# Impact of Groundwater Discharge on Contaminant Behavior in Sediments

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*Region 1*
*Industri-Plex - Joseph LeMay*
*Fort Devens - Ginny Lombardo, Bill Brandon, Rick Sugatt*

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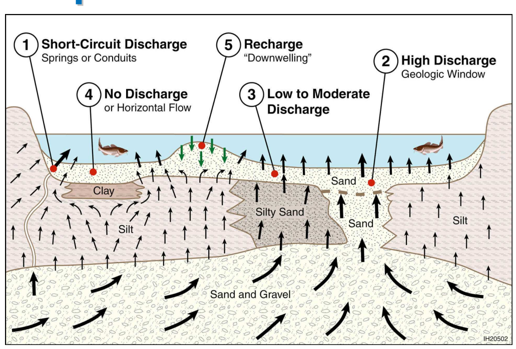
NSF

# Conceptual Model *GW/SW Transition Zone*





EPA-540-R-06-072 Evaluating Ground-Water/Surface-Water Transition Zones in Ecological Risk Assessments
http://www.epa.gov/oswer/riskassessment/ecoup/pdf/eco_update_08.pdf

EPA/600/S05/002 The Impact of Ground-Water/Surface-Water Interactions on Contaminant Transport with Application to an Arsenic Contaminated Site
http://www.epa.gov/ada/download/briefs/epa_600_s05_002.pdf

NARPM 2008 - Ground Water/Surface Water Interaction - Concepts, Field Methods, and Site Management Challenges Panel Session
http://www.ttemidev.com/narpm2008Admin/conference/agenda.cfm

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## Categories of GW Influence

1) Direct contribution of contaminant mass from discharge of the plume through sediments
2) Indirect influence on contaminant speciation due to biogeochemical processes that control sediment properties (precipitation-dissolution)
3) Indirect influence on contaminant speciation or mass due to the influence of groundwater discharge on microbial processes that support contaminant transformation or degradation.

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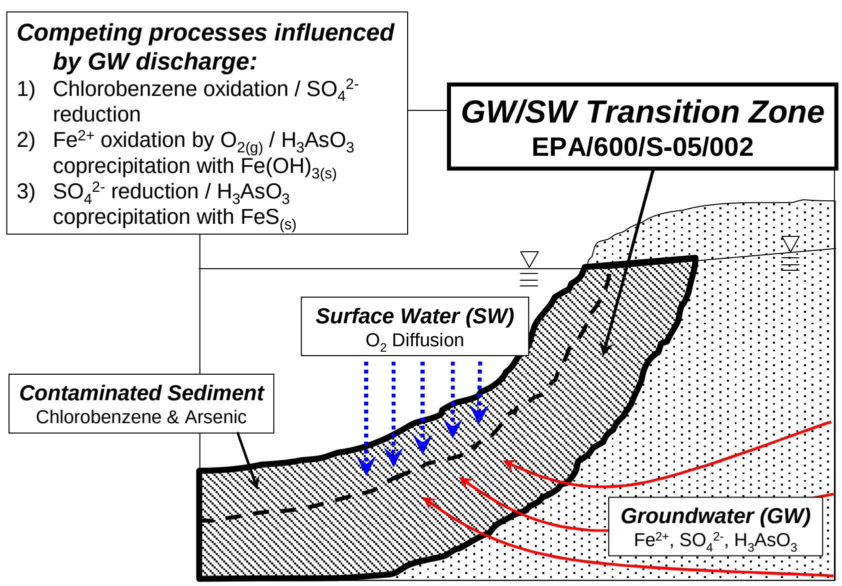
## Conceptual Model - Revisited

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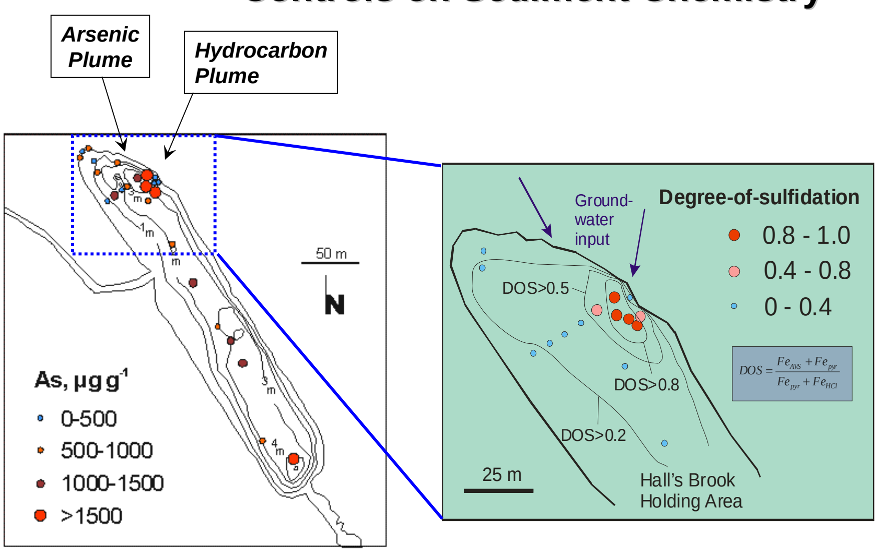
## Potential Influence on Remedy

- **Physical Barrier**
  - Discharge causing physical damage
- **Reactive Barrier**
  - Discharge causing short-circuiting
  - Flux of non-contaminant constituents consume reaction capacity
- **Monitored Natural Recovery**
  - Changes in flux of constituents influence extent or direction of attenuation process (biodegradation or immobilization)
  - Changes in GW flux could cause contaminant transport via advection

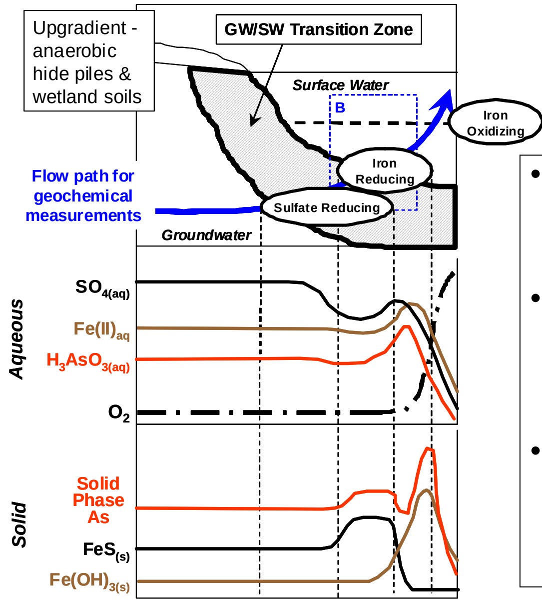


## Industri-Plex Superfund Site

### Controls on Sediment Chemistry



# Industri-Plex Superfund Site




- Sediment chemistry unique at intersection of GW plumes discharging into pond
- Sediments serve as an "incubator" for microbial processes and contaminant transformations
- SW conditions impacted by biogeochemical processes within shallow sediments

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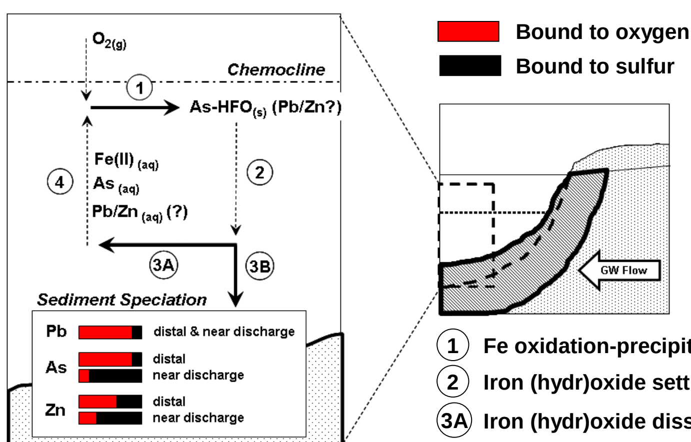
# Industri-Plex Superfund Site

## Fate of Metals entering Pond System




1. Fe oxidation-precipitation
2. Iron (hydr)oxide settling
3A. Iron (hydr)oxide dissolution
3B. Deposition & diagenesis
4. Dissolved Fe & As transport

***Arsenic is most labile***

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## *Fort Devens - Project Objective*

- Project Goals
  - Identification of the mobile form of arsenic in groundwater
  - Identification of the process(es) controlling arsenic uptake onto Red Cove Study Area sediments
  - Evaluation of the stability of arsenic associated with Red Cove Study Area sediments
- Site Characterization
  - GW hydrology and chemistry in Red Cove Study Area
  - Sediment chemistry including arsenic speciation in Red Cove
  - SW chemistry in Red Cove
- Provide recommendations for GW & sediment remedies, where applicable



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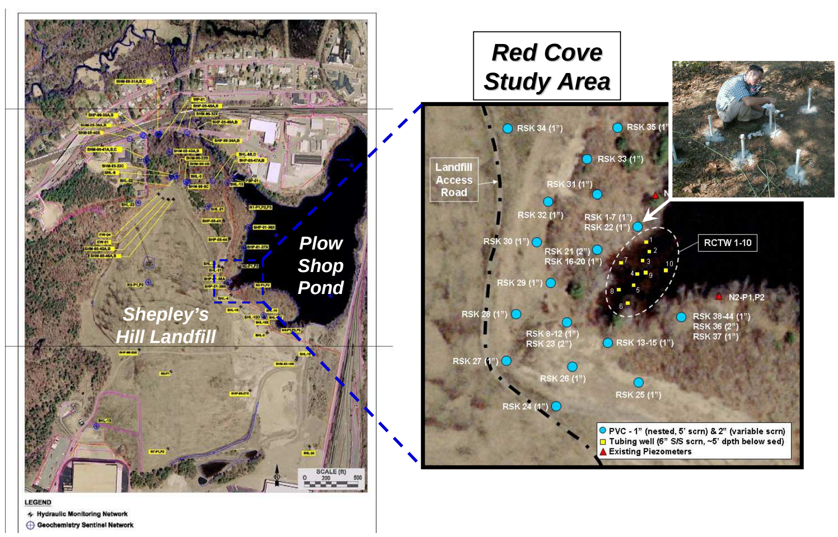
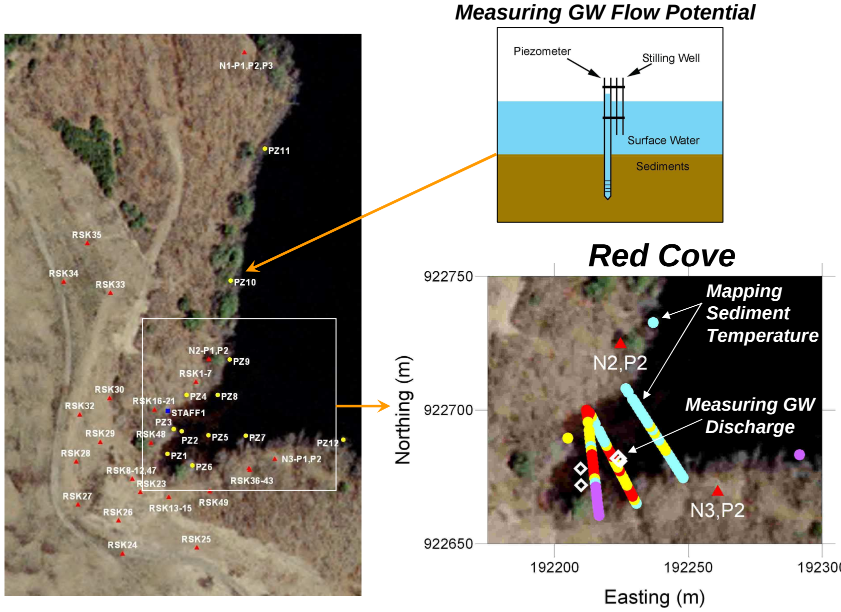
## Site Characterization
### *Monitoring Network*



## Site Characterization: ***Physical***

***Measuring GW Flow Potential***



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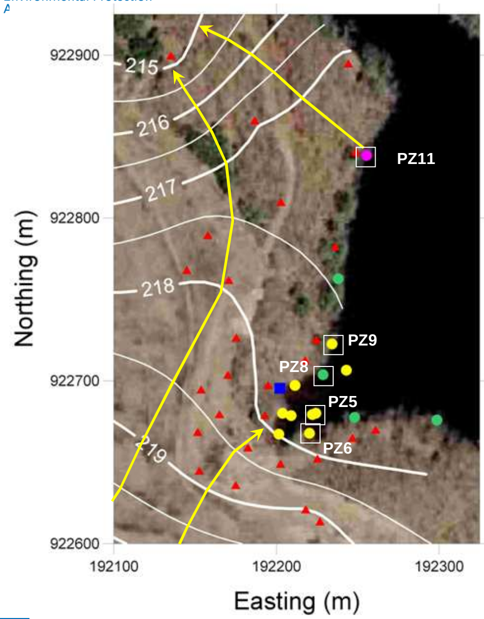
## Site Characterization: ***Physical***




▲ GW wells

*PZ Flow Potential*

- Up
- Negligible
- Down

| GW Flow Potential – Head Difference (ft) | | | | | |
|---|---|---|---|---|---|
| | 9/11/07 | 11/6/07 | 5/1/08 | 8/20/08 | 9/17/08 |
| PZ11 | 0.04 | -0.26 | NM | -0.10 | -0.08 |
| PZ9 | 0.04 | 0.02 | 0.05 | 0.03 | 0.03 |
| PZ8 | 0.00 | 0.03 | 0.02 | 0.02 | 0.01 |
| *PZ5* | 0.05 | 0.08 | 0.13 | 0.11 | 0.10 |
| *PZ6* | 0.11 | 0.14 | NM | NM | 0.17 |

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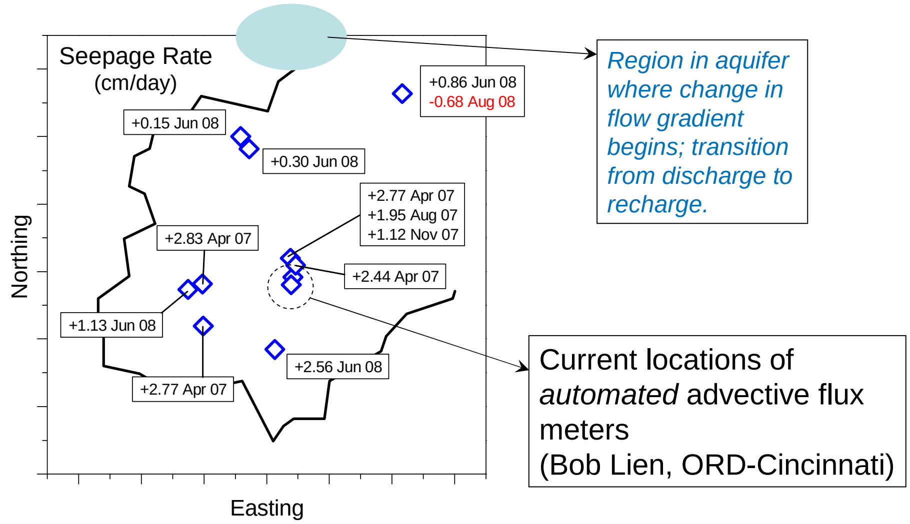
## Site Characterization: ***Physical***

Direct measurement of GW discharge into Red Cove

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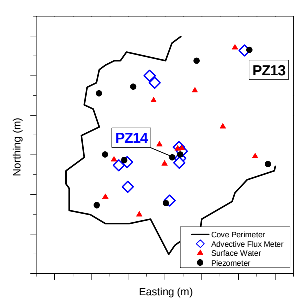
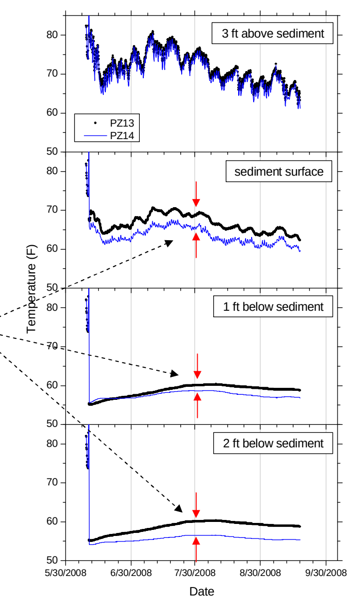
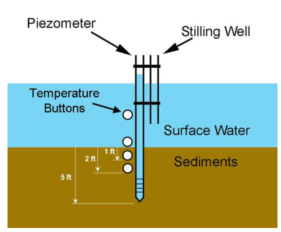
## Site Characterization: ***Physical***




Sediment temperature cooler at location of highest GW discharge.

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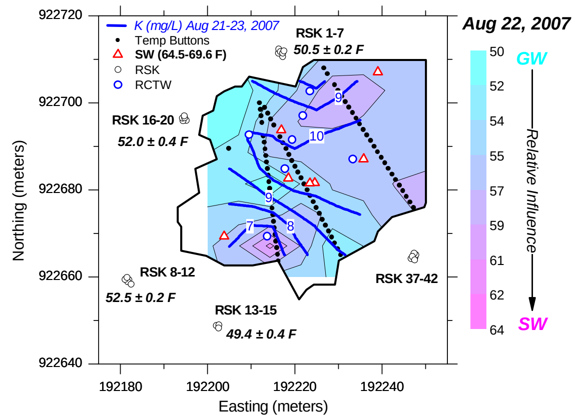
# Site Characterization: ***Physical***

*Signature for Influence of GW Discharge on Sediment Temperature*




- Sediment temperature at 1 foot depth measured continuously at “Temp Buttons” locations
- Cooler temperatures indicative of GW influence; warmer indicates less GW influence
- Distribution of cooler temperatures generally aligns with distribution of high K in shallow GW (5-10 ft below sediment)



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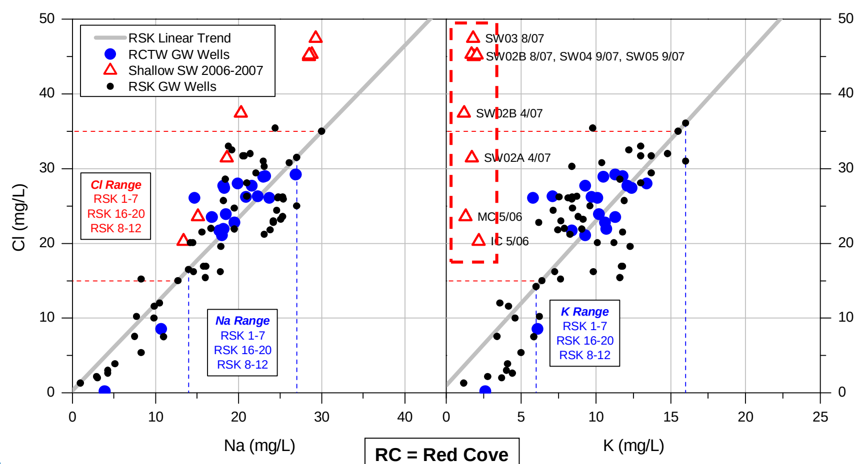
# Site Characterization: ***Chemistry***

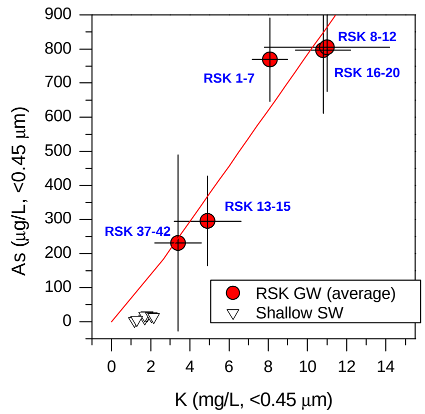
***Upgradient GW – RC GW – RC SW***

- Chloride (Cl) & sodium (Na) are not a reliable indicators of GW discharge
- Potassium in shallow SW relatively constant & low, providing a signature for SW influence in deep SW and sediment pore water



# Site Characterization: *Chemistry*
## *As in Upgradient GW – Shallow SW*

Highest As in upgradient GW wells associated with high K

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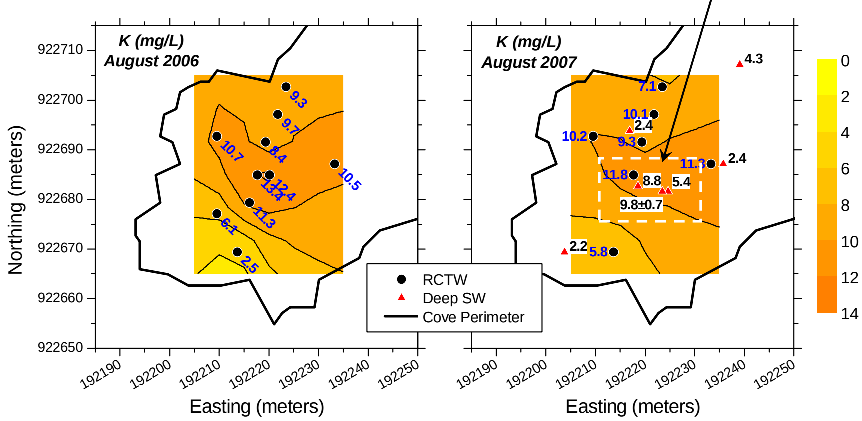
# Site Characterization: *Chemistry*
## *Potassium Signatures*

*Deep SW similar to shallow GW in RCTW wells at known discharge location*

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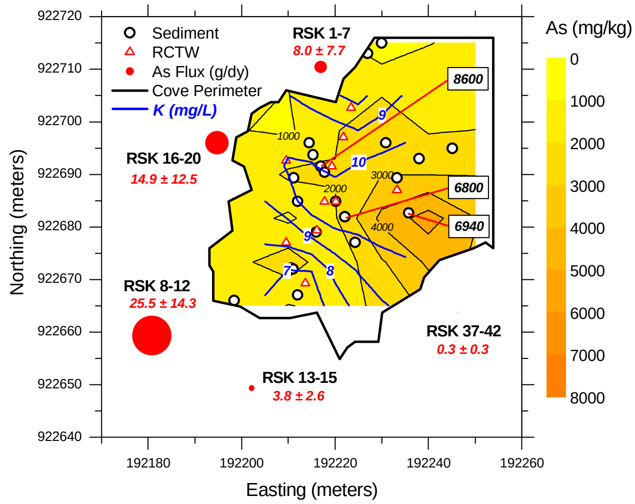
## Site Characterization: *Chemistry*

### *GW As Flux and Sediment As Content*

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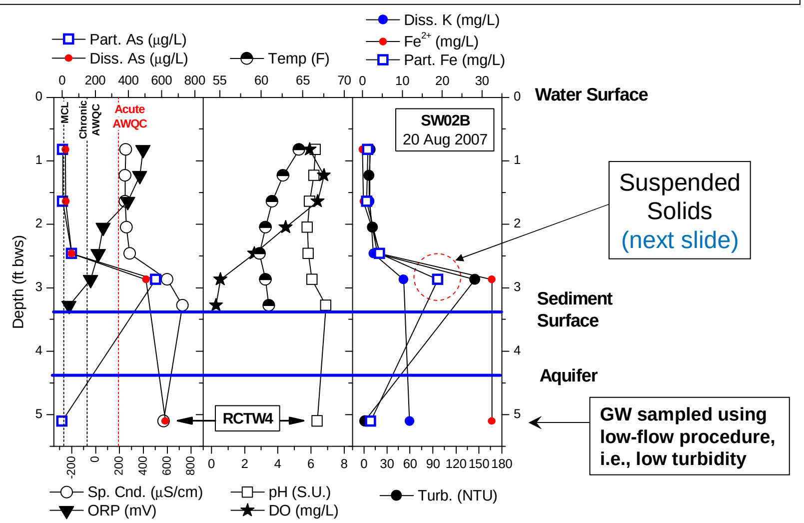
## Site Characterization: *Chemistry*

### *Cross-section through Red Cove*

- High particulate Fe in SW from GW discharge of $Fe^{2+}$
- Oxidation & precipitation of $Fe^{2+}$ captures As, but only after contact with DO in SW

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# Red Cove Surface Water

## *Suspended Solids Composition*

- Seepage meter installed adjacent to location SW02B (suspended solids)
- Orangish-red precipitates in SW are the mineral ferrihydrite
- Zones of high Fe precipitation tend to have low aquatic plant growth

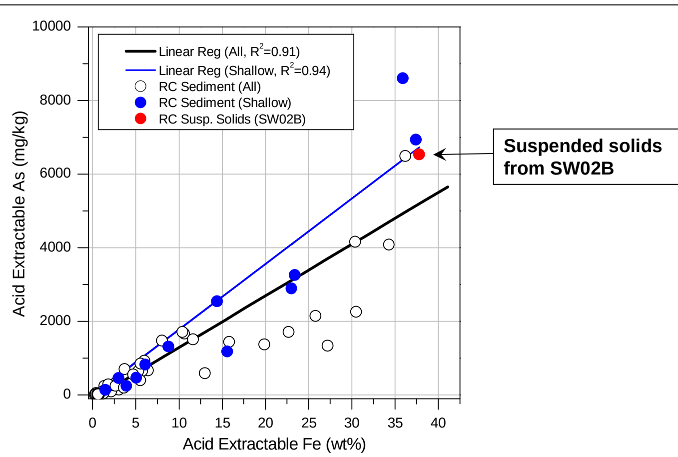
| Major Elements (weight %) | | Minor Elements (mg/kg) | |
|---|---|---|---|
| Fe | 37.81 | As | 6533 |
| Ca | 5.78 | Cr | ND |
| Na | 2.64 | Cu | 41 |
| K | 1.14 | Hg | ND |
| Si | 0.63 | Ni | 14 |
| Mg | 0.53 | Pb | 7 |
| Mn | 0.09 | Zn | 179 |




# Red Cove Surface Water

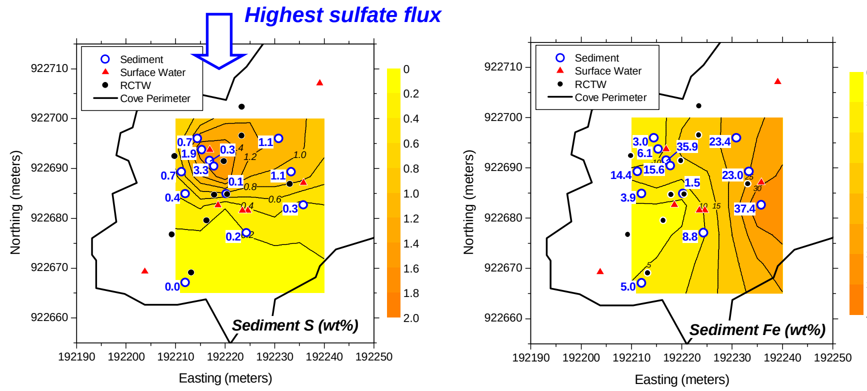
## *Relationship between Suspended Solids & Shallow Sediments*

- Significant correlation between Fe and As in sediments
- Concentration of As in suspended solids from Fe precipitation consistent with most elevated concentrations in shallow sediments



# Red Cove Sediments

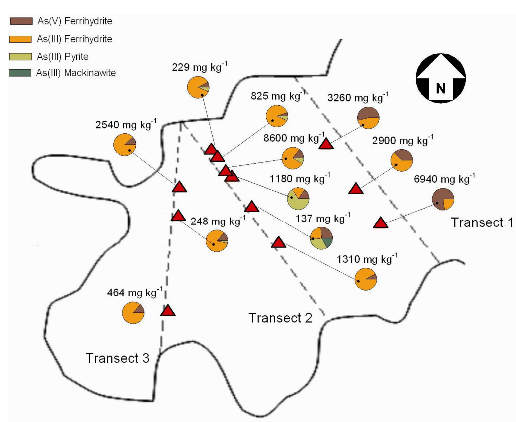
- Spatial heterogeneity in Fe and S distribution in sediment
- S generally higher near location of plume discharge
- Fe generally higher further out in cove where more oxidizing






# Red Cove Sediments

- Sediment As associated with Fe-bearing minerals (mostly Fe oxides)
- Predominantly As(III) in western & central transect; As(V) more significant in eastern transect
- High As concentrations and greater As(V) in eastern transect due to less GW discharge and more oxidizing condition (ferrihydrite more stable)



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# Conceptual Site Model

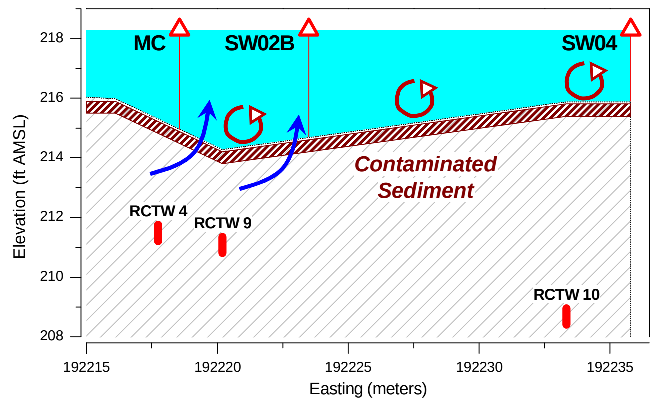
***Red Cove Arsenic***

**Direct**

Contaminated GW discharge introduces high As & Fe into Red Cove

**Recycled**

Fe-oxide rich shallow sediment layer produced from $Fe^{2+}$ precipitation & settling, but As-laden material is not stable due to reducing conditions



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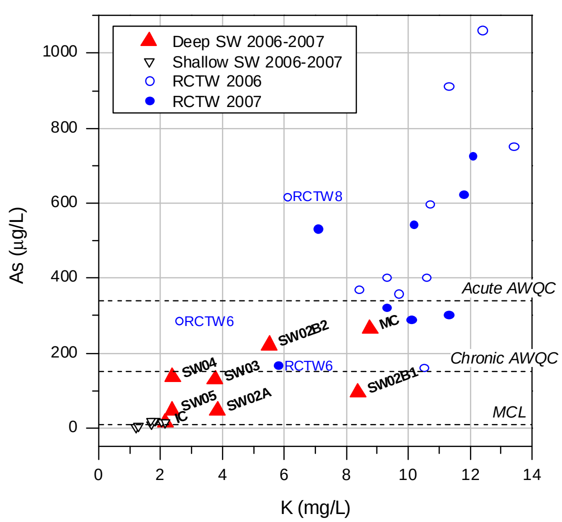
# Surface Water Arsenic Concentrations within Red Cove




- SW02 & MC in known GW discharge area
- SW03 & SW04 in areas with less significant GW discharge (based on sediment temperature measurements)
- Existing contaminated sediments contribute As to overlying SW

## Fort Devens - Existing Data Gaps

1) Improved delineation of As plume discharging into Red Cove
   - Acquisition of additional GW chemistry data to delineate As distribution throughout saturated overburden thickness in central portion of Shepley's Hill Landfill
   - Better targeting for potential remedy to increase efficiency and reduce cost
2) Exposure assessment within cove to characterize risk
   - Differentiate influence of direct GW discharge vs. sediment exposure (*currently in development*)
3) Acquisition of additional depth-resolved SW data to more completely map out the spatial distribution of redox conditions and dissolved contaminants within the water column

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## Acknowledgements

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