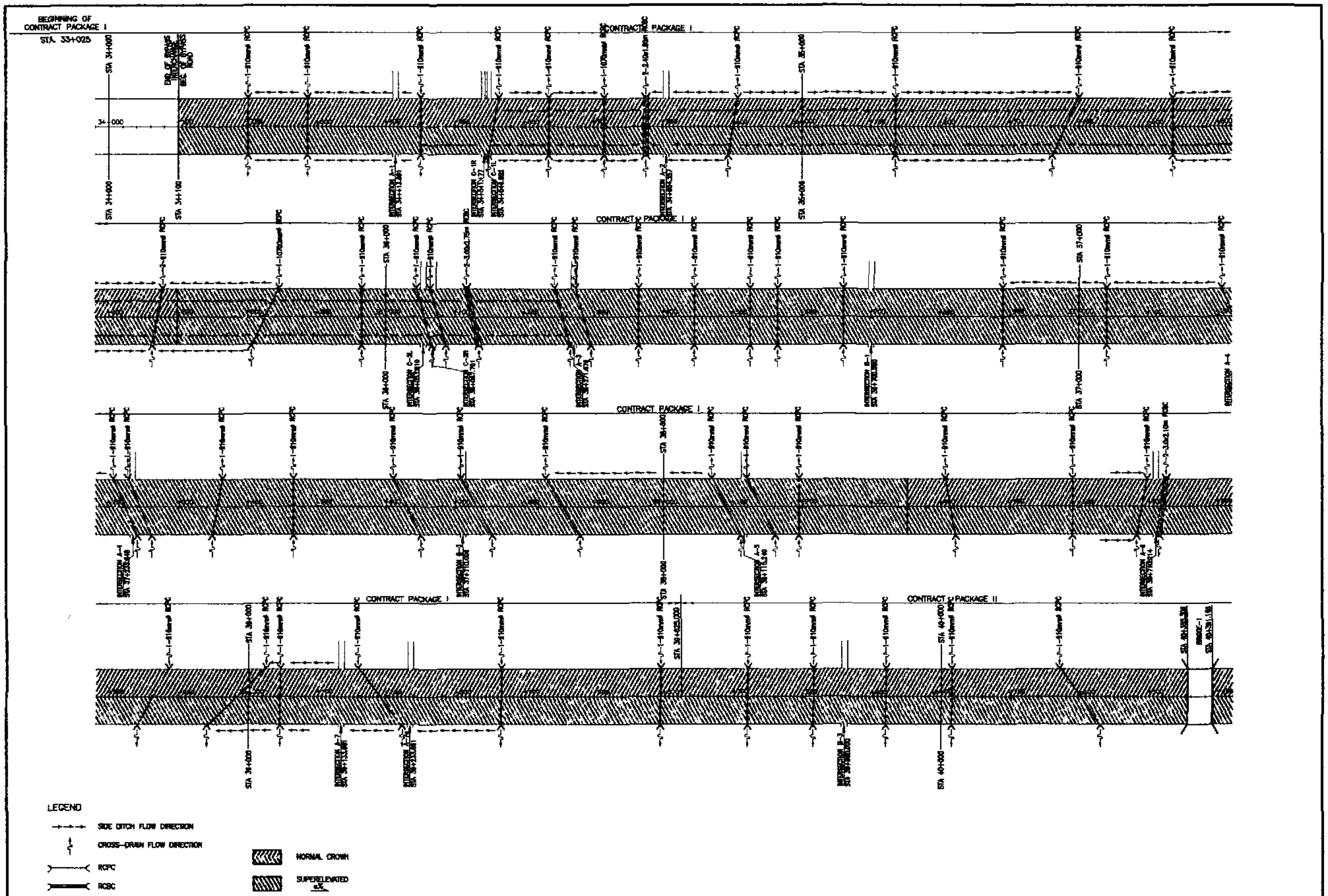


FIGURE 9.3-2 (1/4) DRAINAGE SYSTEM OF PLARIDEL BYPASS (INITIAL STAGE)

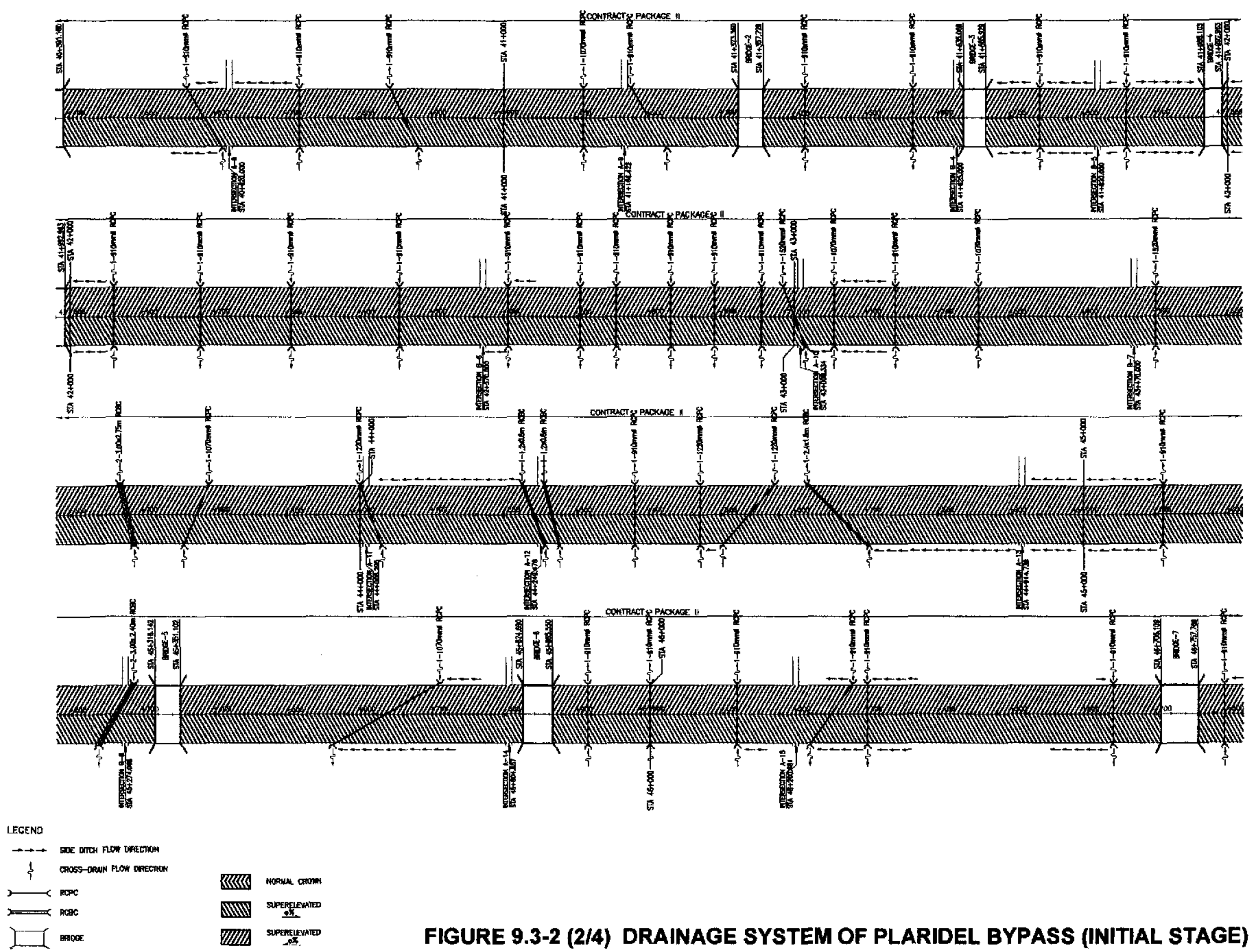


FIGURE 9.3-2 (2/4) DRAINAGE SYSTEM OF PLARIDEL BYPASS (INITIAL STAGE)

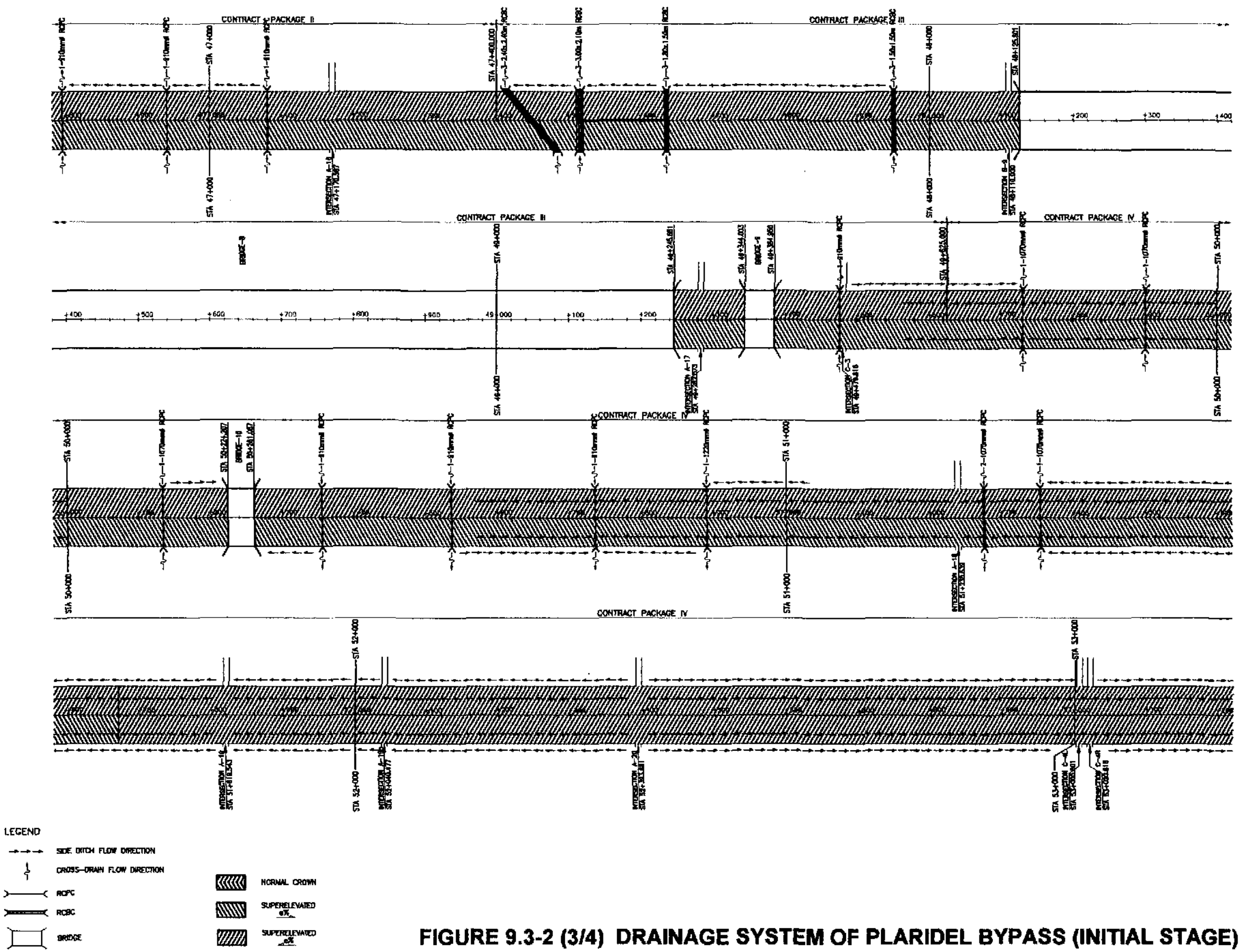


FIGURE 9.3-2 (3/4) DRAINAGE SYSTEM OF PLARIDEL BYPASS (INITIAL STAGE)

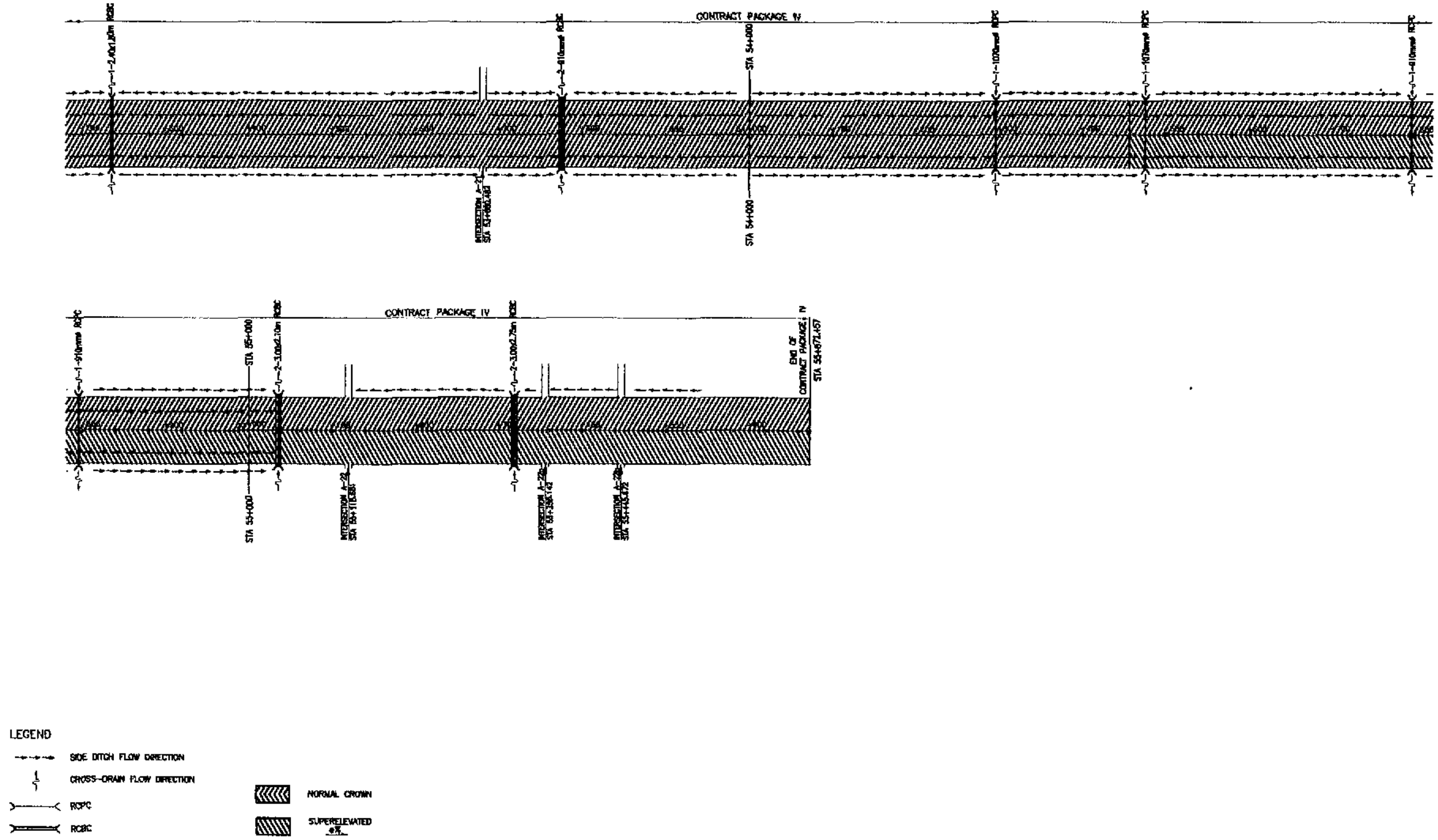


FIGURE 9.3-2 (4/4) DRAINAGE SYSTEM OF PLARIDEL BYPASS (INITIAL STAGE)

9.3.2 Surface Drainage

1) System of Drainage

Figure 9.3-3 is Typical Normal Crown Cross-Section. During the Initial-Stage, the surface water will be drained laterally outside the road to the side ditches and consequently to the cross-drainage locations.

In the Ultimate-Stage, drain of surface water will require the construction of curb inlets, gutters, pipes and manholes. The different surface drainage schemes that can be used to carry out the drainage of the surface water were studied. There are four schemes that can be adopted as shown in Figure 9.3-4. The following criteria were considered to select the best scheme for the surface drainage of the Bypass:

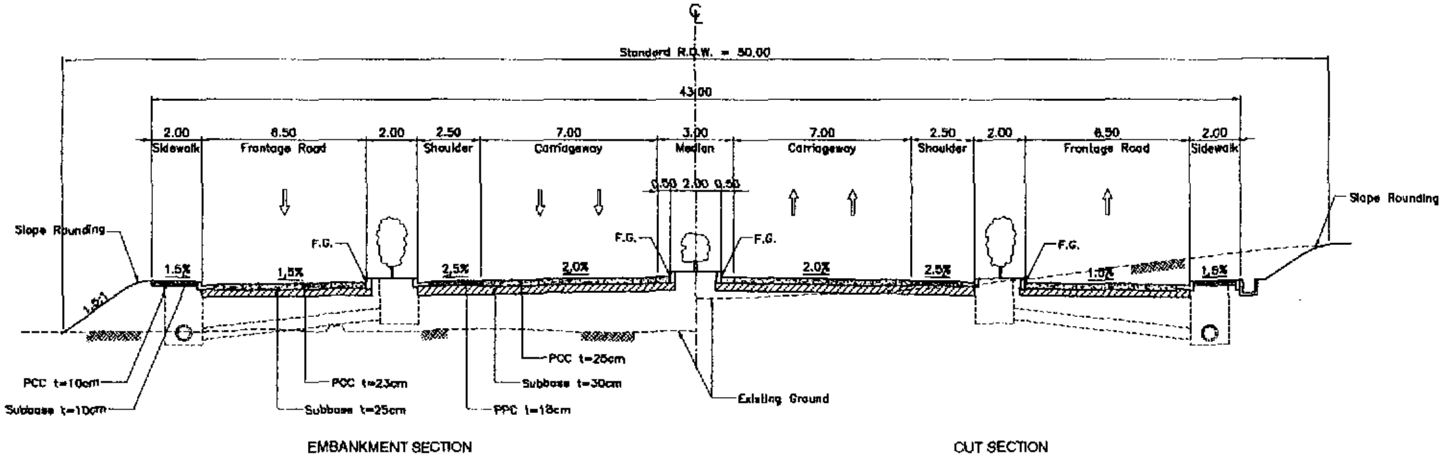
- Safety (spread length of water from the edge of the curb).
- Construction Cost.
- Difficulty of construction
- System requirements for maintenance.

Scheme (I) is to provide repeated openings at median islands, which separates the main carriageway from the tri-cycle lanes/frontage roads to allow the drain of water from the main carriageway to the outer edge curb-inlets. This scheme will be the most economic one but concerning safety it will be in the last rank due to the long spread length of water from the curb edge. Also break down of median at opening locations will be common which will needs periodical maintenance. The local traffic on the tri-cycle lane/frontage road will enter to the main carriageway, thus traffic function of the main carriageway will be hampered and traffic accidents will be expected.

Scheme (II) is to provide two sets of curb-inlets; one for the main carriageway and the other for the tri-cycle lane/frontage road. The collected surface water by the main carriageway curb-inlets will be conveyed through cross-pipes to the outer tri-cycle lane/frontage road curb-inlets. The cost of this scheme will be reasonable and furthermore all the disadvantages of Scheme (I) such as mixing traffic, periodical maintenance and traffic regulation requirements will be avoided.

Scheme (III) follows the same concept of Scheme (I) one but instead of make opening in the median island, a set of hidden concealed pipes under the median will be constructed to drain the water from the main carriageway to the tri-cycle lane/frontage road then to the outer edge curb-inlets. This alternative will overcome the mixed traffic problem but the small diameters of inhumed pipes can easily silted/clogged, thus proper maintenance is always required.

Scheme (IV) is similar to Scheme (II) except that instead of drain water from the carriageway curb-inlets to tri-bicycle/frontage road curb-inlets by cross-pipes, another parallel system of separated pipelines is provided to drain the main carriageway surface water accumulated by its curb-inlets. This system will have the same advantages of Scheme (II) but its construction cost will be higher.



Normal Cross Slope
Planned Urban Area (with Frontage Road)
SCALE 1:200

FIGURE 9.3-3 TYPICAL NORMAL CROWN-SECTION OF PLARIDEL BYPASS

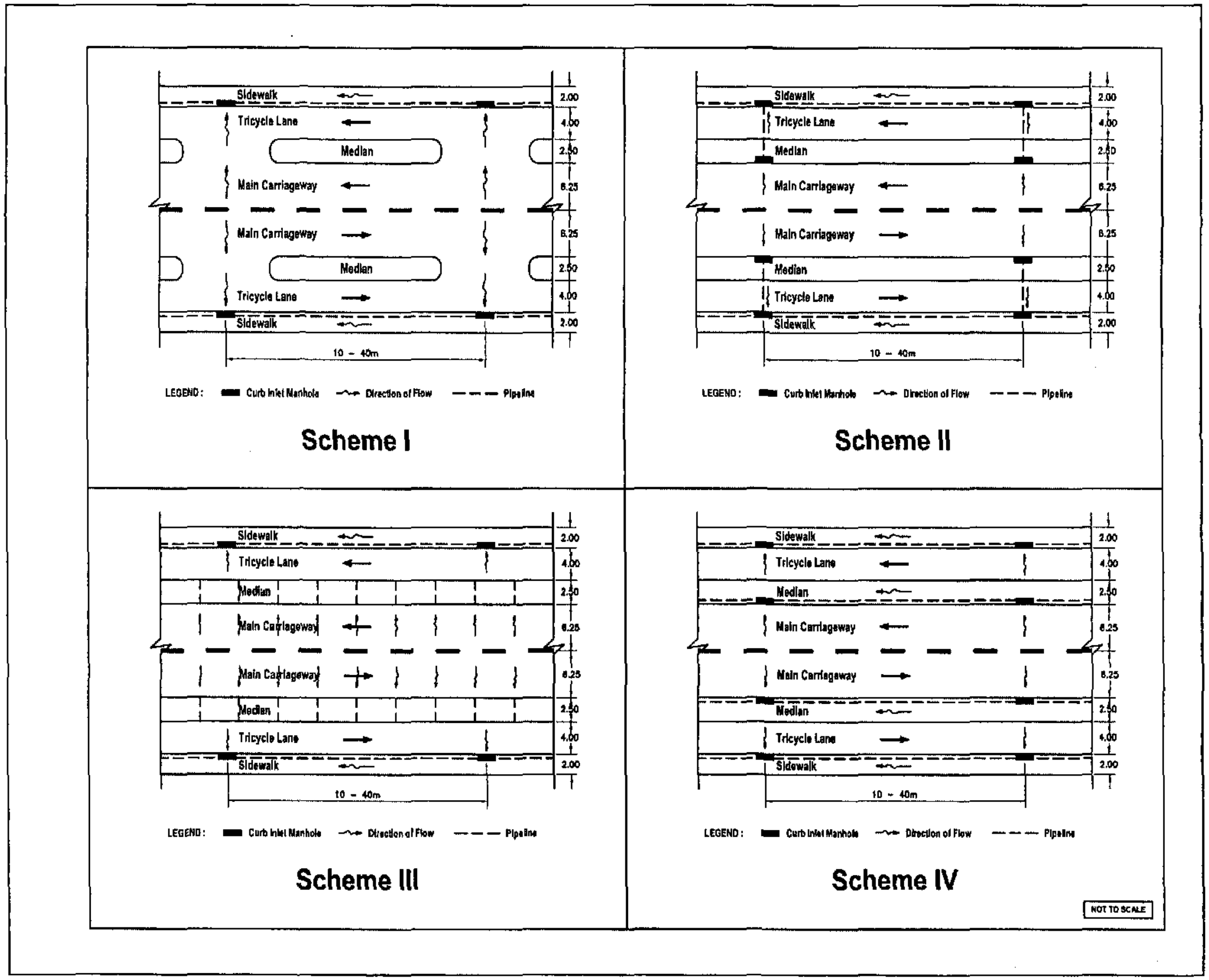


FIGURE 9.3-4 ALTERNATIVE SCHEMES OF SURFACE DRAINAGE

Method of Assessment of Alternative Schemes

The rating analysis method was utilized to clarify the most applicable scheme. The values of weighting analysis are shown in Table 9.3-1. The safety was given the highest weight that means to give higher priority for the scheme that can provide the highest safety for the road users followed by system requirements for maintenance. Construction cost and difficulty of construction are given the same weights.

TABLE 9.3-1 FACTORS OF ASSESSMENT AND THEIR RATING

Criteria	Rating
Safety (spread of water length from the edge of curb)	30
System requirements for maintenance	30
Construction Cost	20
Difficulty of construction	20
Total Weight	100

Result of Assessment

The assessment results are shown in Table 9.3-2.

Based on the results of this assessment, Scheme (II) was selected for the surface drainage of the Bypasses.

TABLE 9.3-2 RESULT OF DIFFERENT SCHEMES ASSESSMENT

	Surface Drainage Scheme			
Criteria	I	II	III	IV
Safety (spread of water)	7.5	30.0	15.0	30.0
System requirements for maintenance	15.0	30.0	7.5	30.0
Construction Cost	20.0	10.0	15.0	5.0
Difficulty of construction	20.0	10.0	15.0	5.0
Score	62.5	80.0	52.5	70.0
Rank	(3)	(1)	(4)	(2)

2) Curb Inlet Locations And Spacing

Geometric Design Consideration

Geometric design almost governs the locations of drainage inlets rather than the spread of water on the pavement and the inlet interception capacity. 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.

The other inlet locations are placed based on the design spread on the pavement and inlet interception capacity.

Flow in Gutters

A pavement gutter is the section of the pavement next to the curb that conveys drained water to the curb inlets. Based on the selected curb types (Type A for main carriageway and Type B for frontage road), the gutter cross-section will have a triangle shape where the curb forming the vertical side of the triangle. The gutter straight cross-slope is equal to 8%. The main carriageway, shoulder and frontage lane cross-slopes are 2.0 %, 2.5% and 1.5% as shown in typical cross-section, respectively.

The Rational Equation estimates the Flow Rate:

$Q = 0.278\ C\ I\ A$

where,

C = Factor = 0.9
I = Rainfall Intensity = 135.6 mm/hr for 5 min. *time of concentration and* 2 *years return* period.
A = Drained Surface Area (km^2) = Inlet spacing (S) x drained width (W),
Two cases of drained width can be specified based on the geometrical design as:

W (for main carriageway)= 14.5 m (in both cases of normal crown & supper elevation)
W (for frontage road) =10.5m (in both cases of normal crown & supper elevation)

Tables 9.3-3 and 9.3.4 show the estimated spread length of water and surface runoff discharge for the main carriageway and frontage road, respectively.

TABLE 9.3-3 SURFACE RUNOFF OF MAIN CARRIAGEWAY

Inlet Spacing	Drained Area	Runoff Discharge	Spread Length
S (m)	A (km^2)	Q (m^3/sec)	T (m)
10	0.000,145	0.0049	0.56
15	0.000,218	0.0074	0.65
20	0.000,290	0.0098	0.72
25	0.000,363	0.0123	0.79
30	0.000,435	0.0148	0.84
35	0.000,508	0.0172	0.89
40	0.000,580	0.0197	0.93
45	0.000,653	0.0222	0.98
50	0.000,725	0.0245	1.01

Note: 50m is the maximum allowable spacing by DPWH Standard

TABLE 9.3-4 SURFACE RUNOFF OF FRONTAGE ROAD

Inlet Spacing	Drained Area	Runoff Discharge	Spread Length
S (m)	A (km^2)	Q (m^3/sec)	T (m)
10	0.000,105	0.0036	0.49
15	0.000,158	0.0053	0.57
20	0.000,210	0.0071	0.64
25	0.000,262	0.0089	0.70
30	0.000,315	0.0107	0.75
35	0.000,368	0.0125	0.80
40	0.000,420	0.0142	0.83
45	0.000,473	0.0160	0.87
50	0.000,525	0.0178	0.90

Note: 50m is the maximum allowable spacing by DPWH Standard

From the above analyses it can be concluded that:

- In case of the main carriageway, the spread water length from the curb edge will be always less than the shoulder width even in case of super elevation.
- In case of frontage road, the spread of water from the curb edge will be always less than one half of the lane width that coincides with USBPR Practice.
- The maximum allowable inlet spacing as defined by DPWH Guidelines is 50 m. However, even this spacing is acceptable by the abovementioned analyses but the maximum spacing is taken 40 m. The reason is the runoff discharge calculation depended in two years return period as specified by Standard while , the surface drainage pipes discharges are calculated based on 10 years return period. Therefore, the pipe drainage efficiency will be higher than inlet drainage efficiency. Decreasing spacing will be in the side of increasing inlet efficiency and furthermore, to maintain the reasonable hydraulic gradient in pipes.

Curb Opening Length

Since in design, the maximum inlet spacing is taken 40m and the curb opening length is taken 1m as an applicable one, it can be concluded based on the maximum estimated runoff discharge of about 0.02 m^3/sec (Table 9.3-3) that the design is acceptable and have the enough safety margin since under this maximum rate of flow the required opening length will be:

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

$$L_T = 0.076 \times 0.02^{0.42} \times 0.02^{0.3} \times (1 / (0.013 \times 0.08))^{0.6}$$

L_T = 0.28 m that is quite less than 1 m.

Figure 9.3-5 presents graphically the relations between inlet spacing and runoff discharges for the main carriageway and frontage road. As can be noticed in figure, regression analyses are carried out. Therefore, the figure can be used as a design chart to estimate the inlet runoff discharge for any value of inlet spacing.

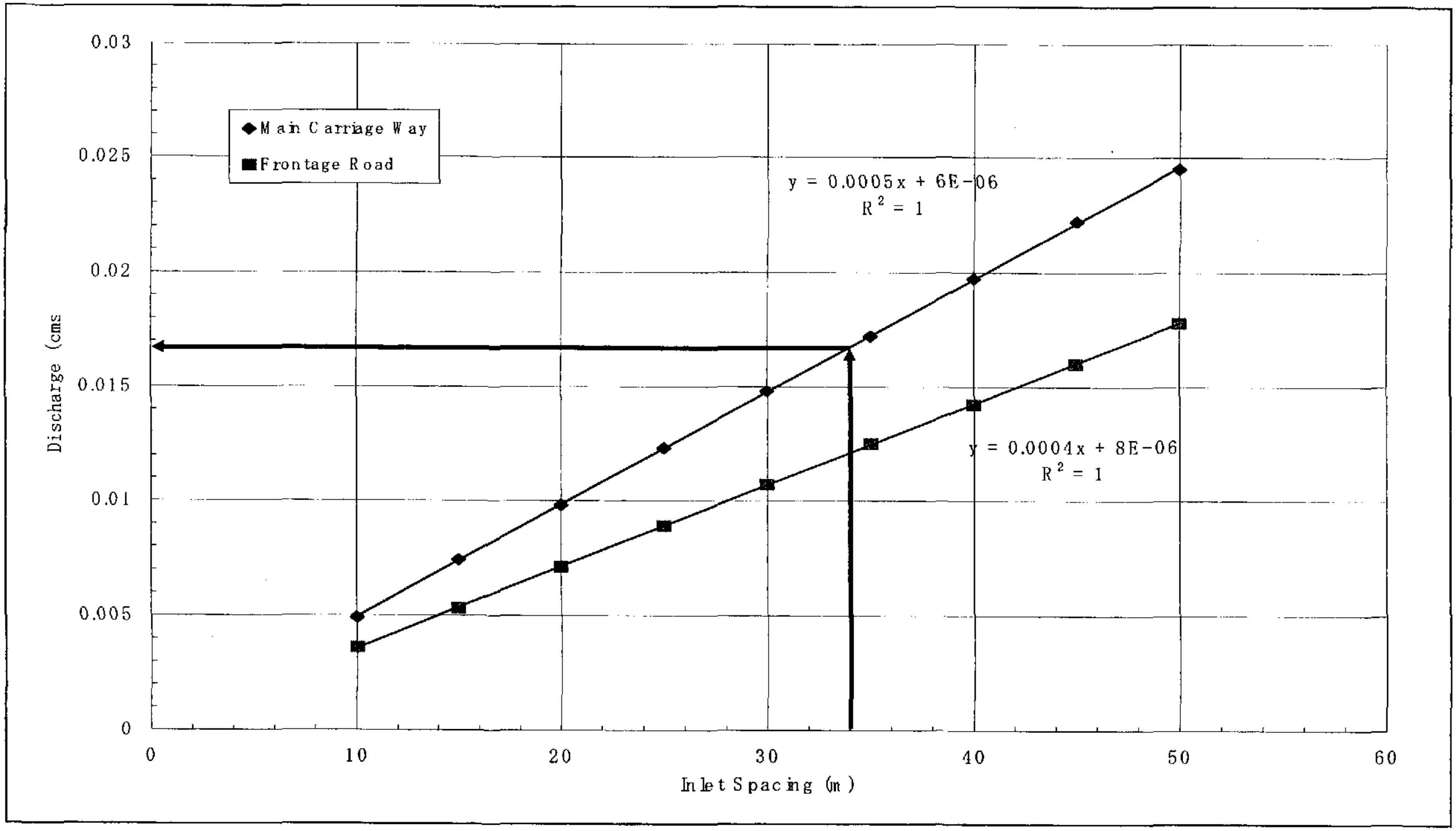


FIGURE 9.3-5 RUNOFF DISCHARGE VERSUS INLET SPACING

Storm Drains Pipe Lines

The 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.

For the different curb inlet spacing, Table 9.3-5 shows the estimated discharges in the different case of geometric design. In the estimation, the runoff coefficient (C) for road is taken 0.9 and for residential areas is taken 0.4. The rainfall intensity for 10 years return period is 254.4 mm/hr.

Figure 9.3-6 presents graphically the relations between inlet spacing and discharges. As can be noticed in figure, regression analysis is carried out. Therefore, the figure can be used as a design chart to estimate the pipe discharge for any value of inlet spacing. With these analyses in correlation with the estimated pipe capacities that mentioned early in Chapter 2 the design will be carried out.

TABLE 9.3-5 ESTIMATED DISCHARGES OF DRAIN PIPE

Spacing	A-MRNC	Q-MRNC	A-MRSE	Q-MRSE	A-FRSE	Q-FRSE	A-Resd.	Q-Resd.	TQ-MRNC	TQ-MRSE	TQ-FRSE
	W= 23 m		W= 34.5 m		W= 10.5 m		W= 50m				
10	0.00023	0.01464	0.000345	0.02196	0.000105	0.006683	0.0005	0.014145	0.028784	0.036104	0.020828
15	0.000345	0.02196	0.000518	0.032939	0.000158	0.010025	0.00075	0.021217	0.043177	0.054156	0.031242
20	0.00046	0.029279	0.00069	0.043919	0.00021	0.013367	0.001	0.028289	0.057569	0.072208	0.041656
25	0.000575	0.036599	0.000863	0.054899	0.000263	0.016708	0.00125	0.035362	0.071961	0.09026	0.05207
30	0.00069	0.043919	0.001035	0.065879	0.000315	0.02005	0.0015	0.042434	0.086353	0.108313	0.062484
35	0.000805	0.051239	0.001208	0.076858	0.000368	0.023392	0.00175	0.049506	0.100745	0.126365	0.072898
40	0.00092	0.058559	0.00138	0.087838	0.00042	0.026733	0.002	0.056579	0.115137	0.144417	0.083312
45	0.001035	0.065879	0.001553	0.098818	0.000473	0.030075	0.00225	0.063651	0.12953	0.162469	0.093726
50	0.00115	0.073199	0.001725	0.109798	0.000525	0.033417	0.0025	0.070723	0.143922	0.180521	0.10414

Notes:

50m = is the maximum allowable spacing by DPWH Standard.
A = Area (km^2),
W = Drained Width (m),
MRNC = Main Road (Case of Normal Crown),
MRSE = Main Road (Case of Supper Elevation),
FRSE = Frontage Road (Case of Supper Elevation),
Resd = Residential,
Q = Discharge (m^3/sec),
TQ = Total Discharge (m^3/sec).

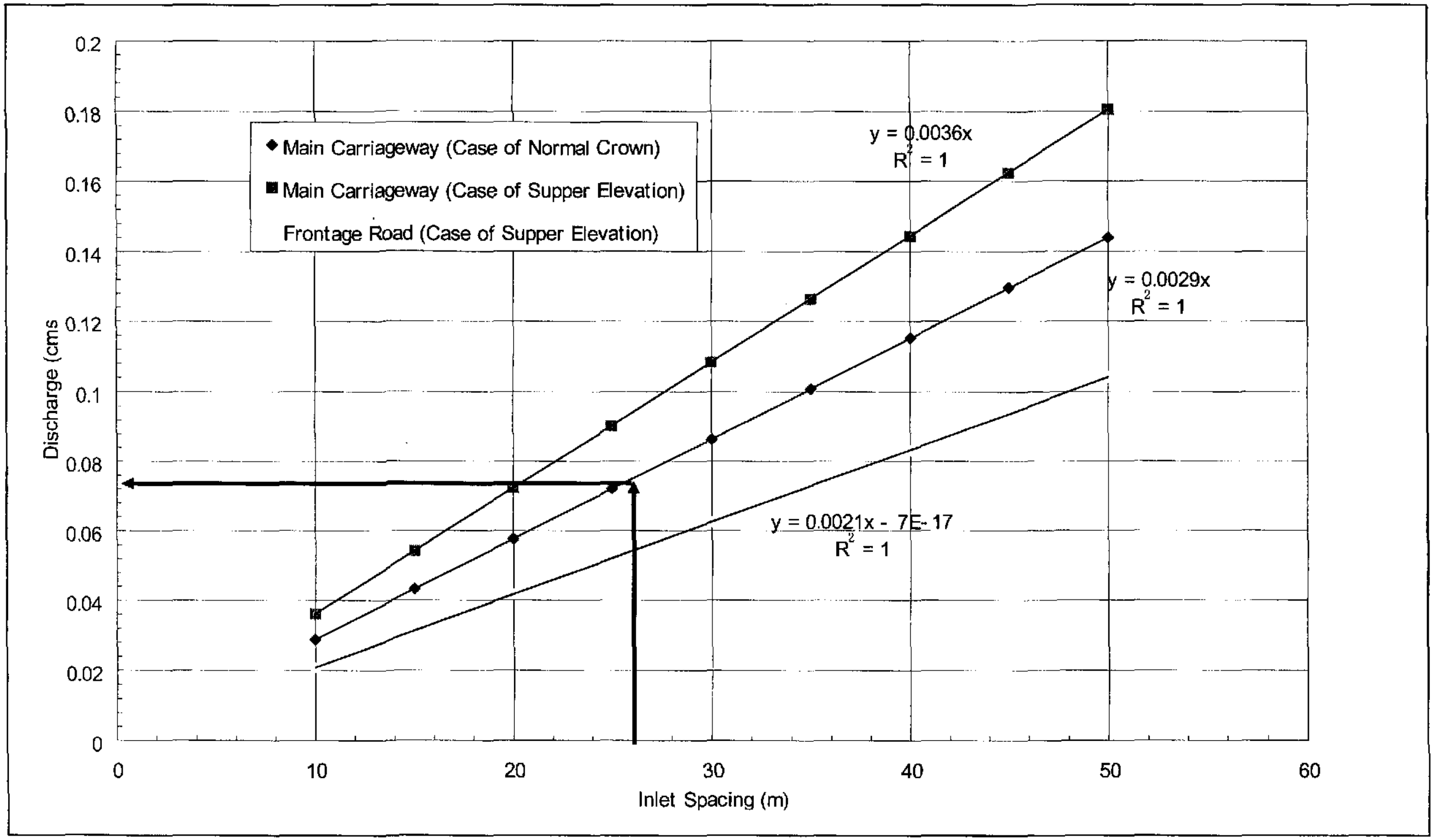


FIGURE 9.3-6 PIPE DISCHARGE VERSUS INLET SPACING

9.3.4 Surface Drainage of Highway Bridges

1) Bridge across Angat River (Bridge No. 8)

The investigation of the geometrical design of the bridges across Angat River shows that during the Initial-Stage and also during the Ultimate-Stage their drained carriageway width is 8.25 m and the cross-section is consisting of two traffic lanes 3.5 m each, two shoulders 0.75 m and 0.5m and two sidewalks 1.1 m and 0.6m. Therefore, the total drained width will be equal to the total width of 9.95m per both traffic directions during the Initial-Stage and per one traffic direction during the Ultimate-Stage. The cross-slope is 2% while the longitudinal slope is almost flat of 0.2%. The rainfall intensity for 5 minutes concentration is 135.6 mm/hr and the runoff coefficient (C) for concrete is 0.9. Figure 9.3-7 shows the layout of the typical cross-section during the initial-stage.

In design of inlet spacing the two following criteria were investigated:

a- Flow in Gutter and Spread of Water.
b- Inlet Interception Capacity.

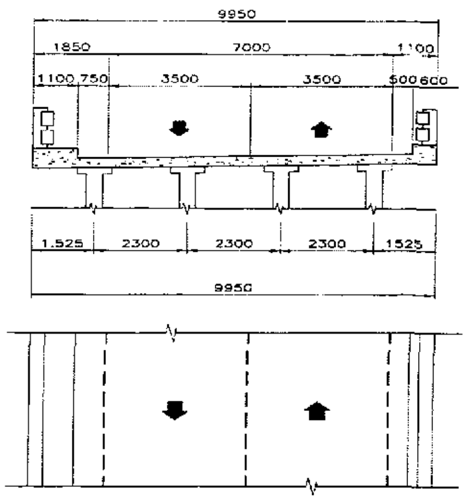


FIGURE 9.3-7 TYPICAL BRIDGE CROSS-SECTION OVER ANGAT

a- Inlet Spacing based on Flow in Gutter and Spread Length

The Rational Equation estimates the runoff discharge:

$Q = 0.278\ ICA$
$Q = 0.278 \times 135.6 \times 0.9 \times (9.95\ xS/10^6)$

$Q = 0.00033\ S$

where, S = inlet spacing

In case the spacing will be taken 6.0 m, the runoff discharge will be 0.00198 m^3/sec. Under this discharge the water spread length will be:

$T = 1.443\ [(Qn) / (S_x^{1.67}\ S^{0.5})]^{0.375}$

$T = 1.443\ [(0.00198 \times 0.013) / (0.02^{1.67} \times 0.002^{0.5})]^{0.375}$

$T = 1.02$ m

Therefore, from the total carriageway width of 8.25 m there will be about 6.75 m of the traffic lanes width plus 0.5 m shoulder width that means in total 7.25 m of the width free of water.

b- Inlet Spacing based on Inlet Interception Capacity

For 15 cm drain pipe diameter, the interception capacity is estimated by:

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

where,

Q = Interception Capacity (m^3/sec)
A = Cross-Section Area of Pipe (m^2)
K = Conveyance Factor
g = Gravity Acceleration (m/sec^2)
h = Operating Head (m)

$Q = (\Pi \times 0.15^2/4) \times 0.67 \times \sqrt{2 \times 9.81 \times 0.015}$

$Q = 0.00642\ m^3/sec$

For pipes design, I = 254.4 mm/hr that is corresponding to 10 years return period.

Therefore, the discharge will be:

$Q = 0.278 \times 0.9 \times 254.4 \times (9.95 \times 6 / 1000,000) = 0.00375\ m^3/sec.$

The Interception capacity is about 1.8 times greater than this estimated runoff discharge in case of 6.0 m inlet spacing.

Finally it is recommended to keep spacing to be not more than 6.0 m. Pipes diameter of 15 cm will be sufficient to drain the surface water runoff within the mentioned inlet spacing.

2) Bridge Numbers 1, 2, 3, 4, 5 and 6

For this group of bridges the drained width is 11.7 m. The cross section during the initial or ultimate-stage is consisting of two traffic lanes 7.0 m *having* 2% cross-slope and 2.5 m shoulder has 2.5% cross-slope.

The spread of water can be accepted to be equal to the shoulder width. Therefore, the discharge corresponding to T equal 2.5 m will be:

$Q = (0.376/n)\ S_x^{1.67}\ S^{0.5}\ T^{2.67}$
$Q = (0.376/0.013) \times 0.025^{1.67} \times 0.002^{0.5} \times 2.5^{2.67}$
$Q = 0.0315\ m^3/sec$

Rational Equation can estimate the inlet spacing:

$0.0315 = 0.278 \times 0.9 \times 135.6 \times (11.7 \times S / 1000{,}000)$

$S = 79.4$ m

By considering the inlet interception capacity for 15 cm pipe diameter the maximum discharge is 0.00642 m^3/sec. This capacity will govern the design. Under this capacity, the maximum inlet spacing is:

$0.00642 = 0.278 \times 0.9 \times 135.6 \times (11.7 \times S / 1000{,}000)$

$S = 16.0$ m

By taken $S = 15$ m,

$Q = 0.278 \times 0.9 \times 135.6 \times (11.7 \times 15 / 1000{,}000) = 0.0058\ m^3/sec$

$T = 1.443\ [(0.0058 \times 0.013) / (0.02^{1.67} \times 0.002^{0.5})]^{0.375} = 1.53$ m

3) Bridges Numbers 7, 9 and 10

For this group of bridges the drained width are 11.2 m and 8.95 m for main carriageway and frontage road, respectively. The cross section during the initial-stage is consisting of two traffic lanes 7.0 m having 2% cross-slope and 2.5 m shoulder has 2.5% cross-slope. During the ultimate-stage two-separated 8.95 width sections will be constructed for the frontage roads. The section consist of 6.5 m lane width has 1.5 % cross-slope.

For the main carriageway of 11.2 m width, the inlet interception capacity for 15 cm pipe diameter will govern the design. The maximum pipe capacity is 0.00642 m^3/sec. Under this capacity, the maximum inlet spacing is:

$0.00642 = 0.278 \times 0.9 \times 135.6 \times (11.2 \times S / 1000{,}000)$

$S = 16.7$ m

By taken the spacing 15 m,

$Q = 0.278 \times 0.9 \times 135.6 \times (11.2 \times 15 / 1000{,}000) = 0.0057\ m^3/sec$

$T = 1.443\ [(0.0057 \times 0.013) / (0.02^{1.67} \times 0.002^{0.5})]^{0.375} = 1.51\ m$

For the frontage road, the design criterion is to accept the spread up to the half of the lane width that mean 3.25 m. Therefore, the inlet interception capacity will govern the design and the maximum spacing will be:

$0.00642 = 0.278 \times 0.9 \times 135.6 \times (8.95 \times S / 1000{,}000)$

$S = 20.89\ m$

By taken the spacing 15m same as the main carriageway,

$Q = 0.278 \times 0.9 \times 135.6 \times (8.95 \times 15 / 1000{,}000) = 0.0046\ m^3/sec$

$T = 1.443\ [(0.0046 \times 0.013) / (0.02^{1.67} \times 0.002^{0.5})]^{0.375} = 1.40\ m$

Table 9.3-6, summaries these design finding.

TABLE 9.3-6 DRAINAGE OF BRIDGES ALONG PLARIDEL BYPASS

Bridge Number	Main Carriageway				Frontage Road (Ultimate-Stage)			
	Max. Inlet Spacing (m)	Runoff (m^3/sec)	Spread (m)	Shoulder Width (m)	Max. Inlet Spacing (m)	Runoff (m^3/sec)	Spread (m)	Shoulder Width (m)
1	15	0.0058	1.53	2.5				
2	15	0.0058	1.53	2.5				
3	15	0.0058	1.53	2.5				
4	15	0.0058	1.53	2.5				
5	15	0.0058	1.53	2.5				
6	15	0.0058	1.53	2.5				
7	15	0.0057	1,51	2.5				
8	6	0.0019	1.02	0.75	6	0.0019	1.02	0.75
9	15	0.0058	1.53	2.5	15	0.0058	1.53	2.5
10	15	0.0058	1.53	2.5	15	0.0058	1.53	2.5

Note: Capacity of 150 mm pipe diameter is 0.0064 m^3/sec.

9.4 Short / Medium Bridge Design

There are 10 bridges along Plaridel Bypass, of which one is a long bridge (Angat River Bridge). Bridge locations are shown in Figure 9.4-1.

Hydraulic and hydrological features of each bridge is shown in Table 9.4-1. Summary of proposed bridges is shown in Table 9.4-2. Detailed description of each bridge is presented in Appendix 9.4-1.

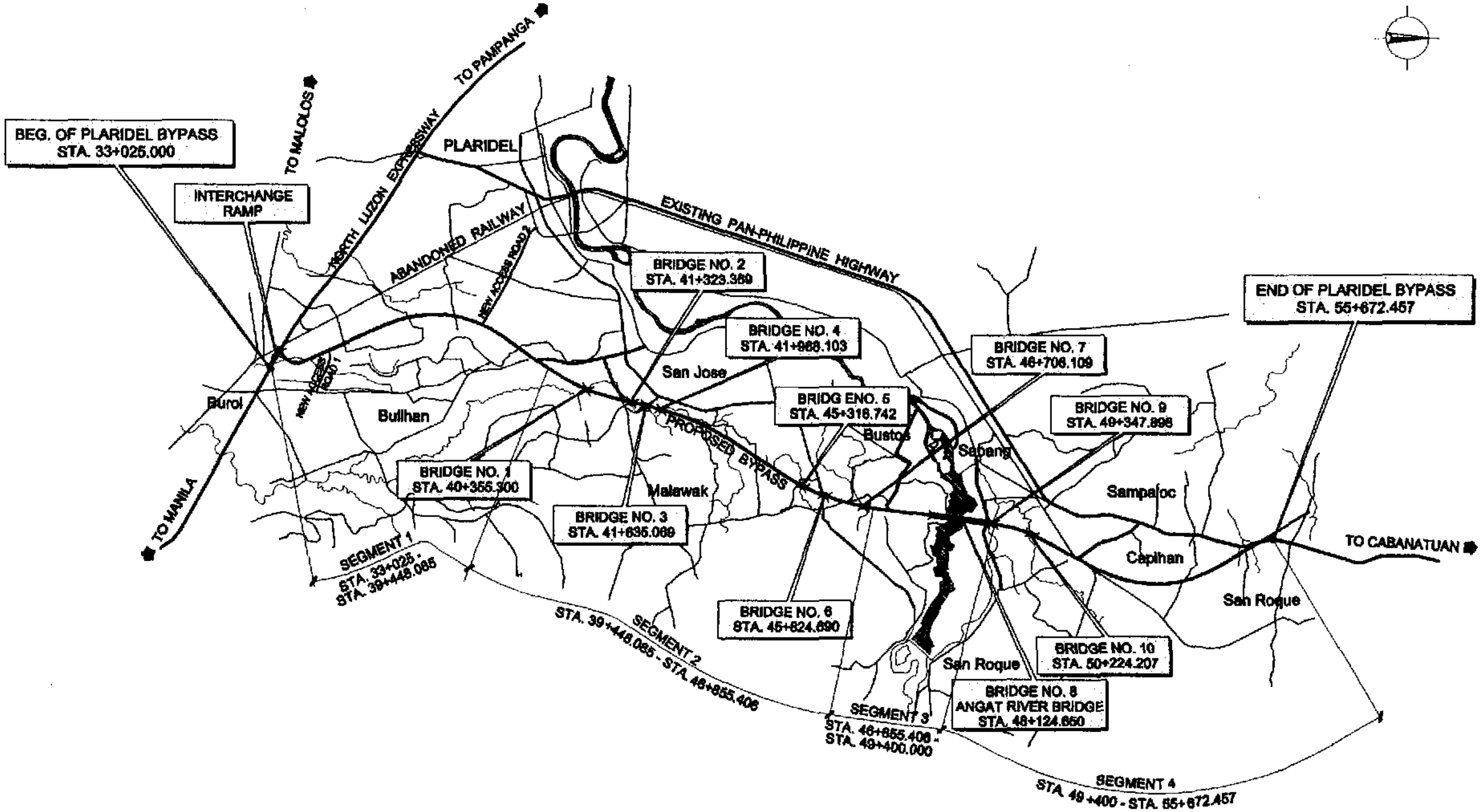


FIGURE 9.4-1 BRIDGE LOCATION : PLARIDEL BYPASS

TABLE 9.4-1 HYDRAULIC AND HYDROLOGICAL RESULTS OF SMALL AND MEDIUM RIVERS (PLARIDEL BYPASS)

Bridge Number	Beginning Station	50 - year Design Hydraulics				River Width,W (m)
		M.F.W.L from Field Survey	Design Flood El.	Discharge Q (m3/s)	Velocity (m/s)	
1	40 + 355.300	9.20	8.857	125.40	2.669	28.70
2	41 + 323.369	10.80	10.728	124.90	2.798	19.20
3	41 + 635.069	11.40	10.500	IRRIGATION		11.70
4	41 + 968.103	11.40	11.041	109.20	3.624	17.20
5	45 + 316.742	14.10	14.658	85.60	1.298	11.70
6	45 + 824.690	15.00	12.700	IRRIGATION		28.20
7	46 + 706.109	17.20	16.477	14.70	1.157	36.70
8	48 + 124.650	15.30	ANGAT RIVER			
9	49 + 347.898	16.80	16.329	119.80	1.924	29.00
10	50 + 224.207	16.90	17.058	101.40	2.133	27.20

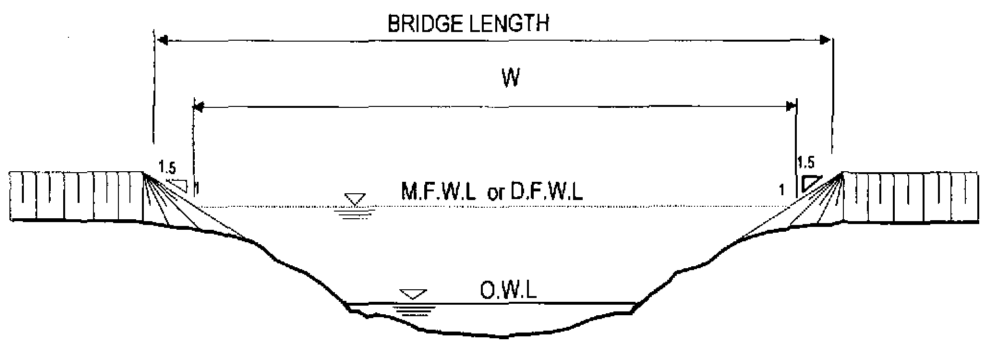


TABLE 9.4 - 2 SUMMARY OF PROPOSED BRIDGES FOR PLARIDEL BYPASS - INITIAL STAGE (1/2)

Bridge No.	Type of Waterway	Beginning		End		Free Board	M.F.W.L EL. (+m)	Bridge Length	No. of Span	Span Length (m)	Superstructure	Substructure			
												Abutment		Pier	
		Station	Elev. (m)	Station	Elev. (m)							Type	Foundation	Type	Foundation
1	River	40+355.300	12.998	40+391.160	12.998	1.500	9.200	35.860	1 - Span	35.000	PSCG (AASHTO Type-VI)	Seat Type	Rc-Pile (450x450) L =8m	-	-
2	River	41+322.369	14.413	41+357.729	14.377	1.500	10.800	34.360	1 - Span	33.500	PSCG (AASHTO Type-V)	Seat Type	Rc-Pile (450 x450) L = 7-9m	-	-
3	Irrigation	41+635.069	14.364	41+665.929	14.389	1.000	11.400	30.860	1 - Span	30.000	PSCG (AASHTO Type-IVB)	Seat Type	Rc-Pile (450 x450) L =9m	-	-
4	River	41+968.103	14.642	41+992.763	14.650	1.500	11.400	24.860	1 - Span	24.000	PSCG (AASHTO Type-IV)	Seat Type	Rc-Pile (450 x450) L =10-11m	-	-
5	River	45+316.742	18.031	45+351.102	17.616	1.500	14.100	34.360	1 - Span	33.500	PSCG (AASHTO Type-V)	Seat Type	Rc-Pile (450 x450) L =13m	-	-
6	Irrigation	45+824.690	18.401	45+865.550	18.377	1.000	15.000	40.860	1 - Span	40.000	PSCG (AASHTO Type-VI Mod.)	Seat Type	Rc-Pile (450 x450) L =12-13m	-	-
7	River	46+706.109	20.672	46+751.769	20.617	1.500	17.200	45.660	3 - Span	15.0+15.0+15.0	RCDG	Seat Type	Rc-Pile (400 x400) L =11m	Single Column	Rc-Pile (400 x400) L =10m
8	River	48+124.650	ANGAT RIVER												
9	River	49+347.898	20.458	49+388.758	20.487	1.500	16.800	40.860	1 - Span	40.000	PSCG (AASHTO Type-VI Mod.)	Seat Type	Rc-Pile (450 x450) L =15m	-	-
10	River	50+224.207	20.81	50+261.067	20.779	1.500	16.900	36.860	1 - Span	36.000	PSCG (AASHTO Type-VI)	Seat Type	Rc-Pile (450 x450) L =22m	-	-

TABLE 9.4 - 2 SUMMARY OF PROPOSED BRIDGES FOR PLARIDEL BYPASS - ULTIMATE STAGE (2/2)

Bridge No.	Type of Waterway	Beginning		End		Free Board	M.F.W.L EL. (+m)	Bridge Length	No. of Span	Span Length (m)	Superstructure	Substructure			
												Abutment		Pier	
		Station	Elev. (m)	Station	Elev. (m)							Type	Foundation	Type	Foundation
1	River	40+355.300	12.998	40+391.160	12.998	1.500	9.200	35.860	1 - Span	35.000	PSCG (AASHTO Type-VI)	Seat Type	Rc-Pile (450x450) L =8m	-	-
2	River	41+314.231	14.377	41+348.591	14.413	1.500	10.800	34.360	1 - Span	33.500	PSCG (AASHTO Type-V)	Seat Type	Rc-Pile (450 x450) L = 7-8m	-	-
3	Irrigation	41+645.069	14.388	41+675.929	14.364	1.000	11.400	30.860	1 - Span	30.000	PSCG (AASHTO Type-IVB)	Seat Type	Rc-Pile (450 x450) L =8m	-	-
4	River	41+971.189	14.650	41+996.049	14.642	1.500	11.400	24.860	1 - Span	24.000	PSCG (AASHTO Type-IV)	Seat Type	Rc-Pile (450 x450) L =10-11m	-	-
5	River	45+305.433	18.168	45+339.793	17.752	1.500	14.100	34.360	1 - Span	33.500	PSCG (AASHTO Type-V)	Seat Type	Rc-Pile (450 x450) L =13m	-	-
6	Irrigation	45+818.926	18.377	45+859.786	18.401	1.000	15.000	40.860	1 - Span	40.000	PSCG (AASHTO Type-VI Mod.)	Seat Type	Rc-Pile (450 x450) L =12-13M	-	-
7	River	46+694.194	20.617	46+739.854	20.672	1.500	17.200	45.660	3 - Span	15.0+15.0+15.0	RCDG	Seat Type	Rc-Pile (400 x400) L =11m	Single Column	Rc-Pile (400 x400) L =10m
8	River	A N G A T R I V E R													
9	River	49+355.321	20.453	49+396.181	20.405	1.500	16.800	40.860	1 - Span	40.000	PSCG (AASHTO Type-VI Mod.)	Seat Type	Rc-Pile (450 x450) L =19m	-	-
10	River	50+216..400	20.779	50+253.260	20.810	1.500	16.900	36.860	1 - Span	36.000	PSCG (AASHTO Type-VI)	Seat Type	Rc-Pile (450 x450) L =22m	-	-

9.5 Angat River Bridge Design

9.5.1 River Condition

(1) River Hydraulics

The river condition along the proposed alignment of Angat river has the following characteristics:

- bank to bank distance is about 1120m with evidence of bank scouring observed on both upstream and downstream of the proposed location,
- main river waterway is 400m wide with an overflow area of about 720m on both sides,
- the main river section has an average water depth of 6.0m,
- the flow velocity during ordinary time is very slow (< 0.5m/sec) and even during peak flood, the flow velocity is only 0.79 m/sec due to the presence of an irrigation dam upstream of the proposed bridge location,
- river soil quarrying is one of the activities in the vicinity of the proposed bridge location that may affect the depth of foundation,
- the river hydraulics design parameter is presented in Table 9.5-1 while the river section at the proposed location is shown in Figure 9.5-1.

TABLE 9.5-1 RIVER HYDRAULICS DESIGN PARAMETER

DESIGN PARAMETERS	*APPROACH 1*	*MAIN WATERWAY*	*APPROACH 2*
50-Year Discharge, Q_{50} (m^3/sec)	1269.3	3164.3	586.4
Flow Velocity, V_{50} (m/sec)	0.41	0.79	0.36
Catchment Area, CA (km^2)	-	889.10	-
Minimum Span Length, S (m)	27	46	23
Design Flood Water Level, (El +m)	15.3	15.3	15.3
Design River Bed Level, (El +m)	5.76	3.06	7.76
Local Scour Depth (m)	2.5	3.0	2.5

(2) Soil Condition

The results of soil investigation (as shown in Figure 9.5-2) at the proposed bridge site indicated that:

- the area is generally covered by thick gravel layer with layers of medium dense sand,
- the N-blows at the upper 5.5m to 9.5m depth is quite erratic but generally ranged from 10 to 50 but N-values at the subsequent depth hits refusal with N>50.

Since most of the SPT procedure conducted exhibited refusal at a shallow depth, the investigation was augmented by a dynamic sounding test (DPH) to verify the soil underlying the gravel layer. DPH data indicates some weaker layer beneath the gravel layer but was also terminated when measured penetration after 60 blows is practically negligible.

With the given soil condition at the proposed bridge site, a comparison of probable foundation type is undertaken resulting to bored piles with diameters of Ø1200mm and Ø1500mm being more appropriate and cost-effective.

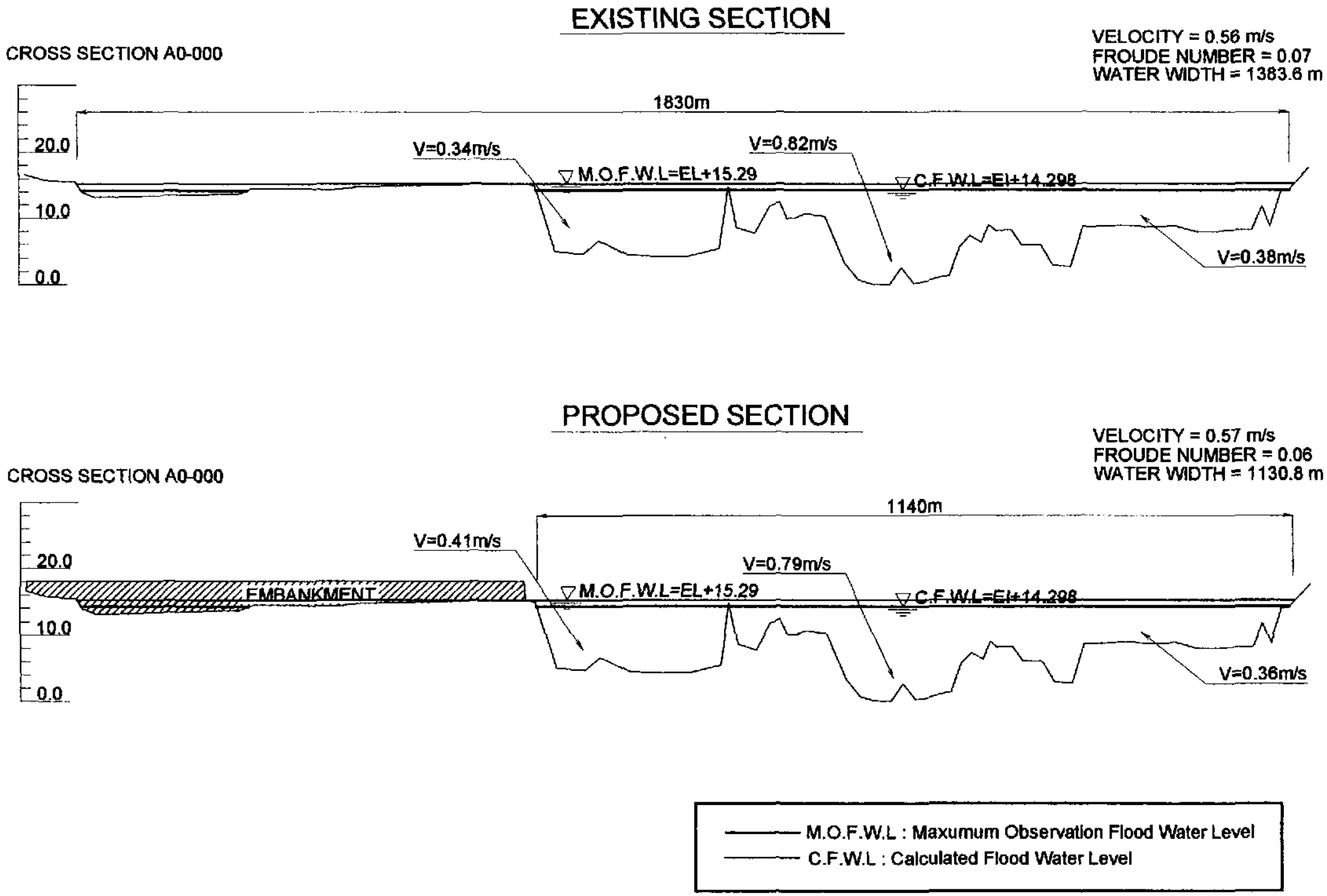


FIGURE 9.5-1 ANGAT RIVER SECTION AND FLOOD WATER LEVEL (50-YEAR RETURN)

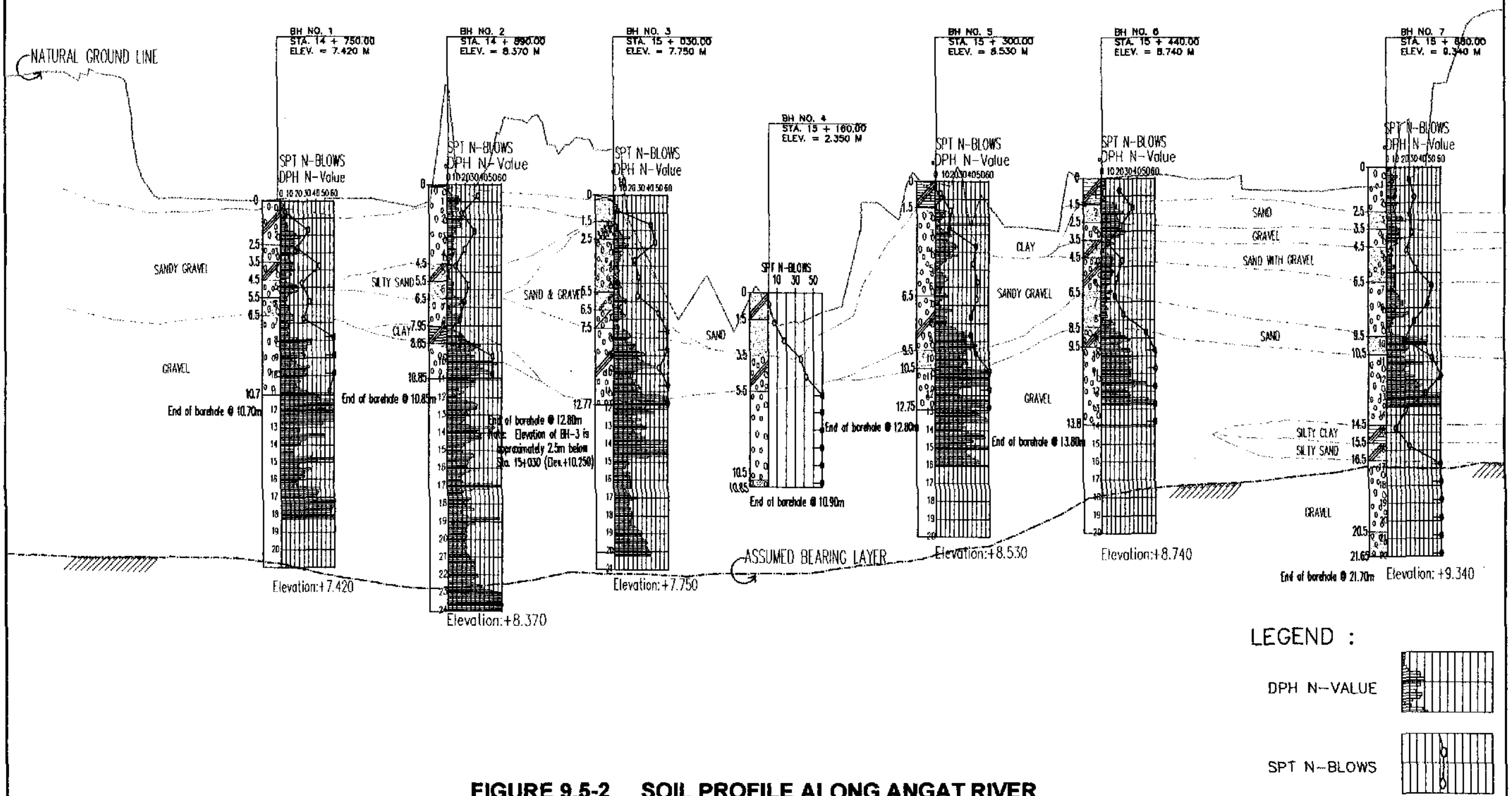


FIGURE 9.5-2 SOIL PROFILE ALONG ANGAT RIVER

9.5.2 Final Bridge Scheme

(1) Design Requirements

The design requirements for the bridge crossing Angat river is presented in Table 9.5-2 below.

TABLE 9.5-2 REQUIREMENTS FOR THE PROPOSED BRIDGE SCHEME

Design Requirements		*Items to be Considered*
1	River Hydraulics	• 50 Year Return Flood: Abutments at 1120m apart to span the area covered by flood at Design Flood Elev. of +15.3m • 50 Year River Discharge: The calculated river discharge of 3,165 m^3/sec requires a minimum pier span of 46m. A 7-span bridge structure is proposed with inner spans of 60m and side spans of 50m.
2	Topography and River Condition	• Main Waterway : Main bridge should span the 400m main river waterway • Existing Ground Level: Pier heights will depend on the existing ground level and the bridge design profile. • Bank and Bed Condition: Scouring observed on the banks and the bed necessitates minimizing pier encroachment on river section
3	Soil Condition and Foundation	• Foundation Type : Bored piles are recommended to support the structure which can be embedded deep into the bearing layer. • General Scour and Local Scour: Depth of foundation embedment should consider the design river bed (general scour elevation as indicated in Table 9.5-1) and the effects of local scour due to pier encroachment. A minimum footing embedment of 2.0m below lowest point of river section is recommended. • Quarrying Activities: The design depth of piles should consider the loss in river bed depth due to quarrying activities around the proposed bridge location.

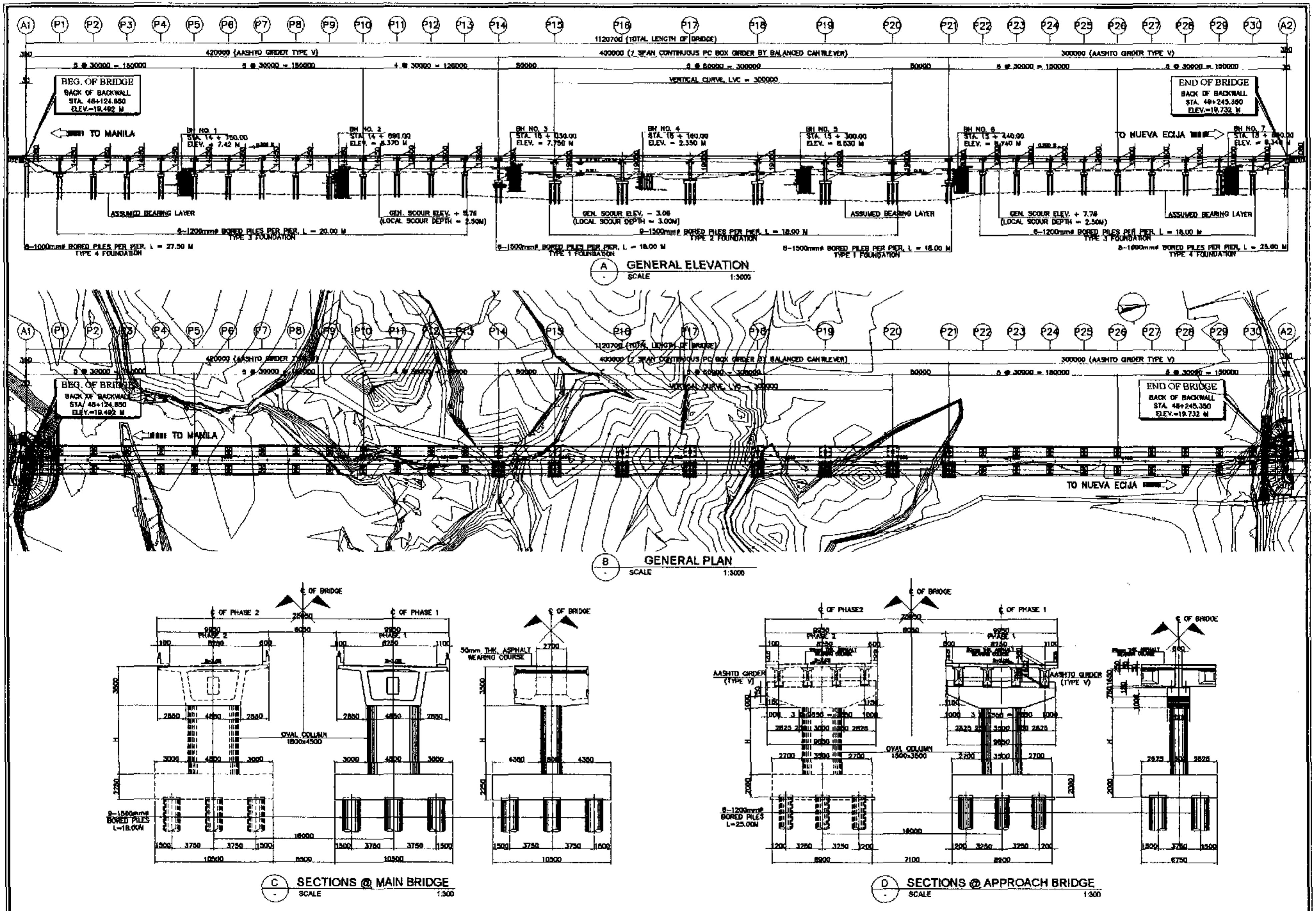


FIGURE 9.5-3 PROPOSED ANGAT RIVER BRIDGE CROSSING

4	Construction	• Ordinary Water Depth: Since the ordinary water depth at Angat river averages 6.0m, the balanced cantilever method at this section of the river is the most appropriate and cost-effective. • Bridge Structure: A 7-span continuous PC box girder bridge is proposed with six piers constructed by balanced cantilever to avoid deep water level. • Cost: Different bridge types and schemes were compared and the proposed scheme is the most cost-effective – longer span scheme tends to be more expensive, e.g. 6-spans at 74m span is 17% more costly than the proposed scheme.

(2) Proposed Bridge Configuration

Considering the design requirements mentioned earlier, the final bridge scheme configuration is a 7-span continuous PC box girder bridge constructed by balanced cantilever method as shown in Figure 9.5-3 and described in Table 9.5-3.

TABLE 9.5-3 FINAL BRIDGE SCHEME FOR ANGAT RIVER BRIDGE

BRIDGE LENGTH	Approach	14 @ 30m = 420m + 10 @ 30m = 300m
	Main Bridge	55m + 5 @ 60m + 55m = 400m
	Total Length	1120m
BRIDGE TYPE	Approach	Type V AASHTO PC Girder with C.I.P. Slab Span Length = 30m Width = 9.95m
	Main Bridge	PC Box Girder by Balanced Cantilever Span Length = 60m Width = 9.95m
SUBSTRUCTURE	Approach	RC Oval Columns on Φ 1200mm Bored Piles
	Main Bridge	RC Oval Columns on Φ 1500mm Bored Piles

The proposed bypass crossing Angat river carries a total of four-lane traffic with two lanes in each direction. However, construction of the bypass will be done in stages with the Initial stage carrying only two lanes and will be used as a two-way bridge. For this reason, the four-lane bypass will be constructed with two separate bridges with the initial stage construction catering for the first two lanes of traffic and the full bypass capacity augmented by the construction of a second bridge as shown in Figure 9.5-3.

9.5.3 Detailed Design of Approach and Main Bridge

The detailed design of the Angat river bridge crossing is carried-out with the principles and methodology outlined below.

- Substructures shall be designed and constructed to safely transmit to the ground or supporting medium the forces from the superstructures and the loads acting upon the substructure itself;
- Foundations shall be stable against bearing, toppling and sliding mechanisms. Reactions at pile head resulting from load application shall not exceed allowable bearing capacity of the pile. Likewise, the deflection of pile foundation shall not exceed the allowable displacement.
- Superstructures shall be designed to resist the contemplated loads both permanent and transient in nature.
- Live loading used in the design of both the superstructures and substructures shall be loaded in a manner to impart the most unfavorable influence upon the structure;

The following design conditions are applied to the detailed design of Angat river bridge crossing:

• Bridge Type	:	Main - Single Cell PC Box Girder by Balanced Cantilever construction Approach – Type V PC AASHTO Girder erected by truck crane with C.I.P. Deck Slab
• Bridge Width	:	Main Bridge = 9.95m Approach Bridge = 9.95m
• Material	:	Prestressed Box Girder , f'c = 41 MPa Prestressed AASHTO Girder , f'c = 41 MPa C.I.P. Deck Slab, f'c = 28 MPa Bored Piles, f'c = 28 MPa Reinforcing Steel, fy = 415 MPa Prestressing Steel, fpu = 1862 MPa
• Live Loading	:	MS 18 (HS 20-44) B.O.D. Permit Live Load (LFD check)
• Seismic Loading	:	AASHTO Div. I-A Peak Ground Acceleration Coef., A = 0.40 Seismic Response Coef., Figure 9.5-8 Importance Classification, IC = 1.0 Seismic Performance Category, SPC = D Soil Site Coefficient = 1.2
• Foundation	:	Ø1500mm Bored Piles for Main Bridge Ø1200mm Bored Piles for Approach Bridge Ø1000mm Bored Piles for Abutment

(1) Basic Dimensional Requirement

Figure 9.5-4 shows the typical cross-section of the approach and the main bridge for a two-lane bridge constructed during the Initial stage. The basic dimensional requirements for the bridge is decided based on the following:

ITEM		DESCRIPTION	BASIS
1.0 General			
Bridge Length	Total	1120m	• this length covers the 50-year return flood and spans the banks of the river at the proposed alignment • the total bridge length should be able to (a) maintain the original river width, (b) maintain the minimum freeboard from maximum flood water, (c) minimize pier encroachment on river section, and (d) the modified cross-section should be able to accommodate the design river discharge and minimize backwater.
	Approach	South – 420m North – 300m	• this length covers the approaches to the main bridge from both sides of the banks
	Main	400m	• this length covers the main river waterway which has the deepest section of the river at this location
Bridge Span	Approach	30m	• the approach span length is the most cost-effective span
	Main	50m & 60m	• the minimum span for the river discharge at this location is 46m; this is the most economical span
Deck	Width	9.95m	• cover 2 lanes @ 3.5m + shoulders (0.75m + 0.50m) + sidewalk & curb (1.1m + 0.60m) • B.O.D. minimum deck width is 9.54m
	Driveway	Lane width – 3.5m Clear roadway – 8.25m	• B.O.D. minimum lane width is 3.35m • B.O.D. minimum clear roadway is 7.34m
Bridge Design Vertical Profile		as shown	• minimum clearance from maximum flood water level to lowest part of structure is 1.5m
2.0 Approach Bridge (5-span and 4-span Continuous Precast AASHTO Girders)			
Deck Slab Thickness		210mm	• determined by structural requirements
Girder Type		AASHTO Girder Type V	• standard for 30m span; reinforcement shall be determined by structural requirements
Pier Column		1.5m x 3.5m Oval	• 1.5m is 5% of span length; other dimension determined by seismic loading requirement
Pile Foundation	Dia.	ϕ1.2m	• determined by structural requirements; most economical

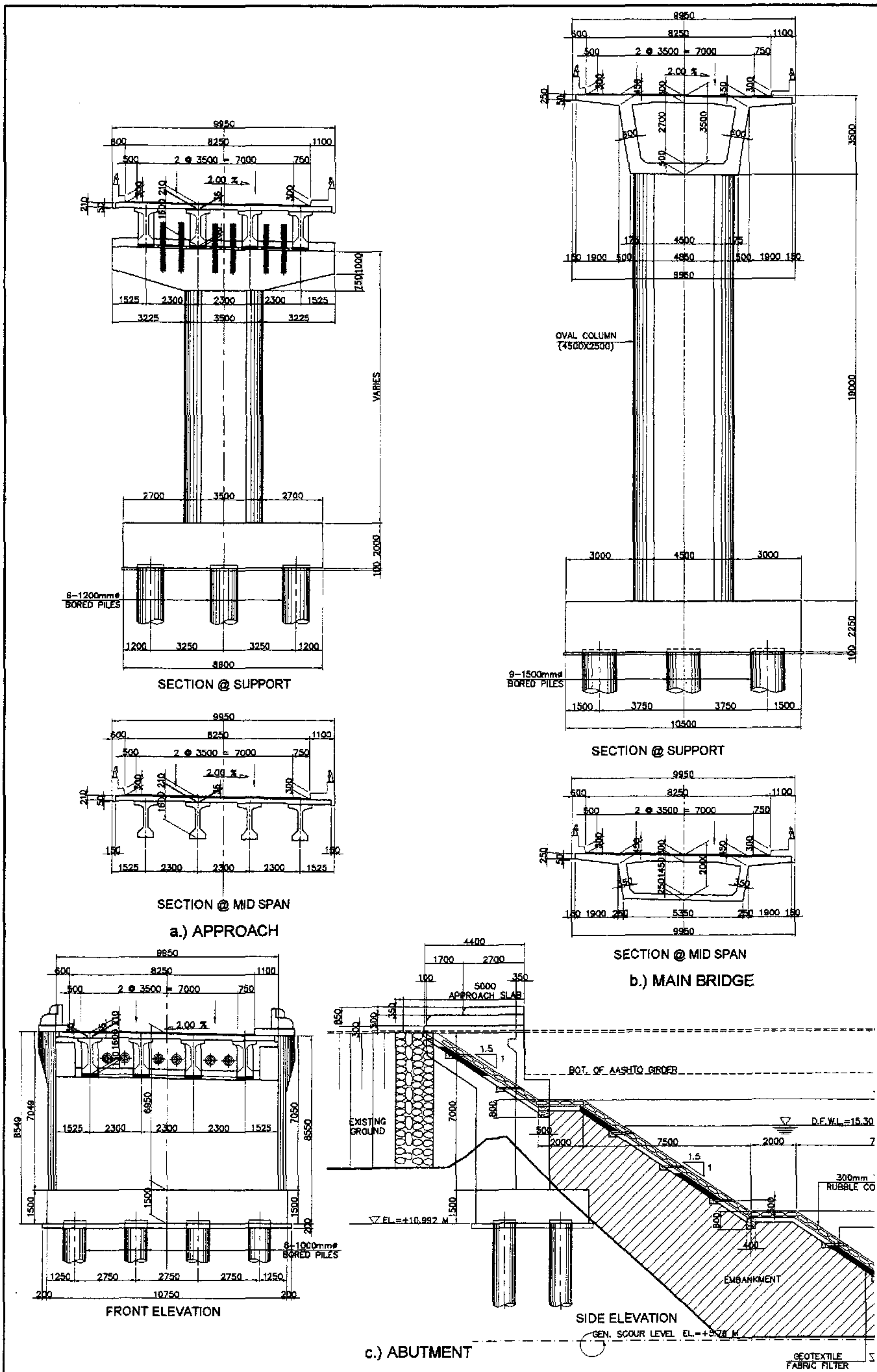


FIGURE 9.5-4 TYPICAL STRUCTURAL LAYOUT

	Length	as indicated	• determined by structural requirements • consideration due to river scour and quarrying at site
Abutment		as indicated	• closed type abutment with superstructure on bearing seats • determined by structural requirements
3.0 Main Bridge (7-span Continuous PC Box Girder by Balanced Cantilever)			
Box Girder	Cell	1 – cell	• Depth to width ratio =1/5 > 1/6, one cell box girder is sufficient
	Depth	Midspan – 2.0m At Piers – 3.50m	• Minimum depth is controlled by deflection criteria under live load, δ < *Span/1000* • Depth to span ratio provided = 1/30 at midspan and 1/17.2 at support; this is sufficient compared to previous ratios
	Flange	Top – 300 Bottom - 250	• determined by structural requirements • minimum thickness – for top is 225mm and for bottom is 155mm
	Web	350mm	• determined by structural requirements • minimum thickness is 300mm
	Cantilever	2.35m	• not to exceed 0.45 times the interior span of top flange
Pier Column		2.5m x 4.5m Oval	• 2.5m is only 4.2% of span length < 5% • other dimension determined by seismic loading requirement
Pile Foundation	Dia.	ϕ1.5m	• determined by structural requirements; most economical
	Length	as indicated	• determined by structural requirements • consideration due to river scour and quarrying at site

(2) Design of Abutment

The detailed design for the abutment at the approach side is carried out to determine the basic structural requirements to support the anticipated loads. The design approach and method of analysis is based on the recommendations of the AASHTO Div. I-A – Sec. 7.4 Foundation and Abutment Design Requirement for Seismic Performance Categories C and D.

The following conditions are being applied in the design of abutment:

- Abutment Type : Closed type Cantilever Wall Abutment on bored piles
- Abutment Width : 9.95m

- Superstructure Support : On sliding bearing
- Material : Reinforced Concrete, f'c = 28 MPa
  Reinforcing Bars, fy =415 MPa
- Live Loading : MS 18 (HS 20-44)
- Earth Pressure : Rankine's formulation due to retained soil
- Seismic Load : Seismic active earth pressure is based on pseudo static Mononobe-Okabe formulation for soil

  Ground Acceleration Coefficient is taken as A = 0.40 and horizontal seismic coefficient is taken as k_h = 0.5A
- Foundation : Multiple bored piles Φ1.0m

Figure 9.5-4 shows a typical layout of the abutment.

(3) Design of Superstructure

The load combinations for the design of superstructure will follow the AASHTO recommendations as outlined in the Bridge Design Criteria. The live loading applied in the design is the AASHTO MS 18 Class (HS 20-44). However, permit design loading P-Load as recommended by BOD, DPWH will be adopted to check the capacity of the members under load factor design.

(a) Precast AASHTO Girders for the Approach Spans

The design of precast prestressed AASHTO girders for the approach spans basically followed the AASHTO Standard Specifications for Highway Bridges.

The superstructure is taken as composite precast prestressed girder with cast-in-place slab made continuous on live load. The girders are supported on elastomeric bearing pads with fix dowel bars on continuous piers. Sufficient bearing support lengths is provided at expansion piers and dowel bars and restraining bars is utilized as fall down prevention device.

The design of the prestressed girder will follow the sequence of construction similar to Talavera river bridge crossing.

Figure 9.5-5 shows a typical layout of the AASHTO girders for the approach bridge.

(b) PC Box Girder for Main Bridge

The design of box girder using balanced cantilever method adopted the recommendations of AASHTO Guide Specifications for Design and Construction of Segmental Concrete Bridges and the AASHTO Standard Specifications for Highway Bridges.

The main bridge for Angat river crossing is a 400m 7-span continuous prestressed box girder constructed by balanced cantilevering (Figure 9.5-6). In this construction method, the structural system changes many times until the completion of the bridge. Figure 9.5-7 shows the construction sequence for the balanced cantilever method of the main bridge.

Analysis. In the design of main bridge, elastic analysis and beam theory is used to determine the design moments, shears and deflections. The effects of creep, shrinkage and temperature differentials is considered including the effects of shear lag. In addition to the usual substructure design considerations, unbalanced cantilever moments due to segment weights and erection loads is accommodated in pier design.

Transverse Analysis. The transverse design of box girder for flexure considered the segments as a rigid box frame. Flanges are analyzed as variable depth sections considering the fillets between the flange and webs. The wheel loads are positioned to provide maximum moments and elastic analysis used to determine the effective longitudinal distribution of wheel load for each load location. Considerations is given to the increase in web shear and other effects on the cross-section resulting from eccentric loading or unsymmetrical structure geometry. Transverse prestressing is applied to the top slab.

Longitudinal Analysis. The analysis and design in the longitudinal direction considered the construction method and construction schedule, as well as the time related effects of concrete creep, shrinkage and prestress losses. The effects of secondary moments due to prestressing is included in the stress calculation at service limit state. For flexural and shear capacity requirements under factored loads, the secondary moments or shear induced by prestressing (Load Factor = 1.0) is added to the factored dead load and live loads. The final structural system is analyzed for redistribution of erection stage moments resulting from the effects of creep and shrinkage, and from any change in statical system including closure of joints.

Since the column is rigidly connected to the superstructure, the inelastic hinging force (plastic hinging force) from the column is considered in the design. Ductile details at column-superstructure connection is provided to resist the longitudinal and transverse plastic demand forces resulting from column plastic hinging.

(4) Design of Substructure

Seismic Design. The principles used in the detailed design of substructure include:

- Small to moderate earthquakes should be resisted within the elastic range of the structural components without significant damage.
- Realistic seismic ground motion intensities and forces are used in the design procedures.
- Exposure to shaking from large earthquakes should not cause collapse of all or part of the bridge.

Where possible, damage that does occur should be readily detectable and accessible for inspection and repair.

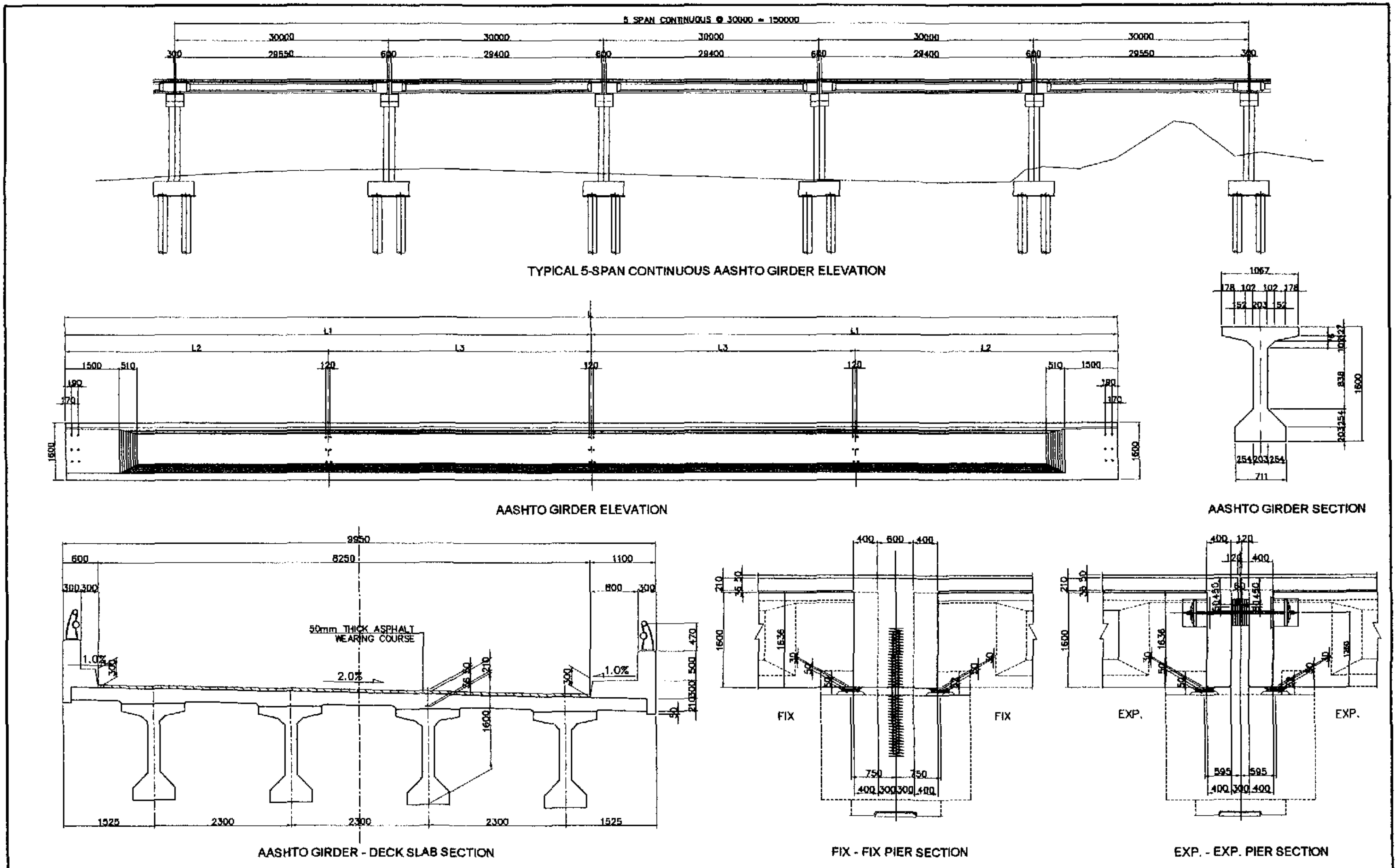


FIGURE 9.5-5 AASHTO GIRDER FOR APPROACH SPAN

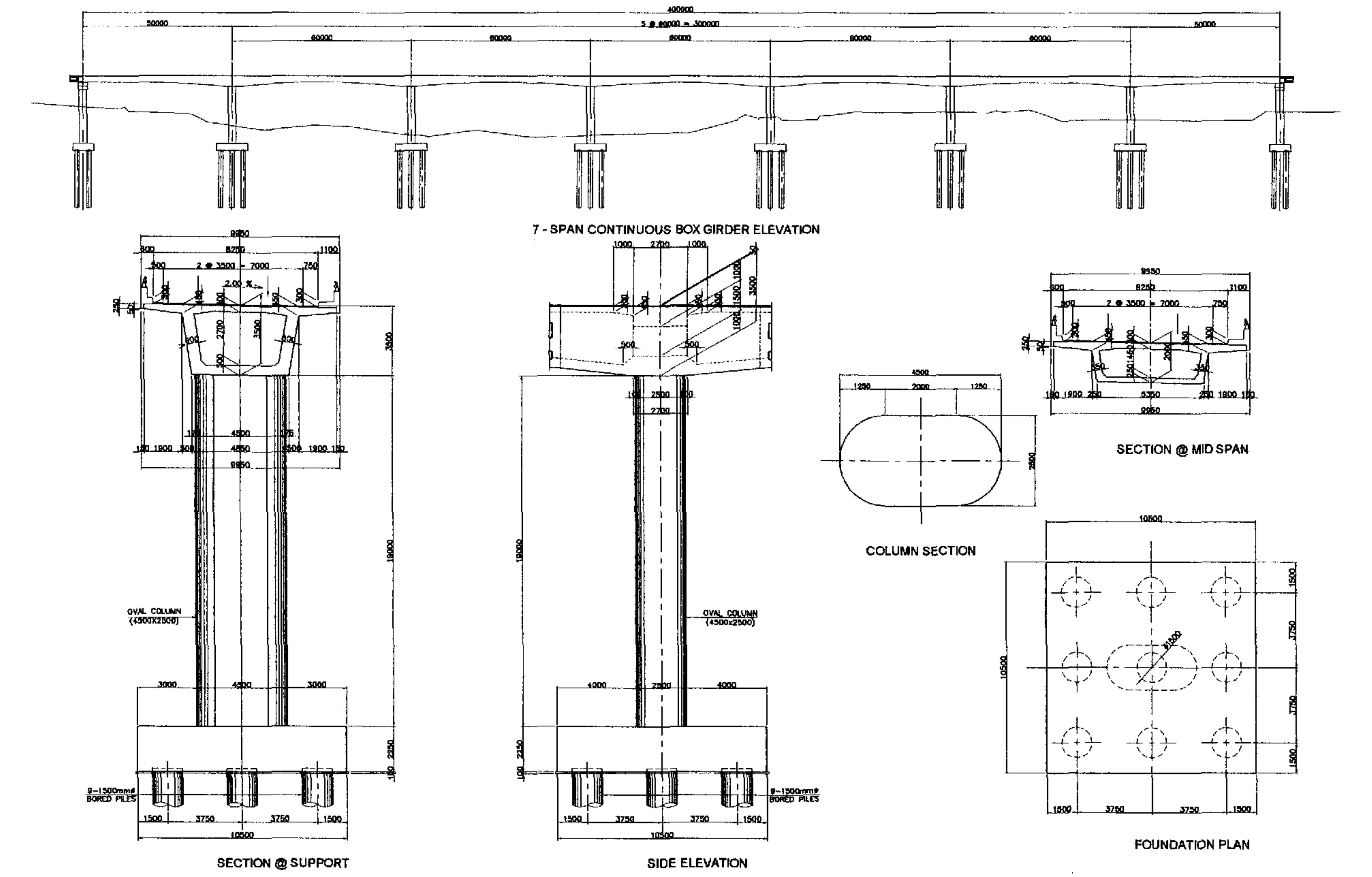


FIGURE 9.5-6 MAIN BRIDGE FOR ANGAT RIVER CROSSING

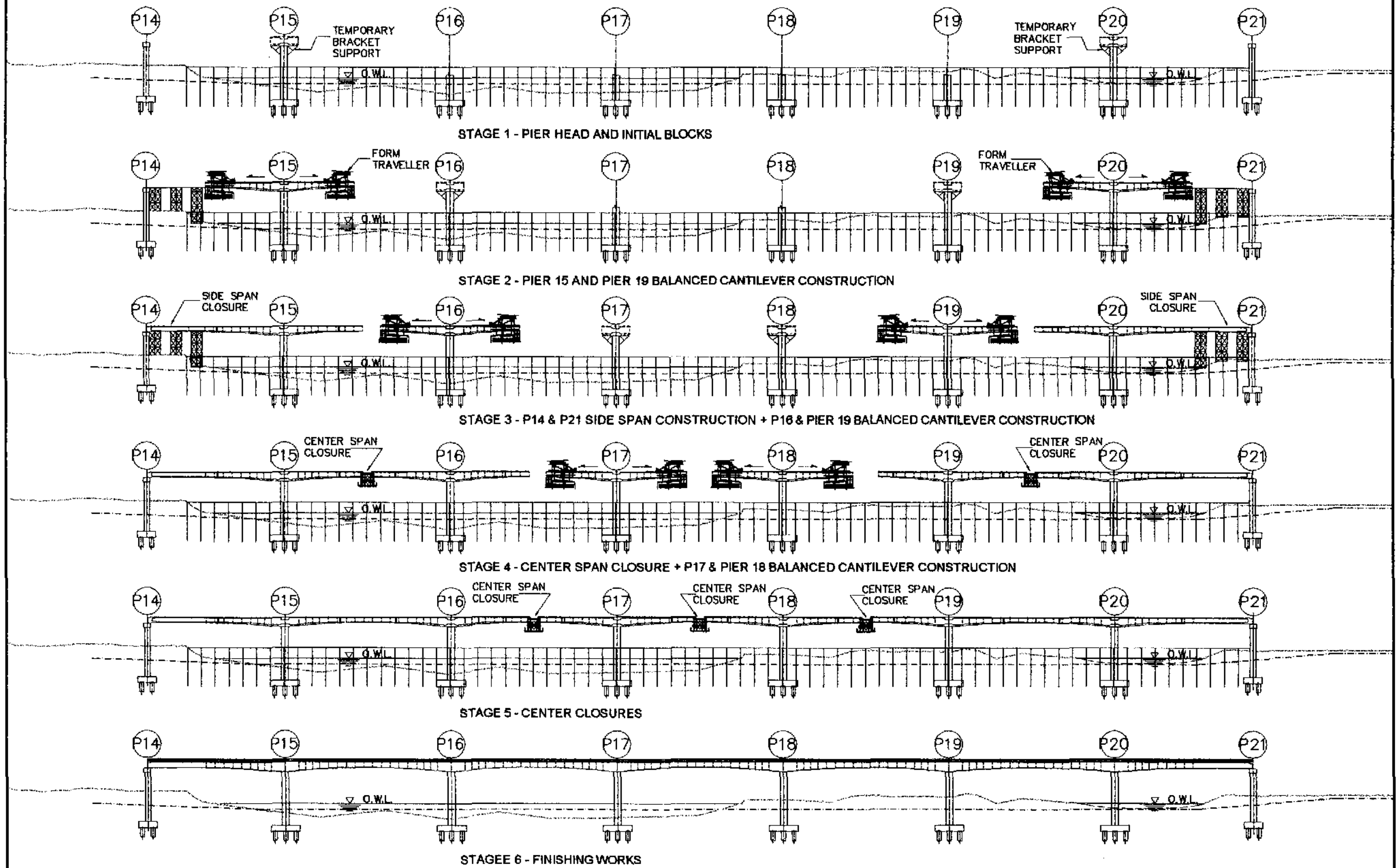


FIGURE 9.5-7 CONSTRUCTION SEQUENCE FOR ANGAT RIVER MAIN BRIDGE USING BALANCED CANTILEVER SEQUENCE FOR MAIN BRIDGE

The design of substructures basically adopted the recommendations of the AASHTO Div. I-A , Seismic Design.

For the seismic analysis, the multi-mode spectral analysis method under Seismic Performance Category D is used to determine the elastic design forces for the pier columns. The seismic response coefficients for various soil types is shown in Figure 9.5-8 while the peak ground acceleration will be based on DPWH recommendations using the acceleration coefficient A = 0.4.

Pier Column Design. Similarly, the design of pier columns followed the procedures described in AASHTO Div. I-A.

A three-dimensional finite element mathematical model using 3D beam elements is used to perform the response analysis under seismic excitation. The elastic forces obtained from the multimode response spectrum analysis are used to determine the design forces for the columns considering the Response Modification Factor R. This R-factor is a function of column ductility which allows plastic hinging to form in the columns with sufficient lateral confinement.

Determination of column structural requirements (size and reinforcement) is done following the resulting modified design forces. Column confinement is detailed using the plastic design shear force derived from the plastic capacity of the column section.

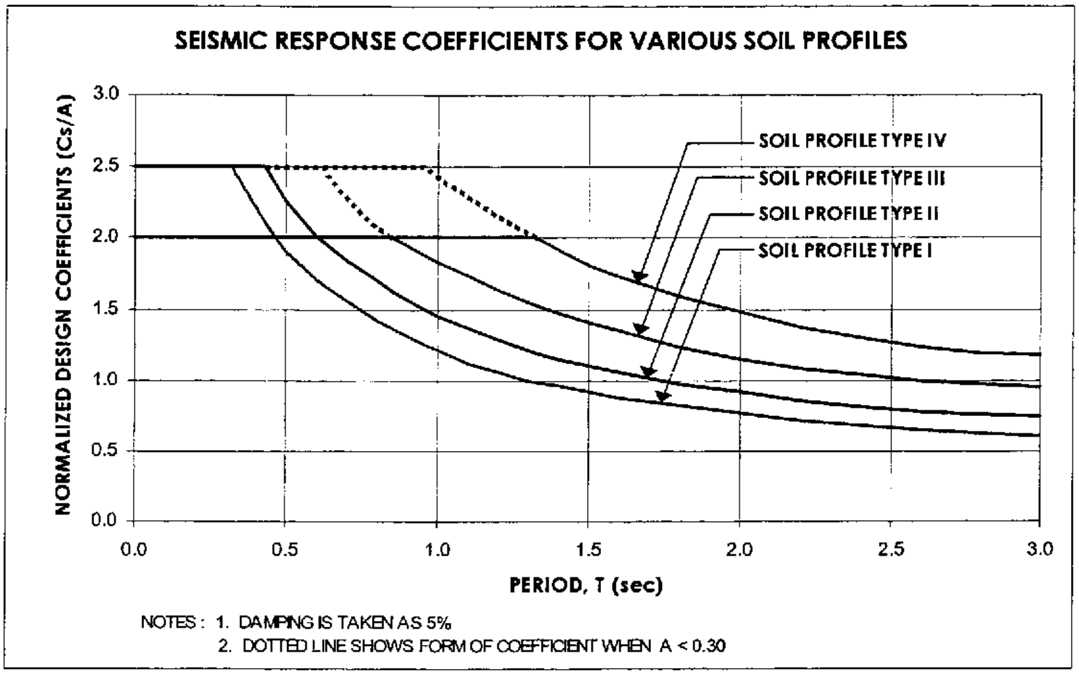


FIGURE 9.5-8 SEISMIC RESPONSE COEFFICIENTS FOR VARIOUS SOIL CONDITIONS

Foundation Design. The design of the Bored Pile foundations is based on the following guidelines:

- Intensities of the vertical subgrade reaction at the foundation bottom shall not exceed the vertical bearing capacity of the soil layer.
- Maximum horizontal subgrade reaction in front of the bored piles shall not exceed the allowable horizontal bearing capacity of the soil layers.

- Displacement of the bored pile shall not exceed an allowable value.
- The structural capacity of pile shall not be exceeded.

In general, since the dimension of the bored piles are relatively large, the piles are assumed to be rigid body. Therefore, the vertical loads sustained by the piles are assumed to be resisted by the vertical ground reaction of the soil layer at the sides of the piles and at the foundation bottom. However, the horizontal loads are assumed to be resisted by the vertical ground reaction and the shearing resistance of the soil layer at the foundation bottom and horizontal reaction of the soil layers in front of the foundation.

The design of foundation for the piers is based on the Capacity Design procedure. Here, the design concept would be to allow yielding or plastic hinges being formed in the column while keeping the foundation in the elastic range. To maintain such behavior, the design forces used for the foundation will be the plastic capacity forces of the columns. This will ensure that forces going into the foundation will be sustained by the foundation in the elastic range. The forces derived in this manner is taken as the ultimate loads which becomes the basis of the Load Factor (Strength) Design for bored piles.

9.6 Interchange Ramp C – NLE Overcrossing

9.6.1 Site Condition

(1) Site Topography

The bridge location for Ramp C of the proposed Interchange for the Plaridel Bypass connection to the North Luzon Expressway has the following features:

- the proposed Plaridel Bypass connection to North Luzon Expressway (Figure 9.6-1) involves the construction of two new ramps (Ramps C and D) for inbound and outbound directions and the upgrading/widening of existing ramps (Ramps A and B),
- the Interchange Ramp C will cross-over the four-lane divided expressway with shoulder to shoulder edge distance of about 32m,
- the present four lanes (2 lanes for northbound and 2 lanes for southbound) will be upgraded to six lanes to increase its future capacity,
- the difference in elevation between the expressway and the adjacent ground at the proposed alignment is more than 5m necessitating high embankment at the bridge approach,
- the ramp alignment is curve at the proposed location with a 100m radius and skewed with the expressway,
- a vertical clearance requirement for the expressway has to be maintained at 5.1m.

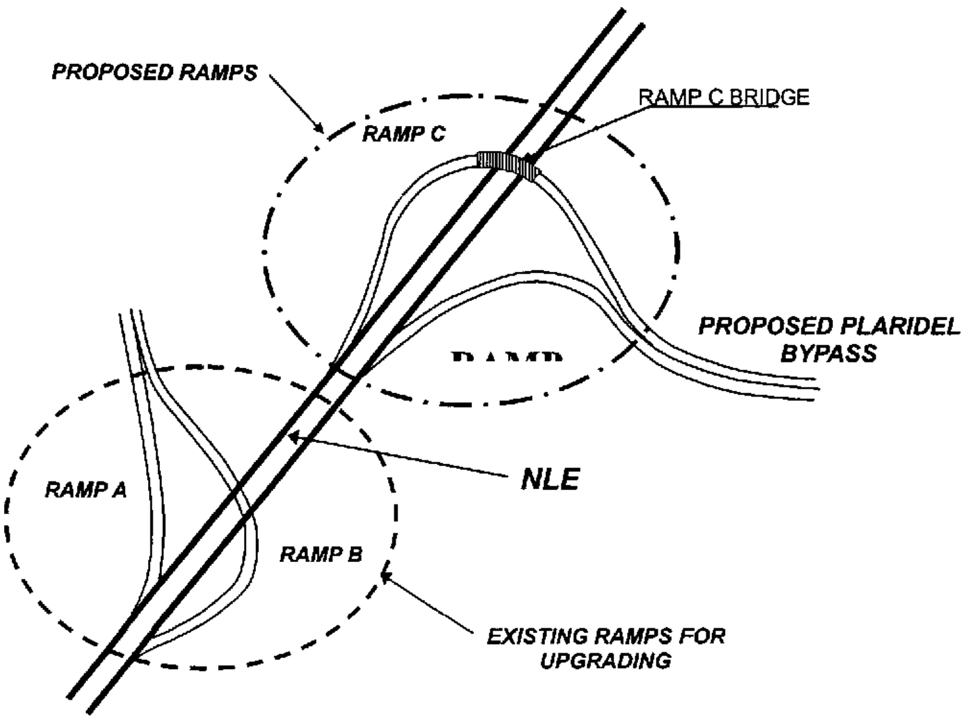


FIGURE 9.6-1 PLARIDEL BYPASS PROPOSED INTERCHANGE

(2) Soil Condition

The results of soil investigation (as shown in Figure 9.6-2) at the proposed bridge site indicated:

- the site is generally underlain by thick cohesive deposits that persisted down to the end of boreholes,
- the thick cohesive soil deposits may be generally described as medium stiff to hard, brown to gray, medium to highly plastic clay and/or silty clay,
- the N-values are seen to increase with depth with N-values of 4 to 10 at the upper 9.0m and gradually increasing from 10 to 50 towards the end of boreholes; practical refusal (N>50) was encountered at about 25.5m deep and 27.5m deep for boreholes B-25 and B-26 respectively,
- natural moisture content ranged from 30% to 40% and liquid limit ranged from 30% to 70%.

Bored pile foundation is thus proposed for this bridge with the assumed bearing at the hard clay layer shown in Figure 9.6-3.

9.6.2 Final Bridge Scheme

(1) Design Requirements

The design requirement used for the final bridge scheme is presented in Table 9.6-1 below.

TABLE 9.6-1 REQUIREMENTS FOR THE PROPOSED BRIDGE SCHEME

Design Requirements		***Items to be Considered***
1	Horizontal and Vertical Clearances	• NLE Travelway: Pier distances to support the bridge superstructure should not pose any conflict with the existing and proposed travelway and shoulders of the expressway. Thus minimum span should clear northbound and southbound lanes plus shoulders. • Vertical Clearance: The minimum vertical clearance required by MNTC at the travelways should be no less than 5.1m.

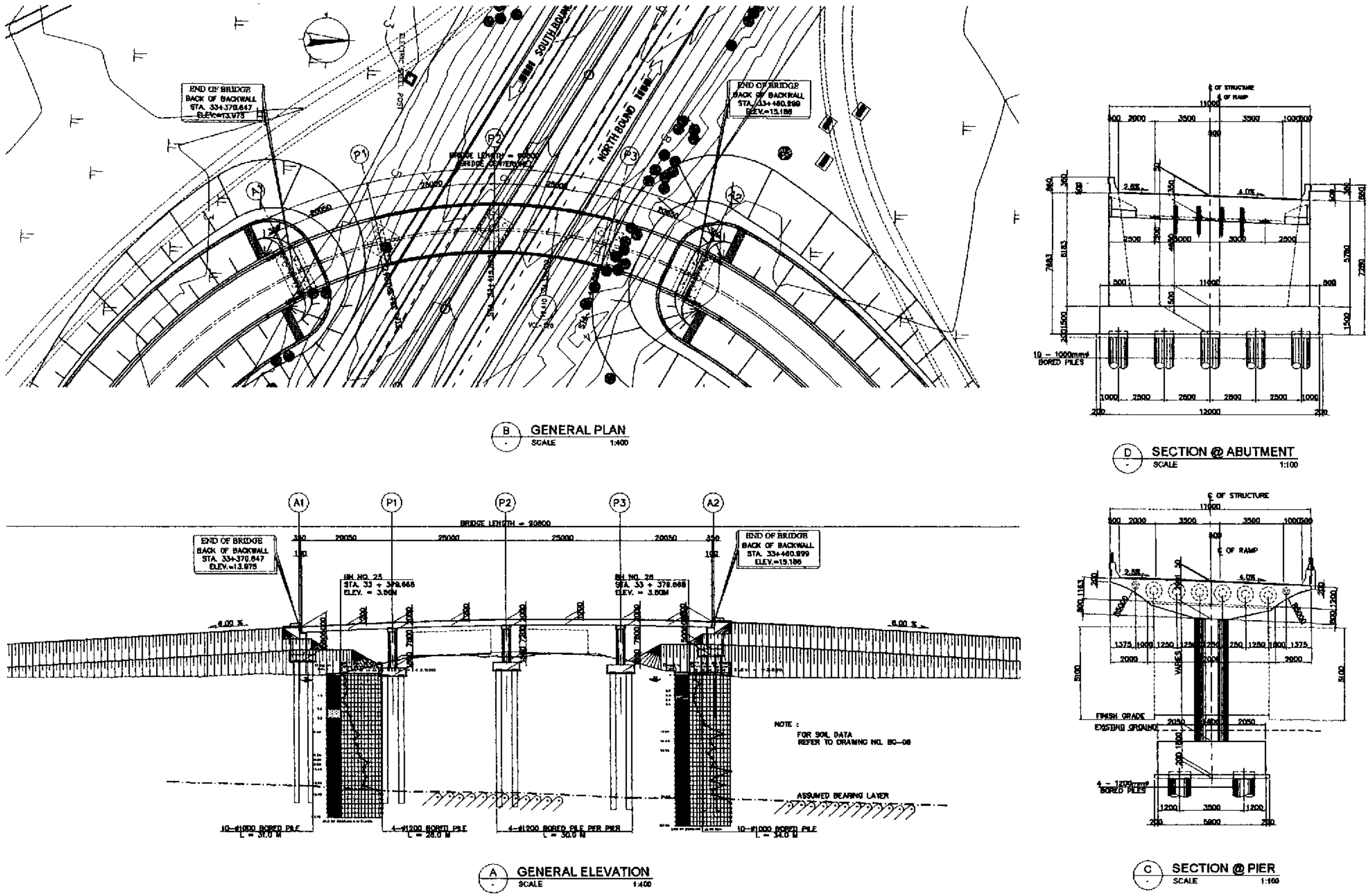


FIGURE 9.6-2 PROPOSED INTERCHANGE RAMP

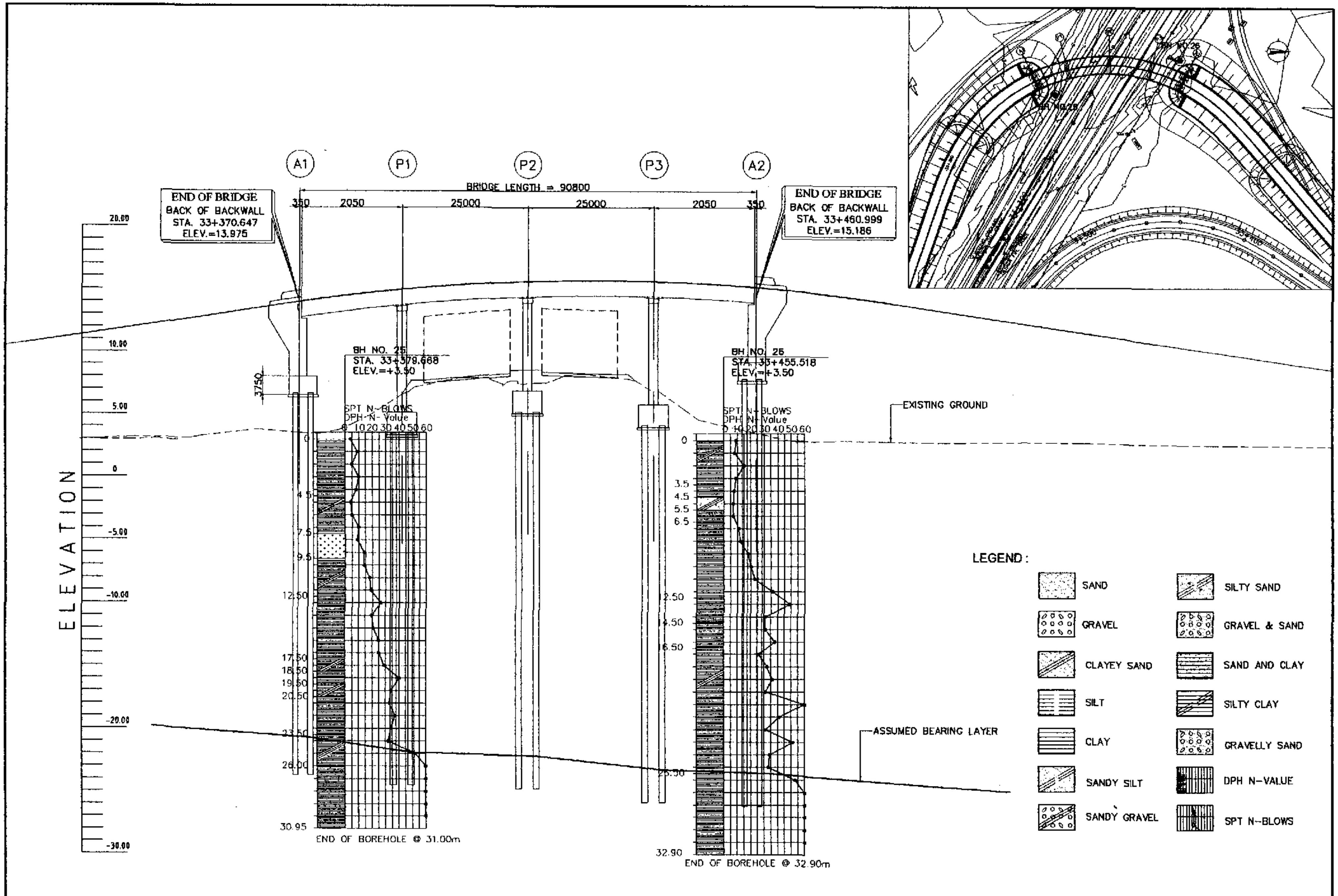


FIGURE 9.6-3 SOIL PROFILE AT PROPOSE BRIDGE LOCATION

<table>
<tr><td>2</td><td>Topography and NLE Condition</td><td><u>NLE Profile an Existing Ground Level</u> : NLE existing ground profile is more than 5m above adjacent ground which makes the approach embankment more than 10m high.
<u>Abutment</u>: Abutment pile cap is placed on embankment to minimize height but requires preloading before construction. Embankment should not encroach on expressway.
<u>Pier Positions</u>: One pier is located at the center of expressway to minimize spans to 25m. Other pier positions are based on the horizontal clearance of the travel way.
<u>Bridge Alignment</u>: The bridge is on a curve alignment with 100m radius and skewed with the expressway. A bridge type with high torsional resistance is recommended.</td></tr>
<tr><td>3</td><td>Soil Condition and Foundation</td><td><u>Foundation Type</u> : Bored piles are recommended to support the structure which can be embedded deep into the hard clay bearing layer.</td></tr>
<tr><td>4</td><td>Construction</td><td><u>NLE Construction</u>: The bridge will cross over the busy NLE and should be constructed considering:
minimum temporary vertical clearance of 4.5m,
minimum temporary encroachment to travelway; maintain minimum of two lanes each way,
safety of all commuters using the expressway
<u>Bridge Structure</u>: The 4-span continuous prestressed voided slab will be constructed by all staging method. Shallow superstructure like voided slab is more advantageous to maintain higher temporary vertical clearance.
<u>Cost</u>: Different bridge types and schemes were compared and the proposed scheme is the most cost-effective – longer span and other bridge type scheme tends to be more expensive.</td></tr>
</table>

(2) Proposed Bridge Configuration

Considering the design requirements mentioned above, the final bridge scheme configuration is a 4-span continuous superstructure (minimum span of 25m on piers) and following the comparative study for bridge scheme, the prestressed voided slab deck is found most cost-effective.

The proposed scheme is taken as the most appropriate scheme since:

- the voided slab is the cheapest alternative,
- the temporary vertical clearance can be made higher since the deck depth is only 1.20m and its integration with the piers make it more shallower,
- the voided slab has high torsional resistance which is more appropriate for curved bridges.

TABLE 9.6-2 FINAL SCHEME FOR INTERCHANGE RAMP C BRIDGE

BRIDGE LENGTH	20 + 2 @25 + 20 = 90m
BRIDGE TYPE	1.20m deep Voided Slab Integral with Pier Columns
SUBSTRUCTURE	Φ 1800mm Circular Columns on Φ 1200mm Bored Piles

The proposed Interchange will be constructed in one Stage providing two lanes of travelway for each ramp.

A typical layout of structures for a single two-lane bridge is shown in Figure 9.6-4.

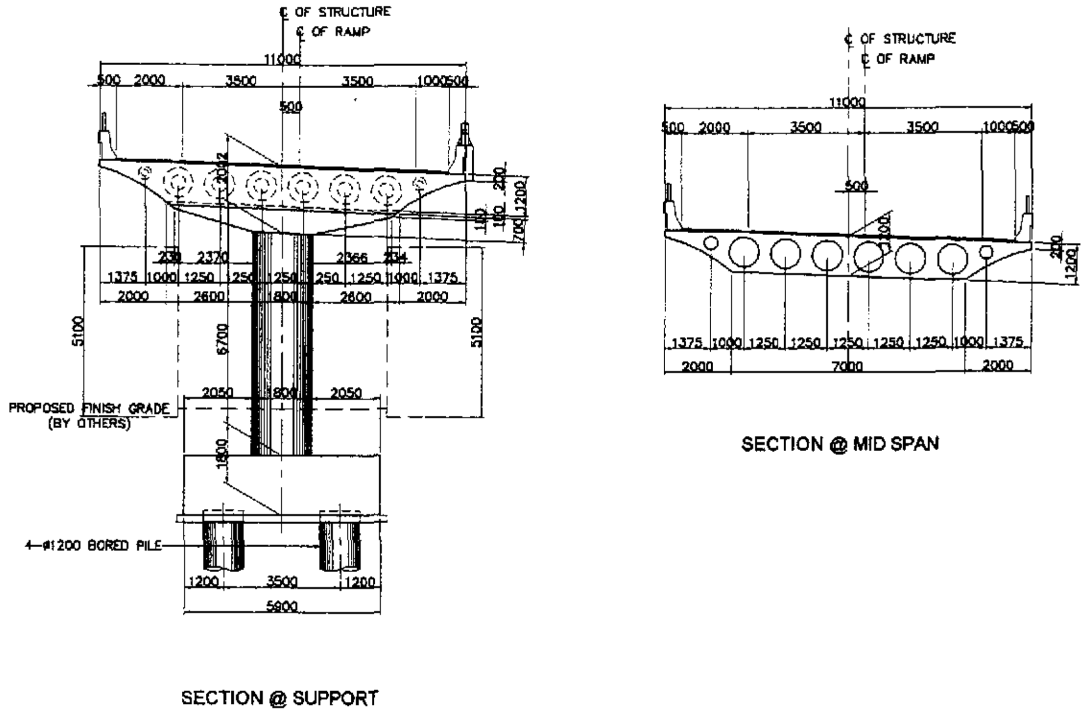
9.6.3 Detailed Design of Interchange Ramp-C Bridge

The detailed design of the Interchange Ramp C bridge crossing the NLE is carried-out with the principles and methodology similar to the Angat river bridge in Section 9.5 of this report.

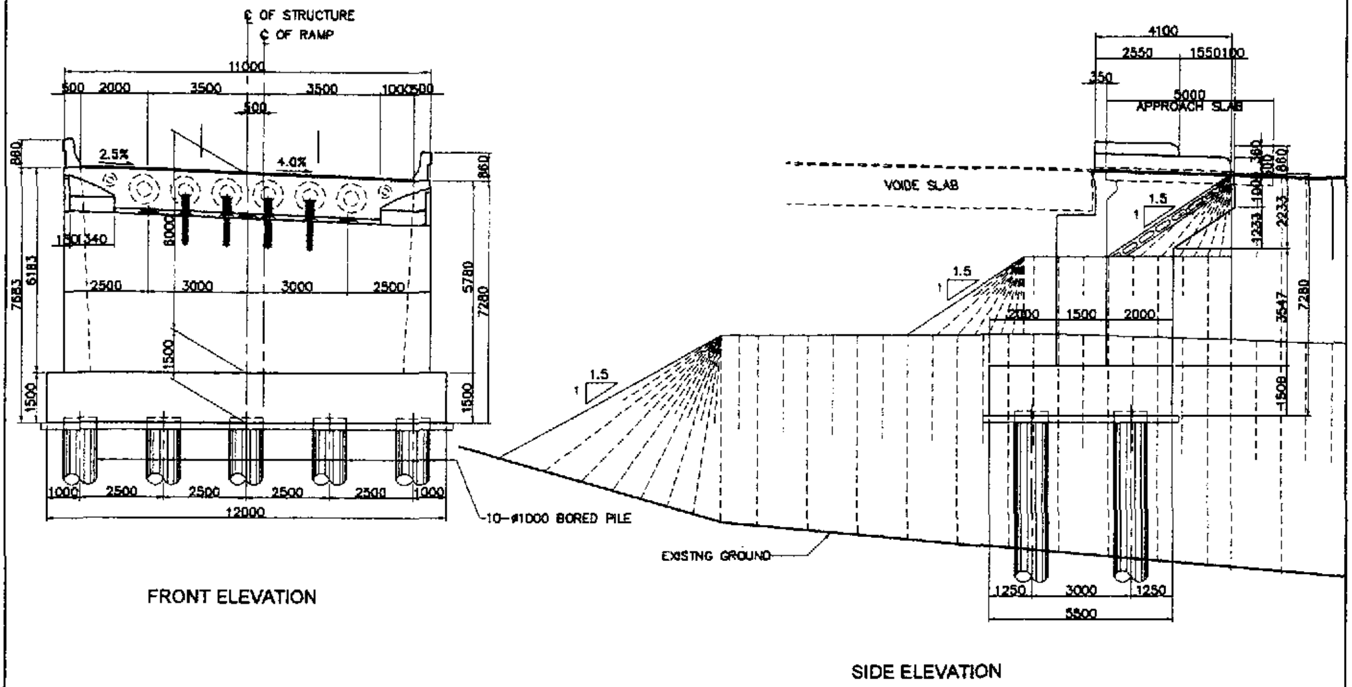
The following design conditions are applied to the detailed design of Interchange ramp:

- Bridge Type : 1.20m Deep Voided Slab Erected by all Staging Method
- Bridge Width : 11.0m
- Material : Prestressed Voided Slab , f'c = 41 MPa
  Bored Piles, f'c = 28 MPa

  Reinforcing Steel, fy = 415 MPa
  Prestressing Steel, fpu = 1862 MPa
- Live Loading : MS 18 (HS 20-44)
  B.O.D. Permit Live Load (LFD check)
- Seismic Loading : AASHTO Div. I-A



a.) BRIDGE



b.) ABUTMENT

FIGURE 9.6-4 TYPICAL STRUCTURE LAYOUT

Peak Ground Acceleration Coef., A = 0.40
Seismic Response Coef., Figure 9.5-8
Importance Classification, IC = 1.0
Seismic Performance Category, SPC = D
Soil Site Coefficient = 1.2

- Foundation : Ø1200mm Bored Piles for Piers
  Ø1000mm Bored Piles for Abutment

(1) Basic Dimensional Requirement

Figure 9.6-4 shows the typical cross-section of the bridge for the ramp to be constructed during the initial stage. The basic dimensional requirements for the bridge is decided based on the following:

ITEM		*DESCRIPTION*	*BASIS*
Bridge Length	Total	90m	• this length covers the horizontal clearance to span the expressway minimizing encroachment to travelway and shoulders, • this is the minimum length to cross the expresway
Bridge Span	Main	25m	• the span length is the most cost-effective span • the minimum span length to clear the expressway
Deck	Width	11.0m	• cover 2 lanes @ 3.5m + shoulders (1.0m + 2.0m) • B.O.D. minimum deck width is 9.54m
	Driveway	Lane width – 3.5m Clear roadway – 10.0m	• B.O.D. minimum lane width is 3.35m • B.O.D. minimum clear roadway is 7.32m
Bridge Design Vertical Profile		as shown	• minimum vertical clearance from expressway is *5.10m*
Deck Slab Thickness		1200mm	• determined by structural requirements
Girder Type		Prestressed Voided Slab	• most cost-effective superstructure type for this ramp
Pier Column		Φ 1.8m Circular	• determined by seismic loading requirement
Pile Foundation	Dia.	ϕ1.2m	• determined by structural requirements; most economical
	Length	as indicated	• determined by structural requirements on geotechnical aspects

Abutment	as indicated	• closed type abutment with superstructure on bearing seats • determined by structural requirements

(2) Design of Abutment

The detailed design for the abutment is carried out to determine the basic structural requirements to support the anticipated loads in a similar manner with the Angat river bridge crossing.

The following conditions are being applied in the design of abutment:

- Abutment Type : Closed type Cantilever Wall Abutment on bored piles
- Abutment Width : 11.0m
- Superstructure Support : On sliding elastomeric bearing
- Material : Reinforced Concrete, f'c = 28 MPa
  Reinforcing Bars, fy = 415 MPa
- Live Loading : MS 18 (HS 20-44)
- Earth Pressure : Rankine's formulation due to retained soil
- Seismic Load : Seismic active earth pressure is based on pseudo static Mononobe-Okabe formulation for soil

  Ground Acceleration Coefficient is taken as A = 0.40 and horizontal seismic coefficient is taken as $k_h = 0.5A$
- Foundation : Multiple bored piles Φ1.0m

Figure 9.6-4 shows the typical layout of the abutment.

(3) Design of Superstructure

The load combinations for the design of superstructure followed the AASHTO recommendations as outlined in the Bridge Design Criteria of this report. The live loading applied in the design is the AASHTO MS 18 Class (HS 20-44). However, permit design loading P-Load as recommended by BOD, DPWH is also adopted to check the capacity of the members under load factor design.

(a) Prestressed Voided Deck Slab

The design of cast-in-place post-tensioned voided slab for the superstructure basically follows the AASHTO Standard Specifications for Highway Bridges.

The continuous 4-span deck will be cast in one time and post-tensioned at the abutment locations. The deck slab is made continuous with the piers at three positions and supported on elastomeric bearings at the abutment locations. Since the deck slab is cast at the same time and post-tensioned, the long-term effects due to creep and shrinkage is considered in calculating the internal forces on the superstructure, Such time effects on column forces is also considered in the design of substructures.

Figure 9.6-5 shows a typical layout of the 3-span continuous voided slab deck.

(4) Design of Substructure

Seismic Design. The principles used in the detailed design of substructure are similar to Angat river bridge in Section 9.5.

The design of substructures basically adopted the recommendations of the AASHTO Div. I-A , Seismic Design.

For the seismic analysis, the multi-mode spectral analysis method under Seismic Performance Category D is used to determine the elastic design forces for the pier columns. The seismic response coefficients for various soil types is shown in Figure 9.5-8 while the peak ground acceleration is based on DPWH recommendations using the acceleration coefficient A = 0.4.

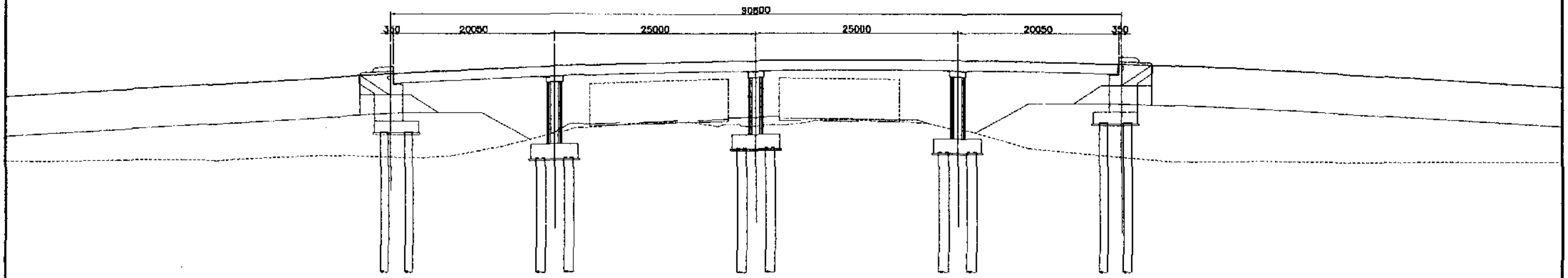
Pier Column Design. Similarly, the design of pier columns followed the procedures outlined in AASHTO Div. I-A.

A three-dimensional finite element mathematical model using 3D beam elements is used to perform the response analysis under seismic excitation. The elastic forces obtained from the multimode response spectrum analysis are used to determine the design forces for the columns considering the Response Modification Factor R. This R-factor is a function of column ductility which allows plastic hinging to form in the columns with sufficient lateral confinement.

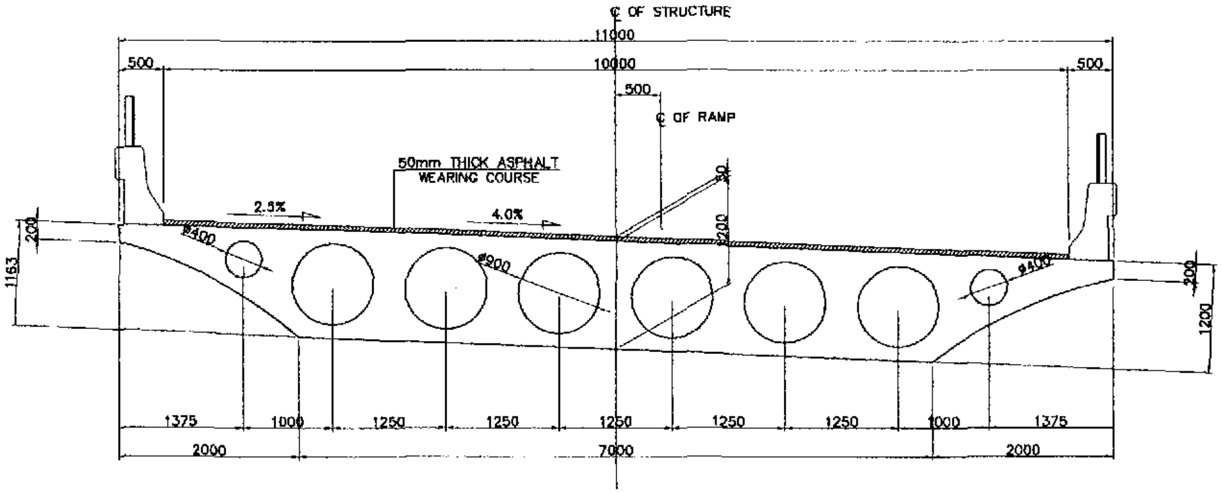
Determination of column structural requirements (size and reinforcement) is done following the resulting modified design forces. Column confinement is detailed using the plastic design shear force derived from the plastic capacity of the column section.

Foundation Design. The design of the Bored Pile foundations is based on the guidelines set similar to Angat river bridge.

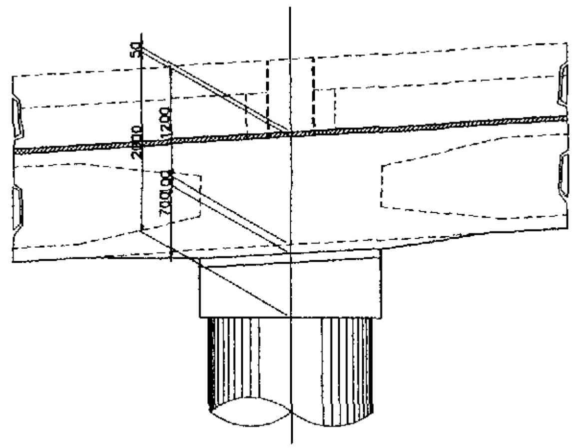
The design of foundation for the piers is based on the Capacity Design procedure. Here, the design concept would be to allow yielding or plastic hinges being formed in the column while keeping the foundation in the elastic range. To maintain such behavior, the design forces used for the foundation will be the plastic capacity forces of the columns. This will ensure that forces going into the foundation will be sustained by the foundation in the elastic range. The forces derived in this manner are taken as the ultimate load which becomes the basis of the Load Factor (Strength) Design for bored piles.



TYPICAL 3-SPAN CONTINUOUS AASHTO GIRDER ELEVATION



AASHTO GIRDER - DECK SLAB SECTION



INTEGRAL PIER SECTION

FIGURE 9.6-5 VOIDED SLAB LAYOUT FOR INTERCHANGE RAMP