CHAPTER 9

ALIGNMENT SELECTION OF DAVAO CITY BYPASS

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9.1 PROCEDURE OF ALIGNMENT STUDY

The procedure of alignment study is shown in **Figure 9.1-1**.

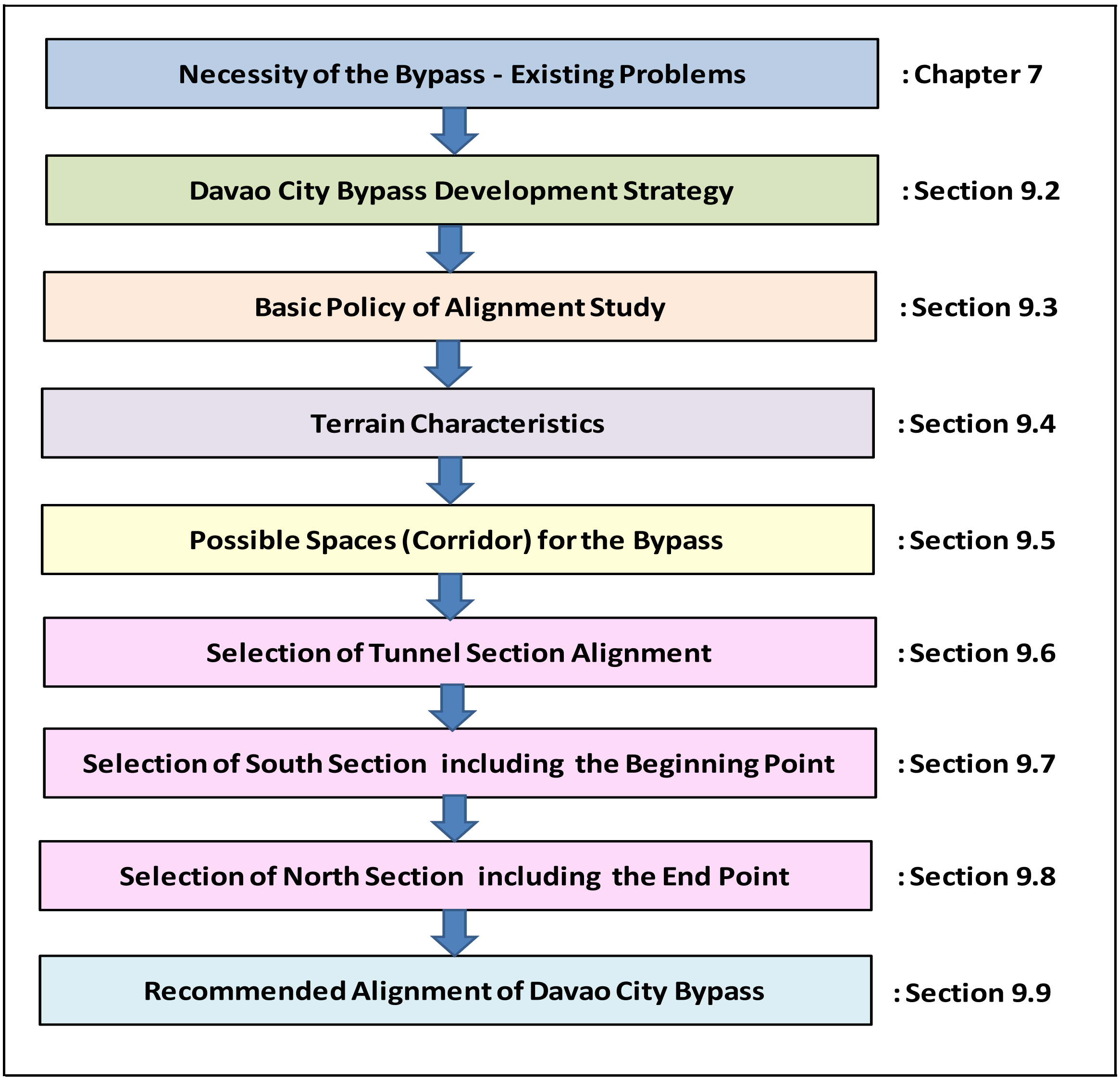


FIGURE 9.1-1 PROCEDURE OF ALIGNMENT STUDY

9.2 DAVAO CITY BYPASS DEVELOPMENT STRATEGY

The Davao City Bypass development strategy was proposed as follows:

- Bypass should be so planned that through traffic can be diverted to the Bypass. (Road standards should be as high as possible and a bypass length should be as shorter as possible.)
- Bypass should also be so planned that the Urban Center related traffic from/to surrounding areas can be diverted to the Bypass. (Existing roads which intersect with the Bypass should be improved.)
- Bypass should be so planned that it will guide sound urbanization of inland areas of the city.
- Bypass should be planned to provide easier access to other transport facilities, such as an airport and sea ports.

9.3 BASIC POLICY OF ALIGNMENT STUDY

Basic policies for selecting the optimum alignment were established as follows:

- Since the alignment selected by BCS has been consulted with Davao City Government, it will be a basis for alignment study.
- Tunnel section will be selected in due consideration of topographic and geological conditions.
- Existing and planned development should not be affected as much as possible.
- Alignment will be so selected to minimize relocation of people.
- How to connect with intersecting roads will be carefully studied.
- Connection with the Davao International Airport, Sasa Port, private ports, etc. will be carefully considered.

9.4 TERRAIN CHARACTERISTICS

Terrain characteristics in terms of ground elevation of the Project Area is shown in **Figure 9.4-1**.

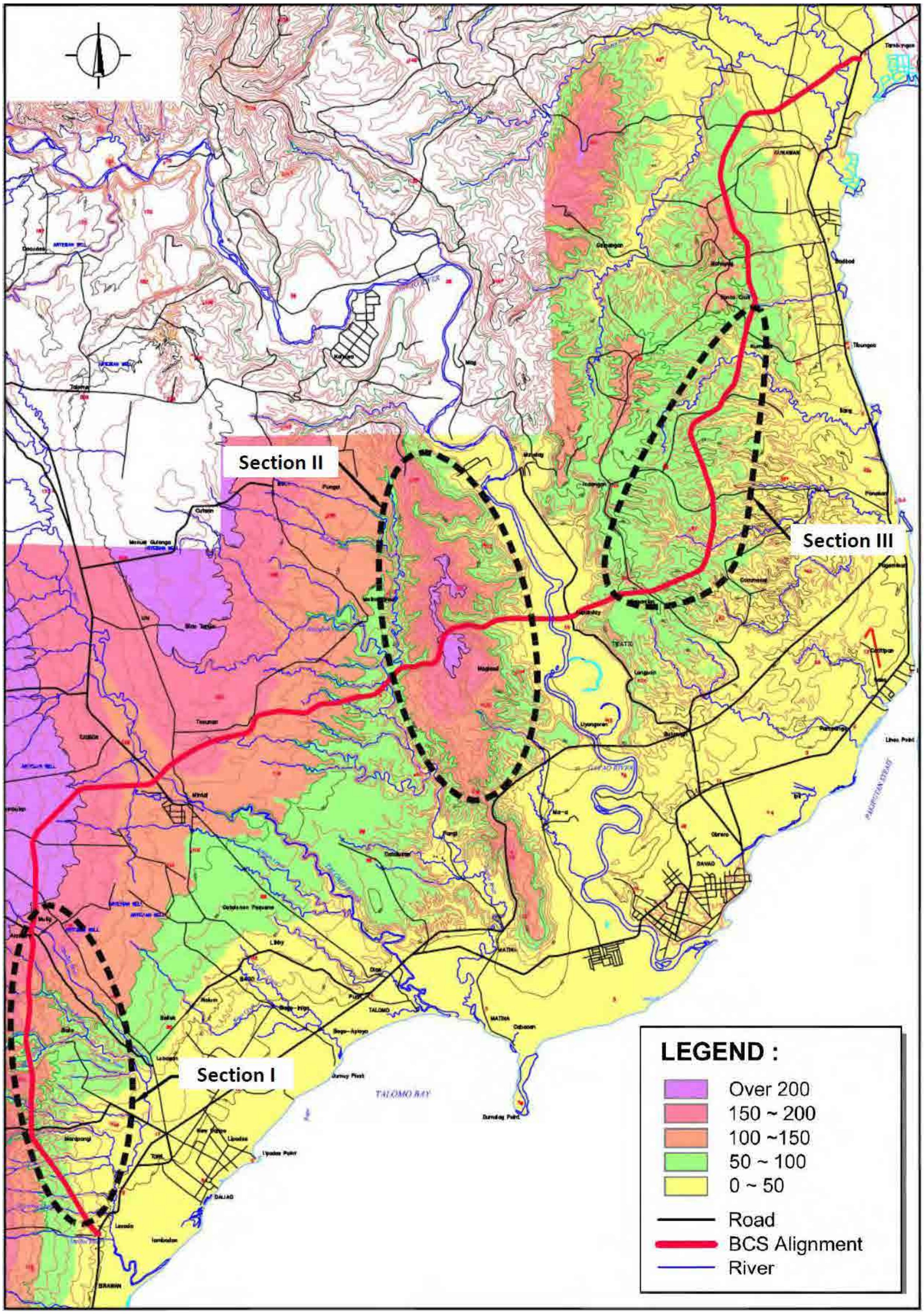
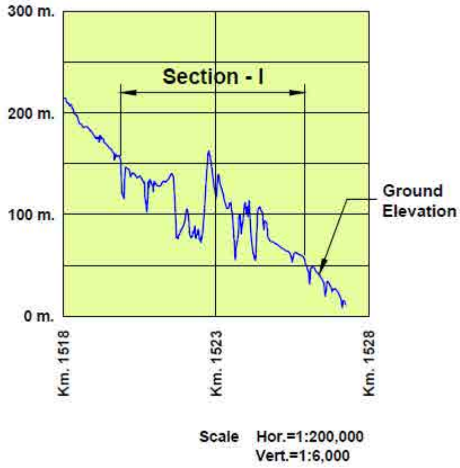
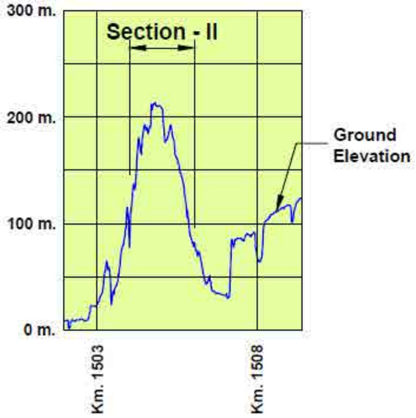


FIGURE 9.4-1 TERRAIN CHARACTERISTICS



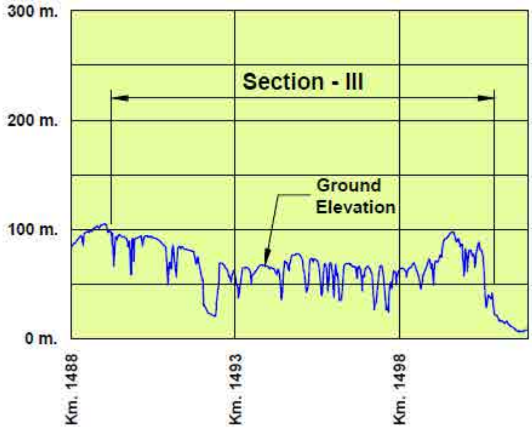
Section-I: South Section

- The topography is quite complex and undulating.
- Located at the foot of Mt. Apo, of which slope has been eroded/scoured and numerous rivers/valleys were formed.



Section-II: Tunnel Section

- Elevation varies from 15m to 215m within 2km section, ground inclination varies from about 10% to 12%.
- A tunnel is needed.



Section-III: North Section

- The topography is quite complex and undulating.
- The Plateau was eroded/scoured and numerous rivers/valleys were formed.

9.5 POSSIBLE SPACES (CORRIDOR) FOR THE BYPASS

Urban development is progressing mainly along the following national roads;

- Davao - General Santos Road in the south
- Davao - Bukidnon Road in the west
- Diversion Road in the center
- Daang Maharlika in the north

Due to existing development along the above national roads, the space where the bypass can pass through (or the bypass corridor) is rather limited.

Based on the latest satellite photos, the possible space (corridor) for the bypass for the above four (4) areas was identified (see **Figure 9.5-1**).

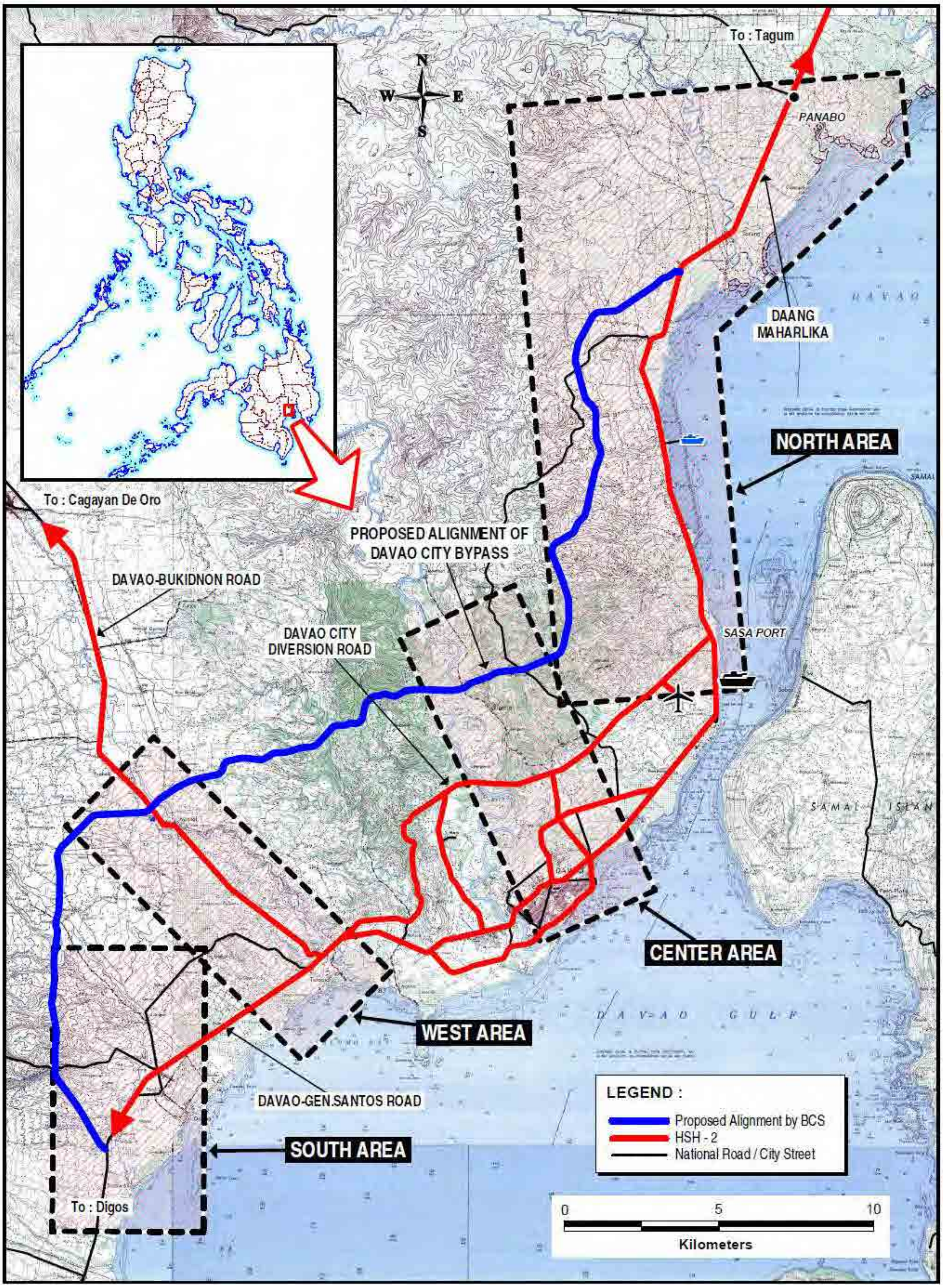


FIGURE 9.5-1 AREAS FOR STUDY ON POSSIBLE SPACE (CORRIDOR) FOR THE BYPASS

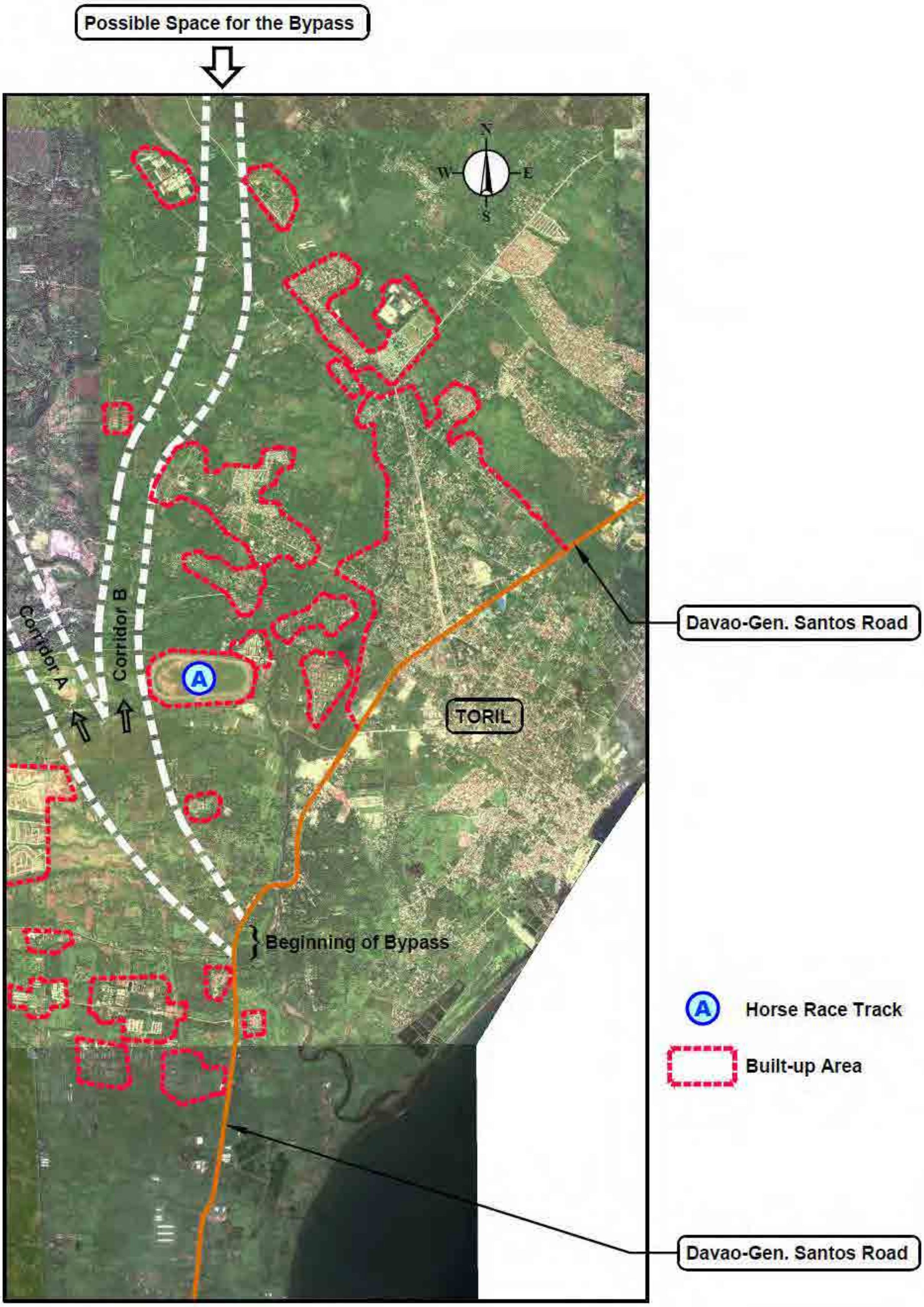


FIGURE 9.5-2 POSSIBLE SPACE FOR THE BYPASS IN SOUTH AREA

(1) Possible Space for the Bypass in the South Area

In the south area, urban development is progressing along Davao – General Santos Road (see

Figure 9.5-2).

<u>Beginning of the Bypass:</u> Since Toril is one of the busiest urban areas in Davao City and there are no large urban areas in the south of Toril, the Bypass should start at the south of Toril.

<u>Possible Space for the Bypass:</u> There are two (2) possible space (corridor) for the Bypass. Corridor A is the space proposed by the Business Case Study which passes through the in-land area along the slope of Mt. Apo and the terrain is quite complex (or undulating). Corridor A passes through far from the urban areas. Whereas Corridor B passes through the open areas closer to the urban center with the shorter road length than Corridor A. Alternative alignments along Corridors A and B are studied for detailed comparison of advantages of alignments.

(2) Possible Space for the Bypass in the West Area

In the west area, road sides along Davao-Bukidnon Road is highly urbanized as shown in **Figure 9.5-3**, there is no space for the Bypass to pass through up to Mintal. Possible space for the Bypass is only located at the north of Mintal.

(3) Possible Space for the Bypass near Davao River in the Center Area

Possible space for the Bypass near Davao River in the Center Area is shown in **Figure 9.5-4.** There is narrow space for the Bypass near the existing Waan Bridge.

(4) Possible Space for the Bypass in the North Area

1) Traffic Condition Along Daang Maharlika

Urbanization and industrial estates are progressing along Daang Maharlika along which relatively high concentrations of commercial activities are observed at <u>Panacan, Tibungco, and Bunawan</u> (see **Figure 9.5-5**). In these areas, through traffic is highly disturbed by parked vehicles on the road and local traffic of tricycles and jeepneys.

Traffic Condition at Panacan

Traffic Condition at Tibungco

Traffic condition at <u>Licanan</u> and <u>Lasang</u> is better than Panacan, Tibungco and Bunawan.

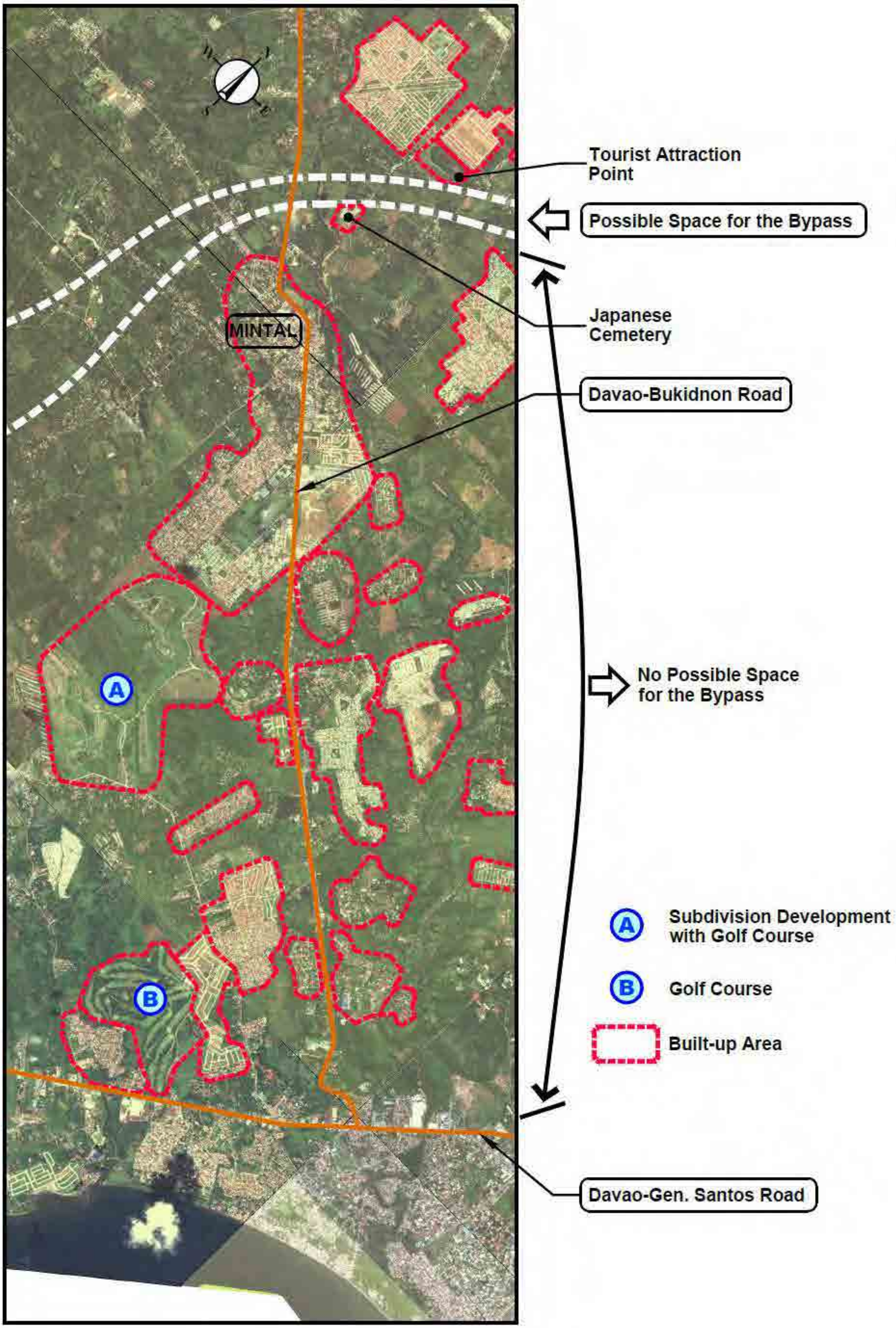


FIGURE 9.5-3 POSSIBLE SPACE FOR THE BYPASS ALONG DAVAO-BUKIDNON ROAD (WEST AREA)

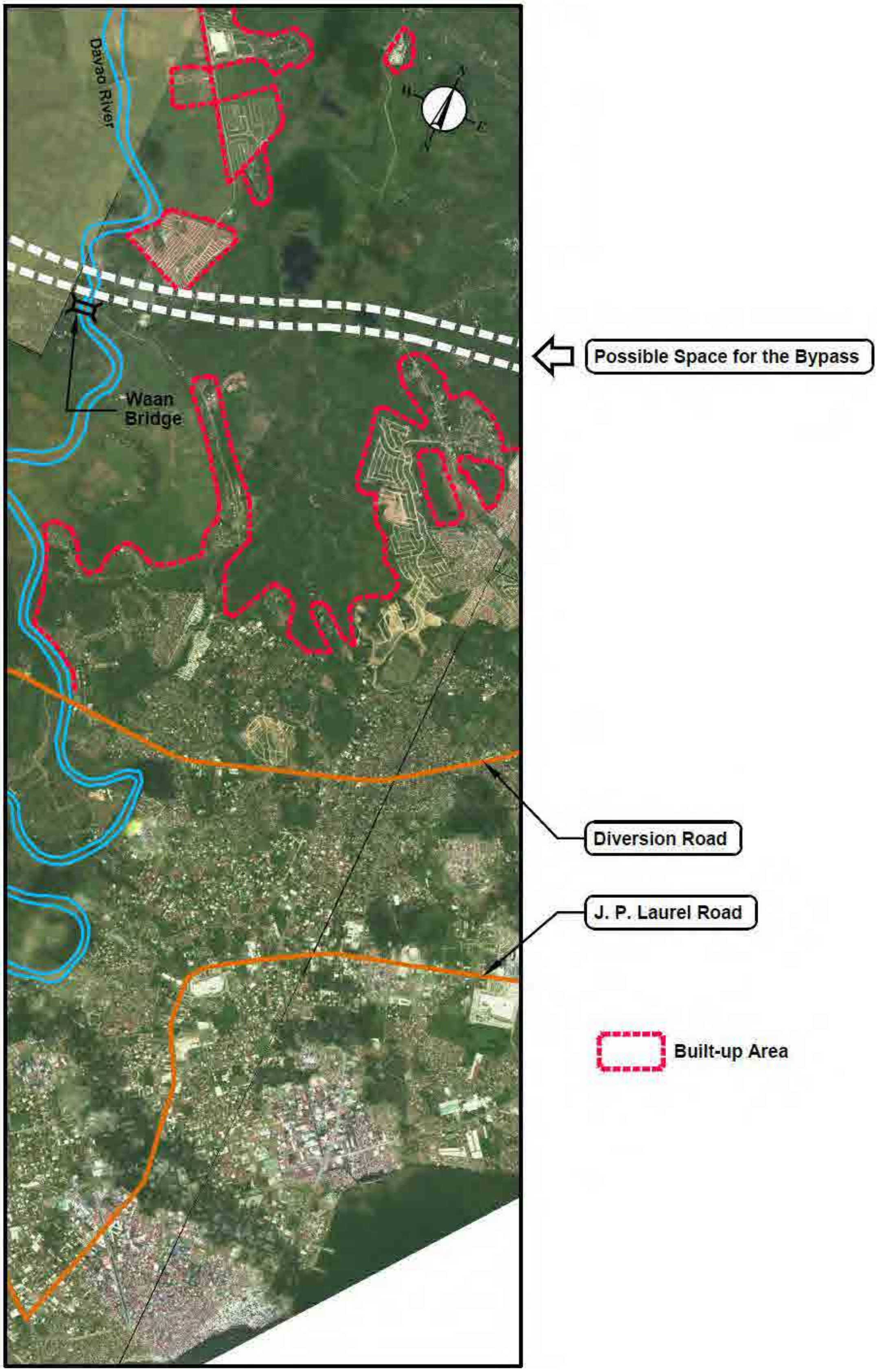


FIGURE 9.5-4 POSSIBLE SPACE FOR THE BYPASS NEAR DAVAO RIVER (CENTER AREA)

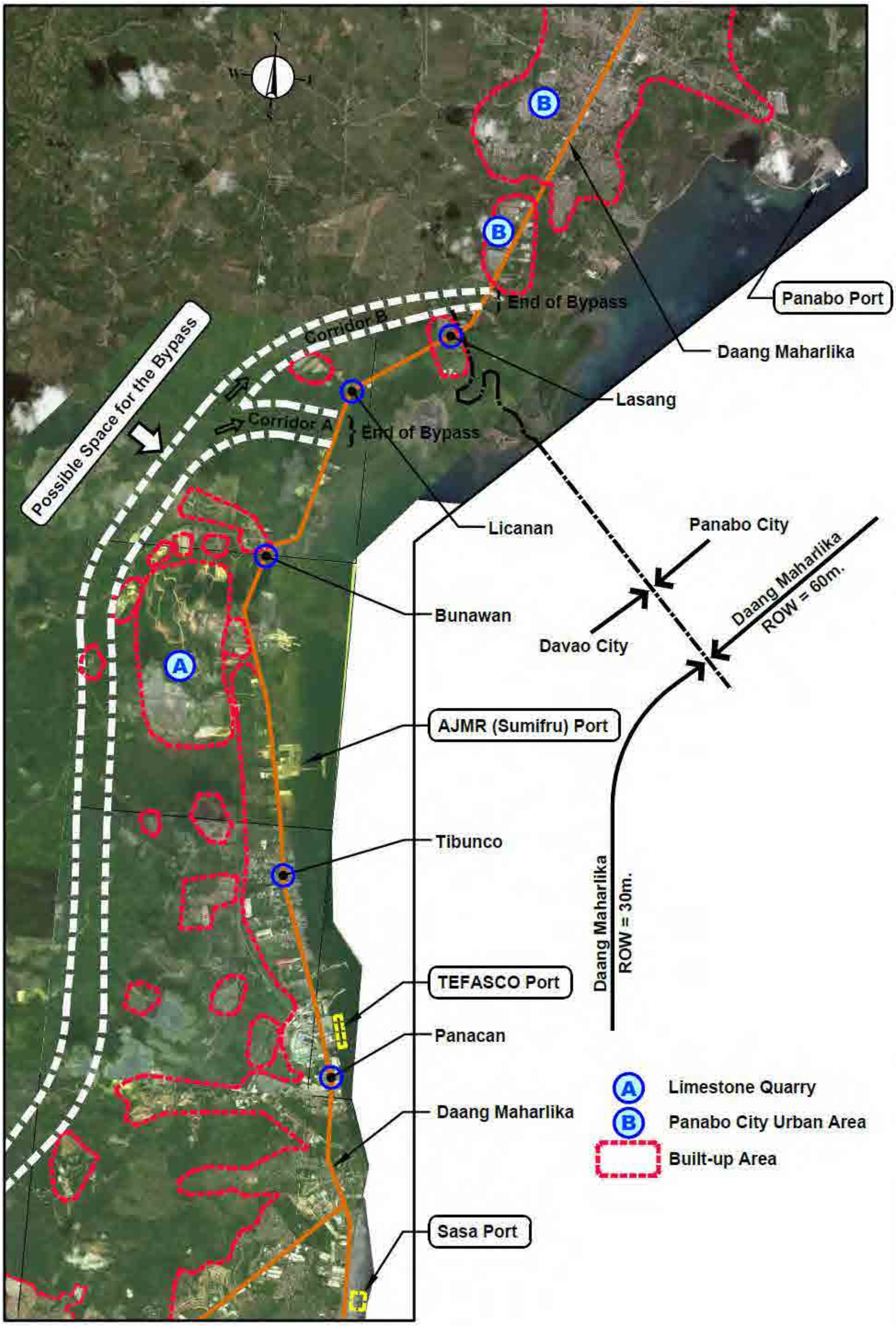


FIGURE 9.5-5 POSSIBLE SPACE FOR THE BYPASS IN NORTH AREA

2) Ports in the North Area

There are one (1) public port (Sasa Port) and three (3) private ports (TEFASCO Port, AJMR (Sumifro) Port and Panabo Port).

The Bypass should be so planned that accessibility to these ports will be improved to support economic development. Some examples how these ports are used by manufacturing companies and agro-industry companies were presented in Chapter 7.

3) Possible Space for the Bypass

In the north area, possible space for the Bypass is available almost in parallel with Daang Maharlika. Available space is found at 2 to 3 km west of Daang Maharlika as shown in **Figure 9.5-5**. There are two options (Corridor-A and Corridor-B) for the end point of the Bypass.

Corridor-A:	Ends at slightly south of Licanan
Corridor-B:	ends at southern end area of Panabo City

Two options are studied in Section 9.8.

9.6 SELECTION OF CENTER SECTION ALIGNMENT

The Center Section includes a tunnel. Firstly, tunnel alternative alignments were studied, and then the Center Section alignments which include approach sections to a tunnel were evaluated.

9.6.1 Topographical Feature

The topographical feature of a tunnel section is shown in **Figure 9.6-1**, and summarized as follows;

- Elevation varies from 15m to 215m within the length of about 1.5km to 2.0km.
- Ground surface gradient ranges from 10% to 15%.
- The mountain is surrounded by two rivers; Davao River at the east side and Matina River at the west side,
- The mountain has been eroded and many valleys are formed.

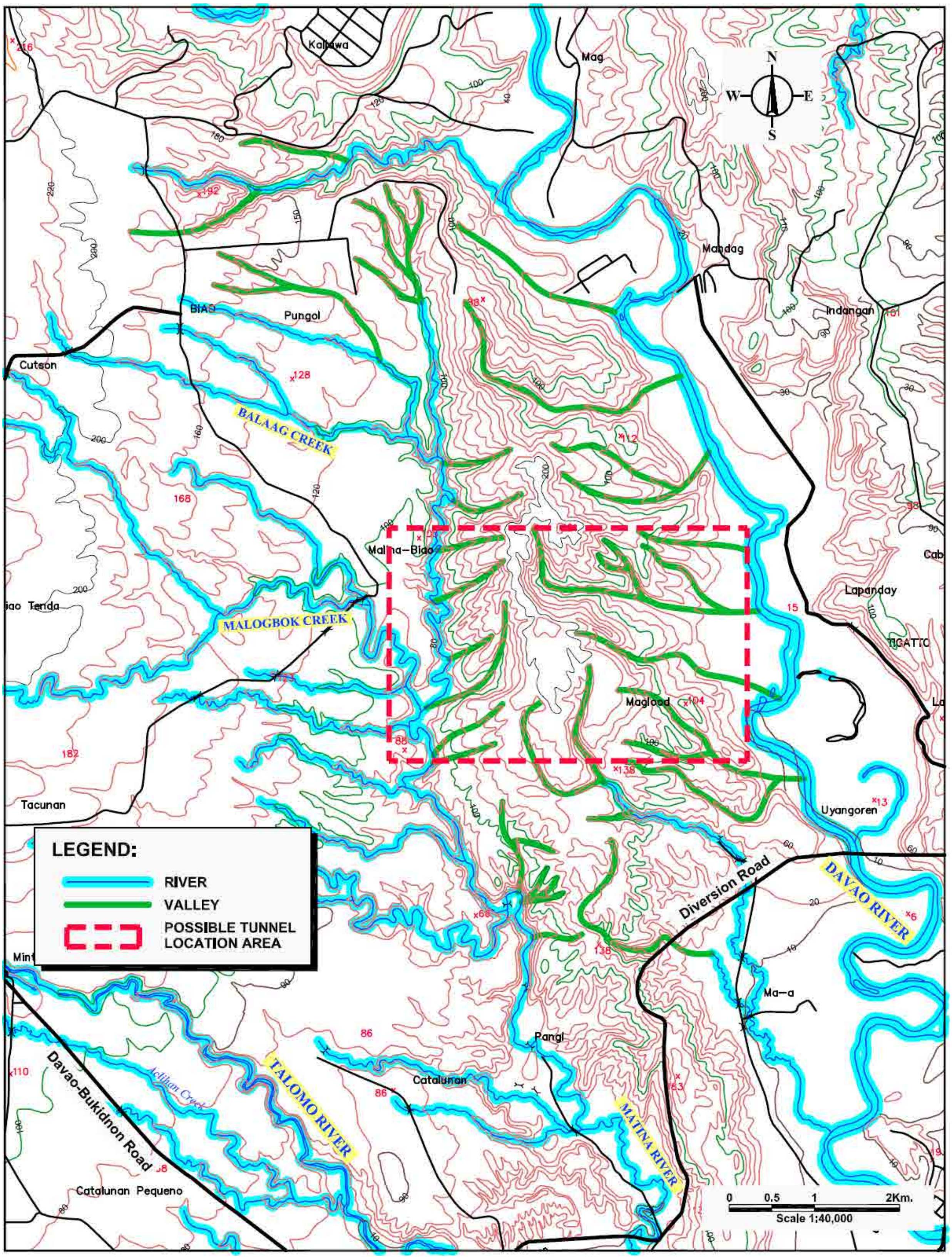


FIGURE 9.6-1 TOPOGRAPHICAL FEATURE

9.6.2 Geological Features

The geological profile is shown in **Figure 9.6-2**. The subject mountain is made of Masuhi Formation. Masuhi formation is composed of sandstone, mudstone, and conglomerate of the Tertiary Miocene Pliocen. It is expected that tunnel excavation can be done without blasting.

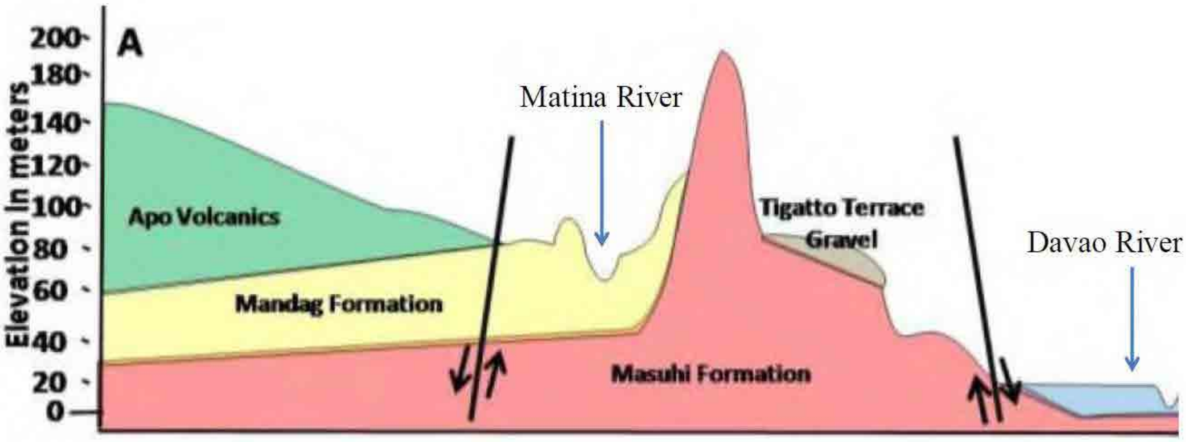


FIGURE 9.6-2 GEOLOGICAL PROFILE

9.6.3 Topography v.s. Tunnel Centerline

A tunnel centerline must be selected in due consideration of easier construction and operation/maintenance. In the selection of tunnel centerline, it is quite important to analyze topographical characteristics of tunnel corridor. **Figure 9.6-3** shows the location of the centerline against topography.

Type-1: Tunnel Centerline is Perpendicular to Mountain Slope

A tunnel centerline is selected almost perpendicular to the mountain slope. This is the most ideal type for a tunnel on the condition that the mountain slope is not subjected to a landslide.

When a tunnel portal is selected at the middle of slope, an access road to a tunnel portal during construction is needed.

Type-2: Tunnel Centerline is Diagonal to Mountain Slope

A tunnel centerline is selected diagonal to the mountain slope. When an inclination of rock layers is the same as that of a mountain slope, unsymmetrical earth pressure is expected, thus, this type of tunnel location should be avoided as much as possible.

Type-3: Tunnel Centerline Passes at Valley

Valley is usually subjected to water flow, debris flow, etc., a tunnel location should not be selected at this type of location.

Type-4: Tunnel Centerline Passes Under Ridge of Mountain

When bedrocks are found and thickness of weathered rock is thin, no problem is expected. There are some cases that talus deposit is quite thick due to past collapse of a mountain, detailed geological analysis is needed.

Type-5: Tunnel Centerline is almost Parallel to Mountain Slope

There are cases that earth thickness over a tunnel drastically changes at one side of a tunnel and unsymmetrical earth pressure is subjected to a tunnel cross section, this type of location should be avoided as much as possible.

In the selection of tunnel location, topographical conditions are evaluated and various tunnel locations are selected for evaluation.

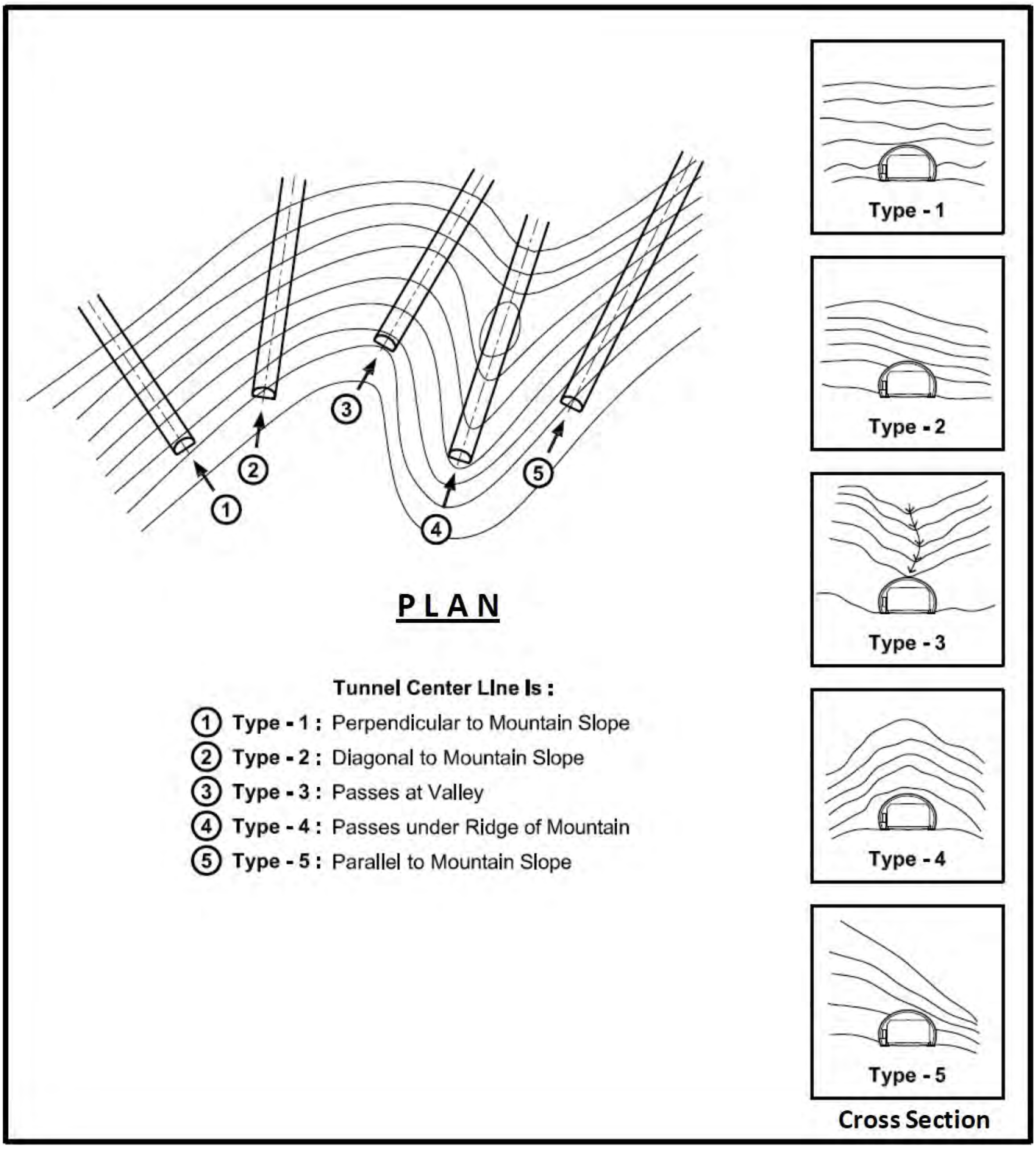


FIGURE 9.6-3 TOPOGRAPHY V.S. CENTERLINE OF TUNNEL

9.6.4 Alternatives of Tunnel Alignment

(1) Alternative Alignments and Pre-screening

The following three (3) groups of alternative alignments were compared:

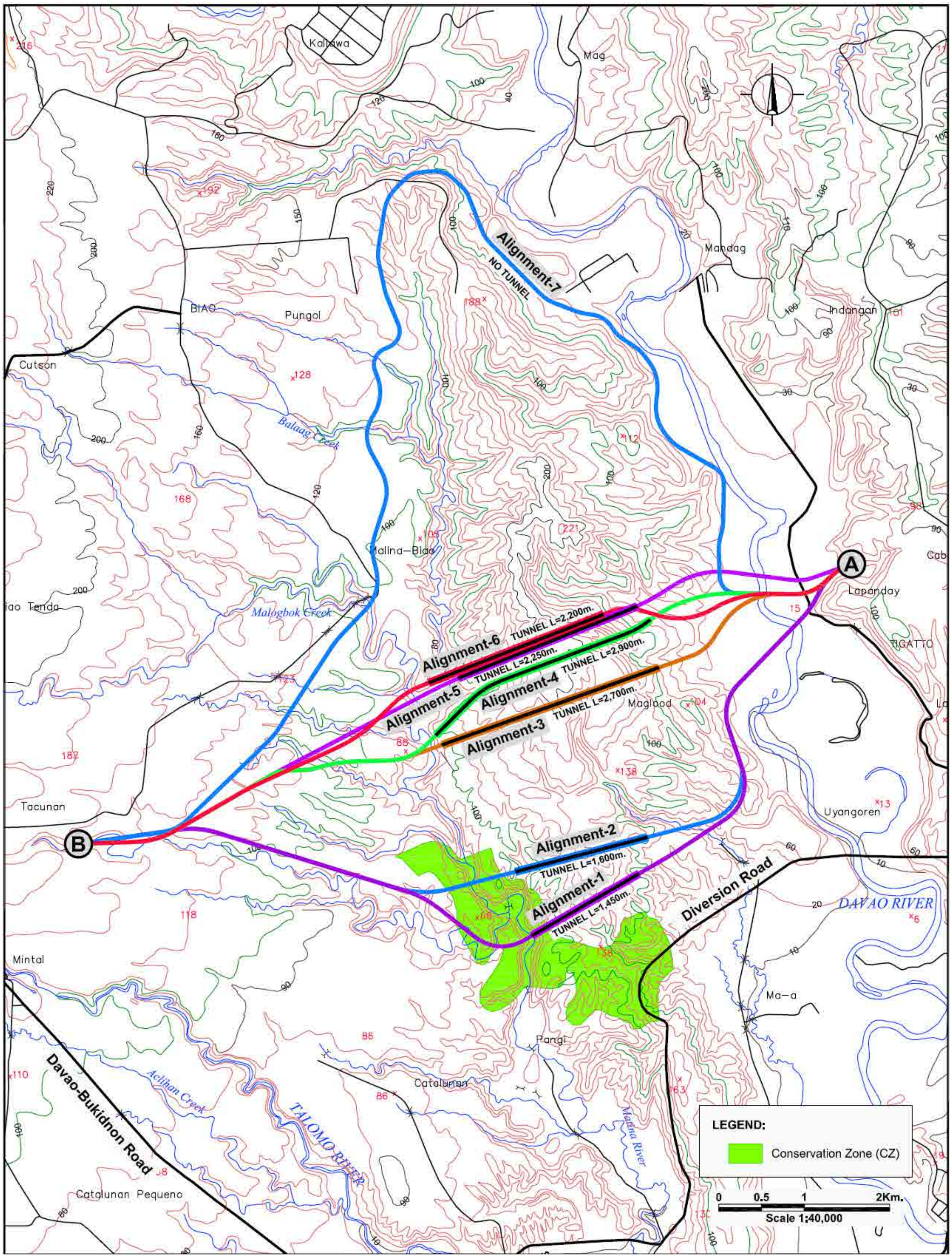
Group-1	Alternative which requires a shorter tunnel length. Topographic conditions are evaluated and two (2) alternative alignments are selected.
Group-2	Alternative which requires a shorter road length and attracts more traffic, since the bypass should attract as many traffic as possible to reduce traffic problems in the Urban Center. Four (4) alternatives are selected.
Group-3	Alternative which does not require a tunnel. This alternative requires a long detour to climb up/down the mountain. This group intends to reduce construction cost; however, function of a bypass is sacrificed. A few traffic is expected to divert to a bypass of this group. One (1) alternative is selected.

A total of seven (7) alternatives were selected and summarized in **Table 9.6-1** as shown in **Figure 9.6-4**.

TABLE 9.6-1 ALTERNATIVES OF TUNNEL SECTION

Group	Alternative	Concept	Road Length between A & B	Tunnel Length	Attracted Traffic (2013 OD) (veh/day)	Pre-screening
1	**1**	• Reduce tunnel length	12.0km (+2.1km)	1,450m	3,500	X
	2	• Reduce tunnel length	11.4km (+1.5km)	1,600m	3,600	X
2	**3**	• Make road length shorter to attract traffic on bypass	9.9km (+0.1km)	2,700m	5,300	○
	4	• Make road length shorter to attract traffic on bypass	9.9km (+0.1km)	2,900m	5,300	○
	5	• Make road length shorter to attract traffic on bypass	9.8km (+0.0km)	2,250m	5,300	○
	6	• Make road length shorter to attract traffic on bypass	9.9km (+0.1km)	2,200m	5,300	○
3	**7**	• Alignment which does not require a tunnel	18.6km (+8.8km)	0 (No Tunnel)	1,600	○

Source: JICA Study Team



Source: JICA Study Team

FIGURE 9.6-4 ALTERNATIVE ALIGNMENTS OF TUNNEL SECTION

Pre-screening

Two (2) alternatives, namely Alternatives -1and -2, are screened out from the alternatives due to the following reasons;

Alternatives-1 and -2

- Although tunnel length becomes shorter than Group-2 alternatives, road length becomes longer by 2.1km (Alternative-1) and 1.5km (Alternative-2).

- Due to longer road length or travel length, attract less traffic on the bypass than Group-2 alternatives, which means less contribution for reduction of traffic problems in the urban center.

- Approach road section to a west tunnel portal passes through **Conservation Zone**, thus it is not favorable for road construction.

(2) Comparison of Alternatives which Passed Pre-screening

Five (5) alternatives, namely Alternatives-3, -4, -5,-6, and -7 passed the pre-screening, which are subjected to the detailed comparison. Profiles of tunnel section of four (4) alternatives are shown in **Figure 9.6-5**. Comparison of tunnels is shown in **Table 9.6-2**.

TABLE 9.6-2 COMPARISON OF TUNNEL PORTION

Alt.	Tunnel Length (m)	Elevation of Portal		Vertical Grade of Tunnel Approach		Issues	Tunnel Construction Cost (Million Php)
		West side	East side	West side	East side		
3	2,700m (+500m)	70.0	49.5	3.4 %	3.7 %	• 500m longer than Alt.6. • East approach requires high embankment or a viaduct.	
4	2,900m (+700m)	65.0	58.2	4.6 %	5.0 %	• Longest tunnel required. • Tunnel has to pass under a deep valley, special construction method for 200m section required.	
5	2,250m (+50m)	60.0	57.5	3.1 %	2.5 %	• 50m longer than Alt.6. • At west side of west portal, low ground area for 500m in length exists where bridges and high embankment is needed.	
6	2,200m (0)	60.0	59.0	3.8 %	4.0 %	• Shortest tunnel • East approach needs high embankment or viaduct	
7	No Tunnel						

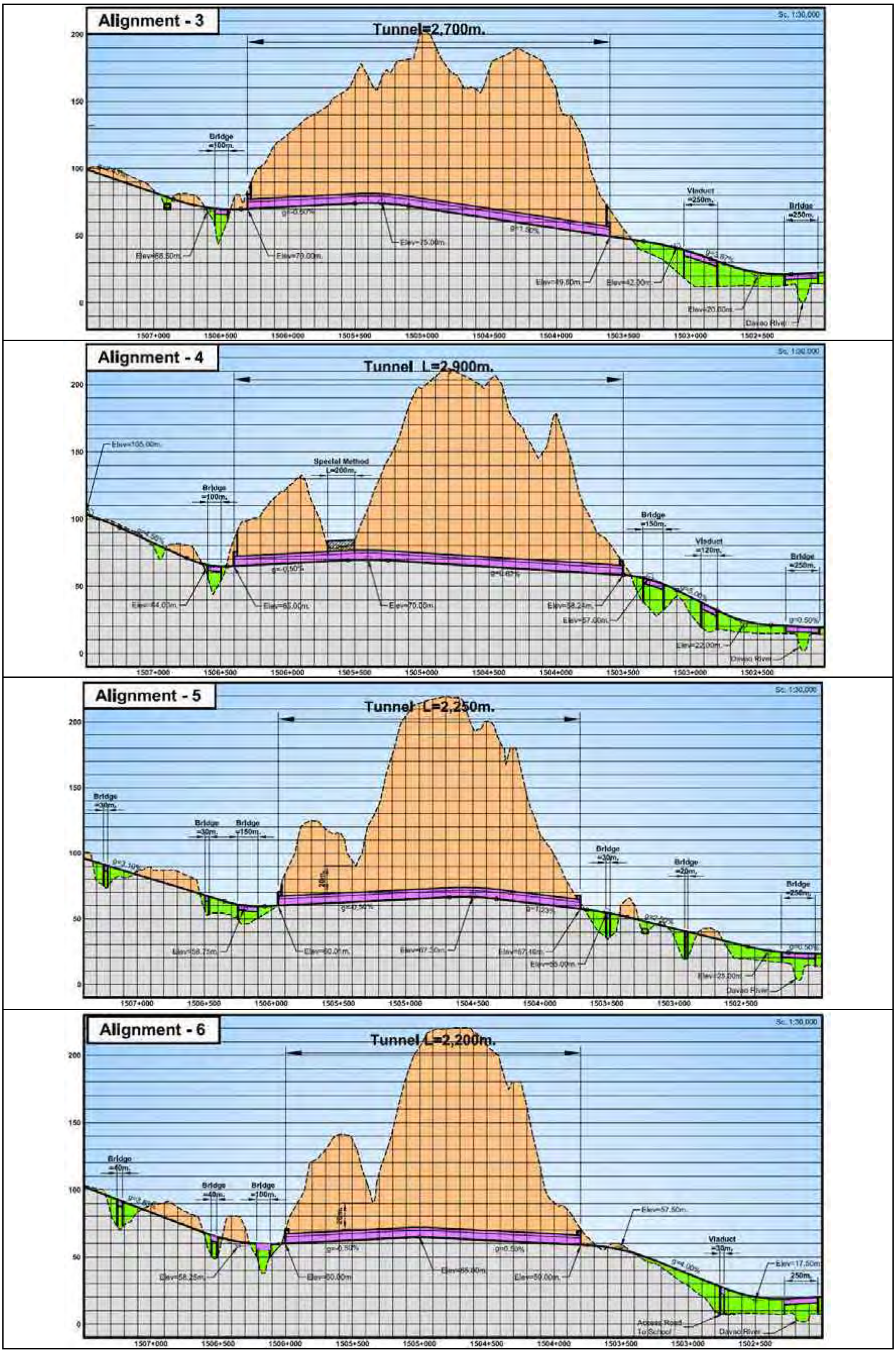


FIGURE 9.6-5 PROFILE OF TUNNEL SECTION

9.6.5 Evaluation of Alternatives of Center Section as a Whole

Alternatives based on a tunnel alignment are shown in **Figure 9.6-6**.

(1) Evaluation Items

The following evaluation criteria were established:

Evaluation Items

1) Traffic Volume Attracted on to the Bypass

When attracted traffic is higher, the better.

2) Project Cost

Construction cost and ROW acquisition cost was estimated. The lesser the cost, the better. Construction cost consists of pavement cost, cut and embankment cost, bridge cost and slope protection cost. Slope protection cost is estimated based on high cut section length.

3) Connection with the Urbanized Area

The bypass should have better connection with the urbanized area. The shorter access distance from the bypass to the urbanized area, the better.

4) Impact on Natural Environment

Five (5) factors were considered.

4-1) Cut Slope Erosion: When a slope is cut, it is subjected to erosion, thus lesser slope cutting in terms of cut volume (m^3), the better.

4-2) Tree Cutting (Less Greenery): When more trees are cut, it is subjected to loss of absorption capacity of CO_2. Thus, the lesser tree cutting, the better.

4-3) Flood: When it rains heavily in this area, flood may occur along the river. Though bridge construction will not affect the impact of flood prone area, the lesser river crossing, the better.

4-4) Earthquake: When high embankment is constructed, it is subjected to high probability of road collapses, thus lesser length of high embankment ($H \geq 5m$), the better.

4-5) Biology: General condition of the proposed route is passing through developed area. Some areas are forest, however, mostly are secondary forest. Mt. Apo is 10km east of the project area, which is home to one of the world's largest eagle: the critically endangered monkey-eating Philippine Eagle is much far from the proposed route, far is better.

5) Social Impact

Two (2) factors were considered.

5-1) Number of Affected Houses/Buildings: When more houses/buildings are affected and more residents will be force to relocate, the more impacts on their lives and livelihood. Thus, the lesser number of houses/buildings affected, the better.

5-2) Affected Agricultural Land: Most of the areas long the Project are agricultural plantation area, such as coconuts, bananas and mangoes. Many people along the Project area relies their livelihood on agricultural plantation. When more agricultural lands are taken by the project, the more people's lives and livelihood are affected. Impact on agricultural plantation was measured by a road length (in km.) which passes through agricultural land.

6) Construction Period

Construction period was estimated. The shorter construction period, the better.

7) Road Network

Additional new link is better to strengthen the road network.

8) Impact of Residential Development

Bypass should support for the future residential area development. The nearer development area, the better.

9) O & M Cost

Operation and Maintenance (O&M) Cost was estimated. The lesser the O&M Cost, the better.

10) Other Aspects

Other aspects were evaluated by segregation of positive impacts and negative impacts.

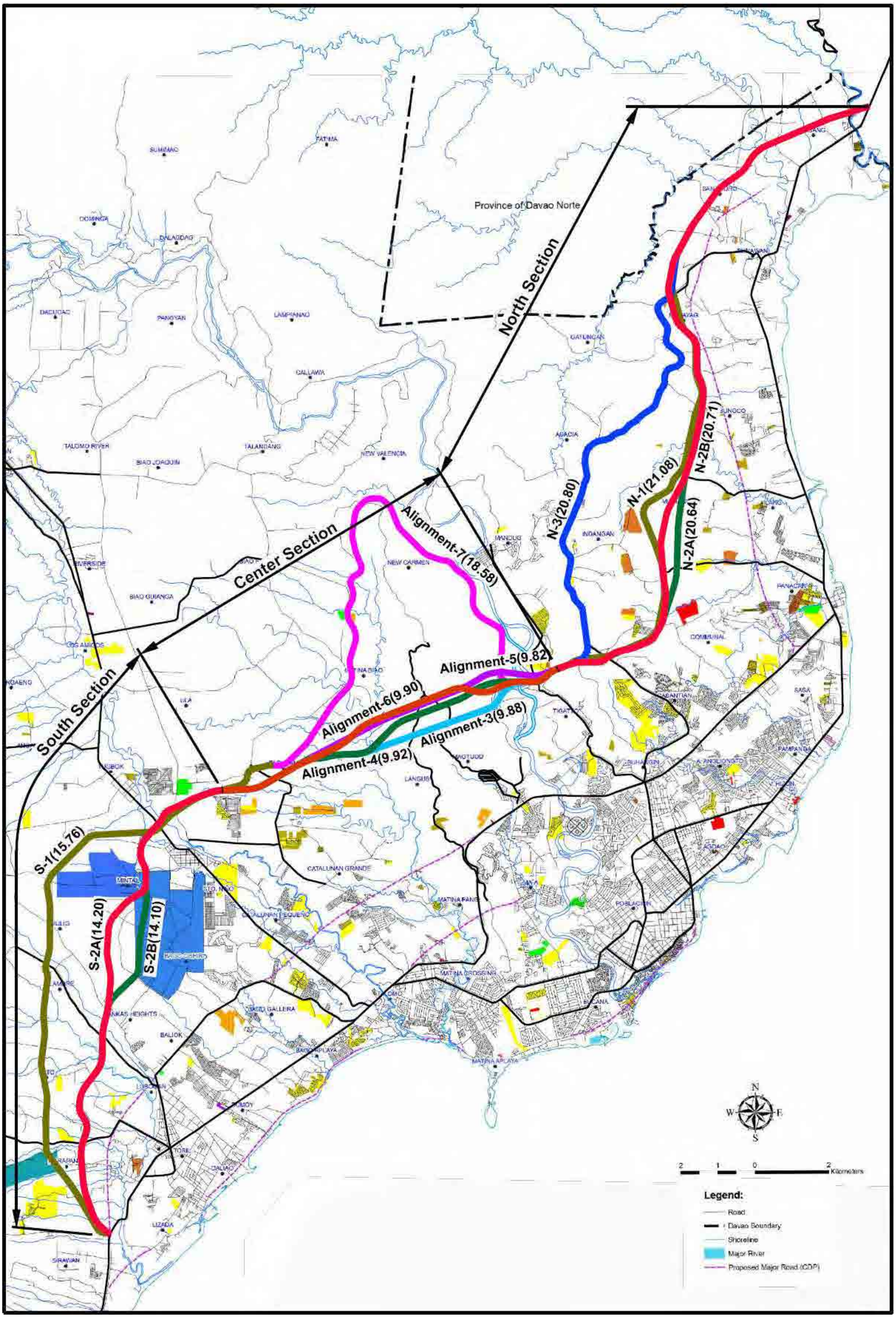


FIGURE 9.6-6 ALTERNATIVES FOR CENTER, SOUTH AND NORTH SECTIONS

(2) Evaluation Criteria

1) For items quantified, the following criteria were established:

For the alternative which achieve the lowest value (or highest value)	⇨ Good (●)
For the alternative within 10% difference compared to the lowest (or highest)	⇨ Medium (▲)
For the alternative over 20% difference compared to the lowest (or highest)	⇨ Bad (X)

2) For items narratively described, impact was subjectively evaluated.

3) When all alternatives have the same value, the item(s) was not evaluated.

4) Evaluation

- Assessed by number of items evaluated as “Good”, “Medium”, and “Bad”.
- An alternative which has more number of “Good” and least number of “Bad”.

5) Overall Evaluation

Two (2) cases were tested as follows;

Case-1: Equal Rating for all evaluation items (or no weight was considered for each item)

Case-2: Weighted Rating: Evaluation items of cost and number of houses/buildings affected were given 3 times heavier weight.

(3) Evaluation of Alternatives

Case-1 evaluation result is shown in **Table 9.6-3** and Case-2 in **Table 9.6-4**.

TABLE 9.6-3 EVALUATION OF ALTERNATIVES OF CENTER: CASE-1

Evaluation Item		Alt. 3		Alt. 4		Alt. 5		Alt. 6		Alt. 7	
Concept of Alternative		• To avoid a tunnel to pass under a deep valley. • To select narrower river crossing at west portal.		• To avoid passing through residential area at east side. • To select narrower river crossing at west portal.		• To achieve shorter tunnel length. • To avoid passing through residential area at east side. • To achieve more than 20m earth cover at a deep valley.		• To achieve shorter tunnel length. • To avoid passing through residential area at east side. • To achieve more than 20m earth cover at a deep valley. • To select narrower river crossing at west portal.		• Alignment which does not require a tunnel	
Road Length (km)		9.87 (+0.05km) (1.01)		9.92 (+0.1km) (1.01)		9.82 (0.0) (1.00)		9.90 (+0.08km) (1.01)		18.60 (+8.78) (1.89)	
Tunnel Length (km)		2.70 (+0.5km) (1.23)		2.90 (+0.7km) (1.32)		2.25 (+0.05km) (1.02)		2.20 (0.0) (1.00)		0	
a) Traffic Volume Attracted (veh/day in 2013 OD)	North Section: N-1 & N-2 South Section: S-2	5,320 (1.00)	○	5,320 (1.00)	○	5,320 (1.00)	○	5,320 (1.00)	○	1,619 (0.30)	X
	North Section: N-3 South Section: S-1	3,490 (1.00)	-	3,490 (1.00)	-	3,490 (1.00)	-	3,490 (1.00)	-	1.060 (0.30)	-
b)Cost (Million Php)	Construction Cost		-		-		-		-		-
	ROW Acquisition Cost		-		-		-		-		-
	Total		△		X		○		○		○
c)Connection with the Urbanized Area		• Same condition with	-	• Same condition with	-	• Same condition with	-	• Same condition with	-	• Same condition	-

Evaluation Item		Alt. 3		Alt. 4		Alt. 5		Alt. 6		Alt. 7	
		the other alternatives		the other alts.		the other alts.		the other alts.		with the other alts.	
d)Impact on Natural Environment	Slope Cutting (m^3)	0.35 Million (1.06)	○	0.33 Million (1.00)	○	0.38 Million (1.15)	X	0.35 Million (1.06)	○	2.16 Million (6.55)	X
	Tree Cutting (km)	5.17 km (1.01)	○	5.10 km (1.00)	○	6.02 km (1.18)	X	5.20 km (1.02)	○	14.40 km (2.82)	X
	Flood(No. of crossing river)	5	-	5	-	5	-	5	-	5	-
	Earthquake(High embankment (km))	2.2 (1.00)	○	2.2 (1.00)	○	2.2 (1.00)	○	2.2 (1.00)	○	4.2 (1.91)	X
	Biology(Philippine Eagle's Habitants)	• Same condition with the other alts.	-	• Same condition with the other alts.	-	• Same condition with the other alts.	-	• Same condition with the other alts.	-	• Same condition with the other alts.	-
e)Social Impact	No. of Affected Houses/ Buildings	45 (3.75)	X	16 (1.33)	X	16 (1.33)	X	12 (1.00)	○	55 (4.58)	X
	Affected Agri-land	4.43km (1.05)	○	4.23km (1.00)	○	4.30km (1.02)	○	4.30km (1.02)	○	14.40km (3.40)	X
f)Construction Period		• Longest construction period(Special construction method required at the middle of the tunnel)	X	• Longest construction period(Special construction method required at the middle of the tunnel)	X	• Shorter construction period than Alt.3 & 4 but longer than alt. 6	△	• At approach section to east portal, bridge construction not needed, thus tunnel construction period is the shortest and easier than other tunnel alternatives	△	• No need tunnel construction, it is easiest among other alternatives	○
g) Road Network		• Almost same as other alternatives, excluding alt-7	○	• Almost same as other alternatives, excluding alt-7	○	• Almost same as other alternatives, excluding alt-7	○	• Almost same as other alternatives, excluding alt-7	○	• Not so much impact as road network formation.	X
h) Impact of Residential Development		• No so much impact of Residential Dev.	-	• No so much impact of Residential Dev.	-	• No so much impact of Residential Dev.	-	• No so much impact of Residential Dev.	-	• No so much impact of Residential Dev.	-
i) O&M Cost(Thousand Php/year)			X		X		X		X		○
Evaluation		○ = 6 △ = 1 X = 3		○ = 6 △ = 0 X = 4		○ = 5 △ = 1 X = 4		○ = 8 △ = 1 X = 1		○ = 3 △ = 0 X = 7	
Recommendation								**Recommended**			

Source: JICA Study Team

TABLE 9.6-4 EVALUATION OF ALTERNATIVES OF CENTER: CASE-2

Evaluation Item	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
Concept of Alternative	• To avoid a tunnel to pass under a deep valley. • To select narrower river crossing at west portal.	• To avoid passing through residential area at east side. • To select narrower river crossing at west portal.	• To achieve shorter tunnel length. • To avoid passing through residential area at east side. • To achieve more than 20m earth cover at a deep valley.	• To achieve shorter tunnel length. • To avoid passing through residential area at east side. • To achieve more than 20m earth cover at a deep valley. • To select narrower river crossing at west portal.	• Alignment which does not require a tunnel
Road Length (km)	9.87 (+0.05km) (1.01)	9.92 (+0.1km) (1.01)	9.82 (0.0) (1.00)	9.90 (+0.08km) (1.01)	18.60 (+8.78) (1.89)

Evaluation Item		Alt. 3		Alt. 4		Alt. 5		Alt. 6		Alt. 7	
Tunnel Length (km)		2.70 (+0.5km) (1.23)		2.90 (+0.7km) (1.32)		2.25 (+0.05km) (1.02)		2.20 (0.0) (1.00)		0	
a) Traffic Volume Attracted (veh/day in 2013 OD)	North Section: N-1 & N-2 South Section: S-2	5,320 (1.00)	○	5,320 (1.00)	○	5,320 (1.00)	○	5,320 (1.00)	○	1,619 (0.30)	X
	North Section: N-3 South Section: S-1	3,490 (1.00)	-	3,490 (1.00)	-	3,490 (1.00)	-	3,490 (1.00)	-	1.060 (0.30)	-
b)Cost (Million Php)	Construction Cost		-		-		-		-		-
	ROW Acquisition Cost		-		-		-		-		-
	Total		△		X X X		○		○		○
c)Connection with the Urbanized Area		- Same condition with the other alternatives	-	- Same condition with the other alts.	-	- Same condition with the other alts.	-	- Same condition with the other alts.	-	- Same condition with the other alts.	-
d)Impact on Natural Environment	Slope Cutting (m^3)	0.35 Million (1.06)	○	0.33 Million (1.00)	○	0.38 Million (1.15)	X	0.35 Million (1.06)	○	2.16 Million (6.55)	X
	Tree Cutting (km)	5.17 km (1.01)	○	5.10 km (1.00)	○	6.02 km (1.18)	X	5.20 km (1.02)	○	14.40 km (2.82)	X
	Flood(No. of crossing river)	5	-	5	-	5	-	5	-	5	-
	Earthquake (High embankment (km))	2.2 (1.00)	○	2.2 (1.00)	○	2.2 (1.00)	○	2.2 (1.00)	○	4.2 (1.91)	X
	Biology(Philippine Eagle's Habitants)	- Same condition with the other alts.	-	- Same condition with the other alts.	-	- Same condition with the other alts.	-	- Same condition with the other alts.	-	- Same condition with the other alts.	-
e)Social Impact	No. of Affected Houses/ Buildings	45 (3.75)	X X X	16 (1.33)	X X X	16 (1.33)	X X X	12 (1.00)	○	55 (4.58)	X X X
	Affected Agri-land	4.43km (1.05)	○	4.23km (1.00)	○	4.30km (1.02)	○	4.30km (1.02)	○	14.40km (3.40)	X
f)Construction Period		- Longest construction period(Special construction method required at the middle of the tunnel)	X	- Longest construction period(Special construction method required at the middle of the tunnel)	X	- Shorter construction period than Alt.3 & 4 but longer than alt. 6	△	- At approach section to east portal, bridge construction not needed, thus tunnel construction period is the shortest and easier than other tunnel alternatives	△	- No need tunnel construction, it is easiest among other alternatives	○
g) Road Network		- Almost same as other alternatives, excluding alt-7	○	- Almost same as other alternatives, excluding alt-7	○	- Almost same as other alternatives, excluding alt-7	○	- Almost same as other alternatives, excluding alt-7	○	- Not so much impact as road network formation.	X
h) Impact of Residential Development		- No so much impact of Residential Dev.	-	- No so much impact of Residential Dev.	-	- No so much impact of Residential Dev.	-	- No so much impact of Residential Dev.	-	- No so much impact of Residential Dev.	-
i) O&M Cost(Thousand Php/year)			X		X		X		X		○
Evaluation		○ = 6 △ = 1 X = 5		○ = 6 △ = 0 X = 8		○ = 5 △ = 1 X = 6		○ = 8 △ = 1 X = 1		○ = 3 △ = 0 X = 9	
Recommendation								**Recommended**			

Evaluation Item	Alt. 3		Alt. 4		Alt. 5		Alt. 6		Alt. 7	

Source: JICA Study Team

9.6.6 Recommendations

- Alternative-7 is the plan to avoid construction of a tunnel. This alternative is slightly advantageous for (construction cost + ROW cost), but slightly only (2% reduction compared to Alternative-6.
- Alternative-7's serious problem is that it does not function as s bypass and attract only 1,619 vehicles (or 30% of other alternatives) which means that it does not contribute to mitigation of traffic problems in the Urban Center and to economic development of Mindanao.
- Alternative-7 passes through forested areas requiring cutting of trees and cutting national slopes, thus environmentally not advantageous compared to other alternatives.

In view of the above, Alternative-7 was not selected.

- Alternative-3 to 6 passed through almost the same areas in natural conditions and show similar evaluation results.
- Alternative-6 has advantages over Alternative-3 to 5 on the following items;
  - Tunnel length is shortest.
  - Least construction and ROW acquisition cost is required.
  - Least number of houses/buildings affected.

In view of the above, **Altenative-6** was recommended for the bypass alignment.

9.7 SELECTION OF SOUTH SECTION ALIGNMENT

9.7.1 General Characteristics of the South Area

Characteristics of the south area are as follows;

- Located at the foot of Mt. Apo.
- Due to rivers and valleys, the topography is undulating.
- Urbanization is progressing towards the mountain side from Davao – General Santos Road and Davao – Bukidnon Road.
- The University of the Philippines-Mindanao (UP-Mindanao) owns wide area of land in the Bypass Corridor.
- The Bureau of Plant and Industry (BPI) and the Philippine Coconut Authority (PCA) owns wide area of land in the Bypass Corridor.
- The horse racing track was recently developed near the beginning of the Bypass.
- Possible space (corridor) for the Bypass is shown in **Figure 9.5-2**.

9.7.2 Alternative Alignments of the South Section

Three (3) alternative alignments were studied as shown in **Figure 9.7-1**.

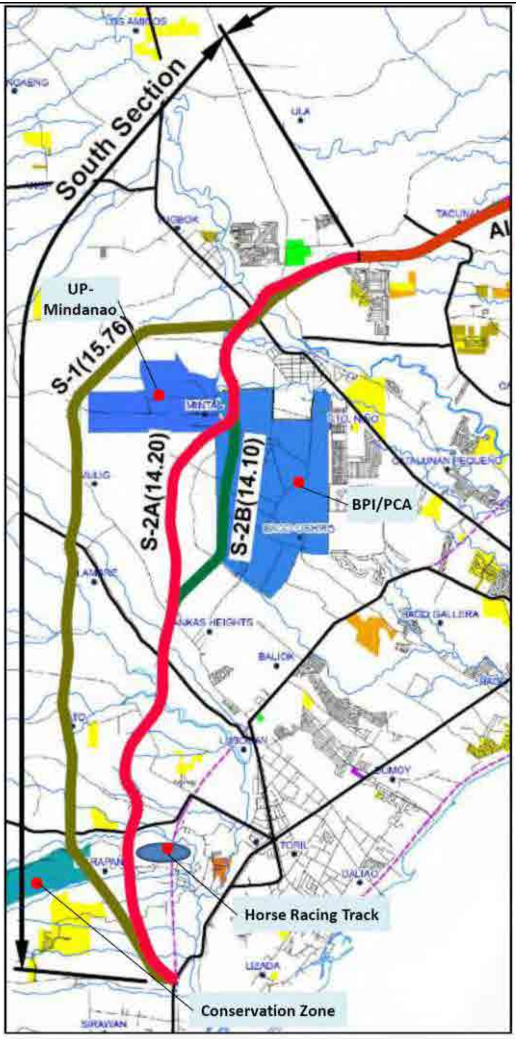


FIGURE 9.7-1 ALTERNATIVE ALIGNMENTS SOUTH SECTION

Alignment S-1

- This is the alignment proposed by the business Case Study.
- The alignment is generally far from the existing urbanized area.
- It avoids passing through UP-Mindanao land and passes west side of UP-Mindanao.
- Topography is undulating, thus high cut of slope, high embankment and longer bridges are required.

Alignment S-2A

- The alignment selected is closer to the existing urbanized area.
- It passes between UP-Mindanao and BPI.
- It avoids the Conservation Area.
- It passes near the recently developed Horse Racing Track.
- The topography is gentler than S-1, but many river has to be crossed.
- Most of the lands along the alignment are designated as “Residential Area” in the Davao City Future Land Use Plan.

Alignment S-2B

- The only difference between S-2A and S-2B is whether the alignment passes through BPI/PCA land. This alternative alignment passes through BPI/PCA land.
- There are many informal settlers in the BPI/PCA land which is a Government Land.

Source: JICA Study Team

9.7.3 Evaluation of Alternatives

The same evaluation criteria adopted for the Center Section were used. Evaluation results are shown in **Table 9.7-1** for Case-1 and **Table 9.7-2** for Case-2.

TABLE 9.7-1 EVALUATION OF ALTERNATIVES OF SOUTH SECTION: CASE-1

Evaluation Item			S-1		S-2A		S-2B	
Concept of Alternative			• Alignment selected by BCS • Not to affect UP Mindanao land		• Closer to existing urbanized area • Pass through future residential area		• Closer to existing urbanized area • Pass through BPI/PCA land	
Road Length (km)			15.8 (+1.7km) (1.12)		14.2 (+0.1km) (1.01)		14.1 (0.00) (1.00)	
a) Traffic Volume Attracted (veh/day in 2013 OD)	North Section	N-1, N-2	2,680 (0.54)	X	4,990 (1.00)	○	4,990 (1.00)	○
		N-3	2,360 (0.52)		4,540 (1.00)		4,540 (1.00)	
b) Cost (Million Php)	Construction Cost			-		-		-
	ROW Acquisition Cost			-		-		-
	Total			X		○		○
c) Connection with the Urbanized Area			• Far from the urbanized area	△	• Nearer to the urbanized area	○	• Nearer to the urbanized area	○
d) Impact on Natural Environment	Slope Cutting (m^3)		1.76 Million (3.59)	X	0.49 Million (1.00)	○	0.50 Million (1.02)	○
	Tree Cutting (km)		13.5 (1.08)	○	12.5 (1.00)	○	12.5 (1.00)	○
	Flood (No. of crossing river)		10	-	10	-	10	-
	Earthquake(High Embankment(km))		2.5 (2.77)	X	0.9 (1.00)	○	0.9 (1.00)	○
	Biology(Location of Philippine Eagle's Habitants)		• Nearer than other alternatives, but still far distance (more than 10km)	△	• Far from Mt. Apo, Philippine Eagle's habitants	○	• Far from Mt. Apo, Philippine Eagle's habitants	○
e) Social Impact	No. of Affected Houses/Buildings		85 (1.55)	X	55 (1.00)	○	64 (1.16)	X
	Affected Agri-land (km)		14.2 (1.03)	○	13.8 (1.00)	○	13.8 (1.00)	○
f) Construction Period			• Same condition with the other alternatives	-	• Same condition with the other alternatives	-	• Same condition with the other alternatives	-
g) Road Network			• Same condition with the other alternatives	-	• Same condition with the other alternatives	-	• Same condition with the other alternatives	-
h) Impact of Residential Development			• Passes through Conservation Area for 400m	X	• Passes through future Residential Area, thus vitally support residential area development	○	• Does not fully support future residential area development	X
i) O&M Cost (Thousand Php/Year)				X		○		○
j) Other Aspects	Positive							
	Negative		• This scheme adversely affect traffic attraction at both centre and north sections	X				
Evaluation			○ = 2 △ = 2 X = 8		○ = 11 △ = 0 X = 0		○ = 9 △ = 0 X = 2	
Recommendation					**Recommended**			

Source: JICA Study Team

TABLE 9.7-2 EVALUATION OF ALTERNATIVES OF SOUTH SECTION: CASE-2

Evaluation Item			S-1		S-2A		S-2B	
Concept of Alternative			• Alignment selected by BCS • Not to affect UP Mindanao land		• Closer to existing urbanized area • Pass through future residential area		• Closer to existing urbanized area • Pass through BPI/PCA land	
Road Length (km)			15.8 (+1.7km) (1.12)		14.2 (+0.1km) (1.01)		14.1 (0.00) (1.00)	
a) Traffic Volume Attracted (veh/day in 2013 OD)	North Section	N-1, N-2	2,680 (0.54)	X	4,990 (1.00)	○	4,990 (1.00)	○
		N-3	2,360 (0.52)		4,540 (1.00)		4,540 (1.00)	
b) Cost (Million Php)	Construction Cost		3,100 (1.77)	-	1,777 (1.02)	-	1,750 (1.00)	-
	ROW Acquisition Cost		292 (1.10)	-	286 (1.08)	-	265 (1.00)	-
	Total		3,392 (1.68)	X X X	2,063 (1.02)	○	2,015 (1.00)	○
c) Connection with the Urbanized Area			• Far from the urbanized area	△	• Nearer to the urbanized area	○	• Nearer to the urbanized area	○
d) Impact on Natural Environment	Slope Cutting (m^3)		1.76 Million (3.59)	X	0.49 Million (1.00)	○	0.50 Million (1.02)	○
	Tree Cutting (km)		13.5 (1.08)	○	12.5 (1.00)	○	12.5 (1.00)	○
	Flood (No. of crossing river)		10	-	10	-	10	-
	Earthquake(High Embankment(km))		2.5 (2.77)	X	0.9 (1.00)	○	0.9 (1.00)	○
	Biology(Location of Philippine Eagle's Habitants)		• Nearer than other alternatives, but still far distance (more than 10km)	△	• Far from Mt. Apo, Philippine Eagle's habitants	○	• Far from Mt. Apo, Philippine Eagle's habitants	○
e) Social Impact	No. of Affected Houses/Buildings		85 (1.55)	X X X	55 (1.00)	○	64 (1.16)	XX X
	Affected Agri-land (km)		14.2 (1.03)	○	13.8 (1.00)	○	13.8 (1.00)	○
f) Construction Period			• Same condition with the other alternatives	-	• Same condition with the other alternatives	-	• Same condition with the other alternatives	-
g) Road Network			• Same condition with the other alternatives	-	• Same condition with the other alternatives	-	• Same condition with the other alternatives	-
h) Impact of Residential Development			• Passes through Conservation Area for 400m	X	• Passes through future Residential Area, thus vitally support residential area development	○	• Does not fully support future residential area development	X
i) O&M Cost (Thousand Php/Year)			947 (1.21)	X	789 (1.00)	○	784 (1.00)	○
j) Other Aspects	Positive							
	Negative		• This scheme adversely affect traffic attraction at both centre and north sections	X				
Evaluation			○ = 2 △ = 2 X = 12		○ = 11 △ = 0 X = 0		○ = 9 △ = 0 X = 4	
Recommendation					**Recommended**			

Source: JICA Study Team

9.7.4 Recommendations

S-1 was not selected due to the following reasons:

- The longest in road length, thus higher cost than other alternatives is required.
- Since the alignment passes through away from the Urban Center, less traffic (or only 52% of traffic of other alternatives) attracted.
- More nature is damaged.
- Number of affected houses/buildings is the highest among alternatives.

S-2A and S-2B show similar evaluation results. One biggest difference is whether the alignment passes through the Bureau of Plant and Industry (BPI)/Philippine Coconut Authority (PCA) areas longer or shorter. In BPI/PCA areas, green land use in terms of coconut/durian and other fruit bearing trees is reserved. The land use outside BPI/PCA area is designated as “Residential Area”.

S-2A passes through shorter in BPI/PCA area and longer in designated residential area, thus S-2A has advantages over S-2A in the following:

- Passes through shorter in BPI/PCA area, thus the green land use is less affected.
- Passes through designated residential area, thus contribute to future urbanization by providing better accessibility to residential area.

9.8 SELECTION OF NORTH SECTION ALIGNMENT

9.8.1 Where to End the Bypass

The Bypass is connected to Daang Maharlika at the north end. There are two (2) options for the end point as shown in **Figure 9.8-1**.

Option-1: End the Bypass between Bunawan and Licanan within Davao City.

Option-2: End the Bypass at the boundary between Davao City and Panabo City.

Option-1 is the end point recommended by BCS, however, DPWH Region XI recommended to extends the Bypass and end at the beginning of Panabo City. The reasons are as follows;

- ROW width of Daang Maharlika is
    - Within Davao City ……….. 30m
    - In Panabo City …………… 60m

- Lasang Bridge at the boundary between Davao City and Panabo City was built with a 4-lane bridge. Both sides of this bridge have been fully developed, thus further widening of the bridge is difficult.

- Lasang area of Daang Maharlika will be a traffic bottleneck in the future.

- Whereas, Daang Maharlika within Panabo City has wide road ROW of 60m. various measures can be adopted, when traffic congestion becomes a proble.

- Panabo City is also fast growing city and urbanization along Daang Maharlika is progressing, thus roadsides will be fully urbanized. Extension of the Bypass to Panabo City will become quite difficult, unless the Bypass is extended now.

- When the Bypass is extended to Panabo City, access to Panabo Port will be improved.

In view of the above, **it is recommended that the Bypass should be extended up to the beginning of Panabo City and connected with Daang Maharlika which has 60m road ROW.**

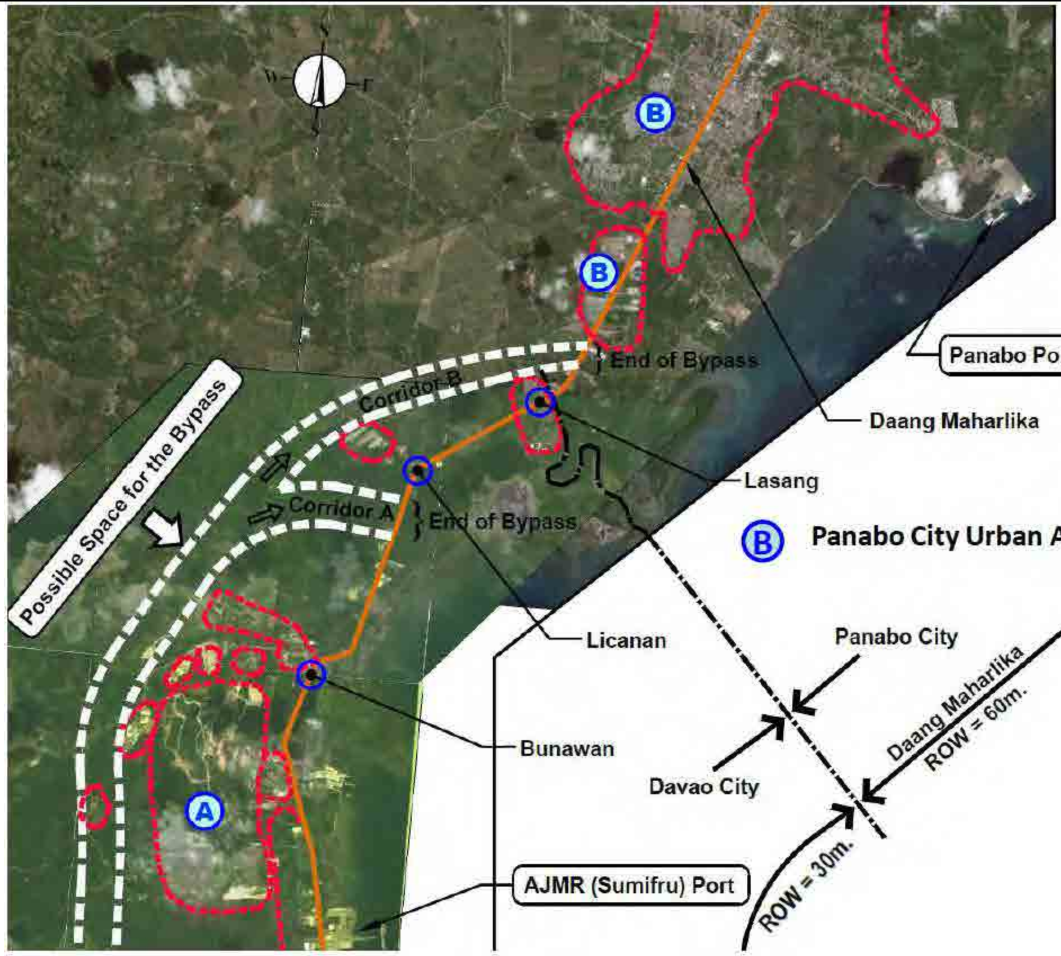


FIGURE 9.8-1 CONDITION OF BYPASS AT THE NORTH END AREA

Cost Comparison

Alignments of Option-1 and Option-2 are shown in **Figure 9.8-2**, and estimated construction cost and ROW cost are shown in **Table 9.8-1**.

TABLE 9.8-1 COST OF OPTION-1 AND OPTION-2

		Option-1	Option-2	
			Option-2 Cost	Additional Cost
Road Length (km)		**2.5**	**5.3**	**+2.8**
Bridge Length (m)		70.0	130.0	+60.0
Cost (Million Php)	Construction Cost			
	ROW Cost			
	Total			

Source: JICA Study Team

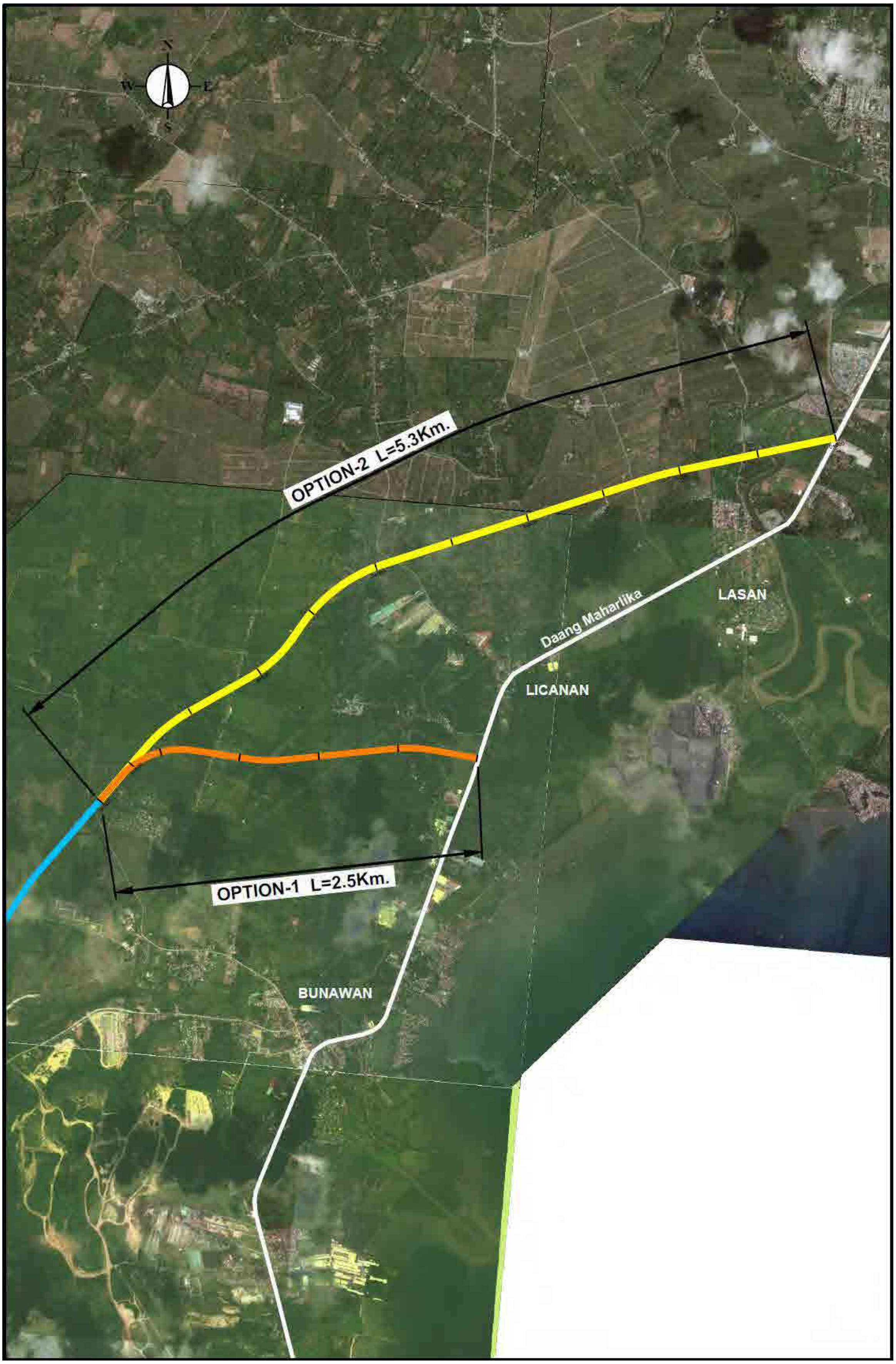


FIGURE 9.8-2 ALIGNMENTS OF OPTION-1 AND OPTION-2

9.8.2 Alternatives of North Section

Four (4) alternatives were developed and compared as shown in **Figure 9.8-3**.

Alignment N-1

- The alignment proposed by BCS.
- This alignment goes towards inland area at the mid-section, resulting in far from the urbanized area and longer road length.

Alignment N-2A

- Closer to the urbanized area and shorter road length than Alternative N-1.

Alignment N-2B

- Same concept as Alternative N-2A.

Alignment N-3

- To convert the existing City Road to the Bypass.

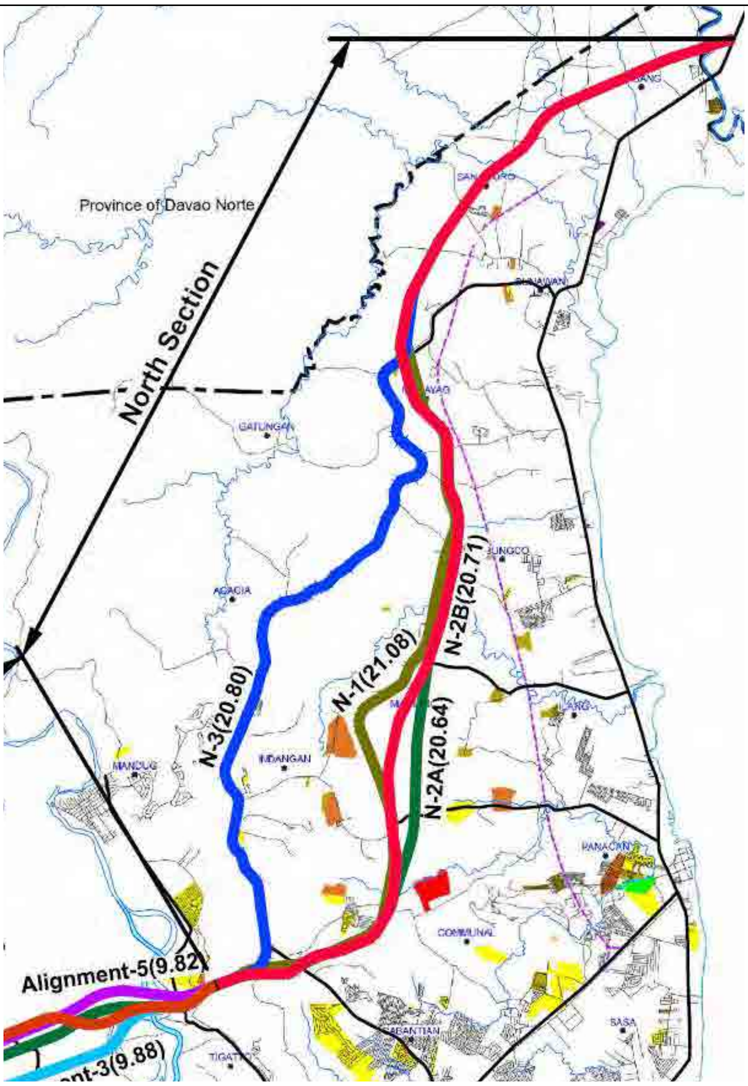


FIGURE 9.8-3 ALTERNATIVE ALIGNMENTS IN NORTH SECTION

9.8.3 Evaluation of Alternatives

(1) Evaluation Criteria

The same evaluation criteria adopted for the Center Section.

(2) Evaluation Result

Evaluation results are shown in **Table 9.8-2** for Case-1 and **Table 9.8-3** for Case-2.

TABLE 9.8-2 EVALUATION OF ALTERNATIVES OF NORTH SECTION: CASE-1

Evaluation Item			N-1		N-2A		N-2B		N-3	
Concept of Alternative			• Alignment selected by BCS		• Closer to urbanized area than N-1		• Closer to urbanized area than N-1		• To convert existing city road to bypass	
Road Length (km)			21.1 (+0.5km) (1.02)		20.6 (0.0) (1.00)		20.7 (+0.1km) (1.00)		20.8 (+0.2km) (1.01)	
a) Traffic Volume Attracted (veh/day in 2013)	South Section	S-2A, S-2B	4,270 (1.00)	○	4,270 (1.00)	○	4,270 (1.00)	○	3,850 (0.90)	△
		S-1	3,150 (1.00)		3,150 (1.00)		3,150 (1.00)		2,690 (0.85)	
b) Project Cost (Million Php)	Construction Cost			-		-		-		-
	ROW Acquisition Cost			-		-		-		-
	Total			X		X		X		○
c) Connection with the Urbanized Area			• Nearer than N-3	○	• Nearer than N-3	○	• Nearer than N-3	○	• Far from Urbanized Area	△
d) Impact on Natural Environment	Slope Cutting (m^3)		2.45 Million (3.45)	X	1.10 Million (1.55)	X	0.96 Million (1.35)	X	0.71 Million (1.00)	○
	Tree Cutting (km)		17.0 (1.06)	○	17.0 (1.06)	○	16.8 (1.04)	○	16.1 (1.00)	○
	Flood(No. of crossing river)		5	-	5	-	5	-	5	-
	Earthquake(High embankment (km))		5.0 (10.0)	X	2.3 (4.60)	X	1.9 (3.80)	X	0.5 (1.00)	○
	Biology(Philippine Eagle's Habitants)		• Same condition with the other alternatives	-	• Same condition with the other alternatives)	-	• Same condition with the other alternatives (far from Mt. Apo, Philippine Eagle's habitants)	-	• Same condition with the other alternatives (far from Mt. Apo, Philippine Eagle's habitants)	-
e) Social Impact	No. of Affected Houses/ Buildings		270 (4.66)	X	60 (1.03)	○	58 (1.00)	○	780 (13.40)	X
	Affected Agri-land (km)		15.7 (1.03)	○	15.8 (1.03)	○	15.3 (1.00)	○	16.3 (1.07)	○
f) Construction Period			• Shorter construction period than N-3	○	• Shorter construction period than N-3	○	• Shorter construction period than N-3	○	• Longer construction period due to utilizing existing road. • Existing traffic on the city road is adversely affected during construction	X
g) Road Network			• Road network in north area is strengthened due to additional new link	○	• Road network in north area is strengthened due to additional new link	○	• Road network in north area is strengthened due to additional new link	○	• Less contribution for strengthening of road network	X
h) Impact of Residential Development			• Same condition with the other alternatives	-	• Same condition with the other alternatives	-	• Same condition with the other alternatives	-	• Same condition with the other alternatives	-
i) O&M Cost(Thousand Php/year)				X		X		X		○
j) Other Aspects	Positive		• Attract more traffic in the south and centre sections	○	• Attract more traffic in the south and centre sections	○	• Attract more traffic in the south and centre sections	○	• This scheme adversely affect traffic attraction at both south and centre sections.	X
	Negative								• Implementation is difficult due to	

Evaluation Item		N-1		N-2A		N-2B		N-3	
								large number of house relocation	X
Evaluation		○ = 7 △ = 0 X =5		○ = 8 △ = 0 X = 4		○ = 8 △ = 0 X =4		○ = 6 △ = 2 X = 5	
Recommendation						**Recommended**			

Source: JICA Study Team

TABLE 9.8-3 EVALUATION OF ALTERNATIVES OF NORTH SECTION: CASE-2

Evaluation Item			N-1		N-2A		N-2B		N-3	
Concept of Alternative			• Alignment selected by BCS		• Closer to urbanized area than N-1		• Closer to urbanized area than N-1		• To convert existing city road to bypass	
Road Length (km)			21.1 (+0.5km) (1.02)		20.6 (0.0) (1.00)		20.7 (+0.1km) (1.00)		20.8 (+0.2km) (1.01)	
a) Traffic Volume Attracted (veh/day in 2013)	South Section	S-2A, S-2B	4,270 (1.00)	○	4,270 (1.00)	○	4,270 (1.00)	○	3,850 (0.90)	△
		S-1	3,150 (1.00)		3,150 (1.00)		3,150 (1.00)		2,690 (0.85)	
b) Project Cost (Million Php)	Construction Cost			-		-		-		-
	ROW Acquisition Cost			-		-		-		-
	Total			XXX		XXX		XXX		○
c) Connection with the Urbanized Area			• Nearer than N-3	○	• Nearer than N-3	○	• Nearer than N-3	○	• Far from Urbanized Area	△
d) Impact on Natural Environment	Slope Cutting (m^3)		2.45 Million (3.45)	X	1.10 Million (1.55)	X	0.96 Million (1.35)	X	0.71 Million (1.00)	○
	Tree Cutting (km)		17.0 (1.06)	○	17.0 (1.06)	○	16.8 (1.04)	○	16.1 (1.00)	○
	Flood(No. of crossing river)		5	-	5	-	5	-	5	-
	Earthquake(High embankment (km))		5.0 (10.0)	X	2.3 (4.60)	X	1.9 (3.80)	X	0.5 (1.00)	○
	Biology(Philippine Eagle's Habitants)		• Same condition with the other alternatives	-	• Same condition with the other alternatives)	-	• Same condition with the other alternatives (far from Mt. Apo, Philippine Eagle's habitants)	-	• Same condition with the other alternatives (far from Mt. Apo, Philippine Eagle's habitants)	-
e) Social Impact	No. of Affected Houses/ Buildings		270 (4.66)	XXX	60 (1.03)	○	58 (1.00)	○	780 (13.40)	XXX
	Affected Agri-land (km)		15.7 (1.03)	○	15.8 (1.03)	○	15.3 (1.00)	○	16.3 (1.07)	○
f) Construction Period			• Shorter construction period than N-3	○	• Shorter construction period than N-3	○	• Shorter construction period than N-3	○	• Longer construction period due to utilizing existing road. • Existing traffic on the city road is adversely affected during construction	X
g) Road Network			• Road network in north area is strengthened due to additional new link	○	• Road network in north area is strengthened due to additional new link	○	• Road network in north area is strengthened due to additional new link	○	• Less contribution for strengthening of road network	X

Evaluation Item		N-1		N-2A		N-2B		N-3	
h) Impact of Residential Development		• Same condition with the other alternatives	-	• Same condition with the other alternatives	-	• Same condition with the other alternatives	-	• Same condition with the other alternatives	-
i) O&M Cost(Thousand Php/year)			X		X		X		○
j) Other Aspects	Positive	• Attract more traffic in the south and centre sections	○	• Attract more traffic in the south and centre sections	○	• Attract more traffic in the south and centre sections	○	• This scheme adversely affect traffic attraction at both south and centre sections.	X
	Negative							• Implementation is difficult due to large number of house relocation	X
Evaluation		○ = 7 △ = 0 X = 9		○ = 8 △ = 0 X = 6		○ = 8 △ = 0 X = 6		○ = 6 △ = 2 X = 7	
Recommendation						**Recommended**			

Source: JICA Study Team

9.8.4 Recommendations

It is recommended that **Alternative N-2B should be adopted for the North Section.** Although Alternative N-3 is the cheapest alternative, it has the following disadvantages.

- It is intended to convert the existing City Road where its roadsides are rapidly urbanizing. It is estimated that 780 houses/buildings (or about 3,350 people) are required to be relocated, which will cause various social problems.
- Implementation of relocation of this magnitude will take a long time, thus completion of the Bypass will be much delayed than other alternatives.
- Since this alignment is far from the existing urban areas, less traffic will be attracted.
- This alignment also affects traffic attraction of South and Center Sections, thus overall viability will be affected.
- This alternative contributes less for strengthening of road network in the north area.
- During construction, existing traffic on this City Road is adversely affected due to construction work.

Alternative N-1 is disadvantageous for the following items compared to Alternative N-2.

- Construction cost is much higher.
- Environmentally less advantageous due to more slope cutting required.
- Socially less advantageous due to high number of houses/buildings to be relocated.

Alternative N-2A and N-2B

Both alternatives were evaluated almost the same. The only difference is the construction cost. Alternative N-2B is recommended due to less construction cost than Alternative N-2A.

9.9 ZERO OPTION

Table 9.9-1 shows the evaluation of with project and without project.

Though Project will affect the pollution, natural environment and social environment, traffic will be drastically improved in the city area.

TABLE 9.9-1 EVALUATION OF WITH/WITHOUT PROJECT

Evaluation Item	Parameter	With Project	Without Project	Remarks
Traffic	Total Travel Time (Y2023)	216,682 veh*hrs/day ○	235,299 veh*hrs/day X	18,617 veh*hrs saving in Davao City
Pollution	Air, Noise	Air pollution and noise will occur during construction X	None ○	Along Bypass Area
	CO_2 (Y2023)	642,400 ton/year ○	676,968 ton/year X	34,568 ton/year decrease during operation
Natural Environment		Tree cutting slope cutting may occur during construction X	None ○	
Social Environment		Resettlement necessary (125 structures) X	None ○	

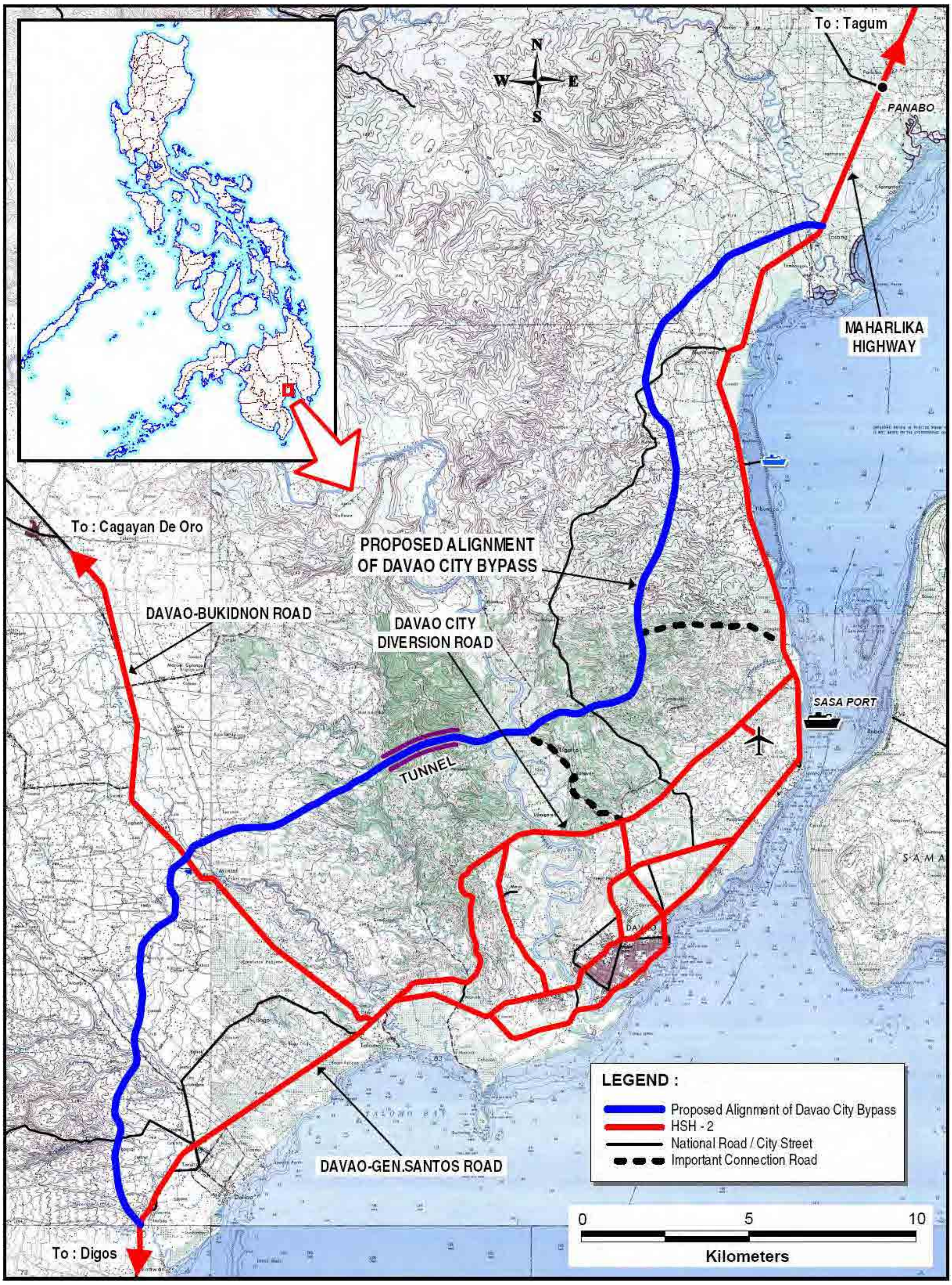
Source: JICA Study Team

9.10 RECOMMENDED ALIGNMENT OF THE BYPASS

Recommended alignment of the Bypass is shown in **Figure 9.10-1**. Outline of the selected alignment is shown in **Table 9.10-1**. **Figure 9.10-2** shows the relation between the selected bypass alignment and the future Davao City Land Use Plan.

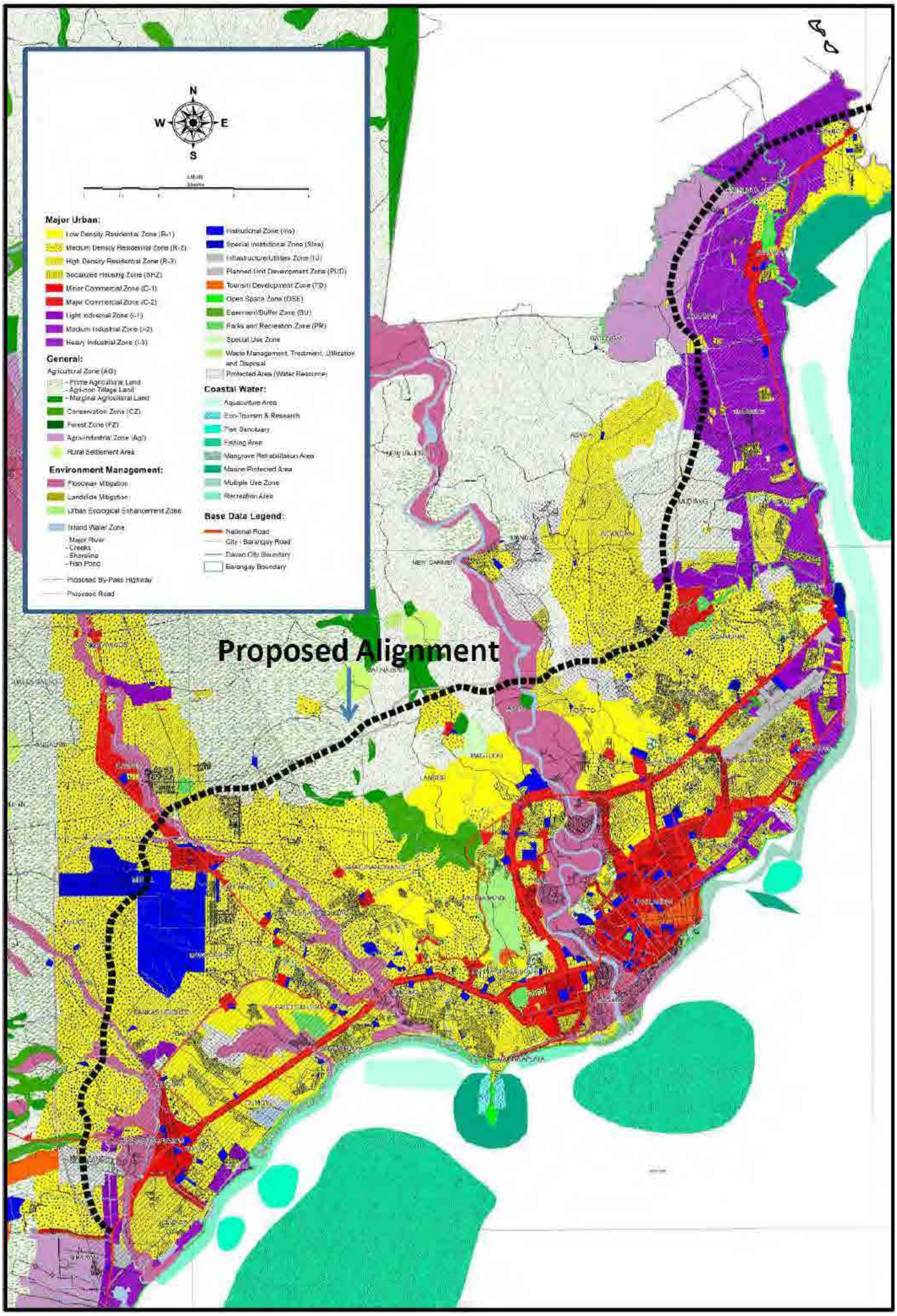
TABLE 9.10-1 OUTLINE OF THE BYPASS

(CONFIDENTIAL)



Source: JICA Study Team

FIGURE 9.10-1 RECOMMENDED ALIGNMENT OF THE BYPASS



Source: JICA Study Team

FIGURE 9.10-2 FUTURE LAND USE PLAN AND THE BYPASS ALIGNMENT

CHAPTER 10

PRELIMINARY DESIGN

CHAPTER 10
PRELIMINARY DESIGN

10.1 ENGINEERING SURVEYS UNDERTAKEN

10.1.1 General

This section describes the engineering surveys undertaken.

(1) Topographical Survey

(2) Soils and Geo-technical Survey

10.1.2 Topographical Survey

Table 10.1-1 shows the summary of survey works conducted.

TABLE 10.1-1 SUMMARY OF TOPOGRAPHICAL SURVEYS

No.	Items	Value	Remarks
1	Coordinate Grid	PRS-92, WGS-84	
2	Methodology	Confirmed to DAO* DENR regulation	
3	Reference for Horizontal	NAMRIA DVS-3569	4th Order
4	Reference for Vertical	NAMRIA DS-19 NAMRIA DS-134	1st Order 1st Order
5	Road Centerline Survey	44.6km	50m interval
6	Road Centerline Profile Survey	44.6km	50m interval
7	Cross Sections Survey		Every 50m interval, 125m both sides from Centerline
8	Structure Survey	All Structures	Total 250m width
9	River Survey	20 rivers	Total Length 500, 5 river cross section
10	Intersection Survey	3 (4 to 6-lane road) 31 (2-lane road)	L = 600m, W = 50m L = 400m, W = 30m

*DAO – Department Administrative Order, DENR – Department of Environment and Natural Resources

10.1.3 Soils and Geo-technical Investigation

(1) General Geology

1) Topography

The general landscape of the project site is marked by complex morphologies which are controlled by the geological structures. Most of the geological structures are associated either by faults and/or stratigraphic lines. The relief varies from rolling hills to rugged mountains with elevations between 10m and 220m.

The topography manifests high dissection particularly towards the mountainous and rugged relief where passages of faults and various geologic lineaments are strongly manifested. The mountainous and high relief areas appear generally elongated towards the north - northwest. This elongation runs roughly co-linear with the direction of anticlines and synclines of Quaternary-Tertiary sedimentary rocks.

Most of the drainage-lines in and around the project site are structurally-controlled. They flow generally from west - northwest towards east - southeast. All empty their loads towards Davao Gulf in the east.

The project site of the bypass road is crisscrossed by several geologic structures and lineaments.

Most prominent are faults, geologic lineaments, synclines and anticlines. In many places in and around the project site, the prominence of geologic structures and lineaments are notably earmarked by the alignment of several structural outliers.

Faults and geologic lineaments are linear fractures or fracture zones along which there has occurred displacement of the slides relative to one another and parallel to the fracture. In and around the project site, faults/geologic lineaments are linear features and semi-straight lines marked with scarps. These scarps characterize the dip-slope displacements. In many places, these scarps appear almost vertical. Also sites exhibits extensive erosion activity along these scarps.

The proposed alignment of the bypass road is intersected with two systems of geologic lineament which are the west - northwest (W-NW) system and the north - northeast (N-NE) system.

The west - northwest (W-NW) system appears older and tentatively classified as “inactive”. This system of geologic lineament variably strikes between 45 degrees northwest and due west. The inclined directions of fracture variably dip toward of the south - southwest between 20 and 35 degrees. Scarps of this fault system are marked with severe weathering and infilling of soil materials, but brecciation is minor. The densely vegetated states of the sites suggest water seepage.

The north - northeast (N-NE) system appears younger and “Recently active” based on morphological features along Davao River. This system of geologic lineament hinders the current of Davao River contributing to the current avulsion, pulsative shifts and migrations of the river channel. This system of geologic lineament variably strike between 30 degrees northeast and due north. The inclined directions of fracture variably dip toward of the northwest - west between 20 and 35 degrees. Associated scarps of this geologic lineament expose poorly weathered bedrocks with minor clay and infilling soils, and brecciation is extensive. Sites are poorly vegetated which suggest poor availability of water seepage.

The project site is underlain by folded Tertiary-Quaternary sedimentary rocks and clastic. Presence of folded structures is discernible on several outcrops of sedimentary rocks. Most observable fold structures are anticlines and synclines in the area between Barangay Langub and Waan which will be crossed by the tunnel alignment. This structural morphology in around the tunnel alignment is characteristic feature of hogback and monoclonal ridges mostly underlain by folded Tertiary sedimentary rocks.

2) Geological Features

The stratigraphic sequence of the subsoil and rock types found along the bypass road and surrounding area is shown in **Table 10.1-2** based on the mapping of the Mines and Geosciences Bureau Region XI.

In addition the geological map of the site is shown in **Figure 10.1-1**.

TABLE 10.1-2 STRATIGRAPHIC SEQUENCE OF SUBSOIL AND ROCK TYPES FOUND ALONG BYPASS ROAD AND SURROUNDING AREA

Formation	Description	Geologic Age
Alluvium	Loose, unconsolidated gravel, sand and clay deposits	Holocene (Recent)
Tigatto Terrace Gravel	Loosely stratified gravel and sand deposits	Holocene

Formation		Description	Geologic Age
Bunawan Limestone		Coralline limestone	Late Pleistocene
Apo Volcanic Complex	Apo Volcanics	Intercalated pyroclastics and volcaniclastics with lenses of volcanic ash	Pleistocene
	Talomo Volcanics	Volcanic flows with intercalated pyroclastics, tuff and volcaniclastics	Pleistocene
	Apo-Talomo Volcanic Cones	Andesitic-dacitic volcanic lava	Pleistocene
Mandog Formation		Interbedded consolidated sand and clay with minor gravels	Early to Late Pleistocene
Masuhi Formation		Interbedded sandstone and shale with lenses of conglomerate	Late Miocene to Early Pliocene

Source: Modified from "Mines and Geo-Sciences Bureau"

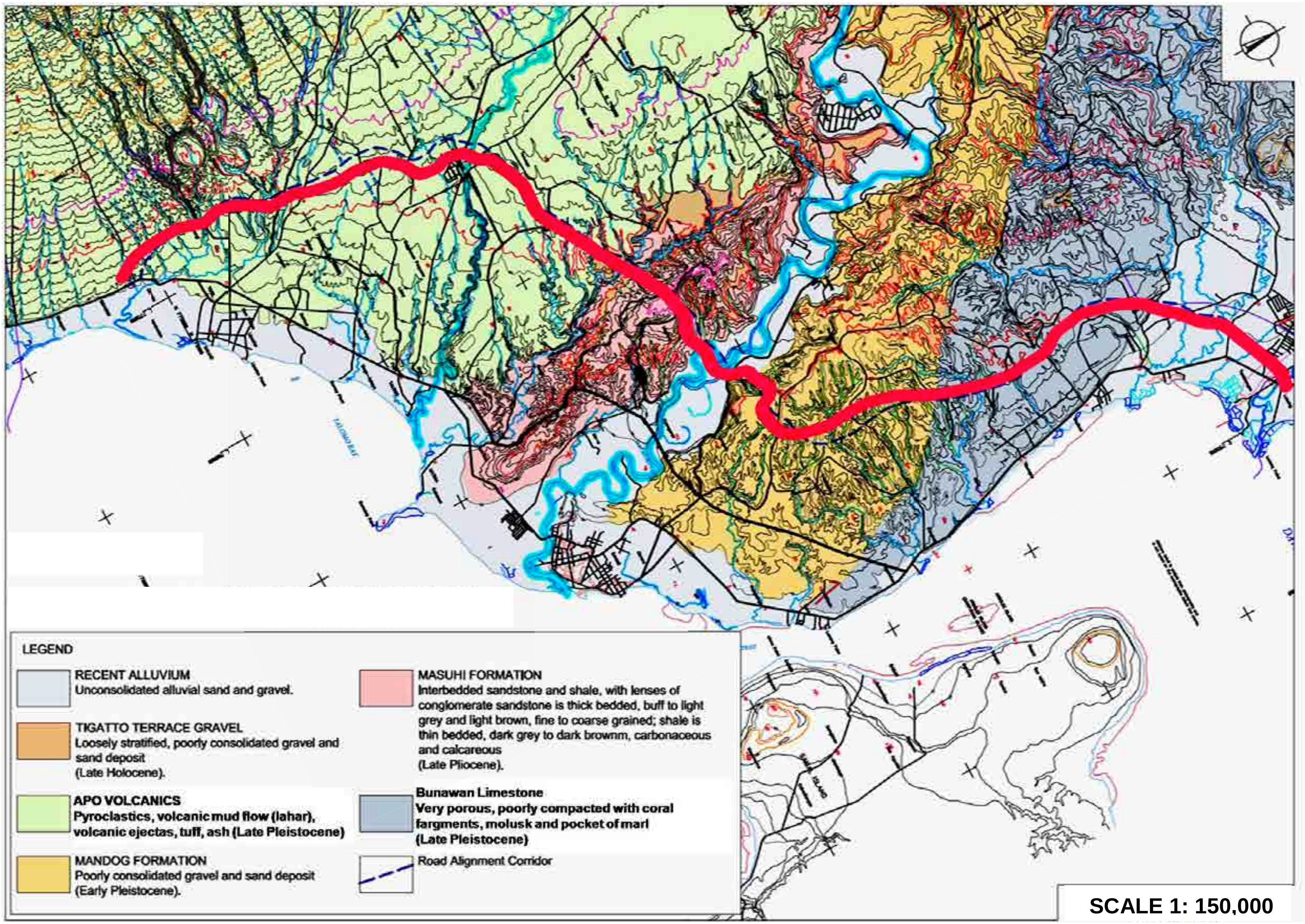


FIGURE 10.1-1 GEOLOGICAL MAP OF THE SITE

The summaries of each subsoil and rocks along the bypass road and surrounding area are as follows:

(a) Alluvium

The alluvium is deposits consisting of alternation layers of soft cohesive soil, loose sandy soil and gravels of Holocene (Recent). This alluvium is mainly laid at the area along Davao River and the end point area of the bypass road (northeastern area).

(b) Tigatto Terrace Gravel

The Tigatto Terrace Gravel is deposits consisting of poorly stratified, poorly compacted layers of gravel and sand with thickness of 0.5-2.5m.

The gravels are mainly rounded gravel, and the maximum size is 20cm diameter.
The sand layers are poorly compacted and consolidated. Also those are composed of moderately sorted grains which are fine to very coarse grains and sub-rounded to rounded grains.

PHOTO 10.1-1 OUTCROP OF TIGATTO TERRACE GRAVEL

(c) Bunawan Limestone

The Bunawan Limestone is the raised coralline limestone and coral breccias found in Matina Hill and Barangay Bunawan. This limestone is porous and cream color.

Incidentally, Bunawan Limestone is the equivalent of Samal Limestone in the published geologic map of the Mines and Geosciences Bureau.

PHOTO 10.1-2 OUTCROP OF TIGATTO BUNAWAN LIMESTONE

(d) Apo Volcanic Complex

The Apo Volcanic Complex which was created in the Pleistocene is composed of basalt, andesite, pyroclastic rocks, pyroclastic flows and volcanic mud flows.

Incidentally, because the basaltic flows are overlain by more recent andesitic flows, the outcrop of basalt of Apo Volcanic Complex cannot practically be found.

The Apo Volcanic Complex can be separated into three groups which are Apo Volcanics, Talomo Volcanics and Apo-Talomo Volcanic Cones.

The Apo Volcanics are dominantly the intercalated pyroclastics and volcaniclastics with lenses of volcanic ash which are generally occupy the broad volcanic footslopes. It is thought the repetitive eruption episodes cause the ejecta deposition of wide area.

The Talomo Volcanics are composed of andesitic-basaltic volcanic flows with intercalated pyroclastics, tuff and volcaniclastics.

Also, the Apo-Talomo Volcanic Cones consist of andesitic-dacitic volcanic lava.

PHOTO 10.1-3 OUTCROP OF PYROCLASTIC FLOW IN APO VOLCANIC COMPLEX

(e) Mandog Formation

The Mandog Formation is composed of alternation layers of consolidated sand and clay with minor gravels. It unconformably overlies the Masuhi Formation.

In addition, the Mandog Formation is folded, and the fold of thin sequence of interbedded sand and clay with gravels is found at outcrops.

PHOTO 10.1-4 OUTCROP OF SAND GRAVEL IN MANDOG FORMATION

(f) Masuhi Formation

The Masuhi Formation is composed of interbedded sandstone and mudstone (claystone/siltstone) with lenses of conglomerate. It is the basement rock of the section of the proposed bypass road.

The Masuhi Formation is thought the marine sediment of Late Miocene-Pliocene. The range of thickness is estimated from 200-250m.

PHOTO 10.1-5 OUTCROP OF MUDSTONE IN MASUHI FORMATION

3) Regional Tectonism

The prominence of lineaments (rock discontinuities such as joints, fractures, beddings, faults) is related to the regional tectonic setting.

The proposed bypass road is located at the southern end of the Agusan-Davao Basin. It is north-south trending elongated basin of 350 km located between the Pacific Cordillera and the Central Mindanao Cordillera.

In Mindanao, the Central Mindanao Cordillera, Agusan-Davao Basin and Pacific Cordillera are part of the Philippine arc. The Central Mindanao Cordillera is thrust westwards over the Lanao-Bukidnon Highlands. Also the Pacific Cordillera is thrust westwards over the Agusan Davao Basin.

The Saranggani Ridge, Davao Gulf and Pujada Peninsula respectively correspond to the volcanic arc, forearc basin and forearc of the Saranggani arc. Saranggani Ridge is convex to the east and is being thrust eastwards over the Davao Gulf.

4) Geo-Structure and Seismicity

The Davao City where the proposed bypass road is located is within a region that is tectonically, seismically and volcanically active. There are several active faults in the region according to **Figure 10.1-2** mapped by PHIVOLCS. Incidentally by the definition, an active fault is one that has moved during the last 10,000 years.

The active or potentially active faults within the 100km radius of the proposed project site are as follows:

(a) Philippine Fault

The Philippine Fault is an active left lateral strike slip fault that cuts across the entire length of the Philippine archipelago over a distance of 1,200 km. The southern segment of the Philippine Fault cuts across eastern Mindanao.

The Davao portion of the fault is associated with a seismic fault where stress is building up and is not being released. Despite its low level of seismic activity, the risk of a major earthquake occurring is actually higher.

The studies done by Quebral (1994) revealed the Philippine fault in the southeastern Mindanao have numerous splay faults not reflected in the PHIVOLCS map (Refer **Figure 10.1-2**).

(b) Davao Gulf Reverse Faults

The faults within the Davao Gulf are important tectonic feature it is not reflected in the PHIVOLCS map. By Wells and Coppersmith empirical relation between fault length and magnitude (1994), these faults can generate approximately 7.2 magnitude earthquake, and become a potential near-source of the tsunami generator against Davao City.

The coastal areas around the Davao Gulf have experienced historical events as in the 17 August 1976 Moro (Davao) Gulf earthquake with computed magnitude of 7.9 in the Richter Scale. The generated tsunami by this earthquake was about 6 meters high that inundated the coastal areas of Davao City. Moreover, It has a velocity of 72km/h and rushed up to 500m inland, leaving damages of 3,564 dead, 1,502 missing , 8,256 wounded, and 12, 183 families homeless (Cabanlit, 2010).

(c) Philippine Trench

The Philippine Trench is one of the two subduction zones that bound the Philippines. It runs a few kilometers offshore of the eastern coastline where the West Philippine Sea plate is being consumed along the west-dipping Philippine Trench. Also, the Philippine Trench is the most seismically active earthquake generator in the Philippines, hosting a big percentage of earthquakes that happened in Mindanao (Cabanlit 2010).

(d) Central Mindanao Fault

The Mindanao Central Cordillera is thrust westwards over the Lanao-Bukidnon Highlands along the Central Mindanao Fault which is north-south trending fault that extends all to Ginoog Bay in the north. In the south, the Central Mindanao Fault runs through the pyroclastic apron of Mount Talomo which is a major Quaternary stratovolcano.

The moderate earthquakes and focal mechanism solutions over the Bukidnon area suggest that the fault might still be active.

(e) Diwata Fault

The north-south trending escarpment formed by the Diwata Fault separates the Pacific Cordillera of Diwata area from the Agusan Davao Basin. This fault is not a splay fault of the Philippine Fault. It is a thrust fault that the cordillera is thrust westwards over the basin.

(f) Saranggani Thrust

The Saranggani Ridge is asymmetrical with a steep eastern flank and a gentle western flank. The anticline, which is convex to the east, is being thrust to the east along an assumed Saranggani Thrust which is associated with earthquake epicenters and thrust focal mechanism solutions.

(g) Daguma Fault

The Daguma Fault, characterized by a prominent NW-SE trending escarpment, separates the Daguma Range from the Cotabato Basin. The 165 kilometer fault, characterized by a prominent NW-SE trending, NE-facing escarpment, is a normal fault with the Daguma Range being on the up-thrown side and the Cotabato Basin being on the down-thrown side. Normal faulting may be attributed to back arc extension of the Cotabato Trench.

There are seismic and geologic indications that the fault is active like seismic reflection profiles and the sharp morphology (Quebral 1993). Along its southeastern end, the fault cuts Quaternary limestone.

5) Considerations for Seismic Design

The near faults that can generate large-scale magnitude earthquake in the area of the proposed bypass road are the Philippine Fault in the northeastern portion and the Davao Gulf Reverse Faults in the southwestern. The Philippine Fault is situated at approximate distances of 5-10km northeast from the north end point of the bypass road. Also, the Davao Gulf Reverse Faults are situated at southern from the vicinity of Samal Island.

Therefore, the earthquake by these active faults should be considered in designing the main structures such as bridges.

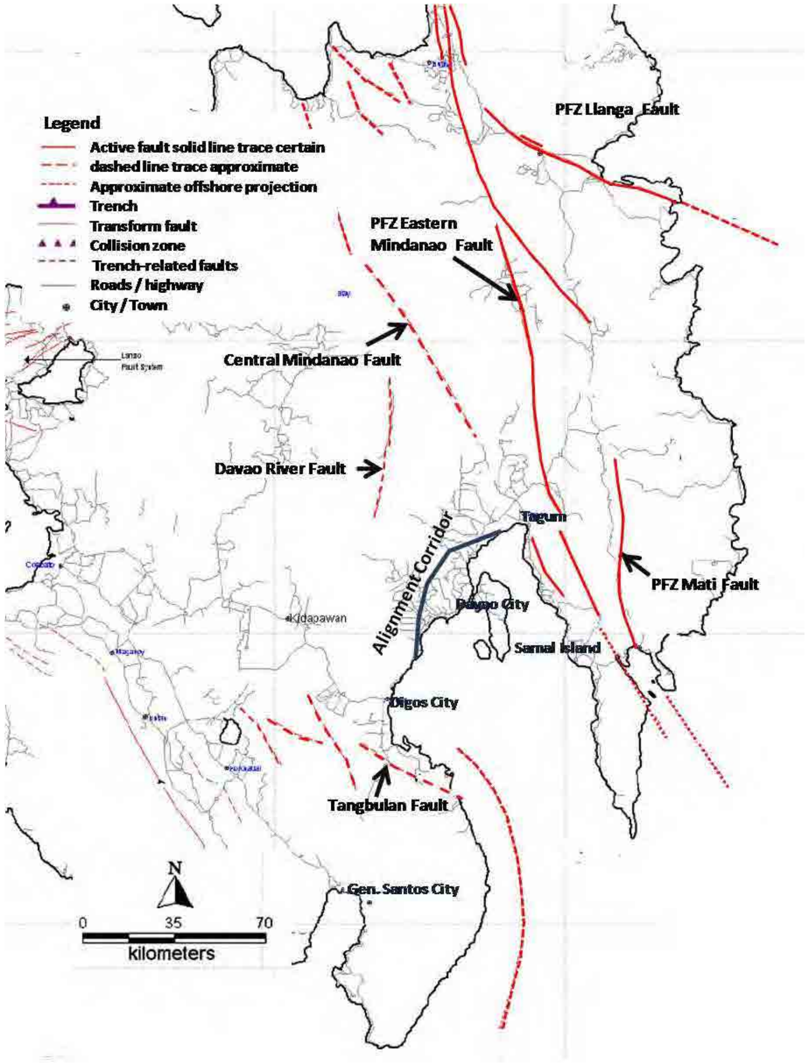
The National Structural Code of the Philippines (NSCP1997) prescribes a value of the design ground acceleration. The value of the design ground acceleration is 0.4g (A=0.4), because the site of the bypass road is situated in the Seismic Zone 4.

6) Potential of Liquefaction

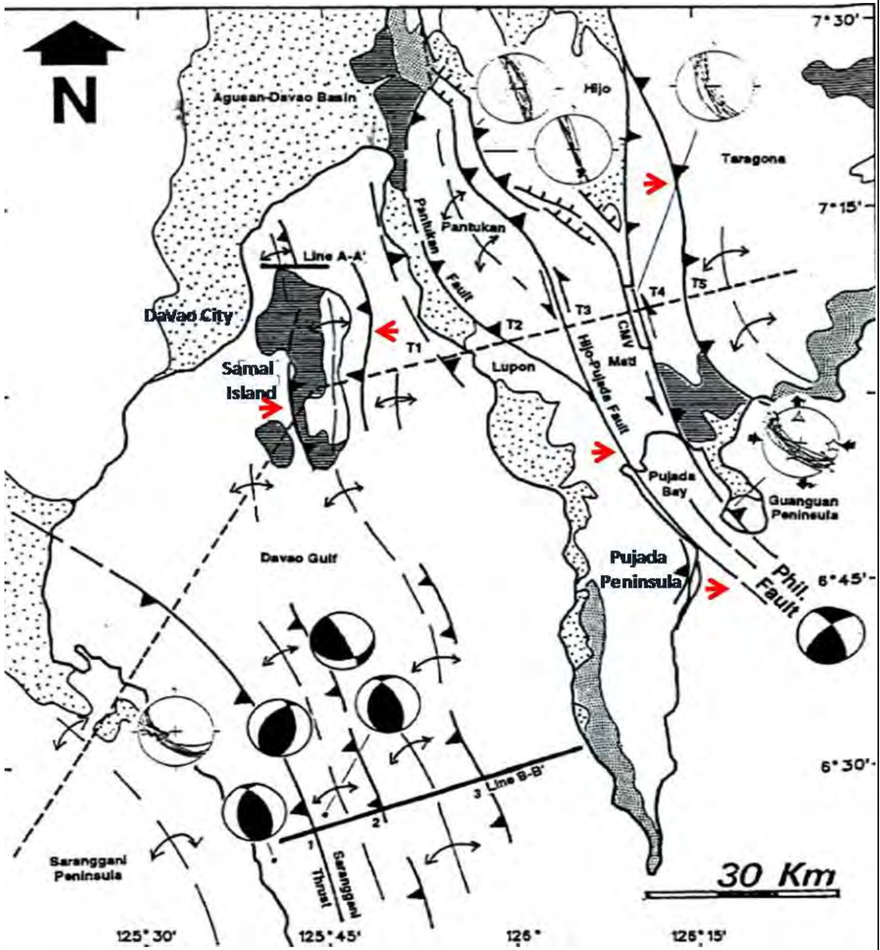
The lowlands of the area of along Davao River and the end point area of the by-pass road (northeastern area) are formed by the alluvium. The alluvium is composed of alternation layers of cohesive soil and sandy soil which are deposits of Holocene (Recent).

The thickness of alluvium along the Davao River is 15-20m, and consisting mainly of cohesive soil. Therefore, a possibility of the consolidation settlement is low, but there is a possibility of liquefaction during the earthquake.

The lowland of the end point area is alluvial lowland formed by Bunawan River (including Tagurot River, Lacanon River) and Lasang River (including Maduao River), the thickness of alluvium is very thick at 40-60m. So, there is a possibility which both the consolidation settlement and the liquefaction would be a problem. Particularly, since the ground of this lowland is mainly a thick soft ground of cohesive soil, there is a possibility which the consolidation settlement occurs over a long period of time, when the embankment is carried out. Therefore, the considerations such as avoidance of the high embankment and an examination of the negative skin friction at the design of pile foundation are necessary when the bypass road is constructed.



Map Showing Active Fault and Trenches (From PHIVOLCS)



Structural map of the southeast Mindanao with focal mechanism, Legend: Recent (dotted) Pleistocene (dashed, Late Miocene (densely dotted). Red arrows points to fault lines not reflected in PHIVOLCS map. From Quebral 1994

FIGURE 10.1-2 MAPS SHOWING ACTIVE FAULTS IN SOUTHEASTERN MINDANAO

(2) Investigation Items and Locations

Investigation items and quantities of the geological survey are shown in **Table 10.1-3**. The locations conducted investigations are shown in **Figure 10.1-3**, and **Figure 10.1-4**. Test pit and auger boring was conducted from 6+300 to 17+400 and from 35+500 to 44+600.

TABLE 10.1-3 INVESTIGATION ITEMS AND QUANTITIES

Items		Unit	Bridge site	Tunnel section	Low embankment section	Total
Boring	Number of boreholes	holes	20	8	-	28
	Total Length	m	548	585	-	1,133
Standard Penetration Test		each	548	290	-	838
Seismic Velocity Logging		each	-	137	-	137
Test pit		each	-	-	20	20
Auger boring		each	-	-	20	20
Laboratory Test of Soil and Rock Samples	Specific Gravity of Soil	samples	60	40	40	140
	Natural Moisture Content of Soil	samples	60	40	40	140
	Grain Size Analysis of Soil	samples	60	40	40	140
	Atterberg Limits of Soil	samples	30	20	20	70
	Unit Weight (Wet Density) of Rock	samples	-	20	-	20
	Axial compression test of Rock	samples	-	20	-	20
	Auger-boring	samples	-	-	20	20

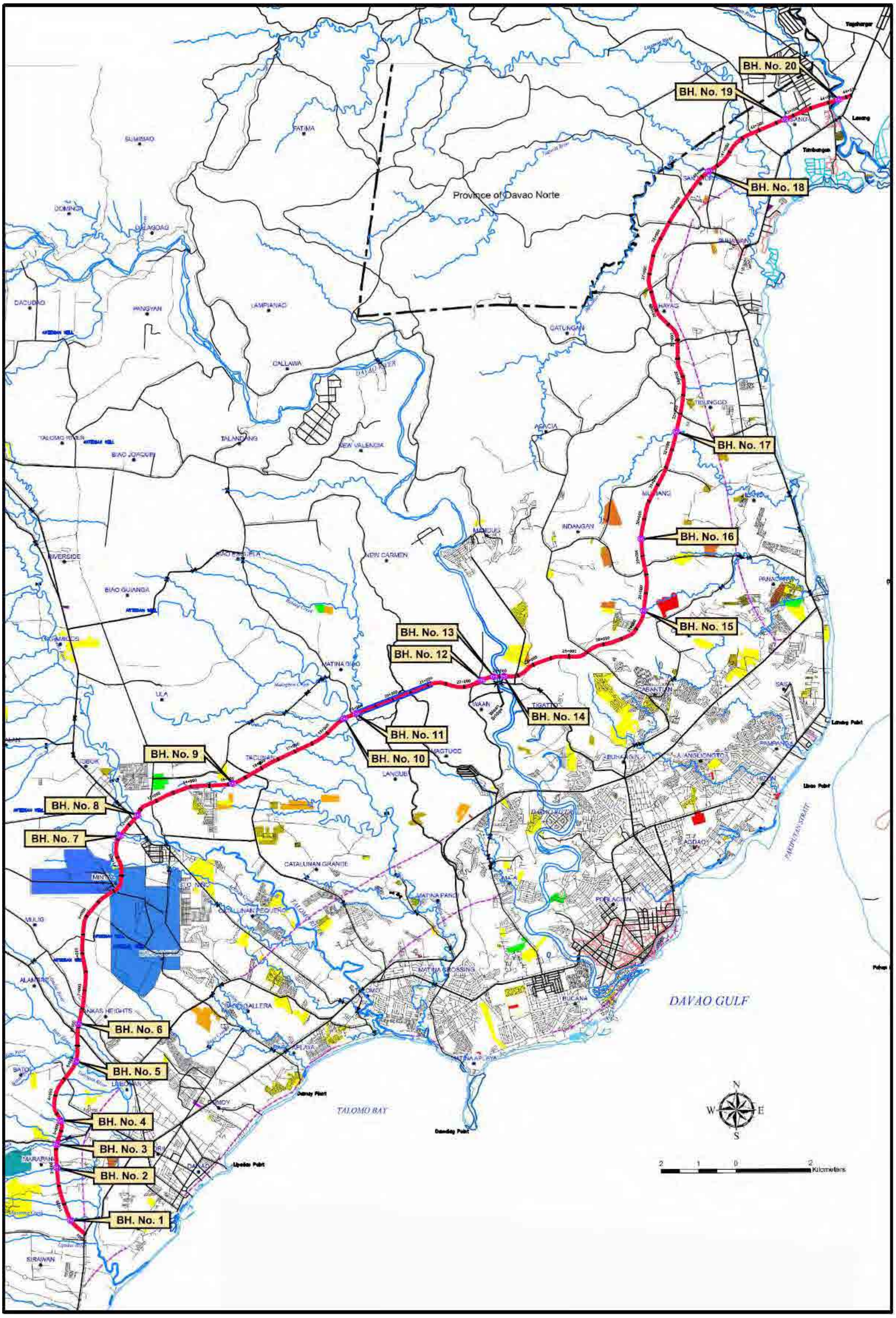


FIGURE 10.1-3 BRIDGE SITE BORING LOCATION MAP

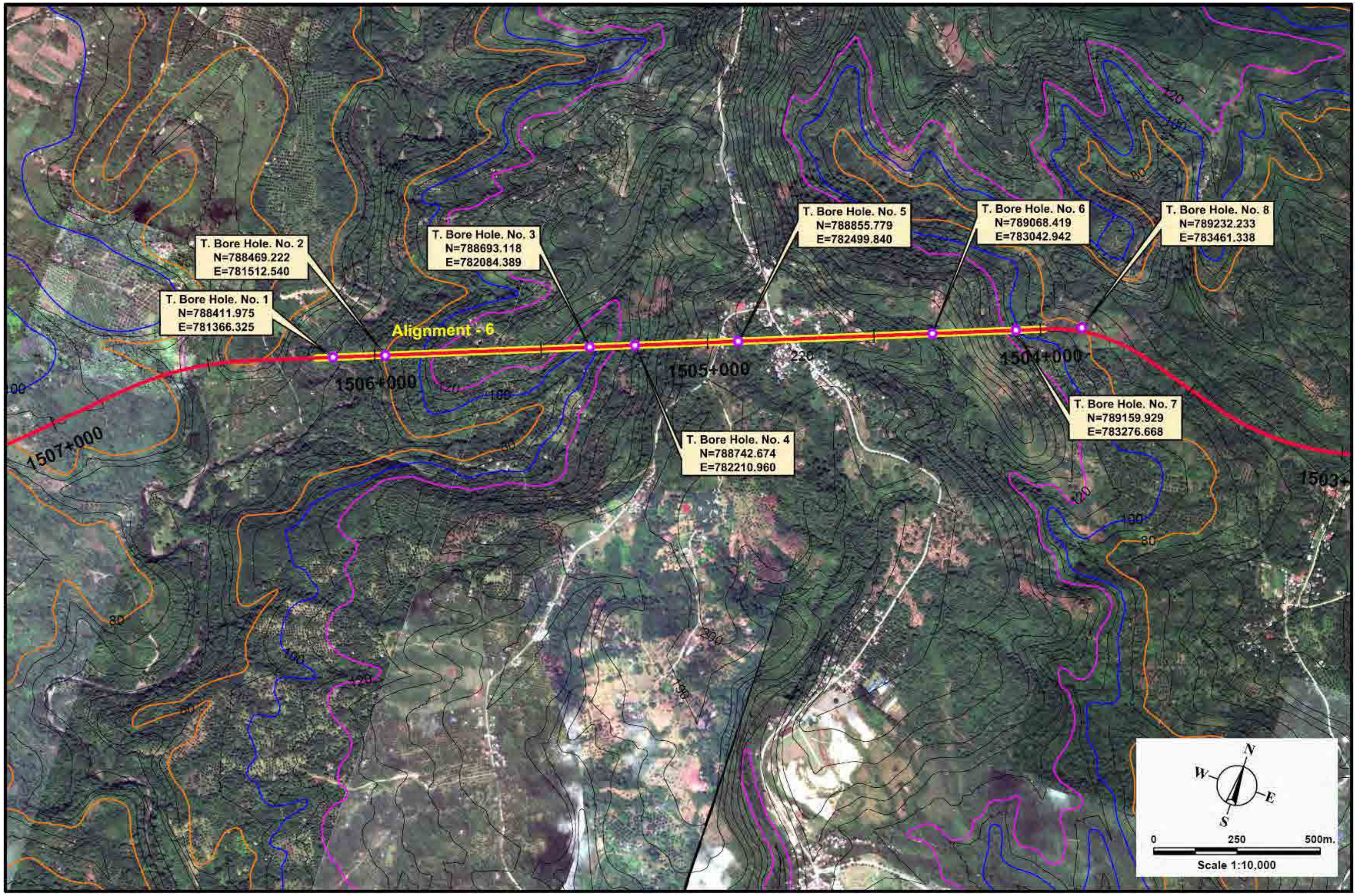


FIGURE 10.1-4 TUNNEL SECTION BORING LOCATION MAP

(3) Investigative Method

1) Boring

The boring which is non-core for soils and all-core drilling for rocks was performed by rotary boring machine. Drilling-diameter had been the φ66mm or more which is possible in-situ tests (Standard Penetration Test and Seismic Velocity Logging).

2) Standard Penetration Test

The standard penetration test was carried out according to ASTM D-1586 at intervals of 1 meter (depth) in the borehole.

3) Seismic Velocity Logging

The velocity logging was performed according to ASTM D-7400 by the down-hole method at intervals of 2m (depth) in the boreholes of tunnel section. The measurement depth had been up to about 50m which is measurable depth of the down-hole method.

4) Test pit and Auger boring

Test pit and auger boring were carried out alternately at about 500-meter intervals at the low embankment section.

The test pits were excavated at sizes of 1 square meter with the depth of 1 meter in principle. And the soil samples for the laboratory tests of CBR tests and etc. were obtained from the test pits.

The auger boring was drilled until 1 meter depth in principle.

5) Laboratory Test of Soil and Rock Samples

Laboratory test of soil and rock samples were carried out on the basis of the standards shown in **Table 10.1-4**.

TABLE 10.1-4 APPLIED STANDARDS FOR LABORATORY TEST

No.	Test Items	Ref. standard No.
1	Specific Gravity of Soil	ASTM D-854
2	Natural Moisture Content of Soil	ASTM D-2216
3	Grain Size Analysis of Soil	ASTM D- 422
4	Atterberg Limits of Soil	ASTM D-4318
5	Soil Description and Classification	ASTM D-2487
6	Unit Weight (Wet Density) of Rock	BS 1377-part 2-7
7	Axial compression test of Rock	ASTM D-2938
8	CBR (California Bearing Ratio) Test	ASTM D-1883

(4) Summary of Results and Findings

1) Bridge Site Investigation Results

Boring, standard penetration test and laboratory test of soil samples were carried out at 20 locations shown in **Figure 10.1-3**, as the investigation of bridge sites. Depths of boring at BH-18, 19 and 20 are more than 35m. These are has a thick presence of very soft to very loose fluvial sediments. BH-1 to BH-17 shows a favorable subsurface condition.

Summary of the survey results are shown in **Table 10.1-5**.

TABLE 10.1-5 SUMMARY OF BRIDGE SITE INVESTIGATION RESULTS

Boring No.	Coordinates		Elevation (GL) (m)	Drilled Depth (GL-m)	Ground Water Level (GL-m)	Depth of Bearing Stratum (GL-m)
	Northing (X-coordinate)	Easting (Y-coordinate)				
BH-1	774830.341	773771.625	41.890	25.0	16.00	2.0
BH-2	776217.359	773539.610	41.298	25.0	15.60	2.0
BH-3	776868.665	773514.471	48.578	25.0	13.80	1.0
BH-4	777509.505	773806.947	50.374	25.0	16.80	3.0
BH-5	779022.566	773882.248	84.316	25.3	12.35	2.0
BH-6	780080.905	774063.112	110.504	25.0	7.50	6.0
BH-7	785049.379	775121.286	139.959	25.0	9.00	6.0
BH-8	785686.768	775691.242	139.856	25.0	18.70	9.0
BH-9	786504.879	777985.845	144.662	10.0	-	5.0
BH-10	788237.480	781195.323	82.558	25.3	13.80	2.0
BH-11	788338.456	781413.040	44.994	25.3	3.15	3.0
BH-12	789242.109	784737.284	12.360	27.1	3.80	22.0
BH-13	789355.205	785066.731	12.510	30.3	5.00	16.0
BH-14	789376.769	785365.964	11.150	25.0	5.60	11.0
BH-15	791115.132	789076.432	30.083	10.3	8.20	4.0
BH-16	792974.033	789000.648	68.132	8.3	4.20	4.2
BH-17	795964.260	789899.020	26.100	18.4	1.00	14.0
BH-18	802794.290	790816.630	11.020	45.45	3.60	35.0
BH-19	804205.502	792995.520	7.171	57.45	1.30	40.0
BH-20	804700.925	794328.247	5.215	65.45	5.60	61.0

Note: - In principle, "Depth of Bearing Stratum" was determined at the top of layer which is consecutive N-value of 20 or more in the case of cohesive soil layer, it is consecutive N-value of 30 or more in case of the sandy soil layer.

2) Tunnel Section Investigation Results

Boring, standard penetration test, seismic velocity logging and laboratory test of soil and rock samples were carried out at 8 locations shown in **Figure 10.1-4**, as the investigation of tunnel section. Summary of the survey results are shown in **Table 10.1-6**. And based on the boring result, the uppermost material consists of sand and clay layer, with recorded blow counts between 14<N<45 in the upper stretches of layer and hitting practical refusals towards the bottom (60>N). This is then followed by a thick sequence of bedrock formation describe in the logs as claystone/mudstone.

P-wave velocity of mudstone, silt, and sandstone in this area shows common figures, ranging 1,200 ~ 1,800 m/sec. Based on P-wave test result, these layers is classified as soft rock layer. It is assumed that there is no aquifer layer between the surface and tunnel plan layer based on the result of the P-wave velocity 1,500 m/sec. So special counter measures shall not be required for underground water of tunnel construction.

The geological profile of tunnel section is shown in **Figure 10.1-5**.

TABLE 10.1-6 SUMMARY OF TUNNEL SECTION INVESTIGATION RESULTS

Boring No.	Coordinates		Elevation (GL) (m)	Drilled Depth (GL-m)	Tunnel Planning Depth (TPD) (GL-m)	P-wave Velocity of TPD (km/sec)
	Northing (X-coordinate)	Easting (Y-coordinate)				
TBH-1	788349.714	781474.675	58.214	30.0	-	-
TBH-2	788429.558	781609.701	83.309	65.0	14.0～21.0	1.2～1.4
TBH-3	788692.269	782105.384	144.659	35.0	74.0～81.0	0.7
TBH-4	788740.799	782314.508	139.256	80.0	66.0～75.0	1.6
TBH-5	788818.141	782623.423	213.658	160.0	141.0～148.0	-
TBH-6	788987.929	783133.111	191.716	130.0	120.0～127.0	1.1～1.2
TBH-7	789107.554	783498.885	115.009	55.0	46.0～53.0	1.2～1.8
TBH-8	789241.484	783565.112	85.466	30.0	17.0～24.0	0.6～0.9

Note: - "Ground water level in boreholes" was not determined because the geological feature of the boring site is mainly composed of mudstone (it is not an aquifer) of low permeability.

- "The depth from top to bottom" of the tunnel is shown at "Tunnel Planning Depth" in the table.

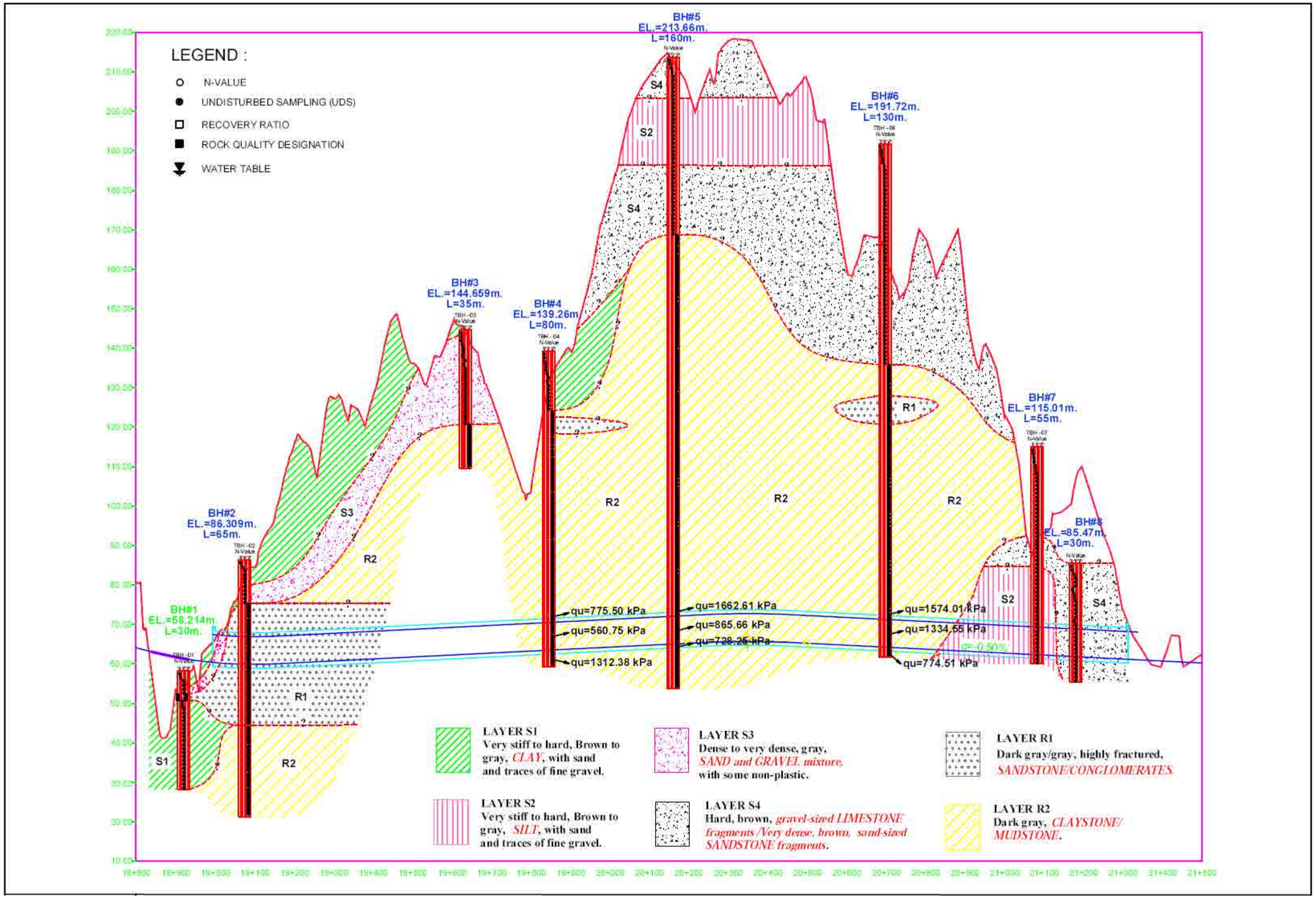


FIGURE 10.1-5 GEOLOGICAL PROFILE OF TUNNEL SECTION

3) Low Embankment Section Investigation Results

Laboratory test (physical test, CBR test) of soil samples taken at each location were carried out. Based on the field and laboratory test results of the twenty (20) test pits and twenty (20) auger holes, the excavated soils taken at the uppermost 1.2 to 2.0 meters depth mainly consisted of cohesive materials described as clay, with some content of sand. Summary of the survey results are shown in **Table 10.1-7**.

TABLE 10.1-7 SUMMARY OF LOW EMBANKMENT SECTION INVESTIGATION RESULTS

Test-pit				Auger-boring		
TP No.	Survey Depth (m)	Soil Description	CBR (%) @95% MDD	AB No.	Survey Depth (m)	Soil Description
TP-1 6+300	0 – 1.00	Clay w/ sand & gravel	11.0	AB-1 6+800	0-1.00	Gray, CLAY, medium plastic, with sand.
TP-2 7+300	0 – 1.00	Clay	3.1	AB-2 7+800	0-0.70 / 0.70-1.00	Brown, CLAY, with sand. / Brown, CLAY, medium plastic, with sand.
TP-3 8+300	0.80 – 1.00	Clay	3.7	AB-3 8+800	0-1.00	Brown, CLAY, medium plastic, with sand.
TP-4 9+400	0.20 – 1.00	Clay	3.3	AB-4 9+800	0-1.00	Brown, sandy CLAY, medium plastic.
TP-5 10+200	0.60 – 1.00	Clay	3.1	AB-5 10+800	0-0.40	Brown, CLAY, high plastic.
TP-6 11+300	0.30 – 1.00	Clay	2.8	AB-6 11+800	0-1.00	Dark brown, silty CLAY, slightly plastic, with sand.
TP-7 12+400	0 – 1.00	Clay w/ sand	7.0	AB-7 12+800	0-1.00	Dark brown, sandy CLAY, medium plastic.
TP-8 13+300	0 – 1.00	Clay w/ sand & gravel	8.8	AB-8 13+800	0-0.20 / 0.20-0.50	Brown, CLAY, with gravel and boulders./ Gray, silty CLAY, medium plastic, with sand and fine gravel.
TP-9 14+200	0.70 – 1.00	Clay	5.6	AB-9 14+800	0-0.90 / 0.90-1.00	Dark brown, CLAY, with some sand and fine gravel. / Gray, silty CLAY, medium plastic, with sand and fine gravel.
TP-10 15+600	0.30 – 1.00	Clay	3.6	AB-10 16+500	0-0.30 / 0.30-1.00	Brown, silty CLAY, with traces of sand. Brown, CLAY, high plastic, with sand.
TP-11 17+400	0 – 1.00	Clayey Gravel	15.0	AB-11 35+500	0-0.30 / 0.30-1.00	Dark brown, CLAY / Brown, CLAY, high plastic, with sand.
TP-12 36+000	0.60 – 1.00	Clay	4.4	AB-12 36+500	0-0.15 / 0.15-1.00	Brown, CLAY, with some fine gravel./ Brown, CLAY, high plastic, with sand.

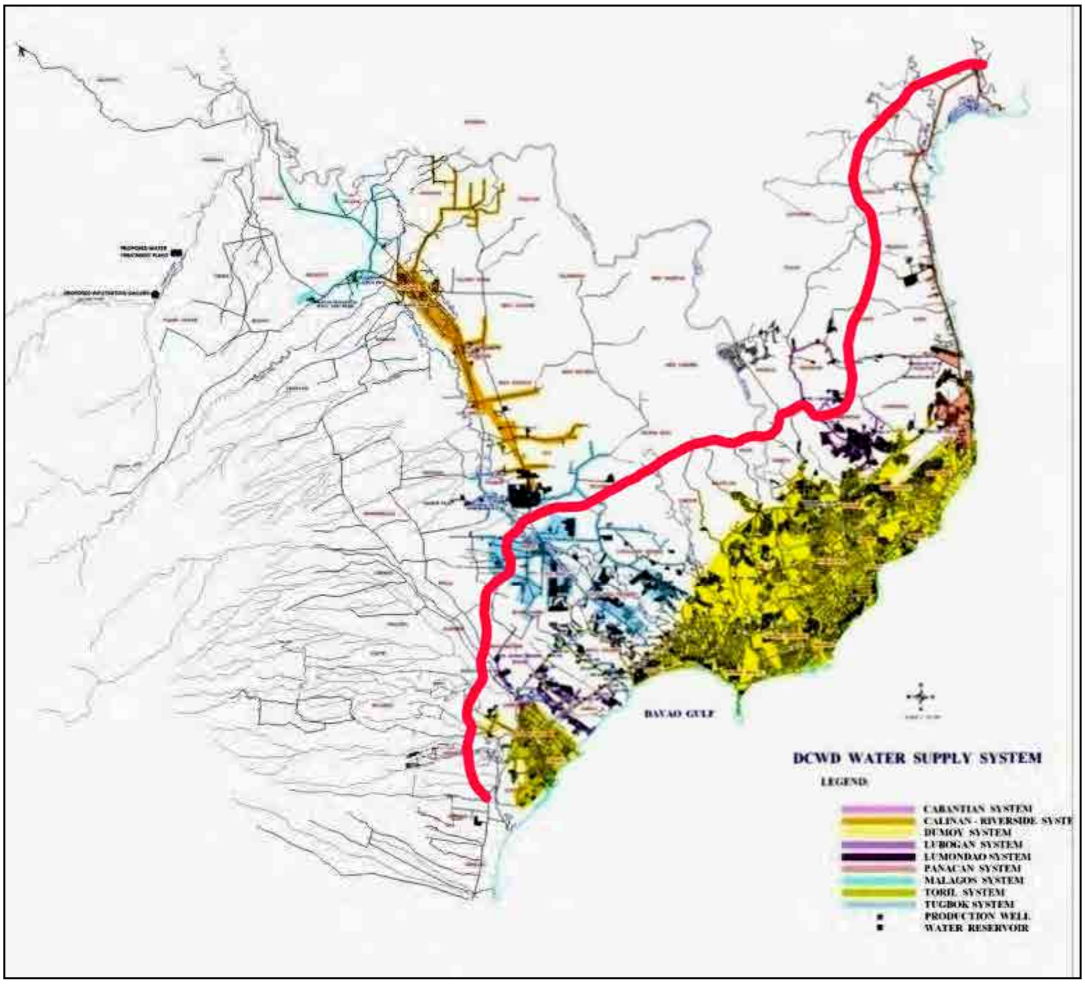
Test-pit				Auger-boring		
TP No.	Survey Depth (m)	Soil Description	CBR (%) @95% MDD	AB No.	Survey Depth (m)	Soil Description
TP-13 36+900	0.60 – 1.00	Clay	5.2	AB-13 37+400	0-0.90 / 0.90-1.00	Gray, CLAY, high plastic, with fine gravel./ Gray, CLAY, high plastic, with sand.
TP-14 37+900	0.40 – 0.95	Clay w/ limestone fragments	11.0	AB-14 38+400	0-0.30 / 0.30-1.00	Dark gray, silty CLAY, slightly plastic,with fine gravel and sand./ Brown, silty CLAY, medium plastic, with sand and fine gravel.
TP-15 39+000	0.25 – 1.00	Clay	3.6	AB-15 39+700	0-0.15 / 0.15-1.00	Dark gray, sandy CLAY./ Brown, sandy CLAY, medium plastic.
TP-16 40+200	0.70 – 1.00	Sand & Clay	9.8	AB-16 40+700	0-0.10 / 0.10-0.90 / 0.90-1.00	Brownish gray, CLAY, with sand./ Light brown, CLAY, medium plastic, with sand./ Light brown, CLAY, medium plastic, with sand.
TP-17 41+200	0 – 1.00	Clay	5.2	AB-17 41+700	0-1.00	Brownish gray, silty CLAY, medium plastic, with sand.
TP-18 42+200	0 – 1.00	Clay	6.5	AB-18 42+700	0-0.15 / 0.15-1.00	Dark brown, silty CLAY./ Light brown, clayey SAND, slightly plastic
TP-19 43+200	0 – 1.00	Clay	5.8	AB-19 43+700	0-1.00	Brown, silty CLAY, medium plastic, with sand.
TP-20 44+200	0 – 1.00	Sand & non-plastic Silt	17.0	AB-20 44+600	0-1.00	Brown, silty CLAY, medium plastic, with sand.

Source: JICA Study Team

10.1.4 Other Geo-technical Information

(1) Surface Water and Groundwater

The data of the surface water and groundwater in Davao City were gathered from studies done by Asian Development Bank (2012), MGB Region XI and those from Davao City Water District. The Davao City Water District (DCWD) is the country's largest district since its creation in 1973. It covers about 106 barangays (about 58% of the total 182 barangays within its jurisdiction). DCWD manages nine water supply systems, which consists of the Cabantian, Calinan, Dumoy, Lubogan, Lumandao, Malagos, Panacan, Toril and Tugbok as shown **Figure 10.1-6**.



Source: Final Report- Feasibility Study on the Use and Development of Surface Water of Tamugan River, June 2010, DCWD

FIGURE 10.1-6 DCWD SERVICE AREAS

The current raw water source of DCWD is not sufficient to meet the increasing demand. The groundwater source is concentrated at Barangay Dumoy located at the skirts of Mount Apo and Mount Talomo, where DCWD operates more than 30 deep wells. Also only small amount of surface water, the water of 36 liters/sec is withdrawn from the Malagos Creek it is a small tributary of the Davao River.

The capacities of the nine systems serving the overall DCWD service areas are summarized in **Table 10.1-8**. As some of the barangays are served by more than one of the water sub-systems and the total of served barangays are more than 106, as indicated in the table. As of 2012, the number of active connections are 174,108 consisting of 167,780 domestic connections, 5,698 commercial and bulk consumers and 630 government consumers.

The capacities of the nine systems serving the overall DCWD service areas are summarized in **Table 10.1-8**. As some of the barangays are served by more than one of the water sub-systems and the total of served barangays are more than 106, as indicated in the table.

Although the data in **Table 10.1-8** is the data of 2010, as of 2012, the numbers of active connections are increased 174,108 consisting of 167,780 domestic connections, 5,698 commercial and bulk consumers and 630 government consumers.

TABLE 10.1-8 DCWD SERVICE AREA AND CONNECTIONS

No.	Water Supply System	Number of Barangays Served	Population Served	Number of Connections		
				Domestic	Commercial and Bulk	Government
1	Cabantian	3	30,128	6,017	30	11
2	Calinan	11	19,873	3,950	101	23
3	Lubogan	6	27,051	5,406	14	5
4	Lumandao	1	56	11	1	0
5	Dumoy	71	553,175	109,584	4,825	428
6	Malagos	3	3,973	793	2	5
7	Panacan	6	32,734	6,516	123	29
8	Toril	8	32,836	6,527	170	33
9	Tugbok	10	84,056	16,763	145	95
Total		119	783,882	155,567	5,411	629

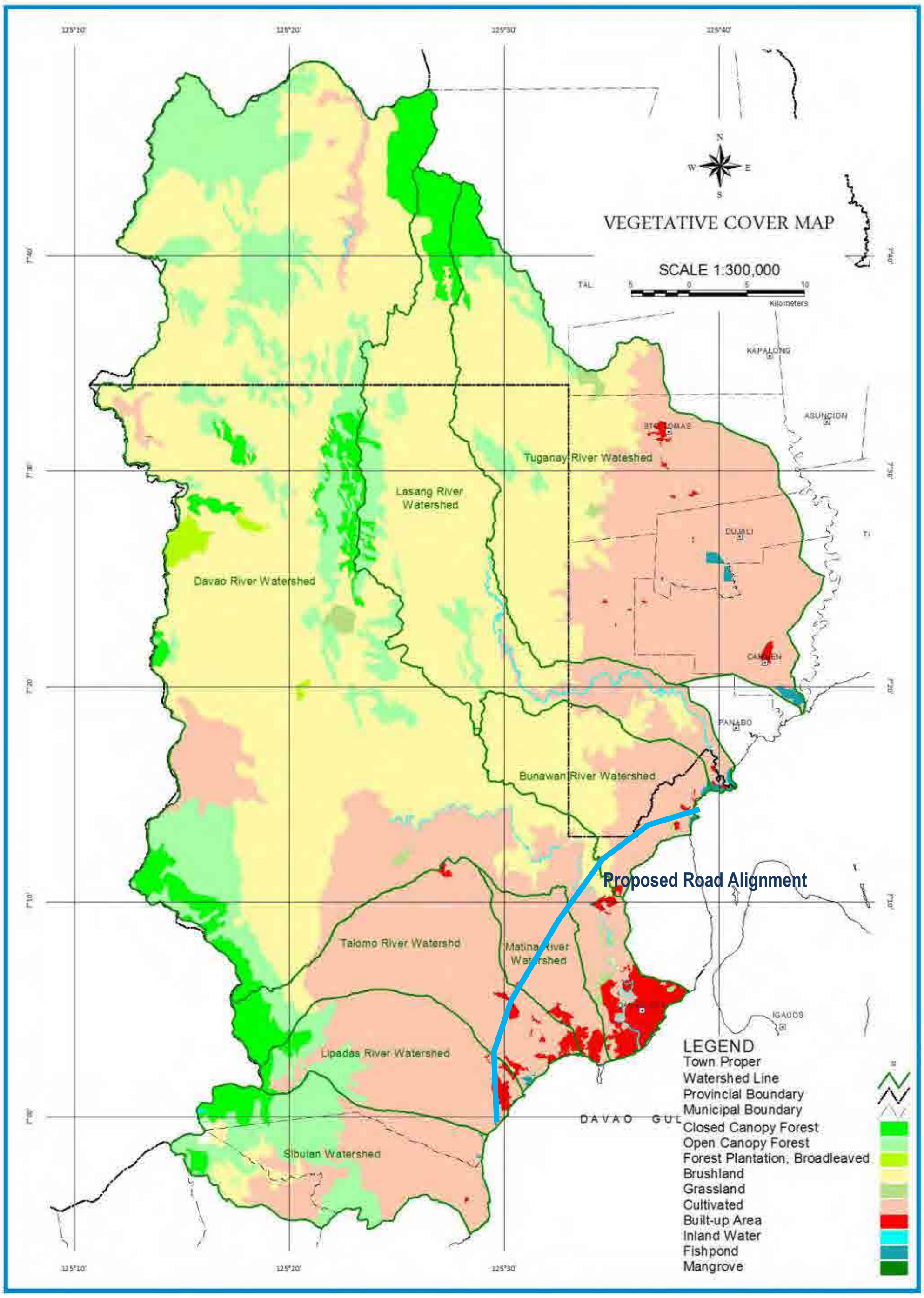
Source: Final Report- Feasibility Study on the Use and Development of Surface Water of Tamugan River, June 2010, DCWD

The raw water will only supply 43% of Davao City's projected population of 2.5 million in 2030 in the capacity without expansion of the water source. There are already some problems as polluted coastal aquifers, decreasing levels of groundwater, increasing land subsidence and saltwater intrusion due to over-extraction of ground water. And these problems compel the need to tap reliable surface water as supply sources.

DCWD intends to shift from groundwater dependent to surface water first. But a move to secure the future source of water for the city is late, due to fear of groundwater contamination by pesticide from the extensive banana plantations and farms on the skirts of Mount Talomo and along the Davao River.

1) Watershed of Surface Water

Davao City's political boundaries overlap eight different watersheds (refer **Figure 10.1-7**) where the Talomo-Lipadas watershed is a major source of drinking water. Ninety nine percent (99%) of the urban population of Davao City get their drinking water from within these river basins.



Source: City Planning and Development Office, Davao City

FIGURE 10.1-7 MAP SHOWING VEGETATION COVER IN 8 WATERSHEDS WITHIN THE POLITICAL BOUNDARY OF DAVAO CITY

Table 10.1-9 provides a summary of the area of the river basins and the area percentage within the political boundary of the Davao city.

TABLE 10.1-9 SUMMARY OF AREA OF EIGHT RIVER BASINS THAT AREA WITHIN THE JURISDICTION OF DAVAO CITY

River Basin (RB)	Hectares in Davao City	% RB within the City	Total Hectares of 8 RB
Davao River	121,385	69%	175,776
Lasang	29,132	64%	45,390
Talomo	21,578	100%	21,578
Lipadas	16,796	100%	16,796
Bunawan	18,328	73%	25,213
Tuganay	18,120	24%	74,747
Sibulan	10,782	38%	28,213
Matina	7,879	100%	7,879
Total Area	244,000	62%	395,592

2) Groundwater Resources

Most of the water wells of DCWD are placed in Dumoy, and the rest of water wells are placed in Tugbok, Panacan, Toril, Dacoville, Batulosa, Lumondado, and Riverside. These wells have an average depth of 120-150 m.

The aquifers of groundwater in Davao City are recharged perennially by rainfall on the southern flanks of Mount Apo, Mount Tipolog and Mount Talomo. These areas are covered by highly porous pyroclastic materials and permeable highly fractured volcanics that receive and store sufficient groundwater to recharge the aquifers in the lowlands.

The aquifers in Davao City are classified based on rock types as below:

(a) Aquifer in Igneous Rock and Volcano clastics

Igneous rocks are poor aquifers with permeability confined along openings of fractures / fissures. Volcano clastics (e.g. pyroclastic flows, sandy tuff, tuff breccias and volcanic mud flows) are very porous and permeable, and there are natural features of very good aquifers.

(b) Aquifer in Sedimentary Rock

Groundwater flow in sedimentary rocks is influenced by the physical property, composition, lithology and faces. In general, coarse grained sedimentary rocks such as conglomerates and sandstones are good aquifers. But fine grained sedimentary rocks like mudstone, siltstone, or shale are poor aquifers due to very poor hydraulic permeability.

(c) Aquifer in Limestone

Limestone is excellent groundwater conveyor by the presence of cavities and caves. Coralline limestone in Davao City has a high percentage of openings that can hold high volume of groundwater. The downsides are the low filtration capacity and the property that is easy to be pollution.

(d) Aquifer in Unconsolidated Sediments

The unconsolidated sediments are mainly deposits of gravel, sand, silt and clay which are laid at the valley floor, alluvial and coastal plains. These are the materials produced by weathering and erosion of the bedrock.

In general, the sand layers of unconsolidated sediments are excellent and efficient aquifers. The porosity and permeability of sand layers are commonly high, but only to be reduced by infilling of fine fraction (silt and clay, very fine sand) between interstices of grains. Therefore, the porosity of sand layers is dependent on grain size, shape and grain-size distribution.

3) Dumoy Well Field

The Dumoy Well Field (Refer **Photo 10.1-6**) is in the southwest of Davao City and the main groundwater source for the DCWD. The well field is located at the foot slopes at the east of Mount Talamo blanketed by volcanic mud flow. The slopes of Mount Talamo serve as the watershed area for the deep aquifers while the shallow aquifers are recharged by the Talamo River. The Dumoy Field is approximately 8 km width and 13 km length along the coast of Talamo Bay. There are 30 wells operated by DCWD and several private industrial wells in the area. The production of each well is range of 1,617-4,700 liters/minute. And the well depth ranges from 90-152m.

PHOTO 10.1-6 THE WELL OF DUMOY WELL FIELD

4) Panacan Wells

The Panacan is located at about 5km northeast of Davao City where the Alluvium is underlain by the Mandug Formation and Bunawan Limestone.

In Panacan, there are two operating wells which average depth is 104m, and total production of the two wells is 2,000 liters/minute.

(2) Influence of Road Construction on Water Sources

The water source of the Davao City Water District (DCWD) is concentrated at the Dumoy Well Field located at the skirts of Mount Apo and Mount Talomo, and other water sources are the Panacan Wells and the Malagos Creek of a small tributary of the Davao River.

Because the water sources above are separated by 2-3km or more from the proposed bypass road alignment, the impact on the water source of the DCWD is not almost.

On the other hand, the neighboring area of the proposed tunnel section of the bypass road is not the service area of the DCWD. So the resident's management wells and the stream water are used as water sources. The influence of tunnel excavation to these water sources cannot be explained in detail from the geological investigation results of this time. But it is estimated the influence is small because the bedrock of the tunnel excavation depth is mainly the mudstone with low permeability of the Masuhi Formation (There is not an aquifer). However, it is desirable to check in detail the influence to the groundwater by the monitoring during tunnel excavation.

10.2 DESIGN STANDARDS

10.2.1 Design Concept

The design concept is to provide a relative high speed road that allows a safe and efficient movement of traffic as a bypass road.

10.2.2 Geometric Design Standards

The following standard is mainly used as reference in Davao City Road.

- A Policy on Geometric Design of Highways and Streets, AASHTO 2011, 6th Edition
- Highway Safety Design Standards Part I Road Safety Design Manual, May 2004, DPWH
- Japan Road Association, Road Structure Ordinance, 2004.

(1) Design Speed

In accordance with Road Safety Design Manual (DPWH, 2004) as well as considering to the topographic condition, the recommended design speed is 60kph.

(2) Summary of Road Geometry

Geometry applied to the road design is summarized in **Table 10.2-1**.

TABLE 10.2-1 SUMMARY OF ROAD GEOMETRIC DESIGN STANDARD (DESIGN SPEED, 60KPH)

Item		Unit	Standard	Absolute Minimum	Remark
Design Speed		kph	60		
Design Vehicle		-	WB-15		
Stopping Sight Distance		m	85		Page 7-3, Table e7-1, AASHTO 2011
Passing Sight Distance		m	180		
1. Cross Section Elements					
Lane Width		m	3.5		Page 53, Table 16.1, DPWH Road Safety Design Manual
Outer shoulder Strip		m	3.0	2.5	
Number of Lanes		Nos.	2		
Normal Cross Slope		%	2		Page 7-4, AASHTO 2011
Maximum Super elevation	Flat	%	6		Page 53, Table 16.1, DPWH Road Safety Design Standard
	Rolling	%	8		
	Mountainous	%	10		
2. Horizontal Alignment					
Minimum Radius		m	123		Page 3-32, Table 3-7, AASHTO 2011, e=6%
Min. Transition Curve Length		m	50		JPN
Min. Radius not requiring Transition Curve		m	1,030		Page 3-45, Table 3-9, AASHTO 2011, cross slope, 2%)
Min. Radius not requiring Superelevation		m	2,000		JPN (cross slope, 2%)
		m	1,500		JPN (cross slope, 1.5%)
Superelevation Runoff			1/167		
3. Vertical Alignment					
Maximum Vertical Gradient	Flat	%	5		Page 7-4, Table 7-2, AASHTO 2011
	Rolling	%	6		
	Mountainous	%	8		

Item		Unit	Standard	Absolute Minimum	Remark
Minimum K value	Sag	%	18		Page 69, Table 16.4, DPWH Road Safety Design Manual
	Crest	%	11		
Minimum Radius	Sag	%	1,000		JPN
	Crest	%	1,400		
Min Vertical Curve Length		m	50		JPN
Max. Composition Grade		m	10.5		JPN
Critical Length of Grade		m	500 (6%)		JPN
		m	400 (7%)		JPN
		m	300 (8%)		JPN
4. Vertical Clearance					
Road		m	5.0		DPWH Requirement, 4.9 m (16 feet) clearance + α

(3) Vertical Clearance

The vertical clearance of the highway and crossing road shall be at least 5.2m (4.9m (16 feet) + 0.3m (overlay).

(4) Number of Lanes

Number of lanes is set as 2 lanes in accordance with the traffic demand. RROW will be secured at 40~60m considering 4 lanes widening in the future.

(5) Carriageway and Shoulder

The carriageway's width is 3.5m in accordance with Road Safety Manual (DPWH, 2004) .The shoulder is design as 2.5m. **Figure 10.2-1** shows the typical cross section.

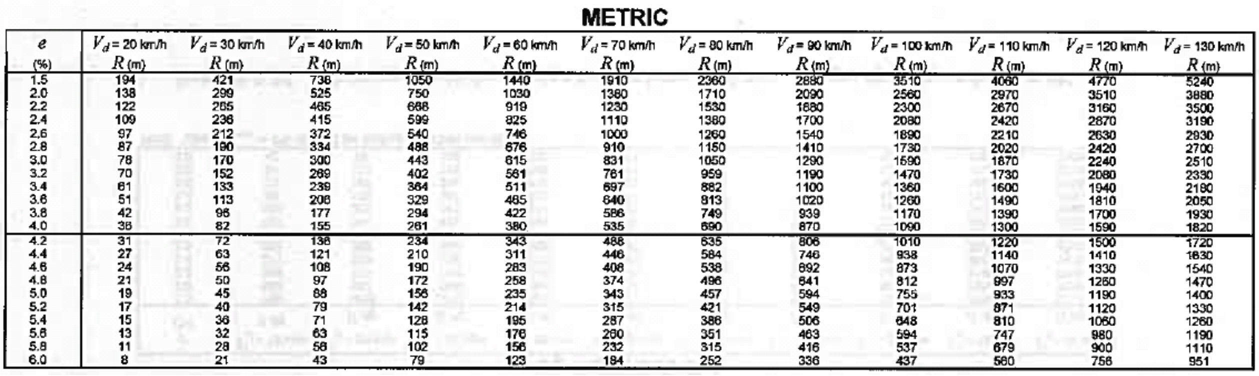
(6) Stopping Distance

According to A Policy on Geometric Design of Highways and Streets (2011 AASHTO); the stopping distance for design speed of 60kph is 85m.

(7) Cross Fall Development

Superelevation of the carriageway shall be considered to accommodate recommendation of AASHTO 2011 as shown in **Table 10.2-2.** The maximum value of superelevation is 6% as guided in Road Safety Manual, 2004 in page 53. The superelevation rate for the applied design speed is shown in **Table 10.2-2.**

TABLE 10.2-2 MINIMUM RADII FOR DESIGN SUPERELEVATION RATES, EMAX=6%



METRIC

e (%)	V_d = 20 km/h R (m)	V_d = 30 km/h R (m)	V_d = 40 km/h R (m)	V_d = 50 km/h R (m)	V_d = 60 km/h R (m)	V_d = 70 km/h R (m)	V_d = 80 km/h R (m)	V_d = 90 km/h R (m)	V_d = 100 km/h R (m)	V_d = 110 km/h R (m)	V_d = 120 km/h R (m)	V_d = 130 km/h R (m)
1.5	194	421	738	1050	1440	1910	2360	2880	3510	4060	4770	5240
2.0	138	299	525	750	1030	1380	1710	2090	2560	2970	3510	3880
2.2	122	265	465	688	919	1230	1530	1880	2300	2670	3160	3500
2.4	109	236	415	599	825	1110	1380	1700	2080	2420	2870	3190
2.6	97	212	372	540	746	1000	1260	1540	1890	2210	2630	2930
2.8	87	190	334	488	676	910	1150	1410	1730	2020	2420	2700
3.0	78	170	300	443	615	831	1050	1290	1590	1870	2240	2510
3.2	70	152	269	402	561	761	959	1190	1470	1730	2080	2330
3.4	61	133	239	364	511	697	882	1100	1360	1600	1940	2180
3.6	51	113	206	329	465	640	813	1020	1260	1490	1810	2050
3.8	42	96	177	294	422	586	749	939	1170	1390	1700	1930
4.0	36	82	155	261	380	535	690	870	1090	1300	1590	1820
4.2	31	72	136	234	343	488	635	806	1010	1220	1500	1720
4.4	27	63	121	210	311	446	584	746	938	1140	1410	1630
4.6	24	56	108	190	283	408	538	692	873	1070	1330	1540
4.8	21	50	97	172	258	374	496	641	812	997	1260	1470
5.0	19	45	88	156	235	343	457	594	755	933	1190	1400
5.2	17	40	79	142	214	315	421	549	701	871	1120	1330
5.4	15	36	71	128	195	287	386	506	648	810	1060	1260
5.6	13	32	63	115	176	260	351	463	594	747	980	1190
5.8	11	28	56	102	156	232	315	416	537	679	900	1110
6.0	8	21	43	79	123	184	252	336	437	580	756	951

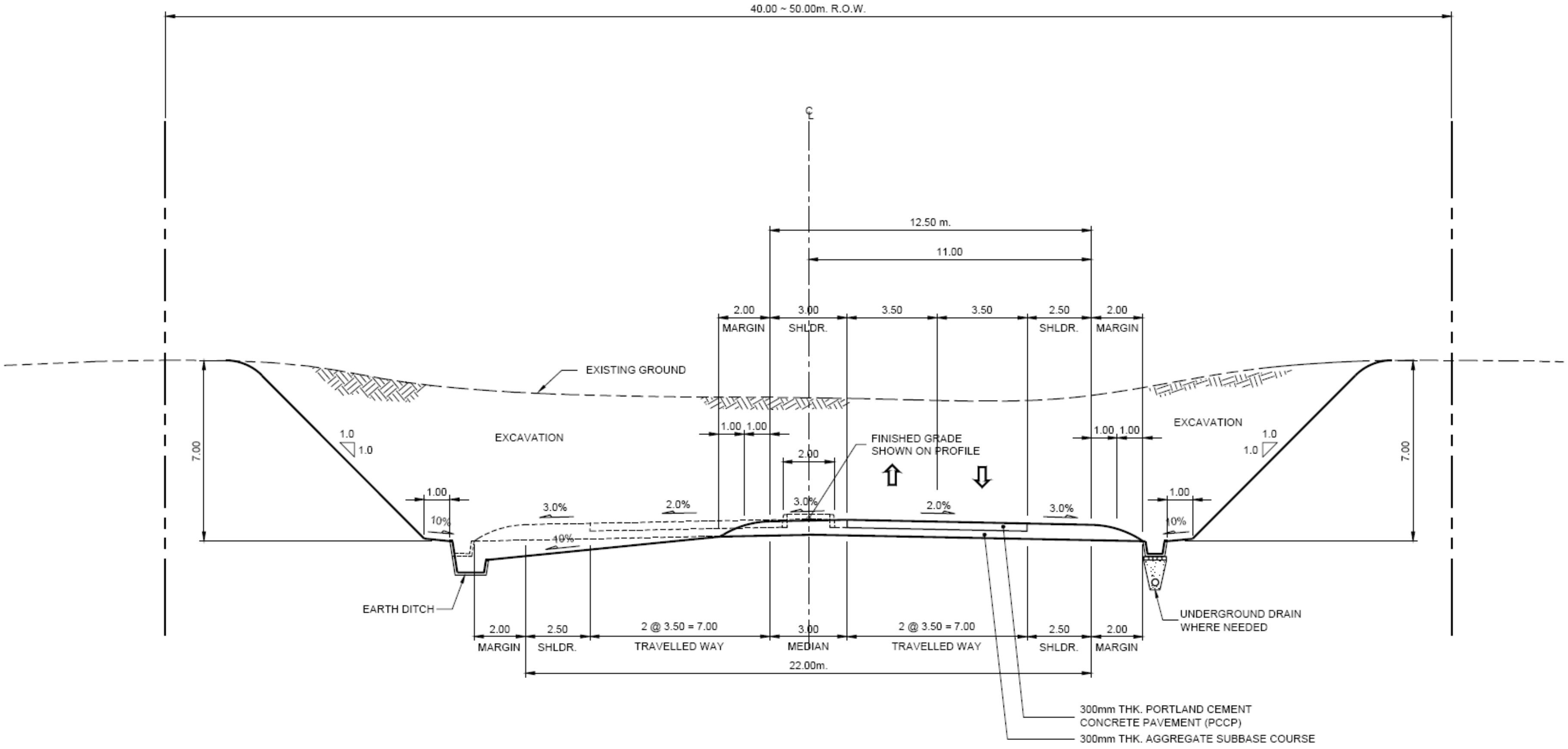
Source: AASHTO 2011

(8) Minimum Radius without Superelevation

When the curve radius is larger than R=1,030m, superelevation can be omitted in accordance with AASHTO 2011.

(9) Maximum Gradient

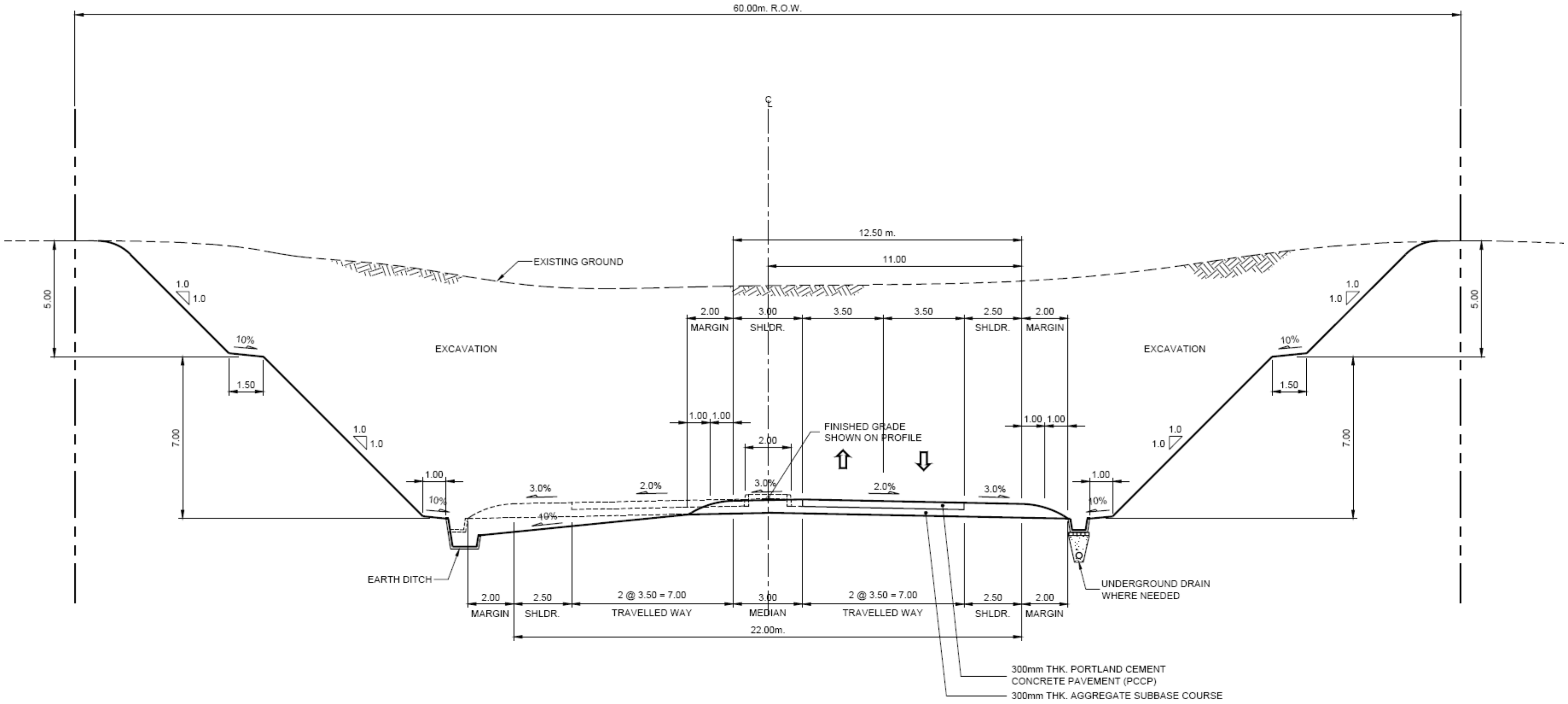
For the main alignment with design speed of 60kph, the maximum vertical gradient based on the Road Safety Manual (2004 DPWH) that could be applied are 6% (flat), 8% (rolling), and 10% (mountainous).



TYPICAL ROADWAY SECTION (Cut Height = Up to 7m.)
Cut (1)

Scale 1:200

FIGURE 10.2-1 (1) TYPECAL ROADWAY CROSS SECTION CUT (1)



TYPICAL ROADWAY SECTION (Cut Height = 7~12m.)
Cut (2)

Scale 1:200

FIGURE 10.2-1 (2) TYPECAL ROADWAY CROSS SECTION CUT (2)

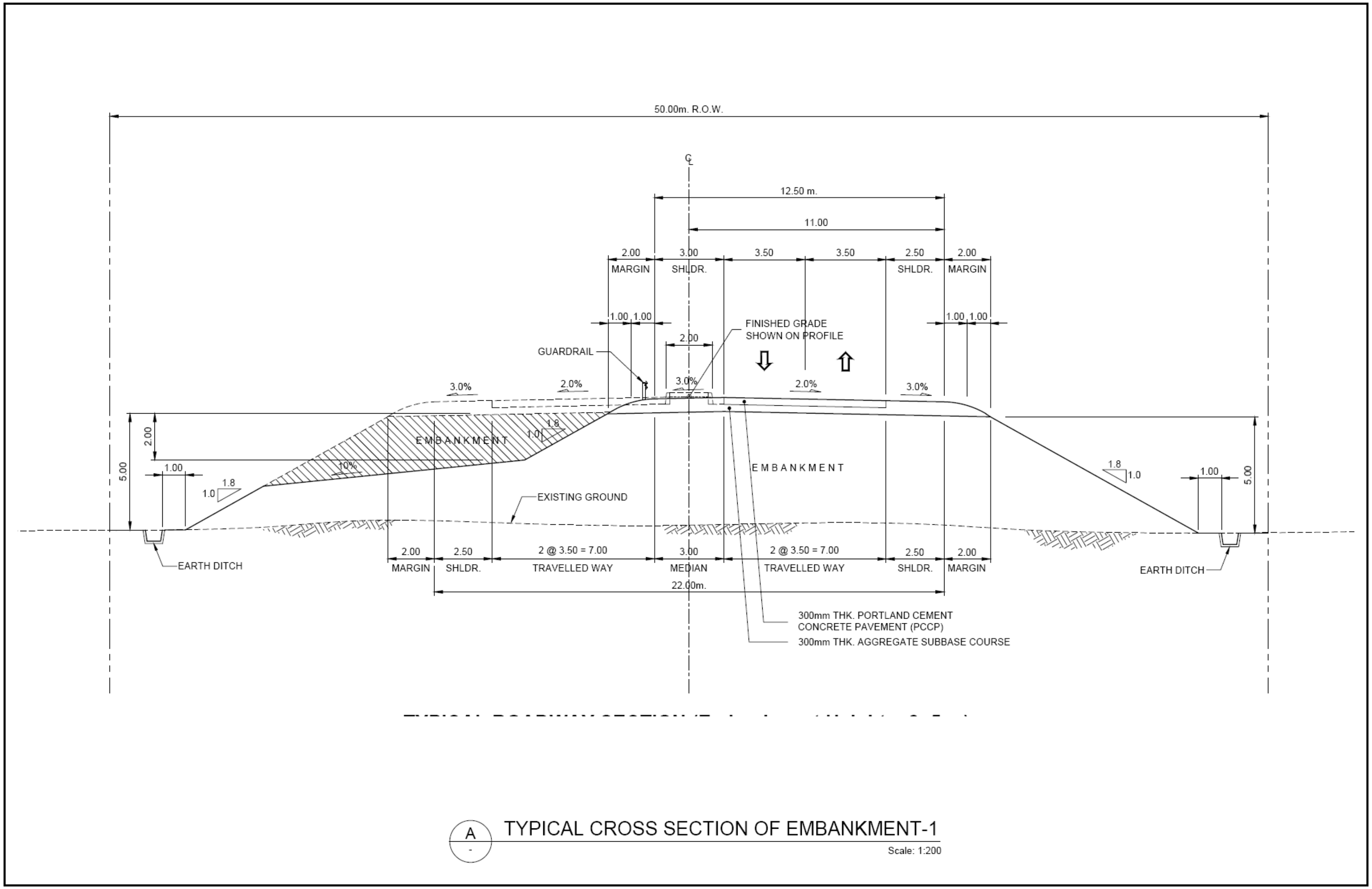


FIGURE 10.2-1 (3) TYPECAL ROADWAY CROSS SECTION EMBANKMENT-1

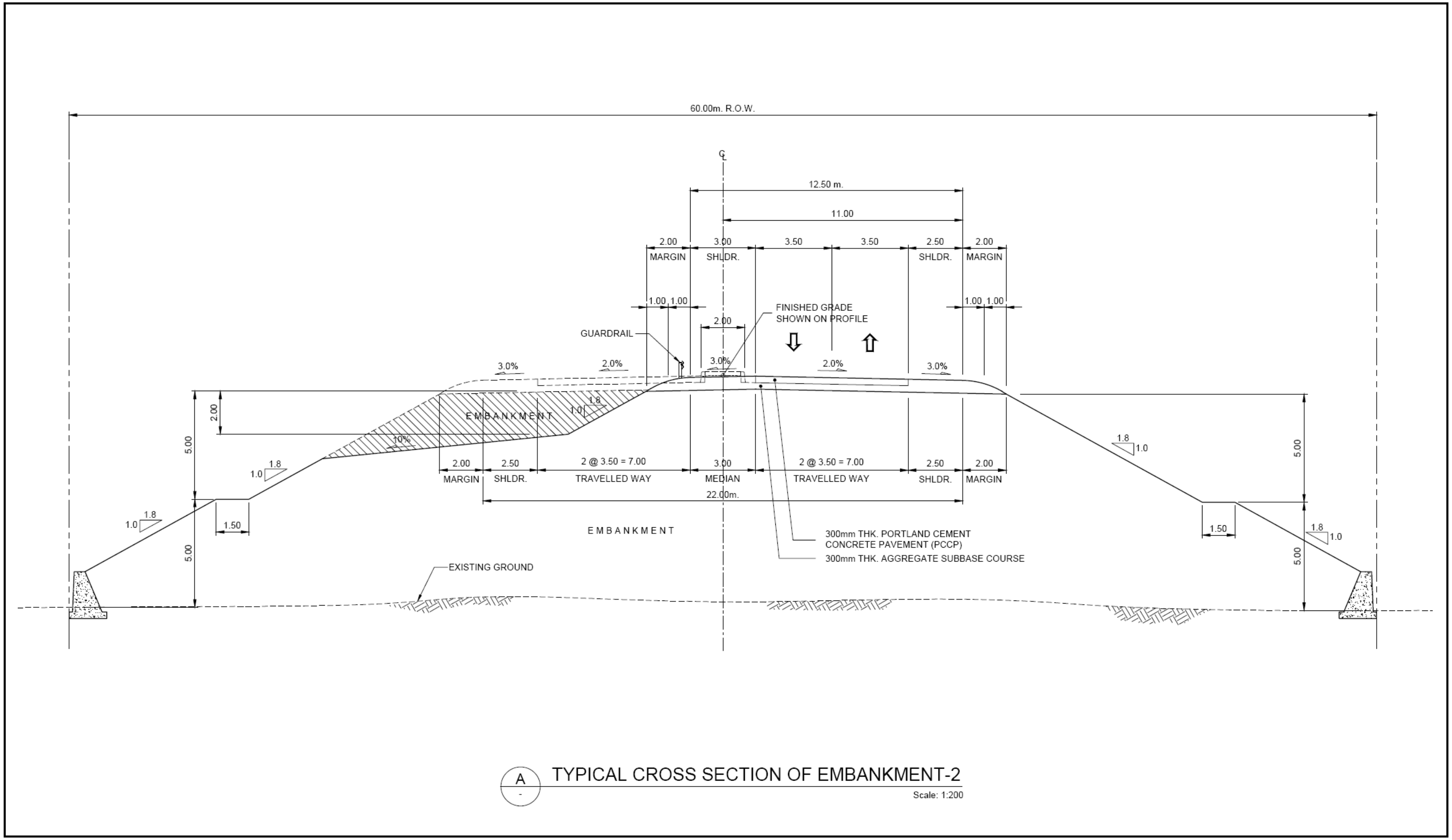


FIGURE 10.2-1 (4) TYPECAL ROADWAY CROSS SECTION EMBANKMENT-2

10.2.3 Tunnel Design Standards

(1) Tunnel Design Standard And Criteria

The following design standards are to be applied to the design for Davao Bypass Tunnel;

1) Basic Geometric Design Standard for Tunnel

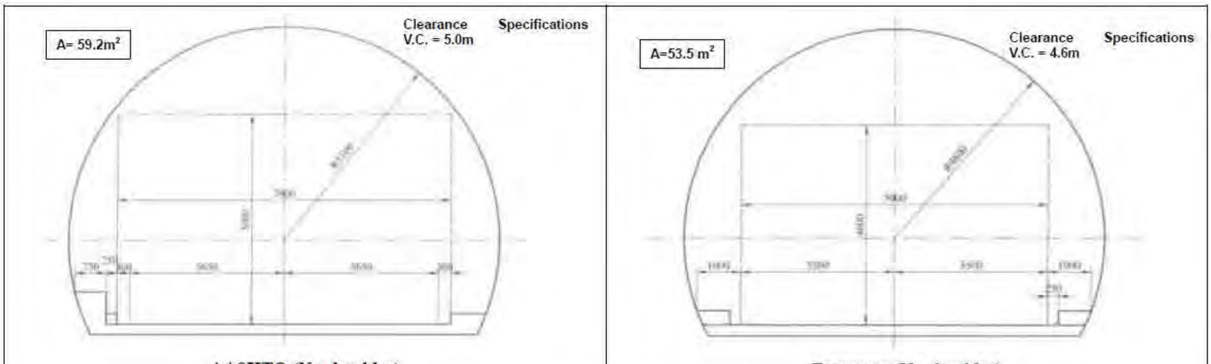
The basic geometric design standards for two lane carriageway tunnel to be adopted are the following;

- Design Speed : 60 km/hr
- Carriageway width :3.5m
- Shoulder : 1.50m
- Maximum super elevation of Carriageway: 5.00 %
- Cross fall of Carriageway: 2.00 %
- Vertical clearance : 5.00m
- Alternatively, the following standards will also be adopted as the Design Standards
- Design Guidelines Criteria and Standards. For Public Works and Highways. Department of Public Works and Highways. Volume 3, Part 3-Highway Design.
- Road Safety Manual 2003 – PIAC Technical Committee on Road Safety
- (Permanent International Association of Road Congresses Publications)
- Japan Standard for Mountain Tunneling. Japan Society of Civil Engineers.

(2) Tunnel Cross Section

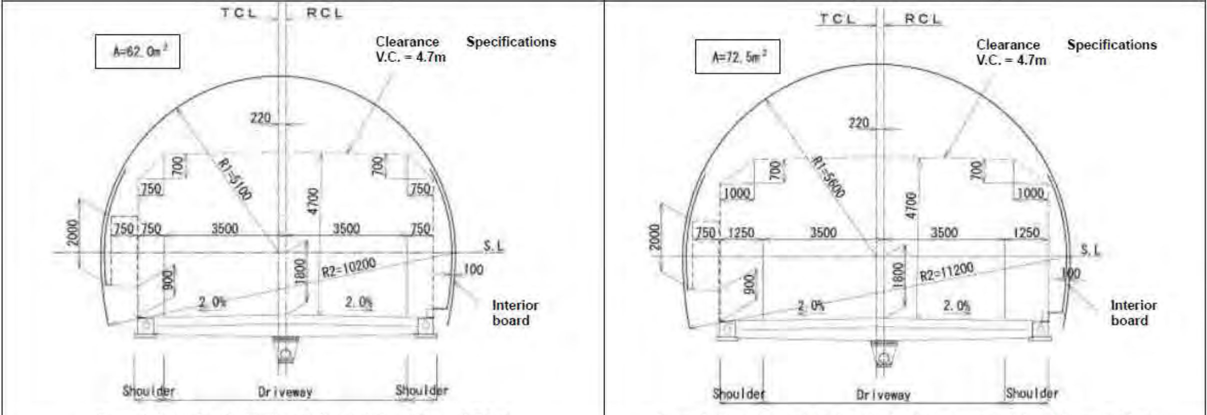
Figure 10.2-3 shows the various tunnel cross sections adopted by various agencies in the US, Europe and Japan.

Figure 10.2-3 shows the typical tunnel cross section for Davao Bypass Project adopted based on the above standard and criteria and Tunnel cross section is likewise shown.



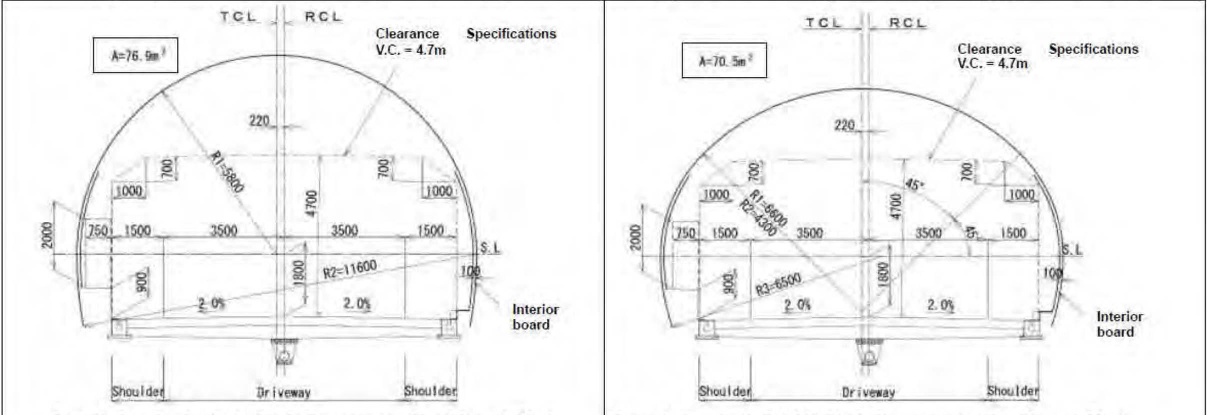
AASHTO (No shoulder)

European (No shoulder)



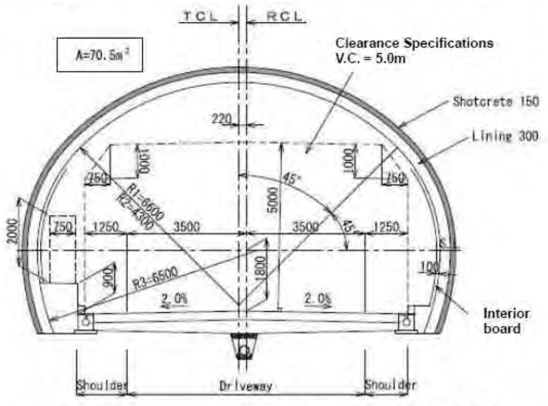
Japan's Standard: National Road (Shoulder = 0.75m)

Japan's Standard: Single Circle Expressway (Shoulder = 1.25m)



Japan's Standard: Single Circle Expressway (Shoulder = 1.50m)

Japan's Standard: Double Circle Expressway (Shoulder = 1.50m)



Proposed for Davao City Bypass Tunnel (Shoulder = 1.25m)

FIGURE 10.2-2 DIFFERENT KINDS OF TUNNEL CROSS SECTION

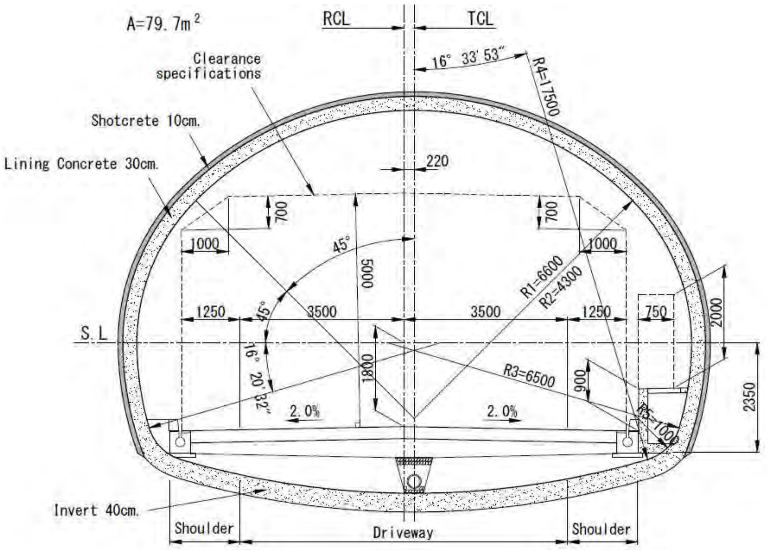


FIGURE 10.2-3 PROPOSED DAVAO CITY BYPASS TUNNEL CROSS SECTION

Photo 10.2-1 shows a sample of a two-lane Japanese tunnel, which was installed with a plastic (flexible) poles to minimize a head-on collision.

PHOTO 10.2-1 TWO-LANE TUNNEL IN JAPAN

10.2.4 Structural Design Standards

(1) Code and Specifications

The Structural Design Standards shall be in accordance with the following codes and guidelines:

- Design Guidelines Criteria and Standards for Public Works and Highways,
- L. O. I. 112, dated August 8, 1973, concerning gross weights of freight trucks and other vehicles.
- P. D. 187 as amended by P. D. 748 and Batas Pambansa Blg. 8. An act of defining the Metric System and its units, providing of its implementation and for other purposes and MPWH Memorandum Circular No. 6 dated January e, 1983, re: Metric System (SI) Tables.
- Standard Specifications for Highways and Bridges, Revised 1995 or latest edition.
- Standard Specifications for Highway Bridges, adopted by the American Association of State Highway and Transportation Officials (AASHTO), 1977 or latest edition.
- Prestressed Concrete Institute (PCI) Design Handbook (Latest Edition).
- Manual of the American Institute of Steel Construction (AISC), 8th or latest edition
- Standard Specifications of American Society for Testing and Materials Joint Circular among Department of Public Works and Highways,

(2) Loadings Specifications

1) General

Structures shall be proportioned with the existence of the following loads and forces:

a) Dead load
b) Live load
c) Impact or dynamic effect of the live load
d) Sidewalk live load
e) Seismic load
f) Wind load
g) Thermal forces
h) Earth pressure

2) Dead Load

The dead load shall consist of the weight of the complete structure, including the roadway, sidewalks, car tracks, pipes, conduits, cables and other public utility services.

The following unit weights shall be used in computing the dead load:

No.	Items	Unit Weight (kN/m^3)
1	Steel or Cast steel	77
2	Cast Iron	71
3	Aluminum alloys	27.5
4	Timber (treated or untreated)	8
5	Concrete, plain or reinforced	24
6	Compacted sand, earth and gravel or ballast	19
7	Loose sand, earth and gravel	16
8	Macadam or gravel, rolled	22
9	Cinder filling	10
10	Pavement, other than wood block	24
11	Railway rails, guard rails, and Fastenings (per linear meter of track)	31
12	Asphalt plank, 25.0mm thick	430Pa
13	Stone Masonry	26

3) Live load

MS18 (HS-20-44)

4) Impact load

I = 15.24/(L+38)
Where

I: Impact fraction (maximum 30%)
L: Length in m of the portion of the span which is loaded to produce the maximum stress in the member.

5) Sidewalk Live load

Span 0 to 7.62m P=4070Pa
Span 7.925m to 30.480m P=2873Pa
Span 30.480m over P = (1435+43800/L) x (16.7-w) / 15.2
Where

P: live load per m2 (Pa), Max 2873Pa
L: Loaded length of sidewalk in m
W: Width of sidewalk in m

6) Seismic load

A= 0.4
SPC: D
Where

A: Acceleration Coefficient
SPC: Seismic Performance Category (A>0.4, Essential Bridges IC = I then SPC D)

(3) Materials and Design Stresses

All materials to be used in the project shall conform to the DPWH Standard Specifications (2004), and AASHTO Code.

1) Concrete

Description	fc' (min.) MPa	Max. Side of Concrete Aggregates (mm)	Minimum Concrete Cover (mm)
a. Superstructure			
- Deck slabs	28	20	Deck slab with BWS Top:50 Bottom:25 Others:35
- Sidewalk, railings, parapet, medians	21	20	
- PSC I-girders	38	20	PSC I-girders:35
b. Substructure			
- PC pier copings, columns, footings	28	20	Pier Copings, RC & PSC: 50
- PSC Pier copings, rotating pier head	38	20	PSC Hammerheads: 40 RC columns: 50
- RC Abutment walls, footings	28	20	Footing and Bored Piles: 75
- Bored piles	28	20	Abutment Walls: 50
c. Earth covered RC Box structures	28	20	Earth covered Box structures: 50
d. Other concrete (normal use)	21	20	
e. Lean concrete (for leveling)	17	25	
f. Non Shrink grout	41	40	

2) Reinforcement Steel

Reinforcing steel shall conform to AASHTO M31 (ASTM A515) GRADE 40, Deformed with minimum yield strength fy =278MPa

3) Prestressing

All Prestressing steel shall be high strength stress relieved wires or strands with an ultimate stress, fs' = 1860 MPa

Prestressing steel shall be free from kinks, notches and other imperfections that will tend to weaken its strength or its bonding properties with concrete.

4) Structural Steel

All structural steel shall conform to the requirements of AASHTO or ASTM Designations as follows;

Steel plates and rolled shapes: AASHTO M183 (ASTM A36)
Bolts: AASHTO M164 (ASTM A325)
Welds: AWS D1.1 – 183, E70XX series

10.2.5 Pavement Design Standards

The pavement design is in accordance with the "Guide for Design of Pavement Structures, 1993" by the American Association of the State Highway and Transportation Officials and in reference also to "Design Guidelines, Criteria and Standards for Public Works and Highways" by the Department of Public Works and Highways.

10.2.6 Drainage Design Standards

(1) General

The hydrological study is developed based on the project area's meteorological/hydraulic data, topographical / hydrological surveys carried out in this project. The catchment area of rivers or channels at the bypass road crossing is measured using of 1:50,000 scale topographical map published by NAMRIA. The cross sections and riverbed profiles of the rivers at bypass road crossing are obtained by project topographical survey.

Hydrological surveys about following items are conducted for calculating the numerical value, etc. necessary to hydrological and hydraulic studies.

TABLE 10.2-3 SURVEY ITEMS FOR HYDROLOGICAL SURVEYS

Items		Institutions Concerned	Remarks
Meteorological Survey	General Weather Conditions (Temperature, Relative Humidity, Wind Speed and Direction, Evapo-transpiration, Sunshine Hours, Station Information, etc.)	PAGASA	
	Rainfall (Annual / Monthly / Daily rainfall, Rainfall Intensity Curve, etc.)	PAGASA	
Hydrological Survey	Annual Maximum Discharge (Peak), Annual / Monthly / Daily Discharge, Annual Maximum High water level, Station Information, etc.	BRS of DPWH	
Bibliographic Survey	Related Design Criteria / Standards / Study Reports, Topographic Maps, etc.	DPWH, Davao City, NAMRIA, JICA, etc.	
Interview Survey	Flood Situation Surrounding Related Bridge Sites	(Local Residents)	

Source: JICA Study Team

(2) Hydraulic Design Criteria

1) Design Criteria and Standards

In general, design criteria and standards concerning hydrology and hydraulics in Philippine, are referred to the following documents:

- DPWH Design Guidelines, Criteria and Standards for Public Works and Highways published in 1980.
- FHWA (Federal Highway Administration, USA), HEC (Hydraulic Engineering Circular) series
- U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-HMS, HEC-RAS and HY-8 Manuals and Technical References.

These standards will be proposed hydrologic and hydraulic design criteria which are appropriate for project requirements. Also, these standards will cover the following items:

- Hydrologic Design
- Design Frequency or Return Period
- Runoff Computation Methods, Runoff Coefficients
- Rainfall Intensity
- Level of Development in the Watersheds
- Hydraulic Design
- Manning's Roughness Coefficient
- Expansion and Contraction Loss Coefficients
- Freeboard

Drainage design criteria of this study are shown in **Table 10.2-4**.

TABLE 10.2-4 DRAINAGE DESIGN CRITERIA OF THIS STUDY

Items of Criteria		Criteria	Applied Standards	Remarks
Hydrologic design		Based on the data from PAGASA	Various documents including DPWH standards	
Design frequency or return period	Rivers (Bridges)	50-year flood with sufficient freeboard to contain the 100-year flood	DPWH standards	
		25-year flood with sufficient freeboard to contain the 50-year flood	DPWH standards	
	Culverts (Box)	25-year flood with sufficient freeboard to contain the 50-year flood	DPWH standards	
	Culverts (Pipe) Esteros/Creeks Drainage pipes	15-year flood with sufficient freeboard to contain the 25-year flood	DPWH standards	
	Embankments	10-year flood	DPWH standards	
	Ditches and road surface	2-year flood	DPWH standards	

Items of Criteria		Criteria	Applied Standards	Remarks
Runoff computation methods, runoff coefficients	Computation methods for waterways with catchment area of 20 km2 or more (Davao, Lasang, Talomo, Lipadas, Matina Rivers)	Specific discharge, by drainage area rate from probable hydrological value (flood frequency analysis) and unit hydrograph method	by calculations	
	Computation methods for other waterways, channels with catchment area less than 20 km2	Rational Formula	DPWH standards, HEC	
	Runoff coefficients	**Table 10.2-5**	DPWH standards, HEC	
Rainfall intensity-duration-frequency		Based on the data from PAGASA	by calculation	
Level of development in the watersheds		Based on the data from land use plan of Davao city	-	
Hydraulic design	Hydraulic computation method (Bridges)	Based on the calculation by HEC-RAS	HEC	
	Hydraulic computation method (Culverts)	Based on the calculation by Rational Formula and confirmed/checked with HY-8 Software	HEC	
	Minimum size of drainage pipes	910 mm	DPWH standards	
Manning's roughness coefficient		**Table 10.2-6**	DPWH standards, HEC	
Expansion and contraction loss coefficients		(Various values)	HEC	
Freeboards		Bridge: 1m minimum freeboard with no debris and 1.5m minimum free board for waterways with debris load. Culverts: avoid to 2 barrel installations in debris prone areas	DPWH standards	

Source: JICA Study Team

TABLE 10.2-5 RUNOFF COEFFICIENT C

Watershed Cover or Type of Surface	Run-off Coefficient, C
Concrete or asphalt pavement	0.80 – 0.90
Steep grassed areas (2:1)	0.50 – 0.70
Flat residential with about 30% of area impervious	0.40
Flat residential with about 60% of area impervious	0.60
Moderate steep residential with 50% of area impervious	0.65
Moderate steep residential with 70% of area impervious	0.80
Flat commercial with about 90% of area impervious	0.80

TABLE 10.2-6 VALUES OF MANNING'S ROUGHNESS COEFFICIENT "N"

Glass, plastic, mechanical metal	0.010	
Dressed timber, joints flush	0.011	
Sawn timber, joints uneven	0.014	
Cement plaster	0.011	
Concrete, steel troweled	0.012	

Concrete, timber forms, unfinished	0.014	
Untreated granite	0.015	- 0.017
Brickwork or dressed masonry	-0.014	
Rubble set in cement	0.017	
Earth, smooth, no weeds	0.020	
Earth, some stones and weeds	0.025	
Natural river channels:		
Clean and straight	0.025	- 0.030
Winding, with pools and shoals	0.033	- 0.040
Very weedy, winding and overgrown	0.015	- 0.300
Clean straight alluvial channels	$0.031d^{1/6}$	
	(d=D-75 size in ft.)	

2) Hydraulic Design Criteria of Bridge

In order to design opening of the bridge waterway, the following design criteria for hydraulics are required.

- The backwater does not significantly increase the flood damage to properties upstream of the bridge.
- The velocity through the bridge does not damage the road facility or increase the damages to downstream properties.
- The existing flow distribution is maintained to the extent practicable.
- The pier and abutment are designed to minimize the flow disruption. (Contraction scour does not occur at proposed bridge site.)
- Potential local scour is within acceptable limits.
- Clearance at the structure is adequately designed to pass safety any anticipated debris. (The elevation of bottom of bridge girder is higher than "Highest high water level + Freeboard or Navigation channel height".)

The design return period, the clearance from the bridge girder to high water level shall be compliant with authorized standards by the organizations concerned. The high water level of related rivers and the estimation of scouring shall be determined based on the HEC standards and HEC-RAS computation.

3) Hydraulic Design Criteria of Culvert

Lateral road drainage is mainly through culverts and bridges. The size of the flood opening is determined by the catchment area parameters and consideration of existing nearby structures.

The hydraulic design requires considering the following points:

- Head loss due to contraction at the entry of the culvert.
- Head loss at the inlet, through the culvert and outlet due to the roughness.
- Tailwater level and downstream condition

The existing topography is taken into consideration in determining the culvert slope in order to minimize excessive excavations at both ends. The type of inlet and outlet is designed according to the site conditions. The culvert cross-section is determined based on the HEC standards and HY-8 computation.

4) Hydraulic Design Criteria of Road Embankment

The embankment which is made of earth and sand material, and bridge super structure is very weak to overtopping and bumping, therefore planner must consider the safety countermeasures such as clearance.

The freeboard as the DPWH standards is applied for the embankment. Protection for the embankment shall be ensured using the suitable protection works. The median size of the loose riprap is determined based on the procedures provided in Design of Riprap Revetment (HEC14).

In order to protect the above mentioned criteria, the high water level (HWL) of the rivers is required. And it will be checked whether the HWL influences the bypass road. All HWL shall be shown in the design drawings.

10.2.7 Slope Design Standards

(1) General

Since the alignment of the proposed bypass road go through the undulating hilly terrain of 50-200m above sea level of 2-8km inland side of the Pan-Philippine Highway, many large-scale cut slopes of 20 meter or more in height are planned in the proposed bypass road.

The unconsolidated soil layers of sand and gravel are widely laying in the section which the cut slopes are planned. Appropriate slope protections of the cut slopes are needed, because the unconsolidated soil layers of sand and gravel will be easily eroded.

The slope protection is intended to protect the slopes by the vegetation or structure for ensuring the stability of the slopes, preserving of the natural environment and landscaping.

On the other hand, the excavated materials of the above-mentioned excavation sections should be used as banking materials of the embankment planned on the valleys, and the excavated materials of the tunnel section planned between the Matina River and Davao River should be also included in the banking materials. Therefore, it is necessary to design the embankment slopes in consideration of the type and characteristics of the excavated materials in the project road section.

In this section, as the cut slope design standards, the contents about Standard Slope Gradients for Cut which is closely related to the slope protection, Cut Slope Protection Types and Purposes, Selection Method of Cut Slope Protection and Considerations for Application of each Cut Slope Protection are mentioned. Also, as the embankment slope design standards, the contents about Standard Slope Gradients for Embankment and Slope Protection of Embankment are mentioned.

(2) Standard Gradient of Cut Slopes

The natural subsoil and rocks are composed of heterogeneous soils (including gravel and boulder) and rocks which the discontinuity (consisting of joints, faults and etc.) and the weathered alteration portion are present.

Because Philippines is a country composed of islands , located on the Circum-Pacific volcanic belt in the same way as Japan, the various geological conditions are very similar to Japan. From this, it is considered that it is appropriate to refer to the standard slope gradient empirically determined which is generally used in Japan when the cut slope gradient is determined.

Therefore, Standard Slope Gradient for Cut which is mentioned in Road earthwork - Guideline for Stability of Cut Slopes and Natural Slopes: June 2009 (issued by Japan Road Association) of Japan is given in the **Table 10.2-7**, as the standard gradient of cut slopes of the project road.

The Standard Slope Gradient for Cut which is shown in **Table 10.2-7** can be applied in a prerequisite condition that the cut slopes may be protected by vegetation and the like, the cut height that can be applied varies by the condition of subsoil and rocks.

When the standard slope gradient in **Table 10.2-7** is applied to the slopes design, the slope gradient of each slope stage should be decided by the condition which the cut height is the height from the bottom of each slope stage to the top of the whole of slope, because the whole slope is divided into the several slope stages by berms.

Besides, in case of the soil slopes, the applicable scope of the standard slope gradient in **Table 10.2-7** is up to the cut height ranging 10-15m. When the cut height is more than the applicable scope, it is necessary the slope gradient is changed at gentle than the standard slope gradient. But, there are many cases which the standard slope gradient is applied if the cut height is within about 20 m (within three slope stages).

TABLE 10.2-7 STANDARD SLOPE GRADIENTS FOR CUT

Condition of Subsoil and Rocks		Height of Cut	Gradient
Hard Rock			0.3:1.0 to 0.8:1.0
Soft Rock			0.5:1.0 to 1.2:1.0
Sand	Not Dense, and Poor Particle Size Distribution		1.5:1.0 or More Gentle
Sandy Soil	Dense	5m or less	0.8:1.0 to 1.0:1.0
		5m to 10m	1.0:1.0 to 1.2:1.0
	Not Dense	5m or less	1.0:1.0 to 1.2:1.0
		5m to 10m	1.2:1.0 to 1.5:1.0
Sandy Soil Mixed with Gravel or Rock Masses	Dense, or Good Particle Size Distribution	10m or less	0.8:1.0 to 1.0:1.0
		10m to 15m	1.0:1.0 to 1.2:1.0
	Not Dense, or Poor Particle Size Distribution	10m or less	1.0:1.0 to 1.2:1.0
		10m to 15m	1.2:1.0 to 1.5:1.0
Cohesive Soil		10m or less	0.8:1.0 to 1.2:1.0
Cohesive Soil Mixed with Rock Masses or Cobblestones		5m or less	1.0:1.0 to 1.2:1.0
		5m to 10m	1.2:1.0 to 1.5:1.0

Source: Road earthwork - Guideline for Stability of Cut Slopes and Natural Slopes : June 2009 (Issued by Japan Road Association)

On the other hand, when the cut height is more than 20 m (within three slope stages), there are problems that the repair and maintenance of the slopes is difficult, due to the several reasons such as the crane cannot reach the slope top. Therefore, on the occasion of deciding the vertical alignment, it is desirable to make an effort the cut height become 20 m or less.

In addition, even if the cut height is more than 20 m (within three slope stages), the standard slope gradient is applicable within the scope of until 10-15 m below the top of whole slope. Therefore the gradient of slope below than 10-15 m from the top should be studied. Alternatively, the case of making the steep slope than the standard slope gradient by the slope structures should be studied. However, because it is common that the condition of subsoil and rocks is as good as the lower part, as a consequence, there are several cases which the whole slope is constructed with the same slope gradient.

(3) Cut Slope Protection Types and Purposes

The strength of the subsoil and rocks is reduced by influences of loosening due to the cut (stress release), weathering, erosion and infiltrating water. Aforementioned standard slope gradient for cut is the experiential stable gradient which is considered the strength reduction of the subsoil and rocks occurring with the progress of time. And the protecting the cut slopes by vegetation and the like is a prerequisite condition for using the standard slope gradient. Therefore, it is necessary to study the slope protection by planting, even if the slope gradient is gentle than the standard gradient. In addition, when the slope gradient is steep than the standard gradient, or in case of a special conditions of subsoil and rocks, it is necessary to consider a high-performance slope protection than planting.

The slope protections can be divided into the planting consisting of sowing and sodding, etc., and the slope structures consisting of mortar/concrete spraying (shotcrete) and grating crib works, etc..

The cases of using the planting and the slope structures individually for slope protection are many. But, there are cases of using the combination of planting and slope structures due to preserving of the natural environment and landscaping at the site of unstable geotechnical conditions.

The main types and purposes of the slope protection are shown in **Table 10.2-8**.

TABLE 10.2-8 MAIN TYPES AND PURPOSES OF CUT SLOPE PROTECTION

Classification	Types	Purposes
Planting	Sowing	The purpose is the erosion prevention for the soil slopes by Planting. This type should be used when the slope gradient is 1.0:1.0 or less (gentle).
	Vegetation Base Material Spraying	The purpose is the erosion prevention for the soil and rock slopes by Planting. This type should be used when the slope gradient is from 0.5:1.0 to 1.0:1.0.
	Vegetation Mat	The purpose is the erosion prevention for the soil and rock slopes by Planting. This type should be used when the slope gradient is 0.8:1.0 or less (gentle).
	Vegetation Sandbag	The purpose is the erosion prevention by Planting for the inside of "Grating Crib Works using Precast Blocks" mainly.
	Sodding	The purpose is the early erosion prevention for the soil slopes by Planting. This type should be used when the slope gradient is 1.0:1.0 or less (gentle).
	Planting of Sapling	The purpose is the landscaping by trees. This type should be used in the soil slopes when the slope gradient is 1.4:1.0 or less (gentle).
Slope Structures	Mortar/Concrete Spraying (Shotcrete)	The purposes are the weathering prevention, the erosion prevention and the prevention of permeation of runoff. This type should be used at the rock slopes.
	Grouted Riprap	The purposes are the weathering prevention, the erosion prevention, the prevention of permeation of runoff and the prevention of slipping of surface soils. This type should be used at the steep soil slopes.
	Concrete Pitching	The purposes are the weathering prevention, the erosion prevention, the prevention of permeation of runoff and the prevention of slipping of rocks. This type should be used at the steep rock slopes
	Grating Crib Works using Precast Blocks	The purpose is the erosion prevention at sandy soil slopes. This type should be used when the slope gradient is 1.0:1.0 or less (gentle).
	Grating Crib Works using Shotcrete	The purposes are the erosion prevention and the prevention of slipping of surface soils or rocks. This type should be used at soil and rock slopes.

Classification	Types	Purposes
	Stone/Rubble-Concrete Masonry	The purposes are the erosion prevention and the prevention of slipping of surface soils or rocks. This type should be used at the underneath of soil and rock slopes.
	Mat Gabion	The purposes are the improvement of drainage and the prevention of slipping of slopes. This type should be used at the underneath of soil slopes where the spring water is present.
	Rock Bolt Type Anchor	The purpose is the prevention of surface failure or slope failure in soil and rock slopes. This type should be used combining with Grating Crib Works and etc.
	Ground Anchor	The purpose is the prevention of slope failure or landslide. This type should be used combining with Grating Crib Works and etc.

(4) Selection Method of Cut Slope Protection

On the occasion of selecting the slope protection, ensuring of slope stability shall first be considered. The conservation and landscaping of the natural environment should also be considered.

The basic policies of the selection of slope protection are as follows;

(a) When the gradient of cut slope is Standard Slope Gradient for Cut which is shown in the **Table 10.2-8** or less (gentle), in principle, the planting that is fit for the soil/rock conditions of the slopes may be selected.

(b) Even if the gradient of cut slope is gentle than Standard Slope Gradient for Cut which is shown in the **Table 10.2-8** or less (gentle), the planting should be combined with the grating crib works using shotcrete when the slipping of the slope is feared. Also, the mortar/concrete spraying (shotcrete) should be selected when the weathering of rock slope is feared.

(c) When the gradient of cut slope is steep than Standard Slope Gradient for Cut which is shown in the **Table 10.2-8**or more (steep), the appropriate slope structures should be selected by the soil/rock conditions of the slopes. The slope structure fitting to soil slopes is the grouted riprap only. The slope structure fitting to rock slopes is the concrete pitching only. Also, the slope structures fitting to both soil and rock slopes are the grating crib works using shotcrete, the stone/block masonry, the rock bolt type anchor and the ground anchor.

(d) The grating crib works using precast blocks, the grating crib works using shotcrete and the mat gabion should be selected in the slopes where the spring water is present. In case of using the grating crib works at slopes where the spring water is present, to be packed riprap at the inside of frames is desirable.

(e) The grating crib works using precast blocks, the grating crib works using shotcrete, the grouted riprap and the stone/block masonry should be selected in the sandy soil slopes where the soils are prone to be eroded.

(f) The selection flowchart of the slope protection based on the above-mentioned policies was prepared in the reference of "Road Earthwork - Guideline for Stability of Cut Slopes and Natural Slopes: June 2009 (issued by Japan Road Association) of Japan", is shown in **Figure 10.2-4**.

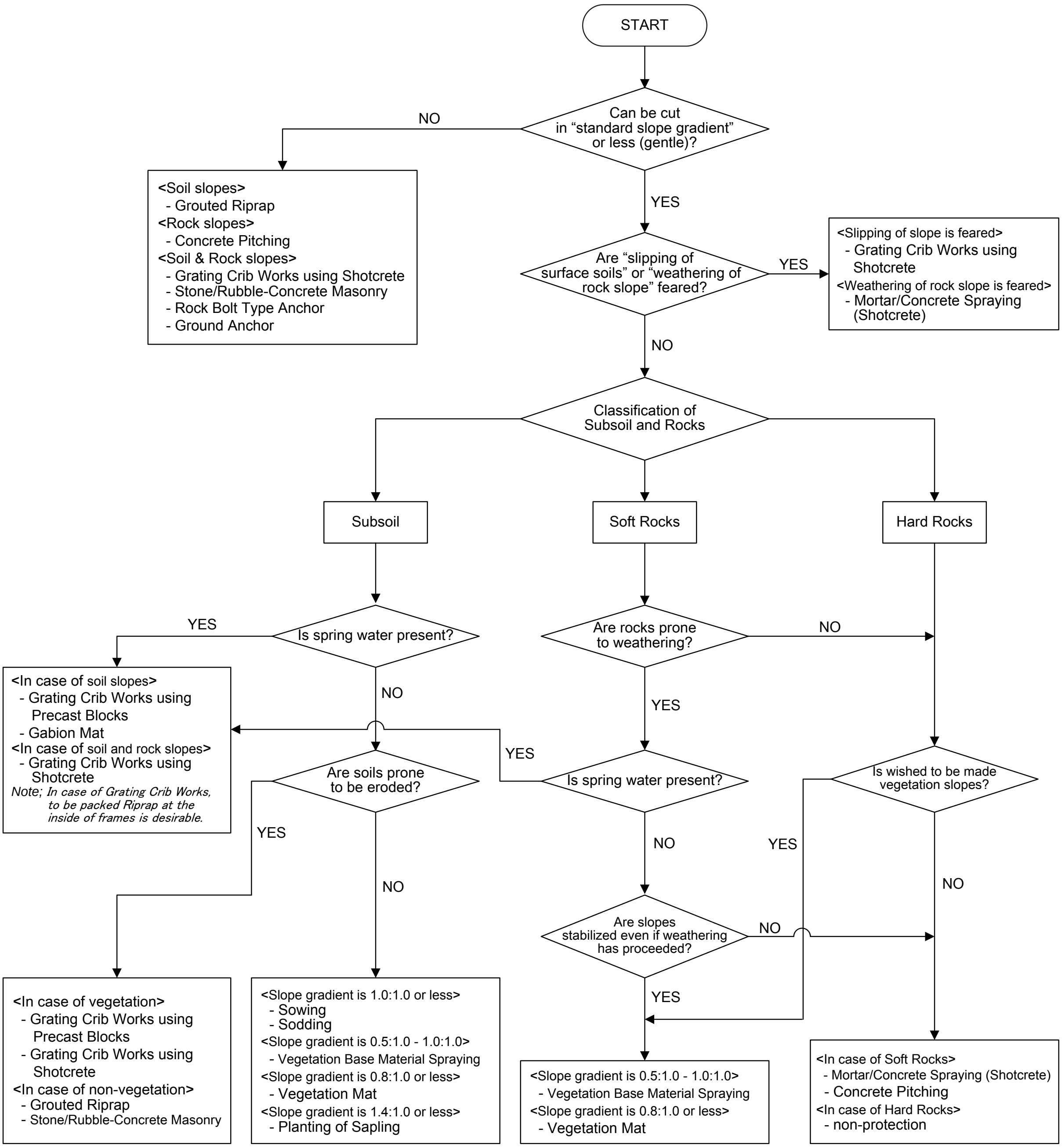


FIGURE 10.2-4 SELECTION FLOWCHART OF CUT SLOPE PROTECTION

(5) Considerations for Application of Each Cut Slope Protection

1) Planting

The optimal weather conditions (temperature, precipitation, etc.) are different; the plant (seed) to be used for the planting should be selected as the proven plant at the neighboring area of construction sites.

In selecting the slope protection type, the applicable conditions (soil type, hardness and gradient) of each protection type described below should be referred.

While in selecting the slope protection type, the applicable conditions (Soil/Rock conditions of the slope, Hardness of the slope, Gradient of the slope) of each protection type described below, should be referred.

(a) Applicable conditions of Sowing

- Soil/Rock conditions of the slope: Cohesive soil, Sandy soil
- Hardness of the ground: Soft (N-value 4-8 or less)
- Gradient of the slope: Gradient of 1.0:1.0 or less (gentle)

PHOTO 10.2-2 WORKING EXAMPLE OF SOWING

(b) Applicable conditions of Vegetation Base Material Spraying

- Soil/Rock conditions of the slope: Cohesive soil, Sandy soil, Gravelly soil, Soft rock
- Hardness of the ground: Hard (N-value 4-8 or more)
- Gradient of the slope: from 0.5:1.0 to 1.0:1.0

Note: - The thickness of the vegetation base material should be changed according with the hardness of the ground. The general range of changing is "1 cm (in case of N-value 4 roughly)" to "10 cm (in case of soft rock)".

- The slopes shall be blanketed by wire mesh for stabilization of the vegetation base material before spraying.

PHOTO 10.2-3 WORKING EXZMPLE OF VEGETATION BASE MATERIAL SPRAYING

(c) Applicable conditions of Vegetation Mat

- Soil/Rock conditions of the slope: Cohesive soil, Sandy soil, Gravelly soil, Soft rock
- Hardness of the ground: Hard (N-value 4-8 or more)
- Gradient of the slope: Gradient of 0.8:1.0 or less (gentle)

Note: - It is necessary to select the optimum product of the vegetation mat according to hardness of the ground.

PHOTO 10.2-4 WORKING EXAMPLE OF VEGETATION MAT

(d) Applicable conditions of Vegetation Sandbag

- Soil/Rock conditions of the slope: Cohesive soil, Sandy soil, Gravelly soil, Soft rock
- Hardness of the ground: Hard (N-value 4-8 or more)
- Gradient of the slope: Gradient of 0.8:1.0 or less (gentle)

Note: - The vegetation sandbag is commonly used as the planting of the inside of grating crib works.

PHOTO 10.2-5 WORKING EXAMPLE OF VEGETATION SANDBAG

(e) Applicable conditions of Sodding

- Soil/Rock conditions of the slope: Cohesive soil, Sandy soil
- Hardness of the ground: Soft (N-value 4-8 or less)
- Gradient of the slope: Gradient of 1.0:1.0 or less (gentle)

Note: - The sodding is commonly used in the narrow slopes that require the slope protection as soon as possible.

PHOTO 10.2-6 WORKING EXAMPLE OF SODDING

(f) Applicable conditions of Planting of Sapling

- Soil/Rock conditions of the slope: Cohesive soil, Sandy soil
- Hardness of the ground: Soft (N-value 4-8 or less)
- Gradient of the slope: Gradient of 1.4:1.0 or less (gentle)

PHOTO 10.2-7 WORKING EXAMPLE OF PLANTING OF SAPLING

2) Slope Structures

The slope structures are commonly used for the prevention of weathering, erosion, permeation of runoff, slipping and surface failure in soil and rock slopes. Also, the slope structures may be used when the reduction of the excavation volume by the slopes of steeper gradient than the standard slope gradient is desired.

When the prevention purposes are against weathering, erosion n and permeation, slipping of surface soils or rocks, the slope structures are generally designed by material, shape and dimensions which have been determined empirically. On the other hand, when the prevention purposes are against slope failure or landslide, the slope structures are generally designed by the stability analysis results which should be carried out based on the geotechnical investigation results.

Considerations for the selection and application of each slope structure are as follows.

(a) Considerations of Mortar/Concrete Spraying (Shotcrete)

- The mortar/concrete spraying (shotcrete) is selected in principle for the prevention purposes against weathering, erosion and permeation of runoff. This type should be used at the rock slopes.
- The spraying thickness should be 8-10 cm, when the slopes are hard rocks with few cracks. Also when the slopes are soft rocks or hard rocks with many cracks it should be 10 cm or more.
- When the spraying thickness is 8-10 cm, the normal spraying material is mortar. Also when the spraying thickness is 10 cm or more, the spraying material is concrete.
- The specified design strength of the sprayed mortar/concrete (shotcrete) shall be 15 MPa or more.
- On the occasion of the spraying of mortar/concrete (shotcrete), the wire mesh, the anchor bar, the anchor pin and the weep hole should be placed on slopes as shown in **Figure 10.2-5**, in principle.

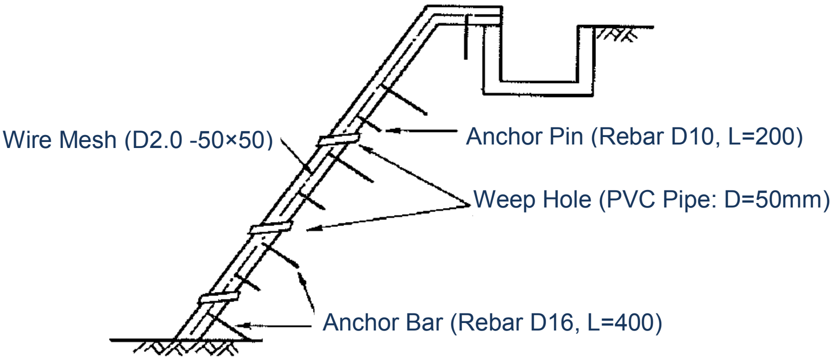


FIGURE 10.2-5 EXAMPLE OF MORTAR/CONCRETE SPRAYING (SHOTCRETE)

PHOTO 10.2-8 WORKING EXAMPLE OF MORTAR/CONCRETE SPRAYING (SHOTCRETE)

(b) Considerations of Grouted Riprap

- The grouted riprap is selected in principle for the prevention of weathering, erosion, permeation of runoff and slipping of surface soils. This type should be used at the steep soil slopes.
- The slope gradient of 1.0:1.0 or less (gentle) is desirable as the slope gradient of construction site.
- The standard thickness of the grouted riprap is approximately 25-35 cm. And it should be decided according to the slope gradient (it should be as thick as the slope gradient is steep).
- The stones of the grouted riprap shall be bedded by the horizontal and vertical grout of mortar, the thickness is 20 mm or more as shown in **Figure 10.2-6**.
- As shown in **Figure 10.2-7**, the finishing mortar shall be applied from slope surface top, so that the exposed face of vertical and horizontal is finished in a straight line. Also the weep hole (PVC pipe) should be placed in the grouted riprap.

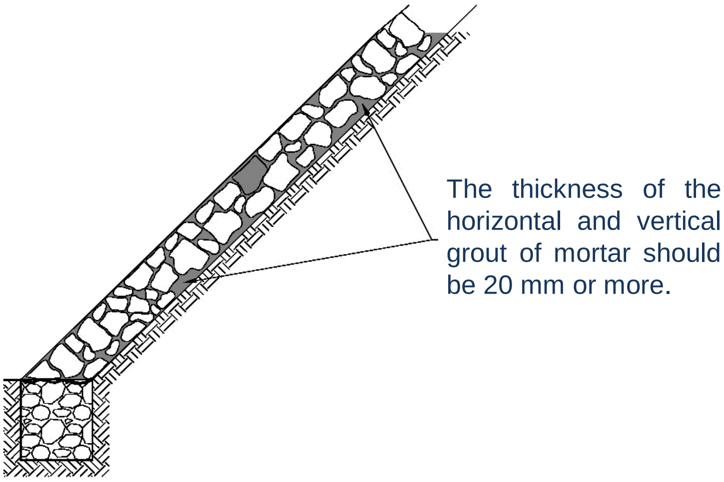


FIGURE 10.2-6 EXAMPLE OF GROUTED RIPRAP (1/2)

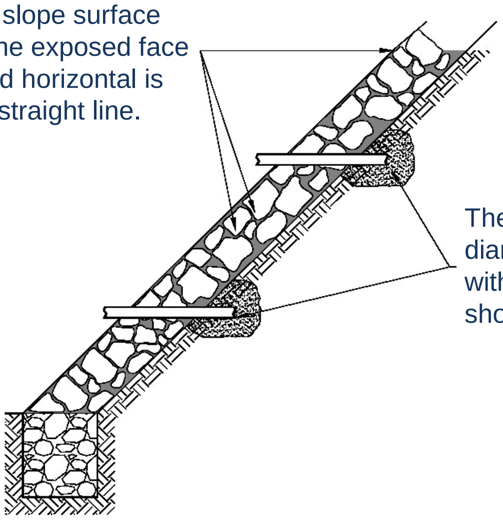


FIGURE 10.2-7 EXAMPLE OF GROUTED RIPRAP (2/2)

PHOTO 10.2-9 WORKING EXAMPLE OF GROUTED RIPRAP

(c) Considerations of Concrete Pitching

- The concrete pitching is selected in principle for the prevention against weathering, erosion, permeation of runoff and slipping of rocks. This type should be used at the steep rock slopes.
- The standard thickness of the concrete pitching is approximately 20-80 cm. And it should be decided according as the slope gradient. The thickness is generally about 20 cm in case of slope gradient 1.0:1.0, and about 60 cm in case of slope gradient 0.5:1.0.
- On the occasion of the construction of the concrete pitching, the H-section steel, the equal-angle steel, the non-slip anchor and the weep hole should be placed on slopes as shown in **Figure 10.2-8**, in principle.

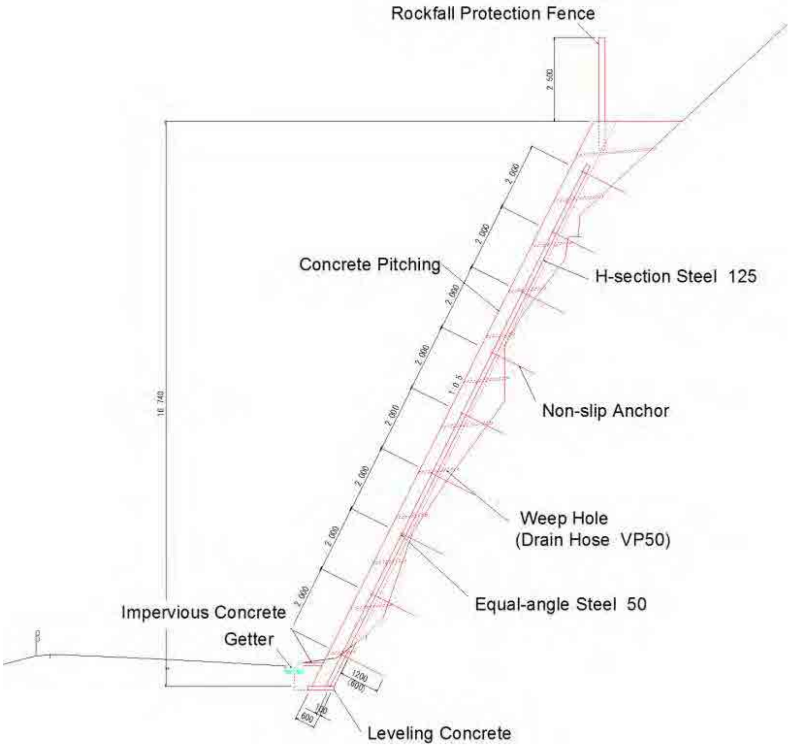


FIGURE 10.2-8 EXAMPLE OF CONCRETE PITCHING

PHOTO 10.2-10 WORKING EXAMPLE OF CONCRETE PITCHING

(d) Considerations of Grating Crib Works using Precast Blocks

- The grating crib works using precast blocks is selected in principle for the purpose of erosion prevention at sandy soil slopes. This type should be used when the slope gradient is 1.0:1.0 or less (gentle).
- Although the vegetation sandbag is commonly packed at the inside of frames of the grating crib works using precast blocks, it is desirable to packed the riprap when the spring water is present.
- On the occasion of the construction of the grating crib works using precast blocks, the anchor bar of 50-100 cm length should be placed at the intersection of frames as shown in **Figure 10.2-9**, in principle.

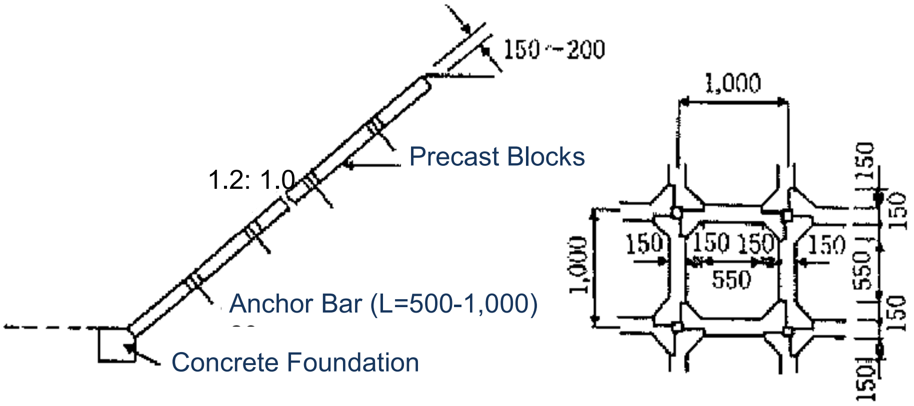


FIGURE 10.2-9 EXAMPLE OF CRATING CRIB WORKS USING PRECAST BLOCKS

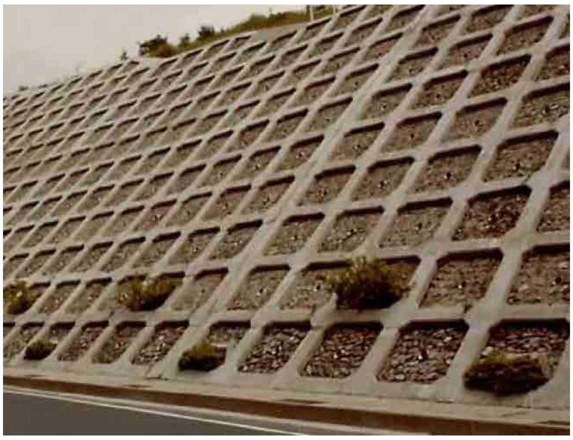


PHOTO 10.2-11 WORKING EXAMPLE OF GRATING CRIB WORKS USING PRECAST BLOCKS

(e) Considerations of Grating Crib Works using Shotcrete

- Although the grating crib works using shotcrete should be generally selected for the prevention purposes against erosion and slipping of surface soils or rocks, there are cases of utilization as the part for connecting the heads of the rock bolt type anchor or the ground anchor.
- The grating crib works using shotcrete is the generic name of the grating crib works of reinforced concrete using shotcrete. It is necessary to select the optimum type according to the slope gradient and the purpose of use, because there are several types which consist of the various shapes and sizes of the frame and the frame intervals as shown in **Figure 10.2-10**.
- On the occasion of the construction of shotcrete, the formworks which are made with the welded wire fabric, etc. and the rebar should be placed on slopes in advance.
- The specified design strength of the shotcrete shall be 18 MPa or more.
- Although the vegetation sandbag or the vegetation base material spraying is commonly constructed at the inside of frames of the grating crib works using shotcrete, it is desirable to pack the riprap when the spring water is present.

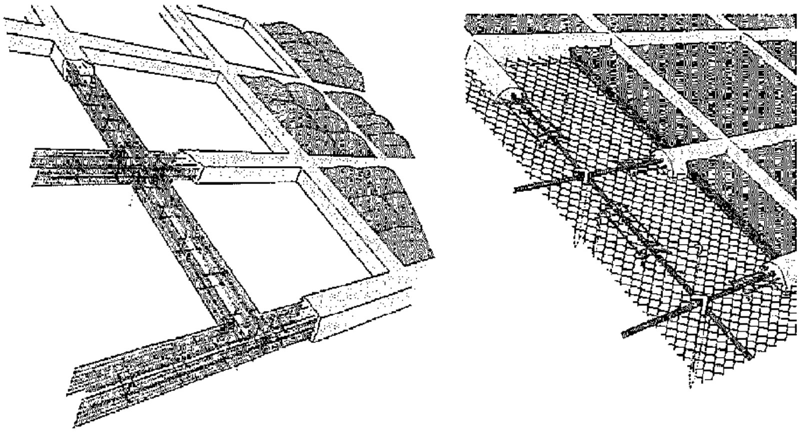


FIGURE 10.2-10 EXAMPLE OF GRATING CRIB WORKS USING SHOTCRETE

PHOTO 10.2-12 WORKING EXAMPLE OF GRATING CRIB WORKS USING SHOTCRETE

(f) Considerations of Stone/Rubble-Concrete Masonry

- The stone/rubble-concrete masonry is selected in principle for the prevention purposes against erosion and slipping of surface soils or rocks. This type should be used at the underneath of soil and rock slopes.
- Although as this type structure, the stone masonry is commonly used, there is the case of replacing with the rubble-concrete masonry on the consideration of economic efficiency.
- The stone/rubble-concrete masonry should be constructed until the required height or dimensions by the use of the 1:2 mortars (cement 1: sand 2). And like the grouted riprap, the weep hole (PVC pipe) should be placed in the stone/rubble-concrete masonry.
- The standard thickness of the stone/rubble-concrete masonry is approximately 45-75 cm. And it should be decided according to the conditions of shown in **Figure 10.2-11** in case of the soil slopes. In case of the rock slopes, it may be 45 cm or more without regard to the slope height; however the slope height is desirable to be 7 m or less.

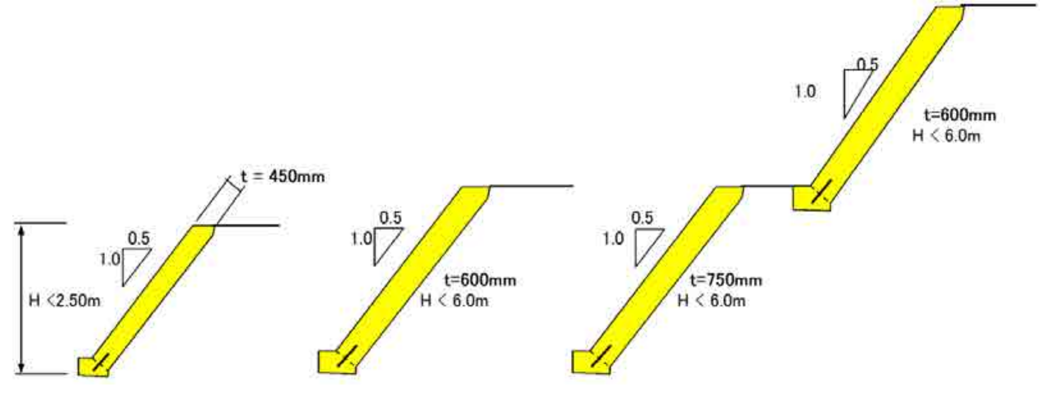


FIGURE 10.2-11 USE CONDITION OF STONE/RUBBLE-CONCRETE MASONRY

PHOTO 10.2-13 WORKING EXAMPLE OF STONE/RUBBLE-CONCRETE MASONRY

(g) Considerations of Mat Gabion

- The mat gabion is selected in principle for the purposes of the improvement of drainage and the prevention of slipping of slopes. This type should be used at the underneath of soil slopes where the spring water is present.
- The mat gabion is the structure that the riprap/rubble is packed in the basket of rectangular parallel piped which is made with the wire mesh.
- The filter cloth should be placed back of the mat gabion as shown in **Figure 10.2-12** when the outflow of soils by suction due to the spring water is concerned.

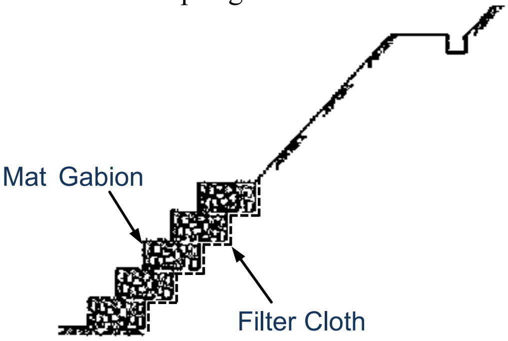


FIGURE 10.2-12 EXAMPLE OF MAT GABION

PHOTO 10.2-14 WORKING EXAMPLE OF MAT GABION

(h) Considerations of Rock Bolt Type Anchor

- The rock bolt type anchor is selected in principle for the purposes of the prevention of surface failure or slope failure in soil and rock slopes.
- The rock bolt type anchor is the method that reinforces the slopes by insertion of the rebars and cement milk into the hole drilled by boring machine. And this method is used frequently when the reduction of the excavation volume by the slopes of steeper gradient than the standard slope gradient is desired.
- The rock bolt type anchor should be designed by the slope stability analysis results which are

carried out based on the geotechnical investigation results in principle.

- The rock bolt type anchor should be used combining with the grating crib works using shotcrete and etc. as shown in **Figure 10.2-13**.

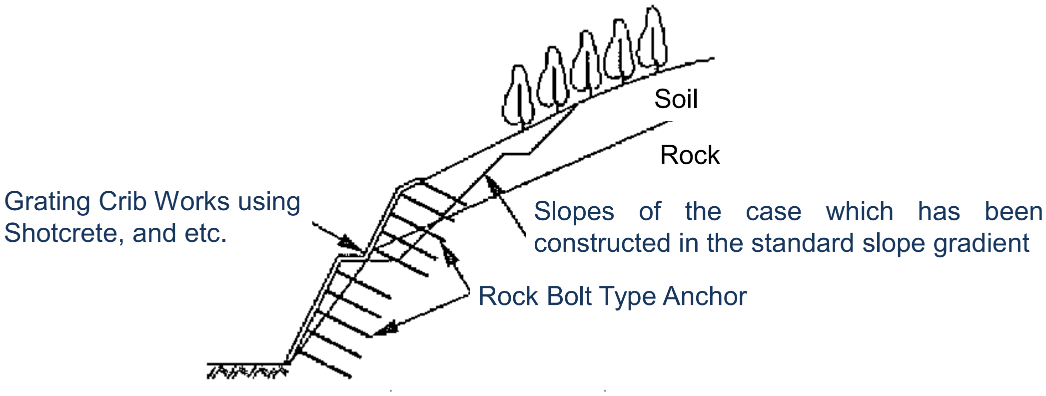


FIGURE 10.2-13 EXAMPLE OF ROCK BOLT TYPE ANCHOR

PHOTO 10.2-15 WORKING EXAMPLE OF ROCK BOLT TYPE ANCHOR
(WITH GRATING CRIB WORKS USING SHOTCRETE)

(i) Considerations of Ground Anchor

- The ground anchor is selected in principle for the prevention purposes against slope failure or landslide. This type should be used combining with the grating crib works and etc.
- The ground anchor is the method to hold down the slopes by the pre-stress of the anchor tendon (pre-stressing steel wire) consisting of the tendon and the anchorage, which should be inserted into the hole drilled by boring machine with the cement milk.
- The ground anchor should be designed by the stability analysis results of landslide, etc. which are carried out based on the geotechnical investigation results.
- The ground anchor shall be used combining with the grating crib works using shotcrete and etc. as shown in **Figure 10.2-14**.

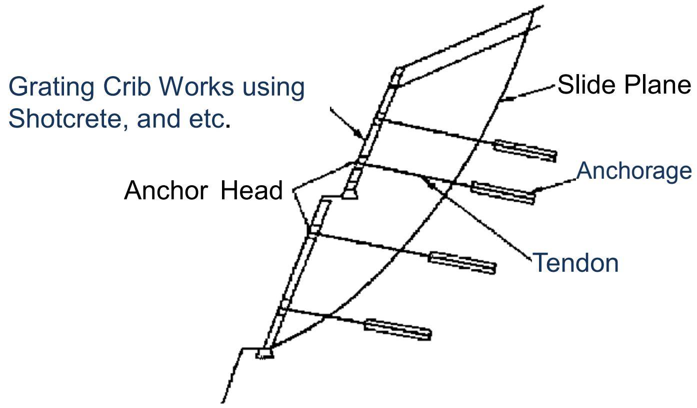


FIGURE 10.2-14 EXAMPLE OF GROUND ANCHOR

PHOTO 10.2-16 CONSTRUCTION STATUS OF GROUND ANCHOR

PHOTO 10.2-17 WORKING EXAMPLE OF GROUND ANCHOR
(WITH GRATING CRIB WORKS USING SHOTCRETE)

(6) Standard Slope Gradients for Embankment

Standard Slope Gradient for Embankment which is mentioned in Road Earthwork - Guideline for Embankment: April 2010 (issued by Japan Road Association) of Japan is given in the **Table 10.2-9**, as the standard gradient of embankment slopes of the project road.

The standard slope gradient of embankment slopes is as shown in **Table 10.2-9**, and the height of embankment that can be applied varies by banking materials.

The height of embankment in **Table 10.2-9** is the height difference between top and toe of the embankment slope. Therefore the same slope gradient should be applied at top-toe of the slope without regard to the existence of berms.

TABLE 10.2-9 STANDARD SLOPE GRADIENTS FOR EMBANKMENT WHICH ARE DEPENDED ON BANKING MATERIALS/HEIGHT OF EMBANKMENT

Banking Materials	Height of Embankment	Gradient	Remark
Well-graded sand (SW), Gravel (GW, GP), Silty gravel (GM), Clayey gravel (GC)	5m or less	1.5:1.0 to 1.8:1.0	The standard slope gradient of embankment slopes can be applied in case of some conditions. The conditions are the enough bearing capacity of foundation ground, the no-influence place of the inundation, the well-compacted embankment. The characters in parentheses of "Banking Materials" are the group symbols of the unified soil classification of ASTM (D 2487). The stability analysis of the embankment should be carried out, when the slope gradient is out of range of the standard slope gradients.
	5m to 15m	1.8:1.0 to 2.0:1.0	
Poorly graded sand (SP)	10m or less	1.8:1.0 to 2.0:1.0	
Rock lump (including Rock debris) (GW, GP)	10m or less	1.5:1.0 to 1.8:1.0	
	10m to 20m	1.8:1.0 to 2.0:1.0	
Silty sand (SM), Clayey sand (SC), Lean clay (CL), Silt (ML)	5m or less	1.5:1.0 to 1.8:1.0	
	5m to 10m	1.8:1.0 to 2.0:1.0	
Volcanic cohesive soil (CH, MH)	5m or less	1.8:1.0 to 2.0:1.0	

Source: Road earthwork - Guideline for Embankment: April 2010 (Issued by Japan Road Association): The group symbols were modified based on the unified soil classification of ASTM (D 2487).

Further, the material classification of AASHTO (M57-80), which the materials for embankments and subgrades are targeted, is different from the unified soil classification of ASTM (D 2487) is shown in **Table 10.2-9**, but the rough relationships of the two soil classifications are shown in **Table 10.2.7-4**.

TABLE 10.2-10 ROUGH RELATIONSHIPS BETWEEN UNIFIED SOIL CLASSIFICATION OF ASTM AND MATERIAL CLASSIFICATION OF AASHTO

Banking Materials	Unified Soil Classification of ASTM	Material Classification of AASHTO
Well-graded sand (SW), Gravel (GW, GP), Silty gravel (GM), Clayey gravel (GC)	SW	A-2-4, A-2-5
	GW, GP, GM, GC	A-1
Poorly graded sand (SP)	SP	A-3
Rock lump (including Rock debris) (GW, GP)	GW, GP	A-1
Silty sand (SM), Clayey sand (SC), Lean clay (CL), Silt (ML)	SM, SC	A-2-6, A-2-7
	CL, ML	A-4, A-6
Volcanic cohesive soil (CH, MH)	CH, MH	A-5, A-7

Note: In AASHTO (M57-80), A-1, A-2-4, A-2-5, A-3 are defined as the embankment materials of "excellent to good" quality, and A-2-6, A-2-7, A-4, A-5, A-6, A-7 are defined as the embankment materials of "fair to poor" quality.

(7) Slope Protection of Embankment

The slope protection of embankment should be applied the planting in principle. However, such the slope protection as the grouted riprap should be applied in the inundation risk sites such of the river flood areas.

In addition, when the rock debris is used as banking materials, the slope should be overlaid by the soil blanket on embankment slope (Cohesive soil) for vegetation, as shown in **Figure 10.2-15**, except the case of slope protection of the grouted riprap. The thickness of the soil blanket on embankment slope shall be 30 cm or more in consideration of the growth of vegetation.

The economical sowing is recommended as the planting of embankment slopes, but the stripped sodding (lined turf) is suitable when the slopes are overlaid by the soil blanket on embankment slope.

Further, the structure of the grouted riprap shall be the same structure with the case of the cut slopes (Refer **Figure 10.2-6** and **Figure 10.2-7**).

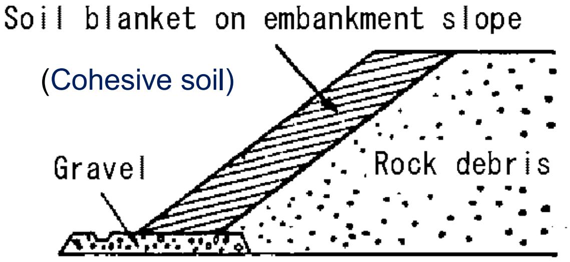


FIGURE 10.2-15 OVERLAYS BY SOIL BLANKET ON EMBANKMENT SLOPE

10.3 ROAD DESIGN

10.3.1 General

Road design concept shows as follows;

- Road design is based on two lanes, considering four lanes widening in the future.
- To minimize the road construction cost and soil disposal impact. The volume of cutting and embankment should be balanced as much as possible.
- To consider not only the accessibility of connecting road and roadside area but also high mobility function as bypass.

10.3.2 Road Cross Section

The centerline of road cross section shows the future four-lane road. Initial stage is to construct the two-lane road at Davao City central side (at seaside) and then the widening stage is to construct additional two lanes at inland side. To minimize the traffic impact during widening road works, demolish and reconstruction of slope protection facilities, it is recommended that cutting and embankment works will be done as four-lane at initial stage. **Figure 10.3-1** shows the typical cross section of embankment and cut at each stage.

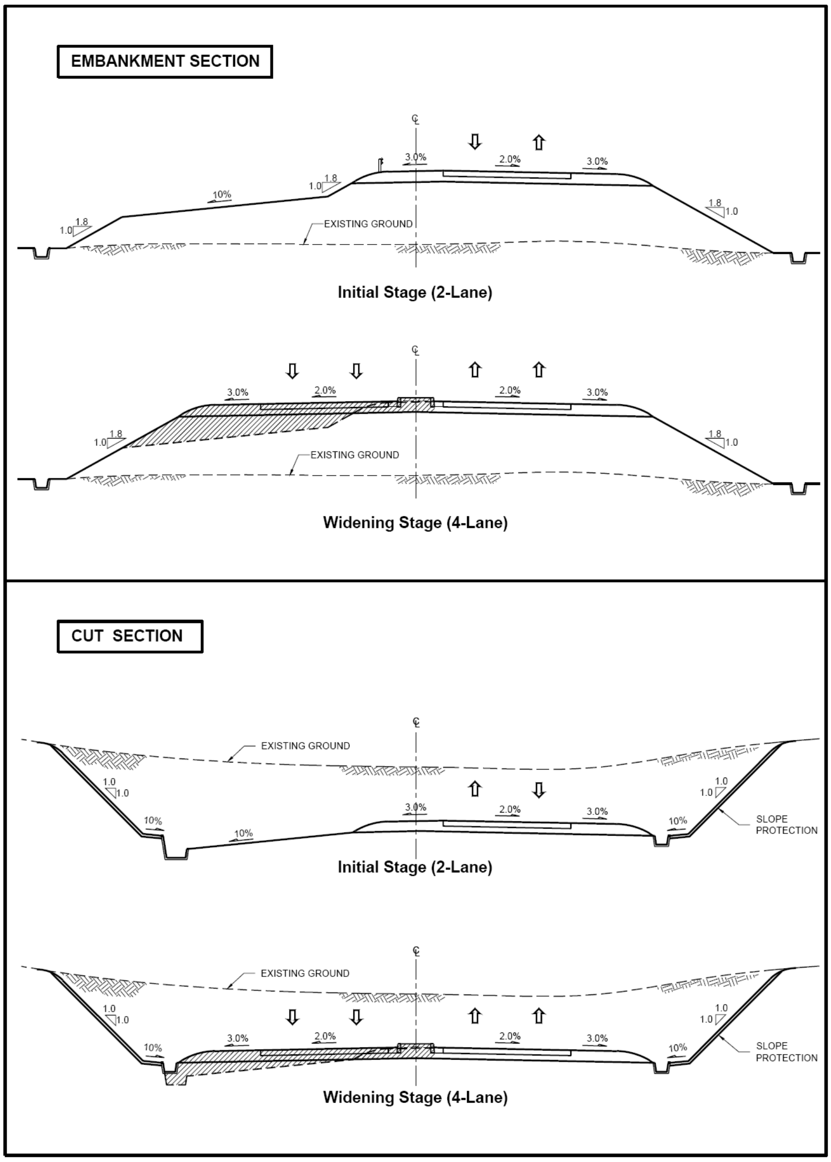


FIGURE 10.3-1 TYPICAL CROSS SECTION (INITIAL AND WIDENING) CONTROL POINT

Major alignment control point was described in Chapter 9 (Alignment Selection of Davao City Bypass).

This section describes the control points for preliminary design based on selected alignment.

- Based on topographical survey result, the preliminary design was conducted to minimize the bridge length, embankment and cut height and to avoid affected structures as much as possible.
- Main changes of horizontal and vertical alignment was done using the above concept.

10.3.3 Embankment and Cut Section

Figure 10.3-2 shows the total length of high embankment and cut section. **Table 10.3-1** shows the total length of high embankment based on the preliminary design.

TABLE 10.3-1 EMBANKMENT AND CUT SECTION LENGTH

Unit: km

	10m > H > 5m	H > 10m	Total
Cut Section	4.28	6.03	10.31
Embankment Section	3.72	1.55	5.27
Flat (H<5m)	-	-	21.59
Total	8.00	7.58	37.17

Note: Not including bridge and tunnel section

Figure 10.3-2 shows the location map for the high cut and embankment section.

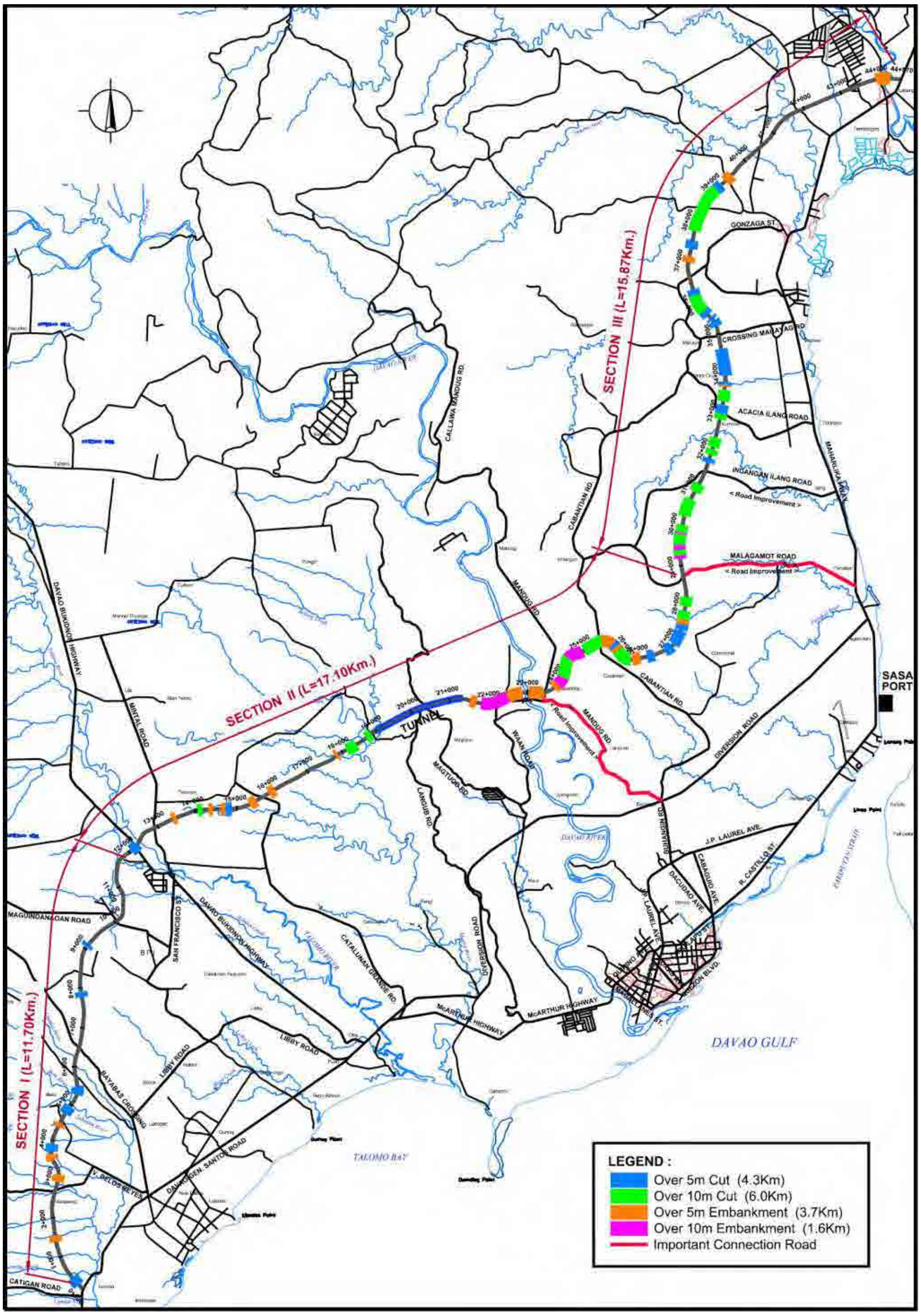


FIGURE 10.3-2 LOCATION MAP OF HIGH CUT AND EMBANKMENT SECTION CROSSING SECTION

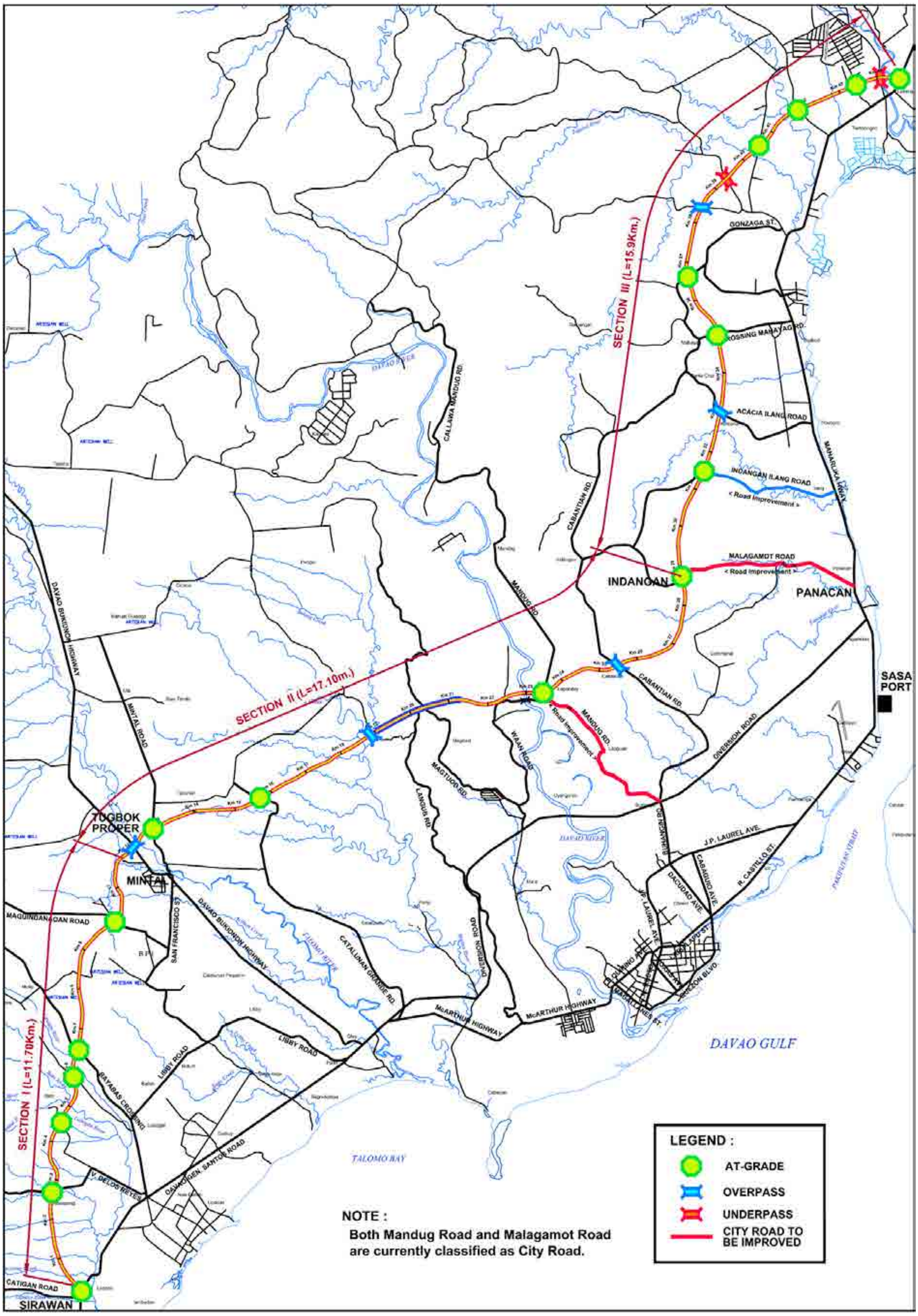
(1) Technical Approach

In order to improve the accessibility after the construction of the Bypass, crossing roads are designed.

Technical approach of design is as follows;

1) To provide crossing road to improve accessibility after the bypass construction.
2) To provide flyover at crossing major road underneath to provide high traffic function at the bypass road users.
    - (Beginning Point) Flyover during widening stage (see **Figure 10.3-4**)
    - (End Point) Flyover during widening stage (see **Figure 10.3-5**)
    - Davao-Bukidnon Road Flyover from the initial stage (see **Figure 10.3-6**)

Figure 10.3-3 shows the location map of intersection type. **Figure 10.3-4 ~ Figure 10.3-6** shows three major intersection types considering future widening.



NOTE :
Both Mandug Road and Malagamot Road are currently classified as City Road.

FIGURE 10.3-3 LOCATION MAP OF INTERSECTION TYPE

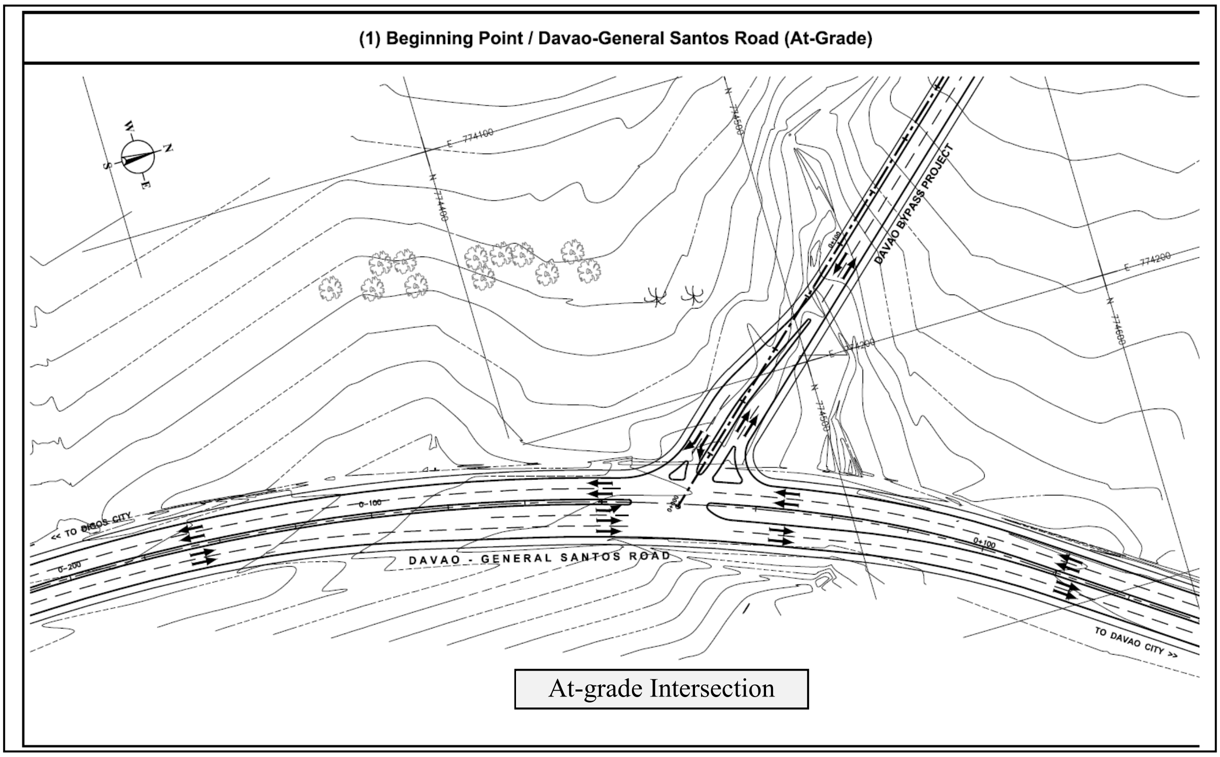


FIGURE 10.3-4 (1) INTERSECTION OF DAVAO-GENERAL SANTOS ROAD (0+000) (INITIAL STAGE)

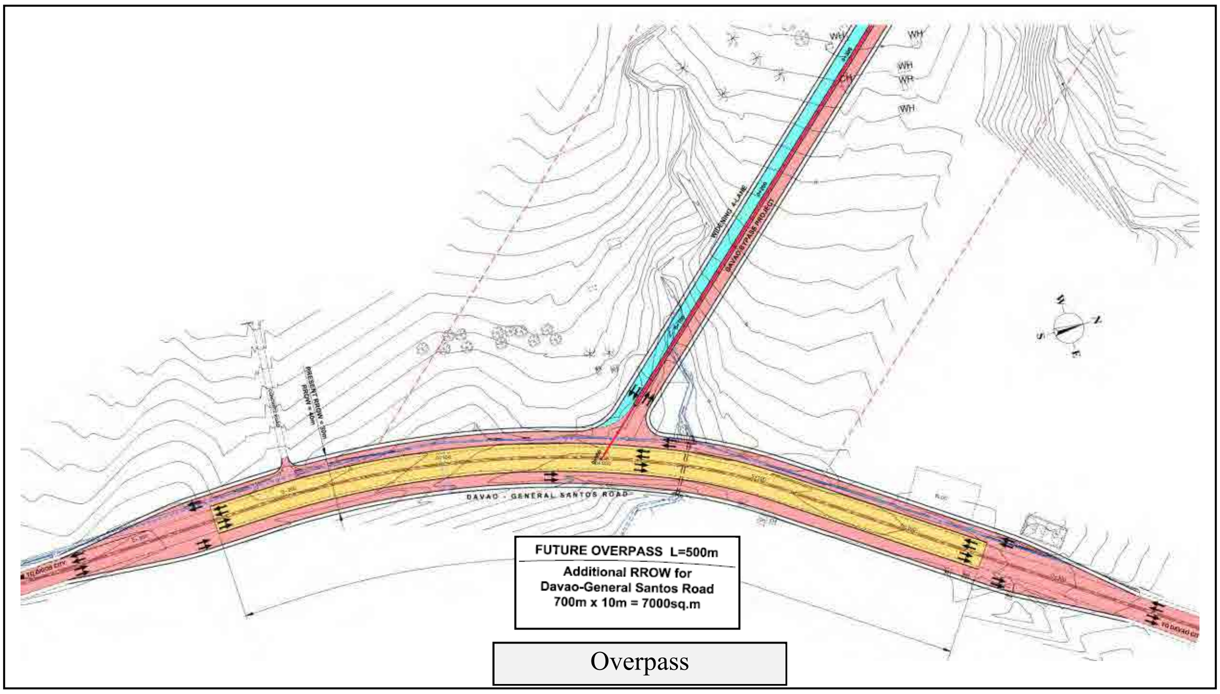


FIGURE 10.3-4 (2) INTERSECTION OF DAVAO-GENERAL SANTOS ROAD (0+000) (WIDENING STAGE)

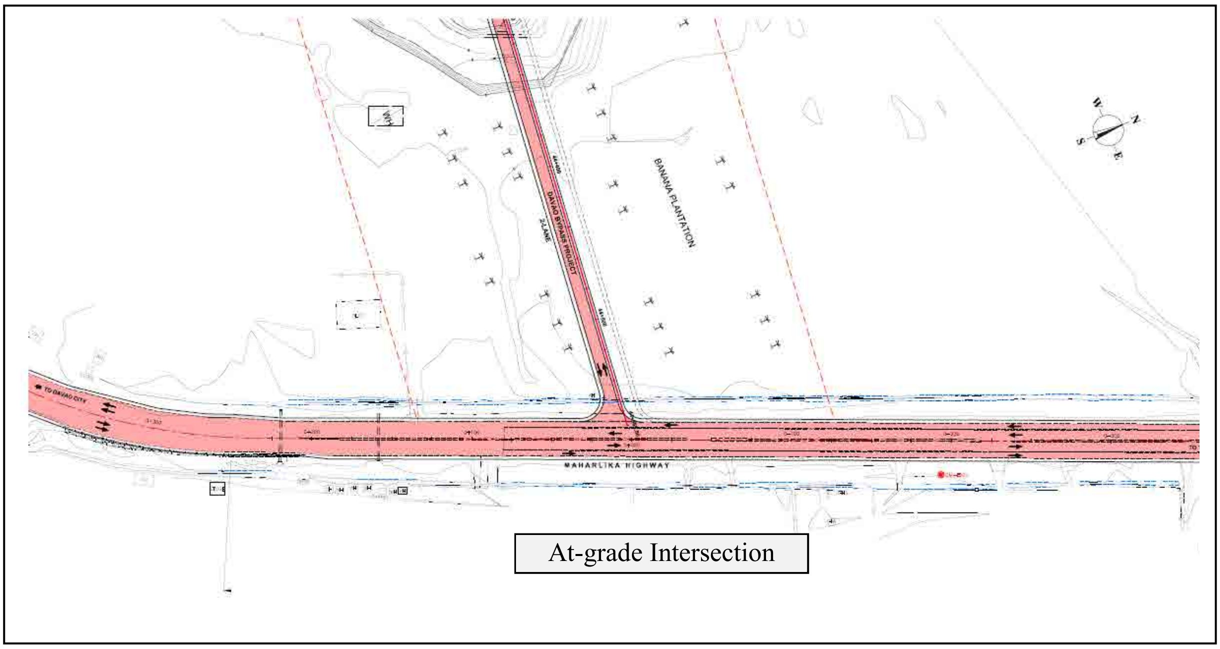


FIGURE 10.3-5 (1) INTERSECTION OF MAHARLIKA HIGHWAY (46+600)
(INITIAL STAGE)

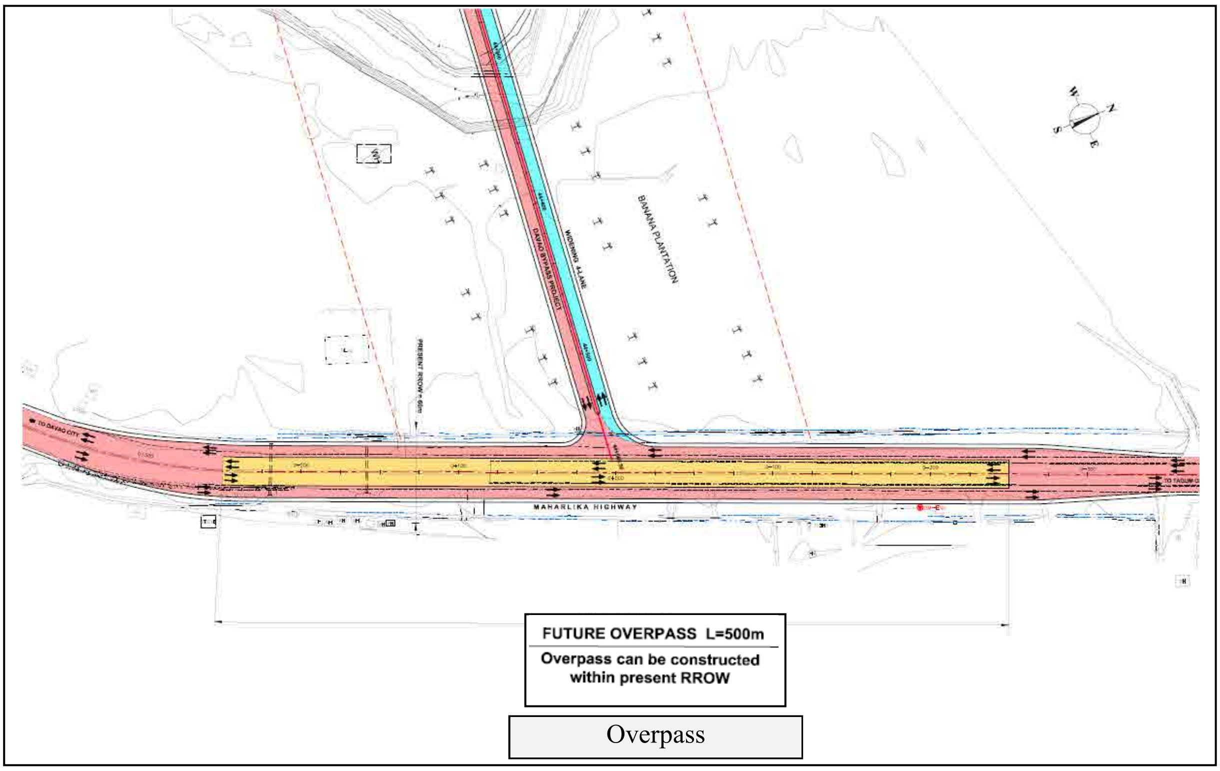


FIGURE 10.3-5 (2) INTERSECTION OF MAHARLIKA HIGHWAY (46+600)
(WIDENING STAGE)

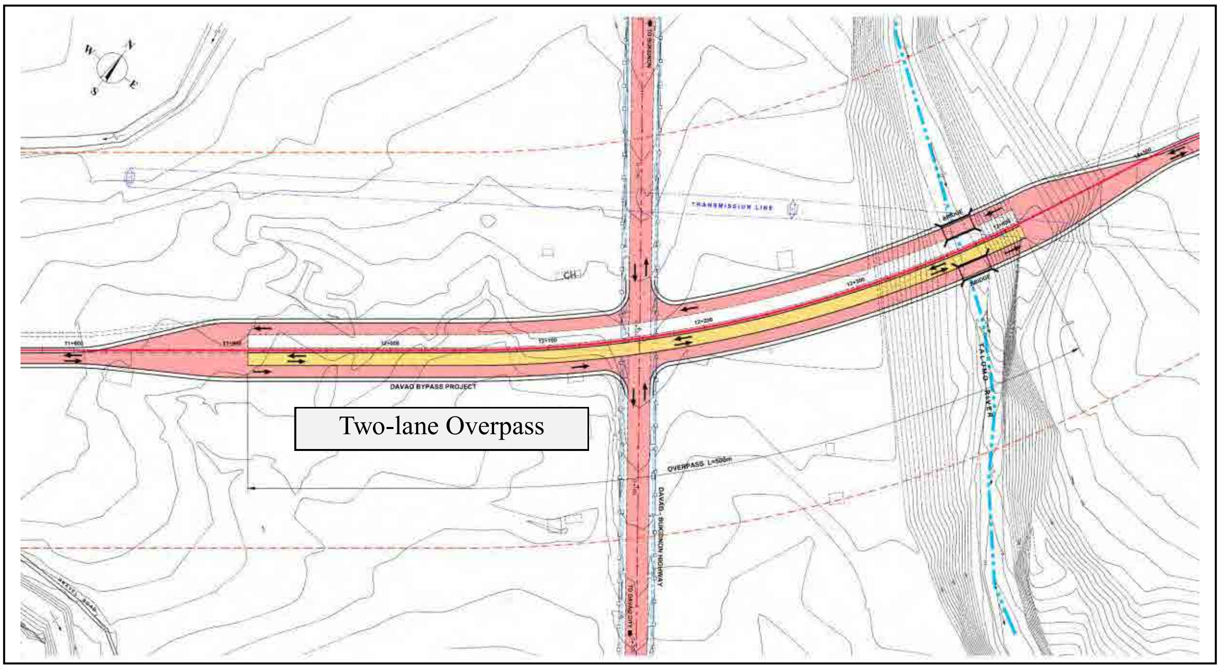


FIGURE 10.3-6 (1) INTERSECTION OF DAVAO-BUKIDNON HIGHWAY (12+150) (INITIAL STAGE)

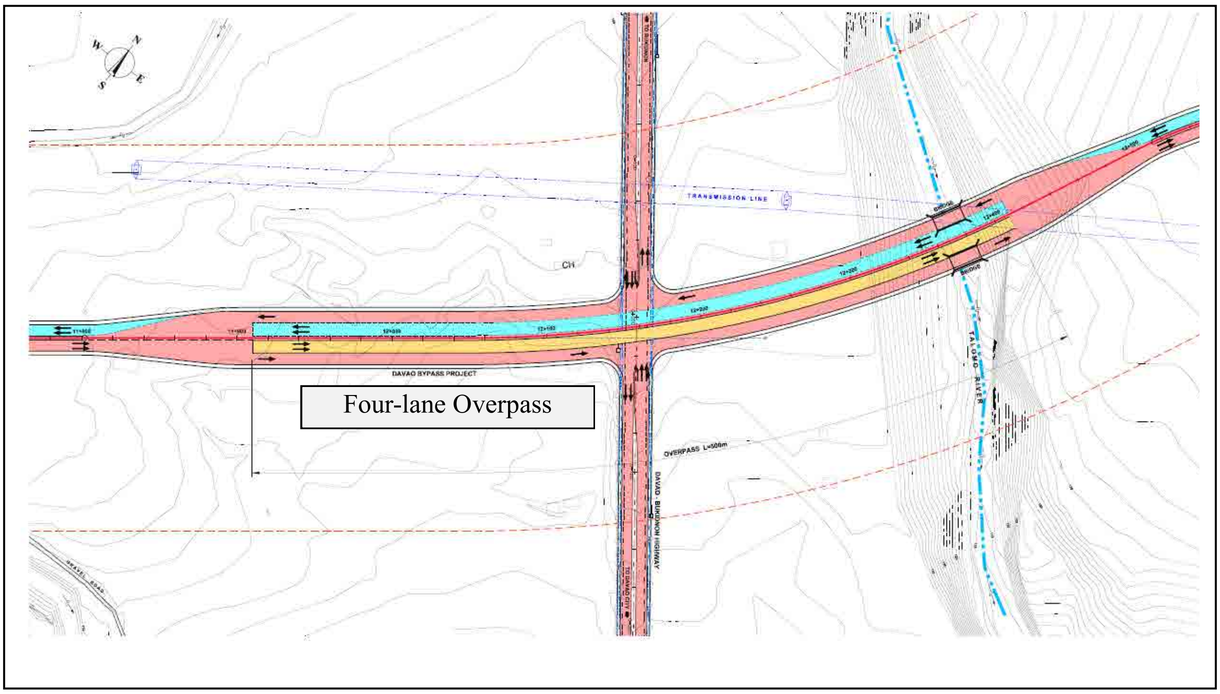


FIGURE 10.3-6 (2) INTERSECTION OF DAVAO-BUKIDNON HIGHWAY (12+150) (WIDENING STAGE)

10.4 TUNNEL DESIGN

The basic tunnel design standards were presented in **Section 10.2.3**.
Total Tunnel Length: 2,280m (19 + 030 – 21 +310)

- Main Tunnel, 2-lane (1 lane per direction)
- Evacuation Tunnel with evacuation adit (3 @ 30m) and personnel adit (2 @ 30m)

Figure 10.4-1 shows the plan of the tunnel section.

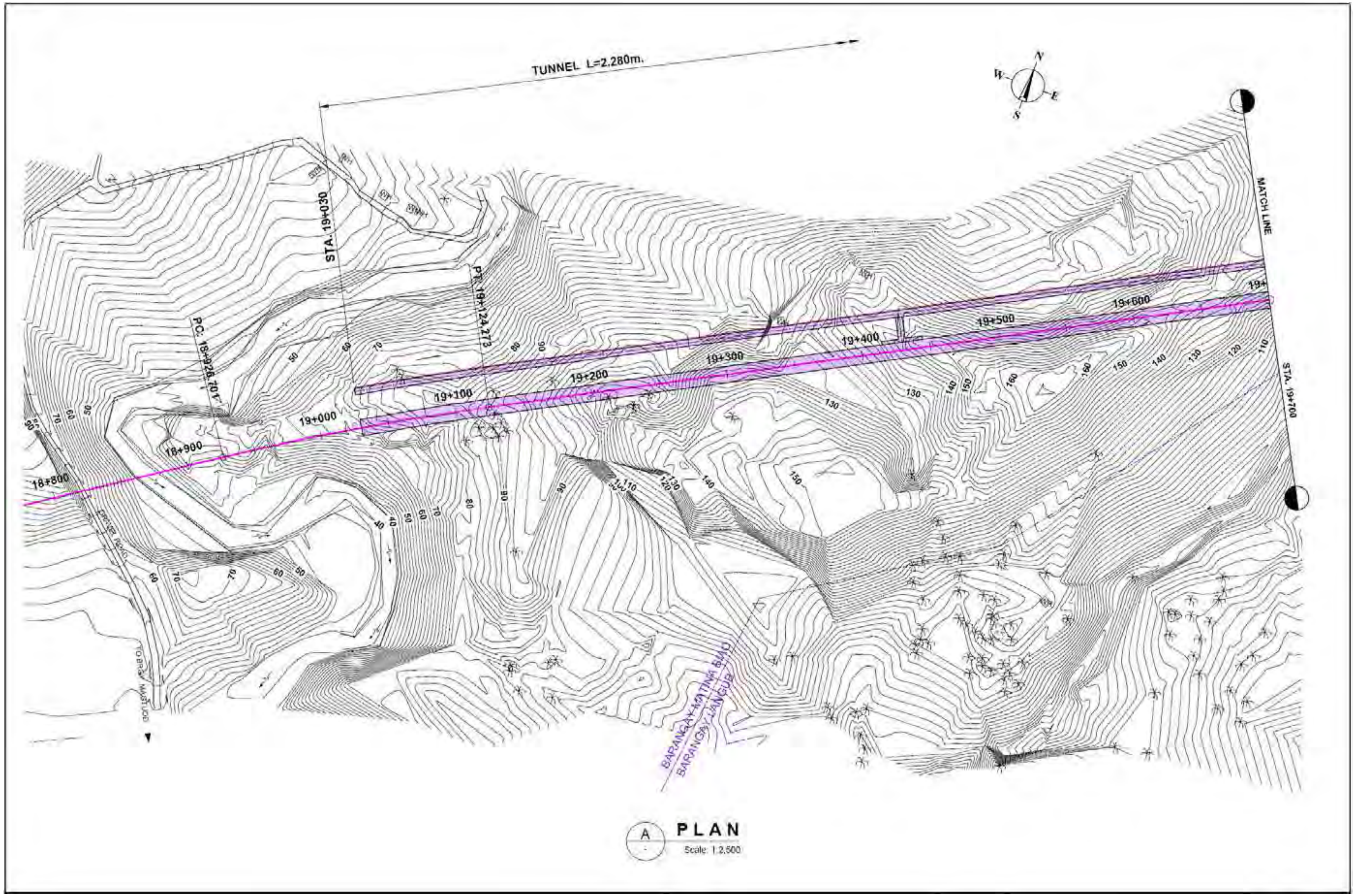


FIGURE 10.4-1 TUNNEL PLAN

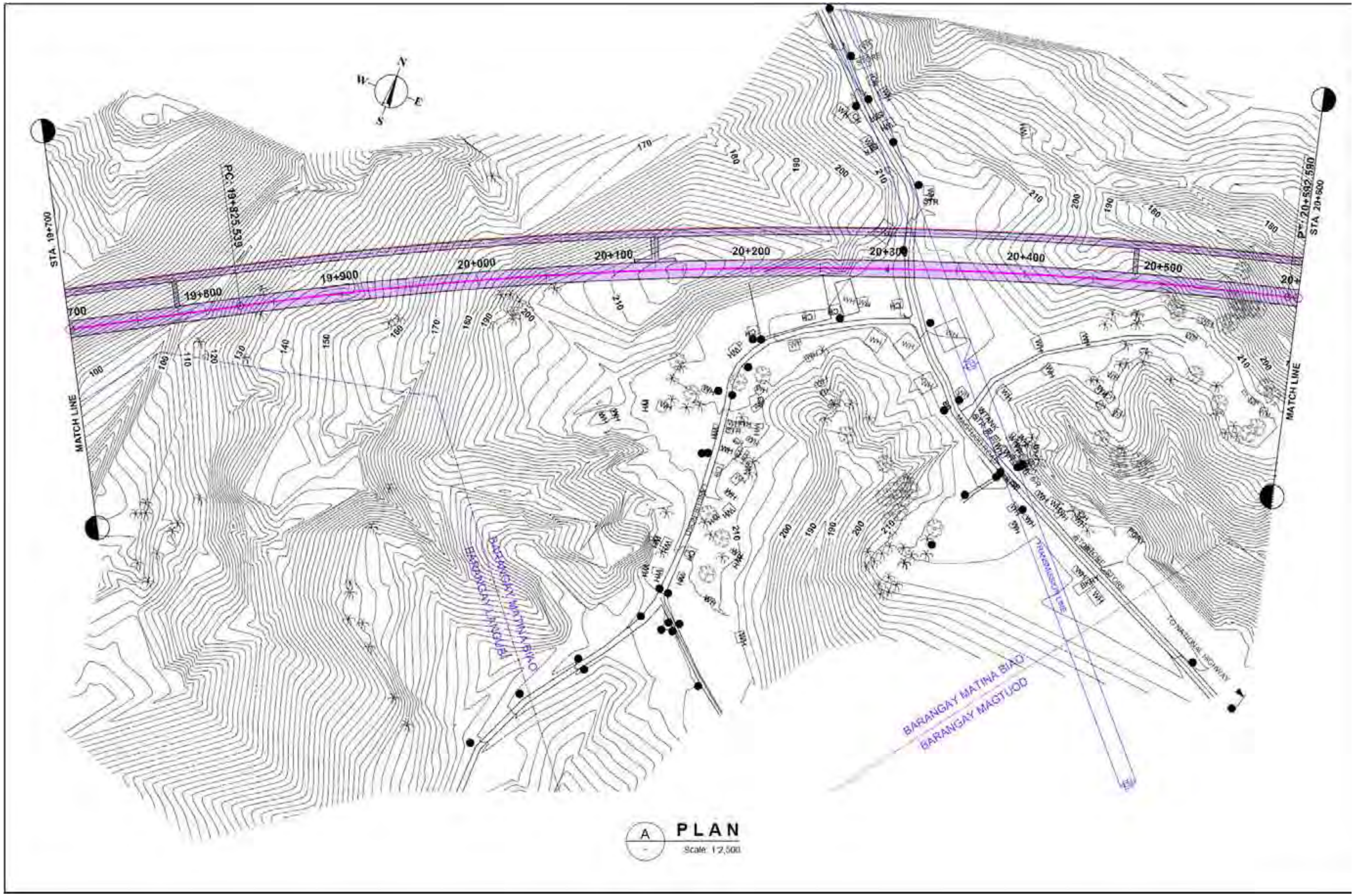


FIGURE 10.4-2 TUNNEL PLAN

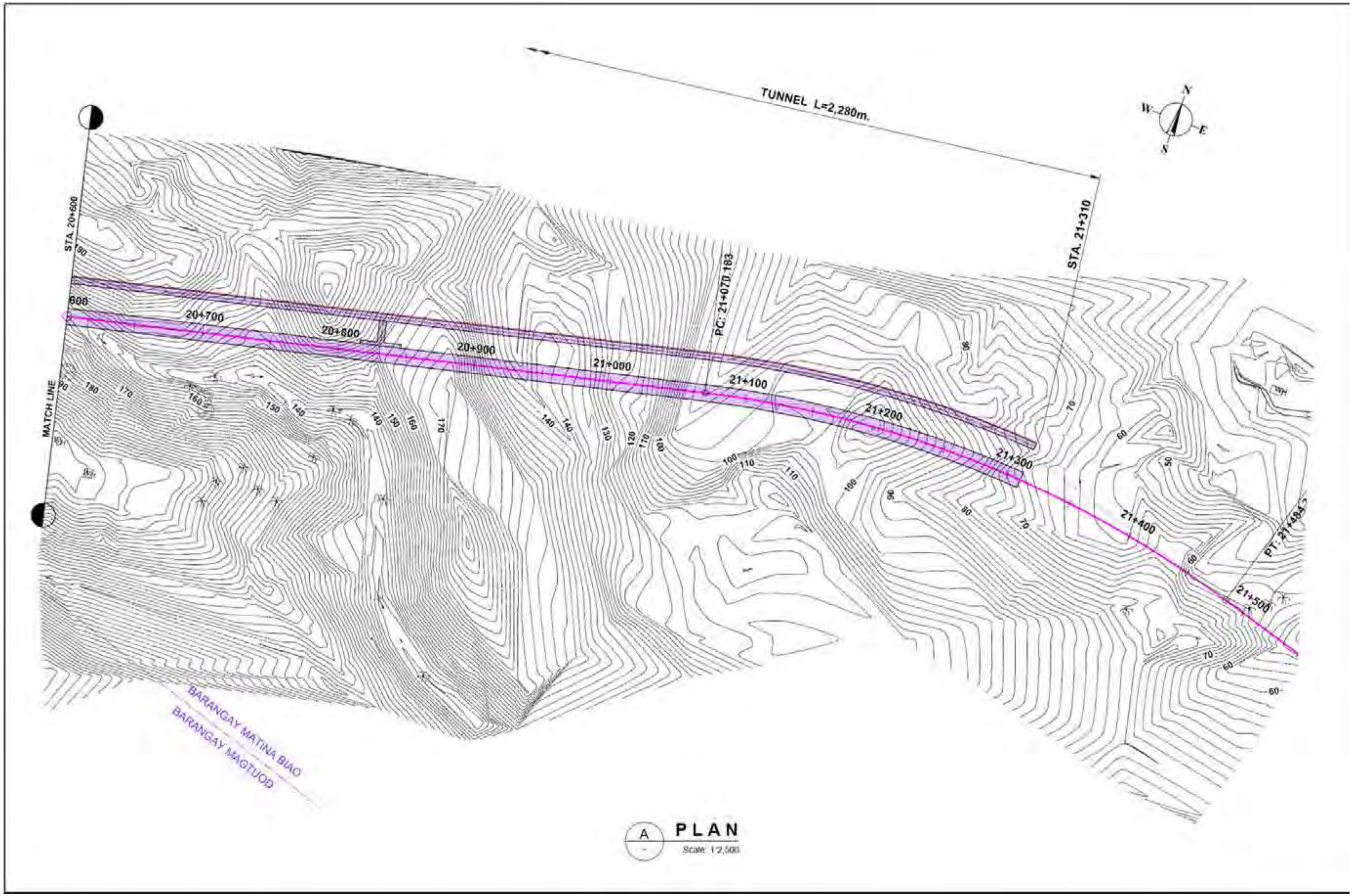


FIGURE 10.4-3 TUNNEL PLAN

10.4.1 Main Tunnel Excavation Pattern

Expected geology on the tunnel route by the geological survey showed the geological profile of tunnel design drawings (see **Figure 10.4-4** and **Photo 10.4-1**). Different excavation patterns were suggested as section 3, C2, D1, and D2. As shown in **Table 10.4-1**, four (4) types of typical cross section were prepared. Based on the geological condition, the tunnel invert is necessary for the whole section due to mudstone. C2, D1 and D2 were selected.

TABLE 10.4-1 LENGTH OF TUNNEL EXCAVATION PATTERN

West Side **East Side**

D2	**D1**	**C2**	**D1**	**D2**	**D1**	**D2**	**D2**
70m	90m	150m	350m	160m	950m	400m	110m
						Total = 2,280m	
Auxiliary Method (AGF): Total 250m							
70m						70m	110m

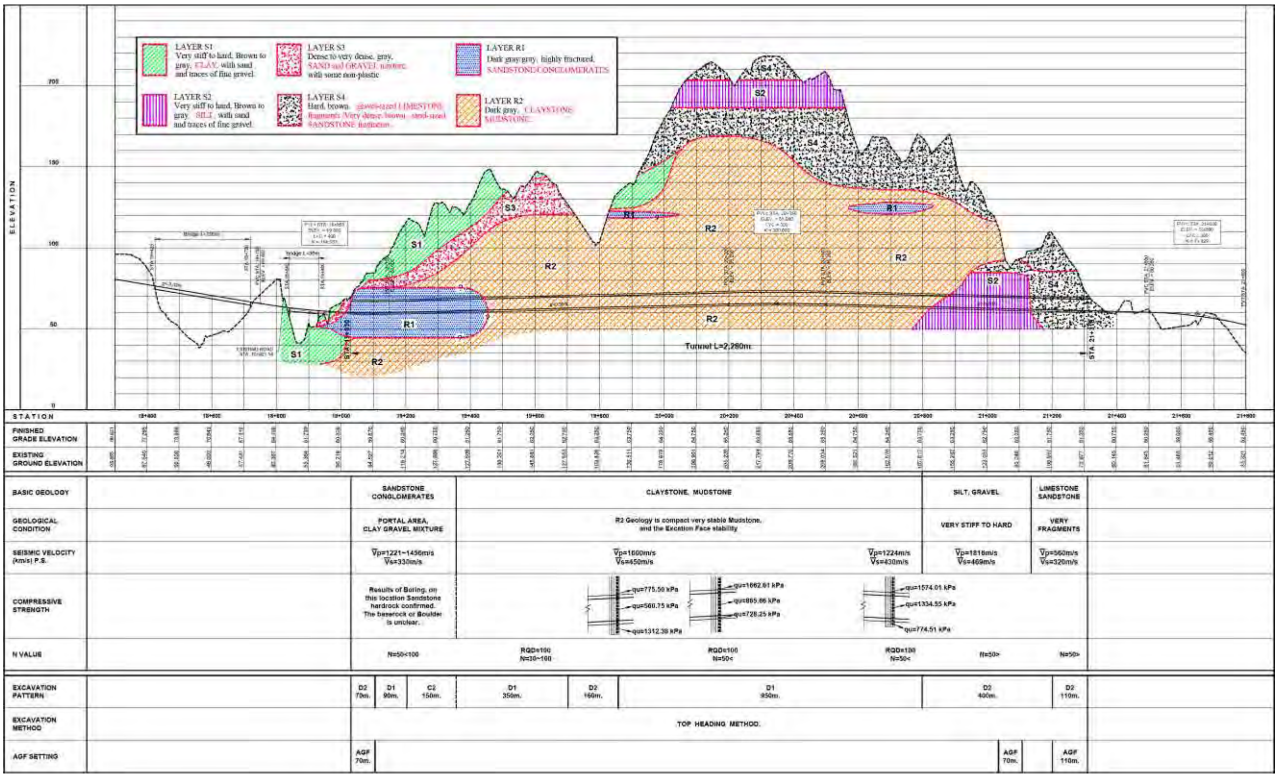
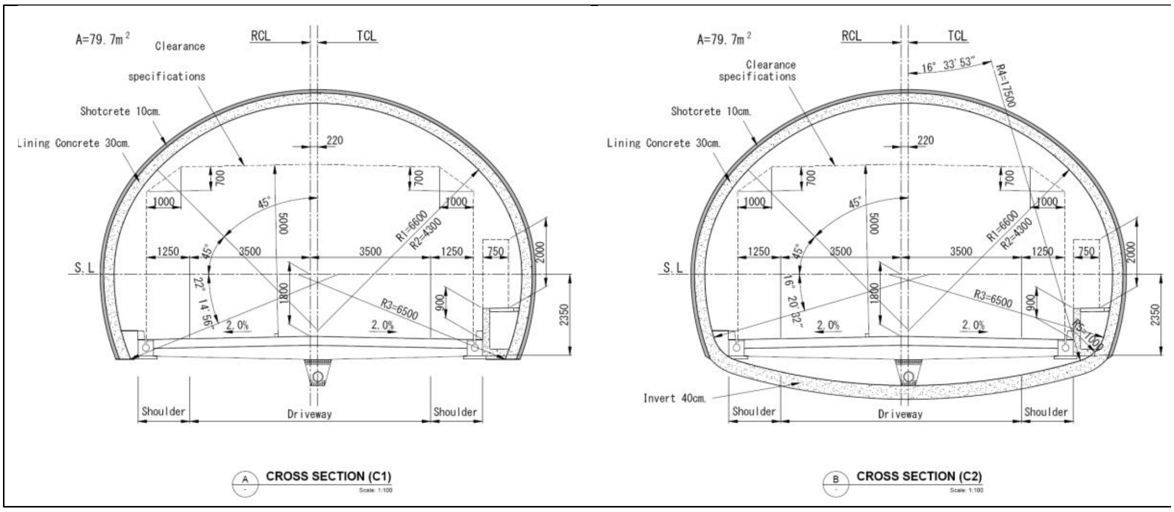


FIGURE 10.4-4 GEOLOGICAL CONDITION, EXCAVATION PATTERN AND AGF SETTING

PHOTO 10.4-1 EXCAVATED CONDITION AT QUARRY SITE
(ABOUT 1KM AWAY FROM THE TUNNEL SECTION)



A CROSS SECTION (C1) Scale: 1:100

B CROSS SECTION (C2) Scale: 1:100

FIGURE 10.4-5 TYPICAL TUNNEL CROSS SECTION (TYPE C)

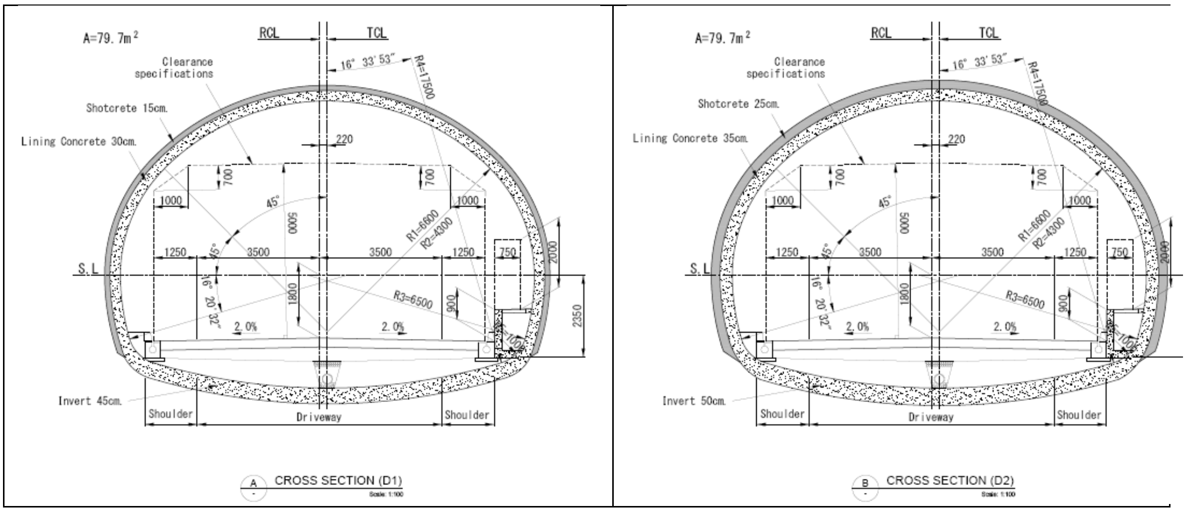


FIGURE 10.4-5 TYPICAL TUNNEL CROSS SECTION (TYPE D)

10.4.2 Tunnel Excavation Method

- Excavation method adopted is conventional NATM. (NATM: New Austrian Tunneling method) based on geological survey results of tunnel route consider the blasting system or mechanical drilling system.
- Mechanical drilling and blasting system for geological criteria uses Japanese bombing scheme. This scheme is economical from over 30Mp of the uni-axial compressive strength of rock.
- Geological condition along tunnel route is considered soft rock ground quality. Therefore, standard excavation method adopted is upper half drilling excavation method for engineering safety and economic efficiency. This excavation Method is shown in **Figure 10.4-6**.
- Efficient management is important item to reduce risks during construction.
- Tunnel drilling soft layer, would require further auxiliary methods. In this case, it require a special construction such as tip of the receive method

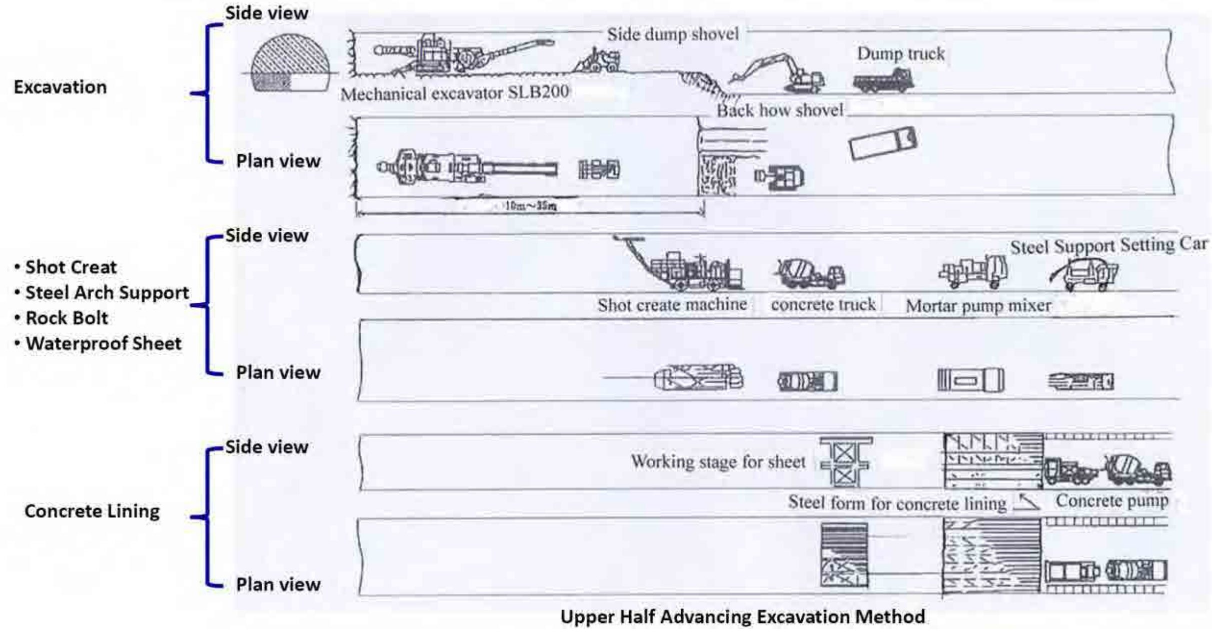


FIGURE 10.4-6 SYSTEM OF EXCAVATION METHOD

(1) Tunnel Excavation Equipment's

Standard facilities and equipment's for tunnel construction are listed in **Table 10.4-2**. Mechanical excavator and breaker machine are used for tunnel excavation, **Table 10.4-3** shows electric consumption of facility and equipment for tunnel construction. 782.0 kW is necessary for the works of tunnel excavation and 648.5 kW is necessary for the works of lining concrete. Accordingly, 4 units of 200KVA generators are necessary.

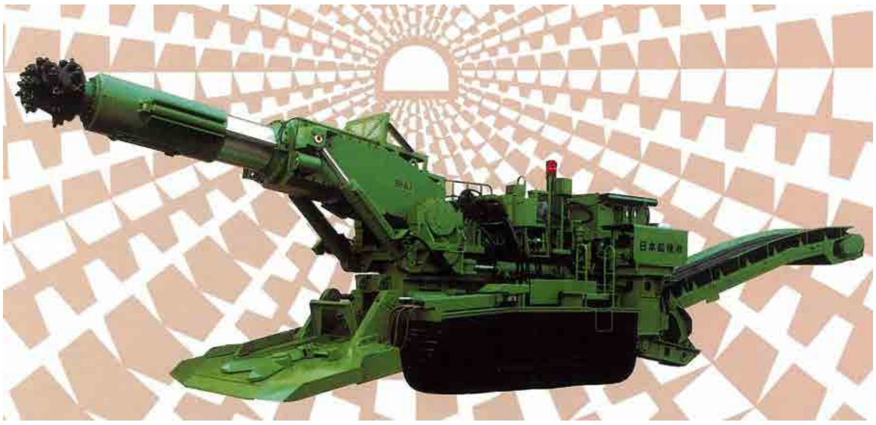
TABLE 10.4-2 TYPICAL FACILITIES AND EQUIPMENT'S FOR TUNNEL CONSTRUCTION

No	Facilities and Equipment's	Quantity (unit)	Motor (kW)	Note
1	Mechanical excavator S200 type	1	300.0	Road Header
2	Dump truck 20t-30t	6		Diesel
3	Side dump shovel	1		Diesel
4	Hydraulic breaker	1		Diesel
5	2-boom Jumbo	1	148.0	
6	Back hoe shovel	1		Diesel
7	Ventilation fan 150kW x 2 motor	1	300.0	Q=1,500 m^3/min
8	Shotcrete machine	1	120.0	
9	Mortar pump mixer	1	5.5	
10	Working stage for sheet	1	7.5	
11	Steel former for concrete lining	1	25.0	L=10.50m
12	Concrete pump	1	75.0	15 m^3/hr
13	Ready mixed concrete truck	4		Diesel
14	Transformer substation truck	1		Diesel
15	Lighting in tunnel	2,100 m	126.0	
16	Lighting outside of tunnel	300Wx10	3.0	
17	Batching plant for concrete	1	35.0	30 m^3/hr
18	Cement Silo 30t	1	5.5	
19	Sand gravel stock yards 200 m^3	3	16.5	
20	Water tank 30t	1	5.5	
21	Mechanical excavator S100 type	1	150	Evacuation TN
22	Shotcrete machine	1	40	
23	Battery units of Battery Locomotive	2	50	
24	Diesel generator 200KVA	4	800	Diesel
25	Electric power station 800KVA	1		
26	Dust-water equipment 40t/hr	1	40.0	Motor
27	Another facility	1	20.0	
	Total of Electric equipment			

TABLE 10.4-3 ELECTRIC POWER REQUIREMENT FOR TUNNEL CONSTRUCTION

Required Electric Power	kW
1. Excavation works	782.0
2. Shotcrete works	648.5
3. Concrete lining works	303.5

Photos below show some Tunnel Construction Machines;



Source : Catalog

PHOTO 10.4-2 ROOD HEADER S-200 TYPE, TOTAL POWER 302.5KW, TOTAL WEIGH 50

Source : Catalog

PHOTO 10.4-3 EXCAVATION BY ROOD HEADER

Also called a partial face machine, A Road Header is a tunneling machine. It is a boom mounted drum with cutting head that revolves to excavate rock or others.

(2) Temporary yard of facilities and equipment's for tunnel construction

Mechanical excavation using both Road Header and Breaker is planned for tunnel excavation, in consideration of the restriction of using electric power.

Standard area of temporary facilities and equipment's are shown in **Table 10.4-4**.

TABLE 10.4-4 STANDARD AREA OF TEMPORARY FACILITIES AND EQUIPMENT'S

	Item	Size（m）	Area（㎡）	No.	Note
1.	Compressor Room	4.0×7.0	28.00	1	
2.	Generator power station	8.5×24.00	204.00	1	
3.	Repair shop	7.2×9.0	64.80	1	
4.	Water supply tank	2.0×5.0	10.00	1	
5.	Turbine Pump	2.0×2.0	4.00	1	
6.	Material stock yard	8.0×15.0	120.00	1	

	Item	Size（m）	Area（㎡）	No.	Note
7.	Concrete mixing plant	8.0×20.0	160.00	1	
8.	Sewerage facilities	5.0×15.0	75.00	1	
9.	Rest room	7.2×9.0	64.80	1	
10.	Supervisor office	4.5×4.5	20.25	1	
11.	Ventilation fan	2.0×6.0	12.00	1	
12.	Muck loader yard	10.0×15.0	150.00	1	
13.	Warehouse	7.0×10.0	70.00	1	
14.	Gantry crane yard	7.0×10.0	70.00	1	
15.	Carriage-way space	8.0×100.0	800.00	1	
16.	Muck stock yard	20.0x40.0	800.00	1	
	Total		2,652.85		

Temporary yard shall be wider than the above area, approximately 30m x 100m = 3,000 ㎡ is necessary for temporary yard. Typical temporary facility plan for tunnel construction is shown in **Figure 10.4-7**.

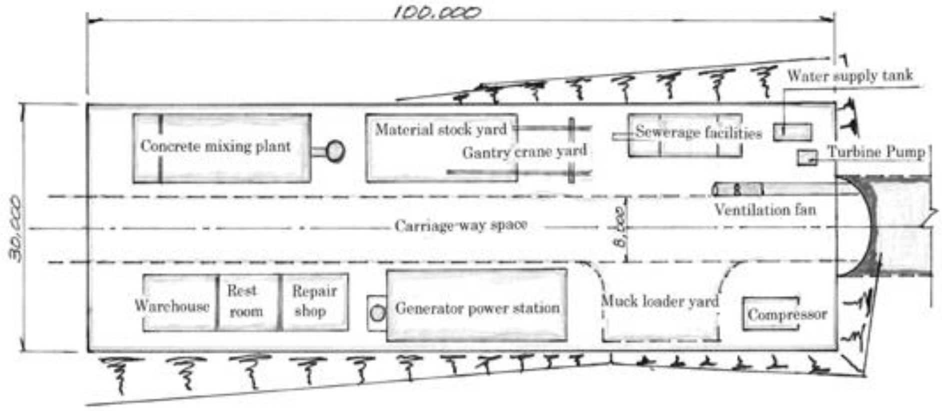


FIGURE 10.4-7 PLAN THE TYPICAL TEMPORARY FACILITIES

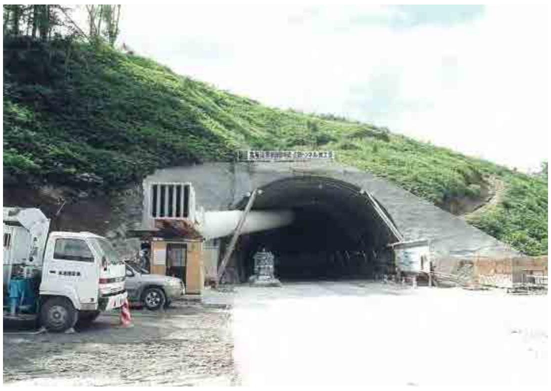
Electric Power Station and Receiving Box

Sewerage Facilities

Dust Water Filter Equipment

Generator Room for Tunnel Construction

Steel Supports Setting Equipment



Entrance of Under Construction Tunnel

All Sources of Photo: Japan Highway Corporation

(3) Works of Tunnel Lining Concrete

a) Steel Form

Following the tunnel excavation, shotcrete, rock bolts and secondary lining concrete as a permanent structure are undertaken. As for the assembly scheme framework, the steel panel of the framework (the arch centre component) is dismantled every time for one span for concrete placing and assembled again for the next concrete placing. These repeated works for the assembling and dismantling need time resulting in the poor progress for concrete lining. The form is shrinkable by extending to up and down, left and right with the jack of hydraulic type and the movement of framework is smooth for every concrete placing. This portable scheme framework is currently used for tunnel lining. The standard length of one framework is 12.0m.

PHOTO 10.4-4 SLIDING STEEL FORM

b) Lining Concrete

Challenges encountered during tunnel concrete construction management include the following items.

① Concrete finish at temperatures reaching 40 degrees Celsius. Resignation of the hair racks of drying shrinkage.
② Concrete honey real property loss due to lack of consolidation, and material separation Cavity occurs due to lack of concrete back fill.

To solve these problems, the Nippon Expressway Corporation (NEXCO) has developed the middle-performance lining concrete. It is proposed to the Davao Bypass Tunnel to adopt this method. It is tighter and of higher quality than the conventional concrete lining

(4) Auxiliary Method for Excavation of Tunnel Entrance

Entrance of tunnel Construction for mountain area is geologically unconsolidated ground range which is composed of sand, clays and gravels. It is necessary to use auxiliary method which is All Ground Fasten (AGF) Method shown in **Figure 10.4-8**.

a) AGF Method

Long steel pipe approximately **φ**100mm tubes are driven into outer surrounding area of the excavation face of tunnel. Then SRF is injected to improve the zone between the steel pipe, stabilized the working face, and prevent surface ground subsidence. Reliable effect can be expected under various fragile conditions ranging from clayey Soil to finely cracked rock.

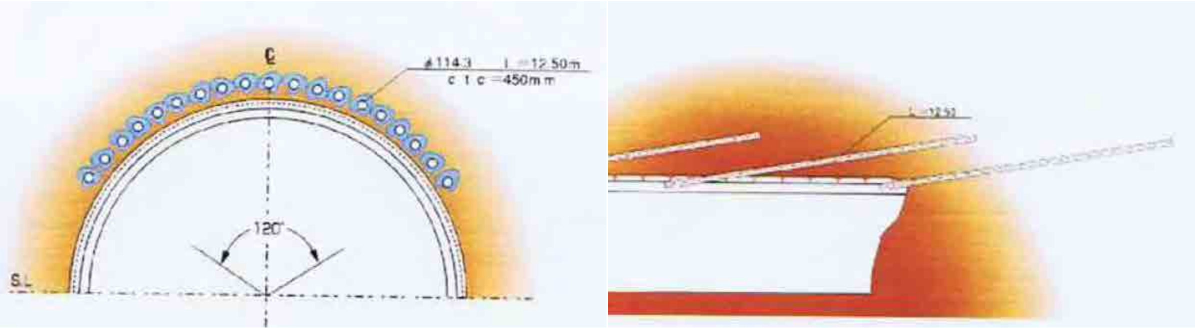


FIGURE 10.4-8 AGF – PIPE LOOP METHOD

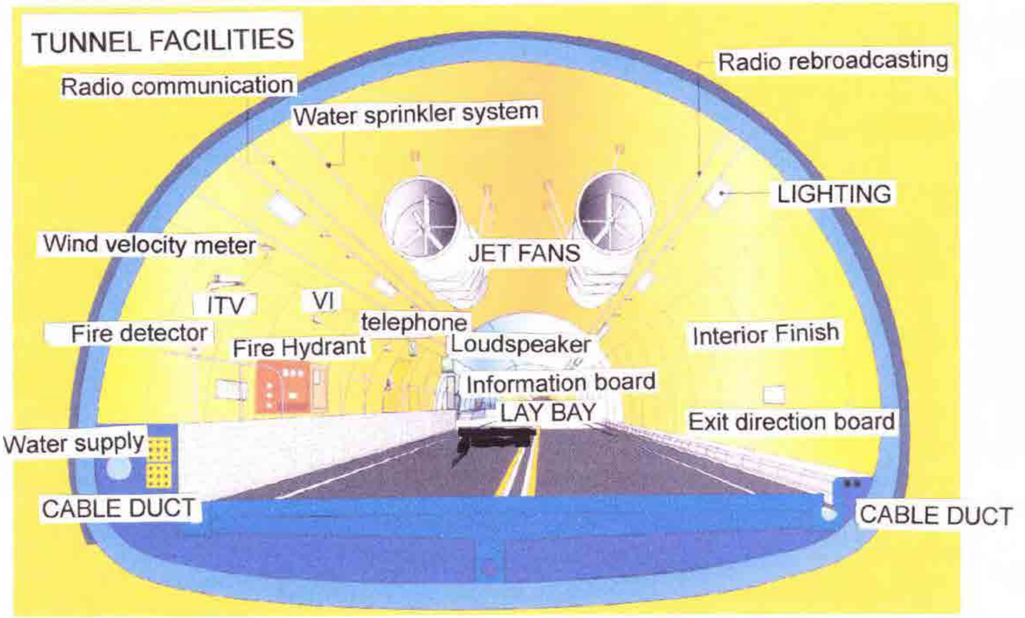
For the proposed Davao Bypass Project, sections to adopt this method are both the East and West portals and the eastern section with a minimum earth covering of 20m.

West portal side	STA. 19+030 ~ STA. 19+100	70m
East portal side	STA. 21+030 ~ STA. 21+100	70m
	STA. 21+200 ~ STA. 21+310	110m
	Total	250m

10.4.3 Tunnel Facilities in General

(1) Typical Layout of Tunnel Facilities

Typical layout of Tunnel Facilities is shown in **Figure 10.4-9.**



Source: Japan Highway Corporation

FIGURE 10.4-9 TUNNEL FACILITIES INSIDE

Before a tunnel, variable information signboard is required as shown in **Figure 10.4.10.**

Source: Japan Highway Corporation

FIGURE 10.4-10 VARIABLE INFORMATION SIGNBOARD (TYPE-D)

(2) Tunnel Ventilation System

Exhaust Gas from vehicle contains Carbon monoxide (CO) and soot which are harmful to the human body. Therefore it is necessary to install ventilation system for more than 500m length of tunnel to remove exhaust gas from vehicles.

a) Guideline for Natural Ventilation

There are two kinds of ventilation systems: the natural ventilation system and the mechanical ventilation system.

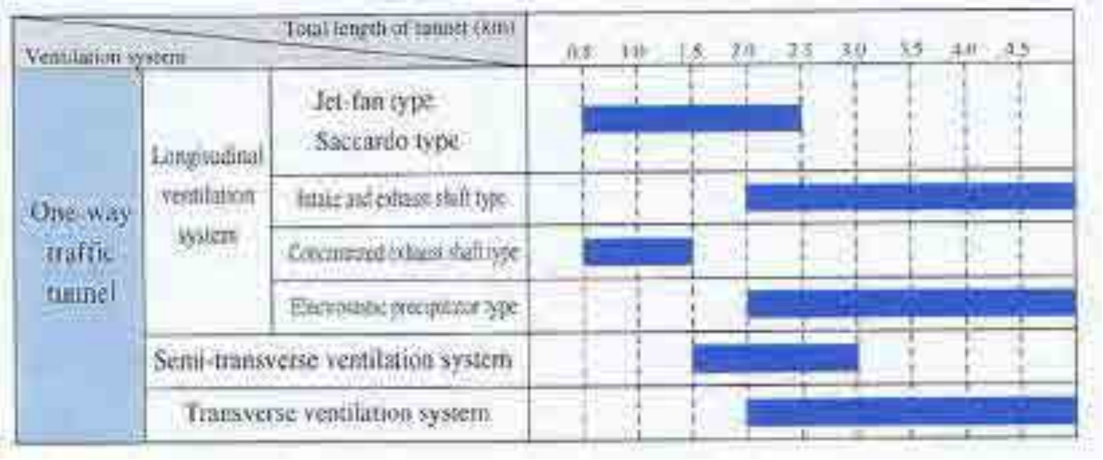
The following formula gives a guideline for border of using either natural ventilation or mechanical ventilation;

Two-way traffic (2 lanes): $L \cdot N \geq 600$
One-way traffic (2 lanes): $L \cdot N \geq 2000$
Where L: Total Length of Tunnel (km)
N: Traffic volume (veh/h)

b) Guideline for Mechanical Ventilation System

The mechanical ventilation system is divided into four (4) basic systems which are the longitudinal flow system, the transverse flow system, the semi-transverse flow system, and combination of these systems. **Table 10.4-5** shows the applicable ventilation system based on tunnel length.

TABLE 10.4-5 TUNNEL LENGTHS AND APPLICABLE VENTILATION SYSTEMS



- **Longitudinal ventilation system:** a system where the air is introduces to or removed from the tunnel roadway at a limited number of points, thus creating a longitudinal airflow within the tunnel. There are two (2) distinct types of tunnel longitudinal ventilation systems: those that employ an injection of air into the tunnel from centrally located fans; and those which use jet fans mounted within the tunnel cross-section.

- **Transverse ventilation system: It is defined by the uniform distribution of fresh air and/or uniform collection of vitiated air along the length of the tunnel**. Space for ventilation duct is provided separately. Mechanical Ventilation sends fresh air across the roadway space from the air supply duct.

- **Semi-transverse ventilation system: Chief characteristic is the uniform distribution of collection of air throughout the length of a tunnel**. The roadway space uses two ventilation ducts of the transverse type and only one separate duct is needed. This system is more economical than the transverse system.

The typical ventilation systems are shown in **Figure 10.4-11** to **Figure 10.4-16**. The longitudinal ventilation system for the tunnel is adopted for many countries. It is utilization of traffic ventilation force produced by running vehicles and natural wind induced by difference in atmospheric pressure and temperature between both outside and inside of a Tunnel.

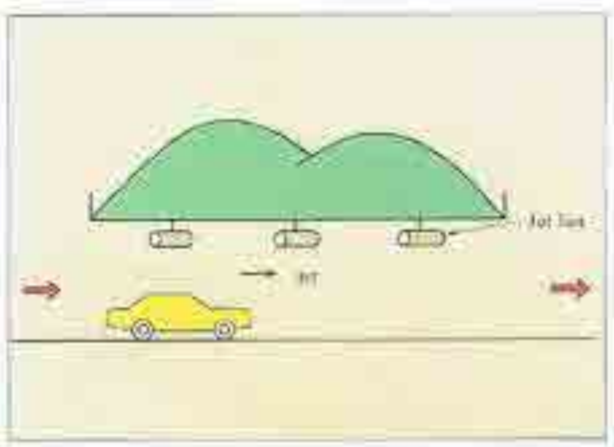


FIGURE 10.4-11 LONGITUDINAL VENTILATION SYSTEM (JET – FAN TYPE)

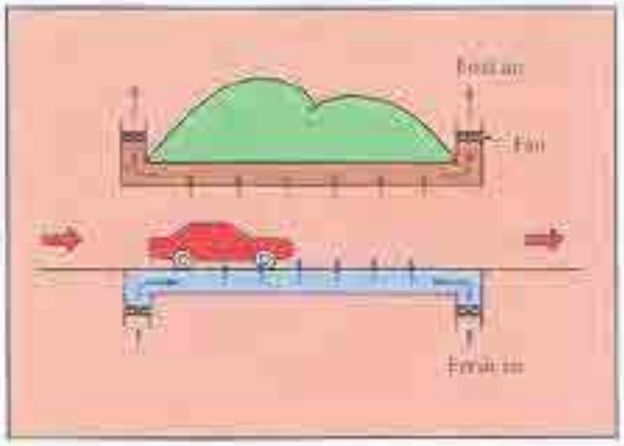


FIGURE 10.4-12 TRANSVERSE VENTILATION SYSTEM

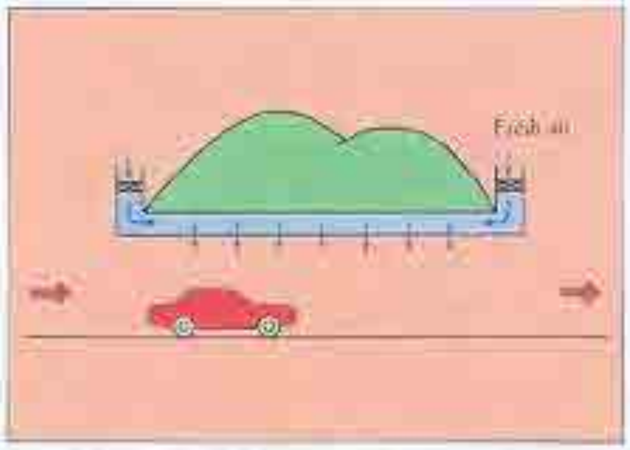


FIGURE 10.4-13 SEMI-TRANSVERSE VENTILATION SYSTEM

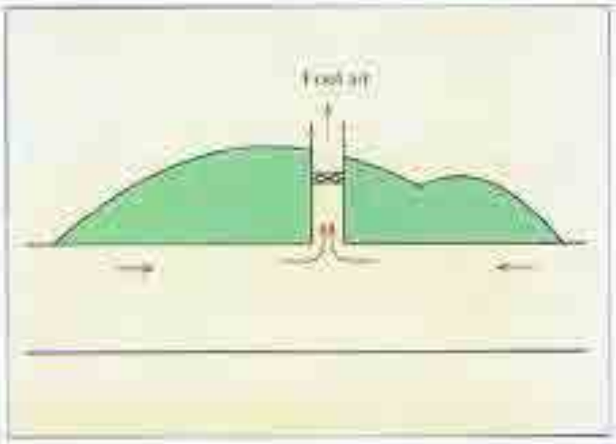


FIGURE 10.4-14 VENTILATION SYSTEM WITH VERTICAL SHAFT (EXHAUST SYSTEM)

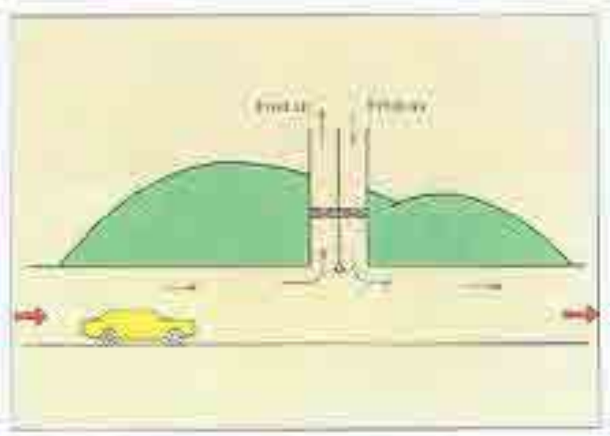


FIGURE 10.4-15 VERTICAL SHAFT TYPE (AIR SUPPLY SYSTEM)

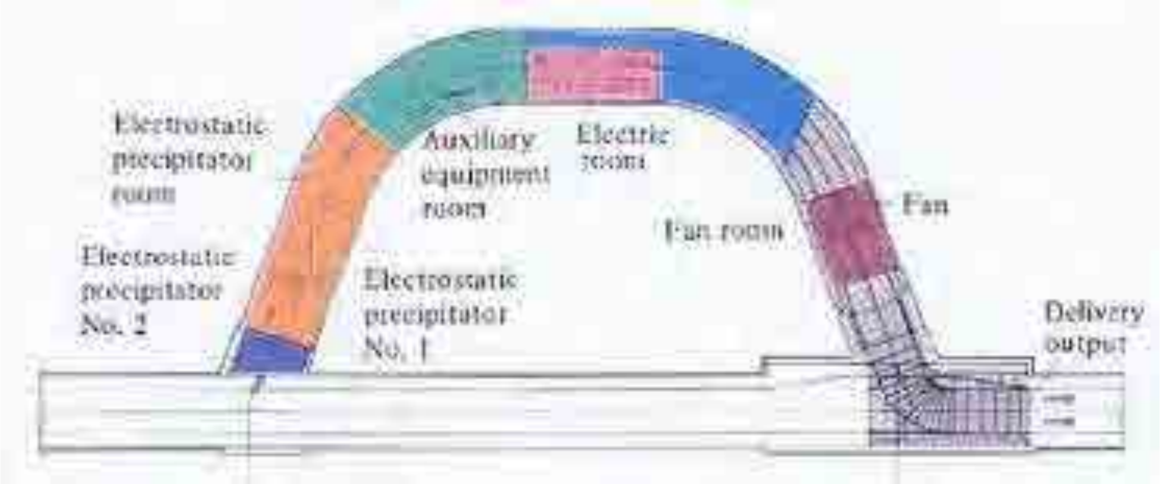


FIGURE 10.4-16 ELECTROSTATIC PRECIPITATOR SYSTEM FRESH AIR REQUIREMENT

The fresh air requirement is based on dilute the CO and soot discharge from vehicle running through the tunnel. The fresh air requirement is obtained as follows:

Fresh air requirement $Q = K \times Qo$

$K = K1 \times K2$

$Qo = q \times N \times L$

Where:
Qo : standard fresh air volume (m^3/s)
K : correction coefficient for speed, longitudinal grade and altitude
K1 : correction coefficient for speed and grade
K2 : correction coefficient for altitude
q : ventilation volume coefficient
N : traffic volume (veh/h)
L : total length of tunnel (km)
Several values need actual calculation.

The unit exhaust rates of soot and CO for Fresh air requirement are shown in **Table 10.4-6** and **Table 10.4-7**, respectively.

TABLE 10.4-6 UNIT EXHAUST RATE OF SOOT AND CO

Type of Vehicle	Unit exhaust rate for soot		Unit exhaust Rate for CO (1/veh/km)
	Average μ (m^2/veh/km)	Standard Deviation S σ (m^2/veh/km)	
Commercial vehicle	2.2	1.0	7.0
Passenger vehicle	0.2	0.3	7.0

TABLE 10.4-7 DESIGN CRITERIA OF SOOT AND CO

Design Speed of Road		For soot (visibility)		For CO Gas
		When reached estimated Hourly traffic volume	When reached potential Traffic capacity	
100 km/h		τ = 50%	τ = 50%	K = 100ppm
80 km/h		τ = 50%	τ = 45%	
60 km/h		τ = 40%	τ = 40%	
When temporary Service in Two-way traffic (Regulated speed)	70 km/h	τ = 45%	τ = 30%	
	60 km/h	τ = 40%	τ = 30%	

It is apparent that the majority of the soot is discharged from commercial vehicles. It is also noted that values are fixed correspondingly to combinations of design speeds and traffic volumes.

(3) Tunnel lighting facilities

Lighting facilities provide a very effective and safe driving and prevents traffic accidents in tunnel.

a) Tunnel Lighting Configuration

Tunnel lighting facilities consist of basic lighting for entrance and emergency lighting systems. Basic schematic tunnel lighting plan is shown in **Figure 10.4-17**.

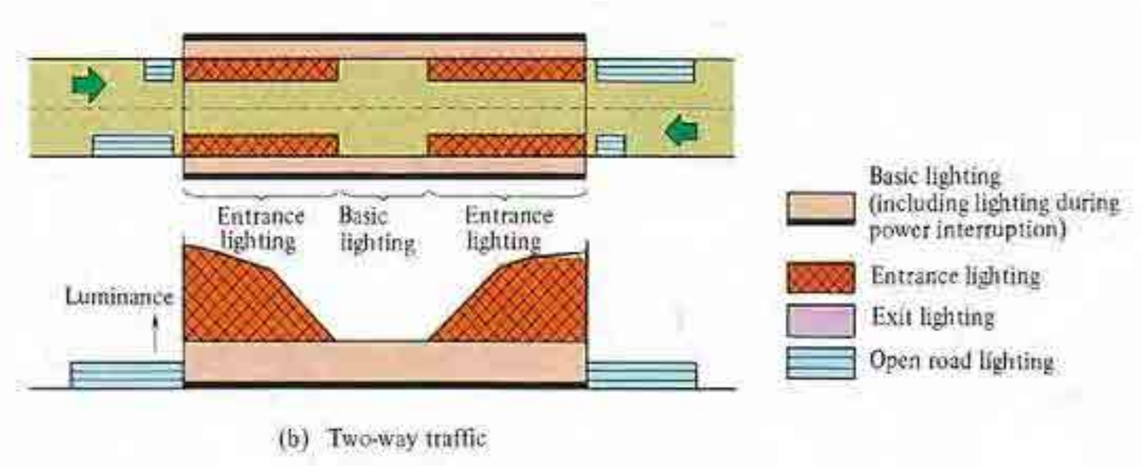


FIGURE 10.4-17 BASIC SCHEMATIC TUNNEL LIGHTING PLAN

b) Basic Lighting

The basic lighting provides drivers with the luminance required to visually perceive obstacles. Lights are distributed evenly along the entire length of the tunnel. Average road surface luminance is specified as shown in **Table 10.4-8**.

The table shows the relationships between vehicle speed and necessary average road surface luminance in ordinary tunnel under 50% light transmittance per 100m.

TABLE 10.4-8 AVERAGE ROAD SURFACE LUMINANCE

Design speed (km/h)	Average road surface luminance (cd/㎡)
100	9.0
80	4.5
60	2.3
40	1.5

c) Control of Tunnel Lighting

The entrance lighting and the inside tunnel basic lighting are controlled independently. The entrance lighting is controlled in four steps according to the luminance of the entrance to outside tunnel road.

The basic lighting is controlled in three steps according to the traffic volume and the luminance of the road. Tunnel lighting is controlled automatically by a photocell with a timer installed at the entrance of the tunnel. It also can be controlled from the operation office.

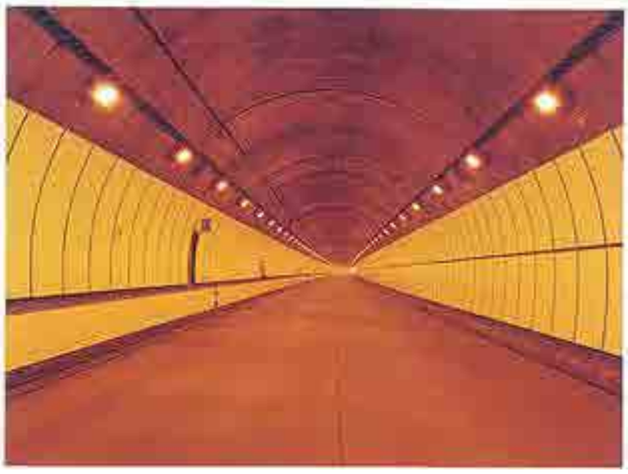


PHOTO 10.4-5 BASIC LIGHTING

(4) Radio broadcast relay system

This system is used to relay AM signals into tunnels, so drivers can catch them without interruption while in the tunnels. Tunnels with a length of 150 meters or over are usually equipped with this system.

(5) Road telecommunications facilities

Highway is equipped with traffic information gathering and providing facilities, such as variable road information signboards, and road lighting facilities.

(6) Emergency Telephone

Emergency telephones are installed on the road side wall in tunnels to permit an immediate emergency call for traffic accident to the road administrator office. The emergency message can be transferred by the switch board to the Police station and Fire station.

Source: Japan Highway Corporation

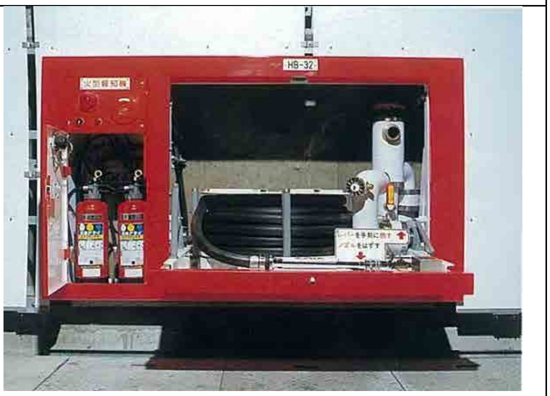
PHOTO 10.4-6 INDUCTION CABLE

(7) Photo for Basic Tunnel Facilities

VARIABLE INFORMATION SIGNBOARD (TYPE-E)

EMERGENCY TELEPHONE

PUSH-BUTTON NOTIFICATION EQUIPMENT

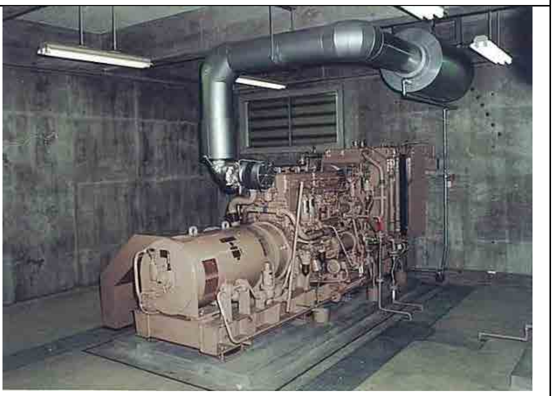


FIRE HYDRANT

AUTOMATIC FIRE DETECTOR

CCTV

DIRECTIONAL SIGNBOARDS



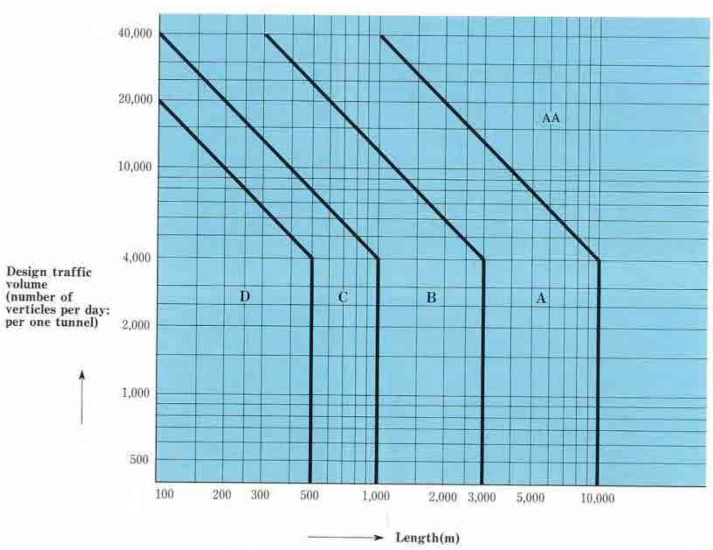
GENERATOR (UNINTERRUPTED POWER SUPPLY)

Source: Japan Highway Corporation

10.4.4 Tunnel Facilities

(1) Tunnel Facilities Required for Each Class of Tunnel

Tunnel Facilities and Emergency Facilities are also important items in road tunnels. Tunnels provide emergency Facilities based on the tunnel classification (length of tunnel and traffic volume) for traffic safety to minimize the occurrence of accidents. Based on **Figure 10.4-18**, Davao Bypass Tunnel is classified as category A.



Source: Japan Standard for Mountain Tunneling

FIGURE 10.4-18 JAPAN STANDARD CLASSIFICATION OF TUNNELS

Each tunnel shall be equipped with emergency facilities listed in **Table 10.4-9** in accordance with the CLASS of tunnel. This is for the prevention of traffic accidents and disaster mitigation as well as danger in cases of other emergencies.

TABLE 10.4-9 JAPAN STANDARD OF EMERGENCY FACILITIES TO BE INSTALLED

Emergency Fcilities		Classfication of tunnel	AA	A	B	C	D	Remarks
Information and alarm equipment	Emergency telephone		○	○	○	○	○	Omitted in class D tunnel less than 200m in length.
	Pushbutton		○	○	○	○		
	Fire detector		○	○				Omitted without ventilation system
	Emergency alarm equipment	Tunnel entrance information board	○	○	○	○	○	Omitted in tunnels less than 200m in length
		In tunnel information board	○	△				To be installed in class A tunnels 3,000m or more in length
Fire facilities	Fire exinguisher		○	○	○	○	○	
	Fire plug		○	○	△			To be installed in class B tunnels 1,000m or more in length
Escape and guidance equipment	Guide board	Emergency exit lamp	To be installed in tunnel with evacuation adits					
		Guide board (A)	To be installed in tunnel with evacuation adits					
		Emergency exit board	To be installed in tunnel with evacuation adits					
		Guide board (B)	○	○	○			To be installed in tunnels Without evacuation adits.
	Smoke discharge equipment and Escape passage		･Evacuation adits to be provided in tunnels of around 750m or more in length. ･Smpke discharge equipment to be provided in tunnel of around 1,500m or more in length. ･Evacuation tunnels provided for those Class AA tunnels and ClassA tunnels of a length 0f 3,000m or more which employ a two-way traffic system and a longitudinal ventilation system in which the length of one ventilation section is more than 2,000m.					
Other equipment	Hydrant		○	○	△			To be provided in ClassB tunnels 1,000m or more in length. Tunnels equipped with hydrants are to be provided with a water supply ports near the entrance.
	Radio communication auxiliary equipment	Leakage coaxial cables	○	△				To be provided in ClassA tunnels 3,000m or more in length.
		Entrance telephone	○	○				Entrances/Exit
	Radio rebroadcast equipment	Interrupt function provided	○	△				To be provided in ClassA tunnels 3,000m or more in length.
	Loudspeaker equipment		To be provided in tunnel equipped with a radio rebroadcasting equipment (with interruption function).					
	Water sprinkler system		○					To be provided in ClassA tunnels 3,000m or more in length. And serviced in two way traffic.
	Observation	Type A (200m intervals)	To be provided in tunnels with water sprinkler.					
		Type B (emergency parking area)		△				To be provided in Class A tunnels 3,000m or more in length.
	Lighting equipment for power failure		To be provided in tunnels 200m or more in length					
	Emergency power supply equipment	Independent power plant	To be provided in tunnels 500m or more in length					
		Non-failure power supply equipment	To be provided in tunnels 200m or more in length					

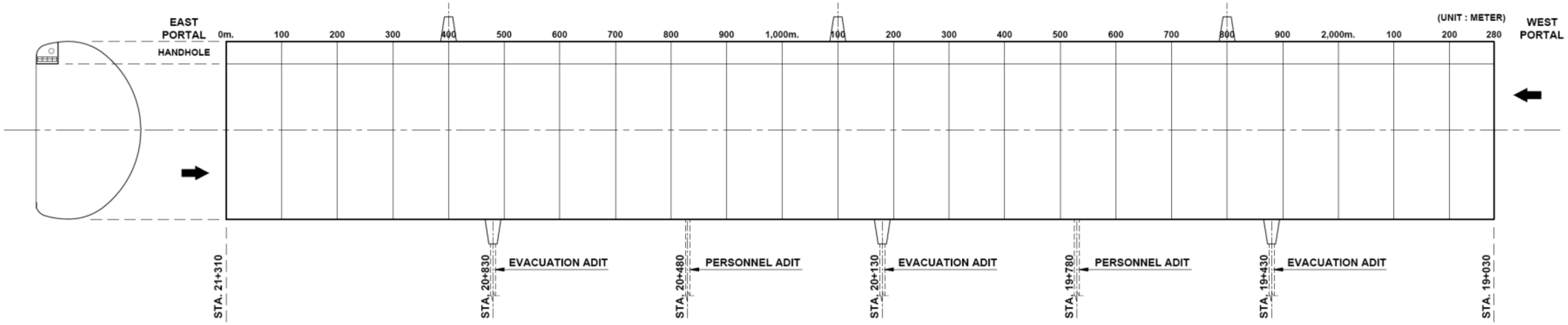
Notes: ○ Mandatory (standard) △ Recommended

Source: Japan Society of Civil Engineers

(2) Tunnel Facilities for the Project

Based on the Japan’s Standard, tunnel facilities are planned and shown in **FIGURE 10.4-19**.

ARRANGEMENT OF TUNNEL FACILITY



EMERGENCY PARKING BAY	400 700 700 480 480 700 700 400
FIRE EXTINGUISHER	25 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 35 20
PUSH BUTTON	25 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 35 20
EMERGENCY TELEPHONE	100 150 150 150 150 150 150 150 150 150 150 150 150 150 150 80
JET FAN	500 600 600 580
CO-METER	400 750 750 380
VI-METER	400 750 750 380
AV-METER	1,150 1,130
CCTV	300 400 400 400 400 380
GUIDE OF EXIT	300 300 300 300 300 300 300 300 300 300 300 300 300 300 300 300 300 300 300 300 300 300 280
OUTSIDE TELEPHONE	20 20
ENTRANCE SIGNAL	SIGNAL SIGNAL
TUNNEL INFORMATION BOARD	300m. 300m.
EVACUATION TUNNEL	2,280

FIGURE 10.4-19 TUNNEL FACILITY ARRANGEMENT

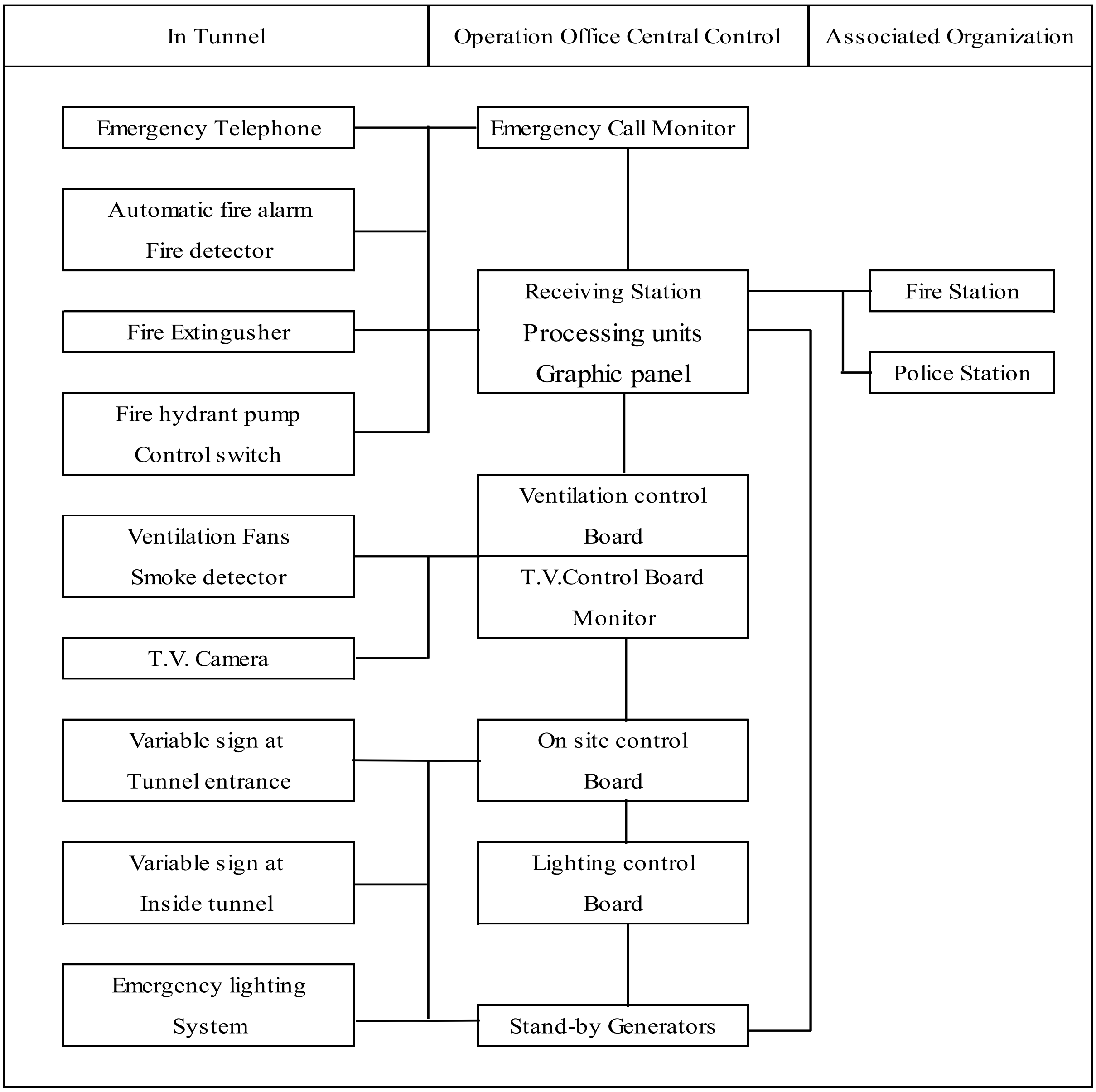
10.4.5 Operation System for Emergency Facilities

Emergency systems are designed so that all the available facilities and functions are integrated to provide an efficient and rapid response to traffic accidents in the tunnel. An accident in the tunnel is generally reported by emergency telephones and push button equipment or CCTV monitoring. Fire is automatically reported by fire detectors.

Notification of an emergency is received first by the switchboard of the central control and is transmitted to the administration office in-charge.

The schematic layout of a typical tunnel operation is shown in **Table 10.4-10.**

TABLE 10.4-10 LAYOUT OF A TYPICAL TUNNEL OPERATION



Source: JICA Study Team

Action flow of each accident type is shown in the **Figure 10.4-20**.

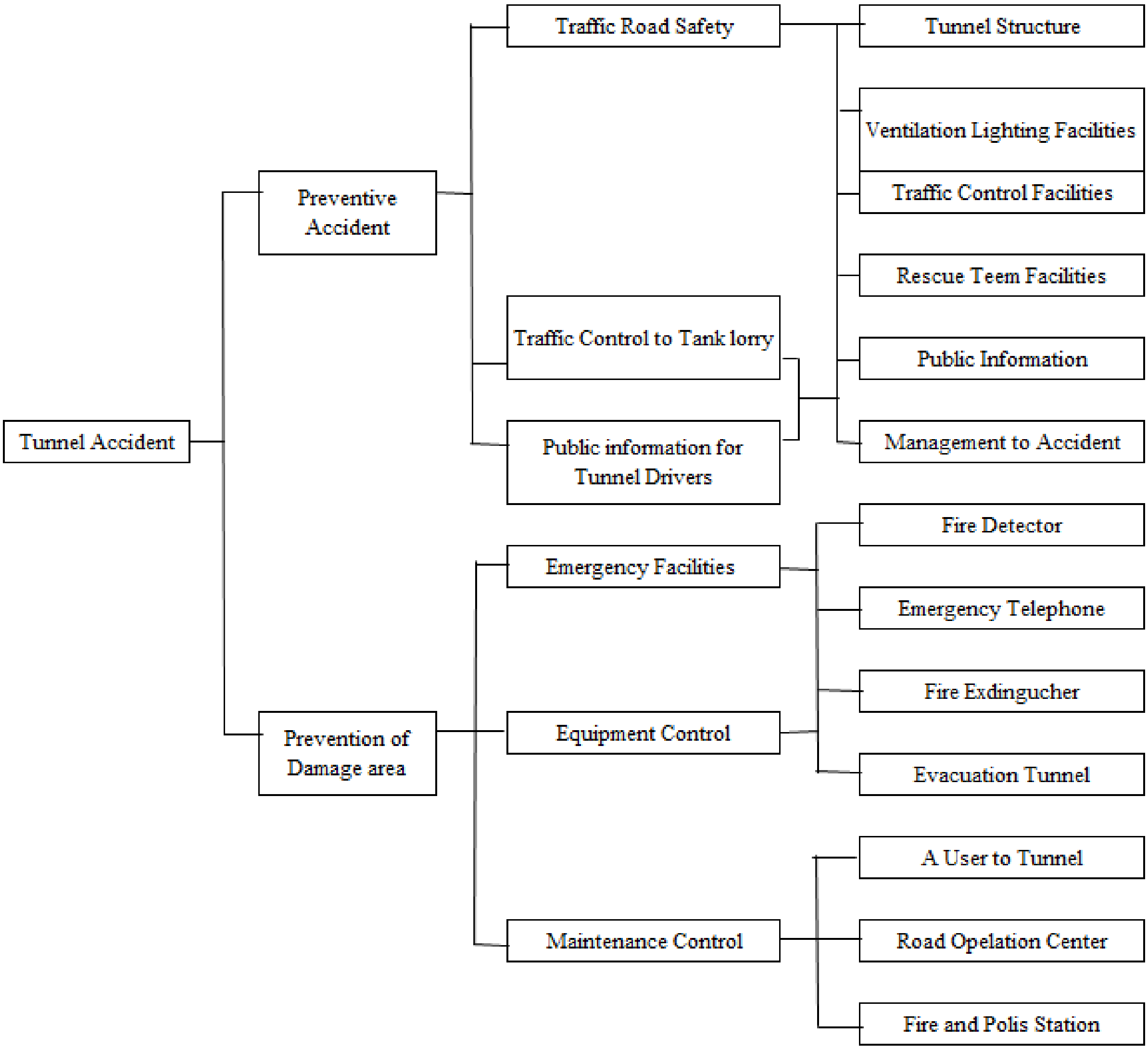


FIGURE 10.4-20 EACH COMPONENT FLOW OF TUNNEL ACCIDENT

(1) Evacuation Tunnel Plan

In case of accidents, road users must determine the situation and do something for evacuation from the tunnel. The facilities especially for emergency exits, user escape from accident point in the tunnel. In this case set up evacuation tunnel shall be established in 2,280 m length of Davao Bypass tunnel. Below photo shows evacuation exit and evacuation tunnel.

Evacuation Exit

Evacuation Tunnel

Source: Japan Highway Corporation

- **Cross Section of Evacuation Tunnel**

Cross section and layout plan for evacuation tunnel is shown in **Figure 10.4-21** and **Figure 10.4-22**. This evacuation tunnel allows for use by small fire vehicle, ambulance vehicle and management vehicle.

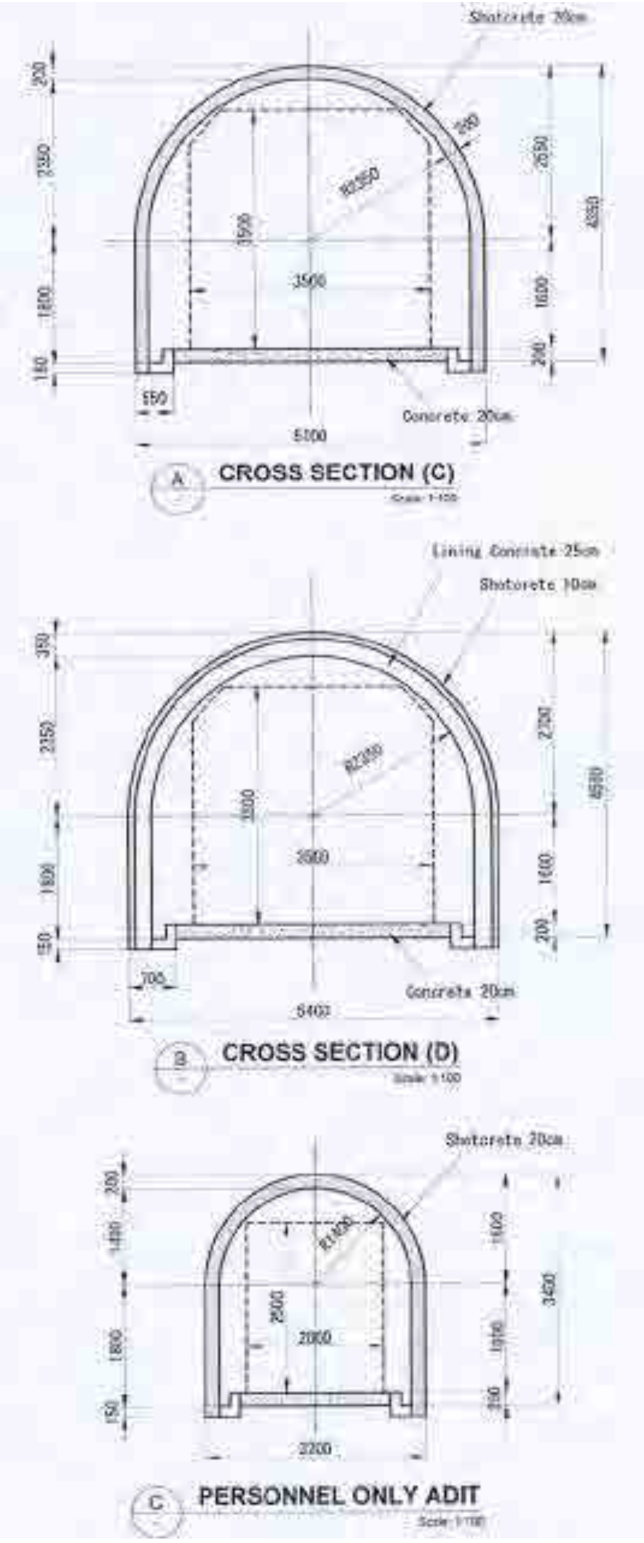


FIGURE 10.4-21 CROSS SECTION OF EVACUATION TUNNEL

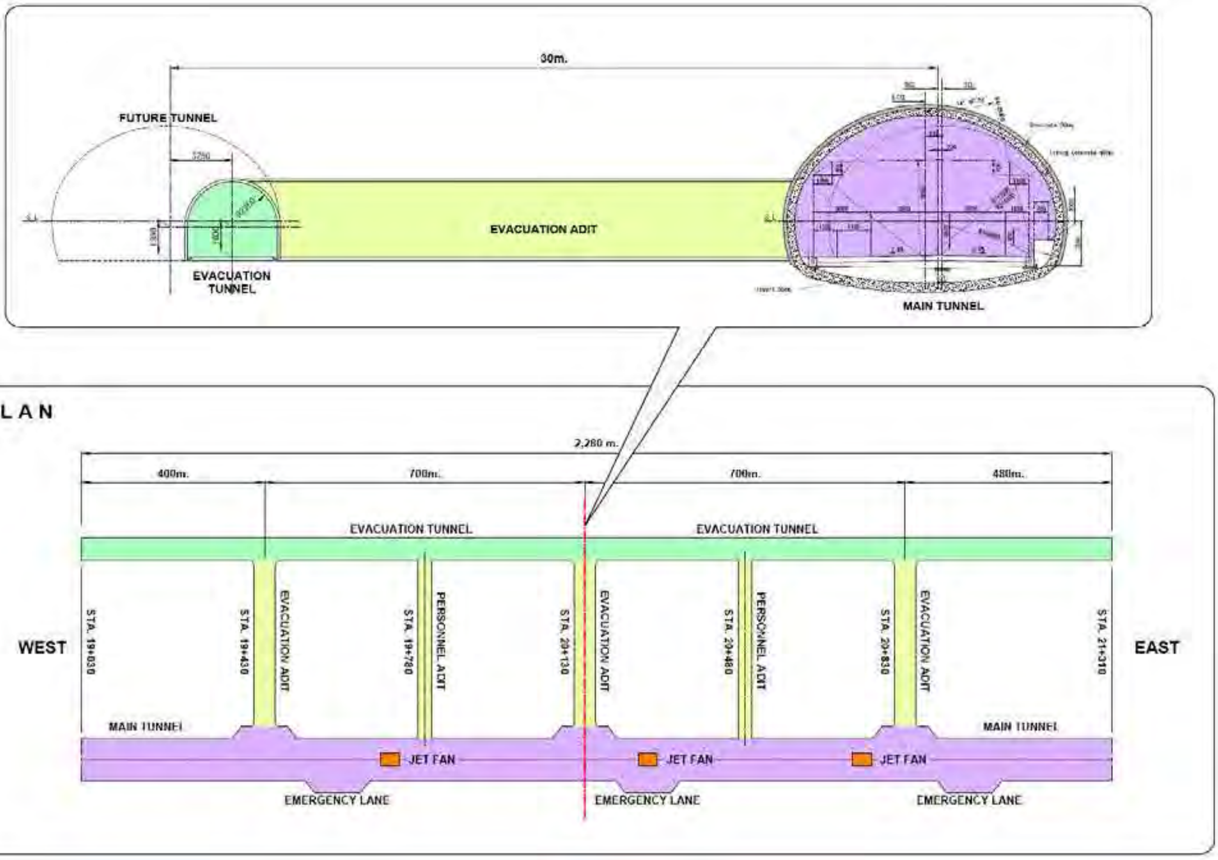


FIGURE 10.4-22 LAYOUT PLAN FOR EVACUATION TUNNEL

10.4.6 Toll Collection Facility

In order to secure the tunnel O & M cost, toll collection facilities was designed.

(1) Required Toll Booth Number

In accordance with traffic demand forecast (see section 6.2), the required toll booth was calculated. Toll Booth will be installed eastside near Davao River. It has enough road space for toll booth and tunnel management office.

TABLE 10.4-11 PEAK HOUR TRAFFIC VOLUME AT TUNNEL SECTION

	AADT 2033 (a)	Peak hour (b)	Peak Traffic Volume(c= a × b)
Eastbound	5,100 veh /day	8 %	464 veh/hr
Westbound	6,800 veh/day	8 %	544 veh/hr

In Japan, the average service time at toll gate is 8 second in case of flat rate. **TABLE 10.4-12** shows the required toll booth, service time and average waiting vehicle at gate. As peak traffic volume is 464 ~ 544, the minimum required toll gate is two (2) booths for average one waiting vehicle level. The study team recommended three (3) booths for both side considering one spare booth.

TABLE 10.4-12 SERVICE TIME, AVERAGE WAITING VEHICLE AT TOLL GATE AND NO. OF TOLL GATE

Service Time / Ave. Waiting Vehicle at Toll Gate / No. of toll gate	6 sec		8 sec		10 sec		14 sec		18 sec		20 sec	
	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0
1	300	450	230	340	180	270	130	190	100	150	90	140
2	850	1,040	640	780	510	620	360	440	280	350	250	310
3	1,420	1,630	1,070	1,230	850	980	610	700	480	550	430	490
4	2,000	2,230	1,500	1,670	1,200	1,340	860	960	670	740	600	670
5	2,590	2,830	1,940	2,120	1,550	1,700	1,110	1,210	860	940	780	850
6	3,180	3,430	2,380	2,570	1,910	2,060	1,360	1,470	1,060	1,140	950	1,030
7	3,770	4,020	2,830	3,020	2,260	2,410	1,620	1,720	1,260	1,340	1,130	1,210
8	4,360	4,630	3,270	3,470	2,620	2,780	1,870	1,980	1,450	1,540	1,310	1,390
9	4,960	5,220	3,720	3,920	2,980	3,130	2,130	2,240	1,650	1,740	1,490	1,570
10	5,560	5,820	4,170	4,370	3,330	3,490	2,380	2,490	1,850	1,940	1,670	1,750
11	6,150	6,420	4,610	4,820	3,690	3,850	2,640	2,750	2,050	2,140	1,850	1,930
12	6,740	7,020	5,050	5,270	4,040	4,210	2,890	3,010	2,250	2,340	2,020	2,110
13	7,340	7,620	5,510	5,720	4,400	4,570	3,150	3,270	2,450	2,540	2,200	2,290
14	7,940	8,220	5,954	6,170	4,760	4,930	3,400	3,520	2,650	2,740	2,380	2,470
15	8,530	8,820	6,400	6,620	5,120	5,290	3,660	3,780	2,840	2,940	2,560	2,650

Source: NEXCO EAST Highway Design Manual, 2005

(2) Toll Booth Layout

FIGURE 10.4-23 shows the toll booth layout for this project. Toll booth will be constructed beside the traffic control center.

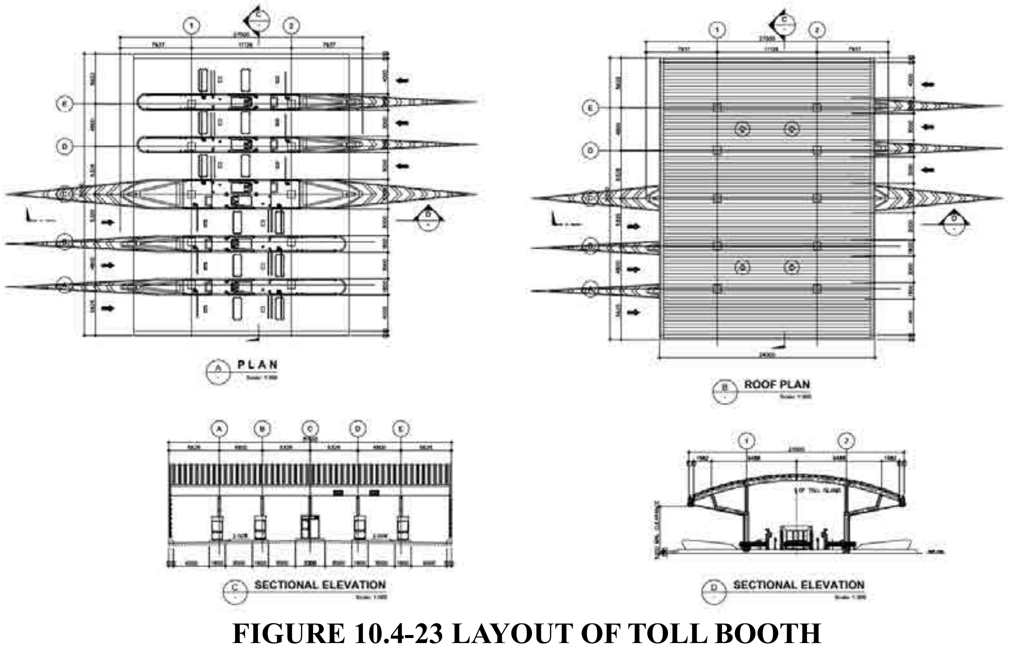


FIGURE 10.4-23 LAYOUT OF TOLL BOOTH