Chapter 7

Database System for Road Disaster Prevention

Chapter 7 Database System for Road Disaster Prevention

7.1 Introduction

7.1.1 Background of the Development of Database System

In order to formulate the road disaster prevention plan, an analysis of the accumulated road disaster records and the recognized critical spots on the national roads is the fundamental. However, ABC has not established the database system for the road disaster prevention. Since this project was commenced, the discussion about road disaster prevention management manual has been made among the organizations concerned. Besides, in order to reflect to the formulation of road disaster prevention plan, the field survey of actual condition of the road hazards was carried out and the results of the survey have been recorded as a diagnosis card by the staff of ABC and Study team. Through these activities in the 1st Field Study in Bolivia, the necessity of the development of the database system for the road disaster prevention has been recognized among organizations concerned.

The database system for planning and management of national road named GIAS (Geographic Information and Analysis System) was installed in ABC headquarters in the year of 2000 and has been operated. Considering the possibility of integration with the GIAS, the database for road disaster prevention has been developed under the close cooperation in the 2nd Field Study in Bolivia. The database system developed is also utilized as a tool for the Capacity Development of ABC.

7.1.2 Activities Carried Out

Considering the background of the development of database system, activities mentioned below have been carried out.

(1) Development of the Database of Diagnosis Card for Road Disaster

The Diagnosis Card including road disaster records created based on the result of site survey during the 1st Study in Bolivia, have been transferred to the MS-Access and to the GIS (Geographical Information System). This database is independent from other database system named “Database of Register of Road Disaster” created in the Study.

(2) Development of the Database of Register of Road Disaster

In order to keep the record after the road disaster occurred including the result of study for measures in each regional office and headquarters, the database system using MS-Access was developed. The data also can be transferred to GIS. This database will be integrated into the road disaster prevention information network system.

(3) Design Concept for Road Disaster Prevention Information Network System

In order to have effective utilization of the road disaster records for the formulation of the road disaster prevention in the future, the design concept for road disaster prevention information network system is examined based on the results of discussions with ABC.

7.2 Existing Database Systems

7.2.1 Database System at ABC Headquarters

(1) GIAS (Geographic Information and Analysis System)

GIAS was developed on the basis of GIS in the year of 2000 for the purpose of establishment of the support system for the planning of regional transport system and the management of the projects of infrastructure in Bolivia. Functions of the GIAS are as follows:

- Display and analysis of various types of layers including transport network, installation of transport, administrative boundary, environmental protected areas, topographic maps and satellite imagery.
- Administration of SRL (Systema de Referenciacion Lineal), that includes the capacity to create and calibrate routes, display routes and control sections, edit and locate along the route and conversion of the distance in kilometers from geographic coordinates.
- Visualization and analysis of alphanumerical data utilized on transport planning and the inventory of the route information such as the road condition, accidents, projects, transit counting.
- Linking with PMIS (Systema de Informacion de Gerencia de Proyectos, no basado en SIG) for the project management and the availability of the preparation of visualized reports, sketch and aerial photos.
- Visualization and map generation
- Access to metadata of layer.
- Three dimensional display using Arcview 3.2 and Spatial Analyst.

Out of those functions, the system for traffic passable conditions has been operated. The information is basically transferred daily from each Regional office to Headquarters and is opened to public on the ABC web site (www.abc.gov.bo).

The geographical information of main roads utilized in the GIAS has some errors and distortion depending on the area, since the data has been created using various sources i.e. GPS measurement, topography map with the scale of 1:50,000 or 1 to 250,000, and orthophotos.

(2) SAM (Management Administration System)

Management Administration System (SAM) has been introduced to ABC in 80's and utilized to manage the maintenance of national road and the activities of the "Micro Empreza" and other contractors. However, since the Year of 2000 problem was occurred, the operation of the system has been forced to stop. Each Regional office transfers the data to the Headquarters every month by digital media using SAM in regional office basis.

Under these circumstances, ABC has started to develop another system which will be integrated to the existing database GIAS.

(3) Geographical Information

Geographic information in Bolivia has been created by using aerial photos taken in 60's to 70's and administered by IGM (Military Geographical Information). By the middle of 90's, the Bolivian Geographic Coordinate System "PSAD56" had been utilized, thereafter, most recently developed and widely used datum "WGS84 (World Geodetic System of 1984)" has been introduced. This datum is the Earth-centered Geographic Coordinate System, and serves as the framework for locational measurement worldwide.

With regard to the projected coordinate system, since the country land is extended to three UTM (Universal Transverse Mercator) zones, there are errors and distortion between zones. Therefore, the Lambert Conformal Conic, which portrays shape more accurately than area, is commonly utilized as a projected coordinate system in Bolivia.

7.2.2 Database System at ABC Regional Office

During the study, interview to the staff of 4 Regional offices was carried out in order to recognize and evaluate the actual condition of database systems and the operational capability of the system. The results of the interviews are summarized in the *Table 7.2.1*.

Table 7.2.1 Database Systems in Regional Office

	Regional Office	Existing Database	Objective of the Database	No. of SE
1	Beni	"MicroBase" (MS-Access)	Administration of "Micro Empreza"	2
2	Santa Cruz	None	-	1
3	Cochabamba	"Provial" (MS-Access)	Administration of "Micro Empreza"	2
		Improved version of the "SAM"	Preparation of the Information to be transferred to HQ	
4	La Paz	None	-	1

7.3 Database System Developed in the Study

7.3.1 General

Since the road disaster data has not been recorded properly in ABC, as a first step of the establishment of the road disaster prevention information network system, two databases i.e, "Diagnosis card of road disaster" and "Register of road disaster", were developed and integrated into the "PMRD Database". The structure of the "PMRD Database" in shown in *Figure 7.3.1*.

Target user of the database of "Register of road disaster" is the regional office, since the regional office is the practical organization to perform activities such as investigation and study of measures related to the road disaster. Headquarters is required to accumulate and store all data created by each Regional office.

Whereas the target user of the "PMRD Database" is the Headquarters, since the structure of the database is designed to integrate all information related to road disaster.

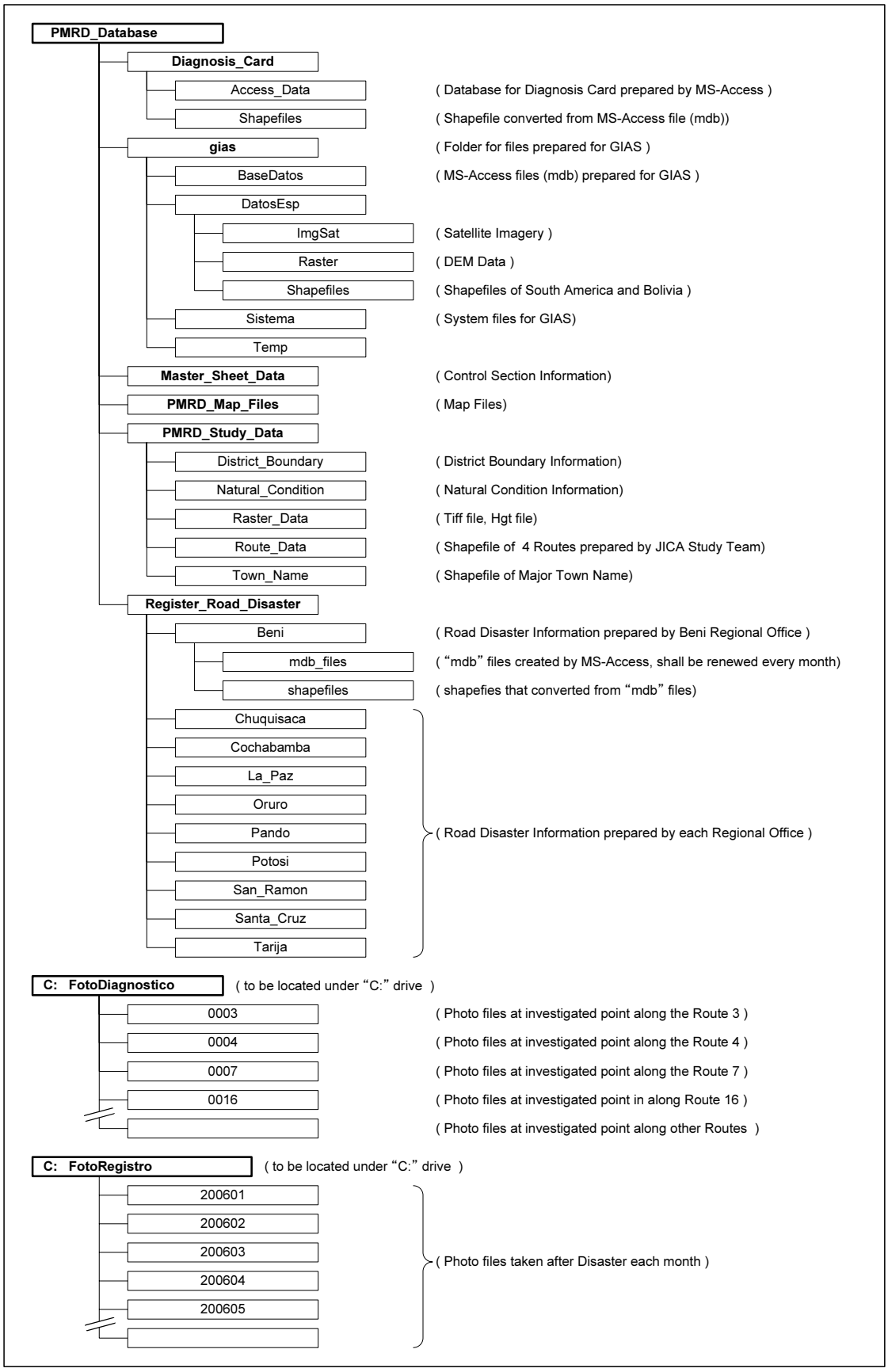


Figure 7.3.1 Structure of PMRD Database

7.3.2 Diagnosis Card Database

(1) Database Developed by MS-Access

The results of the site survey carried out during the 1st study have been entered to the MS-Access. Database is located in the "Access_Data" folder under the "Diagnosis_Card" folder under the "PMRD_Database" as shown in *Figure 7.3.1*. *Figure 7.3.2* shows the example of data input form of the Diagnosis Card Database. This database is preferable to be updated by the geologist of ABC, since the judgment from the geological point of view is required.

Geotechnical explanation of each item of the database is described in the *Chapter 6*.

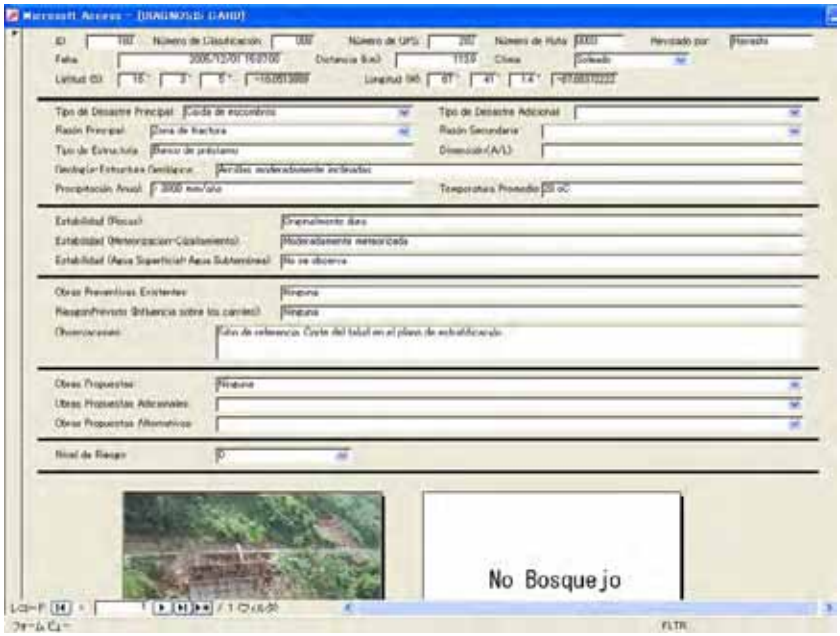


Figure 7.3.2 Example of Data Input Form of Diagnosis Card Database

(2) Database Developed by Geographical Information System (GIS)

Information of the Diagnosis Card has been transferred to the GIS, ESRI ArcGIS 9. No linkage is set up between GIS and MS-Access. The "mdb" file created by MS-Access is converted to shapefile in the GIS. The manual for data conversion is mentioned in the *Appendix A*. Applied Geographic Coordinate System is WGS84. The "Diagnosis_Card" map document file (.mxd) that displays data is located in the "PMRD_Map_Files" folder under the "PMRD_Database" folder. Description of each layers in this map document file is mentioned in *Table 7.3.1*.

Table 7.3.1 Description of the Layers in the "Diagnosis_Card" Map Document File

Name of Layer	Description	Type of File	Source
DGCard_06Jun06	Data of Diagnosis Card prepared by the Study Team	Point	Study Team
Bolivia Town	Capital of Department	Point	ABC
Seccionescontrol_actualCopy	Control section of main road in whole country	Polyline	ABC
bolivia	Boundary of Department	Polygon	ESRI
Contour_500m	Contour line with 500m interval	Polyline	Study Team
Contour_100m	Contour line with 100m interval	Polyline	Study Team
Contour_50m	Contour line with 50m interval	Polyline	Study Team
Selected_GPS_Polyline	Routes traced by GPS	Polyline	Study Team
route_geotiff.tif	Geotiff file created from SRTM data	Raster	Study Team

On the display of "Diagnosis_Card" map document file (.mxd), the reference form of the investigated information including photos taken at the site and overlay analysis with other information such as natural condition and environmental condition are available. *Figure 7.3.3* shows the example of opened window of identified result.

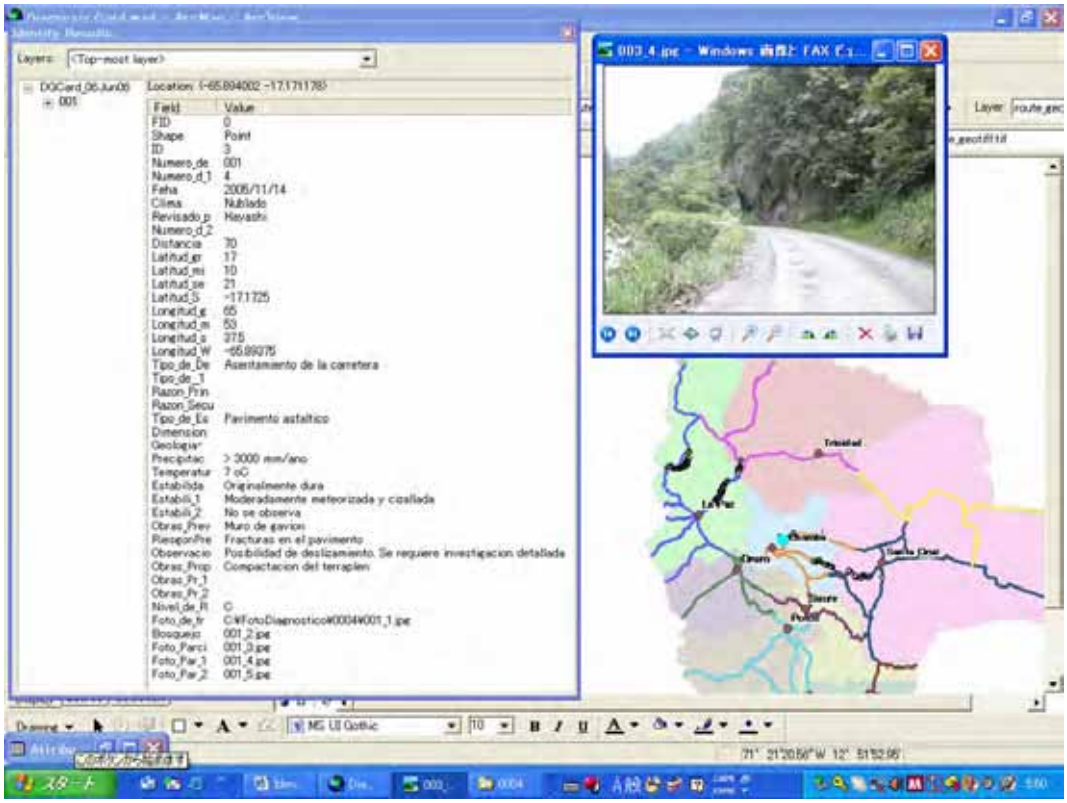


Figure 7.3.3 Example of the Identity Result Window

The description of each field in the Identity Result Window shown in *Figure 7.3.3* is listed in the *Table 7.3.2*.

Table 7.3.2 Description of the Identify Results Window of DGCard_06Jun06 Map Document File in ArcGIS

Field	Description	Data Type
FID	Object ID in ArcGIS	Object ID
Shape	Type of Shapefile in ArcGIS	Geometry
ID	ID Number of Location	Double
Numero_de	Classification Number	Text
Numero_d_1	GPS Number	Double
Feha	Date / Time	Date
Clima	Weather	Text
Revisado_p	Checked by	Text
Numero_d_2	Route Number	Text
Distancia	Distance (km)	Text
Latitud_gr	Latitude (degree)	Double
Latitud_mi	Latitude (minute)	Double
Latitud_se	Latitude (second)	Double
Latitud_S	Latitude (degree in decimal)	Double
Longitud_g	Longitude (degree)	Double
Longitud_m	Longitude (minute)	Double
Longitud_s	Longitude (second)	Double
Longitud_W	Longitude (degree in decimal)	Double
Tipo_de_De	Disaster Type	Text
Tipo_de_1	Type of Structure	Text
Razon_Prin	Main Reason	Text
Razon_Secu	Secondary Reason	Text
Tipo_de_Es	Type of Structure	Text
Dimension	Dimension (H/L)	Text
Geologia	Geology / Geological Structure	Text
Precipitac	Precipitation, mm/year	Text
Temperatur	Temperature, C	Text
Estabilida	Stability: Rocks	Text
Estabili_1	Stability: Weathering / Shearing	Text
Estabili_2	Stability: Superficial / Underground Water	Text
Obras_Prev	Existent Preventive Works	Text
RiesgoPre	Foreseen Risk	Text
Observacio	Remarks	Text
Obras_Prop	Proposed Works	Text
Obras_Pr_1	Additional Proposed Works	Text
Obras_Pr_2	Alternative Proposed Work	Text
Nivel_de_R	Hazard Level	Text
Foto_de_fr	Front Photograph	Text
Baqquejo	Sketch	Text
Foto_Parci	Partial Photograph 1	Text
Foto_Par_1	Partial Photograph 2	Text
Foto_Par_2	Partial Photograph 3	Text

7.3.3 Road Disaster Database

The database of "Register of Road Disaster" is developed by using MS-Access. This data is entered by the staff of Regional Office when the disaster is occurred and is sent to the Headquarters every month. In the Headquarters, data from Regional Office is kept at each folder under the "Register_Road_Disaster" under the "PMRD_Database" folder as shown in *Figure 7.3.1*. *Figure 7.3.4* shows the example of data input form of the Road Disater Database.

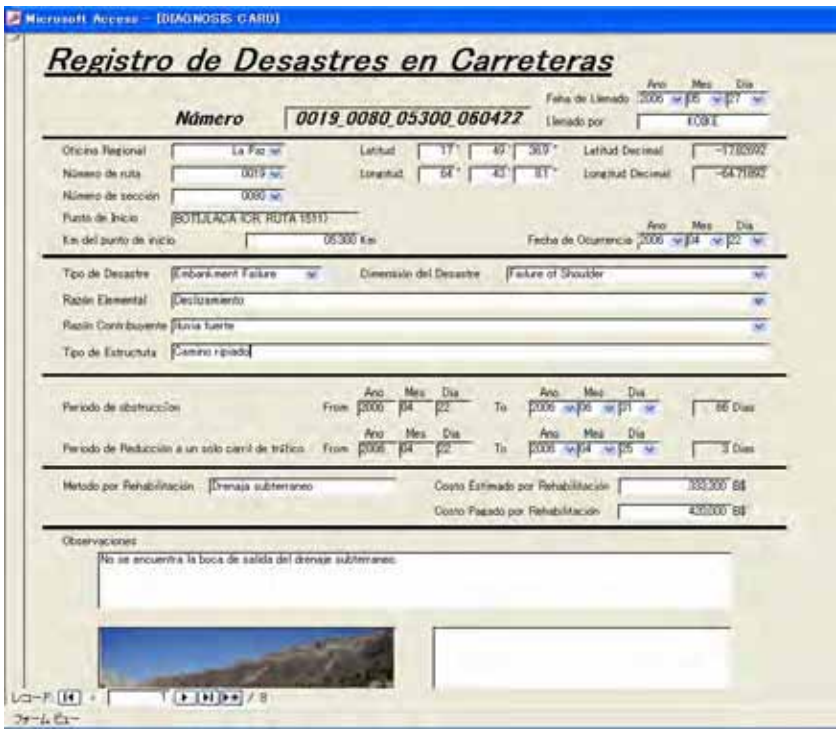


Figure 7.3.4 Example of the Data Input Form of Register of Road Disaster

Information of the Road Disaster is transferred to the GIS, ESRI ArcGIS 9. The "mdb" file is converted to shapefile in the GIS. The manual for data conversion is mentioned in the *Appendix A*. The "Register_Road_Disaster" map document file (.mxd) is located in the "PMRD_Map_Files" folder under the "PMRD_Database" folder. Description of each layers in this map document file is mentioned in *Table 7.3.3.*

Table 7.3.3 Description of the Layers in the "Register_Road_Disaster" Map Document File

Name of Layer	Description	Type of File	Source
RRD_LaPaz and other Dept.	Road Disaster Data of each Department which will be renewed every month	Point	ABC
Bolivia Town	Capital of Department	Point	ABC
Seccionescontrol_actualCopy	Control section of main road in whole country	Polyline	ABC
bolivia	Boundary of Department	Polygon	ESRI
Contour_500m	Contour line with 500m interval	Polyline	Study Team
Contour_100m	Contour line with 100m interval	Polyline	Study Team
Contour_50m	Contour line with 50m interval	Polyline	Study Team
Selected_GPS_Polyline	Routes traced by GPS	Polyline	Study Team
route_geotiff.tif	Geotiff file created from SRTM data	Raster	Study Team

7.4 Examination of the Road Disaster Prevention Information Network System

7.4.1 General

Database system for the preventive measures against road disaster shall have easy access for the renewal and review of data by users to operate system properly and sustainably. In this regard, development of the network system using wide area network (WAN) connecting regional offices and headquarters is the appropriate manner. As a fact, four regional offices interviewed during the study have enough capacity to realize the system from the technical point of view. In addition, the information regarding road disaster shall be open to the public, considering the reason of the existence of ABC. This section describes the examination of the desirable road disaster prevention information network system taking the actual situation of the field into consideration.

7.4.2 Design of Database System

ABC has operated the GIAS. It manages the road network and related information on the line reference system (SRL) which is appropriate to manage line structure. The road disaster, in general, is occurred in the limited area that could be regarded as a point. The length of the segment utilizing in GIAS, is too long to analyze the characteristics of the disaster occurred. According to the ABC, they have an intention to manage the disaster information by georeference like longitude and latitude. Considering the actual conditions mentioned above, the integrated database system composed of existing database system GIAS and georeference database is designed as shown in *Figure 7.4.1* as a part of road disaster prevention information network system. Detail of the integrated database system shall be discussed among staffs of ABC and designed step by step.

During the study, the road disaster database is developed and the high hazard control section and high risk control section are identified. Those basic data will be renewed periodically in principle by the data transfer from each regional office, the former is every one month and the latter is twice a year. In addition, the natural and environmental conditions which are basic information for the analysis of mechanism and tendency of road disasters shall be acquired by ABC and kept the database. The information is managed by the Disaster Unit which is recommended to establish in the ABC headquarters.

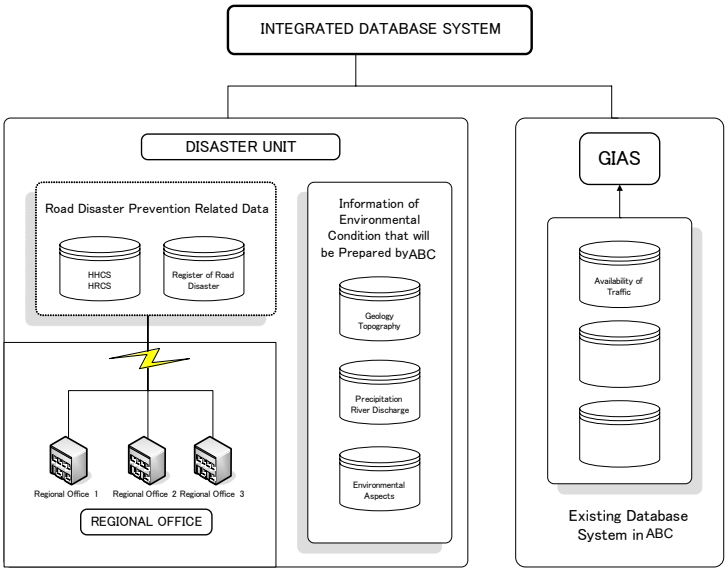


Figure 7.4.1 Outline of the Road Disaster Prevention Information Network System

7.4.3 Organization for Operation of the Database System

For the effective operation of the database system mentioned in the previous section, the full-time unit working at management of the road disaster prevention in the headquarters shall be organized. The unit shall include the administrator, GIS specialist and system engineer. On the other hand, the regional office shall assign a person in charge of the prevention of road disaster.

7.5 Conclusions and Recommendations

(1) Conclusions

- The Diagnosis Card prepared in the 1st Study in Bolivia has transferred to MS-Access and GIS. The database for the road disaster information which will be registered after the disaster occurred is developed. The database will be modified by ABC staff as they operate the system.

- Two databases mentioned above and information obtained through the study are stored in the database named "PRMD Database".

- The integrated database system composed of the existing database GIAS and newly developed database is designed considering future utilization.

(2) Recommendations

- Through the operation of the database system, each Regional office is required to list up the points to be improved. Headquarters is required to collect those opinions and to try to improve the system.

- It was recognized that the capability of human resources in each Regional Office are enough to establish the road disaster prevention information network. The strong initiative of the Headquarters will enable to establish appropriate network.

- Interactive communication between Regional office and Headquarters is recommended in order to possess same information related to the road disaster prevention.

- Discussion for development and operation of database system among system engineers of regional offices shall be held under the strong leadership of headquarters.

- Some functions such as inquiry and analysis in the database system for ABC internal users shall be developed taking into consideration the needs from department related in the headquarters.

<Manual for Data Conversion from MS-Access Data to GIS>

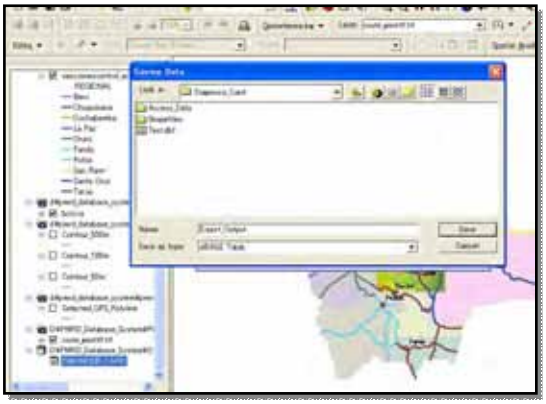
This manual explains the procedure for data transfer from “mdb” files created by MS-Access to GIS, ArcGIS 9.0. Two procedures shall be taken to display the data on GIS. First step is from “mdb” to “dbf”, then from “dbf” to “shapefile”. Detail procedure is described bellow.

Note: The shaded part in the manual, i.e. DIAGNOSIS CARD-SPANISH.mdb, must be changed in accordance with the name of file that you transfer to GIS.

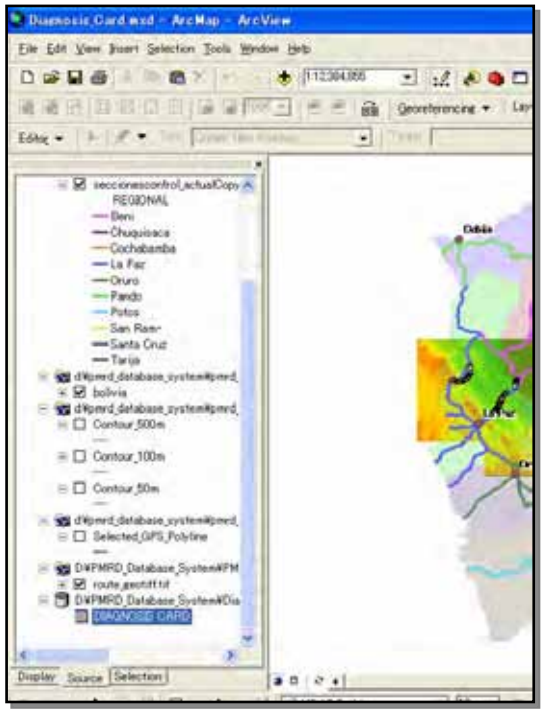
1. Copy “DIAGNOSIS CARD-SPANISH.mdb” File and Paste it in the “Diagnosis_Card” Folder under the “PMRD_Database_System” Folder.

2. Confirm that the “FotoDiagnostico” Folder is located under the “C:” and photos are classified and kept in each route folder, i.e. “0003”, “0004”, “0007” and “0016”.

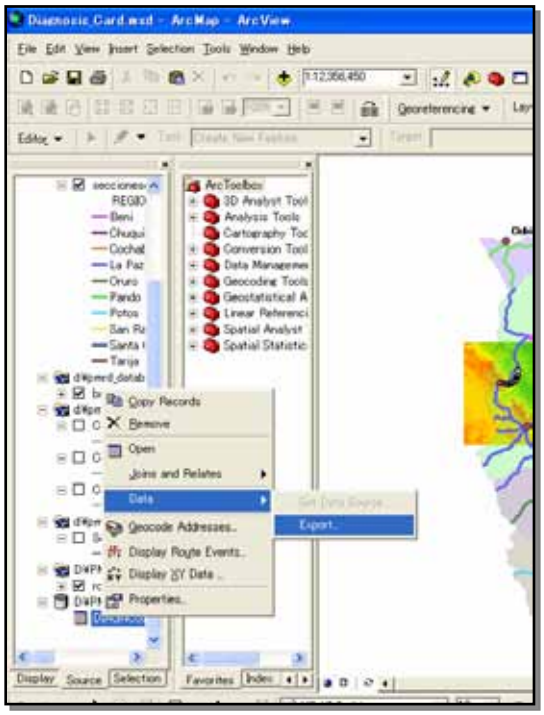
3. Start ArcGIS and open the map file named “Diagnosis_Card.mxd.



4. Push “Add Data” button. Double Click “DIAGNOSIS CARD-SPANISH.mdb” under “Access_Data” folder under the “Diagnosis_Card” folder. Select “DIAGNOSIS CARD”, then push “Add” button. You can find out the layer named “DIAGNOSIS CARD” in the TOC of ArcMap.

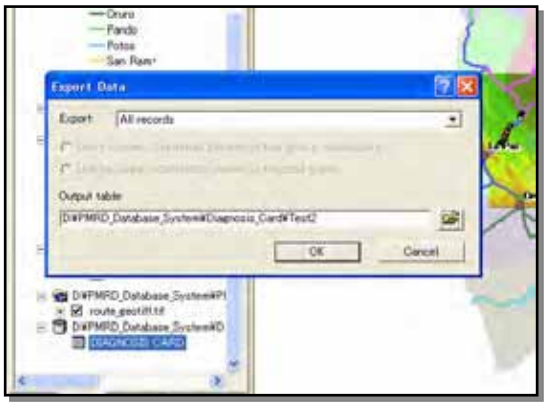


5. Select the layer named “DIAGNOSIS CARD” in the TOC of ArcMap.
Right Click ⇒ “Data” ⇒ “Export”.

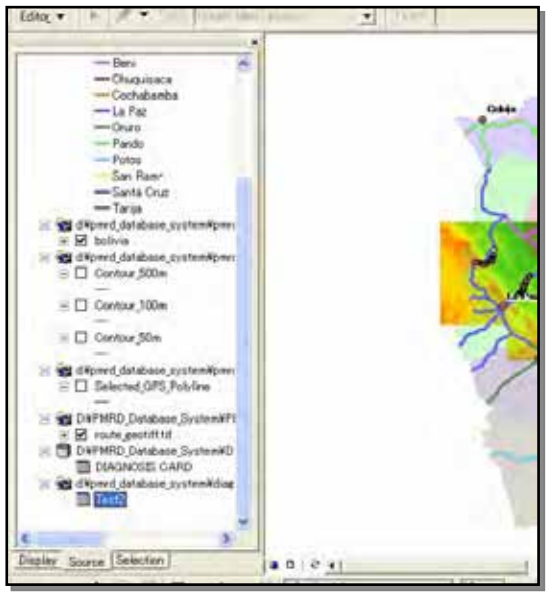


6. Push the “open button” in the “Export Data” window. Open “Diagnosis_Card” folder. Change the name of the file to “DGCard_06Jun” from “Export_Output”, then push the “Save button”.

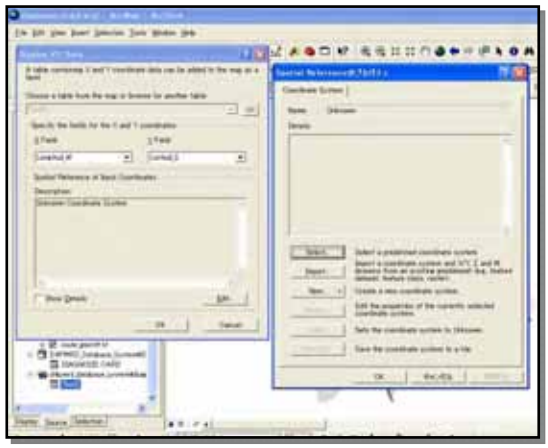
7. Then push the “OK” button in the “Export Data” window.



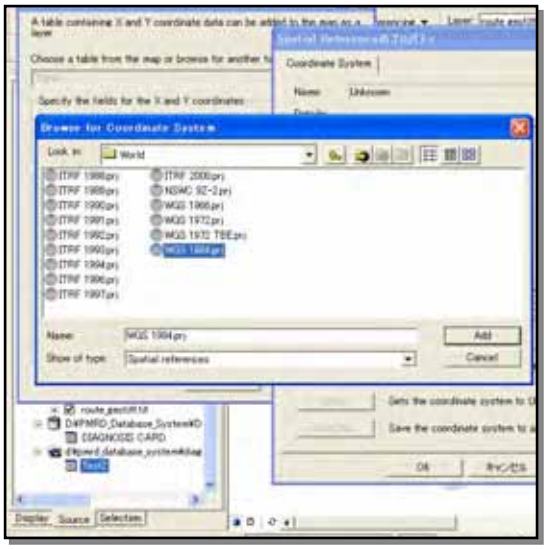
8. When the message “Do you want to add the new table to the current map” appears, push the “Yes” button. You can find the layer named “DGCard_06Jun” on TOC.



9. In the “TOC”, select “DGCard_06Jun”, right click ⇒ “Display XY Data” window. Select “Longitud_W” for “X Field”, “Latitud_S” for “Y Field”. Then push the “Edit” button in the “Display XY Data” window, then “Select” button.



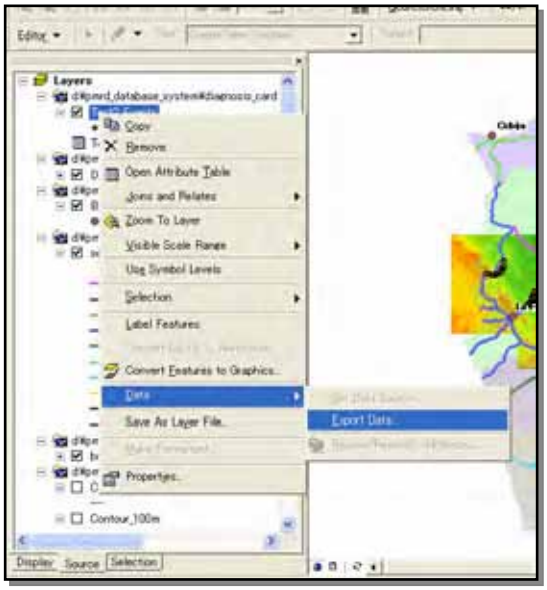
10. Double click “Geographic Coordinate Systems”, then “World”. Click “WGS 1984.prj”, then push “Add” button.



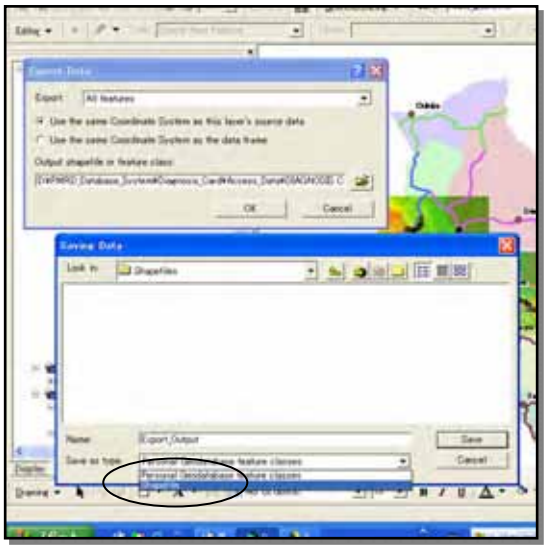
11. Then push “Apply” and “OK” buttons in the “Property of Spatial Reference” window. Then push the OK” button in the “Display XY Data” window. You can find the layer named “DGCard_06Jun Events” on TOC.

    Note: Event file is temporary file, therefore it should be export to the shapefile.

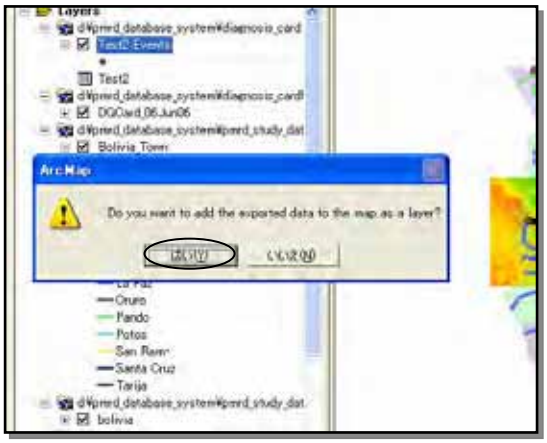
12. In order to export to shapefile, select the “DGCard_06Jun Events” layer in the TOC, right click ⇒ “Data” ⇒ “Export Data”.



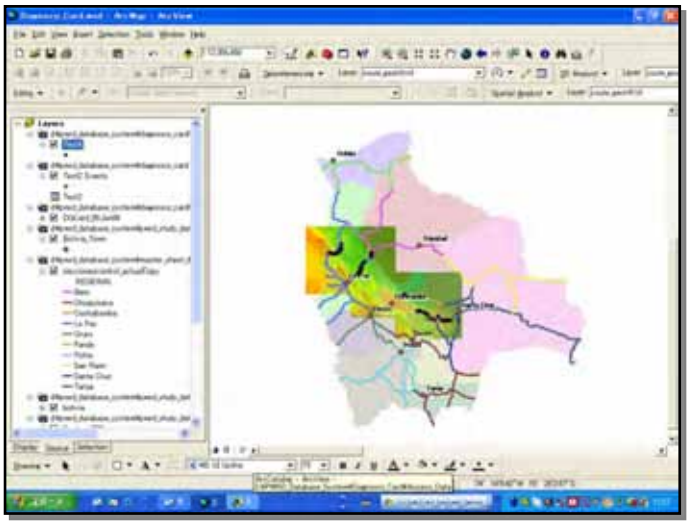
13. Push the “Open” button on the right side of the “Export Data” window, then select “Diagnosis_Card” Folder and select “Shapefile” folder. Select “shapefile” from “Save as Type” and change the name to “DGCard_06Jun.shp“ from “Export_Output.shp”, then push the “Save” button in the “Saving Data” window. The push the “OK” button in the “Export Data” window.



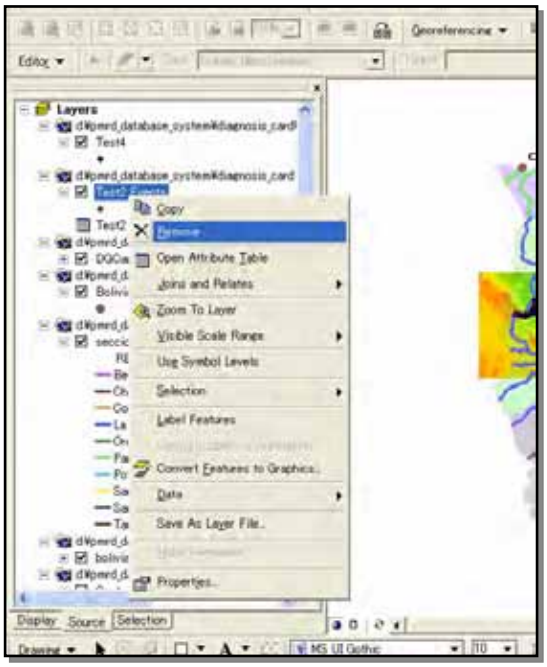
14. The massage window with “Do you want to add the exported data to the map as a layer?” appears, push “Yes”.



15. “DGCard_06Jun (shapefile)“ in the TOC.



16. Select the “DGCard_06Jun Events” layer, right click ⇒ “Remove”. Select the “DGCard_06Jun (table data)” layer, right click ⇒ “Remove”. Then select “DIAGNOSIS CARD (table data), right click ⇒ “Remove”



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Chapter 8

Road Disaster Prevention Management Manual

Chapter 8 Road Disaster Prevention Management Manual

8.1 Manual

8.1.1 Disaster Management

Disaster Management Cycle (DMC)

When we study how to cope with disasters, we have to consider Disaster Management Cycle (DMC). The DMC consists of three steps such as prevention / mitigation measures, emergency measures, restoration / reconstruction as shown *Figure 8.1.1*. Considering with DMC, disaster measures are not transitory.

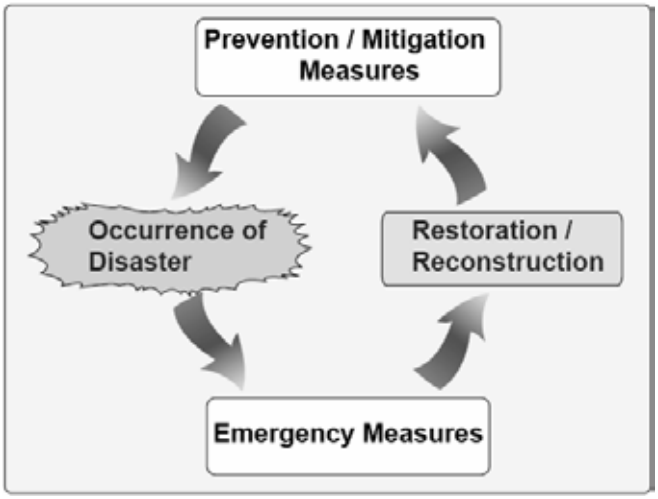


Figure 8.1.1 Disaster Management Cycle (DMC)

The main subject of this manual is prevention / mitigation of disasters, and does not mention restoration / reconstruction. Prevention / mitigation measures shall include measures at ordinary times.

Three types of prevention measures

The following three measures are taken as basic of disaster prevention measures generally.

EVACUATE from disasters
DEFEND against disasters
PREDICT and EVADE disasters

Above measures correspond with following road disaster prevention measures.

Table 8.1.1 Measures for Road Disasters

General Measures	Measures for Road Disasters
AVOID disasters	change road alignments
DEFEND against disasters	prevention works
PREDICT and **EVADE** disasters	traffic control (only protect vehicles and pedestrians against disasters, structure, not protect road structures)

Things to know for prevention measures

Generally, when disaster prevention measures are studied, the following queries shall be solved.

WHERE disasters will occur?
WHEN disasters will occur?
WHAT type of disasters will occur?
HOW disasters will occur?

Method of knowing WHERE disasters will occur

This manual proposes the following three methods to know where disaster will occur.

Slope inspection
Pick over dangerous points along the road

Daily maintenance
Watch road condition in ordinary, and perceive dangers

Disaster record
Disasters are repetitious. Once disasters occurred, the points and the surroundings may be dangerous scenes

Method of knowing WHEN disasters will occur

This manual proposes the following three methods to know when disaster will occur.

Always watch dangerous spots
Always watch the hazardous place when the signs of danger are found
As the case may be, monitor progress of danger by monitoring devises

Setting risk level based on precipitation
Install rain gauges along the highways and monitor the rain fall
Setting of threshold of dangerous status is important

Protection works based on disaster type

Design of protection works shall be changed based on the disaster types
But, for evasion, types of disasters are not important

8.1.2 Formation of the Manual

This manual is aimed at all of the national highways and ABC (Administradora Boliviana de Carreteras) which manages and operates the national highways.

The principle of this manual is;

a. This is the guide for ABC action which puts emphasis on disaster prevention,
b. The disaster prevention means that keeping vehicles and passengers safe in the event of disaster, even if a road has been destroyed, and
c. The most of this manual except Guide IV prescribes the action before disaster.

The object of this manual is landslides include debris flow only, and not included flood, bridge and tunnel disasters.

The flow chart of this manual, which shows contents of the manual, is as shown in *Figure 8.1.2*. This manual relies on the existing national highway maintenance system of ABC in the nation, which consists of the Micro-empresas (micro companies), the Supervisors, ABC Regional Offices, ABC Head Office as shown below.

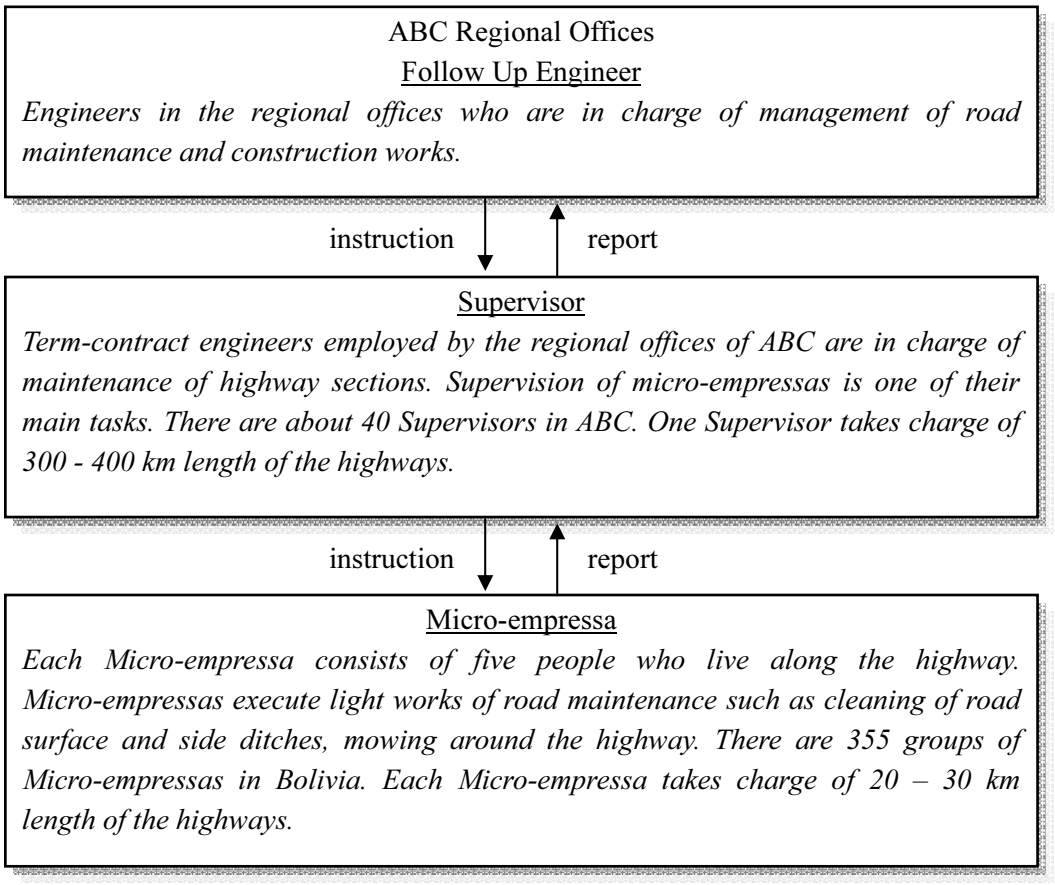


Figure 8.1.2 Organization in the National Highway Maintenance System in Bolivia

As measures of a disaster, one way is to set up protective facilities for a slope (hard countermeasure), and the other way is to defend a disaster indirectly there restricts an entrance and a utilization to a dangerous area through a disclosure of information (soft countermeasure). A goal of a road disaster prevention measure is to make a road safe condition by countermeasure construction along a road. However, for an enforcement of a countermeasure construction, a large amount of expenses and long time are required. We have to put emphasis on soft measures. Even the soft measure can not prevent the occurrence of disasters, the soft measures minimize the damage on humans and vehicles. This manual is based on this approach.

This manual consists of the following five guides.

Guide I : Determination of High Hazard Control Sections
Guide II : Disaster Prevention Works in Routine Maintenance
Guide III : Management for Imminent Danger
Guide IV : Emergency Response
Guide V : Disaster Prevention Works

** soft measure : measures without large scale structures, such as traffic control, warning/evacuation etc.*
** hard measures: measures with large scale structures, such as dam, retaining wall etc.*

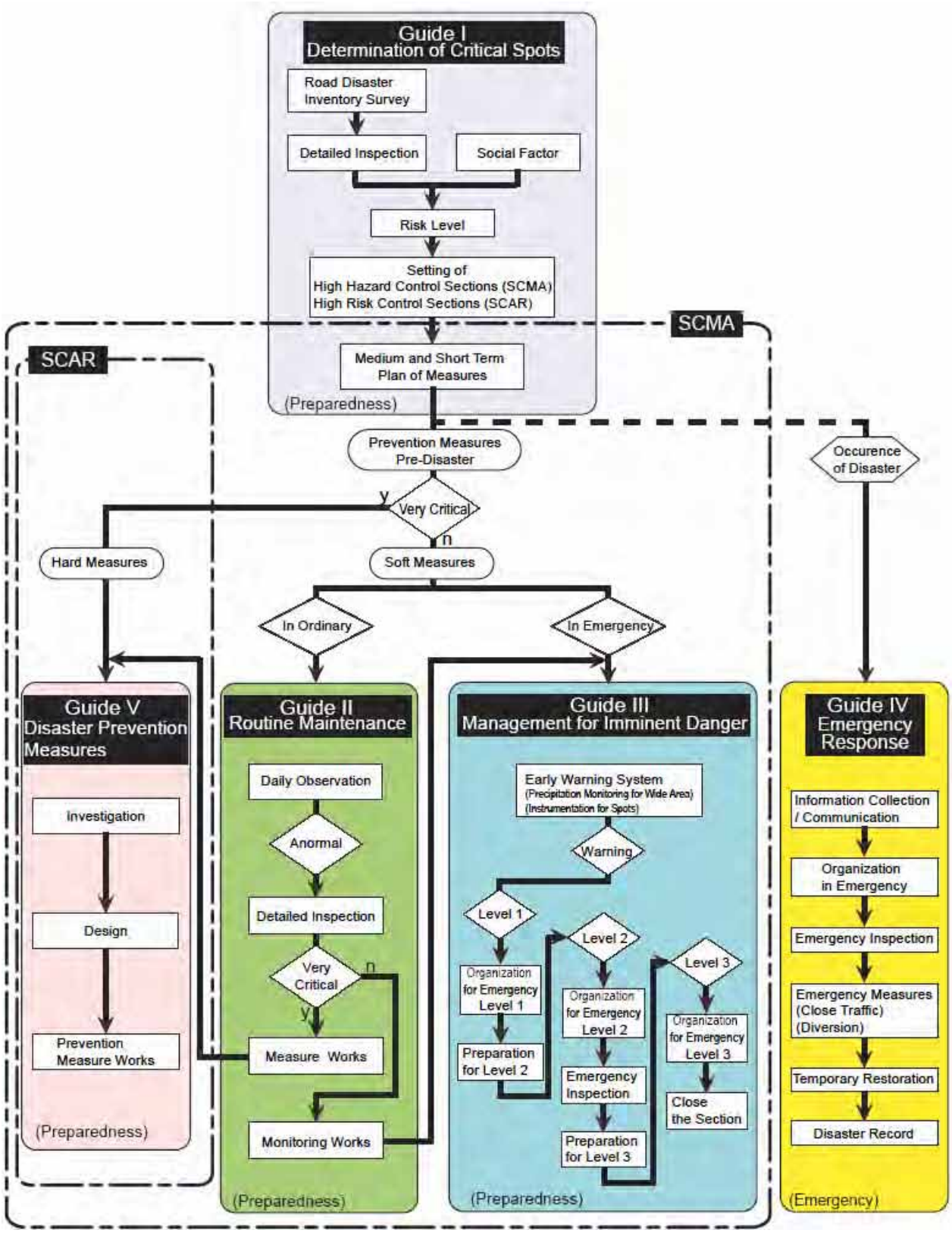


Figure 8.1.3 Flowchart of Road Disaster Prevention Manual

8.1.3 Contents of Each Guide

Guide for Determination of High Hazard Control Sections

This is a guide to recognize critical spots (hazardous spots) on the national highways all over the country. To recognize critic spots means to make hazard maps for disaster prevention program. This inspection for all national highways is executed once or twice a year all over the country, and followed by five steps of program.

(1) Road Disaster Inventory Inspection

The Supervisors will recognize hazardous level of the highways with the object of finding the critic spots in all over the national highways. This inspection will be included in existing road inventory inspection on each 50m along the national highways in the course of road maintenance system. Hazard is classified into four levels from A to D and the results will be registered in tables of inventory inspection.
It is not expected specialized / high level inspections on all of the national highways at the beginning of the inspection work by the Supervisors since the Supervisors' capabilities would not be even at the beginning. This guide especially the part of hazard definition shall be modified by the ABC based on the Supervisors' capabilities after first one year inspections.

(2) Social Factors and Risk Level

To get the risk level from hazard level obtained in Inventory Inspections, the importance of the highways is defined. The importance of the highways is estimate by the traffic volume as the social factors at the moment, because no other factors of data can be found in Bolivia. The social factor is defined from the traffic volume of highways in this Guide.
The risk level is set for planning of measure works and emergency responses on all national highways in the nation. The risk level is defined with following formula;

Risk Level = Hazard Level x Social Factors

(3) Setting of High Hazard Control Sections (SCMA) / High Risk Control Sections (SCAR)

The ABC Regional Offices shall assign High Hazard Control Sections where high hazard locations are concentrated and High Risk Control Sections where high risk locations are concentrated. Both sections are for the plan of prevention measures and maintenance works (Guide II and Guide III). The ABC Regional Offices shall revise and check every year.
The disaster prevention program will be planned based on the risk level. The high risk control sections have generally priority of the disaster prevention program. It is recommendable that the simple prevention measures introduced in Guide V are applied to the high risk control sections with high priority.

Guide for Disaster Prevention Works in Routine Maintenance

This is a guide for ordinary maintenance in order to find the sign of disaster in so early stage as possible.

(1) Daily Observation

The daily observation is defined as the normal road patrol done by the Micro-empresas with attention to anomaly relating to slope stability. The Micro-empresas are appropriate organization to detect these

anomalies in ordinary time, since they are always maintain their sections of the national highways. A simple and instructive manual (a. what is an anomaly, b. emergency methods in case of anomalies detection, c. formulary document) for the Micro-empresas is introduced in this guide.
The daily observation will be covered only on the High Hazard Control Sections (SCMA).

(2) Detailed Inspection

The Supervisor shall execute the detailed inspection to realize anomalies at the location reported by the Micro-empresa in the daily observation. The detailed inspection shall be recorded by the Supervisor. If an emergency is recognized at the location, the Supervisor shall communicate to ABC Regional Office.

Guide for Management for Imminent Danger

This is the guide of reactions and replies in emergency cases which is before disaster. The definition of emergency is important in this program and is discussed firstly related to precipitation and landslide monitoring. The emergency responses will be covered just on the High Hazard Control Sections (SCMA).

(1) Early Warning for Wide Area by Precipitation

Early warning system for wide area shall be established for imminences by the observation of precipitation along the national highways. As the practical method for Bolivia, the guide introduces a simple rain gauge as the warning device. The simple rain gauge can be made of cylindrical shape container with scale and installed at all the Micro-empresas stations, and shall be monitored by the Micro-empresas.

(2) Correspondence for Emergency (Pre-disaster)

Before disaster, when the monitoring shows that the road is in critical moment, emergency level is activated. Emergency level is classified into three levels based on the monitoring of precipitation or ground movement. The activation of emergency is based on the emergency levels. The road traffic on the section of the national highway shall be closed when an emergency is found in highest hazard levels.

Guide for Emergency Response

The guide shows the recovering activities of mid-disaster and post-disaster, and gives description of provisional preventive works and temporary works.
The guide introduces;-

Information collection and communication,
Organization in emergency,
Emergency Inspection,
Emergency measures,
Temporary Restoration and,
Disaster record,

When the disaster occurs, mostly first information could come to the police, and the police inform to ABC regional office.
The ABC regional office shall set up the emergency organization headed by the chief of the ABC regional office (Jefe Regional), and send the supervisor to collect the detailed information as soon as possible. If the supervisor could not reach the spot immediately, the supervisor shall solicit the micro-empresa for

their observation and report to the Supervisor.
All the information shall be concentrated to the Jefe Regional, and the Jefe Regional shall take the responsibility of all the actions done by ABC, the supervisor and the micro-empresa.
The purpose of the emergency measure and the temporary restoration is to keep the safe traffic flow as soon as possible. However, if it is difficult to keep the safety of the road, the traffic shall be controlled.

Guide for Disaster Prevention Works

This is a guide for design of prevention measures as well as investigation for design of prevention measures.

(1) Design of Prevention Measures

Principal methods for preventive measures are described. There have been many road disasters related to water in Bolivia, therefore the drainage of surface water and groundwater are important and recommendable as effective and low cost prevention measures. The standard gradient of cut slopes and simple prevention measures are included in this guide. These simple prevention measures are recommendable for the High Risk Control Sections in preference to the other sections.

(2) Investigation

The geological / geotechnical investigation shall be executed prior to the measure works in order to design the prevention measures properly and to prevent unexpected matter in the construction period.

8.2 Trial of the Manual

8.2.1 Purpose

To find effectiveness of any defects in the draft manual, trial on the manual has been executed in certain section of the national highways after Second Draft Manual were submitted in June 2006. In response to the trail of the draft manual, the manual is revising to applicable to the actual road management of ABC. The trial has been executed on one section of route 3 in the period of July 2006 to April 2007. Preparation of the manual has been finalized in June 2007 according to the trial result.

8.2.2 Method of the Trial

(1) Location

National highway Route 3, Santa Barbara – Quiquibey, 227 km

Figure 8.2.1 Location of the Trial

(2) Sector and Person in Charge

Sector: La Paz Branch Office, ABC

Follow-up Engineer:

Ing. Gabriel Collao Aquirre

Supervisor (in charge of Cotapata – Quiquibey, Route 3):

Ing. Rene Berazain Carrasco

Ing. Andres Flores Montano (assistant)

Micro-empressa:

11 groups

(3) Substance of the Trial

Substance of the Trial is based on the 3rd draft Manual as follows;-

Table 8.2.1 Substances of the Trial

Manual	Substances of the Trial	Action by	Report
Guide I *Determination of High Hazard Control Section*	Inspection on Slopes	SV	Disaster Inventory Sheet
	Institute High Hazard Sections	FE, JICA	Location map of High Hazard Sections
Guide II *Disaster Prevention Works in Routine Maintenance*	Discovery of unusual on road in daily maintenance	ME, SV	Record of report from Micro-empressas
	Inspection on unusual	SV	Inspection record
Guide III *Management for Imminent Danger*	Installation of simple rain gauges	ME, SV	Rain gauge installation report
	Rain gauge monitoring	ME	Rain gauge monitoring report (monthly report)
	Heavy rain alert	SV, ME	Record of alerts
Guide IV *Emergency Response*	Response to occurrence of disaster	FE, ME	Record of responses
Guide V *Disaster Prevention Works*	Construction of prevention measures based on the Manual	FE, ME	Drawings of plans

FE: Follow-up Engineer, SV: Supervisor, ME: Micro-empressa, JICA: JICA Study Team

(4) Time Schedule

The period of the trial is from July 2006 to April 2007.
Significant event of the trial of the manual is shown below;-

Table 8.2.2 Time Schedule of the Trial before July 2006

Date	Description
May, June, July 2006 :	Manual subcommittee meetings (18,25 May, 1, 6, 16, 26 June, 1, 7, 13, 20 July)
6 June 2006 :	Manual conference, participated by chiefs of ABC branch offices
20 June 2006 :	Manual conference, participated by staffs of ABC head office
28 June 2006 :	Meeting with ABC La Paz branch office on the trial
4, 10, 18 July 2006 :	Meeting with the Supervisor in charge of the trial section
7 July 2006 :	Installation of one simple rain gauge as pilot of the trial
11 July 2006 :	Induction course for Micro-empresas organized by the Supervisor at Caranavi (11 groups of Micro-empresas participated)
17-22 July 2006 :	Installation of rain gauges by Micro-empresas
17-22 July 2006 :	Inspection on Slopes by the Supervisor

Time schedule of the trial after July 2006 was as shown *Figure 8.2.2*.

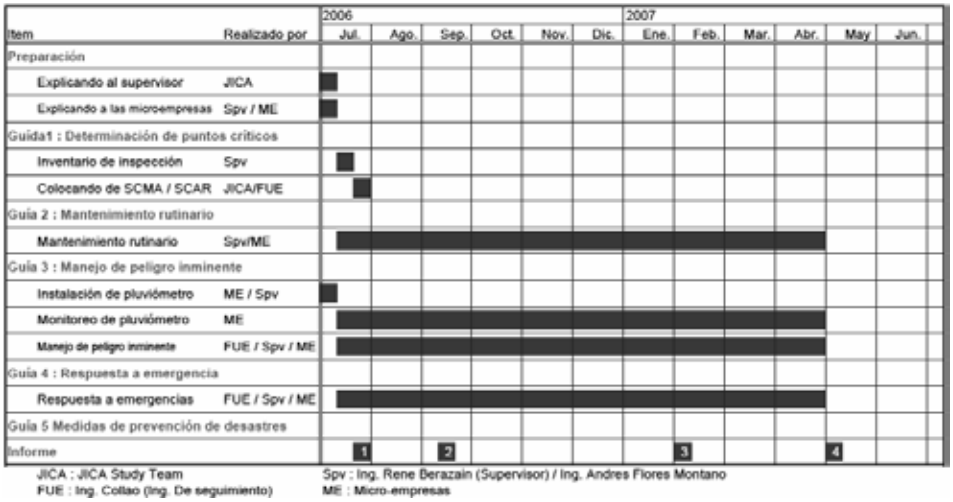


Figure 8.2.2 Time Schedule of the Trial

8.2.3 Result of the Trial

(1) Inventory Inspection according to Guide I

Road Disaster Inventory Inspection in Guide I was executed by a Supervisor and his assistant engineer. The Supervisors prepared and used their own format for the inventory inspection since the inspection time with old format in Guide I took longer time.

The format for the inventory inspection record was revised based on the trial result. The new format is shown below.

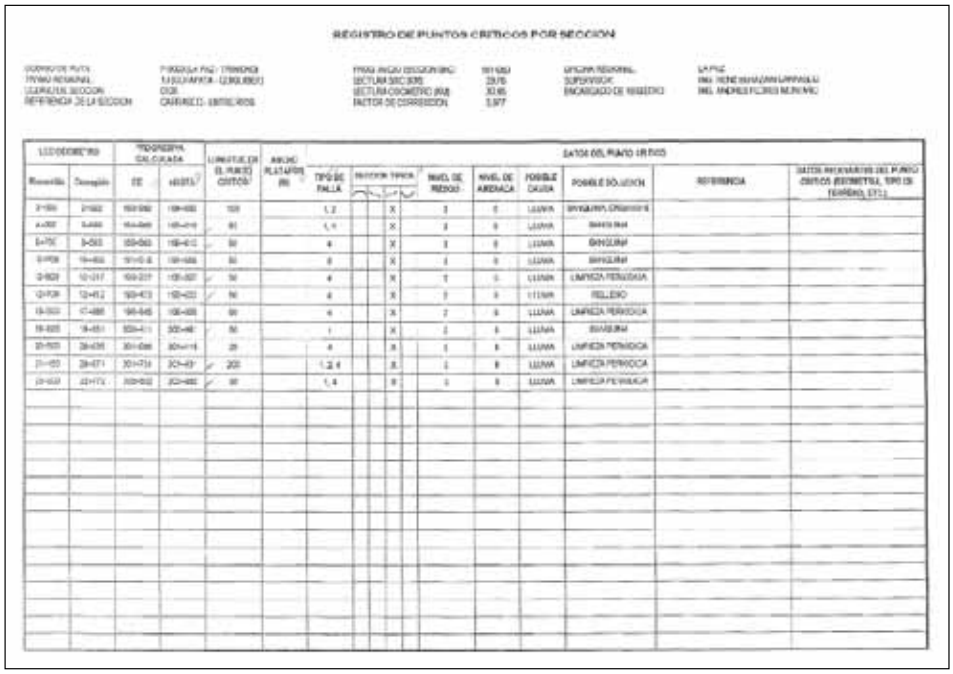


Figure 8.2.3 Disaster Inventory Inspection (Example of the Result of Trial on Route 3)

The type of disasters was revised based on the Supervisor's advise as below. It is based on the common classification in Bolivia.

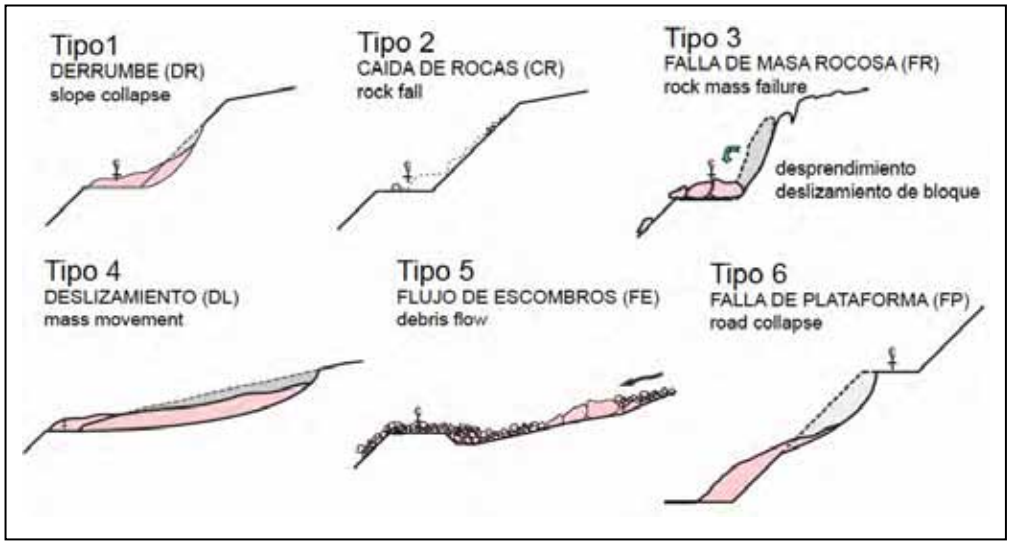


Figure 8.2.4 Disaster Types Classified in the Manual

(2) Setting of SCMA according to Guide I

Total 58 critical spots were recognized by the Supervisor. Various types of disasters continue in some sections on the highway. The sections where disasters continue are called High Hazard Control Sections (SCMA). Total numbers of SCMA shown in the table are six sections as bellow.

1. 96 km – 124 km
2. 137 km – 153 km
3. 163 km – 204 km
4. 218 km – 222 km
5. 263 km – 265 km
6. 276 km – 277 km

The critical spots and SCMA can be managed with simple tables as shown in *Figure 8.2.5*.

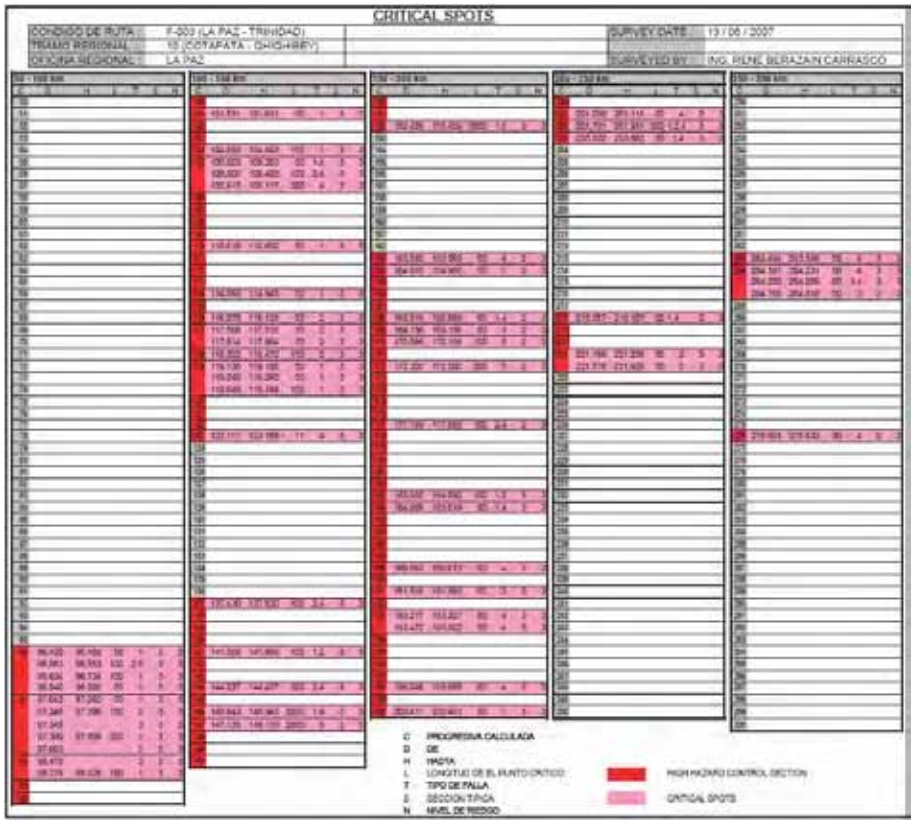


Figure 8.2.5 Critical Spots and SCMA along Route 3

Figure 8.2.6 shows location and type of disasters visually is the result of the trial of the manual carried out in 2007 along route 3. The figure shows that type 2 disasters on left side and type 1 and type4 disasters on right side of the highway. This is because the highway runs the place where mountains locate on right side and ravines locate on left side of the highway. In this way, characteristics of disasters can be clarified with simple figures like this.

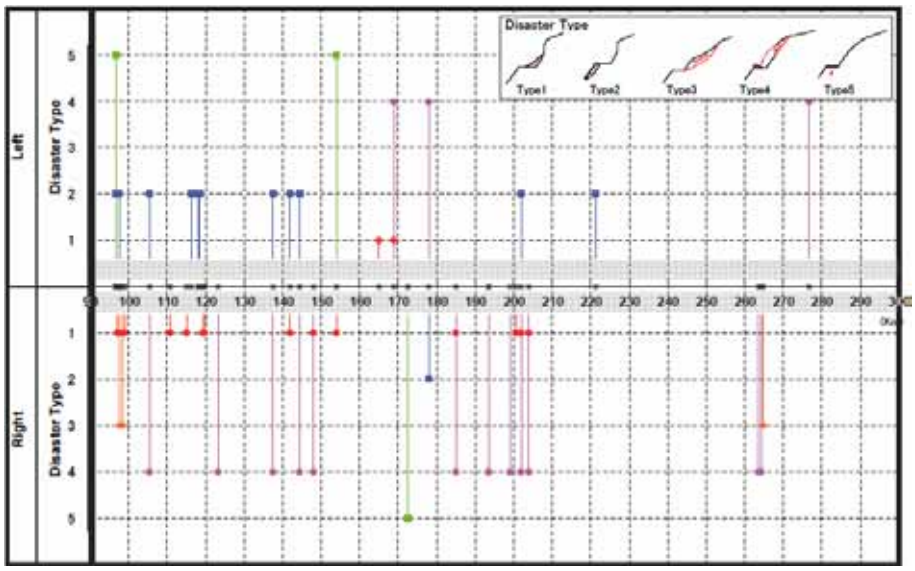


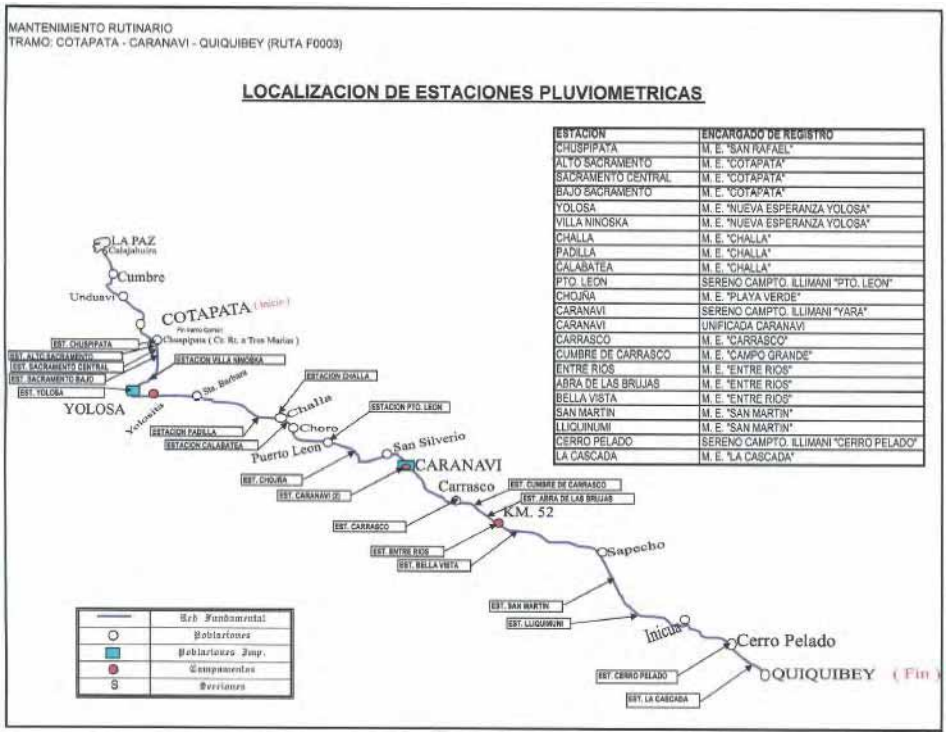
Figure 8.2.6 Location and Types of disasters along Route 3

Disaster classification is not same as the classification in the Final Manual

(3) Rain Fall Monitoring according to Guide III

For the rain gauge monitoring for the management for imminent danger by Micro-empresas in Guide III, an orientation meeting of rain gauge monitoring with Micro-empresas involved in the trial was held by the Supervisor as shown in pictures attached. In the orientation meeting, simple rain gauges and its manual were distributed to the Micro-empresas. Also simplified disaster observation guide for the Micro-empresas directed in Guide III was distributed to the Micro-empresas.

The Micro-empresas installed at least one rain gauge each in their section, and total 22 rain gauges were installed in the trial section, from Caranavei to Quiquibey. Most of the rain gauges seemed to be installed satisfactorily.



ESTACION	ENCARGADO DE REGISTRO
CHUSPIPATA	M. E. "SAN RAFAEL"
ALTO SACRAMENTO	M. E. "COTAPATA"
SACRAMENTO CENTRAL	M. E. "COTAPATA"
BAJO SACRAMENTO	M. E. "COTAPATA"
YOLOSA	M. E. "NUEVA ESPERANZA YOLOSA"
VILLA NINOSKA	M. E. "NUEVA ESPERANZA YOLOSA"
CHALLA	M. E. "CHALLA"
PADILLA	M. E. "CHALLA"
CALABATEA	M. E. "CHALLA"
PTO. LEON	SERENO CAMPTO. ILLIMANI "PTO. LEON"
CHOJNA	M. E. "PLAYA VERDE"
CARANAVI	SERENO CAMPTO. ILLIMANI "YARA"
CARANAVI	UNIFICADA CARANAVI
CARRASCO	M. E. "CARRASCO"
CUMBRE DE CARRASCO	M. E. "CAMPO GRANDE"
ENTRE RIOS	M. E. "ENTRE RIOS"
ABRA DE LAS BRUJAS	M. E. "ENTRE RIOS"
BELLA VISTA	M. E. "ENTRE RIOS"
SAN MARTIN	M. E. "SAN MARTIN"
LLIQUINUMI	M. E. "SAN MARTIN"
CERRO PELADO	SERENO CAMPTO. ILLIMANI "CERRO PELADO"
LA CASCADA	M. E. "LA CASCADA"

Figure 8.2.7 Location of Rain Gauges Installed by Micro-empresas

In spite of Guide III of 3rd Draft Manual indicates the rain gauges shall be monitored at least one hour interval after rain fall started, the rain gauges were monitored by the Micro-empresas only total rain fall of each rain fall period and recorded start time of each rain fall, because it was difficult for the Micro-empresas to monitor the rain fall one hour interval. In response to this problem, Guide III was revised to more usable, e.g., to record the start time of rainfall and to monitor every one hour after the accumulated rain fall has been excess 50 mm. The rain gauge monitoring is for prognostication of disasters, continuous monitoring is important.

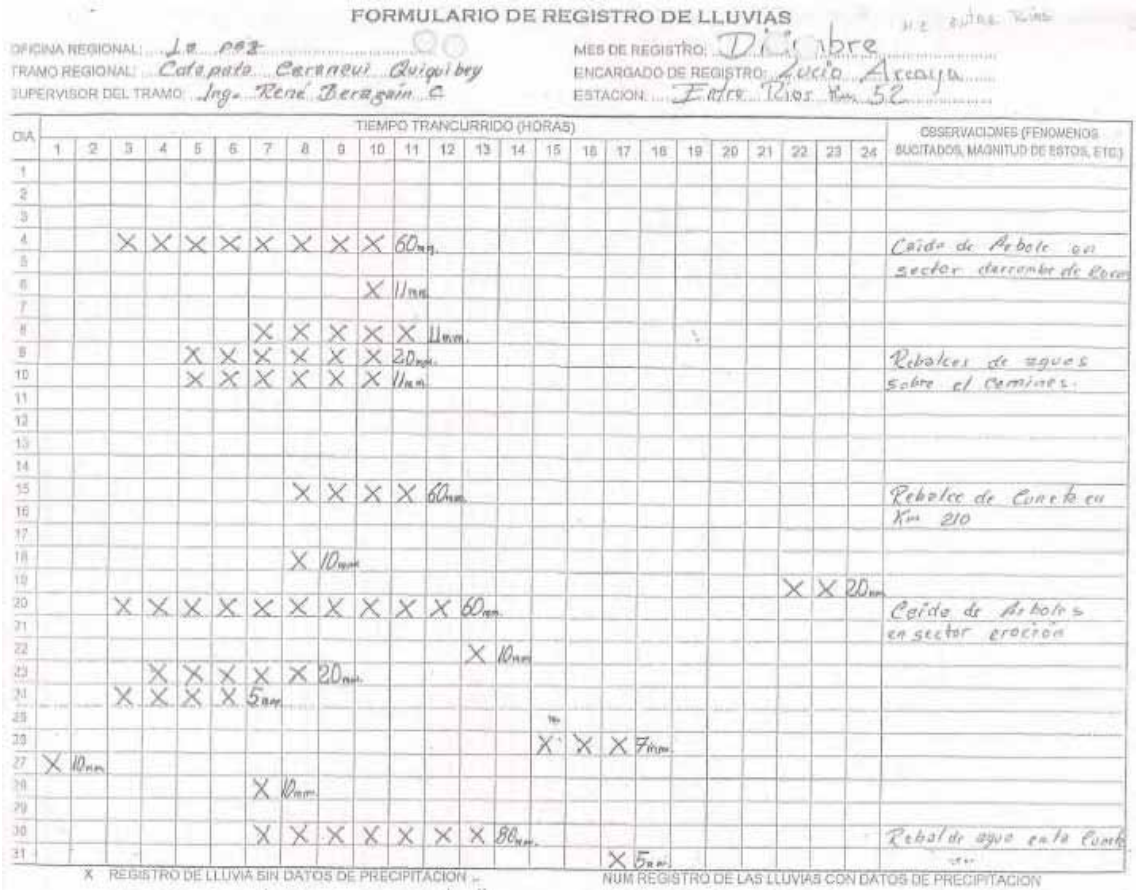


Figure 8.2.8 Recording Form of Rain Gauge Monitoring

(4) Trial of Alert Level Setting by Rain Fall Monitoring according to Guide III

Figures 8.2.9 and *8.2.10* show relations between disasters and rain falls which were obtained by the Micro-empresas using simple rain gauges. The graphs use record of the nearest rain gauges to each disaster. The disaster types are based on *Figure 8.2.4*.

The upper figure shows the relation between disaster type and rain fall accumulation and the lower figure shows the relation between disaster type and rain fall intensity.

Both figures show that disasters occurred in less rain. The reason may be;

1. The disasters have been recorded by the Micro-empresas who are not expert of road disasters, all types of disasters even small phenomena were rerecorded.
2. In Bolivia, occurrence of disasters may not be affected by accumulation of rain fall or rain fall intensity, but by period of rain falls.

The rain fall monitoring by the Micro-empresas using simple rain gauge shall be continue, and the data shall be accumulated for future analysis.

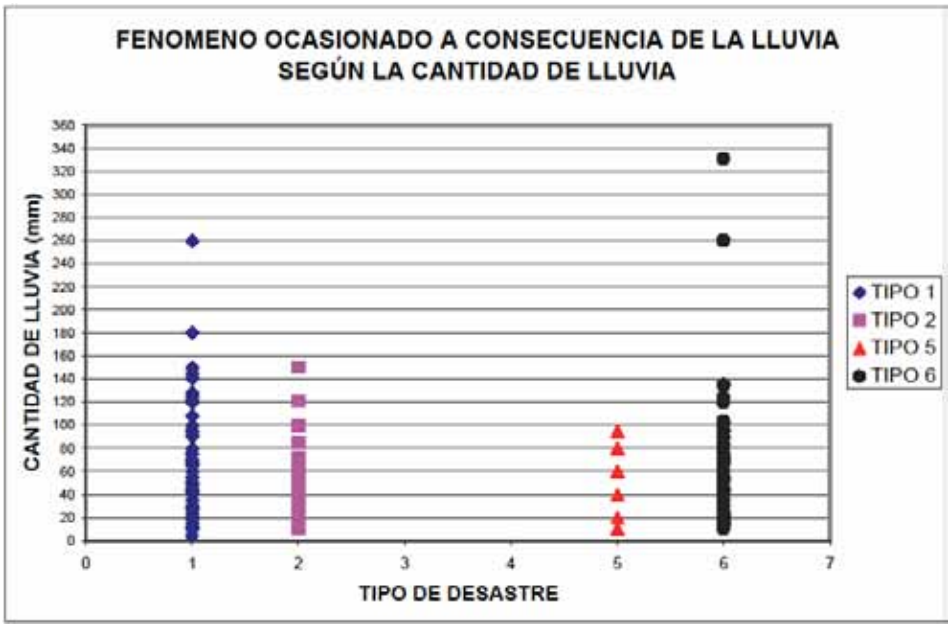


Figure 8.2.9 Disaster Type - Rain Fall Accumulation

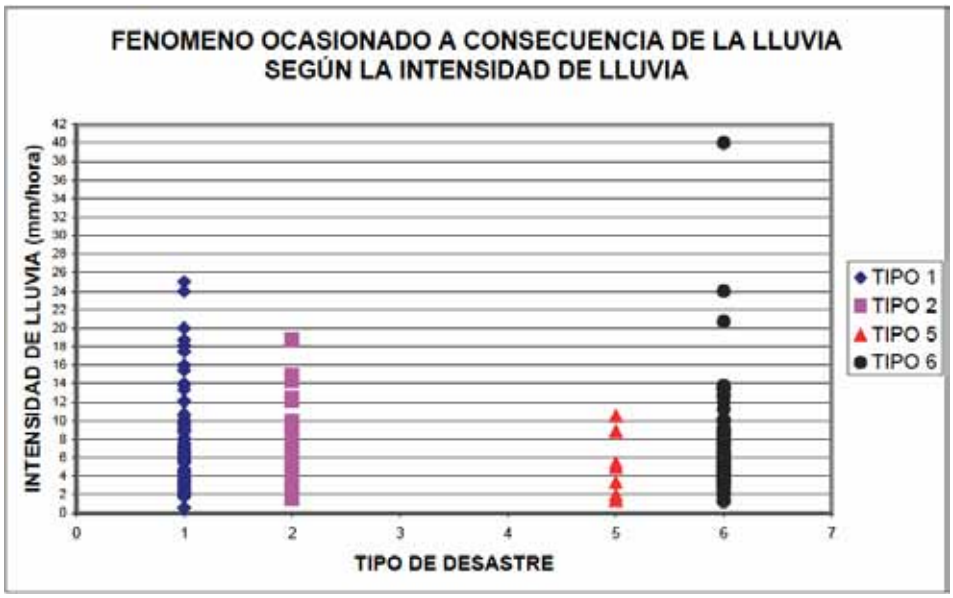


Figure 8.2.10 Disaster Type – Rain Fall Intensity

(5) Trial according to GuideII

There is no report from the Micro-empresas of any unusual on the highway in their daily maintenance works in the trial period as mentioned in Guide II.

(6) Trial according to Guide IV

The Supervisor indicated that the some expression that Guide IV used too general terms and it was difficult to take action in line with the Guide IV. Guide IV was revised based on the Supervisors indication.

(7) Trail according to Guide V

The Supervisor indicated that Guide V should mention not only on pavement roads but also more on non pavement road (gravel and dirt road).
Guide V does not mention only on pavement roads, however, Guide V shall be read again carefully from the point of view of non pavement road.

(8) Supervisor's and Micro-empresas' Attitudes

The Supervisor's and the Micro-empresas' consciousness for road disaster prevention seem very high. The Supervisor prepared interesting presentation for the Micro-empresas in the training meeting, and the Micro-empresas listened carefully the Supervisors presentation. Also, the Micro-empresas showed the installation of rain gauges.

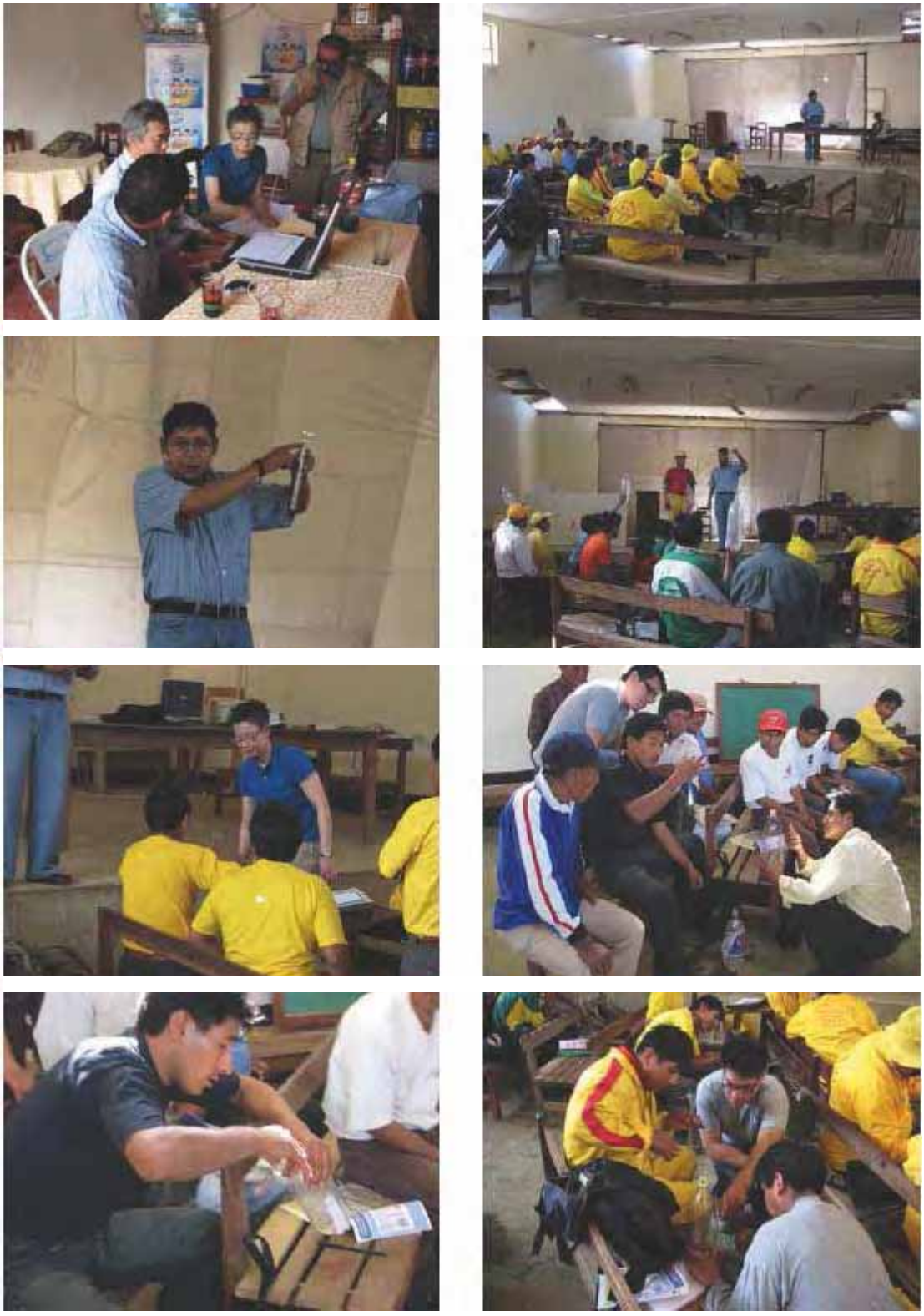


Figure 8.2.11 Photos of Rain Gauge Monitoring Orientation Meeting with Micro-empresas

(11 July 2006)

Chapter 9

Implementation of Pilot Project

Chapter 9 Implementation of Pilot Project

9.1 Basic Course of Pilot Project

The pilot project has been implemented in line with the capacity development (CD) plan created to assist CD in the field of road disaster prevention, which is the objective of this study.

The pilot project entails implementation of the pilot works selected based on the road disaster register and road disaster prevention manual (draft) created jointly with the Bolivian side, improvement of the technical supervisory capacity of the counterparts and provision of OJT in efficient project management.

The aim of the pilot works is to promote capacity development through training in countermeasure work survey (geological, topographical, climate, etc.), planning, design, estimation, preparation of contract documents, bidding and evaluation, supervision of works (quality control, process control, emergency measures, etc.) and completion inspection.

The pilot works implemented in the pilot project include the appropriate technical and systematic contents that correspond to those processes. The aim is to spread universal disaster prevention works for typical disaster patterns throughout the country, without focusing unduly on the scale.

9.2 Selection of Sites for Pilot Works

The four target routes were looked at from the viewpoints of debris flow, embankment failure and collapse as disaster patterns that exert a major social effect (traffic closure, etc.) and sites with high potentiality for effective disaster prevention were to be selected for the pilot works. It was decided to select sites on Route 7 for the pilot works because it was confirmed from the results of the first and second field studies that Route 7 had places where slope collapse of earth cuttings and embankments occurred or places with a high risk of such collapse, and thus it would be effective if the countermeasure works were implemented there.

The sites for the pilot works were decided through the detailed second field study of Route 7 which was selected as a result of the first field study.

As a result of the second field study, it was decided with the consent of ABC that the pilot works of this pilot project would be implemented at the two sites of No.399+000 km (earth cutting) and No.426+300km (embankment) on Route 7 in consideration of the appropriate scale, environmental and social aspects, etc. which meet the basic course of the pilot project.

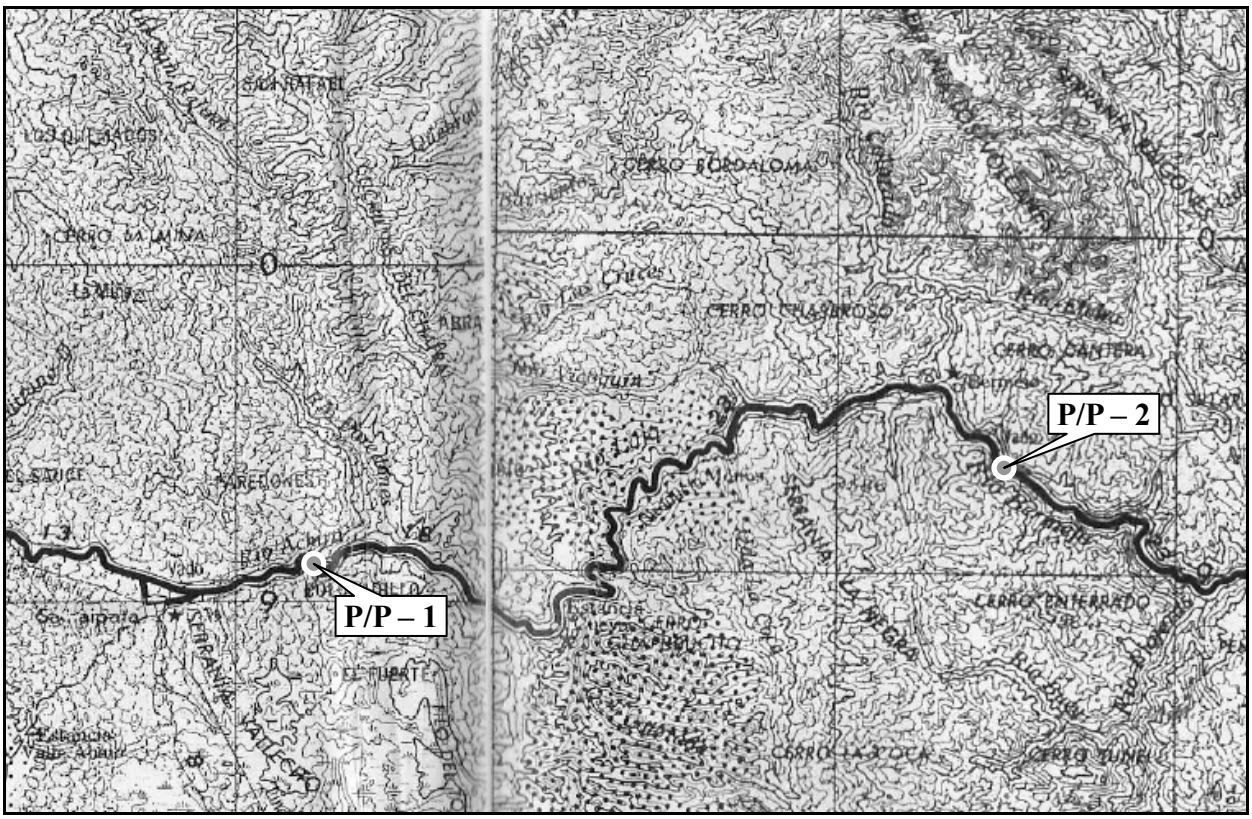


Figure 9.2.1 Location Map

9.3 Policies of Pilot Countermeasure Works

Regarding the methods of the countermeasure works to be employed, discussions were held with the Bolivian side on the danger spots for road disasters on Route 7 identified together by ABC during the first field study and on the pilot works (proposal) that would act as an incentive for future road disaster prevention measures.

In consideration of the results of the first field study and the three aspects of (1) work types at the technically sustainable level by the Bolivian side, (2) the capabilities of local contractors and (3) the budget scale, it was decided that the following countermeasure works will be studied.

Protection of earth cutting slope: slope cribwork
Embankment failure prevention measures: revetment work, reinforced soil wall work and rockfall prevention work

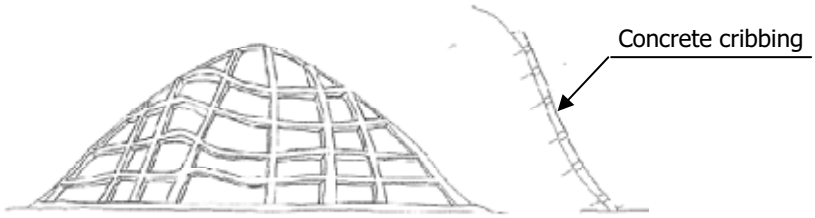


Figure 9.3.1 Slope cribwork

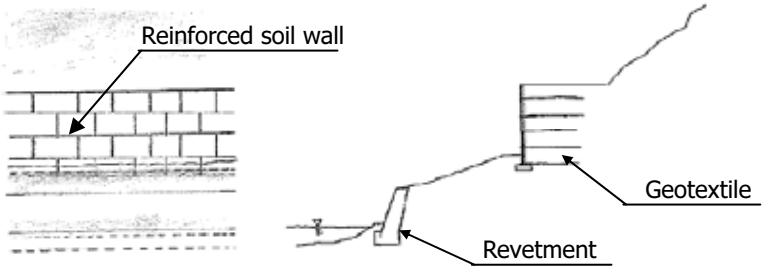


Figure 9.3.2 Revetment work and reinforced soil wall work

In addition, the following items shall be considered in selecting construction methods, based on the results of the geological survey and location survey which will be conducted by local sub-contractors as part of the second field study.

1) Prevention-effective construction methods
2) Sustainable construction methods
3) Construction methods which are effective in disseminating technologies
4) Construction methods which present few problems from the viewpoints of environmental and social considerations
5) Construction methods on an appropriate scale

The pilot works (proposal) which will act as an incentive for future road disaster prevention measures will be decided with the consent of ABC of Bolivia.

9.4 Implementation Method of Pilot Works

Countermeasure works at the selected sites will be executed by local sub-contractors from design work to placing of work orders. The pilot project will be implemented as indicated in *Figure 9.4.1* Pilot Project Implementation Flowchart.

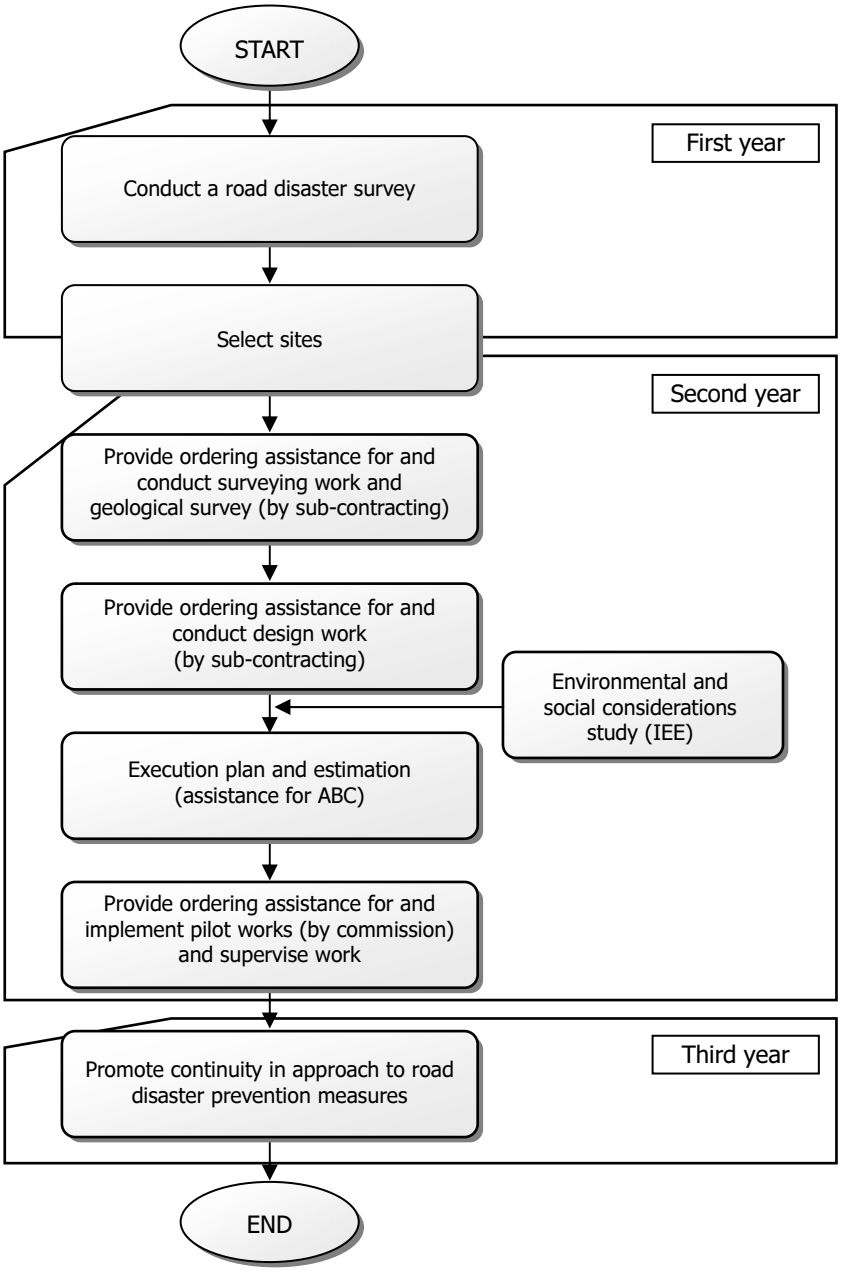


Figure 9.4.1 Pilot Project Implementation Flowchart

Solutions for the problems identified during implementation of the pilot project will be reflected in the organizations concerned, the road disaster prevention manual, etc. in an effort to firmly establish road disaster prevention projects.

9.5 Survey (Topographic Survey and Geological Survey)

(1) Outline of Survey

Objective of surveys: The objective of the surveys is to understand the topographic and geological conditions of the pilot project location and use the findings as reference materials in deciding design, construction methods and works.
Site of survey: 426+300 on Route 7 (extension: 30 m) where the road surface collapsed.
Period of survey: June 6 – June 21, 2006
Ordering party: JICA
Contractor: SERVICONS Geotecnia

Contents of survey:

Topographic survey

- Road crossing survey
  (1 section; Outcome – Longitudinal: 1/200, Transverse: 1/1000, 10m intervals)
- River crossing survey
  (1 section; Outcome – Longitudinal: 1/200, Transverse: 1/5000, 100m intervals)
- Slope crossing survey (150m × 11 sections = 1650m)
- Plane survey (150m × 150m = 22500m^2; Scale: 1/500)

Geological survey

– Boring	4 bores	Extension = 56.10m
– Standard penetration test	4 bores	13 times
– Laboratory soil test	1 set	
・Collecting of disturbed samples		3 locations
・Moisture content test (ASTM D2216)		3 samples
・Grain size test (ASTM D422)		3 samples
・Compacting test (ASTM D4253)		3 samples
・Direct shear test (ASTM D3080)		3 samples
– Analysis	1set	

(2) Results of survey

(a) Topographic survey

The results of the road crossing survey, the river crossing survey, the slope crossing survey, and the plane survey were submitted as electronic data and have been used as base materials for the geological survey and for designing countermeasure works.

(b) Geological survey

The geological survey plan (1:1,000) is shown in *Figure 9.5.1*. The results of the survey is described in detail in the below-mentioned geological survey report, however, it may be summarized as follows.
<Informe de Investigaciones Geotecnicas y Perforaciones a Diamantina No7 km426+300 Junio 2006>

Boring and standard penetration tests

(1) Boring was conducted at the four points indicated in *Figure 9.5.1*. The geological profile of the main section of the road surface collapse is shown in *Figure 9.5.2*. The geological condition of the surveyed area was found to have around 5 – 7m thick, loose embankment and it is obvious that the roadbed collapse has occurred in this layer.

(2) The standard penetration test at the embankment layer showed that the N value of some areas were 1 – 6, indicating that the condition was very loose compaction.

(3) The bedrock is made of fresh tuffaceous sandstone and it is shaped by stream erosion. Thus, it is assumed that it may have a very complicated shape with a lot of irregularities.

(4) The groundwater level did not exist in the embankment at the time of the survey. It is considered that the major reasons for this are that there was no rainfall for a long time because it was the dry season and that the water permeability of the embankment is high.

Laboratory soil tests

(1) The grain size tests of the embankment layer proved that the embankment was made of sand with gravels and it is evaluated as a sandy material (∅ material with small adhesion). It is considered that an embankment made of such material would easily cause flow of fine grains by rain water and create hollow portions in the ground if compaction was insufficient at the time of construction and there was no drainage facility.

(2) The natural moisture content of the embankment layer was 2 – 6%. The compacting test showed that the maximum dry density was 2.0 – 2.1 g/cc and the optimal moisture content was 7 – 9%. Since the soil does not contain many fine grains as an embankment material, it is evaluated that this is a soil which is difficult for compaction.

(3) The direct shear test showed that the adhesion of the embankment was 0.04 – 0.5kgf/cm^2 and the internal friction angle was 16 – 40°.

(3) Overall Evaluation

Based on the results of boring and soil tests, the overall evaluation of the soil of the pilot point and the recommendations for design and construction works may be summarized as follows:

(1) The road surface collapse is assumed to have been caused by poorly compacted embankment and rapid rise of groundwater level due to insufficient treatment of rain water.

(2) It was confirmed that there was no large-scale landslide, which was a concern initially, because the fresh bedrock was confirmed 5 – 7m under the ground surface by boring. If a large-scale landslide had occurred, countermeasure works on quite a large-scale would have been required.

(3) The bedrock under the embankment has been eroded by the Pirai River and it is expected to have a very complicated shape. Thus, it is necessary to pay due attention to the geometry variation of the bedrock in designing and implementing construction works.

(4) Based on the soil tests, it is judged that if the existing empankment is to be reused, it will be better to mix an appropriate amount of fine grains (clay and silt) because the embankment material is sandy soil which is difficult for compaction.

(5) A study on the stability of the countermeasure works needs to be conducted, taking into account the rapid rise of the groundwater level by rain water and the apparent adhesion drop.

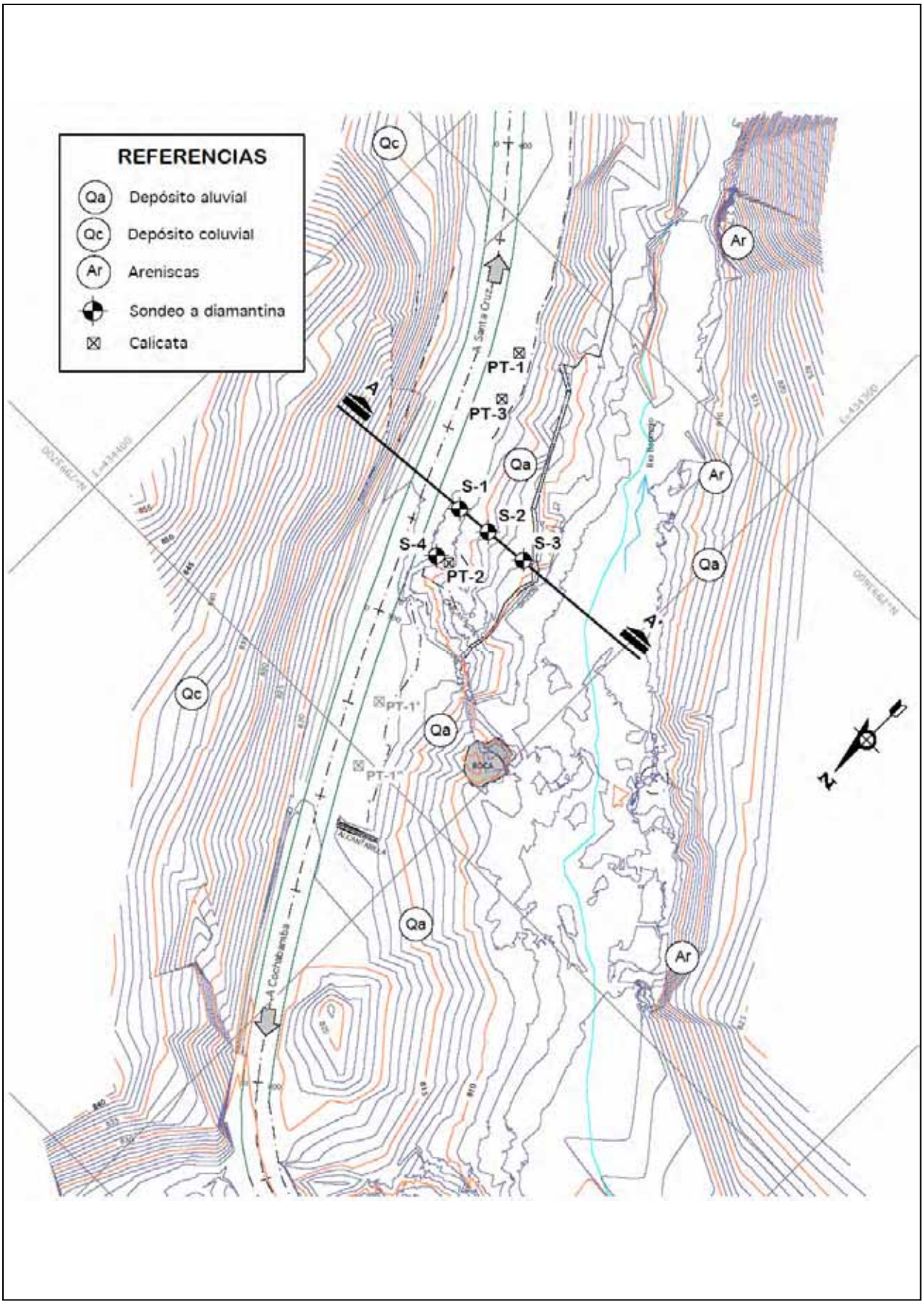


Figure 9.5.1 Geological Survey Plan

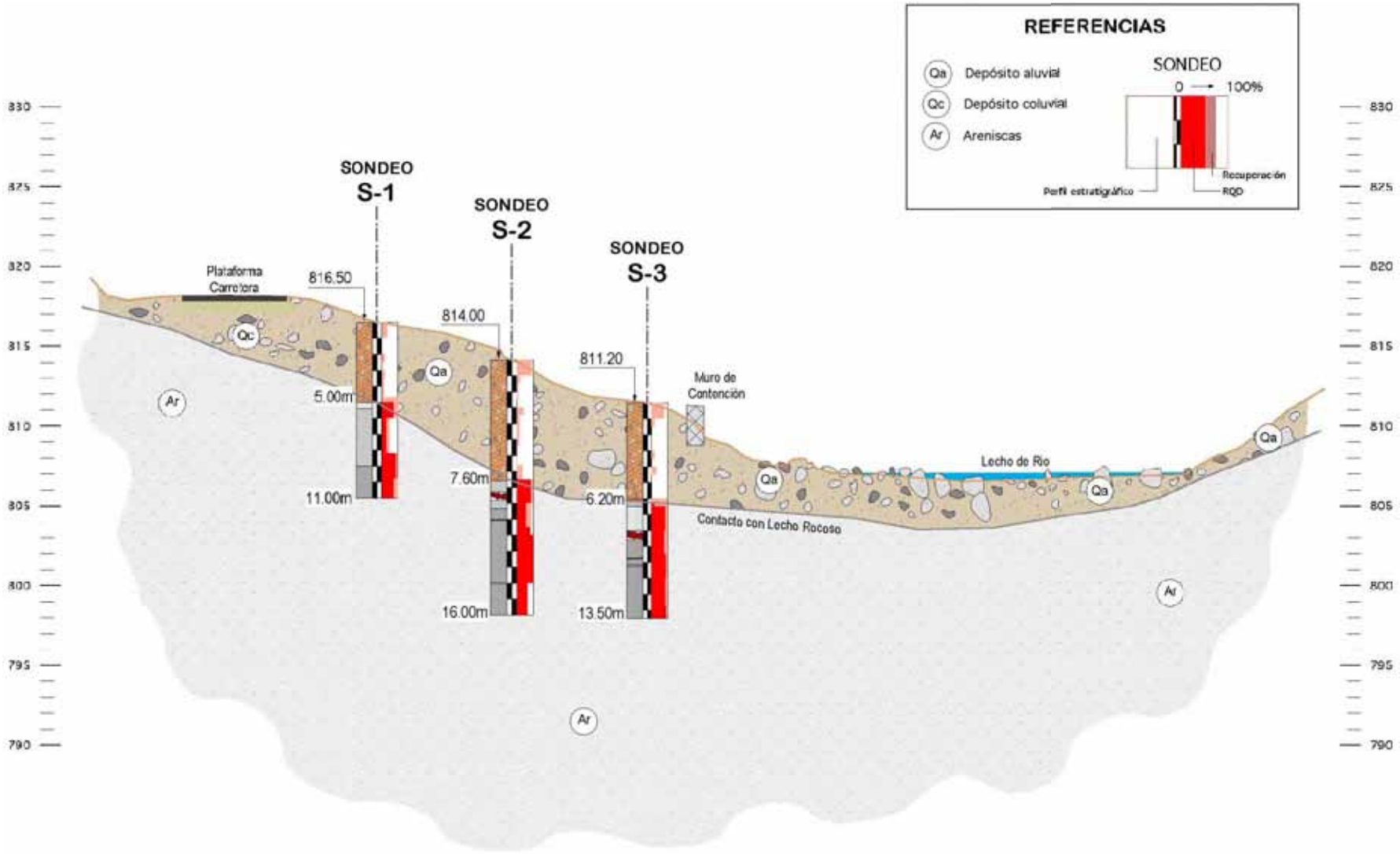


Figure 9.5.2 Geological Profile of the Main Section

9.6 Design and Plan

We worked with ABC for the design and plan of the pilot works in accordance with 9.4 Policies of Countermeasure Works for Pilot Works, based on the results of 9.6 Survey (Topographic Survey and Geological Survey).

The design work was outsourced to a local consultant on the basis of the specifications of Bolivia. The design work was processed while confirming important decisions at each stage as shown in *Figure 9.6.1* Design and Plan Implementation Flowchart.

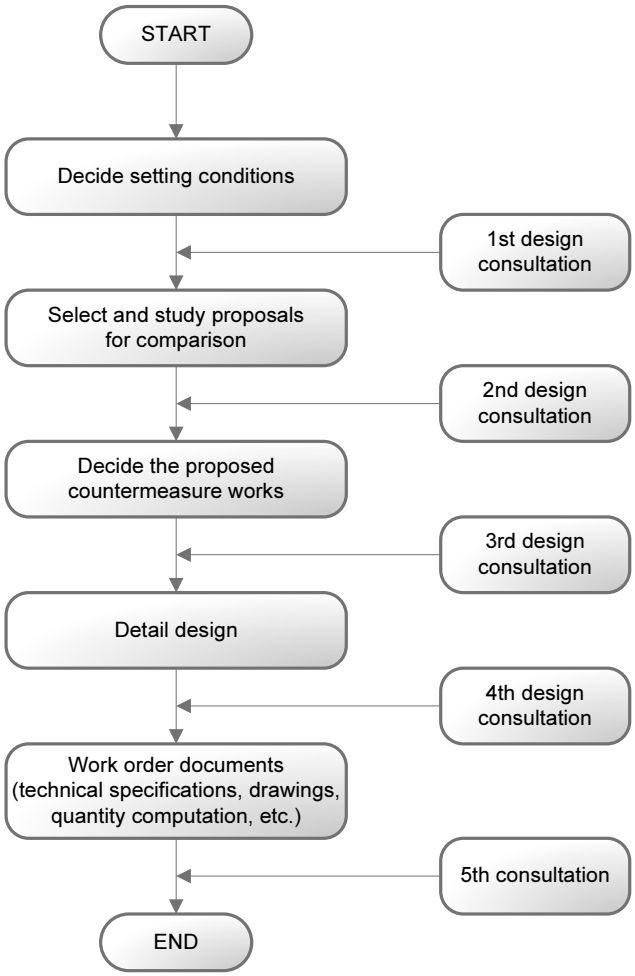


Figure 9.6.1 Design and Plan Implementation Flowchart

9.6.1 Design Conditions

Regarding the countermeasure works to be implemented by this project, the design conditions of No.399+000 km (cut earth) and No.426+300km (banking) are as stated below.

No.399+000 km (earth cutting)

Slope cribwork

Slope cribwork was recommended for the pilot project because it is a construction method which is likely to be widely used in Bolivia in the future. After understanding the processes of slope cribwork from planning and design to execution plan, the optimal dimensions were decided through structural study and then the design work was conducted.

Slope height:	h = 40m
Angle:	$\theta = 50°$
Safety factor of reinforced slope:	Fsp≥1.20 (permanent (long term))

No.426+300km (embankment)

Reinforced soil wall work was recommended for the pilot project because it is a construction method which is likely to be widely used in Bolivia in the future. After understanding the processes of reinforced soil wall work from planning and design to execution, the optimal dimensions were decided through a structural study and then the design work was conducted. And, a structural study was conducted for revetment work and rockfall prevention work including conventional construction methods to decide optimal proposals.

Revetment work:

Estimated flow:	25-year probability
Revetment height:	h=6.3m
Installation length:	L=34m
Points of attention:	The base of the structure should be on sound layer, consideration of remaining water pressure at water level dropping.

Reinforced soil wall work:

Wall height:	h=5.3m
Installation length:	L=25m
Points of attention:	Estimation of soil friction for the backfill and confirmation during execution.

Rockfall prevention work:

Wall height:	h=3.0m
Installation length:	L=40m

9.6.2 Study of Construction Methods for Countermeasure Works

Detailed structural studies were conducted for the following four methods of countermeasure works which were agreed by the Bolivian side as the countermeasure work methods of the pilot works, which would act as an incentive for future road disaster prevention measures, in accordance with 9.4 Policies of Countermeasure Works for Pilot Works.

Protection of earth cutting slopes: slope cribwork
Embankment failure prevention measures: revetment work and reinforced soil wall work
Rockfall prevention work: rockfall prevention wall

No.399+000 km (earth cutting)

It was proved from the results of the structural comparison of slope cribworks that the most economically favorable design is the case that the crib square dimension is 1.5m×1.5m and the crib height is 0.15m×0.15m. See *Table 9.6.1* Structural Study of Slope Cribwork for details.

No.426+300km (banking)

Revetment work

As a structural comparison of revetment works, a reinforced concrete cantilever-type retaining wall, a revetment with square-type gabions, and a revetment with natural stones were compared. It was found as a result of such comparison that the revetment with square-type gabions which is commonly used in Bolivia is inferior to other methods in terms of durability in consideration of the grain size distribution of the river bed and the river water velocity during floods, though it is economically more efficient. Thus, the reinforced concrete cantilever-type retaining wall was selected which is better than the others taking all things into consideration, including durability. See *Table 9.6.2* Structural Study of Revetment Work for details.

Reinforced soil wall work

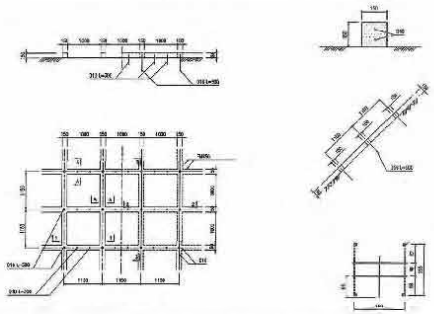
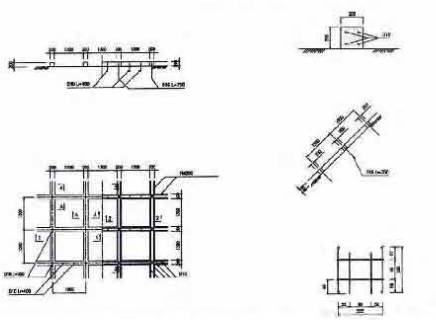
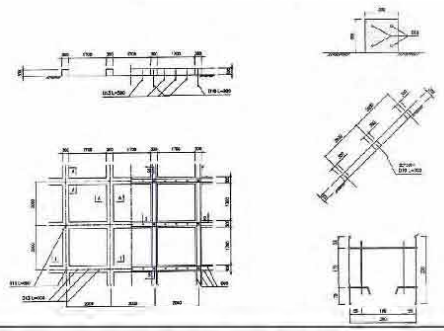
It was found as a result of comparison of the three types of the wall surface material, i.e. pre-cast concrete plate, block, and wall greening net that the pre-cast concrete plate is better than the others taking all things into consideration, including economic efficiency. See *Table 9.6.3* Structural Study of Reinforced Soil Wall Work for details.

Rockfall prevention work

It was found as a result of comparison of the retaining wall type and the square gabion type that the square gabion type is economically more efficient, but it was decided to adopt rockfall prevention work of the retaining wall type in consideration of reduction of maintenance and spread of a new construction method in Bolivia. See *Table 9.6.4* Structural Study of Rockfall Prevention Work for details.

Table 9.6.1 Structural Study of Slope Cribwork

TABLA Nº 3: CUADRO COMPARATIVO DE LAS OBRAS PARA LA GEOGRILLA (FREE FRAME)

SISTEMA	F150 x F150 (1.15m x 1.15m)	F200 x F200 (1.5m x 1.5m)	F300 x F300 (2. 0m x 2.0m)
ESQUEMA			
CARACTERÍSTICAS Y PROCEDIMIENTO DE EJECUCIÓN	El sistema de geogrillas continuas puede ser usado en forma independiente como sistema de protección para protección de taludes contra la erosión o como estructura de soporte para estabilizar taludes. La estructura básica es un reticulado en forma de malla de acero y adicionalmente requiere de armadura de refuerzo. El reticulado es construido en módulos y es colocado sobre el talud, sujetados por pernos de sujeción en algunos casos o por un sistema de anclajes cundo sea necesario. Para el colocado de los anclajes se colocan previamente tubos guías antes de armarse la geogrilla, posteriormente se perfora a través del tubo guía la	longitud necesaria para el colocado del anclaje o del perno, posteriormente es tensado contra la geogrilla que sirve como cabezal de anclaje. Por último se protegen los pernos/anclajes con fundas contra la corrosión. Posteriormente se prepara el hormigón con cemento Portland para utilizarse en el concreto lanzado. El sistema utilizado es el concreto proyectado por vía húmeda, que permite darle homogeneidad, calidad y alta trabajabilidad al hormigon. El requerimiento de la resistencia a la compresión para estas estructuras está dentro del orden de los 15MPa a 24MPa.	El trabajo comprende inicialmente una limpieza de la corona del talud mediante un trabajo manual. Se debe armar las celdas incorporando armadura de refuerzo y los pernos en los cruces y por tramos otros dos. Adicionalmente se debe incorporar una malla de refuerzo en todo el talud para posteriormente una vez fijada puede iniciarse con la aplicación del hormigón lanzado. En el pie del talud y colindante a la vía se ha previsto la construcción de un muro de retención, el que posibilitará mantener limpia la vía., Por encima está previsto una zanja de coronamiento a lo largo del talud.
CANTIDADES			
TIEMPO DE EJECUCIÓN	180 días calendario	180 días calendario	180 días calendario
COSTO UNITARIO Y PRESUPUESTO TOTAL			
EVALUACIÓN TÉCNICO ECONÓMICA	- Sistema nuevo a ser implementado en la presente construcción - Los costos presentados son referenciales, debido a que la construcción de la malla que sirve como encofrado para el shotcrete según especificaciones aponesas es de menor diámetro al existente en mercado, por ejemplo.	- El trabajo con hormigón lanzado requiere de mano de obra y equipo especializado, por lo que pocas empresas pueden dar este servicio - Deberán considerarse obras de señalización y desvío para poder ejecutar el presente trabajo, fundamentalmente por la presencia de la maquinaria para ejecutar el hormigón proyectado	

F150 x F150 (1.15m x 1.15m) — CANTIDADES

Nº	Item	Unidad	Cantidad Total	Precio Unitario [$us]	Precio Total [$us]
1	Hormigon lanzado en vigas	m³	28.52	166.31	4,809.47
2	Hormigon lanzado en celdas	m³	15.36	166.31	2,557.04
3	Barra de Refuerzo d=10 mm	Barra	235.55	5.10	1,201.23
4	Clavo d=12 mm	Barra	30.75	5.10	156.83
5	Clavo d=16 mm	Barra	25.83	13.90	359.04
6	Separador (Elemento Horizontal) d=2.6 mm	m	2 274.00	0.17	376.33
7	Separador (Elemento Vertical) d=2.6 mm	m	1 107.00	0.17	188.19
8	Malla (Elemento Vertical) d=2.3 mm	m	11 057.70	0.17	1 879.81
9	Malla (Elemento Horizontal) d=2.3 mm	m	24 600.00	0.17	4,182.00
10	Malla alambre galvanizado 3"x3"	m²	873.52	2.66	2,368.68
11	Limpieza de corona de talud	global	1.00	1,000.00	1,000.00
	TOTALES				19,168.69

F200 x F200 (1.5m x 1.5m) — CANTIDADES

Nº	Item	Unidad	Cantidad Total	Precio Unitario [$us]	Precio Total [$us]
1	Hormigon lanzado en vigas	m³	40.54	166.31	6,742.37
2	Hormigon lanzado en celdas	m³	15.20	166.31	2,528.58
3	Barra de Refuerzo d=10 mm	Barra	382.00	5.10	1,948.20
4	Clavo d=10 mm	Barra	24.25	5.10	123.70
5	Clavo d=16 mm	Barra	22.65	13.90	317.00
6	Separador (Elemento Horizontal) d=3.2 mm	m	2,027.20	0.17	344.62
7	Separador (Elemento Vertical) d=3.2 mm	m	2,027.20	0.17	344.62
8	Malla (Elemento Vertical) d=2.3 mm	m	10,993.68	0.17	1,857.12
9	Malla (Elemento Horizontal) d=2.3 mm	m	22,588.80	0.17	3,840.10
10	Malla alambre galvanizado 3"x3"	m²	834.56	2.66	2,362.05
11	Limpieza de corona de talud	global	1.00	1,000.00	1,000.00
				total	21,316.87

F300 x F300 (2. 0m x 2.0m) — CANTIDADES

Nº	Item	Unidad	Cantidad Total	Precio Unitario [$us]	Precio Total [$us]
1	Hormigon lanzado en vigas	m³	67.93	166.31	11,297.77
2	Hormigon lanzado en celdas	m³	14.69	166.31	2,442.76
3	Barra de Refuerzo d=16 mm	Barra	271.83	13.90	3,779.85
4	Clavo d=12 mm	Barra	25.50	5.10	129.55
5	Clavo d=20 mm	Barra	13.67	22.80	304.60
6	Separador (Elemento Horizontal) d=4.0 mm	m	2,448.00	0.17	416.16
7	Separador (Elemento Vertical) d=3.2 mm	m	2,448.00	0.17	416.16
8	Malla (Elemento Vertical) d=2.3 mm	m	12,195.12	0.17	2,073.17
9	Malla (Elemento Horizontal) d=2.3 mm	m	22,195.20	0.17	3,773.18
10	Malla alambre galvanizado 3"x3"	m²	816.00	2.60	2,166.20
11	Limpieza de corona de talud	global	1.00	1,000.00	1,000.00
				total	28,976.81

F150 x F150 (1.15m x 1.15m) — COSTO UNITARIO Y PRESUPUESTO TOTAL

TOTAL CANTIDADES	19,168.69
TOTAL MANO DE OBRA	116.04
TOTAL EQUIPO, MAQUINARIA Y HERRAMIENTAS	264.80
TOTAL RECARGOS	90.75
TOTAL GASTOS GENERALES	1,053.99
TOTAL UTILIDAD	1,053.99
IMPUESTO TRANSACCIONES 3%	706.16
TOTAL $US	24,544.82

F200 x F200 (1.5m x 1.5m) — COSTO UNITARIO Y PRESUPUESTO TOTAL

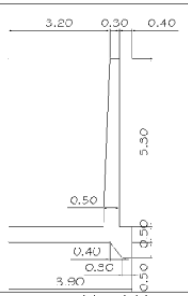
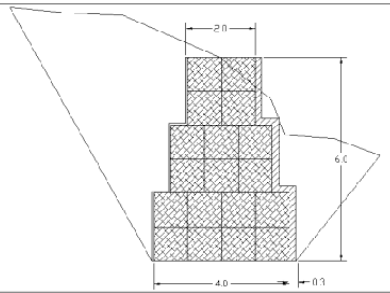
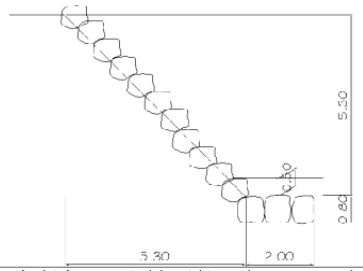
TOTAL CANTIDADES	21,316.87
TOTAL MANO DE OBRA	116.04
TOTAL EQUIPO, MAQUINARIA Y HERRAMIENTAS	264.80
TOTAL RECARGOS	90.75
TOTAL GASTOS GENERALES	2,166.81
TOTAL UTILIDAD	2,166.81
IMPUESTO TRANSACCIONES 3%	783.49
TOTAL $US	26,895.97

F300 x F300 (2. 0m x 2.0m) — COSTO UNITARIO Y PRESUPUESTO TOTAL

TOTAL CANTIDADES	28,976.81
TOTAL MANO DE OBRA	116.04
TOTAL EQUIPO, MAQUINARIA Y HERRAMIENTAS	264.80
TOTAL RECARGOS	90.75
TOTAL GASTOS GENERALES	2,944.80
TOTAL UTILIDAD	2,944.80
IMPUESTO TRANSACCIONES 3%	1,065.85
TOTAL $US	36,553.75

Table 9.6.2 Structural Study of Revetment Work

CUADRO COMPARATIVO DE LAS OBRAS DE PROTECCION DE ORILLA

SISTEMA	MURO DE PROTECCION HORMIGON ARMADO	MURO DE PROTECCION DE GAVION	MURO DE PROTECCION CON ENROCADO Y HORMIGON
ESQUEMA			
PROCEDIMIENTO DE EJECUCIÓN	Realizar el desvío del río con materiales del lugar, luego se procederá a la excavación hasta la cota indicada o hasta 1.0 m por debajo de la superficie rocosa. Por la altura a ser excavada las paredes laterales tendrán una inclinación de 45°, se debe entibar hasta 2.0 m de altura dejando un espacio libre de 1.5m., luego colocar las armaduras en el muro pantalla y encofrar el paramento externo, vaciar el hormigón, con intervalos de altura de 1.0 m. A los cinco días del vaciado deberá rellenarse con material común y compactar con vibroapisonador en tres capas. A cada 1.0 m. de altura, se dejarán tuberías de 0.15 m de diámetro de PVC ESQ 40 forradas con geotextil en la entrada y salida con una separación de 3.0 m. hasta llegar a la losa y se volverá a repetir el mismo procedimiento hasta llegar a la corona del muro	Realizar el desvío del río con materiales del lugar, luego se procederá a la excavación hasta la cota indicada o hasta 1.0 m por debajo de la superficie rocosa. Por la altura a ser excavada las paredes laterales tendrán una inclinación de 45°, se debe entibar hasta 2.0 m de altura dejando un espacio libre de 1.0m., luego construir la primera fila de gaviones, en el paramento interno colocar geotextil para evitar lavado de finos, y en el paramento externo revestir con hormigón, repetir el procedimiento para cada metro de altura.	Realizar el desvío del río con materiales del lugar, luego se procederá a la excavación por tramos hasta la cota indicada, Por la altura a ser excavada las paredes laterales tendrán una inclinación de 45° se debe entibar hasta 1.0 m de altura dejando un espacio libre de 1.0m luego vaciar hormigón en el muro pantalla previo encofrado, con una pala cargadora con capacidad de 4 toneladas ir colocando las rocas lado a lado en tramos de 20 m luego vaciar hormigón en los espacios vacíos, rellenar y compactar con vibroapisonador de rodillo en capas de 0.3 m los laterales y repetir el mismo procedimiento hasta llegar a la cota indicada, luego proceder con el siguiente tramo, el tramo final deberá realizarse desde otra posición por el espacio físico.
CANTIDADES			

N°	ITEM	UNIDAD	CANT. (ml)	LONG. (m)	TOTAL
1	Replanteo	glb.	1,0	1,0	1,0
2	Protección y desvío	ml	1,0	150,0	150,0
3	Excavación	m3	40,0	60,0	2400,0
4	Entibado	m2	4,0	60,0	240,0
5	Hormigón armado	m3	6,0	60,0	360,0
6	Relleno y compactado	m3	35,0	60,0	2100,0
7	Tubería 6" ESQ 40	ml	3,0	60,0	180,0
8	Geotextil	m2	2,0	60,0	120,0

N°	ITEM	UNIDAD	CANT. (ml)	LONG. (m)	TOTAL
1	Replanteo	glb.	1,0	1,0	1,0
2	Protección y desvío	ml	1,0	150,0	150,0
3	Excavación	m3	33,0	60,0	1980,0
4	Entibado	m2	4,0	60,0	240,0
5	Gavión 2*1*1 c/d	m3	18,0	60,0	1080,0
6	Relleno y compactado	m3	85,0	60,0	5100,0
7	Revestimiento hormigón	m3	1,4	60,0	84,0
8	Geotextil	m2	7,0	60,0	420,0

N°	ITEM	UNIDAD	CANT. (ml)	LONG. (m)	TOTAL
1	Replanteo	glb.	1,0	1,0	1,0
2	Protección y desvío	ml	1,0	150,0	150,0
3	Excavación	m3	33,0	60,0	1980,0
4	Entibado	m2	4,0	60,0	240,0
6	transporte de rocas	pza	600,0	1,0	450,0
5	Enrocado	pza	9,0	60,0	540,0
6	Relleno y compactado	m3	40,0	60,0	2400,0
8	Hormigon	m3	6,0	60,0	360,0

TIEMPO DE EJECUCIÓN	90 Días calendario	120 Días calendario	120 Días calendario

N°	ITEM	UNIDAD	CANT	P. U. $us	S. TOT $us
1	Replanteo	glb.	1,0	1500,0	1500,0
2	Protección y desvío	ml	150,0	50,0	7500,0
3	Excavación	m3	2400,0	4,0	9600,0
4	Entibado	m2	240,0	15,0	3600,0
5	Hormigón armado	m3	360,0	350,0	126000,0
6	Relleno y compactado	m3	2100,0	4,0	8400,0
7	Tubería 6" ESQ 40	m	180,0	12,0	2160,0
8	Geotextil	m2	120,0	4,0	480,0
				TOT. $US	159240,0

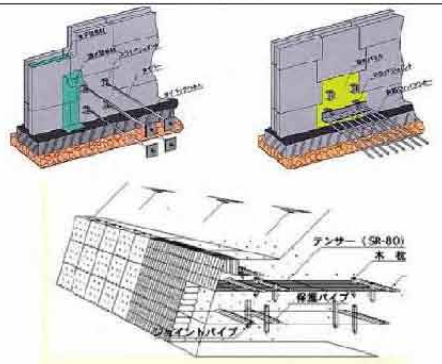
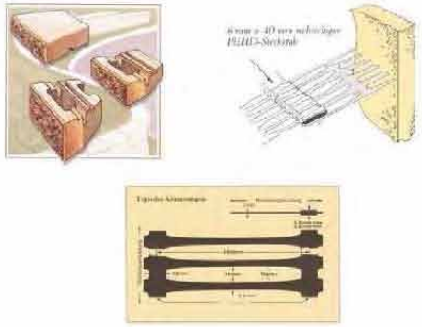
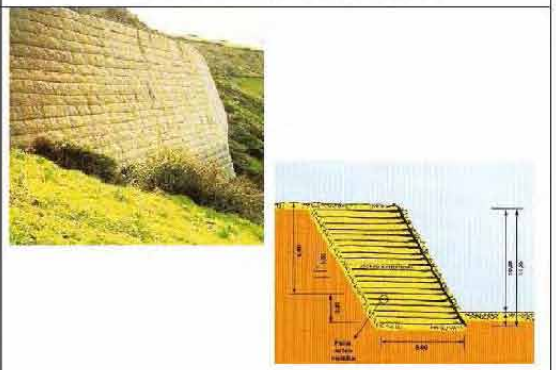
N°	ITEM	UNIDAD	CANT	P. U. $us	S. TOT $us
1	Replanteo	glb.	1,0	1500,0	1500,0
2	Protección y desvío	ml	150,0	100,0	15000,0
3	Excavación	m3	1980,0	4,0	7920,0
4	Entibado	m2	240,0	15,0	3600,0
5	Gavión 2*1*1 c/d	m3	1080,0	50,0	54000,0
6	Relleno y compactado	m3	5100,0	4,0	20400,0
7	Revestimiento hormigón	m3	84,0	40,0	3360,0
8	Geotextil	m2	420,0	4,0	1680,0
				TOT. $US	107460,0

N°	ITEM	UNIDAD	CANT	P. U. $us	S. TOT $us
1	Replanteo	glb.	1,0	1500,0	1500,0
2	Protección y desvío	ml	150,0	100,0	15000,0
3	Excavacion	m3	1980,0	4,0	7920,0
4	Entibado	m2	240,0	15,0	3600,0
6	transporte de rocas	pza	450,0	40,0	18000,0
5	Enrocado	pza	540,0	250,0	135000,0
6	Relleno y compactado	m3	2400,0	4,0	9600,0
8	Hormigon	m3	360,0	80,0	28800,0
				TOT. $US	219420,0

PRECIO UNITARIO Y PRESUPUESTO TOTAL			
EVALUACIÓN TÉCNICO ECONÓMICA	La estructura previamente verificada a la estabilidad, es una alternativa que mejor se adapta a las condiciones actuales y futuras, sin embargo deberá determinarse el costo final que demanda esta estructura.	Por las características de este material y debido a los espacios vacíos que a futuro sufre un reacomodamiento de las piedras este tipo de estructuras sufre asentamientos que a futuro representarán deterioro en el cuerpo de la estructura	Las condiciones topográficas y el poco espacio para maniobrar el equipo pesado dificulta la implementación de esta alternativa, si bien la solución hidráulicaamnte funciona el costo es elevado

Table 9.6.3 Structural Study of Reinforced Soil Wall Work

TABLA Nº 1: CUADRO PRELIMINAR COMPARATIVO DE MUROS DE CONTENCIÓN

SISTEMA	TIERRA ARMADA	GEOBLOQUE	SISTEMA TERRAMESH-VERDE
MATERIAL DEL MURO	BLOQUE DE HORMIGÓN PREFABRICADO	BLOQUE PREFABRICADO	PARAMENTO CON BIOMANTA DE FIBRA DE COCO
MATERIAL DE REFUERZO	TIERRA ARMADA	GEOTEXTIL MT-200 + GEOGRILLA MACGRID WG 40	TERRAMESH – BIOMANTA DE FIBRA DE COCO
ESQUEMA			
CARACTERÍSTICAS Y PROCEDIMIENTO DE EJECUCIÓN	El sistema de tierra armada permite transmitir las cargas de empujes y sobrecargas por fricción al subsuelo. El terraplén se va compactando en bloques compactados, en los cuales se colocan las barras metálicas, las que están sujetadas a las placas de hormigón prefabricado. Estos bloques permiten dar protección y confinamiento a la tierra armada. Los bloques de hormigón prefabricado están fundados en una losa de hormigón no armada.	Los geobloques utilizan geogrillas en vez de barras metálicas, las geogrillas son elementos estructurales que pueden ser unidireccionales o bidireccionales. El paramento puede estar protegido con bloques de hormigón o con elementos prefabricados de menor dimensión. El método constructivo es similar al de la tierra armada. Una caracteristica adicional es que el sector de empalme entre geogrillas es mediante barras o perfiles metálicos. El relleno compactado deberá realizarse con material seleccionado, en preferencia de tipo granular no plástico	El Sistema Terramesh-Verde utiliza como paramento una malla hexagonal extendida cubierta por una biomanta de fibra de coco, con una inclinación de 70º, el elemento resistente es la misma malla hexagonal extendida. El método constructivo es similar al de la tierra armada. El relleno compactado deberá realizarse con material seleccionado, en preferencia de tipo granular no plástico.
CANTIDADES			
TIEMPO DE EJECUCIÓN	120 dias calendario	120 dias calendario	120 dias calendario
COSTO UNITARIO Y PRESUPUESTO TOTAL			
EVALUACIÓN TÉCNICO ECONÓMICA	- De las tres alternativas la mas costosa - Sistema que no tiene un distribuidor en Bolivia, los pocos trabajos realizados se han hecho con todo el materia importaco, por lo que los costos presentados son solo referenciales - El costo de los elementos del paramento (losas de 1m2) deben prefabricarse por lo que no serian tampoco económicas por no ser en mucha cantidad.	- Sistema con cierta experiencia de construccion en Bolivia - Los bloques prefabricados puede que incremente el costo debido a la pequeña cantidad requerida - Las geogrilles existen actualmente en el mercado - Técnica y economicamente son las mas recomendadas, debido a la experiencia que ya se tiene su construcción	- Sistema de mayor uso y construcción en Bolivia - No necesita elementos prefabricados para la protección del relleno compactado, únicamente es necesario una geomante en el traadós - Puede incluirse material orgánico para posibilitar la revegetacion a corto tiempo considerando las condiciones del sector

CANTIDADES

No.	Item	Unidad	Cantidad Total	Precio Unitario [$us]	Precio Total [$us]
1	Trazado y Replanteo	m	25,00	1,50	37,50
2	Excavacion	m³	990,90	3,20	3.946,88
3	Bloque de hormigon prefabricado	m²	125,00	21,00	2.625,00
4	Perno y tuerca	Pieza	500,00	0,50	250,00
5	Barras de Refuerzo ø/30 cm	m	2.000,00	1,86	3.720,00
6	Membrana impermeabilizante	m²	125,00	6,70	837,50
7	Tierra seleccionada y compactado	m³	500,00	5,70	2.850,00
8	Fundación de hormigon	m³	5,00	74,30	371,50
9	Otros elementos	global	1,00	681,92	681,92
				Total Cantidades	14.320,30

No.	Item	Unidad	Cantidad Total	Precio Unitario [$us]	Precio Total [$us]
1	Trazado y Replanteo	m	25,00	1,50	37,50
2	Excavación	m³	421,88	9,01	2.546,88
3	Bloque de hormigon prefabricado	m²	125,00	21,00	2.625,00
4	Geogrilla MacGrid WG40	m²	1.375,00	4,20	6.775,00
5	Geotextil MT 200	m²	265,00	2,30	590,09
6	Tierra seleccionada y compactado	m³	500,00	5,70	2.850,00
7	Fundación de hormigon	m³	5,00	74,30	371,50
8	Otros elementos	globa	1,00	577,50	577,50
				Total Cantidades	16.883,38

No.	Item	Unidad	Cantidad Total	Precio Unitario [$us]	Precio Total [$us]
1	Trazado y Replanteo	m	25,00	1,50	37,50
2	Excavación	m³	990,90	3,20	3.946,88
3	Malla Electrosoldada	m²	135,00	2,40	900,00
4	Alambre Galvanizado No. 10	kg	50,00	1,61	80,50
5	Terramesh Verde 4x6,5x4	piezas	135,00	31,00	15.125,00
6	Paramento con Manto de Coco	m²	250,00	2,00	500,00
7	Tierra seleccionada y compactado	m³	970,00	5,70	2.107,00
8	Otros Elementos	global	1,00	1.012,50	1.012,50
				Total Cantidades	17.139,83

COSTO UNITARIO Y PRESUPUESTO TOTAL

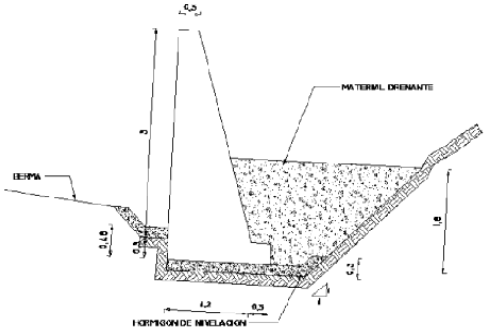
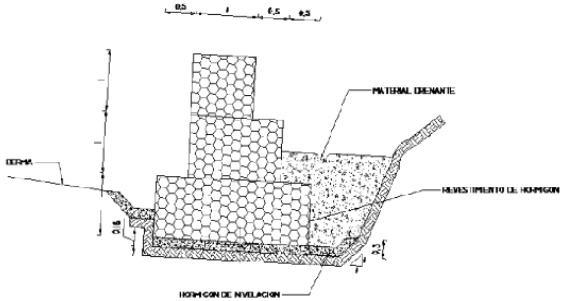
TOTAL CANTIDADES	14.320,30
TOTAL MANO DE OBRA	865,25
TOTAL EQUIPO, MAQUINARIA Y HERRAMIENTAS	43,26
TOTAL RECARGOS	674,90
TOTAL GASTOS GENERALES	1.522,88
TOTAL UTILIDAD	1.522,88
IMPUESTO TRANSACCIONES 3%	568,48
TOTAL **$US**	**19.517,75**

TOTAL CANTIDADES	15.883,38
TOTAL MANO DE OBRA	865,25
TOTAL EQUIPO, MAQUINARIA Y HERRAMIENTAS	43,26
TOTAL RECARGOS	674,90
TOTAL GASTOS GENERALES	1.659,19
TOTAL UTILIDAD	1.659,19
IMPUESTO TRANSACCIONES 3%	617,55
TOTAL **$US**	**21.202,72**

TOTAL CANTIDADES	17.139,83
TOTAL MANO DE OBRA	865,25
TOTAL EQUIPO, MAQUINARIA Y HERRAMIENTAS	43,26
TOTAL RECARGOS	674,90
TOTAL GASTOS GENERALES	1.806,84
TOTAL UTILIDAD	1.806,84
IMPUESTO TRANSACCIONES 3%	666,00
TOTAL **$US**	**23.002,95**

Table 9.6.4 Structural Study of Rockfall Prevention Work

TABLA Nº 2: CUADRO COMPARATIVO DE MUROS DE CONTENCIÓN PARA PROTECCIÓN CONTRA LA CAÍDA DE BLOQUES Y MATERIAL DESLIZADO
KM 426+300 – L= 60m

SISTEMA	MURO DE HORMIGÓN CICLÓPEO	MURO DE CONTENCIÓN DE GAVIONES
ESQUEMA		
CARACTERÍSTICAS Y PROCEDIMIENTO DE EJECUCIÓN	Los muros de hormigón ciclópeo son basicamente estructuras cue trabajan por peso propio. Las verificaciones que deben realizarse para su correspondiente prediseño son la relacionadas a la estabilidad al volcamiento, al deslizamiento, la verificación de la fatiga de fundación o en el caso de taludes la verificación global del sistema muro-talud. En el caso presente deberá considerarse inicialmente un hormigón pobre de nivelación de 15cm en la cota de fundación. La construcción de una base de 1,5m con una altura de muro libre de 3m y una corona de 0,3m. Importante es considerar una inclinación de 15º a 30º de la base. Adicionalmente deberá considerarse un relleno a media altura de material granular de un diámetro no mayor a 3" en el trasdós del muro. Deberá a manera de dreneje prolongarse el hormigón pobre conformando con el talud una cuneta revestida.	Los muros de gaviones permiten la construcción de estructuras monoliticas, flexibles, permeables, de bajo impacto ambiental resistentes y cue se integran facilmente al medio circundante. El muro de gaviones ha ser construido tiene una base de 2.5m de ancho, la misma que está apoyada en hormigón pobre de nivelación de 0,15m, la misma que forma una cuneta interna para desalojo de aguas subterráneas que se introducen en el trascós del muro. La altura prevista del murc es de 3.0m y está con un espesor de fundación equivalente a 0,3m. En el trasdós se ha previsto material drenante hasta mediada altura con pendiente contraria de manera que sirva como estructura de impacto y de depósito de material que haya deslizado. Adicionalmente no las caras que están aledañas a las cunetas se deberán revestir con hormigón pobre.
CANTIDADES		
TIEMPO DE EJECUCIÓN	120 días calendario	120 días calencario
COSTO UNITARIO Y PRESUPUESTO TOTAL		
EVALUACIÓN TÉCNICO ECONÓMICA	- Los costos comparados con el muro de gaviones son casi similares considerando además que se tiene piedra de las anteriores obras realizadas que pueden ser realizadas. - Se he consideraco la construcción de un relleno de material granular a manera de filtro en el trasdós del muro de manera que permita evacuar inmediatamente las aguas a la cureta - Para el relleno en el trascós deberán preverse mantenimiento y limpieza permanente	- Se he considerado la construcción de un relleno de material granular a manera de filtro en el trascós del muro de manera que permita evacuar inmediatamente las aguas a la cuneta - Pare el relleno en el trasdós deberán preverse mantenimiento y limpieza permanente

CANTIDADES

No.	Item	Unidad	Cantidad Total	Precio Unitario [$us]	Precio Total [$us]
1	Trazado y Replanteo	m	70.00	1.50	105.00
2	Excavación	m³	50.89	-	-
3	Capa de hormigon pobre 0.15m	m³	25.84	57.38	1,482.70
4	Muro de H° C°.	m³	164.25	47.24	9,176.37
5	Material drenante c transp. Hasta 10km	m³	137.55	6.51	895.45
	TOTALES			$US	11,554.52

No.	Item	Unidad	Cantidad Total	Precio Unitario [$us]	Precio Total [$us]
1	Trazado y Replanteo	m	70.00	1.50	105.00
2	Excavacion	m³	71.80	-	-
3	Capa de hormigon pobre 0.15m	m³	35.98	57.38	2,064.53
4	Muro de gaviones de 1x1x2	m³	350.00	33.10	11,585.00
5	Material drenante	m³	99.25	3.51	926.59
	TOTALES			$US	14,276.12

COSTO UNITARIO Y PRESUPUESTO TOTAL

TOTAL CANTIDADES	11,554.52
TOTAL MANO DE OBRA	4,566.30
TOTAL EQUIPO, MAQUINARIA Y HERRAMIENTAS	186.62
TOTAL RECARGOS	3,561.71
TOTAL GASTOS GENERALES	1,630.74
TOTAL UTILIDAD	1,630.74
IMPUESTO TRANSACCIONES 3%	693.52
TOTAL $US	23,824.56

TOTAL CANTIDADES	14,276.12
TOTAL MANO DE OBRA	2,012.99
TOTAL EQUIPO, MAQUINARIA Y HERRAMIENTAS	196.20
TOTAL RECARGOS	1,570.12
TOTAL GASTOS GENERALES	1,648.53
TOTAL UTILIDAD	1,648.53
IMPUESTO TRANSACCIONES 3%	640.57
TOTAL $US	21,993.05

9.6.3 Selection of Methods for Countermeasure Works

Based on the results of 9.6.2 Study of Construction Methods for Countermeasure Works, it was decided to adopt the types of constructions methods for slope cribwork, the revetment work, the reinforced soil wall work and the rockfall prevention work, which are shown in *Figure 9.6.2* and *9.6.3*, for No.399+000 km (earth cutting) and No.426+300 km (embankment) selected for the pilot project, as the construction methods for the countermeasures works.

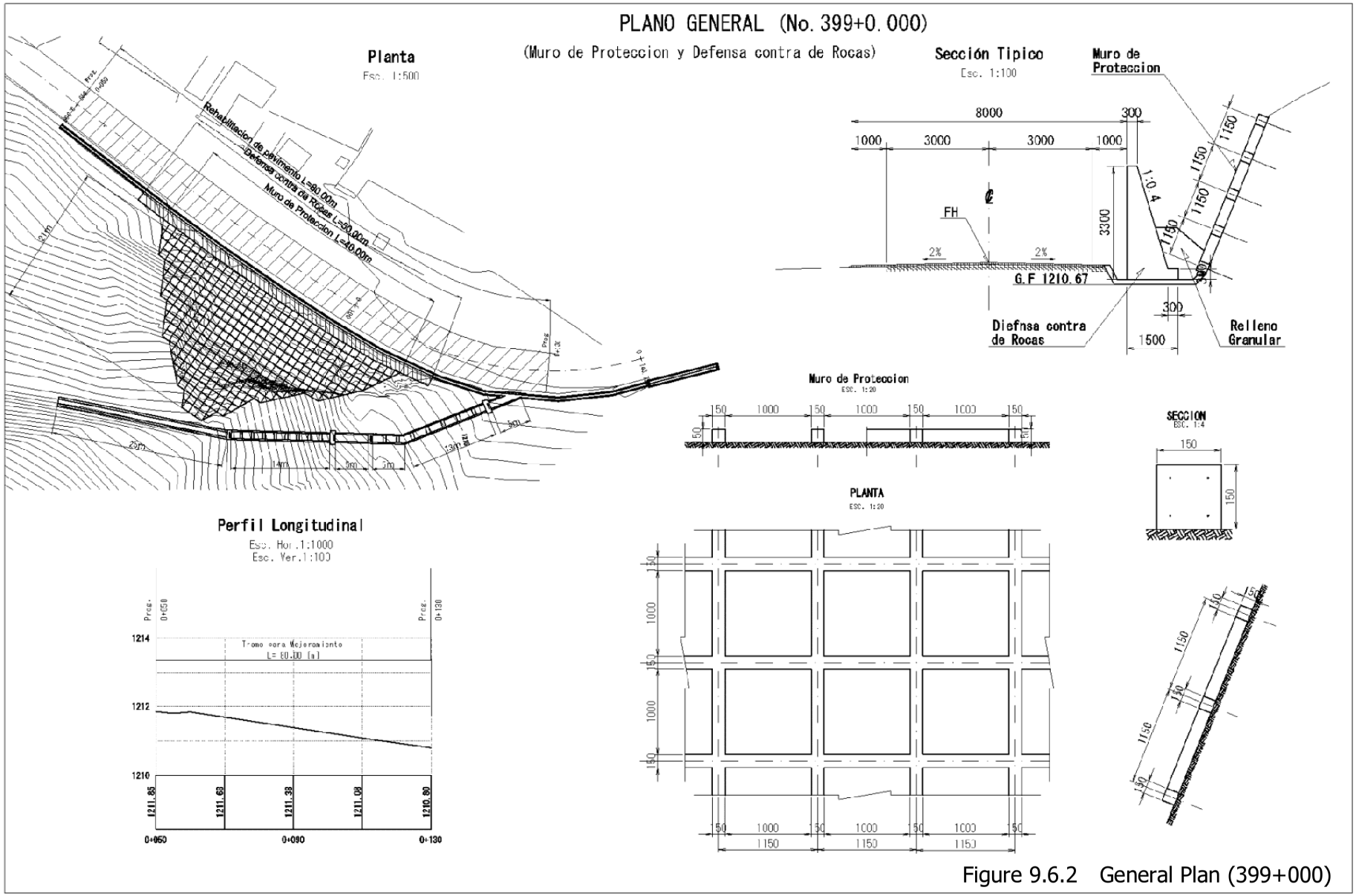


Figure 9.6.2 General Plan (399+000)

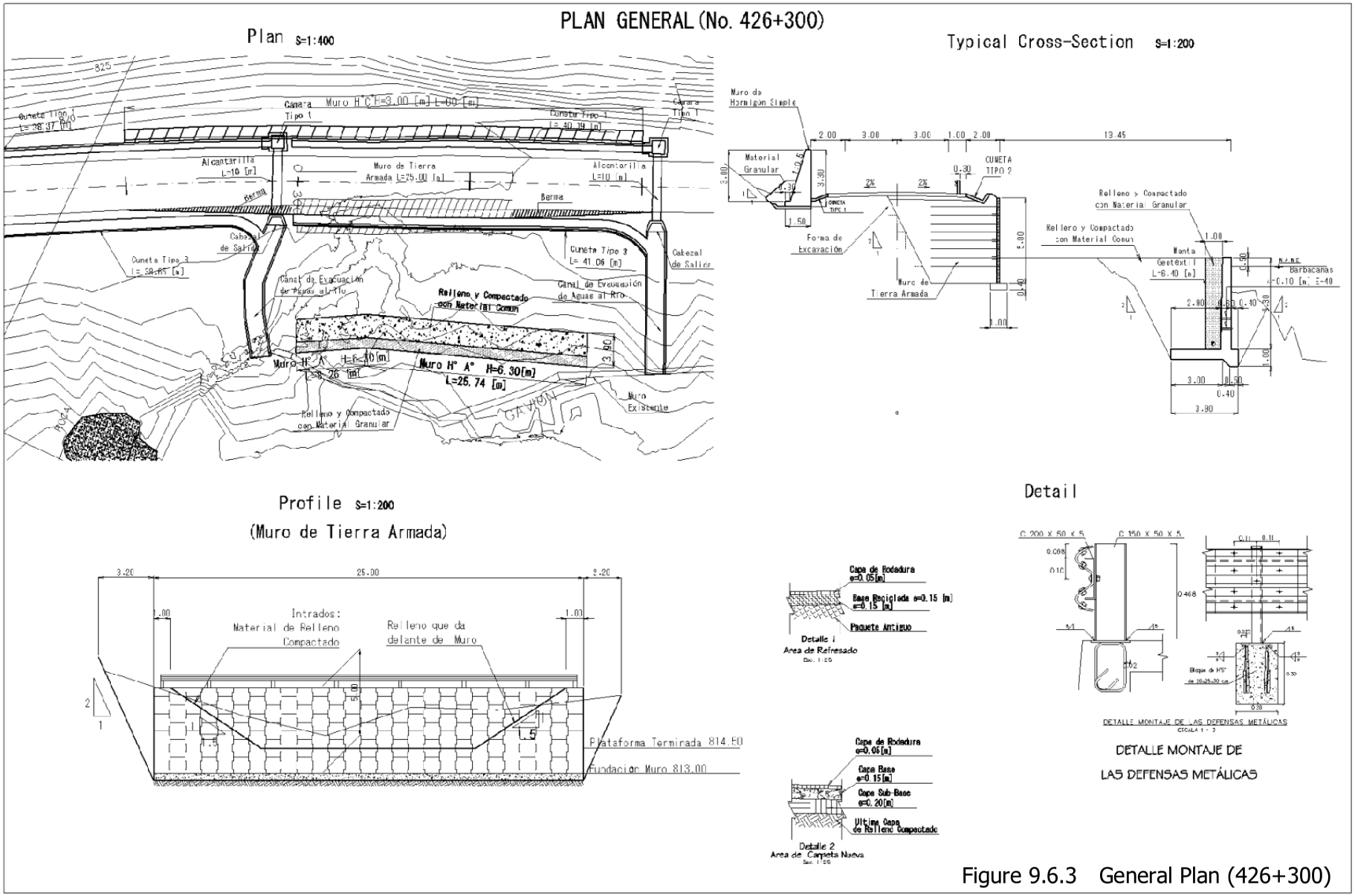


Figure 9.6.3 General Plan (426+300)