Survey, Mapping and Designing of Climate Resilient Infrastructure Including Bio-Engineering works in Disaster Prone Areas of District Nagar:

Miyacher, Hoper and Bar Disaster Prone Areas in District Nagar, Gilgit Baltistan, Pakistan

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This was a hard task therefore we had to work in hard geographical & climatic conditions and travel/walk across disaster prone areas from river bed to top of the mountain.

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This was one of the wild assignments we have experienced, it was a great learning experience, and we owe it to all who made it possible.

Shahid Hussain
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Gilgit, 2019

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Acronyms and Abbreviations

ADP	Annual Development Plan
ALF	Agriculture Livestock and Forestry
CEO	Chief Executive Officer
DoF	Department of Forest
FGD	Focus Group Discussion
HHs	Households
KIIs	Key Informant Interviews
LEK	Local Ecological Knowledge
LSO	Local Support Organization
NGOs	No for Profit Organizations
NTFP	Non Timber Forest Products
PES	Payment for Eco system Services
PMCC	Premier Mountain Communities Consultants

TECHNICAL TERMS

Adventitious roots	Roots that develop from shoots
Berm	Flat section of a terrace of a slope
Container plant	Plants where the roots are secured with a small container of soil or peat
Cuttings	Portion of a branch (usually willows) from the parent plant for the production of a new independent plant by inducing it to form shoots and roots
Pioneer plant	Plants that settle in raw mineral soils and ameliorate them for succeeding plants
Root ball plant	Plants where the roots are covered with a ball of soil
Shrubs	A woody plant smaller than a tree and generally producing several basal shoots instead of a single stem.
Slope toe	The basis of a slope
Stump sprouting	Shoots developing between the stem base and the root crown, e.g. on the root neck of cut trees.

Chapter

INTRODUCTION

District Nagar is the one of fertile Districts in Gilgit Baltistan situated mainly in the Karakoram and a portion in Hindukash Mountain Range. It has adequate amount of forest range especially in Karakoram and Hindukash mountain ranges. The District has largest glaciers out of the polar region in the world and many other small and medium sized glaciers and snowcapped mountain peaks. District Nagar was a princely state previously for a long period of time and annexed with Pakistan as an independent state in November, 1948 and government of Pakistan declared Nagar as administrative district in 2010. There are multiple areas which are disaster prone areas and effect forest range in multifaceted means. The main disaster prone areas are Miyacher, Hoper and Bher in the District which distress the agricultural and forest land and water supply system.

1.1 BACKGROUND

Provision of essential economic infrastructure such as irrigation system is important to stimulate private sector led growth in rural district like District Nagar where more than 98% population rely on agricultural and community forestry for economic empowerment and creating employment. There is a long history of district for participatory development and maintenance of the irrigation system. Since the ancient times people construct the water channels under the princely statesmen and maintain these water channels annually. This approach has often proven more sustainable than modern irrigation schemes constructed by the government through constructors. Government spending is insufficient especially in maintenance of irrigation channels to improve operational efficiency. Fast growing population of the district and intensification of more use, more water resources need to be diverted for land development

and provide required water for proper growth of plants. Effective management of irrigation system is the central to development prospect of the district.

There is no ground water in the district and whole irrigation depends upon water flowing streams. The streams flows from glaciers and snow melt provide the major source of water. Communities constructed open water channels from top of mountains. There is significant variation in availability of water in different seasons and weather conditions. Efficient use of resources (Financial) with community partnership to maintain irrigation system will enhance return from irrigation.

Divisional Forest Office District Nagar has advertised for hiring the services of a consultancy firm from Gilgit Baltistan to Survey, Mapping and Designing of Disaster Prone Areas of District Nagar under the project titled "Disaster Risk Minimization through Bioengineering and Forestry Techniques in District Nagar". The project is funded by the provincial government of Gilgit Baltistan through provincial ADP. PMCC availed the contract through a competitive bidding process and initiated the project under supervision of District Forest Officer District Nagar.

1.2. Structure of Report.

The report is divided mainly in four parts:

1. **Report of Hoper Disaster Prone Area.**

   The report discuses Purpose and Scope of the study; Methods of Investigation, Location and Accessibility, Topography, Geomorphology and Climate, Geotechnical Analysis, Mitigation Measures, Conclusion and Recommendation, Bio Engineering and Annexure. (Designs and Maps)

2. **Report of Miyacher Disaster Prone Area**

   This section provides an overview of the organizations, type of organizations, and number of organizations per geographical location (District wise), Geographical coverage of the organizations.

3. **Report of Bar Disaster Prone Area:**

   This section provides an overview of the organizations, type of organizations, and number of organizations per geographical location (District wise), Geographical coverage of the organizations.

4. Detail Bio-Engineering Works in Project Areas.

This section discuss in detail about the, implementation of bio engineering techniques, methods of seeding, dry seeding etc. slope plantings, brush layering, drain and slope fascines, planted pole wall, live slope grid, live wooden wall, vegetated stone wall, vegetated gabions and mitigation measures & recommendations.

Report

of

Hoper Disaster Prone Area.

Contents

1.1. PURPOSE AND SCOPE:

The primary objective of this geological survey is to identify geo hazards (Landslide, rock fall, debris fall, debris flow, mass wasting), types of geo hazards affecting the loose strata, Agriculture plan settle and strengthen the loose strata and implementation and recommendations for settlement of loose by identification of seeped water from higher altitude, mitigation for prevention of later movement of seeped water, agriculture plan to strengthen the soil cover by vegetation of trees, grass and forest

1.2.METHODS OF INVESTIGATION:

The geological study included the marking of intensive hazards areas, indication of major cracks and seepage points along the proposed area, the emphasis is given to cause of slope failure at hazard area, types of Landslides occurs along the study area, types of sediments involved in Land sliding and recommendations for control of geo hazards at the project area

1.3.LOCATION AND ACCESSIBILITY:

The proposed project area (Hoper) is situated in the extreme north of Pakistan. It is located at a distance of 700 kms from Islam Abad, 85 kms from Gilgit, 40 kms from District Head Quarter Harespo. There is metalled road from District Head Quarter Harespo to Hoper.

1.4.TOPOGRAPHY, GEOMORPHOLOGY AND CLIMATE

The Karakorum range passes from Hoper valley in NW-SE direction. High snow bound mountains with long and narrow valleys are topographic characteristics.

The Difference between valleys and peaks ranges from 2200m to 2700m.The water of Hakalshal village gorge is sufficient for irrigation. The one of the worlds largest glacier Biafo lies in the north of Hoper village and the world 11^{th} highest peak Rakaposhi lies in the south of Project area.

The average height of ridges in Hoper valley is more than 5500m.The rocks found in Hoper are igneous and metamorphic in origin but rocks are weathered and shattered because the process of frost action increases in foliated rocks. Mass movement activity is great due slope unstability and weathering action is rapid in the area. The slope of peaks is mostly greater than 70°. Snow covered high peaks are common along with rock slopes.Scree movement is common throughout Hoper valley.

The Hoper valley has long and extremely cold winter season but spring and summer are short, temperate and pleasant. January is coldest month of winter season. May and June are dangerous months due to melting of snow causing mud flow and rock fall. Rain fall is very scanty in winter season.

The Hoper valley is comprised of lush green grass lands so the major occupation of people living in the area is sheep and goat rearing where as people get handsome cash from cultivation of potato.

1.5.GEOTECHNICAL ANALYSIS

The project area Hakalshal village is settled on landslide, rock fall debris fall glacio fluvial and scree deposits. The project area is badly affected and damaged by various types of landslides e.g. toppling, scree fall, mass wasting and debris fall. The cause of vulnerable landslide is inward water seepage from Hoper Gorge. The seepage/lateral movement of water process is increased in overburden comprised mainly of sand, silt, clay, mud beds along the Hoper Gorge high slope, weathered, shattered and jointed rock strata and abundant loose material on the scarp. The Hoper Gorge water is seeped at higher altitude towards over burden, the continuous lateral and upward water movement has unsettled the upper strata, the upward strata is slide down ward due to high slope and lower strata is still compacted. The seeped water from higher altitude (Hoper Gorge) is acting as major decomposing agent, the seeped water is continuously eroding and transformed hard strata of rock and sand into loose and un settled material for many years.

Figure 1Weathered, shattered and jointed loose strata with high slope

The project area is vulnerable and mass wasting/slope failure occurs due to appearance of seeped water from Hoper Gorge source from higher altitude. The slope saturation by water, the horizontal movement of water by capillary action has increased the moisture content, high slope enhanced the landslide and the unsettled strata saturated site is damaged and slides down.

Figure 2: The seeped water from gorge seeps inward through sand and silt medium landslide deposit

The seeped water from Hoper Gorge accumulate/stored in the bottom of Talus of landslide, the storage of water in bottom of talus built cracks over the bottom due to high slope and increasing mass as a result the landslide initiated from bottom and availability of free space in bottom of Talus rapids movement of loose material on the scarp.

1.6.MITIGATION MEASURES

The project area is under threat of intensive Landslide, Rock fall and Mass wasting zone, mass movement and jointed rock stratas (causes seepage of water are intensive hazards and above mentioned hazards are continuous threat for Hoper Village.

- The mitigation measures to Landslide/reduce effects of landslide on realigned infrastructure are removing of mass from scarp of slope.
- Huge boulders on the scarp and in water stream should be removed at identified size.
- Plantation of trees and grass on landslide source area hardens the soil cover and minimize landslide movement.
- The sumps should be design in the different point where seeped water from higher altitude/glacier source is exposed, the surrounding water spread by capillary action

will be accumulate in the sump and further capillary action of water will be reduce which will automatically reduce the moisture content of landslide deposit.

- The Gabion wall at left side of Hoper Nallah will restrict inward water seepage towards unsettled slope/ Landslide deposit
- It is strongly recommended to use stone from outside rather utilizing stones by excavating within stream bed.
- Excavating for stone within stream may increase in more vulnerability of the site.

1.7.CONCLUSION AND RECOMMENDATIONS:

The Project area (Hoper) is under the threat of various geo hazards needs implementation of modern engineering and geological techniques. The underground water seeped from Hoper Nallah should be mitigated by construction of gabion walls to prevent lateral movement. The digging of cemented sumps at exposed points will decrease the moisture content of loose material. The execution of vegetation will harden the soil cover and restrict the slope failure activity.

1.8.ANNEXURE:

Maps and Designs of Water Channel and Gabions.

Report

of

Miyachar Disaster Prone Area

Contents

2.1. PURPOSE AND SCOPE:

The primary objective of this geological survey is to identify geo hazards (Landslide, rock fall, debris fall, debris flow, mass wasting), types of geo hazards affecting the loose strata, Agriculture plan settle and strengthen the loose strata and implementation and recommendations for settlement of loose by identification of seeped water from higher altitude, mitigation for prevention of later movement of seeped water, agriculture plan to strengthen the soil cover by vegetation of trees, grass and forest

2.2. METHODS OF INVESTIGATION:

The geological study included the marking of intensive hazards areas, indication of major cracks and seepage points along the proposed area, the emphasis is given to cause of slope failure at hazard area, types of Landslides occurs along the study area, types of sediments involved in Land sliding and recommendations for control of geo hazards at the project area

2.3. LOCATION AND ACCESSIBILITY:

The proposed project area (Miachar) is situated in the extreme north of Pakistan. It is located at a distance of 690 kms from Islam Abad, 90 kms from Gilgit, 35 kms from District Head Quarter Harespo. There is metalled road from District Head Quarter Harespo to Pissan after that 7Kms jeepable and narrow link road leads to Project area (Miyachar).

2.4. TOPOGRAPHY, GEOMORPHOLOGY AND CLIMATE

The Karakorum range passes from Miachar valley in NW-SE direction. High snow bound mountains with long and narrow valleys are topographic characteristics.

Figure 3:Weathered, shattered and jointed loose strata with high slope

The Difference between valleys and peaks ranges from 2200m to 2700m.The water of Miachar village gorge is sufficient for irrigation. The one of the worlds

largest glacier Biafo lies in the north of Miachar village and the world 11th highest peak Rakaposhi lies in the south of Miachar Village.

The average height of ridges in Miachar valley is more than 5500m.The rocks found in Miachar are igneous and metamorphic in origin but rocks are weathered and shattered because the process of frost action increases in foliated rocks .Mass movement activity is great due slope un stability and weathering action is rapid in the area. The slope of peaks is mostly greater than 70°. Snow covered high peaks are common along with rock slopes. Scree movement is common throughout Miachar valley.

The Miachar valley has long and extremely cold winter season but spring and summer are short, temperate and pleasant. January is coldest month of winter season. May and June are dangerous months due to melting of snow causing mud flow and rock fall. Rain fall is very scanty in winter season. The Miachar valley is comprised of lush green grass lands so the major occupation of people living in the area is sheep and goat rearing where as people get handsome cash from cultivation of potato.

2.5. GEOTECHNICAL ANALYSIS

The project area Miachar village is settled on landslide, rock fall debris fall glacio fluvial and scree deposits. The project area is badly affected and damaged by various types of landslides e.g. toppling, scree fall, mass wasting and debris fall. The cause of vulnerable landslide is high slope, weathered, shattered and jointed rock strata and

Figure 4:Toppling of boulders, cobbles, pebbles and gravels in the Project area

abundant loose material on the scarp. The glacial water is seeped at higher altitude and exposed at various spots in the mid and bottom of landslide deposit. The seeped water from higher altitude (glacial source) is acting as major decomposing agent, the seeped water is continuously eroding and transformed hard strata of rock and sand into loose and un settled material for thousands years.

The project area is vulnerable and mass wasting/slope failure occurs due to appearance of seeped water from glacier source from higher altitude. The slope saturation by water, the horizontal movement of water by capillary action has increased the moisture content, high slope enhanced the landslide and the unsettled strata saturated site is damaged and slides down.

Figure 5:The seeped water from higher altitude (glacial source) is exposed in the bottom

Figure 6:The seeped water from higher glacier source/higher altitude is exposed on the surface.

Altitudes accumulate/stored in the bottom of Talus of landslide, the storage of water in bottom of talus built cracks over the bottom due to high slope and increasing mass as a result the landslide initiated from bottom and availability of free space in bottom of Talus rapids movement of loose material on the scarp.

2.6. MITIGATION MEASURES

The project area is under threat of intensive Landslide, Rock fall and Mass wasting zone, mass movement and jointed rock stratas (causes seepage of water are intensive hazards and above mentioned hazards are continuous threat for Miachar Village.

- The mitigation measures to Landslide/reduce effects of landslide on realigned infrastructure are removing of mass from scarp of slope.
- Huge boulders on the scarp and top should be removed.
- Plantation of trees and grass on landslide source area hardens the soil cover and minimize landslide movement.
- The fertile environment and supply of water to plants by drip irrigation method will require for vegetation.
- The sumps should be design in the different point where seeped water from higher altitude/glacier source is exposed, the surrounding water spread by capillary action will be accumulate in the sump and further capillary action of water will be reduce which will automatically reduce the moisture content of landslide deposit.
- For construction of gabions existed stone of river side must not be utilized. Utilization may increase vulnerability of the site.

2.7. CONCLUSION AND RECOMMENDATIONS:

The Project area (Miyachar) is under the threat of various geo hazards. It needs implementation of modern engineering and geological techniques. The underground water seeped from higher altitude (Glacial source) exposed at lower altitude should be mitigated by digging of cemented sumps to prevent lateral movement. The digging of cemented sumps at exposed points will decrease the moisture content of loose material. The execution of vegetation will harden the soil cover and restrict the slope failure activity. The construction of gabion walls at Hunza river bank will secure the bank and slope failure zone from inward. The gabions at sharp striking points of Hunza river towards slope failure zone will restrict the inward seepage.

2.8. Annexure:

Maps and Designs of water channel and Gabions.

3. IMPLEMENTATION OF BIO ENGINEERING TECHNIQUES TO CONTROL/REDUCE LANDSLIDE/MASS MOVEMENT

The disaster Prone area especially Miyacher and Bar Villages are under threat of various Geohazards e.g. mass movement on high slope towards Hunza Nagar river in Miaycher and Bar Nallah in Bar Valley, debris fall, scree fall, toppling, inward water seepage and erosion at bottom of landslide deposit/ left bank of Hunza Nagar river. The upper layer of slope becomes unstable due to inward seepage of water from Minapin glacier situated behind the Miyachar Village, the irrigation water provide to upper village is also acting as a key factor for landslide and mass movement, the continuous seepage of water from Minapin glacier and irrigation water utilize for agriculture in upper Miyachar has exaggerated landslide hazard, the seeped water from Minapin glacier and agriculture water in upper Miyachar has transformed the hard strata into loose and unsettled debris. The implementation of bio engineering techniques will harden the soil cover at high slope, the slope are comprised of loose material e.g. sand and silt in high quantity where as gravel, boulders, cobble and pebbles are observed in small amount. The upper soil strata can be strengthen/harden by plantation and vegetation, the soil strata should be develop by providing fertilizers and all needs for plantation and vegetation should be fulfill to control geo hazards e.g. the upper layer should be irrigate by drip irrigation method because the supply of water through water will further destabilize the strata, the upper layer should be smoothen by removal of unnecessary sediments/ huge sediments e.g. gravels, cobbles, pebbles and boulders in order to develop/ enhance quick growth of plants. The inward seepage at left bank of Hunza Nagar River should be planted by adopting above techniques.

For centuries wood and living plants were the only material for hill and slope stabilization works. Today, some of these old techniques have been modified and applied again. Furthermore, new methods have been created which mainly use living material such as willow branches, willow cuttings and rooted deciduous trees.

The time factor for implementing vegetation for slope stabilization works depends on the technique of the soil bioengineering measure and the type of plant. Cuttings and rooted plants should only be used during the dormant season and seeding techniques should be used during the vegetation season.

Various methods are available for hillside and slope stabilizing. Often used methods of seeding are dry-seeding and hydro seeding. On exposed areas the seed will be protected with straw in combination with bitumen or meshes of jute and wire. After revegetation with seeding, the stabilization can be increased through transplanting stump sprout deciduous trees. This method (dry seeding) is more suitable for Miaycher vulnerable site. Because the site has more exposed areas and seeding can not be easily protected without straw with combination with bitumen and meshes of locally produced plants.

With different types of brush layering, loose rock slopes can be stabilized. If the plants are rooted, they are called hedge layer. If they are unrooted, they are called brush layer. A combination of both is a hedge brush layer.

A useful method for dewatering and stabilization of wet slopes is the use of drain and slope fascines. The fascines consist of live branches of willows that are tied together with wire. This method is more suitable for Bar valley site because the slope of the target site is mostly wet slope and water flows from different exits.

There are numerous different hillside and slope stabilization methods which utilize plants in combination with constructions of wood, stone and wire such as planted pole walls, live slope grids, live wooden crib walls, vegetated stone walls and vegetated gabions. Choosing the right method depends on various factors such as the position of slope, ground and available material.

3.1. Methods of Seeding

The most common method of hill and slope stabilization is the seeding of a grass and herb mixture.

3.1.1. Dry-Seeding is an easy method where seed (10-25 g/m^2) and organic fertilizer (100 g/m^2) are scattered by hand or machine. It can be applied on flat slopes with rough surfaces. It is also possible to use hay flowers instead of common seed and then we call it hay seeding.

On steeper slopes where it is necessary to cover the soil quickly, a cover crop seeding is used. Special types of rye (in fall) and barley (in spring) are spread in a mixture of 10 g/m^2 and covered with soil. On this surface normal seed (10 g/m^2) and organic fertilizer (100 g/m^2) were spread.

On less steep slopes with rough surfaces and no erosion problems **tree and shrub seeding** can be spread. Seeds of trees and shrubs are mixed with sand in a ratio of 1:3 and spread as broadcast, pit or row seeding.

On steep slopes which have a smooth surface and mild climate and are also mainly in forests mostly **hydro seeding** is used. Seed (25 g/m^2), organic fertilizer (100 g/m^2), mulch (e.g. cellulose, straw 80 g/m^2) and an alga product as glue (100 g/m^2) are mixed in a special barrel with water and pumped out onto the slopes (2 l/m^2). On very steep slopes it is advisable to fasten a jute mesh on the slope because it fixes the hydro seed.

In **Miayacher** site for slope stabilization seeding of locally grown grass especially of alfalfa is suitable. The seeds of Alfalfa must be seeded as mixture of hay or fertile soil. Kabir can also be grown in Miaycher disaster area for slope stabilization because it requires not more irrigation water. It can grow easily on loose strata as well and have use of medicinal herb. Moreover, Kabir has economical benefits for the poor communities.

In Bar valley, hydro seeding method will be beneficial because there at site water is available in abundance. That may carry seeds along with its organic fertilizer, mulch, straw and alga. The mixture of all these things can be mixed in a container and from top of the slope it can be drained with water slowly. However, it is recommended to fasten jute or local available any mesh on the slop areas especially in dry pockets of the bar disaster site.

3.1.2. Bitumen Straw Seeding from Schiecht is the best method on exposed areas and areas mainly above the forest line. In a 3-4 cm thick layer of straw (700 g/m^2), seed (25 g/m^2) and fertilizer (100 g/m^2) are spread and covered with an unstable bitumen emulsion. The straw effects a mechanical protection and the bitumen emulsion absorbs the warmth, which is necessary above the forest line, and functions like a greenhouse.

On very steep slopes and on failure edges a stable jute mesh instead of the bitumen emulsion covers the straw. We call this method **jute mesh straw seeding.** The life span of the jute mesh depends on the climate and the weather but is normally 1 to 2 years. For areas where this lifetime is too short, it is better to use a coconut mesh, which lasts about four years.

On areas where rock fall could happen or rocks could break out of the soil it is useful to nail an iron mesh into the ground covering the straw layer. This method is called **wire mesh straw seeding.**

Another quick method for slope stabilization is the use of **sods.** They can be obtained from the original slope, for example, as a result of road construction. After the earthwork is completed, they can be put back to cover the new slopes.

3.2. Slope Plantings

Deeper, rooted woody vegetation helps to prevent shallow mass movements. Therefore, after a first slope stabilization with seeding, some stump sprout deciduous trees are transplanted as naked rooted, container or root ball plants. It is advisable to use stump sprout deciduous trees, because if they are cut down by hand or are damaged as a result of an avalanche, or by wind throws or snowfall, they have sprouting capacity and can still grow. Transplanting must be carried out carefully, otherwise root regeneration is slow. As a general rule, the younger a plant is transplanted, the more successful is its root system. On less steep slopes with rough surfaces and no erosion problems, it is also possible to create a deciduous tree stand only by tree and shrub seeding.

3.3. Brush Layering

The use of rooted and un rooted layers is one of the best methods to stabilize loose rock slopes. Fresh, green willow cuttings and rooted plants are layered on 1-1.5 m wide berms on the face of the slope. The berms should have an angle of inclination (sloping up) of 10-20 percent to the outside and are dug out by hand or machine. Wherever there is a risk of slope failure, ditches should only be dug in short segments. The plants are placed close together and the tips or the leafy ends should be allowed to protrude slightly beyond the face of the slope. Rooted and un rooted plants should be used as vegetation and these should be resistant to rock fall and rubble and have the ability to produce adventitious root systems. The plants are buried with the material from the next, above berm, so that 15-20 cm of the tips protrude. Vertical spacing between layers is dictated by the erosion potential of the slope and may be between 1 and 2 m.

This method is also very useful in protecting dumped slopes and dams where the plants are layered in a successive terrace system during the dumping. On very steep dams a coconut mesh should be used to stabilize the earth between the brush layers.

For brush layering we have three different techniques with different names: **brushlayer** consists of only willow cuttings, which have the ability to regrow; **hedge brush layer** or **rooted and un rooted layer** is a combination of willow cuttings and rooted plants; **hedge layer or rooted brush layer** is a method where only rooted plants are used.

3.4. Drain and Slope Fascines

Drain and slope fascines are useful for dewatering and stabilization of wet slopes. They consist of live branches of willows and are tied together with at least 2 mm thick wire. The lowest third should also contain dead branch material which channels the water unhindered. The tip end of the branches always points to the flow direction. Usually the fascines are 30 to 60 cm thick and have no length limit. They are put into ditches and then must be covered with soil so that all the branches are embedded and can take root and grow. To prevent the fascines from sliding or washing away, they are fixed every 2 m with wooden poles.

The effect of the fascines is that they channel water immediately after placement and, after the plants have formed roots, they will desiccate the slope further by transpiration.

3.5. Planted Pole Wall

We use the so-called planted pole walls instead of wattle fences on slopes, since wattle fences are covered with little soil with consequent short lifetime and no protection against soil movement. Iron or wood poles are hammered into the ground and a larch log is attached to them. The deciduous trees are placed on the logs and covered with soil. On sites where there is light rock fall and shallow soil movement and erosion has not been stopped completely, this method can correct these problems gradually. In addition, due to the stabilizing function of the plant, the logs prop up the soil material. It is necessary to use stump sprout deciduous trees since they are so durable that mechanical damage through rock or rubble does not matter much.

3.6. Live Slope Grid

Very steep eroded slopes with compact soil can be secured with a live slope grid. It is essential in repairing a steep slope where the soil must not be dug up and the slope angle cannot be reduced. On vertical larch logs, which are driven into the soil and propped up on the base of the slope, logs are nailed horizontally on to it. The space between the logs is filled up completely with live branches and soil, so that very dense vegetation is quickly obtained. The whole slope grid is secured with iron poles and covered with soil.

3.7. Live Wooden Crib Wall

Live wooden crib walls are one of the best methods to securing immediately endangered parts of slopes and toes of slopes. They can be erected as single or double crib walls and are built from logs and anchor logs held together with nails or bolts. The anchor logs should not be above each other but should be placed alternately. For higher stability against sliding, crib walls should not be placed horizontally on the slope but at an angle of 10-15 percent towards the slope. Additionally, the whole construction is secured with 2-2.5 m long iron poles, which are hammered into the ground. The space between the logs is filled with soil material and plants, which should not stick out of the wall more than a quarter of their length. To reach vegetation quickly it is advantageous to use green willow branches and strong rooted pioneer plants as mentioned for the construction of the hedge brush layer. In order to achieve good plant development the face wall should be 50 percent. If this is not the case the plants will not receive enough light.

3.8. Vegetated Stone Wall

Vegetated stone walls are useful for the stabilization of slope toes or steep slope cuts. They are flexible, permeable, durable and can be adapted to every slope angle. During the building of the stone wall, live plants are placed into the joints between the stones so that they reach into the soil behind the stones. The joints must be filled with soil material to ensure plant growth. Green willow branches and rooted plants which have the ability to produce adventitious root systems should be used as vegetation. The branches should not protrude from the wall more than 10 cm to prevent desiccation. Additionally, a greening with hydro seeding is possible. The function of the plants is the stabilization of the construction with

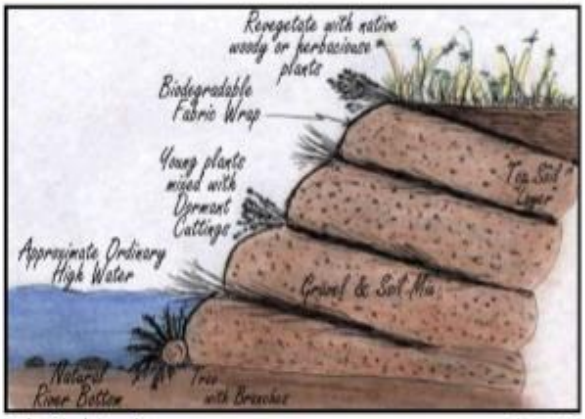
their root system and the absorption and transpiration of water by the vegetation, which drains the slope.

3.9. Vegetated Gabion

Vegetated gabions are used to stabilize slopes and slope toes where a lot of smaller stones are available. They are constructed with a fine wire mesh that is filled with coarse gravel or smaller stones, earth, live cuttings and container plants. To ensure that the plants are covered with material, it is necessary to lift the mesh and shake it to settle the gravel. The plants should protrude slightly beyond the face of the gabion but not more than 10 cm to prevent desiccation. Finally, the wire mesh is pulled together and sewn shut with wire. Moreover, vegetated gabions are a fast and simple construction to secure wet slopes because they are elastic and improve drainage through plant transpiration. The recommended bio engineering solutions to control landslide and inward seepage are:

Brush layering

- brush layer is a layer of plant material intercepted between layers of soil on cut slopes or fill slopes.
- made of live cuttings planted in line, on terraces across the slope, covered with soil.
- Re-vegetation technique, combines layers of dormant or rooted cuttings with soil.
- Brush layers act as live fences to capture debris moving down the slope.



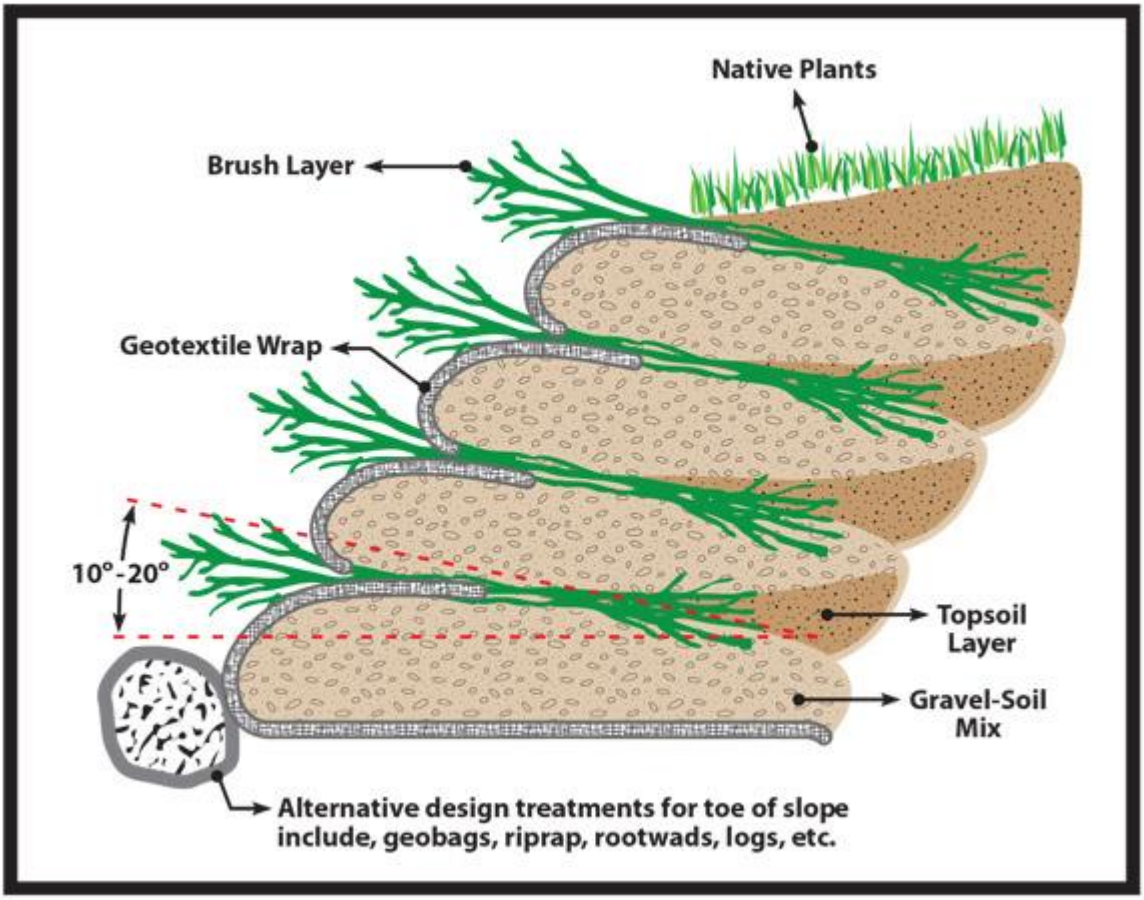
8/28/2013

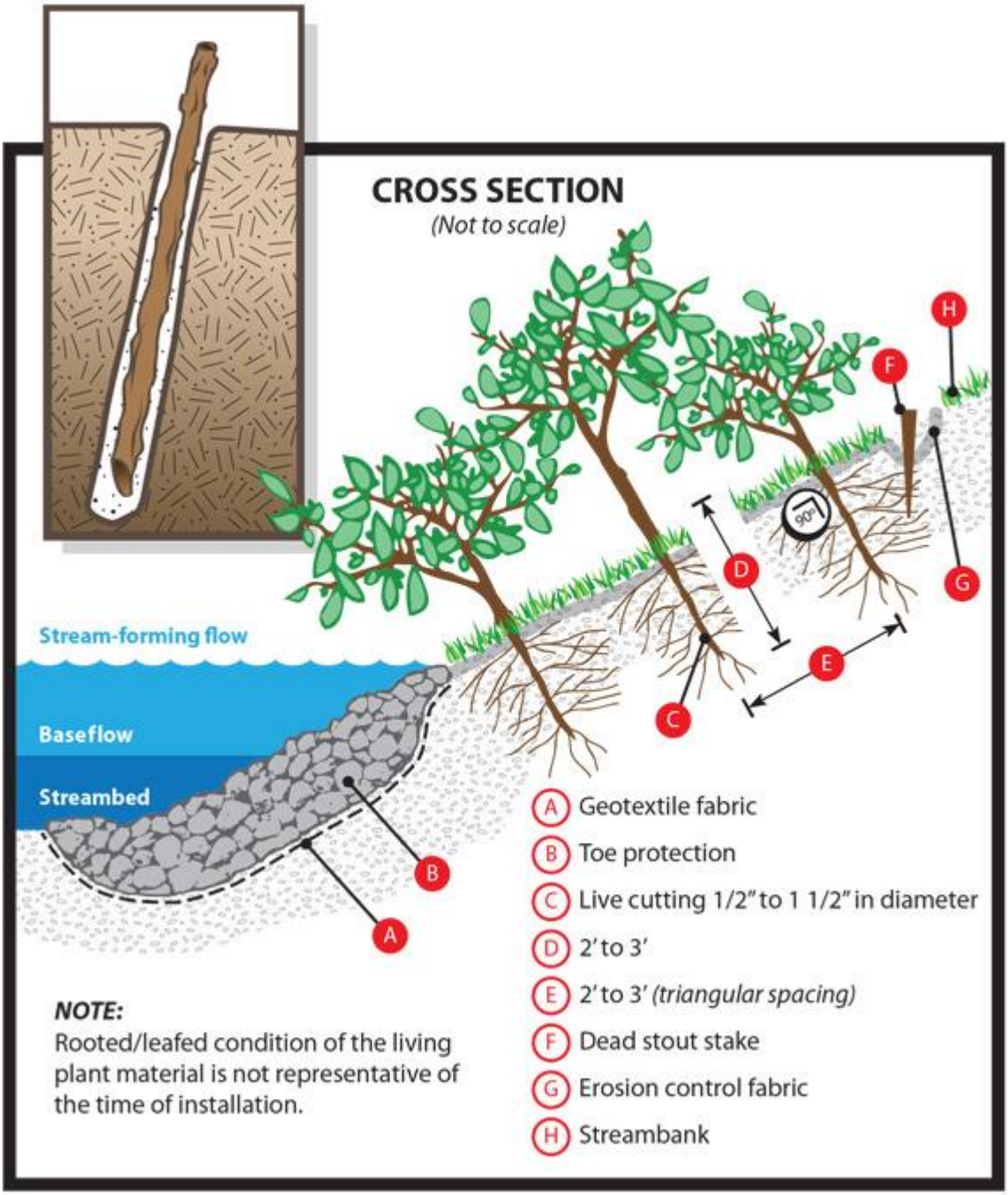
soil bioengineering techniques

The removal of unnecessary sediments from top layer will increase fertility for quick growth of plants

Hedgerow planting contd.....

- improve water quality & provide wildlife habitat.
- a soil conservation measure but also generate fodder & income to marginal farmers.
- contribute to sustainable mountain development through erosion control.


Native Plants
Brush Layer
Geotextile Wrap
10°-20°
Topsoil Layer
Gravel-Soil Mix
Alternative design treatments for toe of slope include, geobags, riprap, rootwads, logs, etc.



The root fibers enhance/ promote strengthening of loose strata

3.10. Mitigation Measures and Recommendations for Bio Engineering

The project area (Miyachar, Hoper and Bar) is under threat of intensive Landslide and mass movement, Rock fall and Mass wasting zone, mass movement and jointed rock stratas (causes seepage of water are intensive hazards and above mentioned hazards are continuous threat for Miachar Village. In Hoper it may risk to communication, pasture as well as long term economic impacts of the community. In Bar disaster already damaged the open water channel which was irrigating thousands Acres of forest land. There are millions of forest trees going to be died because of unavailability of irrigation water and requires urgent repair/widening of water channel to protect completely barren the forest land.

- The mitigation measures to reduce effects of landslide on realigned infrastructure are removing of mass from scarp of slope.
- Water channels should be properly maintained in all three sites and in open water channel requires urgent repair/widen of community constructed water channels
- Huge boulders on the scarp and top should be removed
- Plantation of trees and grass on landslide source area hardens the soil cover and minimize landslide movement by implementation of bio engineering solutions/techniques.
- The fertile environment and supply of water to plants by drip irrigation method will require for vegetation or pipes will be batter at least.
- The sumps should be design in the different point where seeped water from higher altitude/glacier source is exposed, the surrounding water spread by capillary action will be accumulate in the sump and further capillary action of water will be reduce which will automatically reduce the moisture content of landslide deposit.
- The surface/top layer can be stabilize by seeding of a grass and herb mixture whereas the inner layers of slope strata can be stabilize by plantation of deciduous trees, the deciduous trees are important because the slope is highly saturated by water that is why dense plantation will decrease underground water quantity by absorption of roots as well as stabilization of slope will be confirm.
- The irrigation water use for forest/ planted trees /cuttings above vulnerable landslide zone speed up/enhance unstability in slope. The water use for forest plants seeps into landslide zone increases groundwater content and saturation, the main channel above

landslide zone should be cemented where as small sub channels should be vegetated by herbs, unnecessary water supply to agriculture fields should be restricted.

- In Bar the slope is comparatively comprised of fertilized soil and in some areas there is loose strata which requires to be fertilized through fertilizers and normal soil.
- In some parts of Bar site requires to provide normal soil to save water from seepage to grow plants. Minimum of four inches of fertile soil layer should be bedded prior to plan cuttings.
- In Miyacher site almost whole site requires to be fertilized the land prior to crop cuttings because to save water from easily seepage.
- Miyachar disaster site has loose material which may cause fast drying and water seepage there for limited water should be provided and cuttings of local plants should be provided.
- In all three sites planting season must be Spring season especially of March and April. After that cuttings will not survive easily. Month of May can also be suitable if regular water will be provided.
- In wet watery areas of Miyacher; drain and slope fascines are useful for dewatering and stabilization of wet slopes. They consist of live branches of willows and are tied together with at least 2 mm thick wire.
- In Miyacher site use of rooted and unrooted layers is one of the best methods to stabilize loose rock slopes.
- Fresh, green willow cuttings and rooted plants are layered on 1-1.5 m wide berms on the face of the slope. The berms should have an angle of inclination (sloping up) of 10-20 percent to the outside and are dug out by hand or machine.
- In some areas of Miyacher there is a risk of slope failure, therefore, ditches should only be dug in short segments.