Characterizing Contaminant Flux at the Groundwater-Surface Water Interface

Robert Ford
USEPA Office of Research and Development
Cincinnati, OH

Collaborators: Steve Acree, Randall Ross, Bob Lien
The findings and conclusions in this presentation have not been formally disseminated by the U.S. EPA and should not be construed to represent any agency determination or policy.
Plan for Presentation

• Context for evaluating water and contaminant flux from upland groundwater to downgradient surface water bodies (CSM)
• Assessing hydraulic pathway from groundwater to surface water
• Assessing factors controlling contaminant flux to surface water
Understand Interaction Between GW & SW

• Water flux of GW and SW at interface will govern processes controlling contaminant fate

• Dominant chemical processes will be governed by the mass of contaminant and reactive constituents delivered to and mixed at the interface

• Net result of processes will likely vary in time (seasonal) and space (geology)
Effective CSMs - Site Hydrology Issues

• Hydraulic connection between contaminated GW and surface water body
  – Does it exist?
  – If so, is it continuous or episodic?
  – When connected, does the direction of water exchange vary?

• Questions need to be addressed to understand timing and location of contaminant discharge
Conceptual Site Model

- Site topography and stream morphology influence GW flow direction and magnitude.
- May need to characterize this spatial variability relative to GW plume dimension.
- GW is not a static system, but may respond more slowly to changes in water budget (continuous logging).
An effective CSM depends on understanding contaminant transport from source area(s) to SW and dynamics at GW-SW interface.

Contaminant non-detects that occur along some assumed flow path could mean two things:

- Contaminated GW does not reach SW
- Monitoring location is not in the flow path

Hydrologic & chemical measurements across the GW-SW interface bridge upland GW-to-SW transport pathway.
Assessing Hydrology

- Site topography and stream morphology influence GW flow direction and magnitude adjacent to surface water body.

- Characterizing local flow field across GW-SW interface important for understanding dynamic processes governing water exchange & contaminant flux.
Assessing Hydrology

- Hand-Deployed Devices
  - Piezometer (P)
  - Piezometer-Stilling Well (PS)
  - Temperature Profiler (TP)
  - Permeameter (Pm)
- Provide for assessment of the direction and magnitude of water exchange
- Logging sensors allow assessment of variability over time
Assessing Hydrology

Temperature Profile Measurements

Installation of Piezometer-Stilling Well & Temperature Profiler

Vertical Gradient Piezometer-Stilling Well
Develop Integrated Knowledge of GW-SW Interface

• Localized monitoring network used to understand dynamics of flow system with time (seasonal)
  – Horizontal gradient
  – Vertical gradient
  – Horizontal/vertical water flux

• Basis for comprehending processes controlling contaminant flux and fate at GW-SW interface

• Baseline analysis of system provides the basis for interpreting whether upgradient remedial actions are performing as desired
Factors Affecting Contaminant Transport

Inorganic Contaminant Properties & Mass Flux

• Contaminant properties influence types of processes active in controlling fate (adsorption, precipitation, chemical speciation)

• GW-SW interface is typically a zone with major changes in chemistry over distance due to mixing of reactive constituents delivered by GW and SW

• Contaminants with chemical fate sensitive to changes in pH and redox may show changing patterns with season

• Contaminants sequestered in sediments may become a secondary source of contaminant flux to SW
Reduced GW Plume

- SW body with varying water depth in which oxygen reaches sediments in shallow locations but not deep
- Oxidation & attenuation of Fe and As in sediments for shallow depths
- Unhindered transport of As into SW for deeper depths
Case Study

- Arsenic plume flowing from landfill toward cove
- Nested piezometers used to evaluate magnitude & distribution of arsenic flux
Case Study

Picture of cove from north shore

Picture at central cove from boat next to contaminated seepage area

April 2007
Case Study

What influences SW concentrations?

- Sediment arsenic concentrations variable within cove – correlate with iron
- PZ5 location shows sustained discharge with plume chemistry signature in deep SW
- PZ13 in location of low discharge & no plume chemistry signature in deep SW
Case Study

Upland GW

Median Flux Reduction Factors
Flow 2.9  Barium 7.6
Arsenic 4.3  Ammonium 12.8

Calendar Year

Groundwater Flux, m/d

GW Arsenic Flux, mg/d-m²

Measured
Interpolated
Case Study

GW-SW Interface

Sediment Temperature Profile Method

Comparison over entire monitoring period...

Middle of Cove (June - August)
- Pre-Installation (2008)
- Post-Installation (2014)
- Upland GW Flux

Calculated Seepage Flux (cm/d)

Calendar Day

Water Flux, cm/d

Calendar Year
Case Study

Interpolated GW Arsenic Flux, mg / d-m²

Measured Cove Arsenic Flux, mg / d-m²

Calendar Year
Case Study

Outcome

- GW plume diverted away from cove by hydraulic barrier
- Performance metric of GW contaminant flux reduction was realized and could be assessed in multiple ways
- Episodic exceedances of AWQC (As) during late Summer / early Fall, but...
- Spring fish nest building observed immediately after remedy and continues (2014-2018)
• Methods to assess GW flow and seepage flux are relatively easy to implement and provide flexibility to monitor the GW-SW interface

• Knowledge of water flux dynamics improves understanding of processes controlling contaminant fate

• Comprehension of baseline contaminant flux dynamics across the GW-SW interface are critical to assessing response to upland remediation
Acknowledgements

Engineering Technical Support Center
John McKernan, mckernan.john@eda.gov
Ed Barth (Acting), barth.edwin@epa.gov

Groundwater Technical Support Center
David Burden, burden.david@epa.gov

EPA Region 1 – Carol Keating, Bill Brandon, Ginny Lombardo, Jerry Keefe, Dan Boudreau, Tim Bridges, Rick Sugatt, David Chaffin (State of Massachusetts)
Workbook Beta Testing – Region 1 (Bill Brandon, Marcel Belaval, Jan Szaro), Region 4 (Richard Hall, Becky Allenbach), Region 7 (Kurt Limesand, Robert Weber), Region 10 (Lee Thomas, Kira Lynch, Bruce Duncan, Piper Peterson, Ted Repasky), Henning Larsen and Erin McDonnell (State of Oregon)

EPA ORD – Jonathon Ricketts, Patrick Clark (retired!), Kirk Scheckel, Todd Luxton, Mark White, Lynda Callaway, Cherri Adair, Barbara Butler, Alice Gilliland

US Army – Robert Simeone

Don Rosenberry (USGS – Lakewood, CO) – verification studies at Shingobee

Headwaters Aquatic Ecosystems Project