Chapter 4

Landslide Management Plan 2 (Analysis and Interpretation)

4 Landslide Management Plan 2 (Analysis and Interpretation)

4.1 Geological Interpretation

4.1.1 Chitrakoot

A lot of landslide blocks can be found in Chitrakoot by aerial photo analysis and site surveys. Block A which is located in the upper west of Chitrakoot landslide area and Block B which is lower west of Chitrakoot can be distinguished as active blocks. Other blocks in Chitrakoot landslide area show no evidence of landslide activity.

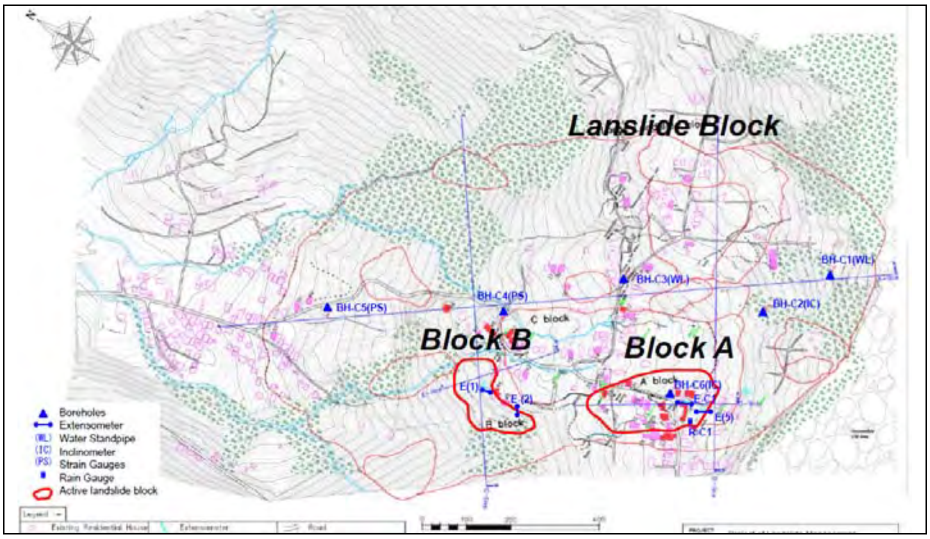


Figure 4.1.1 Landslide Blocks in Chitrakoot (source: JET)

Block A

There is the Chitrakoot Government School and many residential houses in Block A which is 300 m long and 150 m wide landslide block. The school and some houses in the block have deformations and many cracks on their structures. The landslide slip surface is confirmed by inclinometer BH-C2 in Block A at the depth of 7 m.

<u>Geology of Block A</u>

As shown in Figure 4.2.2 geological soil section of Block A, basaltic bedrocks underlie a 7 m - 10 m thick top layer of colluvium.

The material of colluvium is loose and inhomogeneous soil of clay, sand and gravel. The bedrocks under the colluvium consist of basalt and basaltic breccias. Top 2m –5m of bedrock is highly weathered.

The slip surface of the landslide Block A may be at the boundary between colluvium and bedrocks according to the result of inclinometer BH-C6 in Block A.

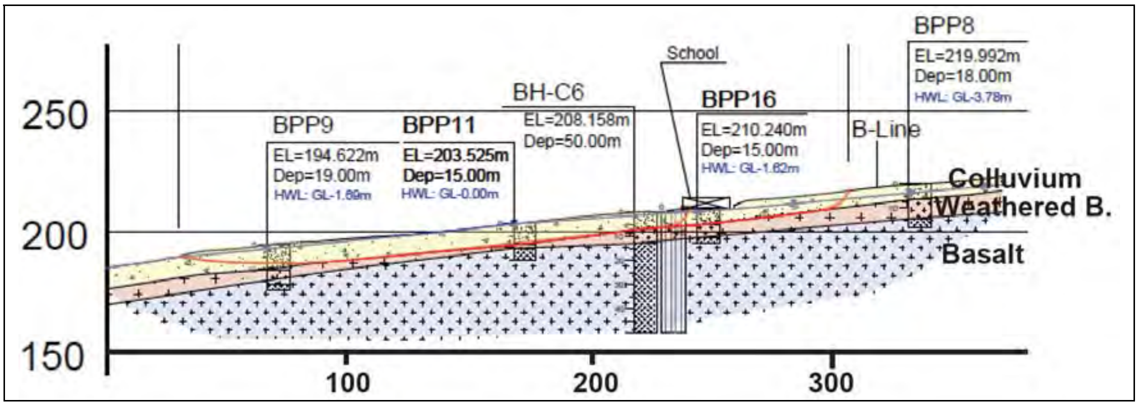


Figure 4.1.2 Geological Section of Block A (North- South) (source: JET)

Groundwater

The groundwater level is high in the whole area of Block A, because water springs and a pond can be seen on the ground surface in lower parts of Block A and because the groundwater level at the borehole rose above the ground surface in the rainy season.

Block B

The most of the area of B Block, which is a 100 m long and 200 m wide landslide block, is wasteland and there are only three residential houses in Block B. All of three houses have some cracks and deformations.

Geology of Block B

As shown in Figure 4.2.3 geological soil section of Block B, basaltic bedrocks underlie an approximately 10 m thick top layer of colluvium.

The material of colluvium in Block B is also loose and inhomogeneous soil of clay, sand and gravel. The bedrocks under the colluvium consist of basalt and basaltic breccias. The top 1 m –2 m of bedrock is highly weathered.

Landslide monitoring has not confirmed a slip surface in Block B, however it is thought that there is a slip surface at the boundary between colluvium and bedrocks according to the size of Block B.

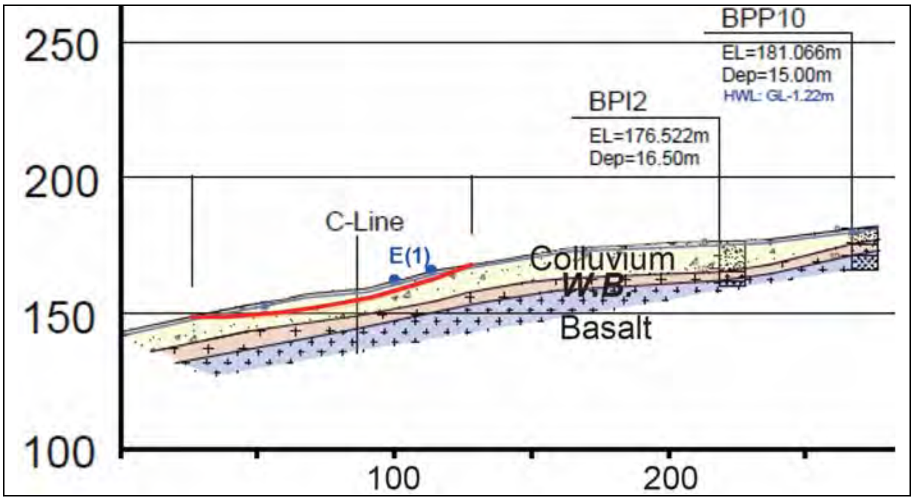


Figure 4.1.3 Geological Section of Block B (North- South) (source: JET)

Groundwater

The groundwater level is high in Block B, because water springs and a pond can be seen on the ground surface near the block and because the groundwater level at the borehole rose to a depth of 1-2 m in the rainy season.

Whole area of Chitrakoot

Deformations and cracks can be seen on the houses in the center and west of the whole area of Chitrakoot. These deformations and cracks indicate that the whole area was active in the past, but now there is no evidence of activity of the whole area.

There are some small blocks such as Block A and Block B within the whole area. These small blocks might have moved separately to the whole area in the past.

Figure 4.1.4 shows geological section of the whole area. The boundary between bedrocks and colluvium is at about 10 m deep and is very shallow compared with the size of whole area, which is 2 km long. This indicates that the small blocks acted separately to the whole area.

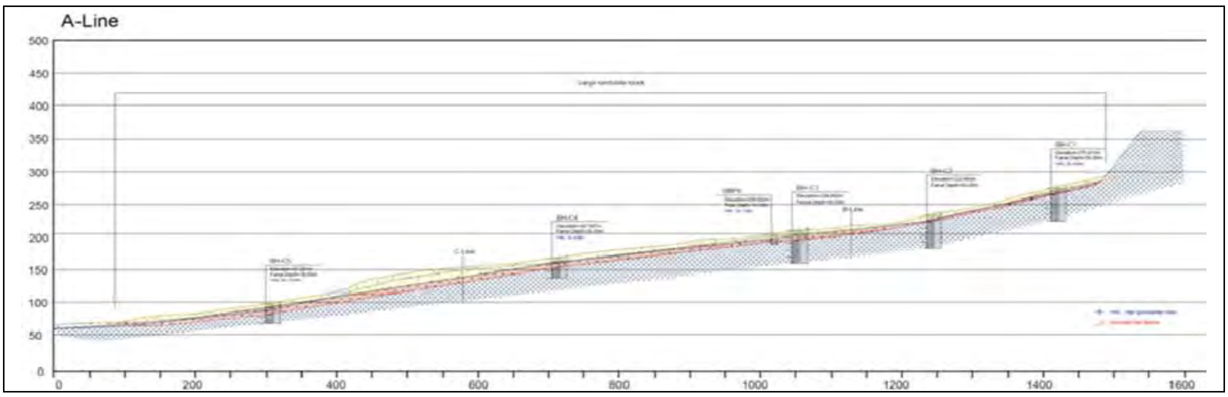


Figure 4.1.4 Geological Section of Whole Area of Chitrakoot (North- South) (source: JET)

4.1.2 Quatre Soeurs

Two blocks can be found in Quatre Soeurs by aerial photo analysis and site survey. Block A, which is located at the toe of the slope in Quatre Soeurs, and Block B, which is located on the upper slope of Quatre Soeurs, can be distinguished as active blocks. Other blocks are not clear in Quatre Soeurs area because there is no deformation on the ground surface and structures.

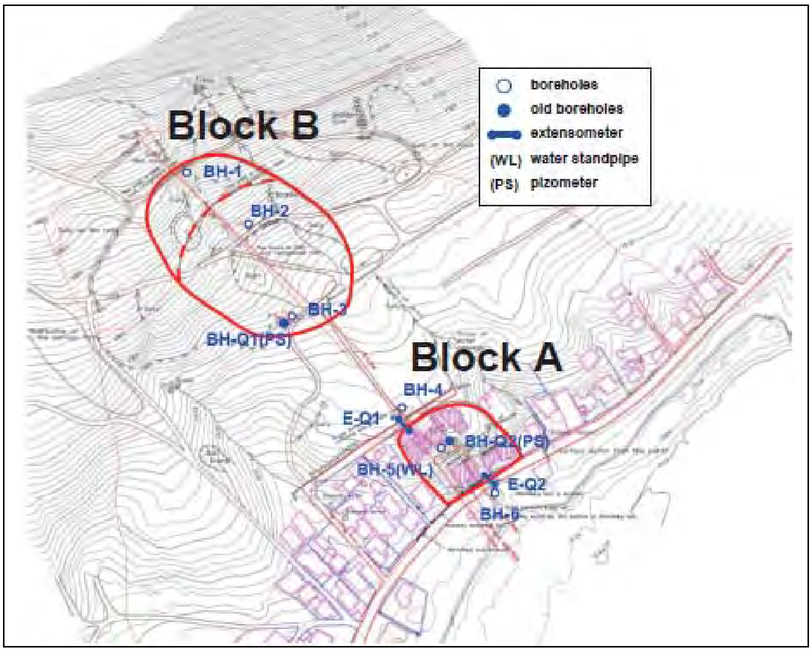


Figure 4.1.5 Landslide Blocks in Quatre Soeurs (source: JET)

Block A

Block A, which is a 60 m long and 50 m wide landslide block on a steep slope, is located in lower part of the slopes of Quatre Soeurs. Bottom of the block adjoins the coastal road. There are many residential houses in the block. The houses in the block have deformations and many cracks on their structures. Most of the deformations and cracks are caused by the landslide activities in the years of 2005 and 2008.

Geology of Block A

As shown in Figure 4.1.6 geological soil section of Block A, colluvium underlies the surface with a thickness of 15 – 20 m.

The material of colluvium is loose and inhomogeneous soil of clay, sand and gravel. The average N value of the colluviums is about 15. The bedrocks under the colluviums in Block A consist of highly weathered basalt and basaltic breccias.

The slip surface of the landslide Block A may be 5-7 m in the colluvium according to the size of Block A.

Groundwater

In Block A, two levels of groundwater have been confirmed, deep groundwater and shallow groundwater. The deep groundwater is the same level as sea level and the change of its level is linked to the tide. The shallow groundwater level rises to almost the ground surface in heavy rain according to groundwater monitoring.

B Block

The surface of Block B, which is a 150 m long and 100 m wide landslide block in a gentle slope, is used for agricultural land without structures such as houses. The activity of Block B may have stopped because there are no observable deformations such as cracks or sinks in the block. And also, the strain gauges in Block B do not show any deformation.

Geology of Block B

As shown in Figure 4.1.6 geological soil section of Block A, bedrocks underlie a thin colluvium layer. The bedrocks consist of basalt and basaltic breccias. The bedrocks in Block B can be classified from top to deep into highly weathered, moderately weathered and slightly weathered. The top 7 – 10 m of bedrock is highly weathered, and moderately weathered layer is below the highly weathered layer with a thickness of 0 – 6 m. The slightly weathered rocks exist below the highly weathered and moderately weathered layers.

Even the strain gauges do not show any clear landslide movements, the slip surface of the landslide Block B can be assumed to exist at the boundary between the highly weathered layer and moderately weathered layer according to the size of Block B.

Groundwater

The level of the groundwater in Block B fluctuates very much in accordance with rainfall. The groundwater level in the borehole BH-Q1 at the toe of Block B is about 15 m deep in the dry season and about 1 m deep in the rainy season. And also, much water flows down on the surface of slopes in Block B in the rainy season. The groundwater in Block B is very shallow in the rainy season.

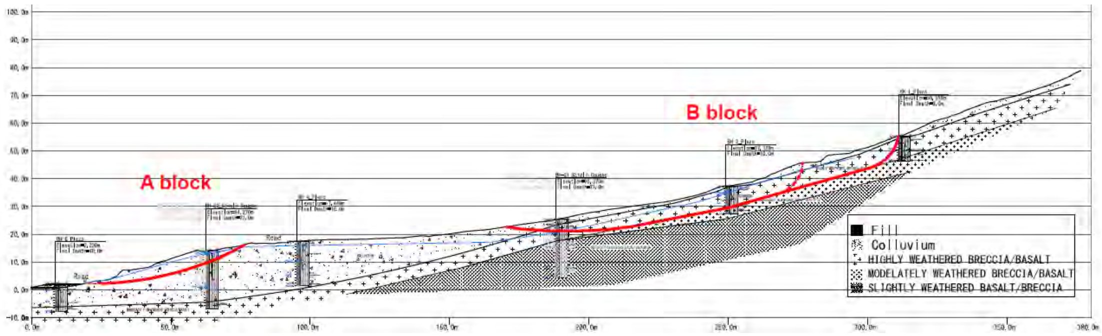


Figure 4.1.6 Geological Section of Slopes in Quatre Soeurs (source: JET)

4.1.3 Vallee Pitot

Vallee Pitot landslide area, which is about 80 m long and 100 m wide, can be divided into five small landslide blocks (A, B, C, D, E), as shown in Figure 4.1.7, according to deformations to the structures in the area. The landslide blocks A, B and C in Vallee Pitot are along the canal.

The most active block in Vallee Pitot is Block A. The more active parts of Block A are further classified into Block A-1 and Block A-2. Block A-1, which is in the bottom part of Block A, has been moving since the rainy season in 2013 and has filled up the canal. Block A-1 is approximately 10 m long and 20 m wide, and the estimated depth is a few meters. The canal has been blocked off for a length of 20 m. Block A-2, which is the top part of Block A, destroyed half of a house in heavy rain in February 2013.

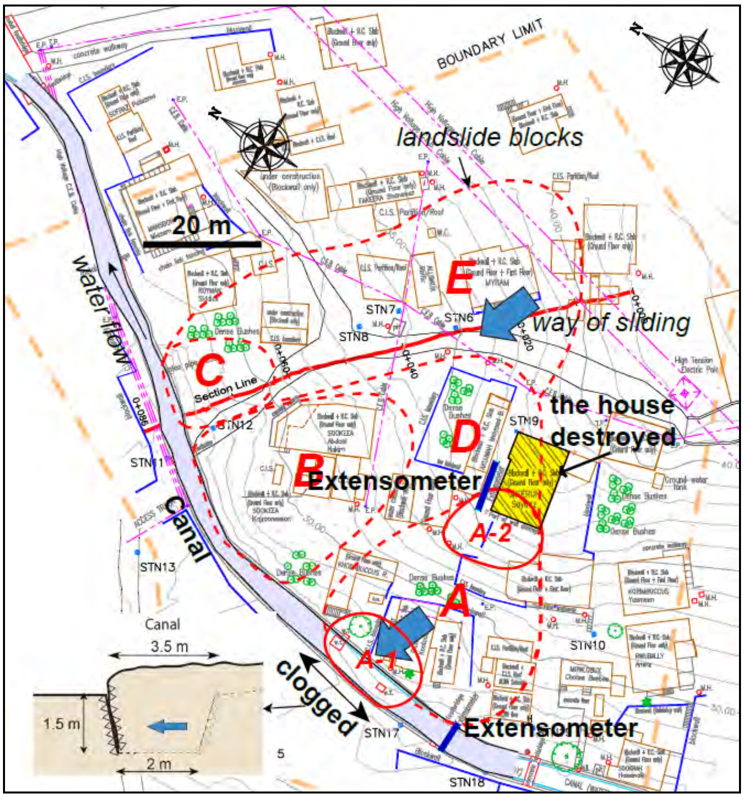


Figure 4.1.7 Landslide Blocks in Vallee Pitot (source: JET)

<u>Geology</u>

Details of geological conditions have not been obtained in Vallee Pitot because no geological investigations have been executed. Figure 4.1.8 is an assumed cross section of the landslide in Vallee Pitot. The slip surface is estimated to be at a maximum depth of around 5-6 m according to the size of the blocks and the topographic features.

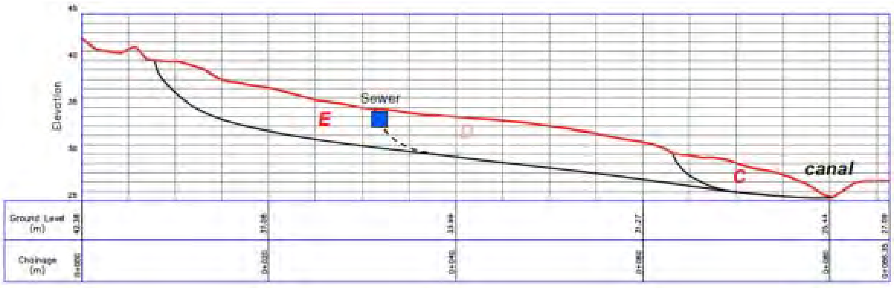


Figure 4.1.8 Assumed Landslide Slips in Vallee Pitot along Red Line in Figure 4.1.7 (source: JET)

Groundwater

The groundwater level is not known as the geological conditions are also unknown. However, it is assumed that the groundwater level is very high in rainy season according to local residents' reports of a lot of water flowing down on the surface in heavy rain.

4.2 Interpretation of Monitoring

4.2.1 Chitrakoot

Block A

Activity of the landslide

Two extensometers, E(5) and E-C1, are installed in Block A.

E(5) shows small displacement about 15mm in the rainy season in 2013. Displacement at E-C1 has been within 10 mm, and large displacement has not been seen through the monitoring period. Even the inclinometer at BH-C6 detected activity of the landslide, two extensometers in Block A did not record the landslide activity of Block A from February 2013 to December 2014. However, both E(5), E-C1 showed 20 to 30mm deformation in January 2015. This big deformation was caused by the landslide activities which damaged houses and road in Block A.

The maximum daily precipitation in January 2015 before 21st January was 38.5mm (20th January). Even around 12th January 2015 when cyclone Bansi was approaching to Mauritius, the daily precipitation was only 33.0mm (9th January) and 24.5 mm (11th January).

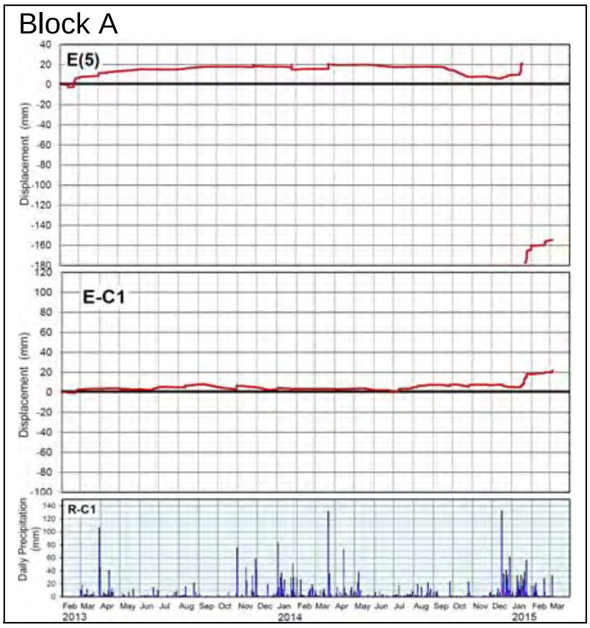


Figure 4.2.1 Record of the Extensometers in Block A in Chitrakoot (source: JET)

Depth of the slip surface of the landslide

Inclinometer BH-C6 in Block A shows clear bend of the pipe at the depth of 7 m. The bend must be slip surface of the landslide. The slip surface has been confirmed at BH-C6 only.

Groundwater

The groundwater level at BH-11 is above the ground surface in rainy season, and below the ground surface in non-rainy season. At BH-C1within Block A, the groundwater level was high in rainy season and low in non-rainy season. Both BH-11 and BH-C1, seasonal variation in the groundwater level is distinct, however the groundwater levels have not followed the daily precipitation or the hourly precipitation.

The groundwater in areas besides Block A record significant level changes according to season, however, groundwater level does not change after heavy rain.

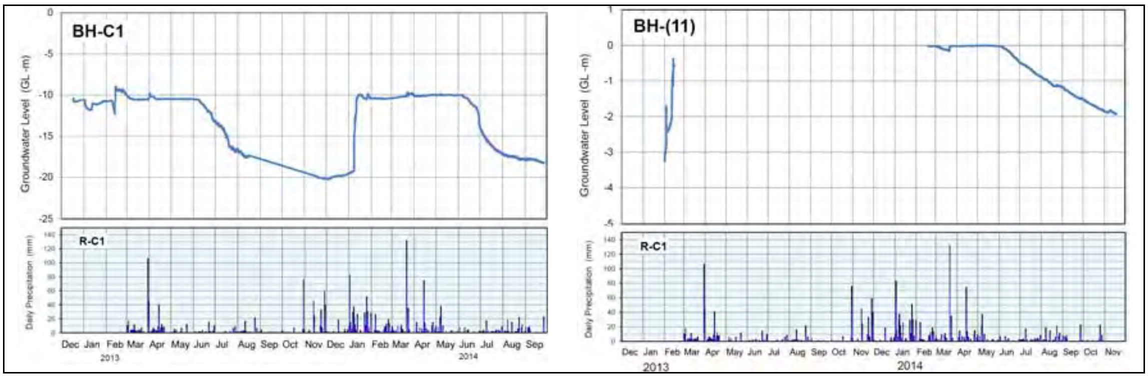


Figure 4.2.2 Groundwater Levels in Chitrakoot Monitored by Piezometers (source: JET)

Block B

Activity of the landslide

Two extensometers, E(1) and E(2), are installed in B block. Both E(1) and E(2) shows deformations from installation. However, as mentioned in Section 3.4, the deformations of E(1) and E(2) are not a result of a big landslide. The activity of Block B may not be so active, since there are no new cracks or new deformations on the houses and structures around the extensometers,

Depth of the slip surface

The depth of the slip surface is not confirmed since instrument which can detect the slip surface is not installed in Block B.

Groundwater

The groundwater level has not been monitored in Block B and the exact groundwater level has not been obtained. The groundwater level in Block B in rainy season seems very high, because the ground surface in Block B is very wet in rainy season and the water levels in boreholes around Block B are shallow around 1 – 2m deep.

Whole Area in Chitrakoot

Activity of the landslide

The instruments which can detect the landslide activities in Chitrakoot are extensometers, inclinometers and strain gauges. The extensometers can monitor the landslide movement automatically.

Only the inclinometer at BH-C6 in Block A detected landslide activities clearly among them. Extensometers and strain gauges did not detect the landslide activities. The inclinometer at BH-C2 shows displacement which may be caused by landslide, but it is not clear.

Activity of the landslide Block A is confirmed by BH-C6, however two extensometers did not show landslide activities clearly. Therefore Block A might be divided into small blocks.

Only limited instruments have been installed in large Chitrakoot landslide area, there may be active landslide blocks other than blocks A and B.

Depth of the slip surface

The inclinometer and the strain gauges can detect the slip surface of the landslide in Chitrakoot. Landslide activity and the slip surface of landslide in Chitrakoot has been confirmed only at BH-C6.

Groundwater

The groundwater level in Chitrakoot did not rise even in heavy rain, and seems to vary seasonally. The groundwater level rose to the ground surface or above at certain places in rainy season in Chitrakoot as seen at BPP(13) (Figure 4.2.3).

On the other hand, the groundwater level at BH-C3 is below 40m deep. There may be two kinds of groundwater, shallow groundwater and deep groundwater. The deep groundwater may be flowing in the rock ground, but its variations are unknown.

The groundwater springed up from the hole of BPP(13) March 2013

Figure 4.2.3 Picture of BPP(13) in March 2013 (source: JET)

4.2.2 Quatre Soeurs

Block A

Activity of the landslide

The distance monitoring at 2 locations at the head and the toe of Block A using the laser distance meter do not show distinct activity of Block A. The strain gauges at BH-Q2 shows some small deformations.

Block A may have moved slightly in the last 2 years, however there has been no sign of the landslide activities observable on the ground surface in last 2 years.

Depth of the slip surface

Strain gauges at BH-Q2 are installed in residential area in order to know the depth of the slip surface. According to the result of the strain gauge monitoring, small deformation which could be slip surface is seen at about 10m deep, but it is not clear.

Groundwater

Piezometer at BH5 at the center of Block A shows large fluctuation of the groundwater level.

The level is about 3.5m to 4.0m deep usually and rises to the ground surface abruptly in heavy rain. The groundwater level in Block A and precipitation is related closely. This groundwater would flow in shallow permeable soil layer.

The groundwater did not affect the landslide activities since the clear landslide activity has not been seen in Block A even though the groundwater level rose to ground surface many times.

Block B

Activity of the landslide

The activity of Block B is not confirmed since instruments to monitor the activity of the landslide are not installed in Block B. However Block B is considered to be stable since the strain gauges installed in Block B do not show any deformation of the ground.

No signs of the landslide activities have been found on the ground surface in last 2 years.

Depth of the slip surface

Strain gauges at BH-Q1 to monitor the depth of the slip surface are installed. No slip surface has been confirmed in the last 2 years.

Groundwater

At BH-Q1 where the groundwater has been monitored once a month, the groundwater was very high with a depth of 1m in February in the middle of the rainy season, and was low with the depth of 14m in non-rainy season. The groundwater level greatly changes throughout the year.

4.2.3 Vallee Pitot

Only two extensometers (EV-1 and EV-2) at the head and the toe of the landslide have been installed in Vallee Pitot. EV1 which is installed at the head of the landslide area shows big tension displacement in rainy season of 2013, however the displacement became small within 10mm after January 2014. EV2 which is installed at the toe of the landslide area shows alternation of slow tension displacement and rapid compression displacement. Compression displacement must show the landslide movement.

Typical landslide movements such as tension on top and compression on toe can be seen ion the results of two extensometers. However, the displacements are small after February 2013, and no significant displacement was monitored even in heavy rain on 21st March 2014. There has been no landslide activity in Vallee Pitot since February 2013 to December 2014.

In January 2015, EV1 recorded about 60mm deformation which may be caused by landslide activities which affected on houses surroundings. However EV2 did not show big deformation in January 2015.

4.3 Consideration of Threshold for Soil Water Index

Conventionally, the early warning and evacuation threshold for the slope disaster are determined by extensometer and cumulative rainfall. However more recently, the Soil Water Index (SWI) is also being considered as an early warning and evacuation threshold for the slope disasters.

SWI is an indicator to ascertain the amount of moisture within the soil during or after the rainfall. Unlike the extensometer and rain gauge which takes into account only the hydrological condition on the surface, SWI considers the amount of groundwater, in which the landslide activities can be estimated more accurately. Therefore, a higher accuracy threshold can be set for early warning and evacuation. SWI is also being introduced by Japan Meteorological Agency for each 5km grid in Japan.

The existing threshold for early warning and evacuation has been considered by this project using the monitoring results of extensometers and rain gauges, however SWI was also taken into consideration as a new parameter. In this project, the SWI of the pilot site will be calculated using the past rainfall data to consider the threshold for landslides.

4.3.1 Method of Analysis

Soil Water Index (SWI) is a method to calculate the moisture volume within soil by applying hourly rainfall data into the Tank Model equation. The greater the amount of moisture accumulated within the soil, the higher the soil water index value that will be recorded, which means a higher the risk of slope disaster.

Generally the 3-Step Tank Model is used for calculation of the soil water index. The first tank indicates surface outflow, the second tank indicates surface infiltration and outflow, and the third tank indicates groundwater outflow. The rainwater flows towards the lower tank as time elapses, and the hourly shifted volume is proportional to the water volume inside the tank.

The purpose of the Tank Model used in SWI calculation is to understand the slope disaster risk. There are a few points to remember as below:

- The Tank Model uses uniform parameters and does not consider the situation such as vegetation, geological and weathering of each slope.
- The modeling is designed more for a shallow surface.

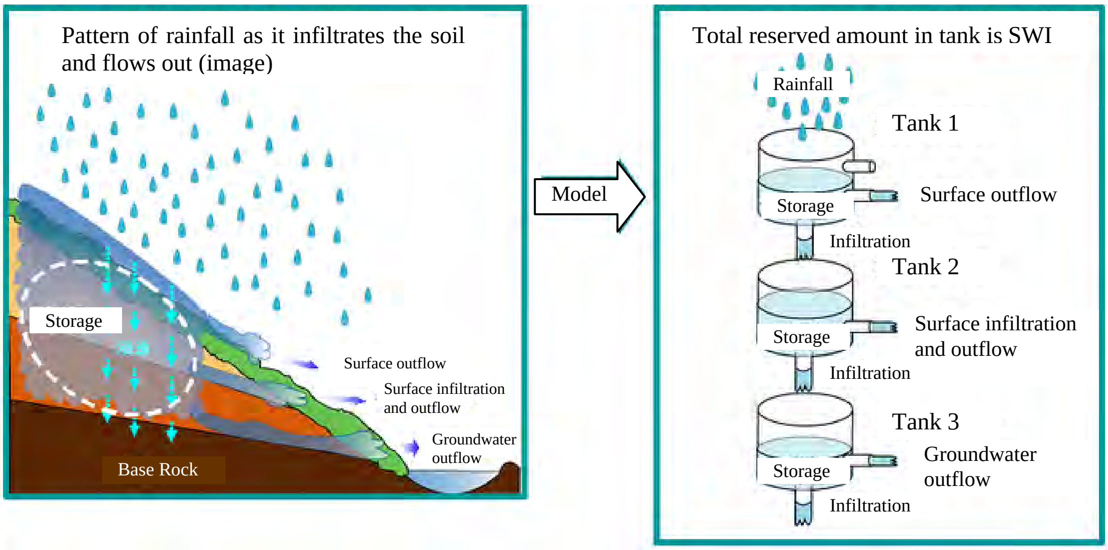


Figure 4.3.1 Image of SWI Model[1]

<u>Calculation formula for the Soil Water Index</u>

The daily rainfall data from Mauritius Meteorological Services (MMS) and hourly rainfall data from Global Satellite Map of Precipitation (GSMaP) were used to calculate SWI. The daily rainfall data was divided into 24 since there was only daily rainfall data available in MMS.

The index number of SWI is the total reserved amount in the tank ($=S_1+S_2+S_3$). The calculation formula for the amount of reserved water ($S_i : i=1,2,3$) in each tank is as follows:

$$S_1(t+\Delta t) = (1-\beta_1\Delta t)\cdot S_1(t) - q_1(t)\cdot\Delta t + R$$

$$S_2(t+\Delta t) = (1-\beta_2\Delta t)\cdot S_2(t) - q_2(t)\cdot\Delta t + \beta_1\cdot S_1(t)\cdot\Delta t$$

$$S_3(t+\Delta t) = (1-\beta_3\Delta t)\cdot S_3(t) - q_3(t)\cdot\Delta t + \beta_2\cdot S_2(t)\cdot\Delta t$$

S_1、S_2、S_3 : Reserve amount of water in each tank
β_1、β_2、β_3: Coefficient of permeability from the infiltration drain of each tank
q_1、q_2、q_3 : Outflow amount from the side drain of each tank

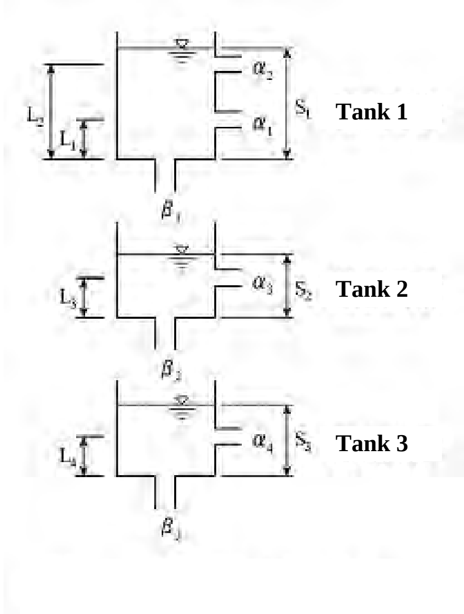


Figure 4.3.2 3-Steps of Tank Model[1]

In this calculation, Δt=1 hour and R *is* analyzed or assumed rainfall in 1 hour. The outflow amount ($q_i : i=1,2,3$) from the side drain is as described below:

$$q_1(t) = \alpha_1\{S_1(t) - L_1\} + \alpha_2\{S_1(t) - L_2\}$$

$$q_2(t) = \alpha_3\{S_2(t) - L_3\}$$

$q_3(t) = \alpha_4\{S_3(t) - L_4\}$

α_1、α_2、α_3、α_4 : Coefficient of discharge from each drain
L_1、L_2、L_3、L_4 : Height of each drain

The parameters used in this project are the one impartially adopted by the Japan Meteorological Agency. Each parameter (Height of drain, Coefficient of discharge and permeability) is shown in the table below. The accumulation of the data will allow Mauritius to set their own parameters in future.

Table 4.3.1 Parameters of Tank Model[1]

	Tank 1	Tank 2	Tank 3
Height of drain (mm)	L_1=15	L_3=15	L_4=15
	L_2=60		
Coefficient of discharge (1/hr)	α_1=0.1	α_3=0.05	α_4=0.01
	α_2=0.15		
Coefficient of permeability (1/hr)	β_1=0.12	β_2=0.05	β_3=0.01

4.3.2 Data

In this section, the data to calculate SWI and necessary information for the consideration are described.

a. Rainfall Data

The hourly rainfall data for the target area are needed to calculate the SWI. In this project, 2 types of rainfall data of the past (MMS and GSMaP) were obtained.

a.1 MMS rainfall data

Originally, the actual monitored hourly data is needed for the calculation of SWI, but there was no hourly data in Mauritius. Therefore, reluctantly the daily rainfall of MMS was divided into 24 hours to replace the hourly rainfall data. The figure below shows the example of daily rainfall data divided into 24 hours.

Date	Daily Rainfall (mm)
2006/3/1	1.8
2006/3/2	4.6
2006/3/3	45.6
2006/3/4	140.2
2006/3/5	7
2006/・・・・・・	・・・
2006/・・・・・・	・・・
2006/・・・・・・	・・・

45.6mm/24
=1.9mm

Date	Hourly Rainfall (mm)
2006/3/3、0:00	1.9
2006/3/3、1:00	1.9
2006/3/3、2:00	1.9
2006/3/3、3:00	1.9
2006/3/3、4:00	1.9
2006/・・・・・・、・・・・	1.9
2006/・・・・・・、・・・・	1.9
2006/3/3、23:00	1.9

Figure 4.3.3 Example of Daily Rainfall Data Divided into 24 Hours (source: JET)

a.2 GSMaP rainfall data

In addition to the daily rainfall data from MMS, the GSMaP data which provides the hourly rainfall data were used for the analysis. In Japan, JAXA (Japan Aerospace Exploration Agency) is the in charge for the GSMaP data creation.

GSMaP data is a rainfall data calculated by GSMaP algorithm using the data obtained from a microwave radiometer mounted in several satellites (such as TRMM TMI, Aqua/AMSR-E, GCOM-W/AMSR2, AMSU of NOAA satellite) and precipitation radar (TRMM satellite only). Microwave radiometer measures the strength of the microwaves emitted from the raindrop and its surrounding to estimate the rainfall while the precipitation radar estimates the strength of the rain or snow by capturing the radar waves reflected back off the rain or snow (rainfall echo).

In this project, 2 types of GSMaP data which are GSMaP_MVK (Motion Vector Kalman) and GSMaP_NRT (Near Real Time) were used for the calculation of SWI. These 2 types of GSMaP data provide the hourly rainfall data.

GSMaP_MVK is a data processed when the observation of the rainfall amount undertaken in two directions which are called forward process (for estimating the rainfall 1 hour before the observation) and backward process (for estimating the rainfall 1 hour after the observation). The rainfall data will be an average result of these two direction observations. This means, the accuracy of rainy area is obtained by taking the average rate of the estimated rainfall distribution for the past and the future.

On the other hand, GSMaP_NRT is prioritized on its prompt data availability and processed only with the data acquired within 3 hours after the observation. Also, the infrared data of the Geostationary Meteorological Satellite (microwave – infrared multiple algorithm) is used to simplify the data process for the area which could not be observed by the microwave satellite.

When comparing these two satellite data, GSMaP_MVK provides higher accuracy rainfall data than GSMaP_NRT which means the GSMaP_MVK is favorable data for SWI calculation in this project. However, the preparation of the GSMaP_MVK takes time and the data of recent years has not been prepared. Therefore, GSMaP_NRT were used for the data after December 2010. Table below shows the summary of the GSMaP data used in this project.

Table 4.3.2 Summary of GSMaP Data (source: JET)

Item	Contents
Period	2004 ~ 2013 (10 years)
Types of data	Hourly rainfall data 2004 ~ November 2010 : GSMaP_MVK December 2010 ~ 2013 : GSMaP_NRT
Coordinates	Chitrakoot : 20° 10` 36.31`` S 57° 32`22.77`` E Quatre Soeurs : 20° 17` 58.70`` S 57° 46`23.14`` E
Area	0.1° x 0.1° grid (around 10km mesh)
Format of data	4 byte, plain binary, little endian

GSMaP data is an average value of each 10km mesh surface and the satellite takes a measurement only once an hour. If the rainfall was weak at that point, the measured value will also be low. As a result, there are many cases reported in which the satellite data value is lower than the rain gauge data value installed on the ground.

Verification of the accuracy of GSMaP data

A comparison between the GSMaP data and rain gauge data installed by this project was made to verify the accuracy of the GSMaP data. Figure below shows the comparison between hourly satellite data (GSMaP) and rain gauge data (JET).

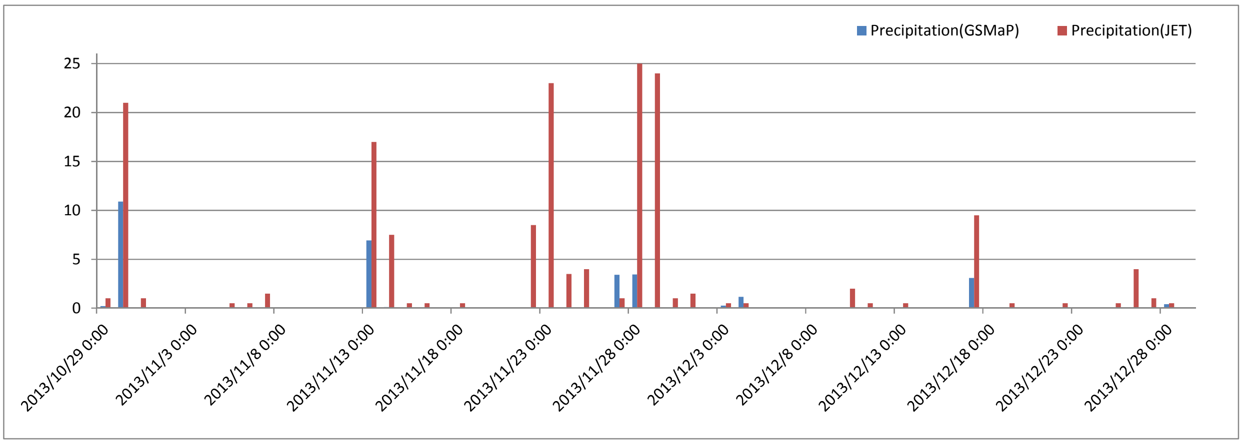


Figure 4.3.4 Comparison between GSMaP Data and Rain Gauge Data (source: JET)

As can be seen in the figure above, the satellite data (GSMaP) shows lower value compared to the rain gauge data (JET). In addition, the satellite data could not read the value when the rain gauge data is relatively low. Therefore, the possibility of the satellite data value being lower than the MMS data shall be considered when calculating the SWI. Although there is a difference in the rainfall rate, this satellite data was used because these two data types display roughly the same rainfall trends.

b. Disaster Record

The necessary information on sediment disaster record at Chitrakoot and Quatre Soeurs were obtained mostly in the feasibility report of this project.

The information regarding disaster record is very important in the consideration of the threshold by SWI. The accumulation of disaster record will allow setting a higher accuracy threshold. Figure below shows the role of the disaster record in SWI.

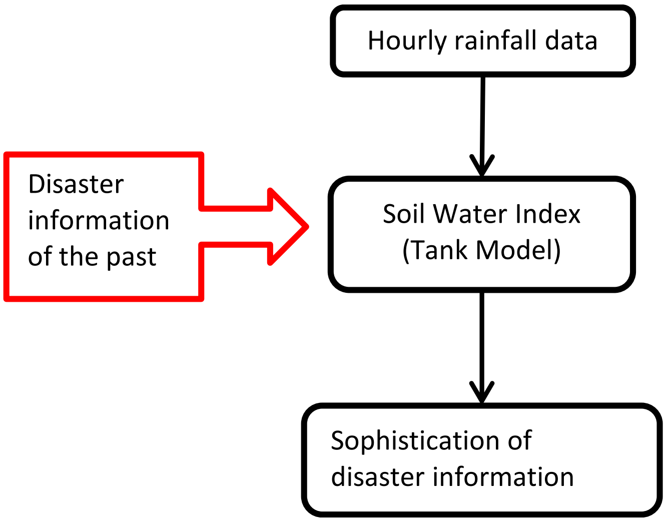


Figure 4.3.5 The Role of Disaster Record in SWI (source:JET)

However, the information regarding sediment disaster record is barely organized in Mauritius and the detailed information (time of disaster, movement etc.) is mostly unavailable and the accumulation and recording of sediment disaster is expected.

c. Cumulative Precipitation

The comparison between the result of SWI and cumulative precipitation, which is conventionally used to set the evacuation threshold for sediment disaster, was made to verify the accuracy. Cumulative precipitation means rain is falling continuously and it will be reset if the rain stops falling or there is a small amount of rainfall over a certain period. When rain starts falling again a new cumulative precipitation value will be recorded.

In Japan, the reference reset time is mostly around three to six hours though it could not be applied in this SWI calculation because the daily rainfall data of MMS has to be divided into 24 hours. Therefore, the reset value will be 24 hours in this SWI calculation which means that the cumulative precipitation will be reset to 0mm if it does not rain for 24 hours.

4.3.3 Result of SWI Calculation

a. Chitrakoot Area

Chitrakoot is one site for the calculation of SWI. Based on the information from disaster records, this area has been affected a few times by sediment disaster in the past. Table below shows the record of sediment disaster in recent years at Chitrakoot. In Mauritius, the information on sediment disaster is barely organized and the detailed information (time, movement etc.) are mostly unavailable.

Table 4.3.3 Sediment Disaster Record at Chitrakoot[2]

Year/Month	Summary of damages
March 2005	Cracks in 54 houses due to heavy rain
March 2006	14 houses were heavily damaged. Relocation were forced
2008	Cracks in many houses. The maximum movement amount monitored was 5cm

The SWI were calculated from January to March (rainy season) where the sediment disaster were reported using the MMS and GSMaP data. The detailed result of the SWI calculation is included in the Supporting Report.

a.1 Result of the SWI calculation by MMS data

The daily rainfall data was divided into 24 hours since there was no hourly rainfall data in MMS. The SWI was calculated by the tank model using the divided hourly rainfall data. Figure below shows the result of SWI and cumulative precipitation in a graph. Also, the rainfall events ①~⑫ for which the SWI exceeded 50 are shown in the table below.

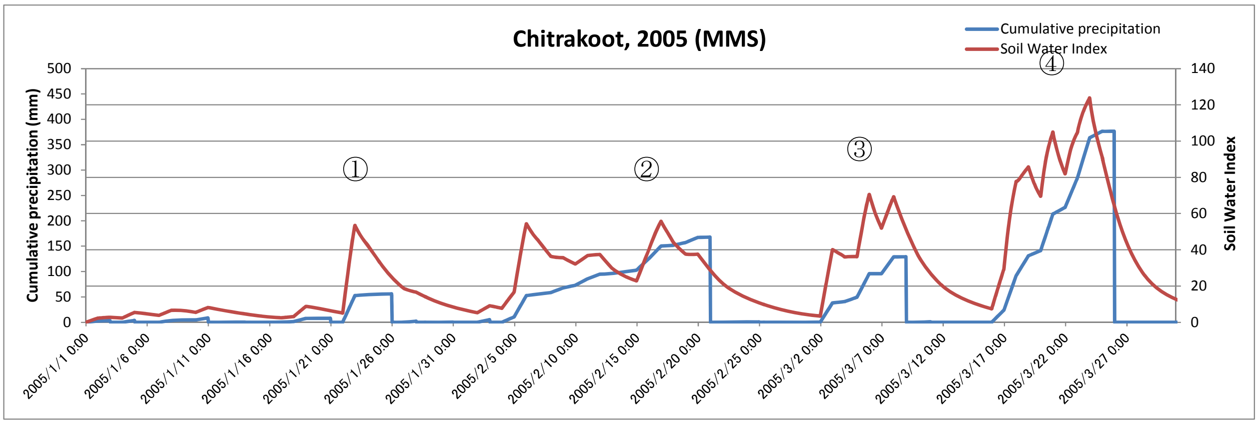


Figure 4.3.6 SWI and Cumulative Precipitation in Chitrakoot (2005, MMS) (source: JET)

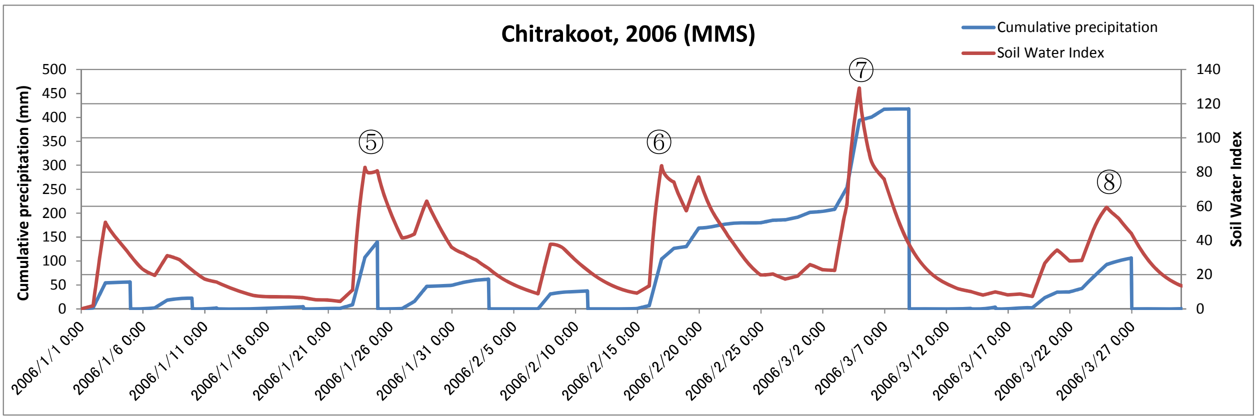


Figure 4.3.7 SWI and Cumulative Precipitation in Chitrakoot (2006, MMS) (source: JET)

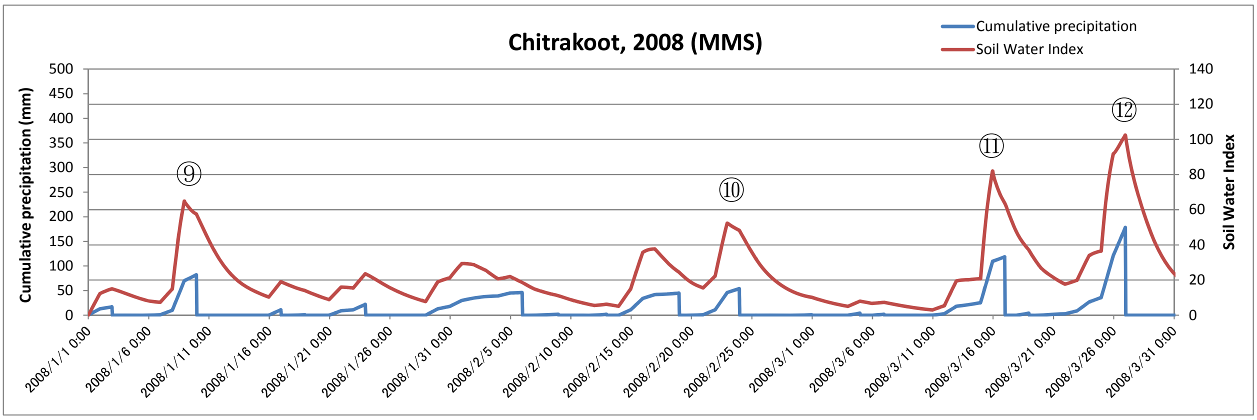


Figure 4.3.8 SWI and Cumulative Precipitation in Chitrakoot (2008, MMS) (source: JET)

Table 4.3.4 SWI and MMS Cumulative Precipitation for Rainfall Event ①~⑫ (source: JET)

No.	Date	SWI	Cumulative precipitation of MMS (mm)	Remarks
①	22nd Jan 2005	53	53	
②	16th Feb 2005	56	150	
③	5th Mar 2005	71	96	
④	23rd Mar 2005	124	364	Hennie Cyclone occurred, Landslide occurred
⑤	23rd Jan 2006	83	108	
⑥	16th Feb 2006	84	104	
⑦	4th Mar 2006	129	394	Landslide occurred
⑧	24th Mar 2006	59	93	
⑨	8th Jan 2008	65	70	
⑩	22nd Feb 2008	52	46	
⑪	15th Mar 2008	82	109	
⑫	26th Mar 2008	102	178	Landslide occurred (estimated)

a.2 Result of the SWI calculation by GSMaP data

Unlike MMS data, GSMaP is hourly rainfall data and the SWI were calculated using the tank model. Figure below shows the result of SWI and cumulative precipitation in a graph format. Also, the rainfall events ⑬~⑳ which the SWI exceeded 50 are shown in the table. below.

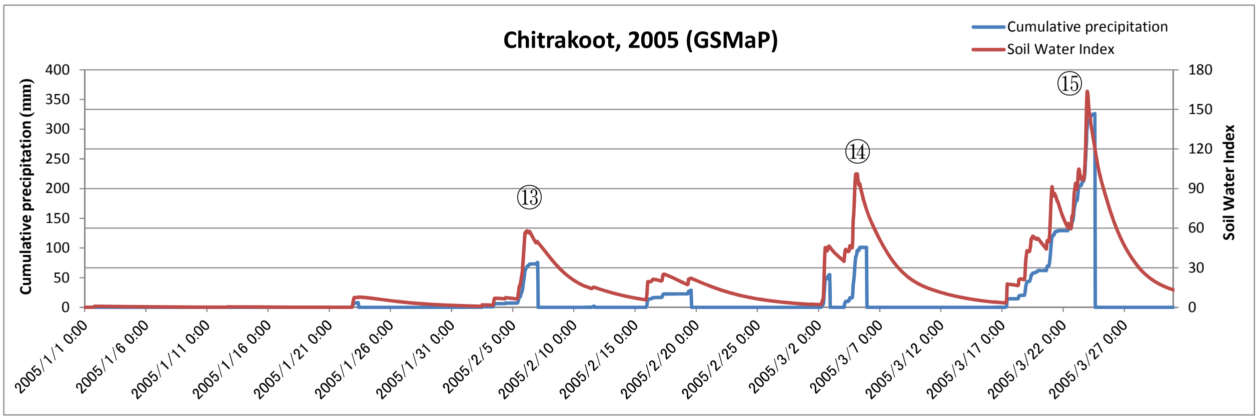


Figure 4.3.9 SWI and Cumulative Precipitation in Chitrakoot (2005, GSMaP) (source: JET)

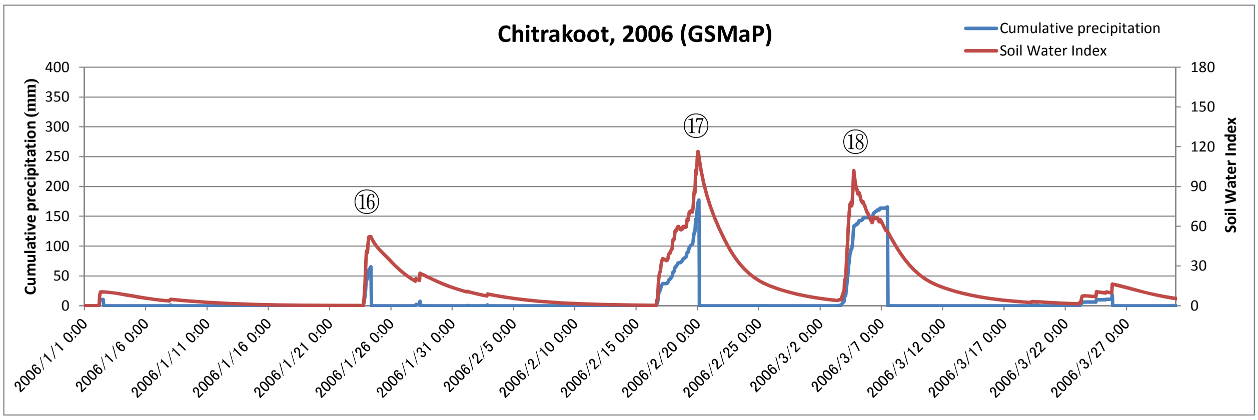


Figure 4.3.10 SWI and Cumulative Precipitation in Chitrakoot (2006, GSMaP) (source: JET)

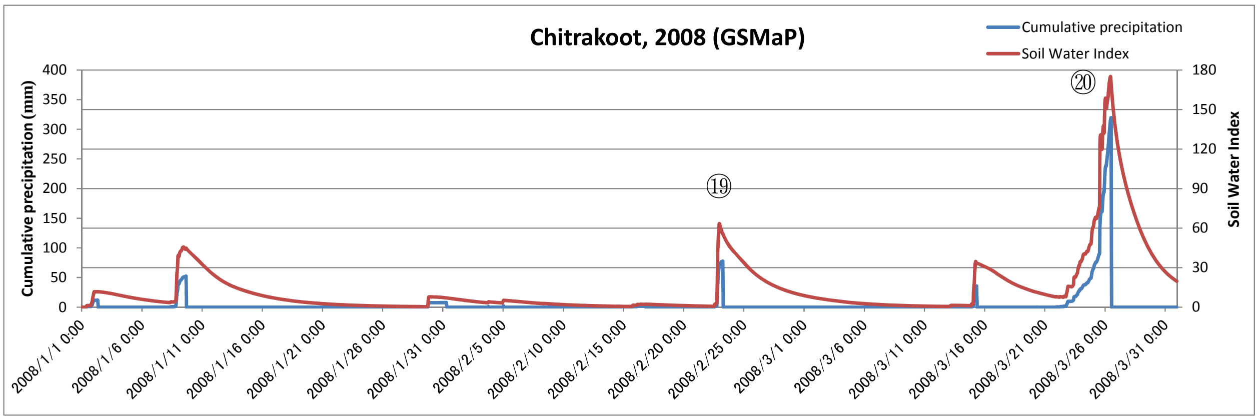


Figure 4.3.11 SWI and Cumulative Precipitation in Chitrakoot (2008, GSMaP) (source: JET)

Table 4.3.5 SWI and GSMaP Cumulative Precipitation for Rainfall Event ⑬~⑳(source: JET)

No.	Date	SWI	Cumulative precipitation GSMaP (mm)	Remarks
⑬	6th Feb 2005	58	68	
⑭	5th Mar 2005	101	96	
⑮	24th Mar 2005	164	305	Hennie Cyclone occurred, Landslide occurred
⑯	24th Jan 2006	52	64	
⑰	20th Feb 2006	116	172	
⑱	4th Mar 2006	102	133	Landslide occurred
⑲	22nd Feb 2008	63	71	
⑳	26th Mar 2008	175	316	Landslide occurred (estimated)

a.3 Consideration of SWI in Chitrakoot

Based on the result of SWI calculation by MMS data, the SWI exceeding 50 were recorded two times (③and④) in March 2005 when the landslide was reported. When comparing these two, no landslides have occurred when the SWI was around 70 and cumulative precipitation around 100mm in the past. Therefore, it is reasonable to think that the landslide occurred during ④.

In the rainy season of 2006, the SWI exceeding 50 were recorded two times (⑦and⑧) in March 2006 when the landslide was reported. When comparing these two, no landslides have occurred when the SWI was around 60 and cumulative precipitation around 100mm in the past. Therefore, it is reasonable to think that the landslide occurred during ⑦.

In the rainy season of 2008, the SWI exceeding 50 were recorded four times (⑨~⑫). Although there was no detailed information on the date of landslide occurrence, ⑫ which was recorded in the end of March marks the highest SWI during the rainy season. Also, from the result of 2005 and 2006, no landslides occurred when the SWI was around 80 and cumulative precipitation around 110mm. Therefore, it is reasonable to estimate that the landslide occurred during ⑫.

From the consideration of MMS data, there is a potential of landslide disaster risk in Chitrakoot when the SWI exceeds 102.

On the other hand, based on the result of SWI calculation by GSMaP data, the SWI exceeding 50 were recorded two times (⑭and⑮) in March 2005 when the landslide was reported. When comparing these two, as cumulative precipitation of MMS data, there is no case of landslide occurrence when the cumulative precipitation is below 100mm. Therefore, it is reasonable to think that the landslide occurred during ⑮.

In the rainy season of 2006, the SWI exceeding 50 were recorded only once (⑱) in March 2006 when the landslide was reported. Therefore, the landslide might have occurred during this period. However, triggers of landslides did not occur during ⑰ though it marks higher SWI and cumulative precipitation than ⑱because the satellite data could not measure weak rain, as mentioned in [verification of the accuracy of GSMaP data] in [Data] section. From the calculation result by MMS data (⑥~⑦in Figure 4.3.7), there was weak rain measured continuously at the same period. The cumulative precipitation was reset for GSMaP data because the weak rain could not be measured. As a result, it is conceivable that ⑰ marks lower SWI than ⑱.

In the rainy season of 2008, the SWI exceeding 50 were recorded two times (⑲and⑳). Although there was no detailed information on the date of landslide occurrence, ⑳, which was recorded in the end of March, marks the highest SWI during the rainy season. Also, from the result of 2005 and 2006, no landslide occurred when the SWI was around 60 and cumulative precipitation around 70mm. Therefore, it is reasonable to estimate that the landslide occurred during ⑳.

From the consideration by GSMaP data, there is a potential of landslide disaster risk in Chitrakoot when the SWI exceeds 102.

b. Quatre Soeurs Area

Sediment disasters were reported in 2005 and 2008 at Quatre Soeurs though no detailed information (date, movement, etc.) was recorded. There was a record of cracks occurred at 11 houses in 2005 but no information regarding damages for 2008.

Table 4.3.6 Sediment Disaster Record at Quatre Souers (source: JET)

Date	Summary of damages
2005	Cracks occurred at 11 houses due to heavy rain
2008	No damages record

The SWI were calculated from January to March (rainy season) of 2005 and 2008 where the sediment disaster were reported using the MMS and GSMaP data. The detailed result of the SWI calculation is included in the Supporting Report.

b.1 Result of the SWI calculation by MMS data

The daily rainfall data was divided into 24 hours since there was no hourly rainfall data in MMS. The SWI was calculated by the tank model using the divided hourly rainfall data. Figure below shows the result of SWI and cumulative precipitation in graph. Also, the rainfall events ㉑~㉚with SWI exceeding 50 are shown in the table below.

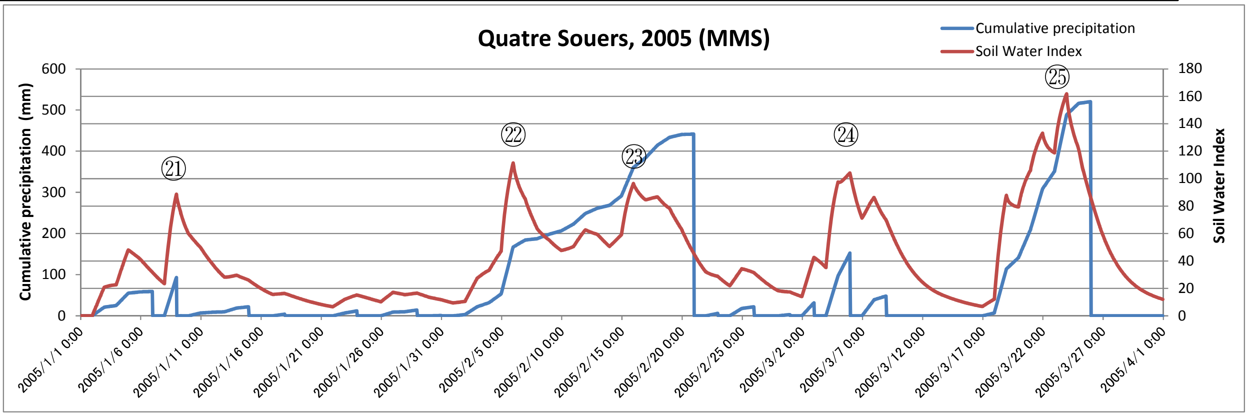


Figure 4.3.12 SWI and Cumulative Precipitation in Quatre Soeurs (2005, MMS)(source: JET)

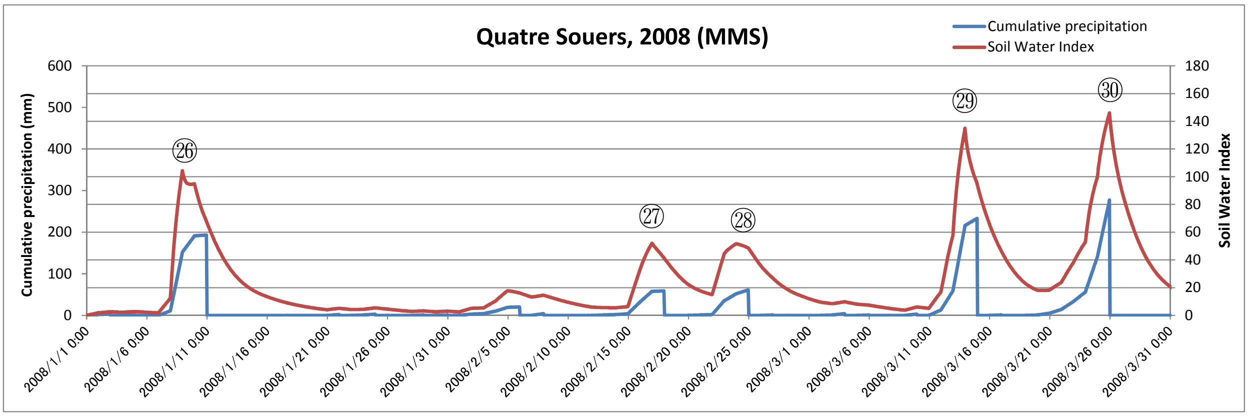


Figure 4.3.13 SWI and Cumulative Precipitation in Quatre Soeurs (2008, MMS)(source: JET)

Table 4.3.7 SWI and MMS Cumulative Precipitation for Rainfall Event ㉑~㉚(source: JET)

No.	Date	SWI	Cumulative precipitation MMS (mm)	Remarks
㉑	8th Jan 2005	89	93	
㉒	5th Feb 2005	111	167	
㉓	15th Feb 2005	96	361	
㉔	5th Mar 2005	104	153	
㉕	23rd Mar 2005	162	488	Hennie Cyclone occurred, Landslide occurred (estimated)
㉖	8th Jan 2008	104	152	
㉗	16th Feb 2008	52	58	
㉘	23rd Feb 2008	52	52	
㉙	13th Mar 2008	135	216	
㉚	25th Mar 2008	146	277	Landslide occurred (estimated)

b.2 Result of the SWI calculation by GSMaP data

Unlike MMS data, GSMaP is hourly rainfall data and the SWI were calculated using tank model. Figure below shows the result of SWI and cumulative precipitation in graph. Also, the rainfall events ㉛~㉟ which the SWI exceeding 50 were shown in the table below.

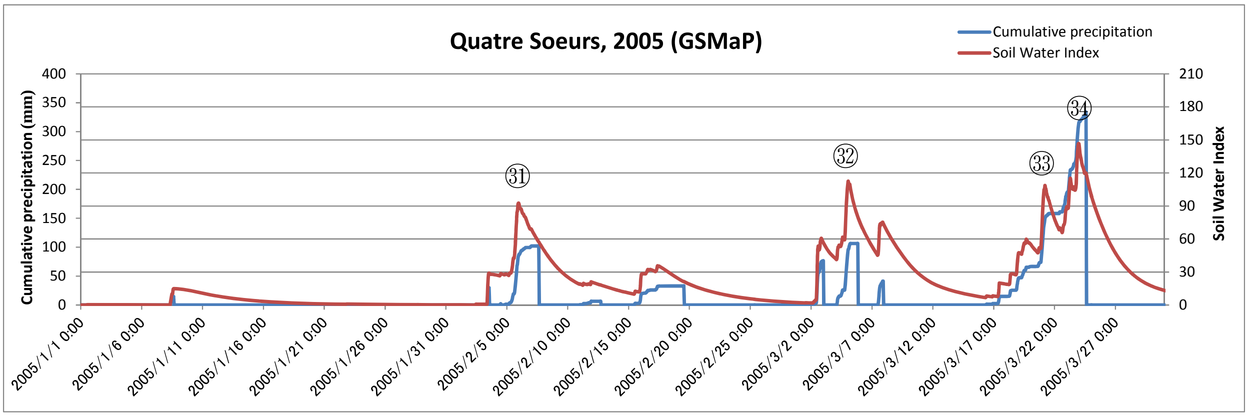


Figure 4.3.14 SWI and Cumulative Precipitation in Quatre Soeurs (2005, GSMaP) (source: JET)

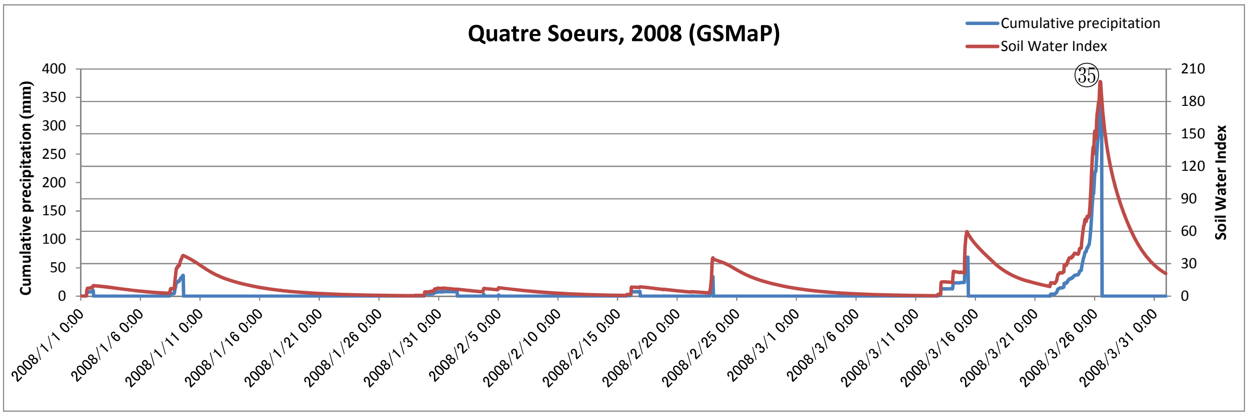


Figure 4.3.15 SWI and Cumulative Precipitation in Quatre Soeurs (2008, GSMaP)(source: JET)

Table 4.3.8 SWI and GSMaP Cumulative Precipitation for Rainfall Event ㉛~㉟(source: JET)

No.	Date	SWI	Cumulative precipitation GSMaP (mm)	Remarks
㉛	5th Feb 2005	93	85	
㉜	5th Mar 2005	113	96	
㉝	21st Mar 2005	109	150	
㉞	24th Mar 2005	147	310	Hennie Cyclone occurred, Landslide occurred (estimated)
㉟	25th Mar 2008	198	335	Landslide occurred (estimated)

b.3 Consideration of SWI in Quatre Soeurs

Based on the result of SWI calculation by MMS data, the SWI exceeding 50 were recorded five times (㉑~㉕) in the rainy season of 2005. In the rainy season of 2008 also, the SWI exceeding 50 were recorded five times (㉖~㉚). Although there was no detailed information on the date of landslide occurrence, it did occur once in each rainy season. The highest SWI were recorded in the end of March of 2005(㉕) and 2008(㉚), and it is conceivable that no landslide occurred at the lower SWI. Therefore, it is reasonable to estimate that the landslide occurred during ㉕ and ㉚.Cumulative precipitation of 361mm was recorded on 15th February 2005 (㉓), however this high value is because weak rain fell continuously from 5th February, meaning these two cumulative precipitation values were counted together, namely the gauge was not reset during this period.

From the consideration by MMS data, there is a potential of landslide disaster risk in Quatre Soeurs when the SWI exceeds 146.

On the other hand, based on the result of SWI calculation by GSMaP data, the SWI exceeding 50 were recorded four times (㉛~㉞) during rainy season in 2005. Although there was no detailed information on the date of landslide occurrence, it did occur once in the rainy season. Therefore, it is reasonable to estimate that the landslide occurred during ㉞.

In the rainy season of 2008, the SWI exceeding 50 were recorded once (㉟). Although there was no detailed information on the date of landslide occurrence, ㉟ which was recorded in the end of March, marks the highest SWI during the rainy season. Therefore, it is reasonable to estimate that the landslide occurred during this period. Also, the overall precipitation is low compared to the result of 2005 and it seems no landslide occurred at other SWI. Therefore, it is reasonable to estimate that the landslide occurred during ㉟.

From the consideration by GSMaP data, there is a potential of landslide disaster risk in Quatre Soeurs when the SWI exceeds 147.

4.3.4 Introduction of SWI in Mauritius

a. The Threshold of Early Warning and Evacuation using SWI

Table below summarizes the result of SWI with landslide risk for Chitrakoot and Quatre Soeurs. It would be appropriate to set the threshold value on the minimum side of each SWI.

Table 4.3.9 SWI with Landslide Risk at Chitrakoot and Quatre Soeurs (source: JET)

Area	MMS data	GSMaP data
Chitrakoot	102	102
Quatre Soeurs	146	147

From the result of the consideration above, the landslide occurrence threshold value using SWI is 102 for Chitrakoot and 146 for Quatre Soeurs.

- Chitrakoot：SWI more than 102
- Quatre Soeurs：SWI more than 146

b. Improvement of Accuracy in Future

The thresholds using SWI in this calculation were based on the MMS data (daily rainfall data divided in to 24 hours) and GSMaP data which originally have to be calculated by the actual hourly rainfall data.

Also, the consideration of the threshold could not be done sufficiently because the disaster record is barely organized and the detailed information (date, movement, etc.) are unavailable in Mauritius. Normally, the detailed information such as date and time and damages of the disaster shall be accumulated and managed. The task for introducing SWI in Mauritius is described below.

1) Introduction of the meteorological system which can measure hourly rainfall throughout Mauritius.

2) The accumulation and management of sediment disaster record by NDRMMCC or MPI.

By solving these two tasks, the SWI can be calculated using actual rainfall data and the higher accuracy threshold could be set from the accumulated disaster record.

The technical transfer of the two tasks mentioned above have already been undertaken in this project and the introduction of SWI as a new reference for the early warning will be anticipated in the near future in Mauritius.

4.4 Stability Analysis

The slope stability analysis is a fundamental procedure for evaluation and designing of countermeasures. Based on the results of the analysis, the countermeasure works can be designed and implemented. Generally, landslides can be divided into two types as primary type and reactivated type. A primary type landslide is one which has no history of occurrence before. Therefore, it is difficult to identify location and dimensions of a primary landslide in advance even though this type of landslide is often seen on steep slope areas, because there are no traces of deformations on the site before the landslide occurs. Therefore, it will be difficult to obtain the exact depth of the slip surface or the required data for stability analysis of a primary type landslide in advance.

On the other hand, reactivated type of landside is easier to be identified compared with a primary type of landside. In case of reactivated type of landslide, the slip surface already exists, and it can be found some trace of deformations by past landslide activities on topographical features. Furthermore, required data for the stability analysis which are the landslide deformation and the triggering factors such as groundwater level variation can be monitored in advance. Therefore, approach of stability analysis of activated and reactivated type landslides is different to that of primary type landslides.

Since the Project targets reactivated landslides, stability analysis for reactivated landslides is described in this report.

Stability of the target landslide is evaluated by factor of safety obtained by stability analysis. Factor of safety (Fs) is defined as the ratio of resistance force against landslide soil mass to force when landslide soil mass starts sliding along the slip surface. Fs =1.0 means that resistance force and sliding force are balanced. Fs >1.0 means the landslide is stable whilst Fs<1.0 is unstable or sliding.

$$Fs = \frac{\text{Resistance force against landslide soil mass}}{\text{Force when landslide soil mass starts sliding along the slip surface}}$$

Required main parameters for the analysis are as follows,

Fs: Factor of safety
γ_t : wet unit weight (wet density)
u : pore water pressure
c’: cohesion (as a shear strength constant)
φ’: shear resistance angle (as a shear strength constant)

These parameter can be obtained by laboratory soil test, geotechnical investigation and monitoring on the site.

4.4.1 Factor of Safety

Stability of a landslide is evaluated based on its factor of safety. The factor of safety is obtained by stability analysis of landslide using result of monitoring and geotechnical investigations. Then a current stability of the landslide, whether it is active (factor of safety Fs<1.0) or it is dormant (factor of safety Fs>1.0) is determined. The factor of safety is not derived from the calculation result only, but the analysis should also reflect the actual deforming situation of the landslide. In reality, true factor of safety changes according to chronological changes in response to triggering factors like groundwater level change. Following figure (Figure 4.4.1) provides an illustration of such changes in safety factor.

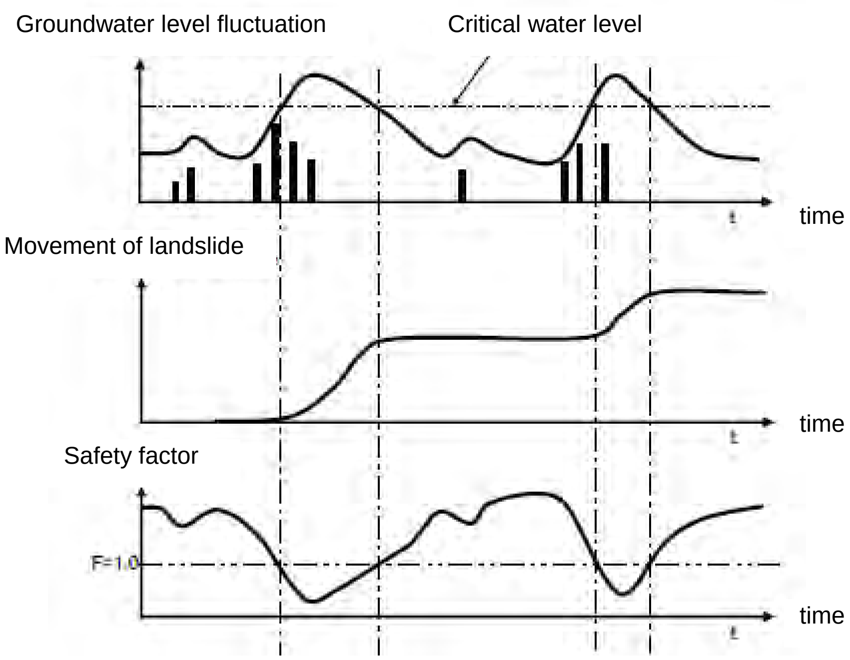


Figure 4.4.1 Changes in Groundwater Level Triggering Mass Movement while also Affecting Values of Safety Factor Over Time (source: JET)

Groundwater level is called critical water level when a landslide starts to slide. Factor of safety at the very moment when a sliding starts is the only true safety factor we can know for sure in a landslide. The factor of safety at the time is Fs=1.0.

Factor of safety at the time of active condition of landslide is proposed for each condition as in Table 4.4.1 in the Disaster Notebook edited by the Japan Construction Engineer's Association (2010). The value of factor of safety is defined empirically. The following proposed safety factors will be used when considering safety factors in the Project.

Table 4.4.1 Definition of Safety Factor for Landslide[3]

Safety factor	Landslide condition
Fs = 0.95	Case in moving continuously anytime
Fs = 0.98	Case in moving continuously for corresponding to rainfall etc.
Fs = 1.00	Case in settling down of the landslide

4.4.2 Setting Parameters

The parameters for landslide stability analysis are as follows;

- γ_t : wet unit weight (wet density)
- u : pore water pressure
- c': cohesion (as a shear strength constant)
- φ': shear resistance angle (as a shear strength constant)

The volume and configuration of the landslide mass is determined by topographical survey, geotechnical investigation and landslide monitoring.

Wet unit weight can be obtained by the unit weight test in laboratory using soil sample taken from the landside mass. Pore water pressure is derived from the critical pore water pressure when the land starts sliding during period of water level monitoring. Cohesion and shear resistance angle are obtained by the shear test or the triaxial compression test of the slip surface soil.

Regarding to the shear strength parameters of slip surface as c’ and φ’, case of embankment slope and primary landslide is easier to obtain than case of reactivated landslide comparatively, because of difficulty of taking sample for the tests. Since slip surface did not exist, shear strength of slip surface is almost same as shear strength of landslide mass in case of landslide on embankment slope or primary landslide. Therefore, sample can be taken from typical soil layer of the slide mass. On the other hand, in case of reactivated landslide, shear strength is different from slip surface and landslide mass. The shear strength parameter of slip surface shall be applied for landslide stability analysis. Therefore, test sample for the shear strength parameters shall be taken from slip surface layer under undisturbed condition. Since, however, slip surface layer is very thin and is difficult to know exact depth, undisturbed sampling is difficult even though a sample could be taken in drilling survey. In case of sample taken from drilling survey, it may show lower shear strength than actual one. Generally, samples taken from slip surface can be obtained when drainage well is dug or when the slip surface is exposed to the ground surface. The result of the laboratory tests will be used for determination of shear strength parameter for stability analysis.

Even though sample could be taken from the slip surface layer, there are many cases that factor of safety obtained by stability analysis using the shear strength parameters is not matched with actual landslide condition. In Japan case, the shear strength parameters are derived from the back analysis empirically (refer to 4.3.3). The shear strength parameters taken from the back analysis shall be determined with referring mechanical test result.

Critical pore water pressure in activated condition is necessary parameter because it is indispensable for ensuring stability analysis accuracy and determining landslide countermeasures. The parameter will be obtained from the groundwater level meter monitoring which will be carried out in the Project.

4.4.3 Method of Stability Analysis

There are various methods of slope stability analysis including “Fellenius method”, “Bishop method”, “Spencer method”, “Janbu method” and “Morgenstern & Price method”. Selected factors and the feature of each method are shown in Table 4.4.2.

Table 4.4.2 Landslide Slope Stability Methods and Selected Factors (source: JET)

Name of method	Selecting factor of stability analysis method						Feature
	Groundwater condition		Acceptable slip surface figure		Type of landslide		
	Confined	Free	Rotational	Others	Rock slide	Others	
Fellenius method	○		○			○	This formula basically gives small exact solution of stability factor
Modified Fellenius method		○	○			○	Using free groundwater, but cannot be used when there is seepage flow
Bishop method	○		○			○	Simplified Bishop method is applied generally for landslide stability analysis. This formula gives almost exact solution of stability factor
Simple Bishop method	○	△	○				
Janbu method	○	△	△	○		○	This formula gives almost exact solution of stability factor. However it is not suitable for submerged slopes, and for rotation slides
New Janbu method	○			○	○		The formula is modified from Janbu method for rock slide phenomenon analysis
Spencer method	○		(1)	(2)	△	○	This formula is good for exact solution of stability factor analysis, but these formula can return differing results depending how parameters are applied; therefore they are not appropriate when one true value is required
Morgenstern & Price method	○			○		○	

Legend- ○ Applicable △ Applicable in some case

Fellenius method and Modified Fellenius method (using free groundwater) are most popular way of stability analysis in Japan because (1) the calculation is very simple, and (2) the calculated values are on the safer side when considering countermeasures.

The appropriate method shall be selected based on the actual conditions of target landslides in the Project.

The main purpose of landslide countermeasure work is to increase the value of safety factor for landslides that have a safety factor of less than one (F<1.0), which indicates that a landslide is in an unstable state. When a landslide is in an unstable condition, either the groundwater has reached the critical water level or there may be some other triggering factor(s) involved. Countermeasure work tries to achieve the factor of safety F≧P.Fs (planning/designed factor of safety). To achieve this objective, possible combinations of types, sizes as well as numbers of countermeasure works should be examined.

To make a suitable and appropriate countermeasure work design, it is necessary to calculate the factor of safety which can reflect the actual stability of a landslide because this calculated factor of safety will become the criteria for the design.

Hence, it is very important to understand sliding process in response to groundwater fluctuation. Furthermore, the shear strength parameters and groundwater level should be carefully determined so that factor of safety derived from stability analysis is as close as possible to the estimated actual factor of safety of a landslide obtained through back analysis approach.

The conceptual (calculated) factor of safety is important, and it is also important to understand the actual factor of safety. As already explained, the factor of safety of a landslide is always changing with the change of triggering factors such as groundwater level fluctuation. The current factor of safety is defined as the factor of safety when the groundwater level reaches the highest level, or the factor of safety when the landslide presents most active condition in a monitoring period. The monitoring period means the period from the beginning of monitoring to present in case of before landslide countermeasure works have been conducted, and it is the period from the completion of countermeasure work to present in case of completion of countermeasure work.

A main section of the landslide for stability analysis shall be set up based on appropriate investigation to detect the sliding surface. Generally, stability analysis of a landslide is proceeded according to following procedure.

1) Monitor landslide deformation in the fixed period;
2) Monitor groundwater level fluctuation and reflect the result in the longitudinal section for stability analysis;
3) Estimate the current factor of safety;
4) Select a suitable method for stability analysis;
5) Set the shear strength parameter for soils in sliding surface;
6) Consider the effect of countermeasure works on the slope stabilization.

The stability analysis in this Project shall be carried out following the procedure mentioned above after getting appropriate data from geotechnical investigation and monitoring result.

4.4.4 Stability Analysis

The stability analysis of landslides was carried out at the three high priority landslide hazard areas: the Chitrakoot area, the Quatre Soeurs area and the Vallee Pitot area. The stability analysis of landslides was carried out according to the procedure below.

<u>Preparation of longitudinal sections for stability analysis</u>

Based on the results of the landslide investigation and monitoring, longitudinal sections for stability analysis were prepared. The items necessary for stability analysis shown below were included on the longitudinal sections.

- Ground surface
- Sliding surface
- Highest groundwater level during the monitoring period
- Slice which was divided

<u>Estimation of the current factor of safety</u>

The factor of safety at the time of an active landslide is proposed for each level of activity as shown in the table below. In this project, the current safety factor (Fs_0) is estimated based on the table below.

Table 4.4.3 Definition of Safety Factor for Landslide[3]

Safety factor	Landslide condition
Fs = 0.95	Case in moving continuously anytime
Fs = 0.98	Case in moving continuously for corresponding to rainfall etc.
Fs = 1.00	Case in settling down of the landslide

<u>Selection of a suitable method for stability analysis</u>

The modified Fellenius method is adopted in this project. This method is suitable because the landslides to be analyzed are of colluvium of simple structures, making the technology transfer to the C/Ps easy.

[Modified Fellenius method]

The modified Fellenius method is based on the balance of the moment between soil weight and the shear resistance acting on the slip surface. In addition, the pore water pressure to act on the sliding surface by introducing effective soil weight (*W-Ud*) in substitution for soil weight is evaluated definitely. The landslide longitudinal section is prepared for stability analysis, and the landslide body is divided into multiple slices. Finally, the total of the sliding force and shear resistance are calculated in each slice, and the safety factor is provided as those ratios.

$$Fs = \frac{S}{T} = \frac{\sum\{c \cdot l + (W - U \cdot d)\cos\alpha \cdot \tan\phi\}}{\sum W \cdot \sin\alpha} \qquad \text{(Formula 4-1)}$$

Fs : Factor of safety
S : Shear resistance
*T : Shear force (S*liding force)
c : Cohesion
φ : Shear resistance angle
l : Slice length of sliding surface
W :Slice weight, *W*= $\gamma t \cdot h \cdot d$
U :Pore water pressure, U= $\gamma_w \cdot h_w \cdot d$
γ_t :Soil unit weight
γ_w :Water unit weight
d : Slice width
h : Slice height
h_w *:* Water height
α : Inclination angle of sliding surface

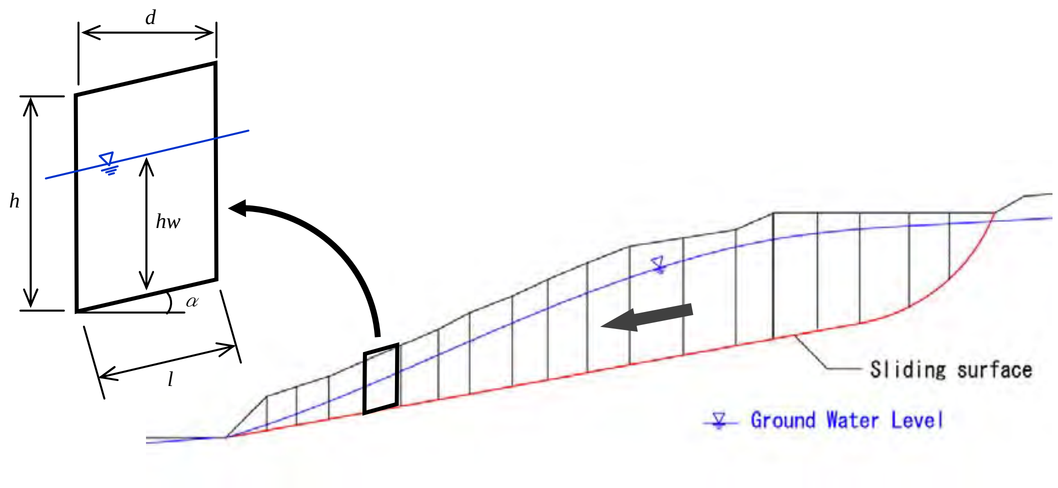


Figure 4.4.2 Schematic Diagram of the Modified Fellenius Method (source : JET)

Stability analysis

The soil parameter to be used for stability analysis is set based on the results of the laboratory soil test. However, the shear strength was not provided in the laboratory soil test because we were not able to get an undisturbed soil sample by an outcrop on the ground surface and drilling in this project. Therefore, the shear strength parameters were obtained from the back analysis, and the validity shall be confirmed by the physical test results of the soil.

Regarding each landslide danger area, the results of the stability analysis are shown below.

a. Chitrakoot Area

The stability analysis of the active landslide blocks (Block A and Block B) was carried out in the Chitrakoot area as follows.

On the other hand, as for the large-scale landslide block and other small landslide blocks, displacement by landslide activity was not observed during the monitoring in the wet season in 2013, and phenomena due to landslide activity (such as damage to houses and new cracks in the ground surface) were not found. Because the large landslide block and other small landslide blocks were judged not to be active, it was not necessary to carry out stability analysis.

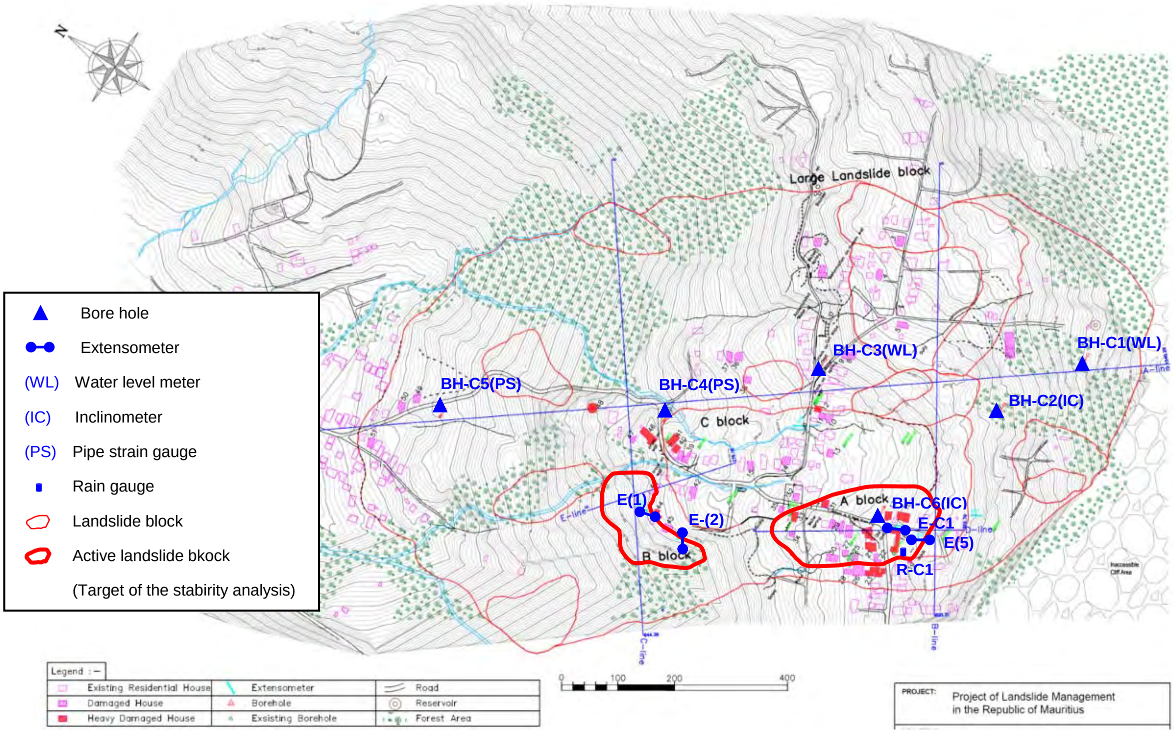


Figure 4.4.3 Location Map of the Landslide Block in Chitrakoot Area (source : JET)

a.1 Longitudinal section for stability analysis

Based on the results of the landslide investigation and monitoring, the longitudinal sections for stability analysis were prepared for Block A and Block B.

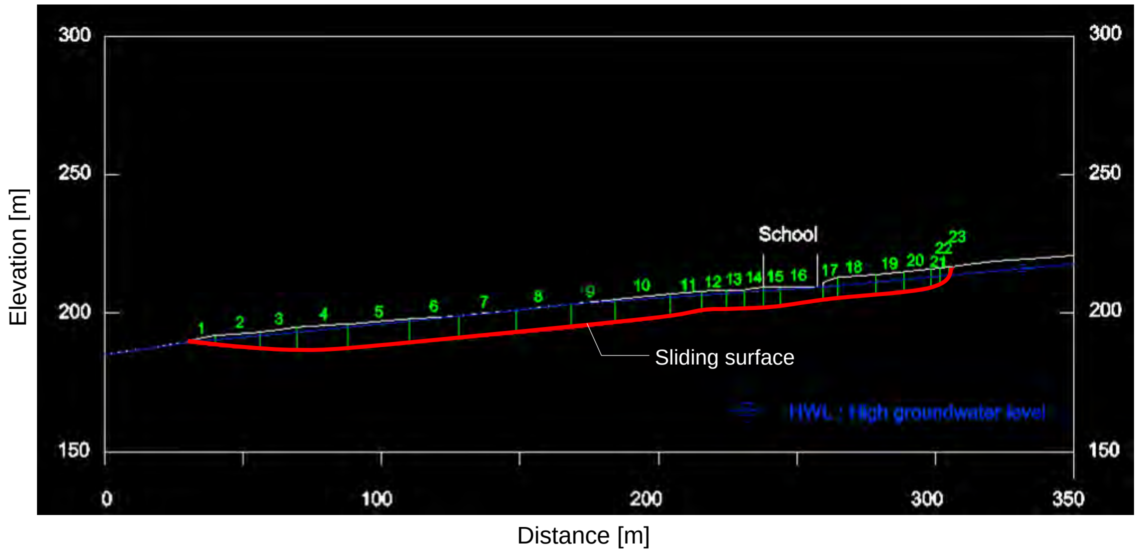


Figure 4.4.4 Longitudinal Section for Stability Analysis, Block A in Chitrakoot (source:JET)

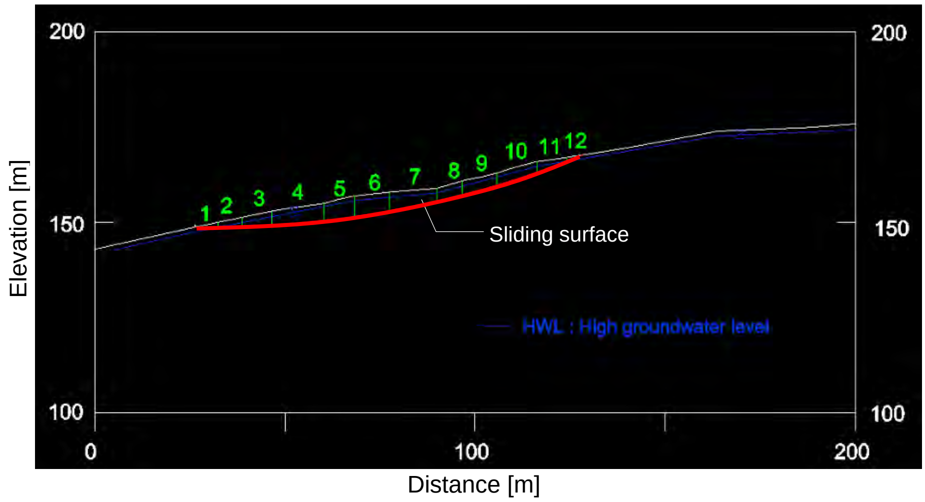


Figure 4.4.5 Longitudinal Section for Stability Analysis, Block B in Chitrakoot (source:JET)

a.2 Estimation of the current safety factor

According to the results of the landslide monitoring, landslide Block A and B in the Chirtakoot area are active only when it rains and are not active when it is dry. Therefore, the current factor of safety (Fs_0) of landslide Block A and B has been estimated to be 0.98.

On the other hand, because the large landslide block and other small landslide blocks are judged not to be active, it is estimated that the current factor of safety (Fs_0) of these landslide blocks are greater than 1.00 (>1.00).

Table 4.4.4 Current Factor of Safety of the Landslide, Chitrakoot area (source: JET)

Landslide block	Current factor of safety (Fs_0)	Current situation of landslide
Block A	0.98	Case in moving continuously for corresponding to rainfall etc. (Source: Japan Construction Engineer's Association, 2010)
Block B	0.98	
Large landslide block and other small blocks	>1.00	Not active, not currently moving.

a.3 Stability analysis

The results of the laboratory soil test carried out by this project and other existing projects are shown in the table below. The results of the existing laboratory soil test in the neighboring La Butte landslide are also shown below. Only the test results of the colluvium which forms the sliding surface are included in these tables.

Table 4.4.5 Result of the Laboratory Soil Test, Chitrakoot area (source: JET)

	Drill hole No.	Depth [m]			Plastic index PI [%]	Bulk(wet) density ρt [kN/m^3]	Single shear test: Cohesion C [kN/m^2]	Single shear test: shear resistance angle ϕ [deg]
This project	BH-C2	4.80	～	5.25	35.1	17.7	-	-
	BH-C4	6.35	～	6.80	44.5	-	-	-
	BH-C5	4.25	～	4.70	68.8	-	-	-
Other existing projects	BPP5	2.00	～	2.50	-	17.8	-	-
	BPP8	4.50	～	5.00	-	17.2	28.5	29.0
	BPP13	1.53	～	2.20	-	18.9	-	-
	BPP13	3.30	～	3.66	-	18.8	-	-
	BPI4	5.40	～	6.00	-	17.1	11.0	22.0
Average					49.5	17.9	19.8	25.5

(Source of the other existing result : Geological investigation at Chitrakoot, Ministry of Environment and National Development Unit, 2007)

Table 4.4.6 Existing Result of the Laboratory Soil Test, La Butte landslide[4]

Drill hole No.	Depth [m]	Plastic index PI [%]	Bulk(wet) density ρt [kN/m^3]	Triaxial shear test: Cohesion C [kN/m^2]	Triaxial shear test: Shear resistance angle ϕ [deg]
S/R-1	～	76.6	18.3	17.7	9.2
	～	-	18.3	-	-
	～	-	17.8	-	-
	～	-	19.1	-	-
S/R-2	～	43.1	19.4	20.6	5.5
	～	-	18.6	-	-
	～	-	18.2	-	-
	～	-	19.2	-	-
D/W-1	～	40.5	16.8	29.4	10.0
	～	-	17.9	-	-
	～	-	16.4	-	-

	～	-	18.6	-	-
	～	-	18.3	-	-
D/W-2	～	46.7	17.2	9.8	28.0
	～	-	18.2	-	-
	～	-	17.4	-	-
Average		51.7	18.1	19.4	13.2
Parameter of the countermeasure design			18.0	10.0	9.0～9.7

Unit weight of soil (γ_t)

The unit weight of soil (γ_t) is provided in the laboratory soil test as the bulk density (ρ_t). According to the test results of this project and other existing projects, the wet density of the colluvium of the landslide bodies concerned is 17.1-18.8 [kN/m^3]. Therefore, the unit weight (γ_t)used for stability analysis is set at 18.0 [kN/m^3]. This unit weight is the same as the parameter used by the countermeasure design of the La Butte landslide (1990).

Stability analysis/back analysis and shear strength (cohesion: C, shear resistance angle: φ)

The shear strength was not provided in the laboratory soil test because an undisturbed soil sample could not be obtained in this project. However, based on the results of the laboratory soil test in the other existing projects and neighboring La Butte landslide, the shear strength parameters are as follows:

Cohesion(C): 9.8 – 29.4 [kN/m^2], Shear Resistance Angle(φ): 5.5 – 29.0 [deg]

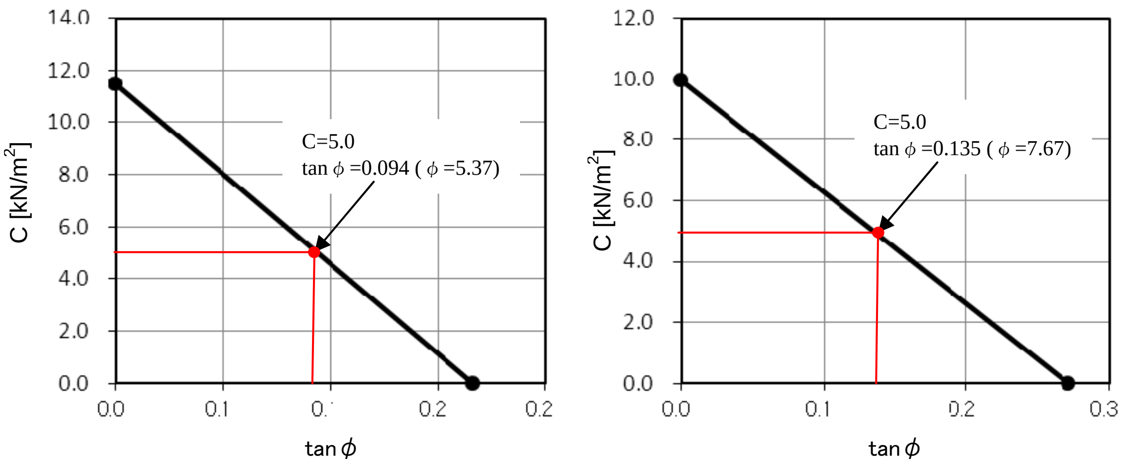
The factor of safety of the landslide is 1.40 in Block A and 1.3 in Block B when the stability analysis is carried out using the minimum value (C=9.8, φ=5.5) of their shear strength. However, because the current factor of safety of Block A and Block B is estimated to be 0.98, it is judged that the shear strength parameter that the laboratory soil test provided is bigger than the actual shear strength. These landslide blocks have been active for at least the past 2,005 years, and it is thought that the actual shear strength of the sliding surface is smaller than the strength of the laboratory soil test as a result of longtime landslide activity. Therefore, the shear strength parameters are obtained from the back analysis, and the validity shall be confirmed by the physical test results of the soil.

For a method to estimate the shear strength of the sliding surface, based on past results of research, combination (C) is predicted by the thickness of the landslide body (Source: Foresight and countermeasure of landslide and slope failure, Watari, Kobashi, 1987). It has been reported that the cohesion and thickness of an average landslide body are almost equal. For example, cohesion (C) is almost 3-6 [kN/m^2] when the thickness of the landslide body is 5m. In the case of 10m, it is almost 8-12 [kN/m^2]. The value of cohesion (C) becomes larger as the thickness of the landslide body increases. This means that the cohesion of the soil becomes strong by a permanent upper load.

Because the thickness of the landslide body of Block A is 6-8m, and Block B is 3-5m, the back analysis of the stability analysis was carried out using 5.0[kN/m^2] as combination (C). The results of the stability analysis are shown below.

Table 4.4.7 Result of the Stability Analysis, Chitrakoot Area (source: JET)

Landslide block	Current factor of safety Fs_0	Unit weight γt [kN/m^3]	Cohesion C [kN/m^2]	Shear resistance angle φ [deg]
Block A	0.98	18.0	5.0	5.37
Block B	0.98	18.0	5.0	7.67



Block A

Block B

Figure 4.4.6 C-φ Diagram, Chitrakoot Area (source:JET)

The relationship between the plasticity index (PI) of various sliding surface clays and the shear resistance angle (φ) is shown in the figure below. The plasticity index (PI) of the Chitrakoot area provided in the laboratory soil test is 35.1-76.6 [%] and the shear resistance angle (φ) is distributed in the range of 4 - 22[ded] according to the chart below. On the other hand, the shear resistance angle (φ) provided by the stability analysis is 5.37 [deg] and 7.67 [deg], and these are in the distribution range of the shear resistance angle (φ) of the figure below. Based on this, it is deduced that the reliability of the shear strength parameter provided by this stability analysis is almost certain.

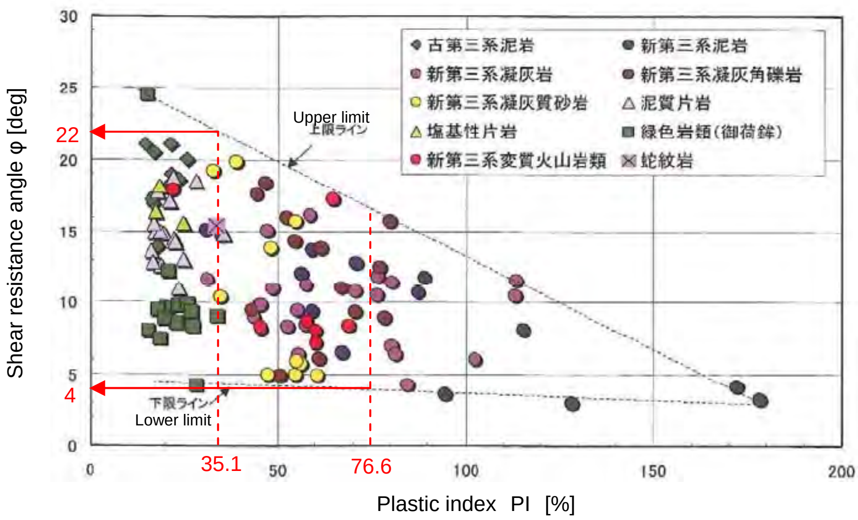


Figure 4.4.7 Relationship of the Plastic Index and Shear Resistance Angle, the Sliding Surface Clay Gathered at the Position of the Source[5]

b. Quatre Soeurs Area

The stability analysis of the two landslide blocks (Block A and Block B) which moved in 2005 was carried out in the Quatre Soeurs area as shown below

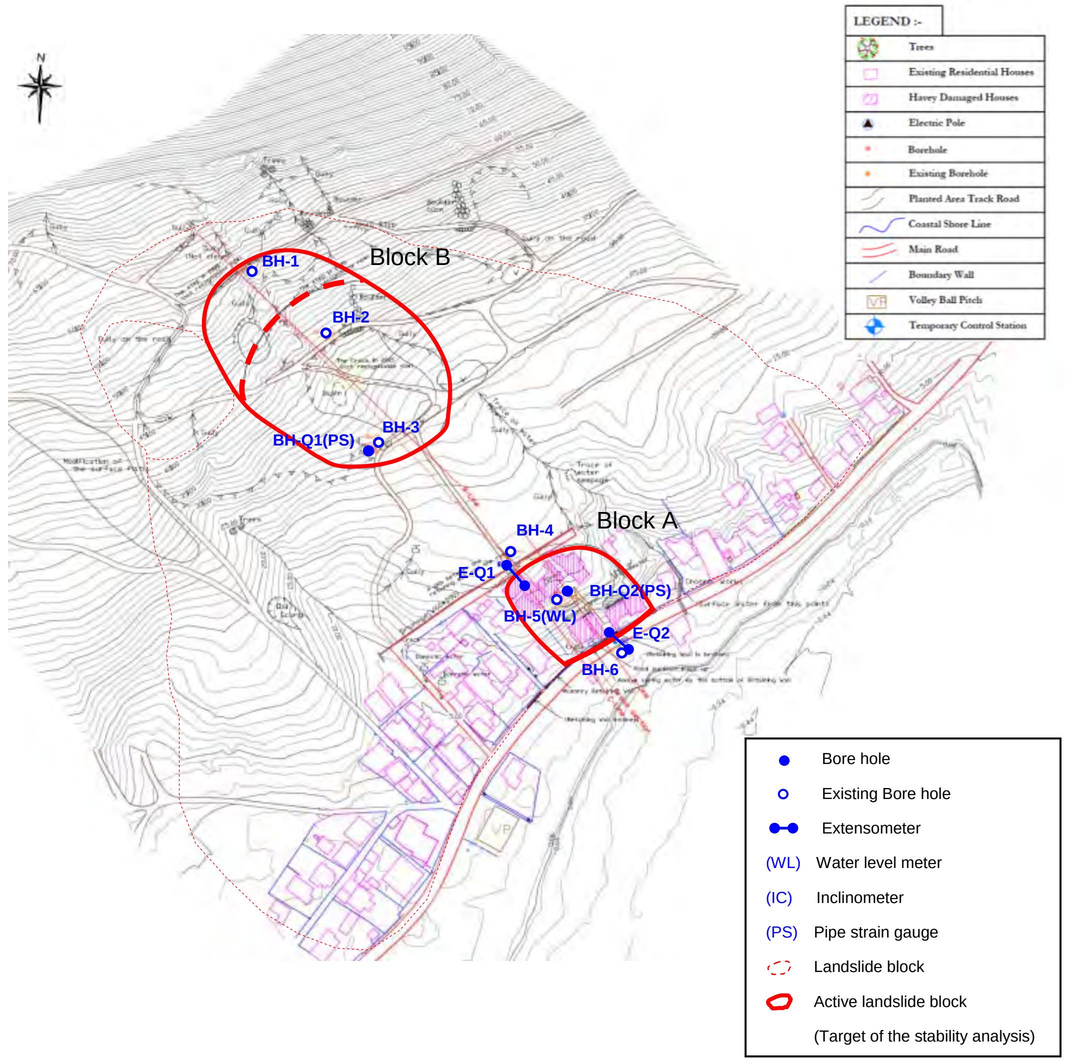


Figure 4.4.8 Location Map of the Landslide Block in Quatre Soeurs Area (source : JET)

b.1 Longitudinal section for stability analysis

Based on the results of the landslide investigation and monitoring, the longitudinal section for stability analysis has been prepared for Block A and Block B.

Figure 4.4.9 Longitudinal section for stability analysis, Block A in Quatre Soeurs (source: JET)

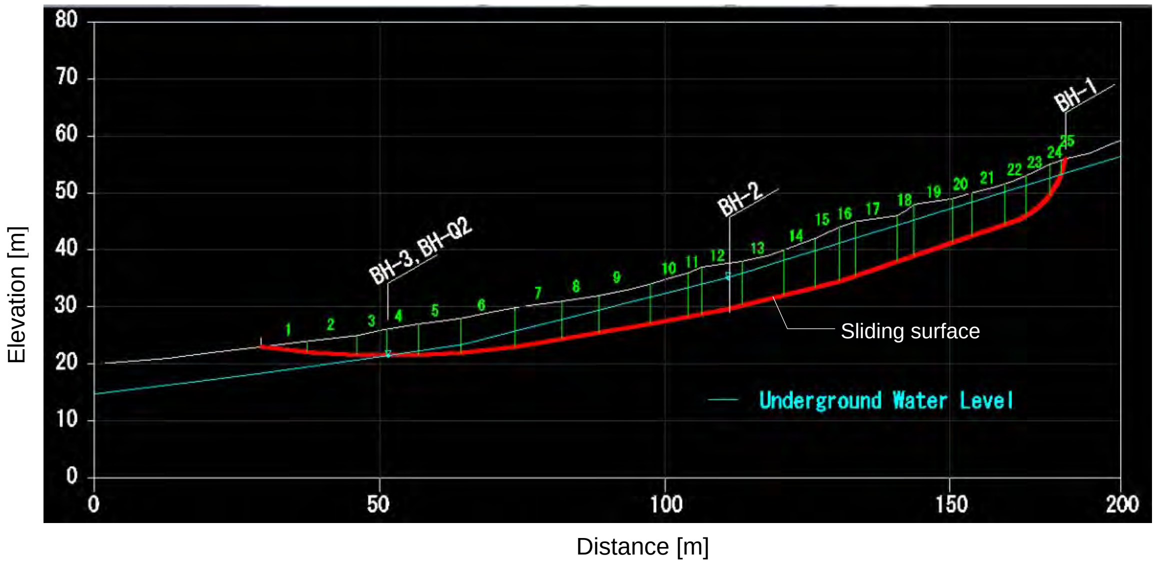


Figure 4.4.10 Longitudinal Section for Stability Analysis, Block B in Quatre Soeurs (source:JET)

b.2 Estimate the current factor of safety

As a result of the landslide monitoring in the wet season (from January to March) of 2013 carried out by this project, displacement by the landslide was not observed in landslide Block A and B of the Quatre Soeurs area. Therefore, in landslide Block A and B, it is reasonable that the current factor of safety is taken as 1.00.

Table 4.4.8 Current Factor of Safety of the Landslide, Quatre Soeurs Area (source : JET)

Landslide block	Current factor of safety (Fs_0)	Current situation of landslide
Block A	1.00	Case in settling down of the landslide (Source: Japan Construction Engineer's Association, 2010)
Block B	1.00	

b.3 Stability analysis

The results of the laboratory soil test carried out by this project and other existing projects are shown in the table below. Only the test results of the colluvium which forms the sliding surface are included in this table.

Table 4.4.9 Result of the Laboratory Soil Test, Quatre Soeurs Area (source: JET)

	Drill hole No.	Depth [m]			Plastic index PI [%]	Bulk(wet) density ρt [kN/m3]	Triaxial shear test	
							Cohesion C [kN/m2]	Shear resistance angle ϕ [deg]
This project	BH-Q1	1.00	～	1.45	53.8	-	-	-
	BH-Q2	9.00	～	9.40	51.5	15.5	-	-
Other existing project	BH5	3.00	～	3.50		16.2	0.4	1.4
	BH5	5.00	～	5.50		16.2		
	BH5	5.50	～	6.00				
	BH6	2.50	～	3.00	18.0			
	BH6	4.50	～	5.00	21.0	16.9		
Average					36.1	16.2	0.4	1.4

(Source of the other existing results : Geological Report for Suspected Landslide at Quatre Soeurs, Ministry of Public Infrastructure Land Transport and Shipping, 2011)

Unit weight of soil (γ_t)

The unit weight of soil (γ_t) is provided in the laboratory soil test as the bulk density (ρ_t). According to the test results of this project and other existing projects, the wet density of the colluvium of the landslide bodies concerned is 15.5～16.9 [kN/m^3]. Therefore, the unit weight (γ_t) used for stability analysis is set as 16.0 [kN/m^3].

Stability analysis/back analysis and shear strength (cohesion: C, shear resistance angle:φ)

The shear strength was not provided in the laboratory soil test because an undisturbed soil sample could not be obtained in this project. However, based on the results of the laboratory soil test in the other existing projects and the neighboring La Butte landslide, the shear strength parameters are as follows:

Cohesion(C): 0.4 [kN/m^2], Shear resistance angle(φ) : 1.4 [deg]

The factor of safety of the landslide is 0.07 in Block A and 0.09 in Block B when the stability analysis is carried out using C=0.4, φ=1.4 as the shear strength parameters. However, because the current factor of safety of Block A and Block B is estimated to be 1.00, it is judged that the shear strength parameter that the laboratory soil test provided is much smaller than the actual shear strength. It is presumed that the soil sample was disturbed at the time of collection and as a result, the shear strength parameter provided in the laboratory soil test is not appropriate for stability analysis. Therefore, the shear strength parameters are obtained from the back analysis, and the validity shall be confirmed by the physical test results of soil.

For a method to estimate the shear strength of the sliding surface, based on the results of past research, combination (C) is predicted by the thickness of the landslide body (source: Foresight and countermeasure of landslide and slope failure, Watari, Kobashi, 1987). It has been reported that the cohesion and thickness of an average landslide body are almost equal. For example, cohesion (C) is almost 3-6 [kN/m^2] when the thickness of the landslide body is 5m. In the case of 10m, it is almost 8-12 [kN/m^2]. The value of cohesion (C) becomes larger as the thickness of the landslide body increases. This means that the cohesion of the soil becomes strong by a permanent upper load.

Because the thickness of the landslide body of Block A is 4-7.5m, and Block B is 5-9.5m, the back analysis of the stability analysis is carried out using 8.0[kN/m^2] as combination (C). The result of the stability analysis is shown below.

Table 4.4.10 Result of the Stability Analysis, Quatre Soeurs Area (source: JET)

Landslide block	Current factor of safety Fs_0	Unit weight γt [kN/m^3]	Cohesion C [kN/m^2]	Shear resistance angle φ [deg]
Block A	1.00	16.0	8.0	16.08
Block B	1.00	16.0	8.0	13.00

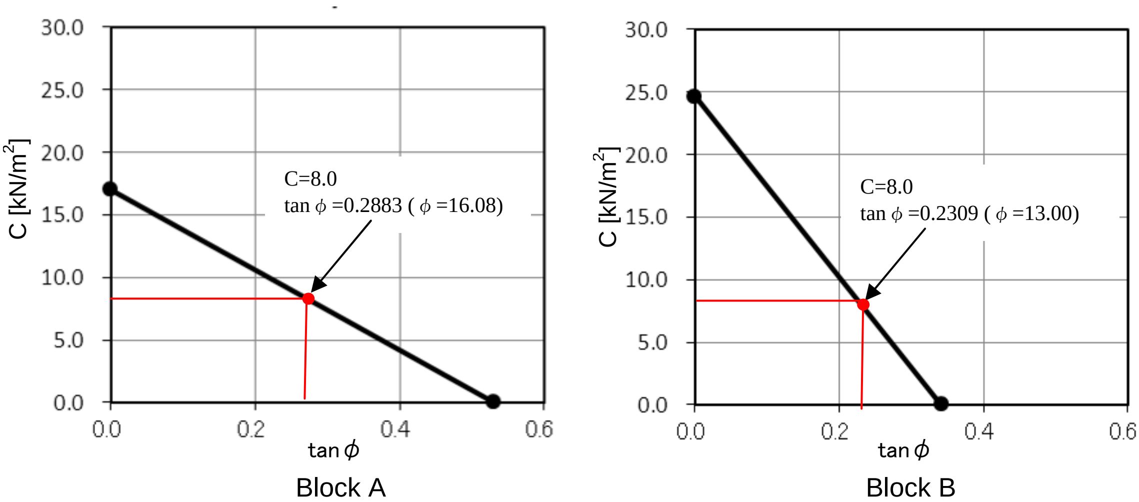


Figure 4.4.11 C-φ Diagram, Quatre Soeurs Area (source:JET)

The relationship between the plasticity index (PI) of various sliding surface clays and the shear resistance angle (φ) is shown in the figure below. The plasticity index (PI) of the Quatre Soeurs area provided in the laboratory soil test is 18.0～53.8 [%] and the shear resistance angle (φ) is distributed in the range of 4.5～24.5 [deg] according to the chart below. On the other hand, the shear resistance angle (φ) provided by stability analysis is 16.08 [deg] and 13.00 [deg], and these are in the distribution range of the shear resistance angle (φ) of the figure below. Based on this, it is deduced that the reliability of the shear strength parameter provided by the stability analysis is almost certain.

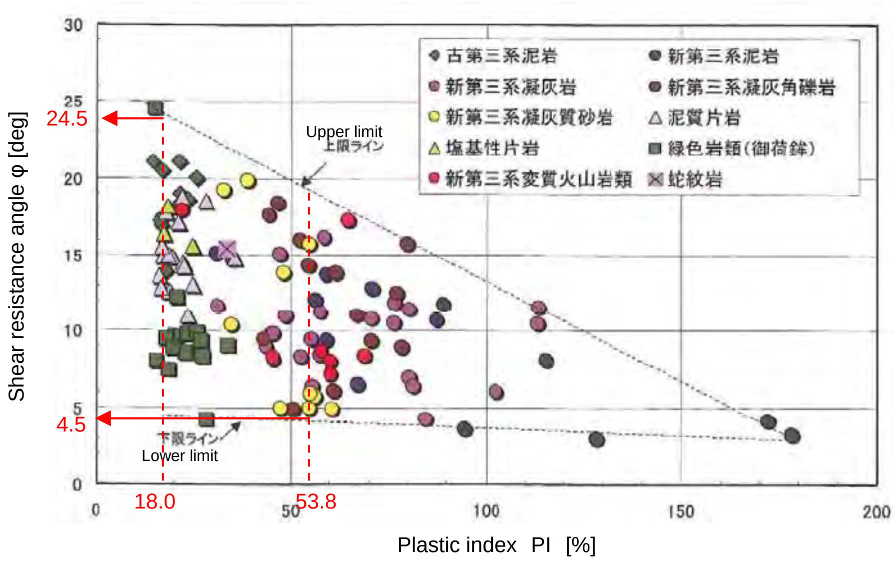


Figure 4.4.12 Relations of the Plastic Index and Shear Resistance Angle, the Sliding Surface Clay Gathered at the Position of the Source[5]

c. Vallee Pitot Area

The stability analysis of the two landslide blocks (Block A-1 and Block E) which moved dramatically in the wet season of 2012 was carried out as shown below.

In addition, MPI is going to carry out a detailed geological survey and monitoring in the Vallee Pitot area after October 2013. Depending on the results of the detailed survey and monitoring, it may be necessary to calculate the stability analysis of this area again.

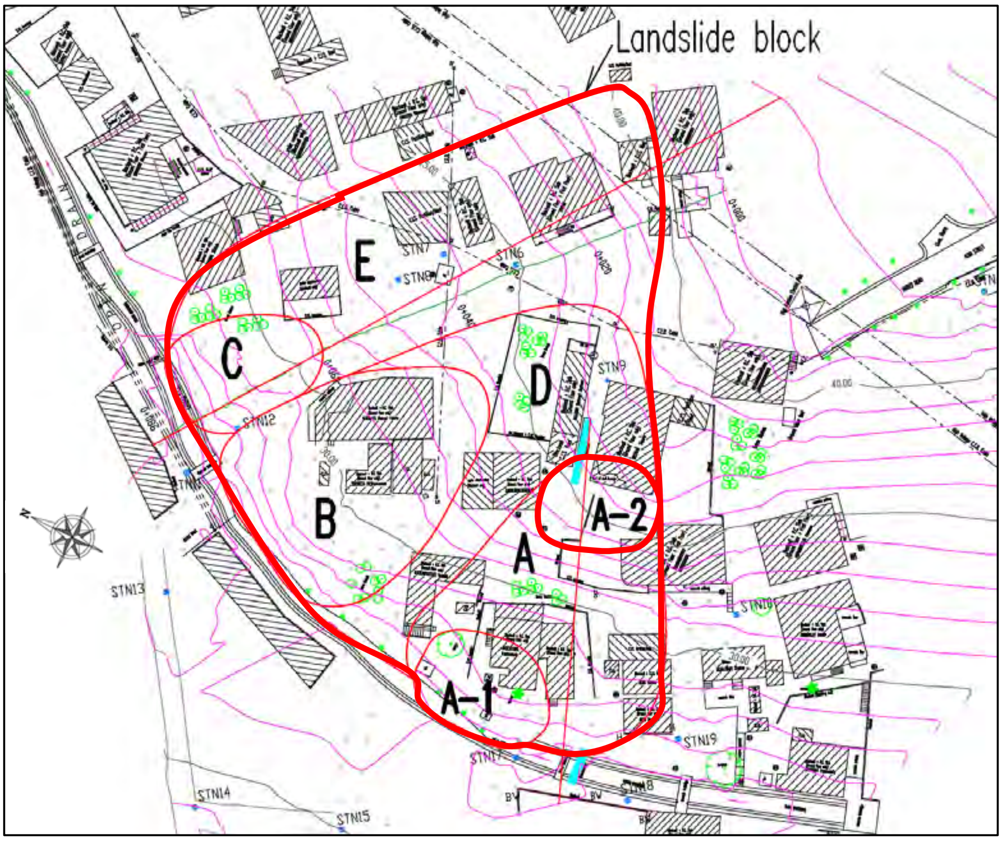


Figure 4.4.13 Location Map of the Landslide Block in Vallee Pitot Area (source : JET)

c.1 Longitudinal section for stability analysis

Based on the results of the landslide investigation and monitoring, the longitudinal section for stability analysis has been prepared for Block A-2 and Block E.

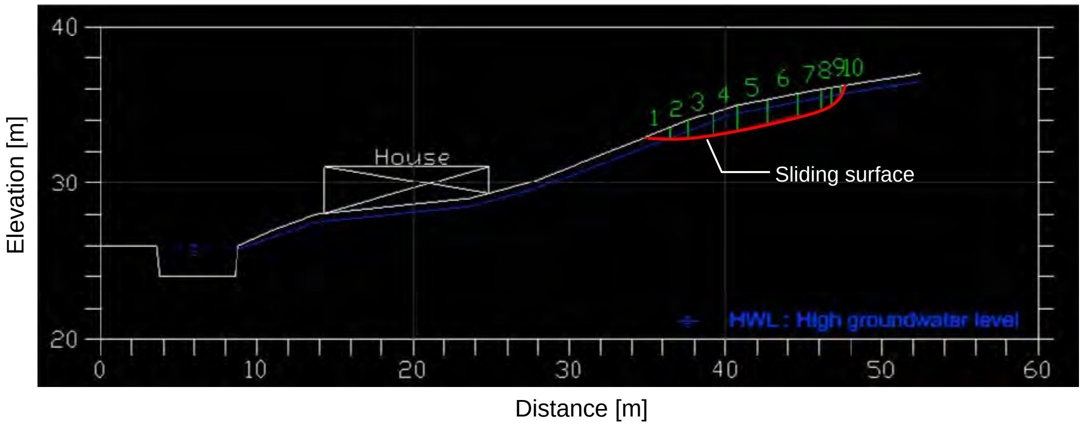


Figure 4.4.14 Longitudinal Section for Stability Analysis, Block A-2 in Vallee Pitot (source:JET)

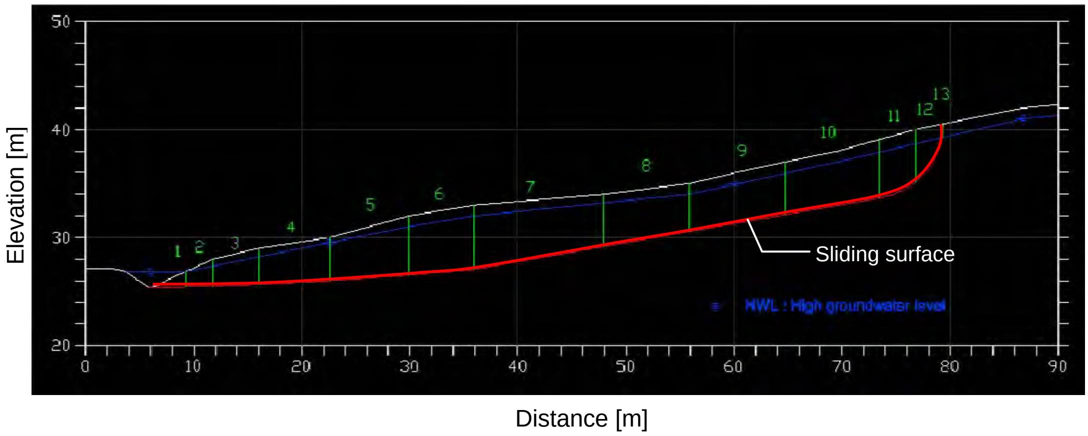


Figure 4.4.15 Longitudinal Section for Stability Analysis, Block E in Vallee Pitot (source:JET)

c.2 Estimate the current factor of safety

Based on the results of the landslide monitoring, landslide Block A-2 and E in the Vallee Pitot area are active only in times of rain and are not active when it is dry. Therefore, the current factor of safety (Fs_0) of landslide Block A-2 and E have been estimated to be 0.98.

Table 4.4.11 Current Factor of Safety of the Landslide, Vallee Pitot Area (source : JET)

Landslide block	Current factor of safety (Fs_0)	Current situation of landslide
Block A-2	0.98	Case in moving continuously for corresponding to rainfall etc. (Source: Japan Construction Engineer's Association, 2010)
Block E	0.98	

c.3 Stability analysis

Unit weight of soil (γt)

In this project, the laboratory soil test in the Vallee Pitot area was not carried out. Therefore, in reference to the neighboring Chitrakoot area, the unit weight of soil (γ_t) is set as 18.0 [kN/m^3].

In addition, MPI is going to carry out a detailed geological survey and monitoring in the Vallee Pitot area after October, 2013.

Stability analysis/back analysis and shear strength (cohesion:C, shear resistance angle:φ)

In this project, the laboratory soil test in the Vallee Pitot area was not carried out. Therefore, the shear strength parameters were obtained from the back analysis. For a method to estimate the shear strength of the sliding surface, based on the results of past research, combination (C) was predicted by the thickness of the landslide body (Source: Foresight and countermeasure of landslide and slope failure, Watari, Kobashi, 1987).As the thickness of the landslide body of Block A-2 is about 1.5m, the back analysis of the stability analysis was carried out using 1.5[kN/m^2] as combination (C). Similarly, combination (c) of Block E was set to 5[kN/m^2] because the thickness of the landslide body was almost 5m. The results of the stability analysis are shown below.

Table 4.4.12 Result of the Stability Analysis, Vallee Pitot Area (source: JET)

Landslide block	Current factor of safety Fs_0	Unit weight γt [kN/m^3]	Cohesion C [kN/m^2]	Shear resistance angle φ [deg]
Block A-2	0.98	18.0	1.5	12.21
Block E	0.98	18.0	5.0	9.88

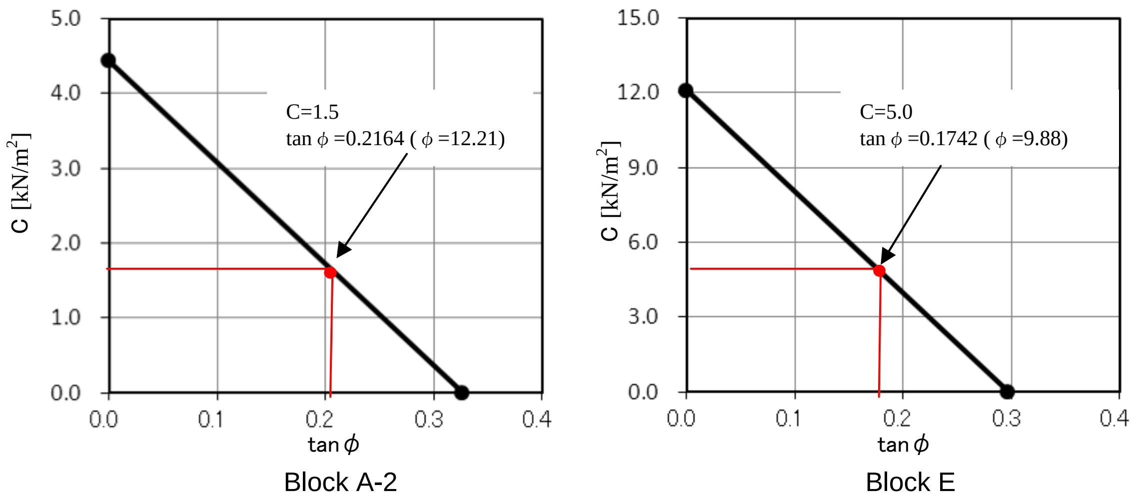


Figure 4.4.16 C-φ Diagram, Vallee Pitot Area (source: JET)

4.4.5 Evaluation of the Soil Strength

The residual strength of the landslide clay is provided by the ring shear test that is one of the laboratory soil tests. The validity of strength C (cohesion) and φ (shear resistance angle) of soil used in landslide stability analysis is inspected through a comparison with the residual strength.

Landslide clay of the slip surface should be collected when submitting soil samples for testing. However, in this project, it is impossible to collect landslide clay at the slip surface because the landslide countermeasures that penetrate the slip surface are not carried out. Therefore the soil sample which relatively resembled landslide clay was collected in the vicinity of the surface and was used for the ring shear test. The results of the ring shear tests of soil samples collected from three landslides, Chitrakoot, Quatre Soeurs and Vallee Pitot, are shown below. In addition, the soil strength used in landslide stability analysis and the shear resistance angles estimated by plasticity index PI are shown in the same table.

Table 4.4.13 Results of Ring Shear Test, Cohesion C and Shear Resistance Angle φ (source: JET)

Landslide	Setting method of the soil strength	Cohesion C [kN/m^2]	Shear resistance angle φ [deg]
Chitrakoot Block A	**Result of ring shear test**	**8.7**	**11.8**
	Soil strength used in landslide stability analysis	5	5.37
	Estimate from plasticity index PI	-	4-22
Quatre Soeurs Block A	**Result of ring shear test**	**5.7**	**12.2**
	Soil strength used in landslide stability analysis	8	16.08
	Estimate from plasticity index PI	-	4.5-24.5
Vallee Pitot Block A-2	**Result of ring shear test**	**1.5**	**12.21**
	Soil strength used in landslide stability analysis	5	9.88

[Chitrakoot, Block-A]

The result of the ring shear test in Chitrakoot Block-A is described in C-φ diagram, which is the result of landslide stability analysis (Figure 4.4.17).

Shear resistance angle φ provided by a ring shear test is distributed within the estimate from plasticity index PI. However, it is shown in the C-φ diagram that it is a value considerably bigger than C and φ of the stability analysis. When stability analysis is carried out using C and φ of the ring shear test, the safety factor is 1.97, and this is different to the current safety factor 0.98. Therefore, it is judged that the result of ring shear test does not accord with the present conditions of the landslide activity. It is thought that this is because the collected soil samples have different characteristics to that of the landslide clay, and the result of the ring shear test is not suitable for stability analysis.

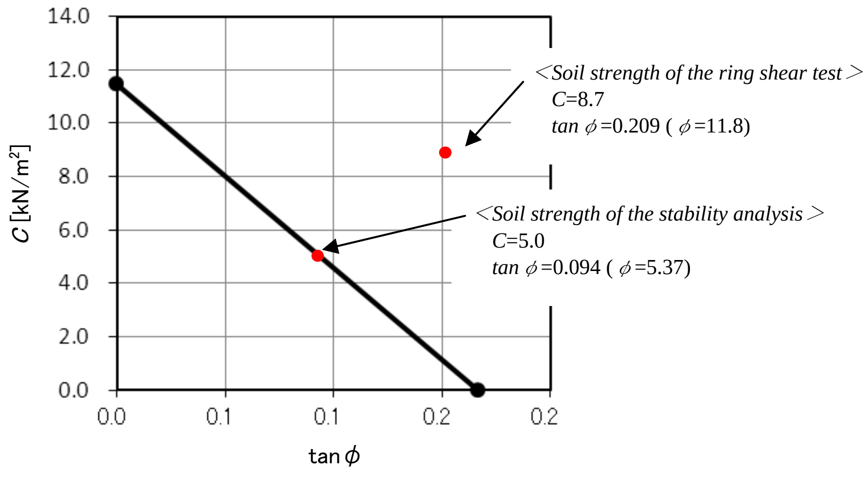


Figure 4.4.17 C-φ Diagram and the Result of Ring Shear Test in Chitrakoot Block-A (source: JET)

[Quatre Soeurs, Block-A]

The result of the ring shear test was described in C-φ diagram provided by landslide stability analysis (Figure 4.4.18).

The result of the ring shear test is slightly smaller than C and φ of the stability analysis but is very near to these values, and it is distributed within the estimate from plasticity index PI. From this, it is judged that the strength of soil used for stability analysis relatively accurate.

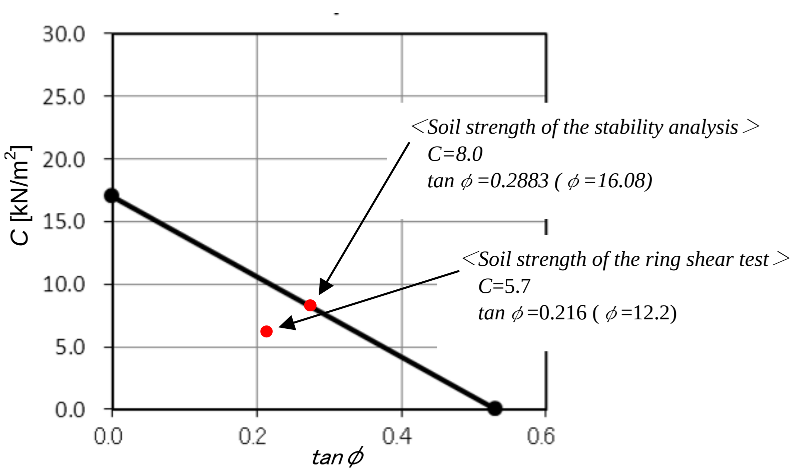


Figure 4.4.18 C-φ Diagram and the Result of Ring Shear Test in Quatre Soeurs Block-A (source: JET)

[Vallee Pitot, Block-A2]

The result of the ring shear test in Vallee Pitot, Block-A2 was described in C-φ diagram provided by landslide stability analysis (Figure 4.4.19).

The results of the ring shear test are distributed extremely close to the C-φ line, and are distributed within the estimate from plasticity index PI. From this, it is judged that the strength of soil used for stability analysis was appropriate.

In Vallee Pitot, a detailed landslide investigation and monitoring will be carried out from 2015 by C/P (MPI). When the detailed design of the landslide countermeasure is carried out in future here, all the results such as results of C-φ diagram, ring shear test and the detailed landslide investigation should be considered, and the strength of the soil should be set again.

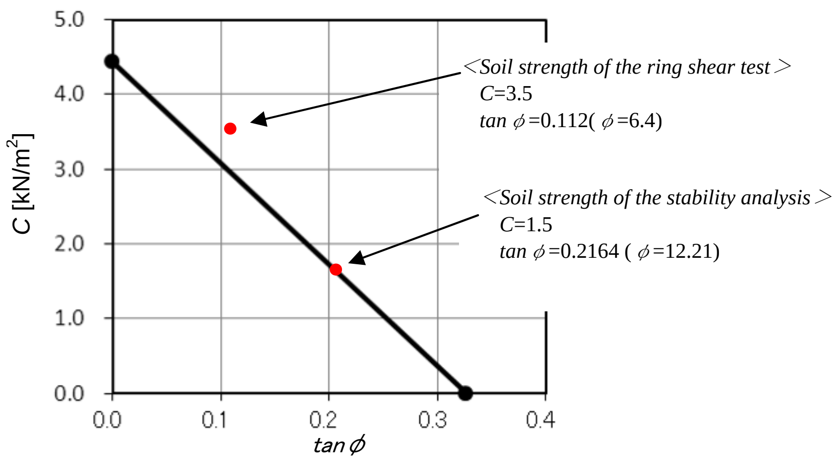


Figure 4.4.19 C-φ Diagram and the Result of Ring Shear Test in Vallee Pitot Block-A2
(source: JET)

[Summary]

In the case of Chitrakoot, because the slip surface is located in the border of colluvium and weathered basalt, it is assumed that the strength of the slip surface was different from the strength of provided colluvium in a ring shear test.

On the other hand, in Quatre Soeurs and Vallee Pitot, because there is a slip surface in colluvium, it is thought that the strength of the ring shear test was about the same as the strength of the slip surface.

4.5 Susceptibility Assessment

Landslide susceptibility will be assessed through consultation between the JET and C/P(MPI) based on the assessment items shown in the table below such as the results of the field survey, monitoring and stability analysis.

Table 4.5.1 Susceptibility Assessment Items (source: JET)

Item	Description
Landslide movement	Displacement from measuring devices such as ground surface displacement from extensometers and slip surface displacement from borehole inclinometers/pipe strain gauges is evaluated in relation to the amount of rainfall and groundwater levels.
Groundwater level	Changes in groundwater level in relation to rainfall amounts, and the relationship between groundwater levels and landslide movement are evaluated.
Rainfall	Rainfall conditions such as the amount and intensity of rainfall are examined and the relationship between groundwater levels and landslide movement is evaluated.
Change in ground surface/structures	New changes or advancement of existing changes of ground surface and structures, and their extent are evaluated.
Stability analysis result	The safety factor (FS) obtained from the stability analysis is evaluated (the possibility of collapse is high when FS is 1.00 or below. Usually in Japan, countermeasures are designed so that FS becomes 1.05 to 1.20 or higher). In this project, the current safety factor was estimated based on the quantity of landslide movement and the change in ground surface/structures.

Chitrakoot area

The susceptibility of the big landslide block and the small active landslide blocks (Block A and Block B) were assessed in the Chitrakoot area as follows:

Table 4.5.2 Results of Susceptibility Assessment in Chitrakoot Area (source: JET)

Item	Description	
	Block A	Block B
Landslide movement And Groundwater level, Rainfall	➢ The groundwater level rose to near the ground surface in the wet season from January to March, 2013. ➢ There was naturally occurring flow from the borehole. ➢ Landslide movement was confirmed after rain. ➢ The occurrence of landslide movement in times of rain was confirmed in the extensometer and inclinometer.	➢ Spring water was confirmed on the ground surface in the wet season from January to March, 2013. ➢ It is estimated that the groundwater level rises to near the ground surface. ➢ The occurrence of landslide movement in times of rain was confirmed in the extensometer.
Change in ground surface/structure	There was damage to sixteen (16) houses and roads in the landslide block	There was damage to three (3) houses in the landslide block
Stability analysis result	Fs_0＝0.98	Fs0＝0.98
Result of Susceptibility Assessment	**High-Risk** ➢ Continuation of monitoring ➢ Immediate implementation of countermeasures	**High-Risk** ➢ Continuation of monitoring ➢ Immediate implementation of countermeasures

Regarding Block A and Block B, the occurrence of landslide movement during rain was confirmed, and houses and roads were damaged by the landslide movement. In addition, it is judged that these landslide blocks are very active because the factor of safety is 0.98. The C/P (MPI) strongly requests the implementation of landslide countermeasures.

Based upon the above, Block A and Block B in the Chitrakoot area is judged to be ***High-Risk***.

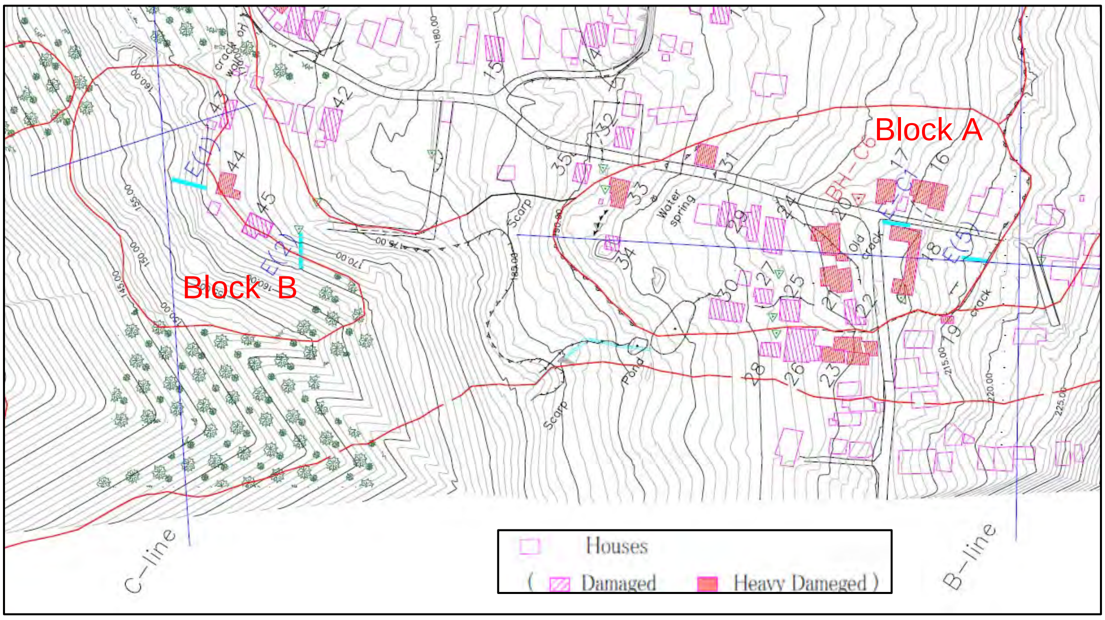


Figure 4.5.1 Result of Damaged House Survey, Chitrakoot area (source: JET)

Quatre Soeurs area

The susceptibility of the active landslide blocks (Block A and Block B) was assessed in the Quatre Soeurs area as follows:

Table 4.5.3 Results of Susceptibility Assessment in Quatre Soeurs Area (source: JET)

Item	Description	
	Block A	Block B
Landslide movement And Groundwater level, Rainfall	➢ The groundwater level rose in the wet season from January to March, 2013. ➢ Spring water was confirmed after the rain. ➢ However, landslide movement was not confirmed during the monitoring period in 2013.	➢ The groundwater level rose in the wet season from January to March, 2013. ➢ Spring water was confirmed after the rain. ➢ However, landslide movement was not confirmed during the monitoring period in 2013.
Change in ground surface/sturacture	➢ In 2005,　eleven (11) houses and roads were damaged in the landslide block ➢ However, in the wet season from January to March, 2013, the	➢ The land in the block is used as farmland, and there are no houses. ➢ Since 2006,　damage to the land has not been not confirmed

	progress of the damage was not confirmed	
Stability analysis result	Fs_0=1.00	Fs0=1.00
Result of Susceptibility Assessment	**Medium-Risk** ➢ Continuation of monitoring ➢ It is necessary to investigate countermeasures	**Medium-Risk** ➢ Continuation of monitoring ➢ It is necessary to investigate countermeasures

As a result of the landslide monitoring in 2013, a rise in water level in times of rain was observed, but landslide movement in Block A and B was not confirmed. The factor of safety is 1.00, and it is judged that the landslide was dormant during the monitoring period. Based on the above, Block A and Block B in the Quatre Soeurs area are judged to be ***Medium-Risk***. However, because a large number of houses were damaged during the landslide movement in 2005, the landslide may become active in times of heavy rain in future. Monitoring should be continued, and it is advisable that landslide countermeasures be investigated in future.

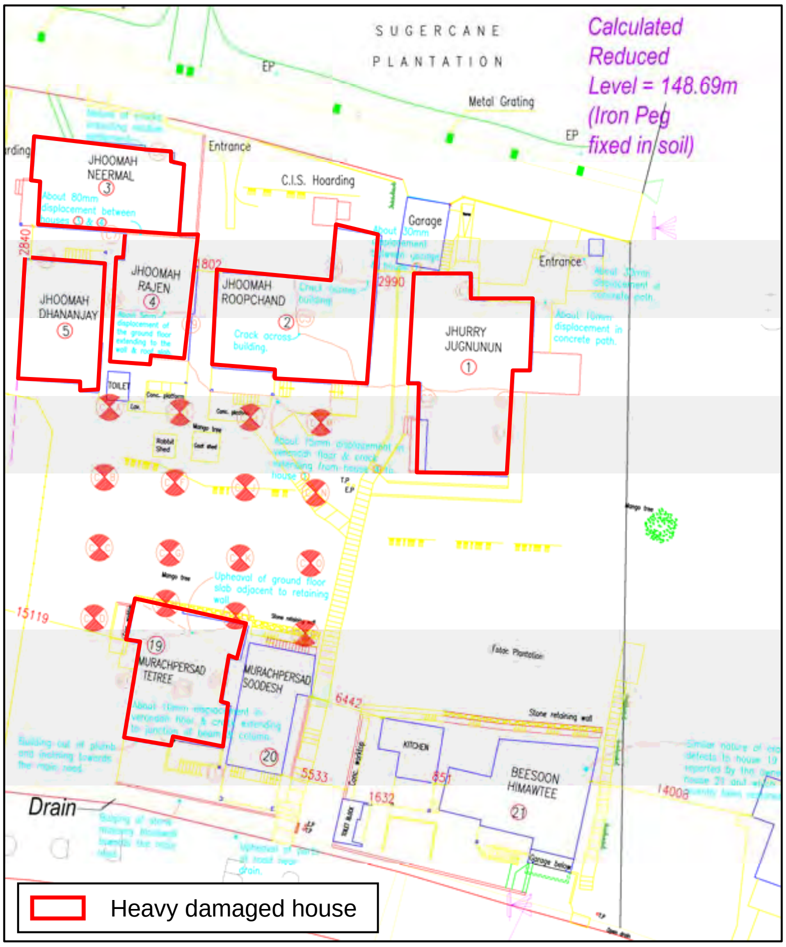


Figure 4.5.2 Location of Heavy Damaged House, Quatre Soeurs Area (source:JET)

Vallee Pitot area

The susceptibility of the active landslide blocks (Block A-2 and Block E) were assessed in the Vallee Pitot area as follows:

Table 4.5.4 Results of Susceptibility Assessment in Vallee Pitot Area (source: JET)

Item	Description	
	Block A-2	Block E
Landslide movement And Groundwater level, Rainfall	➢ Spring water was confirmed in the wet season from January to March, 2013. ➢ The occurrence of sudden landslide movement in times of rain was confirmed in the extensometer.	➢ Spring water was confirmed on the ground surface the in wet season from January to March, 2013. ➢ In times of heavy rain,new cracks formed, and landslide movement was confirmed..
Change in ground surface/structure	➢ In January 2013, two (2) houses were damaged in the landslide block, for a landslide movement, inhabitants relocated ➢ The main scarp and neighboring cracks suddenly spread.	➢ In January 2013, three (3) houses were damaged in the landslide block ➢ The main scarp and neighboring cracks suddenly spread.
Stability analysis result	Fs_0=0.98	Fs0=0.98
Result of Susceptibility Assessment	**<u>High-Risk</u>** ➢ Continuation of monitoring ➢ Immediate implementation of the countermeasures	**<u>High-Risk</u>** ➢ Continuation of monitoring ➢ Immediate implementation of the countermeasures

Regarding Block A-2 and E, the occurrence of sudden landslide movement in times of rain were confirmed, and some houses were damaged by the landslide movement. In addition, the factor of safety is 0.98, and it is judged that these landslide blocks are very active.

Based upon the above, Block A-2 and Block B in the Vallee Pitot area is judged to be ***<u>High-Risk</u>***.

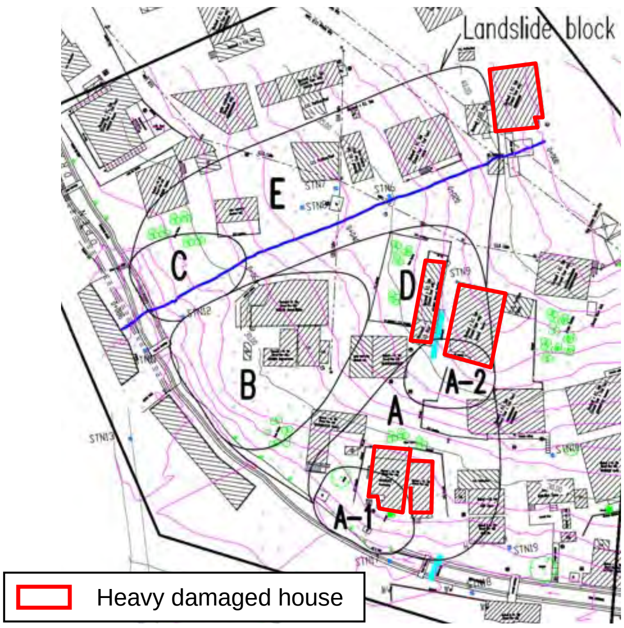


Figure 4.5.3 Location of Heavy Damaged House, Vallee Pitot Area (source:JET)

Reference for Chapter 4

[1] Meteorological HP
[2] JICA feasibility study report for climate change, 2010
[3] Japan Construction Engineer's Association (2010)
[4] Port Louis City, Plan and Investigation for Landslide countermeasures, JICA, 1990
[5] Ring shear characterristics of high purity clay minerals －Correlation with natural slip surface clay －, YAMASAKI, MAYUMI, YOSHITA, 2000

Chapter 5

Feasibility Study

5 Feasibility Study

5.1 Priority Site and Pilot Project site

5.1.1 Selection of Priority Site

Three landslide hazard areas were chosen in Chapter 2, and a detailed landslide survey was carried out by this project (Chapter 3 and Chapter 4). The priority site was selected based on the results of the survey of the three landslide hazard areas. The susceptibility assessment, the disaster scale, the countermeasure workload and the requests from the C/P (MPI) were also taken into consideration in the selection process.

The items considered for selection of the priority site are shown in the table below. Each item was examined and given a degree of the priority (high, middle, low), and the site with the highest total degree was selected as the priority site

Table 5.1.1 Items Considered for Selection of Pilot Project Site (source: JET)

Item	Chitrakoot	Vallee Pitot	Quatre Soeurs
Results of the landslide survey	A landslide occurred in 2005 (maximum accumulated rainfall: 376mm) and destroyed 54 houses and an elementary school. The landslide reoccurred in 2008 (maximum accumulated rainfall: 187mm). Although the large landslide has been stabilized, small landslide blocks (Block A and Block B) are active over 120 mm accumulated precipitations. The Susceptibility Assessment is "very dangerous".	Vallee Pitot has been well known as a landslide hazard area since the landslide that occurred in 2007. There was another landslide in 2013 (maximum accumulated precipitation: 130mm) that destroyed/ relocated 1 house. The landslide is still intensely active. The Susceptibility Assessment is "very dangerous".	A landslide occurred in 2005 (maximum accumulated precipitation: 520mm) and destroyed 11 houses. There was another landslide in 2008 (maximum accumulated precipitation: 244mm). There was no apparent landslide activity in the rainy season of 2013. The Susceptibility Assessment is lower than the two other sites.
Degree	**High**	**High**	**Middle**
Landslide volume	Block A is a landslide approximately 250m long, 100m wide and 6m deep. Block B is a slope failure (creep?) approximately 100m long and 150m wide. Largest landslide of the three, which high efficiency of countermeasures.	The landslide is around 120m long, 90m wide and 6m deep. It is estimated that the landslide consists of seven landslide blocks. Smallest landslide.	Block A is a landslide approximately 60m long, 60m wide and 6m deep. Block B is approximately 140m long and 100m wide. Middle landslide.
Degree	**High**	**Low**	**Middle**
Disaster Scale	・ House: 25 (Block A: 20, Block B: 5) ・ Public road: approx. 500m ・ Elementary School: 1 Disaster scale is so high that the priority for countermeasures is high.	・ Houses: 18 ・ Public road: 0m ・ Canal: 90m	・ Houses: 11 ・ Public road: approx.120m
Degree	**High**	**Middle**	**Middle**
Countermeasure	・ Channel: L=580m ・ Surface drainage: L=755m ・ Subsurface drainage: L=425m ・ Horizontal drilling: L=860m Many measures would be a model case in Mauritius.	・Repairmen of channel: L= 110m ・Surface drainage: L=240m ・Subsurface drainage: L=45m	・ Relocation
Degree	**High**	**Middle**	**Low**

Requests from C/P	This area has received the strongest request from the Mauritius Government, the C/P (MPI), the local municipality and the local residents.	The countermeasures in this area are carried out by MPI. The countermeasure in Chitrakoot in this project is taken into account in MPI	This area has received a request from the Mauritian government. A plan for relocation of the inhabitants of the landslide area is already in progression.
Degree	**High**	**Low**	**Low**
Total Degree	**Priority site (Highest degree on each item)**		

Chitrakoot is one of the largest and most active landslides in Mauritius. Its volume and disaster scale are so large that many countermeasures which are model cases in Mauritius would be adopted. In addition, due to the strong request from the Mauritian government. Therefore, Chitrakoot is selected as the priority site.

For Vallee Pitot area, because MPI requested that they would work on the landslide measures by themselves for improvement of their sustainability it is not chosen in the priority area. MPI is going to start a detailed landslide investigation and monitoring in the Vallee Pitot area after October, 2013.

For Quatre Soeurs area, because the relocation of inhabitants by MPI has made progress, it is not chosen in the priority area.

Priority Site (One sites): Chitrakoot / the Municipality of Port Louis

5.1.2 Selection of Pilot Project Site

In this project, a feasibility study (F/S) was carried out for Chitrakoot, the area chosen as the priority site. The pilot project site was selected based on the results of the (F/S). The results of the F/S are summarized below (The details of the F/S are shown in Chapter 5.6.).

- **Plan for pilot project** : The landslide countermeasures in the pilot project area will be one of the first construction works and will serve as a very important model project in Mauritius, which has many landslides.

- **Pilot project evaluation** : MPI has sufficient organization and budget to carry out the countermeasures, and there is high awareness and cooperative structure among the local government, other related organizations and the local residents. The project was highly evaluated on the five (5) items (relevance, effectiveness, efficiency, impact and sustainability) of the DAC (Development Assistance Committee). The pilot project is judged to be reasonable and effective in terms of technical, economic and social aspects.

- **EIA (Environmental Impact Assessment)** : Based on the JICA Guidelines for Environmental and Social Considerations and the contents of the MoEED's initial environmental impact assessment, land reclamation and backfilling survey, A plan that would avoid or minimize the impact on the ecosystem and relocation of residents were presented.

- **Promotion of fund raising** : The Mauritius Government, including MPI, are extremely positive and have sufficuent budget for the landslide countermeasures. Therefore, it is determined that the Mauritius Government will be able to sustain the landslide disaster management project.

- **Organizational reinforcement plan** : The Landslide Management Unit (LMU) has effectively implemented the capacity development plan on its own initiative. The LMU has accepted the capacity development plan proposed by the Japanese Expert Team (JET) and has been actively working on its capacity development.

In addition, Chitrakoot has following advantages as a pilot project site.

- Chitrakoot is one of the largest and most active landslides in Mauritius. Therefore various countermeasures would be adopted, which could be model cases for landslide countermeasures in Mauritius.

- The site is residence area on gentle slope at the bottom of a mountain. Under analogous condition in Japan, various countermeasures has been constructed for many years, therefore countermeasures in Mauritius could be referred from Japanese examples.

- The site is near Port Luis area, which has geographical advantages such as traffic convenience and national awareness.

Based on above the results of the F/S, the Chitrakoot area is judged to be suitable as the pilot project site.

Pilot Project Site (One site): Chitrakoot / The Municipality of Port Louis

5.1.3 Disaster Scenario at the Pilot Project Site

The disaster scenario should be discussed for consideration of countermeasures in the Pilot Project site.

As mentioned before, the areas where active movement is recognized in the Pilot Project site, Chitrakoot, are following small blocks. The disaster scenario is described for each block.

- Block A: Landslide: length 250m * width 100m * depth 6m

- Block B: Slope failure (creep deformation): length 100m * width 150m

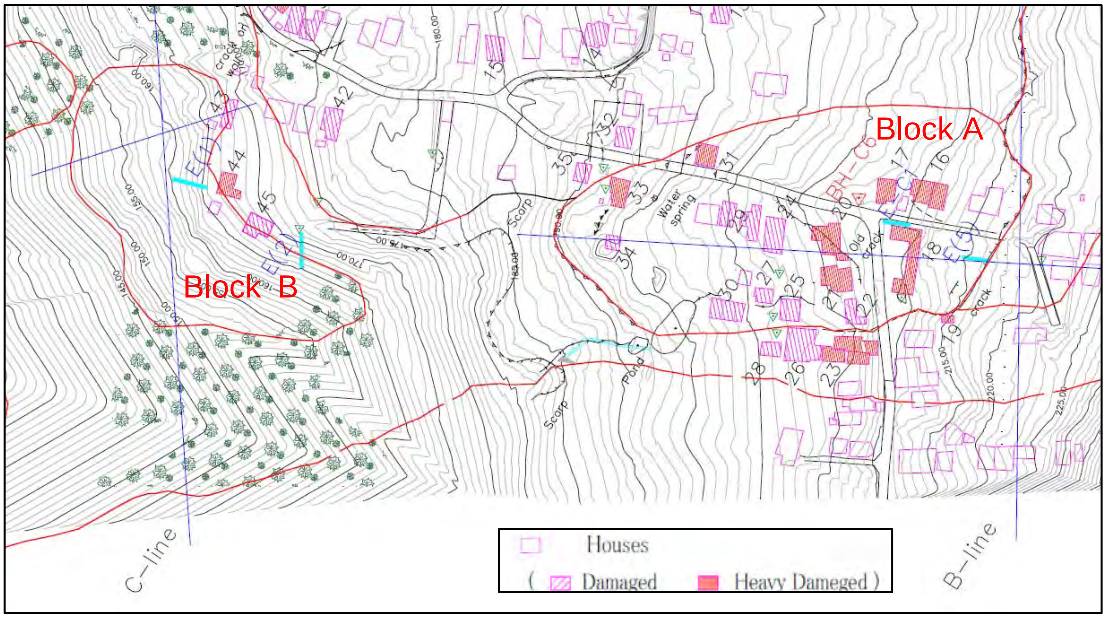


Figure 5.1.1 Location of the block A and B (source: JET)

a. Block A

There are 16 houses in and four (4) houses below the block A. The landslide would affect the total 20 houses at least.

According to the results of monitoring so far, the landslide movement is highly correlated with rainfall amount, and the landslide start to move over 120mm accumulative precipitation. That means that the disaster would happen in the rainy season (January to March).

In case that the landslide happens, cracks and tiling of buildings would be occurs at the 20 houses in/around the landslide. Active movement would be failures of buildings and falling of ceiling/second floor. The failure and falling could cause the local residents killing and injuring. Especially, there is a public elementary school in the landslide area, and the students in the school would be serious damages during a class. In addition, the landslide which runs down quickly due to abrupt increase of ground water level by torrential rainfall would enlarge the damage and loss.

Closure of the public road (approximately 500m) including a public bus line and severed infrastructure such as electric line, telecommunication line and water pipe etc. are affect the life in the area. It would take so long to recover the infrastructures. Closed river and drainage system by the landslide mass soil may trigger new additional landslides/slope failures in the area.

b. Block B

There are three (3) houses in and two (2) houses around the block B. The landslide would affect the total five (5) houses at least.

According to the results of monitoring so far, the movement is a slope failure by creep deformation, not a landslide. Intermittent movement on the surface has been observed even during no rainfall period. However the movement accelerates by rainfall. That means that the disaster would happen in the rainy season (January to March).

In case that the slope failure happens, cracks and tiling of buildings would be occurs at the five (5) houses in/around the landslide. Active movement would be failures of buildings and falling of ceiling/second floor. The failure and falling could cause the local residents killing and injuring. In addition, the slope failure which runs down quickly due to abrupt increase of ground water level by torrential rainfall would enlarge the damage and loss.

Closed river and drainage system by the slope failure mass soil may trigger new additional landslides/slope failures in the area.

5.2 Policy of Countermeasures

Countermeasure work plan was prepared for the three (3) landslide hazard areas which are defined by the landslide survey in this project (Chapter 3.1). Selection of countermeasure work was done based on the flow chart shown below. Landslide conditions were also considered such as topography, geology, sliding mechanism and impact of works on the environment of the surrounding area.

Target landslide blocks in the hazard areas to be considered under the countermeasure work plan were identified, and planned factor of safety (planned FoS) of each landslide block to be achieved through the countermeasure works were set.

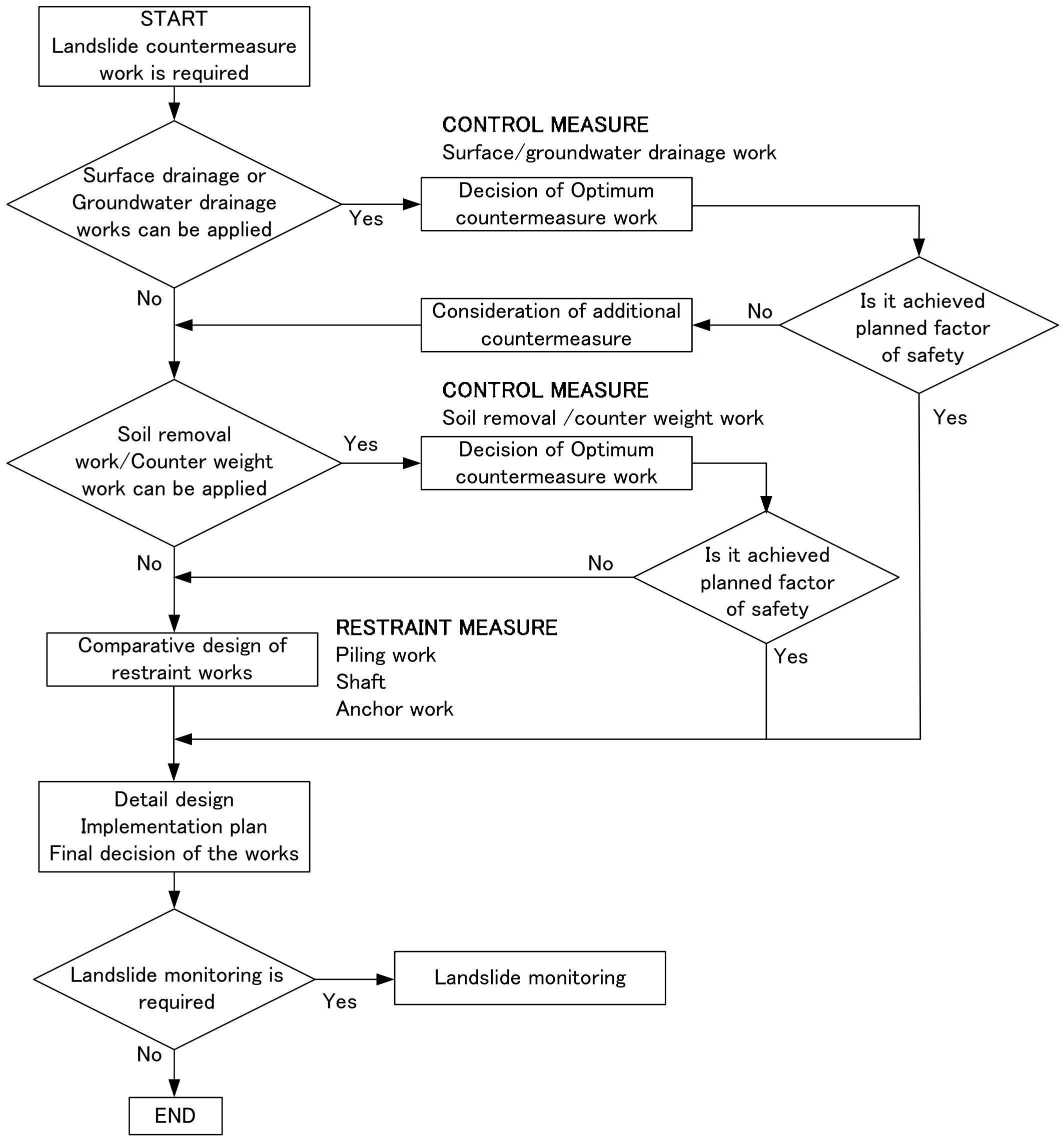


Figure 5.2.1 Flow Chart of Selection for Landside Countermeasure Work1

The following points were considered to select countermeasure works

- Since a large volume of water runs off the three landslide hazard areas in the rainy season, priority shall be given to the installation of drainage work.
- Countermeasure works which can be applied in Mauritius from a sustainable perspective.

- Easiness of maintenance of the facility after installation shall be considered.

- Since the countermeasure work is installed in the landslide hazard area, it shall be considered to avoid impacting the stability of surrounding slopes.

- It shall be considered to avoid impact to the environment of the area due to debris flows or erosion by discharged water.

5.2.1 Plan for Countermeasures Works in Chitrakoot

a. Target Landslide Block

In this project, structural countermeasure works will be conducted in the Chitrakoot area as a pilot project. One huge landslide block with a length of about 2 km and with several smaller landslide blocks within the huge landslide block are identified in the Chitrakoot area by site reconnaissance and interpretation of aerial photograph (refer to below figure).

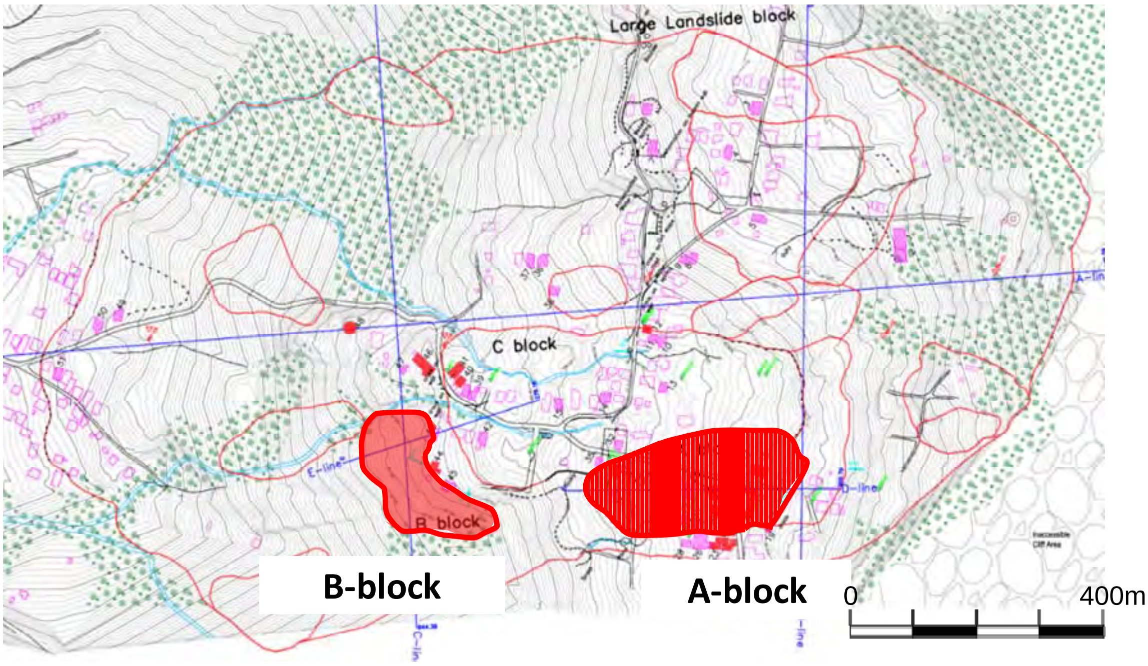


Figure 5.2.2 Target Landslide Blocks in Chitrakoot Area (source: JET)

As the result of detail investigation and monitoring, it was recognized that Block-A and Block-B landslides are active. On the other hand, movement of the other landslide blocks including the huge landslide block has not been found. Thus Block-A and Block -B were selected target landslide blocks to be applied countermeasure work in this project.

For the landslide blocks which are not target landslide block in Chitrakoot area, the detail investigation and countermeasure work shall be considered depending on the result of landslide monitoring or report of abnormality by inhabitants.

Table 5.2.1 Selection of Target Landslide Block in Chitrakoot Area (Source: JET)

Landslide block	Site observation	Monitoring	Activity	Result
Block-A	Many houses and road have been damaged by landslide in the block	Movement of the landslide was detected by extensometer and inclinometer in January to March 2013.	**Active**	**Target landslide**
Block-B	Damaged houses in the block.	Movement of the landslide was detected by extensometer in January to March 2013	**Active**	**Target landslide**
Other landslide blocks	There are houses which are damaged by not landslide activity but erosion or foundation problems	No deformation was detected in January to March 2013	Not active	Not target

b. Planned Factor of Safety

The planned factor of safety (hereinafter planned FoS) is to be achieved by conducting additional countermeasures to those that contributed to attaining the current factor of safety, which is defined in Chapter 4.3 above. The planned FoS can be set depending on importance of the target for protection. Since target for protection in Block A landslide is a residential area that includes a government school, the planned FoS of the Block A was set as **1.20**. Since target for protection in Block B is three houses, the planned FoS of the Block B also was set as **1.20**.

c. Basic Policy of the Landslide Countermeasure Works in Chitrakoot Area

c.1 Feature of landslide Block-A and Block-B in Chitrakoot area

Features of the target landslide Block-A and Block-B in Chitrakoot area are as follows. The countermeasure works shall be selected in consideration with the features.

- Since activity of these landslides has been detected in 2005, those landslides can be categorized as Re-activation type landslide.
- Since the landslide activity is detected in the rainy season only, it can be considered that rainfall and rising up of groundwater level is the main cause of landslide activation.
- Sudden rising up of groundwater level is occurred due to large volume of runoff water from mountain side in rain time.
- Since slip surfaces of the landslides exist at shallow depths, it can be considered that shallow groundwater influences gets involve landslide activity.

- The landslide blocks exist under the residential area.

c.2 Basic policy of countermeasure

The basic policy of countermeasure work was decided as follows based on the features of the target landslides mentioned above.

- Since the landslide blocks will reactivate due to rises in groundwater level, groundwater drainage work is the most effect countermeasure work.
- Drainage work shall be given priority to install to avoid rising groundwater level
- Drainage work with blind ditch shall be installed to collect shallow groundwater
- From sustainability point of view, countermeasure work which can be conducted through a technical transfer in Mauritius shall be selected.
- The selected countermeasure work shall be easy to maintenance after installation.
- The impact of countermeasure works on stability and environment of neighboring slopes shall be kept to a minimum
- Existing hydraulic environment shall not be impacted by discharged water from the drainages

The countermeasure works have been selected according to the basic policy mentioned above.

d. Consideration and Selection of Countermeasure Works

As a result of detailed investigations and monitoring, it can be considered that Block A and Block B landslides become active due to rising up of groundwater level. Thus, countermeasure for blocks A and B shall be selected control works to control groundwater level in the rainy season.

A factor of safety of 1.10 shall be secured by the control works.

Table 5.2.2 Selection of Control Work for Chitrakoot Area (source: JET)

Countermeasure Works			Technical Aspect	Workability by technology transfer	Maintenance aspect	Environment Impact	Applicability
Control Work	Surface Drainage work		The work is expected to control disturbance of the ground surface and rising of ground- water level by diverting runoff water in a rainy season. AA	Since the work is common civil work in Mauritius, there is substantial experience of the work, and it is workable. AA	Since the facility is simple structure, the maintenance of the facility is manageable in Mauritius. AA	It can be minimized the impact to living environment or neighbor slopes by arranging the work place adequately A	**AA** **Applicable**
	Groundwater drainage work	Open - Blind ditch	The work can be expected to control groundwater in shallow level, which rise up in a	Since the work is common civil work in Mauritius, there are engineers with substantial experience of such	Since the facility is simple structure, the maintenance of the facility is manageable in Mauritius.	Since the facility occupies small area on the ground, the impact to the environment by the work can be	**AA**

Countermeasure Works			Technical Aspect	Workability by technology transfer	Maintenance aspect	Environment Impact	Applicability
			rainy season. AA	work, and it is workable. AA	AA	minimize by arranging the work place adequately A	**Applicable**
		Horizontal drainage work	The work is expected to control a rising of groundwater level by discharging the groundwater directly AA	Even though there is no experience of the work in Mauritius, the work will be workable with technology transfer because there are machines available to do the work. A	The maintenance of the facility is manageable in Mauritius if the technology of the maintenance is transferred. A	Since the drainages are installed underground, the work will have a minimal impact on the environment. Arrangement of facility at outlet of the drainage shall be considered carefully. A	**A** **Applicable**
		Groundwater drainage well work	The work is expected to control groundwater level by discharging groundwater directly AA	The machinery and materials for the work is not available in Mauritius. It will be difficult to procure them and costly. B	There is no experience of the work in Mauritius and it will not manageable by short period of technology transfer. B	Since the facility is 5 to 10m on ground surface, positional arrangement of the facility shall be examined carefully. B	B Further examination
		Drainage tunnel work	Application of the work will be difficult because the target slope is gentle. C	The machinery and materials for the work is not available in Mauritius. It will be difficult to procure them and costly. Technology transfer of the work will be difficult for short period. B	There is no experience of the work in Mauritius and it will not manageable by short period of technology transfer. B	The scale of the work will be larger than other works. Therefore, it will be required consideration of environment impact by the work. B	C N/A
	Soil removal work		The work is to reduce sliding force by removing the head part of the landslide block. It can be expect the effect of the work for the landslide.. AA	Since the work is common civil work, it can be workable by technology transfer about the points of the implementation of work AA	The maintenance of the work will be manageable, if the treatment for collapse and erosion of the cut slope has been done. AA	The environment impact by the work will be significant due to large scale changes of topographical feature of the area. The work will not be applicable in the area due to the existence of an important facility, a government school C	C N/A

Countermeasure Works		Technical Aspect	Workability by technology transfer	Maintenance aspect	Environment Impact	Applicability
	Counter weight filling work	The work installed at toe part of the landslide is to increase resistance force against the sliding. It can be expected to be effective in mitigating landslides. AA	Since the work is common civil work, it can be workable by technology transfer about the points of the implementation of work AA	The maintenance of the work will be manageable, if the treatment for collapse, drainage and erosion of the cut slope have been done. AA	The environment impact of the work will be significant due to large scale changes to topographical features of the area. The work will not be applicable in the area because the area is residential area C	C N/A
Restraint Works	Ground anchor work	Since the target slope is gentle, the work will be difficult to apply effectively without large scale excavation for the work. C	The machinery and materials for the work is not available in Mauritius. It will be difficult to procure them and costly. Technology transfer of the work will be difficult for short period B	There is no experience of the work as landslide countermeasure work in Mauritius. Therefore, it will not be manageable in the short period of technology transfer B	Since the scale of the work will be large, it will be required consideration of environment impact by the work. B	C N/A
	Pile work	The work is expected to have a positive effect in mitigating landslide activity. Alignment of piles shall be considered carefully to secure an effect of the work against the material of the landside. A	The contractor of the work is limited in Mauritius. Therefore, the work will be costly. B	There is no experience of the work as landslide countermeasure work in Mauritius. Therefore, it will not be manageable in the short period of technology transfer B	Since the scale of the work will be large, it will be required consideration of environment impact by the work. B	B N/A

AA: Appropriate, A: Applicable, B, Applicable e depending on the situation, C, Not applicable

Table 5.2.3 Comparative Chart of Control Work Selection in Chitrakoot Area (source: JET)

Method	Block A		Block B	
	Condition/Applicability		Condition/Applicability	
Surface drainage work	Effect of the work can be expected for the stability, because large volume of water runs off in the area in a rainy season. Since ground feature shows gentle rolling and gentle slope, it is advantageous to implement the work. Existing drainage can be utilized to conduct the work.	○	Volume of inflow water to the block is small because the water catchment area behind the block is limited. However this method can be expected to effectively stabilize the block. Route of the drainage will be imposed by topographical features and positional relation between existing houses.	△
Groundwater drainage work	This method can be expected to effectively stabilize the block, because the monitoring data revealed that the groundwater level in the area rises up to near the ground surface. When the work is implemented, a pit shall be made to set the drainage point below the ground surface.	○	This method can be expected to effectively stabilize the block, because the groundwater level rises up in the rainy season. On the other hand, it will be difficult to secure work space and to access the site with heavy machinery because the area has steep slopes.	△
Soil removal work	Since many houses and a government school exist on the head part of the landslide block, it will be difficult to conduct this countermeasure.	×	Since several houses exist on the head part of the landslide block, it will be difficult to conduct this countermeasure.	×
Counter weight work	Since potential landslide blocks exist in the landslide hazard area and with landslide Block B being located directly below Block A, it will be difficult to conduct this countermeasure in the toe part of the landslide block.	×	Since potential landslide blocks exist in the landslide hazard area, it will be difficult to conduct this countermeasure in the toe part of the landslide block.	×

○: Applicable, △: Applicable in some cases, ×: Not applicable

Block A

It can be considered that large volumes of runoff water in the rainy season are one of the main causes of destabilization of the landslide block. Thus, surface drainage shall be installed not only on the landslide block, but on the upper slopes of Block A also. The surface drainage on the upper slopes shall be installed transversing against slope direction and with a large dimension to collect a large volume of runoff water from the mountain area. Since many water springs are found on the landslide block in the rainy season, it can be considered that a groundwater level exists at a shallow depth from the ground surface. Thus horizontal drainage and open-blind ditch also shall be applied.

Regarding to restraint works, there are no contractors with experience implementing ground anchor works as landslide countermeasures in Mauritius. Thus, pile work shall be considered as restraint works for the present. After implementation of the control works, effectiveness of the works shall be verified by stability analysis based on monitoring data. In case that the factor of safety after implementation of the control works does not achieve 1.10, restraint works shall be considered.

Planned countermeasure works
Control work: Groundwater drainage work (Horizontal drainage, Open-blind ditch)
Surface drainage work
Restraint work: Pile work

Block B
Regarding landslide countermeasure works in Block B, control work shall be given priority to halt or mitigate landslide activity. According to consideration of countermeasure works for Block B, surface drainage work and horizontal drainage work can be considered as applicable measures for the block. However, the location of those works will be particularly restricted by slope angle, topographical condition and environmental condition in Block B.

Regarding the restraint work, are no contractors with experience implementing ground anchor work as a landslide countermeasure in Mauritius. Thus, pile work shall be considered as restraint work for the present. After implementation of the control works, effectiveness of the works shall be verified by stability analysis based on monitoring data. In case that the factor of safety after implementation of the control works does not achieve 1.10, restraint works shall be considered.

Planned countermeasure works
Control work: Groundwater drainage work (Horizontal drainage, Open-blind ditch)
Surface drainage work
Restraint work: Pile work

e. Verification of Effectiveness of Planned Countermeasure Works

Block A

A factor of safety of 1.10 shall be secured by reducing the groundwater level in the landslide block by implementing control works. Planned reduction depth of groundwater level by the horizontal drainage work and open-blind ditch is -2m from High Water Level (H.W.L.)*[3]. According to the stability analysis based on the condition after implementation of the works, the factor of safety of Block A will be **1.13**.

The effectiveness of the works was verified by stability analysis using the modified Fellenius Method with calculation model, which was applied in the stability analysis for the current factor of safety (refer to Chapter 4.2). The parameters for the analysis were the same as those applied in the current factor of safety analysis. The results of the calculation are attached in the Supporting Report.

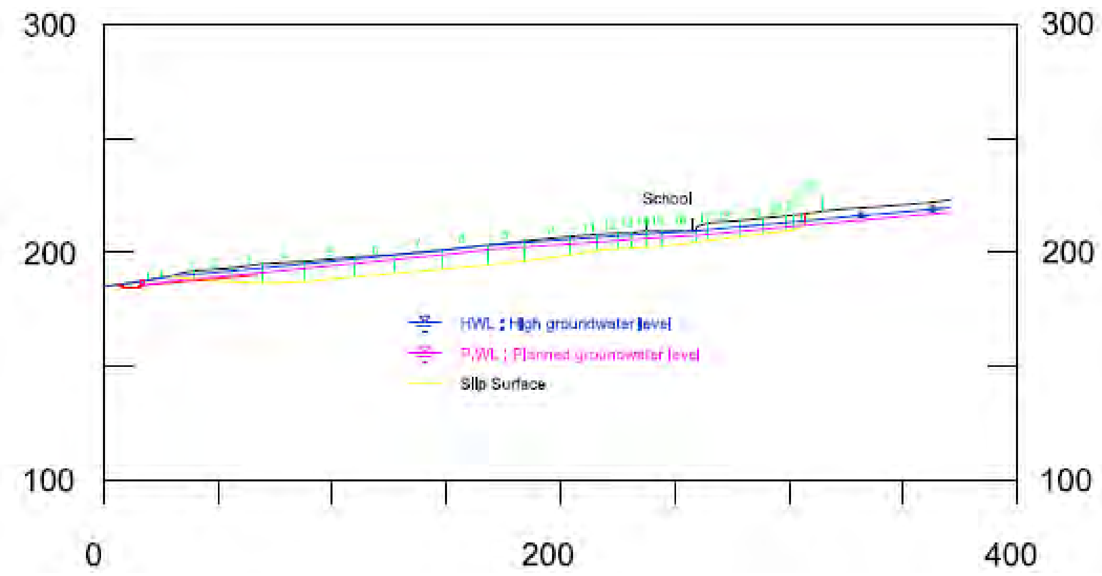


Figure 5.2.3 Calculation Model for Verification of Effectiveness of the Works -Block A in Chitrakoot Area (source: JET)

The effectiveness of the large scale channel which is planned to be installed in the upper slope of the Block A is difficult to be checked in the design phase. The effect of the channel work shall be verified by groundwater level monitoring after installation of the channel work.

Required prevention force for the pile work to achieve the planned FoS can be obtained by the following formula (Formula 5-1). This formula is derived from Formula 5-2 in which the required prevention force adds to the shear resistance force of Formula 5-1.

$$\Pr = PFs\sum W \cdot \sin\alpha - \sum\{c \cdot l + (W - u \cdot d)\cos\alpha \cdot \tan\phi\} \quad \text{------ (Formula 5-1)}$$

$$PFs = \frac{S}{T} = \frac{\sum\{c \cdot l + (W - U \cdot d)\cos\alpha \cdot \tan\phi\} + \Pr}{\sum W \cdot \sin\alpha} \quad \text{---------------- (Formula 5-2)}$$

where,

Pr: Required prevention force for pile per unit width
PFs: Planned factor of safety
γ_t : Unit weight
u : Pore water pressure
c': Cohesion (Shear strength of soil)
φ': Internal friction angle (Shear strength of soil)
α: Angle of the slip surface
W: Weight of the slice
d: Width of the slice

According to the conditions after installation of the control works, shear force: **T** is 3293.95kN/m^2, share resistant force: **S** is 3721.18kN/m^2 and planned FoS is 1.20 (refer to

Result of Calculation for verification of the effectiveness of the control works in Supporting Report).

Pr = 1.20 × 3293.95 - 3721.18 = 232

Therefore, required prevention force is **232** kN/m to achieve a planned FoS of 1.20 from 1.13.

Block B

A factor of safety of 1.10 shall be secured by reducing the groundwater level in the landslide block by implementing the same type of control works as in Block A. Planned reduction depth of groundwater level by the horizontal drainage work and open-blind ditch is -2m from High Water Level (H.W.L.)*[3]. According to the stability analysis based on the condition after installation of the works, the factor of safety of Block A will be **1.17**.

The effectiveness of the works was verified by stability analysis using the modified Fellenius Method with calculation model, which was applied in the stability analysis for the current factor of safety (refer to Chapter 4.2). The parameters for the analysis were the same as those applied in the current factor of safety analysis.. The results of the calculation are attached in Supporting Report.

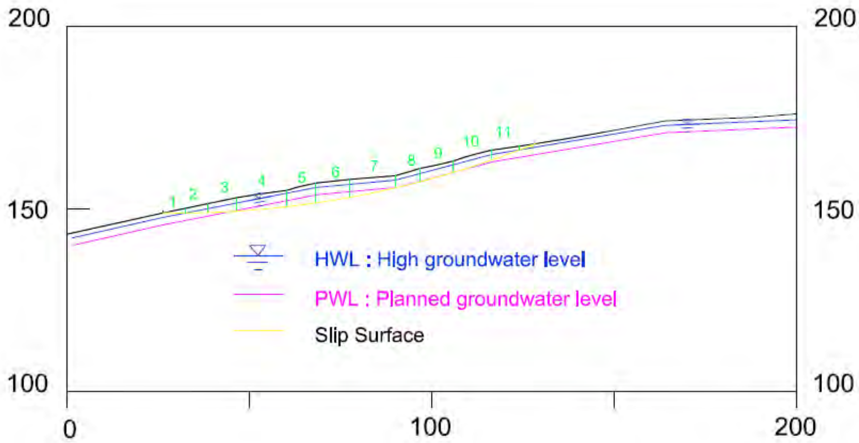


Figure 5.2.4 Calculation Model for Verification of Effectiveness of the Works in Block B in Chitrakoot Area (source: JET)

For the calculation, effectiveness of countermeasure works of Block A is not considered even though these works can be expected to reduce the groundwater level in Block B also. The effect of the works of Block A can be verified by groundwater level monitoring after installation of the works.

Required prevention force for the pile work to achieve the planned FoS can be obtained by the following formula (Formula 5-1). This formula is derived from Formula 5-2 in which the required prevention force adds to the shear resistance force of Formula 5-1.

According to the conditions after installation of the control works, shear force: **T** is 1058.91 kN/m^2, share resistant force: **S** is 1244.09 kN/m^2 and planned FoS is 1.20 (refer to Result of Calculation for verification of the effectiveness of the control works in Supporting Report).

Pr = 1.20 × 1058.91 - 1244.09 = 27

Therefore, required prevention force is 27 kN/m to achieve a planned FoS of 1.20 from 1.17.

Conditions and results of the calculation of blocks A and B are shown in the table below.

Table 5.2.4 Result of Consideration of Effectiveness of Countermeasure Works (source: JET)

Landslide Block	Current Factor of Safety	Planned Factor of Safety	Unit weight [kN/m^3]	Cohesion {kN/m^2]	Internal friction angle [degree]	Required prevention force [kN/m]
Block A	0.98	1.20	18	5	5.37	232
Block B	0.98	1.20	18	5	7.67	27

f. Plan of Countermeasure Works

As a result of selection and consideration of countermeasure work described above, control works shall be arranged as follows,

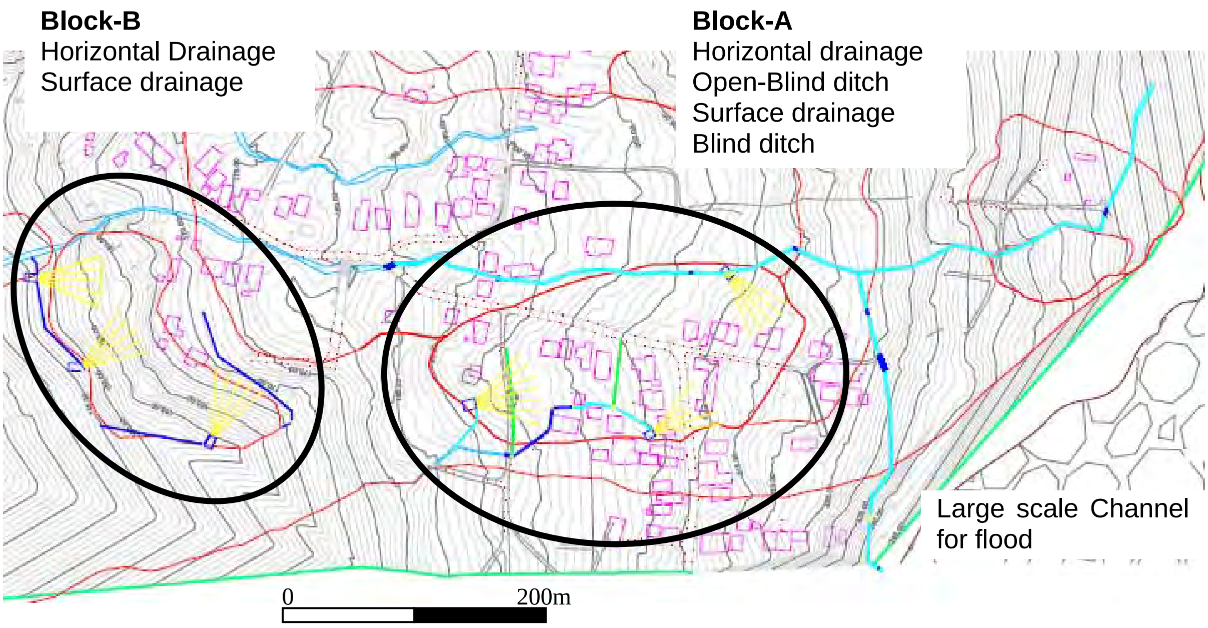


Figure 5.2.5 Plan of Countermeasure Works in Chitrakoot Area (source: JET)

Large scale channels for flood water shall be installed in transverse direction on upper slope of Block A. The channel is installed to collect and divert runoff water from the mountainous slope behind Block A and to mitigate inflow water and rising groundwater level in blocks A and B. The routes of the channels are arranged to be near the boundary of the upper steep slope and the lower gentle slope. Rock falls and debris flows into the channel from the upper slope shall be taken into consideration when conducting this work.

Channel alignment shall be decided in consideration of the following conditions.

・ Place with a minimum volume of excavation work.

- Impact for stability of back slope of the channel by large volume of excavation work for the channel construction.
- Water discharge capacity of existing drainage which will be connected with the channel.

Bridges shall be installed at crossing points of the channel and existing farm roads.

Horizontal drainage work shall be applied to draw down the groundwater level in Block A. The work is installed at three (3) locations around Block A. Installation points were selected at places which have a topographical gap in which to install the drainage pipe at a lower level than the ground surface.

Since it has been realized that the groundwater level rises up near the ground surface in the rainy season, open-blind ditches shall be installed to collect and discharge shallow groundwater. The ditches shall be arranged in transverse direction in the middle part of the landslide block. The ditches are also expected to collect runoff water in the landslide block.

Surface drainage shall be installed to properly collect and discharge the water collected by horizontal drainage and open-blind ditches out of the landslide block. The drainage shall be arranged in longitudinal direction against slope direction. Basically, the drainage alignment shall be in line with the existing drainage in this area to minimize any impact to houses and cultivated land by the work.

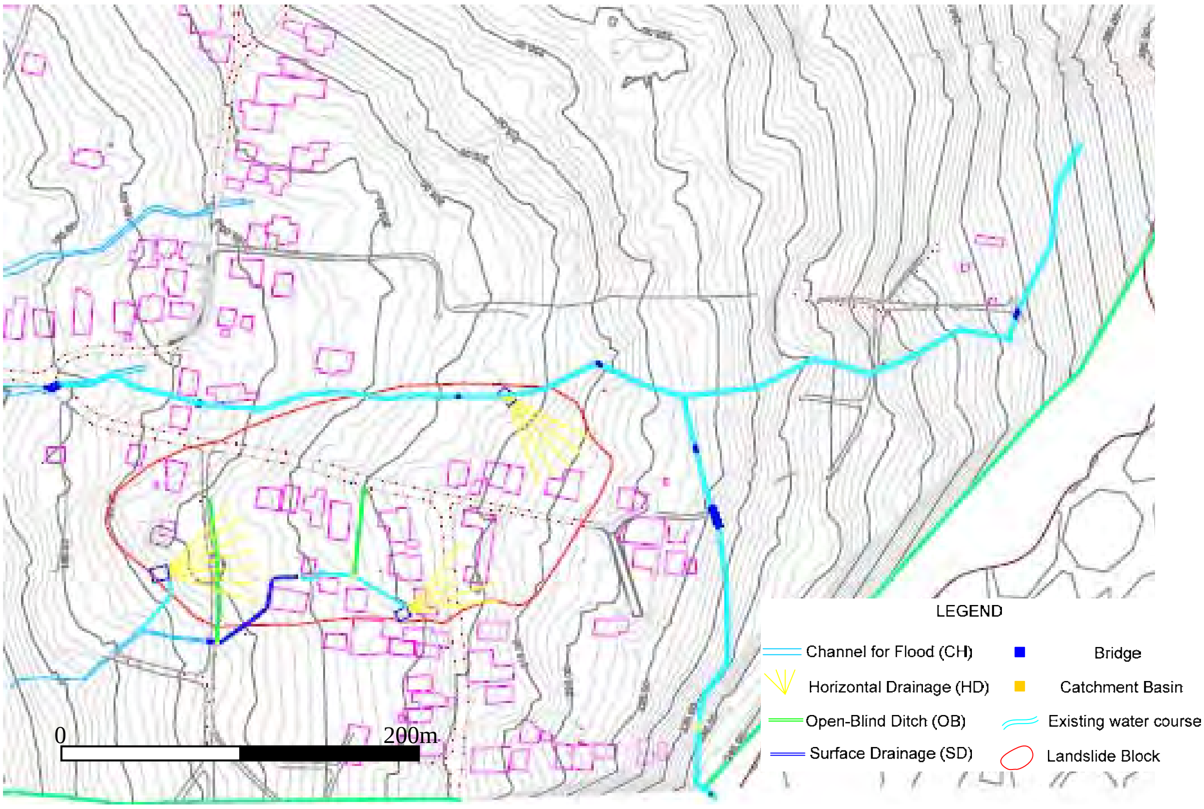


Figure 5.2.6 Plan of Countermeasure Works in Block A (source: JET)

Surface drainage shall be installed to avoid runoff water from upper slope flow into Block B. The water from the drainage shall not be discharged to the existing river to the east (upper part of the following figure), but to the valley in the west (lower part of the following figure) because of topographical restrictions.

Horizontal drainage shall be installed on three (3) points in the toe part of the landslide block to reduce the groundwater level in Block B.

When planning the implementation of the restraint work topographical restrictions shall be taken into consideration.

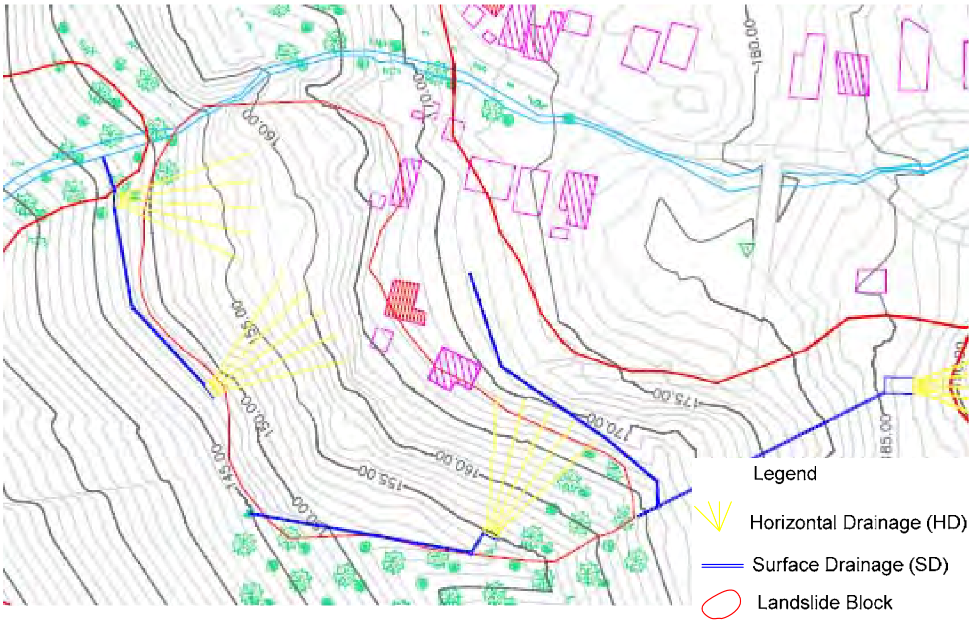


Figure 5.2.7 Plan of Countermeasure Works in Block B (source: JET)

Planning of restraint work shall be done after confirmation of effectiveness of the control works by monitoring data after implementation of the works.

5.2.2 Emergency Works in Vallee Pitot

During/after rainy season in 2013 (March - May in 2013), a soil mass slid from the mountain area and was stacked by a drainage canal in the Vallee Pitot area. The soil mass has destroyed the canal over the length of some 20 meters and totally blocked the water flow therein.

Photo 5.2.1 Upper Side of the Blockage of the Canal

Photo 5.2.2 Lower Side of the Blockage of the Canal

Photo 5.2.3 Seen below the Blockage

No much difference from previous can be seen.

Photo 5.2.4 Seen above the Blockage

No deformation can be seen.

a. Current Conditions

Landslide in the area is divided into five small landslides (A, B, C, D, E) in the following figures. Out of them, the landslide A, B and C are along the current canal. The bottom part of the landslide A (A-1) has been move downward from the rainy season in 2013 and filled up the canal. The A-1 is approximately 10m length * 20m width, and the estimated depth is a few meters. The debris which clogs the canal is 20m along the canal.

As shown in the following figure, the dip of the canal at the Vallee Pitot area inverts at the point of about 100m from the clogged debris. Therefore the catchment area is this 100m zone.

b. Issues

As mentioned in the previous section, the landslide movement has been active in Vallee Pitot since February 2013 so that the bottom of the canal in the area has been buried with sediment from the landslide. The problems and issues in the area are as follows:

- During the next rainy season (January - March 2014), rainfall water will overflow from the blocked canal with landslide debris and will flood lower parts of Vallee Pitot.
- If the rainwater is allowed to overflow in an uncontrolled manner, there is a high risk of provoking soil mass slides

As shown in “Figure 5.2.3 Longitudinal condition of the canal”, the water in the canal flows from south to north at Vallee Pitot, however at about 100m upper stream, the gradient of the canal is changed toward to south. Therefore, volume of the water flowing in the canal at Vallee Pitot is the total volume of rain water and sewerage water which are flowing into this 100m length of the canal. This canal may be expected as a role of gutter in this area.

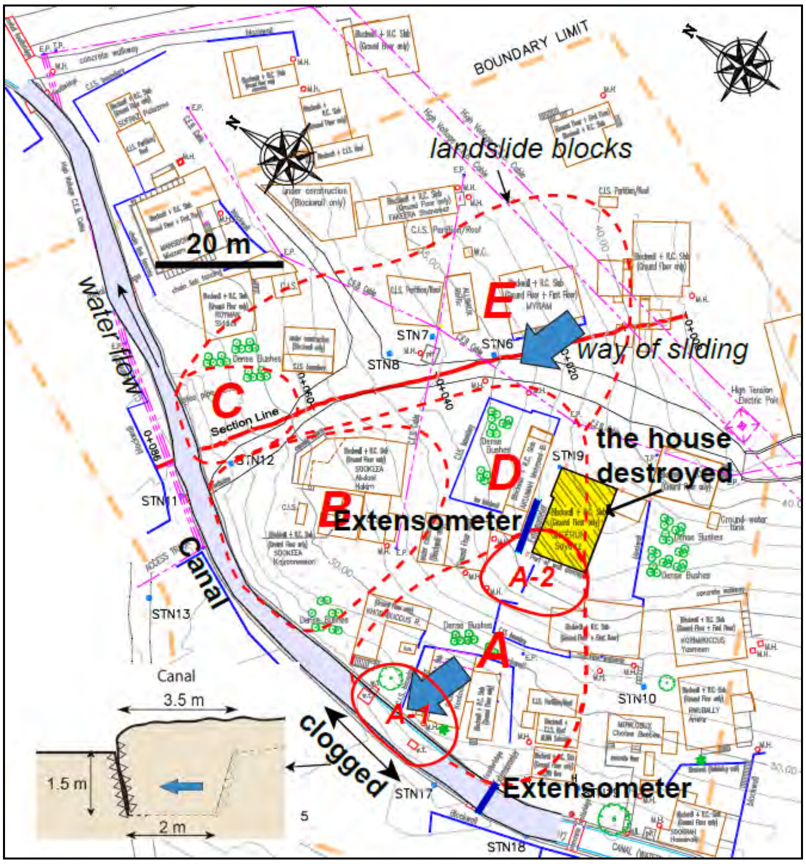


Figure 5.2.8 Location Map with Houses of the Landslides (source: JET)

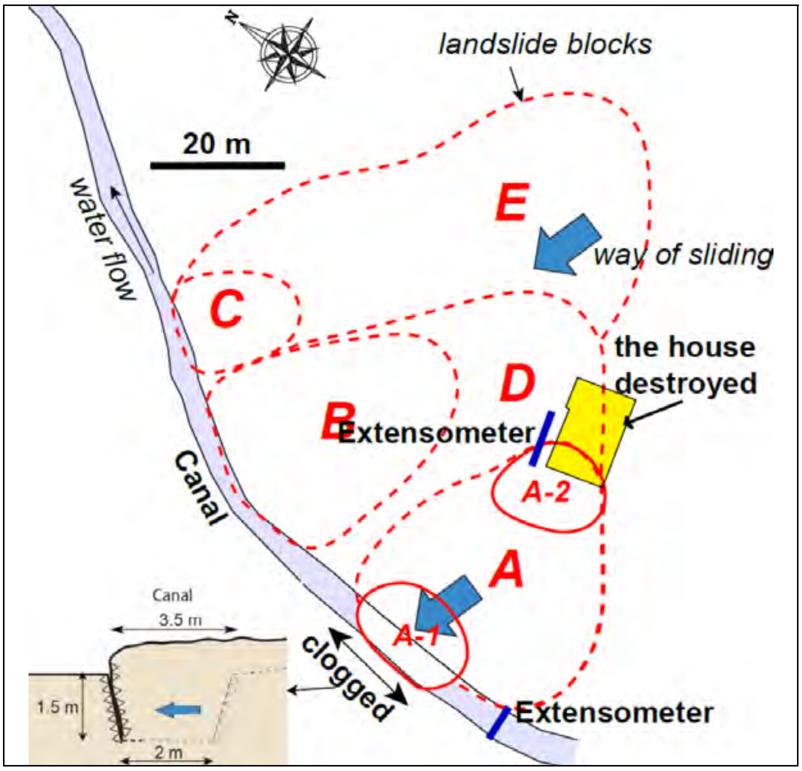


Figure 5.2.9 Location Map of the Landslides (source: JET)

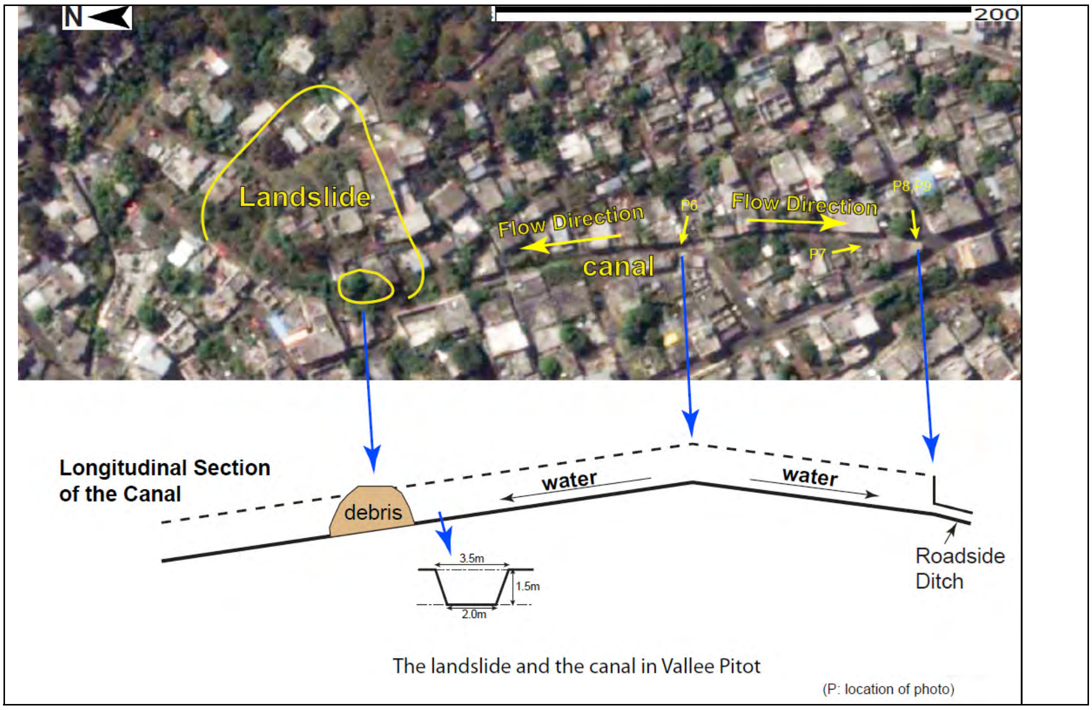


Figure 5.2.10 Longitudinal Condition of the Canal (source: JET)

c. Proposed Countermeasures

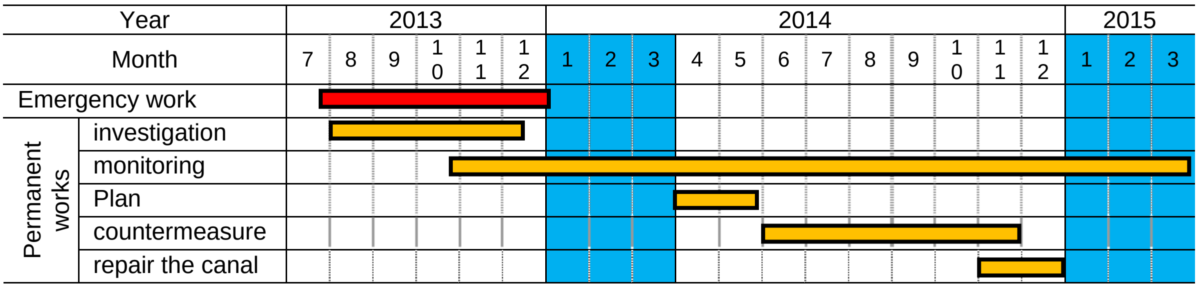
For prevention of floods and subsequent potential landslides, countermeasures should be implemented. The countermeasures in this area are divided into two (2) types as follows;

1) Emergency works for the flood problem: the emergency works must be implemented immediately and completed prior to the next rainy season (January –March 2014) and also should always remain functional until the completion of permanent countermeasure works.

2) Permanent works for the flood problem and the landslide problem: the permanent works should be conducted after detailed investigations (drilling survey/monitoring/analysis/plan) of countermeasures. The canal should be repaired after the countermeasures have been constructed and the site has been stabilized. The countermeasures may include permanent relocation of some local residents probably in the area denoted as a most active “Landslide A”.

The proposed schedule for the countermeasures is as follows.

Table 5.2.5 Proposed Schedule for the Countermeasures (source: JET)



c.1 Emergency works

The emergency works taken in the area have the following alternative options;

Proposal (1) Modification of the canal gradient (Reversal of the canal gradient): the method that the water flows away to the opposite side by filling and cutting partially in the canal

Proposal (2) Provision of sheet piles in the canal to retain the soil mass: the method of installing steel sheet piles on both sides of the canal to protect against soil mass failures and the excavation of debris from the canal to keep the water flow.

Proposal (3) Provision of a pump to lift up water: the method that the accumulated water is lifted up with an electrical pump and pumped out to the other side of the debris.

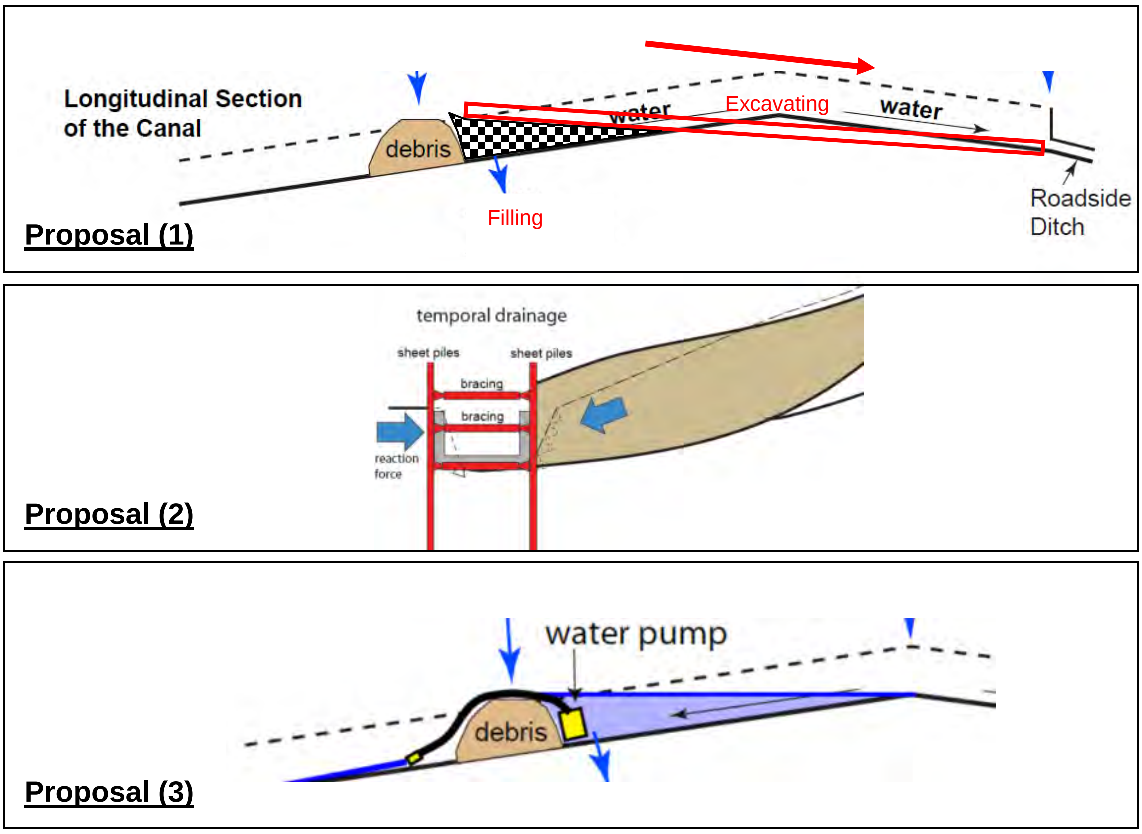


Figure 5.2.11 Proposed Emergency Works (source: JET)

Based on the discussions on the workability/effectiveness/economic efficiency with JET and MPI out of these possible alternative solutions, Proposal (1) "Modification of the canal gradient" is more realistic and suitable as emergency works.

However, cutting and filling must be undertaken with the construction in case of the modification of the canal gradient. Cutting and filling in landslide area may cause landslide movement so prudent construction is needed as follows:

- Cutting and filling shall be minimized.
- Drains shall always be functional during the construction.
- Construction shall be implemented on a span by span basis (continuous excavation may trigger landslide, so that the excavation shall be conducted on sections of a few meters at a time).
- Counterweights such as sand bags shall be utilized during excavation of the canal to prevent triggering landslides.

Figure 5.2.12 Sand Bags as Counterweights as a Landslide Countermeasure (source: JET)

MPI has completed the topographic survey in the area and is conducting the cutting and filling in the canal at present.

c.2 Permanent works

Detailed investigation and continuous monitoring is indispensable for planning of the permanent countermeasures. The flow of permanent works in the area is as follows;

1) Detailed investigation
2) Monitoring
3) Analysis
4) Planning of countermeasures
5) Construction of countermeasures
6) Repair of the canal

MPI is currently conducting the detailed investigation and the monitoring. Points to be considered for the permanent works are as follows;

- Geotechnical investigation for the installation of monitoring devices shall be completed before the rainy season in 2014 to get the monitoring data of the rainy season.
- Monitoring shall be started before the rainy season in 2014 and last until rainy season in 2015 to confirm the effectiveness of the countermeasures.
- Permanent countermeasures envisaged shall consist of surface and subsurface drainage works.
- Construction of countermeasures and the repairs of the canal shall be implemented in the dry season in 2014.
- The areas denoted as a most active "Landslide A" are sliding. It is strongly recommended to evacuate these areas permanently and to prohibit future residential development in the areas.

5.2.3 Relocation in Quatre Soeurs

The following table shows the background and progress of the relocation of the inhabitants of Quatre Soeurs according to the interview survey from MPI and MHL.

Table 5.2.6 Background and Progress of the Relocation of the Inhabitants of Quatre Soeurs (source: JET)

Date	Content
Mar 2005	・ Inhabitants of Quatre Soeurs informed the landslide disaster damage to MPI. ・ MPI conducted the site survey based on the information above.
Nov 2010	・ MPI conducted the detailed survey by a consulting company. ・ The relocation of the inhabitants of Quatre Soeurs was proposed as a countermeasure in the report of the detailed survey ・ In the response of the proposal in the report above, the government has started the negotiation for relocation with the inhabitants.
Dec 2010	・ Ministry of Finance and Economic Development (MoFED) tried to evaluate the asset of the inhabitant's lands/buildings based on the survey by MHL and MPI. However, they could not obtain the results evaluation due to it is difficult to evaluate them.
Mar–May 2011	・ The government side and inhabitants have visited two times the relocation candidate site. ・ The government could not gain consensus about the relocation.
Dec 2011	・ MHL proposed the "Camp Ithier", residential development in progress, where has been developed by National Housing Development Company (NHDC) as a candidate site of relocation. ・ The government could not gain consensus due to the difference between government's proposal and inhabitant's request regarding the area of site and buildings. ・ NHDC proposed a standard type of house which has one kitchen and two bedrooms. ・ The inhabitants have been lived in a house which has the same or more rooms/equipment/parking spaces than the NHDC's proposal. Therefore the inhabitants require the same size or larger size than their existing residential.
Jul-Sep 2012	・ The government side (MPI, MHL and Local Authority) proposed houses/lands wider than the previous meeting (candidate site of relocation: Camp Ithier). ・ The government could not gain consensus due to the difference between government's proposal and inhabitant's request.

Feb 2013	・ Deputy Prime Minister, MPI, MHL, Ministry of Education and Human Resources, Ministry of Foreign Affairs and the inhabitants (10 households) had a meeting in the Deputy Prime Minister's Office of Port Louis. ・ The government side proposed a land (460㎡) and one-story house (total floor area: 110㎡) in Camp Ithier as a compensation. ・ Nine out of ten households agreed to the proposal above.
Mar 2013	・ The negotiation is continued for one household who did not agree to the government's last proposal. ・ The government side has collected detailed request of one-story house floor plans, equipment, etc. from the inhabitants who agreed with the government's last proposal with the accompany of Building Department Staff of MPI.
May 2013	・ The government side and the inhabitants carried out a meeting in Camp Ithier. ・ The house and site drawings were shown to the inhabitants. ・ Several inhabitants signed the agreement. However, two inhabitants did not sign the agreement (because the plot land area is smaller than their existing residential). ・ The agreement of relocation has only basic outline and it does not have detailed information such as compensation payment/contents, etc. ・ The location of the plot lands was discussed with the government side with the inhabitants (location between houses and roads, kindergartens, parks, public facilities, etc.)

In addition to the above, the related information regarding the relocation is shown as below.

- Twenty or more meetings were held on inside the government and ten or more meetings with the government side and the inhabitants were carried out aside from the above table's record.
- The precondition for the negotiation by the government: the government side would like to relocate all the inhabitants (not to relocate individually or separately.
- The basic policy of the negotiation by the government: the government will not compensate by money (because there is possibility that the inhabitants might continue to live in the same landslide risk area after the payment of the compensation).
- The land of the landslide risk area in Quatre Soeurs is owned by the government. The inhabitants have borrowed the land from the government by a contract.
- If the government obtains the agreement with all the inhabitants: the inhabitants will be signed to the agreement of the relocation and termination of the land lease.
- About two years is estimated to complete the relocation of the inhabitants hence the candidate site of relocation Camp Ithier is under construction.
- The structural and non-structural countermeasure (early warning, evacuation, etc.) will be needed.
- Criteria of compensation for relocation: there is no legal scheme/framework which stipulates the designation of the area/household for the relocation, procedure of the compensation, financing, alternative sites/houses, etc.

5.3 Environmental Impact Assessment (EIA)

5.3.1 Procedure of Environmental Impact Assessment

In Mauritius, since the enforcement of the Environmental Protection Act 2002 as the basic law in 2002, environmental and social considerations are implemented on a full-fledged basis, and various laws have been enacted based on this basic law. On the other hand, Environmental Impact Assessment (EIA) is an important management tool for environmental management. The environmental impact assessment system in Mauritius has been stipulated by the Government Notices regarding Part IV of the Environment Protection Act. Previously, almost all the projects were managed under EIA. Since 2002, however, project types have been classified to determine which need the Environmental Impact Assessment (EIA) and which need the Preliminary Environmental Report (PER).

Table 5.5.1 shows the projects that need EIA and PER. To start a project not included in this list, the project operator first consults the district government, which in turn refers to the Ministry of Environment and Sustainable Development, which then determines the level of necessary environmental impact assessment. Whereas a large-scale government project needs either EIA or PER, no Environmental Impact Assessment may be needed from the viewpoint of importance or urgency. Although an EIA procedure generally requires three to four months, a public project is approved in a shorter period of time.

Table 5.3.1 Undertaking Requiring PER and EIA[2]

Undertaking requiring an PER（Preliminary Environmental Report）	Undertaking requiring an EIA (Environmental Impact Assessment)
1. Construction of helipads	1. Asphalt plant
2. Coral crushing and processing	2. Assembly of motor vehicles
3. Creation of bathing areas by mechanical means	3. Block making plant manufacturing above 10,000 blocks per day
4. Depot for 50 buses or more	4. Bulk processing, storage and handling or petroleum products, liquefied gas, coal and petro-chemical products
5. *Discotheque and night clubs	
6. Food processing industry excluding small and medium enterprises	5. Clinic and hospital, including animal hospital
7. Foundry, smelting plant or metallurgical work	6. Construction of airports and runways
8. Galvanizing industry	7. Construction of breakwaters, groins, jetties, revetements and seawalls
9. Industrial-scale laundry and dry-cleaning within 1 kilometre of high water mark	8. Construction of dams and dykes
10. Land reclamation and backfilling	9. Construction of marinas
11. Manufacture of animal feed	10. Conversion of forest land to any other land use
12. Manufacture of ceramics	11. Creation of, and/or development on, barachois
13. Manufacture of paint, pigment and varnish	12. Desalination plant
14. Manufacture of photographic films	13. Distillery
15. Manufacture of plastics and plastic	

products	14. Dye house
16. Manufacture of rubber products	15. Fishing port
17. Mechanical removal of marine flora such as sea grasses and marine algae	16. Golf course
18. Parceling out of land above 5 hectares for agricultural purposes, where the parceling involves infrastructure work	17. Harbour dredging operation, construction and development
19. Quarantine station for livestock	18. Highway and mass transit system
20. Ready-mix concrete plant	19. Hotel and Integrated Resort Scheme, including extension with first boundary within 1 kilometer from high water mark
21. Rearing of livestock including cattle, goat, pig and sheep	20. Housing project and apartments above 50 units within 1 kilometer from high water mark
22. Rearing of poultry above 5000 heads	21. Incineration of municipal solid waste, quarantine waste, medical and clinical wastes
23. Recycling plant	22. Industrial manufacture of beer, wine and spirit
24. Rendering plant	23. Lagoon dredging and reprofiling of sea beds
25. Sawmill	24. Land clearing and development, including installation of high tension lines in environmentally sensitive areas such as water catchment areas, waterlogged areas, wetlands, mountain slopes and islets
26. Slaughter House	25. Landfill
27. Textile industry associated with washing, bleaching and printing	26. Manufacture of batteries
28. Timber treatment plant	27. Manufacture of dangerous chemicals, chemical fertilizers and pesticides
	28. Manufacture of lime
	29. Manufacture and packing of cement
	30. Manufacture of pharmaceutical product
	31. Modification of existing coastline such as beach reprofiling, coastal protection works and removal of basaltic and beach work
	32. Municipal water treatment plant
	33. Offshore sand mining
	34. Parceling out of land above 5 hectares

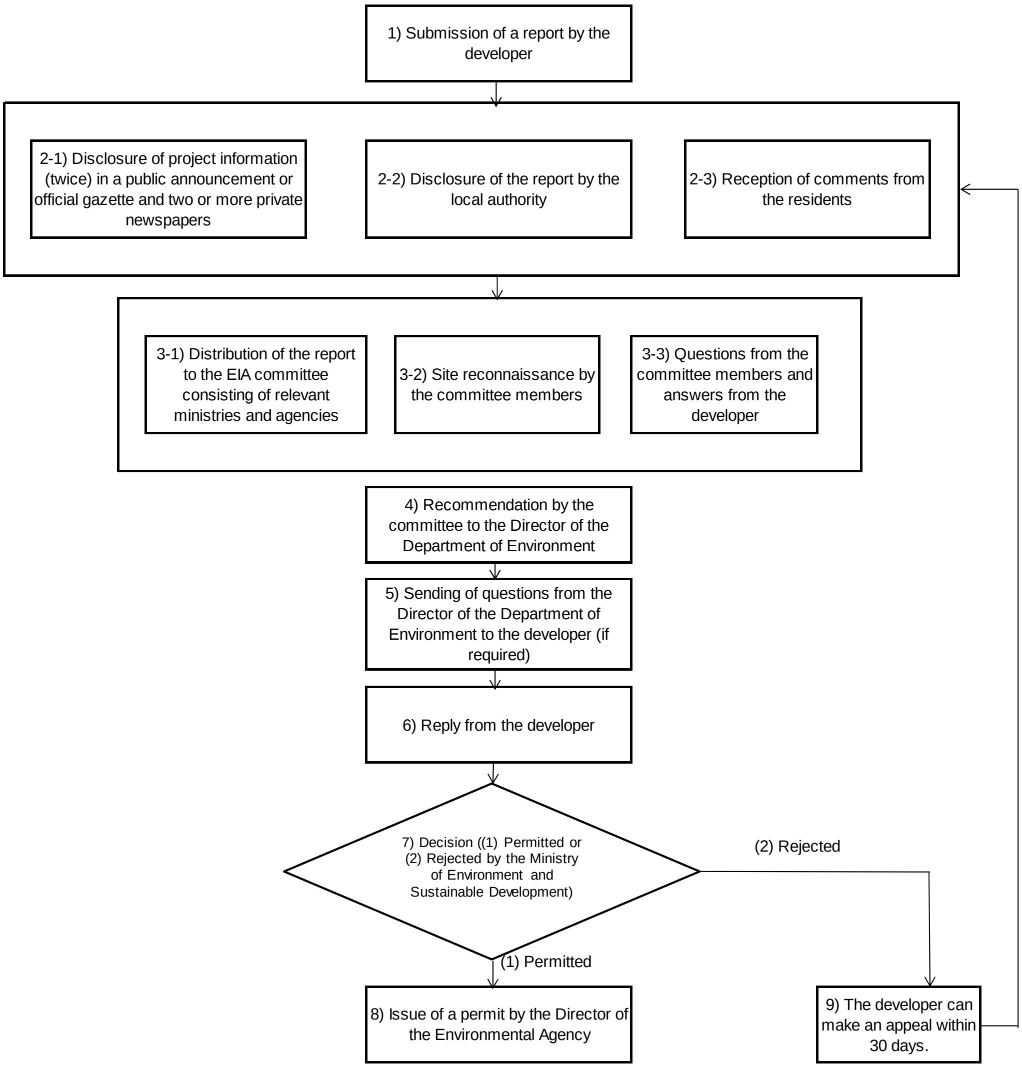


Figure 5.3.1 Procedure of EIA Survey[3]

5.3.2 EIA Related to Pilot Project

As shown in Table 5.5.1 above, this pilot project falls under one of the project categories that require EIA survey, No. 24, “Land clearing and development, including installation of high tension lines in environmentally sensitive areas such as water catchment areas, waterlogged areas, wetlands, mountain slopes and islets.” Therefore, an EIA survey must be conducted.

Additionally, the project implementing body for the EIA survey is the JICA Study Team. Therefore, the project is promoted according to the JICA guidelines as a policy but care was taken to meet the requirements for the EIA survey by Mauritius. The EIA survey started in mid-September 2013 and, at present, mainly the collection and analysis of existing data are being promoted.

5.3.3 Main Environmental and Social Impacts and Mitigation Measures

At present, the Study Team is creating an environmental checklist and examining possible mitigation measures based on the JICA Guidelines for Environmental and Social Considerations. This section describes the main environmental and social impact items expected for the implementation of the pilot project, degrees of these impacts, and proposals of mitigation measures, which are summarized in the table below. The environmental checklist (proposal) as of this moment is provided at the end of this document.

Table 5.3.2 Expected Environmental and Social Consideration and Impact Items and Mitigation Measures (source: JET)

Category	Environmental Item	Assessment	Expected environmental causes and mitigation measures
Pollution Control	Air Quality	C	Exhaust gas from construction machinery during construction Use well maintained heavy machinery
	Water Quality	B	Turbid water from embankment or excavated ground during construction Install stockpiles and silt traps.
	Waste	B	Solid waste, used oil, etc. generated in construction Establish a management plan for waste during construction or carry it to a waste disposal and treatment facility.
	Noise and Vibration	C	Noise and vibration from construction machinery during construction Use noise-controlled construction machinery.
Natural Environment	Ecosystem	C	Obstruction of wildlife movements by construction of surface drainage ditches Install covers in some areas because wildlife movements may be influenced a little in the rainy season.
	Hydrology	C	Although the groundwater level and surface water flow may be changed from now, measures against landslides are required.
	Topography and Geology	B	Soil erosion from excavated ground or embankment during rainfall Provide proper seepage control or dispose of surplus soil properly.
Social Considerations	Resettlement	C	There is no problem of resettlement. Land negotiations are conducted on the responsibility of MPI.
	Living and Livelihood	B	Traffic hindrance by the construction vehicles during construction The contractor conducts traffic control during construction.
	Heritage	C	No problems in particular
	Landscape	C	Take care so that the surface drainage ditches harmonize with the mountain area.

Note: A: Serious impact is expected.
B: Some impact is expected.
C: Unknown (Must be examined.)
D: Little impact is expected. (Not covered by FA/EIA)

5.4 Pilot Project Evaluation

As part of the F/S, a pilot project evaluation has been conducted in the Project. The pilot project on landslide countermeasures is evaluated before/during/after its implementation on technical, economic and social aspects. A simple check-sheet is prepared to check the relevance, effectiveness, efficiency, impact and sustainability and to organize lessons learned and points for improvement.

The following is a general sheet of the pilot project on landslide countermeasures in Chitrakoot.

Table 5.4.1 General Sheet of the Pilot Project (source: JET)

<table>
<tr><td>Name of Project</td><td>Landslide countermeasure construction in Chitrakoot in 2014</td></tr>
<tr><td>Name of Landslide</td><td>Landslides, Chitrakoot, Port Louis</td></tr>
<tr><td colspan="2">Current status</td></tr>
<tr><td colspan="2">A huge landslide was triggered by a hurricane in 2005 (maximum accumulated precipitation: 520mm) and destroyed 54 houses and an elementary school. The landslide was again triggered by a subsequent hurricane in 2008 (maximum accumulated precipitation: 244mm). Although the entire landslide has been stabilized from the results of the drilling survey and monitoring in the Project, small landslide blocks (Block A and Block B) are activated with a few to a dozen millimeters movement in the rainy season. Block A is a landslide which is around 250m long * 100m wide * 6m deep. Block B is a slope failure (creep?) which is around 100m long * 150m wide. More than 120mm of accumulated precipitation is considered enough to trigger both blocks.
It is considered likely that landslides have occurred in the past because the area is characterized by topography indicative of landslides.</td></tr>
<tr><td colspan="2">Targets to be protected</td></tr>
<tr><td colspan="2">・ Houses: 25 (20 houses around Block A and 5 houses around Block B)
・ Chitrakoot elementary school
・ Public road: approx. 500m (including the public bus line of approx. 250m)
・ Water supply and sewerage systems/power lines/telephone lines: approx. 900m</td></tr>
<tr><td colspan="2">Purpose</td></tr>
<tr><td colspan="2">・To stabilize the landslide movement by avoiding excessive supply of surface and subsurface water with heavy rainfall.</td></tr>
<tr><td colspan="2">Countermeasures</td></tr>
<tr><td colspan="2">[Section 1] Channel: 620m, Horizontal drilling: 1set, Surface drainage: 45m, Open-blind ditch: 46m
[Section 2] Horizontal drilling: 2 sets, Surface drainage: 75m, Open-blind ditch: 120m
[Section 3] Horizontal drilling: 3 sets, Surface drainage: 300m</td></tr>
<tr><td>Term of works</td><td>July 2014 – December 2014 (section 1, 2), 2015 (Section 3)</td></tr>
<tr><td>Total cost</td><td>29,500,400 Rs</td></tr>
</table>

5.4.1 Pre Evaluation

The pre evaluation is to confirm the necessity and benefit of the project with five (5) items (relevance, effectiveness, efficiency, impact and sustainability) based on the DAC (Development Assistance Committee) criteria. It is important that the purpose of the evaluation should be set by a quantitative index and that the evaluation plan in future should be clear. The purpose and the check points of the pilot project in the Project and the check sheet in the pre evaluation are indicated as follows;

Purpose: To confirm the necessity and benefit of the project based on the project plan.

Check points: Evaluation of the validity of the plan by checking the necessity, relevance, purpose, contents, benefits (effectiveness), external factors and risks of the project.

Table 5.4.2 Check Sheet of Pre Evaluation in the Pilot Project (source: JET)

<table>
<tr><th colspan="4">Relevance</th></tr>
<tr><td colspan="2">Consistency with policy/guidelines</td><td colspan="2">High 1☐ 2■ 3☐ 4☐ Low</td></tr>
<tr><td colspan="2">Existence of laws and ordinances on slope disasters</td><td colspan="2">Yes ■ No ☐</td></tr>
<tr><td colspan="2">Existence of regulation of land use (landslide hazard area)</td><td colspan="2">Yes ■ No ☐</td></tr>
<tr><td colspan="2">Existence of important public structures</td><td colspan="2">Many ☐ Some ■ No ☐</td></tr>
<tr><td colspan="2">Needs from implementation organization (MPI)</td><td colspan="2">High 1■ 2☐ 3☐ 4☐ Low</td></tr>
<tr><td colspan="2">Needs from target area (local residents)</td><td colspan="2">High 1■ 2☐ 3☐ 4☐ Low</td></tr>
<tr><td colspan="2">Disaster-consciousness in target area (local residents)</td><td colspan="2">High 1■ 2☐ 3☐ 4☐ Low</td></tr>
<tr><td colspan="4">Evaluation of relevance</td></tr>
<tr><td colspan="4">Although there is no policy/guidelines on only disaster prevention, both the “Action Plan for Climate Change (1998)” and “Strategic assessment review report in Mauritius (2010)” deal with disaster preparedness. Additionally, there are descriptions about early warning systems in the designated landslide areas in the “Disaster Scheme” and about the land use regulation in the “PPG”.
Monitoring devices were installed by MPI in the area after the disaster that destroyed 54 houses and an elementary school in 2005. The area is designated as a landslide area in the “Disaster Scheme”. There are several public facilities such as an elementary school and a public bus line in the area. Therefore the area is one of the highest priority areas for the Mauritius Government, the implementation organization (MPI), the local municipality and the local residents.
As above, the relevance for the project is evaluated as “very high”.</td></tr>
<tr><th colspan="4">Effectiveness</th></tr>
<tr><td colspan="2">Relationship between objectives and goals (whether achieving the objectives in turn aids in achieving the goals)</td><td colspan="2">High 1■ 2☐ 3☐ 4☐ Low</td></tr>
<tr><td colspan="2">Multiplier (synergistic) effect with other projects</td><td colspan="2">High 1■ 2☐ 3☐ 4☐ Low</td></tr>
<tr><td colspan="4">Evaluation for effectiveness</td></tr>
<tr><td colspan="4">The landslide movement is highly correlated with increase of surface and subsurface water with precipitation from the results of monitoring in the Project. To achieve the objective that the countermeasures avoid excessive supply of surface and subsurface water, which in turn aid in achieving the goal that the landslide movement is stabilized.
In case that the amounts of rainfall and landslide movement exceed the thresholds in the early warning system, which has been established as a soft countermeasure in the Project, the local residents are supposed to evacuate. Therefore safer systems for disaster preparedness are established with hard and soft countermeasures.
As above, the effectiveness for the project is evaluated as “very high”.</td></tr>
<tr><th colspan="4">Efficiency (cost and benefit)</th></tr>
<tr><td rowspan="4">Cost for relocation</td><td colspan="3">Houses to be evacuated/relocated: 21 houses</td></tr>
<tr><td>Land area: 440 m2</td><td colspan="2">Corresponding value: 1,739,612 Rs</td></tr>
<tr><td>House (total floor area): 110 m2</td><td colspan="2">Corresponding value: 1,419,355 Rs</td></tr>
<tr><td colspan="3">Total relocation cost: 21 * (1,739,612 + 1,419,355) = 66,338,298 Rs</td></tr>
<tr><td colspan="4">Countermeasure cost: 29,500,400 Rs</td></tr>
<tr><td colspan="4">B/C: Benefit/Cost (Total relocation cost / Countermeasure cost) = 2.25</td></tr>
<tr><td colspan="4">Evaluation for efficiency</td></tr>
<tr><td colspan="4">In the pilot project site, relocation of the local residents is needed unless the landslide countermeasures are implemented. As mentioned above, the number of houses which are directly affected by the landslide movement is 21 houses, and the total relocation cost is approximately 66 million Rs. The countermeasure cost in the pilot project is 29.5 million Rs, and much less expensive than the cost for the relocation. The B/C (Benefit/Cost) is also much higher than 1.0.
As above, the efficiency for the project is evaluated as “very high”.

[Reference: calculations of the corresponding value of the relocation cost]</td></tr>
</table>

According to an interview survey for MPI officers, the unit prices of the land and houses for the relocation are; Land: 100,000 Rs/perch (1 perch = 25.293 m2) and House: 1,200 Rs/sq. ft. (1 sq. ft. = 0.093 m2). The values of the provided land and house for each family in Quatre Soeurs, where the landslide seriously affects their houses, are land of 440 m2 and a house (total floor area) of 110 m2. These values are adopted for the calculations of the corresponding value of the relocation cost.	
Impact	
Applicability to other areas	High 1■ 2☐ 3☐ 4☐ Low
Diffusion and development of the technology	High 1■ 2☐ 3☐ 4☐ Low
Compatibility as a satisfactory environment (mitigation of tree harvesting, conservation of living environment, etc.)	High 1☐ 2■ 3☐ 4☐ Low
Evaluation for impact	
This pilot project is implemented by engineers in MPI with the technology and equipment in Mauritius under the support of JET, so that the method for countermeasures is able to be diffused to nationwide. The cost and work period for the countermeasure construction are based on the budget and system in MPI, so that it is applicable in the future. Although the pilot project is evaluated as “appropriate” in EIA, better compatibility as a satisfactory environment will be expected because countermeasures for landslides is first experienced in Mauritius. As above, the positive impact relevance for the project is evaluated as “very high”.	
Sustainability	
Government policy: frame/system for promotion	Enough 1■ 2☐ 3☐ 4☐ Poor
Finance: Budget allocation	Enough 1■ 2☐ 3☐ 4☐ Poor
Technology: Skill/knowledge of engineers	Enough 1☐ 2☐ 3■ 4☐ Poor
Partnership (cooperation system) with target area	Enough 1☐ 2■ 3☐ 4☐ Poor
Evaluation for sustainability	
JET is proposing the practical and sustainable improvement of the “Disaster Scheme” and “PPG” on the pilot project area. The Mauritius government as well as the local municipality and the local residents are cooperative with the pilot project. Moreover the budget for additional countermeasures in the area has been already applied for to the head office in next year’s budget. However there is an issue of a shortage of engineers on geology and disaster prevention in MPI for future projects. As above, the sustainability for the project is evaluated as “high”.	
Overall evaluation	
It is virtually the first time landslide countermeasures such as those in the Project pilot area have been implemented in Mauritius; therefore this is a very important model case for Mauritius, which is very prone to landslides. The organization and budget in MPI are enough for countermeasures, and the local government/other related organizations/local residents have high awareness and cooperative structure. As mentioned before, high evaluations are marked on the five (5) items (relevance, effectiveness, efficiency, impact and sustainability) on the DAC. It is judged that the pilot project is reasonable and effective from technical, economic and social aspects.	

5.4.2 Interim Review

The interim review is to verify the pilot project is achieving its full potential and to review and improve the plan and operational framework of the project. In general, relevance, effectiveness and efficiency are reviewed at the interim stage. The purpose and the check points of the pilot project in the Project and the check sheet in the interim review are indicated as follows;

Purpose: To verify the pilot project is achieving its full potential, and to review and improve the plan and operational framework of the project

Check points: Evaluation of the relevance, effectiveness and efficiency, and verification of the factors that contribution to/hinder these

Table 5.4.3 Check Sheet of Interim Review in the Pilot Project (source: JET)

Relevance	
Progress of the project (whether the project is proceeding on schedule)	On schedule ■ Behind schedule ☐
Progress of the related projects (whether the related projects are proceeding on schedule)	~~On schedule ☐ Behind schedule ☐~~
Change of social/economic conditions (increase and decrease the targets to be protected etc.)	No change ■ Change ☐
Change of needs of target residents	No change ■ Change ☐
Evaluation for relevance	
The pilot project was started in July 2014 and will be completed in December 2014. Although the delay of the land acquisition was concerned for the horizontal drilling, the lands have been acquired in August 2014 with cooperation of the MHL for the implementation of the horizontal drilling. There are no other related projects for the time being. There are neither change of social/economic conditions (increase and decrease the targets to be protected etc.) nor of needs of target residents. As above, the relevance for the project has been evaluated as “very high,” which is same as that at the pre evaluation stage.	
Effectiveness	
Effectiveness (visual check of control of ground water level, restraint of overflow of surface water etc.)	High 1☐ 2■ 3☐ 4☐ Low
Evaluation of effectiveness	
The countermeasures to avoid excessive supply of surface and subsurface water are under construction, which in turn aid in achieving the goal that the landslide movement is stabilized. However the effectiveness of the countermeasures has not been confirmed as of August 2014. The early warning system on landslides has been in operation since December 2013, and therefore was operational during the rainy season of January to March 2014. There has been no rainfall over the threshold. The questionnaire survey for the local residents was carried out after the rainy season, which will be utilized for the revision of the early warning system. As above, the effectiveness for the project has been evaluated as “very high,” which is same as that at the pre evaluation stage because the pilot project has been successfully progressed without any obstacles.	
Efficiency	
Necessity of alternative plan for cost reduction	Not necessary ■ Necessary ☐
Necessity of alternative plan for countermeasures	Not necessary ■ Necessary ☐
Necessity of schedule amendment	Not necessary ■ Necessary ☐
Evaluation for efficiency	
As of August 2014, there has been no necessity for alternative plan for cost reduction, alternative plan for countermeasures nor schedule amendment. As above, the efficiency for the project has been evaluated as “very high,” which is same as that at the pre evaluation stage because the pilot project has been successfully progressed without any obstacles.	
Overall evaluation (amendment of plan/schedule/cost, compatibility with original policy, improvement/alternative plan）	
There is no need of amendment of plan/schedule/cost. The relevance, the effectiveness and the efficiency for the project has been evaluated as “very high” because the project has been successfully progressed without any obstacles. Therefore it is reasonable and effective that the pilot project should be continued in accordance with the original policy.	

5.4.3 Post Evaluation

The post evaluation is to improve future projects effectively and efficiently, and to fulfill the accountability of the project. In general, the five (5) items on the DAC are evaluated after the project. The purpose and the check points of the pilot project in the Project and the check sheet in the post evaluation are indicated as follows;

Purpose: To improve future projects effectively and efficiently, and to fulfill the accountability of the project

Check points: Review of the realization of anticipated benefits and overall evaluation of five (5) items (regarding the items which cannot be evaluated immediately after the project such as impact and sustainability, the prospects of the items are verified).

Table 5.4.4 Check Sheet of Post Evaluation in the Pilot Project (source: JET)

Relevance	
Progress of the project (whether the project proceeded on schedule)	On schedule ■ Behind schedule ☐
~~Progress of the related projects (whether the related projects proceeded on schedule)~~	~~On schedule ☐ Behind schedule ☐~~
Satisfaction of implementation organization (MPI)	High 1■ 2☐ 3☐ 4☐ Low
Satisfaction of target area (local residents)	High 1☐ 2■ 3☐ 4☐ Low
Evaluation of relevance	
The pilot project was started in July 2014 and completed in December 2014. The implementation organization MPI are fully satisfied with the pilot project and prepared the budget for Phase 2 of this project in 2015. The local residents in the target area are also satisfied with the pilot project according to the stakeholder meeting in Chitrakoot. As above, the relevance for the project is evaluated as “very high”.	
Effectiveness	
Relationship between objectives and goals (whether achieving the objectives in turn aids in achieving the goals)	High 1■ 2☐ 3☐ 4☐ Low
Multiplier (synergistic) effect with other projects	High 1■ 2☐ 3☐ 4☐ Low
Evaluation for effectiveness	
The countermeasures have achieved the objectives to avoid excessive supply of surface and subsurface water and to implement safety drainage, which in turn aid in achieving the goal that the landslide movement is stabilized. However the continuous monitoring is needed in the area. The early warning and evacuation system has been established as a soft countermeasure in the Project. Therefore safer systems for disaster preparedness have been established with hard and soft countermeasures. As above, the effectiveness for the project is evaluated as “very high”.	
Efficiency	
Appearance of effectiveness (control/restraint of landslide movement)	High 1☐ 2■ 3☐ 4☐ Low
Evaluation for efficiency	
Although the continuous monitoring is needed to confirm the efficiency of the countermeasures in the area, the 21 houses which could be directly affected by the landslide movement have never been damaged and .relocated by any landslides. As above, the efficiency for the project is evaluated as “very high”.	
Impact	
Applicability to other areas	High 1■ 2☐ 3☐ 4☐ Low
Diffusion and development of the technology	High 1■ 2☐ 3☐ 4☐ Low
Compatibility as a satisfactory environment (mitigation of tree harvesting, conservation of living environment, etc.)	High 1■ 2☐ 3☐ 4☐ Low
Evaluation of impact	

The pilot project is mainly composed of surface and subsurface drainage system, which are applicable to in Mauritius, and was constructed by a local construction company supervised by JET and MPI. Therefore the methodology is applicable to other areas in the future.
The pilot project alleviates negative impacts by EIA beforehand. JET and MPI constructed the safety fences along the ditches and additional bridge for pedestrians so that it has been contributed better compatibility as a satisfactory environment.
As above, the positive impact relevance for the project is evaluated as “very high”.

Sustainability	
Government policy: framework/system for promotion	Enough 1■ 2□ 3□ 4□ Poor
Finance: Budget allocation	Enough 1■ 2□ 3□ 4□ Poor
Technology: Skill/knowledge of engineers	Enough 1■ 2□ 3□ 4□ Poor
Partnership (cooperation system) with target area	Enough 1■ 2□ 3□ 4□ Poor

Evaluation for sustainability

JET has proposed the practical and sustainable improvement of the early warning and evacuation protocol in the “Disaster Scheme” and the landslide prevention areas in the “PPG” on the pilot project area.
MPI allocated the budget of 40-50 million Rs/year for landslide countermeasures. Skill and knowledge on hard/soft countermeasures for landslide of engineers in MPI have been highly improved through the project.
The Mauritius government as well as the local municipality and the local residents are cooperative with the pilot project and understand the importance and necessity of the countermeasures.
As above, the sustainability for the project is evaluated as “very high”.

Overall evaluation

Although It was virtually the first time landslide countermeasures such as those in the Project pilot area have been implemented in Mauritius; the Mauritius government as well as the local municipality, the forest agency, the water resource agency and the local residents are cooperative with the pilot project so that MPI and JET have completed the countermeasures as scheduled.
MPI allocated the enough budgets for landslide countermeasures after 2015. The works are applicable to other areas in Mauritius in the future. However the monitoring is needed to confirm the appearance of effectiveness.
As mentioned before, high evaluations are marked on the five (5) items (relevance, effectiveness, efficiency, impact and sustainability) on the DAC. It is judged that the pilot project was reasonable and effective from technical, economic and social aspects.

5.5 Promotion of Fund Raising

The “promotion of fund raising” in the Project is to secure a budget from the Mauritius Government and to procure fund from other donors in order to implement landslide countermeasures in a sustainable manner. JET has discussed the promotion of fund raising with the related organizations such as MPI based on the schedule and budget for implementation of landslide projects.

MPI declares that LMU will be focused on landslide projects in the future and secure the budget for the countermeasures by themselves. Indian Ocean Commission (hereinafter IOC), which is implementing the natural disaster prevention projects including landslide disasters in Mauritius, has no plan to procure additional funds for landslide countermeasures for the time being. Therefore, basically, the landslide projects are going to be conducted by the budget in Mauritius Government. The schedule and budget for implementation are planned based on the MPI’s stance.

a. 2013 Fiscal Year

In 2013 fiscal year, LMU has 3,457,980Rs as “Acquisition of Equipment for Landslide Management” which has been applied last year. Therefore, JET suggests that LMU makes use of the earmarked budgeted funds towards the investigation required for Vallee Pitot and the monitoring in La Butte as per the following table. MPI agreed to the breakdown of budget in 2013.

Table 5.5.1 Breakdown of Budget in 2013 (source: JET)

No.	Contents	Budget (Rs)
1	Detailed investigation and monitoring in Vallee Pitot	3,400,000
2	Monitoring in La Butte	
3	Acquisition of Equipment for Landslide Management	
4	Approval of Environmental Impact Assessment in Chitrakoot	50,000
	Sum	3,450,000

However the proposed budget in 2013 has not been executed, and it was carried over to 2014. The project will be implemented in late 2014.

b. 2014 Fiscal Year and After

In 2014 fiscal year and after, it is reasonable that countermeasures will be conducted in the areas designated as high priority in the disaster inspection (Chapter 3) among the 37 designated areas in the Disaster Scheme.

In 2014 fiscal year, additional countermeasures will be implemented in the highest priority areas, Vallee Pitot and Chitrakoot; among Rank A areas (Rank A requirescountermeasures as soon as possible, which can seriously affect residents and/or infrastructures).

In 2015 fiscal year, countermeasures and detailed investigations will be implemented in the remaining six (6) areas among Rank A areas. Moreover, data aquisition for the landslide hazard mapping will be needed.

In 2016 fiscal year after the completion in the Rank A areas, countermeasures will be implemented in Rank B areas (Rank B areas require countermeasures due to the potential impact of a landslide disaster on residents and/or infrastructure. However the priority is not higher than Rank A. Therefore the countermeasures can be implemented after the completion of Rank A countermeasures). Moreover, data aquisition for the landslide hazard mapping will be needed. The higher priority is Rank B in the Port Luis area where population, industy and traffic are concentrated.

In addition to the above budget for the countermeasures, a further budget application was made for 1) maintenance and repair of monitoring equipment: 1,000,000 Rs, and 2) overtime and allowance: 500,000 Rs. The breakdown of budget has been proposed by JET and applied to MPI head office. The applied budget and breakdown of the countermeasures on landslide management in LMU in 2014 – 2016 are indicated as follows;

- 2013 FY: 3,450,000 Rs
- 2014 FY: 16,500,000 Rs
- 2015 FY: 36,500,000 Rs
- 2016 FY: 35,500,000 Rs

Table 5.5.2 List of Countermeasures and Budgets in 2014-2016 (source: JET)

FY	No.	Rank	Item	Rs	Detailed works
2014	10	A	Construction of countermeasures in Vallee Pitot	9,000,000	Surface drainage work Subsurface drainage work Repair of existing canal
	9	A	Construction of additional countermeasure in Chitrakoot	6,000,000	Large scale canal
			Maintenance and repair of monitoring equipment	1,000,000	
			Overtime and allowance	500,000	
2015	8	A	Construction of countermeasures in L'Eau Bouillie	5,000,000	Concrete ditch along road Re-pavement/repair of road
	16	A	Construction of countermeasures in Boulevard Victoria, Montagne Coupe	7,000,000	Soil excavation of upper steps Reinforcement of gabion (reinforcement with strong wire net)
	17	A	Construction of countermeasures in Pailles: (i) access road to Les Guibies	7,000,000	Slope cutting/vegetation Raising up of existing retaining wall Surface drainage on slope
	19	A	Construction of countermeasures in Pailles: (iii) Soreze region	3,000,000	Repair of existing ditch Removal of unstable rocks Geotechnical investigation for detailed countermeasures
	26	A	Construction of countermeasures in Riviere des Anguilles, near the bridge	9,000,000	Gabion/concrete wall along river Installation of extensometer near houses
	33	A	Construction of countermeasures in Piper Morcellement Piat	3,000,000	Retaining wall Surface drainage work
			Data aquisition for the landslide hazard mapping	1,000,000	
			Maintenance and repair of monitoring equipment	1,000,000	
			Overtime and allowance	500,000	
2016	15	B	Investigation in Old Moka Road, Camp Chapelon	3,500,000	Geotechnical investigation for detailed countermeasures
	34	B	Investigation in Candos Hill at LallBahadoor Shastri and Mahatma Gandhi Avenues	2,500,000	Geotechnical investigation for detailed countermeasures
	11	B	Construction on countermeasures in LePouce Street	2,000,000	Ditch
	12	B	Construction of countermeasures in Justice Street (near Kalimata Mandir)	8,000,000	Soil excavation in the back of retaining wall Retaining wall

				Surface drainage on slope and new culvert
14	B	Construction of countermeasures in Pouce Stream	6,000,000	Increasing height of existing retaining wall Gabion along river
18	B	Construction of countermeasures in Pailles: (ii) access road Morcellement des Aloes from Avenue M.Leal (on hillside)	3,000,000	Extension of outlet to ditch Concrete wall and filling
19	A	Construction of countermeasures in Pailles: (iii) Soreze region	9,000,000	Surface drainage work Subsurface drainage work Rockfall protection wall/fence/net
		Maintenance and repair of monitoring equipment	1,000,000	
		Overtime and allowance	500,000	

Although JET proposed that MPI should apply the budget within 2013 to the Ministry of Finance, the budget has not been submitted and carried over to 2014. MPI has reconsidered the budget by themselves in 2013 and 2014 as follows.

c. 2015 Fiscal Year and After

In 2015 fiscal year and after, countermeasures are supposed to be conducted in the 37 designated areas in the Disaster Scheme. Detailed investigation and installation of monitoring devices will be implemented in 2015 fiscal year and the construction of countermeasures in 2016 fisical year and after. MPI will reconsider the priority of countermeasures based on the results of the detailed invastigation and analysis in 2015 so that they will start the construction of countermeasures form the high priority areas (Table 5.5.3).

In addition to the above budget for the countermeasures, a further budget application was made for 1) maintenance and repair of monitoring equipment: 1.0 million Rs, 2) overtime and allowance: 0.5 million Rs, 3) preparation of hazard maps: 1.5-2.0 million Rs and 4) expert on retainer basis: 1.0-2.5 million Rs. The breakdown of budget has been proposed by JET and applied to MPI head office. The applied budget and breakdown of the countermeasures on landslide management in LMU in 2015 – 2017 are indicated as follows;

- 2015 FY: 55,650,000 Rs
- 2016 FY: 40,100,000 Rs
- 2017 FY: 44,700,000 Rs

Table 5.5.3 List of Countermeasures and Budgets in 2015-2017[4]

No.	Area name	Disaster	2015 (Rs)	2016 (Rs)	2017 (Rs)
1	Construction Works in Chitrakoot (Block A) - Section 1	Landslide	2,250,000		
	Consultancy Services for Countermeasure Construction Works in Chitrakoot (Block A) - Section 2	Landslide	400,000		
	Construction Works in Chitrakoot (Block A) - Section 2	Landslide	8,000,000		
	Consultancy Services for Countermeasure Construction Works in Chitrakoot (Block B)	Landslide		400,000	
	Construction Works in Chitrakoot (Block B)	Landslide		6,000,000	
2	Consultancy Services for Countermeasure Construction Works at Vallee Pitot (near Eidgah)	Landslide	450,000		

	Countermeasure Construction Works at Vallee Pitot (near Eidgah)	Landslide	9,000,000		
3	Remote Monitoring System in Chitrakoot, Vallee Pitot, Quatre- Soeurs and La Butte	Landslide	7,000,000		
4	Maconde Region Baie du Cap - Phase 2	Rock fall	10,000,000		
5	Morcellement Hermitage, Coromandel	Slope failure	250,000		
6	L'Eau Bouillie	Damage of embankment	250,000	5,000,000	
7	Boulevard Victoria, Montagne Coupe	Damage of wall	7,000,000		
8	Pailles access road to Les Guibies and along motorway, near flyover bridge	Slope failure	350,000	7,000,000	
9	Pailles Soreze region	Slope failure	500,000	3,000,000	
10	Riviere des Anguilles, near the bridge	Stream erosion	450,000	9,000,000	
11	Post Relocation Works at Quatre Soeurs, Marie Jeanne, Jhummah Streert, Old Grand Port	Landslide	250,000		
12	Piper Morcellement Piat	Stream erosion	150,000	3,000,000	
13	Temple Road, Creve Coeur	Damage of wall	100,000		Budget will depend on results of detailed investigations and expert recommendations. Around 40 million Rs is forecasted
14	Congomah Village Council (Ramlakhan)	Stream erosion	100,000		
15	Congomah Village Council (Leekraj)	Damage of wall	100,000		
16	Congomah Village Council (Frederick)	Damage of wall	100,000		
17	Congomah Village Council (Blackburn Lanes)	Damage of Embankment	100,000		
18	Les Mariannes Community Centre (Road area)	Slope failure	100,000		
19	Les Mariannes Community Centre (Resident area)	Stream erosion	100,000		
20	Le Pouce Street	Stream erosion	100,000		
21	Justice Street (near Kalimata Mandir)	Damage of wall	400,000		
22	Pouce Stream	Stream erosion	300,000		
23	Old Moka Road, Camp Chapelon	Landslide	575,000		
24	Pailles access road Morcellement des Aloes from Avenue M.Leal (on hillside)	Stream erosion	150,000		
25	Plaine Champagne Road, opposite "Musee Touche Dubois"	Slope failure	100,000		
26	Chamarel near Restaurant Le Chamarel and Road Side	Damage of embankment	100,000		
27	Baie du Cap: (i) Near St Francois d'Assise Church	Debris flow	100,000		
28	Bambous Virieux, Rajiv Gandhi Street (near Bhavauy House), Impasse Bholoa	Slope failure	100,000		
29	Trou-Aux-Cerfs	Slope failure	100,000		
30	River Bank at Cite L'Oiseau	Stream erosion	100,000		
31	Louis de Rochecouste (Riviere Seche)	Stream erosion	100,000		
32	Candos Hill, LallBahadoor Shastri and Mahatma Gandhi Avenues	Landslide	125,000		
33	Montee S, GRNW	Stream erosion	100,000		
34	Consultancy Services for Preparation of Hazard Maps		1,500,000	2,000,000	1,500,000

35	Consultancy Fees for Expert on Retainer Basis		2,500,000	2,500,000	1,000,000
36	Overtime Work by Landslide Management Counterparts		1,200,000	1,200,000	1,200,000
37	Maintenance and Repairs of Equipment		1,000,000	1,000,000	1,000,000
Budgetary Forecast for Financial Years 2015 to 2017					44,700,000

It is judged that the Mauritius Government including MPI is so positive towards and allocates ample budget for the landlside countermeasures that they have enough sustainability for future landslide disaster management projects.

5.6 Organizational Reinforcement Plan

5.6.1 Capacity Development Plan

a. Definition of Capacity Development

Capacity development is defined as a process through which individuals, organizations and societies strengthen capabilities of solving the issues and achieving their own goals. As capacity development requires a long-term process, the capacity development plan needs to consider independent and sustainable capacity of individuals, organizations and societies.

b. Definition of capacity development in this project

This project aims at enhancing mainly the LMU's technical capacity as well as organizational capabilities. Apart from capacity development through the technical transfer, this project also aims at achieving the following.

1) In order to enhance independent and sustainable capability of the LMU, the current issues and approaches to cope with the issues are cooperatively examined by the LMU and JET. The capacity development plan is also formulated by both parties.

2) A mechanism will be established in order to sustain the effects of the project and the LMU independently undertakes the mid-term and long-term activities.

c. Procedure of formulating a capacity development plan

As capacity development requires a long-term process, the specific activities in a capacity development plan are classified as either short-term or mid-term/long-term. The procedure of formulating the capacity development plan is shown below.

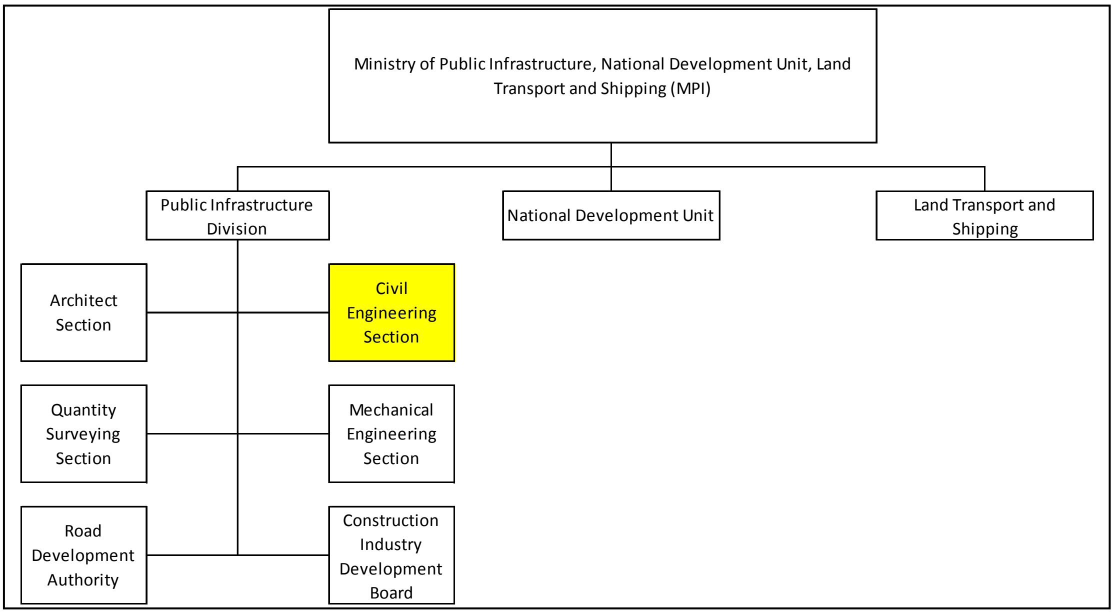
1) Extracting the current issues
2) Defining the goals to solve the current issues
3) Defining the activities undertaken in the short-term period (under the project period) and mid-term/long-term period (after the project period)

5.6.2 Landslide Management Unit (LMU) in MPI

a. Establishment of LMU

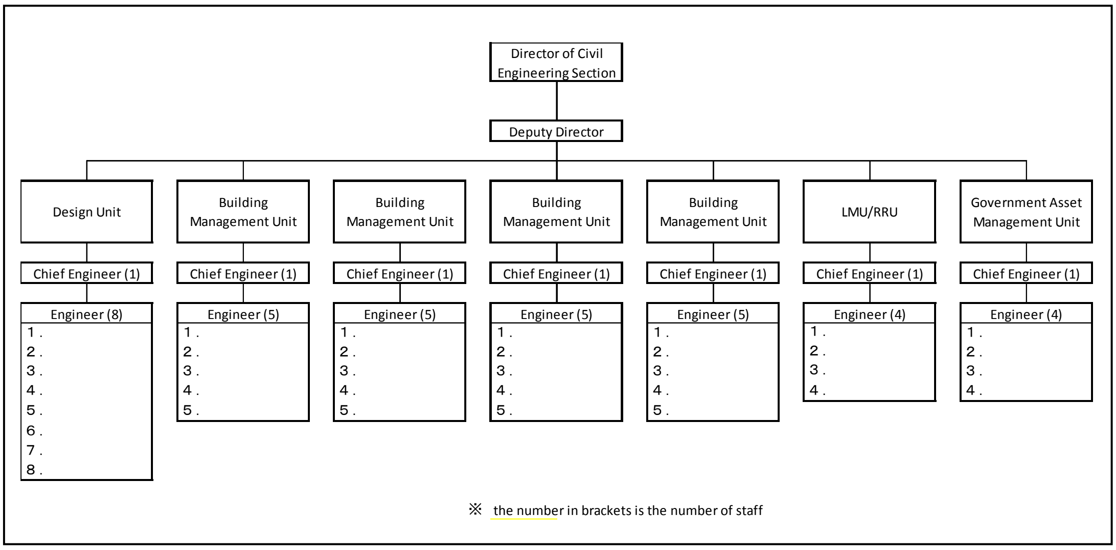
Landslide monitoring, which was previously undertaken by the National Development Unit (NDU), has been transferred to the Landslide Management Unit (LMU) since September 2009. LMU is attached to Repair and Rehabilitation Unit (RRU) in the Civil Engineering Section in order to enhance landslide monitoring. The organizational structure of the MPI is shown in the Table 5.6.1.

Table 5.6.1 Organizational Structure of MPI and Civil Engineering Section[4]



Civil Engineering Section in the MPI consists of seven units of Design Unit, four Building Management units, Landslide Management/Repair and Rehabilitation Unit and Government Asset Management Unit. Table 5.6.2 shows an organizational structure of Civil Engineering Section in the MPI.

Table 5.6.2 Organizational Structure of MPI and Civil Engineering Section (source: JET)



Reference: interview survey with MPI

b. Aim and scope of the LMU

The aim of the LMU is to mitigate the damage to life and assets caused by landslide disasters. LMU is the main and lead organization to manage the landslide issues in the ordinary and emergency situations with collaboration of all stakeholders.

5.6.3 Issues, Goals and Activities in Capacity Development for Medium and Long Term Plan

Issues, goals and action plans were discussed with the director of the Civil Engineering Department and the LMU engineers in 2013. The discussion details are summarised in the table below.

Table 5.6.3 Issues, goals and activities in capacity development plan (source: JET)

Issues	Aims	Activities to achieve the aims	Outcomes
Not enough knowledge and experience of the LMU	Enhancing technical knowledge and experience	• Strengthening on site knowledge and experience by technical transfer by JET	• Technical transfer on landslide investigation/analysis, design and construction/supervision has been achieved through the project activities such as the daily on the job training, seminars and trainings in Japan.
		• Introducing a programme to study geotechnical engineering at MA level	• One LMU technical officer has applied for JICA's ABE initiative to study for a Master's degree in Japan as of November 2014.
		• Attending international seminars and conferences on landslides	• Will be considered in the future. The technical knowledge and experience will also be enhanced through equipment training from the suppliers when purchasing the equipment.
		• Exchanging skills and knowledge with the other countries	
		• Dispatching expert(s)	• MPI requested JICA to dispatch a landslide adviser in August 2014.
Not enough staff in the LMU	Securing enough and appropriate staff	• Shifting from part-time to full-time LMU staff	• Six Engineers/Senior Engineers, three Technical Officers and one Public Relations Officer/Intern will be posted to the LMU according to the official letter from Supervising Officer of the MPI. One engineer has been already posted to the LMU since October 2014.
		• Employing experienced and pre-registration trainee engineers with geology background	
		• Employing public relation officer(s) who is (are) in charge of landslide education	
		• Introducing a retainer system for specialists in order to cooperate with private and academic sectors	• The first priority of the MPI is that JICA's landslide adviser will be dispatched, however, MPI is considering employing a landslide expert on a retainer basis in case JICA's adviser is not dispatched.
Weak coordination with the other stakeholders	Improving the LMU's management capacity for landslide sector	• Defining LMU's tasks and responsibilities and producing official documents	• MPI organised several stakeholder meetings to propose and discuss tasks and responsibilities of LMU and the other stakeholders. Additionally, MPI organised one day seminar in which LMU engineers explained and finalised the tasks and responsibilities of all stakeholders in terms of responses to 37
		• Consulting with the other stakeholders in order to define their own tasks and responsibilities	

			classified sites, emergency responses and possible risk areas. Other stakeholders also presented their tasks and responsibilities for landslide management.
Little popularity of the LMU	Improving LMU's popularity	• Informing LMU's tasks, responsibilities and activities to all stakeholders by an official letter	• The tasks and responsibilities of the LMU were defined and finalised through several stakeholder meetings and hand outs distributed in the one day seminar. Regular stakeholder meetings will be organised in the future where LMU's activities and achievements will be shared with the stakeholders.
		• Issuing and distributing newsletter to introduce LMU's activities	
		• Explaining the LMU's activities on occasions such as NDRRMC	
		• Sensitising the LMU through the NDRRMC	
Not enough knowledge on landslides among the stakeholders	Improving knowledge among the other stakeholders	• Organising landslide seminars for the relevant ministries and local municipalities	• Landslide knowledge among stakeholders has been enhanced by distributing the reports issued under the project, stakeholder meetings and one day seminar organised in November 2014.
		• Issuing and distributing newsletter of landslide management which is a supplementary material for the seminars	
		• Employing temporary assigned staff from private companies in order to train and strengthen private sector personnel	• Will be considered in the future when LMU engineers obtain knowledge and experience on landslide management.
		• Establishing methodology of landslide education along with the other disasters	• Awareness of landslides among public has been strengthened through the meetings with inhabitants. Regular meetings with inhabitants will be conducted to enhance awareness further.
		• Raising awareness on land-use and development regulations	• The Ministry of Housing and Lands (MHL) updates the Planning Policy Guidance (PPG) based on the results of the landslide investigation reported by the MPI.
Evacuation plan and emergency communication network are not fully developed	Taking prompt response in emergency situations	• Strengthening evacuation system of local residents by establishing effective information and communication system	• According to the National Disasters Scheme 2014, the Ministry of Information and Communication Technology with the NDRRMC consider the methodology of disseminating disaster information to the public by Mauritius Telecom and other mobile operators.
		• Creating a hotline for all kinds of disasters for local residents	• Hotline for all kinds of disasters has been established in the NDRRMC. NDRRMC contacts MPI in case a landslide disaster

			occurs.
Emergency operation system of the LMU has not fully established yet	Establishing LMU's emergency operational system	• Creating emergency communication network within LMU	• The emergency operational system within the LMU has been established (see 5.6 d.4)
		• Establishing a dispatch system for night time, holidays and rainy season	
		• Implementing emergency communication drill within the LMU based on the above mentioned network system	• Will be implemented in the future.
		• Implementing emergency reconnaissance exercises at sites	
		• Updating the emergency communication network in order to respond to landslides anytime	• The emergency communications network within the LMU has been established. It will be amended/updated with the review of emergency responses.
Working arrangement with private sector has not been fully established yet	Establishing public/private cooperation system	• Summarising the works of survey, design, cost estimation and construction works which are allocated to the private sector	• Employing experts on a retainer basis is considered to gain the expertise of local or international geotechnical engineers. MPI/LMU will conduct the landslide management with the experts.
		• Summarising the issues in construction management system and proposing a workable arrangement	
		• Summarising the issues in completion confirmation system and proposing a workable arrangement	
		• Strengthening cooperation system with private construction companies and consulting engineers	

5.6.4 Outcomes Achieved and Future Capacity Development Plan

Outcomes of capacity development of the LMU and future capacity development plan are as follows.

a. Technical Knowledge

Technical transfer regarding landslide investigation/analysis, design and construction/supervision has been achieved through the project activities such as the daily on the job training, seminars and training in Japan. The LMU engineers understand and obtain knowledge on landslide investigation and countermeasure works. One of the LMU technical engineers is currently applying for JICA's ABE initiative in order to study geotechnical engineering in master's degree and obtain academic knowledge on landslides. Moreover, MPI has applied JICA's landslide adviser in which MPI aims at enhancing technical experience adding to the abilities obtained through this project. LMU will be the main and lead organization for landslide management with academic knowledge and technical experience.

b. Organizational Establishment

b.1 Human resources

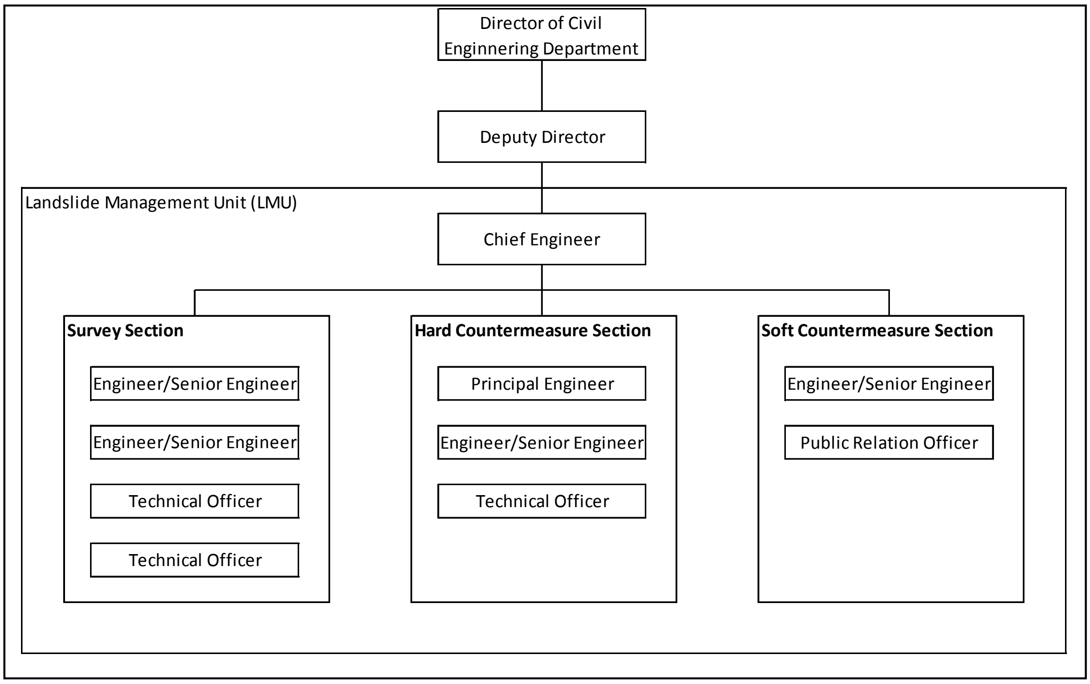
As full-time staffs have not been posted to the LMU since its establishment in September 2009, engineers of the other sections in Civil Engineering Department have been assigned. Engineers have taken additional duties and responsibilities over their normal work. However, posting six Engineers/Senior Engineers was decided in March 2014. Following its decision, one engineer has been posted to the LMU since October 2014. The rest of Engineers/Senior Engineers will be posted after the selection is completed.

Together with six Engineers/Senior Engineers, posting three Technical Officers and one Public Relations Officer was decided at the same time. However, creation of a Public Relations Officer position is pending and one Intern under the Service to Mauritius (STM) programme will be recruited instead.

There are seven Engineers and Technical Officers working for the LMU as of November 2014. The LMU is divided into three sections and engineers and technical officers for one of these sections in order to define clearer responsibilities for each engineer and technical officer.

The LMU will conduct the landslide management with the assignment of the following full-time staff.

Table 5.6.4 Full-time Staff Assignment (Long Term Goal) (source: JET)



b.2 Budget

Budget for the LMU is allocated on a yearly basis. The current budget allocation procedure is as follows: 1) The LMU makes a budget plan based on the estimation made by the JICA Expert Team, 2) The plan is submitted to MPI headquarters, 3) The plan is submitted to the Ministry of Finance through MPI headquarters, and 4) The budget is allocated after approval of the Ministry of Finance.

The table below is a budget plan for the LMU for the period of 2015 to 2017.

Table 5.6.5 Budget for the LMU from 2015 to 2017 (source: JET)

Item	Classification of Disaster	2015	2016	2017
VAT component for Countermeasure Construction Works				
Chitrakoot (Block A) - Section 1	Landslide	2,250,000		
Consultancy Services for Countermeasure Construction Works				
Chitrakoot (Block A) - Section 2	landslide	400,000		
Vallee Pitot (near Eidgah)	landslide	450,000		
Morcellement Hermitage, Coromandel	Slope failure	250,000		
L'Eau Bouillie	Damage of embankment	250,000		
Pailles access road to Les Guibies and along motorway, near flyover bridge	Slope failure	350,000		
Pailles Soreze region	Slope failure	500,000		
Riviere des Anguilles, near the bridge	Stream erosion	450,000		
Post Relocation Works at Quatre Soeurs, Marie Jeanne, Jhummah Street, Old Grand Port	landslide	250,000		
Piper Morcellement Piat	Stream erosion	150,000		

Temple Road, Creve Coeur	Damage of wall	100,000		
Congomah Village Council (Ramlakhan)	Stream erosion	100,000		
Congomah Village Council (Leekraj)	Damage of wall	100,000		
Congomah Village Council (Frederick)	Damage of wall	100,000		
Congomah Village Council (Blackburn Lanes)	Damage of embankment	100,000		
Les Mariannes Community Centre (Road area)	Slope failure	100,000		
Les Mariannes Community Centre (Resident area)	Stream erosion	100,000		
Le Pouce Street	Stream erosion	100,000		
Justice Street (near Kalimata Mandir)	Damage of wall	400,000		
Pouce Stream	Stream erosion	300,000		
Pailles access road Morcellement des Aloes from Avenue M.Leal (on hillside)	Stream erosion	150,000		
Plaine Champagne Road, opposite "Musee Touche Dubois"	Slope failure	100,000		
Chamarel near Restaurant Le Chamarel and Road Side	Damage of embankment	100,000		
Baie du Cap: (i) Near St Francois d'Assise Church	Debris flow	100,000		
Bambous Virieux, Rajiv Gandhi Street (near Bhavauy House), Impasse Bholoa	Slope failure	100,000		
Trou-Aux-Cerfs	Slope failure	100,000		
River Bank at Cite L'Oiseau	Stream erosion	100,000		
Louis de Rochecouste (Riviere Seche)	Stream erosion	100,000		
Montee S, GRNW	Stream erosion	100,000		
Chitrakoot (Block B)	Landslide		400,000	
Construction of countermeasures				
Chitrakoot (Block A) - Section 2	Landslide	8,000,000		
Vallee Pitot (near Eidgah	landslide	9,000,000		
Maconde Region Baie du Cap - Phase 2	Rock fall	10,000,000		
Boulevard Victoria, Montagne Coupe	Damage of wall	7,000,000		
Chitrakoot (Block B)	Landslide		6,000,000	
L'Eau Bouillie	Damage of embankment		5,000,000	
Pailles: (i) access road to Les Guibies	Slope failure		7,000,000	
Pailles: (iii) Soreze region	Slope failure		3,000,000	
Riviere des Anguilles, near the bridge	Stream erosion		9,000,000	
Piper Morcellement Piat	Stream erosion		3,000,000	
Temple Road, Creve Coeur	Damage of wall			Will be decided based on the detail survey
Remote Monitoring System				
Chitrakoot, Vallee Pitot, Quatre- Soeurs and La Butte	Landslide	7,000,000		
Consultancy Services for Investigation				
Old Moka Road, Camp Chapelon	Landslide	575,000		
Candos Hill, LallBahadoor Shastri and	Landslide	125,000		

Mahatma Gandhi Avenues				
Consultancy Services for Preparation of Hazard Maps		1,500,000	2,000,000	1,500,000
Consultancy Fees for Expert on Retainer Basis		2,500,000	2,500,000	1,000,000
Overtime Work for LMU		1,200,000	1,200,000	1,200,000
Maintenance and Repairs of Equipment		1,000,000	1,000,000	1,000,000
	TOTAL	**55,650,000**	**40,100,000**	**44,700,000**

Reference: interview survey with MPI/LMU

c. Coordination with the Other Stakeholders

As collaboration of all stakeholders is essential to deal with landslide issues in Mauritius, the tasks and responsibilities of LMU as well as the other stakeholders were defined and finalised with the procedure below:

1) The tasks and responsible stakeholders in the ordinary and emergency situations were discussed among LMU engineers and technical officers;

2) Based on the discussions above, the responsible organizations and their tasks were summarized in the task flow;

3) The draft task flow was explained to MPI headquarters and the flow was approved by the permanent secretary of the MPI;

4) MPI organized several meetings and invited all main stakeholders such as NDRRMC, police, NDU, RDA, Mauritius Meteorological Services and local authorities to discuss the tasks and responsibilities of each organisation; and

5) The tasks and responsibilities of LMU and the other stakeholders were defined and finalized.

The MPI organized one day seminar on the 27th of November in 2014. MPI headquarters, LMU, MPI/National Development Unit (NDU), MPI/Road Development Authority (RDA), NDRRMC, Ministry of Housing and Lands (MHL) and local authorities participated in the seminar and the tasks and responsibilities for ordinary and emergency situations were finalized. The finalized tasks and responsibilities are as follows:

- Responses to the classified landslide prone areas (37 sites)

The main organizations are identified based on the disaster classification, objects of protection and the scale of disaster. The main responsible organizations will implement the countermeasure works from the high prioritized areas according to the results of annual slope inspection.

Table 5.6.6 Main Responsible Organizations based on Disaster Classification, Objects of Protection and the Scale of Protection (source: JET)

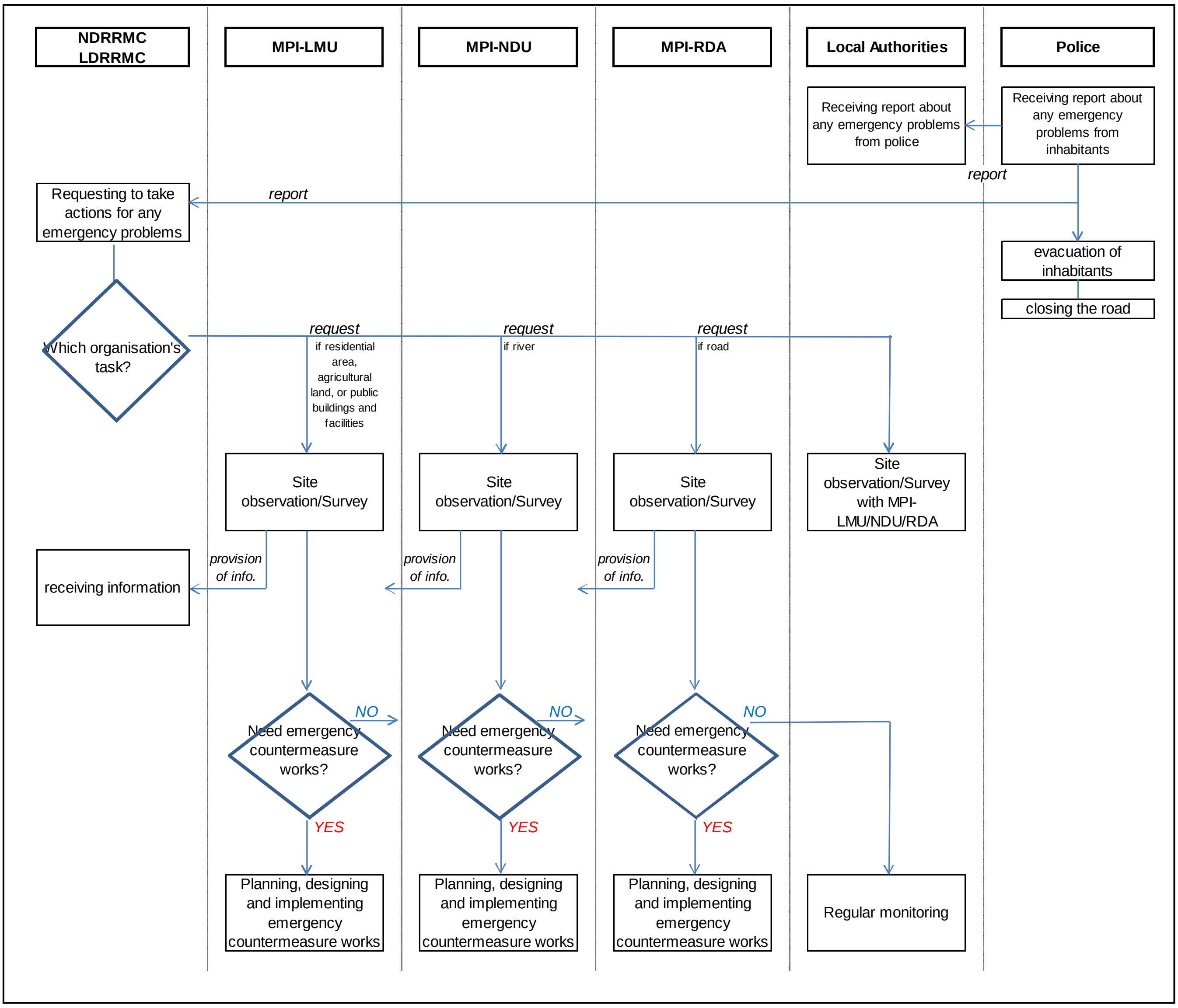
Disaster		Object of protection	The main responsible organisation	
			Large scale disaster	Small scale disaster
Slope disaster	Landslide (mass movement)	Residential houses	LMU	Local authorities
		Agricultural fields		

		Public buildings and facilities		
		Roads	RDA/LMU	
	Rock fall	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Slope failure	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
Slope and river disaster	Debris flow	Residential houses	LMU/NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU/NDU	
River disaster	Stream erosion	Residential houses	NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads		
	Flood	Residential houses	NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads		
Others	Damage of embankment	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Damage of wall	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Damage of house	Residential houses	-	Local authorities
		Agricultural fields		
	Cavern	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	RDA/local authorities

- Responses for emergency situations

In terms of responses for emergency situations, police and local authorities are responsible for taking immediate actions such as evacuation of inhabitants and roadblocks. LMU, NDU and RDA are responsible for the site investigation, consideration of countermeasures and its implementation with the same methodology for 37 classified sites.

Table 5.6.7 Task Flow for Emergency Situation for All Sites (source: JET)



- Responses for the new sites with utilization of a hazard map

LMU will develop a hazard map in order to identify the new landslide prone areas apart from 37 classified sites.

- Early warning

The early warning system is applied for three pilot sites of the project (Chitrakoot, Quatre Soeurs and Vallee Pitot) according to the National Disasters Scheme and protocol. The same early warning system as used at the pilot sites will be established for those new landslide prone areas if identified by the hazard map.

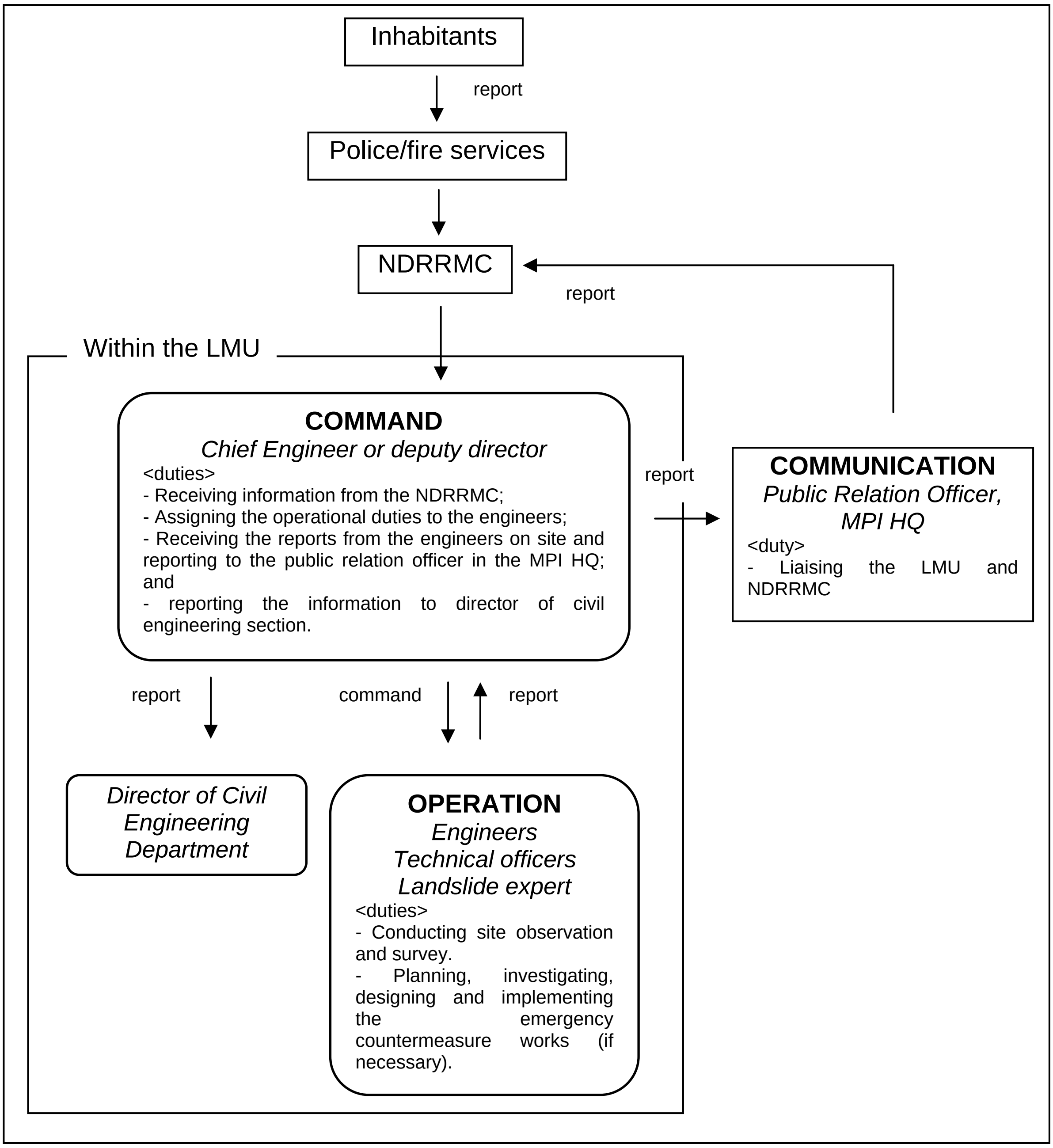
As a result of defining the tasks and responsibilities for all stakeholders, it is expected that all stakeholders will be actively involved in tackling the landslide issues. Moreover, as the stakeholder meeting will be regularly organised in order to share landslide information, the collaboration of all stakeholders will be enhanced.

LMU has actively participated in the stakeholder meetings, for example, LMU engineers presented the tasks and responsibilities of landslide management by themselves in the one day seminar on the 27th of November 2014. This fact proves that the LMU engineers have enhanced their knowledge and understanding of landslides, and are contributing in raising awareness and knowledge among other organizations.

d. Emergency operational system within the LMU

The emergency operational system within the LMU is established as follows.

Table 5.6.8 Emergency Operational System within the LMU (source: JET)



The LMU reviewed the operations in the past emergency situations and considered the emergency operational system to allocate the engineers and technical officers. Several options such as a monthly roster system were discussed, and the LMU has decided to allocate two responsible engineers and technical officers to each region of Rivière du Rempart, Pamplemousses, Port Louis, Black River, Plaines Wilhems, Moka, Flacq, Grand Port and Savanne (three engineers and technical officers are allocated to Port Louis). The emergency operational system will be revised and updated if necessary.

e. Establishment of Public/private Cooperation System

The hiring of expert(s) on a retainer basis is considered in order to support the LMU's task of landslide management. The JICA Expert Team supported to define the scope of work for the expert on a retainer basis and the LMU has submitted the scope of work to the MPI headquarters. The MPI intends to employ a local or international geotechnical engineer.

Reference for Chapter 5

[1] Japan Road Association: Highway Earthwork Series: Manual for slope protection, pp. 405, 2009
[2] Environment Protection Act 2002
[3] This figure was prepared by JET according to Environmental Protection Act 2002
[4] MPI

Chapter 6

Pilot Project
(Landslide Countermeasure)

6 Pilot Project (Landslide Countermeasures)

6.1 Structural Countermeasures

Structural countermeasure work for landslides can be classified broadly into control work and restraint work. Control work is a method to halt or to mitigate landslide activity by changing the natural conditions such as the topographical features or groundwater conditions. Restraint work is a method to halt a part or whole of the landslide block by deterrent force using a structural countermeasure(s).

There is usually more than one type of countermeasure applied for any one landslide. Common methods of landslide countermeasures are shown in the below table.

Table 6.1.1 Classification of Landslide Countermeasure Works[1]

Control Work ・ Surface drainage work (Drainage work, Infiltration prevention work) ・ Groundwater Drainage work Shallow groundwater drainage work (Conduit work, Open-blind ditch, Horizontal drainage work) ・ Deep groundwater drainage work (Infiltration well, Drainage tunnel work, Horizontal drainage work) ・ Soil removal work ・ Counterweight work ・ River structural facility (Dam, Consolidation work, Water control work, Revetment work)
Restraint Work ・ Pile work Pile work (Steal pipe pile work) Shaft work ・ Ground anchor work

Generally, control work is the main method applied, and additional control works or restraint work can be combined to be applied according to the conditions.

As mentioned in Chapter 5.2, the countermeasure works has been designed according to the policy and the plan of countermeasure work which has been studied during the Feasibility Study stage.

6.1.1 Basic design of Countermeasure Works

a. Channel for Flood Water

Steep mountainous slope exists behind the Chitrakoot area. The slope shows reentrant shape. The slope is water catchment area of the landslide area including the Block-A and Block-B landslides. Therefore, large volumes of runoff water by rainfall flow into the landslide area in the rainy season. Flooding occurs regularly due to lack of drainage facilities and existing drainage system has not enough capacity to discharge the runoff water. The floods cause considerable damage to property and disturb the lives of residents.

As the result of the groundwater monitoring, it has been recognized that groundwater in this area rises up near the ground surface in rainy season. It can be considered that the groundwater rises up due to infiltrate surface water to underground. The rising groundwater level was the main cause of activity of the Block-A and Block-B landslides in rainy season 2013. There is possibility that high groundwater level may trigger activity in other landslide blocks activity even though major movement was not detected in those landslide blocks in 2013.

As mentioned above, it has been recognized that the flow of surface water from the mountainous slope contributes to activity of the target landslides and causes flooding in the area. The channel to divert flood water shall be installed behind the landslide area to mitigate landslide activity and flooding in the residential area. It is expected to reduce runoff water into the residential area and to mitigate rising groundwater level in the target landslide area.

The channel to divert flood water shall be installed in a transverse direction against the slope direction to collect surface water from mountainous slope and existing minor water cause and to discharge to existing river and drainage properly. The dimensions of the channel are to be decided based on the area of water catchment behind the channel and based on rainfall intensity.

Bottom and side wall of the channel shall be paved by concrete and mason wall to avoid infiltration of the water and erosion of side slope. Fall prevention fence shall be installed at both side of the channel and bridge will be installed at the cross point of road and channel. The installing place shall be decided after discussion with inhabitants.

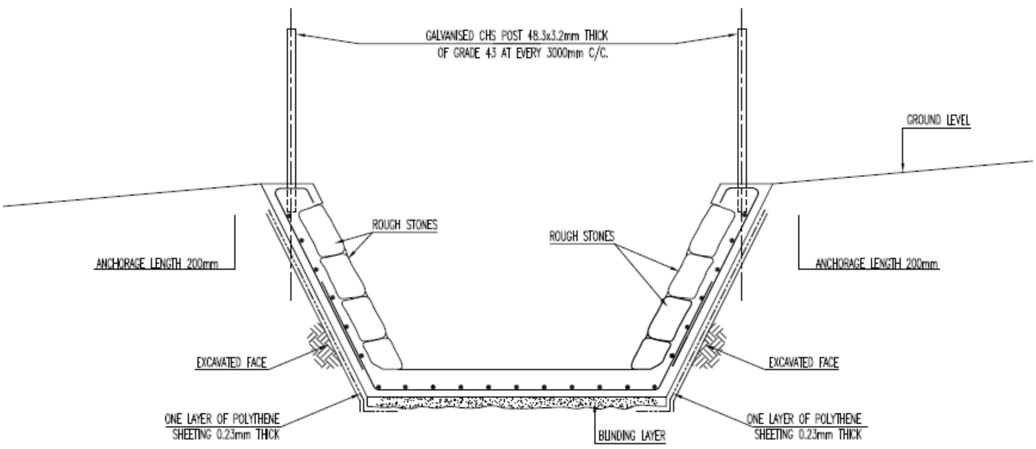


Figure 6.1.1 Typical Cross Section of Channel for Flood Water (source: JET)

Impact of stability of back slope by installation of the channel was examined. The stability analysis has been carried out on the 3 cross sections which are the longest part of the target slope behind the channel. The condition of the analysis is as follows:

Table 6.1.2 Condition of Stability Analysis of Slope behind the Channel for Flood Water (source: JET)

Geology of the target slope	Sandy silt with boulder (Colluvium)
Unit weight [γt]	18 [kN/m^3]
Cohesion [c]	10 [kN/m^2]
Internal Friction Angle [φ]	10 [degree]
Method of calculation	Modified Fellunius（Ordinary method)
Groundwater level	3m below from the ground surface(the highest groundwater level at BBP-8 existing borehole)
Target Factor of Safety	1.15

The result of the analysis and location of analysis cross section is shown below. Result of analysis is attached to the Supporting Report.

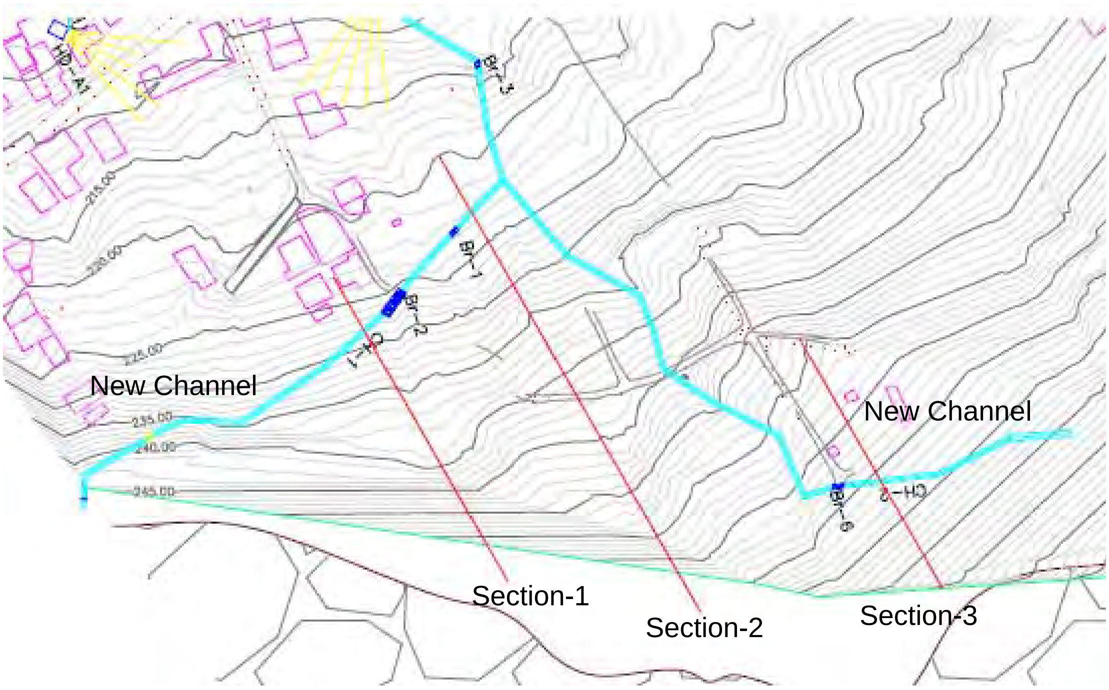


Figure 6.1.2 Location of the Cross Sections for the Analysis (source: JET)

Table 6.1.3 Result of the Stability Analysis of the Slope behind the Channel (source: JET)

Section Name	Minimum Safety Factor	Target New Channel
Section 1	1.32	CH-1
Section 2	1.17	CH-1
Section 3	1.18	CH-2

The target slope for the analysis was the gentle slope behind the new channel, which is consisted of colluvium. The minimum factor of safety of the slope area has been studied. According to the result of the analysis, the minimum factor of safety shows more than 1.15 as the target factor of safety. Thus, it can be considered that slope will be secured safety after the construction of the new channel.

b. Horizontal Drainage

The work shall be undertaken to reduce the groundwater level in the landslide block. In case that target slope has sufficient angle, the pit shall be made to set the drainage point deeper. Basically, the length of the drainage shall be 50 m with 5 degrees upward inclination. One set of the drainage consists of five (5) drainage pipes, and the drainage pipes shall be arranged in a fan shape. Each drain has a 10 m interval at the tip of the drainage. The retaining wall shall be installed around the outlet of the drainage pipes to protect from slope collapse and erosion.

The drainage pipe shall be perforated PVC pipe with 5 mm diameter holes. The internal diameter of the pipe is 40 mm.

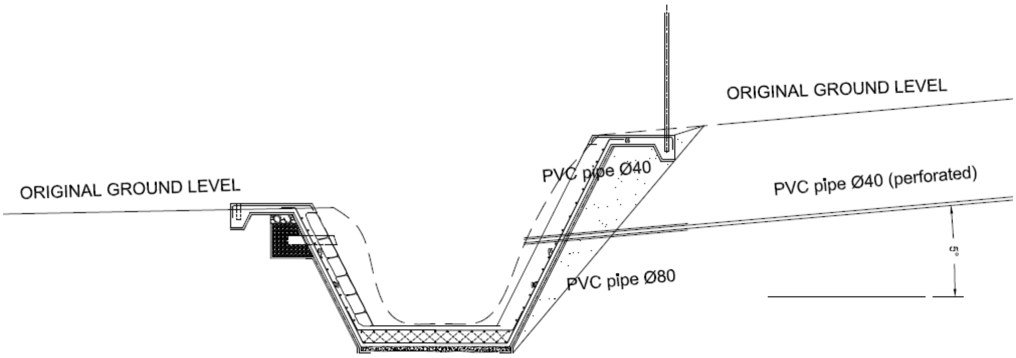


Figure 6.1.3 Typical Cross Section of Horizontal Drainage (source: JET)

c. Open - Blind Ditch

Open-blind ditch shall be constructed in a transverse direction to collect runoff water which flows into the landslide block and shallow groundwater which rises up to near the ground surface in the rainy season. Dimensions of the open ditch part are trapezoidal with a wider top than bottom for ease of maintenance of the ditch. The dimensions of the ditch shall be changed depending on the estimated value of discharged water. The surface of the ditch shall be paved with concrete with masonry to avoid infiltration of the water into the ground.

Conduit in the blind ditch part is set 1 to 1.5 m below the ground surface. Conduit pipe is perforated PVC pipe with 200 mm internal diameter. Waterproof sheet shall be laid on bottom of the blind ditch. In the blind ditch part shall be filled with crush run stone to secure permeability.

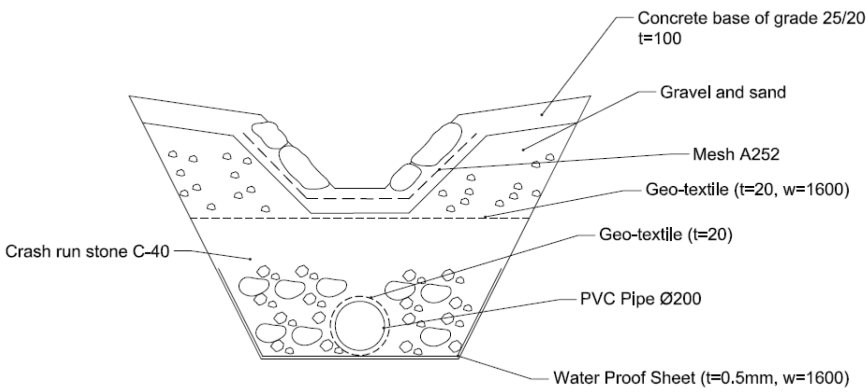


Figure 6.1.4 Typical Cross Section of Open-blind Ditch (source: JET)

d. Surface Drainage

The drainage shall be installed to collect and discharge water which is collected by the horizontal drainage and open-blind ditch to outside of the landslide block. The drainage is not expected to collect runoff water.

Dimension of the open ditch part is trapezoidal with a wider top than bottom for ease of maintenance of the ditch. The surface of the ditch shall be paved by concrete to avoid infiltration of the water to the ground.

It can be considered that drainage in a landslide block has a possibility of being damaged due to deformation of ground surface by landslide activity. In case that a drainage has been damaged, there is possibility that water will infiltrate the ground from the damaged part. Thus, maintenance of the facilities is required at regular intervals. Crush run stone and water proof sheet shall be installed under the paved drainage to avoid water infiltration on a temporary basis until completion of repairs of the damaged part. And, perforated pipe shall be installed in the crash run stone layer to drain the leakaged water promptly. Fall prevention fence shall be installed on both sides of the drainage depending on the site situation.

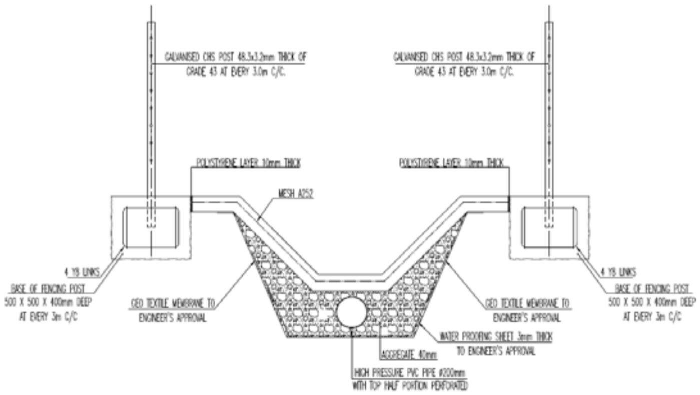


Figure 6.1.5 Typical Cross Section of Surface Drainage (source: JET)

e. Upgrade of Existing Water Course

Collected surface water collected by the channel for flood water is discharged to the existing water course (river). However, some part of the existing water course does not have sufficient capacity for the designed volume of discharge water. Therefore, there is a possibility that the existing water course cannot discharge the water properly in the heavy rain time. Upgrade work such as extension of the river dimension and protection of the river bank will be applied to the section of the water course. The river bank shall be protected by installation of boulder to avoid erosion by water flow. The section of the water course which is located on the landslide boundary will be protected by reinforced concrete structure to resist deformation by the landslide activity.

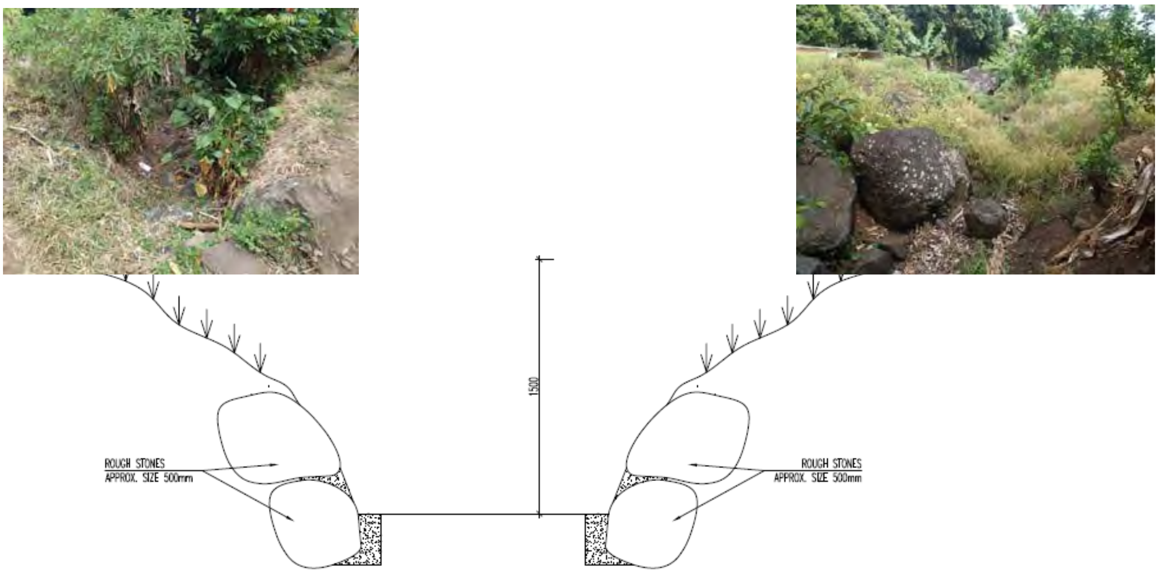


Figure 6.1.6 Typical Cross Section of Upgrade of Existing Water Course (source: JET)

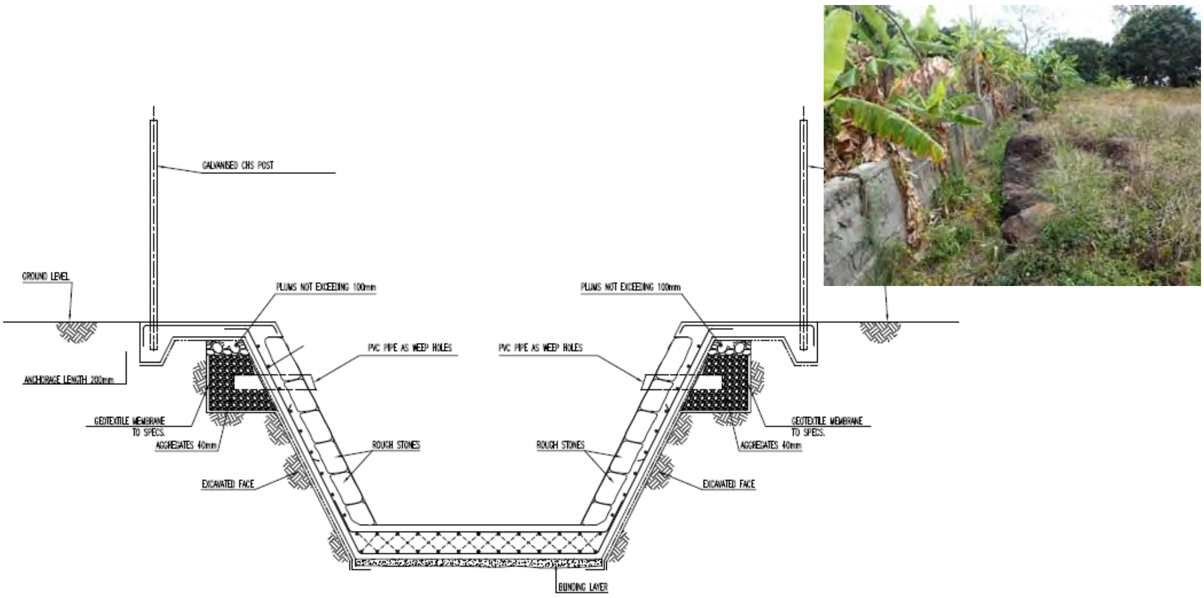


Figure 6.1.7 Typical Cross section of Protection of the Existing Water Course (source: JET)

The surface water on the existing water course (see the Figure below) overflowed in every rainy season because the water course does not have sufficient capacity for the volume of water flow. As a result, the residential area that is on the lower side of the water course is often affected by flooding. In this project, the existing water course will be upgraded to secure sufficient dimension of the drainage to discharge the surface water from the mountain side properly.

Figure 6.1.8 Location of the Existing Water Course that Often Overflows (source: JET)

Since there is a big gap about 5m height at the starting point of the water course, the drop structure will be installed to reduce the speed of water flow and to catch debris from water flow.

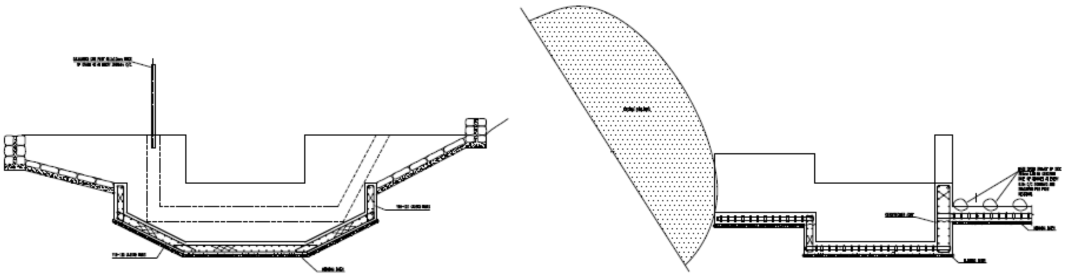


Figure 6.1.9 Typical Drawing of the Drop Structure (source: JET)

f. Ancillary Works

f.1 Bridge

Some parts of the community road or path in the project area will be cut due to the new construction of the drainages and channel. Thus bridges will be installed at those parts on the road or path. Two types of bridge shall be designed, one for pedestrians and one for vehicles according to the purpose of the road or path.

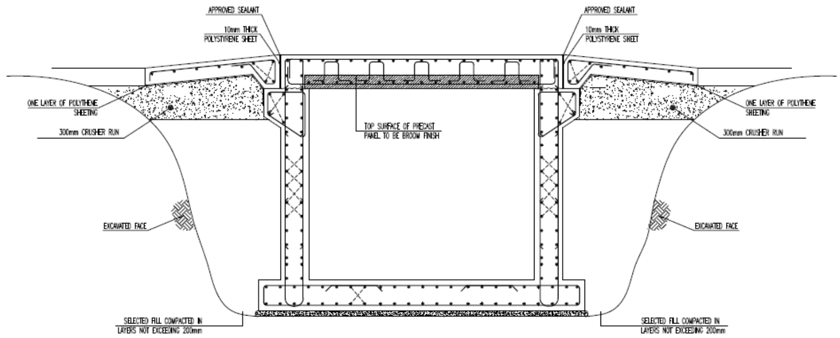


Figure 6.1.10 Typical Cross Section of the Bridge (source: JET)

f.2 Water Catch Basin

Water catch basin is installed at the junction of surface drainage and blind ditch to collect the shallow groundwater. The water catch basin has 20cm depth from the bottom of the connected drainage to catch the debris in the discharged water.

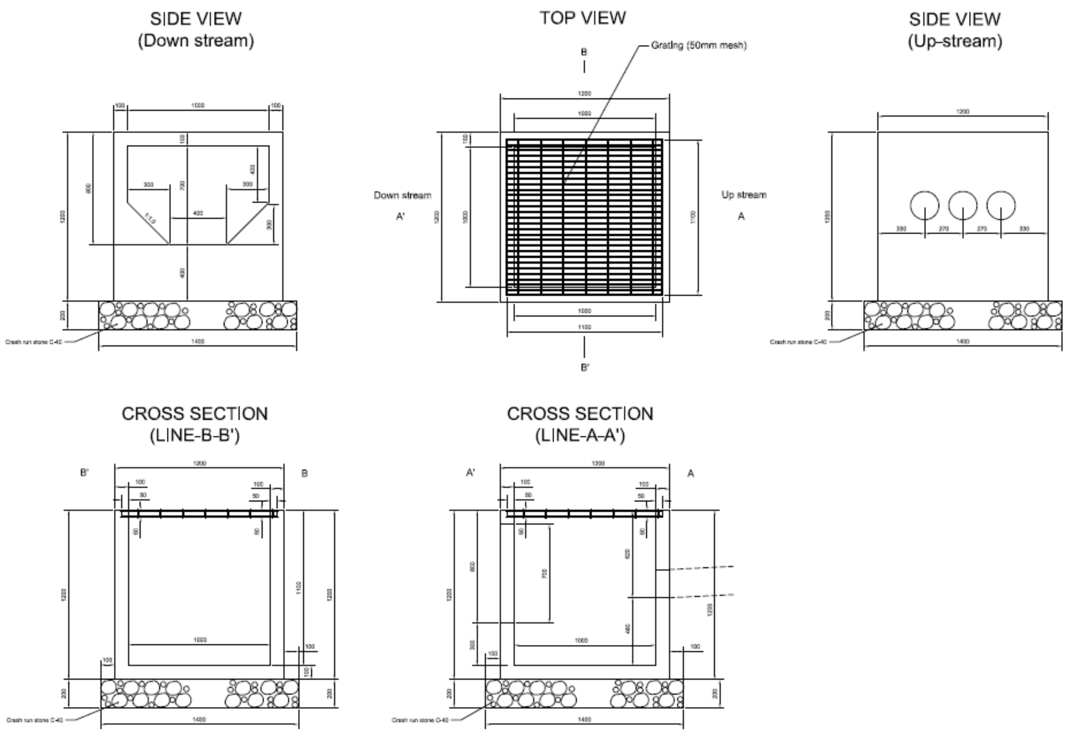


Figure 6.1.11 Typical Drawings of Water Catch Basin (source: JET)

6.1.2 Detailed Design of Countermeasure Works in Chitrakoot

a. Detail Design

Detailed design for countermeasure works in Chitrakoot area as the pilot site was carried out. A detailed specification for the structural countermeasure works was considered. The following structural works were selected.

- Channel for flood water
- Horizontal drainage work
- Open-blind ditch work
- Surface drainage work
- Blind ditch
- Upgrade of existing water course
- Ancillary work (bridge, water catch basin)

The alignment of the countermeasure works above are shown in Figure 6.1.12.

The target landslides in Chitrakoot area, which are evaluated as being active are Block-A landslide and Block-B landslide. As the plan of the countermeasure work mentioned in Chapter 5, the countermeasure works shall be applied prior to the Block-A landslide which is located upward of the Block-B landslide and is evaluated more active landslide than the Block-B landslide. Thus the detail design has been carried out for the countermeasure works for Block-A landslide and the channel for the flood water.

The final design of the countermeasure works for the Block-B landslide shall be carried out after verification of effectiveness of the countermeasure works of Block-A and the channel for the flood. The quantity of the countermeasure work for the Block-A landslide and the channel for the flood shall be as follows,

Table 6.1.4 Countermeasure Works (Control Work) for the Block-A Landslide (source: JET)

Work item		Quantity	Remarks
Channel for the Flood	CH-1	L=215m	
	CH-2	L=130m	
Horizontal Drainage work	HD-1	L=250m	50m*5
	HD-2	L=210m	50m*3＋30m*2
	HD-3	L=350m	50m*7
Open-blind ditch	OB-1	L=55m	
	OB-2	L=85m	
Surface drainage	SD-1	L=75m	
Blind ditch	BD-1	L=35m	Φ200*1
	BD-2	L=32m	Φ200*3
	BD-3	L=40m	Φ200*1
Upgrade of existing water course	UD-1	L=5m	Widening and protection
	UD-2	L=10m	Widening and protection
	UD-3	L=47m	Widening and protection
	RUD-1	L=175m	Widening and protection
	RUD-2	L=55m	Widening, protection and drop structure
Ancillary work	Br (for pedestrian)	2	Br-4, Br-5
	Br(for vehicle)	5	Br-1, Br-2, Br-3, Br-6, Br-7
	Water catch basin	3	

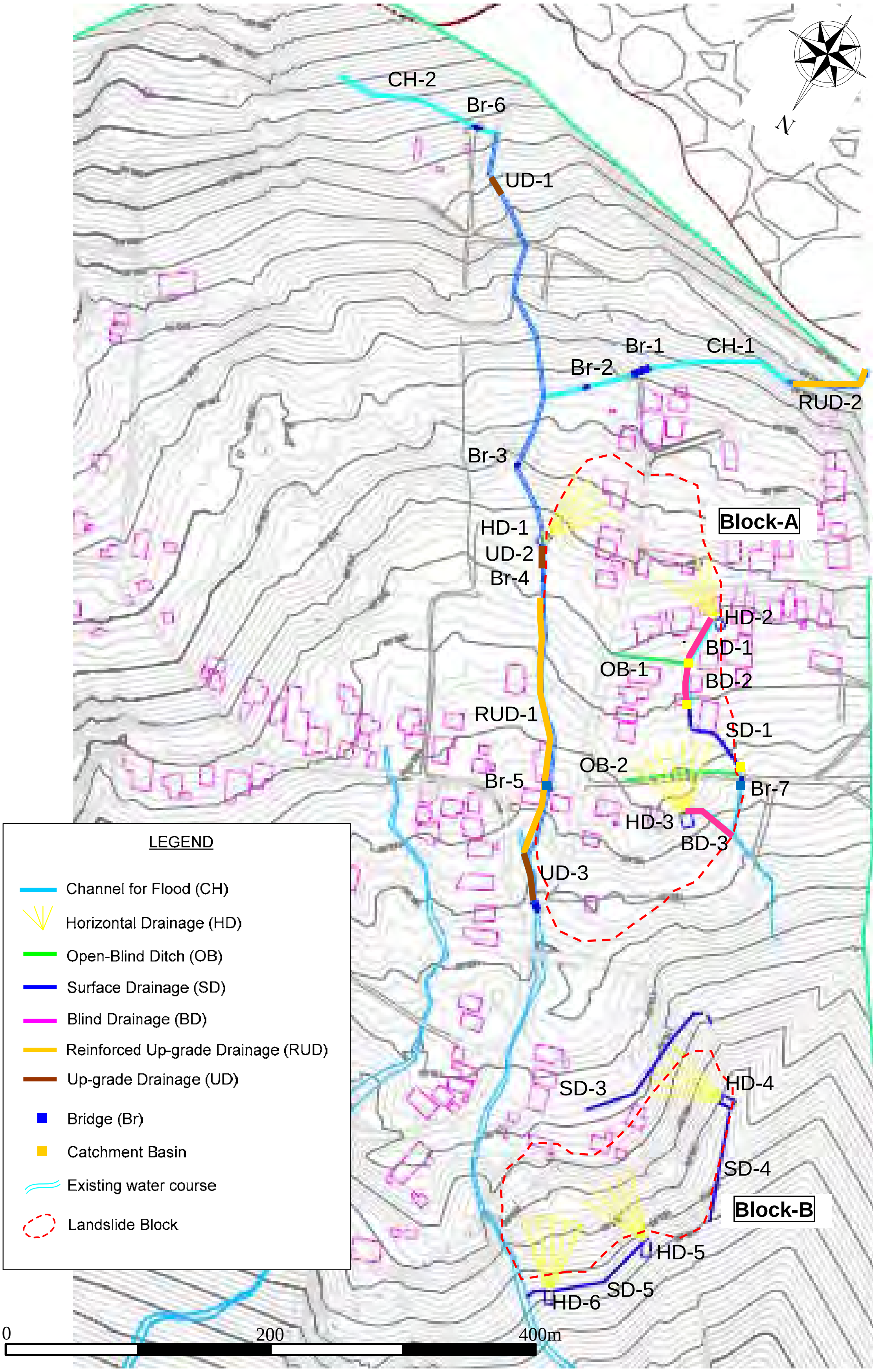


Figure 6.1.12 Location Map of Planned Countermeasure Works in Block A (source: JET)

a.1 Consideration for design of drainage dimension

Main purpose of the planning drainage works is to discharge properly the runoff and surface water at heavy rain. In a heavy rain time, large amount of water flows down with many soil, mud and fallen trees. Thus, designed cross sectional area of flow of the drainage shall be 80% of whole dimension of the drainage due to consideration of flowing down of sediments and trees. And there are many cases of sediment disaster that damage of disaster extended due to clogging of the bridge by flooding woods and changing of flowing course of water with debris. Thus dimension of flow of bridge shall be extended 20% from the dimension of the drainages.

a.2 Calculation of flow in each drainage

The required dimension of drainages was decided based on designed volume of runoff volume. The result of the calculation of the designed runoff volume and required dimension of each drainage is attached in the Supporting Report.

Runoff volume of surface water can be calculated by using the Rational formula.

$Q = 1 / 3.6 \times f \times r \times A$ -- (Formula 6-1)

where,
Q : Runoff volume (m^3/sec)
f : Flow coefficient
r : Intensity of rainfall (mm/hour)
A : Catchment area (km^2)

- Runoff coefficient: f

The runoff coefficient is decided with reference to the table below.

Table 6.1.5 Runoff Coefficient based on Ground Surface Condition[2,3]

Condition of ground surface			Runoff Coefficient
Road surface	Paved road		0.70 ~ 0.95
	Gravel road		0.30 ~ 0.70
Road shoulder, cut slope	Find grained soil		0.40 ~ 0.65
	Coarse grained soil		0.10 ~ 0.30
	Hard rock		0.70 ~ 0.85
	Soft rock		0.50 ~ 0.75
Grass on sandy soil	Gradient:	0 ~ 2%	0.05 ~ 0.10
		2 ~ 7%	0.10 ~ 0.15
		more than 7%	0.15 ~ 0.20
Grass on cohesive soil	Gradient:	0 ~ 2%	0.13 ~ 0.17
		2 ~ 7%	0.18 ~ 0.22
		more than 7%	0.25 ~ 0.35
Roof			0.75 ~ 0.95
Park			0.10 ~ 0.25

Gentle mountainous land	0.20 ~ 0.40
Steep mountainous land	0.40 ~ 0.60
Rice field, Water surface	0.70 ~ 0.80
Cultivated land	0.10 ~ 0.30

- Intensity of rainfall : r (mm/hr)

Intensity of rainfall is obtained from the matrix below. Generally 50 years return period and 15 minutes duration are utilized to estimate intensity of rainfall for design of drainage in Mauritius.

Table 6.1.6 Intensity of Rainfall[4]

		Return Periods (years)					
		2	**5**	**10**	**25**	**50**	**100**
Duration (min)	**5**	1.75	2.25	2.65	3.10	3.45	3.75
	10	1.45	1.85	2.15	2.45	2.75	3.05
	15	1.15	1.45	1.65	1.90	**2.10**	2.30
	30	0.95	1.20	1.40	1.65	1.85	2.05
	45	0.80	1.05	1.25	1.50	1.70	1.85
	60	0.65	0.90	1.10	1.30	1.50	1.70
	120	0.35	0.60	0.75	1.00	1.05	1.25

Intensity Rainfall (mm/min)

Therefore, intensity of rainfall to adopt for the design shall be:

r = 2.10 $\times$ 60 = **126** (mm/hour)

- Catchment area: A (km^2)

Water catchment area for the channel, surface drainage and open-blind ditch to collect runoff water is as follows.

Table 6.1.7 Water Catchment Area for Each Drainage (source: JET)

Drainage	Water Catchment Area (km^2)	Remarks
Channel for the flood (CH-1,CH-2)	0.380	Area I (refer to Figure 6.1.13)
Existing Water Course（UD-3)	0.017	Area II (refer to Figure 6.1.13)
Open-blind ditch（OB-1)	0.015	Area III (refer to Figure 6.1.13)
Open-blind ditch（OB-1)	0.006	Area IV (refer to Figure 6.1.13)

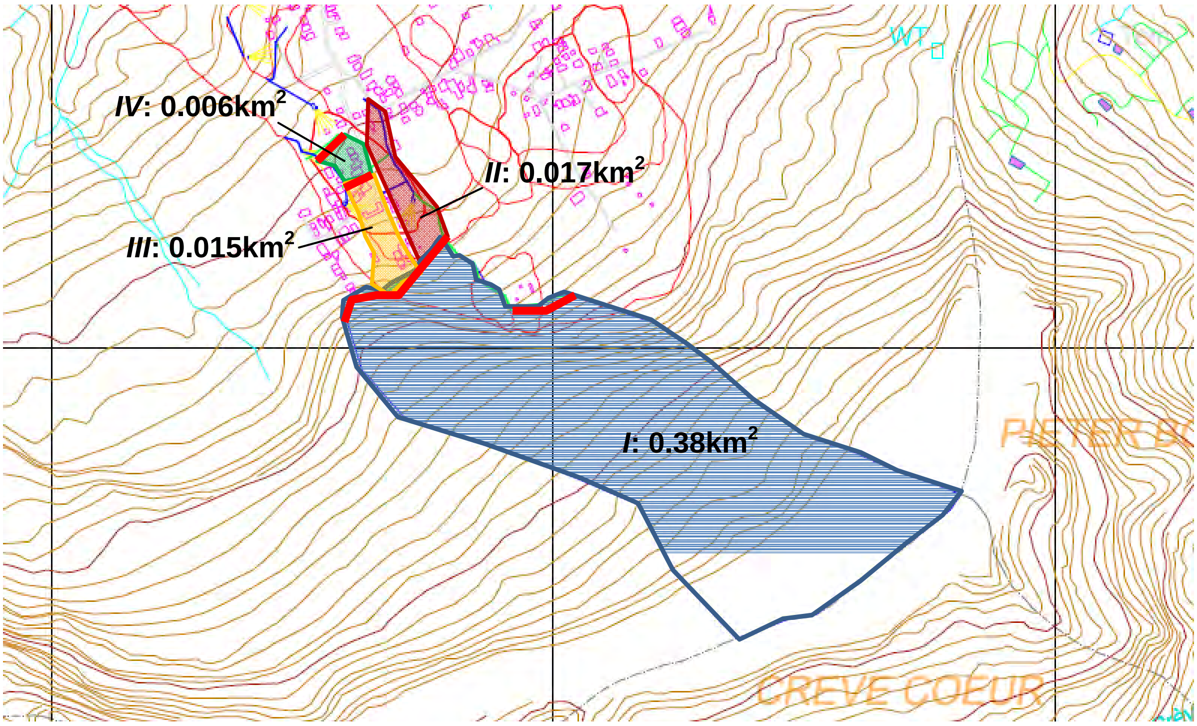


Figure 6.1.13 Water Catchment Area for Each Drainage (source: JET)

Dimension of the other drainages shall be decided based on the discharge capacity of drainage because they are not drainage for collecting surface water directly. Volume of discharged groundwater was calculated in Chapter a2 "Discharge Capacity of Drainage" below.

The result of the calculation of runoff volume of each drainage is shown in the table below. The detail calculation sheets are attached in the Supporting Report.

Table 6.1.8 Condition and Result of the Calculation of Runoff Volume (source: JET)

Drainage	Runoff Coefficient (f:)	Rainfall Intensity (r: mm/h)	Water catchment area (A:km^2)	Runoff Volume (Q:m^3/sec)
Channel for the flood （CH-1,CH-2)	0.4	126	0.380	5.320
Existing water course（UD-3)	0.22	126	0.017	0.131
Open-blind ditch（OB-1)	0.22	126	0.015	0.116
Open-blind ditch（OB-1)	0.22	126	0.006	0.046

Appropriate dimension of each drainage were studied in reference to the above runoff volumes.

a.3 Discharge Capacity of Drainage

The designed dimension of the channel is verified to check whether the channel has enough capacity to drain a sufficient volume of surface water.

Capacity of drainage of drains can be calculated using the following formula.

$Qa = A \times v$ -- (Formula 6-2)

where,
Qa: Discharge Capacity (m^3/sec)
A: Cross section area of flow (m^2)
v: Mean flow velocity (m/sec)

- Cross section area of flow: A (m^2)

The area of the flow of each drainage was applied the planned dimension which were considered during the Basic design stage. Cross section area of flow is 80% of whole cross section.

- Mean flow velocity: v (m/sec)

Mean flow velocity can be obtained by using the Manning formula

$v = 1 / n \times R^{2/3} \times i^{1/2}$ --- (Formula 6-3)

where
v： Mean flow velocity (m/sec)
n： Roughness coefficient ($m^{1/3}$sec)
R：Hydraulic mean depth (m) (= A/P: A:Cross section area of flow, P:Wetted perimeter）
i：Water slope

- Roughness coefficient: n

Roughness coefficient can be obtained from the following table.

Table 6.1.9 Manning's Roughness Coefficient[5,6]

Type of Drainage	Condition of Drainage	Range of n	Average of n
Culvert	Cast-in-place concrete		0.015
	Concrete pipe		0.013
	Corrugated metal pipe		0.024
	P.V.C pipe		0.010
Lining drainage	Steel, no painting, smooth	0.011~0.014	0.012
	Mortar	0.011~0.015	0.013
	Wood, planed finish	0.012~0.018	0.015
	Concrete, trowel finish	0.011~0.015	0.015
	Concrete, gravel bottom	0.015~0.020	0.017
	Masonry filled with mortar	0.017~0.030	0.025
	Dry masonry	0.023~0.035	0.032
	Asphalt, smooth	0.013	0.013
No lining drainage	Soil, straight, uniform dimension	0.016~0.025	0.022
	Soil, straight, with grass	0.022~0.033	0.027
	Gravel, straight	0.022~0.030	0.025
	Rock, straight	0.025~0.040	0.035
Natural drainage	Regular dimension	0.025~0.033	0.030
	Irregular dimension, grass and bush	0.075~0.150	0.100

- Hydraulic mean depth： R

The hydraulic mean depth can be obtained by the following formula.

R = A / P -- (Formula 6-4)

where,
A: Cross section area (m^2)
P: Wetted perimeter (m)

- Water slope: i

Water slope is applied 0.05 as slope of the channel is designed as 5% on average.

a.3.1 Discharge volume from the groundwater drainage work

Since runoff volume of the groundwater drainages cannot be obtained by the Formula 6-1, discharge capacity which will be obtained by Formula 6-2 based on the designed specification of drainage was calculated as discharge volume of the groundwater drainages.

Condition and result of calculation of discharge volume of each horizontal drainage pipe is as follows. Detail calculation sheets are attached on the Supporting Report.

Table 6.1.10 Condition and Result of Calculation of Discharge Volume of Each Horizontal Drainage Pipe (source: JET)

Condition	Area (A:m^2)	Mean flow velocity (v:m/sec)	Roughness coefficient (n)	Hydraulic mean depth (R:m)	Wetted perimeter (P:m)	Water slope (i:%)	Discharge volume (Q:m^3/sec)
Φ40mm, PVC	0.001	1.31	0.010	0.380	0.1005	0.08	0.00132

As the result of the calculation, designed discharge volume of the horizontal drainage work shall be as follows,

Table 6.1.11 Design Discharge Volume of Each Horizontal Drainage Work(source: JET)

Horizontal Drainage Work	Number of drainage pipe	Design Discharge Volume (Q:m^3/sec)
HD-1	5	0.0066
HD-2	5	0.0066
HD-3	7	0.0092

a.3.2 Discharge Capacity of Each Drainage

Dimension of the designed drainages was examined to have enough discharge capacity against runoff volume. The condition and result of the calculation for the discharge capacity is as follows. The detail calculation sheets are attached in the Supporting Report.

Table 6.1.12 Condition and Result of the Calculation for the Discharge Capacity of Each Designed Drainage (source: JET)

Drainage	Area (A:m^2)	Mean flow velocity (v:m/sec)	Roughness coefficient (n)	Hydraulic mean depth (R:m)	Wetted perimeter (P:m)	Water slope (i:%)	Discharge Capacity (Qa:m^3/sec)
CH-1,	1.36	5.33	0.025	0.459	2.96	0.05	7.24
CH-2	1.20	5.34	0.025	0.462	2.60	0.05	6.41
OB-1	0.19	2.45	0.025	0.143	1.34	0.05	0.47
OB-2	0.12	2.24	0.025	0.125	0.96	0.05	0.27
UD-1	1.36	5.12	0.027	0.486	2.80	0.05	6.96
UD-2	1.36	5.12	0.027	0.486	2.80	0.05	6.96
UD-3	1.36	5.12	0.027	0.486	2.80	0.05	6.96
SD-1	0.36	3.62	0.025	0.257	1.40	0.05	1.30
BD-1	0.025	3.00	0.01	0.050	0.50	0.05	0.08
BD-2	0.075	3.00	0.01	0.050	0.50	0.05	0.23
BD-3	0.025	3.00	0.01	0.050	0.50	0.05	0.08
RUD-1	1.36	5.53	0.025	0.486	2.80	0.05	7.52
RUD-2	1.17	5.00	0.025	0.419	2.80	0.05	5.87

Evaluation result of the availability of the designed drainage to discharge the runoff water is as follows,

Table 6.1.13 Evaluation Result of the Availability of Designed Drainages (source: JET)

Drainage	Runoff water volume (Q:m^3/sec)	Inflow volume from the connected drainages (Q:m^3/sec)		Total inflow (Q:m^3/sec)	Discharge Capacity (Qa:m^3/sec)	Evaluation
CH-1,	5.32	-		5.32	7.24	OK
CH-2	5.32	-		5.32	6.41	OK
OB-1	0.12	-		0.12	0.47	OK
OB-2	0.05	-		0.05	0.27	OK
UD-1	-	5.32	CH	5.32	6.96	OK
UD-2	-	5.32 0.001	CH-1 HD-1	5.32	6.96	OK
UD-3	0.131	5.32 0.001	CH HD-1	5.45	6.96	OK
SD-1	-	0.006 0.12+0.23	HD-2 OB-1	0.36	1.30	OK
BD-1	-	0.01	HD-2	0.01	0.08	OK
BD-2	-	0.01	HD-2	0.20	0.23	OK

Drainage	Runoff water volume ($Q:m^3/sec$)	Inflow volume from the connected drainages ($Q:m^3/sec$)	Total inflow ($Q:m^3/sec$)	Discharge Capacity ($Qa:m^3/sec$)	Evaluation
		0.12+0.08 OB-1			
BD-3	-	0.01 HD-3	0.01	0.08	OK
RUD-1	-	5.32 CH 0.001 HD-1	5.32	7.52	OK
RUD-2	5.32	-	5.32	5.87	OK

Since dimension of the bridge as ancillary work is $3.0m^2$ which is more than other drainages, it has enough discharge capacity against designed inflow or runoff water volume. The structure of the drainage and bridge were designed following the design standard for Concrete Structure by JET and MPI jointly.

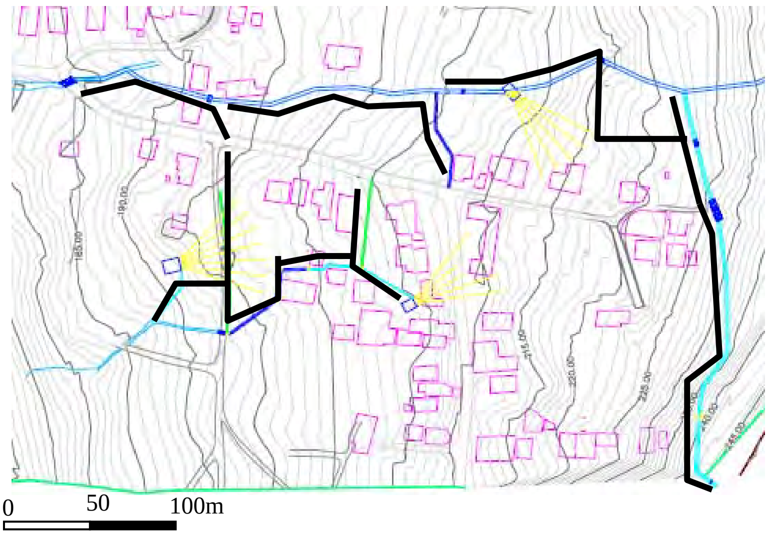
Typical designed drawings of each drainage and ancillary works are attached in the Supporting Report.

a.4 Temporary work (Access road for the works)

The access roads shall be prepared for implementation of the work.

Even though the route of access road shall be finalized by discussions with inhabitants and land owners, the reasonable route from a technical point of view is shown in the following figure. The road shall be at least 2 to 3m wide depending on the site conditions.

Table 6.1.14 Plan of Access Road for the Construction Work (source: JET)

	Total length：1,180m Road width：2~3m Land use Private land, Cultivated field (Banana, Maze, Mango etc) Since the target lands for the access road is flat/gentle, large scale excavation or fill work will not be required.

b. Quantity Survey

Quantity survey was carried out for the planned countermeasure works mentioned above.

The unit cost for each work item is obtained according to the Construction Industry Development Board: National Schedule of Rates (First edition), 2012. Since the unit cost for the horizontal drainage work is not available, cost estimation for the work was carried out with reference to the investigation cost conducted in the Project.

The general cost of the construction work was included cost for site office, felling tree, access road construction, mobilization, communication with relevant authorities, and cleaning of the site.

The result of quantity survey and the cost estimation of each work item is shown below. The detail data sheets are attached in the Supporting Report.

Table 6.1.15 Quantity Survey Result for Countermeasure Works for Block-A Landslide in Chitrakoot Area (source: JET)

Landslide	Countermeasure work	Work item	unit	quantity	Remarks
Common	Channel for the flood (Ch-1, Ch-2)	Excavation	m^3	1529.56	
		Blinding	m^2	552.34	
		Water proof sheet	m^2	849.75	
		Reinforcement	kg	13596.06	
		Rough stone	m^2	764.78	
		Safety fence	m^2	849.75	
		Frame work	m^2	329.31	
		Concrete	m^3	275.34	
Block-A	Horizontal drainage (HD-1, HD-2, HD-3)	Drilling work	m	810	>φ90mm, Installation of PVC pipe
		Excavation	m^3	633	Work space
		Concrete retaining wall	pc	3	Protection for outlet of drainage
	Open-blind ditch	Excavation	m^3	254	
		Stone wall with concrete	m^3	35	
		Mesh	m^2	280	
		Crush run filling	m^3	167	
		Geo-textile	m^2	351	
		Water proof sheet	m^2	224	
		PVC pipe installation	m	140	φ200
	Surface drainage	Excavation	m^3	87	
		Stone wall with concrete	m^3	24	
		Mesh	m^2	160	
		Crush run filling	m^3	34	
		Geo-textile	m^2	104	
		Water proof sheet	m^2	128	
	Blind ditch	Excavation	m^3	251.1	
		Geo-textile	m^2	294.1	

Landslide	Countermeasure work	Work item	unit	quantity	Remarks
Block-A		Water proof sheet	m^2	172.8	
		PVC pipe installation	m	188.0	
		Crush run filling	m^3	56.7	
		Back fill	m^3	108.0	
	Water catch basin	Concrete	m^3	41	
		Reinforcement	kg	2778	
		Excavation	m^3	42	
		Blinding	m^2	83	
		Framework	m^2	107	
	Bridge for vehicle	Excavation	m^3	50	per 1 bridge
		Blinding	m^2	15	per 1 bridge
		Reinforcement	kg	1380.4	per 1 bridge
		Framework	m^2	40.6	per 1 bridge
		Safety fence	m^2	4.8	per 1 bridge
		Back fill	m^3	8	per 1 bridge
		Concrete	m^3	28	per 1 bridge
	Bridge for pedestrian	Excavation	m^3	37	per 1 bridge
		Blinding	m^2	4.64	per 1 bridge
		Reinforcement	kg	149.9	per 1 bridge
		Framework	m^2	14.7	per 1 bridge
		Safety fence	m^2	4.8	per 1 bridge
		Back fill	m^3	2.8	per 1 bridge
		Concrete	m^3	3.04	per 1 bridge

Table 6.1.16 Quantity and Cost Estimation of Countermeasure Works in Chitrakoot Area (source: JET)[7]

Work Item		Quantity	Unit	Unit Cost	Cost of the Work (Rs)
Channel for the flood	CH-1	215	m	16,500	3,547,500
	CH-2	130	m	16,500	2,145,000
Horizontal drainage	HD-1	250	m	5,200	1,300,000
	HD-2	210	m	7,500	1,575,000
	HD-3	350	m	6,920	2,422,000
Open-blind ditch	OB-1	55	M	7,170	394,350
	OB-2	85	m	5,160	438,600
Surface drainage	SD-1	75	m	4,430	332,250
Blind ditch	BD-1	35	m	5,160	180,600
	BD-2	32	m	6,750	216,000
	BD-3	40	m	5,160	206,400
Upgrading of existing water course	UD-1	5	m	16,850	84,250
	UD-2	10	m	16,850	168,500

Work Item		Quantity	Unit	Unit Cost	Cost of the Work (Rs)
	UD-3	47	m	16,850	791,950
	RUD-1	175	m	18,200	3,185,000
	RUD-2	55	m	20,000	1,100,000
Ancillary works	Br (pedestrian)	2	pc	83,000	415,000
	Br (vehicle)	5	pc	300,000	600,000
	Water catch basin	5	pc	93,000	465,000

Rs: Mauritius Rupee

6.1.3 Plan for Construction

a. Work Plan and Schedule

Since the target project site for the countermeasure works is in the residential area and private land, and it is expected to take some time for land acquisition, it was decided to prioritize the measures and to conduct work that can be finished before the rainy season in December 2014 as pilot projects. The time schedule for the land acquisition was made in discussion with Ministry of Housing. As a result, the countermeasure work has been divided into two work sections. Work Section I shall be conducted in this project, and Work Section II shall be conducted by MPI after this project.

The work sections are shown on Figure 6.1.14 below.

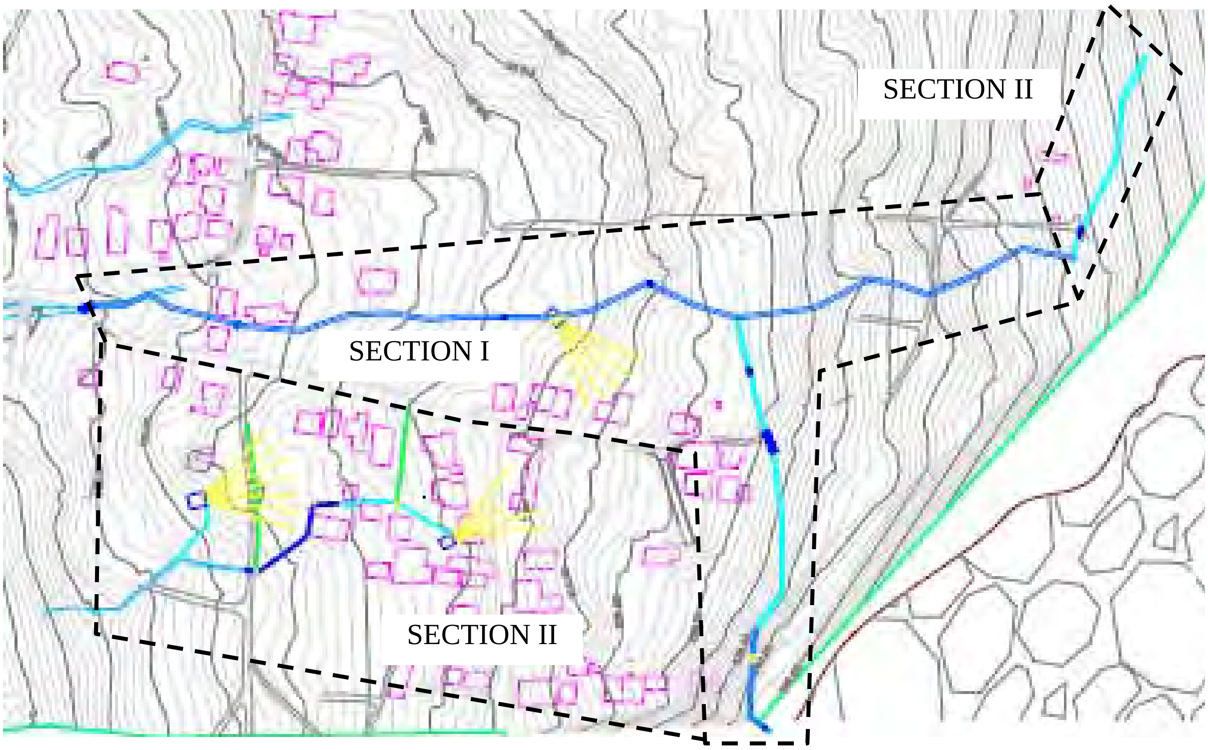


Figure 6.1.14 Work Section in Block-A Landslide (source: JET)

Work Section I was divided into two phases due to the time schedule of the land acquisition. The upgrading work of existing water course that land acquisition is not required is conducted in the Phase 1. Channel for the flood and horizontal drainage work required the land acquisition are in the Phase 2. The work schedule is shown in Figure 6.1.15.

The work is planned to be completed by December 2014 according to the schedule.

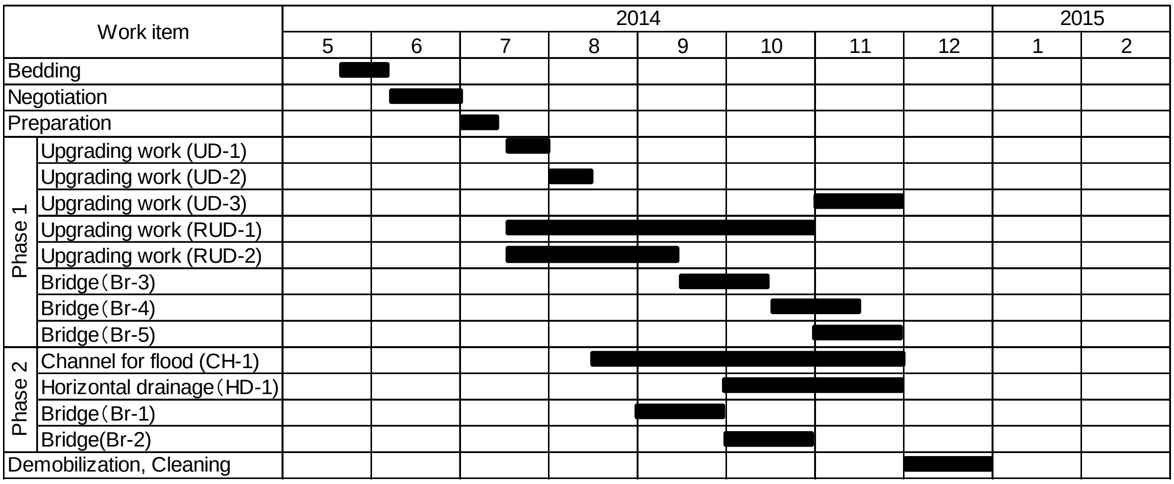


Figure 6.1.15 Work Schedule of Work Section I (source: JET)

b. Major Machinery and Materials for the Works

Major machinery and material for the works is shown in the list below.

Table 6.1.17 Major Machinery and Materials for the Works (source: JET)

Category	Item	Specification/Capability	Applied work
Material	PVC pipe	Internal dia.φ40, φ90, φ200, Radial thickness: > 4 mm	Horizontal drainage work Open-blind ditch work
	Geo-textile	Permeability、t > 5 mm	Surface drainage work Open-blind ditch work
	Water proof sheet	PVC , t > 2 mm	Surface drainage work Open-blind ditch work
	Gabion net	1 m×1 m×2 m	Horizontal drainage work
	Cement	Portland, Premix Grade 20	General
	Crusher run	0-20mm	General
	Natural Aggregate	14-20mm	General
	Rocksand	0-4mm	General
	Coral sand	0-7mm	General
	Rough stone	t=200mm	General
	Reinforcing steel bar		General
Machinery	Excavator	Capacity of bucket: 0.5 m^2, 1 m^2	General
	Dump truck	Max. load: 4 t, 10 t	General
	Skid steer loader	0.4m^3	General
	Bulldozer	D6-D8	General
	Loader		General
	Roller	4 ton	Access road
	Waterbowser	10m^3	General
	Concrete mixer	10/7	General
	Drilling machine	Percussion/rotary Capacity of drilling depth: >100 m Drilling direction can be changed on horizontal position.	Horizontal drainage work

6.1.4 Preparation of Bidding Documents and Bidding

The bidding process upon selecting the local contractor for the construction at the pilot project site is a compromise between Public Procurement Act of Mauritius and JICA's Guidelines for contracts with local contractors (April 2012). Table 6.1.18 shows the outline of the landslide countermeasure work.

Table 6.1.18 Outline of the Landslide Countermeasure Works (source: JET)

Item	Contents
Construction name	Construction of Landslide Countermeasure Works in Chitrakoot Area
Purpose	Implementation of landslide countermeasure works in one of the pilot project sites
Construction site	Chitrakoot area, Mauritius
Contents of the construction	Phase 1 1 Upgrading the existing river : Total length : 666m (Breakdown : Type1=98.0m, Type2=296.0m, Type3=175.0m, Type4=47.0m, Type 5=50.0m) 2 Construction of bridges : Bridge for vehicles : 1, Bridges for pedestrians : 2 3 Ancillary works : Removal of trees, vegetation Phase 2 1 Horizontal drainage works : Total drilling depth : 220m (Breakdown: 50m + 50m + 45m + 40m + 35m), φ40mm Erosion protection wall 2 Construction of new channel : Total length: 203m 3 Construction of bridges : Bridges for vehicles : 2 4 Ancillary works : Removal of trees, vegetation
Construction period	22nd July 2014 ~22nd December 2014 (tentative)

a. Details on Selecting the Local Contractor

As mentioned in the JICA guideline, the competitive bidding among contractors shall be selected for the contract amount above 10 million yen to ensure the transparency of public works. Therefore, the competitive bidding method was selected for this pilot project as the contract amount for the construction was estimated to be 50 million yen.

Also, this construction works may be the model case in Mauritius in future as this is the first time in Mauritius for the local contractor to implement such large scale landslide countermeasure works including the horizontal drainage work. Therefore, there is a need to select a reliable contractor with plenty of experience and that is able to conduct special works such as horizontal drainage work. In addition, the construction works should be finished during the dry season to avoid cyclones (December) which could trigger landslides. Considering the matters above, the selective competitive bidding method was selected through discussions with the counterparts.

Furthermore, the selective competitive bidding is also recommended in the Public Procurement Act of Mauritius if the construction requires special works and the contractors are limited (The Public Procurement Act 2006, Act No.33 of 2006, Part IV 19. Restricted bidding).

a.1 Long List of Local Contractors

For the selection of the competitive bidders, MPI has introduced the contractors which meet the requirements mentioned below (Table 6.1.19).

- Minimum average annual financial amount of construction works of 15 Million Rs over the last 3 years
- Two similar nature work experience (civil engineering) such as construction of surface drainage systems, bridges, culverts, etc. over the last 5 years.
- More than one of each of the following essential machines: horizontal drainage machine, concrete mixer, lorry, backhoe loader and track excavator.
- Registered Professional Civil Engineer to be designated as Contractor’s Representative, having a minimum of 5 years general experience in construction projects.
- Possess more than 2 million Rs of liquid assets and/or credit facilities net of other contractual commitments.

Table 6.1.19 Long List of Local Contractors (source: JET)

Company name	
1	General Construction Co., Ltd.
2	Sotravic Limitee
3	Transinvest Ltd.
4	Colas Ltd.
5	Gamma Civic Ltd.

b. Selecting Process and Schedule of the Bidding

According to the JICA guidelines, selective competitive bidding shall commence with the required screening before the opening of the bid. Then, the lowest bidder (below ceiling price) will be the candidate for the contract negotiation.

In the bidding system under Mauritius law, however, there is no opening of the bid. Generally, each contractor will submit the bidding document in a box installed in front of the procurement office in each organization. Then, the evaluation committee will be established and the successful bidder selected. In addition, if the bidding price exceeds 15% of ceiling price, the bidder will automatically be disqualified. The result of the evaluation shall be informed to every bidder who participated the bidding and at the same time, the results have to be publicized in the website of the Public Procurement Office (PPO) for the bidding price exceeding 15,000,000 Rs. Then an objection period of seven days will be given to the others before signing the contract with the lowest bidder.

Figure below shows the schedule and the process of bidding for this construction which has been discussed with the counterpart.

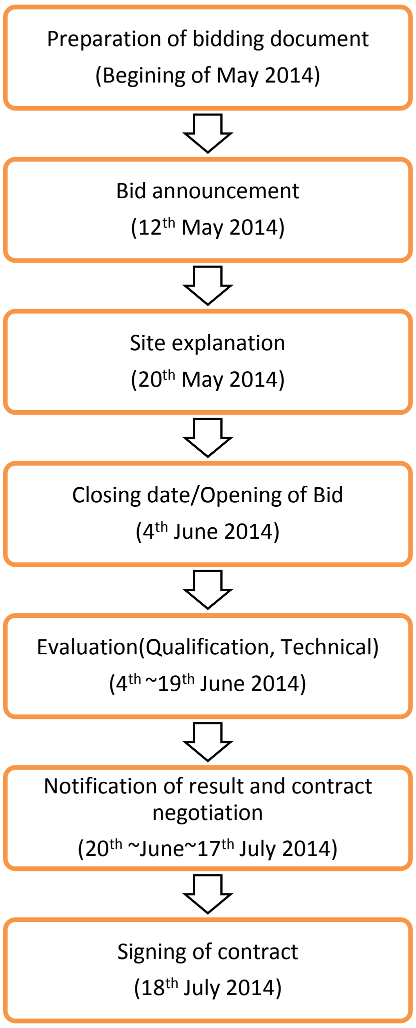


Figure 6.1.16 Schedule of the Bidding (source: JET)

b.1 Preparation of bidding documents

The bidding document was prepared based on the format of PPO. Bidding documents can be divided into three sections.

- Instruction to bidders, bidding data sheet, evaluation criteria
- Employer's requirements
- General and particular condition of contract, contract forms.

The technical specifications and drawings were prepared by the JET members and counterparts.

b.2 Bid announcement

The bid announcement was made to the five local contractors in the long list above. The bidding document and invitation letter were distributed during the bid announcement. The explanation regarding the necessity of participating in the opening of bid was made to the bidders according to the JICA guidelines. Also, the bidders have been asked to submit the bidding price and technical proposal before the opening of the bid.

b.3 Site explanation

The site explanation has been held on 20th May 2014. The explanation was made based on the bidding documents and four out of five local contractors participated.

Table 6.1.20 List of Local Contractors Participated in the Site Explanation (source: JET)

Company Name	Site explanation
General Construction Co., Ltd.	Did not participate
Sotravic Limitee	Participated
Transinvest Ltd.	Participated
Colas Ltd.	Participated
Gamma Civic Ltd.	Participated

b.4 Submission deadline and opening of bid

Two local contractors (Sotravic Limitee and Colas Ltd.) submitted the bidding price and technical proposal before the submission deadline.

The opening of the bid was held on 4th June 2014 at the JET office in the presence of coordinator from JICA Madagascar, counterparts, JET members and representatives from each consultant. The bid was opened at once in front of the concerned peoples only according to the instructions of JICA Madagascar. The reason is to avoid the leakage of the bidding price to the others.

The price was written on the whiteboard in front of the participants to secure transparency of the bidding. Also, the bidding price sheet was checked, confirmed and signed between JICA Madagascar, counterparts and JET members as documentary evidence.

Table 6.1.21 List of Local Contractor Participants in the Opening of Bid (source: JET)

Company Name	Site Explanation	Opening of Bid
General Construction Co.Ltd.	Did not participate	Did not participate
Sotravic Limitee	Participated	Participated
Transinvest Ltd.	Participated	Did not participate
Colas Ltd.	Participated	Participated
Gamma Civic Ltd.	Participated	Did not participate

b.5 Evaluation (requirement / technical)

The evaluation of the bid price and technical proposal of the two bidders were evaluated by the evaluation committee in two phases. First phase was the evaluation of the condition, qualification of the submitted bid and the second phase was the evaluation of the technical proposal by an engineer.

The evaluation committee for the first phase consisted of two JET members and two counterparts and the consideration on the condition and qualification of the bid price and technical proposal. The bid price was double checked to avoid the error of the numbers and calculation. The documents that do not meet the requirements are excluded at this stage, however both bidders met the requirements in this evaluation. The evaluation report was prepared based on the format of PPO.

The contents of the evaluation criteria are as follows.

<u>Mandatory requirements</u>

- Bid submission form duly filled and signed.
- Minimum average annual financial amount of construction of 15 million Rs over the last three years.
- Five years of work experience in civil engineering works
- Two similar works in civil engineering such as construction of surface drainage system, bridges, culverts, etc.
- The key equipment to be made available (horizontal drainage machine, excavator, lorry, concrete mixer)
- One Registered Professional Engineer as contractor’s representative with minimum of five years experience.
- Minimum amount of liquid assets and /or credit facilities net other than contractual commitments of 2,000,000 Rs.

<u>General responsiveness</u>

- Certificate of Incorporation / Bussiness Registration Card.
- Total monetary value of construction works performed for each of the last five years.
- Two similar works in civil engineering such as construction of surface drainage system, bridges, culverts, etc. (same as mandatory requirement)
- Major construction equipment proposed to carry out Contract. (same as mandatory requirement)
- Qualification and experience of the key site personnel and technical personnel.
- Report on the financial standing for the last 3 years.
- Evidence of working capital for this Contract.
- Authority to seek references from Bidder’s bankers.
- Information regarding any litigation during the last five years.

<u>Technical requirement</u>

- Program of works
- Key personnel: One Registered Professional Engineer as contractor’s representative with minimum of five years experience
- The key equipment to be made available (horizontal drainage machine, excavator, lorry, concrete mixer)

The second evaluation was undertaken by one JET member and two counterparts mainly on the adequacy of the technical proposal. The evaluation criteria are as follows;

- Adequacy of the program of works

・ Adequacy of the contents of works
・ The capacity of the horizontal drilling machine

From the evaluation above, both bidders satisfied the requirements of the technical proposal. Therefore, Sotravic Limitée was selected as the first candidate for the negotiation based on the comparison of the bidding price. The result of bidding price is as shown below.

Table 6.1.22 Result of Bidding Price and Selected Bidder (source: JET)

Bidder	Bidding Price (Rs) *Upper (Excluding VAT) Lower (Including VAT)	Contract Price (Rs) *Upper (Excluding VAT) Lower (Including VAT)	Yen (¥) Equivalent of Contract Price	Result
Sotravic Limitée	14,545,723 (16,727,581.45)	14,045,723 (16,152 ,581.45)	48,766,750	Agreement of Contract
Colas Ltd	24,789,305 (28,507,700.75)	–	–	Second Candidate

Rate 1 Rs = 3.472 Yen (OANDA rate on the contract agreement (7/18))

b.6 Notification of the evaluation result and contract negotiation

The Letter of Acceptance was sent to Sotravic Limitée on 20th June 2014 and 21 days was given as the response period. The contractor prepared the Performance Security and Insurance Policies as it needs to be submitted during this period. Also, a meeting was held on 30th June 2014 at JET office with the contractor to discuss about the contents of the Contract. The points discussed are as follows;

1. The period of payment: The contractor will prepare the invoice based on the bill of quantity. The first payment is scheduled in July and the last payment is in December (total: six times). The advance payment is not allowed as in Contract
2. Contingency Fee of 500,000 Rs will be excluded from the Contract as it is an expense for the unforeseen. Amendment of Contract will be made in case the unforeseen event.
3. The re-submission of the Performance bond was requested to the contractor as JICA Madagascar and Kokusai Kogyo Co., Ltd. (JET) will be the claimant of the performance bond which is effective up to the end of the defects liability period.
4. Retention money will be replaced with the bank guarantee for the defects liability period.

b.7 Signing of Contract

The Contract was signed on the 18th July 2014 with the amount of 16,152,581.45 Rs. The JET member at the site was delegated for the signing of Contract as the Project Chief was not in Mauritius.

<u>Refund of VAT (Value Added Tax)</u>

The payment to the local contractor will be made including VAT though it will be refunded through the counterpart government (MPI) after the necessary procedure. The invoice is needed for the VAT refund procedure and the amount of VAT will be deducted during settlement of the payment with JICA. The contract amount without VAT is 14,045,723 Rs (48,766,750 Yen: Rate 1 Rs = 3.472 Yen (OANDA rate on the contract agreement (7/18)).

b.7.1 Overall evaluation of the Contractor

Sotravic Limitée is a one of the largest construction companies in the Mauritius infrastructure industry. This company has also received the contract for the installment of the monitoring devices in this project and has the experience of drilling in landslide areas. Also, this company owns a horizontal drilling machine and it is expected to have knowledge and skills of drilling. This company also has the knowledge of the construction site and therefore can undertake the construction efficiently. Based on the conclusion above, the Contractor is suitable for this construction.

6.1.5 Supervision

JET and MPI counterpart supervised the countermeasure works of this project. The supervision was carried out to check the following items.

- Work performance and quality control
- Work schedule
- Regular site meeting with stakeholders
- Arrangement with relevant authorities
- Dealing with design changes
- Safety control for the works

The progress and issues of the works were checked with weekly and monthly reports which were submitted by the contractor, and shared with stakeholders in the site meeting which was held at the site fortnightly.

6.1.6 Design Changes

Design of the works was changed due to unexpected issues regarding the ground condition and requests from some land owners were raised during the work period. The changed designs are shown in the table below.

Table 6.1.23 List of Changed Design Part (source: JET)

Target work	Changed item	Reason
Channel for the flood (CH-1)	Alignment	An alignment whereby less excavation soil volume than the original alignment was confirmed during the site visit
	Drainage Structure	It was confirmed that the actual ground condition is firmer than was expected based on the existing geotechnical investigation result
Bridge for pedestrian (Br-5)	Location	Land owner requested the bridge to be shifted. Upon discussions with MPI and stakeholders, the location of the bridge was shifted 15m upstream from the original position.
	Bridge Structure	In conjunction with shifting the bridge, the bridge structure was changed.

Upgrading of existing water course (UD-3)	Cancel for whole stretch of the drainage (47m)	Approval from the land owner could not be gained during the project period even though JET and MPI tried to convince the land owner in several times.
Upgrading of existing water course (RUD-1)	Drainage Structure for 70m stretch of upstream	Land owner requested that width of the drainage be made narrower than the original plan. Upon discussions with MPI and stakeholders, the drainage design was changed to one with a discharge area.
	Cancel for 35m stretch downstream	Approval from the land owner could not be gained during the project period even though JET and MPI tried to convince the land owner several times

Other minor changes were done based on discussions with MPI and land owners accordingly.

6.1.7 Future Plan

The countermeasure works of Section I at Block-A landslide has been completed in this Project. Now it is necessary that other countermeasure works are carried out continuously.

Future plan of landslide countermeasure work for the Chitrakoot area shall be carried out according the work flow shown on Figure 6.1.17.

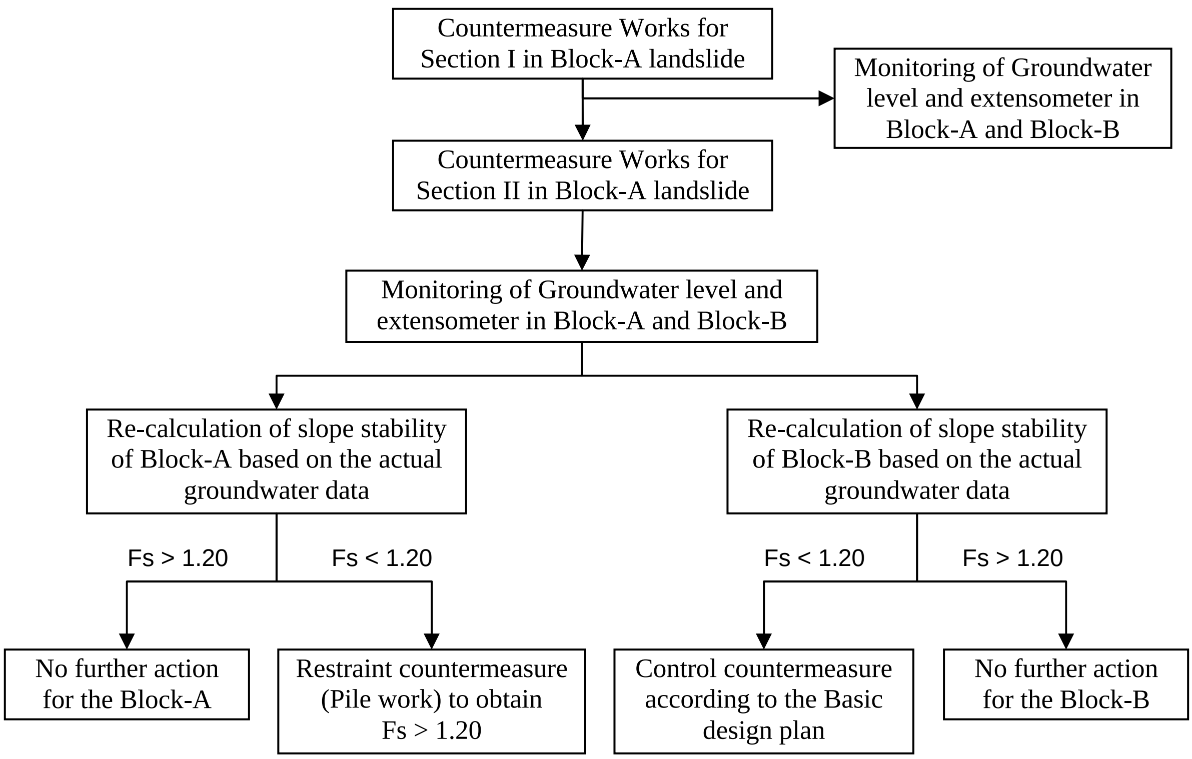


Figure 6.1.17 Flow Chart for Future Plan of Landslide Countermeasure Works in Chitrakoot Area (source: JET)

At present, countermeasure works of Section I for Block-A landslide has been done. After this, the planned countermeasure works of Section II including the cancelled works in the Section I due to issue of land acquisition shall be carried out by the MPI. According to the design of the countermeasure works, planned safety factor of the target landslides will be secured after installation of all planned countermeasure works. Even now a time when the countermeasure works of Section I, monitoring of groundwater level and landslide activity by the extensometer and pipe strain gauges shall be carried out continuously to check the difference from before and after installation of the countermeasure works. It is recommended that the landslide stability analysis shall be carried out to check the change of factor of safety of landslide after installation of the works based on the groundwater level.

Since the work site of Section II is located in a residential area, land acquisition shall be proceeded cautiously. In case that it is difficult to acquire the planned land for the works, it can be changed the location or alignment of the drainage accordingly.

Table 6.1.24 Planned Landslide Countermeasure Works in Chitrakoot Area (source: JET)

Section		Work item	Quantity	unit	Remarks
Block-A landslide	Section II	Channel for the flood CH-2	130	m	
		Upgrading of existing water course RUD-1 (Type3 drainage)	35	m	Cancelled during Section I
		Upgrading of existing water course UD-3 (Type4 drainage)	47	m	Cancelled during Section I
		Horizontal drainage (HD-2)	210	m	
		Horizontal drainage (HD-3)	350	m	
		Surface drainage (SD-1)	75	m	
		Open-blind ditch (OB-1)	55	m	
		Open-blind ditch (OB-2)	85	m	
		Blind ditch (BD-1)	35	m	
		Blind ditch (BD-2)	32	m	
		Blind ditch (BD-3)	40	m	
		Water catch basin	5	pc	
		Bridge	2	pc	For vehicles
		Manhole for maintenance	12	pc	On the blind ditch

After completion of the works of the Section II, groundwater level and landslide activity shall be confirmed by the monitoring. Since the applied groundwater level for the stability analysis is the highest groundwater level which was observed in the rainy season, the data for the analysis shall be applied the highest groundwater level which is observed in at least one rainy season after completion of the countermeasure works of Section II.

Regarding the stability analysis to check the factor of safety of landslide after completion of the countermeasure works, analysis landslide model shall be used the model which was used in the design stage. Parameter for the analysis such as cohesion, internal friction angle or unit weight shall not be changed, but only groundwater level which is observed as the highest level during the rainy season.

In case that the factor of safety of Block-A landslide is more than 1.20 and no movement is detected by the extensometer, additional restraint work can be put on hold. However, the monitoring of groundwater level and landslide movement shall be carried out continuously, and it shall be considered possibility of re-activation of the landslide. If rising of groundwater level or movement of landslide is detected, additional countermeasure works shall be examined.

Reference value of the groundwater level to achieve the planned factor of safety is shown below.

Table 6.1.25 Reference Value of the Groundwater Level to Achieve the Planned Factor of Safety (source: JET)

Monitoring borehole/well	Fs=1.13 (Planned)	Fs=1.20 (Final Target)	Remarks
BPP 16	> GL-2.9m	> GL-3.9m	Near the school
BPP 11	> GL-2.1m	> GL-3.1m	
W-2	> GL-3.3m	> GL-4.3m	
BPP 8	> GL-5.4m	> GL-6.4m	Out of the landslide area

GL: Ground Level

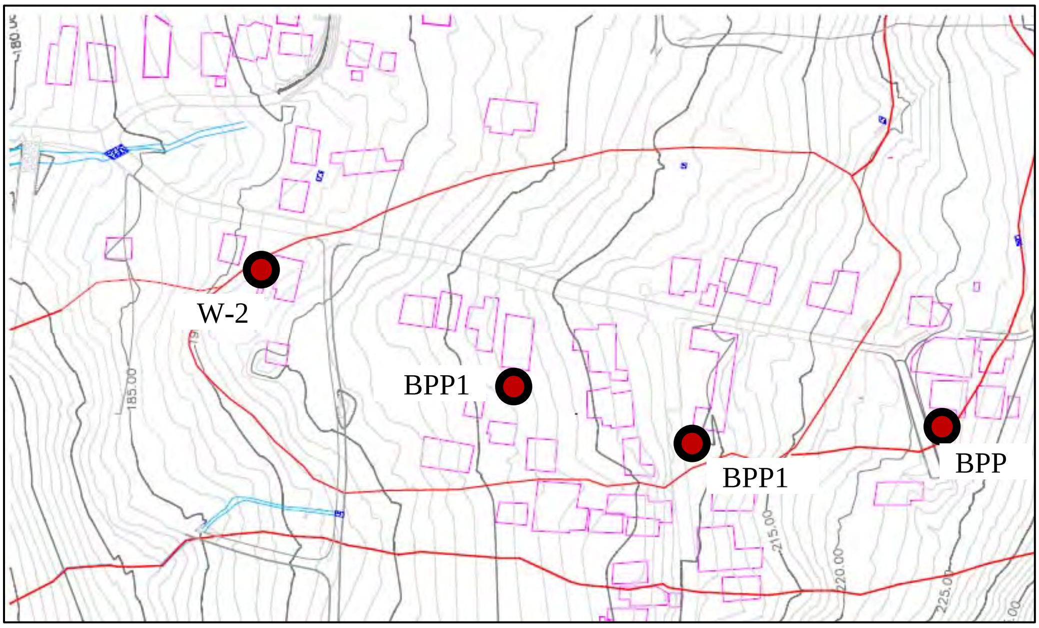


Figure 6.1.18 Location of Monitoring Borehole for Block-A Landslide (source: JET)

Groundwater level at BPP8 shall not be used for evaluation of stability of the landslide directly due to it is out of the landslide area. In case that the groundwater level at other three boreholes is confirmed as the reference values, it can be assumed that stability of the target landslide is achieved the planned factor of safety.

In case that the factor of safety of Block-A landslide is less than 1.20, restraint work shall be planned. According to the condition of topography and land use at the site, pile work shall be recommended. Planning and design of the pile work shall be done in reference to the "Procedure Manual for Landslide" which is prepared in this project.

The countermeasure works for Block-A landslide can be considered to contribute to the stability of the Block-B landslide. Thus, monitoring of groundwater level and landslide movement for the Block-B shall be carried out to check the factor of safety of the landslide. However the existing monitoring borehole namely BPX 2 is not available to measure a groundwater level. Therefore, it can be recommended to install new monitoring borehole on the Block-B landslide area (refer to Figure 6.1.18). The reference value of the groundwater level at each monitoring borehole to achieve the planned factor of safety is shown in Table 6.1.19. In case that factor of safety of the Block-B landslide is more than 1.20 and no movement is detected by the extensometer, the planned countermeasure works for the Block-B landslide can be put on hold. However, the monitoring of groundwater level and landslide movement shall be carried out continuously, as there is a possibility that the landslide may become active again.

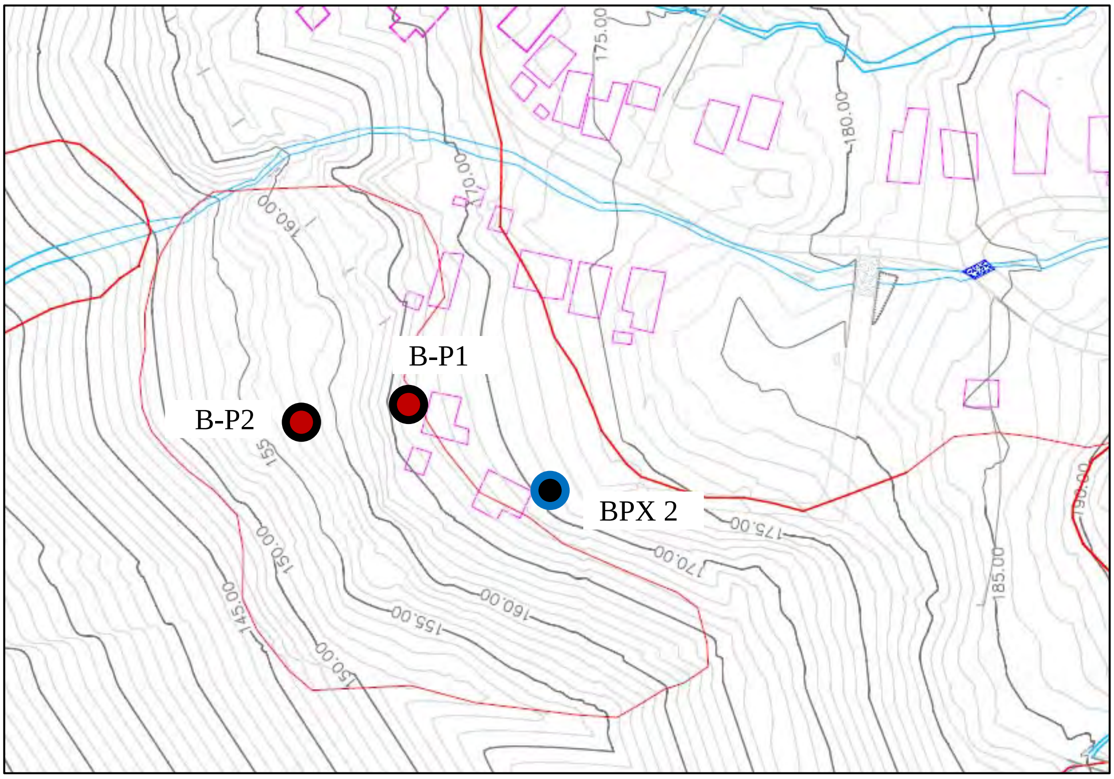


Figure 6.1.19 Location of Monitoring Borehole for Block-B Landslide (source: JET)

Table 6.1.26 Reference Value of the Groundwater Level to Achieve the Planned Factor of Safety (source: JET)

Monitoring Borehole	Fs=1.17 (Planned)	Fs=1.20 (Final Target)	Remarks
B-P1	> GL-3.5m	> GL-4.0m	to be installed
B-P2	> GL-3.4m	> GL-3.9m	to be installed

6.1.8 Available Countermeasure Works in Mauritius

Landslide countermeasure work shall be installed to achieve the safety factor of the target landslide to planned safety factor. If the current safety factor is not achieved to the planned safety factor after installing countermeasure work, additional work shall be considered to installed as necessary. Landslide countermeasure work in Chitrakoot area also shall be followed in same way. The landside stability in Chitrakoot shall be verified after installing the planned countermeasure works.

The countermeasure work which can be considered to be available in Mauritius in the future is as follows,

Table 6.1.27 Available Countermeasure Work in Mauritius(source: JET)

Work item		Purpose	Availability
Control work	Surface drainage work	To collect surface water and to discharge it to out of landslide area	Many experiences of the work in Mauritius.
	Open-blind ditch work	To collect surface water and shallow groundwater and to discharge it to out of landslide area	Even there is not many experiences of the work, difficulty of the work is not high
	Horizontal drainage work	To reduce groundwater level by discharge the groundwater.	The work has experienced to be carried out in the Project
	Drainage well work	To reduce groundwater level by discharge deep groundwater	Excavation of drainage will be available in Mauritius. The issue will be procure the small drilling machine to carry out horizontal drilling in the well
	Soil removal work	To reduce a sliding force of landslide by remove a head part of the landside block	Difficulty of the work is not high. However, since there are many landslide blocks in Chitrakoot area, it shall be carried out with deep caution to avoid extension of the hazard area by the work.
	Counterweight fill work	To increase resistance force against landslide by filling at toe part of the landslide block	Difficulty of the work is not high. However, since there are many landslide blocks in Chitrakoot area, it shall be carried out with deep caution to avoid extension of the hazard area by the work.
Restraint work	Ground anchor work	To stop landslide activity by tightening of anchor which is fixed on stable ground.	There is not experience of the work as landslide countermeasure work in Mauritius. The issue of the work will be procure the materials of the anchor and contractor which has many experiences of the work from abroad. Therefore, the work will be difficult to apply in Mauritius at this time.

	Pile work	To stop landslide activity by resistance force of pile which is fixed on stable ground.	Even there is not experience of the work for landslide countermeasure work done by local contractor, there are many experience of the pile work for building foundation. Therefore the work will be available to apply for landslide countermeasure work if suitable material of the pile which has required restraining force against landslide can be procured.

The additional countermeasure works shall be selected in consideration with topography of planned work area, influence to surrounding environment and workability of the work.

6.1.9 Development in the Landslide Hazard Zone after the Landslide Countermeasure Works

The mechanisms of landslide are complicated and it is very difficult to stop the landslide activity completely. Hence, the role of landslide countermeasure works is to raise the existing factor of safety (Fs) to greater than 1.2 and not to permanently prevent landslide. A landslide might be reactivated by deterioration of the soil strength on landslide slip surface or heavy torrential rain (such as rainfall exceeding a 50 year probable rainfall used to design landslide countermeasures at Chitrakoot) resulting from abnormal natural phenomenon (climate change) in future.

In the country with abundant experience of slope disaster such as Japan, the designation of landslide hazard zone will not be terminated even though after landslide countermeasure works have been implemented. Therefore, there will be no termination of the designation of the landslide hazard zone made by this Project (Chitrakoot, Vallee Pitot and Quatre Soeurs) in the future too.

All kind of development for infrastructure or housing is basically prohibited in the landslide hazard zone. However, the minor maintenance work of houses or roads can be implemented. The table below shows the advisability of the development activities in the landslide hazard zone.

Table 6.1.28 Advisability of the Development Activities in the Landslide Hazard Zone (source: JET)

Type of development	Advisability	Application
Minor maintenance of houses, school building etc.	Possible	Maintenance of roofs and walls only. Maintenance involving excavation of the foundation, cutting/filling is prohibited.
Minor maintenance of public infrastructure such as roads, bridges etc.	Possible	Only maintenance of public infrastructure such as roads, bridges, water and sewage etc. Maintenance involving excavation of the foundation, cutting/filling is prohibited.
New/additional construction	Prohibited	Basically, the new/additional construction of

of houses, schools etc.		building is prohibited
New/additional construction or replacement of public infrastructure such as roads, bridges etc.	Prohibited	Basically, the new/additional construction or replacement of public infrastructure such as roads, bridges, water supply and sewage etc. is prohibited
Development other than mentioned above	Prohibited	Basically, the development activities in the landslide hazard are is prohibited.

<Screening standard for the exceptional development>

In case there is inevitable development activities needed to be implemented in the landslide hazard zone such as new/additional construction or replacement of roads, bridges, water supply and sewage and other public infrastructures, the sufficient investigation/analysis of the points mentioned below shall be undertaken.

- Implementation of stability analysis of the landslide and confirming the factor of safety (Fs) of the landslide is greater than 1.2 after the construction.
- If the factor of safety (Fs) is less than 1.2, the landslide countermeasure works shall be implemented.
- The implementation of the landslide countermeasure works shall be implemented before the development activities.
- The fall of the factor of safety (Fs) during the construction (development activities, landslide countermeasure work and cutting/filling) shall be within 5%, and any works which exceed 5% fall in factor of safety (Fs) shall be prohibited.
- Preventing the water retention from rainfall inside and downstream of the landslide area by installing the water drainage facilities such as surface drainage, retention basins, grit chambers etc.

6.2 Early Warning and Evacuation

6.2.1 Present Situation and Issue in Mauritius

a. The Cyclone and Other Natural Disaster Scheme

The Republic of Mauritius has a robust Early Warning System within the Cyclone and Other Natural Disaster Scheme which includes a preparedness plan for disaster risk reduction. The Scheme has defined the Emergency Operation Plan for hazards likely to threaten Mauritius and/or outer islands with clear response and rehabilitation measures by the relevant authorities. Education and public awareness at community level has also been well established. The defined disasters are:

- Cyclone
- Torrential rain
- Landslide
- Tidal Surge
- Tsunami

b. Landslide Emergency Scheme

Thirty seven (37) Risk Areas have been identified in the Landslide Emergency Scheme, and a program to install rain gauges to monitor rainfall in these areas is indicated. The landslide warning and evacuation system consists of the following five stages: Preparatory, Warning, Evacuation, Emergency and Termination as shown in Table 6.2.1. Stage 4 is related to cyclone warning and is not based on landslide monitoring.

Table 6.2.1 Five Stages in Landslide Emergency Scheme (source: JET)

Stage		Criterion	Monitored by
Pre stage	Invocation	Precipitation: 30mm/12 hours	Meteorological services
Stage 1	Preparatory Stage	Ground displacement of 2mm/day	MPI
Stage 2	Warning Stage	Ground displacement of 1cm/day, or Visual displacement confirmed	MPI
Stage 3	Evacuation Stage	Ground displacement of 2mm/day	MPI
Stage 4	Emergency Stage	Sudden Landslide or Cyclone Warning / Torrential Warning	(on Cyclone Warning)
Stage 5	Termination	Stabilization of ground movement	MPI

Landslide Emergency Scheme has the flowing features:

- The Scheme has defined five stages of the Emergency Operation Plan for Landslides.
- Warning and evacuation levels (stages) goes up from lower stage to upper stage one by one.
- The shift to upper stage is based on the extensometer monitoring basically.
- Stage 4 is different from other stages. Operation and actions in Stage 4 are following cyclone scheme. This means the authority and the inhabitants must take action in cyclone warning, even any landslide movements are not monitored
- Many organizations are involved at each stage. At Stage 2 and Stage 3, the information goes up to Prime Minister’s Office and the Crisis Committee will be called. The action of inhabitants involved in the disaster could be late with huge and lengthy information system.

c. Position of MPI in Landslide Emergency Scheme

Many organizations and authorities are involved in the Landslide Emergency Scheme. Figure 6.2.1. below shows the basic flow of the information.

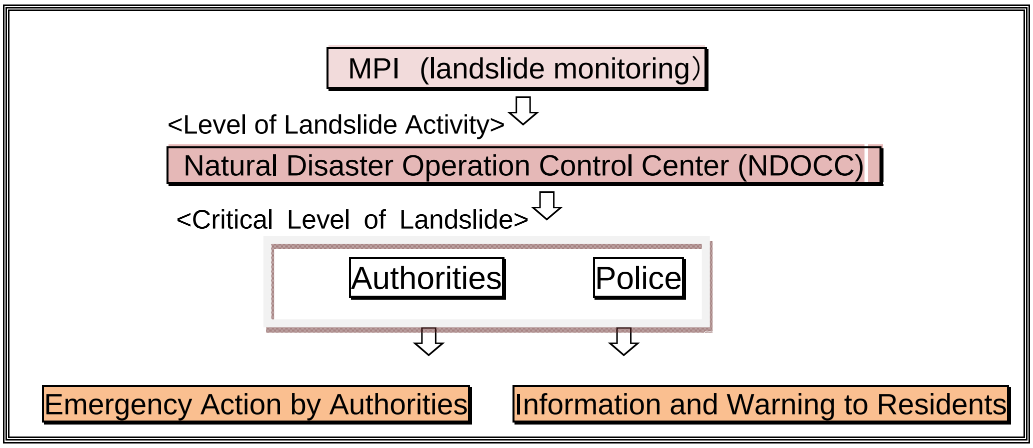


Figure 6.2.1 Circulation of the Information (source: JET)

As shown in Figure 6.2.1, the activity and the risk level of landslide should be informed by MPI to the authorities. The police should inform to the inhabitants involved in the landslide risk area and take care of them. NDOCC is the control center in the warning of disasters.

In the Cyclone and Other Natural Disaster Scheme, disaster information and disaster control system for cyclone and flood are well organized. Meteorological Agency plays a role as an information center and the police play an important role in the refuge instruction of inhabitants in cyclone and flood disasters.

For the landslide disasters, it is necessary to predict where, when and what kind of disaster will occur at every landslide risk areas. This is the most different point from cyclone disaster which involves whole country of Mauritius. Even Meteorological Agency, the police or the inhabitants can not predict the landslide disasters, only MPI can predict the landslide disasters based on their monitoring or observation. Therefore, Landslide Emergency Scheme defines MPI organization responsible for issuing announcements of risk stage.

d. Issues of Landslide Emergency Scheme to be dealt by MPI

In order to inform the risk levels of landslides in accordance with the Landslide Emergency Scheme, there are several problems that should be settled by MPI.

- MPI could not reach to the landslide risk areas in heavy rains because of blockages of roads or floods in the country.
- MPI could not exchange the information according to the stipulated communication framework due to the mobile phones system failures in the country.
- The extensometers are installed at limited places only and they cannot be installed easily because they require strong protection to prevent thefts.
- The rain gauges are installed at limited places only for the same reasons as the extensometers.
- The information system in Landslide Emergency Scheme is very huge, as it requires the information to reach the Prime Minister's Office. Most of the landslides in Mauritius are not big and sometimes only one or two houses are at risk from a

landslide. The huge information system should be reconsidered whether it is necessary for such a small landslide disaster.

6.2.2 Proposal of Early Warning and Evacuation System

a. Alert Level (Threshold)

Fundamental principles of the Landslide Disaster Scheme which is the part of Cyclone and Other Natural Disasters Scheme is the following three points.

- It is early warning. (It does not include response and recovery after a disaster.)
- It protects only people's lives. (It is out of the scheme to protect their possessions including livestock and pets)
- Alert level must be the index of danger to people's lives. (It is not the index of danger to residential houses)
- The subject of Landside Disaster Scheme is only slow-moving landslides, and rockfalls, slope failure, debris flow are not the subject. (especially Chitrakoot, Vallee Pitot and Quatre Soeurs are the main subject)

The third one above is the most important thing to protect people's lives. The warning must be issued anytime when a danger is imminent. Failure to issue a warning when there is imminent danger must be avoided at all costs.

Table 6.2.2 below shows proposed warning stages and their thresholds based on two years landslide monitoring in Chitrakoot, Vallee Pitot and Quatre Soeurs.

Table 6.2.2 Proposed Early Warning of Landslide Disaster (source: JET)

Warning Stage		Threshold	
		Movement of the ground (extensometer)	Deformation of each house
Stage 1	Precaution	20 mm / month or more	<new signs of landslide> New cracks are found in a house. New deformations are found on walls or floors of a house. New crack or deformation are found on the ground, a retaining wall, or a road around the house.
Stage 2	Alert	10 mm / day or more	<progress of cracks or deformation> Opening of the cracks become wider The deformations on the floor or the wall become bigger. The cracks or deformations around the house become bigger. (Opening speed of the cracks : 2 mm/hour)
Stage 3	Evacuation	20 mm / day or more	<further progress of cracks or deformations> New cracks are found in the house. The cracks and deformation become bigger and bigger in the house. The house next door or walls around the house collapses. Opening speed of cracks: 20 mm/hour
Stage 0	Termination	0 mm / hour and, no abnormality can be seen in the house and around the	The residents of the house deformed do not return to their house without architect's inspection. *3 No abnormality can be seen in the house and around the house

		house.	
Additional Stage	Torrential Rain & Cyclone Warning	"Cyclone Warning Class II" or "Torrential Rain Warning" may constitute for the inhabitants a "Landslide Stage 1 Warning". "Cyclone Warning Class III" : cessation of all normal activities, inhabitants of the landslide prone areas may be evacuated	

<Distinction of the proposed Warning Stages>

- Each Warning Stage is raised according to the monitoring of the extensometers and the observation of deformation of the houses.
- The proposed Early Warning System does not include precipitation as threshold.
- In heavy rain, the habitants in the landslide area should follow the Torrential Rain Warning or the Cyclone Warning, not the Landslide Warning.
- Alert level based on extensometer is hourly displacement.
- An extensometer may be able to detect a limited area in the landslide blocks.
- Deformations of a house are more important in the proposed Early Warning System.
- Warning that is based on deformations of the house is issued to only the residents in the house.
- Once the residents evacuate from their house, they never return to their house (termination is not allowed).
- This Early Warning system is effective in Chitrakoot, Vallee Pitot and Quatre Soeurs only, however it can be applied to other landslide (except rockfall, slope failure and debris flow).

b. Technical Source of the Early Warning System and Threshold

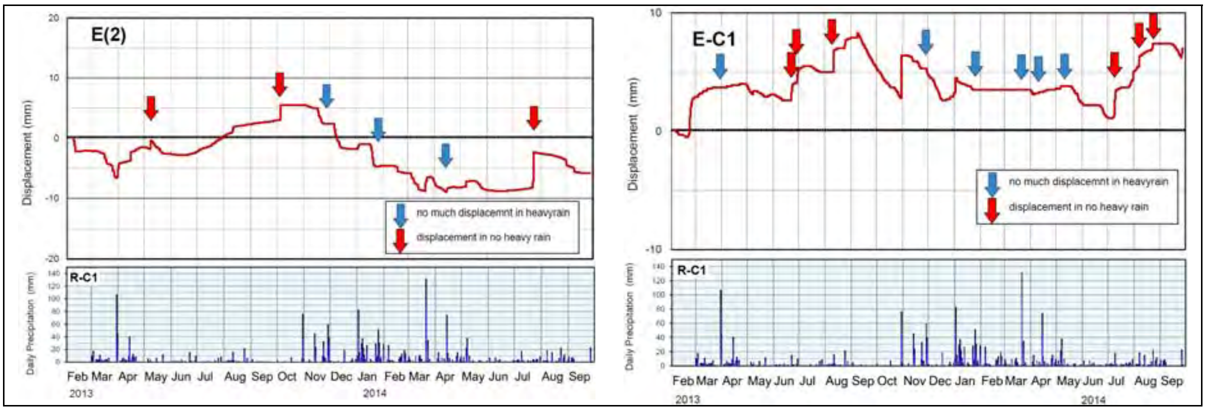
<u>Precipitation is excluded from the proposed Early Warning System</u>

The relation between the landslide activity and rainfall is not obvious judging from one and half years of monitoring of the rain gauges and the extensometers.

Figure 6.2.2 shows the records of the extensometer and the daily precipitation. The records show that the ground moves even in no heavy rainfall, and that the ground does not always move in heavy rain. The significant point is that the ground can move even in small or no rain.

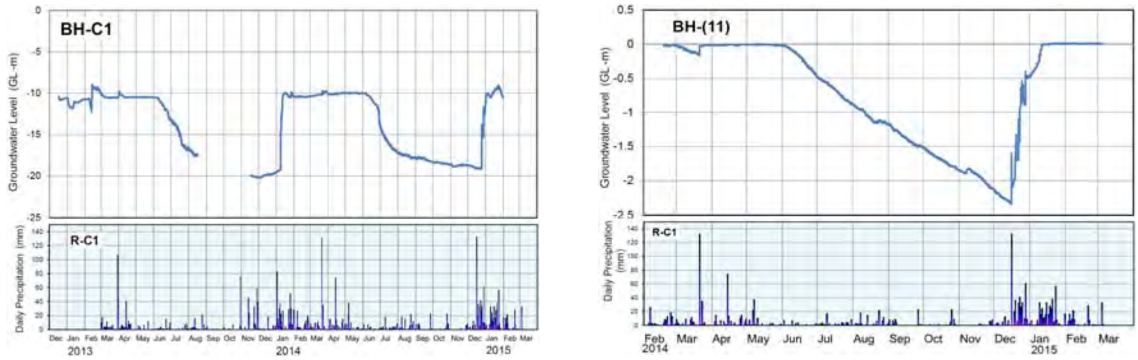
The landslide is not activated by the rainfall, but activated by rising of the groundwater level or the water pressure in the ground in common-sense terms. The results of the groundwater monitoring in three sites show the groundwater does not always increase in heavy rain as shown in Figure 6.2.3. This indicates that the rainfall does not have close relation with the landslide activities. This can be supported by the fact that the landslide activity is not seen in Chitrakoot and Vallee Pitot even in times of heavy rain such as the dates of 30th and 31st March 2014 when more than 150mm of continuously rainfall was recorded.

Also, if Landslide Early Warning System contains the precipitation as indicator of alert level may conflict with Torrential Rain and Cyclone Disaster Scheme. On 21 March 2014, the inhabitants in Vallee Pitot evacuated following the Torrential Rain Disaster Scheme.



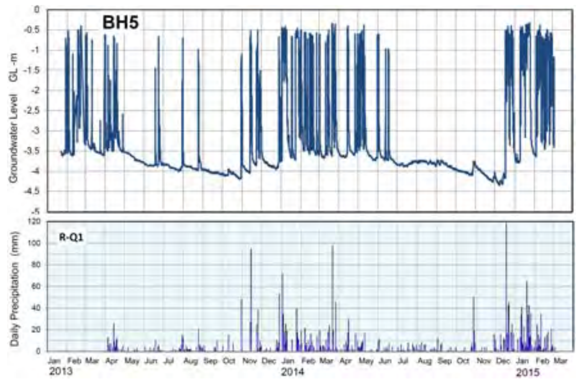
Extensometer results show displacement can be seen even in heavy rain while displacement can be seen in no rain,

Figure 6.2.2 Displacements shown in Extensometer Results in Chitrakoot (source: JET)



Variation of the groundwater level (upper) and daily precipitaion (lower) in Chitrakoot

Even in heavy rain, the groundwater level did not rise



Variation of the groundwater level (upper) and daily precipitaion (lower) in Quatre Soeurs

Even in amall rain fall, the groundwater level rose to near the ground surface immediately

Figure 6.2.3 Relation between Rain fall and the Groundwater Level (source: JET)

Warning level according to the Extensometers

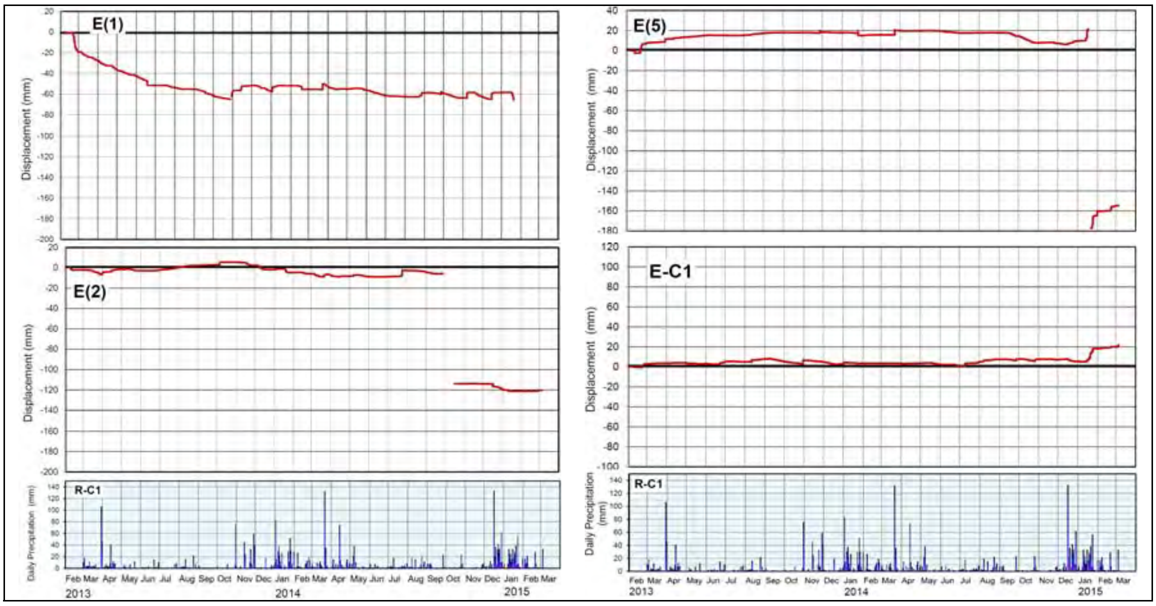
Four extensometers in Chitrakoot and two extensometers in Vallee Pitot are installed and have recorded the ground movement for about 1.5 years. Each of the extensometers in Chitrakoot shows different disposition of displacements, and there seems to be no consistency amongst them (Figure 6.2.4). The two extensometers in Vallee Pitot also show no consistency in their results (Figure 6.2.5). The landslides may consist of smaller blocks than the size expected previously and the extensometers can detect these smaller size of the landslide blocks.

This means that the extensometers can not be the indicator of large-sized landslides but can be the indicator of only small sized landslide bocks in Chitrakoot and Vallee Pitot.

The extensometer has another difficulty for the Early Warning System.

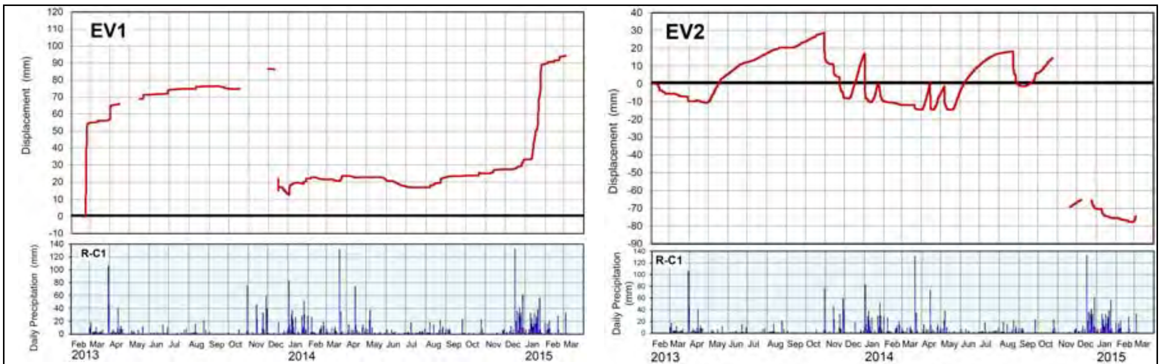
The exact movement of the landslide can not be seen until the completion of data processing by a computer after collect the data from the extensometers. Even every extensometer installed in Chitrakoot and Vallee Pitot has a display on it to show the chart of displacement, however there are some steps to see the display, opening the protection box within a protection cage which is always locked (Figure 6.2.6). Therefore, it is difficult to predict the imminent danger of landslide without automatic waning system attached to the extensometers.

Extensometers are not installed in Quatre Soeurs.



Movements of the ground shown in extensometers are inconsistent each other.

Figure 6.2.4 Extensometer Monitoring Results in Chitrakoot and Vallee Pitot (source: JET)



(Rainfall data of R-C1 at Chitrakoot)

Movements of the ground shown in extensometers are inconsistent each other.

Figure 6.2.5 Extensometer Monitoring Results in Chitrakoot and Vallee Pitot (source: JET)

	
Extensometer Recorder *Display on top surface can show the chart of movement.*	Extensometer installed in site *The system of the extensometer is in protection cage, and the extensometer recorder is in red protection steel box.* *To see the chart on site, some steps are required.*

Figure 6.2.6 Extensometer (source: JET)

<u>Early Warning System not relying on rain gauge</u>

As mentioned above, the rain gauge can not be a warning device for a landslide, and the extensometer is used as landslide warning device for only small landslide area. The extensometer can not cover the whole area of vast Chitrakoot landslide. There are not automatic extensometers in Quatre Soeurs.

Residents in a sound house are safe provided that their house is safe even if a house next door collapses. There must be some signs in a house before it collapses; namely a house will not collapse without any precursory signs.

When a house collapsed in Vallee Pitot in March 2014, only one house collapsed caused by a small landslide without any serious damage on surrounding houses and structures. Some cracks and deformation had been seen previously in the collapsed house. This incident suggests two important things. One is that a house can collapse without any deformations or anomalies around the house. Another one is that there must be various deformations or anomalies in a house before it collapses.

The most reliable way to protect resident’s lives in a house is not to find the risk of landslide but is to find anomalies in the house as early as possible.

<u>Threshold by ground movement</u>

Once a house shows signs of deformation, its collapse may be imminent. Therefore the threshold should not be daily but hourly.

<u>Establishment of threshold at each warning stage</u>

In the project, the following thresholds are proposed.

Table 6.2.3 Proposed Thresholds (source: JET)

Warning Stage		Thresholds
Stage 1	Precaution	20 mm / month or more
Stage 2	Alert	10 mm / day or more
Stage 3	Evacuation	20 mm / day or more

Velocity of the displacement speed was estimated in order to decide thresholds in early warning based on the setting time to the extent of the failure of a landslide.

Saito's formula which is well known in Japan is the formula to obtain the time to the extent of slope failure according as the velocity of strain of a landslide. As there is not the method to obtain the time to the extent of failure of a slow move landslide, the thresholds are estimated in the project based on Saito's formula.

<Forecast formula for time to failure>

$$\log_{10} tr = 2.33 - 0.916 \times \log_{10} \dot{\varepsilon} \pm 0.59$$

where

tr : *time to the extent of the failure of a landslide (minutes)*

$\dot{\varepsilon}$: *velocity of steady strain (x 10^{-4} / minutes)*

$\pm$ *0.59* : *tolerance of base data*

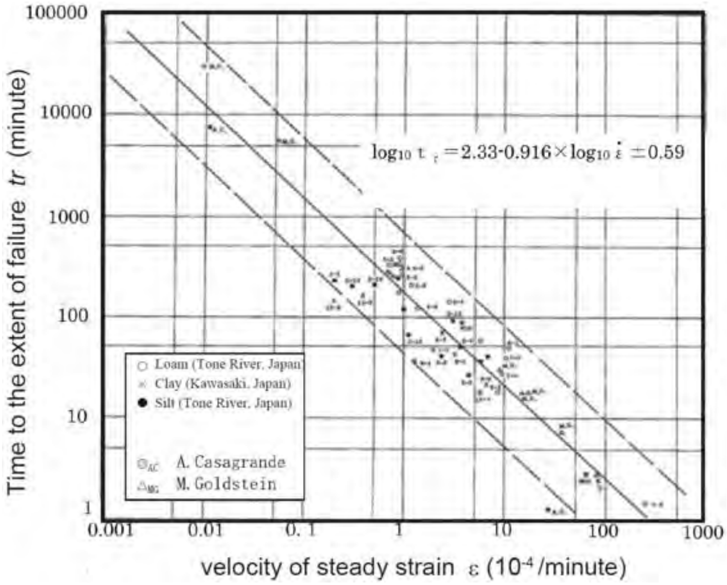


Figure 6.2.7 Relation between Time to the Extent of Slope Failure and Velocity of Steady Strain[8]

<Thresholds of warning level in landslide early warning in Mauritius>

Assuming the average length of wires of extensometers are 10m and the tolerance in the formula is zero (0), the velocities of displacement at each warning stage are estimated on the presupposition that the times to the extent of landslide failure at each warning stage are three months at Stage 1, six days at Stage 2 and three days at Stage 3. Table 6.2.4 shows the results of the estimation.

Table 6.2.4 Estimation of Velocity of Displacement in Accordance with Time to the Extent of Failure (source: JET)

Warning Stage		Time Left (*tr*)	$\log_{10}tr$	$\log_{10}\dot{\varepsilon}$	$\dot{\varepsilon}$	Displacement /10m (cm/min)	Displacement /10m
Stage 1	Precaution	3 months (129,600 min)	5.11	-3.03	0.000933	0.0000933	**40 mm/month**
Stage 2	Alert	6 days (8,640 min)	3.94	-1.75	0.0178	0.00178	**26 mm/day**
Stage 3	Evacuation	3 days (4,320 min)	3.64	-1.43	0.0376	0.00376	**54 mm/day**

<Proposed threshold at each stage>

Considering easy placement and control of warning system with extensometer and easy monitoring of cracks in a house, the threshold at each warning stage are established in accordance with to the results of the estimation shown in Table 6.2.4

Table 6.2.5 Proposed Threshold (source: JET)

Warning Stage		Estimation		**Threshold**
		Displacement speed	Remaining time	
Stage 1	Precaution	40 mm/month	3 months	**20 mm /month or more**
Stage 2	Alert	26 mm/hour	6 days	**10 mm / day or more**
Stage 3	Evacuation	54 mm/hour	3 days	**20 mm / day or more**

<u>Additional Stage (Torrential Rain Waning and Cyclone Warning)</u>

There are cases where a landslide becomes active in torrential rain or cyclone when it also becomes difficult to travel on roads (i.e. due to traffic congestion). In such cases, the inhabitants in the landslide area must follow the Torrential Rain Scheme or Cyclone Scheme regardless of landslide activity.

<u>Termination</u>

Once a house has become deformed, the house may not have enough structural strength. Even if the landslide activities have terminated and it is stable, the residents can not return and stay in the house. Architects decision is required before the residents return to their house.

If the residents are evacuated according to the extensometer indication, the residents should return after the landslide expert confirm the stability of the landslide.

c. Role of LMU in Early Warning

LMU should observe and confirm the site condition at each stage of Early Warning. Especially, LMU should visit the house and confirm the condition of the house when LMU receives the information about cracks or deformations of a house, since sometimes cracks or deformations appeared in a house for other reason than a landslide.

At Stage 1 and Stage 2 according to “Deformation of each house”, the points to be confirmed by LMU are as follows;

- Observe and confirm cracks and deformations
- Decide whether cracks and deformations are caused by a landslide
- If cracks and deformations are not caused by a landslide, find what is a cause of cracks and deformations
- Decide the methods of ascertainment whether cracks and deformations are progressing or not.
- Inform the residents next door how matters stand with their neighbor (i.e. that their neighbor's house has deformations caused by landslide activity).
- Ascertain the possibility of Stage 3, and remind the residents in the house that they should take in Stage 3

At Stage 3, the residents under risk should leave their house and evacuate of their own accord. The upgrading to Stage 3 from Stage 2 is based on extensometer readings or by the level of deformation of a house as ascertained by the residents of the house. The residents in the house must leave the house immediately (self-evacuation). At Stage 3, NDRMMC controls the refugees, and LMU advises NDRMMC on technical matters.

At Additional Stage, the residents in the landslide area should follow Torrential Rain Scheme or Cyclone Scheme. LMU is not involved in the Torrential Rain Scheme or the Cyclone Scheme.

At ordinary times, LMU should work to raise the awareness of the inhabitants in landslide areas. Especially the inhabitants should understand the following things.

- They live in a landslide risk area.
- Their lives must be protected by themselves.
- Once an evacuation warning is issued, they must not care about their possessions.
- Until countermeasures such as stabilization works are complete, there is nothing that can protect their possessions.

Table 6.2.6 Proposed Early Warning of Landslide Disaster in Chitrakoot, Vallee Pitot and Quatre Soeurs (source: JET)

Warning Stage		Threshold		Action by LMU
		Movement of the ground (extensometer)	Deformation of each house	
Stage 1	**Precaution**	20 mm / month or more	<new signs of landslide> New cracks are found in the house New deformations are found on the floor or the wall of the house. New cracks or deformations are found on the ground surface, walls or a road surface	Site inspection by landslide expert (LMU) Installation of extensometer or observation points
Stage 2	**Alert**	10 mm / day or more	<progress of cracks or deformations> Opening of the cracks become wider The deformations on the floor or the wall become bigger. The cracks or deformations around the house become bigger. Opening speed of the cracks : 2 mm/hour	Site inspection by landslide expert (LMU) Installation of extensometer or observation points Increase of frequency of observation Instruct the residents (monitoring)
Stage 3	**Evacuation**	20 mm / day or more	<further progress of cracks or deformations> New cracks are found in the house. The cracks and deformation become bigger and bigger in the house. The house next door or walls around the house collapses. Opening speed of cracks: 20 mm/hour	Evacuation (residents in the house which is deformed only, or residents in the houses which are within 50m of an extensometer)
Stage 0	**Termination**	0 mm / hour and, no abnormality can be seen in the house and around the house.	The residents of the house deformed do not return to their house without architect’s inspection. No abnormality can be seen in the house and around the house.	LMU must confirm no abnormality in the house and around the house.
Additional Stage	**Torrential Rain & Cyclone Warning**	“Cyclone Warning Class II” or “Torrential Rain Warning” may constitute for the inhabitants a “Landslide Stage 1 Warning”. “Cyclone Warning Class III” : cessation of all normal activities, inhabitants of the landslide prone areas may be evacuated		

** 1 the houses subject to be warned: only houses with signs of landslide activity if alert issued without the extensometer.*

6.2.3 Establishment of Early Warning and Evacuation System

An alarm was added to an extensometer as an early warning and evacuation system, to provide early warning to local residents about landslides. The alarm consists of rotary lights and a siren; the yellow rotary light operates on the warning stage, and the red rotary light and siren operate on the evacuation stage.

Table 6.2.7 Specifications of the Alarm Operation (source: JET)

Alarm	Stage	Threshold (for Extensometer)
Yellow rotary light	Warning stage	10 mm/day
Red rotary light and siren	Evacuation stage	20 mm/day

The alarm is connected to an active extensometer in two landslides.

Connected extensometer : Chitrakoot <E5> , Vallee Pitot <E-V1>

Note: It is necessary for the local contact person (the person who will check the alarm and call the police in case of an emergency) to recognize the alarm easily. Therefore, the alarm must be installed near the contact person so that he/she can easily see the rotary light and hear the siren.

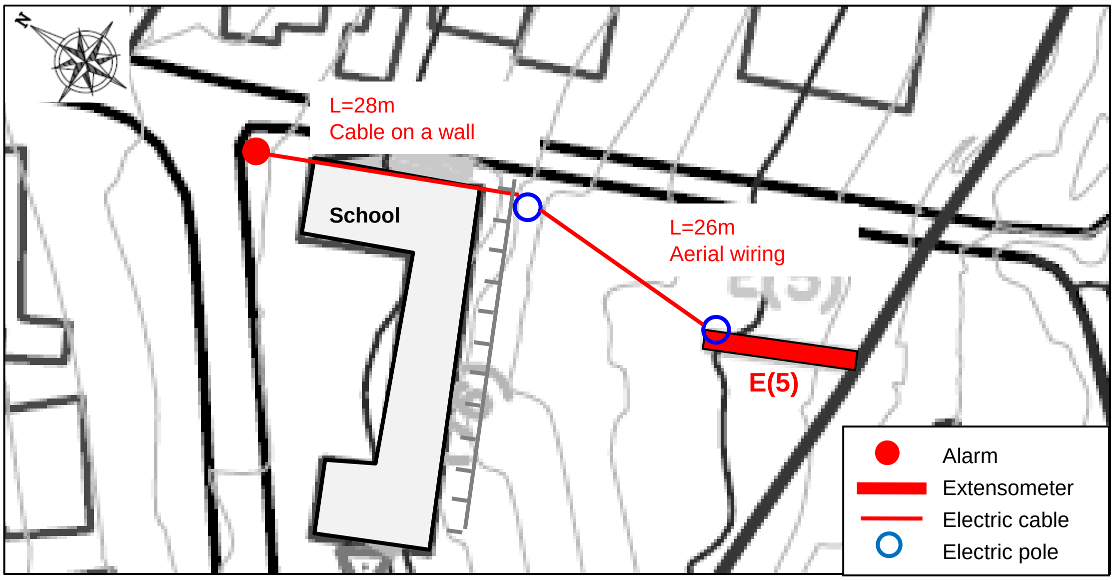


Figure 6.2.8 Location Map of Early Warning and Evacuation System in Chitrakoot (source: JET)

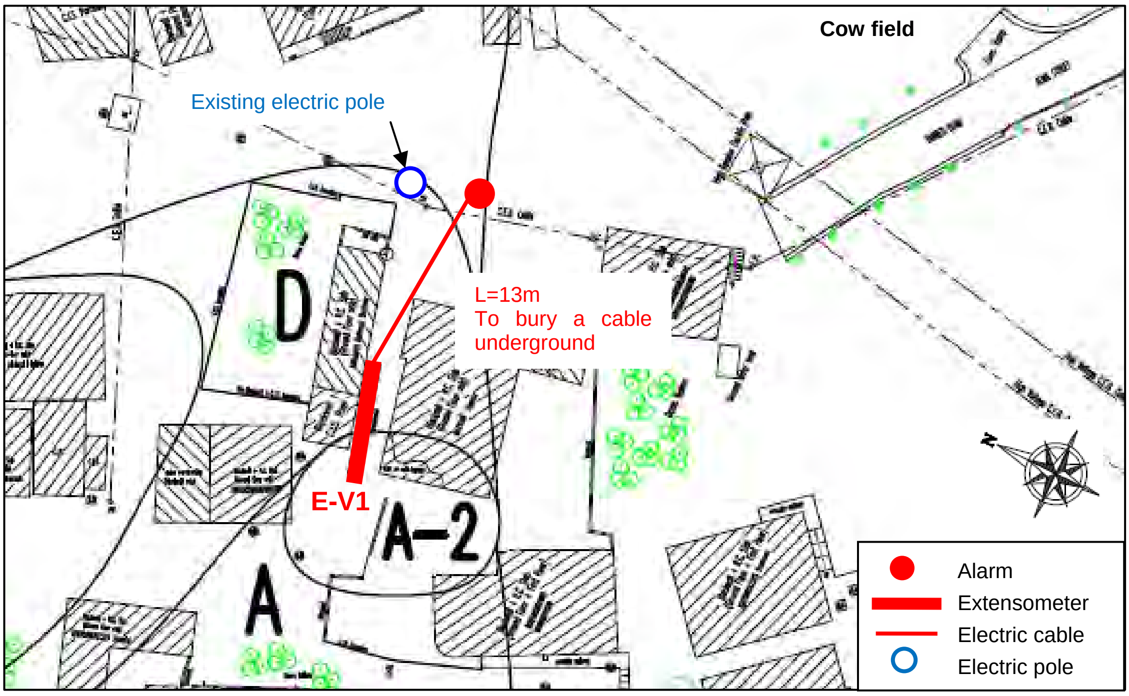
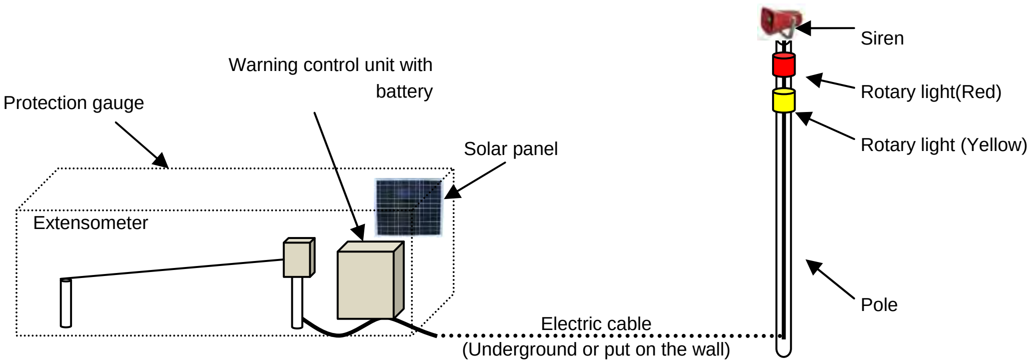


Figure 6.2.9 Location Map of Early Warning and Evacuation System in Vallee Pitot (source: JET)

Equipment

The parts of the alarm added to extensometer consist of a rotary light, a siren, a warning control box (including the battery) and solar panels.



Notice : The electric cable are less than about 80m, because the voltage declines.

Figure.6.2.10 Conception Diagram of Early Warning and Evacuation System (source: JET)

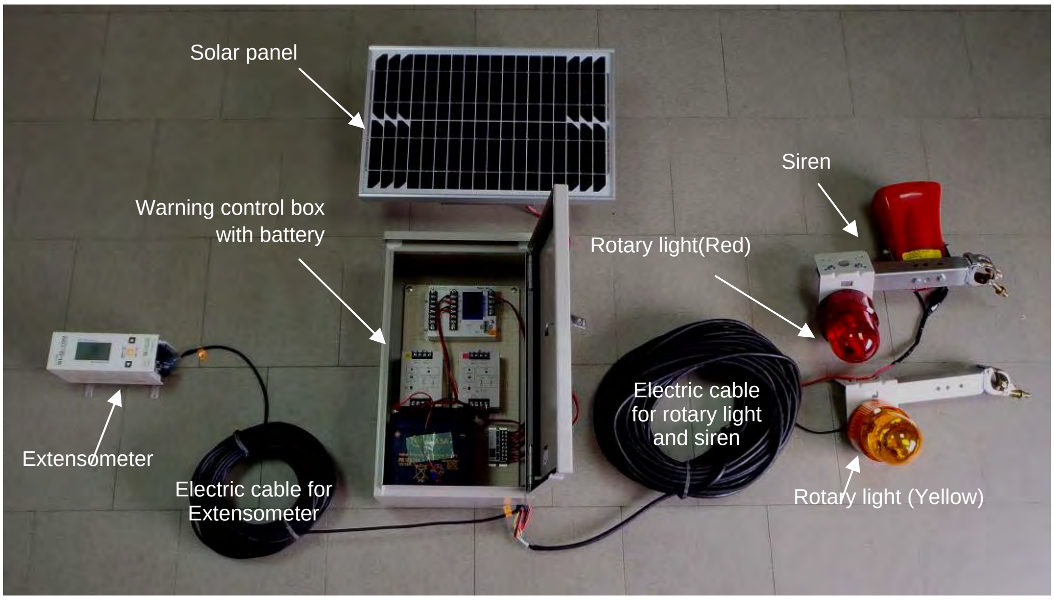


Figure 6.2.11 The Parts of the Early Warning and Evacuation System (source: JET)

Quantity of parts

Table 6.2.8 Quantity of Parts (source: JET)

No.	Name	Quantity	Location	Provider
1	Siren	2	Chitrakoot Vallee Pitot	JICA
2	Rotary light (red)	2		
3	Rotary light (yellow)	2		
4	Warning control box	2		
5	Solar panel	2		
6	Attachment parts for siren and rotary light	2		
7	Attachment parts for control box	2		
8	Attachment parts for solar panel	2		
9	Iron pole for siren and rotary light	2	Chitrakoot, Vallee Pitot	MPI
9	Iron pole for control box	2		
10	Iron pole for solar panel	2		
11	Concrete (foundation of iron pole)	4		
12	Iron pole for aerial wiring (including the attachment parts)	2	Chitrakoot	

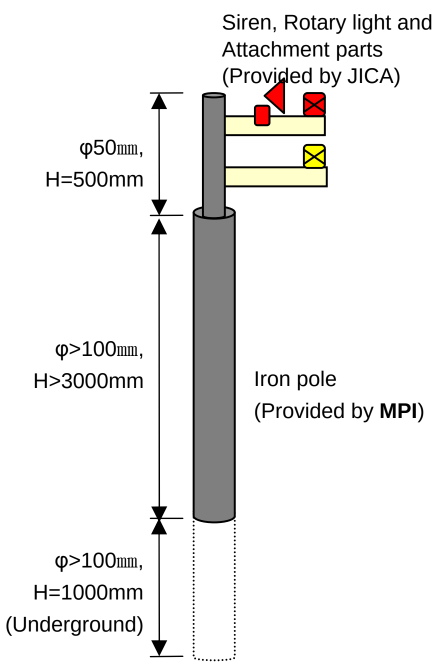


Figure.6.2.12 Structure of Siren, Rotary Light (source: JET)

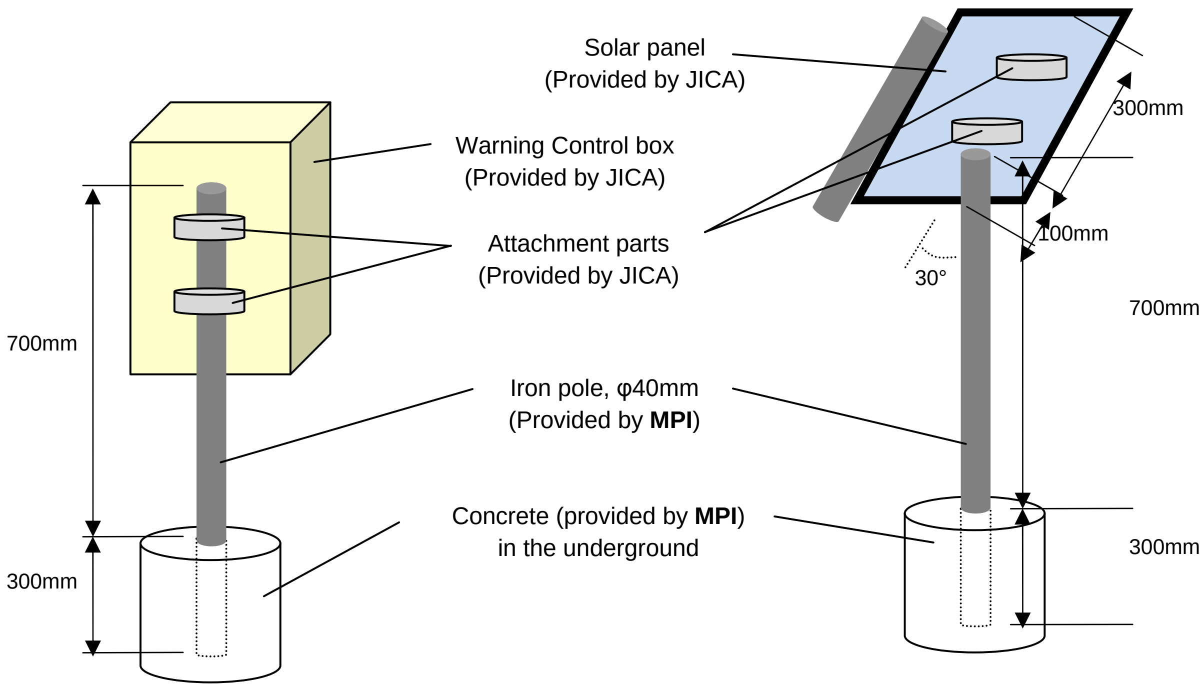


Figure 6.2.13 Structure of Warning Control Box (source: JET)

Figure 6.2.14 Structure of Solar Panel (source: JET)

Installation of the early warning and evacuation system

- The solar panel and warning-control unit are installed inside the protection gauge of the extensometer.
- The siren, rotary light (red) and rotary light (yellow) are attached to a pole.
- They are connected to each other by an electric cable.

Figure 6.2.15 Installation of the Early Warning and Evacuation System in Chitrakoot (source: JET)

Figure 6.2.16 Installation of the Early Warning and Evacuation System in Vallee Pitot (source: JET)

6.3 Information, Education and Communication (IEC)

6.3.1 IEC in the Landslide Management Project

a. What is IEC?

Information, Education, and Communication (hereinafter IEC) is a process of disseminating information between two or more persons who use a service. IEC activities mean that a service provider(s) conducts a variety of activities for disseminating information to give an opportunity to gain a better understanding and cause a behavioral change to the service user(s)[9]. IEC can be categorized as shown below;

Table 6.3.1 IEC Category (source: JET)

	Information	Education	Communication
Definition	Information and/or data in itself to be provided to an individual or the public.	A gradual process of learning through which a person gains knowledge and understanding of a subject.	A two way process of giving information or sharing ideas between two or more persons.

b. Aims of IEC Activities in the Landslide Management Project

The Project, in collaboration with Government Authorities including national government, Local Authorities and relevant public institutions, will carry out IEC activities to disseminate necessary information for landslide management to citizens and the public. These IEC activities aim;

- To raise awareness on landslide disaster management by providing basic information and a better understanding of the importance of preparedness for landslide disasters.
- To mitigate disaster risk by controlling human activities such as urban development and improper construction in high-risk areas.
- To make residents ready for proper actions when landslide disasters occur in future.

6.3.2 Current Status and Issues of IEC activities in the Field of Landslide Management in Mauritius

According to the following procedures, the current status and issues of IEC activities in the field of landslide management were identified. The results are shown in Table 6.3.2

a. IEC activities required by the Hyogo Framework for Action 2005-2015 (HFA) [Table 6.3.2. (a)]

The World Conference on Disaster Reduction (hereinafter WCDR) was held in 2005 in Japan, and adopted the

Table 6.3.2 Current Status and Issues of IEC Activity in the Field of Landslide Management in Mauritius / IEC Activities to be Implemented to Address Issues Identified (source: JET)

Table 6.3.2 Current Status and Issues of IEC Activity in the filed of landslide management in Mauritius / IEC Activities to be implemented to address issues identified

(a) Hyogo Framework for Action 2005-2015（HFA）			(b) Category of IEC			(c) Current Status and Issues of IEC Activity for landslide management in Mauritius	(d) IEC Activities to be implemented to address issued identified
Priorities for action	Key activities	Contents	Information	Education	Communication		
1.Governance: organizational, legal and policy frameworks	Community participation	Community participation is promoted in disaster risk reduction through the adoption of specific policies, the promotion of networking, the strategic management of volunteer resources, the attribution of roles and responsibilities, and the delegation and provision of the necessary authority and resources.			○	Some staff of the Village Council is in charge of measurement of rain gauges, and reporting to government authority.	In order to promote community involvement in the planning process, the Landslide Management Plan will be developed using consultative an participatory approach through stakeholder meeting. In the Pilot Project, the Community Disaste Management Committee (tentateive name) will be established to share the results of monitoring activirties and collate community's views.
2.Risk identification, assessment, monitoring and early warning	National and local risk assessments	Develop, update periodically and widely disseminate risk maps and related information to decision-makers, the general public and communities at risk.	○	○		A Risk Map was developed AAP（Aug. 2012), however, it is difficult to identify communities at risk due to too broad data map targeting the whole country. The map was also shared with relevant stakeholders through the Workshop, but the general public and communities at risk are not informed yet.	Communities at risk will be identified by the field surveys and monitoring works. The Projet will examine to develop an understandable hazard map and disseminate through stakeholer meetings and the project leaflet.
		Record, analyze, summarize and disseminate statistical information on disaster occurrence, impacts and loses, on a regular basis through international, regional, national and local mechanisms.	○	○		Relevant Ministries including MPI, Ministry of Housing and Land, have statistical information on disaster occurrence, impact and loses.	Information on disaster occurrence in the past, impact and loses was summarized on the 1st Project leaflet, and disseminated to the residents at priority areas.
3. Knowledge management and education	Information management and exchange	Provide easily understandable information on disaster risks and protection options, especially to citizens in high-risk areas, to encourage and enable people to take action to reduce risks and build resilience.	○	○		According to the results of Social Survey which was conducted in Aug-Sep. 2012, over 90% of sample residents have never experienced landslide disaster damage, however, more than half worry about the landslide disaster around their current residence. Also, residents feel the need for the following information to be prepared for a lanslide disaster; ①Evacuation sites（70%), ② Hazardous spot around residence（49%), ③Timing of evacuation（27%), ④Evacuation route(26%).	Disaster risks, landslide mechanism, informations inclding evacuation sites, hazardous spot around residence, timing of evacuation, evacuation route, will be informed, especially to citizens in high-risk areas, through stakeholder meetings, the Pilot Project for communities in high-risk areas and project leaflet.
		Institutions dealing with urban development should provide information to the public on disaster reduction options prior to constructions, land purchase or land sale.	○	○		According to the results of Social Survey which was conducted in Aug-Sep. 2012, a quarter residents did not know restrictions that no person shall start development actions and the building construction in a hazard area where is too high above sea level or too steep a slope, as restricted by the government, with the aim of mitigating disasters.	Exisiting restrictions for development actions and building construciton in a hazard area, will be reminded through stakeholder meetings, the Pilot Project for communities in high-risk areas and project leaflet. Additional restrictions will be recommended to Planing Policy Guidance (PPG) if necessary.
4. Reducing underlying risk factors	Education and training	Promote the inclusion of disaster risk reduction knowledge in relevant sections of school curricula at all levels and the use of other formal and informal channels to reach youth and children with information.		○		Education for disaster mitigation has not been included in school curricula.	In collaboration with Ministry of Education(MoE), education for disaster mitigation and evacuation drills at one of the priority areas, will be implemented as a part of Pilot Project Activity. Outcomes and lessons learnt will be shared with MoE, and examine to include in school curricula.
		Promote the implementation of local risk assessment and disaster preparedness programmes in schools and institutions of higher education.		○		No programmes for local risk assessment and disaster preparedness implemented in institutions of higher education such as University of Mauritius.	In collaboration with MoE, ducation for disaster mitigation and evacuation drills will be implemented as a part of Pilot Project. The developed education materials will be generalized to make it applicable to other areas. Methods of local risk assessment and disaster preparedness will be shared with University of Mauritius and University of Technologies throuth the Technical Transfer Seminar.
		Promote the implementation of programmes and activities in schools for learning how to minimize the effects of hazards.		○		Some schoold located on the coastal line in high-risk area against Tsunami disasters, have evacuation plan in which evacuation places and rotes are determined. However, it has not been exercised.	In collaboration with MoE, education for disaster mitigation and evacuation drills will be implemented in schools at one of the priority areas.
		Develop training and learning programmes in disaster risk reduction targeted at specific sectors (development planners, emergency managers, local government officials, etc.).		○		Training and learning programmes in disaster risk reduction targeted at specific sectors have not been developed yet.	The Landslide Management Plan will be developed using consultative an participatory approach with relevant stakeholders including development planners and local government officials, etc. Methods of disaster risk reduction will be shared with related organizations throuth the Technical Transfer Seminar.
		Promote community-based training initiatives, considering the role of volunteers, as appropriate, to enhance local capacities to mitigate and cope with disasters.		○		Some staff of the Village Council is in charge of measurement of rain gauges, and reporting to government authority.	The role and responsibility of community at priority areaswill be clarified in the planning process of the Landslide Management Plan. Then, the possibility to develop community-based disaster management system will be examined by the Pilot Project.
		Ensure equal access to appropriate training and educational opportunities for women and vulnerable constituencies; promote gender and cultural sensitivity training as integral components of education and training for disaster risk reduction.		○		Discrimination by gender and the race does not exist in the Mauritius community. Women can attend the meeting and speack out in public. Creole is main language while most of residents can not understand English. Vallee Pitot, which is one of the project priority areas, is located in low-income area, and residents area skeptical about government policy. Hence, some consideration needs to be given for implemnatation of the Project.	Presentation in the stakeholder meeting will be presented in Creole language by MPI CP. Education and awareness materials should be developed in English and French both. Pilice or community representative who is familiar with the site and people should be accompanied when the Project members visit Vallee Pitot area.
	Public awareness	Promote the engagement of the media in order to stimulate a culture of disaster resilience and strong community involvement in sustained public education campaigns and public consultations at all levels of society.	○	○	○	According to the latest "Cyclone and Other Natural Disasters Scheme 2011-2012", in collaboration with Local Authorities, the Government Information Service (GIS) and the Mauritius Broadcasting Corporation (MBC) are supposed to prepare illustrated posters and film strips to remind the public of the dangers of landslide. Also, the Police, in collaboration with the Meteorological Services and the MBC are requested to arrange to give talks on TV and Radio on dangers to transportation in landslide conditions. Nevertheless, the above activities have NOT been implemented yet. According to the interviews with the above implementing agencies, GIS has developed a leaflet for landslide disaster in March 2010. It also summarized the early warning system Diaster Scheme in March 2010. GIS showed willingness to revise and update the existing leaflet if necessary in collaboration with the Project. GIS has own burget for production and printing of leaflet. And, MBC has felt the need of raising awareness on landslide disaster, so they are also willing to advertise project activity through local news, and to work together for development of TV programme. MoESD is planning to organize an event, which is "Knowledge Fair" with Climate Change as theme in coming October 2012, and JICA Project is requested to involve in.	The Project, in collaboration with Local Authorities, the Government information Service (GIS) and Mauritius Broadcasting Corporation (MBC), will examine to develop illustrated posters and film strips as a part of Pilot Project activity. TV or Radio programme will be also examined with the Police, the Meteorological Services and the MBC to raise awarenss on dangers to transportation in landslide conditions. Project activity will be also advertized as much as possible in collaboration with MBC. In order to advertise the Project activity and raise the public awarenes on landslide disasters, the Project will provide related information and materials to the Climate Change Event MoESD will organize.
5. Preparedness for effective response and recovery		Promote and support dialogue, exchange of information and coordination among early warning, disaster risk reduction, disaster response, development and other relevant agencies and institutions at all levels, with the aim of fostering a holistic approach towards disaster risk reduction.	○	○	○	According to the latest "Cyclone and Other Natural Disasters Scheme 2011-2012", the Central Cyclone and Other Natural Disasters Committee and the Natural Sisaster and Operations Coordination Center are responsible for coordination among early warning and disaster risk reduction from a comprehensive perspective. However, according to the results of Social Survey which was conducted in Aug-Sep. 2012, more than 60% of sample residents did not know about the existing landslide warning system.	Stakeholder meetings inviting relevant Ministries, Department and other organizations, will be organized in the planning process of Early warning system, Evacuation procedure, Procedure manual including the technical guideline, review of the Planning Policy Guidance(PPG). Through these procedures, continuous dialogue, exchange of information and coordination among relevant stakeholders will be promoted.
		Prepare or review and periodically update disaster preparedness and contingency plans and policies at all levels, with a particular focus on the most vulnerable areas and groups. Promote regular disaster preparedness exercises, including evacuation drills, with a view to ensuring rapid and effective disaster response and access to essential food and non-food relief supplies, as appropriate, to local needs.	○	○	○	Mauritius government has developed "Cyclone and Other Natural Disasters Scheme 2011-2012" as disaster contingency plans, but lack of disaster preparedness. MPI has identified 32 landslide areas as a part of the Scheme, however, lanslide management plans and policies with a particular focus on the most vulnerable areas, and disaster preparedness exercises including evacuation drills, have not been implemented yet.	The Landslide Management Plan will be developed with a particular focus on the most critical high-risk disaster area, which includes Chitrakoot, Quatre Soeurs and Vallee Pitot. Pilot Project including disaster preparedness exercises will be implemented one or two priority areas.
		Develop specific mechanisms to engage the active participation and ownership of relevant stakeholders, including communities, in disaster risk reduction, in particular building on the spirit of volunteerism.	○	○	○	The Project is now conducting measurement and geotechnical surveys by drilling and installing extensometer, however, the survey has been delayed as landowners are not willing to provide their lands for these works.	Develop specific mechanisms to engage the active participation and ownership of relevant stakeholders, including communities, in disaster risk reduction, in particular building on the spirit of volunteerism. Stakeholder meetings for residents are organized on a regular basis to engage the ownedship of relevant stakeholders including local authorities and communities. In the Pilot Project, the Community Disaste Management Committee (tentateive name) will be established to share the results of monitoring activities and collate community's views. With consideration for landowners issues, some alternative options will be also examined if necessary.

present HFA (2005-2015): Building the Residence of Nations and Communities to Disasters. Under the HFA, it is highlighted that both communities and local authorities should be empowered to manage and reduce risk by having access to the necessary information, resources and authority to implement actions for disaster risk reduction.

The HFA calls for the pursuit of three three strategic goals and defines five priorities for action, and HFA states, regional and international organizations and other actors concerned are required to implement these activities, as appropriate, according to their own circumstances and capacities.

In this section, based on the perspectives described in Chapter 5.4.1-b, IEC Activities were abstracted from Key activities under the five priorities for action, which were identified as IEC Activities to be implemented in the field of landslide disaster management in Mauritius.

b. Categorization of IEC Activities [Table 6.3.2 – (b)]

IEC Activities abstracted from the HFA, were categorized according to the IEC Category as shown in Table 5.4.1.

c. Current Status and Issues of IEC Activities in the Field of Landslide Management in Mauritius [Table 6.3.2 - (c)]

It was reviewed by the following procedure:

c.1 IEC activities described in Mauritius Landslide Emergency Scheme

Mauritius government has developed “Cyclone and Other Natural Disasters Scheme” every two years. The Scheme clarifies necessary actions, the role and responsibility of each organization and stakeholder in cases of five natural disasters, namely Cyclones, Torrential Rain, Landslides, Tsunami and High Waves. The Landslide Emergency Scheme was added to the Scheme in 2008. According to the Scheme, the MPI is responsible for the monitoring of landslides all over the Island. The Landslide Emergency Scheme includes some descriptions related to IEC activities as shown in Table 6.3.3.

Table 6.3.3 IEC Activities Described in Mauritius Landslide Emergency Scheme (2012-2013)

Section	Description
Action by Local Authorities	- In collaboration with Local Authorities, the Government Information Service and the Mauritius Broadcasting Corporation (MBC) will prepare illustrated posters and film strips to remind the public of the dangers of landslide. - The Police, in collaboration with the Meteorological Services and the MBC shall arrange to give talks on TV and Radio on dangers to transportation in landslide conditions.
Distribution of Landslide Bulletins	- Landslide information and warning stages issued by the Chairperson of the Coordinating Committee are distributed through the MBC, the Press, the Private Radios, the telephone system including Mauritius Telecom Call Centre and the National Disaster and Operations Coordination Centre (NDOCC).

c.2 Conducted interviews with relevant Implementing Agencies to perceive the state of achievement of IEC activities required by Landslide Emergency Scheme

The JET conducted interviews with the implementing agencies including the MBC and the Government information Service (GIS) to perceive the status of achievement of IEC activities required by Landslide Emergency Scheme.

And, JET also discussed with the Ministry of Environment and Sustainable Development (MoESD) about how MoESD will implement the Disaster Risk Reduction Strategy (DRR Strategy) which was developed by African Adaptation Programme (AAP), especially Key objective 5, that is “Empower relevant stakeholders and local communities”.

In addition, JET did an interview with the Ministry of Education to grasp the status of education for disaster mitigation in the existing school curricula, and discussed to examine a future plan to work with.

c.3 Consideration of the results of Social Survey

As a part of the Project activities, the Project conducted a Social Survey from the middle of August 2012 for a month, targeting about 2,000 local households such as those living in the priority areas. The Survey included various aspects, such as resident’s awareness level, experience of landslide disasters, the feeling of insecurity for disaster risk, understanding of relevant regulations, information needed for disaster management and effective information tools. These results were also referred to understand the reality of the situation (refer to Chapter 2.5 for the detailed result of the Social Survey).

d. IEC Activities to be Implemented to address issues identified [Table 6.3.2 - (d)]

In consideration of the above results, IEC activities which can be implemented to address issues identified.

6.3.3 IEC Activities to be Implemented by the Project [Table 6.3.2 -d]

IEC Activities which will be implemented by the Project were selected from among IEC Activities to be implemented to address issues identified in order to achieve the aims of IEC activities of the Project (see 6.3.1–b.) effectively. Table 6.3.4 shows a summary of IEC activities to be implemented by the Project.

Table 6.3.4 IEC Activities to be Implemented by the Project (source: JET)

	IEC Activities to be implemented by the Project (Countermeasures for issues)		
Issues / Countermeasures	**Stakeholder Meeting for residents** at high-risk areas	**Project Newsletter** (Outline of the Project, Progress, etc.)	**Development of Awareness materials** for landslide disaster prevention
1. Community participation and ownership of relevant stakeholders in disaster risk reduction, is not sufficient.	◎	○	○

2. Residents do NOT have necessary information such as evacuation sites and hazardous spot around residence, so that they are feeling a sense of insecurity against landslide disasters.	◎	○	◎
3. Most of residents do NOT know existing restrictions for development actions and building construction in a hazard area.	◎	○	◎
4. Education programme for landslide management is NOT implemented at schools and communities.	◎	○	◎
5. NO programmes for local risk assessment and disaster preparedness implemented in schools and institutions of higher education such as University of Mauritius.	-	○	○
6. Awareness materials, which are required to develop under the Disaster Scheme, have been NOT done yet.	○	○	◎
7. Most of residents are NOT familiar with the existing warning system.	◎	-	◎
8. Residents at priority areas have requested for sharing the progress of Project activities and the monitoring results on a regular basis (from comments given by participants of stakeholder meeting held in Chitrakoot).	◎	◎	○
9. The existing Landslide Emergency Scheme is lack of preparedness perspective and component of evacuation plan. Also, implementing and responsible agency for IEC activities is NOT identified clearly.	◎	-	◎

※ ◎Directly contributed, ○Indirectly contributed

6.3.4 Stakeholder Meeting for Residents at Priority Areas

a. Purpose of the Stakeholder Meeting

The Landslide Management Plan is in the process of planning formulation based on the results of baseline surveys conducted since May 2012, and has been discussed through a series of meetings with CP staff of the MPI and other relevant stakeholders.

To conduct effective landslide countermeasures, taking a land ownership and use into consideration, consensus should be built with local stakeholders, and interests should be coordinated and system should be established with local communities.

It is also desirable that the concept of the Plan including: the need for the Project, selection process of the priority areas, outline of project implementation, and resident's roles and responsibilities should be shared with local residents in the early planning stage. Such interactive communication process with local residents will result in a more realistic plan that reflects the community's real needs.

b. Implementation Plan

The implementation plan of stakeholder meeting is shown in Table 6.3.5. During the Project, five (5) stakeholder meetings were scheduled at priority areas. The timing and its frequency of the meeting were examined flexibly with MPI CP according to the progress of project activity.

Table 6.3.5 Implementation Plan of Stakeholder Meeting (source: JET)

No.		Implementation schedule	Objective	Contents
1	At the start of the Project	Sep. 2012	To explain the outline of the Project and request residents' cooperation	1) To explain the outline of the Project 2) To request their cooperation and understanding for the field survey and monitoring
2	After drafting of Project Implementation Plan	Apr. 2013	To build consensus on Project Implementation Plan and F/S	1) To share the results of field surveys 2) To share the monitoring results, particularly during rainy seasons 3) To collate residents' views on the basic policy of countermeasures (basic design of construction work, soft (non-structure) countermeasures)
3	Before finalization of Project Implementation Plan	Nov. 2013	To build consensus on Project evaluation, EIA and the proposed early warning and evacuation system	1) To collate residents' views on the draft design of construction work 2) 3) To gain agreements on the land use for construction work (house-to-house visit was also be conducted) 3) To share the results of Project evaluation 4) To inform of the proposed early warning and evacuation system
4	Before starting Pilot Project	Jul. 2014	To build consensus on contents of Pilot Project	1) To explain the outline of Pilot Project 2) To share the results of field survey and monitoring 3) To review the practicability of the proposed early warning and evacuation system (to identify effectiveness and lessons learnt) 4) To conduct site visit
5	At the end of Pilot Project	Dec. 2014	To share the results of Pilot Project, feedback to the Landslide Management Plan	1) To review the whole project activities 2) To report the results of Pilot Project 3) To explain the early warning and evacuation system (by using IEC materials) 4) To announce the future plan after the Pilot Project 5) To conduct site visit

c. Implementation Procedures

The implementation procedures are shown below.

c.1 To finalize an implementation plan and presentation material

JET drafted an implementation plan and finalized it through discussion with MPI CP.

c.2 To confirm dates and venues of the meetings

MPI CP contacted community representatives and confirmed their convenient and available dates and times for the meetings. The meetings were normally organized after 5 pm on weekdays or on the weekends as most of residents are at work during the day. The venue place was considered where residents can easily access. When a school is used as a venue for the meetings, MPI head office contacted the Ministry of Education in advance to gain approval for its use.

c.3 To distribute invitation letters to residents and related organizations

An official invitation letter was developed by the administration office and sent to target residents and relevant organizations through the mail service. Community representatives such as a village council officer and local police who are familiar with local conditions and local residents distributed invitation letters to the target residents.

c.4 To develop presentation

Presentation materials were drafted in English by JET and finalized after a series of discussion with MPI CP. Most of residents cannot understand English well, so all the explanations in the meetings were done by MPI CP in common language, which is Creole language, to make residents fully understand the contents.

c.5 To collect feedback sheets

Some residents might not be used to speaking in public, so the feedback sheet was distributed to participants in order to understand the level of their understanding and to collate their views on your work as much as possible. The results of the feedback sheet were shared with MPI CP.

d. Reports of Results of Stakeholder Meetings

The outline and results of all the stakeholder meetings were summarized in the Table 6.3.6.

Table 6.3.6 Reports of Results of Stakeholder Meetings at Priority Areas (source: JET)

1st Stakeholder Meeting (in Sep. 2012)

【Background/Objective】

The Project is planning to conduct a topographic survey, drilling works and installation of monitoring devices at three priority areas in order to understand the landslide mechanism and create maps of micro-landform units and cross-sections of landslides. Before starting these surveys, the Project is required to follow the procedure like; to invite residents concerned, explain the outline of the survey to them and obtain their signatures on a consent form. However, the Project faced a long delay in terms of implementation schedule as it took time to identify landowners and obtain agreements from some of them.

Therefore, the Project decided to conduct Stakeholder Meeting for residents such as those living in the priority areas to explain a background, the needs of the Project, the outline of each survey and monitoring methods. It was expected that stakeholder meetings will make it easier for the Project to gain resident's cooperation for the project activity.

【Target area】

Three (3) landslide areas（Chitrakoot、Quatre Soeurs、Vallee Pitot）

【Target residents】

Residents who live in these places where topographic survey will cover and the monitoring devices will be installed.

【Date of the meeting / The number of participants】

Date	Time	Target area	No. of participants
Fri. 21 Sep. 2012	17:00 – 18:30	Quatre Soeurs	13
Sat. 22 Sep. 2012	13:00 – 14:30	Chitrakoot	46
End of Sep. 2012	15:30 – 17:00	Vallee Pitot	-*

*Note：The meeting for Vallee Pitot was not a success because no residents attended the meeting. The venue was too far to come from resident's residence. As an alternative option for this, a house-to-house visit was conducted, and the Local Police accompanied as due to unsafe area from social perspectives.

【Agenda】

1) Definition of landslide
2) Landslide disaster in Mauritius and the priority area
3) Background and the need of the Project
4) Implementation schedule
5) Methods of landslide monitoring analysis by showing the actual location and number on the map (Measurement, Drilling, Geophysical exploration)
6) Request resident's cooperation and understanding for the above works

[Discussion, Questions and Answer from the audience]

Summary of comments given by residents	Matters to be considered by the Project
[Chitrakoot]	
• In Chitrakoot, Mauritius government conducted some surveys and installed similar monitoring devices 7 years ago. However, the monitoring result has never been informed to residents. • Therefore, the Project received many questions and suggestions from residents like; "Have you reviewed the results of previous survey?" and "should re-use the same drilling points and monitoring equipment which were done by previous survey". • Any development activities are prohibited in Chitrakoot due to the high-risk area in terms of landslide disasters, so residents requested the Project not only for the survey and monitoring works but also concrete construction works as countermeasures.	− MPI and JET answered resident's questions that the results of previous survey were already reviewed, but these data is too old to examine appropriate countermeasures. It was also highlighted that the Project needs to install equipment to the right locations and make it deeper to understand the mechanism of landslide occurrence properly. − The Project agreed to organize Stakeholder Meetings on a regular basis in order to share the results of survey and monitoring. − Residents seem to have high expectations toward construction works as countermeasures – need to highlight the importance of soft components such as early warning and evacuation system.
[Quatre Soeurs]	
• Residents had major concerns on relocation plan which Mauritius government is proceeding. Most of residents were not familiar with the condition of candidate site for their new lands and houses, so they requested MPI and other relevant organizations for organizing a site visit. Some residents expressed unwillingness to relocation due to insufficient land size. More financial assistance was also requested.	− Relocation will be one of the countermeasures, but will require lots of time to be realized. Therefore, soft components such as early warning system should be implemented in this area.

【Photos】

MPI CP explaining the mechanism of landslide occurrence and each parameter of monitoring
(Quatre Soeurs)

Question-and-answer session
（Chitrakoot）

House-to-house visit done by MPI CP to explain about the outline of the project
(Vallee Pitot)

2nd Stakeholder Meeting (in Apr. 2013)

【Background/Objective】

Landslide disaster often occurs in Mauritius, especially during cyclone season in the period from January to March every year. Actually, at end of February 2013, some residents in Vallee Pitot, the place where one of the project priority areas is, were forced to evacuate as their houses were heavily damaged due to occurrence of a landslide disaster after continuous heavy rains. The case was broadcast by local news, and the Deputy Minister accompanied by Minister of Public Infrastructure visited the site where the landslide had occurred. The fatal disaster triggered public concern over the causes of the landslide, how to prevent such disasters, and worries about the future of the residents living in the disaster-prone areas.

The Project has carried out site reconnaissance and collected monitoring data at three priority areas, which include Chitrakoot, Quatre Soeurs, and Vallee Pitot, since August 2012. Based on the results of surveys and monitoring, the Project examined the basic policy for countermeasures including construction works and non-structure countermeasures such as an early warning and evacuation system. According to the basic policy, the works for detailed design and cost estimation will be done by the end of the year 2013. In order to make the plan more realistically reflect the community's real needs, the 2nd stakeholder meeting was conducted.

【Target area】

Three (3) landslide areas（Chitrakoot、Quatre Soeurs、Vallee Pitot）

【Target residents】

Residents who live in these places where topographic survey will cover and the monitoring devices will be installed.

【Date of the meeting/The number of participants】

Date	Time	Target area	No. of participants
Fri. 12 Apr. 2013	17:00 – 18:00	Quatre Soeurs	15
Sat. 13 Apr. 2013	15:30 – 17:00	Chitrakoot	14
Sun. 14 Apr. 2013	10:45 – 12:00	Vallee Pitot	10

【Agenda】

1) Review of the 1st stakeholder meeting
2) Results of landslide site investigation
3) Results of monitoring
4) Basic policy for countermeasures (construction works, early warning and evacuation system)
5) Examination of early warning and evacuation system (at each target area)
   - Thresholds for each stage (warning, evacuation)
   - Assignment of contact persons (who will be in charge of checking of early warning system and simple rain gauge, and communication between Police and community)
   - Examination of evacuation center
6) Work schedule (future plan)

【Discussion, Questions and Answer from the audience】

Summary of comments given by residents	Matters to be considered by the Project
1) Active landslide area [Chitrakoot]	
Most residents do NOT have map-reading skills, so they were concerned whether their own house would be affected by landslide or not.	Stakeholder meeting is insufficient measure to inform the residents of the specific site that is prone to landslide occurrence. In order to give certainty and let all the target residents know necessary information, <u>a door-to-door visit</u> should be carried out before starting construction work and other countermeasures.
Residents suggested setting up the board at site to demarcate an active landslide area from other areas.	MPI will examine how to implement this once the proposed Warning Zone system is authorized through modification of PPG.

Summary of comments given by residents	Matters to be considered by the Project
2) Mechanism of landslide occurrence [Chitrakoot]	
Was the construction of the school the cause of landslide occurrence in Chitrakoot?	Not sure, but the geographical condition of the region was already identified as an area that was prone to landslides before the construction of the school.
3) Construction Work [Chitrakoot]	
− Location of construction work *(Will installation of drainage pipes result in any impact on their cultivation activity and daily life?)* − Maintenance of installed pipes and other facilities *(Who and How to do that?)* − Possibility of landslide occurrence (during the construction work)	The design of construction work should take these concerns into consideration. Environmental impact and social consideration should be taken into account before, during, and after the construction work.
4) Current issues caused by current drainage system [Vallee Pitot]	
− The water that accumulates in the creek, often overflows during heavy rains and comes inside their houses. − Water flow from the mountainside has also started coming into their living area since the road was constructed near the cow yard.	NDU is planning to undertake the work for clearance of the creek (MPI to confirm) JET drafted the basic concept of construction work as countermeasures, but MPI is still considering whether MPI will implement construction work in this area or not.
5) Relocation [Quatre Soeurs]	
Some residents proposed they be allowed to relocate immediately due to insecurity of potential risks/hazards they will face soon.	Ministry of Housing is still under negotiation with some landowners.
6) Warning and Evacuation System [for three priority areas] （*suggestions given from Social Mobile Force (SMF)）	
− SMF can provide transportation if there is a need for emergency evacuation, but also suggested that residents should evacuate to the designed evacuation place by themselves instead of waiting for SMF to come. (⇒Self-evacuation system should be established) − SMF also requested MPI/JET to organize a stakeholder meeting to confirm the proposed system (NDOCC, MMS and other concerned organizations should be involved).	These suggestions to be taken into consideration in examination of early warning and evacuation system.

【Photos】

Presentation by MPI CP
(Quatre Soeurs)

Residents checking the location of their houses with MPI CP
(Chitrakoot)

MPI CP explained the status of rainfall when landslide disaster occurred at end of Feb. 2013 (Vallee Pitot)

3rd Stakeholder Meeting (in Nov. 2013)

【Background/Objective】

The project drafted a project implementation plan reflecting comments given by residents and relevant stakeholders during the 2nd stakeholder meeting. When implementing construction works, the survey for land acquisition needs to be conducted. To do this, the project, in collaboration with Ministry of Housing and Land, needs to identify landowner of each target land and obtain permission for on-site inspection. The project has been taking a long time for the procedure, and it became impossible to implement construction works as scheduled. To avoid further delays, it is crucial to gain understanding and cooperation of residents and relevant stakeholders. In addition, the early warning system and simple rain gauges will be installed in Nov. 2013 and the early warning and evacuation system will start its operation from this rainy season. The outline of the system was also explained in the meeting.

【Target area】

Three (3) landslide areas（Chitrakoot、Quatre Soeurs、Vallee Pitot）

【Target】

- Residents who live in these places where countermeasure works and the early warning and evacuation system will be in place.
- Relevant Ministries/organizations (*only for Chitrakoot (held on Fri. 15 Nov))

(↓ Stakeholders participated in the meeting)

- Ministry of Agriculture
- Ministry of Housing and Land
- Water Resources Unit of Ministry of Energy and Public Utilities
- National Parks and Conservation Service
- Central Water Authority
- SMF/Local Police
- Ministry of Environment and Sustainable Development

【Date of the meeting/The number of participants】

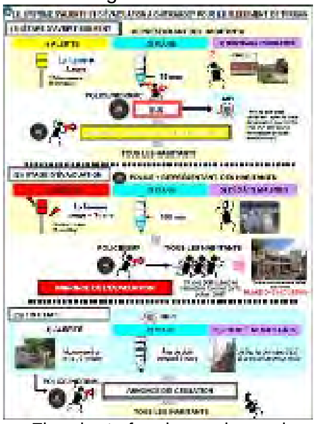
Date	Time	Target area	No. of participants	Target
Fri. 15 Nov. 2013	14:00 – 16:00	Chitrakoot	14	Government organizations
Sat. 16 Nov. 2013	13:00 – 15:00	Chitrakoot	30	residents
Fri. 29 Nov. 2013	16:00 – 17:00	Quatre Soeurs	20	Residents
Sat. 30 Nov. 2013	14:00 – 16:00	Vallee Pitot	20	residents

【Agenda】

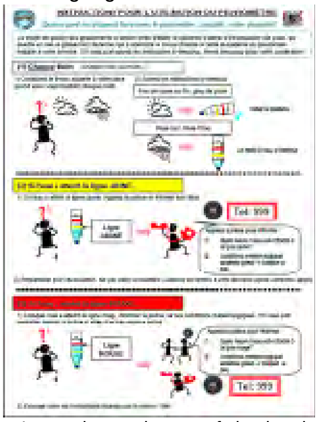
1) Review of Previous Stakeholder Meetings (for residents only)
2) Results of Landslide Site Investigation and Monitoring
3) Draft Project Implementation Plan

- Construction works (for Chitrakoot only)
  - ➢ (for government organizations only) Task and responsibility of each organization for implementation of construction works
  - ➢ (for both government organizations and residents) Consensus building on the locations where construction works will be undertaken.
  - ➢ (for residents only) Request for on-site inspection to conduct a survey for land acquisition
  - ➢ (for residents only) Identification of landowners
- Early Warning and Evacuation System (for all three areas)
  - ➢ Explanation of the finalized early warning and evacuation system
  - ➢ Confirmation of communication network, evacuation center and its route

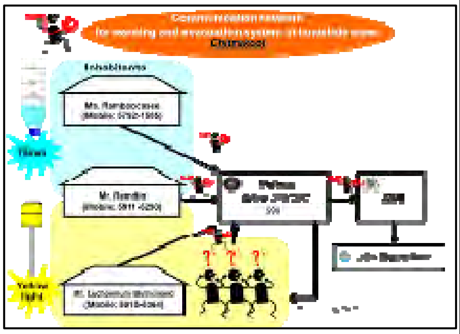
*the following materials written in French language were distributed.



Flowchart of early warning and evacuation system



Instruction on the use of simple rain gauge



Communication network (Residents (contact persons) – Police – MPI)

4) Work Schedule (Future Plan)
5) Site Tour (to check the actual site where the countermeasure works will be installed)

【Discussion, Questions and Answer from the audience】

[Chitrakoot]

・ The project obtained approvals from residents and relevant government organizations on the proposed countermeasure works including early warning and evacuation system.

	Summary of comments given by the audience	Matters to be considered by the Project
	<Government organizations> − The tasks and responsibility to proceed with countermeasure works were specifically defined in the presentation. − Police and the SMF presented during this meeting showed willingness to collaborate and help in case there is a landslide occurrence. They also suggested conducting a simulation or evacuation drill so as to prepare the residents of Chitrakoot in case there is a landslide.	− The Project needs to ensure the officials or divisions in charge are not left to deal with the task on their own, but that an institutional response is made with the appropriate involvement of directors and other senior managers. − Simulation or evacuation drill should be conducted at the initiative of the Police and SMF, not arranged by MPI counterparts. The Project will provide technical advice and information such as landslide hazard areas, evacuee lists, etc.

	− The NDU proposed to examine other ways instead of draining water through the proposed construction work. − NDU and EIA local consultant raised concern where the water will go, and impact on cultivation activity caused by installation of pipes as the water would be drained from the area. EIA consultant also mentioned that flood disasters have occurred so often as water flow is blocked due to littering of waste. − NDU and MHL made comments that land acquisition will take time. ＜Residents＞ - Residents were concerned whether they will be able to gain permits for construction of their houses and so on.	- The Project examined all the options of construction works through the Feasibility Study and concluded the proposed works presented earlier in the meeting were the most feasible. - The Project will follow necessary procedures that need to go through in case there are some cultivation activities at sites where construction work will be implemented. - MPI stated that they need to have permission from landowners, residents and relevant organizations as soon as possible to proceed with the work smoothly. - MPI answered that during and after the construction works no construction shall be done as it will affect the stability of the ground. In case that landslide hazard area is designated as restricted area by PPG, it requires a careful explanation for residents (by MoHL and local Authorities).

【Photos】

Outline of construction works were explained to government organizations (Chitrakoot)

Simple rain gauge was demonstrated based on the instruction manual (Quatre Soeurs)

Early warning and evacuation system was demonstrated on site (Vallee Pitot)

4th Stakeholder Meeting (in Jul. 2014)

【Background/Objective】

Construction work will start in Chitrakoot from the end of July 2014. Prior to the starting of construction work, the project held the stakeholder meeting with relevant government organizations and resident to build consensus on each component of construction works, work schedule, etc.

【Target area】

Pilot project area（Chitrakoot）

【Target】

- Residents who live in these places where countermeasure works and the early warning and evacuation system will be in place.
- Relevant Ministries/organizations

(↓ Stakeholders participated in the meeting)

- Ministry of Housing and Land
- Central Water Authority
- SMF/Police
- Ministry of Environment and Sustainable Development
- City Council of Port Louis
- Albercombie Police (local police who in charge of Chitrakoot area)
- Forestry Department, National Parks and Conservation Service
- National Development Unit, Ministry of Public Infrastructure
- National Disaster Risk Reduction and Management Centre (NDRRMC)
- Water Resources Unit of Ministry of Energy and Public Utilities

【Date of the meeting/The number of participants】

Date	Time	Target area	No. of participants	Target
Fri. 14 Jul. 2014	14:00 – 15:00	Chitrakoot	21	Government organizations
Fri. 14 Jul. 2014	16:00 – 17:00	Chitrakoot	23	residents

【Agenda】

1) Whole Plan of the whole Landslide Countermeasure Work in Chitrakoot
2) Contents of the Construction Work (Section 1) (by showing many photos to make the audience easily understand)
3) Work Schedule

【Discussion, Questions and Answer from the audience】

[Chitrakoot]
・Residents and relevant organizations present agreed with the project implementation plan and showed willingness to corporate. Some questions on the early warning and evacuation system were raised.

Summary of comments given by residents	Matters to be considered by the Project
- One resident asked when they will get a result of construction work.	- The Project answered that we need to wait until next rainy season at least to examine the effectiveness of the works. The Project is planning to conduct monitoring and evaluation works after the completion of construction work.
- Residents added that during the last torrential rain nobody evacuated and that the police brought all school kids to their homes, although all of the parents were not at home. They questioned if any solutions can be proposed on this matter.	- The disaster prevention education and awareness should be strengthened. In addition, the project needs to investigate reasons why residents failed to follow police instructions to evacuate. There should be some reasons behind like; evacuation place was too far from their residence, lack of means of transportation, etc. In order to grasp the real picture of the situation, the Project will conduct an interview survey for residents in Chitakoot through house-to-house visits.
- The main concerns of resident were about the early warning and evacuation system. Residents suggested that the Project should provide more opportunities for education and awareness to community and school kids so as they will be more aware of what is a landslide and actions to be taken.	- MPI/JET will take the comments received into consideration and will examine better solutions with the police. All stakeholders should have common understanding on the early warning and evacuation system. - It is not enough for residents to gain necessary information about landslides through stakeholder meetings. The important information should be compiled in the handbook that will enable residents to access to information concerning landslides when necessary.
- Residents speculated that they are going to cooperate and talk to others about the Project.	

【Photos】

Stakeholder meeting for government organizations (Chitrakoot)

Stakeholder meetings for residents (Chitrakoot)

5th Stakeholder meeting (in Nov. – Dec. 2014)

【Background/Objective】

The construction work will be completed in early Dec. 2014 while the Project will end in Jan. 2015. The Project organized stakeholder meetings at three priority areas on a regular basis, shared the progress activities and issues and requested understanding and cooperation of residents and relevant government organizations. This stakeholder meeting is the last one during the project period, so the Project reviewed the whole activities and highlighted the importance of disaster prevention and the whole system of early warning and evacuation using the Landslide Disaster Prevention Handbook which was developed by the Project. For Chitrakoot area, the Project reported the completion of construction work.

【Target area】

Three (3) landslide areas（Chitrakoot、Quatre Soeurs、Vallee Pitot）

【Target】

- Residents who live in these places where countermeasure works and the early warning and evacuation system will be in place.
- Relevant Ministries/organizations (*only for Chitrakoot (held on Fri. 28 Nov))

(↓ Stakeholders participated in the meeting)

- SMF
- Albercombie Police (local police who in charge of Chitrakoot area)
- Ministry of Housing and Land
- National Development Unit, Ministry of Public Infrastructure
- National Disaster Risk Reduction and Management Centre (NDRRMC)
- Ministry of Environment and Sustainable Development.

[Photos]


Stakeholder meeting and site visit for relevant government organizations (Chitrakoot)

Early warning and evacuation system was explained based on the Handbook (Chitrakoot)

6.3.5 Questionnaire Survey for Residents at Three Priority Area

a. Background and Objective

The Project conducted stakeholder meetings for residents and explained the necessary actions at warning and evacuation stages. However, most residents did not evacuate to the designated place despite the evacuation order being issued in March 2014. Therefore, the project has decided to conduct an interview survey to evaluate the awareness level of residents on landslides and the effectiveness of current early warning and evacuation system. The results will provide useful information for further improvement of the system.

b. Objective

- To know how much residents understand landslide issues
- To review the early warning and evacuation system the Project has proposed.
- To reflect necessary information to IEC materials.

c. Target

- All residents who live in three landslide areas (Chitrakoot, Vallee Pitot, Quatre Soeurs)
- The number of target households: Chitrakoot (21), Vallee Pitot (26), Quatre Soeurs (9)

d. Survey Methods:

- Interview survey through house-to-house visit
- Questionnaire was drafted by IEC Expert and finalized by reflecting comments given by MPI CP and NDRRMC
- Implementation period: Mon 21 July - Wed 31 July (9 days in total)
- The results were analyzed by IEC Expert and were shared with MPI and NDRRMC


Photo 6.3.1 Scenes of Interview Survey

e. Summary of Findings

The following shows the summary of findings (see Supporting Report for more details)

(1) Level of landslide awareness

- ✧ The majority of residents living in three priority areas have a basic knowledge of landslides. However, almost half of residents who live outside of landslide block in Vallee Pitot had some general knowledge of landslides, but did NOT know that they are living in a landslide-prone area.
- ✧ More than 1/3 of residents in Chitrakoot and Vallee Pitot did NOT know MPI is conducting landslide monitoring while all residents in Quatre Soeurs were aware of the monitoring.
- ✧ In Chitrakoot, 25 % of residents still did NOT know that MPI/JICA is now implementing countermeasures on site.

(2) NDRRMC

- ✧ Most of the residents did NOT know about NDRRMC.

(3) Early warning and evacuation system

<Early warning system in Chitrakoot and Vallee Pitot>

- ✧ The early warning system is well-known to residents who live in both Chitrakoot and inside the landslide block in Vallee Pitot. However, in Vallee Pitot, less than 50 % of residents who live outside of the landslide block did NOT know of the system.

<Simple rain gauge system in three priority areas>

- ✧ Most of residents in Chitrakoot and Quatre Soeurs knew about simple rain gauge system. In Vallee Pitot, only 40% of residents who live inside the landslide block knew of the system while NONE of residents who live outside of the landslide block knew of the system.

<Communication at each stage>

- ✧ Police is the first contact organization for residents if they have noticed cracks/subsidence in their buildings. For evacuation, more than 30 % of residents have requested assistance from a relevant authority.
- ✧ The Project has assigned some people who will contact the police when a warning is issued. However, most residents in Vallee Pitot and Quatre Soeurs believed that they should call the police by themselves. Approx. 60 % of residents in Chitrakoot knew that delegated persons should contact the police as their representatives.

✧ Most people in three areas did NOT know the contact number of the delegated persons who will contact the police when conditions reach the warning stage.

✧ People believed that local police would inform them of the timing of the warning and evacuation stages.

<Evacuation order issued in Chitrakoot in March 2014>

✧ 25 % of residents were not at home at that time while no one evacuated even though the evacuation order was issued. The major cause of this was that residents did not take it seriously. Also, some of them were also not aware of where to evacuate.

<Future plan of evacuation>

✧ Approx. 40 % of residents in Chitrakoot and Vallee Pitot replied “No” or “Not sure” when asked whether or not they would evacuate in the event of an evacuation order being issued in future. The main cause of this was that residents did NOT know where they should evacuate to. All residents in Quatre Soeurs were sure of where to evacuate to.

<Responsibility of landslides and associated disasters>

✧ Over half of residents felt that they would be responsible for anything that might happen to them as a result of not evacuating. Less than one third of residents insisted that the government should take more responsibility on this.

✧ Most of residents in three areas believed that MPI should be responsible for landslide monitoring and countermeasures, following by Local Authorities.

<Necessary information and arrangement for evacuation>

✧ The evacuation center is expected to be the place where residents will evacuate to.

✧ 100 % of residents in Quatre Soeurs knew about the location of evacuation center and appropriate route while less than 60 % of residents in Chitrakoot and Vallee Pitot knew the location.

✧ Over 70 % of residents in three areas have felt the need of assistance from relevant assistance for evacuation.

<Review of current system>

✧ Most residents were uncertain if the current system is functioning well or not as they had never experienced a warning issued by the early warning system.

(4) IEC and others

✧ Almost all households have experienced attending the stakeholder meetings which were organized by MPI and JICA.

✧ The three main sources of information related to landslide is; TV, Stakeholder meeting on site and radio. Some people also get information by word of mouth such as from their neighbors.

✧ Residents in three areas knew about JICA Project but most of them who live outside of landslide block in Vallee Pitot did NOT know about it.

f. Conclusions

✧ Awareness activities such as stakeholder meetings should be conducted not only for residents who live inside of the landslide block but also for the ones who live outside of the landslide block as they will be affected by landslide disaster as well. These people should be included in the evacuee list.

✧ NDRRMC should make more effort to raise awareness of the mission of the organization much more. (by mass media, etc.)

✧ At this stage, the Project can’t conclude that the current early warning and evacuation system is working or not as not much experience in operation has been accumulated. The survey provided some matters to be considered as follows;

- The early warning system are easily visible to residents as it has been located in a visible place outside. However, the difference between yellow and red lights should be reminded to residents.
- It might be difficult for residents to identify which households own simple rain gauge unless they did obtain information in the stakeholder meeting.
- Contact point should be the same for any landslide inquiries including during warning and evacuation stages. Police will be the best organization for this.
- The presence of contact person(s) will be useful for the government such as MPI to obtain information of actual site conditions, but for residents, it would be better to let anyone contact police. If this is not the case then all of the residents need to know the phone number of the contact person(s) so that they can contact them to report an emergency.
- “Self-evacuation” should be promoted but assistance for evacuation by relevant authority is still required for some people, especially for elderly. It is important for the government to identify the persons who need assistance in advance.
- The government should not hesitate to issue warning and evacuation orders when it reaches each level. The location of evacuation center and appropriate route should be well informed in advance. And, transport for people who need assistance should be arranged at evacuation stage. Residents will not be able to blame the government if something happens to them because they have not followed instructions and when the government has done everything that it is supposed to do.

✧ Stakeholder meetings in at risk communities are an effective tool to disseminate information, especially specific information to the locality such as location and route of evacuation center. TV and radio are also informative but will be effective to disseminate landslide information in general.

6.3.6 Project Newsletter

The Project issued Project Newsletter (vol.1 – vol.5) every six months. The Newsletter explained about the Project and the progress of Project activities in a manner easily understandable to readers. Two versions of the leaflet, in English and French, were issued since most of residents cannot understand English well. The Project leaflet was drafted by JICA Experts and finalized by reflecting comments given by MPI CP and Permanent Secretary of MPI. The copies of the finalized leaflet were distributed to the local households in priority areas, and also shared with relevant organizations. Both English and French versions of the leaflet are attached in Supporting Report.

6.3.7 IEC Material - Landslide Disaster Prevention Handbook -

As a result of stakeholder meetings and the questionnaire survey (see Section 6.3.6), it was noted that the important information considering landslides should be compiled in a handbook that will enable residents to access information when necessary.

The Project developed the Landslide Disaster Prevention Handbook. In developing the handbook, the contents were generalized and simplified using simple text, many illustrations and photos that enables any age group including school kids to use it. The handbook outlines necessary information people should know about landslide disasters, and emphasizes the importance of disaster prevention, which is a key concept to cope with landslides.

The Handbook was published under joint authorship with MPI and NDRRMC. The handbook was distributed to residents who live in three landslide priority areas and relevant organizations during the 5th stakeholder meeting, Technical Seminar and Steering Committee.

Photo 6.3.2 Handbook, (Left: French Version, Right: English Version)

Photo 6.3.3 Awareness Activity for Residents Using the Handbook (Chitrakoot)

6.4 Technical Summary of the Pilot Project

A combination of “hard” countermeasures and “soft” countermeasures on landslides have been implemented for the first time in Mauritius in the Project.

Hard countermeasures are structural countermeasures in Chitrakoot. JET and C/P have implemented the basic design/detailed, design/cost, estimation/construction, and plan/bidding/contract/construction/supervision for large-scale channels, horizontal drilling, open/blind ditches, surface ditches, river improvement (widening and revetment work), bridges and a collecting channel for the purposes of limiting the inflow of water into the landslide area and draining of water away from the landslide area.

Although large-scale channels, open/blind ditches and surface ditches have been constructed for preventing floods, it is the first time such measures are to be trialed for mitigating landslides in Mauritius. Therefore, explanations of the effectiveness of such measures for landslides were needed to gain the understanding of the C/Ps. Regarding horizontal drilling, which is a major countermeasure for landslides in Japan, JET has explained the purposes, procedures, maintenance, etc., to the C/Ps over and over since the planning stage. As the C/Ps are civil engineers, once they understood the technical grounds and the significance of the works, they conducted the design and construction independently, while asking for advice from JET from time to time. Therefore their cooperation highly contributed to the completion of construction of the abovementioned countermeasures within the schedule. Thanks to the understanding of the C/Ps on the significance and methods of the hard measure procedures, the Pilot Project was able to be divided into Section I by JET and Section II by MPI. It is planned to be conducted next year, 2016.

The effectiveness of the countermeasure works cannot yet be identified. Consequently, it is necessary to wait for the monitoring results of the piezometers and extensometers. However, the effectiveness of these gauges is assumed to be very high as judged from the damage from the activity of a small landslide in Chitrakoot in January 2015. The small landslide generated by heavy rainfall from the Cyclone Bansi in the middle of January in Section II, where MPI will construct the countermeasure works in the next fiscal year. Although the landslide damaged six (6) houses in this area, there was no damage in Section I where the countermeasure works were constructed, such as the horizontal drilling, by JET. This indicates that the landslide disaster was minimized by restraining the whole landslide movement through the countermeasure works in this Pilot Project. The whole of the active landslide area in Chitrakoot would be stabilized by the construction of landslide countermeasures (proposed by JET) in Section II by MPI next year.

Soft countermeasures are the early warning and evacuation systems in the three (3) priority sites, Chitrakoot, Quatre Soeurs, and Vallee Pitot. On the basis of the monitoring results of this Project, JET proposed a new early warning system that is based on the reference values of extensometers and changes in the state of the houses. This proposal was the result of investigations looking into the issues of the current system in the Disaster Scheme of Mauritius. It is proposed to set reference value in the occurrence of cracks or changes on the houses and displacement of borehole extensometers. The thresholds are; “preparation (pre stage)”, “warning (stage 1)”, “evacuation (stage 2)”, and “warning lifted (stage 3)”. The revolving lights (red and yellow) and sirens have been installed to enable voluntary evacuation using the thresholds. Liaison members and communication systems as well as evacuation routes/areas for the early warnings and evacuations have been established.

The early warning and evacuation systems in the Disaster Scheme were purely theoretical because even though no extensometers or rain gauges had been installed to monitor landslides, there were 37 risk sites that were supposed to be monitored by these nonexistent extensometers and rain gauges. JET looked into the issues of the current system in the Disaster Scheme and established a practical and effective system on the three (3) priority sites. The system of voluntary communication and evacuation by local residents and the reference values of "in-home changes" (damage within houses) are considered to be breakthrough initiatives in Mauritius's development of an early warning and evacuation system.

A landslide that exceeded the threshold reference value occurred at Vallee Pitot in January 2015 due to heavy rainfall by the Cyclone Bansi, and the "warning (stage 1)" was issued. Followed by the warning/evacuation protocol installed by JET, the local residents called the local police, the police requested MPI to check immediately at the site, and then MPI (and JET) investigated the extensometers, damage to houses and landslide conditions. MPI checked the conditions regularly until the "warning lifted (stage 3)" (fortunately the landslide has been stabilized because of no rainfall). The C/Ps understand the significance and the responsibility even of soft countermeasures, and voluntarily fulfill the duties based on advice given by JET. This, it can be said, is a direct result of the Pilot Project implementation. MPI will continuously work to raise awareness of local residents under normal conditions, and check the areas and give advice to the related organizations in emergency conditions.

Reference for Chapter 6

[1] Japan Road Association: Highway Earthwork Series: Manual for slope protection, pp. 404, 2009
[2] ASCE: Manual No.37, Design and Construction of Sanitary and Storm Sewers, pp. 43-49, 1960
[3] Japan Sewage Works Association: Manual and Guide for design of sewer facility (First part), 2001
[4] Irrigation Authority of Mauritius
[5] Japan Society of Civil Engineers: Collection of Hydraulic Formula, 1999
[6] Japanese Geotechnical Society: Manual for Corrugated Metal Culvert revised third edition, 1997
[7] Construction Industry Development Board: National Schedule of Rates (First edition), 2012
[8] Saito, M.: Study on Predicting the Time of Slope Failure Railway Technical Research Report, No. 626, Railway Technical Research Institute, 1968 (in Japanese)
[9] https://www.unfpa.org/emergencies/manual/a1.html

Chapter 7

Technical Transfer

7 Technical Transfer

7.1 Methodology

7.1.1 Objectives of Technical Transfer

The objectives and inputs of each item of the technical transfer are summarized as the following table to ensure the technical transfer is effective.

Table 7.1.1 Objectives and Inputs on Technical Transfer (source: JET)

Item	OJT (On-the-Job-Training)	Pilot Project	Training in Japan
Objectives	1. Grasp the flow of survey, analysis, monitoring, design, countermeasures on landslide 2. Propose the institution plan, manual/guideline, actual early warning system	1. Understand actual method of plan/design/cost estimation/construction/maintenance of countermeasures 2. Understand cooperation of residents and stakeholders for construction of countermeasures	[1st] Understand "what is a landslide?" and "what is disaster management?" for landslide management in Mauritius in the future. [2nd] Understand actual landslide countermeasures and their significance/method for landslide countermeasure work in Mauritius in the future.
Inputs	・Collaboration on reconnaissance, monitoring, construction ・Technical transfer seminar ・Workshop ・Establishment of manual ・Establishment of guideline ・Proposal of early warning system	・ Collaboration on plan/design/cost estimation/construction/maintenance of countermeasures ・ Stakeholder meetings ・ Examination for local residents	・Visit Land, Infrastructure and Transportation Ministry in Japan (including information about administrative activities, evacuation, consensus building) ・Visit local authorities in Japan (including information about administrative activities, evacuation, consensus building) ・Visit universities and research institutes ・Visit private consultant

7.1.2 Method of Technical Transfer

a. Confirm MPI's Capacity

To confirm the capacity of MPI, Capacity Assessments (CA) are conducted from three aspects (individual, institutional, society) at the beginning, middle, and end of the Project. The CA helps the Project to achieve its goals.

b. Proposed Gradual Technical Transfer

The technical transfer in the Project is promoted based on Capacity Development (CD) in four stages (Table 6.1.2). The CD is one cycle in one activity, and repeats again and again in the Project period. The repetition helps the improvement of C/P's ability effectively.

Table 7.1.2 Each Development Stage of the CD (source: JET)

Development Stage
① Basic survey, monitoring, analysis of landslides, and establishment of countermeasure plan
② Discussion, design, cost estimation, work volume on actual landslide countermeasures
③ Construction and supervision of countermeasures on pilot site
④ Sustainable survey/design/construction/supervision/maintenance and establishment of systems/frameworks for emergencies

7.1.3 Basic policy of Technical Transfer

a. Consideration of Measures Appropriate to Socioeconomic Conditions in Mauritius

- Discussion of appropriate countermeasures based on landslide mechanisms, the purpose of which is the safety of local residents
- Propose balanced measures, both “hard” (physical) measures and “soft” (non-physical) measures such as early warning systems.

b. Steering Committee

- Organization of regular steering committee to discuss progress and issues for smooth implementation of the Project.

c. Advisory Committee in Japan

- Support by highly technical advice on landslide countermeasures and management.
- Instruction by administrative experts on landslide management for improvement of systems/institution of C/P from a subjective point of view.

d. Regular Meetings

- Organization of regular meetings with C/P from a viewpoint of flexibility.
- Discussion of progress, issues, schedule, solutions to gain mutual understanding.

e. Promote Understanding Among Local Residents

- Organization of resident committees for consensus building. Promotion of simple monitoring by local residents.
- Public relations for local residents by using mass media, seminars, leaflets, etc.

f. Recommendations for Sustainable Improvement

- In order for engineers posted at the LMU to be able to take over the management of landslides after the completion of the Project, it is recommended that they should be sent abroad to undertake a postgraduate degree in Geotechnical Engineering with landslides one of the modules to be studied.

7.2 Structure of Technical Transfer

For the effective and smooth technical transfer, the idea is to form groups based on the respective expertise of both the JET and C/P. The groups are basically comprised as follows in Table 7.2.1. The concept of the technical transfer is to transfer a basic understanding and know-how of landslide surveys, analysis, design, and construction to all the members of the C/P.

Table 7.2.1 The JICA Expert Team Members by Group of Expertise (source: JET)

	Group	JET	MPI
1	**Management** (Chief adviser, Vice chief adviser/ Landslide management)	K. ICHIKAWA T. KUWANO	M. R. JEWON D. CHINASAMY V. RAMDHAN S. P. ANADACHEE M. K. MOSAHEB R. RAMDHAN L. BISSESSUR B. DABYCHARUN
2	**Survey/Analysis** (Landslide survey and analysis, Landslide monitoring, Geophysical prospecting, GIS/Topographic survey)	T. IWASAKI F. YOKOO Y. KASAHARA M. SUGITA	
3	**Design/Construction** (Design/Cost estimation, Environmental and social consideration)	T. HARA T. KURATA	
4	**"Soft" countermeasure** (Policy and planning of urban development and land use, Institution/system analysis/capacity development, Information/education/ communication)	Y. GONAI K. SAITO S. ICHIKAWA Y. KAWABATA H. YOSHIDA M. TOKUDA	

The schematic image of the technical transfer is shown in the Figure 6.2.1. The transfer is made from the group of Japanese experts to the C/P group so that the transfer will benefit most of the C/P regardless of the C/P's expertise. In addition, C/P will learn not only one expertise but also total landslide management skills.

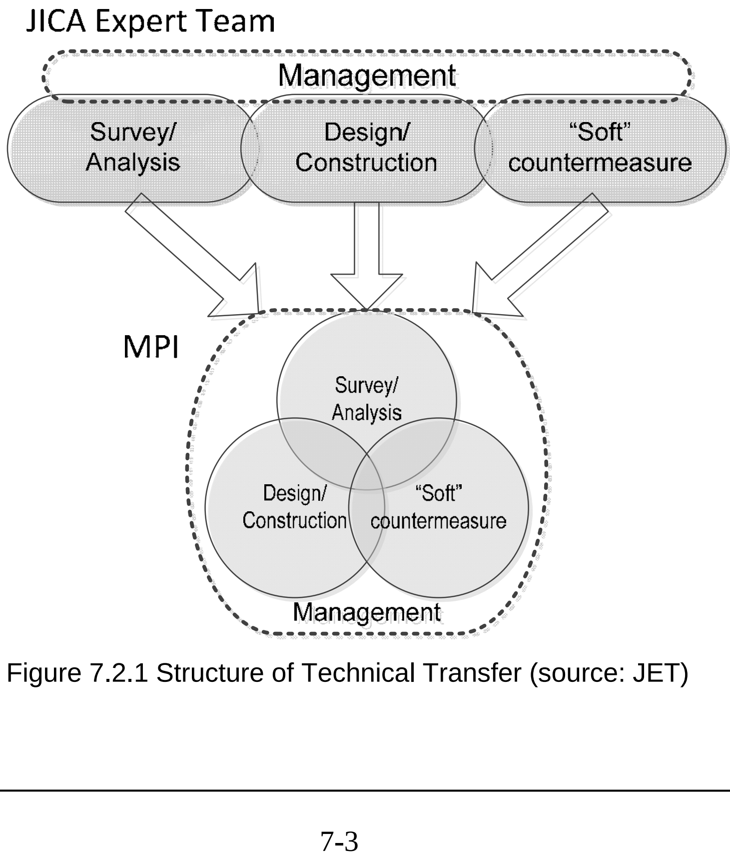


Figure 7.2.1 Structure of Technical Transfer (source: JET)

7.3 Technical Transfer Seminar

7.3.1 1st Technical Transfer Seminar

The 1st technical transfer seminar was held on 10 October 2012 aimed to inform relevant stakeholders of the contents, policy, and procedure of the Project and the results of the basic survey. The seminar was presented by both the JET and C/P. The major contents are shown in the seminar agenda shown as follows. The Seminar was initiated by Mr. V. Lutchmeeparsad, Permanent Secretary of MPI and followed by keynote speech by Mr. K. Ichikawa, Chief Adviser of JET. The Minute of Meeting is in the Supporting Report.

1. Opening speech 10:00-10:10
   Mr. Luchmeeparsad /Permanent Secretary, MPI
2. Keynote speech 10:10-10:20
   Mr. Ichikawa/Chief adviser, JICA Expert Team
3. Outline of the Project 10:20-10:35
   Mr. Kuwano/Vice chief adviser, JICA Expert Team
4. What is a landslide? 10:35-11:05
   Mr. Kuwano/Vice chief adviser, JICA Expert Team
5. Landslide disaster in Mauritius 11:05-11:35
   Mr. Jewon/Deputy director, CE, MPI
6. Basic survey and target landslides 11:35-12:00
   Mr. Iwasaki/Landslide survey & analysis, JICA Expert Team
7. Landslide analysis and interpretation 13:30-14:00
   Mr. Yokoo/Landslide monitoring, JICA Expert Team
8. Collaboration with other project (AAP etc.) 14:00-14:30
   Mr. Ichikawa/Chief adviser, JICA Expert Team
9. Survey plan and monitoring for landslide 14:45-15:05
   Mr. Yokoo/Landslide monitoring, JICA Expert Team
10. Activity plan 15:05-15:20
    Mr. Kuwano/Vice chief adviser, JICA Expert Team
11. Closing speech 15:20-15:30
    Mr. Jewon/Deputy director, CE, MPI

Photo 7.3.1 1st Technical Transfer Seminar (source: JET)

7.3.2 2nd Technical Transfer Seminar

The 2nd technical transfer seminar was held on 20 November 2013 aimed to inform relevant stakeholders of the results of the basic surveys, the landslide management plan and the F/S, and the outline of the pilot project. The seminar was presented by both the JET and C/P. The major contents are shown in the seminar agenda shown as follows. The Seminar was initiated by Mr. V. Lutchmeeparsad, Permanent Secretary of MPI.

1. Opening of the seminar		9:30-9:35
	Mr. Luchmeeparsad /Permanent Secretary, MPI	
2. Keynote speech		9:35-9:40
	Mr. Ichikawa/Chief adviser, JICA Expert Team	
3. Progress of the Project		9:40-9:45
	Mr. Kuwano/Vice chief adviser, JICA Expert Team	
4. Geological interpretation		10:00-10:20
	Mr. Kuwano/Vice chief adviser, JICA Expert Team	
5. Monitoring results for three (3) sites		10:20-10:40
	Mr. Yokoo/Landslide monitoring, JICA Expert Team	
6. Review and recommendation for the Disaster Scheme		10:40-11:00
	Mr. Gonai/Development and land use, JICA Expert Team	
7. Review and recommendation for the Planning Policy Guidance		11:00-11:20
	Mr. Gonai/Development and land use, JICA Expert Team	
8. Training in Japan		11:20-11:45
	Mr. Jewon/Deputy director, CE, MPI	
9. Priority site and Pilot Project site		13:15-13:25
	Mr. Bissessur/Senior engineer, CE, MPI	
10. Structural countermeasures		13:25-13:55
	Mr. Anadachee/Senior engineer, CE, MPI	
11. Early warning and evacuation		13:55-14:20
	Mr. Mosaheb/Senior engineer, CE, MPI	
12. IEC(Information, Education, Communication)/Consensus building		14:20-14:40
	Mr. Dabycharun/Senior engineer, CE, MPI	
13. Pilot Project evaluation		14:55-15:10
	Mr. Ramdhan/ Senior engineer, CE, MPI	
14. Organizational reinforcement plan		15:10-15:20
	Ms. Yoshida/Capacity development, JICA Expert Team	
15. Activity plan		15:20-15:30
	Mr. Kuwano/Vice chief adviser, JICA Expert Team	
16. Closing speech		15:30-15:40
	Mr. Jewon/Deputy director, CE, MPI	

Photo 7.3.2 2nd Technical Transfer Seminar (source: JET)

7.3.3 3rd Technical Transfer Seminar

The 3rd technical transfer seminar was held on 20 January 2015 aimed to inform relevant stakeholders of the results of the pilot project and the early warning system among all activates. The seminar was presented by both the JET and C/P. The major contents are shown in the seminar agenda shown as follows. The Seminar was initiated by Mr. V. Lutchmeeparsad, Permanent Secretary of MPI.

1. Opening of the seminar		10:00-10:10
	Mr. Luchmeeparsad, Permanent Secretary, MPI	
2. Keynote speech		10:10-10:20
	Mr. Nishimoto, Chief Representative, JICA Madagascar Office	
3. Keynote speech		10:20-10:30
	Mr. Ichikawa, Chief adviser, JICA Expert Team	
4. Progress of the Project		10:30-10:40
	Mr. Kuwano, Vice chief adviser, JICA Expert Team	
5. Structural countermeasures in Chitrakoot		11:00-12:00
	Mr. Anadachee and Mr. Ramdhan, CE, MPI	
6. Pilot Project Evaluation		12:00-12:20
	Mr. Mosaheb, CE, MPI	
7. Early warning and evacuation system		14:00-14:45
	Mr. Bissessur, CE, MPI	
8. Organizational reinforcement plan		14:45-15:05
	Mr. Dabycharun, CE, MPI	
9. Closing speech		14:05-15:10
	Mr. Chinasamy, Chief engineer, CE, MPI	


Photo 7.3.3 3rd Technical Transfer Seminar (source: JET)

7.4 Workshop

Several workshops for certain themes have been conducted by the JET to accelerate C/P's understanding for landslide survey, analysis, evaluation and countermeasure in the Project as follows.

Table 7.4.1 Summary of Landslide Workshop (source: JET)

Date/time	Theme	Venue	C/P	JET
19 June, 2012 9: 30-11: 30	Fundamentals and Basics on Landslides	Phoenix, MPI	23	Ichikawa, Kuwano, Iwasaki, Togami, Kasahara, Saito
10 July, 2012 9: 30-12: 30	Landslide Reconnaissance	Phoenix, MPI Chitrakoot, Port Louis	7	Iwasaki, Yokoo, Kasahara, Gonai, Yamamoto
26 July, 2012 10: 00-11: 30	Monitoring device	Phoenix, MPI	11	Yokoo
30 July, 2012 10: 00-12: 00	Land Use Policy for Landslide Disaster	Phoenix, MPI	11	Gonai
6 September, 2012 10: 00-11: 30	Interpretation of Aerial Photo for Landslide	Phoenix, MPI	15	Hara
31 October, 2012 9:30-12:00	Landslide investigation/ analysis/monitoring	Phoenix, MPI	12	Dr. Fukuoka, Kuwano, Iwasaki, Yokoo, Kasahara
31 October, 2012 13:30-14:00	Geotechnical Site Characterization and Constant Volume Direct Shear Test	Phoenix, MPI	10	Dr. Fukuoka, Kuwano, Iwasaki, Yokoo, Kasahara
5 November, 2012 13:00-15:00	Training of the Landslide Monitoring	Quatre Soeurs Landslide	6	Iwasaki, Yokoo, Kasahara
25 February, 2013 13:30-16:00	Monitoring Result and Early Warning	Phoenix, MPI	6	Iwasaki, Yokoo, Hara, Gonai, Yoshida
26 February, 2013 9:30-11:30	Review of Planning Policy Guidance	Phoenix, MPI	19	Gonai
5 March, 2013 13:30-16:00	Stability Analysis and Countermeasures	Phoenix, MPI	6	Iwasaki, Hara, Yokoo, Kuwano
7 March, 2013 10:00-12:00	Monitoring log for pilot site	Phoenix, MPI	4	Yokoo, Iwasaki
16 October, 2013 14:30-16:00	Countermeasure works	Phoenix, MPI	4	Hara, Iwasaki, Yoshida, Tokuda

a. Fundamentals and Basics on Landslides

Table 7.4.2 Outline of "Fundamentals and Basics on Landslides" (source: JET)

Date/Time	19 June, 2012 9:30-11:30
Venue	Phoenix, MPI
Participants	MPI: A. Gopaul, D. Chinasamy, N.K. Ujoodha, S.P. Anadachee, B. Dabycharun, C. Masse, P. Peghan, R. Canhye, M.K. Mosamed, M. Balloo, S.A.SPheerungee, D Rittoo, A R.Baweek, R.Ramdhan, L Ramdin, S Seevathean, Andoo Afack, T.Bhowruth, D.Jhuboo, V Ramdhan, A R.Baweek, L. Bissessur, M. Cowlessur JET: Ichikawa, Kuwano, Iwasaki, Togami, Kasahara, Saito
Contents	• What is "LANDSLIDE"!? • Survey for Landslides • Monitoring of Landslides • Introduction on Landslides in Japan • Countermeasures for Landslides • Free Discussion

Photo 7.4.1 Photo of “Fundamentals and Basics on Landslides”

b. Landslide Reconnaissance

Table 7.4.3 Outline of “Landslide Reconnaissance” (source: JET)

Date/Time	10 July, 2012 9: 30-12: 30
Venue	Phoenix, MPI Chitrakoot, Port Louis
Participants	MPI: L.Bissessur, M.Cowlessur, N.K.Ujoodha, S.A.S Pheerungee, S.P.Anadachee, B.Dabycharun, D.Chinasamy JET: Iwasaki, Yokoo, Kasahara, Gonai, Yamamoto
Contents	• Instructions of the training on the site • Field Practice - Chitrakoot , Port Louis • Landslide Reconnaissance • Stability check sheet • Free Discussion on the site

Photo 7.4.2 Photo of “Landslide Reconnaissance” (source: JET)

c. Monitoring Device

Table 7.4.4 Outline of “Monitoring Device” (source: JET)

Date/Time	26 July, 2012 10: 00-11: 30
Venue	Phoenix, MPI
Participants	MPI: A.Gopaul, L.Bissessur, M.Cowlessur, N.K.Ujoodha, S.P.Anadachee, B.Dabycharun, D.Chinasamy, C.Masse, P.Peghan, R.Deenoo, Kiran Bunjun JET: Yokoo
Contents	• Landslide Monitoring Program - Chitrakoot, Quatre Soeurs, Vallee Petit - • Inclinometer - Inclinometer sensor, indicator, guide pipe - • Strain Gauge Sensors - Strain gauges, logger and data collection - • Automatic Piezometer -Water pressure sensor, logger and data collection- • Extensometer - Extensometer, installation method - • Rain Gauge - Sensor, logger and data collection - • Other Instruments for Landslide Monitoring


Photo 7.4.3 Photo of “Monitoring device” (source: JET)

d. Land Use Policy for Landslide Disaster

Table 7.4.5 Outline of “Land Use Policy for Landslide Disaster” (source: JET)

Date/Time	30 July, 2012 10: 00-12: 00
Venue	Phoenix, MPI
Participants	MPI: A.Gopaul, M.Cowlessur, N.K.Ujoodha, S.P.Anadachee, L.Bissessur, R.Canhye, M.K.Mosamed, M.Balloo MHL: S.Suntah, D.Bhikajee G.Port /Savanne D.Council: S.K.Jeechurn JET: Gonai
Contents	• Project objectives & Objectives regarding to the Land Use Policy in this project • Understanding the existing situation • Clarification of the issues • Discussion/examination of countermeasure for the issues

Photo 7.4.4 Photo of “Land Use Policy for Landslide Disaster” (source: JET)

e. Interpretation of Aerial Photo for Landslides

Table 7.4.6 Outline of “Interpretation of Aerial Photo for Landslide” (source: JET)

Date/Time	6 September, 2012 10: 00-11: 30
Venue	Phoenix, MPI
Participants	MPI: N.K.Ujoodha, L.Bissessur, M.K.Mosamed, M.Balloo, B.Dabycharun, D Rittoo, A R.Baweek, R.Ramdhan, L Ramdin, S Seevathean, Andoo Afack, T.Bhowruth, D.Jhuboo, S.A.S Pheerunggee, V Ramdhan JET: Hara
Contents	• What is Aerial Photo Interpretation for Landslide • Usage of Aerial Photo Interpretation for Landslide • How to Interpret an Aerial Photo

Photo 7.4.5 Photo of “Interpretation of Aerial Photo for Landslide” (source: JET)

f. Special Technical Workshop on Landslide Investigation/analysis/monitoring

Table 7.4.7 Outline of "Landslide Investigation/Analysis/Monitoring" (source: JET)

Date/Time	31 October, 2012, 9:30-12:00
Venue	Phoenix, MPI
Participants	MPI: M.R.Jewon, N.Earally, M.K.Mosaheb, A.R.Bawreek, N.K.Ujoodha, L.Bissessur, R.Ramdhan, V.Ramchurn, S.P.Anadachee, V.Ramdhan, M.A.B.Furzun, R.Deenoo JET: Dr. Fukuoka (Kyoto University), Kuwano, Iwasaki, Yokoo, Kasahara
Contents	• Geotechnical investigation of landslide movement • Analysis of landslide movement • Monitoring of landslide movement


Photo 7.4.6 Photo of "Landslide Investigation/Analysis/Monitoring" (source: JET)

g. Geotechnical Site Characterization and Constant Volume Direct Shear Test

Table 7.4.8 Outline of "Geotechnical Site Characterization and Constant Volume Direct Shear Test" (source: JET)

Date/Time	31 October, 2012, 13:30-14:00
Venue	Phoenix, MPI
Participants	University of Mauritius: A.Chan Chim Yuke Sotravic Ltd: K.Mehboob, K.Kourouma, J.F.Ko Mega Design Ltd: A.Paul, B.Appavoo Water Research Ltd: E.Saldivar, O.Bhoum, N.Choolun IST: Dr. R.Goodary JET: Dr. Fukuoka (Kyoto University), Kuwano, Iwasaki, Yokoo, Kasahara
Contents	• Dr. Chan (Mauritius Univ.): Geotechnical Site Characterization Project for Mauritius • Dr. Fukuoka (Kyoto Univ.): Training of the Constant Volume Direct Shear Test

Photo 7.4.7 Photo of “Geotechnical Site Characterization and Constant Volume Direct Shear Test” (source: JET)

h. Training of the Landslide Monitoring

Table 7.4.9 Outline of “Training of the Landslide Monitoring” (source: JET)

Date/Time	5 November, 2012 13:00-15:00
Venue	Quatre Soeurs Landslide
Participants	MPI: M.K.Mosaheb, B.Dabycharun, L.Bissessur, V.Ramdhan, S.P.Anadachee Sotravic Ltd:J.F.Ko JET: Iwasaki, Yokoo, Kasahara
Contents	• Installation of groundwater level meter • Sampling of ground water • Manual measurement of ground water level • Acquisition of pipe strain gauge

Photo 7.4.8 Photo of “Training of the Landslide Monitoring” (source: JET)

i. Monitoring Result and Early Warning

Table 7.4.10 Outline of "Monitoring Result and Early Warning" (source: JET)

Date/Time	25 February, 2013 13:30-16:00
Venue	Phoenix, MPI
Participants	MPI: M.K.Mosaheb, B.Dabycharun, L.Bissessur, D.Chinasamy, S.P.Anadachee, Visham JET: Iwasaki, Yokoo, Hara, Gonai, Yoshida
Contents	• The results of geotechnical survey/monitoring in the pilot sites • Early warning system in Japan • Review of the early warning system in the Disaster Scheme


Photo 7.4.9 Photo of "Monitoring Result and Early Warning" (source: JET)

j. Review of Planning Policy Guidance

Table 7.4.11 Outline of "Review of Planning Policy Guidance" (source: JET)

Date/Time	26 February, 2013 9:30-11:30
Venue	Phoenix, MPI
Participants	R. Luximon (MoESD), G.Rosunee (MHL), V. Rugler (MHL), J.Bosquet (Council of Grand Port), K.Poomth (Council of Grand Port), Domoh (Council of Port Louis), S.N.Seechmin (Council of Savanne), Baguant-Moonshiram (University of Mauritius) MPI: M.K.Mosaheb, L.Bissessour, Mr. S.P.Anadachee, Gopal woodayesing, J.Suddy, S. Permala, Suntah, K. Santokhee, Jewon Reshad, D.Chinasamy, B Dabycharun JET: Gonai
Contents	• Existing situation of landslide prone areas in Mauritius • Existing legal systems/schemes related with disaster risk management • Japanese legal systems/schemes for disaster risk management • Draft recommendations for PPG


Photo 7.4.10 Photo of "Review of Planning Policy Guidance" (source: JET)

k. Stability Analysis and Countermeasures

Table 7.4.12 Outline of "Stability Analysis and Countermeasures" (source: JET)

Date/Time	5 March, 2013 13:30-16:00
Venue	Phoenix, MPI
Participants	MPI: M.K.Mosaheb, V.Ramdhan, L.Bissessur, D.Chinasamy, S.P.Anadachee, M. Cowlessur JET: Iwasaki, Yokoo, Hara, Kuwano
Contents	• Theory of stability analysis (lecture) • Training of stability analysis • Stability analysis and countermeasure policy on pilot site • Discussion


Photo 7.4.11 Photo of "Stability Analysis and Countermeasures" (source: JET)

l. Monitoring Log for Pilot Site

Table 7.4.13 Outline of "Monitoring Log for Pilot Site" (source: JET)

Date/Time	7 March, 2013 10:00-12:00
Venue	Phoenix, MPI
Participants	STRAVIC Ltd: F.Ko, K.Kourouma, J.Malherbe, L.Lceuih JET: Yokoo, Iwasaki
Contents	• Explanation of monitoring results • Method of compiling of monitoring data • Discussion

Photo 7.4.12 Photo of “Monitoring log for Pilot Site” (source: JET)

m. Countermeasure Works 1

Table 7.4.14 Outline of “Countermeasure Works 1” (source: JET)

Date/Time	16 October, 2013 14:30-16:00
Venue	Phoenix, MPI
Participants	MPI: S.P. Anadachee, D. Chinasamy, B. Dabycharun Enviro-Consult: S. Nadia JET: Hara, Iwasaki, Yoshida, Tokuda
Contents	• Policy of countermeasure in Chitrakoot • Detailed design of countermeasure in Chitrakoot • Discussion of countermeasure for the issues

Photo 7.4.13 Photo of “Countermeasure Works 1” (source: JET)

7.5 Training in Japan

The training in Japan was conducted twice in the Project to ensure that the technical transfer is successfully implemented, and to experience and learn techniques at the sites and research institutes of several organizations. The training in Japan was scheduled for November to December 2012 and August to September 2013. The summary of the training is as follows.

Table 7.5.1 Contents of Training in Japan (source: JET)

Item	1st	2nd
Date	20 November to 15 December, 2012 (26 days)	14 August to 8 September, 2013 (26 days)
Overall goals	1. To understand necessary/utilizable technologies on structural countermeasures, which are suitable in Mauritius, based on landslide countermeasures in Japan. 2. To understand necessary/utilizable technologies and methodologies on early warning/evacuation and consensus building for local residents, which are suitable in Mauritius, based on landslide countermeasures in Japan. 3. To grasp workflows, concepts and perspectives on landslide management and disaster management in government. 4. To comprehend basics of the monitoring and the investigation technologies employed in Mauritius in the project. 5. To gain a better understanding of the significance of the project for achieving the project outputs.	
Purposes	Understand actual landslide countermeasures and their significance/method for landslide countermeasure work in Mauritius in the future.	Understand “what is a landslide?” and “what is disaster management?” for landslide management in Mauritius in the future.
Number	5 members	5 members
Participants	• Mohammad Naim EARALLY • Lalitsingh BISSESSUR • Vishwahdass RAMDHAN • Mohammad Khalid MOSAHEB • Bhoopendra DABYCHARUN	• Mahmad Reshad JEWON • Deevarajan CHINASAMY • Madun BALLOO • Selvanaden Pearia ANADACHEE • Visham RAMCHURN
Visit place	・ Visit Land, Infrastructure and Transportation Ministry in Japan ・ Visit local authorities in Japan ・ Visit universities and research institutes ・ Visit private consultants	

Table 7.5.2 Schedule of the 1st Training in Japan in 2012 (source: JET)

Date	Place/ Transportation	Organization	Contents
20-Nov	Mauritius - Dubai		Emirates Airlines EK3706 18:20-1:10
21-Nov	Dubai - Singapore		Emirates Airlines EK354 3:25-14:40
22-Nov	Singapore	Japanese Embassy	Acquisition of VISA
23-Nov	Singapore	Japanese Embassy	Acquisition of VISA
24-Nov	Singapore		
25-Nov	Singapore - Tokyo		Singapore Airline SQ012 9:20-17:05
26-Nov	Tokyo	JICA Kokusai Kogyo Co. Ltd.	Briefing meeting in JICA Briefing meeting in KKC
27-Nov	Saitama	Japan Conservation Engineers Co. Ltd.	Lecture of investigation/analysis for landslide in JCE Practical training for landslides
28-Nov	Saitama	OYO Chishitsu Co. Ltd.	Lecture of investigation/analysis for landslide in OYO Practical training for landslides
29-Nov	Tokyo	Land, Infrastructure and Transportation Ministry	Lecture of countermeasures for landslides
30-Nov	Tsukuba	Landslide Team/ Geology Team, Public Works Research Institute	Introduction of latest landslide research in Japan
1-Dec	Tokyo		Holiday
2-Dec	Tokyo		Holiday
3-Dec	Tokyo → Kochi	Osashi Techos Limited	Visit to Monitoring device company
4-Dec	Tokushima	Japan Highway Limited	Lecture of countermeasures for landslides Field visit to countermeasure site for landslide
5-Dec	Tokushima	Shikoku Sabo Office, Land, Infrastructure and Transportation Ministry	Lecture of countermeasures for landslide Field visit to countermeasure site for landslide
6-Dec	Tokushima → Kyoto	Shikoku Sabo Office, Land, Infrastructure and Transportation Ministry	Field visit to Zentokuji Landslide
7-Dec	Kobe	Kobe University	Introduction of latest landslide research in Japan
8-Dec	Kobe		Holiday
9-Dec	Kobe → Okinawa		Transportation
10-Dec	Okinawa	Okinawa Development Department	Field visit to countermeasure site for landslide
11-Dec	Okinawa → Tokyo	Okinawa Development Department	Field visit to countermeasure site for landslide
12-Dec	Tokyo	Kokusai Kogyo Co. Ltd.	Meeting in KKC
13-Dec	Tokyo	Japan International Corporation Center (JICE) JICA	Preparation of training report Evaluation meeting in JICA
14-Dec	Tokyo - Dubai		Emirates Airlines EK319 22:0-3:50
15-Dec	Dubai - Mauritius		Emirates Airlines EK3705 10:15-16:55

Table 7.5.3 Schedule of the 2nd Training in Japan in 2013 (source: JET)

Date	Place/ Transportation	Organization	Contents
14-Aug	Mauritius - Singapore		Transportation
15-Aug	Singapore		Transportation
16-Aug	Singapore	Japanese Embassy	Acquisition of VISA
17-Aug	Singapore		Holiday
18-Aug	Singapore		Holiday
19-Aug	Singapore	Japanese Embassy	
20-Aug	Singapore		Transportation
21-Aug	Singapore - Tokyo		Transportation
22-Aug	Tokyo	JICA Kokusai Kogyo Co. Ltd.	Briefing meeting in JICA Briefing meeting in KKC
23-Aug	Tokyo	Land, Infrastructure and Transportation Ministry Disaster Prevention center in Tokyo	Lecture of countermeasures for landslide Disaster education method,
24-Aug	Tokyo		Holiday
25-Aug	Tokyo → Sapporo	Transportation to Sapporo	Holiday
26-Aug	Sapporo	Hokkaido Regional Development Bureau, MLIT	Lecture of countermeasures for landslides
27-Aug	Sapporo	Hokkaido Regional Development Bureau, MLIT	Lecture of countermeasures for landslides Field visit to countermeasure site
28-Aug	Otaru	Hokkaido Regional Development Bureau, MLIT	Lecture of countermeasures for landslide Field visit to countermeasure site
29-Aug	Sapporo → Obihiro	Hokkaido Regional Development Bureau, MLIT	Lecture of countermeasures for landslide Field visit to countermeasure site
30-Aug	Obihiro →Tokyo	Hokkaido Regional Development Bureau, MLIT	Lecture of countermeasures for landslide Field visit to countermeasure site
31-Aug	Tokyo		Holiday
1-Sep	Tokyo		Holiday
2-Sep	Tsukuba	Public Works Research Institute National Research Institute for Earth Science and Disaster Prevention	Introduction of latest landslide research in Japan
3-Sep	Kanagawa	OYO Chishitsu Co. Ltd.	Lecture of investigation/analysis for landslide in OYO Practical training for landslide
4-Sep	Tokyo → Kyoto	Research Center on Landslides, Disaster Prevention Research Institute, Kyoto University	Introduction of latest landslide research in Japan
5-Sep	Kyoto → Tokyo	JICA	Transportation Preparation of training report
6-Sep	Tokyo	JICA	Preparation of training report Evaluation meeting in JICA
7-Sep	Tokyo - Dubai		Emirates Airline EK319 22:00-3:50
8-Sep	Dubai - Mauritius		Emirates Airline EK3705 10:15-16:55

The remarks for the both training trips to Japan are as follows;

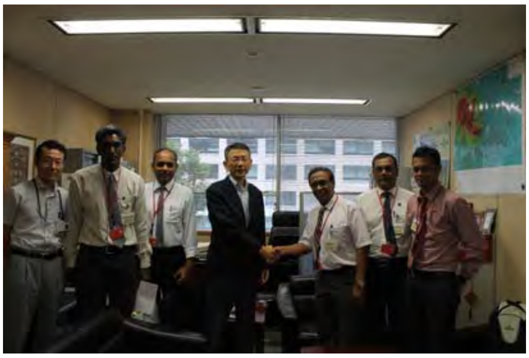
- The trainees were asking lots of question to lecturers at each organization. Those questions were about a wide range of structural countermeasures, government organizations, systems, etc. which are useful for application in Mauritius.

- The trainees were welcomed to all organizations in Japan. They also visit to the Director of the Erosion and Sediment Control Department, MLIT and the Director General of Hokkaido Regional Development Bureau, MLIT as a courtesy call. The lecturers kindly answered the question form the trainees at the sites and the lectures.

- The lecturers included many examples and experiences in Japan to their presentations, which were highly appreciated by the trainees.

- As one of the comments from the trainees, they will report what they have learned in Japan and want to utilize the countermeasures on landslides in Mauritius based on their experiences in Japan, which means that the trainees have learned many things in Japan and have strong motivation to improve the disaster management system in Mauritius.

- The trainees received high quality presentations including what they learned at the evaluation meeting on the last day of the training. The trainees considered the experiences in Japan and analyzed the characteristics in Mauritius in the presentation.



Courtesy call to the Director of the Erosion and Sediment Control Department, MLIT

Sapporo Road Office, Hokkaido Regional Development Bureau, MLIT

Site visit on Sabo countermeasures at Satsunai gawa river

Lecture at the Public Works Research Institute

Lecture at National Research Institute for Earth Science and Disaster Prevention

Visit at the rainfall simulator at National Research Institute for Earth Science and Disaster Prevention

Site Visit to Hayama, Kanagawa Prefecture

Visit to Kyoto University

Photo 7.5.1 The 2nd Training in Japan in 2013 (source: JET)

7.6 Steering Committee

The Steering Committee (hereinafter SC) is held with relevant organizations in Mauritius, in order to establish smooth cooperative system, to have common understanding about the progress and issues on the Project, and to facilitate decision making and problem solving. The establishment and operation of the SC should be handled by C/P, and JET helps the C/P to precede the meetings.

Table 7.6.1 Plan of SC (source: JET)

Item	Contents
Contents	• Approval of activity plan • Confirmation of progress • Discussion of issues • Discussion of necessary matter on the Project
Members	Chairman: MPI PS Member: MPI Civil Engineering Division Director, MPI Civil Engineering Division Deputy Director, PMO, MoEPU, MoHL, MoLG, MoESD, MoFED, PD, MSS, Local Authority, University of Mauritius, Other related organizations, Japan Embassy of Madagascar, JICA Madagascar Office, JET
Schedule	Each period based on report submission
Participants	Around 20

The initial SC was held on 29 May, 2012 to explain the role of the SC followed by the explanation of outline of the Project, the contents of IC/R and the role of stakeholders to the concerned organizations and agencies. The contents of the 1st SC are summarized in the following table and its Minute of Meeting is in the Supporting Report.

Table 7.6.2 The Contents of the 1st SC (source: JET)

Item	Contents
Date/Time	29 May, 2012 10: 30-12: 00
Venue	Conference room, MPI Headquarters
Contents	• Role of the SC • Outline of the Project • Contents of IC/R • Role of stakeholders
Participants	MPI: Mr. Lutchmeeparsad Vidianand (Permanent Secretary) Ms. Bahadoor Savitree (Assistant Secretary) Mr. Jewon Reshad (Deputy Director, Civil Engineering Division) Mr. D. Chinasamy (Principal Engineer, Civil Engineering Division) Mr. S. P. Anadachee (Engineering officer, Civil Engineering Division) Mr. Dookhony (Chief Regional and Development Officer) Ms. N. Subrun (Secretary) Other Ministries/Organizations: Mr. S. Ghunowa (Government Land Surveyor, Ministry of Housing and Lands) Mr. R. Dhurmea(Meteorologist, Mauritius Meteorological Service) Mr. R. Beedassy (Deputy Environment Officer, Ministry of Environment and Sustainable Development) Mr. J. E. Merle (Higher Executive Officer, Ministry of Local Government and Outer Islands) Ms. B. Trilok (Second Secretary, Ministry of Foreign Affairs, Regional Integration and International Trade)

Item	Contents
	Mr. B. Bijloll (Assistant Commissioner, Ministry of Social Security, National Solidarity, and Reform Institutions) Mr. S. Kaleeah (Head, Planning and Research Unit, Ministry of Gender Equality, Child Development and Family Welfare) Mr. K. Nobin (Deputy Commissioner of Police, Natural Disaster and Operations Coordination Centre) Mr. M. Muneesamy (Director Finance and Administration, Mauritius Revenue Authority) Mr. S. Zeadally (Senior Hydrological Officer, Water Resources Unit) Mr. K. Khothandaraman (Assistant Chief Fire Officer, Fire Services Department) Mr. D. Seesahye (Deputy Chief Fire Officer, Fire Services Department) Mr. S. Ramdin (Head of Works Department, Municipal Council of Port Louis) Mr. S. Permala (Head of Works Department, Grand Port/Savanne District Council) Ms. Lacroix (Coordinator, Commission De L'Ocean Indien (COI)) JICA: Ms. Megumi Tsukizoe (Deputy Assistant Director, Global Environment Department, JICA HQ) Mr. Junichi Kawase (Project Formation Advisor, JICA Madagascar Office) Ms. Razafimahefa Manoela (Programme Officer, JICA Madagascar Office) JICA Expert Team: Mr. Kensuke Ichikawa (Chief Advisor) Dr. Takeshi Kuwano (Vice Chief Advisor / Landslide Management) Mr. Tomoharu Iwasaki (Landslide Survey and Analysis) Dr. Hiroshi Hashimoto (Vice Chief Advisor / Coastal Conservation) Ms. Martine Citon (Project Assistant of JICA Expert Team)

The 2nd SC was held on 11 November, 2012 to explain the results of basic surveys, the outline of the landslide management plan and the F/S to the concerned organizations and agencies. Dr. Fukuoka, a member of the Advisory Committee in Japan, Kyoto University, had special lecture in the SC. The contents of the 2nd SC are summarized in the following table and its Minute of Meeting is in the Supporting Report.

Table 7.6.3 The Contents of the 2nd SC (source: JET)

Item	Contents
Date/Time	1 November, 2012 14:00-16:00
Venue	Conference room, MPI Headquarters
Contents	• Results of basic surveys • Outline of the landslide management plan • Outline of the F/S
Participants	MPI: Mr. Putchay (Principal Assistant Secretary) Ms. Bahadoor Savitree (Assistant Secretary) Mr. Jewon Reshad (Deputy Director, Civil Engineering Division) Other Ministries/Organizations: Mr. S. Ghunowa (Government Land Surveyor, Ministry of Housing and Lands) Mr. R. K. Dhurmea (Meteorologist, Mauritius Meteorological Service) Mr. R. Luximon (Environment Officer, Ministry of Environment and Sustainable Development) Mr. O. Sewraj (Second Secretary, Ministry of Foreign Affairs, Regional Integration and International Trade) Mr. S. Kangloo (Principal Social Security Officer, Social Security) Mr. J. Kelly (Team Leader, Mauritius Revenue Authority) Mr. J. Merle (Ministry of local Government and outer Island)

Item	Contents
	Mr. M. Seebaruth (Special Mobile Force) Mr. S. Zeadally (Senior Hydrological Officer, Water Resources Unit) Mr. R. Deenoo (Chief Inspector, City Council of Port Louis) Mr. S. Permala (Head of Works, District Council Grand Port /Savanne) Mr. C. Dawonauth (Chief Inspector, Police Force) Mr. K. Khothandaraman (Assistant Chief Fire Officer, Fire Services Department) Mr. D. Seesahye (Deputy Chief Fire Officer, Fire Services Department) Ms. Kajima (UNDP) JICA: Ms. Kaoru Takahashi (Project Formation Advisor, JICA Madagascar Office) Ms. Razafimahefa Manoela (Programme Officer, JICA Madagascar Office) Advisory Committee in Japan: Dr. Hiroshi Fukuoka (Kyoto University) JICA Expert Team: Mr. Kensuke Ichikawa (Chief Advisor) Dr. Takeshi Kuwano (Vice Chief Advisor / Landslide Management) Dr. Tomoharu Iwasaki (Landslide Survey and Analysis) Mr. Fumihiko Yokoo (Landslide Monitoring) Mr. Yoji Kasahara (Geophysical Prospecting) Ms. Sophie Bundun (Project Assistant of JICA Expert Team)

The 3rd SC was held on 21 November, 2013 to explain the result of investigation/analysis, the Pilot Project and the collaboration with other projects to the concerned organizations and agencies. The contents of the 3rd SC are summarized in the following table and its Minute of Meeting is in the Supporting Report.

Table 7.6.4 The Contents of the 3rd SC (source: JET)

Item	Contents
Date/Time	21 November, 2012 13:30-16:00
Venue	Conference room, MPI Headquarters
Contents	• Results of investigation/analysis • Pilot Project • Collaboration with other projects
Participants	MPI: Mr. Lutchmeeparsad Vidianand (Permanent Secretary) Ms. Bahadoor Savitree (Supervising Officer) Ms. Subrun (Secretary Officer) Mr. Jewon Reshad (Deputy Director, Civil Engineering Division) Mr. Chinasamy (Principal engineer, Civil Engineering Division) Mr. Bissessur (Senior Engineer, Civil Engineering Division) Mr. S.Ramdin (Project Manager, National Development Unit) Other Ministries/Organizations: Mr. A. Sookhareea (ASP, NDRRMC, PMO) Mr. S. Ghunowa (Government Land Surveyor, Ministry of Housing and Lands) Mr. R. K. Dhurmea (Divisional Meteologist, Mauritius Meteorological Service) Mr. D.S Chamillal (AGDEO (Climate Change Division), Ministry of Environment and Sustainable Development) Ms. Li Pin Yuen Maryse (Second Secretary, Ministry of Foreign Affairs) Mr. S. Kangloo (Principal Social Security Officer, Ministry of Social Security) Mr. A. Aubeeluck (Divisional Officer, Mauritius Fire &Rescue Service) Mr. G. Luchoomun (Project Officer, National Development) Mr. S. Zeadally (Senior Hydrological Officer, Water Resources Unit) Mr. Auladin (CIW, Grand Port District Council) JICA Expert Team:

Item	Contents
	Mr. Kensuke Ichikawa (Chief Advisor) Mr. Takeshi Kuwano (Vice Chief Advisor / Landslide Management) Mr. Fumihiko Yokoo (Landslide Monitoring) Mr. Takashi Hara (Design/Cost Estimation) Ms. Yurie Kawabata (Information, Education and Communication) Mr. Yoshimizu Gonai (Policy and Planning of Urban Development and Land Use) Ms. Haruka Yoshida (Institution/System Analysis/Capacity Development) Mr. Makoto Tokuda (Coordinator) Ms. Sophie Bundun (Project Assistant of JICA Expert Team)

The 4th SC was held on 19 January, 2015 to inform the result of the Pilot Project and the early warning system among all activities and the collaboration with other projects to the concerned organizations and agencies. The contents of the 4th SC are summarized in the following table and its Minute of Meeting is in the Supporting Report.

Table 7.6.5 The Contents of the 4th SC (source: JET)

Item	Contents
Date/Time	19 January, 2015 13:30-15:30
Venue	Conference room, MPI Headquarters
Contents	• Submission of DF/R • Structural countermeasure in Chitrakoot • Early warning/evacuation system • Organizational reinforcement plan of LMU • Collaboration with other projects • Future plan after the Project
Participants	Ministry of Public Infrastructure and Land Transport (MPI) Mr. R. Jewon (Director, Civil Engineering Division) Mr. D. Chinasamy (Principal engineer, Civil Engineering Division) Mr. S. P. Anadachee (Senior Engineer, Civil Engineering Division) Mr. Bissessur (Senior Engineer, Civil Engineering Division) Mr. V. Ramdhan (Senior Engineer, Civil Engineering Division) Mr. K. Mosaheb (Senior Engineer, Civil Engineering Division) Mr. B. Dabycharun (Senior Engineer, Civil Engineering Division) Mr. S.M. Ramdowar (Senior Engineer, Civil Engineering Division) Mr. V. Ramchurn (Technical Officer) Mr. H. Bholah (Chief Project Manager, NDU) Other Ministries/Organizations Mr. R. Luximon (Environment Officer, NDRRMC) Mr. G. Rosunee (Principal Planner, Ministry of Housing and Lands) Mr. V. S. Chuckun (Surveyor, Ministry of Housing and Lands) Mr. K. Dhoomun (Ministry of Environment, Sustainable Development, Disaster and Beach Management) Mr. G. Nundlall (Ministry of Local Government) Mr. P. Dooneeady (Divisional Meteologist, Mauritius Meteorological Service) Mr. D. Jokhun (Forestry Service) Mr. S.A. Zeadally (Senior Hydrological Officer, Water Resources Unit) Mr. D. Towakel (Police Inspector, SMF) Mr. I. Kheerdali (Police Sergeant) Mr. S. Jeetun (Head, Public Infrastructure Department; Riviere Du Rempart Disctrict Council Mr. P. Balloo (Head, Public Infrastructure Department; District Council of Black River) Mr. A. Reesaul (Head of Public Infrastructure Department, Municipality of Quatre

Item	Contents
	Bornes) Mr. M. Ragaver (Civil Engineer, District Council Moka) Mr. N. Reemul (Chief Inspector of work- Municipality of Vacoas/ Phoenix) Mr. V. Sookoy (District council of Flacq) Mr. K. Domah (Head of Public Infrastructure, Pamplemousses District Council) Mr. A. Sookun (Head of Public Infrastructure Department, Pamplemousses District Council) Mr. S. K. Seechurn (Civil Engineer, District Council of Savanne) Mr. D. Seebaluck (Head of Public Infrastructure Municipal of Council of Curepipe) Mr. S. Sairally (Head of Public Infrastructure Department) Mr. R. Oodally (Head Public Infrastructure Department) JICA Madagascar Office Mr. Akira Nishimoto (Chief Representative) Ms. Kaoru Takahashi (Representative) Ms. Razafimahefa Manoela (Programme Officer) JICA Expert Team Mr. Kensuke Ichikawa (Chief Advisor) Mr. Takeshi Kuwano (Vice Chief Advisor / Landslide Management) Mr. Fumihiko Yokoo (Landslide Monitoring) Mr. Takashi Hara (Design/Cost Estimation) Ms. Haruka Yoshida (Institution/System Analysis/Capacity Development) Ms. Sophie Bundun (Project Assistant of JICA Expert Team) Ms. Shalina Mangroo (Project Assistant of JICA Expert Team)

7.7 Advisory Committee in Japan

Advisory Committee (AC) is organized in Japan as a supports mechanism of the Project. The AC advises and deliberates the Project from the technical and engineering point of view.

The schedule of contents to deliberate is as follows.

Table 7.7.1 Schedule of Contents to Deliberate in the Advisory Committee (source: JET)

Item	1st	2nd	3rd	4th
Theme	Determination of P/R	Determination of outline of Pilot Project	Determination of Interim Report	Determination of Draft Final Report
Date	31 August, 2012 Before discussion of P/R	28 May, 2013 Before selection/ design of pilot site	30 October, 2013 Before the pilot project	24 December, 2014 Before completion of pilot project
Contents	1. Results of basic survey, landslide condition (type, volume, risk etc.) 2. Outline of landslide management plan 3. Risky site, outline of F/S (countermeasure)	1. Outline of pilot project 2. Detail of management plan (system/ framework, countermeasure)	1. Results of management plan (except feedback from pilot project)	1. Results of pilot project 2. Results of management plan and F/S 3. Proposal for Final Report

The 1st AC was held on 31 August, 2012 to discuss the results of basic survey, the landslide condition (type, volume, risk etc.), the outline of landslide management plan, the risky site, and outline of F/S (countermeasure). The contents of the AC are summarized as follows and its Minute of Meeting is in the Supporting Report.

Table 7.7.2 Contents of 1st Advisory Committee in Japan (source: JET)

Item	Contents
Date, Time	31st August, 2012 19: 30-21: 15
Venue	JICA Headquarters
Contents	• Results of basic survey • Determination of target areas • Monitoring plan • Issues and solutions • Outline of F/S
Participants	Committee member: Hoshina, Fukuoka, Nagata JICA: Sasadate, Noguchi, Yonebayashi, Tsukizoe JICA Expert Team: Ichikawa, Iwasaki, Kikuchi

The 2nd AC was held on 28 May, 2013 to discuss the hazard evaluation for three targeted landslide sites, the hard countermeasures (pilot project), the early warning system, the PPG and the development plan on organization. The contents of the AC are summarized as follows and its Minute of Meeting is in the Supporting Report.

Table 7.7.3 Contents of 2nd Advisory Committee in Japan (source: JET)

Item	Contents
Date, Time	28th May, 2013 19: 30-21: 00
Venue	JICA Headquarters
Contents	• Hazard evaluation for three targeted landslide sites • Hard countermeasures (pilot project) • Early warning system • PPG • Development plan on organization
Participants	Committee member: Hoshina, Fukuoka, Nagata Ministry of Foreign Affairs: Kuriyama JICA: Miyasaka, Yonebayashi, Tsukizoe Iiyama, Sasadate, Takahashi JICA Expert Team: Ichikawa, Kuwano, Iwasaki, Gonai

The 3rd AC was held on 30 October, 2013 to discuss the priority site and Pilot Project site, the hard countermeasures (pilot project) in Chitrakoot, the early warning system and evacuation, the Disaster Scheme, the PPG and the Feasibility Study. The contents of the AC are summarized as follows and its Minute of Meeting is in the Supporting Report.

Table 7.7.4 Contents of 3rd Advisory Committee in Japan (source: JET)

Item	Contents
Date, Time	30th October, 2013 17: 00-19: 00
Venue	JICA Headquarters
Contents	• Priority site and Pilot Project site • Hard countermeasures (pilot project) in Chitrakoot • Early warning system and evacuation • Disaster Scheme • PPG • Feasibility Study
Participants	Committee member: Hoshina, Fukuoka, Nagata JICA: Yonebayashi, Hirano, Iiyama, Takahashi JICA Expert Team: Ichikawa, Kuwano, Iwasaki, Gonai

The 4th AC was held on 24 December, 2014 to discuss the result of the Pilot Project and the early warning system among all activities. The contents of the AC are summarized as follows and its Minute of Meeting is in the Supporting Report.

Table 7.7.5 Contents of 4th Advisory Committee in Japan (source: JET)

Item	Contents
Date, Time	24th December, 2014 16: 00-17: 50
Venue	JICA Headquarters
Contents	• Hard countermeasures (pilot project) in Chitrakoot • Early warning system and evacuation
Participants	Committee member: Hoshina, Fukuoka, Nagata JICA: Yonebayashi, Hirano, Nishimoto, Takahashi JICA Expert Team: Ichikawa, Kuwano, Iwasaki, Yoshida

7.8 Results of Technical Transfer

The technical transfer has been conducted with C/Ps shown in the following table through all activities such as investigation, analysis, design and supervising. The C/P members in MPI have improved their organization and system for landslide countermeasure and management by the activities in the Project so that they will be able to conduct the basic activities for the landslide countermeasure and management by themselves after the Project.

Table 7.8.1 Technical Contents to be Transferred to C/P (source: JET)

Item	Name
Organization	Landslide Management Unit, Civil Engineering Division, Ministry of Public Infrastructure and Land Transport
Persons	Mahmad Reshad JEWON Deevarajan CHINASAMY Vishwahdass RAMDHAN Selvanaden Pearia ANADACHEE Mohammad Khalid MOSAHEB Rameswurdass RAMDHAN Lalitsingh BISSESSUR Bhoopendra DABYCHARUN

The items and outputs of the technical transfer for the C/P in the Project are evaluated for each component as follows.

[Basic survey]

The methodology of basic surveys for landslides has been transferred so that the C/Ps understand the basic methodologies. However, the C/Ps are civil engineers have difficulty understanding the geology and topography of landslides. To overcome this learning difficulty, regular activities on basic surveys for landslides will need to be kept up.

[Formulation of a Landslide Management Plan]

At the start of the project the C/Ps had no knowledge of landslide investigations, monitoring or analysis. Therefore, thought was given into the best ways of conducting such activities. The C/P could systematically obtain the basic knowledge for carrying out activities such as installing and measuring with monitoring devices, field reconnaissance of damaged houses and utilization of the Disaster Scheme and the Planning Policy Guidance etc. However the training and experience of geological analysis/interpretation, stability analysis and disaster inspection will be needed to be conducted by themselves.

Although C/Ps are civil engineers have difficulty in understanding geology and topography, most surveys in the Landslide Management Plan could be contracted out to private consultants. The C/Ps have enough understanding of the outline and concept of the activities to be able to adequately contract them out.

[Implementation of the F/S in Priority Areas]

Activities in the F/S such as the prioritization for project sites and the policy planning have been conducted with C/P through OJT so that they understand the contents and will be able to conduct them by themselves.

Allocation of the budget since next year as well as reinforcement of the organization for landslide countermeasures was successfully proceeded. Regarding the Environmental Impact Assessment, the surveys could be contracted out to private consultants. C/P has enough understanding of the outline and concept of the activity to be able to adequately contract them out.

[Implementation of the Pilot Project]

All activities in the Pilot Project such as planning/design/supervising of the countermeasure works and the early warning/evacuation system have been conducted with the C/Ps through on-the-job training (OJT), and they have shown sufficient understanding of the contents and will be able to conduct them in future. Although the IEC for landslide in this pilot project was the first time it had been conducted in Mauritius, the C/Ps understand the importance and will be able to conduct it as well.

The implementation of "hard" (physical or structural) and "soft" (non-physical) countermeasures on landslides is largely dependent on enough experience. Continuous training on the landslide countermeasures will be needed. In addition, the target of this Project in 2012-2015 is for landslides, not for other slope disasters such as slope failures, rockfalls and debris flows. Since the landslide project will come to an end right after the completion of the countermeasures in the pilot project in Chitrakoot, the maintenance work of the countermeasures is not included in the Project as outlined in the following table.

Table 7.8.2 Contents of the Project in 2012-2015 (source: JET)

	Investigation/ analysis	Design	Construction/ supervision	Maintenance
Landslide	Contents of the Landslide Project in 2012-2015			
Slope failure				
Rockfall				
Debris flow				

Since the mechanisms and patterns of each kind of slope disaster are different, the method and the concept for countermeasures are also different. Therefore, countermeasures that do not take into consideration the different mechanisms of slope disasters may accelerate the damage of the disaster.

Table 7.8.3 Classification of Hazard Areas on the Disaster Scheme (source: JET)

General			Sub classification		
Slope	15	areas	Landslide	6	areas
			Slope failure	7	areas
			Rock fall	1	areas
			Debris flow	1	areas
Other	22	areas	Stream erosion	10	areas
			Damage of embankment	4	areas
			Damage of wall	5	areas
			Damage of house	1	areas
			Cavern	2	areas
			Total	37	areas

The Government of Mauritius has designated 37 disaster sites in the Disaster Scheme as shown in the table above. The slope disasters like landslides, slope failures, rockfalls and debris flows are especially serious disasters in which the countermeasures are almost impossible to implement by MPI only without JICA's support.

MPI has repeatedly requested JET through the Project to support the investigation and analysis for the emergency disasters such as slope failures and rockfalls. On 26 April 2014, a significant rockfall (4m*2m*2m) occurred, causing the closure of a national road. JET has provided technical assistance to MPI for implementing the emergency countermeasures. The permanent countermeasures are inevitable for these kinds of disasters.

MPI has strongly requested JICA to support the survey, analysis, design and construction of countermeasures for slope failures, rockfalls and debris flows. MPI has also learned the importance of maintenance for the countermeasures in the training in Japan in 2012 and 2013 during the Project and has requested to support the maintenance of landslide countermeasures. Therefore, the further technical assistance on slope disasters is necessary for MPI.

7.9 Future Plans by MPI and the Related Organizations

7.9.1 Future Plans by MPI

With regards to the landslide countermeasure construction works which has been completed by JET on December 2014, the constructed works of the Pilot Project site in Chitrakoot are officially handed over from JET to MPI under the terms and conditions stipulated below. MPI shall take the necessary measures to maintain the works after the handover.

a. The Types and Quantity of Works to be Handed Over.

The types and quantity of works which has been constructed by JET are as below. The detailed plan maps and structural figures of each construction works are attached.

- River Type-1 (5m)
- River Type-2 (10m)
- River Type-3 (140m)
- River Type-5 (55m)
- New Channel CH-1 (217m)
- Bridge Br-1
- Bridge Br-2
- Bridge Br-3
- Bridge Br-4
- Bridge Br-5
- Horizontal Drainage (5 boreholes)

The major amendments of design which was made during the construction are as below.

✓ River Type 1 & 2: The height of stone masonry was increased, while the vegetation was shortened.

✓ River Type 3: The design of the wall on the right side was changed to straight wall at some point.

✓ Bridge Br5: The structure of handrail was changed from fence to steel pipe.

b. Further Construction Works to be Conducted by MPI

MPI shall conduct the further construction works for Section II as follows including the works which was cancelled in Section I. After completion of the works of the Section II, groundwater level and landslide activity shall be confirmed by the monitoring.

- Reconstruction of the bridge at the end point of river (scheduled by National Development Unit in MPI)
- Channel for the flood CH-2 (130 m)
- Horizontal drainage (HD-2) (210 m)
- Horizontal drainage (HD-3) (350 m)
- Surface drainage (SD-1) (75 m)
- Open-blind ditch (OB-1) (55 m)
- Open-blind ditch (OB-2) (85 m)
- Blind ditch (BD-1) (35 m)
- Blind ditch (BD-2) (32 m)

- Blind ditch (BD-3) (40 m)
- Water catch basin (5 pc)
- Bridge (2 pc)
- Manhole for maintenance (12 pc)

b.1 The cancelled works in Section I.

- Upgrading of existing water course RUD-1 (Type3 drainage) (35 m)
- Upgrading of existing water course UD-3 (Type4 drainage) (47 m)

b.2 The monitoring for ground water level.

- BPP 16
- BPP 11
- W-2
- BPP 8
- B-P1
- B-P2

c. Cleaning and Maintenance of the Ditches, Channels, Bridges and Horizontal Drainages by MPI

The ditches, channels, bridges and horizontal drainages constructed by JET shall be cleaned periodically to ensure the smooth water flows in the drainage. The maintenance of the works shall be undertaken to maintain its function as below.

c.1 Cleaning and maintenance of ditches and channels

- ✓ Cleaning of soils accumulated in the ditch and channel using shovel and high pressure water.
- ✓ Removing any garbage inside the river.
- ✓ Repairing any cracks occurs along the ditch and channel works

c.2 Cleaning and maintenance of bridges

- ✓ Cleaning of soils accumulated under the bridges using shovel and high pressure water.
- ✓ Removing any garbage under the bridges
- ✓ Repairing any cracks occurs on the bridge works

c.3 Cleaning and maintenance of horizontal drainage

- ✓ Cleaning of soils accumulated inside the drainage pipe using high pressure water (flushing).

c.4 Maintenance of the fences

Fences shall be checked periodically in case of damages by rock fall and debris flow and repaired if necessary.

d. Site Restriction (No Trespassing and Throwing Garbage into the Site)

- ✓ Installation of [No Trespassing] signboard at site
- ✓ Education of the inhabitants regarding the disaster prevention.

e. Utilization of the Landslide Disaster Prevention Handbook

The utilization of handbook for the education of the inhabitants and students is highly expected.

7.9.2 Future Plans by the Related Organizations

As collaboration of all stakeholders is essential to deal with landslide issues in Mauritius, the tasks and responsibilities of LMU as well as the other stakeholders were defined and finalized as follows:

- Responses to the classified landslide prone areas (37 sites)

The main organizations are identified based on the disaster classification, objects of protection and the scale of disaster. The main responsible organizations will implement the countermeasure works from the high prioritized areas according to the results of annual slope inspection.

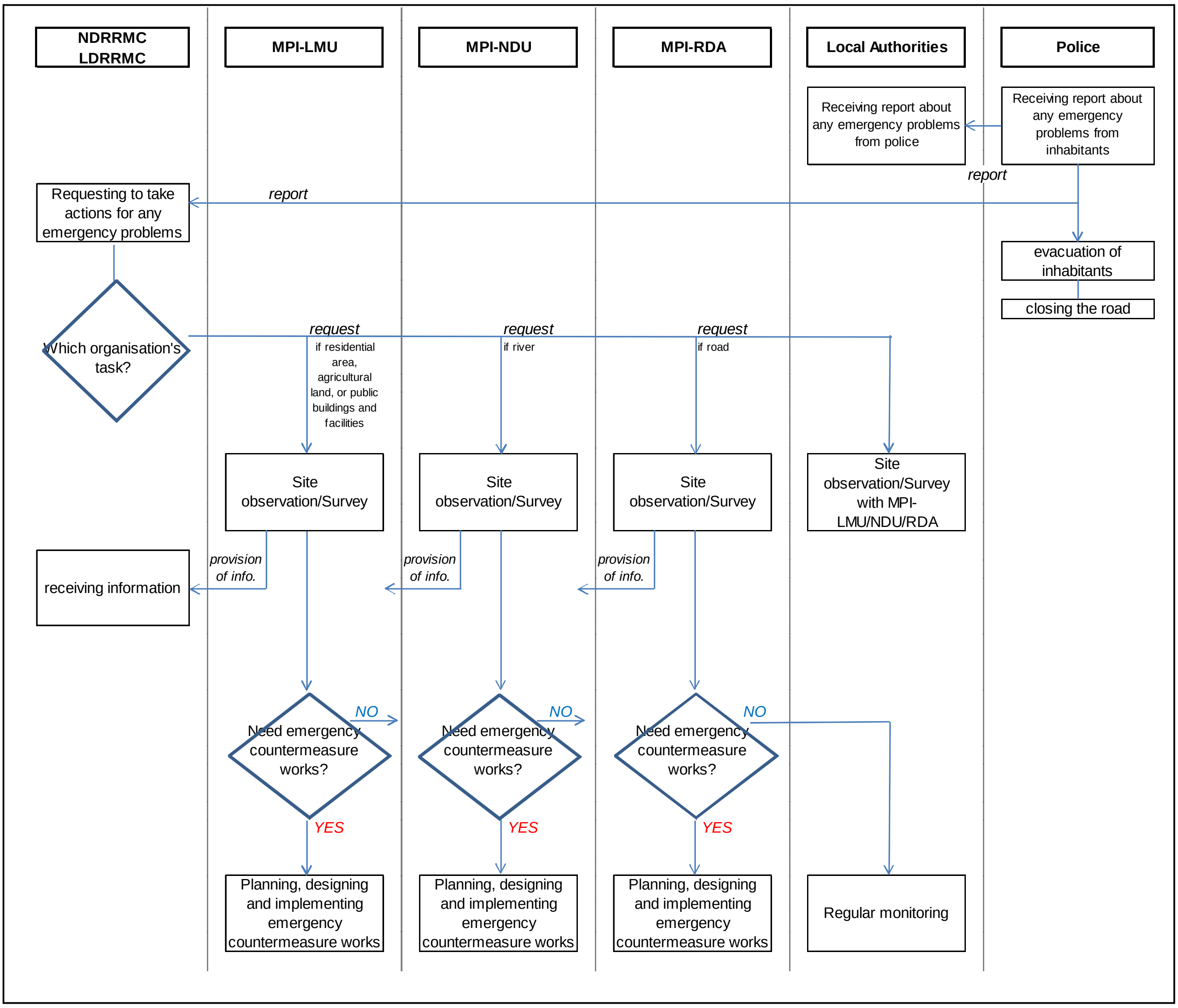
Table 7.9.1 Main Responsible Organizations based on Disaster Classification, Objects of Protection and the Scale of Protection (source: JET)

Disaster		Object of protection	The main responsible organisation	
			Large scale disaster	Small scale disaster
Slope disaster	Landslide (mass movement)	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Rock fall	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Slope failure	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
Slope and river disaster	Debris flow	Residential houses	LMU/NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU/NDU	
River disaster	Stream erosion	Residential houses	NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads		
	Flood	Residential houses	NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads		
Others	Damage of embankment	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Damage of wall	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Damage of house	Residential houses	-	Local authorities
		Agricultural fields		
	Cavern	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	RDA/local authorities

- Responses for emergency situations

In terms of responses for emergency situations, police and local authorities are responsible for taking immediate actions such as evacuation of inhabitants and roadblocks. LMU, NDU and RDA are responsible for the site investigation, consideration of countermeasures and its implementation with the same methodology for 37 classified sites.

Table 7.9.2 Task Flow for Emergency Situation for All Sites (source: JET)



- Responses for the new sites with utilization of a hazard map

LMU will develop a hazard map in order to identify the new landslide prone areas apart from 37 classified sites.

- Early warning

The early warning system is applied for three pilot sites of the project (Chitrakoot, Quatre Soeurs and Vallee Pitot) according to the National Disasters Scheme and protocol. The same early warning system as used at the pilot sites will be established for those new landslide prone areas if identified by the hazard map.

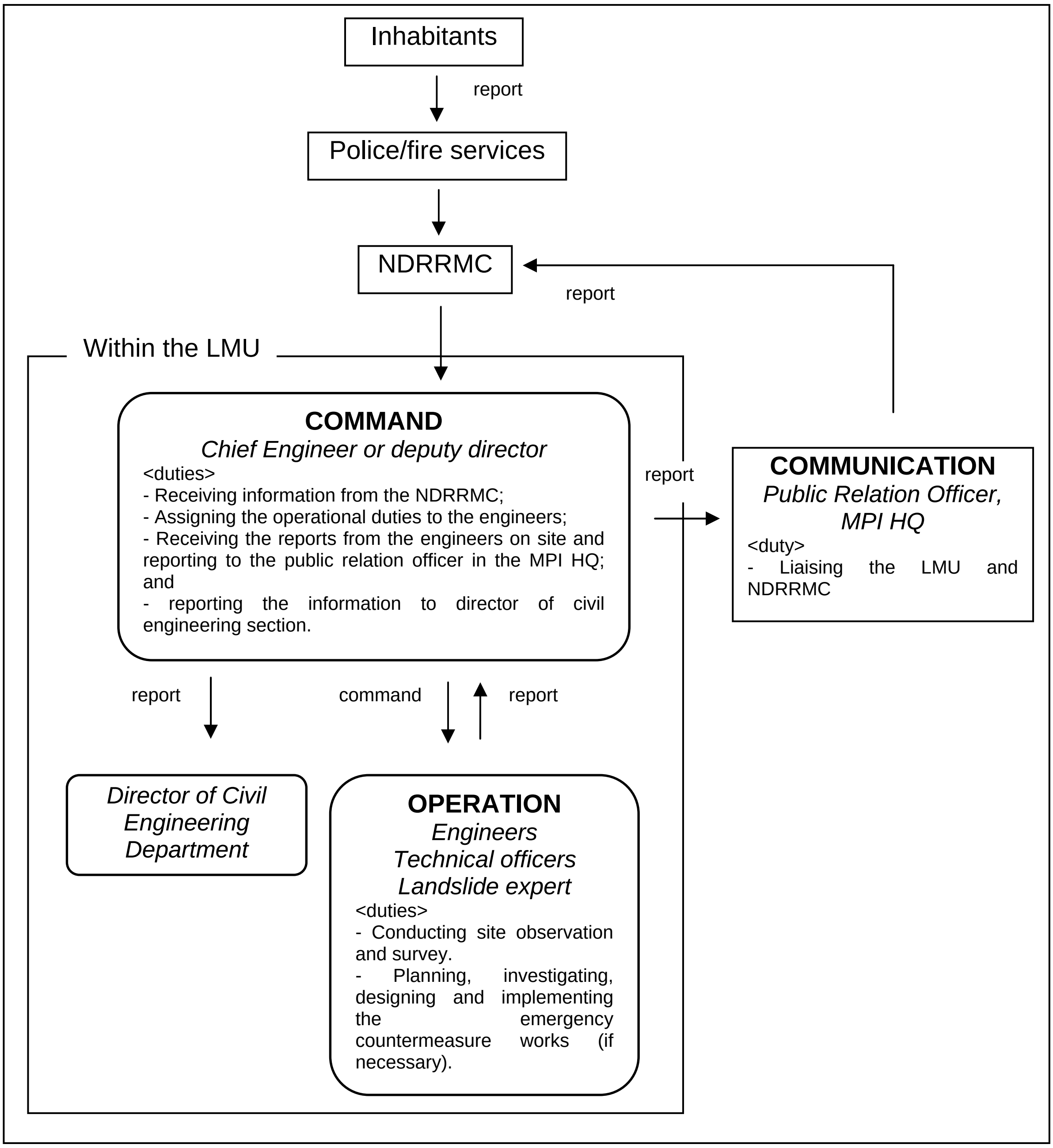
As a result of defining the tasks and responsibilities for all stakeholders, it is expected that all stakeholders will be actively involved in tackling the landslide issues. Moreover, as the stakeholder meeting will be regularly organized in order to share landslide information, the collaboration of all stakeholders will be enhanced.

LMU has actively participated in the stakeholder meetings, for example, LMU engineers presented the tasks and responsibilities of landslide management by themselves in the one day seminar on the 27th of November 2014. This fact proves that the LMU engineers have enhanced their knowledge and understanding of landslides, and are contributing in raising awareness and knowledge among other organizations.

a.1 Emergency operational system within the LMU

The emergency operational system within the LMU is established as follows.

Table 7.9.3 Emergency Operational System within the LMU (source: JET)



a.2 Establishment of public/private cooperation system

The hiring of expert(s) on a retainer basis is considered in order to support the LMU's task of landslide management. The JICA Expert Team supported to define the scope of work for the expert on a retainer basis and the LMU has submitted the scope of work to the MPI headquarters. The MPI intends to employ a local or international geotechnical engineer.

Chapter 8

Environment, Climate Change Adaptation and Disaster Management

8 Environment, Climate Change Adaptation and Disaster Management

8.1 General

In the HFA adopted by the WCDR, signatory countries agreed on a disaster prevention action plan for 10 years under this framework, setting more effective integration of disaster risk considerations with a special emphasis on disaster prevention as a strategic goal. Based on this framework, the Japanese Government announced the Initiative for Disaster Reduction through Official Development Assistance (hereinafter ODA), and the Yokohama Action Plan compiled at the Fourth Tokyo International Conference on African Development (hereinafter TICAD IV) addressed environmental/climate change issues as an urgent challenge. In the Summary by the Chair of TICAD IV, Japan mentioned special considerations to small island states. Meanwhile, various climate change adaptation programs are underway in Mauritius mainly by the Japanese Government, the United Nations Development Programme (hereinafter UNDP) and the IOC.

Under such global circumstances, in Mauritius which is vulnerable to climate change, particularly landslide issues are becoming more serious due to recent natural disasters resulting from environmental changes and the increased number of structures on steep slopes because of tourism and land development. Mauritius has been taking disaster prevention measures. Although the country wishes to draw plans, understand risks and implement measures on scientific and technical grounds in consideration of the environmental impact and safety management, it has not yet found a fundamental solution due to the lack of experts and engineers, and the lack of publicity of climate change adaption measures and disaster prevention administration to local communities.

After the commencement of the Project, the United Nations Conference on Sustainable Development 2012 (RIO +20) and the Fifth Tokyo International Conference on African Development 2013 (TICAD V) were held. The vulnerability of Small Island Developing States (hereinafter SIDS) to climate change was emphasized and acknowledged as an important issue at RIO +20, and a declaration was made under the TICAD V, namely the Yokohama Declaration 2013 and Yokohama Action Plan 2013 – 2017. The following points are noted in relation with the Project.

1. Yokohama Declaration 2013

   Africa is still one of the most vulnerable regions to natural disasters and climate change impacts, thus, the TICAD process will aim to build a resilient society to climate change to facilitate sustainable development.

2. Yokohama Action Plan

   (1) Environmental and Climate Change

   Climate change is compounding existing development challenges as Africa's major economic sectors such as agriculture and fisheries are vulnerable to climate sensitivity and are projected to be increasingly severely impacted by climate variability and change. Special attention must be paid to the building of climate change resilient societies that are capable of anticipating and facing environmental disasters as well as to conservation and sustainable use of biodiversity, prevention of desertification and land degradation.

Measures to address environment and climate change are articulated across various sectors in this Action Plan, such as in infrastructure, agriculture and water.

(2) Disaster Prevention

Out of all natural disasters, droughts occur most frequently and cause the highest number of victims in Africa, while storms and floods due to cyclones cause serious damage to island and coastal countries. As Africa's natural disasters are mostly climate-related such as drought and floods, adaptation to climate change must be directly linked to efforts toward disaster risk reduction. It is critical to mainstream disaster risk reduction into development agendas with special consideration for vulnerable groups such as the elderly, women and disadvantaged persons

In July 2014, Prime Minister Shinzo Abe visited Caribbean Community (herein after CARICOM) member states, and presented Japan's CARICOM policies consisting of three pillars (1.Cooperation towards sustainable development, including overcoming the vulnerabilities particular to small island states, 2. Deeping and expanding fraternal bonds of cooperation and friendship and 3. Cooperation in addressing challenges of the international community). Following that, in November 2014, the Ministerial Joint Statement between Japan and CARICOM, Foreign Minister Kishida reaffirmed Japan will give utmost consideration to the fields of disaster risk reduction, countermeasures and to actively engage in international discussions concerning vulnerabilities particular to SIDS. Over the past decade, Japan focused on the Environment, Climate Change Adaptation and Disaster Management issues as important diplomatic roles. Japanese technologies and expertise nurtured through its similar experience in the fields of disaster risk reduction, countermeasures against environmental degradation and climate change.

Followed by the aforementioned global action, the Landslide Management Project has launched as a component of the Program of JICA Environment, Climate Change Adaptation and Disaster Management Scheme. The Project should also share the view of the Climate Change Adaptation, Environment and Disaster Management in Mauritius to produce the synergistic effect with other components (or projects). The effective technical transfer shall first consider in relation with political and administrative capability of Mauritius together with the collaboration with other relevant Projects by other Development Partners. Figure 8.1.1 shows the relation of JICA Project components and respective Mauritius organizations.

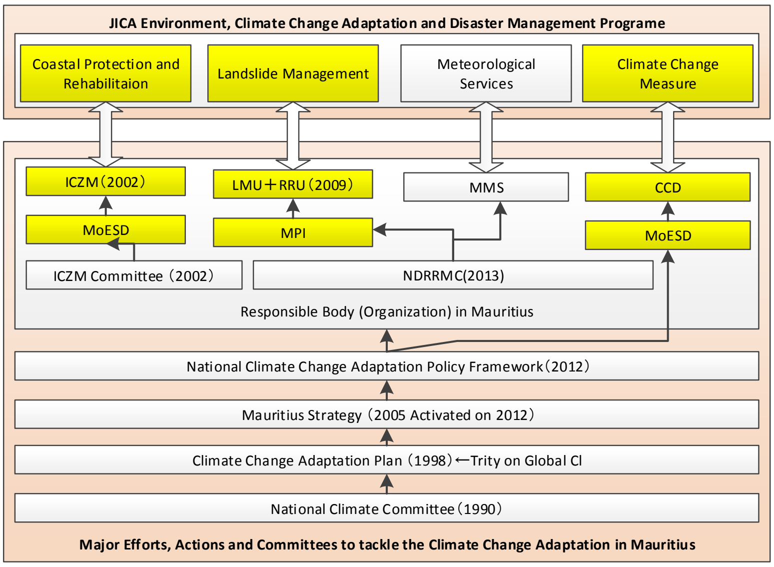


Figure 8.1.1 JICA Environment, Climate Change Adaptation and Disaster Management Program and Related Mauritius Agencies (source: JET)

8.2 Landslide Management and the Environment, Climate Change Adaptation and Disaster Management

The instability of slopes is mainly caused by the increase of surface water flow and high groundwater level caused by heavy rainfall and cyclones which may be indirectly affected by meteorological anomalies caused by climate change.

The landslide management issues shall be discussed mainly within the framework of disaster management. However, most developing countries consider landslide management without knowledge of the mechanisms that cause landslides. Also, lack of basic knowledge of countermeasures for the prevention of landslides is one of the factors. As a result, the countermeasures are not applied. Landslides are deemed to be a natural disaster such as cyclones, earthquakes and tsunamis which are not able to be artificially controlled. Therefore, major measures are taken post-disaster which normally consist of evacuation of local residents, and rehabilitation of important facilities and structures. Mauritius is not an exception.

On the other hand, the landslide distribution is generally concentrated in mountainous areas that are often occupied by poor communities. These residents often decline to evacuate or move out for reasons such as their historical occupation of land as their asset, anxiety about leaving a community they are familiar with, financial difficulties for relocation and fears of losing their means of income.

Landslide disasters can be avoided with effective countermeasures by understanding their mechanisms based on proper surveying and monitoring. However, it is a relatively expensive exercise to undertake proper physical countermeasures for these areas, therefore the government tends to consider relocating at risk residents and their houses and covering construction expenses as compensation after the occurrence of a disaster. Simply for economic reasons, most developing countries tend to place most importance on post-disaster measures.

Mauritius is a higher less-developed nation. The country is willing to prepare a proactive program through the request for the countermeasure works provided to the La Butte area, together with organizing the Landslide Task Unit in MPI. However, the unit does not have enough knowledge and experience to undertake the landslide prevention countermeasures. The “National Disaster Scheme 2014” (hereinafter NDS) (former “Cyclones and Other Natural Disasters 2011-2012”) published by the Prime Minister’s Office provides a relevant evacuation procedure for landslide disasters. However the function of this scheme is still uncertain.

Most of the residents answered that protection of their assets (land and houses) is the vital task in interviews held in landslide areas in Chitrakoot and Quatre Soeurs. This indicates land ownership is a very important issue for the local community considering the lack of land on the island and its historical background. The sense of entitlement and concern over the land at various levels in the community in Mauritius shall be confirmed and extracted through surveys. The technical transfer for the key actors for the sustainable management of landslides shall be achieved based on this range of information.

8.3 The Project and Related Organizations

There are no organizations which execute the landslide countermeasures in Mauritius, but some of them have related functions. The LMU under the Civil Engineering Department of MPI has been given the responsibility to monitor landslides. However the practical activities will be undertaken after the technical transfer to the C/P selected from the Civil Engineering Department followed by the formal activities of LMU by trained staff. The preparedness for the landslide disasters together with the evacuation protocol has been described in "National Disaster Scheme 2014" published by the National Disaster Risk Reduction and Management Committee" held at the PMO followed by the aforementioned "Cyclone and Other Natural Disasters Scheme" published by the Cyclone and Other Natural Disaster Scheme Committee. More than 15 ministries are involved including the Police Department and Para Military and Local Government Authorities for the evacuation procedures. The projects related to the Climate Change Adaptation Program are organized by the Climate Change Division in MoESD such as AAP. The coastal management program "Application of adaptation measures to protect currently vulnerable coastal ecosystem and community features at 3 priority sites: Mon Choisy, Quatre Soeurs and Riviere des Galets" (Adaptation Fund Programme (hereinafter AFP) funded by UNDP) has its function in MoESD as the Project Manager and coordinated by Integrated Coastal Zone Management (hereinafter ICZM) Division. IOC is also a stakeholder in disaster risk reduction. The concept of IOC is to unify the five Indian Ocean island countries on risk reduction, and has a unique approach compared to other development partners.

JET suggested launching a group for collaboration and exchange outputs to avoid the similar activities which may overburden to the related sectors of Mauritius government organizations. This group, the Climate Change Adaptation and Disaster Management Group, consists of a chief advisor and two co-chief advisors, and is tasked with implementing the various components of the Project, namely those related to coastal and landslide management. The Group shall grasp the progress of other related projects and share information to reflect their outcome to the Project.

8.3.1 Government Agencies and Organization of Mauritius

Disaster management scheme in Mauritius basically depends on the "Cyclone and Other Natural Disasters Scheme" as the national strategy against the expected natural hazards in the country. The scheme has been updated and modified at the committee in the PMO. Natural disasters considered are landslides, cyclones, torrential rainfall and tsunami, and the scheme describes actual action plan for the evacuation procedure. The monitoring protocol, emergency warning for residents, command structure, methodology of evacuation and specific plans with responsible bodies are mentioned in this paper. The "Maurice Ile Durable" has begun its action in 2013. It describes the MoESD is the coordination ministry in relation with the environmental issues. The result of AAP was compiled as "National Climate Change Adaptation Framework for the Republic of Mauritius (hereinafter NCCAPF) in 12 December 2012. The Climate Change Information Center was established in August 2013.

The minor change on policies on disaster management was observed after the flood in Port Louis in April 2014. A disaster management advisor was appointed for the formulation and introduction of new policies on disaster management in May 2013. The bill of the new policy on disaster management is expected to be effective in October 2014. The meeting on the establishment of NDRRMC was held in October 2013. The disaster management policies will be formulated under the National Disaster Risk Reduction and Management Committee, which includes introduction of the cross sectorial plan for disaster reduction, measures and management as well as the transition from the former scheme to the new NDS.

At the polls held on December 2014, the new regime defeated the former administration, followed by the re-examination and realignment of government structure, which lead to the change of counterpart in charge of the Project and the related government organizations. Major changes of counterpart ministries are as follows.

Before: Ministry of Environment and Sustainable Development (MoESD)
After: Ministry of Environment, Sustainable Development, Disaster and Beach Management (MESDDBM)

Before: Ministry of Public Infrastructure, National Development Unit, Land Transport and Shipping (MPI)
After: Ministry of Public Infrastructure and Land Transport (MPI)

The major change has not observed and there is no difference on the basic relation between the JET and counterpart organizations in terms of structural and functional. However, the organization for the putting into place of the former Prime Ministers Office has been changed. MID left its tasks on the table, and NDRRMC has been promoted under the umbrella of MESDDBM. There is still uncertainty on the activities that remains on MID. Therefore the description of MID in this report also remains as it is that of the situation of December 2014.

8.3.2 Development Partners

In relation with the Environment, Climate Change Adaptation and Disaster Management scheme, there are 4 active development partners existing including JICA. In those programs, the following two components are related to Landslide Management.

Maurice Ile Durable (MID) under the Prime Minister's Office was inaugurated in 2013. In the MID, the MoESD has the major roll of acting on environmental issues. The results of AAP were projected to the action plan namely "National Climate Change Adaptation Framework for the Republic of Mauritius" (12 December 2012). This framework is currently conducted by Climate Change Division (CCD) of MoESD. The Climate Change Information Center was established in August 2012 under the CCD.

There are changes in policies after the devastating flood in Port Louis in April 2013. The disaster management advisers were called to the Prime Minister's Office at the direction of the Prime Minister, and new policies have been formulated since May 2013. The new disaster policy has been announced by the cabinet and the bill was expected to be passed in a cabinet meeting in October 2013, however, it is currently still pending. A meeting for the establishment of NDRRMC was held on 15 October 2013. It was announced that the government policies on disaster measures will be decided by the National Disaster Risk Reduction and Management Committee, and it is focused on a cross sectorial approach with government agencies, private sector and other academic sectors. The new centre will not only be responsible for disaster schemes that deal with the aftermath of disasters but will research integrated disasters countermeasures (disaster risk reduction and prevention, and emergency relief and recovery efforts) by coordinating with public, private and academic stakeholders. It was also announced that the past disaster manual of "Cyclone and Other Natural Disasters" will be taken over by the NDRRMC's new disaster scheme.

Table 8.3.1 Relevant Programs of Major Development Partners (source: JET)

Organization	Fund	Program	Major Components
UNDP (Japan) - Completed		Africa Adaptation Program（AAP）	･Integrated risk management of disasters ･Climate change adaptation in multi sectors
UNDP + GOM		Climate Change Adaption Program in the Coastal Zone（AFP）	･Design and execution of coastal erosion measures ･Emergency warning, evacuation, capacity building, Knowledge dissemination of coastal management
IOC	AFD, EU, etc	Risques Naturels de la COI	･Risk management of natural hazard risk and disaster prevention in IOC 5 countries ･Knowledge dissemination

a. IOC (Indian Ocean Committee)

Almost half of the fund is from AFD and EU. IOC has commenced the Risk and Natural Disaster Management Project (Risques Naturels de la COI) for five island counties of Madagascar, Seychelles, Le Union, Mauritius and Comoros from 2011 until 2016. There are altogether 16 components including the Chitrakoot Landslide Monitoring Program which is currently undertaken by JICA. The project components and schedule after 2012 are shown in the figure below.

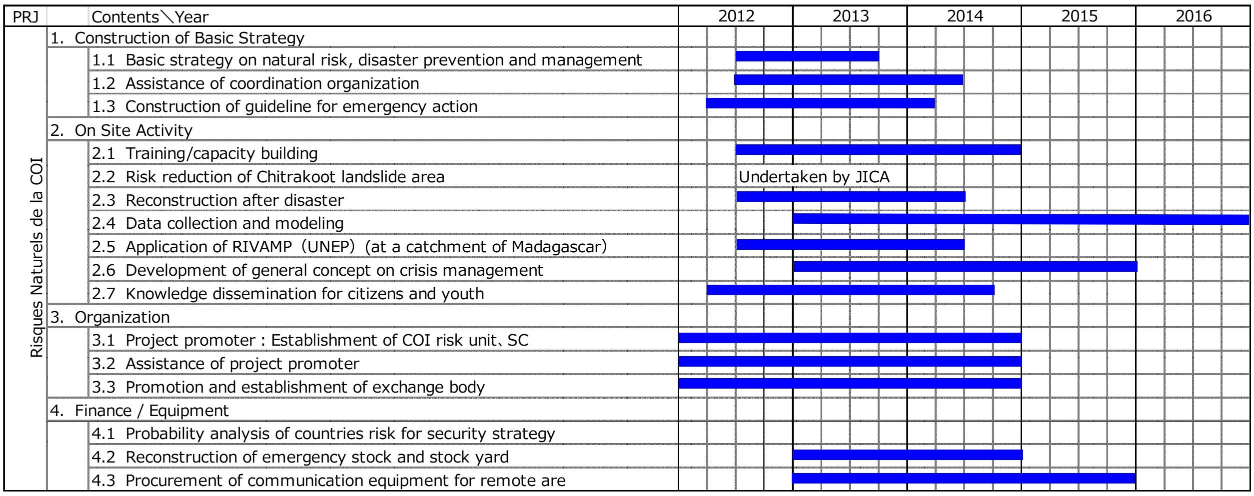


Figure 8.3.1 Major Components of IOC Program[1]

Other than JICA's project component of Chitrakoot Landslide Monitoring Program, the similar or duplicated components are as follows;

2.1 Training/capacity building

2.3 Reconstruction after the disaster

2.6 Development of general concept against risk management

2.7 Education activities for citizens and youth

Information on these areas of duplication is to be shared with IOC, and adjustment of the respective actions will be discussed. The Stakeholder meeting was held on 22 June 2012. The current status and the future direction were discussed. Following the meeting, the site excursion of Chitrakoot was conducted. The explanation of the landslide and the future activities were made by JET to the stakeholders of IOC on 23 June 2012.

The second Steering Committee meeting was called in December 2012. According to the recent information, the ISLANDS project is becoming more active compared to RN-COI.

b. AAP (African Adaptation Program) - "National Climate Change Adaptation Framework for the Republic of Mauritius"(12 December 2012)

AAP is targeted to 20 African countries for Climate Change Adaptation funded by Japan. Several components are covered by the program and it was started in December 2009, and expected to be finalized in December 2012. The Program is titled Development of a DRR Strategic Framework and Action Plan, (December 2012, Studio Galli Ingegneria S.p.A. in association with Centro Euro-Mediterraneo per I Cambiamenti Climatici S.c.a.r.l and Desai & Associates Ltd. Contents of the Project are as follows;

Table 8.3.2 Contents of DRR[2]

No.	Contents
1	Climate change analysis and scenarios
2	National Risk Profile
2.1	Hazard profiling for flooding
2.2	Risk assessment of coastal inundation
2.3	**Hazard profiling for landslides**
2.4	Vulnerability assessment
2.5	Comprehensive national risk profile
3	DRR strategic Framework and action plan
3.1	DRR strategy
3.2	Integrated risk management strategy
3.3	Action Plan
3.4	Detailed actions

This Program targets the risk analysis of landslide, flood and coastal inundation disasters from the macro point of view though risk assessment map utilizing Digital Elevation Models (hereinafter DEM) and satellite imagery. However, the project period was only 6 months and lack of site investigation resulted that frequency of landslide hazards are high in the surroundings of basaltic high mountainous area. It seems to be a general conclusion, and everyone can expect this result. Also integrated risk management strategy and its action plan have some aspects which cannot be realistically executed. Some parts may be utilized in our project, especially the DEM based profile maps.

The results of AAP were projected to the action plan namely "National Climate Change Adaptation Framework for the Republic of Mauritius" (12 December 2012). This framework is currently conducted by Climate Change Division (CCD) of MoESD. The Climate Change Information Center was established in August 2012 under the CCD.

Including DRR, in total 39 projects are planned within five categories, of which cross sectorial programmes have the highest priority. The project period is set from 2013 to 2015, and the major projects (funded projects) are as follows;

1. Preserve healthy natural environment (45,000,000 Rs)

2. Coastal Management Plans for Inundation (45,000,000 Rs)

3. Sound Spatial Data Infrastructure (270,000,000 Rs)

4. Flood Management Plans (937,000,000 Rs)

Currently the Project of Coastal Management Plans for Inundation is active. However only the project “Preserve healthy natural environment” has budgeted and others are still in the preliminary phase without budget. Other 35 projects including the cross sectorial ones are not started. The goals to achieve the results on those projects are still far.

8.4 Summary on Environment, Climate Change Adaptation and Disaster Management by JICA

The whole image of the relation between the projects on climate change and disaster management by international development partners (such as UNDP, AF and IOC) and government of Mauritius is illustrated in Figure 8.4.1. The Figure presents the projects related to climate change and disaster management. The frameworks are extracted based on results and lessons learnt from these projects.

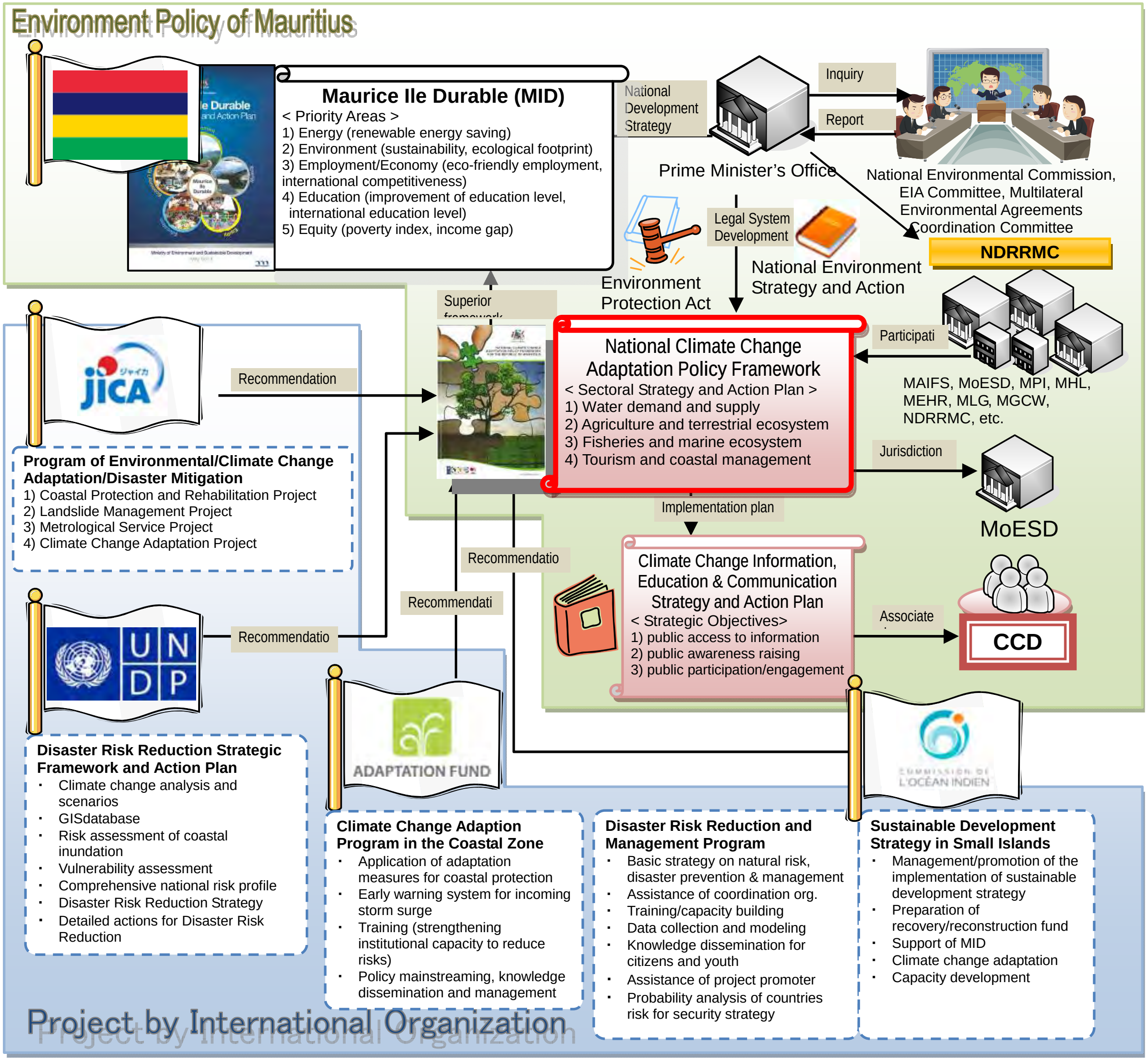


Figure 8.4.1 Relationship between CCD and Related International Organizations/Ministries
(source: JET)

The major outcomes of this project on the disaster management are summarized as follows;

1. The cyclones and heavy rains, particularly torrential rains are intensive in Mauritius. The ability to reinforce and plan measures on landslides, floods and sediment disasters is enhanced.

2. Directional contribution has been made on policies on the disaster management and on

landslide disaster measures to MPI and NDRRMC through survey, monitoring, disaster reduction measures and emergency alarm system as disaster prevention measures within the framework of JICA Climate Change Adaptation and Disaster Management package to the government of Mauritius.

3. The action plan for disaster prevention were transferred not only the policy level but to the communities at the dangerous area through the disaster education and sensitization (community disaster management).

These contributions are summarized in flow chart presented in Figure 8.4.2

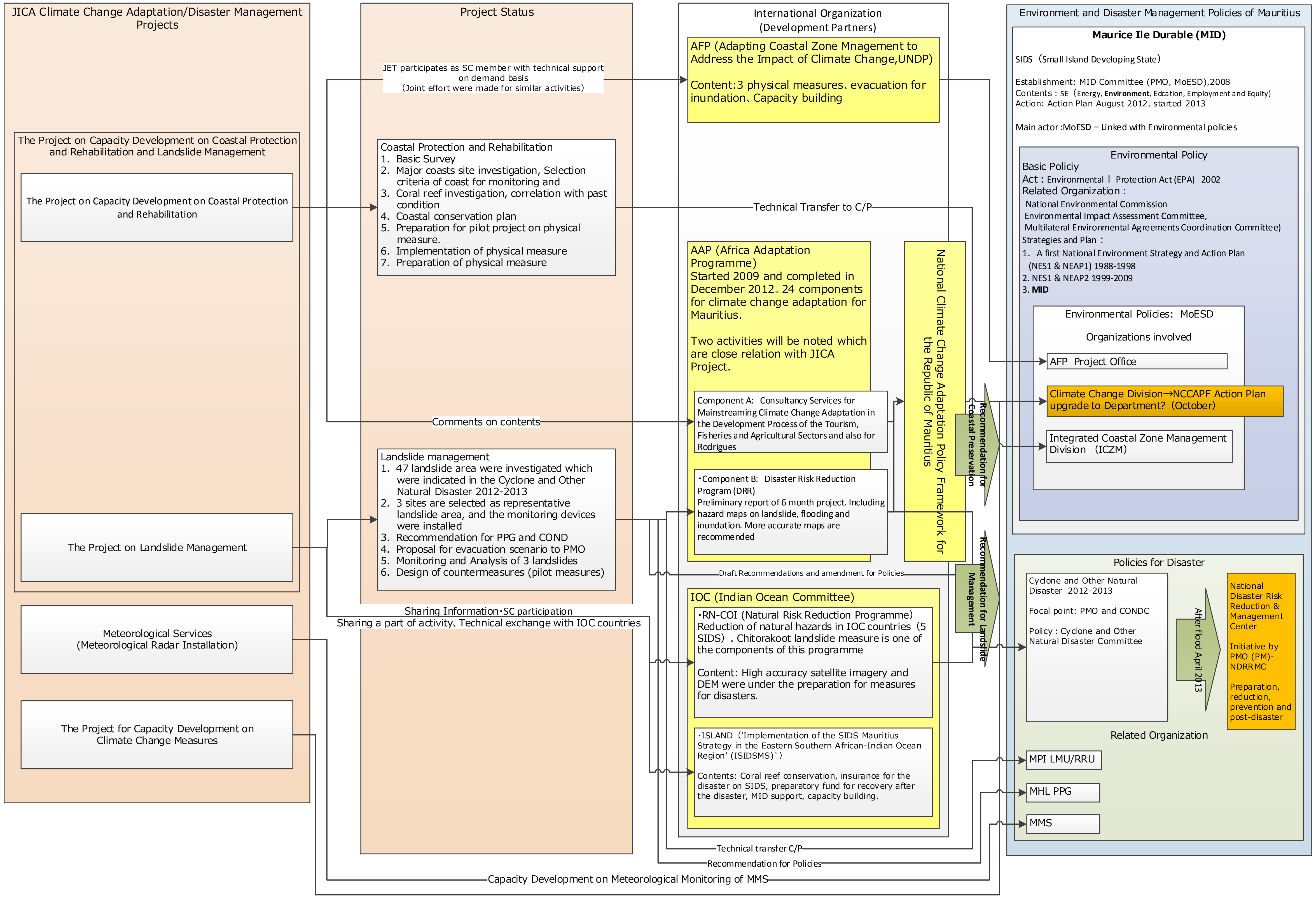


Figure 8.4.2 JICA Climate Change Adaptation/Disaster Management Projects and the Relation with Other International Development Partners, and the Related Policies of Mauritius (source: JET)

8.5 Technical Exchange with the Southwest Indian Ocean Islands

a. Background

In line with the work plan of this project, the regional seminar on the landslide and coastal zone management in the southwest Indian Ocean islands was organized in order to share the outcomes of the project with the neighboring islands. JET sought to cooperate with the other organizations such as the IOC and the UNDP which both have actively implemented the natural disaster risk measures for the southwest Indian Ocean islands. The IOC was supposed to be responsible for funding and logistics for the seminar, however the IOC could not provide the support for organizing the seminar as the IOC has suspended its main project of natural disaster risk management due to lack of funding. Hence the JET initiated to organize the regional seminar.

b. Expected Effects on Climate Change Measures and Disaster Risk Reduction Measures

The expected effects of the regional seminar for the climate change measures and disaster risk reduction measures are as follows:

1) Sharing the outcomes of the JICA's activities in Mauritius to the other southwest Indian Ocean islands which could be an example of JICA's technical exchange on disaster risk reduction for the SIDS at the Third United Nations World Conference on Disaster Risk Reduction in Sendai in 2015;

2) Highlighting the JICA's presence in the southwest Indian Ocean islands as well as the measures on climate change and natural disasters implemented by the Government of Japan as linking the regional seminar to the International Year of Small Island Developing States in 2014 and the Third International Conference on SIDS held in Samoa in September 2014;

3) Emphasizing aid coordination and cooperation of the regional seminar by linking the seminar with the Third International Conference on SIDS held in 2014;

4) Following the JICA's south-south cooperation as the regional seminar provides an opportunity for Mauritius and the neighboring islands for technical exchange;

5) Extending the outcomes of JICA's project on coastal rehabilitation and protection and landslide management in Mauritius to the neighboring islands through the presentation and field visits; and

6) Sharing the issues in the southwest Indian Ocean islands with a consideration of the regional centre such as CCIC in Mauritius.

8.5.1 Summary of the Regional Seminar

a. Seminar Outline

1) Schedule: 5 March 2015 to 6 March 2015 (Day 1: presentation, and Day 2: field visits)
2) Participating islands: Mauritius (including Rodrigues), Madagascar, Seychelles, Comoros and Reunion
3) Participants: one management officer and two technical officers from Madagascar, the islands of Seychelles, Comoros and Reunion, and concerned officers of JICA project from Mauritius (including Rodrigues)

b. Purposes of the Seminar

1) Extending the outcomes of JICA's project on landslide management and coastal protection in Mauritius to the neighboring islands;
2) Organizing the seminar in collaboration with the international organizations in order to initiate the disaster risk reduction including landslide management and coastal protection; and
3) Promoting technical exchange between Mauritius and the neighboring islands.

c. Regional Seminar (Day 1)

92 participants including the Minister for the MESDDBM, the Permanent Secretary for the MPI, the Japanese ambassador to Mauritius, delegations from the southwest Indian Ocean islands, stakeholders of the project and international organizations participated in the first day of the seminar. Following the speeches by the Minister for the MESDDBM and other delegations, the counterparts of the projects and the delegations from Madagascar, Seychelles, Comoros and Reunion gave a presentation. The summary of the presentations is as follows.

Photo8.5.1 Participants of the Seminar (5th March 2015)

Photo8.5.2 Presentation by the Neighbouring Islands (5th March 2015)

(source: JET)

Table 8.5.1 Presentation Details (source: JET)

presenter	Presentation details
Mauritius MPI (landslide C/P)	• Landslide management in Mauritius • Classified landslide sites and main related organizations • Landslide monitoring • Countermeasure works in Chitrakoot
Mauritius MESDDBM (coastal C/P）	• Coastal zone issues in Mauritius (i. e. coastal erosions, coral reef destructions, siltation of lagoon, sea level rise, natural calamities, overfishing, uncontrolled development on the coast, and marine litter) • Coastal zone management (i.e. legal framework, and implementing organizations project details) • JICA's coastal protection and rehabilitation project
Mauritius MESDDBM (climate change C/P）	• Impacts of climate change in Mauritius • Visions and initiatives on climate change and natural disasters
Madagascar	• Natural and human made disasters in Madagascar (i.e. cyclones, landslides, ocean pollution, and oil spills) • Responses for the disasters (i.e. human development, and organizational reinforcement) • Issues of landslide (i.e .soil, environmental degradation, and lack of data)
Seychelles	• Hazard profile in Seychelles (i.e. storm surges, landslides, coastal erosions, heavy rainfalls, and flash floods) • Responses for disasters (i.e. organisational set up, and project implementation) • JICA's project on coastal erosion and flood
Comoros	• Natural disasters in Comoros (i.e. landslides, coastal erosions, and floods) • Impacts caused by the disasters • Responses for the disasters
Reunion	• Natural disasters in Reunion (i.e. landslides, coastal erosions, floods, and sea level rise) • Projects implemented for the natural disasters

d. Regional Seminar (Day 2)

Approximately 60 participants from the southwest Indian Ocean islands, counterparts of the project and stakeholders in Mauritius joined the field visits for the second day of the regional seminar. Participants visited Chitrakoot, where the landslide countermeasure works were implemented under the landslide management project, and Grand Sables, where the flexible revetment (gravel nourishment) was implemented under the coastal protection and rehabilitation project.

Photo8.5.3 Explaining the Monitoring System and Countermeasure Works in Chitrakoot (6th March 2015)

Photo8.5.4 Group Photo taken at Grand Sable (6th March 2015)

(source: JET)

Engineers of the MPI who are the counterpart of the landslide management project explained the countermeasure works, early warning system and monitoring devices in Chitrakoot. At Grand Sables, environmental officers of the MESDDBM explained flexible revetment (gravel nourishment). Additionally, local villagers explained the positive effects of the demonstration project.

e. Discussions

Followed by the presentation of each southwest Indian Ocean islands, participants discussed the ways of cooperation such as technical exchange on climate change adaptation and mitigation measures, and information sharing for disaster risk reduction and management. The three following points; 1) possible areas of cooperation, 2) systems to be introduced and 3) establishment of regional centre were mainly discussed. Discussion details are shown in the table 8.5.2.

Table 8.5.2 Discussion Details (source: JET)

Answered by countries/ organizations	Discussion details
1. What kind of disaster risk reduction measures are taken in each island?	
Comoros	• Mangrove plantation
Madagascar	• Enhancement of the research activities • Introduction of early warning system at the community level • Mangrove plantation
Reunion	• Enhancement of sensitization activities • Establishment of effective and efficient disaster risk reduction measures in the limited budget • Enhancement of soft countermeasures (i.e. information sharing with local residents)
Seychelles	• Enhancement of multi-agency cooperation before and after the disaster in order to prevent duplication of the activities • Establishment of the early warning system • Mangrove plantation • Enhancement of awareness raising activities

2. What are required for disaster risk reduction in future?	
Mauritius	• Enhancement of vulnerability analysis • Establishment of a platform where officers at technical and management level are able to share the information in the region • Capacity building in terms of data collection and monitoring
Comoros	• Enhancement of academic knowledge on coastal zone management • Establishment of a platform to share information and experience in the region • Organizational reinforcement in terms of human resources and equipment
Reunion	• Establishment of a platform to share the information beyond the country
Seychelles	• Collection of data and experience • Accessing fund
IOC	• Cooperation beyond the different level of development and organizational capacity in the islands • Understanding the issue of accessing data rather than lack of data. Firstly data sharing among the different ministries in the same country needs to be strengthened and the data sharing system at the national level is required. • Establishment of database for information and data sharing in the region • Promoting the technical exchange beyond the country
3. What are the ways of cooperation among the southwest Indian Ocean islands?	
Mauritius	• Utilization of the Climate Change Information Centre (CCIC) established by the JICA's support • Sharing the data and materials collected at the CCIC
IOC	• Development of the training programme for island technical officers in order to deal with the island specific issues
4. Landslide early warning system	
MPI Mauritius	• three stages of warning, evacuation and termination • The device has the yellow light for warning stage and red light with alarm for evacuation stage.
5. Landslide monitoring	
MPI Mauritius	• Consulting the monitoring works to the Mauritian private company • Conducting monitoring at three sites
6. climate change adaptation measures for coastal zone	
MESDDBM Mauritius	• Shifting from hard countermeasures to soft countermeasures
7. Examples of information sharing in the region	
IOC	• Sharing the information such as waves and water quality on the website of Mauritius Oceanography Institute (MOI)
8. Any actions taken at the community level for demonstration project	
MESDDBM Mauritius	• Awareness raising of the local residents through beach beautification organized once a month at Grand Sable • Organized stakeholder meeting for more than five times before the demonstration project

Participants including the IOC pointed out that the information sharing system at the regional level is necessary. Caribbean Disaster Emergency Management Centre (CDEMA) in Caribbean Community (CARICOM) in Central and South America could be an example of cooperation, however the southwest Indian Ocean islands have several issues to establish the cooperation system as the islands have different development level, economy and issues on climate change and disaster risk management. The regional seminar could be a first step to establish information sharing system.

The following chart (Figure8.5.1) proposed by the JET was generally accepted as common concepts among countries participated in the seminar.

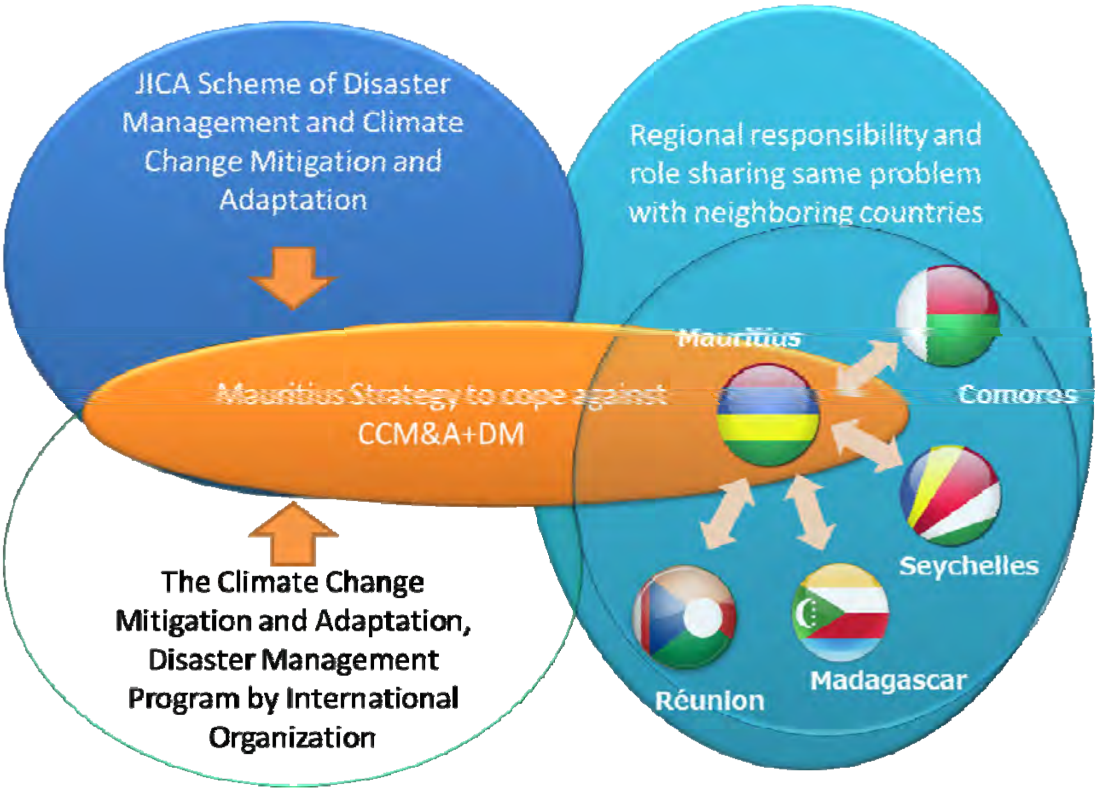


Figure 8.5.1 An Image of Cooperation on Climate Change and Disaster Risk Management among JICA, International Organizations, Mauritius and the Southwest Indian Ocean Islands (source: JET)

f. Outcomes of the Regional Seminar

The outcomes of the JICA'S project on coastal protection and rehabilitation, and landslide management in Mauritius were shared through the presentation in the first day and field visits in the second day. Technical knowledge and experience of the other islands were also shared. Moreover, cooperation on climate change and disaster risk management was emphasized, and participants had a fruitful discussion for continuous cooperation in future.

g. Participant List for the Day 1

Table 8.5.3 Participant List for the Day 1 (source: JET)

	Name	Designation
Ministry of Public Infrastructure and Land Transport		
1	Mr. V. LUTCHMEEPARSAD	PERMANENT SECRETARY
2	Mr. LALLCHAND	SENIOR ADVISOR TO MINISTER MPI
3	Mr. R. JEWON	DIRECTOR, CIVIL ENGINEERING
4	Mr. T. PARBHUNATH	DEPUTY DIRECTOR, CIVIL ENGINEERING

5	Mr. D. CHINASAMY	CHIEF ENGINEER, LMU/RRU
6	Mr. N. EARALLY	CHIEF ENGINEER
7	Mr. S.P. ANADACHEE	ENGINEER/ SENIOR ENGINEER
8	Mr. M. K. MOSAHEB	ENGINEER/ SENIOR ENGINEER
9	Mr. L. BISSESSUR	ENGINEER/ SENIOR ENGINEER
10	Mr. V. RAMDHAN	ENGINEER/ SENIOR ENGINEER
11	Mr. B. DABYCHARUN	ENGINEER/ SENIOR ENGINEER
12	Mr. VISHAN	TECHNICAL OFFICER
13	Mr. V. RAMCHURN	TECHNICAL OFFICER
MINISTRY OF ENVIRONMENT, SUSTAINABLE DEVELOPMENT, DISASTER AND BEACH MANAGEMENT		
14	Hon. JAYESHWUR RAJ DAYAL	MINISTER
15	Mrs. S.L. NG YUN WING	DIRECTOR
16	Mr. S. MOOLOO	DEPUTY DIRECTOR
17	Mr. R. SEENAUTH	DIVISIONAL ENVIRONMENT OFFICER (ICZM)
18	Mr. J. SEEWOOBADUTH	DIVISIONAL ENVIRONMENT OFFICER (CCD)
19	Mrs. S. R. N. B. SOOGUN	ENVIRONMENT OFFICER (ICZM)
20	Mr. A. JHEENGUT	ENVIRONMENT OFFICER (ICZM)
21	Mr. J.R. OH-SENG	ENVIRONMENT OFFICER (CCD)
22	Mrs. T. GUJADHUR	ENVIRONMENT OFFICER (CCD)
23	Mr. H. BHOLAH	CHIEF PROJECT MANAGER
UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP)		
24	Mr. S. SPRINGETT	UN RESIDENT COORDINATOR & UNDP RESIDENT REPRESENTATIVE
25	Mr. S. RAMCHURN	ENVIRONMENT PROGRAMME OFFICER
AFRICAN FUND PROGRAMME (AFP)/UNDP		
26	Mr M N. KHEDAH	PROJECT MANAGER
27	Ms. M. CLARKE	HEAD OF CLIMATE CHANGE CONSULTING
INDIAN OCEAN COMMISSION (IOC)		
28	Ms. G. BONNE	CHARGEE DE MISSION
29	Mr. S. AHAMADA	EXPERT IN MARINE AND COASTAL BIODIVERSITY
30	Mr. J. B. ROUTIER	TECHNICAL ASSISTANT
EUROPEAN UNION (EU)		
31	Mr. H. GRANDJEAN	PROJECT MANAGER
AGENCE FRANÇAISE DEVELOPMENT (AFD)		
32	Ms. S. AMMEARALLY- NISTAR	CHARGEE DE PROJETS
BUREAU NATIONAL DES GESTIONS DES RISQUES ET CATASTROPHES (BNGRC) MADAGASCAR		
33	MR. C. RAMBOLARSON	ADJ. DU SÉCRETAIRE EXÉCUTIF
34	Mr. J. J. RAZAFIARISON	DIRECTEUR DES RÉPONSE AUX URGENCES
MINISTRY OF ENVIRONMENT AND ENERGY, SEYCHELLES		
35	Mr. N. SENARATNE	DIRECTOR, COASTAL ADAPTATION AND MANAGEMENT SECTION
36	Mr. L. PAYET	LOCAL PROJECT MANAGER
37	Mr. H. FIGARO	SENIOR INSPECTOR (CAMS)
DIRECTION GÉNÉRAL DE LA SÉCURITÉ CIVILE, UNION DES COMORES		
38	Mr. COLONEL I. MOGNE DAHO	DIRECTEUR GÉNÉRAL DE LA SÉCURITÉ CIVILE UNION DES COMORES
39	Mr. A. AHMED	CHEF DU CENTRE DES DONNÉES OCÉANIQUE
40	Mr. N. B. ALI MOEGNI	TECHNICIEN AU SERVICE DES ÉTUDES ET PRÉVENTION
DIRECTION DE L'ENVIRONNEMENT, DE L'AMENAGEMENT ET DU LOGEMENT REUNION		
41	Mr. O. BIELIN	CHEF DE L'UNITÉ PRÉVENTION DES RISQUES NATURELS
RODRIGUES REGIONAL ASSEMBLY		

42	Mr. J. L. AZIE	AG. ENVIRONMENT OFFICER
MINISTRY OF HOUSING AND LANDS		
43	Mr. S. GUNNOO	SENIOR TOWN & COUNTRY PLANNING OFFICER
44	Mr. R. SOBORUN	SENIOR PLANNER
MINISTRY OF TOURISM AND EXTERNAL COMMUNICATIONS		
45	Mrs. L. SANSPEUR	PRINCIPAL TOURISM PLANNER
46	Mr. J. GOPAUL	TOURISM PLANNER
MINISTRY OF LOCAL GOVERNMENT		
47	Mr. M.B. RAJABALEE	ASSISTANT PERMANENT SECRETARY
MINISTRY OF OCEAN ECONOMY, MARINE RESOURCES, FISHERIES, SHIPPING AND OUTER ISLANDS		
48	Ms. N. ROOMALDAWOO	TECHNICAL OFFICER
49	Mr. V. MUNBODHE	SCIENTIFIC OFFICER
NATIONAL DISASTER RISK REDUCTION AND MANAGEMENT CENTRE (NDRRMC)		
50	Mr. R. LUXIMON	ENVIRONMENT OFFICER
MAURITIUS METEOROLOGICAL SERVICES (MMS)		
51	Mrs. S. RAMESSUR	AG. DIVISIONAL METEOROLOGIST
WATER RESROUCES UNIT		
52	Mr. S.A. ZEADALLY	SENIOR HYDROLOGICAL OFFICER
FORESTRY SERVICES		
53	MR. N. NAWJEE	DIVISIONAL FOREST OFFICER
54	Mr. Z. JHUMKA	ASSISTANT CONSERVATOR OF FORESTS
SPECIAL MOBILE FORCE/ POLICE DEPARTMENT		
55	Mr. D. RAMGUTEEA	SERGEANT
56	Mr. S. BEEDASY	LIEUTENANT
MAURITIUS OCEANOGRAPHY INSTITUTE (MOI)		
57	Mr. O. PASNIN	ASSOCIATE RESEARCH SCIENTIST
58	Dr. D. BISSESSUR	ASSOCIATE RESEARCH SCIENTIST
ROAD DEVELOPMENT AUTHORITY (RDA)		
59	Mr. V. MULTRA	MANAGER
TRAFFIC MANAGEMENT AND ROAD SAFETY UNIT		
60	Mr. D.P. GOOLJAR	ENGINEER/SENIOR ENGINEER
61	Mr. I. MUSTALLY	TRAINEE ENGINEER
WASTEWATER MANAGEMENT AUTHORITY (WMA)		
62	Mr. N. BANHARALLY	CIVIL ENGINEER
63	Mr. R. JHURRY	WORK MANAGER
UNIVERSITY OF MAURITIUS (UOM)		
64	ASSOC. PROF Dr. NOWBUTH	DEAN OF FACULTY AND OCEAN STUDIES
65	Mrs. Y. BAGUANT	SENIOR LECTURER
BEACH AUTHORITY		
66	Mr. V. TOOFANY	TECHNICAL OFFICER
NATIONAL COAST GUARD		
67	Mr. H. CAULEECHURN	INSPECTOR OF POLICE
NATIONAL PARKS AND CONSERVATION SERVICES		
68	Mr. P. MOOLEE	SENIOR PARK REINGER
69	Mr. S. PANDOO	TECHNICAL OFFICER
CITY COUNCIL OF PORT LOUIS		
70	Mr. R. MADHUB	AG. PRINCIPAL HEALTH INSPECTOR
71	Mr. O.C.G. DOMAH	HEAD, PUBLIC INFRASTRUCTURE DEPARTMENT
MUNICIPAL COUNCIL OF CUREPIPE		
72	Mr. J. JAUNKY	SENIOR HEALTH INSPECTOR
MUNICIPAL COUNCIL OF QUATRE BORNES		
73	Mr. A. REESAUL	HEAD, PUBLIC INFRASTRUCTURE DEPARTMENT
MUNICIPAL COUNCIL OF BEAU BASSIN		
74	Mr. R. OODALLY	HEAD, PUBLIC INFRASTRUCTURE

MUNICIPAL COUNCIL OF VACOAS PHOENIX		
75	Mr. S. LALOO	CIVIL ENGINEER
DISTRICT COUNCIL OF GRAND PORT		
76	Mr. S. SAIRALLY	HEAD, PUBLIC INFRASTRUCTURE DEPARTMENT
DISTRICT COUNCIL OF SAVANNE		
77	Mr. D. KOONJUL	HEAD LAND USE PLANNER
78	MR. A. RUNGASSAMY	CHIEF HEALTH INSPECTOR
DISTRICT COUNCIL OF PAMPLEMOUSSES		
79	Mr. R. RADHA	HEAD, PUBLIC INFRASTRUCTURE DEPARTMENT
DISTRICT COUNCIL OF BLACK RIVER		
80	Mr. P. BALLOO	HEAD, PUBLIC INFRASTRUCTURE DEPARTMENT
DISTRICT COUNCIL OF MOKA		
81	Mr. M. RAGAVEN	CIVIL ENGINEER
EMBASSY OF JAPAN IN MADAGASCAR/MAURITIUS		
82	H.E. Mr. HOSOYa	AMBASSADOR OF JAPAN TO MAURITIUS
83	Ms. TAMOTO	THIRD SECRETARY
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)		
84	Ms. K. TAKAHASHI	PROJECT FORMULATION ADVISOR
85	Mr. CHIBA	INTERN
86	Mr. TSUDA	INTERN
JICA EXPERT TEAM		
87	Mr. K. ICHIKAWA	CHIEF ADVISOR
88	Ms. H. YOSHIDA	PROJECT COORDINATOR
89	Ms. J. BHANDARI	LOCAL CONSULTANT WITH JICA
90	Ms. S.B. MUNGROO	PROJECT ASSISTANT
OTHER		
91	Mr. BEEHUSPUTEE	AG D.C.E D.C.P
92	Mrs. BHENDANEE	

Reference for Chapter 8

[1] JET compiled based on project brochure of COI-RN
[2] Development of a Disaster Risk Reduction Strategic Framework and Action Plan, (December 2012)

Chapter 9

Proposal for Future Tasks

9 Proposal for Future Tasks

9.1 Proposal on a Landslide Management Plan

9.1.1 Disaster Inspection

Thirty-seven (37) slope disaster hazard areas are defined in the Disaster Scheme, which means that the 37 areas are officially identified by the Mauritius Government as “high hazard areas for slope disasters”. Therefore countermeasures which mitigate the risk of disasters are necessary to protect the citizens and the infrastructures in Mauritius

However it is impossible to immediately conduct countermeasures and to diminish the risk completely in a short period for the 37 slope disaster hazard areas because of the limited budget and human resources and the lack of technology. It would take several to a dozen years to complete all of the countermeasures for the areas because they will be conducted one by one.

Therefore a regular disaster inspection is a better risk management method to identify ominous signs that may cause a serious disaster before a slope disaster happens, which should last until the completion of countermeasure construction and the confirmation of effectiveness of the countermeasures. The disaster inspection procedures JET has proposed to MPI will be conducted continuously in the Project.

9.1.2 Disaster Scheme

Figure 9.1.1shows the outline image of the draft recommendation for the Disaster Scheme.

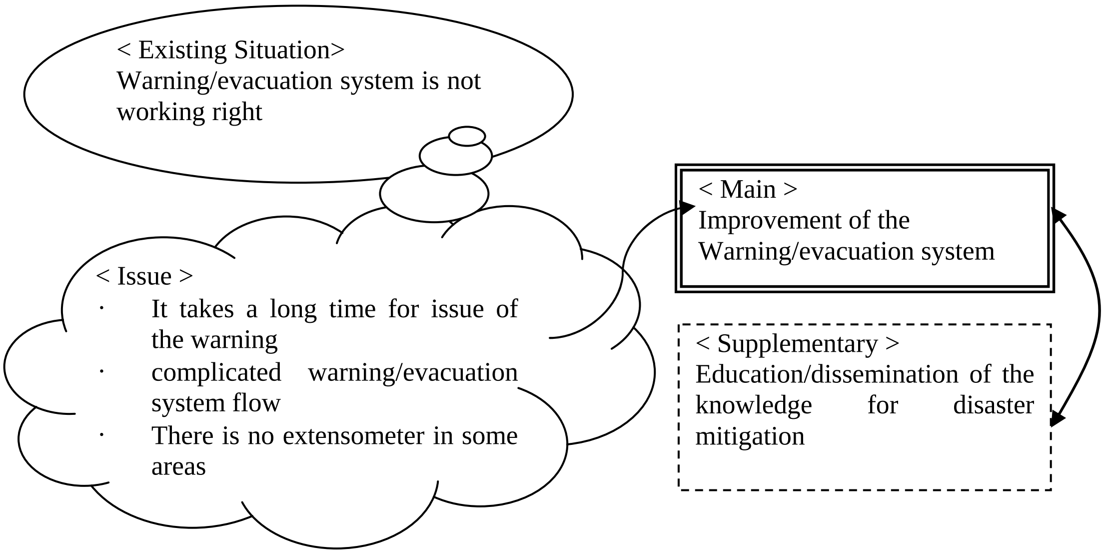


Figure 9.1.1 Outline Image of the Draft Recommendation for Disaster Scheme (source: JET)

- The Disaster Scheme is basically the manual for the warning/evacuation system in a time of disaster/emergency. Therefore, it is required that the response by the related ministries/agencies should be simply described at each stage for prompt action.
- Regular activities for education/dissemination/drill will be required in order for the warning/evacuation system to work properly.

- The education/dissemination has no immediate relationship to the Disaster Scheme as a manual of the warning/evacuation system. Therefore, it is difficult to incorporate the education/dissemination into the Disaster Scheme. But education/dissemination is a matter related to the Disaster Scheme. The incorporation of the contents to the guideline/manual by this project is proposed as a supplemental recommendation.

Based on the above, Table 3.9.3 shows the existing disaster scheme article, draft proposal of addition/modification, reason of addition/modification and necessity as a recommendation for the disaster scheme. Part of the draft proposal of addition/modification is attached to the Supporting Report.

9.1.3 Recommendation of PPG

Figure 9.1.2 shows the outline image of the draft recommendation for PPG.

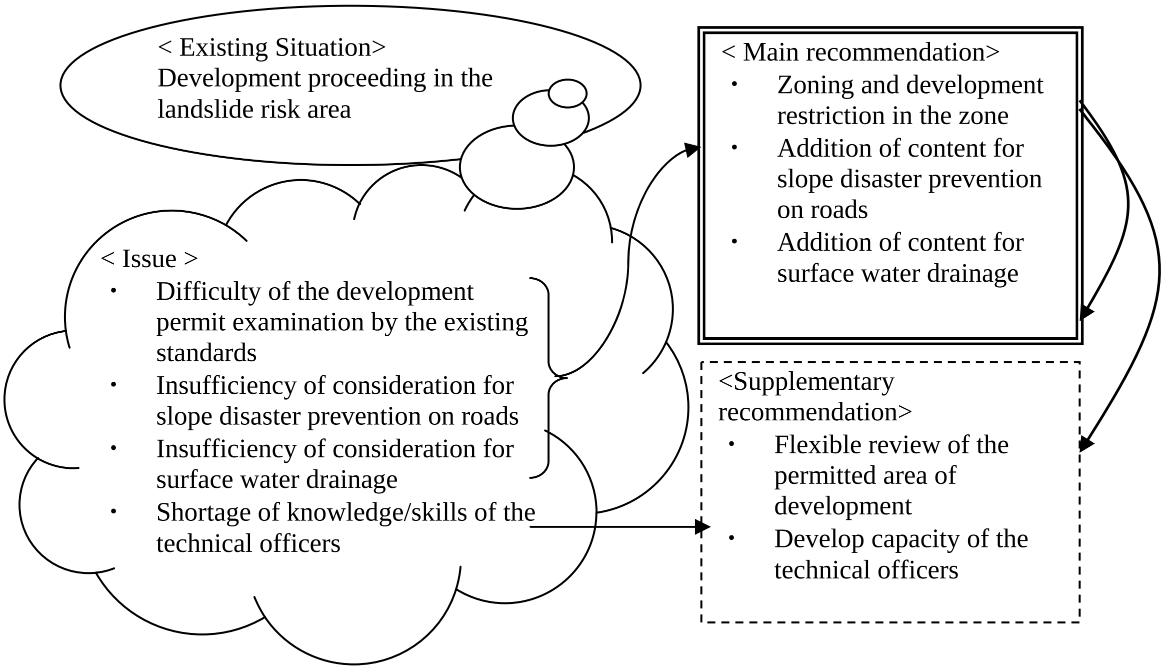


Figure 9.1.2 Outline Image of the Draft Recommendation for PPG (source: JET)

< Existing situation >

PPG has the following criteria regarding development restrictions on sloping sites.

- Development will not normally be permitted on slopes steeper than 1:5 (20%).
- Development above slopes of 1:10 (10%) will be approved conditional on survey completion and implementation of slope stability works.
- Buildings and structures should be set back far enough from ridges and cliff edges so that the structure does not appear to be perched on the edge.

PPG has little content on development restriction in landslide risk areas, but development is proceeding in the risk area.

< Issue >

According to the interview survey result of the local authorities/related ministries, the following issues are confirmed.

- There is no clear zoning of the restriction on a map. It is therefore difficult to identify the restricted area. As a result, a development/building permit application for the landslide risk area can pass the review process by the building/planning/works inspector.
- There is a shortage of an administrative officer/engineer who has knowledge/skills regarding the development restriction at sloping sites.

<Main recommendation>

The following solutions are proposed as a main recommendation to the above issues:

- Designate the hazard zone for a slope disaster
- Restrict development in the hazard zone.

Based on the above, Table 3.10.6 shows the existing PPG Article, Draft proposal of addition/modification, Reason of addition/modification and necessity as a recommendation for PPG. Also, the part of the draft proposal on addition/modification is attached in the Supporting Report.

9.1.4 Technical Guideline for Initial Survey

The Guideline covers what and how landslide disasters should be dealt with, and includes the procedures MPI should implement on landslide disasters. The procedures are composed of literature survey, initial site survey, emergency response, detailed survey plan, etc. The detailed survey/analysis/monitoring and the design/construction after the discussion of the survey plan are described in "Procedure Manual for Landslide" which is elaborated in the next section.

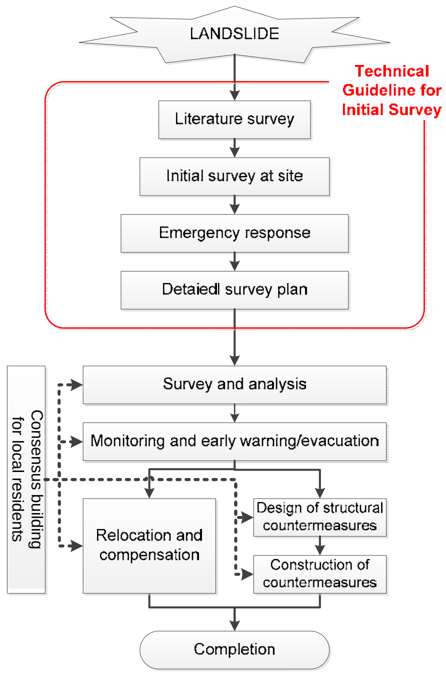


Figure 9.1.3 The Scope of Application of the Technical Guideline for Initial Survey (source: JET)

Table 9.1.1 The Contents of the Technical Guideline for Initial Survey (source: JET)

Cp.	Title	Contents
1	Introduction	- Contents, purpose, flow of the guideline - Outline of landslides in Mauritius - Workflow of initial survey
2	Literature survey	- Data to be collected ant their utilization - Regulation of law and land-use
3	Initial site survey	- Setting of target areas - Site survey and analysis - Monitoring for initial survey
4	Emergency response	- Structure measure - Evacuation and relocation - Early warning system
5	Detailed survey plan	- Outline of detailed survey - Outline of countermeasure policy

Although the Guideline is prepared by mainly JET in the Project, LMU should renew appropriately the contents of the Guideline after the Project so that it becomes more usable and rational based on the case examples and issues in Mauritius.

9.1.5 Procedure Manual for Landslide

The Manual covers what and how to undertake countermeasures to mitigate the disaster risk of landslides, and how to support MPI in conducting surveys/analysis and planning/design/construction of countermeasures for landslides by themselves. It is also formulated based on the review of the early warning/evacuation procedures and PPG. The manual includes strategic methods to induce development and important points to remember, as well as problems found in the F/S and the pilot project and solutions, and how the solutions were reached.

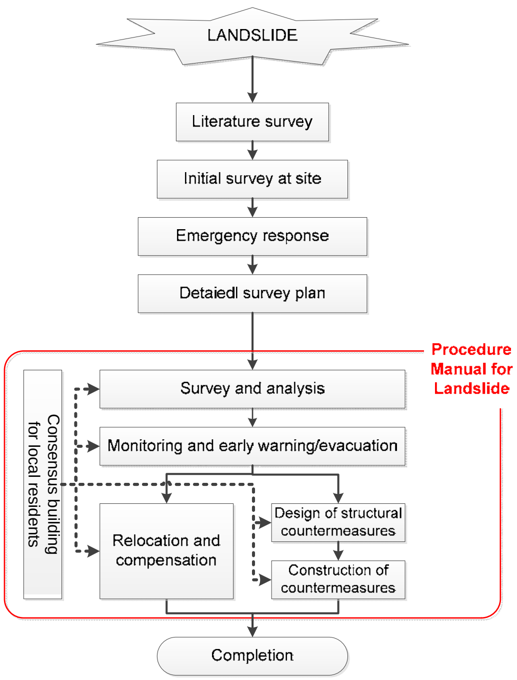


Figure 9.1.4 The Scope of Application of the Procedure Manual for Landslides (source: JET)

Table 9.1.2 The Contents of the Procedure Manual for Landslides (source: JET)

Cp.	Title	Contents
1	Introduction	- Outline of landslides in Mauritius - Contents, purpose, flow of the Manual - Application, composition of the Manual
2	Survey and analysis	- Topographic survey, aerial photo identification, field reconnaissance, drilling, geophysical exploration, laboratory test, water analysis - Installation of monitoring devices - Cross section, active areas/blocks, direction of movement, volume, discussion of slip surface - Basic factor and trigger - Stability analysis and safety factor
3	Monitoring and early warning/evacuation	- Monitoring system and information transmission - Setting of threshold for warning and evacuation - Responsibility and role of related organizations - Evacuation procedure
4	Relocation and compensation	- Existing law (PPG etc.) and planning scheme - Caution area and special caution area - Area setting for relocation/compensation - Implementation of relocation - Implementation of compensation
5	Consensus building for local residents	- Significance of consensus building - Flow of consensus building - When and what to be built for local residents - How to deal opinions and comments from residents
6	Design of structural countermeasures	- Basics of design of landslide countermeasures - Design of restraint works and control works - Environmental and social considerations
7	Construction of structural countermeasures	- Construction plan - Checkpoints for construction - Construction and supervision
8	Initial survey and emergency response	[Excerpt of “Technical Guideline for Initial Survey”]

Although the Manual is prepared by mainly JET in the Project, LMU should renew appropriately the contents of the Manual after the Project so that it becomes more usable and rational based on the case examples and issues in Mauritius.

9.2 Proposal on a Feasibility Study

9.2.1 Promotion of Fund Raising

The “promotion of fund raising” in the Project is to secure a budget from the Mauritius Government and to procure fund from other donors in order to implement landslide countermeasures in a sustainable manner. JET has discussed the promotion of fund raising with the related organizations such as MPI based on the schedule and budget for implementation of landslide projects.

MPI declares that LMU will be focused on landslide projects in the future and secure the budget for the countermeasures by themselves. Indian Ocean Commission (hereinafter IOC), which is implementing the natural disaster prevention projects including landslide disasters in Mauritius, has no plan to procure additional funds for landslide countermeasures for the time being. Therefore, basically, the landslide projects are going to be conducted by the budget in Mauritius Government. The schedule and budget for implementation are planned based on the MPI’s stance.

a. 2013 Fiscal Year

In 2013 fiscal year, LMU has 3,457,980Rs as “Acquisition of Equipment for Landslide Management” which has been applied last year. Therefore, JET suggests that LMU makes use of the earmarked budgeted funds towards the investigation required for Vallee Pitot and the monitoring in La Butte as per the following table. MPI agreed to the breakdown of budget in 2013.

Table 9.2.1 Breakdown of Budget in 2013 (source: JET)

No.	Contents	Budget (Rs)
1	Detailed investigation and monitoring in Vallee Pitot	3,400,000
2	Monitoring in La Butte	
3	Acquisition of Equipment for Landslide Management	
4	Approval of Environmental Impact Assessment in Chitrakoot	50,000
	Sum	3,450,000

However the proposed budget in 2013 has not been executed, and it was carried over to 2014. The project will be implemented in late 2014.

b. 2014 Fiscal Year and After

In 2014 fiscal year and after, it is reasonable that countermeasures will be conducted in the areas designated as high priority in the disaster inspection (Chapter 3) among the 37 designated areas in the Disaster Scheme.

In 2014 fiscal year, additional countermeasures will be implemented in the highest priority areas, Vallee Pitot and Chitrakoot; among Rank A areas (Rank A requirescountermeasures as soon as possible, which can seriously affect residents and/or infrastructures).

In 2015 fiscal year, countermeasures and detailed investigations will be implemented in the remaining six (6) areas among Rank A areas. Moreover, data aquisition for the landslide hazard mapping will be needed.

In 2016 fiscal year after the completion in the Rank A areas, countermeasures will be implemented in Rank B areas (Rank B areas require countermeasures due to the potential impact of a landslide disaster on residents and/or infrastructure. However the priority is not higher than Rank A. Therefore the countermeasures can be implemented after the completion of Rank A countermeasures). Moreover, data aquisition for the landslide hazard mapping will be needed. The higher priority is Rank B in the Port Luis area where population, industy and traffic are concentrated.

In addition to the above budget for the countermeasures, a further budget application was made for 1) maintenance and repair of monitoring equipment: 1,000,000 Rs, and 2) overtime and allowance: 500,000 Rs. The breakdown of budget has been proposed by JET and applied to MPI head office. The applied budget and breakdown of the countermeasures on landslide management in LMU in 2014 – 2016 are indicated as follows;

- 2013 FY: 3,450,000 Rs
- 2014 FY: 16,500,000 Rs
- 2015 FY: 36,500,000 Rs
- 2016 FY: 35,500,000 Rs

Table 9.2.2 List of Countermeasures and Budgets in 2014-2016 (source: JET)

FY	No.	Rank	Item	Rs	Detailed works
2014	10	A	Construction of countermeasures in Vallee Pitot	9,000,000	Surface drainage work Subsurface drainage work Repair of existing canal
	9	A	Construction of additional countermeasure in Chitrakoot	6,000,000	Large scale canal
			Maintenance and repair of monitoring equipment	1,000,000	
			Overtime and allowance	500,000	
2015	8	A	Construction of countermeasures in L'Eau Bouillie	5,000,000	Concrete ditch along road Re-pavement/repair of road
	16	A	Construction of countermeasures in Boulevard Victoria, Montagne Coupe	7,000,000	Soil excavation of upper steps Reinforcement of gabion (reinforcement with strong wire net)
	17	A	Construction of countermeasures in Pailles: (i) access road to Les Guibies	7,000,000	Slope cutting/vegetation Raising up of existing retaining wall Surface drainage on slope
	19	A	Construction of countermeasures in Pailles: (iii) Soreze region	3,000,000	Repair of existing ditch Removal of unstable rocks Geotechnical investigation for detailed countermeasures
	26	A	Construction of countermeasures in Riviere des Anguilles, near the bridge	9,000,000	Gabion/concrete wall along river Installation of extensometer near houses
	33	A	Construction of countermeasures in Piper Morcellement Piat	3,000,000	Retaining wall Surface drainage work
			Data aquisition for the landslide hazard mapping	1,000,000	
			Maintenance and repair of monitoring equipment	1,000,000	
			Overtime and allowance	500,000	
2016	15	B	Investigation in Old Moka Road, Camp Chapelon	3,500,000	Geotechnical investigation for detailed countermeasures
	34	B	Investigation in Candos Hill at LallBahadoor Shastri and Mahatma Gandhi Avenues	2,500,000	Geotechnical investigation for detailed countermeasures
	11	B	Construction on countermeasures in	2,000,000	Ditch

		LePouce Street		
12	B	Construction of countermeasures in Justice Street (near Kalimata Mandir)	8,000,000	Soil excavation in the back of retaining wall Retaining wall Surface drainage on slope and new culvert
14	B	Construction of countermeasures in Pouce Stream	6,000,000	Increasing height of existing retaining wall Gabion along river
18	B	Construction of countermeasures in Pailles: (ii) access road Morcellement des Aloes from Avenue M.Leal (on hillside)	3,000,000	Extension of outlet to ditch Concrete wall and filling
19	A	Construction of countermeasures in Pailles: (iii) Soreze region	9,000,000	Surface drainage work Subsurface drainage work Rockfall protection wall/fence/net
		Maintenance and repair of monitoring equipment	1,000,000	
		Overtime and allowance	500,000	

Although JET proposed that MPI should apply the budget within 2013 to the Ministry of Finance, the budget has not been submitted and carried over to 2014. MPI has reconsidered the budget by themselves in 2013 and 2014 as follows.

c. 2015 Fiscal Year and After

In 2015 fiscal year and after, countermeasures are supposed to be conducted in the 37 designated areas in the Disaster Scheme. Detailed investigation and installation of monitoring devices will be implemented in 2015 fiscal year and the construction of countermeasures in 2016 fisical year and after. MPI will reconsider the priority of countermeasures based on the results of the detailed invastigation and analysis in 2015 so that they will start the construction of countermeasures form the high priority areas (Table 5.5.3).

In addition to the above budget for the countermeasures, a further budget application was made for 1) maintenance and repair of monitoring equipment: 1.0 million Rs, 2) overtime and allowance: 0.5 million Rs, 3) preparation of hazard maps: 1.5-2.0 million Rs and 4) expert on retainer basis: 1.0-2.5 million Rs. The breakdown of budget has been proposed by JET and applied to MPI head office. The applied budget and breakdown of the countermeasures on landslide management in LMU in 2015 – 2017 are indicated as follows;

- 2015 FY: 55,650,000 Rs
- 2016 FY: 40,100,000 Rs
- 2017 FY: 44,700,000 Rs

Table 9.2.3 List of Countermeasures and Budgets in 2015-2017[1]

No.	Area name	Disaster	2015 (Rs)	2016 (Rs)	2017 (Rs)
1	Construction Works in Chitrakoot (Block A) - Section 1	Landslide	2,250,000		
	Consultancy Services for Countermeasure Construction Works in Chitrakoot (Block A) - Section 2	Landslide	400,000		
	Construction Works in Chitrakoot (Block A) - Section 2	Landslide	8,000,000		
	Consultancy Services for Countermeasure Construction Works in Chitrakoot (Block B)	Landslide		400,000	
	Construction Works in Chitrakoot (Block B)	Landslide		6,000,000	

2	Consultancy Services for Countermeasure Construction Works at Vallee Pitot (near Eidgah)	Landslide	450,000		
	Countermeasure Construction Works at Vallee Pitot (near Eidgah)	Landslide	9,000,000		
3	Remote Monitoring System in Chitrakoot, Vallee Pitot, Quatre- Soeurs and La Butte	Landslide	7,000,000		
4	Maconde Region Baie du Cap - Phase 2	Rock fall	10,000,000		
5	Morcellement Hermitage, Coromandel	Slope failure	250,000		
6	L'Eau Bouillie	Damage of embankment	250,000	5,000,000	
7	Boulevard Victoria, Montagne Coupe	Damage of wall	7,000,000		
8	Pailles access road to Les Guibies and along motorway, near flyover bridge	Slope failure	350,000	7,000,000	
9	Pailles Soreze region	Slope failure	500,000	3,000,000	
10	Riviere des Anguilles, near the bridge	Stream erosion	450,000	9,000,000	
11	Post Relocation Works at Quatre Soeurs, Marie Jeanne, Jhummah Streert, Old Grand Port	Landslide	250,000		
12	Piper Morcellement Piat	Stream erosion	150,000	3,000,000	
13	Temple Road, Creve Coeur	Damage of wall	100,000		Budget will depend on results of detailed investigations and expert recommendations. Around 40 million Rs is forecasted
14	Congomah Village Council (Ramlakhan)	Stream erosion	100,000		
15	Congomah Village Council (Leekraj)	Damage of wall	100,000		
16	Congomah Village Council (Frederick)	Damage of wall	100,000		
17	Congomah Village Council (Blackburn Lanes)	Damage of Embankment	100,000		
18	Les Mariannes Community Centre (Road area)	Slope failure	100,000		
19	Les Mariannes Community Centre (Resident area)	Stream erosion	100,000		
20	Le Pouce Street	Stream erosion	100,000		
21	Justice Street (near Kalimata Mandir)	Damage of wall	400,000		
22	Pouce Stream	Stream erosion	300,000		
23	Old Moka Road, Camp Chapelon	Landslide	575,000		
24	Pailles access road Morcellement des Aloes from Avenue M.Leal (on hillside)	Stream erosion	150,000		
25	Plaine Champagne Road, opposite "Musee Touche Dubois"	Slope failure	100,000		
26	Chamarel near Restaurant Le Chamarel and Road Side	Damage of embankment	100,000		
27	Baie du Cap: (i) Near St Francois d'Assise Church	Debris flow	100,000		
28	Bambous Virieux, Rajiv Gandhi Street (near Bhavauy House), Impasse Bholoa	Slope failure	100,000		
29	Trou-Aux-Cerfs	Slope failure	100,000		
30	River Bank at Cite L'Oiseau	Stream erosion	100,000		
31	Louis de Rochecouste (Riviere Seche)	Stream erosion	100,000		
32	Candos Hill, LallBahadoor Shastri and Mahatma Gandhi Avenues	Landslide	125,000		
33	Montee S, GRNW	Stream erosion	100,000		

34	Consultancy Services for Preparation of Hazard Maps		1,500,000	2,000,000	1,500,000
35	Consultancy Fees for Expert on Retainer Basis		2,500,000	2,500,000	1,000,000
36	Overtime Work by Landslide Management Counterparts		1,200,000	1,200,000	1,200,000
37	Maintenance and Repairs of Equipment		1,000,000	1,000,000	1,000,000
Budgetary Forecast for Financial Years 2015 to 2017					44,700,000

It is judged that the Mauritius Government including MPI is so positive towards and allocates ample budget for the landlside countermeasures that they have enough sustainability for future landslide disaster management projects.

9.2.2 Organizational Reinforcement Plan

a. Technical Knowledge

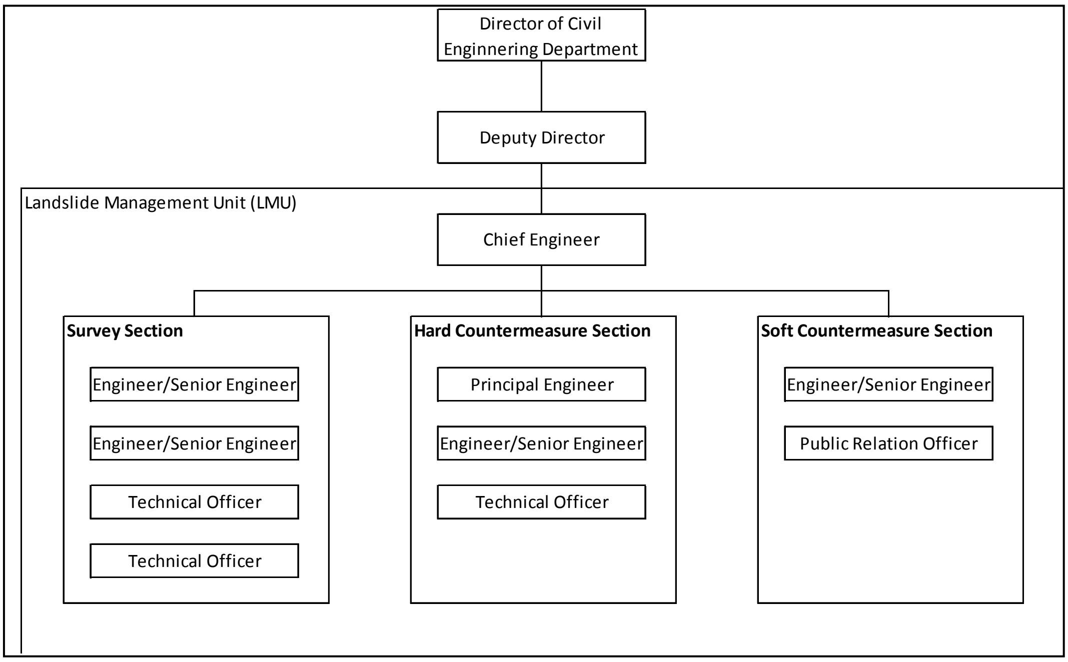
Technical transfer regarding landslide investigation/analysis, design and construction/supervision has been achieved through the project activities such as the daily on the job training, seminars and training in Japan. The LMU engineers understand and obtain knowledge on landslide investigation and countermeasure works. One of the LMU technical engineers is currently applying for JICA’s ABE initiative in order to study geotechnical engineering in master’s degree and obtain academic knowledge on landslides. Moreover, MPI has applied JICA’s landslide adviser in which MPI aims at enhancing technical experience adding to the abilities obtained through this project. LMU will be the main and lead organization for landslide management with academic knowledge and technical experience.

b. Organizational Establishment

As full-time staffs have not been posted to the LMU since its establishment in September 2009, engineers of the other sections in Civil Engineering Department have been assigned. Engineers have taken additional duties and responsibilities over their normal work. However, posting six Engineers/Senior Engineers was decided in March 2014. Following its decision, one engineer has been posted to the LMU since October 2014. The rest of Engineers/Senior Engineers will be posted after the selection is completed. Together with six Engineers/Senior Engineers, posting three Technical Officers and one Public Relations Officer was decided at the same time. However, creation of a Public Relations Officer position is pending and one Intern under the Service to Mauritius (STM) programme will be recruited instead.

There are seven Engineers and Technical Officers working for the LMU as of November 2014. The LMU is divided into three sections and engineers and technical officers for one of these sections in order to define clearer responsibilities for each engineer and technical officer.The LMU will conduct the landslide management with the assignment of the following full-time staff.

Table 9.2.4 Full-time Staff Assignment (Long Term Goal) (source: JET)



c. Coordination with the Other Stakeholders

As collaboration of all stakeholders is essential to deal with landslide issues in Mauritius, the tasks and responsibilities of LMU as well as the other stakeholders were defined and finalised with the procedure below:

1) The tasks and responsible stakeholders in the ordinary and emergency situations were discussed among LMU engineers and technical officers;

2) Based on the discussions above, the responsible organizations and their tasks were summarized in the task flow;

3) The draft task flow was explained to MPI headquarters and the flow was approved by the permanent secretary of the MPI;

4) MPI organized several meetings and invited all main stakeholders such as NDRRMC, police, NDU, RDA, Mauritius Meteorological Services and local authorities to discuss the tasks and responsibilities of each organisation; and

5) The tasks and responsibilities of LMU and the other stakeholders were defined and finalized.

The MPI organized one day seminar on the 27th of November in 2014. MPI headquarters, LMU, MPI/National Development Unit (NDU), MPI/Road Development Authority (RDA), NDRRMC, Ministry of Housing and Lands (MHL) and local authorities participated in the seminar and the tasks and responsibilities for ordinary and emergency situations were finalized. The finalized tasks and responsibilities are as follows:

- Responses to the classified landslide prone areas (37 sites)

The main organizations are identified based on the disaster classification, objects of protection and the scale of disaster. The main responsible organizations will implement the countermeasure works from the high prioritized areas according to the results of annual slope inspection.

Table 9.2.5 Main Responsible Organizations based on Disaster Classification, Objects of Protection and the Scale of Protection (source: JET)

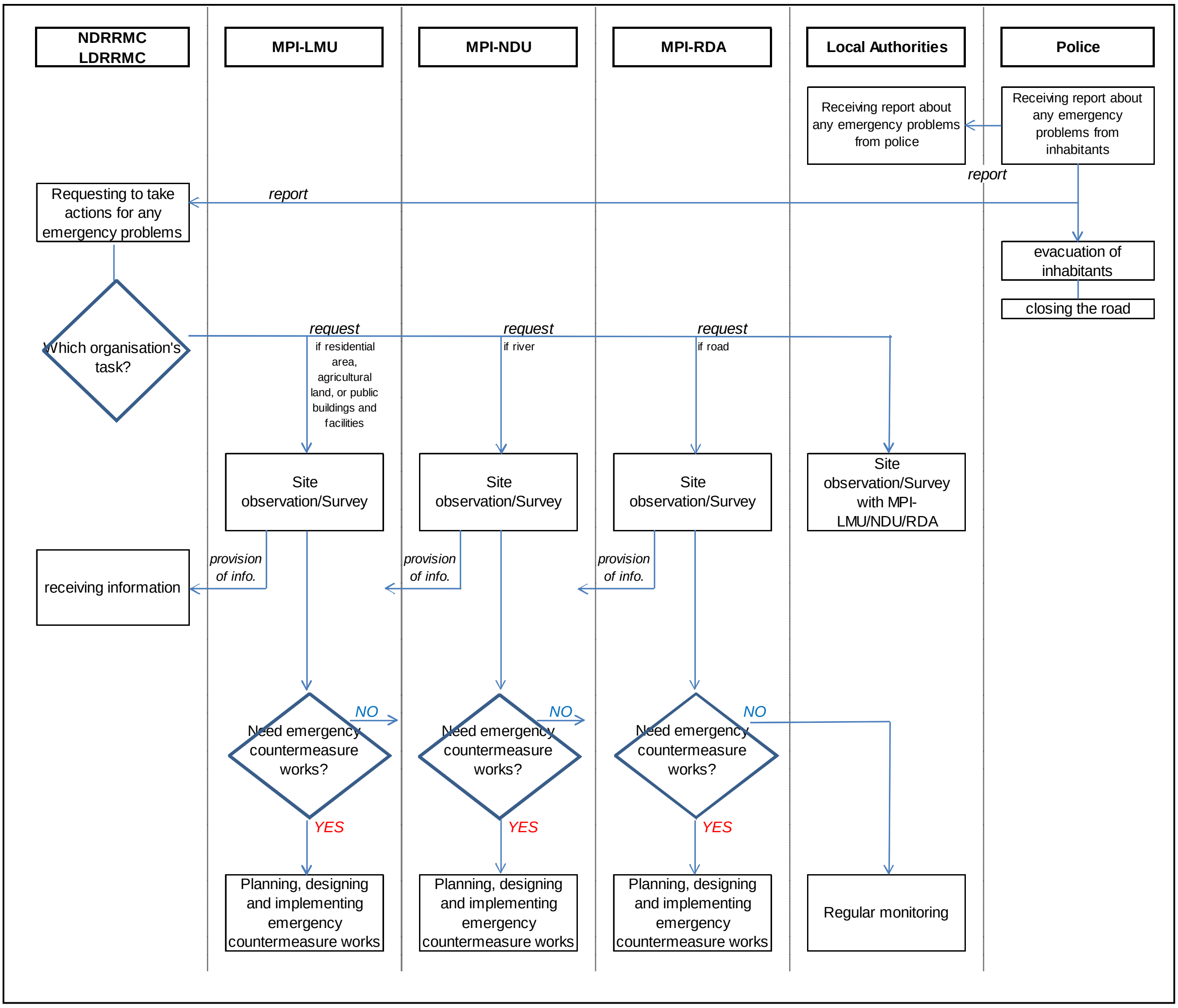
Disaster		Object of protection	The main responsible organisation	
			Large scale disaster	Small scale disaster
Slope disaster	Landslide (mass movement)	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Rock fall	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Slope failure	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
Slope and river disaster	Debris flow	Residential houses	LMU/NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU/NDU	
River disaster	Stream erosion	Residential houses	NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads		
	Flood	Residential houses	NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads		
Others	Damage of embankment	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Damage of wall	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Damage of house	Residential houses	-	Local authorities
		Agricultural fields		
	Cavern	Residential houses	LMU	Local authorities

		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	RDA/local authorities

- Responses for emergency situations

In terms of responses for emergency situations, police and local authorities are responsible for taking immediate actions such as evacuation of inhabitants and roadblocks. LMU, NDU and RDA are responsible for the site investigation, consideration of countermeasures and its implementation with the same methodology for 37 classified sites.

Table 9.2.6 Task Flow for Emergency Situation for All Sites (source: JET)



- Responses for the new sites with utilization of a hazard map

LMU will develop a hazard map in order to identify the new landslide prone areas apart from 37 classified sites.

- Early warning

The early warning system is applied for three pilot sites of the project (Chitrakoot, Quatre Soeurs and Vallee Pitot) according to the National Disasters Scheme and protocol. The same early warning system as used at the pilot sites will be established for those new landslide prone areas if identified by the hazard map.

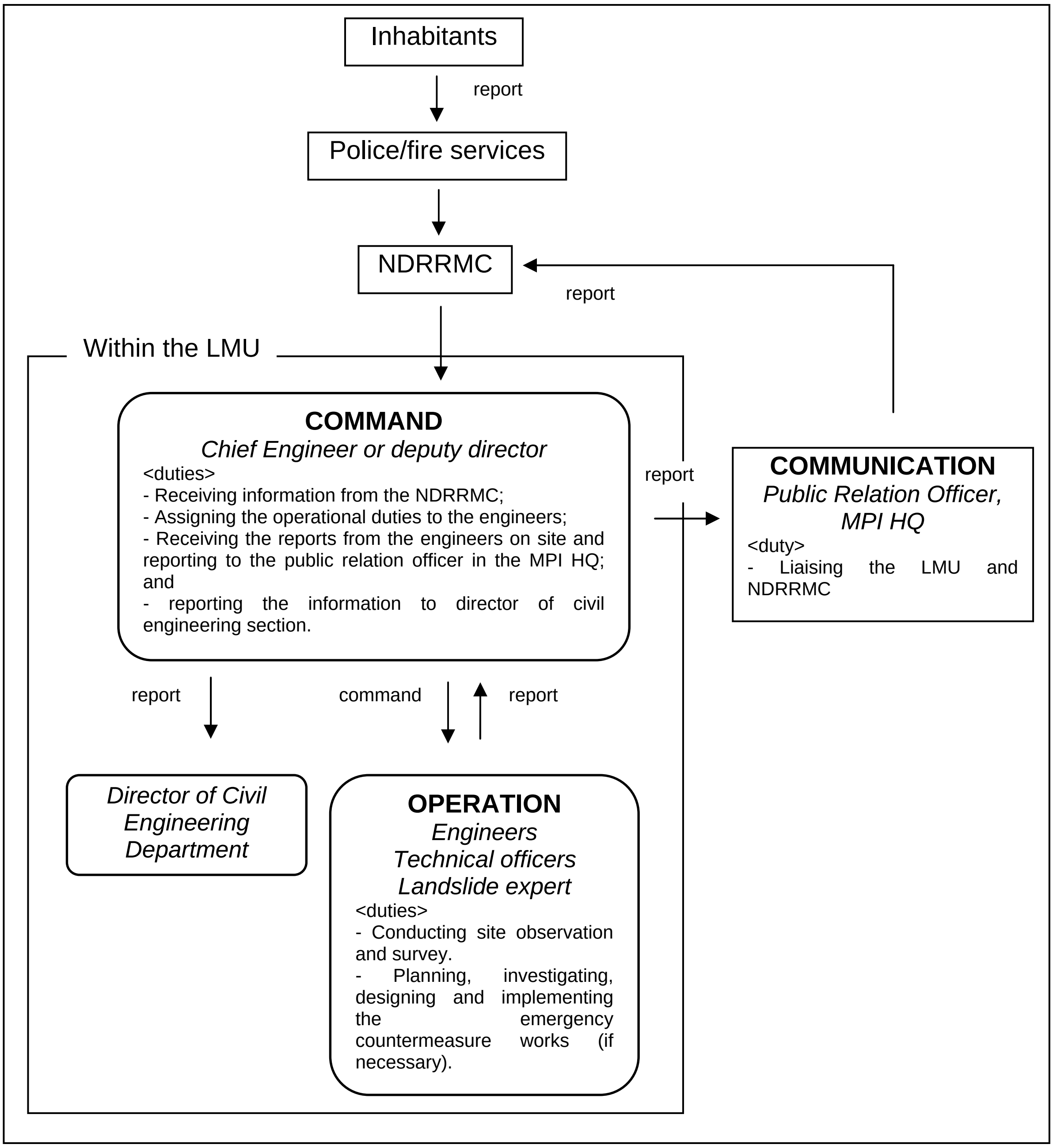
As a result of defining the tasks and responsibilities for all stakeholders, it is expected that all stakeholders will be actively involved in tackling the landslide issues. Moreover, as the stakeholder meeting will be regularly organised in order to share landslide information, the collaboration of all stakeholders will be enhanced.

LMU has actively participated in the stakeholder meetings, for example, LMU engineers presented the tasks and responsibilities of landslide management by themselves in the one day seminar on the 27th of November 2014. This fact proves that the LMU engineers have enhanced their knowledge and understanding of landslides, and are contributing in raising awareness and knowledge among other organizations.

d. Emergency Operational System within the LMU

The emergency operational system within the LMU is established as follows.

Table 9.2.7 Emergency Operational System within the LMU (source: JET)



The LMU reviewed the operations in the past emergency situations and considered the emergency operational system to allocate the engineers and technical officers. Several options such as a monthly roster system were discussed, and the LMU has decided to allocate two responsible engineers and technical officers to each region of Rivière du Rempart, Pamplemousses, Port Louis, Black River, Plaines Wilhems, Moka, Flacq, Grand Port and Savanne (three engineers and technical officers are allocated to Port Louis). The emergency operational system will be revised and updated if necessary.

e. Establishment of Public/private Cooperation System

The hiring of expert(s) on a retainer basis is considered in order to support the LMU's task of landslide management. The JICA Expert Team supported to define the scope of work for the expert on a retainer basis and the LMU has submitted the scope of work to the MPI headquarters. The MPI intends to employ a local or international geotechnical engineer.

9.3 Proposal on a Pilot Project (Landslide Countermeasures)

9.3.1 Structural Countermeasures (Future Plan)

The countermeasure works of Section I at Block-A landslide has been completed in this Project. Now it is necessary that other countermeasure works are carried out continuously.

Future plan of landslide countermeasure work for the Chitrakoot area shall be carried out according the work flow shown on Figure 9.3.1.

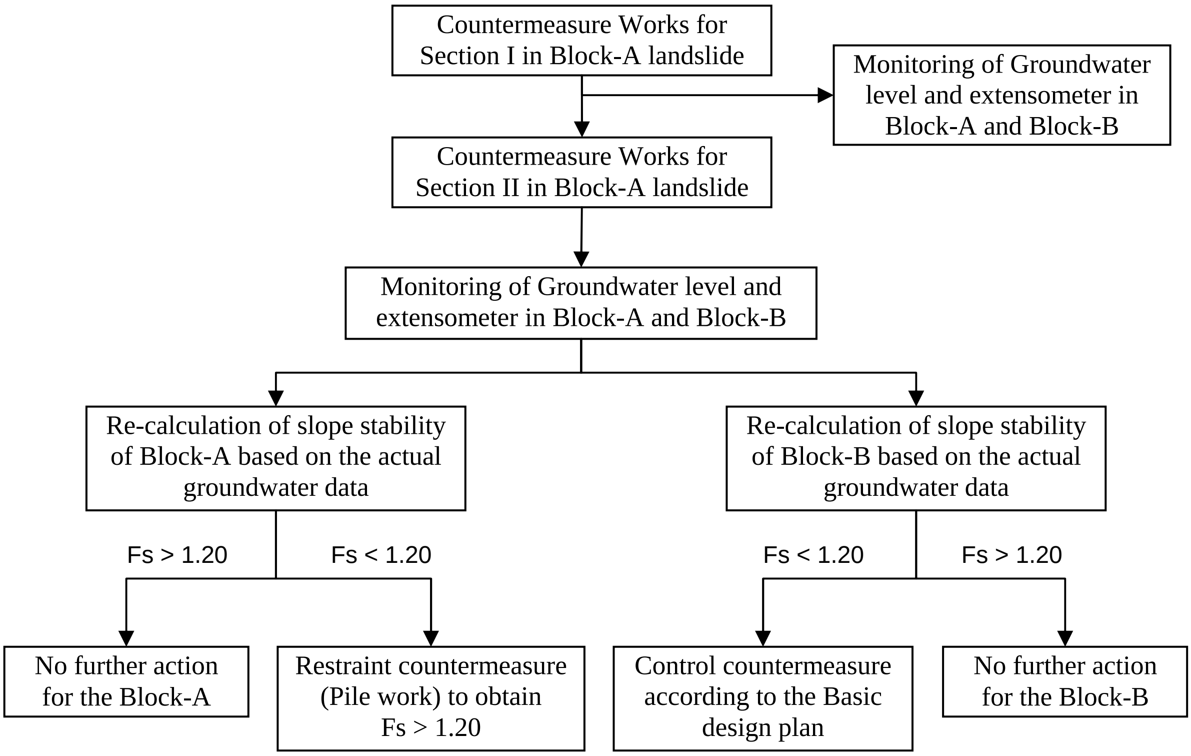


Figure 9.3.1 Flow Chart for Future Plan of Landslide Countermeasure Works in Chitrakoot Area (source: JET)

a. The Types and Quantity of Works to be Handed Over.

With regards to the landslide countermeasure construction works which has been completed by JET on December 2014, the constructed works of the Pilot Project site in Chitrakoot are officially handed over from JET to MPI under the terms and conditions stipulated below. MPI shall take the necessary measures to maintain the works after the handover.

The types and quantity of works which has been constructed by JET are as below. The detailed plan maps and structural figures of each construction works are attached.

- River Type-1 (5m)
- River Type-2 (10m)
- River Type-3 (140m)

- River Type-5 (55m)
- New Channel CH-1 (217m)
- Bridge Br-1
- Bridge Br-2
- Bridge Br-3
- Bridge Br-4
- Bridge Br-5
- Horizontal Drainage (5 boreholes)

The major amendments of design which was made during the construction are as below.

- ✓ River Type 1 & 2: The height of stone masonry was increased, while the vegetation was shortened.
- ✓ River Type 3: The design of the wall on the right side was changed to straight wall at some point.
- ✓ Bridge Br5: The structure of handrail was changed from fence to steel pipe.

b. Further construction works to be conducted by MPI

MPI shall conduct the further construction works for Section II as follows including the works which was cancelled in Section I. After completion of the works of the Section II, groundwater level and landslide activity shall be confirmed by the monitoring.

At present, countermeasure works of Section I for Block-A landslide has been done. After this, the planned countermeasure works of Section II including the cancelled works in the Section I due to issue of land acquisition shall be carried out by the MPI. According to the design of the countermeasure works, planned safety factor of the target landslides will be secured after installation of all planned countermeasure works. Even now a time when the countermeasure works of Section I, monitoring of groundwater level and landslide activity by the extensometer and pipe strain gauges shall be carried out continuously to check the difference from before and after installation of the countermeasure works. It is recommended that the landslide stability analysis shall be carried out to check the change of factor of safety of landslide after installation of the works based on the groundwater level.

Since the work site of Section II is located in a residential area, land acquisition shall be proceeded cautiously. In case that it is difficult to acquire the planned land for the works, it can be changed the location or alignment of the drainage accordingly.

Table 9.3.1 Planned Landslide Countermeasure Works in Chitrakoot Area (source: JET)

Section		Work item	Quantity	unit	Remarks
Block-A landslide	Section II	Channel for the flood CH-2	130	m	
		Upgrading of existing water course RUD-1 (Type3 drainage)	35	m	Cancelled during Section I
		Upgrading of existing water course UD-3 (Type4 drainage)	47	m	Cancelled during Section I
		Horizontal drainage (HD-2)	210	m	
		Horizontal drainage (HD-3)	350	m	
		Surface drainage (SD-1)	75	m	
		Open-blind ditch (OB-1)	55	m	

Section		Work item	Quantity	unit	Remarks
		Open-blind ditch (OB-2)	85	m	
		Blind ditch (BD-1)	35	m	
		Blind ditch (BD-2)	32	m	
		Blind ditch (BD-3)	40	m	
		Water catch basin	5	pc	
		Bridge	2	pc	For vehicles
		Manhole for maintenance	12	pc	On the blind ditch

c. Monitoring and Stability Analysis

After completion of the works of the Section II, groundwater level and landslide activity shall be confirmed by the monitoring. Since the applied groundwater level for the stability analysis is the highest groundwater level which was observed in the rainy season, the data for the analysis shall be applied the highest groundwater level which is observed in at least one rainy season after completion of the countermeasure works of Section II.

Regarding the stability analysis to check the factor of safety of landslide after completion of the countermeasure works, analysis landslide model shall be used the model which was used in the design stage. Parameter for the analysis such as cohesion, internal friction angle or unit weight shall not be changed, but only groundwater level which is observed as the highest level during the rainy season.

In case that the factor of safety of Block-A landslide is more than 1.20 and no movement is detected by the extensometer, additional restraint work can be put on hold. However, the monitoring of groundwater level and landslide movement shall be carried out continuously, and it shall be considered possibility of re-activation of the landslide. If rising of groundwater level or movement of landslide is detected, additional countermeasure works shall be examined. Reference value of the groundwater level to achieve the planned factor of safety is shown below.

Table 9.3.2 Reference Value of the Groundwater Level to Achieve the Planned Factor of Safety (source: JET)

Monitoring borehole/well	Fs=1.13 (Planned)	Fs=1.20 (Final Target)	Remarks
BPP 16	> GL-2.9m	> GL-3.9m	Near the school
BPP 11	> GL-2.1m	> GL-3.1m	
W-2	> GL-3.3m	> GL-4.3m	
BPP 8	> GL-5.4m	> GL-6.4m	Out of the landslide area

GL: Ground Level

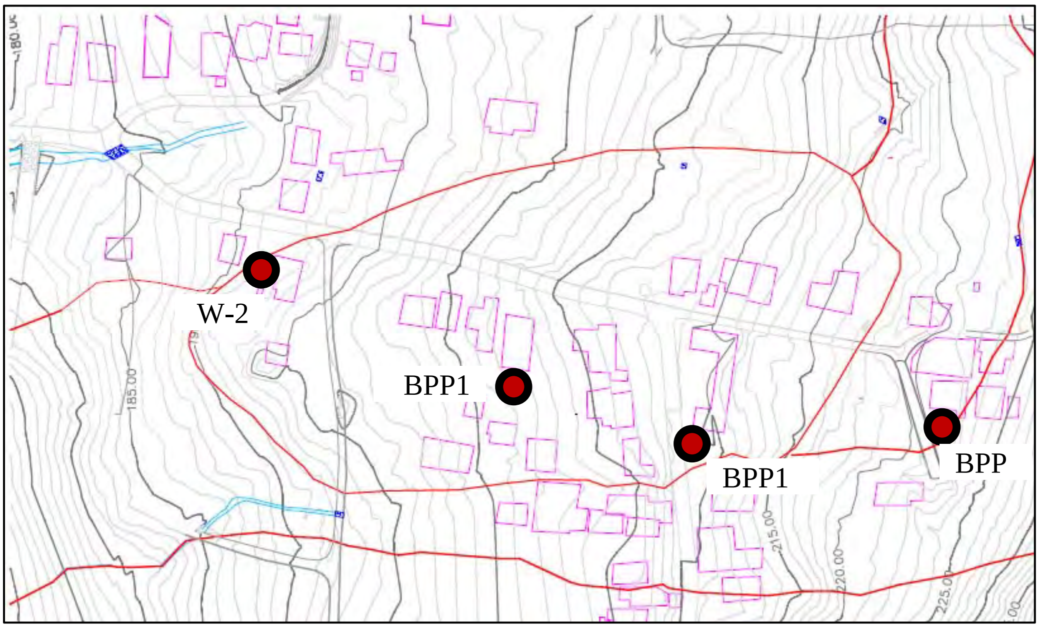


Figure 9.3.2 Location of Monitoring Borehole for Block-A Landslide (source: JET)

Groundwater level at BPP8 shall not be used for evaluation of stability of the landslide directly due to it is out of the landslide area. In case that the groundwater level at other three boreholes is confirmed as the reference values, it can be assumed that stability of the target landslide is achieved the planned factor of safety.

In case that the factor of safety of Block-A landslide is less than 1.20, restraint work shall be planned. According to the condition of topography and land use at the site, pile work shall be recommended. Planning and design of the pile work shall be done in reference to the "Procedure Manual for Landslide" which is prepared in this project.

The countermeasure works for Block-A landslide can be considered to contribute to the stability of the Block-B landslide. Thus, monitoring of groundwater level and landslide movement for the Block-B shall be carried out to check the factor of safety of the landslide. However the existing monitoring borehole namely BPX 2 is not available to measure a groundwater level. Therefore, it can be recommended to install new monitoring borehole on the Block-B landslide area (refer to Figure 9.3.3). The reference value of the groundwater level at each monitoring borehole to achieve the planned factor of safety is shown in Table 9.3.3. In case that factor of safety of the Block-B landslide is more than 1.20 and no movement is detected by the extensometer, the planned countermeasure works for the Block-B landslide can be put on hold. However, the monitoring of groundwater level and landslide movement shall be carried out continuously, as there is a possibility that the landslide may become active again.

About the rainfall and the groundwater relationship monitored continuously, MPI should submit a report to JICA.

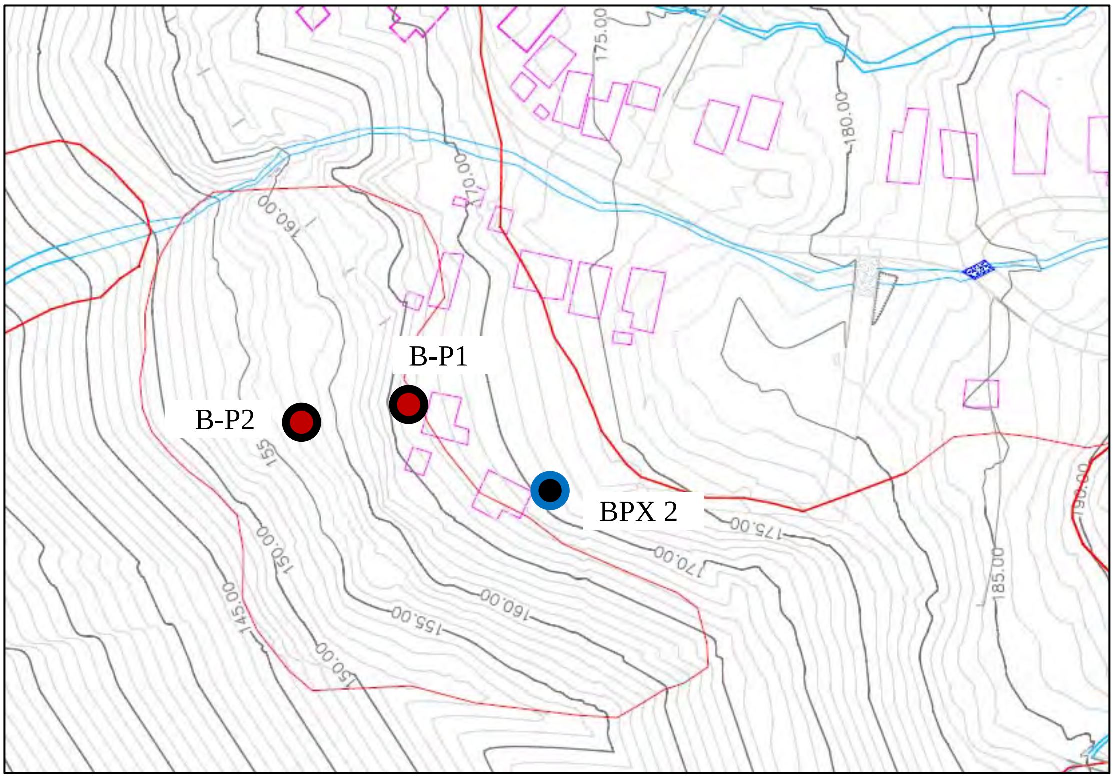


Figure 9.3.3 Location of Monitoring Borehole for Block-B Landslide (source: JET)

Table 9.3.3 Reference Value of the Groundwater Level to Achieve the Planned Factor of Safety (source: JET)

Monitoring Borehole	Fs=1.17 (Planned)	Fs=1.20 (Final Target)	Remarks
B-P1	> GL-3.5m	> GL-4.0m	to be installed
B-P2	> GL-3.4m	> GL-3.9m	to be installed

d. Cleaning and Maintenance of the Ditches, Channels, Bridges and Horizontal Drainages by MPI

The ditches, channels, bridges and horizontal drainages constructed by JET shall be cleaned periodically to ensure the smooth water flows in the drainage. The maintenance of the works shall be undertaken to maintain its function as below.

d.1 Cleaning and Maintenance of Ditches and Channels

- ✓ Cleaning of soils accumulated in the ditch and channel using shovel and high pressure water.
- ✓ Removing any garbage inside the river.
- ✓ Repairing any cracks occurs along the ditch and channel works

d.2 Cleaning and Maintenance of Bridges

- ✓ Cleaning of soils accumulated under the bridges using shovel and high pressure water.
- ✓ Removing any garbage under the bridges
- ✓ Repairing any cracks occurs on the bridge works

d.3 Cleaning and Maintenance of Horizontal Drainage

- ✓ Cleaning of soils accumulated inside the drainage pipe using high pressure water (flushing).

d.4 Maintenance of the Fences

Fences shall be checked periodically in case of damages by rock fall and debris flow and repaired if necessary.

e. Site Restriction (No Trespassing and Throwing Garbage into the Site)

- ✓ Installation of [No Trespassing] signboard at site
- ✓ Education of the inhabitants regarding the disaster prevention.

f. Utilization of the Landslide Disaster Prevention Handbook

The utilization of handbook for the education of the inhabitants and students is highly expected.

9.3.2 Development in the Landslide Hazard Zone after the Landslide Countermeasure Works

The mechanisms of landslide are complicated and it is very difficult to stop the landslide activity completely. Hence, the role of landslide countermeasure works is to raise the existing factor of safety (Fs) to greater than 1.2 and not to permanently prevent landslide. A landslide might be reactivated by deterioration of the soil strength on landslide slip surface or heavy torrential rain (such as rainfall exceeding a 50 year probable rainfall used to design landslide countermeasures at Chitrakoot) resulting from abnormal natural phenomenon (climate change) in future.

In the country with abundant experience of slope disaster such as Japan, the designation of landslide hazard zone will not be terminated even though after landslide countermeasure works have been implemented. Therefore, there will be no termination of the designation of the landslide hazard zone made by this Project (Chitrakoot, Vallee Pitot and Quatre Soeurs) in the future too.

All kind of development for infrastructure or housing is basically prohibited in the landslide hazard zone. However, the minor maintenance work of houses or roads can be implemented. The table below shows the advisability of the development activities in the landslide hazard zone.

Table 9.3.4 Advisability of the Development Activities in the Landslide Hazard Zone (source: JET)

Type of development	Advisability	Application
Minor maintenance of houses, school building etc.	Possible	Maintenance of roofs and walls only. Maintenance involving excavation of the foundation, cutting/filling is prohibited.
Minor maintenance of public infrastructure such as roads, bridges etc.	Possible	Only maintenance of public infrastructure such as roads, bridges, water and sewage etc. Maintenance involving excavation of the foundation, cutting/filling is prohibited.
New/additional construction of houses, schools etc.	Prohibited	Basically, the new/additional construction of building is prohibited
New/additional construction or replacement of public infrastructure such as roads, bridges etc.	Prohibited	Basically, the new/additional construction or replacement of public infrastructure such as roads, bridges, water supply and sewage etc. is prohibited
Development other than mentioned above	Prohibited	Basically, the development activities in the landslide hazard are is prohibited.

<Screening standard for the exceptional development>

In case there is inevitable development activities needed to be implemented in the landslide hazard zone such as new/additional construction or replacement of roads, bridges, water supply and sewage and other public infrastructures, the sufficient investigation/analysis of the points mentioned below shall be undertaken.

- Implementation of stability analysis of the landslide and confirming the factor of safety (Fs) of the landslide is greater than 1.2 after the construction.
- If the factor of safety (Fs) is less than 1.2, the landslide countermeasure works shall be implemented.
- The implementation of the landslide countermeasure works shall be implemented before the development activities.
- The fall of the factor of safety (Fs) during the construction (development activities, landslide countermeasure work and cutting/filling) shall be within 5%, and any works which exceed 5% fall in factor of safety (Fs) shall be prohibited.
- Preventing the water retention from rainfall inside and downstream of the landslide area by installing the water drainage facilities such as surface drainage, retention basins, grit chambers etc.

9.3.3 Early Warning and Evacuation System

Table 9.3.5 below shows proposed warning stages and their thresholds based on two years landslide monitoring in Chitrakoot, Vallee Pitot and Quatre Soeurs.

Table 9.3.5 Proposed Early Warning of Landslide Disaster (source: JET)

Warning Stage		Threshold	
		Movement of the ground (extensometer)	Deformation of each house
Stage 1	Precaution	20 mm / month or more	<new signs of landslide> New cracks are found in a house. New deformations are found on walls or floors of a house. New crack or deformation are found on the ground, a retaining wall, or a road around the house.
Stage 2	Alert	10 mm / day or more	<progress of cracks or deformation> Opening of the cracks become wider The deformations on the floor or the wall become bigger. The cracks or deformations around the house become bigger. (Opening speed of the cracks : 2 mm/hour)
Stage 3	Evacuation	20 mm / day or more	<further progress of cracks or deformations> New cracks are found in the house. The cracks and deformation become bigger and bigger in the house. The house next door or walls around the house collapses. Opening speed of cracks: 20 mm/hour
Stage 0	Termination	0 mm / hour and, no abnormality can be seen in the house and around the house.	The residents of the house deformed do not return to their house without architect's inspection. [*3] No abnormality can be seen in the house and around the house
Additional Stage	Torrential Rain & Cyclone Warning	"Cyclone Warning Class II" or "Torrential Rain Warning" may constitute for the inhabitants a "Landslide Stage 1 Warning". "Cyclone Warning Class III" : cessation of all normal activities, inhabitants of the landslide prone areas may be evacuated	

a. Additional Stage (Torrential Rain Waning and Cyclone Warning)

There are cases where a landslide becomes active in torrential rain or cyclone when it also becomes difficult to travel on roads (i.e. due to traffic congestion). In such cases, the inhabitants in the landslide area must follow the Torrential Rain Scheme or Cyclone Scheme regardless of landslide activity.

b. Termination

Once a house has become deformed, the house may not have enough structural strength. Even if the landslide activities have terminated and it is stable, the residents can not return and stay in the house. Architects decision is required before the residents return to their house.

If the residents are evacuated according to the extensometer indication, the residents should return after the landslide expert confirm the stability of the landslide.

c. Role of LMU in Early Warning

LMU should observe and confirm the site condition at each stage of Early Warning. Especially, LMU should visit the house and confirm the condition of the house when LMU receives the information about cracks or deformations of a house, since sometimes cracks or deformations appeared in a house for other reason than a landslide.

At Stage 1 and Stage 2 according to “Deformation of each house”, the points to be confirmed by LMU are as follows;

- Observe and confirm cracks and deformations
- Decide whether cracks and deformations are caused by a landslide
- If cracks and deformations are not caused by a landslide, find what is a cause of cracks and deformations
- Decide the methods of ascertainment whether cracks and deformations are progressing or not.
- Inform the residents next door how matters stand with their neighbor (i.e. that their neighbor’s house has deformations caused by landslide activity).
- Ascertain the possibility of Stage 3, and remind the residents in the house that they should take in Stage 3

At Stage 3, the residents under risk should leave their house and evacuate of their own accord. The upgrading to Stage 3 from Stage 2 is based on extensometer readings or by the level of deformation of a house as ascertained by the residents of the house. The residents in the house must leave the house immediately (self-evacuation). At Stage 3, NDRMMC controls the refugees, and LMU advises NDRMMC on technical matters.

At Additional Stage, the residents in the landslide area should follow Torrential Rain Scheme or Cyclone Scheme. LMU is not involved in the Torrential Rain Scheme or the Cyclone Scheme.

At ordinary times, LMU should work to raise the awareness of the inhabitants in landslide areas. Especially the inhabitants should understand the following things.

- They live in a landslide risk area.
- Their lives must be protected by themselves.
- Once an evacuation warning is issued, they must not care about their possessions.
- Until countermeasures such as stabilization works are complete, there is nothing that can protect their possessions.

9.3.4 Information, Education and Communication (IEC)

- Awareness activities such as stakeholder meetings should be conducted not only for residents who live inside of the landslide block but also for the ones who live outside of the landslide block as they will be affected by landslide disaster as well. These people should be included in the evacuee list.
- NDRRMC should make more effort to raise awareness of the mission of the organization much more. (by mass media, etc.)
- At this stage, the Project can’t conclude that the current early warning and evacuation system is working or not as not much experience in operation has been accumulated. The survey provided some matters to be considered as follows;
  - The early warning system are easily visible to residents as it has been located in a visible place outside. However, the difference between yellow and red lights should be reminded to residents.
  - It might be difficult for residents to identify which households own simple rain gauge unless they did obtain information in the stakeholder meeting.
  - Contact point should be the same for any landslide inquiries including during warning and evacuation stages. Police will be the best organization for this.

- The presence of contact person(s) will be useful for the government such as MPI to obtain information of actual site conditions, but for residents, it would be better to let anyone contact police. If this is not the case then all of the residents need to know the phone number of the contact person(s) so that they can contact them to report an emergency.
- “Self-evacuation” should be promoted but assistance for evacuation by relevant authority is still required for some people, especially for elderly. It is important for the government to identify the persons who need assistance in advance.
- The government should not hesitate to issue warning and evacuation orders when it reaches each level. The location of evacuation center and appropriate route should be well informed in advance. And, transport for people who need assistance should be arranged at evacuation stage. Residents will not be able to blame the government if something happens to them because they have not followed instructions and when the government has done everything that it is supposed to do.

・ Stakeholder meetings in at risk communities are an effective tool to disseminate information, especially specific information to the locality such as location and route of evacuation center. TV and radio are also informative but will be effective to disseminate landslide information in general.

9.4 Proposal on a Landslide Management Plan for Other Landslide Areas

The Disaster Scheme describes 37 hazard areas in Mauritius. Among them, 15 areas are slope disasters. Of these 15 areas six (6) areas are classed as landslides as defined in the Project (shown in the tables below). The Project has implemented basic surveys, detailed surveys, F/S and a Pilot Project in three (3) priority areas, Chitrakoot, Quatre Soeurs and Vallee Pitot, out of the six (6) abovementioned areas. These three priority areas were selected based on hazard evaluations and requests from the Mauritius Government. In this section, the necessary tasks to formulate landslide management plans on other landslide areas such as La Butte, Old Moka Road and Candos Hill are summarized and proposed.

Table 9.4.1 Classification of Hazard Areas (source: JET)

General classification			Sub classification		Summary
Disaster	Slope	15 areas	Landslide	6 areas	Can be classified as a Landslide Hazard Area
			Slope failure	7 areas	Because it is not a "Landslide", it cannot be classified as a Landslide Hazard Area
			Rock fall	1 areas	
			Debris flow	1 areas	
	Other	22 areas	Stream erosion	10 areas	
			Damage of Embankment	4 areas	
			Damage of wall	5 areas	
			Damage of house	1 areas	
			Cavern	2 areas	
			Total	37 areas	

Table 9.4.2 Hazard Evaluation Results of the 6 Landslides (source: JET)

No.	Area name	Kind of the disaster		Score of landslide hazard evaluation			
		General classification	Sub classification	Landslide landforms and characteristic	Damage to buildings, houses	Existing record of landslides	Total
9	Chitrakoot, Vallee des Pretres	Slope	Landslide	2	2	2	6
10	Vallee Pitot (near Eidgah)	Slope	Landslide	2	2	2	6
13	Mgr. Leen Street and nearby vicinity, La Butte	Slope	Landslide	2	1	2	5
15	Old Moka Road, Camp Chapelon	Slope	Landslide	2	1	0	3
27	Quatre Soeurs,	Slope	Landslide	2	2	2	6
34	Candos Hill	Slope	Landslide	2	1	0	3

9.4.1 Hypothesis on Landslides in Mauritius

Hypotheses for mechanisms and countermeasures on landslides in Mauritius have been discussed based on the survey, analysis and the Pilot Project as follows;

- Slip surface is the boundary between the base rocks like basalt and alluvium/colluvium. The depth is around 5－10 m.
- Length and width of the landslides range from a couple dozens of meters to several km in diamter. Landslides often consist of several small landslide masses.
- Landslides are generated over and over on the locations where landsilide movement was observed.
- Landslide activity is highly correlated with ground water level. A landslide becomes active through increases in the groundwater level.
- However, according to geology and geomorphology, groundwater level is not necessarily correlated with rainfall amount. A landslide may occur without rainfall and conversly may not occur even after heavy rainfall.
- Drainage works for surface/ground water are effective as hard countermeasures.
- As for soft countermeasures, by building an early warning/evaluation system using thresholds for each landslide based on continuous monitoring may be able to reduce the risk posed to humans and the potential for human casualties.
- Relocation of the local residents is one of the countemesures from the viewpoints of cost, effectiveness and requests from the residents.

9.4.2 Proposal on Formulation of a Landslide Management Plan

Proposals on formulation of a landslide management plan in Mauritius are summarized as follows in consideration of the hypotheses for mechanisms and countermeasures on landslides described in the previous section. Actual procedures of the proposed activities are explained in each chapter of the reports: “Technical guidelines for initial surveys” and “Procedure manual for landslides”.

1. The following basic surveys are necessary to grasp the landslide activities, volumes, areas and the relation with circumferences;

(1) Topographic surveys (plan map and cross section)

(2) Site reconnaissance, survey on damage to houses

(3) Laboratory tests (physical tests, dynamics tests, and water quality tests)

(4) Monitoring (rain gauges, extensometers, inclinometers, strain gauges, and ground water level meter)

(5) Geophysical explorations (elastic wave explorations and two-dimensional resistivity explorations)

(6) Drilling surveys

2. The Disaster Scheme and the PPG are reviewed to propose the early warnings and evaluation protocols and other soft countermeasures.
3. The current activities on landslides are determined by the stability analysis using landslide cross sections based on the basic surveys.
4. The relations among the activities, groundwater level and rainfalls are discussed with

the results of the monitoring.

5. Best countermeasures (hard and soft) are considered from the viewpoint of the activities, priorities, request form residents, and budgets.
6. For hard countermeasures, suitable drainage works are selected based on the results of the investigation on surface/ground water conditions. Horizontal drilling is judged to be effective from the results of the pilot project.
7. For soft countermeasures, early warning/evaluation system using a threshold for each landslide is operated. The soft countermeasures are useful until the completion of the construction of hard countermeasures.

Reference for Chapter 9

[1] MPI