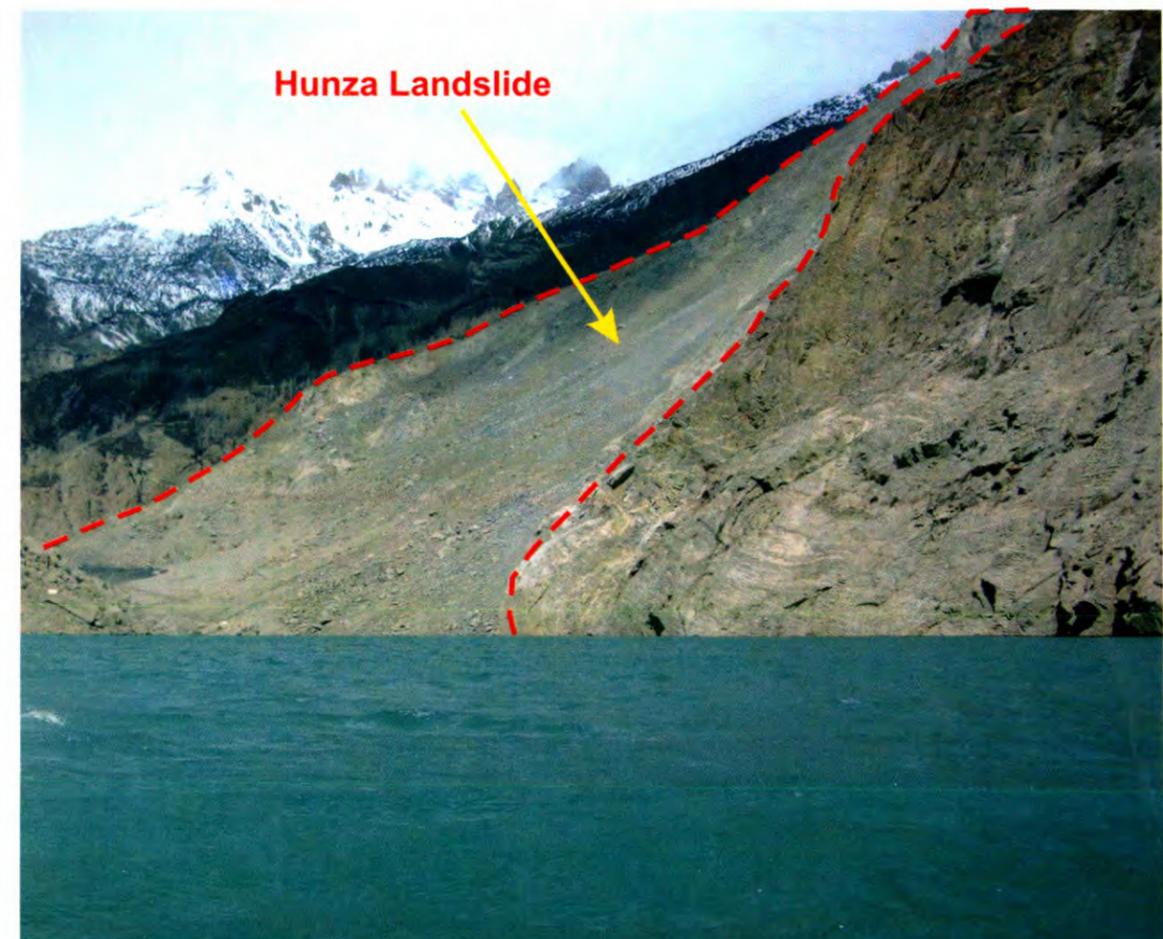


Government of Pakistan
Ministry of Petroleum & Natural Resources
Geological Survey of Pakistan



Information Release No: 893

**POST DISASTER THREATS IN ATTA ABAD AND
ADJACENT AREAS, HUNZA VALLEY,
GILGIT-BALTISTAN**



**Post Disaster Threats in Atta Abad
and Adjacent Areas, Hunza Valley,
Gilgit-Baltistan**

and

other GSP publications can be purchased
from following offices of the

Geological Survey of Pakistan

The Project Director,
Geodata Centre of Pakistan,
National Geoscience Research Complex,
Geological Survey of Pakistan,
Shahzad Town, Islamabad, Pakistan.
Tel: +92-51-9255139-40
Fax: +92-51-9255136
E-mail: geolab@gsp.gov.pk

The Director (Publication),
Geological Survey of Pakistan,
Sariab Road,
Quetta,
Pakistan.
Tel: +92-81-9211048
Fax: +92-81-9211018
E-mail: qta@gsp.gov.pk

by

**S. Hamid Hussain
Simon Sadiq
Mohammad Latif
Environmental & Engineering Geology Division**

**Issued by Dr. Imran Khan, Director General, Geological Survey of Pakistan
April, 2010**

EXECUTIVE SUMMARY

Much anticipated disaster of Atta Abad landslide occurred on 4th of January 2010. The Geological Survey of Pakistan had already given the parameters of the anticipated in its report on 2nd September 2009 i.e. four months in advance of disaster. The post disaster studies of Atta Abad and surrounding areas (Hunza District) were carried out by technical officers of Geological Survey of Pakistan (GSP) in March 2010 on the request of National Disaster Management Authority (NDMA). The landslide is not first of its kind in the area as there have been numerous events in the past owing to the particular tectonics and geomorphology of the Gilgit Baltistan region of Pakistan.

The bedrock exposed in the area mainly consists of granodiorite and gneisses with intrusions of pegmatite, aplite and quartz veins while the overburden comprises mostly glaciofluvial deposits with minor moraines, scree, river bed deposits and lacustrine clay. Other than the faulted contacts of gneisses with metasediments and Karakoram Batholith many local faults with displacement ranging from a few centimeters to one meter have been observed in the area, the bedrock is highly fractured and well jointed. The joint pattern analysis depicts a general probability of wedge failure in the area with relatively low chances of plane failure. The Atta Abad landslide is of complex nature mainly involving plane and wedge failures. It is 1900 m long and 600 m wide and has blocked the Hunza River creating a natural dam whose resultant lake is about 12 km long. The lake is more likely to fail and is a major threat to communities, infrastructure and environment in the downstream as well as upstream areas. The effects of inundation caused by possible dam breach may affect the areas as far as Tarbela and in particular the Tarbela reservoir. Controlled discharge of water is the only possible remedy to avoid the disaster.

The villages of Atta Abad, Atta Abad Paeen, Sarat and partly Salmanabad are not suitable for habitation. The Atta Abad landslide has further weakened the already fractured and jointed bedrock; water infiltration into cracks / joints will further accelerate the mass movement. Atta Abad Paeen and Sarat villages will be directly hit by flood generated by probable dam breach. Sarat is also facing a threat of failure of a large block of rock in its upslope area, its visible detachment from main body is up to one meter. The eastern terrace of Salmanabad is under a threat of undercutting in case of probable dam failure. The only possible remedy to avoid major disaster in these areas is immediate evacuation.

CONTENTS

	PAGE NO.
CHAPTER 1 INTRODUCTION	
1.1 Background	1
1.2 Location and Accessibility	1
1.3 Physiography	2
1.4 Hydrology	3
1.5 Climate	4
CHAPTER 2 GEOLOGY	
2.1 Stratigraphy	6
2.1.1 Baltit Group	6
2.1.2 Karakoram Batholith	7
2.1.3 Quaternary Deposits	7
2.2 Structure	7
2.3 Tectonic History	8
CHAPTER 3 GEOHAZARD ASSESSMENT	
3.1 The Landslide Disaster	9
3.1.1 Landslide Debris Material, Resultant Dam and Mud Flows	13
3.1.2 Dam Stability	15
3.2 Atabad Village	16
3.3 Atabad Paen	19
3.4 Sarat Village	19
3.5 Salmanabad Village	22
CHAPTER 4 CONCLUSIONS AND RECOMMENDATIONS	
4.1 Conclusions	26
4.2 Recommendations	26
ACKNOWLEDGEMENTS	28
REFERENCES	28

FIGURES

FIGURE	PAGE NO.
Figure 1. Location map of investigated area (Atta Abad and surroundings).	2
Figure 2. Rose diagram showing the general joint pattern in the area.	8
Figure 3. View of Atta Abad landslide and the resultant lake.	9
Figure 4. Location of Atta Abad Landslide.	10
Figure 5. View of Atta Abad landslide and resultant lake.	10
Figure 6. View of submerged KKH under lake water.	11
Figure 7. Schematic cross section of Atta Abad landslide area.	12
Figure 8. Spillway construction by FWO is in progress.	13
Figure 9. Mudflow in the downstream area.	14
Figure 10. Mudflow in its full swing (with courtesy from Mr. Abdullah, Geologist Bounji Dam Consultants)	14
Figure 11. Atta Abad landslide, Atta Abad village and Atta Abad Paean demarcated on Satellite image.	16
Figure 12. Schematic cross section of Atta Abad area.	17
Figure 13. Network of cracks in the Atta Abad village.	18
Figure 14. Map showing high hazard areas.	19
Figure 15. Side view of the detached block.	20
Figure 16. Top view of the detached block.	20
Figure 17. Upper and lower water channels above Sarat area.	21
Figure 18. Schematic cross section of Sarat area.	22
Figure 19. Location of 1858 landslide.	23
Figure 20. Crushed marble along slopes of Salmanabad village, right bank of Hunza River.	23
Figure 21. Marble bands on the left bank of Hunza River.	24
Figure 22. Aerial view of Salmanabad village showing different terraces.	24
Figure 23. Schematic cross section of Salmanabad area.	25

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

On 28th of July 2009, Geological Survey of Pakistan (GSP) was requested by National Disaster Management Authority (NDMA) to conduct the survey of the Atta Abad village in Hunza due to reported movement of terrain / ground in the area. The said survey was conducted by technical officers of GSP in August 2009, and they declared the eastern part of Atta Abad as high hazard; a rock avalanche with the potential to block the river was anticipated. On January 04, 2010 a large landslide occurred on right bank of Hunza River, in Atta Abad village of Hunza District, Gilgit Baltistan. The event claimed 19 lives in Atta Abad Paen and injured many others. The huge amount of debris blocked the Hunza River forming a lake in the upstream area. Luckily, no casualties were reported in the actual landslide area as 103 families were already evacuated by the District Administration after the NDMA declared the area as high hazard area on the basis of study of the Geological Survey of Pakistan.

On 16th February 2010, GSP received another request from NDMA for survey of the affected area and its surroundings including Atta Abad Paen and Sarat villages in post disaster period with a view to check whether the areas were still high hazard or they were livable / inhabitable. The resultant field work was conducted by GSP officers in the month of March 2010; during the fieldwork, the district administration of Hunza District requested to include the Salmanabad village in the survey, as well.

1.2 LOCATION AND ACCESSIBILITY

The Atta Abad village is situated in the extreme north of Pakistan. It is located at a distance of 760 km from Islamabad, 130 km from Gilgit, 30 km from Aliabad and 5.5 km from Karakoram Highway (KKH) near Sarat on steep valley slopes in Hunza valley. It lies in Survey of Pakistan topographic sheet No. 42 L/15 within the coordinates:

Upper Left 36° 19' 08.50" N, 74° 47' 58.14" E

Lower Right 36° 18' 35.36" N, 74° 49' 02.45" E

All weather metalled road (KKH) passes through the Hunza valley connecting Islamabad with Gilgit and further to Khunjerab Pass. Crossing Hunza River by suspension bridge after leaving KKH near Sarat, a narrow, steep, rough and unmetaled road leads to Atta Abad village.

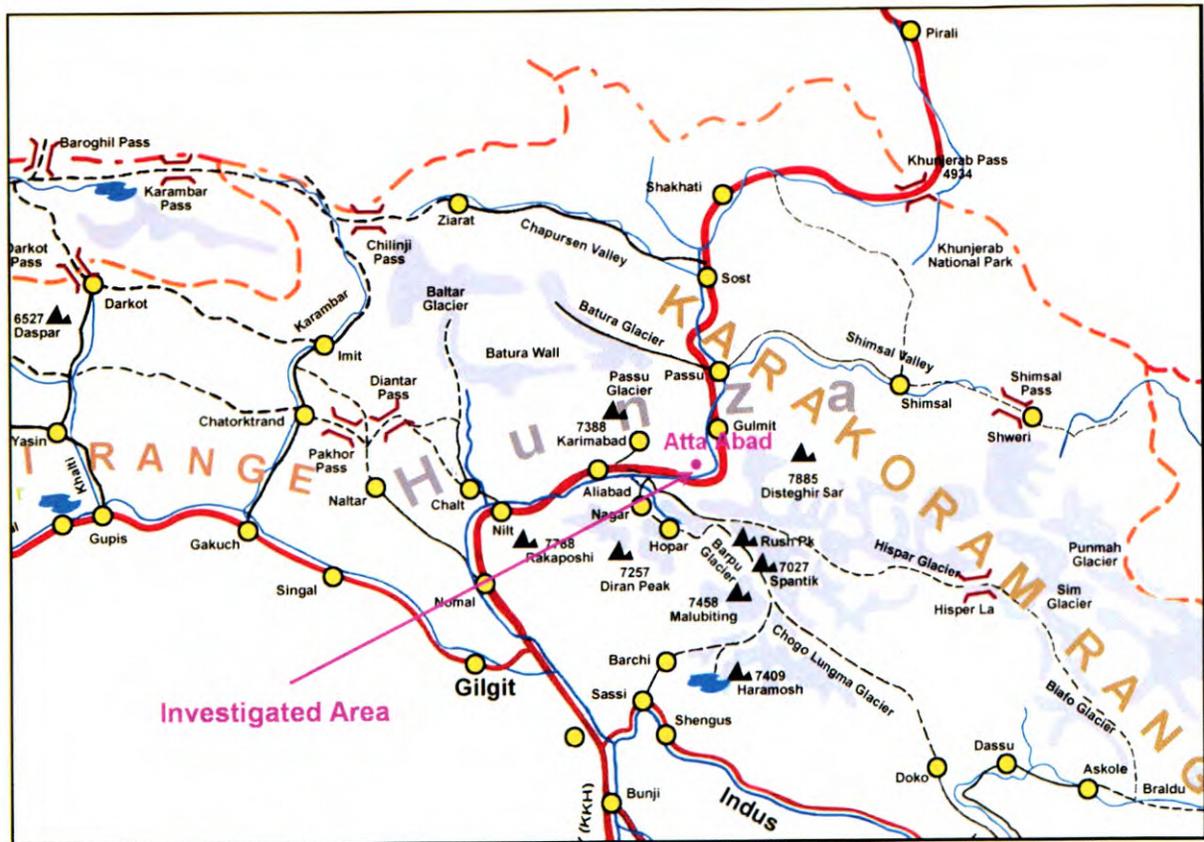


Figure 1. Location map of investigated area (Atta Abad and surroundings).

1.3 PHYSIOGRAPHY

The Hunza valley lies in the Karakoram Range within longitudinal range from $74^{\circ} 02'$ to $73^{\circ} 03'$ and latitudinal range $35^{\circ} 34'$ to $37^{\circ} 05'$ in the Gilgit Baltistan area of Pakistan. The Hunza basin occupies an area of about $16,390 \text{ km}^2$ and mainly contributes to Hunza River flow except a small part of it in the north east which drains in the Chinese territory. Chapursan, Kilik, Khunjerab, Ghujerab, Shimshal and Hispar Rivers are the main tributaries of the Hunza River. The basin borders in the north with China and Afghanistan, in the south with Shigar and Indus River basins, and in the west with Gilgit River basin. Terrain elevation ranges from 1500 meters to more than 7500 meters above mean sea level.

Altitudinal Organization and Geomorphology

The spectacular high relief of the area has facilitated distinctive altitudinal zones each with its characteristic attributes. According to Hewitt (1989) four major altitudinal zones can be delineated in this region:

ZONE I:

It lies above 5,500 m altitude with 90% area under snow, five glaciers lie in this area. Erosion and degradation is mainly due to rock fracture from frost action and extreme variation in diurnal temperature. There are frequent avalanches and rock falls. There are summits from glacial divides with sharp ridges, horns, spires and pinnacles.

ZONE II:

It lies between 4,000 m to 5,500 m altitude. It comprises high, alpine, humid tundra and includes the upper and middle ablation zones. It has a heavy snowfall period of 6-10 months and a short summer. Glacial and cryogenic processes dominate, with abundant mechanical weathering and rock fragmentation resulting in avalanches, rockfalls and debris flow. Valleys contain scree cones, cirques and valley glaciers, glacial moraines or rock glaciers. Spires and pinnacles are common features of this zone.

ZONE III:

It extends between 3,000 m and 4,000 m altitude and has sub-alpine features with seasonal droughts, cold sub-humid winters, warm summers, rarely grassy meadows and clumps of alpine trees. Mechanical rock weathering and periglacial processes are common features with glacial ablation, snow-melt run off, glacial lakes, glacial debris, talus cones, rock falls and landslides. Glaciers are located in this zone and they are covered with thick rock debris. Sharp, narrow and transverse ridges and intervening valleys having wide U-shaped sections characterize this zone.

ZONE IV:

It covers the area between 1,000 m and 3,000 m altitude and is climatically arid to semi-arid, with hot summers and frequent droughts. It comprises mountain valleys and basins which are in a continuous state of degradation resulting from paraglacial, fluvial and aeolian processes. Talus cones, alluvial fans, terraces, glaciofluvial, fluvial and lake bed deposits have formed along the wider stretches of valley flanks. Upper parts of the valleys exhibit U-shaped glaciated valley floor and glaciers descending from tributary valleys often have their snouts close to the confluence with main streams. In the lower reaches this zone contains abundant defiles, gorges and canyons.

1.4 HYDROLOGY

The main tributaries of Hunza River are Chapursan, Kilik, Bola Das, Khunjerab, ghujerab, Shimshal and Hisper. The Hunza river has its maximum flow usually in the month

of July when snow and glacier melt is at its peak while it falls down drastically during winter times. Melting of snow and glacier ice usually results in the highest instantaneous flow in the year (the annual maximum) while the intensity of the monsoon incursions diminishes considerably. In many cases where monsoon rainfall occurs at valley sites there is paradoxically a decrease in river flow. This is because rain occurs under cloudy skies with depressed temperatures which thus reduce glacial melt rate and more than compensates for rainfall inputs to the catchment (Collins, 1987).

Locally, four main streams / nalas flow through the Atta Abad village. They flow from north to south, and their names according to their order from east to west, are Beralisho, Baturkush, Hashkish and Iljimushk. The main source of Beralisho is snow melt, it is normally dry after all the snow on the upslope area has molten. The flow in Baturkush and Hashkish is both from springs and snow melts, that is why, they keep flowing throughout the year, whereas, Iljimushk is the main stream flowing between Atta Abad and Salmanabad villages.

1.5 CLIMATE

Mountain climates are extremely varied and depend on both i.e. broad global circulation patterns and local topographic influences. Singh et al (1995) is of the view that during the winter and spring the Karakoram area is affected by broad scale weather systems originating primarily from the Mediterranean or from the area of the Caspian Sea. Even in the summer some of the higher level precipitation originates from westerly systems (Wake, 1987). However, more local conditions prevail in winter under the influence of the Tibetan anticyclone (Archer, 2001). That is why some high altitude source areas have permafrost and annual precipitation more than 2000 mm while some of the large glacial snouts extending down to semi-arid valley floors receive less than 100 mm of annual precipitation (Roohi et al, 2008). Mountain climates are also influenced on medium and local scale by elevation, valley orientation, aspect and slope and the height and number of upwind barriers to the air flow.

The Gilgit Meteorological Station is the nearest station to the Hunza valley, and has a record of past 50 years. The record shows that the maximum temperature attains a value of normally more than 35°C during summer season while January is the coldest month when maximum and minimum temperature ranges between 10°C and -2°C. Table 1.1 indicates the rainfall data of Gilgit Meteorological Station from 1960-90 which depicts an annual rainfall of 129 mm with a minimum monthly rainfall of 1.8 mm in November and maximum monthly rainfall of 25.3 mm in May (NACS, 2001).

Table 1. 1 Mean rainfall (mm) of Gilgit (1960-90)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
4.0	6.0	12.6	23.0	25.3	6.1	15.6	15.5	6.5	8.4	1.8	4.1	128.9

Source: Northern Area Conservation Strategy (NACS), 2001.

The maps prepared by Pakistan Meteorological Department show that the Atta Abad area has a mean annual temperature of 10-12 °C, calculated on daily basis, while the mean annual rainfall is less than 200mm.

CHAPTER 2

GEOLOGY

2.1 STRATIGRAPHY

The rocks exposed in the area in order of their superposition are as follows:

Formation Name	Age	Lithology
Baltit Group	Pre-Cambrian	Gneisses, schists, quartzite, silicate marble, dolomitic limestone with intrusions of pegmatite, aplite and quartz veins with xenoliths of country rock.
Karakoram Batholith	Cretaceous-Tertiary	Granodiorite, diorite, pegmatite, aplite and quartz veins.
Quaternary Deposits	Pleistocene-Recent	Moraines, fluvio-glacial deposits, clay and river bed deposits.

2.1.1 Baltit Group

The rock units of Baltit Group exposed in the investigated area are gneisses (mostly orthogneiss with minor paragneiss), silicate marble with intrusions pegmatite, aplite and quartz veins. Baltit group has variable lithology which may be the result of varying effects of regional tectonics on it. The two major tectonic events which have affected these rocks are the Nanga Parbat Haramosh looping in Central Karakoram and Main Karakoram Thrust which runs all along its length (Tahirkheli, 1982). Gneissic rocks which crop out in Salmanabad, Sarat and Atta Abad areas are of different types such as orthogneiss, calcareous gneiss and amphibole biotite gneiss.

The gneissic rocks consist of sodic plagioclase, biotite, muscovite and garnet. Biotite is often altering to chlorite, rotational effects in mica crystals are common. Calcareous gneiss is essentially composed of alkali feldspars (perthite), hornblende, diopside and carbonate with sphene, biotite and phlogopite as accessory minerals. Amphibole biotite gneiss is dark grey in colour and composed of hornblende, biotite, quartz and feldspar. This unit has alternate layers of quartz, biotite and feldspar.

2.1.2 Karakoram Batholith

Predominantly granodiorite with minor diorite are the rock units of Karakoram Batholith which are exposed in the upper reaches of Atta Abad and Salmanabad areas. These rocks are profusely intersected by pegmatite, aplite and quartz veins. Xenolith of gneissic rocks are also common in the contact zone with Baltit Group.

Granodiorite consists of quartz, feldspar both micas with zircon, apatite and magnetite as accessory minerals. The stained quartz, bent plagioclase and garnet are indicators of some metamorphism to which this rock has been subjected. The gneissic character is common in this rock but mostly at the contact with country rock.

2.1.3 Quaternary Deposits

Different types of Quaternary deposits are present in the investigated area. These are moraines, fluvioglacial, clay (lacustrine type) and river bed deposits. Most parts of such deposits are under human activities / used as agricultural land.

2.2 STRUCTURE

Structurally, the area is very disturbed. All the major faults and formational contacts almost follow the east-west trend. Two major faults have been observed in the area.

1. Between marble bearing strata and gneisses of Baltit Group (passing through Salmanabad area).
2. Between gneisses of Baltit Group and Karakoram Batholith.

Many other intraformational faults have been studied which have displacement from few centimeters to one meter. It looks like that the fault which passes through the eastern side of Atta Abad village is partially active because activities in Recent deposits have been noticed. A big crack has been noticed by a local in the range of left bank of Hunza River, nearly passing in the north-south direction up to Hopar Power House in Hispar Valley. The opening of the crack is reported to vary from place to place, up to 1 m.

Foliation and lineation in the deformed rocks are the prominent structural features; foliation is very well developed in the area. The trend is always and almost the same throughout the area with minor local variations. The general trend is NW-SE. The dynamothermal metamorphism of rocks in the area has developed many sets of joints. Figure 2 shows the rose diagram of the joint sets data.

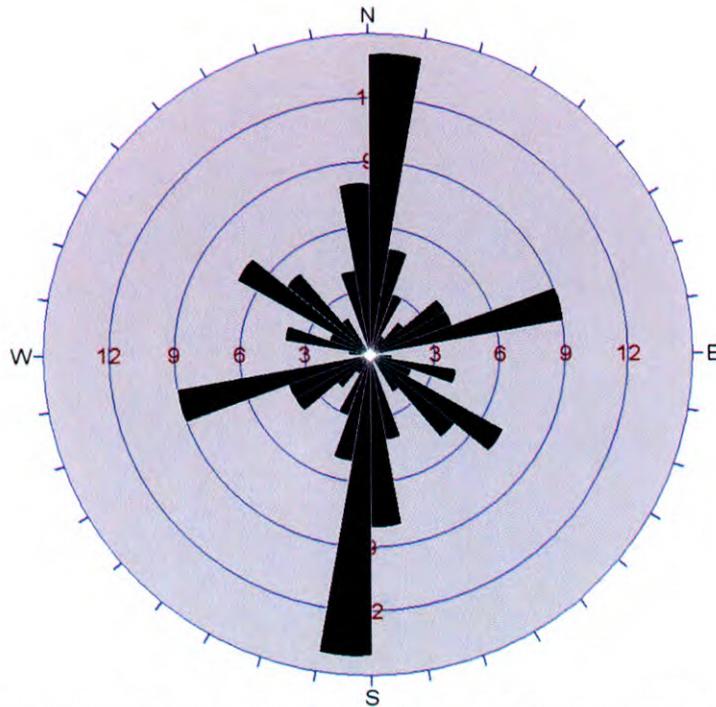


Figure 2. Rose diagram showing the general joint pattern in the area.

2.3 TECTONIC HISTORY

The investigated area lies in the Eurasian Plate, near its southern margin (Karakoram Range). Two major tectonic events which affect and control the Karakoram evolution are the Hazara Syntaxes and the Nanga Parbat Haramosh Massif, the later has a direct effect on Karakoram Range.

On the basis of broad regional tectonic setup, the Karakoram Range is characterized by continent-continent and continent-arc collision zones. The continent-continent collision boundary in southern Tibet is traceable along Indus Tsangpo Suture (ITS) which bifurcates further west into the continent-arc collision zones, the Main Karakoram Thrust (MKT) and the Main Mantle Thrust (MMT). The investigated area is located in the north east of Nanga Parbat Haramosh Massif while the Main Karakoram Thrust (MKT) is passing just in the south near Chalt.

CHAPTER 3

GEOHAZARD ASSESSMENT

3.1 THE LANDSLIDE DISASTER

On 4th January 2010, the much anticipated landslide occurred; it has been estimated as 1900 m long and 690 m wide. It is basically a right bank slope failure of Hunza River which flows there nearly in the east-west direction, and the locality is known as Atta Abad after which the landslide has been named as Atta Abad Landslide. The landslide debris from the right bank after blocking the river moved up towards the left bank where it attained a height of about 200 m. The resultant lake has attained a length of 11.7 km on March 26, 2010 with a maximum height of about 70m; figure 3 shows the landslide, natural dam and resultant lake.



Figure 3. View of Atta Abad landslide and the resultant lake.

The landslide debris hit the houses in Atta Abad Paen about half a kilometer downstream, and it was the area where 19 casualties have been reported. Luckily, there was no life loss in the actual landslide location as the area had already been evacuated in response to the report submitted by Geological Survey of Pakistan. The upstream areas are slowly but steadily submerging under water e.g. more than 12 houses of the village of Aeenabad have already submerged, and the lake level is still rising.

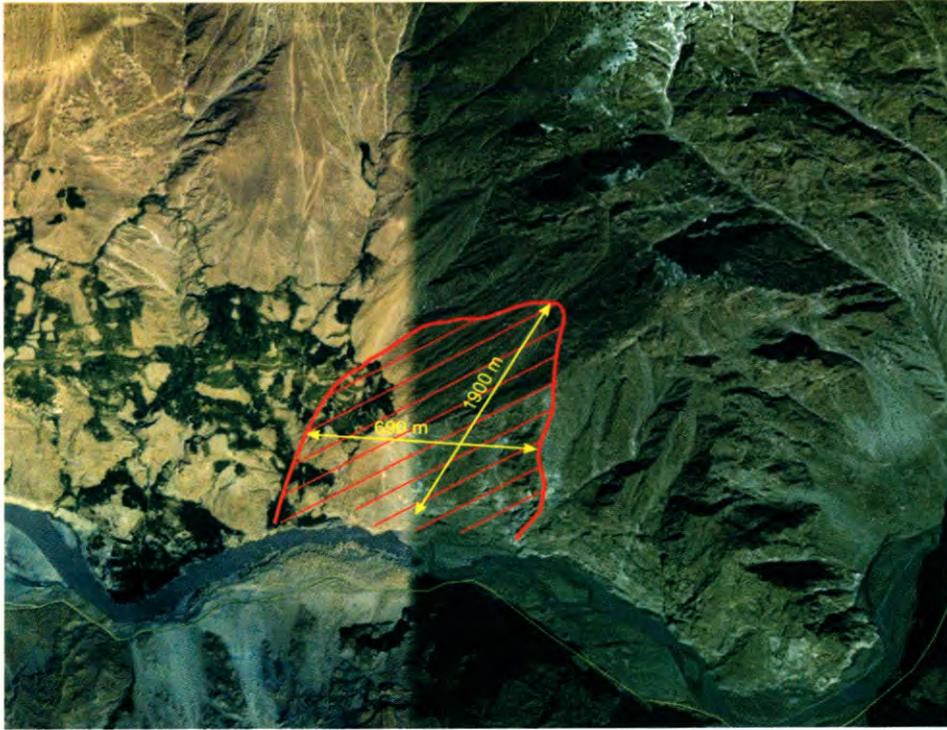


Figure 4. Location of Atta Abad Landslide.



Figure 5. View of Atta Abad landslide and resultant lake.

On the other hand, the disaster has adversely affected the Karakoram Highway which is still blocked due to landslide debris; parts of KKH in the upstream area are submerged under lake water formed by the river damming (Figure 6). This has adversely affected trade with China as the goods have to be transported in the boats in order to cross the lake area. This has increased the cost to a much higher level due to increased time and wages involved in unloading and loading of the goods. The government is bearing extra money in transportation of utilities to the upstream areas through boats as well as helicopters. People moving to and from upstream areas to the rest of the country, specially female and children are suffering a lot as they have to cross a long and uneven area by foot in order to board on the boats to cross the lake.



Figure 6. View of submerged KKH under lake water.

Moreover, the landslide has posed a permanent threat to the downstream as well as upstream areas. The possible dam failure can generate a huge flood in the downstream areas which may have its impacts up to Tarbela. A similar event in the main stream of Indus River in the year 1841 when the river was blocked at the foot of Nanga Parbat for a period of about six months formed a lake stretching 55 km upstream. When it broke out, it swept away

complete villages and towns and a force of 500 Sikh soldiers encamped by the river instantly perished (Archer, 2001). The people from the upstream areas may also suffer from rapid draw down in case of dam failure which may induce mass movements at some places.

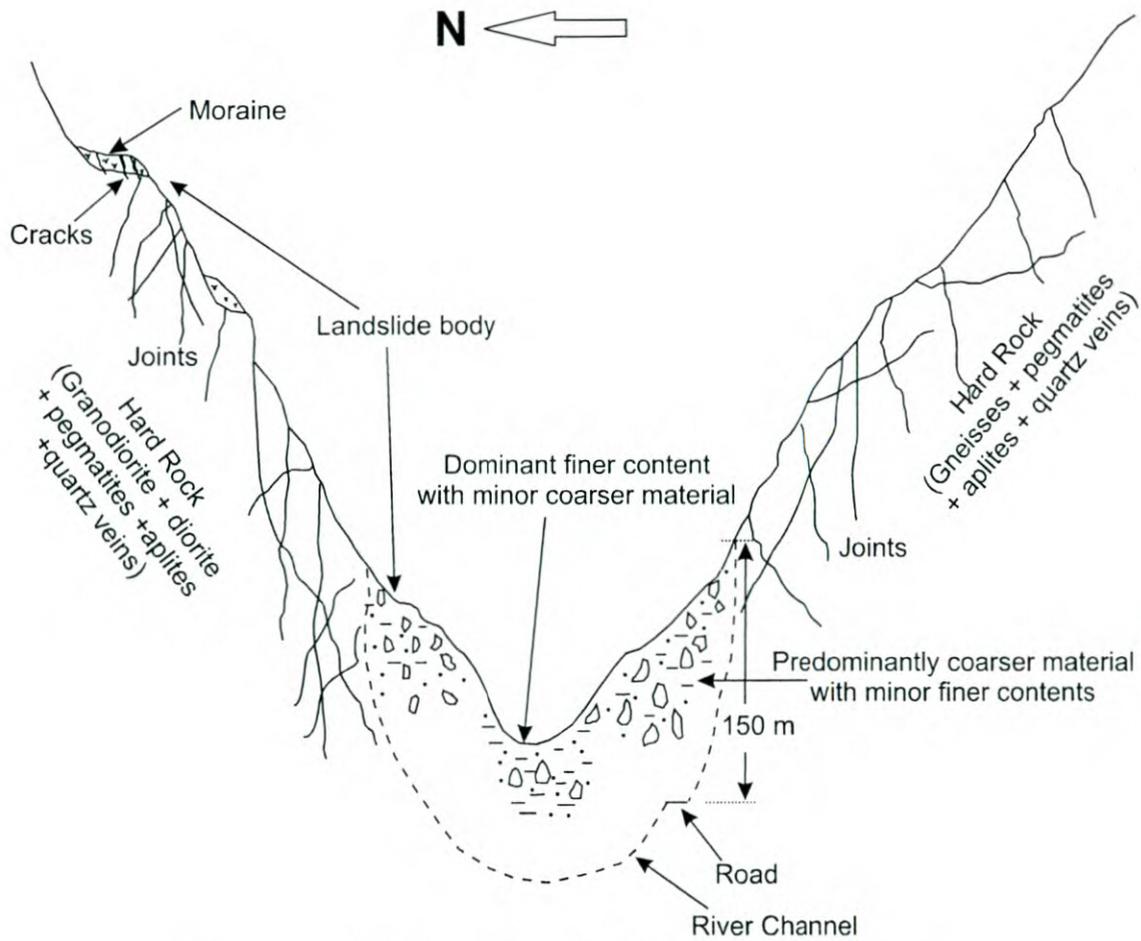


Figure 7. Schematic cross section of Atta Abad landslide area.

The material which slid comprised fluvio-glacial deposits, mainly moraines, lying over bed rock. The moraines are predominantly sandy and silty matrix with rock fragments of pebble, cobble and boulder size; the rock body is predominantly diorite and granodiorite. The analysis of the general joint set data of the area suggests the wedge failure to be the more probable mode of failure with less chances of plane failure, and almost no chances of toppling. Other than general joint sets, there are many other discontinuities in the form of local faults which have been observed at many places. Probably, these local discontinuities in collaboration with general joint sets provided a plane of failure which was reinforced with wedge failure. It is important to note that local people observed large rock pieces falling from the landslide area two days before the actual event happened; it is quite possible that wedge

failure may be the source of that rock fall. So, it can be inferred that Atta Abad landslide is a complex landslide involving more than one sort of failures.

3.1.1 Landslide Debris Material, Resultant Dam and Mud Flows

The landslide material varies in grain size from clay to large boulders. As the source of the debris is bedrock alongwith moraine deposits, the presence of clay shows some lacustrine environment in the area which further suggests the probable damming of the Hunza River in the past. Near Salmanabad village about 2.5 km downstream of the Atta Abad Landslide locality, the signs of an old landslide were noticed which probably belonged to the year 1858, and the clay seen in Sarat area and Atta Abad Landslide debris is, probably, the result of the damming of Hunza River due to that particular landslide.

The size of the embankment is about 250 m wide and the length is more than 1 km. The main landslide material has accumulated on the opposite side (left bank) of the river where it attains its maximum elevation of about 200 m above the river bed. The resultant saddle has the lowest elevation which was about 125 m above the river bed, and this is the area where FWO is excavating for a spillway (Figure 8).



Figure 8. Spillway construction by FWO is in progress.



Figure 9. Mudflow in the downstream area.



Figure 10. Mudflow in its full swing (with courtesy from Mr. Abdullah, Geologist Bounji Dam Consultants)

As most of the landslide mass has crossed the Hunza River so the saddle is more oriented towards the right bank of the river. The clay is very prominent in the downstream area in the form of slush which indicates that the saturated clay flowed in the form of mudflow. Local people witnessed the same type of mudflow in the upstream area as well. Field observations suggest that the clay was deposited at the foot hill of the cliff. It seems that the clay layers were trapped within the landslide debris, and the mud flows were triggered by the phenomenon of liquefaction. The downstream mudflow has been traced to a distance of about 1.7 km. The marks on the river banks show that the mudflow, at the time of its initial mobilization, was much higher than the present level.

3.1.2 Dam Stability

Field visits and previous experience suggests that the sustainability chances of the landslide dam are very rare; it is more likely to fail. The more recent past example in the area is the damming of Hunza River due to snow avalanche from Momhil Glacier near Shishket which could not sustain for more than six months. The mode of failure of the dam is a debatable issue, it seems that the nature of landslide mass will play an important role in formulating its mode of failure. It has been observed that the material size ranging from clay particles to large boulders of the dimensions of 14 m x 5 m x 7 m are present here. It is not possible without drilling to assess whether the main mass beneath mainly comprises the large rock boulders with subordinate matrix or mainly fine particles with some boulders in it. If the scenario favours the dominance of large boulders then the tendency of relatively slow failure increases because the huge boulders, will probably, retard the quick erosion and failure of the dam. On the other hand, if main portion of the mass is fine matrix with some boulders then the probability of a sudden failure increases.

As discussed earlier, it is very difficult to assess the nature of the landslide mass from the surface alone because it has been noticed that the material composition varies from place to place, e.g. the upstream portion and the sides of the embankment material seems to have more boulders while the saddle portion seems to have dominant finer content.

Once the lake starts to overflow, the dam, first few days may be very crucial in formulating the erosion scenario of the dam. The administration and the monitoring teams should be at high alert due to a possible flood in the downstream areas.

As the input flow in the lake is increasing day by day due to approaching summer and the seepage from the lake towards downstream side is also increasing day by day, there is a need to closely monitor the dam for the safety and rescue of people living downstream areas.

Moreover, a big landslide, snow avalanche or a rockfall in the lake can cause a momentum in the reservoir which can push the landslide dam to sudden failure. So, the upstream areas should be studied in this context as well.

It is, therefore, recommended that the dam break analysis for this particular event should be carried out to anticipate the probable mode of dam breach alongwith the possible flood level in the downstream area.

3.2 ATTA ABAD VILLAGE

Atta Abad village is mainly situated on fluvio-glacial deposits mainly consisting of moraines and reworked deposits of moraines due to fluvial activity. The bedrock under the fluvio-glacial deposits is highly fractured and well jointed.

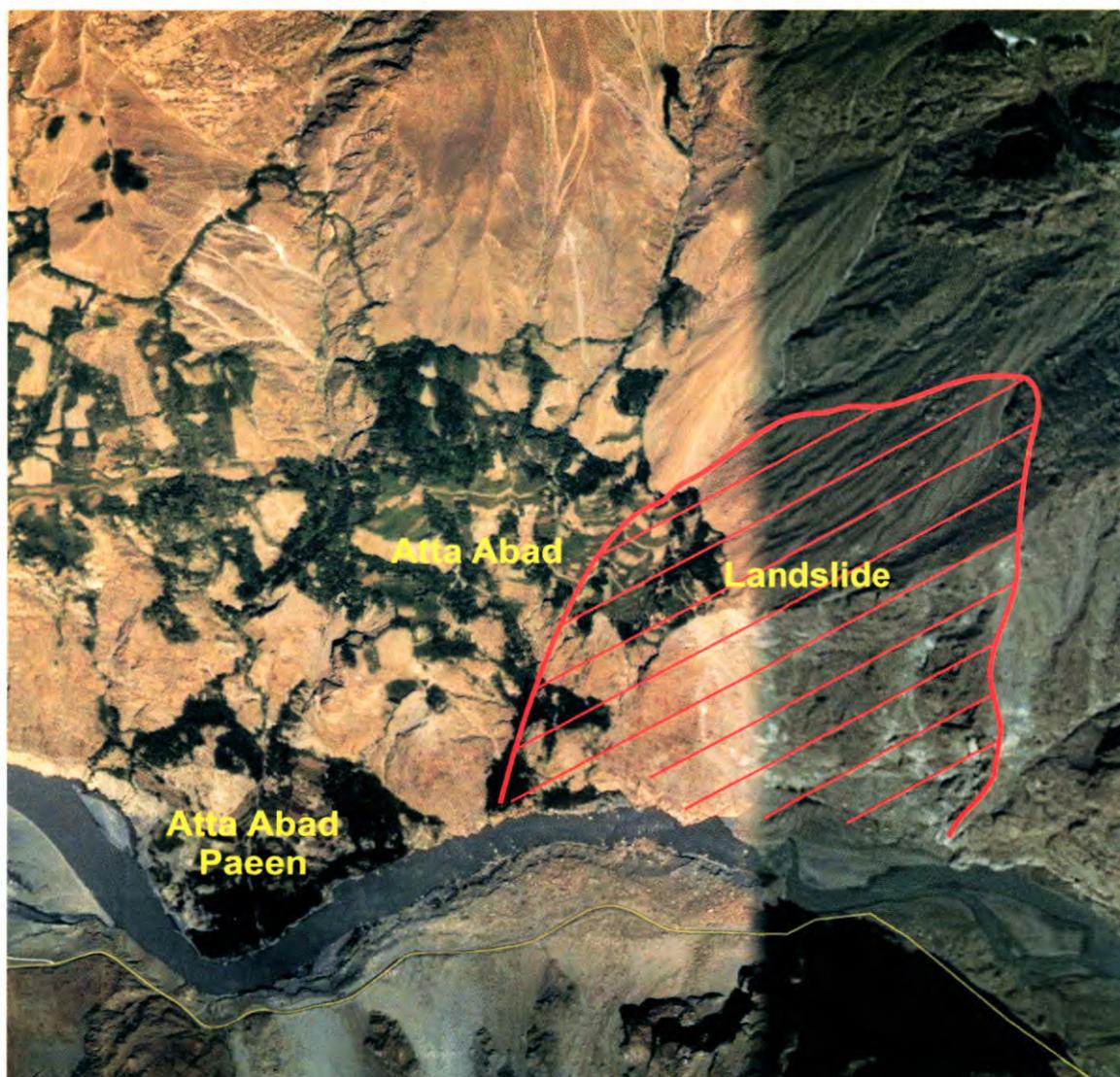


Figure 11. Atta Abad landslide, Atta Abad village and Atta Abad Paeen demarcated on Satellite image.

The eastern part of the village has already slid while cracks of different sizes have been developed in the remaining western part; these cracks have an increasing concentration towards the landslide area. If water enters into the cracks, it will further widen them triggering the mass movement as the slopes are already steep enough to facilitate the movement. Moreover, the rocks beneath the Quaternary deposits are highly fractured and jointed; when water infiltrates the joints, their openings will increase in response to frost and thawing effects, and it will further worsen the situation.

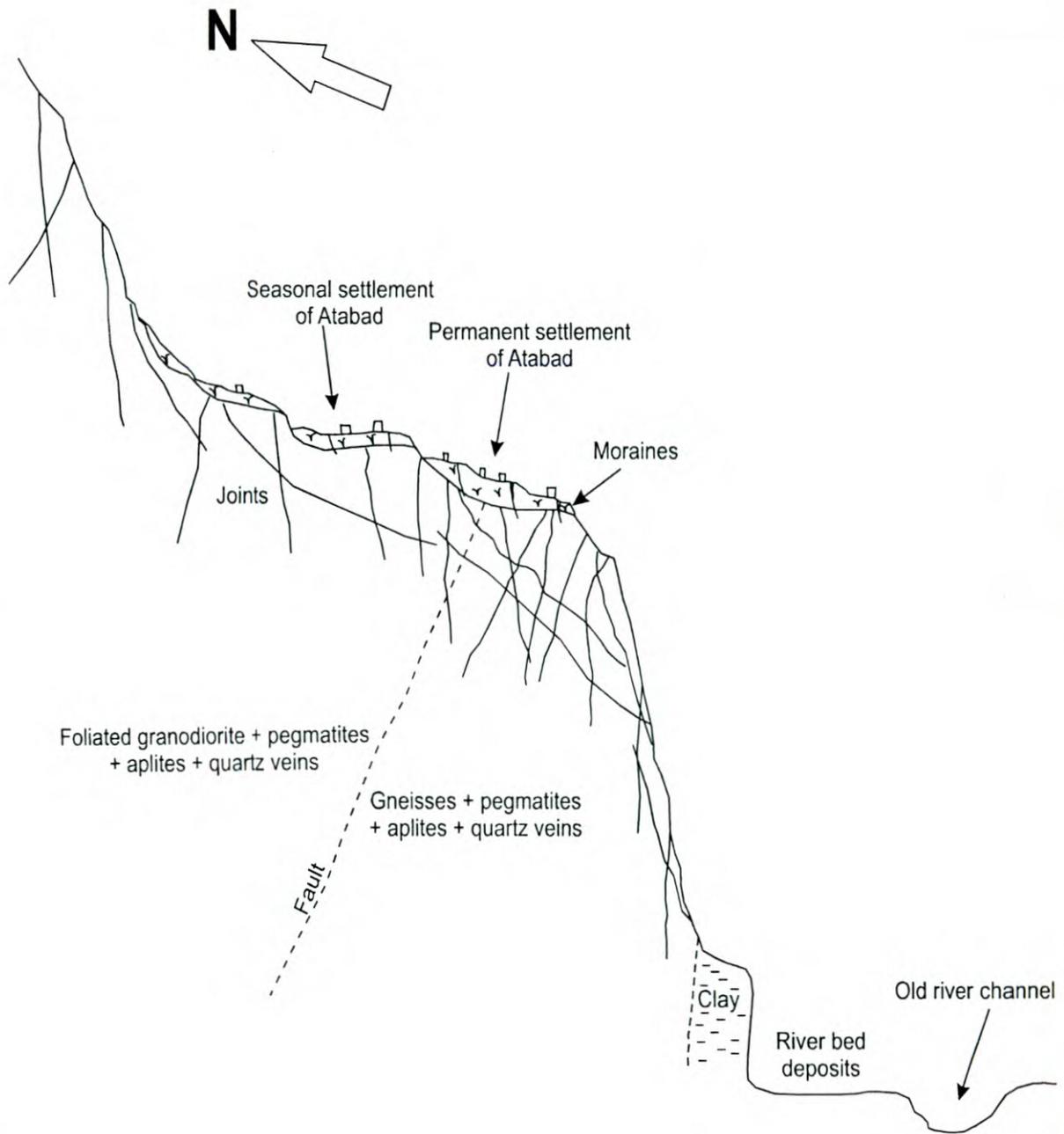


Figure 12. Schematic cross section of Atta Abad area.

The Atta Abad village should be abandoned for habitation as the human activities will cause more water infiltration into the cracks. One thing is important that if the Atta Abad village is evacuated then it can delay the mass movement for some time as no human activities will be involved to accelerate the landsliding process. A map showing high hazard areas has been shown in figure 14; red colour shows high hazard areas which should be abandoned for inhabitation.



Figure 13. Network of cracks in the Atta Abad village.

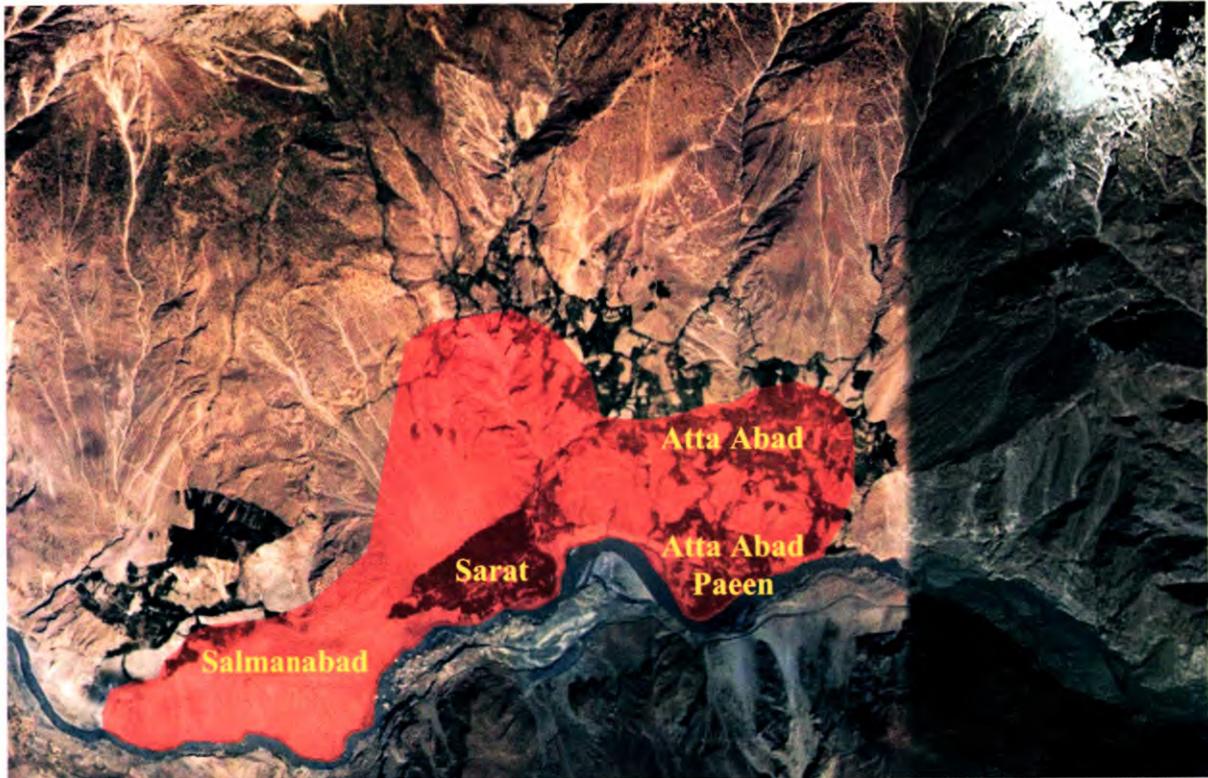


Figure 14. Map showing high hazard areas.

3.3 ATTA ABAD PAEEN

Atta Abad Paeen is located at foot hills of main Atta Abad village, and it is the location where 19 casualties have been reported due to landslide debris. It is at the mouth of the natural landslide dam, and will be directly hit by the flood generated / overflow by probable dam breach. It is a very high hazard area, and all the inhabitants should be shifted to a safer place.

3.4 SARAT VILLAGE

Sarat village is located about 1.5 km downstream of the Atta Abad natural dam, at an elevation of about 20 m from the river bed. In case of dam breach, the Sarat village will be under a direct threat of river undercutting as well as inundation flooding. Other than the dam breach issue, the ridge at the back slope has posed a direct threat to the village. Generally, the rock body of the ridge is highly jointed but a particular rock block of the approximate dimensions of 90 m x 50 m x 45 m is a permanent threat to the inhabitants. The full extension of the crack is not visible in the downslope area due to scree accumulation along the slope. The visible detachment is 50 centimeters to 1 meter from the main body, and its tendency to

fall is towards the main valley where the Sarat village lies as the general slope is towards the river valley.



Figure 15. Side view of the detached block.



Figure 16. Top view of the detached block.

Unfortunately, the locals have been, and are still using the lower part of this huge detachment crack as a water channel. Actually, there are two water channels i.e. the upper water channel and the lower water channel, the part of the former falls down through the detachment crack then join the lower one. According to locals, the crack first appeared about 10 years ago but the opening became much wider 3-4 years ago.



Figure 17. Upper and lower water channels above Sarat area.

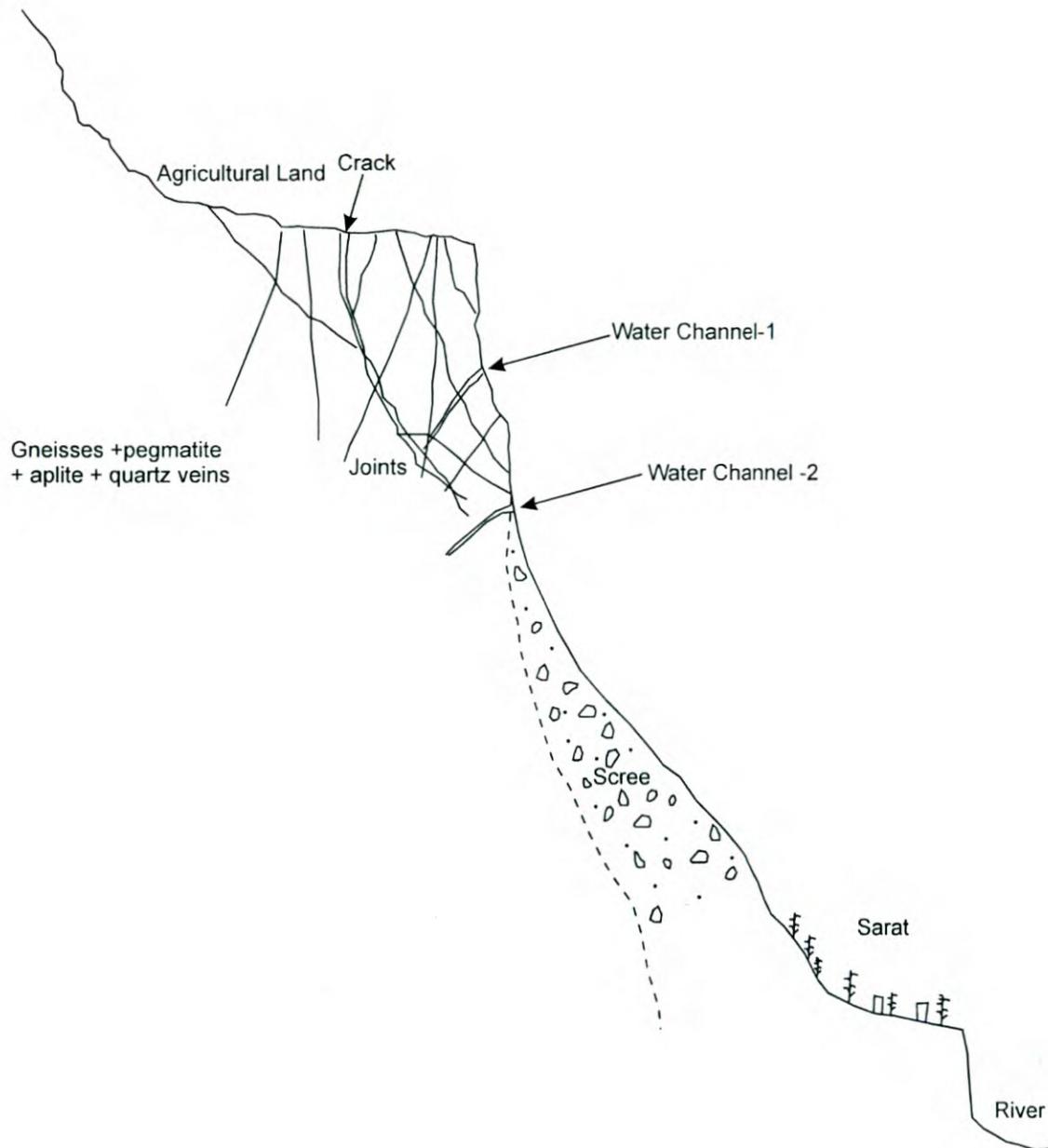


Figure 18. Schematic cross section of Sarat area.

3.5 SALMANABAD VILLAGE

The village of Salmanabad lies at about 1.7 km downstream of the Atta Abad landslide body at an elevation of about 300 m above the river bed. It is the site where historic landslide of the year 1858 occurred creating a natural dam for about 6 months (Drew, 1873); since the building of the Karakoram Highway, this area has deposited the greatest concentration of debris found anywhere on the Highway (Jones et al., 1983; Derbyshire et al., 2001).



Figure 19. Location of 1858 landslide.

The remnants of the old landslide material can be viewed from the slopes of the Salmanabad terraces, the white crushed material, probably, belongs to the marble bands on the opposite side of the river. The absence of marble on the right bank of Hunza River, and marble outcrop on its left bank further strengthens the idea.



Figure 20. Crushed marble along slopes of Salmanabad village, right bank of Hunza River.



Figure 21. Marble bands on the left bank of Hunza River.

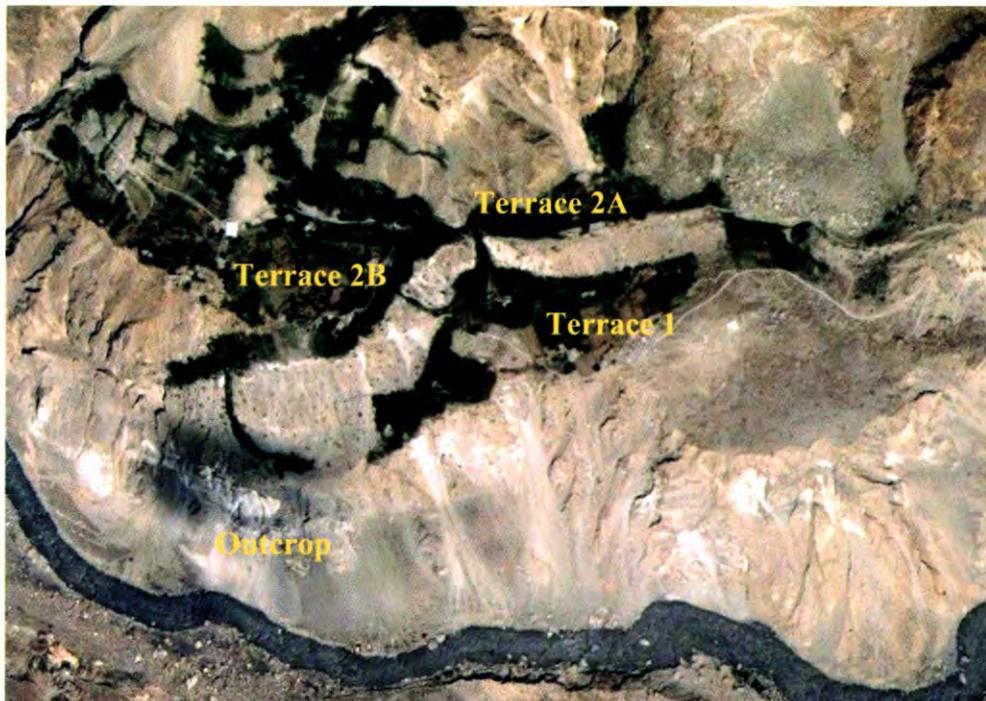


Figure 22. Aerial view of Salmanabad village showing different terraces.

The village can be divided into two distinct terraces, say, terrace 1, and terrace 2; terrace 2 can be further subdivided into terraces 2A and 2B (Figure 22). The back slopes of

the Salmanabad seem to be relatively stable but a possible flood resulting from the dam breach may erode the toe of the terrace 1 as no hard rock / outcrop have been observed at its base. However, terrace 2 is apparently quite safe as it will not be directly hit by the flood waves; moreover, outcrop is also visible at places at its toe.

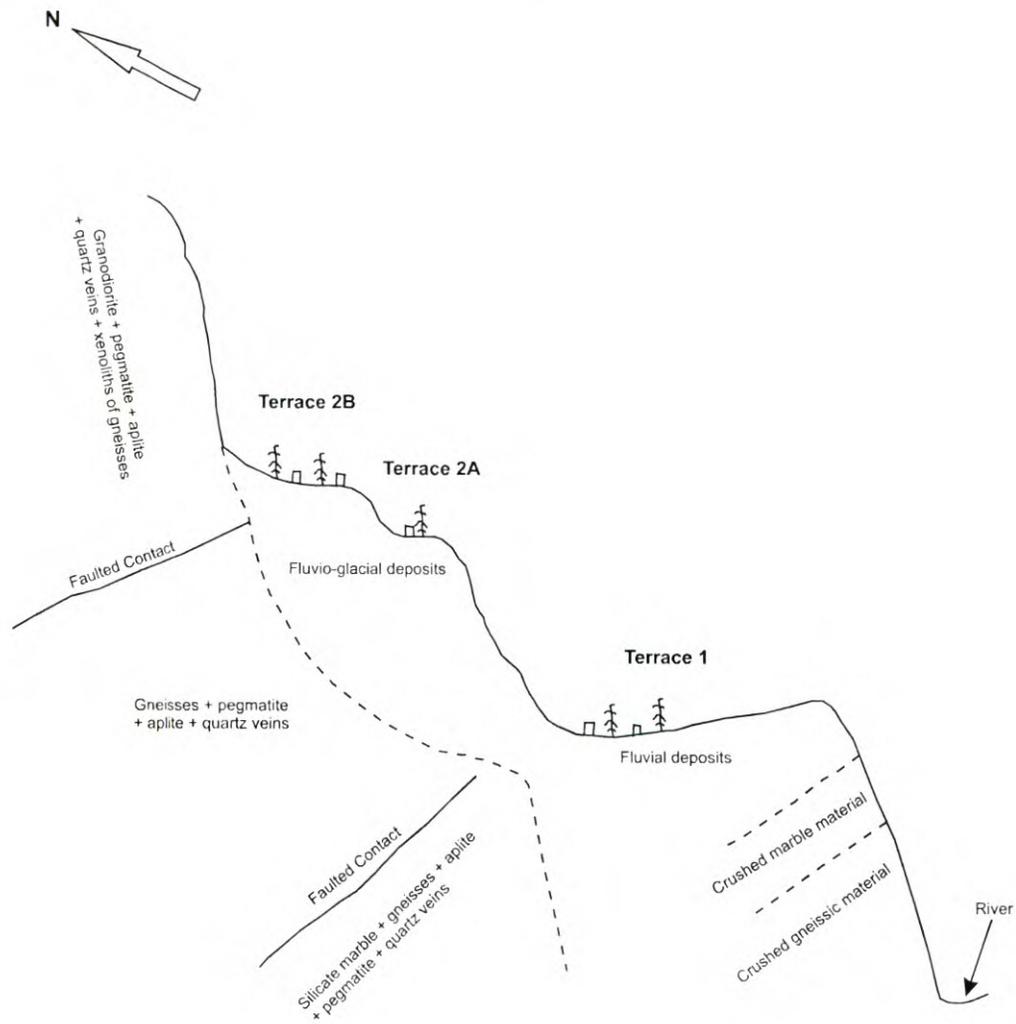


Figure 23. Schematic cross section of Salmanabad area.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The Atta Abad landslide disaster is not first of its kind in the area as large scale mass movement events have been happening in the northern areas of Pakistan, one should be very clear that the same will happen in the future owing to the particular tectonic and geomorphology of the area. The current landslide of January 2010 is of complex nature i.e. involving more than one kinds of mass movement. Normally, such kind of natural dams can not sustain for a long period of time; the more recent past example in the area is the damming of Hunza River due to snow avalanche from Momhil Glacier near Shishket which could not sustain more than six months. The downstream areas are under a threat of severe flooding generated due to probable dam breach. The communities in the upstream areas have also suffered a lot; parts of Aeenabad and Shishket villages have already submerged under water. It is possible that sudden draw down of lake water level in case of dam failure may trigger soil creeping / landsliding in particular areas located on fluvio-glacial deposits. A sudden dam burst will be more severe hazard as compared to a slower breach.

The villages of Atta Abad, Atta Abad Paen, Sarat and some parts of Salmanabad are prone to flood water, flood undercutting and mass movement hazards; the Atta Abad village can resist the mass movement for a prolonged time only after its evacuation i.e. if water infiltration from human activities is stopped immediately. Sewerage water from houses as well as that seeped from water channels is badly affecting the slopes; water which infiltrates into the moraines and cracks is playing a pivotal role in producing future mass movements in northern areas of Pakistan.

4.2 RECOMMENDATIONS

- There are two types of settlements in Atta Abad area, one is permanent and the other is seasonal. The eastern part of permanent settlement has already slid down while the remaining western part has cracks of different sizes; the intensity and size of cracks vary from place to place: so this area falls in high hazard zone and it should be evacuated on top priority.

- Sarat village is facing two types of threats; first one of flash flooding due to lake burst while the other one of rockfall as a big block of 90 m x 50 m x 45 m dimensions has detached up to one meter from the main body. Its failure from the main body will cause huge damage to the population of Sarat; to avoid such destruction evacuation is must.
- The Salmanabad village is located on two terraces; the lower terrace is developed on the material of old landslide. In case of high flood in Hunza River, this terrace will be directly hit by flood water. As the material is composed of crushed marble and gneisses so it is more likely to slide down due to rapid undercutting by flood waves. The population on this terrace should be shifted to a safe place.
- It is common practice in hilly areas that people generally make underground tanks for sewerage water which are not properly treated / drained. Water infiltrates the Quaternary deposits and enters into the joints and fractures of the underlying hard rocks; rockfalls are the result of frost and thawing action, and this water may also produce slip surfaces for the landslides. The sewerage material should be safely drained out of the loose material of Quaternary deposits which are highly permeable.
- The authorities should think about introducing the sprinkler system for irrigation purposes in the area, it will retard the excess water infiltration into the fluvioglacial deposits which are the main settlement areas in the Gilgit Baltistan part of Pakistan.
- To cope with the disaster of probable dam breach, a detailed dam breach analysis should be conducted to present an estimate of the downstream flood wave that would be produced by such failure. The analysis should present the most probable peak elevation, the maximum depth and the peak velocity of the flood wave as a function of the downstream distance and the time. Same elevation levels from the side valleys should also be included while devising a strategy for the outcomes of such an analysis. There should be an effective monitoring system interconnected with quick evacuation plans, if the failure happens. In any case, the people from low lying areas of active and inactive flood plains in the downstream side should be evacuated for some time. When the water initially overflows the natural dam, traffic on KKH, atleast in the areas which are low lying and prone to sudden erosion should also be closely monitored.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the active participation and guidance in every phase of this study by Dr. Imran Khan, Director General, Geological Survey of Pakistan. We are thankful to Mr. Naseer Ali Khan, Director Incharge, Geological Survey of Pakistan, Islamabad for his cooperation in logistics. We also acknowledge the District administration of Hunza especially Mr. Zafar Waqar Taj, Deputy Commissioner, Hunza for his cooperation during our fieldwork.

We are thankful to Mr. Zameer Abbas, Assistant Commissioner, Hunza and Mr. Tikka Khan, Secretary, Ismaili, Regional Council, Hunza for their cooperation. We are also grateful to the local community for their friendly cooperation, hospitality and assistance during our fieldwork.

REFERENCES

- Archer, D. (2001).** The assessment of flood risk to hydropower schemes in the Karakoram mountains of northern Pakistan. A report by GTZ/WAPDA.
- Collins, D.N. (1987).** Climatic fluctuations and runoff from glacierised Alpine basins, *International Association of Hydrological Sciences*, 168, p. 77-89.
- Derbyshire, E., Fort, M. and Owen, L.A. (2001).** Geomorphological hazards along the Karakoram Highway: Khunjerab Pass to Gilgit River, northernmost Pakistan. In: *Erdkunde* 55 (1), p. 49-71.
- Drew, F. (1873).** Alluvial and lacustrine deposits and glacial records of the Upper Indus basin: Part I. Alluvial Deposits. In: *Quarterly Journal of the Geological Society of London* 29, p. 441-471.
- Hewitt, K. (1989).** The altitudinal organization of Karakoram geomorphic processes and depositional environments, *Zeitschrift Geomorph.*, 76 p. 9-32.
- NACS, 2001.** Support project, Northern Areas strategy for sustainable development background paper on *Water*, final draft.
- Roohi, R., Ashraf, A., Mustafa, N. and Mustafa, T. (2008).** Preparatory assessment report on community based survey for assessment of Glacial Lake Outburst Flood (GLOF) Hazards in Hunza River Basin. A report by Water Resources Research Institute, National agricultural Research Centre, Islamabad in collaboration with UNDP, Pakistan.
- Singh, P., Ramashastri, K.S. and Kumar, N. (1995)** Topographic influence on precipitation distribution in different ranges of the Western Himalayas, *Nordic Hydrology*, 26 p 25-30.
- Tahirkheli, R.A.K. (1982).** Geology of the Himalaya, Karakoram and Hindukush in Pakistan, *Geol. Bull. Pesh. Univ. (Special Issue)* 15 p. 29-43.
- Wake, C.P. (1987)** Snow accumulation studies in the central Karakoram, *Proceedings of the Eastern Snow Conference (North America)*, 44th Annual Meeting, Fredericton, p 19-33.