British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Groundwater-surface water interactions

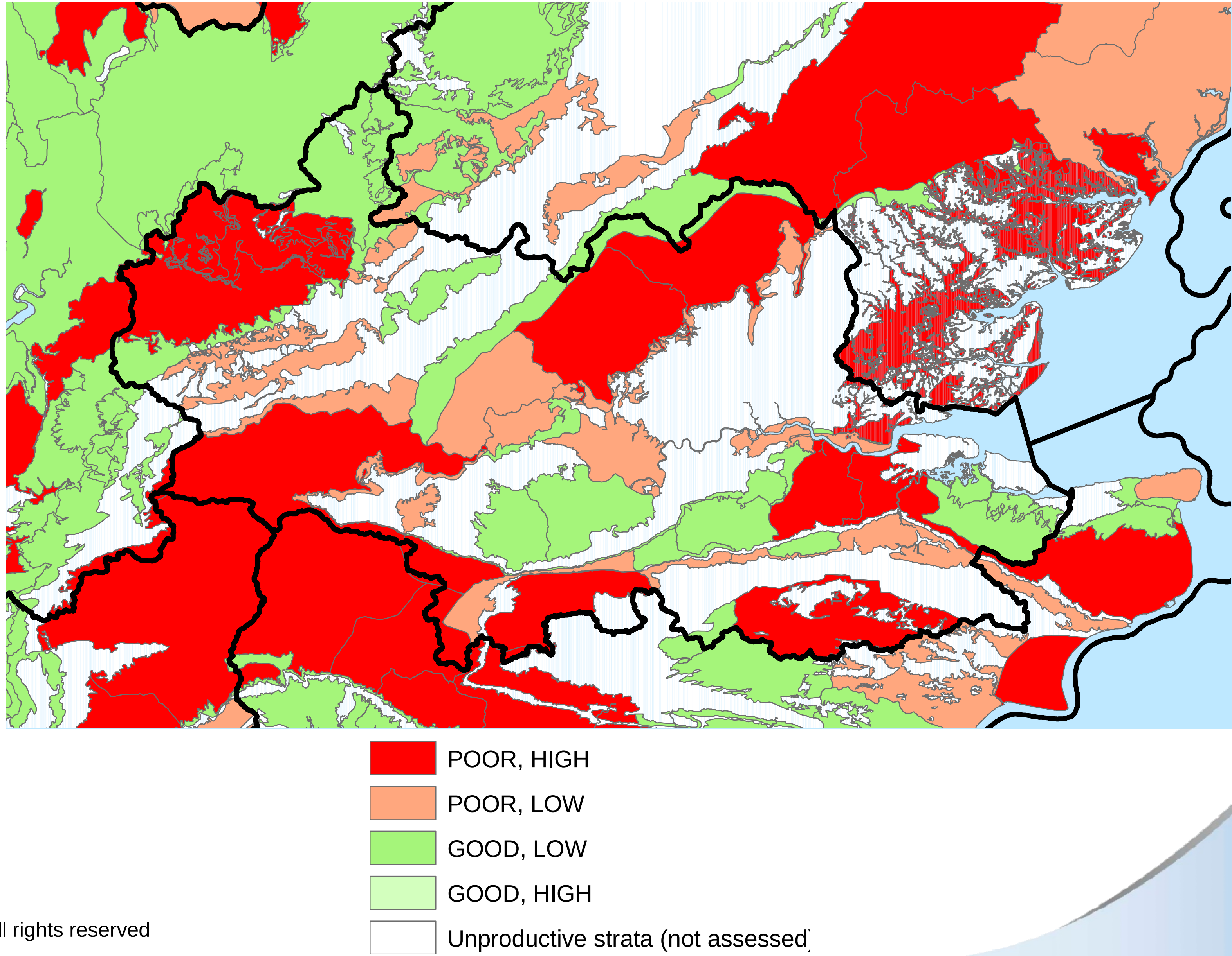
Marianne Stuart

Better Thames

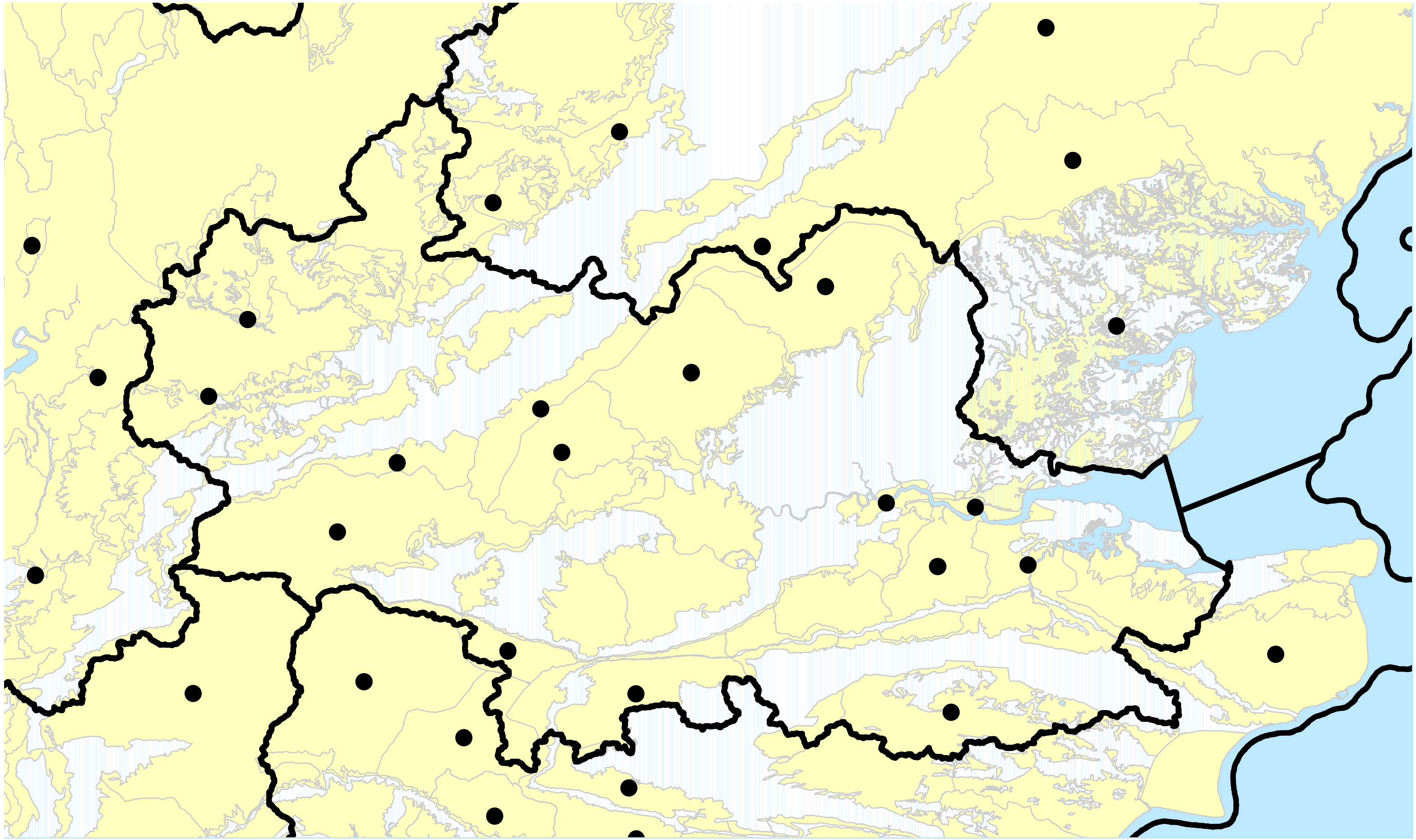
Outline

- Groundwater bodies
- Baseflow
- Nitrate time bomb
- Hyporheic zone
- Boxford Observatory
- Floodplains
- Oxford Port Meadow Observatory
- Water quality
- Flooding
- Climate change

Groundwater bodies – overall chemical status



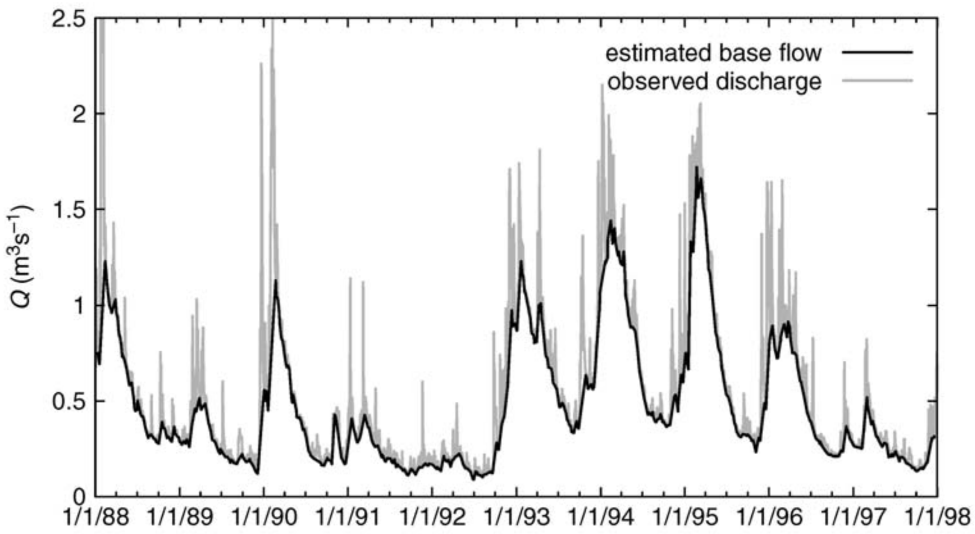
Groundwater bodies – trends



- GWB with significant upward trend
- GWB with trends reversed

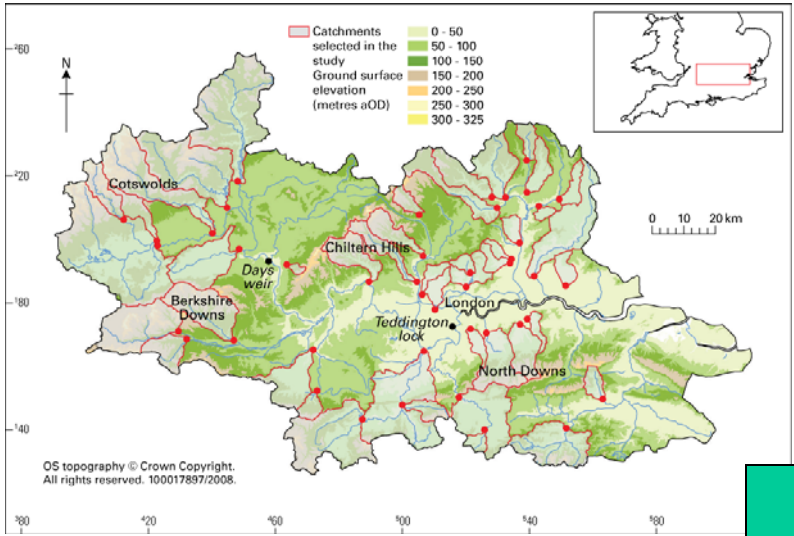
Baseflow index

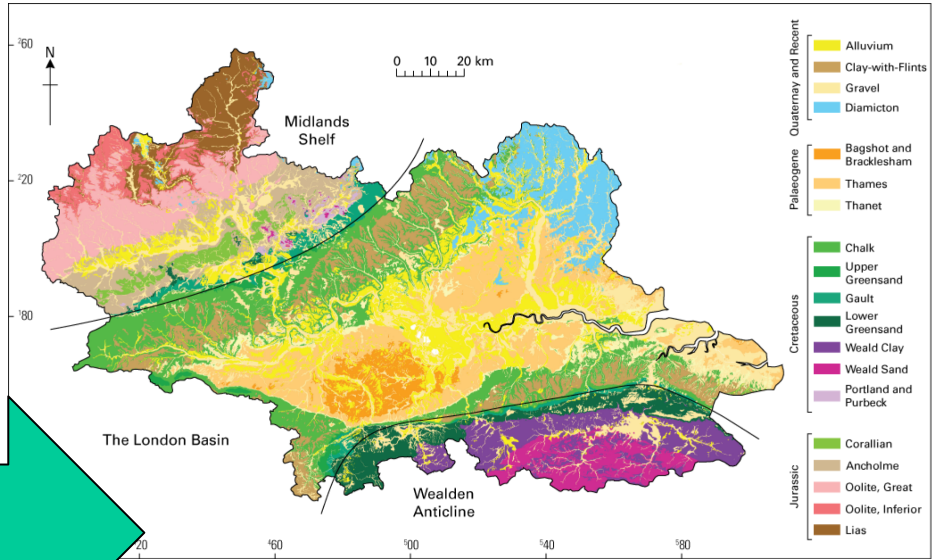
- An estimate of the contribution of groundwater to surface flow, taken as a proportion of total streamflow.
- Typically 0.15 to 0.35 for clay catchments
- >0.9 for chalk streams
- 0.9 for Jurassic limestone catchments
- 0.65 for Thames in West London
- 0.87 Pang at Pangbourne

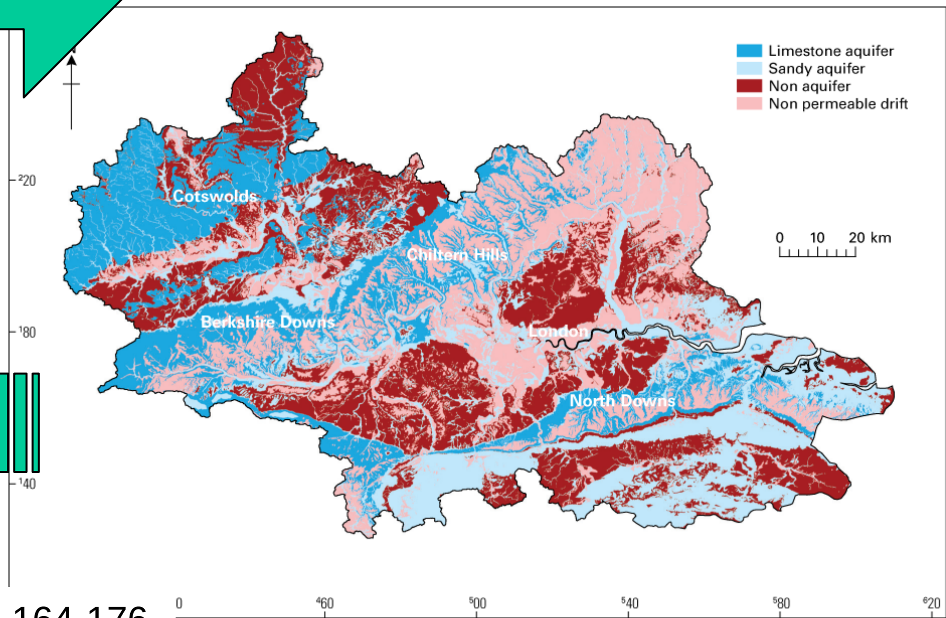


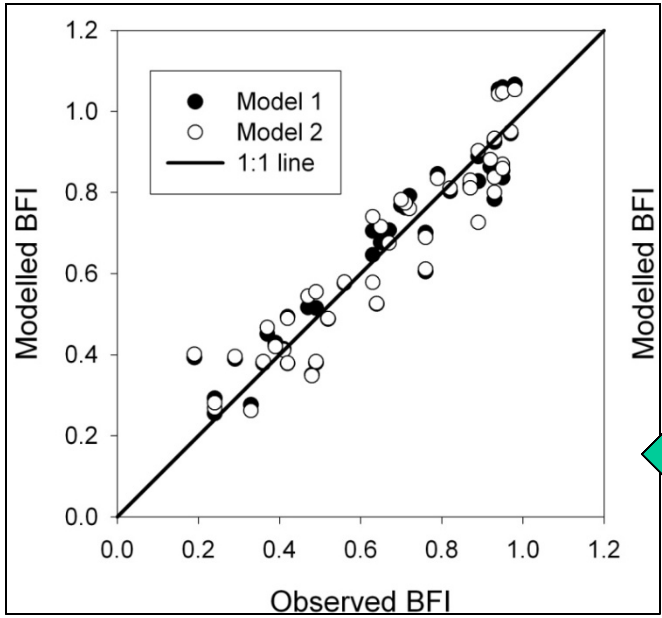
Estimation of baseflow in the Pang at Pangbourne using BFI. From Peters & van Lanen, 2005. Hydrological Processes, 19, 921-936

Geological and hydrogeological statistical models of baseflow in the Thames Basin







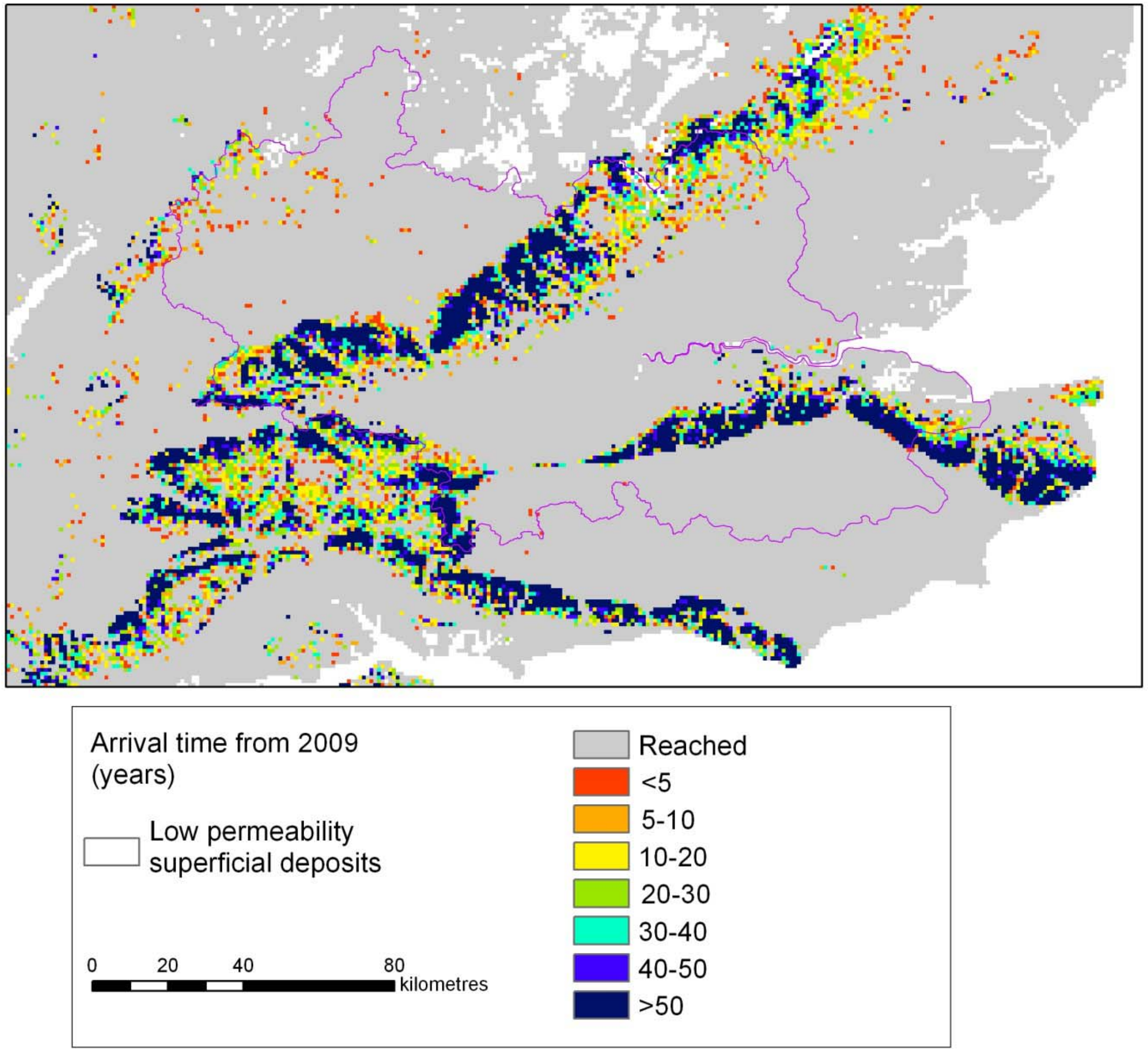


© NERC Bloomfield et al 2009 Journal of Hydrology 373, 164-176

Nitrate in the unsaturated zone

Model relating:

- Unsaturated zone velocity
- Depth to water
- 1980-90 peak nitrate applications

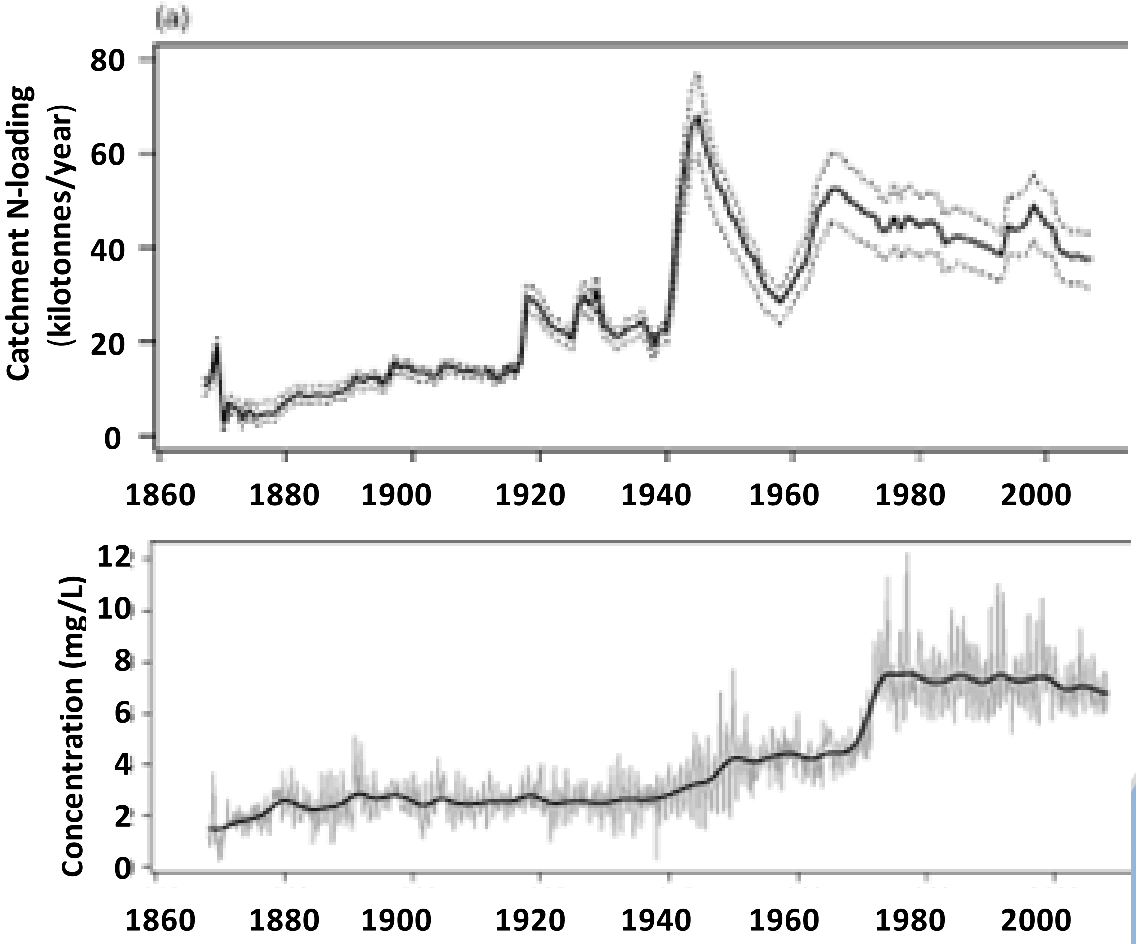


From Wang et al. 2012, Hydrological Processes, 26, 236-239

Nitrate flux in Thames catchment

Nitrate data show:

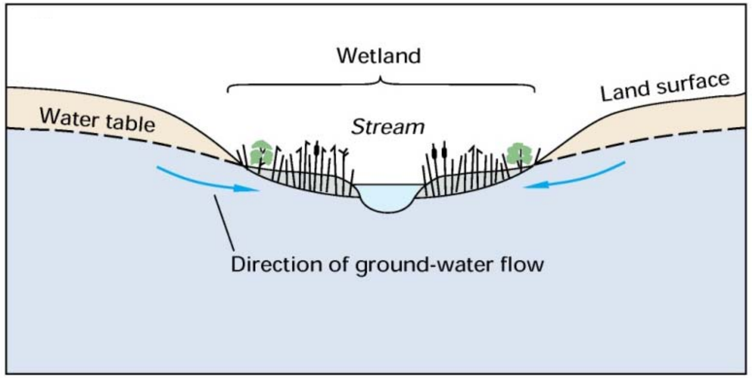
- Rapid response to landuse change
- Slower component due to groundwater pathway
- Overall limited system recovery from



From Howden et al. 2010. Hydrological Processes, 2657-2662

Wetlands

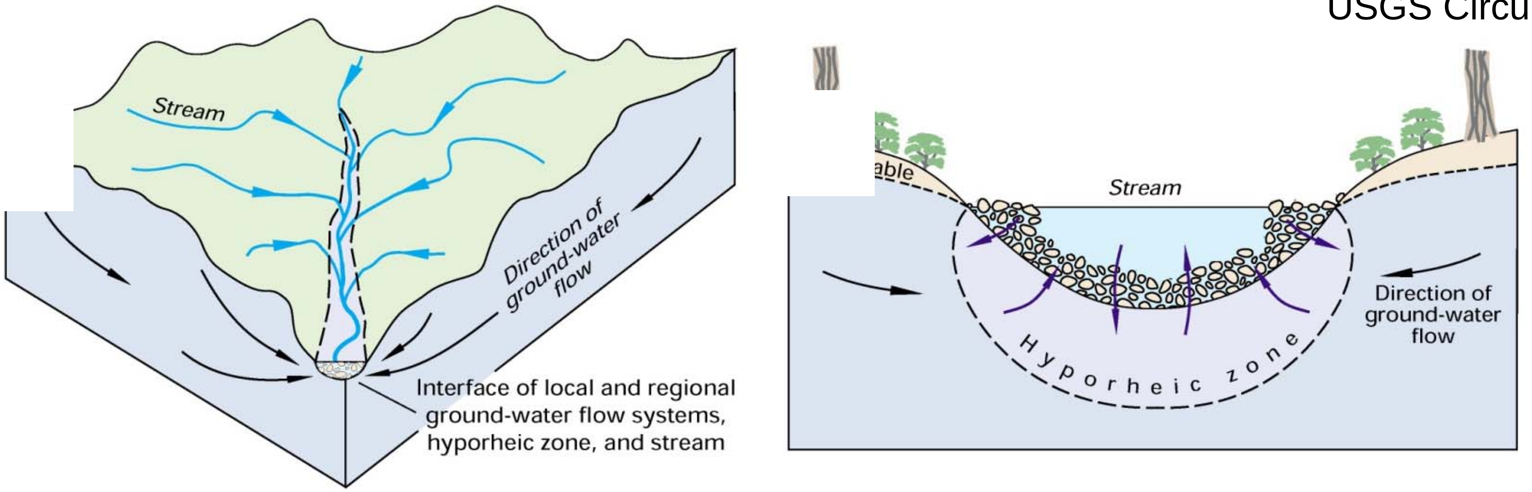
- Good groundwater chemical status requires that the concentrations of pollutants in groundwater would not cause significant damage to the ecological quality of a surface water body or to a terrestrial ecosystem, such as a wetland



From Winter et al ,2008 USGS Circular 1139

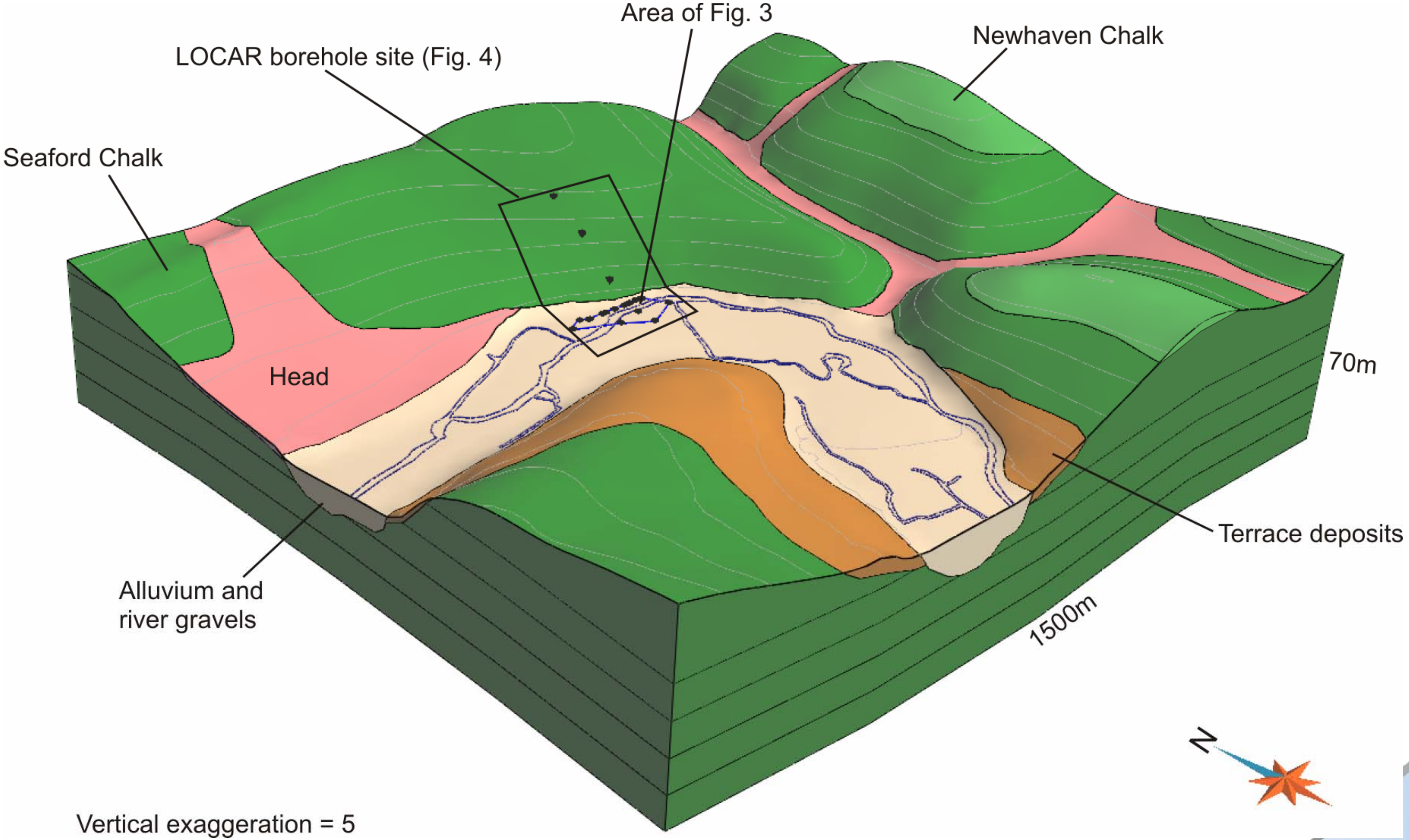
Hyporheic zone

From Winter et al ,2008
USGS Circular 1139



- Exchanges of water, nutrients and organic matter
- Microscale gradients in redox potential and nutrient transformations
- Stream scale gradients in faunal composition, uptake of organic carbon and nitrification
- Catchment scale hyporheic corridor possible km from main channel
- To understand nutrient movement we need to understand residence time, multiple flow paths and hydraulic reversal

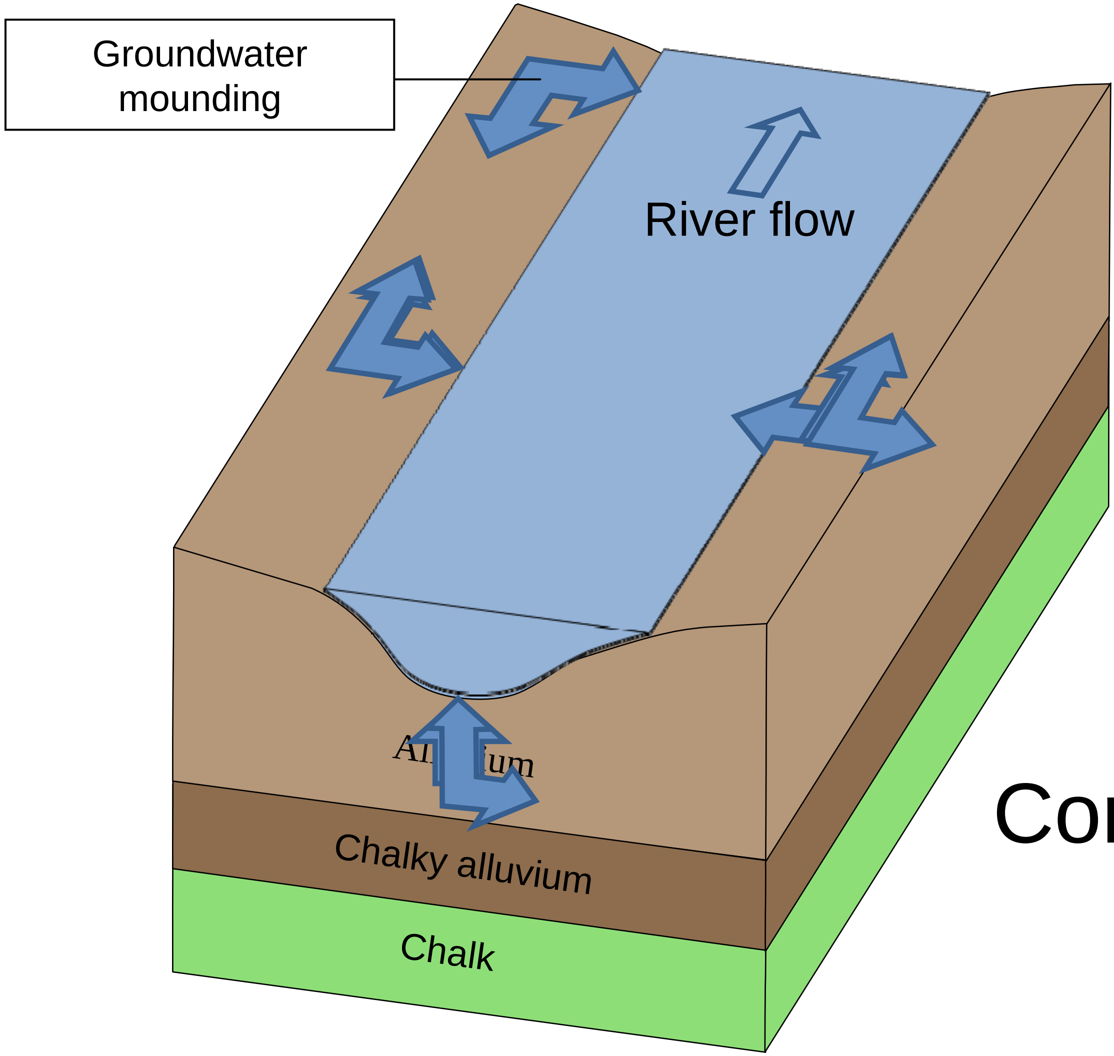
Boxford



Area of Fig. 3
Newhaven Chalk
LOCAR borehole site (Fig. 4)
Seaford Chalk
Head
70m
Terrace deposits
Alluvium and river gravels
1500m
N
Vertical exaggeration = 5

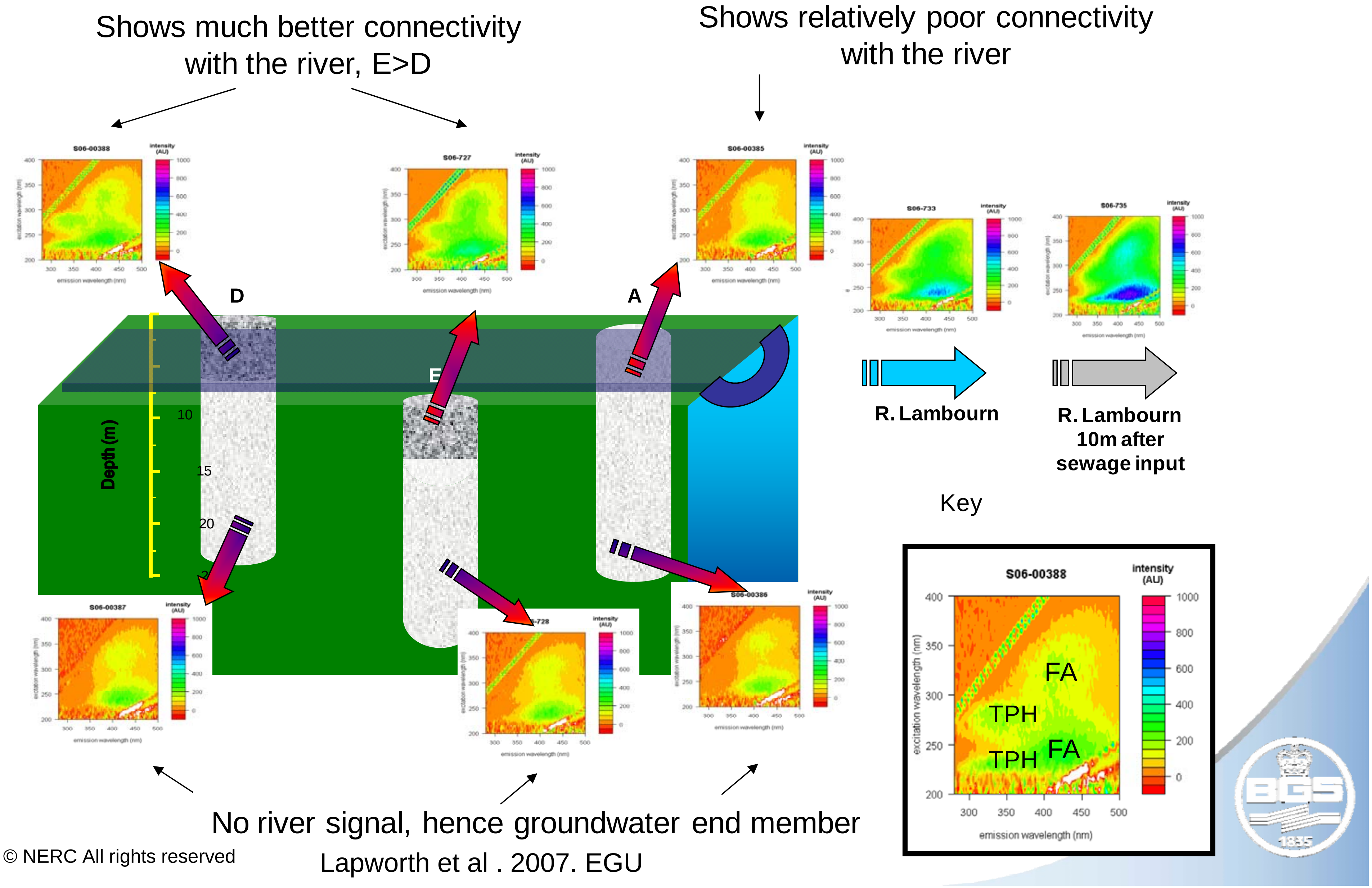
HLigohw river stage

Hydraulic reversal



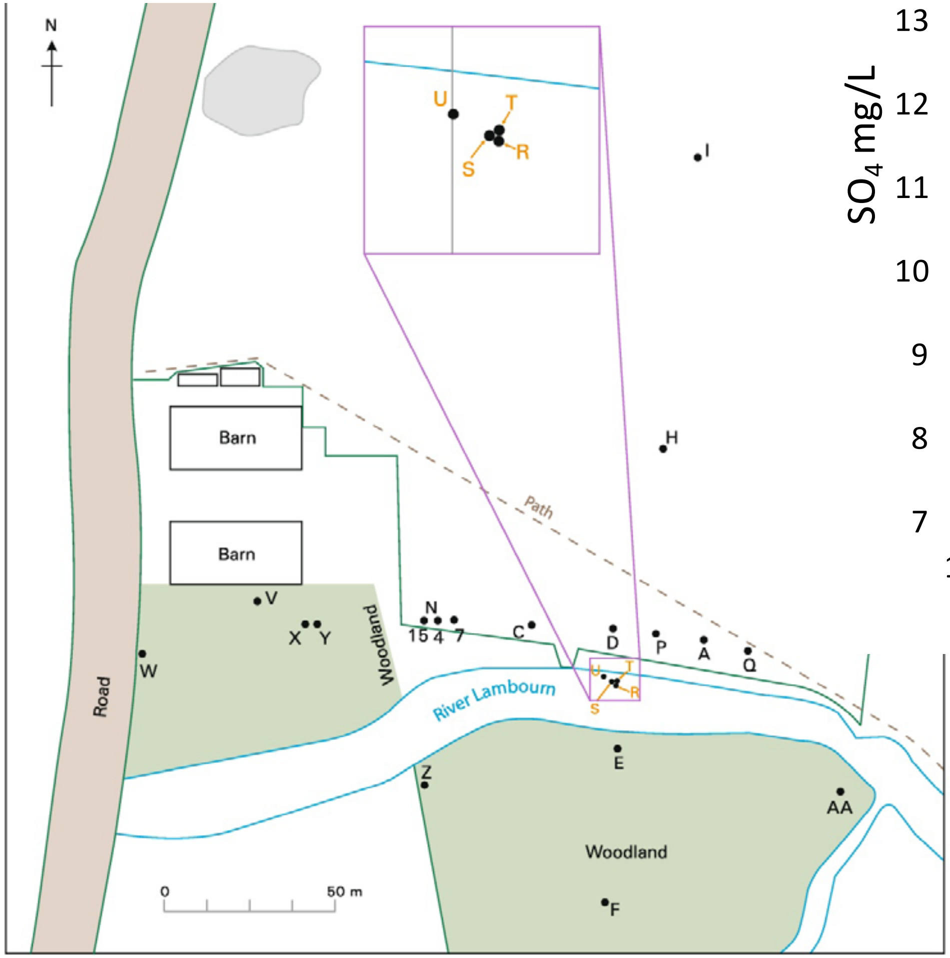
Complicated!

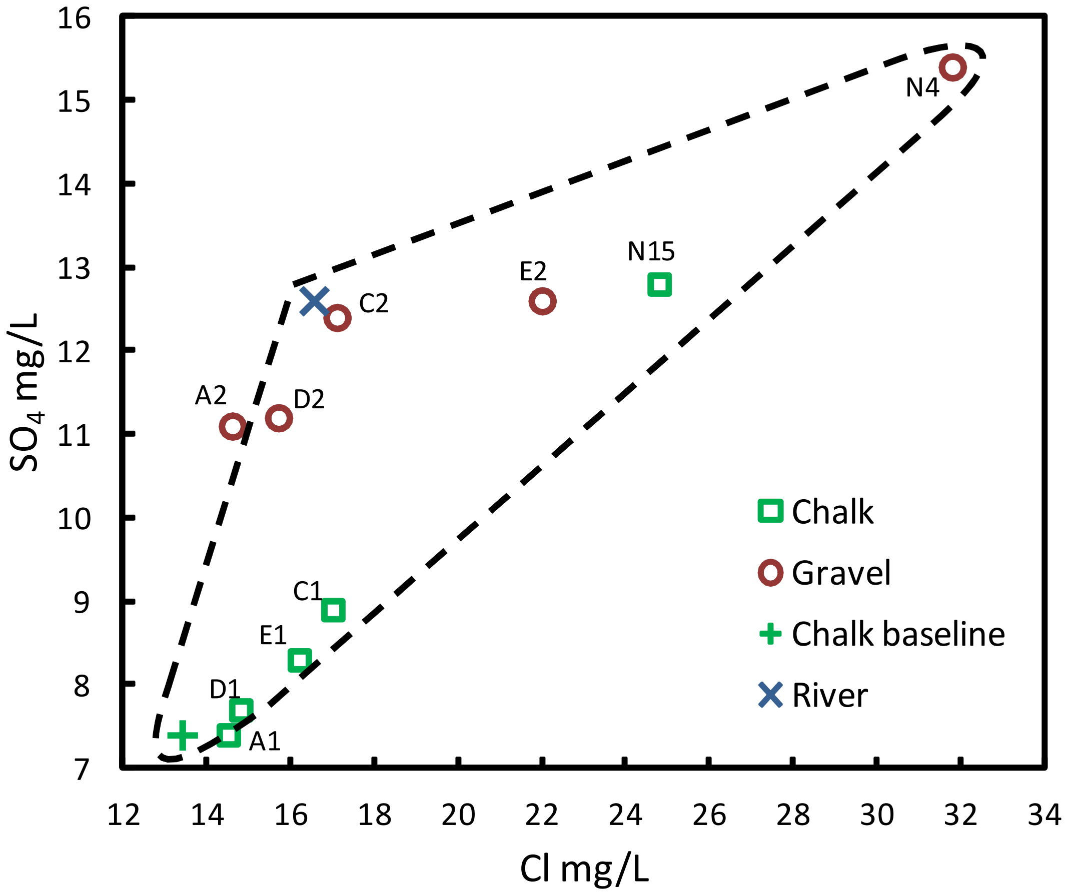
Using fluorescence to show gw/sw interaction



Lapworth et al . 2007. EGU

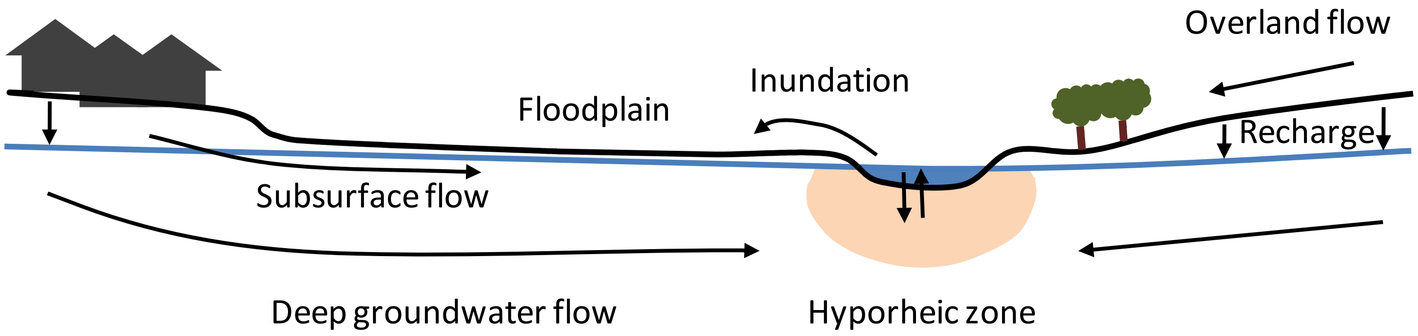
Farm impact





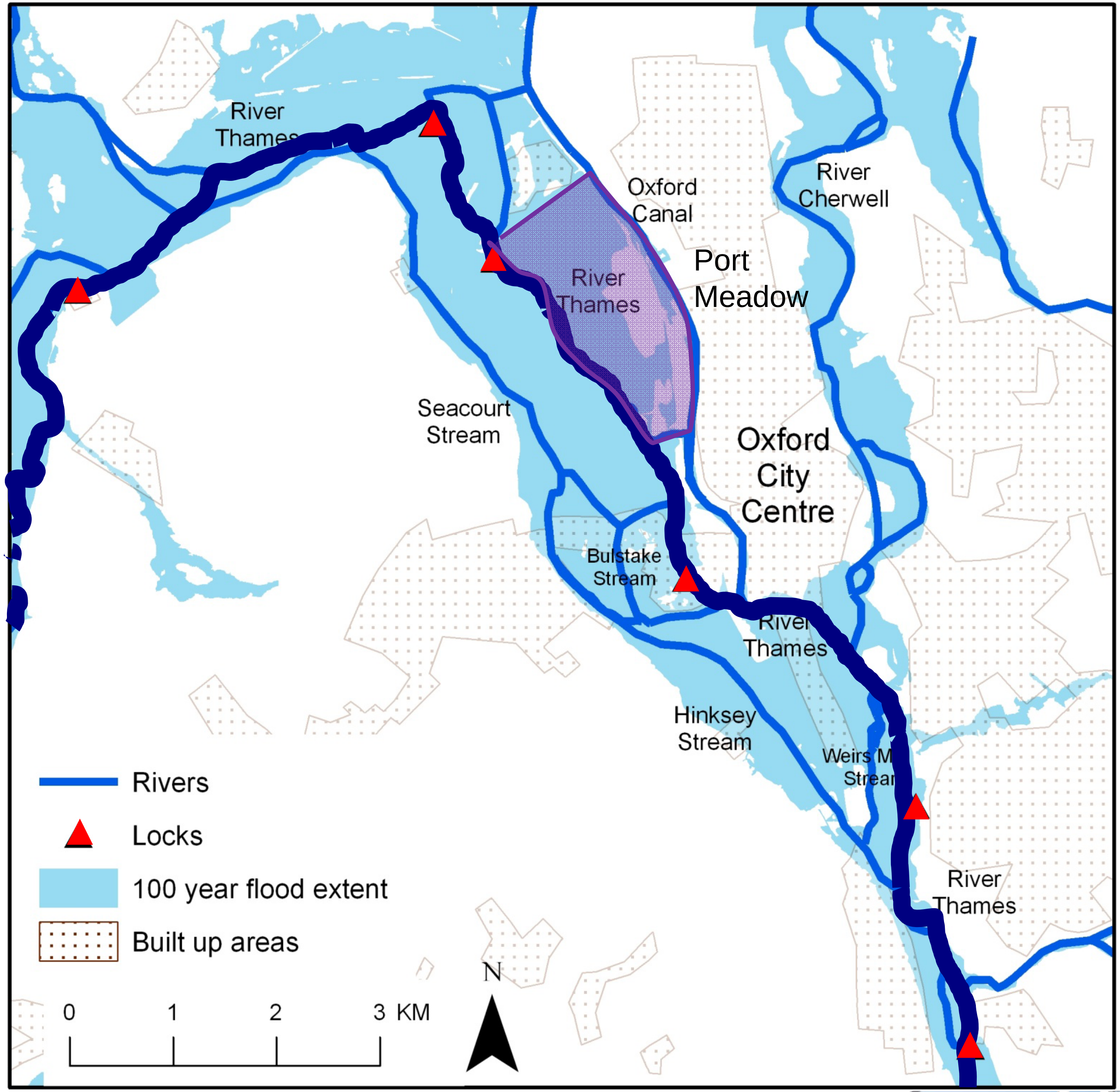
From Allen et al. 2011. Hydrogeology Journal , 18, 5, 1125-1141

Floodplains



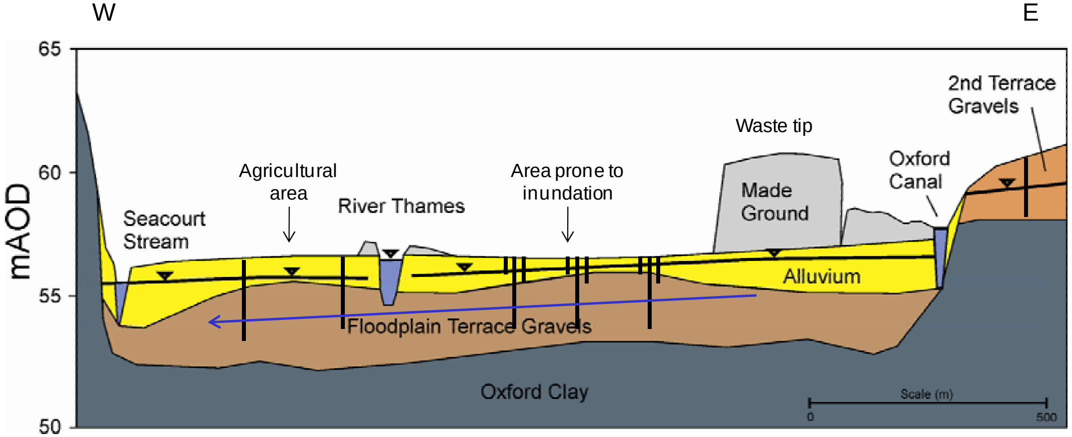
- Collection point for groundwater, overland flow and river water
- Dynamic environment – shallow fluctuating water table, flood inundation, reversal in gradient
- Exchanges of water and nutrients
- Redox spatially and temporally variable
- Significant denitrification but P accumulation
- For many other contaminants may be significant natural remediation
- Implications for attenuation of groundwater pollutants and discharge to rivers

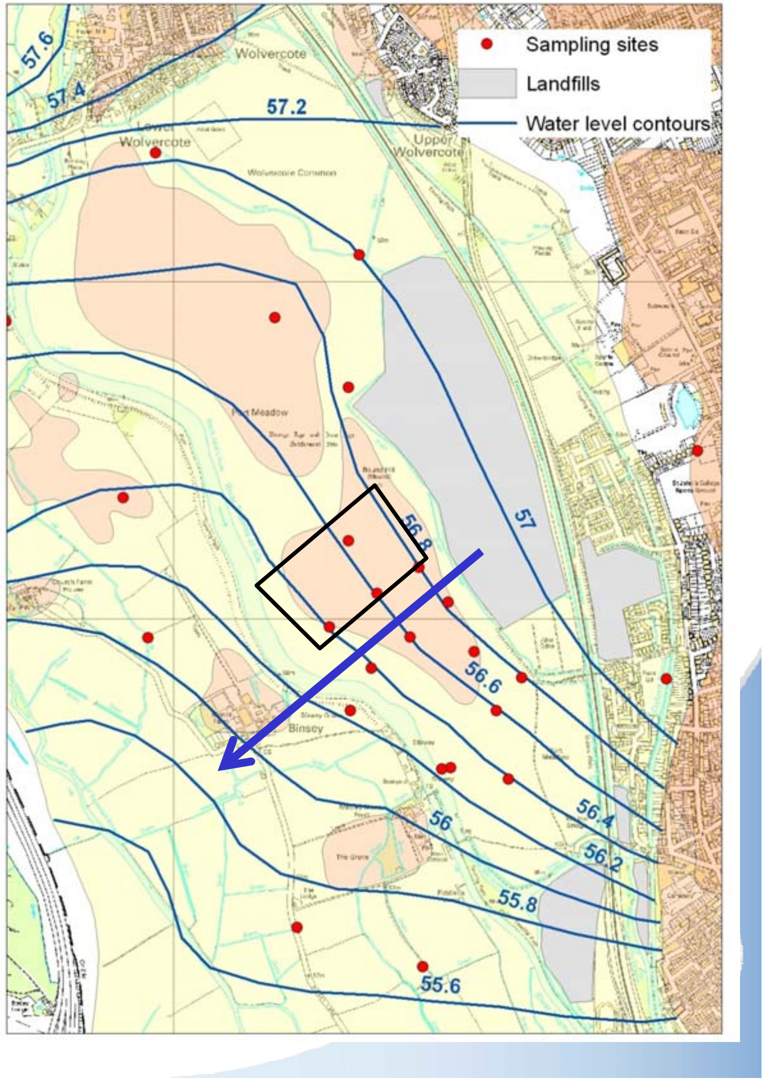
Oxford floodplain



Port Meadow research site

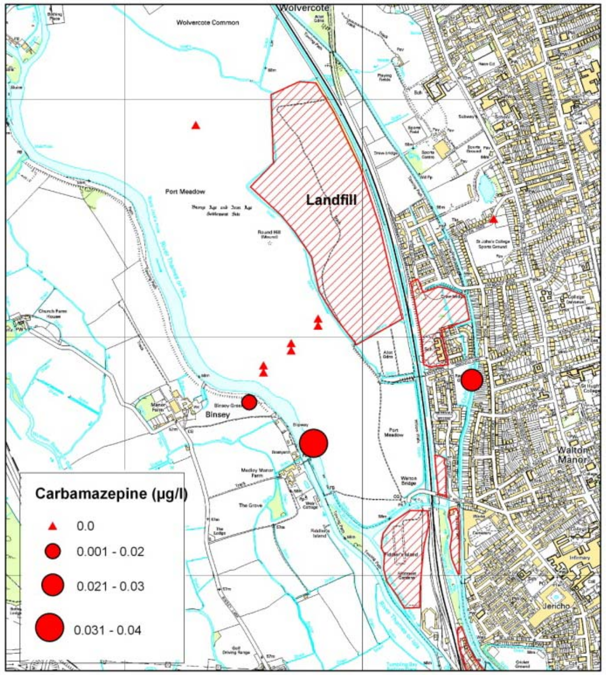
- On Thames floodplain west of Oxford
- Urban area, old landfill, agriculture
- Dynamic environment – shallow fluctuating water table, flood inundation, reversal in gradient
- Implications for attenuation of groundwater pollutants and discharge to rivers

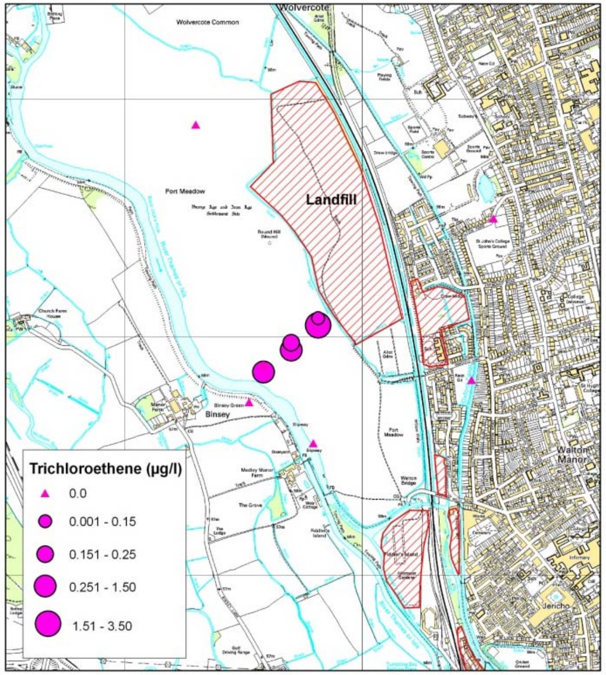


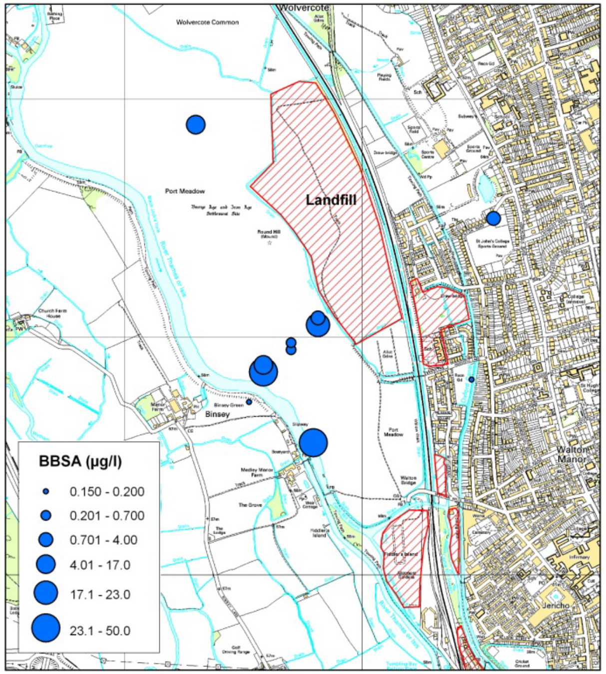


Water quality in Port Meadow

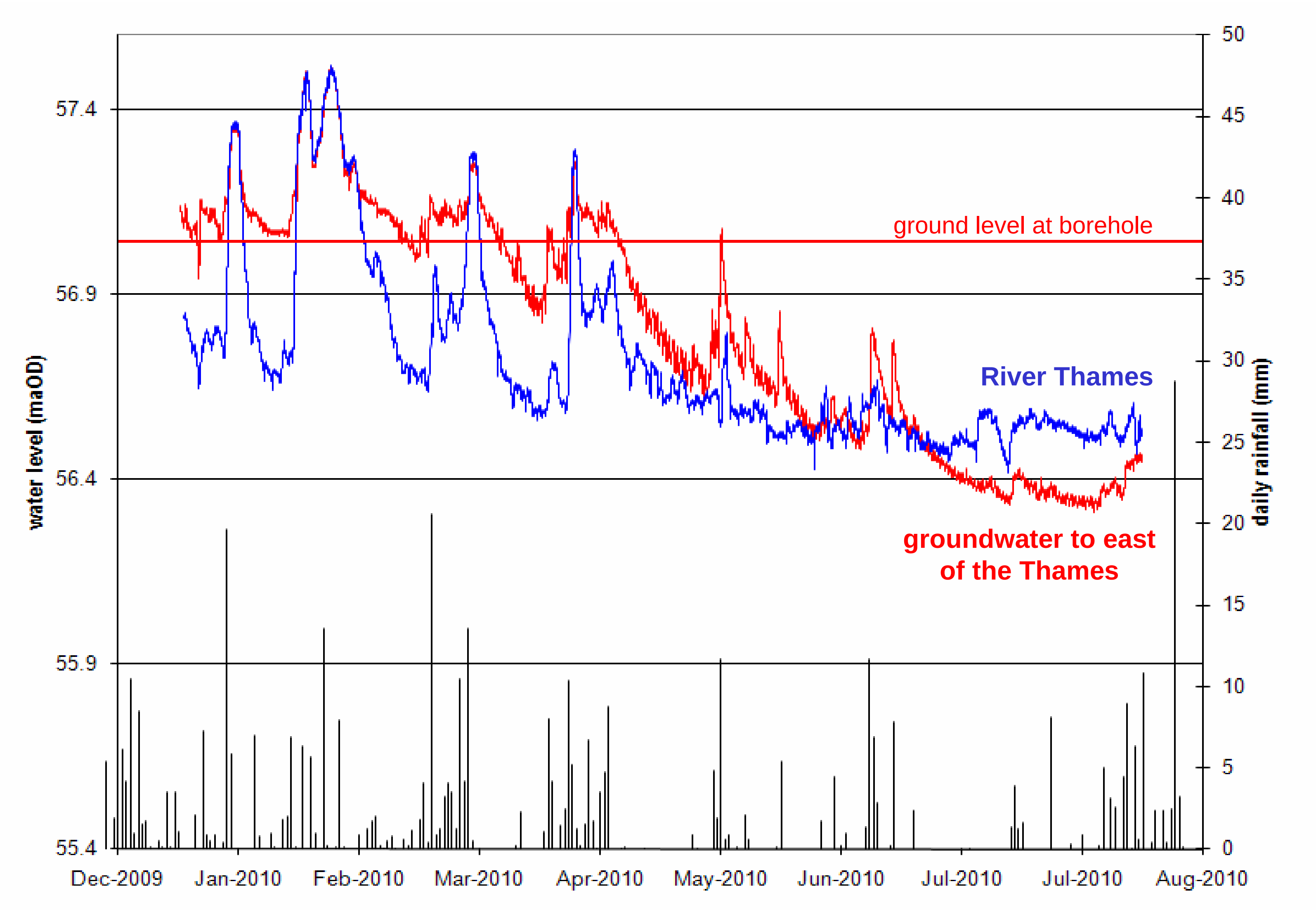
- Flow is to SE towards Seacourt Stream
- Groundwater predominantly reducing – nitrate removal
- Impact of landfill leachate plume from Cl, HCO_3 etc
- Inundated areas
- Microorganics fingerprint different types of water



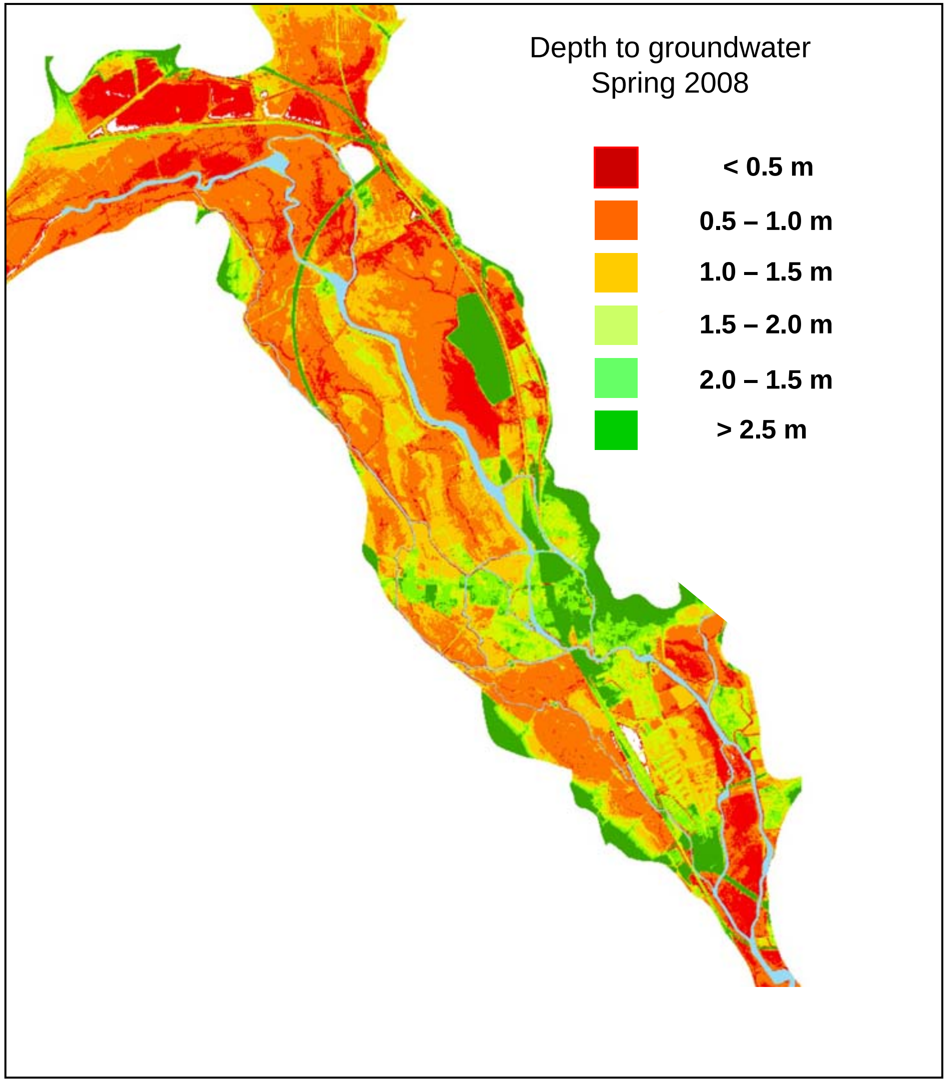


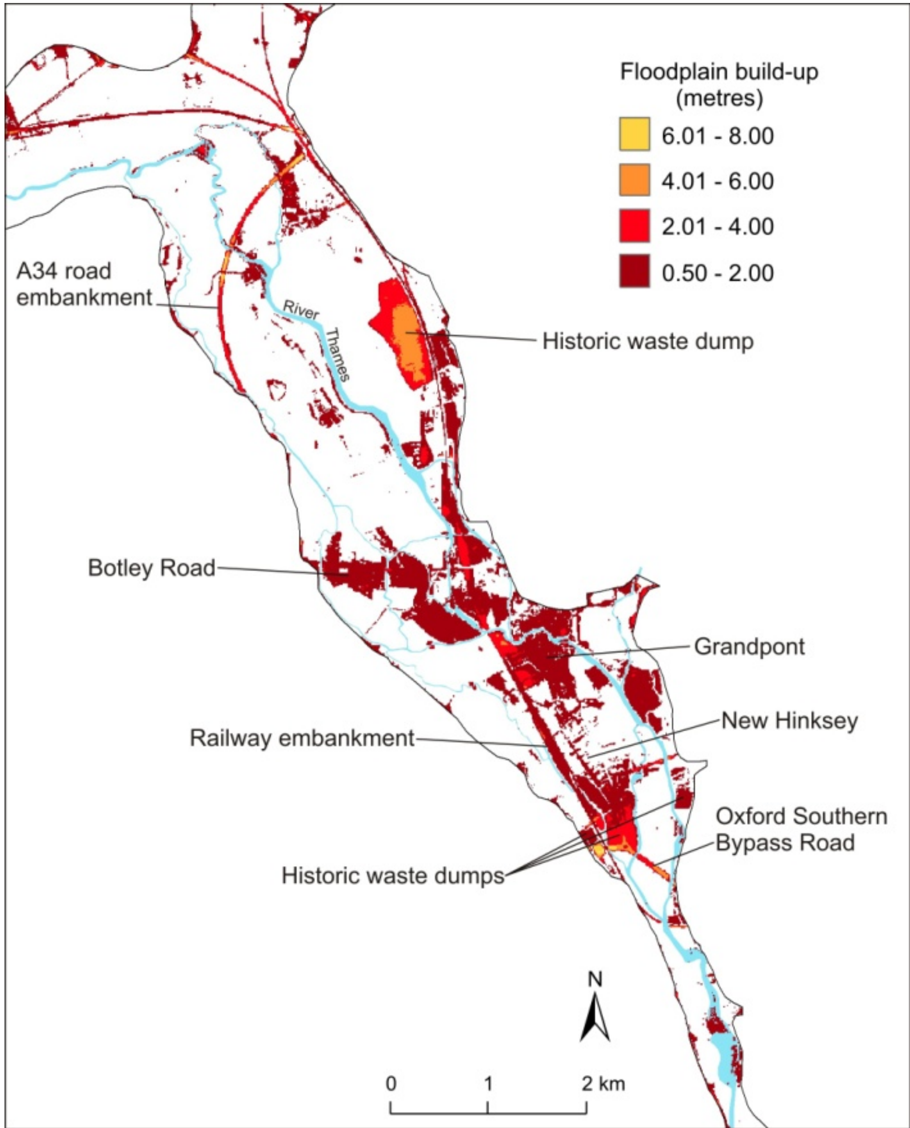


Water levels at Port Meadow

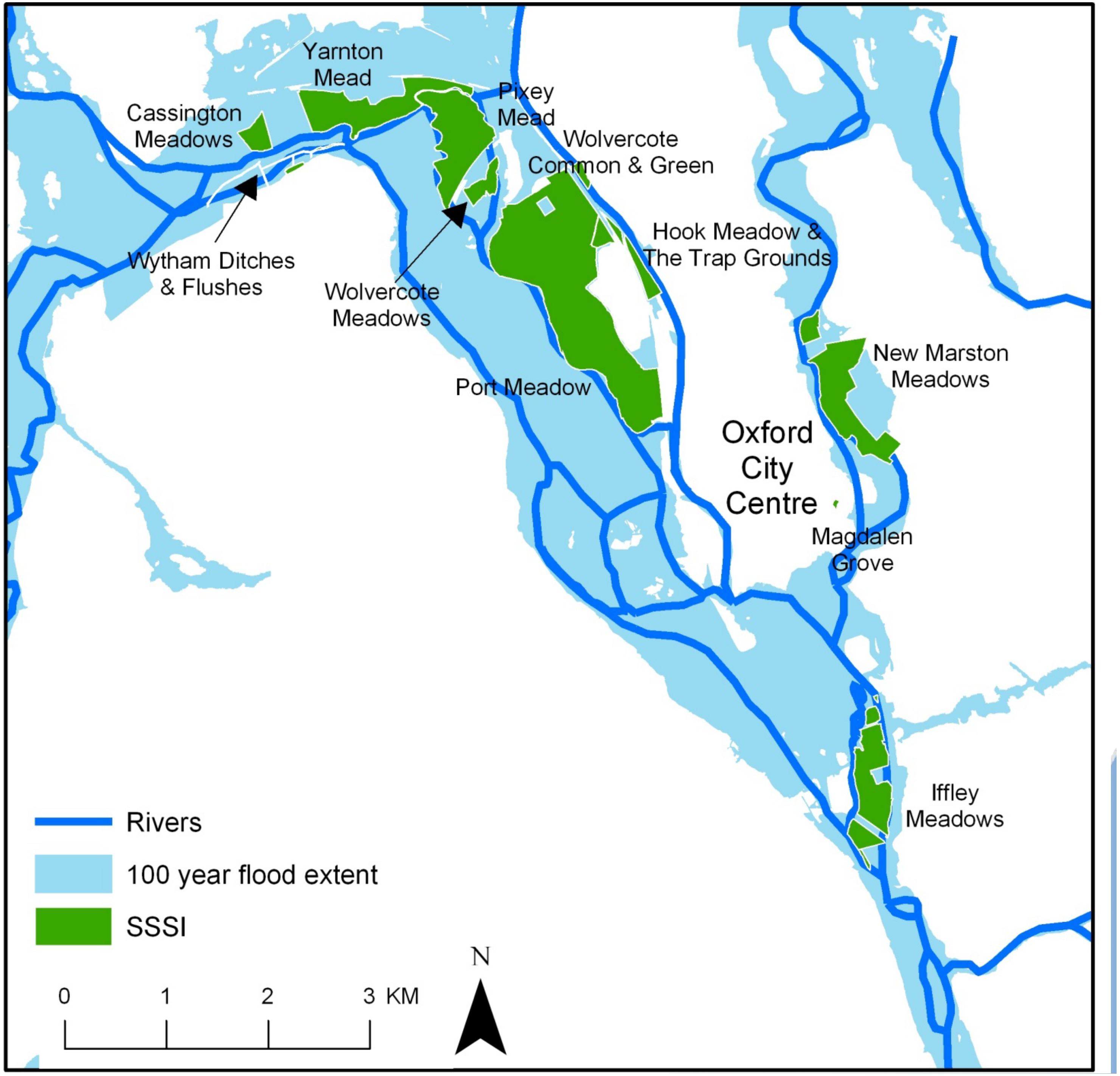


Topography and water levels



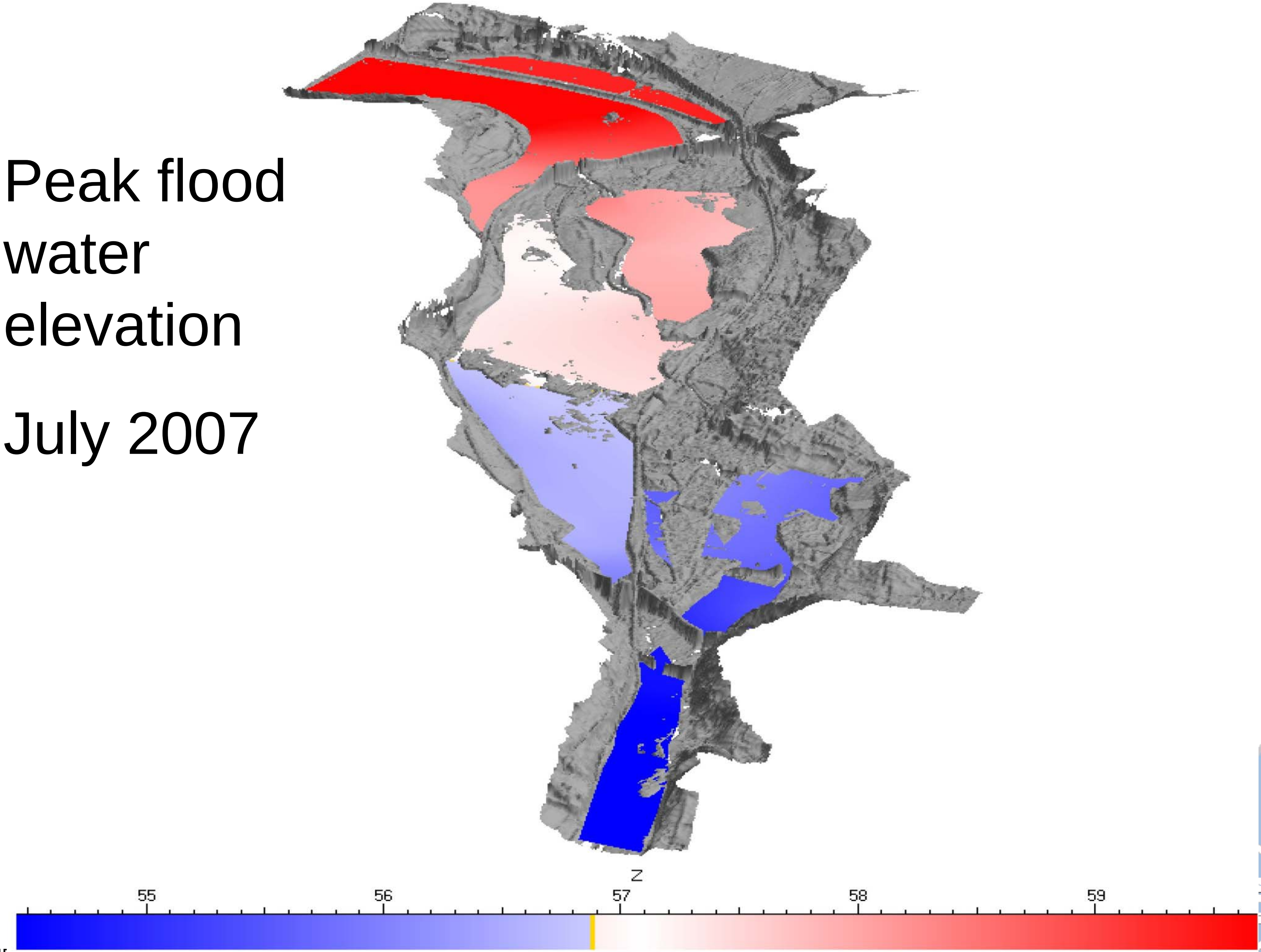


SSSIs


Yarnton
Mead
Pixey
Mead
Cassington
Meadows
Wolvercote
Common & Green
Hook Meadow &
The Trap Grounds
Wytham Ditches
& Flushes
Wolvercote
Meadows
New Marston
Meadows
Port Meadow
Oxford
City
Centre
Magdalen
Grove
Iffley
Meadows
Rivers
100 year flood extent
SSSI
N
0
1
2
3 KM

Peak flood water elevation

July 2007



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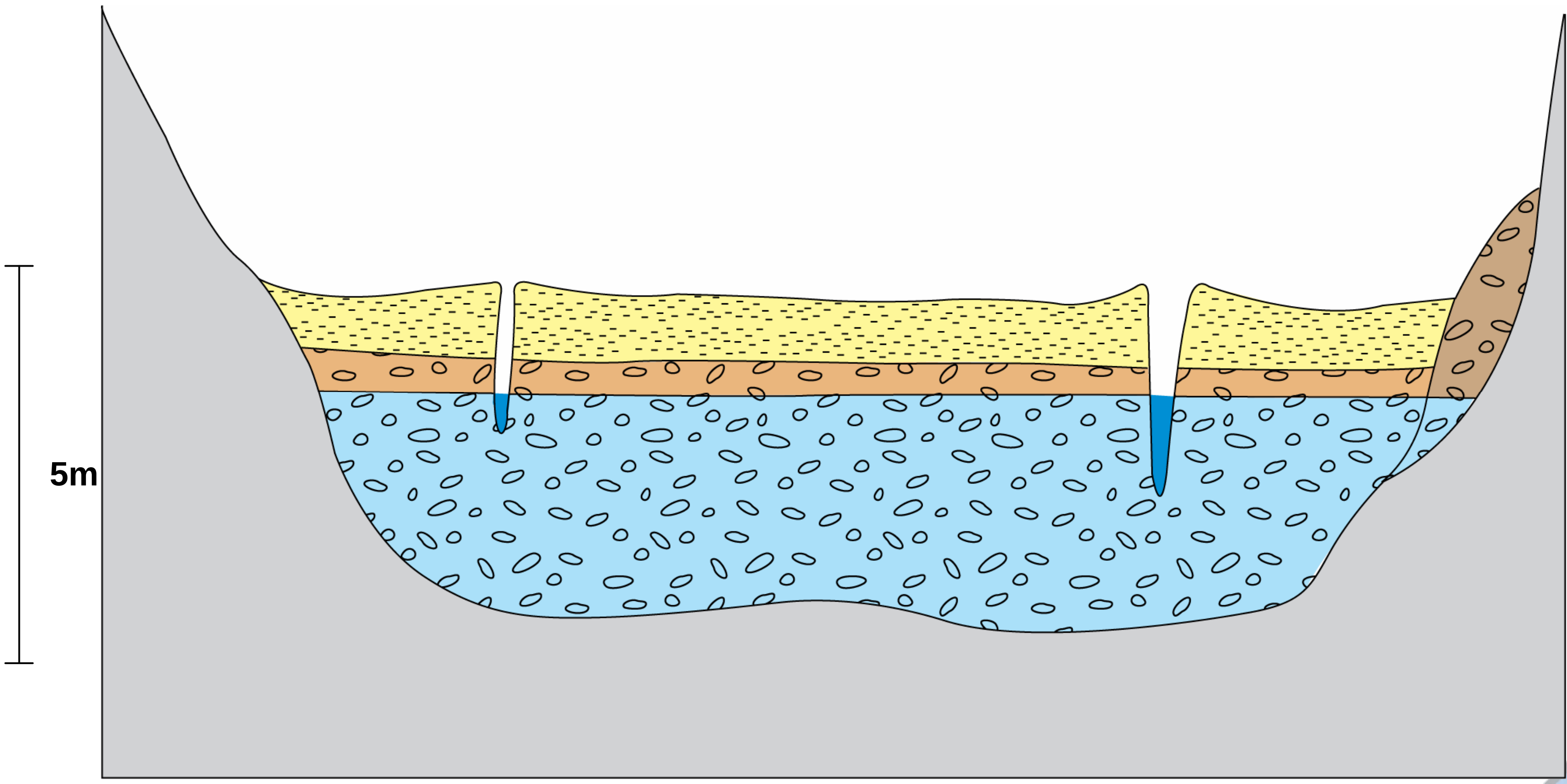
Conceptual model Oxford flooding



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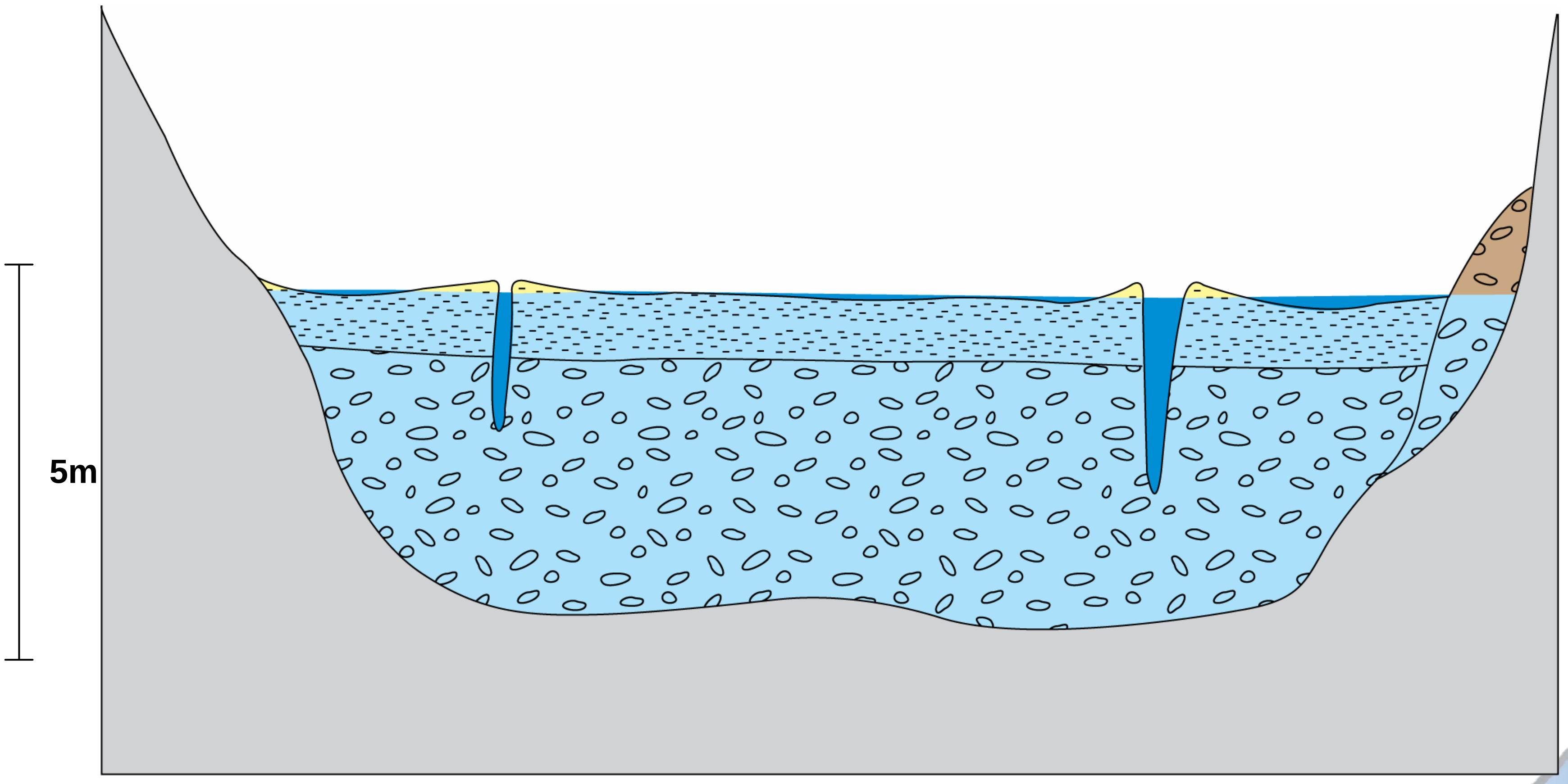

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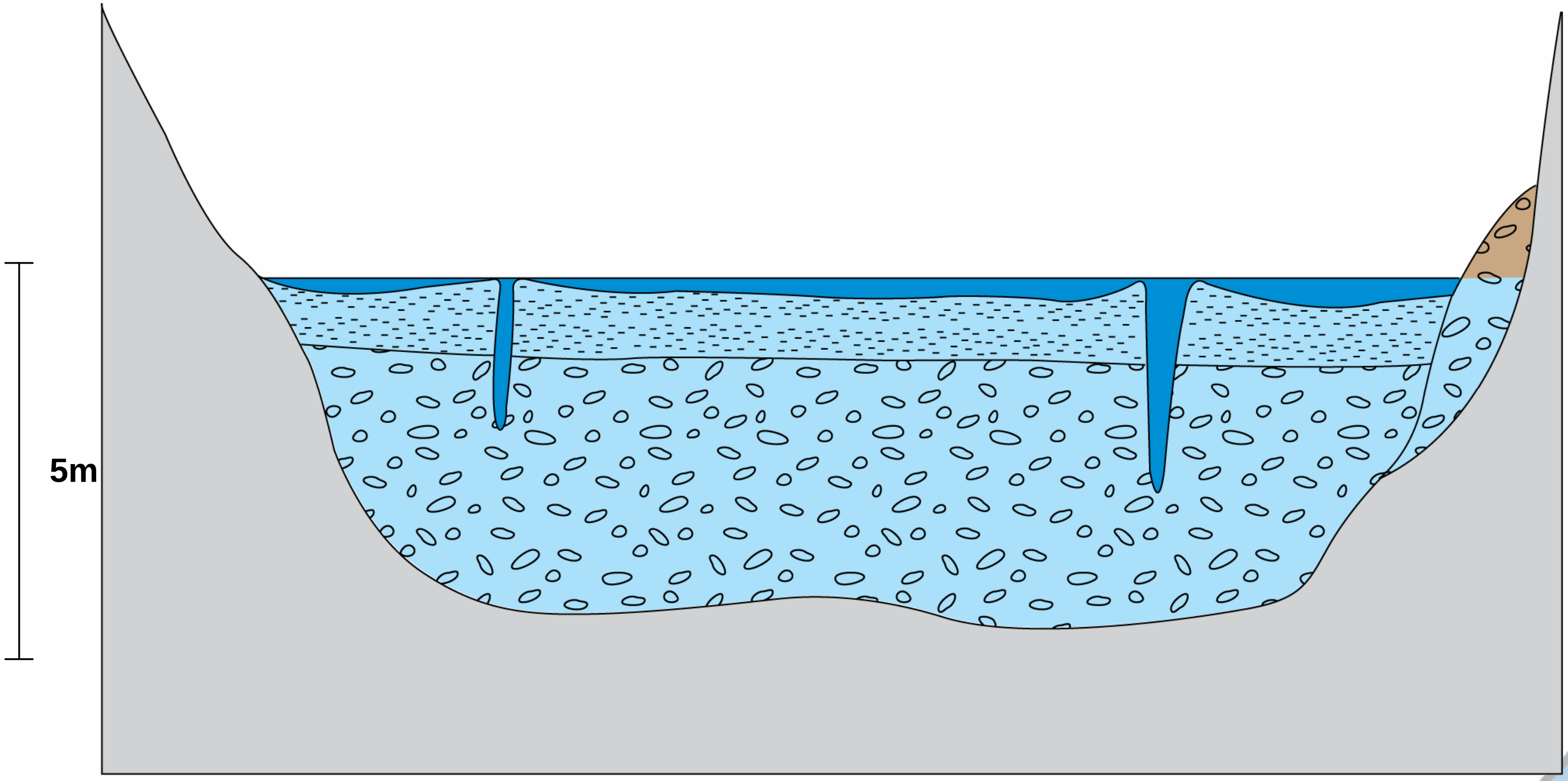

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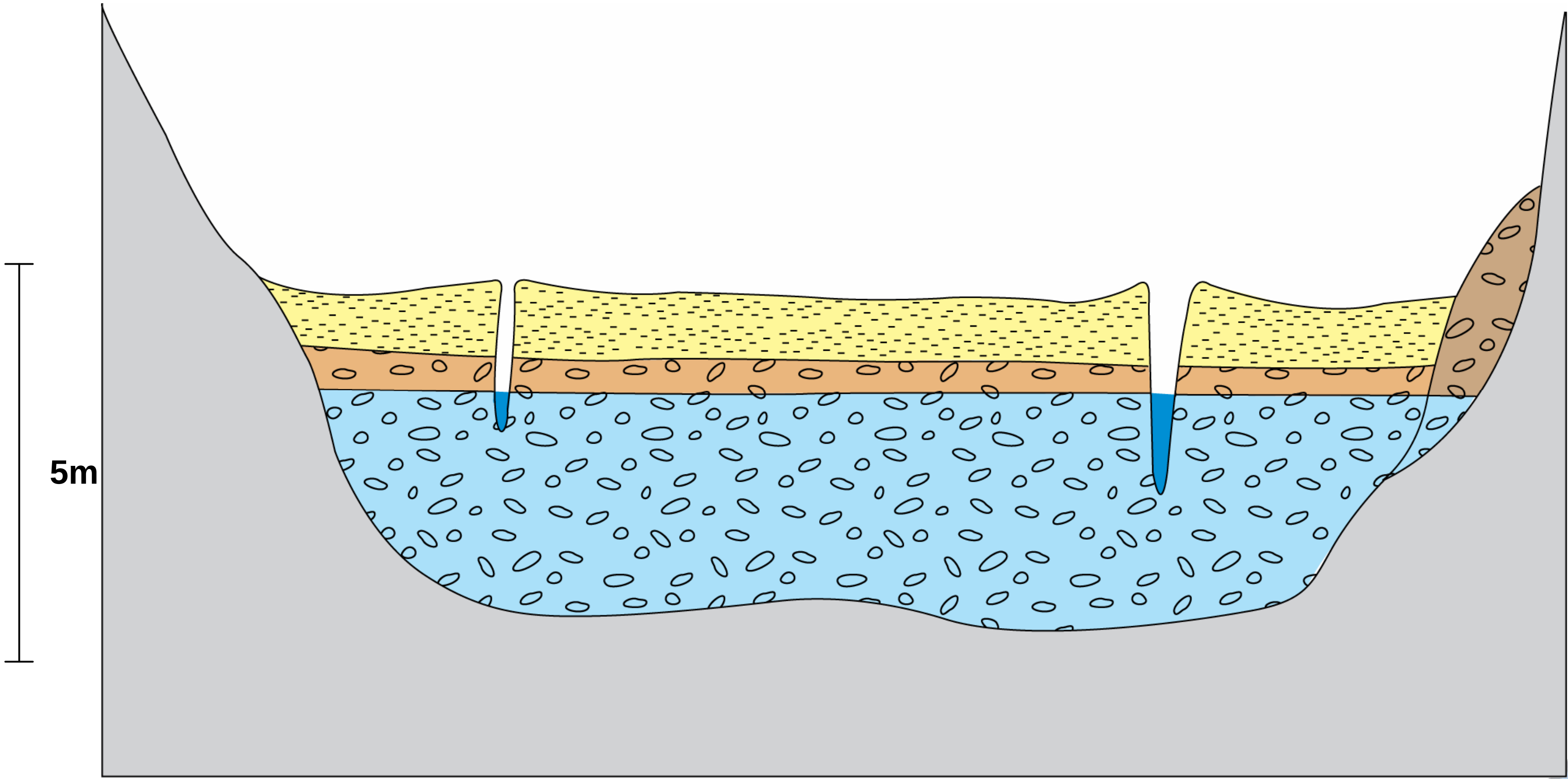

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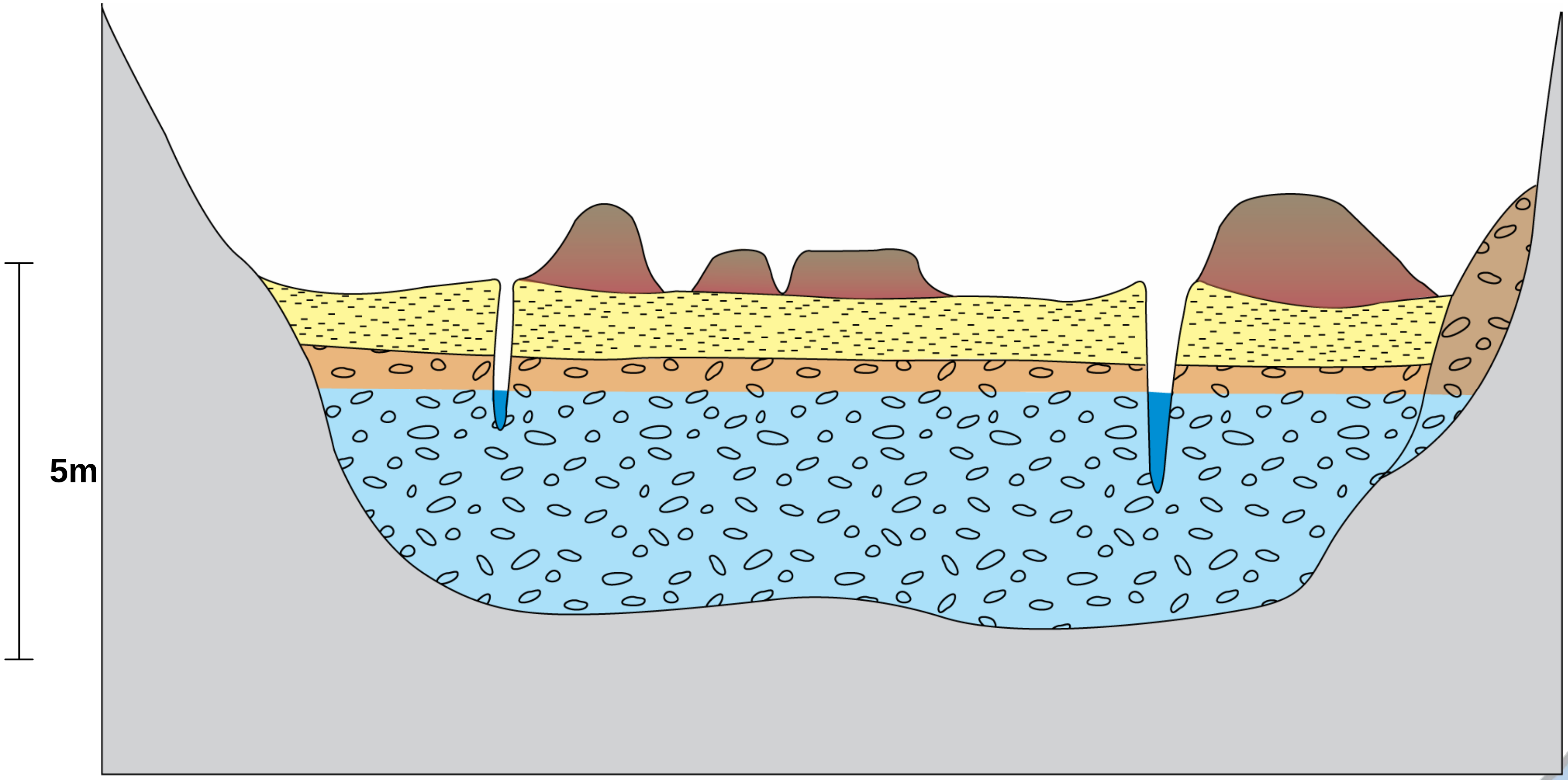

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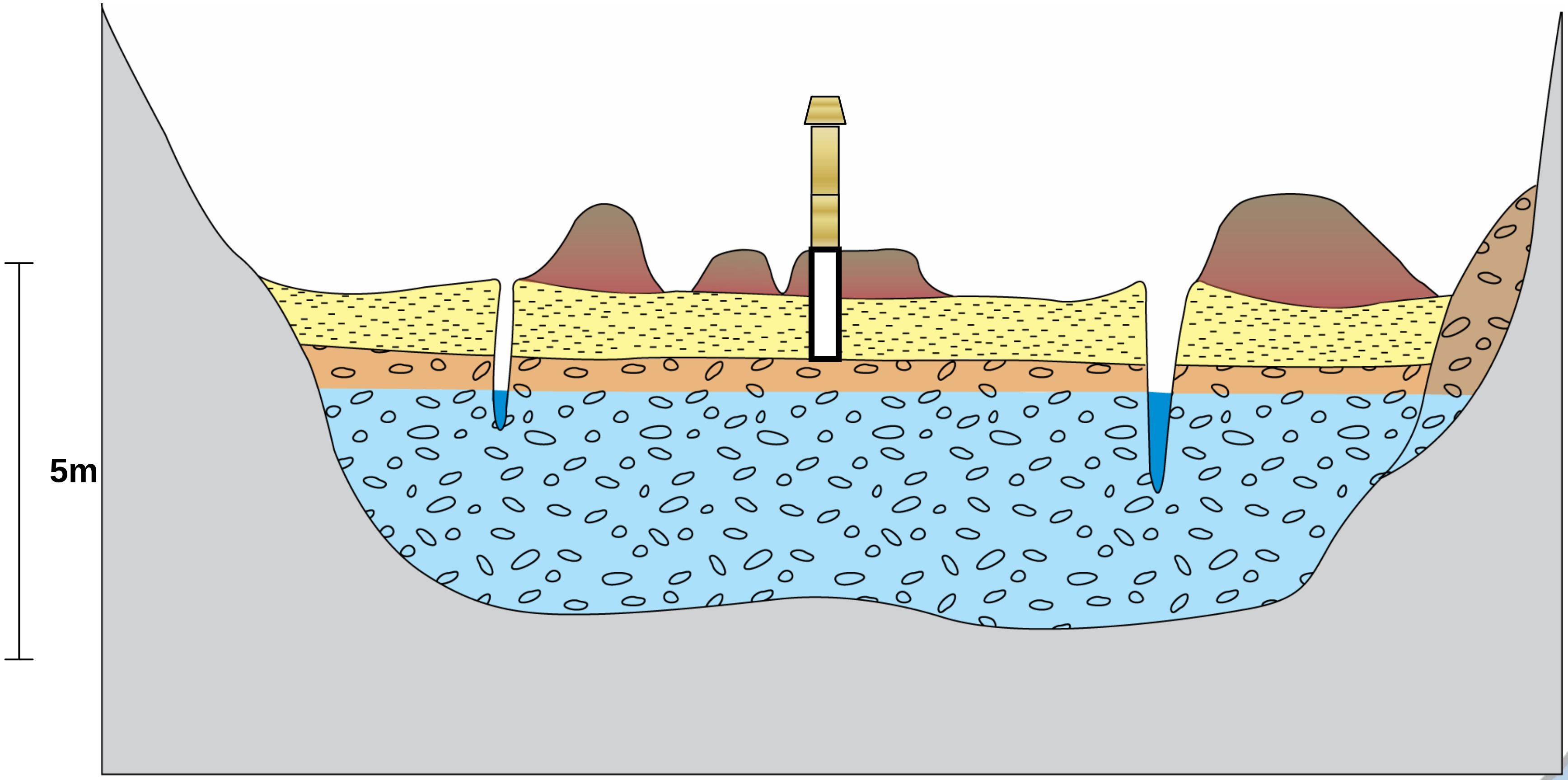

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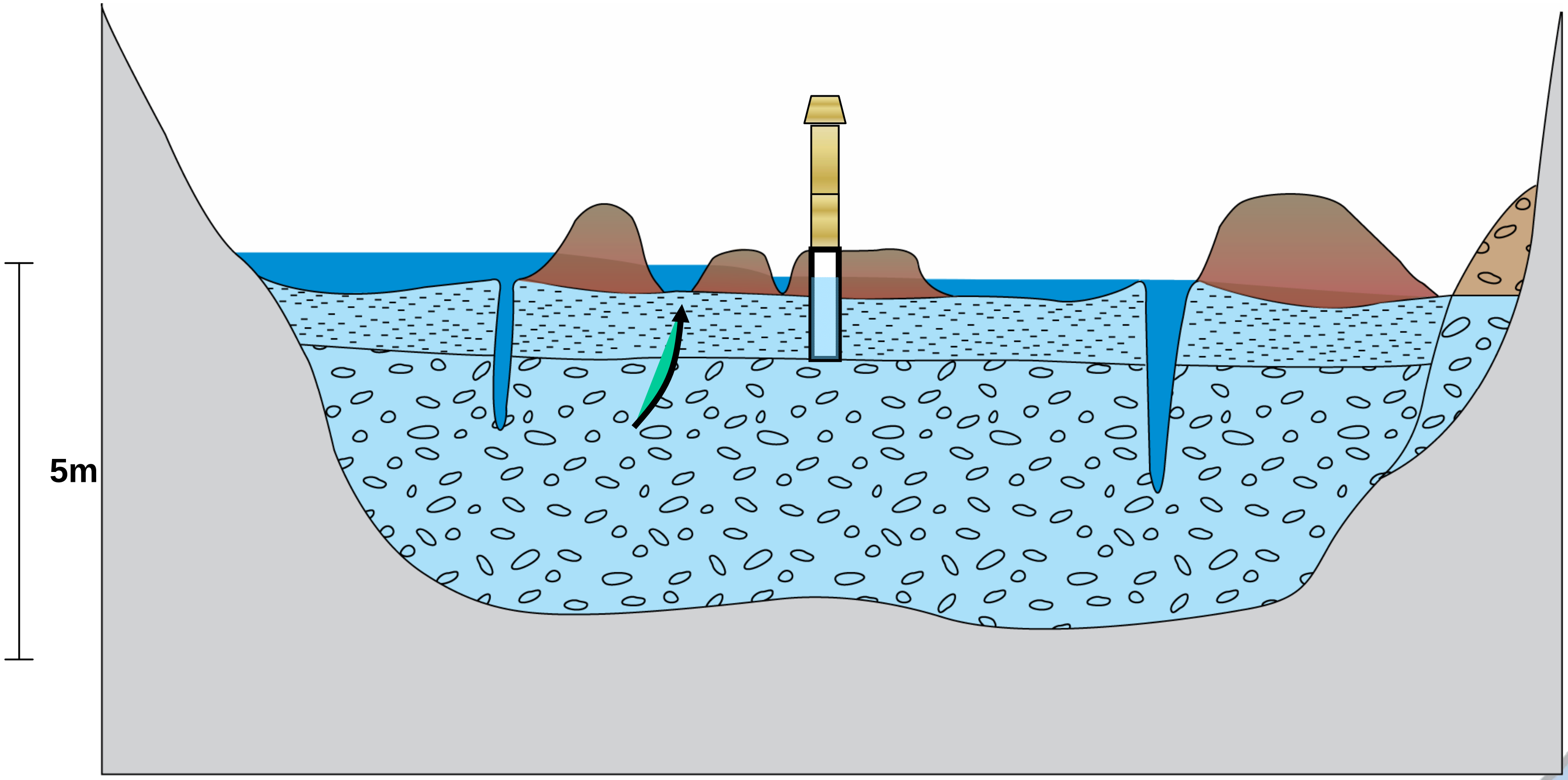

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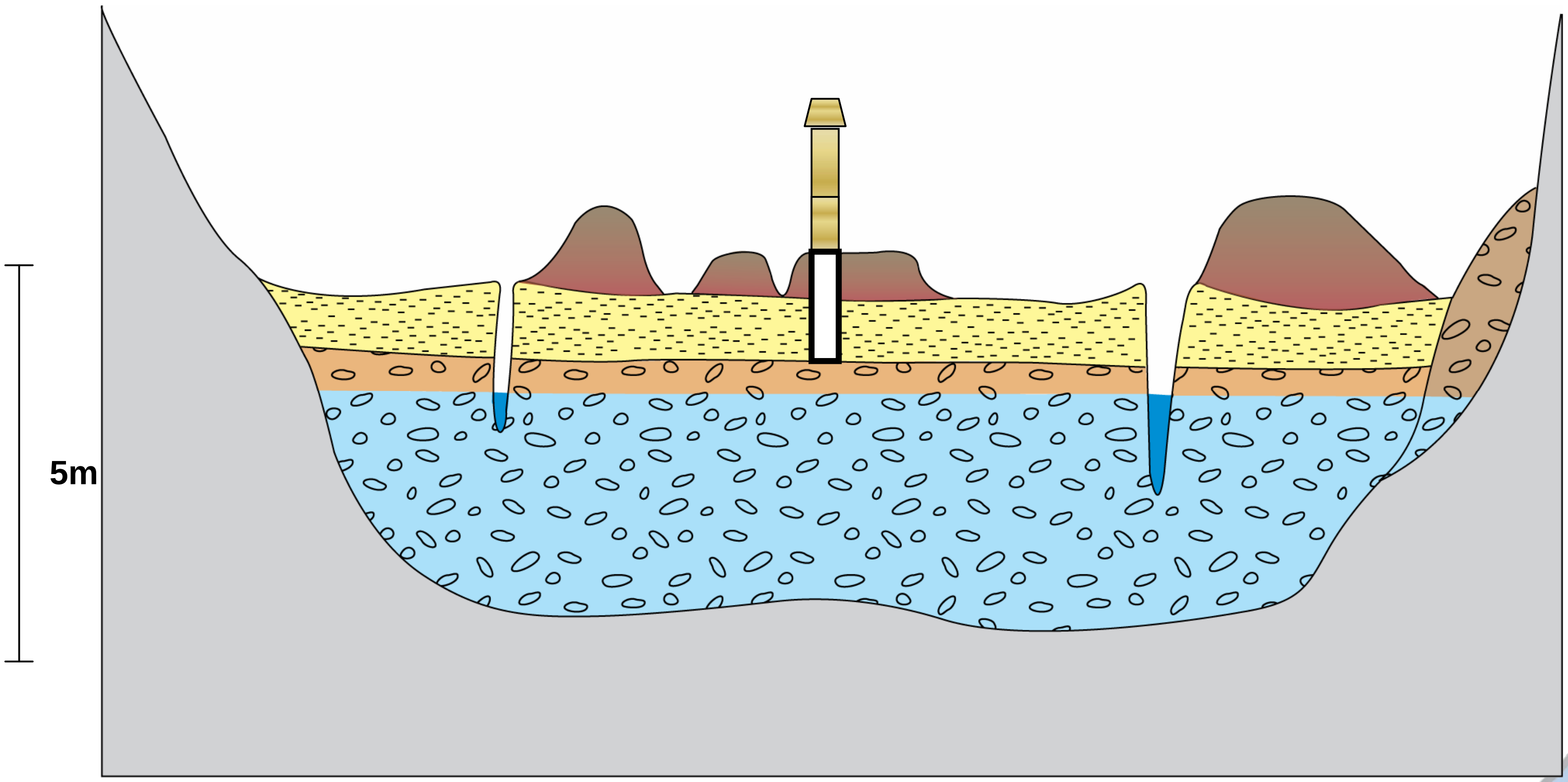
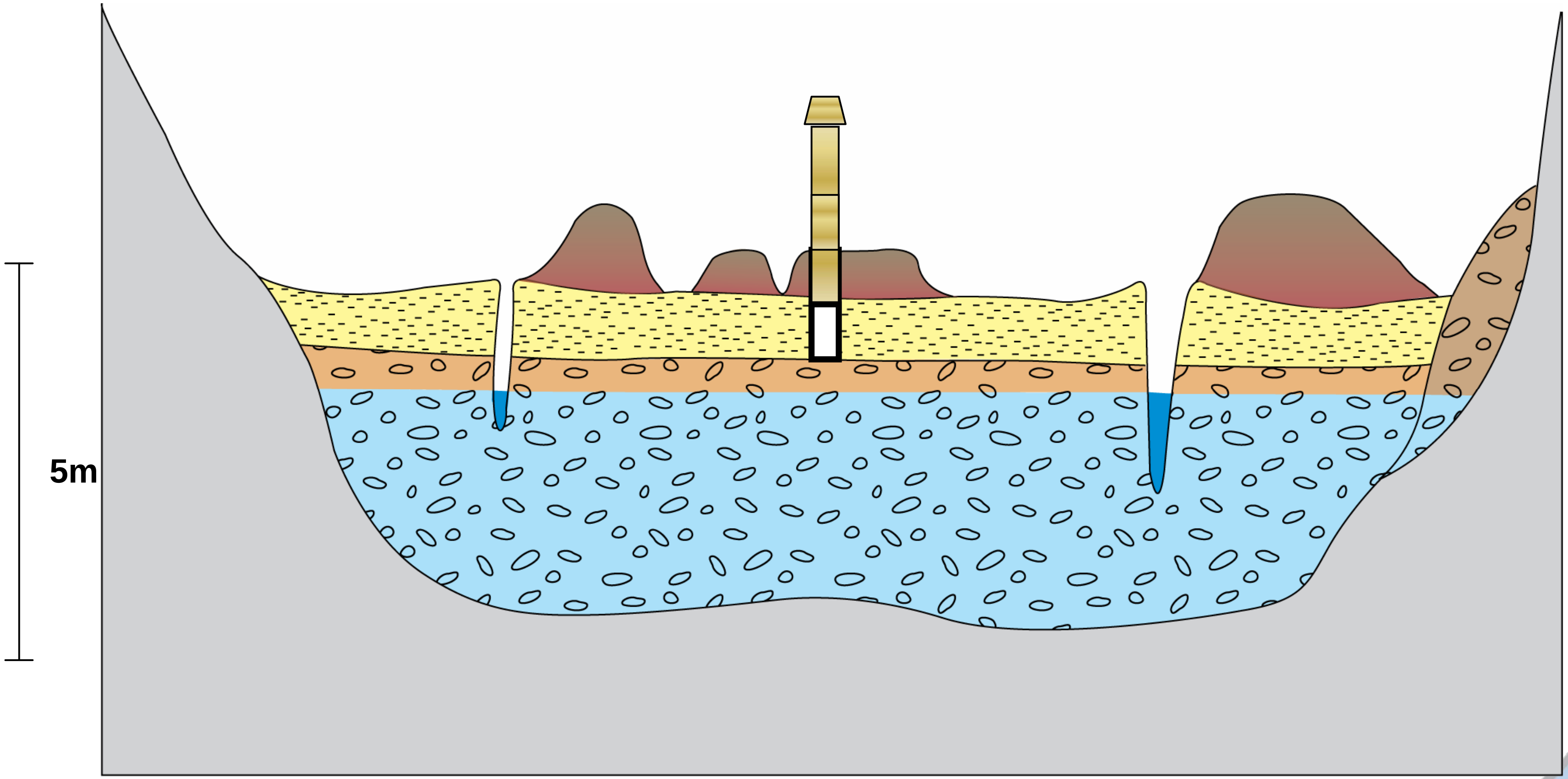
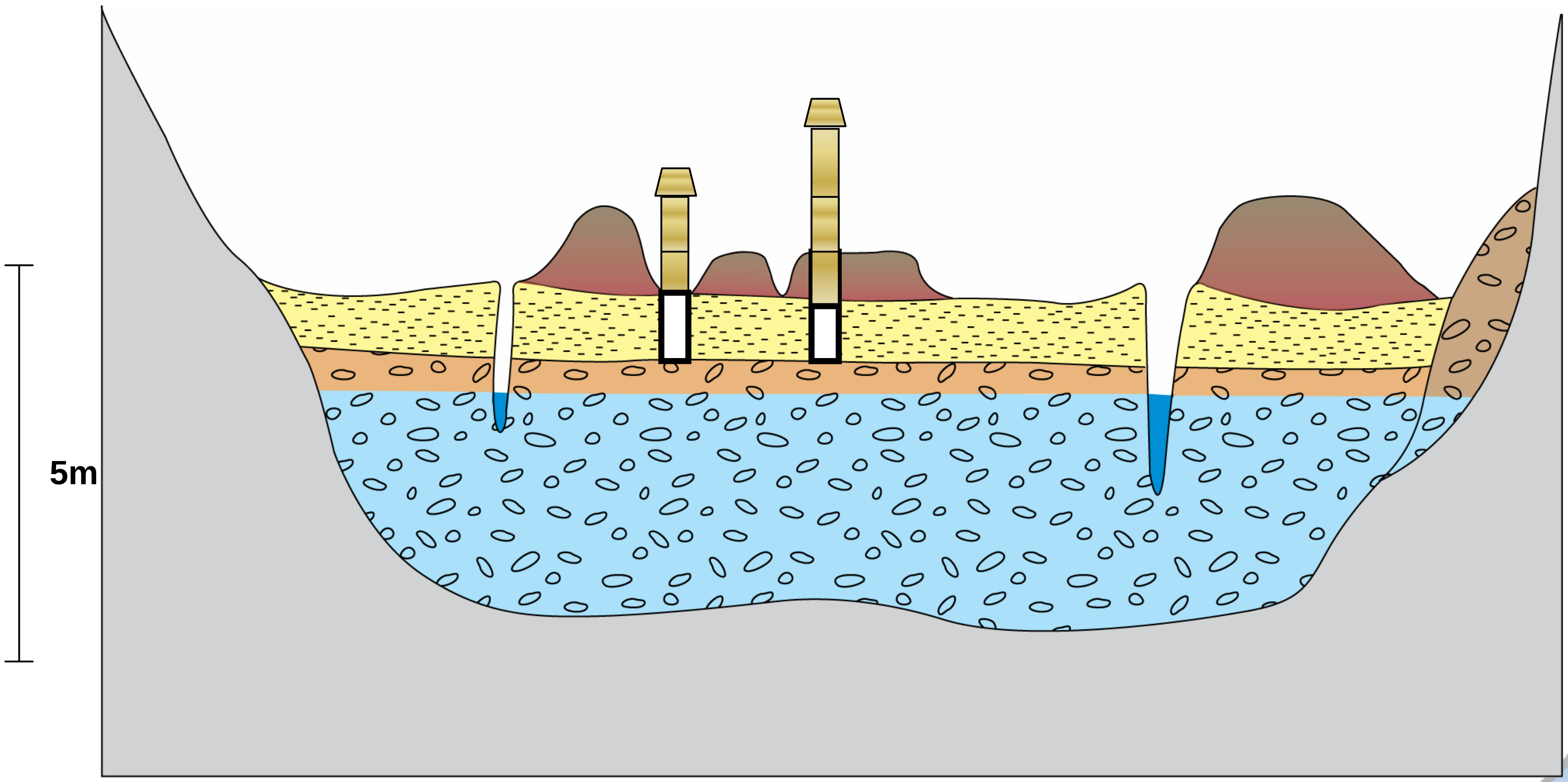


Conceptual model Oxford flooding



Conceptual model Oxford flooding



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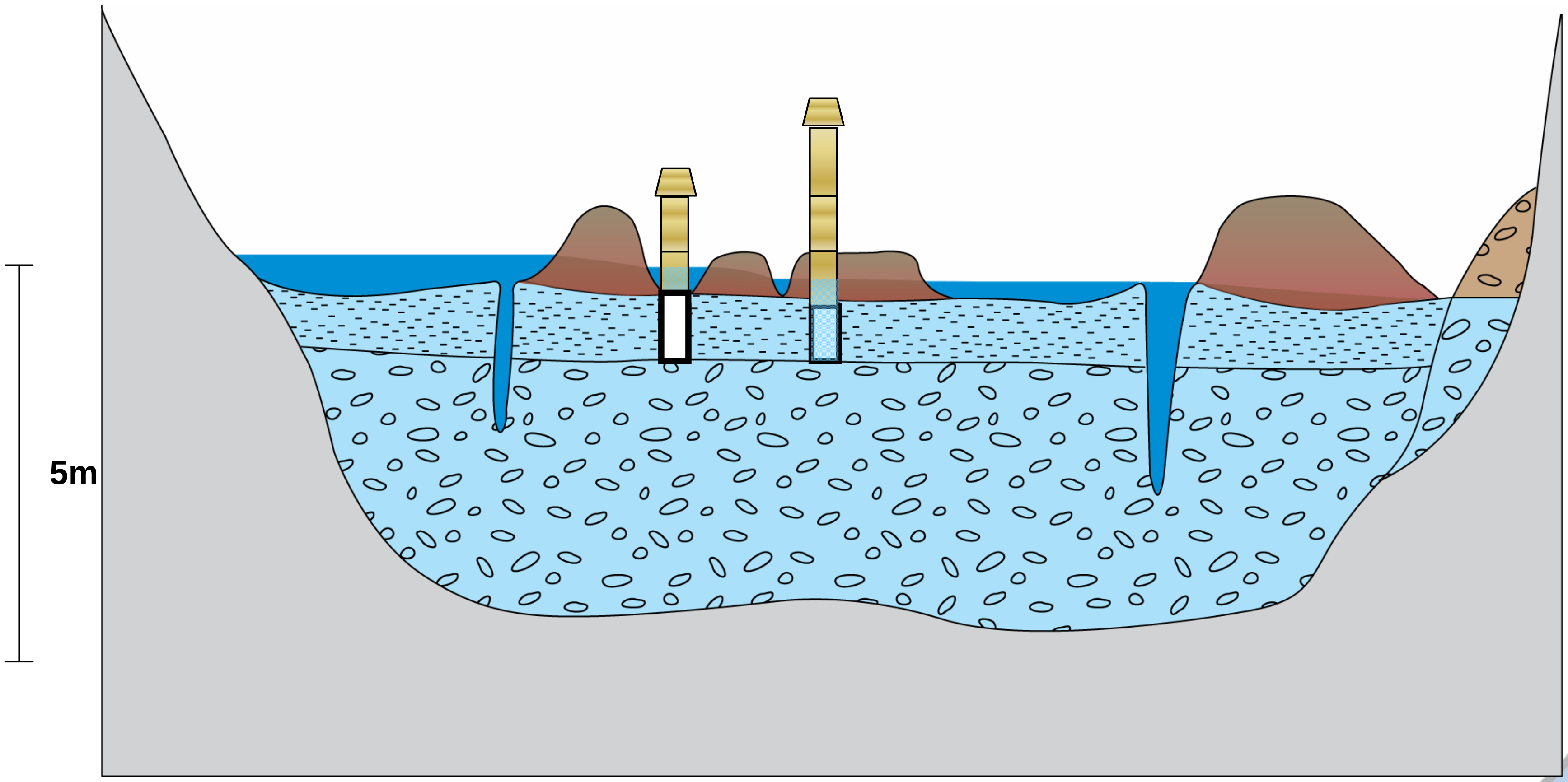
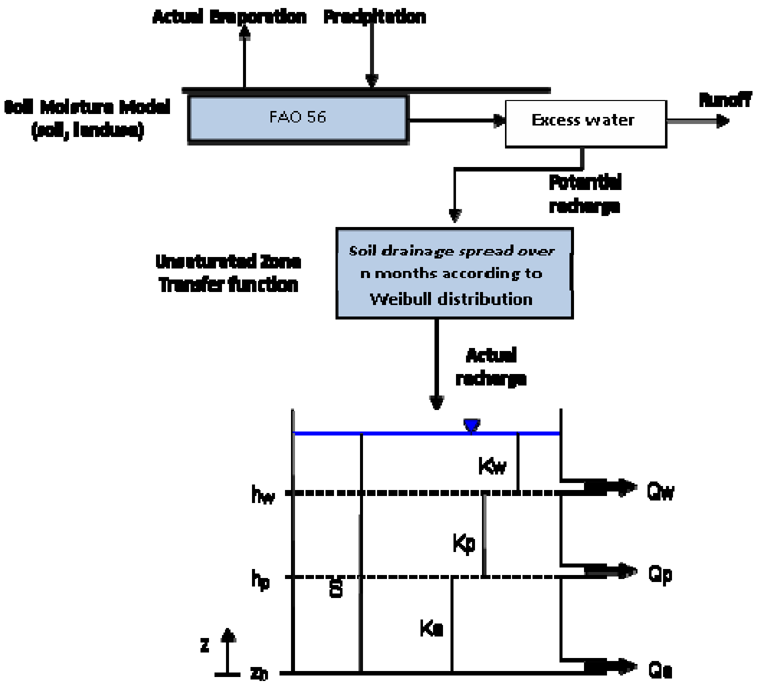
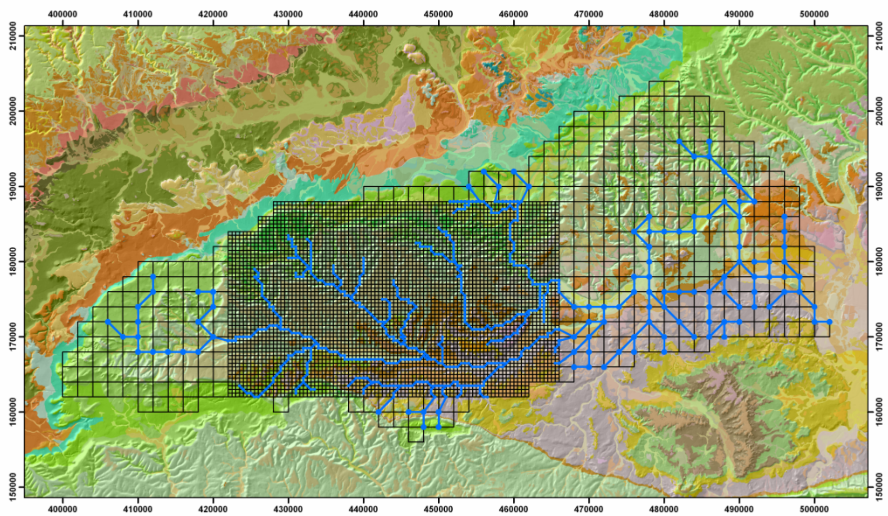


Groundwater flooding of basements

Modelling future groundwater levels

Model	Spatial detail	Parameters	Number sites
R-Groundwater	Lumped	Local calibration through Monte-Carlo process	24 sites
ZOOMQ3D	Semi distributed	Regional parameters	1 - Marlborough and Berkshire Downs and south-west Chilterns

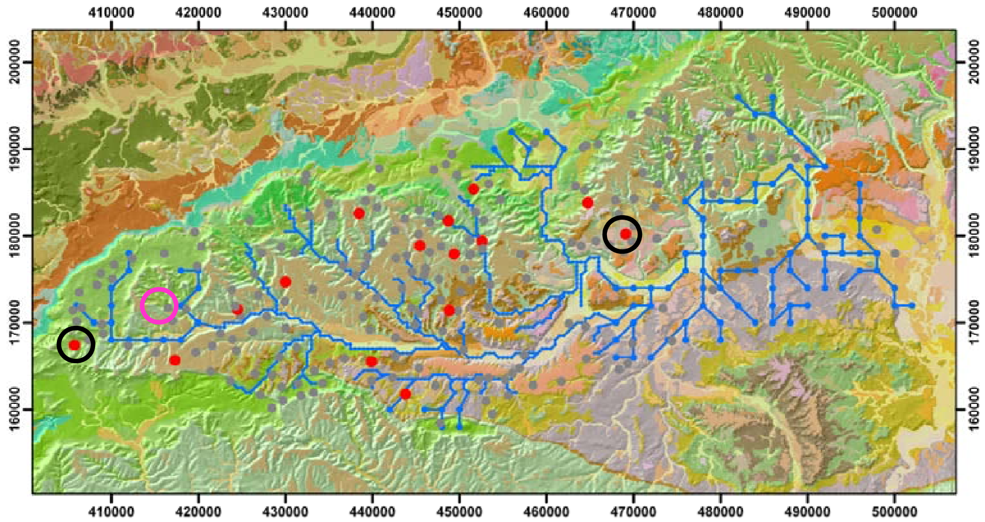


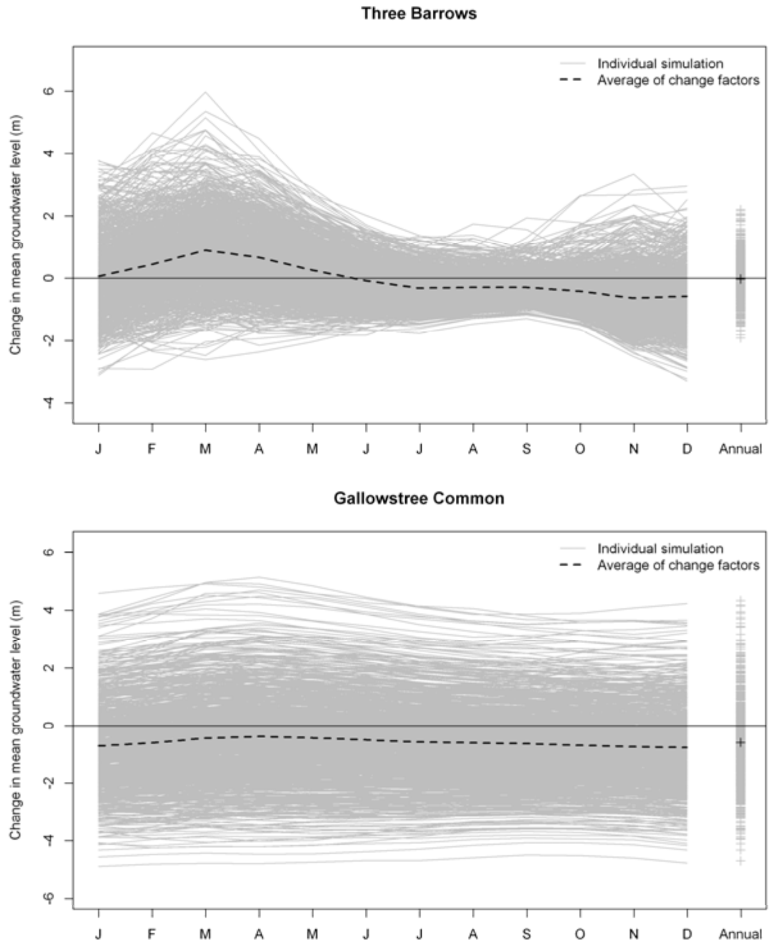


Jackson et al

ZOOMQ3D

- Projections to 2050 under medium greenhouse emissions scenario
- Similarity in projected changes across the selected regional aquifer
- Central estimate of annual change around zero
- Higher late-winter/spring levels? Lower autumn levels?



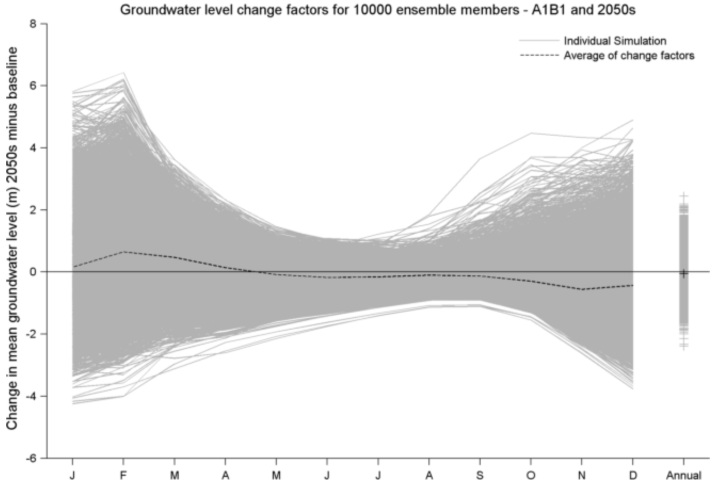


2050s minus baseline (1961-1990) and medium (A1B1) emissions scenario

R-Groundwater

- Mainly National Groundwater Archive 'Index boreholes'
- At least 8-year observed record length
- Support for simplistic approach provided through agreement with detailed regional groundwater model
- Uncertainty is significant.
- Magnitude of change in winter levels greater than changes in summer/autumn levels.

Rockley



Summary

- Groundwater bodies in the Thames basin have poor chemical status and increasing trends
- In chalk and limestone upper catchments surface water is predominantly baseflow and influenced by groundwater quality
- Groundwater and surface water interact in the hyporheic zone
- Flood plains are complex areas with shallow groundwater and are subject to inundation which also has quality implications
- In the future, current climate change scenarios lead to changes in the water balance with higher water levels in the winter and drier summers
- Conceptual models are key to understanding the potential impacts of these processes