Comprehensive GW/SW Evaluations Drive CSM Evolution from *Denial* to *Remedial Success*

Red Cove Case Study

Devens, MA

US EPA Region 10 GW-SW Workshop

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Seattle, Washington

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Technical Support Hydrogeologist

EPA Region 1

ACKNOWLEDGEMENTS (*MOST OF THEM*)

US EPA REGION 1 AND BCT SITE TEAM

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ORD

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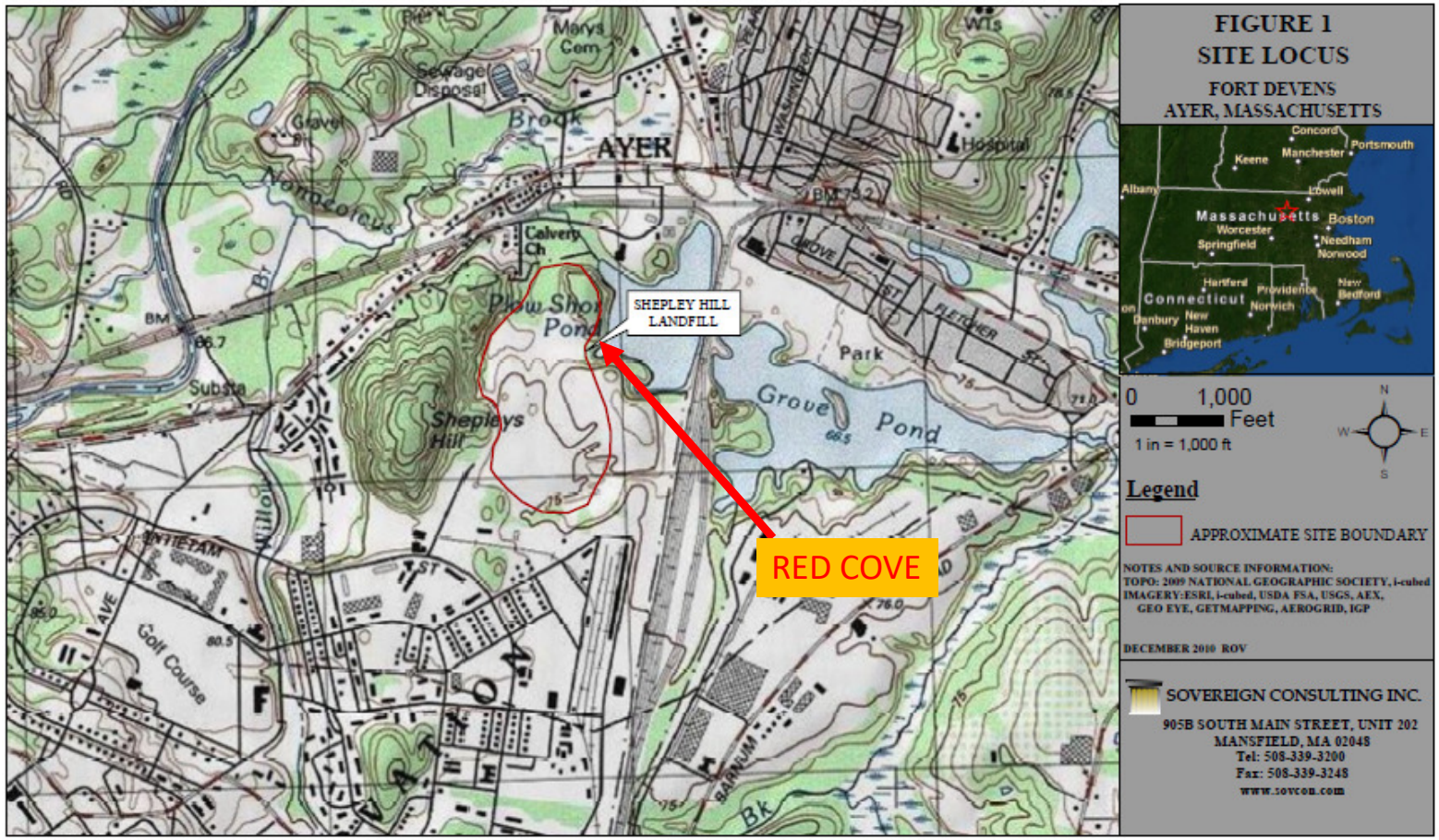
- BOB LIEN
- *AND OTHERS*

DISCLAIMER

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.

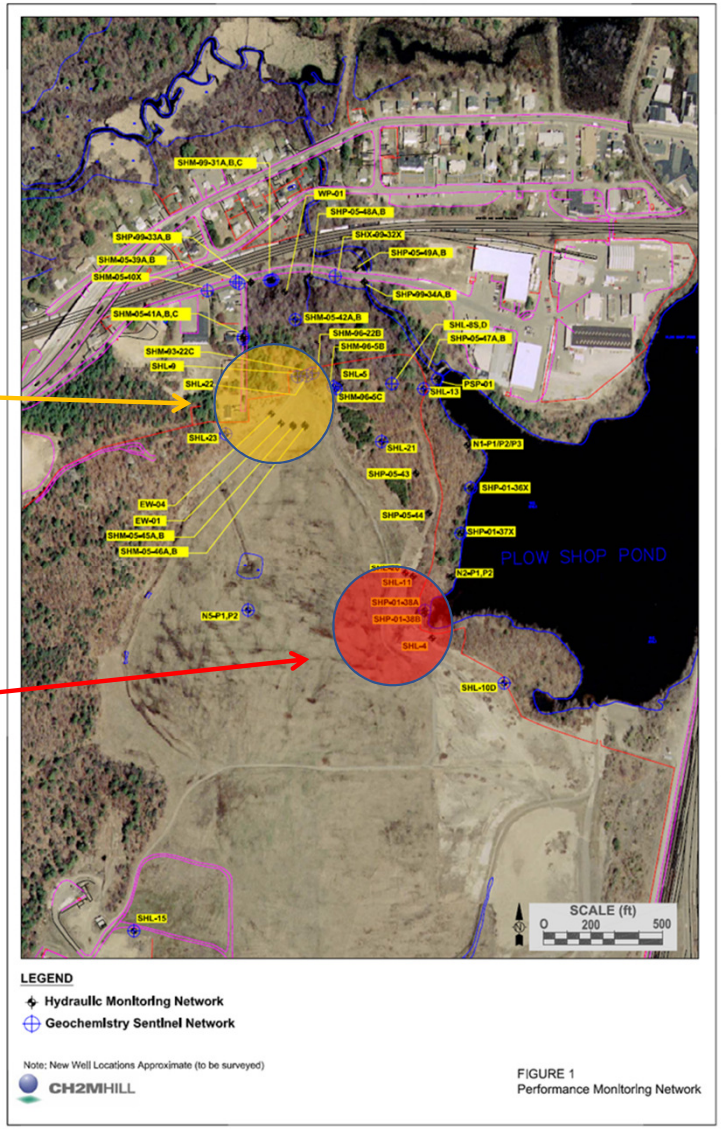
Case Study Devens, MA – *Complex landfill site is a "containment in progress"……*



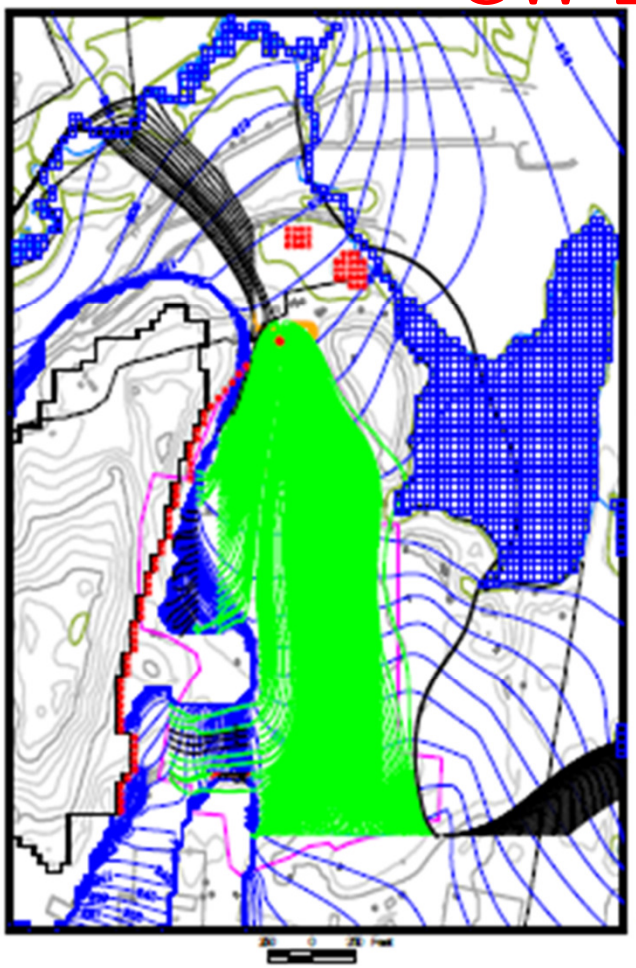
Site Chronology - circa 2005

- 2005 Pump and Treat with Monitoring Initiated at N end of Landfill

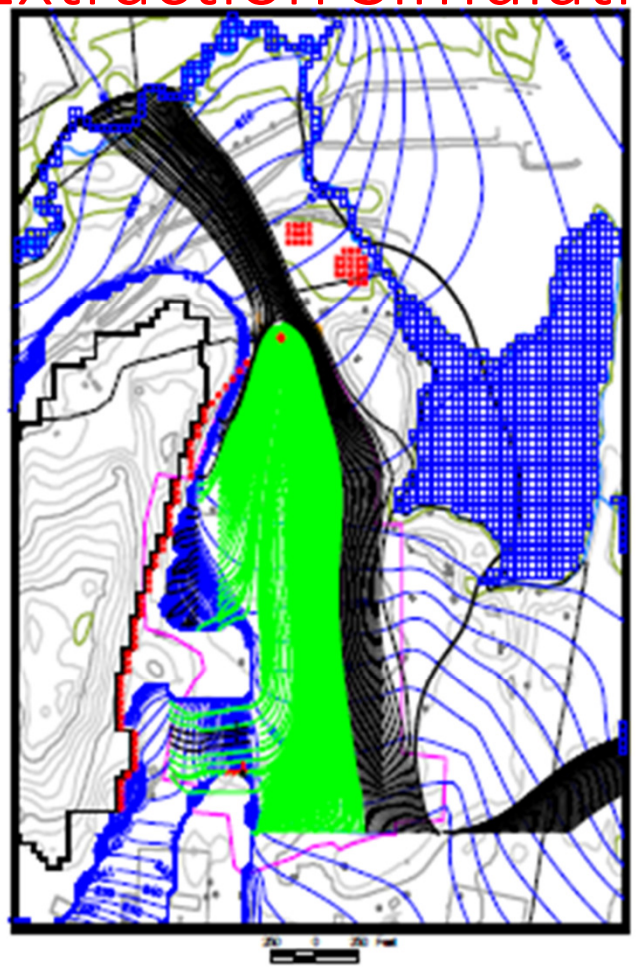
- Ongoing technical Debate:
  - Will Pump and Treat address GW discharge at Red Cove ?!
  - CSM (arsenic F/T)
  - Effectiveness of Capture
  - Landfill inputs to “Red Cove”



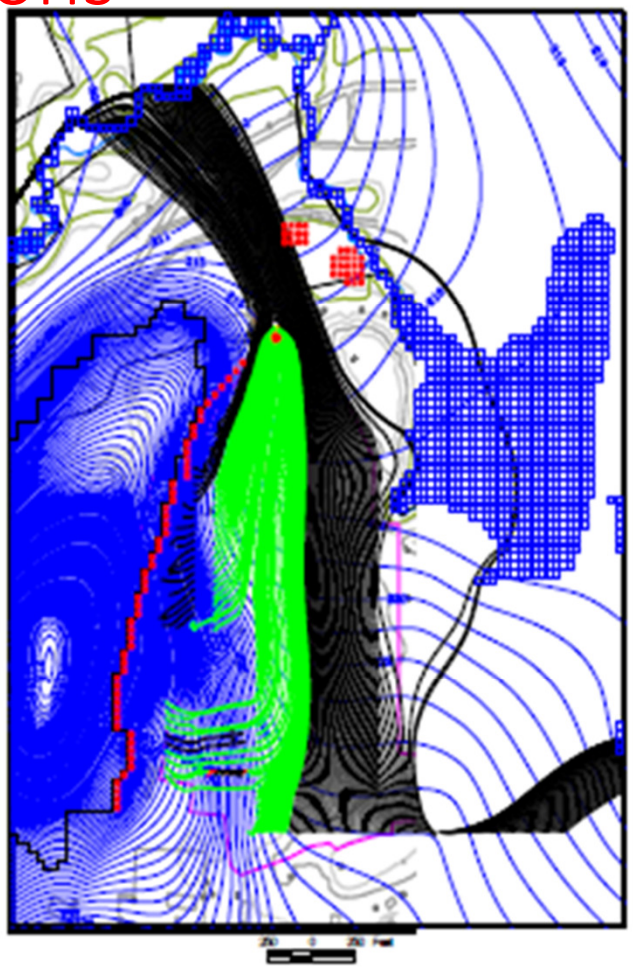
GW Extraction Simulations



Run 401 - EW-01 Pumping at 50 GPM

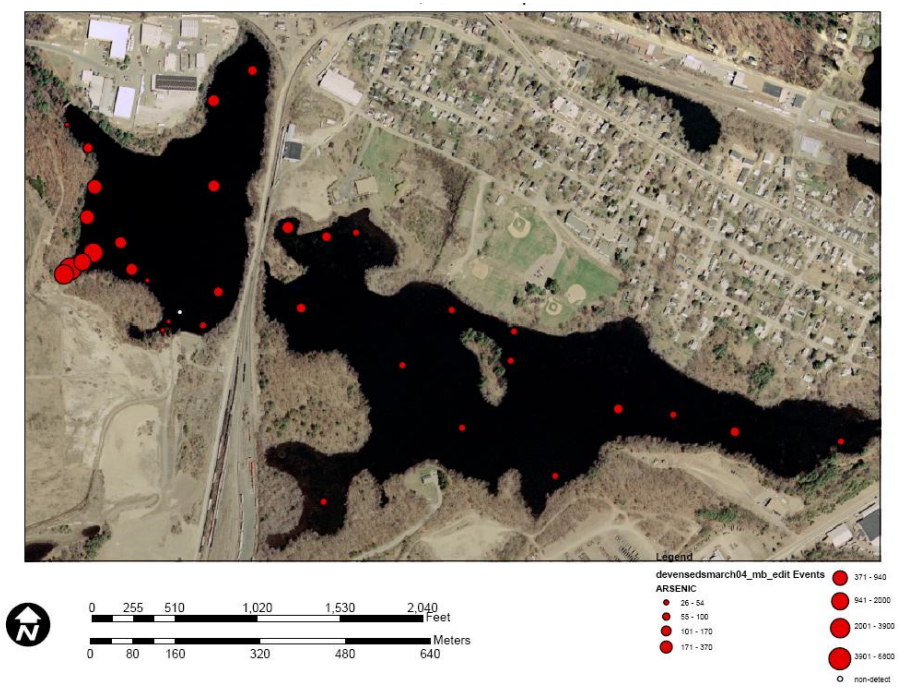


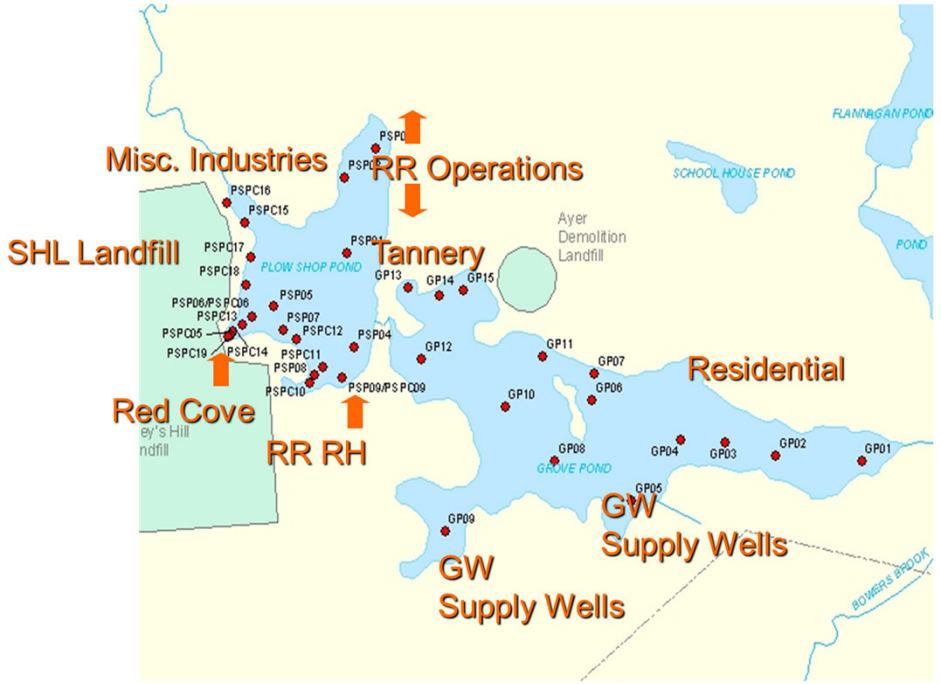
Run 402 - EW-01 Pumping at 40 GPM



Run 403 - EW-01 Pumping at 30 GPM

Sediment Arsenic Concentrations in Grove and Plow Shop Ponds





Working Hypotheses

- Arsenic in pond sediment strongly correlated spatially with Red Cove
- Landfill generates reducing GW conditions
- Reduced Ground Water from SHL discharges to Red Cove (oxidizing environment)
- Arsenic in discharging ground water is deposited into Red Cove Sediments (oxidizing)
- Arsenic from a combination of waste material and naturally-occurring arsenic present in soil and bedrock

Red Cove Investigation Technical Objectives

- Detailed Delineation of COCs in GW, SW, and Sediment
- Focus on Arsenic
- Test Hypotheses for Arsenic Transport and inter-media transport Mechanisms
- Develop Preliminary Conceptual Site Model (CSM) for GW-SW-Sediment Interactions
- Develop Initial Estimates of Contaminant flux from GW to SW and Sediment

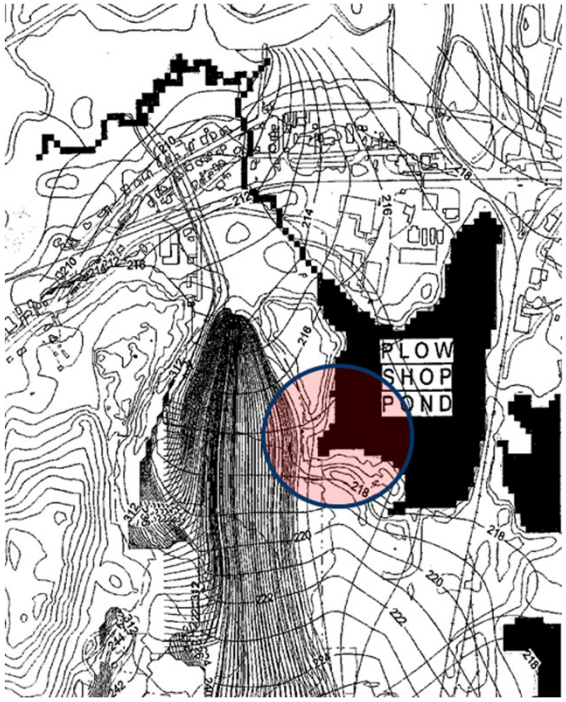
Red Cove Focus Area – GW/SW Investigation Components, Media and Methods

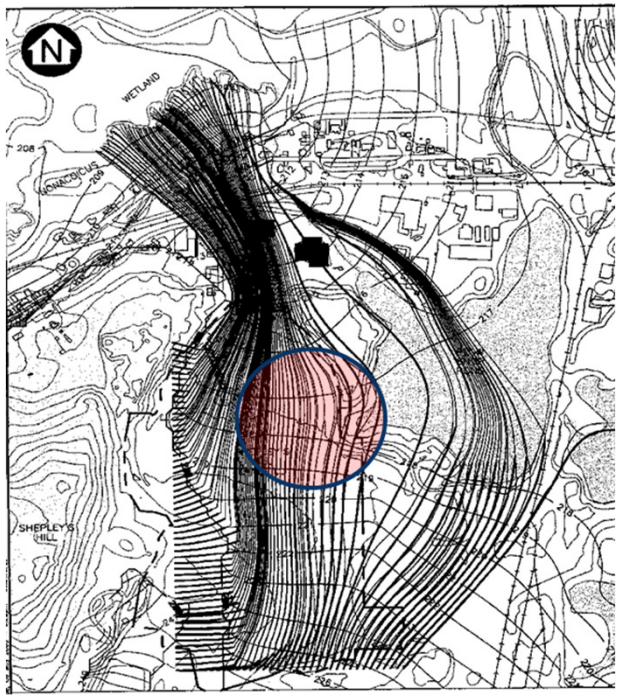
INVESTIGATION COMPONENTS	MEDIA	METHODS
FLOW	GROUNDWATER (GW) SURFACE WATER (SW)	WATER LEVEL MEASUREMENTS IN WELLS SW LEVEL MEASUREMENT CONTOUR MAPPING
TEMPERATURE	GW/SW/POREWATER/ SEDIMENT	HAND-HELD TEMPERATURE PROBE GW TEMP FROM IN-LINE PROBE
CHEMISTRY	GW/SW/SED/POREWATER	LABORATORY ANALYSIS OF FIELD-COLLECTED GW/SW/SED AND POREWATER SAMPLES
TOXICITY	SW/SEDIMENT/BENTHOS	LAB TOXICITY TESTING FOR BENTHIC ORGANISM SURVIVAL AND GROWTH
ARSENIC FLUX	GROUNDWATER FLUX TO POREWATER/SED/SW	CALCULATIONS USING SITE-SPECIFIC DATA

THE FLOW QUESTION: *DOES LANDFILL GW DISCHARGE TO RED COVE* ??

- DOES THIS MATTER?
- MODEL VERSUS REALITY
- HOW WILL THIS CHANGE WITH PUMPING AT NORTH END OF THE LANDFILL
- WHAT DENSITY OF GW WATER LEVEL DATA IS NEEDED TO MAKE A DEFENSIBLE CONCLUSION?
- TIME SERIES WATER LEVEL DATA
- TEMPERATURE DATA AT GW/SW INTERFACE

SHEPLEY'S HILL LANDFILL
MODELED PARTICLE TRACKS (ca. 2002)
Pumping vs. non-pumping conditions

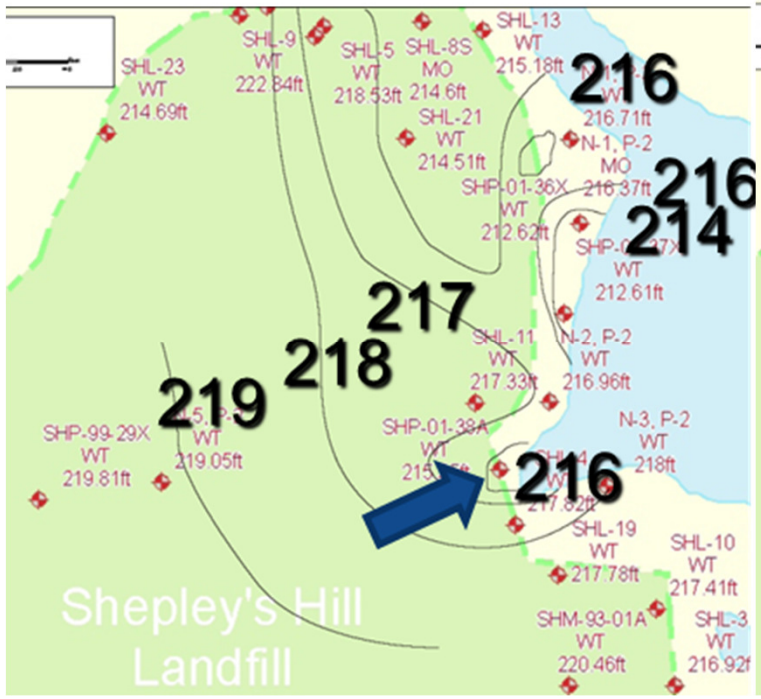




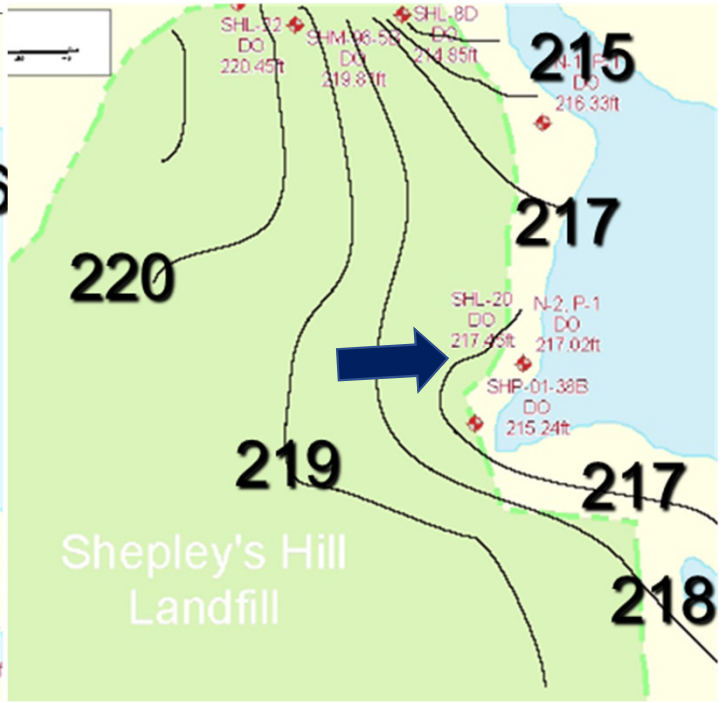
Measured Water Levels and GW Flow Patterns - November 2004

- Consistent Flow Patterns
  - Eastward flow
  - All Hydrogeologic units
  - All times
- *Modeled* particle tracks NOT validated
- Landfill GW Discharges to Red Cove

Water Table



Deep Overburden



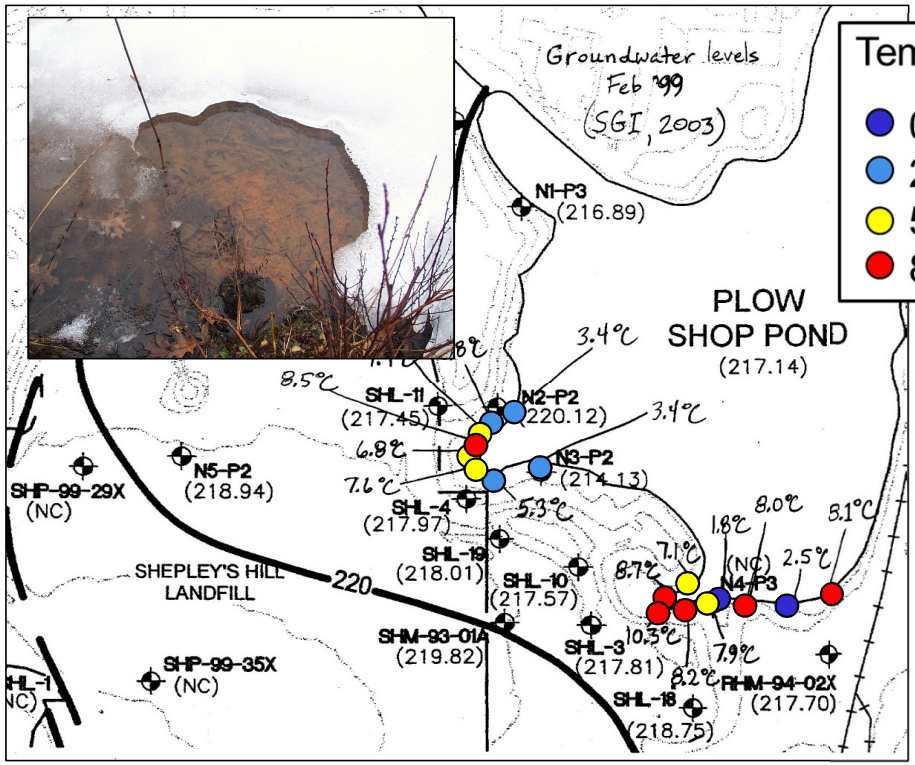
- Thermocouple mounted at tip of 5-ft stainless steel rod
- Insert into sediment up to 60 inches
- Relies on GW/SW temp contrast
- *LOW COST $*

Shoreline Pond Bottom Temperature Survey March 2004

Temperature Survey Results – March 2004

Strongly Support Ongoing GW Discharge to Red Cove

- GW Temperatures warmer than SW
- Ice melted in embayment
- Convergent GW Flow/Discharge)
- Highest GW flux in embayment
- Little open water North of Red Cove

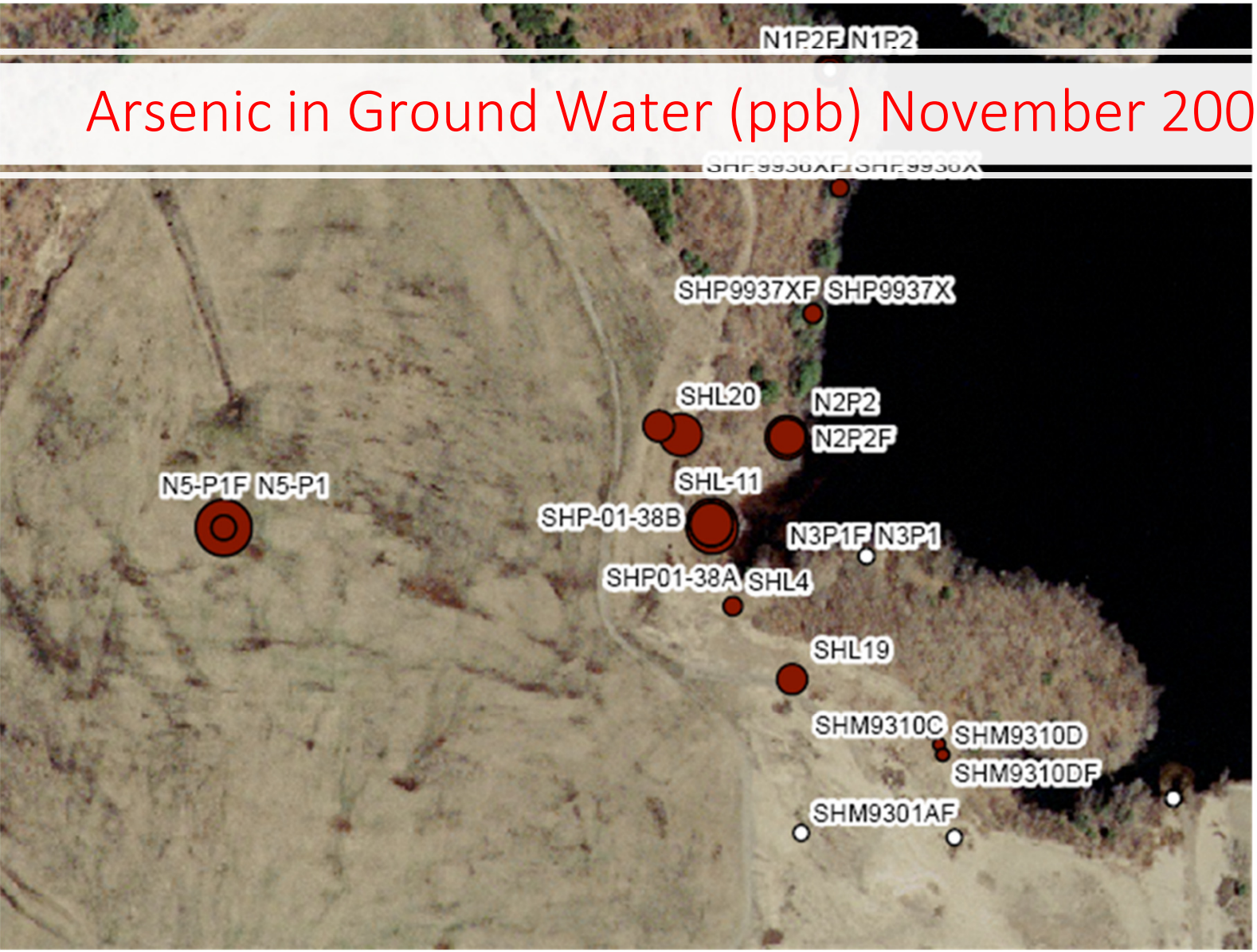


Water Quality Data Collection

- Groundwater Sampling
  - Monitoring well sampling (Army, EPA)
  - Shoreline vertical profiling of GW (EPA)
  - Geoprobe Systems
- Pore Water Sampling:
  - Shoreline and beneath Red Cove (EPA)
  - Push point samplers (MHE products)
- Surface water samples

Vertical Profiling of GW Quality Using Geoprobe - EPA Region 1

Arsenic in Ground Water (ppb) November 2004



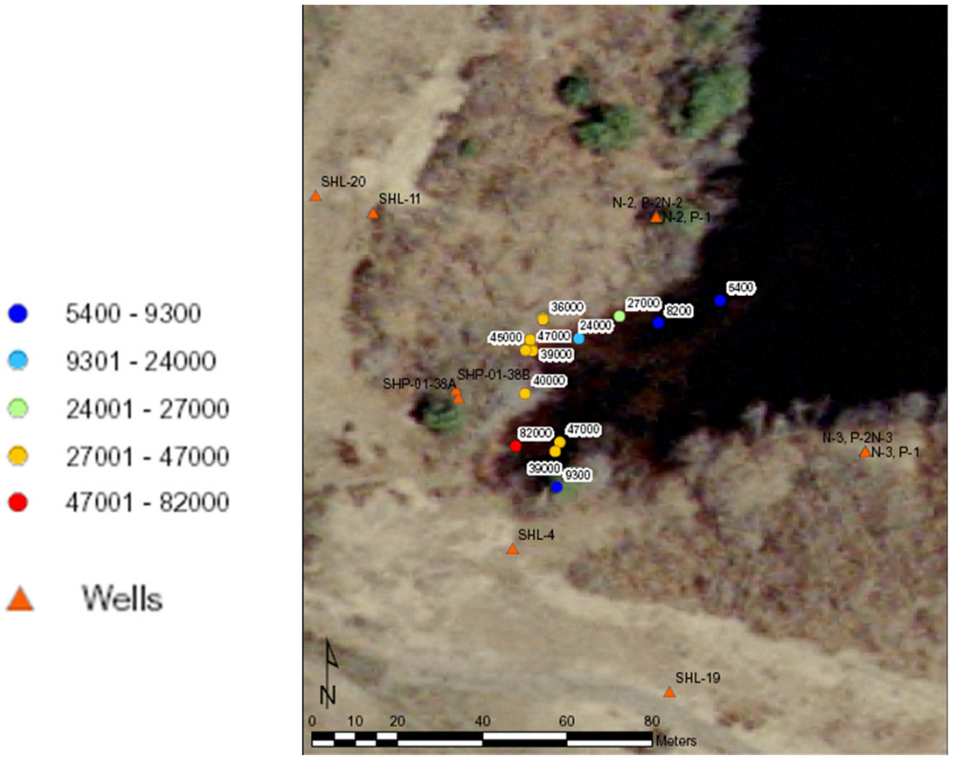
Legend

ARSENIC

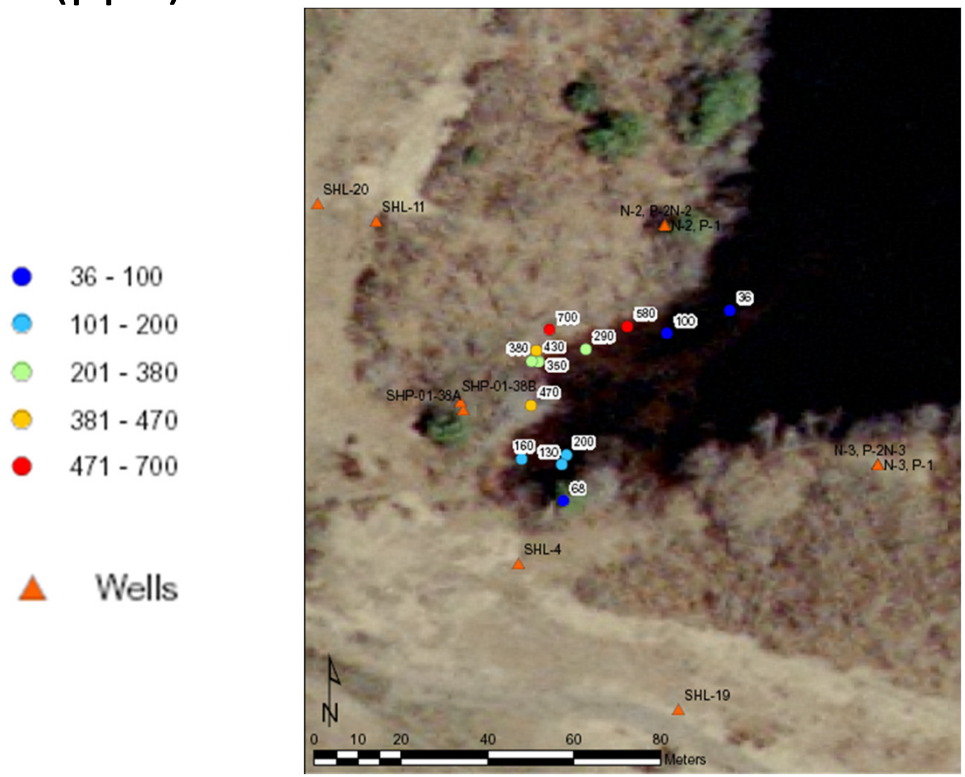
- 2.1 - 7.5
- 7.6 - 17.0
- 17.1 - 36.0
- 36.1 - 130.0
- 130.1 - 330.0
- 330.1 - 540.0
- 540.1 - 650.0
- 650.1 - 1600.0
- Arsenic = non-detect

Pore Water Sampling Results

- Red Cove Pore Water Iron, (ppb) 1-3 ft



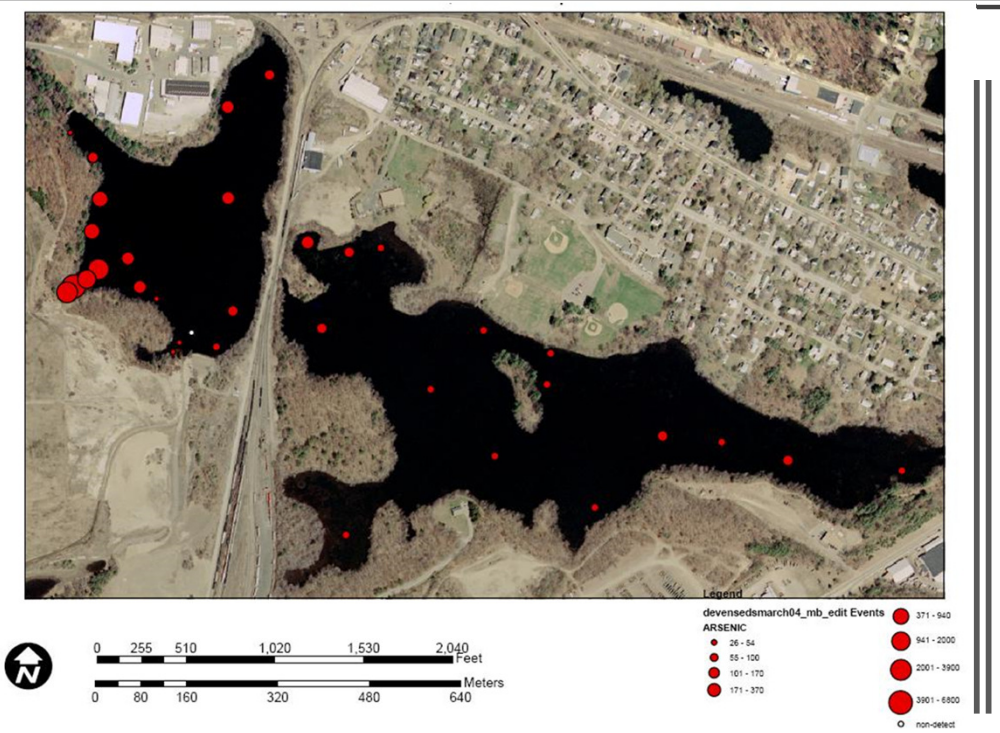
- Red Cove Pore Water Arsenic, (ppb)1-3 ft

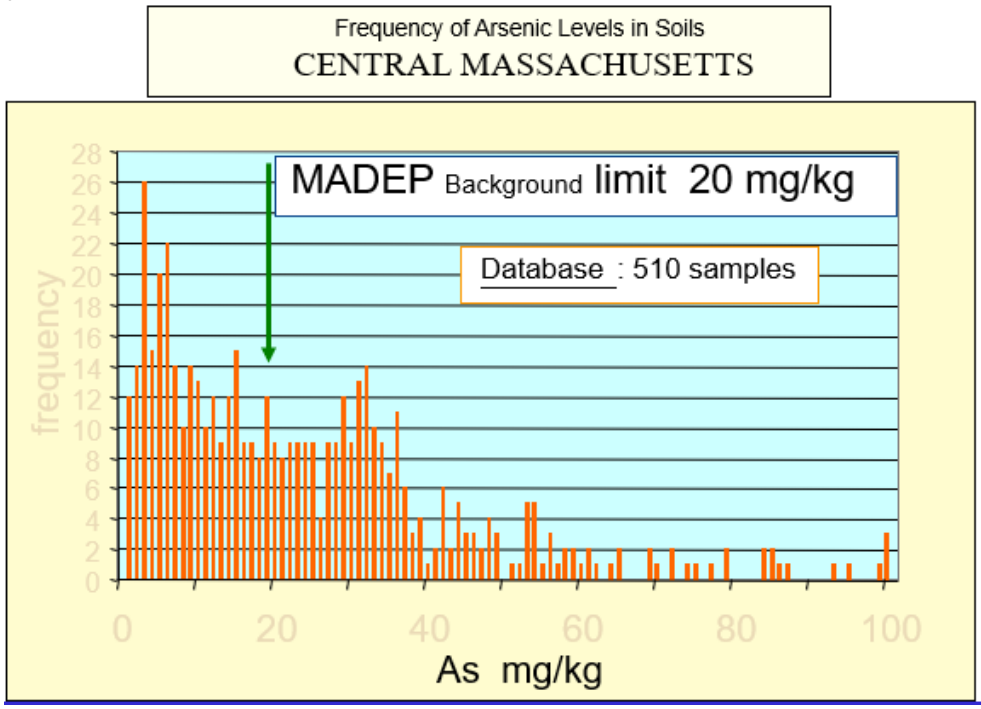


Preliminary Estimate of Arsenic Flux From GW to SW and Sediments at Red Cove

- **Total Mass flux to cove ~** ***17 Kg per year***
- Assumptions:
- GW Approaches Cove through cross sectional area of ~ 11,000 ft^2 (A)
- GW flux (Darcy's Law) (q) = 0.36 ft/d
- Total vol. flow rate to cove (Q) = q x A = 3800 ft^3/d
- Geometric Mean As Conc. In GW (ċ)= 430 ppb
- J = Q x ċ = $4.7x10^4$ mg/day = *17 Kg per year*

Relative Sediment Arsenic Concentrations in Grove and Plow Shop Ponds

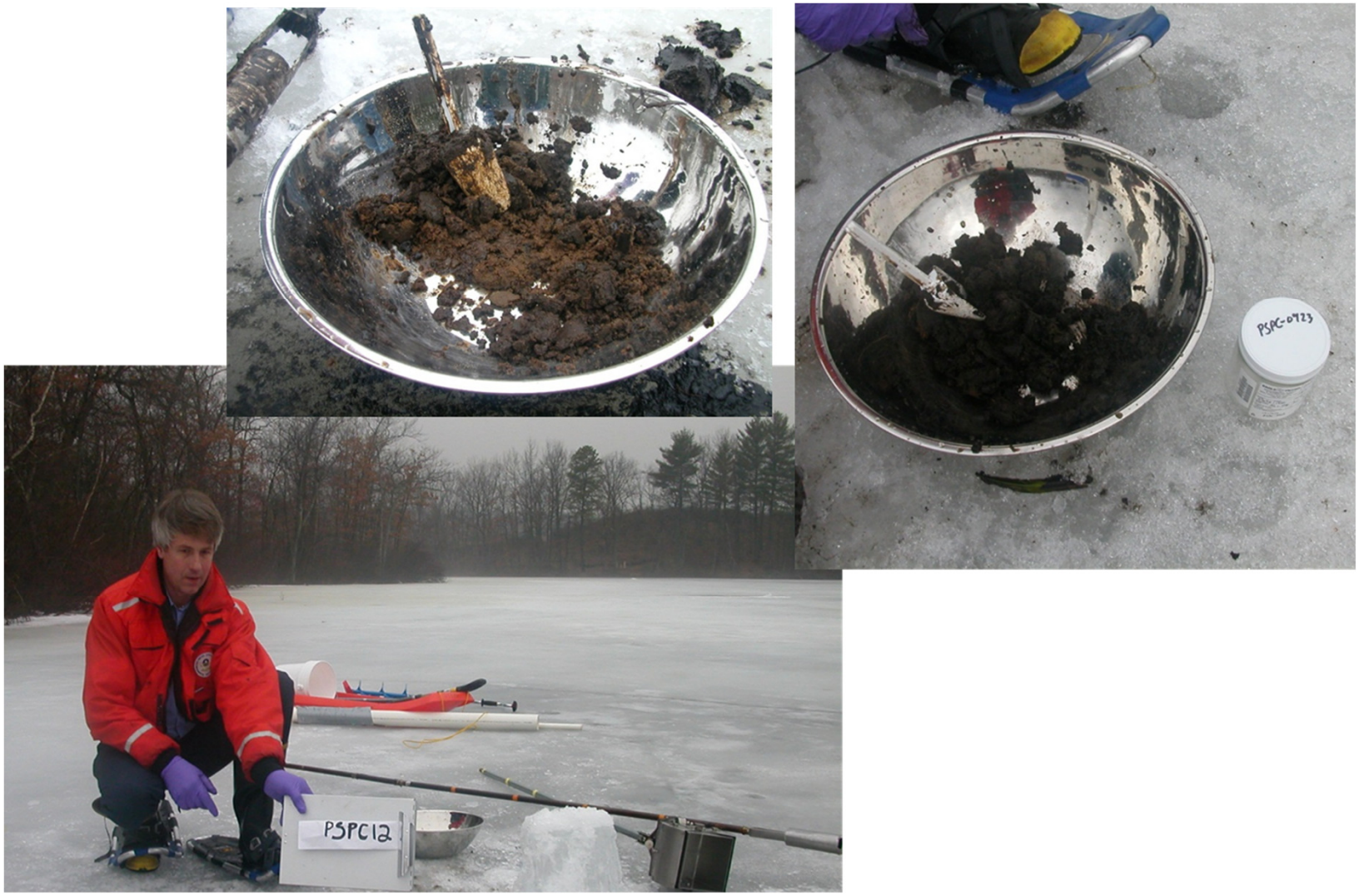




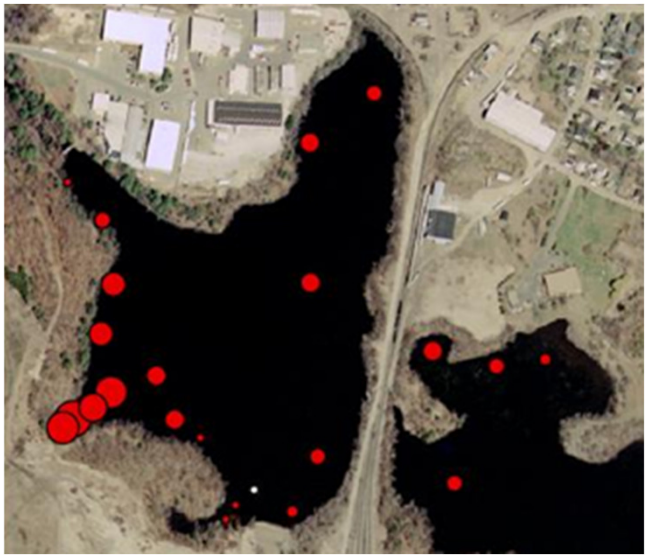
Sediment Data Collection

- **Surface Sediment Chemistry (0-1 ft) Using Eckman Dredge**
  - 15 in Grove Pond
  - 19 in Plow Shop Pond (8 were in Red Cove)
  - 1 in Flanagan Pond
  - 1 in Sandy Pond)
- **Sediment Profiles by Coring (0-5 feet)**
  - 5 Profiles in Red Cove Area

Sediment Data Collection

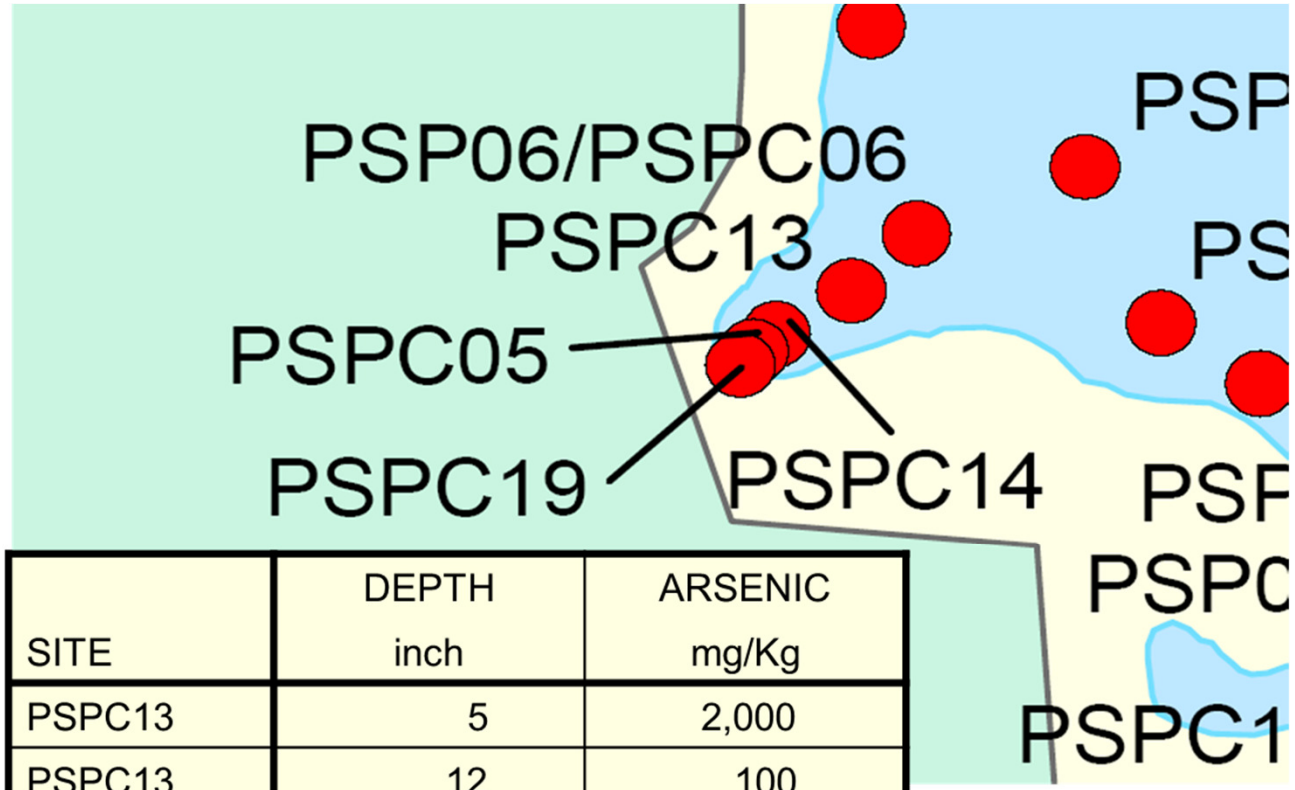


UNITS: mg/Kg



devensedsmarch04_mb_edit Events
ARSENIC
26 - 54
55 - 100
101 - 170
171 - 370
371 - 940
941 - 2000
2001 - 3900
3901 - 6800
non-detect

Arsenic in Surface Sediment

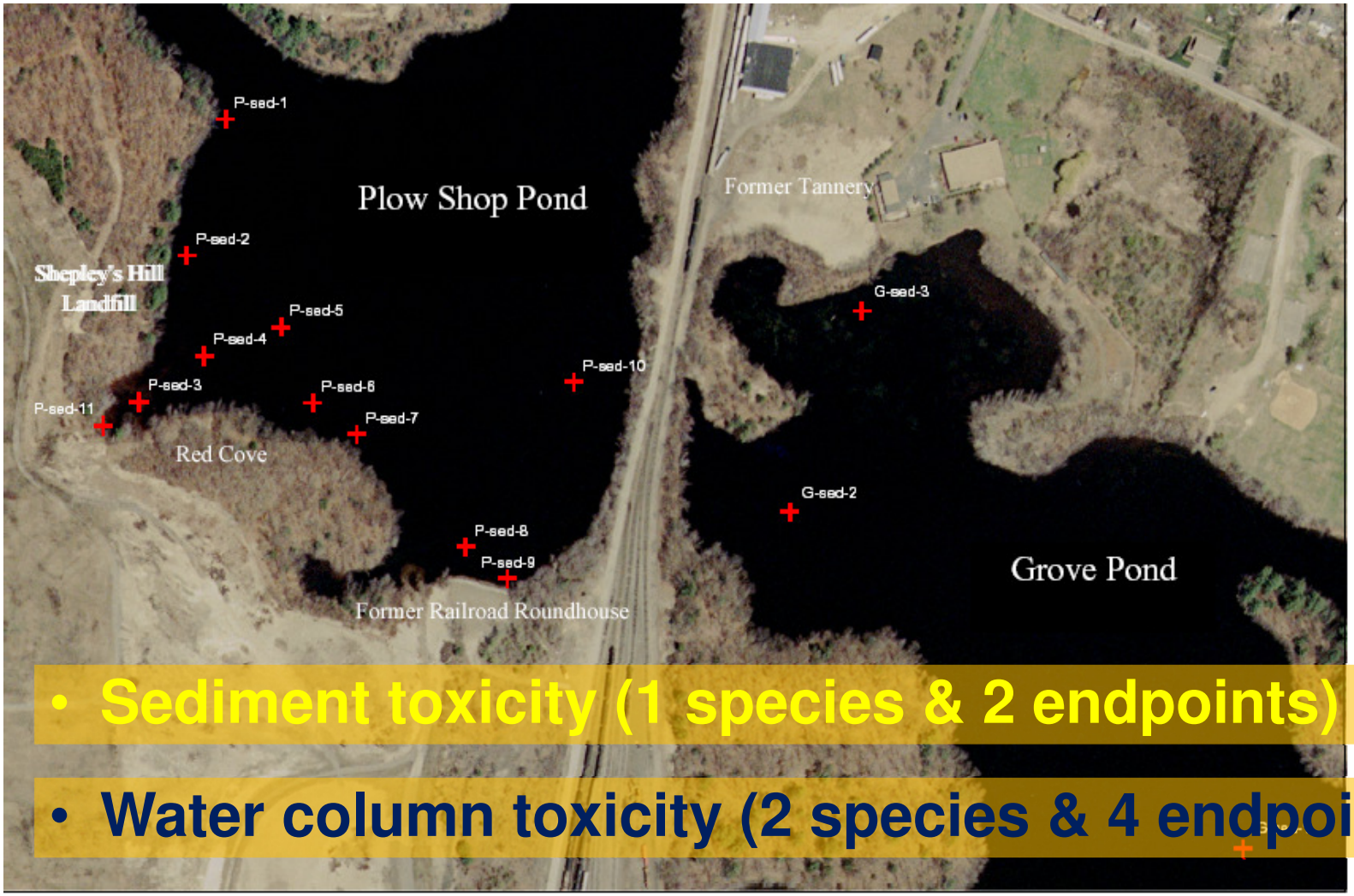


SITE	DEPTH inch	ARSENIC mg/Kg
PSPC13	5	2,000
PSPC13	12	100
PSPC13	23	29
PSPC14	5	6,800
PSPC14	12	820
PSPC14	23	510

Arsenic Concentration vs Sediment Depth

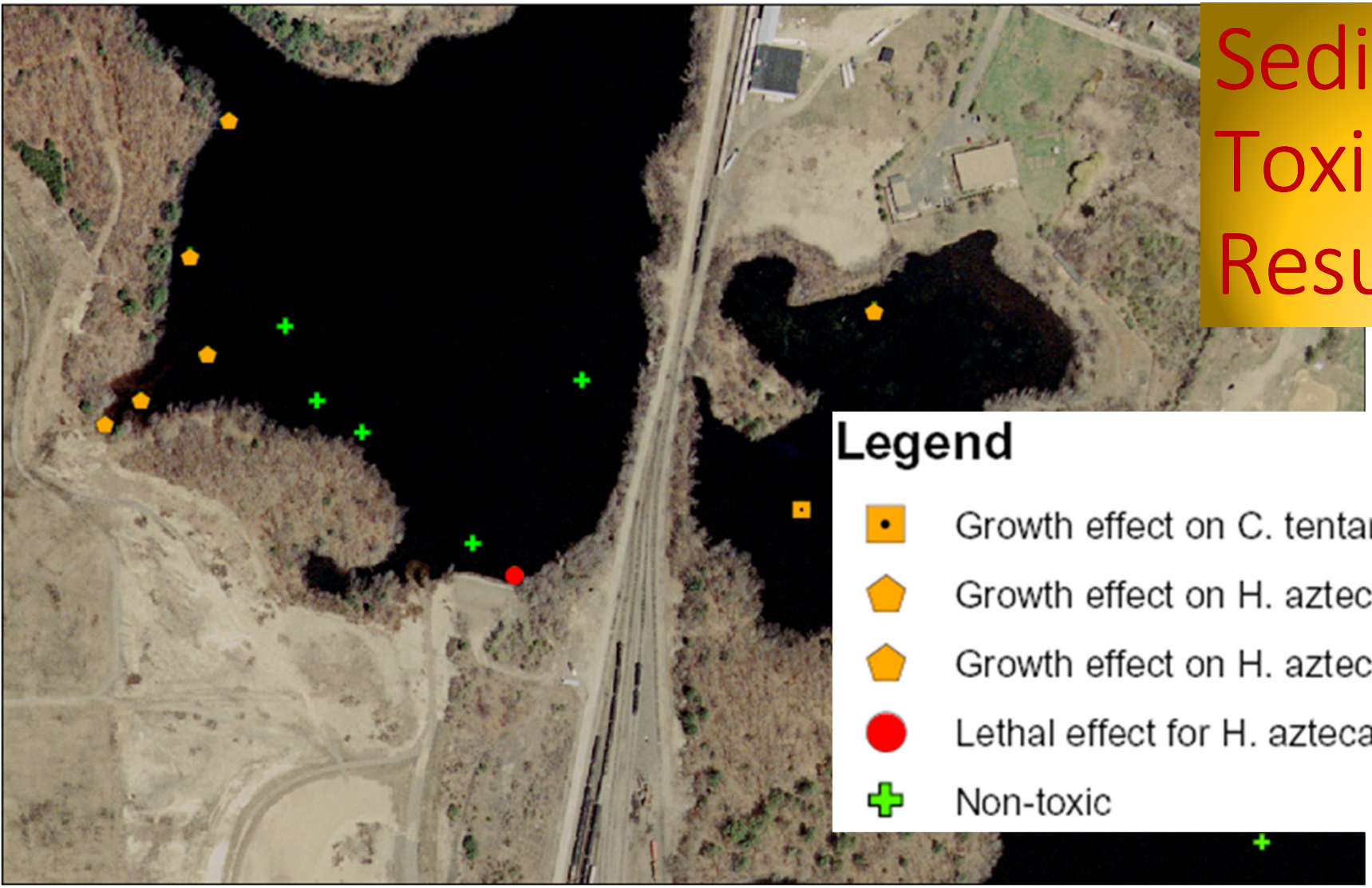
Pond Bottom Sediment Cores

Sediment Toxicity Stations



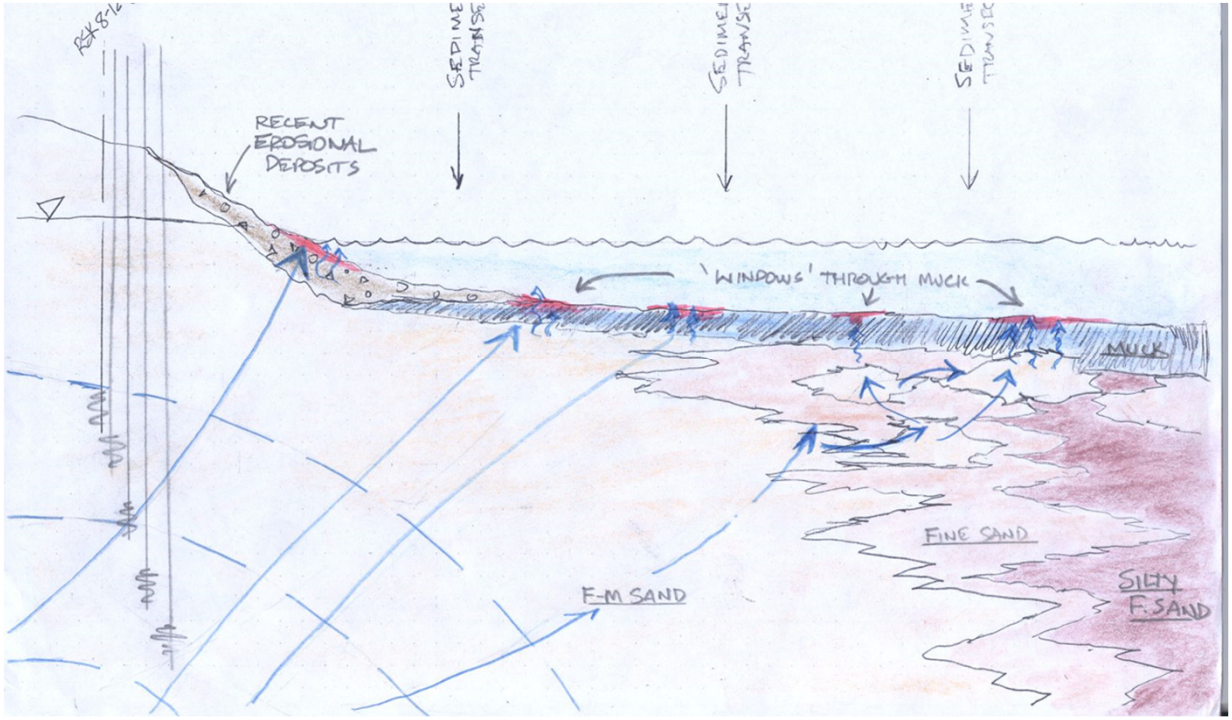
- **Sediment toxicity (1 species & 2 endpoints)**
- **Water column toxicity (2 species & 4 endpoints)**

Sediment Toxicity Results



Toxicity Testing Results

- Sediment toxicity testing indicates toxicity associated with known source areas
- Railroad Roundhouse sediments acutely toxic to both species
- Growth effects associated with Tannery Cove and Red Cove/Shepley's Hill Landfill
- Toxicity Data incorporated into final Ecological Risk Assessment and provided to U.S. Army for further action



Updated Conceptual Model

- **Groundwater**
  - Low ORP, high dissolved Fe and As
  - Discharges to pond
- **Pore water**
  - Fe and As decrease approaching sediment / SW interface
- **Sediment**
  - Fe and As accumulate near interface
- **Surface water**
  - Fe and As very low
- **Ecological impact**
  - Sediment toxicity

CSM Consensus Remains Elusive...

- Despite overwhelming evidence...
- *Site Owner Still Not Convinced ???!!!*
- CSM consensus remains elusive...

- No Momentum to address Red Cove Impacts....
- *When All Else Fails....*

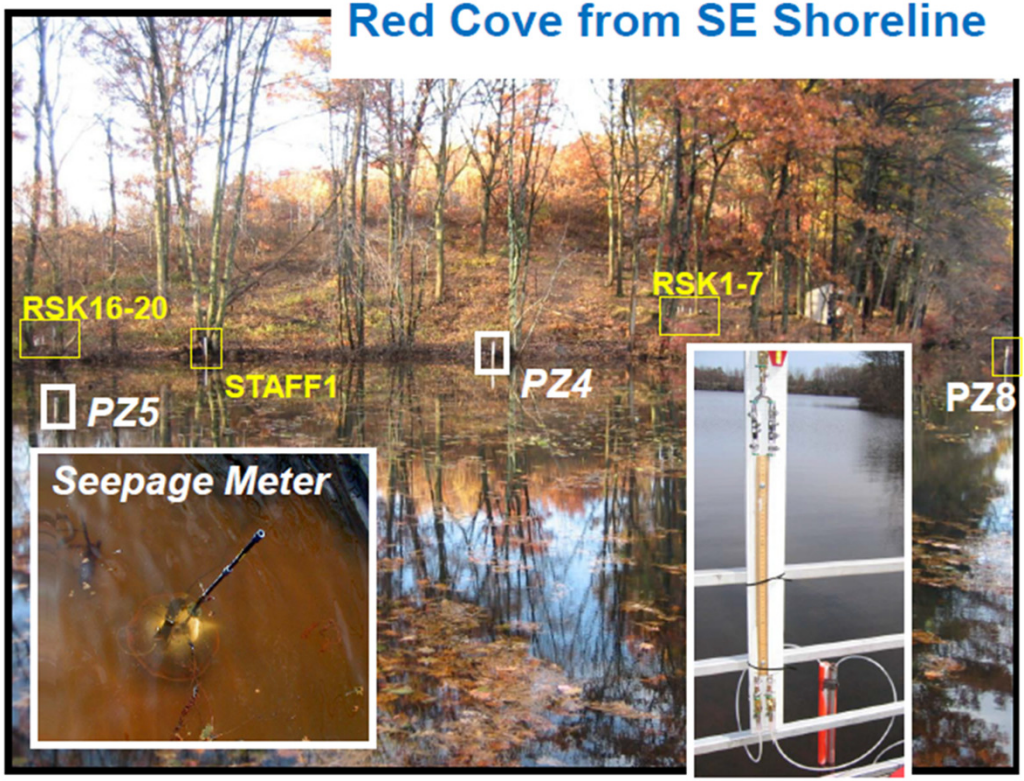
- *WHO YA GONNA CALL !!!!*
- **ENTER EPA ORD !**

ORD Follow-on Investigation Goals

- Document all aspects of As Fate and Transport in Red Cove
  - Hydraulics
  - Chemistry
  - Ecological
- Comprehensive GW/Aquifer Assessment
  - Nested piezometers installed at 5-ft vertical intervals
  - Slug testing
  - Continuous water level recorders/ transducers
  - High resolution GW Monitoring relative to Red Cove and SHL Pump and Treat
- Pond – Aquifer Interactions evaluated at detailed scale of investigation
- Further Evaluation of Ecological Impacts

EPA
United States
Environmental Protection
Agency

Red Cove from SE Shoreline

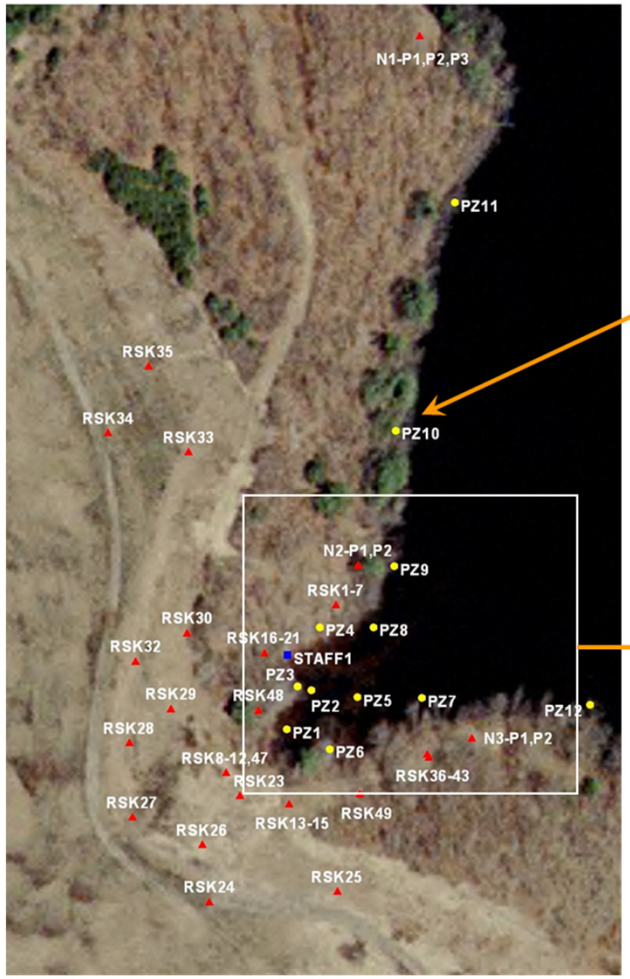


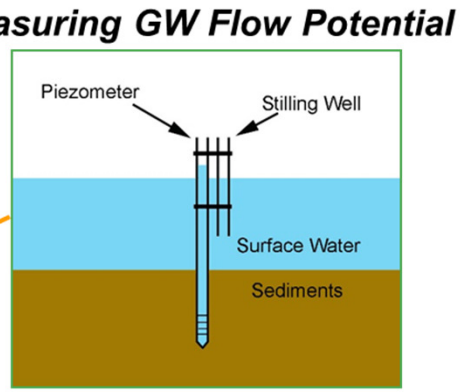
Pond Piezometer

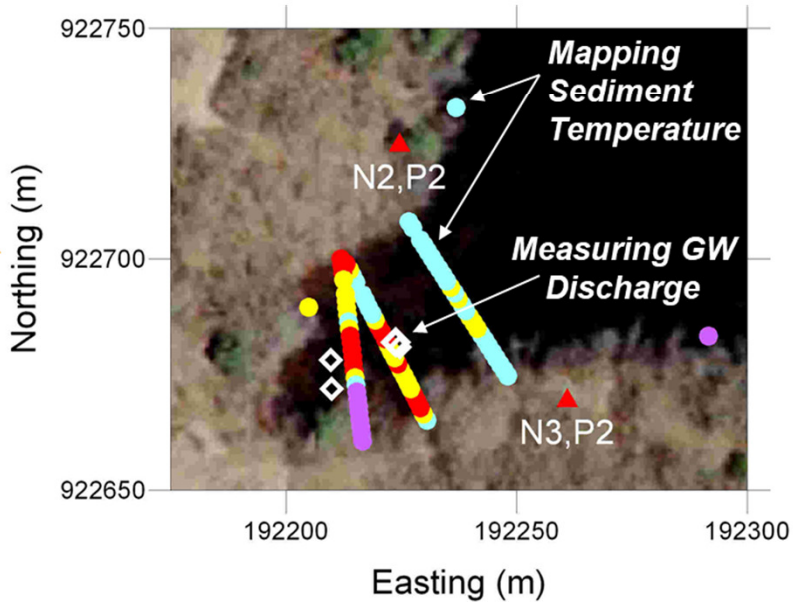
Office of Research and Development
National Risk Management Research Laboratory

Additional Monitoring Relative to Red Cove and SHL Pump and Treat

Additional Groundwater Control Points

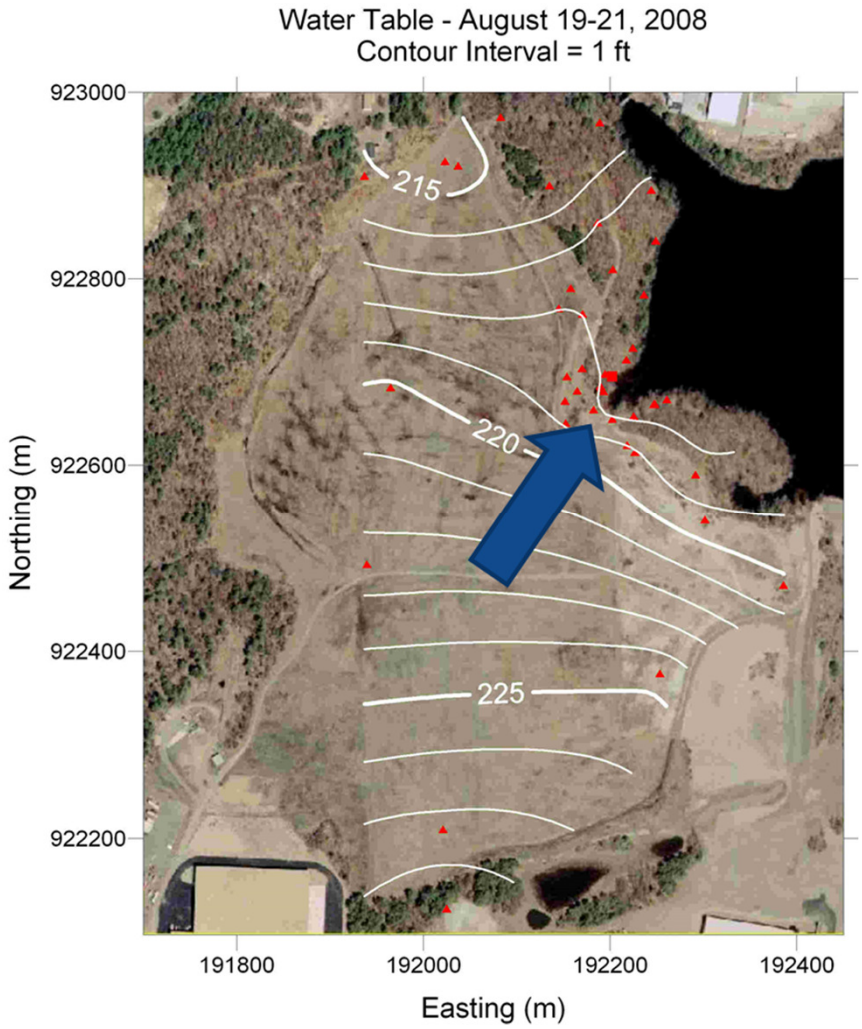




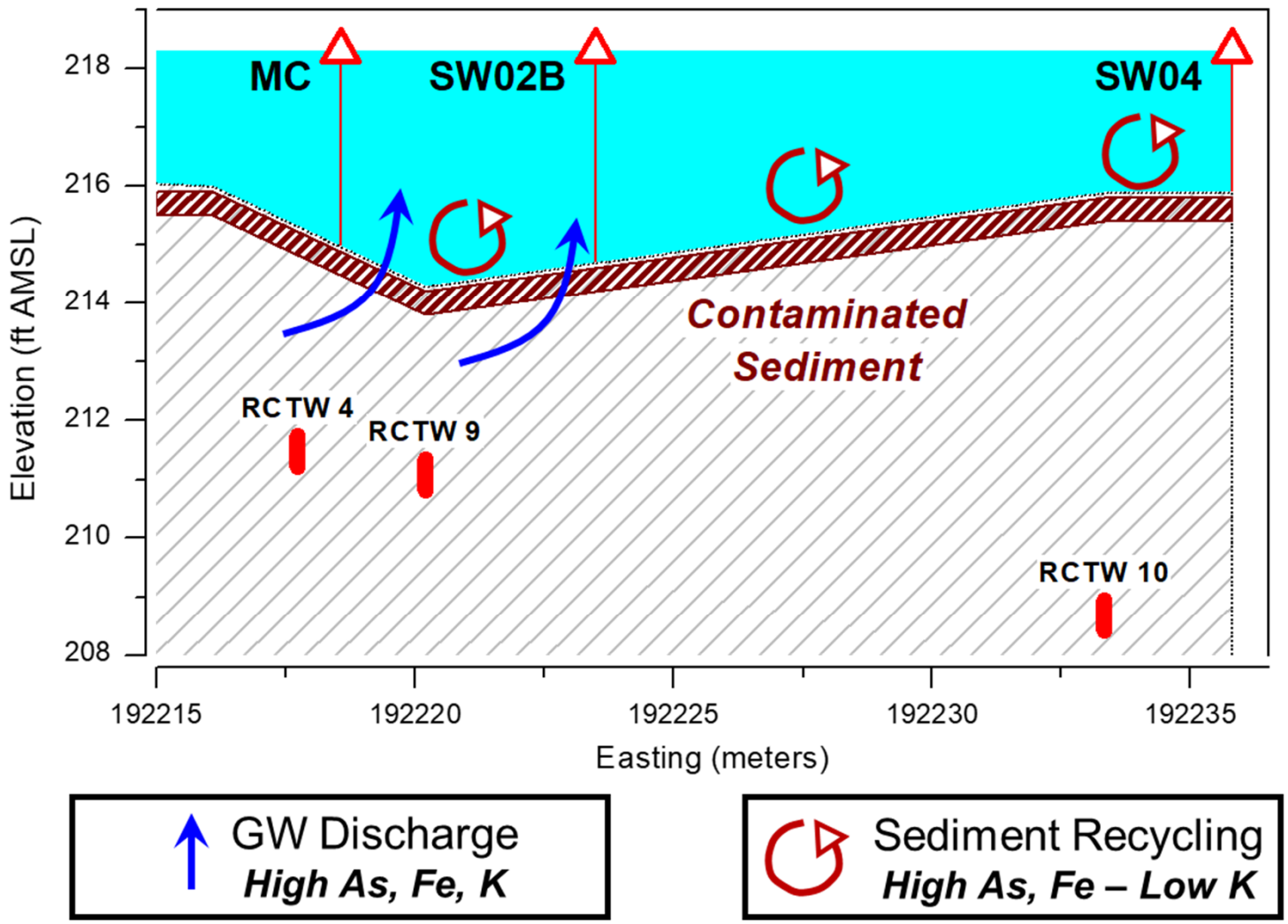


Groundwater Flow August 2008

GW continues to discharge to cove even while P&T operates continuously



Updated Conceptual Site Model



Consensus Conclusion: Additional Containment Needed on East Side of Landfill

- ORD Data and Technical Arguments are ultimately persuasive
- Site Owner Agrees to pursue additional remedial measures focused on Red Cove
- Beach-head to successful Remediation Established !

NEXT STEPS: REVISED CSM HAS AN IMMEDIATE AND SIGNIFICANT IMPACT TO REMEDIATION ACTIONS

- Slurry Wall (GW Containment) installed 2012

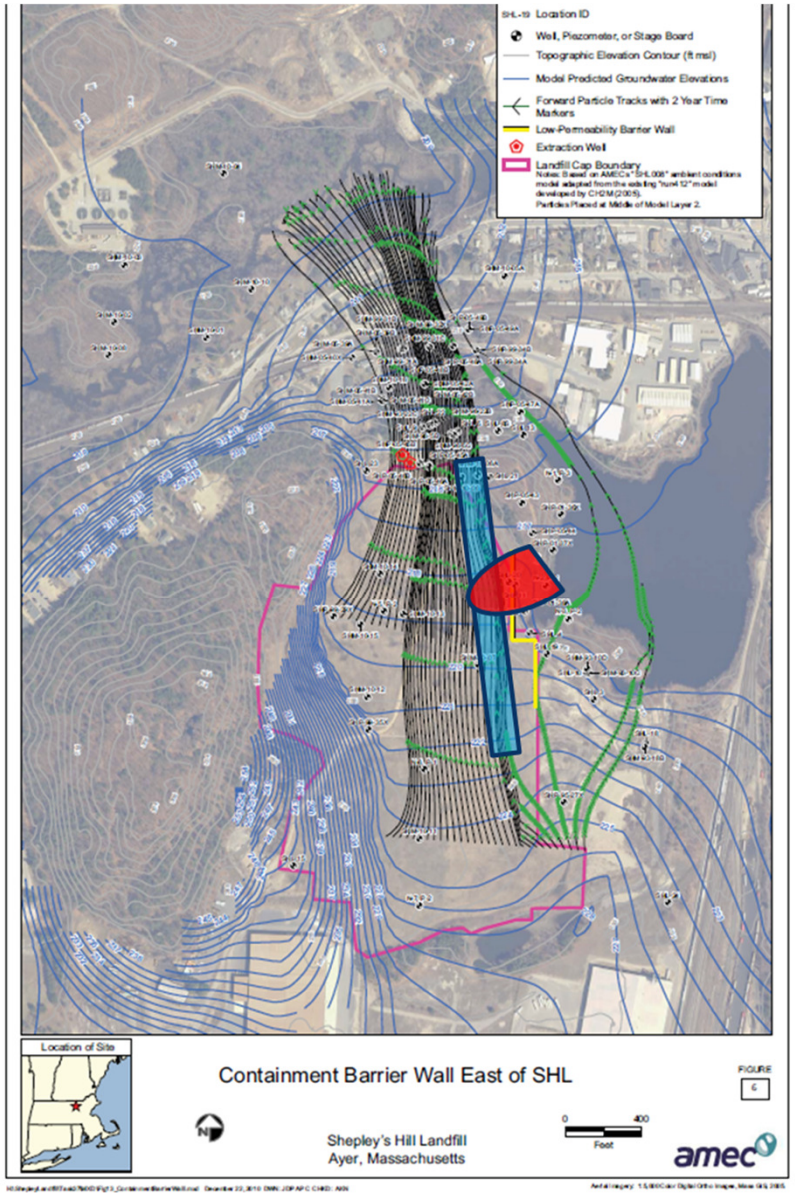
- Ponds dewatered and sediment excavated in 2013

Photo 3: Red Cove Sediment Excavation

Description: View of Red Cove excavation/finger road looking north-northeast from southern bank.
Photo Date: September 13, 2013

Slurry Wall installed for GW Containment

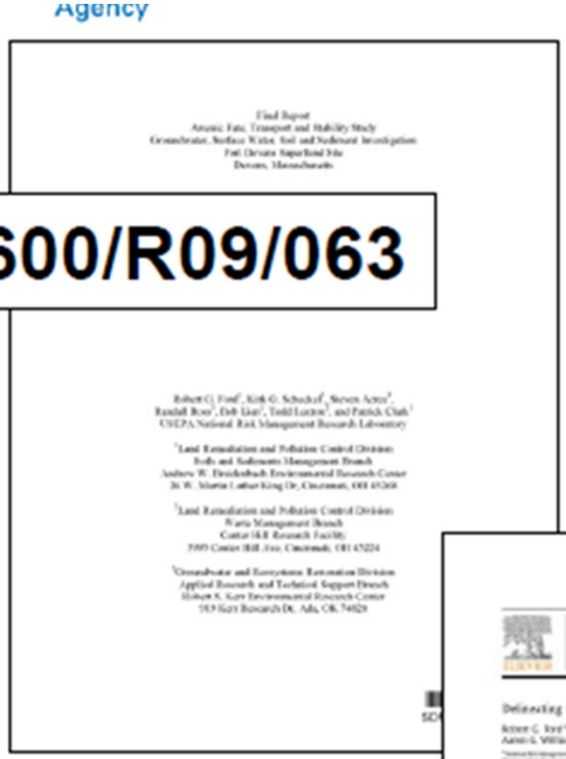
- Containment Success Critical to Red Cove Remediation Path Forward
- 850 ft. Slurry Wall to Bedrock in 2012
- Cut-off GW flow to Red Cove
- Sediment Excavation conducted in 2013
- Post-2013 LTM indicates continued improvement and Restoration of impaired ecosystem



Take-Home Messages

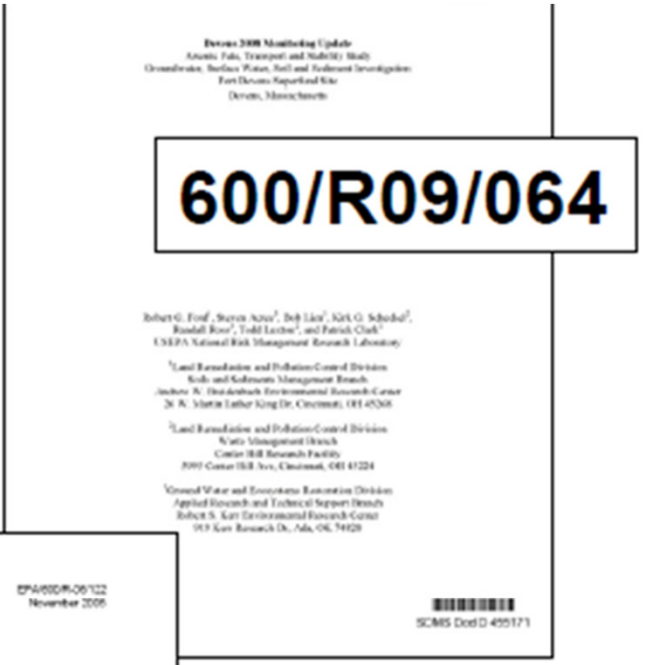
- GW/SW Evaluations can pay big dividends
- Simple, Inexpensive tools can “establish a beach-head” to a better CSM
- More elaborate/in-depth/long-term studies (ORD) may be useful in order to convince the un-enlightened
- Significant Changes in Project Direction and *Momentum* may follow
- Remedy modified twice during LTM because of GW/SW investigations – Now more protective

Publications


Agency

Final Report
Arsenic Fate, Transport and Stability Study
Groundwater, Surface Water, Soil and Sediment Investigation
Fort Devens Superfund Site
Devens, Massachusetts

600/R09/063


Devens 2008 Monitoring Update
Arsenic Fate, Transport and Stability Study
Groundwater, Surface Water, Soil and Sediment Investigations
Fort Devens Superfund Site
Devens, Massachusetts

600/R09/064

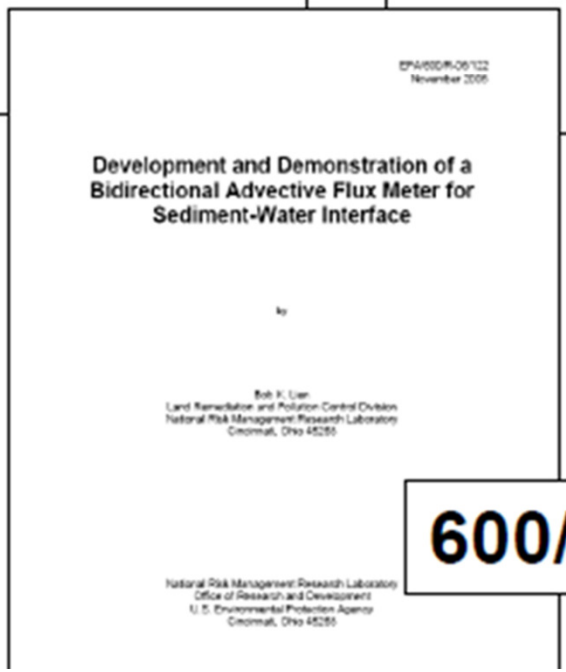
SCMS Doc ID 455171


Author's personal copy

Chemosphere

Delineating landfill leachate discharge to an arsenic contaminated waterway

Journal Article


EPA/600/R-06/122
November 2006

Development and Demonstration of a Bidirectional Advective Flux Meter for Sediment-Water Interface

by

Bob K. Lien
Land Remediation and Pollution Control Division
National Risk Management Research Laboratory
Cincinnati, Ohio 45268

National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

600/R10/110

Selected ORD Publications on Red Cove

- LIEN, B. K. AND C. G. Enfield. AUTOMATED LONG-TERM REMOTE MONITORING OF SEDIMENT-WATER INTERFACIAL FLUX. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-10/110, 2011.
- FORD, R. G., K. G. SCHECKEL, S. ACREE, R. ROSS, B. LIEN, T. LUXTON, AND P. CLARK. Final Report; Arsenic Fate, Transport and Stability Study; Groundwater, Surface Water, Soil And Sediment Investigation, Fort Devens Superfund Site, Devens, Massachusetts. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/063, 2008.
- FORD, R. G., S. D. ACREE, B. K. LIEN, K. G. SCHECKEL, R. R. ROSS, T. LUXTON, AND P. J. CLARK. Devens 2008 Monitoring Update. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/064, 2009.
- Ford, R.G. ,et al., 2011. Delineating landfill leachate discharge to an arsenic contaminated waterway, Chemosphere 85, 1525-1537.
- Ford, R.G. and Lien, B., Tools for Estimating Groundwater Flux to Surface Water, 24th Annual NARPM Training Program, May 2, 2016.
- *And More in Progress*

FINAL WORD – Post Remedy Restoration of Red Cove