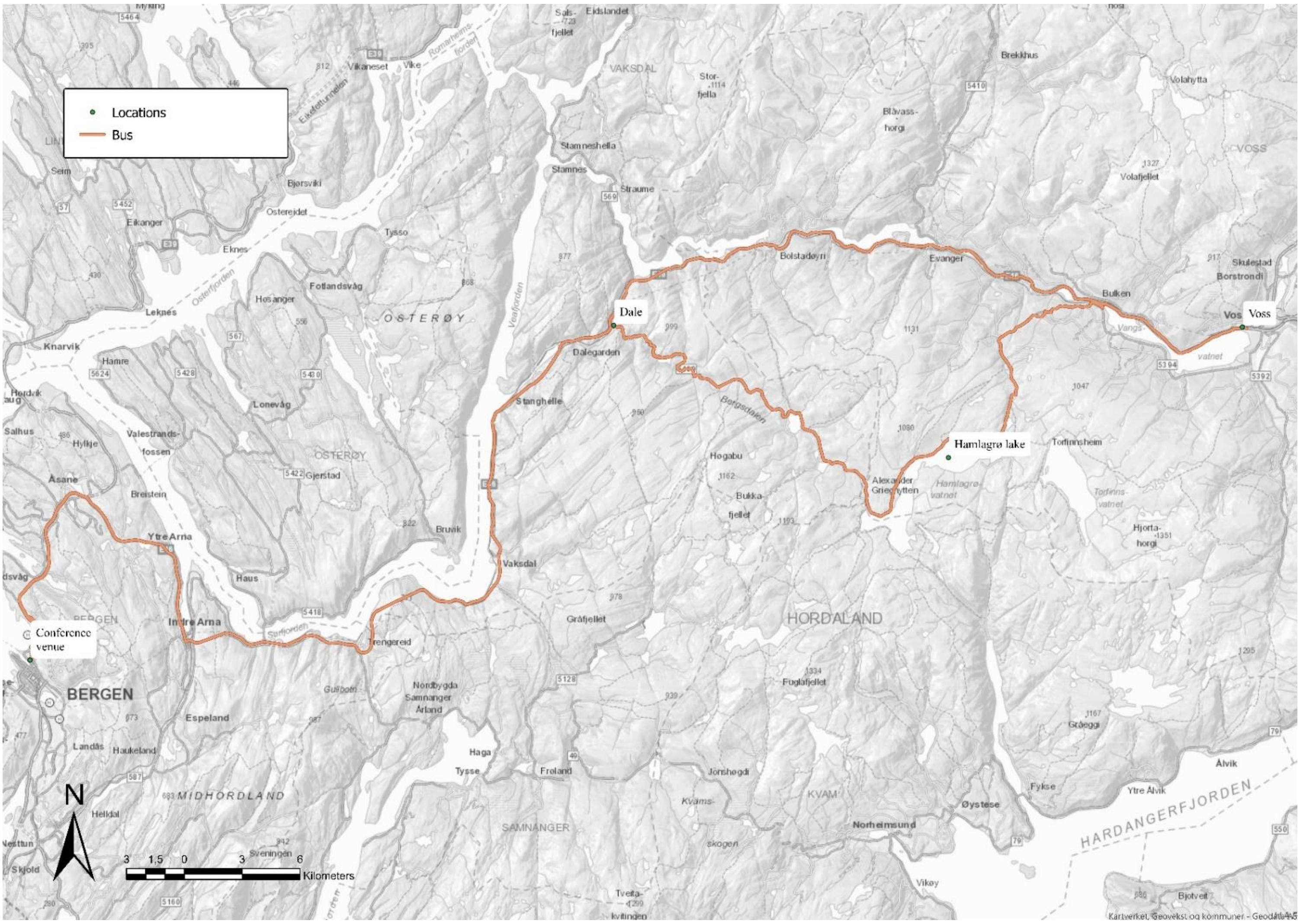
EXCURSION GUIDE

INTERPRAEVENT
2020 – Bergen, Norway

MANAGING NATURAL HAZARDS WITHIN DIFFERENT FRAMES

Date: May 13th



INTRODUCTION

This excursion will demonstrate flood risk management in two catchments, within very different frames: One is heavily influenced by hydropower development (Dale). The other is in a more natural state as it is protected against hydropower development (Voss).

The excursion also presents different measures to manage natural hazards – landslides, rockfall, floods and river erosion - along the national railroad and highway to Bergen.

In Dale, we will see how the power company managed a major flood in 2005, flood protection measures constructed after the flood as well as measures to improve the ecological status.

In Voss, we will see how lake flooding affects the municipal centre, measures already taken to lower flood levels and a major project studying flood diversion through tunnels.

SCHEDULE

07:45	Meet at Radisson Blue Royal Hotel
08:00-09:00	Bus: Bergen - Dale
09:00-09:30	Lecture indoor in Dale
09:30-11:00	Guiding outdoor in Dale
11:00-12:00	Bus: Dale - Bergsdalstunet
12:00-13:00	Lunch: Bergsdalstunet
13:00-14:00	Bus: Bergsdalstunet - Bulken
14:00-14:30	Guiding Bulken
14:30-14:45	Bus: to Vossevangen
14:45-15:30	Guiding Vossevangen
15:30-17:00	Bus: Voss – Bergen, some stops

Location 1: Dale – Hydropower development

Dale is the administrative centre of Vaksdal municipality. There are approximately 1200 inhabitants in Dale.

At this location we will have an introduction about hydropower development, floods control and environmental mitigation measures.

The introduction will be given by the Norwegian Water Resources and Energy Directorate, NVE, the power company BKK and the Vaksdal municipality. A flood in 2005 will be used as an example, together with flood protection measures in Dale, implemented after this event.

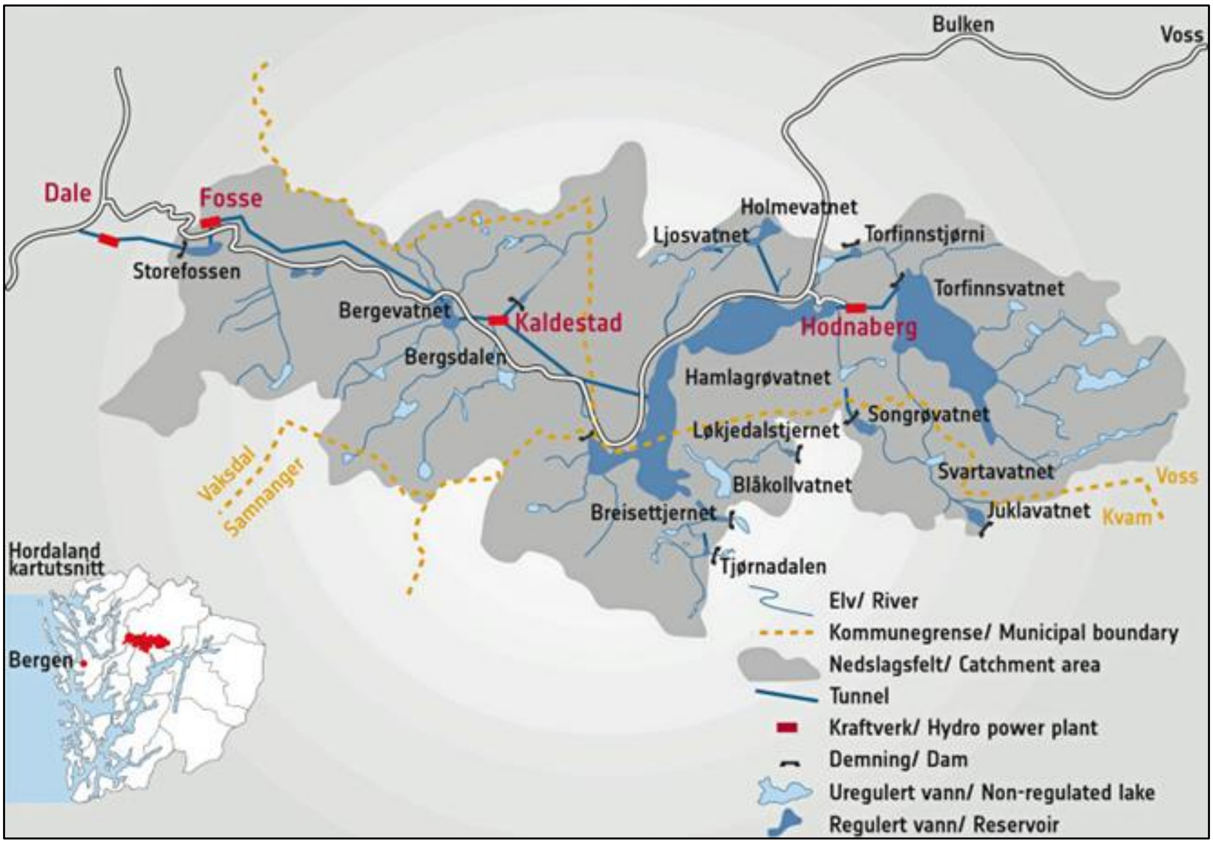


Figure 1. Overview Bergsdalen catchment, reservoirs and power plants (BKK).

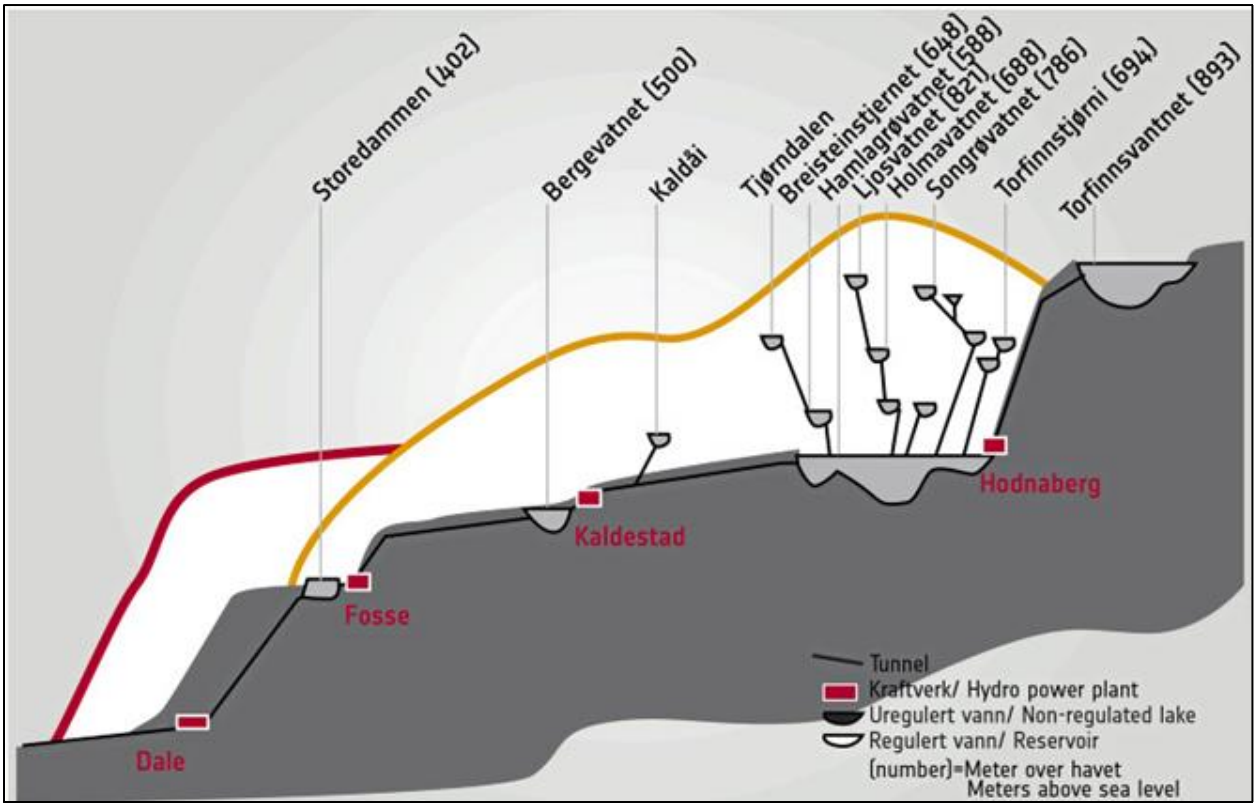


Figure 2. Longitudinal sketch of hydropower system in Bergsdalen (BKK).

Table 1. Information about different power plants, Bergsdalen (BKK).

Power plant	Municipality	Installed capacity	Average annual generation	Head	Commissioned
Kaldestad	Vaksdal	24 MW	91 GWh	83 m	1964
Fosse	Vaksdal	25 MW	143 GWh	96 m	1954
Dale	Vaksdal	146 MW	694 GWh	375 m	1927/1951/1990/2007
Hodnaberg	Voss	32 MW	94 GWh	300 m	1953/1959/2010/2011

Reservoirs:

Hamlagrøvatnet: 175,3Mm^3 – natural lake, 28m regulation, mainly lowering

Torfinnsvatnet: 177,4Mm^3

Bergevatnet: 2,5Mm^3

Storefossen: 1,2Mm^3

Regulation effects on floods

Legislation: Licensing, obligation to minimise damage during floods, can apply for dispensation in order to reduce flood damage.

THE FLOOD IN 2005 AND EFFECT OF THE REGULATION

Year 2005 was one of the wettest year in Western Norway, ever measured. The annual precipitation in Bergen was recorded 3055mm, only 15 mm less than the highest record in 1967.

After huge snowfalls in the mountains, the reservoirs filling was high in the autumn 2005. Rainy days started from the middle of August. The reservoir filling was as high as 97% after the first week of November. The following week, new heavy rainfall occurred.

The weather forecasts before the flood indicated a transition to colder weather from Wednesday 9th November. However, when the reservoirs were full and the long-term forecast indicated more precipitation the following week, BKK started drawing down the reservoir Hamlagrøvatnet 9th November. Several creek intakes in Bergsdalen were diverted in order to reduce inflow to the reservoir Hamlagrøvatnet.

On November 11th, BKK received first notice of possible heavy rainfall from November 14th. A low pressure system lying between Newfoundland and the southern tip of Greenland was rather intense, but there was still considerable uncertainty about further depression development, both intensity and direction.

BKK decided to keep high power generation during the weekend. Releasing of water from the reservoir in Hamlagrøvatnet continued. In addition, the gate at Torfinnstjern was closed in order to avoid spill water from the lake Torfinnsvatnet to enter Hamlagrøvatnet, i.e. the river Torfinno was returned into the original river bed continuing to the river Vosso. The overall strategy for BKK was to gain as much available storage volume in reservoirs as possible.

The storm “Loki” hit Western Norway with full strength from night to Monday 14 November. During the night we experienced heavy rain, and the water flow increased rapidly in a number of smaller watercourses. Flood damages like landslides and inundations of roads were reported from all over the region.

Stations:	Fosse	Oksebotn	Stordalen	Åsebotn	Samnanger
	Precipitation (mm)				
12.nov	42,4	25,1	27,6	17,5	25,8
13.nov	10,1	6,8	22	7,4	19,9
14.nov	179	108,5	132,8	79,3	200,2
72-hour precipitation	231,5	140,4	182,4	104,2	245,9

Figure 3. Precipitation at different stations nearby.

Based on a flow frequency analysis, we calculate the flood to have a return interval in the order of 30-50-year flood.

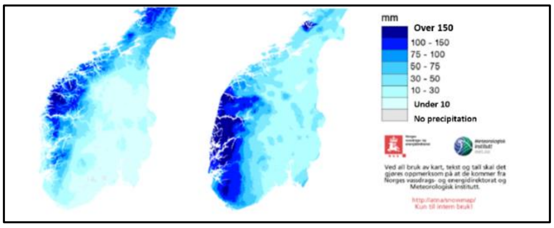


Figure 4. Maps show precipitation the week before the flood incidents of 13.-14.sept (left) and 14. - 15.nov (right) 2005 (xgeo.no).

What if there had been spill from Hamlagrøvatnet at the same time, or the reservoir had been full before flooding?

The Hamlagrøvatnet was drawn down the last few days before the storm and therefore no spill water contributed to the flood flow at Dale. The last 4 hours before the flood reached its peak at Storefossen with 240m^3/s, the water level raised in the lake Hamlagrøvatnet by 5 - 6 cm/hour, i.e. an average inflow over the 4-hour period of 170m^3/s. When the reservoir level in Hamlagrøvatnet reaches the highest regulated water level (HRWL), the vertical stop log gate (needle gate) must be opened. This would have given an additional flow of 34m^3/s, and this extra flow would have caused severe damages to the Dale community.

If the reservoir had been full at the time of flooding, the inflow mentioned above (of 170m^3/s) would, despite the flood damping in the reservoir, caused an additional outflow which. This would have jeopardised the whole Dale community.

ENVIRONMENTAL / HABITAT MEASURES:

Research:

Environmental design and long term investigations of salmon and sea trout in regulated rivers. Methods to map rivers to identify bottle necks and develop river specific measures to strengthen the recruitment of fish in regulated rivers. River Dale / Bergsdalen was one of the investigated rivers. Research by Norwegian Research Centre, Laboratories for Biology in Fresh water (NORCE LFI):

https://www.norceresearch.no/en/research-area/miljo

CEDREN:

https://www.cedren.no/english/About-CEDREN

ENVIpeak:

https://www.cedren.no/english/Projects/EnviPEAK

Environmental measures in the regulated river shown in figure 5.

Weirs in the river:

Weirs can have different purposes:

- Measures for river bottom stabilization (figure 6, weirs downstream HPP).
- Measures to create larger water surface (figure 6, weirs upstream Dam Storefossen).
- Measures to prevent erosion in streams along lake rim (figure 6, weirs around lake Hamlagrøvatnet).

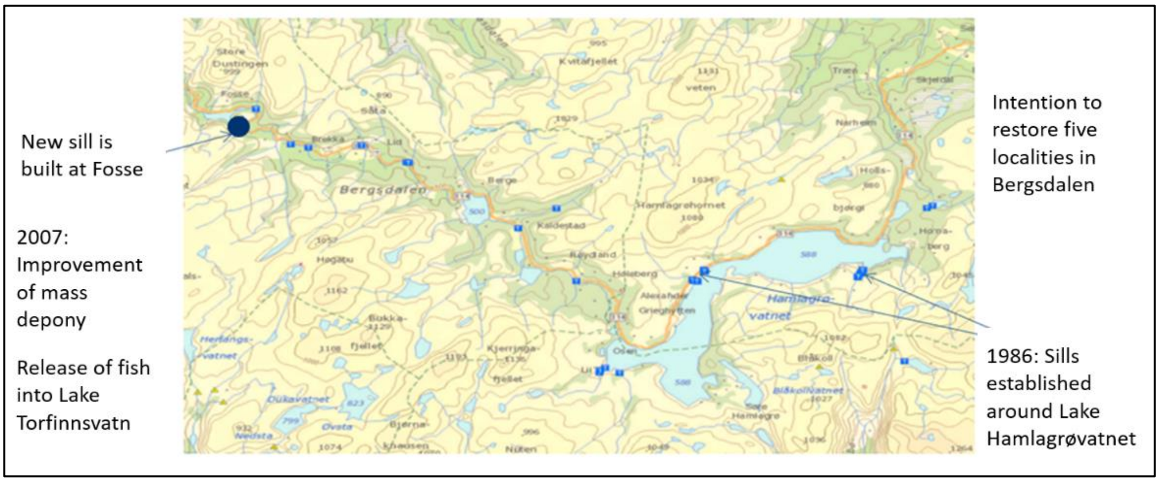


Figure 5. Mitigation measures in the regulated river (BKK).

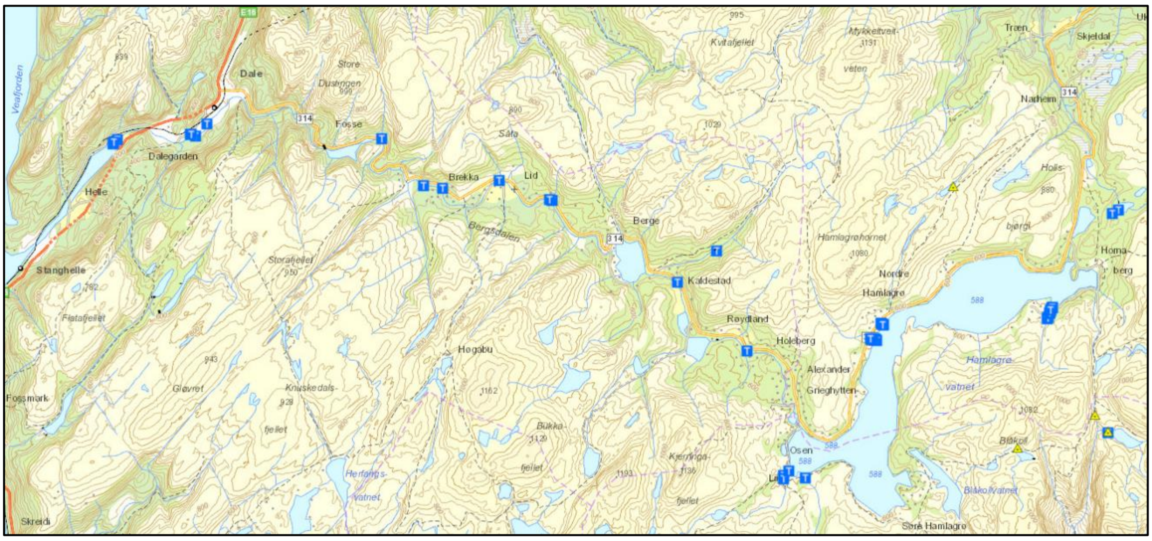


Figure 6. Weirs/sills built in the Dale river (BKK).

Figure 7. The small pond near Bergdalstunet (BKK).

Figure 9. The lake area seen before reconstruction of the weir (BKK).

Figure 8. Weir keeping the water table stable and makes refugees for birds and brown trout. It is also improves the landscape (BKK).

Location 2: Dale – Power plant

Dale power station, which is located approximately 65km east of Bergen. The old Dale I HPP (figure 10) is replaced by the new Dale II HPP (figure 11). The Dale II HPP consist of two Francis units and is located 450m inside the mountain.

The intake reservoir for Dale II is Storefossen at elevation around 400 m (HMWL = 404 m a.s.l).

From the intake gate there is a 2,1km long headrace tunnel, continued by a vertical pressure shaft and then a short pressurised tunnel.

There is installed an energy dissipator, which purpose is to instantaneously maintain minimum water discharge in the event of an unplanned stop. Downstream the underground powerhouse, there is a 630m long tailrace tunnel which ends in a canal leading the water back to the Dale River.

BKK has dedicated Dale power plant (one unit) to be a «test lab»; a place to implement new technology and to gain experience before rolling out the technology to other power plants.

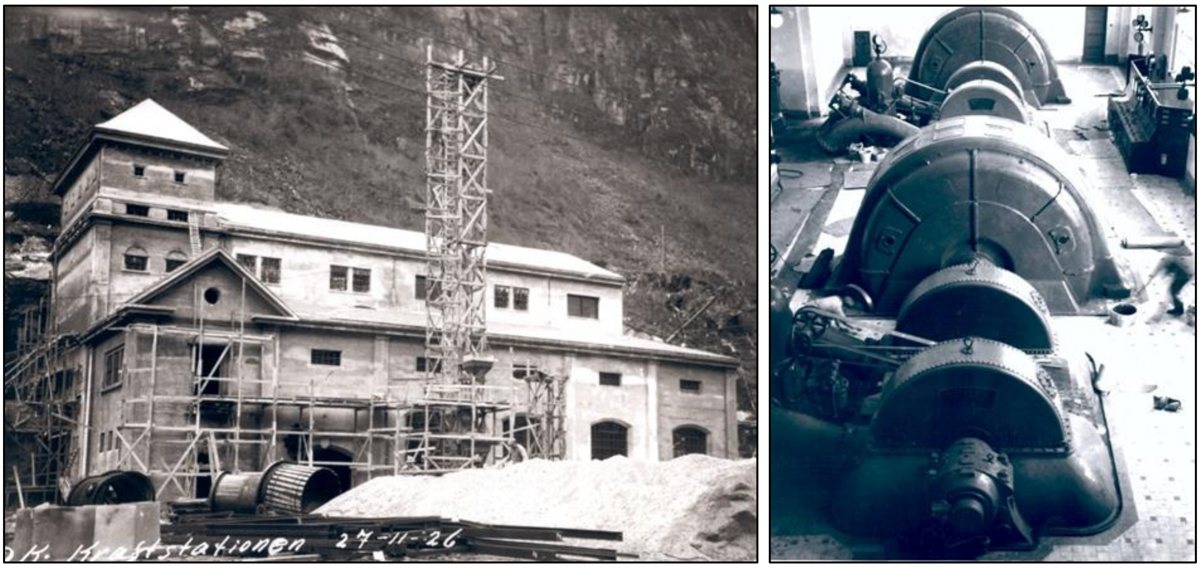


Figure 10. First power plant (1927) (BKK).

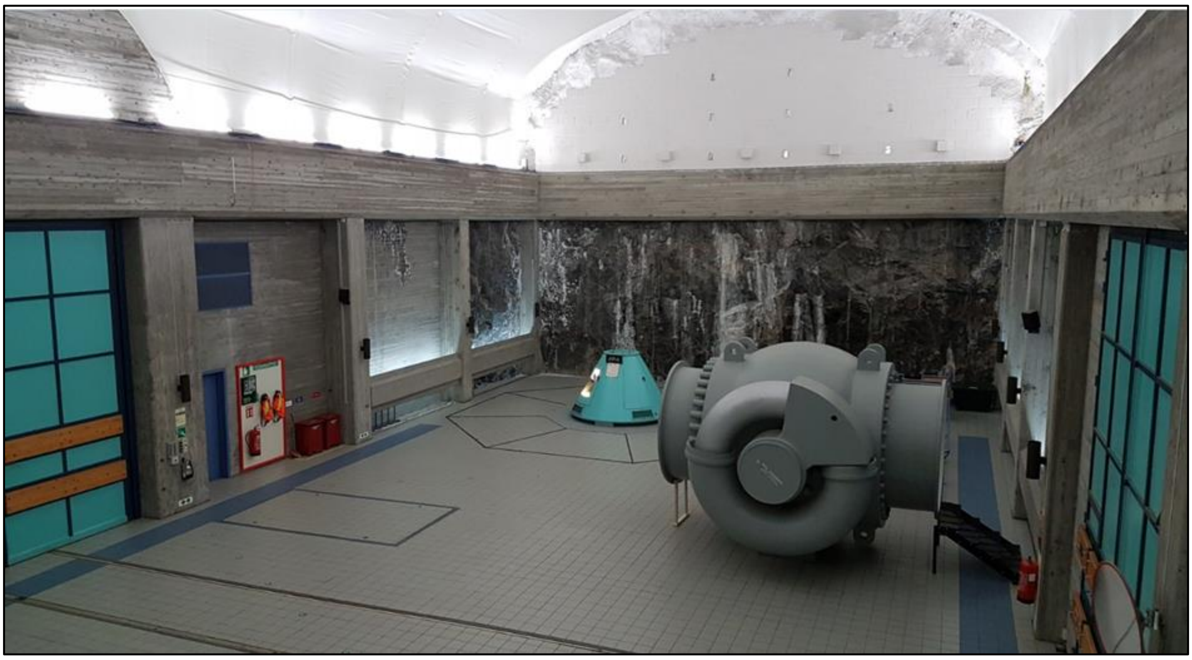


Figure 11. Inside the new power plant (2007) (BKK).

Location 3: Dale

FLOOD PROTECTION

The measure was initiated after the 2005 flood, which caused substantial damage. The measure protects residential and industrial areas along the river in Dale, as well as public areas for outdoor life etc.

The flood inundation map for Dale was produced in 2003 (figure 12). It is now being revised to take into account the flood protection and climate change.

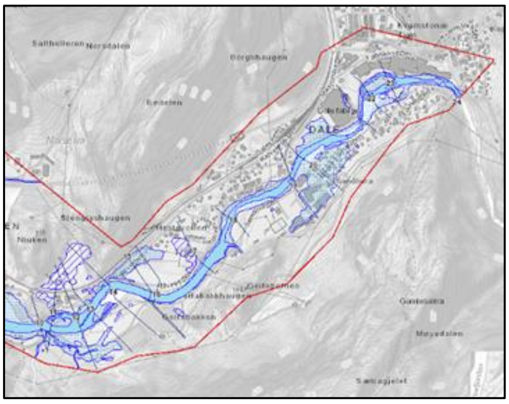


Figure 12. Flood inundation map for Dale (NVE).

Key information about measure:

- Design flood: Q200 = 381 m^3/s with a freeboard of 50cm. The 500 year flood will not overtop.
- Cost: 15,2 mill. NOK (approx 1,5 mill. euros)
- Measures:
- 1300m levee/ erosion control.
- 1200m^2 revetment and groynes – rock sorted from nearby talus
- Removal of approx 20 000m^3 material front he river bed to increase the capacity during floods

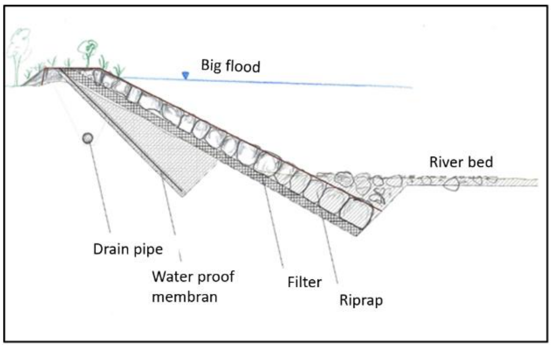


Figure 13. Principal sketch: The embankment included a membrane to prevent leakage.

Figure 14. Construction phase (BKK).

Location 4: Dale River

ENVIRONMENTAL MEASURES

It is important to combine better flood control with improved ecological status in rivers. NVE and BKK have used NORCE LFI's research to develop more eco-friendly flood control measures such as nature-like bank protection and river restoration to increase hydraulic capacity and energy dissipation, but also aquatic life (Research Project, Flood & Environment, NVE).

In rivers with regulation the researchers use mitigation measures, such as spawning and rearing habitats for Atlantic salmon and sea trout and restoring side channels. On the excursion, we will show examples of more eco-friendly flood control and ecological mitigation measures.

Measures done by BKK and NVE in Dale River. Spawning areas, fish trap, weirs and other measures.

Figure 15. Smolt trap in the Dale River (BKK).

Figure 16. Special concerns were taken to prevent damage to the spawning areas during construction.

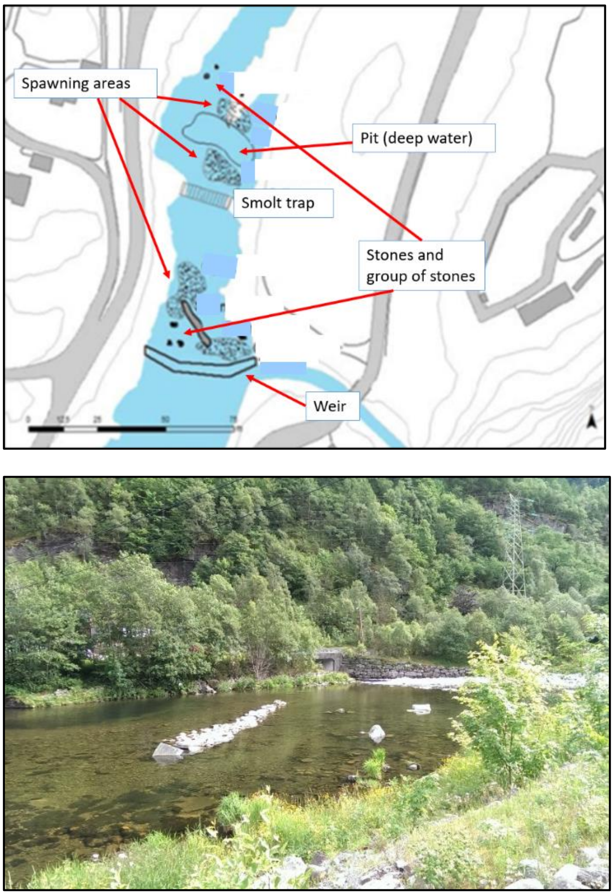


Figure 17. Upper: Sketch showing mitigation measures just upstream the outlet from Dale HPP. Lower: Picture from same area (BKK).

Location 5: Water fall Storefossen

DAM / WATER FALL

Dam Storefossen regulates a small reservoir at the intake to the hydropower plant in Dale. During the flood in 2005, the water level was 1,91m over the spillway.

Figure 18: Dam Storefossen today (BKK)

Figure 19: Dam Storefossen during the flood 2005 (BKK).

Figure 20: Storefossen waterfall before development (BKK).

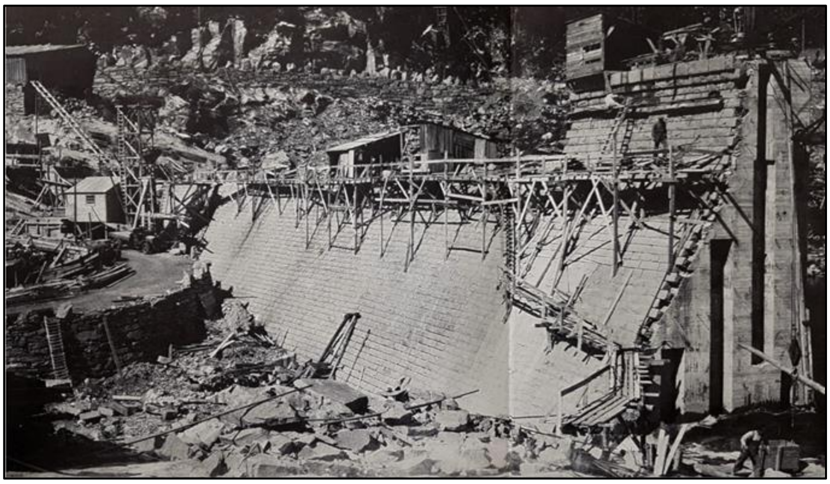


Figure 21: Dam Storefossen under construction (BKK).

Location 6: Lake Hamlagrøvatnet

DAM AND RESERVOIR

At this location, we will have a brief orientation about the reservoir, mitigation measures in and around the lake Hamlagrøvatnet and the newly reconstructed dam.

In the licence, there is a restriction not to utilize water from early May until mid-August, or until the water level has reached elevation 584 m a.s.l. Mitigation measures consist of construction of weirs and erosion protection work of lake rim.

Figure 22. Dam and spillway before reconstruction (BKK).

Figure 23. Lake Hamlagrøvatnet, before reconstruction (left) and after (right) (BKK).

Location 7: Bulken

Lake Vangsvatnet has a very narrow outlet leading to historic flood levels up to 10 meters above low water level. Around 1855 the first widening of the outlet was made. In 1991 the outlet was again widened, and deepened. A weir was constructed to maintain the low water level. This measure led to lowering of flood levels up to 1,6 meters.

We will make a short stop at the outlet before continuing to municipal centre Voss.

Figure 24. The outlet of Lake Vangsvatnet. (NVE, 2019)

Figure 25. Vosso river (NVE).

Location 8: Voss

FLOODING

The water level in the Lake Vangsvatnet has always been challenging for those living by the lake.

The water level has been monitored in Vangsvatnet since 1892, and the outlet of the lake has been lowered twice. Huge flood events has caused large damage in the settlement along the river Vosso and Lake Vangsvatnet (figure 26 & figure 27)

After the major floods in 2014 and 2015, there has been a local crave for increased safety against flood damage.

FORMER FLOODS:

Tabell 2. Known floods in Lake Vangsvatnet (Roald, 2013).

Year	W.S.elev (m a.s.l.)	Water flow (m3/s)	Comment
1604	55,47	900	Flood mark on the church Vangskyrkja
1719	54,21	700	Approximately like 1743
1743	54,21	700	Water to the church choir
1745	53,90	650	The water level reach the church
1790	54,21	700	Approximately like 1743
1864	51,63	400	Minor damage
1865-66: Outlet of lake Vangsvatnet was widened and deepened			
1873	51,63	600	Minor damage
1884	52,29	703	26 inches taller than 1873
1888	51,63	615	5 inches taller than 1918, approximately same height as in 1873
1918	51,50	598	
1990-91: Outlet of lake Vangsvatnet was widened and deepened			
2014	51,30	813	Larges ever *monitored* in Vangsvatnet!

Figure 26. Flood at Voss October 1918.

Figure 27. Flood at Voss December 2015 (NVE).

FLOOD INUNDATION MAP:

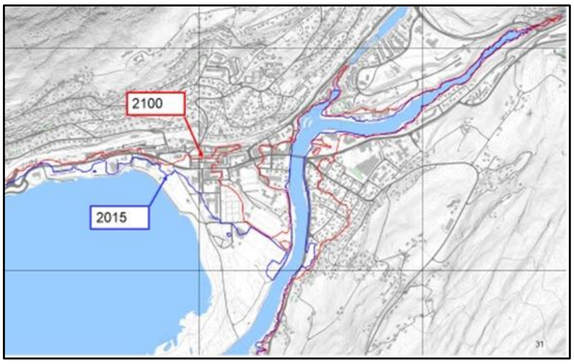


Figure 28. Observed water levels in December 2015, and preliminary estimation of the year 2100 (NVE).

FLOOD PROTECTION:

A pre-project is running concerning flood tunnels to lower the floods in the lake. Several tunnel options have been considered:

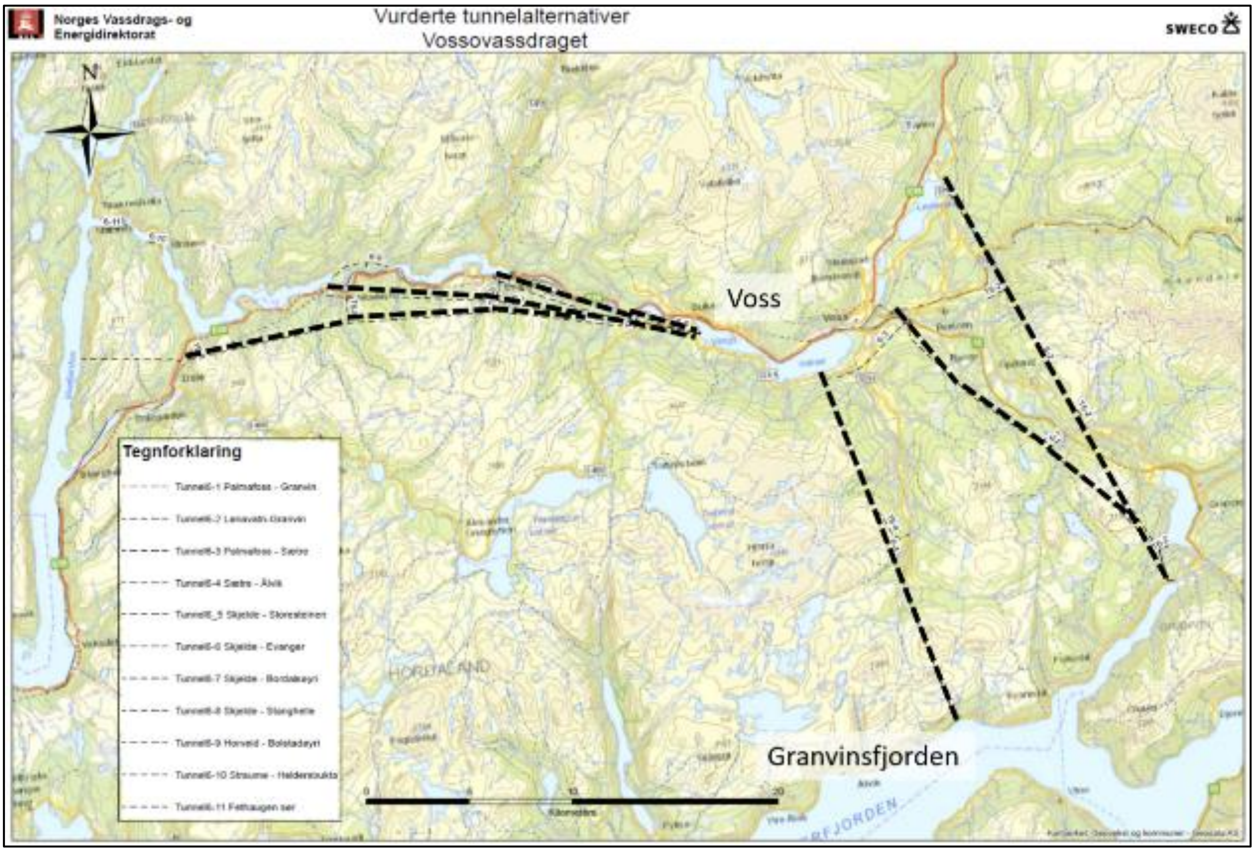


Figure 29. Tunnel options (NVE)

Location 9: Highway E16 and railway

EXPOSED HIGHWAY E16 AND RAYLWAY BERGEN-VOSS

We will be introduced to examples of how natural hazards are managed along a challenging section of the national highway E16 and the railway connecting Oslo and Bergen.

This includes managing rockfall, debris flows, floods and river erosion. The mitigation measures include both structural protection and monitoring systems.

Figure 30: Photo from Bogelia along highway E16, where an automatic detection and warning system has been installed (NPRA).

Figure 31: Photo after a rockfall event in April 2013 hitting both E16 and the railway. Protection has now been installed (Bane NOR).

Figure 32: Visual inspections of rock slopes have proved to be important (Bane NOR).

Figure 33: Protection systems under construction (Bane NOR).

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Notes

INTERPRAEVENT
2020 – Bergen, Norway