Arsenic Speciation, Mobility and Treatability at a Former Industrial Site In Edgewater, New Jersey

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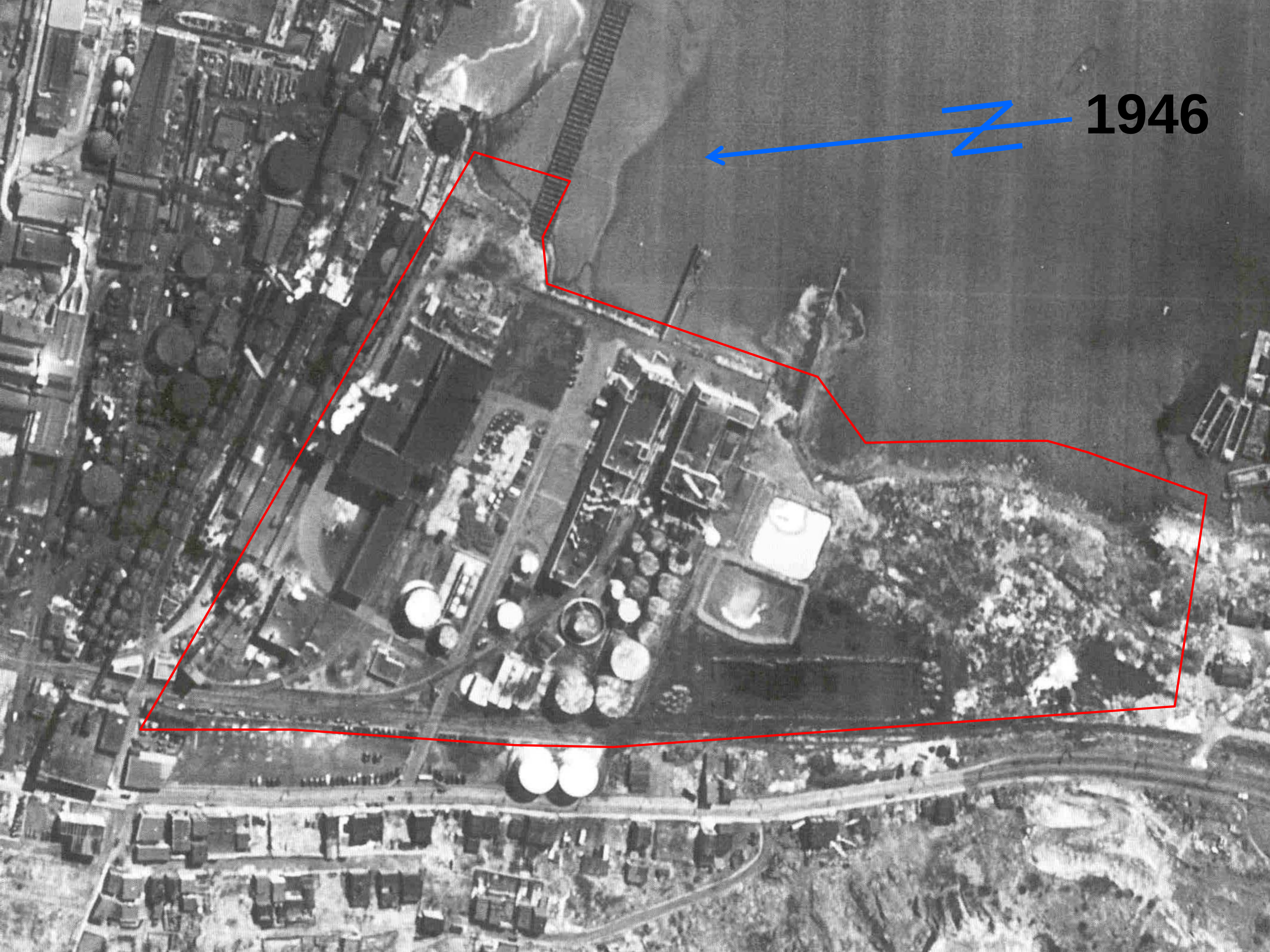
Project Overview

- 15-Acre Riverfront Property
- Former Industrial Usage: chemical mfg, roofing pitch storage, hydrogen gas plant, edible oil, soap and detergents
- Proposed Redevelopment as a Mixed Use Residential and Commercial Property
- Contaminated with Arsenic (Metals), Roofing Tar/Pitch Material, Benzene
- Northern Portion of Site Impacted by Adjacent Superfund Site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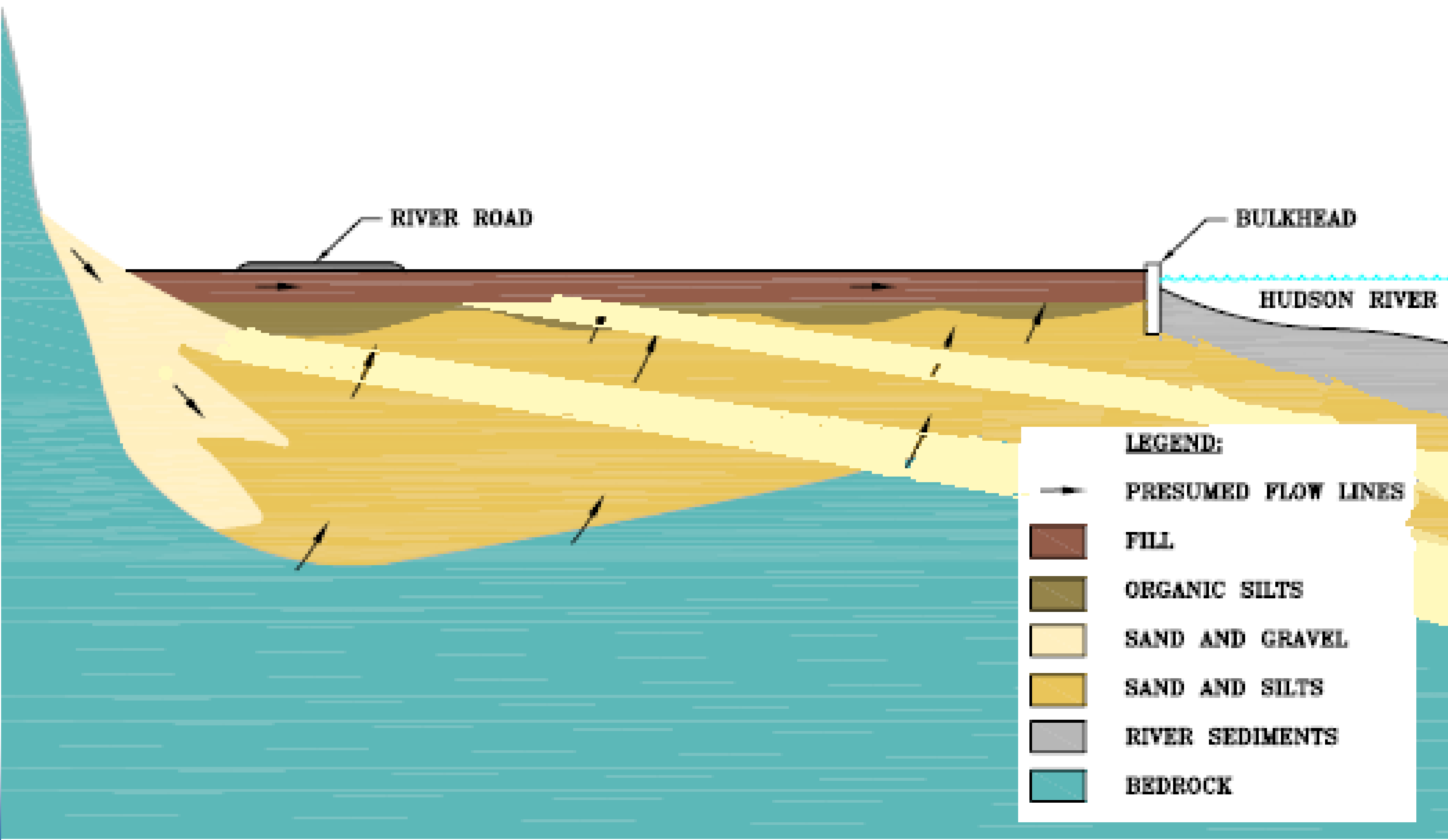
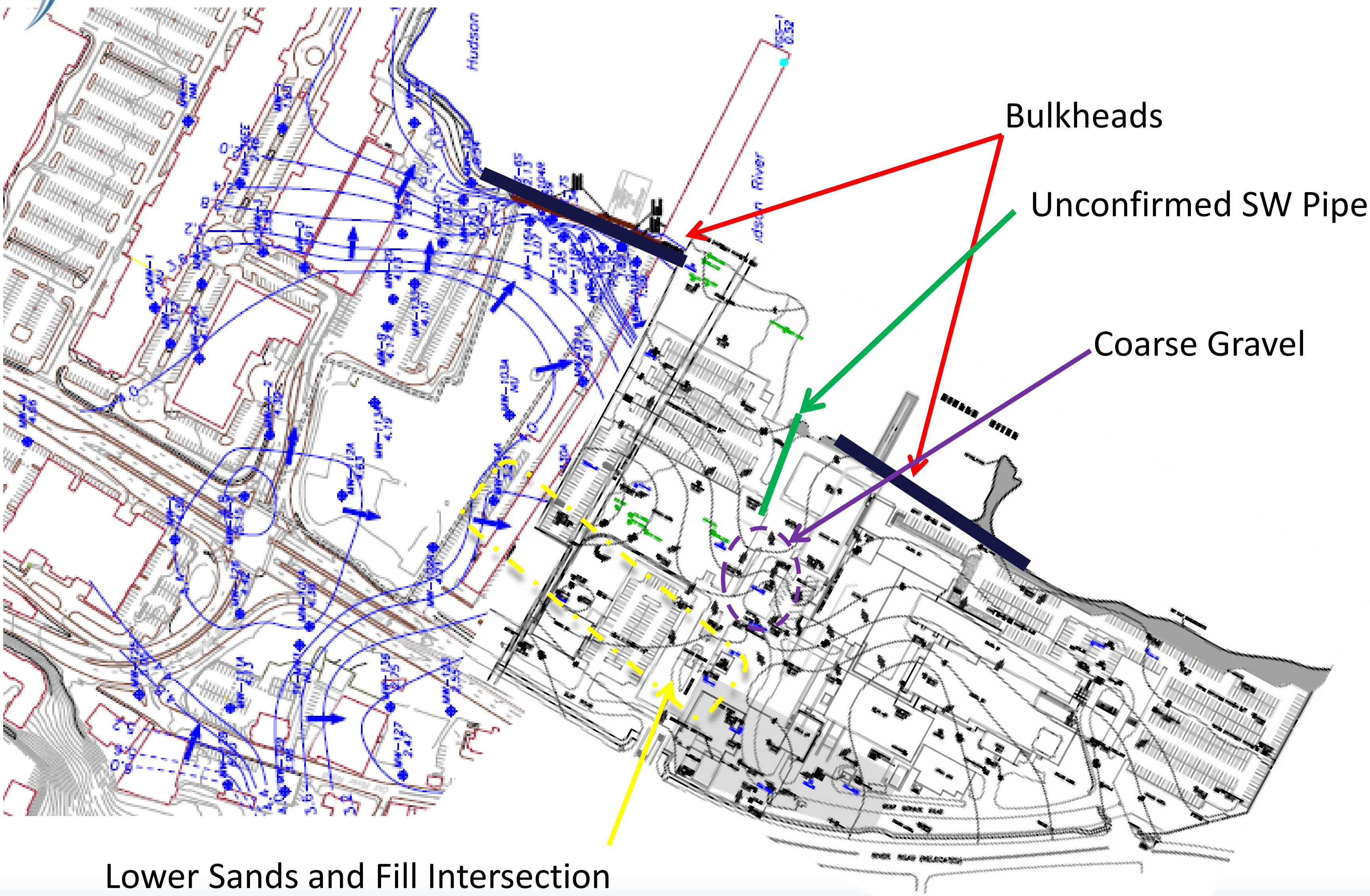
Site Geology/Hydrogeology

- Fill – Silts, Sands, Debris. 5-25’ Thick.
  - 20 to >100 ft/day
- Upper Sands. F/M Grain. Lacustrian Fan
  - 2 to 20 ft/day
- Organic Silts and Clays. Swamp/Marsh
  - 0.001 to 2 feet/day
- Lower Sands. F/M w Gravel. Lacustrian Fan
  - 5 to 20 ft/day
- Stockton Formation. 50 to >90 feet bgs

Site Geology/Hydrogeology



Shallow Groundwater Flow



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Background/Concerns

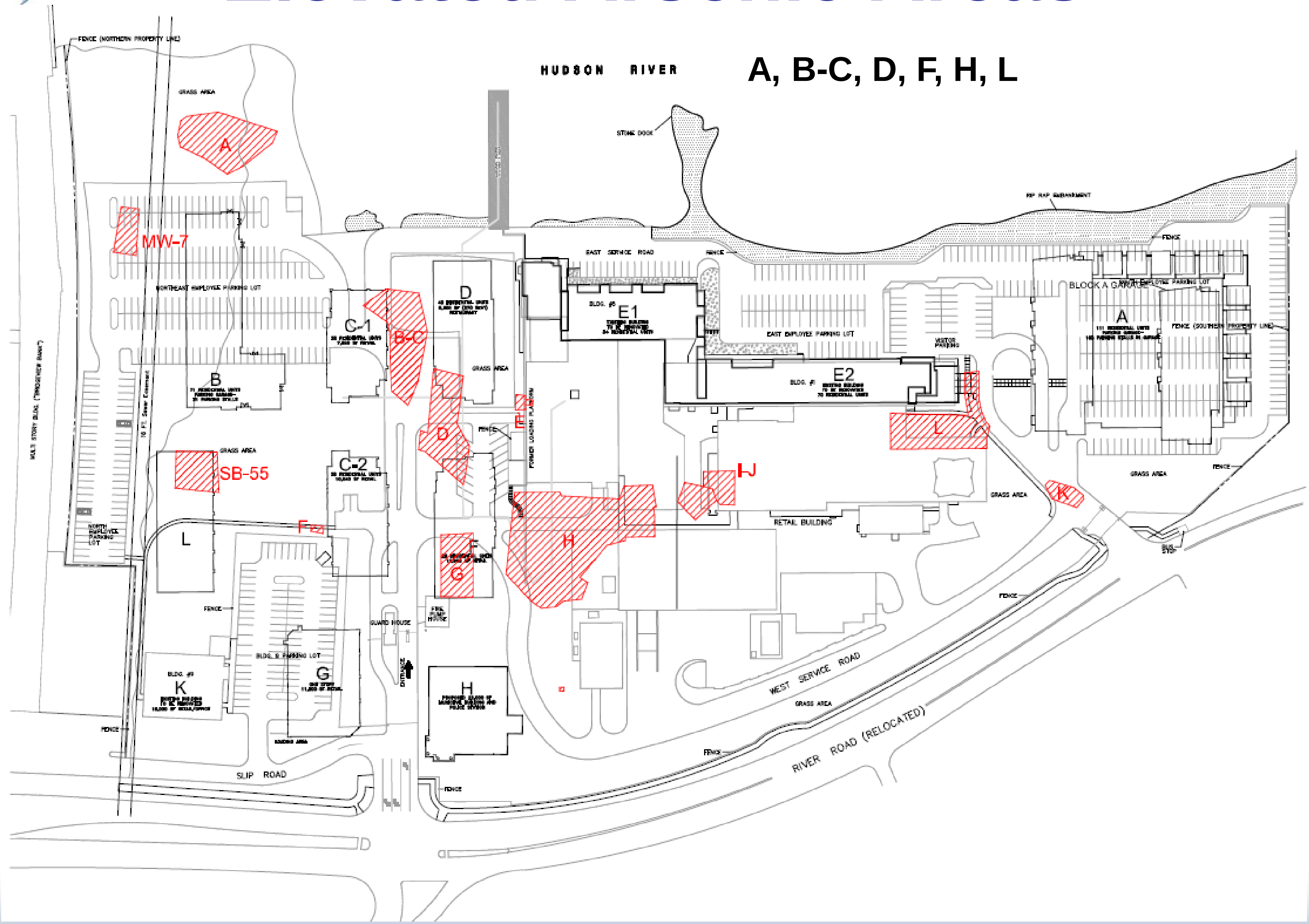
- Extent and Magnitude of Arsenic Initially Under Reported
- Substantial amounts of fill placed between 1880 and 1930
- High Concentrations of Arsenic in Soils and Groundwater
- Sulfuric Acid Plant located North of Site
- USEPA and DEP believed Arsenopyrite-Rich Slag was Source of Arsenic
- Capping and Institutional Controls Not Sufficiently Protective of Groundwater or Hudson River

Procedure

- Conduct Petrographic and XRD Study
- Evaluated Site Geochemistry and Speciation
- Develop ARS for Arsenic per NJDEP Guidance
- Evaluated Solidification/Stabilization Technologies to Address Arsenic Impacted Soils

Elevated Arsenic Areas

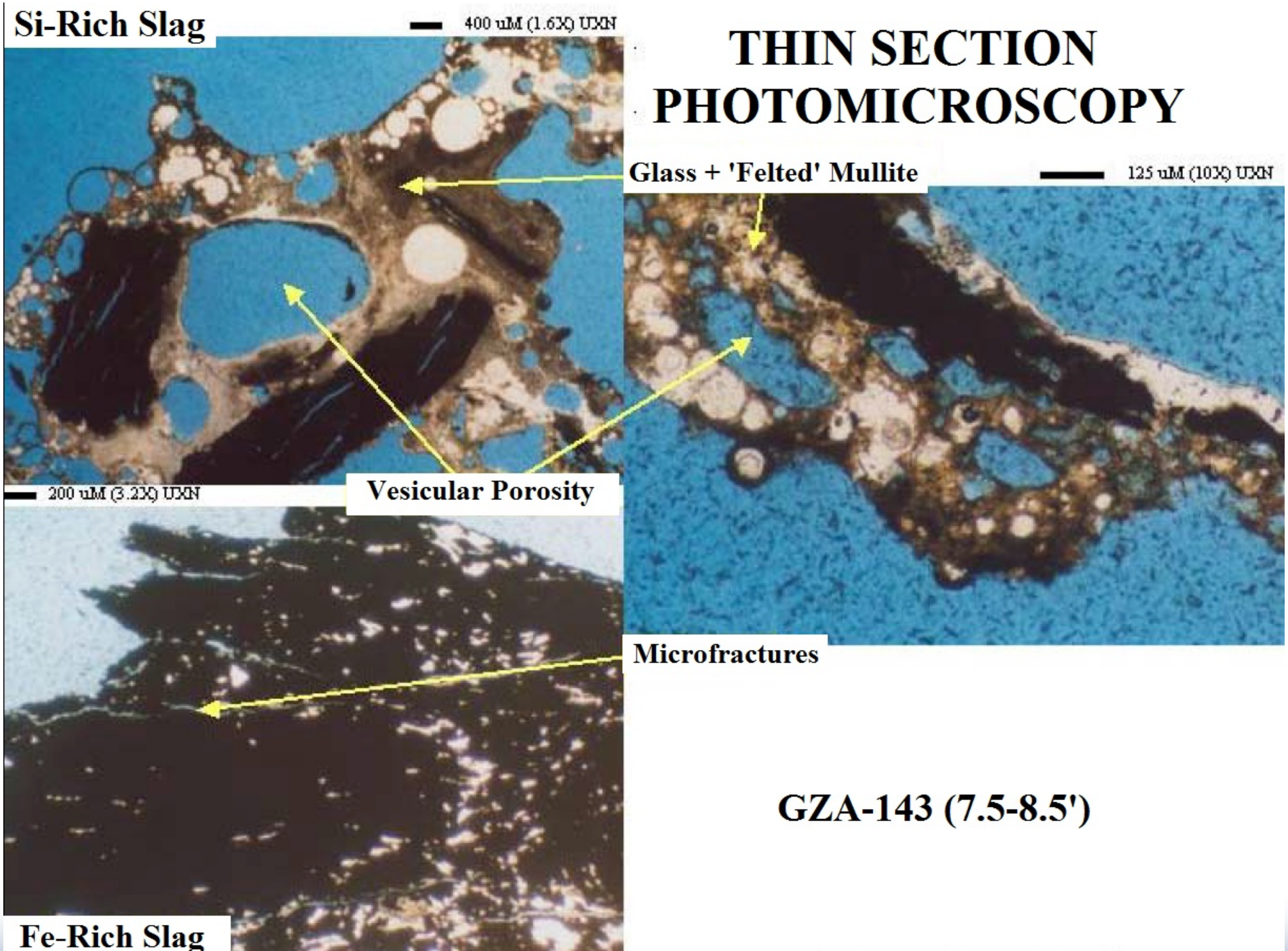
A, B-C, D, F, H, L



Petrographic and X-Ray Difraction Investigation

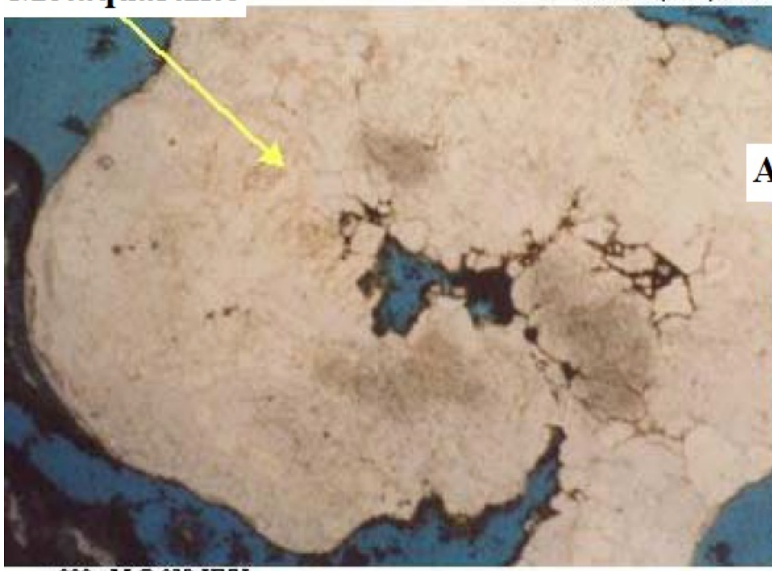
- Petrography on Cinder/Slag Samples indicated:
  - Amorphous glass
  - Mullite,
  - Iron Oxide
  - Spherulitic Chalcedony
  - Arsenopyrite (found precipitated gabbro and quartzite
  - Pyrite

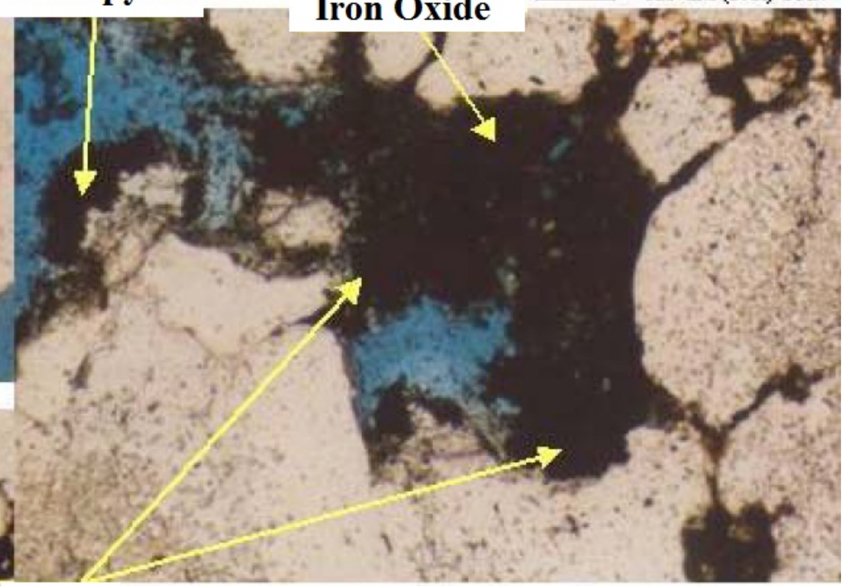
THIN SECTION PHOTOMICROSCOPY

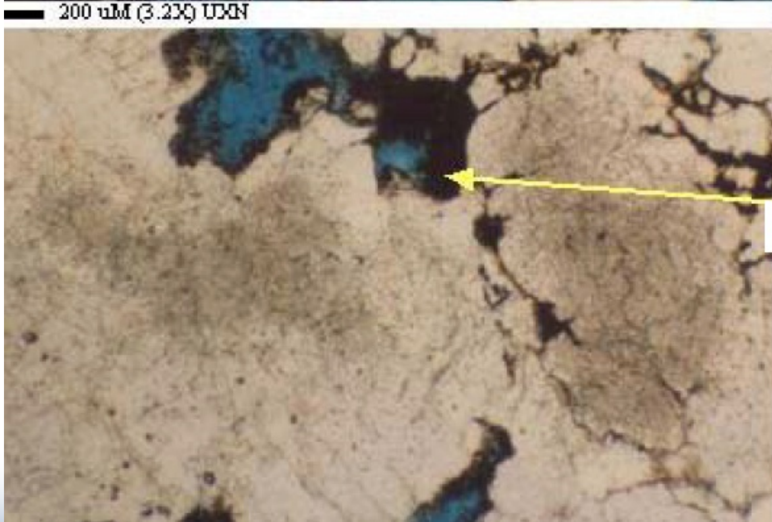


GZA-143 (7.5-8.5')

THIN SECTION PHOTOMICOSCOPY

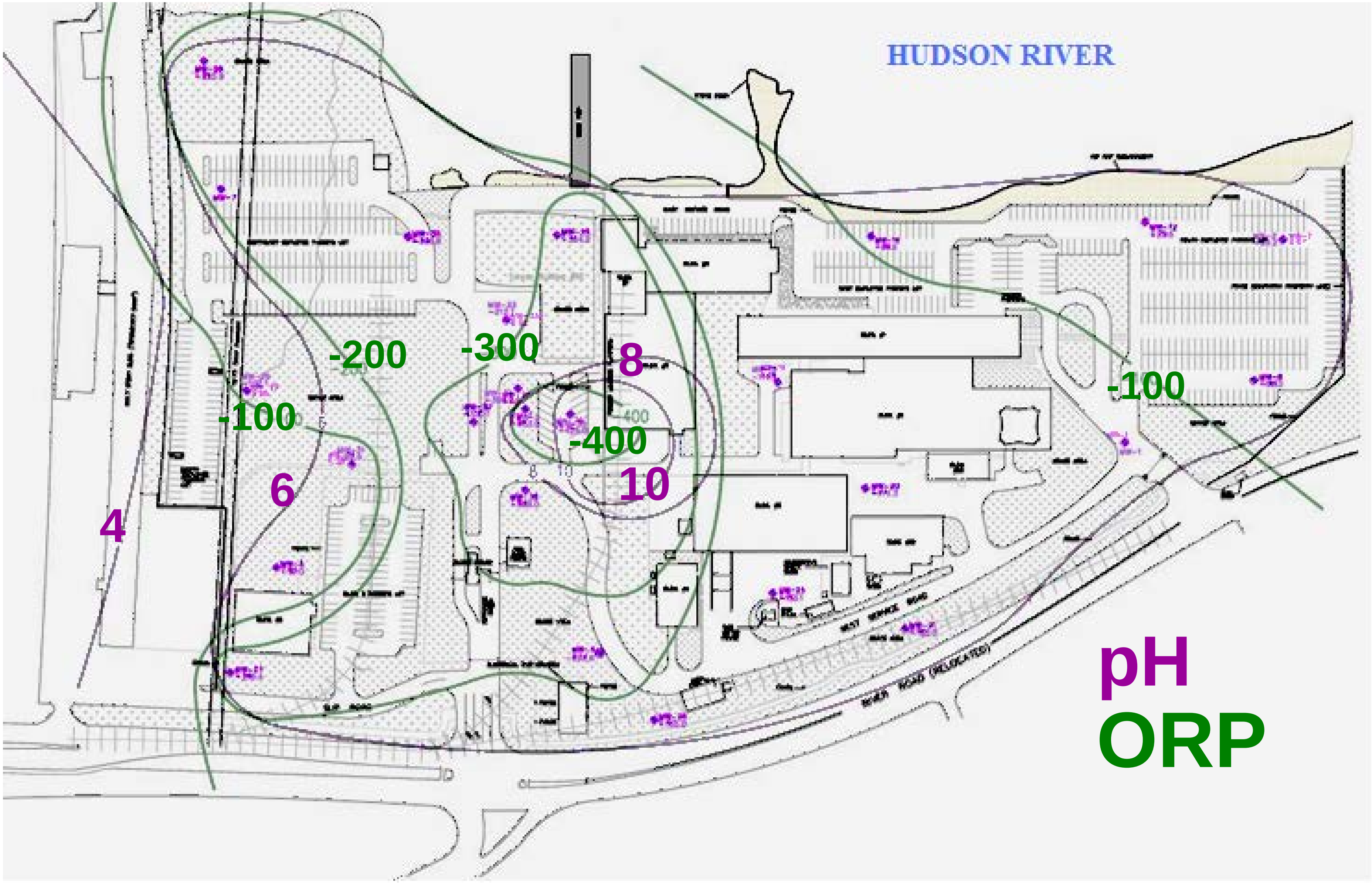






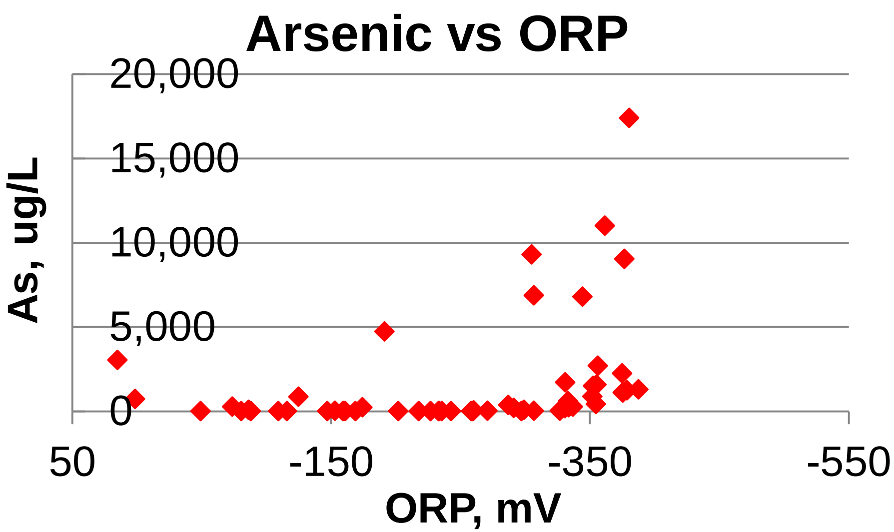
GZA-163 (1.6-1.7')

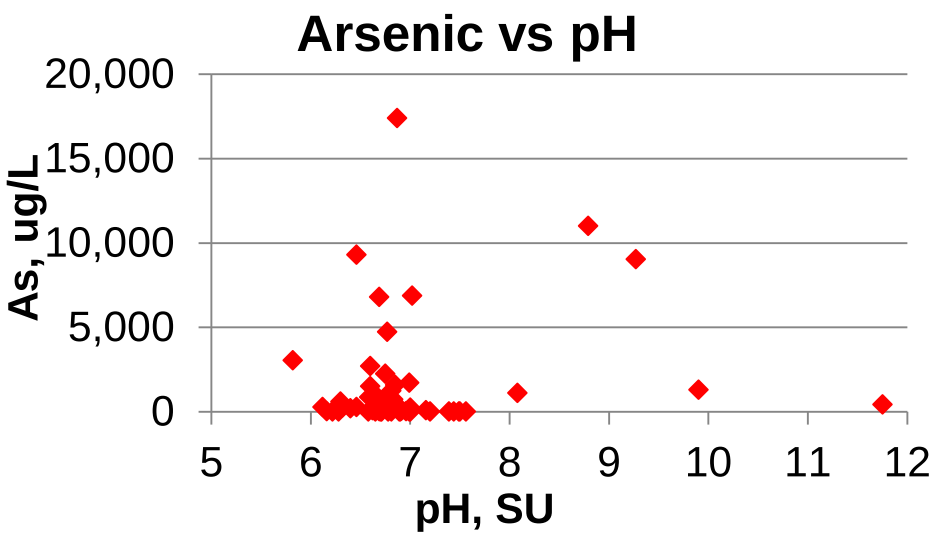
pH and ORP Distribution



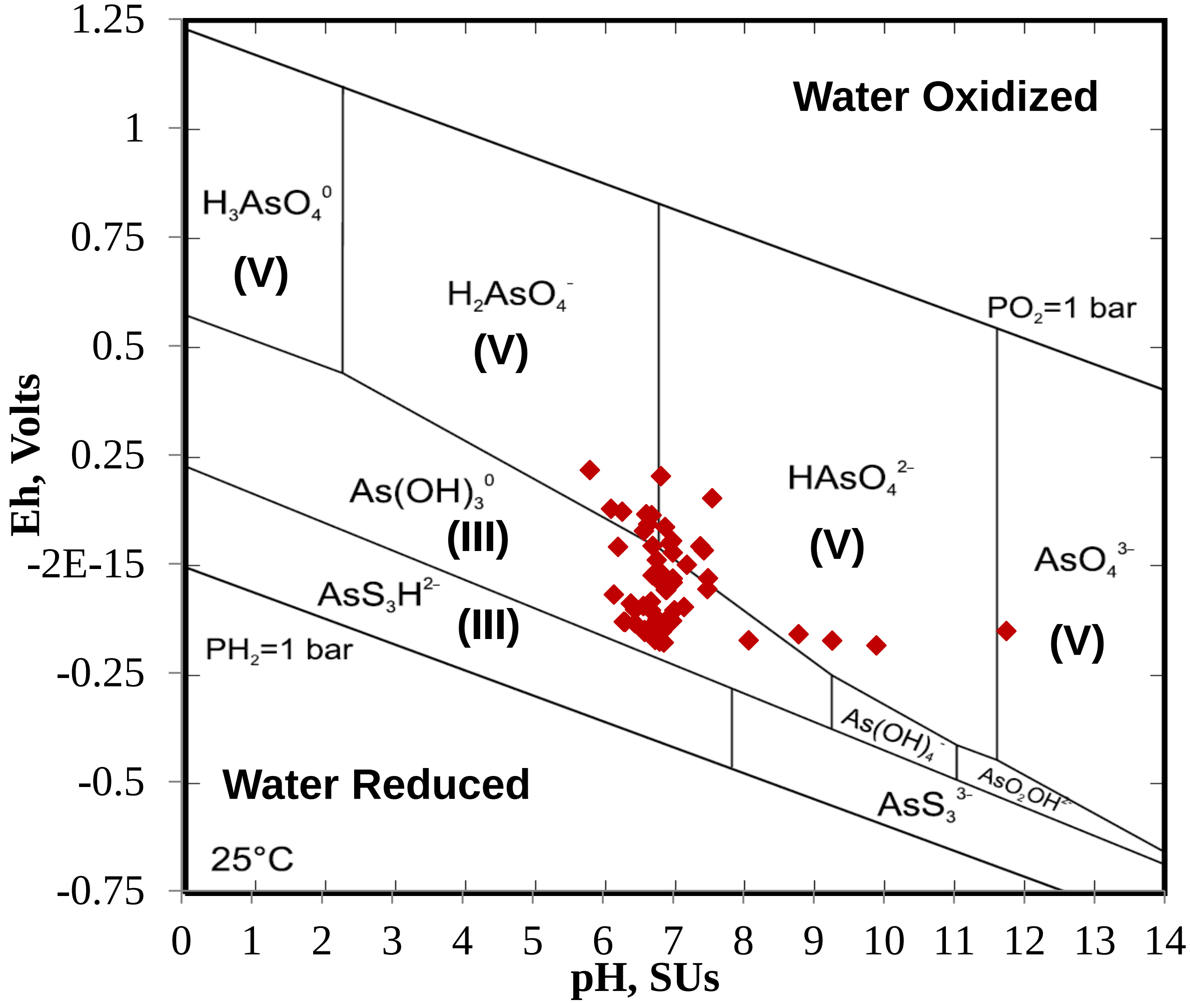
Arsenic and Groundwater Geochemistry

- Found Different Geochemical Zones Corresponding with Dissolved Arsenic
  - Low Eh / High pH (Zone 1)
  - High Eh / Low pH (Zone 2)

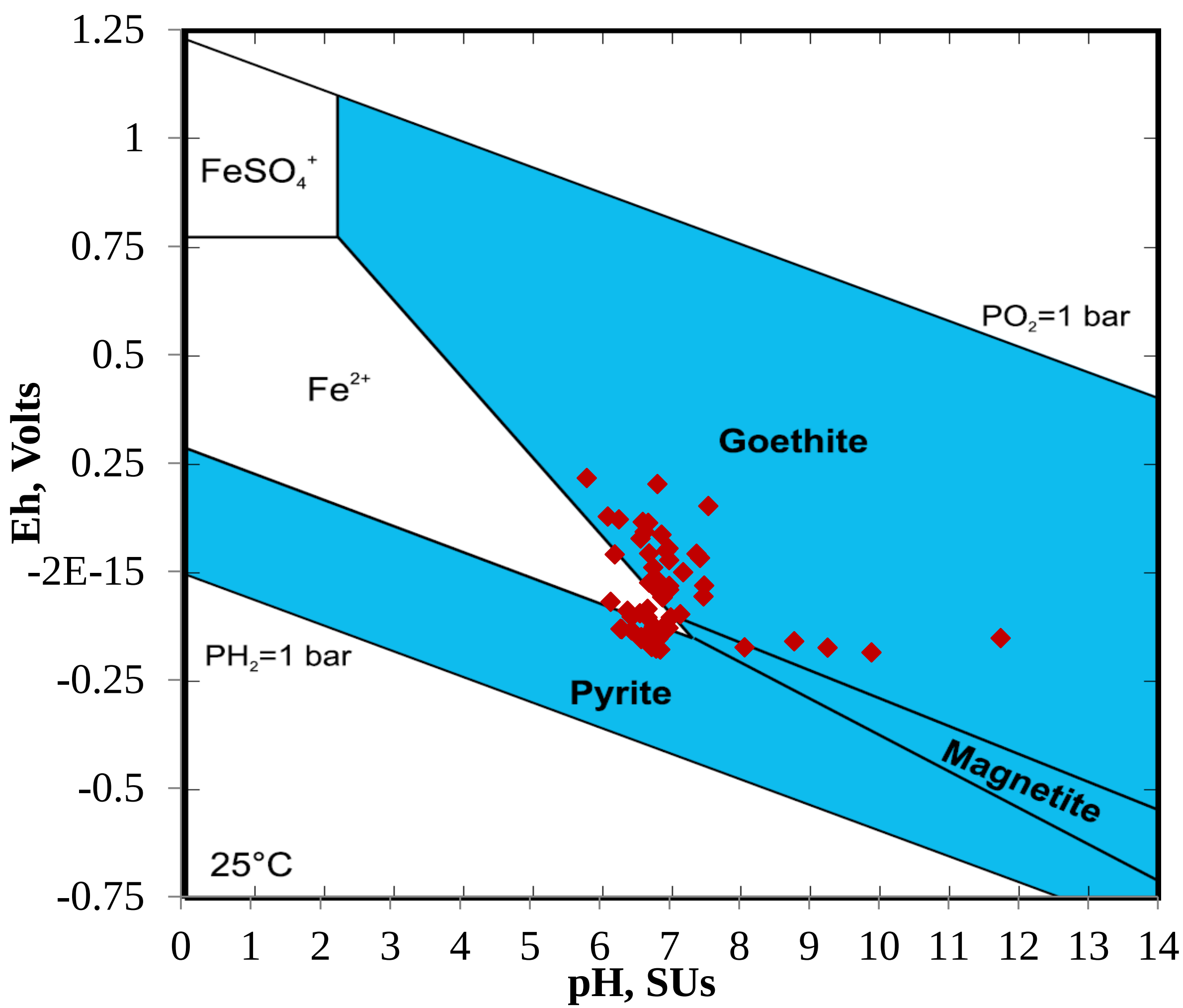




- Eh/pH range indicated groundwater zones straddled the Arsenite (As[III]) stability field



- Eh/pH range indicated groundwater in two zones fell outside iron oxyhydroxide stability field

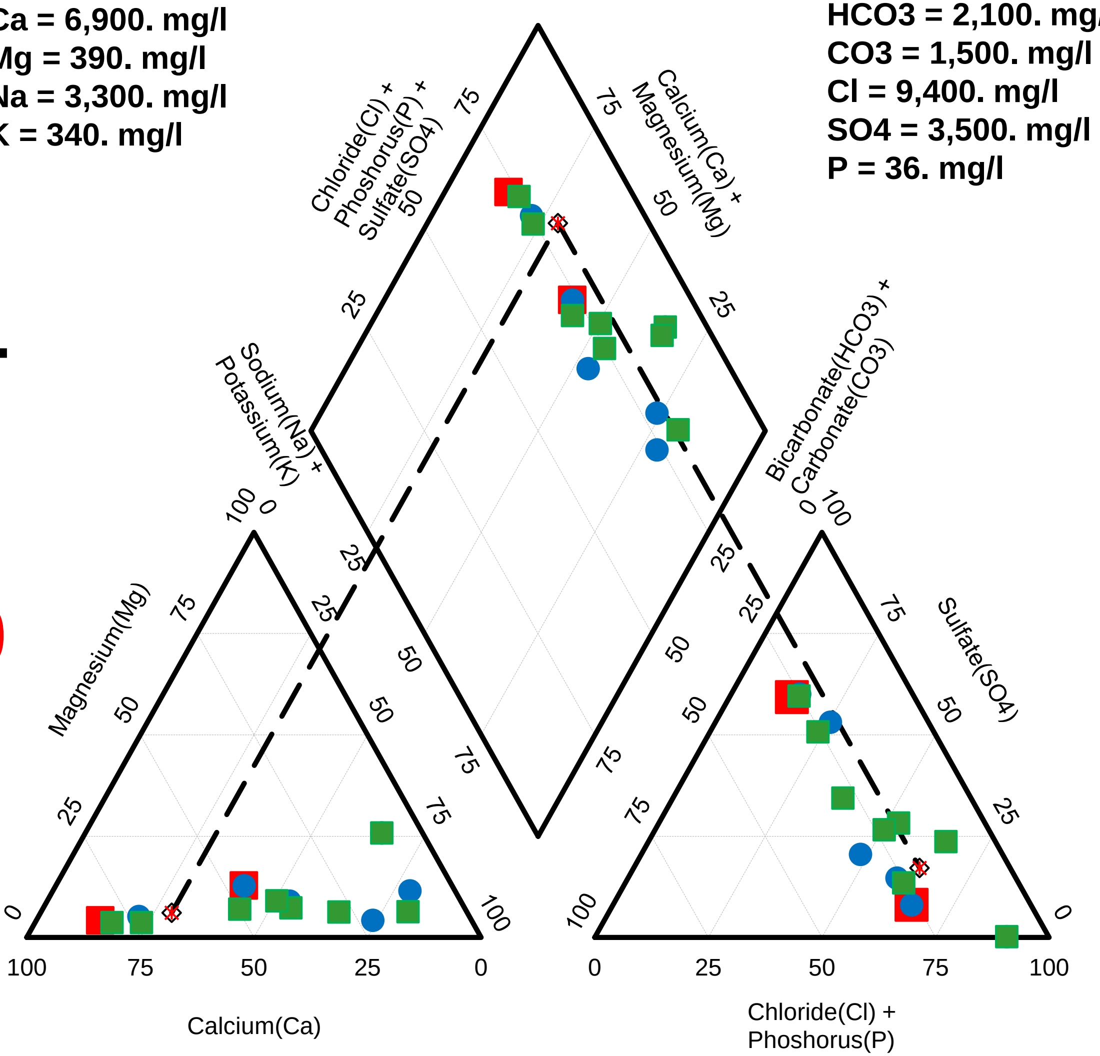


Groundwater Piper – Arsenic

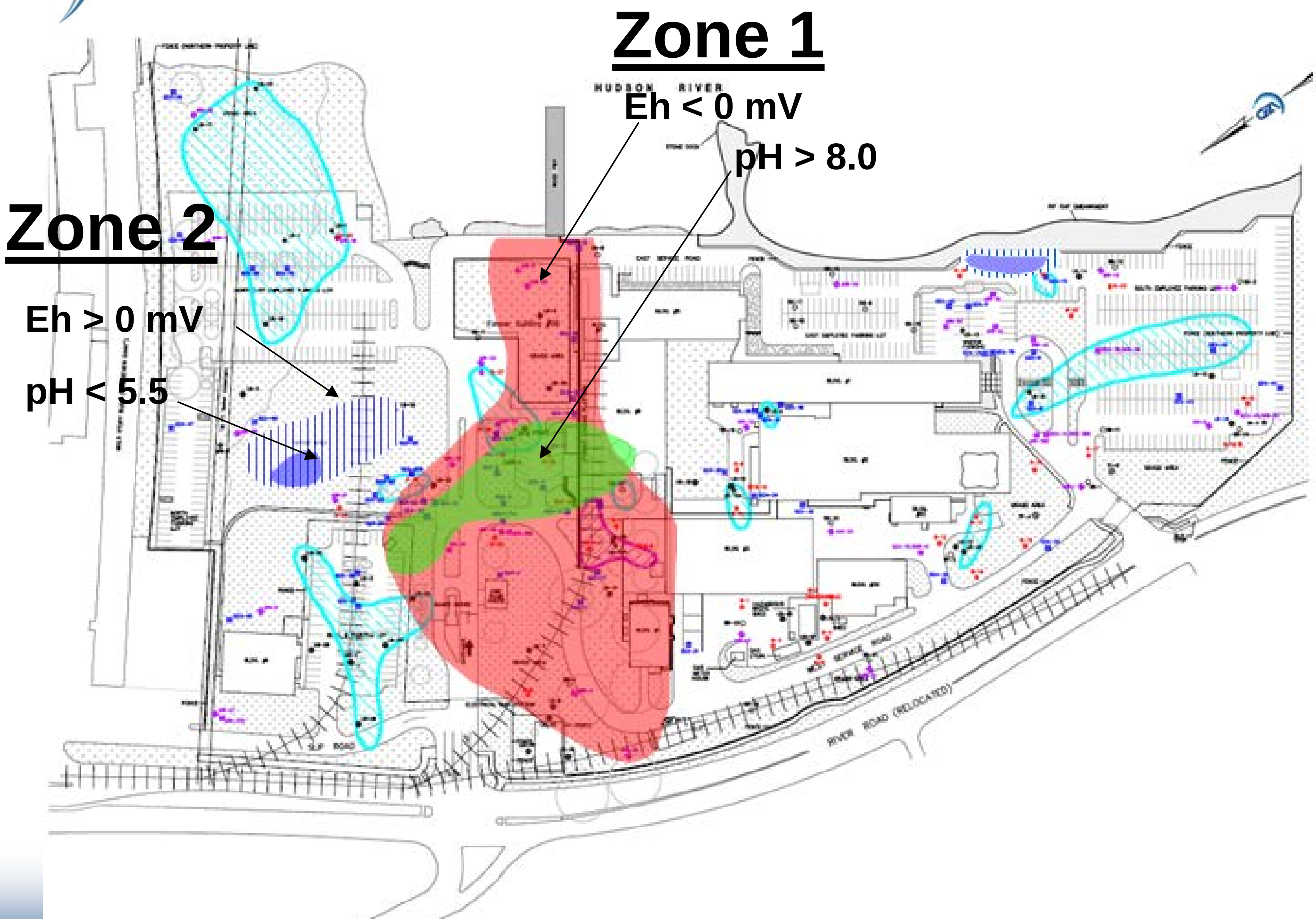
CATIONS
Ca = 6,900. mg/l
Mg = 390. mg/l
Na = 3,300. mg/l
K = 340. mg/l

ANIONS
HCO3 = 2,100. mg/l
CO3 = 1,500. mg/l
Cl = 9,400. mg/l
SO4 = 3,500. mg/l
P = 36. mg/l

As, ug/L
> 1,000
> 5,000
> 10,000



Groundwater Arsenic Distribution



Arsenic Cleanup Standard

- NJDEP set direct contact SCC
- Issued guidance for calculating Impact to Groundwater ARS
  - Analyze soils for SPLP compare to LS (3 ppb)
    - ARS = Highest C_T for which C_L d LS = 22 ppm
    - ARS Using site Specific Kd

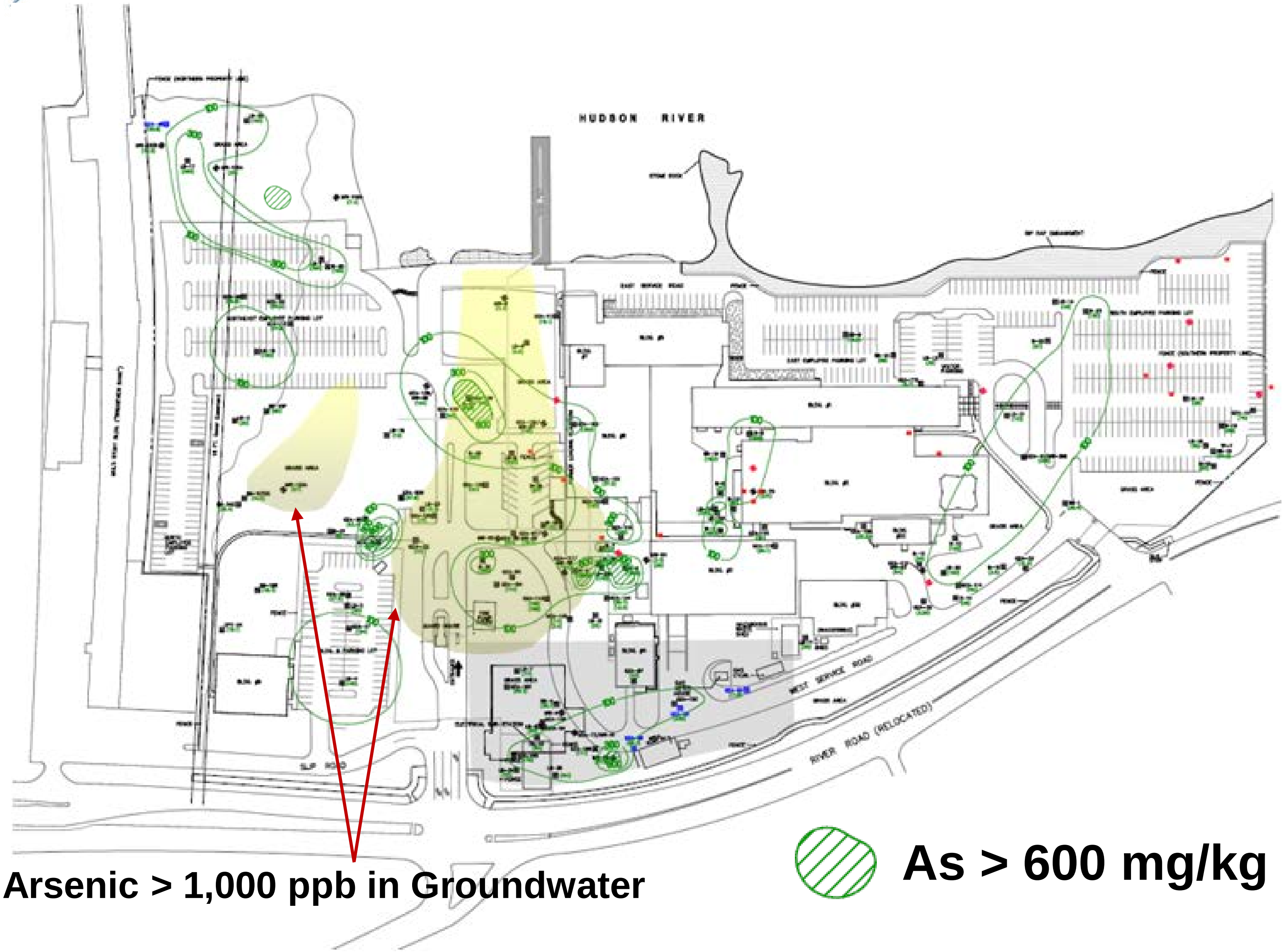
$$K_d = \frac{(C_T M_S - C_L V_L) / M_S}{C_L} \qquad ARS = C_{gw}\left\{K_d + \frac{\theta_w + \theta_a H'}{\rho_b}\right\}DAF$$

    - Kd ranged from 22 to 17,000 L/kg. ARS using 22 = 0.8 ppm
    - Regression Analysis of C_T vs C_L = Failed

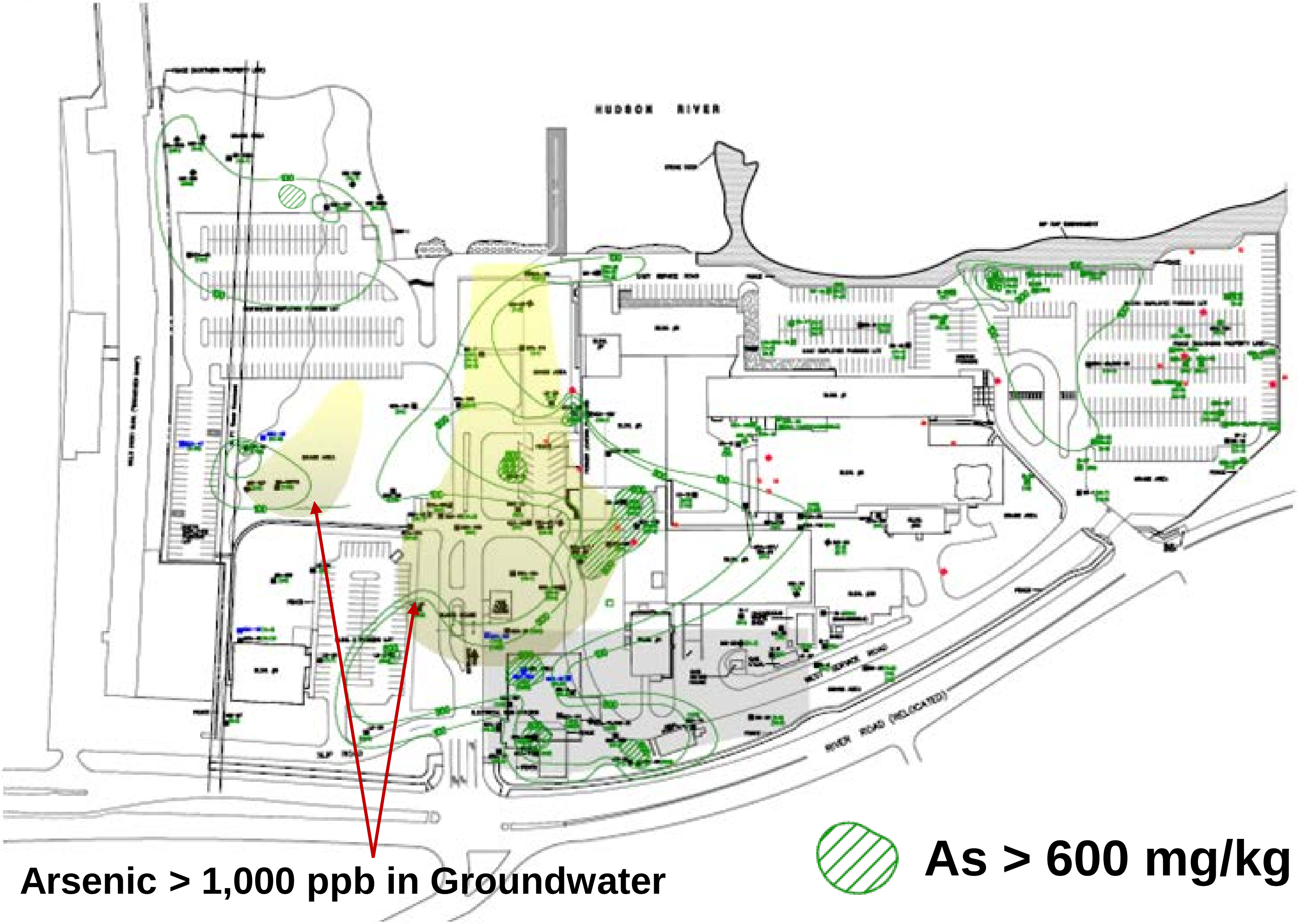
Arsenic Cleanup Standard

- Arsenic cleanup Standard Very Dependent on Site Geochemistry
  - No clear correlations with SPLP results or Kd
- Argued that Arsenic solubility was dependent on Eh, pH and Ironoxyhydroxide stability. We would excavate soils above HFM Maximum of 1,096 ppm
  - NJDEP willing to compromise
  - Look at correlations between soil and groundwater hot spots

Arsenic in Unsaturated Soil



Arsenic in Saturated Soil



Arsenic > 1,000 ppb in Groundwater

As > 600 mg/kg

Treatability Study

- Prepared Standard Operating Procedures
- Mixture Designs Applied
  - Type I Portland Cement
    - Addition rates of 10%, 7.5%

- Bench scale Hobart type mixer
- 4-inch diameter plastic cylindrical curing molds
- Cured for 28 days

Treatability Study Results

- PAHs and VOCs Passed NJDEP Default Leachate Criteria
- Compressive Strength Strong
- Low Permeability
- Leachate Results
  - Lead Present in One Sample
  - Arsenic Present In Leachate

Treatability Study Results

- Lead
  - Lowering Cement Content to 7.5% Reduced Lead Leachability
- Arsenic
  - Arsenic Present as Arsenite, Soluble Under Reducing Conditions
  - Add Ferric Sulfate to Increase Oxidation State of Arsenic Yielding Arsenate
  - Ferric Sulfate Resulted in Formation of Iron Oxyhydroxides Promoting Arsenic Bonding

Conclusions

- Arsenic Source Cinder-Ash Coal, not Arsenopyrite-Rich Slag
- Arsenic Solubility Due to Site Specific Geochemical Parameters
- Established Reasonable ARS for Arsenic
- NJDEP Required Groundwater Cut-off Wall to Control Future Arsenic Discharge to the Hudson River
- Demonstrated that ISS was a Treatment Technology for Arsenic Impacted Soils