3.6.6 Preliminary Design of Countermeasure of Penanpang-Tambunan-Keningau Road

The study team also selected S05 slope as a landslide and S19 slope as a rock fall for case study of preliminary design of counter measure at Sabah.

(1) S05 Slope

Disaster occurred as subsidence of road, and the pavement has been broken by landslide, and now sinkage reached more than 2 m. The cause of landslide is assumed that the fill of road added the normal force of landslide, the stability of landslide decreased a little, and ground water level rose in the landslide mass, and then landslide moved toward down slope.

The stability factor of this landslide is estimated almost Fs = 1.00 on actual condition, and filled condition of first construction of road is less than 1.00.

Table 3.6.15 Result of stability analysis (Sabah S 05)

S 05	Unit weight γ_t(kN/m^3)	Cohesion C (kN/m^2)	Internal friction angle ϕ(degree)	Stability factor construction stage	Stability factor on actual condition
	18	20.0	20.545	0.986	1.00

Case I Counterweight embankment and horizontal drain holes.

Designed safety factor : Fsp = 1.20

On the assumption that the ground water level decrease 3 m at drain hole of ground water by construction of horizontal drain hole, the safety factor of landslide is follows;

Table 3.6.16 Result of stability analysis after construction of drain hole and counterweight embankment

S 05	Unit weight γ_t(kN/m^3)	Cohesion C (kN/m^2)	Internal friction angle ϕ(degree)	Stability factor after drain holes	Stability factor after drain holes and embankment
	18	20.0	20.545	1.127	1.192

The counter weight embankment should be done at the toe of landslide. As the result of stability analysis the required dimension of counterweight embankment is follows;

Crest level : 1465.5m
Width of Crest : 3m
Gradient : 1:1.8
Width of berm : 5m

Height of slope : 10m
Volume : 20,000m^3

- Gabion wall at toe of embankment
  Height : 4m
  Volume : 800m^3
- Horizontal drain holes
  Length : 50m
  Layer : 2
  Total holes : 20 nos.
  Total length : 1000m

Case II Counterweight embankment and drain well.

Designed safety factor : Fsp = 1.20

On the assumption that the ground water level decrease 5 m at drain well by construction of drain well, the safety factor of landslide is follows;

Table 3.6.17 Result of stability analysis after construction of drain well and counter embankment

S 05	Unit weight γ_t(kN/m^3)	Cohesion C (kN/m^2)	Internal friction angle ϕ(degree)	Stability factor after drain well	Stability factor after drain well and embankment
	18	20.0	20.545	1.127	1.212

The counter weight embankment should be done at the toe of landslide. The required dimension of counterweight embankment is follows;

Crest level : 1465.5m
Width of Crest : 3m
Gradient : 1:1.8
Width of berm : 5m
Height of slope : 10m
Volume : 13,000m^3

- Gabion wall at toe of embankment
  Height : 4m
  Volume : 800m^3
- Drainage well
  Length : 15m
  Catchment drain holes (layer : 2)
  Total holes : 16 nos.
  Total length : 560m

Case III Counterweight embankment and horizontal drain holes.

Designed safety factor : Fsp = 1.20

On the assumption that the ground water level decrease 3 m at drain hole of ground water by construction of horizontal drain hole, the safety factor of landslide and required shearing resistance are follows;

Table 3.6.18 Result of stability analysis after construction of drain hole and counter embankment

S 05	Unit weight γ_t(kN/m^3)	Cohesion C (kN/m^2)	Internal friction angle ϕ (degree)	Stability factor after drain hole	Required shearing resistance (kN/m)
	18	20.0	20.545	1.127	714.94

Design of steel pipe pile work is contained in Attachment **.

- Steel pipe piles
  - ϕ : 450 mm
  - t : 24mm
  - τ sa : 490 kN/mm^2 (SKK 490)
  - Pitch : 2.0 m (horizontal)
  - Length : L = 17.5m
  - Nos. : n= 40
  - Total length : 17.5*40 = 700 m
- Horizontal drain holes
  - Length : 50m
  - Layer : 2
  - Total holes : 20 nos.
  - Total length : 1000m

Case IV Counterweight embankment and drainage well.

Designed safety factor : Fsp = 1.20

On the assumption that the ground water level decrease 5 m at drainage well by construction of drainage well, the safety factor of landslide and required shearing resistance are follows;

Table 3.6.19 Result of stability analysis after construction of drainage well and counter embankment

S 05	Unit weight γ_t(kN/m^3)	Cohesion C (kN/m^2)	Internal friction angle ϕ (degree)	Stability factor after drainage hole	Required shearing resistance (kN/m)
	18	20.0	20.545	1.151	476.01

Design of steel pipe pile work is contained in Attachment **.

- Steel pipe piles
  - ϕ : 350 mm
  - t : 21mm
  - τ sa : 490 kN/mm^2 (SKK 490)
  - Horizontal pitch : 2.0 m
  - Length : L = 17.5m
  - Nos. : n= 40
  - Total length : 17.5*40 = 700 m
- Drainage well
  - Length : 15m
  - Catchment drain holes (layer : 2)
  - Total holes : 16 nos.
  - Total length : 560m

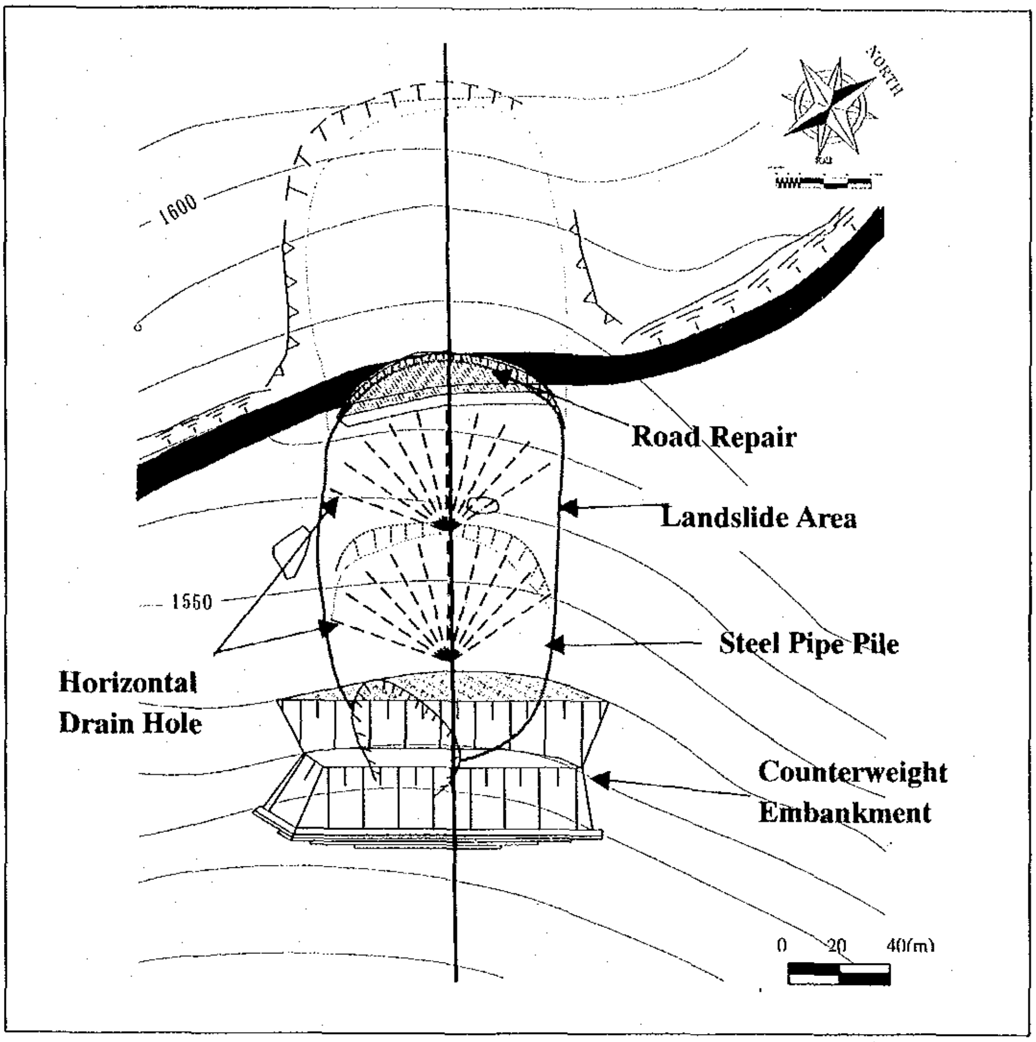

Figure 3.6.11 Plan (Horizontal Drainage and Counterweight Embankment)

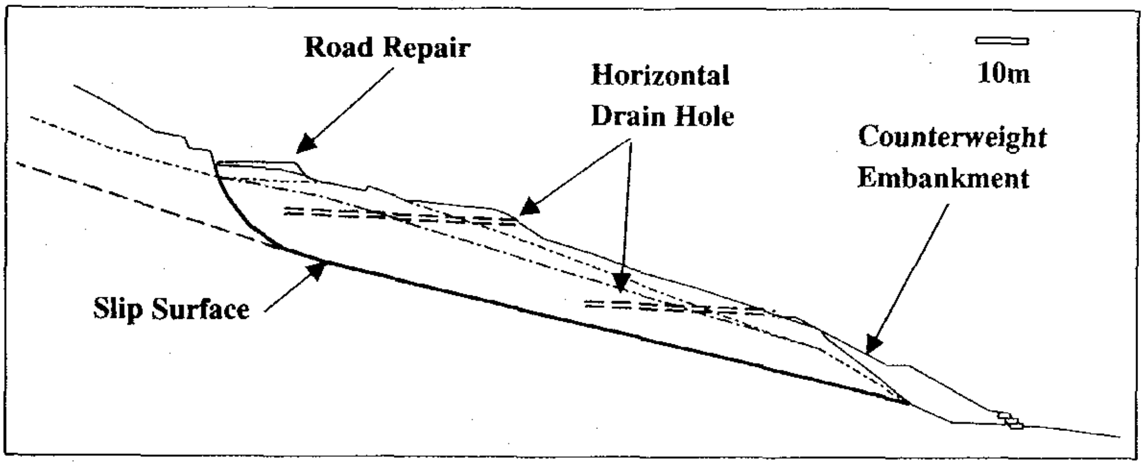

Figure 3.6.12 Cross Section (Horizontal Drainage and Counterweight Embankment)

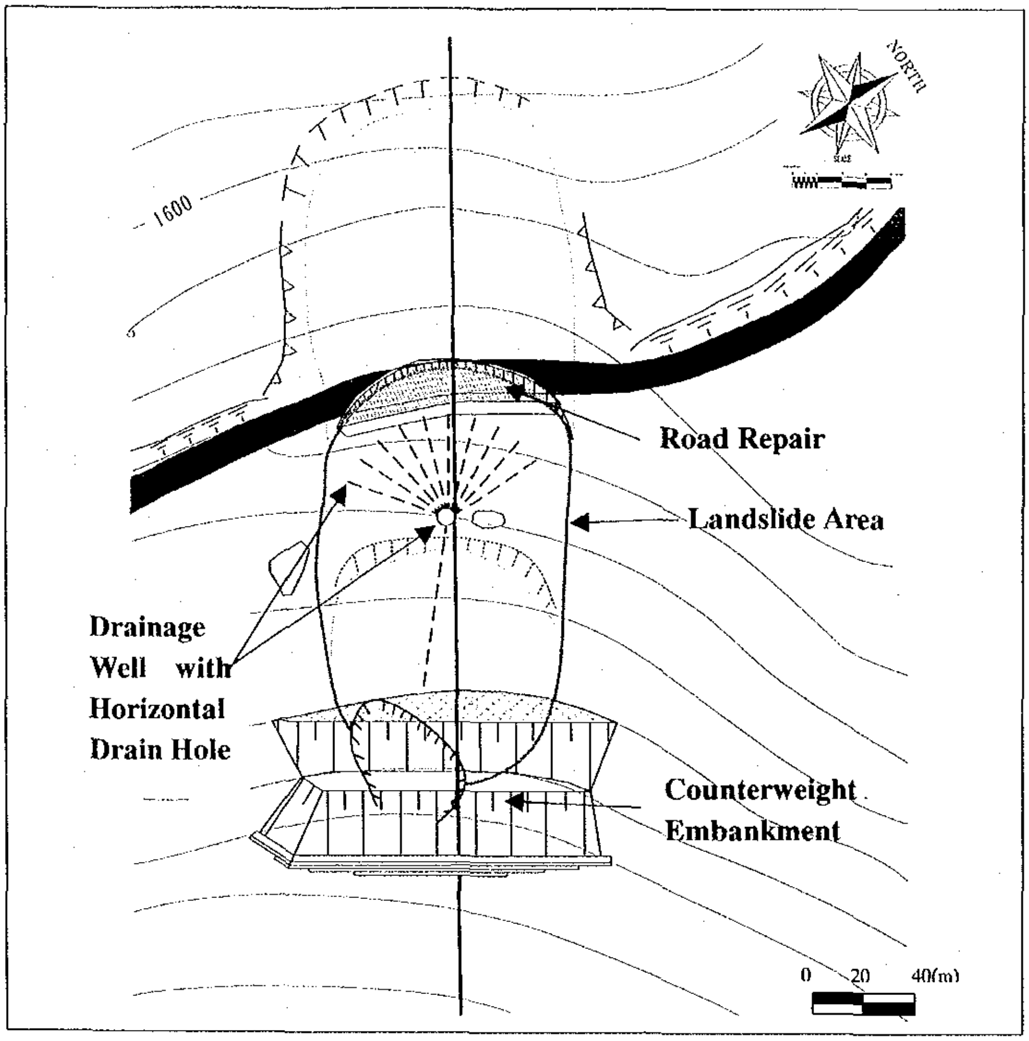

Figure 3.6.13 Plan (Horizontal Drainage and Counterweight Embankment)

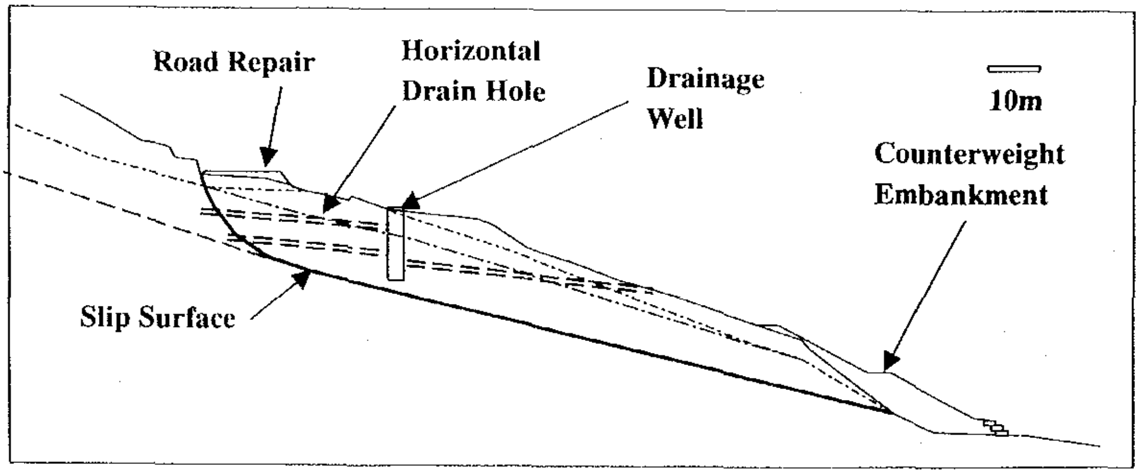

Figure 3.6.14 Cross Section (Horizontal Drainage and Counterweight Embankment)

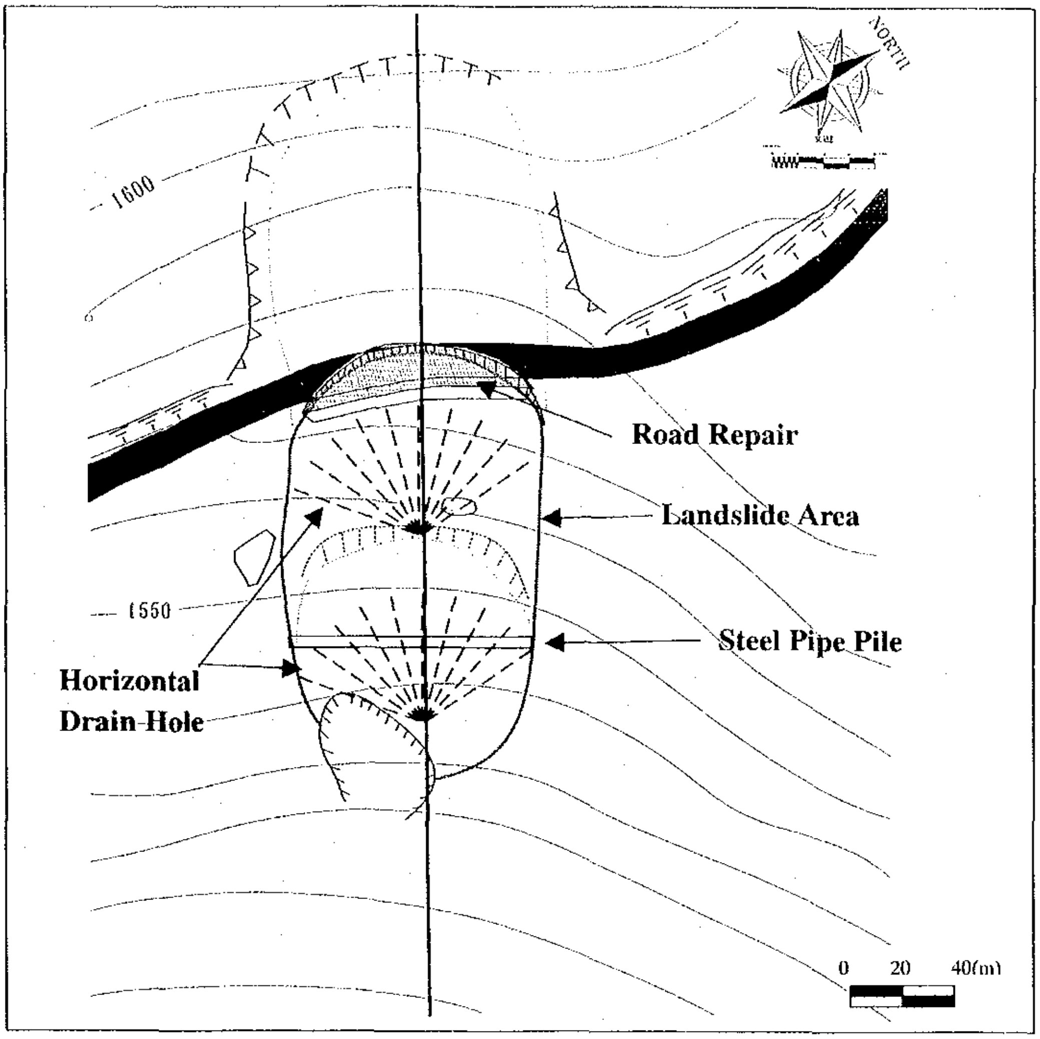

Figure 3.6.15 Plan (Steel Pipe Pile and Horizontal Drainage)

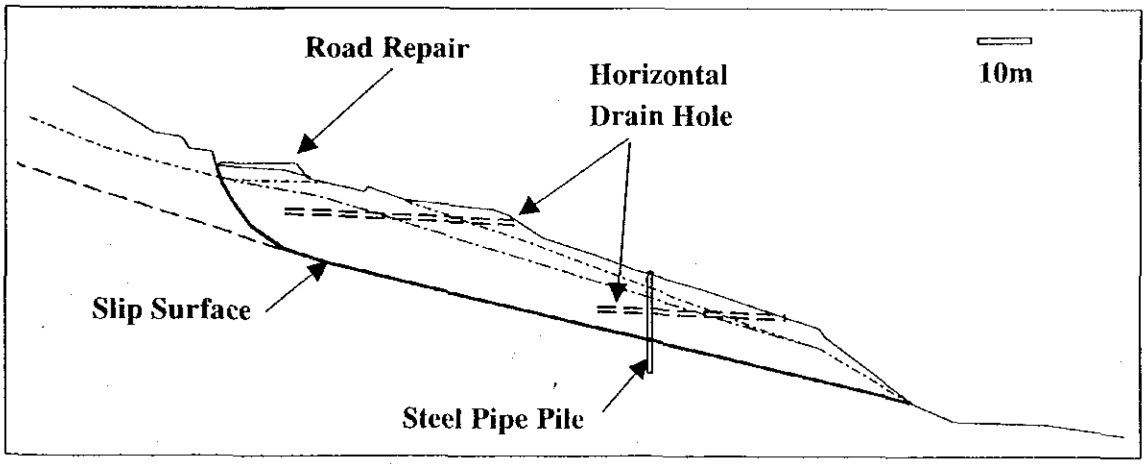

Figure 3.6.16 Cross Section (Steel Pipe Pile and Horizontal Drainage).

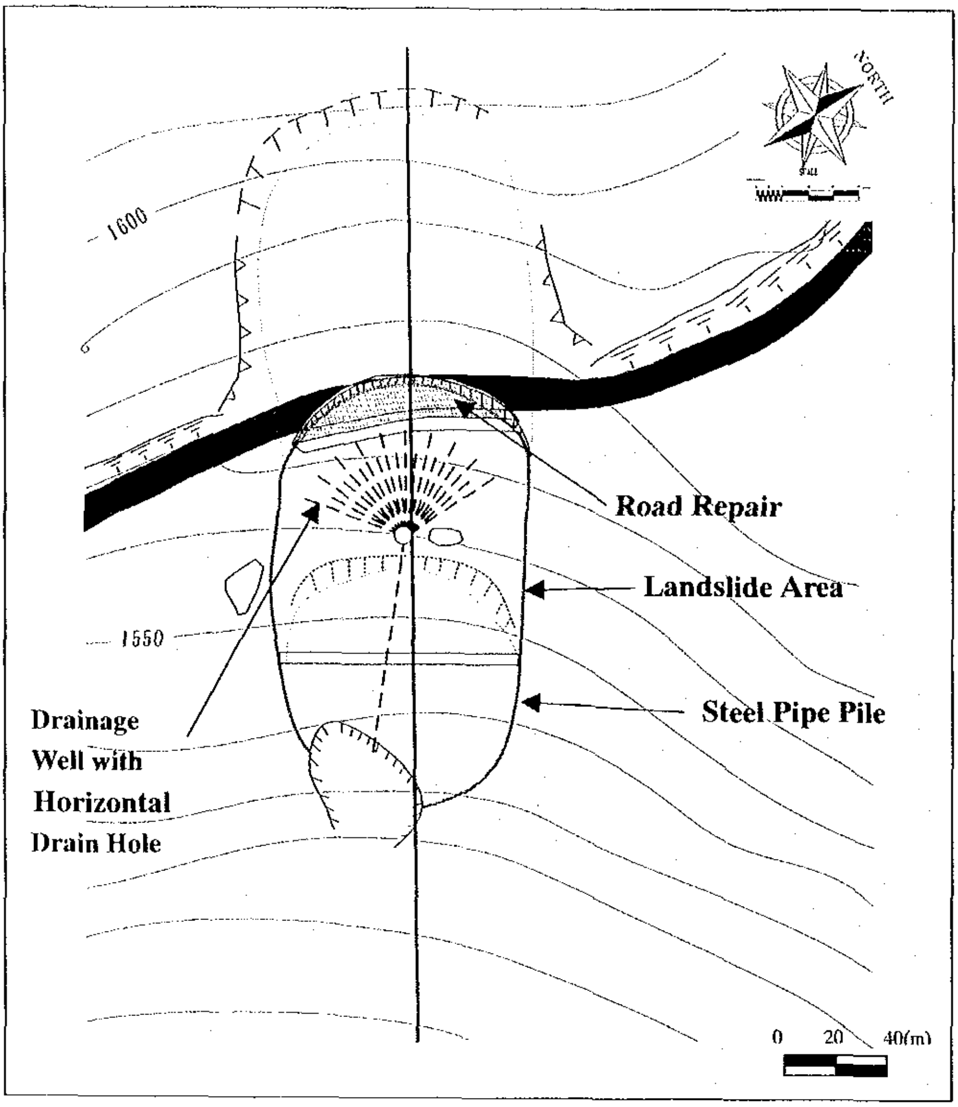

Figure 3.6.17 Plan (Steel Pipe Pile and Drainage Well)

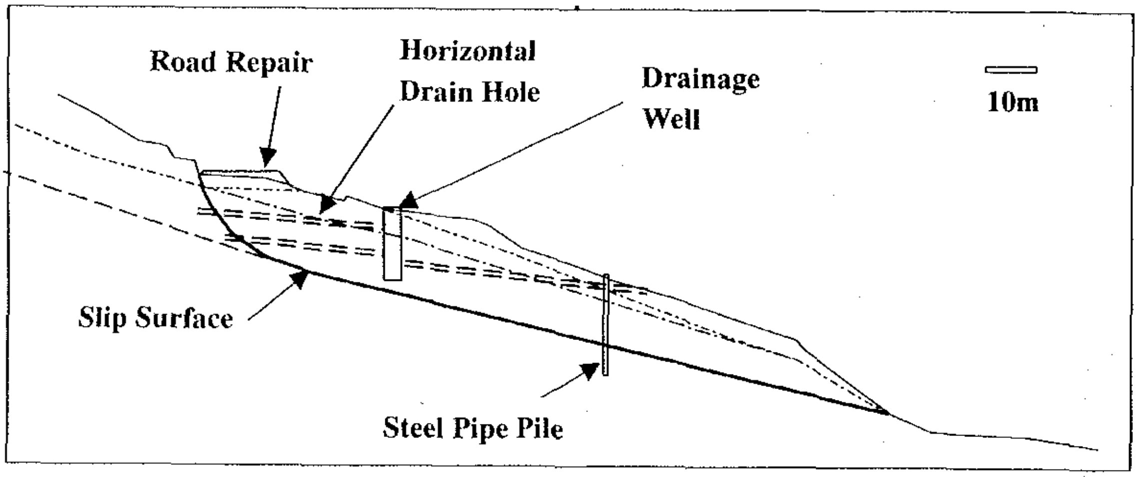

Figure 3.6.18 Cross Section (Steel Pipe Pile and Drainage Well)

(2) S19 Slope

Collapse is occurred in Mountainside slope. Upper part of slope is consisted of unstable residual soil, boulder and highly weathered rock. Middle and lower part of slope is consist of boulders and soft soils which is fallen from upward. Roadside drain is buried and broken by fallen rocks. Boulders and soils in the slope are unstable

Case I Road shifting and catch gabion wall

Route has to shift to make a pocket between gabion wall and toe of slope to catch falling rocks. Unstable boulders in slope should be removed and residual soil at upper slope should be cut off. Vegetation is also required on soils in slope.

- Route shifting
  Length of road: 40m
- Gabion wall
  Height: 2m
  Length: 40m
  Volume: 120m^3
- Removal rocks
  Volume : 20m^3
- Cutting
  Width of berm: 3m
  Gradient: 1:1.0
  Height of slope: 10 –15m
  Volume: 500m^3
- Roadside drain
  Length: 40m
- Vegetation
  Area of Vegetation: 120m^2

Case II Ground anchor with crib

- Ground anchor
  Nos. of steps: 6
  Horizontal interval: 3.0m
  Strength of tendon: 500 kN/unit (D32)
  Fixed Length: 4.5m
  Total Numbers: 66 nos.
  Total Length of anchors: 15m × 66 = 990m
- Crib
  Horizontal interval: 3m
  Width of crib: 60 cm
  Area of crib: 33m × 18m = 594m^2

- Roadside drain
  Length: 40m

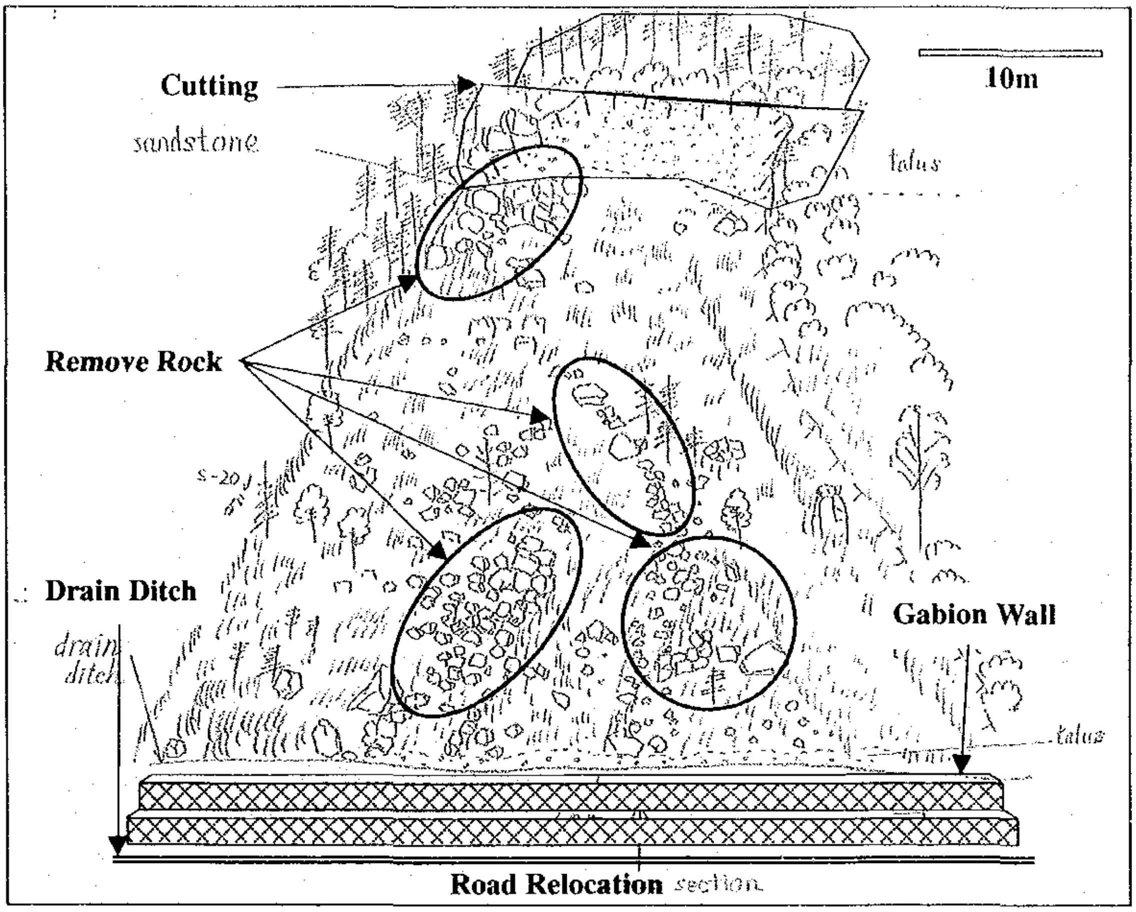

Figure 3.6.19 Plan (Route relocation and gabion wall)

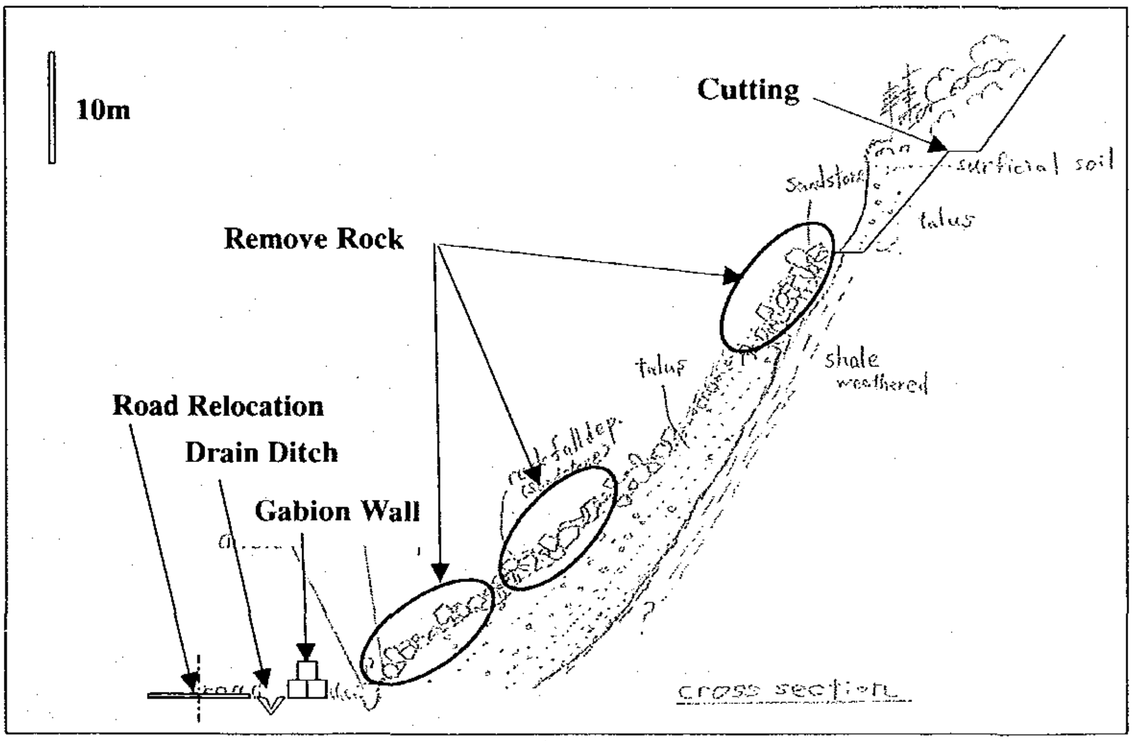

Figure 3.6.20 Cross section (Route relocation and gabion wall)

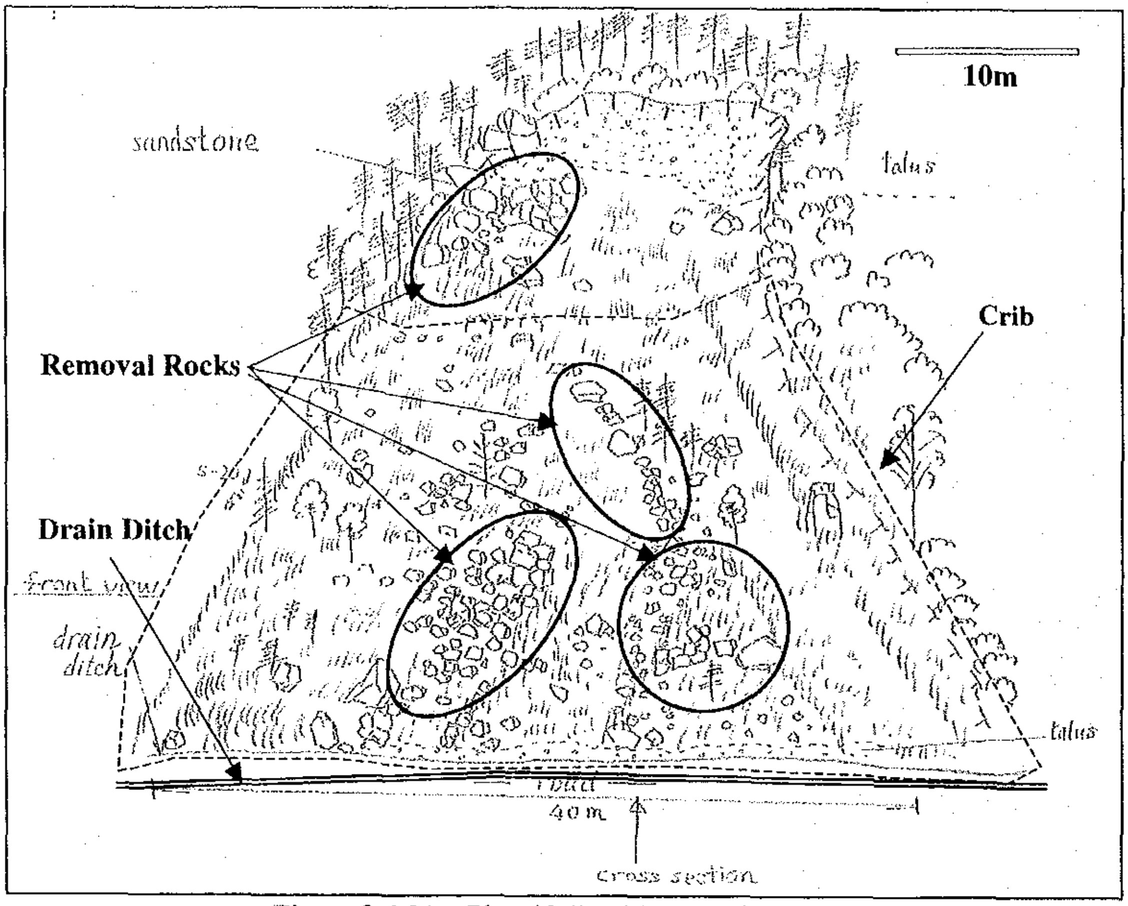

Figure 3.6.21 Plan (Crib with ground anchor)

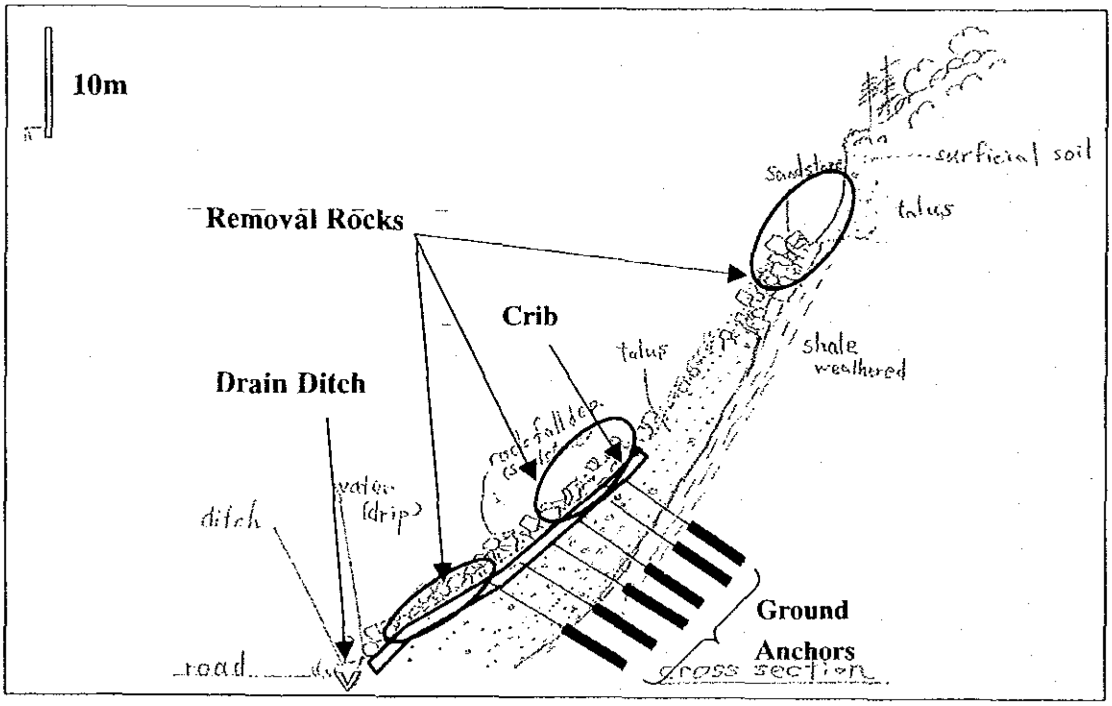

Figure 3.6.22 Cross Section (Crib with Ground Anchor)

3.6.7 Cost Estimate of Countermeasures

Estimated cost of the each case study site is follows;

(1) S 05 Slope (Landslide)

- **Case I** Horizontal drain holes and Counterweight embankment

Table 3.6.20 Cost of Horizontal drain holes and Counterweight embankment

	Countermeasures	Unit	Unit Rate	Quantity	Amount
1	Road Repair	m	300	100	30,000.00
2	Counterweight Embankment	m^3	8	20,000	160,000.00
3	Rock Gabion Wall	m^3	65	800	52,000.00
4	Horizontal drain holes	m	70	1,000	70,000.00
5	Vegetation	m^2	3	4,000	12,000.00
TOTAL					324,000.00

- **Case II** Drainage well and Counterweight embankment

Table 3.6.21 Cost of Drainage well and Counterweight embankment

	Countermeasures	Unit	Unit Rate	Quantity	Amount
1	Road Repair	m	300	100	30,000.00
2	Counterweight Embankment	m^3	8	13,000	104,000.00
3	Rock Gabion Wall	m^3	65	800	52,000.00
4	Drainage well	m	30,000	15	450,000.00
5	Drain holes	m	70	560	39,200.00
6	Vegetation	m^2	3	4,000	12,000.00
TOTAL					687,200.00

- **Case III** Horizontal drain holes and Steel pipe piles

Table 3.6.22 Cost of Horizontal drain holes and Steel pipe piles

	Countermeasure	Unit	Unit Rate	Quantity	Amount
1	Road Repair	m	300	100	30,000.00
2	Horizontal drain holes	m	70	1,000	70,000.00
4	Steel pipe piles	m	3,500	700	2,450,000.00
TOTAL					2,550,000.00

- **Case VI** Drainage well and Steel pipe piles

Table 3.6.23 Cost of Drainage well and Steel pipe piles

	Countermeasure	Unit	Unit Rate	Quantity	Amount
1	Road Repair	m	300	100	30,000.00
2	Drainage well	m	30,000	15	450,000.00
3	Drain holes	m	70	560	39,200.00
4	Steel pipe piles	m	3,000	700	2,100,000.00
TOTAL					2,619,000.00

(2) S 19 Slope (Rock fall)

• **Case I** Road shifting and catch gabion wall

Table 3.6.24 Cost of Road shifting and Catch gabion wall

	Countermeasure	Unit	Unit Rate	Quantity	Amount
1	Road shifting	m	300.00	40	12,000.00
2	Gabion wall	m^3	45.00	120	5,400.00
3	Removal rocks	m^3	2.00	100	200.00
5	Roadside drain	m	30.00	40	1,200.00
	TOTAL				18,800.00

• **Case II** Ground anchor with crib

Table 3.6.25 Cost of Ground anchor with Crib

	Countermeasure	Unit	Unit Rate	Quantity	Amount
1	Ground Anchor	m	550.00	990	544,500.00
2	Crib	m^2	200.00	594	118,800.00
3	Roadside drain	m	30.00	40	1,200.00
	TOTAL				664,500.00

3.7 Slope Disaster Management

3.7.1 Summary of Risk Rating of Slope in the Case Study

(1) Result of Slope Inspection

As was described in 3.2, the selected slopes of 471 in number along the case study route were carefully inspected in accordance with the criteria and specification of slope inspection, developed in this study. The slope inspection data collected by trained geologists were recorded on the query sheets, then later were input into the newly developed information system, SIMS, to be the slope database. By way of the function of SIMS, these data were processed and the risk rating of each slope was calculated. Table 3.7.1 shows the summary of Hazard Rating score of the case study.

Table 3.7.1 Number of Slopes rated as Very High and High

Type of Slope Failure (Disaster)	Number of slopes		
	Hazard Rating Score (H)		total
	H>=75	75>H>65	
1 Collapse (CL)	4	9	13
2 Rock Fall (RF)	0	0	0
3 Rock Mass Failure (RM)	1	4	5
4 Landslide (LS)	3	1	4
5 Deberis Flow (DF)	0	0	0
6 Embankment Failure (EB)	1	4	5
total	9	18	27

Hazard score (H) is thought as a good indicator of slope stability itself as it does not include consequential factors, such as traffic volume, neighbouring conditions, etc., nor economic factors. In respect of hazard rating score the highest risk to slope are expected for Collapse (CL), Landslide (LS) and Embankment Failure (EB), then for Rock Mass Failure and Rock Fall (RF). As far the case study section is concerned, there was not found any slopes of likely causing Debris Flow.

(2) Categorization of Slope Management Level by Risk Rating (R)

As earlier mentioned, the priority risk ranking, and the categorization of slope management level are suggested to determine based on Risk Ranking (R), which is defined as the function of Hazard Risk (H) and Consequence (C).

Table 3.7.3 shows the summary of Risk Rating of slope in Case Study, with categorization of slope management level. The boundary risk rating value of each category is proposed as below in the Case Study.

Very High Risk:	$75 \leq R$
High Risk:	$65 \leq R < 75$
Moderate Risk:	$50 \leq R < 65$
Low Risk.:	$R < 50$

Note: The boundary risk rating value may be determined flexibly for each road, taking the importance of the road, volume and type of likely slope failure, allocation of budget for slope disaster management, and so on.

Table 3.7.2 Slope Management Level for Slope in Case Study

Level of Slope Management	Risk Rating Grade	Risk Rating (R)	Number of slopes (Case Study)	Management Program
Level I	Very High	H≥75	9 slopes	Countermeasure
Level II	High	75>H≥65	18 slopes	Regular patrol; Monitoring
Level III	Moderate	65>H≥50	80 slopes	Periodical Inspection
Level IV	Low	R<50	660 slopes	----------
Total			767 slopes	

3.7.2 Suggested Priority of Preventive Countermeasure Implementation

(1) *Priority Risk Ranking List*

Table 3.7.4 shows the suggested Priority Risk Ranking List, which contains a list of slopes categorized into Level-I (Very High Risk) and Level-II (High Risk) based on the Risk Ranking (R). As well as the value of (R), it also can be referred to the Hazard Rating (H), Consequence (C), Estimated Cost of Countermeasure. (Economic analysis is also under study to provide information for support to decision-making, which is to be referred in the output of SIMS). Thus this table would work to help the decision of implementation planning and annual/mid-term budgeting.

(2) Proposed Concept of Priority in Implementation Program

For avoid possible damage and loss by occurrence of slope failure, soonest implementation of slope countermeasure work is desired, particularly at VERY HIGH-risk slope, at least within a couple of years. However there exists a certain limitation in budget for countermeasure implementation. Then it becomes very important to make priority in implementation of those works. According to the above standard, we have now 9 slopes rated as VERY HIGH risk on the case study route.

Table 3.7.3 Priority Risk Ranking List (Case Study)

No	Slope ID	New Score ID	Type of Slope	Type of Failure	Hazard Score	Conse-quence	Risk Rating	Risk Level	Estimated Cost (RM)	Economic Indicator (V_T/C)	Final Decision
1	-	0004/071/500RC	1	4	85	8	**85**	**V.H**	2,427,500		
2	1091	0004/081/150LC	1	4	85	7	**84**	**V.H**	727,000		
3	385	0004/031/460RC	1	1	82	7	**81**	**V.H**	356,935		
4	396	0004/032/080RC	1	1	79	7	**78**	**V.H**	995,000		
5	-	0004/072/680LC	1	4	77	8	**77**	**V.H**	674,606		
6	415	0004/033/300RC	1	1	79	6	**77**	**V.H**	120,755		
7	392	0004/031/920RC	1	3	77	7	**76**	**V.H**	309,600		
8	-	0004/069/520LC	1	1	77	7	**76**	**V.H**	2,108,267		
9	647	0004/050/900RC	2	6	75	8	**76**	**V.H**	206,988		
10	432	0004/035/530LC	1	3	74	6	73	H	1,312,314		
11	441	0004/036/140LC	1	4	69	8	70	H	1,428,400		
12	332	0004/027/350RC	1	1	70	7	70	H	191,267		
13	433	0004/027/910RC	1	1	71	6	70	H	214,812		
14	474	0004/038/800RC	1	1	72	5	70	H	264,318		
15	442	0004/032/950RC	1	1	71	5	69	H	152,143		
16	468	0004/038/530LE	2	6	68	7	68	H	422,521		
17	533	0004/042/380LC	1	1	69	6	68	H	130,023		
18	1083	0004/080/700RE	2	6	70	5	68	H	115,800		
19	345	0004/028/240RC	1	1	69	5	67	H	356,250		
20	628	0004/049/680RE	2	6	65	7	66	H	95,338		
21	1019	0004/076/100LE	2	6	65	7	66	H	1,126,000		
22	435	0004/035/860LC	1	3	66	6	65	H	57,200		
23	-	0004/072/410LC	1	1	66	6	65	H	238,600		
24		0004/027/680RC	1	1	67	5	65	H	73,800		
25	452	0004/036/830LC	1	3	64	7	65	H	654,680		
26	466	0004/038/310RC	1	1	65	6	65	H	247,615		
27	537	0004/042/710LC	1	1	65	6	65	H	259,913		
									15,267,644		

Figure 3.7.1 shows a suggested concept of priority in implementation, taking into both of geotechnical factors and importance of road. The former factor can be represented by Hazard Rating (H), while the latter can be the consequence score, economic analysis result and other administrative requirement.

Importance of Road \ Hazard Rating Score (H)		Very High H≥ 75	High 65≤H<75	Moderate 50≤H<65	Low H<50
Highly important road	Likely large impacts on industrial/ social activities	A	B	D	
Moderately important road	Likely moderate impacts on industrial/ social activities	B	C		
Less important road	Likely minor impacts on industrial/ social activities	D			
Notes:	1) Priority in Implementation should be in the order of A-->--> B--> C 2) Zone 'D' will not require preventive program, except for emergency. 3) Importance of road can be determined by consequence, economic analyais, and other administrative requirement.				

Figure 3.7.1 Concept of Priority in Countermeasure Implementation

(3) Definition of Importance of Road

This subject is the one to be continuously studied by JKR to establish a practical criteria for decision-making.

Table 3.7.4 summarizes various kinds of indicator that may give impact on possible damage by slope disaster. In another words these items can be used to measure the importance of road/slope in disaster management.

As the table shows, some of them are included as the part of Consequential factor, and others are being studied in economic analysis in this study. This table also shows other items which be taken into consideration in final decision-making in disaster management plan.

Anyway it is recommended to use **the traffic volume** as a basic indicator, in evaluation of importance of the road by simple and practical decision-making.

Table 3.7.4 Major Indicators of Importance in Management of Road Slope

	Consequence (SIMS)	Economic Analysis (under study)	Additional consideration
Evaluation of relevant Road conditions	Traffic volume	Traffic volume	
	Alternative road		
	Service & Public Utilities		
		Population	
		Industrial and agro products	
			Other industrial activities (tourism etc.)
			Future Development Plan
			Local community requirements
			Administrative requirements
Evaluation of relevant Slope conditions	Nearby Residential houses		
	Geometry (slope crest/toe)		
	By-pass availability		
	Possible failure size		
		Countermeasure cost	

(4) Implementation of Slope Management Plan

Based on the concept of slope risk categorization (slope management level category) and the concept of priority in implementation, the implementation plan of countermeasure can be prepared. Table 3.7.5 shows a suggestion of implementation plan framework in respect of time schedule of implementation.

Actual plan shall be set as a combination of scheduled countermeasure program and other maintenance measures such as regular patrol, monitoring using instruments and periodical inspection.

Table 3.7.5 Framework of Implementation Plan

Time Frame	Time Period	Slope Criteria [Risk Ratez+Road Importance]	Note
a) Urgent Plan	To be implemented urgently (by this year's budget)	Rated as VERY HIGH on [Extremely] Highly important road	To be treated as similar to urgent repair work after disaster
b) Short-term Plan	Within 1 to 2 years (by the following years' budget)	Rated as VERY HIGH risk on HIGHLY important road	Zone 'A' (figure 3.7.1)
c) Medium-term Plan	Within 3 to 5 years	Rated as VERY HIGH risk on the road of Moderately important road or ---------- Rated as HIGH risk on HIGHLY important road	Zone 'B' (figure 3.7.1)
d) Long-term Plan	Within 6 to 10 years	Rated as HIGH risk on Moderately important road	Zone 'C' (figure 3.7.1)

3.7.3 Implementation of Countermeasures

(1) Priority in Implementation in Case Study

According to Priority Risk Ranking List, nine (9) slopes were identified as Very High risk. Then regarding the importance of road, it is acknowledged without doubt that the case study route, the East-West Highway (Fed.No.4) is a one of important road among federal road network. (As earlier mentioned, the criteria of importance of each road should be studied and established reflecting local conditions and administrative requirement).

Total cost is estimated as RM 7,881, 921, as shown in Table 3.7.3, if countermeasure work were implemented for all of nine slopes of very high risk (Level-I).

(Notes: Just for information, at present one contract of countermeasure work is undergoing along East-West Highway under supervision of Hulu Perak District Office. The approximate amount of the contract is around RM 11 million for 15 slopes including design and construction, with contract period of 2 years.)

(2) Selection of Countermeasure

Countermeasure of most suitable method should be selected for the implementation plan. The total list of recommended method of countermeasure, with basic idea of its selection, is described in Guide IV: Guide to Countermeasure Selection and Cost Estimation, in the separate volume of this study report.

3.7.4 Slope Maintenance Program

As described in Table 3.7.1, in general countermeasure work will be implemented first to the slopes rated as very high risk, while other slopes of lower risk rating will be managed by slope maintenance program. **(It should be note that even the slope rated as of very high risk should be monitored by the same slope maintenance program, until the countermeasure is actually implemented.)**

Some of the main points in slope maintenance program are described below, while the detail is described in Guide I, in the separate volume.

1) Regular Patrol
2) Periodical Inspection
3) Recording System of Slope Maintenance

(1) Regular Patrol

In the case study, eighteen (18) slopes were rated as of High risk, which shall be monitored by regular patrol and monitoring using instrument. The frequency of regular patrol is generally twice a week. The more detail will be explained in Guide I: Guide to Slope Maintenance and Disaster Management, in separate volume.

(2) Periodical Inspection

Besides the regular patrol, periodical inspection is suggested to carry out for check the slope stability. The target slope of periodical inspection include the slope of Level III (of moderate risk) as well as Level I and Level II. The contents of periodical inspection shall be defined as simple, just by visual inspection of roadside structures from the road. But the difference with regular patrol is that inspector should to it not form the patrol car, but getting off the car at each slope. The frequency is recommended to be twice a year.

(3) Recording System of Slope Maintenance

Recording and reporting on the slope maintenance work is essential procedure in the slope disaster management. District office in charge of each federal road should make, report and keep the information related to slope stability. Such record of slope maintenance should cover three items as below:

A) Slope Patrol Record
B) Slope Disaster record
C) Slope Countermeasure Record

More details including these formats are described in Guide I, Chapter 6, in the separate volume.

3.8 Other Field Study

3.8.1 Aerial Photograph and Mapping

(1) Objectives of work

The purpose of this work is making the base maps for the slope investigation and GIS system (SIMS) for creating a database for slope disaster management system on East–West Highway. The survey work consists of aerial photography, orthophoto Mapping, photogrammetric mapping, topographic mapping, cross-section and ground control survey.

(2) Location of Survey Area and Volume

The project area (East West Highway) was located in the state of Perak and Kelantan. The starting point of the highway located at approximately 20 km NE of Grik, State of Perak and extended along the highway across the border of the State of Kelantan. The total length of the highway to be photographed is 61.2 km (chainage 23.1 km to84.3 km) with a corridor width of 2 km (total area of 100 sq. km).

Work volume are listed below:

(a) Aerial photography (Including ground control survey)

The section between 23.1km to 84.3km with 2km width was aerial photographed. (100 sq.km)

(b) Digital Orthopho mapping

Making orthophoto map of the area(scale ; 1:20,000 with 10m contour)

(c) Photogrammetric digital Mapping

Making photogrammetric digital map (scale ; 1:5,000 with 5mcontour)

(d) Topographic Survey

(i) Chainage27.0 km circumference
The area of 600 sq. m. A map scale of 1: 500 with contour interval of 1m.

(ii) Chainage30.3 km circumference
The area of 400 sq. m. A map scale of 1: 500 with contour interval of 1m.

(iii) Chainage81.3 km circumference
The area of 900 sq. m. A map scale of 1: 500 with contour interval of 1m.

(iv) Cross-section Survey

1) The chainage27.0 km :	scale of 1:200 (200m width)
2) The chainage30.32 km and 30.38km :	scale of 1:200 (200m width)
3) The chainage81.33 km :	scale of 1:200 (300m width)

(3) Final Deliverable Results

Following results were obtained by the survey

1) Field survey data and calculation sheets:	1 set
2) Description of photo control point:	3 sets
3) Digital Orthophoto Mapping (scale of 1: 20,000)	
i) Original (hardcopy) of orthophoto map with lamination:	2 sets
ii) Image files in GEOTIFF format (in CDROM):	2 sets
iii) AutoCAD DWG files 10-metre interval (in CDROM):	2 sets
iv) ArcView Shape files(in CDROM):	2 sets
4) Photogrammetric mapping(Line map) (scale of 1: 5,000)	
i) Original hardcopy) of topographical map:	2 sets
ii) Digital copy of AutoCAD DWG files (in CDROM):	2 sets
iii) Digital copy of ArcView Shapes files (in CDROM):	2 sets
5) Topographic map (scale of 1: 500)	
i) Original (hardcopy) of topographic map:	2 sets
ii) Digital copy of AutoCAD DWG files (in CDROM):	2 sets
iii) Digital copy of ArcView Shapes files (in CDROM):	2 sets
6) Cross-section (scale of 1: 200)	
i) Original (hardcopy) of cross-section:	2 sets
ii) Digital copy of AutoCAD DWG files:	2 sets
7) Final reports:	3 sets

(4) On the Survey Result

In general, the work has been smoothly carried out. The key to success was that the aerial photography work had been planned in suitable time for taking photography, i.e., best season of the weather. And the survey firm had good experience in similar works.

The accuracy of ground control and aerial triangulation are sufficient result was acquired. Photogrammetric mapping of contour line accuracy is generally 1~2 m. But height at forested area is estimation only. And culvert and drains that were not visible on photographs were deduced from field verification information.

Detailed survey methods and results are recorded at Appendix 3.8.

3.8.2 Environmental

Regarding new construction of the roads, certain considerations against the environmental impact has been regulated by the environmental impact assessment procedure as its details had been described in Progress Report 1. However, there is no regulation related to environmental impacts for maintenance of the roads.

Photos of 2nd East-West Highway, which is under construction, are shown below. This construction has followed the regulations, which are concerned with turbid water treatment, consideration for ecological system, etc.

Figure 3.8.1 Road Under Construction

Qualitative environmental issues regarding operation and maintenance of the roads are described below because there has not been quantitative information of its environmental impact.

Main environmental problems, which could be occurred through operation and maintenance of the roads, are an inflow of the turbid water into stream by heavy rain and a destruction of the vegetation by slope failure. Particularly, an inflow of the turbid water has to be paid attention for its environmental impact, because it could have an influence on wide area of the downstream.

At East-West Highway, the most slopes have been vegetated artificially by spraying grass seeds. However, the both slopes of mountain and valley sides, which have been naked by the slope failure, have to be taken proper measures immediately according to the related regulations in case of new road construction as possible, because those could tend to produce more turbid water than usual. Furthermore, remedial works against the slope failure also might be followed the regulations of equal degree in case of new road construction.

Photos of East-West Highway are shown below.

Figure 3.8.2 Naked Slope Caused by Slope Failure

The forest cover area according to requirements of mammals and protected areas in peninsular Malaysia are shown in Figure 3.8.3 for reference.

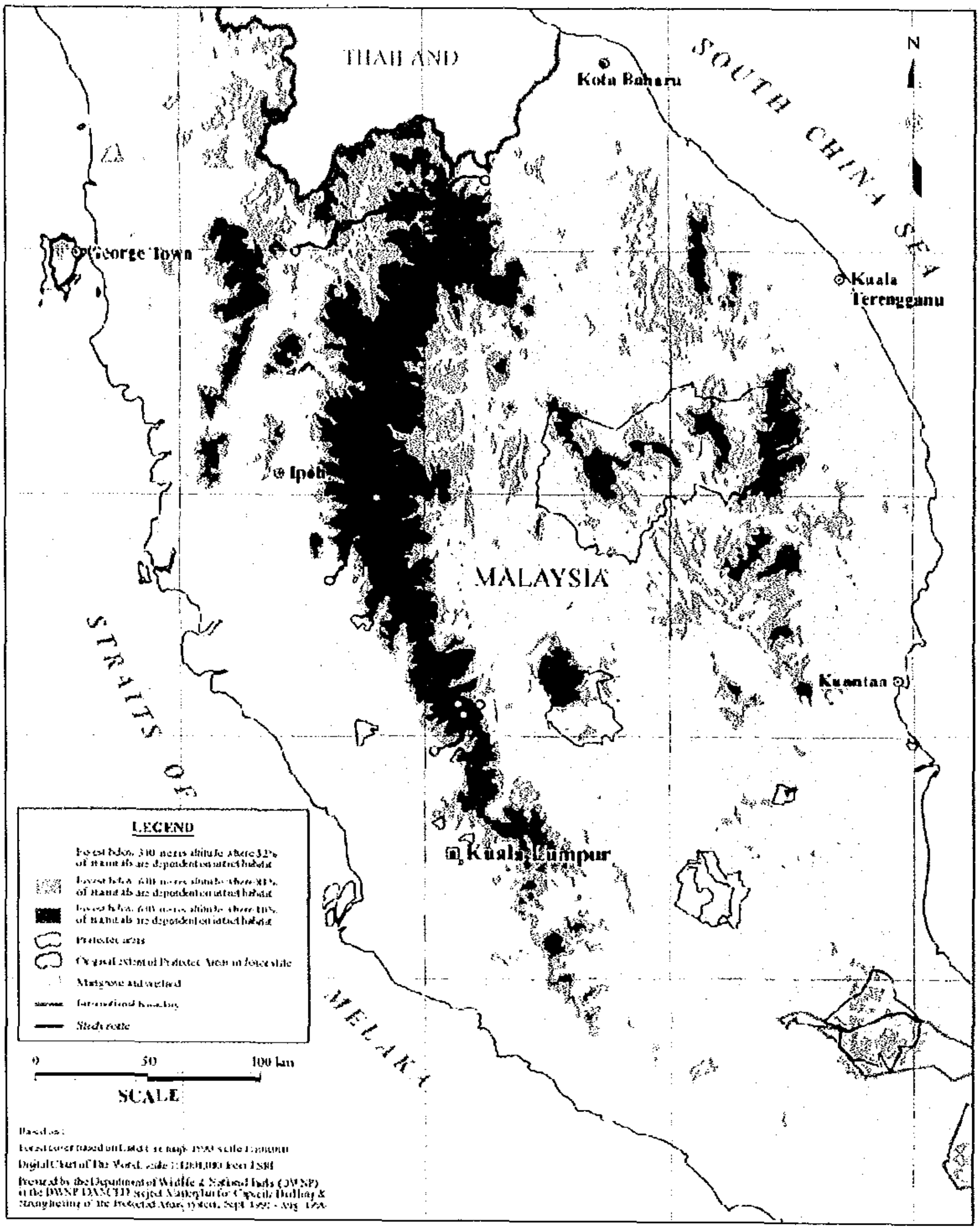

Figure 3.8.3 Forest Cover According to Requirement of Mammals and Protected Areas in Peninsular Malaysia

CHAPTER 4 DEVELOPMENT OF SLOPE INFORMATION MANAGEMENT SYSTEM (SIMS)

The development of a slope information management system (SIMS) application was conceived to assist in managing slope information and slope disasters all across Malaysia. To ensure that the development of this application addressed the needs and the working environment of JKR in Malaysia, the design concept was outlined before beginning any development efforts.

As part of the concept development efforts, the working environment was studied within which activities for Slope Disaster Management for Federal Roads in Malaysia would be conducted. This background information, along with the review of previously developed applications provided the background for the design concept.

The functionality required from the proposed system was identified with the help of the different domain experts in the JICA Study Team, through review of past applications, and through meetings with JKR resource persons.

Through iterative technical committee and steering committee meetings the scope of the SIMS application and its technological architecture were defined. Based on this background the application design and development activities were undertaken.

4.1 Design Concept of SIMS

The design of the application was developed in coordination with the field based slope inspection methodology prescribed by the JICA Study Team. Using a combination of a relational database and a Geographic Information System, SIMS brings together the required functionality for Slope Information Management into a user-friendly, windows-based application.

It is expected that SIMS will be used extensively through Malaysia and has been designed to be installed and useable at many regional (State/ District/ Local) offices within Malaysia but will essentially be managed through the headquarters office at Kuala Lumpur, where all the data will be received, integrated, synchronized from all district/ local installations.

Based on the design concept developed by the JICA Study Team, in coordination with JKR, additional design guidelines for the development of the Slope Information Management System (SIMS) were established.

At the outset of this project, the design concept of SIMS was clearly articulated as:

- Application Appearance
    - o Simple to use application functional on a PC with Microsoft Windows Operating System
    - o A menu-based simple application workflow with guidance for data entry through drop-down lists and defined choice options where possible.
    - o Provide standard/ default settings for ease of use/ uniform use

- Provide customisation possibility for experienced user

- Application Deployment
    - Applicable and useable all over Malaysia through a common set of standard information and procedures incorporated into the application
    - Main installation at JKR Headquarters in Kuala Lumpur with information for all of Malaysia.
    - Provide for a multiple-seat installation at headquarter, using a centralized database, and a stand-alone installation functionality for remote/ district offices
    - Similar installation of application for district/ local offices to collect and use regional information, in coordination with headquarters
    - An appropriate mechanism for data exchange must be developed to ensure data from district offices to be integrated together in a master-database at the Headquarters, and updated information from Headquarters to be made accessible back to the districts.
- Application Technology
    - A relational database environment be used to manage the entire slope information, recognizing that this application will have to address slope information for all of Malaysia.
    - GIS Functionality required in the overall design of the proposed system
- Application Functionality
    - Desired application functionality to be clearly defined through iterative guidance from JICA Study Team and JKR.
    - Clearly evident functionality through simply organized menu structure
    - General user of application should not require knowledge of databases technology
    - GIS Functionality should be simply presented to ensure that the general user will not be required to have detailed knowledge of GIS to use this application

Through a menu structure that clearly identifies different functional areas, and using pre-defined values/ options as far as possible, it ensures standardization of use across the many users and locations that it will finally be available at. While the predominant function of this application is to deliver a standardized risk rating approach that will help better manage slope disasters, other relevant functionalities as defined by the JICA Study Team, along with JKR, have been incorporated into SIMS.

The design guidelines were formally presented in the seminar held on 22nd May, 2001, in the interim report at the 4th Steering Committee meeting on 7th June 2001, and the development of the application based on these guidelines was demonstrated during the Workshop held on 26th September, 2001.

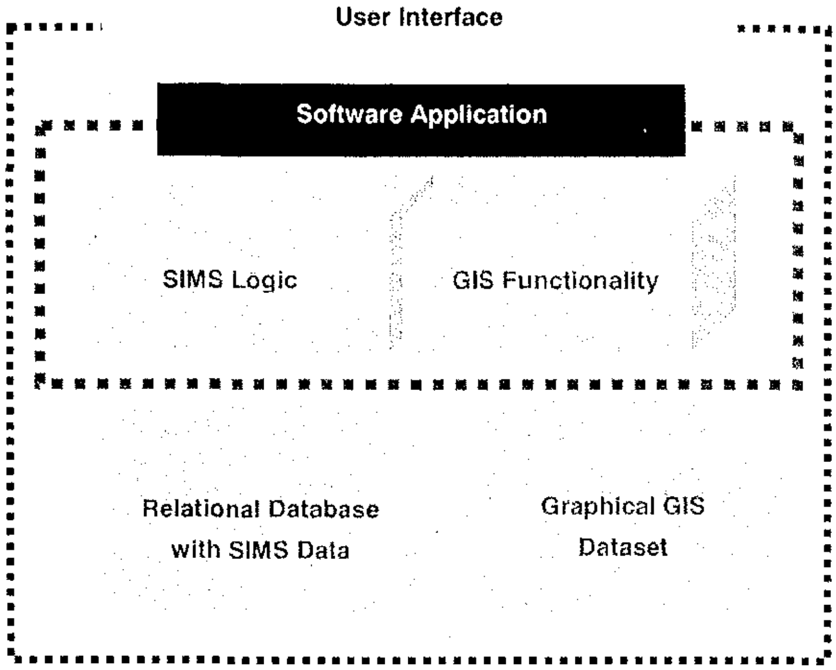

Figure 4.1.1 Basic Design of SIMS

4.1.1 User Needs Assessment

To clearly develop the design of the application, it was essential to understand who were the identified users of this application, as well as review the existing applications available to these users.

During the period of this project, the move towards privatisation and outsourcing of work have introduced a degree of uncertainty in clearly identifying the final users of the application and including them into the development process. For this reason, most of the interactions and needs assessments have been conducted through the participation of JKR resource persons from the Roads Maintenance Unit and from those attending the Steering Committee meetings, Technical Committee meetings, and the seminars conducted by the JICA Study Team.

The current users of the existing software applications for Slope Management are the staff within the road maintenance unit in JKR. The use of these applications has been distributed between the main office in Kuala Lumpur and the local offices responsible for federal highway maintenance.

The local office uses these applications for their efforts in collection of information pertaining to regular inspection and maintenance activities associated with identified slope features. Using standardized forms to manually note down the field inspection information, the information is expected to be assimilated into the software application. Consequently, their main function is Slope Inspection and collection of associated information.

The main office uses a software application to assimilate this and additional information to assess/ reassess the hazard and risk associated with each slope. While slope risk rating is becomes a major functional activity, they also develop a cost estimate of the countermeasure, prioritise the slope features to be addressed, and outline annual slope disaster prevention budgets.

Discussions were held with key persons within JKR, at the main office and at the local offices responsible for the East-West Highway, to understand the needs of the Road Maintenance Unit and define their expectations of a software application developed for their use.

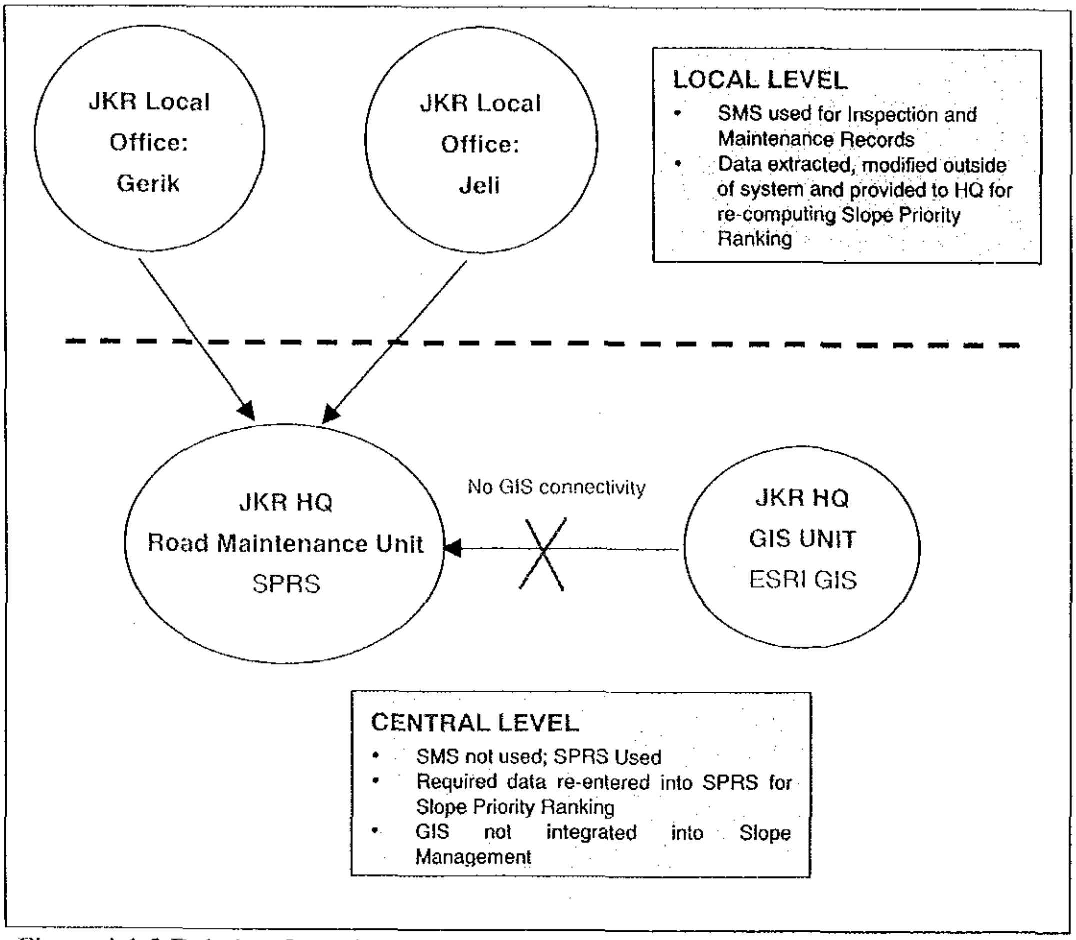

Figure 4.1.2 Existing Organizational Distribution and Software for East-West Highway

These two different "domains" of slope management activity, i.e., the headquarters and the district/ local offices, are hampered in their ability to work smoothly since the different functions required are not available in the same application and data exchange between the applications, and the between the district offices and Headquarters is a complex activity with no definitive mechanism in place to facilitate it.

4.1.2 Functional Scope of Proposed Application

Understanding the functional components from the review of existing applications such as the SMS, SPRS, and MEHMS (See Chapter 2 for details on these applications), the expectations of the users and the functionalities desirable in the proposed application were better understood. The functional scope of SIMS addresses these functionalities desired, in the present setting of the methodologies as developed by the Study Team for Slope Inspection, Hazard/ Risk Rating, Countermeasure Design and Cost Estimation, and Economic Analysis. Integrating these functionalities into a single application will also overcome current limitations of data exchange as experienced by JKR.

Recognizing the benefits of viewing and analysing information using maps, the use of GIS has been requested by JKR, encouraged by JICA, and is proposed to be an integral part of the proposed system. To coordinate the introduction of GIS into the efforts of slope management with other GIS related activities within JKR, discussions have been held with key persons within the GIS Unit with an added interest in determining the availability of digital spatial data and securing its use for this application.

Based on the discussions with JKR staff the functionality expected from the proposed application is conceived of as having the functionality to facilitate:

- Slope Inspection and Maintenance (currently available in SMS)
- Slope Hazard and Risk Ratings (currently available in SPRS)
- Countermeasures Selection
- Cost Estimation of Countermeasure
- Facilitate Economic Analysis for Prioritization of Countermeasure Implementation
- Create maps of slope features to best represent analyses

These functionalities will be provided through the SIMS application, developed using the design concepts outlined earlier in this report.

The use and distribution of this application is expected to be initially at the JKR Headquarters, followed by a distributed use at the local/ district offices (dependent on the restructuring and privatisation efforts that are underway). Although the scope of this project will be spatially limited to the defined study areas, the final application will be scaleable to handle all federal highways within Malaysia.

4.2 Program Design and Development

Prior to initiating development of the application a clear application design must be developed that addresses the functional scope of the application, adheres to the design guidelines established, and addresses the environment within which it is to be used.

For the development of SIMS, different application design structures were considered to examine the appropriate combination of technologies applicable, be cognizant of the infrastructure limitations for deployment of the application, and operate within the organizational constraints of JKR's restructuring and staff availability.

4.2.1 Conceptual Structure of Application

Two different concepts for development of SIMS were explored. The major difference in these two concepts is based on an internet-dependent or independent application design. While the functional aspects of the overall application in either case would be the same, the path followed in the conception and development of the application will be very different depending on the approach selected.

Below the two options considered are outlined as Option I and Option II.

(1) OPTION I: Networked/ Stand-alone Application Environment, Not Internet Dependent

A simple to install, maintain, and use, stand-alone application that uses locally installed software (custom developed and commercial software) and interacts with alphanumeric and spatial data warehouses that can be on local or LAN servers. Database integrity is protected and administered through controlled data upload events and appropriate account permissions.

- Software Application Platform:	Visual Basic
- Relational Database:	MS Access/ MS SQL Server
- Mapping Functionality:	ArcView 3.2/ MapObjects
- Report Output:	PDF File Format
- Operating System:	Win98/ Win2000/ Win NT

The software application is conceived of a VB based program. The underlying data is managed in a relational database environment (Microsoft Access/ MS SQL Server). Data Addition/ Updation is handled through user-friendly forms. Querying functions are command/ interaction form based. Results of queries are delivered as reports generated in from the database and output in MS Excel/ MS Word / Adobe PDF format. Mapping functionality is provided through ArcView on select system, with general systems using ArcExplorer for GIS data viewing functions.

Benefits:

- Easy and relatively quick to develop
- Easy to install and deploy at multiple locations
- Provides modular and incremental deployment functionality

- Required GIS software already purchased
- Has lower-level GIS technical support requirement

Limitations/ Drawbacks:

- Database synchronization and database integrity much more difficult to achieve
- More dependent on trained users to ensure database integrity and completeness
- Individual installation and configuration may be required
- Susceptible to failure from changes made to computer system reconfiguration/ upgradation

(2) OPTION II: Web-Integrated Environment for Application Deployment

The same underlying functionality can also be developed in a web-centric environment. Such an application would differ significantly from the more conventional Client-Server application. These differences will essentially be in the:

- selection of commercially available GIS and Database software
- custom software development environment
- the installation and maintenance of the application
- procedures and protocols for data exchange
- level of development effort
- level of user ability and interactivity

Benefits:

- Database synchronization and database integrity assured
- Multi-level user access provided for different modules/ functions if desired
- Easier to use, consequently requiring less training and support.
- Easier to install and maintain. Limited local level installation which application upgrades achieved through web-downloads.
- Less susceptible to failure from changes in operating systems and computer system reconfiguration/ upgrades

Limitations/ Drawbacks:

- Fundamentally dependent on good internet access which may not be currently available at locations of installation/use of application software.
- Longer development and testing time required
- Higher skill level required for development
- Higher skill level required for maintenance at central location
- Requires less frequent, but more intense technical support for Web-Application Configuration, with high dependency on networking issues
- May require purchase of additional software that may not be within allocated budgets.

4.2.2 Preferred Approach

Based on our assessment of the limitations of infrastructure, resources available within JKR, limited connectivity to JKR offices outside Kuala Lumpur, and the limited time period for actual development and testing of the application, it was agreed by the JICA Study Team and by JKR that the application be developed along the lines as outlined in Option I. This approach would also allow the team to focus on the development of sound functionality and underlying methodologies that would make the application more useful to JKR, expending less effort on addressing problems arising from evolving technology and infrastructure constraints.

The application structure was conceived of as having a custom developed software program that would encompass the intellectual framework for each of the modules as established by the JICA Study Team. Through this custom developed software, functionalities of the database software and the GIS software would be leveraged for the user, eliminating the need for them to have technical knowledge of either technology. The application will have overall dependencies on a relational database which would house the slope information and related data, and a physical space on a system that would act as a repository for the GIS related information. Keeping this information outside of this relational database, as also any other graphics and images required by the final system, will keep the database flexible and efficient in managing slope information for all federal highways in Malaysia.

The proposed application is summarily represented as:

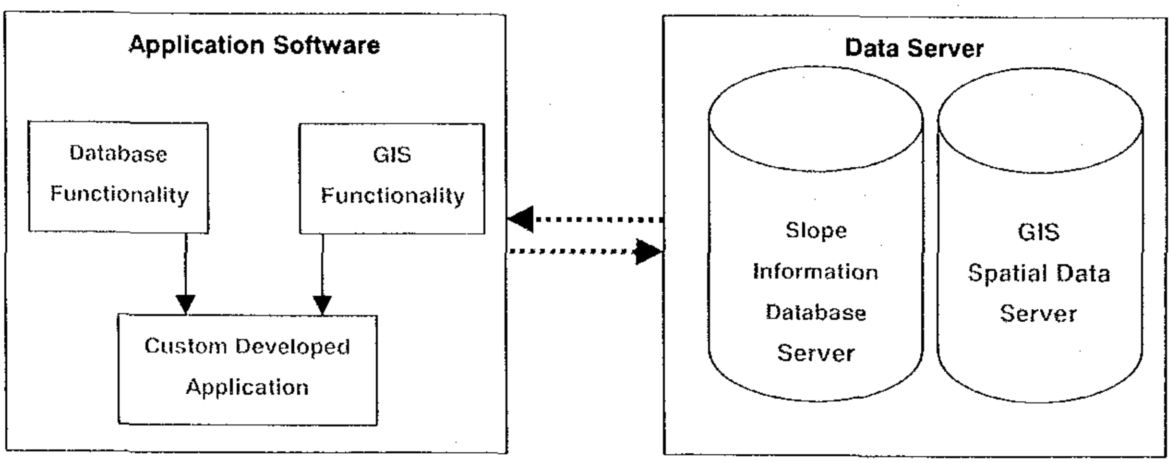

Figure 4.2.1 Proposed Application

The design approach finally selected was also influenced by the need for its extensive deployment as part of the mandate to be used for all of Malaysia. Based on the evolving organizational structure and extensive privatisation it was determined that the expected number of installations at the Headquarters would be approximately five users, while the deployments outside of Kuala Lumpur would be determined on a Zonal basis (as per the privatisation plan), or by district, in which case the installations could vary in number.

The distribution of the application is envisioned to be initially functional at the Head Office of JKR, followed by the Zonal/ other Offices. The Headquarters will function as the central node for all installations, managing the application and the data for all Federal Highways in Malaysia. The database for the entire application will also be centralized at the headquarters, providing a common resource to all users at HQ. This database would be periodically updated with information provided by the Zonal office.

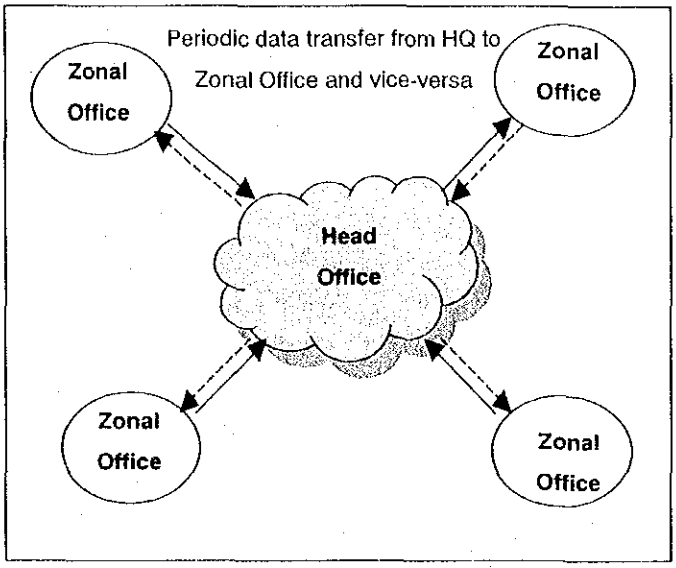

Figure 4.2.2 Deployment Structure of Proposed Application

At the main office, the data from distributed locations will be checked for quality, completeness and errors, after which it will be assimilated into a master database. This "Checked" version of the database will be redelivered as a consolidated data delivery to the local/ zonal offices, with only the data pertinent to their spatial extent included.

This data exchange will be handled through exchange of digital media such as floppy disks or CD's, and occasionally by e-mail transfers when the data size is within reasonable limits for electronic transfer. With such an approach, the application can be developed using simpler technologies, skill sets for which are more easily available, and there is no dependency on the internet or on internet-based technologies which are currently in various stages of accessibility and evolution across Malaysia.

The GIS functionality remains very simple at this stage, placing limited burden on the available staff. All the necessary information visualization and analysis, as well as standard map creation functionalities are delivered through simple user-interfaces. The relatively complex functions of GIS data creation, editing and updation will be handled through a centralized mechanism at the Head Office. Updated data layers will also be provided to the district offices in much the same manner as the slope feature data through periodic updates as and when essential.

4.2.3 Software Required

After after reviewing the functionality required, the deployment of the application at multiple locations, and the possible extent of data to be managed for Slope Disaster Management for Federal Roads, the selection of the software was reassessed and re-determined. This software configuration was discussed with JKR and after approval was confirmed as the technology for the development of SIMS.

- Development Environment:	Visual Basic
- Operating System:	Windows 2000
- Database:	Microsoft SQL Server
- GIS:	ESRI's MapObjects
- Internet Connectivity:	None essential

Development Environment: Electing to use more commonly available technologies, for which skill sets could be easily accessible in Malaysia, Visual Basic was selected as the development environment for the application.

Operating System: Working across multiple operating systems would make it difficult to ensure the smooth operation and functioning of the application. By standardizing the *operating system requirement for the application to MS Windows 2000*, a uniform development and deployment platform was established on which the application could be delivered.

Database: While the original database intended for the application development was Microsoft Access, considering the need to have a robust relational database that could easily manage the slope information from all federal roads in Malaysia, it was determined that an alternative database had to be considered. Microsoft SQL Server was selected due to a greater accessibility to resource persons in JR's IT Unit with SQL Server expertise. Also, the more accessible and more affordable technological support for this software and lower license fees made this a preferable database platform.

GIS: Reviewing the relatively simple GIS functionality required in SIMS, and recognizing the need to keep the application as simple as possible, options for customisation and integration of GIS as a sub-component of the overall application were explored. Also, reviewing the multiple installations required at the Headquarters and at Zonal offices, GIS software availability and licensing was reviewed. It was determined that the general GIS functionality to be made available in SIMS could be better addressed through the use of MapObjects, a GIS application development environment available from ESRI. ArcView would then facilitate the more advanced functions of data creation, editing, revision, that were to be managed by a limited group with higher GIS expertise, and best handled outside the operating restrictions of SIMS.

4.2.4 Application Modules

Organizing the application functionality into distinct and easily recognizable modules, the user will find the application simpler to comprehend and integrate into their workflow. The development, testing, and deployment of the application is also better managed through a module based approach.

At the same time, since the modules are inter-dependent, with information or results from one being used into the other modules, changes in one module are likely to affect the other, however these changes and revisions to the application are easier to manage.

Drawing upon the functionality defined by the JICA Study Team in coordination with JKR, the table below identifies the different modules and potential sources of guidance in their development.

Table 4.2.1 Different Modules and Potential Sources of Guidance

No.	*Modular Functionality of Proposed Software*	*Guidance Sources*	*Notes/ Comments*
1.	Slope Inspection	SMS	Use forms similar to those from Field Inspection Methodology
2.	Hazard/Risk Rating	SPRS/ JICA Team	While the currently in-use SPRS logic will be reviewed carefully, this rating system will be based on the Field Inspection Methodology developed by the JICA team
3.	Countermeasure Design and Cost Estimation	JICA Team/ SPRS	The functional logic of this to be designed with assistance of Geotechnical experts in JICA Team. The costing function addresses a similar functionality provided in SPRS
4.	Economic Analysis	JICA Team	Based on easily accessible information, an Economic Analysis ratio is used to comparatively evaluate the Slope Features.
5.	GIS Functionality	JICA Team	Review of Slope Features based key attributes such as slope type, risk rating, countermeasure cost, etc.
6.	Administrative Functions		Database Maintenance/ User Permissions/ Version Control.

4.2.5 Data and Data Types for Application

The data to be used in SIMS can be readily categorized into Slope Feature Information that is textual (alpha-numeric) in nature (slope inspection information), Slope Feature Graphics (slope inspection sketches and photographs), and GIS related data (slope polygons defining the spatial extent of the slope feature, other geographical information).

(1) Slope Feature Information

The SIMS application uses a relational database design to manage the different textual (alpha-numeric) information required for the effective use of the application. This information can be organized as:

- Slope Feature Information: information specific to an individual slope feature, either directly input, or computed from a formula integrated in the application
- Standard Tables: These tables provide the standardized values used in the SIMS user interfaces to guide the data entry process.

- Scoring Tables: Tables which assign scores or values based on pre-defined rules or ranges, against which the input data for a specific attribute of a slope feature is evaluated. For example, this helps assign hazard scores based on field inspection information, assigns a qualitative risk rating based on a numeric risk rating range interval.

The design of the database will reflect a normalized data structure, archiving information relating to individual domains in tables appropriate for them, and distinctly separating them from other domain areas. The efficiency and functionality of the proposed application is dependent to a large extent on the design of this relational database structure.

The data entry into the database must be supported by the use of standardized look-up tables that can ensure consistency of data entry as the database grows for use at multiple locations and takes on a the role of addressing slope management at a nation-wide level.

The relational database structure will also facilitate the link to the GIS by using an identified key field that is uniquely common for all mapped slope features and their correlating database records. This linkage and database integrity are critical elements in ensuring that the application will deliver the necessary functionality.

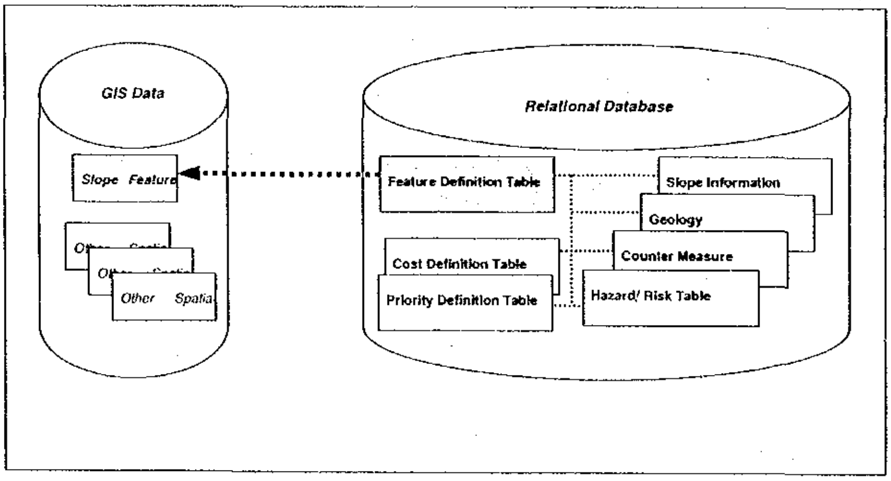

Figure 4.2.3 Graphic Showing Conceptual Database Structure and Relation to GIS

This data will be accessed through custom designed forms that will use check buttons/ drop-down lists, and any other methods to make data entry/ data review easier for the user, as well as ensure that data integrity is maintained.

A detailed understanding of the database, its design structure, and the tables, and the fields, will be provided as part of the technical documentation delivered along with the application.

(2) Slope Feature Graphics

Photographs taken in the field and sketches made by the field investigation teams will be converted into standard sized digital format and associated with the appropriate slope feature. These graphic files will be named in a manner that makes it easy to identify which slope they are associated with. Since this graphic data will be voluminous, these graphic files will be archived in a folder but not embedded into the database. The graphic file name and path will be associated and defined in the application to make them accessible to SIMS during slope information review and report generation. This path can be pre-set or revised as part of the SIMS system environment, making sure the graphics can be easily accessed by the application.

(3) GIS Data

Each individual slope feature will be represented as a polygon within an ArcView data format Shape File. This slope feature shape file will assimilate slope features for all slopes associated with federal highways in Malaysia. These individual polygons will be associated with the database information through a key field, uniquely identifying them to the GIS functionality as well as to the database. Other spatial information included in SIMS will be data specifically associated with each highway, and general background information to provide a contextual setting for review of slope information. The data expected to be available for use with SIMS is described in the table below. Additional spatial data may be considered for inclusion if already available in GIS compatible, digital format from JKR or other sources in Malaysia. All GIS data will be formatted into a common file format, coordinate system, and projection. As advised by the GIS Unit at JKR, the commonly used projection in Malaysia is Rectilinear Skew Orthomorphic. The data will be delivered in this pre-defined projection, and in ArcView compatible format, unless otherwise specified.

Table 4.2.2 Spatial Data Features for Application

GIS Data For Study Area					
No.	**Category**	**Description**	**Scale**	**Format**	**Source**
1	Slope Features	Slope Polygons from Field Investigations	1:5,000	Vector	Mapped by JICA Study Team
2	Land Cover	Generalized maps for project area, drawn up by photo-interpretation and field work	1:5,000	Vector	Mapped by JICA Study Team
3	Geology	Generalized maps for project area, drawn up by photo-interpretation and field work	1:5,000	Vector	Mapped by JICA Study Team
4	Topographic Survey Maps	<Background Reference Map>	1:50,000	Raster	Survey Department
5	JKR Highway Maps	<Background Reference Map>	Variable	Raster	JKR
6	Orthophoto Base	Digital photomosaic being prepared under JICA contract	1:10,000	Raster	Jurkur Perunding under JICA subcontract
7	Topography	5m Contours of study area derived from orthophotos	1:10,000	Vector	Jurkur Perunding under JICA subcontract
GIS Data For Entire Malaysia					
No.	**Category**	**Description**	**Scale**	**Format**	**Source**
1	Administrative Boundaries	National, State, and District Boundaries	1:50,000	Vector	Generated by JICA Study Team
2	Geology	Generalized maps available from govt. depts.	1:500,000	Raster	Malaysia Survey Dept.
3	Soils	Generalized maps available from govt. depts.	1:500,000	Raster	Malaysia Survey Dept.
4	Physiography	Generalized maps available from govt. depts.	1:500,000	Raster	Malaysia Survey Dept.
5	Rainfall	Generalized maps available from govt. depts.	1:1000,000	Raster	Malaysia Survey Dept.

4.2.6 Application Development

Having defined the software technology and the functional scope of the SIMS application, the functionality proposed was more explicitly defined and conceptual user interfaces were prepared to give the JICA Study Team and JKR a better understanding on the appearance of the application. These user interfaces and the modular functionality were presented to JKR in the seminar and workshop held on May 22, 2001.

As part of this presentation, detailed workflow, required standard information, and decision logic rules for each module were collected from members of the JICA Study Team. This information provided the Slope Inspection form, to be used as the basis for the design of the Slope Information Module. The hazard and consequence scoring information, the risk score calculation formula, and the risk rating developed by the JICA Study Team provided the essential foundations for the development of the Hazard/ Risk module.

The workflow also established a range of countermeasures, and their likely associations with slopes based on their most likely failure types. This information provided the basis for the countermeasure module, which when combined with standardized rates, would help develop design and estimate cost for countermeasures. Criteria for assessing different indicators under the Economic Analysis module were also established.

With these main analytical modules defined, a standardized system of reporting and mapping was established. Recognizing the different data types associated with a slope feature (Slope Information, Pictures, Sketches, and Maps), an electronic output report in the Adobe PDF file format was defined. Standard report types for each module, and pertinent standardized maps were also defined.

The functionality for application administration (such as revising standard information tables), or technical administration (managing the database, managing the users and possible permissions/ restrictions, database backup), would also be provided in this application.

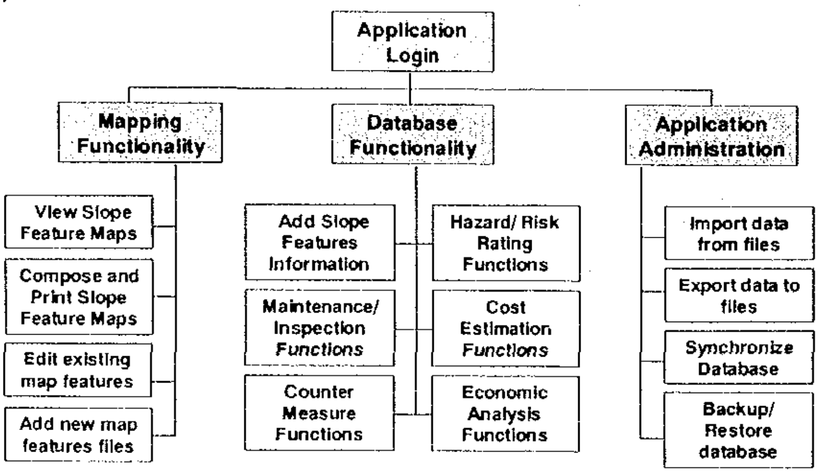

Figure 4.2.4 Application Functions Summarized

Assimilating all this information provided the necessary guidance information for Application Development, and following established JICA requirements, a local contractor was selected and provided this information for development of the application.

Based on review of the application development, and comments from the JICA study Team, the application menu structure was revised to reflect each of the four earlier identified **main modules**, (Slope Information, Hazard/Risk, Countermeasure, Economic Analysis), the **GIS module** incorporating the mapping and analysis functionality as a distinctively separate module, and a **new module**, *Integrated Reporting*, to provide an easily identifiable functionality in the application to help the user generate reports based on any of the main modules.

Through successive presentation of the development of the application in the seminar on 26th September, 2001, and through formal and informal discussions, training sessions, and reviews with the JKR and the JICA Study Team, the application design was refined with the following changes:

- The Slope Inspection Form was revised after careful consideration by JKR and the JICA Study team in October 2001. These changes revised some of the slope information, the associated hazard scores and the consequence scores.
- The Slope Feature Identification was redefined to establish a unique ID for any slope feature on any federal highway in Malaysia. This unique ID, also labelled as the JKR ID was to be generated from a composite set of information including the Federal Highway Code, the Start Chainage, the sectional measure, side of road, type of slope, and the original or revised alignment of the highway
- The Economic Analysis functionality was modified based on the availability of information
- The functionality encompassed in the application under the menu section "Administer Database" and "Tools" was to be reorganized more effectively so as to be more meaningful to the users.

Following the guidance given, and the revisions indicated, the application was tested with data entry from the project study area. Further enhancements to the user interfaces, workflow, standardized reports and standardized maps have been undertaken as a result of this testing.

Additional testing and review of SIMS was done by JKR on two mini-training sessions held on December 27, 2001 and on January 03, 2002. Based on these sessions, enhancements to the Countermeasure Module have been done to include information on the status of the countermeasure (executed/ not executed), design cost, executed cost, and information on the contractor/ tender associated with the countermeasure execution.

Table 4.2.3 Comparison of SIMS with Earlier Systems

Proposed Module	Function	SMS		MEHMS		SPRS		JICA (SIMS)
Slope Information	Slope Inventory	Yes	Data Entry Available through Inspection/ *Functions*	Yes	No data entry forms available	Yes	Data entry forms provided	**Create in consideration of SMS & SPRS**
	Slope Inspection	Yes	Available through Inspection sub-menu functions	Not designed		Not designed		**Create in consideration of SMS**
	Slope Maintenance	Yes	Available through Maintenance sub-menu funct	Not designed		Not designed		**Create in consideration of SMS**
	Countermeasure	Not designed		Yes	*Using CHASM* Module	Yes	Functionality for *rough estimation of* countermeasure cost available	**Create in consideration of SPRS**
Railing Analysis	Hazard Rating	Yes	Designed but not functional	Yes	CHASM Factor of Safety can be considered as Hazard Rating	Yes		**Create with reference to SPRS**
	Consequence of Slope Failure	Yes	Designed but not functional	Not designed		Yes		**Create with reference to SPRS**
	Risk Railing	Yes	Designed but not functional	Not designed	* Factor of Safety has been equated to Risk Rating in JKR article comparing Slope Management Systems	Yes		**Create with reference of SPRS**
	Economic Analysis	Not designed		Not designed		Yes	Functionality for rough estimation of countermeasure cost available	**Create**
GIS Application	Location Map	Yes	Designed external to SMS but n functional	Not designed		Not designed		**Create**
	Thematic Mapping	Yes	Designed external to SMS but n *functional*	Not designed		Not designed		**Create**
	Spatial Analysis	Not designed		Not designed		Not designed		**Create if available**
Disaster Support	Emergency Response	Not designed		Not designed		Not designed		**Create if available**
	Route Analysis	Not designed		Not designed		Not designed		**Create if available**
Administrative Functions	Data management	Yes	Limited functionality available	Yes	Ability to import new data and replace existing	Not designed		**Create**
	User management	Not designed		None Available		Not designed		*Create*

4.3 Managing Slope Disaster Using SIMS

Designed to coincide with the Slope Inspection Forms developed by the Geotechnical Experts in the JICA Study Team, this application provides a unified system for use all across Malaysia. With information collected on the field inspection forms providing the basis for Slope Disaster Management using SIMS, the input data is organized, managed, and assigned values for hazard and consequence of slope failure. These values are uniformly applied to all the slopes. This standardization of assigning values forms the basis of a Risk Rating System that provides an identical scale for comparative evaluation of all slopes for which information is provided in the system.

The application also provides for guidance in design and costing for developing countermeasures for identified slopes. Using this system, a rough design cost estimate can be prepared based on the countermeasures selected, quantities input, and standard rates pre-defined. Capturing information on consequences of slope failure and comparing them against the cost of executing countermeasures, the application also guides the user performing an economic analysis to compare the cost to benefit of the slopes.

The application also facilitates the review of slope information by major evaluative criteria such as slope type, most likely failure type, hazard score, risk rating, countermeasure design cost, and economic analysis. The mapping functions will also generate standard map compositions making it easier to generate map-based reports and review the required information in a more graphic and spatial manner. Within each module, a reporting function provides for the creation of standard reports, as appropriate to the module. Embedded mapping functionality in each module also allows the display of maps based on the context of the module. Details of the reporting and mapping functionality are described further in this report.

To access the application, and use its different functional modules, a detailed user manual is provided seperately. In summary however, assuming that the application has been properly installed and is functional on the system, the workflow involves:

- Identify and click on SIMS icon
- Enter user name and password (as provided by Application Administrator)
- Use the "Slope Inspection" Module to input and review information on Slope Inspection
- Use the " Hazard/ Risk" Module to review hazard scores and risk ratings, and if necessary, test customized formulae to reassess hazard/ risk scores
- Use the "Countermeasure" Module to develop a conceptual design of the countermeasures required to prevent slope disaster, and estimate the cost of this countermeasure design.
- Use the "Economic Analysis" Module to compare the Costs and Benefits of specific Slope Features

- Use the "Integrated Reporting" Module to generate reports for any of the earlier described modules
- Use the "GIS" Module to generate and review maps of individual slopes or collections of slopes
- Use the "Administration" Module to address Application and Database administration functions
- Use the "File" module to login/ logout and to export information from the application.

The functional activities for Slope Disaster Management using SIMS are described in further detail below.

4.3.1 Slope Inspection using SIMS

The Slope Information Module of the SIMS application has been designed to closely mimic the Field Inspection Forms. The user-interface design for this module helps the user enter and review information in a sequence similar to that as is entered on the Inspection Forms, making it easier to incorporate slope inspection information into the application database.

Using the SIMS application, slope inspection data from the project study area has been entered into the database. This activity helped refine the application and synchronize it with the inspection forms, as well as make revisions to the inspection forms where necessary.

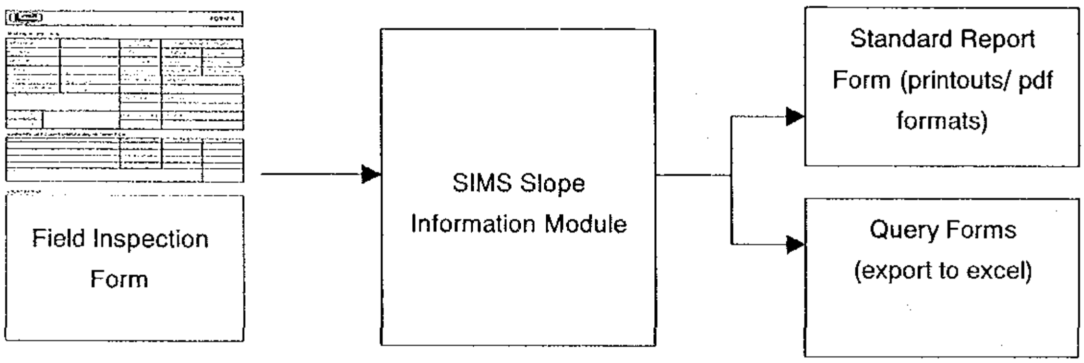

Figure 4.3.1 Relationship between Field Inspection and SIMS

To facilitate the creation of the Slope Feature ID as per the procedures outlined by JKR, the application has been designed to automatically generate the "JKR Slope ID" using a combination of the following elements of information:

1. Route Number ID
2. Start Chainage consisting of Section Number and Sub-Section with 3 decimal places
3. Side of Road on which slope is located
4. Type of Slope

5. Alignment revision number of road (default alignment is set at 00)

By generating this JKR Slope ID through SIMS in this manner we are better assured of having the correct slope feature identification, as well as avoiding any duplication within the system for entire Malaysia.

The application also provides for the following alternate identification systems for the slope features:

Alias ID:

to be used by contractor/ field inspection people and to be entered onto the Slope Inspection Form

GIS Link ID:

An internal ID used by SIMS to link the database records to the GIS Slope Feature Polygons.

To provide easier use of the application, the Slope Information Module has been designed keeping in view the forms developed for the Slope Inspection by the JICA Study Team. Replicated as on-screen forms, using an on-screen arrangement similar to the inspection forms, it is easier for the user to relate between the field inspection activities and the use of the system.

The forms developed under this module are:

- Form A: Slope Type and Location Information
- Form B: Slope Sketch
- Form C: Slope Photographs
- Form D: Slope Inspection Information
- Form E: Slope Hazard Score Assessment
- Form F: Slope Consequence Score Assessment

For Form E, 5 versions of the form have been prepared, one form each slope failure type

- Form E1: Collapse/ Rock Fall
- Form E2: Rock Mass Failure
- Form E3: Landslide
- Form E4: Debris Flow
- Form E5: Embankment Failure

These forms capture the detailed information for each slope feature inspected and provide the essential information for all the other modules.

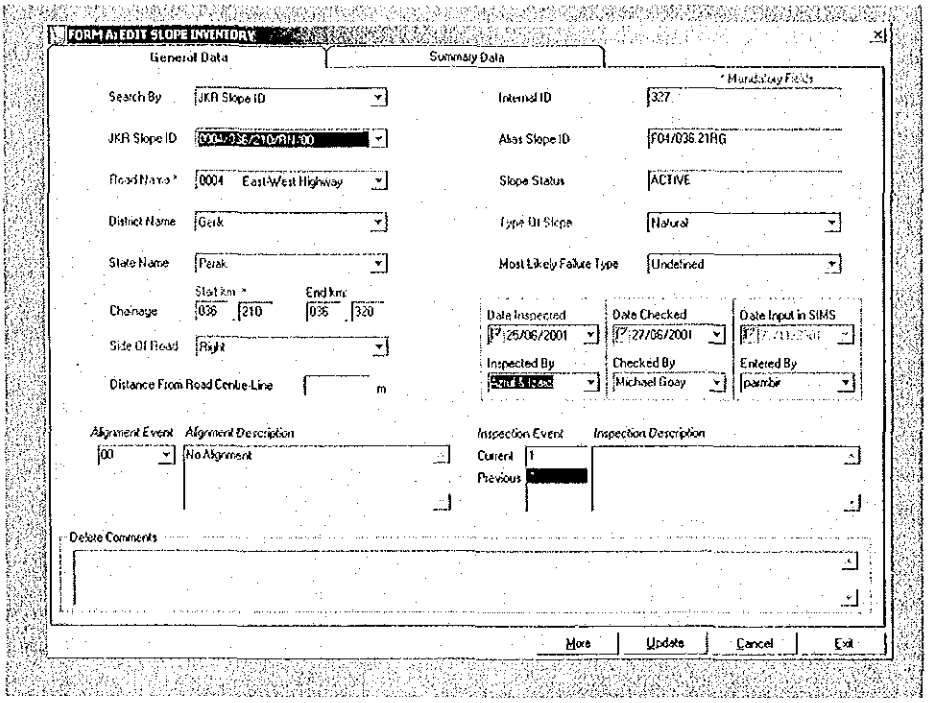

Figure 4.3.2 SIMS Application Showing Slope Information for Form A

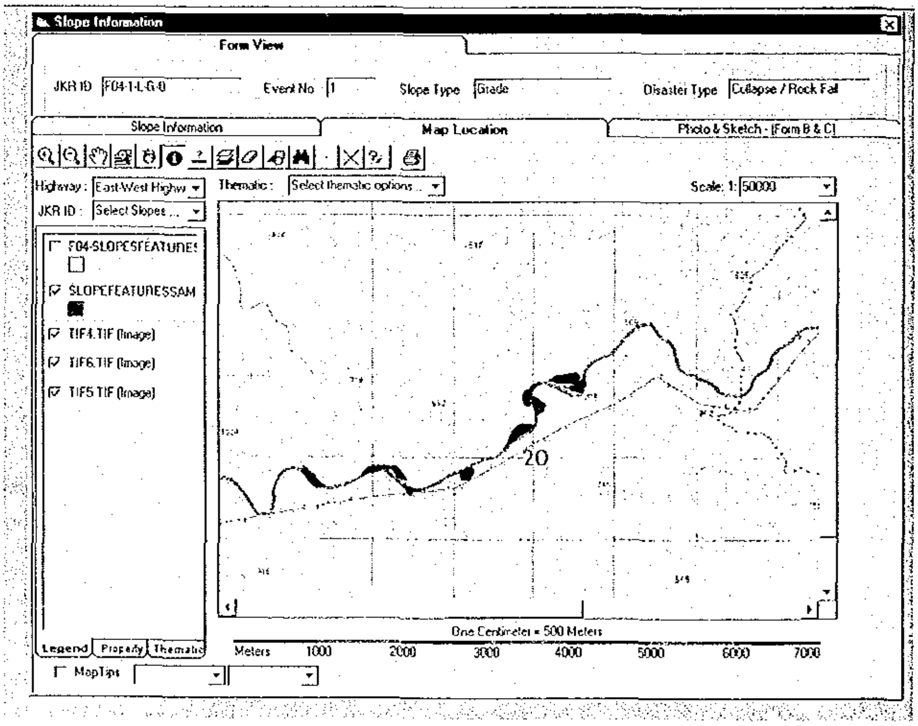

Figure 4.3.3 SIMS GIS Functionality Showing Map Location for Form A

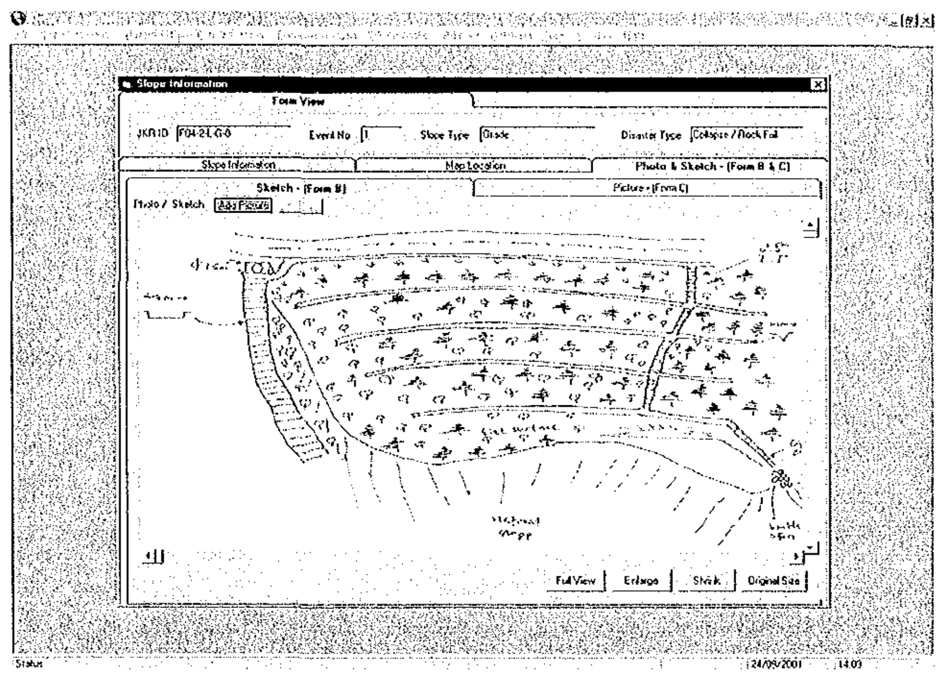

Figure 4.3.4 SIMS Form B Showing Sketch Made in Field for Specific Slope Feature

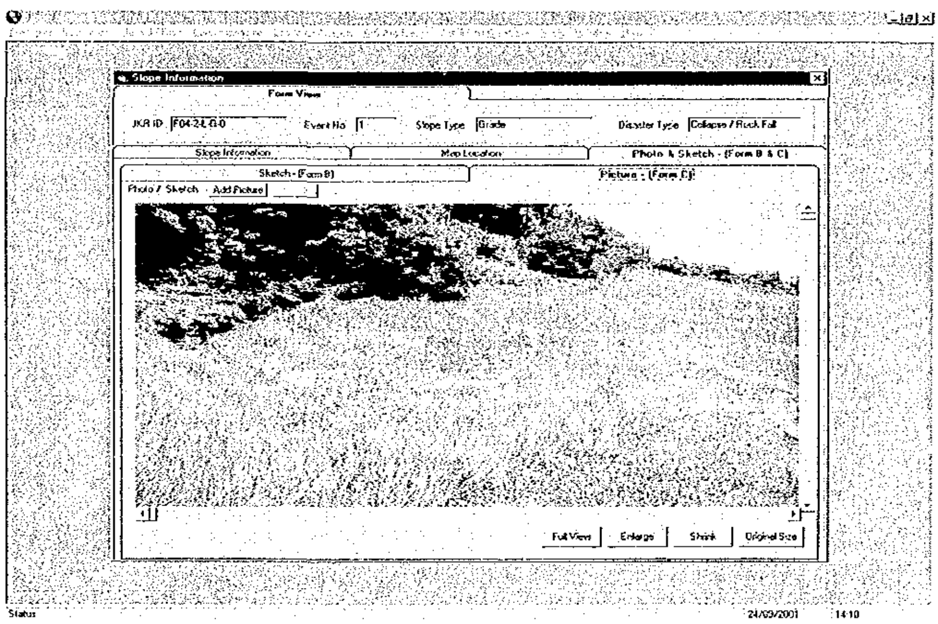

Figure 4.3.5 SIMS Form C Showing Photograph Taken in Field for Specific Slope Feature

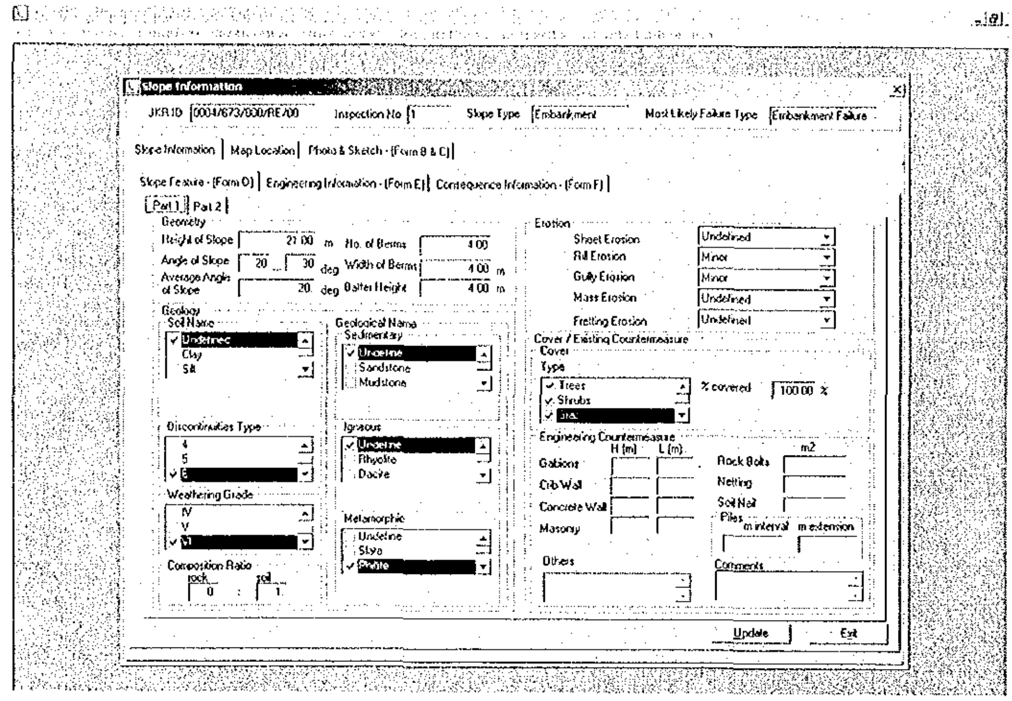

Figure 4.3.6 SIMS Form D Showing Field Inspection Information for Specific Slope Feature

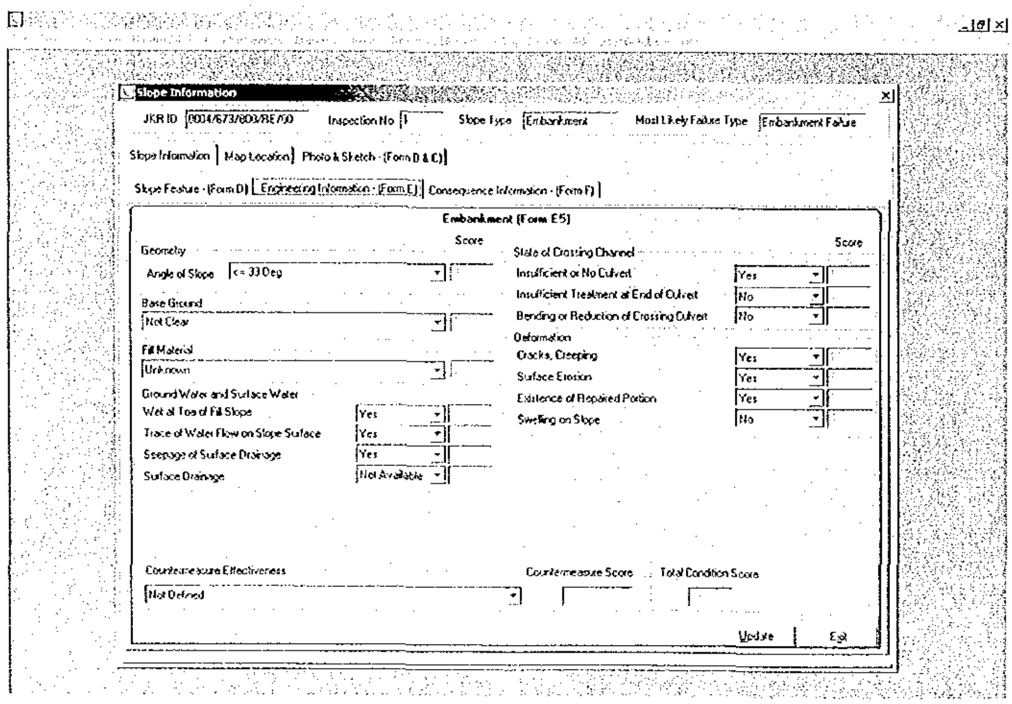

Figure 4.3.7 SIMS Form E Showing Hazard Score Information for Specific Slope Feature

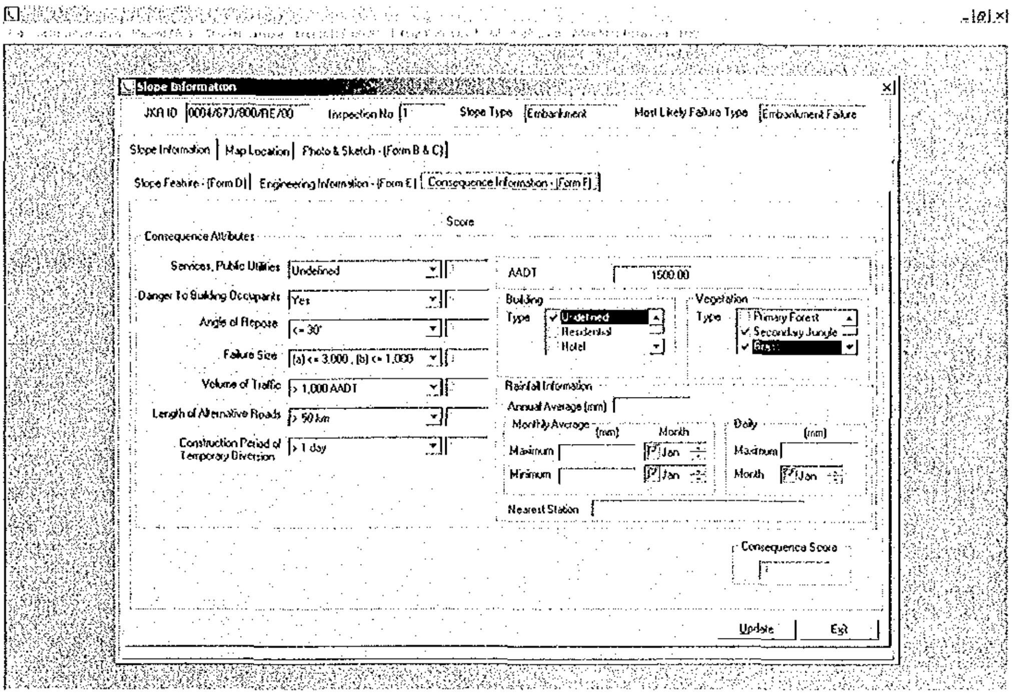

Figure 4.3.8 SIMS Form F Showing Consequence Information for Specific Slope Feature

4.3.2 Hazard and Risk Rating using SIMS

Once the slope inspection information is completed for Form E (based on the nature of the most likely slope failure type) and Form F, the application assigns pre-designated scores for each field in the forms. These scores provide the required information to compute the Hazard Score and Consequence Score, which is computed once the Hazard/ Risk Module is accessed. These hazard scores and consequence scores are summed up separately for use in the risk rating formula.

During inspection, if no likely failure type was determined for a slope feature, then information for Forms E and F are not collected, hence are not input into the system. Consequently, these slopes have no hazard or consequence scores and the application will display an appropriate message should such slopes be reviewed in this module.

The application is being designed to provide risk ratings based on the formula determined by the JICA Study Team. The risk rating numeric values calculated for each slope feature are archived in the database for each slope feature. Using a range threshold, these numeric values are translated into a qualitative ranking of Very High, High, Moderate and Low Risk Rating.

Provisions have been made in the application design to review the risk ratings based on an alternative Risk Rating formula that is similar to that used in the earlier application, SPRS. The hazard and consequence scores, as well as the risk scores and risk ratings, using the information categories and scoring rules of SIMS cannot be considered to be the same as those generated under the SPRS application and should not be compared directly. This functionality is only to help the user examine the risk rating possible with an alternative formula that has been commonly used by JKR in the past.

This application module also provides for a third, undefined formula, designated as a "custom" formula, through which the user can mathematically combine the hazard and consequence scores using any single digit coefficient and any given mathematical operator to assess the possible risk scores from such a formula.

The standard reports generated under this module provide for an tabular listing of the selected slopes (one or more based on the query criteria used) providing the JKR ID's, Slope Type, Most Likely Failure Type, Hazard Score, Consequence Score, Risk Score and Risk Rating based on the JICA Study Team Formula. Additional fields can be added to the report. The report will be generated in a Adobe PDF format and displayed on screen, printer to the printer, or archived as a digital file, based on the option selected.

The standard map generated under this module will display the slopes for an identified highway, or section of highway within a district (based on selection) thematically representing them in different colours to distinguish them by Risk Rating. These maps will also be output as PDF file formats making them easy to view, print, or exchange electronically.

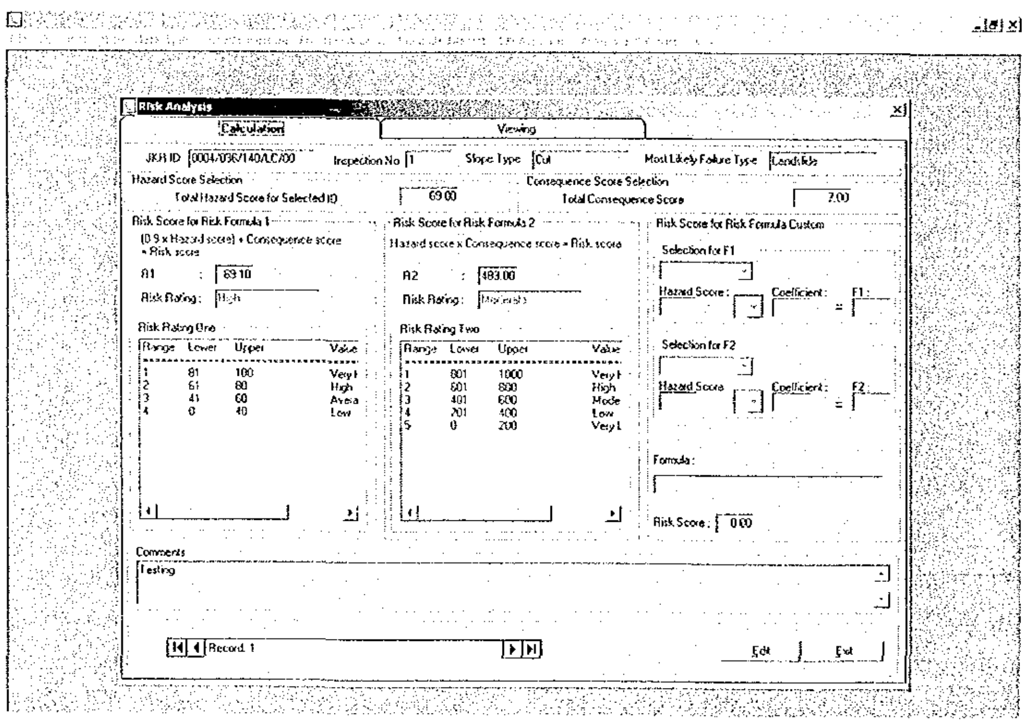

Figure 4.3.9 SIMS Hazard/ Risk Module Showing Risk Rating for Specific Slope Feature