INTEGRATING CLIMATE CHANGE ADAPTATION AND WATER MANAGEMENT IN THE DESIGN AND CONSTRUCTION OF ROADS

Assessment of Opportunities in Tajikistan

WORLD BANK GROUP

Roads for Water

META META

Contents

1. Introduction

This report[1] assesses the scope for making use of roads for building climate resilience and improving water management in Tajikistan. Roads have a major impact on surface and subsurface hydrology: they change how water moves through the land. Conversely, the movement of water across the landscape affects the condition of the roads and the area surrounding them. At present this is often a cause of problems: erosion, landslides, flooding. Water is also the main cause of damage to roads: globally 35% of the damage to paved roads is attributed to water; for unpaved roads this is close to 80%. The situation in Tajikistan is not much different. A special challenge in Tajikistan are the mountain areas – that cover more than 90% of the country. Whilst this environment is challenging at the best of times, changing weather is causing more snowmelt and triggering more rain showers than before. It is also causing bigger river floods. All this is increasing the risk to the road infrastructure.

However, this negative relationship between water and roads can be turned around. Precisely because of the close linkage between roads and water management, roads can be turned into instruments of climate resilience. There is a range of opportunities to do that that can be systematically exploited – in road development, rehabilitation and maintenance. This report aims to give an overview of the most promising opportunities in Tajikistan and discusses the ways forward. Adopting this approach can enable a triple-win:

- The damage to roads and down time of road connectivity can be reduced;
- The damage caused by uncontrolled road drainage in the form of sedimentation, erosion and local flooding can be reduced
- The water captured by the road bodies, if guided properly, can be used productively

This report describes such opportunities in Tajikistan, with special emphasis on the Gorno- Badakhshan Autonomous Region (GBAO). It is based on assessment undertaken jointly with the Ministry of Transport under the program "Integrating Climate Change Adaptation and Water Management in The Design and Construction Of Roads".

2. Road sector in Tajikistan

Tajikistan has 14,000 kilometres of registered roads (62% local, 23% national, 15% international), with the main roads dating back to 1960-70s (ADB, 2011). In addition, the country has 12,600 to 18,000 km of "common use roads", which used to be maintained by kolkhozes but now fall under the responsibility of local governments. Like much of Tajikistan's infrastructure, a large majority of roads were built during the Soviet period and as of now many are in need of major rehabilitation and upgrading.

Tajikistan is actively participating in the Central Asia Regional Economic Cooperation (CAREC) Program. CAREC aims to develop inter-country connectivity in the region. Tajikistan has one of Central Asia's least developed transport sectors and among the world's highest transport costs. However, since 2000 the country has improved its transport infrastructure because regional trade—especially with the People's Republic of China (PRC) and other Central Asian countries—has grown rapidly.

Road assets worth an estimated $1 billion were lost between 1990 and 2010, and 80% of the registered 14,000 km road network is in a state of disrepair. For the common use roads this percentage may be equally high or higher. Over 50% of the road network has an average international

[1] This assessment was undertaken by MetaMeta. The Mission consisted Frank van Steenbergen (Team Leader), Marta Agujetas Perez (Water Management and Environmental Expert) and Jonathan Demenge (Climate Change Adaptation Expert).

roughness index (IRI) of over 7 meters per km, which results in lower travel speeds, increased fuel consumption, and higher vehicle operating cost. Average vehicle speeds across the road network have declined from 50 km per hour to 30 km per hour. Poor road quality affects access and mobility and hinders economic growth. Moreover, vehicle overloading has increased and road safety has deteriorated. In Tajikistan, limited economic resources need to be shared between many competing needs. This has affected budget allocations for preventive measures such as risk reduction and infrastructure maintenance (ADB 2009). It is hence imperative to examine mechanisms that reduce the maintenance burden of roads and make roads more resilient to weather events.

The public expenditure allocated for Kazakhstan's transport sector between 2010 and 2025 is massive. It stands at $2.3 billion, out of which $1.7 billion are earmarked for roads. The medium-term road infrastructure priorities (2016–2020) are to continue rehabilitating international corridors, to start rehabilitating key national roads and to improve and complete connections to PRC. The long-term objectives (post 2020) are to complete the rehabilitation of international and national roads, and gradually expand investment to local roads.

3. Water-related challenges, land degradation and climate change

Tajikistan is one of the countries most vulnerable to climate change. The main challenges are flooding, landslides and droughts (USAID 2016). For instance, 36% of Tajikistan's land surface is exposed to landslides, with more than 50,000 landslide sites registered. Of these, 1,200 threaten human settlements, roads, irrigation, and other facilities (UNDP 2010). The average population affected annually by flooding in Tajikistan is about 100,000 (World Bank 2015). Water scarcity is also an issue in certain parts of the country. Even though there are more the 947 rivers longer than 10 km, there is shortage of water during the dry season in many of the areas in the country. As average temperatures increase due to global warming, as glaciers and snow melt increase, as the number of rainy days decrease, as the frequency and intensity of extreme weather event increase; the issues described above and the risk of disasters will also increase.

Erosion is a widespread issue in Tajikistan. In total, 82.3% of all land and 97.9% of agricultural land in Tajikistan suffers from some level of erosion (UNDP-UNEP 2012). Government statistics indicate that since 1991, 4% of the land has been completely destroyed by land degradation due to unsustainable agriculture practices. Heavy degradation is also observed along infrastructure, such as roads and water canals, mainly due to uncontrolled run-off and drainage.

Overgrazing on pasture lands is a major cause of erosion and land degradation. Deforestation is also a common problem. Natural forest coverage in Tajikistan has experience a dramatic decrease in the last century, falling from 25% to 2% (Wolfgramm et al, 2011), accelerated because of the energy crisis after the unwinding of the Soviet Union.

The present occurrence and exposure to disasters such as landslides, floods and droughts- combined with land degradation and augmented by the impact of climate change- mean that a significant part of the population and infrastructure is at risk in Tajikistan, particularly in the south-central part of the country (see figure 1).

Measures must be taken to improve water management and climate resilience of the road and road environment, through adapted planning, construction, adaptation and maintenance. Measures should also be taken to protect and restore degraded environments that have a direct impact on or increase risks to the infrastructure. Finally, in regions that are affected by water scarcity and droughts, roads that integrate water management and design/maintenance are also a way to improve the resilience of people and their environment and help them cope with climate change.

Table 1. Climate change impacts in Tajikistan

Climatic change effects	Impact
Warming above the global mean in Central Asia	- Increase in average plain region temperatures by 0.5 to 0.8 C and mountain region temperatures by 0.3 to 0.5 C in 60-year period - Increase in ice melt and snow melt triggering floods and mudslides - Melting of permafrost increasing landslides - Shift from dry snow to wet snow
Increase in the number of days over 40°C	Increased evaporation, increased water demand, greater aridity
Increase in evapotranspiration	Increase in evaporation by 5-14 percent and vapor transpiration by 10-20 percent
Reduction in snow and ice field and declining glaciers	Reduced amount of water in streams, springs and seasonal streams drier earlier, droughts
Increasing frequency and intensity of extreme events, particularly intense rainfall; decrease in number of rainy days	Heavy rains, high waters caused by mudflow, high air temperature accompanied by droughts, strong winds and dust storms, frost and extreme cold temperature; increased risk of landslides
Warmer winters (temperatures expected to increase by 2 degrees), and increase in the number of frost free days	Spread of pests

(Source: Wolfgram et al., 2011 and personal interview[2])

[2] Tajikistan - Strategic Programme for Climate Resilience Pilot Programme for Climate Resilience http://climatechange.tj/SPCR.pdf

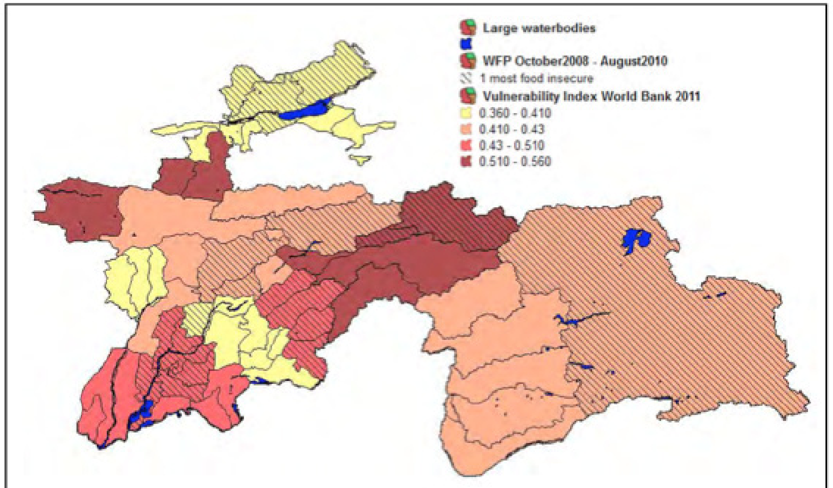

Figure 6 Household vulnerability to climate change (Heltberg and Bonch-Osmolovskiy 2011) and most food insecure districts according to WFP surveys between October 2008 and August 2010

Figure 1: Household vulnerability to climate change in Tajikistan (Source: Wolfgram et al., 2011: 37)

4. Challenges and opportunities in Tajikistan

4.1 Overview

Currently road development and water resource management are not integrated in Tajikistan, but there is a large need to make a strong connection. Even in essential work such as designing the drainage from road bodies many mistakes are made – leading to premature damage to the roads and to degradation of the environment around the road.

It is not uncommon for new roads to have significant damage due to badly designed drainage A key example is the Dushanbe-Kanak Road (see figure 2). Similarly, several road sections between Dushanbe-Khorog have similar

Figure 2. Images from the Dushanbe-Kanak road with 163 drainage structures collapsed, causing erosion, and the side slopes of bridges undermined

problems (see figure 3). Such cases also contain many opportunities to turn things around. Rather than putting up with erosion triggered by bad road drainage in short events, the same water can be guided and spread to drought prone areas, and to recharge zones of storage reservoirs if possible. The urgency for harvesting water from roads is felt more in areas where the impact of climate change in most severe, with longer and more intense droughts and less water stored in glaciers.

Several practices are recommended to lessen the vulnerability of road infrastructure to climate change. The first is to plan all roads and road environments using analysis of current hydrological data and future scenarios as captured in data sets by Hydromet. Such data can be used to come to a more integrated planning of the roads, so that the surrounding landscape is able to withstand extreme events and climate change.

The table below presents examples of such data/ data analysis and how it can contribute to planning, design and maintenance of roads:

Table 2. Hydrological data needed for road planning

Data/ Data analysis	Contribution
Flood occurrence	Prioritizing protection work
Future flood peaks	Determining Height and safe distance of the road, Protection works
Future river flows	Locating embankments
Risks of landslides/ mudflows	Special landscape protection measures and road protection measures
Future water availability and possible shortages	Retailoring road drainage for water harvesting
Future precipitation	Applying foresight to water-friendly road drainage
Opportunities for strengthening of catchment	Special landscape protection measures
Opportunities to harvest water	Integration of water harvesting measures in road design (road alignment, drifts) and road drainage

Secondly, a closer cooperation should be sought with the Ministry of Transport and the Department of Land Improvement and Irrigation to out all this in practice. For instance, all water related road infrastructure (road drainage, bridges and flood protection measures, landscape management and water harvesting measures) could be designed by professional water engineers. There should be also be greater alignment with the Committee for Emergency Situation and Civil Defence (particularly the Geology Department) and avoid building roads in areas recognised by the department as disaster-prone should be avoided where possible.

Figure 3. Images from the Dushanbe-Khorog road with several examples of road induced erosion

Thirdly, these approaches should not be focussed narrowly on the roads. Resilience comes from managing the road as part of the immediate environment. This should follow some principles:

- Preserving and strengthening the water resources/environment should be a standard and well-resourced component of road construction
- Preserving and strengthening the water resources/catchments should be done both to create more productive environments, and to protect and make the best use of the roads
- Where possible the road itself can be used for beneficial use, for instance to harvest water and establish road side plantations

It is important to emphasize that these measures should not be seen as ‘additional costs’ but instead as ‘good practices’. The additional measures in improved catchments/environment are economically worthwhile investment in their own right – they just need to be coordinated with road programs. Besides, while many measures to manage water better with roads come at low additional costs, they make a considerable savings in the form of lower future operation and maintenance costs and reduced downtime. Many measures can also be used to generate employment (for instance in gabion manufacturing).

It is also important to realize that different measures can be used in different parts of the country. This is discussed in the next section.

4.2 Measures for different parts of the country

A diversity of measures can be taken across different parts of Tajikistan to improve water management and climate resilience of the road and road environment; through adapted planning, construction, and maintenance. Measures should also be implemented to protect and restore degraded environments that have a direct impact on or increase risks to the infrastructure. Finally, in regions that are affected by water scarcity and droughts, roads that integrate water management are also a way to improve the resilience of people and their environment and help them adapt to climate change. Four main areas are identified in figure 3, each with its own set of challenges and solutions.

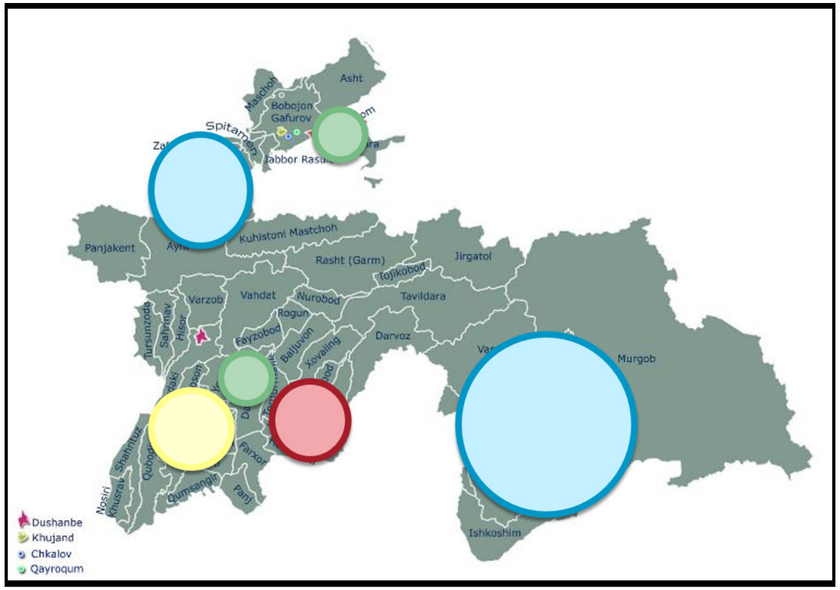

Figure 4. Four areas identified in Tajikistan with different road-water challenges and opportunities

The sections below explain the challenges and the set of measures suitable for the areas identified in the map above, namely: mountain environment, low rainfall hills, medium rainfall hills, and large irrigation systems.

4.2.1 Mountain environment

The mountains of Tajikistan are very prone to natural hazards, witnessing floods and landslides every year. Glaciers provide water during the dry season, but they are not always easy to tap. Some events damaging the road and the environment are almost impossible to avoid, but a lot can still be done to improve the condition of the scarce but vital road network.

Table 3. Overview of challenges and measures to create more resilient roads and environments in the mountain areas of Tajikistan

Districts with typical mountainous environment	**Darvorz, Ishkoshim, Roshqala,Vanj, Rushon, Shugnon**
Road challenges	Exposure to floods due to high river flood peaks; inun-dations by temporary lakes; landslides/ mudflows and rockfall
Water and environment challenges	Increased risk of landslides and mudflow; high pressure on limited land; changing climate and less secure water availability
Measures for resilient roads	- Road design aligned with predicted hydrological scenarios - Planning roads at safe elevation and distance from rivers; - Planning tunnels and galleries in sensitive areas - Bank protection, as well as 'room for the river' - Reinforced Irish bridges at stream crossings; - Bio-engineering at some places
Measures for resilient road water environments	- Land use planning and controlled pastures - Possible water/snow retention measures - Protected springs - Artificial glaciers - Land development with melt water - Controlled grazing

Road challenges

The main road challenges observed in mountain environments are:

- exposure to floods due to higher river flood peaks leading to erosion of river banks, road sides and road infrastructure
- inundations by temporary lakes formed after landslides
- landslides
- avalanches, mudflows and rockfalls

With the predicted increase in heavy rainfall events associated with higher temperature and ice melt, the likelihood of disaster risks will only increase.

Figure 5a: Bank erosion in GBAO

Figure 5b: Damaged bridges

Figure 5c: Landslides and temporary lakes

Figure 5d: Washed out roads

Solutions for resilient roads in mountain areas of Tajikistan

The mountain environment of Tajikistan is highly challenging for roads. The risk of landslides and mudflows that is common in the young mountain region with steep, unstable slopes is exacerbated by climate change. This is manifest often in unusual spells of warm weather, or high rainfall, or wet snow. Though there is close vigilance at some of the most serious problems spots – like glacier lakes – landslides and mudflows occur frequently with devastating impact. The lack of vegetation and the encroachment of high risk debris cones around residential areas has further heightened disaster risks. A recurrent disaster in Badakshan and other mountain areas is landslides and mudflows from small valleys. This blocks the river, creating overnight lakes. The lakes cause water levels to increase for the duration of the water blockage, inundating land, houses and road infrastructure. Several solutions to create more resilient roads in mountain areas are presented in figure 5.

Tunnels and protection galleries in sensitive areas

Protection galleries (Figure 6 a) can be very important to safeguarding certain roads in case of rockfall impacts, avalanches, and landslides. They provide protection against high energy impact and, compared to other measures, are more appropriate solutions for more frequent events due to their low maintenance costs. Additionally, since galleries are placed right above the road, they eliminate the risk of uncertainty in predicting the trajectories of the falling objects.

Bank protection

Bank protection structures include several types of hydraulic works along the river course. Their construction is usually planned along stretches of the banks susceptible to erosion. Bank erosion can render natural/artificial banks and steep slopes unstable. Traditional bank protection works include concrete walls, cemented stone, and bricks. However, bank protection can also be done using low-cost and locally available materials such as sandbags, rock boulders, gabions and vegetation. In the case of vegetation, fast-growing plants with long root systems are most suitable.

The banks of highly erosive rivers – such as the Panj River - can be hardened with riprap, concrete, sheet pile, or other inert materials. Riprap is recommended over other material because the particles shift to adjust to the changing form of a river bank or bed. Riprap is placed in a layer that is multiple-particles-thick, and can adjust to local movement of material scour, to settlement, and to surface irregularities; without complete failure of the installation.

Bio-engineering

Bio-engineering on a stone toe (Figure 6b) consists of bank stabilization with a combination of vegetation; or bioengineering on the upper bank and a stone toe base. A stone toe is used to hold the bank and prevent weakening and scour in a medium to high energy system. Bio-engineering should also be designed on the upper bank to reduce erosion. Live stakes should be installed while they are dormant, not with roots or leaves.

Boulder clusters

Boulder clusters can be used at the toe of bank slopes to reduce erosion that is weakening the banks. The use of boulders is limited to rocky areas where they are easily available. Regular maintenance should be done after high flow events. Boulder clusters should be combined with other protective measures since they create a zone of local scour immediately downstream from the boulders.

Room for the river

The "room for the river approach" entails giving the river more room to overflow when it reaches higher water levels. Measures include lowering the flood plain, deepening the river bed, relocating dykes, and removing obstacles. Lowering sections of the flood plain gives the river more space during periods of high water. Removing obstacles involves works such as lowering or eliminating ferry pier banks and widening bridge openings.

Reinforced Irish bridges at stream crossings

Non-vented drifts or Irish bridges (figure 6c) are low-cost road crossings constructed on dry riverbeds. In seasonal rivers in arid and semi-arid areas, they can act both as low volume traffic road conduits and as water retaining structures. They are important structures that help capture and store flood water and retain it for use during the dry seasons.

Unlike vented drifts, non-vented drifts are not equipped with culverts. Thus, they enable retention of sand and water on ephemeral rivers. Because of the absence of culverts in the drift, coarse sand and gravel is halted and accumulated on the river bed upstream of the drift. This creates a

Figure 6a: Gallery protecting a road from landslides in GBAO, Tajikistan

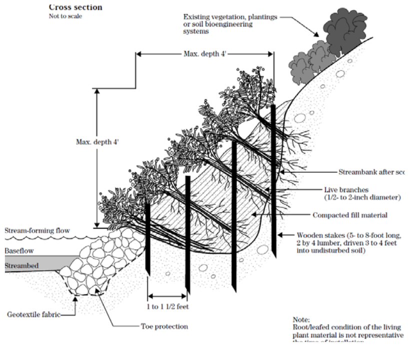

Figure 6b: Example of stone toe with bio-engineering for bank protection (Source: US 2015)

Figure 6c: Irish bridge harvesting water upstream in Kenya

Figure 6d: Protection wall in GBAO, Tajikistan

small man-made aquifer of sand and water. A non-vented drift therefore builds upon the natural capacity of a sandy riverbed. The newly deposited material will store floodwater and make it available for use during the dry season.

A non-vented road drift consists of the following elements: the body of the drift itself, the approach road, the upstream protection measures, and the downstream apron. The drift approaches should be extended by 10m on either side of the river banks on rivers with spans equal or greater than 50m; and by 5m in rivers of spans less than 50m. The slab of the structure should be extended beyond the experienced flood level to ensure there is no damage done at the road end when the floods are high. The figure below shows an overview of the design considerations of a typical non-vented drift.

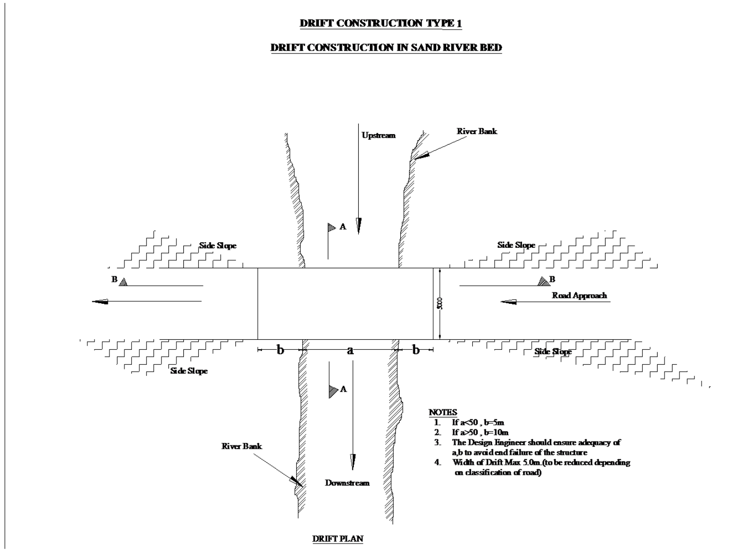

Figure 7. Diagram of a non-vented drift or irish bridge

Resilient road water environments

A key strategy in the mountain areas is to improve the road environment- not just to reduce risk of damaging events but also to increase the value of the road environment. There are measures to better retain meltwater in the mountain catchment to reduce and regulate the outflow, to revegetate the area, and to plan land use to create intense land uses. The measures are explained below:

Land use management

Mountain areas are characterized by steep slopes, strong climatic gradients, and low population density due to the relatively small proportion of cultivable land. Infrastructures and communications are generally poorly developed. However, mountains are a major source of water, are important for recreation and tourism, and are vital areas of biodiversity. Land use management in high mountain areas should take into account all these features and adopt a holistic approach. The measures should target different parts of the catchment depending on the topography, rainfall and other features.

Measures such as Joint Forest Management are important in these areas. The practice is already underway in Tajikistan. It involves leasing forest land to local people over the long term. The tenants can then rehabilitate and use their forest plots according to management plans often recommended by local forest enterprises. Other areas could be used to grow animal fodder or for controlled livestock grazing. Areas close to water sources could be developed to establish fruit orchards. Other measures include snow retention measures, spring protection, tree plantations both for restoration and for economic benefit, and the creation of artificial glaciers.

Water and snow retention measures

Snow retention with snowsheds (Figure 9) help keep the snow on the slope and lessen the risk of avalanches, hence protecting the infrastructure and

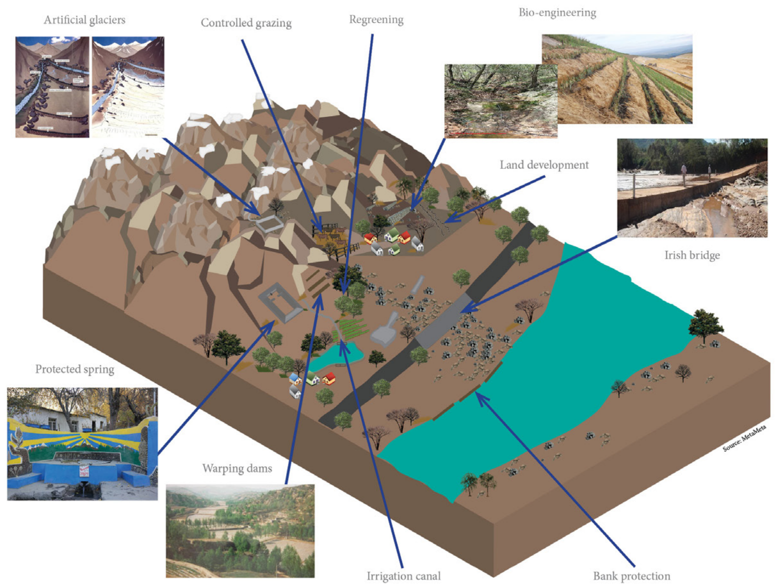

Figure 8. Overview of landscape management measures to be implemented in mountain areas

populations downstream. The snowsheds should be solidly anchored in the ground. Reforested areas and enclosures increase water retention in the soil, and therefore decrease the amount of water streaming down. Percolation ponds and trenches can also help the water penetrate the soil.

Check dams, diversion channels and ponds can also be used to decrease the amount of water streaming down the gradient of the land, and delay peak floods. Another advantage is that they provide an additional source of water that can be used in summer when seasonal streams and springs dry up. However, these infrastructures should be carefully planned, be of small size, and not increase the risk of floods and mudslides for population downstream.

Figure 9. Snowshed in alpine environment

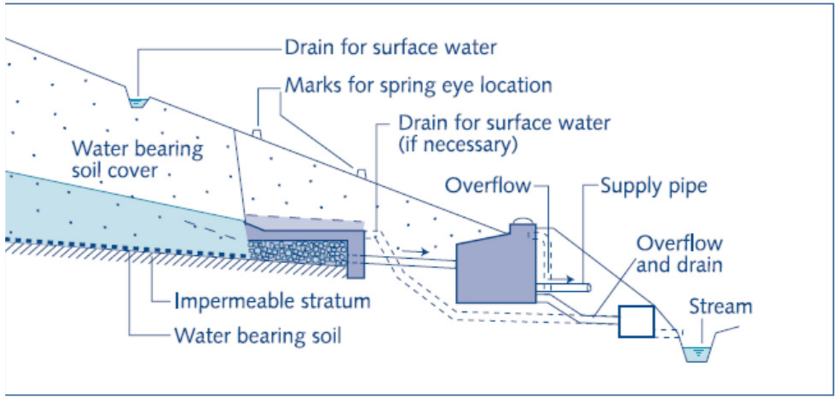

Figure 10. Lay-out of a spring water supply system (Source: Tayong 2003)

Protected springs

Springs are found mainly in mountainous or hilly terrain. They can be defined as "places where a natural outflow of groundwater occurs" (Tayong 2003). Spring water is usually fed from a small mountain aquifer or a water flow through fissured rock. Road cutting in hilly terrain often creates new springs, which may damage the road surface. At the same time, these springs could be used for water supply.

The design and construction of a spring-fed water supply must ensure that pathogenic contamination and pollution of the source is avoided, and that the water supply from the spring is reliable in terms of quantity. The main components in the design of a spring water supply system include the spring water collection area (where water from the aquifer is channelled to a single discharge point), the supply pipe, the collection chamber, and the outlet to a storage tank. In a protected spring the outflow is regulated and retained – creating storage in the mountain aquifer and prolonging the duration for which water is available.

The catchment area of the spring should be protected to improve the recharge of the aquifer, and to prevent contamination of the groundwater. The immediate surrounding of the spring (at least a 50 m radius) should be fenced. No human activities such as farming and grazing should be allowed in this area. Protection activities could include soil conservation, erosion control measures, and planting of trees, shrubs and grasses.

Artificial glaciers

Artificial glaciers are formed by diverting and storing water as ice during fall and early summer. The water can then be used during spring time, when the glacier melts, to irrigate the land, fields and plantations. The technique has been developed over the past two decades in Ladakh (North India), a high-altitude area that receives scant precipitations (50-100 mm under the form of snow) and where agriculture depends exclusively on water from glacial streams.

The principle consists in retaining and storing water from glacial streams[3] by diverting it through canals and pipes (up to 4 km long) in shaded, colder and flatter areas, where the difference in temperature and lower velocity of water are sufficient to make the water freeze. When the water reaches the site, it is released and spread over a large area. Retaining walls (stones or concrete) built in series help store the water and make it freeze. The water is stored there during the entire winter season, and melts in spring when temperatures and sun radiations increase. It is a low-cost engineering technique that mainly uses local construction material and community labour, and can therefore be integrated easily into local water management practices.

The advantages – for agriculture but also for the road infrastructure – are multiple:

- making water available before higher glaciers start melting, enabling farmers to start cultivating earlier in the agricultural season
- reducing the amount of water that is wasted during autumn.
- differing the timing of ice melt between high and low elevation, hence reducing peak floods in spring when snow fields and glaciers melt
- spreading water in and between catchment areas through diversion channels, thereby reducing peak flood and erosion

By using difference in micro-climates determined by location, elevation and orientation, this technique can be used along with water tanks to store more water and make it available at the adequate time in sufficient quantities. Thus, potential peak floods or water shortages due to climate uncertainties and weather patterns are minimized; and the resilience of people and their environments to climate change is boosted.

[3] It was developed by an engineer called Chewang Norphel. In 20 years, around 12 such glaciers have been created, forming ice fields up to 2km long and 2.3 meters deep that melts between the months of March to May.

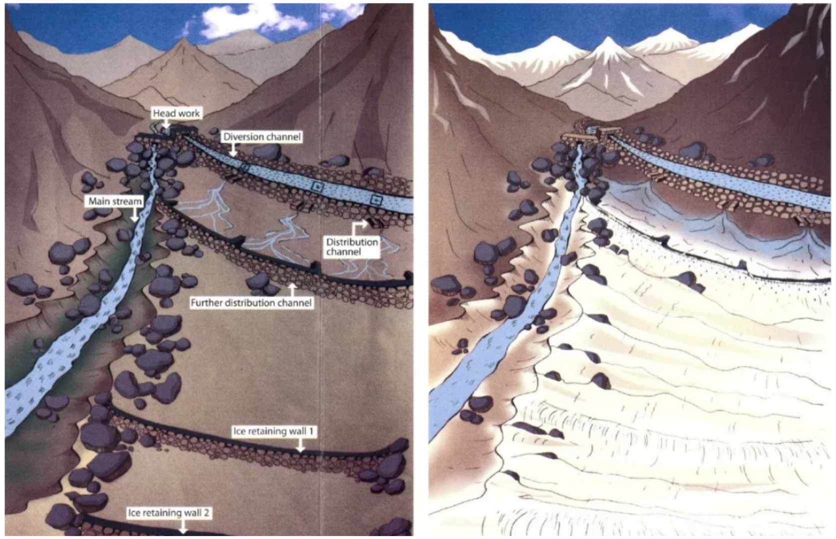

Figure 11. A technique for creating artificial glaciers in mountain areas (Source: Fondation Ensemble)

<u>Land development with melt water or "warping"</u>

Sedimentation is a big challenge in Tajikistan. It is largely due to sedimentation that Nurek reservoir's capacity has decreased by 33%over 43 years. However, in some cases sedimentation is not necessarily a hazard; it can be an asset as well. It helps build up or renew soils – creating new land and plugging gullies and depressions. So-called 'warping' has been used in many parts of the world to trap sediments for beneficial use. Warping entails building up land with moisture-rich soil along rivers and streams. It also refers to the practice of letting turbid water flood onto agricultural land, so that its suspended sediments settle and form a layer, before letting the water flow away. In this way, poor soils are enriched with fertile fine silt (or warp).

Warping dams (Figure 12) are dams built on gullies to harvest and intercept sediments and thereby create new land. The dams are of substantial height - typically up to five metres. The development of a warping dam consists of two stages: (a) the land development stage, and (b) the consolidation and management stage. The land development stage takes several years (on average 3-5 years, but sometimes more than 10 years). By then warping dams have collected enough sediment for farming to begin. When the dams are completely filled with sediment, stabilization is necessary, for example through the creation of controlled water overflow structures. This can be done by changing existing spillways into a circular shape, redesigning the top of the shaft as spillway, constructing a side spillway, or designing an earth dam as overflow dam (Steenbergen, F. van et al., 2011).

Figure 12. Warping dams in China, source: World Bank Beijing

Controlled grazing

Overgrazing is a major cause of land degradation in Tajikistan. It decreases the fertility and the absorptive capacity of the soil, leading to higher runoff; increased erosion downstream; and augmented siltation of canals, rivers and the road infrastructure. In fact, many erosion and siltation issues at the road level can be attributed to overgrazing and land erosion upstream. To reverse this trend, area enclosures, better pasture management and reduced livestock herds are recommended to restore pastures.

'Resting' (or non-disturbance of land by livestock or fire) is generally proposed to restore perennial grasslands. This may result in an initial burst of growth in vegetation that was being overgrazed and can now grow freely. But within a few years, rested perennial grasses grow rank and start to oxidize, as indicated by their grey colour (Steenbergen, F. van et al. 2011). Properly grazed and impacted grasslands act like sponges, storing humus and carbon. The roots of grasses perforate the soil and open it up, increasing porosity and infiltration capacity. The trampling of the sealed soil surface, or soil crust by animals helps this process. The increase in porosity and infiltration capacity allow water to soak in where it can be used by plants, or eventually trickle down to feed springs, rivers, and boreholes or wells, thus increasing the residence time of the rainfall in the catchment. Controlled grazing also decreases risks for flood, siltation downstream and resulting damage to the road infrastructure.

Another method is rotational grazing, in which pasture is divided into several plots based on its productivity. Grazing periods and grazing systems are fixed according to the carrying capacity of each plot.

4.2.2 Medium rainfall hills

Medium rainfall hills have distinct challenges such as high erosion rates, heavy grazing and uncontrolled road drainage. The rainfall is approx. 600-700 mm/year. In these areas there is high potential to implement road water harvesting and soil and water conservation measures at scale. Below is an overview of challenges and also ways to create more climate resilient roads and road environments.

Table 4. Overview of challenges and measures to create more resilient roads and environments in the medium rainfall hills

Districts surveyed in medium rainfall hill areas	Shuronod, Muminobod
Road challenges	Uncontrolled road drainage damaging roads
Water and environment chal-lenges	Erosion related to deforestation, uncontrolled grazing
Measures for resilient roads	Adequate drainage system; downstream protection of drainage disposal
Measures for resilient road water environments	Water harvesting from road drainage: storage ponds, converted borrow pits or water spreading Regreening using road water; Slope protection through bio-engineering or vetiver hedges

Figure 13. Common erosion problems found in the medium rainfall hills of Tajikistan

Road challenges

The soils in the medium rainfall hills surveyed during this study are highly erodible. This, combined with uncontrolled road drainage, is causing severe erosion in the roadsides and beyond. Rock cutting also leaves the soil barren and prone to erosion.

Moreover, the lack of water retention in the landscape due to deforestation and uncontrolled grazing pose a great challenge to road infrastructure.

Resilient roads

<u>Adequate drainage system and downstream protection of drainage disposal</u>

Road drainage through culverts and road drains is essential to evacuate the run-off that would otherwise damage the road. However, in places where the water used to flow evenly, road drains and culverts tend to concentrate the runoff in limited places, creating erosion and threatening the infrastructure itself. Attention should be paid to providing enough drainage points, spreading the run-off, and ensuring that the areas around drain points are adequately protected.

Areas downstream of the road are particularly prone to floods and erosion, creating damage to the land, fields, and the road infrastructure itself. Scour-checks, check dams, trenches, percolation ponds or vegetation (grass, bush and trees that help keep the soil in place) contribute to checking erosion caused by drainage disposal. Eroded areas should be restored and ideally prevented. Percolation ponds and trenches can also be used to help the water penetrate the ground rather than flow as a stream and cause erosion.

Scour-checks

Scouring of road-side drains should be avoided. This can be done by creating regular lead-offs, installing scour-checks, or planting vegetation. Scour-checks prevent erosion in the ditches by slowing down the flow of the water. They are mainly used in hilly terrain with steep gradients. They are constructed in natural stone or with wooden or bamboo sticks.

The appropriate distance between scour-checks depends on the road gradient (shown in table 5).

Table 5. Interval between scour-checks, depending on the road gradient

Road gradient	Scour check interval
4	Not required
5	20
6	15
7	10
8	8
9	7
10	6

Resilient road water environments

Water harvesting from road drainage

There is a wide range of road water harvesting techniques that may be considered. Many of these are in practice in other countries but not yet applied in Tajikistan. These techniques consist of harvesting the water from the road surface or from the catchment, channelling it through road culverts and drains.

The opportunities to make better use of culverts and run-off from the road surface are plentiful. This can be done by using techniques such as:

- Floodwater spreaders along paved road surface – these spread road surface run off to adjacent land
- Floodwater spreaders at culverts – these channel water from road culverts and spread it widely over the land, preventing the development of gullies in the process.
- Road side infiltration trenches – these are recharge structures that collect run-off from roads
- Road side infiltration or storage ponds – Depending on the geology, these filling ponds can be used either for surface storage, or infiltration to and recharge of groundwater.
- Borrow pits that can be re-used as storage ponds

The location of drains, culverts and borrow pits can be planned to maximize rainwater harvesting and direct the water towards productive areas such as agricultural land and forests, instead of just evacuating the water from the roads. It is important that the drainage water is brought to a safe distance from the road surface. The measures listed above can be implemented in combination with other measures such as reforestation, green enclosures, planting of vetiver hedges, roadside tree plantations, etc. Road-adjacent communities will benefit from the supplemental water available through these measures, At the same time, they will protect slopes and roads from floods and erosion.

Figure 14a: Infiltration trenches downstream of road

Figure 14b: Water spreaders from road surface

Figure 14c: Water spreaders from box culvert

Figure 14d: Converted and lined borrow pit

Regreening using road water

Regreening through water harvesting can be done by modifying local topography to capture runoff water and concentrate it in areas where it can be used by plants. Roads can play a key role in this process. Small diversion channels can be constructed along roadside drainage systems to slowly divert their flow towards tree seedlings, bushes or grasses. In combination can be used methods like micro-catchment water harvesting, microbasins and bunds, infiltration trenches, swales and contour bench terraces.

Creating **micro-catchments** is one of the methods used to collect surface runoff from a small catchment area and direct it into the root zone of an adjacent infiltration basin. This infiltration basin can be used for planting. Micro-catchments are alterations of the topography to direct rainfall runoff to plants. They are simple, inexpensive, and provide many advantages over alternatives, such as irrigation. Micro-catchment techniques are most effective on slopes not exceeding 7–8 percent. The optimal size of the micro-catchment depends on the site characteristics and the size of the seedlings.

Microbasins are small, circular and stone-faced structures used for tree planting. They are suitable for medium and slightly low rainfall areas. They can be built on steep and degraded hillside with a maximum slope of 50%. The diameter of the microbasin should be between 1-1.5m, with a planting pit of size 40 cm wide by 50 cm deep. Around microbasins, Controlled grazing is essential since even light trampling will compromise their function.

Trenches are large and deep pits that protect cultivated land from flooding and erosion while recharging groundwater. The average size of trenches is 1.5m long x 0.4m wide x 0.5 m deep. Road runoff can be channelled to infiltration trenches where water will percolate and increase the soil moisture levels in the area. Trees can be planted next to the trenches, where the roots of the seedlings will benefit from the increased soil moisture.

A **swale** is a broad, shallow channel (natural or manmade) designed to promote infiltration and reduce the flow velocity of runoff, while trapping pollutants. Their main purpose is to slow, spread and infiltrate run-off. They are appropriate for silty, contaminated runoff such as those from roads. Swales are never compacted or sealed, as their main purpose is groundwater recharge. On the contrary, the swale soils can be loosened to increase recharge and infiltration rate. Swales also provide an opportunity for tree planting, thanks to the increase in soil moisture that takes place around them.

Contour bench terraces are structures carved on cut or fill slopes that capture and store runoff water and sediments from road surfaces, road shoulders, and the slopes above. Contour bench terraces are designed to collect water to recharge soils and provide sufficient water for plant growth during the dry season. They also protect from erosion during peak rain events. Design criteria for determining the distance between terraces include slope gradient, rainfall intensity, and infiltration rates.

When terraces are filled with growing media (topsoil or amended subsoil) and planted, they become “planting pockets”. Planting pockets must have adequate soil depth to store the intercepted runoff and allow the establishing of planted seedlings. The surface of the planting pocket should be in-sloped to capture water and sediment, and the face of the pocket should be protected from surface erosion (figure 16).

In combination with the above measures, water from roadside ponds can be used to establish tree nurseries by the roadsides. The seedlings can be subsequently used for roadside tree plantations. The roadside plantations will bring a wide array of benefits such as absorbing road dust, reducing erosion and flooding along the road, and economic benefits when commercial species are used.

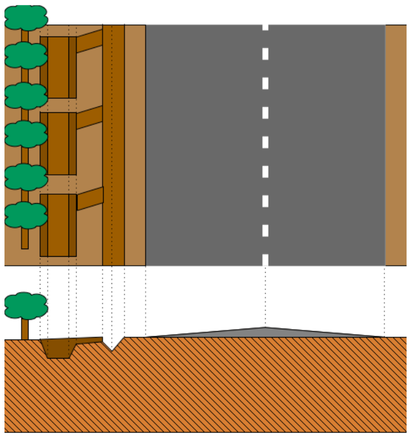

Figure 15. Combination of road water harvesting and road-side plantation

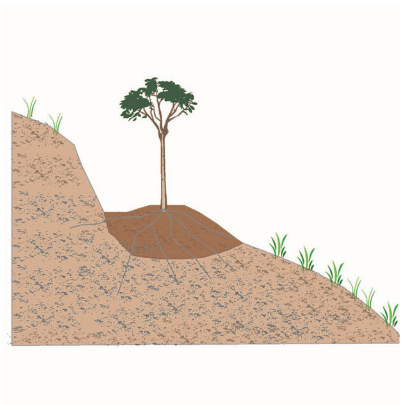

Figure 16. Planting pockets can be installed to harvest road runoff

Figure 17a: Scour checks helping reduce roadside erosion

Figure 17b: Pond retaining water by the road side

Figure 17c: Slope stabilisation through bio-engineering

Figure 17d: Potential for road water harvesting along a side road (blue arrow) through proper location of drains

Slope protection through bio-engineering or vetiver hedges

Bio-engineering is the use of vegetation for slope stabilisation, and control of run off and its negative effects (soil erosion and transportation of sediments). Examples include: planting grass lines along contours vertically or diagonally, netting jute together with seedlings, brush layering, live check dams, and vegetated stone pitching (Devkota et al. 2014).

Grass plantations protect the slopes with their roots and provide surface cover, reducing surface runoff and catching sediments. To establish grass plantations, rooted stem cuttings or clumps grown from seeds are planted over the slope in different ways (e.g. along contour lines, vertically, diagonally or randomly). Vetiver grass (Chrysopogon zizanioides) has been widely used to protect slopes. Its deep roots make the grass able to withstand high runoff speeds and volumes. In grass plantations, the spacing of the line should increase as slope increased (1 m for slope < 30°, 1 m - 1.5 m for slope > 30° & < 45°, 1.5 m - 2 m for slope > 45°). The spacing also depends on the root system of the plant being used.

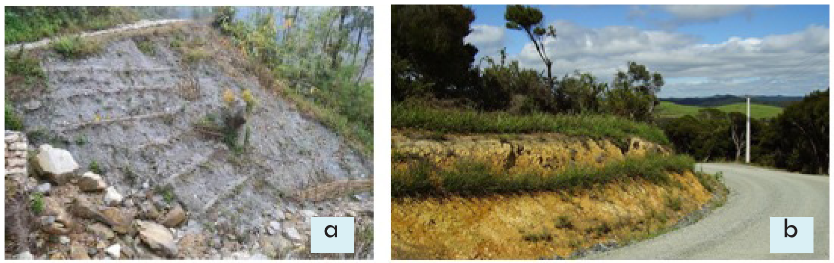

Figure 18. a) Bio-engineering along roadside in Nepal (Source: S. Devkota, 2014) and b) vetiver grass plantation to prevent erosion (source: Vetiver Network)

Live check dams are built by planting woody cuttings of shrubs or large tree species across a gully, generally following the contours. These form a barrier to trap sediments and reduce runoff speed. After some time, a small terrace will be formed at the floor of the gully. The maximum slope of the gully should be 45°. The spacing between live check dams should be between 3 to 5 meters, depending on the slope profile and the depth of the gully. Other measures are brush layering (placing woody cuttings in lines across the slope following the contour), gabion walls combined with vegetation, and vegetative stone pitching (dry stone walls with vegetation planted in the gaps between the stones).

4.2.3 Low rainfall hills

The low rainfall hills visited as part of this study also showed severe erosion along roadsides and on the hills. Rainfall in these areas ranges between 400 and 600 mm/year. Hence, erosion control measures are much needed. Since rainfall is low, the potential for water harvesting is also low. Nevertheless, water harvesting is much needed.

Districts surveyed in low rainfall hill areas	**Hissor, Kulob, Rudaki, Khuroson**
Road challenges	Gully erosion
Water and environment chal-lenges	Modest erosion, scour, dust
Measures for resilient roads	Adequate drainage and scour control
Measures for resilient road wa-ter environments	Road side tree planting; Modest opportunities for water harvesting – combined with low water consumption crops; In some areas flood water spreading

Road challenges

The main road challenge in this type of environment is the formation of gullies by the road side threatening the integrity of the road. These gullies should be prevented by proper scour control measures such as the scour-checks described in 4.2. Other solutions are presented below.

Figure 19a. Roadside gully in Kulob

Figure 19b. Land degradation on hill slopes around Kulob

Resilient roads

Low rainfall hills tend to encounter the same issues as high rainfall hills. However, less rainfall means less damage to the road and less erosion. On the other hand, there is also less vegetation to check floods and erosion. Hence similar measures as high rainfall hills can be applied here, particularly road plantations, but with species that are better adept to dry environments (juniper, acacia, poplar trees etc.). Road plantations also minimize wind erosion and spread of road dust.

Resilient road water environments

Since there is less rainfall, the potential for rainwater harvesting is lower. At the same time, a small increment in water availability can also make a big difference in terms of increased vegetation or increased watering of fields in areas where rainfed agriculture is practised. It is also in these areas that storing water during the water season – either in ponds, tanks, or in the water table – in order to use it during droughts– is most important.

<u>Roadside plantations acting as windbreaks and checking erosion</u>

Roadside vegetation is any vegetation growing on a road reserve. Planting trees, shrubs and grasses along the road alleviates the negative effect of roads on the local environment. The dust rising as vehicles pass on roads (especially on unpaved ones) has a direct effect on the environment and the health of people living near the roads. Road side plantations will not only check the deterioration of roads and the environment but will also create productive assets for local communities.

Evaporation of soil moisture caused by the wind exacerbates droughts in the low rainfall hills. The establishment of windbreaks entail planting trees in lines perpendicular to the prevailing direction of the wind, resulting in wind speed on the ground slowing down as the wind force is deflected to a higher altitude. Some recommended trees are Russian Silverberry (Elaeagnus angustifolia), Sea Buckthorn (Hippophae rhamnoides), and Poplar trees.

Roadside plantations with strategic location have numerous potential benefits:

- They protect crops and pastures from drying winds
- They protect livestock from cold or hot winds
- They provide shade to protect livestock from the effects of heat stress in summer
- They provide habitat for wildlife and natural biological control agents
- Help minimize salinity and soil erosion
- Conservation of soil and water; extending the growing season (pasture) and reducing soil erosion and nutrient loss
- Minimizing of roadside erosion

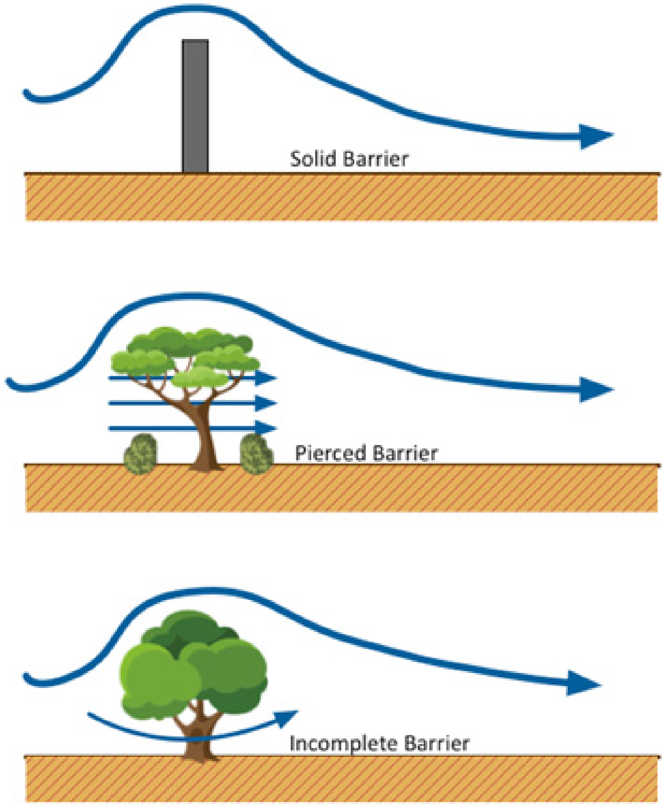

Figure 20. Well-designed roadside plantations act as windbreaks

5. Recommended follow up

As discussed in this report, there is in Tajikistan a great need and an opportunity to make a strong connection between the development and maintenance of road infrastructure and water management. The preceding sections described the different opportunities in four different areas of the country.

The current attention to the upgrading of international road infrastructure and the increasing interest in long-neglected feeder roads give rise to many opportunities 'to do it right' and to systematically introduce improved practices. Many of the measures discussed in the preceding sections come at modest additional costs; compared to the reduction in risk of damage and disruption, and the potential benefits to use water from road drainage systems productively.

The follow up proposed here was discussed in the one-to-one meetings and in a workshop on 11 November 2017. The recommended follow up can be grouped in three sets of activities:

(1) Immediate follow up activities;

(2) Mainstreaming roads for resilience approaches as standard practice in Tajikistan.

5.1 Immediate follow up activities

Under the current assignment, an assessment of opportunities was undertaken; and its findings discussed and shared in a workshop (on November 11). In addition, several additional outputs will be produced:

- Brochure with key aspects of the recommended 'Roads for Resilience' approach will be printed and distributed
- Two short videos to be used for awareness and training will be produced and disseminated through www.thewaterchannel.tv
- An infographic/ poster on landscape management around roads in medium and high-altitude areas will be produced

5.2 Mainstreaming roads for resilience approaches as standard practice in Tajikistan

A main recommendation has been to more closely integrate road development with other disciplines (see section 4.1), in particular to:

- have water-related road infrastructure (road drainage, bridges and flood protection measures, landscape improvement and water harvesting measures) designed by professional water engineers
- plan roads and road environments using future scenarios based on hydrological analysis, based on data sets by Hydromet
- align with the Committee for Emergency Situation and Civil Defense (particularly the Geology Department) and avoid road construction in disaster-prone areas as much as possible

To support a closer relationship between the Ministry of Transport, the Ministry of Water and Energy (especially the Directorate of Land Improvement and Irrigation) and the Committee for Emergency Situation and Civil Defense[4], a number of distinct activities are proposed:
(1) To jointly develop Guidance Notes by the three organizations with support from the Roads for Water Alliance on selected topics such as:

- use of Irish bridges for water retention in middle and high-altitude areas
- road drainage for beneficial water use
- conversion of borrow pits into safe water ponds
- road side tree planting and landscape management around roads

Guidance Notes prepared earlier by the Roads for Water Alliance can serve as a starting point. They would need to be tailored to the challenges and situation in Tajikistan. Cooperating on these Guidance Notes would forge relations between the different organizations. The preparation of the Guidance Notes should be accompanied by special visits, documentation exercises, and field meetings.
(2) Training staff at the region and oblast offices – from the three different organizations-- and other interested parties.

To familiarize staff working on the ground and to get their inputs into the Guidance Notes up to three trainings could be organized. The trainings will present material on the various techniques (tailored to the Tajikistan conditions), undertake practical assessment exercises, and discuss the most promising opportunities. The trainings could discuss practical cases and improvements in the organizational work processes. Topics could include:

- Climate change and forward-looking hydrological analysis for road development
- Standards for resilience
- Road water harvesting techniques
- Integrated landscape improvement and protection (including bio-engineering)
- Community consultation

One consideration could be to invite observers from other Central Asian countries to such training events, especially Kyrgyzstan that faces similar challenges and opportunities.
(3) Make a model design for a select road sections

It would be worthwhile to make a detailed design for given road sections using the forward-looking hydrological analysis (also described in 4.1). This will serve as a reality check/ standard, will allow cost and benefit calculations, and in the end will serve as a reference. The choice of road sections could represent the four different areas discussed earlier (section 4.2). The design work would again be done with the involvement of the three main organizations with coaching and support by the Roads for Water Alliance.

[4] Other may be added – such as Committee for Environmental Protection

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Annex 1 Mission overview

Activities	Date	
Arrival, kick-off briefing	30 October - 01 November	Logistical arrangements Meeting World Bank Meeting Deputy Minister of Transport Mirzoev Suhrob Begmatovich
Transect road visit in two different regions (Oblast) along main highway and two feeder roads to make first assessment and documentation of the opportunities for road water harvesting/ management for resilience	02 – 06 November	Joint visit with Head of Maintenance, Planning and Evaluation of Roads Department to: Khatlon Oblast Gorno-Badakshan Aunotomous Oblast Main districts visited: Kulob, Darvoz, Khorog, Roskhala
Discussion with stakeholders at national level to explore issues and opportunities and identify on-going programs in which better integration of roads and water management can be promoted	07-09 November	Organizations met: - Ministry of Transport - Ministry of Agriculture - Ministry of Water - Committee for Emergency Situations - Agency for Land Reclamation and Irrigation - Hydromet - UNDP - GIZ - FAO

Half-day workshop with main stakeholders discussing and agreeing on the opportunities of road water management in Mozambique	10 November	Venue: World Bank office Organizations invited: - Ministry of Transport - Agency for Land Reclamation and Irrigation - Committee for Emergency Situations - Ministry of Water - GIZ - Caritas Switzerland - EBRD - European Union Delegation - Cesvi (Italian NGO) - Swiss Cooperation - World Bank

Annex 2 List of people met

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