Making Roads Work for Water
Scoping Study for Mugu District

Report to RAP 3, submitted by
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Acronyms

ADB	Asian Development Bank
AMS	Asset Management Systems
DDCs	District Development Committees
DFID	Department for International Development
DoLI	Department of Local Infrastructure
DoLIDAR	Department of Local Infrastructure Development and Agricultural Road
DoR	Department of Road
EIA	environmental impact assesement
LBES	Labour Based Equipment Supported
LRN	Local Road Network
MHLR	Mugu Humla Link Road
MoFALD	Ministry of Federal Affairs and Local Development
MoLAGA	Minitry of Local Affairs and General Administration
MoPIT	Ministry of Physical Infrastructure and Transport
RAP3	Rural Access Programme Phase 3
RBGs	Road Building groups
RMGs	Road Maintenance Groups
SDC	Swiss Agency for Development and Cooperation

1. Introduction

1.1 Road construction in Nepal

In Nepal in general there has been upsurge in road construction in the last decade. The length of road network has tripled in the past 10 years (World Bank, 2013), with most of the increase taking place in the rural road network. Since the end of civil war in 2006, road building activities in the hill districts have increased significantly. The road inventory of Nepal amounts to 12,893 km (DoR, 2016) of national and feeder roads and 60,000 km of rural roads.

The road density is around 48 km per 100 sq. km. This is high compared to neighbouring mountainous countries like Bhutan and Pakistan. Transportation is considered the crucial driver of development, bringing socioeconomic opportunities within the reach of the poor and enabling economics to be competitive (Word Bank 2013).

Yet many of the roads are not properly constructed and often unmaintainable. Also, the green road approach formulated in several document is often not followed. Roads built in the hill districts is highly susceptible to landslides causing increasing number of fatalities (Petley et al., 2007) due to destabilizing effect while inadequate spoil disposal increases weight and alters the natural drainage system (Sidle et al, 2006).

Department of Road (DoR) under Ministry of Physical Infrastructure and Transport (MoPIT) , Department of Local Infrastructure (DoLI), previously known as DoLIDAR (Department of Local Infrastructure Development and Agricultural Roads) under Ministry of Local Affairs and General Administration (MoFAGA), are the main government unit to look at the strategic and local road network respectively. DFID, World Bank, Asian Development Bank (ADB), and Swiss Agency for Development and Cooperation (SDC) are major supporting agencies for the strategic and local road network development in Nepal.

Road construction in Nepal has increased to a new high level in the last three years[1]. A central element of the new 2015 constitution of Nepal has been the decentralization of power and budgetary means to local units (municipalities). Prior to this road construction was the responsibility of DoLIDAR and its local units. This ensured a uniformity of approaches and control of road quality. The decentralization has changed this rapidly – even to the point that local road construction is becoming a major cause of environmental degradation in Nepal.

The budgetary control by municipalities has accelerated road construction: the development of a local road is one of the most coveted program activities. Most of the roads constructed by the municipalities and rural municipalities connect to villages within their judiciary.

[1] In case of Local Road Network (LRN), for fiscal year 2011/12, the total budget estimated was NPR 26 billion which become 6% of the national budget for the same year. In case of Strategic Road Network (SRN), the total budget allocated in the same year was NPR 31 billion (8% of the national budget). Nepal have set a target for budget allocation for the maintenance of LRN. The national target for local road maintenance fund is 10% of the total fund allocated for local road network. The study made under title "Nepal Road Sector Assessment study" has show that only 4-5 % funding is allocated for maintenance of LRN from different funding sources. The report has also shown that financial accountability and transpernacy are areas requiring improvement in the road sector.

Construction is very often machine based: using excavators and bulldozers. This is reflected in the increase of registered earth moving equipment by 200 percent in 2015/16. The number again increased by 50 percent in 2016/17.

In the municipality programs the nemesis of the Green Road approach, the 'cut and throw' technique is also most common. It has replaced the mass balance method where by road cuts were not too deep and the material from the road cut was used to build the road foundation on the lower side. This 'Green Road' practice ensured that there was not much unused road spoil too whereas with the current cut and throw practice road much downhill land is affected.

In the absence of a technical capability at the municipalities, most of the roads are aligned and opened up by excavator operators themselves. This is usually done without taking care of impacts on the environments and local communities. In construction many short cuts are taken. As the local budget usually is limited, minimum safe road slopes for the steep mountain environment are not observed and there is no consideration for drainage or creating tilted roads slopes. Provision for cross drainage are often ignored – creating unstable road sections where a stream or a spring crosses the roads. Typically, the cut and throw method is used that if not handled wells leads to more unstable road slopes and as observed during the filed visit, this typically leads to road that are too steep and dangerous to travel. Add to this the rapid erosion, and many newly built roads are abandoned for vehicles eroding quickly.

1.2 Practice of Green Roads

This report discusses the opportunities for beneficial road water management in Nepal with a focus on the mid-hill areas where the Rural Access Programme-3 (RAP3) program is implemented[2]. The assignment was undertaken for the RAP3 project. The objective as described in the Terms of Reference was to scope the potential for road water harvesting.

The RAP3 was jointly planned by the UK and Nepal Governments. The Ministry of Federal Affairs and Local Development (MoFALD) is the Executing Agency on behalf of the Government of Nepal, and the Department for International Development (DFID) for the UK Government. RAP3 is a UK AID funded pro-poor programme aimed at improving people's connectivity and creating livelihood opportunities. The objective of RAP3 is to boost income and resilience of poor. RAP3 aims to

- Build capacity for the management of sustainable rural transport infrastructure in Nepal
- Create employment for the poor and disadvantaged
- Improve access by developing a more resilient rural transport network
- Improve access to economic opportunities through training, income generation activities, building economic infrastructure and development of the private sector

[2] An earlier assessment evaluated the opportunities for beneficial road water management in the lowland Terai (Mohotarri District) – see http://roadsforwater.org/wp-content/uploads/2018/03/Nepal-report-fnal-layout-2.pdf

The RAP project follows the Green Roads approach[3], developed in Nepal with a number of distinguishing features, among others:

- Use of labour based and hybrid methods – working through local construction teams
- Preference for maximum road slopes – preferably (where possible) 2% or less, but not exceeding 10% to as to ensure road passability and safety
- Preference for out sloping road crowns rather than road drainage canal networks – as the latter have a tendency to concentrate run-off and create uncontrolled spill-over when blocked whereas out sloping crowns dispose of the run-off evenly
- Mass balance method whereby the material from the road excavation is as much as possible reused to make the downslope toe of the road. In this way the road width is not fully excavated from the hill slope – causing less excavation and less disruption to hill sides. This requires the road to stabilize over time and the road widening to be done in phases
- Use of bio-engineering methods to stabilize hill-sides
- Down slope protection, among others with breast walls

RAP3 is engaged in constructing a total of around 97.5 km new roads in the hilly/ mountainous district of Bajura, Humla, Kalikot and Mugu. In addition the project is involved in constructing 67km of a new inter district road to link DDCs of Mugu and Humla. RAP3 project supports 8 core districts in western Nepal with further 6 pilot districts for developing and testing the GON's new Local Road Network (LRN) Asset Management Systems (AMS). One of the key features of LRN AMS includes "Labour Based Equipment Supported (LBES) Approach which promote labour based approaches wherever possible to maximise employment and increase incomes of roadside communities and allows use of appropriate equipment to overcome localized difficulties and accelerate access to other income generation opportunities. The implementation modalities includes the use of Road Building groups (RBGs) and Road Maintenance Groups (RMGs). Recently under the use of earth moving equipment was introduced in combination with labour-based method, for reasons of economy and ability to work

The current report is based on field assessment along three road sections:

- Gamgadi-Gila section of Gamgadi-Dhaina-Dhulachaur district road (RAP3 road, using labour based methods)
- Gamgadi – Dharke Khola Section of MHLR[4] (RAP3 road, using hybrid method): In figure 1

[3] Mulmi, A. D. (2009), Green Road Approach in Rural Road Construction for the Sustainable Development of Nepal. Journal of Sustainable Development, 2, 3, pg 148-164.

[4] When the field visit was made, of Gamgadi Dharke Khola section of MHLR, RAP 3 have almost completed constructing road upto Dumkot section and further.

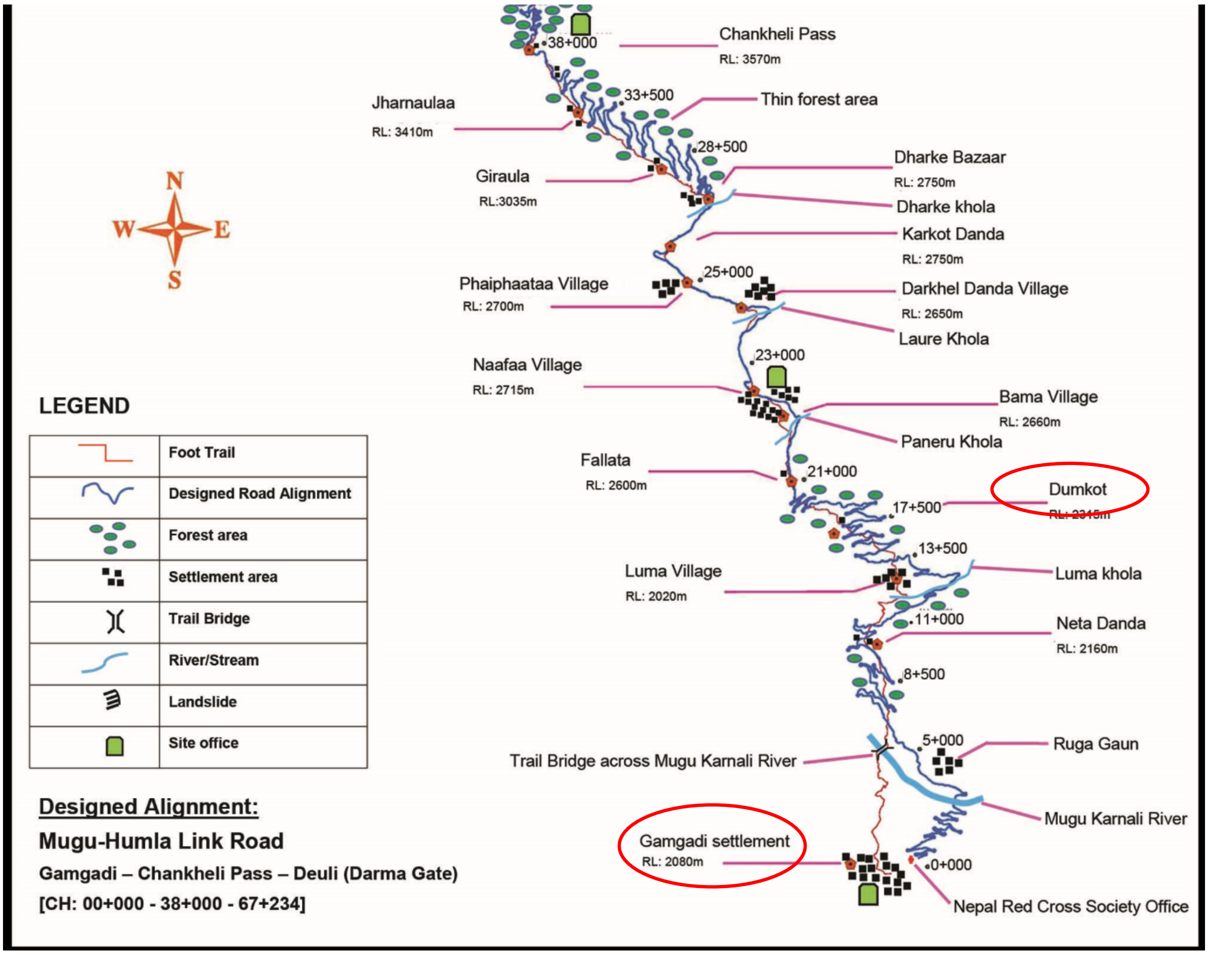

Figure 1: Map of Mugu Humla Link Road (Section Gamgadi-Dumkot)
(Source: RAP 3)

The report explores how to integrate Roads for Water activities into road construction under RAP3 and elsewhere in Nepal. Chapter 2 is an introduction to the project area visited and assessed, in particular Mugu. In Chapter 3, methodology of the study is discussed. Chapter 4 about the impact of roads in the project area is discussed – in particular on hydrology, hydrological connectivity, micro-climate and sedimentation/ erosion. In chapter 5 the recommended practices are given, whereas chapter 6 concludes with recommendations.

1.3 Scope of the Work

The scope of the work for this assignment was defined as below:

- Visits to the ongoing / proposed road alignments, nearby community and agricultural areas influenced by the road and meetings with a variety of stakeholders
- Assessment of the current approaches being undertaken by RAP3 in the construction of roads and their related infrastructure with a view to assessing its adequacy and potential for enhancement,

- Understanding how communities currently store and source water and what their challenges and desires are,
- Assessment of additional features that could be implemented to achieve meaningful water harvesting and to improve the road's resilience to other climate related effects,
- Consideration of how any proposed water storage will relate to monsoon periods and periods of demand e.g. crop cultivation,
- Technical means of concentrating, trapping and storing water in a safe manner including the treatment of sediments,
- Consideration to preventing water storage from saturating or raising water tables to the detriment of surrounding lands,
- Consideration of availability of water storage areas bearing in mind the preparedness of landowners to donate or facilitate suitable spaces, together with their sustainability including maintenance and other demands,
- Understanding equity issues of how the harvested water would be shared amongst potential users and the target use for the water,
- Dealing with cleanliness of water bearing in mind that the road pavements are earthen and vehicles are often of poorly maintained standards (e.g. frequent oil leaks, etc.)
- Safeguards against 'cloudbursts' and other extreme weather events and how these might affect any proposed infrastructure.

2. Methodology

2.1 Desk Study

A team from MetaMeta led by Dr. Frank Van Steenbergen, roads for water specialist, including Saroj Yakami, water resources expert, is involved for roads for water scoping study of Mugu Humla Link Road (MHLR) project. Support was given by Manoj Devkota.

Terms of Reference for Roads for water study was Scope of a study was clarified by the team of Kirsteen Merrilees, Michael Green and Ram Prasad Thapaliya from RAP 3 on 13th of September, 2018 before heading to the field. A checklist for field observation and cluster focus group discussion (FGD) was also prepared (Annex 1). Furthermore, documents related to RAP such as climate change resilience audit reports, EIA, Nepal Rural Road Standards, guidelines related to RMGs and documents and guidelines related to road water harvesting were reviewed. A very short summary of the reviewed documents are presented in Annex 6.

2.2 Field Visit

The field visit was made on 16th September 2018. On that day, the study team made a small meet with RAP 3 team in Mugu to provide short overview of a study. On the way to the office on suggestion of the team stops were made along the Airport-Mugu road, primarily for reference. On the same day, the study team along with RAP 3 team in Mugu, walk along the Gamgadi-Gila section of GDDR. On the 17th study team and field team took a road trip[5] on MHLR from Gamgadi to Dharke Khola observing roads as well as discussing with field team and interview with beneficiaries of the roads. The study team have observed road constructed by RAP up to Dumkot and observed road alignment up to Dharke Khola section. The day end with the study team briefing the RAP field team member about the observation the study team had made and about roads for water opportunities. On the 18th, the study team walk back to Gamgadi from Dharke khola section of MHLR. On the way, the study team along with field team of RAP 3 had an opportunity to further discuss with member of RBGs, local people along the way, local commuters. (Annex 2 for list of people met and interviewed)

On the 19th, the study team travelled back to Kathmandu. In Kathmandu, the study team had a time to meet and brief the preliminary observation and findings to the programme Manager of RAP 3 with the help of PowerPoint presentation[6]. The final draft of the report was submitted to the RAP 3 team for the feedback.

[5] upto BAMA we were transported by a tractor and from BAMA to Dharke khola we made it happened walking.
[6] We could not present our preliminary observation and findings to other concerning members due to their unavailability during the time when study team arrived in Kathmandu.

3. Mugu District

The assignment was to scope the potential for Road Water Harvesting, based on a field assessment in Mugu District. Mugu and the adjacent Humla District are located in Western Nepal and rank among the least-connected in the country.

The development of the roads is expected to bring a number of significant changes in the area, apart from the continued need to address food insecurity and poverty in the area:

- Larger accessibility and easier transportation – more opportunity for cash crops
- Opportunity and interest in new income opportunities
- Opportunity to improve the tapping of springs for drinking water and scope to develop more dry season farming by retaining water from the rainy period

Details on the geology, climate, soils and the socio-economic situation in the Mugu – Humla area are summarized in table 2-1, largely taken from the EIA of the road[7]. The area surveyed is among the poorest in Nepal. Population density is low and land holdings are very small. In some instance land holding are further reduced by the road construction. Most agriculture is moreover rain-dependent and has low productivity. Given the isolation of the area, it comes as no surprise that most agriculture is self-subsistence. It is only in recent years that the cultivation of vegetables was introduced.

Table 3-1: Geology, Climate, Soil and Socioeconomics of Mugu and Humla along MHLR

Parameters	Description
Geology	High Mountain Physiographic – Rock of Kuncha Formation of lesser Himalaya and high grade metamorphic rocks of Higher Himalayan sequences of western Nepal. Along the road alignment: Mugu: Phyllite/Quartzite/Schist/Gneiss Humla: Gneiss/Schist
Climate	Temperate to subalpine climate. The major areas are in upper temperate (1,200-2,000 m) climate followed by lower temperate (2,000-3,000m) and subalpine (3,000-4,000m).
Rainfall/ Temperature	More than 80% of the rainfall occurs between June and late September (rainy season). The average rainfall is 918 mm per annum which is low compared to national average (i.e. 1500 mm per annum). The maximum temperature is 30 ^{0}C and minimum is below 0 ^{0}C
Soil type	Colluviums, residual and alluvium deposits. Residual soil is deposited dominantly in between Gamgadi and Bama village. It develops due to weathering of the parent rocks of phyllite
Land Use	The environmental impact assessment (EIA) report of MHLR shows that the road alignment and road itself covers 71.1% of forest and 14.4% agriculture
Population	Population density of Mugu and Humla is 16 and 9 per sq. Km which is far less than the national average of 180 per sq. Km

[7] RAP 3. 2016. Environmental Impact Assessment Study of Gamgadi-Chankheli-Darma Road (Mugu and HUmla Districts). May 2016. Rural Access Programme Phase 3, Lalitpur, Nepal

Economic occupations	For more than 95% of households, except in headquarters where main occupation is business through hotels and shops, agriculture is main source of livelihood with some family member engaged in government services, pottering, handicraft businesses Seasonal and permanent outmigration to India is a major source for family revenue.
Agriculture	Major crops grown in the project area are paddy (majorly in low land and progressing in the upland too), millet, wheat, Barley, potato, Buckwheat and beans. Other crops includes maize, soybean, grams, chino (porso millet), Kaguno (foxtail millet), Marse (Amaranths) in low land and high land, mustard. The area have subsistence agriculture that depends mostly on rain and some land with paddy cultivation have irrigation facility in Luma and Laurigad[8] through Luma khola and Laure khola respectively. Though in small quantity, in some location, people started growing leafy vegetables, chilly, cauliflower with new irrigation technologies like ponds or tanks as storage system and drip and sprinklers as water delivery means. The area is very good for fruits and high value horticultural crops. For instance, the area have very suitable environment for apple, walnut, apricot, plum.
Cropping calendar	Agriculture is rain fed except few patches of agricultural lands with irrigation facilities. Farmers start growing large varieties of crops/vegetables from the onset of pre-monsoon. 1. Apr-Oct: Paddy, Millet, Maize, Chino, Vegetables, potato, Buckwheat 2. Nov-May/June: Wheat, Hill Barley (nov-apr), mountain barley (feb/mar-Jun/Jul) Some of the crops grows in 2 years cycle. For instance Maize-wheat-finger millet
Livestock	Common livestock in the area: cow, bullock, buffalo, goat, sheep, horse, mules. The purpose of livestock rearing is different and ranges from milk purposes to farm cultivation and transportation. Livestock keeping is integral part of agriculture.
Other local enterprises	Radipakhi, Liu, Feruwa weaving Broom, rope, thunse, supo, Doko Watermill, Transporting goods through animal
Food sufficiency	42.3% of the surveyed households have food shortages, due to limited availability of cultivable land and low productivity. Mugu and Humla ranked among the lowest in the poverty ranking i.e. 75th and 73rd respectively out of 75 districts in Nepal.
Major source of drinking water	1. Majority uses Spring Water with few households use water from tap 2. Karnali River: Cluster like Rugha living nearby River use water from river
Energy sources	MHLR section in Mugu Cooking: 100% firewood (except in Gamgadi where only 70% depends on wood Lighting: >90% in Luma, Bama and Darke depends on Solar. Majority in Gamgadi and Ruga cluster depends on micro-hydro

[8] Supported by community irrigation project (CIP) for 25 ha. Paddy land for the land owned by WN 6, 7, & 8 of Rugha VDC.

4. Effect of roads on surrounding landscape

This section summarizes the effect of road construction on water and land management in the surrounding landscape and serves as the backdrop for the suggested improvement practices.

Constructing roads in the mountain environment of Nepal is challenging. As observed in the Mugu area, the impact of road construction on the hydrology, connectivity, micro-climate, and on the sedimentation process is significant. These changes are discussed below. These impacts without due attention risk being negative, yet can also be turned around in positive factors in land and water management, by deploying the techniques suggested in section 5.

4.1 Changing hydrology

It is unavoidable that the development of roads changes the hydrology of mountain area. The changes concern several dimensions.

First, the development of a road changes surface run-off patterns. The natural run-off is interrupted, as hill slopes are opened up for the construction of the road. In particular, where a road is ascending along a steep hill section using several bends, the slope is interrupted several times.

Rather than flowing down a smooth gradient, the run-off is interrupted once or several times, whilst descending from the newly cut hill-side. The flow velocity is reduced as the run-off touches the road surface and erosive force is released. As the run-off touches the road surface it may concentrate and accumulate along the road surface, effectively changing the natural drainage pattern. The effect of this depends very much on the road drainage systems that is superimposed on the natural drainage pattern. In the RAP3 approach the preference is to have outward sloping road crowns. This is close to the natural run off pattern, whereas the use of road side drains and cross drainage will in general concentrate run-off more.

Secondly, in a similar fashion the subsurface flows are interrupted in road construction (figure 2b). The degree to which water travels in the upper soil layers and geological formations differs from place to place and from road section to road section. The roads however will disrupt these shallow moisture flows and in some areas (see section 5.5) cause new springs to emerge.

(a) **(b)**

Figure 2: (a) Increased air-surface exposure of hill slope and (b) Interrupted subsurface flow due to road openings (photo taken at Dumkot area of MHLR road)

A third effect on hydrology is that with the opening of the hilly terrain the road cut also opens up fresh mountain side and increase the air-surface exposure of the hill slope (figure 2a). This will dry out the hill slopes, the more so when the slopes are freshly cut. There is more over the gully effect of reduced soil moisture up to a certain distance from the newly made road cut. Unless it is covered again with vegetation, it may lead to a bleeding of the subsurface streams, drying up hillsides.

The fourth effect is that with the construction of the roads following in particular the first and second effect many road water crossings emerge. This may be perennial or temporary streams and rain water torrents. The development of roads also affects springs and seeps - opening up new springs and seeps and disturbs existing ones, often changing the orifice of the spring. This is significant – as a large portion of the population in Nepal relies on springs for its water supply. It is also significant because typically the springs and seeps unless taken care off and protected will constantly moisten the road surface, creating deep points under the impact of traffic that often collect excess run-off in rain showers, causing breaches of the mountain side. The extent to which these hydrological changes affect the landscape and the road stability depends on the road construction method chosen (see section 5.7) and the additional measures taken (section 5.1 to 5.6).

4.2 Changing hydrologic connectivity

The construction of roads will also increase the so-called hydrological connectivity of the watershed. Hydrologic connectivity describes the degree to which different elements in a landscape are interconnected. The higher the connectivity the faster the rainfall run off, causing peak flows in the rivers to emerge earlier and generally be more pronounced (Meng, Wu, & Allan, 2013).

Hydrological connectivity is linked to ecological integrity of the landscape (water-mediated transfer of matter, energy and/or organisms within or between elements of the hydrologic cycle). Among other due to road construction, but also due to the large use of fresh water for irrigation or the conversion of wetland, hydrological connectivity is changing at an unusual rate affecting global aquatic biodiversity and ecosystem integrity.

4.3 Changing micro-climate

The opening of the roads in steep mountain terrain has a large bearing on the micro-climate (see figure 3) of the road side areas, the more so when forest areas are traversed. The impact on the micro-climate comes from several factors, in particular the changed hydrology and the larger exposure to sun and wind.

The overall changes in the hydrology were described above (section 4.1). The introduction of road alters the hydrology of the area. It interrupts the natural water flow system - of both surface and subsurface streams. The sides of the roads will are opened up, causing in the first years in particular a moisture bleeding of the surface – the more so when cut and throw methods are used. This ultimately leads to a lower capacity to retain water. This in itself can effect soil temperatures and with soil microbiology. As soils will be dryer there is less microbial action in the soil which will reduce the capacity to fix nitrogen for instance with repercussions on vegetative growth.

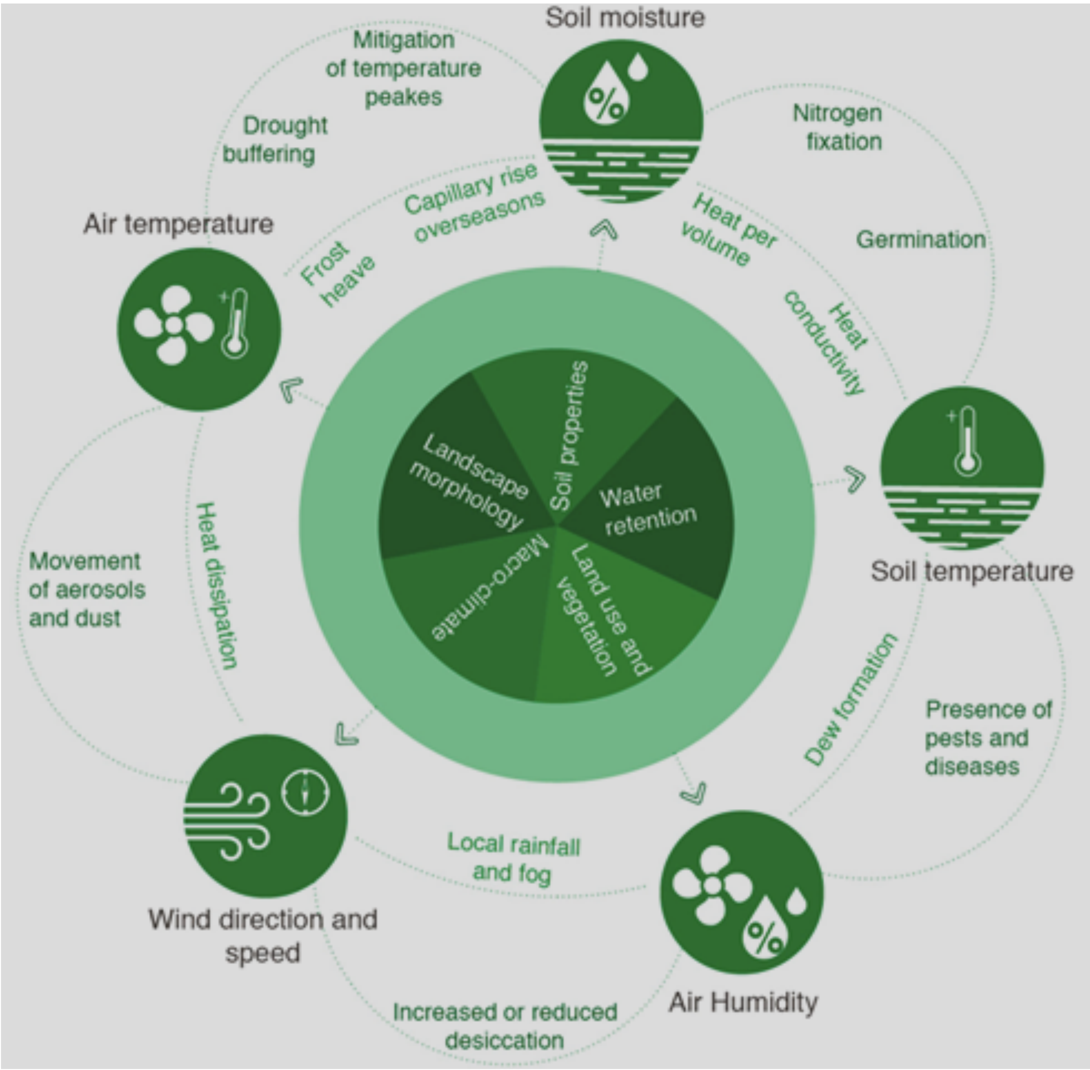

Figure 3: Parameters of micro-climate

In addition to the changes in the hydrology, the forest micro-climate is also effected by exposure to sun-light – reducing air humidity and increasing air temperature. The hill side that are cut during the road construction are also exposed to direct sunlight. This will cause the soil moisture to be further reduced. The cutting of tree leads to less canopy and shade and more open space. This increases day temperatures and reduces nigh temperatures.

A third effect is the exposure to wind. The opening up of the roads also give more exposure to wind, which will increase the desiccation of both soils and remaining vegetation.

The expected cumulative effect of these changes are a gradual drying and am increase in day temperature and a lowering of night temperature. This may also effect local rainfall patterns and the occurrence of dew – which is an important source of moisture for the vegetation. To rebalance this measures should be taken to retain moisture and regreen the area.

4.4 Sedimentation and erosion

The fourth main environmental effect is the increased sedimentation. The cut and fill section of the road and road surfaces itself are very vulnerable to erosion. Much erosion occurs during road construction, accelerated when the slopes are not stable. The rainy period may bring gullies and slides – multiplying the sediment run off (figure 4b). In addition the road surface is a source of sediment too. No studies are known from Nepal, but the construction of the road typically increases erosion with at least 12 to 40% compared to the natural catchment (Bryan and Schnabel 1994; Luce et al, 2001, Megahan et al. 2001)[9]. This effect can however be almost halved with sound road location and adequate road drainage.

(a) (b)

Figure 4: (a) agricultural land facing problem due to sedimentation (in between Rugha and Neta Danda); (b) water collected from the catchment and road itself washed away road section forming a small gully like structure (in between zero point in Gamgadi to Mugu Karnali River).

[9] When a catchment is heavily eroded the additional impact of the road on sedimentation is proportionally less and in fact roads can help mitigate some of the erosion. Hence in relatively pristine watershed the contribution of a road to sedimentation process is proportionally higher, than maybe lower in absolute numbers.

5. Recommended Practices

The RAP3 program is very significant in introducing good practice in road building in Nepal. To counter the negative effects of road development on their immediate environment and to improve, a number of practices should be added to the repertoire of Green Roads in Nepal. These measures will reduce the negative effect on hydrology, sedimentation and micro-climate due to road development and in some cases will contribute to better resource management. They will also protect the roads from water damage and make the roads more climate resilient. The measures proposed are all low cost and in many cases making use of the spoil material from the road construction. The measures are also proposed so that they can be integrated in the work of the Road Maintenance Groups.

Table 5-1 below shows an overview of the different techniques proposed, the objective that they contribute to and their beneficial or mitigating effect on hydrology, connectivity, micro-climate, sedimentation and erosion and on road quality.

Table 5-1: Practical measures and techniques for improved road water management and their effect on hydrology, hydrological connectivity, microclimate, sedimentation and road quality

Measures	Techniques	Hydrology	Connectivity	Micro climate	Sedimentation	Road quality
Improved road water crossings	Tilted causeways Dissipation blocks Check dams Down road protection		+		+	+
Improved moisture retention	Semi-circular bunds (half-moons) Reuse excavated soils Stone bunds	+		+	+	
Water harvesting in ponds	Water ponds Sediment traps	+				
Reducing sediment wash in on farmland	Infiltration bunds Temporary water bars	+			+	
Manage mountain springs and seeps	French mattresses Spring boxes Gravel sections in earth roads	+				+
Reduce road damage at hairpin bends	Water exits				+	+

5.1 Improved road water crossings

When a road is opened up, many new road water crossings are created. These may be of regular streams that are interrupted or of torrents that only flow during the rainy season and now descend on the road body. Unless measures are taking, these interrupted streams and torrents will damage the road surface by their erosive force and by creating extensive wet road sections that are easily damaged under traffic impact. The erosion may easily extend to the land alongside the road. To reduce the damage from these water crossings three techniques are proposed:

- Dissipation blocks
- Tilted causeways
- Check dams and down-road protection

Dissipation blocks
Streams and torrents during the rainy season, especially where rain concentrates and flow, have high tendency erode the surfaces. In steep slopes the eroding capacity of torrents increases multifold, as the velocity is very high. Where the stream descends on the road, the use of dissipation blocks is recommended (figure 5).

In the mass balancing method care is take to manage the road spoils, among others by stacking up stone blocks for further use. These stockpiled stoneblocks can serve as dissipation blocks. if they are placed where a stream or torrent hits the road. The placement of the dissipation blocks will breaking the speed and erosive power of the streams. This measure would come at no extra cost in many cases, as the stoneblock are being stockpiled for use in future repairs, yet are now often placed off-stream. The blocks are best placed 30-40 centimeters away from the side-slope and some flat stones may be placed inbetween the the torrent coming from the hill-slope and the dissipation block in order to break the velocity impact of the descending water. After this, the stockpiled stones will further ‘baffle’ the force of the mountain stream.

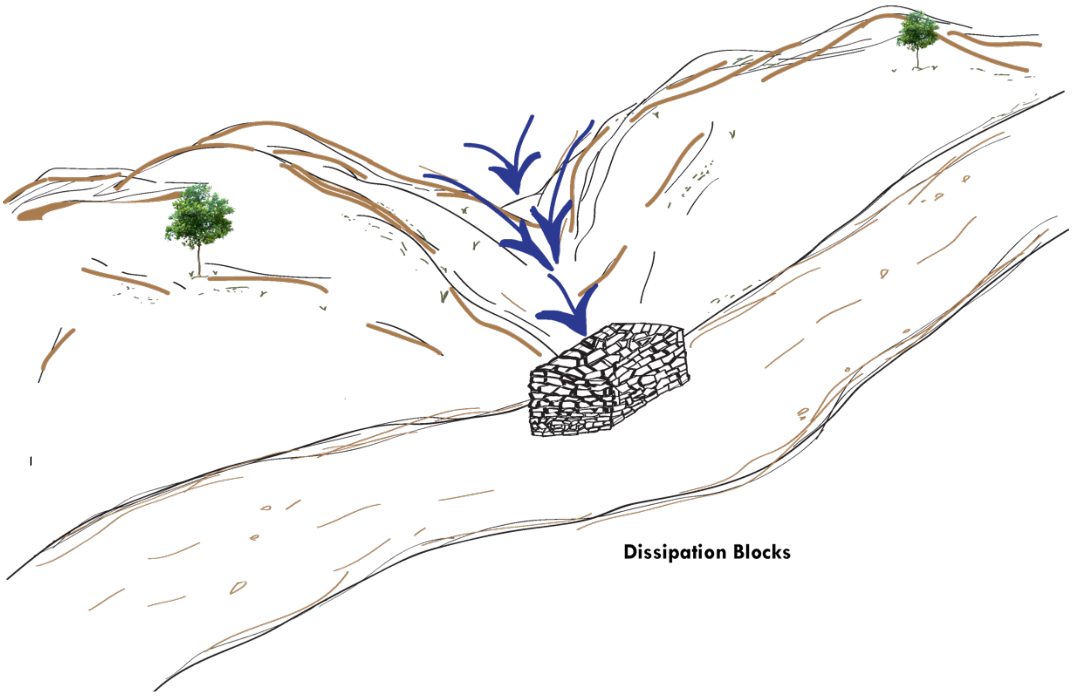

Figure 5: Schematic diagram for Dissipation Block placement on the road

Reinforced tilted causeways

Roads are traversed by several streams. Prior to the construction of the road such stream followed their natural course. With the construction of the roads the stream flows are interrupted and the gradient is broken. Depending on the local topography and the nature of the stream, a hydraulic impact is created on the road surface. The streams differ – some are perenial, some seasonal, but they will all increase their discharge, velocity and erosive/ torrential power during monsoon.

The current practice in RAP3 is to use reinforced causeways made of flat stones. The causeways – like the entire road – are tilted at a slight angle (max 4 to 5 degrees[10]) towards the downhill side so as to facilitate the drainage of the water from the stream. This is a good practice. It is making use of local material and provides for structures that are easy to maintain.

To improve and guide the removal of water, It is proposed to make a depression in the middle of such causeway (see figure 6). This depression is to be modest. In case the causeway has a width of 25 meter the lowered section should be 25 to 50 cm. This will have several benefits:

- it forces the stream and torrent flows towards the middle of the causeway and continue their flow – among others avoiding erosion of the banks of the downroad part of the water course
- It will reduce the chance of side-spills from the causeway during high discharges that may damage the road body.

[10] As per the Nepal Rural Road Standard (NRRS), the maximum cross slope is different for different on the road types. For, earthen road: 5%, Gravel road: 4% and Bituminous seal coat road: 3%

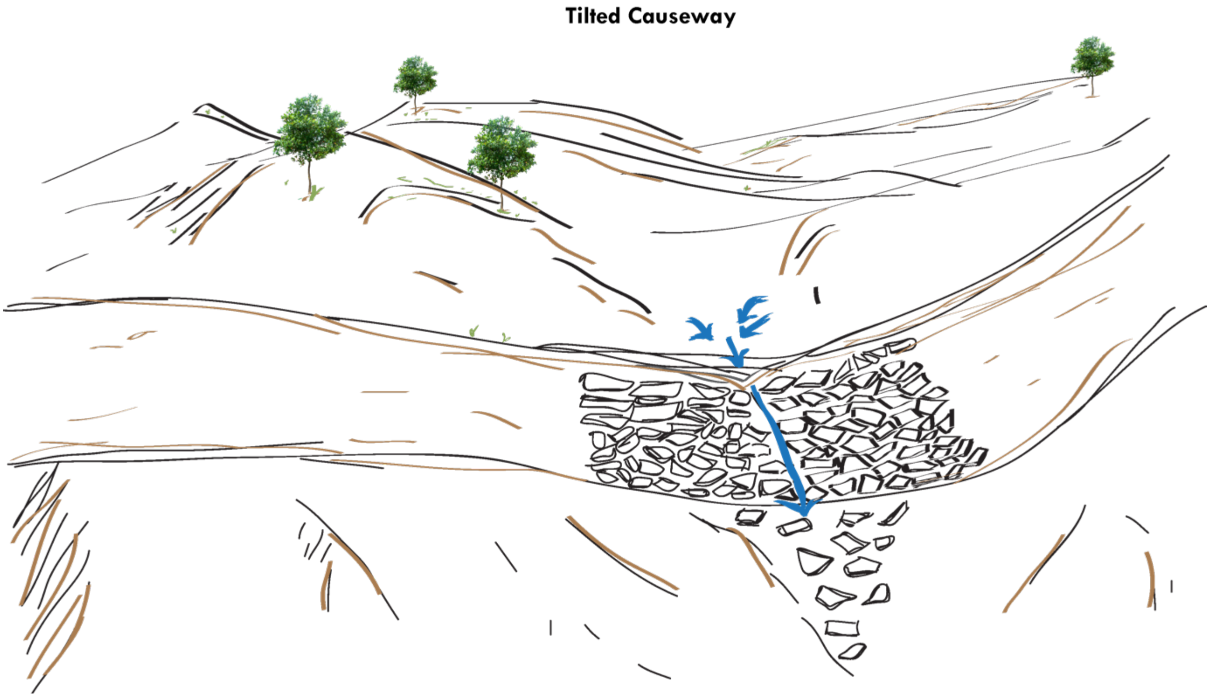

Figure 6: Schematic of Reinforced tilted Causeways

The depression should be at angle of maximum 5 degrees so as to not interfere with the road passibility. Where the road water exits the tilted causeway, it may be useful in many places to armour the down stream parts of the stream.

Checkdams and downstream protection

In the accidented terrain of Nepal most streams will flow at high velocity. The development of a road section creates a hydraulic jump in these chutes that can do considerable damage to the road surface and side slopes. Making checkdams in the upstream section of these road streams will reduce the velocity of water crossing the road. The spare stone blocks from road construction may be used to build up small checkdams in the upstream part of the streams (figure 7). The excess material may also be used to armour the down road part of the stream by placing some stones there. This will prevent damage from erosion to the landscape and avoiding upward gully development that could effect the road body.

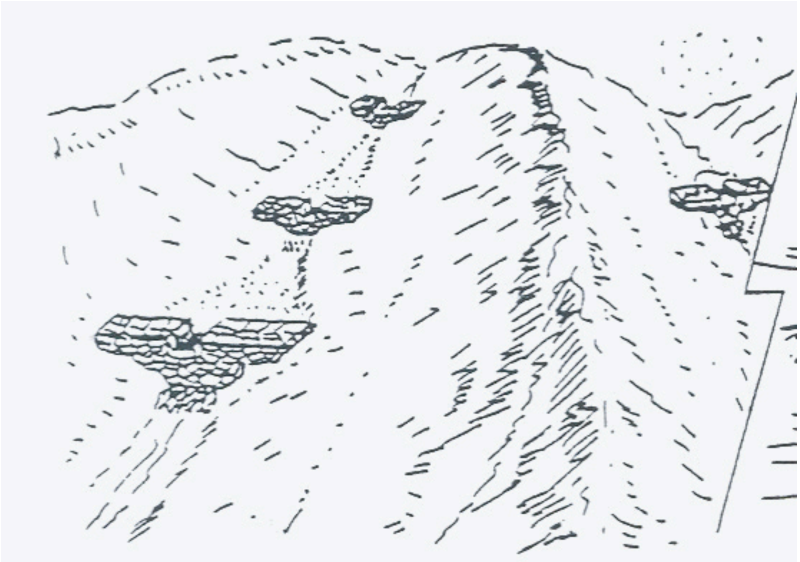

Figure 7: Schematic of cascade of Check dams in the upstream of road in a stream

The general criteria[11] for such checkdams are:[12]

- Spacing between check dams = height * 1.2/ slope of stream in decimals
- Side key of check dams 0.7-1 meter each side
- Bottom key and foundation 0.5 meter deep
- Height of checkdams 1 m (maximum excluding foundation)
- Stone face vertical to horizontal ratio 1:3 to 1:5
- Spill way (preferably in trapezoidal shape) width 0.75-1 m; depth./ freeboard 0.25 m
- Using rock rubble for apron immediately downstream: length 1 m and width 0.5 m

5.2 Improved moisture retention in forest/pasture areas

The different changes that come with the road construction were described in chapter 4 (changed hydrology, opened up hill slopes, more exposure to sunlight and wind). They add up to a severe effect on the micro climate that could affect the forest stands or the quality of the pasture. The impact on the microclimate will be less water retention and hence loss of moisture and increase in temperature and more dissipating effects.

To counterbalance this effect, the capacity of the affected area to retain moisture should be increased. This will also reduce the risk of erosion and degradation of forest hill slopes. This will contribute to the regreening of the area, including the compensation of those trees removed during the road construction. The presence of large quantities of spoils (rocks and boulders) from the road construction again presents the material for these measures. Proposed is the use of eyebrow/ half-moons and stone strips/ rock bunds.

Eyebrows/half moon terraces

Eyebrows/halfmoon are small, semi-circular and stone-faced structures that open in the direction of the run-off (figure 8). They can be built on steep slopes, usually with a maximum

[11] From Desta et al (2005)

[12] Based on ICIMOD and Desta et al (2005)

preferred slope of 50%, yet steeper gradients are possible, especially when rainfall is not torrential, as in the project area. On a slope also the steepest sections should be avoided and the eyebrows may be recondstructed.

The steeper the gradient, the more the bunds have to be reinforced (by stone) in the downward toe and the higher the downward toe section becomes. The typical diameter of the eyebrow should be betweeen 1.4-2.5m with a infiltration or planting pit of size 40 cm wide by 50 cm deep. The suggested size of eyebrows with different gradients are given in table 5.2 below

Figure 8: Eyebrows in Ethiopia

Table 5-2: Sizes of Eyebrows with gradient

Gradient	Stone ring diameter	Inner cross width	Backwall height	Reinforced backwall
30	30 cm	220 cm	70	-
45	30 cm	180 cm	120	10 cm
60	30 cm	140 cm	180	20 cm

Abundant spoil material can be used to build up the semi circular eyebrows. The topsoil that was removed whilst making the road can can be used to fill the inner side of the semi-circular stone structure. This can be be used for tree planting and can contribute to the regreening of the area. Around eyebrows/halfmoon, controlled grazing is essential if the area is regreened. In the forest areas, it is good to have high density of eye brows (see figure 9). The preferred distance between lines of eye brow terraces is given in table 5.3.

Table 5-3: Preferred distance between lines of eyebrows terraces

Gradient		Distance between lines of eybrow terraces (meter)
30		15-20
45		10-15
60		8-10

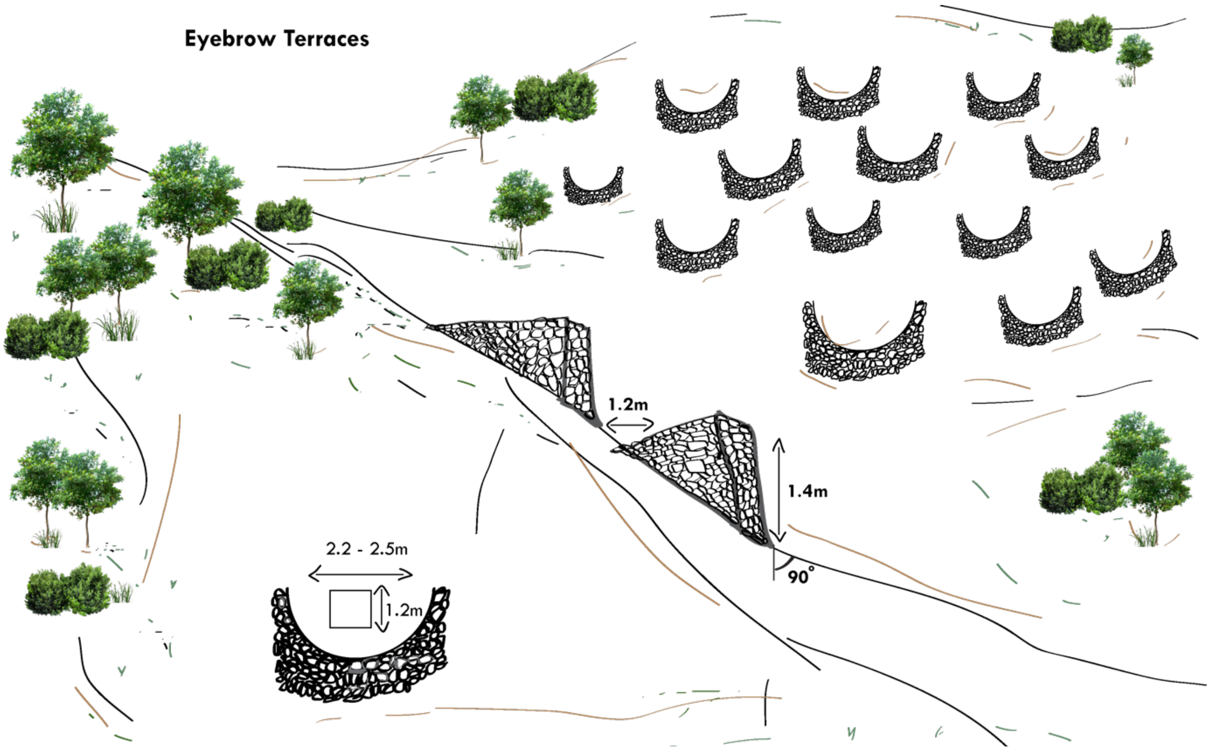

Figure 9: Schematic of Eyebrows in the hill slope

Stone strips

The eyebrow can be complemented by by stone strips or rock bunds, in particular on slopes that are relatively even and not too steep (<50 degrees). They are built from coarse stones and boulders (see annex 3). These stone strips will slow down run-off, intercept sediment and built up soil layers. They will stretch over the width of the slopes, allowing water to filter through as they are permeable. See figure 10 and table 5.4 for layout and design of Stone stripes for different gradients. In the atmospheric conditions of Karnali the stone bunds and the eye brows will also act as dew traps in part of the year, including the important post-monsoon period when moisture availibility is at premium. This is particularly true for spoil that contains mica and that has high thermal conductivity and will cause the stones to cool off significantly at night, triggering the formation of dew.

The minimum criteria of the stone strips are:

Table 5-4: Basic Parameters for Stone at different gradients

Gradient	Heigth (m)	Vertical Interval (m)	Distance between stone strips (m)
30	1	2.8	6
40	1	2.8	5
50	1	2.8	4

Note: Though the table shows the possibility to build stone stripes even in 50% slope, the field situation need to be observed carefully when the slope increases.

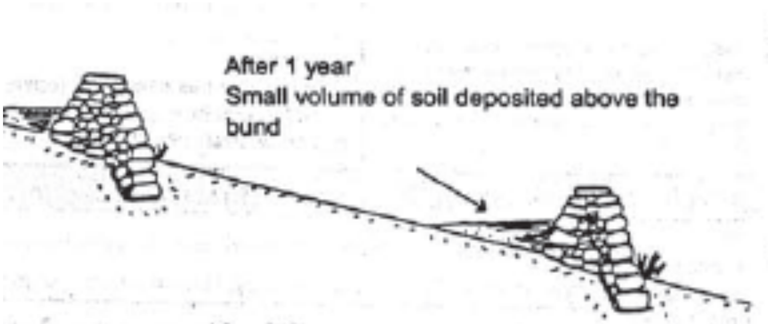

Figure 10: Side view of stone strips (from Lakew et al, 2015)

Make better use of soil

The construction of 3.5 meter new section of road for 1 kilometer with soil depth of 30 centimeter would in principle yield 1050 cubic meter of soil.

This is a valuable asset in land development and in regreening hill sides. These hillsides are often deforested and stripped of vegetation during the road building process. By setting aside this soil in combination with eye brow and stone strips the replanting of tree on the hill slopes can be accelerated and the watershed can be protected again. This is already recommended practice, but appears not to be used regularly

5.3 Reducing sediment wash in on farmland

The new roads cross agricultural areas (figure 11) in the numerous locations (for instance the MHLR crosses Rugha, Neta, Luma, Bama and Darke villages in Mugu road section). In some of the areas, farmers do a year round agriculture. In other cases farmers practice agriculture during rainy season only.

During the monsoon, fine material from the unpaved roads is washed into the adjoining agricultural land causing loss or damages to the crop. Though no data are available for Nepal, the surface of unpaved roads are known to be major contributors to the sediment load in water catchment (see also chapter 4.4). In the project area the road material consist of relatively unconsolidated material, and the washing of road material is an important concern, reported so by farmers.

The good practice in RAP3 and the Green Roads in Nepal is to use outward sloping road surface so as to drain water evenly from the road to the adjacent land. The slopes preferably have an inclination of maximum 5% and hence in principle avoid that run-off traverses on the road surface. Even so a certain amount of concentrated flow along road sections is unavoidable, in particular in slopy road sections.

The sediment inflow requires farmers to replant several times which negatively effects agriculture. To reduce this it is recommended in areas with farm land adjacent to the road to:

- Use Infiltration bunds
- Use temporary water bars during the monsoon.

Figure 11: Road crossing agricultural areas in the MHLR (photo location: in between Luma and Neta Danda)

Infiltration bunds

It is proposed to apply infiltration bunds in the downslope road reserves in areas where road water is expected to wash in to agricultural land. Infiltration bunds can be made of the road spoils, in particular using uniformily flat stones – of a 8-10 cm thickness (figure 12). The flat stones are placed in a dense mosaic in the road shoulder at downstream side of the road. The width of the infiltrating bunds may be equal to the width of the road shoulder, i.e. 50 centimeter. The stones are placed in a pattern where by larger stones (diameter of 20-25 centimetres) are placed close to the road surface with a row of smaller stones – diametre 15 and 10 centimetres) towards the mosaic – as shown in the illustration (figure 13). The open space is preferably equal to 25% of the surface.

The infilration bunds will act to intercept the road sediment flushing to the lower side of the road to the adjoining farm land. The infiltration bunds have two functions: they will dissipate the flow velocity and they capture the sediments. This combines well with the outsloping free-draining road crown, as used in RAP3 and other Green Road projects in Nepal. The infiltration bunds prevent sediment coming from the cut slopes and road surface on tot he farm land. The construction of the infiltation bunds should be added to the work of the RBGs and RMGs.

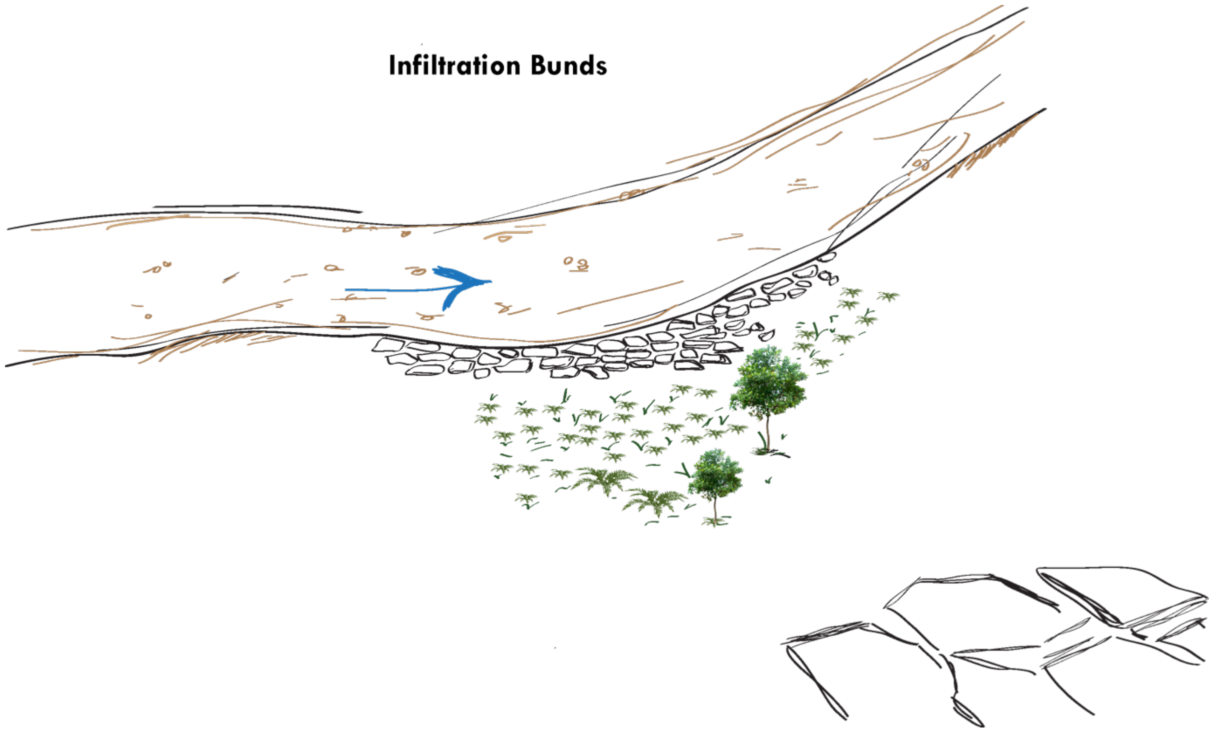

Figure 12: Schematic of the location of Infiltration bunds

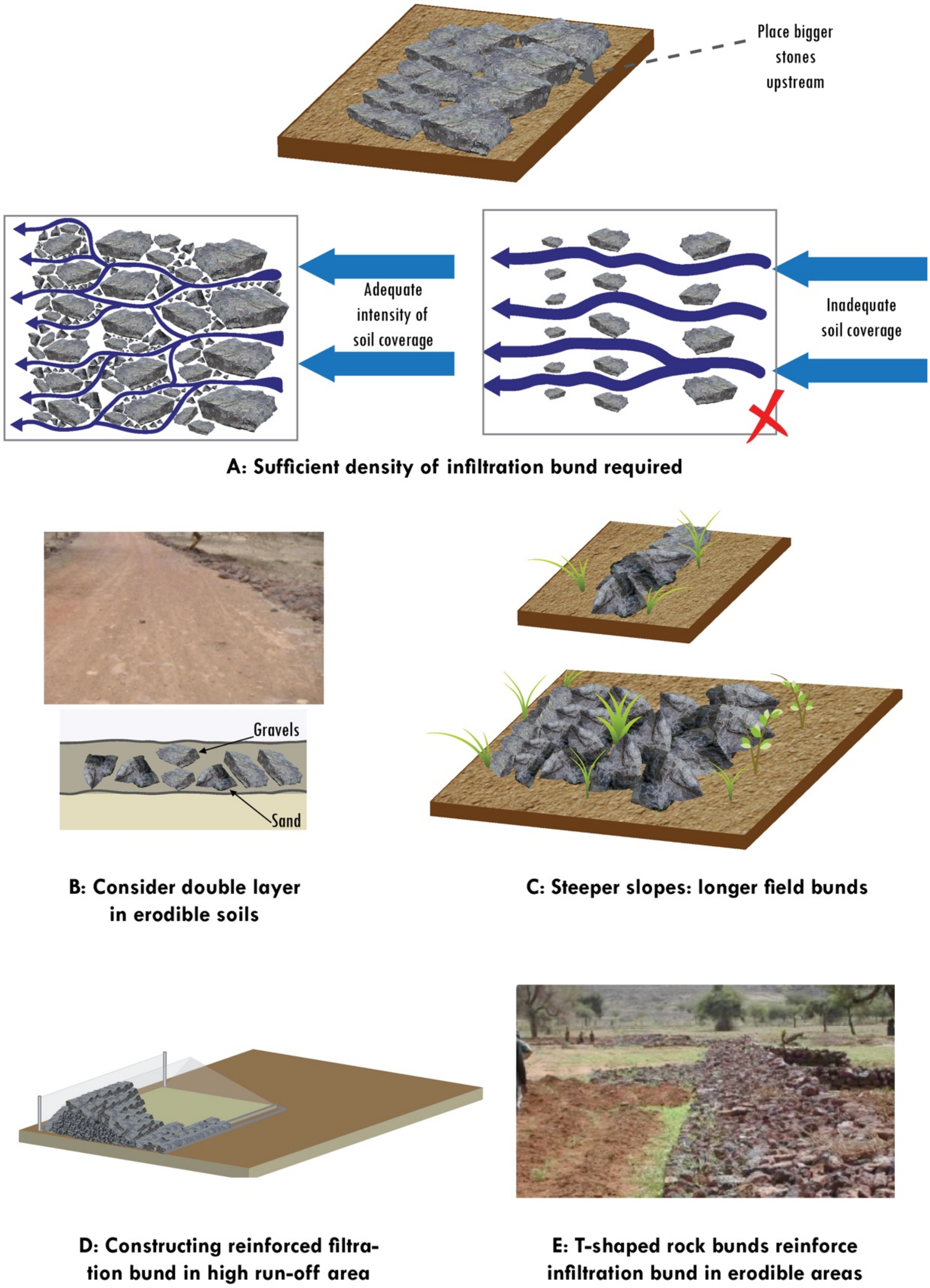

Figure 13: Illustration of Infiltration bund for different scenarios

Temporary water bars

Water bars are effective methods to halt water run-off along the road surface. They prevent that water runs along a long stretch of the road, gathering volume and velocity and in the process eroding the road surface.

They are already in practice in few locations of RAP3 roads. Water bars are a good measure to safely dispose water from the road surface to adjacent land. Water bars are narrow earthen structures build at an angle (preferably 120-150 degrees) across roads to reduce the speed of water and consequently reduce erosion and uncontrolled runoff (figure 14). They generally have a height of 75 to 150 mm, with a travel length of 0.3 to 1 meter. They are easy to constuct by Road Maintenance Groups at no cost and can be removed during the dry period as they may slows down traffic. These structures can be constructed with hand tools.

Water bars should dispose excess runoff at place where it does not do any harm in the adjacent land or where it is even of beneficial use (in groundwater recharge areas or in water ponds). As the road run off may carry unwanted sediment for such beneficial use, it is a good practice to trap some of the sediment by running it across a low use field (with fodder grass for instance) or using a small sediment excluding device (such as an infiltration bund – see above). Runoff should be disposed into vegetated areas or water harvesting structures to avoid erosion. In dry years water bars combined with infiltration bunds can function as to add water in the productive uses.

Figure 14: Water bar in the place (source: United States Forest Service, 2017)

5.4 Road water harvesting for agriculture

In Mugu and Humla districts, rainfall is low (988 mm) when compared to national average. Most rainfall is concentrated between June to September (figure 15). Not more than 20% of the rainfall fall outside this period. As a result in the post monsoon period drought sets in relatively quickly[13]. The area for its agricultural water is also dependent on two other sources: the snow melts in particular in the pre-monsoon period and the dew that forms in several areas (depending on the air moisture and the surface temperature).

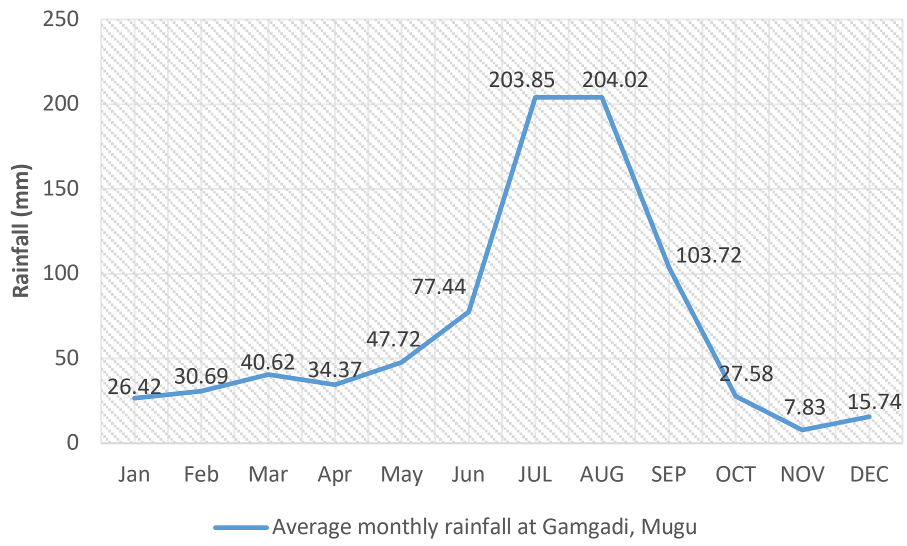

Figure 15: Average monthly rainfall at Gamgadi, Mugu
(Source: EIA of MHLR)

The dry period following the monsoon is a critical period. In this dry periond access to stored water can make a big difference in terms of increased cultivation (vegetables) or increased watering of the fields in the areas where rainfed agriculture is practised. The crop calender is described in Chapter 3. It is in these areas that storing water during the rainy season – either in ponds, tanks in order to use during dry and droughts is most important. The use of groundwater wells is not common in the area – the steep slopes and the prevalent geological formations (see chapter 3) preclude this. Instead groundwater is used in the shape of springs. These may be better managed and utilized (section 5.5).

It may also be possible to improve water availabilty post monsoon by developing small storage ponds along the roads, that are then fed by road run-off. This is a common practice in some other countries and also occurs in a limited number of places in Mugu, including along the MHLR. The overall scope for road water harvesting ponds in the Mugu area is relatively limited for a number of reasons:

- Because of the steep terrain the potential locations for ponds are limited – there are no natural depressions that can be used and much of the potential land is already in use for farming
- The soils are relatively coarse – hence without lining there is considerable seepage

[13] In the pre-monsoon period the lack of rainfall is compensated by snow melt.

Even so, given the large food insecurity, the still relative isolation and the general poverty in the area, it is useful to promote more water harvesting ponds. Such storage ponds because of the nature of the terrain will be small – and will best be used for supplementary irrigation or for the cultivation of seedlings or small vegetable plots. It is best combined with a (vegetative sediment trap) and small micro-irrigation (bucket drip) or greenhouse. The method to calculate the optimal size of the pond is given in *annex 4*.

5.5 Manage mountain springs and seeps

Particularly in mountain areas, the development of roads - either though the removal of unconsolidated material or the cutting of rock formations - will affect the occurrence of springs. Table 5.5 shows the effect of road opening in the different spring types. The development of roads may distort existing springs but may also create new ones. Given the importance of springs for domestic water supply or for agricultural use, the management of mountain springs in road development should be integral part of road construction. This is an important given that in the mountain region of Nepal, where as elsewhere in the Hindu Kush and Himalys springs are the major source of domestic and irrigation (Poudel and Deux 2016). Drying up of springs triggered by changes in land use and in hydro meteorological conditions is an important concern.

As mentioned, there are several types of springs. Geomorphology and geological fabric (i.e rock type, tectonic fabric – faults and fissures and orientation of the rock layers) determine the type of springs that occur. There are two broad categories– springs with concentrated discharge through one or more clear orifices and those springs with more diffuse discharge. The different springs and the effect that road development will have is given below.

Table 5-5: Effect of Road development in different type of springs

Springs' Type	Description	What roads will do
Springs with concentrated discharge (through one or more orifices)		
Fracture springs	Fault, fractures and cleavage in semi-permeable and permeable formations connected with a water source (seepage, flow shallow or deep aquifer)	Road development may expose the spring; rock cutting may change the location of the orifices – either blocking old or creating new ones
Contact spring	Permeable layer overlays an impermeable layer, forcing water to come out – often in a line of springs	Road may distort the outflow of the spring, causing orifices to be blocked or new ones to be created – much dependent on the geological faulting
Fault spring	Due to geotectonic movement a permeable layer is moved on top of a impermeable layer	Road may distort the outflow of the spring, causing orifices to be blocked or new ones to be created – much dependent

		on the geological faulting
Depression springs	The groundwater table reaches the surface in topographical low	Road may create new depression springs where the roads are made in cut or dry existing one by lowering the groundwater table
Karst springs	Relatively large flow from large openings – typically in karst areas where water erodes the calcium formation	Roads may expose new springs and expose new cavaties
Springs with diffuse discharge		
Seep	Diffuse direct discharge of water usually from soils or unconsolidated sediments (sand or gravel)	Road development may create many seeps, especially where roads are developed in areas with deep soil profiles
Secondary springs	Water issued from a primary spring that is typically covered by debris or rockfall	Road development may expose springs or change the outlet, in particular where unconsolidated material is removed

The springs and seeps are also main sources of road damage, either by affecting the road surface directly or by creating (minor) depressions in the roads that enlarge during the monsoon and cause the uncontrolled and erosive exit of run-off water from the road bodies. The construction of new road have opens up number of seeps and springs (at the cut section) along the road stretch between Falaata-Bama-Darke Khola. Also in the Airport to Gamgadi a large number of springs were opened or distorted.

To manage the springs along the mountain roads is important hence to safeguard road quality and ensure water supply for domestic and agricultural use. The following general practices are recommended.

Preparation:
Before the road is made, the geology must be understood and the areas where springs occur or are likely to occur should be made. When road are being made, they effect the location of the spring, if not handled carefully. The use of bulldozer or excavators in the areas of high potential springs should be avoided and instead manual labour should be used to excavate the road in such sections.

Development:
Once the road is developed the presence of springs and seeps will be evident. A choice has to be made whether the spring or seep will be used or not. In areas with a low population density, spring may not be utilized but should still be manage to prevent that their discharge will damage the road body (table 5.6).

The following are the main types of spring and how they are affected by road building and are best managed:

Table 5-6: Recommended Practices for spring management

Springs' Type	Description	How can we manage?
Spring with concentrated discharge	Not used	Construct retaining wall
	Used for agriculture	Retaining wall and collection point with French mattresses underneath road
	Used for domestic water supply	Spring box and conveyance to benefitting community
	Used for domestic water supply and storage	Spring box and conveyance to benefitting community. Include possibility of spring closure (tap) to store water inside the mountain aquifer (esp in karst areas)
Spring/ seep with diffuse discharge	Not used	Develop road drainage in uproad section to collect seepage and convey
	Used for agriculture	Use gravel section in road to have water conveyed tp agricultural land

French Mattress

It is a structure under a road consisting of coarse rock wrapped in geotextile through which water can freely pass (figure 16 & 17). It is used in saturated soils such as wetlands, to support the road bed while allowing unrestricted water movement. It allows the free movement of water through road base and help to stabilizes the road base. This technique is good suit where roadside springs result in road base saturation. The water passed from French mattress, laid across the road width, can be collected in the collection point in the downstream of road.

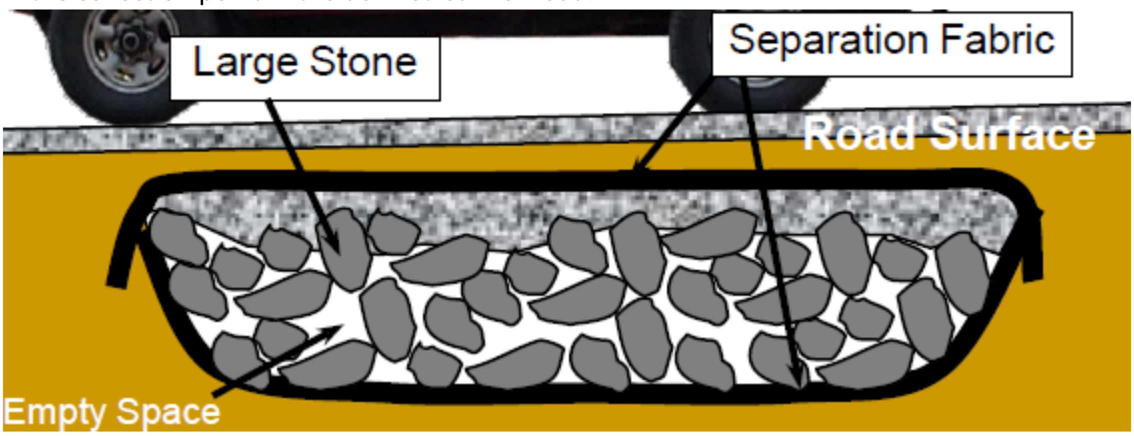

Figure 16: Schematic of a French Mattress (source: PennState, 2019)

Figure 17: French mattress in the place (source: PennState, 2019)

Steps

i. Excavate trench to desire depth and slope, allowing for minimum of 12 inches of compacted cover over the mattress.
ii. Place geotextile fabric in the trench. Make sure enough fabric to overlap the top piece geotextile.
iii. Place stones on fabric in the trench and spread it uniform of desire depth
iv. Place geotextile fabric on the top of the stone. The overlap of a fabric joint need to be at least 12 inches
v. Place enough fill of minimum 12 inches of compacted cover over the geotextile fiber and surface aggregates on top of it.

Spring Box

A spring box function as a chamber to collect water from the springs. Spring box are the protective structures that assure water supply either for irrigation or domestic purpose. These structures not only increases the volume of water that can be diverted but also protect sites from contamination from surrounding activities.

The following steps are for spring box design

i. Locate spring site and clean out the area surrounding the spring. It is necessary to make sure water flows to the collecting area.
ii. Pile loose stones and gravel against the spring before putting in the spring box. It is good to dig deep enough to reach impervious layer as it make good foundation for spring box. The stones serve as a foundation for the spring box and help support ground near the spring opening to prevent dirt from washing in.
iii. The spring box can be laid near the spring source or a bit far depending on the spring location and surrounding areas. It is necessary to lay down pipe that will take water to the spring box. The spring box can be constructed using stone and cement or any other types of container. Need to locate exit pipe in the spring box to convey water from spring box or to directly use water from the spring box.
iv. Good to dig a trench above the spring source for diverting surface runoff and erosion from the surface water flow depending on the spring site location.

5.6 Avoid erosion in hairpin bends

By maintaining a gentle road slope of average 7%, the road constructed by necessity have a large number of (hairpin) bends. It is observed that in the construction of hairpin bend often times excess material is placed in the outer bend. This prevents water during rain fall events from evacuating the road (figure 18). It forces water to stay on the road and typically cause degradation and water logging in the lower inner bend and beyond. It is proposed to revisit the different hairpin bends and even out of the outer bends and ensure that water is safely disposed at these bends.

Figure 18: Hairpin section in MHLR. Hairpin section in the road have inner slope

6. Follow up

6.1 What can be done where

The term-of-reference requested the identification of measures that could be implemented. These are described in chapter 5. The table 6.1 below describes what can be done where on the Mugu Humla Link Road up to Dharke Khola.

The measures proposed in most cases build on what RAP3 has been doing and in general are low cost, making use of excess material and local labour. It is proposed to implement these on a trial basis prior to the monsoon season and to observe how the different low cost structures (such as eye-brows, stone strips, infiltrating bunds, tilted causeways, dissipation blocks stand up in the monsoon season) and if required fine-tune the specifications.

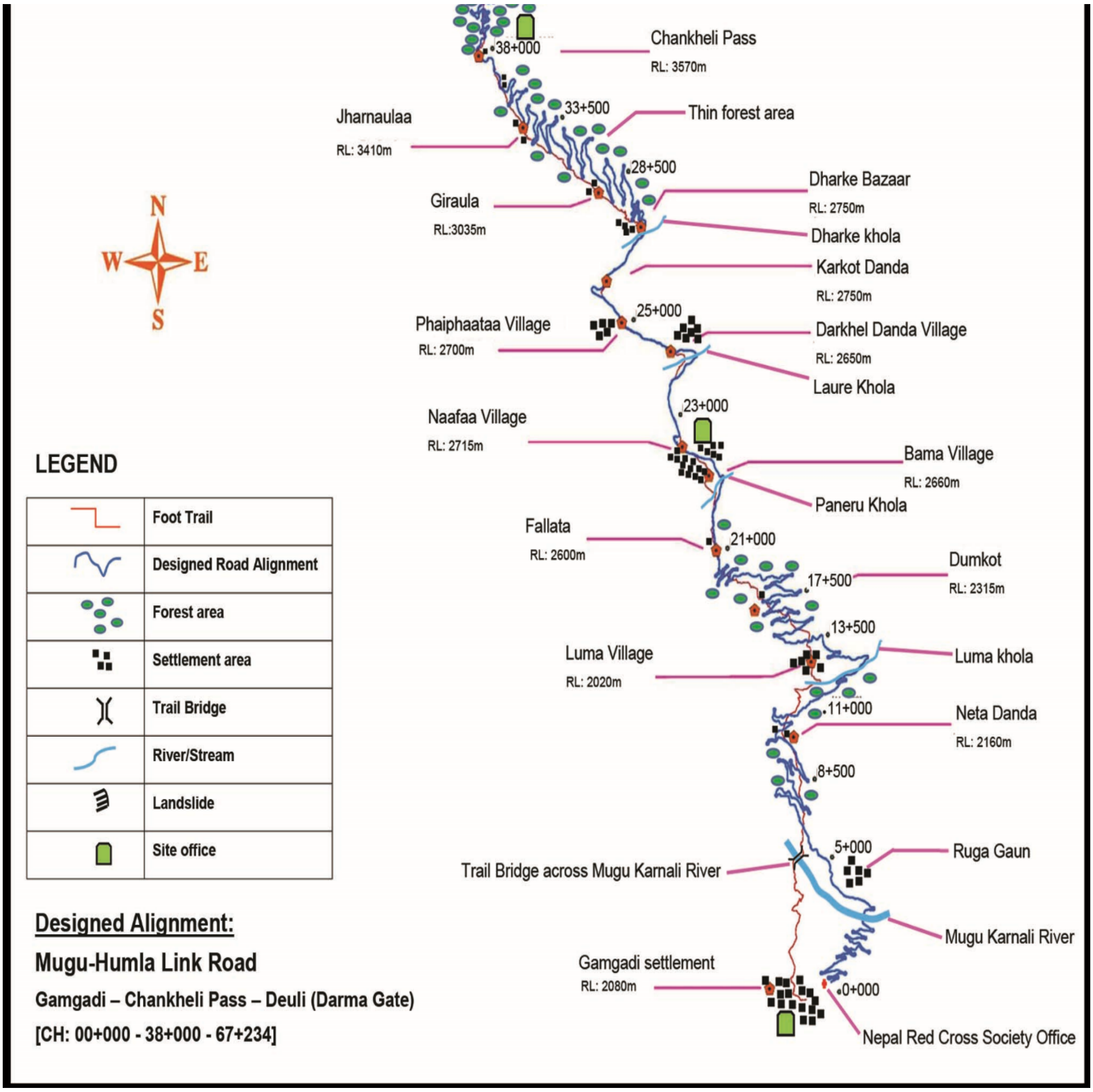

Table 6-1: Area specific recommendation for road water harvesting techniques

	Objectives	Techniques	Recommended Location/area
1	Improved road water crossings	Tilted causeways Dissipation blocks Check dams Down road protection	- Number of water crossings (either active in monsoon or year round) in MHLR up to Dumkot. Also in between Dumkot and Darke Khola. - Gamgadi to Gila roads too have number of water crossings which have negative impacts on the roads itself.
2	Improved moisture retention	Semi-circular bunds (half-moons) Reuse excavated soils Stone bunds	Forest areas from Luma to Dumkot and further up to Falata both in the upstream and downstream of the road Note: Semi-circular bunds (half-moon/eyebrows structure) can be also established in new proposed plantation area. As per the norms, the project has to plant 25 plants for each plant destroyed or cut down during construction work.
3	Water harvesting in ponds	Water ponds Sediment traps	There are good agricultural areas i. In Gila area of GDDR road ii. After crossing Neta Danda iii. Luma Village (These techniques are also suitable for other areas like Bama and Nafaa villages along the proposed road alignment)
4	Reducing sediment wash in on farmland	Infiltration bunds Temporary water bars	i. After Neta Danda (can be suitable in Bama and Nafaa village along the road alignment) ii. In GDDR road in Gila area where agriculture practices were observed
5	Manage mountain springs and seeps	French mattresses Spring boxes Gravel sections in earth roads	- Number or springs were observed in the at the cut part of road section in GDDR road and MHLR from Bama to Dharke khola.
6	Reduce road damage at hairpin bends	Water exits	Number of hairpin bends along road section i. Rugha to Neta danda and; ii. Luma khola to falata passing Dumkot village

Note: Though the road construction with RAP 3 was up to Dumkot area at the time of field visit, those recommendations made are still valid in Bama, falata up to Dharke khola

6.2 Adding to Guidelines and Capacity Building for Municipalities

Whereas in selected projects such as RAP3, many good practices are implemented with regards to new mountain road development, the same cannot be said for the road building activities initiated by many municipalities following the devolution of development budget.

In general, the massive road development activities by municipalities do not observe the basics such as the mass balancing methods, the adherence to maximum slope and the use of free draining road surface. They make use of earth moving equipment rather than engaging local labour. The impact of these municipalities programs on the surrounding landscape in many cases is very negative. The main issue is the often unskilled use of the earth moving equipment in the hand of inexperienced operators. A main recommendation is to train the capacity of those in charge of the local road building programs.

It is important that the experiences of RAP3 and Green Roads, that were earlier partly anchored in DOLIDAR (now DoLI), as well as the new opportunities for road water management as described in this study, are mainstreamed again. This will require capacity building for the engineering staff of the municipalities and the excavator operators who de facto often take the decisions on what is done where. There are more than 750 municipalities and Department of Local Infrastructure (DoLI) is considering to cluster these so that it can give appropriate support. There is an urgent need to reverse current practice that are not only extremely damaging to the environment, but often produce roads that have no useful life. This requires the development of instruction and guidance material, in the shape of flyers and videos, as well as the roll out of a training program including the reorientation of DoLI staff in a new supporting rather than commanding role.

It is also useful to consider the inclusion of road water management practices in the different guidelines that apply to road development and road maintenance and the engagement of the Road Maintenance Group as well as consider it to be part of the Climate Resilience Assessment by RAP3.

6.3 Promotion: Green Roads for Water Initiative

RAP3 has much to offer and to share, both in the design of roads and the use of the labour based approach, including the experience with RBGs and RMGs. Added with the opportunities for better road water management as described in Chapter 4 it is recommended to promote these for other areas with similar challenges, in particular construction in mountain environments, and working following labour based approach.

Based on Roads for Water activities in twelve countries, MetaMeta is launching a main green infrastructure initiative. The Green Roads for Water Initiative will promote road for water activities and ultimately make ‘green roads’ an industry standard as well – with regards the techniques used as well as the recommended governance. With this a major contribution to larger climate resilience will be made. It is suggested that RAP3/ DFID also joins in this.

The negative effect on roads as erosion, flooding, sedimentation, and dust will be turned around and additional measures and even road realignment should become the industry standard.

The Guidelines being developed for the World Bank distinguish three categories of roads resilience:

- Zero Category: the road is made climate proof
- Plus 1 Category: additional measures are undertaken along existing roads to improve the resilience of the roads and the environment surrounding the road
- Plus 2 Category: the design of the road or method of working is modified so as to improve the resilience of the roads and the environment surrounding the road: the labour based approach as used by RAP3 is a good example of this.

The Green Road Initiative will in particular:

- Serve as a service unit to promote better road for water practice in 25% of countries in Asia and 50% of countries with SSA as well as to other countries
- Promote Green Roads at highest level and at operational level
- Developing Green Road project templates and support activities
- Work with infrastructure and climate financers to pave the way for environmental and climate funding for green roads, including opening up green bond facilities or special attention in climate funding.

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Annex 1: Checklist i. Field Observation and ii. FGD

i. **For Field Observation**

Terracing	Along roads? Risk of damage because of (1) dumping excavation material (2) destabilized hill slopes (3) uncontrolled run-off
Causeways	Combine with sand dams Serve to stabilize erosive streams
Road alignment	Maintain slope and curviture – stabilize slopes and create more opportunities to retain water in critical areas
Road surface	Now outward sloping 5% Can also have water bars Filtration bunds along roads?
Borrow pits	Convert and strategic locations
Reuse topsoil	Current practice?
Ponds to maintain soil moisture	Current practice?
Gully	Divert road water to gullies – not ravine formation – better divert from gullies and gully plugs
Make additional ponds and infiltration trenches once road construction is started	Can we do?
Upstream land protection	Tajikistan examples – combine with productive use
Designing the road drainage systems	Inward drain? Cross drain – leading it to where? How much you concentrate
Forest area	Shallow groundwater flow affected by compaction by road?
Sediment release from unpaved roads	Do we know how much? Affecting aquatic bodies (or is there lots of sedimentation anyhow)
Springs	Opening up springs? Capture them
Road bodies as storage dams	Useful, possible?
Harvest snowfall	

Climate

- Snow
- Wetter
- Rainfall
- Seasonability
- Droughts?
- Soil type
- Better soil moisture better crops?

RAP3

- Work on good practices documents
- Contribute to climate resilience audit (three levels)
- Local value chains

ii. For FGD

Project Siting	
Parameter	Observation/measurement
Appreciation of this place - How is to live here? - What are the greatest joys? - What are the greatest worries? - How is for others (young people)?	
Appreciation in comparison to other places - How does this place compare to others?	
Appreciation of this place in time - How does it compare with ten years ago – better, worse, different - What are the main changes and the main constants? - What will the future hold?	
Characterize the area - Slope - Dry or wet slope (rain shadow, sunny side) - Where does water drain to - Geomorphology - Soils - Quality of soil - Land size - Local micro-climate climate - Water sources - Drainage	
Special challenges - Erosion - Landslides - Droughts - High rainfall - Pest attacks - Fires - Shortage of land - Moisture deficits etc.	T
Understanding the farming systems – what is most important	
Agriculture – opportunities and threats - moisture - droughts - inputs etc - harvests	
Livestock – opportunities and threats - fodder - grazing	

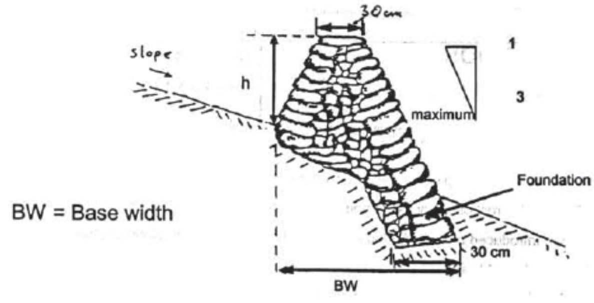
- controlled grazing - quality of pastures - breeds			
Forestry - – opportunities and threats			
Barren land			Present
Watershed/catchment condition along the alignment (v good, good, poor)			
Existence of landslides, erosion including other types of slope failures along the alignment			
What changes will the road bring - to local drainage - sedimentation - moisture - opportunities to harvest water - spring development - erosion			
Parameter/Driver	Y	N	Consultations/Observations
Can the road:			
Improve water availability			
Secure moisture			
Control erosion			
Prevent downstream degradation			
Change drainage patterns in positive way or non-disruptive way			
Bioengineering and road side tree planting			
What would local landowners do themselves			
How do RMGs function			
Risk of water damage to the road - describe			
Past experience of extreme climate events			
Do the communities have experiences of shifting of precipitation pattern (snow, rain, timing, composition, wind)? If yes explain consequences.			
Do the communities have experiences of cloudburst/extreme event within the watershed? If yes explain events and consequences			
Is erosion a major problem? Where does it occur the communities have experiences of torrential rainfall/ flooding/landslides within the corridor catchment? If yes explain consequences			
Do the communities have experiences of changing wind patterns, more dust, changing soil temperature, air temperature, moisture, or unusual events?			
Would it be envision that CC impact bring extreme precipitation and flooding, which may lead to blockage of surface drains and damage the road structures? ? If yes explain consequences. • Floods, rainfall patterns, drought, cropping			
What recommendations on the road?			

Annex 2: List of activities and People met (during field and desk study)

SN	Name of Person (s)	Occupation	Address	Remarks
1	Ms. Kirsteen Merilees Mr. Michael Green Mr. Ram Thapaliya (RAP 3 Kathmandu team)		RAP office, Lalitpur	Sept 13, 2018 (Debriefing of ToR and field support by RAP 3 Kathmandu team)
2	Mr. Bishnu Ram Bista and Mugu technical team (RAP 3 Mugu team)		RAP 3 office, Mugu	Sept 16, 2018 (Prepare plan to move to GDDR and MHLR road)
3	Mr. Dhana Lal Lawat	Farmer	Neta Village	Sept 17, 2018 (interview)
4	Mr. Keshar Singh Kami	Farmer	Luma, WN 13	Sept 17, 2018 (Interview)
5	Mr. Ratan Buda	Farmer/local leader	Bama	FGD led by Ratan Buda (Sept 17, 2018)
6	Mr. Bishnu Ram Bista and Mugu technical team (RAP 3 Mugu team)		At Darke Khola	Sept 17, 2018 (Debriefing on the observation up to Dumkot RAP 3 road and further up to Darke khola road section)
7	Women group (women group participating in road building)	Farmers	At luma village	Sept 18, 2018 (FGD)
8	Mr. Michael Green		IMC office, Lalitpur	Sept 20, 2018 Debriefing of the observation from GDDR and MHLR road visit
9	Mr. Maheshwor Ghimire	Senior Divisional Engineer, DoLI	Shreemahal, lalitpur	Sept 21, 2018 (related to DoLI stakes in LRN)

Annex 3: Designing stone strips

Fig 1. Design of stone bunds



$$BW = \text{Base width} = \frac{h}{2} + 30\text{-}50\text{cm (minimum)}$$

Fig 2. Bunds that cross depression points without following exact contour lines: Reinforcements at depression points + keys

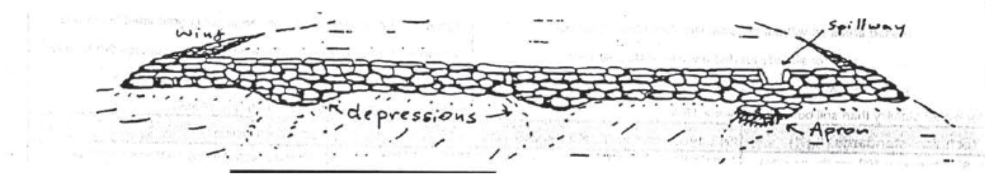


Fig 4 Stone bunds provided with trenches

Fig 6

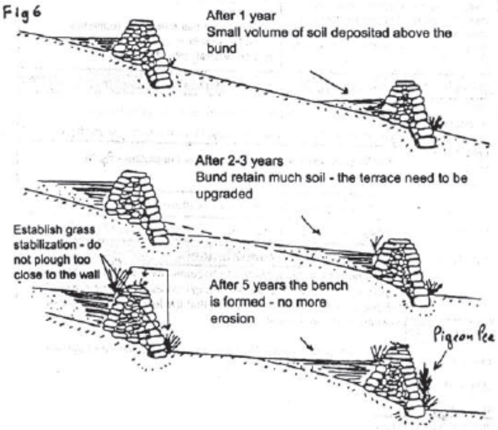


Fig 3. Stone bunds provided with spillways

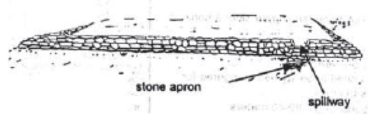
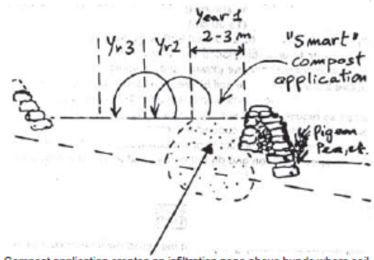


Fig 5. Stabilization and application of compost above bunds



Compost application creates an infiltration zone above bunds where soil is (1) deeprer and (2) moisture is higher. This area becomes the "butter" of the land and suitable for cash crops or high producing varieties. See infotechs on compost making for detail.

(Source: Desta, 2005)

Annex 4: Calculating Pond Capacity

The capacity of a road side farm pond depends on the purpose for which water is needed and by the amount of inflow that can be expected in a given period. The seasonal water yield can be estimated using past historical weather data (i.e. mean annual, mean seasonal or certain probability-based rainfall (mm) multiplied by runoff coefficient which is usually 0.1 to 0.3 and multiplied by catchment area.

The capacity of the pond depends upon the catchment size and factors affecting its water yield. The pond should be of sufficient capacity to meet the demand of the crops or integrated farming system for which it is constructed. On a conservative estimate, a dependable minimum value of 20% of the seasonal rainfall can be expected to go as runoff in case of black soils and 10% in case of red soils with mild to medium slopes.

The storage losses such as seepage and percolation losses would also influence the storage capacity of pond. The type of soil in the catchment area contributes to the siltation and this has to be considered as it affects the storage capacity of pond. Natural soil type seepage losses (in mm/day is given in table 4.8 below as per FAO, 1981).

Table Annex 4: Natural soil type seepage losses

Soil type	Seepage Loss (mm/day)[14]
Sand	25.0 – 250.0
Sandy loam	13.0 – 76.0
Loam	3.0 – 20.0
Clayey loam	2.5 – 15.0
Loamy clay	0.25 – 5.0
Clay	1.25 – 10.0

In addition, a suitable provision should be made for the loss in storage capacity due to silting which is generally kept as 5-10 per cent.

Estimating Water Demand

Water demand estimation is central to the design of farm ponds, because they inform the preferred capacity of the pond. The following formula help to assess the water demand for applied for irrigation, livestock and human needs.

$$Ir\ (m^3) = \frac{10 \times ETcrop\ (mm) \times Ca\ (ha)}{Ef}$$

Ir: Irrigation water requirements in m^3 for the whole dry period

[14] http://www.fao.org/fishery/static/FAO_Training/FAO_Training/General/x6705e/x6705e02.htm#84s

ETcrop: Crop water requirement in mm during the dry period
Ca: Area irrigated with water from the reservoir in ha
Ef: Overall water application efficiency

$$WL = \frac{NL \times Ac \times T}{1000}$$

WL : Water needed for livestock during the whole dry period in cubic meters
NL: Number of animals to be watered from the reservoir
Ac: Average rate of animal water consumption in liters per day per animal <u>25 - 60 liter/animal/day</u>
T: Duration of the dry period in days

$$Wd = \frac{Po \times Dc \times T}{1000}$$

Wd : Domestic water supply during the dry period in cubic meters
Po : Users of the reservoir
Dc : Average rate of water consumption in liters per day per person <u>40 liters / person / day</u>
T : Duration of the dry period in days

Rainfall Analysis

The demand must be linked to an understanding of the rainfall and run-off patterns. Rainfall is one of the most important and critical hydrological input parameter for the design of farm ponds. Its distribution varies both spatially and temporally in semi-arid and humid regions of the country. The quantity of surface runoff depends mainly on the rainfall characteristics like intensity, frequency and duration of its occurrence.

- Frequent rains mean the pond may fill up several times of the year. This will make it possible to have a smaller (and less costly) pond. The timing of the rainfall and filling of the pond vis-à-vis the agricultural requirements are important.
- High intense rainfall exceeding infiltration capacity of soil can produce more runoff than the rainfall event with low intensity for longer duration

Rainfall analysis is very critical for optimal economic design of farm pond. But long-term data on rainfall intensity is seldom available in the country. So, this available rainfall has to be estimated based on probability analysis.

Design rainfall (DR) is defined as the total amount of rain during the cropping season at or above which the catchment area will provide sufficient runoff to satisfy the crop water requirements. If the actual rainfall in the cropping season is below the design rainfall, there will be moisture stress for crop. If the actual rainfall exceeds the DR, there will be surplus runoff, which may cause damage to the structures. Timing is important: the creation of storage as in the development of ponds will transfer water from peak period to periods of scarcity.

Design rainfall is calculated from the probability analysis. It is assigned some probability level of occurrence or exceedance. Suppose the probability of 67% is given to rainfall, it indicates that the seasonal rainfall may occur or exceed 2 years out of 3 and therefore, the crop water requirements would also be met two years out of three in a crop season. The higher the probability of the rainfall, it is more reliable for getting assured runoff into the farm ponds

Annex 5: Document Reviewed

1. Roads: Instruments for Rainwater Harvesting, food security and Climate Resilience in Arid And Semi-arid Areas

   - The development of roads is a major factor in the change of landscapes and the drainage patterns. Thus the roads often acts as a conveyance systems often impacts negatively leading to erosion, waterlogging and flooding. But it can be turn around and road can be made instruments for rainwater harvesting, food security and climate resilience.
   - Case from Ethiopia and Yemen: Two approaches to collect water with roads. i. Adapting to the road i.e. involves utilizing directly or indirectly the runoff ans water flows generated by roads nearby the already constructed roads (for instance: spreading water from road surface and culverts; harvesting water from culverts, side drains, depressions; gully plugging; spring capture) and ii. Adjusting the road i.e. optimizing road design for water harvesting and erosion control can increase groundwater recharge and retention (for instance: carefully planning road alignment and culvert location, permeable road foundations, fords combined with sand dams)

2. Water harvesting from roads: climate resilience in Tigray, Ethiopia

   - The development of roads often has negative impact such as floods and water logging along the way. These negative impactss are often related with the practice in road engineering to evacuate water away from the roads as soon as possible rather than making use of the water for beneficial purposes
   - In Tigray, Ethiopia, steep slopes have been cultivated for many centuries and are subjected to serious soil erosion which is further exacerbated by improperly planned road development posing threat to the agriculture based livelihoods of people adjacent to the roads. This study explores the status and opportunities for water harvesting from roads in the Freweign-Hawzien-Abreha Weatsbeha-Wukro route in Tigray, Northern Ethiopia.
   - Impacts of road water harvesting: Use of ponds/pits to harvest water from road; channeling water from culvert, bridges into series of deep trenches and into farm land; shallow groundwater development upstream of Irish bridges and conversion of borrow pits to water storage and recharge structures. This study shows 64 km roads can harvest about 1.34 million cubic meter of surface water and the same time water related maintenance cost can be reduced.

3. Environmental Impact Assessment: Roads to the Rescue, Bangladesh

   - Road to rescue project emphasized potential roal of roads for water management, drainage and flood resilience in three polders in Coastal Bangladesh. It also analyze the potential environmental and socio-economic impactss of the interventions
   - Problem in polders were drainage and waterlogging due to insufficient water crossings and poor quality internal roads. Main causes were heavy rainfalls, lack of cross drainage, lack of routine maintenance and poor quality of road construction materials for carpeting.
   - To improve water management: basic hydrological consideration, integrating cross drainage from beginning of road development, using road structure as controlling measures to control water level, roads combined with flood embankment.

4. Road Water Harvesting in Kenya

    - The study was done in Kitui County Kenya by considering 30 farmers practising road water harvesting in their farms.
    - Practices: diversion cut-offs/ditches, trenches, furrows and terraces and on-farm storage ponds, takingg water from road drainage.
    - Result: incresed income generation from agriculture production, 4 out of 5 farmers had indicated their food security has improved. Furthermore, the farmers were providing additional benefits by safeguarding roads and landscapes at no cost.

5. Nepal Rural Road Standard 2071 (NRRS, 2071)
    - The basic idea of NRRS is to set classification and geometric desin standards for the local road network (LRN). This NRRS, 2071 is a second revised version of NRRS developed in 2055. It suggest to change the approachh to new construction and concentrate on upgrading the core network of maintainable, all-weather roads linking the district centre to the local unit headquarter.

    - In terms of Water management in rural road, this document provide design standard for horizontal and vertical road alignment, culvert and bridge etc)

   <u>Other reviewed document related to Rural Access Programmes are listed below</u>

6. Local Road Network (LRN) Implementation Manual, RAP Phase 3
    - This document has provided all the minute detail of the process for local road network implementation for RAP phase 3 from planning and design to implementation phase.

7. Environment Impact Assessment (EIA) Study of Gamgadi-Chankheli-Darma Road (Mugu and Humla Districts)
    - This MHLR document have environmental baseline information, identified both beneficial and adverse environmental impacts, and formulated appropriate mitigation measures, proposed environmental management plan (EMP) and monitoring plan for effective implementation.
8. Road Maintenance Group (RMG) Guidelines 2016
    - This guideline consists of the detail process of creating and contracting RMGs for emergency, routine, recurrent, specific and periodic maintenance of DRCN in Nepal. This guidelines also focuuses on generating employment opportunities for the poor in the corridor of impact through maintenance, and capacity building of the local institutions to maintain rural transport infra in a sustainable way.

<u>Institutions engaged in water management in Nepal</u>

i. Department of water resources and irrigation (DWRI): One of the important objective of this department, under Ministry of Energy, Water Resources and Irrigation, is effective water and watershed management to minimize the damage from water induced disaster.
ii. Department of Forest and soil conservation: This department work in soil conservation work particularly through President Chure Terai Madhesh Cosnervation project. Previously, Department of soil conservation and watershed management (DSCWM) was actively involved in watershed management activities.
iii. International NGOs (WWF, ICIMOD etc)