Tools

How to characterize the transition zone?

Important CSM Considerations

- Plume Geometry
- Hydrostratigraphy
- Physiochemical behavior of the COCs
- Hydraulics of the system
- Permeability of the sediments
- Sediment bedforms
- Geochemical environment
- Biotic processes
- Abiotic processes
- Residence time in transition zone

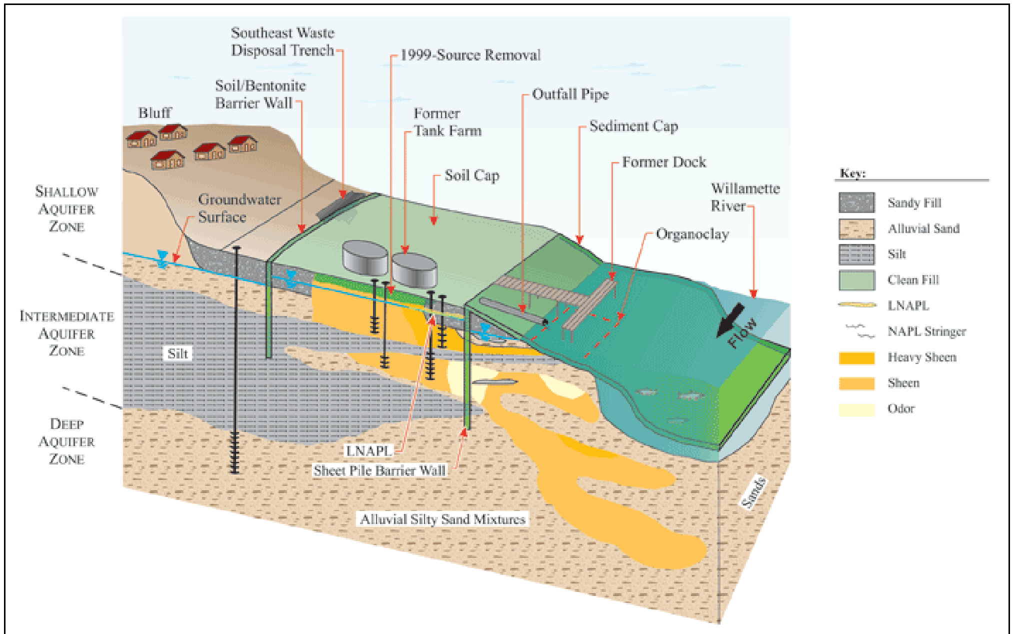


Figure 3. Stylized CSM of a contaminated sediment site remedy with an active source.

GW SW Workshop RTDF/Sediments Remediation Action Team. October, 2002

https://clu-in.org/contaminantfocus/default.focus/sec/sediments/cat/conceptual_site_models/

Technical Needs

- Ecological Characterization
- Development of Remedial Alternatives

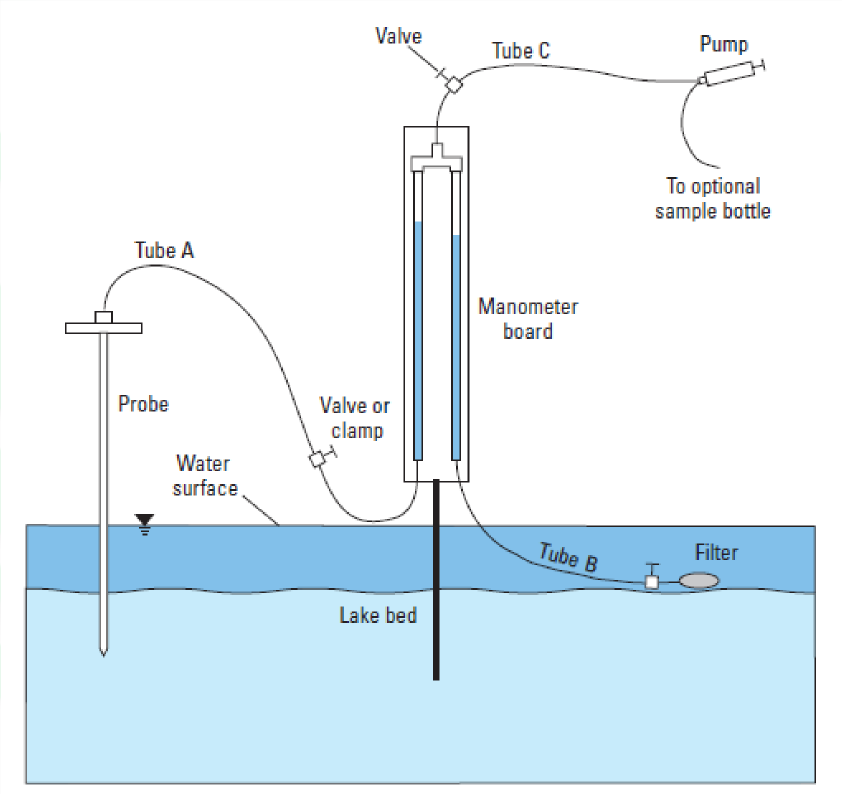
Ecological Characterization

- Basic Ecology
  - BMI Scores, Fish Counts, Vegetation, etc.

- Indicators of Effects
  - See Above
  - Concentration Data
    - Hydraulic Potentiomanometer
    - Micro-Push Probe
    - Permeable Membrane Diffusion Samplers (e.g. Peepers)
  - Mass Flux

Hydraulic Potentiomanometer

- Mini Piezometer
- Manometer board
    - One side in stream/lake bed sediments
    - One side in surface water
- Easy to obtain gradients (even when small)
- Pore water samples may be collected from sediments

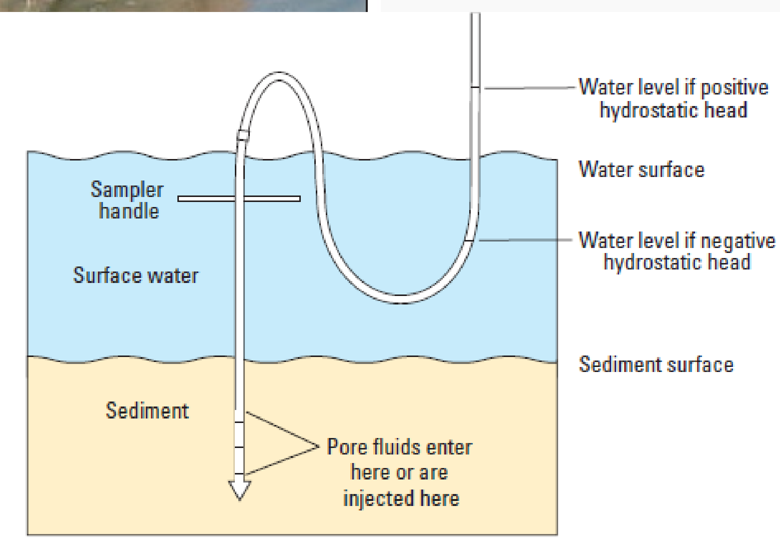


Rosenberry et al. 2008. USGS TM4-D2. Figure adapted from Winter et. al 1988.

Micro Push Point

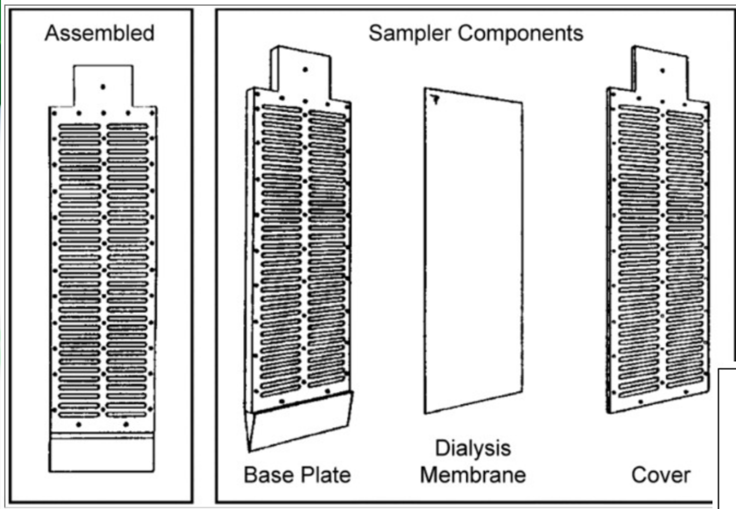
- Similar to mini-piezometers
- Easily deployed in field
- More challenging to obtain gradient information
- Regularly used in R8 to collect pore water samples for ecological risk assessments

PP27 used as a piezometer/manometer to determine the elevation of ground water relative to surface water



Rosenberry et al. 2008. USGS TM4-D2. MHE PP27 probe modified from Henry, 2000. Photography by Mark Henry, MDEQ.

Diffusion Based Methods



Peeper Plate Device (Source: EPA 2001)

Permeable Membrane separating "clean" water from sampled water

Advantages (Adapted from EPA 2001)

Provides high resolution of pore water changes in the sediments.

Can monitor most analytes including dissolved gases.

Can preserve inorganic speciation under anaerobic conditions (Carr and Nipper 2001).

Inexpensive and easy to construct.

Some selectivity possible depending on nature of sample via specific membranes.

Wide range of membrane/mesh pore sizes.

Useful in determining contaminant availability.

Limitations (Adapted from EPA 2001)

Cell sample volume may limit types of analysis that can be performed.

Requires special transport and handling when sampling potentially anoxic pore water.

Requires hours to weeks for equilibration (varies with site and chamber).

Some membranes such as dialysis/cellulose are subject to biofouling and over time dialysis/cellulose is subject to microbial attack and destruction.

Some construction materials may yield chemical artifacts.

Must deoxygenate chamber and materials to prevent oxidation effects when sampling in anoxic environments.

A high degree of technical competence and effort is required for proper use (Carr and Nipper 2001).

A: Diffusion Bag with Polyethylene Mesh
B: Diffusion Bag Without Mesh
C: Diffusion Bag and Mesh Attached to Bailer Bottom

https://clu-in.org/characterization/technologies/default.focus/sec/Passive_(no_purge)_Samplers/cat/Diffusion_Samplers/

Mass Flux Measurements

- Needed to ensure exposures scenarios in risk assessment are accurate
- Needed for Remedial Design
  - Target areas of high flux

Photos courtesy of Dr. Rory Cowie, Mountain Studies Institute

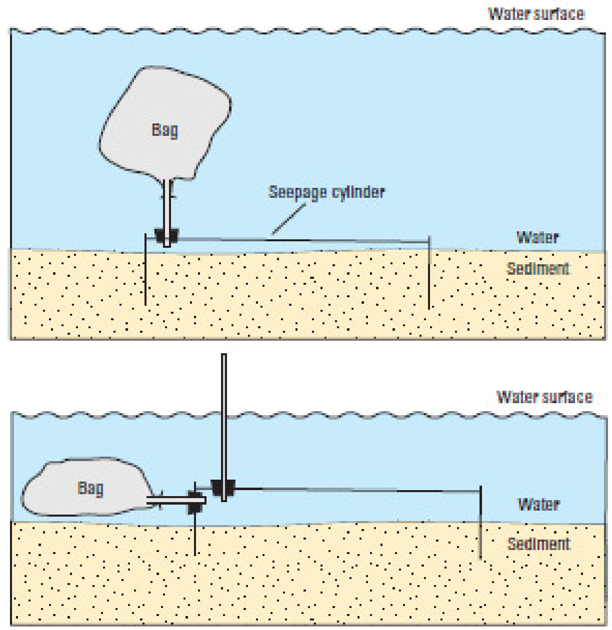
Mass Flux Estimation

- Direct Measurements of Flux
  - Seepage Meter
- Heat Based Methods
  - Distributed Temperature Sensors
  - FLIR
  - Trident Probe
- Mass Balance Approaches
  - Incremental Streamflow
  - Surface Water or Groundwater Tracers
  - Point Velocity Probe
- Methods Based on Darcy's Law

Seepage Meters

- Controlled flow through the meter into the bag
- Can be converted to flux (useful for comparisons)

- Issues
  - Incomplete Seal
  - Insufficient Equilibration time
  - Leaks
  - Accumulation of trapped gas
  - Correction Coefficient



Rosenberry et al. 2008. USGS TM4-D2. Half Barrel Seepage Meter Modified from Lee and Cherry, 1978.

Distributed Temperature Sensors

- Fiber Optic Cable
  - Temperature can affect glass fibers and locally change light transmission characteristics of the fiber
  - Difference between wavelength of laser source and the shifted photons can be measured and is Temperature Dependent
  - Identify heterogeneity in streambed and identify areas of enhanced seepage
  - Must be combined with other data to determine flux

Figure 1. Charles Harvey (MIT) and Fred Day-Lewis (USGS) prepare fiber-optic distributed temperature system for deployment at Waquoit Bay National Estuarine Research Reserve, Massachusetts.

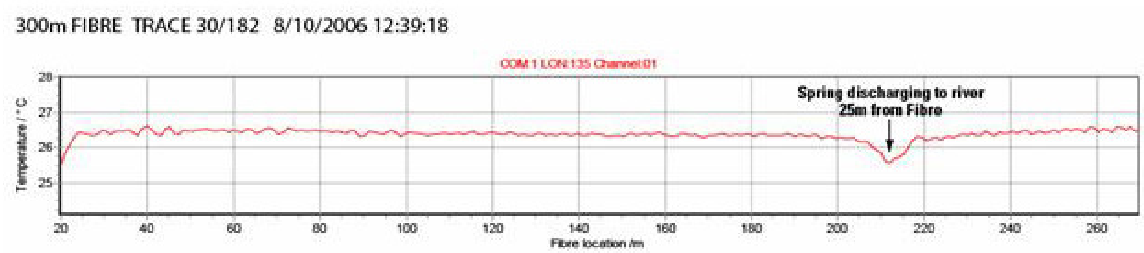
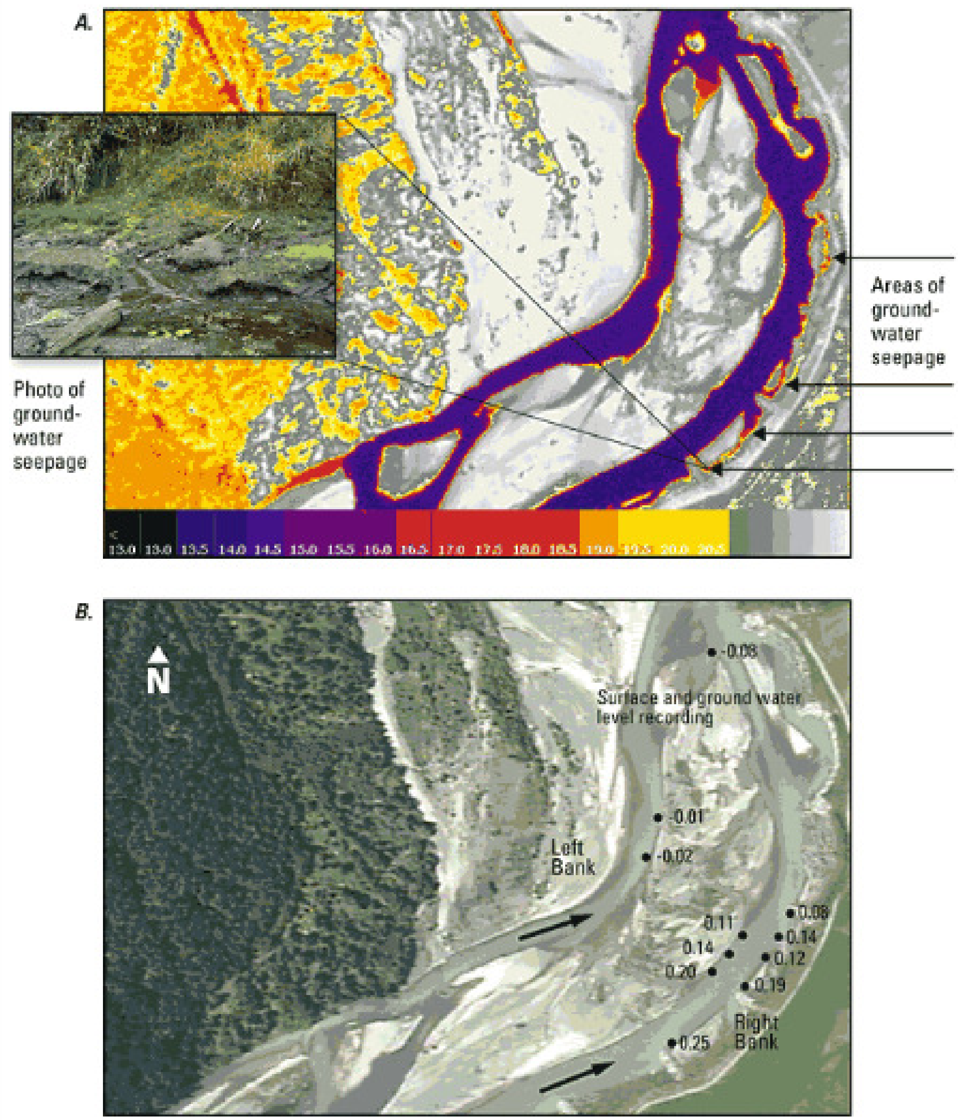


Figure 2. Sample temperature data from fiber-optic distributed temperature sensor deployed in the Shenandoah River.

https://water.usgs.gov/ogw/bgas/fiber-optics/

Forward Looking Infrared (FLIR)

- Aerial and handheld platforms
- Non-quantitative but useful for identifying seeps and springs

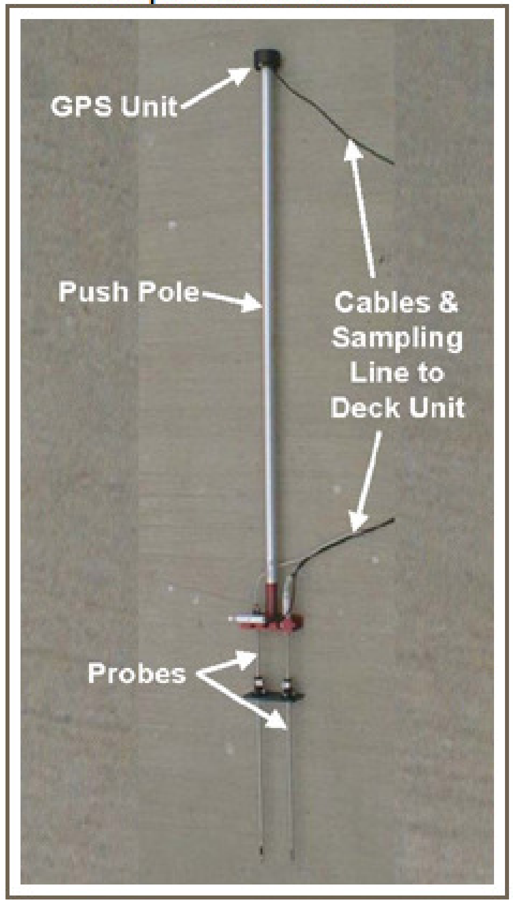


https://pubs.usgs.gov/sir/2005/5255/section5.html

Trident Probe

- Conductivity
- Temperature
- Pore Water Sampling
- Easily integrated for analysis (GPS)

FIGURE 2.
Example of a Trident Probe



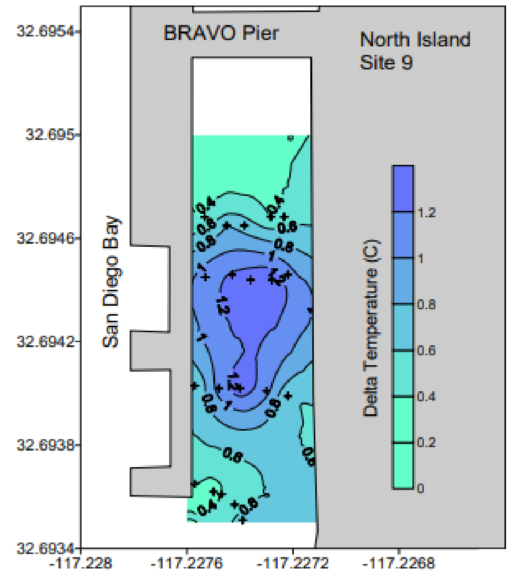


Figure 2-20. Temperature contrast contour map.

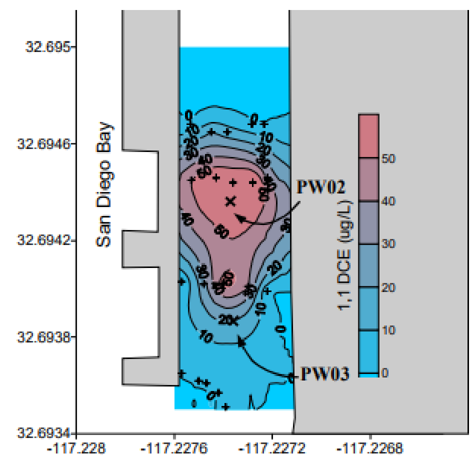


Figure 2-21. 1,1 DCE contour map from porewater samples collected with Trident probe.

https://clu-in.org/programs/21m2/navytools/gsw/
Also: https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Monitoring/ER-200422

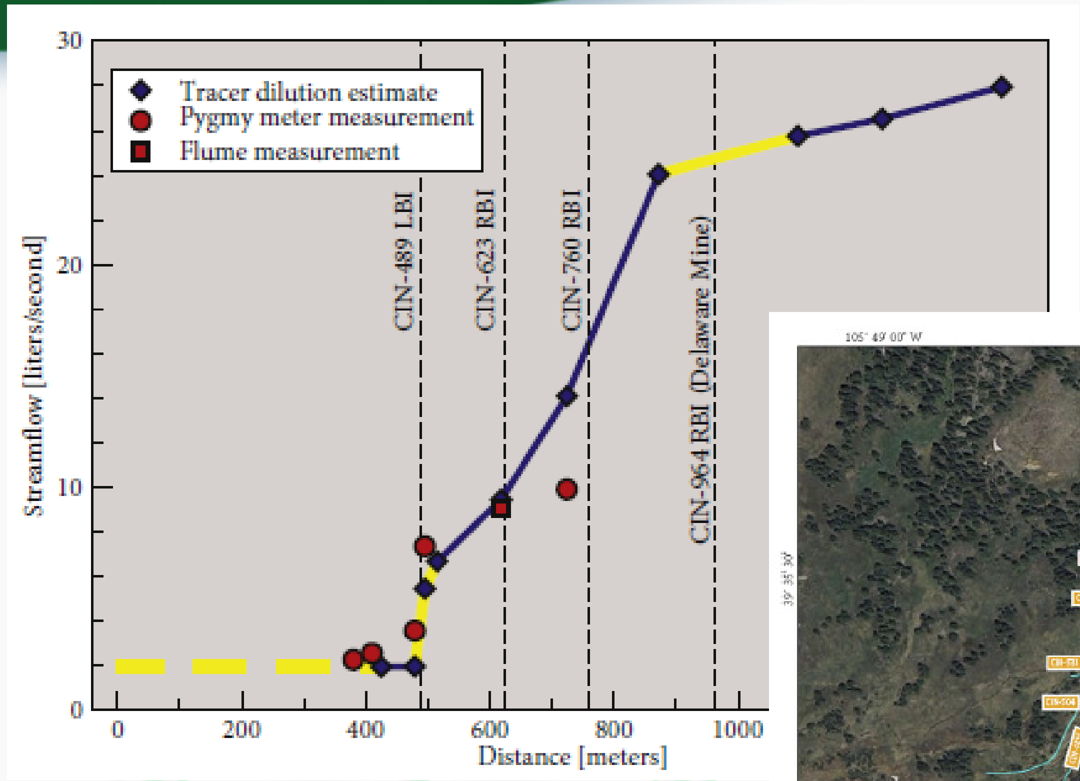
Incremental Streamflow

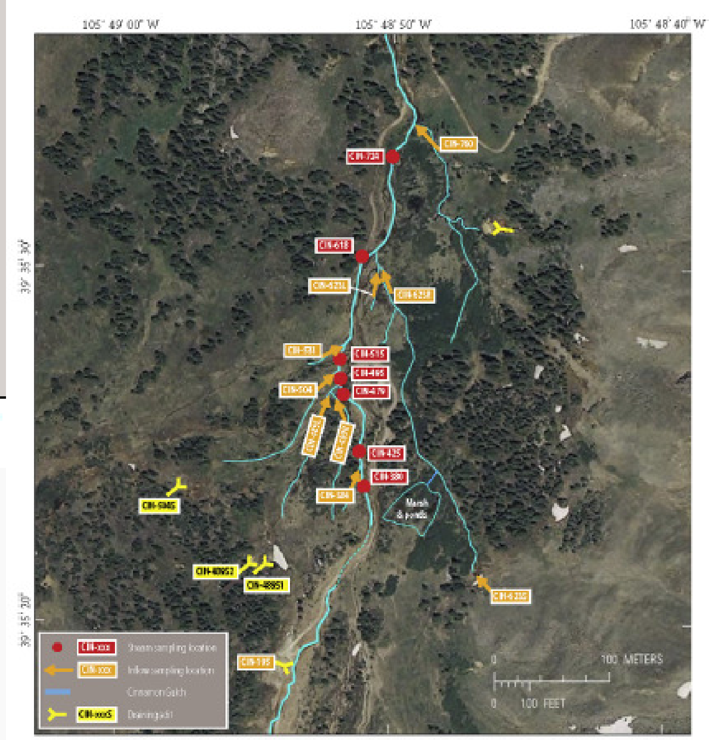
- Estimate Streamflow velocities across transect of Stream (Pygmy Meter, Flow Tracker, Marsh McBirney)
- Use velocities and depth to estimate streamflow
- Collect streamflow estimates along a spatially detailed profile
- Can be combined with concentration data to determine mass load in the stream

Dr. Rory Cowie collecting streamflows with a Marsh McBirney

Tracer Dilution

- Tracer Dilution Method
- Inject tracer at constant rate
- Measure tracer along stream
- Dilution is related to streamflow
- Can provide very accurate and detailed estimates of flow (and load)





Runkel et al. 2018. Applied Geochemistry, 95, 206-217.

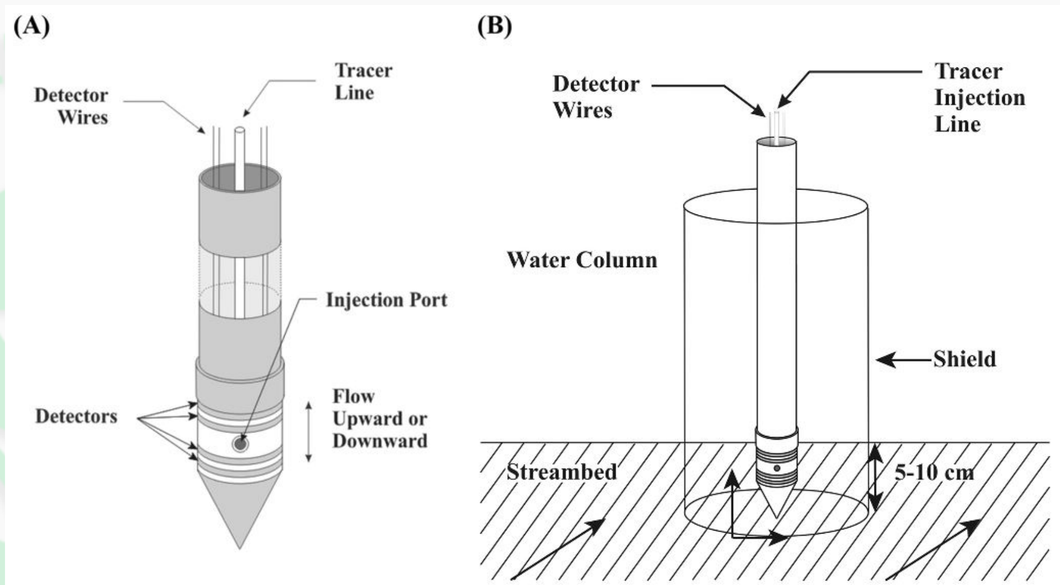
Applied and Natural Tracers

- Applied Tracers can definitively show connections between suspected sources of water and seeps, springs, mine tunnels, etc.
  - Many tracers available (Dyes such as Flouroscein, or Rhodamine; Salts such as Lithium Bromide)
  - Tracer characteristics should be considered (pH dependence?)
- Natural Tracers are potentially cost effective ways to understand flow paths
  - Stable Isotopes (H and O in water, S in Sulfate, Strontium are common)
  - Conservative constituents (Contaminants, anions)

Photo Courtesy of Dr. Rory Cowie, Mountain Studies Institute.
See also: Cowie et. al 2014. Water, 6, 745-777

Point Velocity Probe

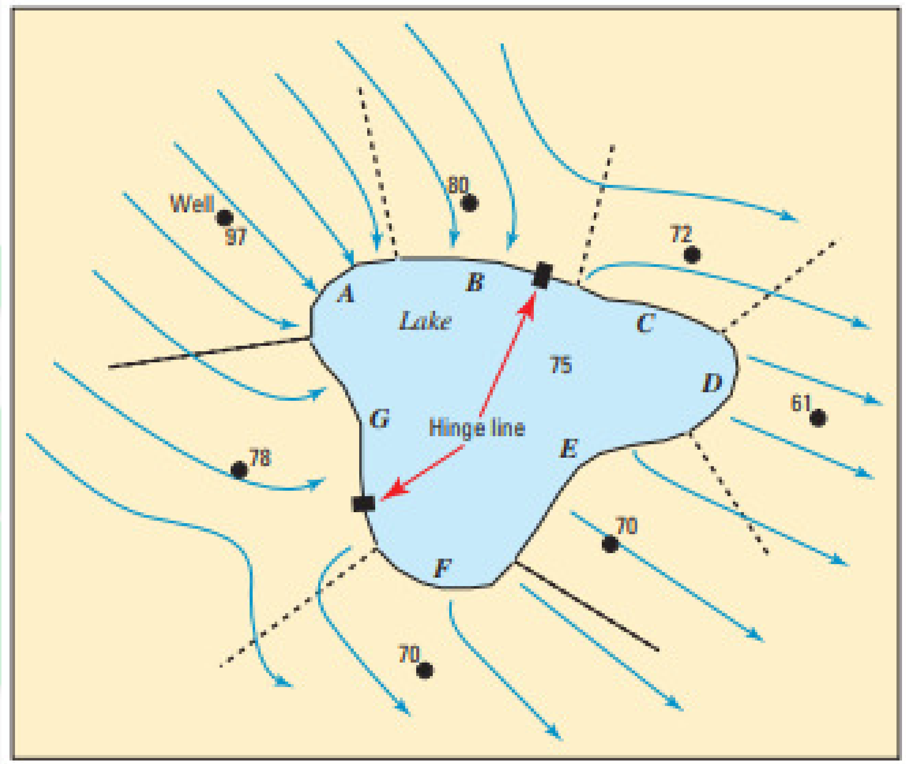
- Small Scale Tracer Test
- Groundwater flow velocity measurement that does not depend on Darcy's Law
- Useful in nearly any porous media
- Tracer is injected and is transported along probe surface where it can be detected
- Applications for horizontal and vertical flow
- Stream Bed PVP (SBPVP) is a special application for characterizing the transition zone



Cremeans et. al, 2018. Journal of Contaminant Hydrology, 211, 85-93.

Darcy's Law

- q = -ki where q = flux, k = hydraulic conductivity, and i = gradient
- Relies on estimates of hydraulic conductivity and gradient
- Commonly Used Approach, but often does not provide information at the scale required for remedial decisions



Rosenberry et. al, 2008.
https://pubs.usgs.gov/tm/04d02/pdf/TM4-D2-chap2.pdf

Putting it all together

- Many techniques available to get the same information
- CSM and site characteristics should be used to guide approach

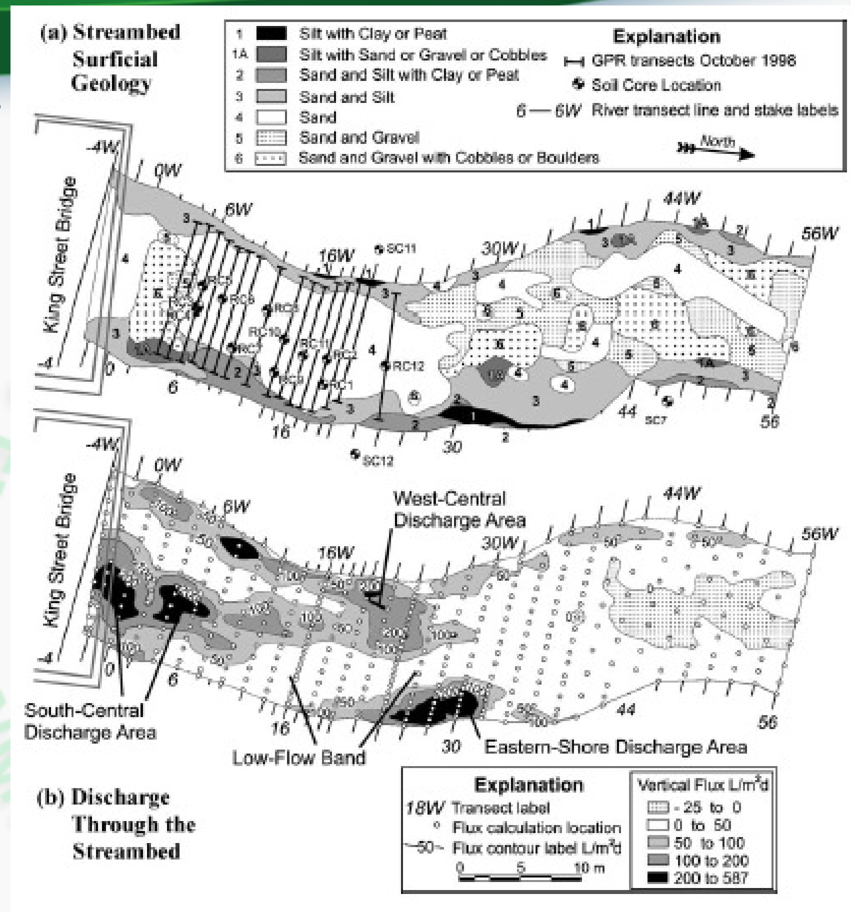
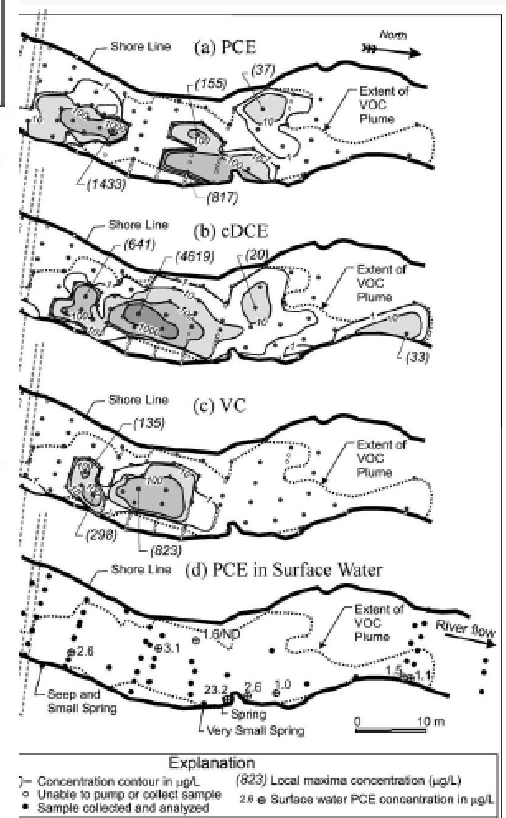


Fig. 3. (a) Map of surficial geology of the streambed and (b) map of vertical water fluxes through the streambed for February 1999.



Conant, Cherry, and Gillham, 2004. Journal of Contaminant Hydrology, 73, 249-279.

Acknowledgments

- Dr. Rory Cowie and the entire BPMD team
- Dr. Dan Wall
- Dr. Rob Runkel
- Dr. Rick Devlin (and students)

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