Flood mitigation by hydropower in Norway

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Hydropower and flood mitigation

Hydropower may decrease flood risk by technical structures

- Reservoirs can store water and reduce flood peaks
- Diversion/Bypass structures (tunnels, canals, …)

The operation of structures is important
- Operation need to consider two or more objectives
- Energy production
- Flood damage
- Other uses (Irrigation, transport, tourism, …)
- Who will pay and who will benefit?

How to balance between these objectives?
Hydropower system – Dam safety

Hydropower may also increase flood risk –
Always consider Dam safety

Roppa dambreak May 1976
Possible Case studies Flood/Hydropower in Norway

- Nea-Nideli river (Large reservoirs – flood volume)

- Gaula (Small reservoirs, sharp flood peaks)

- Vosso – (Diverting flood by hydro tunnels)

- Telemark (Complex hydro system, forecast model)

- Glomma (Three major floods, Land use and Hydro)
Potential case studies in Norway - Locations

- (1) Nea-Nidelv river
- (2) Gaula
- (3) Vosso
- (4) Telemark
- (5) Glomma
Nea-Nidelv catchment and hydropower system

Area  > 3000 km²
Elev  10-1700 masl

20 Hydropower stations
7 Large reservoirs
700 MW, 2700 GWh

Flood prone areas
In downstream area
From Nea-Nidelv catchment
Nea-Nidelv Floods - Summary

- Large reservoirs for hydropower
- Snowmelt floods most important
- Long term optimization (seasonal) needed for reservoirs
- First flood forecasts by models issued in 1976
- Very significant flood reduction observed – due to reservoirs
- Well documented case
Telemark river system
Telemark – major river basins

Tinn (4119 km²)
Hjartdal-Tuddal (1000 km²)
Bø-Seljord (1056 km²)
Tokke-Vinje (3640 km²)
Norsjø (999 km²)

Catchment area 10777 km²
Average flow 263 m³/s
Telemark – the most flood prone areas

- Notodden
- Norsjø
- Skien Hjellevatn
Telemark- Main hydropower reservoir areas

1. Mår,
2. Tokke-Vinje,
3. Møsvatn
Telemark – Extensive hydropower system

Some summary data:
33 HPPs
2179 MW
9932 GWh/year
7.5% of Norway
A complex hydropower system

The Tokke - Vinje scheme

- SONGA 120 MW
- KJELA 60 MW
- Haukelia 6 MW
- VINJE 300 MW
- LIO 40 MW
- Børte 20 MW
- Tokke 430 MW

Legend:
- Tunnel
- Dam
- Power st.
- Main road tunnel
- Lake used for reservoir
- Other
- Songa
- Power station
- Lake/dam
Tinnelva – Major flood in 1927
Rjukan - Flood and landslides in 1927
Hjartdøla (close to Notodden) – Flood in 2015
Telemark flood forecasting model system

- Rainfall Temp Prognosis
- Upstream hydrop. inflow
- Reservoir operation

Hydrological prognosis

Reservoir & river routing

Flood mapping

Hydrol. Prog
WSEL Q
• Significant flood risk in the river basin in downstream areas
• Many large flood events recently – high media focus
• Flood damage can be mitigated by hydropower reservoirs
• Conflicts between flood mitigation and power generation
• Difficult to find optimal operation for reservoirs
• The Telemark flood model was developed as a tool
• Tested during several years of operation since 2008
• «Acid test» during the 2015 flood «Petra»
Vosso river system
Vosso river system – Flood risk in Voss town

2014 Flood in Voss

200 yr flood in Voss
Flood risk in Voss town – can inflow be diverted?

Could floods in Voss town be reduced/avoided by diverting rivers?
Rivers could be diverted through tunnels to nearby fjord at Granvin.

Hydropower plants in the tunnels could pay for the tunneling cost (500 GWh/yr)…
Glomma river system

Area 40 000 km²
Avg flow 600 m³/s
Max flood > 4000 m³/s

Hydropower:
2500 MW, 12300 GWh
In 1995 the biggest floods in this century occurred in Norway, in a two week period from May 27th to June 10th.

This flood created damage in the order of 1800 Mill. NOK, equivalent to 300 Mill US $.

The flood was caused by a combination of large initial snowpack, a delayed spring and unusual but not extreme precipitation in combination with high air temperature during the flood event.
A large research program called HYDRA was initiated as one of the measures taken by the government to be better prepared to meet possible future floods.

The main research topics in this program were:

- To understand combined effects on flood of land use changes in the catchment
- To improve flood forecasting methods
- To improve methods to reduce damage in flood prone areas
- To make optimal use of hydropower reservoirs during floods
The HYDRA flood model

The HYDRA River System Model is using these type of objects to represent a real river system:

- Reservoir
- Power plant
- Diversion
- Flood protection works
- Urban area
- Other ("Natural") components:
  - Lake (ureg.)
  - River reach
  - Catchment
Hydropower structures - Impact on 1995 - flood
HYDRA - Some conclusions

• Floods in Glomma have been affected by anthropogenic influence from 1900 to 1990

• This has led to a flood reduction, not larger floods, practically everywhere in the river

• The major part of the flood reduction is caused by hydropower regulation reservoirs

• Urbanization may lead to increasing floods, but the effect is only visible locally in small catchments and have no detectable effects in the main rivers

• The greatest potential for further reduction in floods is probably to improve the operation of regulating reservoirs and if possible to build new reservoirs
Hydropower may decrease flood risk by technical structures
- Reservoirs storing flood peaks
- Diverting flood water through tunnels/canals/pipes

Optimal operation of flood/hydropower reservoirs is challenging
- Operation need to consider multiple objectives
- Energy production require reservoirs as full as possible
- Flood mitigation requires reservoirs as empty as possible
- Other uses (Irrigation, transport, tourism, …) mostly full?
- Reservoirs should be lowered just before flood arrives
- With «perfect» forecasts this may be possible (not always)
- Still – generation will usually be reduced (and money lost)
- Who will pay the cost and who will benefit?

Key question: How to balance between these objectives?
Thank you!

Questions?