Hydrogeological studies and groundwater modelling in the project sites in Finland

EU LIFE Project EC Meeting

16th April 2025

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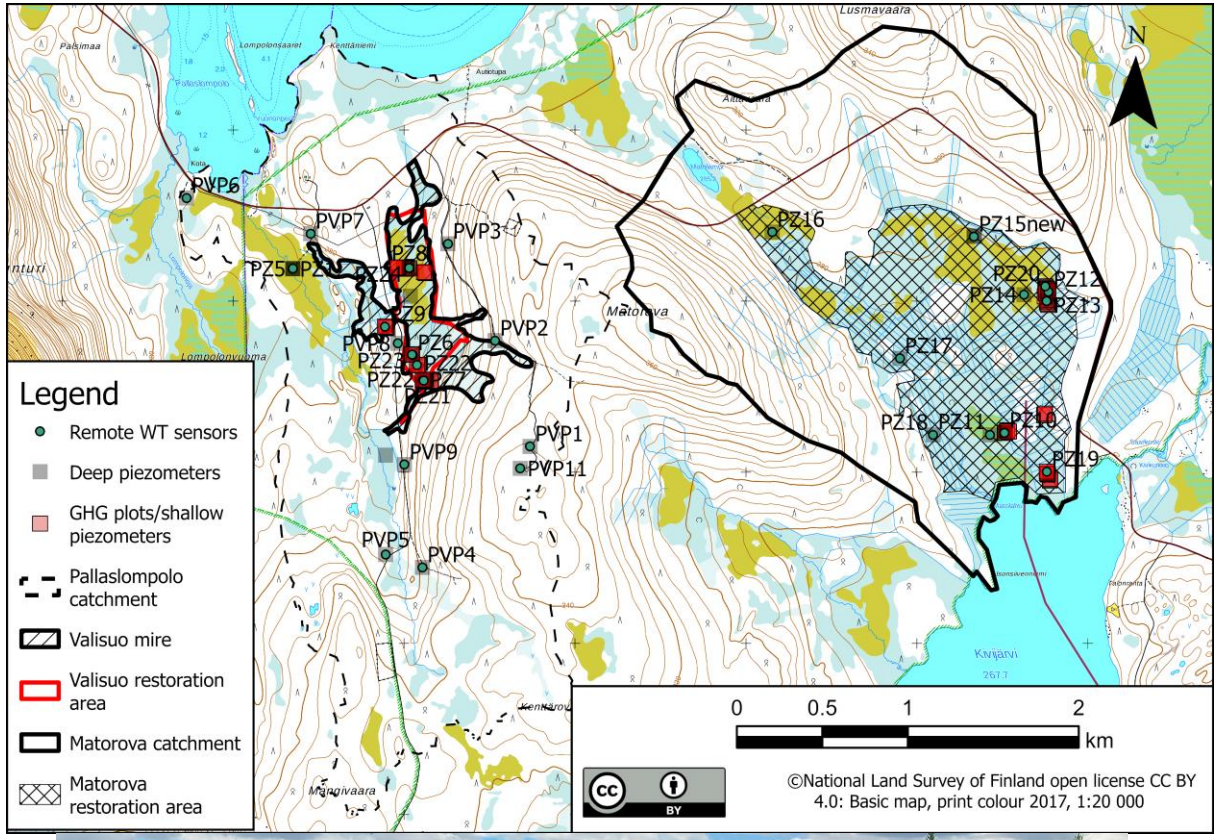
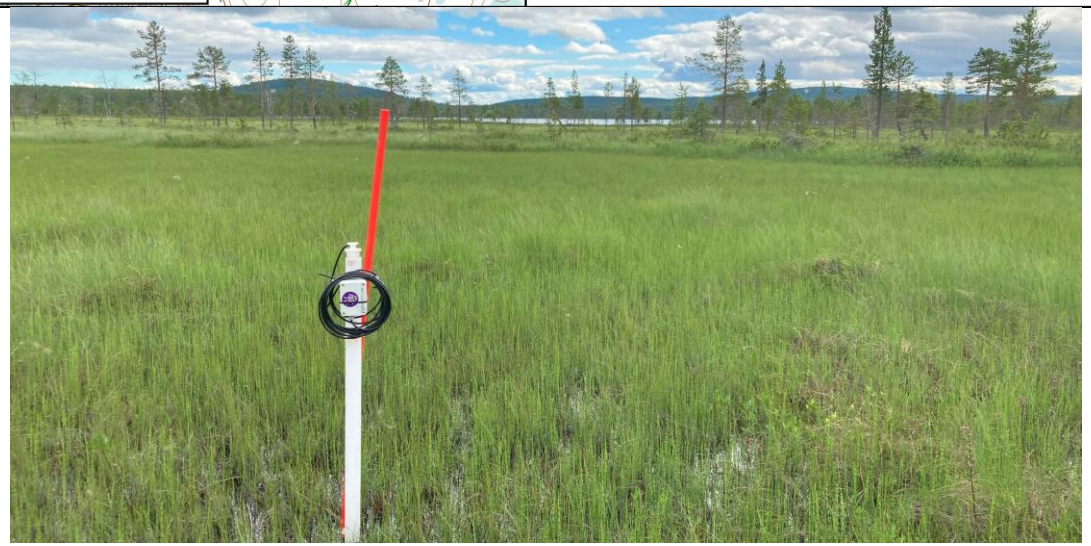
University of Oulu





Hydrological monitoring

-First indicator of successful restoration

Setup:
-Short open-pipe piezometers in ~80 locations to monitor shallow WT as part of GHG & vegetation plots
-Long deep piezometers in 14 locations to monitor hydraulic gradients
-~20 operating remote loggers (14 in long piezometers and ~6 short open-pipe piezometers)
-First sensors installed in November 2022

Key reached milestones for hydrological studies and modelling in 2024

Field work activities:

- Winter Ground Penetrating Radar (GPR) campaign on the 4th-8th April 2024
- Installation of remaining monitoring wells and sensors in May 2024
- Summer GPR campaign on the 9th-13th June 2024
  - Two seismic refraction lines
  - Manual peat depth probing
- Autumn manual GW monitoring and piezometer mapping campaign 23rd-27th September

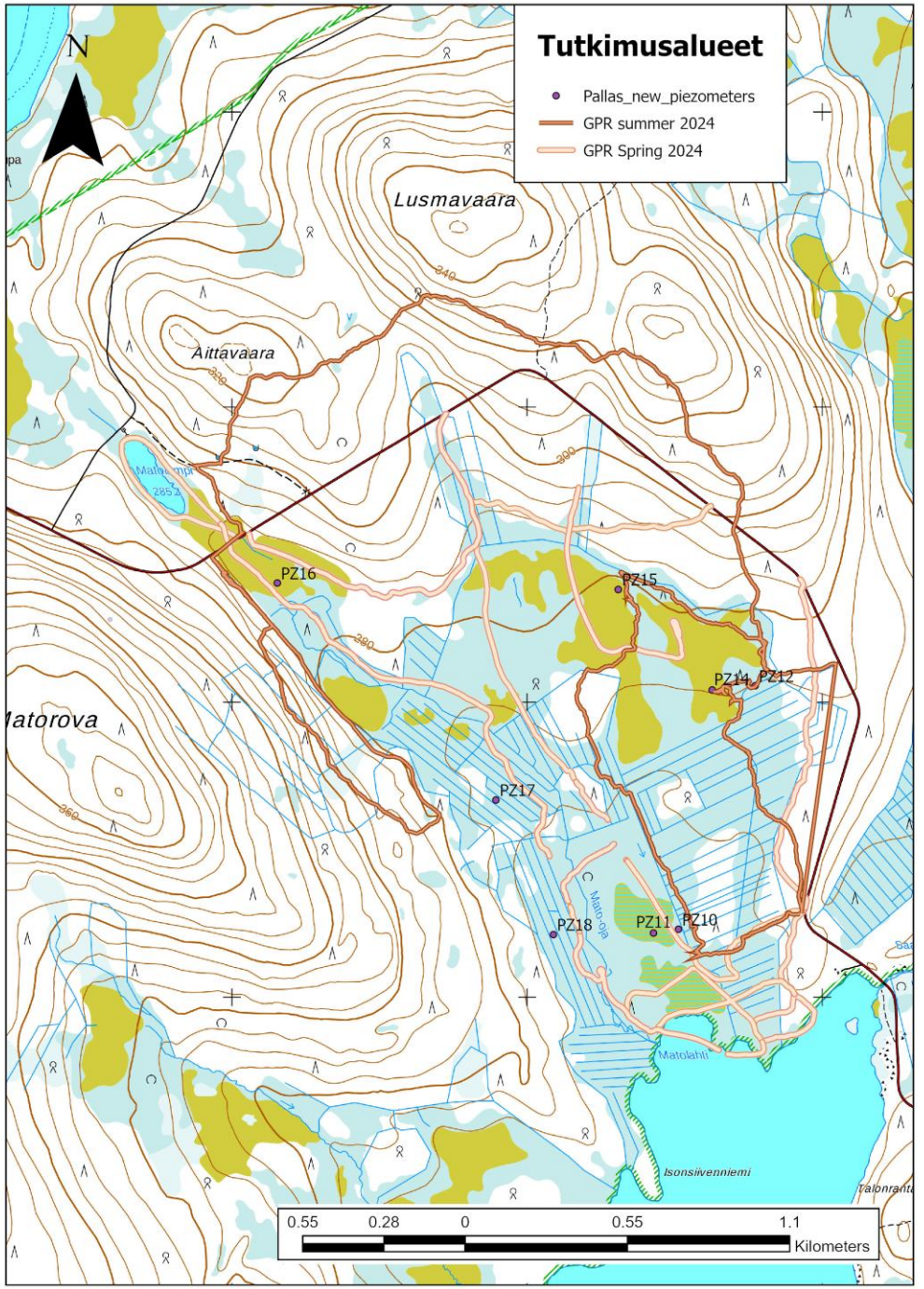
Modelling and data analysis:

- Steady-state model of Matorovasuo construction and management scenario modelling (pristine/pre-management, drained, restored)
- Mesh update and testing for the Pallaslompo model
- Geophysical data processing and interpretation
- Geological model building
- Monitoring data preliminary processing and analysis

Geophysical and geological measurements

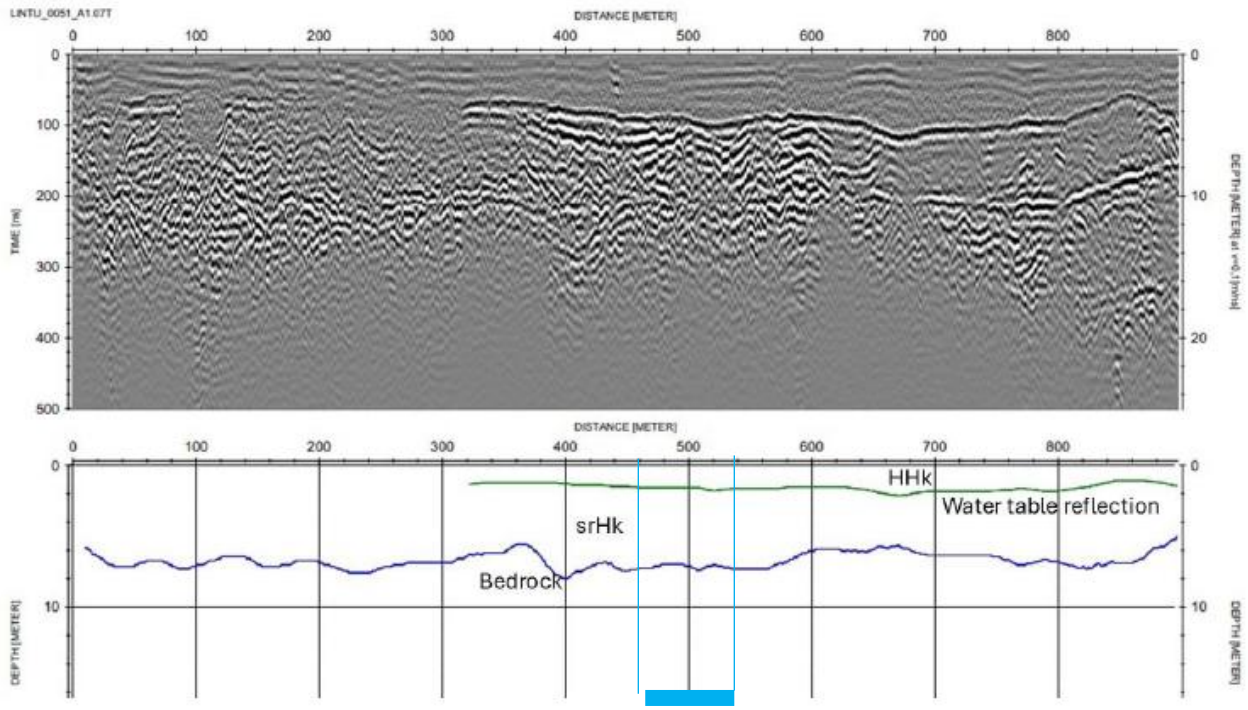
- Ground Penetrating Radar (GPR)
  - Winter 2024 campaign covered 14.2 km (100MHz shielded and 50 MHz RTA antennas)
  - Summer 2024 campaign covered 12.402 km (50 MHz RTA antenna)
- Seismic refraction
  - 2 lines with a total length ~220 m in Pallaslompolo catchment
- Manual peat depth probing in 73 locations

Geophysical measurements were done and analysed for the Master's thesis of Khizer Jadoon (to be submitted February/March 2025)



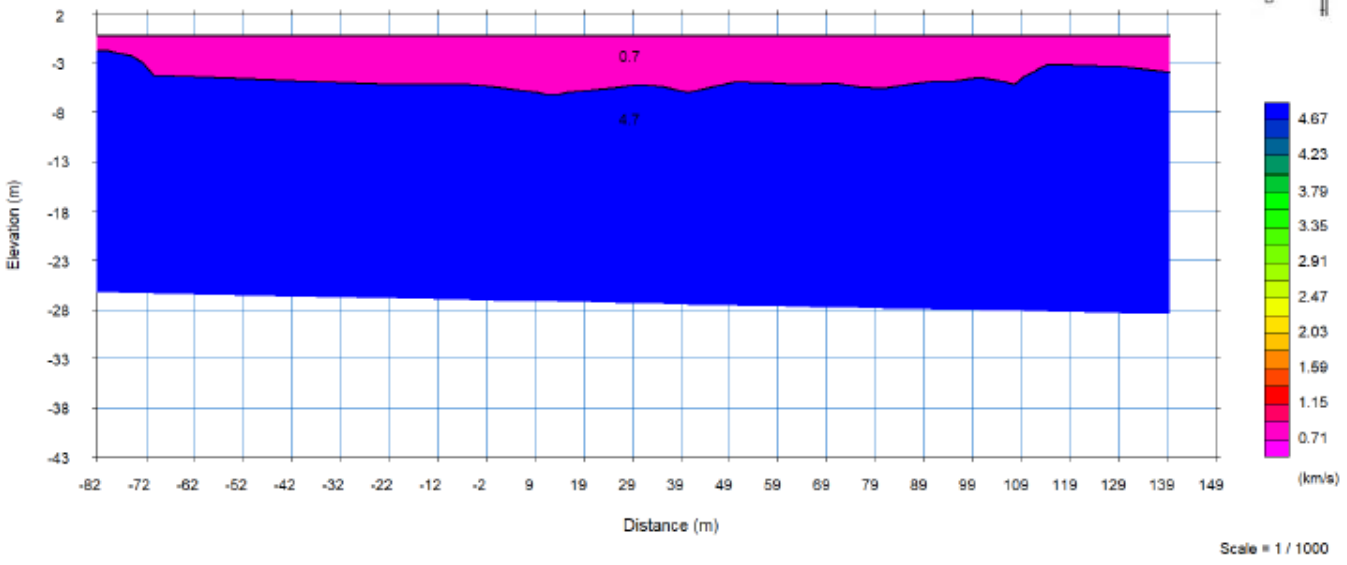
Geophysical data - interpretations

GPR



Seismic refraction

Seismic refraction



- Seimic refraction measurements confirmed the bedrock interface derived from GPR data

Synthesis – Peat depths

Synthesis
of the geophysical geological data done by Khizer Jadoon in his Master's thesis: *Geophysical Investigations of Pallas-Yllästunturi Region Using GPR and Seismic Refraction,* April 2025

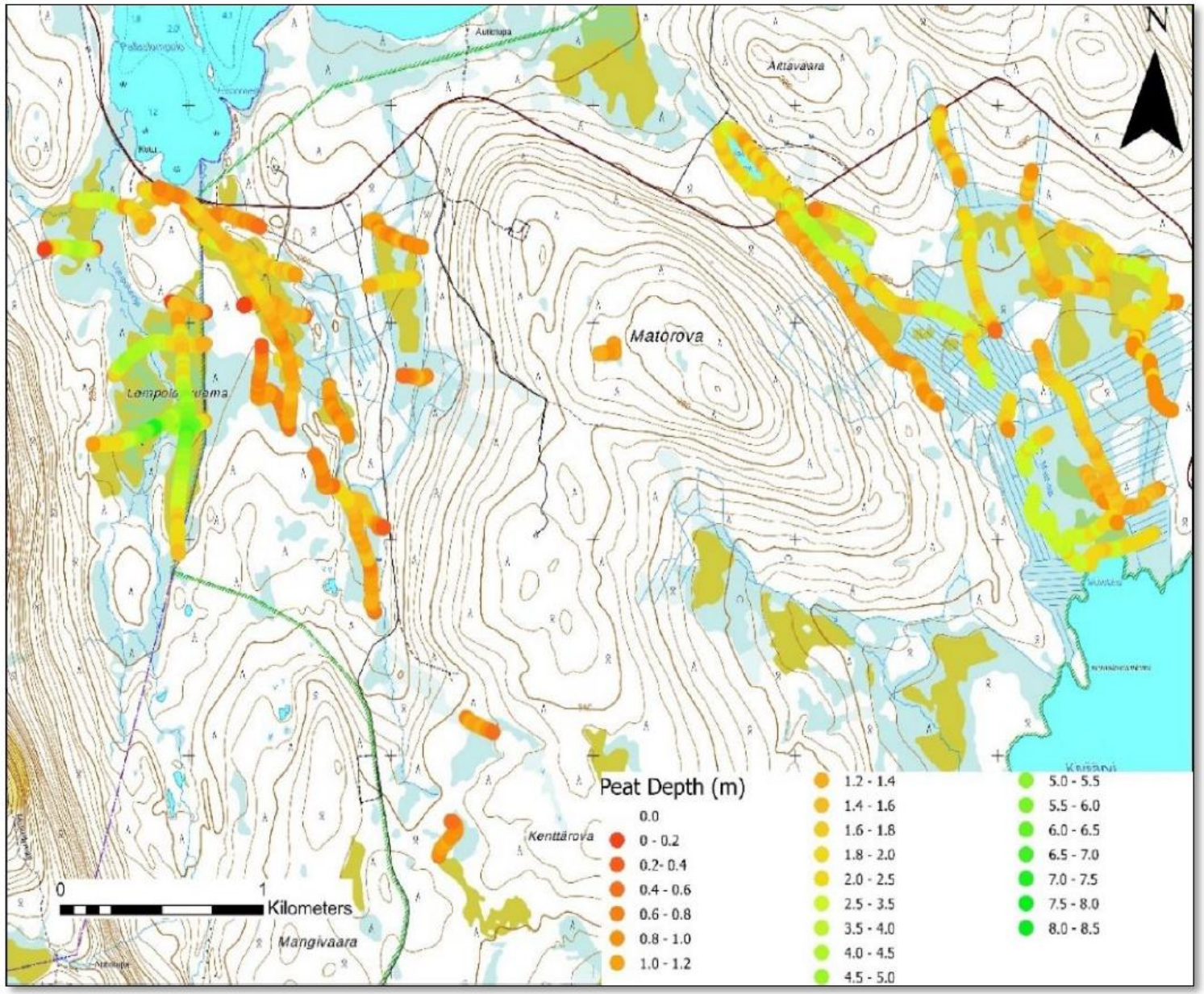
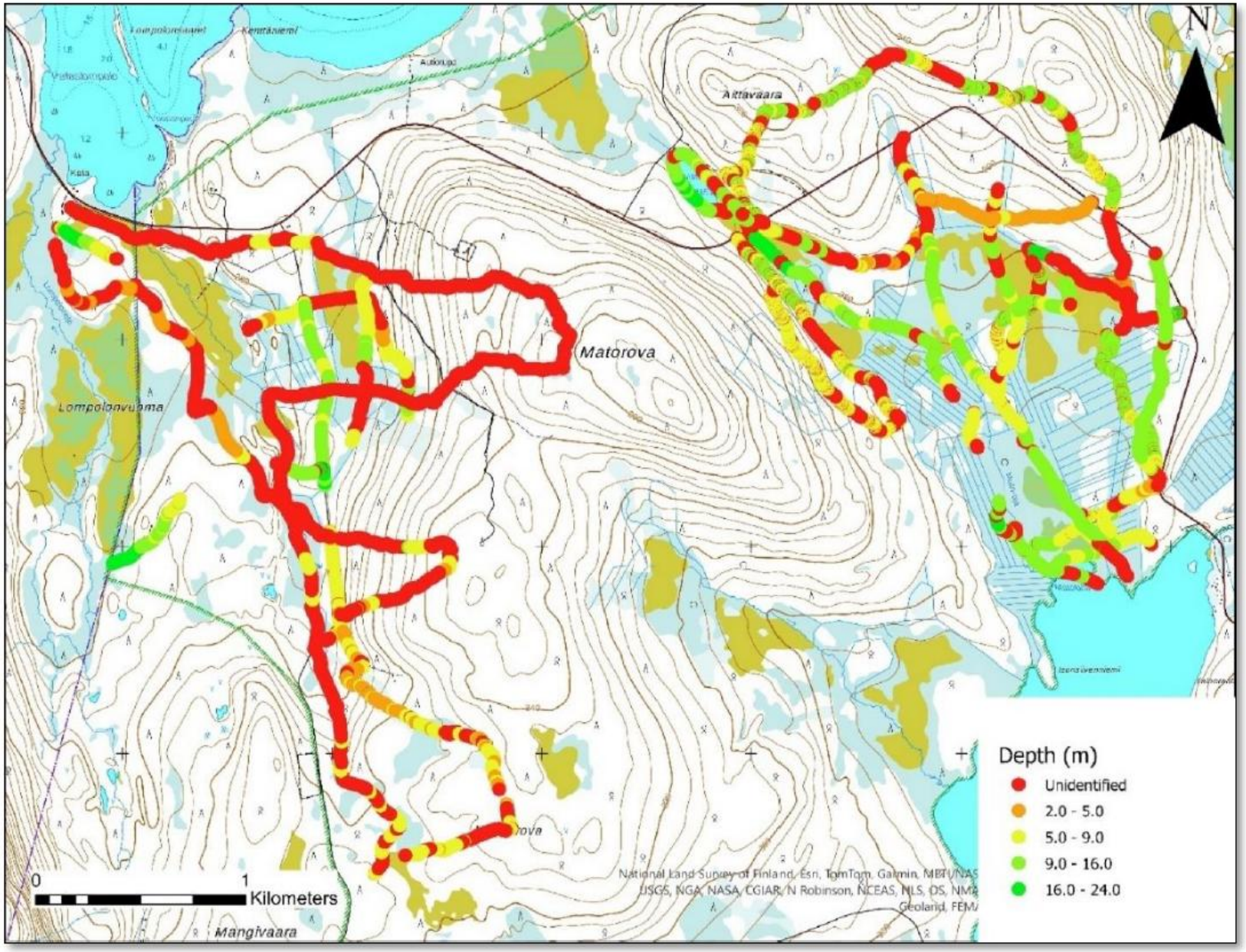
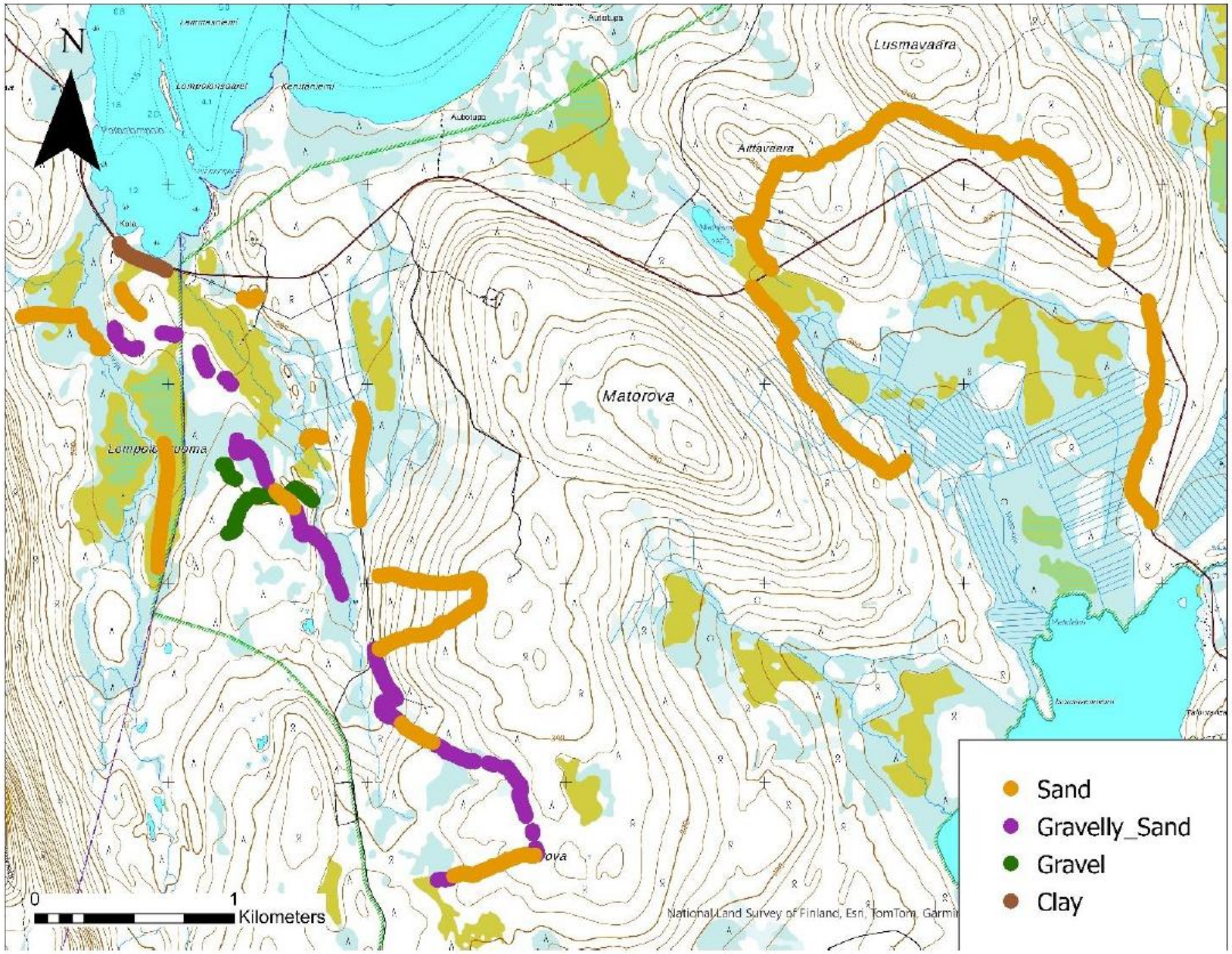


Figure by Khizer Jadoon

Synthesis – Bedrock depth

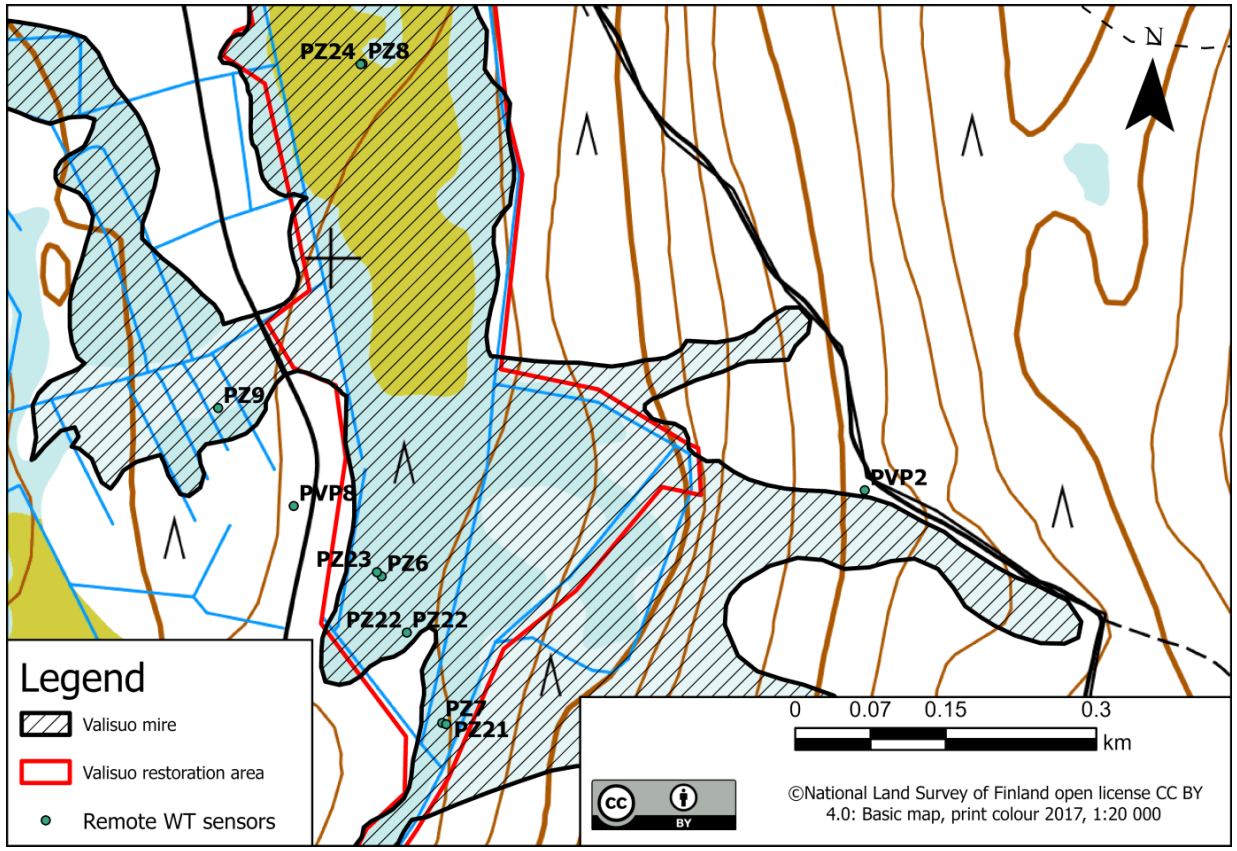


Synthesis – Glaciofluvial deposits



Välisuo

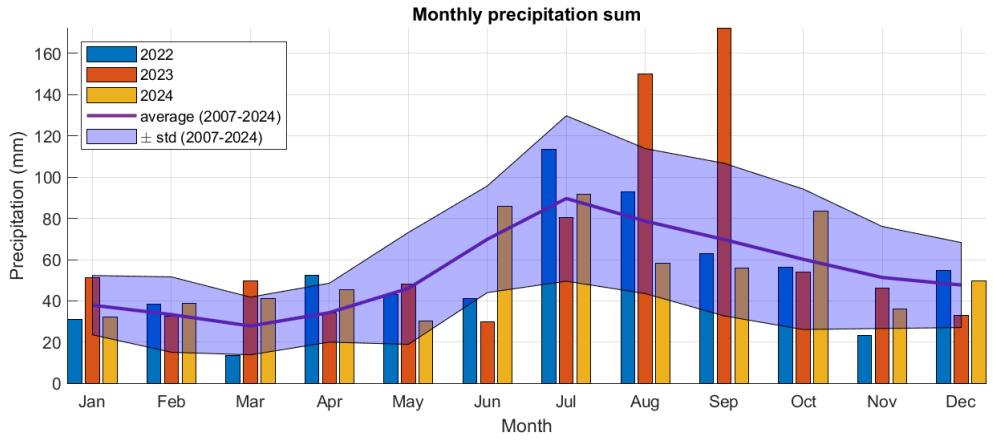
Välisuo mire monitoring

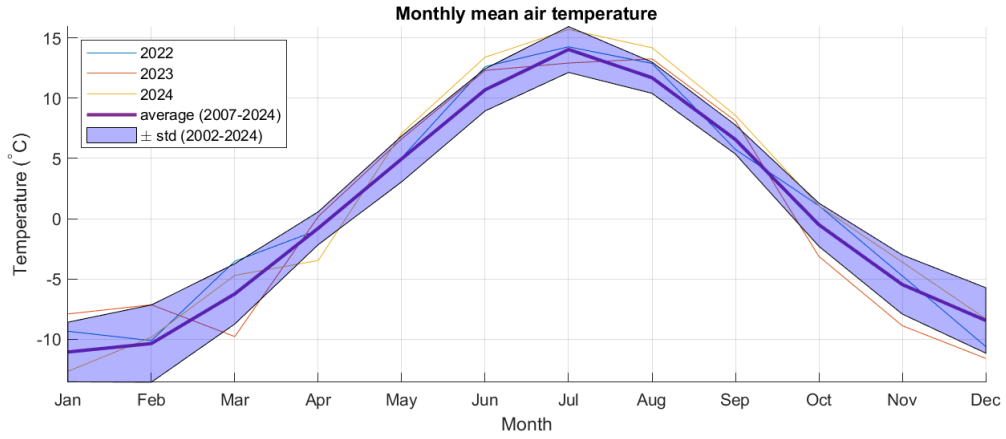


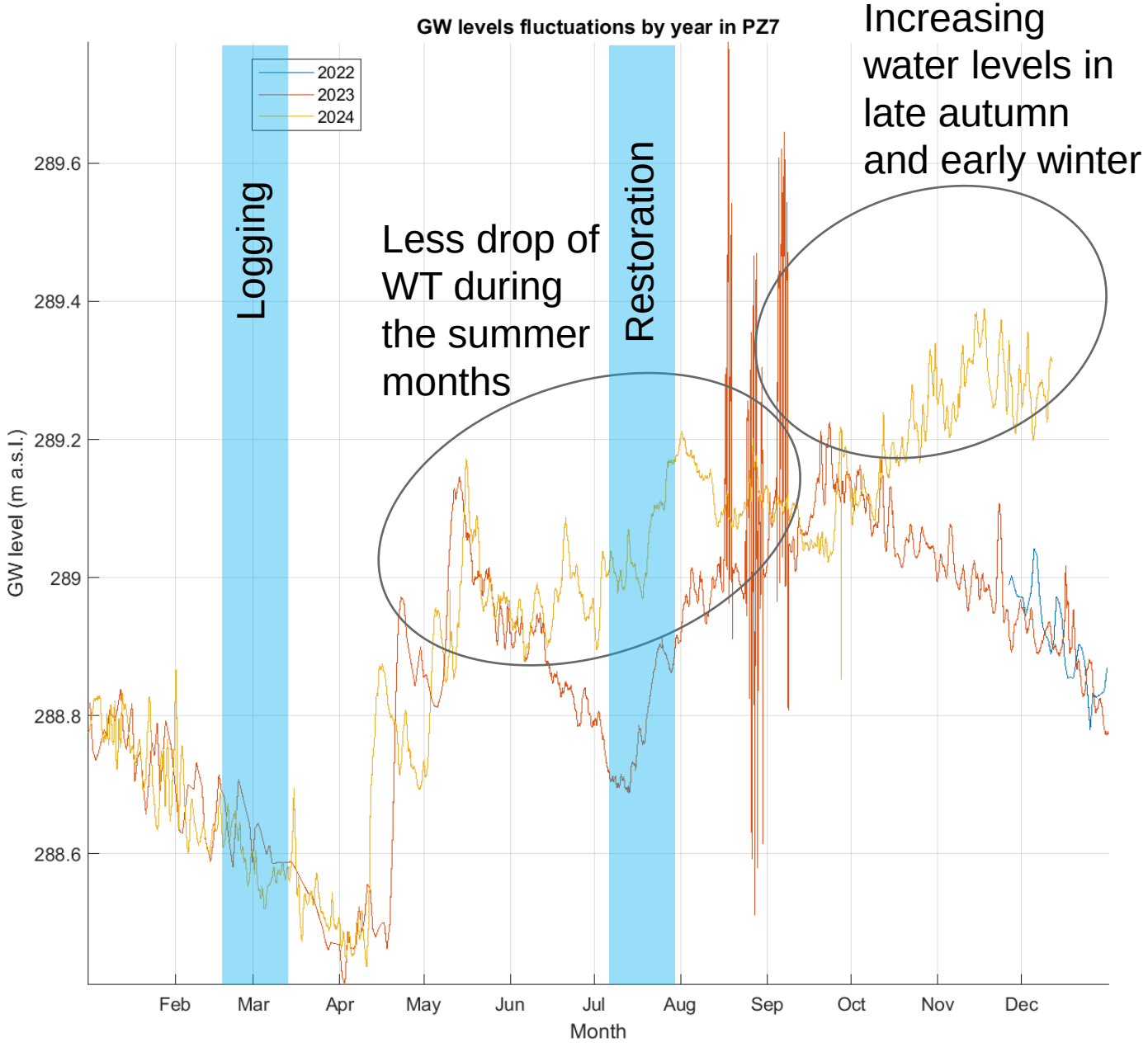
- Currently 7 operating remote WT loggers (Decentlab-26)
- First measurements starting in November 2022
- Additional piezometers in mineral soil within the whole catchment area allow for holistic tracking of the hydrological state holistically

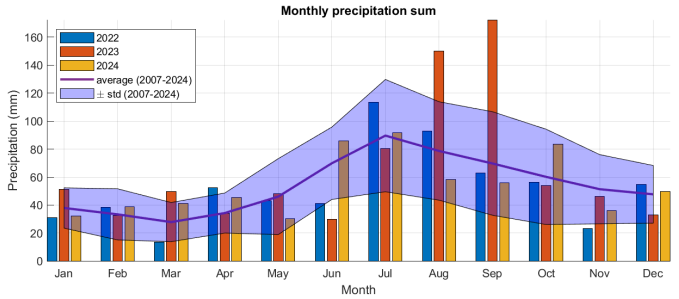
Hydrological monitoring first results

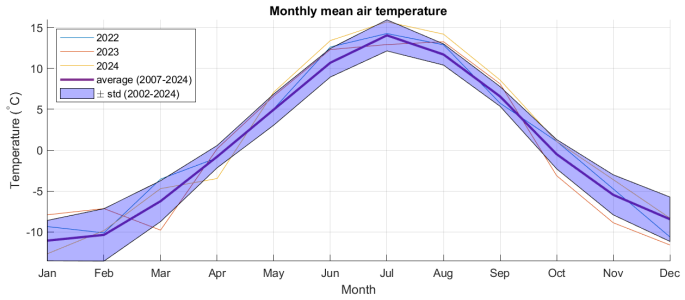
- Preliminary analysis indicates that WT levels in well drained peatland areas experienced less drop during summer time in comparison to wetter undrained (less affected areas) in both peatlands.
- peatlands' hydrological state and its dynamics are dependent on the preceding hydrological state so these first indications need to be confirmed by continuing monitoring and numerical modelling





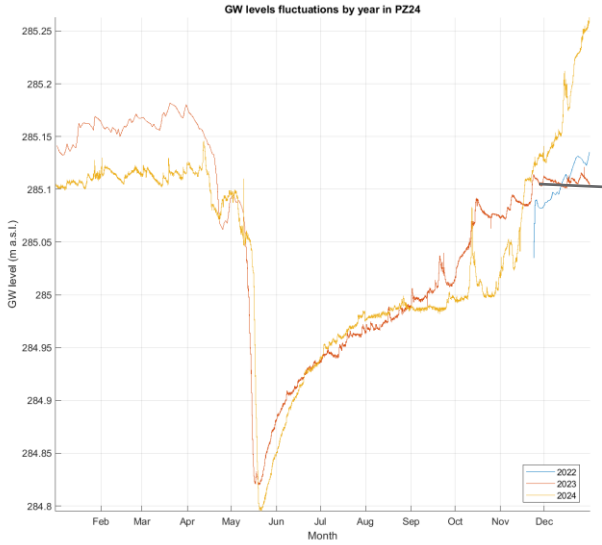

GW levels fluctuations by year in PZ7
2022
2023
2024
Logging
Restoration
Less drop of WT during the summer months
Increasing water levels in late autumn and early winter
GW level (m a.s.l.)
289.6
289.4
289.2
289
288.8
288.6
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

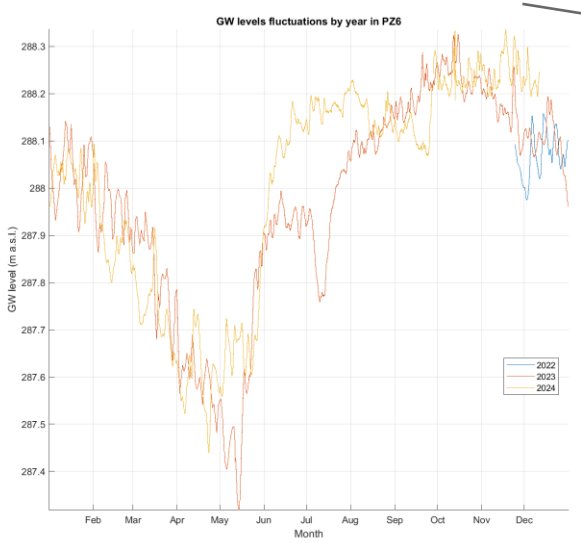

Monthly precipitation sum
2022
2023
2024
average (2007-2024)
± std (2007-2024)
Precipitation (mm)
160
140
120
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

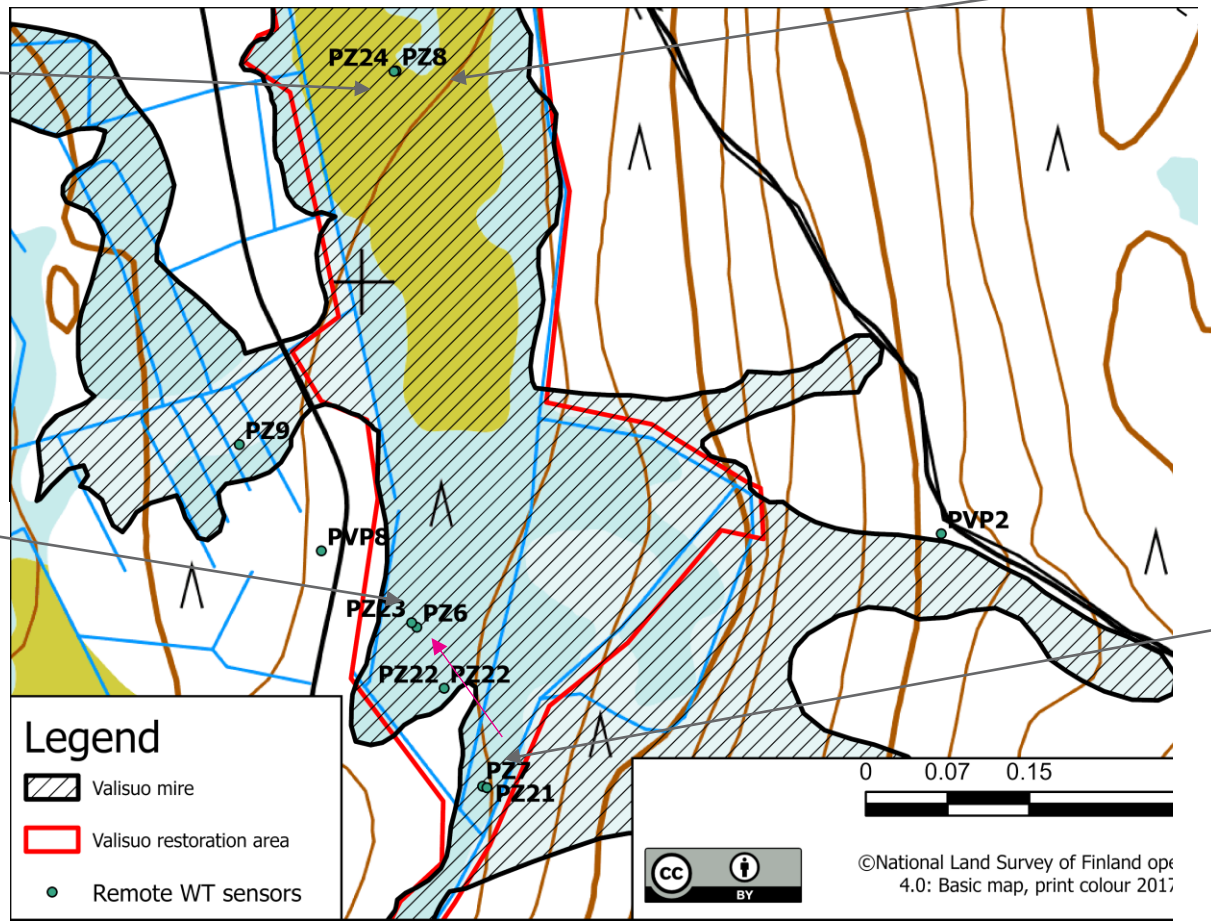

Monthly mean air temperature
2022
2023
2024
average (2007-2024)
± std (2002-2024)
Temperature (°C)
15
10
5
0
-5
-10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Välisuo

Deep peatland piezometer

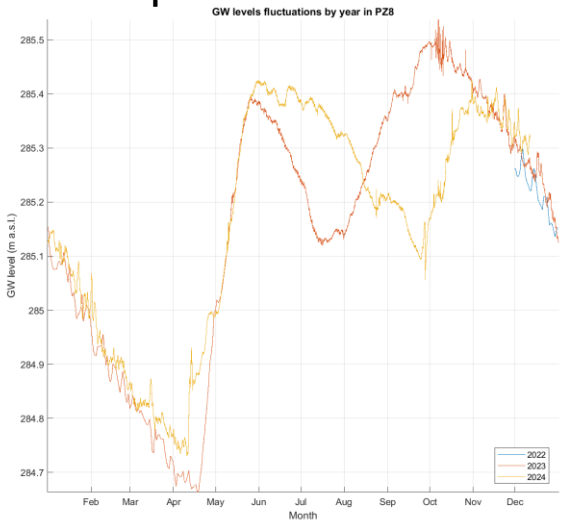


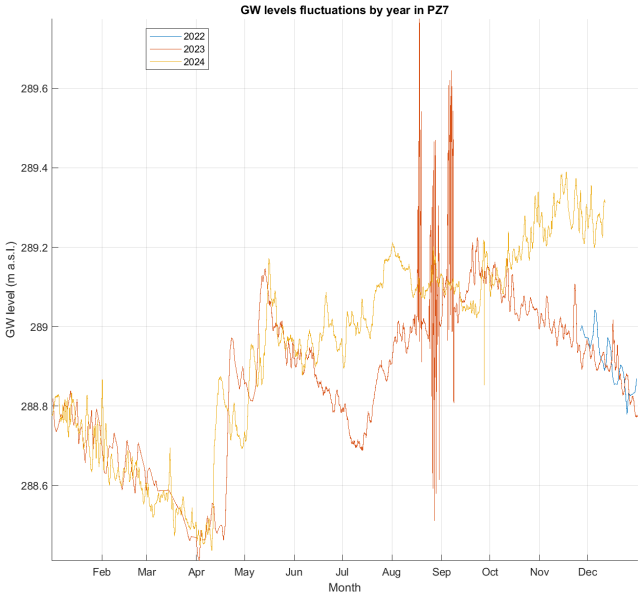




→ Direction of hydraulic gradient

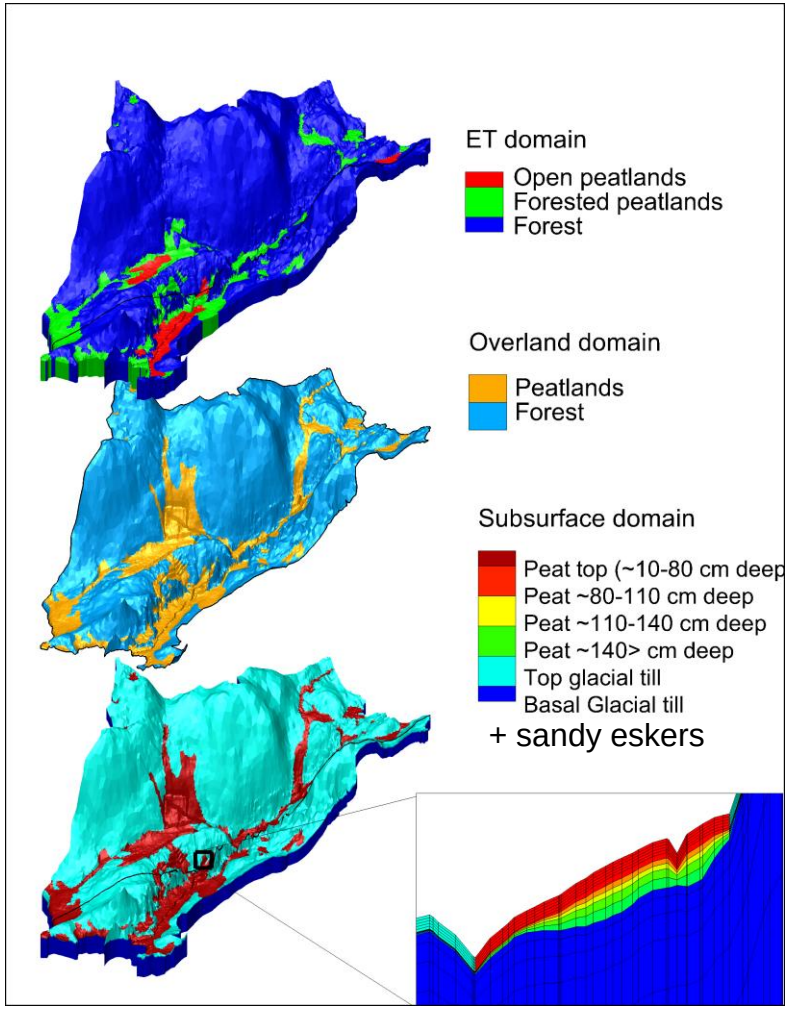
Deep GW





Välisuo model

- Objectives
  - Focasting hydrological observations -> validation of hydrological conditions for carbon balance simulation
- Integrated physically based groundwater-surface water (GW-SW) modelling with HydroGeoSpehere
- Modiefied model for whole Pallaslompol catchment
  - Hypothesis: In sucesfully restored fen/aapa mire system GW input to mire should significantly increase
  - Densified mesh to inclue implicitly various resotration structures



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Research papers

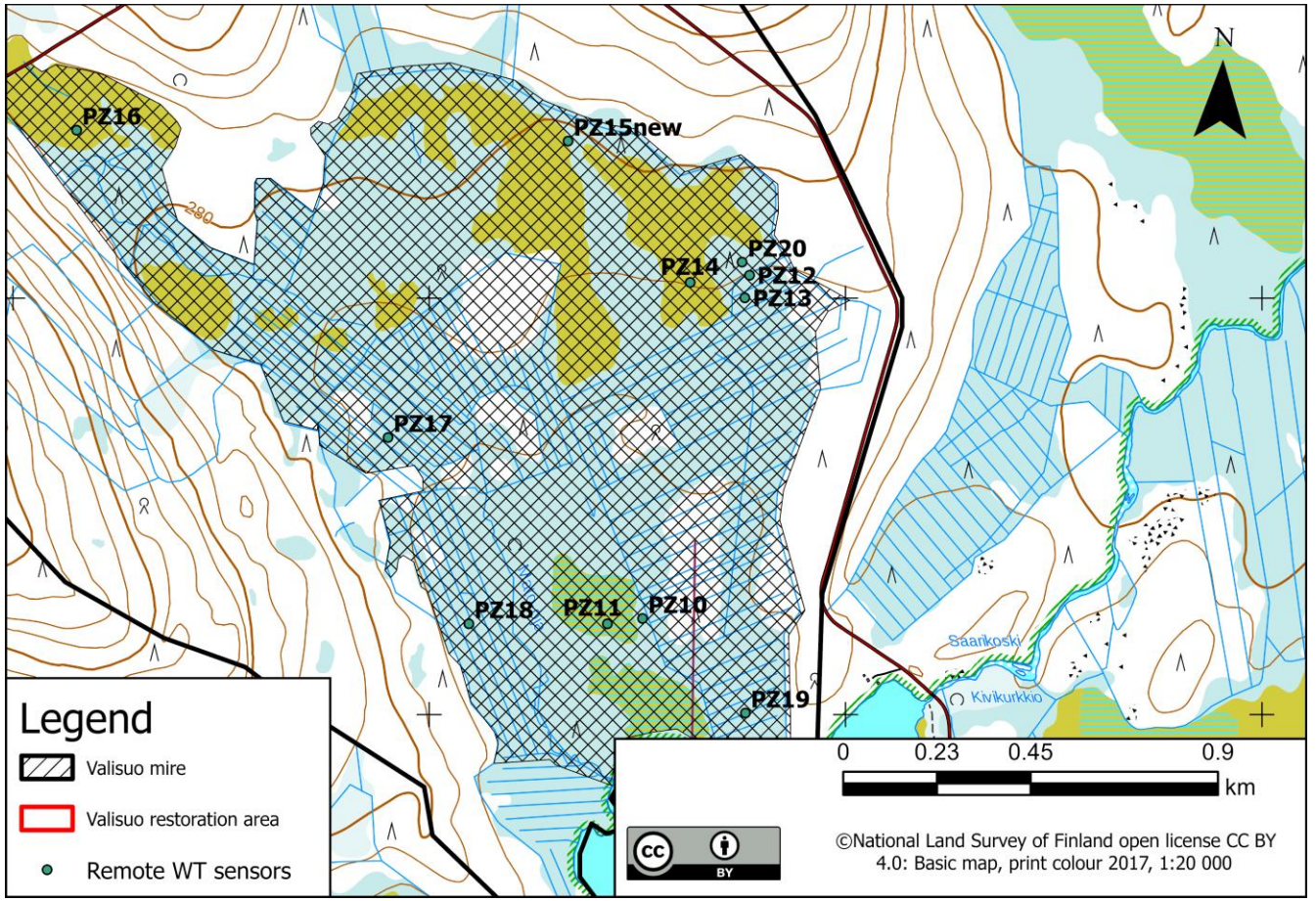
Groundwater exfiltration pattern determination in the sub-arctic catchment using thermal imaging, stable water isotopes and fully-integrated groundwater-surface water modelling

Anna Autio [a,*], Pertti Ala-Aho [a], Pekka M. Rossi [a], Anna-Kaisa Ronkanen [a,b], Mika Aurela [c], Annalea Lohila [c,d], Pasi Korpelainen [e], Timo Kumpula [e], Björn Klöve [a], Hannu Marttila [a]

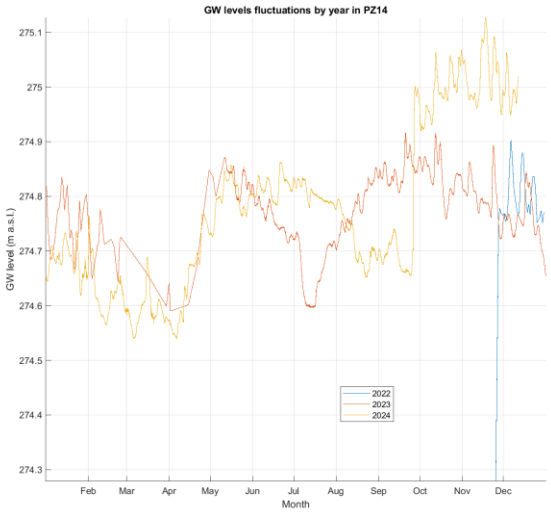
Matorovasuo

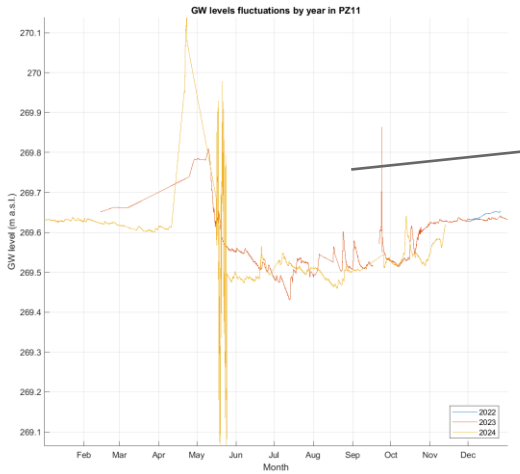
Matorovasuo monitoring

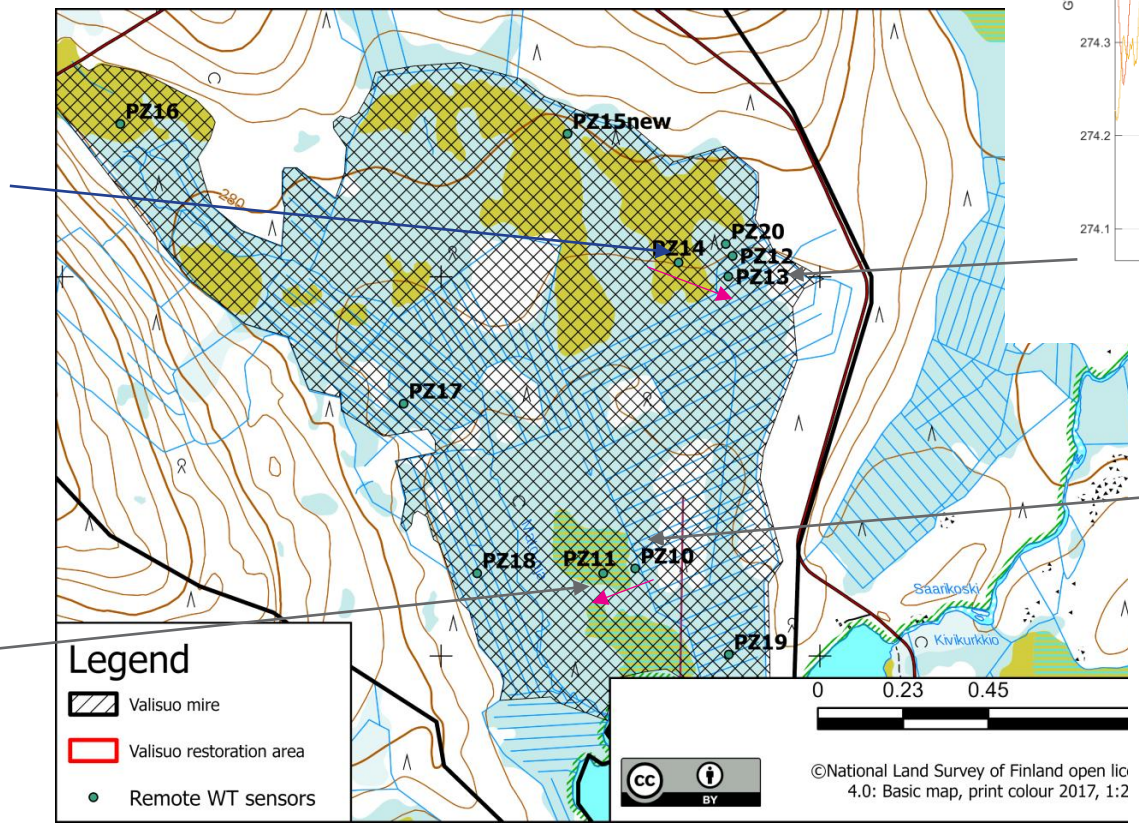
- Currently 12 (+3) operating remote WT loggers (Decentlab-26)
- First measurements starting in November 2022

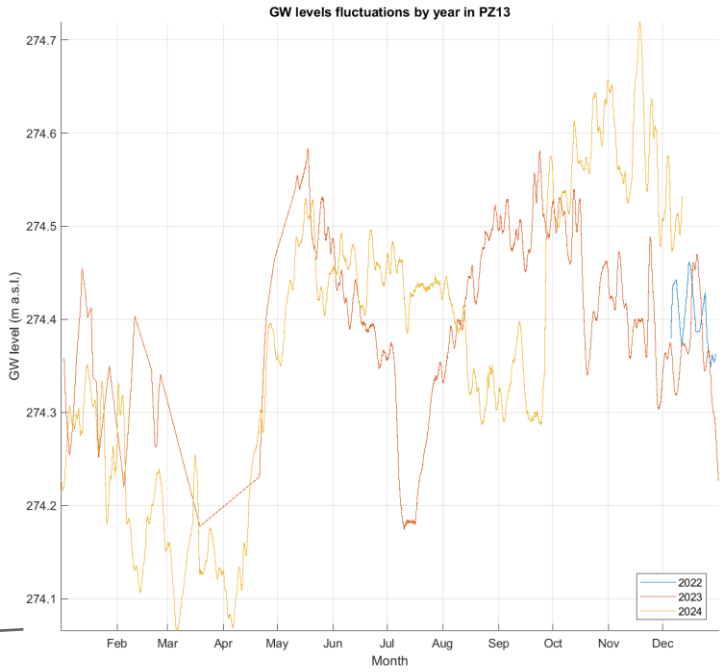


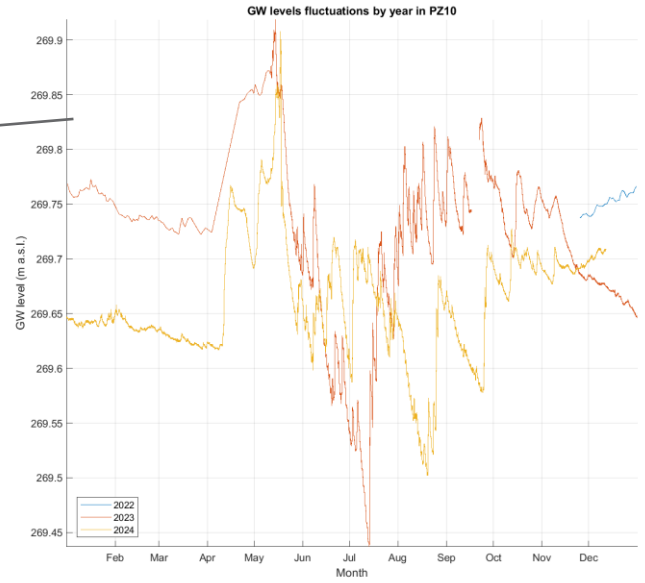
Matorovasuo





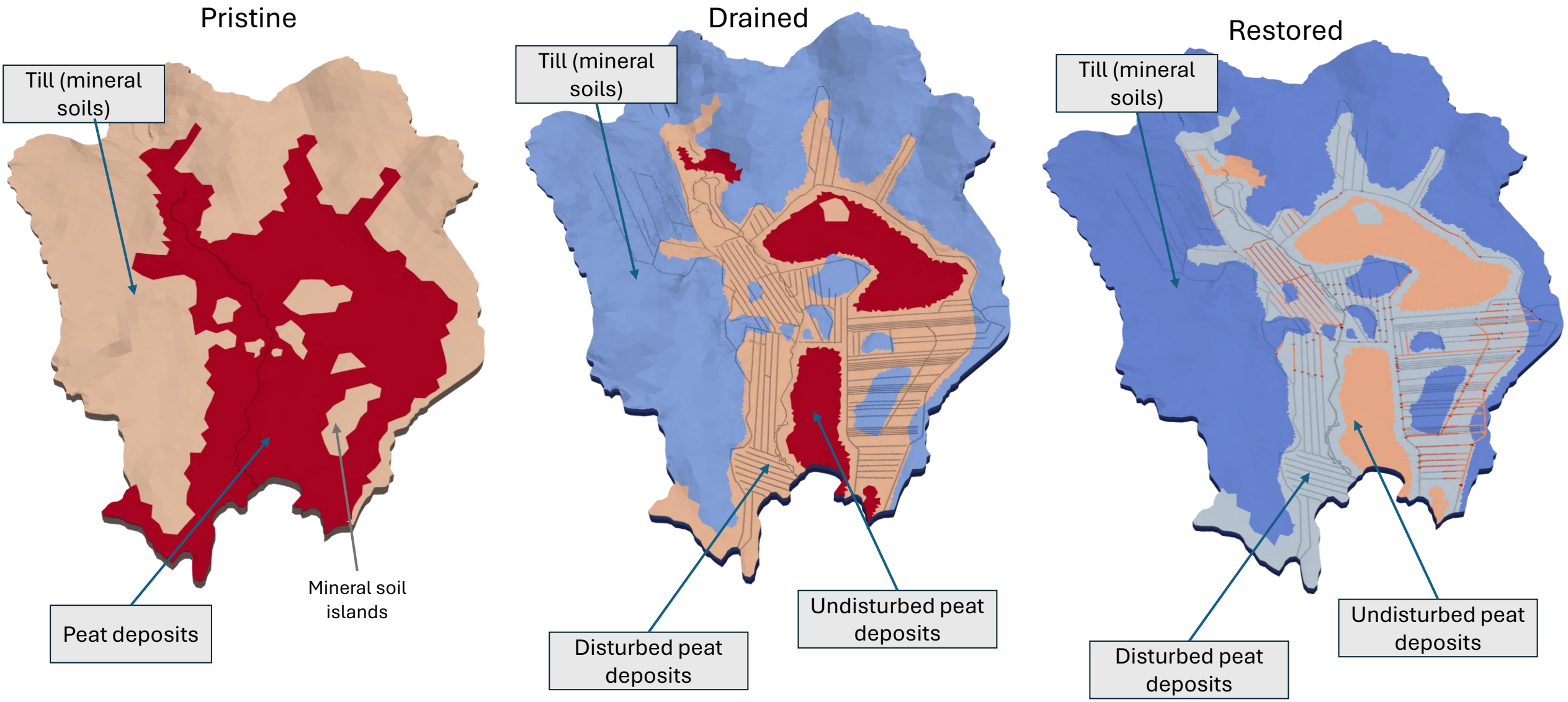






→ Direction of hydraulic gradient

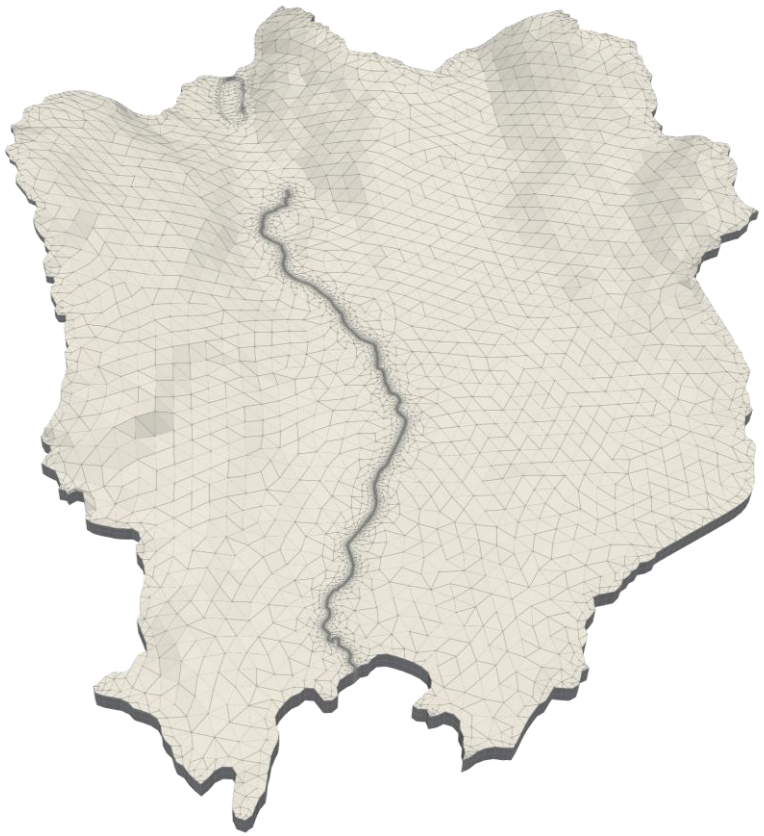
Matorovasuo modelling (Proof of concept)



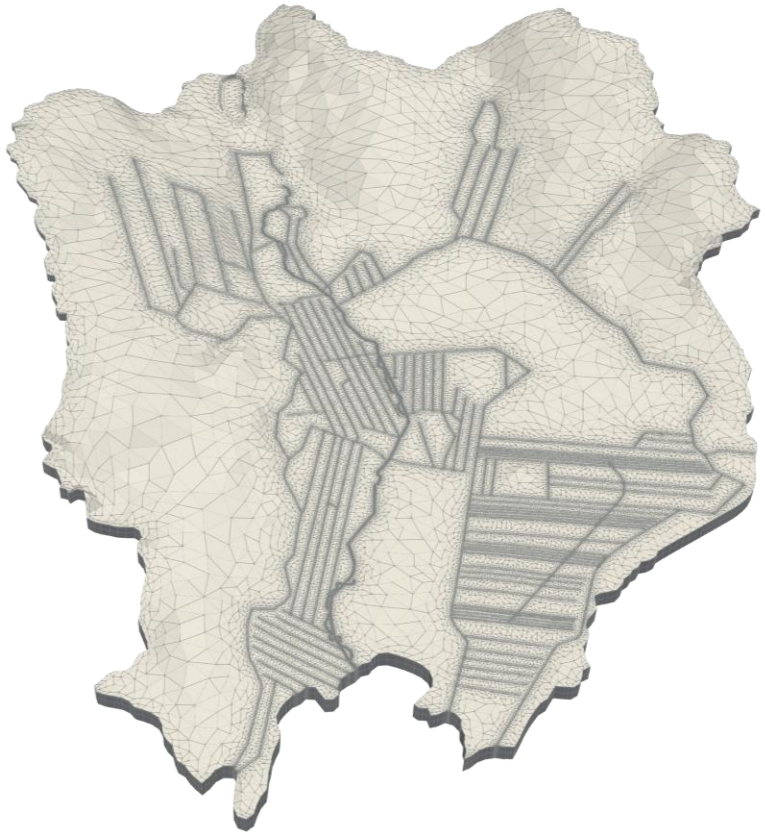
Matorova Catchment

Terrain models/ computational meshes

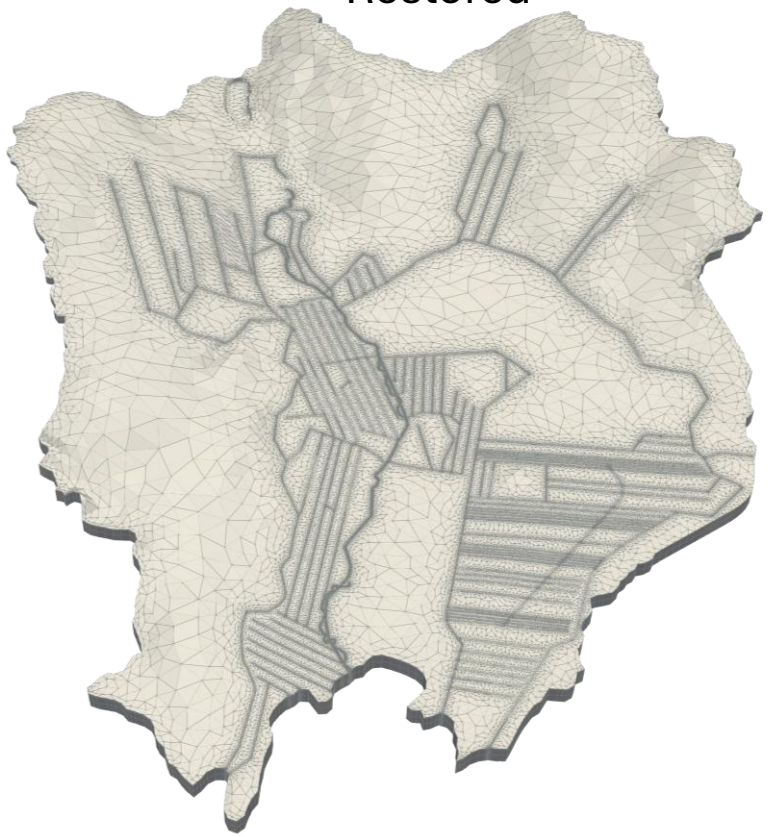
Pristine



Drained



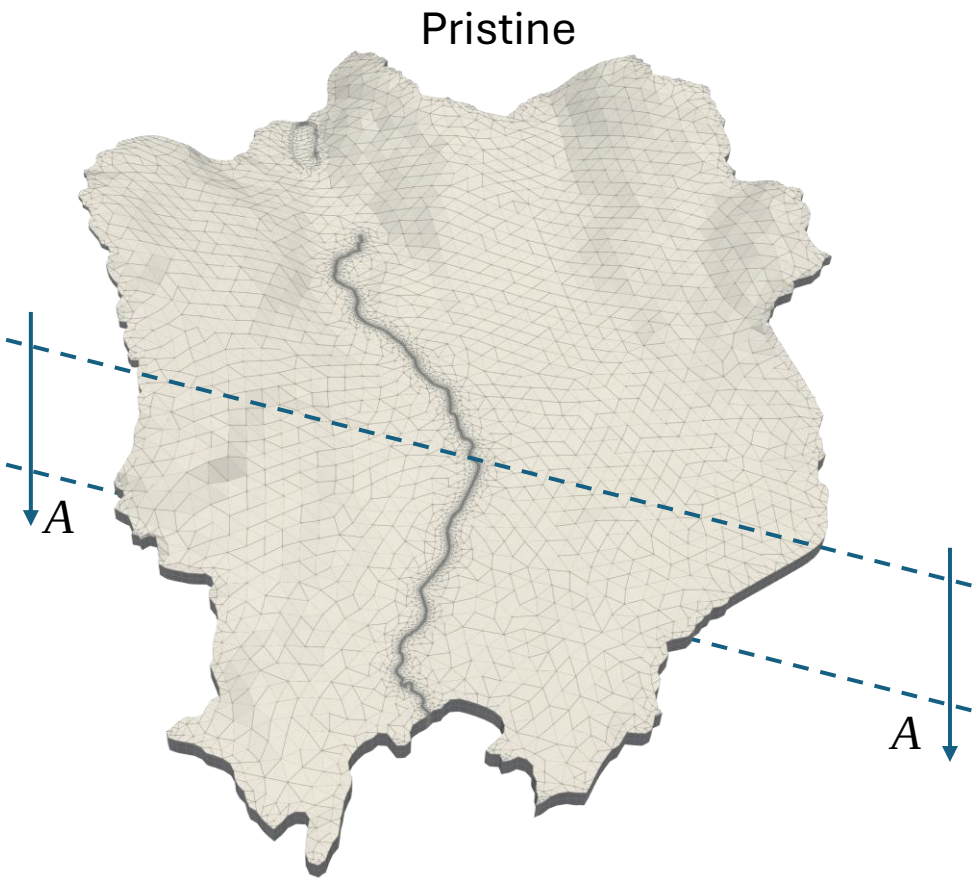
Restored



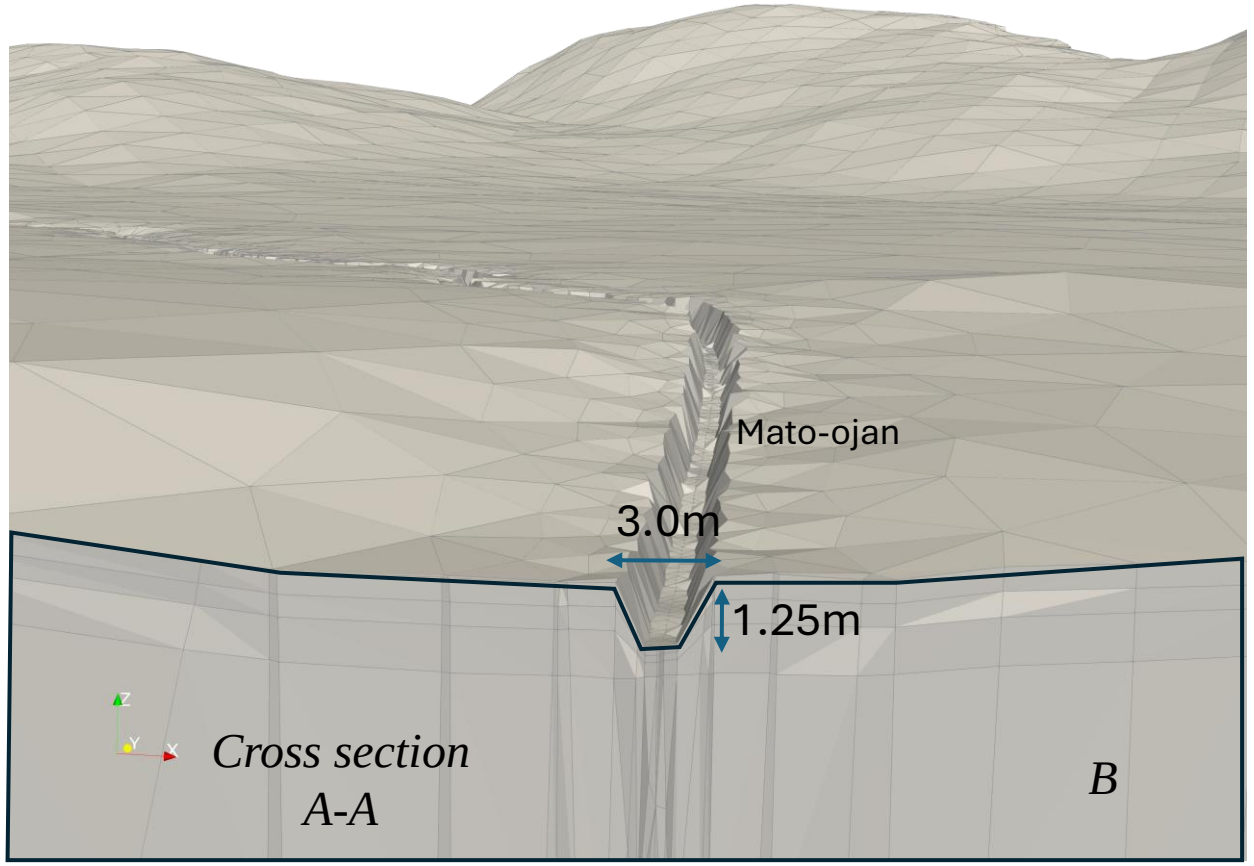
13,000 surface nodes
24,000 surface elements

Both drained and restored meshes
57,000 surface nodes
110,000 surface elements

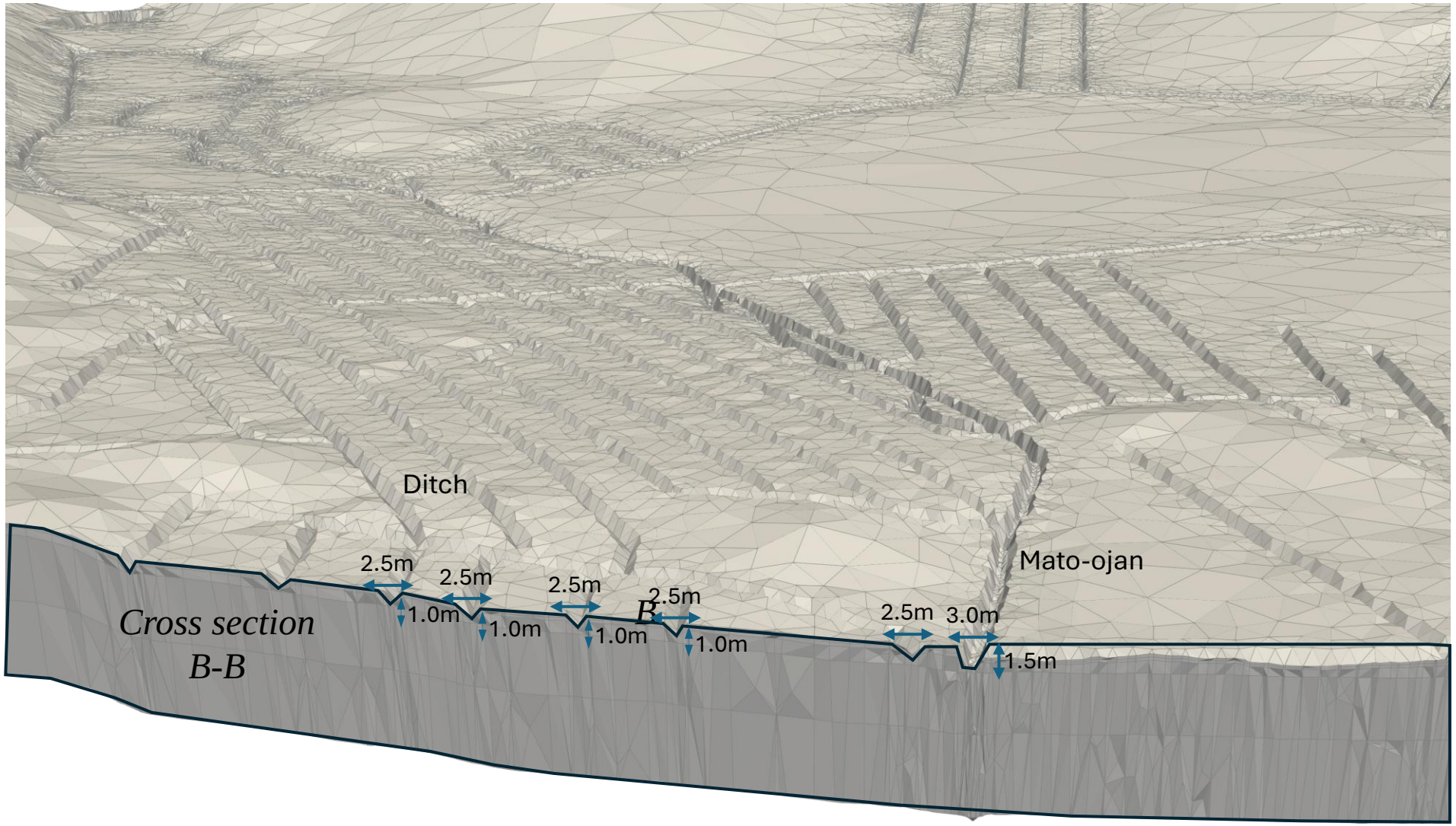
Cont. terrain models/ computational meshes

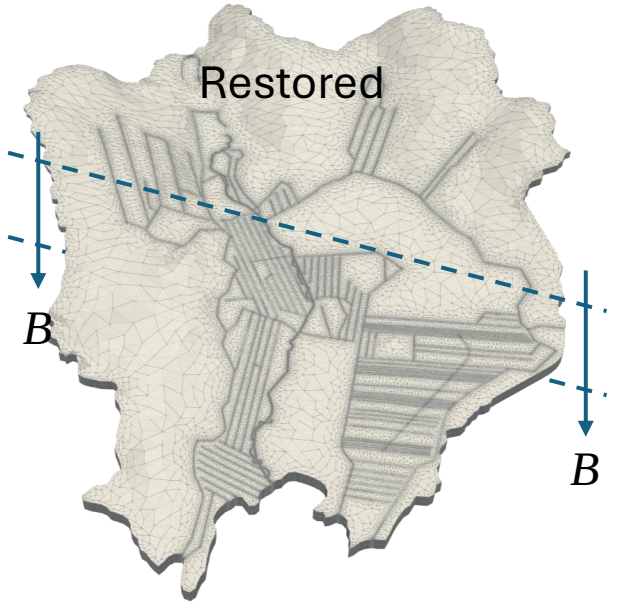


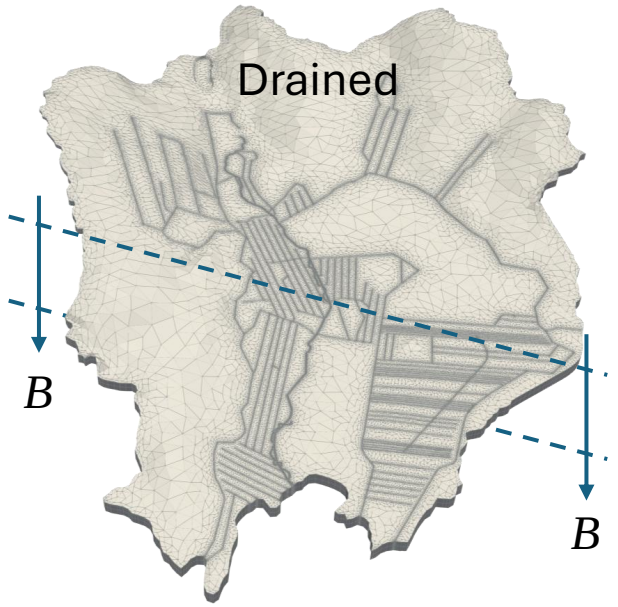
13,000 surface nodes
24,000 surface elements



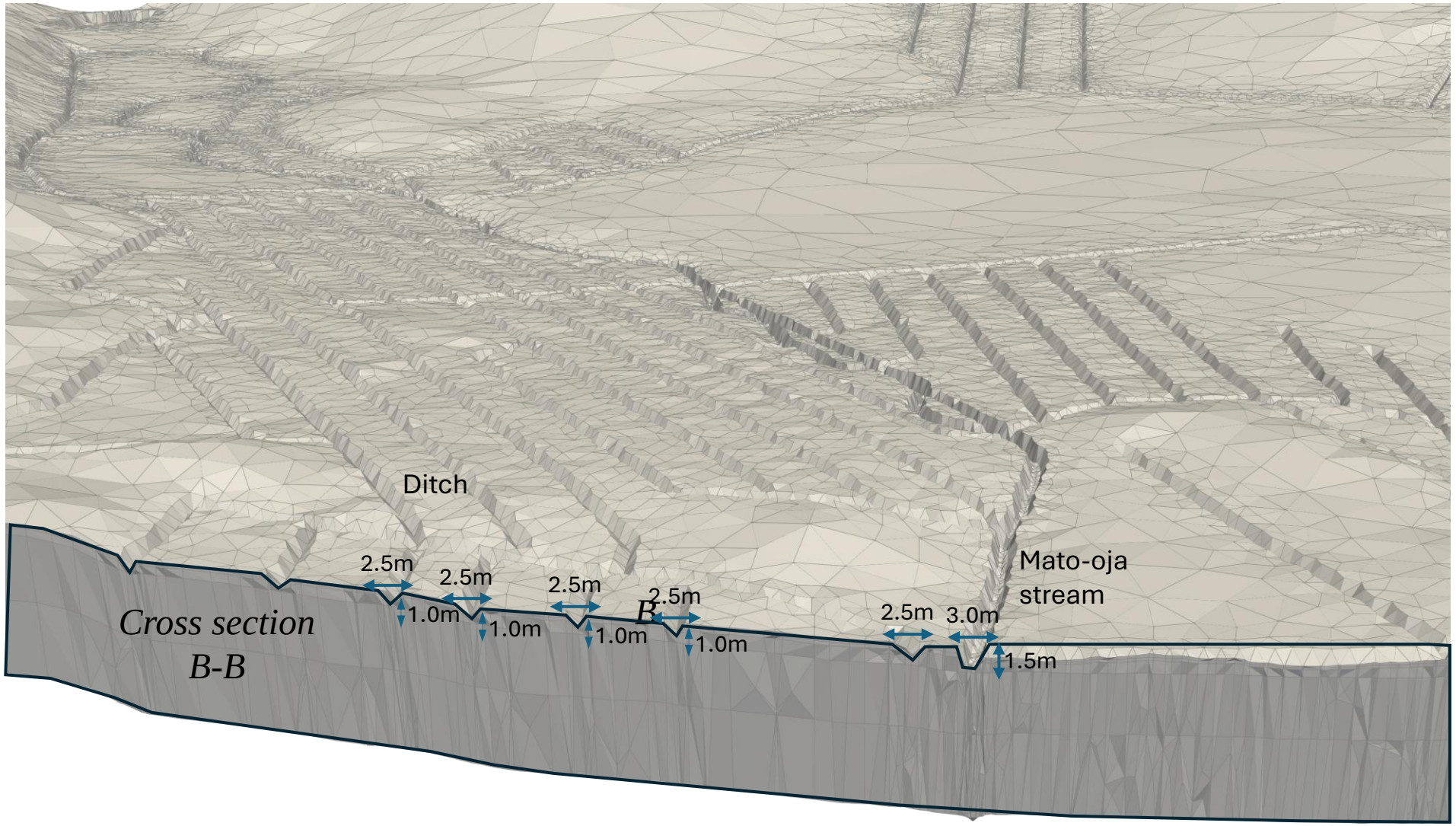
Cont. terrain models/ computational meshes

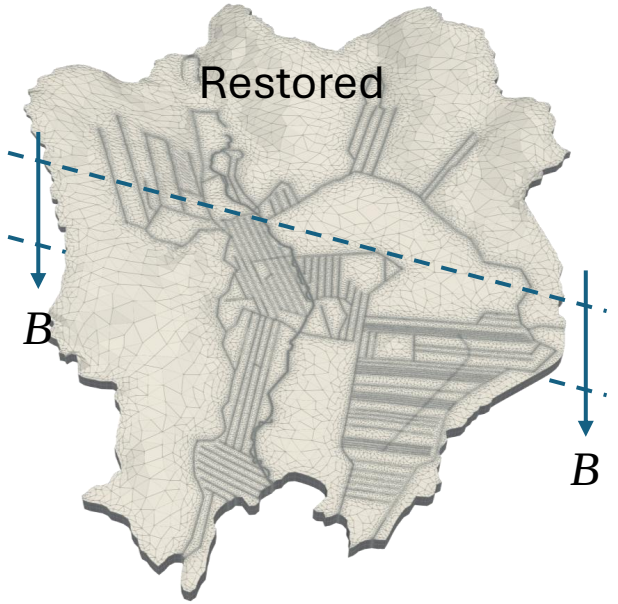


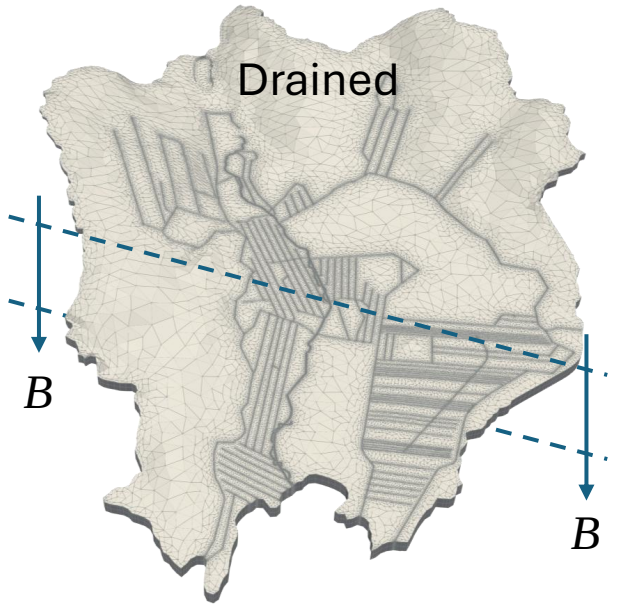




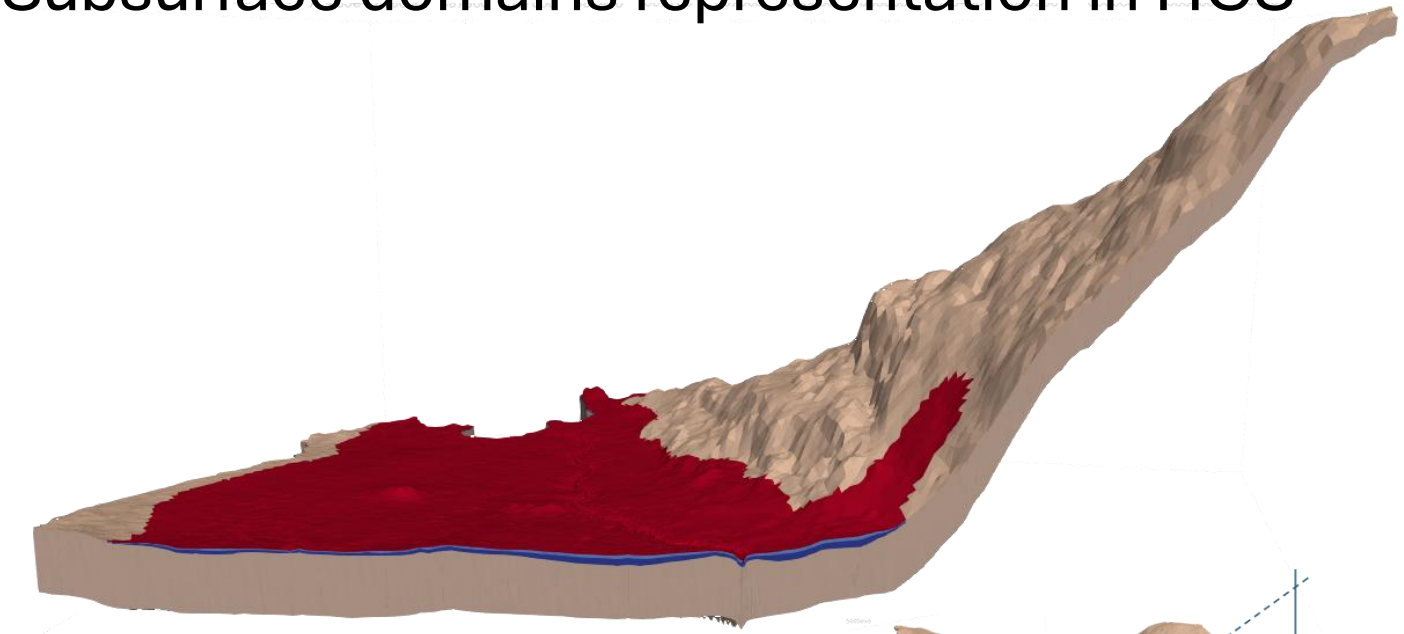
Cont. terrain models/ computational meshes



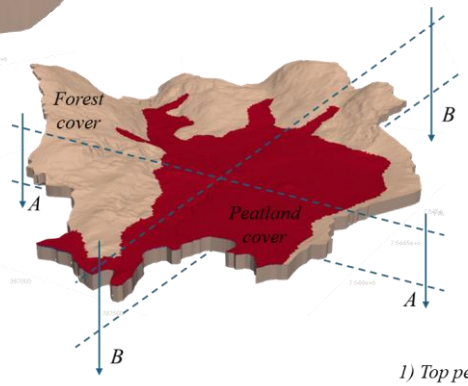




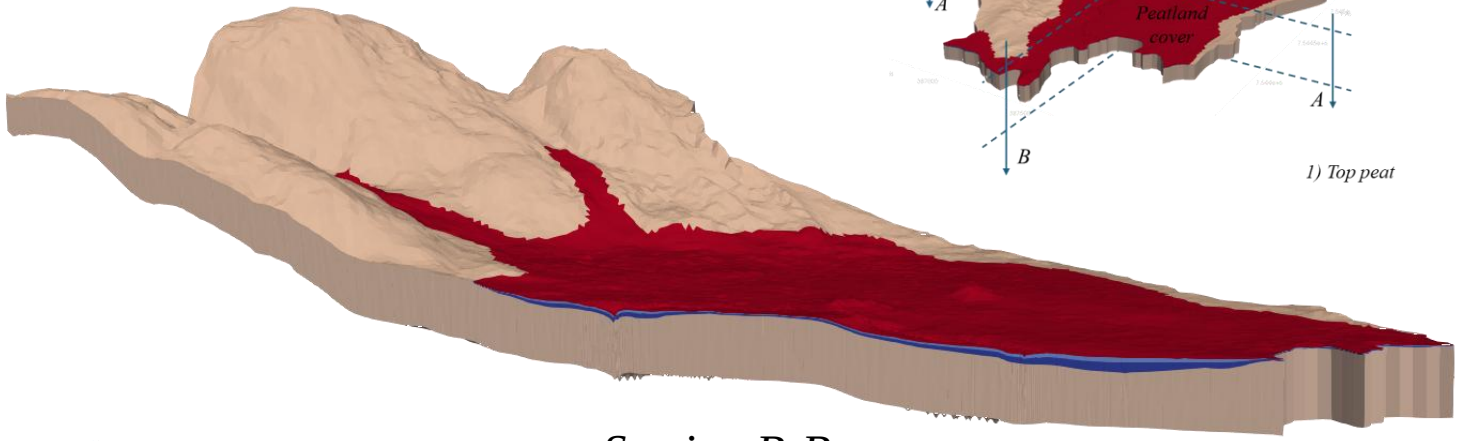
Subsurface domains representation in HGS



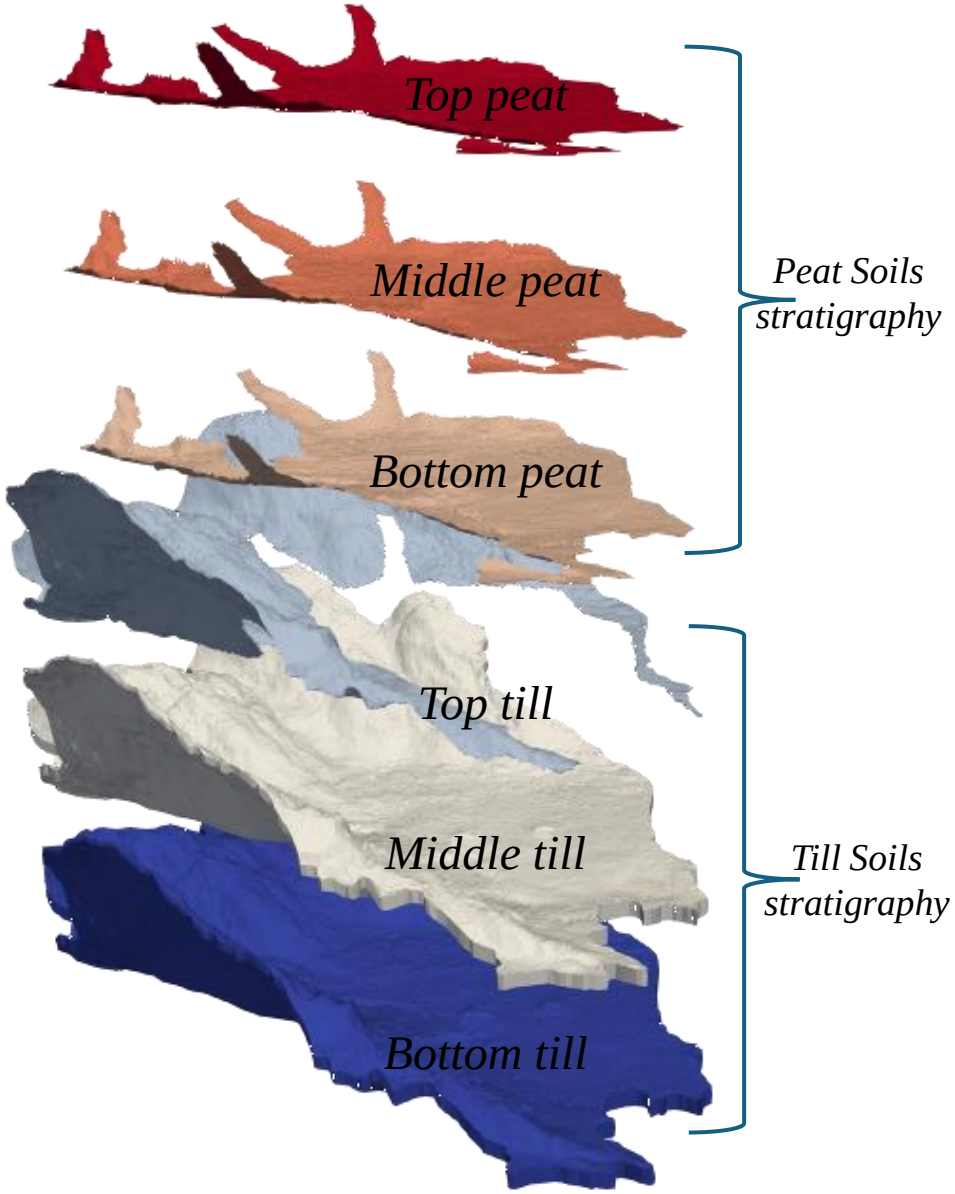
Section A-A



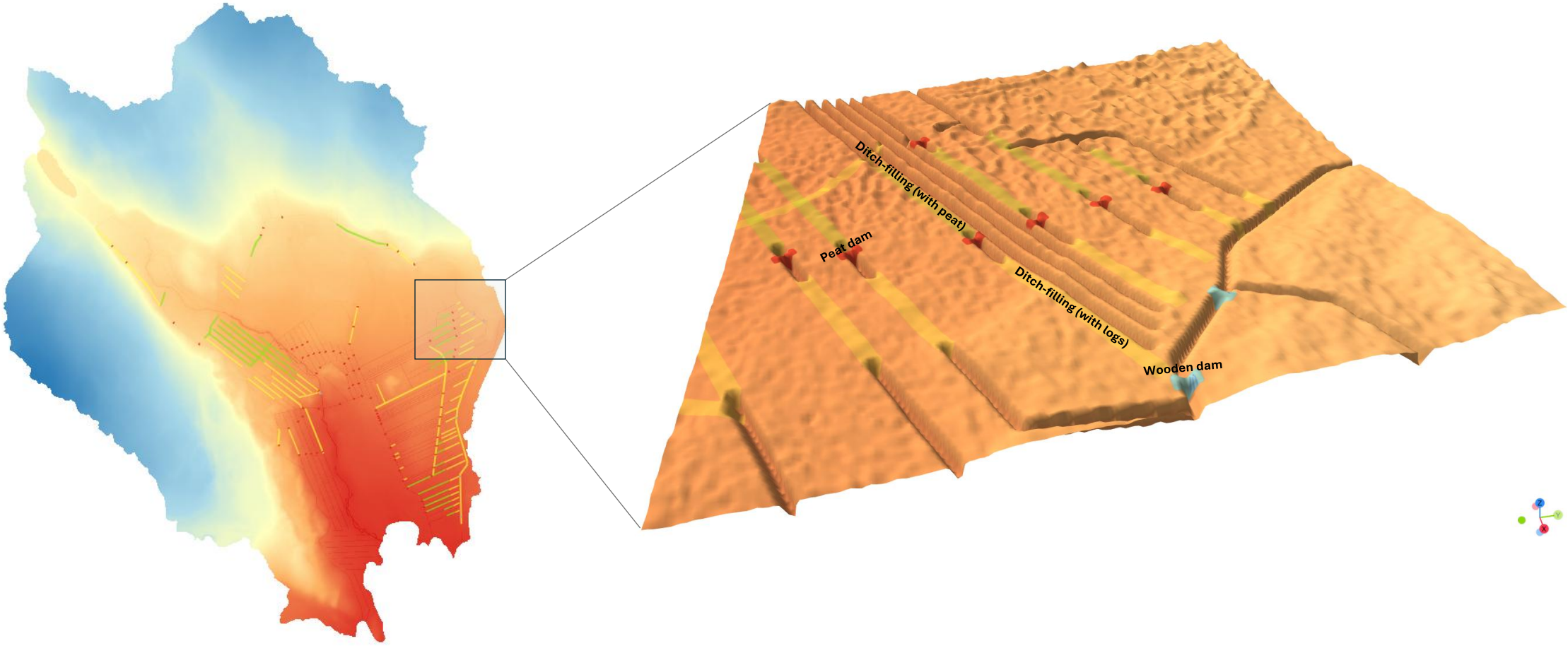
1) Top peat



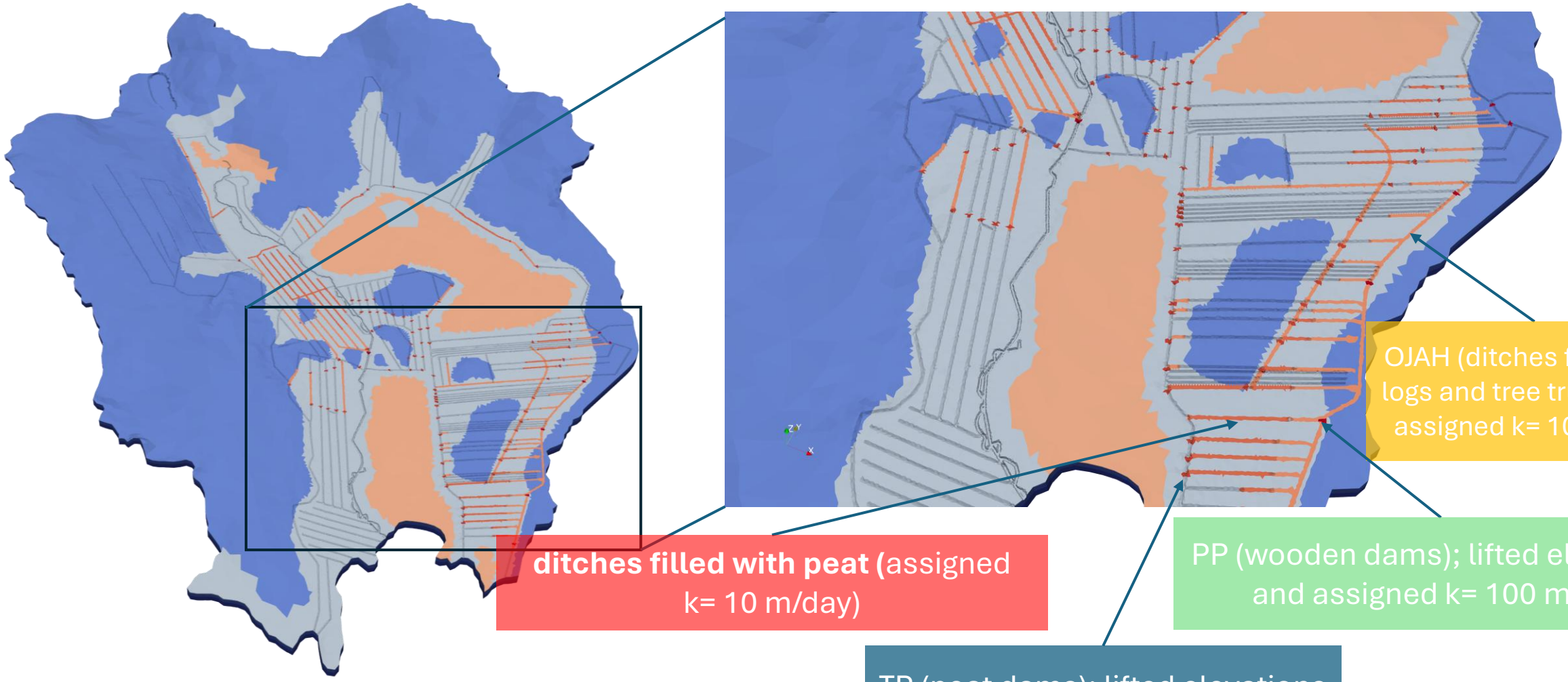
Section B-B



Restoration activities – implementation in the model



Adjusting the restoration activities to the model



ditches filled with peat (assigned k= 10 m/day)

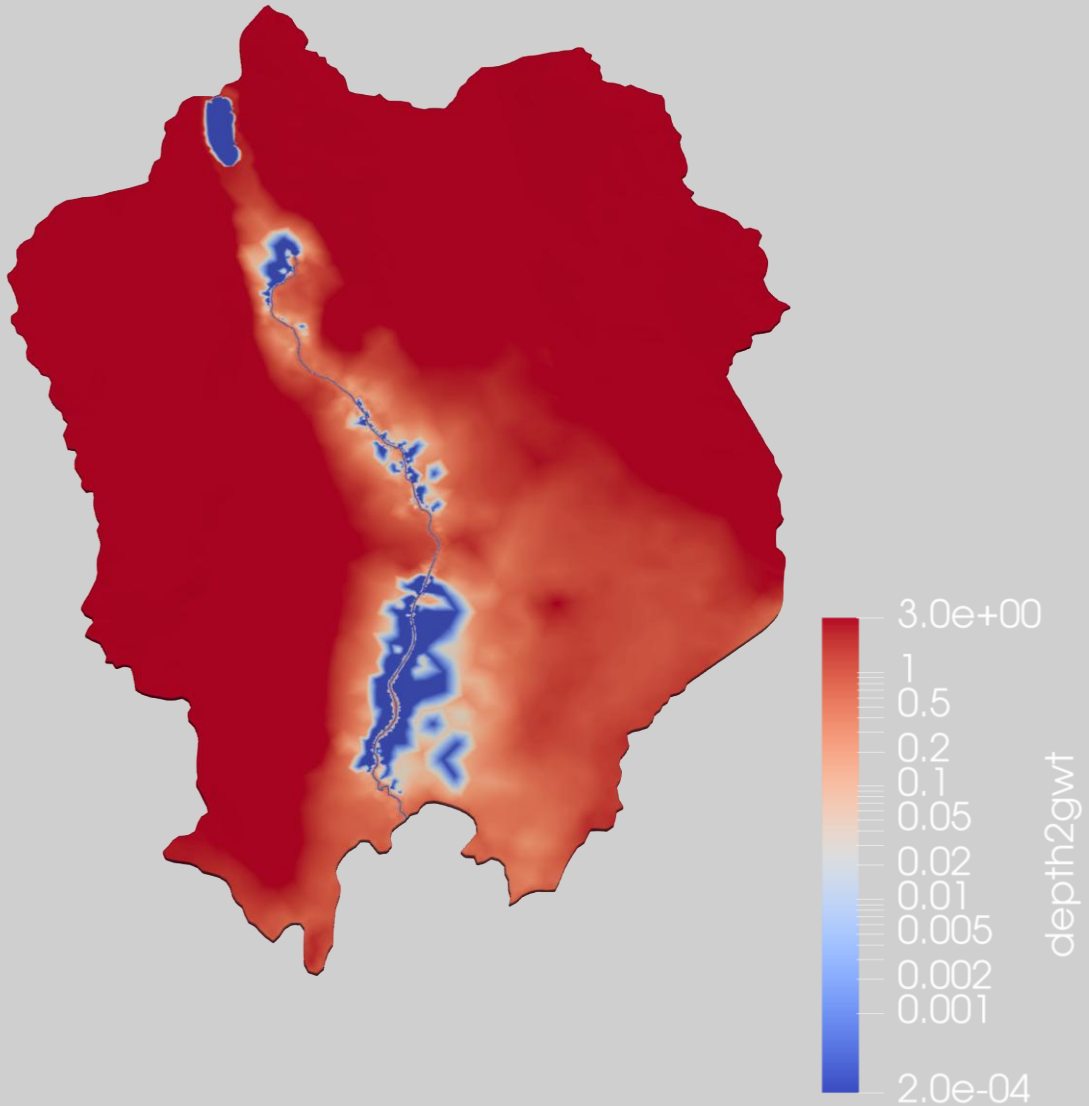
OJAH (ditches filled with logs and tree trunks) and assigned k= 100 m/day

PP (wooden dams); lifted elevations and assigned k= 100 m/day

TP (peat dams); lifted elevations and assigned k= 10 m/day

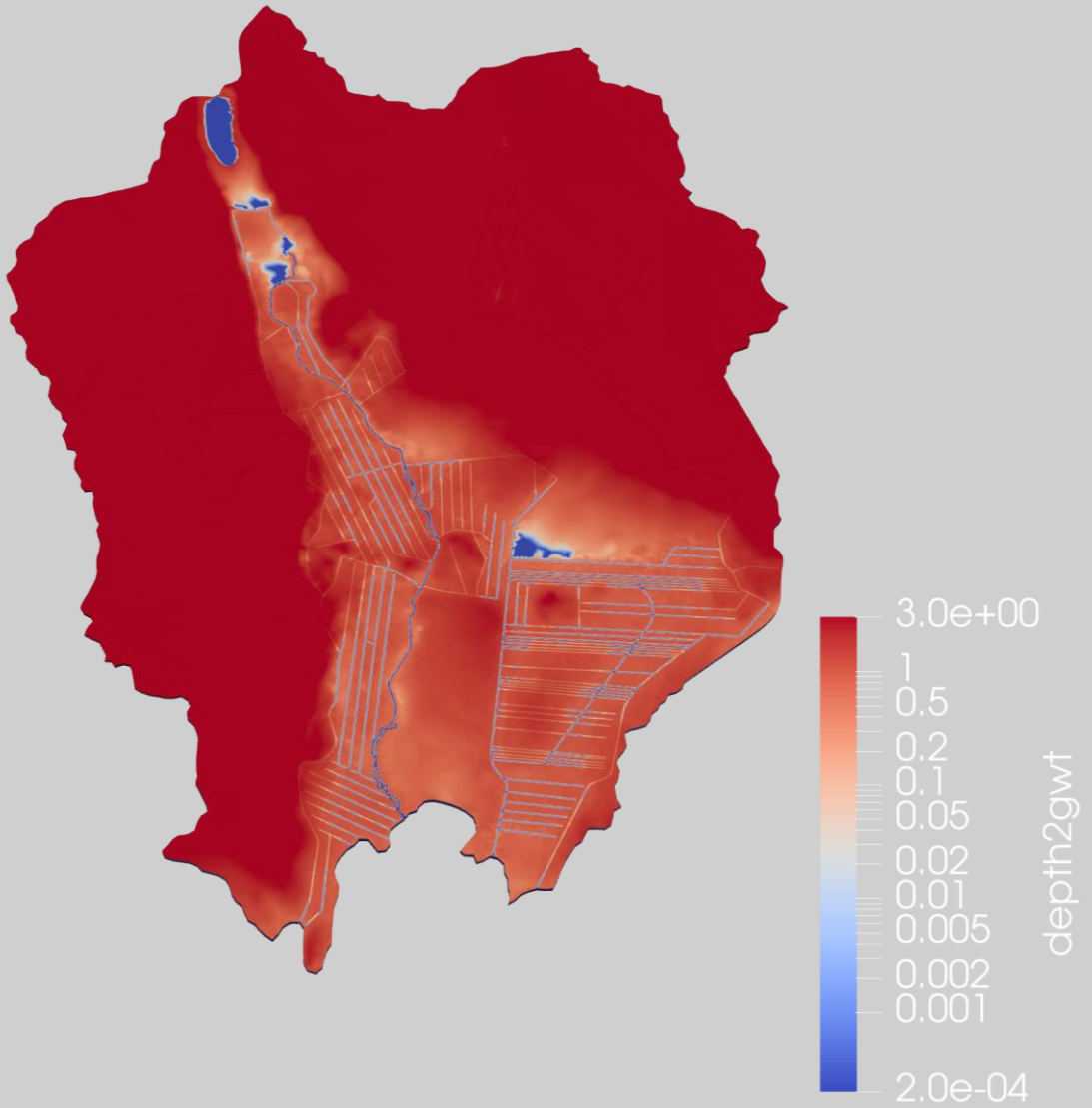
Steady state simulation results

Pristine Setup



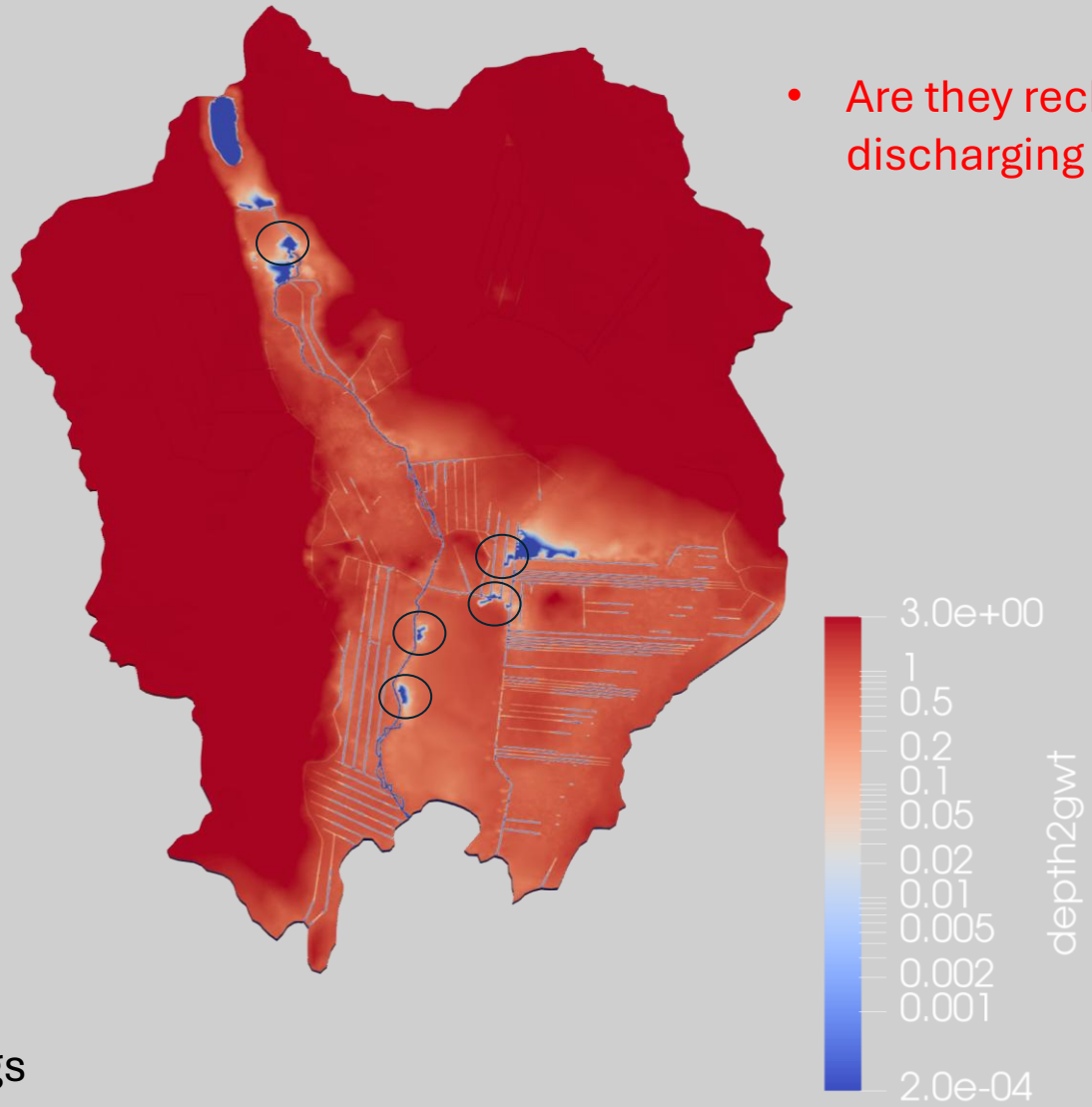
Cont. steady state simulation results

Drained Setup



Cont. steady state simulation results

Restored Setup

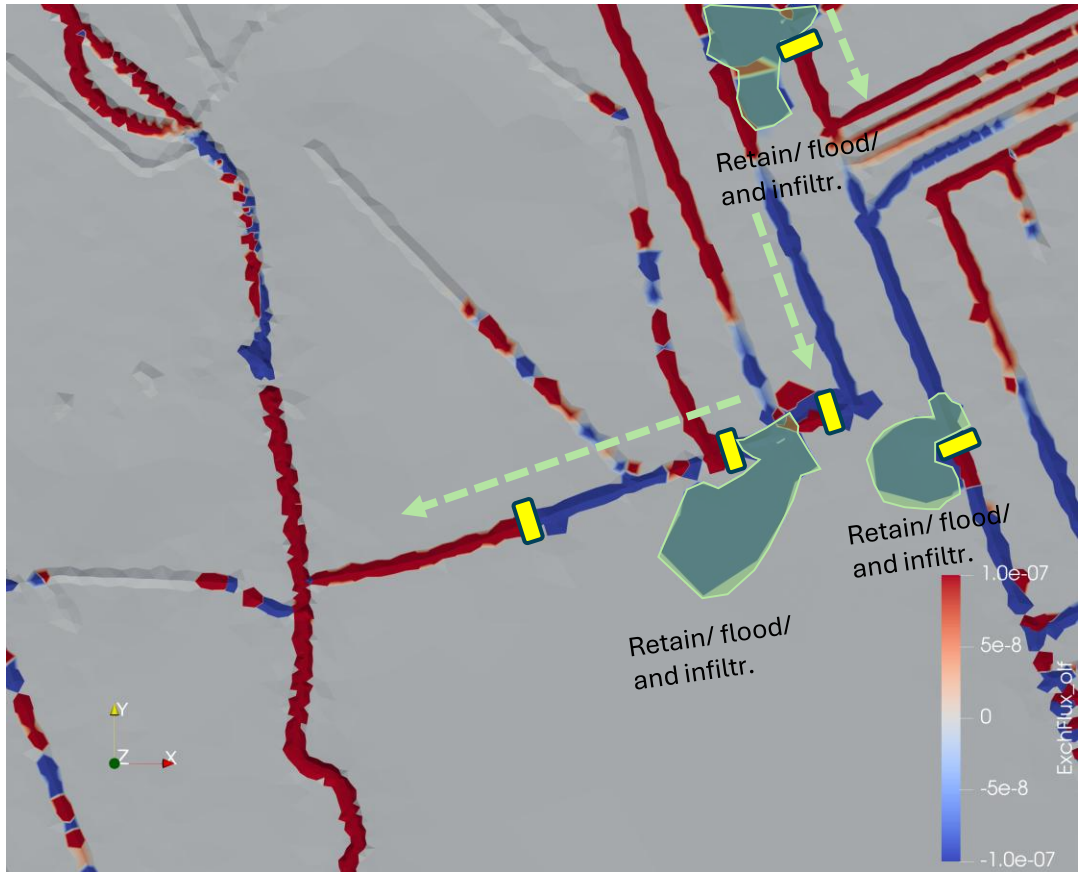


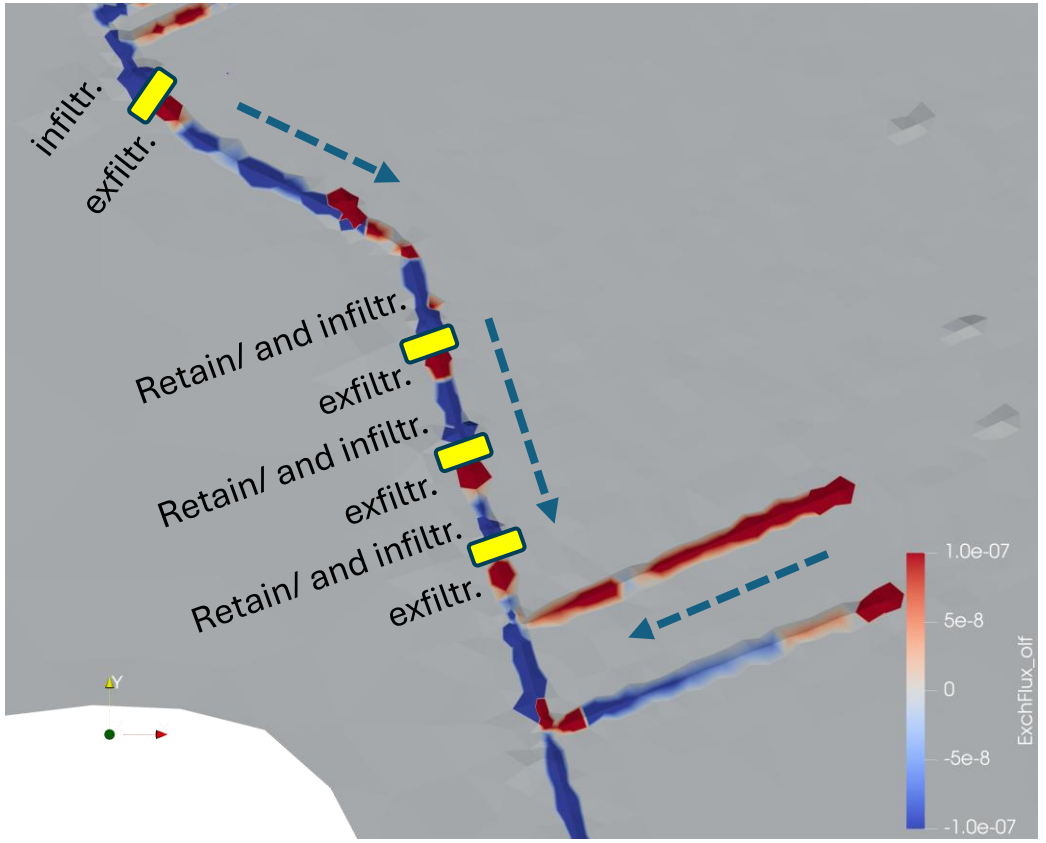
- Are they recharging (infiltration) pools/ or discharging (exfiltration) pools (?)

- Emerging of new water pools
- Global rising in GWT, specially in eastern, central and northern bogs

How restoration activities perform (?)

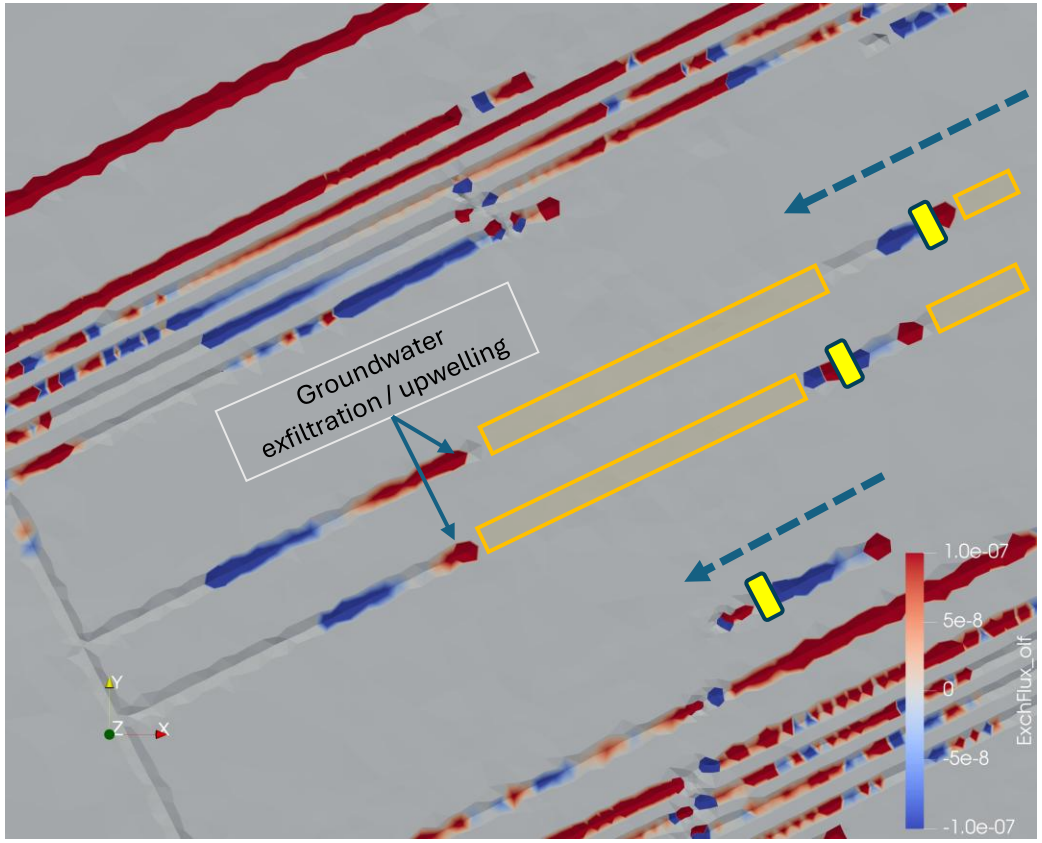
Effect of peat-dams (water retaining/ flooding)

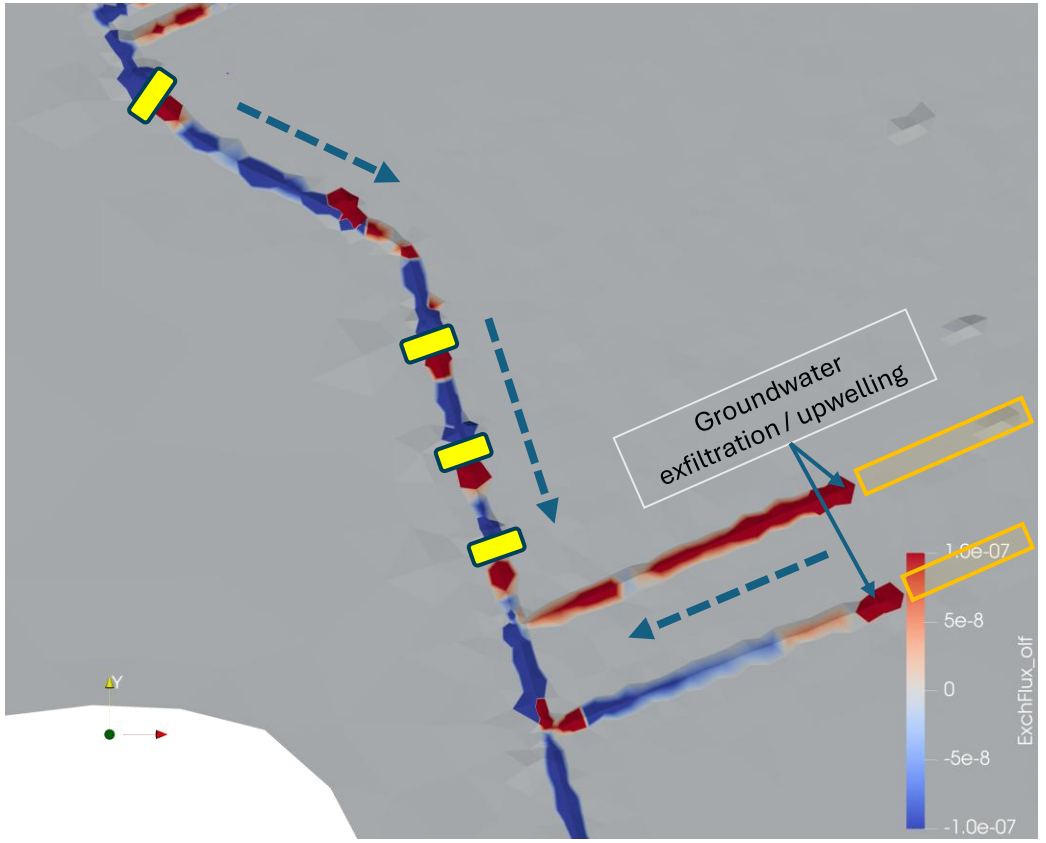




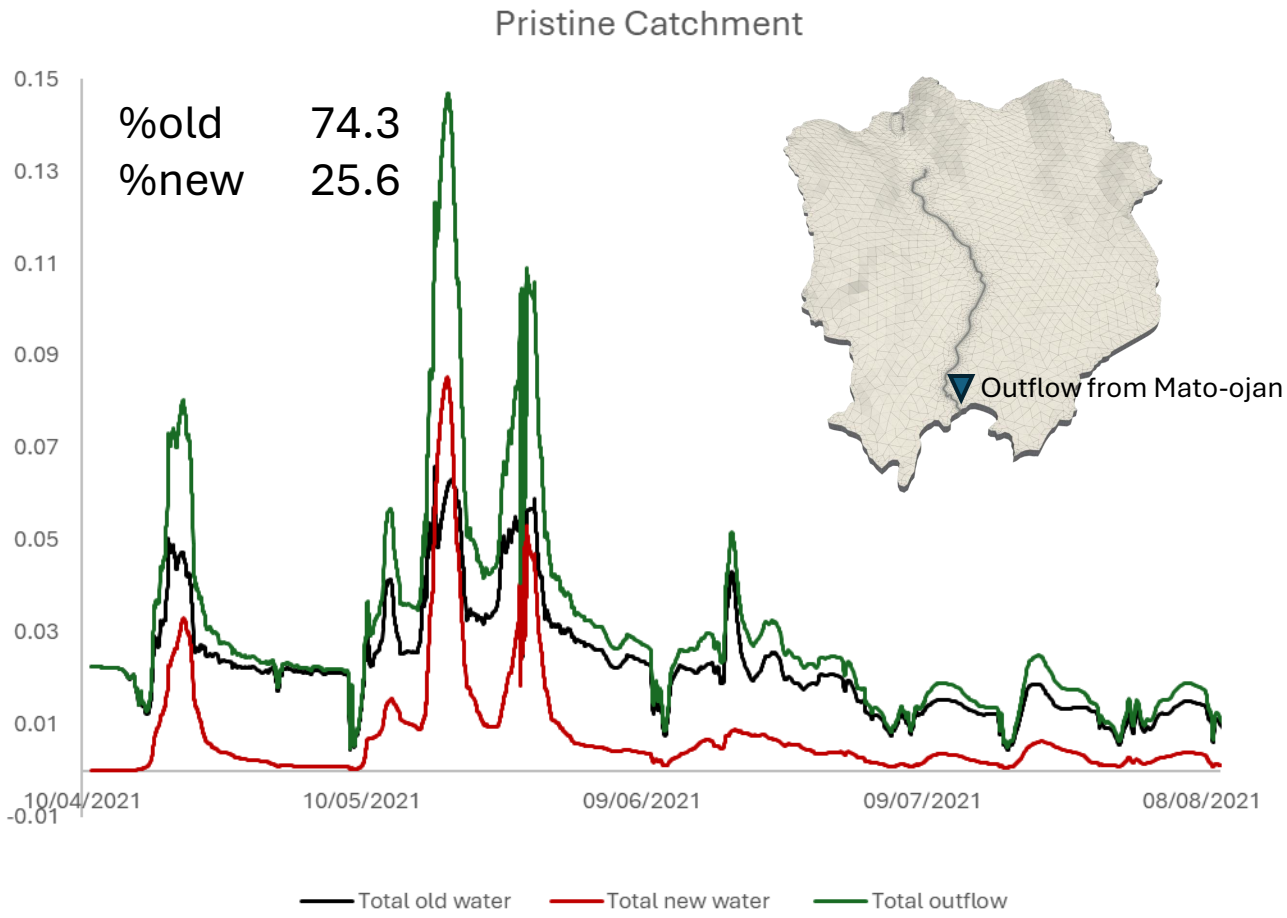
How restoration activities perform (?)

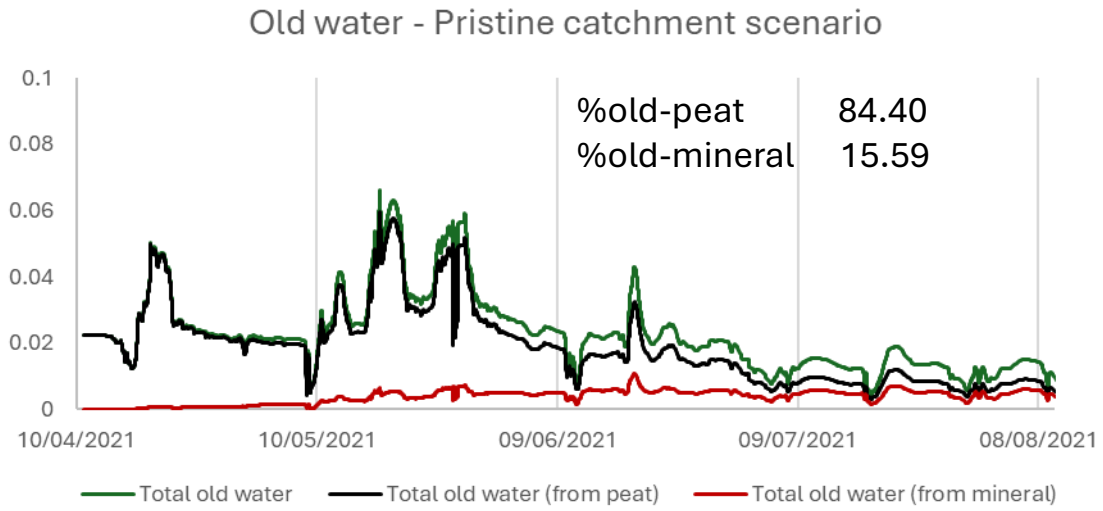
Effect of ditch-filling (groundwater diffuses at the tips of unfilled ditches)

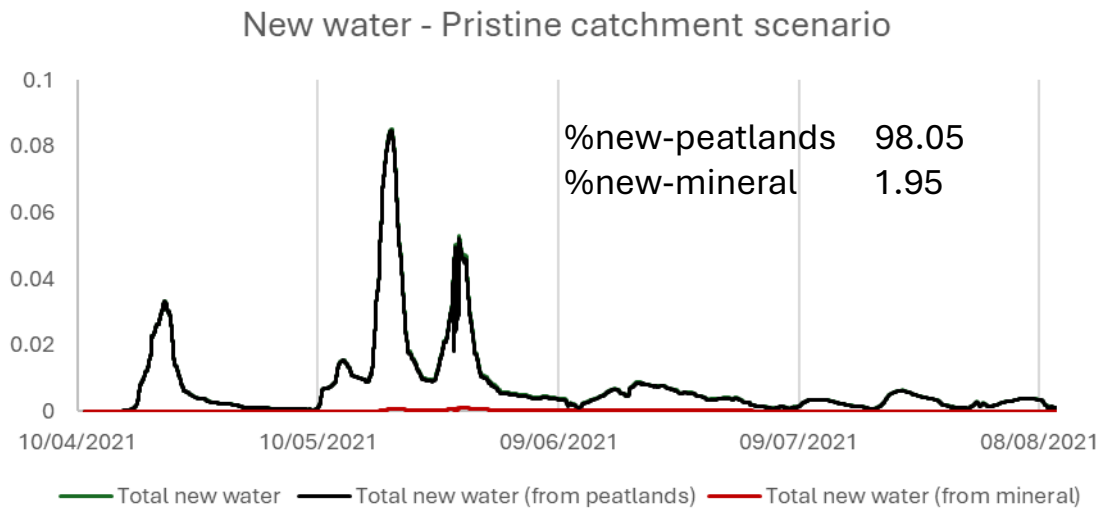




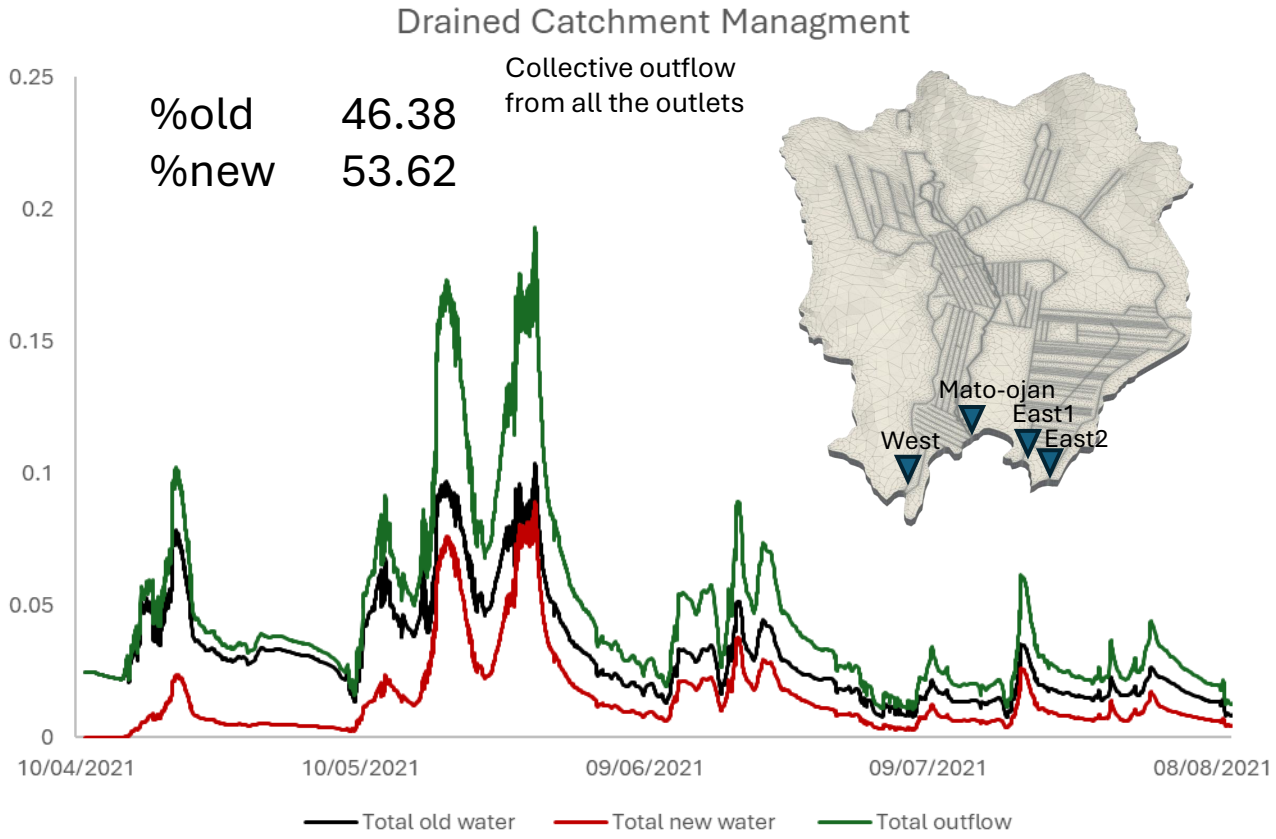
Hydrograph source separation using HGS+HMC (old/ new waters)

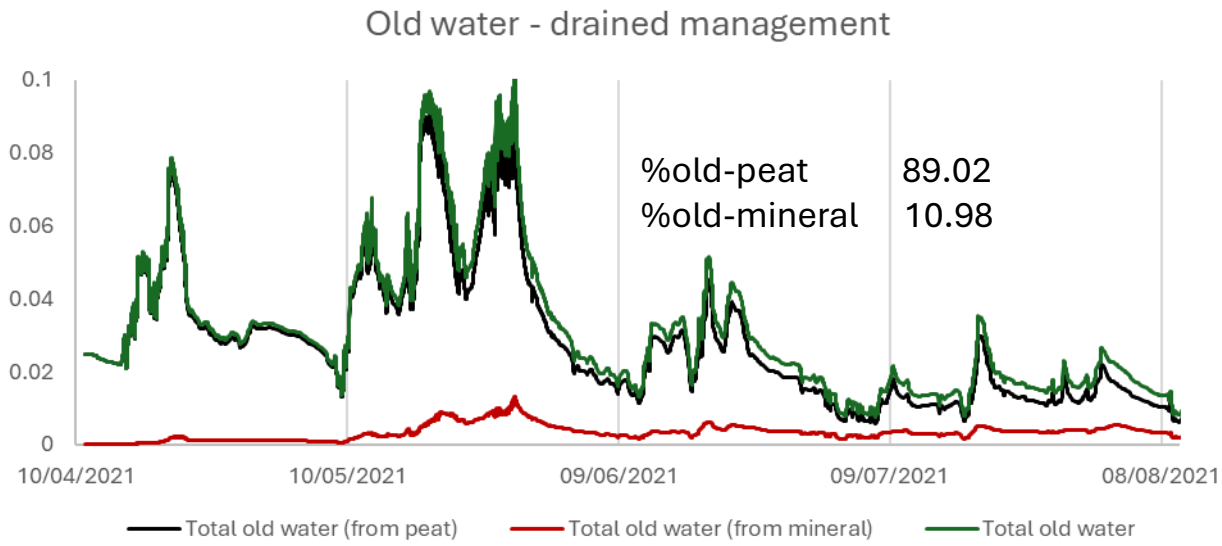


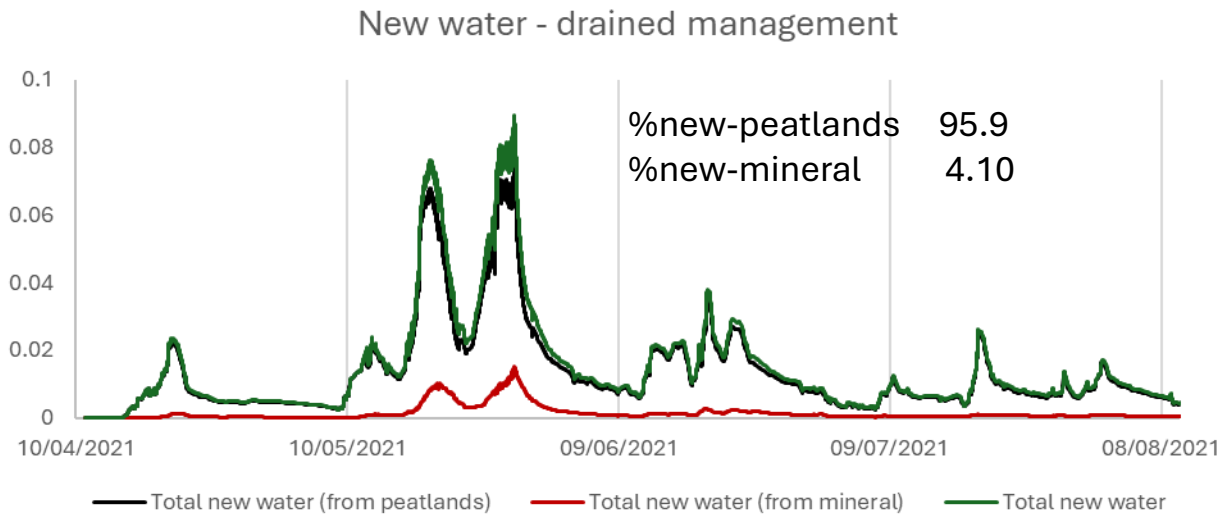




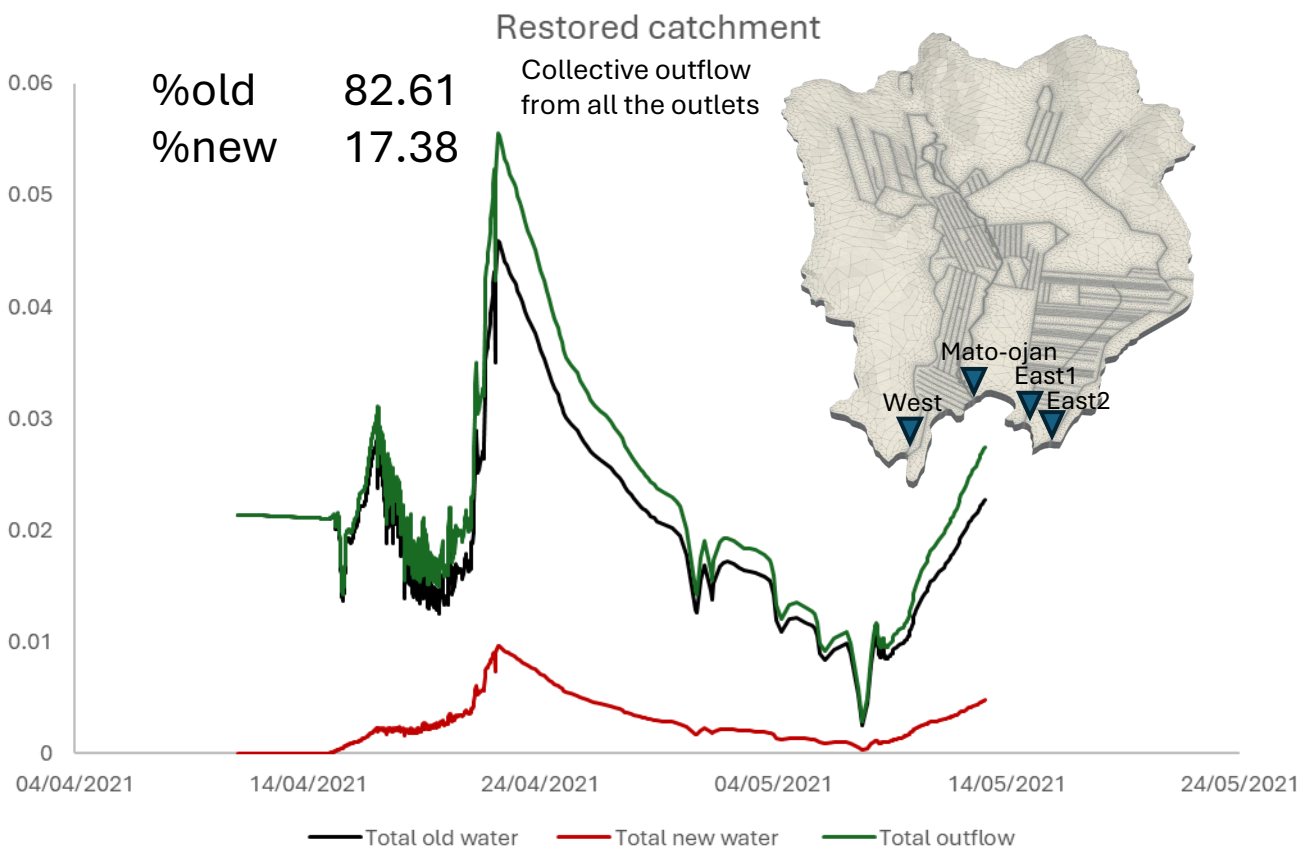
Hydrograph source separation using HGS+HMC (old/ new waters)

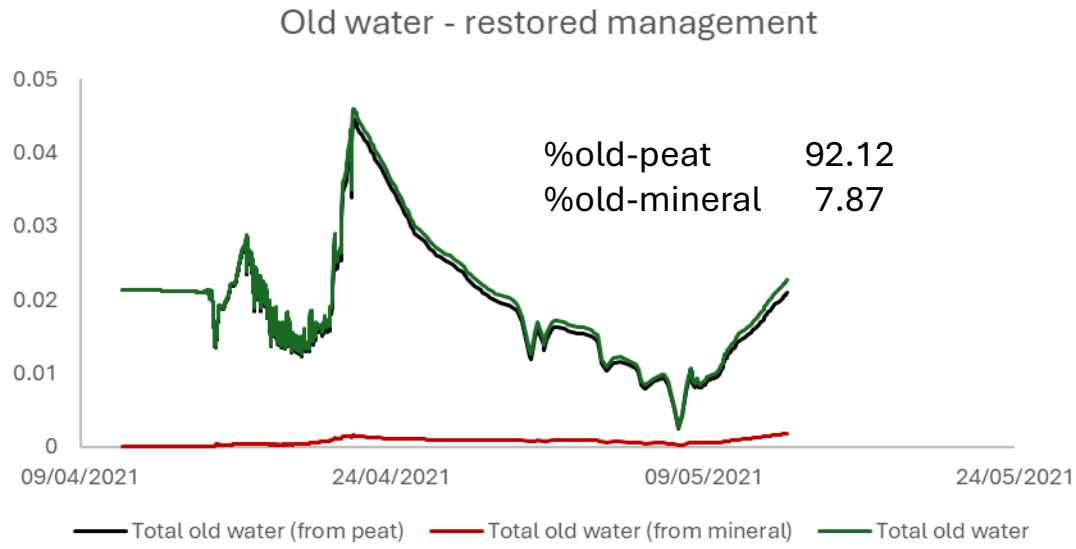


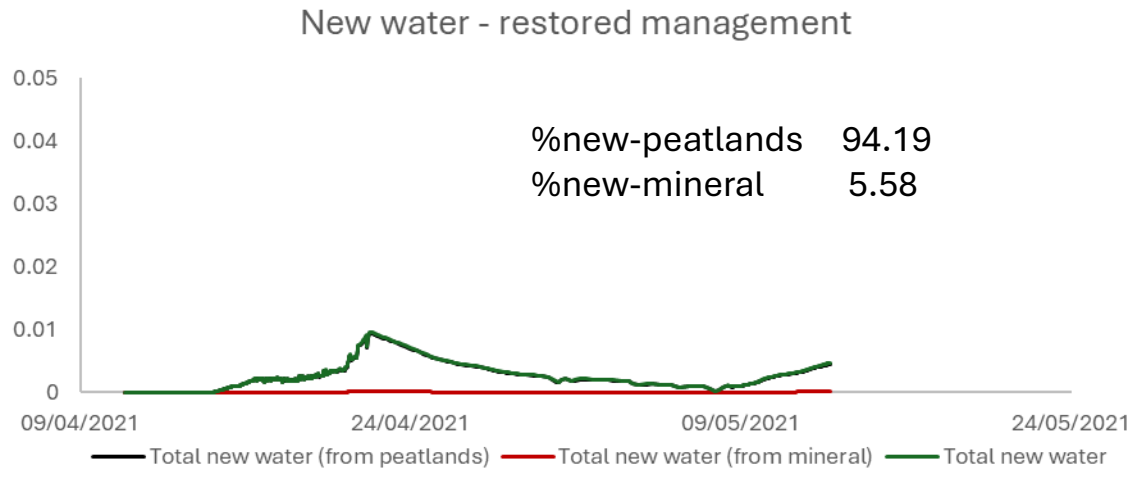




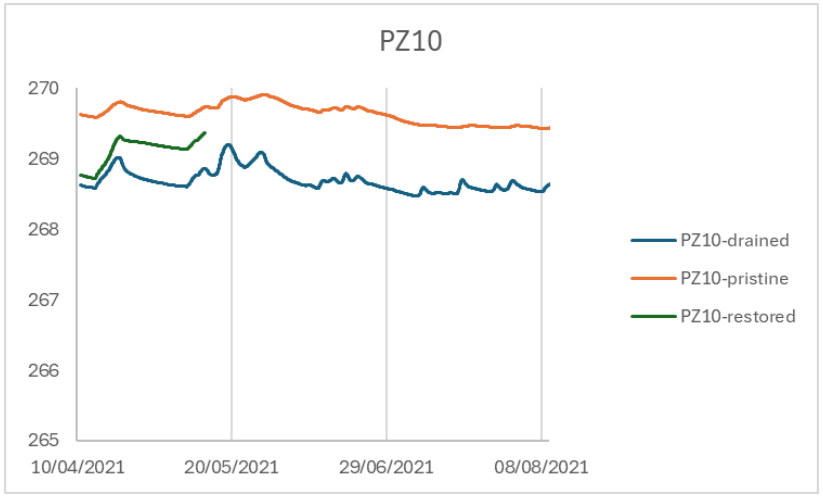
Hydrograph source separation using HGS+HMC (old/ new waters)

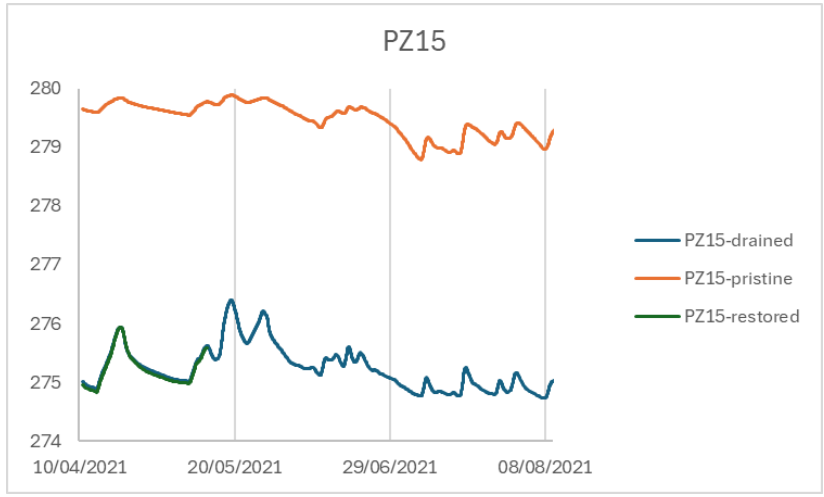


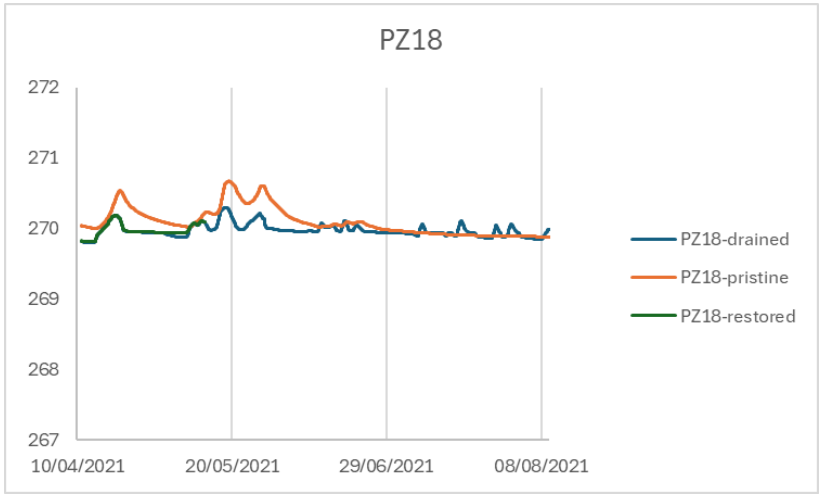


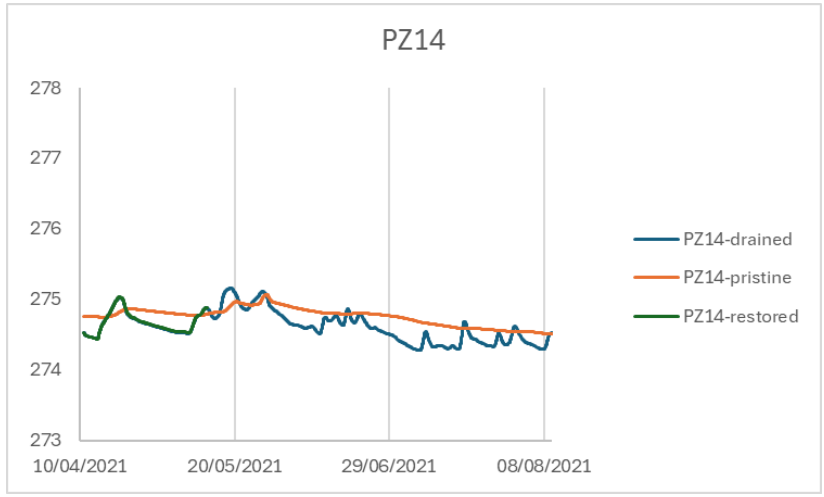


GW wells





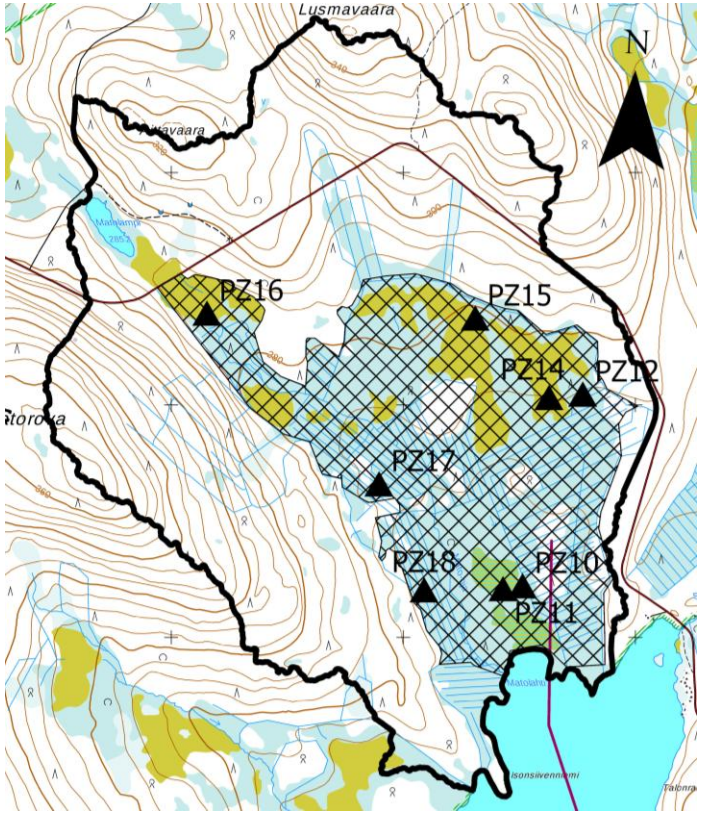


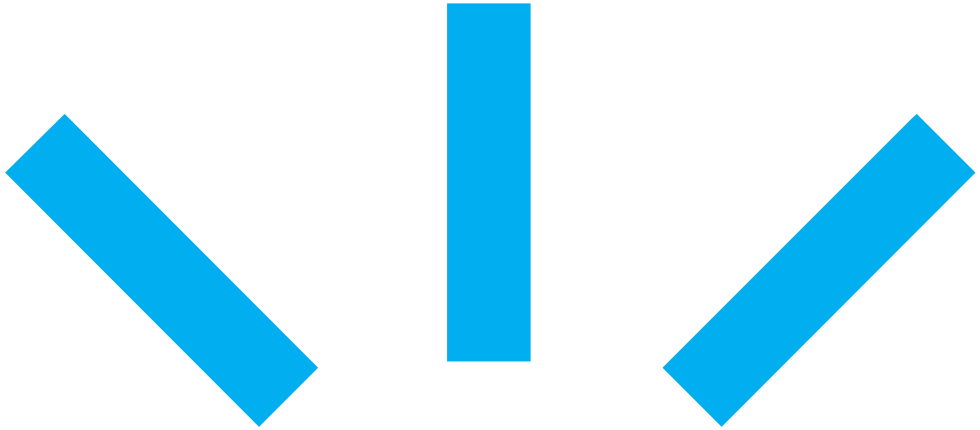


PZ18: Western peatlands are almost unaffected in terms of GWT drop

PZ10: Central undisturbed (non-ditched) peatlands still affected considerably with a drop of 1.5m approx.

PZ15: Northern most/ east peatlands are significantly affected by the drainage; almost 5.0m drop in gwl





Thank you