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Analysing the role of the regolith over the placement of the discharge areas

Comsol 157 project

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25 YEARS 1994 2019

BREAKING THROUGH

Introduction

- The biosphere is considered a key part of the safety assessments → The main consequences of a potential release of radionuclides arise here.

- Hydrogeological and safety studies use a future regolith structure based on a landscape development model → Uncertainty

- Previous studies indicate that bedrock structure is key in determining the location where radionuclides may reach the surface of the future landscape.

- These studies did not account for uncertainties in the distribution and heterogeneity of the permeable materials in the regolith.

Objectives

- The primary objective is to ascertain the degree to which heterogeneities in regolith structure may affect the spatial distribution of radionuclides reaching the surface.
- A secondary objective is to examine how simplifications in the parameterization of the hydraulic properties of the regolith materials affect the predictive capacity of particle transport models.
- The study has been carried out using a three-dimensional, numerical hydrological model representing the future landscape (5000 AD) of Forsmark.

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Model scenarios

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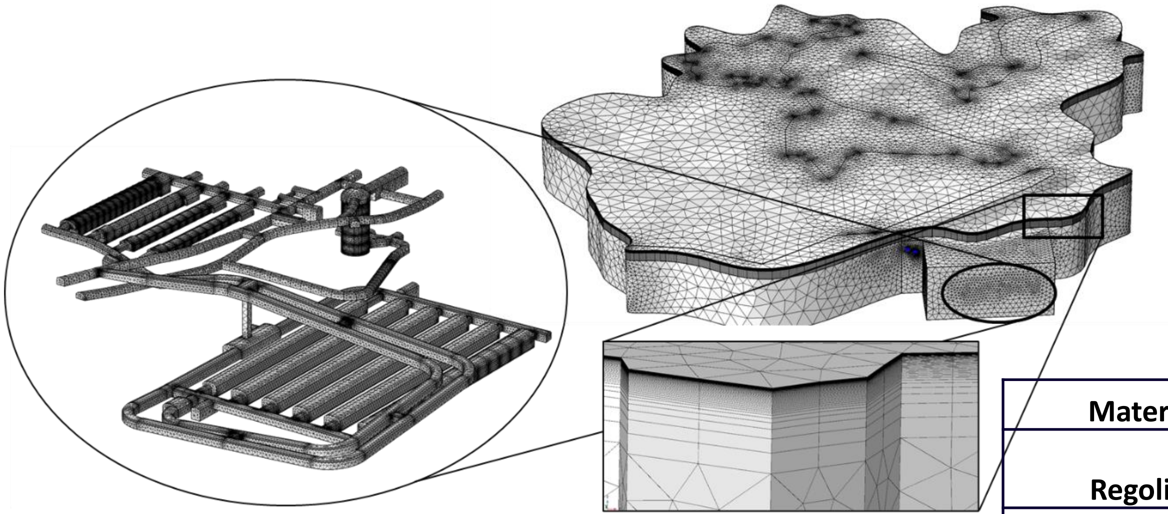
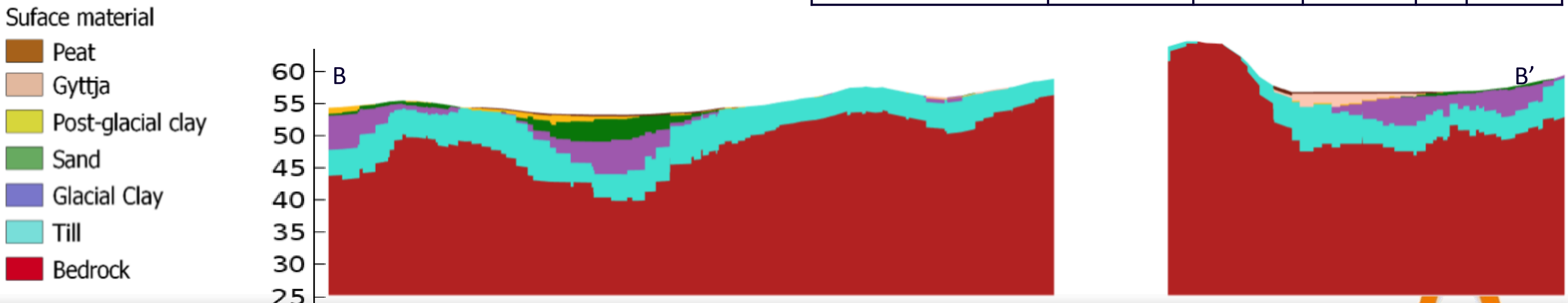
Model scenarios

- 6 scenarios were analyzed
  - **Base case**

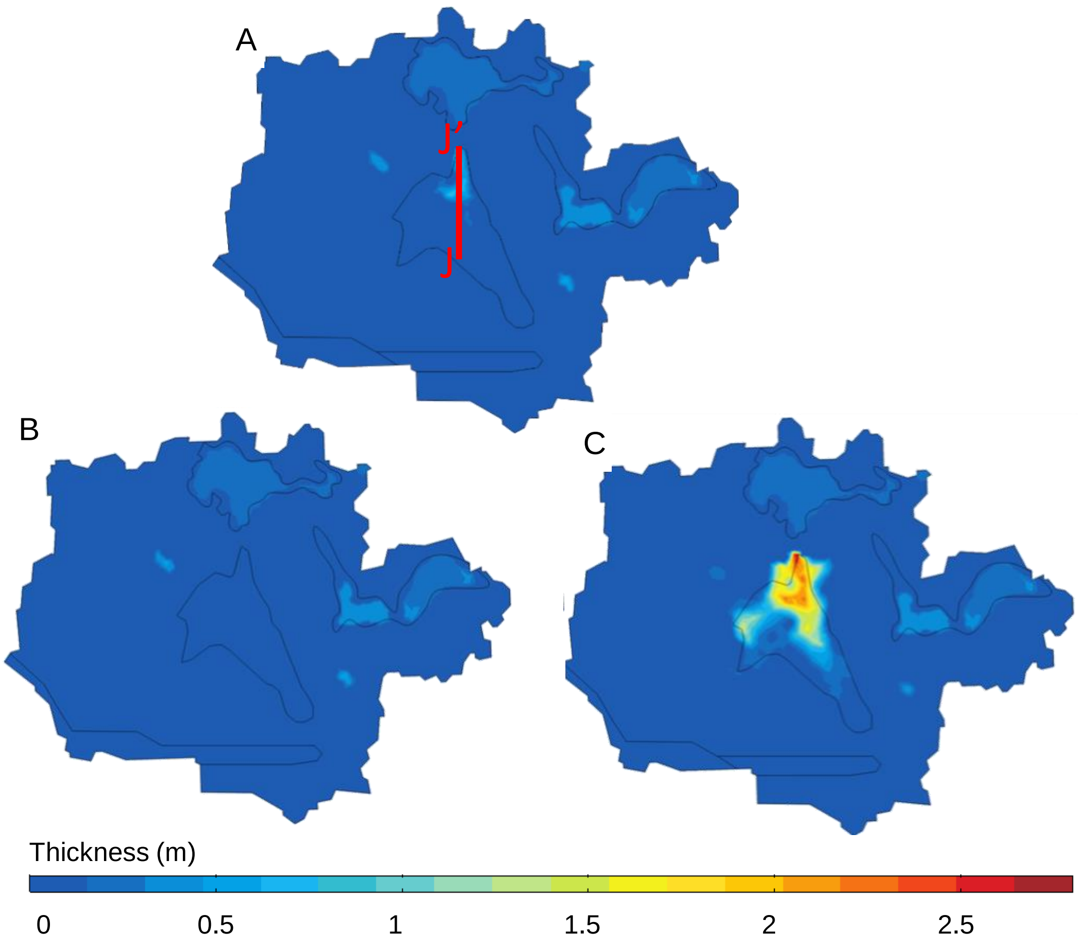


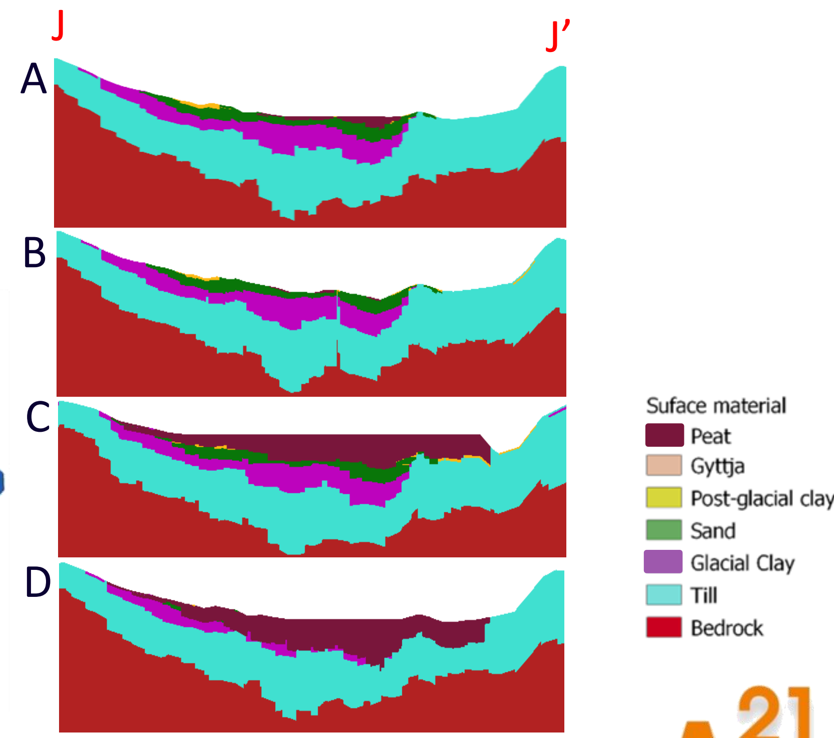
Material	Kx/Ky (m/s)	Kz (m/s)	θ	Sy	Ss (1/m)
Regolith			From R-13-18		
Peat	5.00E-06	5.00E-07	0.9	0.2	0.02
Gyttja	3.00E-07	3.00E-07	0.92	0.03	0.01
Postglacial clay	5.00E-06	5.00E-07	0.92	0.05	0.01
Postglacial sand	1.00E-04	1.00E-04		0.2	0.35
Glacial Clay	1.50E-08	1.50E-08	0.75	0.03	0.01
Till	7.50E-06	7.50E-07	0.21	0.05	0.00



Model scenarios

- 6 scenarios were analyzed
  - Base case
  - **Alternate peat extension**
    - **Different extensions of the peat in basin 157_2**





Model scenarios

- 6 scenarios were analyzed
  - Base case
  - Alternate peat extension
    - Different extensions of the peat
  - **Homogeneous isotropic**
    - **Regolith with a constant permeability**
    - **$K = 1.85 \cdot 10^{-5}$ m/s**

Model scenarios

- 6 scenarios were analyzed
  - Base case
  - Alternate peat extension
    - Different extensions of the peat
  - Homogeneous isotropic
    - Regolith with a constant permeability
  - **Homogeneous anisotropic**
    - **Regolith with a constant permeability and anisotropy**
    - **$K_h = 1.85 \cdot 10^{-5}$ m/s and a single $K_z = 8.5 \cdot 10^{-8}$ m/s**

Model scenarios

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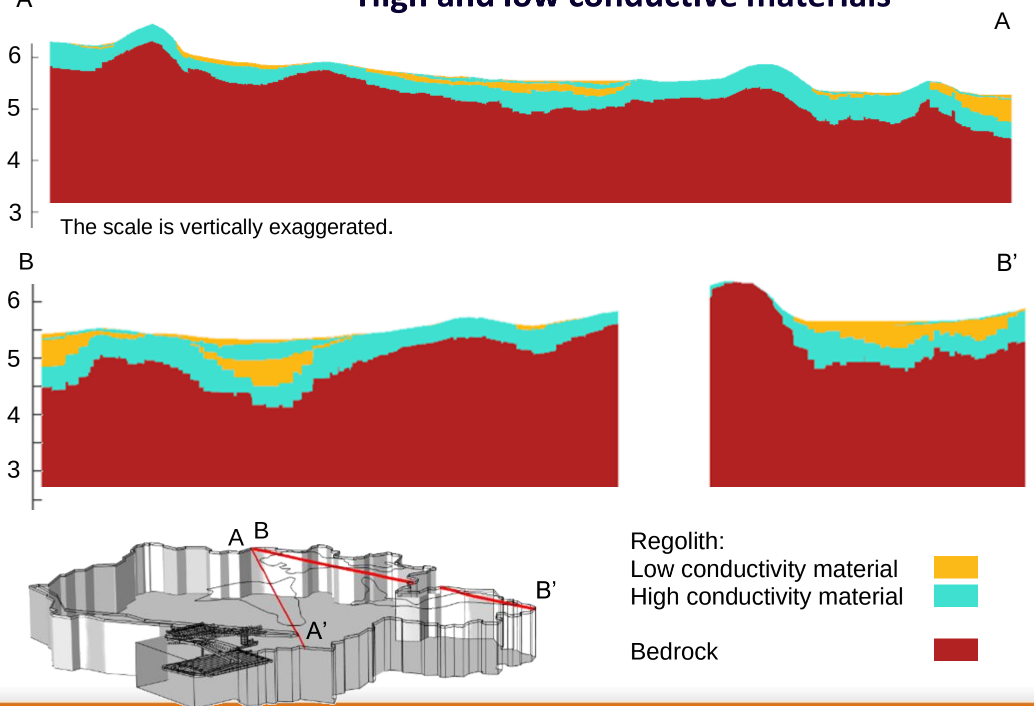
  - Homogeneous anisotropic
    - Regolith with a constant permeability and anisotropy
  - **Two materials case**
    - **High and low conductive materials**



Regolith material	Classification	$K_x = K_y$	K_z
Peat	Low conductivity material	2.58E-06	5.68E-08
Gyttja			
Postglacial clay			
Glacial Clay			
Postglacial sand	High conductivity materials	5.25E-05	1.40E-05
Till			

Model scenarios

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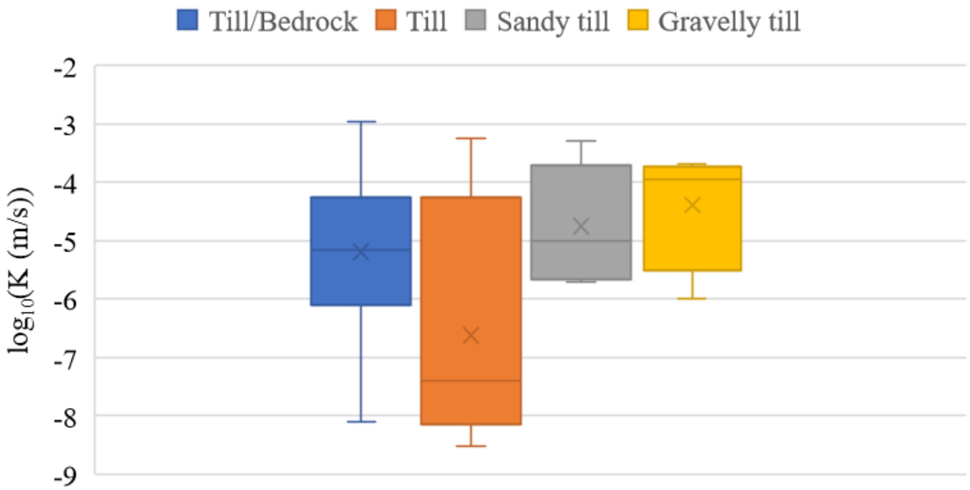
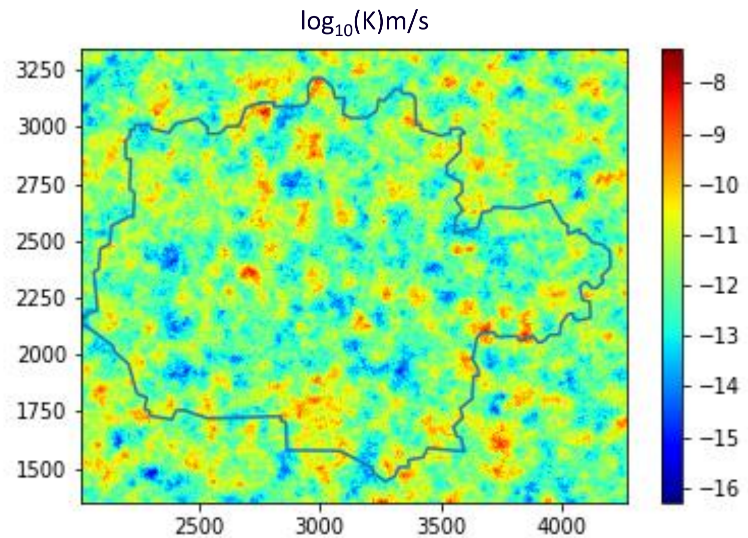
  - Two materials case
    - High and low conducive materials
  - **Heterogeneous till permeability distribution**
    - **Random distribution of permeabilities in the till**





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Results

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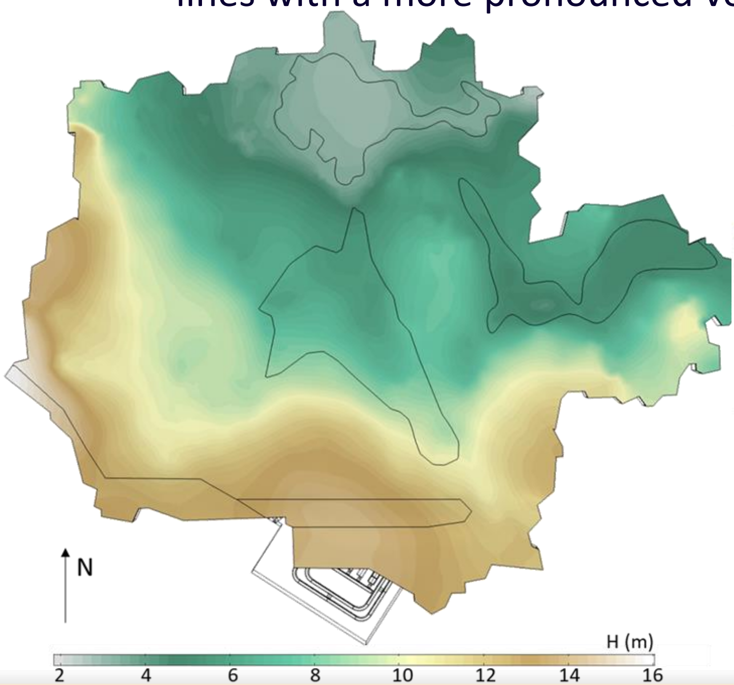
Base case

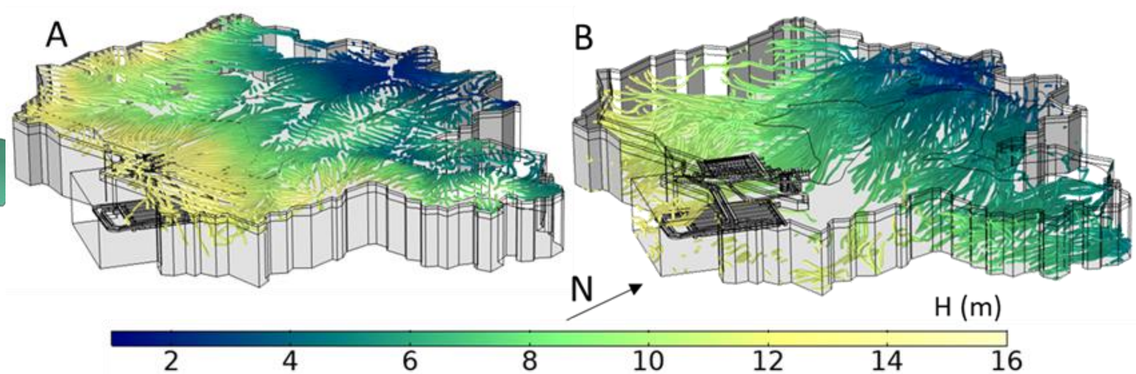
Groundwater flow direction:

- Recharge zones are located where elevations are higher than the surrounding areas (south and west). Groundwater moves towards the north and east.

- The discharge areas coincide with the low topographic areas of the three basins ➔ defined as biosphere objects of interest.

- Groundwater in the regolith is characterized by short flow lines with a mainly horizontal component. The deep groundwater flowing through the bedrock is characterized by large flow lines with a more pronounced vertical component.



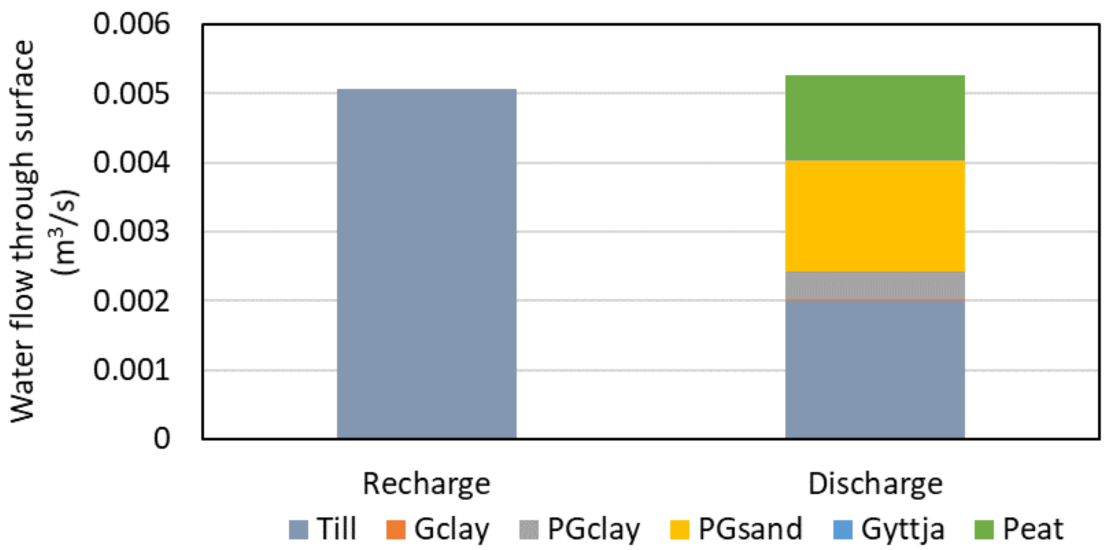


Base case

Water balance:

- Recharge through the surface is 34% of the total inflow and discharge through the surface is 35% of the total outflow ➔ There is 1% more discharge that recharge, which suggest that the local topographic depressions act as discharge zone for regional groundwater flows.

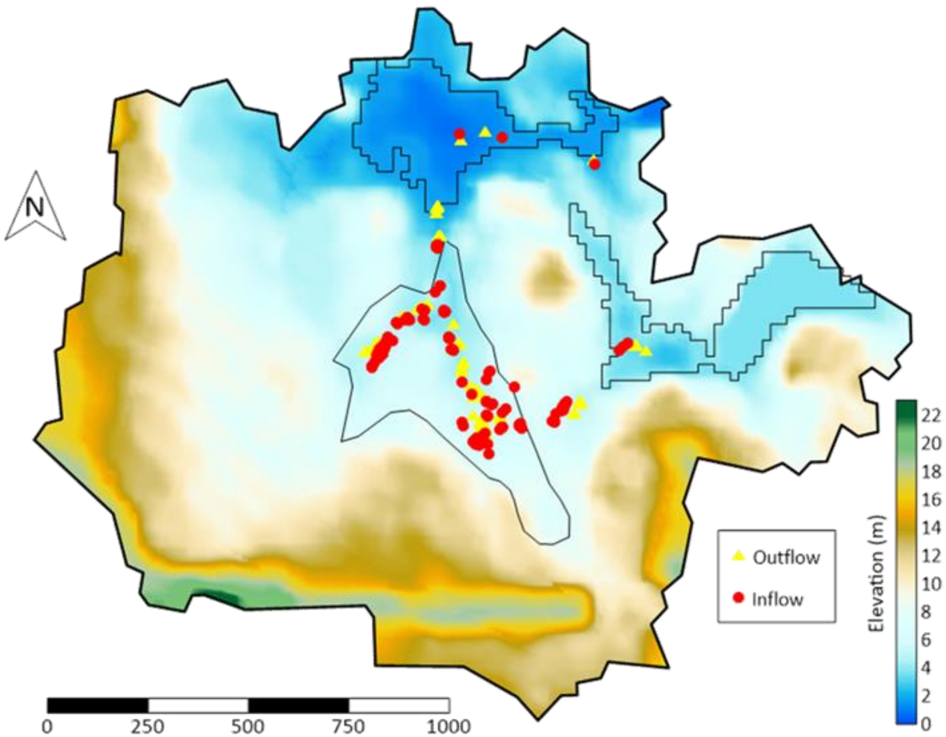
- Water comes out mainly through the outcrops of high permeable materials ➔ postglacial sand and till.

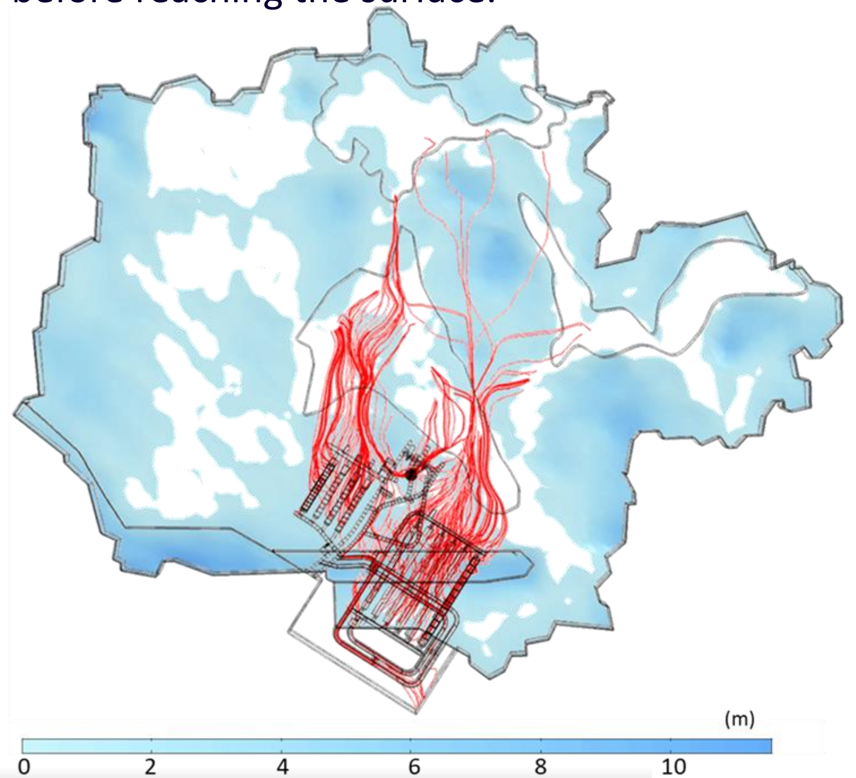


Base case

Particles entry and exit points:

- Groundwater from the repository discharges to the surface mainly in the biosphere object of basin 157_2. There is also a connection with basins 157_1 and 159.
- The entry points in the regolith are controlled by the alignment of deformation zones in the bedrock under the low topographic area.
- Most particles show vertical paths, enhanced by the reduced regolith thickness.
- Some particles show longer horizontal paths through the upper part of the bedrock. and moving hundreds of meters through the regolith before reaching the surface.

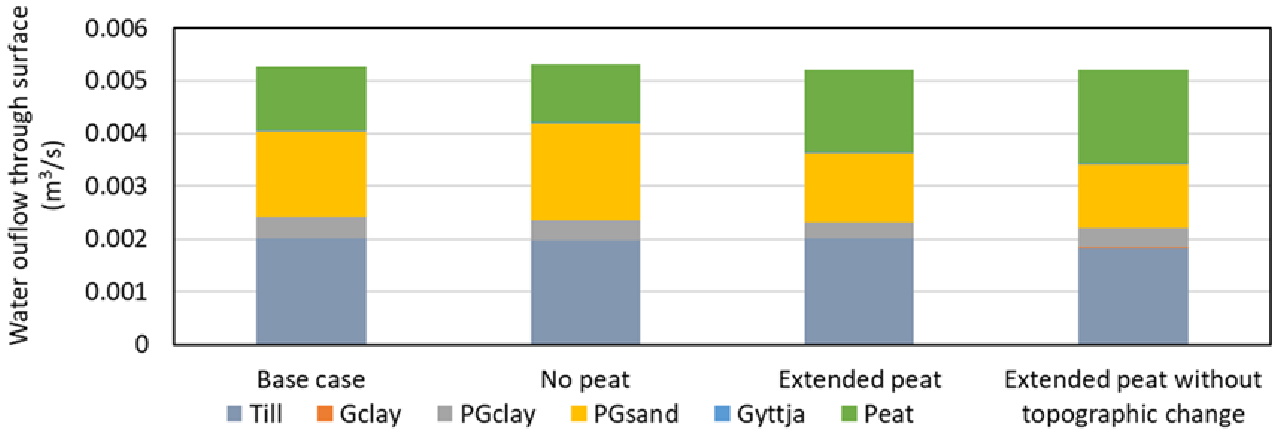




Alternate peat extension

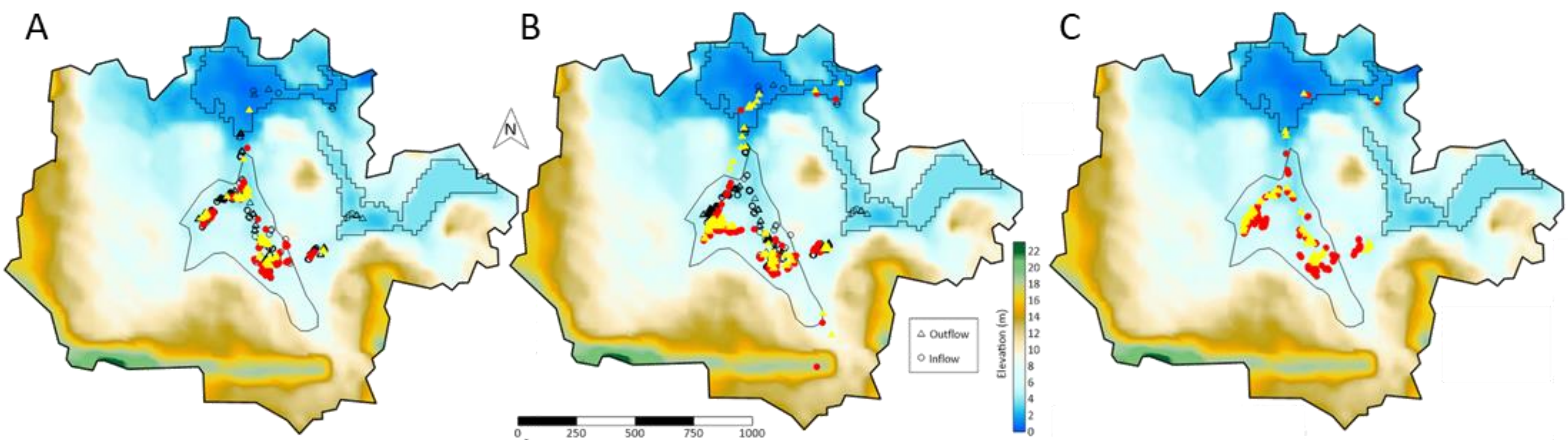
- **Groundwater flow direction:**
  - Changes in the peat extension don't influence the groundwater heads.
  - The presence or absence of peat produces local changes in the hydraulic head
  - When the surface elevation does not increase neither do the piezometric heads in the discharge zone ➔ The main factor affecting the piezometry in the discharge zones is the elevation of the topographic surface.

- **Water balance:**
  - Groundwater flow through the regolith is similar for all the scenarios analysed ➔ the amount of water discharging through the peat is directly related to the outcrop extension of the peat.



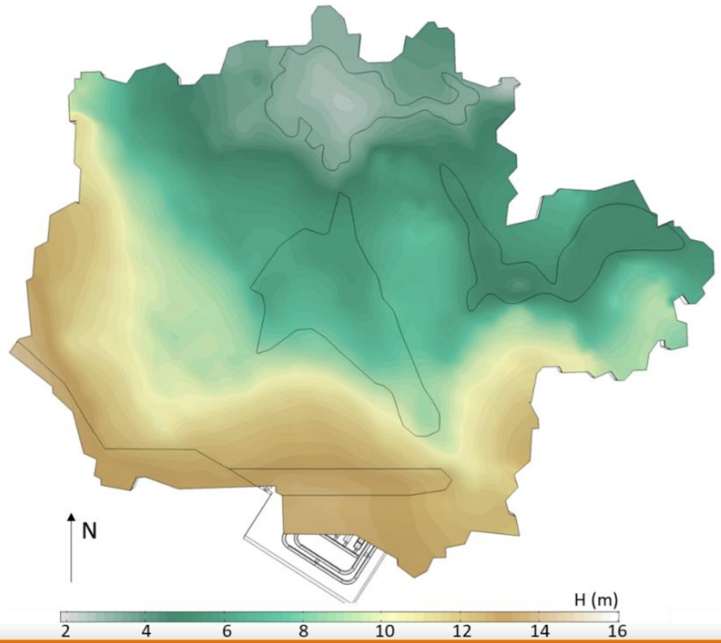
Alternate peat extension

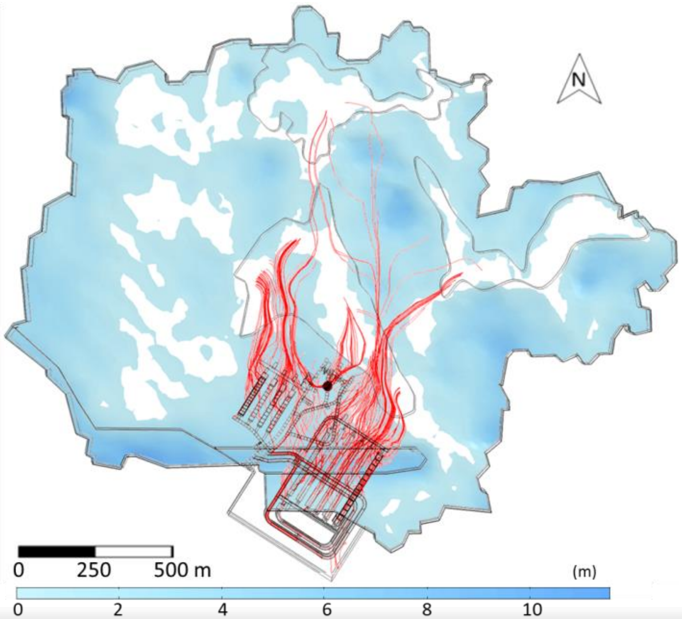
- **Particles entry and exit points:**
  - The low permeability of the overlying peat layer hinders the vertical transport of the water and promotes horizontal flow through the regolith ➔ The effect is small and restricted to a small area because most of the water flows to the surface through the till and postglacial sand.
  - The change in the topography of the model surface is responsible for the increased movement of particles to basin 157_1.



Homogeneous anisotropic

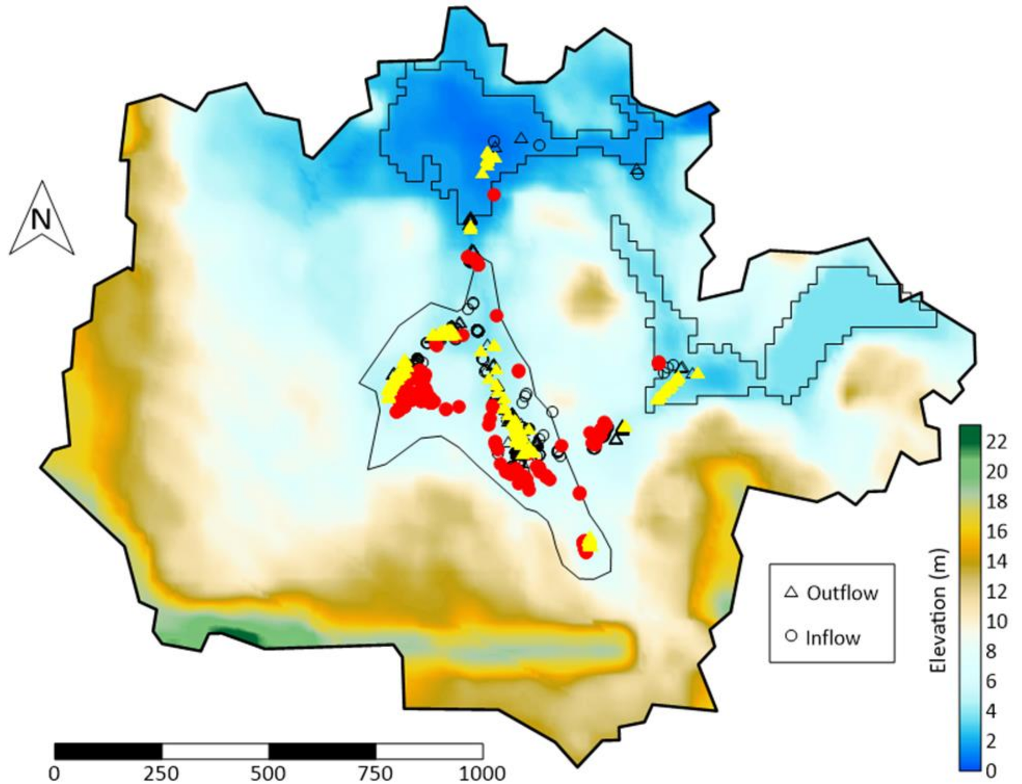
- **Groundwater flow direction:**
  - Groundwater flow direction is similar to the base case and homogeneous isotropic case.
- **Water balance:**
  - Flows through both the regolith and bedrock increase relative the base case scenario (recharge increased by 7% and discharge by 21%).
  - There is more water leaving the model via the top surface.
  - Increased hydraulic connection between the bedrock and the regolith because of the increase of the hydraulic conductivity of the regolith materials in the discharge areas increases the





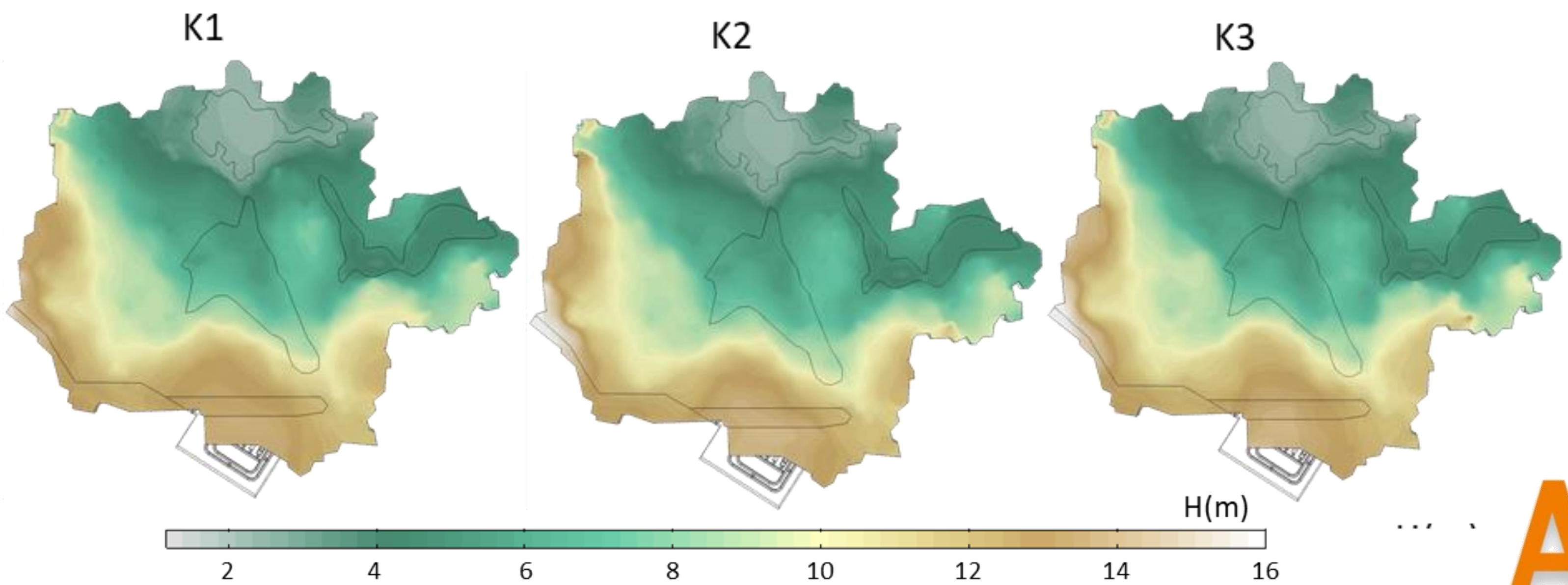
Homogeneous anisotropic

- **Particles entry and exit points:**
  - The spatial distribution of the particles entry and exit points to and from the regolith is not altered. Exit points overlap the entry points along the deformation zone lineaments, which illustrates the prevalence of the vertical flow component at the discharge areas.
  - Among all cases that represent a simplified regolith, the distribution of the particles in this scenario resembles the most that of the full representation of the regolith in the base case.



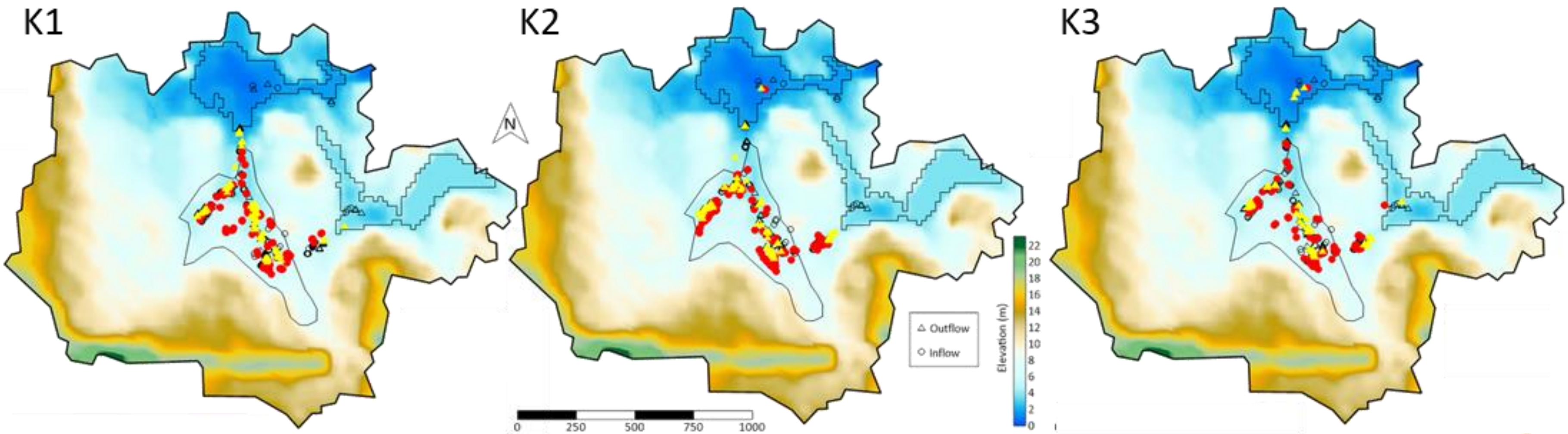
Heterogeneous permeability distribution in the till

- **Groundwater flow direction:**
  - Not substantial variability in the groundwater heads for the three realizations and with respect to the base case.
  - The spatial variation of the till properties produces local changes in the flow field that increases the dispersion of flow paths connecting the repository to the surface.
- **Water balance:**
  - The change in the bedrock inflow and outflow is less than 2%.
  - The surface discharge increases up to 8% for one of the three realizations
  - This variability is produced by the local changes in the till permeability that modifies locally the groundwater flows



Heterogeneous permeability distribution in the till

- **Particles entry and exit points:**
  - The variability in the hydraulic properties of the till affect the position of the particles entering then regolith.
  - The exit points do not display that variability and they follow the valley axis, as in the base case ➔ the exit points are mainly controlled by the topography and the outcrop of materials at the surface.



Conclusions

- The change in topography (alternate peat extension) affects the groundwater elevation, the groundwater flows and the location of the exit points.

- The homogeneous anisotropic regolith is the best simplified representation of the full regolith representation (base case) in terms of the groundwater flow and the characterization of advective paths

- The change in the properties of the outcropping materials impact the amount of water flowing through the regolith and the groundwater elevation (homogeneous anisotropic case, homogeneous isotropic case, two material case).

- The location of the exit points is mainly controlled by the topography.

- The variability in the till properties does affect the location of the entry points and does not affect the groundwater elevation, the flows through the regolith and the exit points of the particles.

On going work

- Currently we are performing transport simulations of a nonreactive tracer.
- The objective is to see if the results obtained with the groundwater flow and particle simulation are still valid when the diffusion and dispersion act a relevant role.
- Thus, Groundwater flow simulation are used as input for the ADE simulation
- The simulation focus on the transport through the regolith

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