JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
EARTHQUAKE RECONSTRUCTION AND REHABILITATION AUTHORITY (ERRA)

THE URGENT DEVELOPMENT STUDY ON REHABILITATION AND RECONSTRUCTION IN MUZAFFARABAD CITY IN THE ISLAMIC REPUBLIC OF PAKISTAN

FINAL REPORT I
VOLUME 3 : SECTOR REPORT

January 2007

PACET Corp.

NIPPON KOEI CO.,LTD.

Report Organization

This report consists of the following volumes:

Final Report I

Volume 1	**:**	**Summary**
Volume 2	**:**	**Main Report**
Volume 3	**:**	**Sector Report**

Final Report II

Urgent Rehabilitation Projects

In Final Report I, **volume 1 Summary** contains the outline of the results of the study. **Volume 2 Main Report** contains the Master Plan for rehabilitation and reconstruction in Muzaffarabad city, Pakistan. **Volume 3 Sector Report** contains the details of existing conditions, issues to overcome, and proposals for future reconstruction by sector.

Final Report II deals with the results and outcomes on **the Urgent Rehabilitation Projects** which were prioritized and implemented in parallel with master plan formulation work under the supervision of JICA Study Team.

The exchange rate applied in the Study is:

(Pakistan Rupee)		(Japanese Yen)
Rs.1	=	¥1.91
(Pakistan Rupee)		(US Dollar)
Rs.60.30	=	US$ 1

PREFACE

In response to the request from the Government of the Islamic Republic of Pakistan, the Government of Japan decided to conduct a Urgent Development Study on Rehabilitation and Reconstruction in Muzaffarabad City in the Islamic Republic of Pakistan and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched the Study Team headed by Mr. Ichiro Kobayashi of Pacet, consisted of Pacet and Nippon Koei, to the Islamic Republic of Pakistan from February 2006 to August 2006. JICA set up an Advisory Committee chaired by Dr. Kazuo Konagai from the University of Tokyo, which examined the study from the specialist and technical points of view.

The Study Team held discussions with the officials concerned of the Government of the Islamic Republic of Pakistan and conducted the Study in collaboration with the Pakistani counterparts. Upon the last return to Japan, the Study Team finalized the study results for delivery of this Final Report.

I hope that this report will contribute to rehabilitation and reconstruction of Muzaffarabad city and to the enhancement of friendly relationship between the two countries.

Finally, I wish to express my sincere appreciation to all the officials concerned of the Government of the Islamic Republic of Pakistan for their close cooperation extended to the Study.

January 2007

Kazuhisa Matsuoka
Vice President
Japan International Cooperation Agency

Mr. Kazuhisa Matsuoka
Vice President
Japan International Cooperation Agency
Tokyo, Japan

January 2007

Letter of Transmittal

Dear Mr. Kazuhisa Matsuoka,

We are pleased to formally submit herewith the final report entitled "The Urgent Development Study on Rehabilitation and Reconstruction in Muzaffarabad City in the Islamic Republic of Pakistan".

This report compiles the results of the study, which was undertaken in the Islamic Republic of Pakistan from February 2006 to August 2006 by the Study Team organized jointly by Pacet and Nippon Koei under the contract with the JICA

The Final Report is composed of the "Executive Summary", "Main Report", and "Sector Report". In the Main Report, the emphasis was given that Muzaffarabad City should be reconstructed with strong urban structure against natural disaster as primary policy, including project long list for early implementation of the rehabilitation and reconstruction. In addition, the Sector Report compiles overall policies and procedures of rehabilitation and reconstruction in each sector. It is truly hoped that the outcomes of the Final Report will contribute to enhance rehabilitation and reconstruction of Muzaffarabad City and victims of earthquake will back to normal life soon.

Finally, we would like to express our sincere gratitude and appreciation to all the officials of your agency, the JICA advisory Committee, the Embassy of Japan in the Islamic Republic of Pakistan, and Ministry of Foreign Affairs. We also would like to send our great appreciation to all those who have extended their kind assistance and cooperation to the Study Team, in particular, relevant officials of Earthquake Reconstruction and Rehabilitation Agency (ERRA) and Azad Jammu Kashmir (AJK) Government.

Very truly yours,

Ichiro Kobayashi
Team Leader, JICA Study Team
The Urgent Development Study on Rehabilitation and Reconstruction in Muzaffarabad City in the Islamic Republic of Pakistan

Images of Proposed Project

The following pictures illustrate some of action plan projects (see *page 6-20 in Main Report*) which were selected in view of urgency and effectiveness among the entire long list of projects and programs.
(Under the supervision of JICA study team experts, Sathi Bagh Government Girls High School was successfully constructed, and West Bank By-pass road was studied on preliminary design.)

Image of Satellite Town

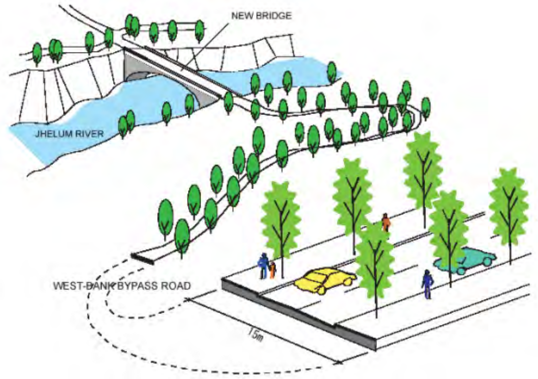
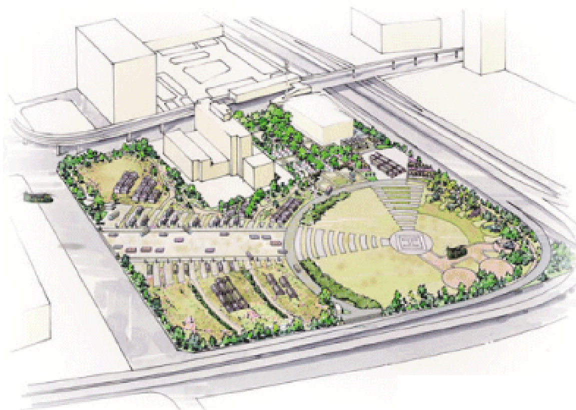
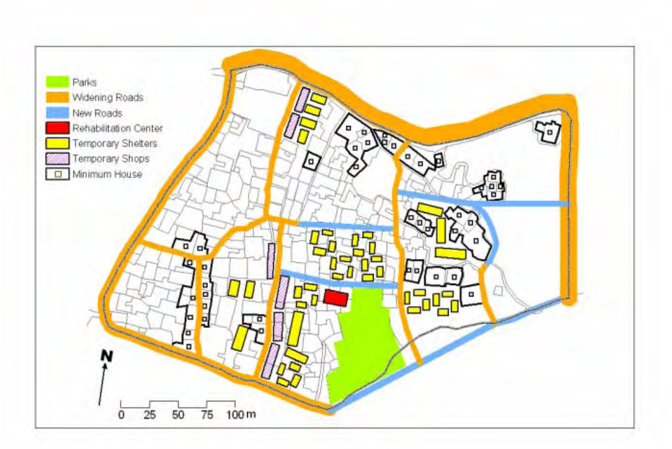


Image of West Bank By-pass Project

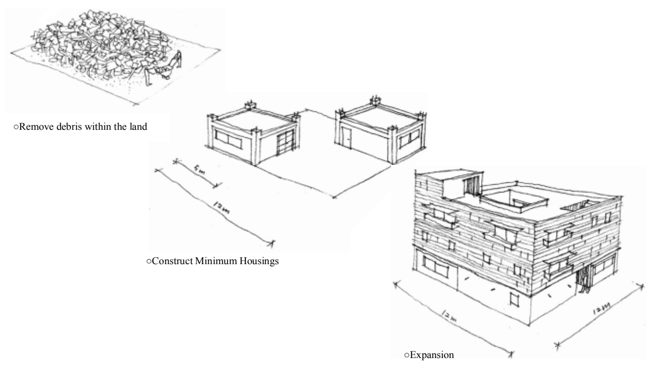


Disaster Management Park View



Temporary Urban Area

Sathi Bagh Government Girls High School



Construction of Minimum House

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List of Abbreviations

Abbreviation	Name
ADB	Asian Development Bank
AJK	Azad Jammu and Kashmir
AJKED	AJK Electricity Department
AJK-EPA	AJK Environmental Protection Agency
AJK-EPC	AJK Environmental Protection Council
CBO	Community Based Organization
CDO	Central Design Office
CIRES	Cooperative Institute for Research in Environmental Sciences
CMH	Combined Military Hospital
CMO	Camp Management Organization
DFID	Department for International Development
DRAC	District Earthquake Reconstruction and Rehabilitation Agency
DRU	District Reconstruction Unit
EDO	Executive District Officers
EIA	Environmental Impact Assessment
ERRA	Earthquake Reconstruction and Rehabilitation Authority
FWO	Frontier Works Organization
GIS	Geographic Information System
GOAJK	Government of Azad Jammu and Kashmir
GSP	Geological Survey of Pakistan
HFT	Himalayan Frontal Thrust
HIC	Humanitarian Information Center for Pakistan
IDA	International Development Association
IEE	Initial Environment Evaluation
IOM	International Organization for Migration
ISPR	Inter Services Public Relations
JICA	Japan International Cooperation Agency
JPF	Japan Platform
LOC	Line of Control
MBT	Main Boundary Thrust
MCM	Municipal Corporation Muzaffarabad
MDA	Muzaffarabad Development Authority
MGD	Million gallon per day
NGO	Non Governmental Organizations
NESPAK	National Engineering Service Pakistan
NHA	National Highway Authority

NWFP	North West Frontier Province
ODA	Official Development Assistance
PCU	Passenger Car Unit
PEPC	Pakistan Environment Protection Council
PEPA	Pakistan Environment Protection Agency
PERRA	Provincial Earthquake Reconstruction and Rehabilitation Agency
PGA	Peak Ground Acceleration
PHED	Public Heath Engineering Department
PIMS	Pakistan Institute of Medical Science
PSC	Programme Steering Committee
PWD	Public Works Department
RGH	Rawalpindi General Hospital
SERRA	State Earthquake Reconstruction and Rehabilitation Agency
TOR	Terms of Reference
TTC	Technical Training Center
UN	United Nations
UNICEF	United Nations Children's Fund
USGS	US Geological Survey
USAID	U.S. Agency for International Development
VTC	Vocational Training Center
WB	World Bank
WTP	Water Treatment Plant

1. HAZARD ANALYSIS 1 (EARTHQUAKE HAZARD AND EARTHQUAKE RESISTANT STRUCTURE)

1.1. EARTHQUAKE SOURCE FAULT

1.1.1. Brief Overview

October 8, 2005 a massive earthquake struck the northern part of Pakistan. Regarding the source fault of this earthquake, many report and papers were published all over the world. The tectonic issue has also been reported by NESPAK in detail and the content of this report is well organized. Therefore the main point of this chapter is to identify how the findings are to be interpreted and how the findings are to be applied to the master plan.

Earthquake is caused by faults. A fault, which slipped in the past and is still moving, is called an active fault. It is known that specific earthquakes occur comparatively cyclically and each of them has similar characteristics. This is so called “characteristic earthquake”. Therefore the fault needs to be dealt with in planning when some evidence of past slip is found.

It must be recognized that the return period of the earthquake is comparatively long and uncertain even though occurrence of earthquakes is periodic, because our scientific knowledge of earthquake history is short compared with return period of the earthquake. Needlessly excessive placing a limit on construction may obstruct economic activity, and then it does not lead to a reasonable result. It may be more important to recognize the risk and prepare countermeasures other than placing excessive limitation. How the corresponding fault is understood must be discussed carefully. The targets of disaster reduction need to be set for following two kinds of decisions:

A) Decision on land use plan and limitation

B) Decision on needed capacity of structure built at a specific place

Above A) is discussed in this chapter.

1.1.2. Fault Near to Muzaffarabad

Regarding two existing faults, the main point of this report is summarized below.

Tanda fault

（The fault that is designated as Himalayan frontal thrust in NESPAK’s report “Seismic Hazard Microzonation of Major Towns Affected by Earthquake of October 08, 2005 (DRAFT)” 1）and designated Tanda fault in GSP list2)）

It is said that the main part of ground acceleration at 2005 Kashmir Earthquake was caused by fault slip, which activated around 70～100 km in this fault plain. This may be the characteristic earthquake or one near to the characteristic earthquake because magnitude was significantly large M7.3～7.6. Dominant Slipped area is close to Muzaffarabad.

This earthquake is used as the target earthquake of disaster reduction because any other effective one which has sufficient accuracy may not found in candidates.

Jhelum fault

（The fault that is designated as Main boundary thrust in NESPAK’s report “Seismic Hazard Microzonation of Major Towns Affected by Earthquake of October 08, 2005 (DRAFT)” 1））

In this report the name of Jhelum fault is going to be used because the name of Main boundary thrust is likely used for more wide-ranging movement. The location of this fault is taken into consideration but ground shaking caused by this fault is not taken into consideration because accuracy of location of this fault and slip coverage at a time is comparatively low.

1.3. Location and Accuracy of Related Fault

The result of inversion analysis is shown in Figure 1.1.1. Distribution of the fault slip that caused 2005 Kashmir Earthquake was examined by Yagi (Tsukuba University) using some seismograph record adopting newly concepted inverse operation method.

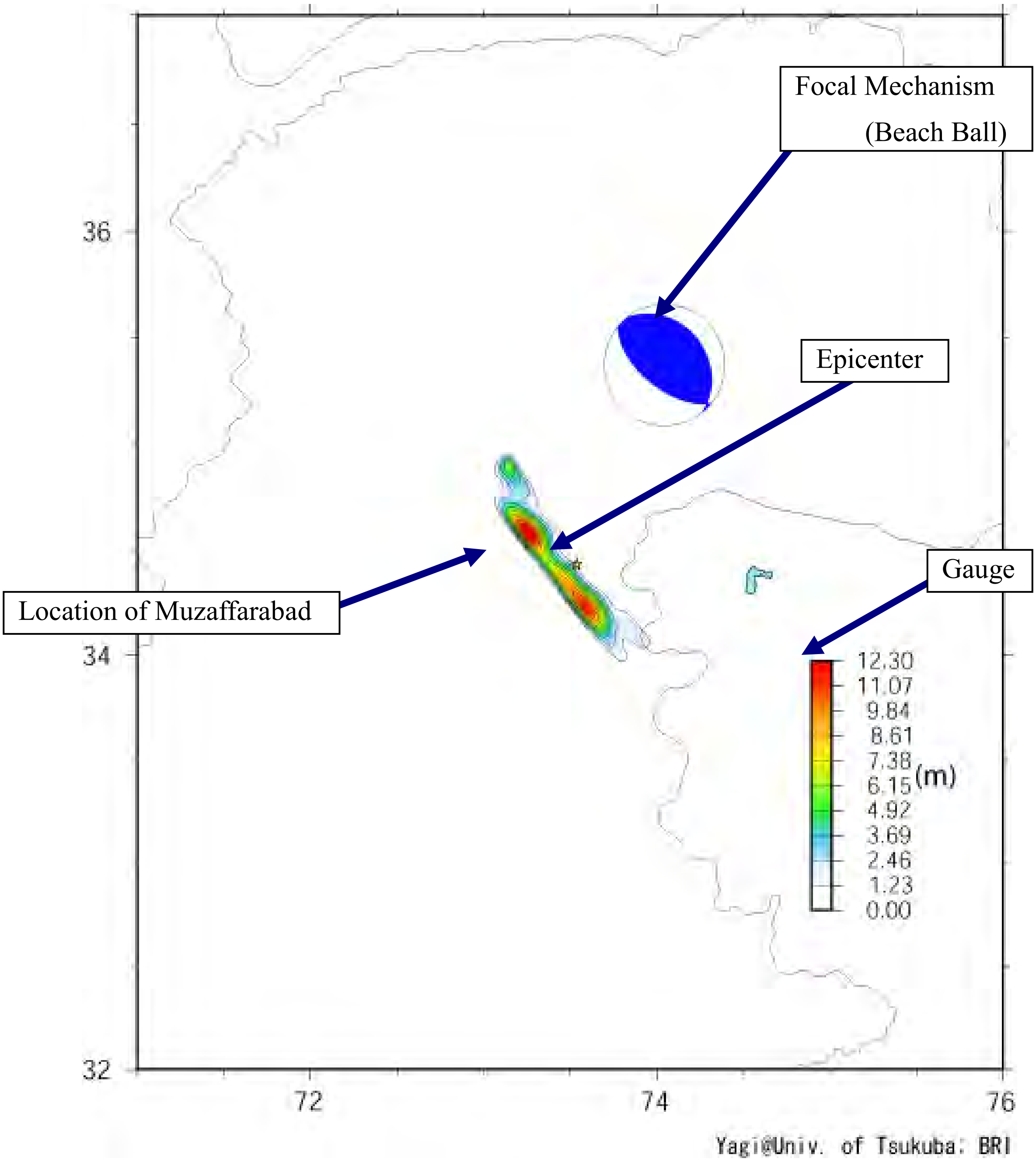
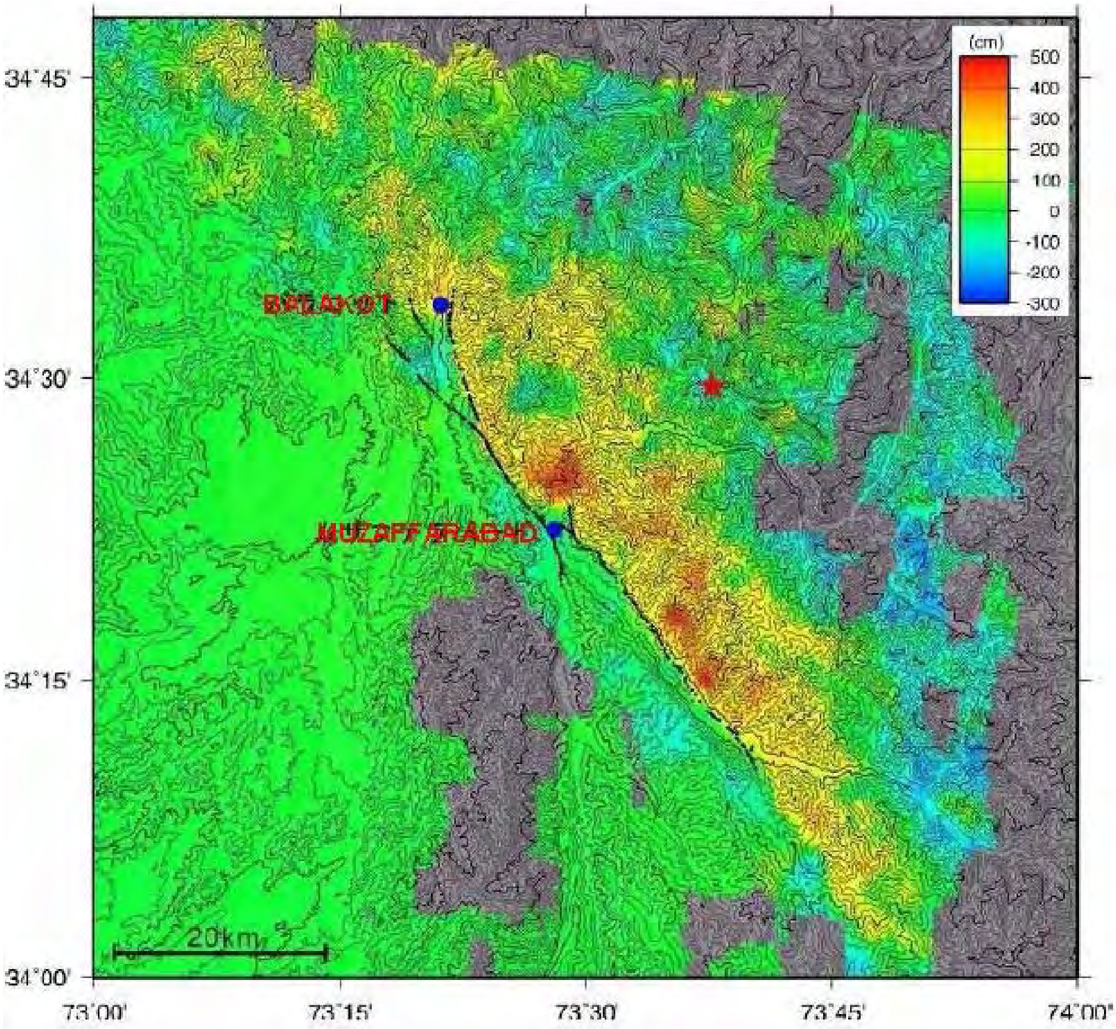


Figure 1.1.1 Distribution of the fault slip by（Yagi et al., 2004)
(http://www.geo.tsukuba.ac.jp/press_HP/yagi/EQ/2005Pakistan/)

Distribution of the ground surface shift is shown in Figure 1.1.2. This figure was obtained by "image matching method" using the image from synthetic aperture radar. This analysis was done by Japan Geographical Surveying Institute.

This figure gives clear explanation why the earthquake motion of the northern part of Muzaffarabad (Ward 18) and Balakot was so large.

Figure 1.1.2 also shows the location of Tanda fault by black line and epicenter (red star) identified by USGS.



(a) Japan Geographical Surveying Institute (JGSI)

Figure 1.1.2 Distribution of the ground surface shift (Japan Geographical Surveying Institute)

It is suggested that shift of considerably large slip area is related for ground acceleration of this earthquake when Figure 1.1.1 and Figure 1.1.2 are examined.

- Crust shift was concentrated to the northern part of Muzaffarabad close to the area designated Ward 18
- Significantly large effect of Balakot can be understood since Balakot is located hanging wall side of the fault plane

Characteristic features of Tanda fault was clarified through the investigation done by GSP's and some Japanese researchers[1] after 2005 Kashmir Earthquake. According to their impressions that fault has the potential to slip again near future because strain of the crust of

[1] Y. Kumakura, T. Nakata: Active Fault in the Epicentral Area of the 2005 Pakistan Earthquake, Research Center for Regional Geography Hiroshima University, March 2006

this area was not released completely. However in most views, the rupture may not grow toward Jhelum fault.

Website of CIRES shows a fault, which is similar to Jhelum fault, but they reported that the data of earthquake in Kashmir that occurred in 1555 is insufficient to assign it a magnitude or location. (Figure 1.1.3)

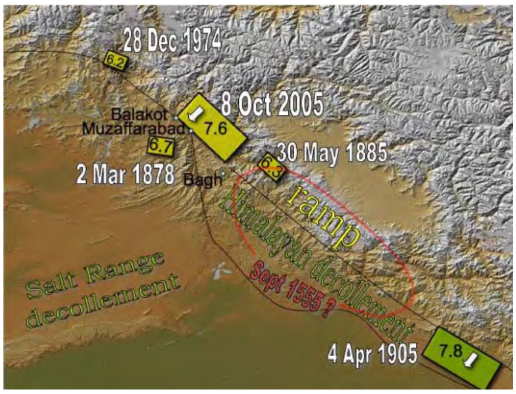


Figure 1.1.3 Earthquake in 1555

Source : http://cires.colorado.edu/~bilham/Kashmir%202005.htm

When tectonics within the wide range is considered, the faults around this site are assumed to be a part of Himalaya front. (See the part marked by red circle 2005 in Figure 1.1.4)

Return period of occurrence in this area is assumed from 1000 to 2000 years.

Large earthquake events along Himalaya front (modified from Wright, 2005)

Figure 1.1.4 Himalaya Front

It is possible to conclude the following:

- It is needed to understand that the fault, which caused 2005 Kashmir Earthquake, because it is used as a target of disaster reduction for Muzaffarabad
- Careful discussion is needed to evaluate the intensity of risk considering the precision of already-known information.
- Some comparison between risk and feasibility is needed for next step

【for reference】

For example, government of Japan will promote a project in order to accurately determine location of fault and probability of earthquake caused by corresponding fault. Major active faults are reexamined and are classified into 3 categories. If the probability of exceedence in 30 years is larger than 3%, the risk of that fault is classified into “Very high”. If simple definition is applied, the above situation corresponds to 985 years return period, but the period of last occurrence of earthquake and whether the strain is released sufficiently is taken into account for the evaluation.

1.2. EARTHQUAKE DAMAGE OF BUILDING

1.2.1. Brief Overview

This paragraph describes the situation of the building damage due to “2005 Kashmir Earthquake”. Good PGA accuracy cannot be obtained by conventional attenuation equation because the epicenter of “2005 Kashmir Earthquake” is extremely near to Muzaffarabad（about 20km）

On the other hand, the distribution of the damaged buildings can offer good information on ground motion. Thus the building investigation at this time gives a broader perspective of earthquake motion of ground surface in Muzaffarabad although it was not necessarily as detailed as an inventory study.

1.2.2. Investigation method

The damage rate was evaluated by general observation since the accurate number of buildings cannot be specified because basic data of the building census, etc. cannot be obtained in the locale.

The damage ratio is a value defined in Equation (1.2.1).

$$Damage \cdot ratio = \frac{Number \cdot of \cdot Damaged \cdot Buildings}{Total \cdot Number \cdot of \cdot Buildings} \qquad (1.2.1)$$

It is assumed that the Number of Damaged Buildings is the number of buildings where damage state was more than Very heavy damage in European Macroseismic Scale 1992.

Investigation area was divided into 30 zones with reference to the boundary of regional division. Representative area with all sides of 100 m was selected, and the *Number of Damaged Buildings* and the *Total Number of Damaged Buildings* was counted.

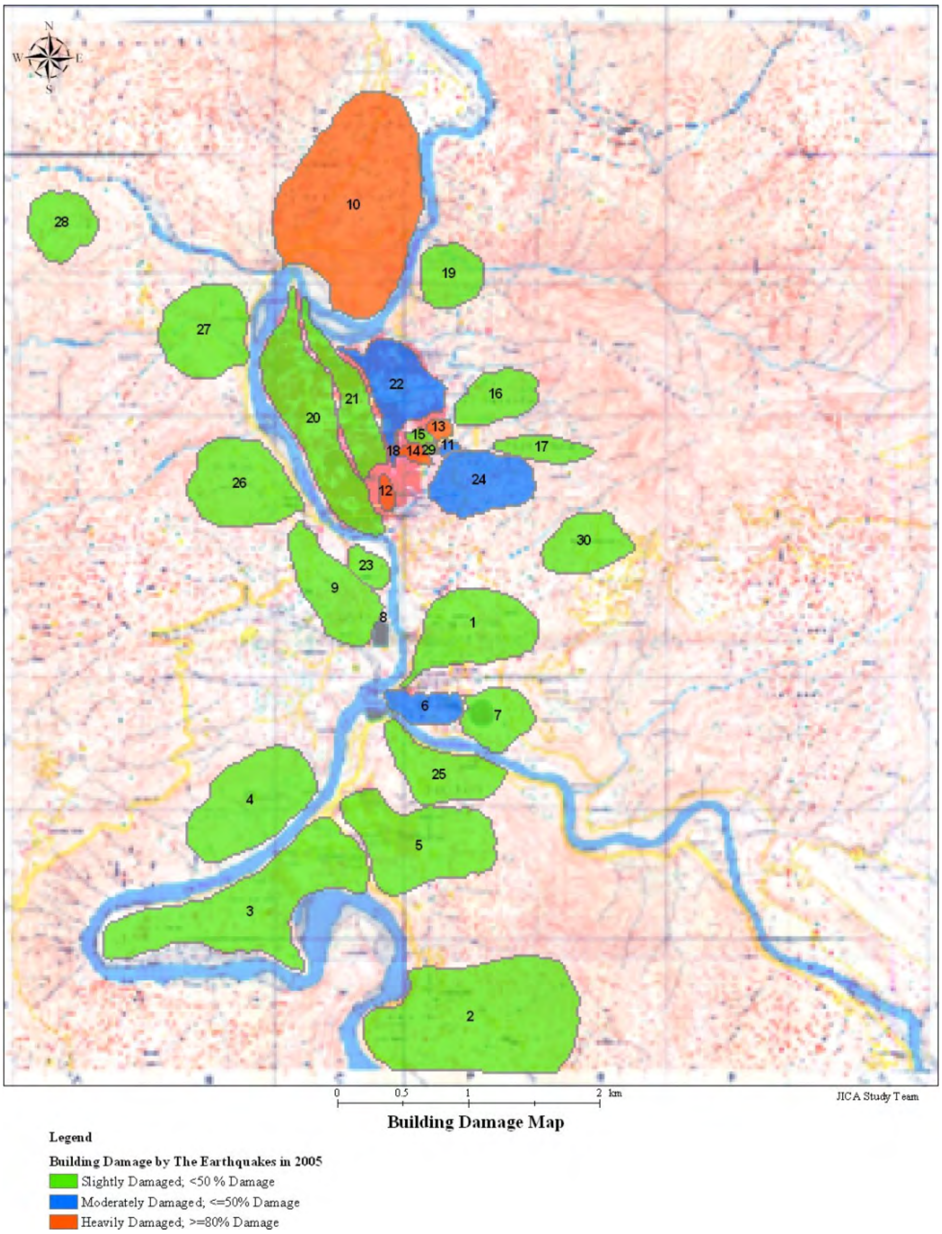
1.2.3. Damage Ratio

The investigation results are shown in Table 1.2.1. The distribution map of damage ratio is shown Figure 1.2.1. The value of damage ratio in each zone was made difficult because each damaged buildings was in close contact with another. In addition, it was exceeding difficulty to identify each building when they were totally collapsed.

Table 1.2.1 Building Damage Assessment Survey Results

Zone	Location	Damage Ratio (%)	
		From	To
1	Jalalabad	40	45
2	Upper Ambor	20	25
3	Lower Chatter	12	15
4	Naluchi	40	45
5	Upper Chatter	20	25
6	Domel Syedian	50	55
7	Narrul	20	25
8	Chinar Camp	10	12
9	Gojra	15	20
10	Chela Bandi	70	75
11	A G Office (Satra Hill)	40	50
12	Madina Market	50	60
13	Sethi Bagh Mohalla	60	70
14	Shah Nara	60	65
15	Khawaja Mohalla	70	80
16	Dheri Syedian	30	45
17	Ranjatta	40	45
18	Gulshan Colony	50	55
19	Makri	20	30
20	Lower Plate	15	20
21	Center Plate	25	35
22	Upper Plate	45	55
23	Shaukat Line	20	30
24	Tariq Abad	50	60
25	Sund Gali (Upper Domail)	30	40
26	Baila Norr Shah	20	30
27	Panjgran	5	10
28	Shahwai	10	15
29	Babu Mohalla	40	45
30	Maira Tanoulian	35	40

Source: JICA Study Team



Source: JICA Study Team

Figure 1.2.1 Distribution Map of Damage Ratio

1.2.4. Factor of Damage

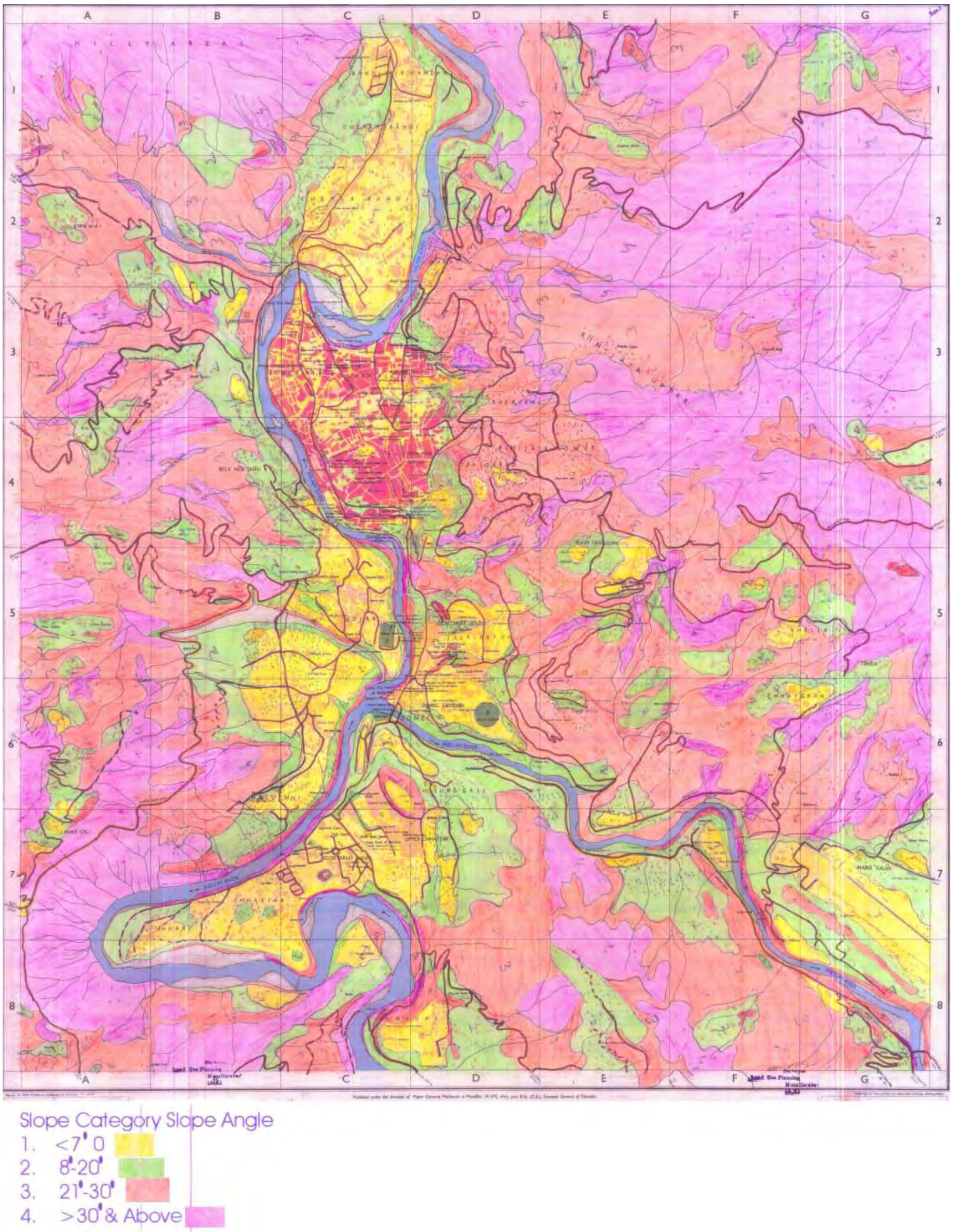
Damage state is caused by a combination of ground motion, capacity of ground, and seismic resistance of the building. If the attributes of the buildings in each area were specified it could provide good data to calibrate the survey results and to identify the ground motion of each area. The attributes of the buildings in each area are shown in Table 1.2.2.

Table 1.2.2 Attributes of Buildings by Area

Sr.No	Location	Building Types % ages								
		RC Frame		Reinforced Masonry		Non Engineered Masonry				
		A	B	C	D	E	F	G	H	I
		RC frame with RC wall	RC frame with Brick wall	Cement Block	Brick (with RC floor)	Cement Block	Brick	Square shaped stone	Cobble	Adobe
1	Jalalabad	0.00	23.08	15.38	15.38	15.38	23.08	0.00	7.69	0.00
2	Ambor	0.00	0.00	0.00	50.00	0.00	50.00	0.00	0.00	0.00
3	Lower Chatter	0.00	0.00	0.00	20.00	20.00	60.00	0.00	0.00	0.00
4	Naluchhi	0.00	0.00	0.00	0.00	33.33	33.33	33.33	0.00	0.00
5	Upper Chatter	0.00	40.00	20.00	0.00	0.00	40.00	0.00	0.00	0.00
6	Domel Syedian	14.29	42.86	0.00	14.29	14.29	0.00	0.00	14.29	0.00
7	Narrul	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Chinar (Army)	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Gojra	0.00	40.00	0.00	0.00	40.00	0.00	0.00	20.00	0.00
10	Chehla Bandi	15.38	30.77	15.38	30.77	7.69	0.00	0.00	0.00	0.00
11	AG Office (Satra Hill)	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Madina Market (Old City)	0.00	0.00	50.00	50.00	0.00	0.00	0.00	0.00	0.00
13	Sethi Bagh Mohalla	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00
14	Shah Narra	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00
15	Khawaja Mohalla	0.00	0.00	57.14	42.86	0.00	0.00	0.00	0.00	0.00
16	Dherian Syedian	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
17	Ranjatta	0.00	0.00	20.00	60.00	0.00	0.00	0.00	20.00	0.00
18	Gulshan Colony (Eid Gah Road)	0.00	33.33	50.00	16.67	0.00	0.00	0.00	0.00	0.00
19	Maakri	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
20	Lower Plate	0.00	20.00	20.00	20.00	20.00	0.00	0.00	20.00	0.00
21	Center Plate	0.00	36.36	54.55	9.09	0.00	0.00	0.00	0.00	0.00
22	Upper Plate	0.00	28.57	57.14	14.29	0.00	0.00	0.00	0.00	0.00
23	Shaukat Lines	0.00	0.00	20.00	60.00	0.00	0.00	0.00	20.00	0.00
24	Tariq Abad	0.00	14.29	57.14	0.00	0.00	0.00	14.29	14.29	0.00
25	Sund Gali (Upper Domail)	0.00	8.33	50.00	0.00	25.00	0.00	8.33	8.33	0.00
26	Baila Noor Shah	0.00	33.33	66.67	0.00	0.00	0.00	0.00	0.00	0.00
27	Panjgran	0.00	40.00	20.00	40.00	0.00	0.00	0.00	0.00	0.00
28	Shawai	0.00	33.33	0.00	0.00	0.00	33.33	0.00	33.33	0.00
29	Babu Mohalla	0.00	80.00	0.00	0.00	0.00	20.00	0.00	0.00	0.00
30	Maira Tanoulian	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A	(E) RC frame with RC wall		B	(E) RC frame with Brick wall			C	(R.M) Cement Block		
D	(R.M) Brick (with RC floor)		E	(N.E) Cement Block			F	(N.E) Brick		
G	(N.E) Square shaped stone		H	(N.E) Cobble			I	(N.E) Adobe		
E	**Engineered**		**R.M**	**Reinforced Masonry**			**N.E**	**Non Engineered**		

Source: JICA Study Team

It was reported that a lot of buildings were damaged by landslide. Such landslides were found at several slopes. They were caused by supporting slope failures triggered by the earthquake. The slope inclination distribution map is shown in Figure 1.2.2 for reference.



Source: JICA Study Team

Figure 1.2.2 Slope Inclination Map

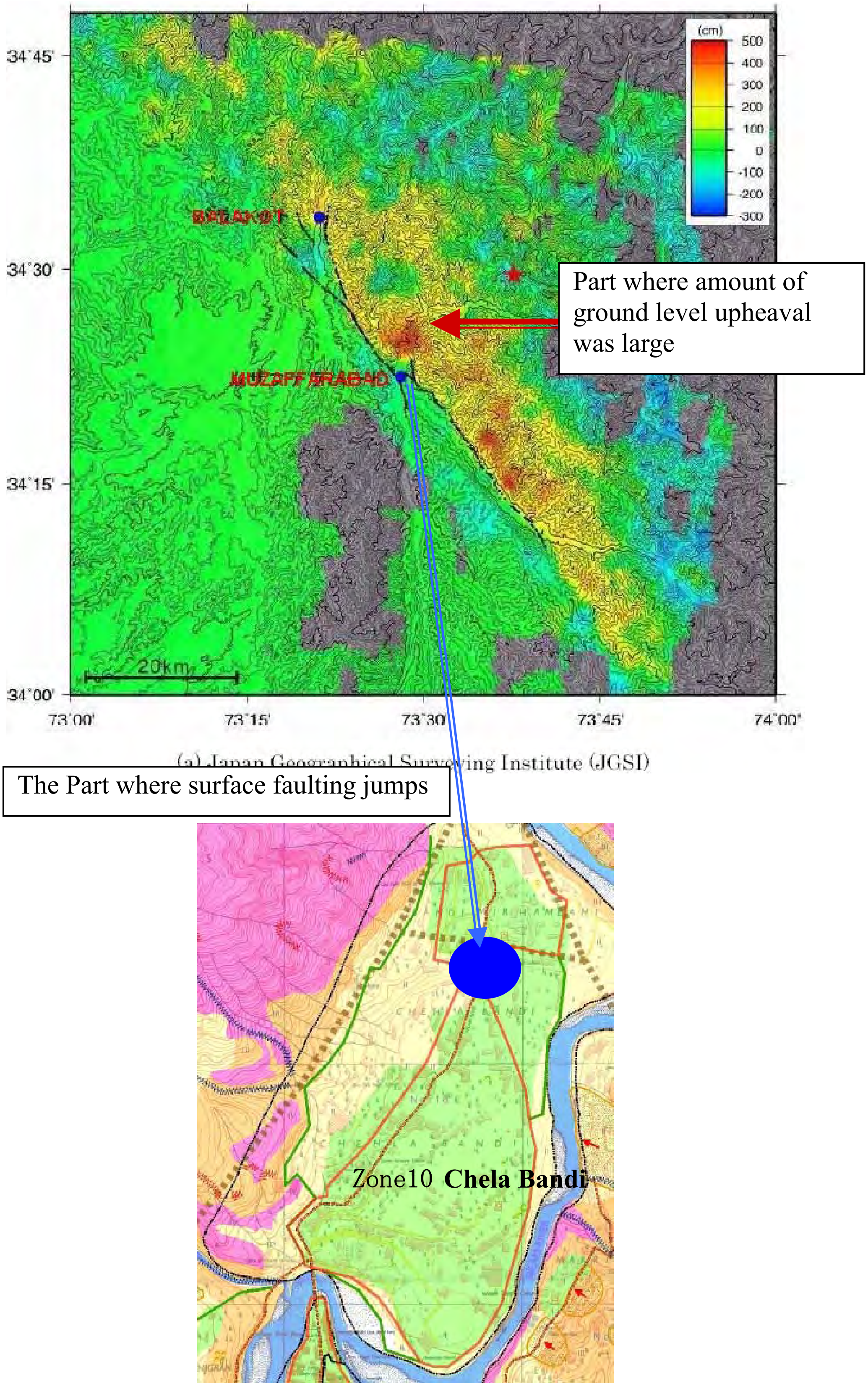
1.2.5. Understanding from Building Damage

Some observations from Table 1.2.1, Table 1.2.2, Figure 1.2.1 and Figure 1.2.2 are described below.

- The first impression from Figure 1.2.1 is that the damage ratio of "Chela Bandi" (Area number 10) is very large compared with that of other areas. This finding is supported by Figure 1.1.1 and Figure 1.1.2 which show the source location of "2005 Kashimir Earthquake". Figure 1.2.3 shows relation between the location of "Chela Bandi" and that of the source location of "2005 Kashimir Earthquake". In a word, the location of "Chela Bandi" was the nearest to the relative displacement of the fault plane that caused "2005 Kashimir Earthquake". Moreover, the surface faulting is winding in this part and surrounding "Chela Bandi".

Based on these findings, it is reasoned by analogy that the earthquake motion of the base rock of this area was larger than that of other parts.

On the other hand, it is understood that there was a little difference of the amplification in the surface layer of different parts of "Chela Bandi" when damage of each part is observed in detail. In general, a comparatively high place vibrates freely and easily because the surface layer is thick. Therefore, damage of these parts was large because the earthquake motion was amplified.



Source: JICA Study Team

Figure 1.2.3 Situation near "Chela Bandi"

- The damage ratio of "Madina Market" (Zone 12), "Sethi Bagh Mohalla" (Zone 13) and "Shah Nara" (Zone 14) was also large compared with that of another area.

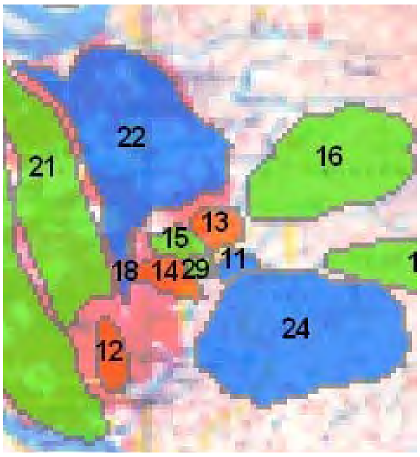
The reason why the damage ratios of these areas were large is that they are in comparatively high places where the ground vibrates freely and easily because the surface layer is thick. More over these parts are located at the ridge of a cliff. A lot of examples of high ground motion were found in the areas in the previous earthquake disaster area. Therefore, damage of these parts was large because the earthquake motion was amplified.

- "Tariq Abad" (Zone 24) is an area where the slope is steep and the buildings are overcrowded. Insufficient masonry retaining wall was a common condition.

In this small developed area, each building with insufficient masonry retaining walls was destroyed due to circular slip of ground.

- The damage ratio of "Gulshan Colony" (Zone 18) and "Upper Plate" (Zone 22) are also large compared with that of other areas.

The reason why the damage ratios of these areas were large is also because they are comparatively high places where the ground vibrates freely and easily because the surface layer is thick. Another reason of high damage ratio of this area is that the predominant building type in this area was masonry.



Source: JICA Study team

Figure 1.2.4 Part where damage ratio was high (50%～80%)

As mentioned above reasonable explanations were given to each observation of very severely damaged area (over 80%) and severely damaged area (50%～80%).

1.3. HAZARD ASSESSMENT

1.3.1. Hazard Evaluation

(1) Earthquakes

a. Basic Consideration

The cause of the earthquake damage is ground acceleration and relative displacement induced by the earthquake. In this section some considerattions about ground motion and relative displacement are described while referring to damage situation generated in Muzaffarabad.

Ground Acceleration

The factors related to intensity of the ground acceleration are summarized as follows.

Distance from fault plane where slipping occurs

The dip of the Tanda fault which caused the earthquake at this time was towards the northeast. As for the Muzaffarabad city region, earthquake motions were not very large even though the city is very close to the fault.

It is believed that the acceleration of base rock in Muzaffarabad area was almost same because the gentle tendency of attenuation is generally shown in a range near the fault.

However, only the acceleration of A Zone (Ward #18), where the strike line of the fault is inflective, was larger than that of other parts.

Amplification in surface layer

The shear wave velocity of surface layer is assumed to be 400 m/s in NESPAK's report 1). The value of this layer can be considered equal to base rock for the dynamic analysis carried out for engineering purposes. Therefore difference of amplification in the surface layer may be almost negligible.

Amplification caused by shape of ground surface

Amplification caused by shape of ground surface can be seen at the following locations:

1) Place where soft surface layer becomes shallow gradually, and it touches an outcrop in stiff stratum

2) Place where free vibration can be excited (i.e. cliffs, etc.)

3) Place where the quake converged on it (i.e. isolated hills, etc.)

There is no soft surface layer in Muzaffarabad area. Therefore, some cliffs and isolated hills are the places where the quake can be amplified.

As a result, the average intensity of earthquake motion of Muzaffarabad area estimated as about MMI[2] 9. Intensity of earthquake motion of A zone described later and the specific part described above in item "Amplification caused by shape of ground surface" is thought to be about MMI 10.

Relative displacement on fault

Relative displacement is a motion that each side of the ground moves to opposite direction at the fault line. Structures that are built on the fault line will be torn apart when relative displacement occurs. Thus the effect of the relative displacement is limited just on the fissure caused by earthquake.

Regarding Tanda fault, the location of fault line can be identified comparatively accurately because the 2005 Kashmir Earthquake gave effective findings. The place where Tanda fault is located is almost limited to the steep area and A Zone as described at next section. Development must be avoided at steep area inherently. There must be comparatively strict regulation of new construction in these areas.

It is hard to identify the location of Jhelum fault compared with Tanda fault. Part of E Zone, F Zone and G Zone have Jhelum fault, thus fissure can develop within this region and needs measure. Therefore a regulated belt along forecasted fault line about 400 m width is recommended that further damage of structure will not develop. However excessive regulation of construction is not realistic when thinking the extent of accuracy of fissure location. Some kind of moderate restriction is needed. Emergency response facilities especially facilities that give emergency assistance must avoid to be constructed in this belt areas. Small size buildings, mainly individual residences, may be built in the area, yet need to follow earthquake resistant design.

b. Evaluation for Each Area

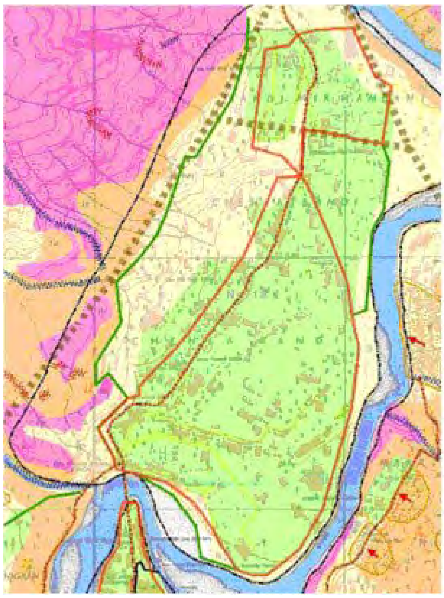
The possibility of the earthquake hazard in Muzaffarabad city region is almost the same basically as previously described in section 5.2.1. In a word, the possibility of the earthquake hazard in the entire city region is comparatively high. The earthquake hazard for each part is described below.

[2] Modified Mercalli Intensity

A Zone (Ward #18)

Special consideration is needed for this area because there may be comparatively large ground motion when the Tanda fault slips. Comparatively large damage was reported in this area for the 2005 Kashmir Earthquake. The strike line of the fault is inflective, so this zone is enclosed from the north side and the west side by the surface faulting

- Special consideration of earthquake resistant design and construction is needed for lifeline structures such as water supply and electric power lines. Adopting flexible joints or some other special elements is possible for this purpose.



Source: JICA Study Team

Figure 1.3.1 A Zone

B Zone (Ward #8, #9, #10, #12, #13, #14, #15, #16, #17)

The matter which requires attention for this area is special consideration for the buildings which are located at the edge or bottom of cliffs.

- Construction of a public building should be avoided at the edge or bottom of cliffs.
- Some limitations are needed for private buildings which are located at the edge or bottom of cliffs.

In case of constructing buildings on cliffs, exceeding 3 m in height, it is preferable to avoid the constructing new buildings at the position where the horizontal distance from the bottom is less than twice the height of the cliff. If buildings are constructed in this danger area, protection work to prevent fall of the cliff and suitable measures to prevent the penetration of the cliff should be installed.

In case of buildings exceeding 3 m under the cliff, it is preferable to avoid construction of new buildings at the position where the horizontal distance from the top is less than twice the height of the cliff. (reference was made to the Japan ordinance in the above-mentioned description.)

Source: JICA Study Team

Figure 1.3.2 B Zone

C Zone (a part of Ward #11and Ward #4, Ward #6)

Many landslides were observed which may have been caused by shaking radiating through the fault in this zone, but those are limited to steep ground (about 30°or more). This area is not suitable for urbanization.

The judgment of NESPAK's report1), which specifies that the range of 250 m from the fault line on map is "attention necessary" zone, is also supported in this report. A similar zone is shown also in the hazard map in this report, but this does not mean that all building construction should be forbidden in this area. The construction of the small-scale buildings for agriculture work is assumed to be acceptable, but some warning needs to be announced to inform landowners of the risk. An effective method should be sought for how to execute the announcement.

Source: JICA Study Team

Figure 1.3.3 C Zone

D Zone (part of Ward #7, Ward #5 and Ward #4)

The part section of the small river under the cliff has high risk. Avalanche Landslide of rocks and earth is expected when during the rainy season although this is not an earthquake hazard.

Source: JICA Study Team

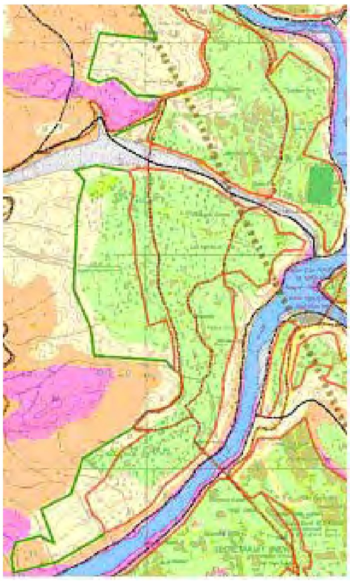
Figure 1.3.4 D Zone

E Zone (Ward #19, Ward #20)

Jhelum fault has crossed this area. The following structures need to be prohibited as far much as possible.

- Hospitals, Schools (They are important for Urgent rescue and relief operations after an earthquake)
- Bridges (They are needed for access between a damaged area and other areas)
- Administration Buildings

Special consideration of earthquake resistant design and construction is needed for lifeline structures such as water supply and electric power lines. Adopting the flexible joints or some other special elements is possible for this purpose.

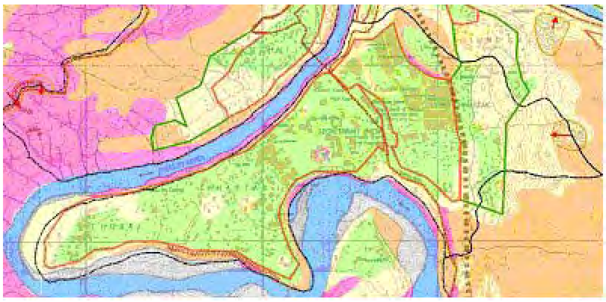


Source: JICA Study Team

Figure 1.3.5 E Zone

F Zone (Ward #2)

Notes for this zone are similar to F zone. Regarding part of the cliff top on the north side, the measures mentioned in B zone are necessary.



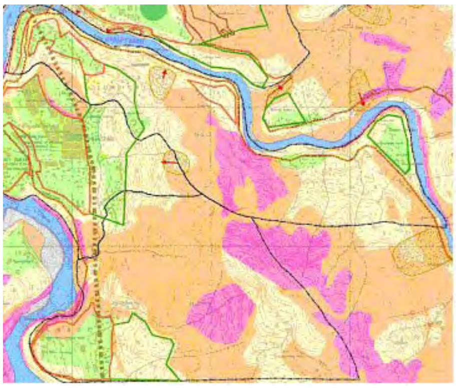
Source: JICA Study Team

Figure 1.3.6 F Zone

G Zone (Ward #1, Ward #3)

The majority of this zone is the steep ground. This area is not suitable for urbanization.

An isolated hill, where the quake may converge, exists in this area.



Source: JICA Study Team

Figure 1.3.7 G Zone

1.4. MAKING OF BUILDING EARTHQUAKE-RESISTANT

1.4.1. Management system

It is rare that the demand of earthquake resistance is made by the building owners voluntarily. Therefore, a public organization should enforce/compel making buildings searthquake-resistant by law. Otherwise only rich building owners and earthquake conscious owners will have the earthquake-resistant buildings. The majority of other buildings will be left with low earthquake-resistance.

Responsible organization, which has to provide necessary legal process, is Muzaffarabad Development Authority. Regulation of building permission and inspection system defines the content of compulsion. In general, regulation of building permission and inspection system is divided into two parts: the building structure edition and the planning edition. The building structure edition covers direct effect of physical earthquake-resistance of buildings.

In Japan the building standards law and the enforcement orders, which are officially announced, cover the matters which should be observed. They are national laws with compulsion power covering the whole Japanese country and the enforcement jurisdiction is the Ministry of National Land and Transport.

However, in Pakistan the law of building permission and inspection is not under the jurisdictions of the national government. Building permission and inspection is usually enacted as regulation of local government. This local government regulation does not exist yet in AJK. Therefore, it is indispensable to enact regulation of local government with enforcement power by the AJK government.

New buildings must be designed according to this regulation of local government, and it is necessary to perform an engineering check by a public body at each stage of construction and before starting use. When the building does not meet regulations, the legal use of the building should be denied. It is necessary to execute the legal enforcement according to the stated system.

1.4.2. Earthquake Resistant Design Code

(1) Contents of Code

A structural regulation is called Earthquake Resistant Design Code, and this directly affects earthquake-resistance of the buildings. It is necessary to provide for the following three matters in this regulation:

- Design requirement of building frame
- Construction technique of building
- Decision thing concerning parts other than building frame: i.e. evacuation, fire prevention, and influence on environment, etc.

This paragraph describes the content of the design requirement of building frame that has a definite influence in the damage scale during an earthquake.

Regarding the above mentioned three matters, Ministry of Housing & Works, Environment & Urban Affairs Division publishes "Building Code of Pakistan" as a guideline

This guideline is now under revision of the method of the design for earthquake-resistance provided by “1997 UNIFORMBUILDINGCODE”(UBC 1997 here in after) published by “International Conference of Building Officials” is provisionally applied.

In UBC 1997, design base shear is provided as a design earthquake.

NESPAK has made a draft of guideline “CRITERIA FOR SEISMIC RESISTANT DESIGN OF BUILDING IN PAKISTAN (JUNE,2006)” (CSDBP 2006). In CSDBP 2006, spectral acceleration coefficient is recommended as a design earthquake. The map which shows the distribution of peak ground acceleration coefficient (PGA) is offered in this draft. As for the design earthquake which this peak ground acceleration coefficient shows, probability of exceedance corresponds to 10% in 50 years. 2.5 times this value correspond to the peak value of the response spectrum, and it is called “Elastic seismic load” in this draft.

The model is assumed to be elastic although the building is modeled, and frame analysis is done in the design calculation. Because the structure excited by the earthquake motion of this size the reaches the elasto-plastic domain, actual response of the structure will be different from the response obtained by elastic assumption. The response spectrum is decreased by reduction factor R to consider the effect of ductility and redundancy.

As for the obtained stress, safety is checked by allowable stress design or ultimate stress design. Factors applied to load combination are different depending the way of checking (i.e. allowable stress design or ultimate stress design). Safety is checked according to calculation method which American Concrete Institute (ACI) provides. above is an outline of the design calculation in Pakistan.

As mentioned above, “Design Earthquake" and “strength design method” must be provided in the earthquake resistant design code.

The following is considered regarding the earthquake resistant design code applied to the Muzaffarabad city.

PGA value around the Muzaffarabad city is proposed 0.36g-0.43 g in peak ground acceleration map which CSDBP 2006 proposes. When these values are multiplied by 2.5, the peak value of the response spectrum will be obtained and that becomes about 1.0 g. If equivalent lateral load method is applied and the maximum R value for RC frame structure 7.0 is applied, the base shear coefficient becomes 0.15-0.22.

【Comparison with seismic criterion of Japan】

It is mentioned that the peak value of the response spectrum for Muzaffarabad region recommended by CSDBP 2006 will be about 1.0 g. This setting is similar to the standard base shear coefficient for ultimate limit state design provided by the building standards law and the enforcement orders in Japan. However, the system of ultimate limit state design method of Japan is different from the system of CSDBP 2006 and ACI. In the Japanese system of ultimate limit state design, non-linear frame analysis is applied and *Structure characteristic coefficient Ds* is defined in order to give careful thought to the effect of ductility and redundancy. Consequently, the Japanese calculation by ultimate lateral strength method brings severer judgment than the calculation by the combination of CSDBP 2006 and ACI.

It is thought that earthquake-resistant capacity of many existing buildings in Muzaffarabad does not come up to 0.1 as the value of base shear coefficient. It is difficult to obligate all of building in this region to satisfy the requirement, which the combination of CSDBP 2006 and ACI proposes. It is possible that base shear coefficient for an important building is set as 0.15-0.22, but it is not feasible to obligate small-scale individuals building owners to satisfy the same requirement as base shear coefficient.

Generally earthquake resistant design code defines acceptable limit of the damage caused by earthquake implicitly or explicitly, and an example is shown in Table 1.4.1.

Table 1.4.1 Earthquake performance level" in VISION 2000

Damage Range & Damage Index	Performance level	Thresholds
10 Negligible 9	***Fully Operational***	No damage, continuous service. Continuous service, facility operates and functions after earthquake. Negligible structural and nonstructural damage.
8 Light 7	***Operational***	Most operations and functions can resume immediately. Repair is required to restore some non-essential services. Damage is light. Structure is safe for occupancy immediately after earthquake. Essential operations are protected, non-essential operations are disrupted.
6 Moderate 5	***Life Safe***	Damage is moderate. Selected building systems, features or contents may be protected from damage. Life safety is generally protected. Structure is damaged but remains stable. Falling hazards remain secure.
4 Severe 3	***Near Collapse***	Structural collapse prevented. Nonstructural elements may fall. Structural damage is severe but collapse is prevented. Nonstructural elements fall.
2 Complete 1	***Collapse***	Portions of primary structural system collapse. Complete structural collapse.

Source: Performance Based Seismic Engineering of Buildings (SEAOC 2000)

It is pertinent that *Performance level* for important buildings is set as *Operational* or more, but it can not be avoided that *Performance level* for a small-scale individual building owners is set as *Life Safe*. Otherwise the earthquake resistant design code will not be observed. As a solution, *Importance factor I* can be set in the value less than 1.0 or another table of *Structural Behaviour Factor R* can be prepared in order to correspond to lower *Performance level*.

(2) Check Method

An analytical calculation method is needed to check whether the building design follows the Earthquake Resistant Design Code or not. At least a mathematical analysis using frame model is indispensable. Stress generated in the main part of the structural members should be calculated. However, computer software is necessary to carry out this method. Most designers use computer software made in US (for example "SAP" and "ETABS", etc.) because their countries do not develop their own computer software. One of the problems in using these computer software programs is language. It is almost impossible to accurately operate for the average engineer whose mother tongue is not English. When software is used without accurate knowledge of technical terms in structural mechanics, wrong input can not be avoided. This is a form of willful negligence.

Previously, it was described that structural analysis of the frame was indispensable. It is known that the deformation of structural members of the major buildings exceed the domain of analysis with linear force-deformation. Realistically speaking, it is necessary to cover the behavior of the non-linear domain by the equivalent linear analysis (where elastic assumption can not be applied in its strict meaning).

It is presumed that the revision standard of Pakistan will follow UBC 1997 or IBC 2000 of the United States. Over strength factor R is set in UBC to cover the behavior of the non-linear domain. This idea is realistic, but it can cause essential mistakes when it is copied without enough examination.

Let us consider the application of conventional construction method when structural analysis is not feasible. "Wooden" and "Masonry structures" are designed without calculating either intensity of stress or the displacement of the structural member by a structural analysis in the strict meaning. The large majority of houses, masonry structures, and the reinforced masonry structures correspond to this building type. A considerable number of the buildings are built by this construction method even if they are public buildings (the government office, the hospital, and the school). The general public usually think that even these kind of buildings can resist against earthquake effects the same as the buildings built by modern structural methods. This is a problem which should be emphasized together with “Earthquake performance level” previously described.

(3) Structure detail

In Pakistan, many buildings can be found with careless construction. In many cases, installation of reinforcement bar and concrete placing method are inappropriate. Those buildings can not resist against earthquake even though the design is appropriate. The minimum rule, which the architect-engineer should comply with, should be clearly shown in the code.

1.4.3. Building Code Enforcement Mechanism

Building code enforcement must be performed linked with Building permission. The outline of building permission and inspection system is shown below.

- When the design of the building is completed, the builder submits the drawing and the structural calculation book.
- Only when district surveyor checks the drawing and the structural calculation book, and the earthquake-resistance is secured, will the construction be permitted to start.

- District surveyor goes to the construction site at important term of construction and conducts in-process check. Improvement recommendation is performed when there is a problem in the quality of the used material or problem in the craftsmanship.
- District surveyor goes to the construction site when the building is completed and the completion inspection is done. Only when finish is corresponding to an initial state in the completion inspection, the use of the building is permitted.

1.5. Projects

Table 1.5.1 Projects

Project Title	Legislation of Building Code
Background and Objectives	The law of building permission and inspection does not exist in AJK now. Therefore, legal grounds when building permission and inspection is done do not exist. There is "Building Code of Pakistan" as the guideline for the whole Pakistan, but the revision is being worked now. "CRITERIA FOR SEISMIC RESISTANT DESIGN OF BUILDING IN PAKISTAN (JUNE,2006)" was recommended as the draft limited to structural regulation.
Project Component	➢ Writing of Building Code ➢ Distribution of Building Code
Construction period	12 months
Implementation Agency	Muzaffarabad Development Authority
Projects Effects	Effective building permission and inspection can be done by enacting Building Code.

Project Title	Training of Building Engineers and Building Administrative Officials
Background and Objectives	First of all, it is indispensable that the district surveyor on the municipality side knows the Building Code well in order to have an effective building permission and inspection system. In addition, it is necessary to inform the system and get it well-known by the engineers who belong to construction industry in the region.
Project Components	➢ Building Code training material for district surveyor ➢ Execution of Building Code training to district surveyor ➢ Building Code training material for the engineers who belong to construction industry in the region.
Construction period	12 months
Implementation Agency	Muzaffarabad Development Authority Municipal Corporation of Muzaffarabad
Projects Effects	Effective building permission and inspection system will be constructed.

Source: JICA Study team

2. HAZARD ANALYSIS 2 (LANDSLIDE)

2.1. INTRODUCTION

2.1.1. General

The October 8, 2005 earthquake (M-7.6) in Pakistan caused widespread damage and landslides in many parts of the Muzaffarabad City and its surroundings. After the earthquake, some landslides have become more active and enlarged. Most of local people in the earthquake-affected areas have lived in landslide areas or their impact areas. Further, these landslides present great problems in rehabilitation and reconstruction of the Muzaffarabad City.

As one of the main work items of The Urgent Development Study on Rehabilitation and Reconstruction in Muzaffarabad City in the Islamic Republic of Pakistan, landslide hazard assessment was carried out on the basis of topographical interpretation and field check. The investigation area includes the Muzaffarabad City and its surroundings with an area of about 40 km^2.

2.1.2. Purpose of Landslide Hazard Assessment

The purpose of landslide hazard assessment was mainly to:

1) Identify landslide areas that are active and potential
2) Make preliminary hazard and risk assessment of identified landslide areas
3) Prepare a landslide hazard map covering the Muzaffarabad City and its surroundings
4) Make a landslide hazard zoning map in terms of hazard levels
5) Give some suggestions for landslide hazard mitigation.

2.1.3. Definition and Classification

(1) Classification of landslides

Slope instability (natural and artificial) and subsequent movement of the collapsed materials occur due to various factors, such as heavy rainfall, earthquake, weathering, loss of soil strength, artificial alteration of the topography, and changes in surface cover (vegetation) and so on. In this study, the term "landslide" is, in broad sense, used to describe all types of slope failures, including slow-moving earth flows, rotational and translational slides, and fast-moving debris flows.

Landslides were classified, in terms of their mode of failure, into the following five types and roughly defined below.

a. Soil collapse (CL)

This failure type is marked by sudden and rapid movement without prior indication. In many cases, soil collapses occur because of a heavy rainfall, but they rarely occur because of artificial earth works and earthquakes.

Soil collapse can be described in the following terms.

- Soil collapse has little relation to geological conditions; mostly occur in loose materials such talus deposit, residual soil, loosened rock and so on.
- Increasing of groundwater and infiltration of run off by heavy rain or loosening of slopes by earthquakes.
- Ground movement is very rapid, and collapsed mass is scattered and spread widely, the characteristics of which are quite different from the slide.
- Its size is generally small because only the loosened area of soil slope surface collapses down.

b. Rock mass collapse (RM)

Mass collapses in a rock slope such as planar collapse, wedge collapse, and toppling. They often occur at geological discontinuities. Deformation of the rock mass often indicates impending collapse.

c. Rock fall (RF)

Rock fall is free fall or rolling down of a rock or few rocks individually from a steep slope or cliff. This collapse type is also marked by sudden and rapid collapse that and is prone to occur in a heavy rainfall or during and after earthquakes, although it happens occasionally with no relation to weather conditions.

Rock mass collapses and rock falls occur in similar topography/geological conditions.

d. Slide (SL)

Slides are mass movement by sliding on the surface at the bottom of the moving mass, referred to as the sliding surface. The speed of a slide is usually less than that of collapse. Slides have the characteristic of sliding surfaces, so they are prone to occur in particular geologic circumstances or in geotectonic areas.

In general, slides have the following characteristics.

- Slides occur on slopes with slope gradient less than 35 degrees, and the ground movements are relatively slow, mostly with continuous and recurrent characteristics.

- Geology is colluvial deposit, weathered rocks, and soft rocks.
- Slides are triggered mainly by increase of ground water level as a result of heavy rains, and sometimes by the shock of earthquake.
- Prior to occurrence, on the ground surface, show some signs of deformation such as cracks, subsidence, bulging, toe collapse, springs, and so on.

e. Debris flow (DF)

Debris flows occur along streambeds or along valley type slope in mountainous area, and are the rapid flow of boulders, gravel, sand, silt and earth mixed with large amounts of water. They tend to occur in steep streambeds where there are unstable debris deposits, and in drainage areas where soil collapses or rock mass collapses occur during heavy rain fall or earthquake. They flow down riverbeds of over 20 degrees and generally start depositing debris as the gradient falls below 10 degrees.

Debris flow can be generally characterized by the following descriptions.

- Debris flows occur suddenly on steep slopes and have the following necessary conditions: namely, steep gradient, heavy rain supply and unstable debris.
- Debris flows are caused by heavy rain or earthquake.
- Speed of debris flow depends on water content, slopes and so on. The existence of surface water and ground water influence the speed of debris flow to a large extent.
- The most frequent form of debris flow is connected with collapse at the head of torrents.
- Debris flows are subdivided, in terms of their process and movement, into three areas: namely, source area, path area and deposition area. The most devastating damages are caused mostly in path and deposition areas.

(2) Main factors of slope instability

The occurrence of landslides depends on both the causative factors and slope characteristics, such as slope angle, geology, topographic character, surface water, groundwater, etc. Many factors influence the development of landslides, as listed in Table 2.1.1. These factors cause slope instability either by increasing shear stress or by reducing shear strength.

Table 2.1.1 Factors of Slope Instability

Types		Typical Factors
Increase of Shear Force	1. Removal of lateral support	• Stream undercut, rainfall water, sea waves, or glacial erosion. • Weathering, wetting/drying, and frost action. • Slope gradient increased by slope collapses, uplift of land, volcanic and fault activities • Artificial soil work: Quarries, pits, cutting, etc.
	2. Overloading	• Weight of rainfall infiltration, snow, new talus deposit, collapse mass. • Embankment structures.
	3. Transitory stresses	• Earthquake. • Vibration.
	4. Lateral pressure	• Pore pressure in cracks, fissures, etc. • Freezing of water. • Swelling by hydration of clay and clay minerals.
Reduction of Shear Strength	1. Reduction of strength	• Weak and sensitive materials such as volcanic tuff and sedimentary clays. • Easily weathered or jointed materials such as mudstone, shale, and so on. • Loosely consolidated materials such as collapse material talus. • Easily liquefied materials such as sand or silt deposits.
	2. Physico-chemical reaction	• Cation exchange. • Hydration of clay. • Drying of clays.
	3. Vegetation	• Removal of trees, reducing normal loads and apparent cohesion of tree roots.

Source: JICA Study Team

(3) Definition of terms

The following provides a brief description of main terms used in this study for uniformity of engineering practice.

Active landslide

A landslide where new ground deformations are considered to happen during or after the 2005 earthquake, and also observable at field check. These ground deformations include chiefly open cracks at the upper portions and at sides, compressive cracks at the lower portions, small collapse at the toe due to landsliding, sinking at the head, unusually bent or bulged areas at the lower portions, and so on.

Dormant (inactive) landslide

A landslide that had moved in geological past and has a clear landslide topographical features, but no new ground deformations are recognizable at field check. Such a landslide is stable at present and is susceptible to reactivation in future earthquake or heavy rainfall.

Suspected landslide

A landslide that is identified by topographical interpretation without field check. In this study, suspected landslide is catalogued into Hazard level D group.

Hazard

A condition with the potential for causing a landslide. The description of landslide hazard include mainly the location, volume (or area), types and likelihood of its occurrence within a given period of time.

Risk

A measure of the probability and severity of an adverse effect to health, property or the environment Risk is estimated simply by the product of hazard x consequences.

Consequence

The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

Hazard level

A qualitative description of probability or hazard of landslide occurrence. In this study, the evaluation of landslide hazard level is based solely on field check results — the degree of ground deformation.

Elements at risk rating

Meaning the population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

2.1.4. Procedure and Criteria of Risk Assessment

(1) Preparation of landslide check sheet

Prior to the field check, landslide check sheet form was prepared to correctly and effectively record information at field check and to future manages the landslide inventory. The landslide check sheet focuses on the following points.

1) Slope characteristics, including the gradient, direction and morphology of slope and the density and type of vegetation.
2) Nature of slope materials, such as soil type, predominant soil constituents, and average soil thickness and bedrock.
3) Geologic structure, for example, bedding orientation, discontinuity space and its trend, crack types, faulting and folding.

4) Landslide characteristics, including landslide type, occurrence location on the slopes, activity and dimension of landslide, and so on.

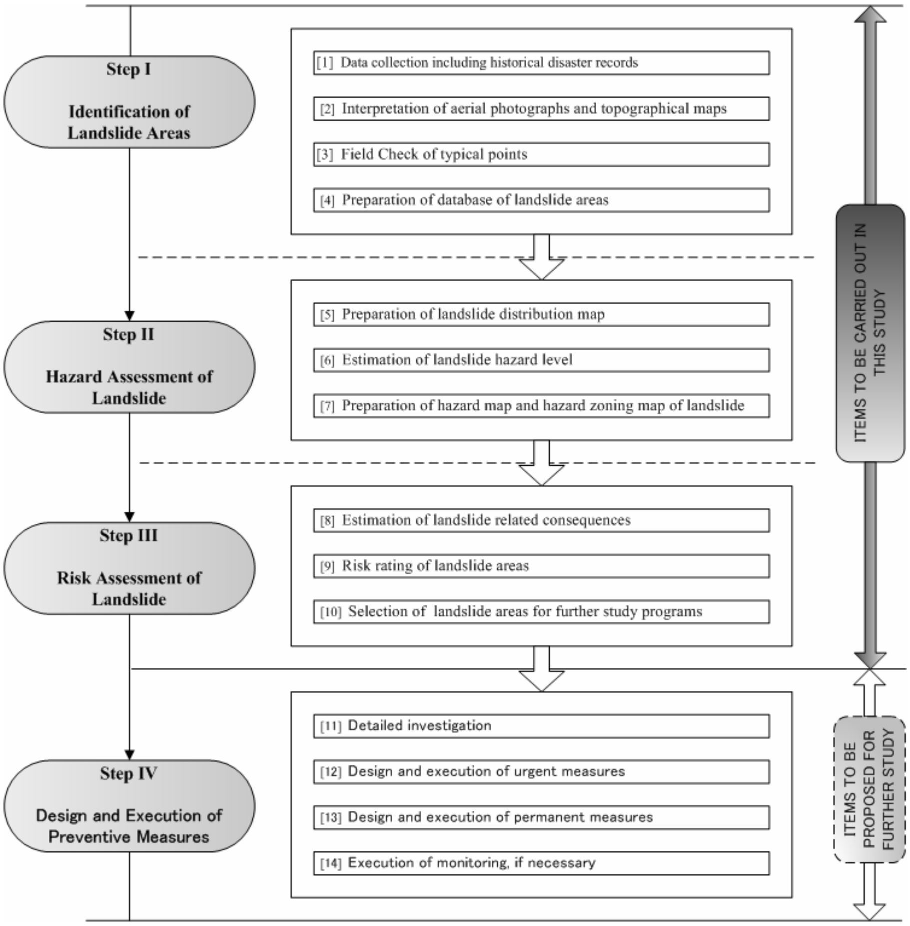
5) Main causes of landslide occurrence, such as steepness of slope, pore pressure buildup, intense weathering, undercut, load at head, low shear strength, discontinuity, earthquake, and so on.

6) Landslide risk assessment, including structure damage, future activity potential, enlargement potential, open cracks and hazard rating.

Field check is made basically by visual observation to the sites. The checked site includes landslide area and its impact areas. During the field check, careful attention is paid on slope deformation and related consequences.

(2) Method and approach of risk assessment

Figure 2.1.1 gives the general flowchart of the hazard risk assessment of landslide, including the performed works in this study and the proposed additional work to be done in the future. Detailed procedure and methodology for the performed works are described below.



Source: JICA Study Team

Figure 2.1.1 Flowchart of Risk Assessment and Selection of Landslide for Further Study Programs

a. Step I — Identification of landslide areas

Step I consists mainly of: 1) Data collection and review of existing data, 2) Interpretation of aerial photographs and topographic maps, 3) Field check, and 4) Final interpretation of aerial photographs and topographic maps. The information obtained through the above-mentioned activities was prepared as database, analyzed to evaluate the landslide hazard and used to make landslide hazard map and hazard zoning map.

Data collection

The collected data are as follows.

- Satellite image (approximate1/10,000)
- Topographic maps (1/10,000 and 1/50,000)
- Geological maps (1/50,000)
- Existing geological investigation reports and study reports
- Scientific research papers

Interpretation of aerial photographs and topographic maps

Because aerial photographs were not available, potential and new landslides were identified in and around the Muzaffarabad City with an area of about 40 km2, through interpretation of satellite image (S=1/10,000) and topographic map (S= 1/10,000). Schematic illustration of landslide feature is given in Figure 2.1.2.

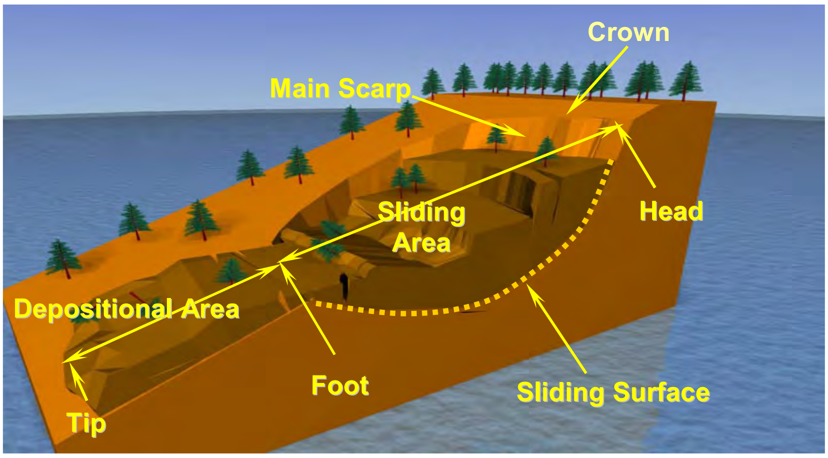


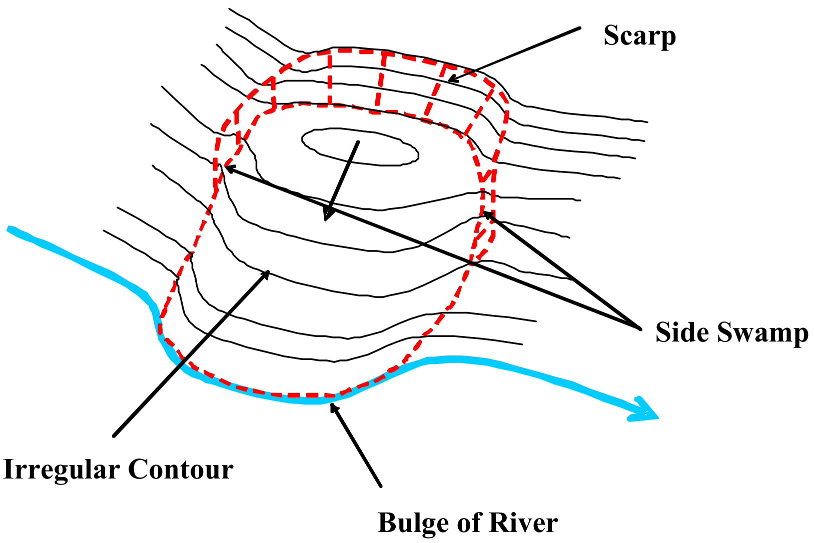
Figure 2.1.2 Schematic Illustration of Landslide Feature

Commonly, the upper part of landslide area shows a horseshoe-shape or rectangular scarp, and the middle part a flat or gentle slope. There are concavities, depressions, cracks, etc. or there is a long and narrow depression in hillslope or at the top of mountain. The typical points for the identification of landslide area are listed in Table 2.1.2 and shown in Figure 2.1.3.

Table 2.1.2 Main items for the identification of landslide areas

Item		Remarks
1	Surface deformation	head scarps, cracks, toe collapses, a marshy zone or a crack on one or both sides of landslide area
2	Micro-relief	depressions, bulge, small steps, and irregular undulation of slopes
3	Abnormal landforms	convex ridge, concave mound, steep scarp on a gentle slope
4	Water fluctuation	pond, swamps, marshes, linear alignment of springs, and small gullies
5	Irregular contour lines	contour lines are dense in the upper section of a landslide area, spares in the middle section, and dense again in the lower section
6	Vegetation	landslide area is generally covered by thin vegetation than its surrounding areas
7	Landslide area	bordered by head scarps (or cracks), toe bulges (or small collapses) and side cracks
8	Movement direction	perpendicular to head scarps or head cracks, and almost parallel to side cracks
9	Landslide type	landslide is generally subdivided, in terms of deformation processes, into rocks slides, weathered rock slide and soil slides
10	Depth of sliding surface	approximately equal to the 1/7 to 1/10 of the width of a landslide
11	Shape of sliding surface	by using the locations of toe and head of a landslide, landslide type and the depth of sliding surface
12	Geologic information	lineament, rock type, joint condition, weathering

Source: JICA Study Team



Source: JICA Study Team

Figure 2.1.3 Topographical Identification of Landslide Area

On the basis of the landslide characteristics of the identified items, landslide areas are identified and plotted on “Landslide distribution map” (S=1/10,000) for field check.

Field check

Field check was carried out for all the identified landslides and these landslides to found out at field check in order to collect the information for the hazard and risk assessment of landslides. Items to be checked are given in Field Check Sheet.

Because of the difficulties of access, a few landslide areas were not field checked. This mapping represents only features that were observed at filed check, and was not representative of all the landslide activity in the study area.

Preparation of database

The information that was collected during field check was prepared as database for hazard and risk assessment.

b. Step II — Hazard assessment of landslide

Preparation of landslide distribution map

On the basis of the field check results, all landslides, active and potential, were determined and correctly designated on "Landslide Distribution Map" on a scale of 1/10,000.

Estimation of landslide hazard level

A hazard level assessment of landslide was carried out on the basis of the following criteria regarding topographic conditions and ground deformation. A hazard level was defined as A to C (from high to low) as a result of the hazard level assessment.

Table 2.1.3 The Assessment Criteria of Landslide Hazard

Hazard Level		Description
Slide	(A) High	A large number of obvious slide topography such as scarps, bulges, stepped land, ponds and swamp, and Many visible ongoing and active movements of cracks, subsidence, upheaval, toe erosion, small toe collapse as well as spring.
	(B) Medium	Obvious slide topography such as bulge, stepped land, ponds and swamp but, Less or small ongoing movements of cracks, subsidence, upheaval, small toe collapse.
	(C) Low	No obvious slide topography such as bulge, stepped land, and Invisible ongoing movements of cracks, subsidence, upheaval, small toe collapse.
Soil Collapse and Rock Mass Collapse	(A) High	A large number of obvious traces of collapse, toppling and rock slopes of daylight structures, and Visible ongoing slope collapse.
	(B) Medium	Obvious traces of slope collapse, toppling and rock slopes of daylight structures, but Less or small ongoing slope collapses.
	(C) Low	A large number of obvious slide topography such as scarps, bulges, stepped land, ponds and swamp, and Many visible ongoing and active movements of cracks, subsidence, upheaval, toe erosion, toe collapse as well as spring.

Source: JICA Study Team

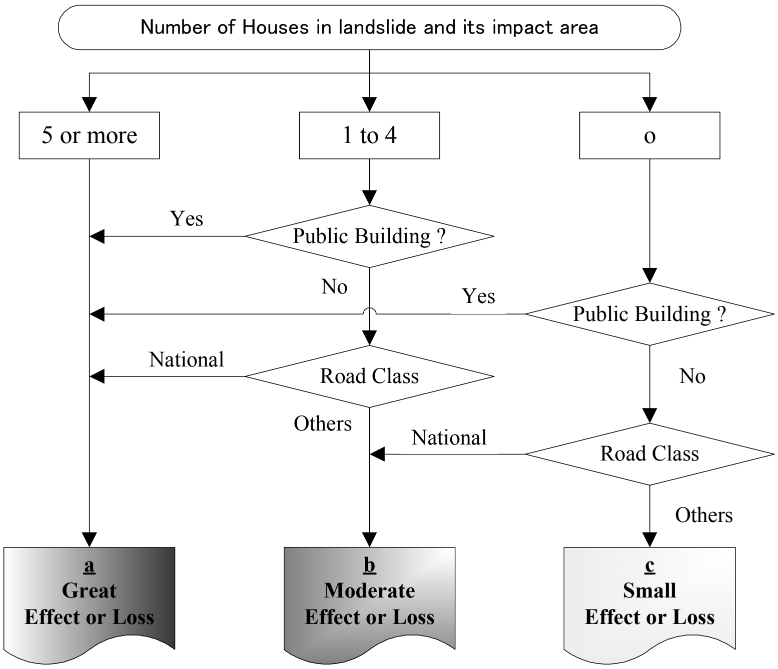
Preparation of landslide hazard map

Following the estimation of landslide hazard level, these landslides were divided, in terms of hazard level into A, B and C, and prepared as Landslide Hazard Map with different colours. The hazard map shows: a) the areal extent of threatening processes, b) where landslide processes have occurred in the past, c) where they occur now, and d) the likelihood in various areas where a landslide may occur in the future.

c. Step III — Risk assessment of landslide

Estimation of landslide related consequences

Estimation of landslide related consequences is to evaluate loss potential and other potential socio-economic impacts when a landslde occurs. In the study, the landslde related consequences include public building, residential houses and roads. Figure 2.1.4 gives the estimation procedure.



Source: JICA Study Team

Figure 2.1.4 Estimation Procedure of Landslide Related Consequence

Risk Rating of landslide areas

Risk assessment was carried out in consideration of: 1) landslide hazard level, and 2) landslide related consequences as shown in Table 2.1.4. According to the result of the assessment, the necessity of further study was determined.

Table 2.1.4 Risk Rating of landslide areas

Landslide Risk Assessment (I to IV)		Consequences		
		a	b	c
Hazard Level	A	I	II	III
	B	II	III	IV
	C	III	IV	IV

Source: JICA Study Team

2.2. FIELD CHECK AND LANDSLIDE HAZARD ASSESSMENT

2.2.1. Field Check Results

(1) Distribution of landslides

71 landslide areas were identified by interpretation of topographical map and satellite image and field check. The distribution of these landslides is shown in Landslide Hazard Map, while more detailed field check results for each landslide area are given in Appendix 1.

An outline of the 71 landslide areas is shown in Table 2.2.1. As shown in Landslide Hazard Map, the landslides are distributed mostly on eastern part of the Muzaffarabad City, and concentrated especially along the active fault.

Table 2.2.1 An Outline of Landslide Distribution

Number of landslides in the study area (nos)		71	
Area of landslides in the study area	Area of active landslides[1)] (m^2)		
	Area percentage of active landslides (m^2)		
	Area of potential landslides (m^2)		
	Area percentage of active landslides (m^2)		
	Total area of landslides (m^2)		
	Area percentage of landslides (m^2)		
Size of landslides	Number of landslides with width of over 200 m[2)] (nos)	33	
	Number of landslides with width of less than 200 m (nos)	38	

Note: 1): Active landslides include hazard A and B landslides, and potential landslides include hazard C landslides.
2): A landslide having a width of over 200 m is generally considered to be large-scale one.
Source: JICA Study Team

(2) Types and features of landslides

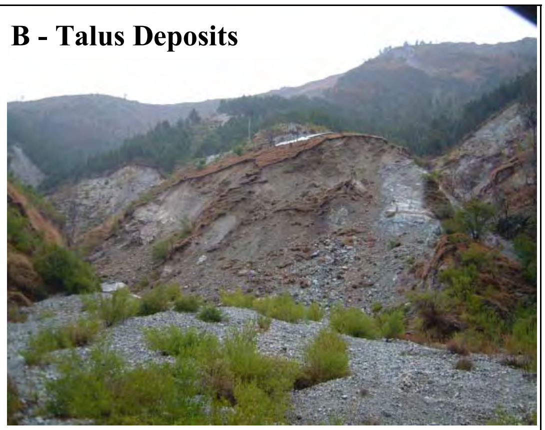
The landslides in the study area mainly include three types: a) soil collapses, b) Slides, and c) Rock mass collapses. Their typical characteristics and occurrence mechanism are respectively summarized below.

a. Soil collapses

Soil collapses can be subdivided, in terms of their locations and geological constituents, into two subgroups: one occurs in stream channel deposit in populated area (Figure 2.2.1A, Landslide No. NL30), and the other happens on talus deposit on the mountainous areas Figure 2.2.1B, Landslide No. NL43).

The former lies mainly on the steep cliffs of stream channel deposit, which have a height of approximately 50 to 100 m and a slope angle of 70 to 80 degrees. The stream channel deposit, which consists of silt, sand and gravel, is loose and susceptible to erosion. In spite of the shaking of the 2005 earthquake, its occurrence is attributed mainly to stream erosion and human activities such as house building and road construction. Further, because the soil collapses are distributed mostly in populated area, they may cause a great loss of lives when they fail.

In comparison with the former, the latter involves talus deposit overlying on bedrocks in mountainous areas. The talus deposit, which is generally 1 to 3 m, occasionally up to 5 m in thickness, is composed mainly of silt, sand, gravel and rock fragment. Because the soil collapses are distributed on the mountainous areas, they would cause less direct damage except for farm lands and forest. However, they are the main source sites of debris flows. The subsequent debris flow may reach the populated areas, similarly posing a much considerable hazard to life and property.



Source: JICA Study Team

Figure 2.2.1 Soil Collapses Occurred mainly on the Cliff Face of (A) Stream Channel Deposit and (B)Talus Deposits

b. Slides

More than 30 slides were identified in the study area. The slides lie mainly on the gentler hillslopes of 20 to 40 degrees and have a width of 150 to 500 m. They mainly involve surficial deposits and partially bedrocks.

Most of the slides are old ones and are reactivated by the 2005 earthquake. After the 2005 earthquake, many slides become active and have large and continuous tension cracks on the upper slope of slide areas. Slide materials remain mostly on the slope of slide areas (Note: A and B showing large and continuous tension cracks and sinkings at their head , C and D showing that many houses stand in slide areas and their impact areas. Arrows show sliding direction.

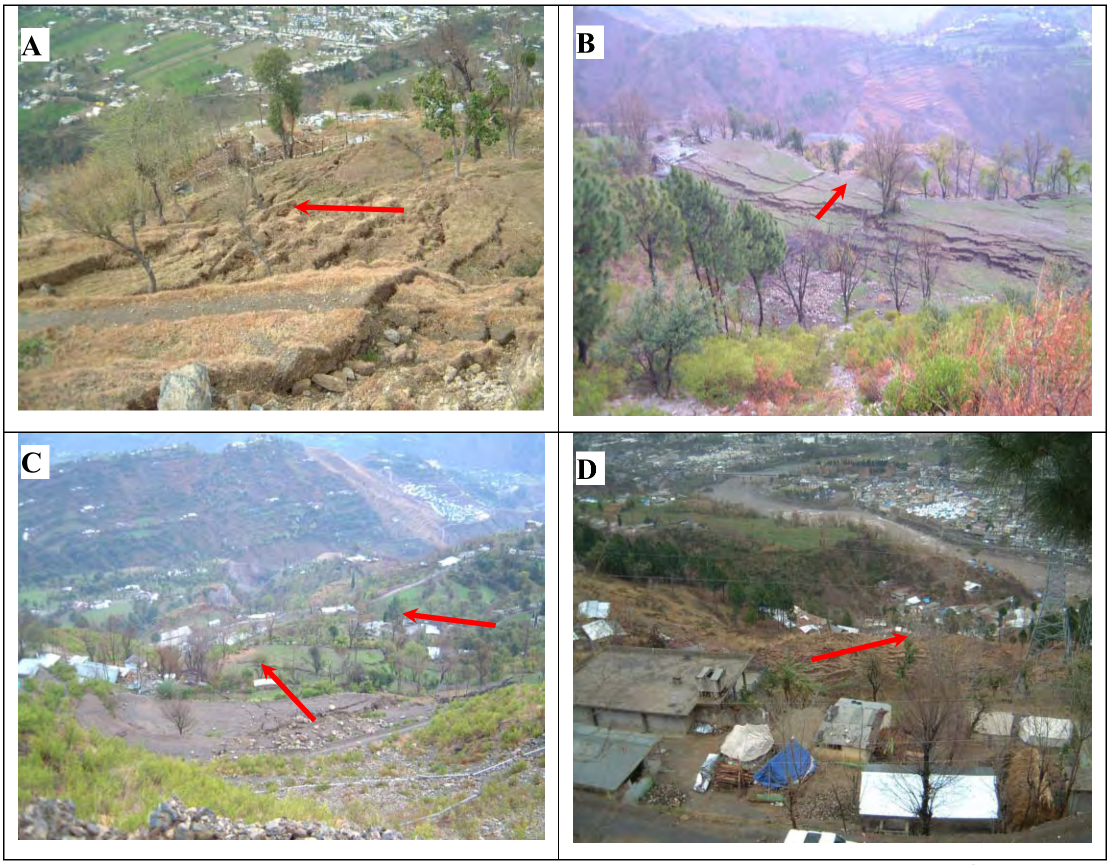
Source: JICA Study Team

Figure 2.2.2 A and B, respectively from Landslide Nos. NL5 and JL 43).

Because of old slides, pre-existing sheared or weakened planes (sliding surface) are present in these slide areas. The earthquake shaking not only pushes out the unstable parts above the sliding surface and also leads to reduced strength of the sliding surface by liquefying it if underground water exists around the sliding plane.

The slides, which have large and continuous tension cracks, are very likely to move out during the coming rainy season, if no actions are taken to stabilize them. The presence of the tension cracks at their head contribute largely to infiltration of surface water and rainfall into the sliding surface, leading to increased pore water pressure and reduced strength of the sliding surfaces, thereby reducing the stability of the landslide areas, consequently causing the sliding down of the whole slide areas. On the basis of local interviews, NL 65 slide (Figure 2.2.2D) started to move without any rainfall in the middle of this February; this indicates that the present safety factor of the slide is almost equal to 1 and could slide down with little or no external force.

Further, the slides are distributed in or close to populated areas, shown in Figure 2.2.2 C and D. The slides thus pose considerable threat to people and property.



Note: A and B showing large and continuous tension cracks and sinkings at their head , C and D showing that many houses stand in slide areas and their impact areas. Arrows show sliding direction.

Source: JICA Study Team

Figure 2.2.2 Slide Areas

c. Rock mass collapses

Various sizes of rock mass collapses are distributed primarily on the steep rock outcrops of limestone, sandstone and shale that are strongly jointed and cracked. After rock mass collapses, the exposed rock faces are mostly deteriorated into CL class and locally into D class rock mass (Figure 2.2.3 A and B).

Source: JICA Study Team

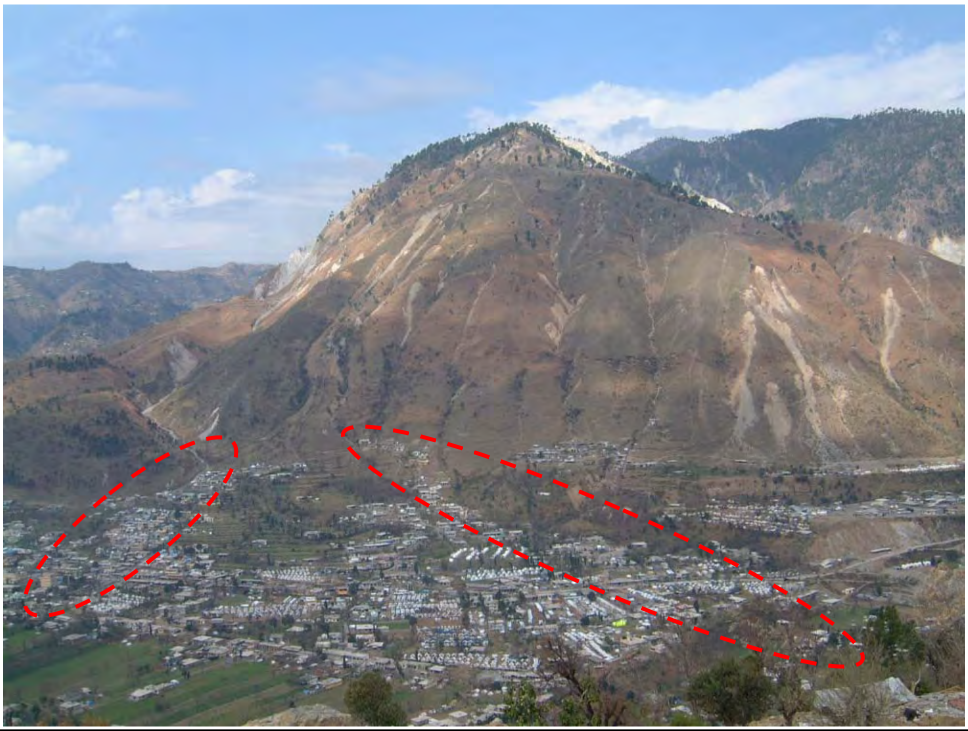
Figure 2.2.3 Rock Mass Collapses occurred on (A)Limestone and (B) Sandstone and Shale

On the basis of the field check, further rock mass collapse in the study area are considered to be less likely to occur because of the exposed CL class or higher class rock mass. However, some rock fall, minor rock mass collapse around the scars of collapses may take place during and/or after earthquake or heavy rainfall. The collapses are small in volume, but they may cause a considerable damage to road facilities and local people.

d. Debris flows

Debris flows are of limited occurrence up to the field check. However, as shown in Figure 2.2.4 as well as Landslide Hazard Map, in the eastern part of the Muzaffarabad City, distributed are various sizes of landslides that are mostly active and much likely to landsliding during this coming rainy season. Subsequent to landsliding during rainy season, the landslide materials could become fluidized by mixing rainfall water. Once fluidized, the landslide materials may move rapidly downslope, killing people and destroying houses or other structures in their path.

In the worst case, a severe rainstorm may trigger many landslides at the same time, and the landslides materials could come together and form a huge debris flow, which causes a devastating damage to the Muzaffarabad City. Therefore, similar to other types of landslides, debris flow also poses a great potential hazard to people and property.



Source: JICA Study Team

Figure 2.2.4 High Potential Hazard from Debris Flow on the Eastern Part of the Muzaffarabad City

e. Ground liquefactions

Ground liquefaction is a public concern, particularly in the central Muzaffarabad City.Although no detailed investigation related to ground liquefaction was conducted in the study, after undertaking this field check, we think that the likelihood of ground liquefaction in the central Muzaffarabad City is very small for the following reasons:

1) The outcrop of bedrocks is observable along the Neelum River. The overlying deposits are semi-consolidated river terrace that consists primarily of gravels and boulders. Geologically, such constitute and structure is very resistant to liquefaction.

2) During the field check, no evidence was found of ground liquefaction, such as large-area ground sinking and collapse in the central Muzaffarabad City.

(3) Main causes of landslides

a. Earthquake and landslides

On the basis of the field check results, after the 2005 earthquake, 55 landslides (including hazard A and B landslides) show movement indications such as crack, collapse, sinking and so on. They account for 77.5% of the identified 71 landslides. Evidently, the 2005 earthquake was the main trigger of the landslides.

b. Fault and landslides

The relationship between distribution of landslides and distances from landslides to faults was examined as shown in Table 2.2.2. The faults used for this examination were the ones shown in Landslide Hazard Map, and the distance of landslides from these faults was based on the topographical map with a scale of 1:10,000.

As Table 2.2.2 shows, about 80% of landslides are distributed within 1 km of these faults. This indicates that the distribution and occurrence of landslides in the study area is related closely to these faults.

Table 2.2.2 Distribution of Landslide and its Distance from Faults

Fault	Proximity of Fault					
	< 1km		1 – 5 km		> 5 km	
	Number	Percentage	Number	Percentage	Number	Percentage
HFT Fault	45	63.4	13	18.3	0	0
MBT Fault	11	15.5	2	2.8	0	0
Total	56	78.9	15	21.1	0	0

Note: Total number of landslides identified are 71.
Source: JICA Study Team

c. Stream erosion and landslides

On the basis of the field check and the prepared Landslide Hazard Map, the relationships between the 71 landslides and rivers as well as streams were analyzed and the results are shown in Table 2.2.3.

Table 2.2.3 Relationship between the Identified 71 Landslides and Rivers/Streams

Location of Rivers and Streams		Landslide Areas	
		Number	Percentage
1	At toe of landslides	29	40.9%
2	At sides of landslides	14	19.7%
3	Within landslide areas	9	12.7%
4	No relationship	19	26.7%

Note: When rivers are located at toe and at sides of a landslide, number of landslides was counted only one time.
Source: JICA Study Team

As shown in Table 2.2.3, more than 70% of landslides are influenced by river/stream flow (1, 2 and 3 in the table).

2.2.2. Assessment of Hazard and Risk of Landslides

The identified 71 landslides were first classified according to the assessment criteria of landslide hazard, as mentioned in Chapter 1, thereafter classified by Risk rating, into four catalogues. The assessment results are outlined in Table 2.2.4.

Table 2.2.4 Summary of Hazard and Risk Assessment Results

Level of Hazard and Risk		Landslide Areas	
		Number	Percentage
Hazard Level of Landslides	**A**	22	31.0%
	B	31	43.7%
	C	18	25.3%
Risk Level of Landslides	**I**	18	25.3%
	II	12	16.9%
	III	13	18.3%
	IV	28	39.5%

Source: JICA Study Team

It is noted that a landslide with a high hazard level is not always the one with a high risk level because risk is a function of location and proximity to human settlement and property whereas hazard just indicates the likelihood of a potential landslide.

The assessment results show that 18 landslides are much likely to move out and my cause great damage.

2.3. SUGGESTIONS AND RECOMMENDATIONS

2.3.1. Prioritization of Further Actions for Landslide Hazard Mitigation

As Landslide Hazard Map shows, a large number of landslides triggered by the M-7.6 earthquake of October 8, 2005, as well as some potential landslides are distributed mostly in or close to populated areas. Some active landslides are very likely to be triggered by heavy rainfall during the upcoming rainy season because many tension cracks are present at their top and sides. Further, the landslides generally involve relatively large masses of debris and earth, if they were triggered and transformed into debris flow during intense rainfall in the worst case, would destroy houses, wash out roads and bridges, sweep away people and vehicles, and obstruct roadways and streams with thick deposits of debris.

Therefore, these landslides, especially active, pose a great hazard to both property and lives. In order to mitigate hazard from landslides, following the landslide hazard assessment, further actions need to be taken.

Hazard from landslides can be divided, in terms of emergency of landslide related damage, into the following three classes:

1) Short-term hazard from landslides triggered by heavy rainfalls during the upcoming rainy season

2) Hazard from debris flow that could be triggered by intense rainfall

3) Hazard from landslides that would be triggered by human activities such as cutting and filling of road construction and house building, exhausted agricultural land use, deforestation, and so on.

In response to the above three classes of hazard, listed below is a prioritized list of actions that should be taken to mitigate landslide hazards in the Muzaffarabad City and its surroundings.

a. First priority — Design and execution of urgent measures for landslides with highest risk

This project will focus on landslides that are active and would cause great loss of life, as listed in Table 2.3.1. This project should be commenced immediately and be completed before the coming rainy season.

The following basic urgent measures to be proposed for each landslide area, which is listed in Table 2.3.1 are based mainly on the brief field check, and should be thus revised after more detailed geological mapping.

Table 2.3.1 Summary of Landslides Necessitating Urgent Measures

No.	Landslide No. 1)	Types of Landslides 2)	Hazard Level	Risk Level	Remarks
1	NL05	2	A	I	
2	NL16	1	A	I	
3	NL19	2	A	I	
4	NL20	2	A	I	
5	NL21	2	A	I	
6	NL34	2	A	I	
7	NL35	1	A	I	
8	NL36	1	A	I	
9	NL37	2	A	I	
10	NL38	2	A	I	
11	JL39	1	A	I	
12	JL41	2	A	I	
13	JL45	2	A	I	
14	JL46	2	A	I	
15	JL47	2	A	I	
16	JL48	2	A	I	
17	JL49	2	A	I	
18	NL65	2	A	I	

Note: 1) Landslide No. is same as that in Landslide Check Sheet.
2) Types of Landslide, 1 = Soil collapse, 2 = Slide.
Source: JICA Study Team

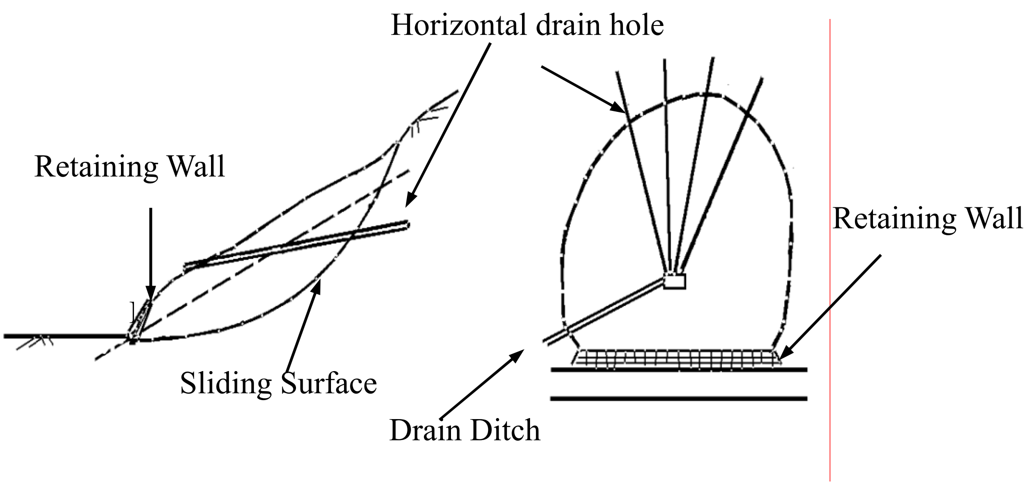
Surface drainage

Surface water should be prevented from infiltrating the landslide areas to avoid any hydraulic thrusts in open cracks within the landslides that may act in an adverse direction. Preventive works are surface drain ditches and crack filling with clay. These measures are effective and economic to the active landslides, and should be accomplished regardless of any results from stability analyses.

Subsurface drainage

Horizontal drainage holes at a gradient of 5 to 10 degrees upwards should be drilled to drain water from landslide areas and through its sliding surface. Figure 2.3.1 gives conceptual image of horizontal drain holes arrangement in a landslide area. The length and number of horizontal drainage holes depends mainly on the dimension of landslide.

The drainage measures mentioned above will not provide increased stability, but will only keep landslide area building up water pressures that do not exist before the rainy season. That is, drainage will maintain the current lack of significant water pressures within the landslide area and the nearby sliding surface. This work should be accomplished regardless of any results from stability analyses.



Source: JICA Study Team

Figure 2.3.1 Typical Arrangement of Horizontal Drain Holes

Removal of unstable landslide debris

Removal of unstable landslide materials is one of the main urgent measures. However, total removal of unstable landslide materials will be expensive and not feasible because of a large amount of landslide debris and probable subsequent collapse at its upper slope. Partial removal of landslide debris at its head is thus an effective way of improving the Factor of Safety for unstable landslide.

Catch type concrete or gabion wall

Catch type concrete or gabion wall appears to be a viable option if the space between the landslide toe and the objects to be protected is available. This work, which is constructed behind the objects (for example, institutions) to be protected, is intended to catch the landslide debris, thereby mitigating the hazard from landslide.

Relocation of houses in landslide area and its impact area

If none of the urgent measures mentioned above is viable, the only way to eliminate the possibility of additional landslide related losses or injuries is to remove the all houses and institutions from landslide area or its impact area to a stable place. Temporary evacuation, for example during rainy season should be also considered.

b. Second priority — Installation of early warning system for debris flow

Hazard from debris flow that is triggered during rainy season is also very great. The most hazardous area is Sunbal Nalla Stream and Manal Paian Nalla Stream in the eastern part of the Muzaffarabad City; on the upper slope of the streams, concentrated are active landslides that are much likely to occur during the upcoming.

In order to increase the ability of emergency managers to respond to future landslides and related debris flows, early warning systems based on weather forecasts and rainfall information should be developed and installed. The early warning system should cover all debris flow areas, namely, source area (landslide areas), path area and deposition area.

Several components are necessary for an early warning system to be effective. First, detailed maps depicting areas that are at high risk of debris-flow activity are essential. Secondly, standard management rainfall, such as rainfall intensity-duration thresholds for triggering of landslides, should be carefully determined by comparing the amount of rainfall necessary to trigger floods and landslides in several different storms and the storm events that are insufficient to trigger landslides (null events) These zones should be canvased with an automated network of rainfall stations upstream of areas susceptible to debris flows; this gives authorities the ability to issue warnings or evacuations if heavy rainfall is likely to exceed the intensity-duration thresholds.

As additional measures, regular inspection by qualified engineer should be also conducted to increase the ability to issue warnings or evacuations.

Further, public education on how to respond to warnings and safe means of evacuation are at least as important as the establishment of a warning system.

c. Third priority — Non-structural measures for landslide hazard mitigation

Approaches to landslide hazard mitigation can be generally divided into those involving construction of some type of physical structures and those involving non-structural measures. Non-structural measures can be generally cost-effective. The non-structural measures for landslide hazard mitigation include the restriction of activities in respect to landslides, converting and regulating development, instructions and advice for measures against disasters, establishment of warning and evacuation systems, identification of landslide hazard and risk areas, and so on. For example, land-use regulations can be used to reduce landslide hazards by limiting the type or amount of development in hazardous areas. A community can zone landslide hazard-prone areas for open space uses, such as parks, grazing, or certain types of agriculture. Alternately, within high hazard zones, the intensity of development can be kept to a minimum.

d. Fourth priority — Introduction of permissions in landslide damage area

Debris or earth resulting from slides or soil collapses could reach far distance from its original location and cause a great damage. Further, subsequent to landsliding, enlarged collapse may be induced on its upper slope. Landslide damage area should thus be introduced to mitigate landslide hazard.

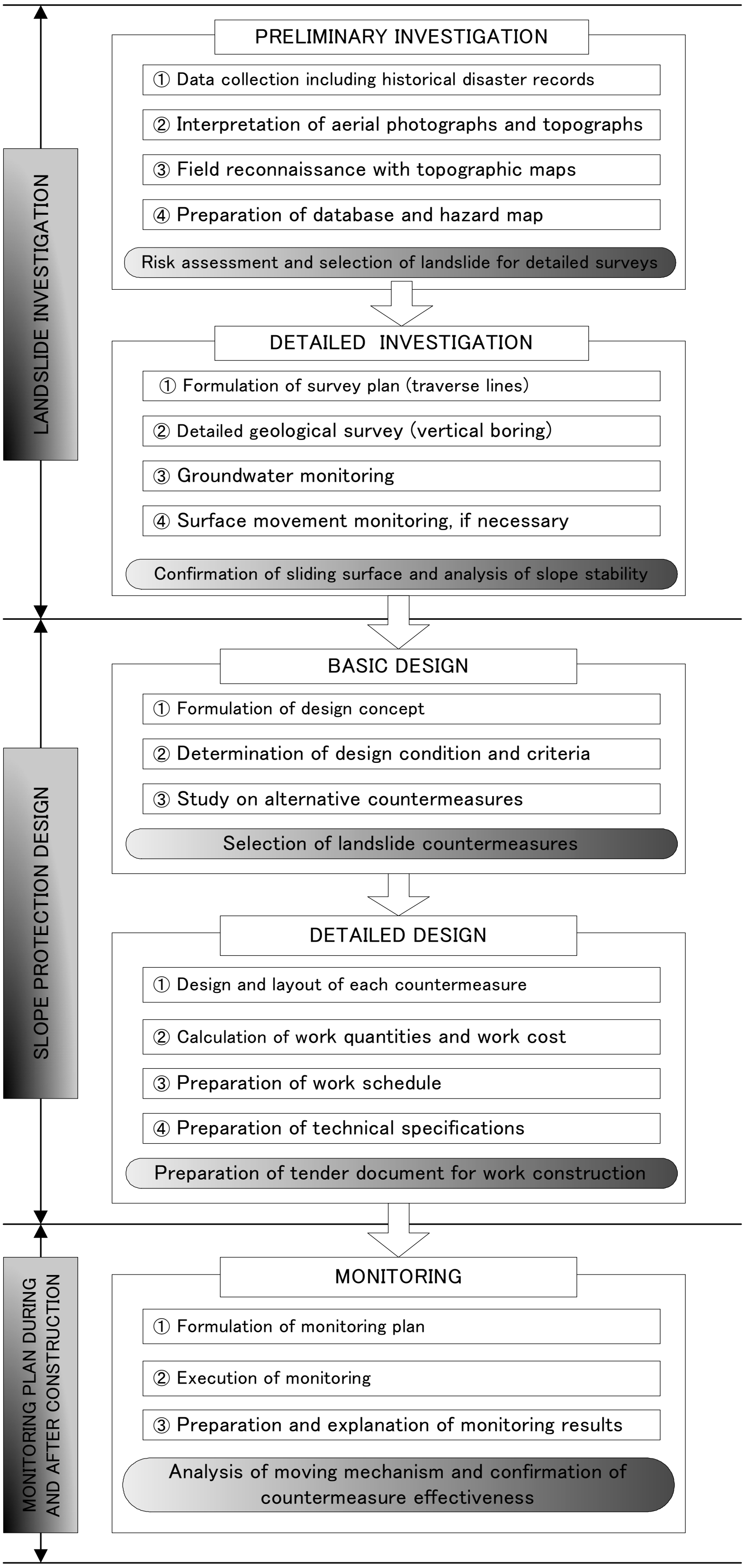
Japanese experience shows that more than 90% of landslides have slip distances less than 50 meters, this indicates that the area is safe when its distance from the landslide toe is more than 50 meters. Accordingly, the extent of landslide damage area is suggested to extend to 50 meters from its top and toe, respectively.

In a landslide damage area, such activities as house building, road construction, discharge and retention of water, excavations, filling, deforestation should require permission from local government.

e. Fifth priority — Execution of more detailed geological and geotechnical study and permanent stabilization works

In spite of the urgent measures mentioned in the above First Priority, permanent stabilization works should be planned and constructed for each landslide area listed in Table 2.3.1, if feasible technically and economically. The permanent stabilization works should be planned and constructed only after a more detailed geological and geotechnical study is conducted. When possible economically, the geological and geotechnical study should begin as soon as possible, to exactly analyze the slope stability of landslide area.

Figure 2.3.2 gives the proposed procedures for landslide investigation and design of stabilization works. Table 2.3.2 shows various countermeasures and their applicability.



Source: JICA Study Team

Figure 2.3.2 General Flowchart for Landslide Investigation and implementation of Preventive Measures

Table 2.3.2 Applicability of Countermeasures against Landslides

Classification		Type of works	Types of Landslides		
			LS	C	DF
1. EARTHWORK	Earthwork	Removal	○	○	○
		Rock Cutting	○	○	○
		Rock Pre-Splitting	△	○	○
		Soil Cutting	○	○	○
		Filling	○	○	△
2. VEGETATION	Vegetation	Re-Vegetation	△	○	△
		Hydroseeding	○	○	○
3. WATER DRAINAGE	Surface Drainage	Drain Ditch and Cascade	○	○	△
		Subsoil Drainage Hole	○	○	×
	Subsurface Drainage	Culverts	△	△	○
		Horizontal Drain Hole	○	○	△
		Drainage Well	○	×	×
		Drainage Tunnel	○	×	×
4. SLOPE WORK	Shotcrete Work	Shotcrete (mortar)	×	○	○
		Shotcrete (concrete)	×	○	○
	Crib Work	Crib work (Precast)	△	△	×
	Pitching	Stone Pitching	×	○	×
5. ANCHORING	Anchoring	Soil Nail	△	○	△
		Rock Bolt	○	○	△
		Ground Anchor	○	○	△
6. WALL AND RESISTING STRUCTURES	Retaining Wall	Stone Pitching Wall	○	○	△
		Concrete Block Wall	○	○	△
		Supported Wall	△	○	△
		Crib Wall	○	○	△
		Gabion Wall	○	○	○
		Pile Wall	○	○	△
		Reinforced Soil Wall	○	○	×
	Catch Work	Catch Fill	×	△	×
		Catch Gabion	×	△	○
		Catch Concrete Wall	×	△	△
7. PILING WORK	Piling Work	Steel Pipe Pile	○	△	×
		H Steel Pile	△	△	×
		Shaft Work	○	△	×
8. PROTECTION WORK	Protection Work	Rock Fall Catch Net	×	△	×
		Rock Fall Catch Fence	×	△	×
	Rock Shed	Rock Shed	×	△	○
		Debris Shed	×	△	○
	Sabo (Check) Dam	Slit Dam	△	×	○
		Check Dam (Sabo Dam)	○	×	○
9. OTHERS	Avoiding Problem	Diversion (Shifting)	○	△	○
		Route Relocation	○	△	○

Note: ○ : Applicable △ : Limited case × : Not applicable
SL : Landslide C : Soil collapse and rock mass collapse DF : Debris Flow
Source: JICA Study Team

2.3.2. Proposal of Pilot Project of Landslide Hazard Mitigation

The following two projects are proposed as pilot projects:

1) The Study on Landslide Hazard Mitigation in Muzaffarabad City
2) Design and Execution of Urgent Measures for High-risk Landslides

The outline and purposes of each of the two pilot projects are presented below.

(1) The Study on Landslide Hazard Mitigation in Muzaffarabad City

From these landslide areas identified in this study, one high-risk landslide area (for example, JN No. 30) is selected for pilot project. This project will involve geological investigations, monitoring, analysis of landslide mechanisms and stability, planning urgent and permanent preventive measures, and so on.

Objectives of the pilot project are:

1) Exhibition of Japanese high technology in landslide hazard mitigation
2) Technical transfer to the counterpart experts and local community
3) Dissemination of knowledge to inhabitants in the landslide area.

The preventive measures will mainly include subsurface drainage, retaining wall, anchor work.

(2) Design and Execution of Urgent Measures for High-risk Landslides

The target landslides are those high-risk ones, as listed in Table 2.3.1. In spite of the above objectives, this project is carried out to eliminate further loss due to landsliding and to improve the ability of local government in landslide hazard management.

The urgent measures are mainly surface drainage, subsurface drainage, removal of unstable landslide debris, relocation of houses within landslide area, and so on. This project should be commenced immediately and be completed before the coming rainy season.

(3) Raising Community Awareness- Based Landslide Hazard Mitigations

Community awareness campaign should be launched, in order to raise awareness in the community about the hazards of landslide. This campaign should be launched with cooperation and coordination of government, and private organisations. For the campaign, public seminars and meetings should be held with community. Monitoring and observation of landslide movement as well as field trips could be conducted by local people.

The project should include the following issues:

1) To provide basic tools of scientific/technical knowledge during the seminar and field trips for people in landslide areas to understand the phenomena they have experienced.
2) To make people aware of the real figures on how landslide movement is going on or may change in the near future on individual sites in a landslide area, in order to think how to behave or react by themselves. A simple monitoring by local people with simple equipment, existing landslide hazard map to be prepared, will be good tools for the subject.
3) To make people aware that the infiltration of water into the ground, either piped water or from streams, is the critical issue for landslides in general, and that correct management of infiltration water is most important.
4) To develop crisis management that is able to be adopted by people themselves in the event of landslide, which would include how to predict the time, speed and extent of the threatening movement.
5) To establish a "Village League" for landslide management, in order to exchange information and experiences, to cooperate for self-help and to make submissions for their requirements to the government.

This project should be commenced as soon as possible. The execution cost of this project is estimated to be about 2 to 3 million Yen.