2.8 Existing Slope Information Systems

This section will summarily review the existing systems, outlining our understanding of the systems, their intended purpose, inherent strong and weak points, nature of deployment, and use history. The intent is to leverage past experience to benefit the design and deployment of a new system.

The systems available for review are:

(1) Slope Management System (SMS)
(2) Malaysian Engineered Highway Management System (MEHMS)
(3) Slope Priority Ranking System (SPRS)

2.8.1 Slope Management System (SMS): 1996

(1) Background and Purpose

Developed as a result of the East-West Highway Long Term Preventive Measures and Stability Study, the purpose of the system was to identify and prioritize short and long term remedial works to be carried out on the slopes along the highway. Supported by extensive data from the study, SMS was implemented in 1996 for the East-West Highway. Designed to address just the East-West highway, its anticipated use was essentially at the local offices at Gerik and Jeli, JKR offices managing that highway before privatisation of maintenance operations.

From a review of the available versions of SMS, review articles, and documentation about the system, it was understood that the application was designed to:

- assimilate extensive information on the identified slope features
- calculate their hazard and risk ratings
- map their location using a GIS

The SMS application available for review lacked the key functional components of the Hazard and Risk Rating System as well as the GIS. It was limited to the database dependent SMS application providing access to maintenance and inspection information collection and reporting.

(2) Software Dependency and Operating Platform

The available SMS application has been run successfully on a computer with Windows 95 operating system, using Microsoft Access 97, and with 64 MB of RAM. It does not however operate using Microsoft Access 2000, the more commonly used database version now on most systems.

Developed as a stand-alone application, it has no dependencies on external systems other than the machine it is installed on. It's communication with other stand-alone installations is addressed by the exchange of externalised database files that can be uploaded into the system desired. The menu structure of the application does however indicate that its primary location was intended to be Gerik, with data from Jeli occasionally delivered to Gerik and integrated into it.

The system design and deployment had no integration with or dependency on the internet.

The technology underlying the overall system was designed to consist of:

(a) A database application developed in dbase IV
(b) Statistical Analysis Software SPSS
(c) Geographic Information System SPANS GIS
(d) A graphics package CorelDraw

Most of the underlying data pertaining to each of the identified slope features is retained in the database application. The analysis of the hazard and risk ratings for the slope features was undertaken in SPSS. The features themselves are mapped and identified in the GIS, output maps from which were generated and then enhanced and printed through the graphics package.

(3) Application Components

The functionality of the SMS application is essentially limited to the data entry and retrieval of Maintenance and Investigation information for the identified slope features. The state of current application does not permit an interactive review of the Hazard/ Risk Ratings or the GIS Mapping functions intended to be part of the system.

(a) Data Entry and Retrieval Systems

Information is collected from the field inspection and maintenance works on forms printed out from SMS. These standard forms serve as a common template for all the slope features and are used by both the local offices. The planned procedure in the use of SMS is to enter the revised data from these forms into the database. These updated forms can be printed for future information review.

This functionality of the system is provided by the underlying database application that includes within it:

- Menu forms for guiding the user
- A relational database environment with tables for slope feature data and associated lookup tables
- Standard forms for data entry/ editing/ updation
- Queries for reviewing the data

(b) Hazard and Risk Analysis

From discussion with JKR it is understood that the underlying logic, statistical modeling, data, or any software application developed to compute the hazard and risk ratings were never finally handed over to JKR. With this limitation it is not possible to review the methodology used to compute these ratings but the database within the current version of the tool does contain deterministic hazard and risk ratings.

The need for functionality is now addressed by extracting the relevant data from SMS and assimilating it to SPRS which is generally being used by JKR for slope Hazard/ Risk ratings for all federal roads.

(c) GIS Mapping Integration

The GIS application used along with SMS also remains unavailable and from conversations with JKR it is understood that the SPANS system was not updated and has not been in use for a few years. The spatial data in the GIS was apparently limited to the individual slope features along the East-West Highway. Appending the hazard and risk values derived from the database to these polygonal features, thematic Hazard and Risk maps were created, with each feature being represented by it feature type (embankment/ cut/ fill) and thematically shaded to represent a Very High/ High/ Moderate/ Low/ or Very Low Hazard or Risk rating. Although the assigned ratings have never been updated on the maps (as advised on the original map books), they still assist the SMS user in spatially locating the slope feature and then looking up the current status from the database reports.

Some of the digital mapped data of the slope features (completeness cannot be assured) used with SMS may be available with the GIS unit at JKR but due to its relatively old data format, it is yet to be integrated and used in any newer system/ mapping efforts. The final output of the SPANS GIS application are available in the form of hardcopy, color, A-3 sized map books identifying the slope features mapped from field work, with the calculated hazard and risk ratings.

(4) Application Functionality and Current Use

The version of SMS used by the local offices of JKR provides them with the limited ability to enter data and review maintenance and inspection data on the slope features. It cannot revise hazard/ risk ratings, generate cost assessments, compute any economic analyses, or generate priority rankings for the slope features.

Designed for the East-West Highway, the system is used only at JKR Offices in Gerik and Jeli. Although accessible at the Road Maintenance Division in the JKR Head Office, it is not in use at this office.

In its current state, SMS is used in a very limited manner. Its functionality is restricted to the local offices where it serves the purpose of maintaining and updating Inspection and Maintenance Records. The standard slope inspection and maintenance form in the system provides a consistent and common format for the local offices to operate with.

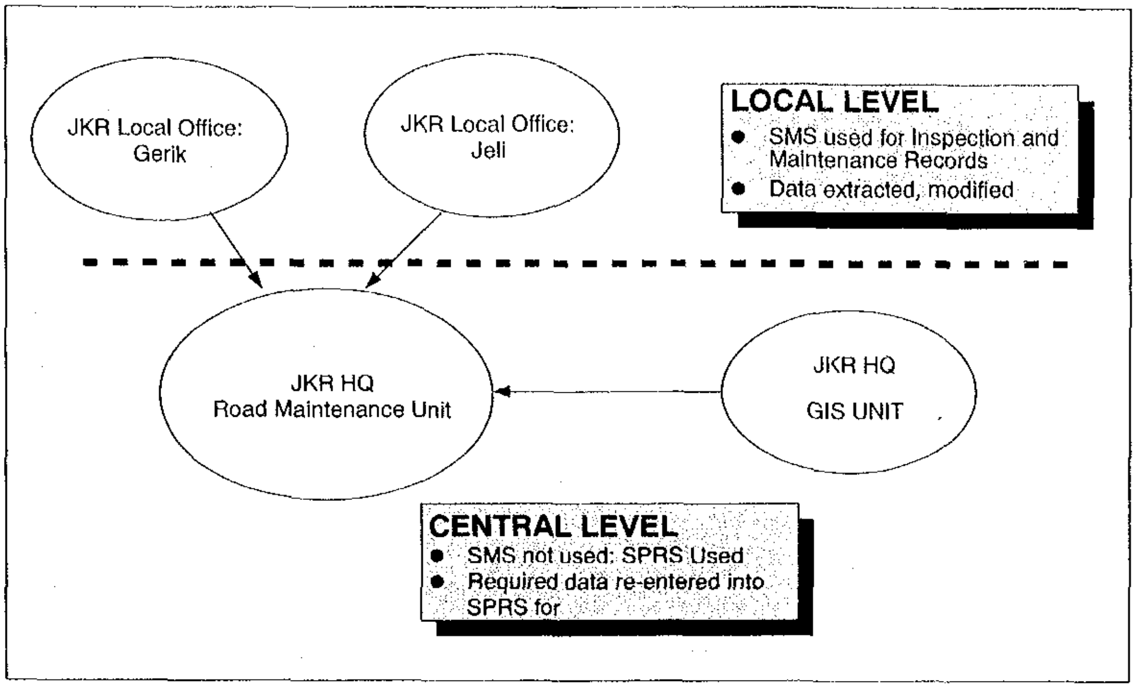


Figure 2.8.1 Current Status of SMS

Limited by the level of computing skills, lack of technical support, and absence of periodic guidance or refresher training , the local offices are not very comfortable or confident in the use of this system . With inadequate understanding and appreciation of the system, the staff at the local office is not unduly inclined to use this system on a regular basis. As a result, *maintenance and inspection information may or may not be updated in the system on a* regular basis. They also do not find a good fit between the system and the tasks that need to be performed by them in providing data to the head office, which requires that the data be extracted from SMS and be reformatted and edited to fit the format of SPRS.

Without the capability of reassessing slope priority rankings it does not find any use at the JKR head office where the activities have so far been less concerned with maintenance and *inspection on a regular basis but more on a planning and budgeting function* that requires prioritisation and cost estimates for slope re-engineering efforts. Relevant data from SMS is normally extracted and re-processed in SPRS to re-assess the Hazard and Risk ratings as well as the Slope Priority. Also, with SMS having data limited to the East-West Highway, it is further limited in its use for the Head Office which is concerned will all the federal roads, not just one highway.

(5) Summary of Limitations of SMS

The major limitations of SMS can be categorised as:

(a) *Application Based*

- Hazard and Risk Rating functionality is not available

- Cost Estimation function is not available
- Ability to edit/ update existing data or add new data not explicit
- Application developed in earlier version of software and operating system and is incompatible with newer systems.

(b) Content

- Data limited to East-West Highway
- Data possibly limited to 1996 information only
- Location, Completeness, and accuracy of updated database undefined
- Spatial data of slope features is not available in digital format
- There is no explicit spatial accuracy standard for the mapped features available in hardcopy in A3 sized maps.

(c) Institutional

- Trained users no longer available
- Current users have limited technical knowledge
- Technical support and maintenance/ upkeep for SMS Application not available
- Application lacks adequate integration with workflow
- Very limited internet connectivity to exchange data
- No defined methodology for inspection and oversight on use of application
- Stewardship of Application and its implementation lacking key technical ownership and mentoring within the organization

2.8.2 Malaysian Engineered Highway Management System (MEHMS): 1998

(1) Purpose and Background

Developed in 1998 for JKR by Pernding ZNA and the University of Bristol, UK, the focus of the application and the data initially included in it was on the Gunung Raya Road, Langkawi. The purpose of this software was to provide the users with a simple to use software application that could facilitate the assessment of slope stability, site investigation and design.

The purpose of this application was determined to be different from that of SMS by its inclusion of a detailed site investigation and design of slope stability solutions. By integrating CHASM (Combined Hydrological and Stability Model), a commercial, third-party software, the site investigation data was used to develop slope stability designs.

Developed as a tool to prioritise slope maintenance and remedial measures through a database linked to CHASM, the application reviewed was a beta version with documentation indicating that this application may have required further development and improvement. There does not however appear to be any further developments from the beta version delivered to JKR and the same having been reviewed by the JICA Study Team.

With this detailed site investigation data, and the ability to modify the Hydrological and Slope functions in the model, the application provided JKR with a design analysis function that could be used to develop slope features that conformed to acceptable levels of slope safety factors.

In summary, the application was designed to:

- assimilate site investigation data on identified slope features
- calculate their factor of safety values
- recalculate these values by using CHASM to develop slope solutions using different design criteria and design charts.

In our review of the application, we identified the Slope Safety Factors determined by the software to be similar in concept to the purpose of the risk rating function that was intended to be part of the SMS Application (but was not available for use and reanalysis of slope data).

(2) Software Dependency and Operating Platform

Unlike SMS, this application was developed as an integrated software package, which integrated within it the database files, the CHASM modelling functions, and all other user functionality evident. Installable on any standard Pentium PC, with 32MB of RAM, using a Windows operation systems of Win 3.x/ Win95 or WinNT 4.0, the application is independent of underlying software, avoiding some of the problems faced in the software dependency of SMS. Provided on a set of 5 floppies, this software is easily installed however in operation, some error messages are encountered although they do not affect the functioning of the application itself.

Developed as a stand-alone application, it has no dependencies on external systems other than the machine it is installed on. The system design and deployment had no integration with or dependency on the internet.

The data in the application is well organised into distinct tables, although any relational data structure/ diagram was not evident in the documentation. Written in visual basic, the application uses a custom data search engine, and integrates Crystal Reports for generating output reports in a pre-formatted manner.

This application does not have any connectivity with a GIS software.

(3) Application Components

- The functionality of MEHMS can be categorised as:
- Data Management Functions: Data History Review/ Data Import
- Data Review Functions: View/ Edit: Existing Data/ Simulation Parameters
- Data Query Functions: By Slope/ By Location/ Assisted SQL

- Analytical Functions:
  - (i) Slope Stability Analysis: Launches the CHASM Module
  - (ii) Hazard Analysis: Calculates Factor of Safety; from inventory; from both values

Due to functional limitations of the installed software and missing background data/ control files it was not possible to review every function in explicit detail, however the MEHMS manual provided a valuable addition to the software review, underscoring the benefit of documentation with each software development effort.

(a) Data Management Functions: Data History Review/ Data Import

The application provides a very good system for reviewing the vintage of the data files, at a glance providing the user with a good understanding of the date on which each data file was last updated.

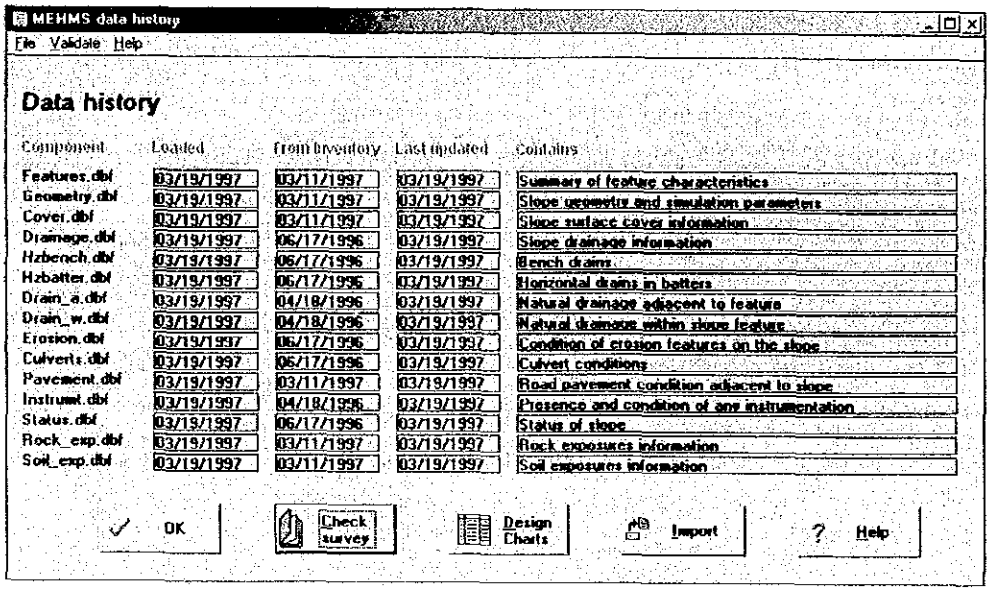


Figure 2.8.2 Display of MEHMS Data History

This same module also provides the user with the ability to import new data sets, with the limitation that this creates a new set of data files, replacing the earlier data inventory. Consequently, adding to an existing data set by way of importing information is a limitation.

(b) Data Review Functions

The application provides the user with the functions of reviewing and editing

- The Slope feature data
- Simulation parameters of soil strength, water table, and permeability for slope stability analysis.

The functionality for review and editing the Feature Data and the Simulation Parameters is well designed with pre-loaded options for data for the variables. The clear selection of information from the drop-down lists ensures easy operation and increased accuracy in data reporting.

(c) Data Query

The software uses an integrated, specialized database search engine from Borland. This search mechanisms is intended to provide search capability by Slope Feature, by location, or by assisted SQL.

Although the assisted SQL search function is the only functionality within the Query module that was functional in the package reviewed, it was found to be more complex than could be easily used by most persons who would be available to use this application. Due to non-functionality, the other query functions could not be tested.

(d) Analytical Functions

Slope Stability Analysis and Hazard Analysis are the two main analytical functions that are provided by the MEHMS software application.

CHASM, the commercially available software package for Slope Stability Assessment is integrated into the software and accessed through this module. Launched in a separate window, the user is given the full functionality of this software for design purposes.

The Hazard Analysis functionality was evidently designed to assess hazard from CHASM design charts, from the inventory data, or from both. This functionality generates the Factor-of-Safety calculation for the selected slope feature, used in a manner similar to that of the Risk Rating used in SMS or in SPRS. Again, with all the functions of the application not being enabled, for unknown reasons, it was only possible to review the hazard ratings from the design charts.

(4) Application Functionality and Current Use

The application as reviewed in its current state is not fully functional, with many of its sub-menu functions being disabled due to unknown reasons. Also, although it was developed for use in Langkawi, the application reviewed only contained data for the East-West Highway.

No known users were identified for the overall application or for the inbuilt CHASM software. MEHMS is evidently not in use at this time. The application upgrades identified in the documentation, or revisions based on limitations identified by past users, especially the limitation experienced in adding additional data have apparently not been addressed.

Summarily, lacking dedicated users, refresher training, efforts to upgrade the application, and to collect and include data for additional highways, the application does not currently find any use in the operations at JKR, especially at the Headquarters.

(5) Summary of Limitations of MEHMS

The major limitations can be categorised as:

(a) Application Based

(i) Data Addition functionality missing
(ii) Cost Estimation function is not available
(iii)Disabled/ Missing functionality in application reflects missing patch fixes/ upgrades/ development efforts, leaving the application incomplete in its designed functions
(iv)Factor-of-Safety numeric value does not automatically equate to a Qualitative Risk Rating and has to be manually assigned if so required.
(v) No Mapping/ GIS functionality

(b) Content

(i) Data limited to East-West Highway

(c) Institutional

(i) Trained users no longer available
(ii) Technical support, application maintenance/ upkeep not available
(iii)Application Slope Stability and Hazard Analysis not used
(iv)CHASM design functionality not used
(v) Lack of additional data may have limited interest in use of MEHMS on multiple Highways

2.8.3 Slope Priority Ranking System (SPRS): 1999

(1) Purpose and Background

Developed by JKR in response to the need for a system that would assist in establishing a numerical value that quantified a risk score for each slope feature. This numerical ranking addressed the purpose of establishing relative priority rankings, as well as categorising the slope features into an ordinal range of a qualitative measurement scale, which in this case used five categories, ranging from very high risk to very low risk.

(2) Software Dependency and Operating Platform

Designed as a very simple application, focussed on the purpose of providing a risk rating methodology, all the functionality of SPRS is completely embedded into a Microsoft Access Database. Using forms, queries, and reports, the application delivers all its functionality and has no dependency outside of Microsoft Access. It can consequently be run on Access2000, the currently available version of Access, rather than Access97, the version in which it was developed without facing the version change problems faced by SMS.

(3) Application Components

SPRS has two main aspects to it:

- Data Entry/ Review/ Update
- Slope Priority Ranking

All the data entered for a slope feature is retained in one large table. The fields in this table are given below. Access to this data/ data structure to review existing information or to input additional information is provided through one form, designed as a set of sub-forms to help the user organise the data review/ entry into useful sub-sections.

The Slope Priority Ranking section of the menu provides with the user with the ability to generate the Priority Ranking value for all the slope features included in the database. The report of the priority rankings can be ordered by rating, feature number, district. The pre-formatted report provides the user with a summary set of information on each slope feature, as well as its risk rating score and the risk category of very high, high, medium, low, and very low.

The methodology for generating the ranking is however completely hidden from the user and is embedded in the application in the form of a set of queries which collectively perform the following functions:

- Using pre-determined categories, assign numeric scores to each of the data elements visible in the data review form
- Use these scores to determine a numerical risk rating
- Assign a qualitative risk rating category based on the risk rating numerical ranges pre-determined and embedded in the application
- Generate an approximate cost of countermeasure for each slope feature using pre-determined cost categories

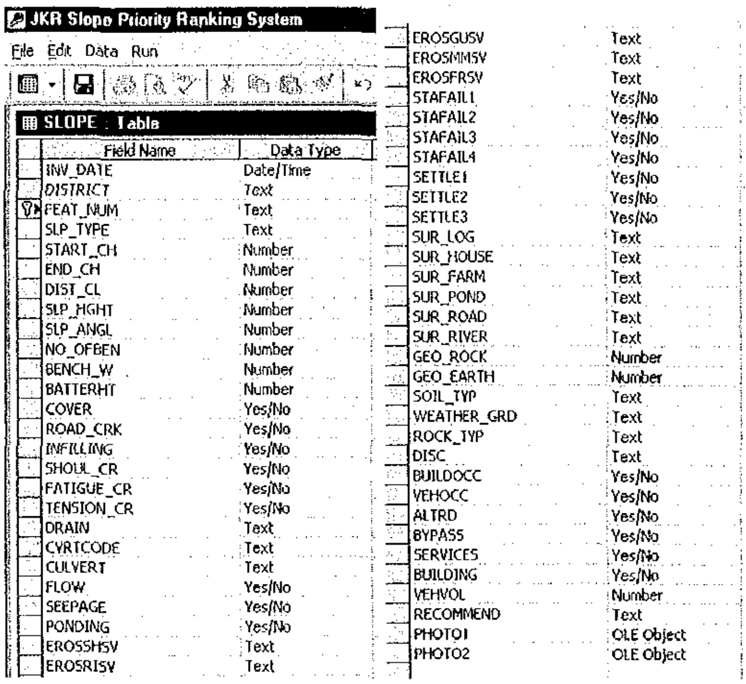


Figure 2.8.3 Display of SMS Slope Priority Ranking System

(4) Risk Rating Methodology

The risk rating methodology adopted in SPRS is based on assigning scores to data categories considered important in assessing the risk rating. The data categories are sub-divided into factors considered important in determining the hazard rating (potential hazard of slope failure) and consequence rating (consequences of slope failure). These two scores multiplied together provide the final numeric risk rating for each slope feature. Summarily put,

Hazard Rating × Consequence Rating = Risk Rating

The resultant score from this formula are then ranked into a qualitative risk categories ranging from very high, high, medium, low, and very low. Shown below are the risk categories in relation to the numeric score.

Table 2.8.1 SPRS Rating

Cut Slope		Fill Slope	
Points	Risk grade	Points	Risk grade
76 - 192	Very High	76 - 192	Very High
56 - 75	High	56 - 75	High
36 - 55	Moderate	36 - 55	Moderate
16 - 35	Low	16 - 35	Low
0 - 15	Very Low	0 - 15	Very Low

The data criteria considered essential for determining the risk rating and the scoring ranges are summarily listed on pages 1 through 4 of the SPRS documentation, and are represented below for review. (See Table 2.8.2 and Table 2.8.3)

For Cut Slopes:

Table 2.8.2 Scoring Ranges for Cut Slope

HAZARD ATTRIBUTES	POINTS		
	0	1	2
I. Height of Slope	< 12 m	12 m - 24 m	> 24 m
ii. Slope Angle (0)	< 45 °	45 ° - 63 °	> 63 °
iii. Slope Cover	> 20 %	< 20 %	-
iv. Surface Drains	Good	Blocked or Reqd	Need Repair
v. Natural water Path	No	-	yes
vi. Seepage	No	-	yes
vii. Ponding	No	Yes	-
viii. Erosion	Slight	Moderate	Critical
ix. Slope Failure	No	-	Yes
x. Surroundings Upslope	No	-	Yes
xi. Soil Type *	Sand/ Gravel	Silt	Clay
xii. Weathering Grade	I	II, III	IV, V, VI
xiii. Discontinuities +	I	II, III, VIII	IV, V, VI, VII

* Soil Slope Only
+Rock Slope Only

CONSEQUENCE ATTRIBUTES	POINTS		
	0	1	2
I. Danger to building occupants	No	-	Yes
ii. Danger to vehicle occupants	< 200 AADT	200-1,000 AADT	> 1,000 AADT
iii. Alternative road exists	Yes	No	-
iv. By-pass possible	Yes	No	-
v. Angle (α)	< 19 °	19 ° - 27 °	27 °

Risk = Hazard x Consequence

max Risk Score = max hazard score x max consequence score

= 24 x 8 = 192

For Embankments:

Table 2.8.3 Scoring Ranges for Embankments

HAZARD ATTRIBUTE	POINTS		
	0	1	2
i. Slope Angle	< 45 °	45 ° - 63 °	> 63 °
ii. Height of Slope	< 12 m	12 m - 24 m	> 24 m
iii. Slope Cover	> 20 %	< 20 %	-
iv. Pavement Fatique cracks	No	Yes	-
v. Tension Cracks	No	-	Yes
vi. Surface drains	Good	Blocked or Reqd	Need Repair
vii.Culvert condition	Good	Need cleaning	Need repair
viii.Seepage	No	-	Yes
ix. Ponding	No	-	Yes
x. Erosion	Slight	Moderate	Critical
xi. Slope failure	No	-	Yes
xii.Settlement of road	No	-	Yes
xiii.Soil Type	gravel / sand	silt	clay
xiv.Surrounding downslope	No	-	Yes

CONSEQUENCE ATTRIBUTES	POINTS		
	0	1	2
i. Danger to building occupants	No	-	Yes
ii. Danger to vehicle occupants	< 200 AADT	200-1,000 AADT	> 1,000 AADT
iii. Alternative road exist	Yes	No	-
iv. By-pass possible	Yes	No	-
v. Angle (β)	< 19 °	19 ° - 27 °	> 27 °

Risk = Hazard x Consequence

max Risk Score = max hazard score x max consequence score

= 25 x 8 = 200

(5) Cost Estimation Methodology

The main purpose of this functionality was intended to provide an approximate budgetary estimate of cost for slopes with very high risk, and with slopes that could collapse. The cost estimation function is mainly applicable to embankment slopes and uses erosion score, slope height, and slope angle to categorize them and assign different cost function formulae to each category. Cost estimates are also generated for slopes other than embankments if their collapse is capable of disrupting traffic flow.

Table 2.8.4 Cost Estimation Methodology in SRPS

CATEGORY	EROSION SCORE	SLOPE TYPE	SLOPE HEIGHT	SLOPE ANGLE	COST AMOUNT
COST 1	2	E	<=6	-	0.5*9500*[SLOPE LENGTH]*1000
COST 2	2	E	>6	<=60	0.5*23000*[SLOPE LENGTH]*1000
COST 3	2	E	>20	>60	0.5*31500*[SLOPE LENGTH]*1000
COST 4	2	E	>6 TO <=20	>60	0.5*23000*[SLOPE LENGTH]*1000
COST 5	1	E	<=6	-	0.25*9500*[SLOPE LENGTH]*1000
COST 6	1	E	>6	<=60	0.25*23000*[SLOPE LENGTH]*1000
COST 7	1	E	>20	>60	0.25*31500*[SLOPE LENGTH]*1000
COST 8	1	E	>6 TO <=20	>60	0.25*23000*[SLOPE LENGTH]*1000
COST 9	0	E	<=6	-	0.1*9500*[SLOPE LENGTH]*1000
COST 10	0	E	>6	<=60	0.1*23000*[SLOPE LENGTH]*1000
COST 11	0	E	>20	>60	0.1*31500*[SLOPE LENGTH]*1000
COST 12	0	E	>6 TO <=20	>60	0.1*23000*[SLOPE LENGTH]*1000
COST 13*	2	<>E	<=5	-	0.5*1590*[SLOPE LENGTH]*1000]
COST 14*	1	<>E	<=5	-	0.25*1590*[SLOPE LENGTH]*1000
COST 15*	0	<>E	<=5	-	0.1*1590*[SLOPE LENGTH]*1000

Where: E= embankment slopes

* Costs Categories 13, 14, 15 are for slopes where collapse can disturb vehicular traffic. (based on field interpretation).

This rough cost estimation function may not be very precise but provides a numerical cost ranking of the slope features. It is important to note that this functionality is completely hidden from the application user and is automatically run for the appropriate slopes when a risk report is generated. There is no menu option available to activate/ de-active it, or to inform the user about the availability of this functionality.

JKR has also made the observation that these cost estimates generated from the application are not accurate enough and revisions are needed. Since the underlying methodology is inaccessible, and there is no documentation on the cost estimation procedure, it remains difficult for the users to understand or adapt to be more responsive to their needs.

(6) Application Functionality and Current Use

SPRS is currently used in JKR to determine risk priority ratings for all slope features for which data is available. As a simple to use application, and with the much needed risk rating functionality, SPRS is addressing a much-needed function of helping JKR determine the relative priority ranking of all slope features in a quantitative, unbiased manner.

Although the cost-estimation functionality is not exclusively called for in use, its being intrinsically tied to the risk rating function does provide the cost estimates for embankment slopes. These numbers however may not find frequent use since they do not provide accurate enough measures for budgeting purposes.

The SPRS application is currently used extensively in the JKR main office in Kuala Lampur. Since it does not include the inspection and maintenance functionality, it does not find such extensive use at the field offices visited in Gerik and Jeli on the East-West Highway.

(7) Summary of Limitations of SPRS

- Risk rating methodology is enshrouded and is not easily accessible for any modifications
- Users feel that the risk rating values generated need to be improved to better serve JKR's need.
- Users express low confidence in results generated from cost estimation function
- To be a complete application for JKR, it needs to include functions of maintenance and inspection, as well as location based mapping using a GIS

Table 2.8.5 Comparison of Available Slope Management Applications

SMS	MEHMS	SPRS
Main Purpose and Functionality **Based on available functionality and not on original design intent*		
Slope Maintenance and Inspection	Slope Stability Design using CHASM	Slope Priority Ranking
	Factor of Safety Calculation	Cost Estimation for Budgeting
Risk Rating Methodology		
None available**	Factor of Safety calculated	Risk Rating Computed
** Many alternate methods were tested and discriminant analysis technique was finally selected as being the best approach. The ratings entered in the database were originally estimated using this technique in an externalised statistical analysis software, SPSS, and manually entered for each slope feature.	Data required for the calculation of the Factor of Safety includes slope height, slope angle, soil strength, water table, and permeability for each slope feature. The exact formula is not known.	Predefined data categories to which scores are assigned. The data is categorised as : Hazard Criteria (H) and Consequence Criteria (C) The final Risk Rating (R) is calculated by: R = H * C
Cost Estimation Methodology		
None available	None Available	Developed predominantly for embankment slopes, the individual slope feature are categorized based on their Erosion Score, Slope Height, Slope Angle For each defined category an approximate cost factor is assigned. The individual slope cost is estimated by multiplying this pre-assigned cost value the slope length.
GIS Functionality		
Originally designed but none available	None available	None available
Software Dependency		
Microsoft Access97; Wing95 or equivalent. *Not compatible with Access 2000*	Visual Basic, CHASM Software Module, Borland Search Engine, Dbase IV	Microsoft Access97; Win95 or equivalent

2.9 Method of Slope Risk Rating

Following the review of the Malaysian three (3) slope systems in the previous section, further review will be carried out particularly on the method of slope risk rating, in comparison with those in Japanese current system and new system developed in this JICA study. Here are the items to be discussed in this section.

2.9.1 Approaches for Slope Risk Evaluation
2.9.2 Comparison of Inspection Method
2.9.3 Review of Each Factor in Risk Rating

2.9.1 Approaches for Slope Risk Evaluation

In the slope disaster management, evaluation of slope risk is one of most important part. As there are several approaches for this purpose, it is necessary to choose most appropriate approach in accordance with the stage of disaster management, required accuracy, affordable cost and time etc. There are four (4) different stages in slope management program as slope risk evaluation is concerned as shown in Table 2.9.1.

Table 2.9.1 Approaches of Slope Risk Evaluation

Stage	Proper Approach	Requirement
a) Screening	Preliminary study (Aerial photo etc.); Quick visual inspection	Relatively Low, but for quick judgement
b) Slope Inspection for implementation priority	Detailed slope inspection	Moderate
c) Design of countermeasure	Stability analysis, based on detailed soil investigation and hydrological study	High Accuracy
d) Emergency action (Evacuation, traffic control etc.)	Quick visual inspection	Relatively Low, but for quick judgement

Figure 2.9.1 shows workflow of slope management in respect of slope risk evaluation. As shown in the figure, Reconnaissance Survey and preliminary study (maps, aerial photos etc.) is suitable method for the stage a), screening of slopes. And Slope Inspection is to most suitable for the stage of b) and d), namely evaluation for priority in countermeasure and management. And Stability Analysis is considered as most suitable to the stage c), design of countermeasure, as it requires lots of time, budget and man power for more sophisticated calculation based on lots of investigation for in-put data.

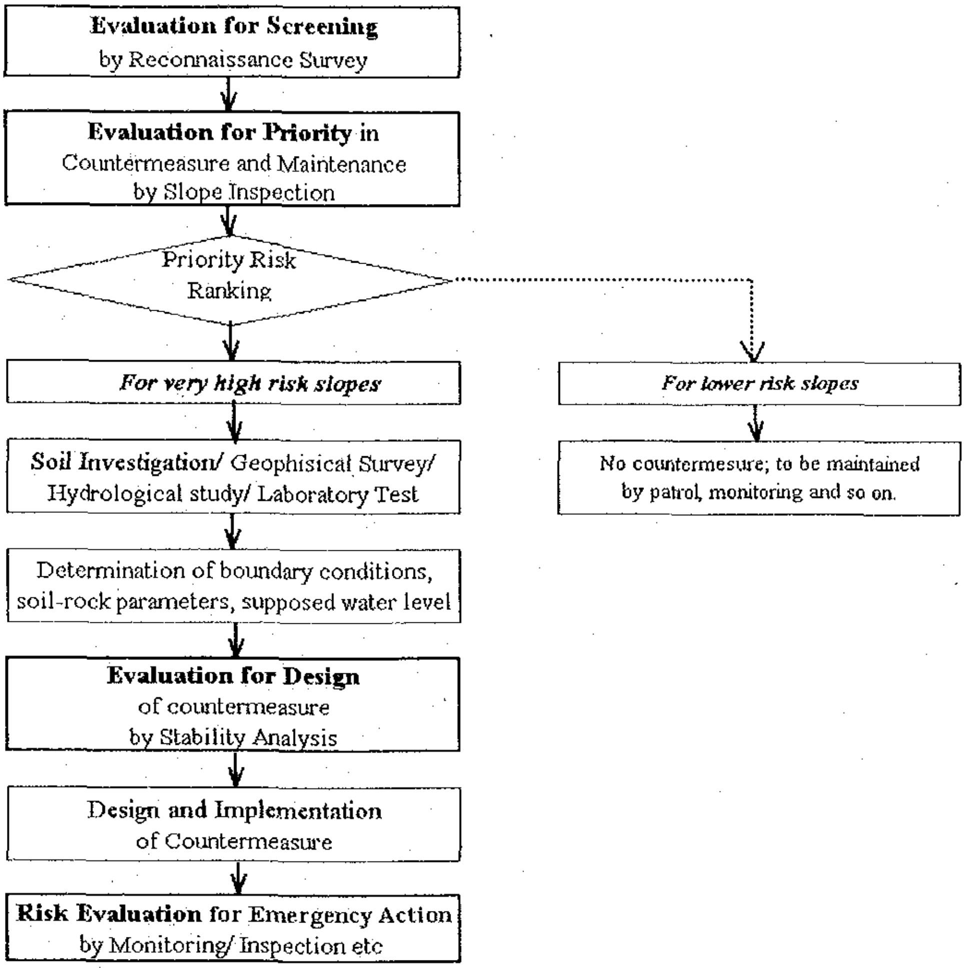


Figure 2.9.1 Several Steps of Slope Risk Evaluation in Slope Study

Table 2.9.2 compares and summarizes the difference of the three (3) existing slope management systems, SMS, MEHMES and SPRS, in respect of risk rating methodology. Stability Analysis is employed in MEHMS and SMS, and as the major weapon of slope risk evaluation in the former one, while as the secondary tool in SMS. Slope Inspection technique is adopted as major tool of slope risk evaluation for prioritisation in countermeasure planning in SMS, SPRS, as well as Japanese current management system.

Table 2.9.2 Slope Risk Evaluation Technique

Basic Approach	Slope Stability Analysis	Slope Inspection
Methodology	By use of slope stability analysis software, (In MEHMS, CHASM was employed), in which safety factor is calculated using soil parameters, groundwater level, rainfall effects, etc.	The rating score system is established using geological/ geotechnical expertise and experience, supported by quantitative analysis when available.
Advantage	Stability Status of each slope can be rated theoretically. Also calculation is possible for forecasting at change of water level conditions, and comparison of effects with other countermeasure options..	Stability (or risk) of each slope, is assessed with quantitative score so that priority in countermeasure implementation can be easily decided, only by slope inspection and without soil investigation at each slope
Limitation	Lots of site investigation and testing are required for determination of soil parameters and groundwater conditions for each slope, particularly for cut/natural slope.	Hazard rating score system should be continuously improved reflecting the actual data of failure occurrence.
Preferable application area	Recommended for detailed design of countermeasure work after selected as high risk slope, not .for priority decision purpose.	Recommended for use as the base of priority ranking in countermeasure implementation program.
Example of adopted System	- MEHMS (*as main tool*) - SMS (but in secondary procedure only)	*Most of slope management systems,* including; SMS, SPRS, Japanese current system

2.9.2 Comparison of Inspection Method

Following the precedent description, comparison between existing slope systems is made in respect of slope inspection methodology and subsequent risk evaluation procedures.
Table 2.9.3 summarizes these features of SMS, SPRS, and Japanese current system, in all of which slope risk is determined based on the result of slope inspection. (As mentioned, MEHMS are neglected as it is not based on slope inspection rating.) Some brief discussion of difference between each system is presented as follows:

Here are brief comment on comparison of several important item between four (4) systems in Malaysia and in Japan.

Table 2.9.3 Comparison of Inspection-based Slope Management System

	SMS (1996)	SPRS (1999)	Japanese system (current)	Proposed new system (SIMS)
1) Objective	**Prioritisation** of slope work, and **database for slope management**	**Prioritisation** of slope work, and budget plan	**Prioritisation** of slope work, and **database for slope management**	**Prioritisation** of slope work, and **database for slope management**
2) Target Road	East-West Highway	Nationwide federal road	Nationwide federal road	Nationwide national and main local road
3) Personnel for Inspection	Slope inspection (by **slope specialist)**	Slope inspection (by **trained JKR technician)**	Slope inspection (by **trained geologist of consulting firm)**	Slope inspection (by **trained geologist of consulting firm)**
4) Slope Category and Failure Type	**1) Cut and natural slope (1 type)** **2) Embankment**	**1) Cut and natural slope (1 type)** **2) Embankment**	**1) Cut and Natural** (5 types plus snow avalanche) **2) Embankment**	**1) Cut and Natural** (**5 types** plus snow avalanche) **2) Embankment**
5) Risk Rating Formula	Risk is calculated by: R = H x C H: Hazard C: Consequence	Risk is calculated by: R = H x C	Current system is operated only to evaluate hazard risk, and not consequential factors.	**Risk is calculated by: R = 0.9H + C**
6) Hazard score factors	Geometry, geology, Erosion, Cover, Drain, Soil type (for embankment) etc.	Ditto to the left	Similar to the left, **but with evaluation of: deformation and effectiveness of installed works**	. Similar to the left, **but with evaluation of: deformation and effectiveness of installed works**
7) Hazard score distribution	Score weighted to each factor is **based on discriminative analysis.**	Each factor is given **un-weighted score for simplicity.**	Score distribution is **based on specialists' expertise** (supported by discriminative analysis)	Score distribution is **based on specialists' expertise** (supported by discriminative analysis)
8) Consequence score	**5 subjects** (Building/ Traffic Volume/ Angle from centre/ Temporary diversion/ Alternative roads)	**5 subjects** as same with ones in the left	Consequence is not evaluated in the system.	**7 subjects**;: 2 additions are: **(Failure volume & Service and Public Utilities)**
9) Economic Analysis	Not applied	Not applied	Not applied	**Simplified method** was introduced in SIMS, where more complicated one is tested in the report.
10) Countermeasure Selection and cost estimation	Simple system	Simple system	Separately arranged from slope info system	**Detailed system was installed in SIMS**

2.9.3 Review of Each Factor in Risk Rating

(1) Objective

The common objective of slope inspection in each system can be said as prioritisation in the planning of countermeasure implementation.

At the same time, another objective is establishment of a big database of road slope, which should be useful resources for future slope management for road administrator. It can be compared to historical medical record for human body, making it possible to quick and proper treatment when any problem happen.

(This database function may be applicable only to SMS and Japanese system, because SPRS provides limited information on rating and cost estimation due to its design concept of simplicity.)

(2) Target Road of the System

SMS was developed for slope management of East-West Highway, there are restrictions in some features which is not sufficient to apply to nationwide road; some examples of which include limitation to the types of geology, topography, slope failure type, and so on. On the other hand, SPRS and Japanese system are devised from the beginning for application to nationwide road.

(3) Personnel for Slope Inspection

This is the item to which careful attention should be paid in future system planning. In case of SIMS, a team of slope specialist; engineering geologists and geotechnical engineers from University, Government and Private sectors have cooperated together not only as routine engineering contract but also as research development. So lots of time, money and expertise were mobilized for slope inspection and refinement of the rating system.

In case of SPRS, JKR has been carrying the slope inspection and slope rating out by own staff of district office, with taking training program, and there was no outsourcing for the job. The main reason for this is that nationwide federal road was targeted, and efficiency in time, cost and man power was requested.

On the other hand, in Japanese system, all the slope inspection and slope rating work have been carried out by the teams of experienced engineering geologists who belong to private geotechnical consulting company. Special training program was arranged by the Government for the involved geologist to give the output of uniform and high technical standard. (Similar arrangement for outsourcing and training course will be recommended for the implementation of new system.)

(4) Classification of slope by Failure Type

As shown in Table 2.8.1, each system is common in dividing the slope into two categories for slope inspection.

a) Cut slope and natural slope
b) Embankment.

But there is a big difference in further working process in current Malaysian systems and Japanese system. In case of SMS and SPRS, cut and natural slopes are treated as one group in inspection and rating, while Japanese system divides the slope into 5 categories in accordance with type of failure most likely expected.

The five (5) types of slope failure is as below:

1) Collapse (CL)
2) Rock fall (RF)
3) Rock mass failure (RM)
4) Landslide (LS) and
5) Debris Flow (DF)

The reason of defining such five types is that the mechanism of failure is different with the type, and that observation, investigation, hazard rating, and up to the appropriate countermeasure. If we think about application of many roads nationwide in the future, the slope management system should be applicable to all of types of slope failure, as well as geological and geographical conditions supposed to encounter. Thus the introduction of this concept of classification should give much benefit to higher accuracy of slope rating and further process in slope disaster management.

(5) Risk Rating Formula

To prepare the implementation plan of slope countermeasure and other disaster management program, the priority of each slope is essential. As shown in Table 2.9.3, 7) and 8), in the systems of SMS and SPRS, the priority in implementation plan was determined to base on the slope risk ranking, where slope risk was a function of Hazard score and consequence score. The used equation is as follows:

$$R = HC$$

Where,

R: Risk rating of slope
H: Hazard Rating of slope (100 in Max)
C: Consequence (8 in Max)

It is considered to base on a reasonable idea in which the risk of disaster including the level of its total damage could be measured by both factors, the risk (or probability) of slope failure occurrence, and the consequential factor, which is the indicator of influence on overall damage caused by slope failure.

On the other hand in Japan, due to social and political requirements, the process of hazard rating and consequent damage assessment has been clearly separated. The main reason of it is considered that hazard rating can be determined based on scientific and engineering methodology, while it is not so easy to establish a standard formula or scoring system for assessment of consequent damage for unique ranking list. For example it may arise tough discussion on the prioritisation between high risk slope along heavy traffic road and very high risk slope along much less traffic road. Actually in such case, decision-making in priority may be made on case-by-case basis at the higher level, taking into consideration various administrative or political factors, some of them may be not suitable to disclose for the moment.

Note 1): In the new system, SIMS, the concept of SPRS, the current practice in Malaysia, is followed with minor modification in additional consequential items and calculation formula.

Note 2): Recently research and trial application of economic analysis has made in many countries including the road disaster management program. So far no legislative implementation has been made both in Malaysia and Japan in this area. But in this study the application of this approach are suggested as a supporting tool of final decision-making of implementation program, for the purpose of prioritisation in slope level and road level, and also general justification of slope countermeasure work among public investment.

(6) Hazard Score Factors

In the development of SMS, items and score distribution of each hazard attributes were carefully studied by specialist and finally determined in reference to the result s of discriminating analysis. And SPRS has basically succeeded to adopt the same concept, but with some modification for simplicity.

In Japanese system items and score distribution of hazard attributes were established based on the result of intensive research program by the group of slope specialists including engineering geologist, geotechnical and civil engineer etc., which was organized by former Ministry of Construction. The scoring system was repeatedly reviewed at every regular nationwide inspection with several year interval, and revised in accordance with the adaptability with actual sloe failure occurrence. Also numerical verification was carried out in use of discrimination analysis.

(7) Hazard Score Distribution

Table 2.9.4 summarizes the comparison of hazard score distribution between SPRS and Japanese system. The main points in comparison between both are listed as below:

1) Most of the items for evaluation is almost similar between both.
2) As was mentioned, Japanese system divides cut/natural slope into five groups by type of failure type, while SPRS does not. Accordingly in Japanese system score distribution differs according to the type of failure.
3) Japanese system assesses the effectiveness of present countermeasure.(-20 in Max)
4) Japanese system assesses the conditions of culvert, upstream, and river score.

Table 2.9.4 Comparison of Hazard Score Distribution

Item for Evaluation	SPRS		Japanese system/ SIMS				
	Cut & Natural	EB	Cut & Natural Slope				EB
			CL& RF	RM	LS	DF	
Topography	8	8	6	10	46	0	0
Geometry	17	16	18	12	0	0	0
Geological Structure	25	0	14	27	28	0	0
Geological Condition	17	0	20	6	11	0	9
Deformation of Slope	17	36	17	42	0	0	13
Surface Conditions	33	32	25	4	15	0	26
Culvert Condition	0	0	0	0	0	0	26
Filling Materials	0	8	0	0	0	0	4
Catchment Area	0	0	0	0	0	17	0
Riverbed Gradient	0	0	0	0	0	17	0
Cond. of Upstream Slopes	0	0	0	0	0	66	13
Score in River Stream	0	0	0	0	0	0	9
Total	100	100	100	100	100	100	100
Effectiveness of Present Countermeasure	0	0	(-20)	(-20)	(-20)	(-20)	(-20)

Note: EB: embankment, CL: collapse, RF: rock fall, RM: rock mass failure LS: landslide, DF: debris flow

(8) Consequence Score

Consequence Score system was proposed first in SMS, then later similar system was adopted in current SPRS. Five (5) items were selected as the consequential factors to evaluate possible damage of disaster caused by slope failure. The range of score for each item are listed in Table 2.9.5 Comparison of Consequence Score.

On the other hand, in Japanese system, no scoring system for "Consequence" is provided. The reason of that is, as mentioned earlier, these factors are to take into consideration in the final decision of implementation plan by road administration authority, and they are not disclosed to the public.

Table 2.9.5 Comparison of Consequence Score

Current System			*[Reference]:*	
SMS/ SPRS		Japanese System	*SIMS (Proposed System)*	
1. Danger to building occupant	0-2	No scoring system is provided as "Consequence Score". These factors are taken into consideration in the final decision by road administration authority.	*1. Danger to building occupant*	*0-2*
2. Danger to vehicle occupant (traffic volume)	0-2		*2. Danger to vehicle occupant (traffic volume)*	*0-2*
3. Angle â(angle from road center to slope crest or embankment toe)	0-2		*3. Angle â(angle from road centre to slope crest, or embankment toe)*	*0-1*
4. Alternative road exists	0-1		*4. Alternative road exists*	*0-1*
5. By-pass possible	0-1		*5. By-pass possible*	*0-1*
			6. Service and public utilities (gas, telecom, power, water etc.)	*0-2*
			7. Failure Size (volume)	*0-1*
Total	**0-8**		***Total***	***0-10***

(9) Economic Analysis

As Table 2.9.3 shows no existing system in Malaysia and Japan introduced economic analysis. In this JICA Study some effort was carried out to offer supporting information to decision-making in priority in implementation of countermeasure, and to verification of those slope management work.

(10) Countermeasure Selection and Cost Estimation

So far simple method was adopted in SMS and SPRS, while no system in Japanese current system. In SIMS, more refined system for countermeasure selection and cost estimation has been studied and introduced.

CHAPTER 3 CASE STUDY

3.1 Objective of Case Study

(1) The Position and Role of the Case Study

As shown in Figure 3.1.1, the Case Study was conducted and the study route was selected in the 2nd stage among the three of this study routes. The Case Study is a very important step to the final study, because it is the step of finding and solving the actual possible problem to likely arouse during the slope management. Experience in model case should benefit to final study for nationwide application.

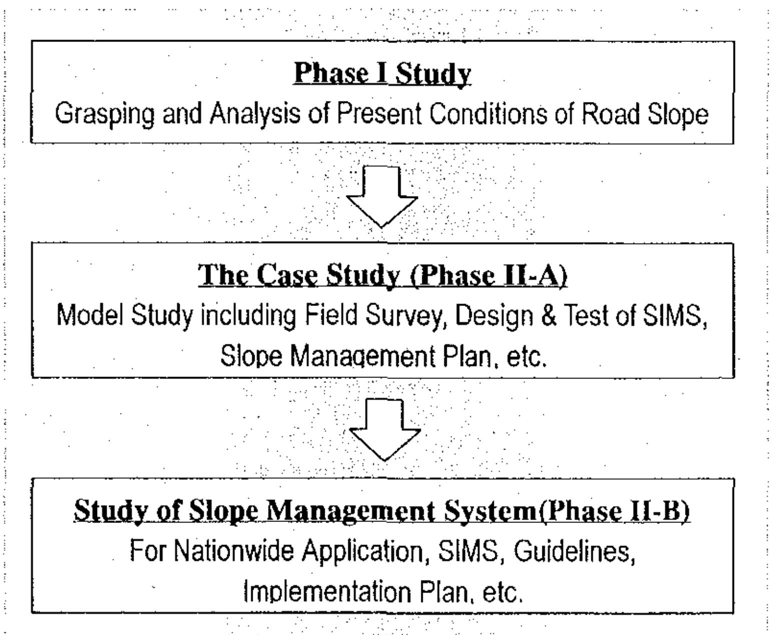


Figure 3.1.1 Position of The Case Study

The study shall contribute:

1) To study and establish the criteria and the standard procedure of slope inspection, investigation and monitoring through the Case Study.
2) To develop a new slope information management system (SIMS) using the actual data from Case Study.
3) To establish the procedure of slope maintenance and disaster management through the Case Study.
4) To propose on effective implementation plan of the slope disaster management system, including the study of organization and human resources on the Case Study

It is expected that carrying out the Case Study on an actual route make it possible to develop a more realistic and efficient management system for practical application.

(2) Study Area of the Case Study

The Case Study was carried out along the following road section.

Route: The East-West Highway (Federal Road No.004)
Section: From Chianage 25.000 to Chainage 83.2000.
State: Perak
District Office in charge: Hulu Perak District Office
(Please refer to Location Map on the first page.)

(3) Study Period

The Case Study was carried out from May 2001 through September 2001, with successive monitoring by the end of November 2001.

The schedule of actual performance of each work are shown in Table 1.5.1.)

(4) The Scope of the Case Study

The Case Study consists of two portions;

1) Field work and
2) Office work

They are summarized in Table 3.1.1.

Table 3.1.1 Scope of Case Study

Group	Items	Works	Notes
Field Work	Slope Inspection	- Inspection Record of all slopes, more than 815 in numbers.	Along the section from 25.00 km To 82.30 km
	Aerial Survey & Mapping	- Orthophoto Map (1/20,000) - Digital Map(1/5,000)	
	Hydrological/ Environmenatal Study	- Site Observation and data collection along study route	
	Topographical Survey	- Land topographical survey (ground plan/cross sections)	At three model slopes: - 81.3 km [Landslide (LS)] - 27.0 km [Collapse (CL)] - 30.4 km [embankment (EB)]
	Geological. Investigation	- Drilling and coring - Geophysical Exploration (Seismic Refraction Survey and Resistivity Imaging)	
	Instrumentation and Monitoring	- Rain Gauge - Extensometer/ - Inclinometer - Water Pressure Gauge	
Office work	Data Processing	- Analysis of field data	-
	Slope Database	- Inspection data and other site survey data	-
	Countermeasure design/ cost estimation	- Preliminary model study	At three slopes
	Slope Info. System (SIMS)	- System development and application to the case study route	-
	Institutional Study	- Review and proposals for organization/ human resources	-

3.2 Concept of Slope Disaster Management

3.2.1 Flow of Road Slope Disaster Management

Figure 3.2.1 shows the flow of road slope disaster management planning, which can be divided into three steps as below:

The 1st Step: Step of Evaluation of Slope Disaster Risk

The 2nd Step: Step of Prevention of Slope Disaster Risk and Maintenance

The 3rd Step: Step of Emergency Management

Each step consists of procedures as below:

(1) The 1st Step: Step of Evaluation of Slope Disaster Risk

In this step, the risk of failure should be evaluated to the target slope. Prior to inspection of each slope, preliminary study, reconnaissance survey and screening shall be made. In the course of preliminary study and reconnaissance survey, picking up of area of possible landslide or debris flow, and tentative classification of likely slope failure type of each slope shall be determined.

1) Preliminary Study/ Reconnaissance Survey/ Screening
2) Slope Inspection:
3) Evaluation of Hazard Rating:
4) Evaluation of Consequence Score
5) Evaluation of Risk Rating
6) Listing of Priority Risk Ranking List:
7) Estimation of Cost for the countermeasure:

(2) The 2nd Step: Step of Prevention of Slope Disaster Risk and Maintenance

Based on the slope risk evaluation by slope inspection, the slope management level are determined, and classified into one of four categories, Level I, II, III and IV.

(a) Categorization of Slope Risk Ranking

According to the risk rating, all the inspected slopes are divided into four (4) categories; 'Very High', 'High', 'Medium' and 'Low'. The threshold value of each category may be studied and determined reflecting the number and percentage of slopes corresponding to each category. Particularly the number of slopes rated as VERY HIGH could be adjusted so that the implementation of countermeasure could almost completed within few years, checking with expected annual budget for countermeasure work for the relevant road section.

(b) Definition of Slope Management Level

Using the result of risk rating category, level of slope management can be defined; Each of the four risk categories of VERY HIGH, HIGH, MEDIUM, and LOW shall correspond to Level I, Level II, Level III and Level IV, respectively. The suggested item for management in the above is summarized in Table 3.2.1.

Table 3.2.1 Slope Management Level in terms of Risk Rating Value

Level of Slope Management	Risk Rating	Basic Policy of Slope Management
Level I	Very High	Implementation of preventive countermeasure
Level II	High	Regular Patrol and Monitoring
Level III	Medium	Periodical Inspection
Level IV	Low	Screening out of slope follow- up list

(c) Implementation of Slope Management Plan

Based on categorization of management level as mentioned above, implementation plan of preventive slope countermeasure work shall be prepared. Implementation plan shall be prepared taking the annual budget constraint for countermeasure work into consideration.

From the time frame point of view, implementation plan should be divided into four (4) scheme as below:

1) Urgent plan
2) Short-term plan
3) Medium-term plan
4) Long-term plan

The period and contents for each plan will be discussed later in Table 3.6.2.

(3) The 3rd Step: Step of Emergency Management

Despite the implementation of well studied program of preventive countermeasure and slope maintenance, it is impossible to avoid entire risk of slope failure. However, it is requested at least for the Government and the Road Administration Office to make best efforts to prevent disaster, and to mitigate possible human loss and other damages caused by slope failure. In this context, emergency management shall be carefully studied and established.

For emergency management plan, there shall be prepared for two aspects of action;

1) Emergency Preparedness Plan and
2) Emergency Response Plan

The detail of suggested idea for these plans shall be described in Guide I, separate volume of this study report.

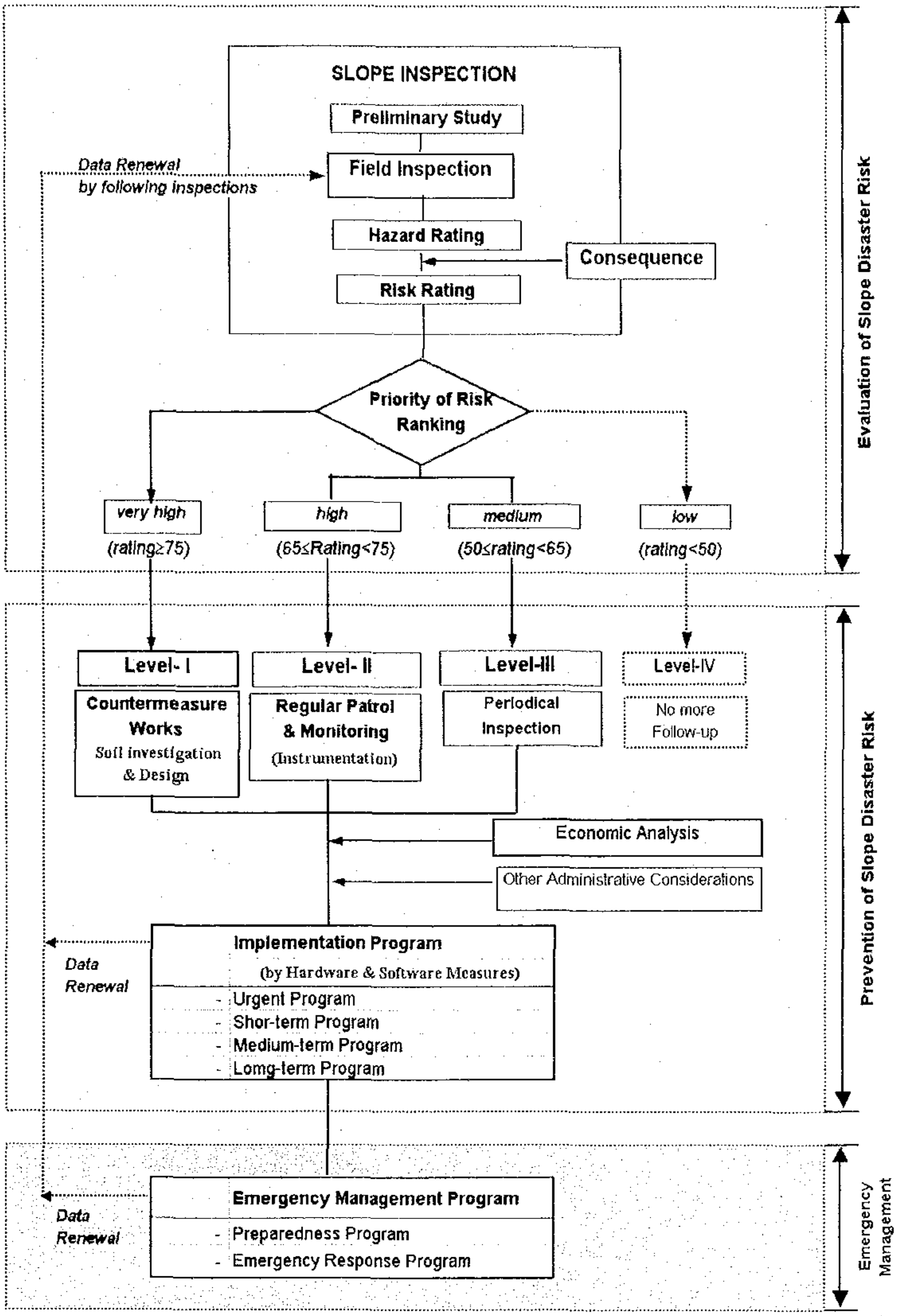


Figure 3.2.1 Flow of Road Slope Disaster Management

3.3 Slope Inspection

3.3.1 Work Flow of Slope Inspection

The slope inspection shall provide core data of SIMS, Slope Information Management System that is used for planning road slope disaster management.

By the slope inspection the stability of slopes must be evaluated with precision in order to prevent the road slope disasters or to minimise the damage.

Chainage of 25.00km to 82.30km of Federal Road Rout Four (4) namely East – West Highway were selected as case study route in this project after the first study of federal roads in Malaysia. Workflow of this slope inspection is as follows.(Figure 3.3.1)

(1) Preparatory work in office
(2) Selection of slope (Screening)
(3) Slope inspection
(4) Data base creation and reporting

Slopes inspected was selected according to the criteria mentioned in the 3.2.3.

The data that were collected in the slope inspection were;

1) General information of the slopes
2) Slope stability / hazard score
3) Cost of countermeasures in outline

Slope inspection was carried out on the site and filling in the Proforma namely Slope Inspection Sheets which was prepared for SIMS. It consists of six (6) forms, Form A, Form B, Form F. And furthermore, Form E consists of five (5) forms, Form E1, Form E2, Form E3,Form E4, Form E5.

Form A is general information and result of inspection.
Form B is Sketch sheet.
Form C is Photograph sheet.
Form D is Slope Feature.
Form Es are Condition of Slope.
Form F is Countermeasure score and Consequential Factor sheet.

All forms except Form C shall be filled in on site. All forms are attached with this report. The forms used in the case study were slightly different from attached forms since attached forms are revised after completion of the case study. (Refer to Guideline volume, Guide II)

Malaysian Study Team under supervision of JICA Study Team carried out this slope inspection.

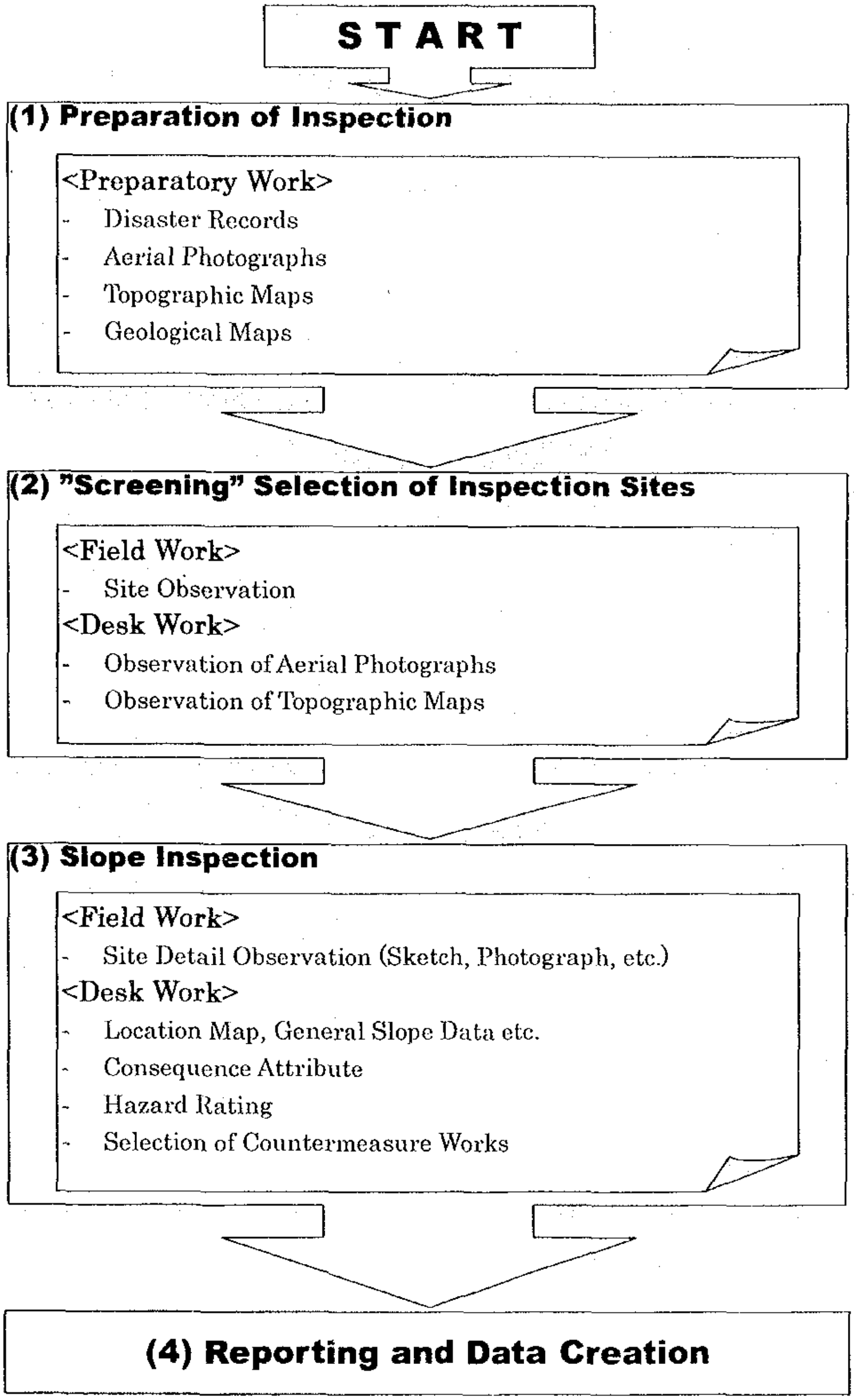


Figure 3.3.1 General Flow of Slope Inspection

3.3.2 Hazard Rating and Risk Rating

(1) Method of Rating

The stability evaluation includes the following three aspects.

1) Assessment of main causes such as topography, geology, gradient, height and slope deformation – Condition of Slope Score
2) Assessment of the effect of the existing countermeasure work – Countermeasure Score
3) Assessment of the effect of the disaster expected – Consequence Attributes Score

The total evaluation scores are obtained by the maximum of the evaluation scores of main causes and countermeasure works, plus the evaluation score of disaster records, as shown in Figure 3.3.2.

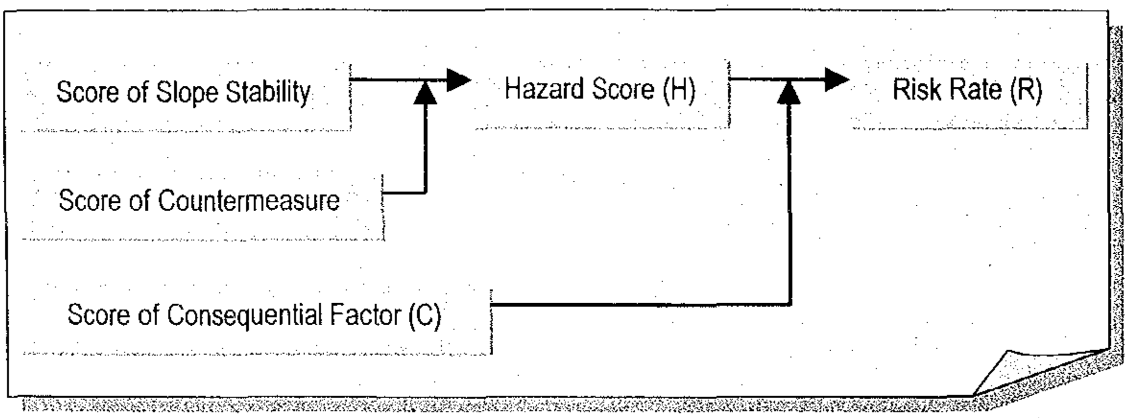


Figure 3.3.2 Determination of Stability Evaluation Score

Risk Rate is obtained by following formula.

Risk Rate = Hazard Score H* 0.9 + C(Consequence Attribute)

where:

Full mark of each score is as follows;

Condition of Slope Score :	100
Hazard Score :	100
Consequence Attribute :	10
Risk Rate :	100

(2) Hazard Score

Weighting for each item was determined through careful study of the existing system defined by Malaysian and Japanese Criteria. Then the effectiveness of existing countermeasures is assessed and hazard rating estimated.

Geological structure and condition is an important item when evaluating Collapse, Rock Fall, and Landslide. Deformation, or cracks or settlement, upheaval, side movement etc. of ground or structure, is taken as an important item for Rock Mass Failure, Landslide and Embankment. The condition of crossing culvert is only important items for Embankment. The condition of catchment area is important items for the debris flow in evaluating the probability of occurrence.

Condition of Slope Score is evaluated by the following items.

Table 3.3.1 Items for Evaluation of Slope Instability

Item	Cut and Natural Slope	Debris flow	Embankment Slope
Topography, Geometry, Geological structure	X		
Geological condition, Deformation of slope, Surface conditions	X		X
Culvert Conditions, Filling Material Scoring of River			X
Conditions of Upstream Slopes		X	X
Catchment Area, Riverbed Gradient		X	

Table 3.3.2 shows weighting of points in Condition of Slope Score at each disaster type. Full score of Condition of Slope Score is 100 points for each failure type.

Table 3.3.2 Maximum Slope Hazard Attribute Point

Items	Collapse/ Rock Fall	Rock Mass Failure	Landslide	Debris Flow	Embankment Failure
Topography	5	11	50	43	0
Geometry	30	14	0	0	10
Geological Structure	14	33	10	0	0
Geological Condition	16	31	3	0	5
Deformation	15	7	32	34	26
Surface Condition	20	4	5	23	51
Others	0	0	0	0	8

(3) Consequential Factor

Form F requires scoring of Consequential Factor for estimate disaster on the socio-economic environment. Consequence attribute items on Form F are determined basically following the ones employed in SPRS and SMS system.

The items for Consequential Factor in the case study version were as follows. In the final inspection manual, one more factor "Services Public Utilities" was added according to requirement of JKR.

1) Danger to building occupant
2) Angle β : road at centre line to crest or embankment toe
3) Failure size (volume)
4) Construction period of temporary diversion
5) Volume of traffic (annual average daily traffic)
6) Length of Alternative Road

10 points are given as maximum for this rating.

Above information collected shall was recorded in From F of Slope Inspection Sheet, Countermeasure and Consequential Factor sheet.

Danger to building occupant, Angle β, Failure size and Construction period of temporary diversion shall be estimated on the site by the inspector. The information of Volume of traffic and Length of Alternative Road shall be obtained from JKR and filled after the site inspection. Following two things shall be taken note.

Danger to building occupant

Yes or No is required for Form F considering any building in 2H distance from toe of the slope, however Form E requires the kind of building.

Construction Period of Temporary Road

This can be tentatively decided by the location of disaster. If the road can collapsed by the disaster, construction period of temporary road can not be less than one day. If debris such as soil or rock fragments cover the road only, it takes less than one day.

3.3.3 Proposed Countermeasure and Cost Estimation

Comprehensive evaluation of countermeasure should be carried out by professional engineers, in consideration of the disaster causes and impact, the effects of the existing countermeasure works and the circumstances around the site, to suggest maintenance plans for each site, including:

1) Where some factors leading presumable to road disaster are recognized, such site needs Additional Countermeasures.
2) Where additional countermeasures are considered necessary in the future, such site should be managed by Preparation of Engineer Inspection for Maintenance.
3) Where no factor leading presumable to road disaster is observed, such site has no need for additional Maintenance.

The proposed countermeasures shall be filled in Form A by the inspector on the site.

The estimation of countermeasures should correspond to the occurrence mechanism and mode of a given unstable slope. Careful considerations should be made especially over items expected such as rainfall, scale and type of slope failure, movement speed and geological and topographical characteristics of unstable slopes. For example, where slope failure is closely related to the rainfall, surface and subsurface drainage should be implemented immediately to preventing seepage of the short rainfall water into the unstable block. Also, comparing the economy, effectiveness, environment and appearance should be considered in the estimation of countermeasures.

Since the estimation of countermeasure is, however, the part of routine site inspection work in limited time schedule, it could be a tentative proposal.

The main purpose of estimation of countermeasure is not for the detail design of countermeasure but for estimation of the budget of road maintenance. Enter proposed countermeasure and quantity based on the countermeasure estimation table bellow. Cost also specified in the table.

Table 3.3.3 Countermeasure Options

Work Item	ID	Countermeasure (Type of works)	Description (Specification)	Unit	Rate (RM)
1 Earthwork	11	Removal	--	m^3	2.00
	12	Rock Cutting	Rock Excavation	m^3	15.00
	13	Rock Pre-Splitting	Rock Blasting	m^2	70.00
	14	Soil Cutting	Soil Excavation (bulk quantity)	m^3	5.00
	15	Embankment	Backfill & Import Suitable Fill	m^3	8.00
2 Vegetation	21a	Re-Vegetation	Supply & lay spot turfing including 100mm thick top soil	m^2	3.00
	21b	Re-Vegetation	Close turfing	m^2	3.50
	22	Hydroseeding	--	--	2.50
3 Water Drainage	31	Drain Ditch and Cascade	Concrete G15 cast-in-situ at any inclination along the berm of slopes including excavation, BRC A7 joints with existing drain	m	160.00
	32a	Subsoil Drainage Hole	Layer of coarse sand as subsoil drainage blanket	m^3	35.00
	32b	Subsoil Drainage Hole	Approved filter media layer	m^3	45.00
	33a	Horizontal Drain Hole	Supply, drill & install ϕ 75mm perforated PVC pipe wrapped with a layer of Geotextile filter fabric of 3.0m into rock slopes	nos.	450.00
	33b	Horizontal Drain Hole	Supply, drill & install ϕ 50mm perforated PVC pipe wrapped with a layer of Geotextile filter fabric of 9.0m length including construct drain outlet to existing berm drain	nos.	600.00
	34	Drainage Well	(To be estimated each case)	--	--
	35	Drainage Tunnel	(To be estimated each case)	--	--
4 Slope work	41a	Shotcrete (Mortar)	Minimum 75mm thickness shotcrete facing c/w one layer welded steel mesh ; supply BRC, ϕ 50mm PVC pipe with geotextile	m^2	100.00
	41b	Shotcrete (Mortar)	Minimum 125mm thickness shotcrete facing c/w two layers welded steel mesh	m^2	150.00
	42	Shotcrete (Concrete)	--	m^2	300.00
	43	Cribwork (Precast)	--	m^2	200.00
	44	Stone Pitching	--	m^2	500.00
5 Anchoring	51a	Soil Nailing	60 kN working load with minimum required length of 6 m inclusive of 0.5 m fixed length into rock	nos.	600.00
	51b	Soil Nailing	--ditto—with minimum required length of 9m	nos.	850.00
	51c	Soil Nailing	--ditto—with minimum required length of 12m	nos.	1,200.00
	51d	Soil Nailing	--ditto—with minimum required length of 12m in soil	nos.	1,000.00
	52	Rock Bolt	200 kN working load with minimum required length of 4.0 m	nos.	1,500.00
	53	Ground Anchor	Design & construct post-tensioned trial permanent ground anchors ; 300 kN working load	nos.	5,000.00
6 Wall	61a	Gabion Wall	Galvanized (For dry application)	m^3	45.00
	61b	Gabion Wall	PVC coated (For wet condition)	m^3	65.00
	62	Stone Pitching	--	m^3	70.00
	63	Concrete Block Wall	Precast concrete block	m^3	280.00
	64	Retaining Wall (Supported Type)	Concrete + reinforcement	m	400.00
	65a	Crib Wall (Precast)	Single header (4.5 m – 5.0 m)	m	210.00
	65b	Crib Wall (Precast)	Double header (5.0 m – 8.0 m)	m	300.00
	65c	Crib Wall (Precast)	Triple header (8.0 m – 12.0 m)	m	500.00
	66	Pile Wall (PC / RC)	Spun pile ϕ 800 mm : Supply + install	m	260.00
	67	Pile Wall (PC/RC)	RC pile (400 x 400) : Supply + install	m	110.00
	68a	Pile Wall (in-place)	Bored pile ϕ 600 mm : Concrete + Reinforcement + Link + Boring	m	170.00
	68b	Pile Wall (in-place)	Bored pile ϕ 750 mm : Concrete + Reinforcement + Link + Boring	m	250.00
	68c	Pile Wall (in-place)	Bored pile ϕ 900 mm : Concrete + Reinforcement + Link + Boring	m	350.00
	68d	Pile Wall (in-place)	Bored pile ϕ 1,050mm: Concrete + Reinforcement + Link + Boring	m	450.00
	69a	Pile Wall (Steel Sheet Pile)	Supply & deliver to site Type FSP IIIA steel sheet pile	kg	2.10
	69b	Pile Wall (Steel Sheet Pile)	Handle, pitch and drive steel sheet pile	nos.	100.00
7 Pilling	71	Steel Pipe Pile	Steel pipe ϕ 400 mm	m	2,000.00
	72	H Steel Pile	H steel (400 x 400) --	m	2,000.00
	73	Shaft Work for Resistance Slide	(To be estimated each case)	--	--
8 Protection Work	81	Rock Fall Catch Net	--	m^2	100.00
	82	Rock Fall Catch Fence	Supply & erect PVC coated chain link fence including concrete kerbs, posts, structs, staining wires, barbed wires etc. (Reservoir compound)	m^2	200.00
	83	Rock Shed	--	m^3	400.00
	84	Debris Shed	--	m^3	400.00
	85	Slit Dam	--	m^3	300.00
	86	Check Dam (Sabo Dam)	--	m^3	300.00
9 Others	91	Diversion (Shifting)	(Earth work and structure work should be estimated each case)	m	300.00
	92	Route Relocation	(To be estimated each case)	m	

3.3.4 Methodology of Slope Inspection

The slope inspection was performed based on "Guide to Slope Inspection" attached.

(1) Preparation

Prior to the site work, topographic maps (scale 1:5,000), aero photographs and geological maps (scale 1:200,000) were collected and studied the condition of topography, geology, land cover, slope. Also locations of landslide and debris flow were studied prior to the site work.

(2) Criteria for Slope Selection to Inspect

Following criteria for disaster types were adapted to the slope selection.

1) Collapse / Rock fall

Inspection slopes for rock fall and collapse should meet at least one of the following:

a) The cutting or natural slope of over 15 m high, or the natural slope of over 45° in gradient.
b) The slope covered with loose rocks or boulders.
c) The slope contains soil, rocks and structures, which are susceptible to collapse.
d) The existing countermeasure works are getting deteriorated and their effectiveness needs to be examined.

2) Rock Mass Failure

Inspection slopes for Rock Mass Failure are the cutting or natural rock slopes of over 15 meters high, regardless of implementation of the shed works over the corresponding slopes.

3) Landslide

Landslide shall be searched on aero-photos and topographic maps prior to the site inspection. Active landslide shows usually anomaly of topographical features or vegetation features on aero-photo and disturbed contour lines on topographic map usually. On the site, the inspection on Landslide shall be done on the location picked up.

4) Debris flow

Inspection slopes for debris flow are mountain river and stream that cross the road and meet all the following conditions.

a) The road crosses the stream over a bridge, a box culvert, ford excluding the cases that the road traverses a stream through a tunnel or the girder of a bridge is over 10 m in height and the water channel is over 20 m in width.
b) The catchment area pertaining to the road is over 1 ha (0.01 km2).
c) The bed slope at the crossing point is greater than 2 degrees.
d) The highest upstream gradient of the streambed is greater than 10 degrees.

5) Embankment

Embankment which are over 5m in height and meet at least one of the following criteria;

a) Particular conditions or features of base ground such as landslide, concave feature, talus slope, steep slope, riverside, bottom of ravine, reclamation land, swap or soft soil land, abutment of bridge.

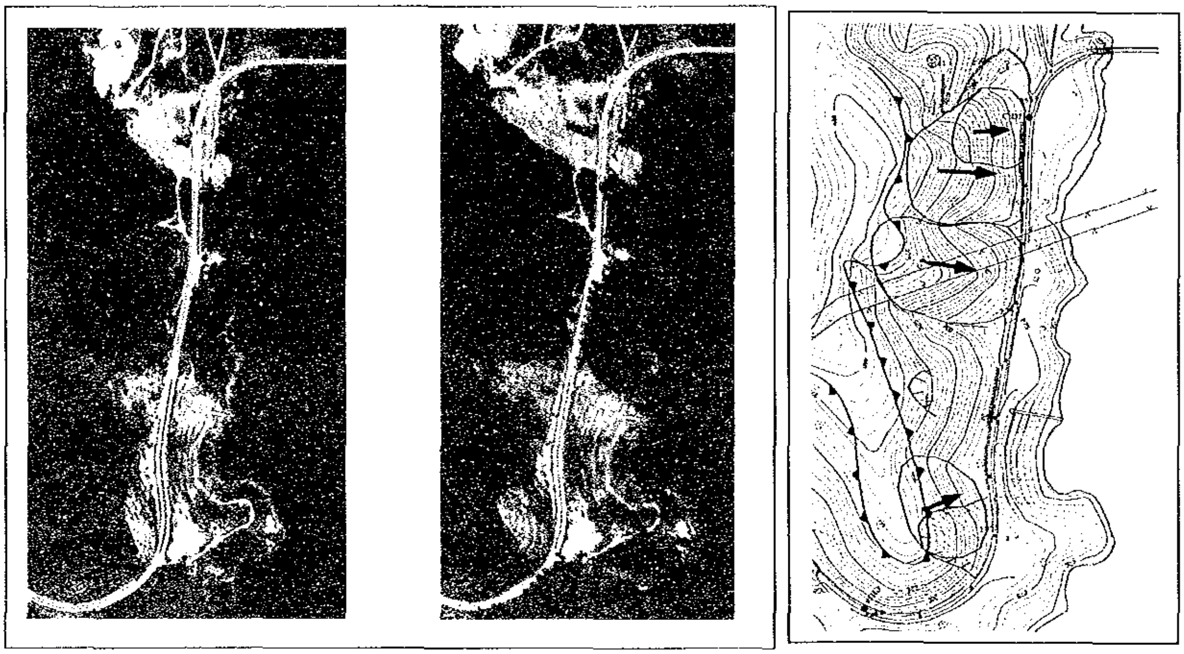
b) Embankment where drainage facilities are defective

A slope, when corresponding to (a) or (b) below, should be also inspected even if it is inapplicable to any of the criteria 1) to 5) above.

(a)The site has obvious factors leading presumably to a road disaster.

(b)The previous disaster records imply a need for inspection.

According to the methodology to identify slopes to inspect, aerial observation was carried out in the office using aerial photograph produced in the case study. Some landslide was found but no debris flow probability was found in this observation.



(a) Aero-photographs(Stereo View) (b) Results

Figure 3.3.3 Example of Ariel Photograph Observation

Example of aerial photograph observation and checking landslide probability are shown in the Figure 3.3.3 and Table 3.3.4.

Table 3.3.4 Example of Aerial Photograph Interpretation and Judgement of Landslide (East-West Highway)

No.	Map No	Chainage Start	Chainage End	Side	Geology	Topography	Width (m)	Length (m)	Depth*1 (m)	Volume*2 (m^3)	Description	Decision	No.
1		25.00	25.20	R	Sedimentary Rock	Convex	200	200	20	267,000	Small Collapse, Crack	○	
2		26.50	27.10	LR	Sedimentary Rock	Straight	600	500	60	6,000,000		×	
3		27.00	27.10	R	Sedimentary Rock	Straight	100	100	10	33,000	Collapse Occur	○	
4	1	28.63	28.70	R	Sedimentary Rock	Concave	70	100	7	16,000	Flat	×	LS1
5		28.63	28.83	R	Sedimentary Rock	Convex	200	180	20	240,000	Hard Rock	×	LS2
6		28.86	29.18	R	Sedimentary Rock	Convex	320	250	32	853,000	Hard Rock	×	LS3
7		28.88	29.13	R	Sedimentary Rock	Convex	250	120	25	250,000	Hard Rock	×	LS4
8		32.10	32.20	R	Sedimentary Rock	Convex	100	200	10	67,000	Hard Rock	×	LS5
9		32.20	32.30	R	Sedimentary Rock	Convex	100	200	10	67,000	Hard Rock	×	LS6
10		32.40	32.75	R	Sedimentary Rock	Straight	350	400	35	1,633,000		×	
11		36.20	36.40	L	Sedimentary Rock	Convex	200	150	20	200,000		○	
12	2	36.65	36.83	L	Sedimentary Rock	Convex	180	250	18	270,000	Hard Rock	×	LS7
13		36.83	37.05	L	Sedimentary Rock	Convex	220	200	22	323,000	Hard Rock	×	LS8
14		36.83	37.00	L	Sedimentary Rock	Convex	170	150	17	145,000		○	
15		36.93	37.05	L	Sedimentary Rock	Straight	120	120	12	58,000	Hard Rock	×	LS9
16		38.67	38.77	R	Sedimentary Rock	Concave	100	100	10	33,000	Flat	×	LS10
17		38.77	39.07	R	Sedimentary Rock	Convex	300	180	30	540,000	Hard Rock	×	LS11
18		39.10	39.35	LR	Sedimentary Rock	Concave	250	300	25	625,000		×	
19	3	39.46	39.68	R	Sedimentary Rock	Convex	220	150	22	242,000	Hard Rock	×	LS12
20		41.28	41.40	R	Sedimentary Rock	Convex	120	240	12	115,000	Hard Rock	×	LS13
21		41.70	41.98	R	Sedimentary Rock	Convex	280	200	28	523,000	Hard Rock	×	LS14
22		43.30	43.52	L	Sedimentary Rock	Convex	220	80	22	129,000	Hard Rock	×	LS15
23	4	43.30	43.58	L	Sedimentary Rock	Concave	280	150	28	392,000	Flat	×	LS16
24		44.18	44.28	L	Sedimentary Rock	Concave	100	60	10	20,000	Flat	×	LS17

(3) Site Record

1) Sheet

Form E of Collapse, Rock Fall, Rock Avalanche and Embankment shall be completed on the site. Form E of Landslide and Debris Flow might be checked partially on the site and completed in house.

2) One Slope

One Slope means continuous sections where topographical feature and design condition of countermeasure are same.

3) Slope ID

The new Slope ID, which has twelve figures, is defined based on the road number, chainage, side, and slope feature.

Example : Slope ID = **0004/056/700RC**

0004:	Road number, Federal Road 04
056/700:	Chainage at starting point (56.700km)
R:	Right side of road, (L: left side of road)
C:	Cut feature, (E: embankment, N: natural slope)

(4) *Skip of inspection*

If the slope height is more than 15m or the embankment height is more than 5m, the slope inspection shall be continued.

(5) Sketch

Sketch the slope overview and section.

Specify;

1. Height of slope
2. Width of slope
3. Angle of slope
4. Geology
5. Weathering grade
6. Discontinuity type
7. Major crack
8. Structures on slope
9. Trace of collapse
10. Other information

(6) Photo

Take at least two photos by digital camera, one is overview and the other one is showing any special feature of slope. (Photograph) was taken by digital camera and downloaded into the computer at the end of day.

All photos shall be taken with scale, such as measuring tape, measuring staff or man.

(7) Landslide and Debris Flow

Most of the forms in Inspection Sheets are shall be filled except Form E4 and Form E5. To fill in the form E of Landslide and Debris Flow, Form E3 and Form E4, desk work is necessary after completion of site work. As it is difficult to obtain the condition of catchment area by site inspection, aerial photographs and maps are important material in evaluating the risk of debris flow.

3.3.5 Result of Slope Inspection

(1) Number of Slopes Inspected

Slope Inspection was executed by Gue & Partners Sdn. Bhd. under supervision of JICA Study Team using the old inspection sheets.

The slope inspection work started on 6 June 2001 and was completed on 15 July 2001. Three (3) teams of engineering geologist were involved in the slope inspection. Each team was divided into three (3) personnel and was given a designated chainage along the East – West Highway to inspect. The study area inspected by the different teams is:

- Team 1 – KM 24.95 until KM 45.30
- Team 2 – KM 45.21 until KM 62.65
- Team 3 – KM 62.65 until KM 82.30

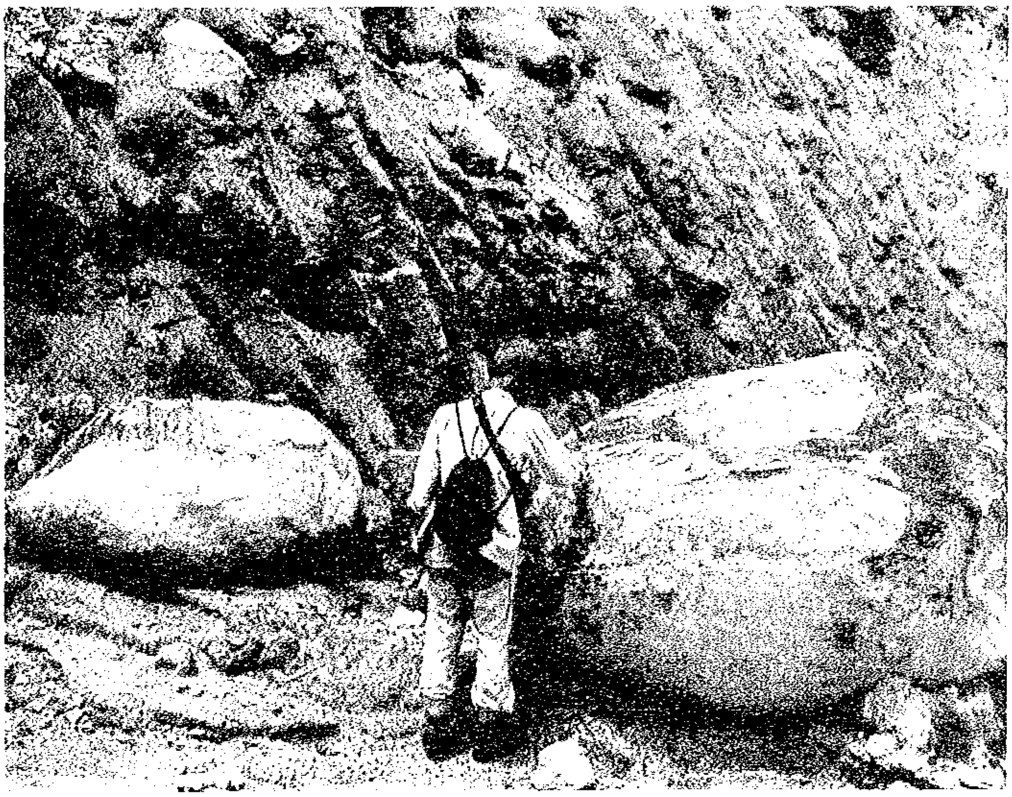


Figure 3.3.4 Slope inspection

Total 767 slopes were checked on the site and 471 slopes are inspected. 296 of remains were not inspected because of low height slope (less than 15 m cut slope or less than 5 m embankment). All data collected in the slope inspection are input into the SIMS which will be able to show the detail result of the slope inspection.

The summary of the completion of slope inspection with the associated type of disaster is presented below. Example of Slope Inspection Sheets are attached in Appendix 2-2 of this report. Embankment is the largest number in the disaster type and Collapse and Rock Fall are following.

Collapse	81
Rock Fall	4
Collapse and Rock Fall	102
Rock Mass Failure	11
Landslide	3
Landslide and Collapse	3
Debris Flow	7
Embankment Failure	260
Total	471

(2) Risk Rate

Only three slopes mark over 80 in Risk Rate. There are one hundred seven (107) slopes mark over 50 Risk Rate in total 770 inspection sheets.

Table 3.3.5 Summary of Slope Inspection Result

Type of Slope Failure (Disaster)	Hazard Score										
	≥85	84-80	79-75	74-70	69-65	64-60	59-55	54-50	≤49	no point	Total
Collapse	0	0	1	4(3)	3	5	13	7	51		84
Rock Fall	0	0	0	0	0	0	1	1	2		4
Collapse / Rock Fall	0	1	3	1	4	6	10	6	71		102
Rock Mass Failure	0	0	0	2	2	2	2	1	2		11
Landslide	1	1	1	1	0	0	0	0	2		6
Debris Flow	0	0	0	0	0	1	0	0	6		7
Embankment	0	0	1	0	4	2	9	14	230		260
Out of Inspection										296	296
Total	1	2	6	8(3)	13	16	35	29	364	296	770

* ( ) : number of slopes counted both Collapse and Landslide

Countermeasure

The results from the slope inspection will provide a general cost estimate for any proposed countermeasure required for the slopes. The cost estimate is shown in Form A of the Slope Inspection Sheet. The typical rates for the types of various measures use for calculation the cost in Form A is shown in Table 3.3.3. It is important to be aware the proposed countermeasures and cost estimation are based on direct observation by the engineering geologist during inspection of the slopes. It is conceptual and crude proposal before taking into consideration of engineering aspects such as analysis and design. Therefore it shall not be relied upon completely for budget or planning but should treat as information for some of the possible measures that can be considered. Further subsurface investigation survey, geotechnical analysis and design are required before preliminary design can be produced for budget and planning. Detailed geotechnical design is required before construction of the measures works can be carried out at the site. The countermeasures for slopes above 65 in risk rate are listed in Table 3.3.6

The identification of slopes in this study with high hazard score will allow the priority of immediate remedial works compared to slopes with low hazard score.

(3) Hazard Score

The relation between Hazard Score and height of slope, average angle of slope are shown on Figures 3.3.5 to 3.3.6. The relations are not seen clearly.

In less than 40m height of slopes, higher slopes may tend to be higher hazard score as shown on Figure 3.3.5. Also in under 45 deg. of slopes, steeper slopes may tend to be higher hazard score as shown on Figure 3.3.6.

The relations between geology and disaster type are shown on Figures 3.3.7 and 3.3.8. The relations are not clear on the figures. However, Granite, Quartzite and Rock Fall, Debris Flow have comparatively low score.

Table 3.3.6 List of Risk Rate and Countermeasure

Line No	Slope ID	New Score ID	Type of Slope	Type of Failure	Hazard Score	Conse-quence	Risk Rating	Proposed Countermeasure: Countermeasure	ID	quantity	unit	unit rate	cost	total cost
1	-	F04/071.50RC	1	4 (LS)	85	8	85	Cut slope to gentle - rock	12	110,000	m3	15.00	1,650,000	
				1 (CL)	72	8	73	Cut slope to gentle - soil	14	110,000	m3	5.00	550,000	
								Horizontal drainage 50m * 9nos	33a	150	/3m	450.00	67,500	
								berm drain	31	1,000	m	160.00	160,000	2,427,500
2	1091	F04/081.15LC	1	4 (LS)	85	7	84	Counter weight embankment	15	16,500	m3	8.00	132,000	
				1 (CL)	71	7	71	Horizontal drainage	33a	150	/3m	450.00	67,500	
								Rock Cutting	12	22,500	m3	15.00	337,500	
								Re-cutting of berms	14	6,000	m3	5.00	30,000	
								berm drain	31	1,000	m	160.00	160,000	727,000
3	385	F04/031.46RC	1	1 (CL)	82	7	81	Remove unstable hanging rock	12	293	m3	15.00	4,395	
								Construct staging mansonar H=50m L=5m	62	500	m2	70.00	35,000	
								Put gabion at the toe of the slope H=2m L=400m	61a	1,600	m3	45.00	72,000	
								Construct berm drain in every berm (V shape) width= 1m	31	1,000	m	160.00	160,000	
								Vegetation	21b	24,440	m2	3.50	85,540	356,935
4	396	F04/032.08RC	1	1 (CL)	79	7	78	Netting Area: 50mx 120m	71	6,000	m2	100.00	600,000	
								rock bolts 5m Interval : Area: 50mx 120m	52	240	no.	1,500.00	360,000	
								Construct a staging masonry H: 25m L: 10m	62	500	m3	70.00	35,000	995,000
6	-	F04/072.68LC	1	4 (LS)	77	8	77	cut slope to gentle above first berm	12	36,000	m3	15.00	540,000	
				1(CL)	73	8	74	Put the berm drain	31	704	m3	160.00	112,694	
								vegetation	21b	6,260	m2	3.50	21,911	674,606
6	416	F04/033.30RC	1	1 (CL)	79	6	77	Splitting rock blocks	13	15	m3	70.00	1,050	
								Cut off hanging rocks	11	15	m3	15.00	225	
								Construct berm drain in every berm (V shape) width= 1m	31	500	m	160.00	80,000	
								Vegetation	21b	11,280	m2	3.50	39,480	120,755
7	392	F04/031.92RC	1	3(RM)	77	7	76	Remove unstable /overhang rock (2m*1m*5m)=10m3	13	10	m3	70.00	700	
									12	10	m3	15.00	150	
								Netting, (area of netting A= 50x30= 1500)	71	1,500	m2	100.00	150,000	
								Rock bolts (area of netting A= 50x30= 1500)	52	94	no.	1,500.00	140,625	
								Put gabion at the toe of slopes H=3m L=50m	61a	225	m3	45.00	10,125	
								Put berm drain (V shape W.1m L.50m)	31	50	m	160.00	8,000	309,600
8	-	F04/060.52LC	1	1 (CL)	77	7	76	Slope work- cut, etc (for existing slope)	12	120,000	m3	15.00	1,800,000	
								Construct berm drain in every berm (V shape) width= 1m	31	1,507	m	160.00	241,067	
								Vegetation	21b	19,200	m2	3.50	67,200	2,108,267
9	647	F04/050.90RC	2 (EB)	6 (EB)	75	8	76	Earthwork- refill the material 800m3	15	13,125	m3	8.00	105,000	
								Berm drain (L=120mx4 berm)	31	480	m	160.00	76,800	
								Cascade drain :100m	31	100	m	160.00	16,000	
								Vegetation- plant grass: 100m2	21b	2,625	m2	3.50	9,188	206,988
10	432	F04/035.53LC	1	3 (RM)	74	6	73	Slope work- cut, above third berm + additional	12	30,300	m3	15.00	454,500	
								Construct berm drain in every berm (V shape) width= 1m	31	1,489	m	160.00	238,272	
								re-vegetation	21b	18,612	m2	3.50	65,142	
								Rubble wall	63	1,930	m3	280.00	554,400	1,312,314
11	441	F04/036.14LC	1	4 (LS)	69	8	70	Re-cut and remove the unstable rock and soil	12	76,667	m3	15.00	1,150,000	
								Construct berm drain in every berm (V shape) width= 1m	31	1,320	m	160.00	211,200	
								Vegetation	21b	19,200	m2	3.50	67,200	1,428,400
12	332	F04/027.35RC		1(RM)	70	7	70	Remove unstable rock (Volume: 33m3)	12/13	33	m3	95.00	3,135	
								Construct a berm drain at every berm, width: 1m L 200m	31	767	m	160.00	122,667	
								Construct a staging masonry at collapse place (H. 5m L: 4m	62	20	m3	70.00	1,400	
								re-vegetation	21b	19,200	m2	3.50	67,200	191,267
13	433	F04/027.91RC	1	1 (CL)	71	6	70	Re-cut above second berm	12	12,810	m3	15.00	192,150	
								Construct berm drain in every berm (V shape) width= 1m	31	100	m	160.00	16,000	
								Vegetation	21b	1,904	m2	3.50	6,662	214,812
14	474	F04/038.80RC	1	1	72	6	70	re-cut to 45 deg. From Ch. 38.800 - 38.900	12	8,800	m3	15.00	132,000	
								Construct berm drain in every berm (V shape) width= 1m	31	693	m	160.00	110,933	
								re-vegetation	21b	6,110	m2	3.50	21,385	264,318
15	442	F04/032.95RC	1	1 (CL)	71	5	69	re-cut to 45 deg.	12	6,559	m3	15.00	37,880	
								Construct berm drain in every berm (V shape) width= 1m	31	347	m	160.00	55,467	
								re-vegetation	21b	2,513	m2	3.50	8,797	152,143
16	468	F04/038.53LE	2 (EB)	6 (EB)	68	7	68	Earthwork- refill the material: 800m3	15	850	m3	8.00	6,800	
								Berm drain (L=140mx4 berm)	31	560	m	160.00	89,600	
								Cascade drain :100m	31	100	m	160.00	16,000	
								Vegetation- plant grass: 100m2	21b	4,606	m2	3.50	16,121	
								stone pitching for wave absorb	62	4,200	m3	70.00	294,000	422,521
17	533	F04/42.38LC	1	1 (CL)	69	6	68	Gabion (H=2m, L=50m) Ch. 42.4-42.45	61a	200	m3	45.00	9,000	
								Stone pitching in gully erosion with cascade drain (H=15m,	62	60	m3	70.00	4,200	
								Stone pitching on surface collapse (3mx3m)x3	62	27	m3	70.00	1,890	
								Berm drain	31	560	m	160.00	89,600	
								re-vegetation	21b	7,238	m2	3.50	25,333	130,023
18	1083	F04/080.70RE	2 (EB)	6 (EB)	70	5	68	Refill soil	15	900	m3	8.00	7,200	
								Gabion	61a	300	m3	45.00	13,500	
								Protection work-stone pitching (after gabion) (3mx10m)	62	90	m3	70.00	6,300	
								Surface Drainage- especially cascade to divert water from	31	75	m	160.00	12,000	
								Berm drain (L=120mx4 berm)	31	480	m	160.00	76,800	115,800
19	346	F04/028.24RC	1	1 (CL)	69	5	67	Remove detached blocks (50m3)	11/13	50	m3	72.00	3,600	
								Catch wire net (3000m2)	71	3,000	m2	100.00	300,000	
								Gabion	61a	1,170	m3	45.00	52,650	356,250
20	628	F04/049.68RE	2 (EB)	6 (EB)	65	7	66	Gabion (H=2m, L=100m)	61a	400	m3	45.00	18,000	
								Stone pitching in gully erosion with cascade drain (H=15m,	62	60	m3	70.00	4,200	
								Stone pitching on surface collapse (3mx3m)x3	62	27	m3	70.00	1,890	
								Berm drain	31	373	m	160.00	59,733	
								re-vegetation	21b	3,290	m2	3.50	11,515	95,338
21	1019	F04/076.10LE	2 (EB)	6 (EB)	65	7	66	Drainage-berm, cascade and horizontal drain (New and	31	1,900	m	160.00	304,000	
								Retaining- repair and add gabion	61a	1,600	m	45.00	72,000	
								Slope work- construct crib with soil nail	51a	1,250	nos	600.00	750,000	1,126,000
22	435	F04/035.86LC	1	3 (RM)	66	6	65	Remove the unstable rock	11/13	50	m3	72.00	3,600	
								Netting- 50mx40m=200m2	71	200	m2	100.00	20,000	
								Drainage and cascade- 50m+60m+80m	31	210	m	160.00	33,600	57,200
23	-	F04/072.41LC	1	1 (CL)	66	6	65	berm drain	31	1,215	m	160.00	194,400	
								Cascade= 40m	31	40	m	160.00	6,400	
								Vegetation= L=270mx H=40m)	21B	10,800	m2	3.50	37,800	238,600
24		F04/027.68RC	1	1	67	5	65	Re-cutting of berms	14	360	m3	5.00	1,800	
								Berm drain	31	360	m	160.00	57,600	
								Cascade	31	90	m	160.00	14,400	73,800
25	452	F04/036.83LC		3	64	7	65	Remove unstable rock (Volume: 65m3)	13/11	65	m3	72.00	4,680	
								netting area = 6500m2	71	6,500	m2	100.00	650,000	654,680
26	466	F04/038.31RC	1	1 (CL)	65	6	65	remove unstable rocks 10m3	13/11	10	m3	72.00	720	
								gabion 160m * 3m	61a	1,440	m3	45.00	64,800	
								plaster the gully trace with dental concrete	41a	254	m2	100.00	25,380	
								berm drain	31	979	m	160.00	156,715	247,615
27	537	F04/042.71LC	1	1 (CL)	65	6	65	remove unstable rocks 10m3	13/11	10	m3	72.00	720	
								gabion 250m * 3m	61a	2,250	m3	45.00	101,250	
								plaster the gully trace with dental concrete	41a	761	m2	100.00	76,140	
								berm drain	31	511	m	160.00	81,803	259,913
								Total						15,267,641

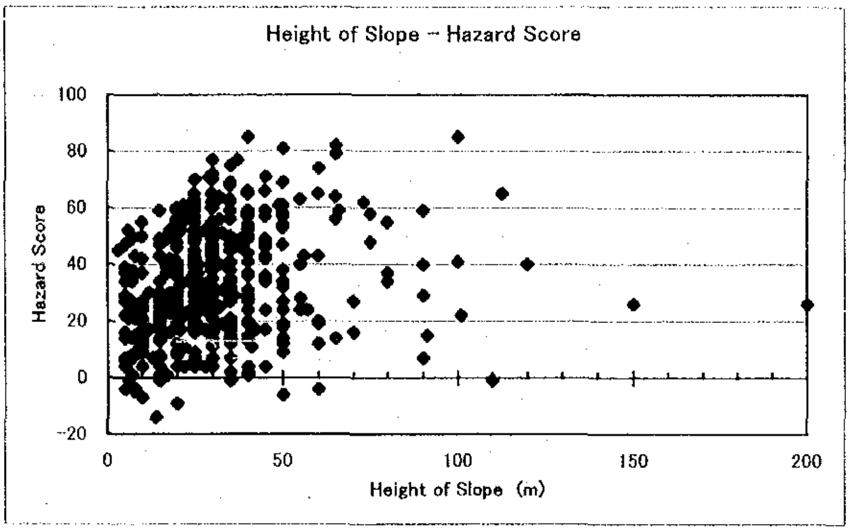


Figure 3.3.5 Height of Slope – Hazard Score

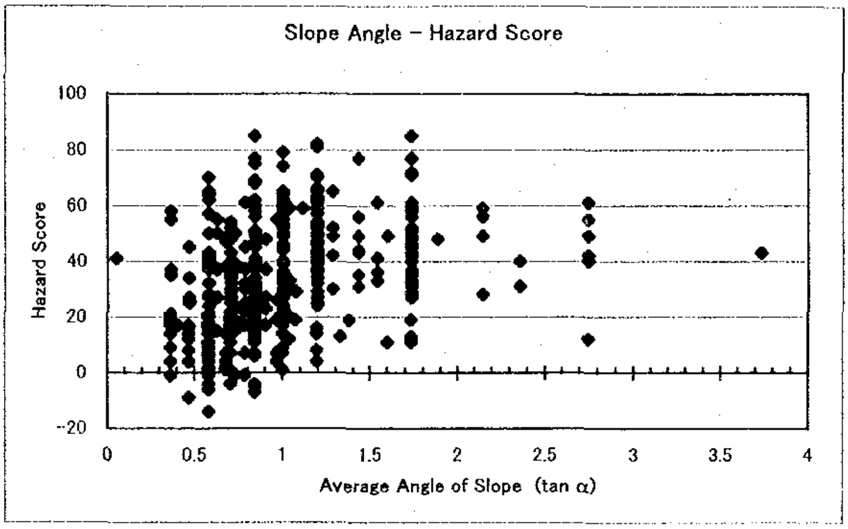


Figure 3.3.6 Average Angle of Slope – Hazard Score

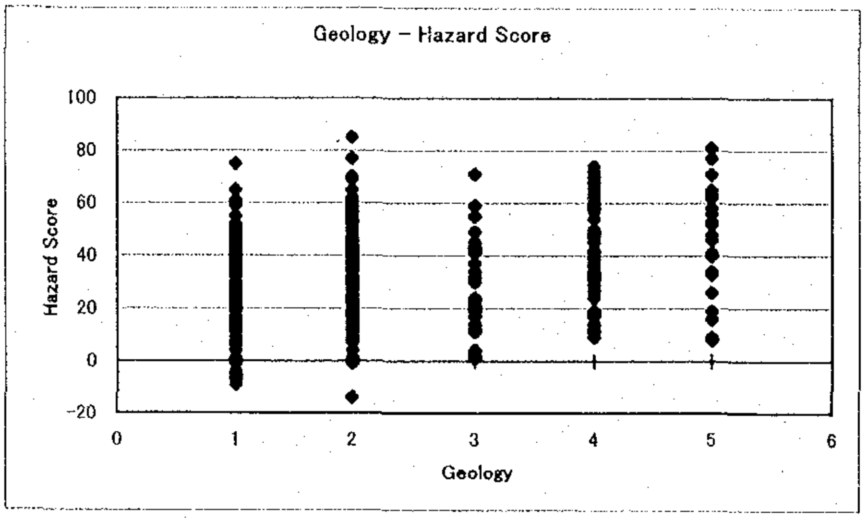


Figure 3.3.7 Geology – Hazard Score

1. *Granite*
2. *Schist*
3. *Quartzite*
4. *Phyllite*
5. *Sandstone*

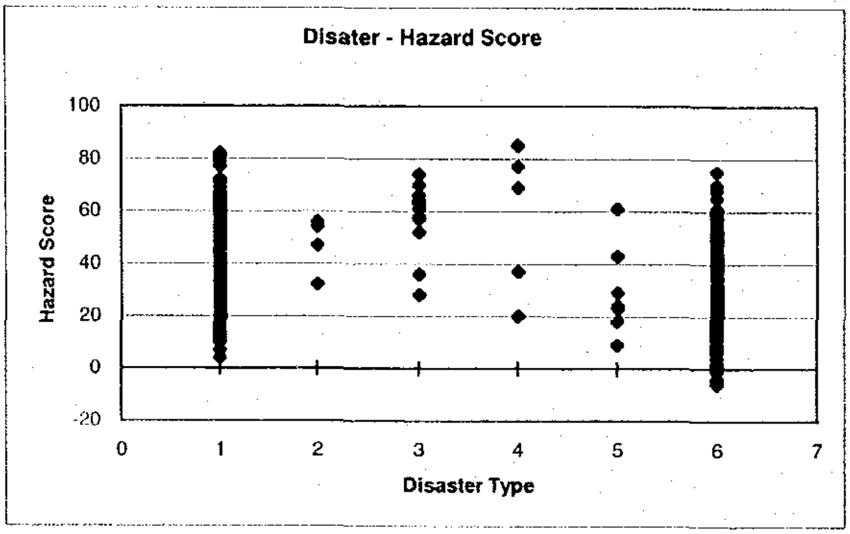


Figure 3.3.8 Disaster Type – Hazard Score

1. *Collapse*
2. *Rock Fall*
3. *Rock Mass Failure*
4. *Landslide*
5. *Debris Flow*
6. *Embankment Failure*