

The logo for 'esi' is displayed in a blue, lowercase, sans-serif font within a white rectangular box in the top-left corner of the image.The background of the slide is a photograph of a large-scale construction project. A massive, cylindrical cutterhead, heavily encrusted with grey mud, is the central focus. It is situated inside a large, circular concrete structure under construction. Two workers in orange safety gear and white hard hats are visible on the left, providing a sense of scale. The concrete walls of the structure feature several 'morgan=est' logos. A yellow warning sign with a radiation symbol is also visible on the right wall. The overall scene is one of industrial-scale earthmoving or tunneling work.

Predicting the effects of civil engineering projects on the groundwater environment: choosing the right tool for the job

Mike Streetly

esi

One Size Fits All?



- **Planning**
 - Conceptual model
 - Data
 - Selecting the right approach
- **A tiered approach**
- **Solving other problems**

The big question

How do we get
from HERE?

To HERE?

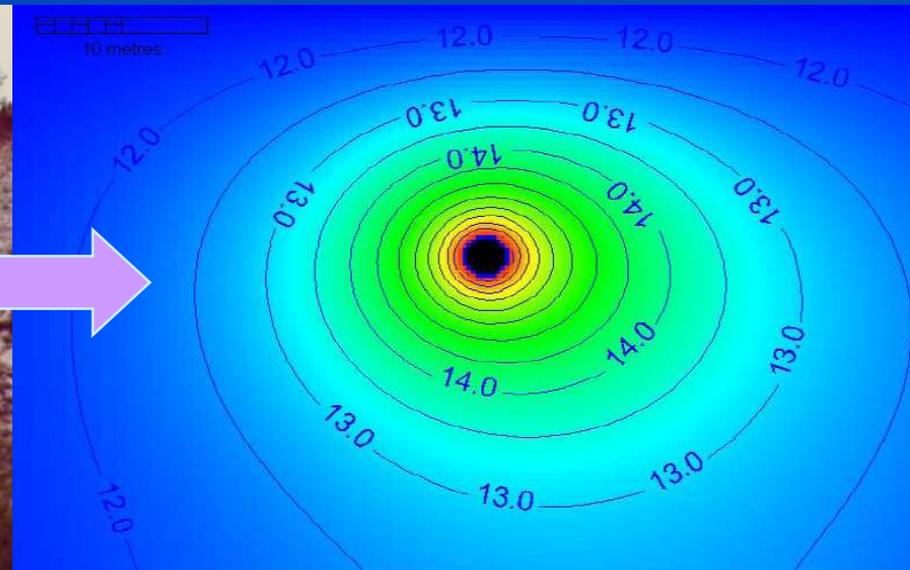


Figure 3.1 b): Isotherms 10 years after tunnel activation



Uncertainty

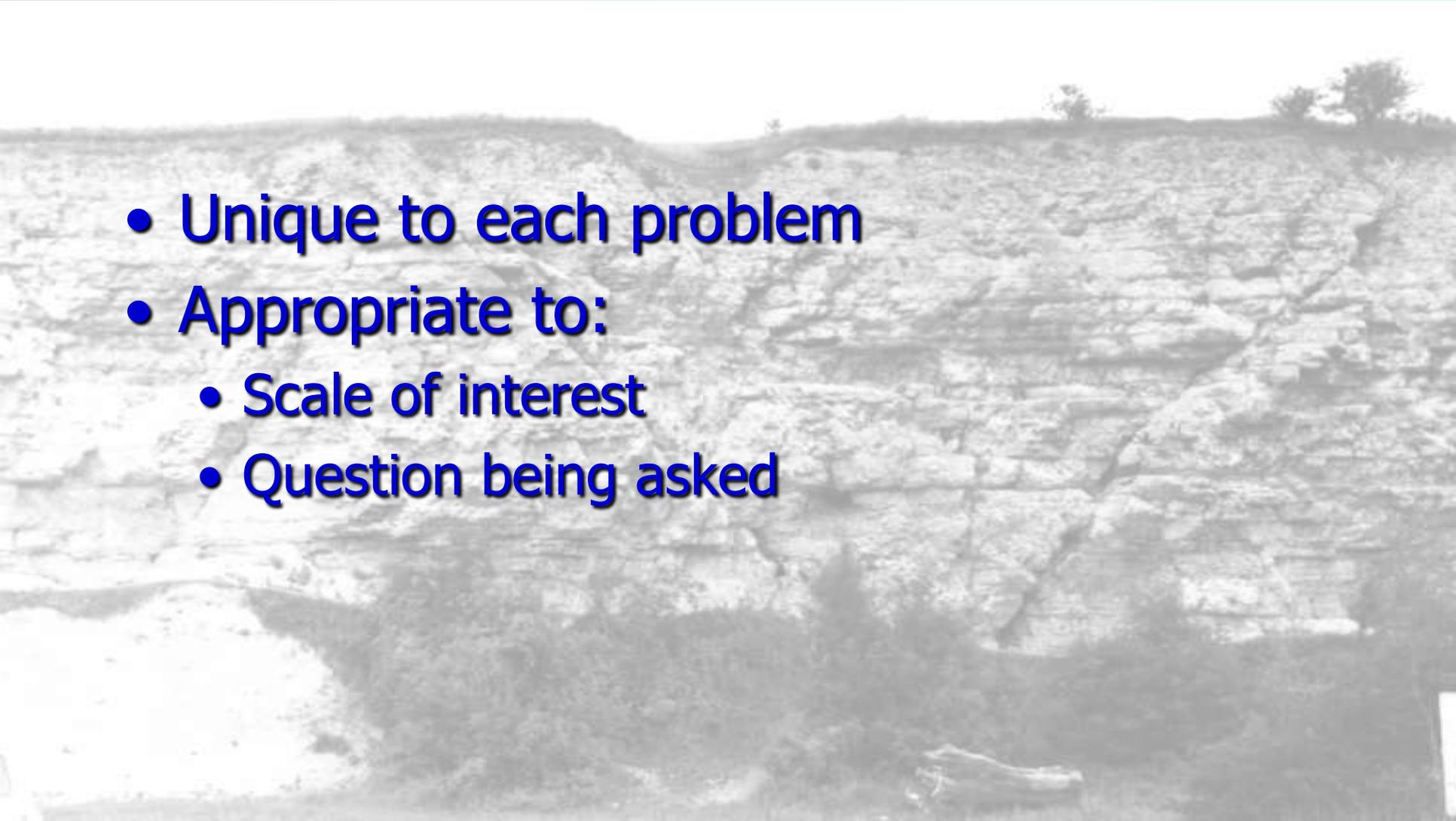
“The trouble with the world is that the stupid are cocksure while the intelligent are full of doubt”

Bertrand Russell



Conceptual model

- Unique to each problem
- Appropriate to:
 - Scale of interest
 - Question being asked

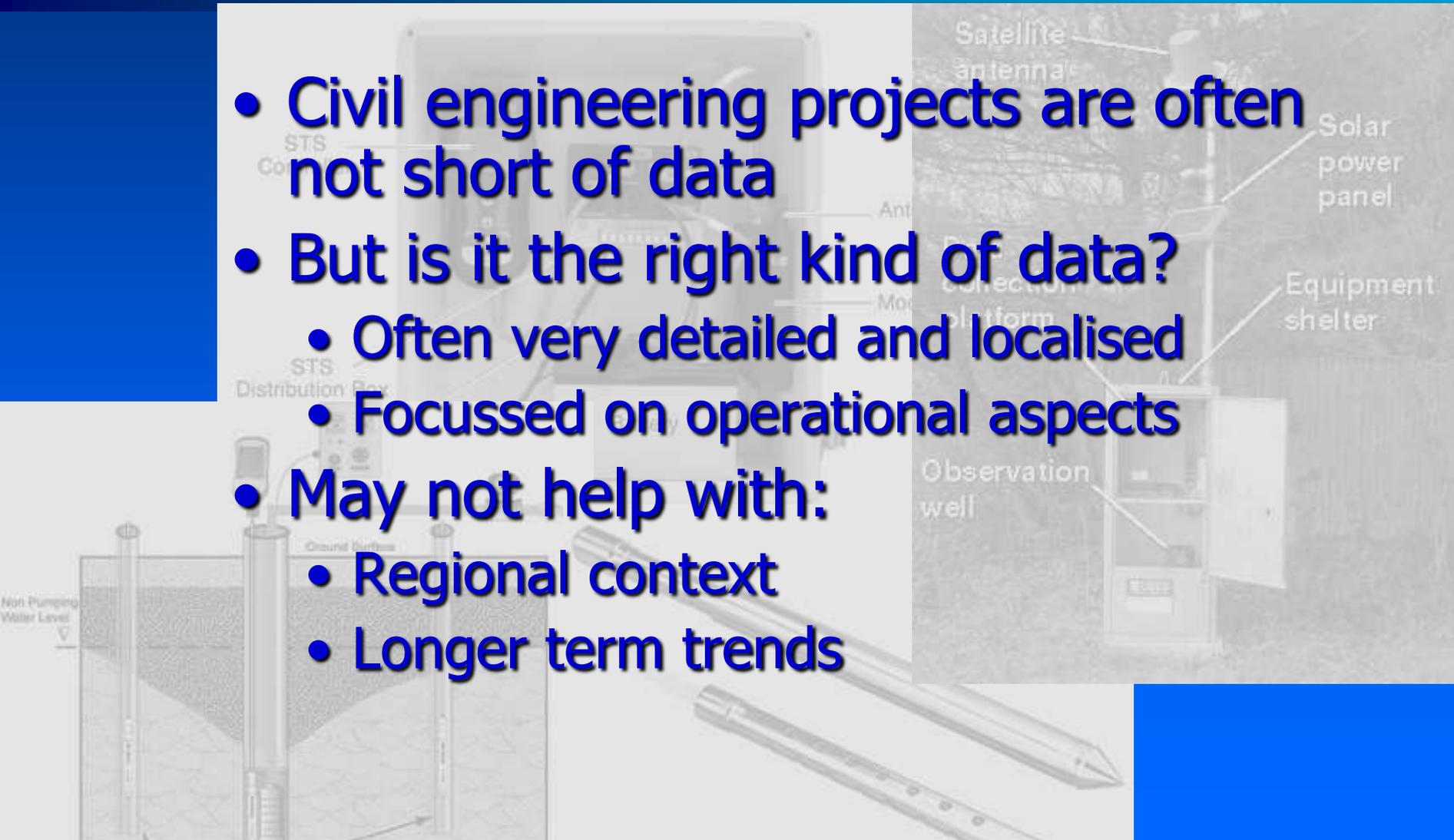


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Scale of interest

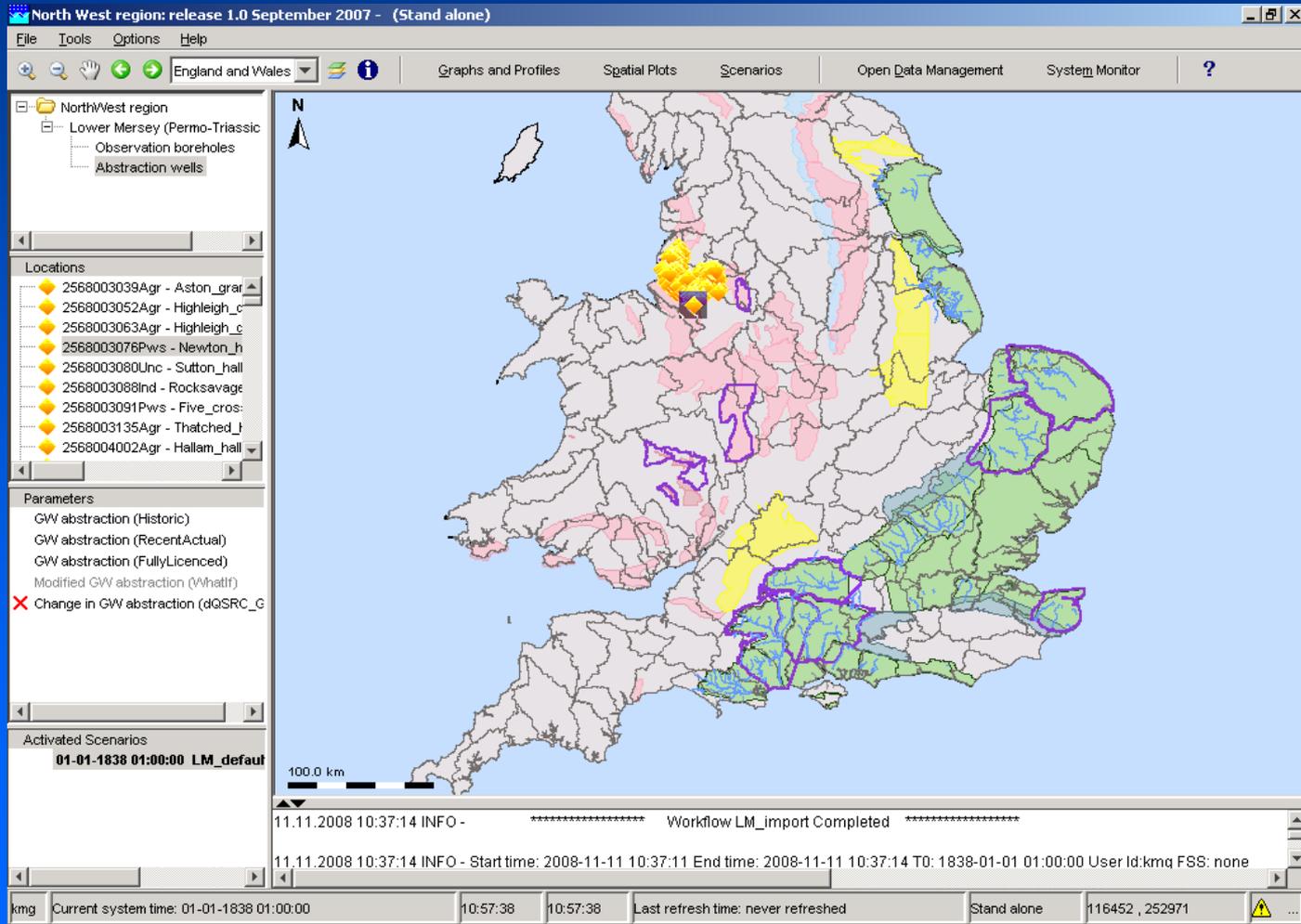


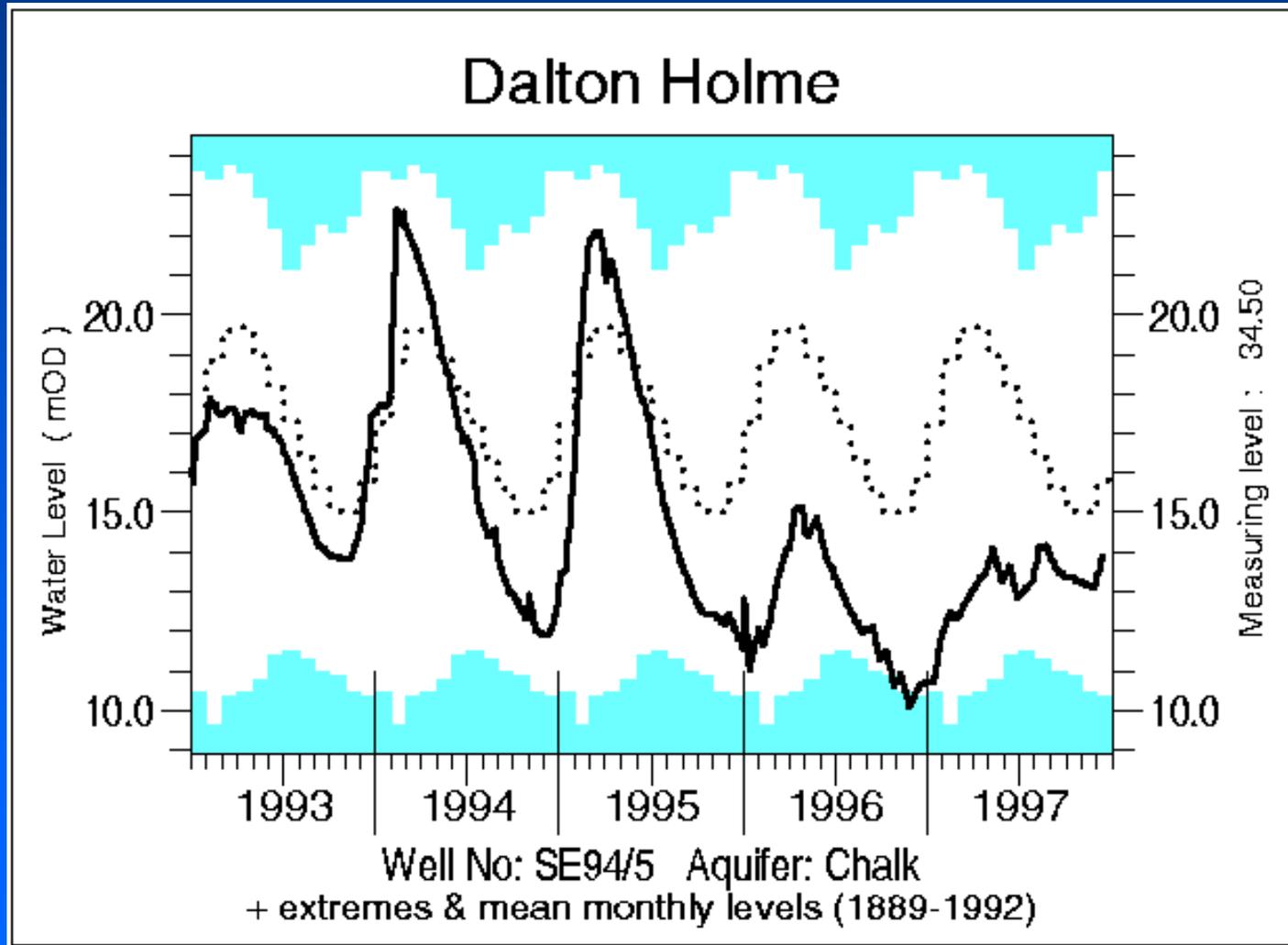
- Civil engineering projects are often not short of data
- But is it the right kind of data?
 - Often very detailed and localised
 - Focussed on operational aspects
- May not help with:
 - Regional context
 - Longer term trends





Regional Context





- Environment Agency and National Groundwater Level Archive



Approach to modelling

- How much:
 - Data?
 - Time?
 - Money?
 - Much certainty do we need?
- A tiered approach is needed



Tools available

- Analytical solutions
- Analytical models
- Simple numerical models
- Complex, 3D solute and density modelling

Increasing

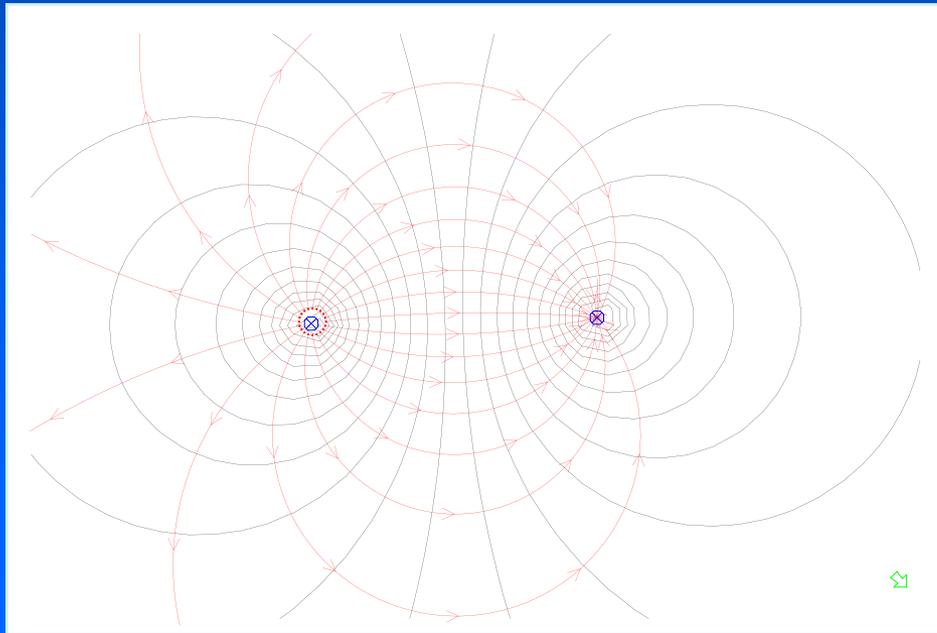


Complexity (data requirements)

Time needed

Cost

- Nothing new to report
- But we still have this problem



$$\frac{\partial \theta_f}{\partial t} + v \frac{\partial \theta_f}{\partial x} = - \frac{K_m}{\rho_w c_w} \frac{\partial \theta_f}{\partial z} \Big|_{z=b} \quad x \geq 0$$

$$\frac{\partial \theta_m}{\partial t} = \kappa_m \frac{\partial^2 \theta_m}{\partial z^2} \quad 0 \leq z \leq b$$

$$\theta_f(x, 0) = \theta_m(x, z, 0) = 0$$

$$\theta_f(x, t) = \theta_m(x, b, t)$$

$$\theta_f(0, t) = \begin{cases} \theta_0 & 0 \leq t \leq t_0 \\ 0 & t > t_0 \end{cases}$$

Solution :

$$\theta_{out}(t) = \theta_0 F(t, t_0, t_B, t_{cb}, \sigma)$$

$$\sigma = \frac{2b\rho_m c_m}{a\rho_w c_w}$$

$$t_{cb} = \frac{b^2}{\kappa_m}$$

$$t_a = \frac{x}{v}$$

and t_B is the breakthrough time.

esi Analytical Solutions

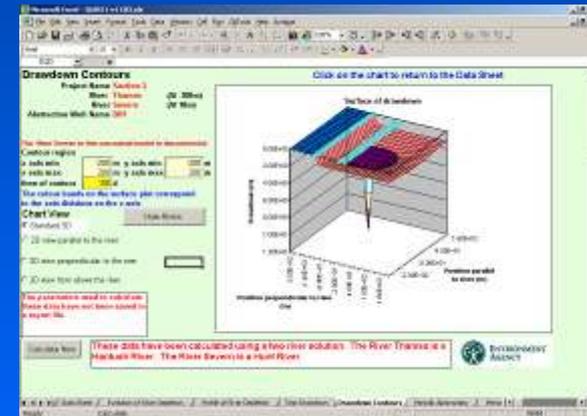
- If we add:



This product is li

Michael Evans
Millard School Di
Product ID: 506

Copyright © 1985-15
This program is prot
as described in Help



The screenshot shows the ESI software interface for configuring a river model. At the top, there are menu options: 'Data', 'Window', 'Cell', 'Run', 'QTools', 'Help', and 'About'. Below the menu is a toolbar with various icons. The main interface has three dropdown menus: 'Aquifer', 'Well', and 'River (Hunt)'. The 'River (Hunt)' dropdown is selected. Below these menus is a large diagram showing a cross-section of a well and a river. The well is a vertical cylinder, and the river is a horizontal channel. Arrows indicate flow directions. Below this diagram is a 'River Name' field containing 'Severn'. To the right of the main diagram are three smaller diagrams labeled 'Theis', 'Hantush', and 'Hunt', each showing a different cross-section of a river and well. Below these is a coordinate system with x and y axes and a red dot at the origin. A vertical arrow indicates the 'Direction of river flow' from 'Downstream' to 'Upstream'. Below the coordinate system is a text box that reads: 'The Well is always positioned at (0,0)'. At the bottom left, there is a text box with the following text: 'This is a single river system using the Hunt solution. HUNT SOLUTION: The river is narrow and partially penetrating with no significant reduction in saturated thickness of the aquifer beneath the river. There is a zone of low hydraulic conductivity material beneath the river characterised by a river bed hydraulic conductivity, thickness and a width. There is a head drop across the river bed sediments. Aquifer storage on both sides of the river is accessible. The river is in hydraulic continuity with groundwater throughout its reach.' At the bottom right, there is an 'ENVIRONMENT AGENCY' logo and a 'Change Model' button.

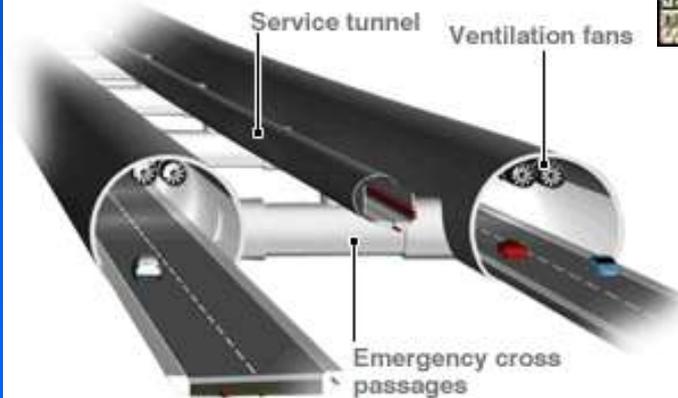
- Easy to set up and use
- Only moderate amounts of spatial complexity
- Useful for scoping calculations



Tiered approach – lumped water balance



Twin-tube bored tunnel



Source: Highways Agency



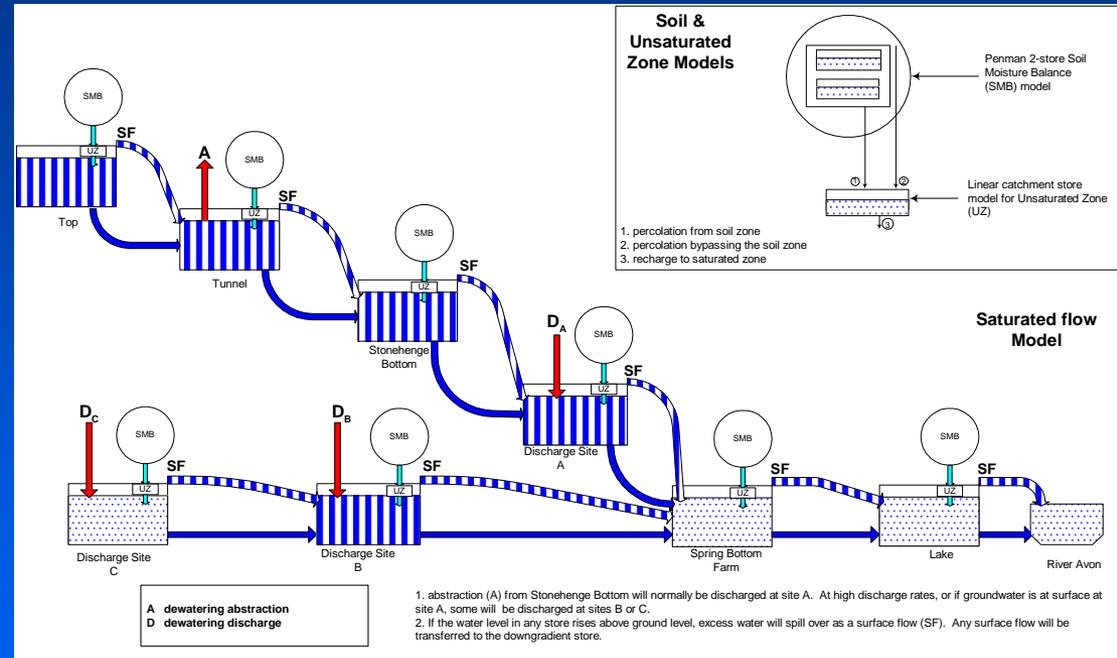
Stonehenge Tunnel – lumped water balance

- Saturated Chalk in places
- Return water via soakaways
- Regulators still concerned about potential impact on River Avon SAC



Stonehenge Tunnel – lumped water balance

- Chalk very heterogeneous
- Insufficient data to characterise/model with confidence
- Selected a lumped water balance approach
- Regulators were happy



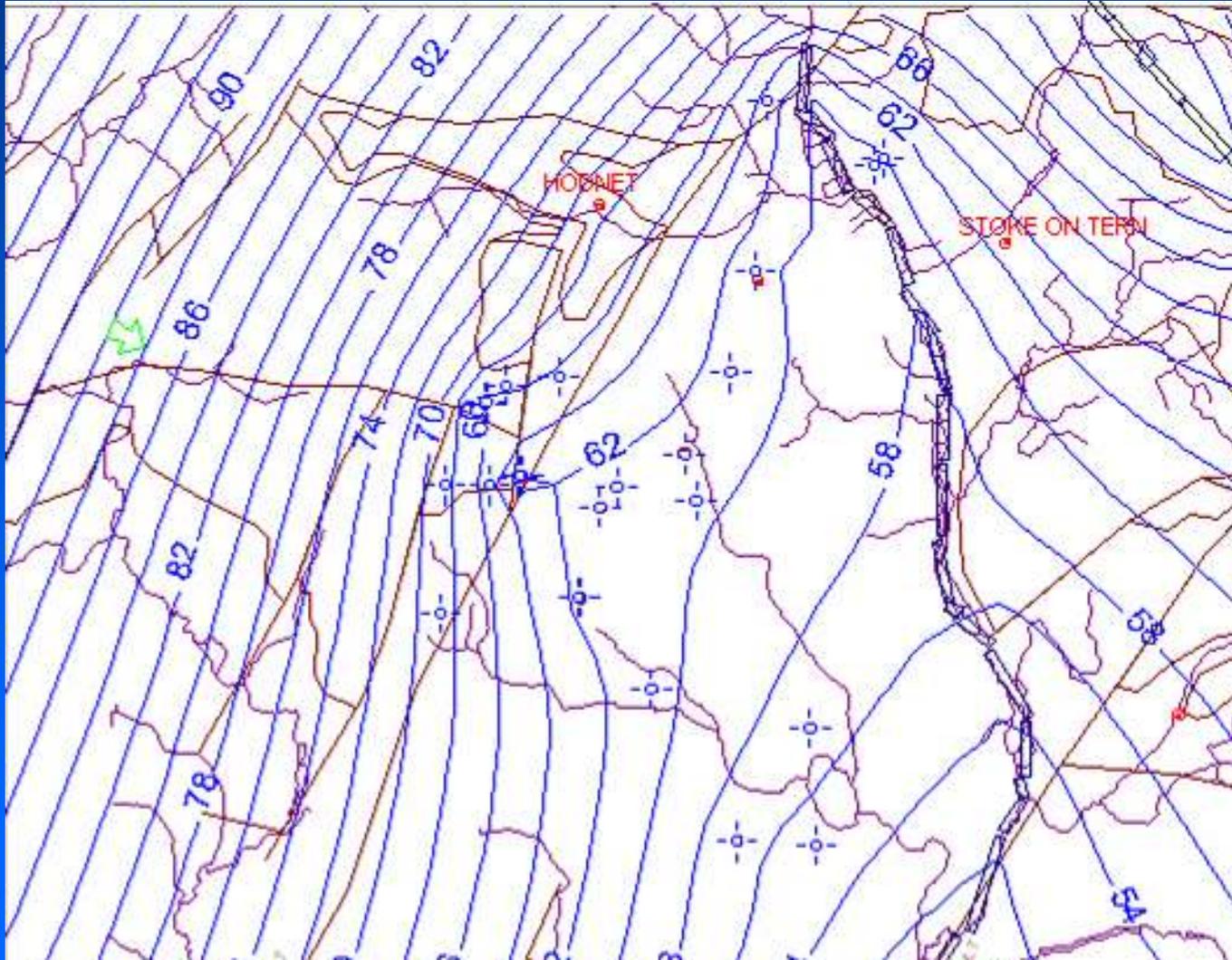


Tiered approach - simple analytical models

- **Pluses:**
 - Quick (and therefore cheap)
 - Easy to keep track of assumptions
- **Minuses:**
 - No spatial heterogeneity
 - Not as flexible as MODFLOW

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WINFLOW analytical model

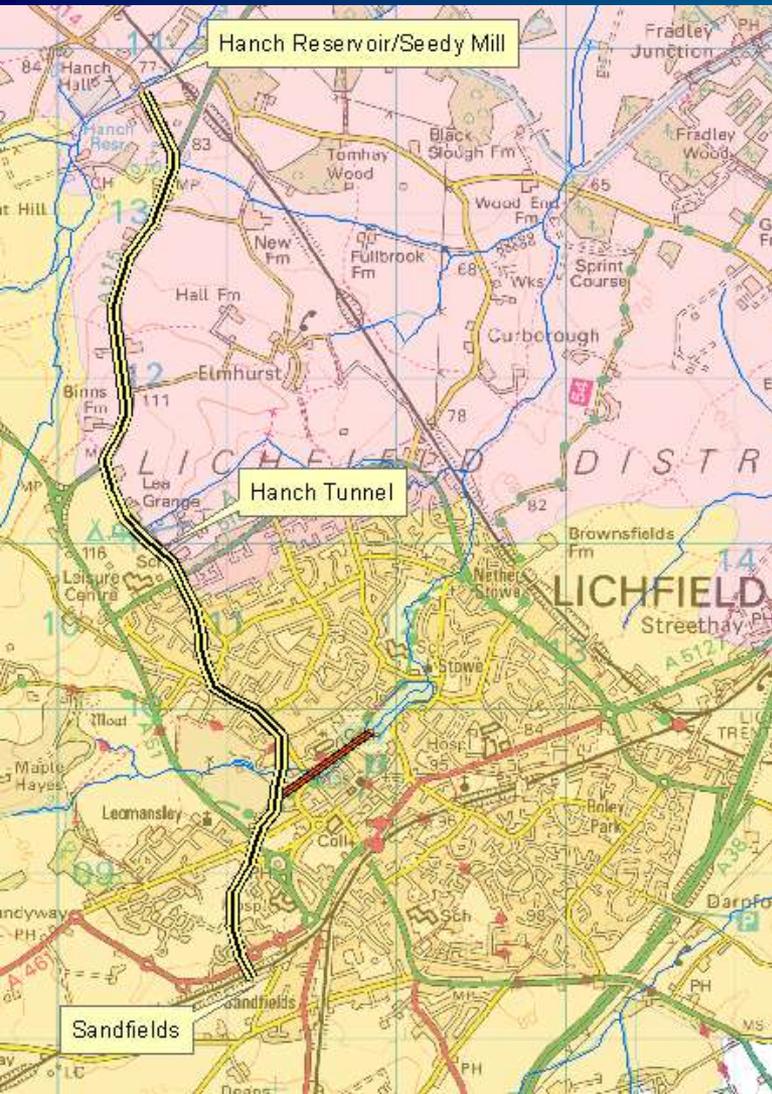




Tiered approach - MODFLOW

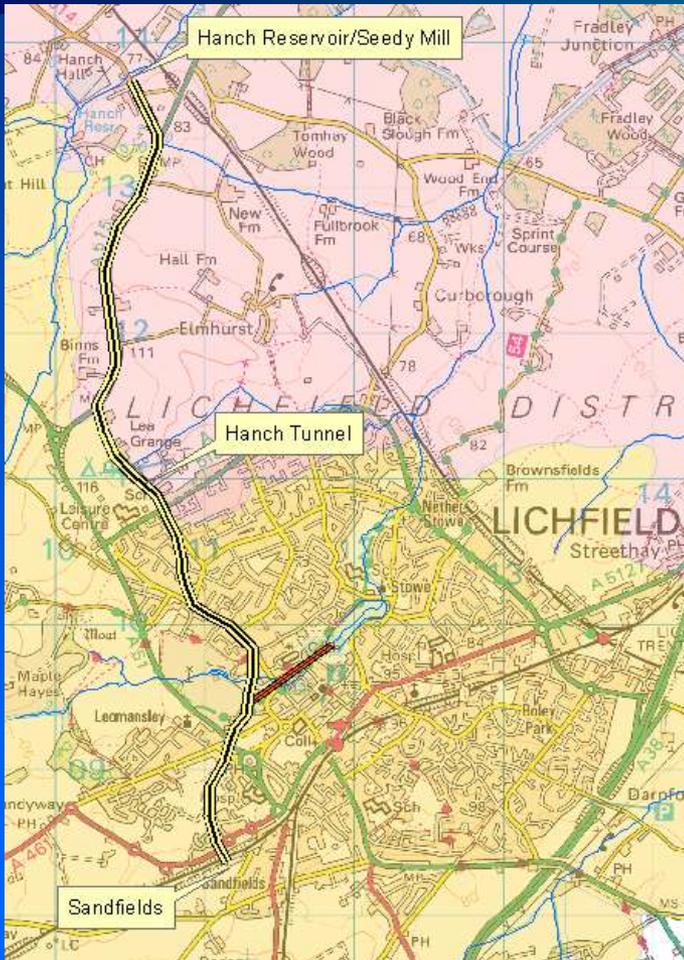
- **Pluses:**
 - Well established and widely used
 - Environment Agency standard
 - Wide range of GUIs (pre/post-processing)
 - Many add-ons
- **Minuses:**
 - Limited geometry

Tiered approach – MODFLOW plus add-ins

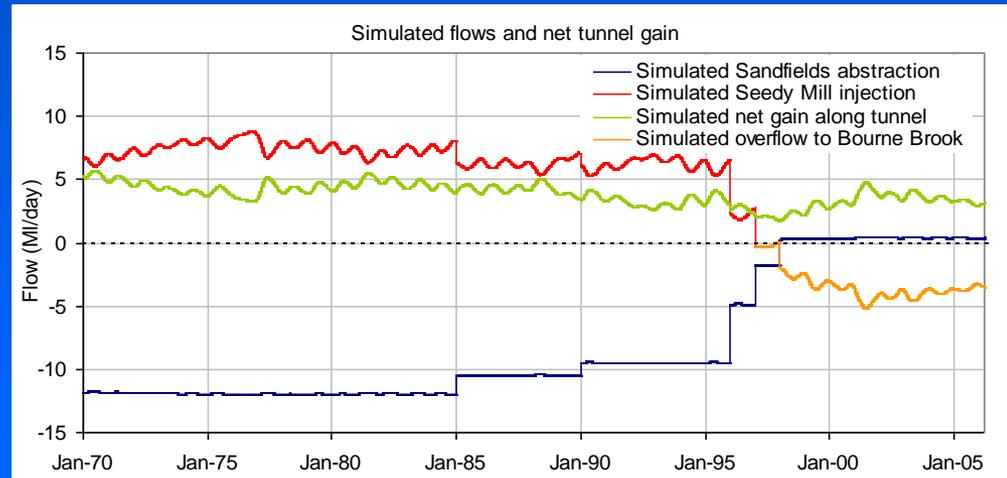


- 6km long Victorian adit
- Excavated in PT Sandstone
- Now runs under SSSI

Simulating a long adit in a regional model



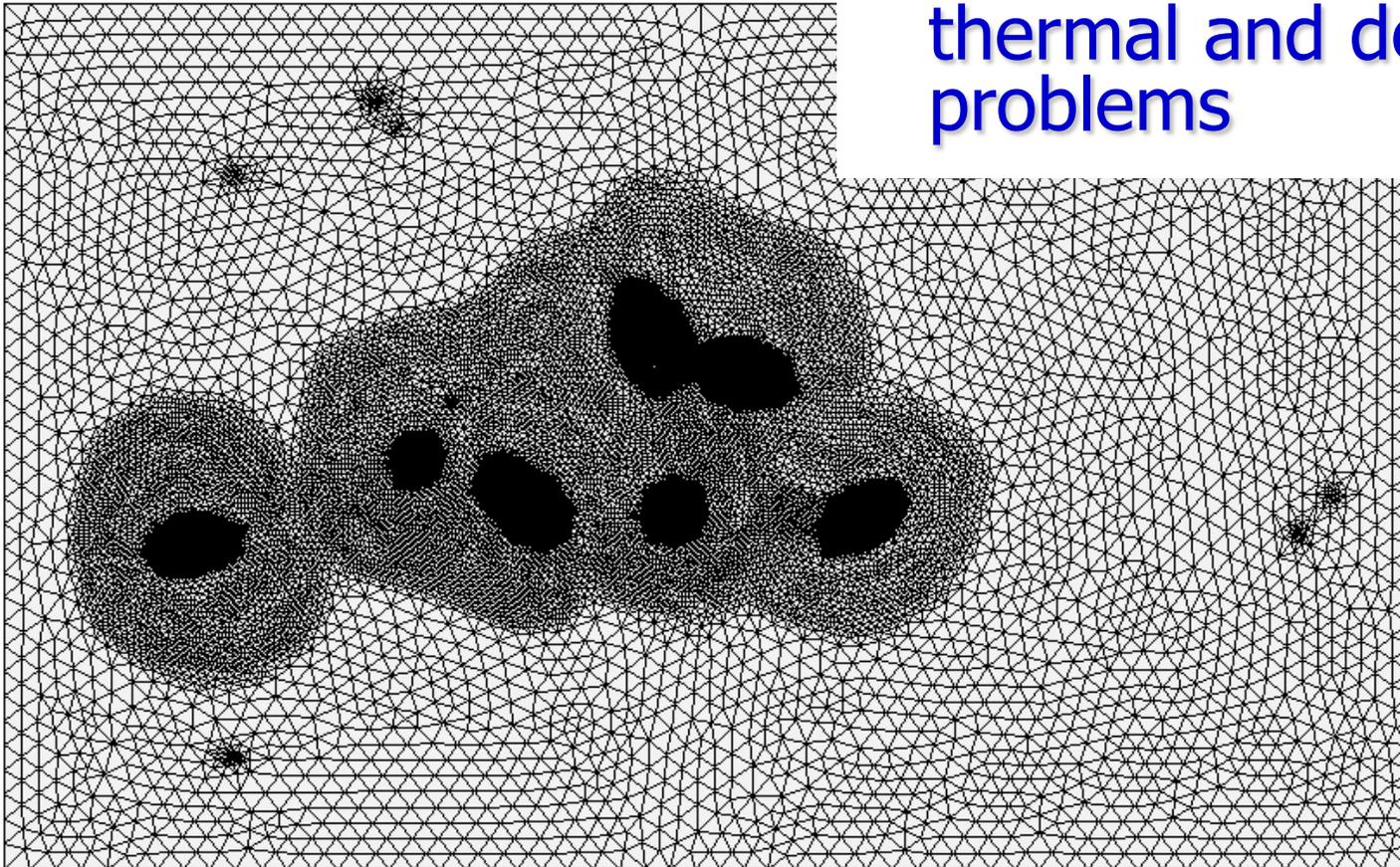
- USGS MODBRNCH code (adapted by Sheffield Uni)
- Issues
 - Time stepping
 - Boundary conditions (stage and flow)
 - Model stability
 - Non-steady state
- Successfully calibrated
- Simulated observed flows





Tiered approach – Finite element modelling e.g. FEFLOW

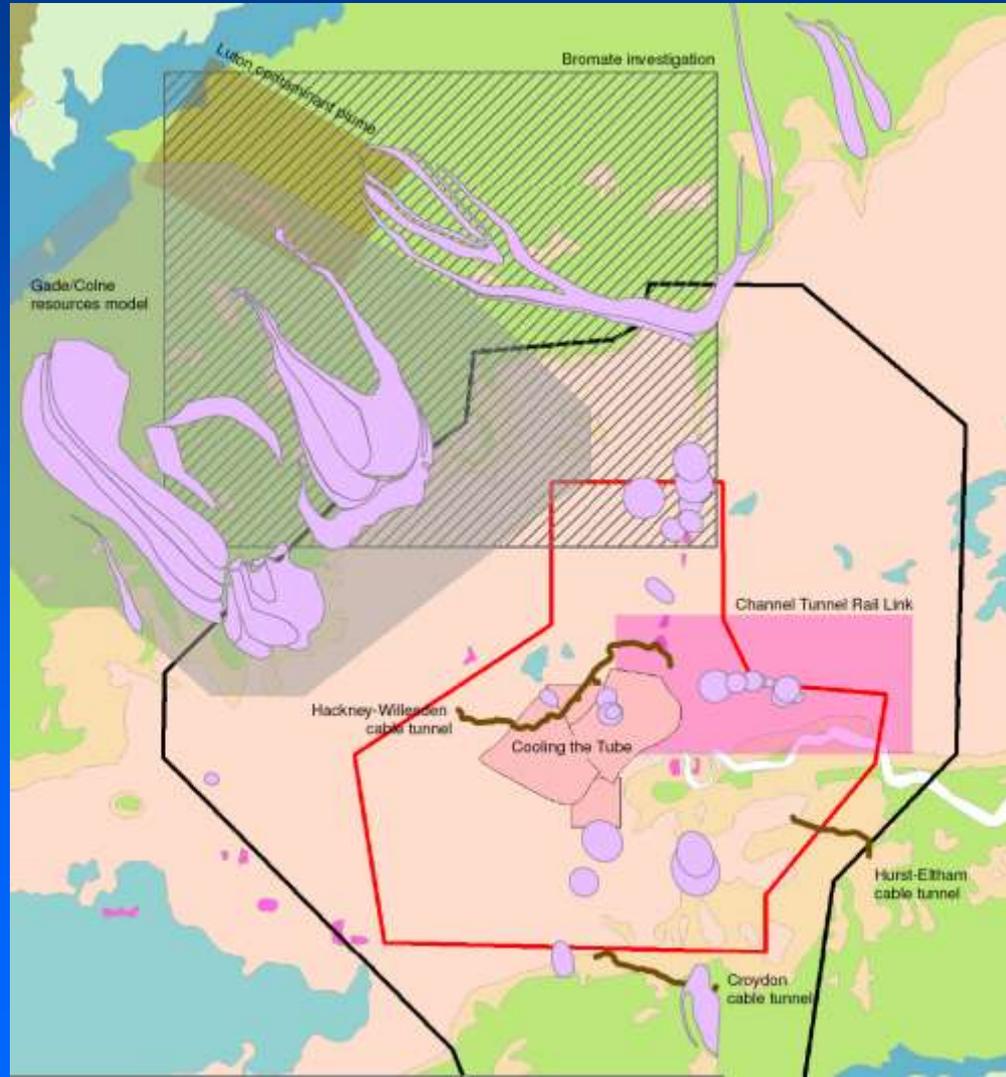
- Improved geometry
- More effective simulation of thermal and density problems





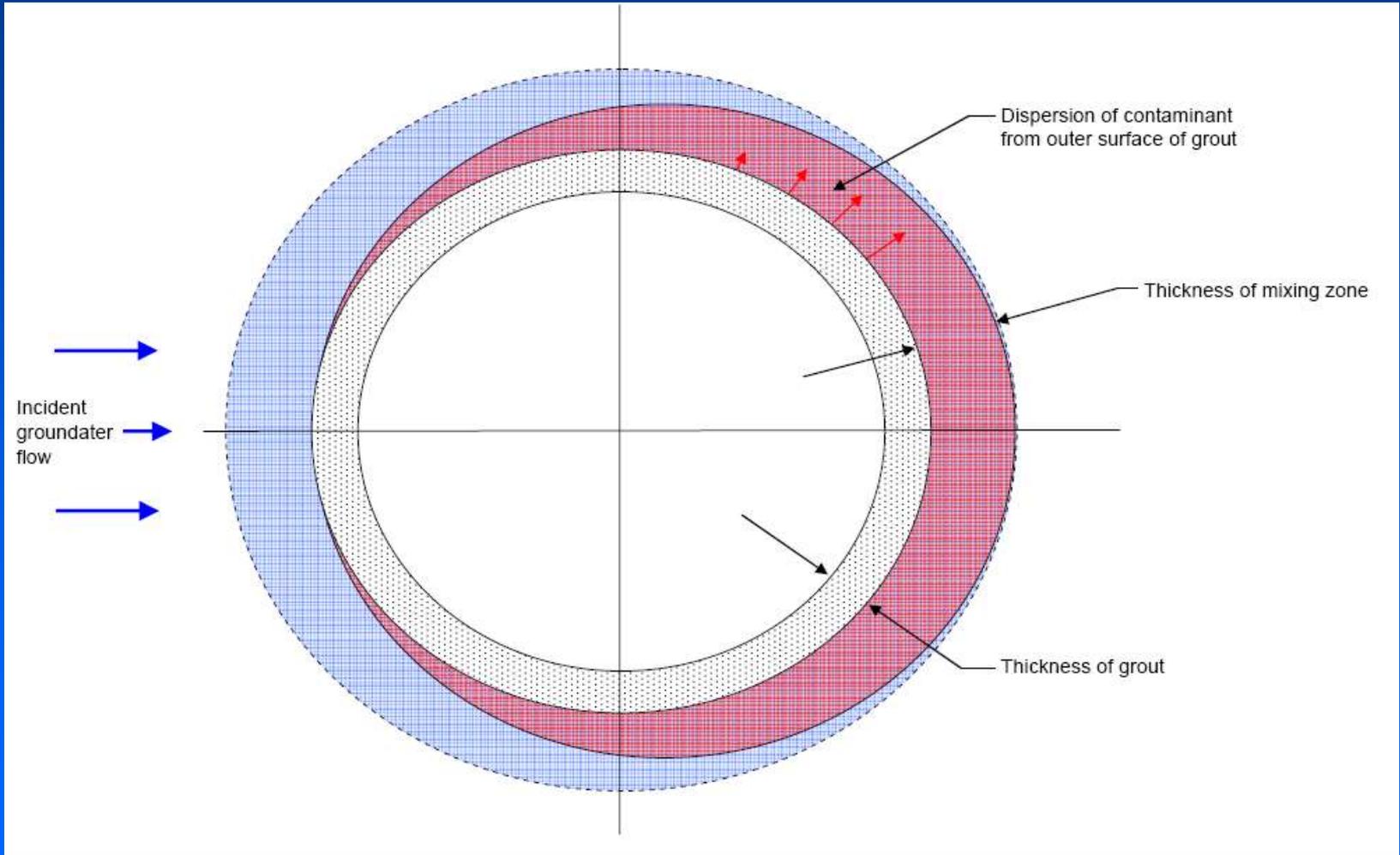
Other Issues

- Largely driven by Environment Agency plus water company concerns
- Contamination:
 - Suspended solids
 - Grout
- Thermal influences





Potential Contamination - Grout



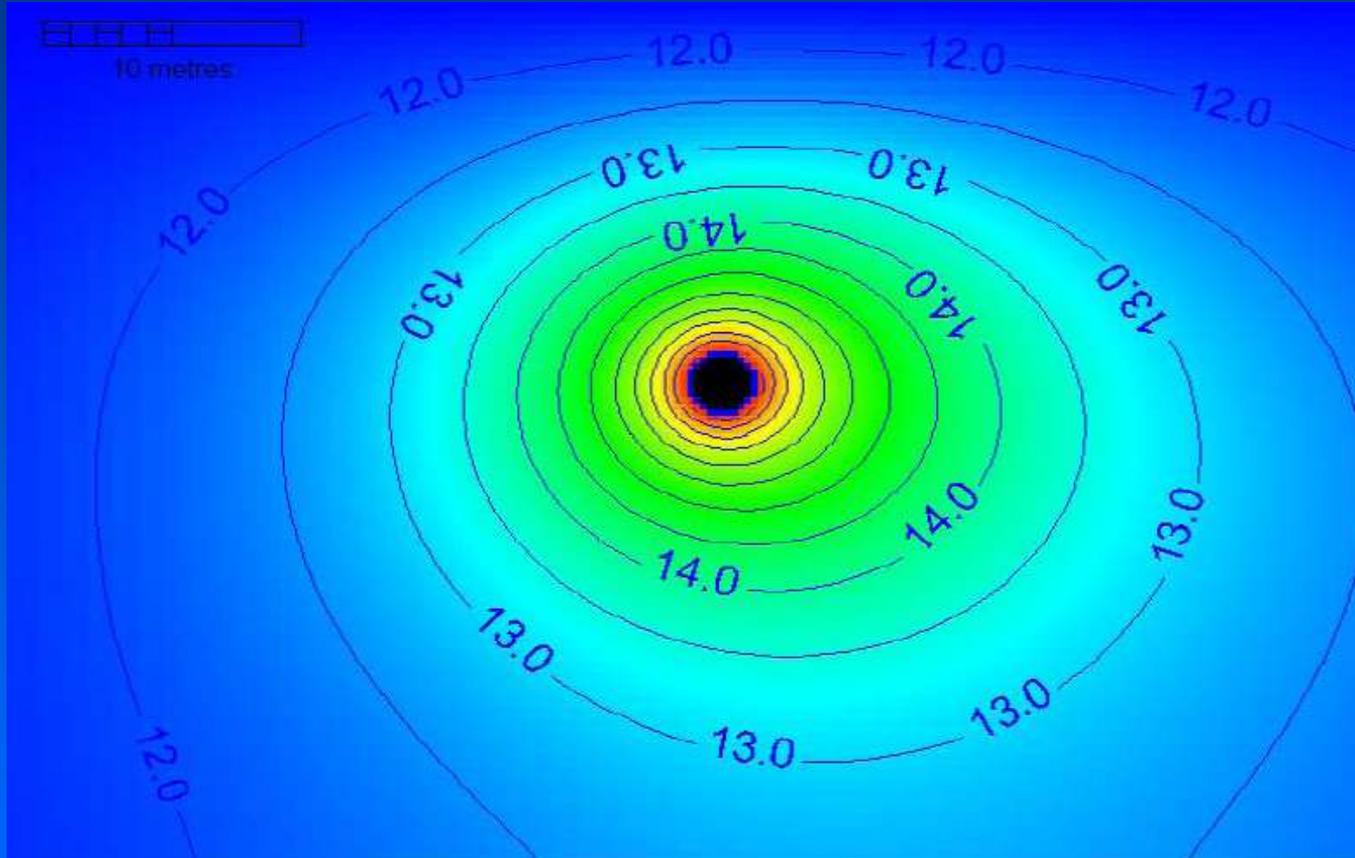
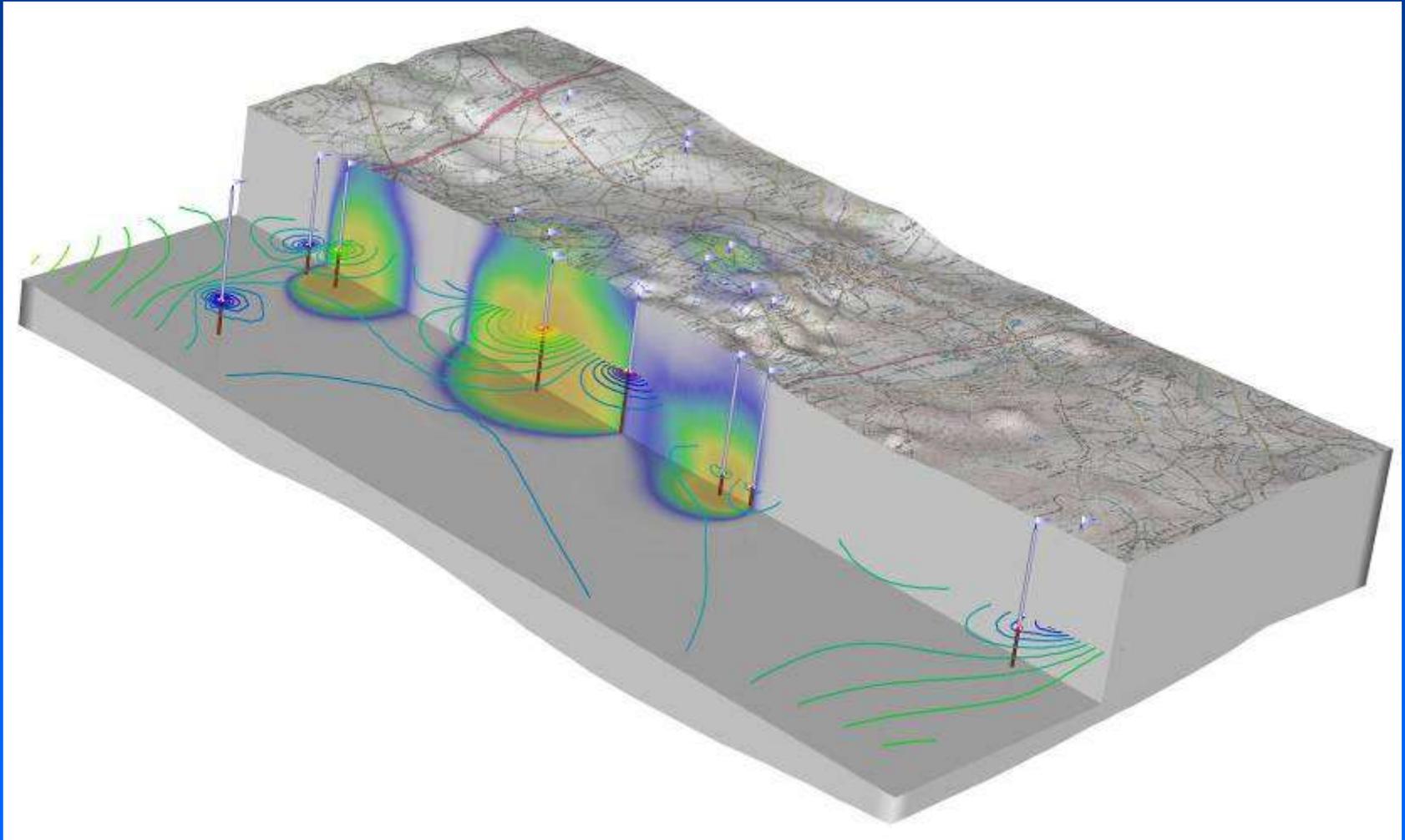


Figure 3.1 b): Isotherms 10 years after tunnel activation



Potential Contamination - Thermal



- One size doesn't fit all
- Planning:
 - What question are we trying to answer?
 - What data do we need?
 - What is our conceptual model?
 - How much money/time have we got?
- *Then select the right approach*