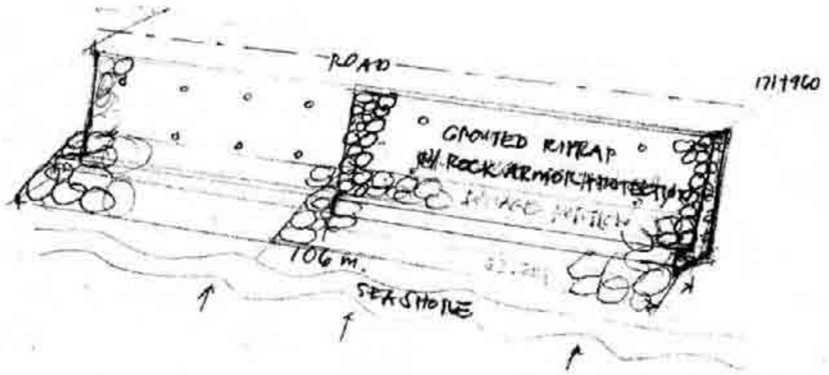
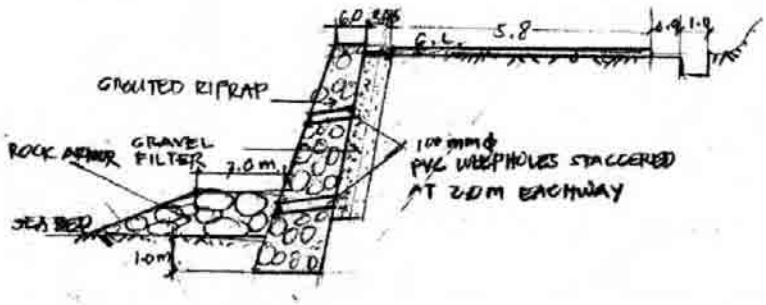
Inventory Sheet 4-2 Planning of Countermeasures Alternative II

Road Name	Toledo-Barili-Santander Rd						
Station from	km	171	m	960	Side of survey	Left side of road	

4-1 Plan of countermeasures (plane layout and descriptions)



4-2 Section of countermeasures



4- 3 Cost estimation with 20 years maintenance

No.	Work	Unit	Quantity	Unit price (pesos)	Amount (pesos)
1	Grouted riprap	m	106	5,616	595,296
2	Rock armor protection	m	106	36,000	3,816,000
3	Maintenance Cost		1	2,205,648	2,205,648
4					0
5					0
6					0
7					0
	Total Cost				6,616,944

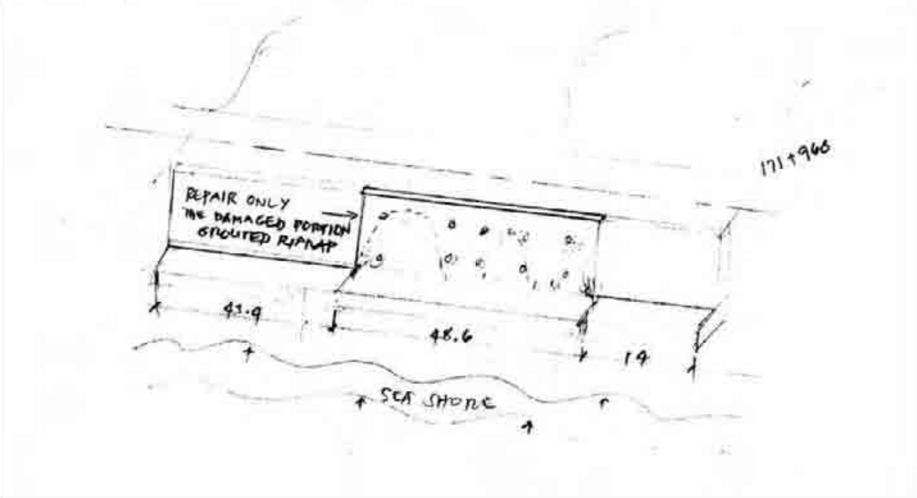
Note
- (pink) Numerical value or terms should be inputted.
- (light blue) Numerical value is automatically inputted.

Figure 5.49 Example of Inventory Sheet 4-2: Planning of Countermeasure Alternative II for Costal Erosion

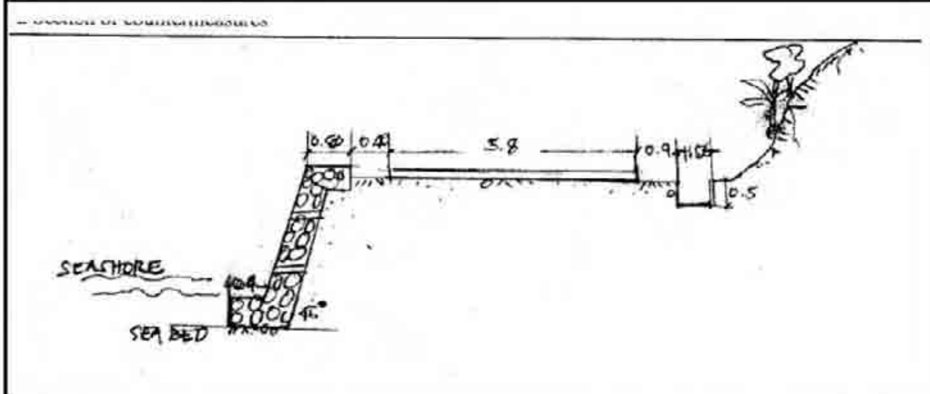
Inventory Sheet 4-3 Planning of Countermeasures Alternative III

Road Name	Toledo-Barili-Santander Rd						
Station from	km	171	m	960	Side of survey	Left side of road	

4-1 Plan of countermeasures (plane layout and descriptions)



4-2 Section of countermeasures



4- 3 Cost estimation with 20 years maintenance

No.	Work	Unit	Quantity	Unit price (pesos)	Amount (pesos)
1	Grouted riprap (repair damaged portion only)	m	48.6	5,616	272,938
2	Maintenance Cost		1	136,469	136,469
3					0
4					0
5					0
6					0
7					0
	Total Cost				409,406

Note
- (pink) Numerical value or terms should be inputted.
- (light blue) Numerical value is automatically inputted.

Figure 5.50 Example of Inventory Sheet 4-3: Planning of Countermeasure Alternative III for Costal Erosion

Inventory Sheet 5-7 **Indicative Feasibility Assessment for CE**

Road Name	Toledo-Banili-Santander Rd				
Km station from		km	171	m	960
Side of survey	Left side of road				

Items	symbol	equation	Unit	Quantity	Remark
(1) Disaster Frequency and Magnitude					
1-1) Potential frequency of road closure disaster	FRCDp		nos. per year	0.278	sheet 2
1-2) Length of road closure site	LRC		m	106	refer 3.4.2 1-2) of the Guide
(2) Annual Losses Without Countermeasure					
2-1-1) Reopening cost per length of road closure site (excluding fixed cost)	h		pesos per m	375	refer 3.4.2 2-1-1) of the Guide
Fixed cost for reopening per RCD	i		pesos per RCD	40,000	
2-1) Annual reopening cost	j	j=FRCDp*(h*LRC+i)	pesos per year	22,171	[illegible]
2-2-1) Average number of human deaths per RCD	k	k=0.006	[illegible]	0.006	[illegible]
2-2-2) Unit value of human life lost (death)	l		[illegible]	2,300,000	[illegible]
2-2) Annual value of human lives lost	m	m=FRCDp*k*l	pesos per year	3,836	[illegible]
2-3-1) Length of survey road (from entry to exit point of detour road to avoid road closure site on survey road)	n		km	142	[illegible]
Length of detour road (from entry to exit point of survey road to avoid road closure site on survey road)	o		km	179	[illegible]
2-3-2) AADT: Annual Average Daily Traffic on the survey site	p		vehicles per day	500	[illegible]
2-3-3) Nos. of predicted closure days of the whole width of the road on the survey site per RCD	q		days	2.0	[illegible]
2-3-4) Average Vehicle Operating Cost per km on survey road	r		pesos per vehicle*km	7.80	[illegible]
Average Vehicle Operating Cost per km on detour road	s		pesos per vehicle*km	9.55	
2-3) Annual detour cost	t	t=FRCDp*p*q*(o*s-n*r)	pesos per year	167,314	[illegible]
Total Annual Loss	u	u=j+m+t	pesos per year	193,321	[illegible]
(3) Feasibility Indicators of Countermeasures					
Countermeasure alternative I					
3-1) Cost of countermeasure with 20 years maintenance	v I		pesos	7,098,778	evaluated in sheet 4
3-2) Risk reduction ratio in RCD due to countermeasure	w I		ratio	0.9	[illegible]
3-3) Decrease in annual loss due to countermeasure	x I	x I = u* wI	pesos per year	173,989	[illegible]
Potential frequency of road closure disaster with countermeasure	FRCDwc I	FRCDpwc I = FRCDp*(1- wI)	nos. per year	0.028	[illegible]
Benefit/cost ratio at 15% discount rate	BCR I		ratio	0.18	
Economic net present value at 15% discount rate	ENPV I		pesos	-5,225,845	
Economic internal rate of return	EIRR I		percent	-6%	
Countermeasure alternative II					
3-1) Cost of countermeasure with 20 years maintenance	v II		pesos	6,616,944	evaluated in sheet 4
3-2) Risk reduction ratio in RCD due to countermeasure	w II		ratio	0.6	[illegible]
3-3) Decrease in annual loss due to countermeasure	x II	x II = u* wII	pesos per year	115,993	[illegible]
Potential frequency of road closure disaster with countermeasure	FRCDpwc II	FRCDpwc II = FRCDp*(1- wII)	nos. per year	0.111	[illegible]
Benefit/cost ratio at 15% discount rate	BCR II		ratio	0.13	
Economic net present value at 15% discount rate	ENPV II		pesos	-5,122,528	
Economic internal rate of return	EIRR II		percent	-8%	
Countermeasure alternative III					
3-1) Cost of countermeasure with 20 years maintenance	v III		pesos	409,406	evaluated in sheet 4
3-2) Risk reduction ratio in RCD due to countermeasure	w III		ratio	0.2	[illegible]
3-3) Decrease in annual loss due to countermeasure	x III	x III = u * w III	pesos per year	38,664	[illegible]
Potential frequency of road closure disaster with countermeasure	FRCDpwc III	FRCDpwc III = FRCDp*(1- wIII)	nos. per year	0.222	[illegible]
Benefit/cost ratio at 15% discount rate	BCR III		ratio	0.68	
Economic net present value at 15% discount rate	ENPV III		pesos	-145,560	
Economic internal rate of return	EIRR III		percent	7%	

Note:
- (pink) Numerical value or terms should be inputted.
- (light blue) Numerical value is automatically inputted.

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Figure 5.51 Example of Inventory Sheet 5: Indicative Feasibility Assessment for Costal Erosion

CHAPTER 6

FEASIBILITY STUDY

6.1 General

The priority slopes for RCD mitigation measures on national highways will be selected using the results of risk management planning. A feasibility study is required as preparatory work for the implementation of countermeasures for these slopes. The general flow of countermeasure implementation is shown in Figure 6.1.

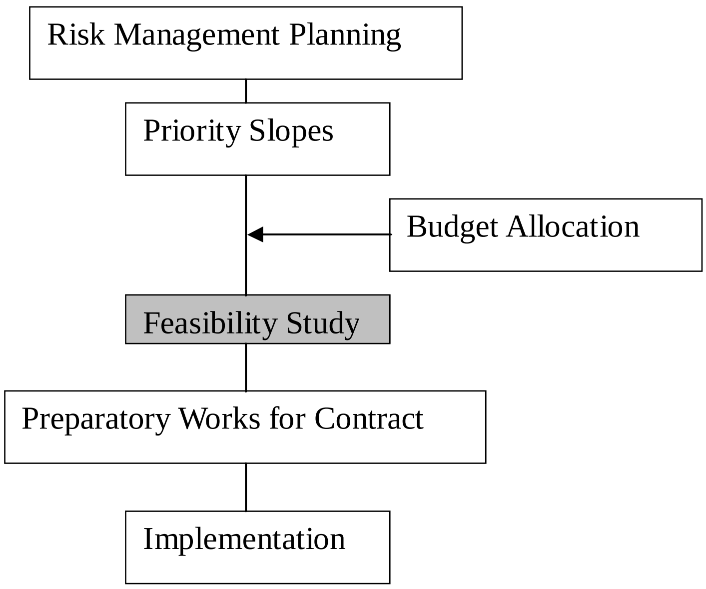

Figure 6.1 Flow of Countermeasure Implementation for Priority Slopes

Feasibility studies have been carried out for five sites selected as model studies. The feasibility study is composed of five tasks: Field Survey, Initial Environmental Examination (IEE); Social Survey; Countermeasure Design; and Feasibility Assessment.

The method for conducting the feasibility study is described in Chapter 6.3, and detailed study items, procedures, and results are attached in Appendix 6-1.

6.2 Selection of Survey Slopes and Study Method

6.2.1 Selection Criteria

The selection criteria are; 1) Equitable regional distribution, 2) Area must be secure and safe, 3) Slopes Requested by RO or DEO, 4) Urgency of the need for a countermeasure, and 5) Applicability of various engineering methods.

Table 6.1 Selection Criteria for Feasibility Study Slopes

	Selection Criteria	Remarks
1)	Equitable regional distribution	Sites in Regions CAR, II, VII, and VIII, were selected.
2	Security restrictions	Regions X and XI can not be selected due to security restrictions.
3	Slopes Requested or RO and DEO	
4)	Urgency of the need for a countermeasure	Countermeasure is urgently required to mitigate the risk. - Slopes in which disturbances are progressing - Potential RCD may cause long term road closure and large losses.
5)	Applicability of various engineering methods to the slope	Various engineering methods are found to be applicable in the field survey technique and countermeasures works.

6.2.2 Selected Sites

Five sites from the five regions were selected as feasibility study sites based on the selection criteria shown in Table 6.1, the results of the inventory surveys, and requirements of the engineers responsible for each route. The five sites are shown in Table 6.2 and Figure 6.1. The disaster types selected are Road Slips (RS), Landslides (LS) and Coastal Erosion (CE), which are the most common disasters that require suitable solutions to improve the traffic function of the national highways.

Table 6.2 Sites Selected for Feasibility Study

No.	Road Section Location	Station	Region	Responsible DEO	Disaster Type
1	Kennon Rd	232 km	CAR	Benguet 1st	Road Slip (RS)
2	Nueva Vizcaya- Ifugao- Mt Province Rd (Lagawe-Banaue)	301 km	CAR	Ifugao	Landslide (LS)
3	Daang Maharlika (LZ) (Dalton Pass)	211 km	II	Nueva Vizcaya- Sub	Road Slip (RS)
4	Toledo- Baliri-Santander Rd (Ginatilan-Alegria)	172 km	VII	Cebu 4th	Coastal Erosion (CE)
5	Wright-Taft Borongan Rd	846 km	VIII	Samar 2nd	Road Slip (RS)

Figure 6.2 Feasibility Study Location Map

6.2.3 Study Items and Work Flow

The survey items for each study site are shown in Table 6.3. Detailed results of the field surveys are attached as Appendix 6-2.

Table 6.3 Work Items for the Five Study Sites

Work Item		Kennon Rd 232 km	Lagawe Banaue 301 km	Dalton Pass 211 km	Ginatilan Alegria 172 km	Wright Taft 846 km
(1) Review of Inventory Survey Data(T)		Y	Y	Y	Y	Y
(2) Engineering Inspection(T)		Y	Y	Y	Y	Y
(3) Field Survey(C)	3.1 Topographic Survey	Y	Y	Y	Y	Y
	3.2 Geo- Engineering Inspection	Y	Y	Y	Y	Y
	3.3 Drilling Work		Y	Y	Y	Y
	3.4 Sounding for Foundation	Y	Y	Y	Y	Y
	3.5 Ground Water Logging		Y	Y	Y	Y
	3.6 Ground Water Monitoring	Y	Y	Y	Y	Y
	3.7 Pipe Strain Gauge Monitoring		Y			Y
	3.8 Movable Stake Installation		Y	Y		Y
(4) Initial Environmental Examination (IEE)(T)		Y	Y	Y	Y	Y
(5) Social Survey (T)		Y	Y	Y	Y	Y
(6) Countermeasure Design (T)		Y	Y	Y	Y	Y
(7) Feasibility Assessment (T)		Y	Y	Y	Y	Y

Note Y=Yes, Blank=No
(T); Conducted by Study Team and Counterpart Team, (C); Local Consultant

6.2.4 Methods for the Feasibility Study

(1) Flow of the Feasibility Study

The feasibility studies undertaken in this study have been carried out as model studies in the process of the work flow shown in Figure 6.3. This same work flow can be applied in the actual feasibility studies that will be conducted after the formulation of the "Risk Management Plan for Nationwide National Highways." Work item No.2, "Engineering Inspection", which is the identification of the current condition of the slopes, is very important in the feasibility study from the viewpoint of engineering judgment. In this stage it will influence the procedures and the results of the feasibility study. Therefore, road engineers and geotechnical engineers of the study team worked together in the field to discuss countermeasure alternatives and the methods to be used in the field survey.

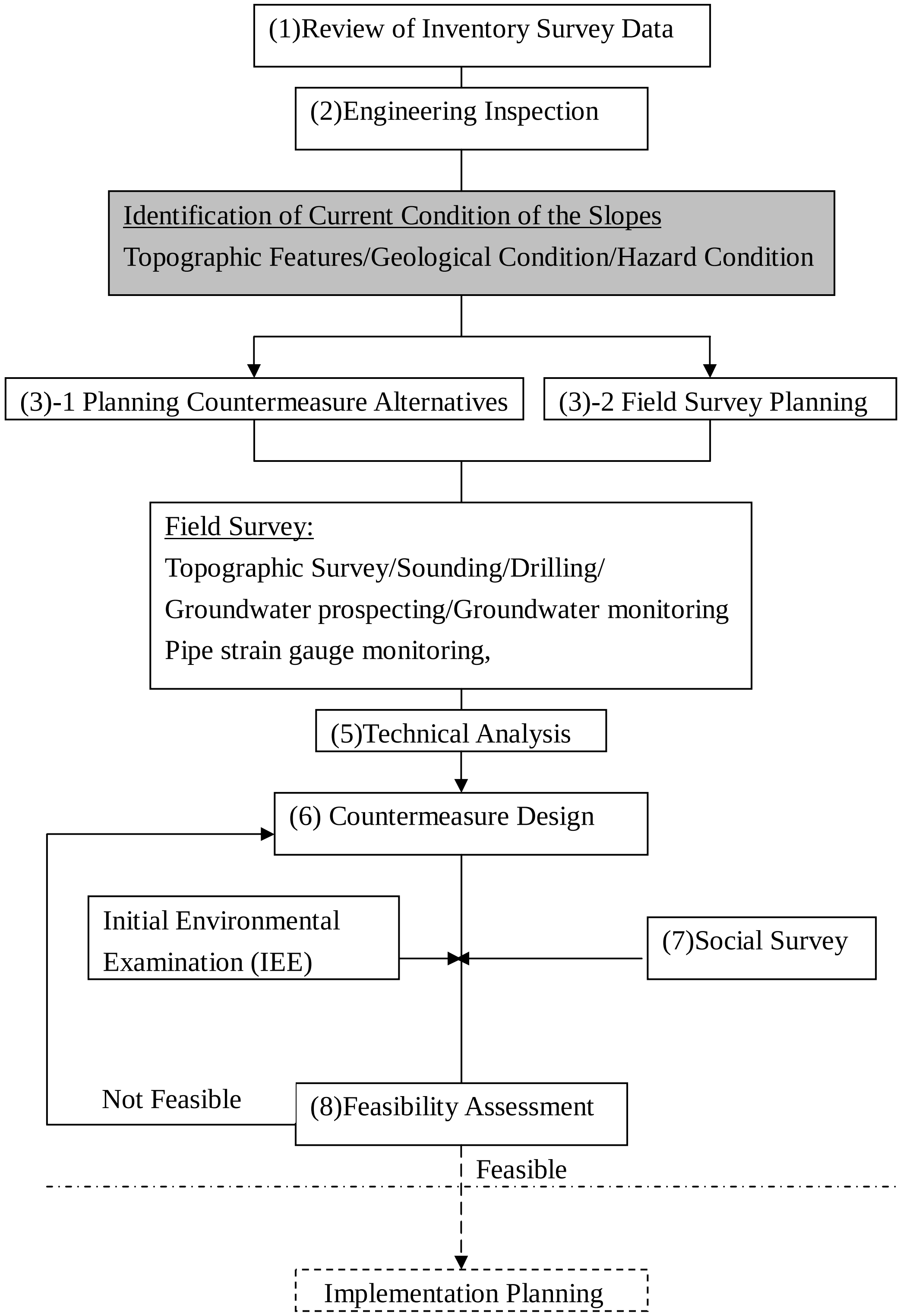

Figure 6.3 Flow of Feasibility Study

(2) Survey Method

The outline of the survey methods and output of each work item are shown in Table 6.4. The detailed procedures are attached as Appendix 6-1.

Table 6.4 Outline of Survey Methods Applied in the Feasibility Study

Survey Item	Survey Method	Objective
Engineering Inspection	Joint inspection by engineers of various fields	- Identification of current situation - Planning and discussion of solutions - Planning of detailed survey methods
Field Surveys:	-Topographic Survey -Geo- Engineering Inspection -Drilling Work -Sounding for Foundation -Ground Water Logging -Ground Water Monitoring -Pipe Strain Gauge Monitoring -Movable Stake Installation	- Making topo maps - Making geo-engineering maps - Geological structure - Depth of foundation layer - Properties of layers - Hydro-geological condition - Identification of slip surface (for landslides) - Deformation mode (for landslides)
Technical Analysis	In office	- Arrangement of field data for design work - Arrangement of design conditions
Countermeasure Design	In office	- Design countermeasures - Cost estimation
Initial Environmental Examination (IEE)	IEE method of DPWH	- Existing environment - Project impact - Mitigation methods
Social Surveys	- Collection of statistical data - Questionnaire survey - Traffic count survey	- Outline of the area - Matters affected by the project - Traffic volume of the site
Feasibility Assessment	Estimation of technical and economic viability	- Feasibility indicators: (BCR, ENPV, EIIR) - Comprehensive solution

6.3 Countermeasure Design and Cost Estimates

6.3.1 Kennon Road Km 232 (Region CAR)

(1) Damage Condition

This disaster was a Road Slip (RS), and half of a carriageway lane was closed for approximately 70 m in length as shown in Photo 6.1. According to the information from the District Engineering Office, the original road alignment on the collapsed section ran along the valley side, but, it slipped down and then later, the road was re-aligned to the mountain side.

(a) Front View (b) Side View

Photo 6.1 Conditions of Collapsed Road Shoulder

Based on the topographic features of the site, the road slip incident is supposed to have occurred by the following mechanism;

- Surface waters from rain from the back of the mountain gathered towards the road slip section as shown in Photo 6.2.
- The groundwater to be distributed in the terrace deposit increased because rainfall water was concentrated in the slip section.
- Since the collapsed grouted riprap was not provided with sufficient drainage facilities such as weep holes and drain

Photo 6.2 Surface water flowing from behind the mountain

filters in the back fill, excess pore water pressure formed behind the riprap.

- Also, the embedment of the riprap wall foundation looks unstable and did not resist the the ground water pressure. These factors caused the retaining wall to collapse and consequently, the road slip occurred.

(2) Approach to Countermeasure Planning

The following viewpoints were taken into consideration in the planning of countermeasures:

- Since houses are located behind the mountain and along the road at the Baguio City side, the negative impacts to the said residents are expected to be minimal.
- Kennon Road is one of the major trunk roads in CAR Region and functions as an important tourism route, therefore the ordinary traffic flow should be restored even during the restoration work.
- The foundation of the new retaining wall should be embedded in the rock layer (andesite) to ensure the stability of the wall.
- Since the new retaining wall will stand on a very steep cliff, a vertical wall or high gradient wall should be planned.
- The road should have a carriageway width of 6.2 m and a road shoulder of 1.5 m on both sides.

(3) Options

The following options were considered for the countermeasure design;

Option-1 : Reinforcement Embankment Method by Terre Armee Wall,
Option-2 : Crib Grouted Riprap Retaining Wall, and
Option-3 : Shelf Type Reinforced Concrete Retaining Wall.

(a) Reinforcement Embankment Method by Terre Armee Wall (Option -1)

Figures 6.4 and 6.5 show the typical cross section, plan and side view of the embankment reinforced by Terre Armee. Major features of the design are described as follows:

- As the road alignment will be shifted to the valley side, the existing traffic can continue to flow during the construction period. The total length of the road will be 152.2 m (Km 232+140.0 to Km 232+292.2)
- The strips to reinforce the embankment are installed at 75 cm intervals and the lengths of the bottom strips are to be 4.0 m long.

- The Terre Armee wall is embedded in the concrete gravity wall, and the gravity wall is embedded in the base rock layer. The loading of the Terre Armee embankment is taken into consideration in the stability design of the gravity wall.
- Total length of the Terre Armee wall and concrete gravity wall will be 139 m (Km 232+140.0 to Km 232 279.0).
- Underground drain filters are installed along the terrace deposit layer at 10 m intervals in the longitudinal direction.

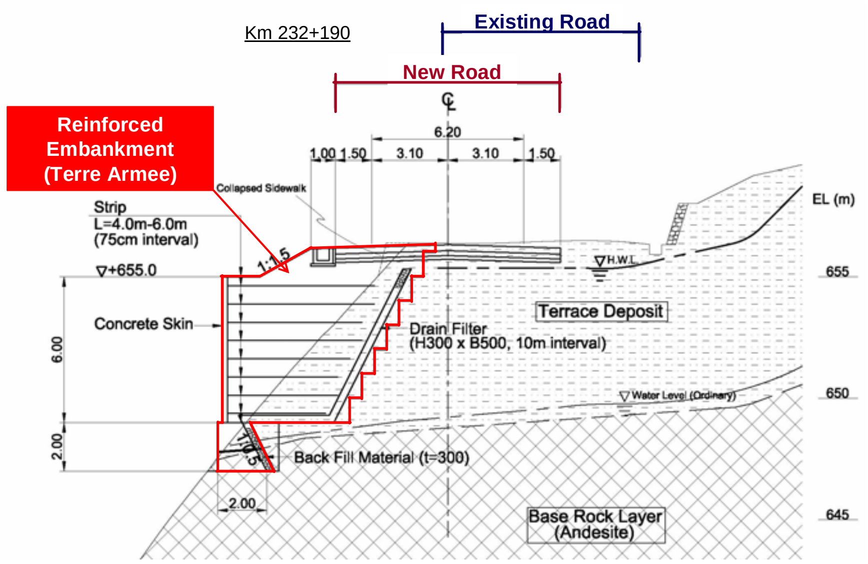

Figure 6.4 Typical Cross Section of Reinforced Embankment

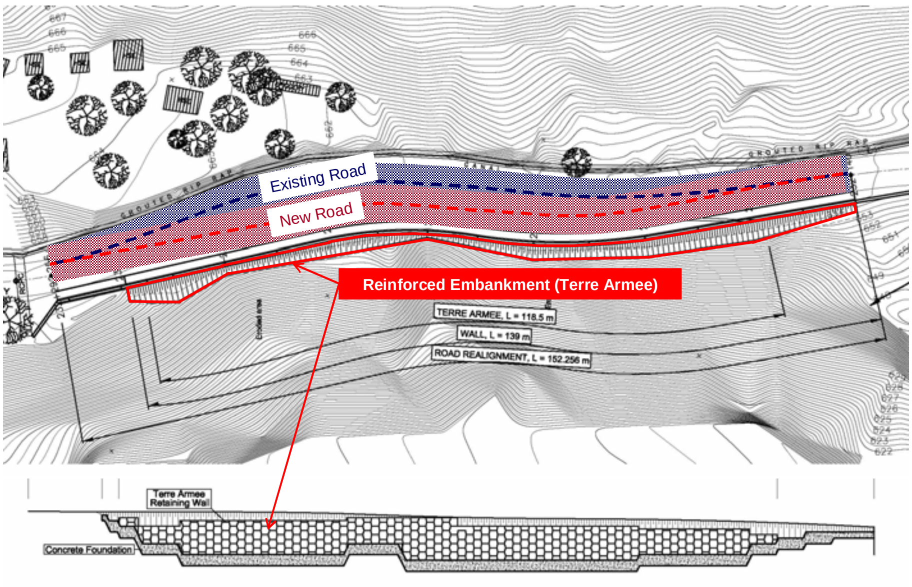

Figure 6.5 Plan and Side View of Reinforced Embankment

(b) Grouted Riprap Crib Retaining Walls (Option -2)

Figure 6.6 shows the typical cross section of a grouted riprap crib wall. Major features of this countermeasure design are described as follows:

- The grouted riprap retaining wall, which is 8.5 m high and has a gradient of 1:0.3, is embedded in the concrete gravity wall.
- The external forces, such as dead load of the riprap and earth pressure, are taken into consideration in the stability design of the concrete gravity wall.
- In order to maintain stability of the gravity wall as well as the riprap wall, anchor bars are installed to reduce the external horizontal force at the intervals indicated in Figure 6.6.
- A shear key at the bottom of the gravity wall is provided to ensure the target design safety factor against sliding of the gravity wall.
- Total length of the grouted riprap wall and the concrete gravity wall will be 100 m (Km 232+165.0 to Km 232+265.0).
- The road alignment should be the same as the existing. Only the 70 m length of the pavement of the closed lane (left side lane in Figure 6.6) is re-constructed. Therefore, traffic control measures should be adopted in the construction period.

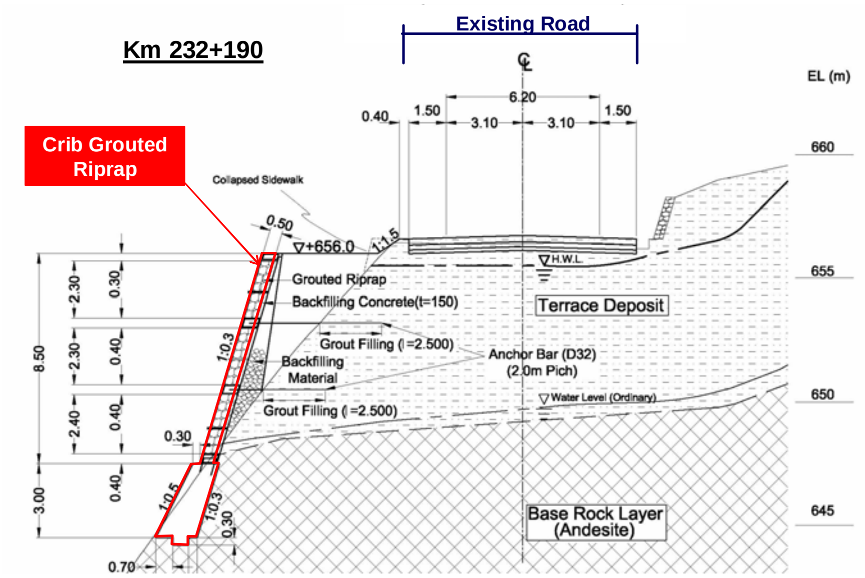

Figure 6.6 Typical Cross Section of Grouted Riprap Crib Retaining Wall

(c) Shelf Type Reinforced Concrete Retaining Walls (Option -3)

Figure 6.7 shows the typical cross section of a shelf type reinforced concrete wall. Major features of this countermeasure design are described as follows:

- A shelf slab is provided to reduce the earth pressure acting on the vertical wall.
- The heel slab is embedded in the andesite base rock. In addition, a concrete foot is provided at the toe of the heel slab to ensure the stability of the wall.
- Total length of the reinforced concrete wall will be 100 m (Km 232+165.0 to Km 232+265.0).
- The road alignment should be the same as the existing. Only 70 m length of the pavement of the closed lane (left side lane in Figure 6.7) is to be re-constructed. Therefore, traffic control measures should be adopted in the construction period.

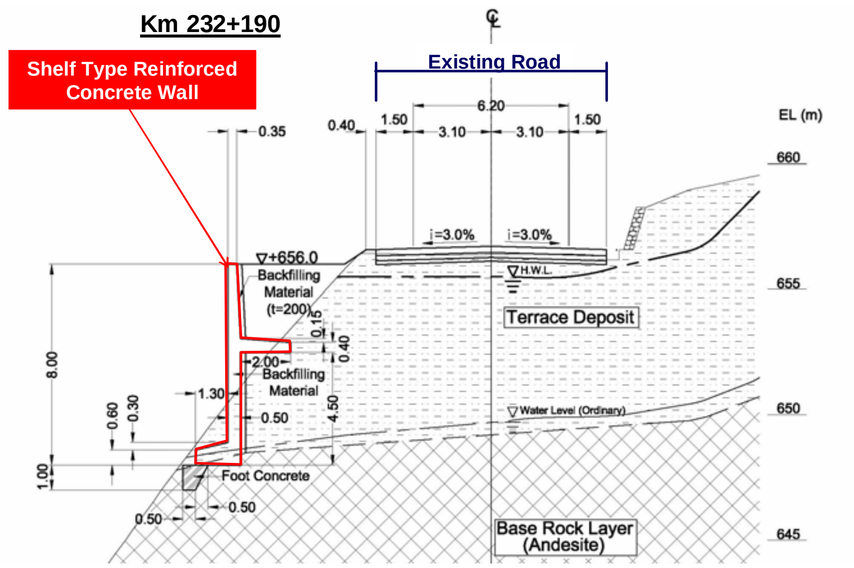

Figure 6.7 Typical Cross Section of Shelf Type RC Retaining Wall

(4) Cost Estimates

The unit costs for engineering cost estimates include material cost, labor cost and equipment cost. In addition, the following indirect costs are taken into consideration in the unit costs;

- Overhead of Expenses : 5 % of Labor Cost,
- Contingency : 10 % of Direct Cost,
- Miscellaneous Expenses : 1 % of Direct Cost,
- Value-added Tax (VAT) : 12 % of Labor Cost and Equipment Cost, and
- Contractor's Administration Cost & Profit: 10 % of Direct Cost.

Table 6.5 shows the result of engineering cost estimates for Option-1 to Option-3. Construction costs for each option are estimated as follows:

- Option -1 : 18,475,390 Pesos
- Option -2 : 15,148,565 Pesos
- Option -3 : 13,378,763 Pesos

Table 6.5 Cost Estimate for Countermeasures at Kennon Road (Km227)

a) Option-1 : Embankment Reinforcement with a Terre Armee Wall

Work Item	Unit	Unit Rate (Pesos)	Q'ty	Amount (Pesos)	Note
1. Terre Armee Retaining Wall Embankment Reinforcement					
1) Staging Type Scaffolding	m^3	470	3,353	1,575,675	
2) Structure Excavation by Hand	m^3	1,620	2,034	3,295,582	Soft Rock
3) Concrete Foundation (Class B)	m^3	4,030	398	1,603,436	
4) Terre Armee Skin and Strip	m^2	9,751	620	6,047,804	
5) Filter Material	m^3	1,220	95	116,083	- Manual backfilling with plate compactor - Gravel 3/4" ~ 1"
6) Strainer PVC Pipe (φ200)	m	347	166	57,667	
7) Embankment (Borrow Material)	m^3	400	4,741	1,896,572	
8) Sodding on Embankment Surface	m^2	90	318	28,600	
sub-total :				***14,621,419***	
2. Road Pavement					
1) Removal of Existing Concrete Pavement	m^2	200	1,116	223,200	
2) Sub-grade Preparation	m^2	35	1,401	49,026	
3) Aggregate Sub-base Course (t=200)	m^3	800	280	224,121	including spreading and compaction
4) Aggregate Base Course (t=150)	m^3	860	210	180,697	including spreading and compaction
5) Portland Cement Concrete Pavement (t=250)	m^2	1,160	1,401	1,624,876	
6) U-shape Concrete Drain Ditch	m	1,770	181	320,370	size : 500 x 500
7) Metal Guardrail (Metal Beam)	m	2,300	153	351,900	
sub-total :				***2,974,191***	
3. Provisional Sum and Other General Requirements	LS		1	***879,780***	5 % of Construction Cost
Total :				**18,475,390**	

b) Option-2 : Grouted Riprap Crib Retaining Wall

Work Item	Unit	Unit Rate (Pesos)	Q'ty	Amount (Pesos)	Note
1. Grouted Riprap Crib Retaining Wall					
1) Staging Type Scaffolding	m^3	560	7,700	4,312,000	
2) Structure Excavation by Hand	m^3	1,620	466	755,374	Soft Rock
3) Concrete Foundation (Class B)	m^3	4,030	432	1,739,348	
4) Concrete for Crib (Class A)	m^3	4,240	151	638,650	
5) Steel Reinforcing Bars for Crib (Grade 40)	kg	50	15,063	753,125	
6) Formwork for Crib	m^2	340	537	182,495	
7) Concrete Backfill Class B (t=150)	m^3	4,030	105	423,150	
8) Formwork for Concrete Backfill	m^2	340	685	232,824	
9) Grouted Riprap	m^3	2,660	305	811,204	
10) Weep holes (PVC φ=50)	m	90	377	33,943	
11) Backfill Material	m^3	1,220	497	606,584	- Manual backfilling with plate compactor - Gravel 3/4" ~ 1"
12) Backfilling with Borrow Material	m^3	490	2,210	1,082,988	Manual backfilling with plate compactor
13) Anchor Bars (Grade 40, D32)	kg	50	3,724	186,222	
14) Grout Filling for Anchor Bars	m	6,100	255	1,555,500	including Horizontal Darling (φ66)
15) Sodding on Embankment Surface	m^2	90	228	20,521	
sub-total :				***13,333,926***	
2. Road Pavement Restoration for Collapsed Lane					
1) Removal of Existing Concrete Pavement	m^2	200	252	50,400	
2) Sub-grade Preparation	m^2	35	252	8,820	
3) Aggregate Sub-base Course (t=200)	m^3	800	50	40,320	including spreading and compaction
4) Aggregate Base Course (t=150)	m^3	860	38	32,508	including spreading and compaction
5) Portland Cement Concrete Pavement (t=250)	m^2	1,160	252	292,320	
6) U-shape Concrete Drain Ditch	m	1,770	183	323,910	size : 500 x 500
7) Metal Guardrail (Metal Beam)	m	2,300	150	345,000	
sub-total :				***1,093,278***	
3. Provisional Sum and Other General Requirements	LS		1	721,360	5 % of Construction Cost
Total :				***15,148,565***	

c) Option-3 : Shelf Type Reinforced Concrete Retaining Wall

Work Item	Unit	Unit Rate (Pesos)	Q'ty	Amount (Pesos)	Note
1. Reinforced Concrete Retaining Wall					
1) Staging Type Scaffolding	m^3	560	6,325	3,542,000	
2) Structure Excavation by Hand	m^3	1,620	504	817,193	Soft Rock
3) Foot Concrete (Class B)	m^3	4,030	75	302,250	
4) Concrete (Class A)	m^3	4,240	570	2,418,496	
5) Steel Reinforcing Bars (Grade 40)	kg	50	57,040	2,852,000	
6) Formwork	m^2	340	1,767	600,848	
7) Weep holes (PVC φ=50)	m	90	302	27,158	
8) Backfill Material	m^3	1,220	129	157,624	- Manual backfilling with plate compactor - Gravel 3/4" ~ 1"
9) Backfilling with Borrow Material	m^3	490	1,858	910,312	Manual backfilling with plate compactor
10) Sodding on Embankment Surface	m^2	90	228	20,521	
sub-total :				***11,648,401***	
2. Road Pavement Restoration for Collapsed Lane					
1) Removal of Existing Concrete Pavement	m^2	200	252	50,400	
2) Sub-grade Preparation	m^2	35	252	8,820	
3) Aggregate Sub-base Course (t=200)	m^3	800	50	40,320	including spreading and compaction
4) Aggregate Base Course (t=150)	m^3	860	38	32,508	including spreading and compaction
5) Portland Cement Concrete Pavement (t=250)	m^2	1,160	252	292,320	
6) U-shape Concrete Drain Ditch	m	1,770	183	323,910	size : 500 x 500
7) Metal Guardrail (Metal Beam)	m	2,300	150	345,000	
sub-total :				***1,093,278***	
3. Provisional Sum and Other General Requirements	LS		1	***637,084***	5 % of Construction Cost
Total :				**13,378,763**	

(5) Selection of Countermeasure

Each option was evaluated from four evaluation items consisting of construction cost, construction aspect, structural aspect, and social environmental aspect including safety for ordinary traffic, and the evaluation result is simply rated with three ranks from good (3 points), fair (2 points) and poor (1 point) as per the following criteria to be established in this feasibility study;

[Construction Cost]

Poor : More than 35 % above cost of lowest cost option

Fair : Less than 1.35 times cost of lowest cost option

Good : Lowest cost

[Construction Aspect]

Poor : Construction difficulties may cause serious accidents due to site topographic conditions.

Fair : Construction difficulties may be expected due to site conditions.

Good : Construction is not very difficult.

[Structural Aspect]

Poor : The design may have to be changed due to findings of subsequent detailed geological survey.

Fair : The design may have to be modified to maintain stability due to findings of subsequent detailed geological survey.

Good : The design can be expected to maintain structural stability.

[Environment Aspect]

Poor : Resettlement of inhabitants in nearby dwellings will occur or serious impacts to ordinary traffic flow such as road closure and/or risk of accidents may be expected due to the construction.

Fair : Traffic control during the construction period will be required.

Good : None of the above negative impacts are expected.

Furthermore, each evaluation item was weighted with a multiplying factor considering the importance of the item. In this study, the following multiplying factors were applied.

Table 6.6 Multiplying Factors for Selection Criteria

Evaluation Items	Multiplying Factor	Reason
• Construction Cost	3	Most important element in the development of infrastructures
• Construction Aspect	2	Risks/Ease of construction is important considering severe site conditions
• Structural Aspect	1	Especially for reliability of stability
• Social Environment Aspect	2	Negative impacts on residents such as resettlement/land acquisition, or impacts on ordinary traffic flow due to the construction work

In this feasibility study, each multiplying factor for the evaluation items in Table 6.6 was established as follows:

[Multiplying Factor for the Construction Cost]

Economic aspect shall have the highest priority.

[Multiplying Factor for the Construction Aspect]

Countermeasure works to be selected for the feasibility study are to be executed on slopping terrain; therefore there is the risk of accidents that could result in the loss of the life of a construction worker due to site conditions and construction methods. From this viewpoint, the factor is 2.

[Multiplying Factor for the Structural Aspect]

Normally, the slope protection countermeasures must be individually designed for the actual geological conditions. The geological site surveys to be conducted in this study are at the preliminary design level. Therefore, the stability of the structures should be reexamined at the detail design stage based on the detailed surveys.

[Multiplying Factor for the Social Environment Aspect]

During implementation of public works in the Philippines, the social environmental considerations constitute an important issue to lead to the success of the project. From this viewpoint, the factor is 2.

Considering the above criteria, individual scores and the total points for each option were estimated, and Option-1, the Terre Armee Wall Reinforced Embankment may be selected for the countermeasure as shown in Table 6.7.

Table 6.7 Evaluation Results of Options for Kennon Road (Km 232)

Option	Cost (*3)	Construction (*2)	Structural (*1)	Social Environment (*2)	Total Points
Option-1	Poor (3)	Good (6)	Good (3)	Good (6)	18
Option-2	Fair (6)	Poor (2)	Fair (2)	Poor (2)	12
Option-3	Good (9)	Poor (2)	Good (3)	Poor (2)	16

6.3.2 Lagawe-Banaue Road, Km301 (CAR)

(1) Damage Condition

This disaster was classified as a Landslide (LS). According to the District Engineering Office, the slope has collapsed repetitively over the past decades. Every time a landslide covered the road, it was simply removed to reopen the road to traffic. The length of the damaged section is approximately 120 m, as shown in Photo 6.3.

The geological survey found that the conglomerate layer is distributed on the sandstone layer, and inclines toward the Lagawe-Banaue Road. The groundwater level was observed to be near the surface. The scale of the landslide block that caused damage to the road is approximately 140 m long as shown in Figure 6.7. Furthermore, the said landslide block is located at the lower part of an old and huge landslide block of approximately 250 m long.

The debris was placed at the side of the road, which is supposed to act as counter force against the landslide. Consequently, the current landslide block was observed to be in a stable state.

Photo 6.3 Front View of Damaged Section (Lagawe-Banaue Road Km 301)

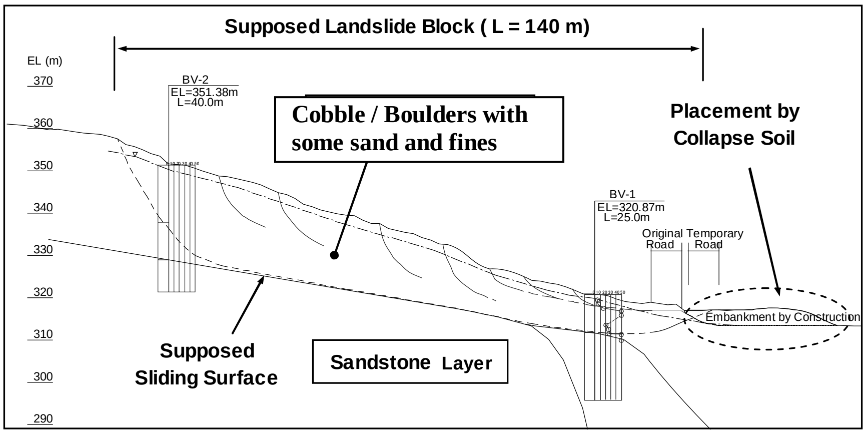

Figure 6.8 Supposed Landslide Block at Lagawe-Banaue Road (Km 301)

(2) Approach to Countermeasure Planning

The following viewpoints were taken into consideration in the planning of countermeasures:

- Soil removal at the head of the landslide block to reduce the landslide force shall not be considered, since this measure will have an impact on the back portion of the huge landslide block of 250 m size.
- As mentioned above, the debris placed at the road side performs as a counterforce or counterweight against landslide. Therefore, the said existing bank area should be kept as it is.
- In the countermeasure option planning, the resettlement of the inhabitants of the houses along the road may become significant.

(3) Choosing an Option

The following options were established for the countermeasure design;

Option-1 : Horizontal Drain Hole + Steel Pipe Piles
Option-2 : Horizontal Drain Hole + Counter Embankment

(a) Horizontal Drain Holes + Steel Pipe Piles (Option-1)

A plan and typical cross section for option-1 countermeasure are shown in Figure 6.9 and Figure 6.10, respectively. Major features of the countermeasure design are described as follows:

- The safety factor against landslide under the existing conditions is assumed as Fs=1.0, because the current condition is stable, and Fs=1.2 was chosen as a required safety factor for the countermeasure design.
- As a result of stability analysis, the groundwater level is expected be lowered by 2 m by the horizontal drain holes, and the safety factor may increase to Fs=1.127 from Fs=1.0. Horizontal drain holes are proposed to be arranged at three locations, as shown in Figure 6.9.
- In order to achieve the required safety factor of Fs=1.2, the stability against the landslide force is ensured by the resistance of the piling. Steel pipe piles are applied, and the following type, length and interval of the piles were proposed as the result of stability analysis;

  - Diameter : φ608 (t = 45) - Length : 17.5 m - Interval : 1.8 m

- The damaged pavement, of which the length is approximately 80 m, will be restored to the original alignment.

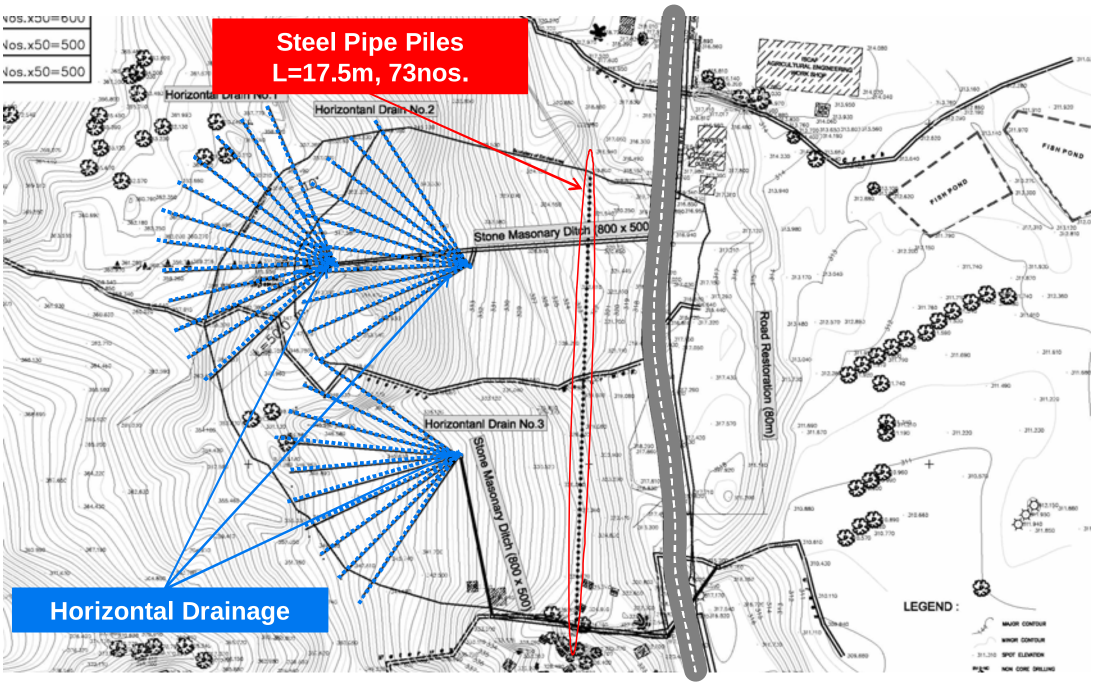

Figure 6.9 Countermeasure Plan of Option-1

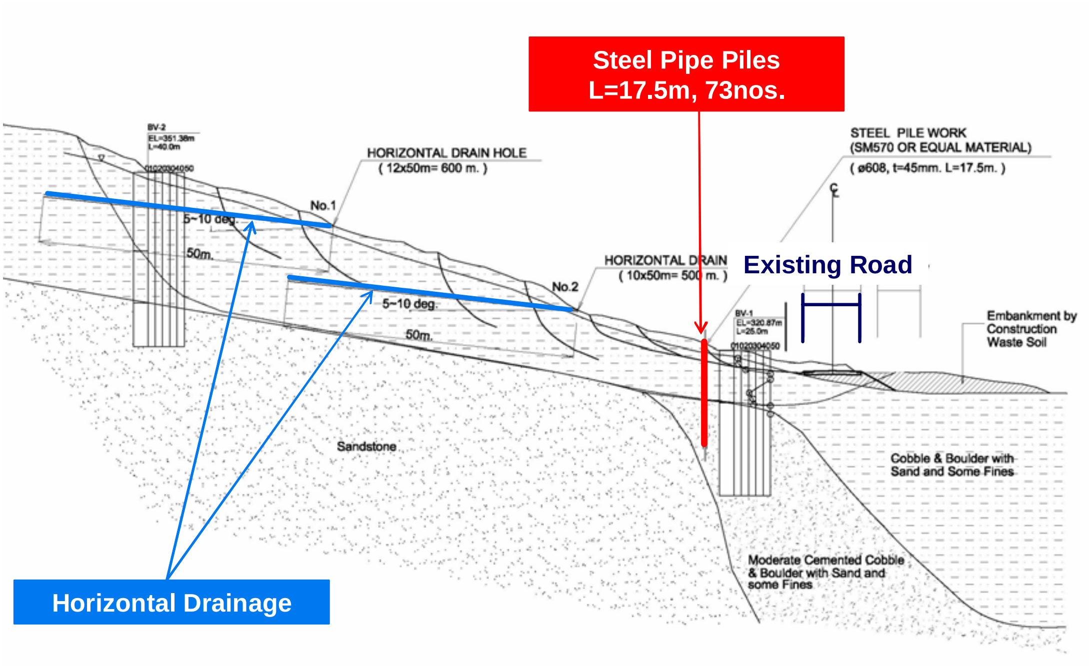

Figure 6.10 Typical Cross Section of Option-1

(b) Horizontal Drain Holes + Counter Embankment (Option-2)

The plan and typical cross section for option-2 countermeasure are shown in Figure 6.11 and Figure 6.12, respectively. This countermeasure also lowers the groundwater level by 2 m as in option-1, and other major features are described as follows:

- The required safety factor of Fs=1.2 is ensured by the weight of the counter embankment. As a result of trial stability analysis, a counter embankment of approximately 3 m thickness will be required at the toe portion of the landslide block.
- The existing road will be covered by the counter embankment. Therefore, the new road alignment with a length of 330 m should be constructed, as shown in Figure 6.11.
- For the construction of the new road alignment and the counter embankment, the resettlement of two houses, compensation for the fence and land acquisition of the agriculture college are required.

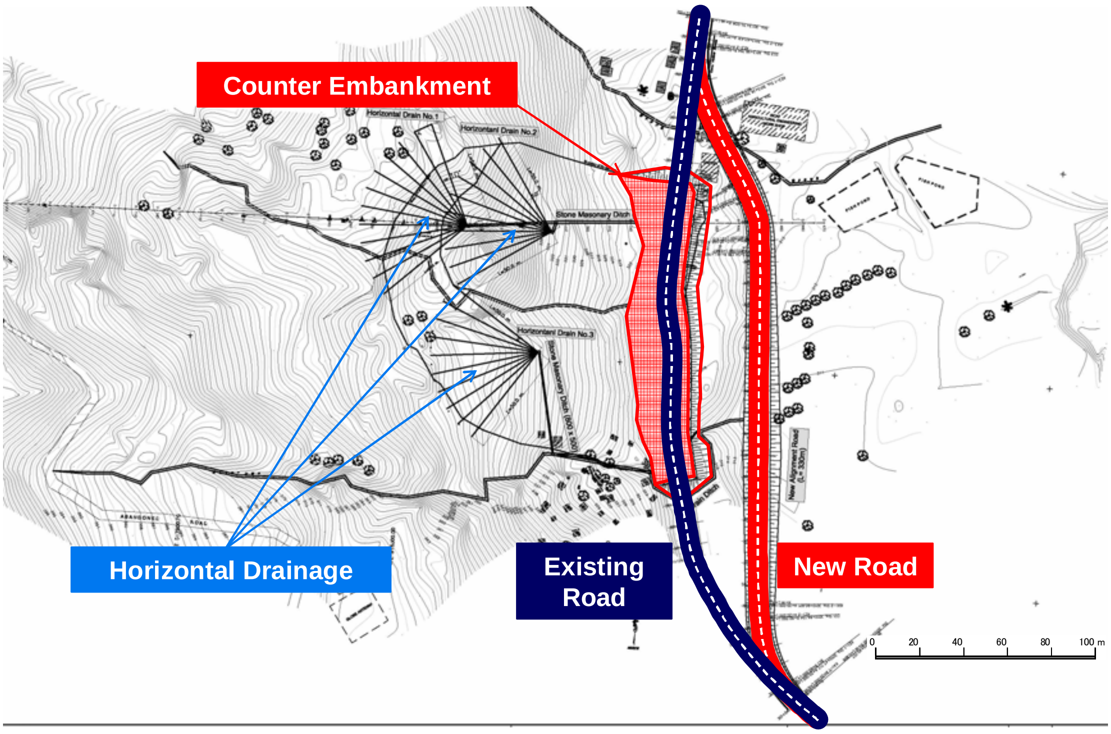

Figure 6.11 Countermeasure Plan of Option-2

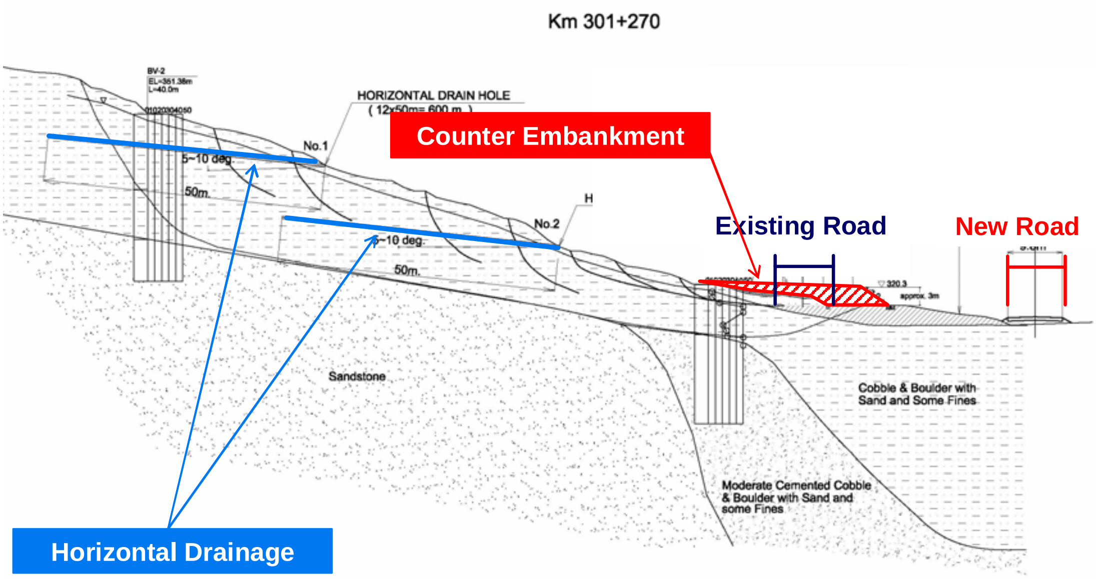

Figure 6.12 Typical Cross Section of Option-2

(4) Cost Estimates

Table 6.8 shows the result of engineering cost estimates for Option-1 and Option-2. Construction costs for each option are estimated as follows:

- Option -1 : 81,220,755 Pesos
- Option -2 : 22,644,256 Pesos

Table 6.8 Cost Estimate for Countermeasures at Lagawe-Banaue Road (Km 301)

a) Option-1 : Horizontal Drain Holes + Steel Pipe Piles

Work Item	Unit	Unit Rate (Pesos)	Q'ty	Amount (Pesos)	Note
1. Horizontal Drain and Surface Drain					
1) Horizontal Drilling (φ86)	m	5,700	1,600	9,120,000	
2) Strainer PVC Pipe (φ75)	m	130	1,600	208,000	
3) Grouted Riprap Wall	m^3	2,660	14	37,240	
4) Concrete Catch Basin	ps	5,700	5	28,500	size : 1,000 x 1,000 x 500 (t=200)
5) Stone Masonry Ditch	m	850	200	170,000	size : 800 x 500 (t=200)
sub-total :				***9,563,740***	
2. Steel Piles (φ608, t =45)	m	52,200	1278	***66,711,600***	including Borehole and Mortar Filling
3. Road Pavement Restoration for Damaged Lane					
1) Removal of Existing Concrete Pavement	m^2	200	640	128,000	
2) Sub-grade Preparation	m^2	35	640	22,400	
3) Aggregate Sub-base Course (t=200)	m^3	800	128	102,400	including spreading and compaction
4) Aggregate Base Course (t=150)	m^3	860	96	82,560	including spreading and compaction
5) Portland Cement Concrete Pavement (t=250)	m^2	1,160	640	742,400	
sub-total :				***1,077,760***	
4. Provisional Sum and Other General Requirements	LS		1	***3,867,655***	5 % of Construction Cost
Total :				***81,220,755***	

b) Option-2 : Horizontal Drain Holes + Counter Embankment

Work Item	Unit	Unit Rate (Pesos)	Q'ty	Amount (Pesos)	Note
1. Horizontal Drain and Surface Drain					
1) Horizontal Drilling (φ86)	m	5,700	1,600	9,120,000	
2) Strainer PVC Pipe (φ75)	m	130	1,600	208,000	
3) Grouted Riprap Wall	m^3	2,660	14	37,240	
4) Concrete Catch Basin	ps	5,700	5	28,500	size : 1,000 x 1,000 x 500 (t=200)
5) Stone Masonry Ditch	m	850	200	170,000	size : 800 x 500 (t=200)
sub-total :				***9,563,740***	
2. Counter Embankment					
1) Common Embankment	m^3	400	9,904	3,961,460	Borrow Material
2) Under Ground Drain (H300 x B500)	m	320	262	83,702	- Gravel 3/4" ~ 1" - Covered with Geotextile Filter Fabric
3) Under Ground Drain (H500 x B500)	m	560	154	86,445	- Gravel 3/4" ~ 1" - Covered with Geotextile Filter Fabric
4) Structure Excavation by Hand	m^3	230	95	21,839	
5) Gravel Bedding	m^3	1,320	2	2,475	
6) Foundation Concrete Class B	m^3	4,030	3	13,702	
7) Grouted Riprap	m^3	2,660	66	174,563	
8) Backfill Material	m^3	1,220	14	16,806	- Manual backfilling with plate compactor - Gravel 3/4" ~ 1"
9 Weep holes (PVC φ=50)	m	90	59	5,285	
10) U-shape Concrete Drain Ditch	m	1,770	224	397,128	size : 500 x 500
sub-total :				***4,763,404***	
3. Road Realignment					
1) Common Embankment	m^3	450	5,421	2,439,558	Borrow Material
2) Sub-grade Preparation	m^2	35	3,234	113,190	
3) Aggregate Sub-base Course (t=200)	m^3	800	647	517,440	including spreading and compaction
4) Aggregate Base Course (t=150)	m^3	860	485	417,186	including spreading and compaction
5) Portland Cement Concrete Pavement (t=250)	m^2	1,160	3,234	3,751,440	
sub-total :				***7,238,814***	
4. Provisional Sum and Other General Requirements	LS		1	***1,078,298***	5 % of Construction Cost
Total :				***22,644,256***	

(5) Selection of Countermeasure

Table 6.9 Evaluation Results of Options for Lagawe-Banaue Road (Km 301)

Option	Cost (*3)	Construction (*2)	Structural (*1)	Social Environment (*2)	Total Points
Option-1	Poor (3)	Good (6)	Good (3)	Good (6)	18
Option-2	Good (9)	Good (6)	Fair (2)	Poor (2)	19

As a result of the comprehensive evaluation as shown in Table 6.9, Option-2 consist of Horizontal Drain Holes + Counter Embankment may be selected as the countermeasure.

6.3.3 Dalton Pass, Km211 (Region III)

(1) Damage Condition

This disaster was classified as the Road Slip (RS). According to the District Engineering Office, cracks on the pavement surface were observed several times in the same area, and the current pavement surface was over-laid in 2005 due to the cracks. The length of the damaged section is 84 m, as shown in Photo 6.4.

(a) Overview

(b) Supposed Crack Line

Photo 6.4 Conditions of Dalton Pass (Km 211)

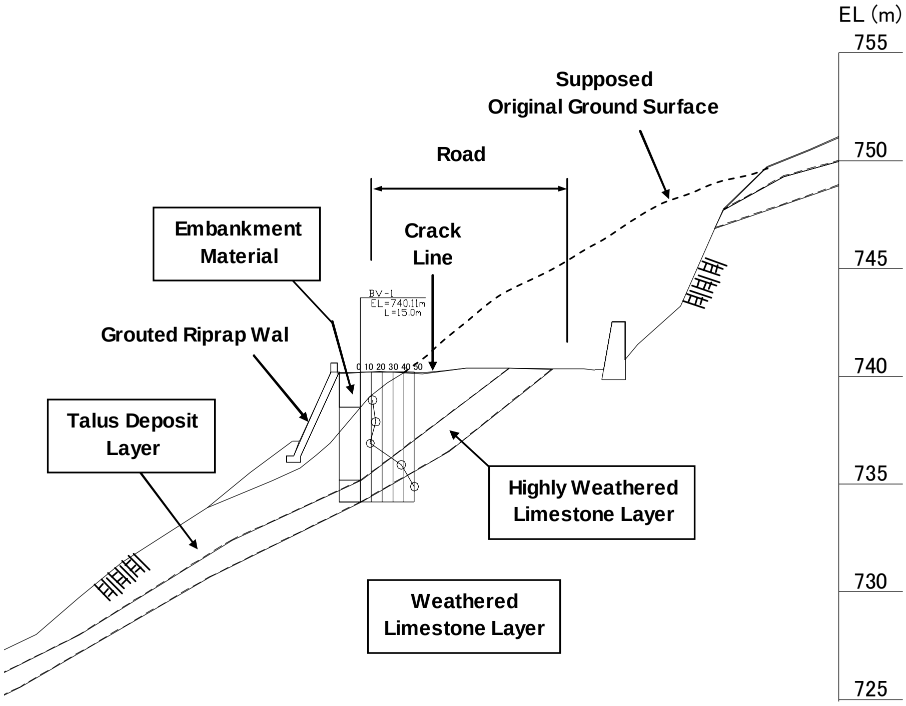

Figure 6.13 Engineering Geological Profiling at Dalton Pass (Km211)

Figure 6.13 shows an engineering geological profile based on the geological survey conducted in the Study. From the geological and geotechnical points of view, the road slip on the study section probably occurred due to the following mechanisms;

- From the topographic condition, the road slip seems to have occurred at the embankment section. The cracks probably developed at the boundary between the cut and fill, as presented in Figure 6.13.
- The grouted riprap retaining wall was constructed on a slope of talus deposits. The said materials are relatively loose and soft where the N-value from SPT is approximately 10. One of the possible causes for the road slip is that the bearing capacity of the foundation for grouted riprap is not sufficient, hence the road embankment slipped together with the riprap wall.
- In addition, the circular slip stability analysis of this section resulted in a minimum safety factor of Fs=0.97 as shown in Figure 6.14, which means that the entire road embankment slipped.

Layer		Unit Weight γ (kN/m³)	Shear Strength	
			c (kN/m²)	f (deg.)
1	Embankment	19	0	25
2	Talus Deposit	18	0	30
3	Highly Weathered Limestone	20	180	0
4	Weathered Limestone (Base Rock)	21	-	-

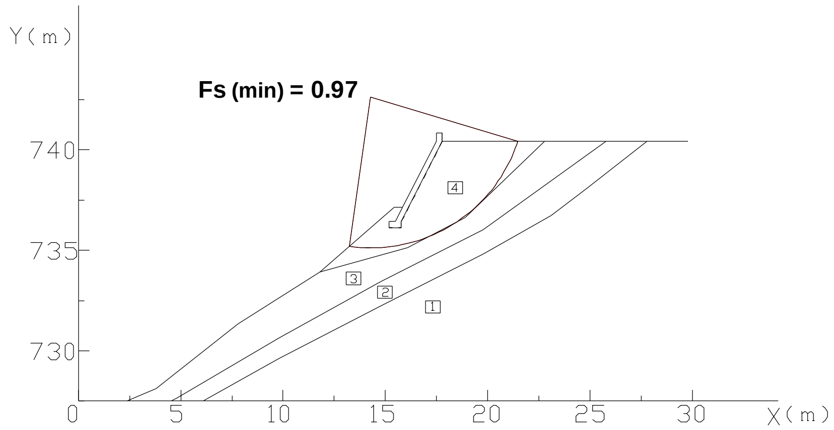

Figure 6.14 Result of Circular Slip Stability Analysis for Existing Condition at Dalton Pass (Km211)

(2) Approach to Countermeasure Planning

The following viewpoints were taken into consideration in the planning of the countermeasures:

- The current grouted riprap retaining wall is assumed to stand on unstable subsoil (fill material or talus deposit). This means that many countermeasures which would be technically feasible would require large-scaled excavation work at the foundation of the existing retaining wall but these were eliminated from consideration in order to avoid any adverse impact on the road.
- If the allowable design range for the bearing capacity of the foundation soil for the new retaining wall can not be achieved, the bearing capacity of the structure should be ensured by installing small piles, not with the depth of embedment for the same reason stated above.
- The stability of the road embankment body against circular slip failure should be improved to Fs=1.2 from the existing Fs=0.97.

(3) Choosing an Option

The following options were established for the countermeasure design:

Option-1 : Leaning Concrete Wall + Concrete Block Masonry Wall

Option-2 : Double Concrete Block Masonry Wall

(a) Leaning Concrete Wall + Concrete Block Masonry Wall (Option-1)

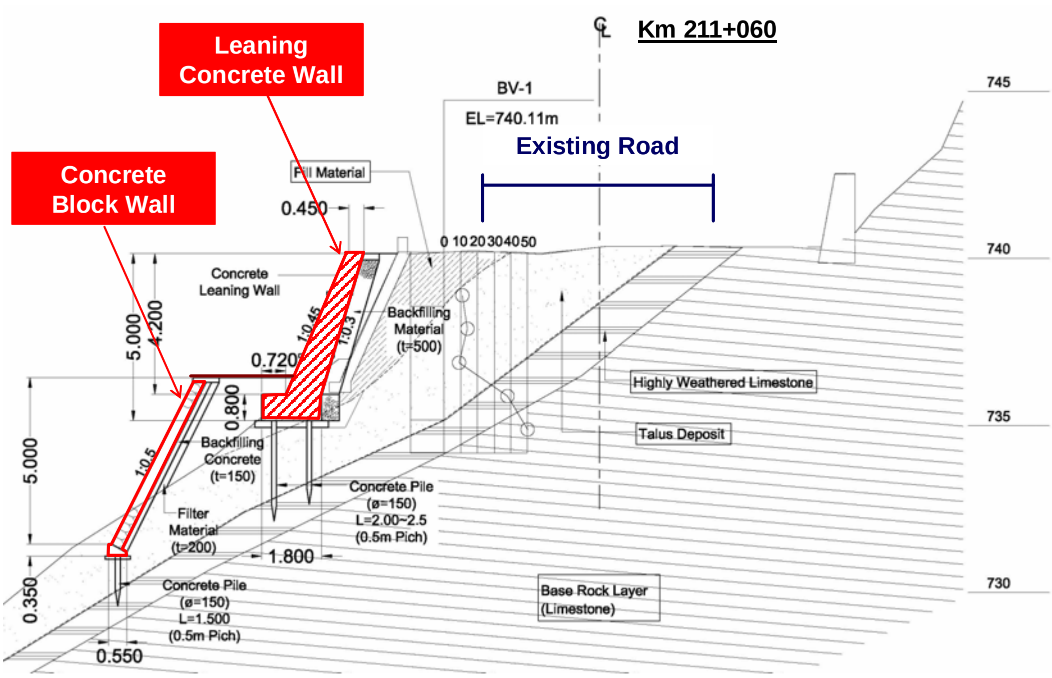

Figure 6.15 Typical Cross Section of Option-1

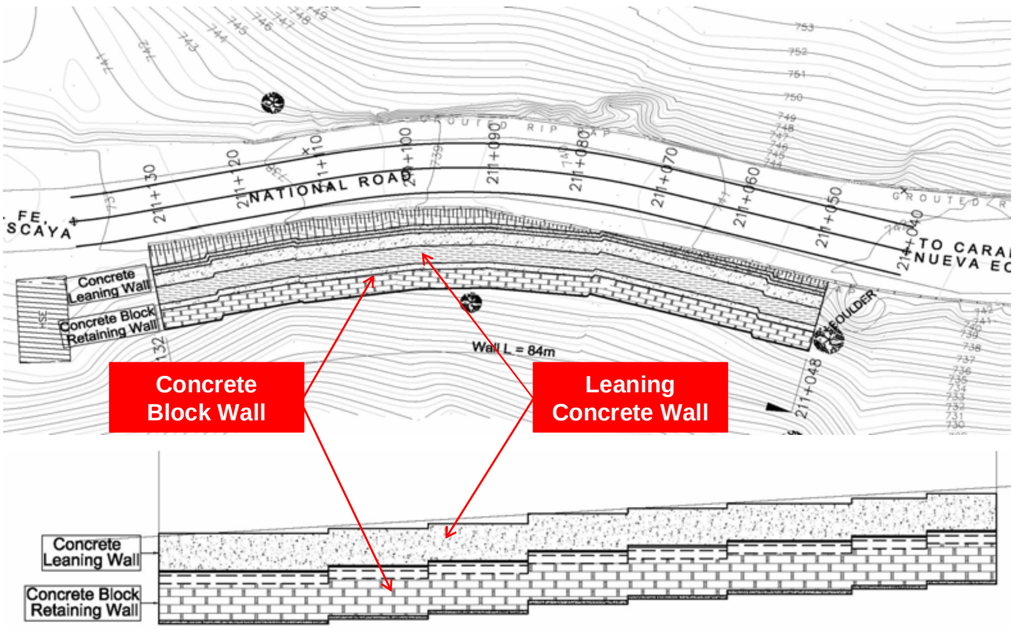

Figure 6.16 Plan and Side View of Option-1

The typical cross section, plan and side view of option-1 countermeasure are shown in Figures 6.15 and 6.16. Major features of the countermeasure are described as follows:

- The total height of the leaning concrete wall is 5.0 m including the thickness of the heal slab of 80 cm.
- Since the bearing capacity of the foundation soil for a leaning concrete wall is not within the allowable range based on the structural stability calculations, concrete piles (φ150) are proposed in a double row arrangement in the cross sectional direction, and at 0.5 m intervals in the longitudinal direction.
- In order to ensure the design safety factor (Fs=1.2) against circular sliding failure, a counter embankment to be protected by the concrete block masonry retaining wall is proposed at the lower portion of the leaning concrete wall. The safety factor is improved from Fs=0.97 (in Figure 6.12) to Fs=1.41, as shown in Figure 6.17 by this counterweight on the slope.

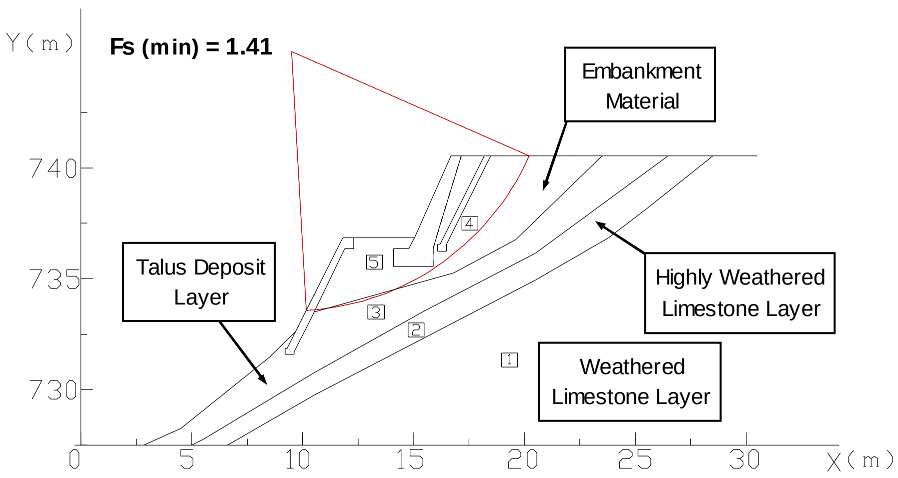

Figure 6.17 Result of Circular Slip Stability Analysis for Option-1 Countermeasure at Dalton Pass (Km211)

- For concrete block masonry, the maximum height allowed is only five meters. Thus, if the height required is more than 5 m, another type must be selected. Stone masonry may be substituted for the concrete blocks.
- The total length of the new retaining will be 84 m (Km 211+048 to Km 211+132).

(b) Double Concrete Block Masonry Wall (Option-2)

The typical cross section, plan and side view of option-2 countermeasure are shown in Figures 6.18 and 6.19. The basic design concept for this countermeasure is the same as Option-1, but the upper retaining structure is altered to concrete block masonry wall from the leaning concrete wall due to economic reasons. It should be noted that the structural reliability of Option-2 is inferior to Option-1.

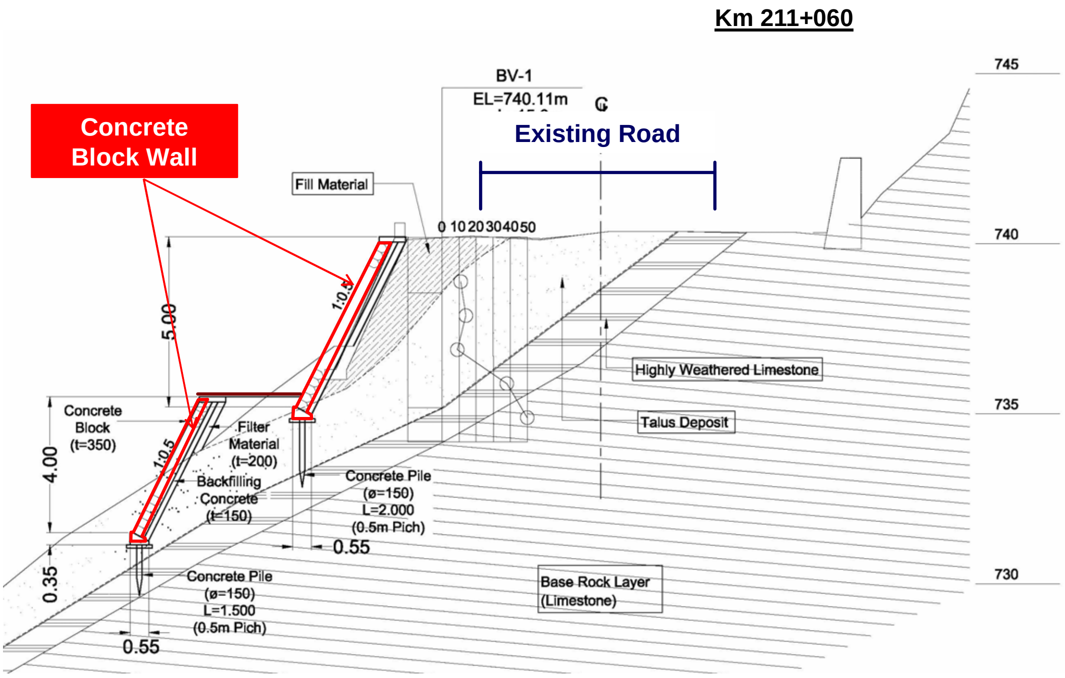

Figure 6.18 Typical Cross Section of Option-2

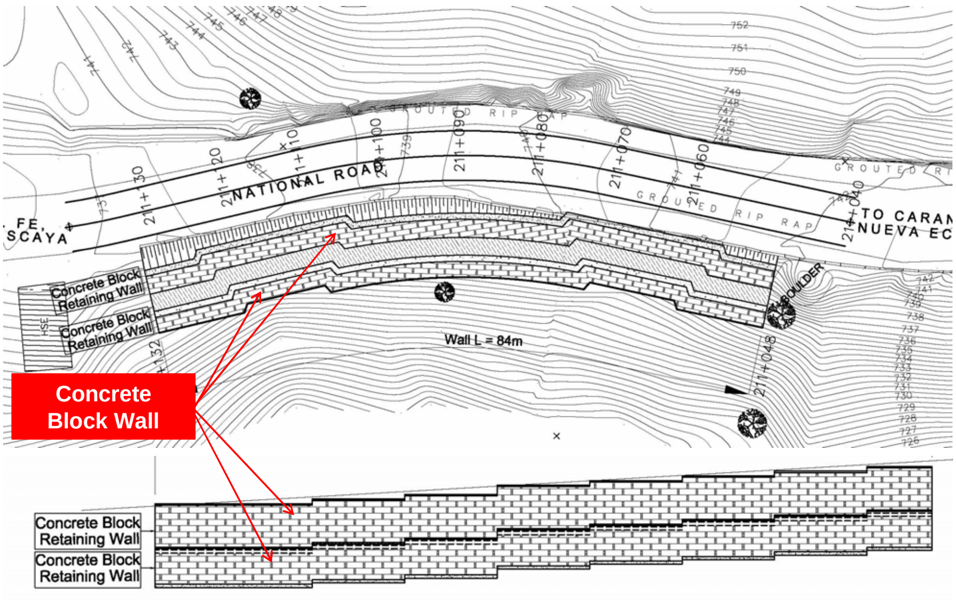

Figure 6.19 Plan and Side View of Option-2

(4) Cost Estimates

Table 6.10 shows the result of engineering cost estimations for Option-1 and Option-2. Construction costs for each option are estimated as follows:

- Option -1 : 5,649,532 Pesos
- Option -2 : 4,174,739 Pesos

Table 6.10 Cost Estimate for the Countermeasures at Dalton Pass (Km211)

a) Option-1 : Leaning Concrete Wall + Concrete Block Masonry Wall

Work Item	Unit	Unit Rate (Pesos)	Q'ty	Amount (Pesos)	Note
1. Leaning Concrete Wall					
1) Removal of Existing Riprap Retaining Wall	m^3	550	252	138,600	
2) Structure Excavation by Hand	m^3	230	715	164,355	
3) Gravel Bedding	m^3	1,320	37	48,787	
4) Foundation Concrete Piles (φ=150)	m	570	761	433,485	
5) Class B Concrete	m^3	4,030	399	1,608,309	
6) Formwork	m^2	340	906	308,191	
7) Weep holes (PVC φ=50)	m	90	477	42,959	
8) Backfill Material	m^3	1,220	215	262,349	- Manual backfilling with plate compactor - Gravel 3/4" ~ 1"
9) Backfilling with Borrow Material	m^3	490	433	211,977	Manual backfilling with plate compactor
sub-total :				***3,219,011***	
2. Concrete Block Masonry Wall					
1) Structure Excavation by Hand	m^3	230	160	36,781	
2) Gravel Bedding	m^3	1,320	6	8,316	
3) Casting and Installation of Concrete Block (t=350)	m^3	6,040	162	979,712	
4) Backfilling and Top Concrete Class B (t=150)	m^3	4,030	81	326,672	
5) Foundation Concrete Class B	m^3	4,030	11	46,039	
6) Formwork	m^2	340	541	184,041	
7) Weep holes (PVC φ=50)	m	90	159	14,347	
8) Foundation Concrete Piles (φ=150)	m	570	254	144,495	
9) Backfill Material	m^3	1,220	57	69,896	- Manual backfilling with plate compactor - Gravel 3/4" ~ 1"
10) Backfilling with Borrow Material	m^3	490	386	189,176	Manual backfilling with plate compactor
11) Staging Type Scaffolding	m^3	310	523	162,021	assumed 12.5 m^3/m
sub-total :				***2,161,495***	
3. Provisional Sum and Other General Requirements	LS		1	***269,025***	5 % of Construction Cost
Total :				***5,649,532***	

b) Option-2 : Double Concrete Block Masonry Walls

Work Item	Unit	Unit Rate (Pesos)	Q'ty	Amount (Pesos)	Note
1. Concrete Block Masonry Wall (Upper)					
1) Removal of Existing Riprap Retaining Wall	m^3	550	252	138,600	
2) Structure Excavation by Hand	m^3	230	415	95,358	
3) Gravel Bedding	m^3	1,320	6	8,316	
4) Casting and Installation of Concrete Blocks (t=350)	m^3	6,040	162	979,712	
5) Backfilling and Top Concrete Class B (t=150)	m^3	4,030	81	326,672	
6) Foundation Concrete Class B	m^3	4,030	11	46,039	
7) Formwork	m^2	340	541	184,041	
8) Weep holes (PVC φ=50)	m	90	159	14,347	
9) Foundation Concrete Pile (φ=150)	m	570	338	192,660	
10) Backfill Material	m^3	1,220	49	59,643	- Manual backfilling with plate compactor - Gravel 3/4" ~ 1"
11) Backfilling with Borrow Material	m^3	490	346	169,368	Manual backfilling with plate compactor
sub-total :				***2,214,754***	
2. Concrete Block Masonry Wall (Lower)					
1) Structure Excavation by Hand	m^3	230	164	37,629	
2) Gravel Bedding	m^3	1,320	6	8,316	
3) Casting and Installation of Concrete Blocks (t=350)	m^3	6,040	129	781,334	
4) Backfilling and Top Concrete Class B (t=150)	m^3	4,030	67	270,139	
5) Foundation Concrete Class B	m^3	4,030	11	46,039	
6) Formwork	m^2	340	447	152,111	
7) Weep holes (PVC φ=50)	m	90	127	11,388	
8) Foundation Concrete Pile (φ=150)	m	570	254	144,495	
9) Backfill Material	m^3	1,220	41	49,752	- Manual backfilling with plate compactor - Gravel 3/4" ~ 1"
10) Backfilling with Borrow Material	m^3	490	259	127,077	Manual backfilling with plate compactor
11) Staging Type Scaffolding	m^3	310	429	132,908	assumed 12.5 m^3/m
sub-total :				***1,761,188***	
3. Provisional Sum and Other General Requirements	LS		1	***198,797***	5% of Construction Cost
Total :				***4,174,739***	

(5) Selection of Countermeasure

As a result of comprehensive evaluation as shown in Table 6.11, Option-2, the Double Concrete Block Masonry Wall may be selected as the countermeasure.

Table 6.11 Evaluation Results of Options for Dalton Pass (Km211)

Option	Cost (*3)	Construction (*2)	Structural (*1)	Social Environment (*2)	Total Points
Option-1	Fair (6)	Fair (4)	Good (3)	Good (6)	19
Option-2	Good (9)	Fair (4)	Fair (2)	Good (6)	20