# Influence of permafrost distribution on groundwater residence time and groundwater-surface water interactions

**CatchNet – SurfaceNet Joint meeting, Sep. 2022**

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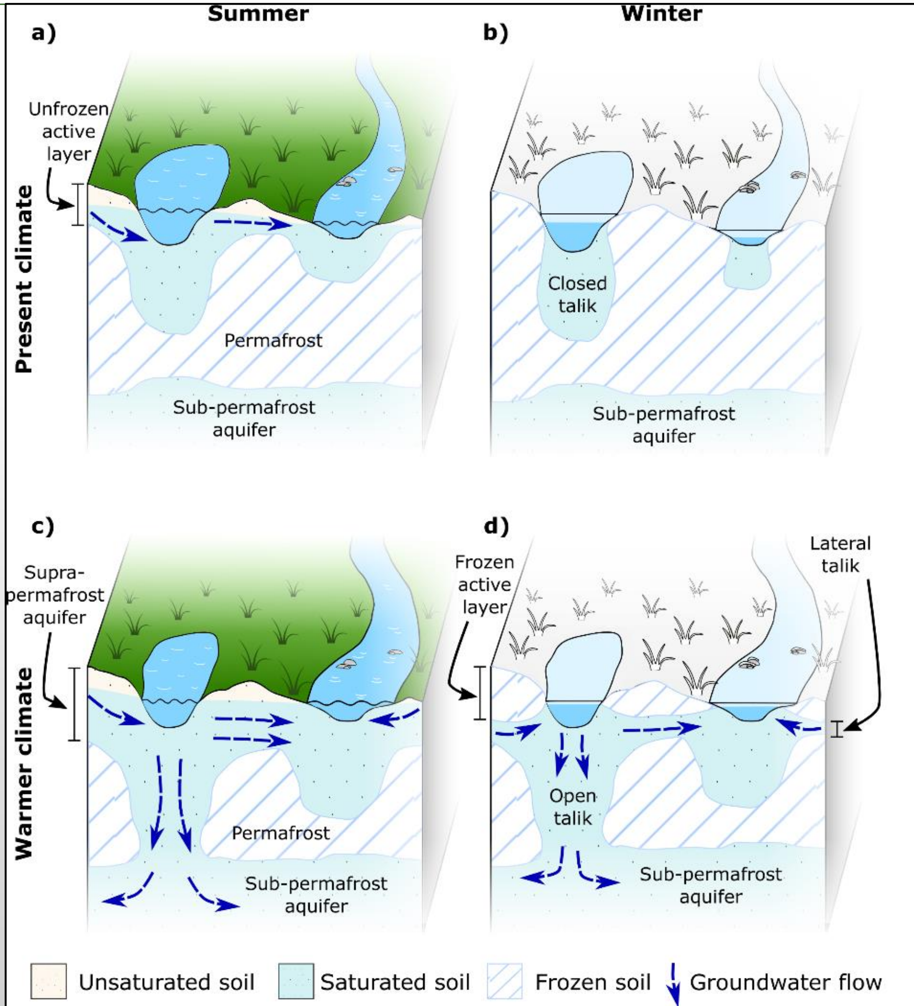
# Background

A future warming climate is expected to increase connectivity between groundwater and surface water.

What role does groundwater play in an alpine permafrost setting?

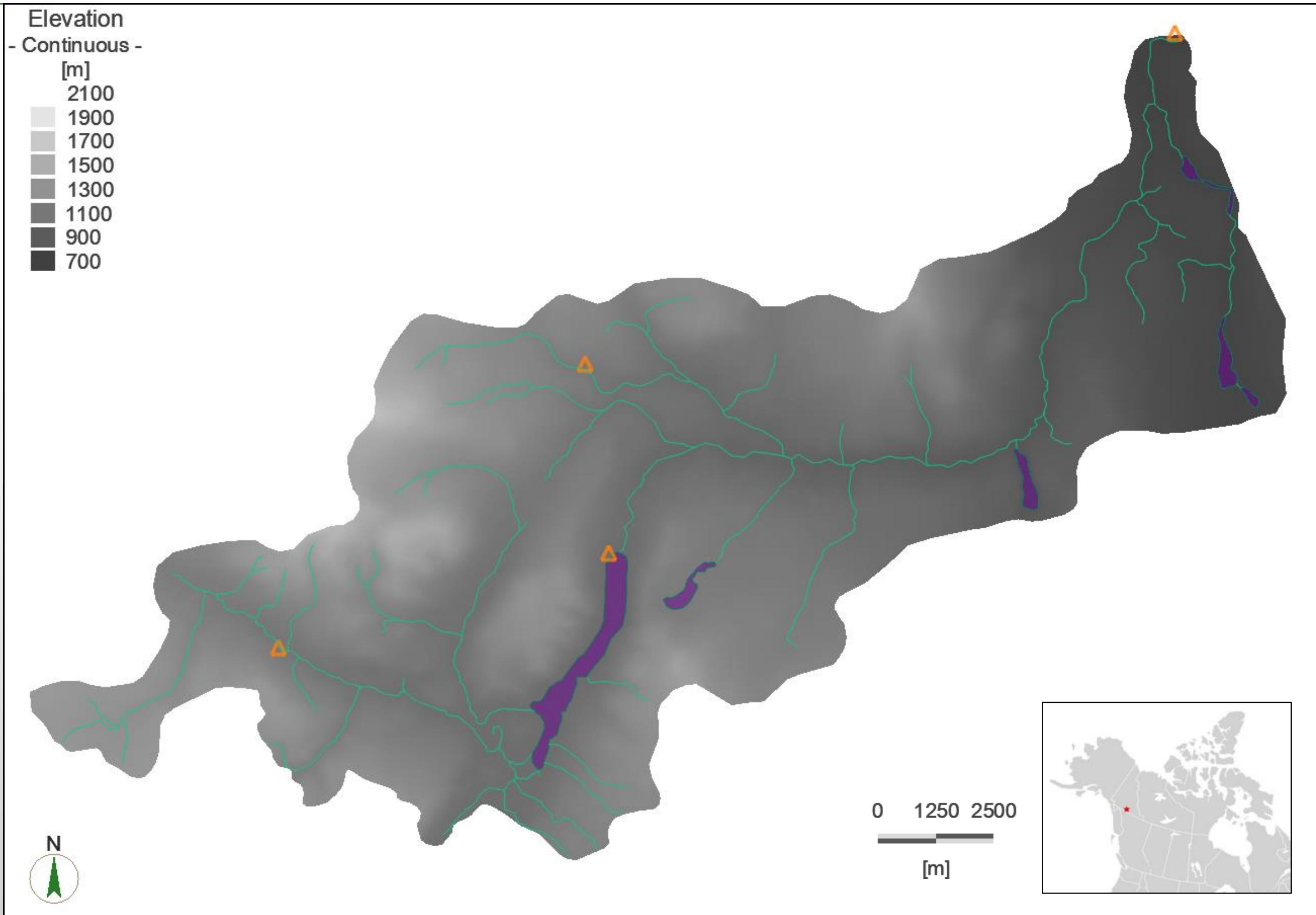
How does permafrost formation impact groundwater-surface water interactions?




Lamontagne-Halle *et al.*, 2020

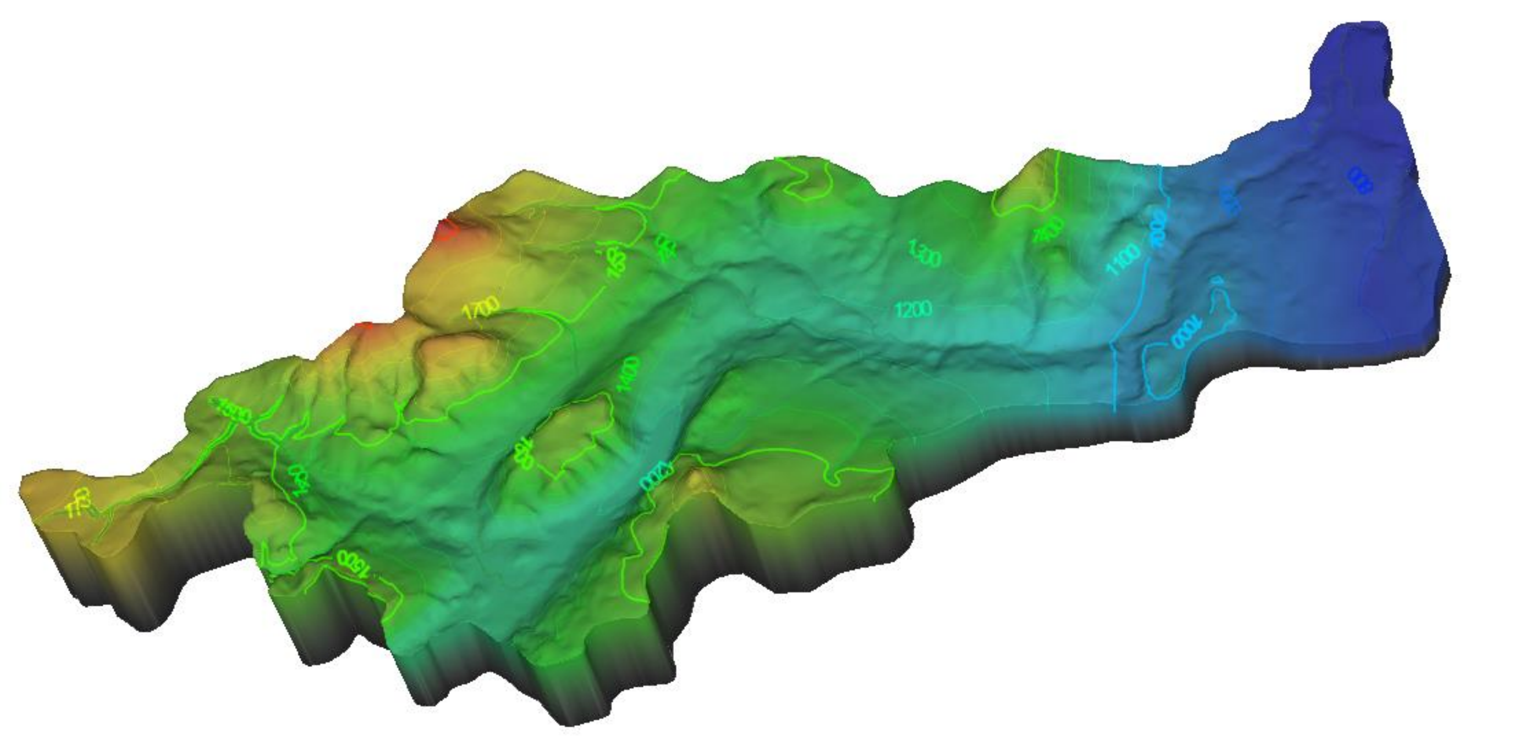
# Study site, Wolf Creek

- Extensive surface water network comprising streams and lakes.
- Significant variability in topography, slope and aspect and surface water distribution.
- Has been extensively monitored for over 25 years.
- Range of permafrost distribution in transition for the subcatchments.



# Methods

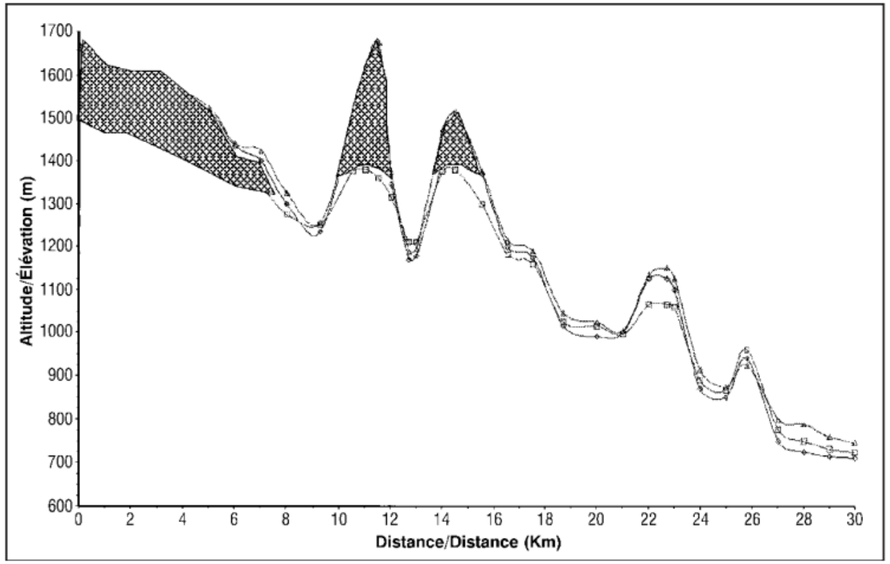
- 3D modelling approach – necessary for catchment but difficult for permafrost studies.
- Model constructed in FEFLOW.
- Model run as a steady state scenario after equilibrium is met.
- Low hydraulic conductivity zones assigned to represent permafrost distribution.



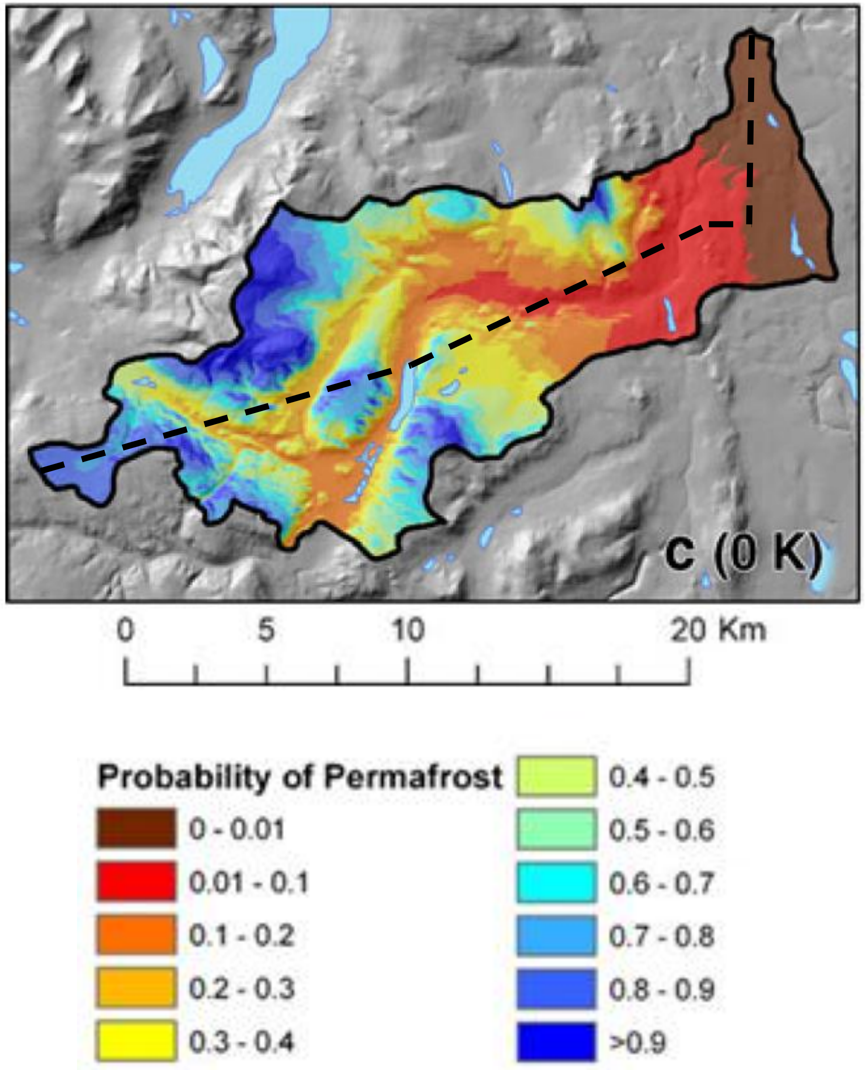
# Present day permafrost setting

Previous Wolf Creek studies suggest that permafrost occurrence is largely tied to elevation and to slope and aspect to some extent.

Permafrost likely absent at elevations lower than ~ 1400m

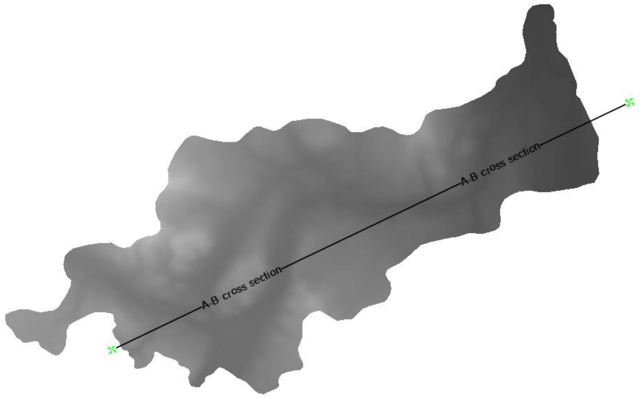



Seguin et al., 1998

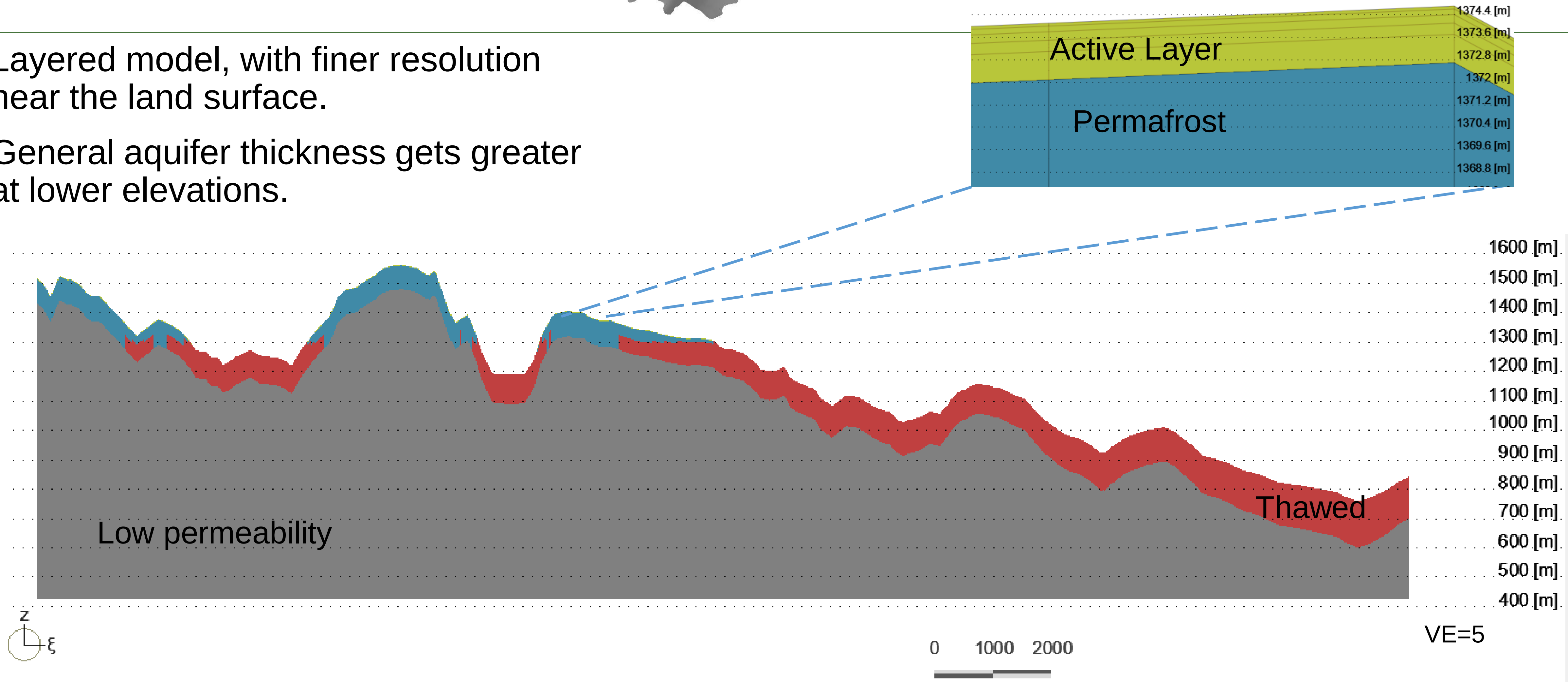



Bonnaventure and Lewkowicz, 2011

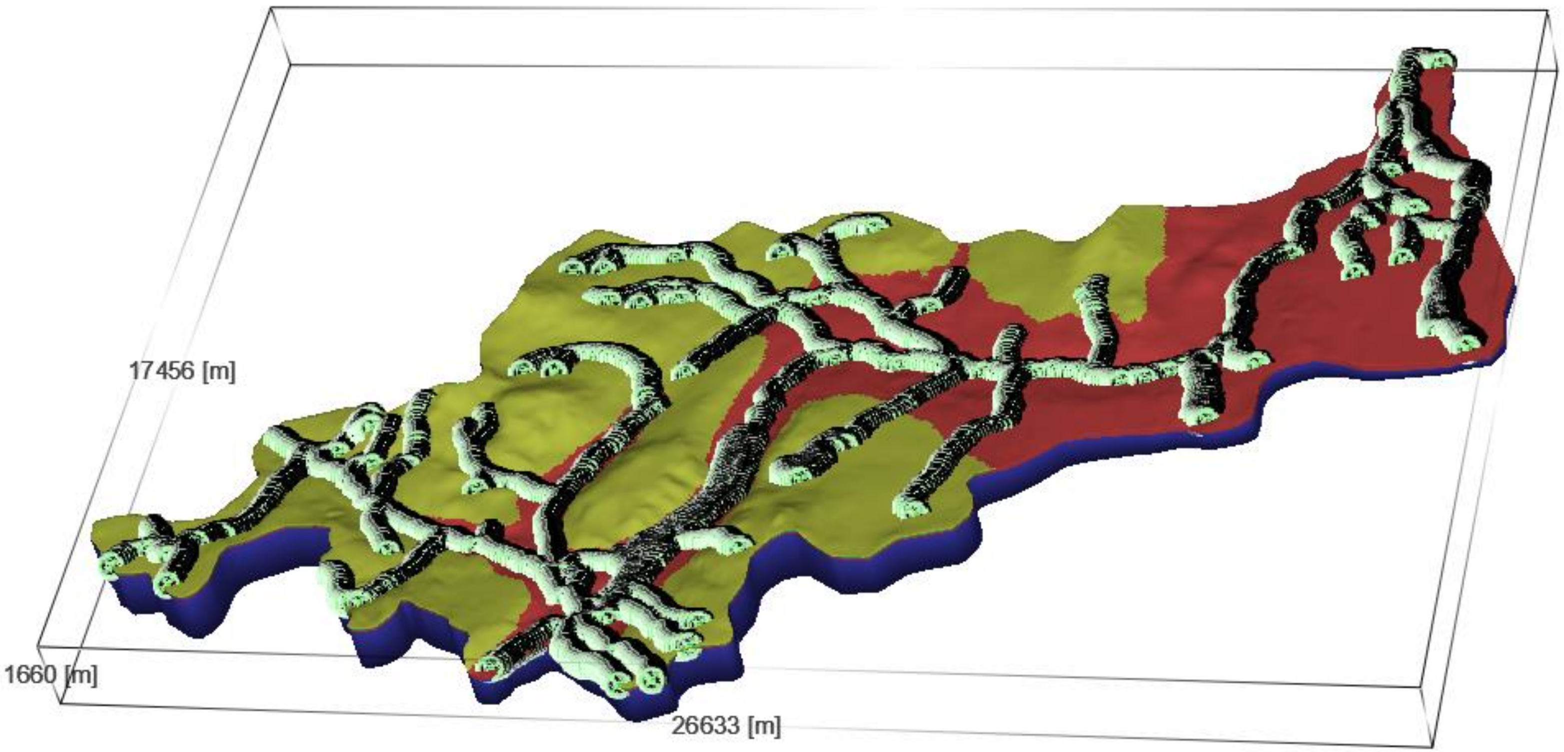
# Model Domain



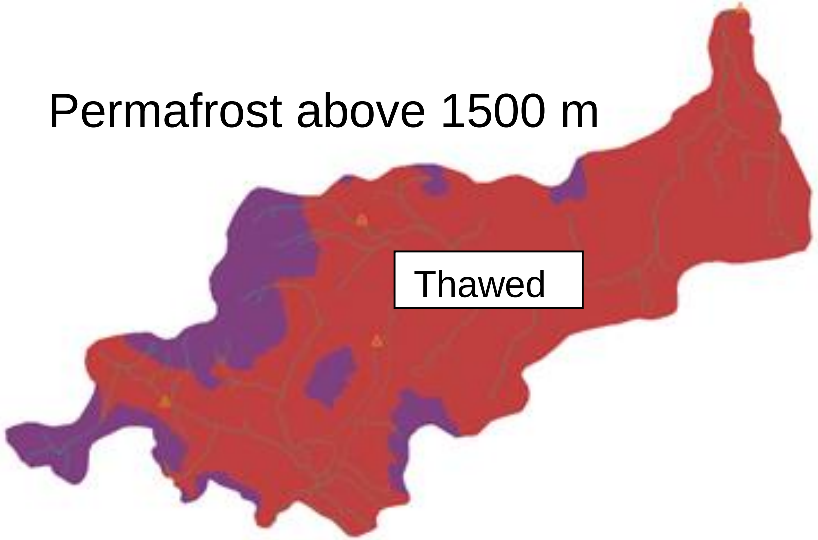

- Layered model, with finer resolution near the land surface.
- General aquifer thickness gets greater at lower elevations.



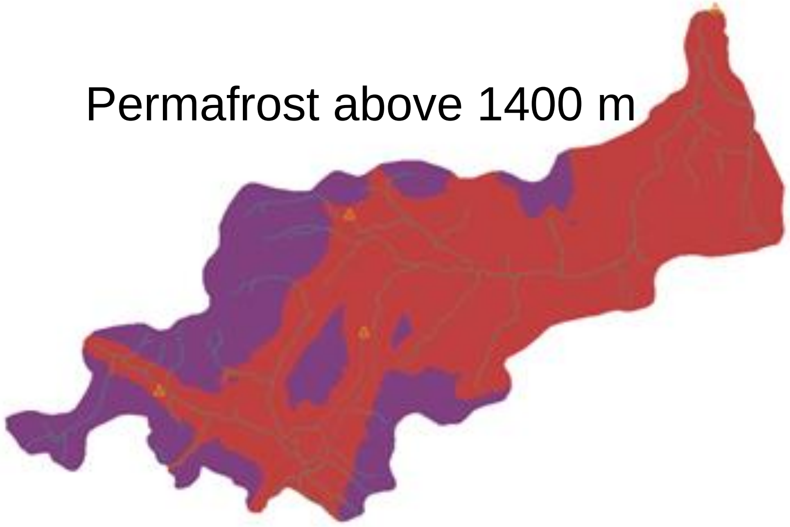
# Model setup



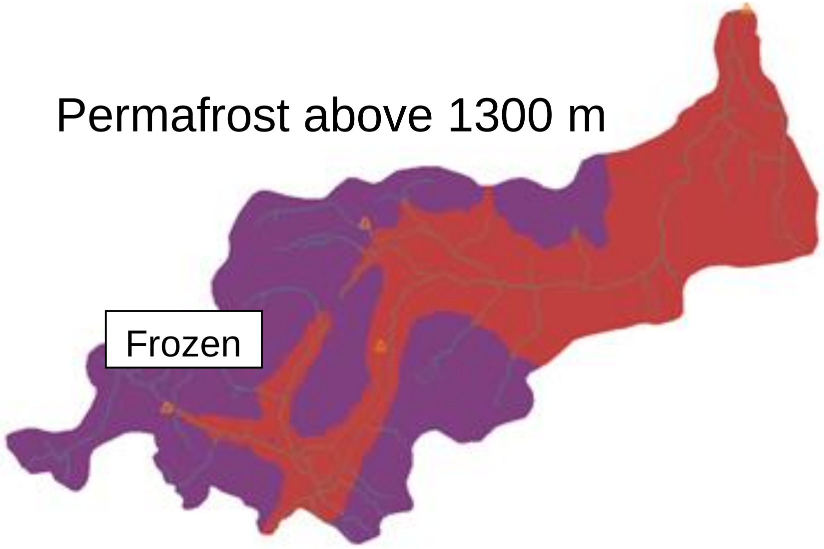

Permafrost above 1500 m



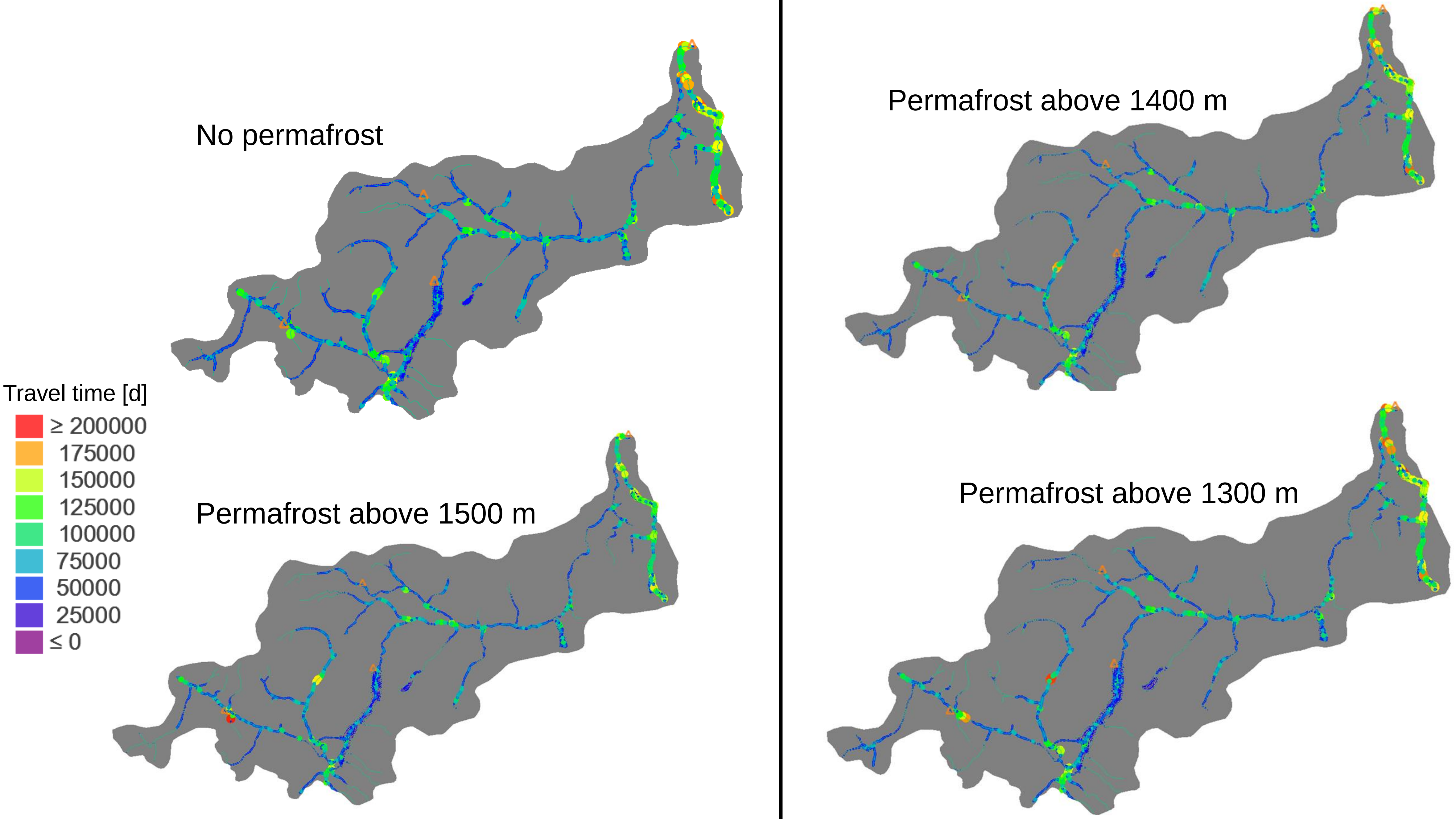

Permafrost above 1400 m



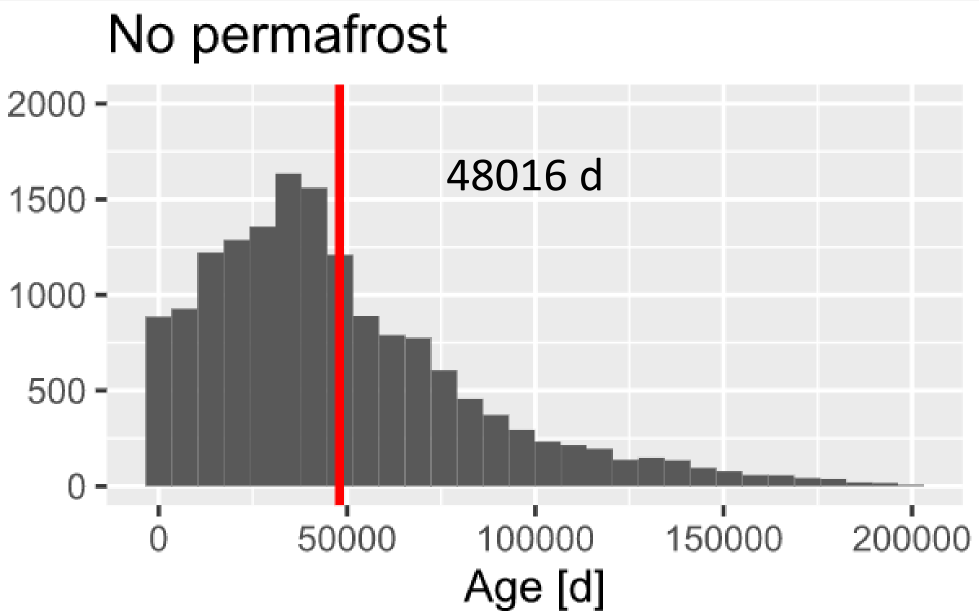
Permafrost above 1300 m

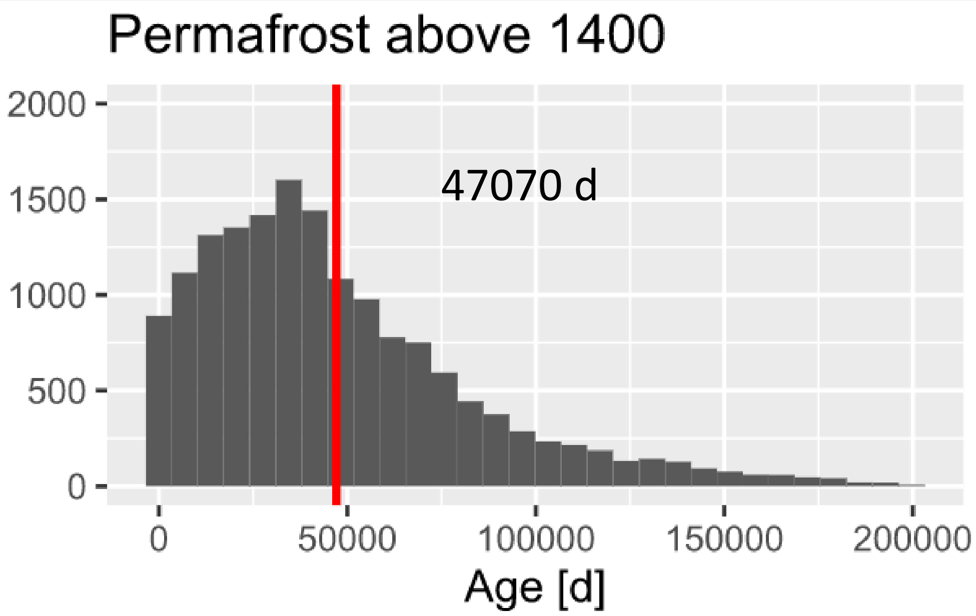


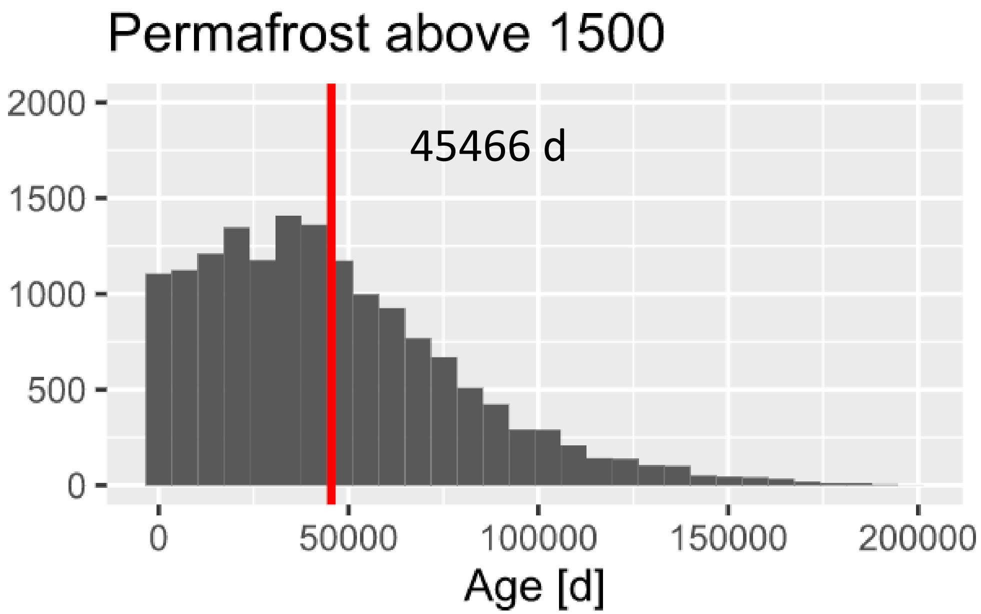
# Groundwater travel times

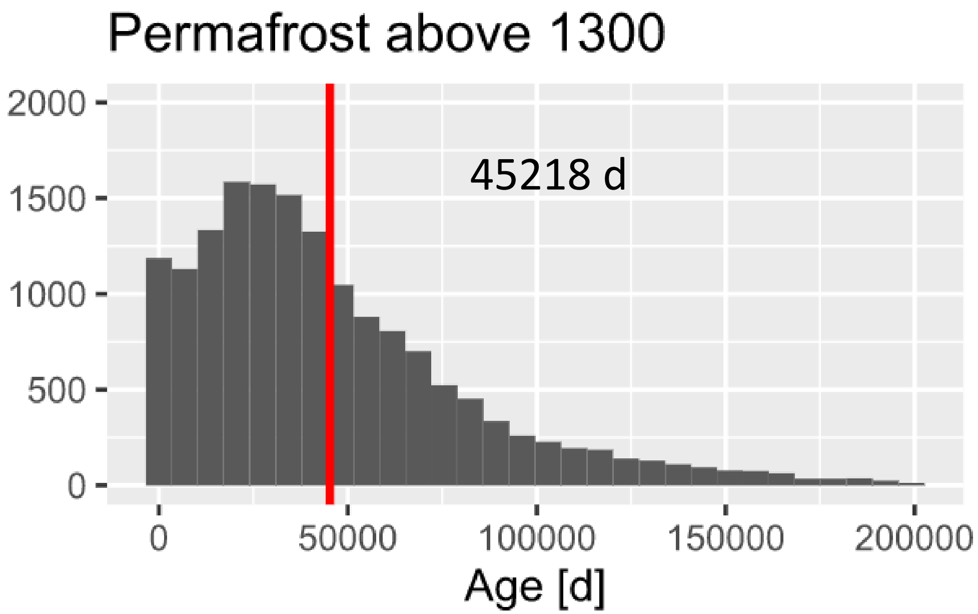


# Groundwater age for all stream nodes

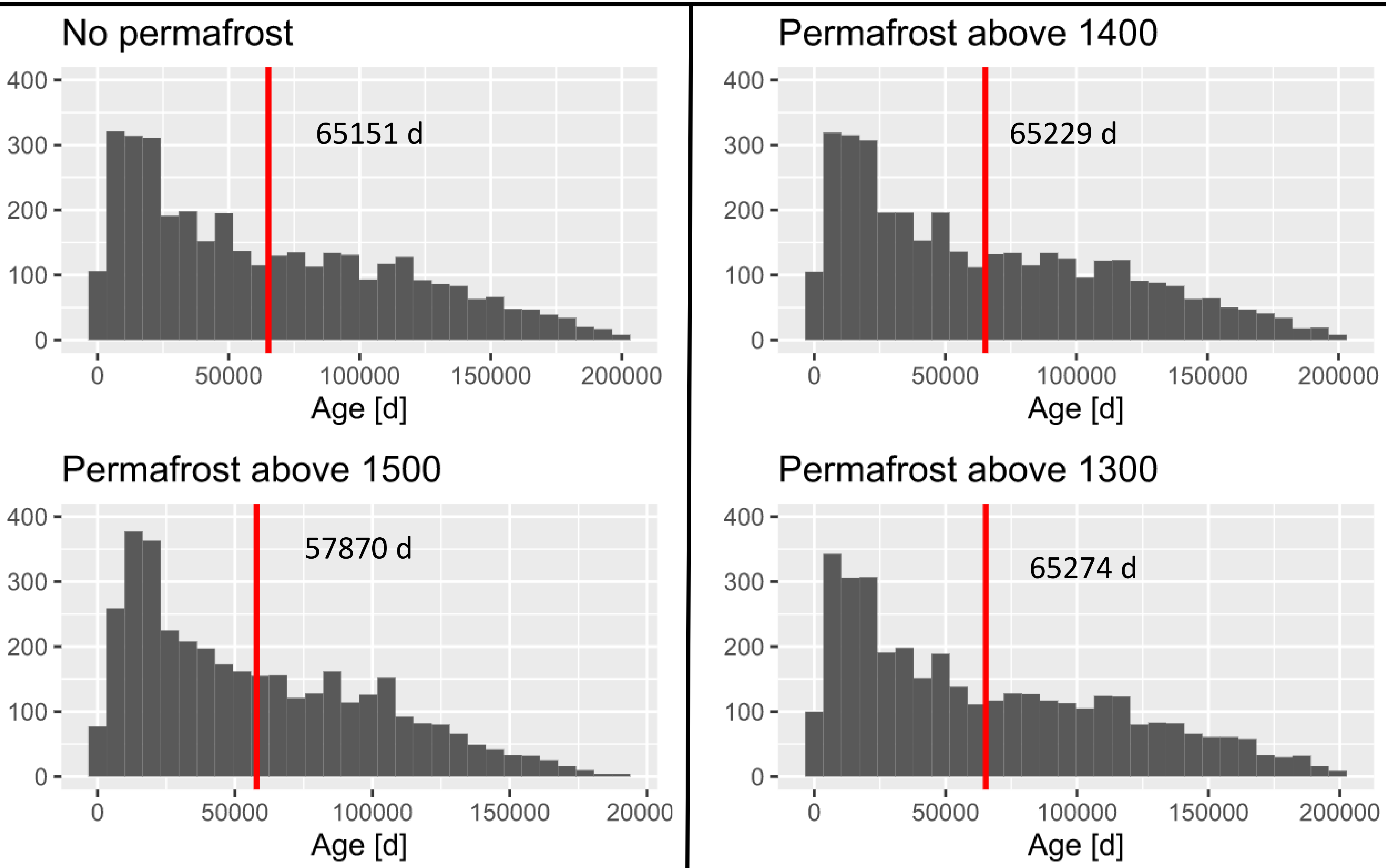


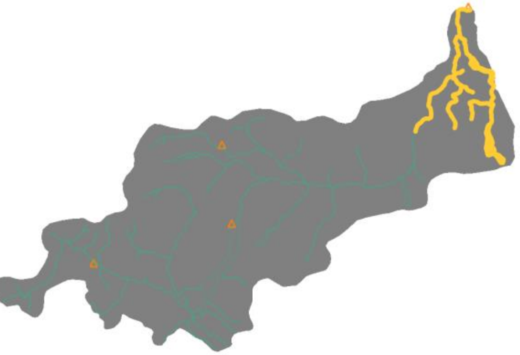



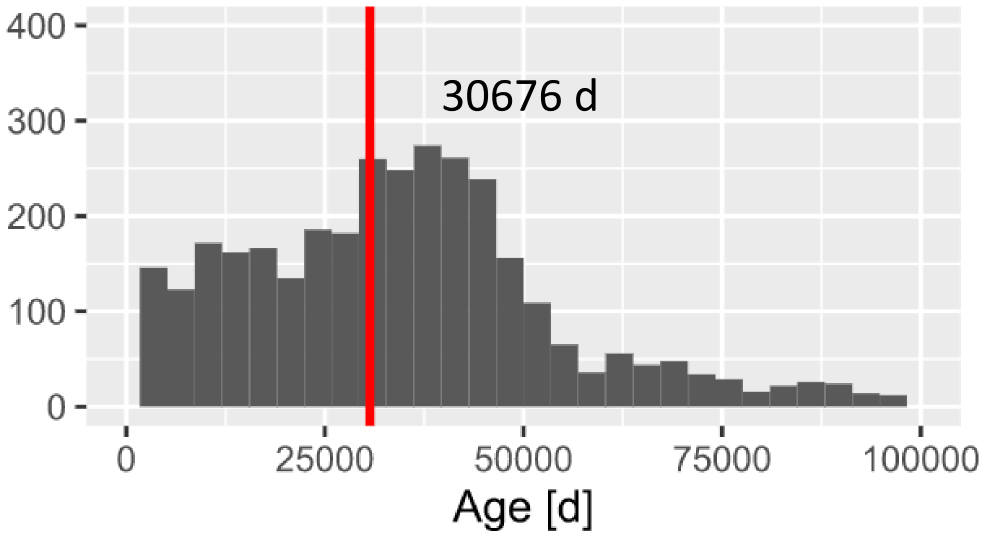

# Groundwater age for streams lower than 900 m



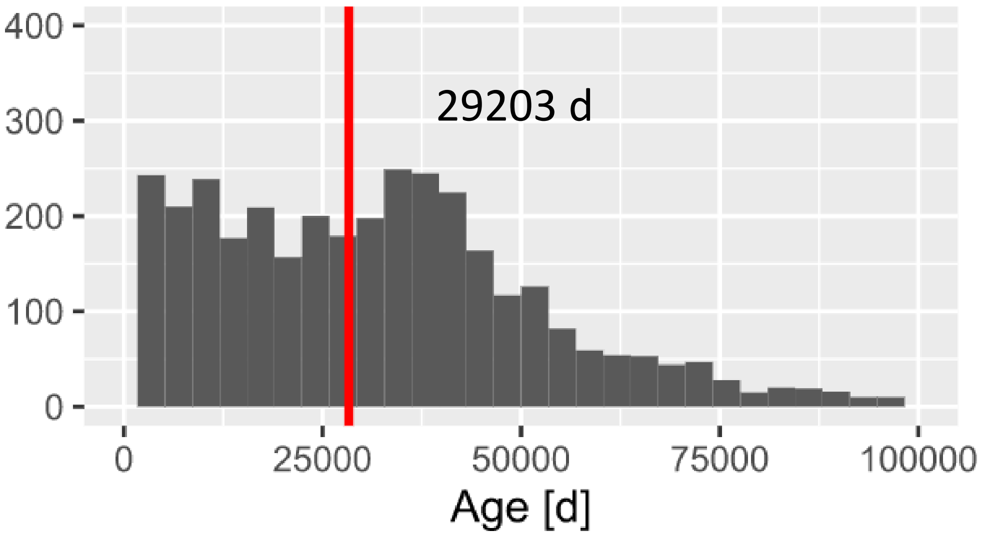



# Groundwater age for streams higher than 1300 m

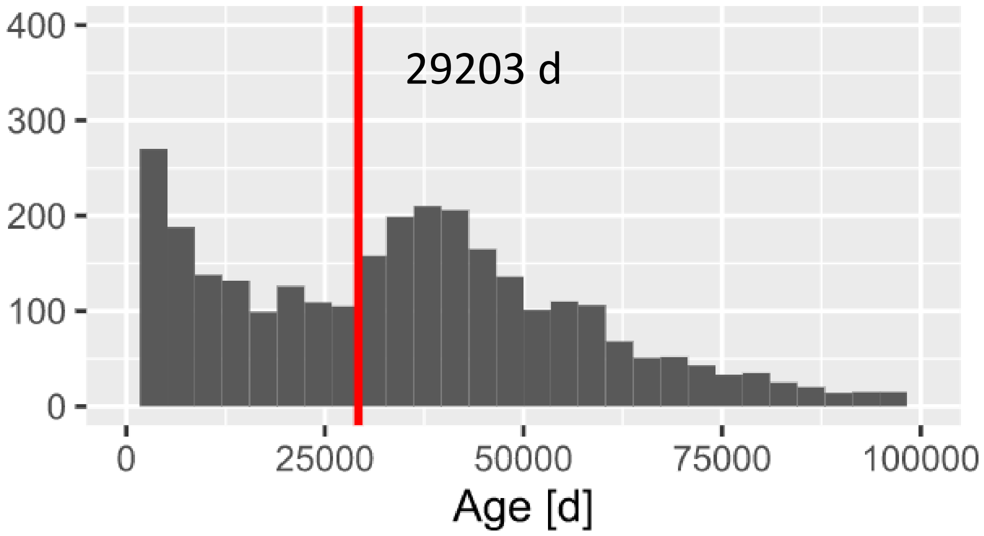
No permafrost



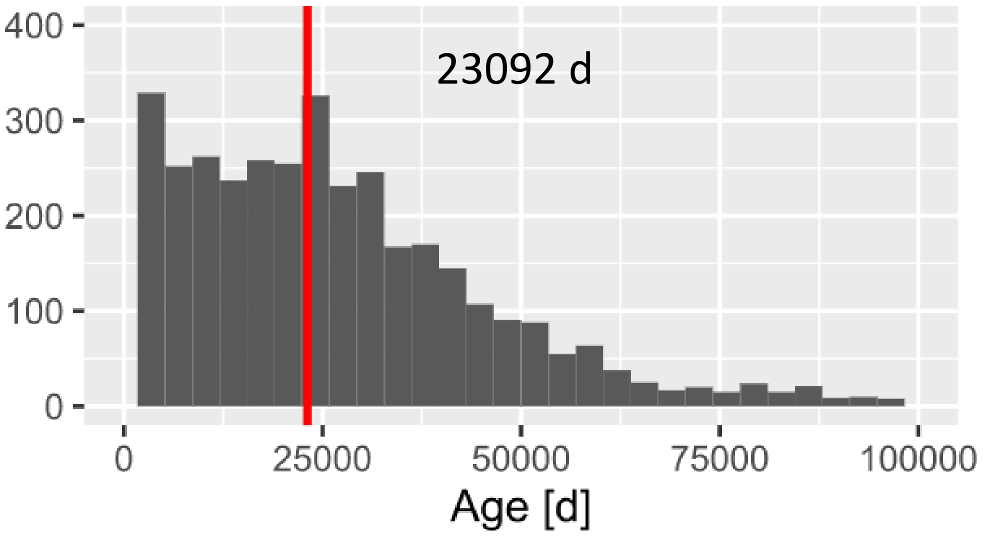

Permafrost above 1400




Permafrost above 1500

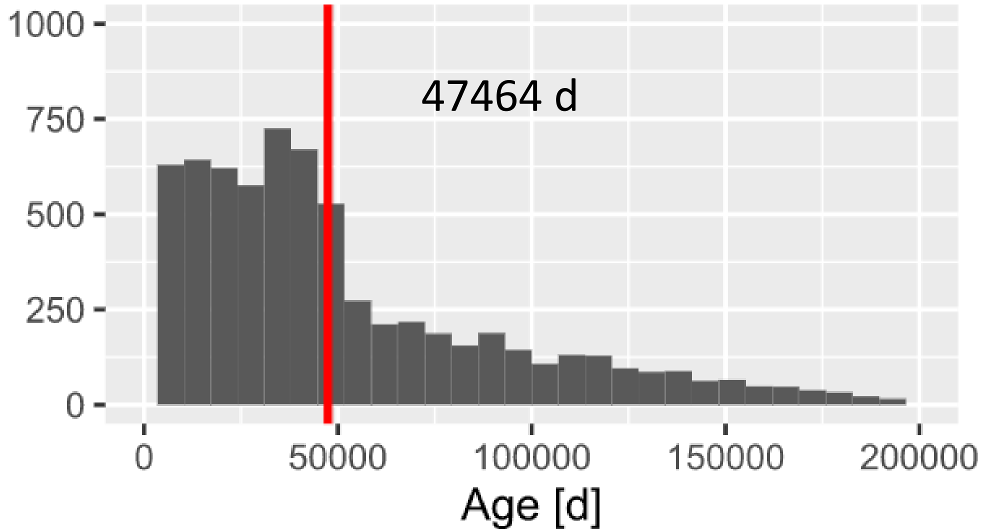



Permafrost above 1300

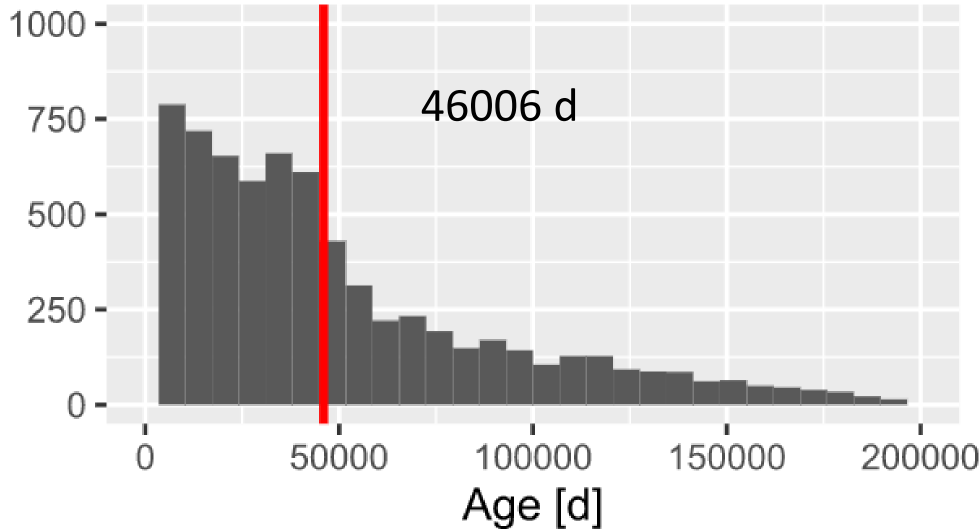



# Groundwater age for streams between 900 and 1300 m

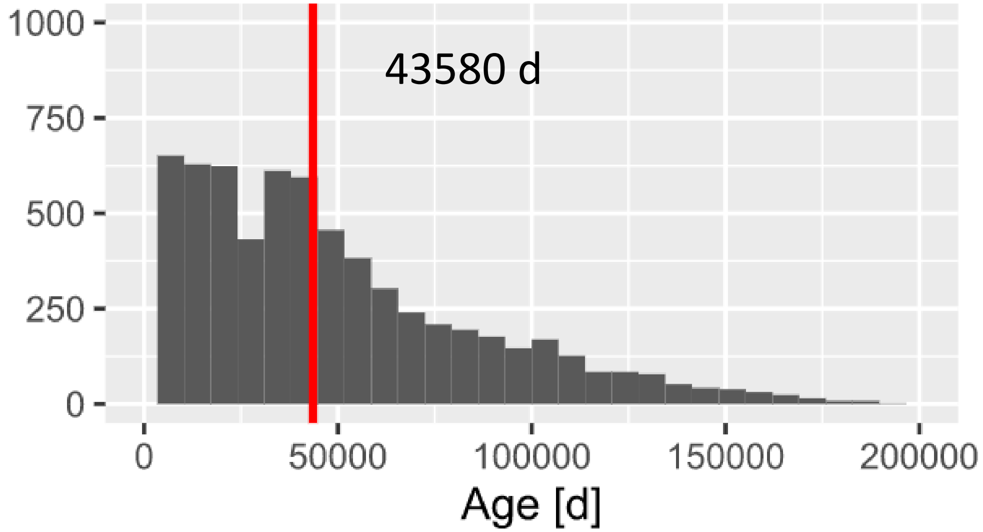
No permafrost



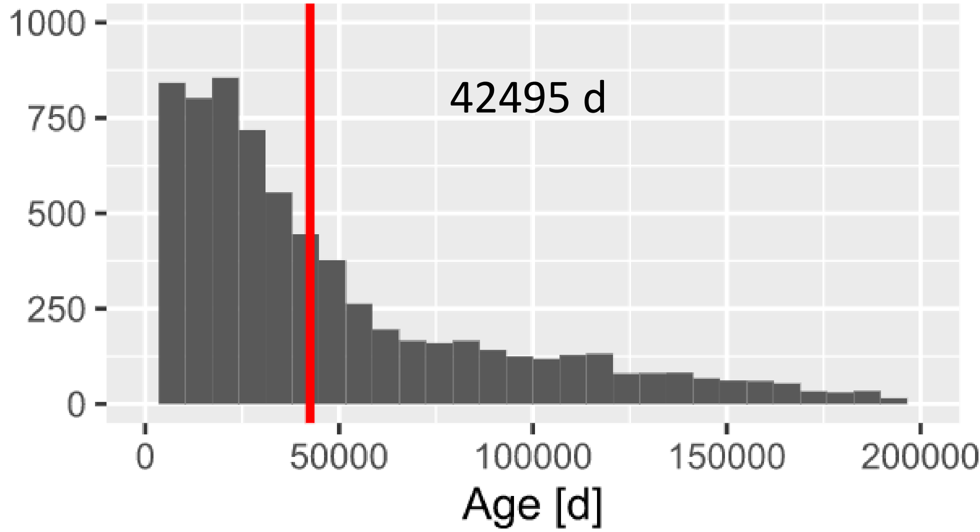

Permafrost above 1400



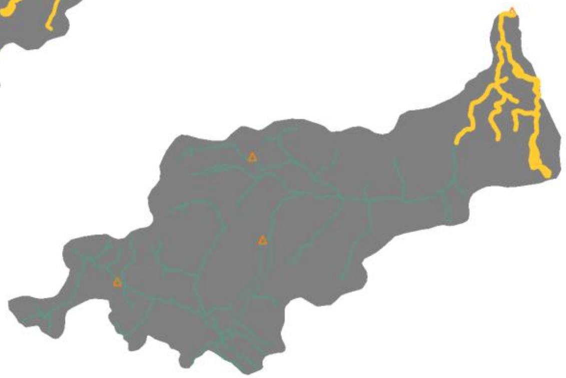

Permafrost above 1500




Permafrost above 1300



# Data summary



| No permafrost | Mean [y] | Median [y] |
|---|---|---|
| all nodes | 132 | 100 |
| <900 | 178 | 144 |
| >1300 | 84 | 85 |
| 900-1300 | 130 | 100 |

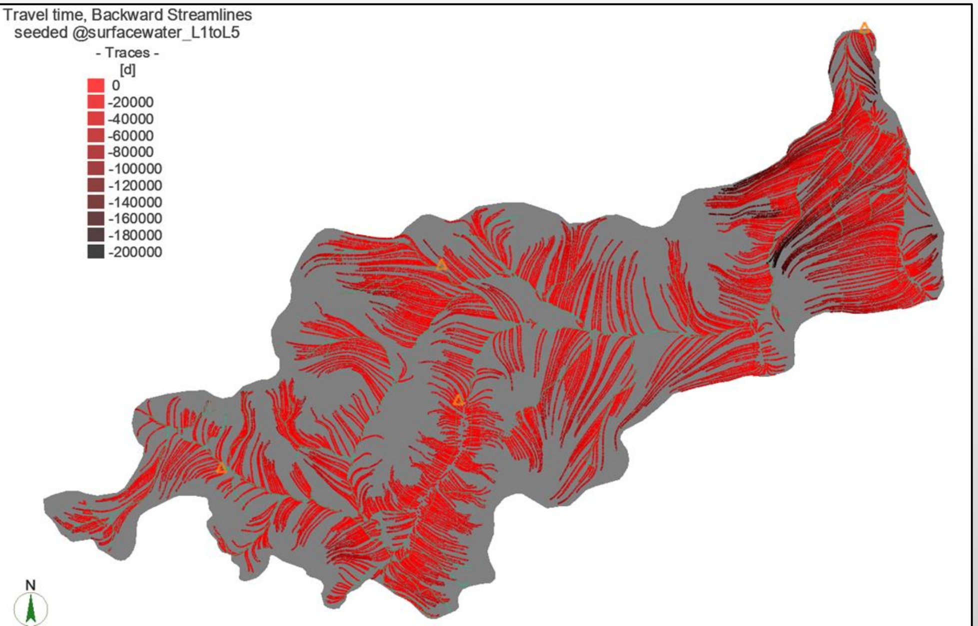
| Above 1400 m | Mean [y] | Median [y] |
|---|---|---|
| all nodes | 129 | 107 |
| <900 | 179 | 145 |
| >1300 | 80 | 72 |
| 900-1300 | 126 | 95 |

| Above 1500 m | Mean [y] | Median [y] |
|---|---|---|
| all nodes | 125 | 109 |
| <900 | 159 | 132 |
| >1300 | 80 | 78 |
| 900-1300 | 119 | 97 |

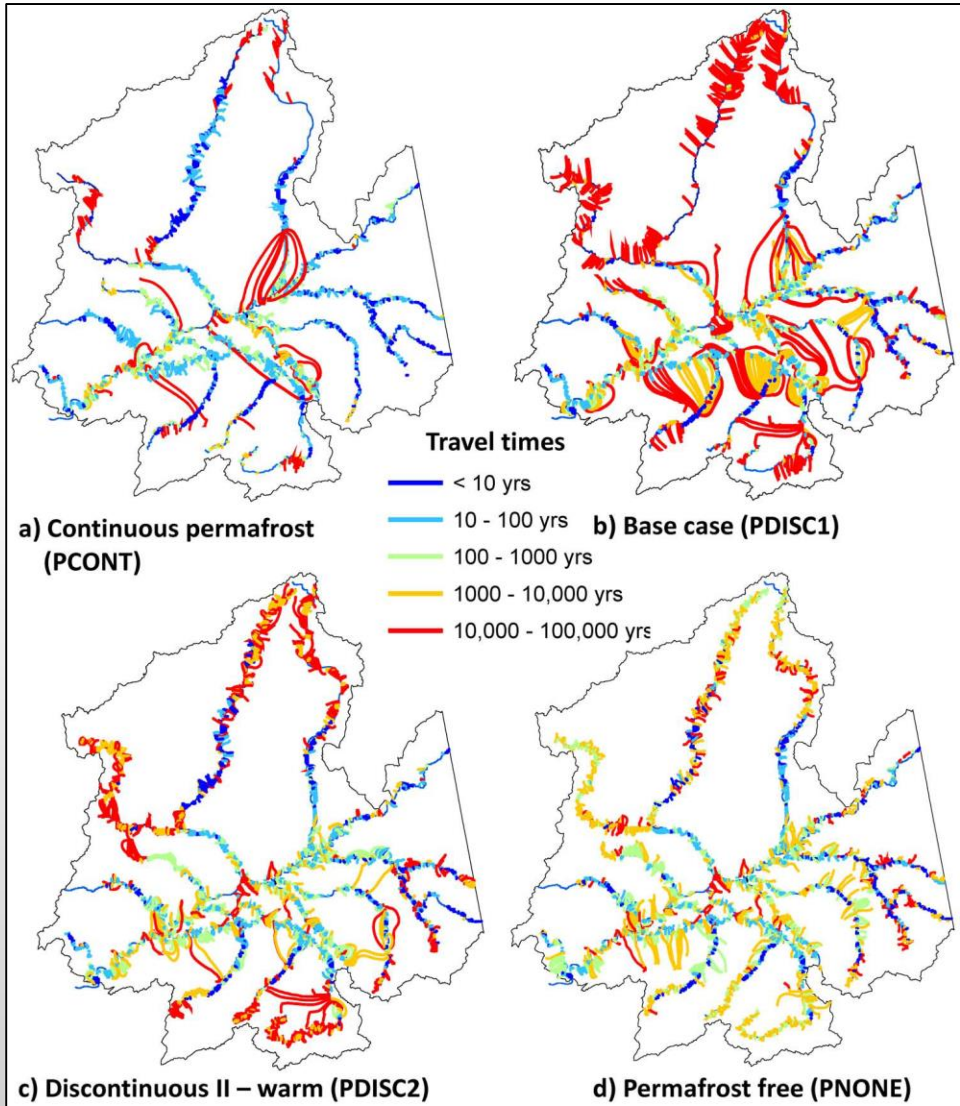
| Above 1300 m | Mean [y] | Median [y] |
|---|---|---|
| all nodes | 124 | 100 |
| <900 | 179 | 144 |
| >1300 | 63 | 55 |
| 900-1300 | 116 | 76 |

# Discussion

- Similar approaches have been used for large-scale studies (e.g., Walvoord et al., 2012).
- The density of the stream network used in the current study reveals significant differences over short distances.
- Results show stream talik dynamics are important but challenging to understand.




Walvoord et al., 2012



# Findings

- The presence or absence of permafrost affects travel times, but pattern of change (e.g., longer or shorter) is complex.
- The permafrost distribution has a large impact on flow paths and travel times.
- 3D models can provide more nuanced information about flow paths, and how permafrost affects these.
- The presence of permafrost in high-elevation sub catchments influences the travel times to streams and low elevation areas without permafrost.

# Next steps

- Investigating the spatial patterns in stream discharge.
- Investigate the role of slopes and aspect.
- 2D transient modelling to investigate groundwater flow paths and permafrost in transition and the potential role of hysteresis.
- Permafrost formation will elucidate present day permafrost distribution, which is used in permafrost thawing studies.


Thank you for your attention!
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HYDROGEOLOGY