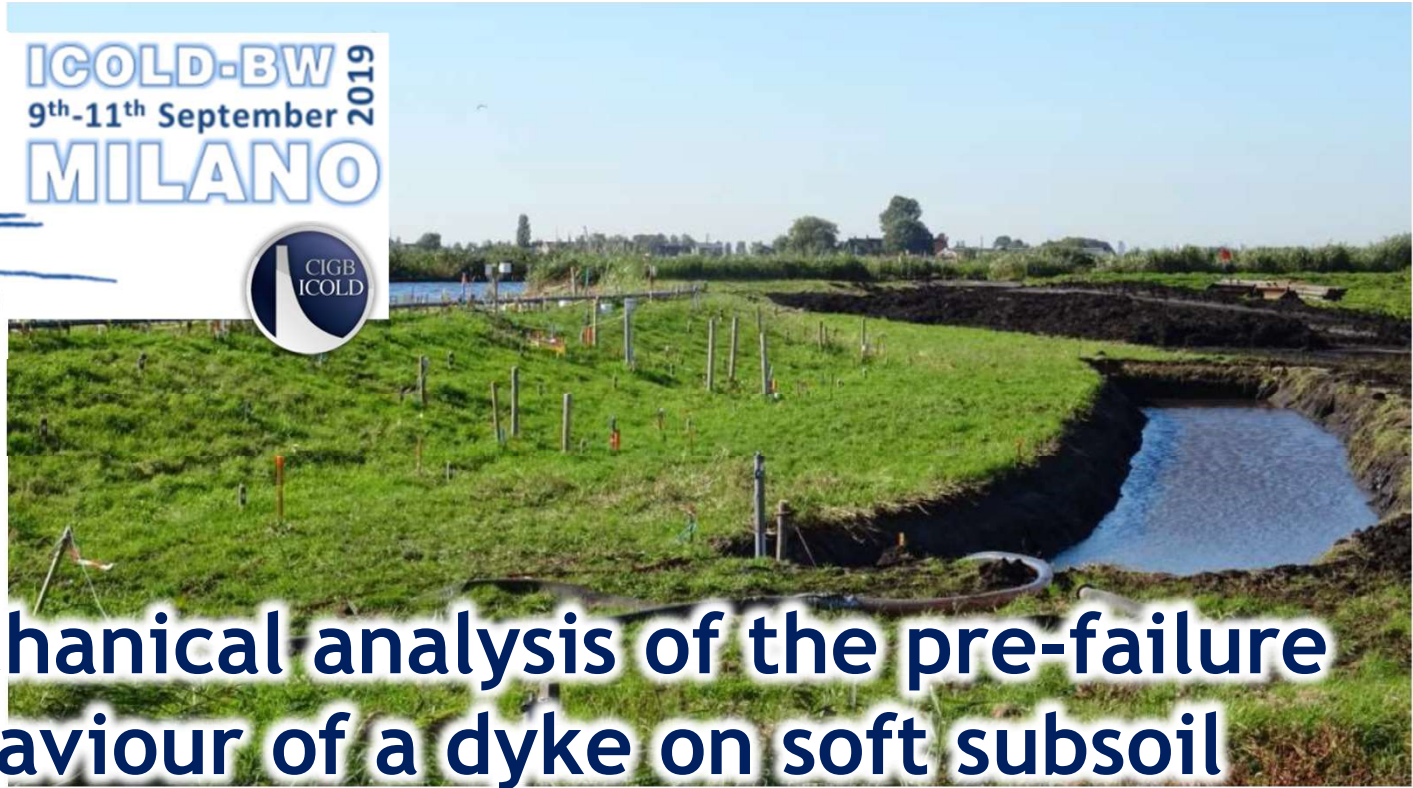


ICOLD-BW
9th-11th September 2019
MILANO



10th September 2019

Theme C: Coupled hydro-mechanical analysis of the pre-failure and the failure behaviour of a dyke on soft subsoil

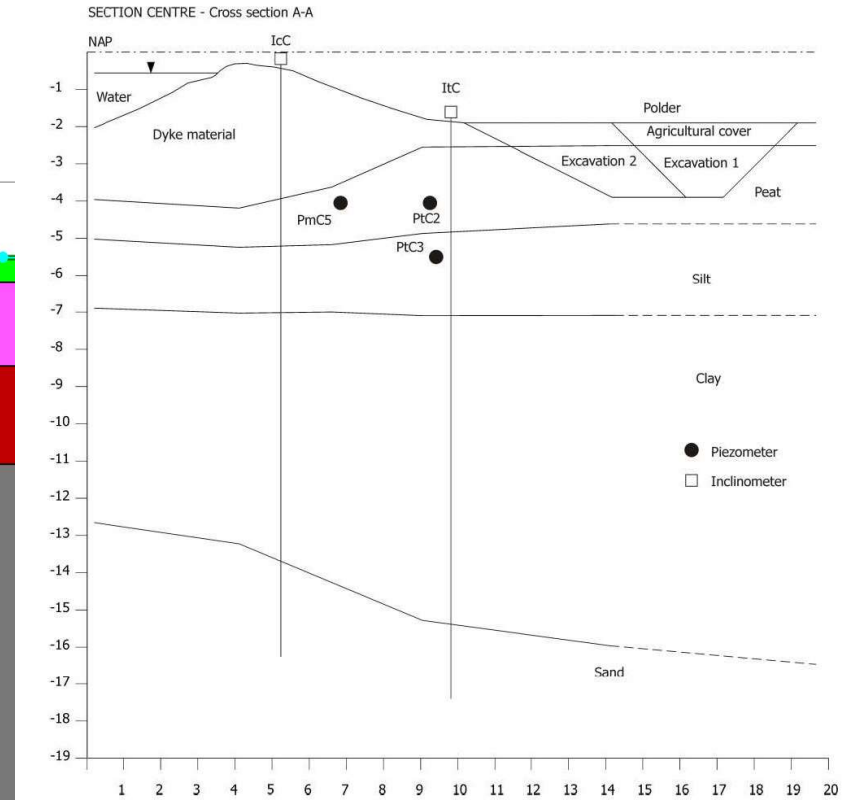
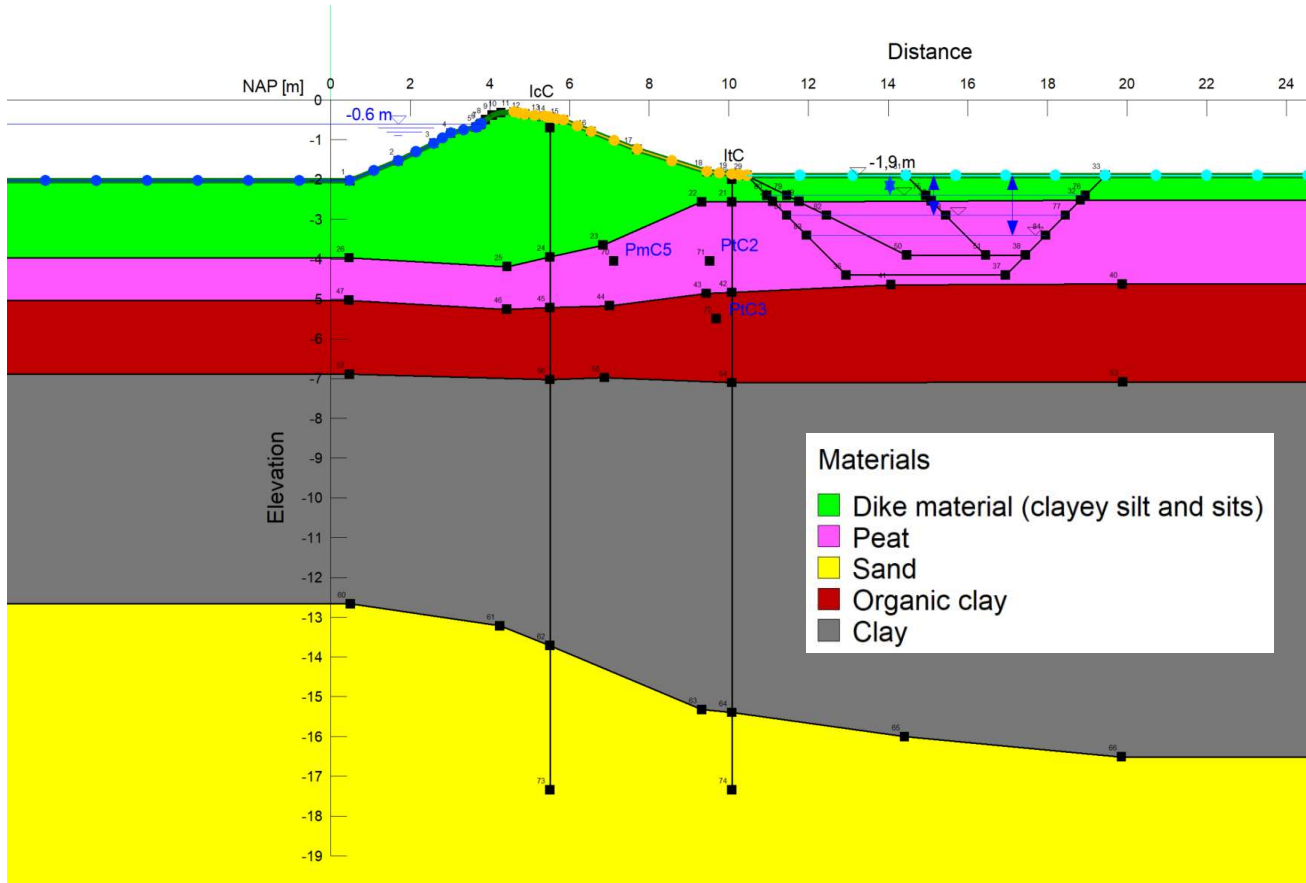


Bakeš M., Mészáros T., Minárik M.

*VODOHOSPODÁRSKA VÝSTAVBA, SOE, Department of dam safety,
Bratislava, SLOVAKIA*



Geostudio 2016 - geometry, meshing and materials



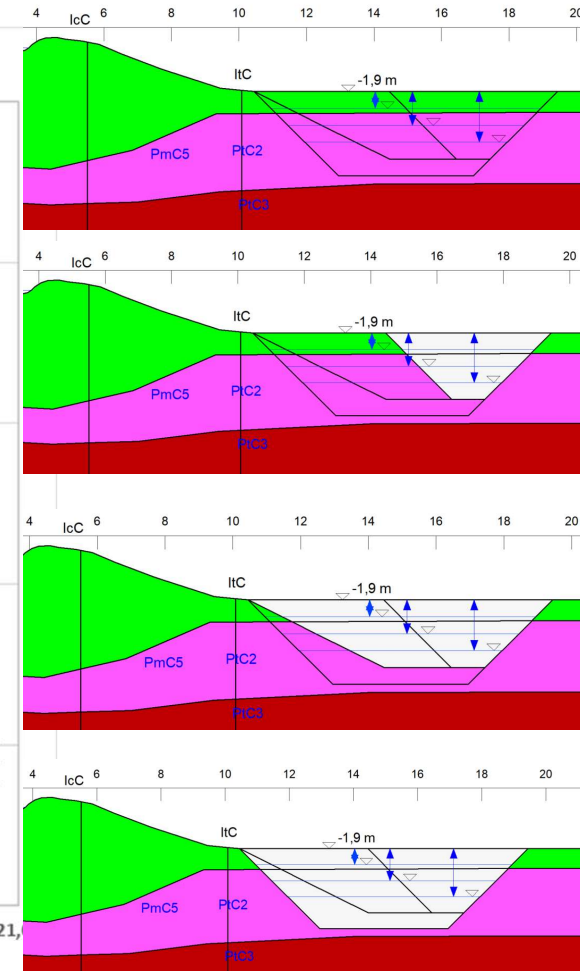
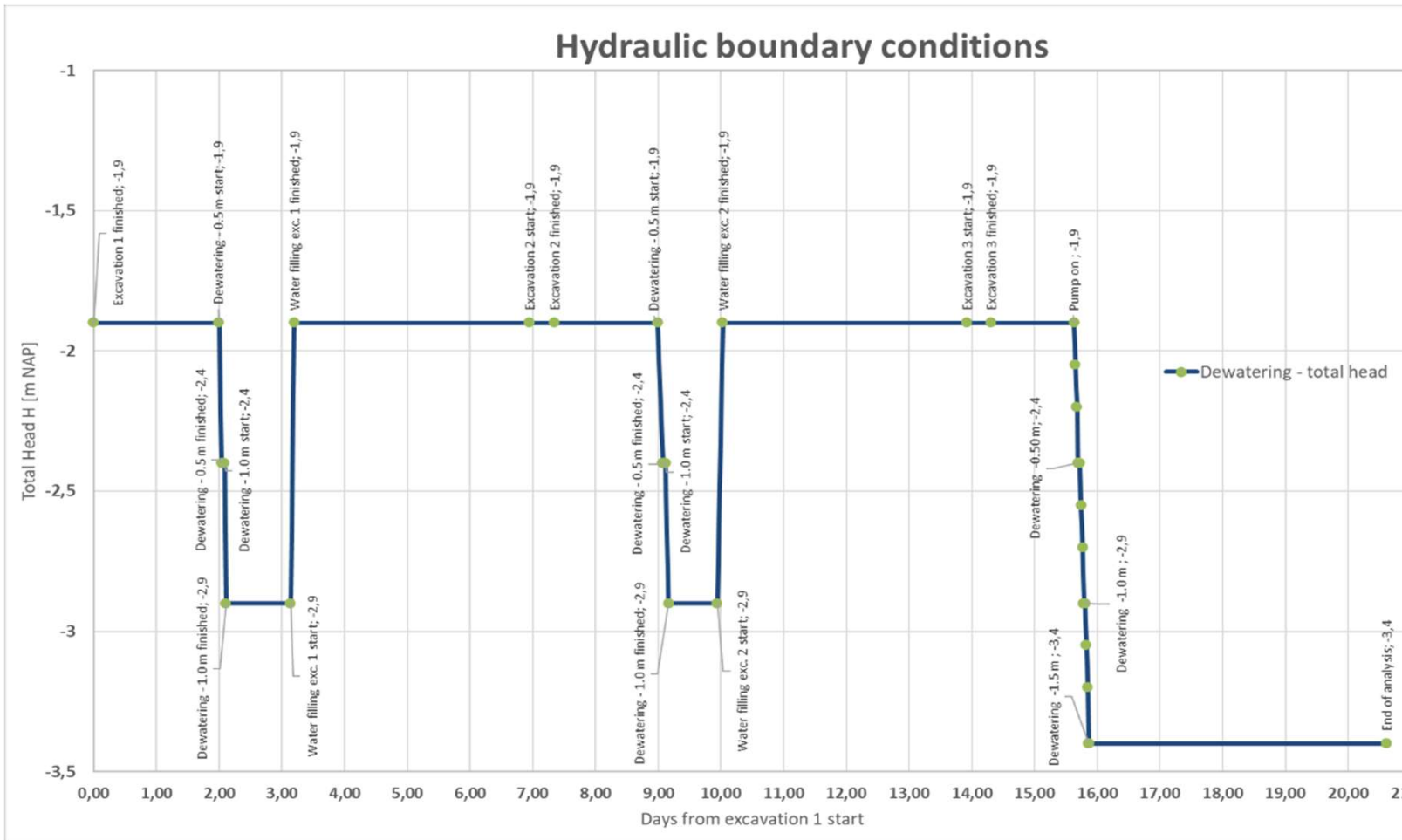
4596 quad and triangle elements average size of 0.5 m with 4500 nodes

Numerical model - Analysis tree in GeoStudio



1. Stage – Initial conditions
 - 1. analysis – steady-state seepage
 - 2. analysis – in situ stress
2. Stage – 1. Excavation and dewatering – (0 – 600 000 [s])
 - 3. analysis – fully coupled hydro-mechanical
3. Stage – 2. Excavation and dewatering – (600 000 – 1 202 400 [s])
 - 4. analysis – fully coupled hydro-mechanical
 - 5. analysis – FEM slope stability
4. Stage – 3. Excavation and dewatering – (1 202 400 – 1 780 800 [s])
 - 6. analysis – fully coupled hydro-mechanical
 - 7. analysis – FEM slope stability

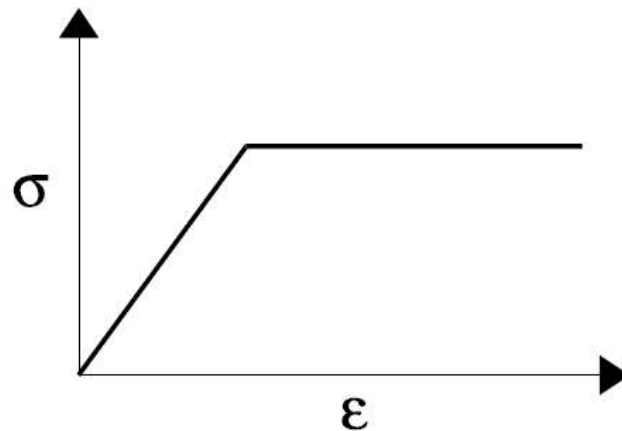
Time stepping and boundary conditions



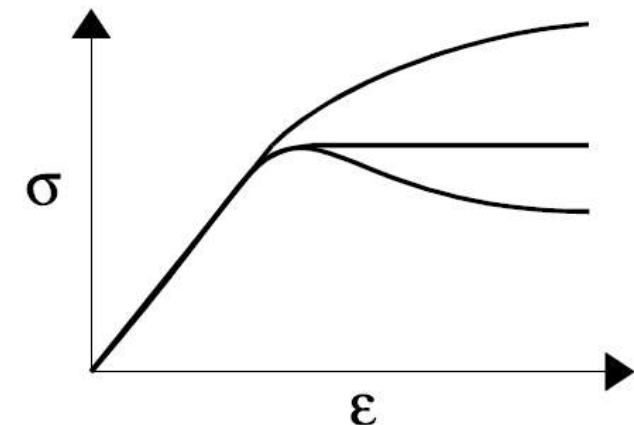
Material properties and models

Col.	Name	Model	γ	c'	ϕ'	E'	K_f	λ	κ	ν	e
[-]	[-]	[-]	[kN/m ³]	[kPa]	[°]	[kPa]	[m/s]	[-]	[-]	[-]	[-]
	Clay	El.-Pl.	14	8	21.7	870	1e-7			0.42	
	Dike	El.-Pl.	16.5	3.9	30.35	600	1e-6			0.39	
	Or. cl.	MCC	13.5	8	21.7		1e-7	0.214	0.016	0.42	2.8
	Peat	MCC	9.7	3.7	29		1e-8	1.063	0.167	0.33	9.5
	Sand	El.-Pl.	20		35	10000	1e-4			0.25	

- Elastic-plastic (Mohr-Coulomb or Tresca)



- Soft Clay - Modified Cam-clay (Critical State)

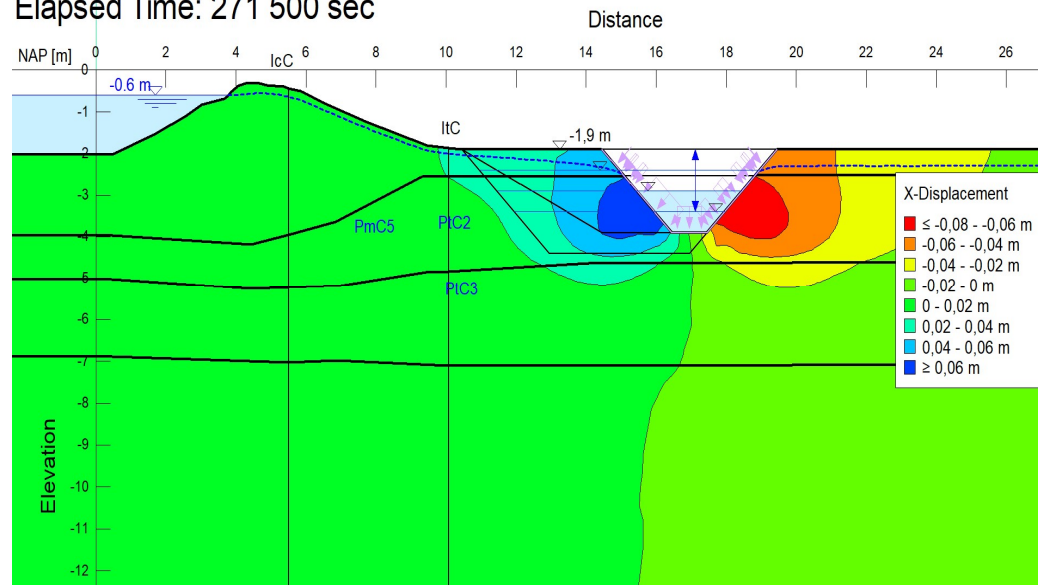


Computed results

Horizontal displacements

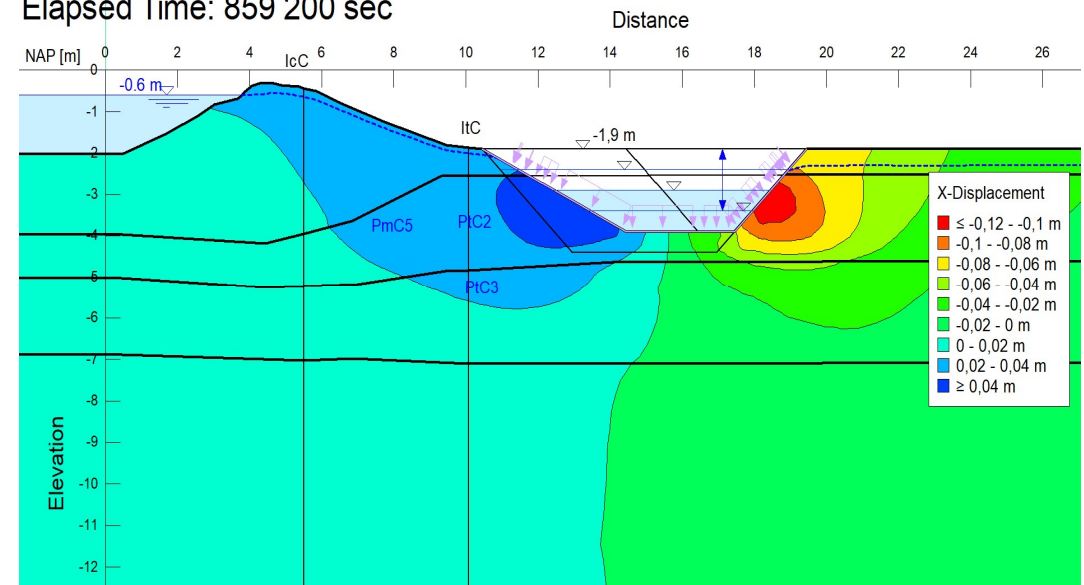
First operation sequence

Elapsed Time: 271 500 sec

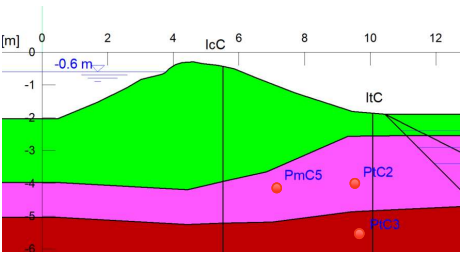
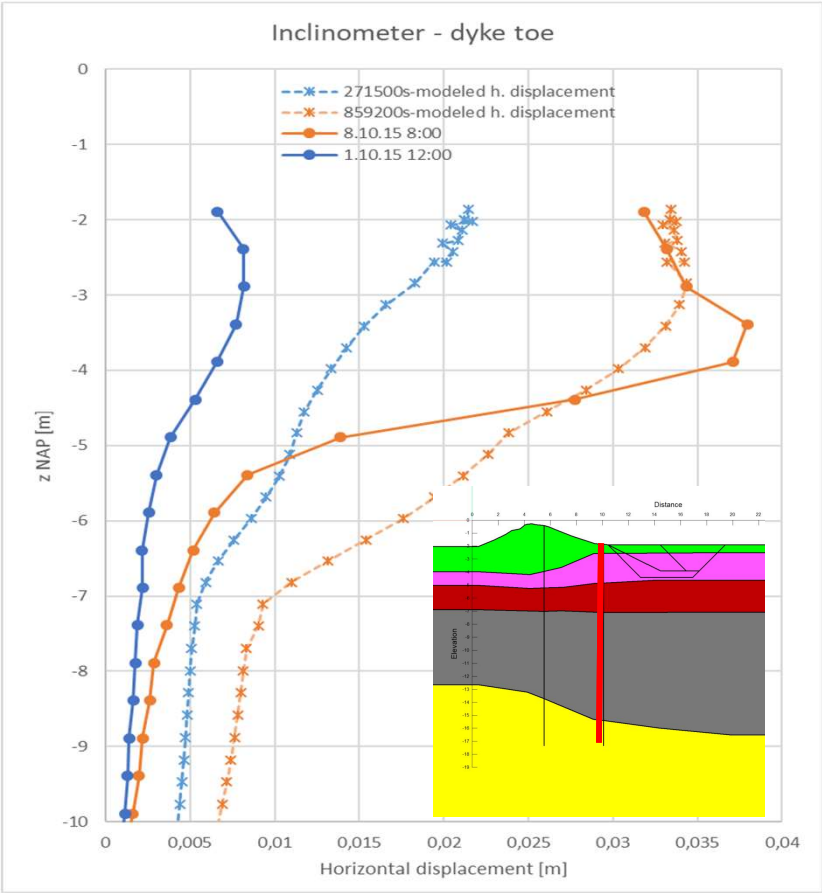


Second operation sequence

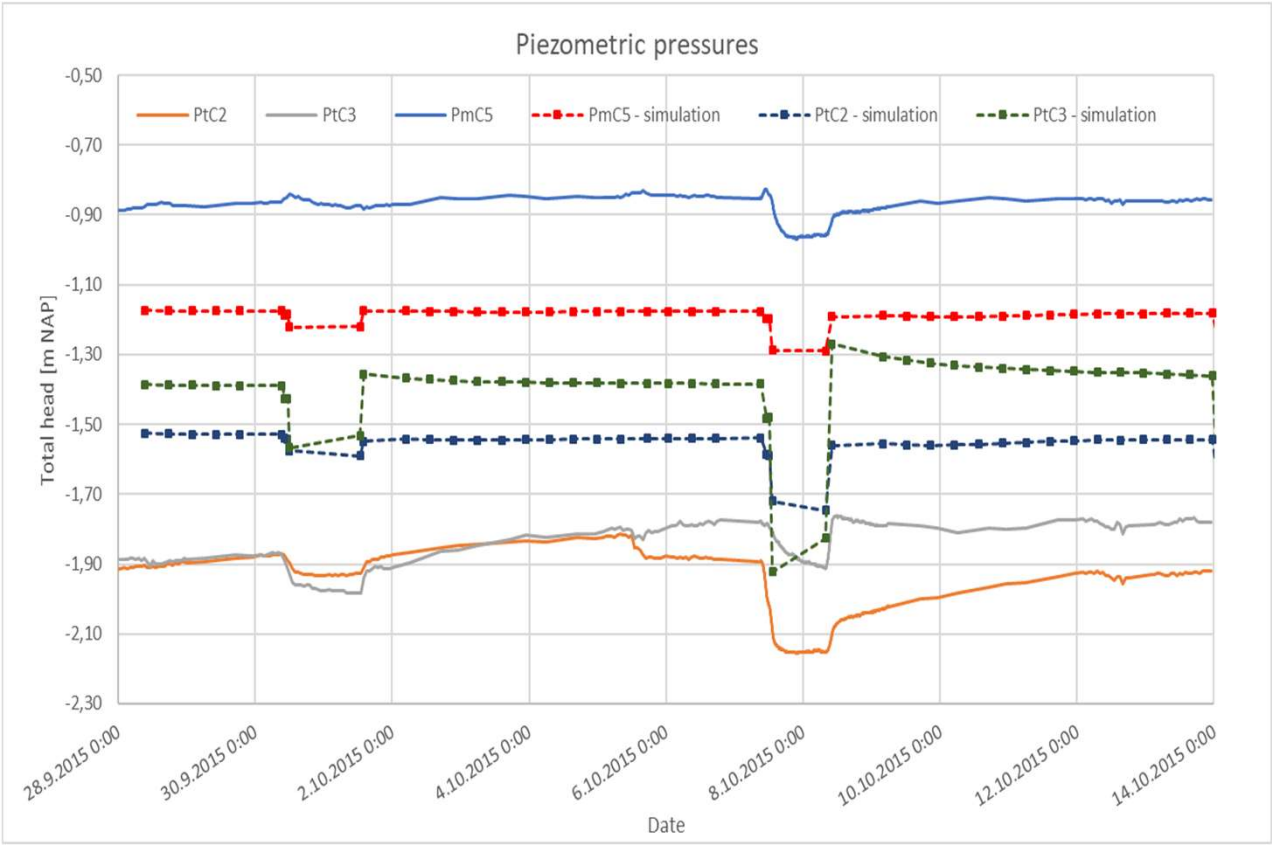
Elapsed Time: 859 200 sec



Computed and measured displacement at the
Inclinometer located at the dyke toe

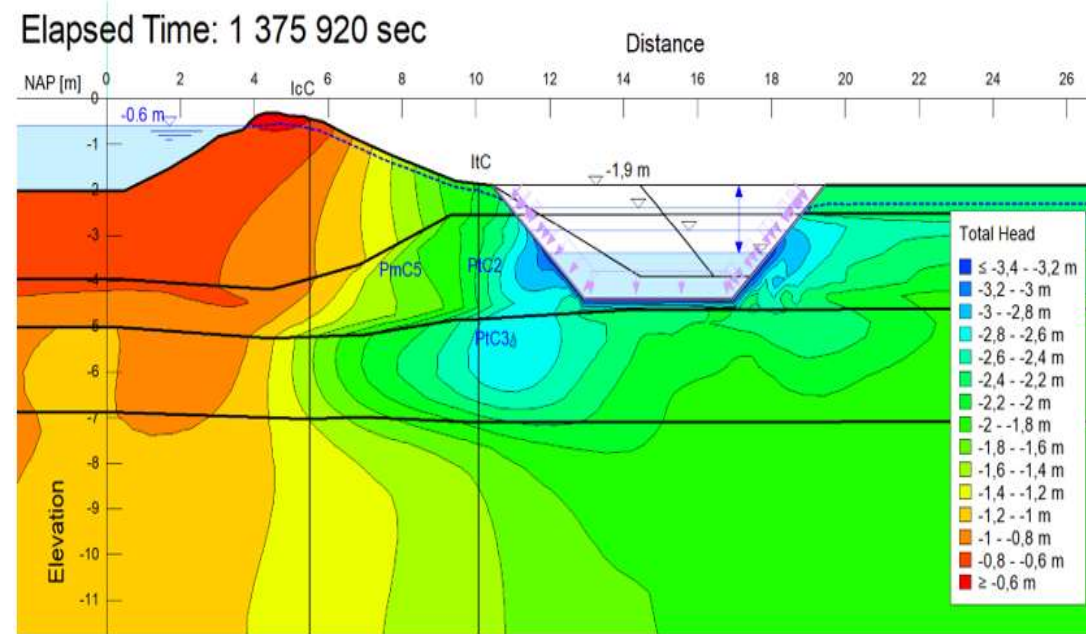
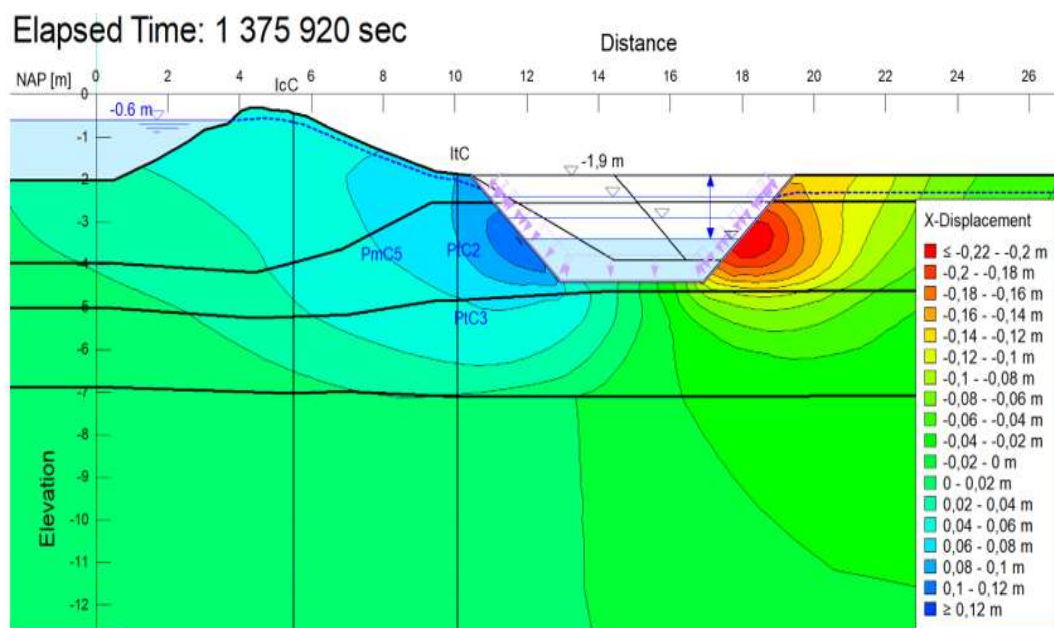


Total head at the excavation bases

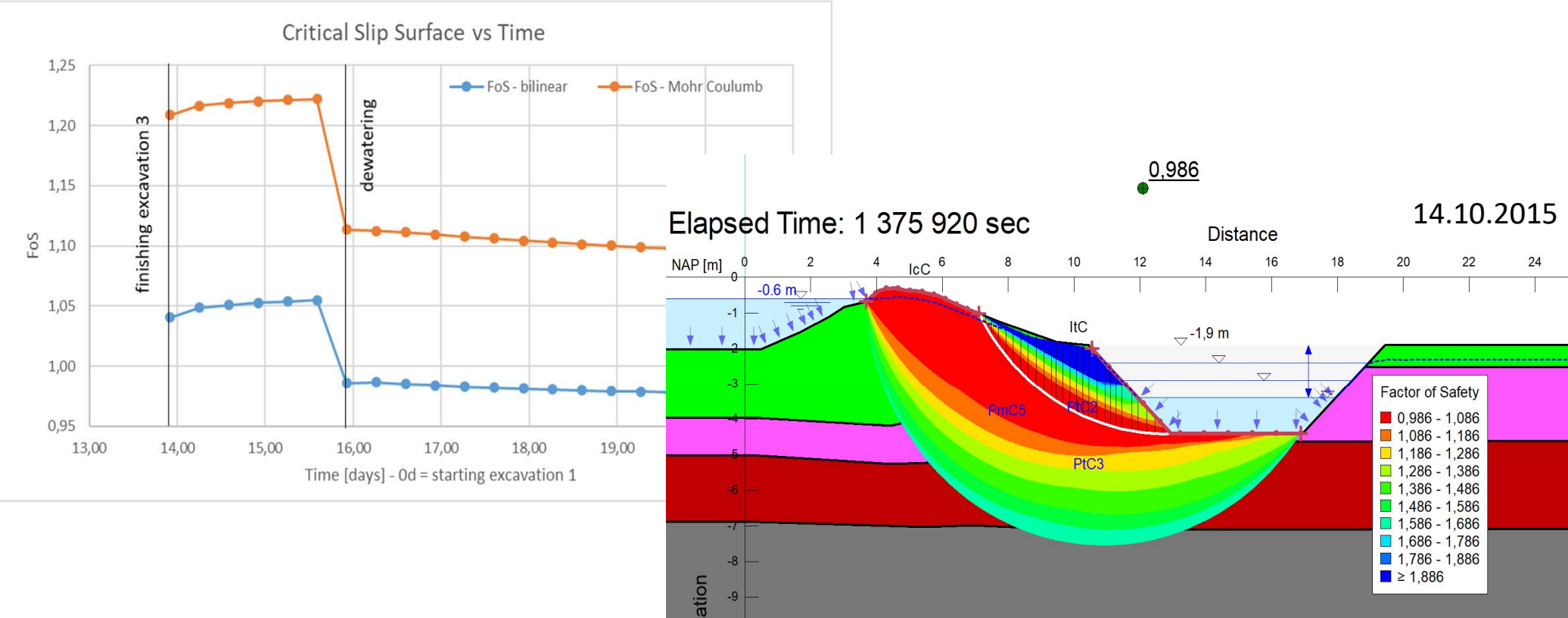


Results after third operation sequence

The horizontal displacements, computed at the dyke toe after the third excavation and its dewatering to -3.4 m NAP, varied in a range from 6 to 12 cm on the dike side



FoS of the critical slip surface during the modelled period



FoS after third excavation sequence, with bilinear model in case of the peat layer

Conclusions

1. **Failure of the structure** occurred 14.10.2015 (16 days), after dewatering the excavation to -3.4 m NAP, after the second operation sequence F_o varied in a range close to its critical value.
2. **The shape of the critical slip surface** should be considered cylindrical or curved, as used in our solution.
3. Uncertainty of the solution is emphasized by the **lack of** a thorough investigation of the **hydraulic material properties**.
4. **GEOSTUDIO 2016** is a powerful solver for computing coupled hydro-mechanical analyses. However, it offers **only the elastic, elastic-ideally plastic and the modified cam clay constitutive models**.
5. In the performed analyses, we have not been able to achieve match of the **pore pressure** with measurements. Although, we achieved a good match of the computed **displacements** with their measured counterparts.
6. **Back-analysis** was performed based on the monitoring data. All the performed refinements were in a framework of some reasonable assumption, further refinements could lead to confusing results or to their misinterpretation.