Forecasting weather driven earthwork asset performance

Ground Related Risk to Transportation Infrastructure Conference

The Geological Society

26th October 2017

Newcastle University
University of Southampton
BGS 1835
University of Bath
Loughborough University
Durham University
Queen's University Belfast
EPSRC
iSMART

.....in 2012.....

Train derails in Cumbria after landslide

Early-morning train carrying about 100 passengers left tracks following landslide near St Bees, but no injuries reported

Helen Nugent
guardian.co.uk, Thursday 30 August 2012 11.11 BST

The landslip nea

Two feared dead in Dorset landslide

Man and woman feared dead after being buried in their car for more than a week following a landslide caused by heavy rain

Steven Morris
guardian.co.uk, Tuesday 17 July 2012 16.03 BST

r tunnel. Dorset police said one body had been found in a car
e and a second was thought to be concealed in the mud. Phot
NS.com

Thornhill, Dumfrieshire, 22.11.12

29 June 2012 Last updated at 13:21

Landslides and fire disrupt rail services as rains hit Scotland

Rail disruption continues

BBC NEWS UK

News Sport Weather iPlayer TV Radio

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UK floods: Landslides cause rail disruption

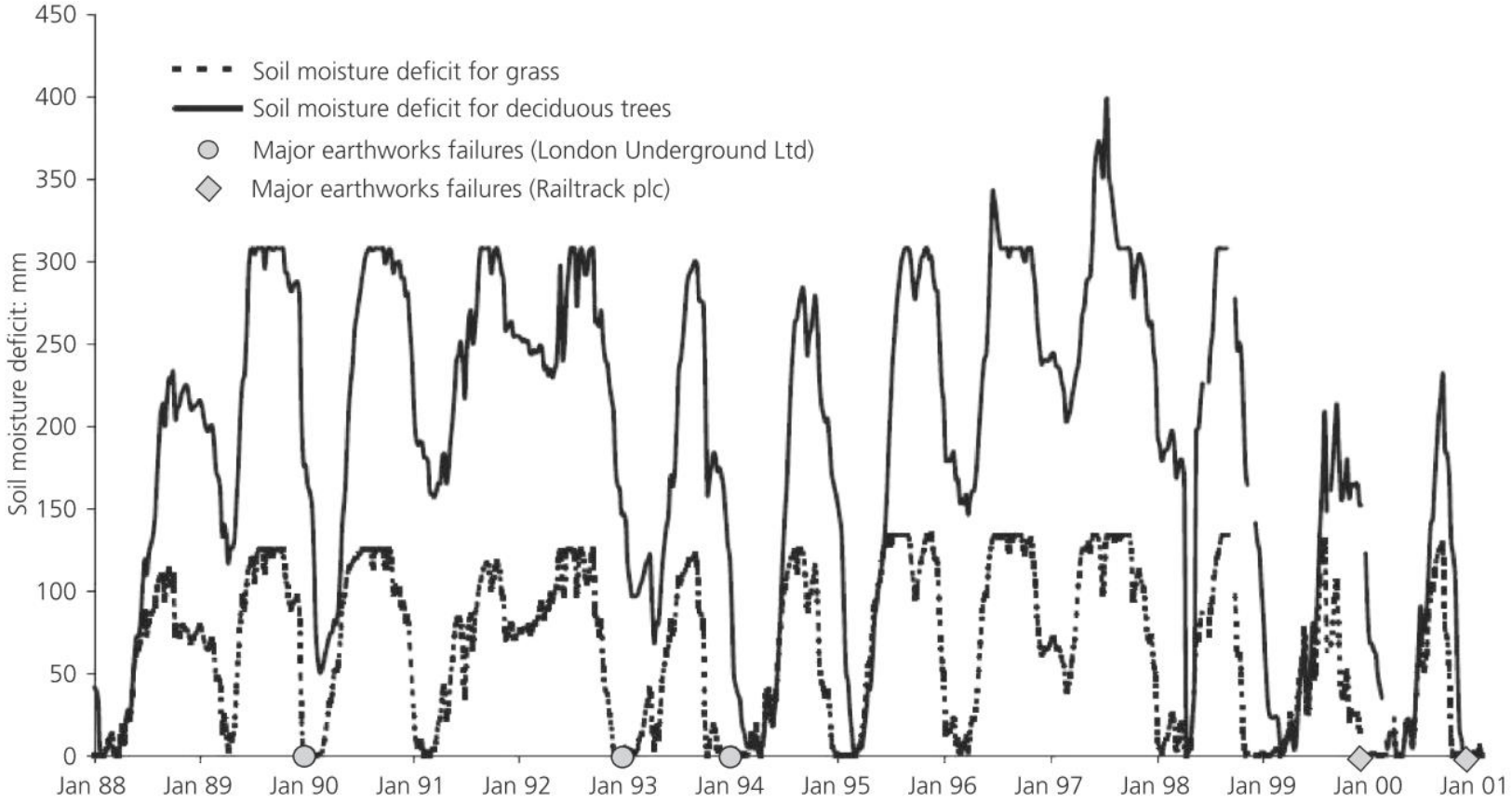
29 June 2012 Last updated at 10:51

The East Coast main line between Newcastle and Berwick-Upon-Tweed remains closed after landslides overnight, and delays continue between Newcastle and Carlisle.

At Edinburgh's Waverley Station, Ben Hall from Network Rail said there was a lot of work to do before the line could be reopened. Mr Hall also warned travellers to expect delays and disruption for some time to come.

See Briggs, K. M., Loveridge, F. A. and Glendinning, S., 2017. Failures in transport infrastructure embankments. Engineering Geology, 219, pp. 107-117

Soil Moisture Deficit and Slope Failure



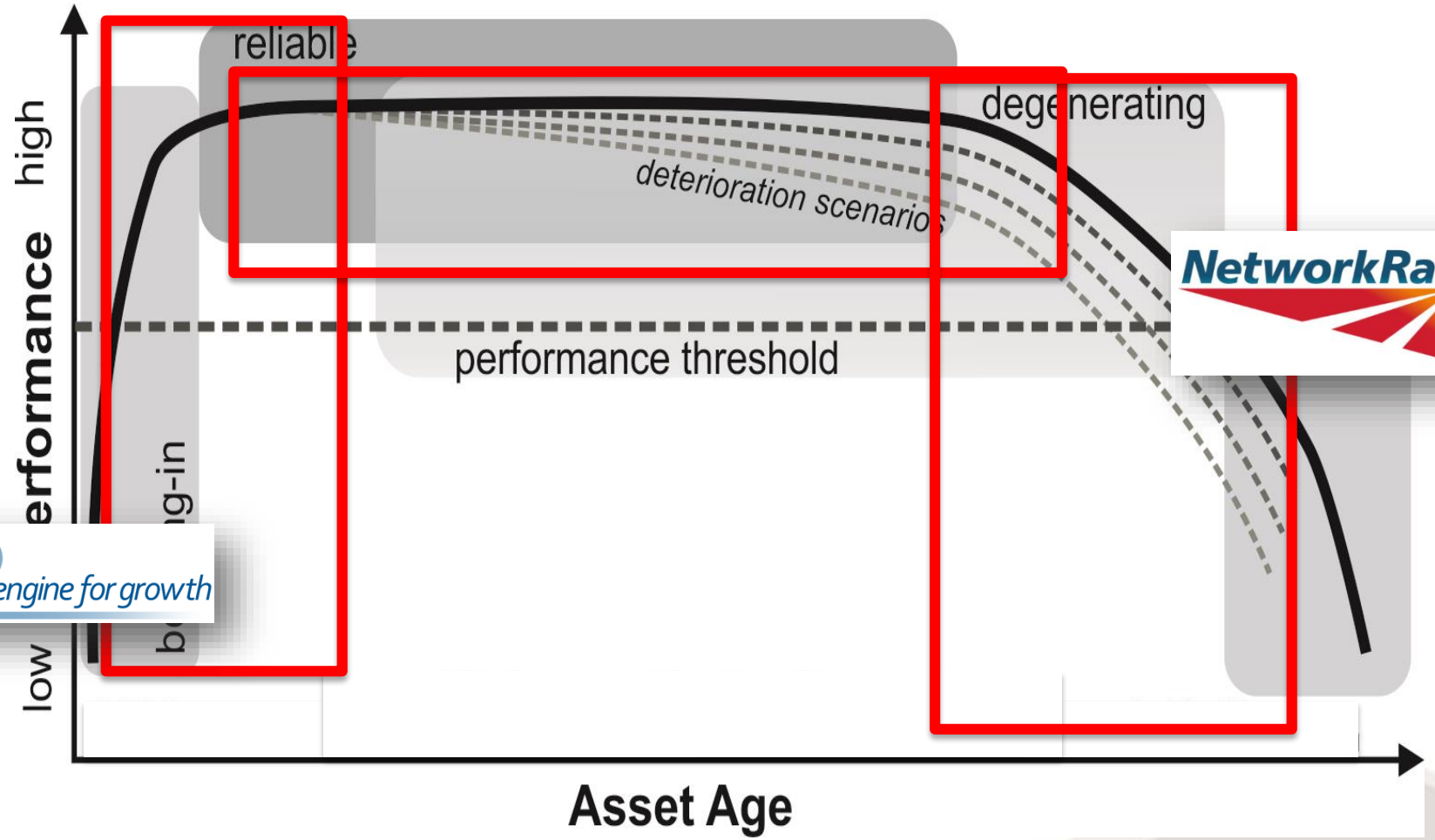
SMD – Amount of water in mm which the soil surface will absorb before further precipitation cannot be stored in the profile
Data – SMD for clays around the London area

Landslips

- Associated with periods of low (often zero) SMD
- Frequently occur during the longer low SMD periods

Taken from - Briggs, K.M., Smethurst, J.A., Powrie, W. and O'Brien, A.S. (2013a). Wet winter pore pressures in railway embankments. *Proceedings of the Institution of Civil Engineers: Geotechnical Engineering*. **166**(5):451-465.

Asset deterioration

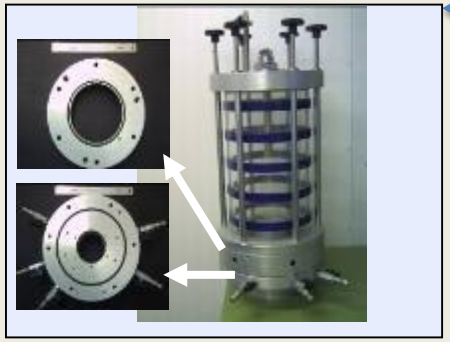


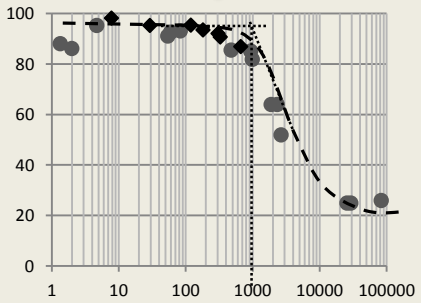
Generalised deterioration model for transport earthworks

(adapted from Thurlby, 2013)

iSMART - Summary

Scale 1





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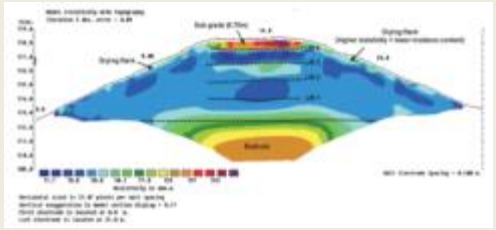

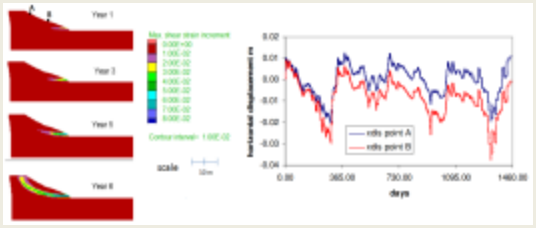

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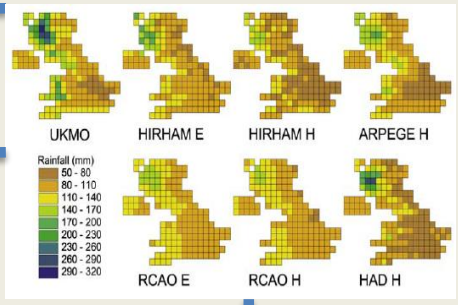

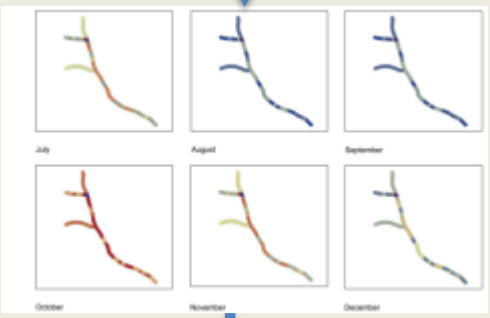

iSMART - SUMMARY

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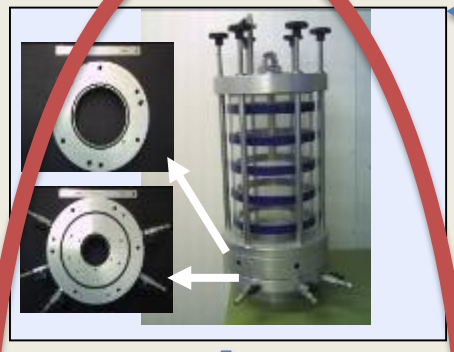

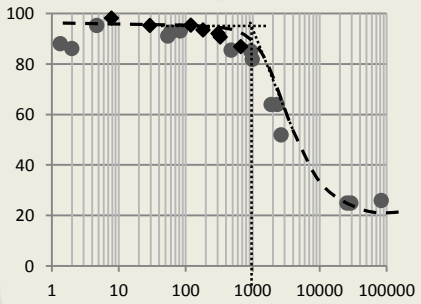

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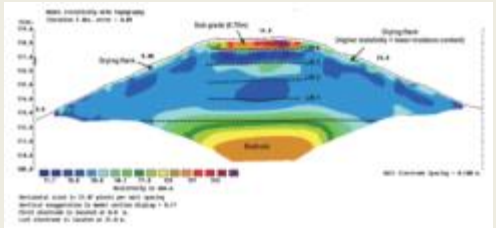

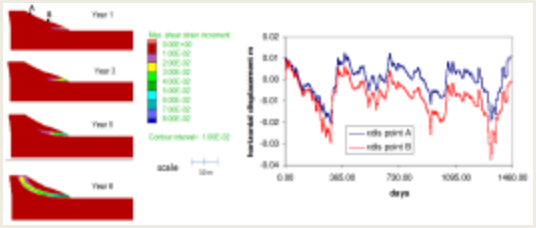

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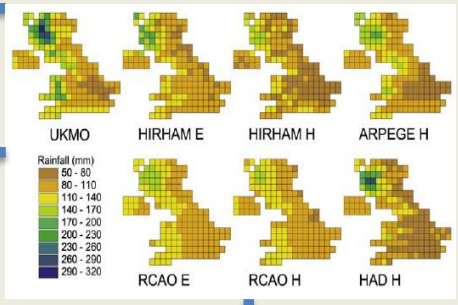
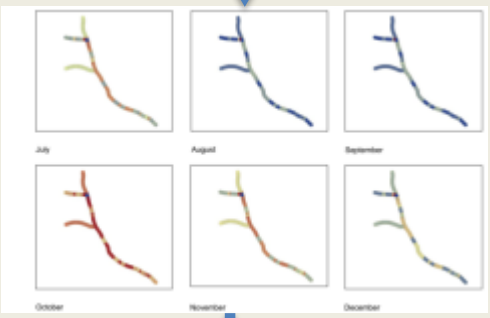
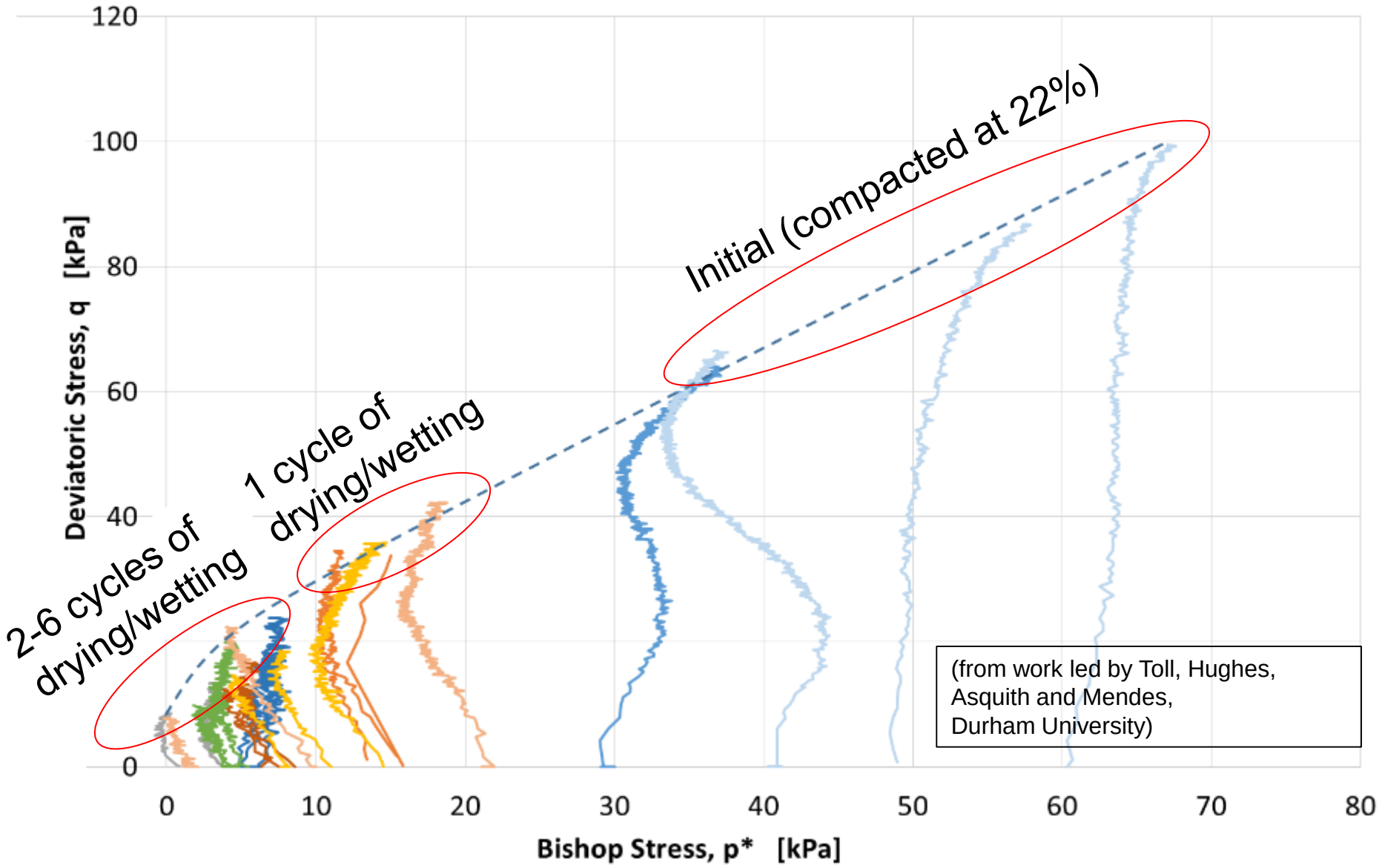
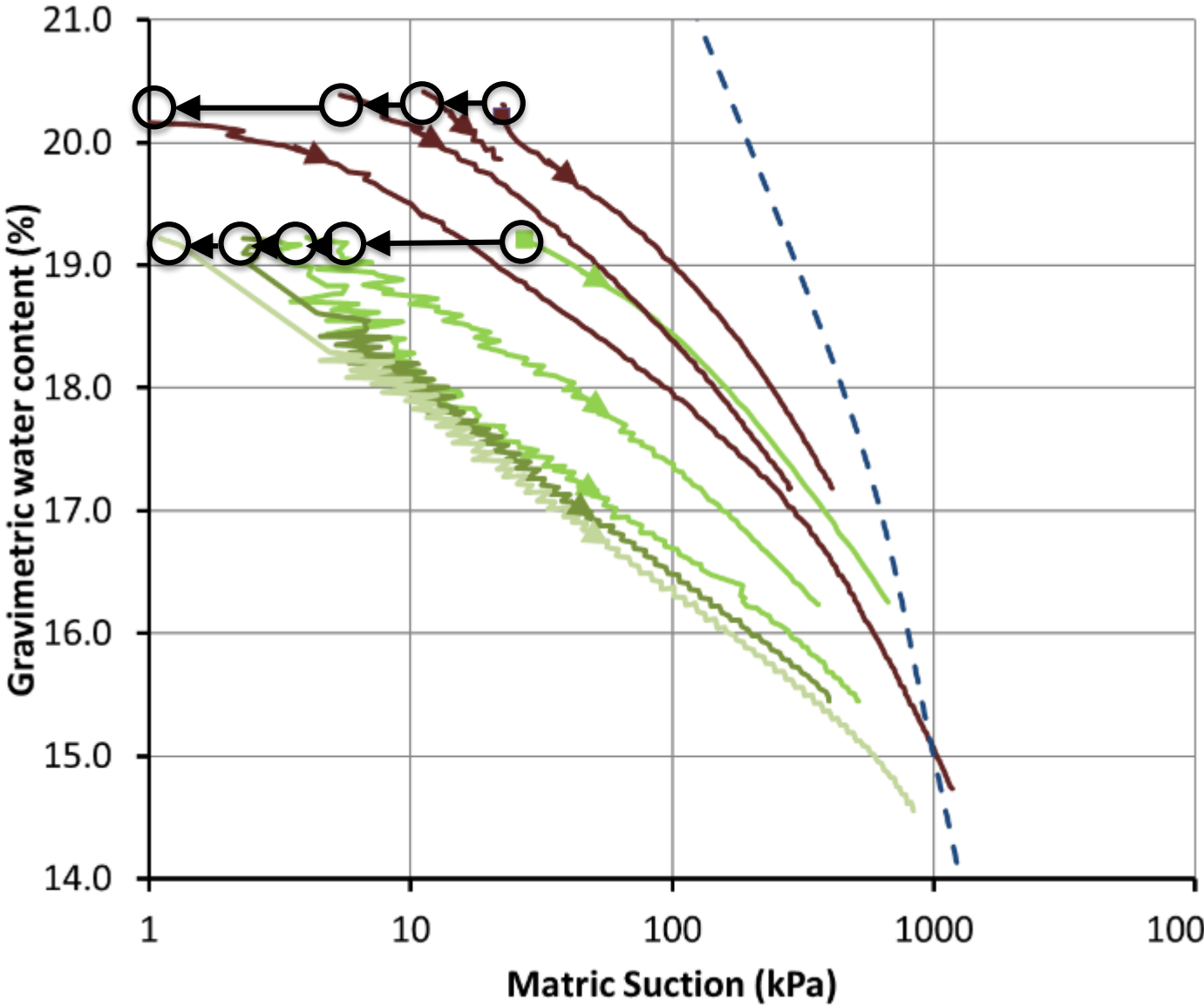




Unsaturated soil strength



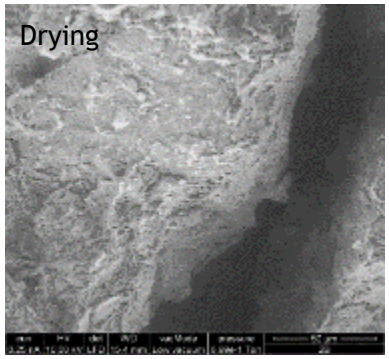
Soil water retention curves (dry-wet)

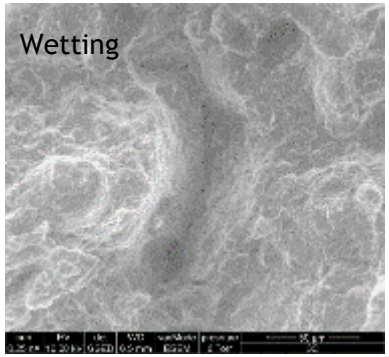


A progressive shift in the SWRC with each cycle of drying/wetting

(from work led by Toll and Hughes, Durham University)

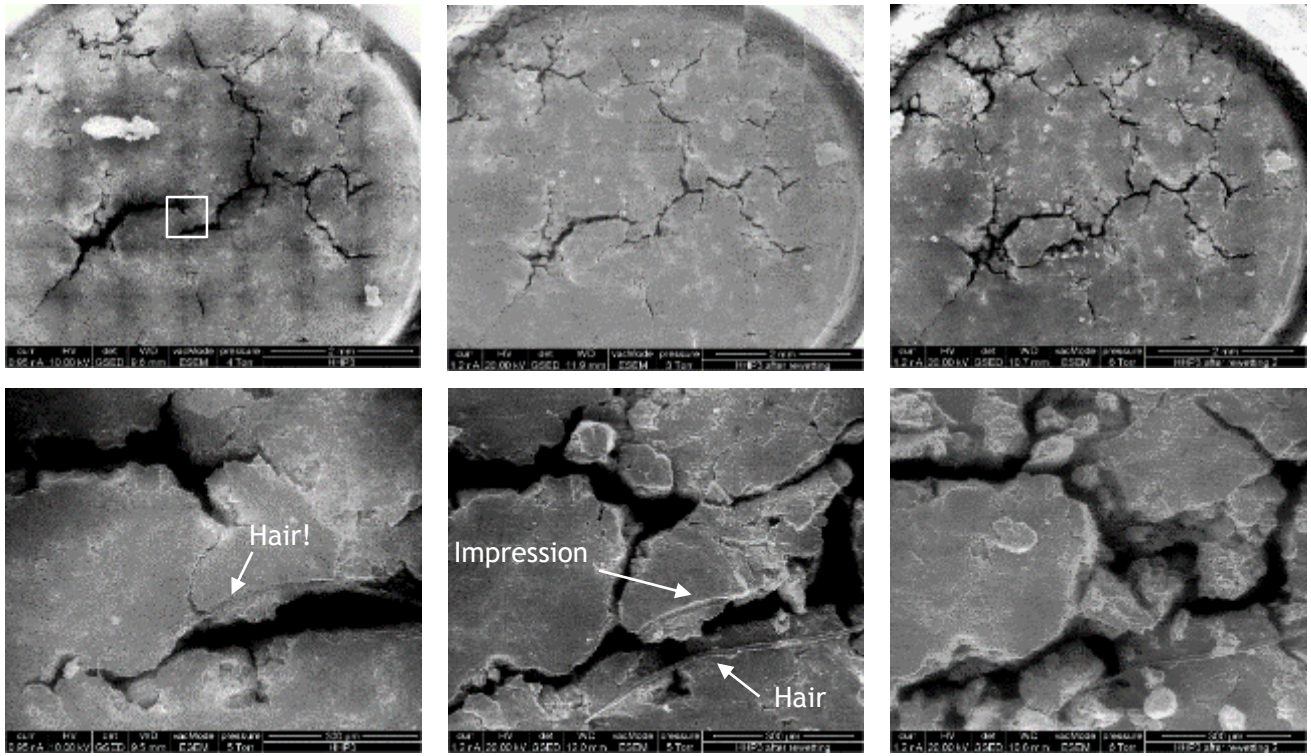
Deterioration at the micro-scale: Scanning Electron Microscopy





E-SEM scan of medium plasticity clay (BIONICS) at 5% and 22% respectively

1st Drying | 2nd Drying | 3rd Drying

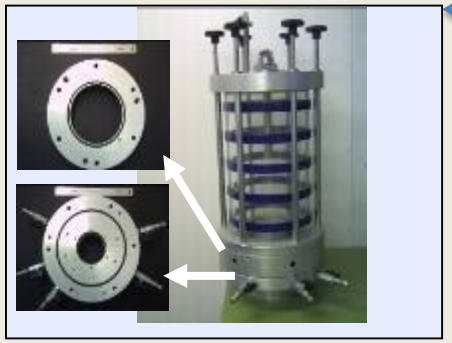


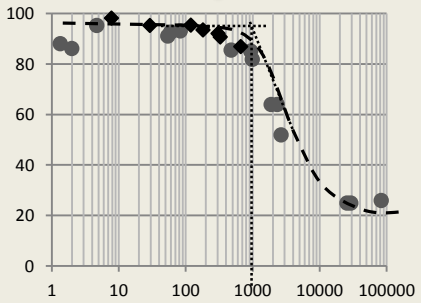
SEM imaging showing the development of micro-cracking during repeated cycles of wetting and drying.

(from work led by Stirling Newcastle University)

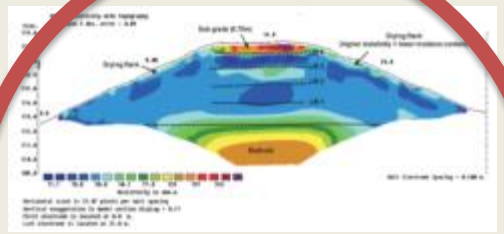
SCALE 2 - NUMERICAL MODELLING

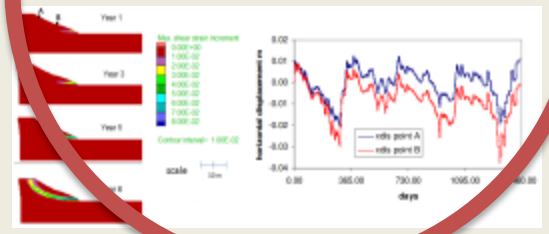
Scale 1





Scale 2





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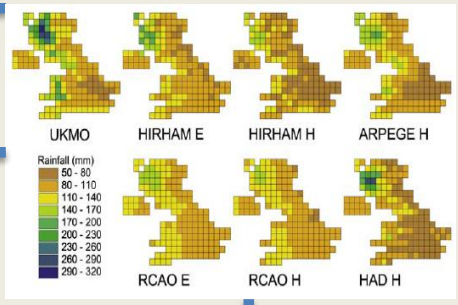
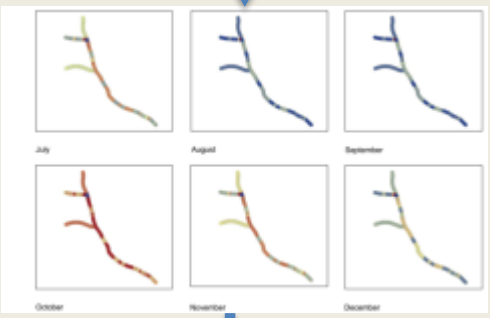
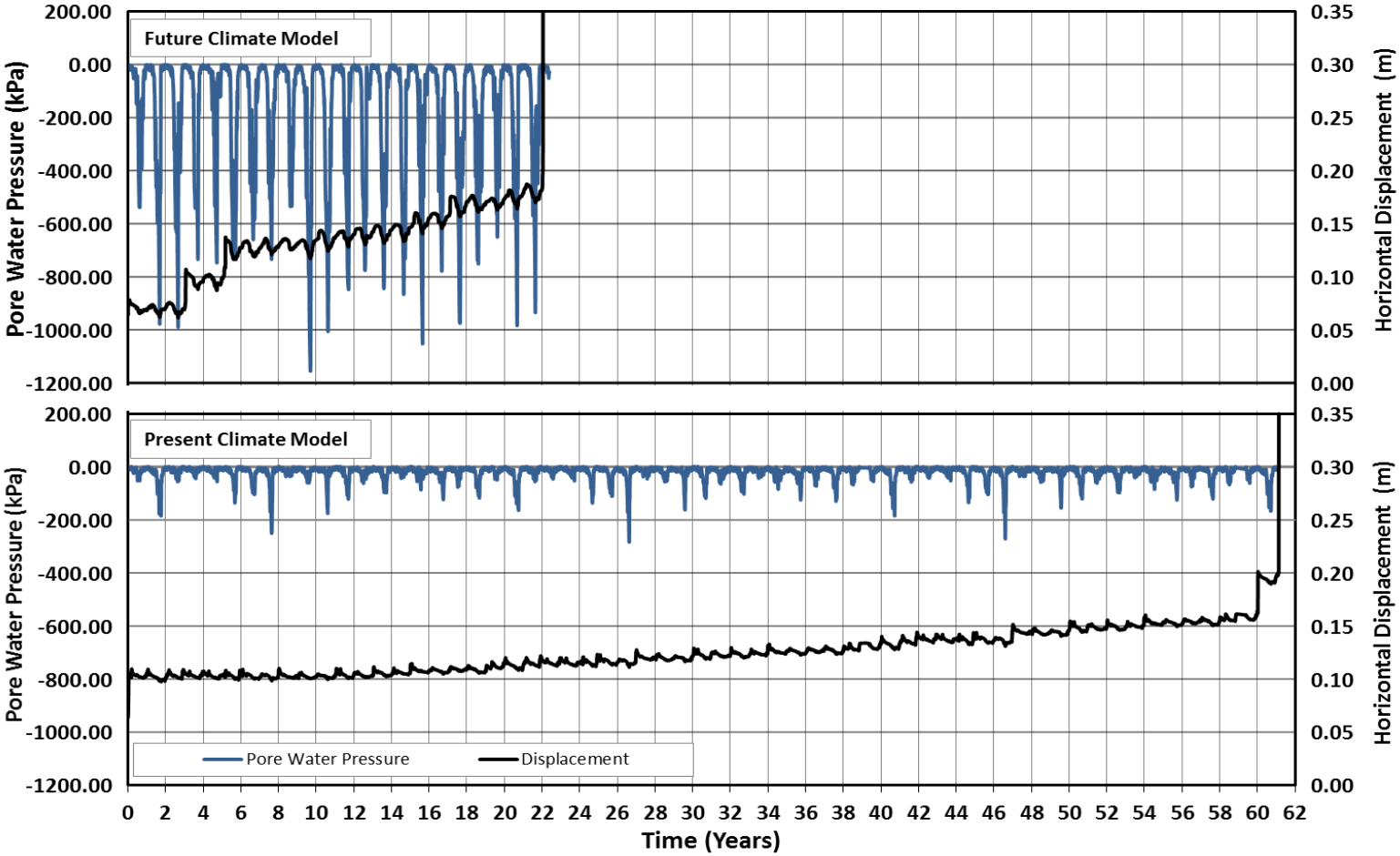




Numerical Modelling

Developed a methodology to allow the influence of meterological parameters and climate on a slope to be investigated

Model makes use of coupling between SHETRAN and FLAC with Two Phase Flow



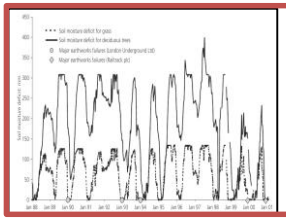
(from work led by Helm and Rouainia, Newcastle University)

Modifications to the models

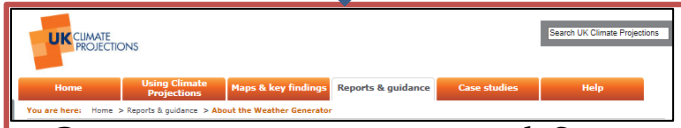
- Input parameters:
  - Strength – progressive reduction with strain
  - Stiffness – for small strains and variability with effective stress
  - Permeability – variability with depth
  - Hydrological – derived from SWRC
    - (literature, parametric study, lab and field data)
- Mesh dependency – to allow for deformations – local vs non-local strain softening; consistency between models
- Weather – to account to current and future climate, regional and local conditions

Using the UKCP09 data

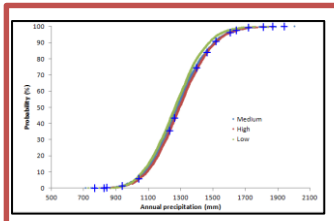
Choose representative locations in the UK



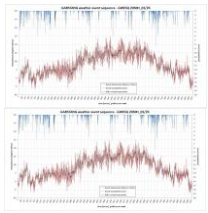
Calculate in terms of Soil Moisture deficit (Water Balance)



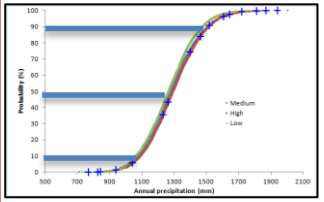
Generate current and future weather event sequences



Generate pdfs of (max to zero) SMD

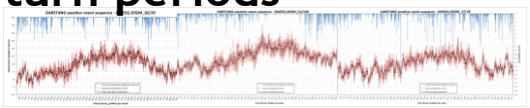


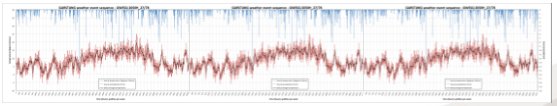
Present
2020
2050 All for the high emissions scenario
2080



Select 5 years - 10%, 20%, 50% 80%, 90%

Reassemble years to generate *scenarios* containing sequences with known return periods



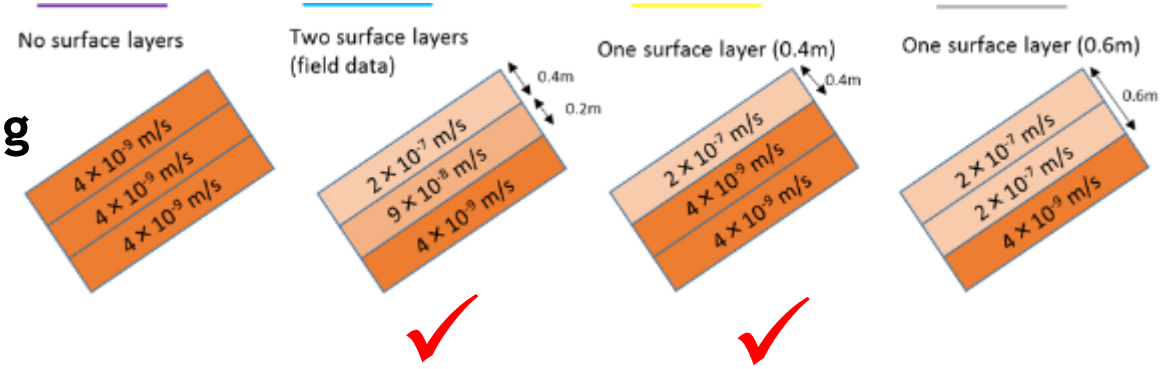


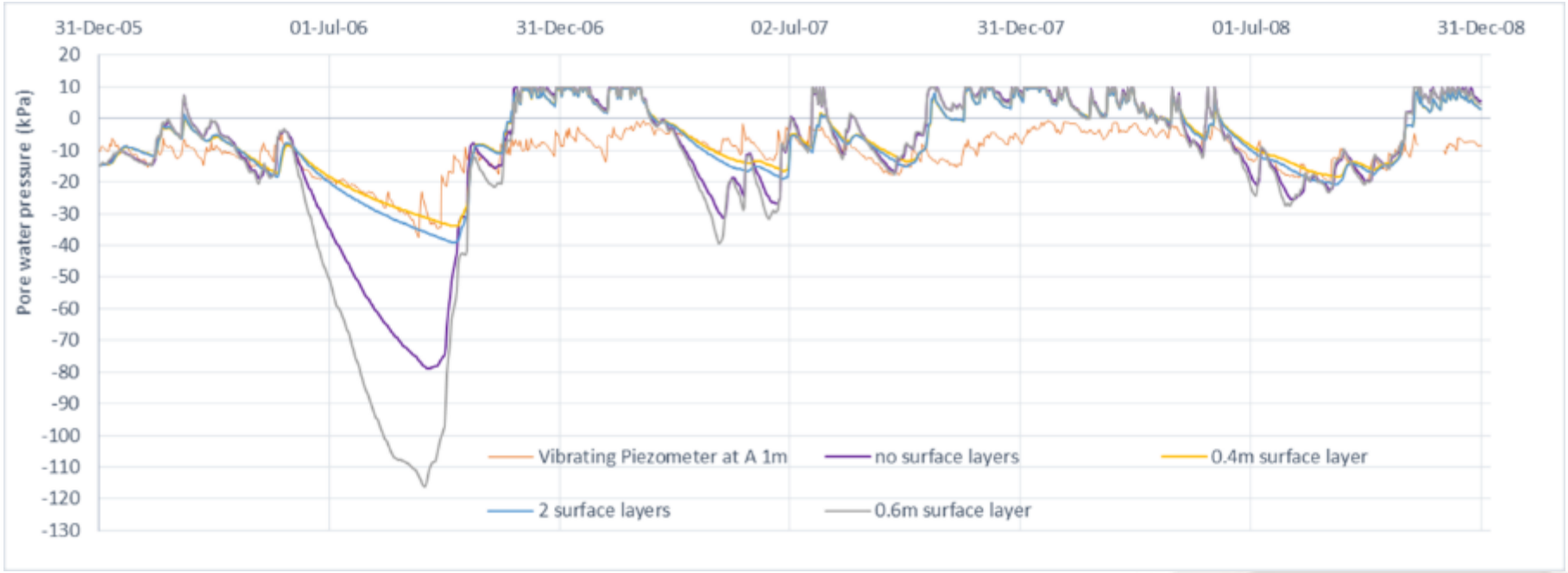
(from work led by Smethurst & Woodman, Southampton University)

Near surface permeability: Simulation results

Results

Newbury highway cutting





Pore water pressure at 1m depth – a comparison with piezometer data

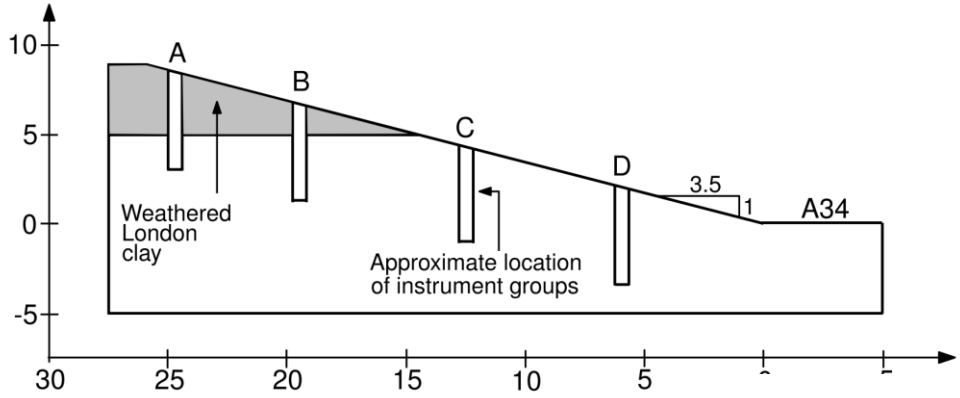
(from work led by Briggs & Muddle, Bath University)

Model Calibration & Validation

Developed a methodology to allow the influence of meterological parameters and climate on a slope to be investigated

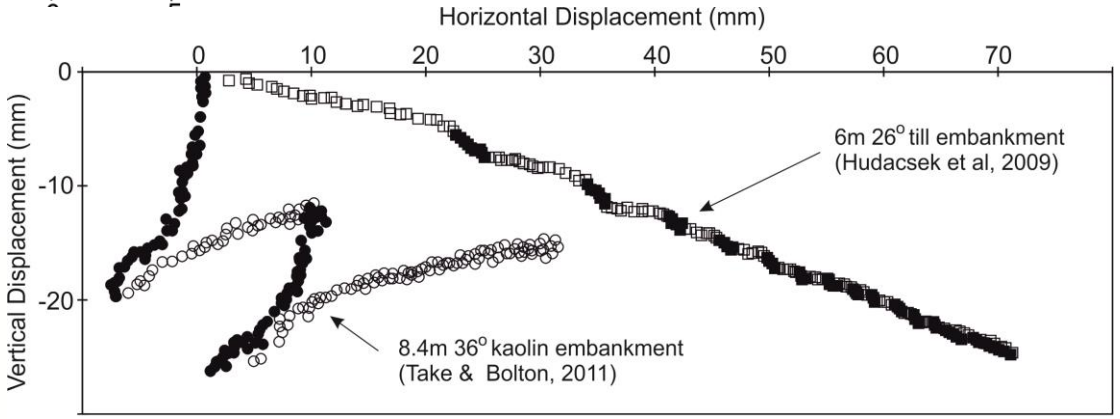
Model makes use of coupling between SHETRAN and FLAC with Two Phase Flow

Modelling approach calibrated using Newbury Cutting and Take and Bolton Centrifuge tests



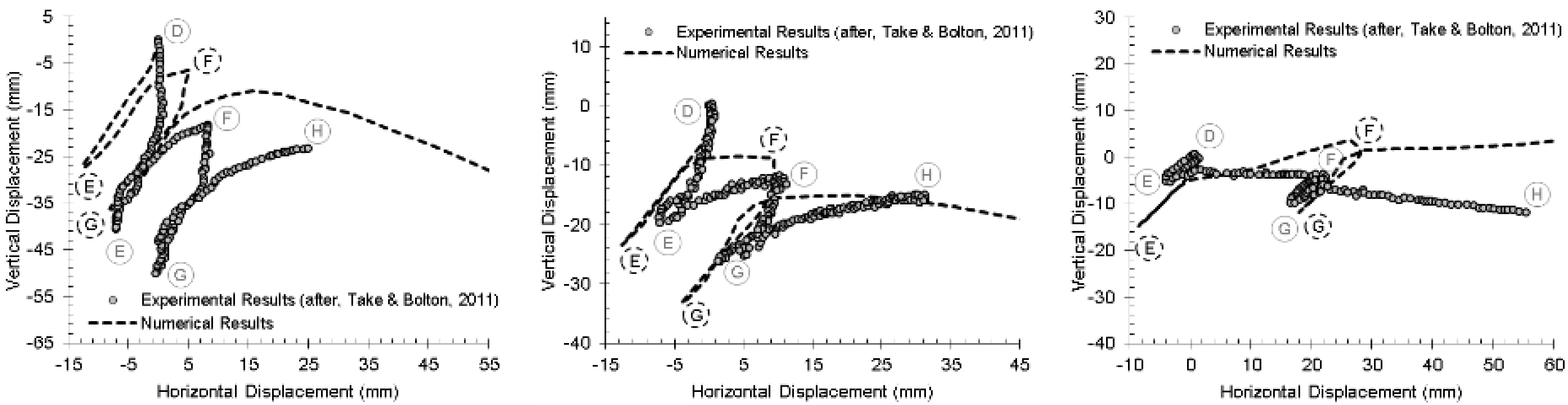
Take & Bolton – mid-slope displacements

Newbury – pore water pressures



Model validation of seasonal ratcheting

Mechanical Results



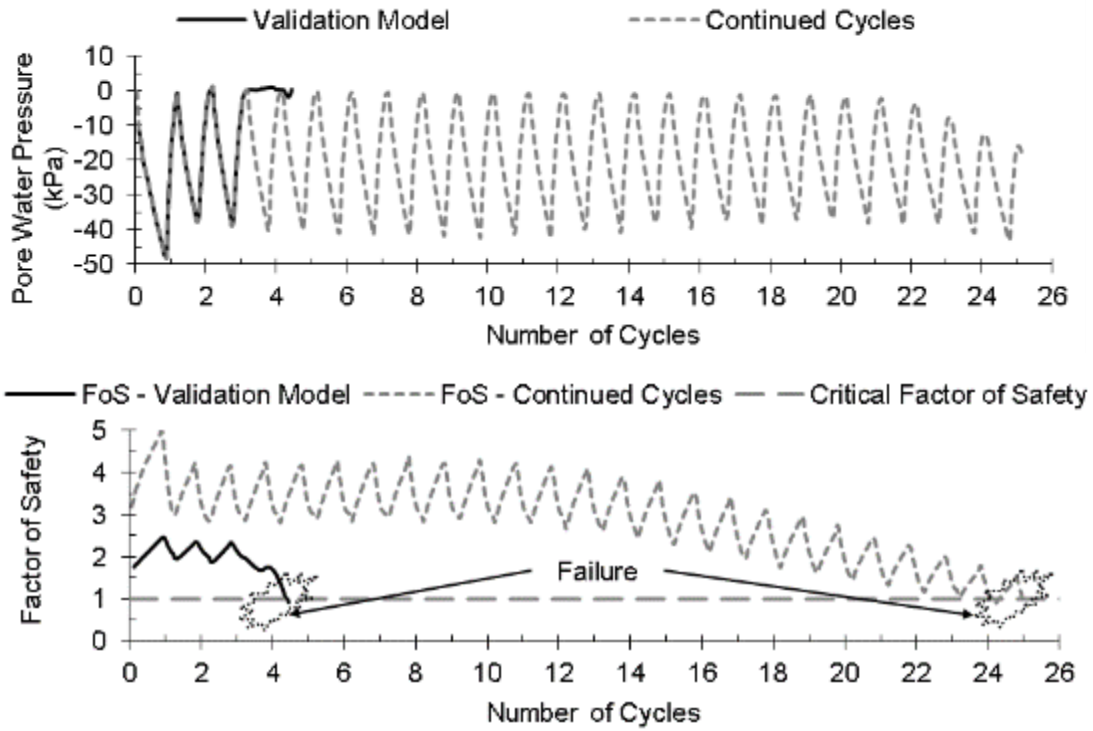
- Magnitude and nature of mid-slope and toe displacements are very good;
- Crest displacements are slightly different;
- Progressive failure begins at toe – more important that this behaviour is correct!

Physical modelling results from Take & Bolton (2011)

(work led by Dixon & Postill, Loughborough University)

Numerical models of seasonal ratcheting

Transient Factor of Safety

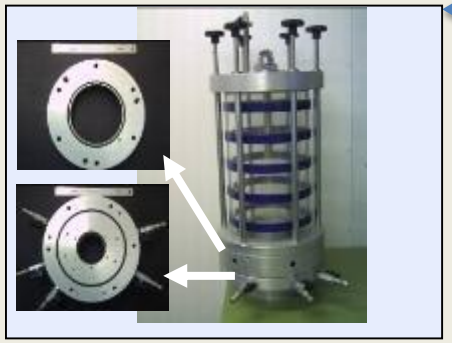


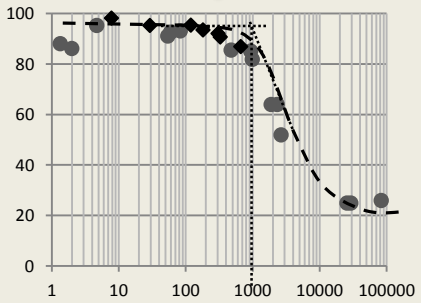
- Demonstrates simplistic, transient factor of safety method for two scenarios;
- Again, shows significance of wet years on the performance of a slope compared to gradual deterioration under continued seasonal cycles.

(from work led by Dixon & Postill, Loughborough University)

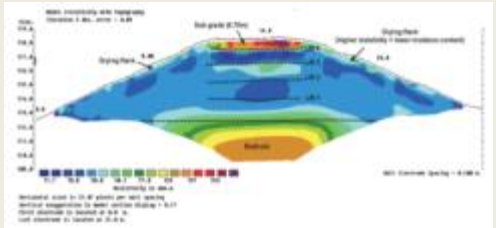
iSMART – Scaling up

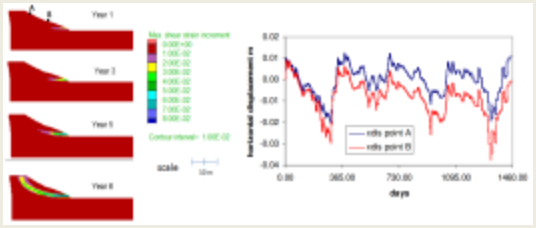
Scale 1



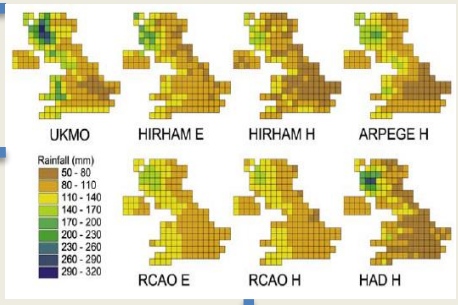


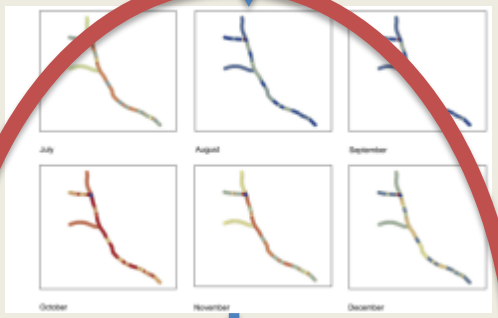
Scale 2





Scale 3

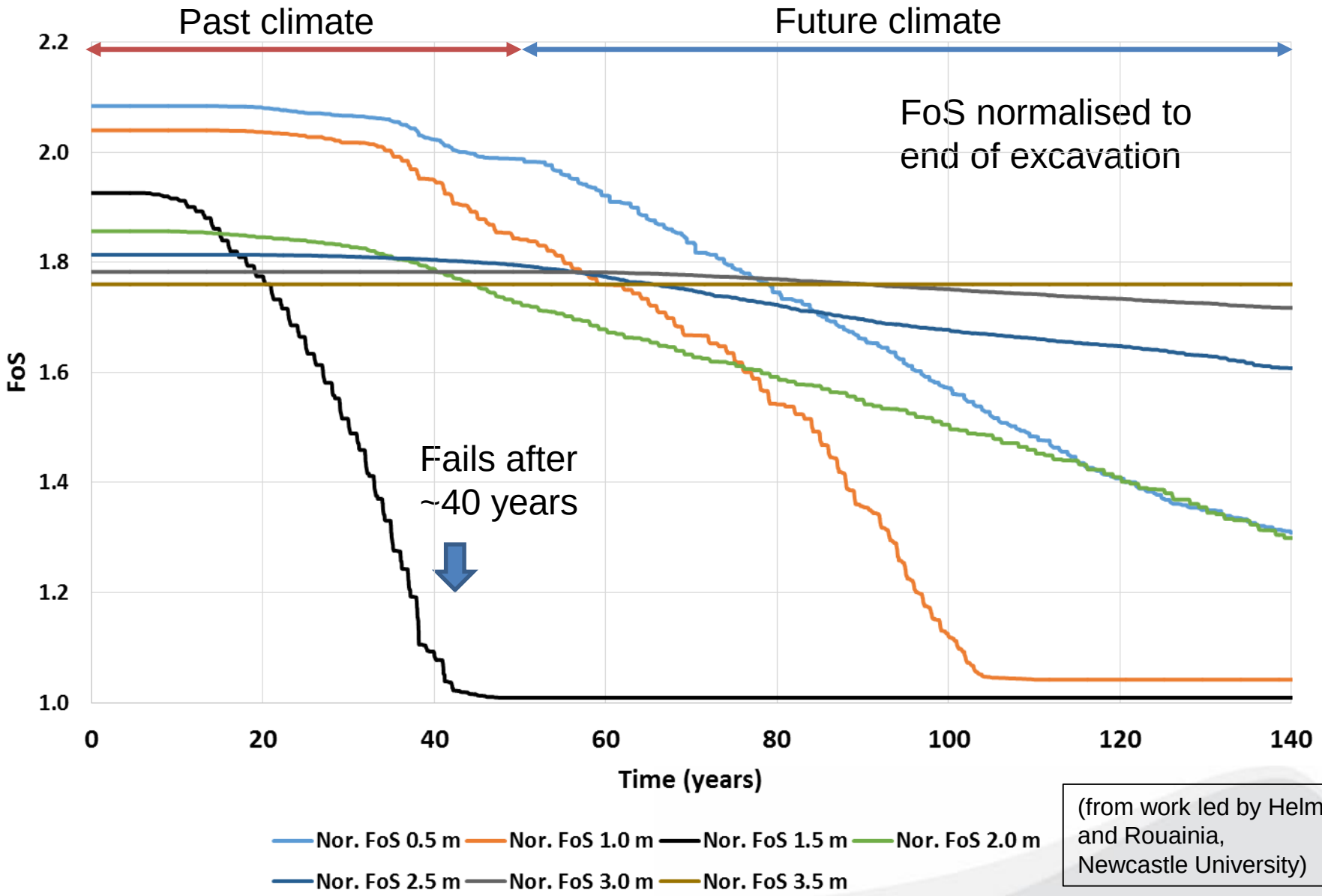




Upscaling approach

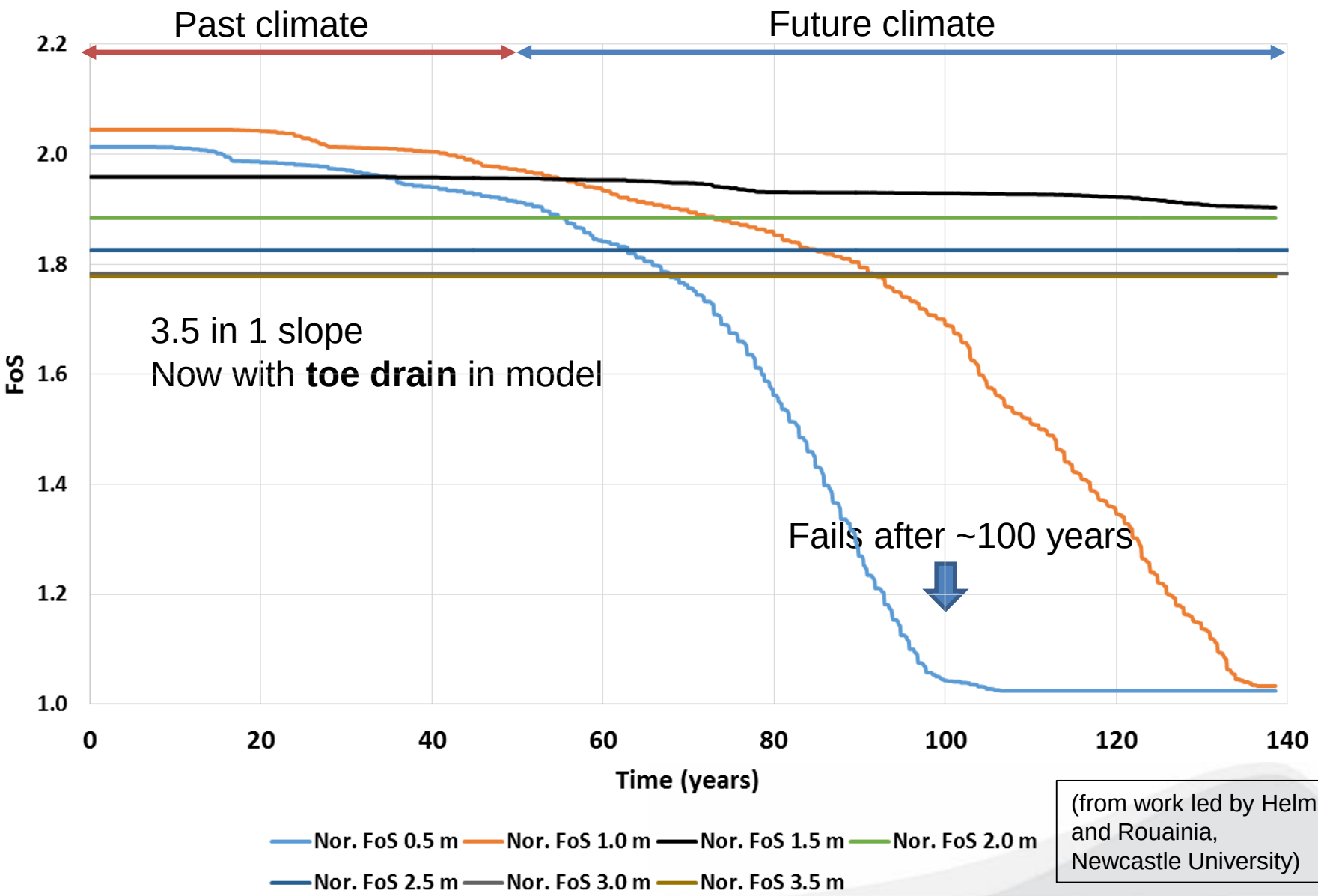
- Selected a route(s) (M4 & London-Bristol rail line)
- Determined range of representative geometry and geology
- Modelled with current and future climate
- Generated deterioration curves

Deterioration Curve



(from work led by Helm and Rouainia, Newcastle University)

Deterioration curve - with toe drain



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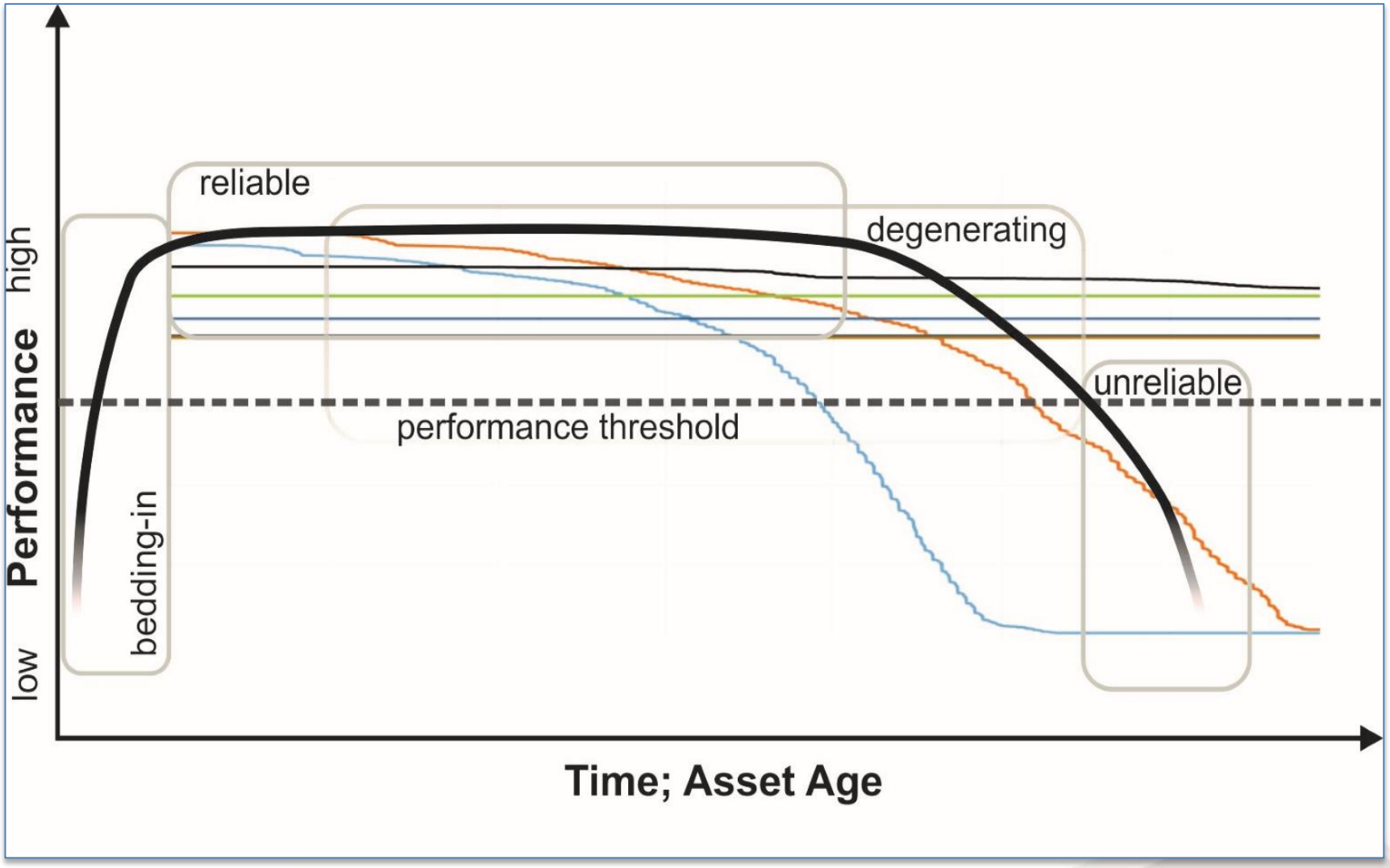
Deterioration curve

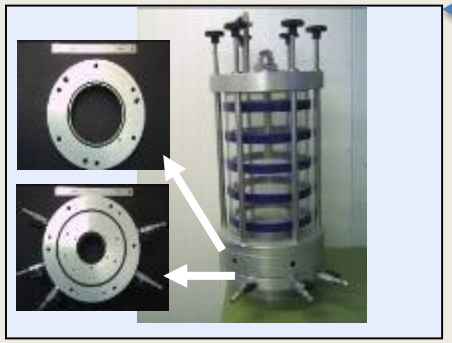


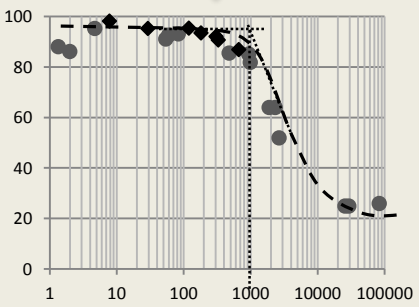
Conclusions

- Weather-driven deterioration of soils exists
- Climate change is likely to accelerate deterioration
- Prototype modelling tools to assess *future* deterioration of transport earthworks have been produced

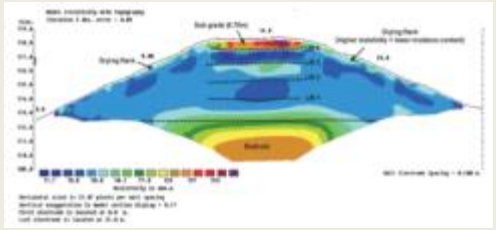
iSMART

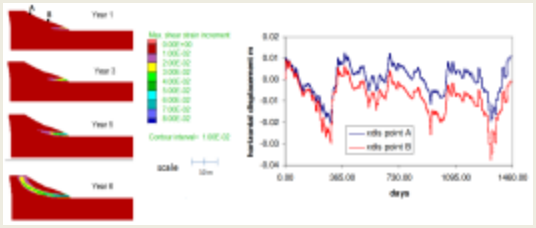
Scale 1





Scale 2





Scale 3