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

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One Size Fits All?

Outline

- 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?

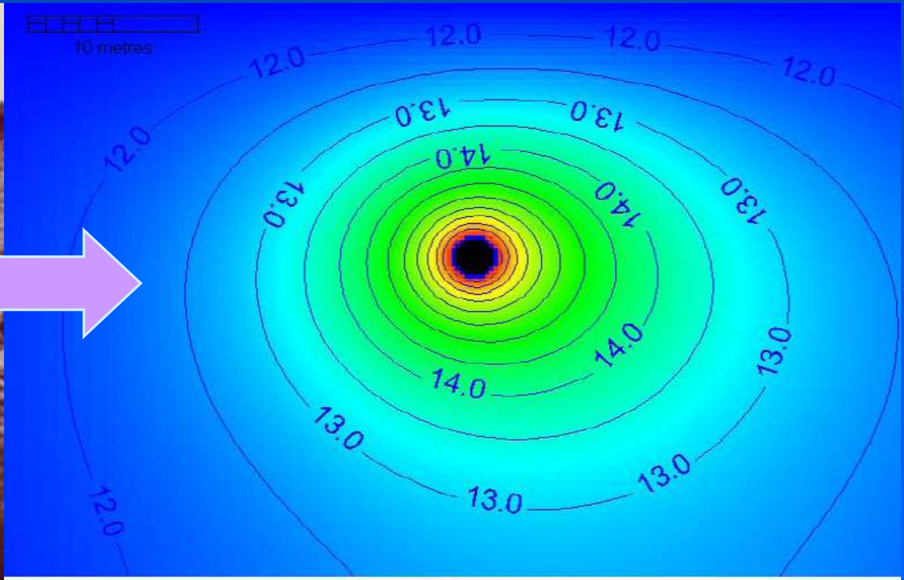


Figure 3.1 b): Isotherms 10 years after tunnel activation

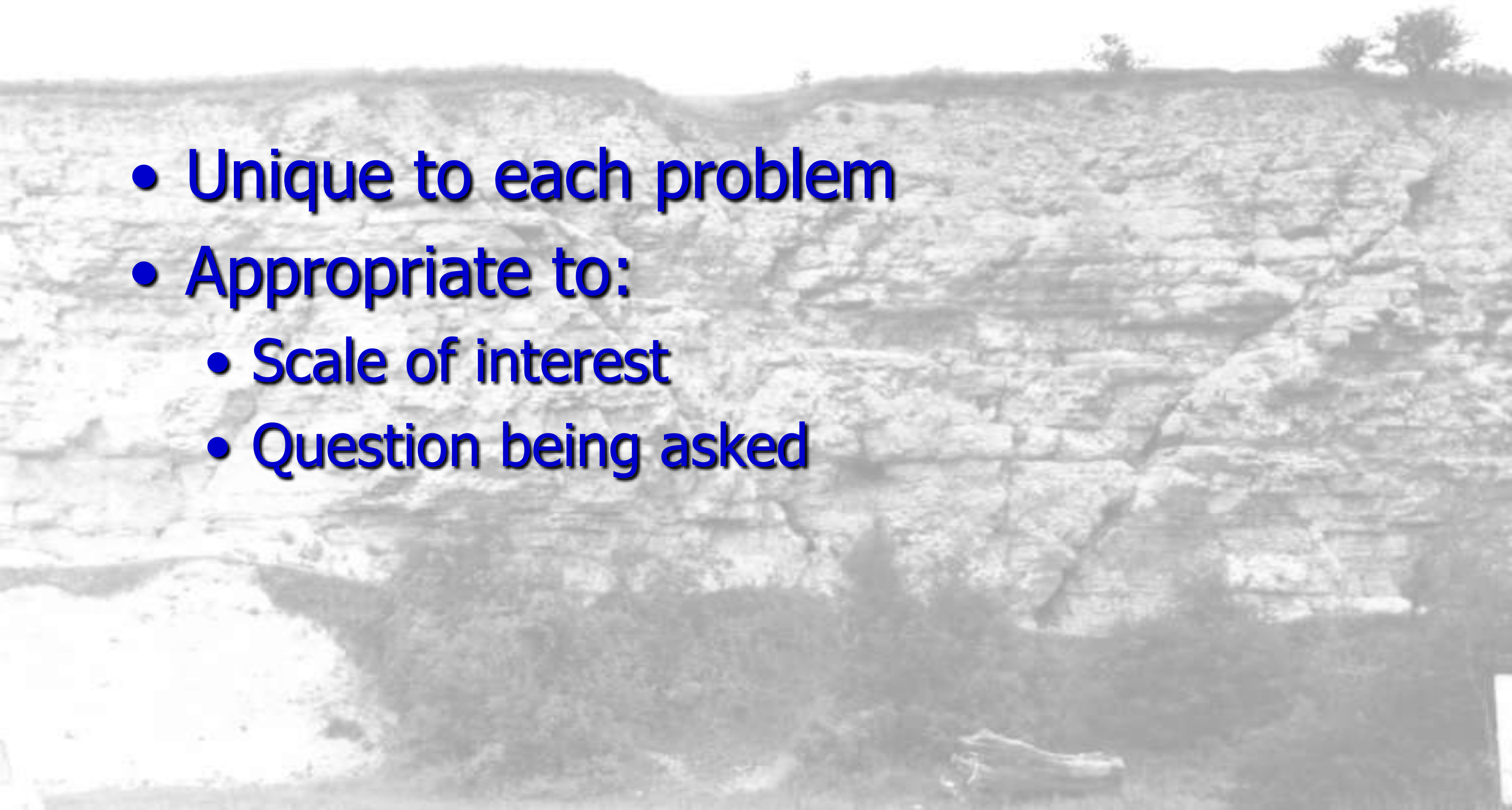
Uncertainty

"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

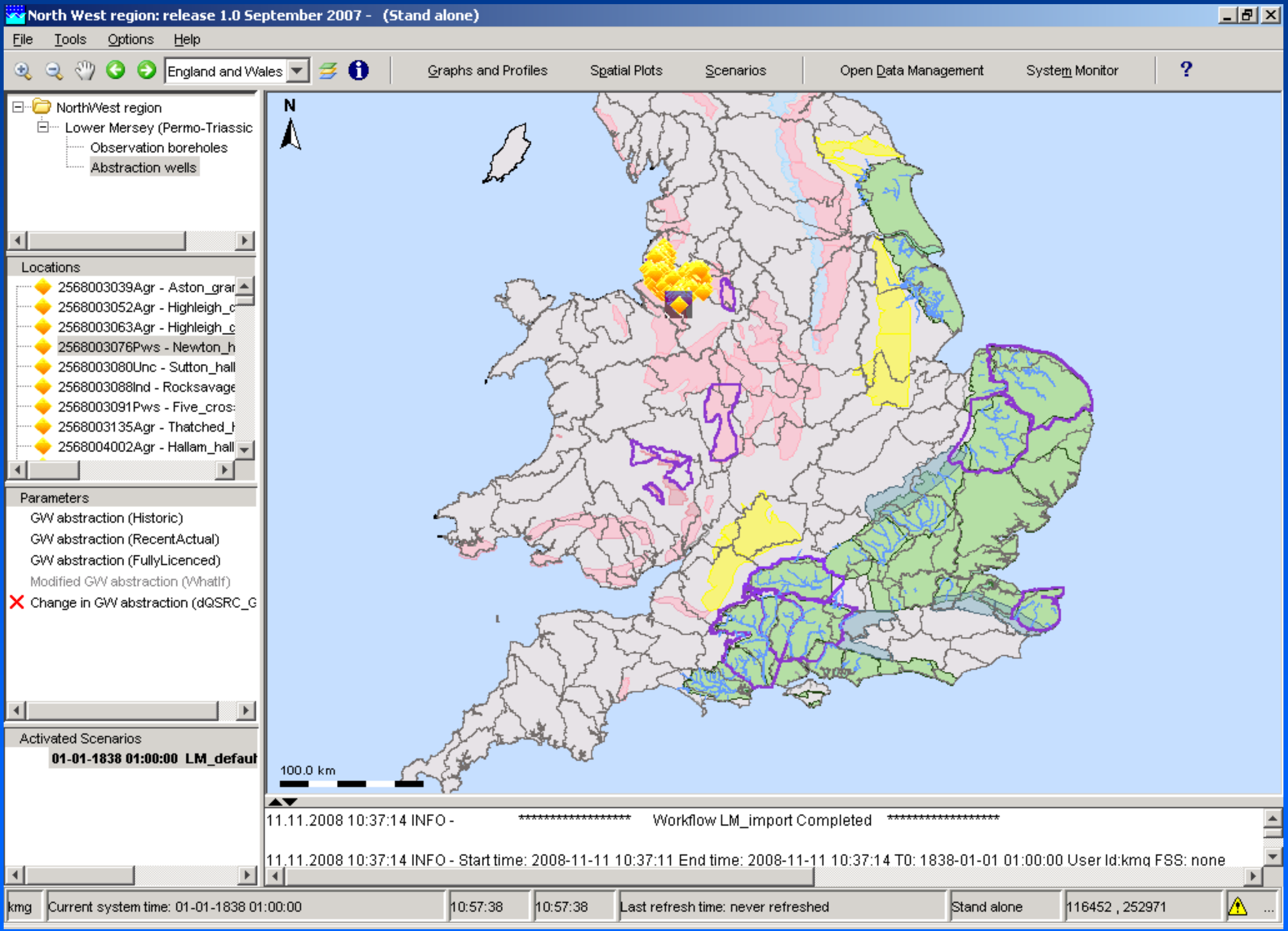


Scale of interest

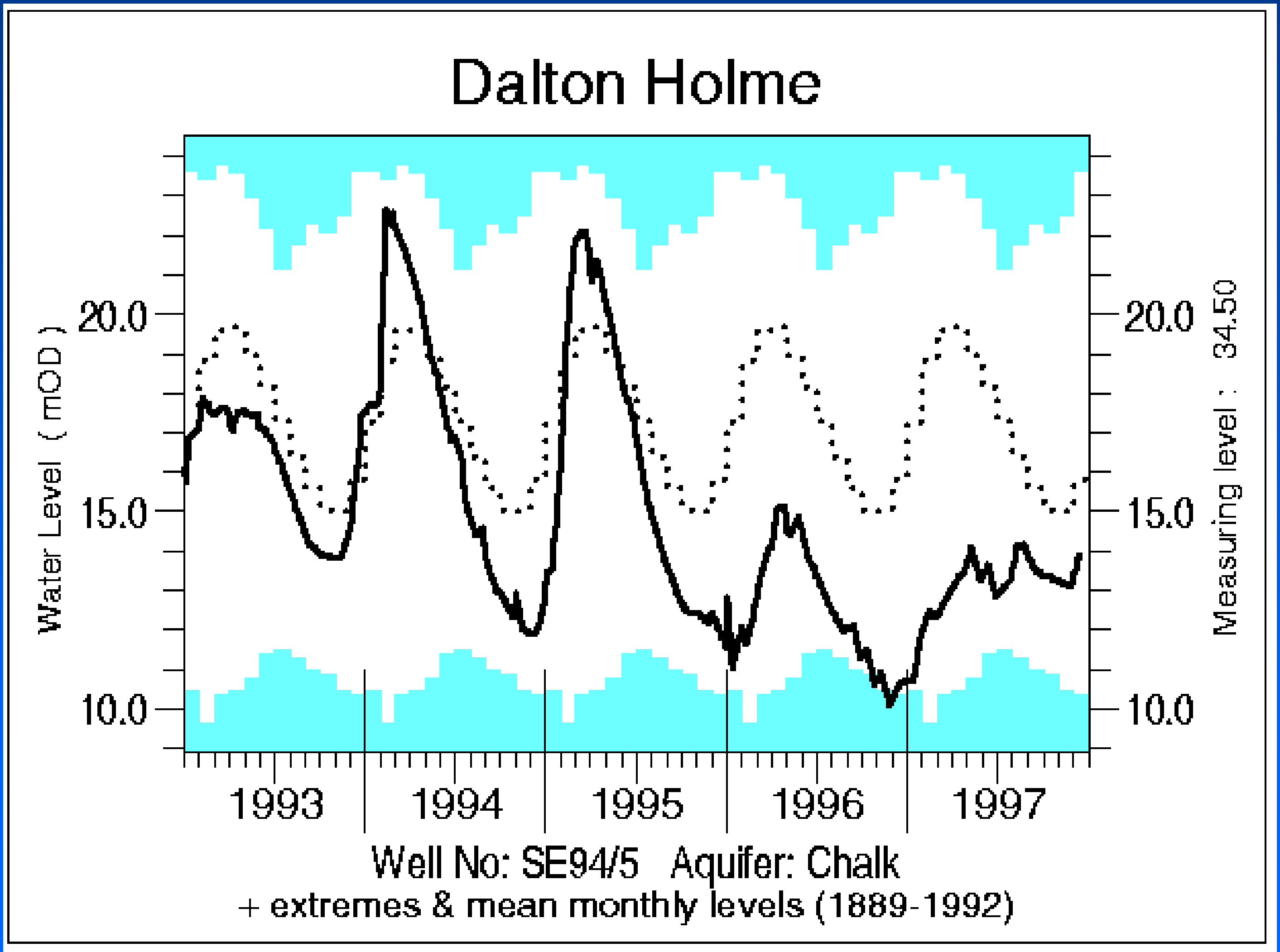
A word about data

- 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



Temporal Variations



- 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

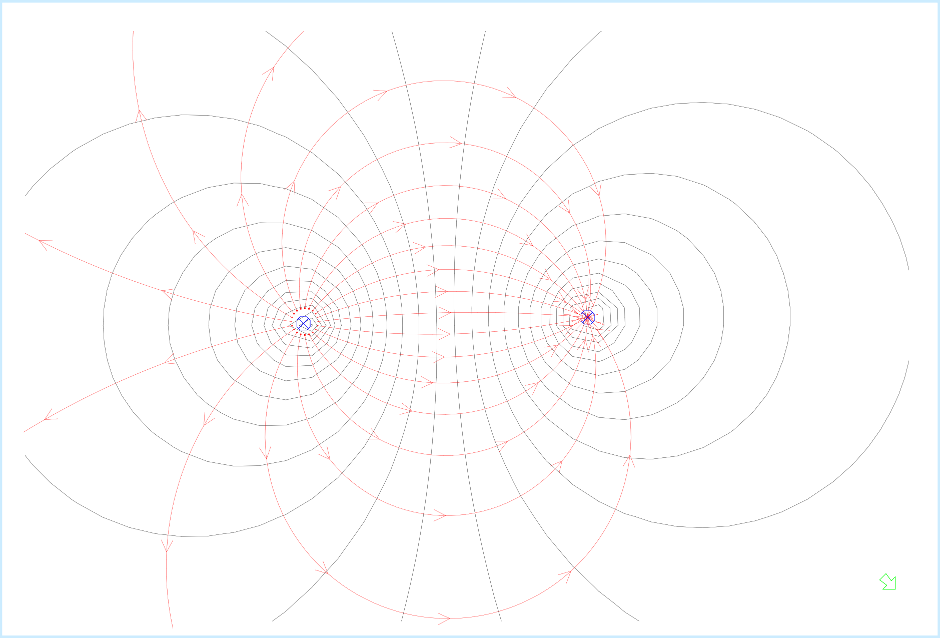
Complexity (data requirements)

Time needed

Cost

Tiered approach - Analytical Solutions

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



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

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

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

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

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

Solution :

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

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

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

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

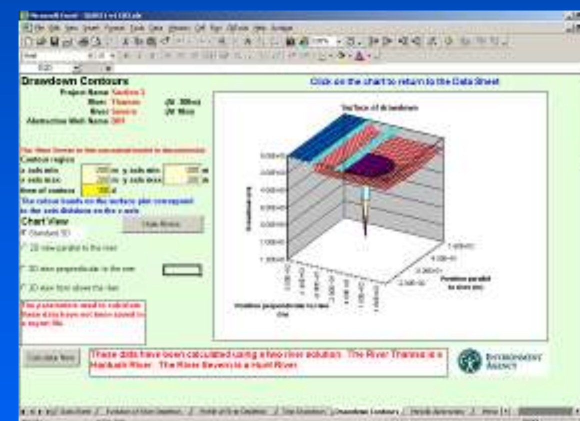
and t_B is the breakthrough time.

esi Analytical Solutions

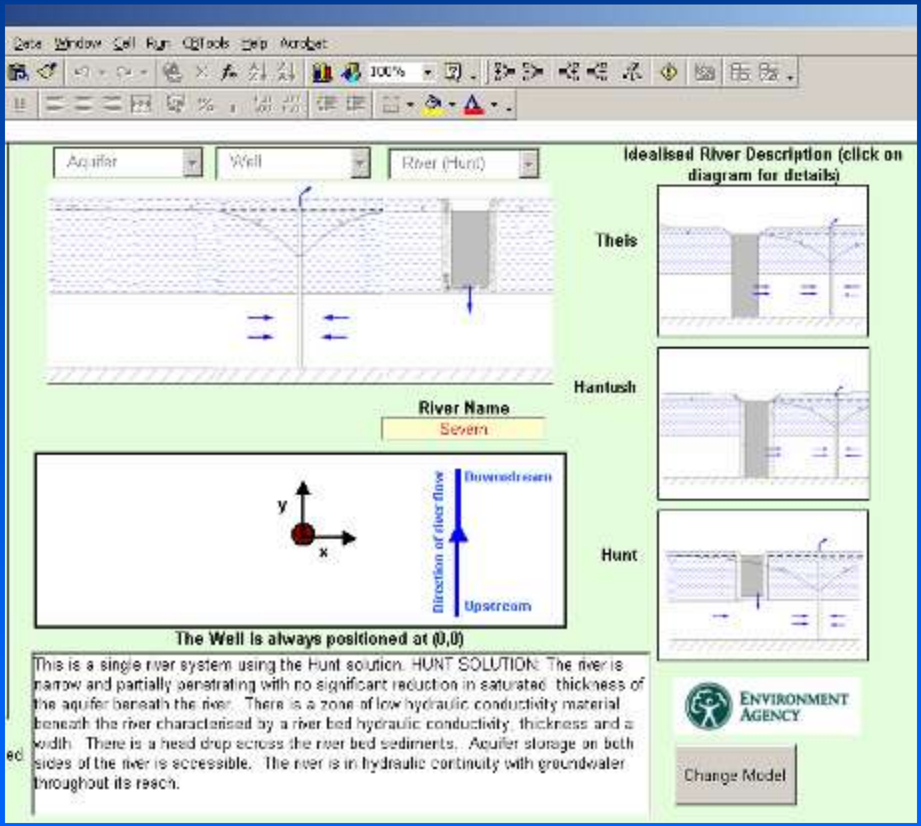
- If we add:

+

=

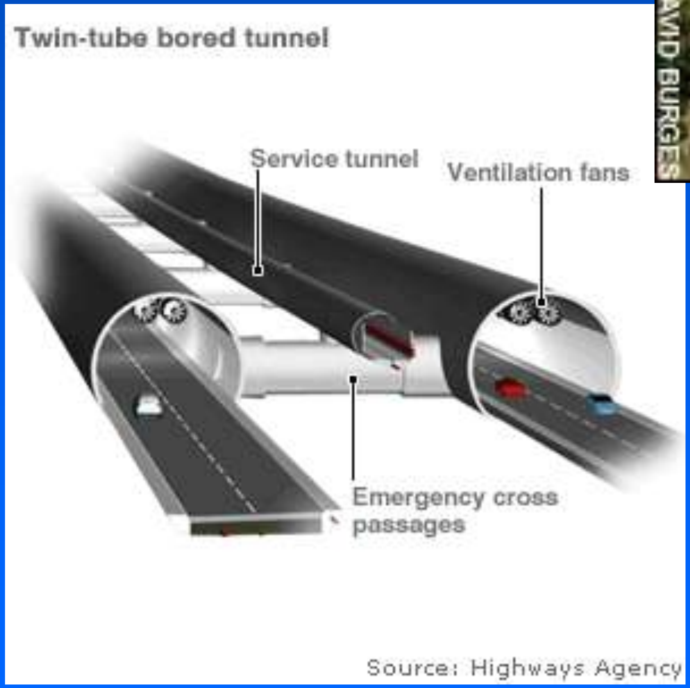


New Analytical Solution Tools



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

Tiered approach – lumped water balance

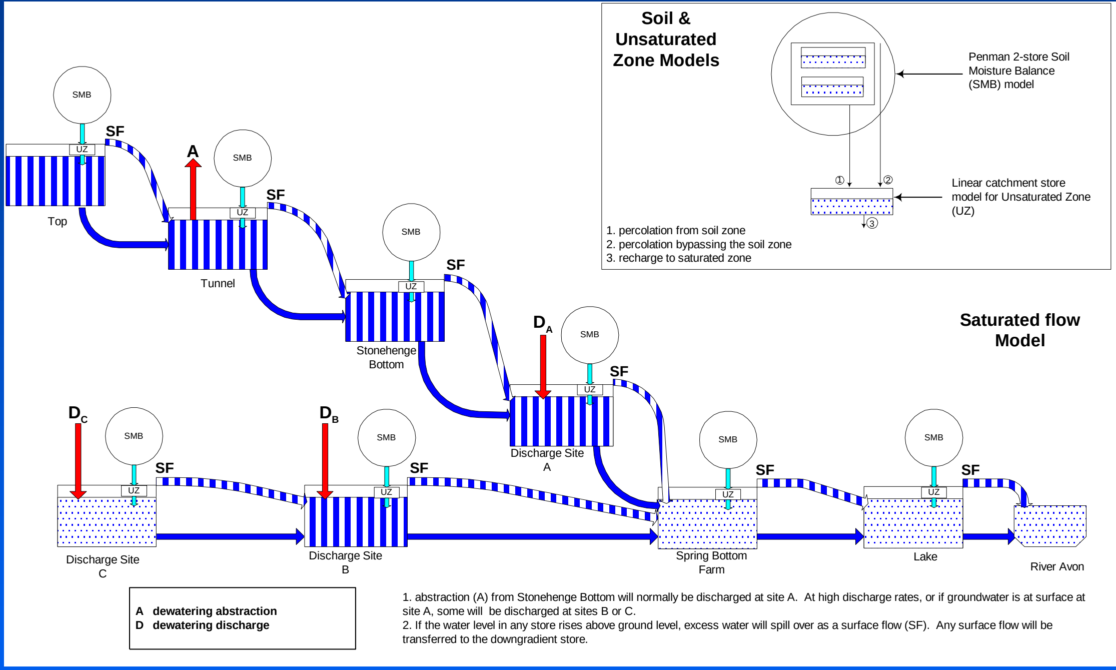


Stonehenge Tunnel – lumped water balance

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

Stonehenge Tunnel – lumped water balance

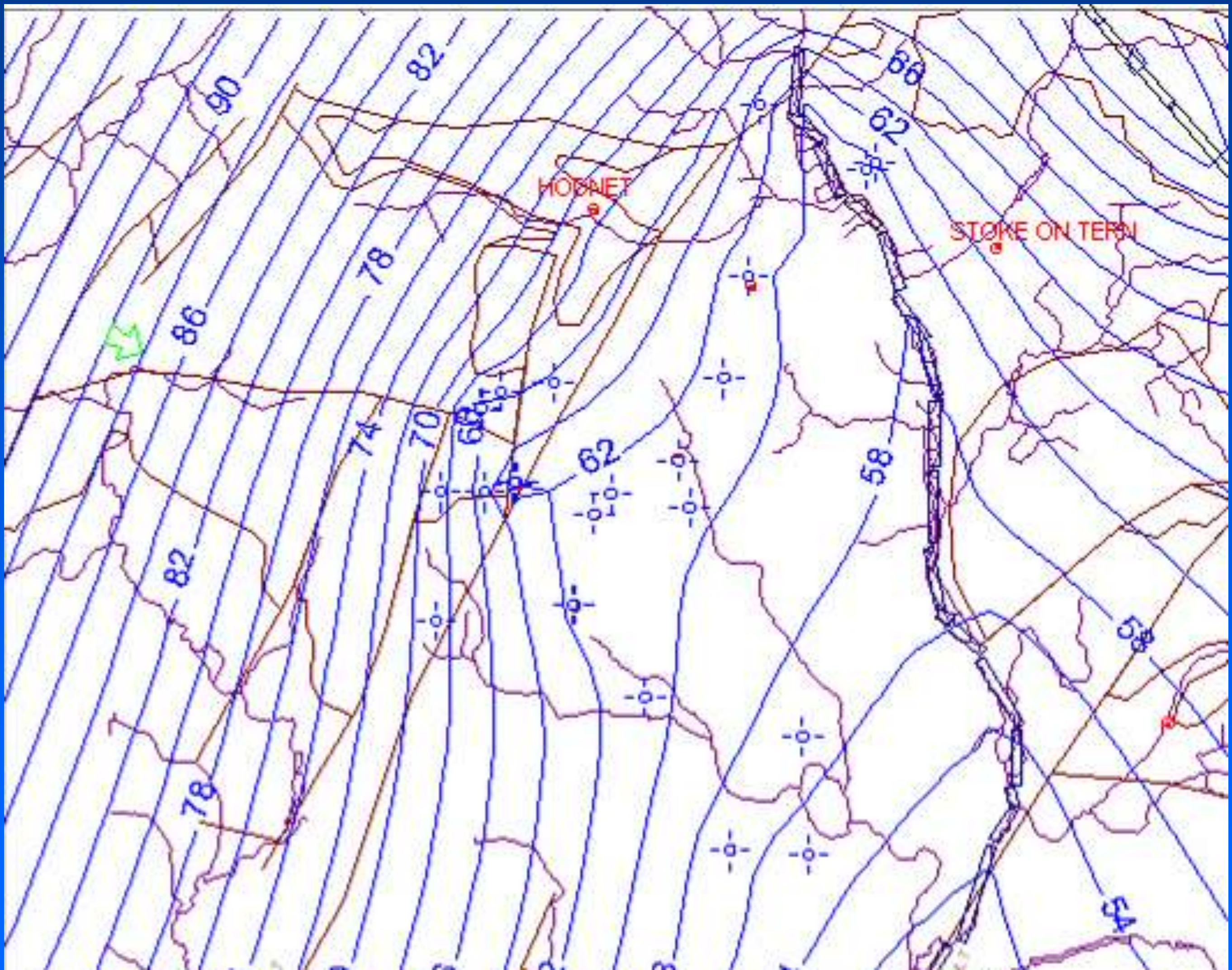
- Chalk very heterogeneous
- Insufficient data to characterise/model with confidence
- Selected a lumped water balance approach
- Regulators were happy



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

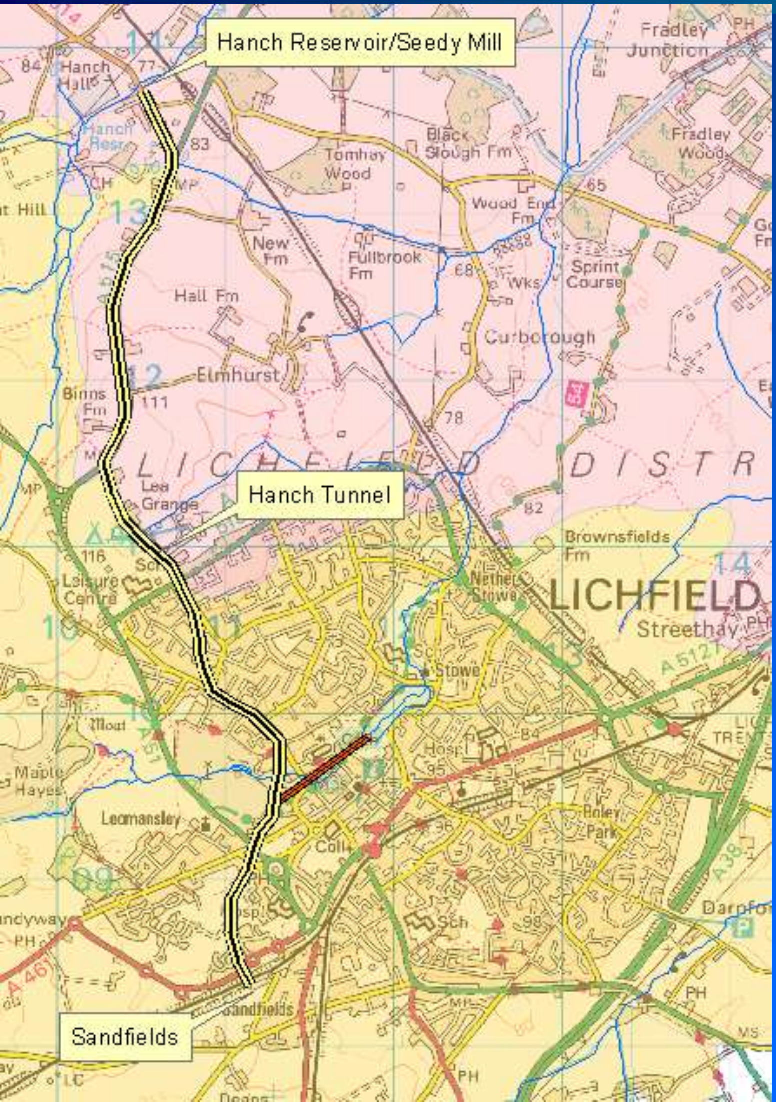
WINFLOW analytical model



Tiered approach - MODFLOW

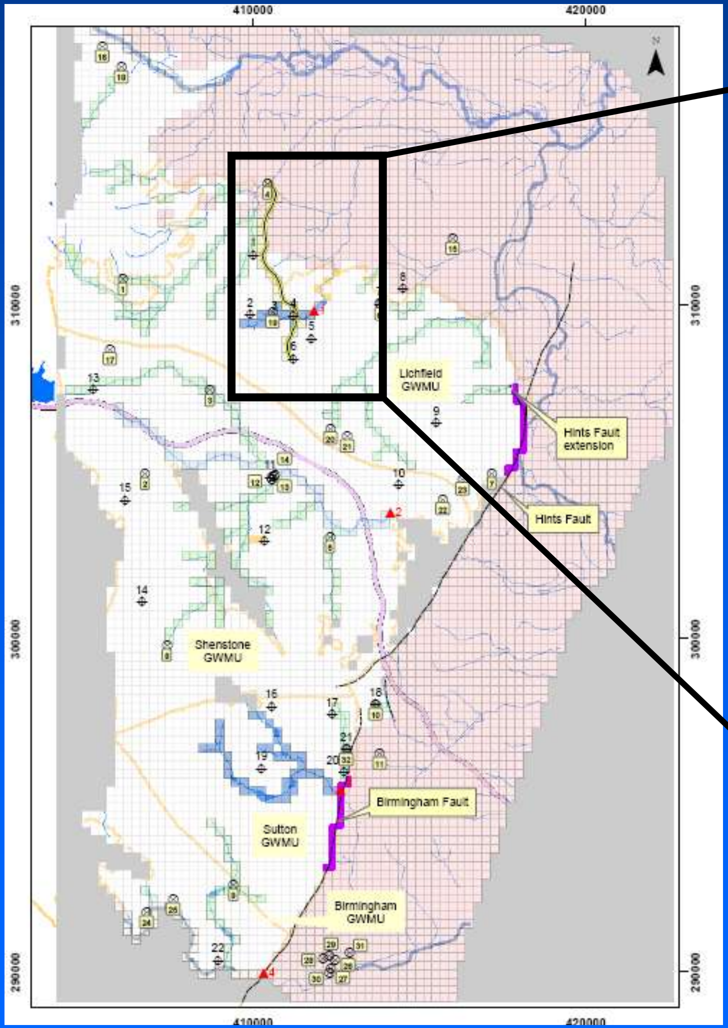
- Pluses:
  - Well established and widely used
  - Environment Agency standard
  - Wide range of GUIs (pre/post-processing)
  - Many add-ons
- Minuses:
  - Limited geometry

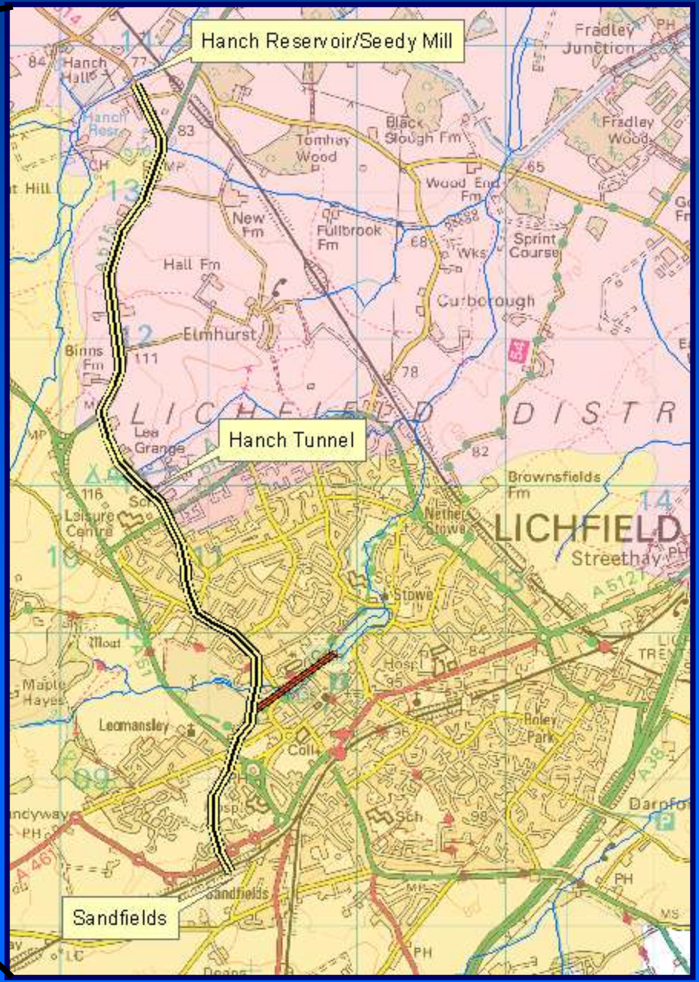
Tiered approach – MODFLOW plus add-ins



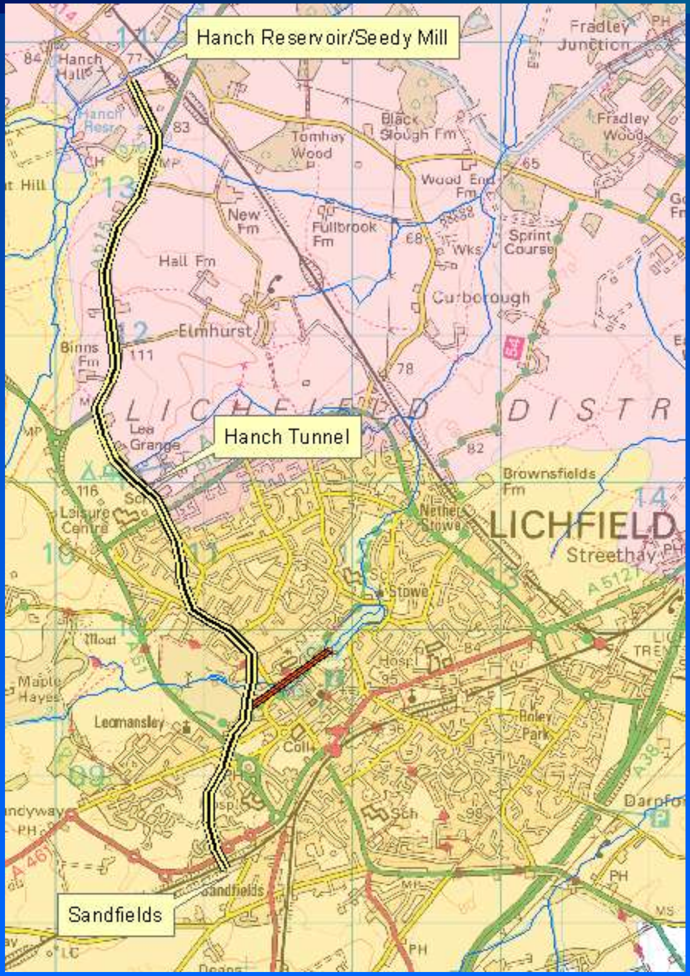
- 6km long Victorian adit
- Excavated in PT Sandstone
- Now runs under SSSI

Simulating a long adit in a regional model

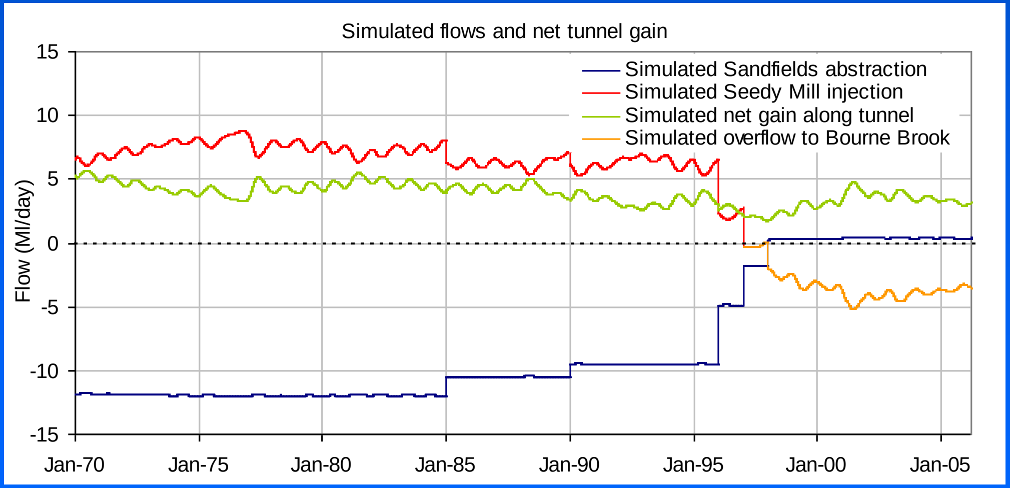




Simulating a long adit in a regional model

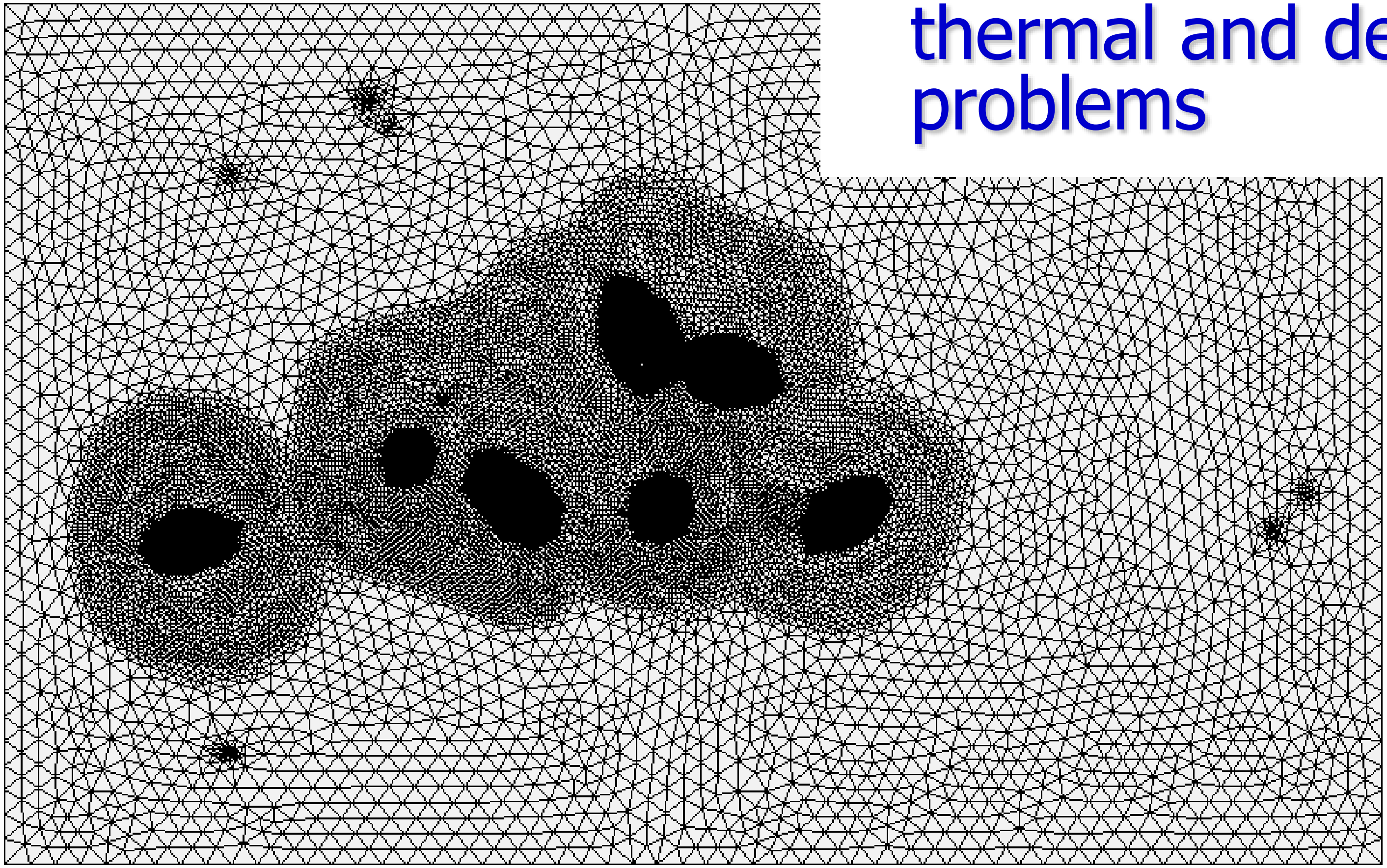


- USGS MODBRNCH code (adapted by Sheffield Uni)
- Issues
  - Time stepping
  - Boundary conditions (stage and flow)
  - Model stability
  - Non-steady state
- Successfully calibrated
- Simulated observed flows



Tiered approach – Finite element modelling e.g. FEFLOW

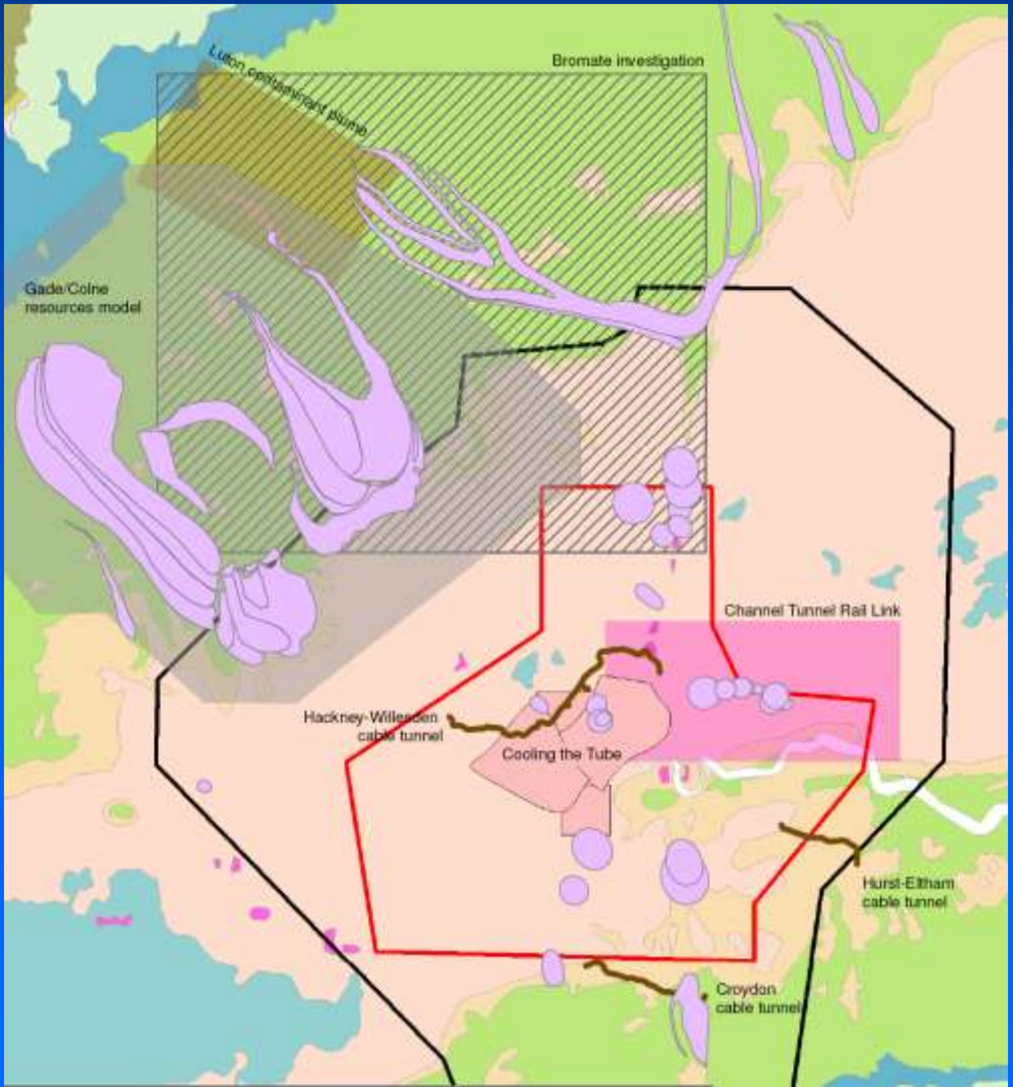
- Improved geometry
- More effective simulation of thermal and density problems



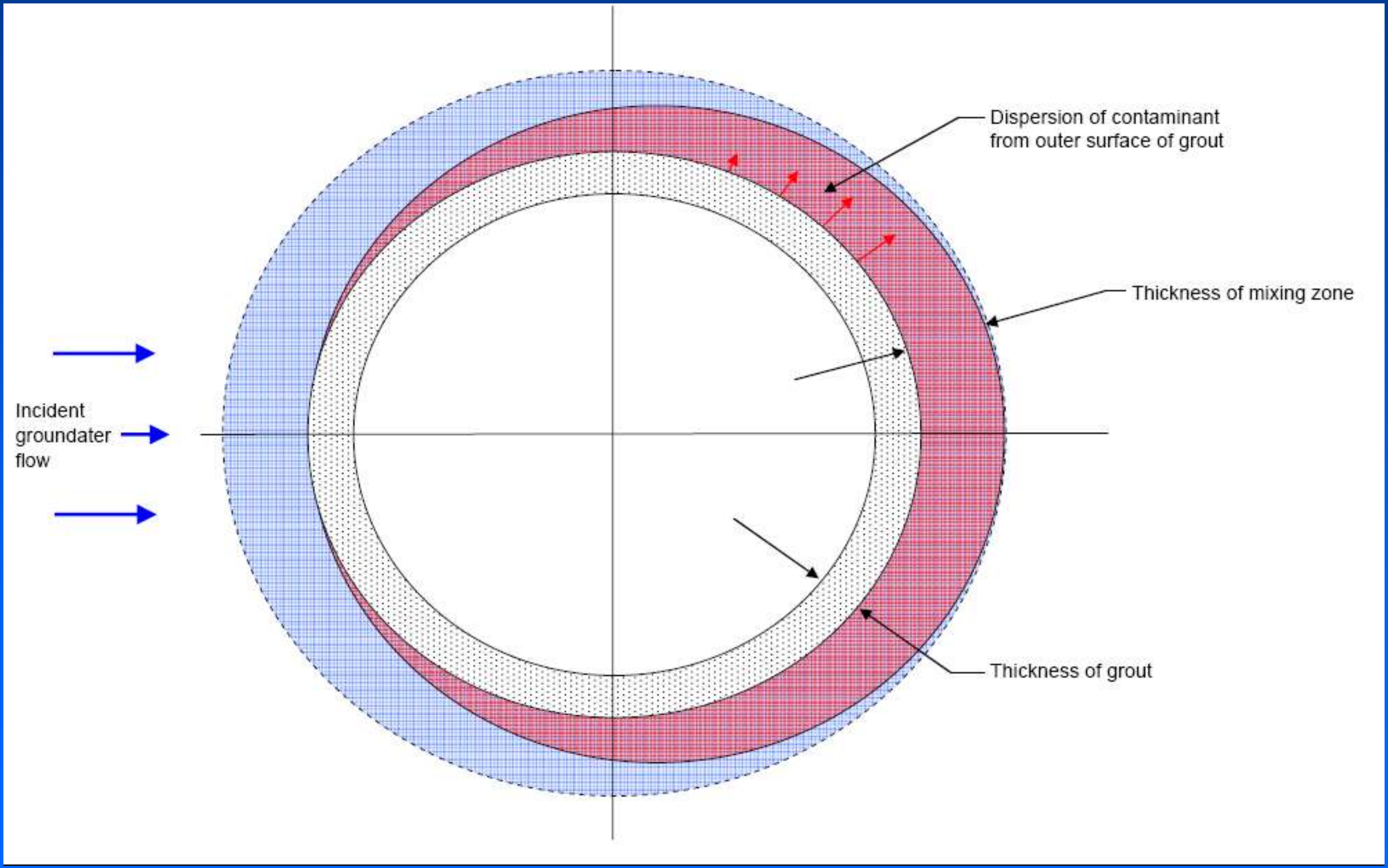
Other Issues

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

London Models



Potential Contamination - Grout



Potential Contamination - Thermal

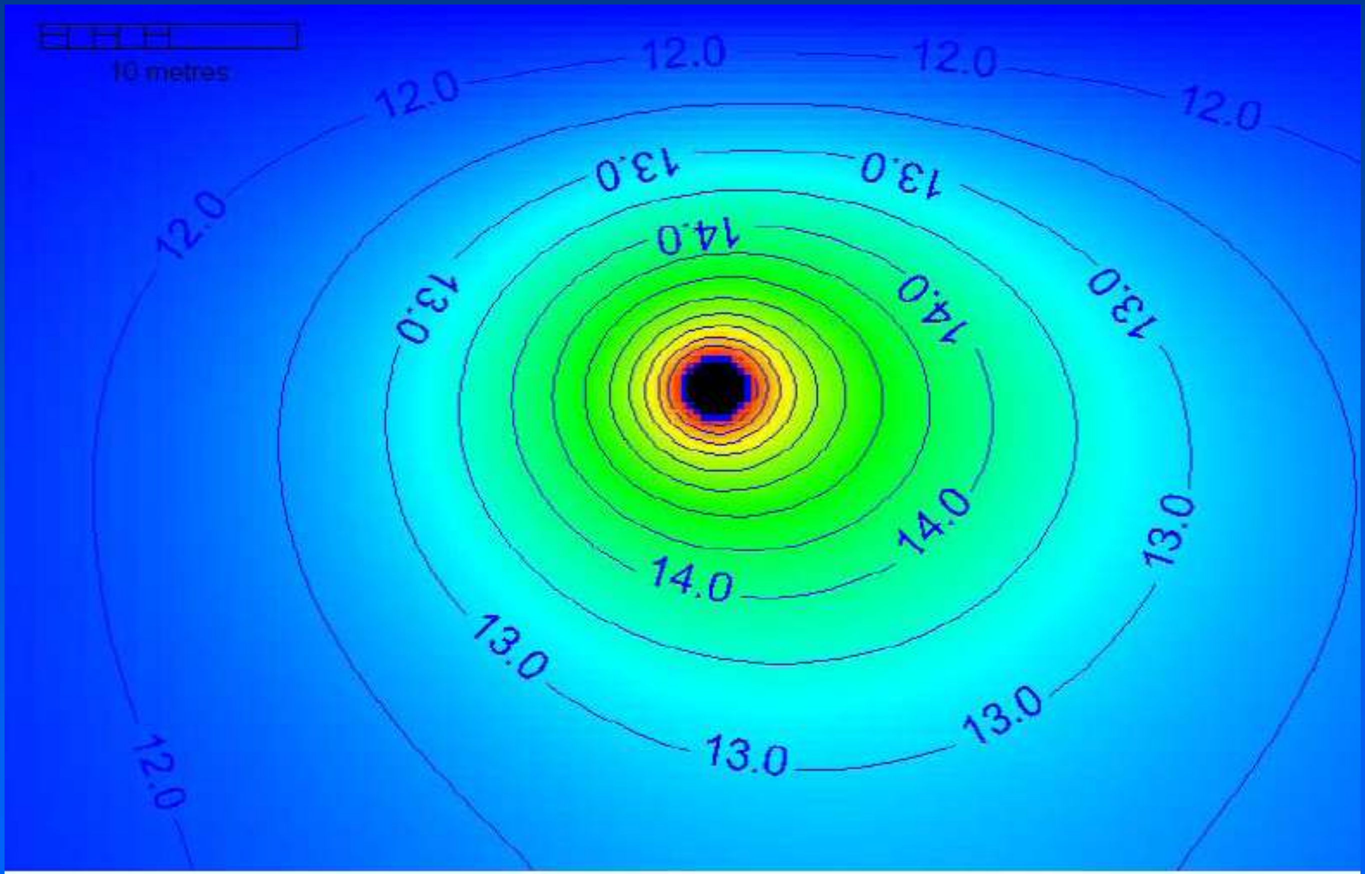
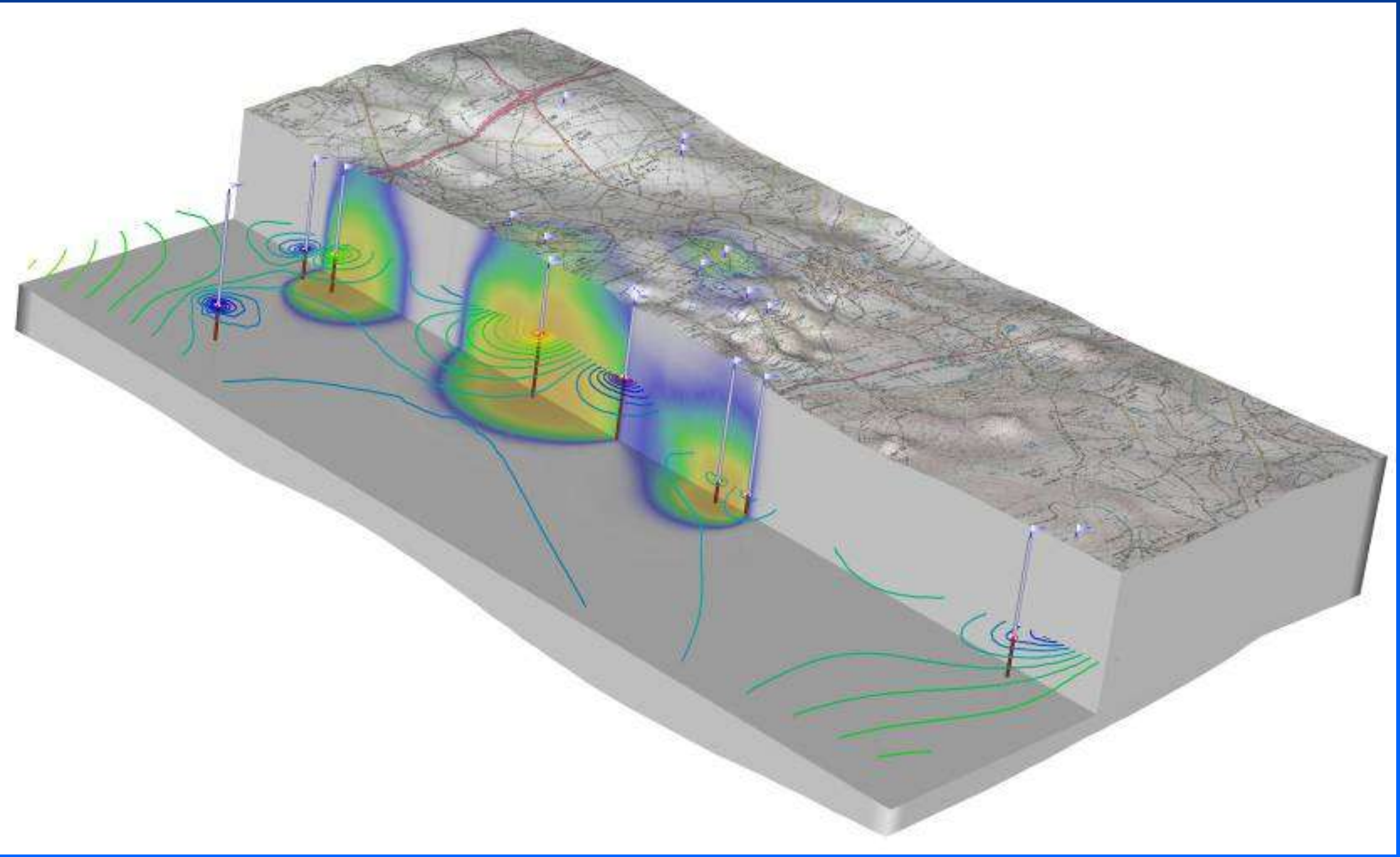


Figure 3.1 b): Isotherms 10 years after tunnel activation

Potential Contamination - Thermal



Conclusions

- 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