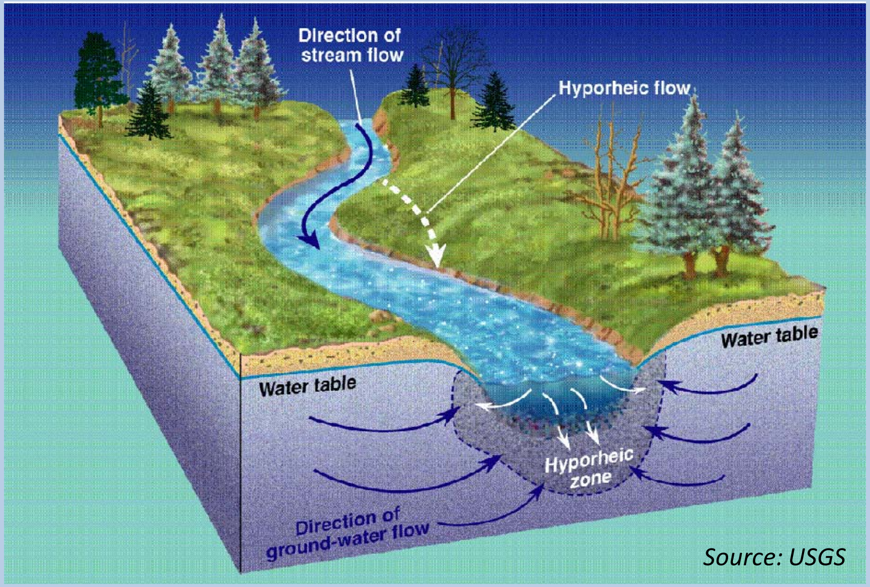
Accounting for the Groundwater-Surface Water Interface in Contaminated Land Assessments

Catchment Science Centre



Source: USGS

The University Of Sheffield.

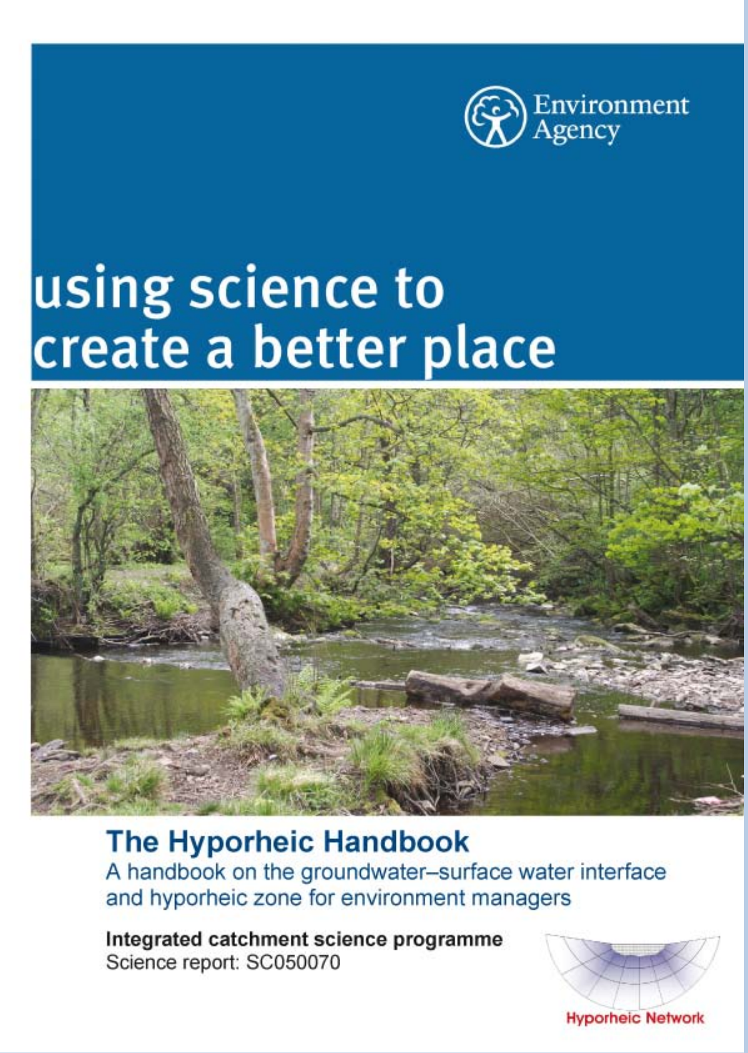
MARIE CURIE FELLOWSHIPS
Marie Curie Fellowships

Tristan Ibrahim, David Lerner, Steve Thornton and John Wainwright
Tristan.Ibrahim@teagasc.ie

Environment Agency

Current Issues in Contaminated Land Risk Assessment – 21st December 2011 CL:AIRE

References

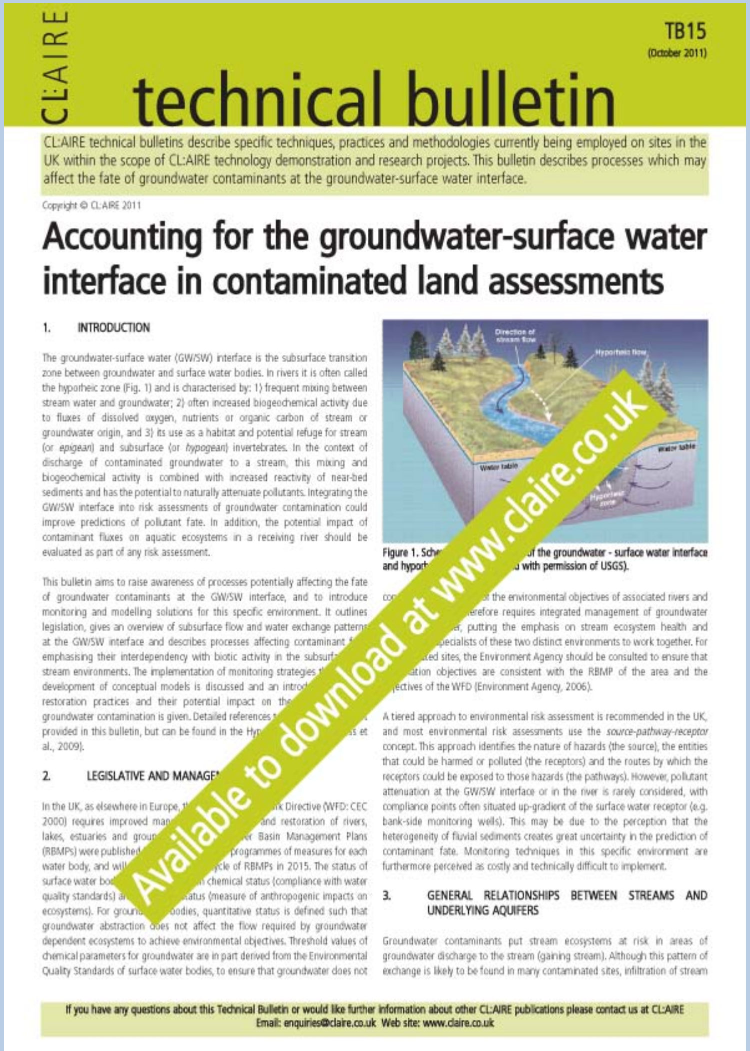

Environment Agency

using science to
create a better place

The Hyporheic Handbook
A handbook on the groundwater–surface water interface and hyporheic zone for environment managers

Integrated catchment science programme
Science report: SC050070

Hyporheic Network


CL:AIRE

technical bulletin

TB15
(October 2011)

CL:AIRE technical bulletins describe specific techniques, practices and methodologies currently being employed on sites in the UK within the scope of CL:AIRE technology demonstration and research projects. This bulletin describes processes which may affect the fate of groundwater contaminants at the groundwater-surface water interface.

Accounting for the groundwater-surface water interface in contaminated land assessments

1. INTRODUCTION

The groundwater-surface water (GW/SW) interface is the subsurface transition zone between groundwater and surface water bodies. In rivers it is often called the hyporheic zone (Fig. 1) and is characterised by: 1) frequent mixing between stream water and groundwater; 2) often increased biogeochemical activity due to fluxes of dissolved oxygen, nutrients or organic carbon of stream or groundwater origin, and 3) its use as a habitat and potential refuge for stream (or *epigean*) and subsurface (or *hypogean*) invertebrates. In the context of discharge of contaminated groundwater to a stream, this mixing and biogeochemical activity is combined with increased reactivity of near-bed sediments and has the potential to naturally attenuate pollutants. Integrating the GW/SW interface into risk assessments of groundwater contamination could improve predictions of pollutant fate. In addition, the potential impact of contaminant fluxes on aquatic ecosystems in a receiving river should be evaluated as part of any risk assessment.

This bulletin aims to raise awareness of processes potentially affecting the fate of groundwater contaminants at the GW/SW interface, and to introduce monitoring and modelling solutions for this specific environment. It outlines legislation, gives an overview of subsurface flow and water exchange patterns at the GW/SW interface and describes processes affecting contaminant f… emphasising their interdependency with biotic activity in the subsurf… stream environments. The implementation of monitoring strategies t… development of conceptual models is discussed and an introd… restoration practices and their potential impact on the… groundwater contamination is given. Detailed references … provided in this bulletin, but can be found in the Hyp… …s et al., 2009).

2. LEGISLATIVE AND MANAGE…

In the UK, as elsewhere in Europe, t… …k Directive (WFD: CEC 2000) requires improved man… and restoration of rivers, lakes, estuaries and groun… …r Basin Management Plans (RBMPs) were published … programmes of measures for each water body, and wil… …ycle of RBMPs in 2015. The status of surface water bo… …n chemical status (compliance with water quality standards) a… …tatus (measure of anthropogenic impacts on ecosystems). For groun… …bodies, quantitative status is defined such that groundwater abstraction does not affect the flow required by groundwater dependent ecosystems to achieve environmental objectives. Threshold values of chemical parameters for groundwater are in part derived from the Environmental Quality Standards of surface water bodies, to ensure that groundwater does not

Figure 1. Sche… …f the groundwater - surface water interface and hypor… …d with permission of USGS).

co… …f the environmental objectives of associated rivers and … …erefore requires integrated management of groundwater … …r, putting the emphasis on stream ecosystem health and … …pecialists of these two distinct environments to work together. For … …ted sites, the Environment Agency should be consulted to ensure that … …ation objectives are consistent with the RBMP of the area and the … …ectives of the WFD (Environment Agency, 2006).

A tiered approach to environmental risk assessment is recommended in the UK, and most environmental risk assessments use the *source-pathway-receptor* concept. This approach identifies the nature of hazards (the source), the entities that could be harmed or polluted (the receptors) and the routes by which the receptors could be exposed to those hazards (the pathways). However, pollutant attenuation at the GW/SW interface or in the river is rarely considered, with compliance points often situated up-gradient of the surface water receptor (e.g. bank-side monitoring wells). This may be due to the perception that the heterogeneity of fluvial sediments creates great uncertainty in the prediction of contaminant fate. Monitoring techniques in this specific environment are furthermore perceived as costly and technically difficult to implement.

3. GENERAL RELATIONSHIPS BETWEEN STREAMS AND UNDERLYING AQUIFERS

Groundwater contaminants put stream ecosystems at risk in areas of groundwater discharge to the stream (gaining stream). Although this pattern of exchange is likely to be found in many contaminated sites, infiltration of stream

If you have any questions about this Technical Bulletin or would like further information about other CL:AIRE publications please contact us at CL:AIRE
Email: enquiries@claire.co.uk Web site: www.claire.co.uk

Available to download at www.claire.co.uk

http://www.hyporheic.net

Talk outline

- Legislative and management drivers
- Geometric relationships between streams and underlying aquifers
- Development of Hyporheic Exchange Flow
- Biogeochemical gradients, dilution, sediment reactivity and fauna/flora
- Issues of scale
- Monitoring strategies and modelling tools
- River restoration
- Conclusions

Legislative and management drivers

- Water Framework Directive

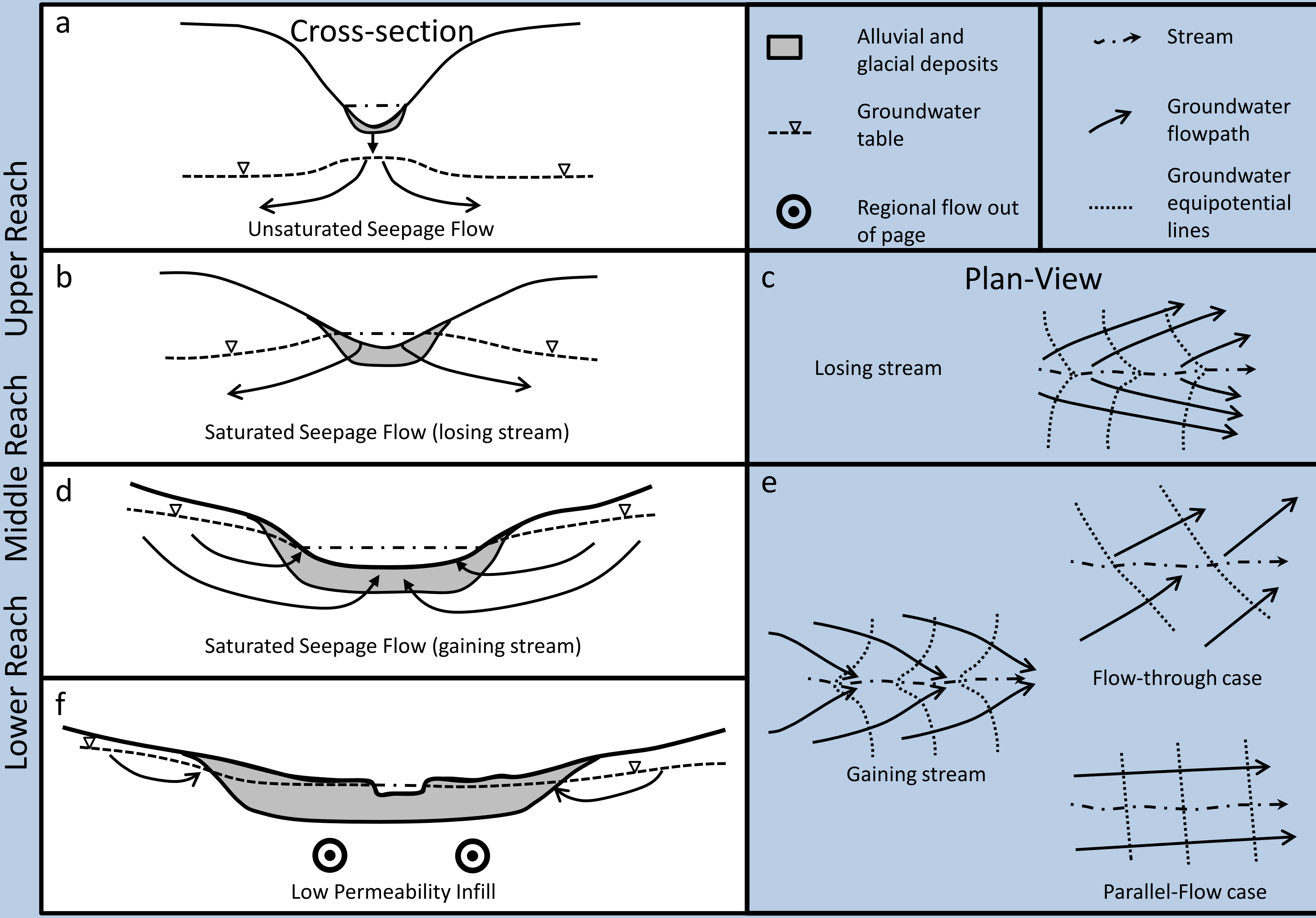
- Integrated assessment of water bodies

- Groundwater status. Drinking water quality/quantity AND dependant ecosystems

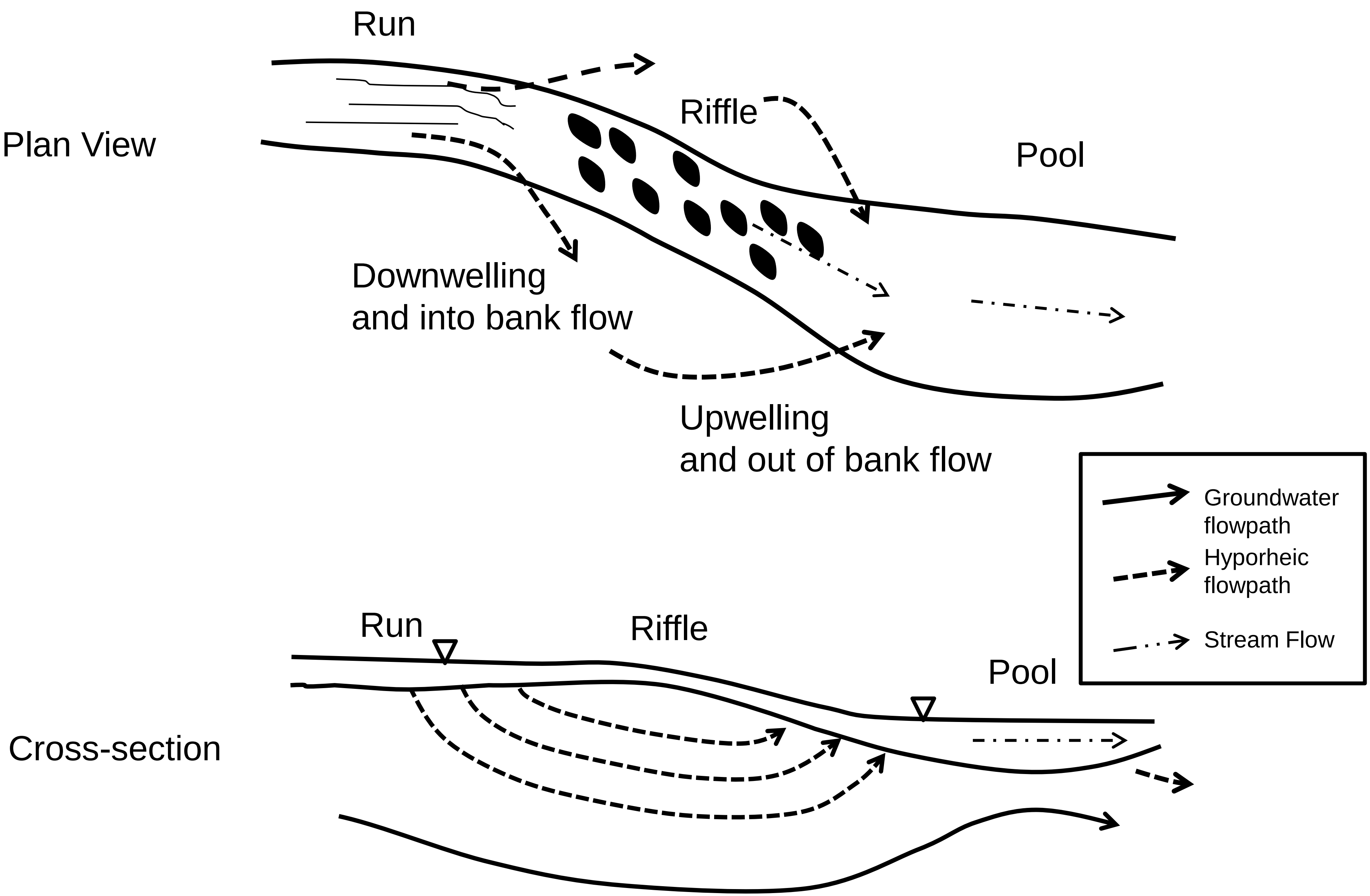
- Holistic and interdisciplinary approaches

- Groundwater/surface water interface: legal requirement AND opportunity for pollutant attenuation capacity

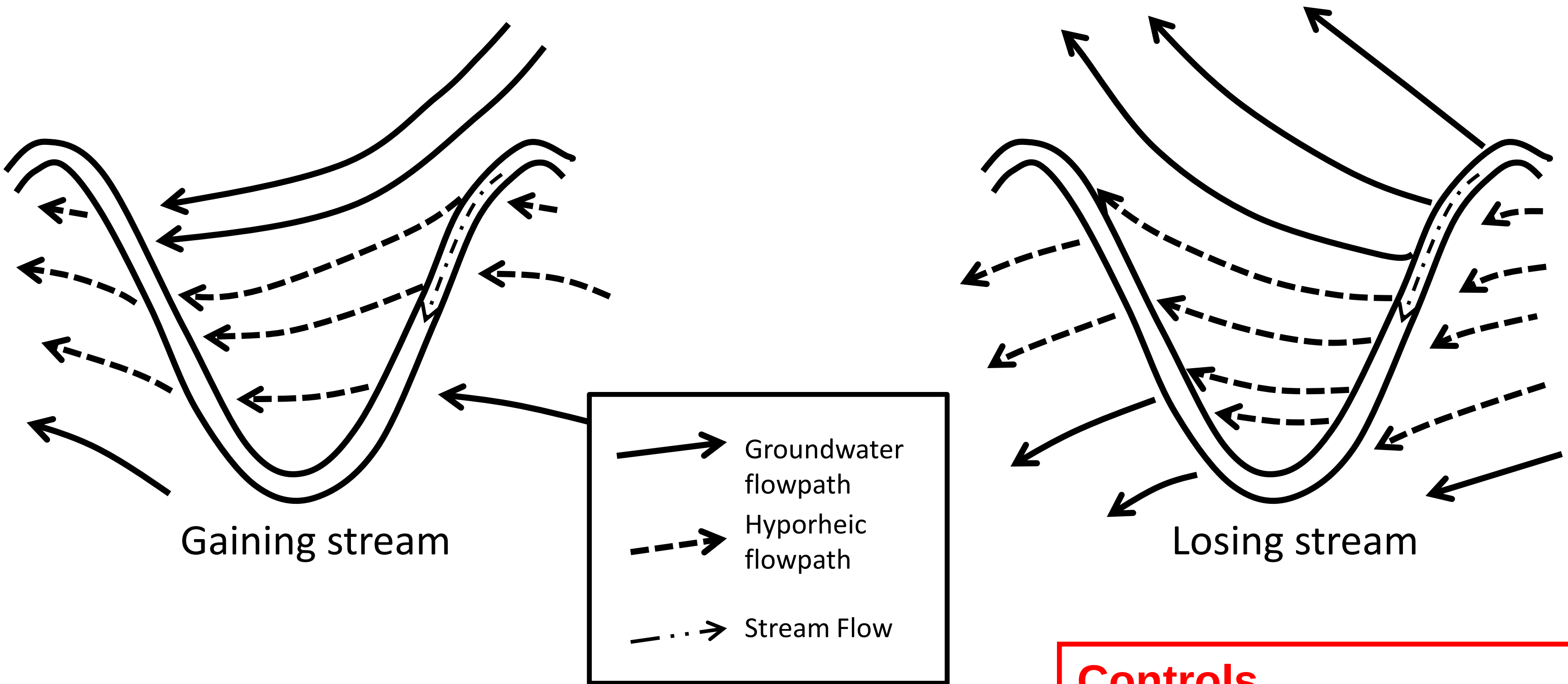
Geometric relationships between streams and underlying aquifers



Development of Hyporheic Exchange Flow (HEF)



Development of Hyporheic Exchange Flow (HEF)

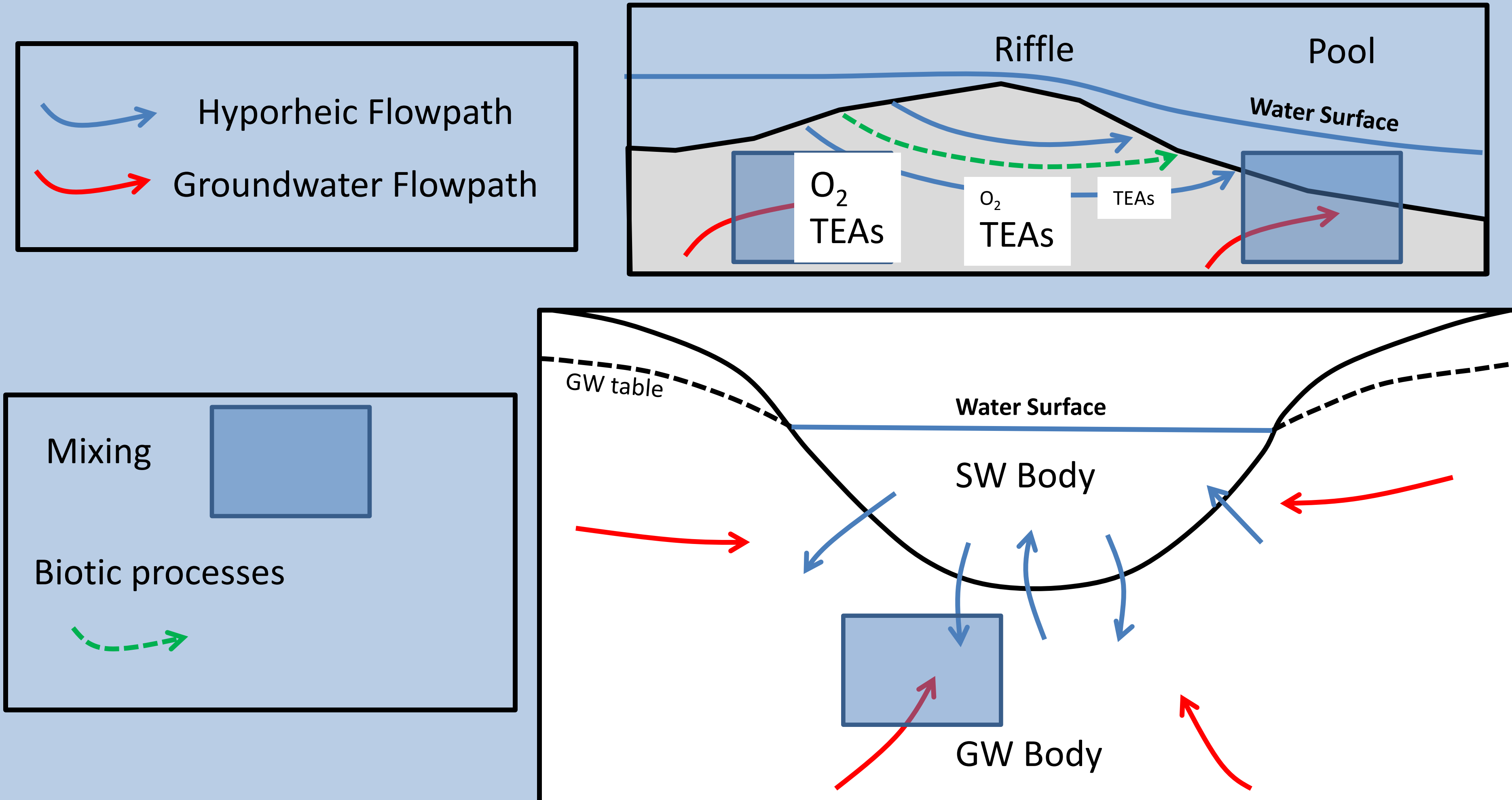


Controls

- **Head gradients**
- **Sediment Permeability**
- **GW discharge**

Biogeochemical gradients and water mixing

- A potential hotspot in the environment



Reactivity of shallow sediments

Pictures: T. Ibrahim & Nick Riess

Upland Stream (River Don)

Lowland Stream (River Tern)

The importance of fauna and flora

- Organic matter recycling

Source: ecologyadventure2water.edublogs.org

- Bioturbation

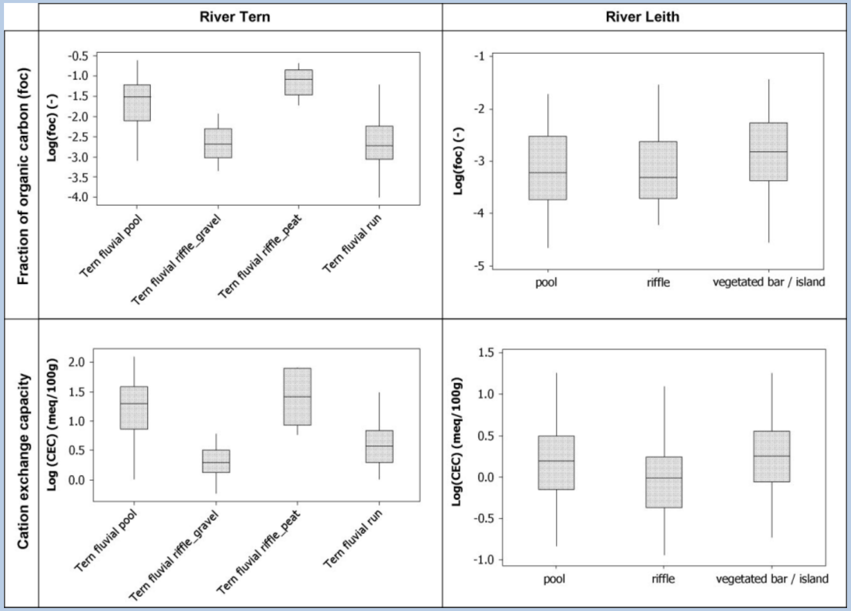
Source: schursastrophotography.com

- Solute uptake and sedimentation

Source: lfu.bayern.de

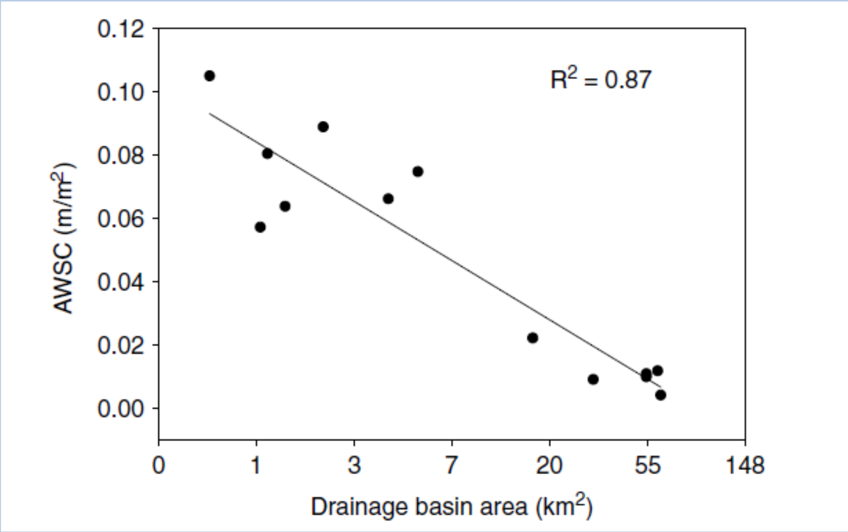
Issues of scale: catchment trends

Attenuation capacity



Smith and Lerner, 2008. Hydrological processes. DOI: 10.1002/hyp.7078

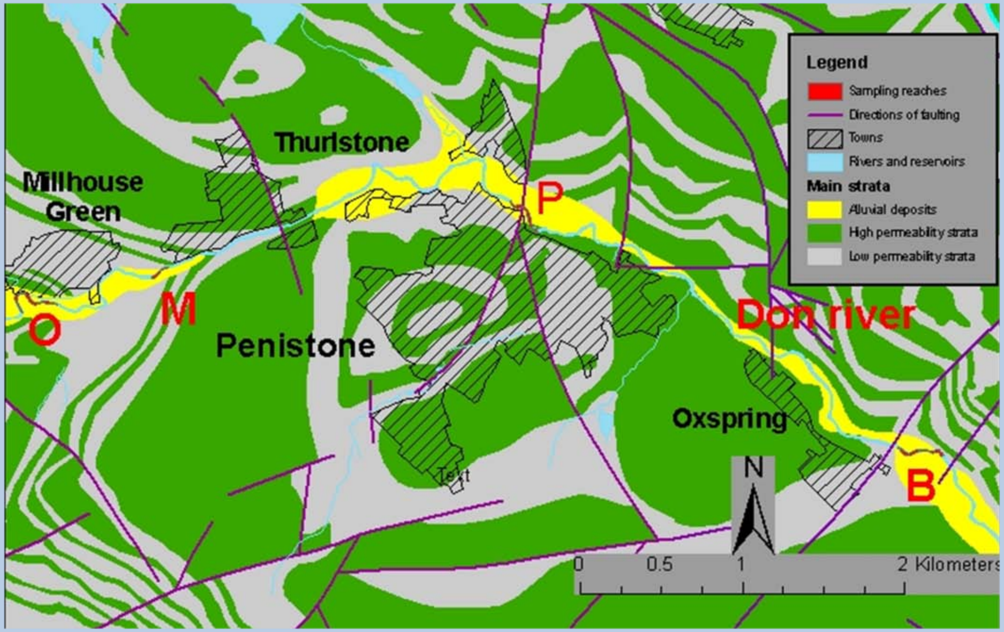
HEF development

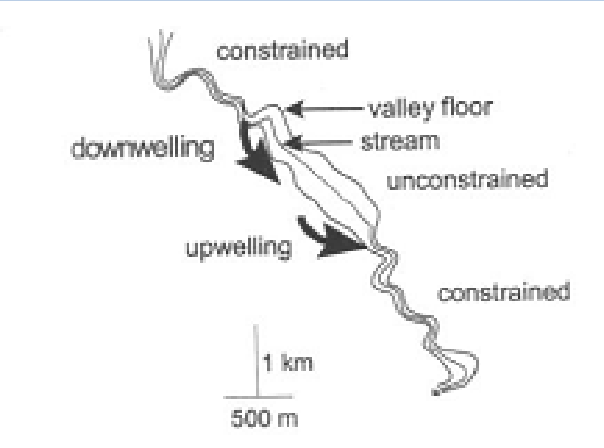


Anderson et al., 2005. Hydrological processes. DOI: 10.1002/hyp.5791

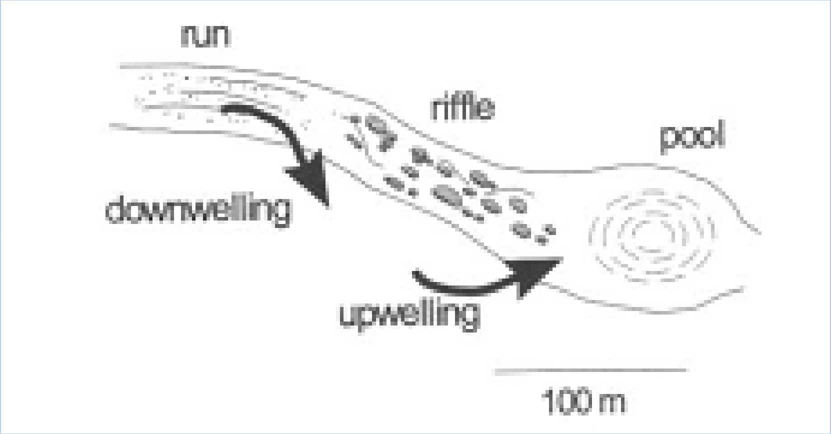
Issues of scale: multi-scale controls on hyporheic processes

Ibrahim et al., 2010. Hydrogeology Journal. doi:10.1007/s10040-010-0623-z



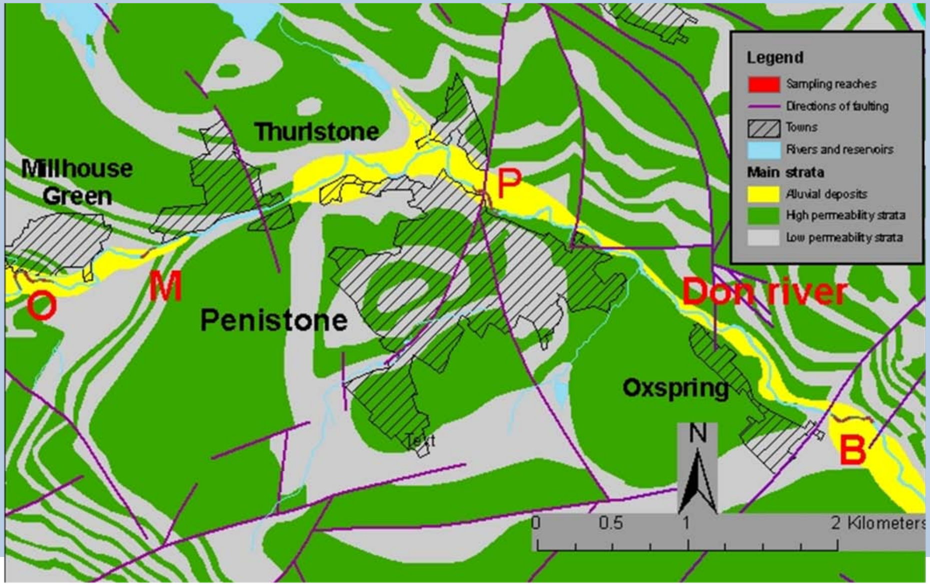


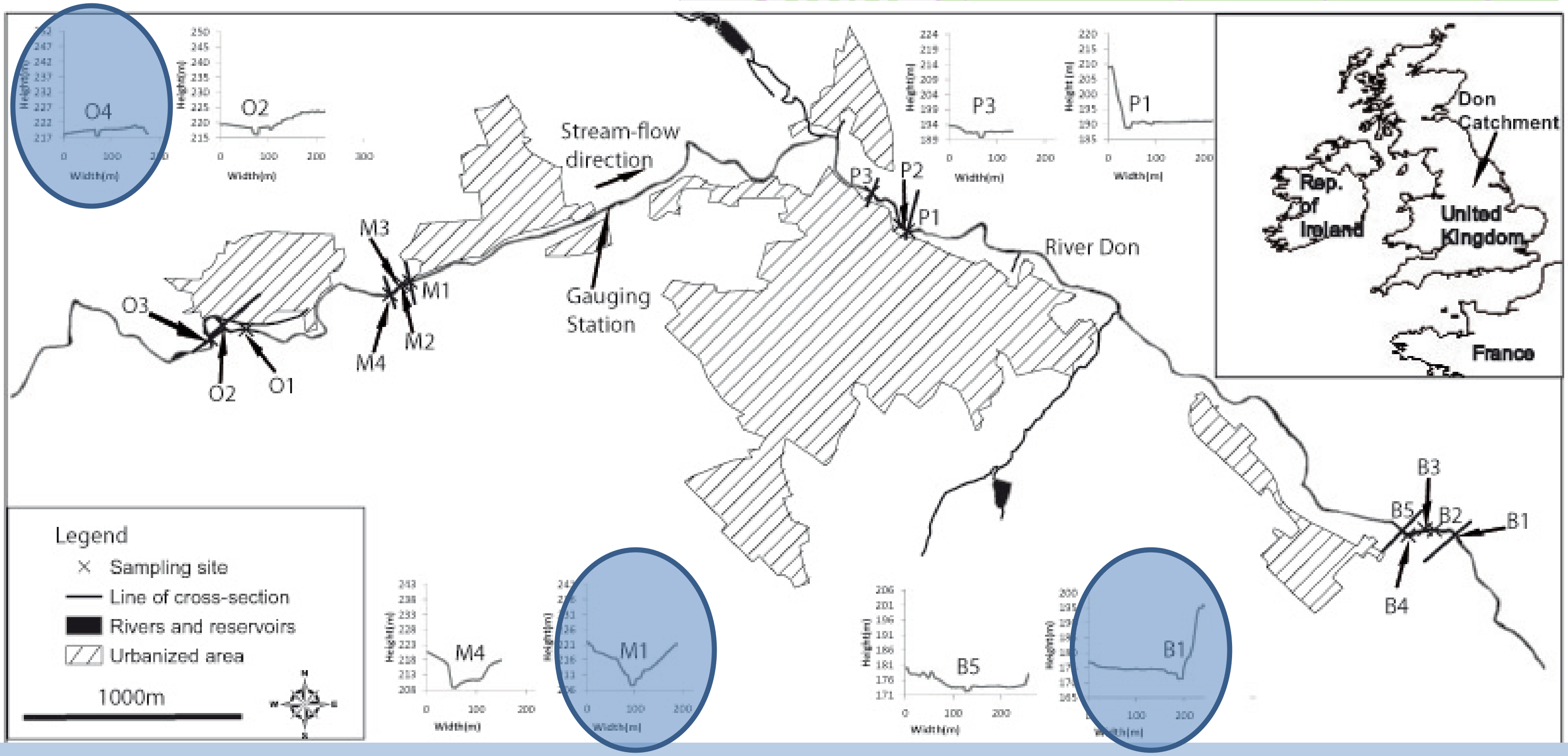
Reach scale subsurface flowpaths (RSSF)



Channel unit scale hyporheic flowpaths (CUSHF)

Issues of scale

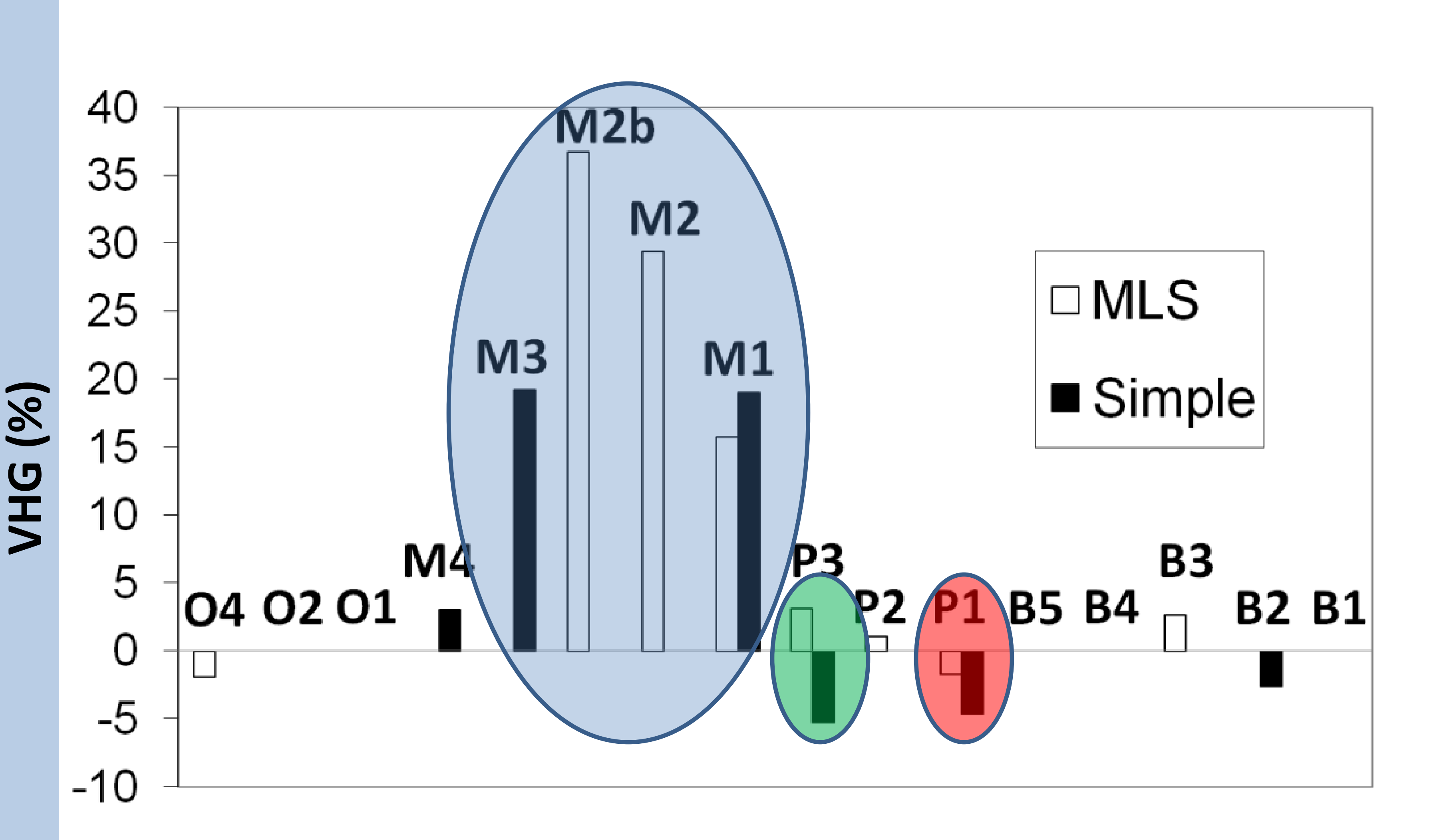




Ibrahim et al., 2010. Hydrogeology Journal. doi:10.1007/s10040-010-0623-z

Issues of scale

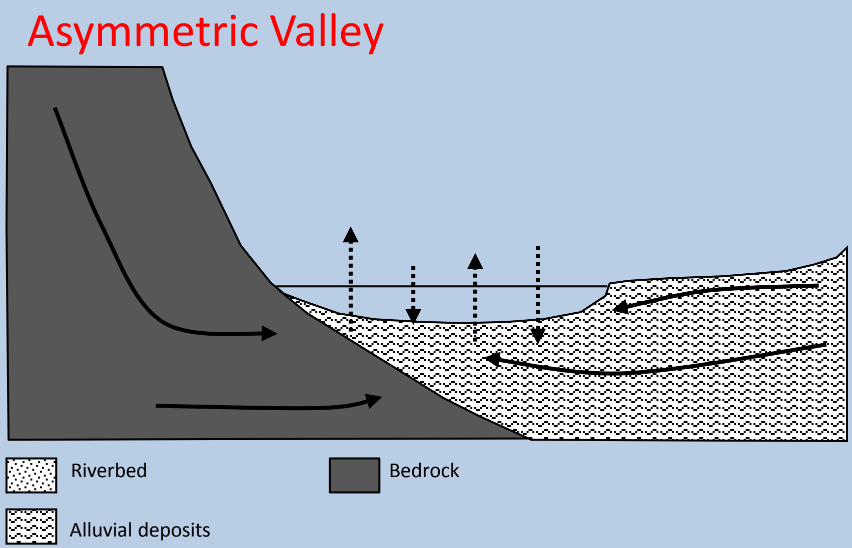
- Vertical Hydraulic Gradients

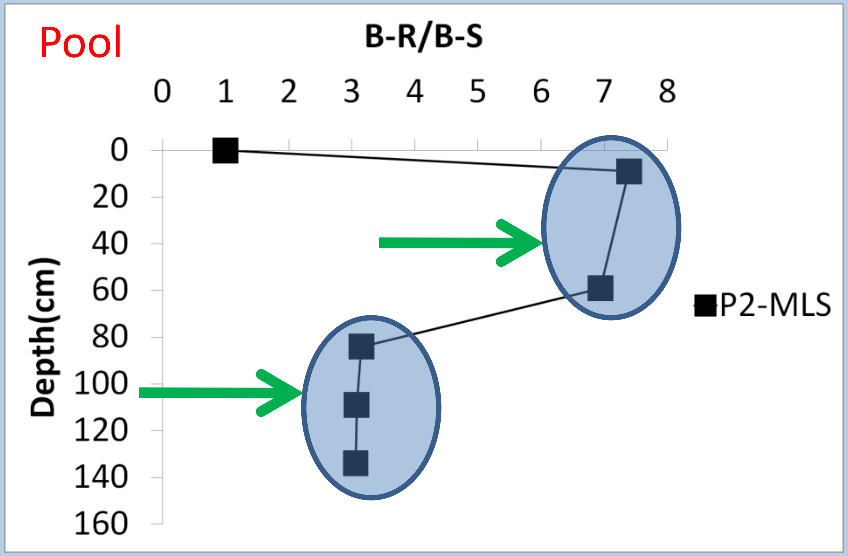


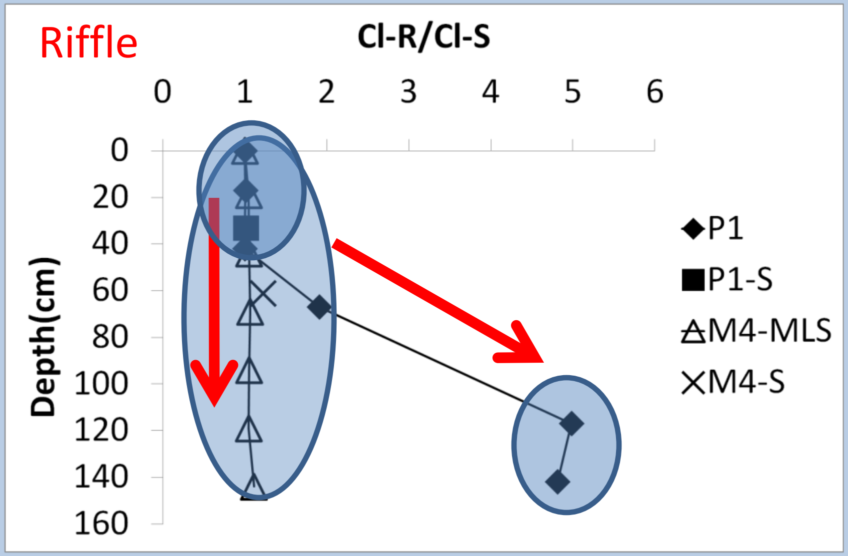
Ibrahim et al., 2010. Hydrogeology Journal. doi:10.1007/s10040-010-0623-z

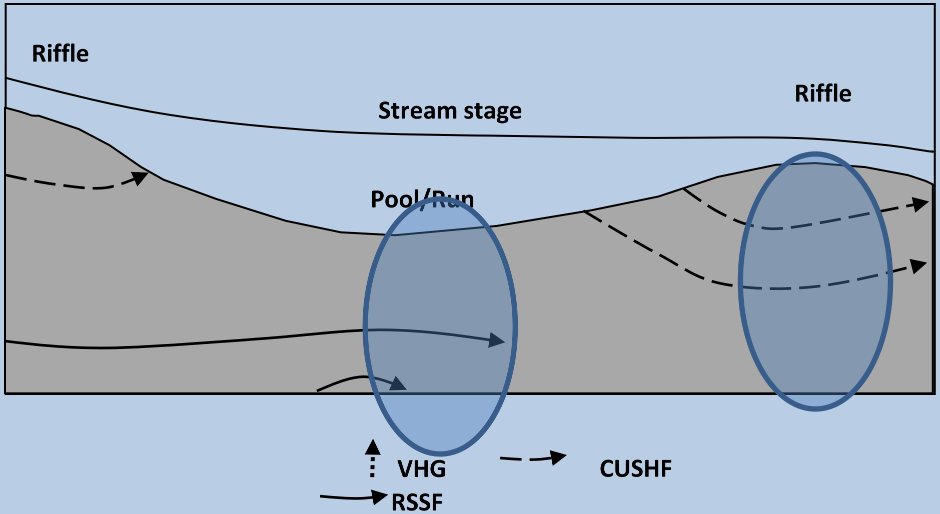
Issues of scale

- Flowpath discrimination





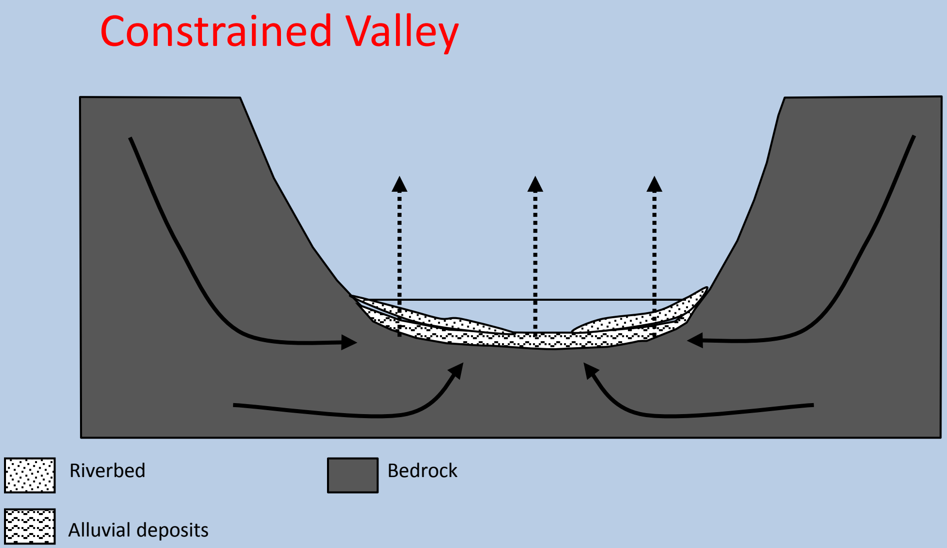


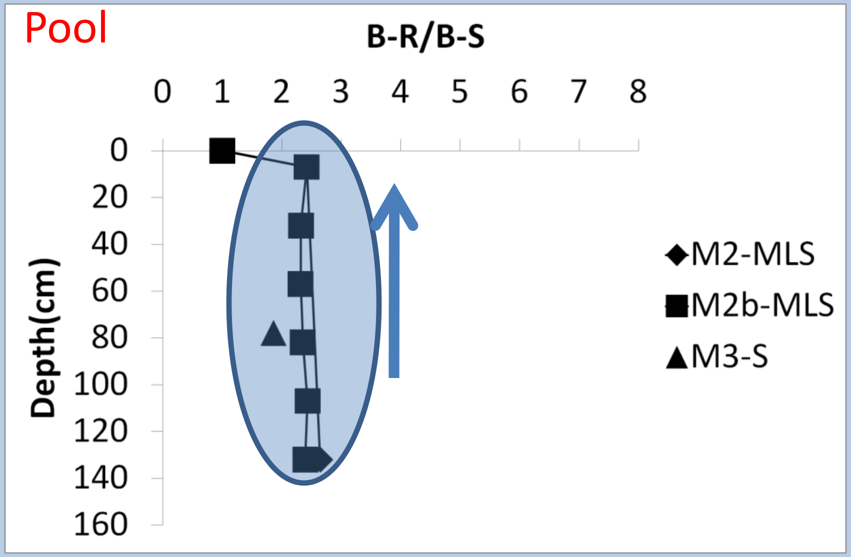


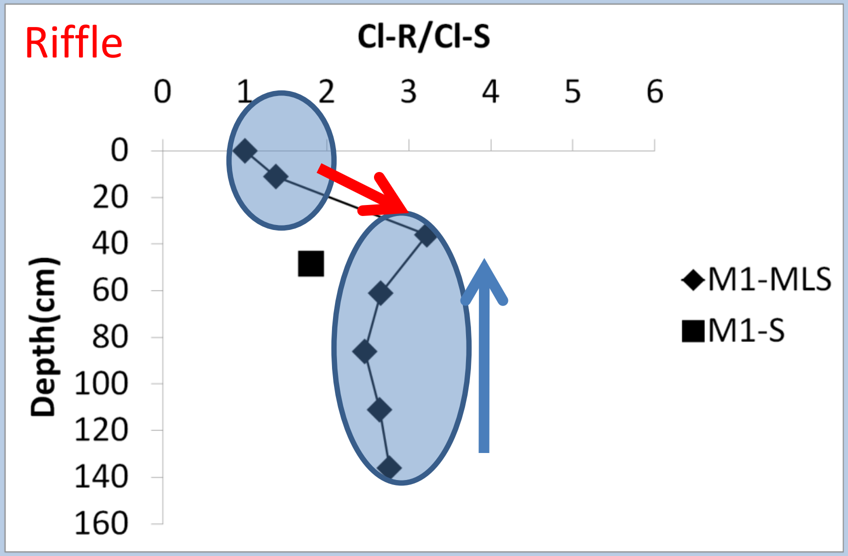
Ibrahim et al., 2010. Hydrogeology Journal. doi:10.1007/s10040-010-0623-z

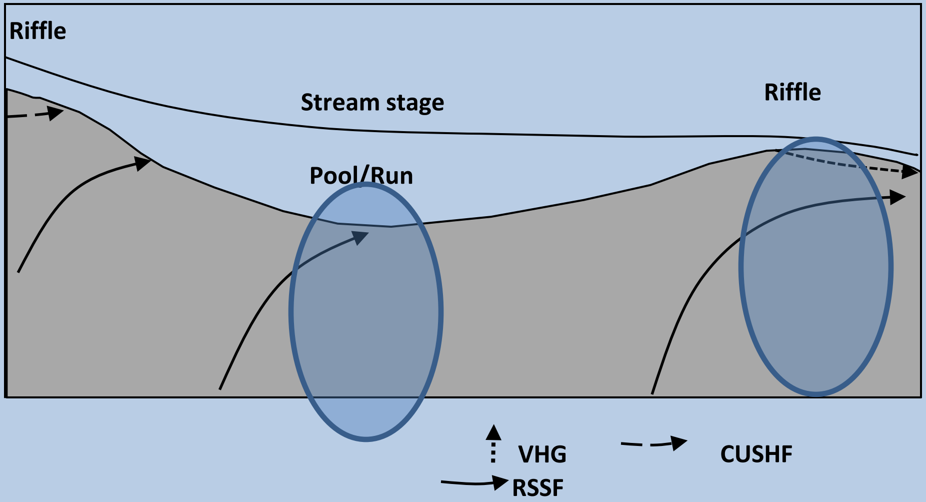
Issues of scale

- Flowpath discrimination



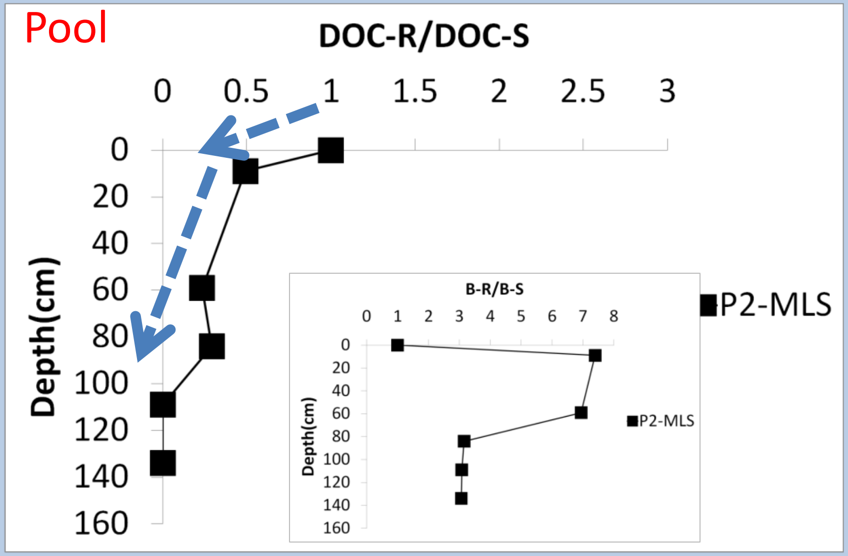




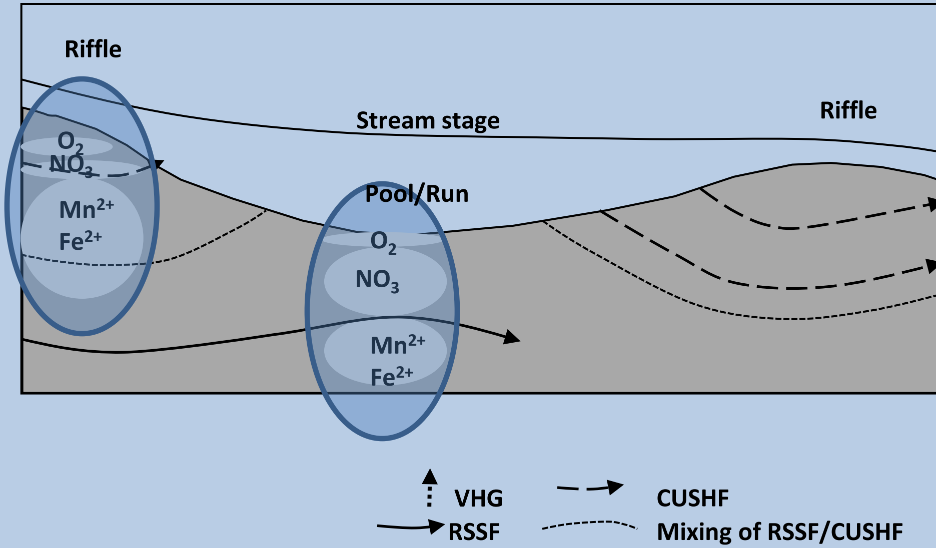


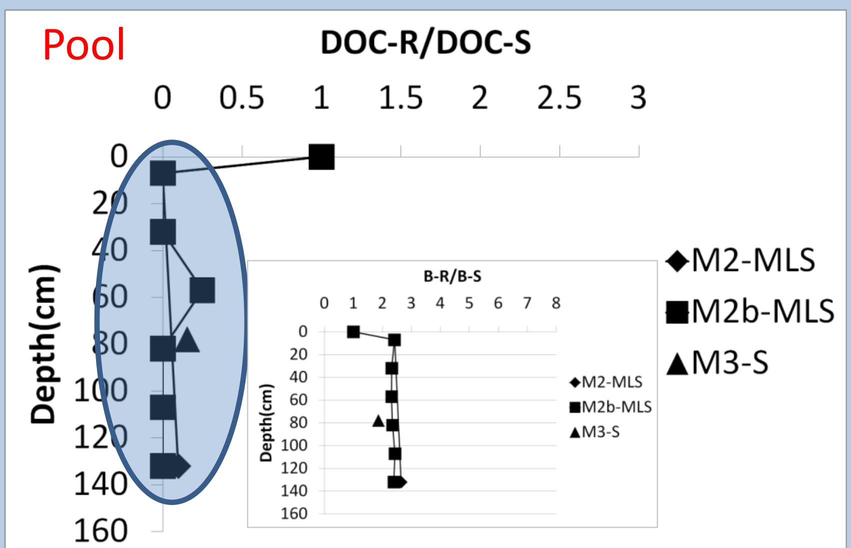
Ibrahim et al., 2010. Hydrogeology Journal. doi:10.1007/s10040-010-0623-z

Issues of scale

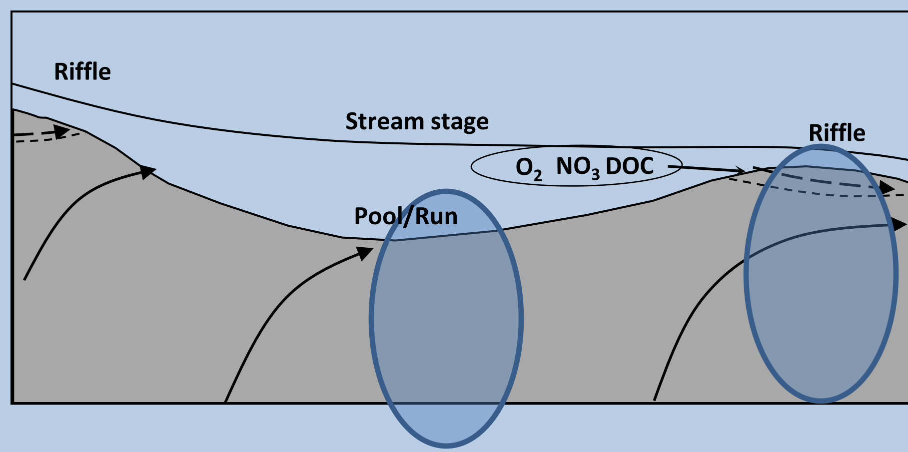


Asymmetric Valley





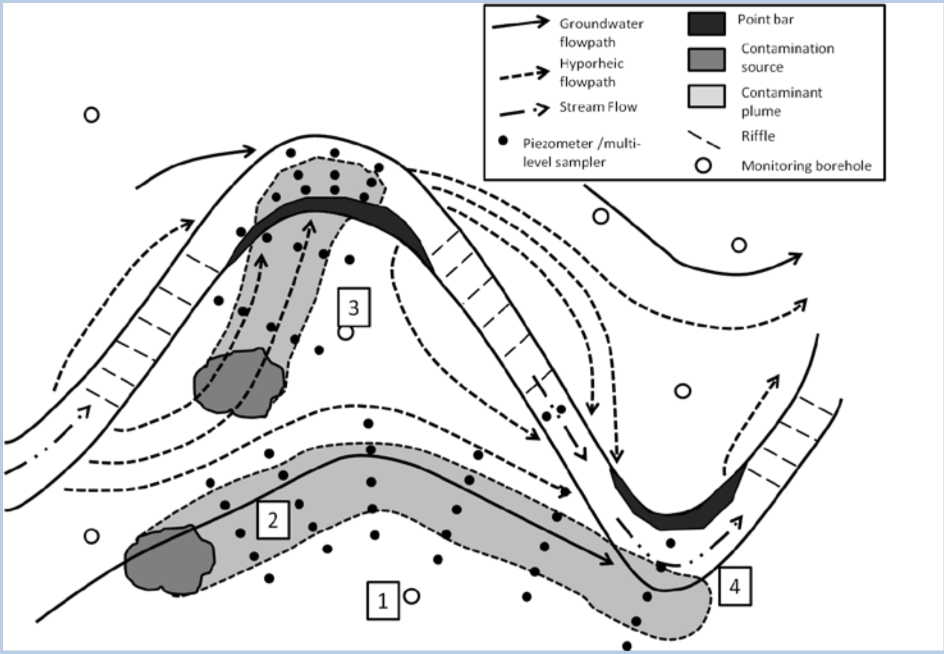
Constrained Valley



Ibrahim et al., 2010. Hydrogeology Journal. doi:10.1007/s10040-010-0623-z

Monitoring strategies and modelling tools

- **Conceptual models**
- Aquifer and stream types. Contaminant of concern
- Local geomorphology. Access to sites
- Directions of water exchange. Deposit types
- Contaminant fluxes and attenuation.
  Ecosystem health.
- Redefinition of compliance points
- Modelling solutions



River restoration

Picture courtesy of the River Restoration Centre (RRC)

•Restoring lateral and longitudinal connectivity and “natural” river geomorphology

•Enhancing/reducing HEF?

•Contaminant attenuation/risk to stream ecosystem?

Conclusions

- GW/SW interface: legal requirement/opportunity
- Holistic and interdisciplinary approach
- “Rescaling hydrogeologic thought”
- Integration with river management

Thanks !

Questions?

Preparation of this review was supported by NERC grant NE/E002714/1, *Hyporheic Network - a Knowledge Transfer Network on Hyporheic Zone Processes*.
We also wish to thank the Environment Agency and the Marie Curie Early Stage Research Fellowship program