NTNU

Kunnskap for en bedre verden

Hydraulic Engineering Master Thesis 2022

Master oppgåver i Vassbygging 2022

Thesis	Student	Supervisor
Optimization and engineering geological evaluation of headrace tunnel system of Akavreta HPP in Georgia	Vladimer Birkadze	Krishna K. Panthi
Frå kraftverk til pumpekraftverk	Marianne Aske	Leif Lia
Experimental study into the overtopping and breaching of rockfill dams with erosion protection	Raj Kumar KC	Fjola Sigtryggsdottir
Hydraulic Modelling using image derived bathymetry	Eyob Simanesew	Knut Alfredsen
Stability assessment of the underground powerhouse cavern for Tamakoshi V Hydroelectric Project	Kamal Ghalan	Krishna Kanta Panthi
Overtopping and breaching of rockfill dams with and without a central core	Saroj Sapkota	Fjola Sigtryggsdottir
Assessment of the suitability of WEAP for studies of the flood dampening effects of reservoirs in Norway	Sajana Pramudith Hemakumara	Tor Haakon Bakken
Produksjonssimulering av Tjørhom pumpekraftverk	Olav Magnus Egeland	Leif Lia
Construction of Kayak Waves	Maren Johanne Mood	Elena Pummer
3D numerical modeling of a river confluence – movable bed implications	Ayda Mirzaahmadi	Nils Rüther
2D Numerical Modelling of Sediment Diversion in River Bend	Rajeev Shrestha	Nils Rüther
Oppgradering av Tunnelsystem og Vasskraftverk	Håkon Veivåg Tveit	Leif Lia
Evaluation Of Flood Control in Stryn With Potential Hydropower Production	Christine Kaggwa Nakigudde	Oddbjørn Bruland
Machine Learning Methods for Bathymetry Generation in Rivers	Raffa Ahmed Osman Ahmed	Knut Alfredsen
2D Numerical Modelling of Hydraulics and Sediment in a Reservoir	Moyinjah Micheal Bello	Nils Ruther
Multipurpose use of reservoirs	Mone Seifu Gragne	Tor Haakon Bakken
Comparision of enviromental foot print of renewabel energy	Mihret Hailu Fenet	Tor Haakon Bakken
On the added value of ensemble forecasts	Jiyoung Kim	Elena Pummer
Comparison of Kinematic wave and Hydraulic model simulated water level along river sections	Mohammadreza Memarzadehashtiani	Oddbjørn Bruland
Retrofitting of non-hydro reservoirs and dams in Menderes river basin, Turkey	Quentin Adjetey Okang	Tor Haakon Bakken
Investigating the potential in retrofitting of non-hydro reservoirs and dams	Kristina Shrestha	Tor Haakon Bakken
Distributed hydrological modelling of Lærdal catchment to investigate changes in flow pattern	Tamba C'Diem Yancy	Knut Alfredsen

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Optimization and engineering geological evaluation of headrace tunnel system of Akavreta HPP in Georgia

By
Vladimer Birkadze

The Norwegian University of Science and Technology (NTNU)
Department of Geoscience and Petroleum

Dr. Krishna K. Panthi
Professor of geological engineering, main supervisor

2022

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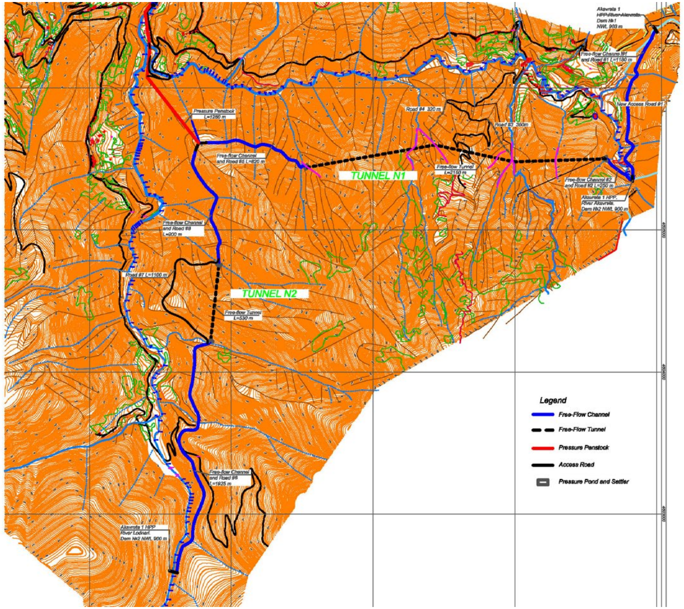
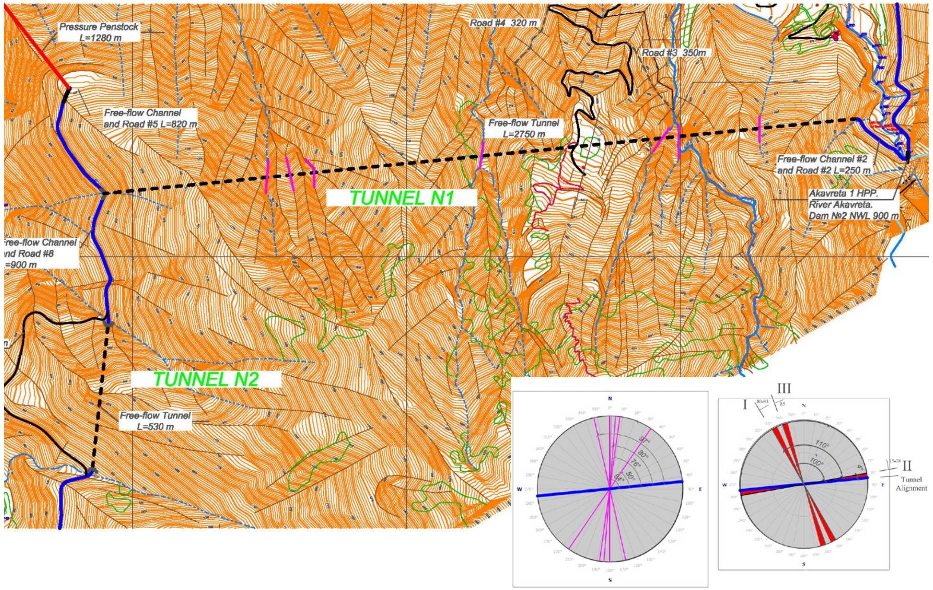
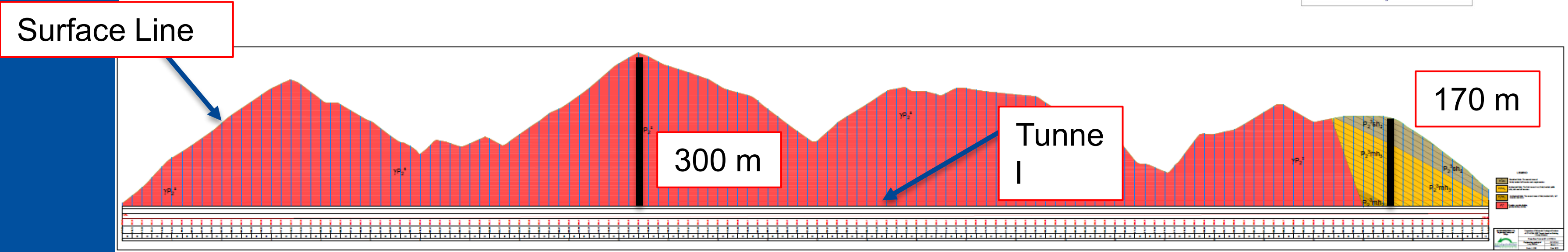
- Literature review
- Review the Akavreta HPP
- Evaluate current design
- Determine stability challenges
- Present alternative design
- Numerical Modeling
- Conclusion and recommendation

Current Alignment

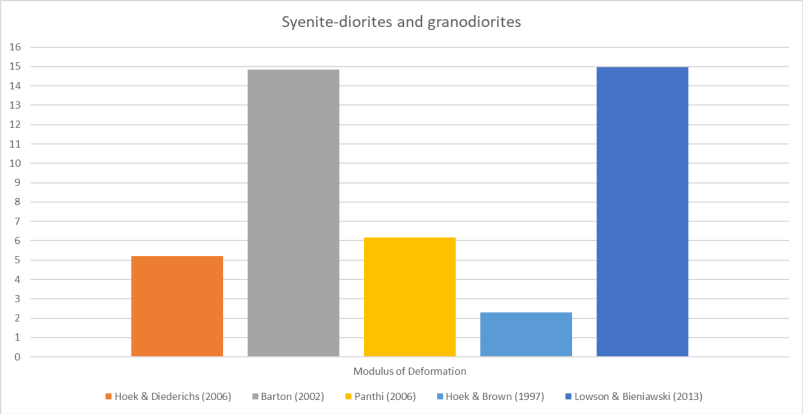


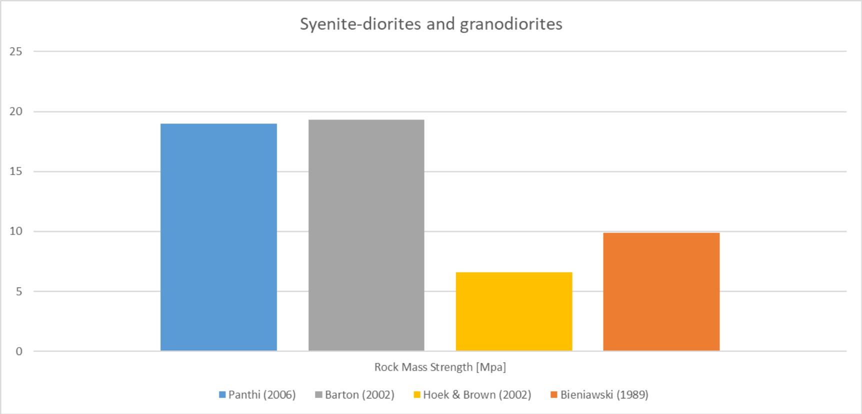
Alternative Alignment





Input Parameters





Rock Type	Panthi (2006)	Barton (2002)	H & D (2006)	H & B (1997)	L & B (2013)	Min	Max	Mean	Std
Tuff breccias and conglomerates	1	3	1	2	6	1	6	2	2.06
Syenite-diorites and granodiorites	6	15	5	10	15	5	15	10	4.62

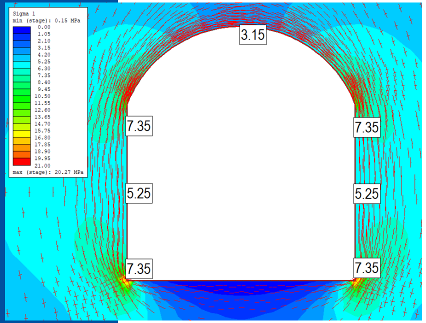
Rock Type	Panthi (2006)/(2018)	Barton (2002)	H & B (2002)	Bieniawski (1989)	Min	Max	Mean	Std
Tuff breccias and conglomerates	3	4	1	1	1	4	2	1.44
Syenite-diorites and granodiorites	19	19	7	10	7	19	14	6.44

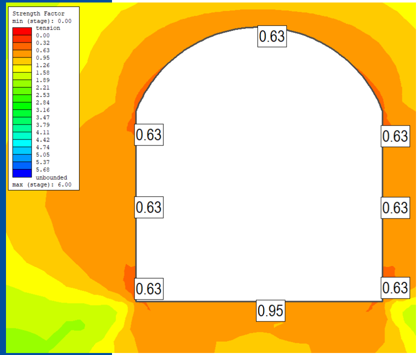
Rock Type	RMR	GSI	Q - Value
Tuff breccias and conglomerates	40	35	0.1
Syenite-diorites and granodiorites	55	50	3

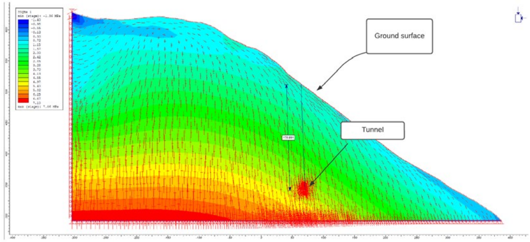
Rock Type	Poisson's ratio	Modulus ratio (MR)	Young's modulus [GPa]
Tuff breccias and conglomerates	0.18	300	9
Syenite-diorites and granodiorites	0.22	350	35

Numerical Analysis and Support system

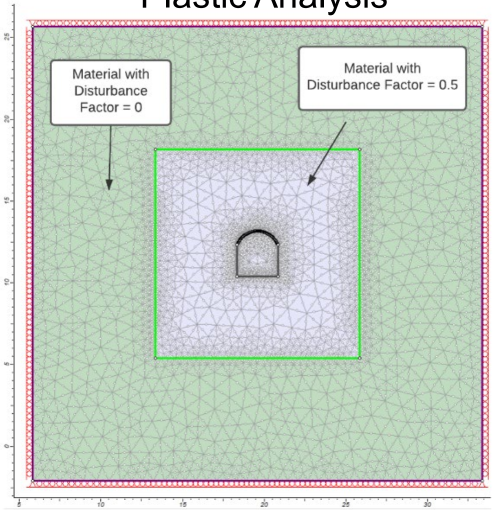
ELASTIC



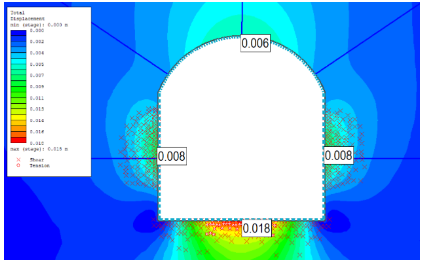


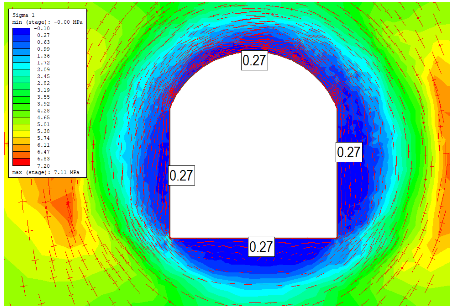


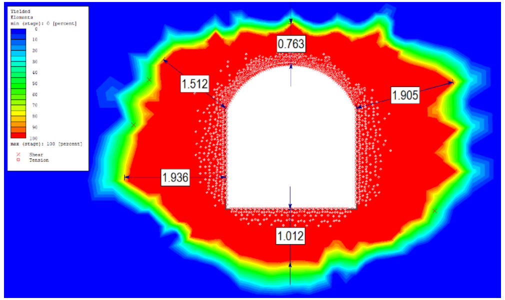
Confined area for Plastic Analysis

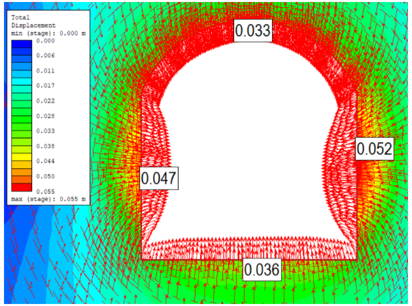


PLASTIC

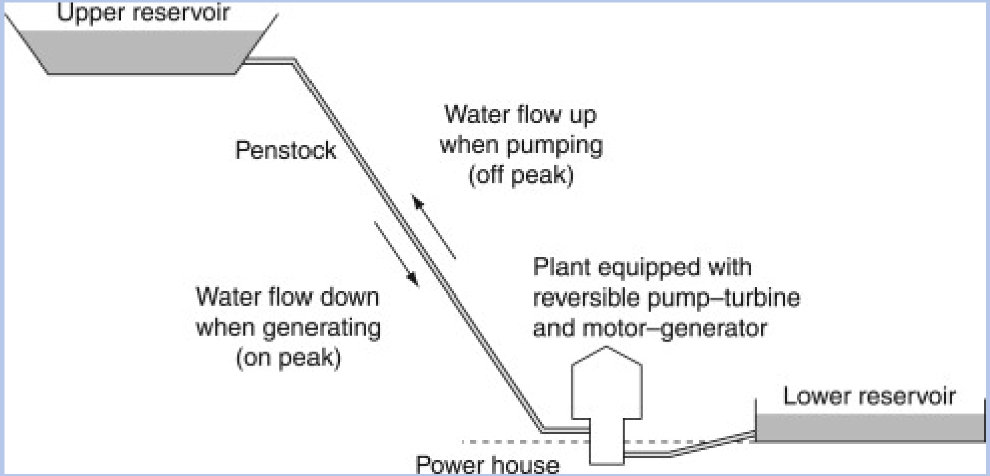






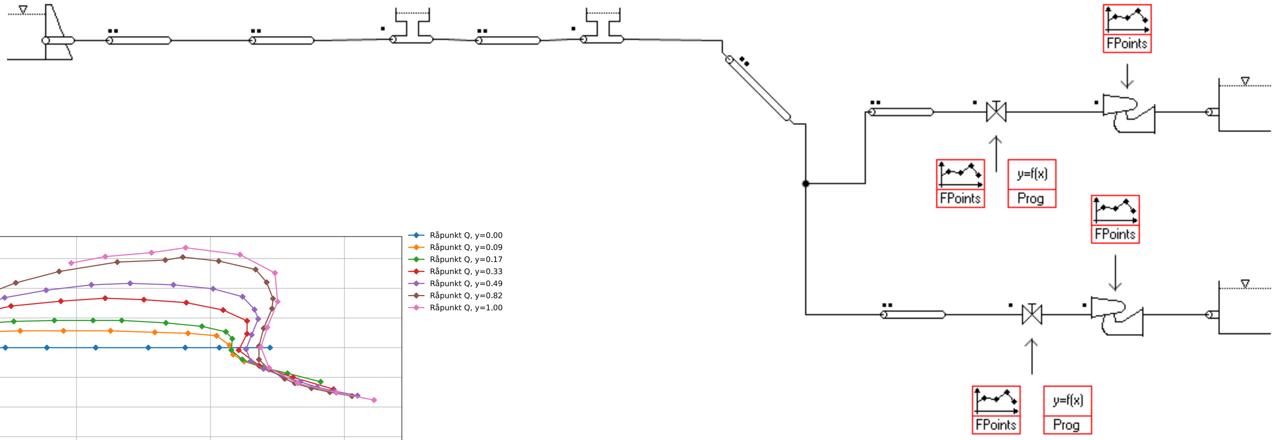


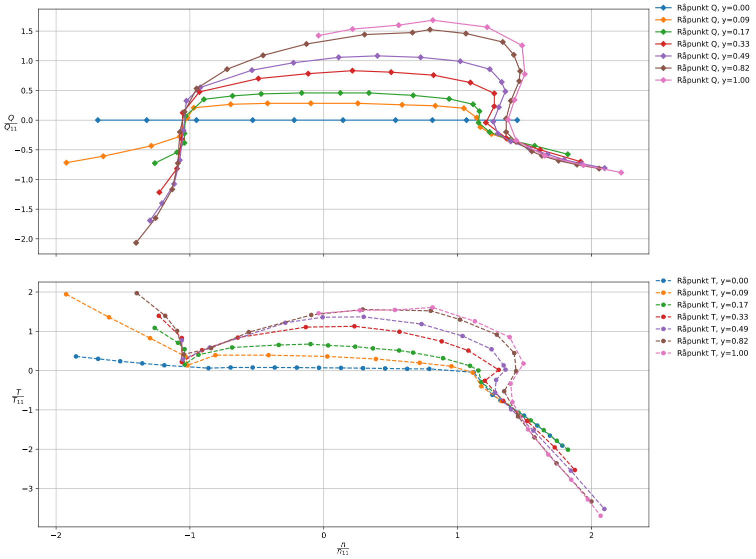
Mål: Finne ut om det er mulig å bygge om kraftverk til pumpekraftverk



Student:
Marianne Aske
Veileder
Leif Lia:

Metode: Numerisk modellering og litteraturstudie

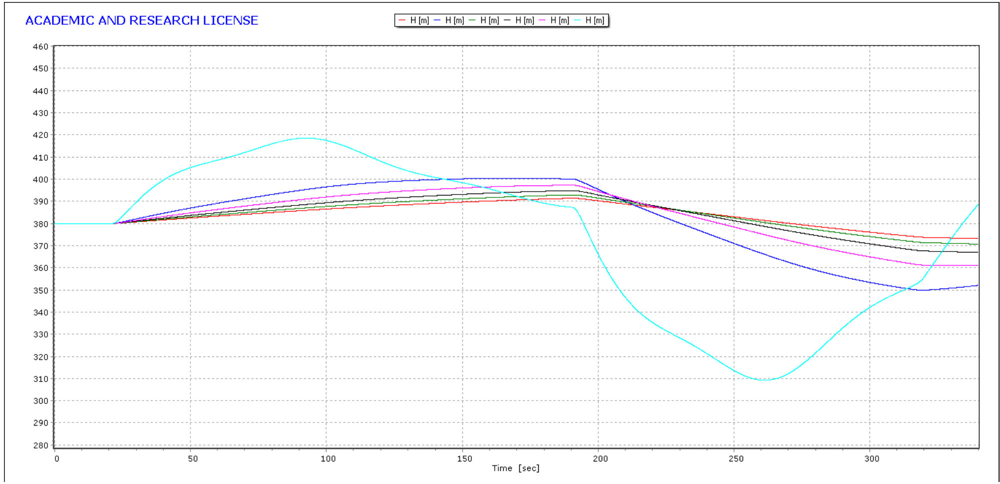


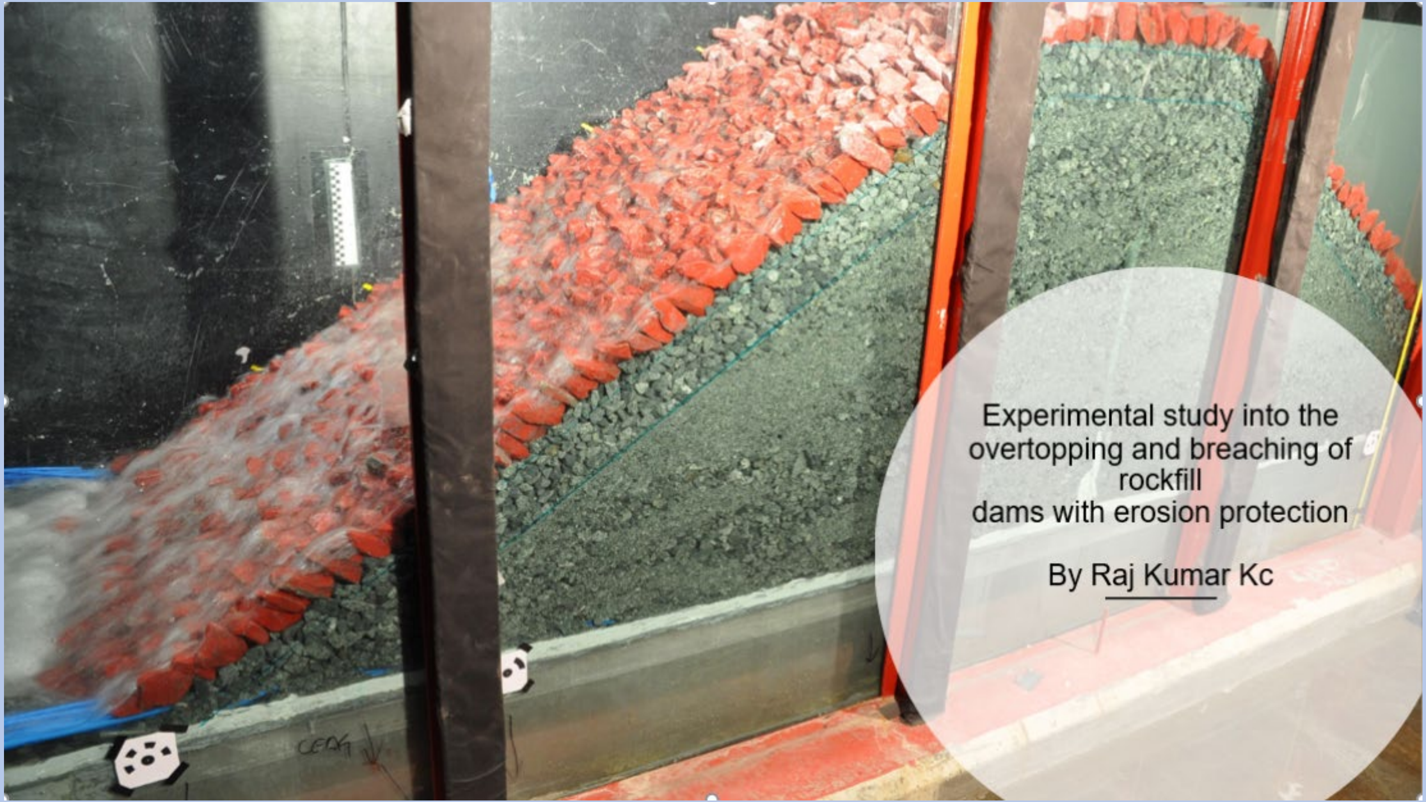


Numerisk modellering av reversibel pumpeturbin hvor eksisterende turbin er byttet ut med en reversibel pumpeturbin.
Litteraturstudie basert på publiserte artikler som kartlegger hva som må bygges nytt dersom de bygger ut pumpekraftverk i parallell

Utfordringer knyttet til ombygging

- Eksisterende inntak er nedstrøms reguleringsmagasinet
- Oppsving i bekkeinntak eller svingekammer
- Luftinnsug i bekkeinntak eller svingekammer
- Hyppige poretrykksendringer
- Stålfóret trykksjakt underdimensjonert
- Drukning av kraftstasjonen
- Manglende mottrykk på pumpen
- Manglende dykking av pumpen
- Manglende sandfang i nedre tilløpstunnel
- Krevende å dimensjonere en turbin som tåler vannstandsendringene
- Behov for svingekammer i nedre tilløpstunnel
- Eksisterende utløp er for høyt i nedre tilløpstunnel
- Eksisterende utløp går i kanal eller elveleie
- Aggregatet har høy brukstid – gjør det krevende å prioritere ombygging



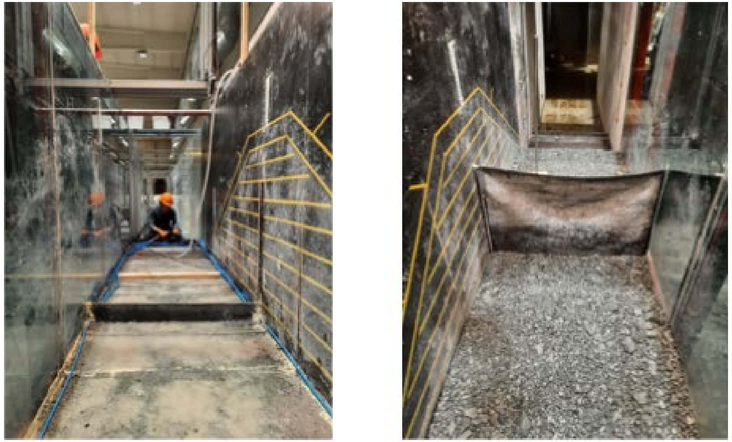

Experimental study into the
overtopping and breaching of
rockfill
dams with erosion protection
By Raj Kumar Kc

Goals

- Qualitative and quantitative analysis of the breaching process
- Failure mechanism and location of failure initiation
- pore water pressure measurements
- Inflow and outflow flood discharges
- PIV analysis for calculation of velocity during breach

Methodology

- Model setup
- Conducted tests
- Materials
- Construction
- Testing procedure



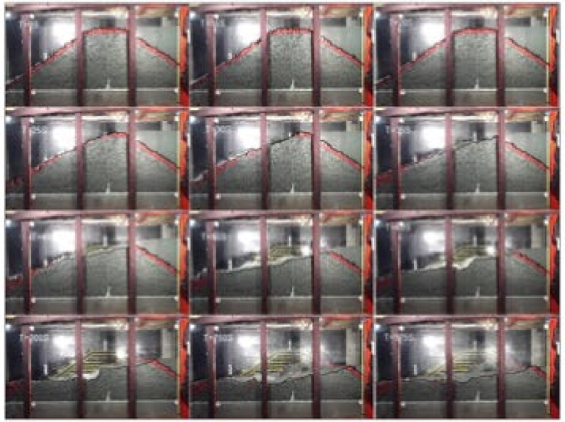
Construction

Testing procedure

Results

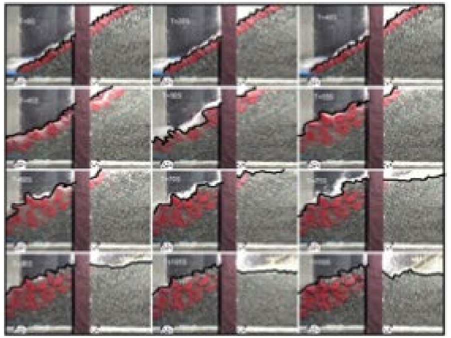
Tests carried out in the Hydradulic Lab

Test	Riprap Type	Pilot channel	Discharge (l/s)	Camera	Ramping Interval(min)
M1	Dumped(double layer)	Yes	30	6	30
M2	Dumped(single layer)	No	20	9	30
M3	Placed(single layer)	No	25	9	30

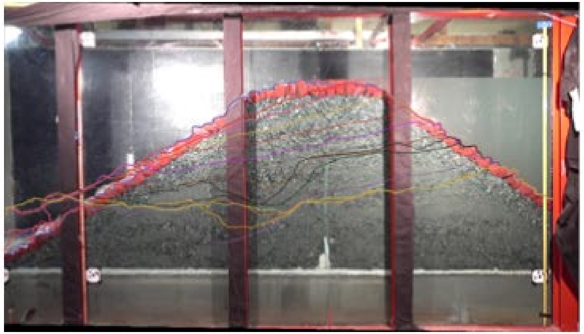


Breach Development Process

Location of failure initiation

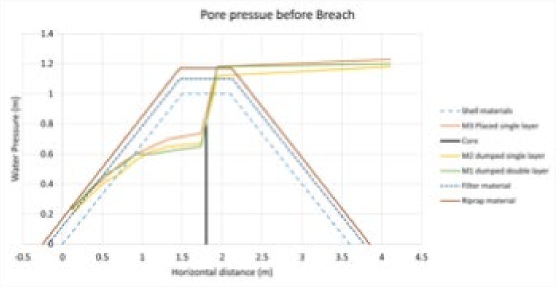


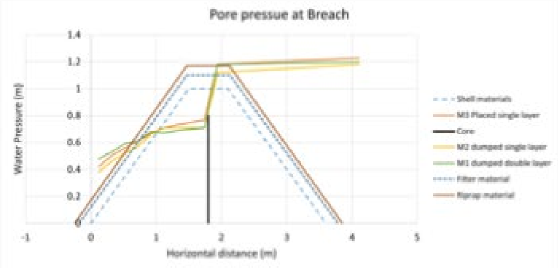
Breaching process at toe of placed riprap



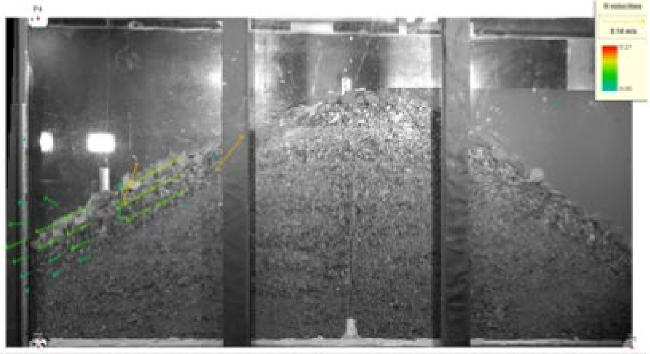
Temporal evolution of breach process in placed riprap

Cont..

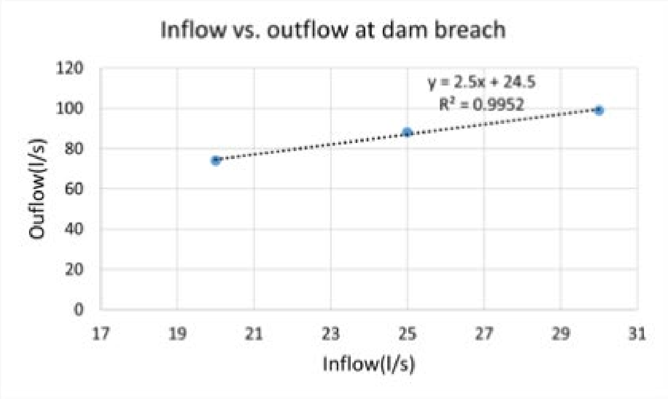




Pore pressure measurements



PIV analysis to calculate particle velocity during breach



Inflow breach and outflow flood discharge

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Hydraulic Modelling using image derived bathymetry

By:

Eyob Simanesew

Supervisor:
prof. Knut Alfredsen
Co-supervisors:
Mahmoud Awadallah

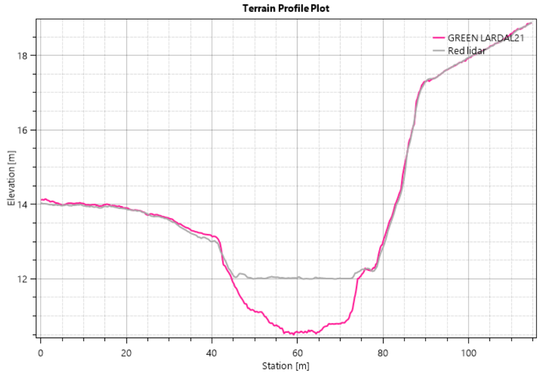
28,May 2022

Aim to do

From google

Aerial Imagery

LIDAR-Model



- Build a bathymetric model combining ***Aerial Imagery*** and ***topographic LiDAR.***

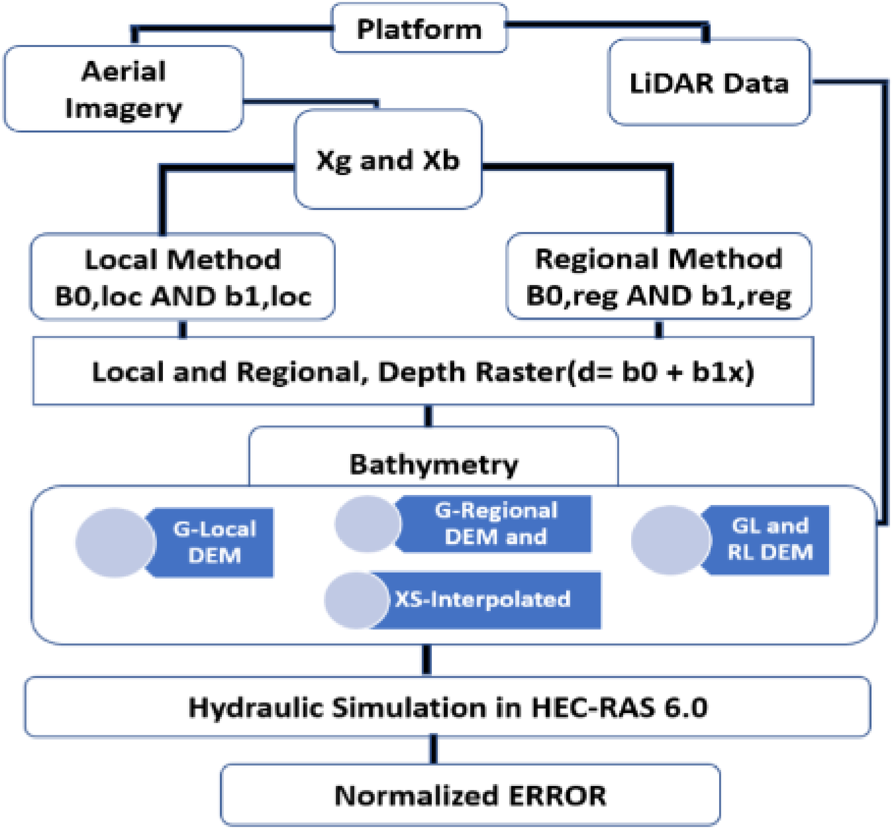
•Compare this result with the bathymetric model from GL- LiDAR data.

•Prepare the Hydraulic Model for derived Bathymetry.
•Compare the Flow simulation between derived Bathymetry and GL-LIDAR.

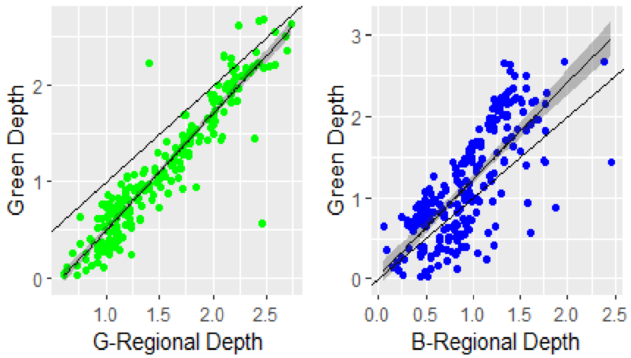
Why?

TO check the possibility of Calculating bathymetry from Aerial Imagery.

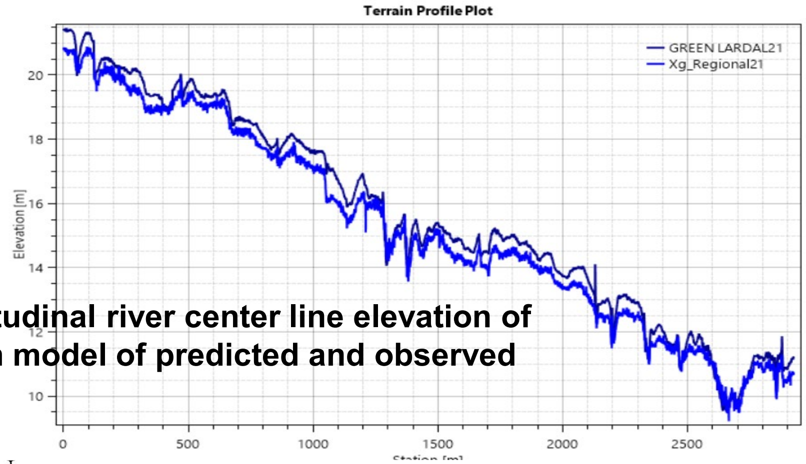
Methods


Platform
Aerial Imagery
LiDAR Data
Xg and Xb
Local Method B0,loc AND b1,loc
Regional Method B0,reg AND b1,reg
Local and Regional, Depth Raster(d= b0 + b1x)
Bathymetry
G-Local DEM
G-Regional DEM and
GL and RL DEM
XS-Interpolated
Hydraulic Simulation in HEC-RAS 6.0
Normalized ERROR

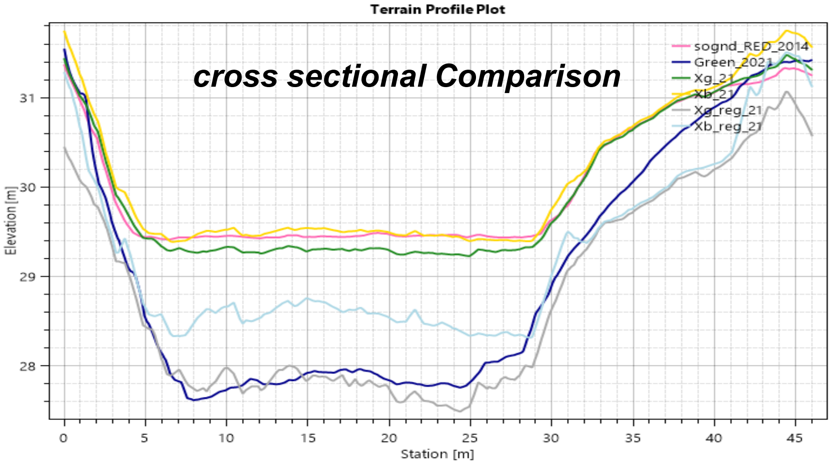
Result



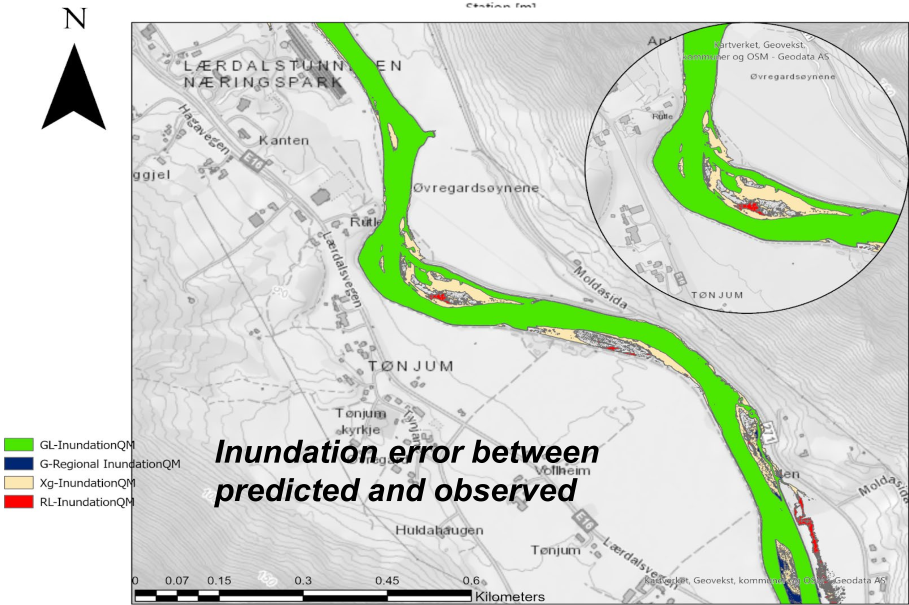
Comparison of model with Linear Regression



Longitudinal river center line elevation of terrain model of predicted and observed



cross sectional Comparison



Inundation error between predicted and observed

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Submitted by: Saroj Sapkota

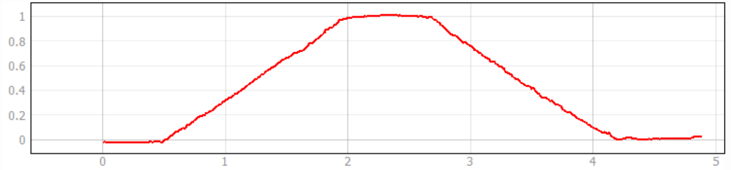
Overtopping and breaching of rockfill dams with and without a central core

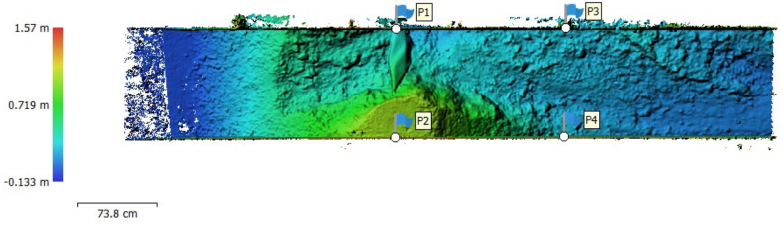
Why Rockfill dam study?

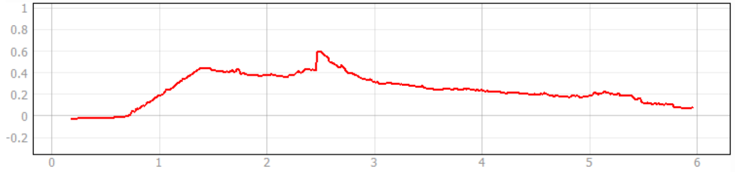
- Vulnerable to excess throughflow and overtopping
- Pervious and erodible material
- Represents > 70% of total dams worldwide
- Breaching process and parameters are important to estimate downstream flooding in case of failure
- Flood zone mapping and flood hazard mitigation
- Information for reliable consequence classification of dam and dam design requirement

How and where?

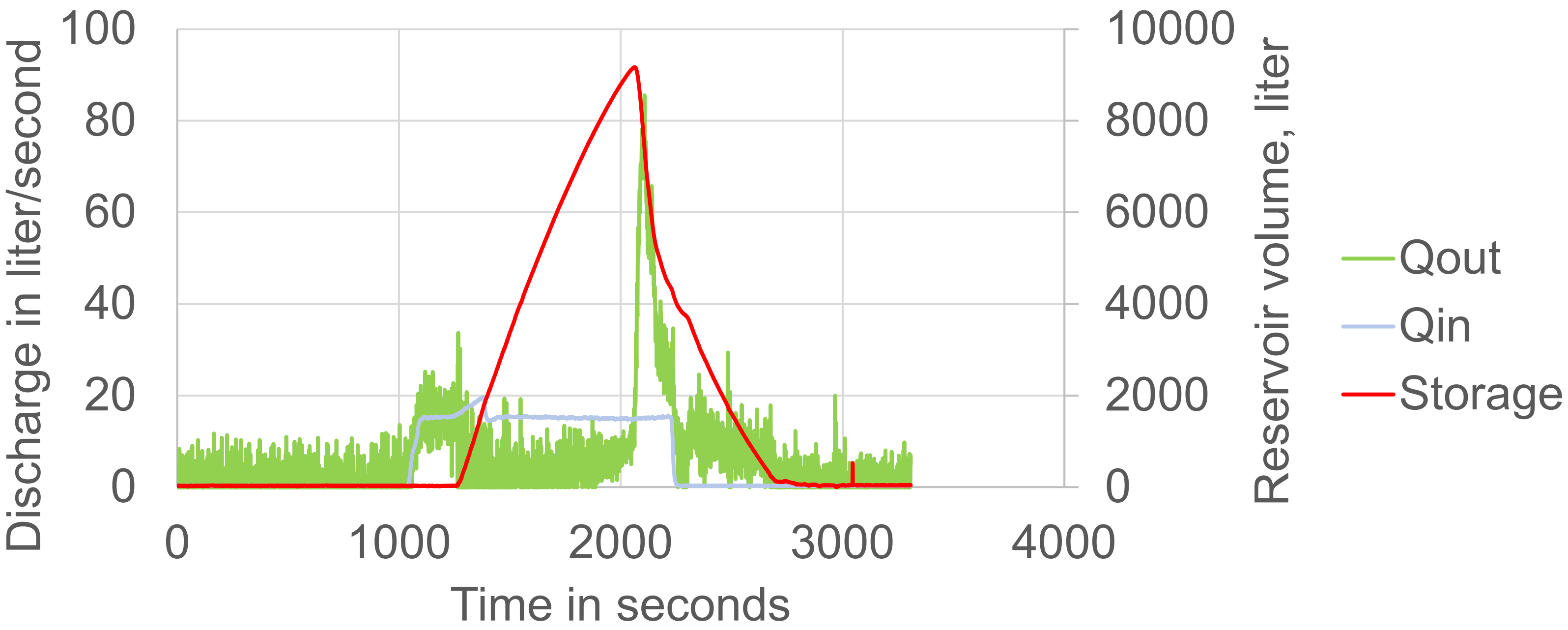
- **Physical model**
- Rockfill dam with and without core
- Four model tests conducted for each
- Scaled down to 1:10
- **In flume setup in hydraulic lab, NTNU**
- Result analysed in SFM (Agisoft)







Breaching discharge



Parametric model

- Statistically derived regression equation based on historical dam failure
- To estimate breaching parameters such as breach opening, failure time and peak discharge, for example peak discharge in different models below.

Model 15	Peak discharge, Q_p	Unit
Physical model test	0.09	m^3/s
MacDonald 1984	0.36	m^3/s
Froehlich 1995b	1.02	m^3/s
Xu Zang 2009	0.11	m^3/s
Froehlich 2016b	0.31	m^3/s

Conclusion

- Breaching process and parameters vary with dam configuration, material used, building methodology and protection measures
- Failure includes complex combination of different mechanism
- Dams without core suffer more through flow while dams with core fail mostly with overtopping and downstream slope erosion
- No sudden collapse of dam as like in dam with protection layer, the failure progresses smoothly
- No single model (physical or parametric) can be fully trusted for analysis and decision making as there is larger variation in result

Thesis Title: Stability assessment of the underground powerhouse cavern for Tamakoshi V Hydroelectric Project

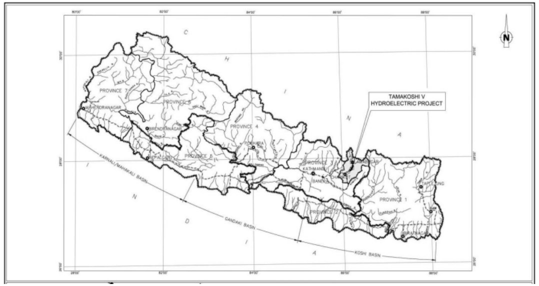
Supervisor: Dr Prof. Krishna Kanta Panthi

Co-supervisor: PhD. Fellow Bikash Chaudhary

(Department of Geoscience and Petroleum)

Submitted By: Kamal Ghalan

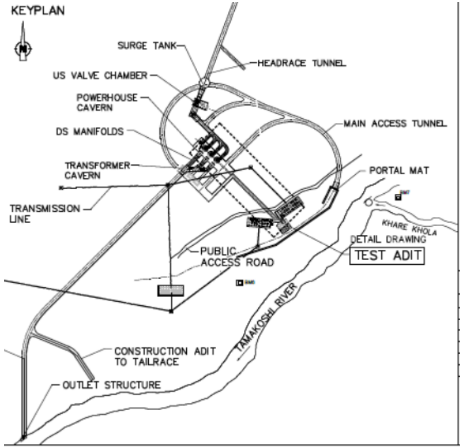
Background and General information about the Tamakoshi V HEP



- Cascade tandem project with Upper Tamakoshi HEP(456 MW) owned by Nepal Electricity Authority (NEA).
- Installed Capacity of 98.8 MW, with all the major civil components underground.
- Feasibility study was done in 2011, Detailed Design Report in 2019.
- Currently in the phase of starting construction.

Location:

- E=425299.640 & N=3077757.465 and E=418732.327 & N=3077799.811 in the north and
- E=418682.953 & N=3070443.874 and E=425252.312 & N=3070401.607 in the south
- Powerhouse site is at Suritar about 4 km north of Singati Bazar. 200m from the public road.



Background for Thesis Study:

- Long-term stability and sustainability of the project.
- Optimum stability, accessibility, cost and construction of the time.
- Located very near to the Main Central Thrust (MCT) of the Himalayas, persistent tectonic movement.

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Thesis Task

- Review theory on an underground powerhouse cavern design and prevailing stability assessment methods.
- Briefly describe Tamakoshi V Hydroelectric Project. Present the extent of engineering geological investigations carried out for the underground powerhouse cavern.
- Assess and estimate engineering geological and mechanical input parameters needed for stability assessment using empirical, analytical, and numerical modelling methods.
- Critically evaluate the existing location, orientation, and underground powerhouse cavern placement design. Assess whether there exists a possibility for an alternative location.
- Carry out an extensive assessment of the type of stability challenges that the underground powerhouse cavern may face during construction. Evaluate each challenge using prevailing rock engineering theory (empirical and analytical methods) discussed in the chapter on the theory review.
- Carry out the stability assessment of underground powerhouse caverns using 2D and 3D numerical modelling and optimize the rock support need.
- Make a comprehensive assessment of the impact of earthquake load on the long-term stability of the underground powerhouse cavern.
- Compare and discuss the stability condition of the cavern under both static and dynamic(earthquake) loading.

Methodology

- **Rock mass classification:**

i. **Empirical:** Q-system (Barton and Grimstad, 1993), GSI (Hoek and Brown, 1997) and RMR(Beiniawski, 1993)

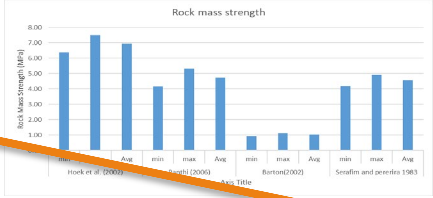
- **Stability Assessment**

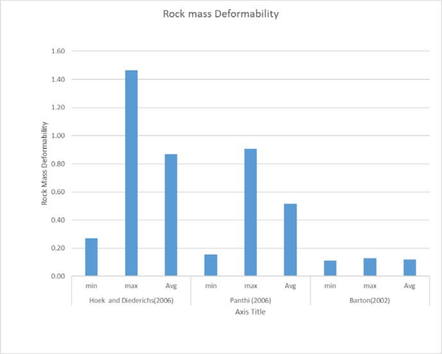
i. Empirical: Singh et al.(1993), Hoek et al. (2002), Goel et al.1995)
ii. Analytical: CCM (Carranza-Torres and C, Fairhurst (1999)
iii. Numerical: RS2, RS3, Unwedge, RSdata

- **Input Parameter Establishment and Estimation**

i. Rock mass strength(σ_{cm})
ii. Rock mass deformability(E_{rm})

	Minimum	Maximum	Average
Intact Uniaxial compressive strength UCS, σ_{ci} [MPa]	40	47	43
GSI	41		
Poisson's Ratio	0.25		
Unit wt (t/m3)	2.65		
Disturbance Factor, D	0.5		
S Peak value	0.000383		
a Peak value	0.511		
Mi	26.000		
Mb	1.535		
RMR_{lab}	46		
Q_{lab}	0.833		





- **Failure Analysis**
- i. brittle failure(rock spalling or burst)
- ii. plastic analysis (Squeezing)
- **Support Estimation**

i. Q-System(adopted), RMR

- **Static and Dynamic Loading**
- Pseudo dynamic analysis /simplified dynamic method.

Results

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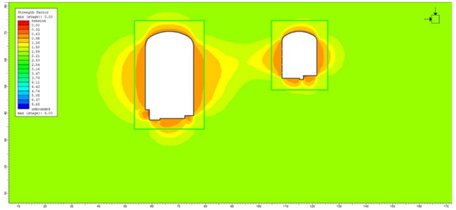
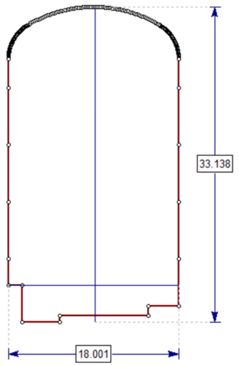
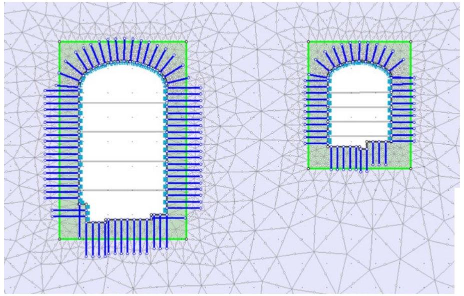
	Overburden [m]	Poisson's ratio	Stress ratio k	Horizontal Stress σh[MPa]	Vertical Stress [MPa]	Tectonic Out of plane [MPa]	Tectonic in-plane [MPa]	Horizontal stress Out of plane [MPa]	Horizontal stress in-plane [MPa]
powerhouse	186.84	0.25	0.33	1.68	5.04	0.52	2.95	2.20	4.64
TC	167.08	0.25	0.33	1.50	4.51	0.52	2.95	2.02	4.46







Support Calculations

Empirical methods

1. Q system $Q = RQD/Jn \times Jr/Ja \times Jw/SRF$

De 2*Q^0.4 1.859037
OR
De limiting span or height of the opening/excavation support ratio
25.71429 ESR is taken as 0.5-0.8 for underground powerplant
18 ESR is taken as 0.90-1.1 for powerstation

a. Bolts for powerhouse
For roof Length(L) 4.7
for wall Length(L) 6.971
spacing 1.6m
For permanent roof support pressure
$Pv = 0.2 / Jr \times Q$^−0.33 MPa
0.014162 MPa

b. shotcrete
9-12 cm thick

b. bolts for transformer cavern
For roof Length(L) 3.95
for wall Length(L) 4.6925

For permanent wall support pressure
$Pv = 0.2/ Jr \times Qw$^−0.33
0.035405 MPa

Barton et al. (1974) recommended that if the Joint Set Number (Jn) is less than 3 which means three joint sets or two joint set plus random--is generally defined as the limiting case for three dimension rock block.

For permanent roof support pressure
$Pv = 0.2 \times Jn$^0.5/(3×Jr) × Q^−0.33
0.016353 MPa

For permanent wall support pressure
$Pv = 0.2 \times Jn$^0.5/ (3×Jr) × Q^−0.33
0.040882 MPa

Table 3-6 Description of Support system with respective Support Class (after Barton et al., 1993)

Support Class	Description of Support
SI-I	Systematic Bolting @ 2.1m c/c and Plain shotcrete of 4 cm thickness
SI-II	Pattern Bolting @ 1.7m c/c and Fiber reinforced shotcrete of 5 cm thickness
SI-III	Pattern Bolting @ 1.3m c/c and Fiber reinforced shotcrete of 12cm thickness
SI-IV	Pattern Bolting @ 1.2m c/c and Fiber reinforced shotcrete of 15cm thickness
SI-V	RRS with 6 Bar Reinforcement at a single layer of diameter 16 mm with 35cm thickness of shotcrete @ 2.3m c/c with pattern bolting of 1m spacing c/c
SI-VI	RRS with Double layer reinforcement of nos. 6 and 4 with the thickness of shotcrete 40 cm and spacing 1m c/c

Table 3-5 Range of the support Category

Defining the support class		
Maximum Q-Value	Minimum Q-value	Support Category
1000	4	SI-I
4	1	SI-II
1	0.1	SI-III
0.1	0.04	SI-IV
0.04	0.01	SI-V
0.01	0.001	SI-VI

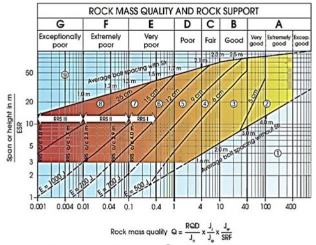
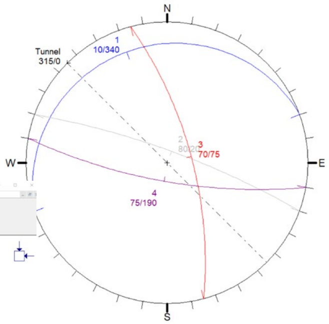


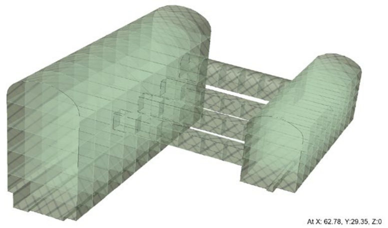
Table 2-5 Wall factor for respective Q-value (after Singh and Goel, 2011)

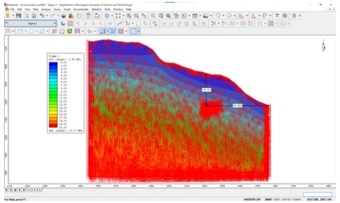
Range of Q	Wall factor Q_w
>10	5.0 Q
0.1-10	2.5 Q
<0.1	1.0 Q

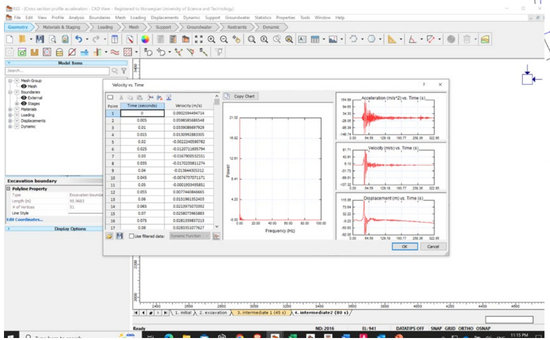
Table 2-4 Table of ESR (after Singh and Goel, 2011)

	Type of excavation	ESR
A	Temporary mine openings, etc.	2-5
B	Permanent mine openings, water tunnels for hydropower (excluding high pressure penstocks), pilot tunnels, drift and headings for large openings, surge chambers	1.6-2.0
C	Storage caverns, water treatment plants, minor road and railway tunnels, access tunnels	1.2-1.3









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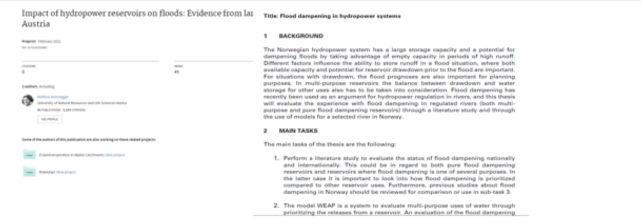
Assessment of the suitability of WEAP for studies of the flood dampening effects of reservoirs in Norway

Water Evaluation And Planning

SEI Stockholm Environment Institute

- **Supervisor** : Professor Tor Haakon Bakken
- **Submitted by:** Sajana Pramudith Hemakumara

Perform a national and international literature study to evaluate flood dampening from reservoirs.


Impact of hydropower reservoirs on floods: Evidence from la[r]
Austria

Title: Flood dampening in hydropower systems

1 BACKGROUND

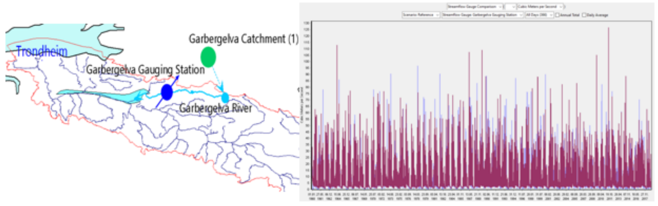
The Norwegian hydropower system has a large storage capacity and a potential for dampening floods by taking advantage of empty capacity in periods of high runoff. Different factors influence the ability to store runoff in a flood situation, where both available capacity and potential for reservoir drawdown prior to the flood are important. For situations with drawdown, the flood prognoses are also important for planning purposes. In multi-purpose reservoirs the balance between drawdown and water storage for other uses also has to be taken into consideration. Flood dampening has recently been used as an argument for hydropower regulation in rivers, and this thesis will evaluate the experience with flood dampening in regulated rivers (both multi-purpose and pure flood dampening reservoirs) through a literature study and through the use of models for a selected river in Norway.

2 MAIN TASKS

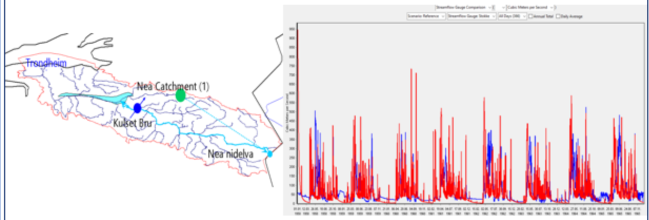
The main tasks of the thesis are the following:

1. Perform a literature study to evaluate the status of flood dampening nationally and internationally. This could be in regard to both pure flood dampening reservoirs and reservoirs where flood dampening is one of several purposes. In the latter case it is important to look into how flood dampening is prioritized compared to other reservoir uses. Furthermore, previous studies about flood dampening in Norway should be reviewed for comparison or use in sub-task 3.
2. The model WEAP is a system to evaluate multi-purpose uses of water through prioritizing the releases from a reservoir. An evaluation of the flood dampening

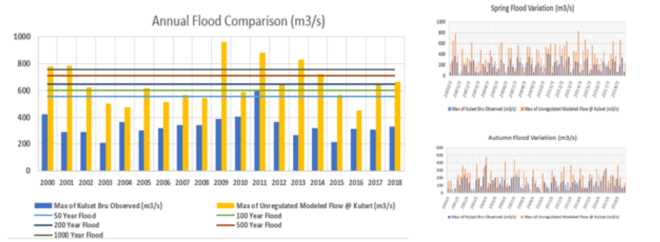
Configure and assess the performance of WEAP to Garbergelva river basin (an unregulated neighbor basin to the Nea river basin).



Configure WEAP to the highly regulated Nea river basin and perform simulations of runoff and floods in Nea in an unregulated state.



Select episodes that highlights the effect of reservoirs on discharges/floods.



Aim of the Thesis

- Assess the suitability of WEAP in addressing the role of reservoirs in dampening of floods in a regulated system in Norway
- Assess the suitability of WEAP developing and calibrating a hydrological model in Norwegian climatic conditions.
- Transferring of the calibrated parameters from a neighbouring catchment.

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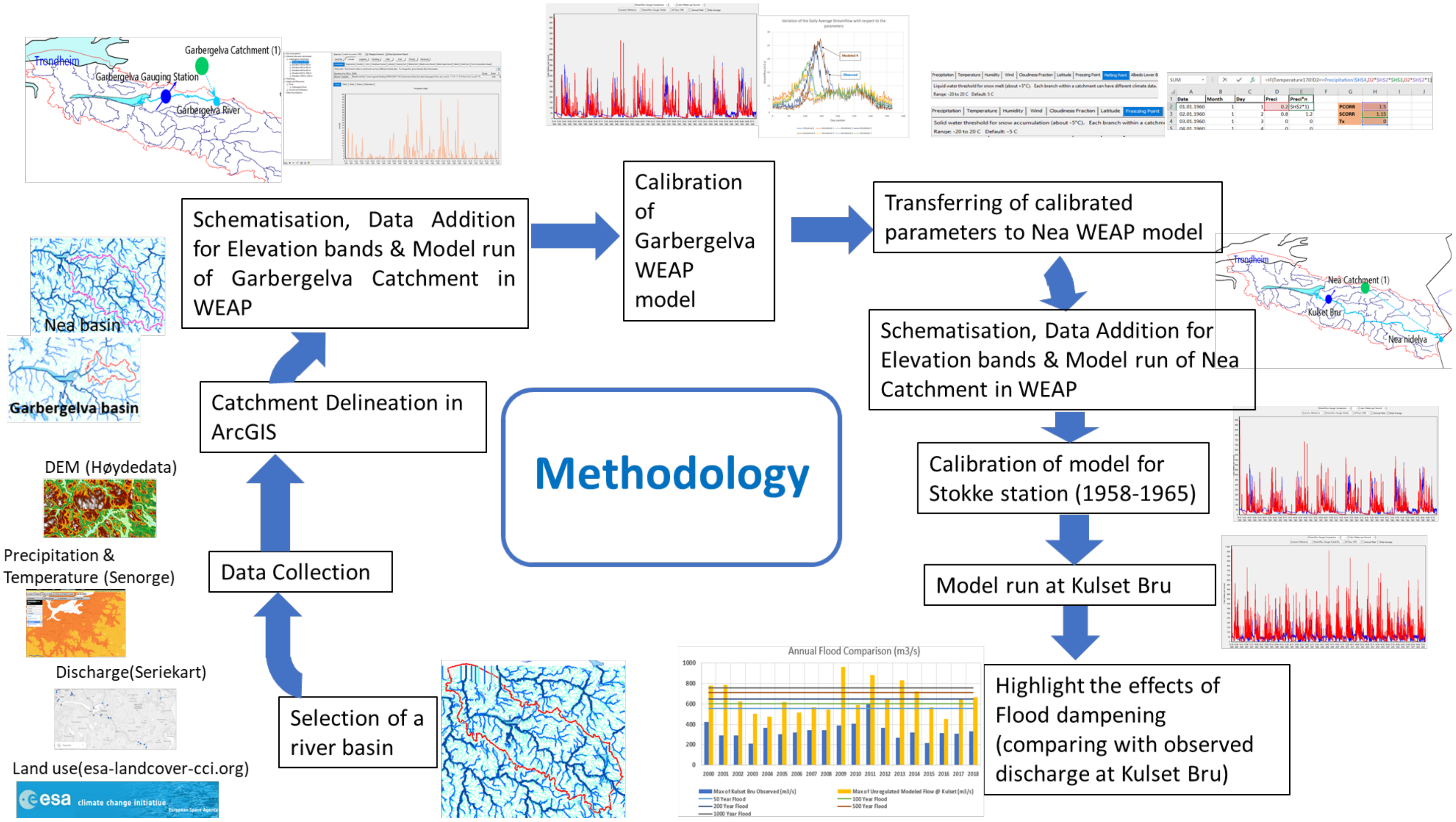
Trondheim
Garbergelva Catchment (1)
Garbergelva Gauging Station
Garbergelva River
Nea basin
Garbergelva basin
DEM (Høydedata)
Precipitation &
Temperature (Senorge)
Discharge(Seriekart)
Land use(esa-landcover-cci.org)
esa climate change initiative
Selection of a river basin
Data Collection
Catchment Delineation in ArcGIS
Schematisation, Data Addition for Elevation bands & Model run of Garbergelva Catchment in WEAP
Calibration of Garbergelva WEAP model
Transferring of calibrated parameters to Nea WEAP model
Trondheim
Nea Catchment (1)
Kulset Bru
Nea nidelva
Schematisation, Data Addition for Elevation bands & Model run of Nea Catchment in WEAP
Calibration of model for Stokke station (1958-1965)
Model run at Kulset Bru
Highlight the effects of Flood dampening (comparing with observed discharge at Kulset Bru)
Methodology
Annual Flood Comparison (m3/s)
Max of Kulset Bru Observed (m3/s)
Max of Unregulated Modeled Flow @ Kulset (m3/s)
50 Year Flood
100 Year Flood
200 Year Flood
500 Year Flood
1000 Year Flood

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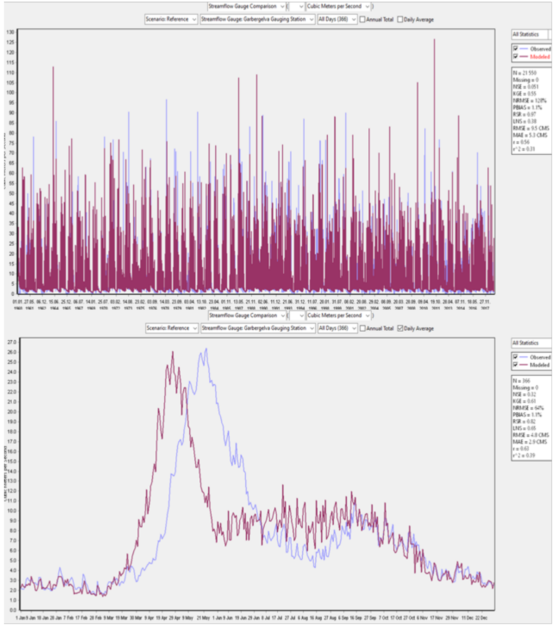
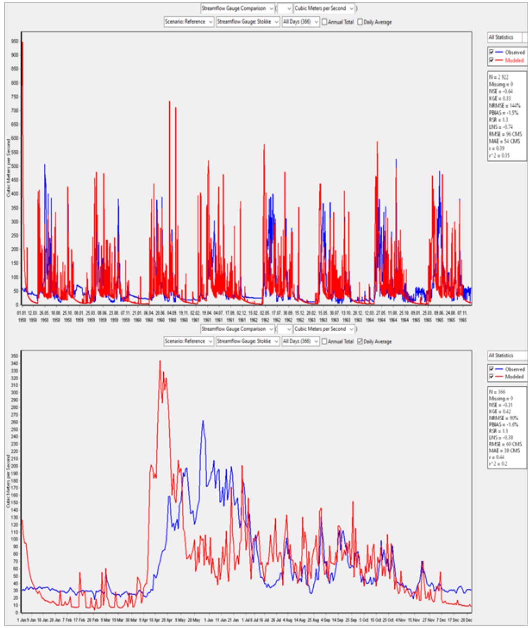
Model Results

Garbergelva Streamflow Results



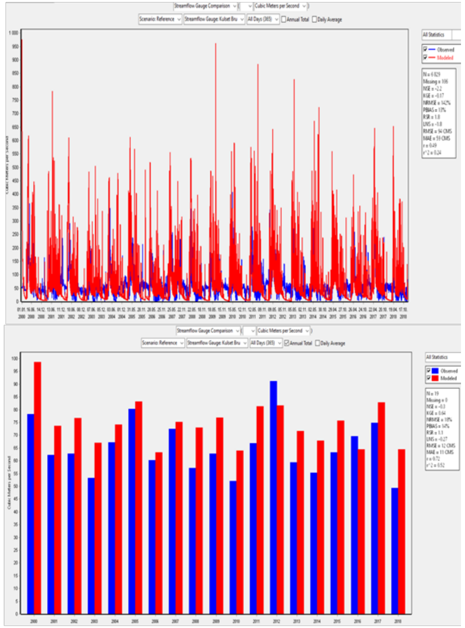
1960-2021
PBIAS = 1.1%
PCORR=1.5, SCORR=1.15

Stokke Streamflow Results



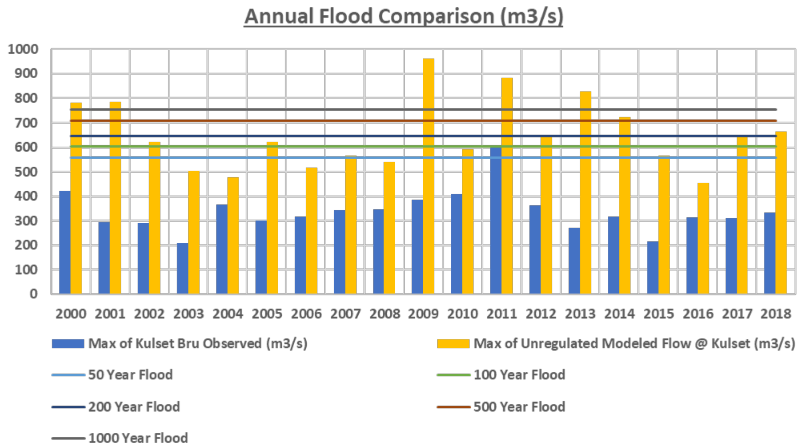
1958-1965
PBIAS = -1.5%
PCORR, SCORR= 1.15

Kulset Streamflow Results

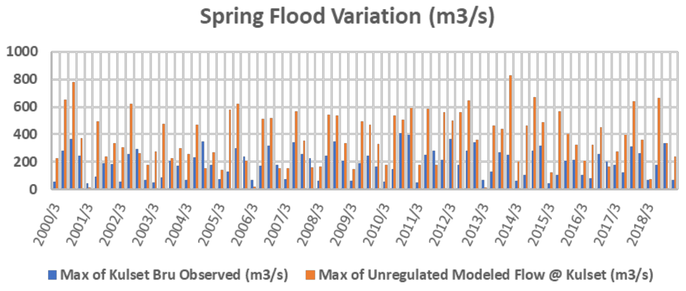


2000-2018
PCORR, SCORR= 1.15

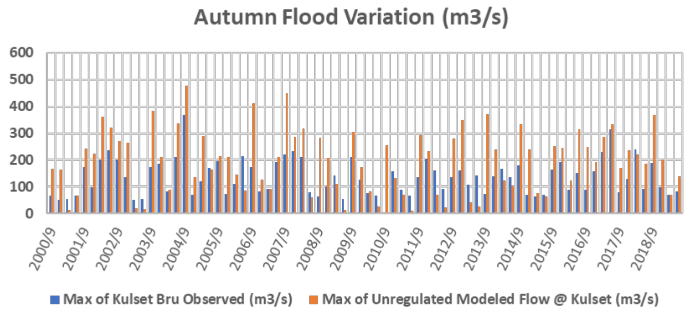
Analysis



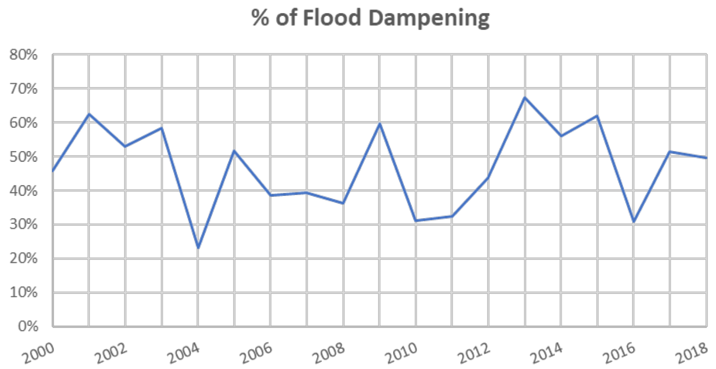
Annual Flood Comparison (m3/s)
1000
900
800
700
600
500
400
300
200
100
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Max of Kulset Bru Observed (m3/s)
Max of Unregulated Modeled Flow @ Kulset (m3/s)
50 Year Flood
100 Year Flood
200 Year Flood
500 Year Flood
1000 Year Flood



Spring Flood Variation (m3/s)
1000
800
600
400
200
0
2000/3 2001/3 2002/3 2003/3 2004/3 2005/3 2006/3 2007/3 2008/3 2009/3 2010/3 2011/3 2012/3 2013/3 2014/3 2015/3 2016/3 2017/3 2018/3
Max of Kulset Bru Observed (m3/s)
Max of Unregulated Modeled Flow @ Kulset (m3/s)



Autumn Flood Variation (m3/s)
600
500
400
300
200
100
0
2000/9 2001/9 2002/9 2003/9 2004/9 2005/9 2006/9 2007/9 2008/9 2009/9 2010/9 2011/9 2012/9 2013/9 2014/9 2015/9 2016/9 2017/9 2018/9
Max of Kulset Bru Observed (m3/s)
Max of Unregulated Modeled Flow @ Kulset (m3/s)



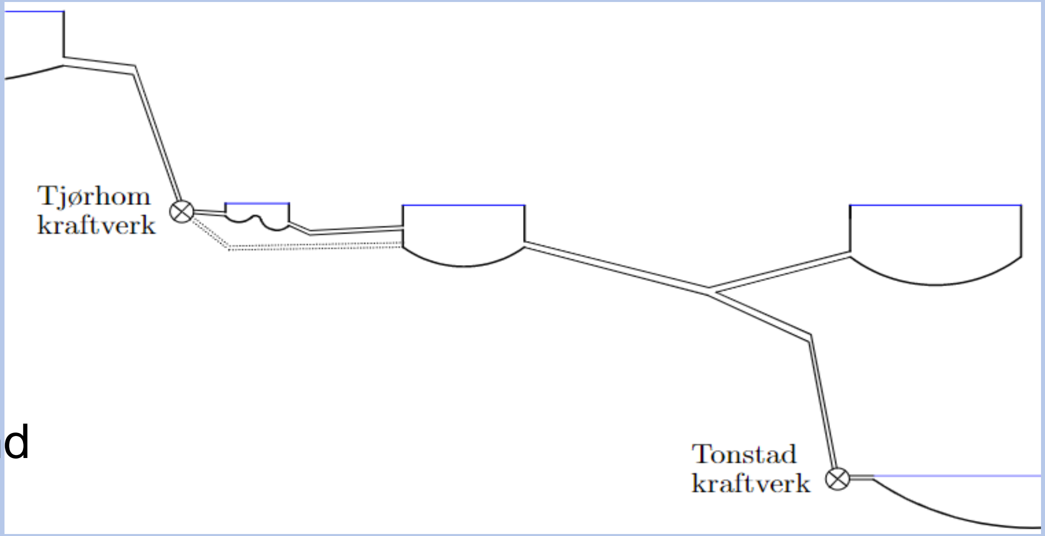
% of Flood Dampening
80%
70%
60%
50%
40%
30%
20%
10%
0%
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018

Produksjonssimulering av Tjørhom pumpekraftverk

Modellerast for 2010-2019
Treng:

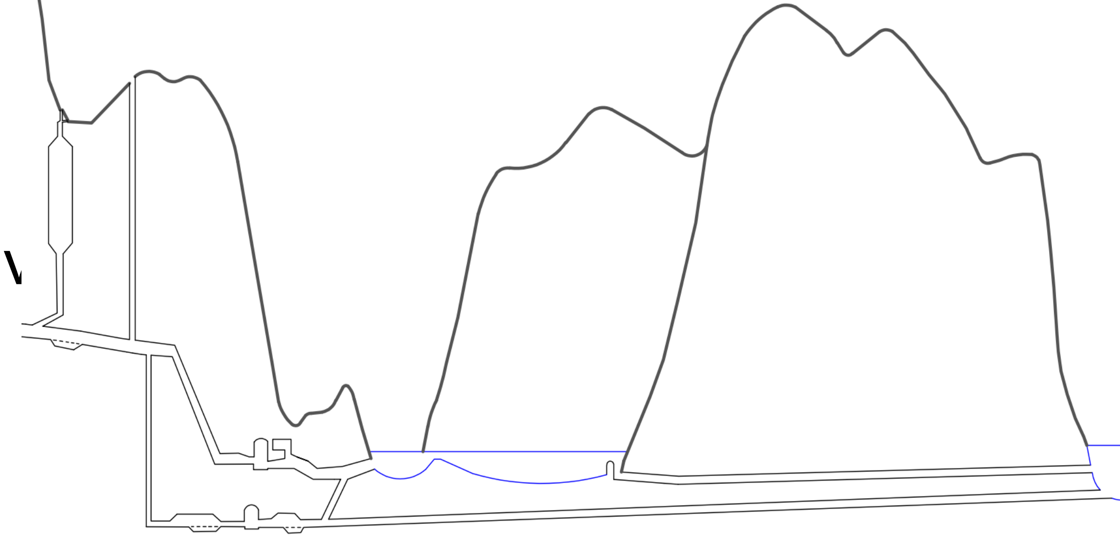
- Falltap
- Verknadsgrad
- Historisk produksjon
- Tilsig

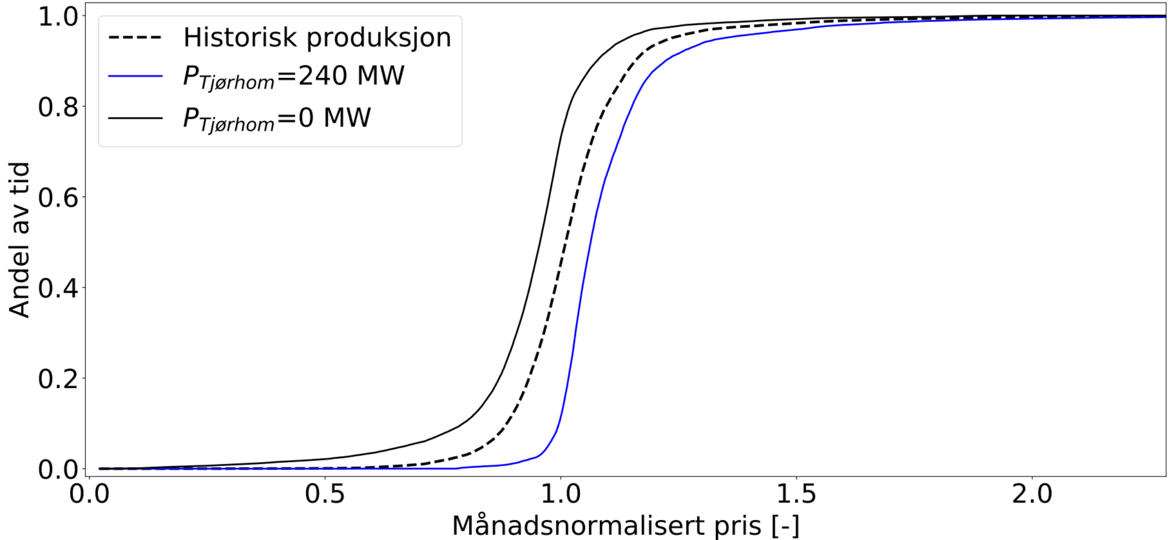
Student: Olav Magnus Egeland
Veileder: Leif Lia



Metode

- Tre utbyggingsalternativ
  - $Q_{Tonstad}$=250 m^3/s
  - $Q_{Tjørhom}$=86/166 m^3/s
  - $Q_{Pumping}$=70 m^3/s

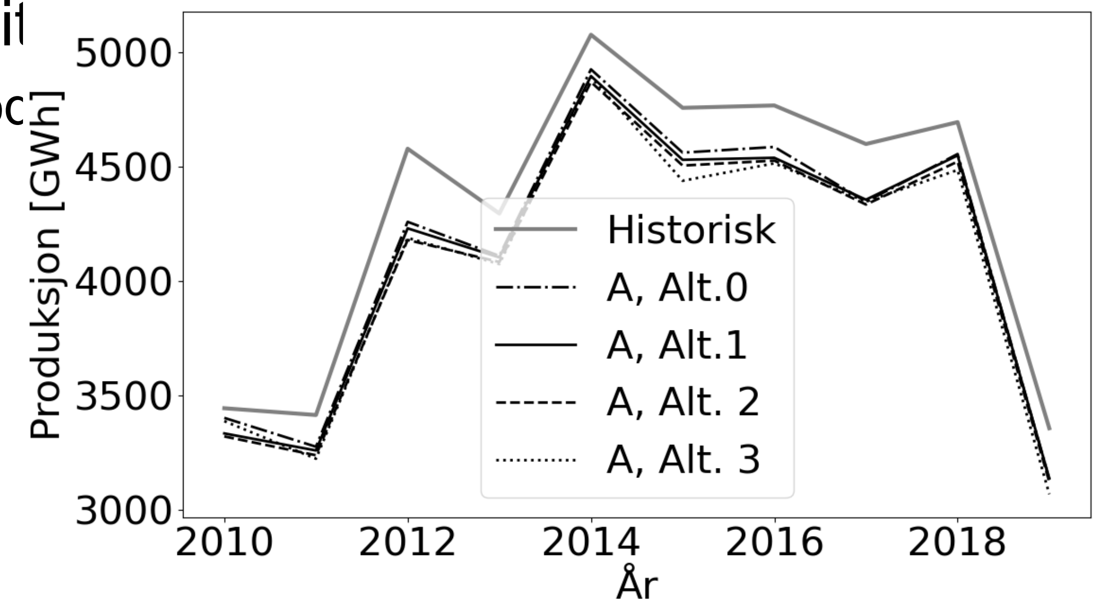




- Utviding av Tjørhom kraftverk
  - Deretter pumpekraftverk
  - Mindre prisvariasjon tilgjengeleg

Resultat

- Statkraft (2021): Ikkje gode nok resultat
- Egeland (2022): dit
  - Avgrensingar i mod
  - Feil i talgrunnlag



PRESENTASJON AV MASTEROPPGAVE

CONSTRUCTION OF KAYAK WAVES

MAREN JOHANNE MOOD

VEILEDER: ELENA PUMMER

MÅL

NIDELVA

Brukes omtrent hver dag til rekreasjon av flere sportsforeninger. Erosjonssikret i 2017. Fjernet kajakkbølgene.

DØDENS DROP OG SLUPPENBRUA

To områder i elva med tidligere gode kajakkbølger.

DEN PERFEKTE KAJAKKBØLGE?

Hva kjennetegner en perfekt kajakkbølge?

GJENOPPRETTE BØLGENE

Undersøke mulighetene for å gjenopprette kajakkbølgene for en varierende mengde vannføring (40, 140 og 200 m3/s) ved å endre elvebunnen.

METODE

STUDERE KAJAKKBØLGE

Dialog med Trondheim kajakklubb, NTNUI Padling, samt litteratursøk. Studere bølger med ulikt Froude tall, bruke det som indikator på bølgen. Finne et mål eller indikasjon på en ideell kajakkbølge.

FYSISK MODELL

En fysisk modell av Dødens drop. Skalert 1:50. Kjøre modellen med ulike vannføringer. Se hvordan det påvirker vannstandsspranget. Måle hastighet og vanndybde. Regne ut Froudetallet. Lage et hastighetsprofil. Endre elvebunnen.

NUMERISK MODELL

I forbindelse med prosjektet lages en numerisk modell i OpenFOAM lages for å simulere det aktuelle området i Nidelva.

RESULTATER

KAJAKKBØLGEN

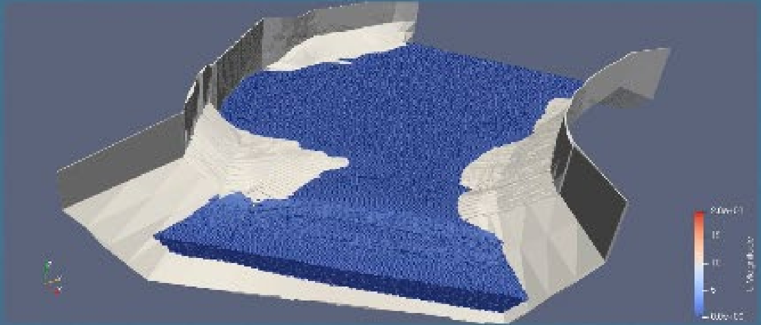
Kajakkere gjør samme bølge om igjen, virvler er essensielt. Bratt bølge, ujevn vannflate .
Oscillating jump, 2,5 < Fr < 4,5

NUMERISK MODELL

Kjører modellen for ulike vannføringer.

FYSISK MODELL

Modellen kjører. Utfordringer knyttet til skalering, da det er snakk om lave vannstander og vannføringer. Har fått simulert et fint vannstandssprang for Q = 73,9 m3/s



3D numerical modeling of a river confluence – movable bed implications

Supervisor: Nils Rüther

Co-supervisors: Behnam Balouchi

Hans Bihs

Presented by: Ayda Mirzaahmadi

May 2022

NTNU Norwegian University of Science and Technology

Photo from https://www.theimpactivate.com/

1. Introduction

- ✓ River confluences are morphodynamic challenging sections of river networks
- ✓ The complex three-dimensional flow structure leads to large scour and deposition zones (Problems: **navigation** and **threat to riverine structures)**

In the present study:

- The technical possibilities of 3D numerical modeling of a river confluence are investigated
- The results are calibrated and validated with a data set from laboratory work
- The effect of variables such as discharge ratio, downstream densimetric Froude number, confluence angle, channel geometry, and sediment properties on flow and sediment will be investigated.
- Besides evaluating the effect of hydraulic, sediment, and numerical parameters on flow and sediment pattern,
  model the structures for decreasing scour depth such as collar

2. Material and Methods

2.1. Numerical model: REEF3D

- An open-source hydrodynamics software written in modular C++ at NTNU
- Different hydrodynamic modules such as **SFLOW**, **CFD**, FNPF, and NSEWAVE
- REEF3D::CFD model uses three dimensional Reynolds Averaged Navier-Stokes equation

$$\frac{\partial u_i}{\partial x_i} = 0$$

$$\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} = -\frac{1}{\rho}\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\left[(\nu + \nu_t)\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\right] + g_i$$

- The 5th-order Weighted Essentially Non-Oscillatory (WENO) scheme for space discretization
- The 3rd order Runge-Kutta scheme for time discretization
- Turbulence is modeled with the k-ω and k-ϵ models
- Sandslid algorithm is considered
- Bedload is calculated by Van Rijn and Meyer-Peter-Muller equations

2. Material and Methods

2.2. Experimental data

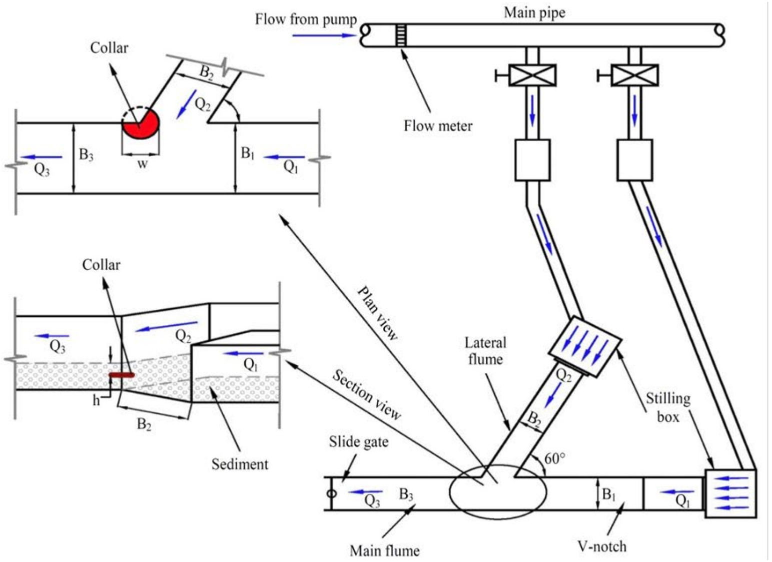


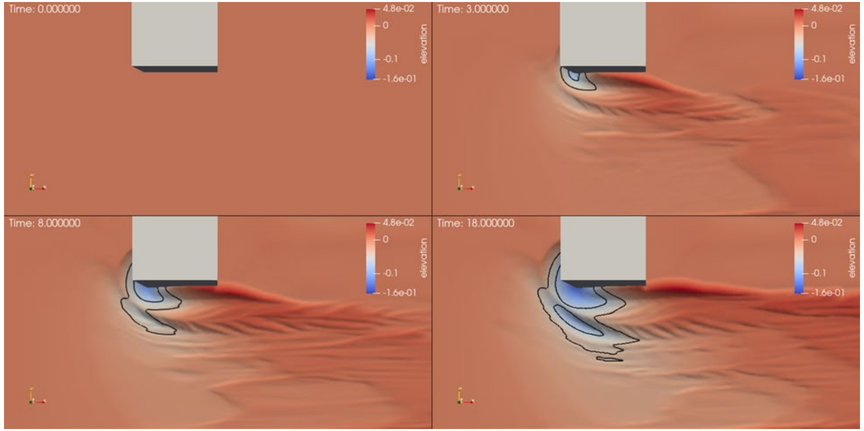
Figure 1. detail of the experimental model by Amini N. et al. (2017)

Table 1. parameters used in the laboratory for one of the cases

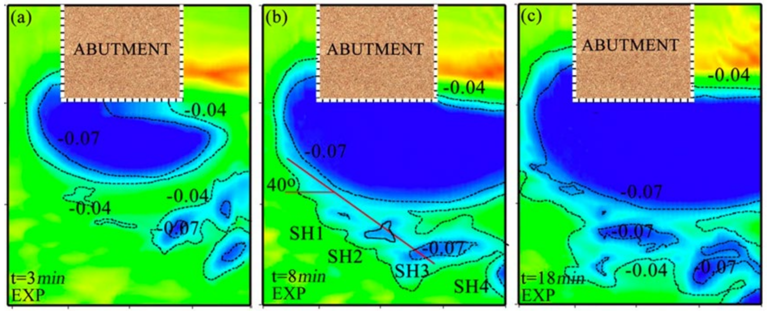
D50 (mm)	Q1 (l/s)	Q2 (l/s)	Q3 (l/s)	Frg3	B (m)
1.95	10	10	20	2.52	0.25

3. Results

The first case: Abutment



a. Numerical results



b. Experimental results

Figure 2. Numerical and experimental (by Khosronejhad A., et al) results of abutment

3. Results

The second case: Confluence

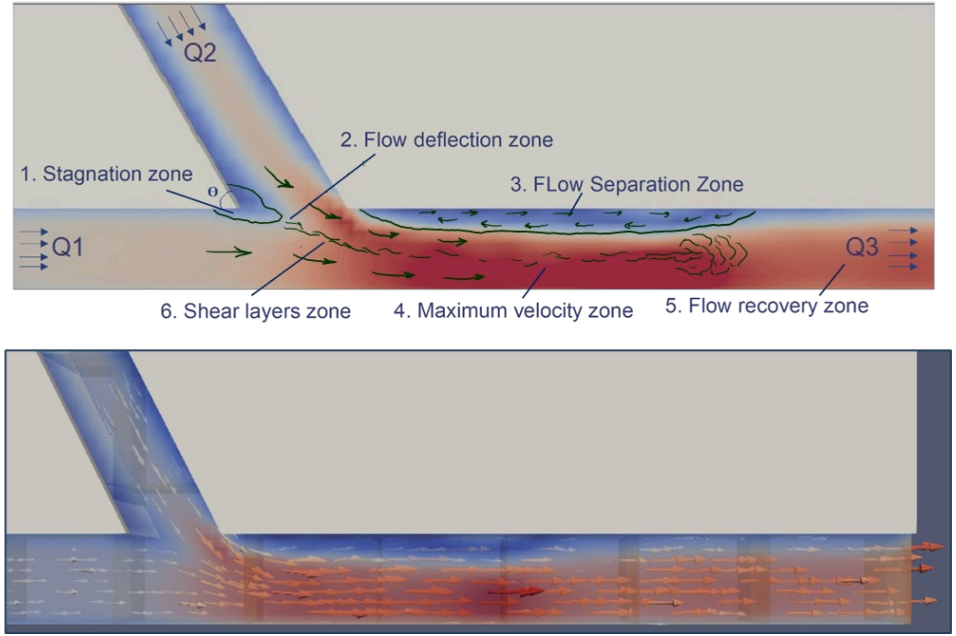
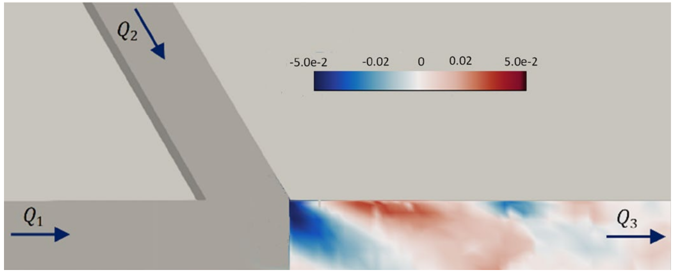
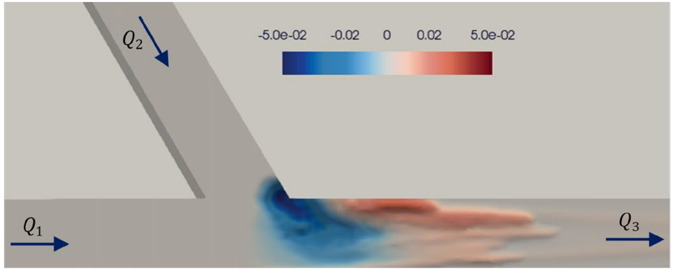


Figure 3 .Velocity vectors and flow pattern

3. Results



a. Experimental results



b. Numerical results

Figure 4. Sediment pattern of a. Experimental and b. numerical results

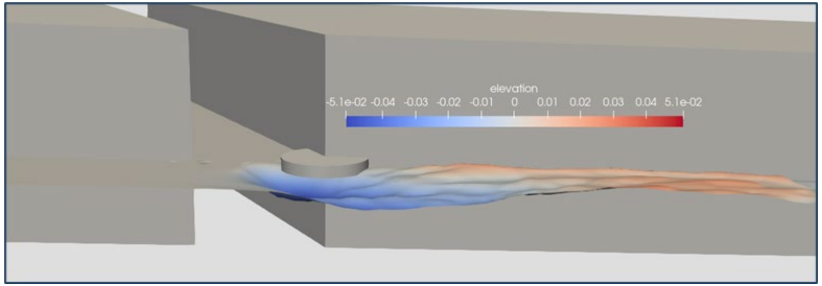


Figure 5. Sediment transport pattern in a confluence with a collar

Parameter	**Model**	
	Experimental	Numerical
Ds/B3	0.192	0.200
Hs/B3	0.131	0.128

Table 2. Experimental and numerical results

NTNU

References

- Amini N., Balouchi B., Shafaei Bejestan M., (2017). Reduction of local scour at river confluences using a collar, International Journal of Sediment Research, 32 (2017), 364- 372
- Ahmad N., Bihs H., Kamath A., Arntsen Ø. (2015). Three-dimensional CFD modeling of wave scour around side-by-side and triangular arrangement of piles with REEF3D, 8th International Conference on Asian and Pacific Coasts
- Afzal M., Bihs H., Kumar L. (2020). Computational fluid dynamics modeling abutment scour under steady current using the level set method, International Journal of Sediment Research, 35 (2020), 355-364
- Khosronejhad A., Ghazian Arabi M., Anglidis M., Bagherzadeh A., Flora K., Frhadzadeh A. (2020) A comparative study of rigid-lid and level-set methods for LES of open-channel flows: morphodynamics, Environmental Fluid Mechanics (2020) 20:145–164

2D Numerical Modelling of Sediment Diversion in River Bend

-Rajeev Shrestha

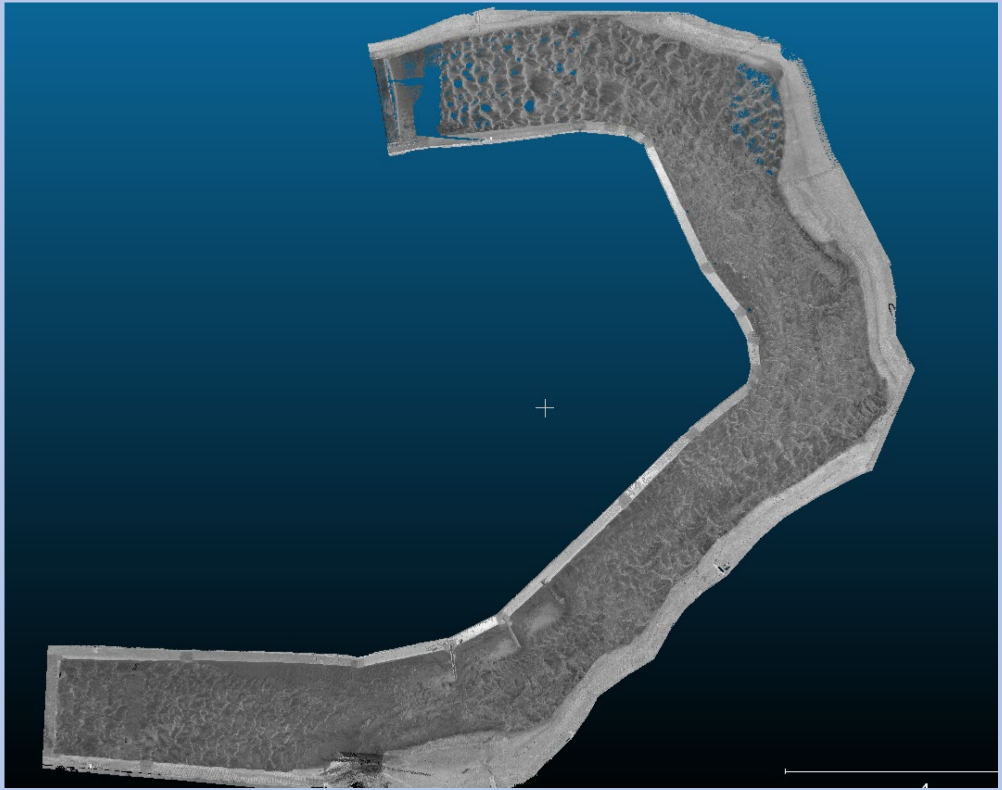
-Nils Ruther -Diwash Lal Maskey

Introduction

- Physical Model in Hydraulic Lab, NTNU
- Bed load transport and bed changes
- Efficiency of Sediment Bypass Tunnel
- Numerical Model

Objective

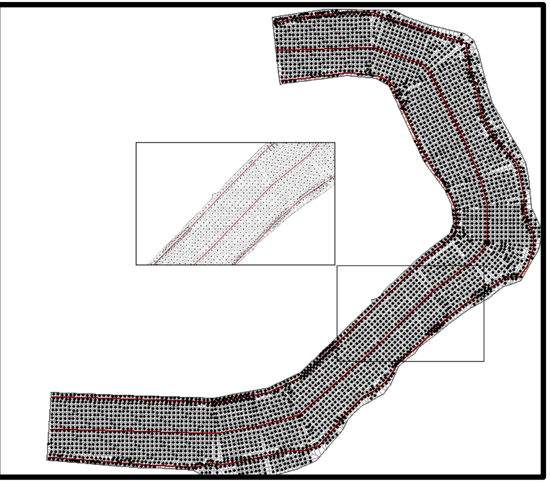
- Sediment Modelling capabilities of HEC-RAS 2D
- To what extent can the modelling be done?
- Advantages of 2D over 3D and how useful it is.
- Numerical verification of the results obtained from physical model



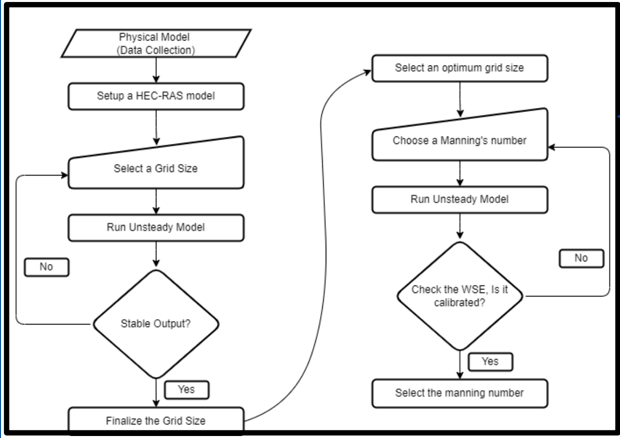
METHODOLOGY

Physical Model

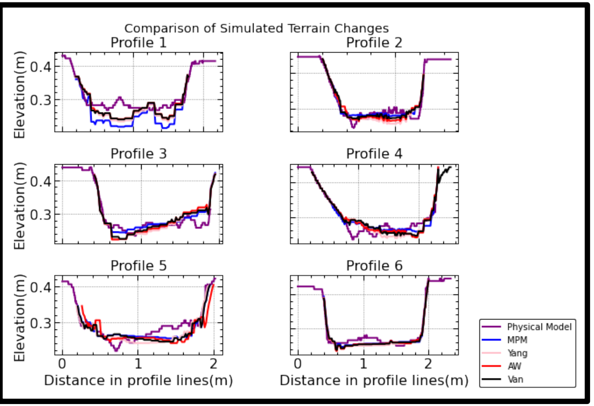
Numerical Model Development



Hydraulic Calibration

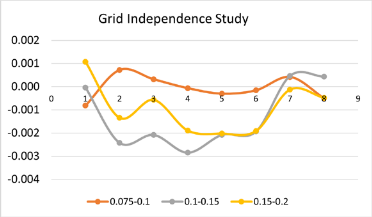


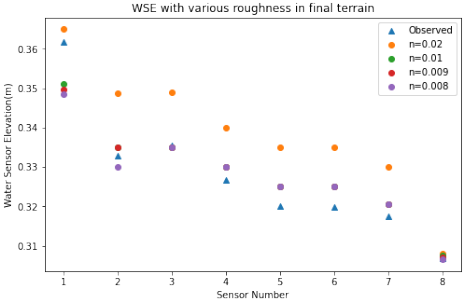
Sediment Transport Calibration

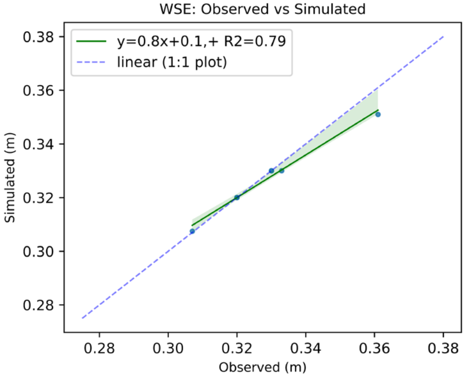


Case A: Sediment Transport in River Channel)

Requirement – Calibrated Hydraulic Model







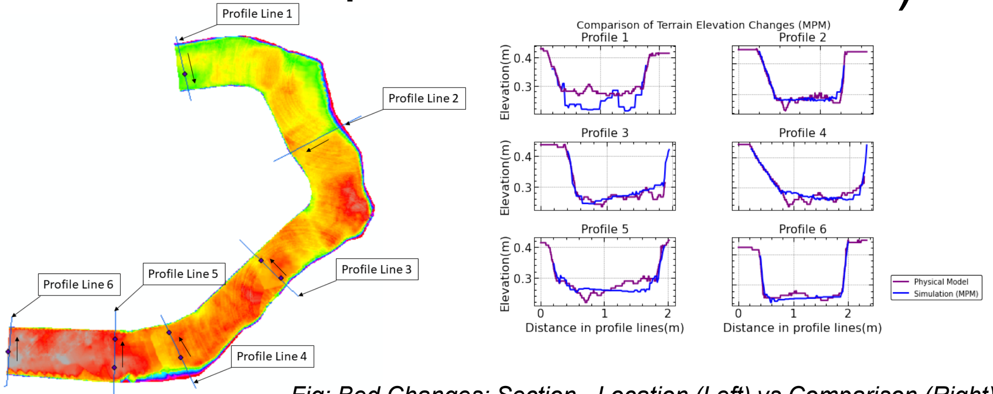


Fig: Bed Changes: Section - Location (Left) vs Comparison (Right)

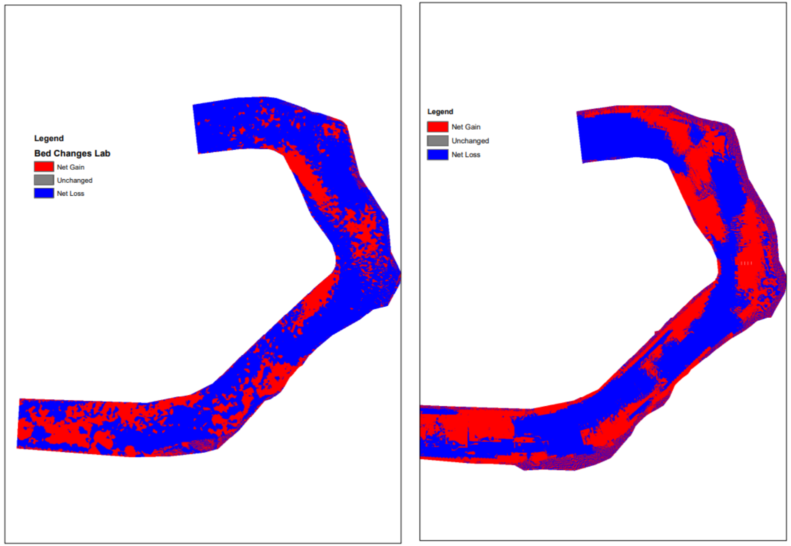
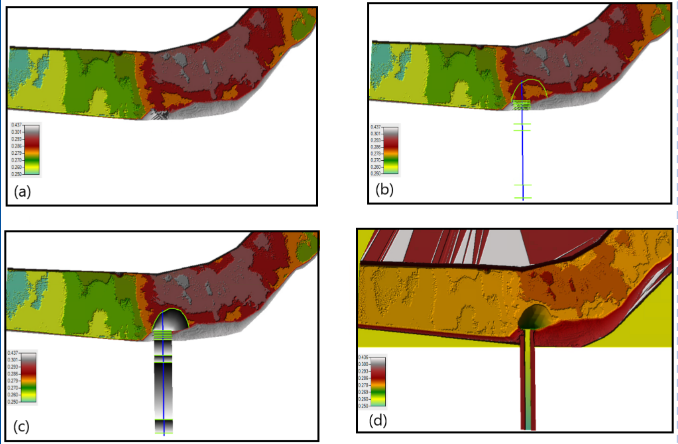


Fig: Bed Changes: Plan - Observed (Left) vs Simulated (Right)

Terrain Modifications



Case B : Sediment Bypass Channel

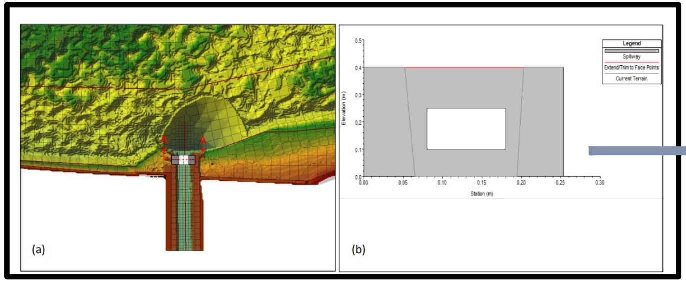
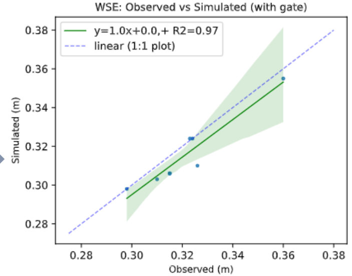


Fig: Defining Intake Gates



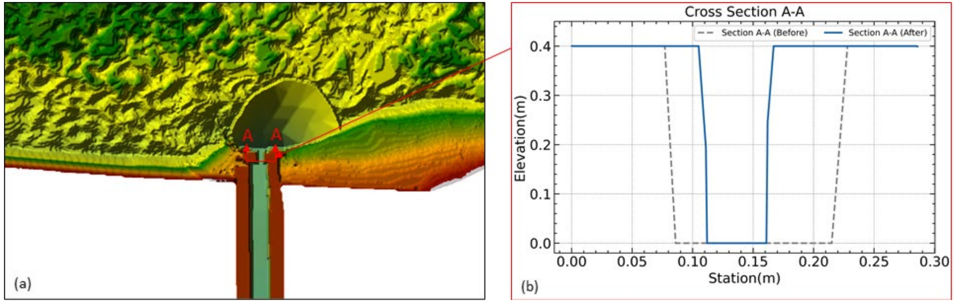
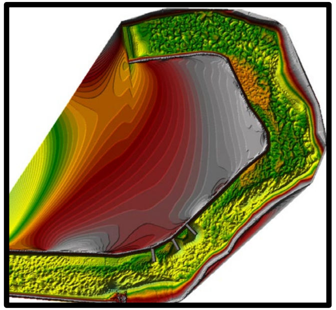
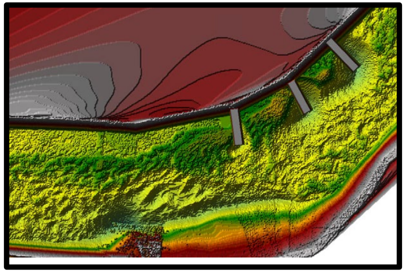


Fig: Modification to Inlet (Workaround Method without gate)

Case C : Guide Walls





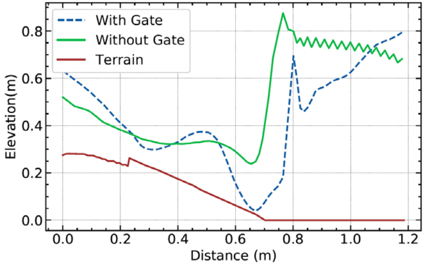


Fig: Velocity at inlet (Gate vs No Gate)

Conclusion (Preliminary)

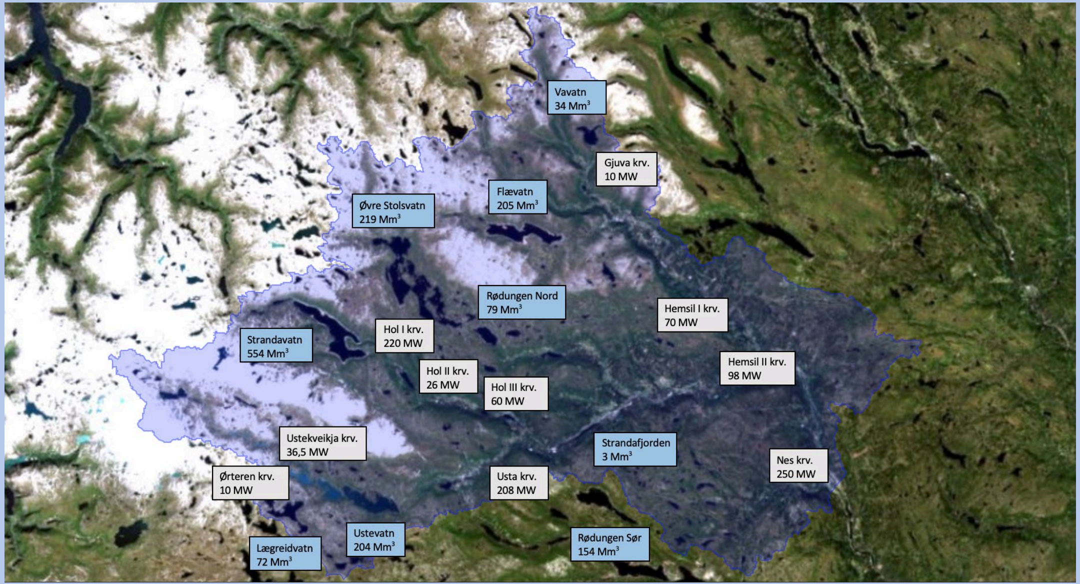
- HEC-RAS 2D provides a good result in a river channel and it confirms with the physical model (pattern and mass).
- With proper hydraulic and sediment calibration, bed changes and sediment output can be modelled properly.
- Hydraulic Structures do not work with Sediment yet!
- From the results, diversions do not seem to work properly unless depth is maintained. Needs further studies.
- Internal Boundary Conditions do not work with Sediment!
- Bed changes are not updated with time.
- Less computation time and system demand

AlternaFuture – Oppgradering av Tunnelsystem og Vasskraftverk

Målet for prosjektet er å oppnå ei **tredobling av effekten i vassdraget**.

Student: Håkon Veivåg Tveit

Veileder: Leif Lia



Metode

Nyttar «**spelekort**»

Spelekorta blir delt i fire kategoriar:

A. *Ombygging av eksisterande*
B. *Nye pumpekraftverk*
C. *Nye effektkraftverk*
D. *Nye installasjonar*

Forslaga blir simulert i ***nMag2004***.

Økonomisk analyse.

Kostnadsgrunnlag for vannkraft.

Kategori B – Pumpekraftverk

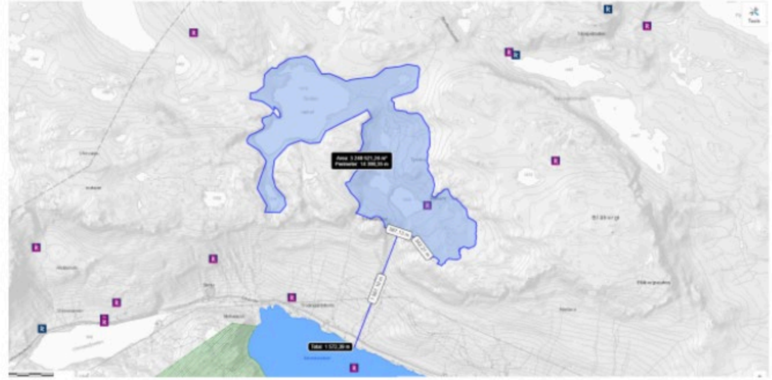
B.2

Strandavatnet pumpekraftverk - Stor

Designprinsipp: Pumpekraftverk

Byggekostnad: **3090** MNOK

Effekt:	$P_{prod.} = 750$ MW $P_{pump} = 750$ MW	**Turbintype:** Vertikal pumpeturb.
Brutto fall:	$H_0 = 560$ m	**Eining:** 3x290 MVA
Vassføring:	$Q_{prod.} = 150\ m^3/s$ $Q_{pump} = 142\ m^3/s$	**Frekvenskonv.:** 3x290 MVA **Pumpestart:** Frekvenskonverterer
Tunnellengde:	$L = 1{,}6$ km	**Turtal:** 375
Tverrsnittsareal:	$A = 70\ m^2$	



Resultat

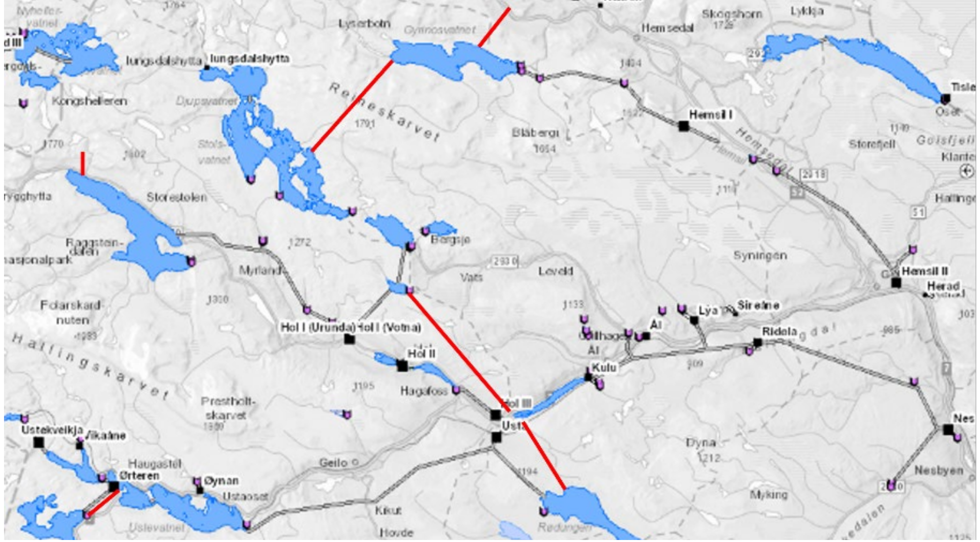
Ser på 4 scenarioer

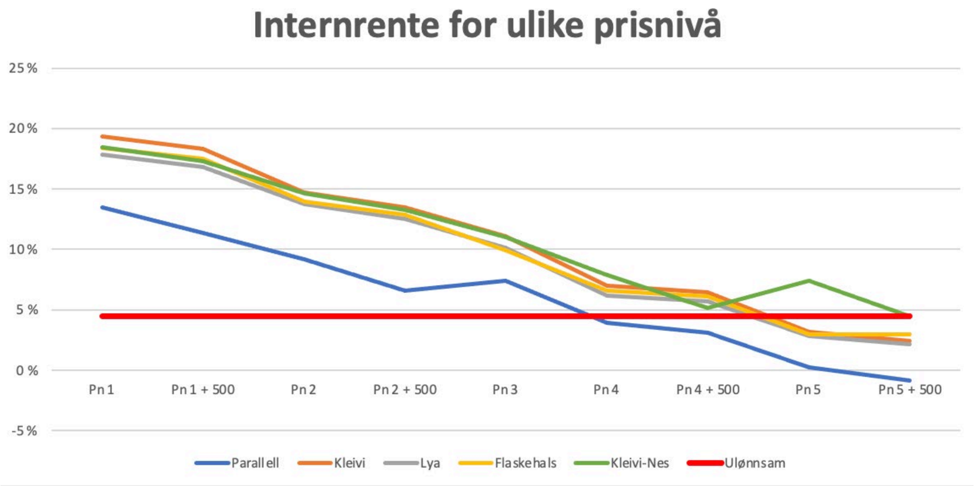
1. *Tredobling i parallell*
2. *Kleivi*
3. *Lya*
4. *Auking av Hol-strengen.*

Resultat

1. Kleivi mest lønnsam
2. 15% falltap
3. Tre tunnelar treng oppgradering
   1. Nes, Hemsil II og Usta
4. Tre pumpekraftverk
   1. Alternativ til Rødungen PSP
5. Bruk av tunnelmagasin

Også sett på auka avrenning i systemet.





Evaluation Of Flood Control in Stryn With Potential Hydropower Production

By Christine Kaggwa Nakigudde
Main supervisor: Oddbjørn Bruland (Professor)

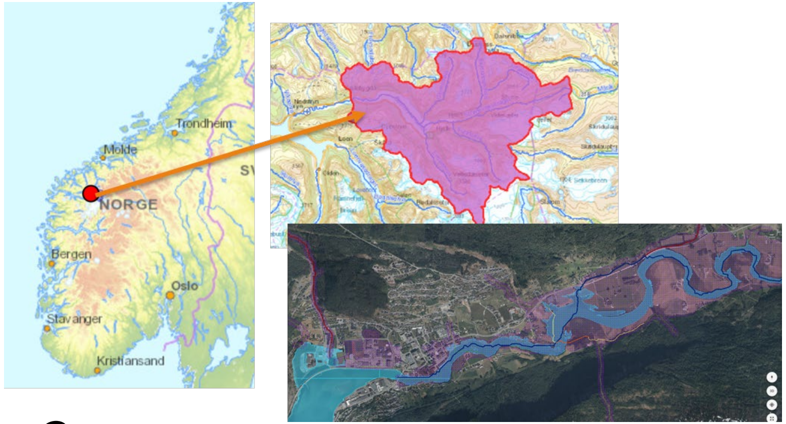
Main Objective

To investigate the feasibility of flood control in Stryn with a proposed hydropower production

- Flood frequency analysis in Stryn Catchment.
- Evaluation of the hydropower potential of the region
- Economic and cost analysis of proposed solution
- Evaluate flood reduction with proposed hydropower development
- Effect of flow regulation on salmon population
- Effect of climate change on flood magnitude and hydropower production

Study Area

Location and Catchment

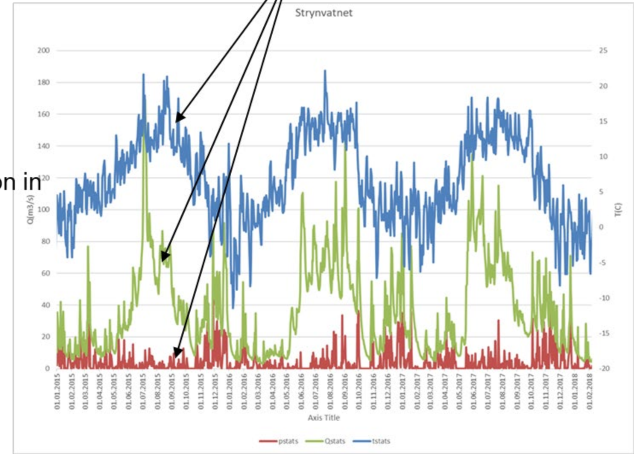


Catchment Area = 478 km2
Specific runoff = 60.5 l.s.km2
Annual precipitation = 1353 mm
Summer = 465 mm
Winter = 888 m

Hydrology

High Temperature-High discharge-Low Precipitation

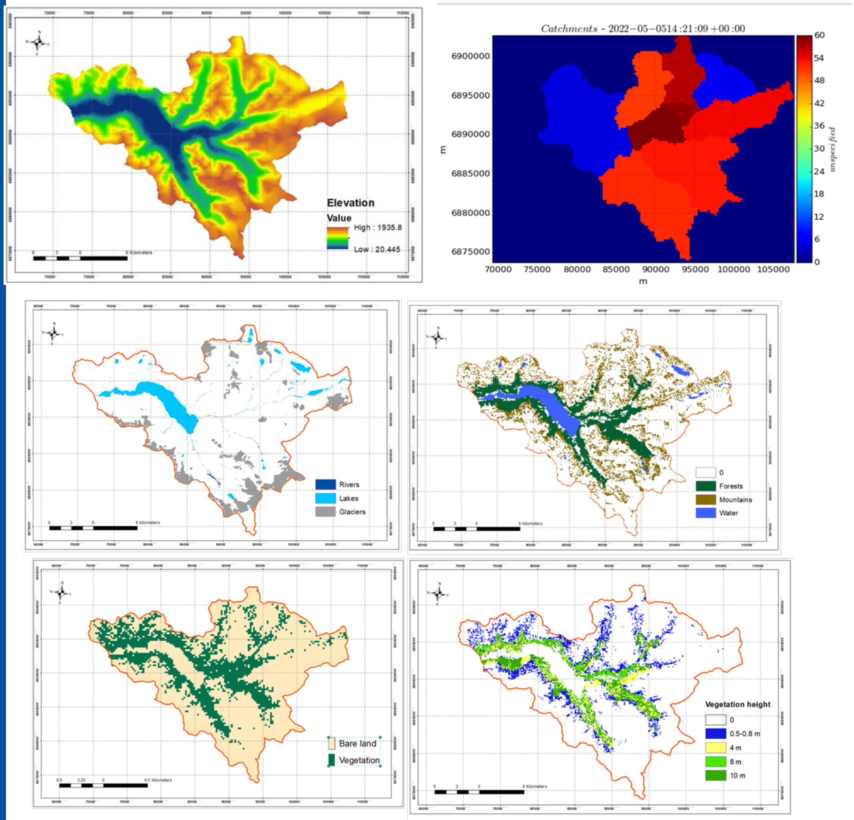
High precipitation in Winter- Low discharge



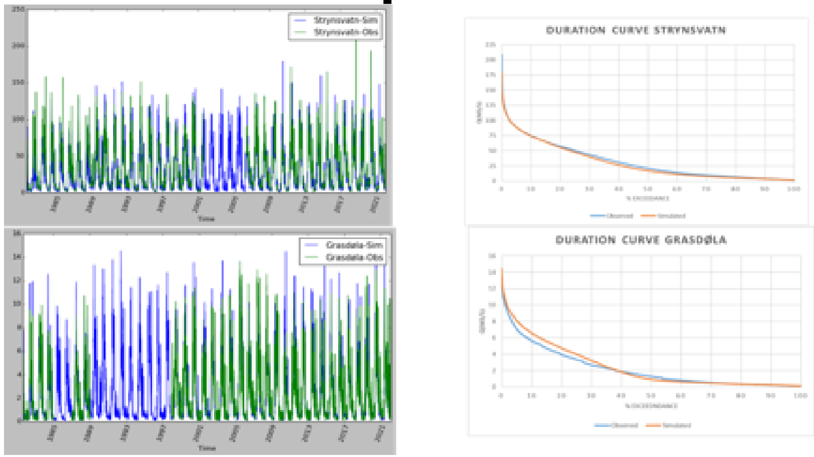
Floods- Mainly snow-melt driven
Possible combination of snowmelt and rain floods

Hydrological Modelling- Distributed Model

GIS Data

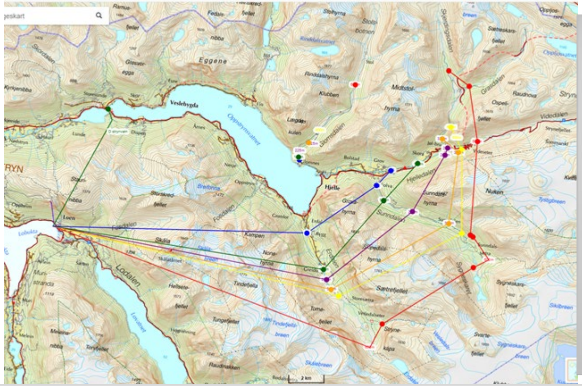


ENKI - Model performance

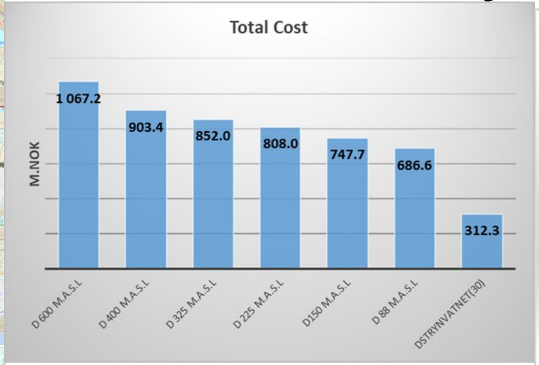


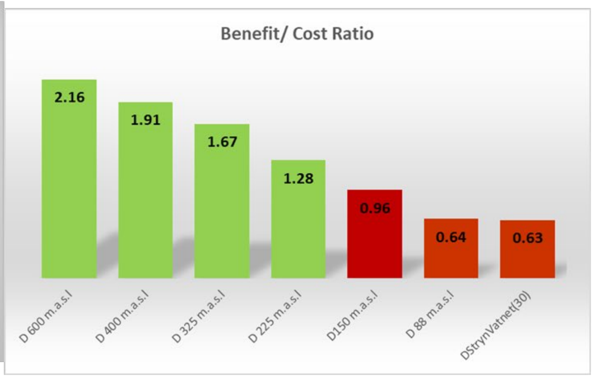
Regulation and Energy Production

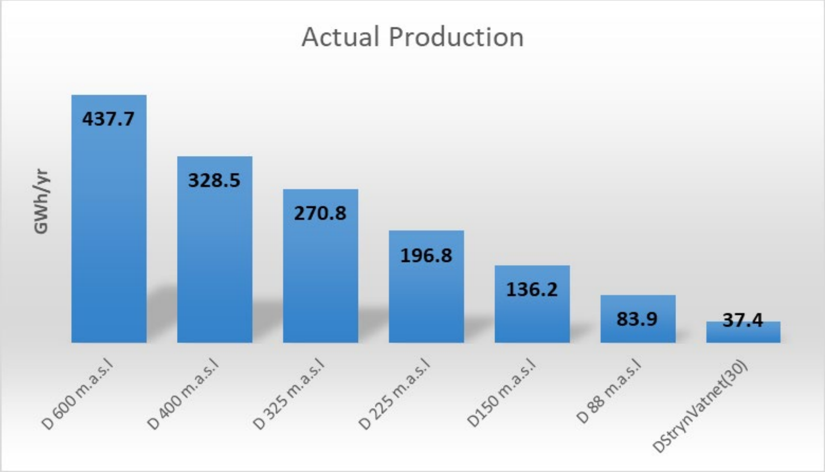
Diversion and Energy Production



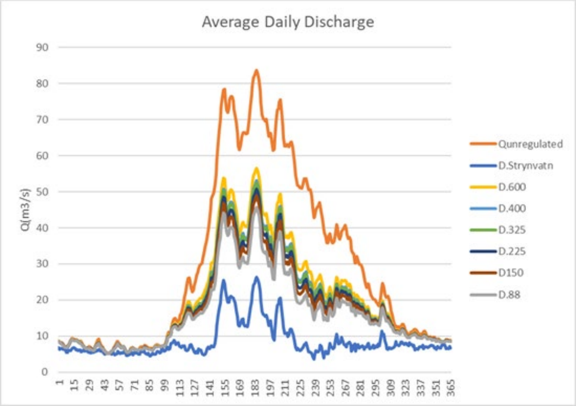
Cost analysis





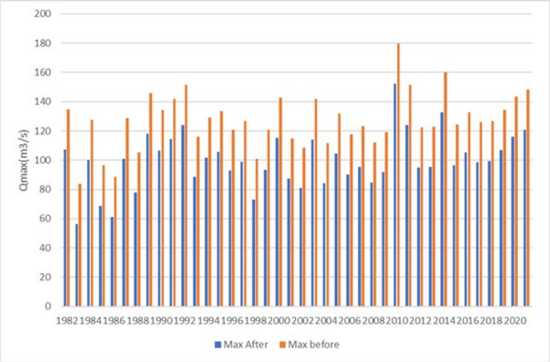


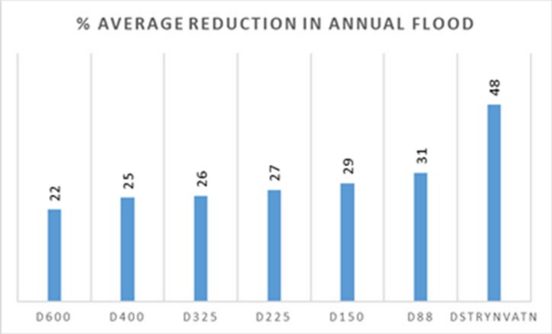
Changes in average flow



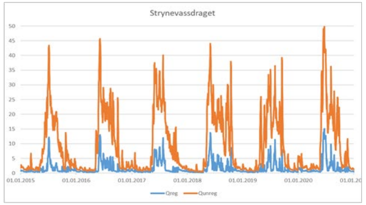
Changes in river flows

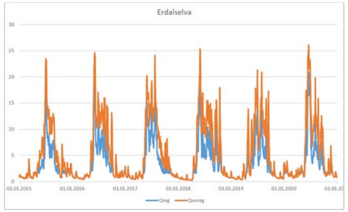
Changes in flood levels

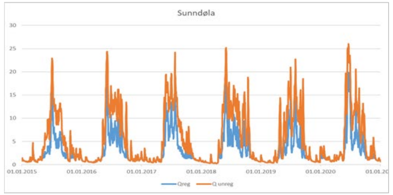


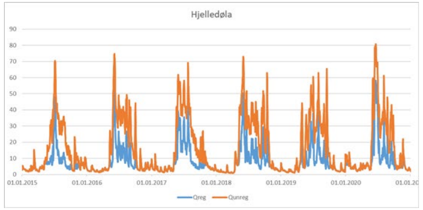


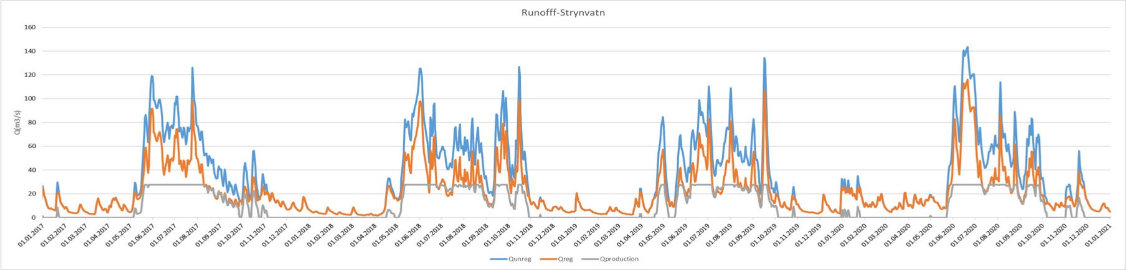
Optimum Alternative D600: Regulated Flow





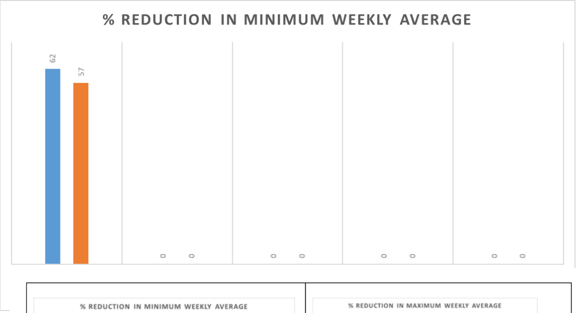


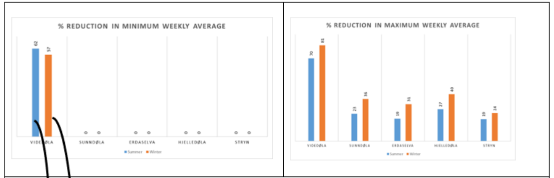




Further analysis

Hydrological indicators for Lowest weekly average



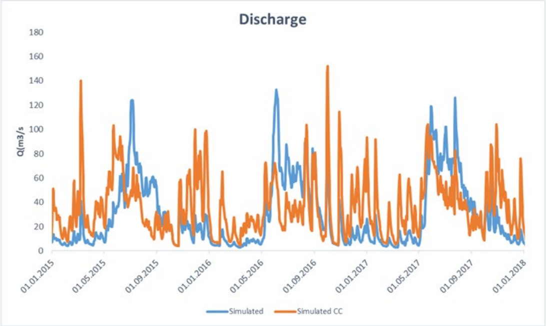


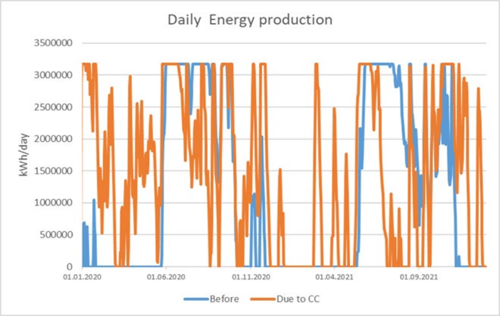
Season	Change in lowest weekly average	Impact on population
Summer	Increase	Positive
	Reduction < 20%	No bottleneck
	Reduction 20-40%	Weak bottleneck
	Reduction 41-60%	Moderate bottleneck
	Reduction < 60%	Severe bottleneck
Winter	Increase	Positive
	Reduction < 10%	No bottleneck
	Reduction 10-30%	Weak bottleneck
	Reduction 31-50%	Moderate bottleneck
	Reduction < 50%	Severe bottleneck

Increased Tunnel Capacities

	Capacity 1	Capacity 2	% Change	
Tunnel capacity Q_{max}(m3/s)	26.3	38.4	46.0	
Annual Prod (GWh/h)	437.7	506.8	15.8	
Annual revenue MNOK	125.8	144.9	15.2	
PV revenue (50 years)	2416.1	1999.3	17.3	
Total investment cost (M.NOK)	1120.6	1241.2	10.8	
B/C ratio	2.2	1.6	25.3	
Flood reduction(%)	22.0	31.0	40.9	

Effect of climate change





Conclusion

Most feasible alternative: **Diversion at 600 m.a.sl**

Production Scenario 1

- Power production= **437.7** GWh/year
- Benefit cost ratio= **2.16**
- Effect of flood regulation= **22%**

Production Scenario 2

- Power production= **506** GWh/year
- Benefit cost ratio= **1.6**
- Effect of flood regulation= **31%**
- Climate change therefore shows an average increase of **22.6%** in the mean yearly flood.

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Machine Learning Methods for Bathymetry Generation in Rivers

Supervised by:

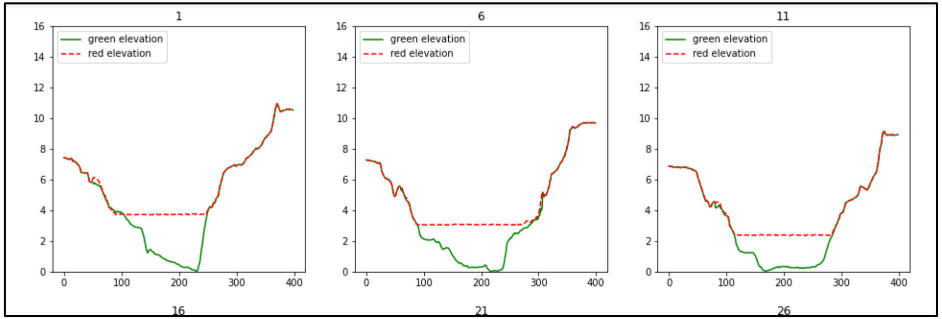
Knut Alfredsen
Elhadi Mohsen
Mahmoud Awadallah

Prepared by:

Raffa Ahmed
24.05.2022

Introduction

- River cross sections required for flood analysis
- River bathymetry: costly, effort and time consuming, limited accessibility
- Remote Sensing: Green Lidar, Red Lidar
- Red Lidar does not penetrate the water
- Green Lidar is expensive and has less spatial coverage



Study objective

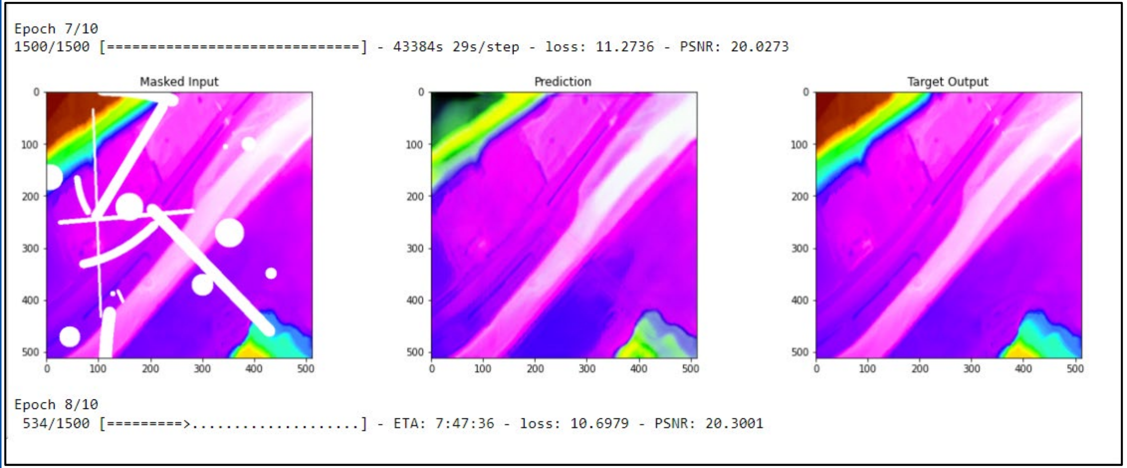
- This study aims to **find a method to obtain the river bathymetry** (wetted zone) from the **Red Lidar**

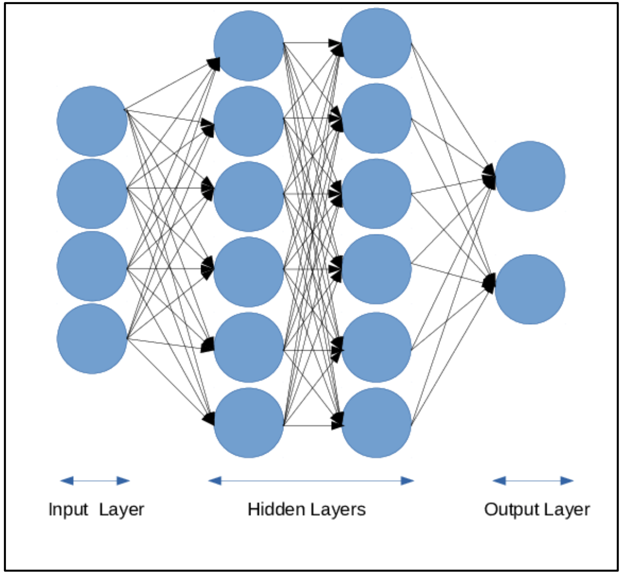
- **Specific objective:**

1. To **develop a machine learning algorithm** that can predict the river bathymetry using Red Lidar and Green Lidar for the selected river.
2. **Testing the algorithm in different rivers** and investigate the model performance
3. **Set up a hydraulic model for flood discharge** and compare the inundation area from prediction and Green Lidar.

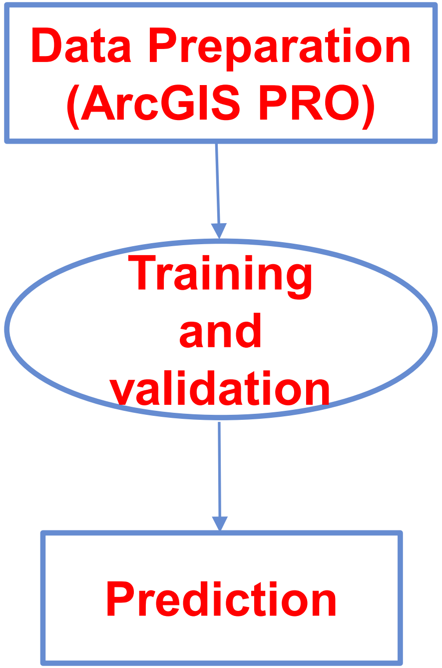
Methods

- Image inpainting using deep learning CNN
- 1-dimensional cross-section training using ANN





ANN method for bathymetry prediction




```python
import numpy as np
import pandas as pd
from matplotlib.backends.backend_pdf import PdfPages
from matplotlib import pyplot as plt

count = 1

fig = plt.figure(figsize = [16,16])
pdfFile = PdfPages("fullsection.pdf")

for j in range(2500,2600):
    data_cross = Gaula_data.loc[Gaula_data["ORIG_FID"] == j]
    data_cross = data_cross.reset_index(drop=True)

    Min = data_cross['green_elevation'].min()
    data_cross["green_elevation"] = data_cross["green_elevation"] - Min
    data_cross["red_elevation"] = data_cross["red_elevation"] - Min
    Green = data_cross["green_elevation"]
    Red = data_cross["red_elevation"]

    #filling the df with the prediction input for j cross section

    if len(Red)== z-1:
        new_row = Red.iloc[z-2]
        Red.loc[z-1] = new_row


    df = pd.DataFrame(0, index= np.arange(0,1,1), columns = [np.arange(0,400,1)])

    df.iloc[0,0:len(Red)] = Red.values



    #input_pr = pd.merge(Left,Right,left_index=True, right_index=True)
    predictions = model.predict(df,batch_size=1,verbose=1)
    predictions = np.transpose(predictions)
```

```python
# Trainning
model.fit(
Red_frame,
Green_frame,
batch_size=1,
epochs=250, verbose=2,
callbacks=None,
validation_split=0.2,
validation_data=None,
shuffle=True,
class_weight=None,
sample_weight=None,
initial_epoch=0)
```

```python
# compile model
model.compile(optimizer ="rmsprop",
              loss= "mse")
model.summary()
```

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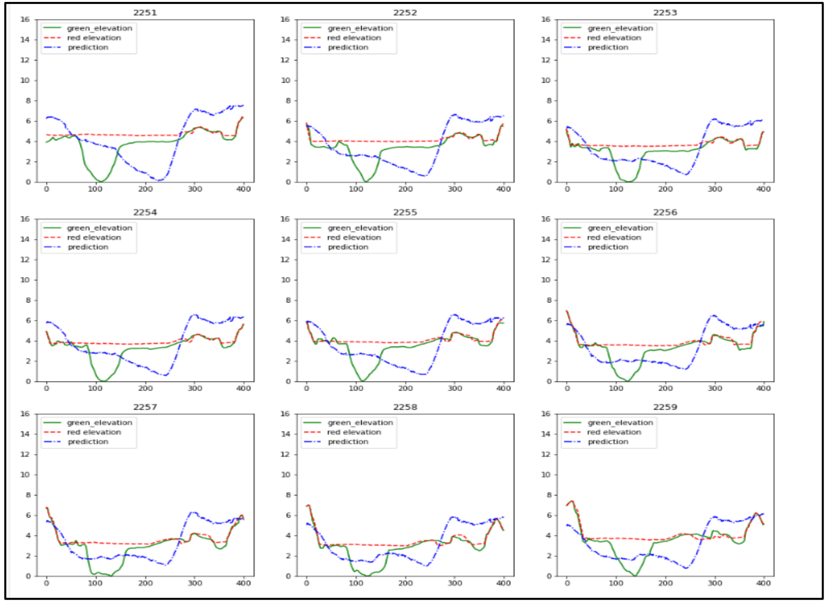
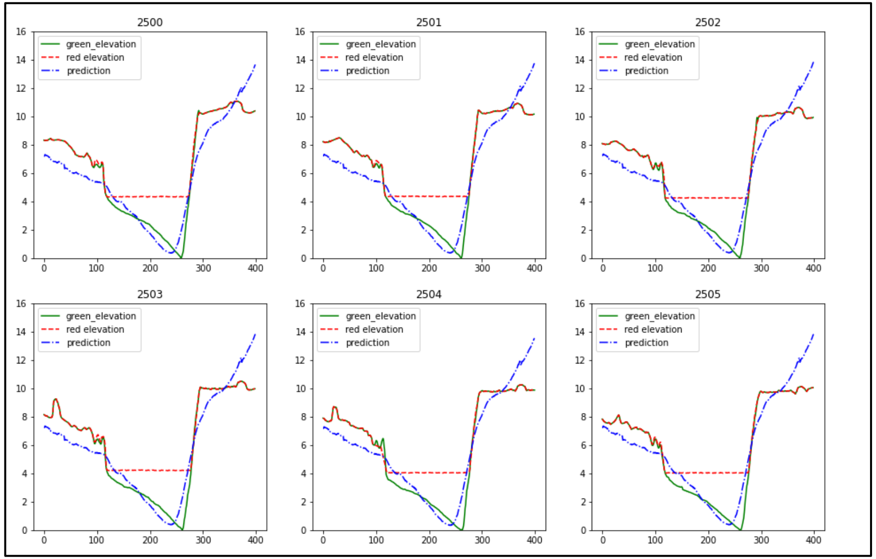
Results

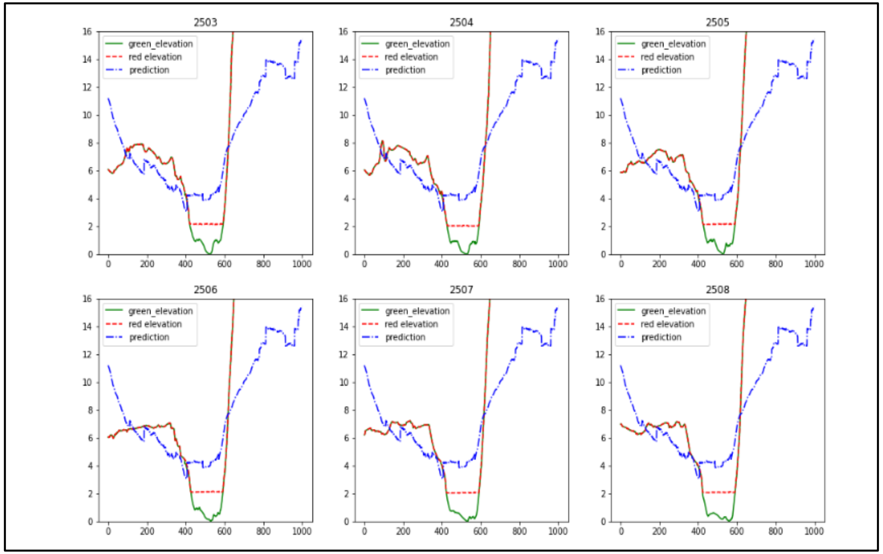
- The algorithm is reasonably predicting for Gaula, but still, misses the prediction at some cross-sections

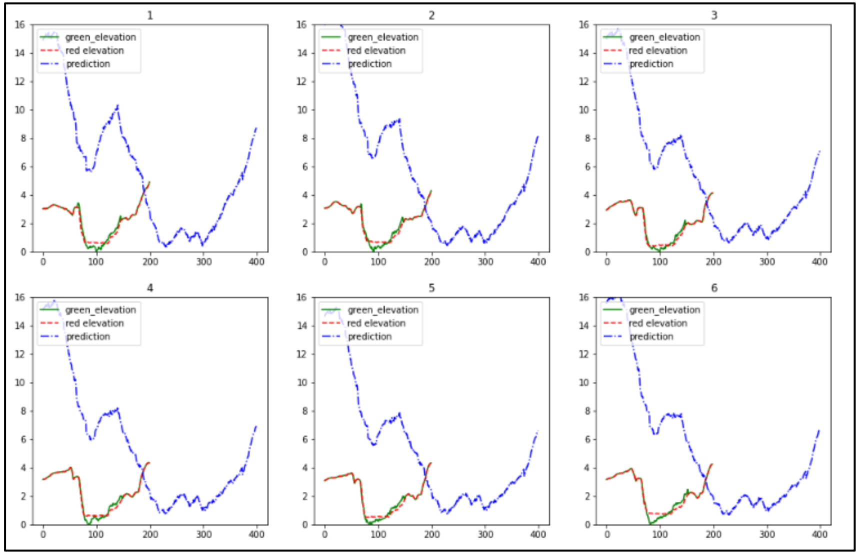




Results

- The training considers the river size/proportion with banks steepness (Storane testing)
- Not perfect prediction but could improve the simulation





Forthcoming Work

- Set up a hydraulic model for flood discharge and compare the inundation area from prediction and Green Lidar
- Run normal average discharge and investigate the results
- Improve the algorithm by retraining the model using different rivers
- The algorithm should be able to predict the river bathymetry in different rivers with an uncertainty zone

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2D numerical modeling of hydraulics and sediment in a reservoir
Case Study: Binga Reservoir

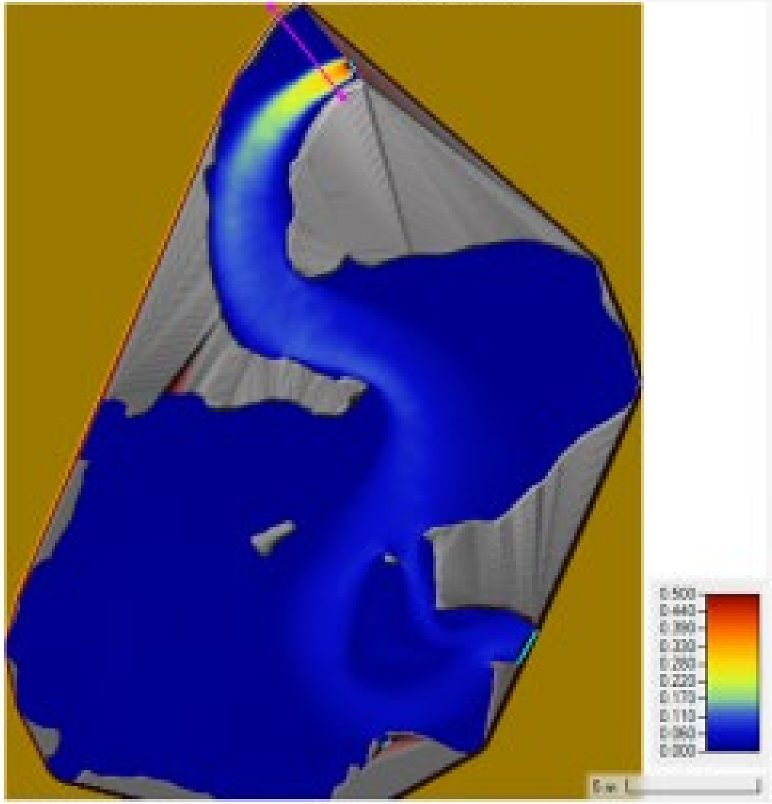
Model Calibration
Hydraulic Simulation
Sediment Transport Simulation
Physical Scale Sediment Transport Simulation

By: Moyinjah Micheal Bello
Supervisor: Nils Ruther

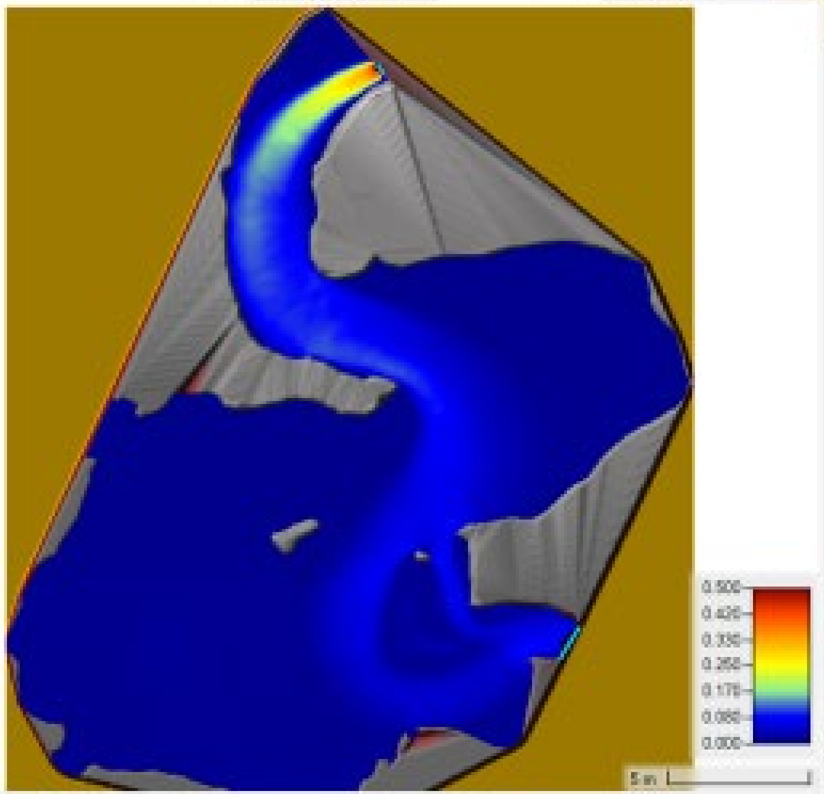
Methodology

Results

With HPP Intake

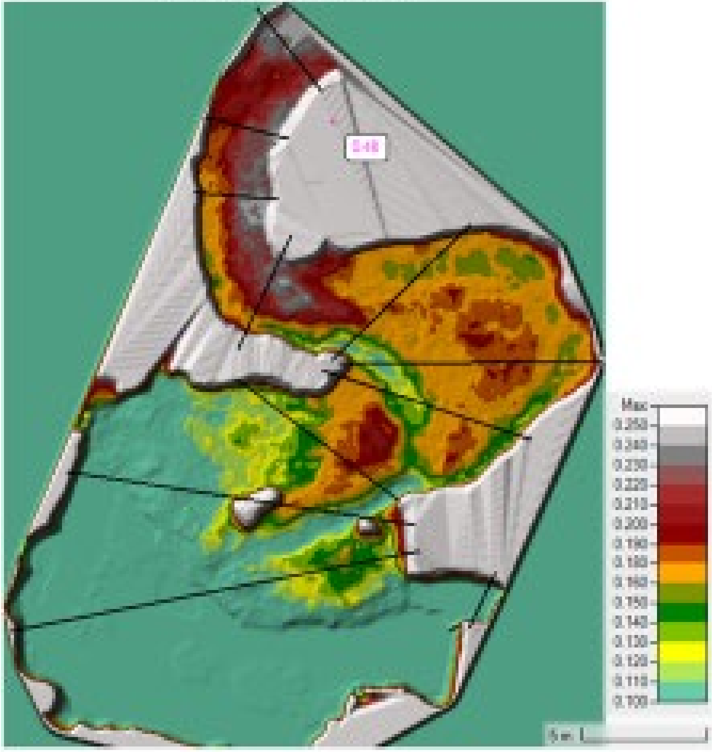


Without HPP Intake

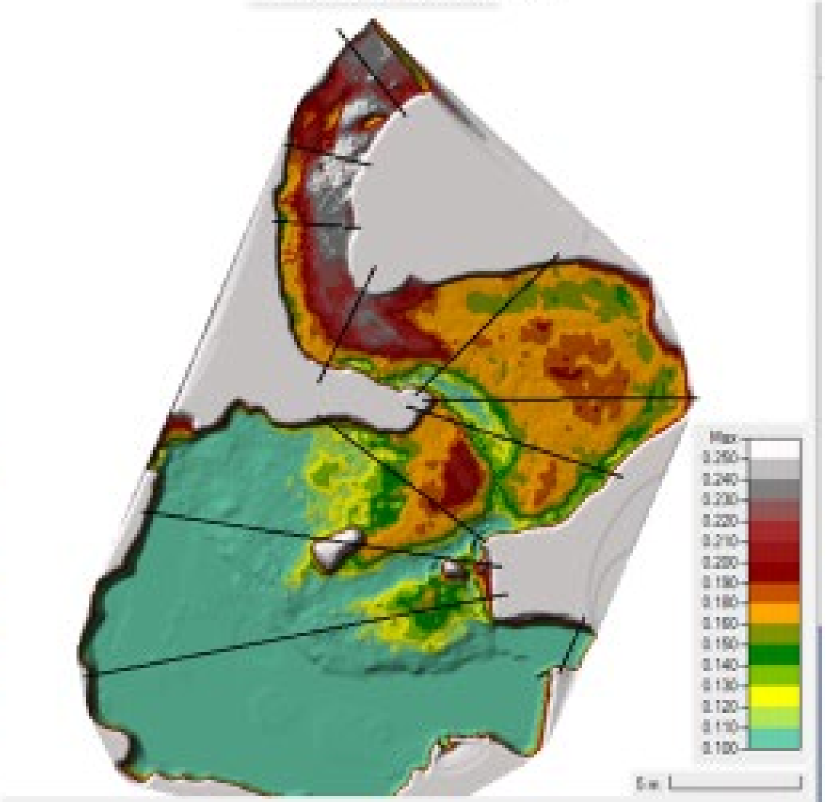


Results

Simulated



Observed



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TVM 4195 HYDROPOWER DEVELOPMENT MASTER THESIS

Investigating the technical concept of retrofitting of non-hydro reservoirs and dams

Submitted by:

Kristina Shrestha
MSc. Hydropower Development

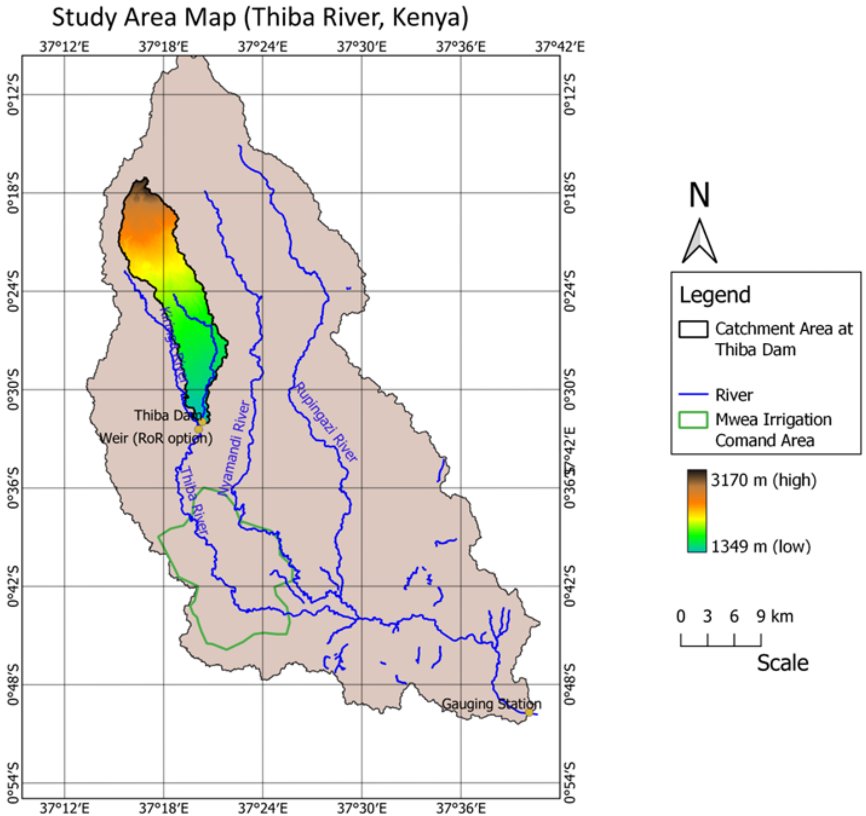
Supervised By:

Prof. Tor. H. Bakken
Co.Supervisor: Prof. Leif Lia

Main Objective of Thesis

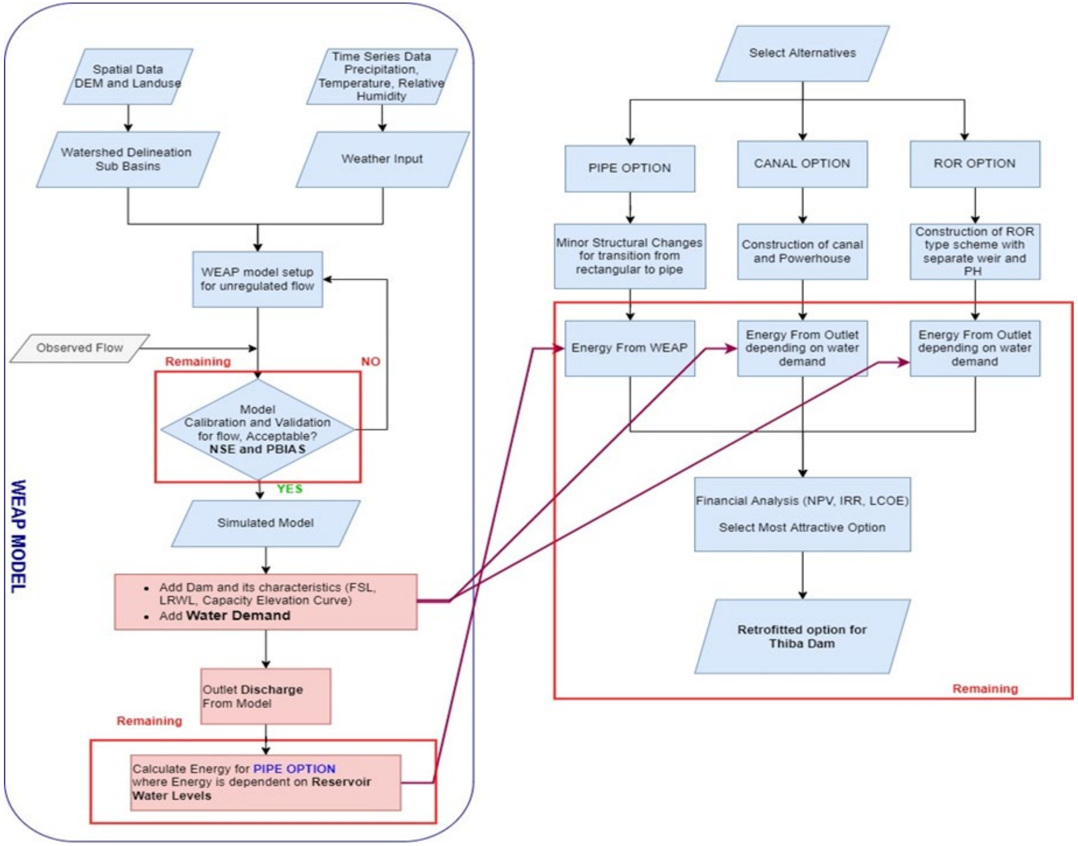
- Identify a non-hydropowered dams with a potential for retrofitting, where technical information about the dam and dam site can be found
- Assess the overall hydrological potential for retrofitting with use of modelling tool (WEAP) for selected reservoirs/dams
- Assess the possible technical solution for the installation/implementation of hydropower technology in selected/studied sites (dams/reservoirs).
- Estimate the economic costs of the investigated technical solution

SITE AREA



Study Area Map (Thiba River, Kenya)
Thiba Dam
Weir (RoR option)
Nyamandi River
Rupingazi River
Thiba River
Gauging Station
N
Legend
Catchment Area at Thiba Dam
River
Mwea Irrigation Comand Area
3170 m (high)
1349 m (low)
0 3 6 9 km
Scale

Methodology Flow Chart



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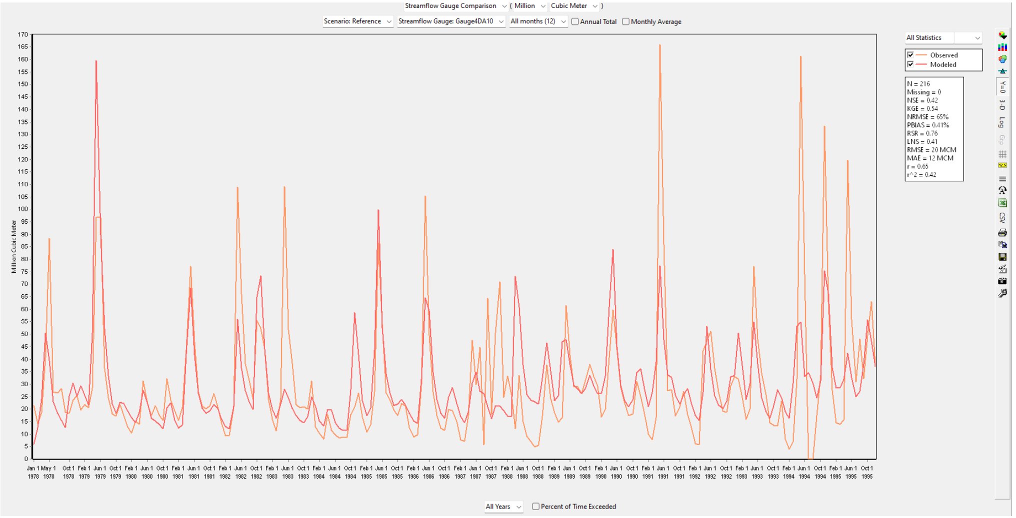
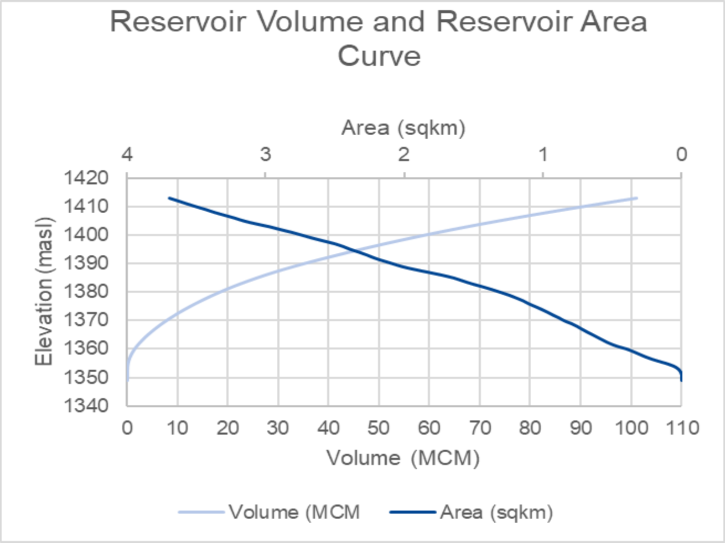
RESULTS





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Kunnskap for en bedre verden

Comparison of environmental footprint across RE

Prepared by :Mihret Hailu

Supervisor by Pro Tor Haakon and PHD Mahmoud seber

NTNU

This study aims at selecting several existing renewable electricity project (hydropower and wind) and systematically compare their environmental footprint, i.e., with respect to selected environmental indices, such as, e.g., land use occupation, impacts on wilderness areas, habitat degradation, and other relevant environmental indicators

Research Questions

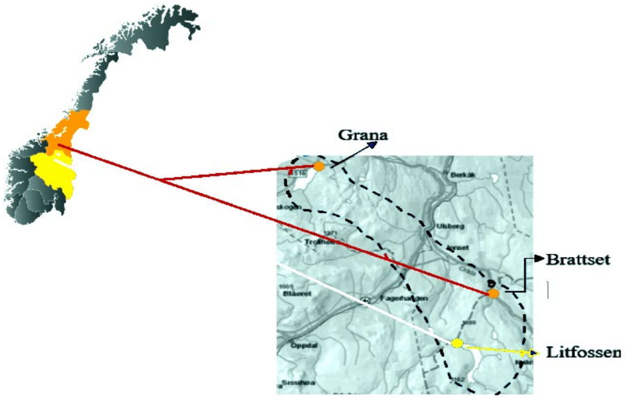
- What is the direct footprint of RE deployment?
- What is the most optimum energy system in terms of land occupation?
- How the land use dynamics change due to RE deployment?
- What are the accompanying impacts due to this dynamic change (i.e., Deforestation, Urbanization.)

Study Area HP

- Grana
  - 75 MW
  - 3 Intakes, 1 Reservoir, 1 outlet
  - 1982
- Litjfossen
  - 75 MW
  - 3Intakes, 1 Reservoir, 1 outlet
  - 1982
- Brattset
  - 80 MW
  - 2 Intakes,1 outlet
  - 1982

Study area WP

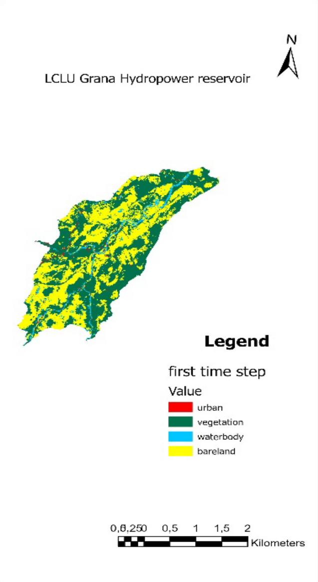
- Geitfjellet:
  - 180 MW, 43 turbines
- Stokkfjellet:
  - 88 MW, 21 turbines
- Hitra,Hitra2:
  - 55.2+93.6 MW, 24+26 turbines

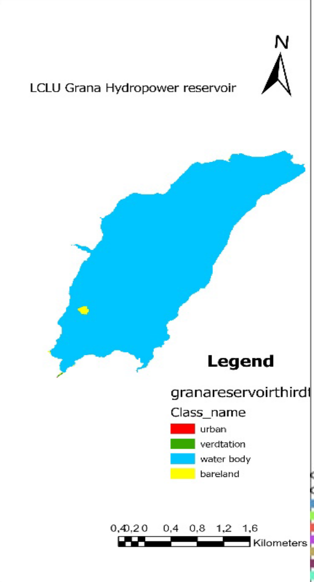


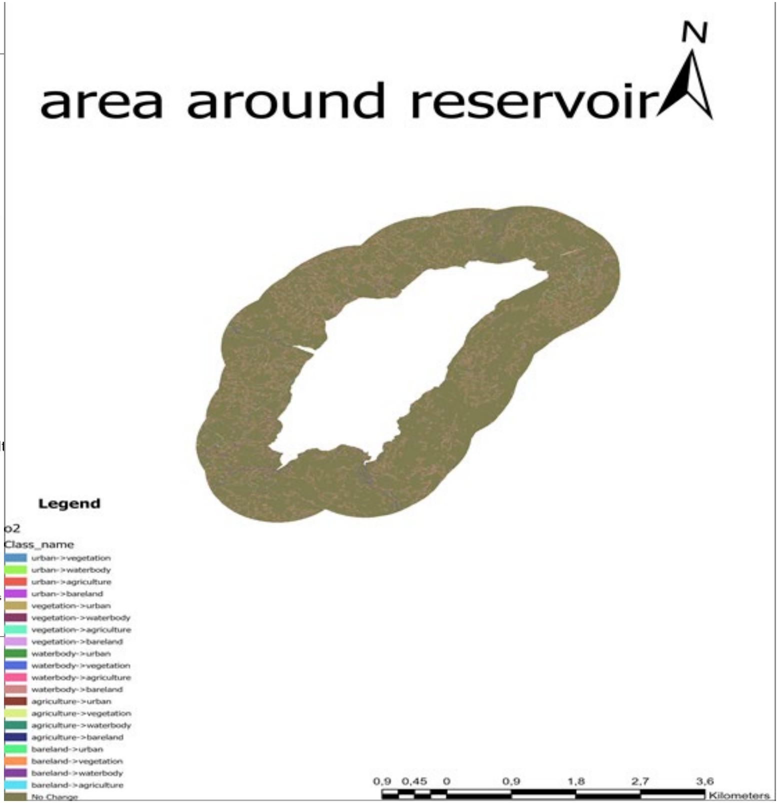
Tasks and data source

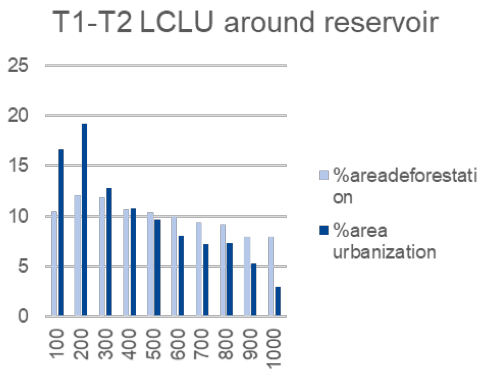
- LU Dynamics on Three Time Steps:
  - Before Deployment
  - After
  - Long term evaluation
- Images
  - Norge I bilder:
  - Landsat: https://www.sentinel-hub.com/
- Production data (NVE)

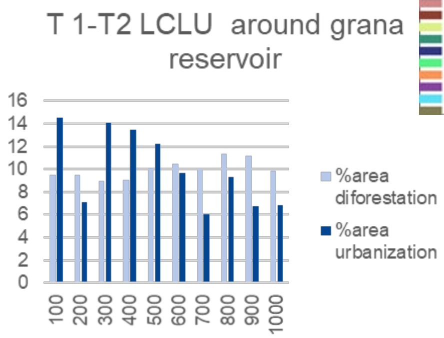
LCLU Grana reservoir



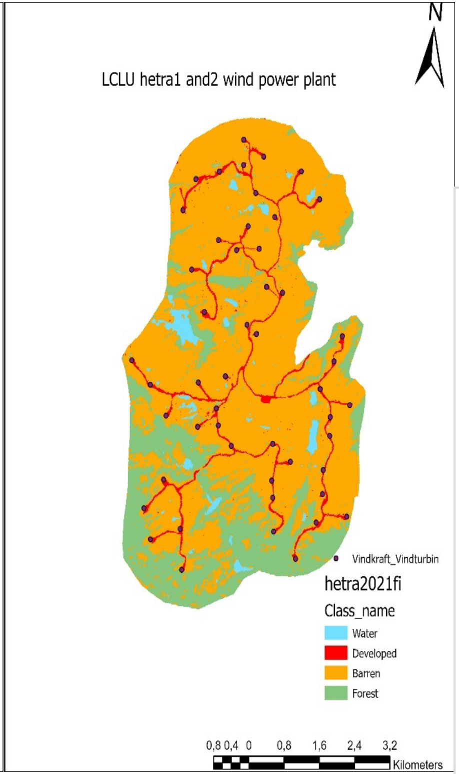


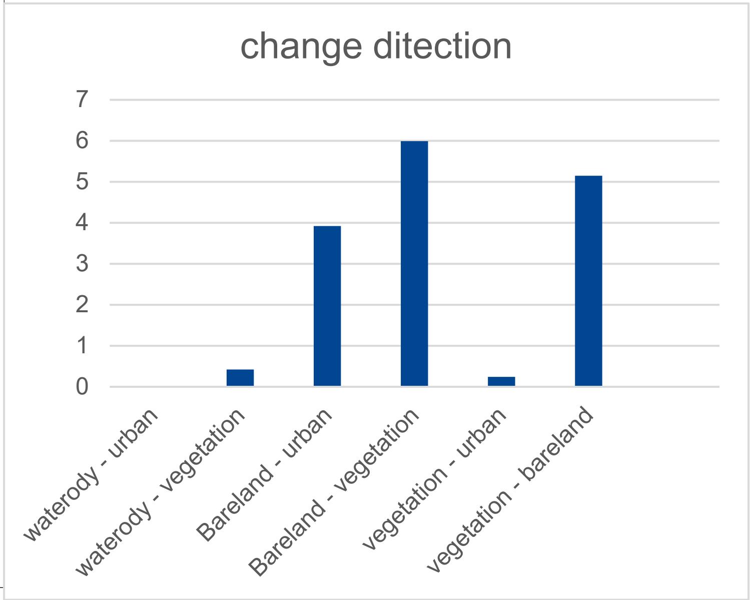






Hetra 1and 2 wind power

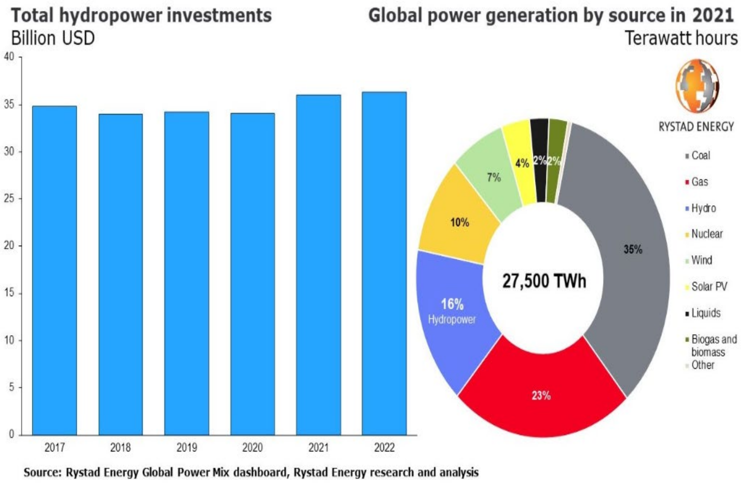


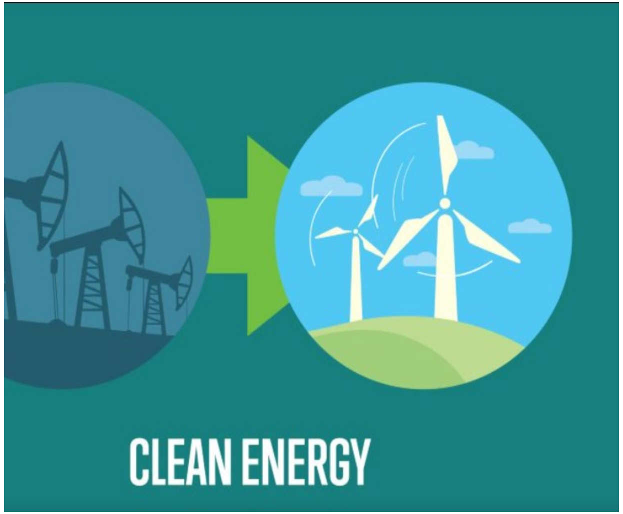


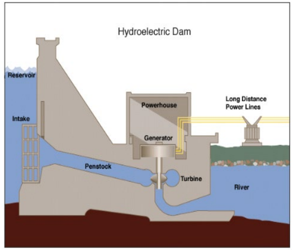
RETROFITTING OF NON-HYDRO RESERVOIRS AND DAMS IN MENDERES RIVER BASIN, TURKEY

by: Quentin Adjetey Okang
SUPERVISOR: TOR HAAKON
CO SUPERVISOR :ASLI BOR TURKBEN

IS THE ENERGY TRANSITION ACHIEVABLE BY 2040?







HYDROPOWER RETROFITTING

- **Opportunity**
- 57,985 dams out of which 29,163 are non-powered dams (ICOLD, 2019)
- Retrofitting : Addition of power production functionality to non-powered dams
- Not every dam is retrofittable
- Dams must satisfy technical requirements (Head, Water availability, and capacity)

Student: Quentin Adjetey Okang
Supervisor: Tor Haakon Bakken

Methodology

- Data needs (Climatic and Hydrological)
- Data sources:
- Princeton Data Center- Climatic data
- HydroSHEDS-Digital Elevation Model
- ESA-CCI-LC- Land cover data
- Turkish State Hydraulic Works-Discharge and dam information

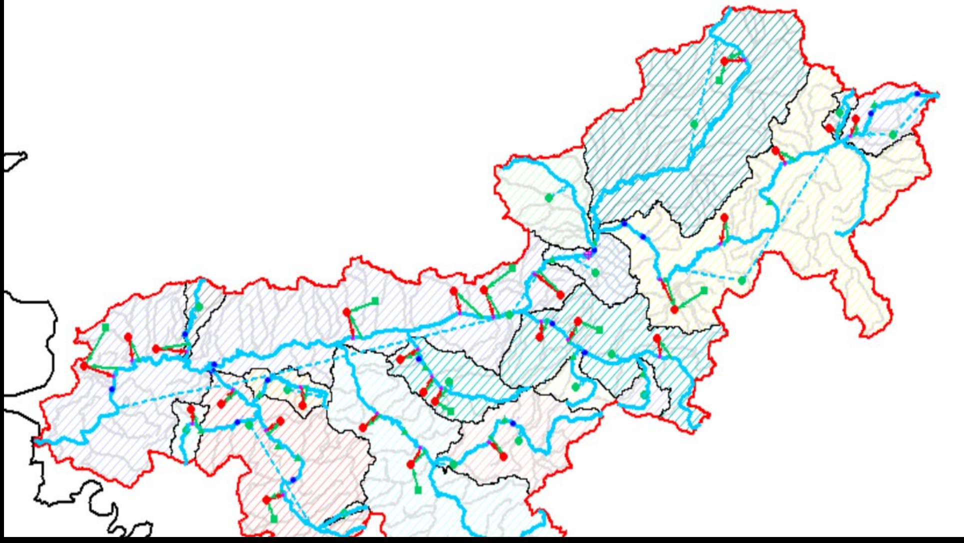
- Data refinery(Double mass plots, regressional analysis)
- Schematisation of the model with WEAP elements to reflect reality
- Data input
- Model calibration/verification (PBIAS)

WEAP software is used to verify the retrofitting potential of 11 non powered dams within the Buyuk Menderes Basin

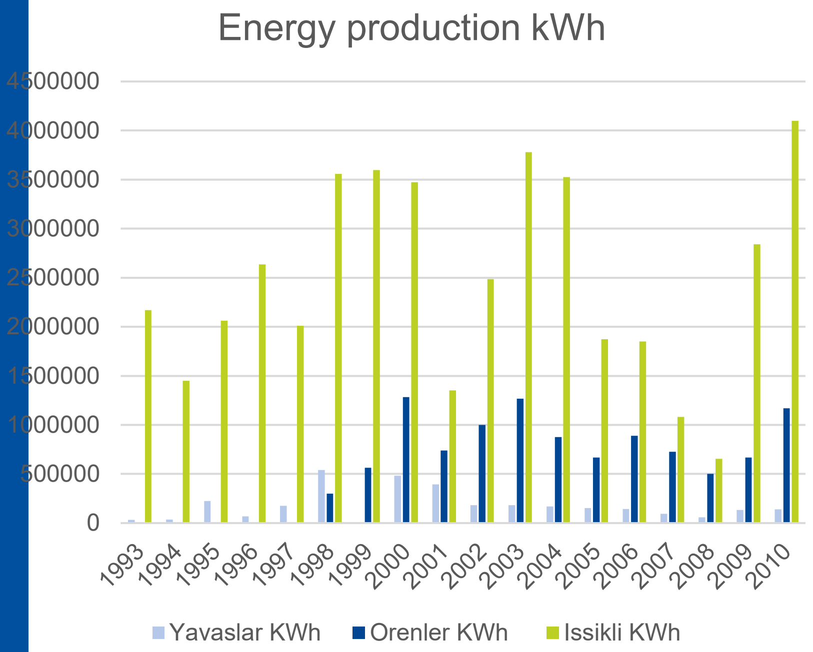
Annual energy produced from these non-powered dams was subjected to economic viability with NPV, IRR and LCOE as the main economic indicators

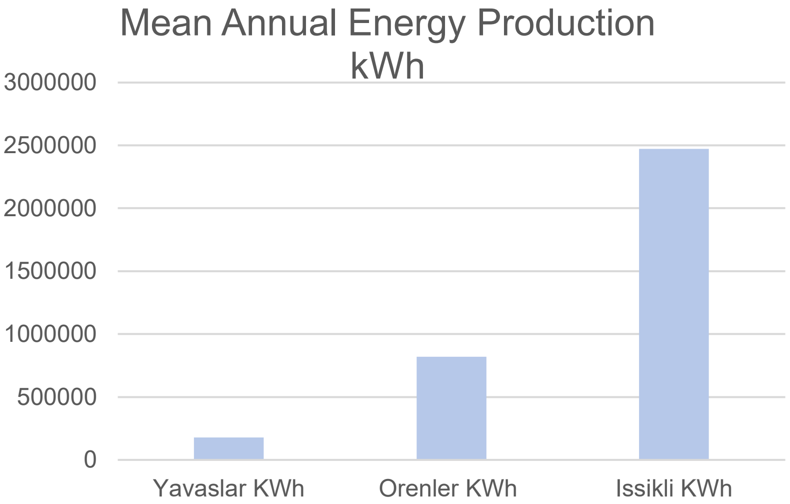
An assessment is conducted on the impact of the release of environmental flow to support fish and fauna life at the downstream section of the reservoir

Findings of the study guides investments into retrofitting of these nonpowered dams and water resource management within the basin



Preliminary results from Kufi sub-basin (Buyuk Menderes)





Comparison of Kinematic wave and Hydraulic model simulated water level along river sections

Figure 2.1.5.20 The flood st

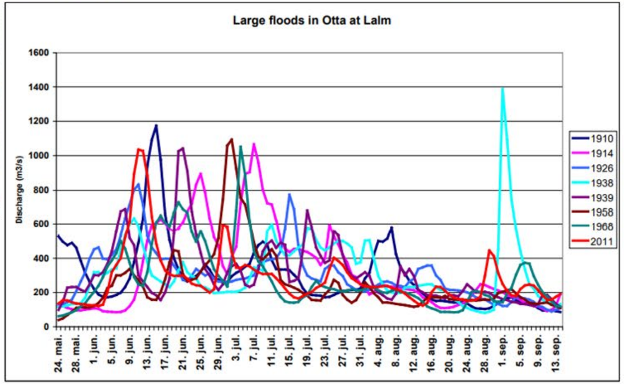


Figure 2.1.5.21 Daily discharges of the largest observed floods in River Otta at Lalm

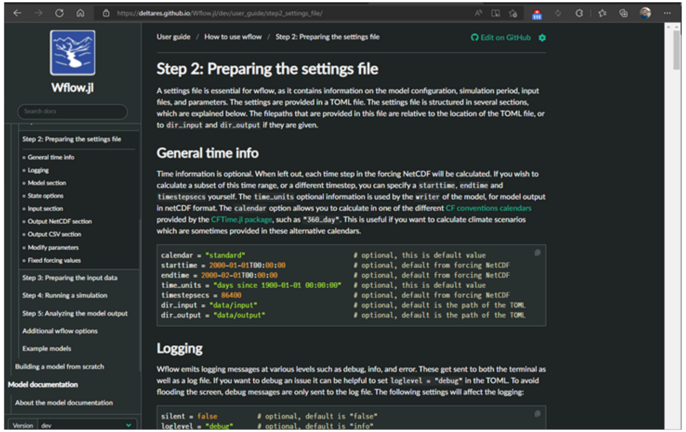
Oddbjørn Bruland
NTNU

Ana Adeva Bustos
SINTEF

Corine Ten Velden
Deltares

Flomrespons prosjekt

Wflow model (developed by Deltares)



https://deltares.github.io/Wflow.jl/dev/user_guide/step2_settings_file/

Wflow.jl

Search docs

- Step 2: Preparing the settings file
  - General time info
  - Logging
  - Model section
  - State options
  - Input section
  - Output NetCDF section
  - Output CSV section
  - Modify parameters
  - Fixed forcing values
- Step 3: Preparing the input data
- Step 4: Running a simulation
- Step 5: Analyzing the model output
- Additional wflow options
- Example models
- Building a model from scratch

Model documentation

- About the model documentation

Version dev

User guide / How to use wflow / Step 2: Preparing the settings file — Edit on GitHub

Step 2: Preparing the settings file

A settings file is essential for wflow, as it contains information on the model configuration, simulation period, input files, and parameters. The settings are provided in a TOML file. The settings file is structured in several sections, which are explained below. The filepaths that are provided in this file are relative to the location of the TOML file, or to `dir_input` and `dir_output` if they are given.

General time info

Time information is optional. When left out, each time step in the forcing NetCDF will be calculated. If you wish to calculate a subset of this time range, or a different timestep, you can specify a `starttime`, `endtime` and `timestepsecs` yourself. The `time_units` optional information is used by the `writer` of the model, for model output in netCDF format. The `calendar` option allows you to calculate in one of the different CF conventions calendars provided by the CFTime.jl package, such as `"360_day"`. This is useful if you want to calculate climate scenarios which are sometimes provided in these alternative calendars.

```
calendar = "standard"                            # optional, this is default value
starttime = 2000-01-01T00:00:00                  # optional, default from forcing NetCDF
endtime = 2000-02-01T00:00:00                    # optional, default from forcing NetCDF
time_units = "days since 1900-01-01 00:00:00"    # optional, this is default value
timestepsecs = 86400                             # optional, default from forcing NetCDF
dir_input = "data/input"                         # optional, default is the path of the TOML
dir_output = "data/output"                       # optional, default is the path of the TOML
```

Logging

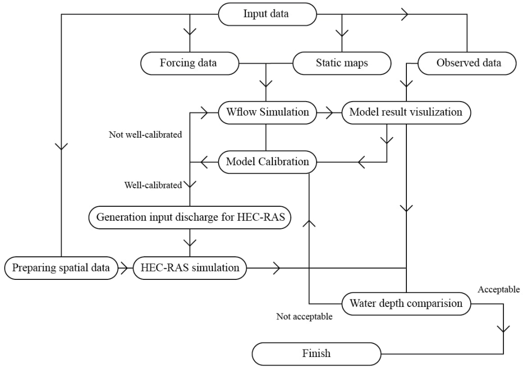
Wflow emits logging messages at various levels such as debug, info, and error. These get sent to both the terminal as well as a log file. If you want to debug an issue it can be helpful to set `loglevel = "debug"` in the TOML. To avoid flooding the screen, debug messages are only sent to the log file. The following settings will affect the logging:

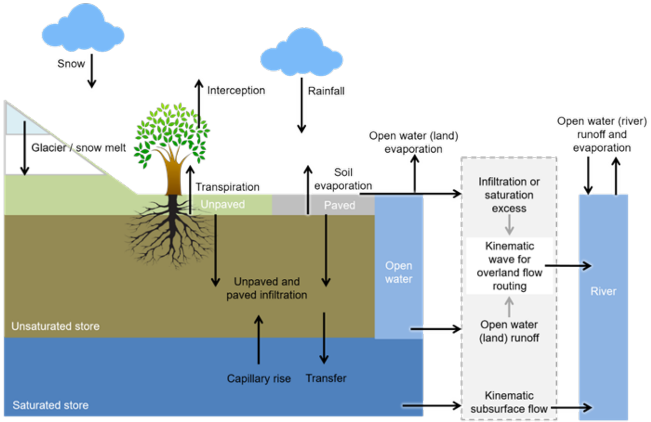
```
silent = false          # optional, default is "false"
loglevel = "debug"      # optional, default is "info"
```

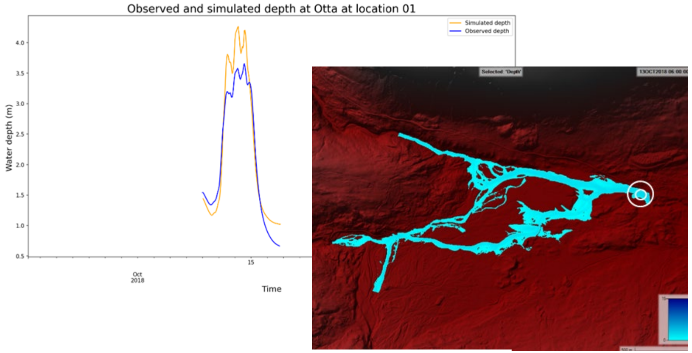
What we need to run the model:

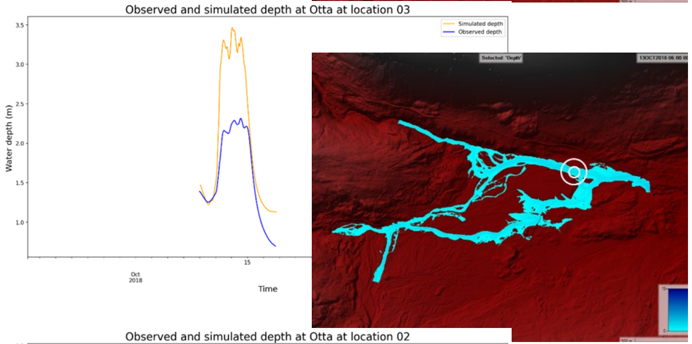
1- Input data for precipitation, temperature and evaporation

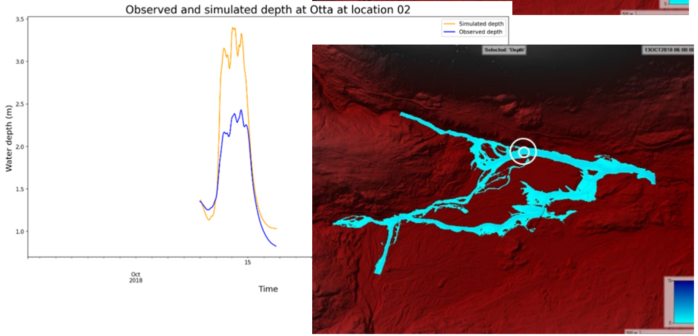
2- Spatial information (locations of the gauges, land-use, drainage direction, etc,)

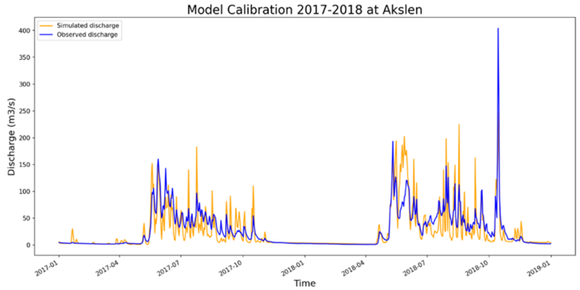


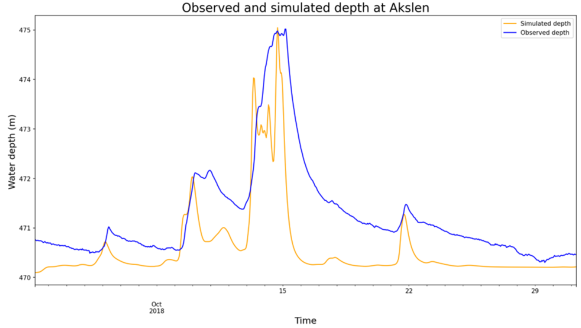


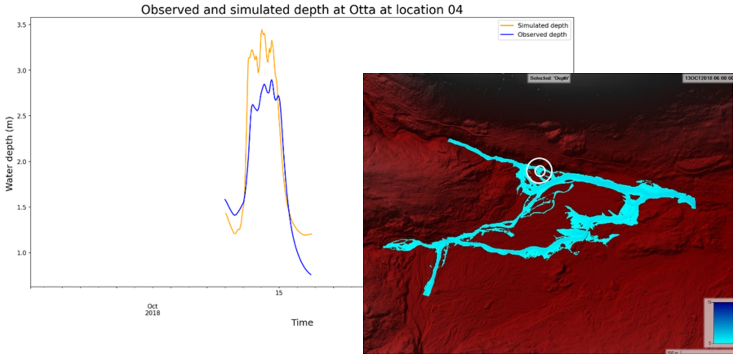

Observed and simulated depth at Otta at location 01
Simulated depth
Observed depth
Water depth (m)
Oct
2018
15
Time

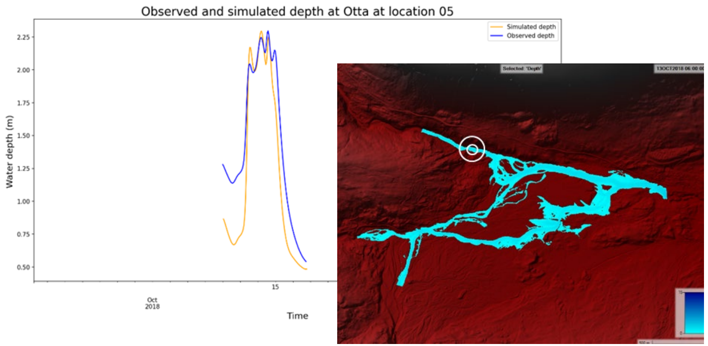

Observed and simulated depth at Otta at location 03
Simulated depth
Observed depth
Water depth (m)
Oct
2018
15
Time

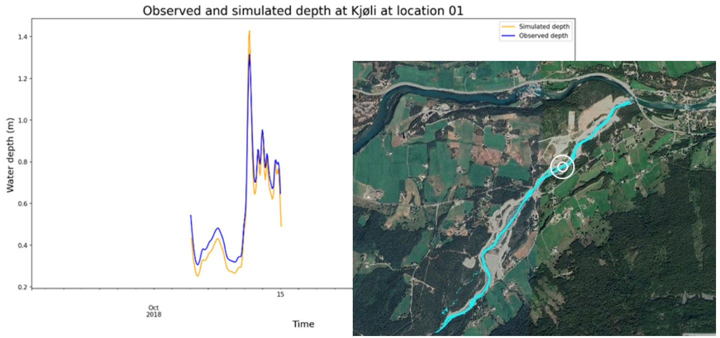

Observed and simulated depth at Otta at location 02
Simulated depth
Observed depth
Water depth (m)
Oct
2018
15
Time

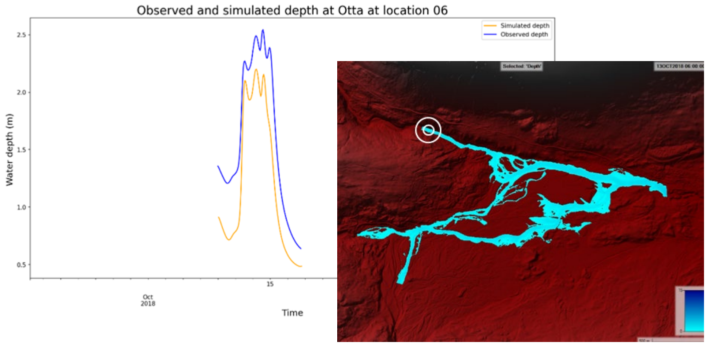

Model Calibration 2017-2018 at Akslen
Simulated discharge
Observed discharge
Discharge (m3/s)
Time

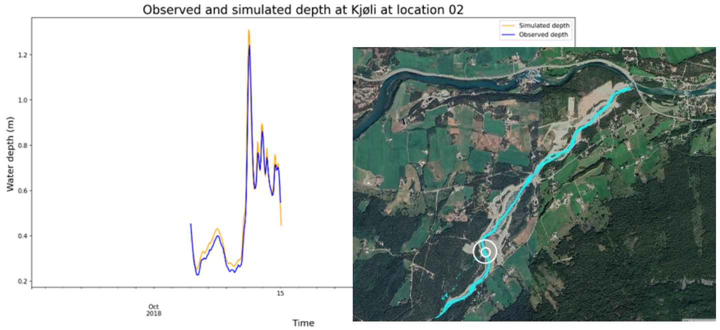

Observed and simulated depth at Akslen
Simulated depth
Observed depth
Water depth (m)
Oct
2018
15
22
29
Time


Observed and simulated depth at Otta at location 04
Simulated depth
Observed depth
Water depth (m)
Oct
2018
15
Time









Up to now:

1- Discussing about possible locations

2- Model Setup

3- Preparing required files

4- Model modification (gauges, land-use etc,)

5- Hydraulic model set-up

6- Model calibration and updating local datasets…

Challenges:

1- Preparing special datasets for river updating

2- Unfamiliarity with model

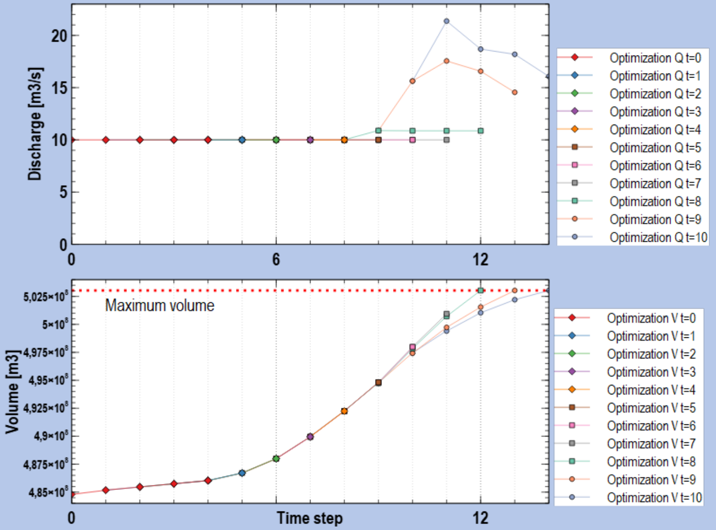
3- Access to data resources

4- Access to developers

5- Model calibration

On the added value of ensemble forecasts for reservoir operation

Source : Siso kraftverk



Jiyoung Kim

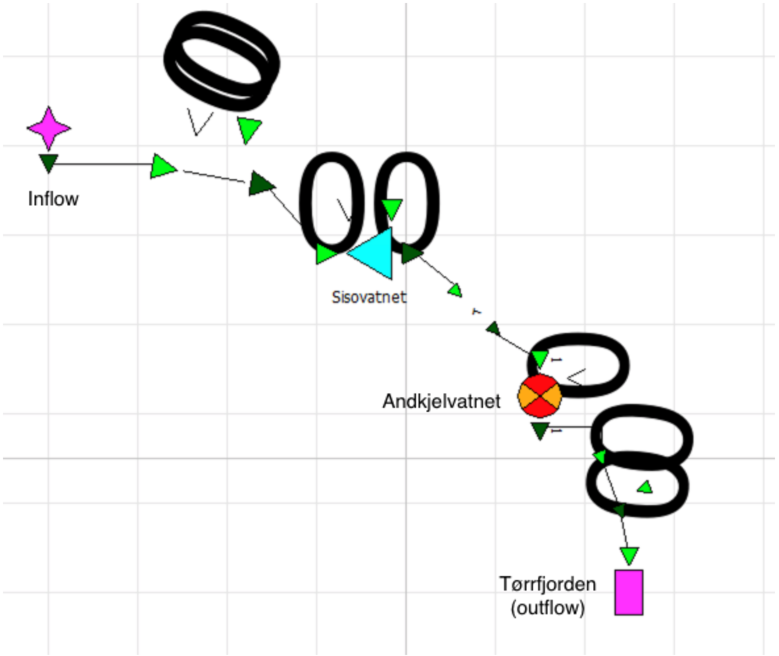
Supervisor : Elena Pummer, Bernhard Becker (Deltares)

Introduction

- Forecast based reservoir operations
- Deterministic model is commonly used in short-term planning
- Uncertainties with inflow forecasts -> Ensemble model
- **Goal** : Find the added value of using ensemble forecasts in short term (14 - 30 days) reservoir operation with focus on flood situations
- Test with glacier outburst situation (jøkulhlaup)

Methods

- Data - inflow, reservoir volume curve
- Linear optimization model
  (Open Modelica)
- RTC - Tools
- Different methods of ensemble optimization
    - Optimization for each ensemble members
    - Ensemble mode
    - Tree based optimization
    - Moving window approach



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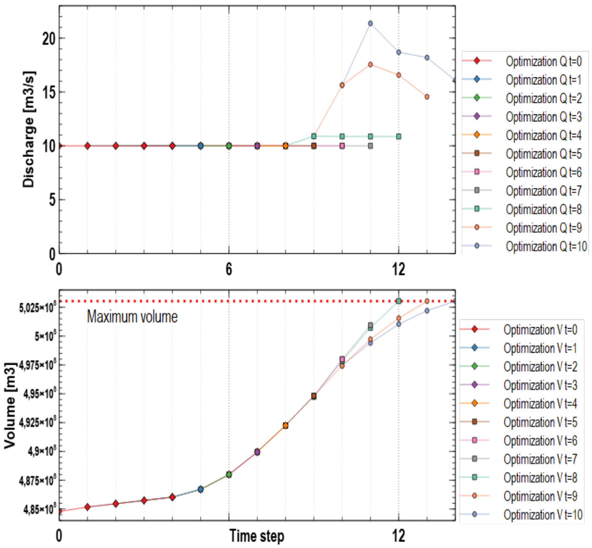
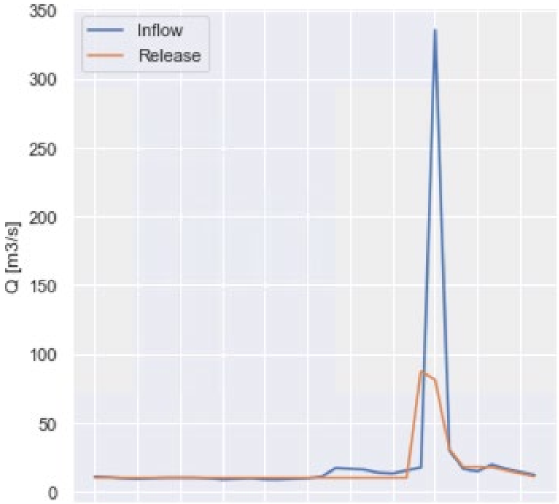
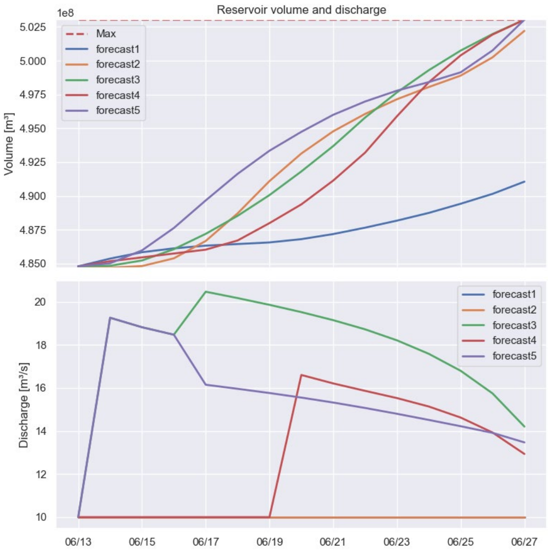
Results







- Reservoir volume & release scheme for different scenarios and modes
- Visualization of uncertainties
- Ensemble mode – conservative scheme for flood vulnurable area
- Importance of setting breaching points, updating the model
- Jøkulhlaup