The Lågen plan

Regional master plan for the Gudbrandsdalslågen and its tributaries

- *Measures to reduce damage from flooding and landslides*

Foreword

We are living in a time of climate change in which we must prepare ourselves for more frequent and more unpredictable extreme weather. The major floods in 2011 and 2013 were the driving factor behind our initiative to draw up a regional master plan for the Gudbrandsdalslågen and its tributaries.

Our work with the Lågen plan has been instructive, and has contributed to the acquisition of much new knowledge and constructive cooperation between social actors.

There have been high levels of engagement throughout the process. The purpose of the plan is to help improve safety for the community against damage from floods and landslides, while also safeguarding water-related, natural and outdoor assets. In such cases, it can be demanding to reconcile different views, but I am pleased that the plan has received high praise from many stakeholders.

The Lågen plan has already contributed to our inclusion in the Horizon 2020 PHUSICOS application together with 15 partners from seven different countries, in which the Gudbrandsdalslågen is one of three demonstration areas. This is an international project with a budget of NOK 100 million. It will facilitate opportunities for research and testing of new, nature-based solutions to prevent floods and landslides.

Now the work begins to implement the measures recommended. I look forward to constructive cooperation to achieve the greatest possible success.

Even Aleksander Hagen
Mayor of Oppland

Summary

This is a regional master plan pursuant to section 8-3 of the Norwegian Planning and Building Act (PBA), prepared by Oppland County in cooperation with several other actors. A regional master plan is not legally binding but has the following effect: The plan will be used as a basis for municipal planning, as well as for planning activities at the regional and national levels. The affected authorities may submit objections to new municipal plans that are not in line with the regional master plan. Adopted development plans will continue to apply.

While working on the plan, efforts have been made to find measures that could better protect life and health, infrastructure, residential areas and business areas. This applies not only to concrete measures, but also to plans and guidelines for how to prevent damage. It is not possible to avoid all damage caused by floods. This plan aims to ensure that our community is better equipped to cope with floods, by highlighting measures that should reduce and limit the damage.

This plan does not cover sediment removal desired for reasons other than flood control, but municipalities are encouraged, where appropriate, to draw up a municipal sub-plan / area plan for this type of measure.

The flood control effect of watercourse regulation is described in Chapter 6 of the *"Knowledge base"* document. Watercourse regulation has a flood control effect. During the major flood of 1995, the effect was calculated to be a reduction of the flood peak by 42 cm. Following this flood, a Commission on Flood Protection Measures was set up to investigate opportunities to reduce the vulnerability of society to floods, including by means of watercourse regulation. The commission proposed a number of measures that either have been implemented or were unfeasible due to conservation plans. It may be appropriate to study other measures, but the scope of the regional master plan does not include regulation reservoirs as flood control measures beyond what is described in the knowledge base. Regulation as flood control is related to attenuation in bogs, which the plan recommends to follow up through measures in the programme of action.

Uncontrolled landslides and uncontrolled water flows on the valley flanks

Damage records show that much of the damage is caused by incidents on hillsides and is associated with human intervention that increases and changes runoff, increases sediment transport and thereby increases the extent of damage. We must focus on ensuring that roads and interventions in the landscape do not lead to increased risk of erosion, and that the water will run off where nature itself has prepared the way. These areas are more stable than where people have altered the terrain. There is a lot to be gained here by looking at the construction and maintenance of roads, culverts, farmland and forestry.

During work on this plan, it has not been possible to make detailed plans for every measure that is needed on the valley flanks, because there are hundreds, if not thousands, of measures required. On the other hand, it is very important to increase the competence of different actors in terms of various climate adaptation measures. This applies to target groups such as municipalities,

contractors, landowners, Bane NOR, the Norwegian Public Roads Administration and the consulting industry.

In particular, the areas that require more expertise are:

- Planning, construction and maintenance of roads.
- Planning and implementation of measures in watercourses such that they both take consideration of river wildlife and reduce the damaging effects of floods.
- Forestry – planning and execution of felling, as well as transporting timber out of the area.

Therefore, in terms of competence-boosting initiatives, several courses and theme days have been initiated and completed – and there are plans for more. Thanks to good cooperation between the county, the Oppland County Governor and the Norwegian Mapping Authority, flood maps have been drawn up that may be useful in land planning and administrative work related to the Norwegian Planning and Building Act.

Sediment transport in tributaries

In the many tributaries that transport sediment to the Gudbrandsdalslågen, we can propose more specific measures. Sediment transport cannot be prevented, but it can be reduced by constructing permanent sediment removal sites. Sediment removal has been practised in many rivers and streams for many years, usually by creating depressions in longer stretches of the river, leading to the destruction of the natural riverbed and the reduction of good habitats for fish, plants and animals. This also causes the river bottom to become more unstable and vulnerable to new erosion and increased movement of stones and gravel. If it is possible to limit sediment removal to certain stretches of the river and ensure that it does not result in an increased risk of erosion, this could limit the destruction of important fish habitats. It will also provide better control over erosion, excavation of the river bottom and sediment transport. Impact assessments of a number of proposed measures show that such measures will have a positive effect, both locally and regionally. Based on this, there are now concrete proposals for measures in over 20 rivers and streams.

Complex issues in and along the Lågen

Along the Gudbrandsdalslågen itself, it is especially the agricultural sector that is negatively affected by high through-flow and flooding of farmland. The most vulnerable areas are located in Ringebu municipality. Here, the Lågen flows slowly, and many believe that the river bottom has risen in recent years due to deposits of large quantities of sand. This is likely to be largely the result of the volumes of soil and rock that were carried out into the Lågen by the many landslides and debris flows that took place in Veikledalen and other areas in 2011 and 2013. Whether this sand will remain there for a long time before it is carried on and out into the Losna Lake is dependent on the frequency and magnitude of floods in the future, and whether new landslides and floods result in large sediment deposits.

In recent years, Ringebu municipality has conducted surveys of sand banks in the Gudbrandsdalslågen to see how they change over time. It was clear visually that they increased in height and volume after the floods in 2011 and 2013, but the measurements show that they are now decreasing in height and that they are moving slowly but surely into the Losna Lake. Many have

proposed extensive sediment removal as a way to lower the Lågen in order to reduce the flood risk. However, the long-term effect of such removal is highly uncertain.

In order to calculate which areas are vulnerable to flood damage and to assess the effect that a number of measures in and along the main watercourse would have on the waterline, a decision was made to create a hydraulic model. The hydraulic model includes the Gudbrandsdalslågen from the water level marker at Rosten, north of Nord-Sel, to the outlet of the Mjøsa Lake. This represents a stretch of around 130 km. In addition, the model includes the outlets of the Gausa (around 4.2 km) and Otta rivers (around 4.5 km). The tool used for the hydraulic model is a HEC-RAS 1D model version 5.0.3.

Sediment removal

One of the aspects examined by the hydraulic model is the effect of sediment removal in the Gudbrandsdalslågen on the waterline in a flood situation. Generally, sediment removal will have little effect on the waterline if the sediments are extracted in wide, slow-flowing areas with a low gradient. Examples of this are the Lågen delta and the wide, slow-flowing stretches through Gudbrandsdalen.

Since sediment removal in the main watercourse would seem to have such a minor effect on flood levels, while at the same having major negative effects on the natural assets, such measures have only been recommended for the area around the village of Fåvang.

Flood embankments

The hydraulic model was also used to test what effect flood embankments would have on the waterline. It shows that flood embankments could have a positive effect as a safety measure on stretches of the river that are wide and slow-flowing. This is because the capacity of the river at these points is so great that raising the banks will not have a significant impact on flood levels.

It may therefore be appropriate to construct new flood embankments or raise existing flood embankments on certain stretches of the river. The flood embankments should then be placed as far away from the riverbank as possible, both to provide more room for the water and to safeguard the natural riverbank. Flood embankments must be designed to withstand overtopping without causing new erosion damage.

It is recommended to assess a possible flood embankment along the Gausa between the alluvial forest and the farmland to safeguard residential areas, the Jorekstad sports facility and farmland. Furthermore, raising the flood embankment at Kvitfjell will not adversely affect the waterline in flood situations, and can be worked on further to safeguard farmland.

The water level in the Losna Lake is crucial for the water lever over a long stretch

The results of the modelling show that, during major floods, the Losna Lake's water level is dimensioned based on how high the water level rises far up the Lågen. Sediment removal on the stretch from the Losna Lake and upwards towards Vålebru will therefore have little effect on the waterline on this stretch in flood situations. If we are to reduce the damage along the main

watercourse from the area south of Vålebru and down to Tretten, lowering the flood water level in the Losna Lake may be a long-term and effective solution.

Therefore, while working on the plan, three different solutions were considered to lower the flood water level in the Losna Lake: Lowering Trettenstryka, lowering combined with an adjustable weir, and a flood tunnel. These are very costly and controversial measures, but further study on the flood tunnel option is recommended, to get a better overview of the areas this measure would safeguard and to see whether it is possible to design a measure that would protect the area's natural assets to the greatest extent possible.

Cultivating farmland so that it is better able to withstand flooding

The hydraulic model shows that there are few measures along the main watercourse that could reduce flood risk. It is therefore important to focus on ensuring that the soil is cultivated and profiled in such a manner that it can withstand a flood. Much can be gained by careful selection of crop species, trenching, mixing in sand, etc.

When sourcing sand for mixing into farmland, it is recommended to investigate the possibility of using sediments from areas in the Lågen where sediment removal would have little negative effect on natural assets (and possibly also a small effect on the waterline).

Impact of different routes for the new E6 on flood water levels

Testing in the hydraulic model shows that if the E6 is placed on the bank of the river, it could increase the risk of flooding along several stretches due to the raised flood water level. None of the other measures tested in the model, such as sediment removal, will have an effect that balances out the negative effect that placing the road along the riverbank would produce.

Guidelines and technical advice

To reduce the risk of floods and landslides, there are a number of factors that must be taken into consideration in order to ensure success. Work on the plan included examining a number of potential measures for implementation, as well as considerations that can be taken in terms of land planning, agriculture, forestry, road construction and maintenance. Guidelines have been developed for municipal planning in accordance with the PBA. Furthermore, technical advice has been provided on agriculture, forestry, planning, construction and maintenance of roads and comprehensive water management. A decision was made to call this technical advice, as it cannot be linked to legislation in the same way as guidelines in accordance with the PBA, for example.

Need for changes in national framework conditions

Work on the plan has revealed the need for several changes to various national frameworks that can contribute to improving provisions for support and compensation schemes, as well as management practices. These proposals do not come from the different government agencies, but are proposals by the steering committee for the regional master plan regarding issues that require further work. They concern changes to the Norwegian Natural Perils Pool, proposals for changed support schemes for flood and landslide protection of farmland, proposals for differentiated compensation for damage along watercourses, changes to the Norwegian PEFC Forest Standard to better take into account considerations related to floods and landslides, and proposals for changed use of protective forests.

Monitoring and warnings

In accordance with NVE's comprehensive management model for landslide and flood damage prevention, additional needs for monitoring, warnings and emergency preparedness have been examined. There is a need for increased knowledge of sediment transport in the watercourses.

Contents

1. Introduction

Two major floods in 2011 and 2013 were the impetus for the work on the Lågen plan. The floods caused massive and costly damage. Following input from municipalities and regions in the area vulnerable to flooding, the county council decided that a regional master plan should be prepared pursuant to section 8-3 of the Norwegian Planning and Building Act (PBA). The purpose of the plan was to reduce the amount of damage caused by floods and landslides, while safeguarding natural assets.

The Norwegian Water Resources and Energy Directorate (NVE) has developed a comprehensive management model for landslide and flood damage prevention (Figure 1). This model includes mapping, land planning, protection, monitoring/warnings, crisis management and research/dissemination. Work on the regional master plan has been based on this model, but we have chosen to focus primarily on mapping, land planning and protection. Regarding crisis management, this is largely addressed in the County Governor's emergency response plan, municipal emergency response plans, comprehensive risk and vulnerability analyses conducted by the municipalities and the regional master plan for civil protection and preparedness. Monitoring/warnings and research are discussed but are not the main focus.

Figure 1. Comprehensive management model for landslide and flood damage prevention.

Therefore, this plan focuses on the following:

- Specific regional guidelines for planning, use and protection of areas vulnerable to landslides and floods, cf. the PBA. It is expected that the municipalities will follow these guidelines in their land planning.
- Technical advice for agriculture, forestry, roads and organisation with regard to the use and protection of areas vulnerable to landslides and floods. A decision was made to call this technical advice, as it cannot be linked to any legislation.

- Advice on how to achieve a binding cooperation between different actors, in order to implement measures to reduce the risk of flooding and landslides.
- An overview of where it may be appropriate to carry out sediment removal in the main watercourse and tributaries, given that it may have a flood control effect. The plan also provides an overview of the guidelines that should be included in zoning plans which should be prepared in the event of the establishment of permanent sediment removal sites and sediment basins. In addition, it includes details of what any operational agreements between the different stakeholders should contain.
- An overview of training initiatives that should be implemented to increase the level of competence within climate adaptation among a number of stakeholders.
- Need for changes in national framework conditions.
- A programme of action with specific, relevant measures that should be implemented to reduce the risk of flooding and landslides in Gudbrandsdalen.

There has been a great deal of focus on finding measures that can reduce the risk of flooding and landslides while safeguarding considerations related to natural assets. Municipalities, agencies, local organisations and associations have contributed actively in a broad collaborative process to provide input on a number of measures. All measures in and along the main watercourse have been tested in the hydraulic model. To demonstrate the effect of the various measures on the waterline, they have been described in relative detail in the plan document; this is also the case for measures that have been shown to have no effect on flood water levels.

However, the list of possible measures is not exhaustive. There will probably be questions about other relevant measures both during the lifespan of the plan and afterwards. The goal is that the results of this plan will largely contribute to assessing other measures based on general assessments of the impact of different measures.

The plan consists of four documents:

- The plan
- The programme of action
- The knowledge base
- Guidance and advice for planning and implementing measures to reduce damage from flooding and landslides

The actual **plan document** describes all proposed measures. Furthermore, it contains brief guidelines for planning in accordance with the PBA, and technical advice for agriculture, forestry and road management. The background to the guidelines and the technical advice is described in detail in the document *“Guidance and advice”*.

The programme of action contains an overview of all the different measures, who is responsible for initiating the projects, who should be co-responsible for the project and other stakeholders. Furthermore, it contains a prioritisation of the measures.

The **"*Knowledge base*"** document contains a comprehensive overview of all surveys and studies used as the basis for the plan.

The **"*Guidance and advice*"** document contains advice for planning and implementing measures to reduce damage from flooding and landslides. It describes roles and responsibilities, land planning, operation and maintenance of protection measures, advice for agricultural and forestry measures, organisational measures, supervision, and warnings and preparedness.

Oppland county is the planning authority and has prepared the plan in binding cooperation with several other actors in accordance with section 8-3 of the PBA. A regional master plan is not legally binding, but shall form the basis for municipal planning, and for planning and plan-related activities by regional and state authorities. The affected authorities may submit objections to new municipal plans that are not in line with the regional master plan. Adopted development plans will continue to apply.

In addition, a number of studies have been conducted that form the basis for the plan. Please refer to these for a more detailed description of the measures.

Bane NOR, the NVE and the Norwegian Public Roads Administration have joined forces to establish the inter-agency cooperation project NIFS (Natural hazards, Infrastructure, Floods and Landslides). The project has a broad reach and highlights challenges related to natural hazards, from the strategic to the operational. The project was completed in the period 2012–2015. Work on the regional master plan for the Gudbrandsdalslågen has been conducted in close contact with the NIFS project. Results from the NIFS project have provided useful input to the regional master plan, including in relation to guidelines and measures on the valley flanks. The NIFS project is being followed up further through the Natural Hazards Forum. The purpose of the Natural Hazards Forum is to improve coordination and interaction with regard to management of the risks associated with natural hazards, and to achieve:

- Better resource management
- Improved quality of services
- Greater awareness and understanding across areas of responsibility
- Better and easier access to information

Work on the regional master plan and pilot projects have been submitted to the Natural Hazards Forum. An assessment has also been made of the effect of watercourse regulation measures in Gudbrandsdalen on flood control, and possibilities for further flood control in the event of any new regulations of the watercourse. However, these are major projects that require major impact assessments and are therefore not discussed in more detail in this plan. An overview of potential alternatives is nevertheless included in the *"Knowledge base"* document.

2. Background for work on the plan

2.1 Background

The occurrence of flood situations involving numerous major incidents in recent years shows that the Gudbrandsdalslågen and the valley flanks are at considerable risk of flooding and landslides. Following a preliminary flood risk analysis conducted by the NVE, based on requirements set out in the EU Floods Directive, the Gudbrandsdalslågen has also been defined as carrying a significant flood risk with the potential to affect life and health, cultural heritage, the environment and the economy. The EU Floods Directive has not been implemented in Norway, but regardless of the status of the Directive, the Gudbrandsdalslågen and its tributaries will represent a significant flood risk.

The EU Floods Directive states that flood hazard / flood risk maps and a comprehensive flood risk management plan should be drawn up for areas at a significant risk of flooding. In addition to flooding, the plan should also focus on landslides.

Against this background, it was decided to draw up a comprehensive plan for the Gudbrandsdalslågen and its tributaries, and work began in autumn 2013. This is a regional master plan for which Oppland County is responsible, in a binding cooperation with several other actors, pursuant to section 8-3 of the PBA.

While working on the plan, efforts have been made to find measures that could better protect life and health, infrastructure, residential areas and business areas. This applies not only to concrete measures, but also to plans and guidelines for how to prevent damage.

Work on the plan was based on the Norwegian Directorate for Civil Protection's report "*Evaluation of the authorities' prevention work and management of the May 2013 flood*", the County Governor of Oppland's report following the spring flood of 2013, and the Regional master plan for civil protection and preparedness.

2.2 Main goal

Main goal:
To help improve safety for the community against damage from floods and landslides, while also preserving water-related, natural and outdoor assets.

This will be achieved through:

- Implementation of measures in the programme of action
- Guidelines and advice for use of areas vulnerable to landslides and floods
- A binding cooperation between various actors to implement measures to reduce the risk of flooding and landslides
- A comprehensive plan for where sediment removal in the main watercourse and in the tributaries could have a flood control effect. Further guidelines for where, when and how

sediment removal in the watercourses should be carried out. This will form the basis for municipal plans for sediment removal and the establishment and operation of permanent sediment removal sites and sediment basins

As a result of this plan, the following effects are expected:

- Comprehensive planning
- Increased competence and awareness
- Simpler and better administrative procedures for matters related to watercourses
- Improved cooperation between different actors across sectors and municipal boundaries
- Less damage due to flooding and landslides

2.3 National and regional guidelines

- Report to the Storting, white paper No. 42 (1996–1997) "*Measures against floods*"
- Report to the Storting, white paper No. 15 (2011–2012) "*Living with the risks – flooding and landslides*"
- Report to the Storting, white paper No. 26 (2006–2007) "*The Government's Environmental Policy and the State of the Environment in Norway*"
- Report to the Storting, white paper No. 21 (2011–2012) "*Norwegian climate policy*"
- National expectations
- Regional master plan for civil protection and preparedness
- Regional master plan for water management in the Glomma water region 2016–2021

A number of laws and regulations regulate responsibilities and measures of significance with regard to floods and landslides. These include the Norwegian Civil Protection Act, the PBA, the Norwegian Water Resources Act, the Norwegian Natural Damage Act and the Norwegian Regulations on Technical Requirements for Building Works.

The Lågen plan is coordinated with the Regional master plan for water management in the Glomma water region 2016–2021, so that the measures in the two plans are not in conflict, but complement each other.

2.4 Organisation of the work and public participation

In the steering committee:

- County Mayor
- County Governor
- County Executive
- County Emergency Response Manager
- Regional Manager, NVE
- Regional Roads Manager
- Rail Director, Bane NOR

- Mapping Director, The Norwegian Mapping Authority
- Regional council leader in Nord-Gudbrandsdal
- Regional council leader in Midt-Gudbrandsdal
- Regional council leader in the Lillehammer region
- Heidi Eriksen, Advisor in Oppland County, was the Project Coordinator and Steering Committee Secretary

A working group was established to work closely with the project coordinator in the preparation of the plan.

Members of the working group:

- Kristin Hasle Haslestad, NVE
- Tord Smestad, Oppland County Governor
- Jon Sylte, for the municipalities
- Steinar Myrabø / Per Wiréhn / Marianne Myhre, Bane NOR
- John-Ludvik Dalseg, for the municipalities
- Jon Halvor Midtmageli, Oppland County Council
- Heidi Eriksen, Oppland County Council

In addition, a project group was appointed to submit input to the executive committee during the planning work. The project group met 2–4 times each year.

Members of the project group:

- Kristin Hasle Haslestad, NVE
- Marianne Myhre, NVE and Bane NOR
- Ola Hegge, Oppland County Governor
- Tord Smestad, Oppland County Governor
- Odd Henning Stuen, Project Manager for the Mjøsa Water Area
- Heidi Eriksen, Oppland County Council
- Jon Halvor Midtmageli, Oppland County Council
- Jon Sylte, Lillehammer region
- John-Ludvik Dalseg, Midt-Gudbrandsdal region
- Ola Næprud, Nord-Gudbrandsdal region
- Anders Nybakken, Midt-Gudbrandsdal region
- Steinar Myrabø, Bane NOR / Per Wiréhn, Bane NOR
- Bjørn Hjelmstad, the Norwegian Public Roads Administration
- Eivind Bergseth, Oppland Farmers Union
- Astrid Olstad, Oppland Farmers and Smallholders Union
- Oddgeir Jørstad, Lågen Fishing River
- Ole Morten Fossli, Forum for Nature and Outdoor Recreation, Oppland division

Public participation

An open meeting was held at the start of the planning work. In addition, there was a meeting with the Oppland division of the Forum for Nature and Outdoor Recreation, as well as an information meeting for the Lågen fishing river and for the Nord-Gudbrandsdal, Midt-Gudbrandsdal and Lillehammer regions. There was also a lecture on the planning work at a national conference on ecological restoration and a national conference on the aquatic environment.

In connection with the public consultations on the plan, a consultation conference was held on 16 October 2017, at Rudi Farm in Sør-Fron municipality.

3. Description of the area and the problem

3.1 The plan's territorial and technical scope

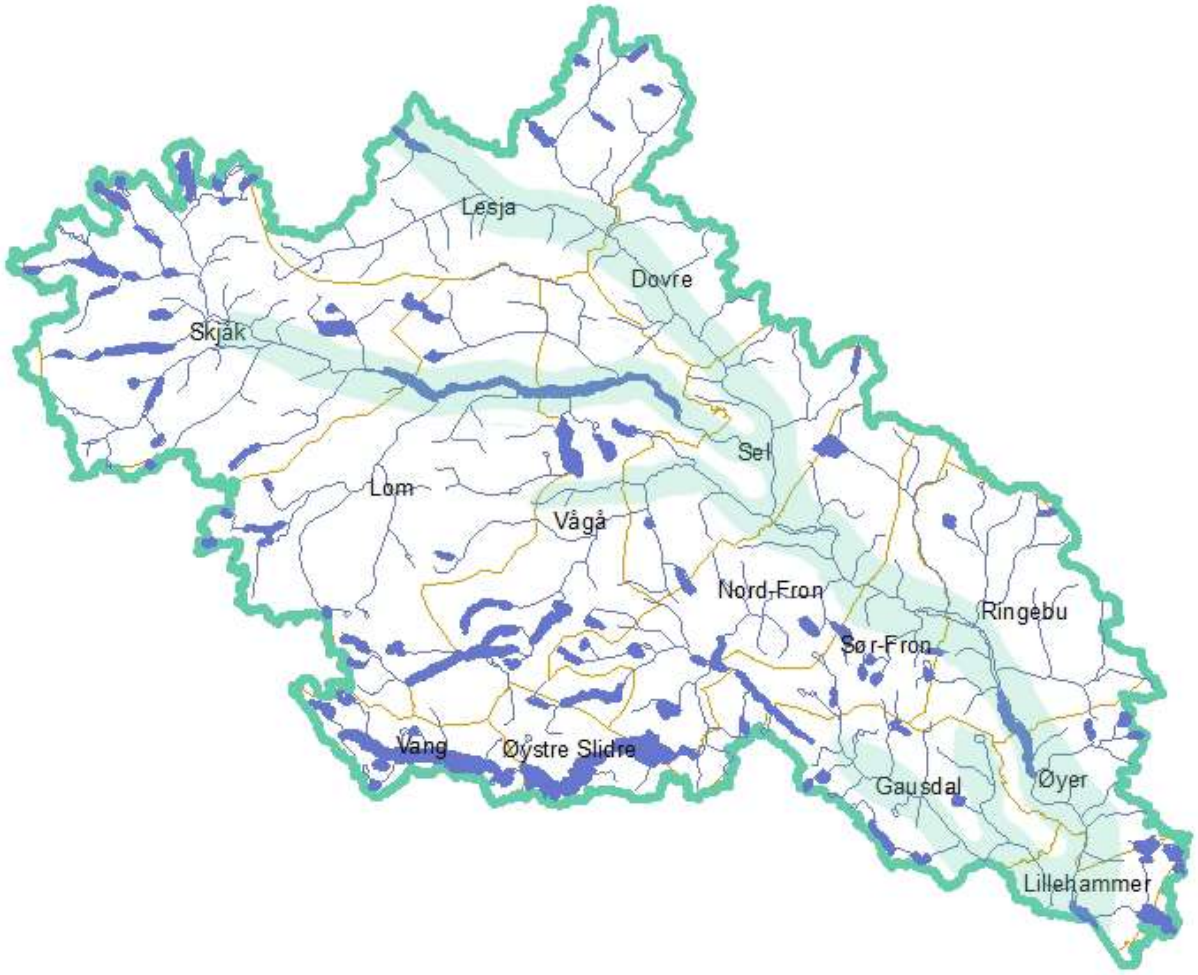

Figure 2. Map of the plan area, and the Gudbrandsdalslågen catchment area. Areas in light green indicate where measures have been considered.

The plan covers the Gudbrandsdalslågen and its tributaries from Lesjaskogsvatnet to Lillehammer (12,678 km²) (Figure 2). Tributaries in this context include everything from large tributaries such as the Otta, the Sjoa and the Gausa, to small streams and gorges that barely flow during normal through-flow, but which may become large rivers during periods of heavy precipitation. The work is concentrated on areas where studies and modelling have revealed a need for measures.

The Gudbrandsdalslågen flows through the municipalities of Lesja, Dovre, Sel, Nord-Fron, Sør-Fron, Ringebu, Øyer and Lillehammer, from Lesjaskogsvatnet (611 m.a.s.l.) to Mjøsa Lake (123.2–119.6 m.a.s.l.). From the west, it takes in tributaries from mountain areas, including Jotunheimen, and carries meltwater from many glaciers. This gives the river its distinctive green colour, and is also the reason for the relatively high through-flow throughout the summer. The most important tributaries

from the west are the Otta, the Sjoa, the Vinstra and the Gausa, and from the east the Jora, the Ula, the Frya, the Tromsa and the Mesna (close to the outlet of Mjøsa Lake).

At Sel, the Lågen flows through Selsvollene, an almost 10 km flat stretch where large agricultural areas have been recovered by measures including the construction of embankments along the Lågen and by measures in the tributary river Ula. The main river has few fall areas and few natural, large waterfalls – Harpefossen, Hunderfossen and Einsbyfallene all have a fall height of 7–15 m. On the border between Ringebu and Øyer, the river course widens to become the narrow Lake Losna. The Jevnefjord in Øyer is also a natural lake in the watercourse, while the power plants at Hunderfossen and Harpefoss have associated hydropower plant dams in the Gudbrandsdalslågen.

The catchment area covers more than half of Oppland County's land area. Several of the tributary watercourses are protected in the watercourse protection plan. This applies primarily to protection against hydropower development, but it also takes into account the protection of conservation assets from other interventions.

The Gudbrandsdalslågen usually has two flood peaks during spring and summer. Both floods are mainly due to the melting of snow. The first flood comes from the eastern and northern parts of the watercourse. It usually comes in the first week of June. Around the summer solstice, a new flood comes from the western parts of the watercourse through the Otta, the Vinstra and the Sjoa (among others), which is often called the Otta Flood.

The tributary watercourses in Gudbrandsdalen can cause flooding and landslides several times a year, especially during spring and autumn. The spring floods are often due to a combination of the spring thaw and heavy precipitation, possibly combined with frozen ground. The autumn floods are caused by intense precipitation. In 2011, for example, there was a lot of precipitation and many events along the valley flanks in spring and autumn.

Work on the regional master plan is concentrated on the areas from the valley bottom, where the Gudbrandsdalslågen, the Otta, the Sjoa and the Gausa flow, and further in and along the major tributary watercourses and up the valley flanks to the edge of the mountains.

The plan therefore covers the following issues:

- Flooding of areas due to a high through-flow in the rivers causing the water to rise and flood over its banks
- Stormwater management on the valley flanks
- Landslides and debris flows as a result of heavy precipitation in a short period of time
- Landslides and erosion that lead to the transport of large quantities of sediments in the watercourses

3.2 Sediment transport in tributaries and the Gudbrandsdalslågen

Many of the flood and landslide problems in Gudbrandsdalen are caused by the transport of large quantities of sediments in streams and rivers. This can cause major problems locally by eroding land, and during major floods, farmland may be washed away in some places, while sediments may be deposited and cause problems elsewhere. To better understand what the largest sources of sediments in Gudbrandsdalen are, NVE has conducted a mapping project.

The report can be downloaded here: http://publikasjoner.nve.no/rapport/2016/rapport2016_89.pdf.

This mapping shows that much of the sediments come from the larger tributaries, and that the Lora, the Hjellåi, the Ilka, the Ula, the Sjoa, the Veikleåi, the Vinstra, the Frya, the Våla, the Sjoa and a number of tributaries to the Otta carry a lot of sediments. In the lower parts of Gudbrandsdalen, the Gausa carries large quantities of sediments. Stones, gravel and sand that are transported during major floods can cause flood problems not only in the various rivers, but also in the main watercourse, because they cause the river bottom to rise and the water may then find new routes.

However, in the main watercourse, these coarse sediments are deposited in natural lakes such as the Losna and the Jevnefjorden, and in the regulation dams established in connection with power plants (Figure 3). In the Gudbrandsdalslågen, this applies to the dams at Harpefoss and Hunderfossen. In addition, the new power plant in Rosten will stop the sediment from upstream in the future, thus affecting the sediment deposition in the Gudbrandsdalslågen at Selsvollene.

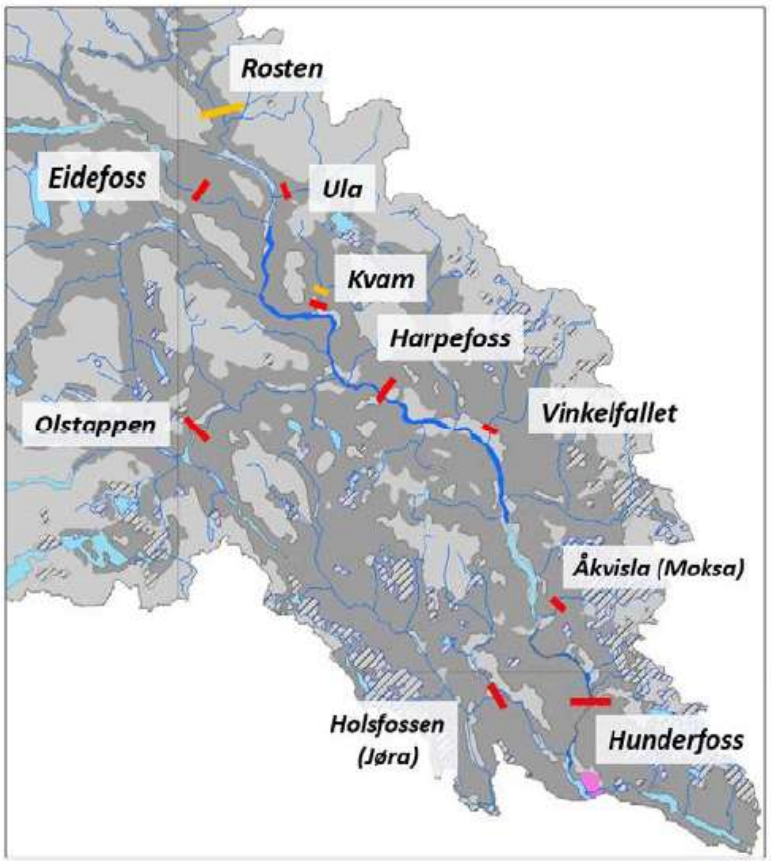

Figure 3. Dams in Gudbrandsdalen that stop the transport of course sediments.

In Ula, a dam has been built to capture the sediments. However, this dam was never emptied until 2016, and rock and gravel have previously flowed over the dam. The cleanout in 2016 will stop the sediments again for many years, and further after this, provided that the dam is cleaned out regularly. This will affect the deposition of sediments in Gudbrandsdalslågen from the outlet of the Ula and down to Harpefoss.

The Otta river has several large tributaries that carry vast amounts of sand, gravel and stone. This is especially true of the Tundre, the Åstri, the Skjøle, the Bøvra and the Visa, which all originate from glaciers. The sediments from these rivers can sometimes cause problems in the areas upstream of Vågåvatnet, but the sediments being transported downstream will largely be deposited here. The Finna is also a river that brings with it a lot of sediments, and these sediments will generally not go beyond the power plant dam at Eidefoss.

In the Veikleåa, a small sediment basin was built in 2014, and in 2017 a large sediment barrier was completed that will be able to capture around 98,000 m³ of sediments. This will affect the deposition of sediments in Gudbrandsdalslågen from Kvam and down to Harpefoss.

In the Våla, there is a hydropower dam that stops all sediment transport in the Lågen. This has an effect on sediment transport into the Lågen and down to Losna Lake.

When we look at all the rivers together, and the measures and interventions that are being implemented and that contribute to stopping sediment transport in the Gudbrandsdalslågen, intentionally or not, it is probably the Frya that is the tributary that carries the most sediments into the main watercourse.

The Gausa watercourse also carries large quantities of sediments. This applies to both the Jøra in Vestre Gausdal and the Vesleelva in Østre Gausdal. The sediments from the Jøra are deposited when they reach the Holsfossen power plant. The sediments from the Vesleelva are carried down the watercourse and past the dam at Follebu Farm, as this is currently full of gravel and stone. The Gausa is the river that carries the most sediments into the Lågen delta and Mjøsa Lake.

3.3 Population, settlements, industry and transport

Most of Gudbrandsdalen is a U-shaped valley, mainly formed by the ice during the last ice age. This has resulted in a landscape with relatively steep valley flanks and a flat bottom. The Gudbrandsdalslågen flows along the bottom of the valley, and it has changed course throughout the ages due to erosion and sediment deposits. There are still traces of meanders in some places in the valley.

In earlier times, the population of Gudbrandsdalen was spread over a wide area, with farms up on the hillsides. As the population increased, the flat river plains were also taken into use, and especially over the last century these have been intensively used for the cultivation of grass, grains and potatoes. The river has therefore more or less been forced into a fixed course.

In earlier times, the road network was higher up on the valley flanks, which can be seen by the location of the historic King's Road higher up in the valley. In the late 19th century, the railway came to Gudbrandsdalen, and was mainly located further down or on the river plain. As the community developed and new villages sprang up, these were located near the railway. The tributaries were important for the operation of mills, sawmills, etc., and villages were also established near these. The alluvial fans were taken into use, and today almost all the settlements in Gudbrandsdalen are on alluvial fans.

Since the river plain at the bottom of Gudbrandsdalen and the alluvial fans have been utilised so intensively, the entire community in the valley is highly vulnerable to flooding. Massive sediment transport from the tributaries leads to a risk of damage in the villages. Roads and the railway are vulnerable to flooding and landslides, and the large flatlands along the Lågen are prone to flooding.

3.4 Description of the problem

The Gudbrandsdalslågen and its tributaries have a long history of flooding, but in the past 10–20 years, many have started to believe that the challenges related to flooding and flood damage have changed. The Gudbrandsdalslågen has always flooded farmland from time to time, sometimes causing damage to settlements. Most of the towns that are vulnerable to slowly rising floods from the Gudbrandsdalslågen have gradually been protected by embankments. However, the potential damage from the flooding of farmland remains high in many municipalities. In recent years, floods in tributaries, which are experienced as rapidly rising water levels and uncontrolled water flows, have been a major challenge, with the potential for major damage to buildings, infrastructure and agricultural land.

Increased pressure from the development of town centres and construction areas on alluvial fans and along watercourses, infrastructure in and along watercourses, the construction of cabins on the hillsides, road construction and logging can affect both surface water runoff and the potential for flood damage.

In the past it was common for landowners to extract gravel from the tributary watercourses, and it was also a priority task to walk along the watercourses in spring and autumn to clear debris and prevent the risk of obstructions, flooding and erosion.

3.4.1 Overview of typical areas vulnerable to flooding and landslides in Gudbrandsdalen

In order to get a better understanding of the challenges that flooding and landslides present in Gudbrandsdalen, this section provides an overview of areas where challenges related to flooding and landslides can easily arise and shows what may be an underlying cause of damage. Problems often start high up in the hillsides and continue down through rivers and streams that transport sediments, and into the main watercourse (Figure 4).

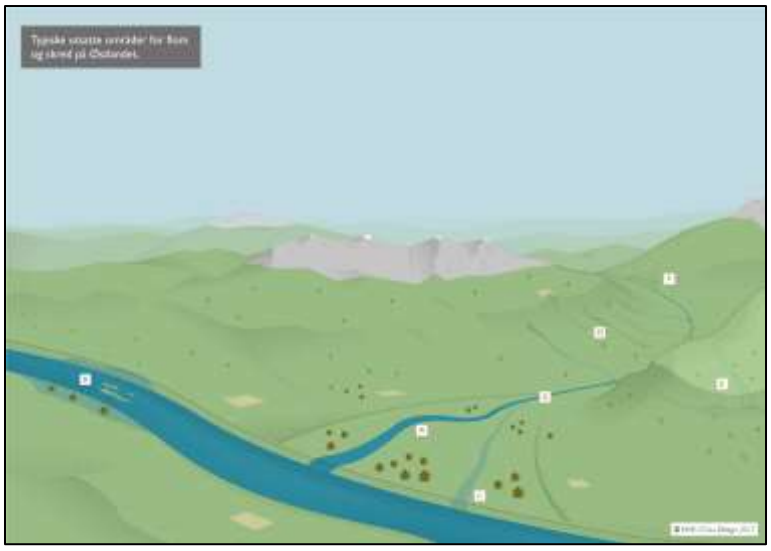

Figure 4. Typical areas vulnerable to flooding and landslides in Gudbrandsdalen

Outlets of streams and rivers are particularly prone to flooding and debris flows (Figure 5). Alluvial fans are composed of sediments transported by floods or debris flows over many years, and the sediments are deposited in a typical triangular-shaped fan. Following heavy rain and/or the spring thaw, debris flows may begin on the valley flanks, perhaps several kilometres away from the fan, but they move fast and deposit material on the alluvial fan. Settlements on the alluvial fans are at risk of flooding and damage caused by flood and materials from debris flows.

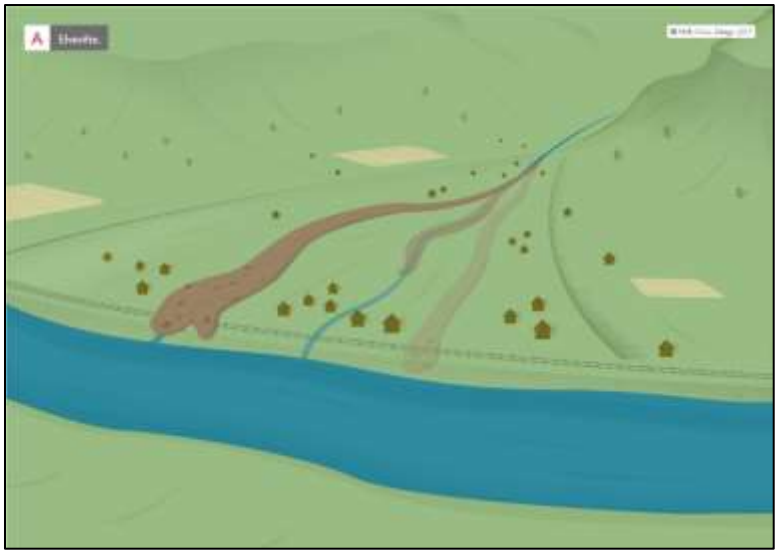

Figure 5. Alluvial fans often have major challenges associated with floods caused by heavy rainfall and the spring thaw.

Flat areas next to the rivers are at risk of being inundated when there is a flood (Figure 6). Settlements, roads, the railway and agricultural areas on the valley bottom along large waterways are often prone to flooding.

Figure 6. Infrastructure such as roads and railways as well as settlements on river plains are highly vulnerable to flooding.

Embankments constructed for roads and railways can lead to an increased risk of flooding and debris flows (Figure 7 and 8). This is because they often change or destroy the natural drainage routes. Areas alongside infrastructure, where surface water is channelised through culverts, are prone to flooding. Culverts may become clogged due to sediment build-up, or due to insufficient capacity or maintenance. Clogged culverts in road and rail embankments that prevent water from draining off can result in flooded areas behind the embankment during heavy rains or a heavy spring thaw.

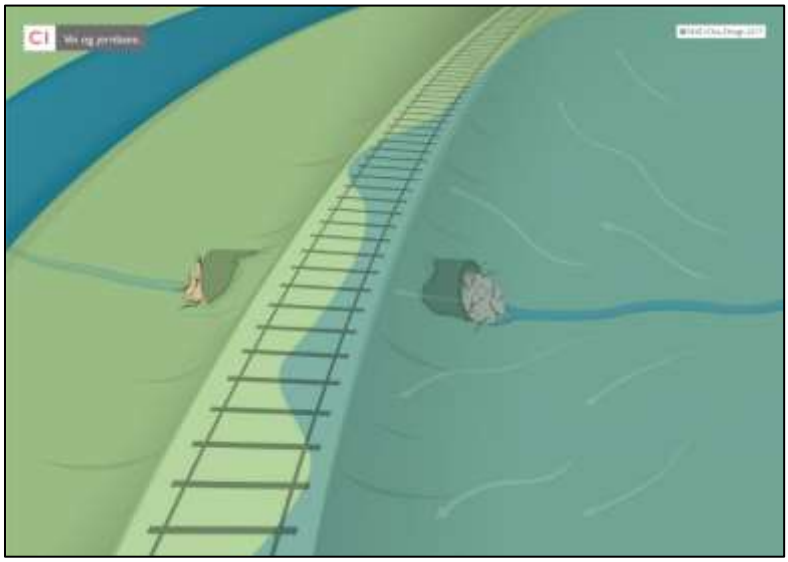

Figure 7. Clogged culverts in road and rail embankments that prevent water from draining off can result in flooded areas behind the embankment during heavy rains or a heavy spring thaw.

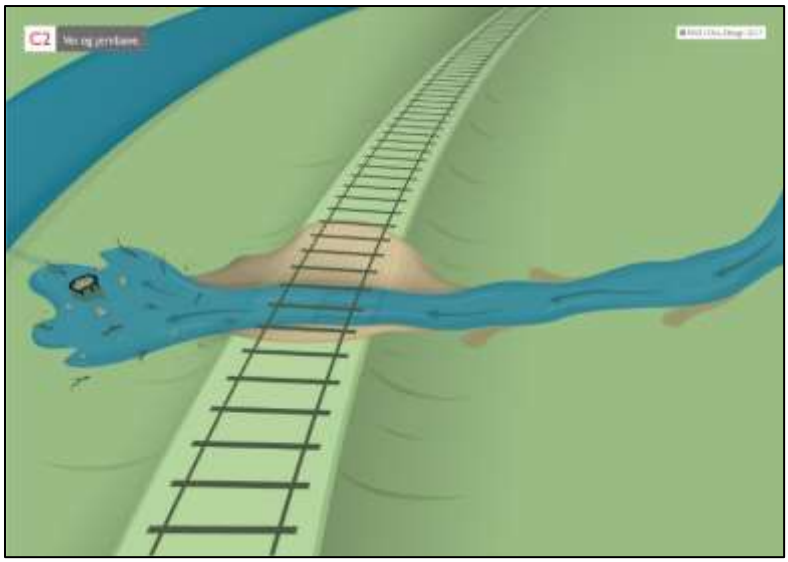

Figure 8. Clogged culverts may cause the water to find other routes and can lead to major damage to roads and railways due to erosion and undermining.

Human intervention on valley flanks can often lead to challenges related to flooding and landslides. Examples of such interventions include areas of felling, forest service roads, agriculture and cabin areas (Figure 9). Steep slopes are prone to landslides, debris flows and debris slides. Landslides and debris flows usually start where there are natural concave formations in the terrain. This is often in connection with depressions, existing channels and temporary streams. Human intervention on slopes can create new areas that collect water during heavy rains. Landslides can start in farmland and outlying pastures, along forest service roads or near cuttings for development areas with lack of protection measures and drainage routes. The melting of frozen ground and the spring thaw contribute to increasing the risk.

Figure 9. Steep valley flanks with human intervention such as areas of felling, forest service roads, agriculture and cabin areas.

Felling, cutting for forest service roads without flood protection and a lack of drainage can lead to increased runoff (Figure 10). Surface water can quickly erode slopes of morainic material, and a lack of drainage can cause water to flow freely down slopes, thus causing problems. Small debris slides are often formed on both sides of a forest service road. Some can turn into landslides and debris flows and continue several kilometres down the valley flanks.

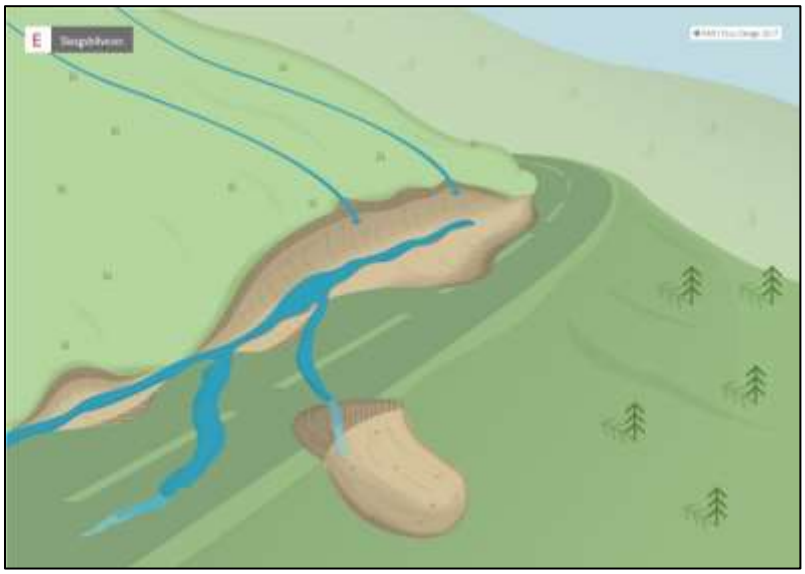

Figure 10. Forest service roads can cause problems with flooding and landslides.

During heavy rains and/or the spring thaw, the through-flow can increase rapidly in small streams and rivers (Figure 11). High through-flow can erode the steep river banks and cause debris slides. Debris slides can dam up rivers and streams, or mix with the through-flow and cause debris flows.

Figure 11. High through-flow can erode the steep river banks and cause debris slides.

If there are obstacles in the terrain or in the waterways, the water will find other routes (Figure 12). Human influence, such as forestry, agriculture and settlements/urbanisation can often change and

destroy the natural drainage routes. ATV trails, clearcutting, tractor roads, forest service roads and local roads without ditches or with poor drainage solutions, and areas around buildings can often end up as new, undesirable drainage routes.

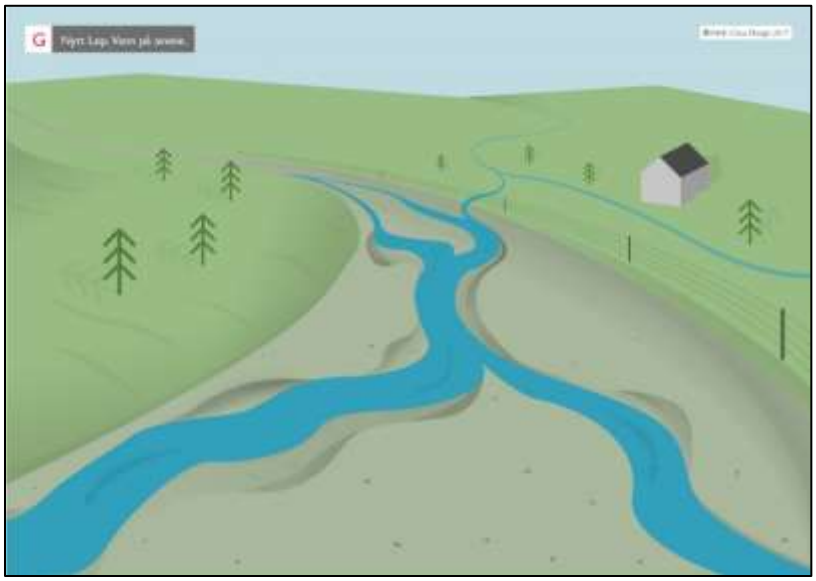

Figure 12. Human influence, such as forestry, agriculture and settlements/urbanisation can often change and destroy the natural drainage routes.

3.4.2 Climate change and comprehensive management

Climate changes, with an increased frequency of high-intensity local rainfall, are affecting the risk of flooding and landslides associated with the tributary watercourses. This is precipitation that is difficult to forecast and can hit anywhere in the valley. The soil on the hillsides of Gudbrandsdalen is vulnerable to water saturation and uncontrolled water flows, which increases the risk of landslides and debris flows in combination with flood events. The potential for damage is thus very great.
For the climate profile for Oppland, see:
https://klimaservicesenter.no/faces/desktop/article.xhtml?uri=klimaservicesenteret/klimaprofiler/klimaprofil-oppland

Registered damage over time and concrete measurements of rainfall show an increase, especially in short-term precipitation (Hanssen-Bauer et al. 2015). This implies a clear need to examine measures and to focus on the watercourse as a whole. Comprehensive management of the watercourses will be essential to prevent damage caused by flooding and landslides in the future.

3.5 Damage statistics

In order to form a basis and increase understanding of the need for measures and their location, it has been important while working on the plan to gain an overview of costs related to flooding and surface water. However, it is difficult to compile and analyse comprehensive statistics and total costs of flood events in detail. In the report "*Socio-economic costs of the 2013 flood in Gudbrandsdalen*"

(Siedler 2015), the total cost of the 2013 flood is estimated at over NOK 1.092 billion. The report does a good job of summarising the uncertainty surrounding the estimation of flood-related costs. Table 1 shows costs broken down by society sector. As many of the costs for each sector only reflect reconstruction, the overall socio-economic cost is expected to be significantly higher for flood events. This is highlighted by the figures for the railway sector, which also include costs that are not directly linked to reconstruction (see Table 1).

Table 1. Overview of social costs after the 2013 flood, by society sector. Based on "Socio-economic costs of the 2013 flood in Gudbrandsdalen" (Siedler 2015).

Description	Amount (NOK million, 2013 value)	Comments
Railway sector	>380.7	Reconstruction alone after the 2013 flood is estimated to have cost more than NOK 170 million
Road sector	>165.0	Reconstruction costs alone
Payments from insurance companies	410	
Municipal infrastructure	>136.7	Reconstruction costs alone
Total	>1,092.4	In addition to the above figures, NOK 93 million was paid out in 2013 from the Norwegian Natural Perils Pool in Oppland County. Most of that compensation can be directly linked to the flood event

In order to improve the data basis, work on localising and digitalising damage records from the Norwegian Natural Perils Pool was initiated during the work on the plan. So far, all the damage reported to the Norwegian Natural Perils Pool from Ringebu, Sør-Fron and Nord-Fron in 2011 and 2013 and from Gausdal in 2013 has been localised, digitalised and analysed. From the Midt-Gudbrandsdalen region, in 2011 there were a total of around 430 reported incidents of natural damage to the Norwegian Natural Perils Pool, with a total cost of almost NOK 50 million. The work of registering flood damage is expected to continue during the plan period.

The map in Figure 13 shows compensation paid out by the Norwegian Natural Perils Pool during the 2011 flood in the municipalities of Ringebu, Sør-Fron and Nord-Fron. The red dots show damage that is recorded as "flood damage", i.e. damage caused by flooding in the Gudbrandsdalslågen and larger tributaries. The blue dots show damage connected to landslides, sediment transport and uncontrolled water flows on the valley flanks of the Gudbrandsdalslågen and its tributary watercourses.

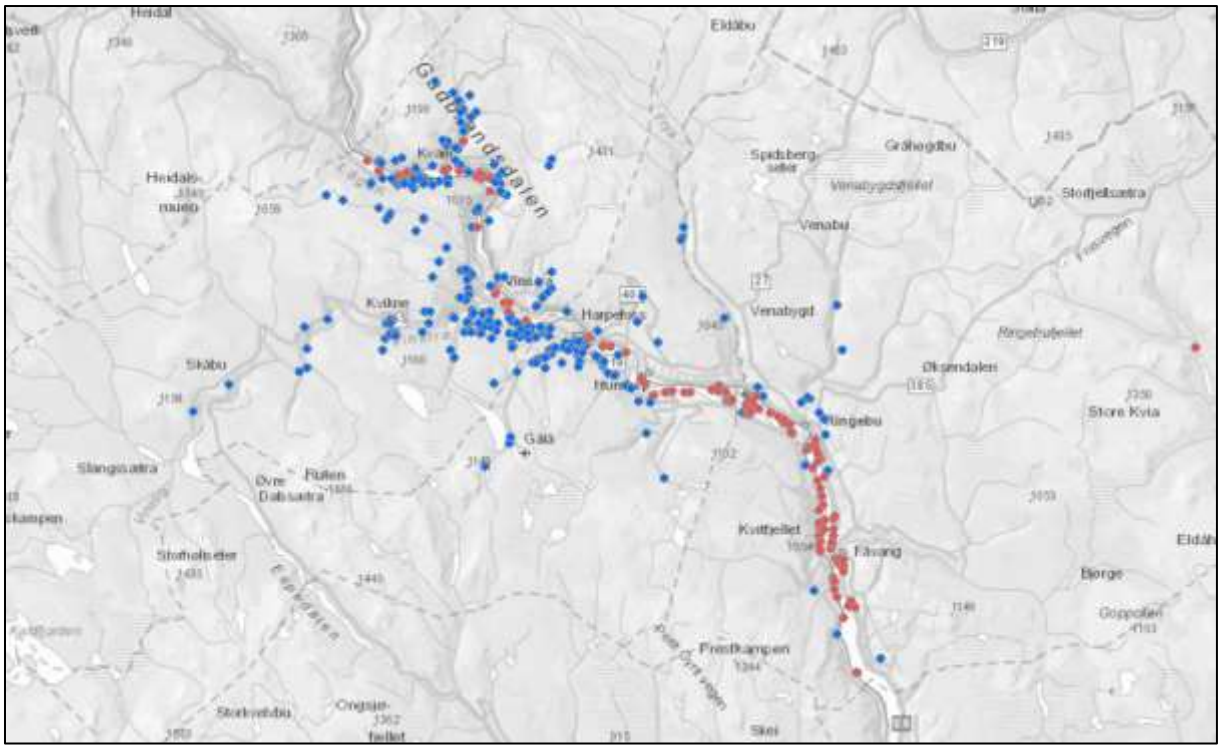

Figure 13. Damage registration from the Norwegian Natural Perils Pool in 2011 in the municipalities of Ringebu, Sør-Fron and Nord-Fron. Source: Norwegian Natural Perils Pool and Oppland County.

The data set with localised compensation from the Norwegian Natural Perils Pool contains a variety of variables such as event type, cause, estimated cost, and more. This makes it possible to sort and analyse the events in detail. For the three mentioned municipalities, for example, the distribution of the total costs will be around NOK 12 million, which can be connected to increased water levels in the Gudbrandsdalslågen and tributary watercourses, while the costs along the valley flanks are around NOK 38 million. Such data may reflect the type of flood, but also serve as the basis for decisions and priorities. Statistics from the data set can be seen in the "*Knowledge base*" document. Damage records will also be made available (with some restrictions) through InnlandsGIS.

Link to Siedler 2015: http://www.naturfare.no/_attachment/1088139/binary/1072583

4. Knowledge base

Existing knowledge and need for new knowledge

Work on the plan was based on existing knowledge in the fields of natural and social sciences. An overview can be found in the "*Knowledge base*" document. A review of the existing knowledge base revealed that there was a need for more knowledge on a number of topics related to the plan's objectives.

Fish

In order to get a better overview of the most important sites for the various species of fish in the Gudbrandsdalslågen, a decision was made to carry out a survey of important important areas for fish in Gudbrandsdalen. This was carried out by the Norwegian Institute for Nature Research (NINA).

- *Survey of important important areas for fish in Gudbrandsdalen, NINA Report 1173*

Damage records

In order to be able to say something about the extent of the damage and the underlying causes, all damage reported to the Norwegian Natural Perils Pool was registered. So far, all claims in Sør-Fron, Nord-Fron and Ringebu from 2011 and 2013 and all claims in Gausdal from 2013 have been registered. These have been entered into a GIS solution and will be made available on www.innlandsgis.no.

Hydraulic model

In order to calculate which areas are vulnerable to flood damage and to assess the effect that a number of measures in and along the main watercourse would have on the waterline, it was decided to create a hydraulic model. The hydraulic model includes the Gudbrandsdalslågen from the water level marker at Rosten, north of Nord-Sel, to the outlet of Mjøsa Lake, and corresponds to a stretch of around 130 km. In addition, the model includes the outlets of the Gausa (around 4.2 km) and Otta rivers (around 4.5 km). The tool used for the hydraulic model is a HEC-RAS 1D model version 5.0.3. Please refer to the following report for more detailed descriptions of the various measures in the main watercourse:

- *Hydraulic calculations – The Gudbrandsdalslågen (Hydrauliske beregninger – Gudbrandsdalslågen), Dr Blasy and Dr Øverland*

Sediment sources and sediment transport

In order to be able to say something about the importance of sediment transport within the plan area, Jim Bogen of the NVE has completed a project to analyse and map erosion and sediment deposits from the main sources in the Gudbrandsdalslågen's catchment area. An investigation has also been conducted to examine the effect on stretches downstream of the origins of the sediments, to provide background on possible measures.

- *The Gudbrandsdalslågen: Sediment sources and sediment transport – As a background to measures in the management plan (Sedimentkilder og sedimenttransport - Som bakgrunn for tiltak i forvaltningsplanen), NVE report 89/2016*

Measures in tributaries

Based on the sediment source report, a number of measures have been considered in the tributaries to the Gudbrandsdalen and the Otta, as well as in the Gausa. These are described in a separate report:

- *Relevant measures in the tributaries to the Gudbrandsdalslågen (Aktuelle tiltak i tilløpselver til Gudbrandsdalslågen). Memorandum – NVE and Oppland County 2017*

Impact assessment

Impact assessments have been conducted by Asplan Viak for all measures that have been evaluated and analysed in the hydraulic model, as well as for all measures in the tributary watercourses. Topics that have been considered include flood safety, the business community, the landscape, the local environment and outdoor recreation, biodiversity, the cultural environment and natural resources.

- *Flood protection measures in the Gudbrandsdalslågen and its tributaries – Impact assessment (Flomsikringstiltak Gudbrandsdalslågen med sidevassdrag - konsekvensvurdering), Asplan Viak*

Pilot projects

In order to gain more knowledge of certain issues, relevant measures and processes to implement these, project funds have provided financing for two pilot projects. One is the design and planning of a permanent sediment removal site in Frya, and the other is a comprehensive surface water plan for Follebu. These are described in the "*Knowledge base*" document.

On the basis of this knowledge base, the assessment is that there is an adequate basis for drawing up a plan for the Gudbrandsdalslågen and its tributaries, within the level that can be expected in a regional master plan.

Need for further new knowledge

Work on this plan has revealed the need for further studies and proposals for measures that should or could be implemented. Measures include the completion of the registration of damage after the floods in 2011 and 2013 and the development of 2D models for selected stretches of the Gudbrandsdalslågen to gain more knowledge of flow conditions for planning measures. Hydraulic modelling of the Gudbrandsdalslågen through Lesja should also be carried out to document the effect of possible measures on Lesjaleira. There is also a need for more knowledge about sediments, erosion, transport, and better data on through-flow and precipitation.

5. Sediment removal in watercourses as flood protection

Early on in the work on the plan, municipalities, local organisations and associations and government agencies provided input that sediment removal in watercourses was seen as a highly effective measure for reducing flood damage. Therefore, while working on the plan, there was a great deal of focus on determining the effect of sediment removal as a flood control measure. This plan does not cover sediment removal desired for reasons other than flood control, but municipalities are encouraged, where appropriate, to draw up a municipal sub-plan / area plan for this type of measure.

A thorough review has been made of which rivers carry large amounts of sediments and localised areas where this can cause problems. Hydraulic modelling of possible sediment removal has also been carried out in the main watercourse, to see what effect this would have on the waterline in different flood situations.

Sediment removal in watercourses generally has the greatest negative impact on fish stocks and on natural assets in general. Therefore, a survey has been carried out of important areas for a variety of fish species in the Gudbrandsdalslågen to find the most vulnerable areas. Furthermore, an assessment has been made of what consequences the individual measures will have on businesses, the landscape, the local environment and outdoor recreation, biodiversity, the cultural environment and natural resources. All together, this provides an overview of where sediment removal may be appropriate to reduce future flood damage.

However, the results show that sediment removal in the main watercourse has very little effect on the waterline in flood situations. Therefore, very few places have been proposed where this could be a relevant measure. On the other hand, permanent sediment removal sites in a number of tributaries could be a flood control measure.

Although this plan has focused on sediment removal as a damage reduction measure, the results from modelling, the impact assessment and the ichthyological study may also be an aid for assessing whether individual areas may be relevant sites for sediment removal based on a need for gravel.

Sediment removal in watercourses is regulated by various legislation, including the Norwegian Water Resources Act, the Act relating to Salmonids and Freshwater Fish, and the PBA. For the removal of deposits exceeding 10,000 m^3 during the lifetime of the site, an application for an operating licence must be submitted to the Norwegian Directorate of Mining (DMF) (cf. section 43 of the Norwegian Minerals Act). An operating licence does not replace requirements for permits under other legislation.

5.1 What effect does sediment removal have on the waterline in various areas?

The hydraulic model examines the effect of sediment removal in the Gudbrandsdalslågen on the waterline in a flood situation. Generally, sediment removal will have little effect on the waterline if the areas in which the sediments are extracted are in wide, slow-flowing areas with a low gradient. Examples of this are the Lågen delta and the wide, slow-flowing stretches through Gudbrandsdalen.

On the other hand, sediment removal and lowering of the river course may have an effect if the river section is narrower, and in areas with higher flow rates. Generally, sediment removal will only have a flood control effect if it leads to lowering a weir that is damming up the water upstream of the weir.

5.2 Need for zoning plans for the establishment of sediment basins and permanent sediment removal sites

Zoning plans should be developed for all major sediment basins and permanent sediment removal sites, to provide guidelines on when and how the removal should be carried out. Examples of such guidelines can be found in Chapter 13. Section 12.1, third paragraph, of the PBA requires a zoning plan for all major building and construction projects and other projects that may have substantial effects on the environment and society. A zoning plan will help to ensure that the project is properly executed, and will provide a comprehensive overview of the total impact on the environment and society. For projects and interventions in watercourses that affect significant environmental protection areas, a zoning plan may replace the licensing process under the Norwegian Water Resources Act and processing according to the Regulations on Physical Measures in Watercourses for each individual measure. However, this requires that relevant measures and interventions be described and assessed according to the requirements set out in the various special laws and that relevant mitigation measures be described in the plan provisions. The DMF is the licensing authority under the Norwegian Minerals Act, and for permanent sediment removal sites of more than 10,000 m^3 during the lifetime of the site, an application must be submitted to the DMF for an operating licence (cf. section 43 of the Norwegian Minerals Act). When the DMF is to process a licence application with an operating plan, it is advantageous for the sediment removal site to have an approved zoning plan, as factors related to the Norwegian Pollution Control Act and the Norwegian Nature Diversity Act will be discussed.

For a number of smaller sediment removal sites, it may be more appropriate to treat the removal sites as dispensations. This applies to smaller removals that may only happen once or very rarely, for example only every ten years or less. However, in these cases, the same guidelines as in a zoning plan should apply as a condition for the removal.

Provisions on who should carry out the cleanout, and any sales of sediments from these sediment basins and permanent sediment removal sites, cannot be included in the zoning plan. However, it is very important that this be clarified and that a private legal agreement be concluded on the matter.

Someone should be responsible for ensuring that cleanout is performed when necessary, and in practice, it will be either the municipality or the landowner who has this responsibility.

5.3 Financial considerations for sediment removal

In this plan, the cost of establishing and operating sediment removal sites is assessed. A cost of NOK 200/m³ has been calculated for rigging, excavation and transport of material from large sediment removal sites over 50,000 m³. For smaller removal sites, a cost of NOK 250/m³ is assumed. However, these are rough figures, and for the removal of large volumes at easily accessible sites, the cost could drop to NOK 100–150/m³.

The price is also based on this being purely related to removal costs. In some cases there will be high demand for this raw material, depending on the quality of the extracted material and the need for the product within a reasonable area. The costs and utility value of the extracted material may therefore change based on this need.

5.4 Sediment removal in tributaries to the Gudbrandsdalslågen

The major sources of sediments in the Gudbrandsdalslågen come from a number of tributaries. Both measurements and observations specifically show many tributaries transporting large quantities of sediments. In addition, there are larger tributaries that currently do not transport such large quantities, but may potentially do so if slopes begin to be affected by erosion. Therefore, interventions that may initiate sediment transport in these rivers are undesirable. However, these should be monitored through measurements of sediment transport and/or laser monitoring of the valley flanks.

The impact assessment shows that if it is possible to limit some of this sediment transport before it reaches the main river, it could reduce damage related to sediment transport and sedimentation both in the tributaries and in the Gudbrandsdalslågen.

Sediment removal has been practised in many rivers and streams for many years, both to extract raw materials and to clean up after previous flood events. Sediment removal and clean-up can lead to the destruction of the natural riverbed and the reduction of good habitats for fish, plants and animals. This may also cause the river bottom to become more unstable and vulnerable to new erosion and increased movement of stones and gravel.

If it is possible to limit sediment removal to certain points in the river and ensure that it does not result in an increased risk of erosion, it could limit the destruction of important fish habitats. It will provide better control of erosion, excavation of the river bottom and sediment transport. In order to further improve the conditions for aquatic organisms, it may be appropriate to implement habitat measures along certain stretches between various permanent sediment removal sites. Work on the plan has included studies and impact assessments of a number of permanent sediment removal sites and sediment basins.

5.5 Other minor sediment removal sites

Where there is a need for minor sediment removal in some areas of the municipality for reasons other than flood protection, the municipality should prepare a municipal sub-plan / area plan. Such plans ensure comprehensive assessments and public participation, and can simplify the application process for the individual sites.

5.6 Assessed measures in the tributaries to the Gudbrandsdalslågen

This chapter briefly describes assessed measures in the tributaries to the Gudbrandsdalslågen. Detailed descriptions of the individual measures can be found in the following reports:

- Relevant measures in the tributaries to the Gudbrandsdalslågen (*Aktuelle tiltak i tilløpselver til Gudbrandsdalslågen*). Memorandum – NVE and Oppland County 2017
- *Flood protection measures in the Gudbrandsdalslågen and its tributaries – Impact assessment (Flomsikringstiltak i Gudbrandsdalslågen med sidevassdrag - konsekvensvurdering), Asplan Viak*

5.6.1 Lora, Lesja (A)

The Lora is responsible for most of the through-flow at the confluence with the Lågen. Both the Lora and the tributary watercourses run through areas with large soil deposits. The lower part of the river course has an embankment that collects most of the course sediments. This section is also zoned for sediment removal, from the property boundary of Lordalen common land and down to the Lågen. The zoning provisions allow for the removal of dry and barren river gravel banks upon application to the municipality. Other, larger removals require a permit/licence pursuant to the Norwegian Water Resources Act / Act Relating to Salmonids and Freshwater Fish / Norwegian Minerals Act.

However, removal activity has been low here in recent years, and there are now large amounts of fine sand in the lower parts, and some coarser material further up. Large amounts of fine sand from the Lora have also been transported further down the Gudbrandsdalslågen through Lesja, which has led to the elevation of the river bottom. This is causing increasing problems with flooding of farmland during flood periods.

Figure 14. Key map of Lora.

Upper area: A lot of sediments have been deposited in the upper area, where the river widens. This is mainly coarse sediments, but probably also with some finer sediments beneath. There is easy access from the road along the right river bank. During sediment removal, it will be beneficial to pile the extracted material at a few points on the left side to increase the height of the left bank. This will prevent the river from flooding over its banks in the event of high through-flow, into the terrain and depositing material and debris in the forest.

Middle area: Here, there is a bend in the river, and large quantities of sediments are deposited on the left river bank. There is an erosion protection embankment on the right bank that protects the road against erosion. The erosion protection embankment is in good condition, but the presence of the deposited sediments is resulting in the river being forced against the embankment. In the longer term, it will be beneficial for the road and the erosion protection embankment to extract the sediments from this area.

Lower area: Just before the confluence with the Lågen and upstream of the bridge over the Lora, the river flattens out and becomes wider. According to the NVE Atlas, two weirs have been set up here, although only the weir directly upstream of the bridge is visible today. This area works well as a sediment basin, and lots of fine sand is deposited here. There is a good opportunity to extract a lot of material here. This will be a place where it is easy to establish a sediment removal site that may have a positive effect on the Lågen through Lesja.

Cost estimate: Not calculated.

Flood control effect: Will reduce sediment transport further down the Gudbrandsdalslågen through Lesja municipality, and reduce the raising of the riverbed.

Priced consequences: Utility is not considered as there is no basis for assessment. However, it can be assumed that the measure will lead to a reduction in the extent of the damage to farmland.

Non-priced consequences: The measure will primarily have a positive effect by limiting particulate deposits in farmland downstream in the event of a flood. The measure has the greatest negative impact on fish, but trout rivers of this type are relatively robust against this type of intervention.

Assessment and prioritisation: This is a measure that will in the long term be able to provide better protection of farmland throughout Lesja municipality. It is also possible to extract sediments in several places within the zoned area of the Lora. It is most important to extract the fine sediments in the lower area, as this provides the best effect in terms of preventing finer sediments from being transported on to the Lågen. It would also be beneficial if some sediments were also extracted from the middle and upper areas. It is recommended to implement a fixed routine for sediment cleanout in the lower areas at regular intervals to keep the weirs ready for new deposits of fine sediments. In the upper and middle parts, removal should be assessed as needed.

5.6.2 The Lågen through Lesja (B2)

Downstream of the outlet of the Lora, large quantities of fine sediments have caused an elevation of the river course all the way down to Lesja town centre, possibly even slightly further. There are many artificial channels that run out into the main watercourse. Most of these originate in streams coming down from the valley flanks. Many of these streams transport sediments, and in flood situations and periods of heavy rain, there have been episodes of massive sediment transport and erosion in them. The coarse sediments are deposited where the stream flattens out at Lesjaleirene, while the fine sediments are transported further and deposited in the channels and in the main river. In order to limit sediment deposition, it may be appropriate to establish sediment basins in two of the streams where they flatten out.

There is also a desire to clean up a number of these channels. However, it is uncertain whether this measure will achieve the desired effect. If flooding of farmland is due to large amounts of water from the streams, it may have an effect, but if it is the water level in the main river that determines what is being flooded, it will likely have a marginal effect as a flood protection measure.

Downstream from Lesja Church, there are two points where there is a drop in the river. One is at the first bridge south of Lesja Church, at Hattrem (Figure 15). Here, it may be possible to create a spillway on one side of the bridge, either by burying a culvert that will take effect in the event of high through-flow or by building a new bridge with a wider span. The second point is at Bottheims bridge, where it may also be possible to lower the bottom somewhat, thus lowering the waterline further up in the river in the event of a flood.

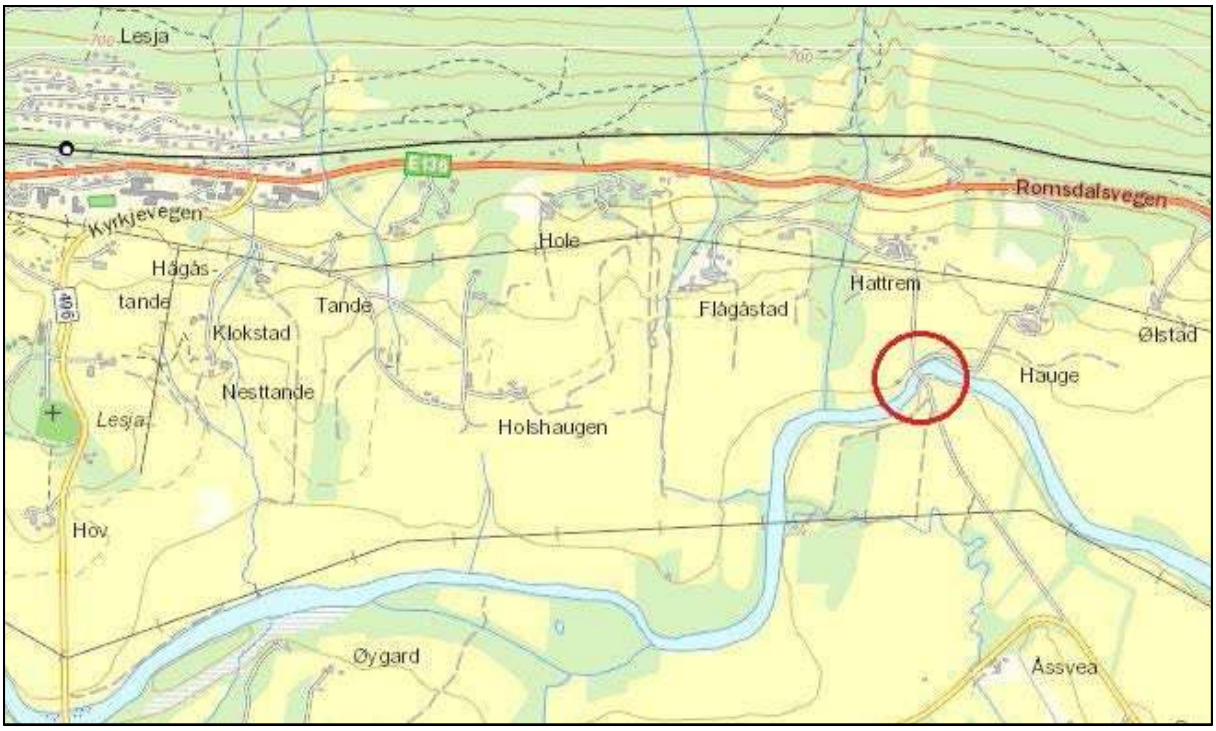

Figure 15. Possible placement of spillway past Hattrem bridge.

Flood control effect:
The sediment basins will reduce the rate at which the bottom rises in the channels and out in the Lågen. The effect of cleaning up the channels should be studied further.

Cost estimate: Clean-up of the channels as well as the establishment of sediment basins is estimated at NOK 1.5 million. Other measures have not been calculated.

Priced consequences: Will reduce flood damage to farmland.

Non-priced consequences: The measure is considered to have positive consequences for the natural environment as it reduces sedimentation downstream in wetlands and thus may reduce overgrowing. Clean-up of the channels will probably improve the drainage of farmland and the establishment of sediment basins will reduce the extent of future sedimentation of the channels. This must be seen in connection with the waterline in the Gudbrandsdalslågen along the stretch and what effect it has on the channels.

Assessment and prioritisation: This is a measure that will in the long term be able to provide better protection of farmland throughout Lesja municipality. It is recommended to build the two sediment basins and further investigate the need for clean-up in the channels. Clean-up of the channels must be seen in connection with the Lågen through Lesja in general, and a possible measure to increase flood capacity beyond Hattrem bridge. Therefore, a hydraulic model should be developed for the area to show the effect the various measures will have.

5.6.3 Einbugga, Dovre (E)

The Einbugga is a river that transports sediments. In the 1990s, flood protection was implemented here, between the railway and the old E6. This was done by building flood embankments well out to the sides so that the river is unconstrained between within the embankments. This is a way to build flood protection that should be seen as a positive example for flood protection in other smaller rivers. However, it is sometimes necessary to remove excess sediments.

It is proposed to establish two sediment capture dams just upstream of Kongsvegen to reduce sediment transport to the main watercourse (No. 2 and 3, Figure 16). To reduce the risk of the river taking a new course, sediments should be removed after large floods at an area further up in the river (No. 1, Figure 16).

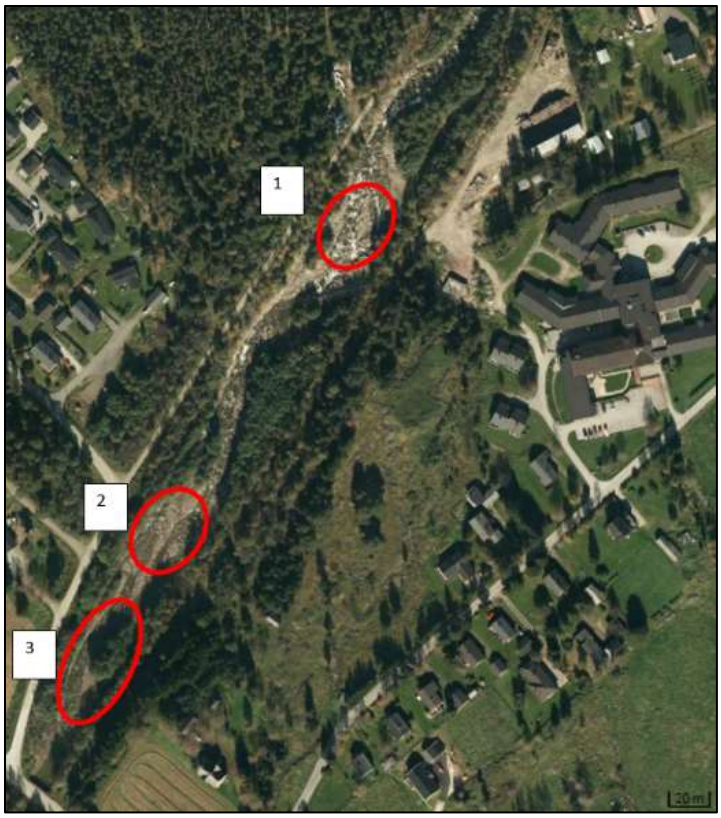

Figure 16. Locations of possible sediment removal sites in the Einbugga.

Flood control effect: Will reduce sediment transport into the Gudbrandsdalslågen, reduce the risk of flooding of Kongsvegen and the E6, as well as reduce the risk of the river taking a new course.

Cost estimate: Cost estimate has not been calculated, but it is assumed that there will be a demand for the extracted material.

Priced consequences: Sediment removal will reduce the risk of flooding of settlements and farmland.

Non-priced consequences: Minor negative effect on fish and minor positive effect on pollution.

Assessment and prioritisation: This is a measure that will improve the protection of the E6 and Kongsvegen, as well as ensuring that the river does not take a new course, which could have an impact on both the Fredheim care facility and several homes. It is recommended to proceed with this measure. If sediment basins are established, a zoning plan should be developed for the area.

5.6.4 Ilka, Dovre (F)

The Ilka is a river that transports large quantities of sediments. In order to reduce sediment transport to the Lågen, a capture dam can be established in the lower part of the river (Figure 17). In order to raise the bottom of the river, a bottom protection measure and repair of damage to embankments should be carried out.

Figure 17. Locations of possible sediment removal sites in the Ilka.

Flood control effect: Will reduce the risk of flooding of the village of Ilka. Will reduce sediment transport out into the Lågen, and reduce the deposition of sediments in places where they could cause problems on the stretch down to Rosten.

Cost estimate: Cost estimate has not been calculated, but it is assumed that there will be a demand for the extracted material.

Priced consequences: Will protect residential areas.

Non-priced consequences: The measure is considered to have a major negative impact on the natural environment and a medium negative effect on fish. Areas with vegetation should be avoided during sediment removal.

Assessment and prioritisation: The need to protect buildings indicates that the embankments should be repaired. The NVE has prepared a flood damage plan for Ilka in 1.12.2011-VV1558C, but this plan has not been implemented. It is recommended that this plan be revised and implemented.

5.6.5 Tundre/Åstri, Skjåk

An embankment has been built on the north side of the river Åstri to protect two or three farms. The river, however, deposits so much sediment that some gravel should now be removed to protect this embankment. The river is also eroding the opposite side, and erosion protection should be established along this stretch in order to prevent the river from breaking through and over Tundramoen.

It may be appropriate to plan a sediment capture dam at the confluence of the Tundre and the Åstri. It is important that the relationship between the main river and the branch of the river is adjusted so that there is a controlled distribution between the two branches. In this context, a possible erosion protection embankment on the right bank must also be considered – not for protection, as it is only forest land, but due to the quantity of sediments entering the river. Sediment removal from the river is also being considered.

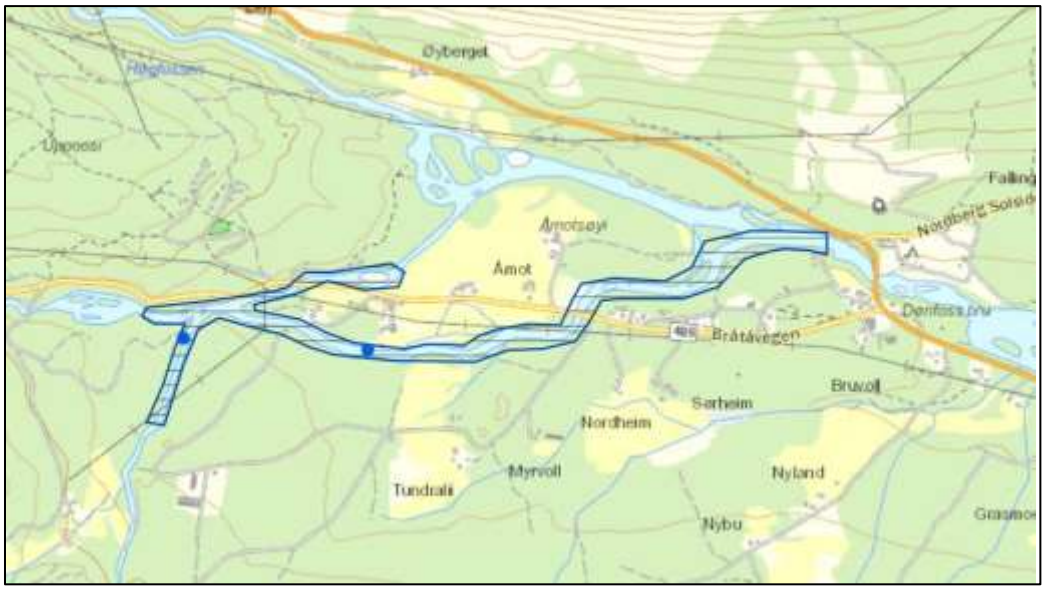

Figure 18. Map of area where measures are being considered in the Tundre/Åstri.

Flood control effect: Will protect several houses from flooding.

Cost estimate:

- Dam: NOK 50,000
- Erosion protection embankment (100 m): NOK 50,000–100,000
- One-time sediment removal: NOK 500,000
- Total: NOK 600,000–650,000

Priced consequences: The measure is considered positive, as it reduces the risk of flood damage to farmland. There is little information about the extent of flood damage and associated costs. It is therefore not possible to conclude whether the measure will be profitable.

Non-priced consequences: Minor negative impact on fish, the landscape and the cultural environment.

Assessment and prioritisation: This is an initiative that will protect several houses. It is recommended to continue working with this measure. This is a challenging and complicated area that also has great importance in terms of the safety of the properties on the west bank between the right branch of the river race and the road. It is therefore a measure that requires a comprehensive plan, where all issues can be seen together.

5.6.6 Skjøle, Skjåk (H)

The Skjøle is a river that transports large quantities of sediments. The NVE has carried out extensive sediment removal and constructed erosion protection embankments along this stretch. Large quantities of sediments are deposited directly upstream of the bridge (Figure 19). This area is easily accessible, and is well suited as a permanent sediment removal site. A little further down, it seems that the river has begun to erode the embankment on the south-eastern bank. Here, it should be considered whether it is possible to construct a pier that leads the water away from the embankment.

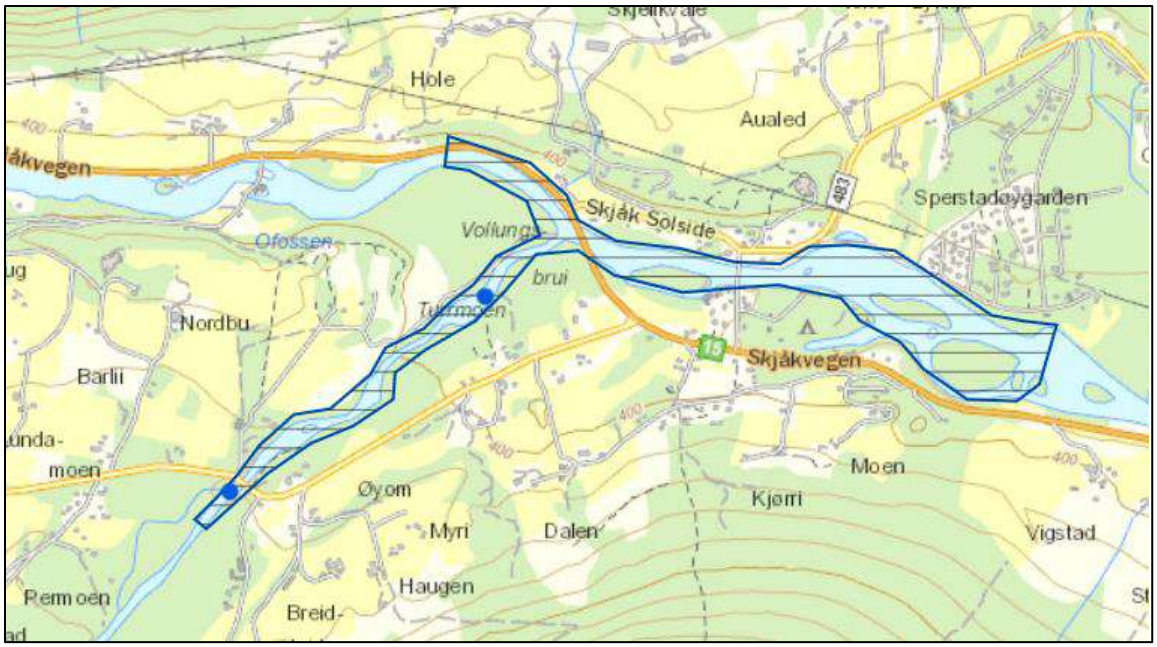

Figure 19. Map of area where measures are being considered in Skjøle.

Flood control effect: Sediment removal will reduce the build-up of sediments downstream. Piers will stabilise/prevent water from running towards the embankments.

Cost estimate: Costs have not been calculated. It is assumed that sediment removal from the river will be profitable.

Priced consequences: There is no known flood damage historically, but there is risk associated with damage to the Rv 15 road. Suitable place for sediment removal and storage on the side. The measure will probably be profitable to implement.

Non-priced consequences: Minor negative effect on fish.

Assessment and prioritisation: This is a measure that will provide better protection of the Rv 15 road. Given that there is profitability related to sediment removal, the measure is likely to have a net positive impact on the environment and society. In the long term, any repair of damage to the erosion protection embankment should be considered in conjunction with a need for new piers. The relevant site for permanent sediment removal should be determined through the preparation of a plan. It is recommended to implement the measure.

5.6.7 Finna, Vågå (J)

The Finna flows into the Otta near Vågåmo, and has repeatedly led to flood situations through the town centre. Further up the river, large amounts of sediments have led to problems. The river is channelised and flood-protected through the centre of Vågåmo. Here, weirs have been built to capture the sediments. Six weirs have been established in the Finna. In the winter of 2016, these were repaired and emptied under the auspices of the NVE.

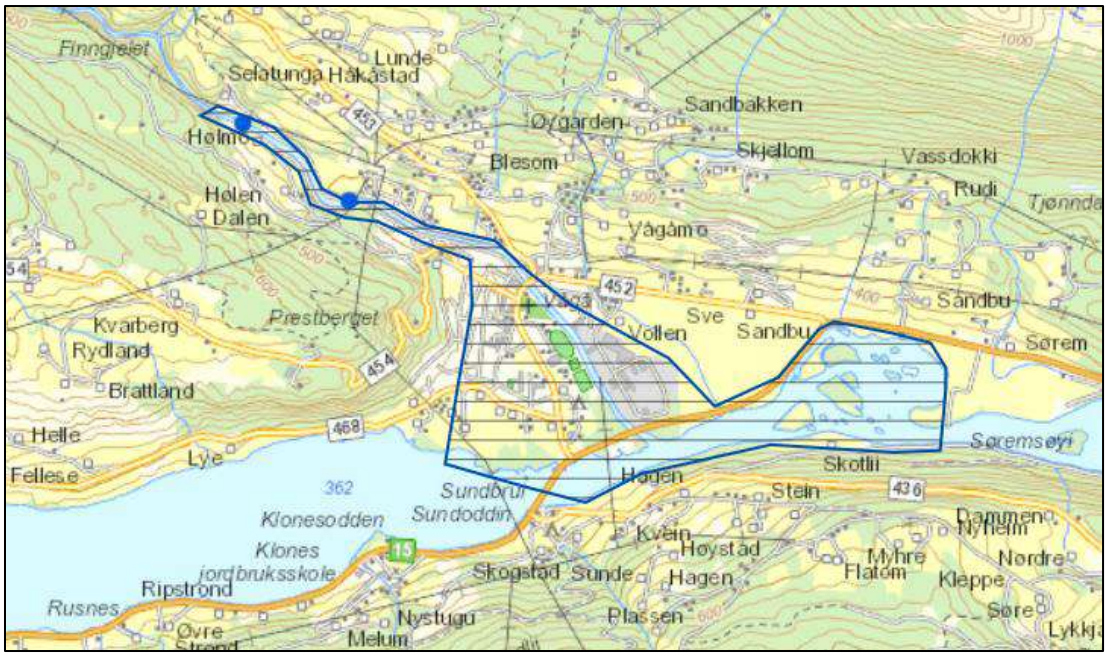

Figure 20. Map of area where measures are being considered in the Finna

However, these weirs are not suitable as permanent sediment removal sites due to difficult access. Therefore, an area upstream has been considered for capturing sediments, where access for cleanout is easier. In connection with repair of the weirs in the Finna, around 5,500 m³ of sediments were removed in 2016 at the lowest sediment removal site shown (Figure 20).

Flood control effect: A permanent sediment removal site will reduce sediment transport through the lower parts of the Finna, and reduce the need for costly and difficult cleanout of the weirs downstream.

Cost estimate: Not calculated.

Priced consequences: Positive impact for society and industry. The investment cost will probably be less than the cost to society if the current situation continues over time, especially if there is a demand for sand and gravel in the area.

Non-priced consequences: Further interventions in a river that is already heavily influenced by flood protection measures. The measure is planned in parts of the river that are currently relatively intact. Overall, half the river (which is in contact with the Otta) has been reduced by physical interventions, and consequently, the impact on fish may be relatively great. Impacts on fish and freshwater biology should be mapped out in more detail. Mitigating measures should be considered if there is a desire to proceed with the measure.

Assessment and prioritisation: This is a measure that will provide better protection for Vågåmo town centre. Overall, the measure is considered to have a net positive impact on the environment and society. This area should be set up as a permanent sediment removal site. A zoning plan should be developed for the area to regulate the removal.

5.6.8 Sjoa, Sel (K)

Sjoa is a river that transports large quantities of sediments, and in order to reduce the amount of damage caused by floods, two permanent sediment removal sites have been considered.

Figure 1. Aerial view of the area where measures are being considered in the Sjoa.

Flood control effect: May prevent sediment deposits in areas where they could lead to raising the waterline and a risk of damage in several places in the river.

Cost estimate: Not calculated.

Priced consequences: The measure will primarily have a positive impact on industry/agriculture. Planned sediment removal in the Sjoa will prevent rising groundwater levels as a result of obstruction.

Non-priced consequences: Intervention in a protected watercourse. Sediment removal has great potential to damage the fish stocks, as it is a direct intervention in the river and may cause a major negative impact. However, a permanent sediment removal site may be a better alternative than clean-up work after flood damage.

Assessment and prioritisation: It is recommended to establish two permanent sediment removal sites in the Sjoa. Zoning plans should be developed that regulate the sediment removal.

5.6.9 Frya, Ringebu (N)

The Frya is a river that transports large quantities of sediments, sand, gravel and stone, which are deposited in the Lågen. A sediment capture dam has been assessed but rejected due to the high cost. Work is now under way to establish a permanent sediment removal site in the river.

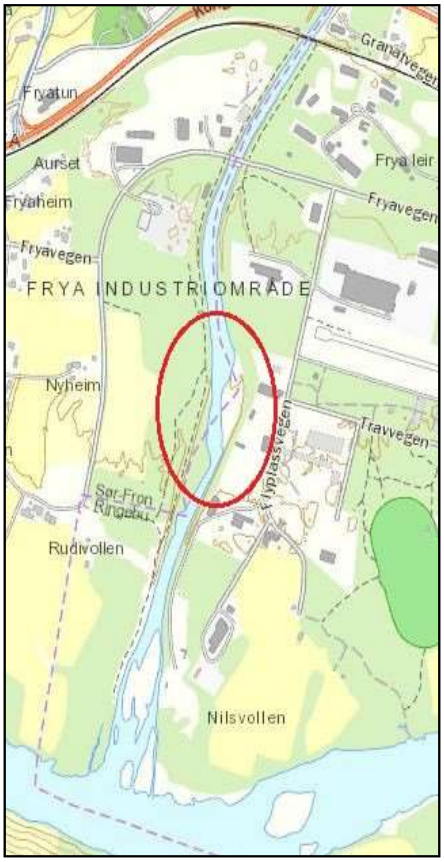

Figure 2. Map of area where measures are being considered in the Fyra.

Flood control effect: Will provide better protection for agricultural areas and water purification plants.

Cost estimate: Not calculated.

Priced consequences: The measure is considered to have a medium positive effect on business and society. Local actors want to remove sediments in the area.

Non-priced consequences: There will be a risk of washout of fine particles during the construction period. Overall, the measure is considered to have a net positive benefit to the environment and society, given that it can be documented that the consequences for fish and the natural environment are acceptable.

Assessment and prioritisation: This is a measure that will protect an industrial area and the Ringebu waterworks. Work is currently under way on a zoning plan to regulate sediment removal within a limited area of the river. The effect of such a permanent sediment removal site should be monitored on a continuous basis and evaluated after a few years to see whether the measure has the desired effect. If it turns out that large quantities of sediments are still being transported into the Gudbrandsdalslågen, a sediment capture dam should be reconsidered.

5.6.10 Dørja, Gausdal (O)

The Dørja is a river that transports large quantities of sediments, and the extensive through-flow / sediment transport during the floods of 2011 and 2013 caused major damage to Helleberg Sag. The studies conducted by Jim Bogen at the NVE provide good documentation of the extensive sediment transport in the Dørja, which flows out into the Jøra. In recent times, there has been a focus on the use of sediment barriers to reduce this transport. A possible location has been considered at the bottom of the valley.

A comparison of aerial photographs shows that it is mainly undermining in the side slopes that leads to erosion and landslides, and that the deposition of sediments in the river course has caused the river to take a new course. This leads to new erosion and sediment transport. It is therefore also necessary to secure the bottom of the valley flanks where there are high and steep slopes with frequent debris slides.

The narrowest part has been examined in particular, where there is currently bedrock on both sides of the river. The possibility of anchoring a barrier dam to the bedrock allows for the use of concrete.

This will usually be a less expensive and easier construction to build than a dam made of uncompacted material. The quality of the bedrock must be investigated more closely at an early phase of the planning, in addition to the depth of the bedrock in the river and on the sides. There will normally be some uncertainty associated with assessments of how much a sediment barrier should be able to hold back. However, as for the Dørja, Bogen et al. have calculated a sediment budget based on high-resolution digital terrain models built on laser data from 2010 and 2013/2015. The volume of net sediment transport deposited from debris flows, erosion in the hillsides and erosion of the river course is estimated at around 80,000 m³ for the floods in 2011/2013, of which bedload transport from the river amounts to around 47,000 m³. If this is shared equally between the two events, it amounts to around 23,500 m³ for each event.

The NVE has set up a terrain model in GIS based on a height model with a 1x1 metre grid, and used it to calculate what volume of sediments is retained by dams with a height of 7, 8 and 9 metres, respectively. The calculations are based on the sediments having a flat surface. There will be some uncertainty related to the level of the river bottom, but the deviation will not be more than 1–2 metres. Figure 23 shows the size of the sediment basin at the three dam heights.

Figure 3. Terrain model that shows the size of the sediment basin at the three dam heights in the Dørja.

- Dam height 7 metres, contour line 430: Sediment volume approx. 10,500 m³
- Dam height 8 metres, contour line 431: Sediment volume approx. 15,600 m³
- Dam height 9 metres, contour line 432: Sediment volume approx. 22,200 m³

A sediment barrier in this area must comply with the Dam Safety Regulation and the requirements it imposes on technical design, monitoring of implementation and qualifications of both the designers and the contractors.

Flood control effect: Will prevent large quantities of sediments from reaching the Jøra, as well as protecting several houses and businesses in the event of a flood.

Cost estimate: Not calculated.

Priced consequences: Positive. Will protect several houses and businesses.

Non-priced consequences: Not assessed.

Assessment and prioritisation: This is an initiative that will safeguard several houses and businesses, and further investigation of a sediment barrier is recommended.

5.6.11 Jøra, Gausdal (P)

The Jøra is a river that transports large quantities of sediments, and the Dørja is one of the rivers that transports large quantities into the Jøra. Any measures in the two rivers must therefore be seen in relation to each other. It may be appropriate to create a sediment removal plan for several relevant locations, as sediments are deposited over time. This applies to several places in Svatsum, the Helleberg area, Aulstadgrenda and Bødalen. This should be combined with a measured profile that shows how sediments accumulate and as a basis for determining when sediment should be removed.

Figure 4. The three locations in the Jøra that have been assessed for sediment removal.

Øvre Svatsum: There is easy access right down to the river from the road, and a site already exists near the river where sediment material has been deposited. The location is well suited for sediment removal. There is an area of roughly 6.4 acres of cultivated land around 160 metres above the removal site.

Downstream from Helleberg Sag: There is easy access from the farm road along the river, and the site is well suited for sediment removal. After the flood in 2011, erosion protection embankments were constructed along this stretch, and the terrain on the inside has been raised. It is possible to build a weir, but the exact location has not been considered.

Downstream from Aulstad Church: There is easy access via the farm road and access to the river from the field. There is farmland on both sides of the river in this area. The location is well suited for sediment removal. It is possible to build a weir if desired, but the exact location has not been considered.

Flood control effect: Will reduce sediment deposition in areas where it could cause flooding problems.

Cost estimate: Not calculated.

Priced consequences: Positive.

Non-priced consequences: The measures will have a minor positive effect on pollution and industry, but may have a small to medium negative effect on fish.

Assessment and prioritisation: These are measures that could reduce flood damage mainly on farmland. Knowledge of the consequences of measures implemented at Øvre Svatsum indicates that this measure could have undesirable effects, such as eluviation to farmland. Sediment removal in the Jøra must be considered in more detail in connection with possible sediment removal in the Dørja. The measure at Aulstad could have a positive effect by reducing sedimentation downstream. It is recommended to continue working with these measures.

5.6.12 Augga, Gausdal (Q)

The Augga is a slow-flowing river, and through the years, large quantities of fine sediments have been deposited in the river. According to locals, there are now almost annual problems with the flooding of farmland during the spring flood and during other periods of heavy precipitation. In order to improve the flood situation, sediment basins have been assessed for the lower part of the Djupåa: one in the Finnsrudbekken stream, and two in the Augga itself. In addition, sediment should be removed from three stretches in the Augga.

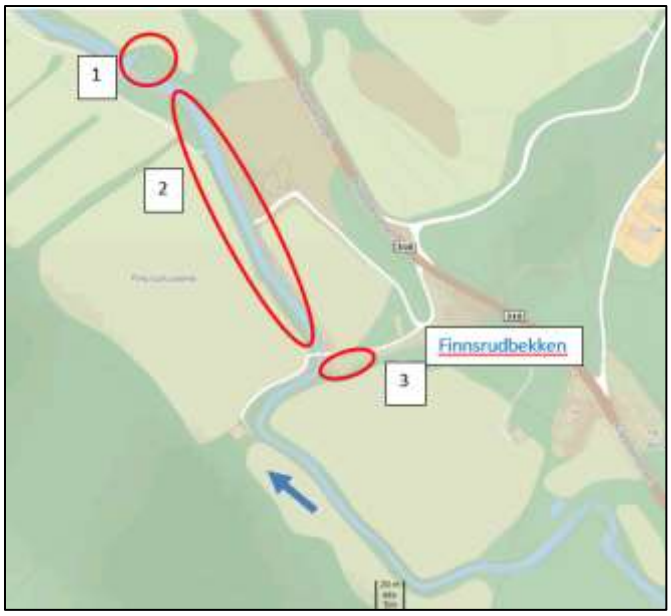

Figure 5. The Augga near Finnsrud. 1: Construct sediment capture dam for fine sediments. 2: Sediments are removed from the river. 3: Establish a sediment capture dam at the outlet of the Finnsrudbekken.

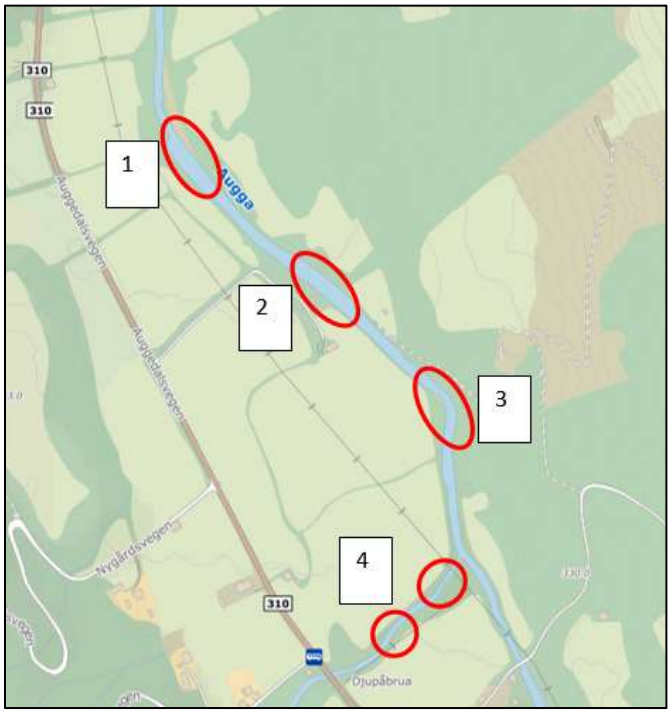

Figure 6. The Augga near Djupåa. 1: Sediment basin established. 2: Sediments extracted. 3: Sediments extracted. 4: Sediments are removed from the Djupåa, and two sediment capture dams can be built to reduce sediment transport to the Augga. The sediment capture dams are established between the outlet and Djupåa bridge.

Cost estimate: Not calculated.

Priced consequences: Positive.

Non-priced consequences: The measure will probably have positive consequences for industry/agriculture, but there will be some negative consequences for the natural environment and

fish that should be studied further. Compared with the Jøra, sediment deposits are smaller, and the measure will have a more limited local effect.

Assessment and prioritisation: The measure will have positive consequences for agriculture, but there is great uncertainty as to whether the effect of the measures will be as great as desired. This is not a measure that has top priority as it only protects farmland. At the same time, this is a measure that will not have major negative effects on non-priced assets and should be considered if the municipality or landowners want to pay for and implement it.

5.6.13 Gausa, Gausdal (R)

The Gausa in Eastern Gausdal is a river that transports large quantities of sediments, and in recent years, large amounts of sediments have been deposited on the stretch from the area below Liesfossen and down to Segalstad bridge. A lot of sediment has been removed in recent years, and erosion protection embankments have been constructed. This is a river where efforts should absolutely be made to solve the problems related to sediment deposition by establishing permanent sediment removal sites. This allows us to concentrate the removal sites in certain areas, and allow longer stretches in between to remain relatively untouched.

There is an area upstream of Fykse bridge that may be well suited to a sediment capture site. There is room to widen the river and construct a sediment basin, which will provide a large area where sediments can be deposited. There is also a lot of sedimentation at Myre bridge. A weir has been considered here to capture more sediments. This could also reduce the strain on bridge supports. At Follebu farm, there is a weir at the inlet to the power plant. This is currently full of gravel. This should also be cleaned out at regular intervals and act as a sediment basin.

Flood control effect: Will reduce sediment deposition in areas where it could cause flooding problems.

Cost estimate: Not calculated.

Priced consequences: Positive.

Non-priced consequences: The measure will probably have positive consequences for industry/agriculture, but could have negative consequences for fish, the natural environment, landscape and society (in the construction phase).

Assessment and prioritisation: These are three measures that could reduce the need for major clean-up measures after future floods. It will primarily protect farmland, but it will also protect the natural environment and fish on the stretches between the various areas where measures are being considered. It is therefore recommended to implement the measures.

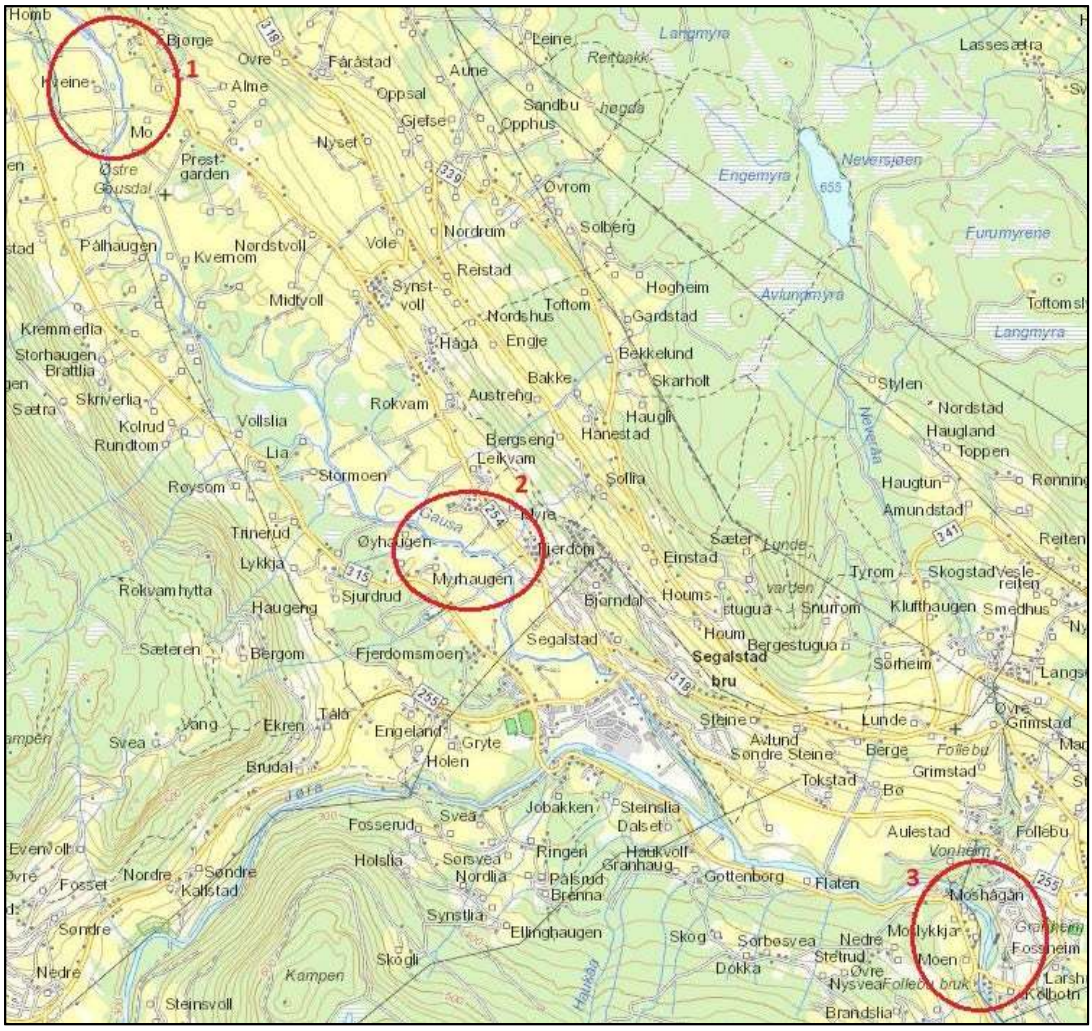

Figure 7. Areas where it may be appropriate to establish sediment basins in the Gausa.

5.7 Recommended measures in tributaries, summary

- Sediment removal site in lower parts of the Lora, Lesja
- Sediment basins in two tributary streams in Lesja
- Sediment basin in the Hjellåi, Dovre
- Sediment removal site in the Einbugga, Dovre
- Sediment removal site and sediment basin in the Ilka, Dovre
- Sediment removal site and sediment basin in the Tundre/Åstri, Skjåk
- Sediment removal site in the Skjøle, Skjåk
- Sediment removal site in the Finna, Vågå
- Sediment removal site in the Sjoa, Sel
- Sediment removal site in the Frya, Ringebu
- Sediment removal site and sediment basins in the Jøra, Gausdal
- Sediment removal site and sediment basins in the Augga, Gausdal
- Sediment removal site and sediment basins in the Gausa, Gausdal

5.8 Assessed sediment removal in the Gudbrandsdalslågen

This chapter describes sediment removal that has been assessed and tested in the hydraulic model. Further descriptions of the various measures can be found in the following reports:

- Hydraulic calculations – The Gudbrandsdalslågen (*Hydrauliske beregninger – Gudbrandsdalslågen*), Dr Blasy and Dr Øverland
- Flood protection measures in the Gudbrandsdalslågen and its tributaries – Impact assessment (*Flomsikringstiltak i Gudbrandsdalslågen med sidevassdrag - konsekvensvurdering*), Asplan Viak

5.8.1 Lower parts of the Gausa / Lågen delta, Lillehammer (9 and 9a)

Several alternative sediment removal sites have been evaluated and tested for the lower parts of the Gausa and in the Lågen delta.

Measure	Quantity	Cost estimate
9 Sediment removal sites in the Gausa and in the Lågen delta (I+II+III+IV+V+VI_1+VI_2)	55,000 m³	Per removal site: NOK 11 million
9a Sediment removal sites in the Gausa (IV+V)	25,000 m³	Per removal site: NOK 6.25 million

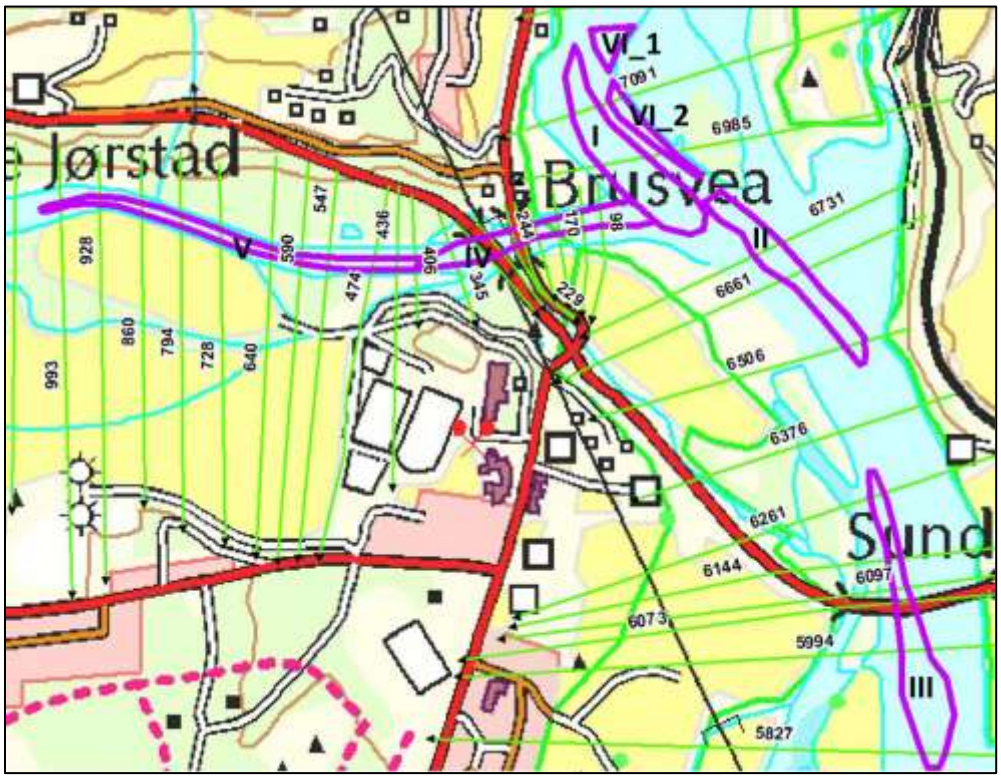

Figure 8. Map of assessed sediment removal sites in the Lågen delta and the lower part of the Gausa.

Flood control effect: The hydraulic calculations show that a combined sediment removal in the Lågen delta and lower parts of the Gausa has a very low impact on the waterline in flood situations in the Lågen delta. The measure will, however, lower the waterline in the Gausa in situations where the Gausa is flooding but the Lågen is not. On the other hand, if there is high through-flow in the Lågen, the water will stop up the water from the Gausa, and the lowering of the river bottom will have no effect on the waterline in the Gausa.

Priced consequences: The priced consequences for both options are negative.

Non-priced consequences: Both options are considered to have a major negative impact on fish, and option 9 will additionally involve interventions in important areas for biodiversity in the nature reserve and is considered to have a major negative impact.

Assessment and prioritisation: This is a measure that will work well for the flood situation along the Gausa when there is a high through-flow in the Gausa, but a lower through-flow in the Lågen. If the Lågen and the Gausa both flood at the same time, lowering will not have any effect on the flood situation along the Gausa. However, the analysis of the measure in the hydraulic model shows that building a flood embankment between the edge of the field and the alluvial forest upwards along the lower parts of the Gausa will protect several houses, farmland and the Jorekstad sports facility in the event of flooding in both watercourses. It is therefore not recommended to continue working with sediment removal, but rather to investigate the possibility of a flood embankment (measure 12d).

5.8.2 The village of Fåvang at the outlet of the Tromsa and down towards Losna Lake, Ringebu (17a, b, c)

At Fåvang, three alternative sediment removal sites have been assessed and tested.

Measure	Quantity	Cost estimate
17a Sediment removal at Fåvang (I)	84,000 m³	NOK 16.8 million
17b Sediment removal at Fåvang (I+II)	189,000 m³	NOK 37.8 million
17c Sediment removal at Fåvang (I+II+III_1+III_2)	929,000 m³	NOK 185.8 million

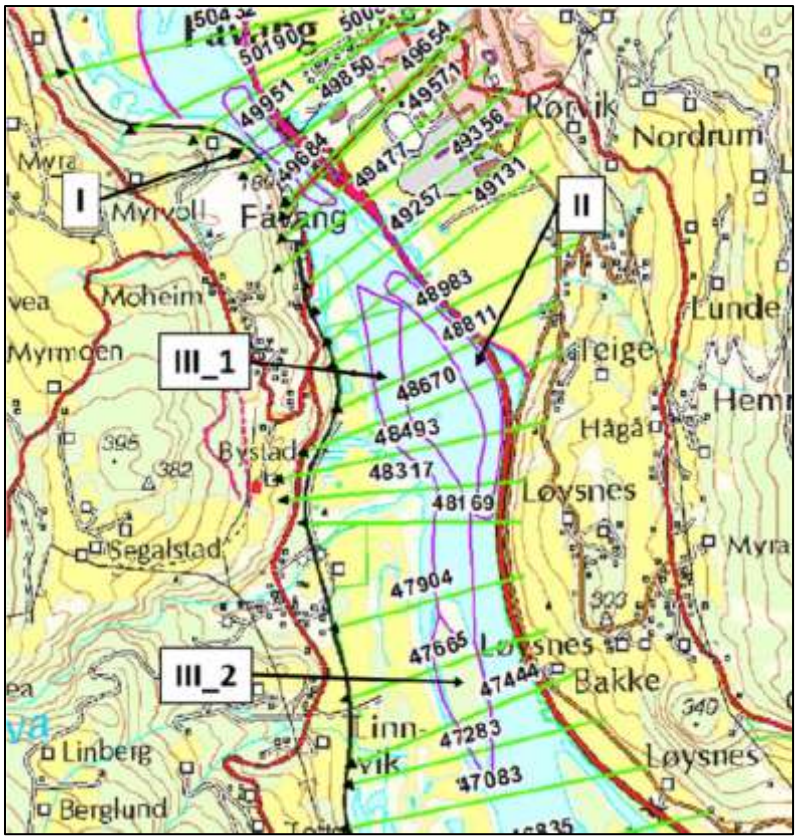

Figure 9. Map of assessed sediment removal sites in the Tromsa and down towards Losna Lake.

Flood control effect: The results show that, at Fåvang, sediment removal under the bridge could lead to a lowering of flood levels during both medium-sized floods and larger floods by up to 17 cm directly upstream of Fåvang bridge. At Vålebru, the effect will be 11 cm during a 200-year flood. Additional sediment removal further south of the bridge will only produce a marginal further lowering of the waterline during flood events.

Priced consequences: All three options will be negative in terms of priced consequences.

Non-priced consequences: All three options are considered to have a positive impact on agriculture and pollution, while for the environment and for society, the measures are considered to have a medium/major negative and minor negative impact, respectively. The impact on the natural environment and fish will depend on the extent to which mitigation measures are implemented.

Assessment and prioritisation: Measure 17a has no major flood protection effect, but may be important for a large area of farmland in the event of large floods. There will probably be demand for the removed material, so the cost of the measure can be reduced. However, mitigation measures should be considered for fish and the natural environment. It is therefore proposed to further investigate the measure with the least sediment removal. However, the measure must be seen in the context of a possible flood tunnel or an adjustable weir at Tretten, which would be a more effective measure in terms of the waterline, thus making this measure unnecessary.

5.8.3 Risøya/Kvitfjell, Ringebu (26e)

Testing of a number of measures in the hydraulic model shows that there are very few measures that would have a beneficial effect on the waterline along the Gudbrandsdalslågen. This has led to the desire to further study measures that can enable farmland to better withstand flooding and also reduce damage to crops. This could involve profiling, trenching, and mixing in sand (see the document "*Guidance and Advice*"). In order to obtain sand for such measures, the possibility of removing sediments from the flatter areas of Gudbrandsdalslågen has been considered. Removal of 500,000 m³ of sand in the flat areas outside Kvitfjell has been considered.

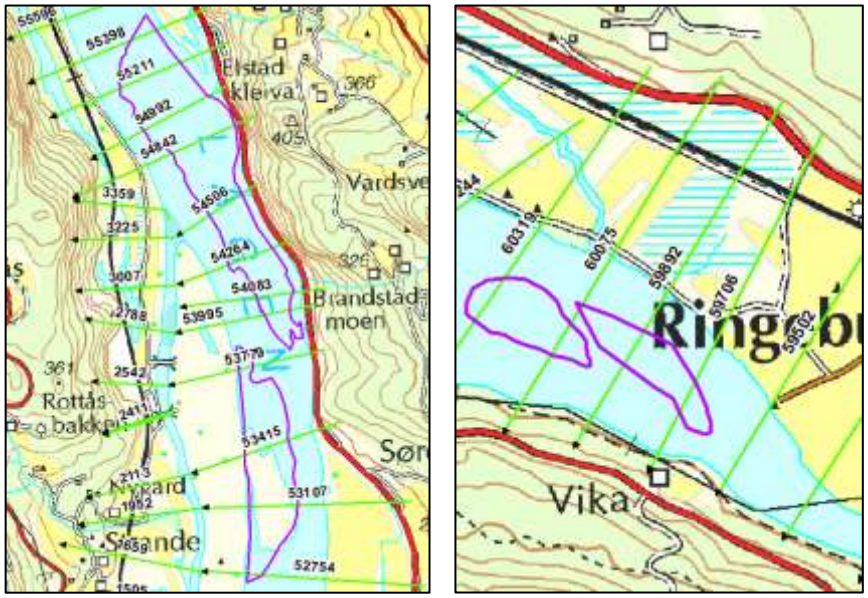

Figure 10. Map of assessed sediment removal sites at Risøya/Kvitfjell.

Flood control effect: Testing in the hydraulic model shows that the measure has no effect on the waterline.

Impact assessment: The measure came at a late stage of the planning work, and therefore no impact assessment has been carried out.

Assessment and prioritisation: If the agricultural sector views this as an interesting measure, it is proposed to study the measure further. A study must then include the consequences of the sediment removal itself, as well as the consequences that mixing in the sand will have on farmland.

5.8.4 Gåsøya and Olstadøya, Ringebu (21a, b, c, d)

At Gåsøya and Olstadøya, four alternative sediment removal sites have been assessed and tested.

Measure	Quantity	Cost estimate
21a Sediment removal site east of Gåsøya (I)	100,000 m³	NOK 20 million
21b Sediment removal sites west of Gåsøya and Olstadøya (II+III)	465,000 m³	NOK 93 million
21c Sediment removal sites west and east of Gåsøya and Olstadøya (I+II+III)	565,000 m³	NOK 113 million
21d Sediment removal site outside the outlet of the Våla (IV)	170,000 m³	NOK 34 million

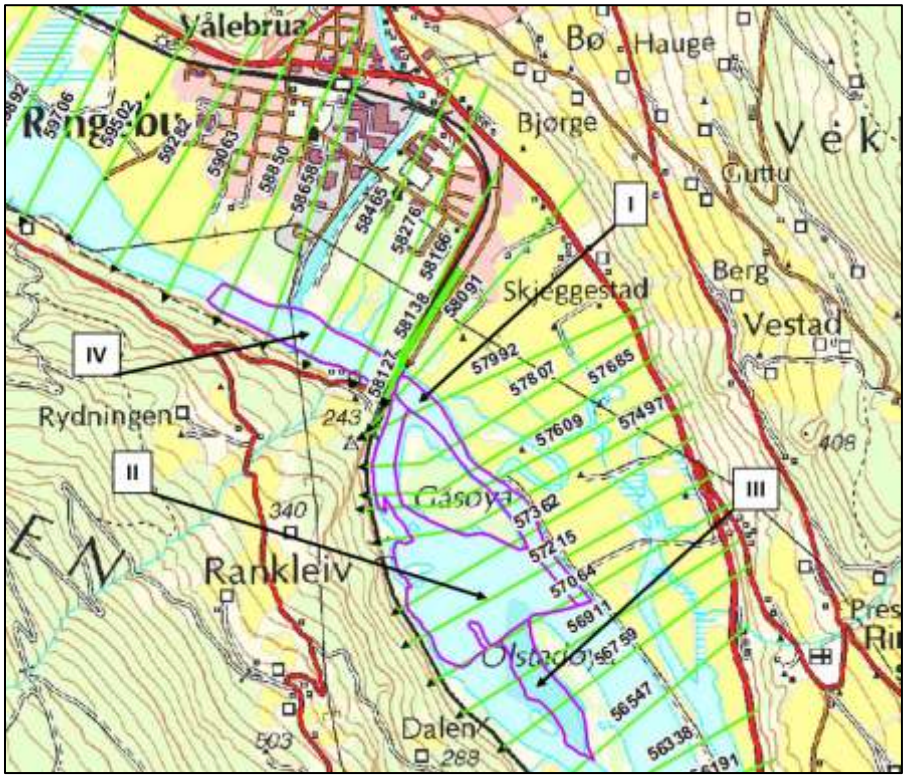

Figure 11. Map of assessed sediment removal sites at Gåsøya and Olstadøya.

Flood control effect: The results show that the largest sediment removal site (21c) could lower the waterline during smaller floods by up to 25 cm just below the railway bridge, but during a 200-year flood the effect is only 7 cm. Options 21a and 21b have only a limited effect of 13 cm and 16 cm respectively during a medium-sized flood and 4 cm and 4 cm during a 200-year flood. Sediment removal downstream of Våla (21d) could lower the water level just upstream of Våla by up to 33 cm during a 200-year flood, but the effect decreases rapidly upstream. At the outlet of the Frya, the water level will be lowered by 13 cm during a 200-year flood.

Priced consequences: The priced consequences are negative.

Non-priced consequences: The measure affects important natural assets and spawning areas, and is considered to have a major negative impact. The measure will have a limited effect on flood protection for the industrial area and farmland.

Assessment and prioritisation: The flood protection effect of this measure will be very marginal for larger floods. This is also a very expensive measure that will have to be repeated on a regular basis. The consequences for brown trout will also be very negative, and it is recommended not to proceed with this measure.

5.8.5 Risøya/Gunstadmoen/Børkøya/Langøya, Ringebu and Sør-Fron (26a, b, c, d)

At Risøya/Gunstadmoen/Børkøya/Langøya, four alternative sediment removal sites have been assessed and tested.

Measure	Quantity	Cost estimate
Sediment removal directly upstream and on the sides of Risøya and Børkøya (26a)	180,000 m³	NOK 36 million
Sediment removal upstream of the outlet of the Frya (26b)	190,000 m³	NOK 38 million
Combination of 26a and 26b (26c)	370,000 m³	NOK 74 million
Measure 26c + sediment removal right at the outlet of the Frya	453,000 m³	NOK 90 million

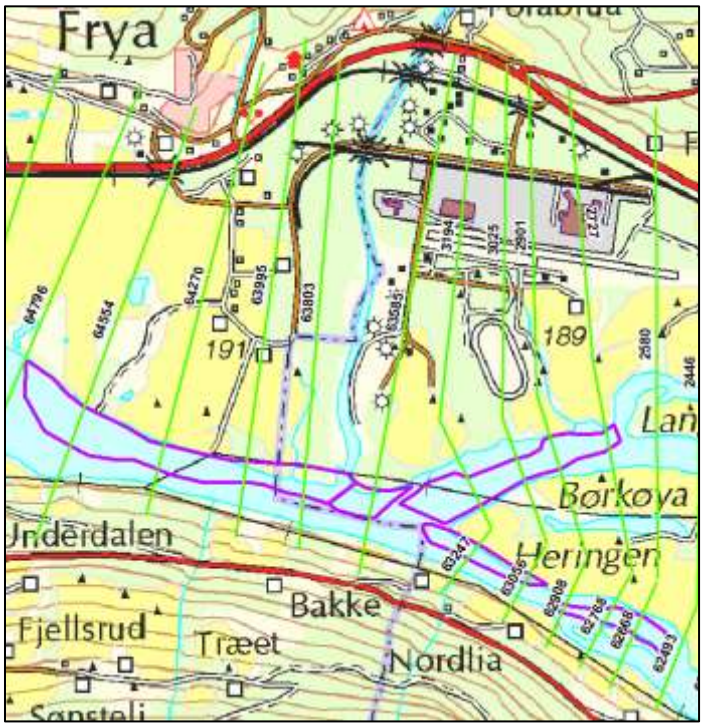

Figure 12. Map of assessed sediment removal sites at Risøya/Gunstadmoen/Børkøya/Langøya.

Flood control effect: The results show that the maximum sediment removal will lower the waterline by up to 36 cm during small floods. For larger floods, the measure will have a marginal effect.

Priced consequences: The impact assessments show that if sediment removal is to have a flood control effect, sufficiently large amounts of sediment must be removed that the cost of the measure will be very high. This is also a measure that will have to be repeated if it is not possible to limit sediment transport out to the Gudbrandsdalslågen from e.g. the Frya.

Non-priced consequences: The measure affects important fish habitats and is considered to have a major negative impact on the natural environment and fish. Furthermore, it is considered to have medium positive consequences for industry (for smaller floods) and in society.

Assessment and prioritisation: It is recommended not to proceed with this measure as it has only a marginal flood protection effect, a high cost and a major negative impact on fish and the natural environment.

5.8.6 Jetlund, Sør-Fron (29)

A sediment removal site has been assessed and tested at Jetlundsanden.

Measure	Quantity	Cost estimate
Sediment removal at Jetlundsanden	532,000 m³	NOK 106 million

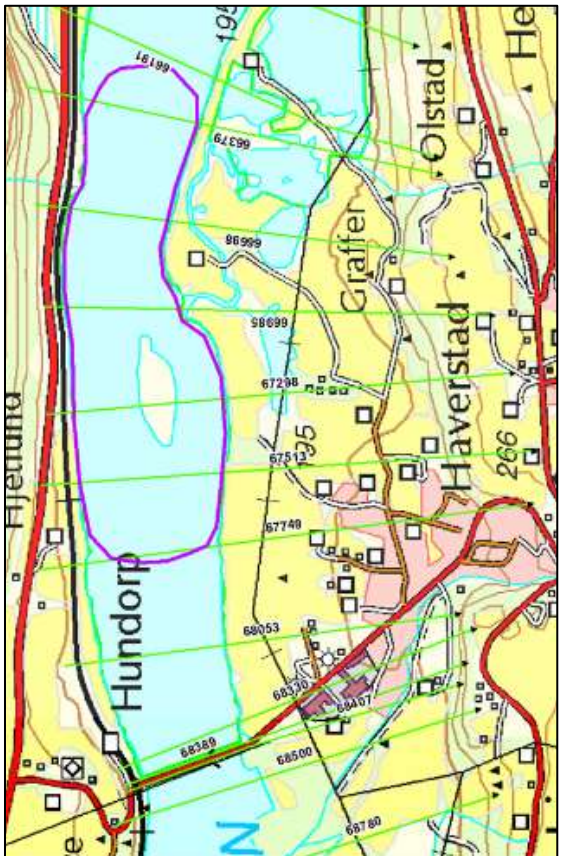

Figure 13. Map of sediment removal site at Jetlundsanden.

Flood control effect: The results show that the measure has no flood protection effect.

Priced consequences: The priced consequences are negative.

Non-priced consequences: The consequences for fish and the natural environment are negative.

Assessment and prioritisation: It is recommended not to proceed with this measure as there is no flood protection effect.

5.8.7 Solhjem, Sel (25b)

A sediment removal site has been assessed and tested at Solhjem.

Measure	Quantity	Cost estimate
Sediment removal at Solhjem	125,000 m³	NOK 25 million

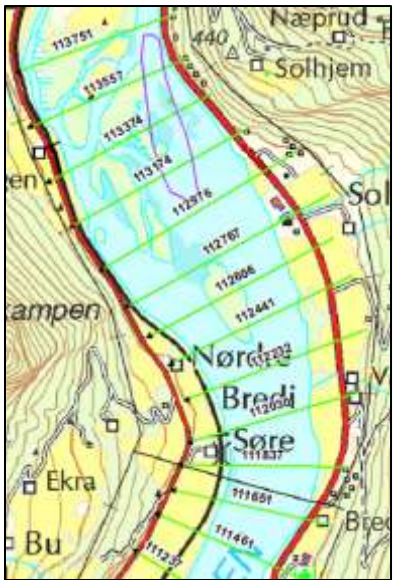

Figure 14. Map of sediment removal site at Solhjem.

Flood control effect: The measure has no significant flood protection effect.

Priced consequences: Negative.

Non-priced consequences: The measure is considered to have a major negative impact on the natural environment and fish.

Assessment and prioritisation: It is recommended not to proceed with this measure.

5.8.8 Otta, Sel (36)

A sediment removal site has been assessed at Otta.

Measure	Quantity	Cost estimate
Sediment removal at Otta	25,000 m³	NOK 5 million

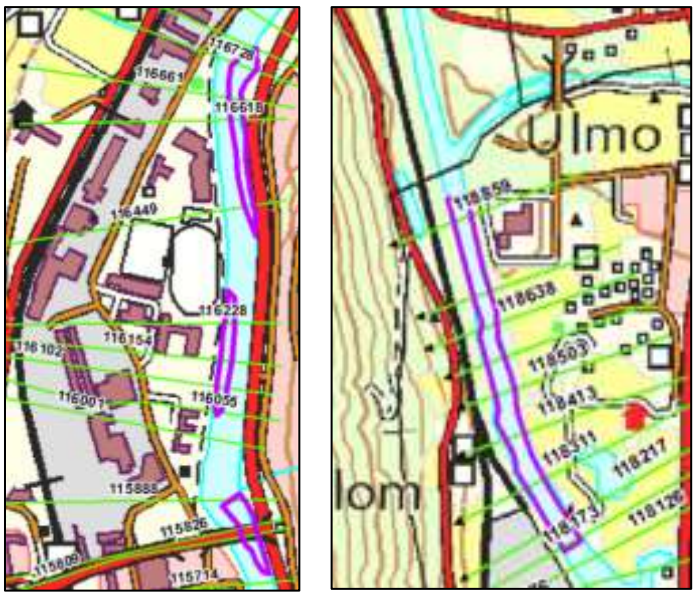

Figure 15. Map of assessed sediment removal sites at Otta.

Flood control effect: The measure will reduce flood water levels from Ulvolden to Selsverket. The measure could reduce flooding at some points towards Otta town centre by up to 17 cm. The overall effect for the buildings in Otta is considered to be minor.

Priced consequences: Negative.

Non-priced consequences: The measure is considered to have a medium negative consequence for fish but has positive consequences for pollution, industry and society.

Assessment and prioritisation: It is important to implement the measures to improve the safety of Otta town centre.

5.8.9 Selsvollene, Sel (39a, b, c)

Three alternative plans for lowering the river bottom have been assessed and tested at Selsvollene.

Measure	Quantity	Cost estimate
Lowering river bottom 30 cm (39a)	150,000 m³	NOK 30 million
Lowering river bottom 60 cm (39b)	298,000 m³	NOK 60 million
Lowering river bottom 90 cm (39c)	447,000 m³	NOK 89 million

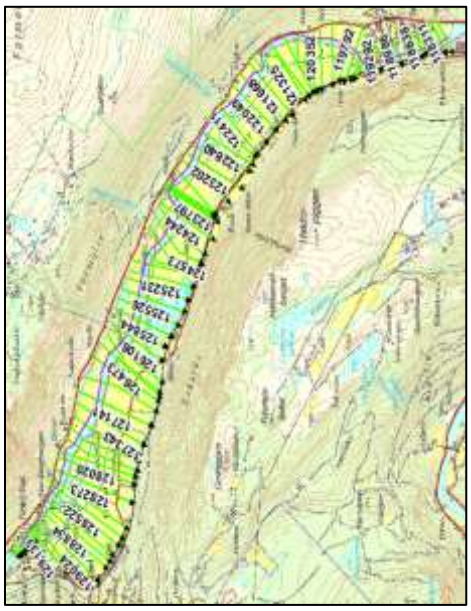

Figure 16. Map of assessed sediment removal sites at Selsvollene.

Flood control effect: Option a) will only reduce flood water levels in the upper half of Selsvollene. Options b) and c) will reduce flood water levels along the entire stretch by up to around 50 and 60 cm, respectively. For option b) the effect will be greatest at medium flow (small floods), while option c) will have a relatively large effect for all flood levels.

Priced consequences: Options a) and c) negative. Option b) 0.

Non-priced consequences: Options b) and c) will have a positive impact on industry/agriculture and pollution. The measure is considered to have a major negative impact on the natural environment.

Assessment and prioritisation: It is recommended not to proceed with this measure.

5.9 Recommended measures in the Gudbrandsdalslågen, summary

- Sediment removal at Fåvang bridge, option a) should be studied further.
- Sediment removal at Risøya/Kvitfjell for soil improvement should be studied further.
- Sediment removal in the Gudbrandsdalslågen as part of the flood protection plan for Otta town centre

6. Flood embankments

6.1 Flood embankments as protection measures

This chapter describes flood embankments that have been assessed and tested in the hydraulic model. Further descriptions of the various measures can be found in the following reports:

- Hydraulic calculations – The Gudbrandsdalslågen (*Hydrauliske beregninger – Gudbrandsdalslågen*), Dr Blasy and Dr Øverland
- Flood protection measures in the Gudbrandsdalslågen and its tributaries – Impact assessment (*Flomsikringstiltak i Gudbrandsdalslågen med sidevassdrag - konsekvensvurdering*), Asplan Viak

Which types of areas are suitable for flood protection with flood embankments

Generally, the capacity to transport large amounts of water is better on the stretches where the river is wide and slow-flowing than on stretches where the river is narrow. That is, constructing a flood embankment along the river bank on a broad stretch of the river will most often have little effect on the waterline, and will only to a small extent affect other areas further upstream, downstream or on the opposite river bank. On such stretches, establishing a flood embankment can be a good measure to protect farmland and buildings.

On stretches where the river is narrower, the capacity to transport water will be poorer in the event of high through-flow. The waterline on these stretches is affected to a greater extent by various measures, but this also largely depends on the water velocity. A flood embankment along the river bank here will most often raise the waterline to a greater extent, which may have a negative impact on other areas upstream, downstream or on the opposite side. Read more about the placement of flood embankments, overflows, design, etc. in the document "*Guidance and Advice*".

6.2 Assessed measures

6.2.1 Jørstadmovollene south, Lillehammer (2a, 3a, b)

At Jørstadmovollene south, three different alternatives for flood embankments have been assessed: one that runs along the edge of the river, one that is right up close to the buildings and one that is a little way from the river, on farmland.

Figure 17. Map of assessed flood embankments at Jørstadmovollene south, 2a, 3a and 3b.

Measure	Length	Cost estimate
Flood embankment along the river bank (2a)	930 m	NOK 4.6 million
Flood embankment close to the buildings (3a)	1,400 m	NOK 7.0 million
Flood embankment on farmland (3b)	950 m	NOK 4.8 million

Flood control effect: The results of the hydraulic calculations show that none of these flood embankments would have a significant effect on the waterline in a flood situation. The impact assessment shows that the option where the flood embankment is constructed close to the buildings is not appropriate because the buildings and infrastructure are not directly threatened by flooding.

Priced consequences: The priced consequences will be negative for all three options.

Non-priced consequences: A flood embankment on the river bank will have a positive impact on pollution and industry/agriculture, but a small negative consequence for fish and a large negative impact on the natural environment.

A flood embankment a little way away from the river is considered as negative for the cultural environment, the landscape and agriculture. There will be a risk of increased erosion and runoff of agricultural soil to the Lågen if current protection measures are removed. The measure involves returning the river bank to a more natural situation and may be beneficial for the natural environment.

As a mitigation measure, it is proposed to create an embankment within the zone with alluvial vegetation, and maintain the existing spillway. The area is located within the Lågen delta nature reserve and Lågen delta bird sanctuary, and measures here must be clarified according to conservation regulations.

Assessment and prioritisation: It is recommended to continue working with option 3b. This option may be beneficial for the natural environment as it returns the river bank to a more natural situation, but the negative consequences of appropriating farmland must be weighed against the flood protection effect gained for 62 acres of farmland west of a new flood embankment. The measure must be studied in advance and clarified according to the conservation regulations for the Lågen delta nature reserve and the Lågen delta bird sanctuary.

6.2.2 Lower parts of the Gausa, Lillehammer (12a, b, d)

Several alternatives for flood embankments have been assessed in the area in the lower parts of the Gausa.

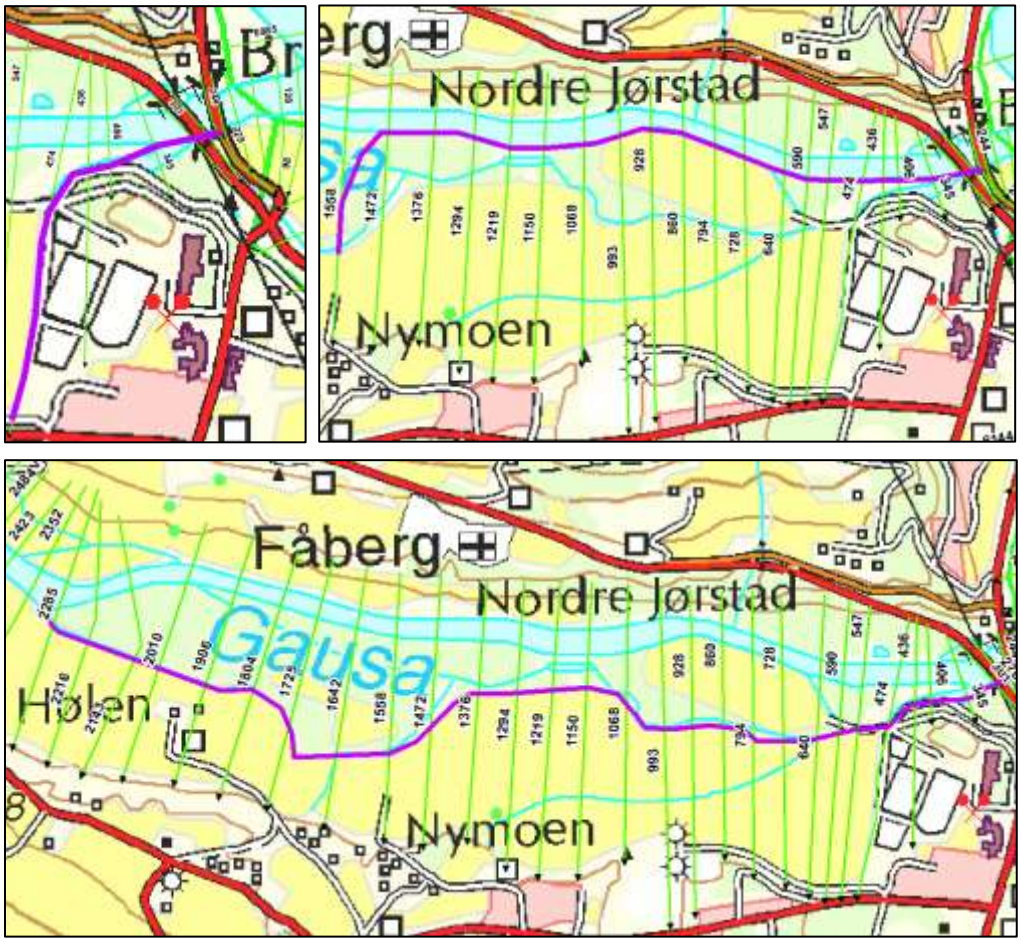

Figure 18. Map of assessed flood embankments in the lower parts of the Gausa.

Measure	Length	Cost estimate
Flood embankment that only protects the Jorekstad sports facility (12b)		
Flood embankment on the river bank along the lower parts of the Gausa protecting housing, the Jorekstad sports facility and farmland (12a)	1 km new embankment 600 m raising of embankment	NOK 13 million
Flood embankment along the edge of the field protecting residential housing, the Jorekstad sports facility and farmland, but which preserves the alluvial forest along the Gausa (12d).	Move 400 m of embankment and build 200 m new embankment	NOK 4 million

Flood control effect: The flood embankment around the Jorekstad sports facility has no effect on the waterline in a flood situation, while the other two options will raise the waterline along this stretch. However, this will not lead to increased damage, as the flood embankment will protect farmland, houses and the Jorekstad sports facility.

Priced consequences: Positive for all three options.

Non-priced consequences: Option 12a affects important natural assets in protected areas and is considered to have a major negative impact on the natural environment. The flood embankment will have a negative impact on the landscape and the cultural environment. The measure is considered to be positive for pollution, industry and society (the sports facility).

Option 12b is considered to have negative consequences for the landscape, pollution, the cultural environment and agriculture. The measure entails returning the river bank along the Gausa to a more natural state and is considered to be positive for fish. Depending on how this is implemented, it may also be beneficial to the natural environment. The measure will protect the Jorekstad sports facility against flooding. Option 12d is considered to be negative for the landscape, the cultural environment and pollution, while it is considered to have positive consequences for society, industry and the natural environment.

Assessment and prioritisation: Measure 12d will protect housing, the Jorekstad sports facility and farmland. It is recommended to continue working with this measure.

6.2.3 Kvitfjell (Strande/Mæhlum), Ringebu (18a, b, 19)

Two flood embankment options and an opening of a spillway at Strande/Mæhlum have been assessed.

Measure	Length	Cost estimate
Raising of existing flood embankment (18a)		
Moving flood embankment towards the railway (18b)	4,800 m	NOK 24 million
Open spillway (19)		

Flood control effect: Moving the embankment and raising the embankment will have very little effect on the waterline at different flood intervals. Both measures will also provide good protection of the railway, and raising the flood embankment will also provide good protection of farmland on the inside of the embankment. Measure 19 has no effect on the waterline during a flood.

Priced consequences: The priced consequences are considered negative for all three measures.

Non-priced consequences: Moving the flood embankment is considered to have positive consequences for the natural environment and society (the railway), while it may have negative

consequences for industry/agriculture, pollution and the landscape. Opening the weir could have positive effects on natural resources, the natural environment and fish, by bringing the river closer its natural state and preventing overgrowth in the long run.

Assessment and prioritisation: This is a measure that will primarily protect farmland. Whether it has significance for the railway should be studied further. Further study is recommended concerning raising the flood embankment. However, the possibility of opening the spillway so that water flows there during normal through-flow should be examined. This could improve the conditions for fish. However, in order to protect farmland, it is important that there is not much water there during a flood situation, and gates that can be closed at both ends during a flood should be investigated as a possibility.

6.3 Recommended flood embankments, summary

- Construction of flood embankment to protect farmland along Jørstadmovollene
- Construction of flood embankment to protect houses, the Jorekstad sports facility and farmland along lower parts of the Gausa
- Raising of flood embankments to protect farmland and the railway at Kvitfjell

7. Possible measures to reduce flood water level in Losna Lake

This chapter describes measures that have been assessed and tested in the hydraulic model. Further descriptions of the various measures can be found in the following reports:

- Hydraulic calculations – The Gudbrandsdalslågen (*Hydrauliske beregninger – Gudbrandsdalslågen*), Dr Blasy and Dr Øverland
- Flood protection measures in the Gudbrandsdalslågen and its tributaries – Impact assessment (*Flomsikringstiltak i Gudbrandsdalslågen med sidevassdrag - konsekvensvurdering*), Asplan Viak

Hydraulic calculations show that during large flood events, the water level in Losna Lake determines how high the water level is in the Lågen all the way up to Fåvang, and also affects the water level right up to Vålebru. Sediment removal on the stretch from Losna to Fåvang will therefore have little effect on the waterline in flood situations on this stretch.

In order to reduce damage along the main watercourse from the area south of Vålebru and down to Tretten, it is more effective to lower the flood water level in Losna Lake than to carry out regular sediment removal. As a long-term flood protection measure, lowering the flood water level in Losna Lake will probably be the most effective measure. While working on the plan, three different solutions were therefore considered to lower the flood water level.

7.1 Assessed measures

7.1.1 Lowering of Trettenstryka, Øyer (15b)

One possible measure is to lower Trettenstryka itself by removing large quantities of gravel and stone. Without any additional measures, this will permanently lower the water level in Losna Lake.

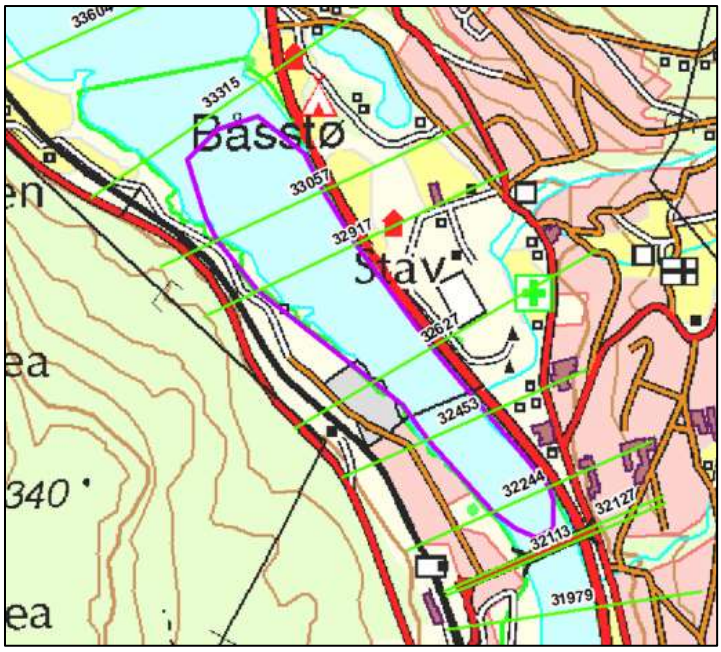

Figure 19. Area tested for sediment removal in Trettenstryka.

Measure	Quantity	Cost estimate
15a Sediment removal	90,000 m³	NOK 18 million
15b_0 Sediment removal	170,000 m³	
15b_1 Sediment removal	624,000 m³	NOK 125 million

Flood control effect: Impact assessments show that measures 15a, 15b_0 and 15b_1 will lower the flood water level in Losna Lake by 7 cm, 54 cm and 78 cm, respectively, during a 200-year flood. At Fåvang bridge, the various measures will lower flood water levels during a 200-year flood by 5 cm, 42 cm and 54 cm, respectively. At the outlet of the Våla, the various measures will mean a lowering of the water level during a 200-year flood by 2 cm, 12 cm and 16 cm, respectively.

Priced consequences: Negative.

Non-priced consequences: The measure will have major negative effects on the natural assets in the river. Two nature reserves will be affected, and important spawning and breeding environments for brown trout will be destroyed.

7.1.2 Adjustable weir in Trettenstryka, Øyer (15d)

Combining a lowering of Trettenstryka with an adjustable weir upstream of the lowered area will allow normal water levels to be maintained, but lower the flood water level.

Flood control effect: Will be the same as options 15a, 15b_0 and 15b_1.

Priced consequences: Negative.

Non-priced consequences: The measure is largely similar to 15b. Constructing an adjustable weir that maintains the normal water level at the current level could reduce the negative consequences for the natural environment somewhat compared with permanently lowering Trettenstryka. However, it will cause major damage to the natural assets along the stretch.

7.1.3 Flood tunnel at Tretten, Øyer (15c)

A third alternative would be to construct a flood tunnel from above Trettenstryka and past the rapids. Here, three different alternatives have been simulated with a capacity of 500, 1,000 and 1,500 m³, respectively.

Flood control effect: Impact assessments show that a flood tunnel with a capacity of 500, 1,000 and 1,500 m³, respectively, will lower the flood water level in Losna Lake by 55 cm, 108 cm and 158 cm, respectively, during a 200-year flood. At Fåvang bridge, the various measures will lower flood water levels during a 200-year flood by 42 cm, 70 cm and 88 cm, respectively. At the outlet of the Våla, the various measures will mean a lowering of the water level during a 200-year flood by 12 cm, 20 cm and 25 cm, respectively. A tunnel with a capacity of 1,000 m³/sec will reduce the flood water level right up to the outlet of the Frya (reducing the flood water level by up to 20 cm for a 200-year flood), but will have the greatest effect up to Trøstakervollene (a reduction of up to 50 cm for both small and large floods).

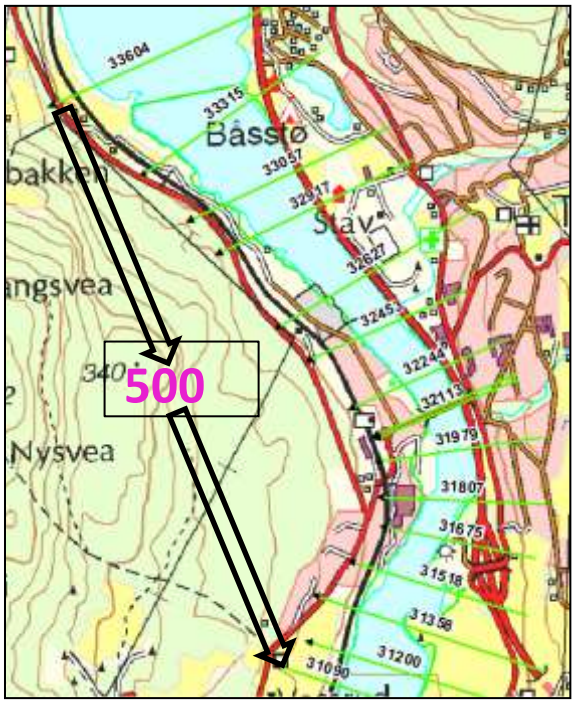

Figure 20. Map of possible flood tunnel at Tretten.

Priced consequences: Negative.

Non-priced consequences: The measure is considered to have a major negative impact on the natural environment. However, the extent of damage will not be nearly as great as with the two

lowering measures, as it will not physically affect the nature reserve directly. However, in order to protect the natural assets, it is important that smaller floods, up to ten-year floods, are allowed to run in the river as normal, as regular flooding is essential for protecting the natural assets.

Assessment and prioritisation of the three measures: Testing shows that lowering the flood water level in Losna Lake will be the most effective measure to lower flood water levels from Tretten and around 30 km upstream. The impact assessment has concluded that these measures could harm the natural assets. The two measures that involve lowering Trettenstryka will have the most negative consequences. These are very costly measures, and the impact assessment estimates a cost for an adjustable weir to be a minimum of around NOK 130 million. The cost of operating a flood tunnel is estimated at NOK 105 million. In addition, there would be transverse tunnels, access roads, hatches/gates, intake structures and unforeseen expenses. Given that both lowering measures involve major damage to the nature reserve, it is recommended not to proceed with these measures.

The flood tunnel does not directly affect the most valuable stretch, and assuming flooding up to a 10-year flood can continue as normal, this could be a good measure. It is therefore recommended to explore the possibility of a flood tunnel, but it is important to see the need for such protection against the work now being done at Fåvang with a local flood embankment that will protect, among other things, Fåvang Sag.

7.2 Recommended measures

- Further examine the possibility of a flood tunnel past the rapids at Trettenstryka.

8. Other specific measures to reduce flood damage

This chapter describes other measures that have been considered. Further descriptions of the various measures can be found in the following reports:

- Relevant measures in the tributaries to the Gudbrandsdalslågen (*Aktuelle tiltak i tilløpselver til Gudbrandsdalslågen*). Memorandum – NVE and Oppland County 2017
- Hydraulic calculations – The Gudbrandsdalslågen (*Hydrauliske beregninger – Gudbrandsdalslågen*), Dr Blasy and Dr Øverland
- Flood protection measures in the Gudbrandsdalslågen and its tributaries – Impact assessment (*Flomsikringstiltak i Gudbrandsdalslågen med sidevassdrag - konsekvensvurdering*), Asplan Viak

8.1 Jora, Lesja (C)

Following the flood in 2011, the NVE implemented a measure to direct most of the flow to the south-eastern branch of the river (top star in Figure 41). The purpose of this is to prevent further erosion on the fields adjacent to the Jora delta on the Lesja side, and to prevent water from being diverted towards the waterworks in Dovre municipality. The weir that was intended to direct the water was built from local, very coarse material. A physical inspection on 16 June 2016 showed that much of this weir had been washed away by the water. Currently, only a small amount of water is present in the north-western branch of the river, but in the event of a new major flood, there is reason to believe that the water could break through further and cause a larger part of the river to follow this route.

Figure 21: Aerial view of Jora. The upper star shows the weir that should be repaired, and the lower star shows the location of the waterworks.

In order to ensure that the south-eastern branch becomes the main branch, the weir should be repaired. The weir should be built with local material with a gradient of 1:3 on the water side and 1:10 on the land side. The foot of the weir on land and on the water side must be reinforced with coarse stones from the area to prevent erosion.

Assessment and prioritisation: To protect the waterworks and prevent further erosion, it is recommended to implement the measure.

8.2 Hjellåi, Dovre (D)

There have been extensive changes to the ravines up along the valley flanks in recent years, probably due to increased precipitation intensity. Increased sediment transport can be expected in the next few years, with an increased risk that the culvert under the railway line could become clogged. If this occurs during a period of heavy precipitation, a lake may form on the upper side of the railway embankment. There will be a great risk of a breach in the embankment, causing the railway line to collapse, and a flood wave could come down the valley flank, where two farms and the E6 could be damaged. The measures that have been assessed are to build a weir / sediment basin on the top side of the culvert, or to replace the culvert.

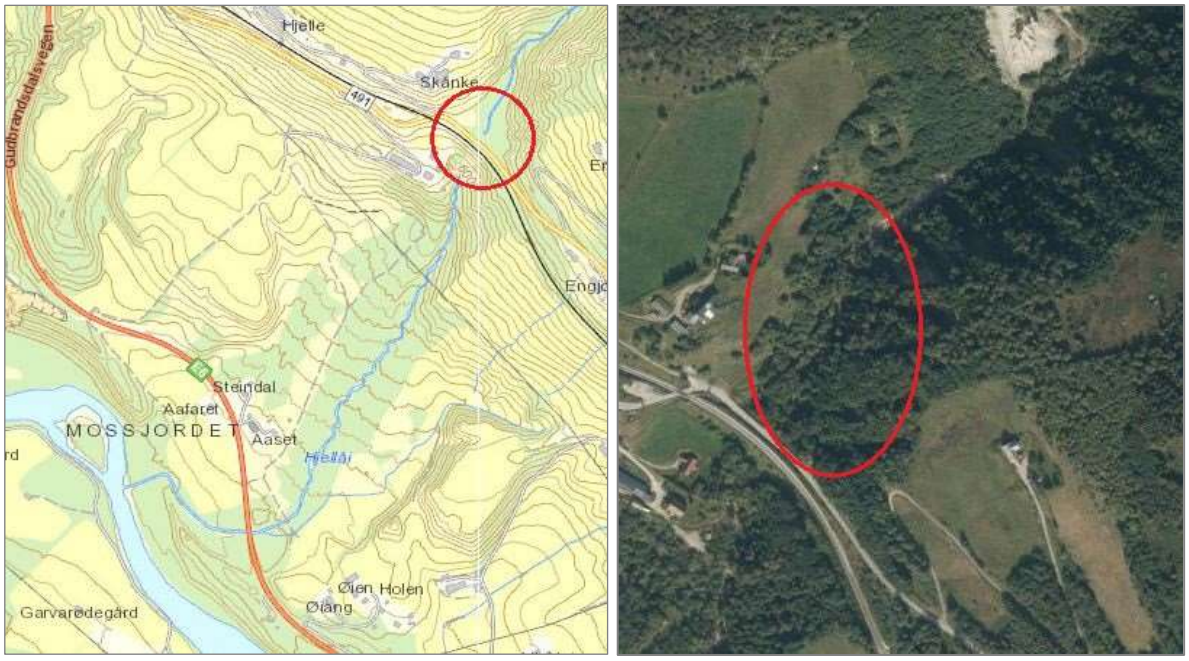

Figure 22. Map of relevant area where measures are being considered in the Hjellåi.

Priced consequences: Cost of dam with warning station: NOK 600,000. The benefit of the measure is associated with a probability assessment for a breach in the embankment. There is no basis or relevant need to calculate the estimated benefit of the measure. Possible risk to life and health related to any breach indicates that the measure should be taken. Establishing a sediment basin could be an adequate measure, but the final choice of solution should be assessed on the basis of a more detailed risk assessment and technical assessment of the area.

Non-priced consequences: None.

Assessment and prioritisation: This is a measure that must be prioritised and implemented. Initially, a warning station should be established that sends out an alert when the water level on the top side of the railway embankment rises, and a contingency plan should be created for the clean-up of the culvert in a crisis situation. Here too, an inspection procedure must be established to ensure that the culvert is open at all times, as well as the clearance of vegetation in the immediate vicinity of the river course up in the valley.

8.3 Hundorp bridge, Sør-Fron (30)

The bridge over the Lågen at Hundorp is partly built on an embankment in the river. This leads to a narrowing of the river course, and it is suspected that this could stop up the water upstream. Therefore, an assessment has been made of a measure to increase the gap under the bridge to see whether it would have any effect on the waterline in flood situations.

Figure 23. Hundorp bridge.

Flood control effect: The bridge does not stop up the water as it is today, and a larger gap would therefore have no effect.

Priced consequences: The priced consequences are negative.

Non-priced consequences: The measure will be positive for the landscape and for fish (except during the construction phase). The overall impact on nature and society is negative.

Assessment and prioritisation: It is recommended not to proceed with this measure.

8.4 Railway bridge near Sjoa, Sel (34)

Various measures to increase the gap under the railway bridge north of Sjoa have been assessed and tested. The measure has been tested with the idea of lowering the flood water level in the Lågen upstream.

Measure		Cost estimate
Replace today's railway bridge with a new and longer bridge		Cost of new bridge: NOK 25 million excl. VAT, plus administration costs and planning.
Replace today's railway bridge with a new and longer bridge, remove sediments from the river on either side of the bridge		Cost of new bridge: NOK 25 million excl. VAT, plus administration costs and planning. Cost of sediment removal: NOK 8 million

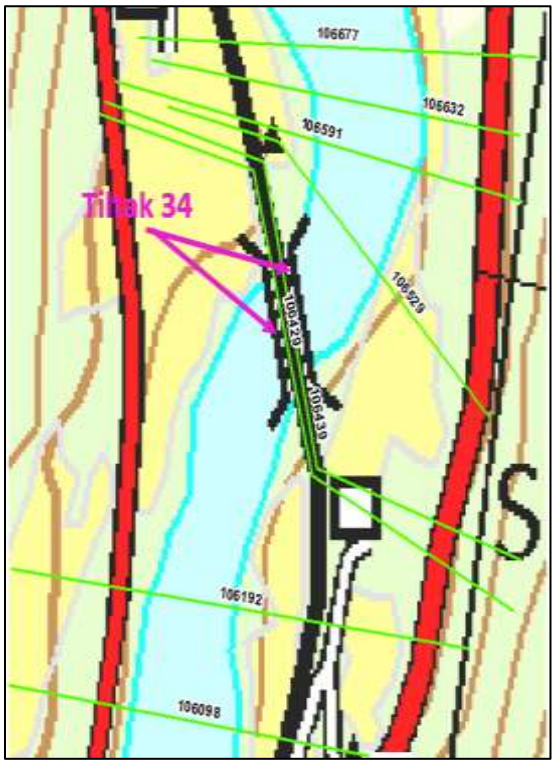

Figure 24. Railway bridge near Sjoa.

Flood control effect: The measures will reduce flood water levels upstream of the railway bridge and almost up to Otta. Replacing the bridge alone will reduce flood water levels by up to around 60 and 90 cm during a small and large flood, respectively, while the combined measure will reduce flood water levels by up to around 70 and 100 cm during a small and large flood, respectively.

Priced consequences: The measure will likely reduce flood damage to farmland in the areas closest to the Lågen.

Non-priced consequences: The measure is considered to have a medium negative impact on the natural environment, but may be beneficial to fish and the landscape.

Assessment and prioritisation: There is great uncertainty linked to price estimates for a new railway bridge. It is proposed not to investigate the measure further.

8.5 Measures in agriculture to reduce flood damage

Based on current forecasts, we must expect more precipitation in the coming years. This will lead to increased risk of flooding and damage. Measures must therefore be implemented to make society better equipped to cope with these challenges, including in agriculture.

The area along the Gudbrandsdalslågen is mostly agricultural land, which is vulnerable to flooding during major floods. It will not be possible to protect these areas 100 per cent against flooding during larger floods. On the other hand, it is possible to implement measures to make the land better able to cope with flooding, which will reduce flood damage and damage to crops, while still taking into account the natural environment in the watercourse. This implies, however, that we must take an innovative approach in many areas in relation to how the land is managed and designed.

Relevant measures are:

- Profiling the land
- Drainage of surface water
- Trenching
- Channelising
- Sand mixing

The document "*Guidance and Advice*" provides advice on how agricultural land should be prepared to handle flooding as well as possible. Work has been started to find out areas in which such measures may be appropriate. It is important to continue this work during the planning period.

8.6 New routes for the E6 – impact on the waterline in the Gudbrandsdalslågen

In connection with the planning work, the hydraulic model has tested the effect of certain alternative routes for the new E6 on the waterline in the Lågen.

Elstad–Frya: The "Inner Line" (*Indre linje*) and "Lågen Line" (*Lågenlinje*) on the Elstad–Frya stretch have been assessed and tested in the hydraulic model.

Flood control effect: It is assumed that the water balance will remain unchanged, i.e. the E6 is not planned as an impenetrable flood embankment. The hydraulic model shows that the Lågen Line will lead to an increase in the waterline of up to 22 cm during larger floods, while the Inner Line will raise the waterline during flood situations by up to 9 cm.

Impact assessment: The Lågen Line has negative consequences for the natural environment and the cultural environment. The measure will result in the appropriation of extremely valuable natural habitats north of the Elstad campsite. The measure has positive consequences for industry and society. The measure will reduce runoff from farmland.

The Inner Line may be positive for wetlands, but could lead to increased pollution due to increased runoff from farmland. Constructing the E6 entails appropriating farmland, but the measure will protect areas inside from flooding.

Assessment and prioritisation: It is not the mandate of this plan to prioritise which route should be built, but it can be concluded that the outer line will lead to an increased flood risk for some areas in Ringebu, and that sediment removal in the Lågen will not be able to compensate for this.

9. Competence-boosting initiatives and cooperation

Damage records show that much of the damage comes from events in the hillsides and is associated with human intervention. These are interventions that lead to increased and changed runoff, increased sediment transport, and thus increased damage levels. There must be focus on ensuring that roads and interventions in the landscape do not lead to increased risk of erosion, and that the water will run off where nature itself has prepared the way. These areas are more stable than where people have altered the terrain. There is a lot to be gained here by looking at the construction and maintenance of roads, culverts, farmland and forestry.

During work on this plan, it has not been possible to plan in detail all measures needed on the valley flanks. There are hundreds, if not thousands, of measures required. On the other hand, the planning process indicates that it is very important to increase the competence of different actors in terms of various climate adaptation measures. This applies to target groups such as municipalities, contractors, landowners, Bane NOR, the Norwegian Public Roads Administration and the consulting industry.

In particular, the areas that require more expertise are:

- Planning, construction and maintenance of roads
- Planning and implementation of measures in watercourses such that they both take consideration of river wildlife and reduce the damaging effects of floods
- Forestry – planning and execution of felling, as well as transporting timber out of the area

Therefore, in terms of competence-boosting initiatives, a number of courses and topical seminars have been initiated and held, and it is recommended that more be held. This chapter provides an overview of offerings that should be prepared.

9.1 Planning and cooperation

Experiences after the recent major flood events have shown that there is a need for better cooperation between the various actors in order to achieve more comprehensive planning and implementation of measures. It is therefore important to increase competence within flood and landslide protection and to determine how this can be done within different actors to preserve natural assets.

Land planning in areas vulnerable to flooding and landslides

The flooding and landslide events in recent years have in some cases caused major damage to settlements and infrastructure. It is therefore important that the municipalities be aware of their responsibility to ensure that considerations related to flooding and landslides are properly addressed during land planning.

Need: The NVE's professional development days. Concrete meetings with the municipalities, either through regional planning forums in Oppland or specific meetings with individual municipalities where concrete plans or issues are discussed. The NVE is continuing to work on professional development days based on feedback provided during previous professional development days.

Target group: Municipal executive officers.

Use of flood maps in land planning and administrative work related to the Norwegian Planning and Building Act.

Flood maps are a useful tool for finding out where the water may flow during periods of heavy precipitation in a short period of time. The Oppland County Governor, Bane NOR and the Norwegian Mapping Authority have now prepared flood maps for large parts of Hedmark and Oppland. They are a tool that can be used in land planning, building applications, road planning and tree felling, etc.

Need: Course in the use of flood maps for planning in smaller catchment areas.

Completed: In the autumn of 2016, a course was held on how to use flood maps, and examples were given of how different municipalities have made use of them. However, there will be a need for further training.

Target group: Area planners, executive officers processing building applications, technical agencies, emergency planning officers, Bane NOR, the Norwegian Public Road Administration, the forestry industry, the consultancy industry and GIS consultants.

Operational activities / technical agency

The flooding and landslide events in recent years have in some cases caused major damage to settlements and infrastructure. It is therefore important that the municipalities be aware of their responsibility to ensure that considerations related to flooding and landslides are properly addressed during day-to-day operations. This could include the operation and maintenance of culverts, flood ways, etc.

Need: Course / topical seminars for municipal employees who are responsible for day-to-day operations, road inspections, etc.

Target group: Municipal technical agencies, operations managers at the Norwegian Public Roads Administration, Bane NOR, etc.

Professional development days regarding flood and landslide protection measures for an interdisciplinary group

Experiences after the recent major flood events have shown that there is a need for better cooperation between the various actors in order to achieve more comprehensive planning and implementation of measures. In this connection, it may be appropriate to create meeting places and space for knowledge-sharing across areas of responsibility. Such professional development days can be held one or two times a year.

Need: Professional development days on flooding and landslides.

Target group: Area planners, executive officers processing building applications, technical agencies, emergency planning officers, Bane NOR, the Norwegian Public Road Administration, the forestry industry, the consultancy industry and machine contractors.

Landowner's responsibility, role and rights

The responsibility, role and rights of landowners in relation to watercourses can be perceived as complicated and unclear. This is the case in relation to flood prevention measures, liability for damage, ownership, and what should be done on their own property in order to better be equipped to handle damage caused by flooding. Work on the plan has revealed a need to communicate knowledge and boost competence in this field, and a clarification of the legislation.

Need: Professional development days / seminars / courses, leaflets.

Target group: Landowners.

Routines for comprehensive planning

In flood damage prevention work, it is important to take a holistic approach and have good cooperation in terms of relevant issues, land, and financial considerations. It is therefore important to have established routines for competence-boosting and cooperation between different agencies.

Need: Based on the NVE's comprehensive management model for landslide and flood damage prevention, routines should be developed to guide how competence-boosting and cooperation between agencies should be handled regionally.

Target group: Municipalities, County Governor, county council and state authorities.

Regional planning forums

Regional planning forums are a formal meeting point in accordance with the PBA, arranged once a month by the County Council. The purpose of the meetings is for municipalities to present municipal plans and other development plans to get input and as many binding statements as possible on these plans.

Need: It is desirable to make greater use of planning forums for matters relating to landslides and floods.

Target group: Municipalities, County Governor, county council and state authorities.

9.2 Roads – planning, construction and maintenance

Administrative procedures for road construction

The municipalities are responsible for approving the construction of private roads, forest service roads and municipal roads. They also have a supervisory responsibility for these. Unfortunately, many municipal executive officers lack knowledge of what requirements must be made for the construction process and road design to ensure that they do not represent an increased risk of flooding and landslides.

Need: Course in administrative procedures for matters related to roads.

Skogkurs has, in cooperation with Oppland County Council, the Oppland County Governor, Mjøsen Skog and Skog og Landskap, developed a course plan entitled “Prevention of landslide and flood damage in road and land management in Gudbrandsdalen”. Three courses were conducted in Gudbrandsdalen (Midt-Dalen, Nord-Dalen and Sør-Dalen) in winter 2016. Fifty executive officers from the agriculture, land planning, technical and emergency preparedness departments of the twelve municipalities in Gudbrandsdalen and seven representatives from Mjøsen Skog’s forest management team participated in the meetings in addition to the lecturers.

There will be a need to further develop this topic and follow up with new professional development days.

Target group: Municipal executive officers, forest service road planners.

Construction and maintenance of roads focusing on water management

Incorrect construction of roads and poor maintenance is the cause of much of the damage in Gudbrandsdalen during recent floods. There should therefore be a focus on correct procedures to ensure that roads can meet the challenges of large amounts of precipitation. Planning is important, but it is also important that the person doing the practical work has good knowledge of this matter.

It is important to gain insight into how concrete measures that address issues related to flooding and landslides should be included in the basic training of machine drivers. This is especially true within agriculture, fishing and forestry in the upper secondary programme Forestry and Construction Technology, or any other relevant programmes. It is also important to update the knowledge of many existing contractors.

Need: New subject in education of new machine drivers (upper secondary education). In-service training for contractors.

Target group: Machine contractors, new and existing.

9.3 Measures in watercourses

Administrative processing – measures in watercourses

There is a need for more knowledge in the municipalities about what is required in terms of administrative procedures for measures in watercourses. This applies to those who will be making consultative statements, which legislation should be used when processing measures, etc. This can be solved by means of a course for the municipalities. The NVE regularly holds professional development days for the municipalities, and the administrative processing of measures in watercourses should be included as a topic on one of these days.

Need: Course in administrative processing of measures in watercourses.

Target group: Municipal executive officers.

Planning of measures in watercourses – How to safeguard flood, landslide and environmental considerations

Municipalities are often responsible for measures that affect watercourses, such as river crossings in connection with water and wastewater plants, new construction work, road construction, etc. Furthermore, actors such as Bane NOR and the Norwegian Public Roads Administration are constantly implementing measures either to repair damage or in connection with the design of new roads etc.

Sometimes, these actors perform the design and planning work, but consultants are often hired in to do the work. Here, one can see that many measures are planned without taking into account the risk of flooding and landslides or environmental considerations. There is therefore deemed to be a need for a knowledge boost within this topic, both for those responsible for designing and planning such measures and for those who may order such services.

Need: Courses and professional development days on planning measures in watercourses.

Target group: Municipalities, the Norwegian Public Roads Administration, Bane NOR, consultancy firms.

Practical implementation of measures in watercourses

Floods often result in a need for clean-up in small and medium-sized streams and rivers. There may also be a need for protection against future floods and landslides with flood embankments, erosion protection embankments, etc. Many of these streams and rivers have brown trout populations which it is important to protect for both biodiversity and recreational reasons.

In recent years, the NVE has spent a lot of time on preliminary inspections and planning and implementing such measures. Many measures have been implemented as emergency measures, and have been implemented without taking into account aquatic life.

In many cases, the NVE's own machine drivers perform this work, and they have extensive experience of excavations in rivers. Due to the scope of measures in recent years, it has been

necessary to hire local contractors for some assignments. These are skilled contractors, but many lack the knowledge and experience of implementing measures in watercourses. In many places, rivers and streams now have a design that is poorly suited for fish habitats. Therefore, competence-boosting initiatives should be developed for machine contractors who will be implementing measures in watercourses, so that it is possible to protect fish and aquatic life while also preventing future damage to buildings, roads and farmland.

Need: New subject in education of new machine drivers (upper secondary education). In-service training for contractors.

Target group: Machine contractors, new and existing.

9.4 Forestry

When it comes to taking into account flooding and landslides in connection with forestry, there is continuous follow-up of and training for planners, landowners and forestry contractors. Important topics are planning, operating methods, felling procedures, transportation and restoration.

It is important for the work to continue and to ensure that there is cooperation between the various agencies such as municipalities, the NVE, the forestry industry and research institutions. The training should be evaluated on an ongoing basis.

Need: Courses and professional development days on the topic of climate adaptation.

Target group: Landowners, planners and forestry contractors.

10. Monitoring and warnings

According to the NVE's comprehensive management model for landslide and flood damage prevention, additional needs for monitoring, warnings and emergency preparedness have been examined. There is primarily a need for increased knowledge of sediment transport in the watercourses.

10.1 Proposals for measurement stations, measurement points and permanent profiles in Gudbrandsdalen with tributaries

There is a need for monitoring in several areas and on several levels. This includes monitoring of precipitation, water levels and through-flow in order to provide adequate warnings and preparedness, and of sediment transport and sediment deposition in rivers and sedimentation basins to know when follow-up measures should be taken. This plan provides a brief overview of what should be monitored based on the need for follow-up and preparedness in Gudbrandsdalen.

Monitoring and sediment measurement stations

Existing sediment measurement stations in the area

There are currently the following permanent sediment measurement stations in Gudbrandsdalen:

- Harpefoss: Located at the outlet of the tunnel from the power station. Main measurement station for monitoring the transport of suspended sediment in the Lågen.
- Rådåe: Created on the initiative of Bane NOR to measure water levels / transport of suspended sediment in tributaries where culverts under the railway line can become obstructed.
- Foksåi: Measurement station for monitoring the transport of suspended sediment and bedload transport. The bedload transport is registered by measuring the volume in the capture dam.
- Atna/Lia: The transport of suspended sediment in the Atna is measured at Lia bridge. The background for the measurements is that the Atna is a biological reference watercourse.

Proposals for new sediment measurement stations with through-flow / water level

Dørja: The station is proposed to be established just upstream of the planned capture dam, to measure the transport of suspended sediment and bedload transport by measuring the volume in the capture dam. Variations in the concentration and volume of suspended sediment provide indications of erosion activity in the catchment area. In addition, it is possible to measure bedload transport. The purpose of the station is to have more reliable monitoring of the waterway. A water level logger should also be used to measure/calculate through-flow.

Frya: Following the flood in 1995, measurement stations were established in the Lågen at the outflow of the Harpefoss power plant and upstream of Rudifossen in the Frya to monitor the transport of suspended sediment. The measurement station in the Frya was in operation for two seasons, i.e. in 1996 and 1997. The results showed that suspension transport during the period was

2,650 and 3,292 tonnes, giving an average transport of around 3,000 tonnes per year. The measurement period was from May to October. There is a need to monitor sediment transport in the Frya, and this measurement station should therefore be re-established.

Proposal for monitoring erosion of river slopes

Tromsa: The river slopes in the Tromsa seem very stable and there are only minor scars from landslides, but here too there is an alluvial fan at the outlet into the Lågen that evidences greater activity in earlier times. It must therefore be assumed that there may be more erosion activity and landslides in the future. There should be a measure to monitor erosion activity and investigate the slopes along the watercourse, to clarify which sediment sources may be activated.

Cross profiles showing changes in the topography of the river bottom

The topography of the river bottom is adapted to the through-flow and sediment deposits. If there are a lot of sediments, the river bottom could be raised, but it could also be lowered during a flood if conditions are correct. In both cases flood damage may occur. In order to follow developments, and thus be able to take necessary preventive measures, a number of permanent profiles should be established and followed up on a regular basis.

Below is an overview of permanent profiles that should be created, both in tributaries and in the Gudbrandsdalslågen. The locations of these can be found on www.innlandsgis.no, thematic map *Regional plan for Gudbrandsdalslågen med sidevassdrag* ("Regional master plan for the Gudbrandsdalslågen and its tributaries").

Tributaries

Jora: Three cross profiles have been proposed for the Jøra. Slope erosion along the Dørja river course is best documented by radar measurements that describe the volume of erosion material and changes to the river course.

Gausa: One cross profile has been proposed for the Gausa.

Ilka: Three cross profiles have been proposed for the Ilka. The purpose of these profiles is to monitor stability along the erosion embankment. Laser scanning shows that a lot of material accumulates in the middle of the river course, which is eroded along the edges. If the erosion embankment were to collapse during a major flood, this could damage the buildings at the bottom of the Ilka's alluvial fan.

Sjoa: Three groups of cross profiles have been proposed. At location 1, the profiles will monitor changes to the gravel bank and erosion in the river bank on the opposite side. At location 2, there seems to be deposition of gravel and stone on the bank and on the upstream side of the island where the river course branches into two parts. The profile downstream of the island will monitor possible sediment accumulation. This area was heavily affected by the flood in 2011.

Lågen: Thirteen cross profiles have been proposed for the Gudbrandsdalslågen. They have been selected to register sedimentation in the river course. These are measured and recorded from the laser scanning of the watercourse that was made as the basis for the hydraulic model.

Water discharge stations and precipitation measurements

During the work on the plan, a need was discovered for increased monitoring of through-flow, especially in smaller watercourses, and of precipitation. However, it is not a priority to work out specific proposals for types of stations and locations. This should be followed up during the plan period. The establishment of a measurement station for through-flow and possibly also for sediments in connection with the implementation of concrete measures should also be considered, as this may result in savings.

11. Need for changes in national framework conditions

Work on the plan has revealed the need for changes to various national frameworks that can contribute to improving provisions for support and compensation schemes, as well as management practices. These proposals do not come from the different government agencies, but are proposals by the steering committee for the regional master plan regarding issues that require further work.

11.1 Proposals for changes to the Norwegian Natural Perils Pool

The Norwegian Natural Perils Pool (*naturskadeordingen*, formerly *Statens naturskadefond*) was changed on 1 January 2017. As of 2017, applications for compensation must be sent directly to the Norwegian Agriculture Agency via www.naturskadeordningen.no.

Section 5, first paragraph, of the Norwegian Act on compensation for natural damage (Natural Damage Compensation Act) states: *"Compensation shall be determined based on the cost of necessary measures to return the damaged object to the same condition as immediately prior to the time of damage."*

Section 10, second and third paragraphs, of the Norwegian Regulation on documentation, case handling and compensation following natural damage (the Natural Damage Compensation Regulation) state: *"A grant may be provided if the damage can be improved in such a manner that the damaged object is strengthened or the risk of natural damage is decreased, and the improvement is carried out in connection with the restoration of the damage. The claimant must document the utility of the grant in the application."*

"Additional costs may be covered by up to 20 per cent of the restoration cost as calculated pursuant to Section 5 of the Natural Damage Compensation Act, and capped at NOK 30 000."

This is an improvement over previous legislation and regulations, but this is still not deemed to be good enough. The Norwegian Natural Damage Act should, to a greater extent, allow for an upgrade of the damaged object to a condition that is able to cope with, for example, a 200-year event. Here, it should be possible to use discretion.

11.2 Proposal for support schemes for flood and landslide protection of farmland

Within today's schemes, it is mainly the NVE that can provide support for flood and landslide protection of various areas. The NVE prioritises assistance based on risk, i.e. the hazard level and consequences of damage to existing buildings and the risk to life and health, and where investment in protection will give the greatest socio-economic benefit in relation to the cost of the measure.

In Gudbrandsdalen, large-scale projects have previously been carried out to protect farmland. Lesjaleira, Selsvollene and areas in Ringebu were channelised and flood embankments were built. These measures were largely financed through the Norwegian Ministry of Agriculture and Food. There are currently no funds for such measures in the agriculture sector, and emergency maintenance of the protection facilities has not been carried out, as the NVE lacks funds for such work.

However, soil conservation has very high priority in Norway, and it is therefore a paradox that there is not a greater focus on farmland protection. Every year, flooding and erosion destroy crops worth millions of kroner, and this level of loss should be reduced.

We therefore believe that flood and landslide protection of farmland should take place by means of grants in a separate item in the national budget.

11.3 Proposals for differential compensation for damage along watercourses

Moving flood embankments and establishing new ones much further away from the river can be a good measure, but this also raises a number of issues: private land, multiple landowners, farming operations, flood risk and finances.

Moving flood embankments can take place voluntarily or following a decision by public authorities. A voluntary solution means that the affected parties, the landowners, enter into an agreement with the public authorities. Relevant authorities are the municipality and/or the NVE. If a responsible authority considers it important to move a flood embankment but does not reach a voluntary agreement with the counterparties, one must consider establishing a system for obtaining such a decision and having a legal basis for it.

An agreement or decision to move a flood embankment raises a number of questions of a financial nature. Proposed solution:

1. Flood embankments are moved and costs are covered by the authorities.
2. Responsibility for the supervision and operation of the flood embankment will be the same as before it was moved.
3. If new landowners receive protection after moving, they must participate in supervision and operation.
4. Compensation must be made for agricultural land that goes out of service because a flood embankment is moved. This compensation should be in the form of farmland, financial compensation, or a combination of both.
5. Agricultural land that can be operated without the protection of embankments should be used for grass production or cultivated according to special guidelines determined for such areas. Such land forms the basis for applying for financial grants, such as production grants,

regional environmental plan funds and other schemes. Cultivating crops that make the land highly vulnerable to erosion provides no basis for applying for financial grants. Manure from livestock must be used in quantities that are adapted to the relevant crops during the growing season.

6. For those areas that can be operated with the aforementioned limitations (see item 5), the owner should have financial security. This can be formulated in several ways:

    - Fixed annual compensation for the farmland between the river and the flood embankment

    - Crop damage caused by flooding: deductible is currently 30 per cent, but in this situation it must be set to 0 per cent.

11.4 Need for clarification of how planning provisions should be designed based on forestry and landslide expertise

The purpose clause of the PBA states, among other things, that: “Planning pursuant to this Act shall facilitate the coordination of central government, regional and municipal functions and provide a basis for administrative decisions regarding the use and conservation of resources.” The municipalities are required to prepare land plans covering the entire municipality. In the municipal plan, forest areas are mainly allocated for agricultural, nature and outdoor purposes. Therefore, a municipal plan governs forestry only to a small extent apart from a clarification of which areas are to be managed for forestry and agriculture or nature/outdoor areas.

For areas in the municipality with known natural hazards, zones requiring special consideration may be adopted, with special provisions prohibiting or setting conditions for measures and/or activities. Zones requiring special consideration in terms of landslides are based on nationwide maps of areas requiring special consideration (see www.skrednett.no). These maps are based on GIS analyses and must be regarded as rather rough. The maps do not provide a basis for establishing zones requiring special consideration with restrictive provisions for e.g. tree felling.

The next level of hazard mapping is hazard zone maps. These are based on an expert assessment in the field. So far, these cover only small areas of the country. These maps provide a technical basis for the establishment of zones requiring special consideration (Section 11-8, third paragraph, letter a of the PBA) in the land planning portion of the municipal plan with related provisions that set conditions for measures and/or activities. There should be an investigation into how detailed a framework for forestry should be, potentially based on a zoning plan. In any case, it is important that landowners be actively involved in the process.

In connection with housing construction, where the forest above is considered to serve as protection against various types of landslides, it may be possible to develop zoning plans that include this forest area in the plan area. In such a plan there may be requirements for the preparation of provisions on

silviculture, felling method, transportation in the terrain, the size of any felling areas, etc. Such provisions must be formulated in a dialogue between forestry and landslide experts.

The scope of such zoning plans is not very extensive today. This may be due to several factors. One reason may be uncertainty as to how such provisions should be designed and followed up. Another reason may be uncertainty about possible compensation claims as a result of the usage restrictions imposed on the felling area. A third reason may be that there is some form of mutual understanding that special consideration must be given to a certain area, and that it is considered unnecessary to formalise a framework for forest management.

There is a need to clarify how planning provisions should be designed based on forestry and landslide expertise, as well as what potential legal claims for compensation this may trigger.

11.5 Proposal for changes to Norwegian PEFC Forest Standard to better take into account the risk of erosion and landslides

The forestry industry's own certification scheme, the Norwegian PEFC Forest Standard (formerly the Living Forest Standard) comments on planning and implementing forestry activities, in a long-term and sustainable forestry industry that takes into consideration the risk of *erosion and landslides*, among other things.

For felling in difficult terrain using an aerial cableway, the Municipal Agriculture Administration should make an advance assessment regarding the risk of landslides, flooding and rockslides, which is then sent to the County Governor before any grant for such operations is awarded. Here, there are rules and schemes that point to the consideration of natural hazards, but the question is how the regulations are handled and followed up in practice. Regarding the certification scheme, the question of routines for the surveillance of trenches and culverts, as well as self-inspection after felling and transport in the terrain in order to ensure that the drainage pattern has not been changed, should be considered to be included in the certification scheme and included as a requirements specification under the item for transport in the terrain. However, it is also equally important that road and rail transport are planned in such a way that the risk of erosion and landslides is taken into account. Therefore, a requirements specification should be included in this under the item on felling and transport in the terrain.

11.6 Proposal for increased use of protective forest as protection against natural damage

Section 12 of the Norwegian Forestry Act, regarding protective forest as a means of protection, should be considered for greater application than is currently the case, to prevent damage to infrastructure and buildings. It is the County Governor who may adopt municipal regulations for forests that function as protection for other forests or against natural damage. Such protective forests mainly comprise forest areas that are up near the treeline, i.e. close to the mountains. The

purpose is primarily as a climate protection for the forests below. Smaller areas where there is a possible risk of landslides are also covered by the provisions on protective forests.

Here, one can ask whether the municipality can come up with proposals for areas that should be used as protective forest against natural damage. Such an initiative may come from the municipality in connection with the revision of the land planning portion of the municipal plan, where the entire area is assessed together and where such issues are addressed together with the forestry manager and other agricultural expertise. Comparing maps of zones requiring special consideration in relation to landslides, debris flows, rockfalls, etc. with areas where there are existing buildings and planned building areas could provide a basis for assessments related to the risk of performing felling and final cutting. In areas designated as protective forest, there is a need to develop good provisions on how the protective forest should be managed in order to prevent damage from landslides and flooding. There is clearly an opportunity to use this instrument more actively to prevent unwanted activity in forests.

When developing new areas, the developer is responsible for ensuring adequate protection of the individual measures. In some cases, this could mean that forests must be redeemed and that a management plan must be prepared to guarantee the protection effect of the forest area concerned.

In addition, one should consider including consideration of erosion and landslides in the Norwegian Regulation on sustainable forestry (Sustainability Regulation) as a separate point under Section 5, Environmental considerations in forestry projects.

12. Regional guidelines for planning, use and protection of areas vulnerable to landslides and floods

12.1 Impact of the plan

Pursuant to Section 8-2 of the PBA, regional master plans shall form the basis for the activities of regional bodies and for municipal and central government planning and activities in the region. Legally binding land use is determined in the municipal land planning pursuant to the PBA. Previously approved municipal plans, municipal sub-plans and zoning plans within the plan area apply independently of this regional master plan.

Considerations related to cultural heritage sites are clarified for all measures through a zoning plan or a dispensation pursuant to section 19 of the PBA. Even minor measures not clarified pursuant to the PBA should be submitted to the cultural heritage authorities in Oppland County and the Norwegian Maritime Museum for assessment, cf. Section 9, first paragraph, of the Cultural Heritage Act.

Measures that only affect areas underwater or areas constantly affected by flooding are considered to have a low potential for the discovery of preserved, automatically protected cultural heritage sites. Unless there are known, automatically protected cultural heritage sites in the immediate area, these measures need not be submitted to the cultural heritage authorities.

This plan sets out a number of guidelines that are instructive for municipal planning in accordance with the PBA. More detailed descriptions can be found in the document "*Guidance and Advice*".

12.2 Guidelines for land planning under the Norwegian Planning and Building Act

a. Measures should be planned, established and operated on the basis of a zoning plan
b. Required knowledge must be acquired as early as possible – mapping of flood, erosion and landslide processes should take place as early as possible in planning processes
c. The effects of a change in climate must be taken into account – allowance for climate change
d. The catchment area and natural processes related to landslides should be considered as a whole, even if this leads to assessments and measures outside the original plan area
e. If the watercourse cannot accept more water, requirements must be set for local retention schemes and zero discharges – create flood and surface water plans
f. Open watercourse solutions should be chosen – these are more durable than closed solutions
g. Natural processes associated with flooding and landslides should be given enough space
h. Natural hazards should appear on plan maps and be given adequate provisions that provide good land use and which, at the same time, provide adequate safety, cf. the Norwegian Regulations on technical requirements for building works

i. Good agreements and procedures for the operation and maintenance of protection systems should be prepared

12.3 Guidelines for permanent sediment removal sites and sediment basins

a) It should be clarified at what time of year sediment removal can take place. Normally, in rivers and streams with brown trout, this will be in the period from 15 June to 15 September, but a specific assessment must be made in each case. In rivers with a high through-flow during the summer, approval may be given for sediment removal in the spring and autumn when this can take place on dry land.

b) It should be clarified under what circumstances sediment removal must be initiated. Here, when establishing the protection system, profiles should be measured that show how the river bottom / dam should be shaped when it has been emptied and profiles showing when cleanout will be necessary. It could be beneficial to measure this digitally/GIS.

c) The zoning plan should contain areas and provisions relating to intermediate storage of removed material. It is important that this be adapted to the real need for intermediate storage.

d) The zoning plan should also say something about access for cleanout, and where machinery and transportation of material will take place.

Provisions on who should carry out the removal and any sales of sediments from these sediment basins and permanent removal sites cannot be included in the zoning plan. However, it is very important that this be clarified and that a private legal agreement be concluded on the matter. Someone should be responsible for cleanout when necessary, and it would be best if the municipality had this responsibility.

13. Programme of action

According to section 8-1 of the PBA, a programme of action must be created for the regional master plan:

"A programme of action shall be drawn up for implementing the regional master plan.

The programme of action shall be adopted by the regional planning authority and shall be rolled over annually as deemed necessary."

Chapter 8 of the PBA sets the frameworks that serve as the basis for implementing guidelines and programmes of action, and how often these must be updated. As the regional plan is implemented, it is important to roll over the plan to ensure that, on the basis of experiences gained, it is a well-functioning plan in the long run. The same applies to the programme of action.

The programme of action is adapted to the issues encountered during planning work.

An annual assessment should be made as to whether there is a need to roll over the programme of action. The main rollover of the plan is set to take place every four years, coinciding with election periods, the training of politicians, and rollover of the regional master plan for water management in the Glomma water region.

13.1 About the programme of action

The programme of action contains an overview of measures that should be implemented both regionally and nationally, as well as follow-up points for the plan. The programme of action shall be rolled over annually as deemed necessary, and therefore is available as a separate document.

The programme of action includes:

- Permanent sediment removal sites and/or sediment basins that should be established
- Relevant flood embankments that should be established
- Other physical measures
- Competence-boosting initiatives
- Measures for binding cooperation
- Relevant measurement stations and surveys that should be carried out
- Overview of the need for improvements to the knowledge base
- Proposals for changes to national framework conditions

A more comprehensive description of the individual measures can be found in this plan document and in the appendix "*Relevant measures in tributaries of the Gudbrandsdalslågen*". This plan is not exhaustive in relation to the need for measures, but addresses the challenges in Gudbrandsdalen assumed to be most important. Proposed measures here will also provide good experience and form

the basis for continued work on similar measures in other parts of the Gudbrandsdalslågen and in other rivers and streams. The programme of action contains a number of measures, but it does not exclude the possibility that there may be a need to implement measures also in other locations.

Responsible and co-responsible/stakeholders
The programme of action specifies who should take the initiative to implement the individual measures. Furthermore, it defines who should be designated as co-responsible and/or may have an interest in seeing the measure implemented. This applies where there are proposals for establishing a permanent sediment removal site, and where certain stakeholders may be interested in using the extracted material, for example.

Financing and monitoring
There is no guarantee that the measures described in this plan will be implemented, but the plan is indicative for how the various agencies should prioritise measures and cooperation. Most of the proposed measures are new and require studies to be carried out prior to any implementation.

Neither does the plan include funding for implementing the measures. Financing of each individual measure will be clarified after studies have been carried out and in agreement with affected parties in line with the programme of action. All proposed measures will require applications and permits from various agencies, in the same way as other measures.

Prioritisation of measures
A number of concrete measures have been considered that may have a flood control effect on various types of areas, such as residences, other buildings, roads, railways and farmland. Risk is assessed when deciding on which measures to continue working on, i.e. the level of risk and consequences for damage to existing buildings and the risk to life and health, and where investment in protection will provide the greatest socio-economic benefit in relation to the cost of the measure. If a measure has a positive impact on the natural environment, this is also emphasised. This gives the following order of priority:

1. Life and health – residences, institutions
2. Other existing buildings and infrastructure
3. Farmland

Various agencies will have the responsibility for other existing buildings and infrastructure. The cost of certain measures must be expected to be covered by the individual owner, while in other cases it may be appropriate for the authorities to provide funding.

The programme of action includes a recommendation for when the various measures should be implemented and completed. However, this depends on the initiator submitting an application to begin the process. Furthermore, it is dependent on budgetary and capacity-related factors.

The programme of action includes some measures that will only safeguard farmland and that will have no significant negative consequences for other stakeholders. Within the currently available

financial frameworks for mitigation measures against floods and landslides in Norway, it will likely be impossible to implement such measures with public funding. Nevertheless, the plan recommends that such measures be implemented, as food security and soil conservation are important issues. Agriculture is an important industry for the municipalities along the Gudbrandsdalslågen. We should therefore work to increase government funding for measures that prevent flooding and rockslides in farm areas.

In general, this plan should provide guidance with regard to how individual agencies prioritise measures. As a result of Norway's participation in the *PHUSICOS* project, which is linked to the European Union's Horizon 2020 research and innovation programme, there may be changes in the order of priority of measures in the programme of action during the first four-year period.

13.2 Follow-up of the plan

Oppland County Council is responsible for regional master plans, and thus responsible for following up this plan. Oppland County Council is therefore responsible for putting together a group that has 2–4 meetings per year. The group should consist of representatives from the same actors who contributed to the planning work, i.e. the Oppland County Governor, the municipalities in Gudbrandsdalen, the NVE, the Norwegian Public Roads Administration, Bane NOR, and Oppland County Council. The Oppland Farmers Union and the Oppland Farmers and Smallholders Union are encouraged to agree on one representative. Regional councils are encouraged to appoint one municipal representative per region. The group's main responsibility is to follow up, evaluate and roll over the programme of action.

14. Bibliography

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