7.2.4 Hydrologic and Hydraulic Studies

(1) Objectives and Work Flow

Taking account of the goals of the recommended project, the objectives of the hydrological and hydraulic studies are set as follows:

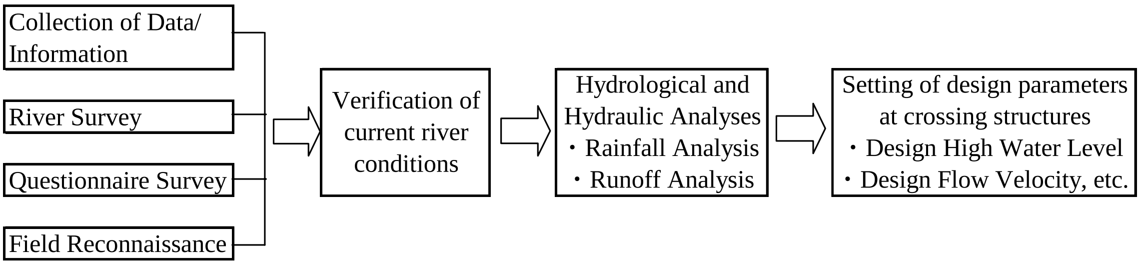
(i) To clarify the current conditions of river channel and riparian areas, which are subject to proposed road network.

(ii) To estimate the flood discharges of the rivers in various return periods through statistical approach at crossings along proposed road alignment.

(iii) To recommend betterment of drainage system along the proposed alignment, where deterioration of present drainage conditions due to implementation of the project is predicted, if any.

In order to accomplish the objectives above mentioned, the work flow of sectoral studies has been set up as follows:

Figure 7.2.2 General Work Flow of Hydrological Analysis



(2) Available Data, Maps and Documents

(a) Topographic Maps

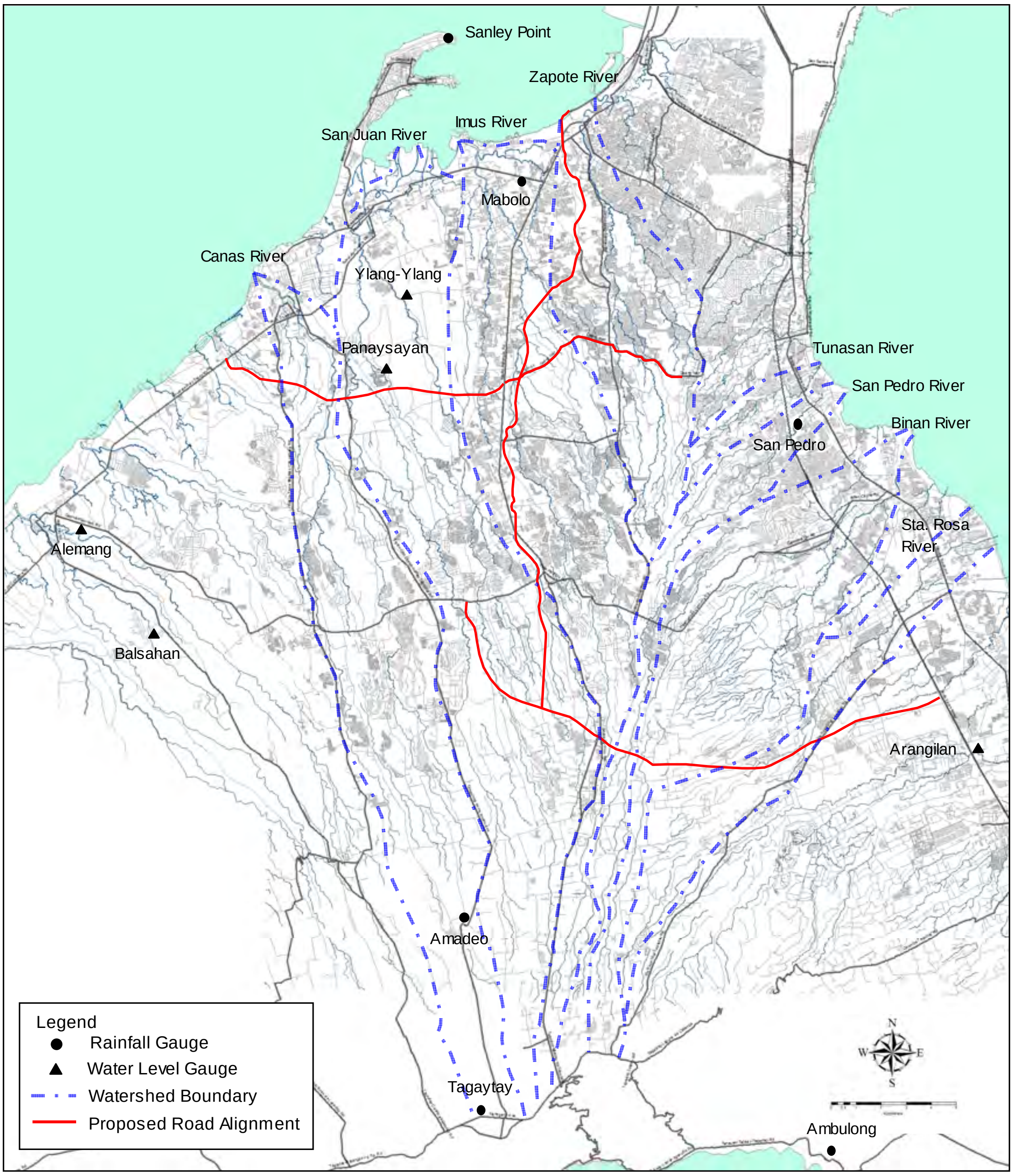
Topographic maps of the Study Area were obtained from NAMRIA Map Sales Office in Fort Bonifacio, Manila. These maps of scale 1:50,000 and 1:10,000 were utilized to confirm the watershed boundaries of river basins and road crossings, which are concerned to the road/bridge design of three routes, i.e. CALA Expressway, North-South Road and Daang Hari Extension.

On the other hand, the cross sections with 50 m intervals and plan along the proposed road alignment with 100 m wide became available exclusively for the present study together with the aerial photographs. Consistency of river cross sections at bridges sites and topographic conditions in the vicinity was duly checked by means of the new survey outcome.

(b) Rainfall Record

Daily rainfall records at total six gauging stations (Sangley Point, Ambulong, Amadeo, Bacoor, San Pedro and Tagaytay) in and around the Study Area were collected at the Climate Data Center of PAGASA, Quezon City. The longest duration of daily record is available from 1951 to date at Ambulong, Laguna. The name of gauging station, location (longitude and latitude) and duration are presented in Appendix 7.1 Table A.1 and location of these stations is shown in Figure 7.2.3.

Figure 7.2.3 Watershed Boundaries with Rainfall and Water Level Gauging Stations



(c) Discharge Record

Mean daily discharge records at total ten gauging stations in and around the Study Area were collected from Hydrological Division, Bureau of Research and Standards, DPWH. The records are divided into two categories, i.e. old and new coding system. The available data of the old and new systems cover the period from 40's to 1979 and from 1983 to date, respectively, since there was a suspension of discharge measurement by DPWH between 1979 and 1983. Two gauging stations have been operated in the Study Area namely at Alapan in Ilang-

Ilang River and at Palubluban in Panaysayan River (Pasong Camachile River, a tributary of Ilang-Ilang River). However, those were all closed and stopped measurement in 1979 and 1984 respectively. Available duration and other related information is shown in Appendix 7.1 Table A.2 and location of water level gauging stations is marked also on Figure 7.2.3.

(d) Land Use Maps

The future land use pattern is required to estimate flood peak discharge at arbitrary points of crossing structures such as bridge, viaduct and culvert. As for the flood runoff analysis, the land use map created on GIS format prepared though the present study is available.

(e) Satellite Imagery

Geographical information of the Study Area can be extracted at free-access web site of Google Earth. A satellite imagery taken in 2005 can provide the latest information of ground cover in the Study Area. The imagery was utilized to examine relationship between proposed road alignment and river channels concerned.

(f) Related Study Reports and Guidelines

Among the related reports, documents and guidelines related to the hydrology, hydraulics and river engineering issues, in particular, following are to be referred for the Study:

(i) The Feasibility Study of the Proposed Cavite Busway System, JICA, November 2002

Among the volumes of the Final Report of the Feasibility Study, Appendix A – Natural Conditions involves useful information for hydrological analysis. Since the study of Busway System covers same target area of the present Study, the methodology shall be referred.

(ii) Specific Discharge Curve Rainfall Intensity Duration Curve Isohyet of Probable 1-day Rainfall, JICA, March 2003

This Report was prepared under the Project for the Enhancement of Capabilities on Flood Control and Sabo Engineering of DPWH, a Project Type Technical Cooperation from JICA. Specific discharge curves and rainfall intensity curves in short and long duration curves at synoptic stations of PAGASA are available in the Report.

(iii) Design Guidelines, Criteria and Standards for Public Works and Highways, Volume II (Part 2- Hydraulic Design, Part 3-Hgihway Design, Part 4-Bridge Design), DPWH (to be hereinafter referred as to “DPWH Design Guideline”)

Design procedure and key factors for hydraulic design are presented with miscellaneous design data and standard drawings.

(iv) Technical Guidelines of River and Sabo Engineering (Draft), Ministry of Infrastructure and Transport, Japan

Details on methodology of rainfall and flood runoff analyses are included with key design parameters such as runoff coefficient by deferent land cover and traveling time of flood flow, etc.

(3) River Cross Section Survey

In order to obtain the sectional data at rover crossing points along the proposed three routes, river cross section survey was carried out from February to May 2006. The survey works were sublet to RASA Surveying, Quezon City, through procurement procedure as specified by JICA. Total 22 sites, where the proposed routes cross over major rivers, were selected as follows:

Proposed Road	Number of Site
(i) CALA Expressway	9 sites
(ii) North-South Road	6 sites
(iii) East-West Road	7 sites
Total	22 sites

The location of major crossing points is shown in Figure 7.2.4 as well as the sites for river cross section survey. Related information at each crossing point is tabulated in Table 7.2.3.

Figure 7.2.4 Location Map of Crossing with River along Proposed Roads

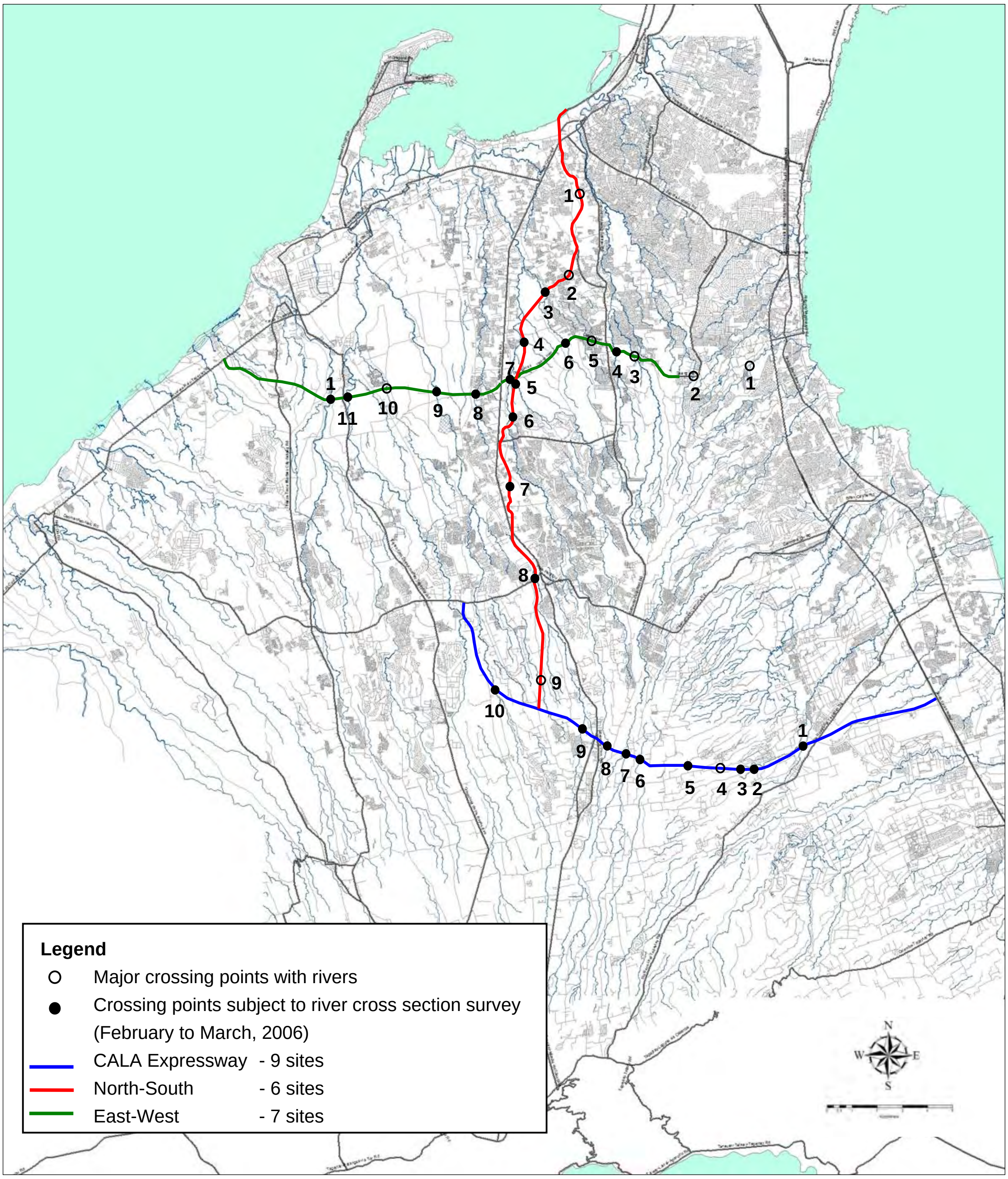


Table 7.2.3 River Crossings along Proposed Three Routes

Ref. No.	Crossing Points (1	Name of River	Name of Tributary	Municipality	Drainage Area (km2)	Proposed Structure (Tentative)	Notable Existing Conditions	Cross section survey
I.	**CALA Expressway (CE)**							
Start	Sta.0+000			Santa Rosa			SLEX	
CALA1	Sta.5+820	Banava	-	Silang	12.3	Bridge		CE-R1
CALA2	Sta.7+200	Banava	-	Silang	1.6	Bridge	moderately deep	CE-R2
CALA3	Sta.7+720	Banava	-	Silang	4.5	Bridge	moderately deep	-
CALA4	Sta.8+500	Banava	-	Silang	2.2	Bridge		CE-R3
CALA5	Sta.9+200	Biñan	-	Silang	1.4	Bridge		CE-R4
CALA6	Sta.10+840	Biñan	-	Silang	8.8	Bridge		CE-R5
CALA7	Sta.13+250	San Pedro	-	Silang	12.7	Bridge	Downstream of confluence, deep valley with thick vegetation	CE-R6
CALA8	Sta.15+320	Imus	-	Silang	13.2	Bridge	deep valley	CE-R7
CALA9	Sta.16+800	Dasmariñas	-	Silang	4.9	Bridge		CE-R8
CALA10	Sta.19+300	San Juan	Ylang Ylang	Silang	8.8	Bridge		CE-R9
End	Sta.22+881			Silang			Dasmarinas - Naic Road	
								9 sites
II.	**Daang Hari Extension (DH)**							
Start	Sta.0+000			Muntinlupa City	-	-	Boundary of Muntinlupa City and Municipality of Imus	
EW1	Sta.3+200	-	-	Muntinlupa City	-	Bridge	moderately deep valley	-
EW2	Sta.3+420	-	-	Imus	3.4	Bridge		-
EW3	Sta.6+100	Zapote	Don Cella	Imus	10.9	Bridge		-
EW4	Sta.7+100	Zapote	-	Imus	4.6	Bridge		DH-R1
EW5	Sta.8+100	-	-	Imus	1.3	Bridge		-
EW6	Sta.9+300	Imus	-	Imus	7.7	Bridge		DH-R2
EW7	Sta.12+050	Imus	-	Imus	54.6	Bridge	near new bridge under construction	DH-R3
EW8	Sta.13+640	Imus	-	Imus	8.7	Bridge		DH-R4
EW9	Sta.15+220	San Juan	-	Imus	52.0	Bridge		DH-R5
EW10	Sta.17+300	San Juan	Pasong Cama Chili	General Trias	11.4	Bridge		-
EW11	Sta.17+400	San Juan	Rio Grande	General Trias	51.1	Bridge	near existing suspension bridge	DH-R6
EW12	Sta.18+960	Cañas	Cañas	General Trias	95.8	Bridge		DH-R7
End	Sta.24+268			Tanza			Coastal Road	
								7 sites
III.	**North-South Road (NS)**							
Start	Sta.0+000			Imus			Coastal Road	
NS1	Sta.4+150	-	-	Imus	-	-	small creek	-
NS2	Sta.7+950	-	-	Imus	4.9	Bridge		-
NS3	Sta.8+750	Imus	-	Imus	9.9	Bridge	near new bridge already constructed, land reclamation is on-going for expansion of Citta Italia estate	NS-R1
NS4	Sta.11+300	Imus	-	Imus	1.8	Bridge		NS-R2
NS5	Sta.12+900	Imus	Baluctot	Imus	20.9	Bridge	moderately deep	NS-R3
NS6	Sta.14+000	Imus	-	Imus	34.7	Bridge	near suspention bridge	NS-R4
NS7	Sta.17+250	Imus	-	Dasmariñas	3.0	Bridge	near existing irrigation weir	NS-R5
NS8	Sta.21+500	San Juan	Dasmariñas	Dasmariñas	11.8	Bridge	near Bucal Bridge under construction of widening	NS-R6
NS9	Sta.25+500	San Juan	Ylang Ylang	Silang	2.9	Bridge		-
End	Sta.26+700			Silang			Proposed CALA Expressway	
								6 sites

Note: (1, Tentative figures to be further veirfied through finalization of alingment in the feasibility study
Source: JICA Study Team

(4) Current Conditions of River Channels along Proposed Road Network

The Study Area is located at south of Tagaytay mountain ridge, where situated at perimeter of Lake Taal at south, in Provinces of Cavite and Laguna. In terms of watershed areas related to the road network, the Study Area falls in 40 km from north to south and 25 km from east to west, namely, in around 1,000 km^2. The altitude of the watershed varies from EL 680 m at Tagaytay City to the sea level at the coastal area facing to Manila Bay.

The watershed area is characterized by a number of rivers originating at Tagaytay Ridge and running in parallel, which flows into Manila Bay and Laguna de Bay with feeding valuable water resources in the area. Relatively narrow strips of watershed from south to north (Manila Bay) and to northeast (Laguna de Bay) forms such unique topography. The major river basins emptying toward Manila Bay are Zapote, Imus, San Juan and Canas (from east to west), and those toward Laguna de Bay are Tunasan, San Pedro, Binan and Santa Rosa (from north to south) as shown in Figure 7.2. 2. The size of catchment areas approximately varies between 20 to 120 km^2. The length of river course is around 50 km for the longest. The longitudinal profiles of major nine rivers such as Santa Rosa, Binan, San Pedro, Imus, Dasmariñas, Ilang-Ilang, Baluctot, Rio Grande and Canas Rivers, in which the proposed road alignment traverses.

It is noted that in the Study Area, more than 70 small scale ponds/reservoirs with under 10 m high dams are located. Most of them were constructed by National Irrigation Administration (NIA) or Local Government Units (LGUs) for irrigation purposes. In accordance with the interview to the local people, most of them were constructed 20 to 40 years ago and its function has been deteriorated due to lack of proper maintenance and appropriate repair of gate facilities. As urbanization progressed in Cavite, the necessity of the pond has been declined due to drastic decrease of irrigation water demand. In fact, agricultural land is rapidly changing to residential areas in the Study Area. The approximate location of the pond can be confirmed on the General Layout that was obtained at the “Cavite Friar Lands Irrigation System Office” (Branch of NIA regional office), Naic.

Further detailed conditions on the rivers running through the Study Area are presented dividing into three routes in the subsequent sub-sections. Principal feature of the crossings along the proposed routes is summarized in Table 7.2.1.

(5) Questionnaire Survey on Flooding Conditions

In order to confirm the flooding conditions such as flood prone area, information on severe floods, notable inundation damage and river improvement plans/on-going works, etc., questionnaire survey to 15 municipalities (11 in Cavite and 4 in Laguna Provinces) was conducted in February 2006. The questionnaire sheets were distributed to Engineering Department of each municipality and were retrieved after filled up. The questionnaire is divided into five sections, namely, (I) General Information, (II) Record of Flood Event, (III) Existing Water Impounding Pond, (IV) Discharge Measurement Record and (V) River Improvement Plans. The answers on questionnaires from each municipality are summarized in Appendix 7.1 Table A.3. Some important issues confirmed through the survey are described as follows:

Section I: General Information

(1-1) In the coastal area facing to Manila Bay, in particular, Bacoor, Imus, Kawit, Noveleta, and in lakeshore municipalities of Carmona, San Pedro and Biñan, flood prone area is identified in the low lying Barangays. Extraordinary high tide in addition to the insufficient inland drainage system is major reason of flood occurrence.

(1-2) A total of 974 ha (approximately 10 km^2) flood prone area in Bacoor, Imus, Kawit and Noveleta was identified with some particular barangays suffering from frequent inundation, where are the most susceptible zone to heavy storm in monsoon seasons. Among those, the largest area of 801 ha (82%) falls in Kawit. Nonexistence of major river outlet in Kawit might be one of the main reasons.

Section II: Record of Flood Event

(2-1) Severest flood in each municipality is summarized as below:

Nov. 1995	: Carmona
Nov.1998	: Bacoor
Jun.1999	: Silang
Sep.1999	: Gen. Mariano Alvarez
Oct.-Nov.2000	: Imus, Kawit, Noveleta, General Trias
Nov.2001	: Naic, Biñan
Oct.-Nov.2002	: San Pedro

(Rosario, Tanza, Dasmariñas and Trece Martires answered “None” or blank)

(2-2) According to the answers, due to the flood in Nov. 2000, relatively wide area was inundated at Imus, Kawit and Noveleta, in particular, Manila Bay coastal area. The inundation depth reached about 1.0 m above the ground surface and inundation lasted 4 hours (Noveleta) to 3days (Imus), which caused serious damage to houses, other properties and livestock. No description regarding inundation is found in the questionnaire sheets from Bacoor. Since the origin of the North-South Road will be located in Bacoor, careful treatment of flood water in Bacoor is required.

Section III: Existing Water Impounding Pond

(3-1) Three municipalities of Dasmariñas, Trece Martires and Carmona reported information on impounding ponds. Dasmariñas described information on five dams with 6m to 10m high. Agriculture is predominant function of small scale reservoirs in the Study Area. Most of them were constructed in 40 to 20 years ago.

Section IV: Discharge Measurement Records

(4-1) Among 15 municipalities, only Gen. Mariano Alvarez answered “Yes”, but no technical document is available fort the records.

Section V: River Improvement Plan

(5-1) Only four municipalities of Bacoor, General Trias, Carmona and Biñan responded that they have river improvement plans. For instance, Bacoor has a plan to dredge the NIA's Creek (L=3.4 km) near Molino Highway for enhancement of cultivation. In other municipalities there is no river improvement plan/activities.

(6) Methodology of Hydrological Analysis

In order to set appropriate methodology of hydrological analysis to determine the probable flood discharge and other design parameters at arbitrary crossings where structures are to be designed, following factors were examined:

(i) Basin parameters: size of catchments, channel length, riverbed gradient (traveling time of discharge)

Relatively small catchments (> 200 km^2), short river length (> 50 km) and 1/80 to 1/100 of average riverbed gradient

(ii) Existing structures for flood control

No major control structures, which can retard and store flood discharge and no inter-basin connection or floodways

(iii) Availability of rainfall and discharge record

Fairly reliable daily rainfall records (sufficient duration and coverage of area) but no flood discharge measurement record in the subject river basin (no measured hydrograph)

(iv) Requirement for design parameters of structure (bridge, culvert, revetment and embankment, etc.)

Flood peak discharge can be converted to the flood water level based on the channel geometry by means of appropriate runoff model.

(v) Future flood control/drainage improvement plan
No major flood control/drainage improvement plan to be taken account to estimate flood discharges is not identified in DPWH except minor channel improvement managed by LGUs

As the result of examination, flood runoff analysis by rational formula and uniform flow theory will be applied to estimate probable peak discharges and associated water levels at arbitrary locations in the Study Area.

(7) Hydrological Analysis

(a) Characteristics of Rainfall Pattern

Monthly rainfall amount at six stations is tabulated in Appendix 7.1 Table A.4 and illustrated in Figure 7.2.5. It is distinct that August and July are predominant rainy period and January to April is very dry in the Study Area. Although the monthly pattern is similar among six stations, the rainfall amount at Amadeo is rather high compared with others. According to the record from PAGASA, in fact, annual rainfall in most of years are extraordinary high, which shows equal or more than 2.5 to 2.8 times of the amount at Sangley Point and Bacoor.

Because the reliability of the daily rainfall record at Amadeo seemed low, the Study Team wrote a letter to confirm the issue to the Chief of Climate Data Division, PAGASA, before starting hydrological analysis. As the results of the consultation, PAGASA informed to the Study Team by their letter dated on February 28, 2006 that the records at Amadeo should not be included in any analysis. PAGASA recognized that it was entirely their mistake on data processing. Therefore, the records at Amadeo were omitted in the subsequent analysis in the present Study. A chronological annual rainfall fluctuation is shown in Figure 7.2.6.

Figure 7.2.5 Monthly Variation of Rainfall

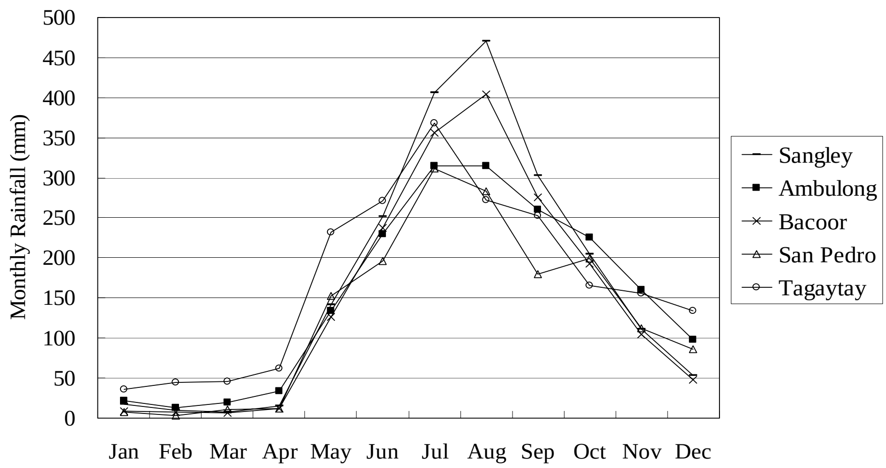
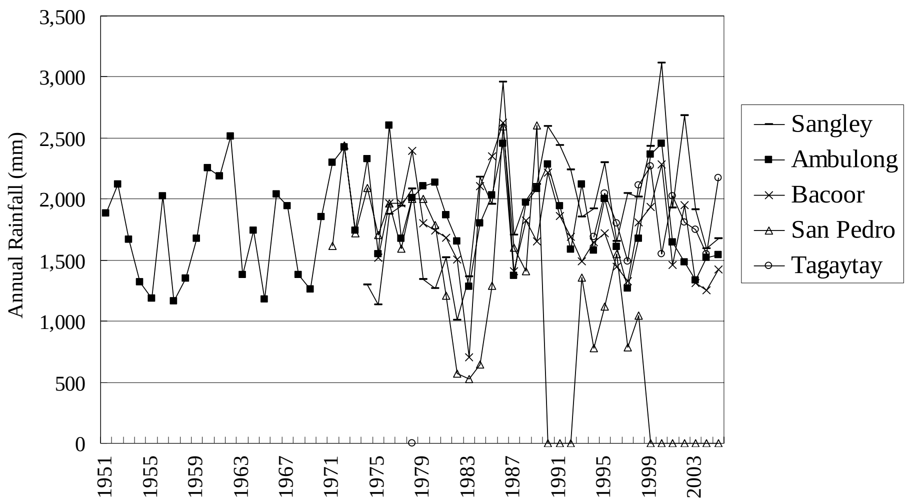


Figure 7.2.6 Chronological Annual Rainfall Pattern



(b) Probable Rainfall

Annual maximum 1-day rainfall at four stations (point rainfall) is tabulated in Appendix 7.1 Table A.5. Based on the series of records, probable 1-day rainfall was estimated by Gumbel Method and as summarized in Table 7.2.4.

Table 7.2.4 Probable 1-day Rainfall (point rainfall)

(Unit: mm)

Return Period (Year)	Sangley Point	Ambulong	Bacoor	San Pedro
1.01	41.6	38.8	24.4	11.5
2	147.8	138.8	144.4	105.5
5	211.3	198.6	215.4	161.7
10	253.3	238.2	262.8	198.9
25	305.3	287.1	321.3	244.9
50	345.8	325.3	366.9	280.8
100	385.0	362.1	411.0	315.4
200	423.9	398.8	454.8	349.8
Years of data available	32	55	31	25

Source: Analyzed based on the rainfall record from PAGASA

As seen in Appendix 7.1 Table A.5, the significant rainfall (193.2 mm at Sangley Point and 214.5 mm at Bacoor) was recorded on October 28, 2000, which caused serious inundation along the coastal area. The municipalities at coastal area answered to the questionnaire that most serous flooding has occurred in November 2000. Although no available direct measurement record of flood discharges is available, the magnitude of the flood of November 2000 might be approximately 10-year recurrence 1-day rainfall probability based on the probable rainfall tabulated above.

(c) Runoff Analysis

(i) Runoff Record

Based on the available daily discharge records, annual peak discharges at eight gauging stations are summarized in Appendix 7.1 Table A.6. The table shows the specific discharges per one km^2 of catchment as well. In the Study Area at Alapan (CA=60 km^2: Ylang-Ylang River) and Palubluban (CA=29 km^2: Panaysayan River), maximum value of annual peak discharge is 346.5 m^3/s and 227.7 m^3/s respectively. In terms of specific discharge, both are 5.8 $m^3/s/km^2$ and 7.9 $m^3/s/km^2$. Since the reliability of the records could not be justified based on the actual discharge measurement and/or rating curves, etc. at gauging stations concerned, statistical analysis to estimate probable discharges was not conducted based on the discharge data. Therefore, those were handled as a guide of magnitude of flood peak discharges.

(ii) Probable Flood Peak Discharge

As mentioned in the above Sub-section (6), the flood peak discharge was calculated by means of Rational Formula. The formula of the theory is represented as follows:

Q = * C * I * A
where,

- Q: Peak discharge (m^3/s)
- I : Intensity of rainfall for a duration equal to the time of concentration (mm/hr)
- A: Drainage area or catchment contributing to storm flow (km^2)
- C: Runoff coefficient depending on catchment characteristics

Runoff coefficient

Runoff coefficient (C) shall be decided taking account of land cover, vegetation, shape of catchment and land development, etc. Different figures recommended in guidelines commonly applied in sewerage design and land development are introduced in the Technical Guidelines of River and Sabo Engineering, Ministry of Infrastructure and Transport, Japan.

On the other hand, future land use plan targeted in year 2020 was prepared in the current Study. Based on the presumed built-up conditions in the Study Area versus the criteria as above, 0.6 was applied to estimate the peak discharges at crossing points.

Time of concentration

Time of Concentration in the Rational Formula is usually defined as required time for reaching of the flow in the channel from the most remote point to the outlet of the catchment concerned. Three methodologies by Kraven's formula, Rziha's formula and Ven Ti Chows formula were tested. The one developed by Ven Ti Chow is recommended to apply in the Design Guidelines, Criteria and Standards for Public Works and Highways Volume II, DPWH (Page 696). Those formulas cited above are described as follows:

1. Kraven's formula

T = L/W

I	I > 1/100	1/100 < I <1/200	I< 1/200
W	3.5 m/s	3.0 m/s	2.1 m/s

where, I: Slope of channel, W: Flow velocity (m/s)
L: Length of channel, T: Time of concentration

2. Rziha's formula

T= L/W

W= 20 $(h/L)^{0.6}$

where, W: Flow velocity (m/s), h: Elevation gap (m)
L: Channel length (m) T: Time of concentration (s)

3. Ven Ti Chow (DPWH's Guideline)

$$Tc = \frac{L^{1.15}}{51H^{0.385}}$$

where, Tc: Time of concentration (min)
L: Length of watershed along the mainstream (m)
H: Difference in elevation between the most distant ridges in the watershed

and point under review (m)

The results of calculation by three methods are compared as tabulated in Appendix 7.1 Table A.7. As the results of examination, Ven Ti Chow's formula was applied to estimate the time of concentration, because that tends to give moderate figures between other two methods. Especially as for the small catchments with short channel length, Kraven and Rziha formula return comparatively short time concentration, which would cause too large rainfall intensity and overestimate of flood discharge.

Longitudinal profiles of major rivers subject to design of proposed road network are illustrated Appendix 7.1 Figure A.8.

Rainfall intensity

In order to decide the rainfall intensity applying to the rational formula, analyzed data of rainfall (intensity-duration-frequency) in short duration at Sangley Point in Cavite was collected from Hydrometeorological Investigations and Special Studies Section, Flood Forecasting Branch, PAGASA. The computed extreme values of rainfall and equivalent average intensity of computed extreme values are available as shown in Appendix 7.1 Table A.9. The table was prepared by hourly rainfall records for 11 years from 1978 to 1988.

On the other hand, probable annual maximum 1-day rainfall at Sangley Point was estimated based on 32-year records till 2005 as presented in the above Sub-section (7).(c). However, since the probable values were estimated in the basis of 1-day rainfall not 24-hour data, an adjustment to 24-hour by adding 5% was conducted. The adjusted intensity-duration-frequency values are tabulated in Appendix 7.1 Table A.10 with graphs corresponded.

Hydraulic Analysis

All data required for estimate of the flood peak discharge at 22 sites, where cross sections are available, have been set up in the Appendix 7.1 A.9 and A.10. The results of computation divided into three routes such as CALA Expressway, Daang Hari Extension and North – South National Highway are summarized in Appendix 7.1 Table A.11.

(i) Flood Water Level/Design Water Level

Based on the flood peak discharge at 22 sites, flood water levels were estimated by uniform flow theory with Manning's Formula as shown below:

$$Q = V \times A$$

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

where, V: Flow velocity (m/s), n: Roughness coefficient, R: Hydraulic radius (m), Q: Discharge (m^3/s), I : Slope of channel bed

The proposed bridge sites for three highway routes cross the river strectches where covered by moderately thick vegetation and/or shrub at even low flow section. The roughness coefficient of 0.040 for “n” were uniformly applied to the proposed sites. The flood water levels are shown under the cell of the 50-year peak discharge (Q) in Appendix 7.1 Table A.11. New river cross sections were utilized to estimate the water levels.

In accordance with the DPWH Design Guideline (Page 697), design storm frequency is specified for different type of structures as below:

Kind of Structure	Design Storm Frequency
Bridges	1 in 50 years
Box Culverts	1 in 25 years
Pipe Culverts	1 in 10 years
Embankments	1 in 10 years
Ditches and Road Surface	1 in 2 years

Source: DPWH Design Guideline (Page 697)

(ii) Free board / bridge length

The free board under the bridge girder shall be kept at minimum 1.5 m. On the other hand, if the additional clearance of the bridge crossing over the dike and related structures and for navigation, etc. shall be considered, if necessary. As for deciding bridge length, any encroachment by abutment construction into the flow area (river side) shall be definitely avoided to keep smooth carrying of flood flow and protect river banks against unfavorable erosion.

(iii) Evaluation of Results

In the Feasibility Study of the Cavite Busway System carried out by JICA in 2002, runoff analysis to estimate flood peak discharges at 12 crossing point along the proposed busway. The proposed route is corresponded with the North-South road in the present Study. Estimated peak discharge and specific discharge at the subject points is tabulated in Appendix 7.1 Table A.12. The specific discharge for 50-year return period varies between 2.7 to 14.9 $m^3/s/km^2$. On the other hand, those estimated by the current study fall into between 9 to 36 $m^3/s/km^2$ based on the flood peak discharge-catchment area shown in Appendix 7.1 A.11. Therefore, it is noted that the current study resulted larger values in terms of specific discharges compared with those estimated by Busway System Study.

On the other hand, Specific Discharge Curves in different return periods are available in the Report of “Specific Discharge Curve, Rainfall Intensity Duration Curve, Isohyet of Probable 1-day Rainfall”, which was prepared in the Project for the Enhancement of Capabilities in Flood Control and Sabo Engineering of the DPWH under JICA in March 2003. As Appendix 7.1 Table A.14 illustrates, three curves in each region, such as Luzon, Visayas and Mindanao were developed based on the peak flood discharges estimated in 14 major river basins in the country. The distributed range of the specific discharges becomes closer to the envelope curve of Luzon.

Therefore, it is proved that the result of runoff analysis was preliminarily justified in the feasibility study level. However, further verification and updating of the design discharges and flood water levels should be conducted during the detailed design stage.

(9) Particular Issues on River Engineering related to the Proposed Alignment

(a) CALA Expressway from Sta.1+000 to Sta.1+500

The alignment of CALA Expressway near connection with the SLEX near Santa Rosa will cross the small creek of the Santa Rosa River. Since the proposed alignment will run along the creek, appropriate alignment not to deteriorate of the local drainage conditions considering the drainage system in the new residential estates, where are under developing in the vicinity will be required.

Although flood discharge will not make influence to the vertical design of the proposed expressway, it is recommended to confirm existing outlet connected with the creek should be further investigated in the feasibility design stage.

(b) North-South Road from Sta.14 +000 to Sta. 15+000

Near the starting point in Bacoor of the North-South Road, interchange is planned on the ground level. In order to decide appropriate elevation of land reclamation and required related structures in the coastal area considering high tide (storm serge) of Manila Bay, probable maximum tide levels were studied.

In Manila Bay, tide levels are observed at Pier No.7 of Manila South Harbor (14°37′N, 120°58′) by the Coast and Geodetic Survey Department, National Mapping and Resource Information Authority (NAMRIA), DENR. The maximum tide levels were collected from NAMRIA Binondo Office as tabulated in Appendix 7.1 Table A.14. Based on the historical records, probable maximum high tide of 50-year return period was estimated at EL.2.42 m by Gumbel Method. In order to protect the structure extraordinary high tide, it is recommended that this tide level should be considered in structural design of road facilities.

(c) Daang Hari Extension from Sta.0+000 to Sta.3+000

Along the proposed alignment of Daang Hari Extension in Citta Italia estates in Municipality of Imus, NIA's irrigation canal is running in parallel. Considering the availability of the limited space of right-of-way, encasing is one of the possible solutions to keep the required width of the road design.

The Study Team wrote an official letter to confirm the opinion to NIA. Discussion with the Chief Engineer of the NIA's Operation Office in Municipality of Naic as well as joint filed inspection was made on May 30, 2006.

As the result of the discussion with NIA, they basically accepted to encase (or to cover) the irrigation canal, since it has been already abandoned due to decrease of irrigation water demand in their command area. In fact, it seems no maintenance of the canal is currently provided and confirmed spotted water stagnation in the canal. However, the NIA staff requested to remain the flow space, because presently the canal has a function of drainage in the neighboring area of the sub-division.

Based on the findings and recognition by NIA, in order to fit the road alignment within the right-of-way, it is recommended to encase the canal to keep present flow area tentatively. In the detailed design stage, appropriate drainage network should be studied.

(d) North-South Road from Sta.21+000 to Sta.21+500

Proposed alignment of NS-Road will cross the Dasmariñas River at around 100 m to 200 m upstream of Bucal Bridge, where construction of widening span is progressed. A river cross section (NS-R6) is available at this section. Based on the runoff analysis, the 50-year probable flood water level will be reached a little higher than the right bank. It is recommended that the proper protection for the side slope of embankment at bridge pier will be required. In particular, as for the vertical formation of the proposed alignment crossing this point, due care shall be paid.

(10) Bank Erosion

No serious erosion or local scour of river bed and/or river bank may become realize under the current conditions as far as at the crossing site along the proposed alignment of three routes. However, appropriate treatment to stabilize the slope of river bank in association with construction of bridge and other crossing structures will be required.

Sediment deposition along the channel is rather small considering steep river bed gradient and relatively thick vegetation cover of the watershed. Further, the river bed and foot of bank slopes are formed with hard rock and thus these are less susceptible to erosion by strong current under the current conditions.

However, specific consideration of countermeasures at crossing points shall be made if present channel geometry is remarkably changed due to construction works of new road and related structures.

7.3 Proposed Geometric Design Criteria for Project Roads

Based on the proposed structure of projects given in Table 7.1.1, the geometric design criteria for the road design were proposed. Table 7.3.1 shows the proposed geometric design criteria for project highways (main line) of North-South Road, Daang Hari Extension and CALA Expressway.

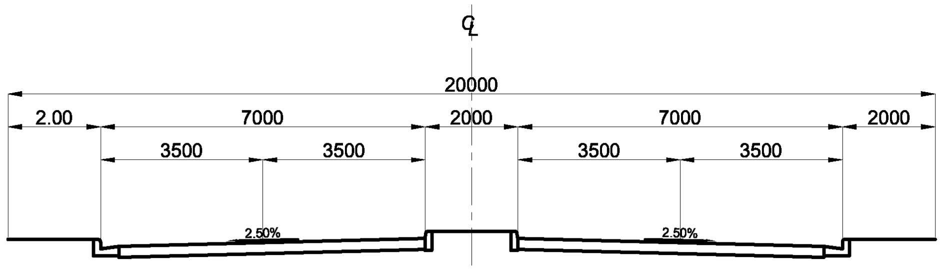
Table 7.3.1 Proposed Geometric Design Criteria for Highways

Design Speed	**60km/hr** North South Road Daang Hari Extension	**100 km/h** CALA Expressway
Horizontal Alignment		
Desirable Minimum Radius (m)	200	700
Minimum Radius (m)	150	460
Exceptional Minimum Radius (m)	120	380
Minimum Curve Length (m)	100	170
Minimum Transition Curve Length (m)	50	85
Minimum Radius allowed to omit a Transition Curve Desirable Minimum Radius (m) Minimum Radius (m)	 1,000 500	 3,000 1,500
Vertical Alignment		
Maximum Grade (%)	5	3
Exceptional Maximum Grade (%)	8	6
Critical Lengths for Exceptional Grade (m)	6%: 500 7%: 400 8%: 300	4%: 700 5%: 500 6%: 400
Vertical Curve Radius Crest: Desirable Minimum (m) Minimum (m)	 2,000 1,400	 10,000 6,500
Sag: Desirable Minimum (m) Minimum (m)	1,500 1,000	4,500 3,000
Minimum Vertical Length (m)	50	85
Minimum Stopping Sight Distance (m)	75	160
Normal Crossfall (Cement Concrete Surfacing) (%)	2.00	2.00
Vertical Clearance (m)	5.10	5.10

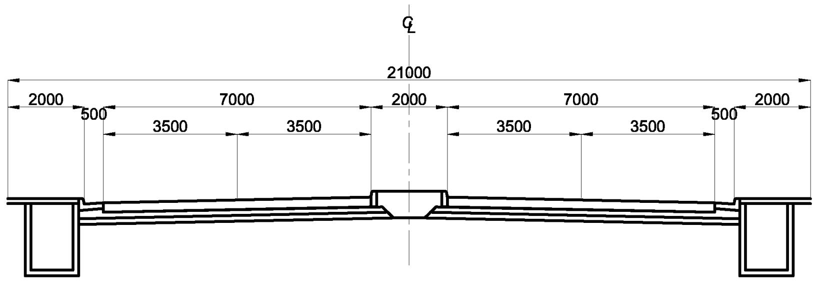
7.4 Proposed Typical Cross Section

Based on the proposed structure of projects, typical cross sections for North South Road, Daang Hari Road and CALA Expressway were proposed as shown in Figure 7.4.2, 7.4.3 and 7.4.4, respectively. It is noted that proposed sections for North South Road and Daang Hari Road were intended to be consistent with the dimension of existing roads illustrated in Figure 7.4.1.

Figure 7.4.1 Cross Section of Existing Roads

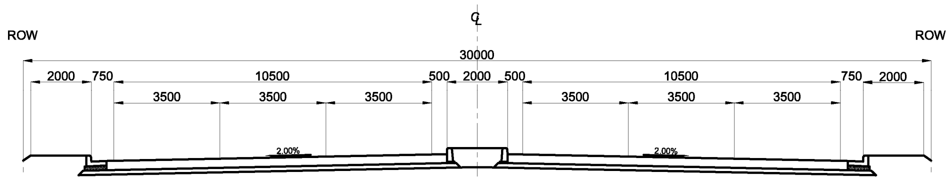


Cross Section of Existing Molino Boulevard
(Measured by JICA Study Team)

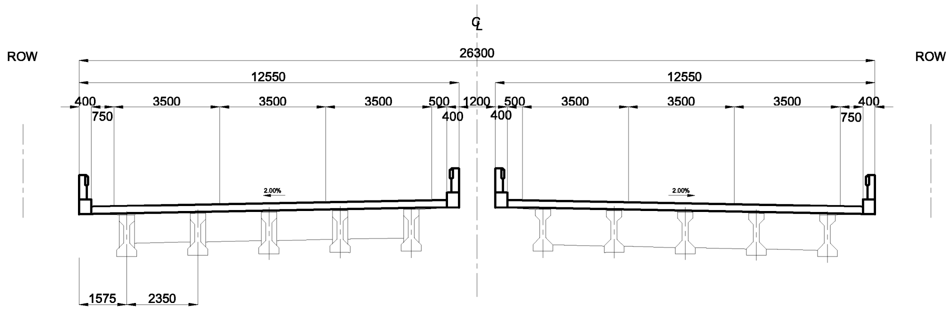


Cross Section of Existing Daang Hari Road
(Based on the DPWH Drawings)

Figure 7.4.2 Typical Cross Section of North-South Road



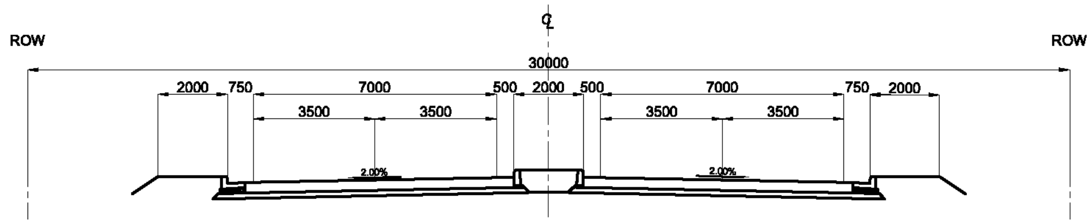
Earthwork Section



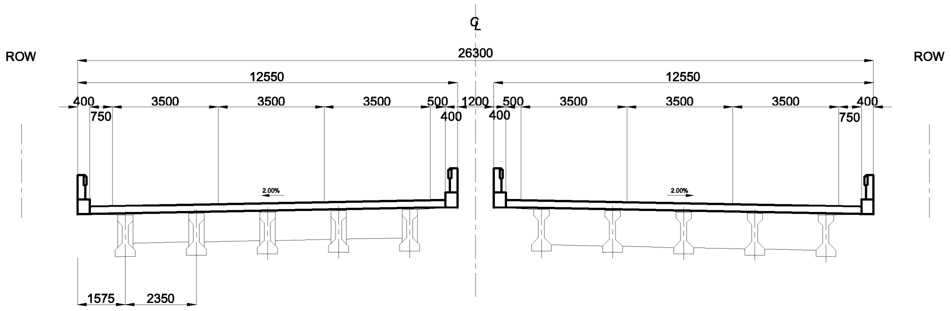
Viaduct/Bridge Section

Daang Hari Road was proposed to construct as a dual 2-lane road initially. As the proposed ROW is 30 m, it is expected to upgrade Daang Hari Road to a dual 3-lane road in future. Taking into consideration of this future upgrade into a dual 3-lane road, it was proposed to construct a bridge structure having a dual 3-lane dimension.

Figure 7.4.3 Proposed Typical Cross Section for Daang Hari Road

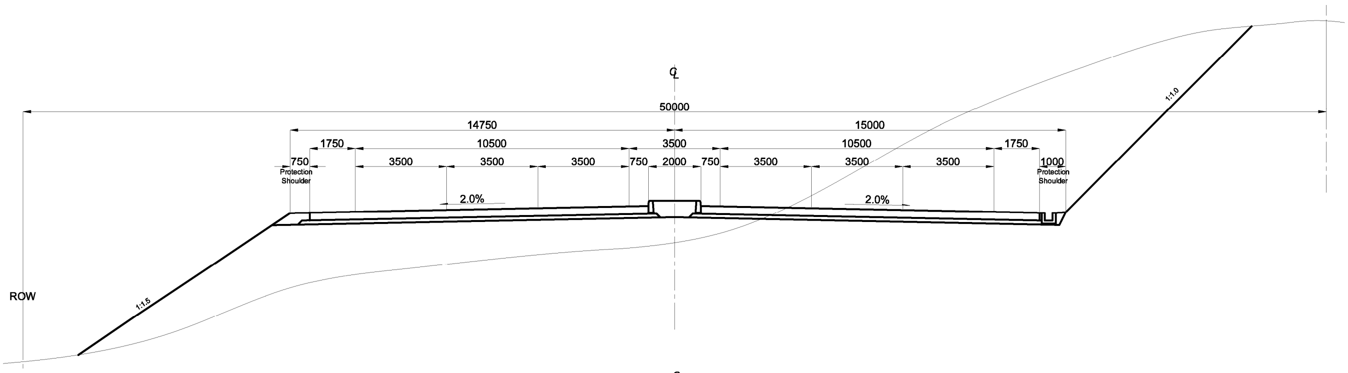


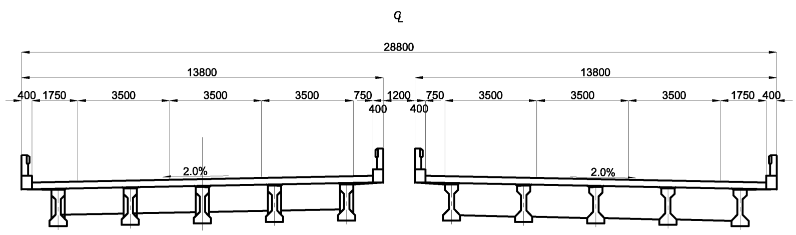
Earthwork Section



Viaduct/Bridge Section

Figure 7.4.4 Typical Cross Section of CALA Expressway





Viaduct/Bridge Section

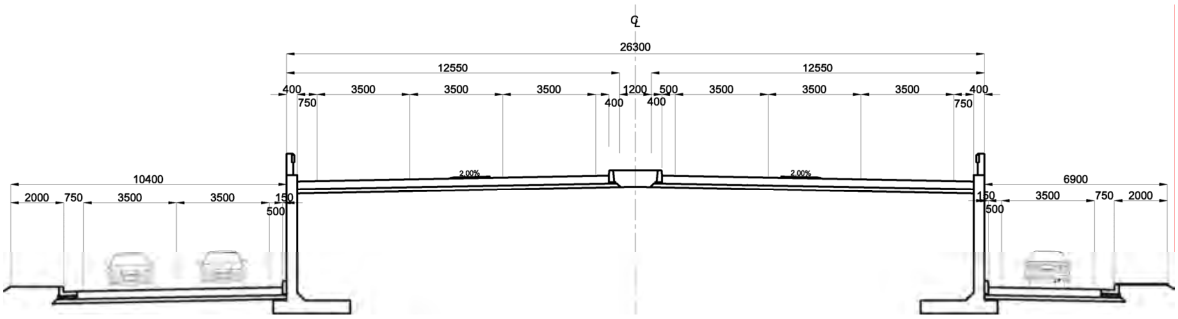
7.5 Issues in Engineering Studies

7.5.1 Flyovers and Intersections

The flyovers will be consisting of Pre-Stressed Concrete Deck Girder (PCDG) or Pre-Stressed Concrete Hollow Slab (PCHS) type of superstructure and approach roads on both sides of the flyover on embankment. The maximum gradient for the approach road is set at 4% and maximum height of approximately four meters. The vertical clearance of 5.1 m is considered in crossing existing major roads.

In case for grade separation intersections access between the project road and existing major road through the provision of ramps and side roads shall be studied and designed. The configuration of the side roads one lane or two lanes, will be determined by the expected traffic volumes and the availability of the road existing right-of-way.

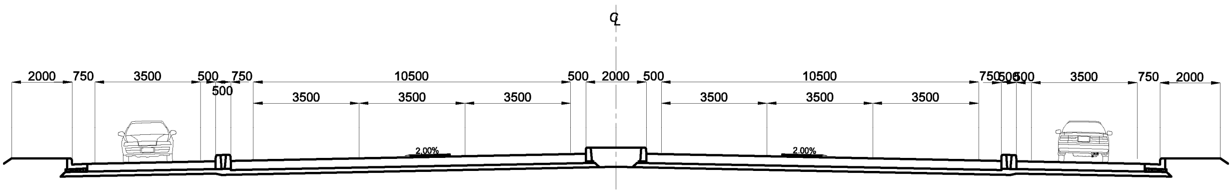
Figure 7.5.1 Side Road Arrangement at Grade Separation Intersection



7.5.2 Service Roads

The NS-1 and NS-3 sections are proposed as a toll road. Hence, it is recommended to design these sections with full access control to ensure non-interrupted traffic flows. Along NS-2 wherein it is partially controlled access, it would be essential to provide service roads for neighboring community traffic. For safety, the cross section of NS Road will be separated with service road with a 50 cm wide raised separator as illustrated in Figure 7.5.2.

Figure 7.5.2 Proposed Cross Section of NS Road with Service Road



7.5.3 Bus Stops

In view of the high commuter traffic demand along the NS road, it is proposed to provide bus stops outside the main carriage way. Japanese Road Structure Ordinance recommends the design of bus stop on suburban and urban road as shown in Table 7.5.1. For the bus stop on North-South Road, design values for roads in suburban area with 60 km/h design speed were applied. The proposed bus stop design for the project is as shown in Figure 7.5.3. The size of bus stop platform would be 15.00 m long, 3.00 m wide. It is recommended to apply the width of 3.50 m for the bus lane. The length of bus stop section would need approximately 70.00 m, including the 25.00 m deceleration lane and 30.00 m acceleration lane.

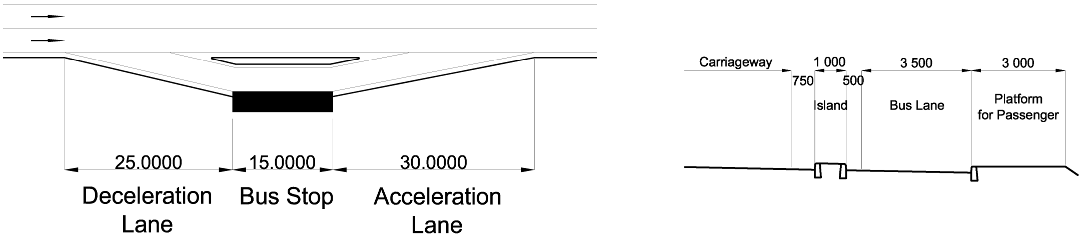
Table 7.5.1 Recommended Design of Bus Stop

(Unit: m)

Design Speed (km/h)	Suburban Area				Urban Area		
	80	60	50	40	60	50	40
Deceleration Lane	35 (95)	25	20	20	20	15	12
Bus Stop Lane	15	15	15	15	15	15	15
Acceleration Lane	40 (140)	30	25	25	25	20	13

Note: Length in parentheses is for a controlled access road.

Figure 7.5.3 Proposed Bus Stop Arrangement



Layout Arrangement | Cross sectional Arrangement

The Feasibility Study on the Proposed Cavite Busway System by JICA proposed 13 bus stops. As much as possible, the location of bus stops on the North-South Road was adopted based on the identified Cavite Busway bus stop locations in view of easy access to the existing main road and neighboring communities.

7.5.4 Toll System

North South Road is to decongest traffic along the Aguinaldo Highway and to encourage the further regional development in the project area. Based on the traffic demand forecast, it is recommended for the immediate implementation of NS-1, NS-2 and NS-3 sections as a toll road.

The applicable toll collection system in these sections would be an open toll system having barrier type toll plazas on the main line. The toll plaza on main line could become a traffic bottleneck with long queue, if the toll plaza capacity is smaller than the road section's traffic capacity. The careful consideration is required for the toll collection system and scale design of toll plaza, so as not to create bottleneck on the toll road.

The average toll payment transaction time for different type of toll collection system were obtained from Traffic Management Corporation, the operator of North Luzon Expressway (NLEX), and Citra Metro Manila Toll ways Corporation, the operator of Skyway and South Luzon Expressway (SLEX). Data of NLEX were derived from the measuring of actual transaction time at their toll gate sites, and that of SLEX were obtained during an interview with the person in charge of toll collection system. Table 7.5.2 shows the average transaction time for different type of toll collection system.

Table 7.5.2 Average Actual Toll Payment Transaction Time

Gate type	Transaction time (sec)	
	NLEX	SLEX
Dedicated ETC lane	5.1	3.0
Manual payment lane (closed system)	20.0	10.0
Manual payment lane (open system)	16.0	6.0
Mixed lane (open system) assuming 80% case and 20% ETC	16.0	
Exact toll lane (open system)	12.0	

Source: North Luzon Toll Management Corporation and Citra Metro Manila Tollways Corporation

Note: “Closed system” means a closed toll system in which toll amount is set proportional to the distance traveled. It has two gates, entry gate and exit gate. Vehicles pick up a ticket at entry gate and surrender it and settle the payment at exit gate.

“Open system” adopts flat toll and toll is colleted at entry gate or main line gate. There is no gate at exit.

Although there is a large difference between the data of two toll road operations, these data indicate that toll transaction on ETC lane takes 1/3 to 1/4 of the manual collection. The shorter transaction time of ETC lane suggests that the number of toll booths required can be much reduced if ETC system is extensively used by toll road users. The transaction time data by the former Japan Highway shows the capacity of about 300 vehicle/hour for manual collection and around 800 vehicle/hour. Based on the data in the Philippines and Japanese expressways, transaction time and capacity to be used in this analysis are assumed as follows:

Table 7.5.3 Toll Transaction Time for the Study

Gate type	Transaction time (sec)	Transaction capacity (PCU/hour)
Dedicated ETC lane	4.5	800
Manual payment lane	12	300

Source: Study Team

In a steady state when the traffic volume is constant, queue develops at toll plaza when arriving traffic volume exceeds the total capacity of toll booths. Queue grows as long as the same situation continues. In order to prevent queue to develop during peak hours, sufficient number of toll booths must be provided.

Based on the transaction capacity shown in Table 7.5.4, the required number of toll booths per lane was calculated for different arriving traffic volume for manual collection system only or ETC system only as shown below.

Table 7.5.4 Required Number of Toll Booths for Different Traffic Volume

Traffic Volume per Lane (PCU/hour)	Required Number of Toll Booths	
	Manual Only	ETC Only
1800	6	3
1900	7	3
2000	7	3
2100	7	3
2200	8	3

Source: Study Team

As North-South Road is proposed as a dual 3-lane road, the required number of toll booth for North-South Road was estimated as shown in Table 7.5.5.

Table 7.5.5 Required Number of Toll Booths for North-South Road Toll Plaza

Traffic Volume per Lane (PCU/hour)	Required Number of Toll Booths	
	Manual Only	ETC Only
1800	18	9
1900	21	9
2000	21	9
2100	21	9
2200	24	9

Source: JICA Study Team

The estimated number of toll booths for North-South Road ranging from 18 to 24, in case of manual transaction only, is neither realistic nor economical as they occupy a huge area and requires more number of toll collection facilities and staff. Introduction of ETC system was ascertained as inevitable.

Case studies of waiting queue length for toll payment, corresponding to the incoming traffic volume of 1,800 to 2,200 pcu/hour, were conducted taking into consideration the mixed lane arrangement of manual transaction and ETC. If both types of payments, manual and ETC, were installed at a toll plaza, the required total number of toll booths would be reduced in reverse proportion to the increment of ETC toll booths. In order to attain the agreeable minimum scale of toll plaza area, share of ETC transaction is to be as high as possible.

Based on the case studies which aim to maintain the payment waiting queue length within reasonable level, the number of toll booths to be provided at a toll plaza was recommended as shown in Table 7.5.6. This recommendation assumes that more than 80% of transaction will be made by ETC system.

Table 7.5.6 Recommended Number of Toll Booths for North-South Road

Total	Manual Transaction Booth	ETC Booth
12	8	4

Based on the above study result, the toll plaza having 12 toll booths were proposed in NS-2 and NS-3 sections. Figure 7.5.4 shows the proposed layout of the two toll plazas.

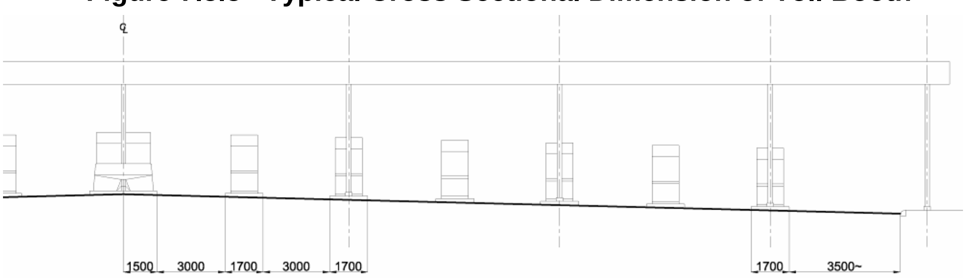
Figure 7.5.4 Proposed Layout of North-South Road Toll Plaza

NS-2 Toll Plaza at STA. 4+580

NS-3 Toll Plaza at STA. 11~900

Applied cross sectional dimension of toll gate was shown in Figure 7.5.5. As illustrated, a reversible toll booth on the centerline would have 3.0 m width, and toll booths for one direction would have 1.7 m width. The width of toll lanes would be 3.0 m, except the most outer lane of 3.5 m width, which is provided for exceptional cars such as an ambulance. The proposed toll plaza will necessitate the area of about 120 m by 250 m. In addition to this area, it is noted that the administrative area of about 60 m by 30 m will be needed for office building and other toll road facilities.

Figure 7.5.5 Typical Cross Sectional Dimension of Toll Booth



7.5.5 Alignment Studies

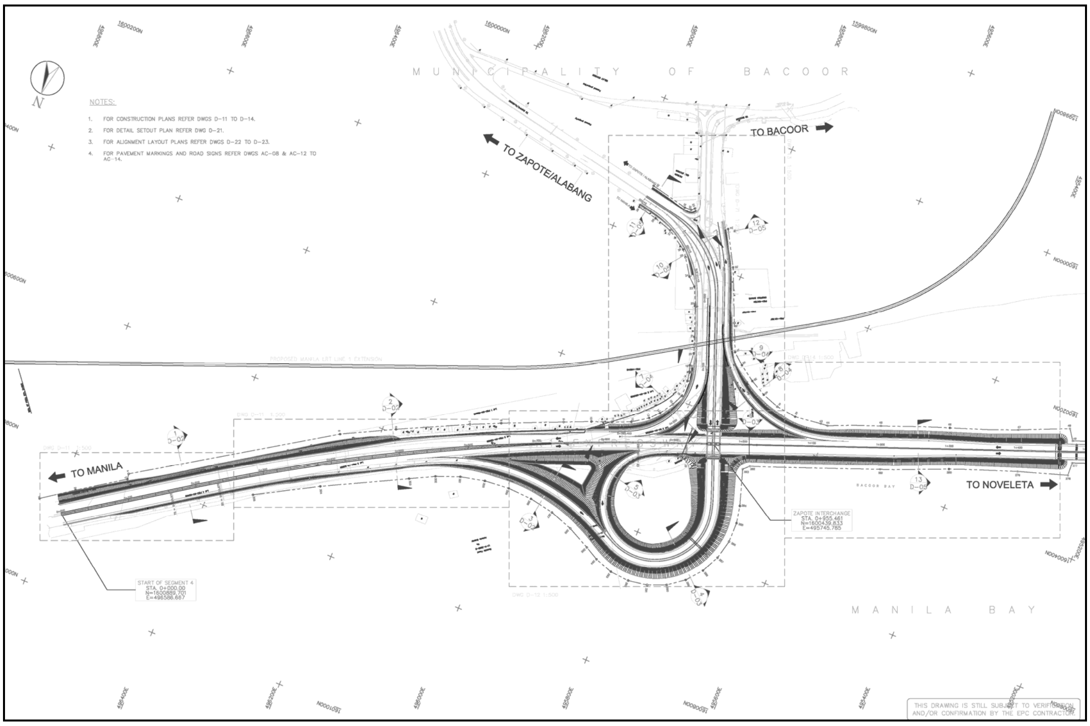
The horizontal alignment for the project was established with the participation and approval of the communities traversed, concerned LGUs, affected land owners and developers, and NGOs. During the more detailed alignment studies of these roads, modification and adjustment of the established road alignments were introduced to: (i) minimize adverse effects to development plans, (ii) avoid existing important and expensive structures and (iii) design interphase with existing and proposed projects. The areas where more detailed studies were required are presented in the succeeding discussion.

(1) North-South Road (NS)

R-1 Connection

The NS road is proposed to link with the proposed extension of Manila Cavite Toll Expressway (MCTE) from Bacoor to Rosario in Cavite. Initially, MCTE suggested that the NS connection be located south of their first proposed bridge in order that the functionality of their proposed Bacoor interchange will not be affected. Their main concern is the anticipated weaving problems of vehicles to and from both toll roads. To negate this problem, a plan where the NS road will be located at the center of the R-1 expressway on elevated structure is an acceptable solution, as shown in Figure 7.5.6.

Figure 7.5.6 Zapote Interchange proposed by MCTE



The scheme however, would require adjustments of the MCTE plan and approval from TRB involving the following:

(i) additional reclamation works;

(ii) longer bridge structure of the Bacoor interchange to span 11 lanes;

(iii) transition from the existing six (6) lanes of the R-1 expressway to 11 lanes; and

(iv) shifting of the center line westward to the sea due to difficulty of land acquisition.

Under the original scheme considered, the implementation of NS road ahead of the R-1 expressway will include all adjustments and required works cited above including the construction of the east-bound ramp of the interchange. Just recently however, MCTE got financial loans from local banks for the extension of R-1 expressway to Rosario. This would mean that the implementation of the R-1 Expressway will now proceed ahead of the NS Road. In order that the proposed NS Road could be accommodated in the plan to be implemented by MCTE, it is recommended that immediate coordination meeting be held between DPWH, TRB and MCTE to resolve the issues.

<u>Citta Italia Area</u>

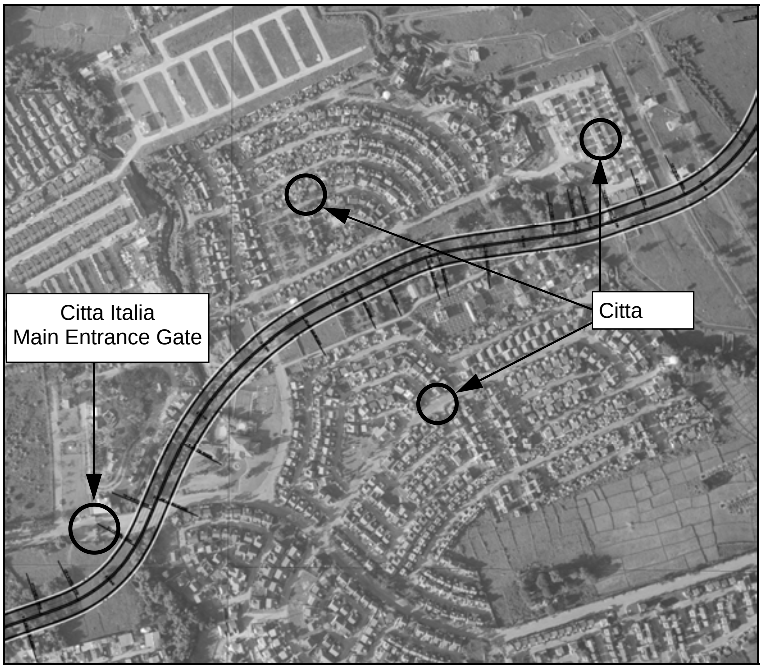
NS Road is proposed to utilize as much as possible the existing Molino Boulevard. Before Molino Boulevard merges to Molino Road, NS Road diverts westward, towards Aguinaldo Highway, and goes southwards towards Pala-pala area. As the area between Molino Boulevard and Aguinaldo Highway is currently a highly developing area, there is no vacant area for the new road construction, and it is unavoidable for the project to traverse developed private lands.

Initially, the NS road generally follows the recommended busway alignment conducted during the feasibility study conducted in 2002 with some adjustments and modifications to consider present condition of the area. The original alignment established in the Citta Italia runs on the less developed sections to minimize adverse social and environmental effects as shown in Figure 7.5.7. In 2005 and 2006, massive construction activities were undertaken in Citta Italia and adjacent subdivisions. The 2006 aerial photo prepared indicates that the proposed alignment will affect the clubhouse under construction and newly-built houses in the residential subdivision. Modification and adjustments of the alignment were undertaken in coordination with the developers to avoid these new developments. However, this involves the construction of an elevated structure.

<u>One Asia Development Corporation</u>

Passing through Citta Italia area, NS Road runs another private developer’s land area. This developer, One Asia Development Corporation (OADC), was once a stakeholder of Cavite Busway System Study. Due to this experience, One Asia Development Corporation prepared their development plan incorporating proposed Busway alignment as a trunk road into their plan. However, since the proposed NS Road has been widely shifted west of the busway alignment, OADC strongly requested that the NS Road alignment be shifted back to the original busway alignment. And since both alignments are within the OADC property and has no technical implications to the already established alignment outside One Asia, the final alignment of the NS Road now follows the busway alignment.

Figure 7.5.7 Proposed North-South Road Alignment at Citta Italia Area



De La Salle Medical Center

During the surveys and investigations conducted for the engineering studies and environmental impact assessment, the original alignment would affect several institutions and buildings such as the National College for Science and Technology and AMA. The modification of the alignment to avoid these buildings is still possible, but was informed by the La Salle management that they plan to construct five (5) multi-storey buildings adjacent to their Medical Center to be completed in five years. The construction of the first building has just started. The Study Team investigated the least developed area east of Aguinaldo Highway for the realignment of the affected section. Several lines were considered. The recommended alignment in the La Salle area is presented in Figure 7.5.9.

2) Daang Hari Road (DH)

Extension to SLEX

The National Development Company (NDC) is now responsible in the finalization of the DH-2 alignment in close coordination with the management of the National Bilibid Prison (NBP) so as not to affect the security of the NBP as well as with the private developers that will be traversed by the project.

The original proposal is a simple connection to SLEX for vehicles to and from Manila from Daang Haru, with the traffic from Manila at-grade and on an elevated structure across SLEX for traffic bound for Manila. Due to the topography of the