Using Process Understanding to Assess The Feasibility And Timeframe Of Remediation By Natural Attenuation

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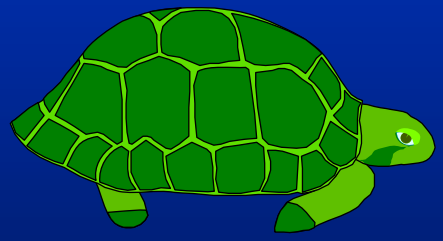
U. S. Geological Survey

USGS

Natural Attenuation poses special challenges that require new insights

- Background
  - Community expectations
- Challenges
  - Geochemical conditions
  - Timeframe
  - Risk pathways
- Progress and new tools
  - Sampling
  - Modeling



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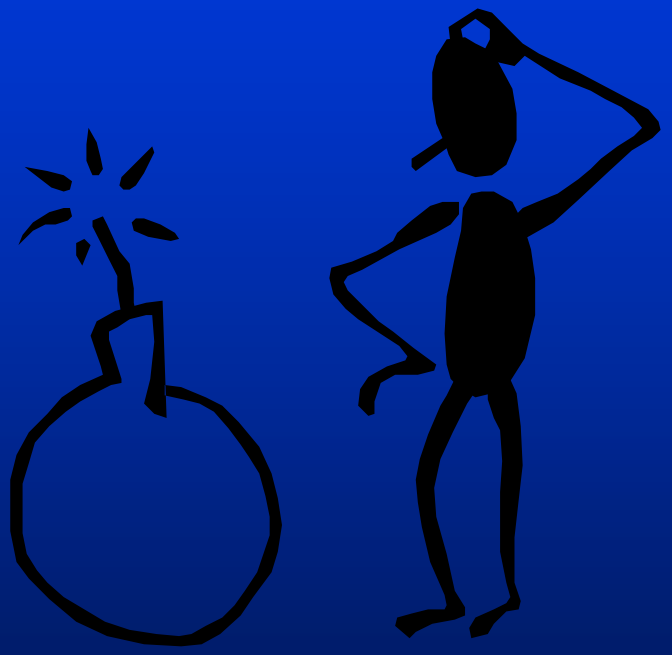
Sophisticated community members beliefs about natural attenuation

- A "do nothing" approach
- Legitimizes dilution
- Scientific basis is lacking
- Monitoring requirements are insufficient
- Effects of mixtures are uncertain
- Time line may be long



Source: NRC, 2000

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Knowledged-based technology requires greater understanding

- Dilution and dispersion alone are inadequate because they continue to spread risk.
- Requires proof that processes either destroy or immobilize contaminants.
- Organics degraded to innocuous forms.
- Metals transformed to more immobile forms.

Source: NRC, 2000

USGS

Each of the major contaminants have distinctive reaction potential

Non-halogenated organics:

BTEX, PAHs, MTBE, nitroaromatics, nonvolatile aliphatics

Halogenated organics:

ethenes (TCE, PCE), ethanes (TCA), methanes (DCM), aromatics (phenols, benzoates, and benzenes)

Inorganic:

metals (Ni, Cd, Cr), nonmetals (As), oxyanions (perchlorate, nitrate), radionuclides (Co, U, Pu)

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Source: NRC, 2000

Challenge 1: Critical NA processes occur only under favorable conditions

- Success is contaminant and site specific
- Process understanding required
  - Degree of characterization depends on site complexity
  - New compounds or site chemistry require testing of conceptual models

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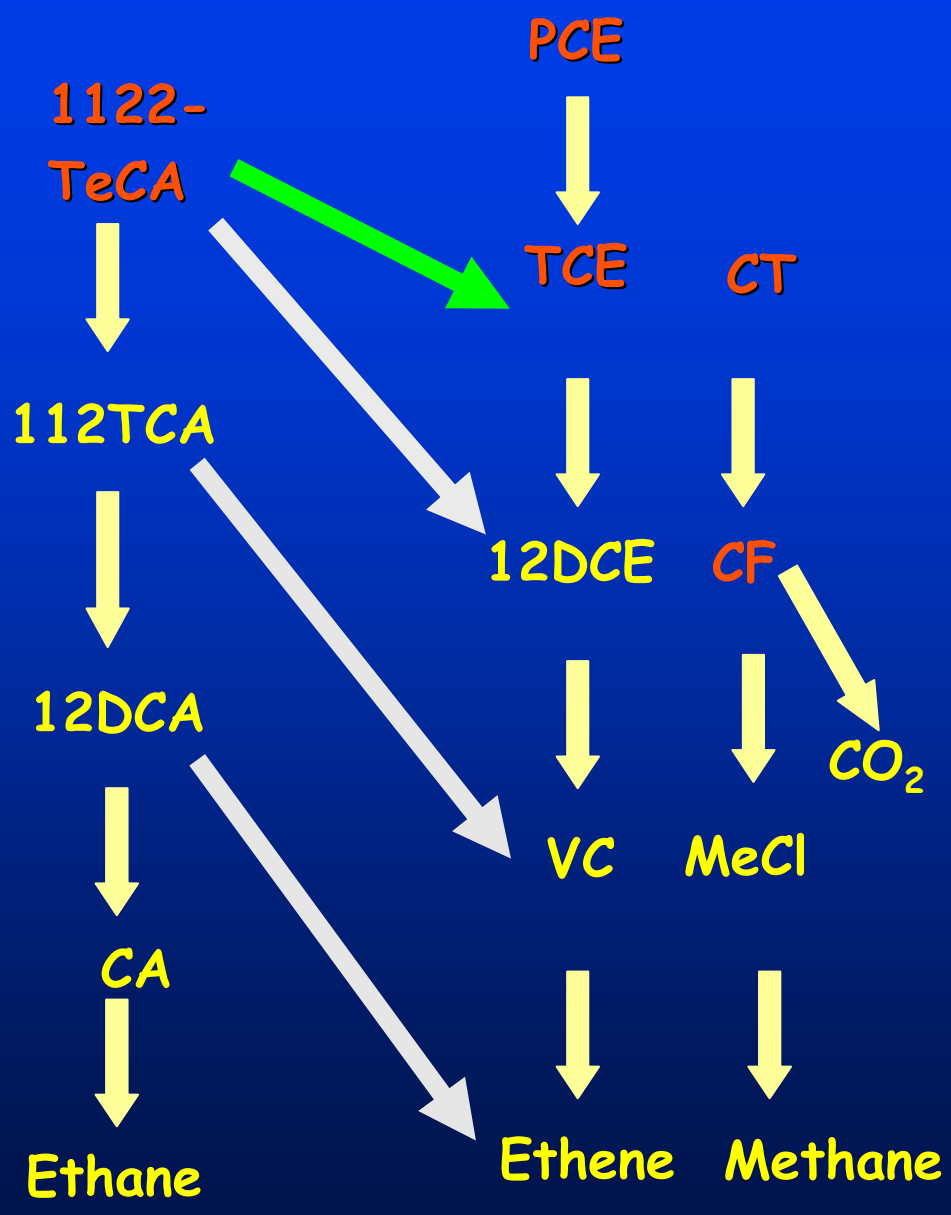
Source: NRC, 2000

For example complete reductive dechlorination occurs reliably only under methanogenic conditions



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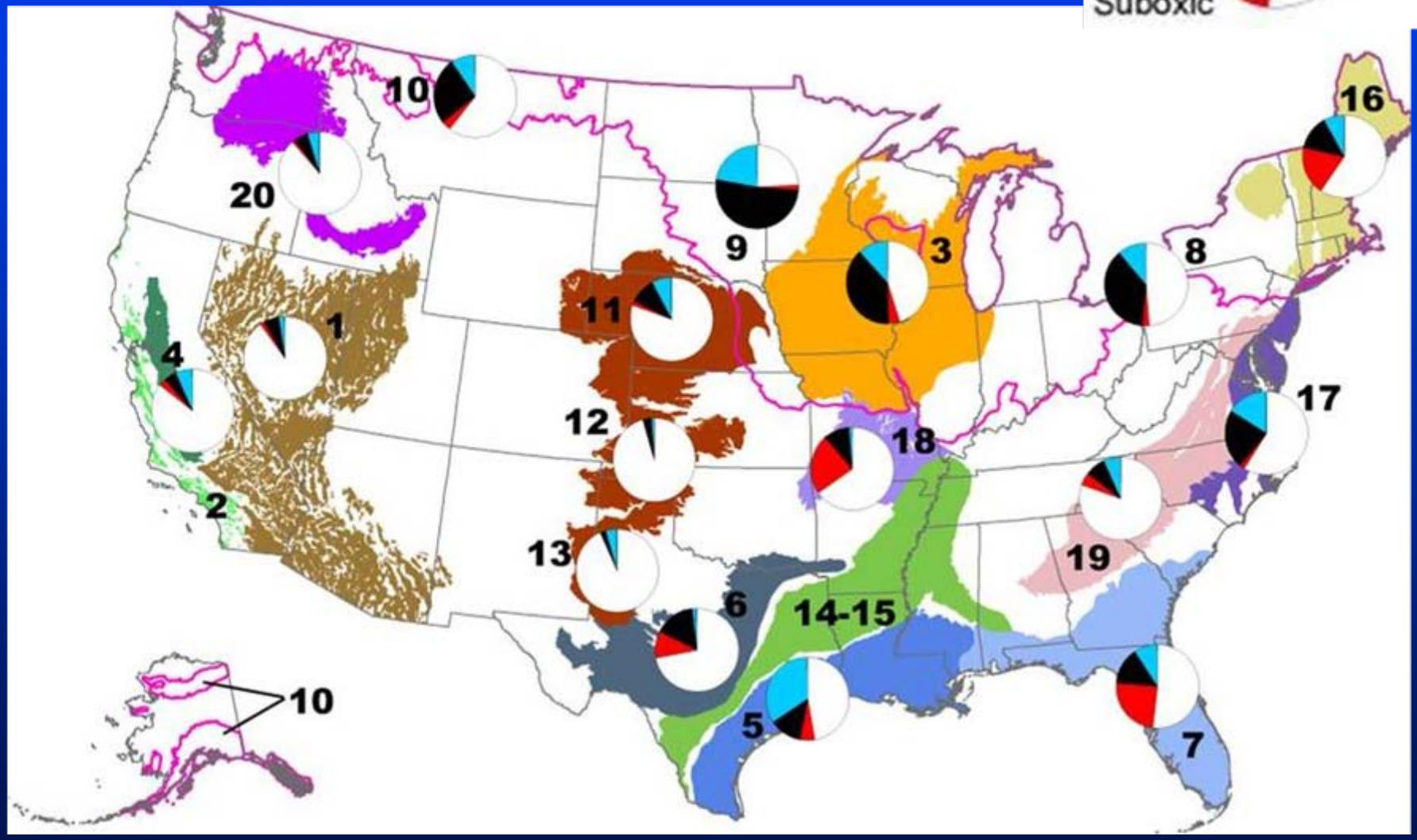
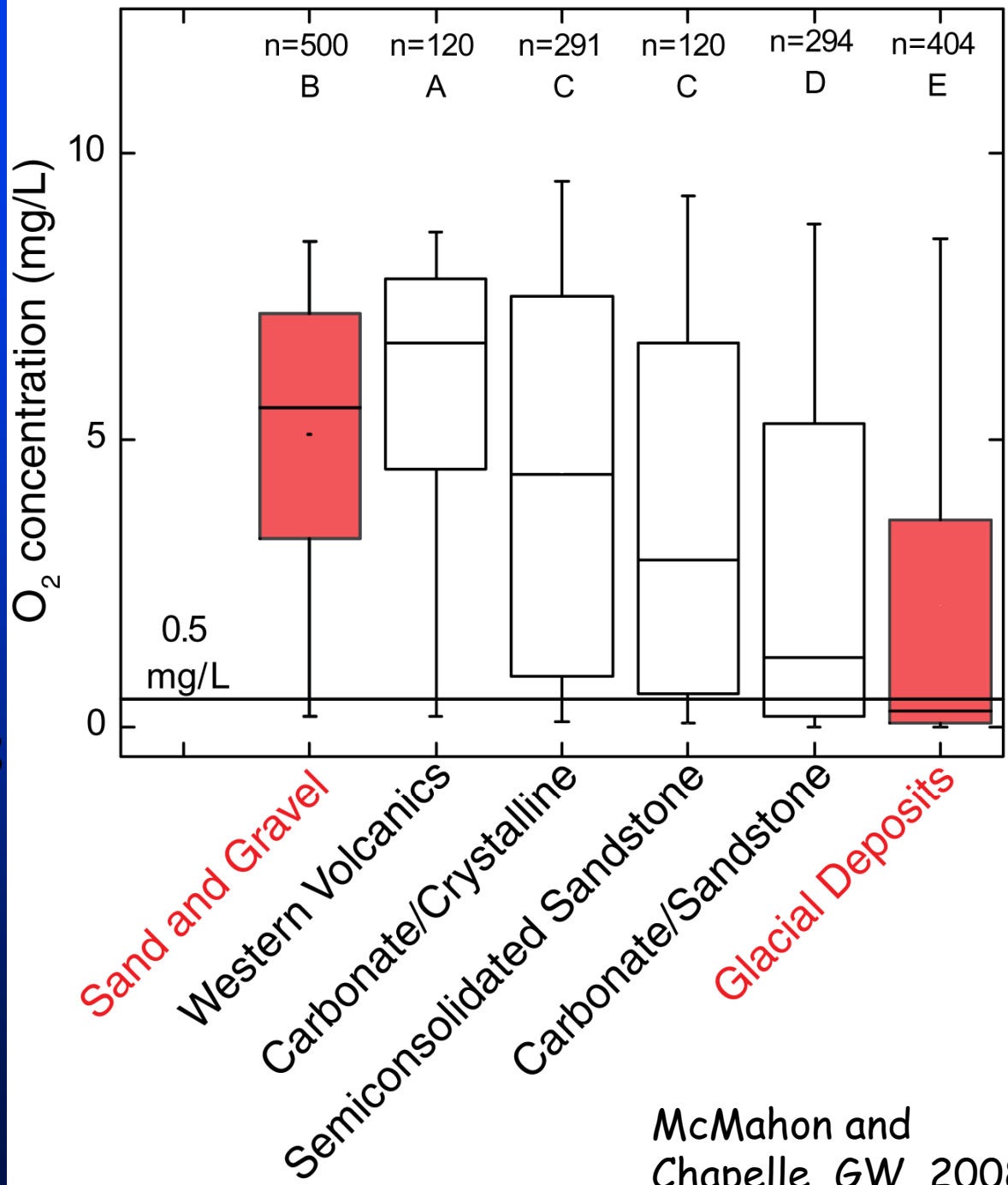
Most shallow aquifers are oxic



USGS

McMahon and Chapelle, GW, 2008

Oxic conditions persist for 1000's of years in sand and gravel aquifers or change over short distances in glacial deposits



McMahon and Chapelle, GW, 2008

USGS

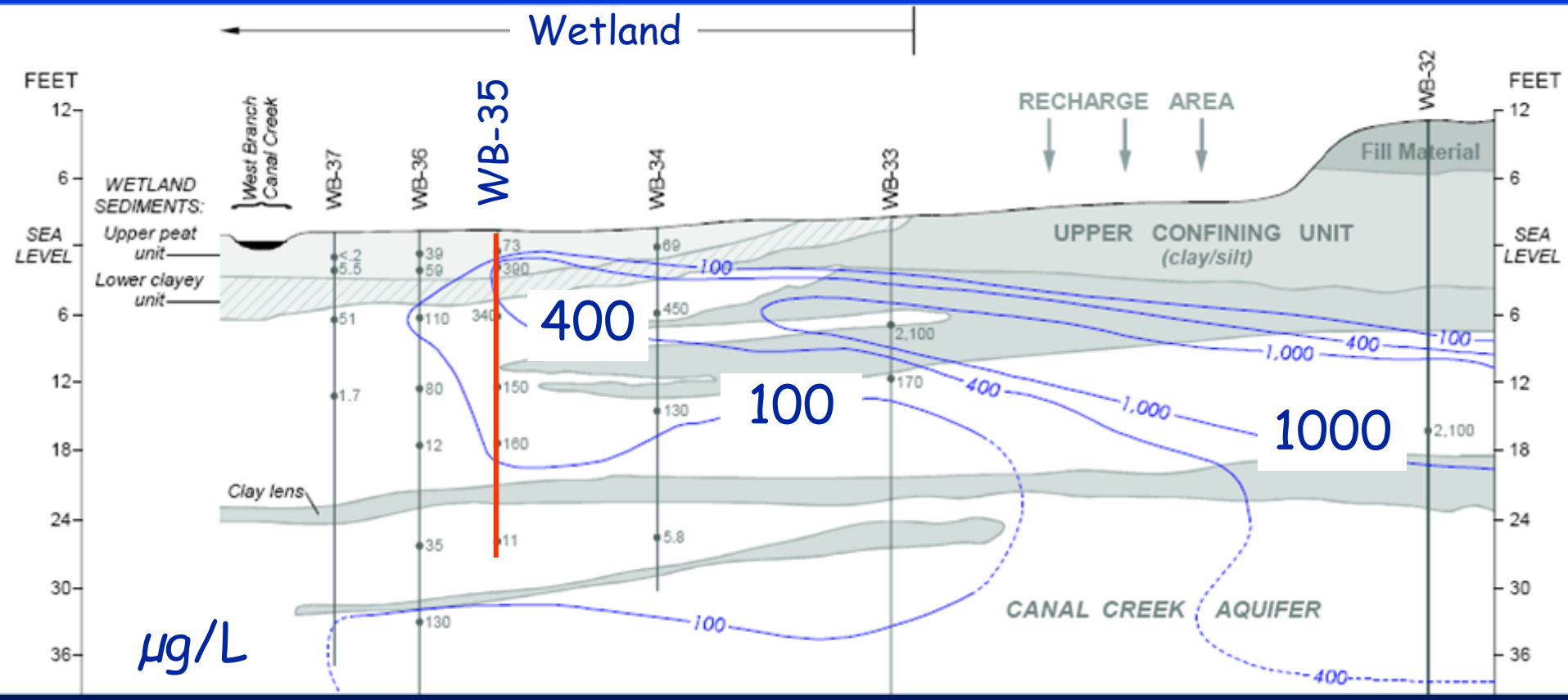
Progress in understanding has been made at West Branch Canal Creek, Aberdeen Proving Ground, MD

Source: Michelle Lorah, USGS, MD

USGS WRIR 97-4171

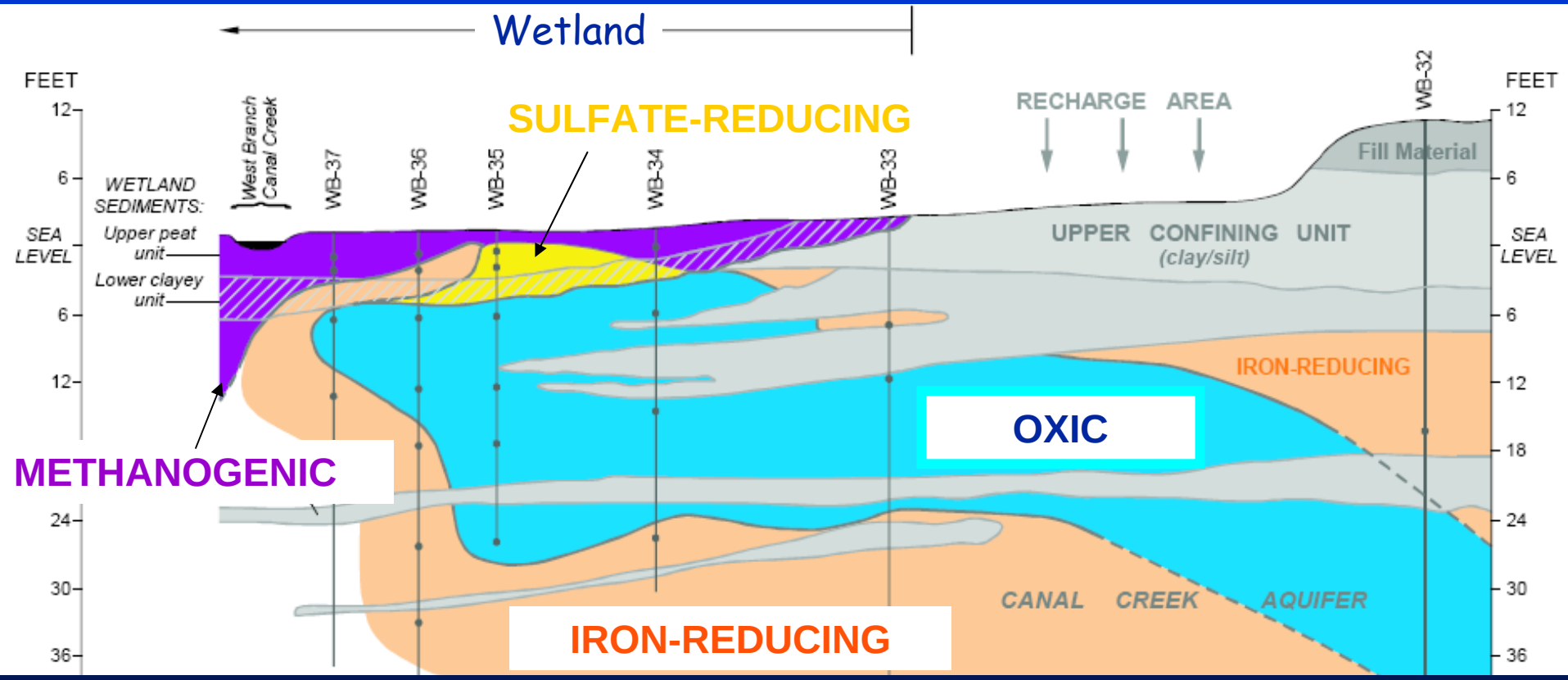
USGS

VOC's show little change until the plume reaches the anaerobic wetland



Lorah et al., 1997, USGS WRIR 97-4171

Methanogenic conditions are present only in the wetland



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Lorah et al., 1997

Progress in tools

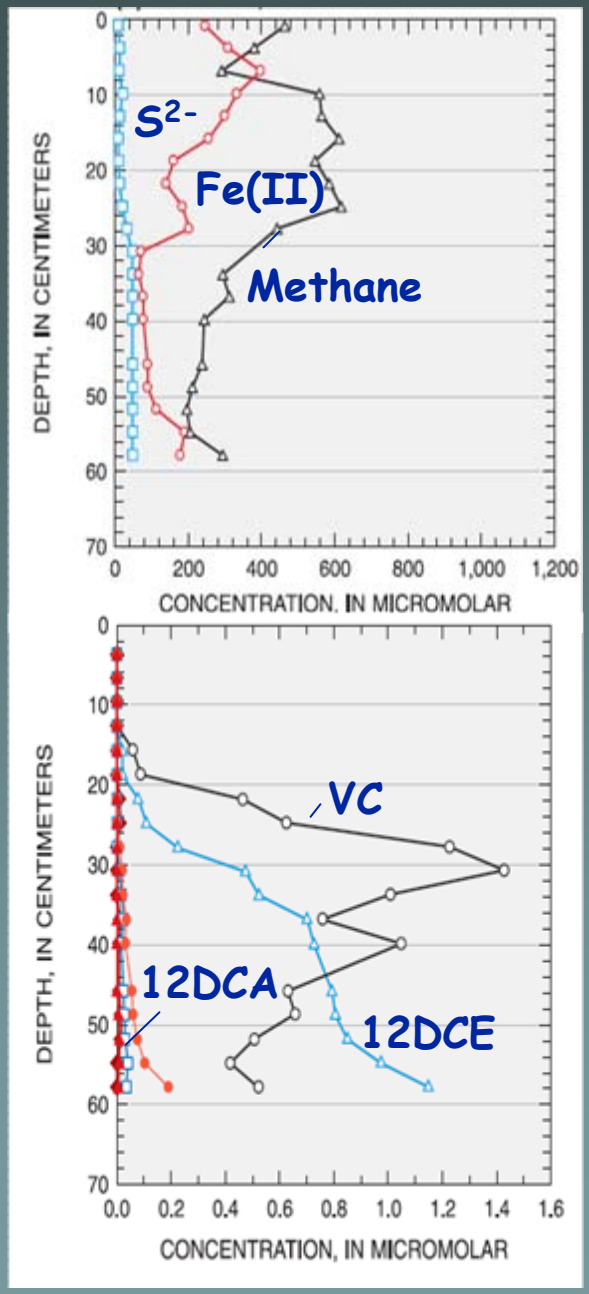
Peeper Samples

Lorah et al., 1997

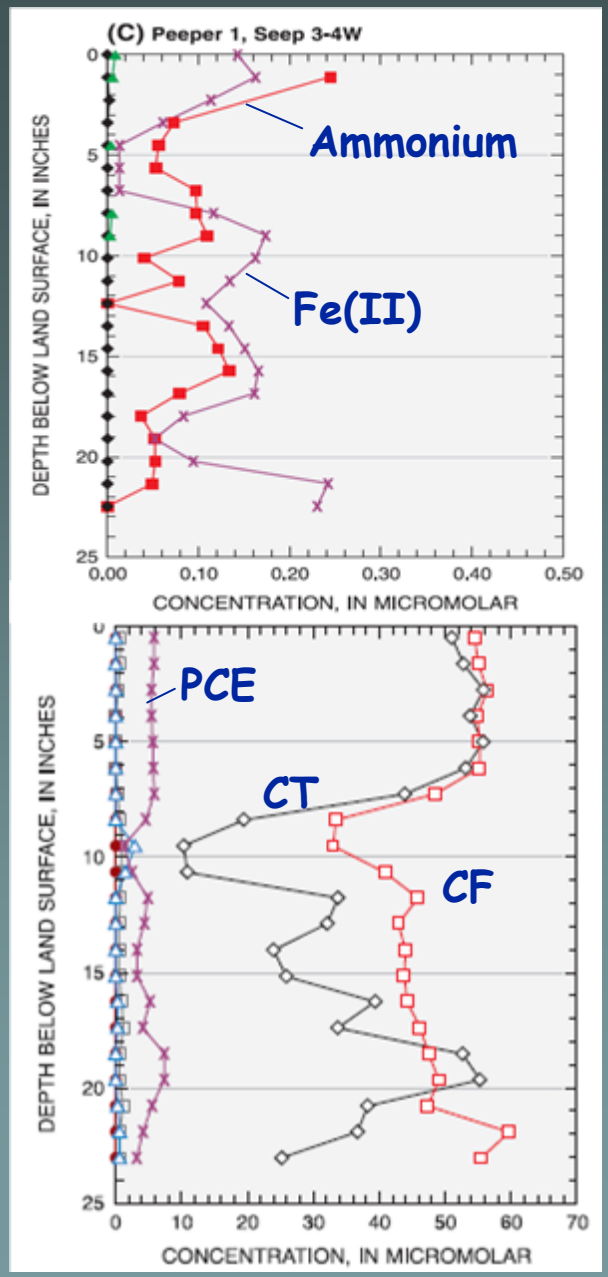
USGS

Upward flow

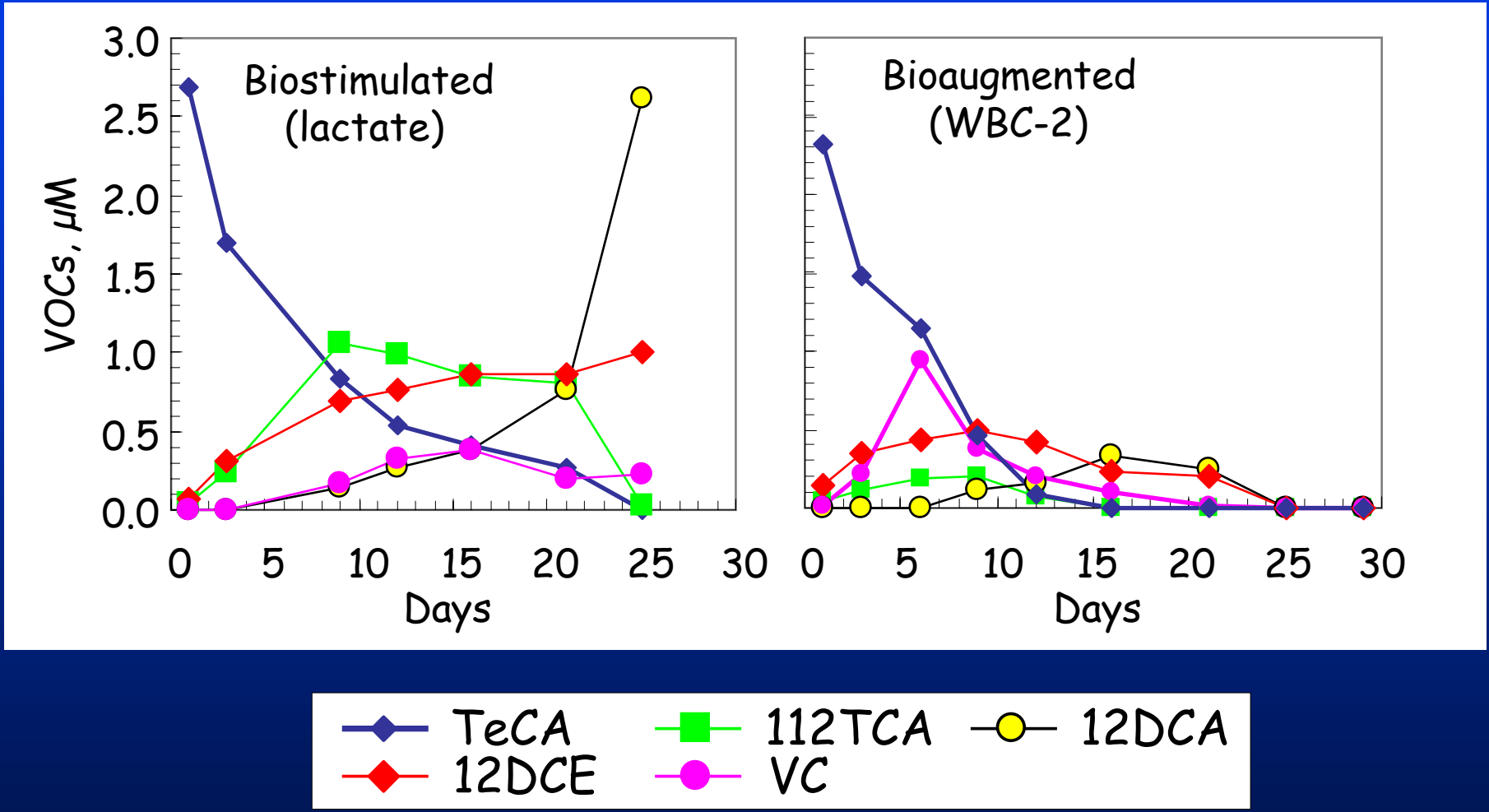
NON-SEEP AREA



SEEP AREA



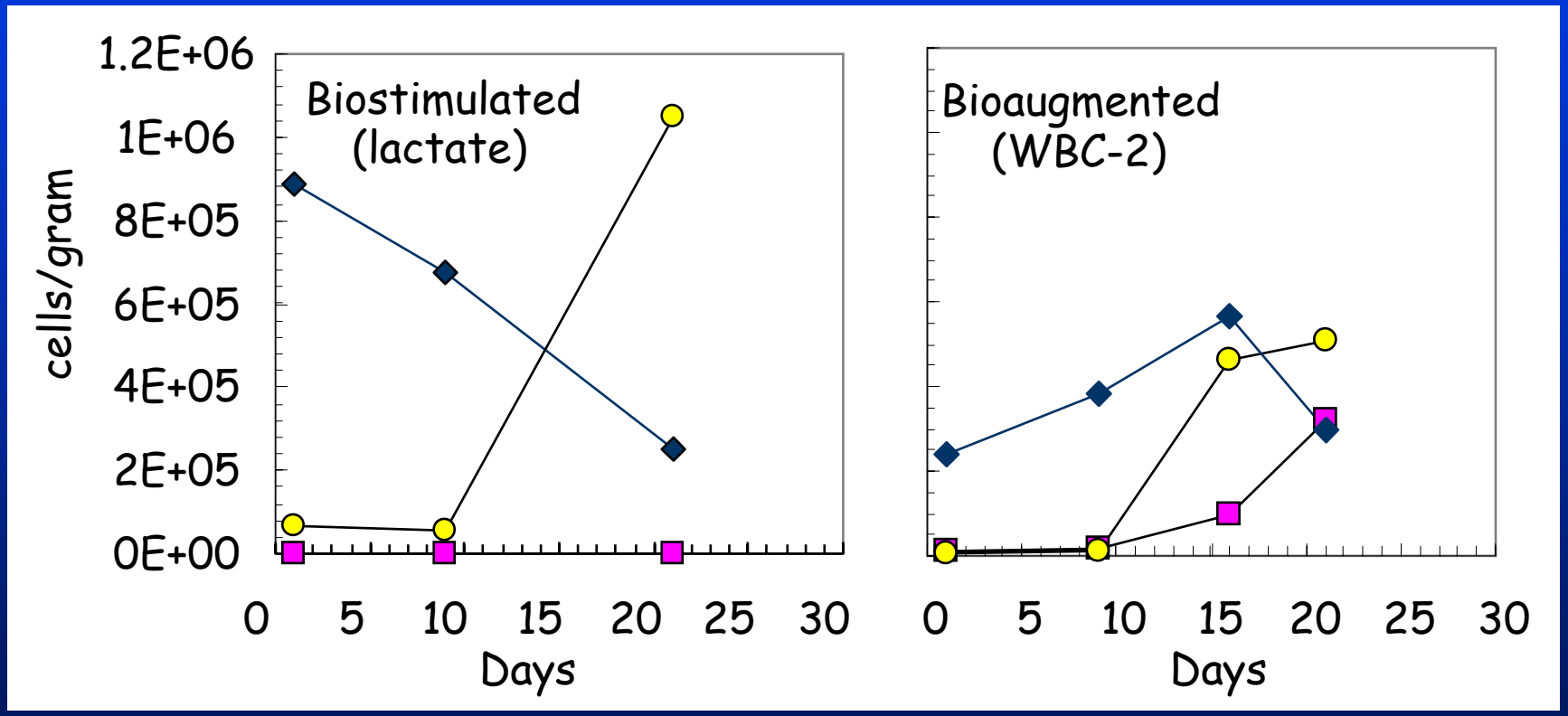
Progress: Mixed culture from the non-seep site (WBC-2) produces complete mineralization



Lorah et al., 1997

USGS

Dehalococcoides population expanded onl in the bioaugmented treatment



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Lorah et al., 1997

Challenge 2: NA Timeframe is long

Retrospective Study of Closed Leaking Underground Storage Tank (UST) Sites in Wisconsin

A.M. Pelayo, T.A. Evanson
Wisconsin DNR

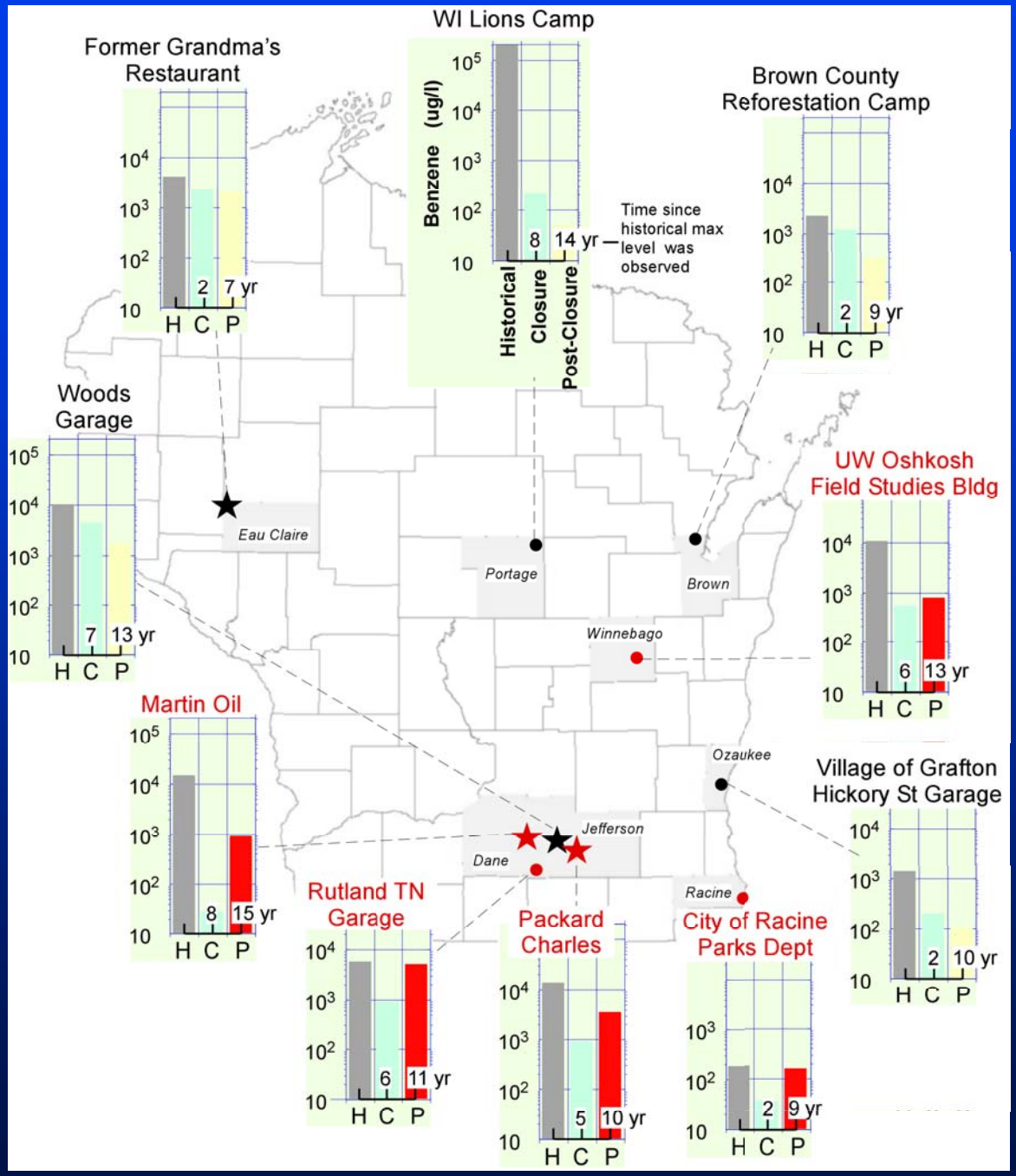
J.M. Bahr & M.E. Gordon, U of WI

10 post-closure field sites

http://gsa.confex.com/gsa/2008AM/finalprogram/abstract_149663.htm

WISCONSIN
DEPT. OF NATURAL RESOURCES

Half the sites had higher benzene than the value at closure



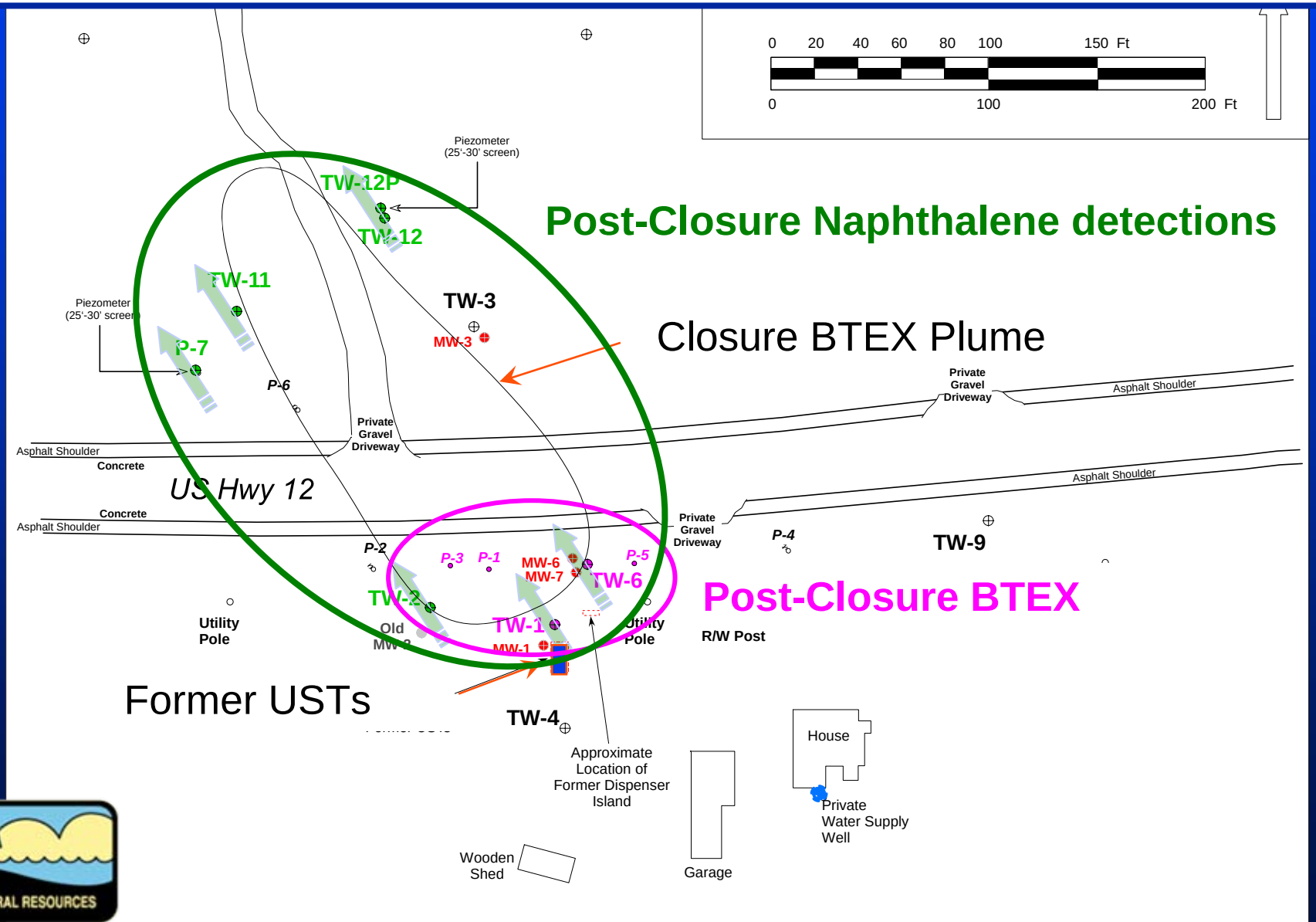
Red

Post-Closure > Closure

WISCONSIN DEPT. OF NATURAL RESOURCES

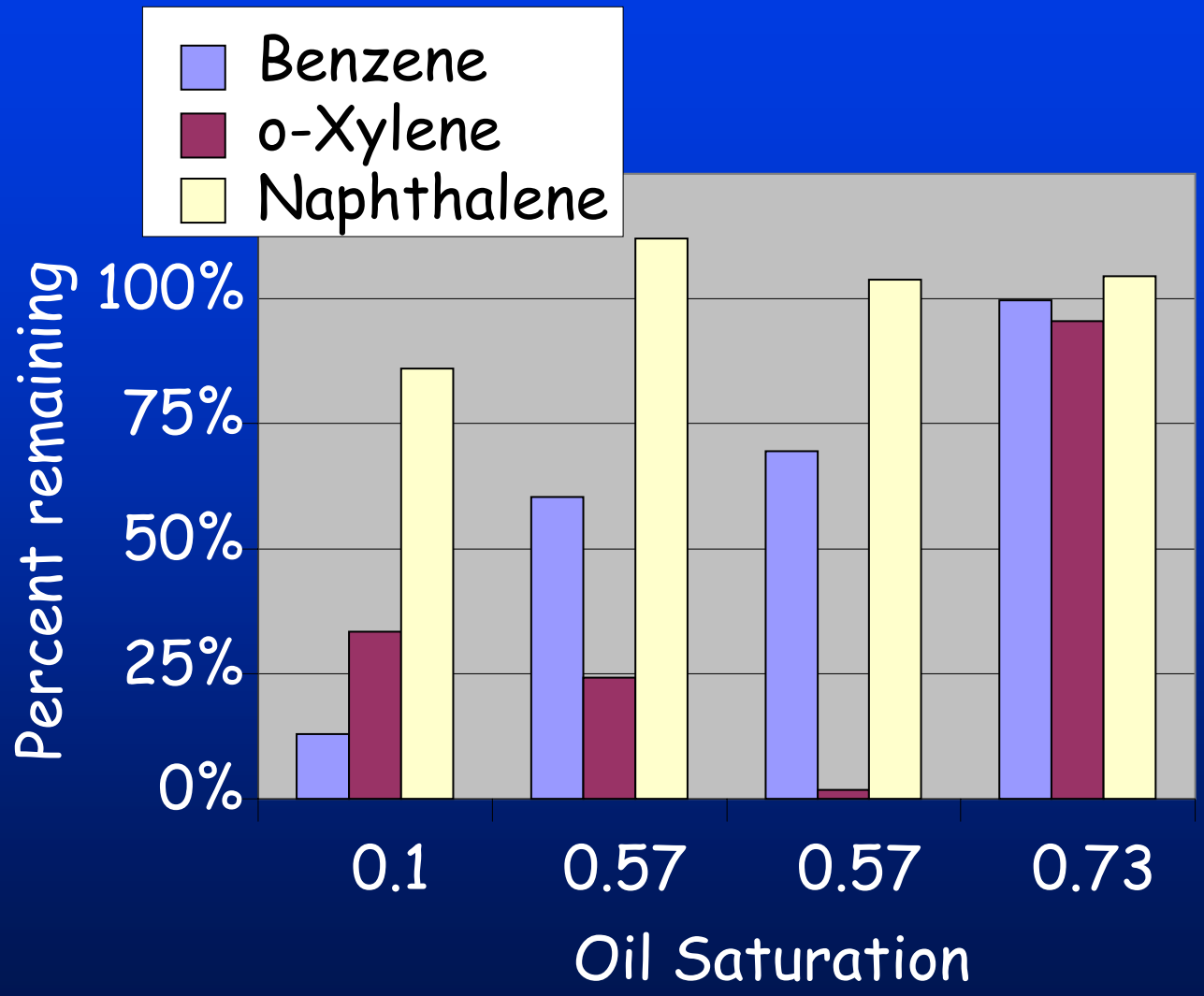
Benzene plume more spatially constrained

Naphthalene levels at the source wells as high as *historical* max, <u>and</u> plume extended farther from the source.



WISCONSIN DEPT. OF NATURAL RESOURCES

Bemidji crude oil after 30 years



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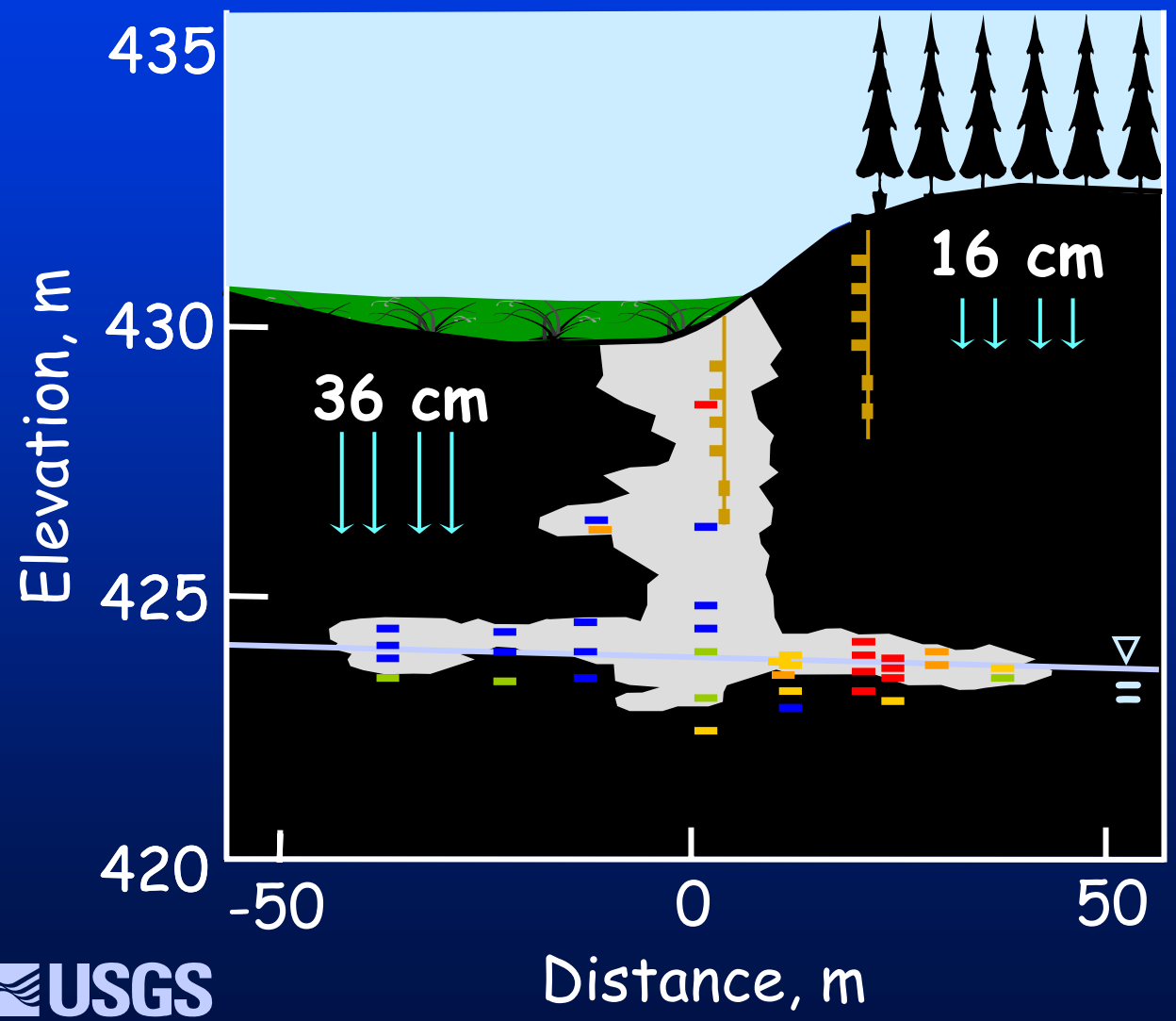
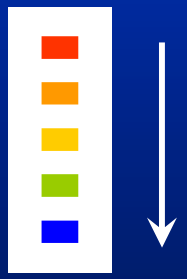
Baedecker et al. poster

Progress: Degradation rate is greater where higher recharge carries nutrients



2002
Precipitation
60.1 cm

Least degraded



Most degraded

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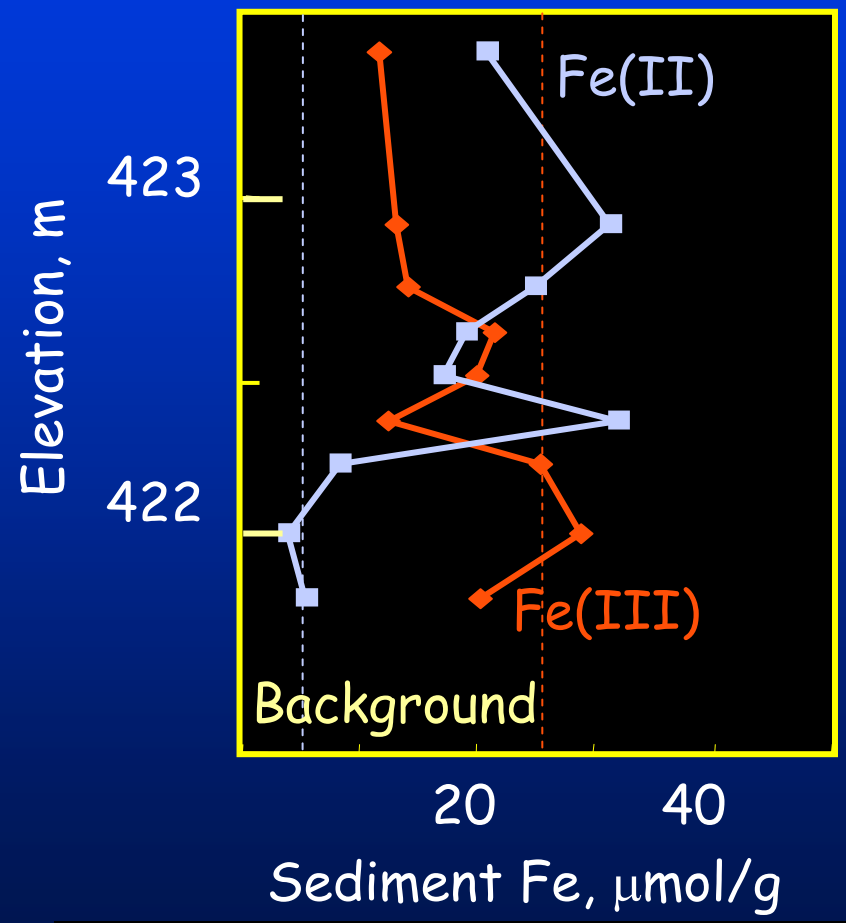
Progress mass balance: Models now account for LNAPL, water, solid and gas phases

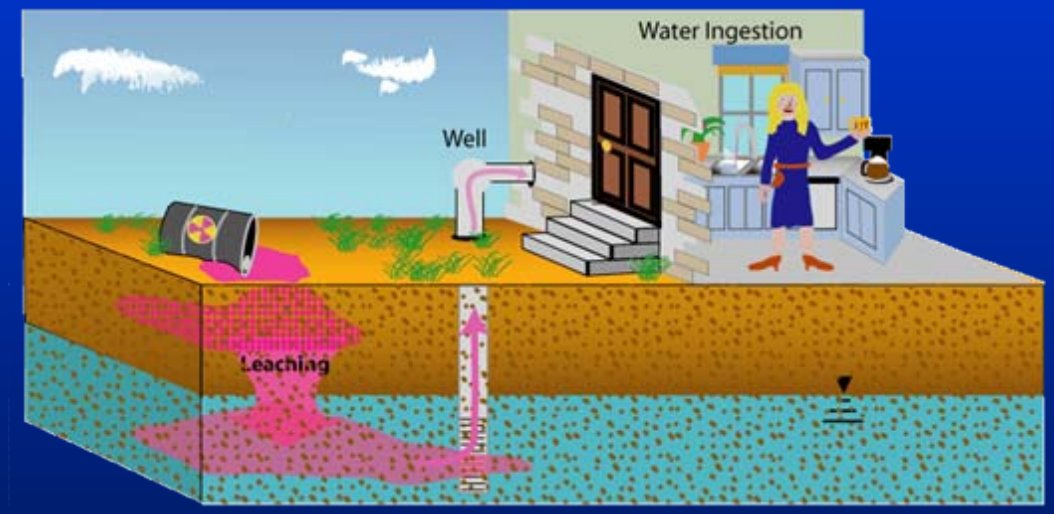
Methane > saturation



Solid Fe(III) and Fe(II)

Challenge 3: Transport may outpace reaction and occur by unexpected paths

- Transport mechanisms and paths must be thoroughly understood
- Governs monitoring location and frequency
- Input for risk analysis



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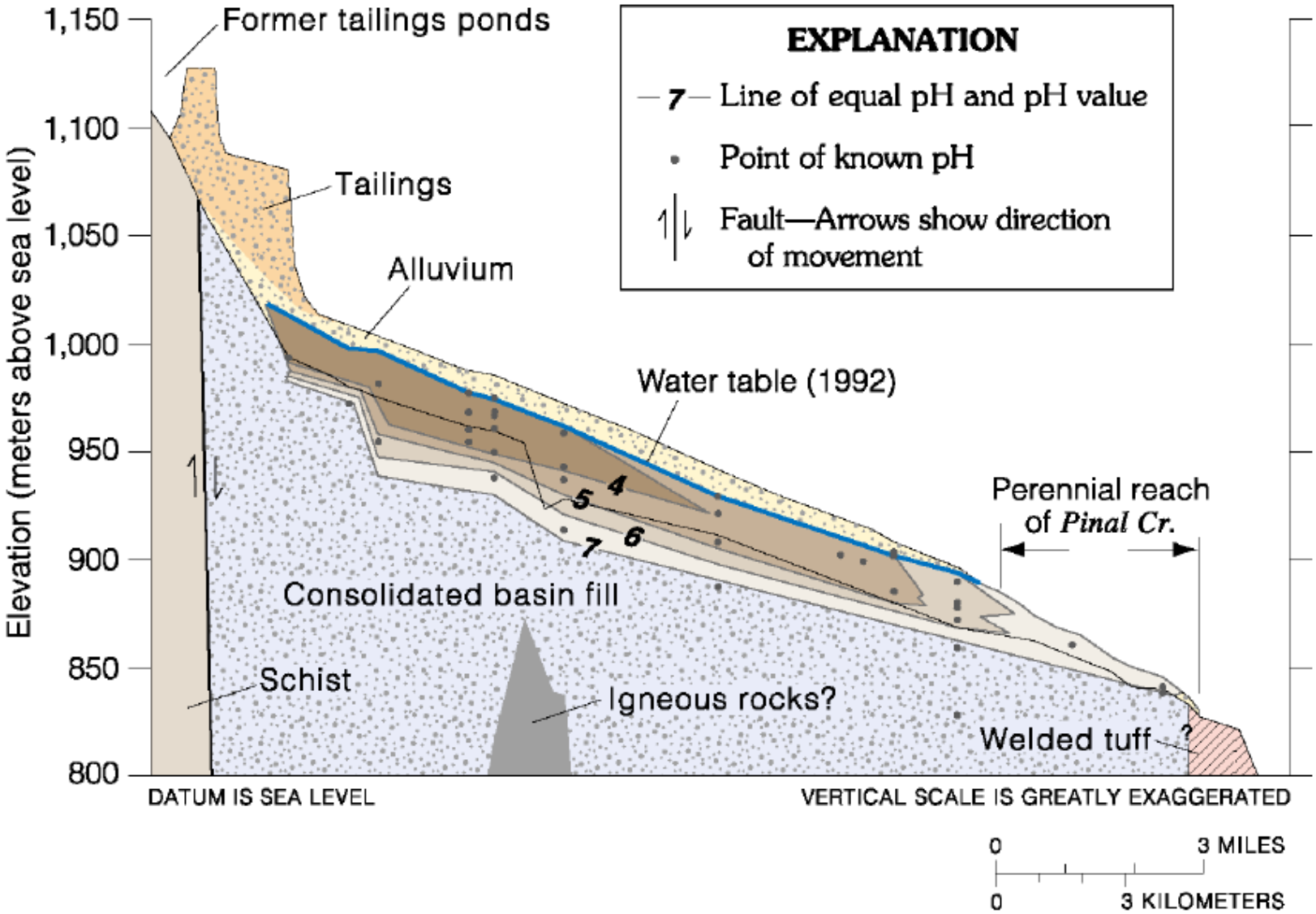
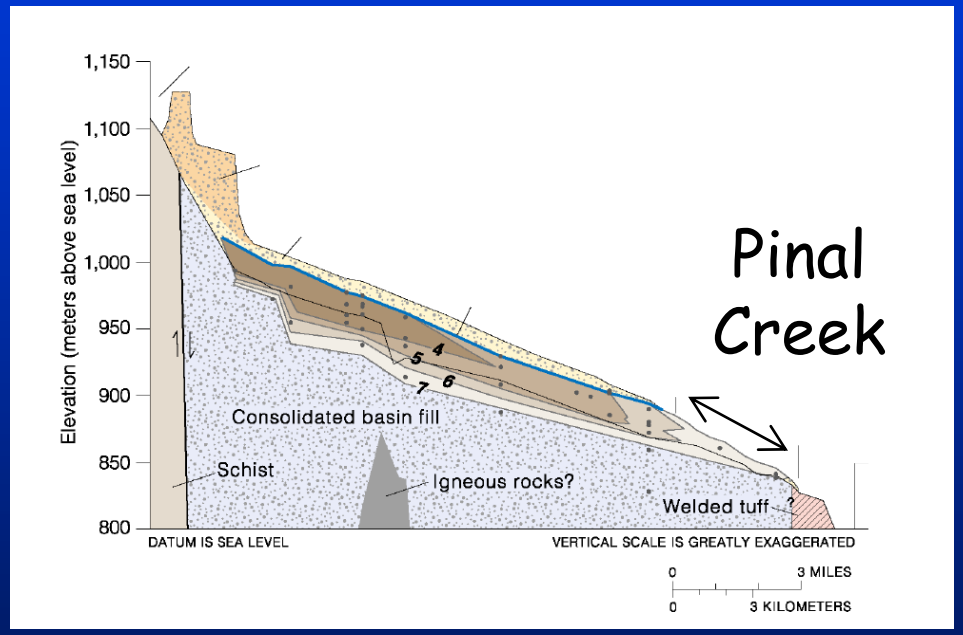
Pinal Creek Acid Mine Drainage Site



Acid-base reactions slow the plume to 1/7 the ground water flow

- Neutralization reactions in the carbonate aquifer precipitate the metals.
- These are redissolved as the acidity overwhelms the carbonate in the aquifer.
- Ultimately the plume discharges into Pinal Creek



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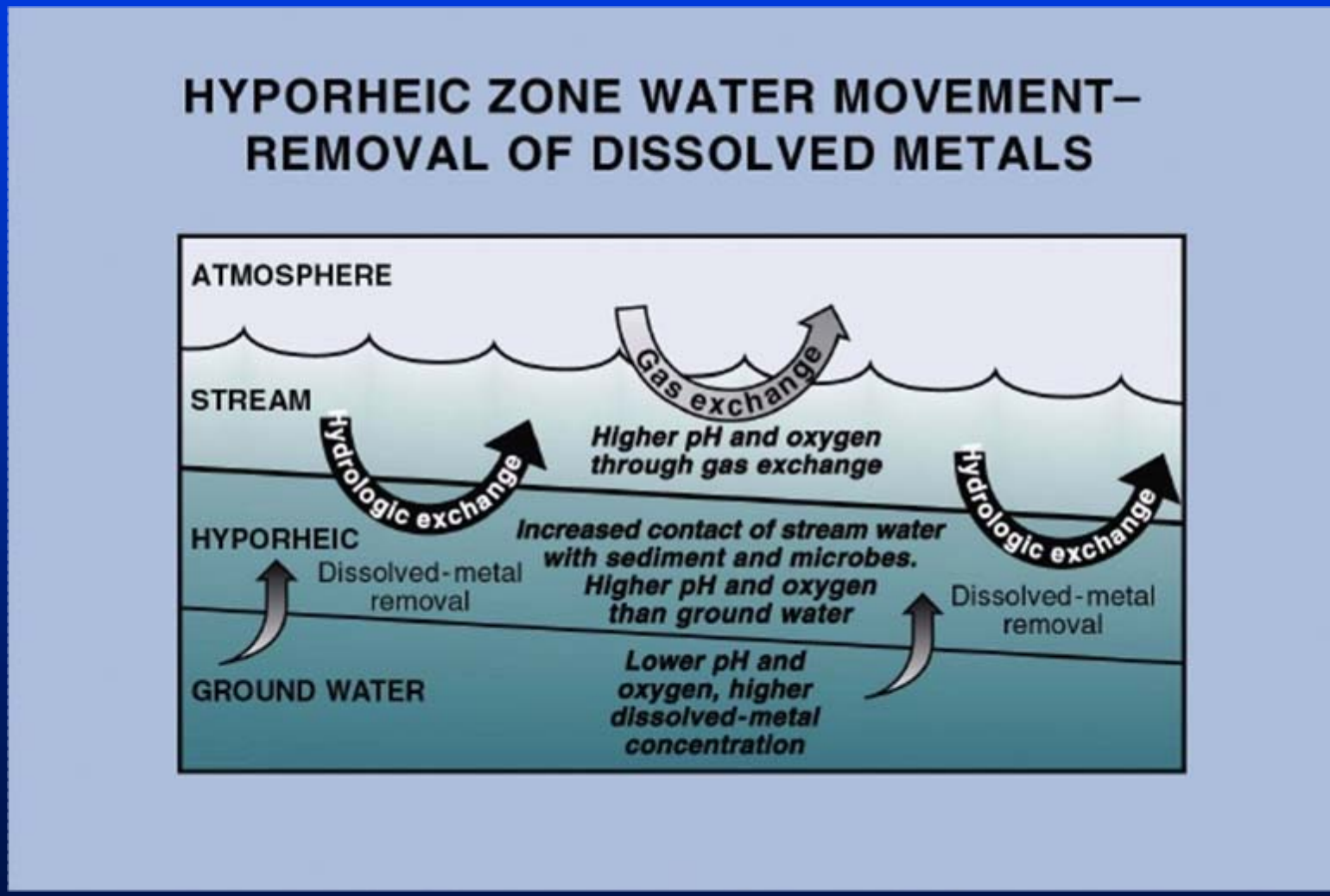
Progress: In the creek precipitation of manganese oxides immobilizes about 20% of the dissolved manganese

Sorption onto the manganese oxides also reduces the dissolved mass of nickel, zinc, and cobalt in the stream by 12-68%



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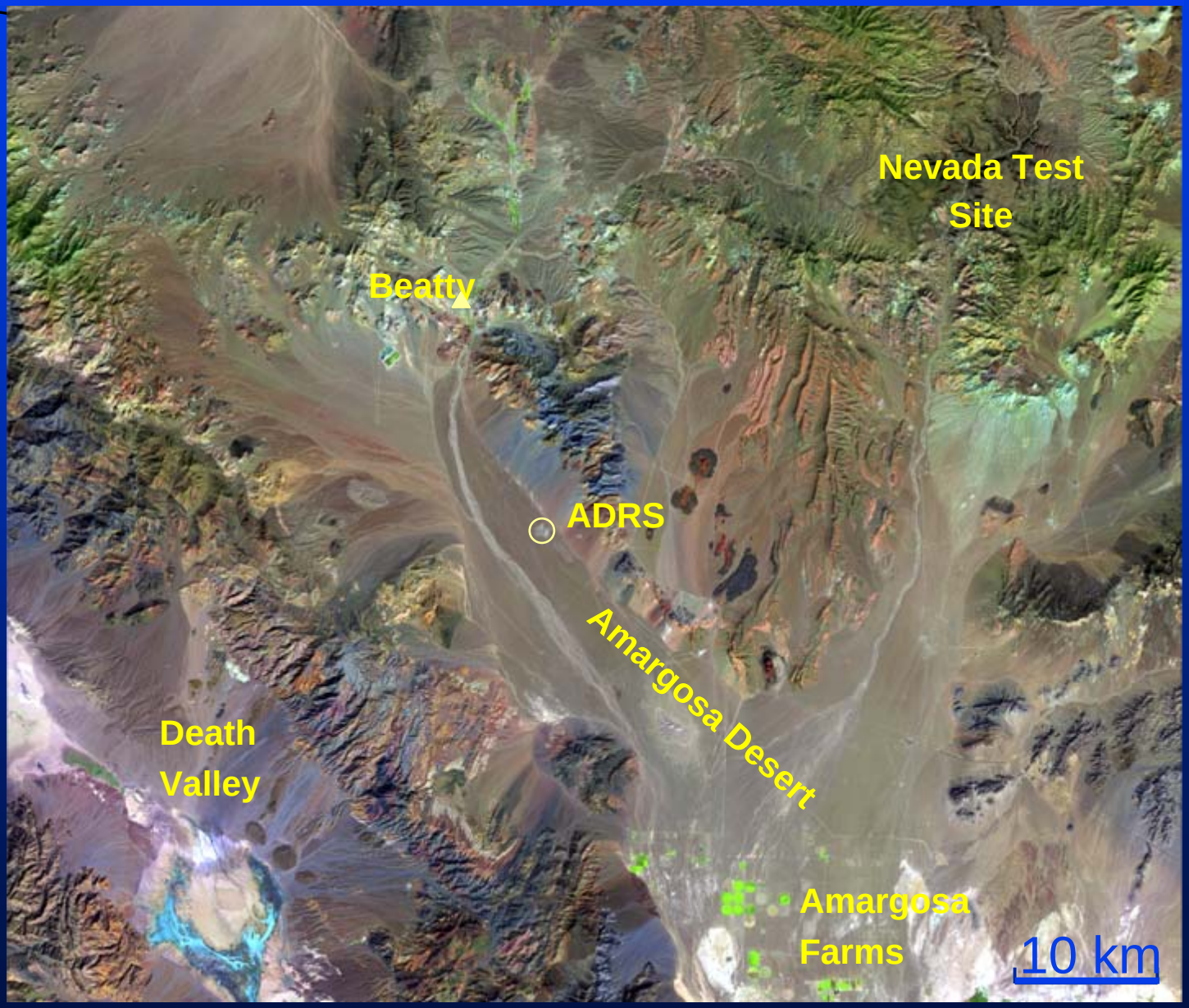
Transport in the vapor phase

Amargosa Desert Research Site (ADRS)



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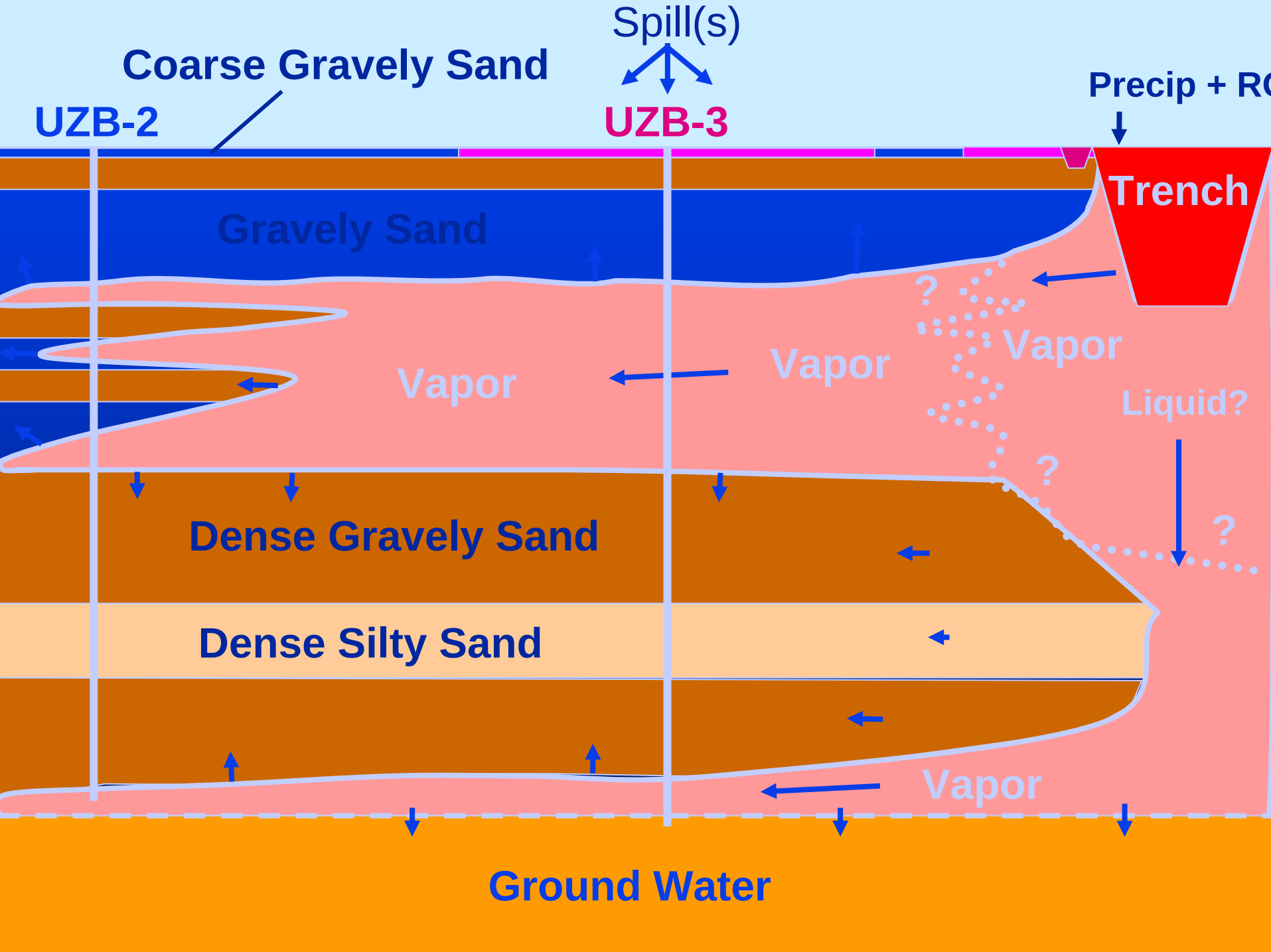
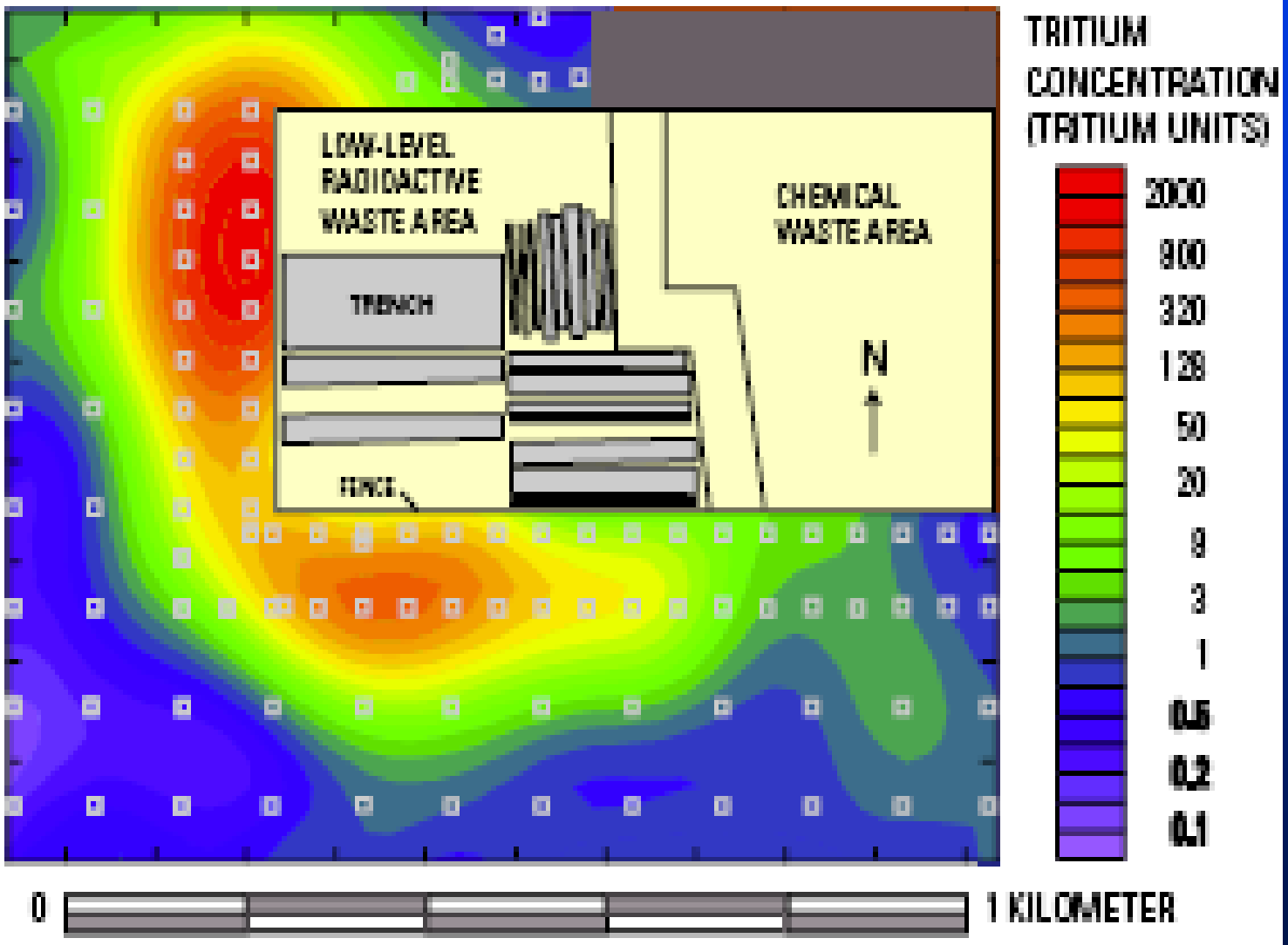

Spill(s)
Coarse Gravely Sand
UZB-2
UZB-3
Precip + RO
Trench
Gravely Sand
?
Vapor
Vapor
Vapor
Liquid?
?
?
Dense Gravely Sand
Dense Silty Sand
Vapor
Ground Water

Progress: the tritium plume was mapped from creosote plants



Summary and conclusions

- NA is a knowledge-based remedy requiring thorough process understanding
- New tools have greatly improved understanding of localized reactions
- Use of models can better quantify timeframes and NA capacity
- Understanding of vadose zone migration is improving

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Future research goals

- How physical processes control 3-D transport:
  - Pathways
  - Migration rate
- Elucidate Reactions
  - Major and emerging contaminants
  - Tie microbial consortia to reactions
- Improve mass balance techniques
  - Timeframe
  - Sustainability

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