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# Reestablishing vegetation on interventions along rivers

## A compilation of methods and experiences from the Tana River valley

29
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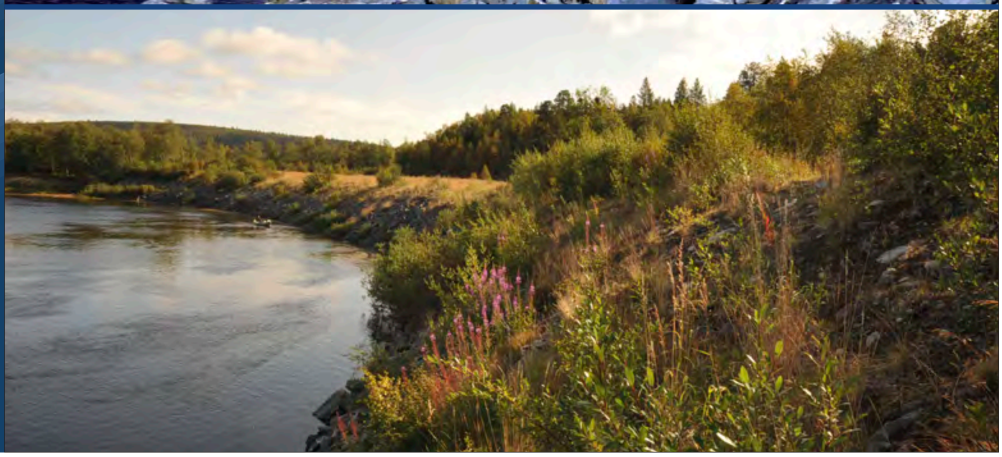

RAPPORT

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# Reestablishing vegetation on interventions along rivers

## A compilation of methods and experiences from the Tana River valley

Norwegian Water Resources and Energy Directorate
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## Report no 29

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**Editor:** Silje Hansen

**Authors:** Silje Hansen, Gunnar Kristiansen and Jukka Ylikörkkö

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**Abstract:** This report compiles methods and experiences gained by Finnish and Norwegian authorities in the project *Tana River Valley - developing cooperation between the authorities of Finland and Norway.* Tana is the largest and most productive salmon river in both Finland and Norway that is still in its natural state. There are also important conservation values associated with the riparian zone along Tana with several eastbound endemic plants and insects. Erosion control constructions have been constructed along the river bank in certain areas to protect adjacent land and roads from damage caused by erosion. Environmental measures has been conducted to improve the growth conditions for riparian vegetation on the erosion control constructions. Re-establishing vegetation on coarse unconsolidated rock embankments are challenging, and in most cases, active measures are needed to improve the growth conditions. The report describes the measures and corresponding methods that have been successful along the Tana River. Recommendations are made, and guidelines for similar conditions are given, with the aim at conveying knowledge and experiences from the project, with special emphasis on subarctic areas like the Tana river valley.

**Key words:** Environmental measures, erosion control construction, riparian vegetation, sub-arctic area, methods and guidelines

Norwegian Water Resources and Energy Directorate
Middelthunsgate 29
P.O Box 5091 Majorstua
0301 OSLO

Telephone: 22 95 95 95
Fax: 22 95 90 00
Internett: www.nve.no

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# Preface

The Tana River is a free flowing river that is part of the border between Finland and Norway. The significance as a tourist attraction and a source of recreation is important. The river is in its natural state and with the world largest stock of Atlantic salmon. The pure and unique subarctic environment attract travelers from all over the world.

The project Tana River Valley- developing cooperation between the authorities of Finland and Norway has been carried out in the period 2011 – 2014. The purpose of the project is to strengthen and develop the cross-border cooperation between authorities and improve networks between actors in the planning area. Prior to this project, it has been executed three related projects with the same participants from the two countries.

One of the objectives in this last project has been to produce a guideline about re-establishing vegetation on erosion control constructions in sub-arctic areas like the Tana River valley. The guideline that is presented in this report compiles the best practices and methods suitable for the area according to present knowledge. Even though based on experience from techniques used along the Tana river, the report gives examples and knowledge that may be valuable when considering environmental issues along rivers in other areas as well.

# 1 Introduction

In an international context Nordic nature in general, and fresh water ecosystems in particular, are especially diverse, varied and ecologically valuable. Norway and Finland combined has a high density of rivers, lakes, waterfalls and fjords, which together create a varied landscape, and habitats for a diversity of plants and animals. The Tana River is located in the northern part of Norway and Finland, forming the official boarders between the two countries over a stretch of 280 km. Hence, managing the river is a matter of both Norwegian and Finish interest and responsibility.Tana is one of the most valuable Atlantic salmon Rivers and the watershed has vast areas of untouched nature. One of the characteristics of the Tana River are the active sedimentation and erosion processes influencing the river form and function. Erosion of the river banks have in some cases along Tana lead to the need to secure parts of the river to reduce the stress on the riverbank and adjacent farm land and buildings. Erosion control constructions are constructed by covering the eroding slopes with coarse stone material to stabilize the riverbank and stop the erosion of the slope. Characteristics of the eroding slopes along the Tana River are areas partly or completely free of vegetation. The vegetation has been worn off by water, wind and ice, and left the river bank open, with exposed substrate of white sand and silt. These white river banks are one of the characteristic landscape features of the Tana River valley.

Former erosion control constructions were built at a time when the main focus was to control the river and limit the natural river processes, in order to avoid damage caused by erosion and flooding. This view has changed and the attention is increasingly focused on adapting and adjusting policies and practice. To avoid extensive interventions, and avoid compromising the natural processes in a river. Today every intervention in and connected to rivers needs to be adjusted to current environmental standards. The purpose is to move away from the wish to control the rivers, and aim at conducting security measures without compromising nature and vice versa.

Mapping of the erosion control constructions along the Tana River have been carried through in earlier projects on both Finnish and Norwegian side of the river. Vegetation establishes poorly on the erosion control constructions with low coverage, and diversity, of plants, bushes and trees. This is due to lack of finer growth substrate, nutrition and moisture. Measures to improve the conditions are needed to increase the rate of succession. The aim is to establish vegetation on the slopes, equivalent to those sections of the river that are not affected by erosion. Measures that has proven to be particularly successful on erosion control constructions along the Tana River are moving soil and growth substrate to increase water retention and nutrition. Transplanting vegetation mats and turfs to quickly establish continuous vegetation cover. Planting cuttings and trees to establish a bush layer, and use of biodegradable geotextiles to stabilize the growth substrate. These measures have been part of a collaborative effort between Finish and Norwegian authorities on managing the Tana River through the Inter-regional project: Developing cooperation between Finnish and Norwegian authorities in the Tana Valley 2011-2014. The main purpose was to improve the environment and the landscape in, and along the affected parts of the river, and to secure an integrated management of the Tana valley across national borders through the strengthening of dialog and cooperation.

This report covers experiences and lessons learned as part of one of the subprojects of the project. The report will function as a compilation of experiences drawn from this project as well as a guideline with methods and techniques for re-establishing riparian vegetation where interventions have been made. The report seeks to add knowledge on the field of ecological restoration for managers and practitioners with special emphasis on similar conditions along rivers in the northern hemisphere.

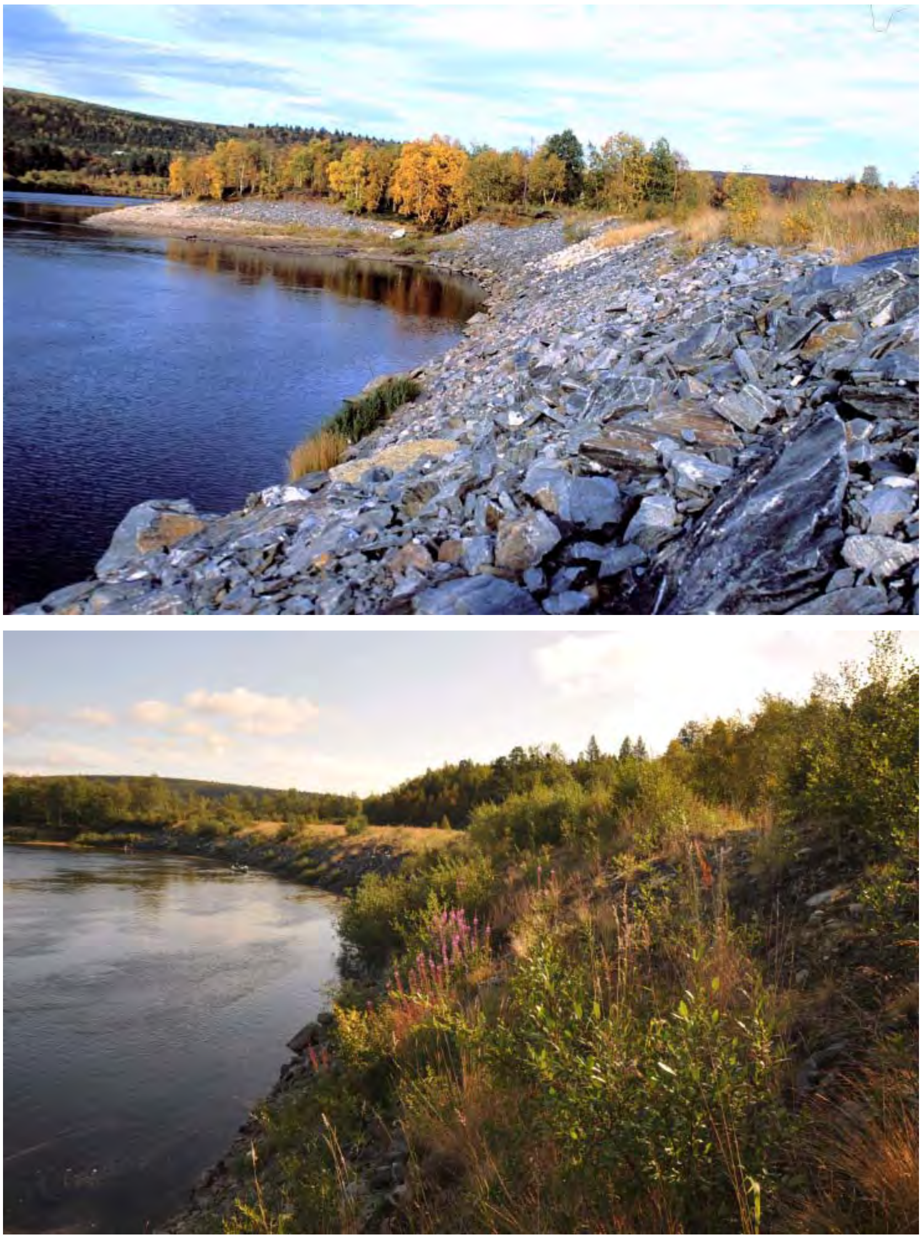


**Figure 1.1 Former sterile erosion control construction at Jeabmelisnjarg has now almost complete cover of riparian vegetation and the slopes are completely stabilized. Photo: Gunnar Kristiansen, NVE**

# 2 Area Description

## 2.1 Tana River basin district

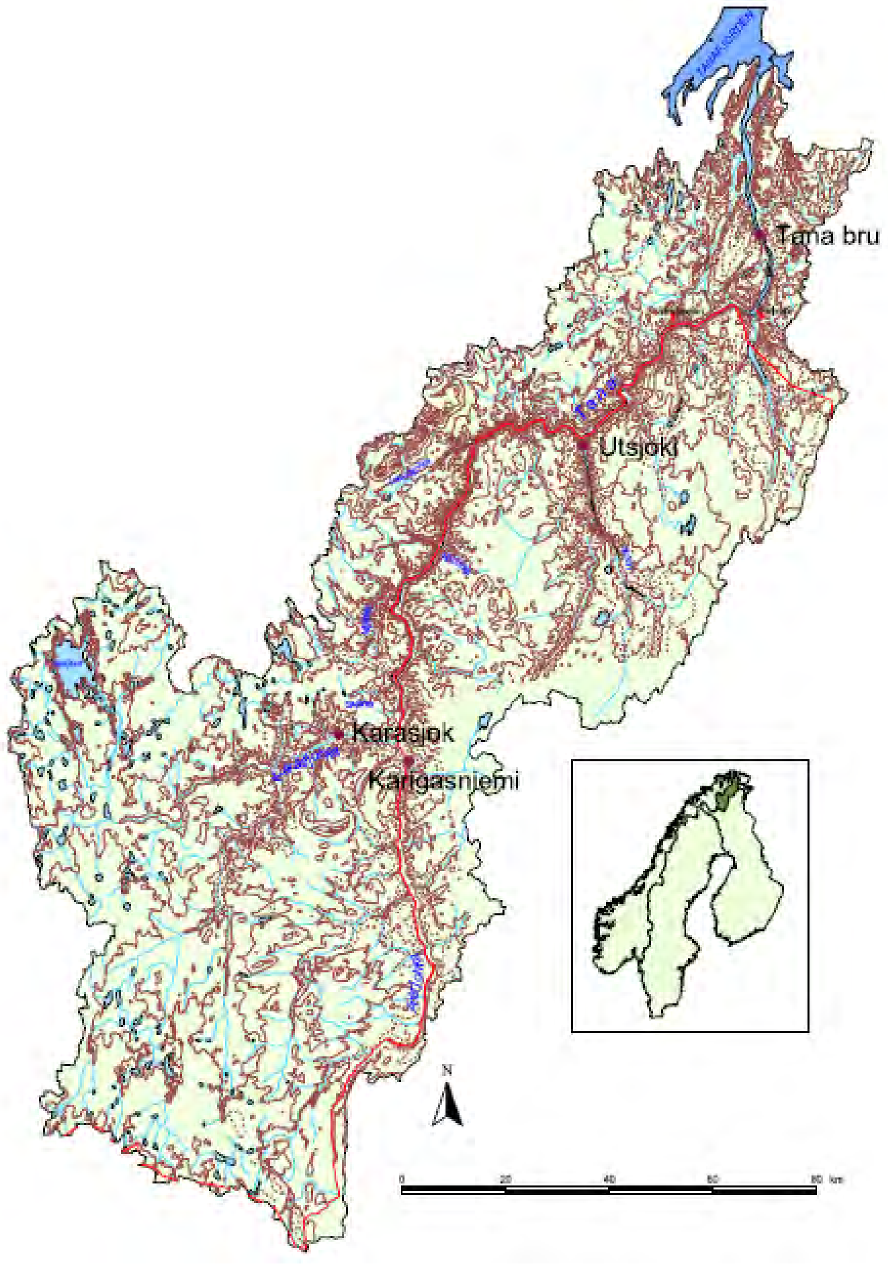



**Figure 2.1.1 Map of the location of the Tana River Basin**

The Tana River basin (Deatnu in Sámi, Tenojoki in Finnish and Tanaelva in Norwegian) is located in the midst of the Sapmi area of Northern Norway and Finland. The Tana River is by far the most valuable Atlantic salmon River in both countries and one of the largest salmon rivers of its kind in the world. The total catchment area of the river is 16.389 km2. One third is located in Finland and two third, including the mouth and outlet, is in Norway. The river forms the official border between Norway and Finland over a stretch of 280 km from the source of Ánárjohka downwards to Polmak. Kárášjohka and Anarjohka are the two main tributaries in the catchment area which together drains the entire eastern part of the Finmark plateau (Eie, Faugli & Aabel 1996). Tana is also the river with the largest discharge (Q = 4800 $m^3/s$) and the largest ice jam processes in Norway. Tana is protected in the second plan for protected rivers in Norway. The catchment area is characterized by large areas of pristine nature and there are great conservation values both along the main river and along the tributaries.

**Figure 2.1.2 Aerial photography of the The Tana river valley. Photo: Gunnar Kristiansen, NVE**

## 2.2 Geographic description

A key feature of the Tana River is vast stretches of sandbanks and shallow, tranquil river sections alternating with sections of rapid flowing water. The lake percentage of the catchment area is 3.1 and the total height of fall in the main channel is 380 m. The outlet of the river forms an extensive river delta with wide-ranging areas of silt sand banks, some places in the outlet of the river the width is as broad as 2km (Annamo & Kristiansen 2012). The bedrock in the north consists mainly of sandstone, farther south gneiss is the most important rock type in the catchment area. The southern part of the plateau is covered with moraine. The main valley is glacial characterized, and there are large unconsolidated deposits in the bottom of the valley.

The catchment area of the Tana River is characterized by open mountain plateau and mountain areas above the timberline. The mountain plateau consists of a landscape mosaic of scattered occurrence of mountain birch-, birch, pine forest and peat bogs. Forest account for approximately 60% of the area, whereas 12% is consisting of peat bogs.

The Tana river is naturally prone to erosion. Soil erosion and sediment transport is important features of the natural river dynamic. There are large sources of sedimentation along the watercourse with active natural erosion and sedimentation processes. These processes are related to the water discharge and ice flows and vary from year to year. The former marine boundary stretches to the area of Storfossen (Ala Köngäs) and there are marine deposits (clay) in parts of the river slopes along the main river and the tributaries below this area. Erosion processes and landslide activity is consequently more active and unpredictable downstream Storfossen (Ala Köngäs) than in the upper reaches of the river. Downstream Tana Bru the river is affected by tides and the sedimentation areas of the river is mainly found here. The flow rate decreases, the river course expands and sandbanks are formed and creates several varying river courses. The form of the river course in this section can vary from year to year depending on the sedimentation processes and the material transportation. The water course is exposed to major ice drift and studies show that the ice is essential for the erosion and sedimentation processes of the river.

The catchment area of the Tana River is located in a subarctic area with low winter temperatures and low rainfall. During summer there is low amount of rain often combined with relatively high temperatures. The spring flood is distinctive and the water discharge is low during winter. The water discharge increases rapidly in late April and the spring flood is at its peak sometime between mid-May and June. Annual mean discharge at Båteng (Nuorgam) is approximately 170 $m^3/s$, while the average flood is approximately 1600 $m^3/s$. Highest recorded flood water discharge occurred in 1920 with approximately 3850 $m^3/s$. There are rarely large autumn flooding with the exception of the autumn of 1999 when the water discharge reached approximately 1400 $m^3/s$ (Annamo & Kristiansen 2012).

A large amount of the erosion occurring in the Tana River is caused by natural processes. Human activity related to recreation, agriculture or construction of roads cause some erosion. However the impact from this is fairly moderate compared to the ice drift and other natural processes.

## 2.3 Vegetation

The catchment area of the Tana River belongs to the dominating north boreal vegetation zone that covers the lowlands of Finmark. The zone is characterized by birch forest and low grown coniferous forest. Willow species form vital riparian vegetation, and along the Tana River different species of willow create contiguous forests. These vital edge zones and floodplains of willow forest and swamp forest have high productivity, high biodiversity, and provide living conditions and a variety of habitats for specialized bird, insect and plant species.

**Figure 2.3** ***Thymus serpyllum tanaënsis*** **(Tanatimian, Tenonajuruoho) Photo: Gunnar Kristiansen, NVE**

In combination with these edge zones of willow forest we find more open, flood and erosion prone riversides that consist of a mosaic of willow thickets, grasses, herbs and partly exposed stone and sandbanks free of vegetation. In these varied edge zones along Tana we find a distinctive eastern flora element that is unique in Norway. Species that are rare or red-listed in Norway and characteristic along the Tana River include *Thymus serpyllum tanaënsis (*Tanatimian, Tenonajuruoho*)*, *Veronica longifolia* (Storveronika, Rantatädyke), *Lactuca sibirica* (Sibirturt, Siperiansinivalvatti), *Polemonium acutiflorum* (Lappflokk, Kellosinilatva), *Thalictrum minus ssp. kemense* (Russefrøstjerne, Keminängelmä), *Oxytropis campestris* ssp. *sordid* (Russemjelt, Idänkeulankärki), and *Thalictrum simplex ssp. boreale* (Finmarksfrøstjerne, Pohjanhoikkaängelmä). *Thalictrum kemense* is also red-listed in Finland. *Elymus fibrosus* (Russekveke, Siperianvehnä), a species growing on sandy river banks, is considered endangered in both countries and found in few places in the area.

Another characteristic of the catchment area of Tana River is the extensive areas of exposed surfaces of sand and silt that occurs through the river stretch. These areas accounts for a particulate nature element or a nature type that forms the livelihoods for a variety of insect species, so called riparian insects. We find several very rare and red listed insect species like several species of beetles that depends on the livelihood associated with these river banks.

# 3 Interventions in rivers

Rivers adjust their channel form by erosion and deposition of sediment. Erosion of the bed and banks occurs when the shear stress exerted by water on the channel perimeter exceeds the strength of the material. Erosion occurs to a greater or lesser extent in all channels, particularly during high flows, and in certain locations, such as the outer bank of river bends, in virtually all flows. Erosion, flooding and sediment transport are natural processes that shape the landscape. It creates important aesthetic values with contrasts between deep slow flowing water and fast flowing sections, rivers with alternations between low vegetation and trees along the banks, and rivers that meander naturally on a flood plain (Fergus & Hoseth et.al 2010). Erosion and flood processes combined with the impact from human activity can at the same time cause damage to settlements, infrastructure, agriculture, and in the worst case scenario, cause loss of life. The focus on security was previously stronger than the environmental and ecological consideration, which in many cases resulted in extensive interventions. Measures were made in many cases to secure adjacent land from flooding and erosion without any consideration made for either landscape or biodiversity. The prevailing thought was in most cases to control the river in order to be safe. Today the focus has shifted from the ‘control view’ to a more adaptive way of thinking in the managing and planning sector. The term ‘interventions in rivers’ are here used as a general term for all interventions done directly in the river, and, or in, the connecting riparian zone.

Many and various interests are linked to Norwegian and Finish rivers. A variety of extensive interventions have been made in relation to the exploitation of the larger rivers for hydropower and logging like damming and channelization. The consequences of these interventions are in many cases channel-like, homogenous river courses with relatively high water velocity. The value of the connecting riparian zone and flood plain has in many cases also been highly compromised. Compared to a natural river, the variation in water velocity, depth, and flow pattern is greatly reduced in many Norwegian and Finnish rivers. In addition to the extensive interventions in the larger rivers, smaller interventions have been made in tributaries and smaller rivers. Examples of this are trenching, scraping, straightening, closing of river courses, and establishments of culverts. Separately these interventions can be considered small. Though, combined, they can cause severe effects on the river systems due to the substantial amount of biological production that takes place in the smaller tributaries.Within a large river system as the Tana River with approximately 16 000 km2 there are few inhabitants and limited agricultural activity, and the vast majority of the river and the areas close by are untouched by interventions. Nevertheless, measures have been made in regards to erosion. The major erosion control constructions are mainly found in the outlet of smaller tributaries and in denser populated areas along the main river. In the context of this guideline we will further on focus mainly on interventions in rivers related to security measures such as erosion control constructions.

## 3.1 Erosion control constructions

Erosion control constructions and other protection measures have been built along Norwegian and Finish rivers dependent on the available technical means at the time of construction. Up until the sixties, all measures were mostly performed by hand and methods used were mainly dry walling or embankments constructed of smaller rocks. Today heavy machinery is available and the use of larger rocks for the constructions is more common. Making environmental considerations and measures during the construction fazes have only become an important factor recently.

The most common method for constructing erosion controls, and the method applied along Tana, is to cover the erosion prone riversides with rocks, see figure 3.1.1 and 3.1.2 below. While rocks offer some resistance against mass movement, the primary purpose is to prevent loss of bank material by fluvial erosion, to increase the stability and prevent the river to dig and erode. Solid stone material is less erodible, making the slopes less prone to erosion and so protecting adjacent land, farmland, roads and buildings. Erosion controls constructed of rocks are in general highly durable and suitable to protect against erosion caused by both water, wind and ice (Fergus & Hoseth et.al.2010).

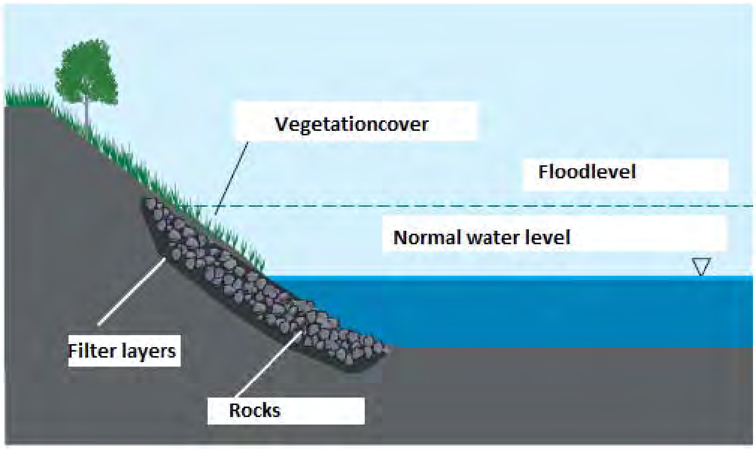



**Figure 3.1.1 Sketch of erosion control construction of rocks. The sketch show a modern construction where vegetation measures are included in the plan. (Sketch modified from Vassdragshåndboka, Rune Stubrud, NVE)**

**Figure 3.1.2 Erosion control construction in the outlet of the Tana River. Photo: Knut Aune Hoseth, NVE**

The Tana River is characterized by active erosion and sedimentation processes. Mapping of the erosion slopes along Tana has been performed by both Finnish and Norwegian authorities. There are many, and extensive erosion slopes along the river, this is a result of deposits located along the river which are particularly prone to erosion because of the inclination and composition of the sediments. The slopes are often steep and consist of fine or coarse sand and gravel which makes it difficult for vegetation to establish and makes the slopes further prone to erosion from water and ice. Strains on the slopes from the annual ice drift and flooding can be extensive. Erosion can increase by concentrating runoff, resulting in the formation of ravines. This also applies for the concentration of runoff along paths down steep slopes used by fishers to access the river. Lappland ELY-Centre and their predecessors have secured approximately 9, 2 km of the main river on total 12 sites on the finish side, along the stretch of Nuorgam and up to Anarjohka in the period 1976-1990. The Norwegian Water Resources and Energy Directorate (NVE) have in the same period secured approximately 7 km of the main river against erosion on total 9 sites. Aside the wanted positive effects of the erosion control constructions there are some disadvantages associated with the constructions. The use of large rocks that do not occur naturally on the riverside, effects the landscape and creates an artificial image of the river. Especially in areas where nonnative stone is the used e.g. Polmak. And the conditions for plant growth are poor with lack of growth substrate, water and nutrition unless measures are made to improve the conditions.

**Figure 3.1.3 Example of erosion control constructions with no vegetation cover. The stone material used in the erosion control construction below is an example of a type of rocks not common along the Tana River. The color is not adjusted to the landscape and emphasizes the interventions. Photo: Gunnar Kristiansen, NVE**

# 4 Riparian vegetation

Rivers and the associated riparian zone represent some of the most valuable landscape elements and habitats in nature. The riparian zone is defined as the area along the river which is regularly flooded during flood periods. The width of the zone is mainly determined by the flow regime and the topography of the landscape. The plant community is dominated by vascular plants that need to withstand stress related to alternating flooding and drying, frost, glacial erosion, and mechanical attrition from ice drift and transportation during spring. The composition of the riparian vegetation reflects the above mentioned and consists most often of perennial species of grass, sedge and herbs with underground shoots and well developed root systems for these environmental conditions. Small trees and bushes, mainly different willow species, is also commonly found.

**Figure 4.1 Section of the Tana River showing natural riparian vegetation and the variation in substrate with parts of open sand and silt, rocks and vegetation growing almost down in the river. Photo: Gunnar Kristiansen, NVE**

Large trees (except from Alnus incana) are not adapted to flooding and are rarely found close to the river due to lack of available oxygen during flooding. Riparian vegetation is essential for the river environment and provides a variety of functions and features:

**Connectivity** Riparian vegetation frames the river and creates contrast, variation and corridors in the landscape.

**Important landscape element** Vegetation can hide, shield and downplay unsightly stone embankments along the river. In addition, riparian vegetation protects the scenery against the adverse effects of technical installations, roads and buildings.

**Important biotope** Riparian vegetation is in itself a biotope which constitutes great biodiversity. Willow forest along the river for instance is of great importance for birds, and as pasture and shelter for wildlife.

**Source of organic matter to streams** Organic material from riparian vegetation is an important source of nutrients for benthic organisms in fluvial ecosystems.

**Filtering pollutants** Riparian vegetation filters the runoff and absorbs excess nutrients from diffuse pollution. Riparian vegetation can act as a trap for sediments, and reduces the runoff and material transportation.

**Streambank stabilization** Riparian vegetation binds the soil and prevents erosion. This applies for the direct erosion from the main river as well as erosion from superficial runoff and erosion from tributaries in the system.

**Flood control** Roots of the riparian vegetation make the soil porous and thus increase the soil drainage capacity, which also is beneficial in events of flooding.

## 4.1 Riparian vegetation and the river environment

A functional riparian zone is important for the river environment for multiple reasons. If we study cross-sections of a river it shows that we can divide the river bed in two main parts, the river and the riverside. While the river course is primarily under water throughout the year, the river side is heavily affected by changing water levels and is defined as the area between highest and lowest water level. The majority of the production of organic material in the river is produced by the riparian vegetation which falls into the river and account for a large part of the benthic feed source. Running water can therefore be regarded as open ecosystems that are largely affected by the ecosystems associated by the surroundings (Økland 1983).

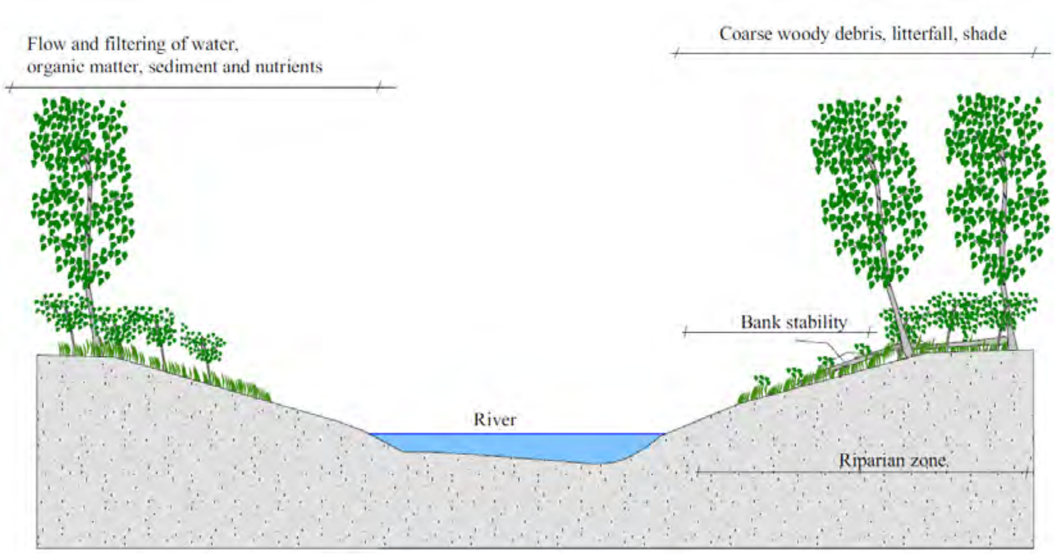



**Figure 4.1.1 Cross section of a river and the riparian zone. Illustration: Anders Bjordal, NVE**

Access to, and amount of allochthonous material determines the amount and composition of benthic fauna, which further affect the livelihood and amount of fish produced in the river. Riparian vegetation can be divided in zones according to the flood zone and the proximity to the water (Bjerketvedt & Pedersen 1996). Closest to the river the vegetation is characterized by moist demanding mosses and annual herbs. This zone is regularly exposed to flooding and perennial herbs are not common because flooding and following dry periods cause the substrate to crack which in turn damage the root system of the plants. The subsequent zone is characterized by a well-developed layer of mosses and dominated by perennial grass and sedges. Bushes and small trees also occur in this zone. Above this zone larger trees can be found in combination with an extensive cover of vegetation of perennial grass, sedges and herbs (Økland 1983).

Vegetation offers protection against superficial erosion on slopes and provides some degree of protection against small scale, shallow mass movement. Vegetation physically binds or restrains soil particles through the root system of the plants. It reduces the transportation of the sediments and reduces the runoff-speed. Vegetation and trees increases the soil infiltration capacity and the uptake of rainwater. In addition vegetation cover can reduce the amount of freezing and thawing in the soil through the provision of insulation. Vegetation provides shade, cover and organic debris affecting in-stream habitats. Over time the leaf litter from the willows will add to the productivity of the river and the trees will provide shelter for many aquatic insects.

Intact riparian vegetation functions as important corridors in the landscape. Uninterrupted, vegetation provide connections between fragmented landscape elements along the stretch of the river, and by this preserves upstream and downstream connectivity. The corridors promote movement and dispersal for both plants and animals. Relatively natural areas in urban and semi-urban landscape offer refreshing contrasts. As a result of their linear nature, greenways lend themselves to recreational trails and travel ways and promote visual amenity and recreation.

# 5 Relevant legislation and regulations

Restoration and rehabilitation of interventions in nature are not often directly mentioned or emphasized in the Norwegian and Finnish environmental legislations and associated regulations. It is however, important to mention the legislations and regulations that are relevant in this context, and stress the relevance in regards to the preliminary planning, implementation and follow up of projects. Bellow follows a brief overview of the most central legislation and regulations in Finland and Norway related to rivers and the riparian zone.

## 5.1 The Norwegian Nature Diversity Act

The Norwegian Nature Diversity Act entered into force in 2009 replacing the former Nature Conservation Act. The Nature Diversity Act provide the legal framework for the protection of biological, landscape and geological diversity and the associated ecological processes in nature, through the combination of conservation and sustainable use. The Nature Diversity Act is an extensive legislation which aims at coordinating the objectives, principles and rules related to use and protection of biological diversity. The act provides the appropriate measures to secure biodiversity in- and outside protected areas, and function as a framework for other legislations and regulations related to the use and protection of nature.

Chapter four in the act concerning alien species states the requirements for careful consideration related to the release of viable organisms in the environment. The associated regulations has not yet entered into force, but this section of the law is under preparation and is expected to be completed in the close future. Chapter four and the associated regulations is expected to be relevant in relation to projects concerning restoration and rehabilitation of riparian vegetation and the associated use of plant material. Although the chapter has not yet entered into force it is important to focus attention on the potential damage alien species can do in protected and vulnerable areas. Sound decision-making in accordance with the Nature diversity act is fundamental in all projects concerning nature and habitat improvement. When moving vegetation mats and soil from the river and riverbanks § 6-8 must be allowed for by the act. Measures can not be done without knowledge of the biodiversity and how to avoid interventions which may influence secured species and habitats.

## 5.2 The Finnish Nature Conservation Act

Certain biotopes and plants or habitats of specific plants are protected under Nature Conservation Act (20.12.1996/1096), which should be taken into account when moving plants or landmasses. Of the plants growing in the Tana valley Thalictrum minus ssp. kemense is endangered and protected in Finland, and Elymus fibrosus is considered endangered.

## 5.3 The Water resource Act

Particularly relevant for projects related to riparian vegetation along rivers is the Norwegian Water Resource Act. The purpose of the act is to ensure a socially responsible use and management of water bodies and groundwater. This also includes issues such as maintenance of vegetation along waterways, restoration of river channels and reopening of closed water systems. Chapter two concerning general rules related to rivers states in §11 the requirements of maintaining riparian vegetation to prevent runoff and erosion and preserve habitats for plants and animals connected to the riverine ecosystems. Chapter five concerning protected rivers, § 35, point nine, states that along protected rivers the water authorities may impose a decision to re-establish vegetation that is naturally in an area in a zone along the banks. This zone should be determined in the legally binding plan regulated by the Planning and Building Act.

## 5.4 Land use and Building Act

Generally land management or building in the shoreline in Finland is prohibited by the Land Use and Building Act (5.2.1999/132). In Utsjoki building code the minimum distance of 20 m from shoreline is required from new permanent buildings (Utsjoen kunnan rakennusjärjestys 2010). The building code advises to preserve riparian vegetation, but thinning is allowed.

## 5.5 Land Extraction Act

Finnish Land Extraction Act (24.7.1981/555) states that soil extraction cannot impair landscapes or natural values. Soil extraction in a river shoreline is prohibited. Land extraction permit is generally required for large-scale operations.

## 5.6 Other relevant legislation

In addition to the Norwegian Water resource Act, relevant regulations specifically related to protected rivers is found in the **National policies for Protected Rivers**. The guidelines defines the management goals of the protected rivers, guidelines related to the river channel and defines who is responsible authorities on local, regional and national level. The purpose of protecting rivers can be related to a variety of values such as recreational value, biological diversity, and cultural heritage. The purpose of the protection can vary from river to river. Decisions concerning protection of rivers have in general a purpose of conserving a representative selection of Norwegian river nature for the future.

**The Norwegian Act on food production and food security** (the food act) is also relevant in regards to re-establishing vegetation. It is an extensive act regulating food production in Norway and the associated terms and conditions for production, use and distribution of seed material which includes use and distribution of plant material.

**The European Water Framework Directive (WFD)** is implemented in both Norway and Finland. In Norway through the EEA agreement, and in Finland as a member state of the European Union. The objective of the directive is to achieve good ecological status of all fresh water and ground water bodies, to ensure clean drinking water and protect the ecological and biological processes and functions of fresh water ecosystems. Measures are to be made where there is risk of not achieving good ecological status. Environmental measures in the Tana River is not directly linked to the WFD. However, environmental measures in the riparian zone are in line with the WFD in regards to improving natural habitat and as a landscape element important for e.g. recreation and fishing. The WFDs ecological quality assessment includes aquatic plants- macrophytes, as a biological quality element. Erosion control constructions may impair plant communities, such as helophytes, which are not easily restored. At the moment macrophytes in rivers are not monitored for the WFD in Tana River.

**The Norwegian-Finish Transboundary Water Commision** was established in 1980 as a response to the need for joint coordination and management of the Norwegian- finish Border Rivers. The commission function as a platform for cooperation and coordination of interests between local, regional and central Norwegian and Finish authorities regarding the rivers Tana, Pasvik, and Neiden. The commission meet at least once a year to discuss questions and exchange information regarding the rivers. The trans boundary water commission has an advisory role and gives recommendations to the respective governments and management authorities. The commission can initiate projects concerning the management of the rivers. Examples of conducted projects are multipurpose plans for Border Rivers, and the project “Conserving Tana as a salmon river in natural condition”.

**European Landscape Convention**

The convention agrees on promoting protection of landscape values and urges to integrate measures for preserving them in planning and management procedures. The convention is signed in Finland and Norway. The Tana river valley is recognized as nationally valuable natural and cultural landscape in Finland (Regional Council of Lapland 2005). River banks are an essential part of the valley landscape and, as noted in the earlier chapters, vegetation alleviates the injury from man-made structures on the shoreline appearance.

**The Convention on Biological diversity** is an international treaty regarding conservation and sustainable use of biological diversity and resources. 193 countries have signed the treaty and are committed to develop national strategies and plan of actions to follow up the treaty. Finland and Norway has both signed and ratified the convention and included the recommendations in the respective countries legislations and regulations.

# 6 Environmental measures and methods

Interventions in rivers and the riparian zone often involves changed conditions for life in the river, and affect the user interests on varying degrees. Some of the negative consequences for biodiversity, fish, recreation, landscape and aesthetics can be reduced and avoided if conscious environmental measures are made during or after interventions. There are various forms of environmental measures and a variety of terms refers to different measures to improve, adjust, rehabilitate or restore nature.

**Mitigation measures** are measures made to reduce the adverse effect of interventions in rivers. This is a broad term covering all activities and interests regarding recreation, landscape, fish and biodiversity.

**Biotope adjustments** are measures made in a particulate part of a river or connecting riparian zone. These measures are made to improve habitat for fish and other organisms.

**Rehabilitation** embodies measures made to recreate parts of the river to its natural form and function.

**Restoration** refers to complete reversal of interventions to restore the river form and function.

In the context of Tana, revegetation measures on the erosion control constructions are considered mitigation measures that include both the aspect of biotope adjustment and rehabilitation of riparian vegetation. Some of the interventions along the Tana River have been planned in accordance with the new environmental standards including measures to mitigate the adverse effects on the ecosystem. Other erosion control constructions are older and not adjusted to the current environmental standard.

Recently, ecological restoration has gained more focus and attention by managers, researchers and practitioners. Natural revegetation and ecological restoration has become an important premise for many projects implemented by national authorities in both Finland and Norway e.g. road constructions like the Oslo fjord connection and Lofoten mainland connection. Restoration projects like Hjerkinn shooting range and revegetation of spoil heaps from hydropower development. See for example Hagen & Skrindo 2010, Skrindo & Pedersen 2003.

The figure below is a simplified illustration of some of the methods used in Tana to re-establish vegetation on erosion control constructions.

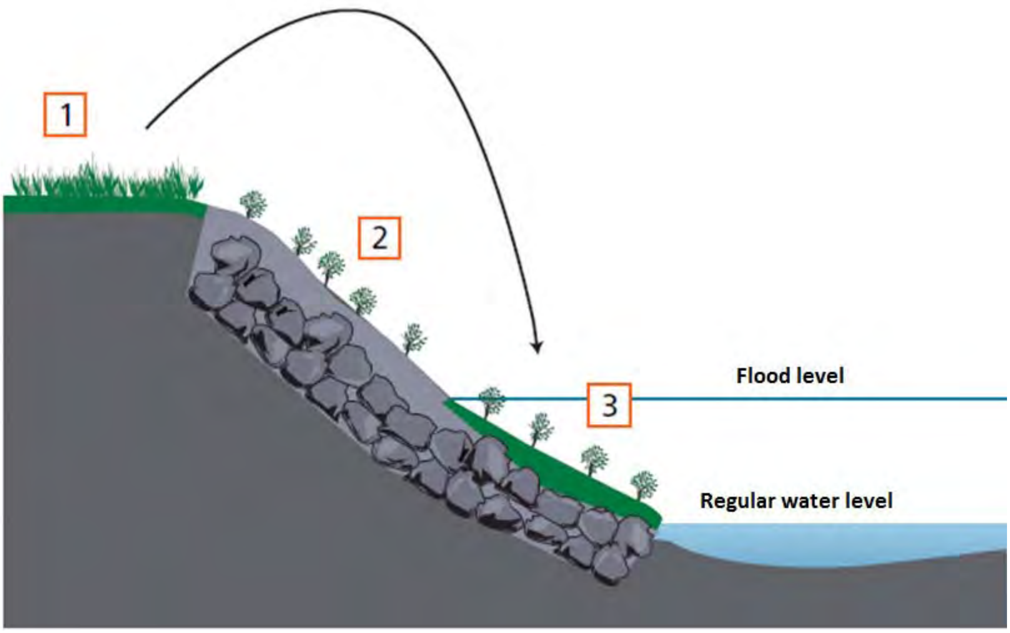



**Figure 6.1 Sketch of revegetation process. Moving soil and growth masses over the erosion control, moving vegetation mats below the floodline, planting trees and bushes, and planting willow cuttings. Illustration: Rune Stubrud, Vassdragshåndboka**

A variety of methods for environmental measures regarding reestablishing vegetation can be applied. The main methods used in Tana are:

- Moving soil and preparation of growth substrate
- Transplanting entire mats and turfs of vegetation
- Transplanting trees
- Planting cuttings
- Use of biodegradable geotextiles, both as erosion control and as revegetation method

The methods applied in the riparian zone of the Tana River is based on experiences from other similar projects, as well as gained knowledge and experience from the Finnish and Norwegian authorities.

In the following sections explanation of each of the measures will be described and guidelines for the methods will be given.

# 7 Soil and preparation of growth substrate

The main challenge for plant growth on erosion control constructions is lack of soil and growth masses. Some trees, bushes and plants will manage to grow in the coarse unconsolidated sediments, but the growth rate is very slow, and rarely leads to a continuous cover of vegetation. Some of the erosion control constructions along rivers in Northern Norway have been there for more than 50 years without vegetation re-establishing naturally. Considering the added benefit vegetation have on preventing or limiting further erosion and damage on the slopes, environmental measures to re-establish vegetation should be emphasized.

The erosion control constructions along the Tana River have completely different properties than the indigenous top soil at the site, see fig. 7.1. The fraction size of the stone masses in the erosion control constructions often consist of particularly coarse-grained sediments. These are essentially nutrient poor and with low amount of available minerals for plant growth. Type of rocks can play an important part in relation to the plants access to minerals. Rocks consisting of more shale, which is commonly used in erosion control constructions along the Tana River, excrete more minerals. For the establishment of vascular plants (and mosses) the plant nutrients nitrogen (N) and phosphorus (P) are the minimum factors for growth. Both the N and P are related to proteins in the organic mass (humus). By natural immigration, pioneer species will build up a reserve of humus from dead plant material. A portion will be deposited by wind from adjacent areas and transported with the river water after flooding. If fine particulate material is added on the erosion control constructions use of mineral fertilizer (nitrogen) is an option if available soil is limited. Fertilizers should however be used with caution. Adding fertilizers influence the growth conditions and if exaggerated, may result in a different composition of the vegetation than what is naturally in the area. Coarse rock embankments usually have medium or low permeability of water, and the ability of the stone material to retain and store water is low. It is important to add a mix of top soil composed of finer soil and organic material from above the construction on top, and in between the unconsolidated rocks and sediments. This will increase the retention of water and provision of nutrients on the slopes, which in time restores some of the basic ecological conditions on the construction. See figure 7.1

Crushing the stone on the erosion control constructions are also an option, and can be done with heavy machinery. This way the plants gets access to mineral nutrients that are being released when the stone are crushed. This has been done in other environmental measures conducted by NVE, and has showed good results in regards to the plant growth conditions. This method do not compromise the purpose of the erosion control construction, which is to prevent erosion of the river bank, if larger stones are left uncrushed close to the river.

Some of the added substrate on the erosion control construction should be of very fine particle size; preferably silt. Clay can be an alternative if it is mixed well with coarser sediments. For optimal growth and establishment of vegetation at least 5 -10% of the material in the root layer should be in particle size clay (<0.002 mm) and silt (0.002 to 0.063 mm). It is important to ensure that the soil has sufficient content of finer material while the top deck is fixed so that surface water can be absorbed and minerals are made available.

**Figure 7.1 Erosion control constructions with coarse rocks, resulting in sterile and harsh environmental conditions (above). Excavator moving soil over the slope, covering the rocks with growth masses and improves the conditions for plant growth (below). Photo: Gunnar Kristiansen, NVE**

The soil should be moved over the erosion control construction in early autumn or winter, this way, the spring flood is avoided and the growth masses have time to “settle” during autumn and winter. The soil can be used in its natural condition or mixed with sand. It is possible to use sand from the river bottom as substrate. However, close consideration is needed to not harm valuable areas for fish and other life in the river. In many cases the erosion control constructions have been constructed very steep, which further hampers the conditions for re-establishing vegetation. In these cases, it is essential to reduce the inclination of the slope prior to further measures. This can be done by shaving/cutting of the upper part of the erosion control constructions, and move the excess masses downwards and add a substantial amount of soil and fine material to gentle down the slope.

By using native soil it is possible to draw benefits from the seed bank found in the soil. Soil contains seeds and plant material and by careful and appropriate treatment, the results can be successful without sowing or use of mineral fertilizer.The top layer of the soil (5-20 cm) will contain spores, seeds and plant material, even small amounts of the top layer added on the erosion control constructions could have a major impact on the growth conditionis. However, dry humus is quickly transported away by wind and water, hence it is an advantage to mix this with pure mineral soil (silt / sand). In Tana, good results was achieved by mixing as little as 10% of top layer soil with silt / sand.

Sand from the river bottom was extracted with permission from the landowner and used as growth substrate at Valljok, one of the sites along the Tana River. Vegetation started to form a good cover the first couple of years after the environmental measures was completed. The bottom vegetation covered approximately 50 % of the areas covered with added sand from the river bottom. The bottom vegetation was dominated by *Equisetum arvense* (Åkersnelle), with a large proportion consisting of *Achillea millefolium* (ryllikk, siankärsämö), *Solidago virgaurea* (gullris, mesiangervo) and *Chamerion angustifolium* (geitrams, maitohorsma). Stem cuttings of Salix was also planted and 100% of these are established and growing, composing an even bush layer of willows with a height of 0, 5-1 meter. Some of the cuttings are even up to 2 meter tall. Other species that occur less frequently are *Stellaria graminea* (grasstjerneblom), *Rumex acetosa* (engsyre), *Rhinanthus* (engkall), *Festuca ovina* (sauesvingel) and *Elymus caninus* (hundekveke).

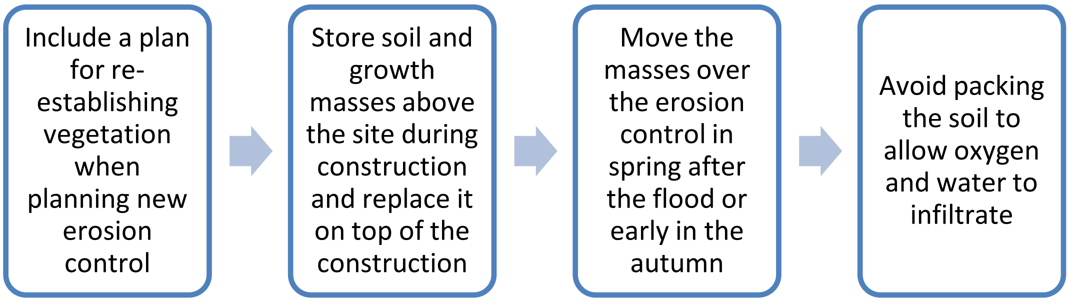
Meadow species such as *Elytrigia repens* (Kveke), *Festuca rubra (rødsvingel), Poa praténsis L* (engrapp) has established in the edge zone, which has probably spread from the adjoining pasture as we do not find these species other areas in the Tana valley. The composition of the vegetation clearly show a substantial influence and dominance of grass and herbs from the pasture close by. In 2013 there were a high density of *Elytrigia repens* (kveke), and raigras on the areas with sand, which the year before had low cover of vegetation. These crop species has spread from the pasture when the farmer sowed and the vegetation appears somewhat artificial with a different character than the natural riparian vegetation associated with the Tana valley, see fig.7.4. During some years of natural succession, in combination with natural processes like ice drift and flooding, the native vegetation will probably dominate the plant community again. Dispersal of commercial seeds from agricultural land is a general challenge. Including buffer zones of trees and natural vegetation between the riparian zone and adjacent agricultural land reduces the dispersal of agricultural plant varieties, and should be a measure to preserve the native riparian vegetation along all rivers.

**Figure 7.2 Sterile erosion control construction of coarse stone material. The same section after sand from the river bottom have been added., and vegetation mats moved from the toparea to the stone area. Eight years after the measure a complete cover of vegetation is established Photo: Gunnar Kristiansen, NVE**

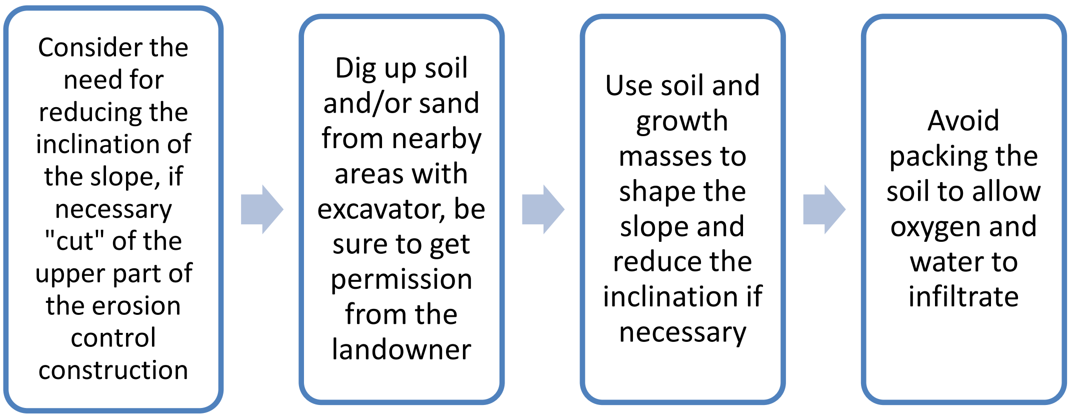
During new constructions it is beneficial to remove the original top soil, sand and sediments and store it above the construction and replace it on top of the stone embankment after construction is completed. In many cases this measure can be sufficient for vegetation to re-establish, although the time needed to form a continuous vegetation cover might be substantial.

## Key Points

Environmental measures on new erosion control constructions




Environmental measures on old erosion control constructions



# 8 Sowing

Preventing introduction of alien species is highly emphasized in Norwegian and Finish nature conservation and biodiversity legislations. Hence, in planning and implementing new interventions in nature, requirements regarding use of native seeds and plant material should be followed. Indigenous plant material should be used in new environmental measures and restoration of interventions in areas such as the riparian zone along rivers. Sowing with grass seed can be a suitable measure along rivers if sowed with low density and in combination with other methods. Grass quickly bind the top soil in steep areas, wind prone areas, and areas affected by moderate erosion from running water. At the time when the environmental measures was conducted along the Tana River, seed mixtures of native seeds from the area was still not available, hence sowing was not one of the methods used.

However, Norway has recently initiated development of seed mixtures of native grass species naturally belonging in various ecosystems. 'Fjellfrø' is a project managed by Bioforsk (Norwegian research institute), in cooperation with sector authorities, that aims at developing mixtures of native seed that can be commercially distributed to managers working with ecological restoration. This is achieved by collecting seeds of native ecotypes /provenances of at least 10 species (mainly grasses, but also herbs), and to develop methods for cost effective seed propagation of these species. Seed breeding and development work takes place partly by members of seed breeding teams.

Grass species that are developed in these specific seed mixtures can currently be used mainly in southern Norway because this is where the genetic material originate from. It is possible to buy *Poa alpine* originated from Saltfjellet, a mountain located south in northern Norway. In addition, Klett is available, which is a conventional seed variety of *Festuca rubra* originating from Misvær in northern Norway . This is two of the commercially produced seeds that can be used in environmental measures located in northern Norway, and along the Tana River. More emphasis should be put on propagating seeds of species adapted to the natural conditions in the subarctic areas. In Alta, a local project regarding propagation of grass seeds from natural populations has been developed. Seeds of *Deschampsia cespitosa*, *Festuca ovina* and *Festuca rubra* from this project is commercially available for use in nature areas in Norway. However, a ready-made mixture of these varieties are still not available and hence requires expertise from a biologist to put together a suitable mixture.

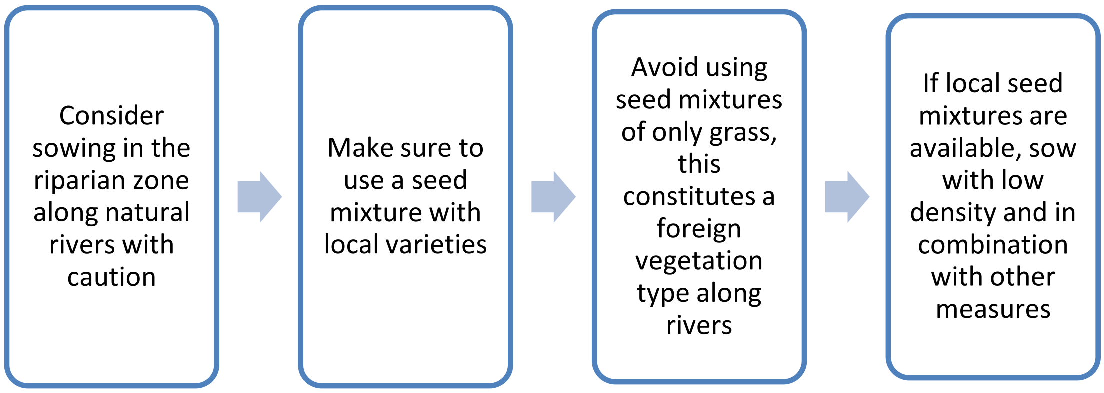
The problem with conventional mixtures of grass seed is that they contain varieties and species not associated with natural ecosystems. They can displace native species, or contribute to genetic contamination of natural varieties. Further they create an impression of a monoculture of bright green grassy lawn on land originally characterized by a mosaic of multi-layered grass, herbs, bushes and trees.

**Figure 8.1 Meadow species are dominating the composition of the vegetation at Valjok. This example illustrate how grass species can dominate the plant community in the riparian zone if sowed with no considerations for the local vegetation. Pictures below illustrate a natural mosaic of vegetation with great diversity in both species and layers of grass, herbs, and bushes. Photo: Gunnar Kristiansen, NVE**

An appropriate seed mixture that could be used in the local conditions in the riparian zone of the Tana River could consist of natural occurring Festuca ovina (sheep's fescue), Deschampsia cespitosa (silver stack), Festuca rubra (red fescue) and Poa alpine (alpine meadow). Sheep's fescue and silver stack grows in turfs, and does not give an impression of bright green grass lawn. Alpine meadow and silver stack has strong root system that can effectively bind the soil and reduce erosion from water and wind. Research from erosion controls along Karasjohka show that species such as *Solidago virgaurea* (gullris, mesiangervo), *Epilobium angustifolium* (geitrams, maitohorsma), *Achillea millefolium* (ryllikk, siankärsämö) and partly *Trifolium repens* (kvitkløver, valkoapila), *Elymus caninus* (hundekveke, koiranvehnä) and *Astragalus alpinus* (setermjelt, tunturikurjenherne) are caracterspecies that occurs frequently when vegetation establish and succession occurs naturally after some years. These species seem to tolerate the altered conditions on the erosion controls. If possible some of these species could be included when developing seed mixtures in the future.

A seed mixture consisting of native seed from local areas displaces the natural vegetation to a lesser extent, providing good conditions for native vegetation to re-establish compared to the commercial grass seed mixtures available at the market. To develop and propagate seed mixtures of native vegetation is costly but the cost may be acceptable in projects intended to restore visible and unsightly encroachments along rivers. And in a longer perspective the costs are limited compared to the benefits of restoring important vegetation.

## Key Points



# 9 Transplanting and moving mats and turfs of vegetation

Transplantation of mats and turfs of native vegetation was conducted as a method to re-establish the vegetation on many of the erosion control constructions along the Tana River where plant growth was scarce. Existing plants in the close proximity was moved with an excavator with the attached root system and replanted on the erosion control construction. The method can take many forms but are usually distinguished by the amount of plants and size of transplanted areas. Experiences from the environmental measures made along the Tana River show that this method have been particularly successful to re-establish vegetation, especially in combination with planting stem cuttings of different Salix-species. It is possible to transplant mats and turfs of vegetation from nearby areas without harming the existing vegetation. The areas left open when vegetation is removed need to be of limited size so the intervention is gentle on the surrounding vegetation and give good grounds for the plants to breed in to the uncovered area. Small continuous mats of vegetation is easily digged up with excavator. Equipment like rotor shovel is particularly suitable. The zone or area removed should be approximately 50-100 cm in diameter to reduce the impact on the surrounding areas. Preliminary mapping of the vegetation on the donor area is important to avoid harming threatened or vulnerable species. Make sure to get permission to use the area from the landowner.

**Figure 9.1 Excavator moving large and smaller vegetation mats with soil and growth substrate, completely covering the slope. Photo: Gunnar Kristiansen, NVE**

At Iskuras along the Tana River, environmental measures were conducted on an erosion control construction over a stretch of 400 m. Vegetation had established poorly at the site with only a few clusters of willow. Quite large vegetation mats composed of different herbs and Salix-species were removed from areas above the embankment and down to the areas below the flood line. Above these levels and to the top of the embankment growth substrate, bushes and stems were added.
The vegetation mats established well and has formed a good cover of vegetation see fig. 9.2 below.
It is established a dense bush layer of tall grown willows with a height up to 4 meters. The bottom layer has 100% coverage of different grass and herb species. Dominant species are *Achillea millefolium* (ryllik siankärsämö), *Solidago virgaurea* (gullris, mesiangervo), *Calamagrostis phragmitoides* (skogrørkvein), *Elymus caninus*

(hundekveke, koiranvehnä), *Veronika longifolia* (storveronika), *Rhinanthus* (engkall), *Oxyria digyna*, (fjellsyre) and *Festuca ovina* (sauesvingel) . A good cover of mosses has also developed.

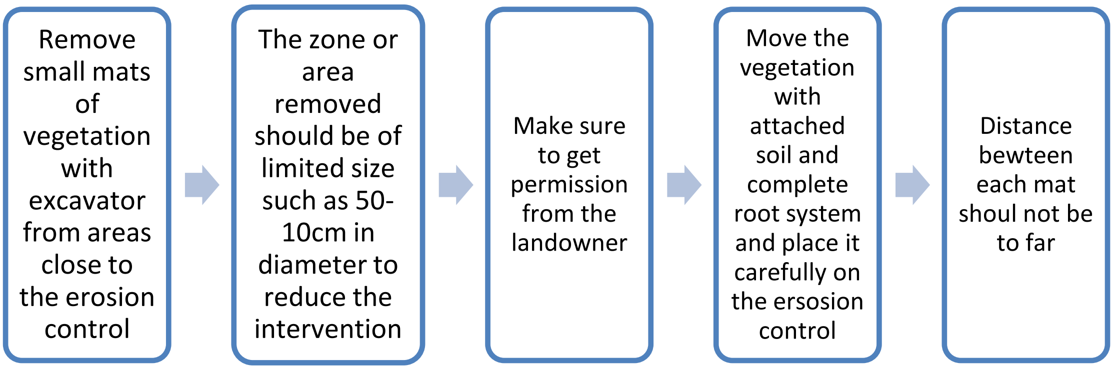
**Figure 9.2 Iskuras. Before environmental measures almost completely sterile erosion control construction. Successfully re-established vegetation by transplanting vegetation mats and trees. Photo: Gunnar Kristiansen, NVE**

At Jeambelsnjarg the same technique was used, the mats were however more loosely placed on the erosion control construction with more space between each mat. Emphasis was put on transplanting trees and bushes particularly. The site was initially covered with fairly coarse stone material and only some turfs of grass and herbs managed to grow here. The stone material used for this erosion control construction was in addition not adjusted to the riparian zone of the Tana River. The blue/black stone creates a sharp contrast and stands out as artificial in the landscape see fig. 9.4. The measures made at this site was very successful and after a short amount of time a good cover of vegetation was established. A dense shrub layer of willow with a height from 0.5 to 2 meters have established. The bottom vegetation layer have developed well with 70-80 percent coverage. There is a great diversity of mosses, herbs and grass on the slope. The most common species found are *Equisetum arvense* (åkersnelle), *Astragalus alpinus* (setermjelt) *Chamerion angustifolium* (geitrams), *Rubus arcticus* (åkerbær), *Solidago virgaurea* (*gullris)* , *Elymus caninus* (hundekveke*)* and *Deschampsia cespitosa* (*sølvbunke)*. Less frequent species that even occur are *Veronica longifolia* (storveronika), *Ranunculus acris* (engsoleie), *Campanula rotundifolia* (blåklokke ), *Molinia caerulea* (blåtopp), *Rhinanthus* (engkall), *Calamagrôstis purpûrea* (skogrørkvein), *Poa pratensis* (engrapp), *Agrostis capillaris* (engkvein) and *Hieracium*. (svever sp) Some small mats and turfs with heather, blueberries and lingonberries has started to grow. An even layer of mosses has also established. See fig.9.4.

**Figure 9.3 The erosion control construction at Jeabmelsnjarg before environmental measure. Moved soil and clusters of vegetation first year after the flood. Four years after measures where made show that a dense cover of vegetation has established. Photo: Gunnar Kristiansen, NVE**

**Figure 9.4 Moved turfs of sea shore vegetation in the transition between the outlet of Storelva and the tidal zone. The turfs was temporarily stored at the plant for approximately two years, the pictures show the site only weeks after they were placed out in 2013. Photo: Statens Vegvesen/v Elisabet Kongsbakk**

## Key Points


Remove small mats of vegetation with excavator from areas close to the erosion control
The zone or area removed should be of limited size such as 50-10cm in diameter to reduce the intervention
Make sure to get permission from the landowner
Move the vegetation with attached soil and complete root system and place it carefully on the ersosion control
Distance bewteen each mat shoul not be to far

# 10 Tree-planting and transplantation

Because of flooding, erosion and sedimentation, we rarely find old, “mature” plant communities close to rivers. Tall trees along the riparian zone of Tana is not widespread in general, and natural establishment of trees on coarse erosion control constructions will likely take a long time. Small trees composing a bush layer is however, common and widespread. The functions of the bush layer in the riparian zone is substantial. The extensive root system binds the soil and stabilize the substrate. Leafs of the bushes intercepts precipitation and thus reduce erosion from runoff. Litter fall provide nutrients and organic matter to the ground and the river. Trees and bushes shade the ground and modify the temperatures, and provide shield for both animals and fish.

Bushes and smaller trees can be moved and transplanted to the erosion control constructions. They will most likely survive and thrive if there is sufficient growth substrate, water and nutrients available. Species of willow like *Salix phylicifolia* (grønnvier, kiiltopaju), *Salix myrsinifolia* (svartvier, mustuvapaju) and *Alnus incana* (gråor, harmaaleppä) have a higher tolerance for submersion and are often found in the riparian zone along rivers. These species are suitable to be planted when conducting environmental measures on erosion control constructions. Small trees of these species do not need a complete root system to survive after being moved either.

**Figure 10.1 Clusters of trees and bushes mooved and planted on erosion control construction at Mollisjok along Karasjohka. Photo: Gunnar Pedersen, NVE**

**Figure 10.2 Example of transplanted turfs of vegetation and birch trees on a spoil heap covered with moraine in alpine areas in south in Norway. Photo: Arne Hamarsland, NVE**

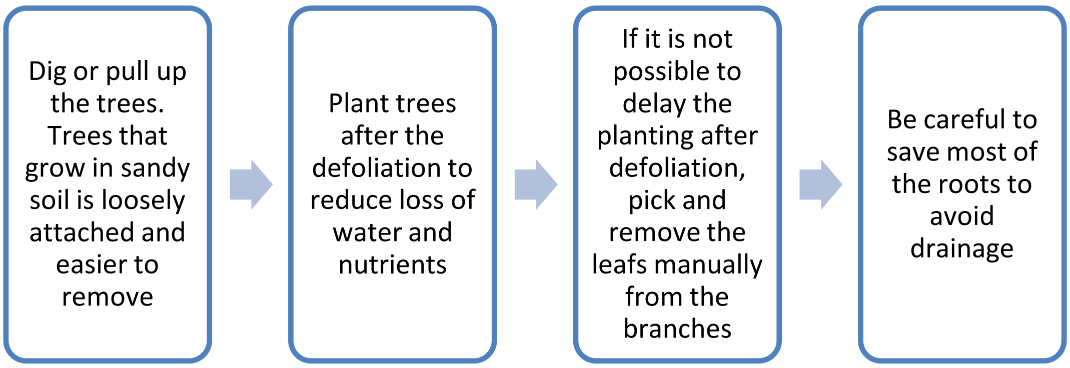
The most successful method used in Tana is transplanting small trees taken in close proximity to the erosion control. Trees from plant nurseries are in most cases too fragile to withstand the harsh environmental conditions on the erosion controls, and add unnecessary costs to the projects. Transplanting trees from nearby areas gives the added benefit of getting trees with an already established root system.

It is possible to pull up the trees quite easy by hand in areas with sandy soil where the roots are loosely attached to the soil. This reduces the harm to the root system and is less labor intensive. It is also possible to dig up the trees and use the soil surrounding the roots, plant the trees with the attached soil and root system, and hence enhance the growth conditions.

**Figure 10.3 Environmental measures conducted in Vigda, Skaun involving among other methods, tree planting and transplantation. The picture to the right shows the result of the measures after only one growth season. Photo: Mads Johnsen, NVE**

Planting of trees should be done early in the spring or in the late autumn. Summer is often hotter and dryer making the conditions harder for the trees. It is important to do the work after the defoliation to avoid drainage. If the work is carried out earlier in the season one option is to manually remove the leafs from the tree. In some places, especially places nearby settlements, adult trees of *Betula pubescens* (bjørk, koivu), *Sorbus aucuparia* (rogn, pihlaja) and *Salix caprea* (selje, raita) can be moved and transplanted to the erosion control constructions.

## Key Points



# 11 Planting cuttings

To increase the speed of succession on erosion control constructions, planting willow cuttings as part of the total environmental measure has proven to be very successful along the Tana River. Planting cuttings from a plant or a tree is a technique of vegetative propagation, and is done by cutting off a stem or a single leaf of the plant or tree, and place the cutting in water or appropriate soil. The cutting will develop a new root system and are able to grow and survive independently of the parent plant. One of the benefits of vegetative propagation is that the plant or tree gets the same genetic material as the original plant. Hence, this is also a good method for establishing native vegetation if the cuttings are taken from local trees. Different species of willow is beneficial to plant because of the extensive root system and corresponding soil-binding ability that stabilize the substrate, create good conditions for plant growth, and prevents erosion. Willow species has in addition a particular ability to develop shoots from the trunk of the tree. The parent tree do not in this sense take significant harm from this method. New shoots will grow out of the trunk and develop into new branches or stems (Hagen 1994). The most common method is to take the cuttings and propagate the root system in greenhouses prior to planting the cuttings out in the nature, in gardens or in pots. At many of the sites along the Tana River stem cuttings were taken from young trees and bushes close to the site. The cuttings was then piled in buckets and planted directly, without propagation in greenhouses, see figure 11.1.This has proven to be successful and the survival and growth rate of the plants are good. Approximately 90% of the cuttings had survived and rooted well in the new habitat one year after they were planted.

The stem cuttings should be planted in growth substrate with low amount of nutrients. The cuttings will form roots and these will start searching for nutrients and water, expanding into a more extensive root system. *Salix phylicifolia* (grønnvier, kiiltopaju), *Salix myrsinifolia* (svartvier, mustuvapaju) are both willow species that can thrive in conditions like these and reproduces easily by cuttings.

The stem cuttings should be taken from trees close to the site. They should be 20-40 cm in length and 1-3 cm in diameter. When put in the ground 1/3 of the cuttings should be above ground, giving the cutting good anchorage. The best results from planting stem cuttings on erosion control construction was achieved when the cuttings was covered with 2/3 sand/soil after being planted and added together with bushes and mats in great scale, which have been done on the four sites; Iskuras, Holganjarg, Jeambelisnjarg and Valljok.

A functional bush layer of willows in the riparian zone have successfully established on all erosion control constructions along the Tana River where this method has been applied. Planting stem cuttings reduces the time and labor needed compared to the more labor intensive tree planting. When partly cover of willow bushes are re-established, these will promote the development of vegetation as they add organic material to the ground and at the same time function as sediment traps so mineral and nutrition is deposited.

**Figure 11.1 Planting cuttings directly after preparation. The cuttings are being propagated naturally in the ground and new branches are sprouting resulting in small bushes of willow, and in time forms a bush layer on the riverbank. Photo: Gunnar Kristiansen, NVE**

Cuttings of Salix grow well in sandy mineral substrate like illustrated in figure 11.1.The cuttings can also be planted in coarse stony substrate if there is some finer substrate in between the stones for the cuttings to attach to. If the cuttings are not washed away by the first flood; they grow well in the coarse material. See figure 11.2.
Make sure to plant the cuttings the right way. Planting the cuttings the wrong way is not necessarily detrimental but may produce a poorer result. Cutting the branches diagonally in the end that is supposed to go in the ground can make it easier to recognize the right way. If it is uncertain which way is up and which is down, looking at the nodes on the branches is usually a clue, they face upwards.

**Figure 11.2 Stem cuttings of willow grown into a viable tree in the coarse substrate creating a functional bush layer in the riparian zone Photo: Gunnar Kristiansen, NVE**

In Finland some techniques with willow material have been applied on bare soil as erosion control itself. Three locations on the Finnish side of the Tana River

(Polvarinniemi, Reisti and Pajuniemi) were landscaped with soil, willow cuttings and trees in 2004. 10-20 cm moraine layer was brought to the sites as substrate, but it was washed away the first spring in Pajuniemi, and the plant material generally did not root well. Failure was likely caused by erosion and drying. Some surviving willow cuttings have been reported.
On Finnish side of the Tana River willow cuttings were prepared during February-March, and stored in cold until the spring. In spring the soil is moist, but the cuttings can also be kept in water for 1-3 days before planting, which would help their revival. The upper tip remaining on surface should not be soaked.
The slips were planted in rows with 1 meter between each cutting. After three weeks the revival success was checked and the rows supplemented with more cuttings if needed. After three years, the remaining willows can be cut short again in winter to increase shoot growth.

Planting cuttings on erosion control construction can be a good method to re-establish a bush layer in the riparian zone. Along most natural rivers there is good access to trees and bushes of different species in the surroundings to harvest cuttings from. There are many different techniques, and it is possible to experiment with theses to develop the best appropriate method for each site. Below follows a brief compilation of methods tried in the attempt to re-establish vegetation and reduce erosion on different sites in Finland.

**Willow mat**

Willow material can also be used as a mat-like structure that is laid as a cover on the shore. It cannot resist draught before it’s rooted so one end needs to be placed under water or buried into the soil. It has been experimented in Lake Porttipahta reservoir in Lapland, among other places in Finland (Riihimäki 2001). If successful the structure itself somewhat holds back erosion and later grows and roots into the soil. Depending on the location 10-80 % of the mat’s area sprouted. The best results in the long run came from sheltered shores. The mat also enhances the growth of herbaceous plants from under it by stabilizing the substrate and retaining moisture.

- Willows of 1-3 cm in diameter is cut and cleaned from branches while the plant is dormant.
- Willow is woven tight together by using strong string or wire.
- One mat in Riihimäki (2001) was 120x240 cm in size and weighed 10-15 kg.
- Mats are stored in a dark, cool, and dry place.
- Mats are laid usually on the lower shore, even partly below the average water level. The lower end is planted at least 20 cm, or as deep as necessary for continuous moisture. The mat need to be anchored by poles or sticks. It may also be covered by soil and stones.

Willow mat requires fairly deep soil for proper attachment and moisture, hence it is not likely to be successful on erosion control.

**Willow stems**

An alternative for willow mat is to cover the shore with loose willow stems that are anchored by smaller poles installed on top. It can also be tied together and attached to the poles with iron wire. This is a faster method for similar effect as from willow mat. However, the stems is even more prone to drought and easily washed away by flood and ice. To prevent it from drying the stems may also be covered by soil and watered in summer. By these means some positive results have come from experiments on bare soil in Kyrönjoki River and Päntäneenjoki River in Southern Finland (Huhtala et al. 2003, Savea-Nukala 2003).

**Willow bundles**

Willows can also be planted in large bundles. The method described by Savea-Nukala (2003) living willows of 1-2 m are cut saving the uppermost branches and tied together in bundles. Wooden support poles were placed in the middle.  The bundles were planted in line to create a wall against erosion. Rootless willows are sensitive to draught and they need to be dug deep –so that only the upper branches is visible. Deep planting also stabilizes them. Bundles can be used even below the average water level (Järvelä 1998). The method worked well in Kyröjoki River (Savea-Nukala 2003), where it was used together with willow cutting. If the willows survive the bundles forms dense bushes fast. However, it is difficult to bring and retain adequately deep soil in on the Tana erosion control constructions. The bundles have also proven to be easily detached by ice.

## Key points

- Delay the planting of the cuttings until the willows are dormant
- Ideal cuttings are approx. 30 cm long and 2-3 cm in diameter
- Plant the cuttings by sticking them into the soil and pry it to the substrate
- Do not plant the cuttings upside-down. They will probably sprout but why make life difficult for the plant!
- Be creative, experiment to find the best method for each specific site

# 12 Biodegradable geo-textile

Biodegradable geo-textile is a mesh of various natural materials that primarily is used to stabilize eroding river banks, as an alternative to erosion control constructed of rocks. The geo textile is providing a direct stabilizing bank protection by dissipating the force of heavy rains, floods and run off water. It improves the growth conditions for riparian vegetation by providing more stable conditions for vegetation, which further protect the river bank from extensive erosion. Geo-textiles made of coconut coir fiber are well suited to support and increase the growth of new vegetation by absorbing and storing water and preventing the topsoil from drying out, creating a good micro-climate for seed germination. It is naturally resistant to rot and molds and is highly durable.

Biodegradable geo-textiles made of coconut coir fiber was used at Hoassinjarga along the Tana River, mainly as an erosion measure to stabilize the bank and promote plant growth. The geo-textile used need to be durable because it is likely to be the primary stabilizing medium for some time before being supplemented by vegetation growth.
The coir nets at this site was in some sections almost completely decomposed after approximately 15 years, in other sections partly decomposed and still visible but with estimated ninety to hundred percent vegetation cover.

The vegetation is composed of a good cover of *Rhinanthus minor* (småengkall pikkulaukku), *Astragalus alpinus* (setermjelt, tunturikurjenherne), *Festuca ovina* (lampaannata), some *Deschampsia caespitosa* (sølvbunke, nurmilauha), *Agrostis capillaris* (engkvein, nurmilauha), *Achillea millefolium* (ryllikk, siankärsämö), *Solidago virgaurea* (gullris, mesiangervo),some *salix nigricans* and *Salix phylicifolia* (black and green willow), and *Ericaceae* (heather) covering the mats.

In the lower section of the site the coir nets are almost completely decomposed while in the higher and steeper sections the mats are still visible but are about to disintegrate. Mechanical stress from ice drift has most likely been dominating at this site. In total, the use of coir nets have been successful, erosion have completely ceased, and there have been established almost complete plant cover.

**Figure12.1 Prepared slope at Hoassinjarga before installing the coir nets. The growth substrate consists of a mix of soil, organic material, silt and rocks. After a period of time vegetation is starting to establish. After 15 years the coir nets is partly and completely decomposed. The slope is stabilized and complete cover of vegetation has been established. Erosion of the slope has fully ceased. Photo: Gunnar Kristiansen, NVE**

The time needed for the decomposition of the geo-textiles depends on the material it is made of, and the location where it is used according to environmental factors such as topography, amount of precipitation, temperature, humidity etc. Geotextiles made of straw, jute, and/or wood materials, are generally used temporally, and last for about six to nine months. Semi-temporal erosion control mats usually last for about nine to twenty-four months. For a more permanent erosion control, coconut coir fiber mats or nets are preferable. These are supposed to last four to eight years depending on the local environmental conditions. The tensile strength and durability of the coir mats make it a useful material in areas prone to severe erosion caused by ice drift and the consequent mechanical stress on the river bank. Geotextiles are reasonable in prize and are applicable in areas were fast stabilization is needed.

In the context of Tana it is clear that the rate of decomposition of the coir nets is much slower than what is estimated and expected. The coir nets are in general expected to last four to six years, at the location Hoassinjarga the coir nets are still partly visible after 15 years. In this sense, a different material may be recommended if geotextiles will be used in other projects along the Tana river or in areas with similar environmental conditions.

The dry climate, latitude and low temperatures are factors causing the slow rate of degradation of the coir nets. However, the rate of natural succession and growth rate is also slow in subarctic areas like the Tana valley and requires a material suited for the environmental conditions at the site. 15 years on the other hand is probably more than necessary. Alternatives for materials may be geotextiles made of straw which are supposed to be less durable.

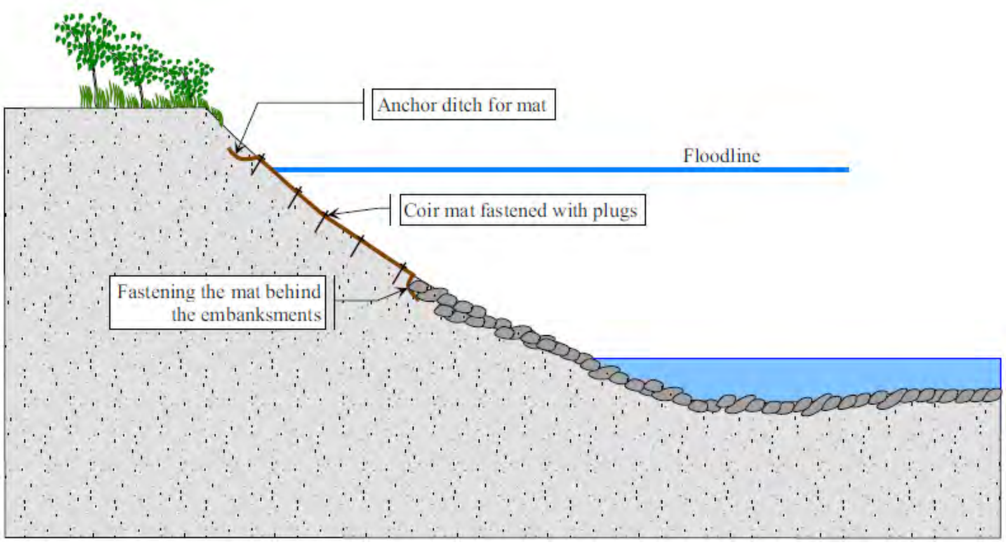
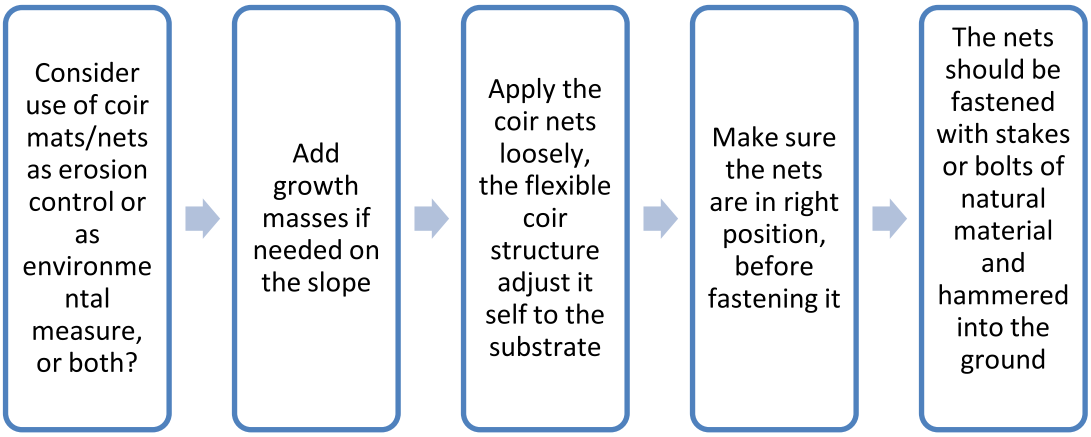



**Figure12.2 Schematic figure illustrating the use of coir mats on erosion prone slopes, and how to install the mats Illustration: Anders Bjordal, NVE**

**Figure 12.3 Erosion prone slope at Mollisjok along the tributary river Karasjohka, secured with geotextiles from further erosion of the slope. At this site soil and turfs of plants and bushes was moved over the slope immediately after applying the geotextile. Photo: Gunnar Pedersen, NVE**

Research show positive results on plant growth compared to not using geo textiles on erosion prone sites (See for example Bjørklund & Hagen 1998). An important factor determining the effect of the geotextiles is the materials ability to retain sufficient water without drying or being oversaturated with water, and this in turn is dependent on the site in question. Coir mats with tighter structure compared to coir nets have the benefit of retaining more water. On sites close to rivers where flooding is frequent, use of coir mats can result in too much water and lack of oxygen for the vegetation. On these sites nets is preferable because of the structure that allow oxygen to the plants and provide more space for the vegetation to grow through. On sites such as old erosion controls completely free of riparian vegetation, geo textiles can provide stable growing surfaces that help the invasion of surrounding riparian vegetation.

## Key points



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Norges vassdrags- og energidirektorat

Middelthunsgate 29
Postboks 5091 Majorstuen
0301 Oslo

Telefon: 09575
Internett: www.nve.no