Managing a Large Dilute Plume Impacted by Matrix Diffusion: MEW Case Study

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Outline

SITE CONDITIONS – A LARGE DILUTE PLUME

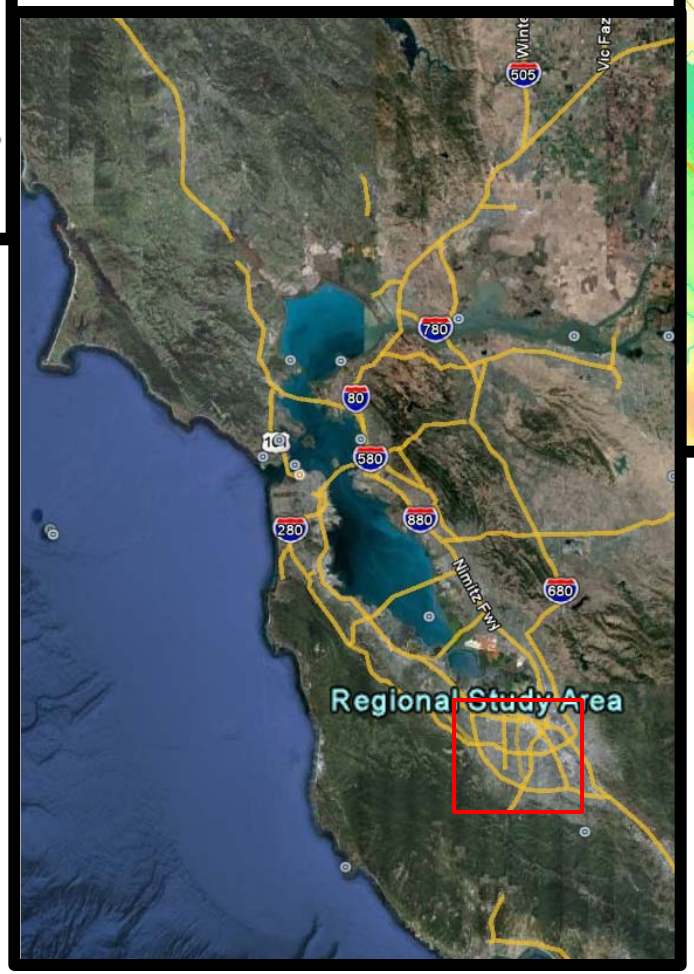
- Performance of Groundwater Remedy (25 years of P&T)
- Conceptual Model – Matrix Diffusion

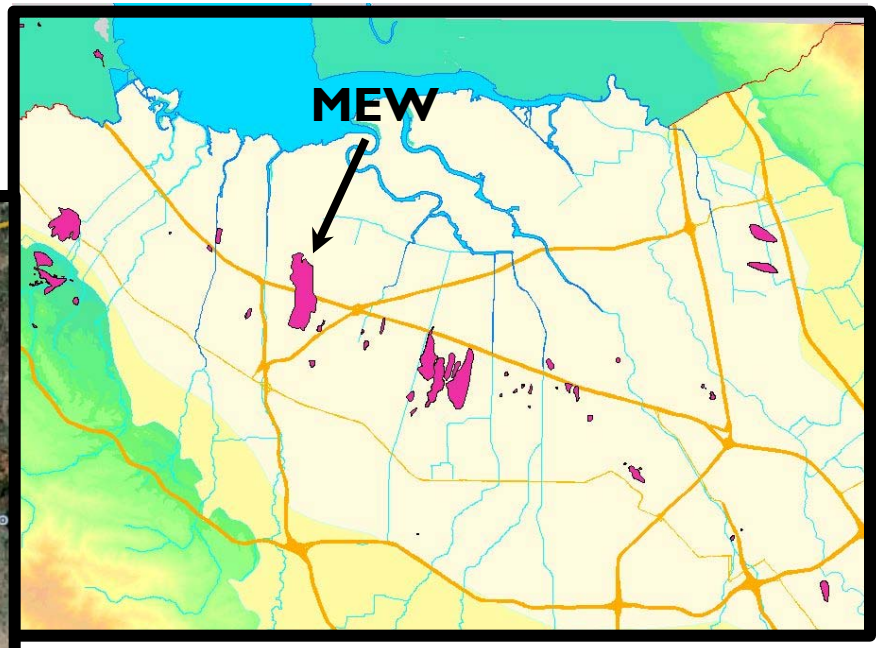
SITE MANAGEMENT

- EPA-Authored Focused Groundwater Feasibility Study (GWFS)
- Site Challenges to GWFS
    - Large Scale
    - Matrix Diffusion
- Clean-Up Time Evaluation

CONCLUSIONS

Site Location

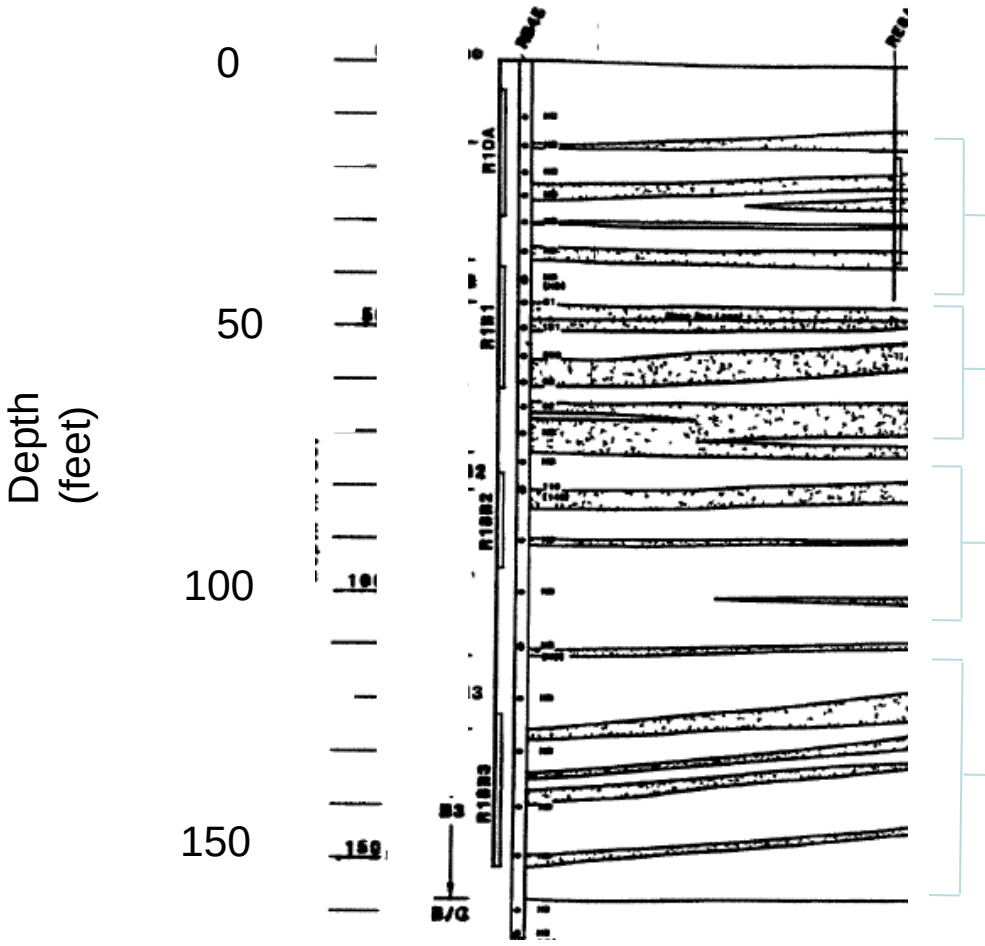




Middlefield-Ellis-Whisman (MEW) Area

Mountain View, CA

Simplified Cross Section



A Zone 10 to 45 feet

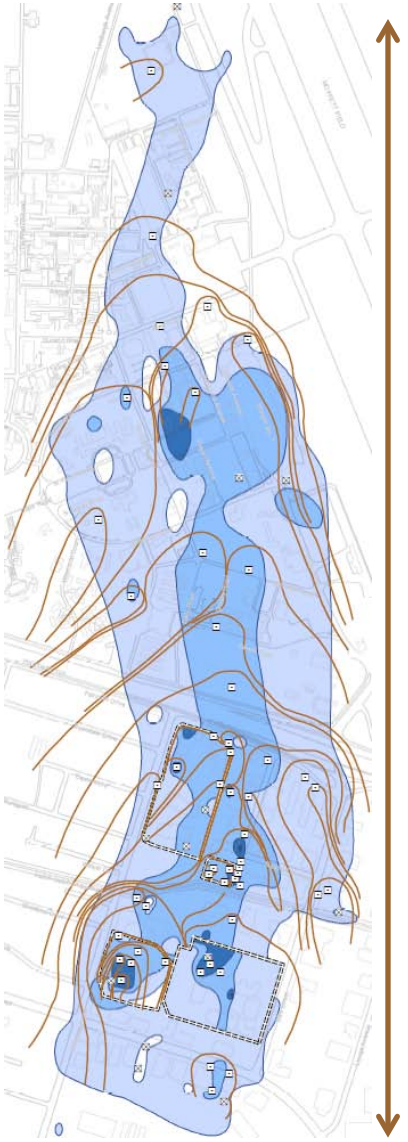
B1 Zone 50 to 75 feet

B2 Zone 75 to 110 feet

B3 Zone 120 to 160 feet

Deeper Zones > 200 feet

MEW Summary



- 1981: Investigations and P&T began
- 1989 ROD: SVE, excavation, slurry walls, P&T
- Site Characteristics:

COCs: Chlorinated solvents (TCE)

Affected Depth: 110 ft bgs (A and B1 zones)

Plume length: 1.5 miles

Extraction Wells: 100+

Combined Flow Rate: 500 gpm

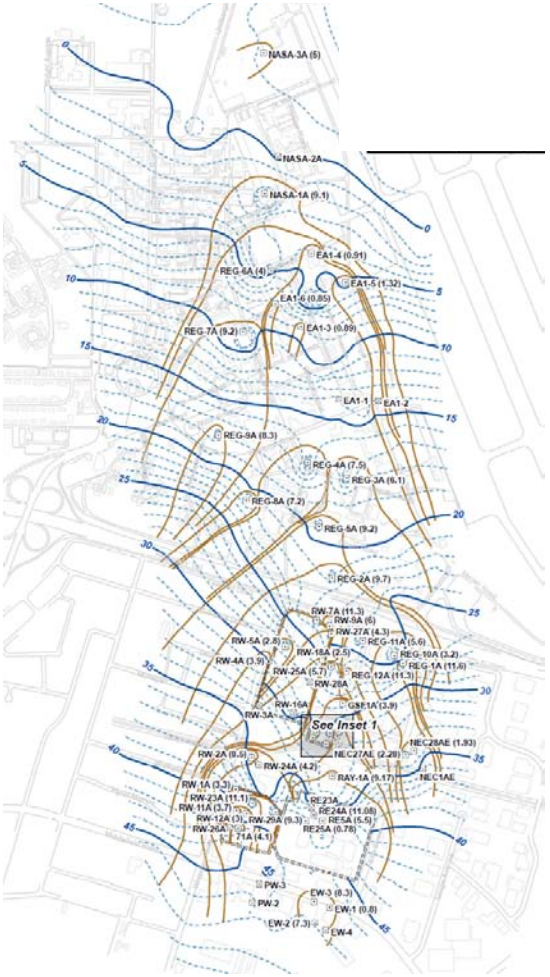
Annual Mass Removal: 2,500 lbs VOCs

Cumulative Mass Removal: 97,000 lbs VOCs

Vapor Intrusion ROD Amendment

- ROD Amendment was adopted by EPA in August 2010
  - VI remedy was selected
  - New Remedial Action Objective was included:
    - Accelerate VI source reduction in shallow groundwater
    - Goal of source reduction – to minimize or eliminate need for VI remedy

Pump &Treat Remedy
A Zone



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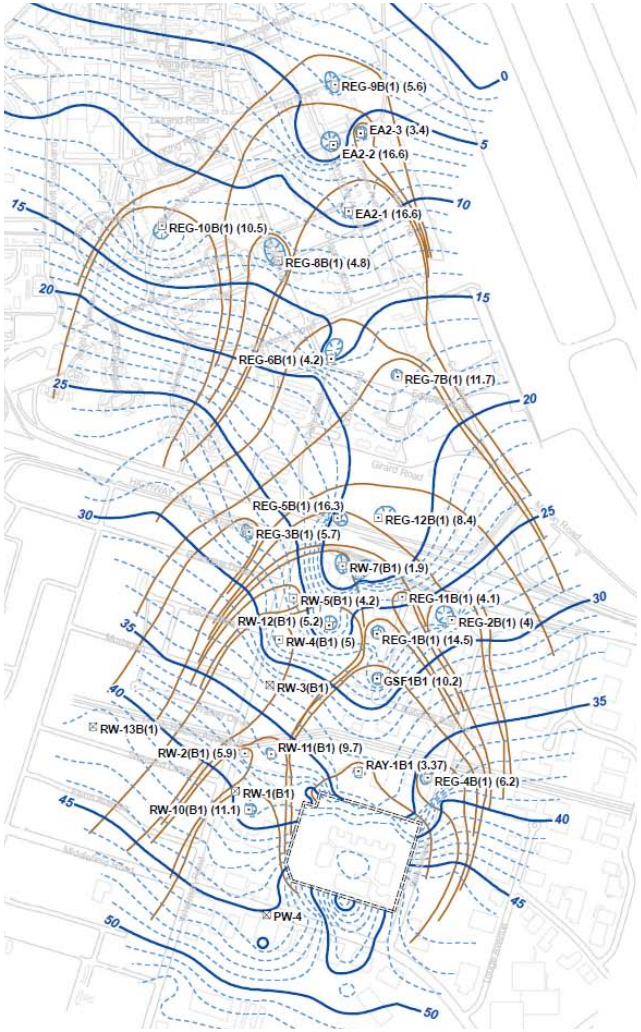
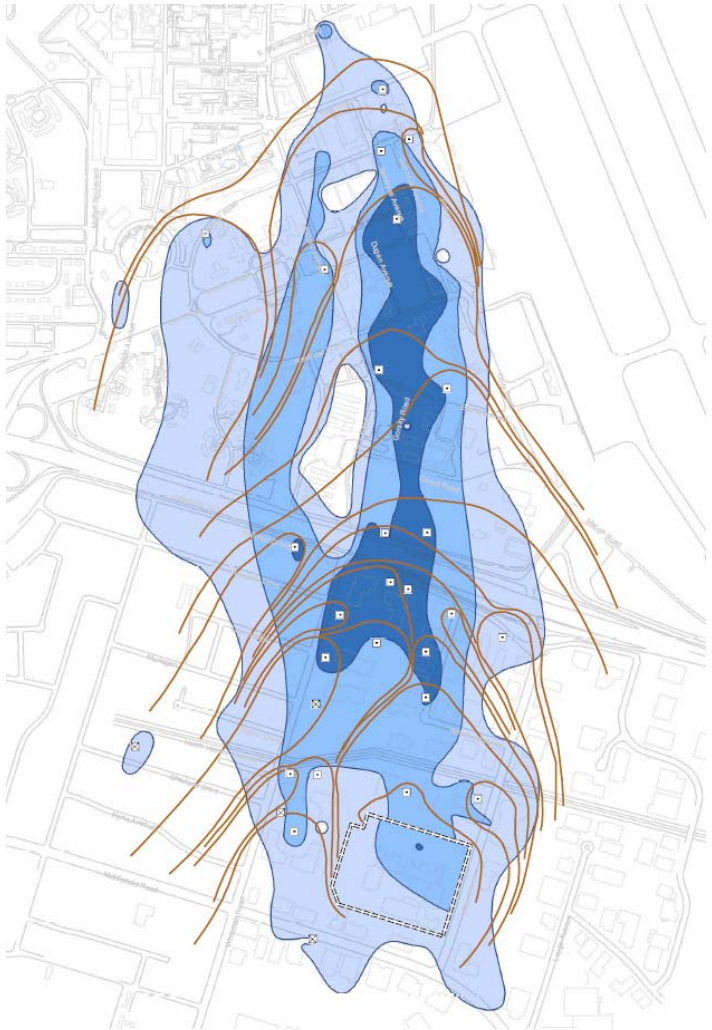
Pump &Treat Remedy
B1 Zone





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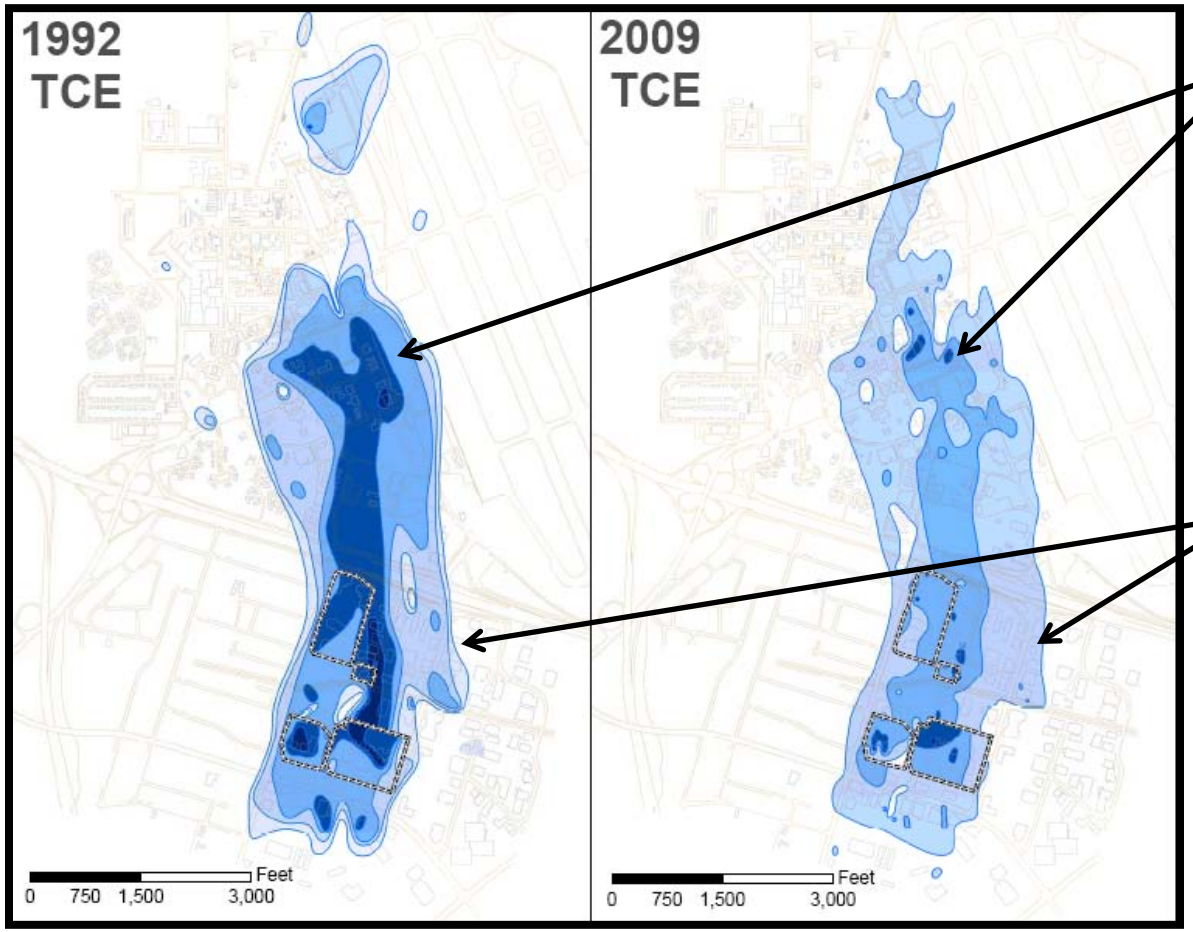
A-Zone Remedy Progress

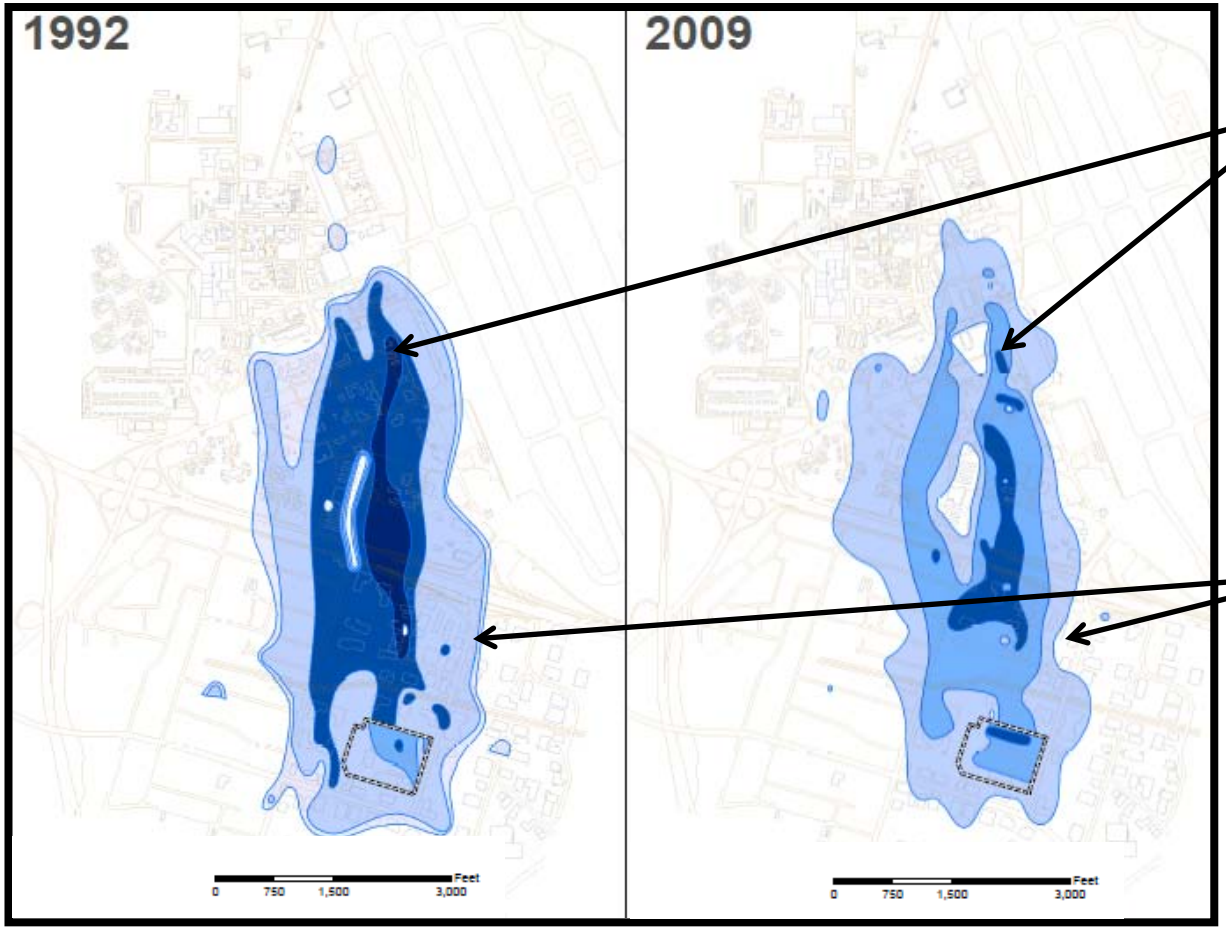


Large reduction in 1,000 µg/L and 10,000 µg/L footprints

Little to no observable reduction in 5 µg/L footprint

90% reduction in TCE dissolved plume mass

B1-Zone Remedy Progress



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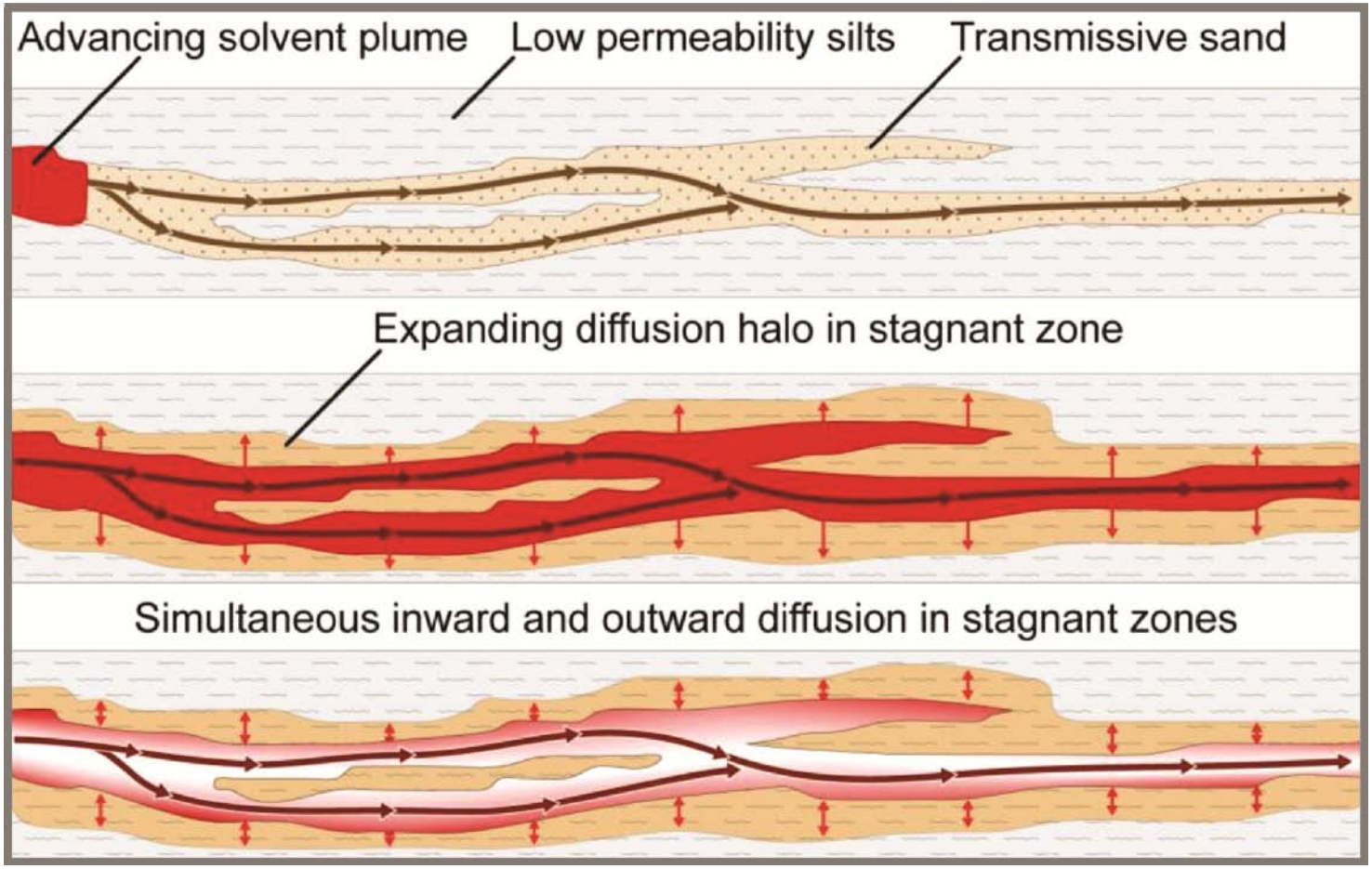
Conceptual Model
Mass in Storage

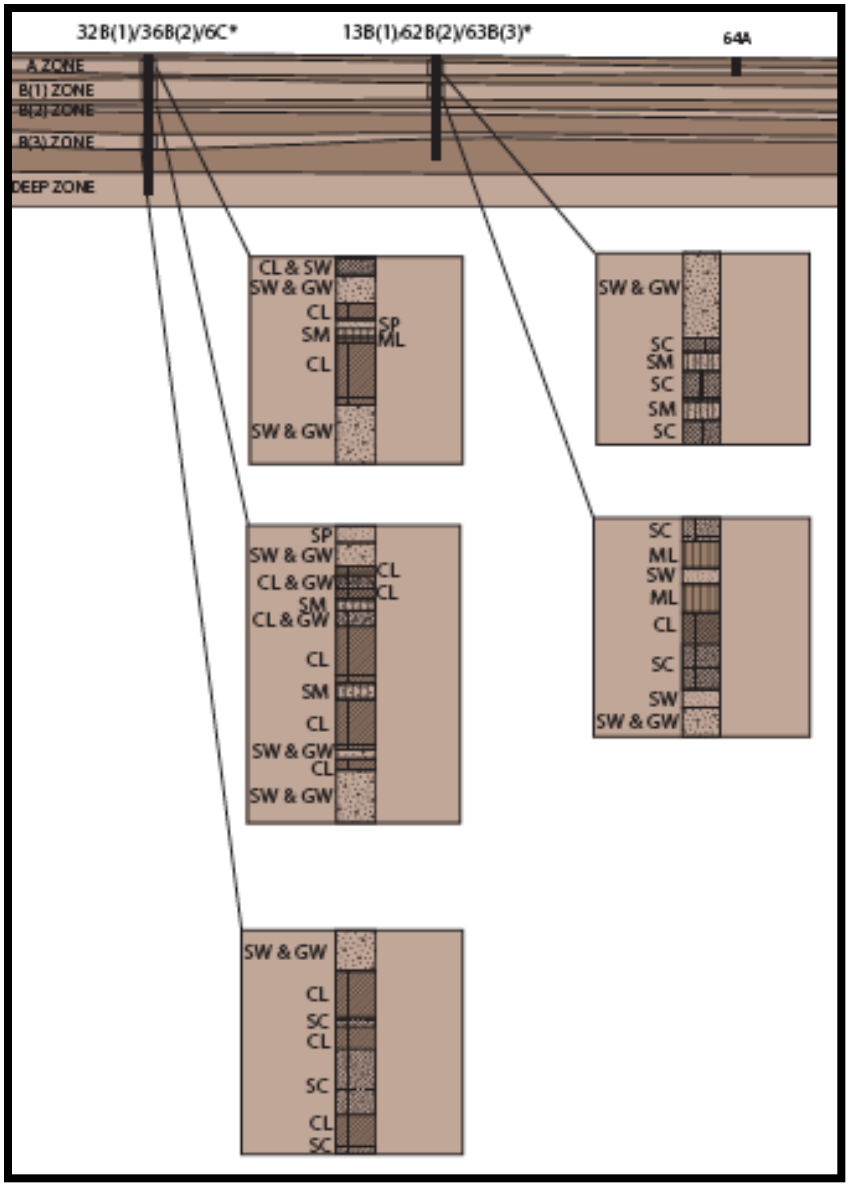
- During the 2002-2006 period, the combined P&T systems removed mass (16,000 lbs of TCE) more than 5 times greater than the rate of reduction in the dissolved TCE plume (2,800 lbs of TCE)
- Therefore, approximately 80% of TCE being removed by the P&T system (after more than a decade of pumping) is coming out of storage
- And, there must be significant mass stored (i.e. not in direct equilibrium with the mobile groundwater sampled in monitoring wells).
  - DNAPL? -- possible localized residual, source areas only
  - Matrix Diffusion? – widespread, historical dissolved plume

Matrix Diffusion



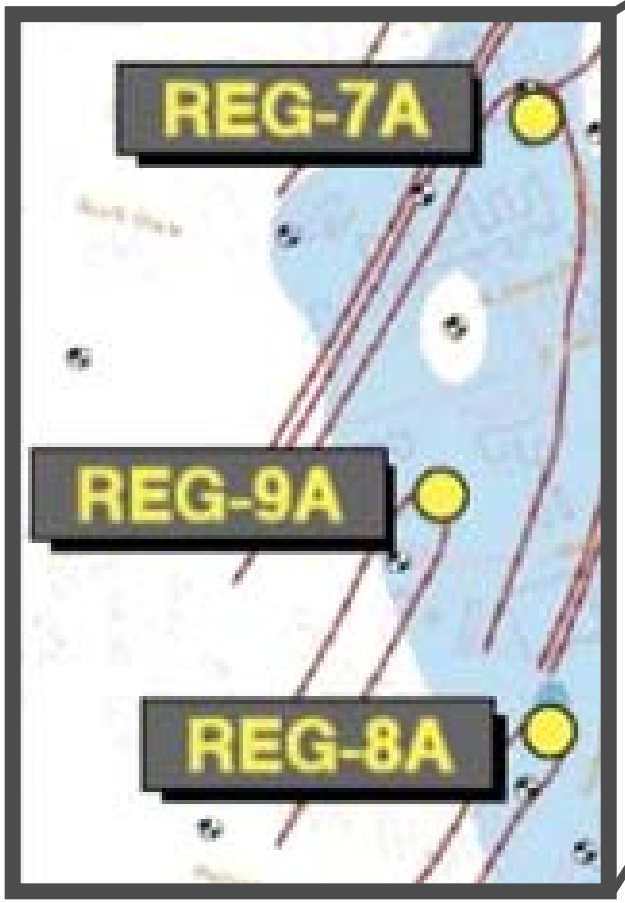
After NRC 2005

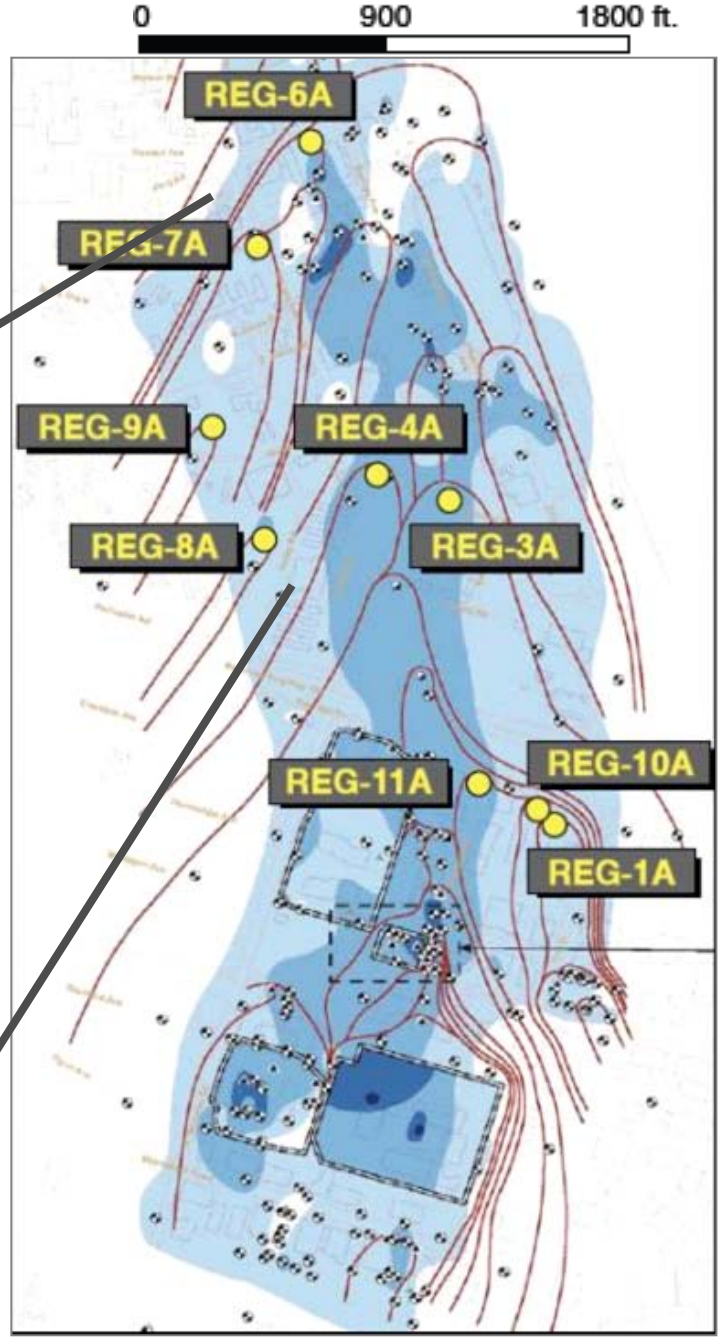
Evidence of Matrix Diffusion



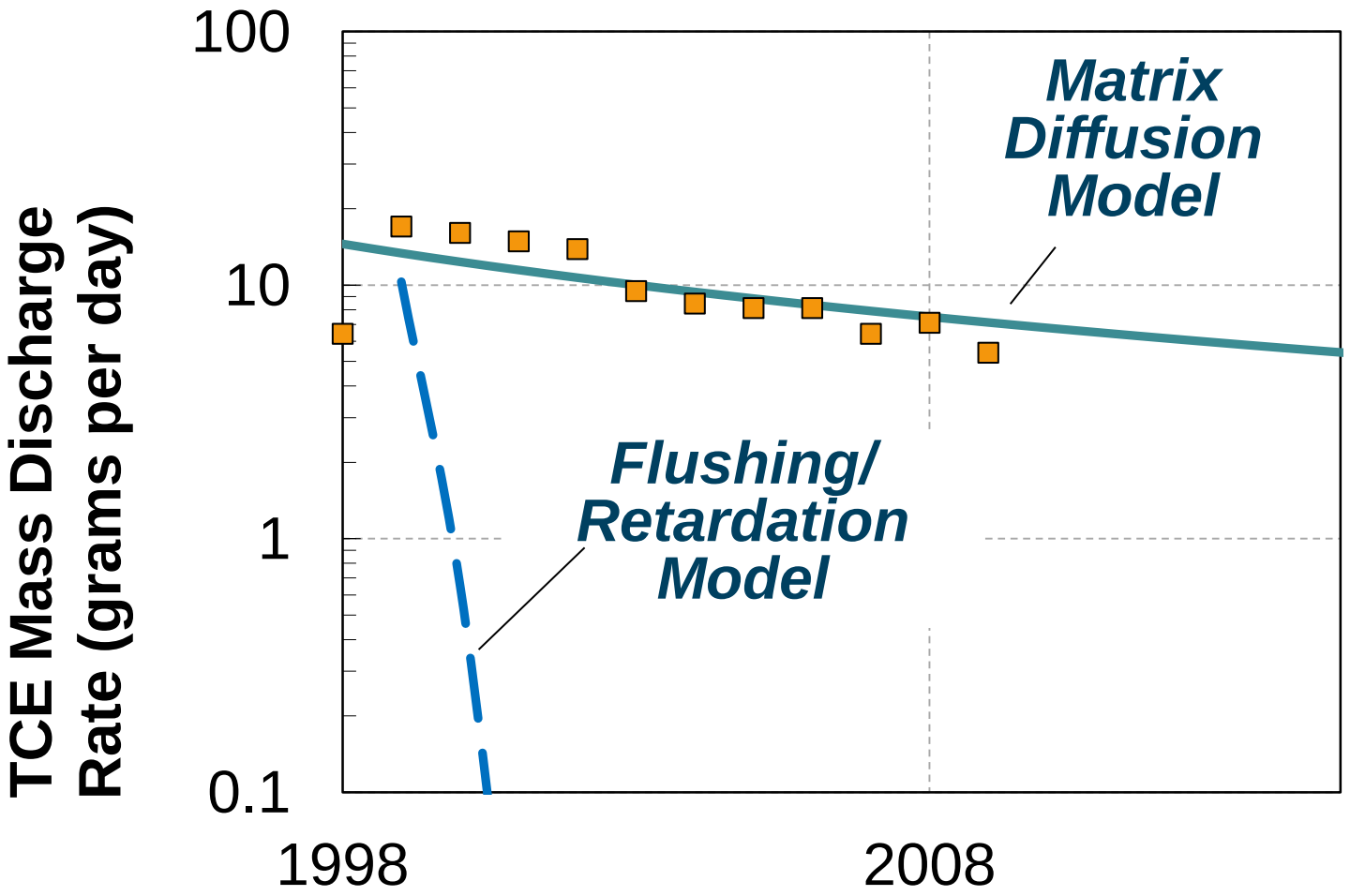
- Heterogeneity at every scale
- Site-specific retardation for TCE estimated in 1988: 6.5 to 12
- No plume detachment downgradient from controlled sources
- Matrix diffusion better explains observed extraction well data (Newell, et al.) … see following slides

Analyzed Extraction Wells With No Source Contact in Capture Zone





Applied “Square Root” Matrix Diffusion Model to Recovery Well REG-8A After 10 Years, 30 Pore Volumes of Pumping



"Square Root" Matrix Diffusion Model

$$M_D = \phi_{LowPerm} C_{SAT} L_p \left[\sqrt{\frac{R_{LowPerm} D_{effective}}{\pi t}} - \sqrt{\frac{R_{LowPerm} D_{effective}}{\pi (t - t')}} \right]$$

- M_D: **Mass Discharge** from Low Permeability Unit (grams per day)
  assuming no concentration in transmissive zone
  (no resistance to back diffusion)

- Low Permeability Unit Porosity, $\phi_{LowPerm}$ *(, $\phi_{LowPerm}$ =0.3)*
- Effective Diffusion Coefficient of Low Perm Unit, D_e
- Retardation Factor of Low Perm Unit, $R_{LowPerm}$ *(R=5.0)*
- Time Loading Started, years before simulation time, *t*
- Time Loading was Removed, years before simulation time *t'*

•Parker et al. (1994) adapted by T. Sale (AFCEE, 2007).

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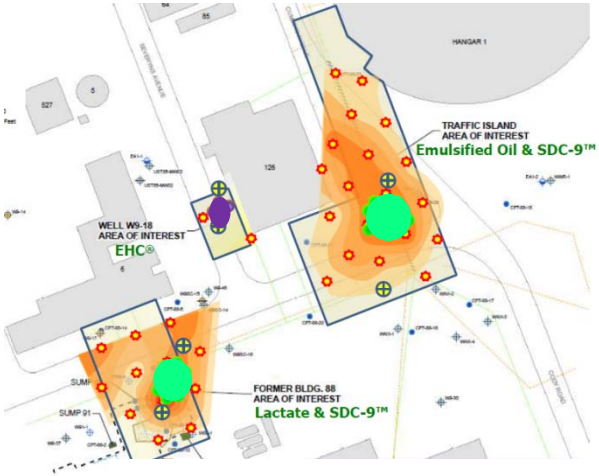
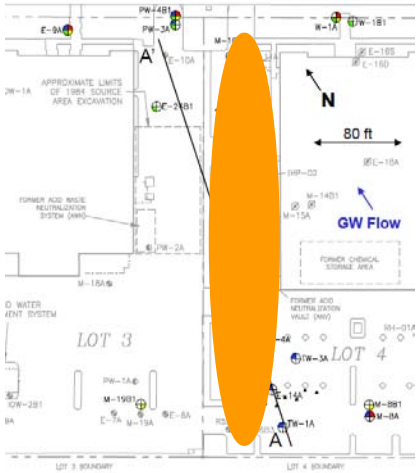
EPA-Authored Focused Groundwater FS

- Motivated by:
  - Technology advances
  - VI ROD Amendment
- Considers:
  - “Optimized” P&T
  - In-Situ treatment of shallow high concentrations
  - Monitored Natural Attenuation (MNA)
  - Permeable Reactive Barriers
- EPA led effort with technical input from RPs
- Primary effort January-June 2011
- Completion Expected in 2012

Challenge of Large Scale Plume



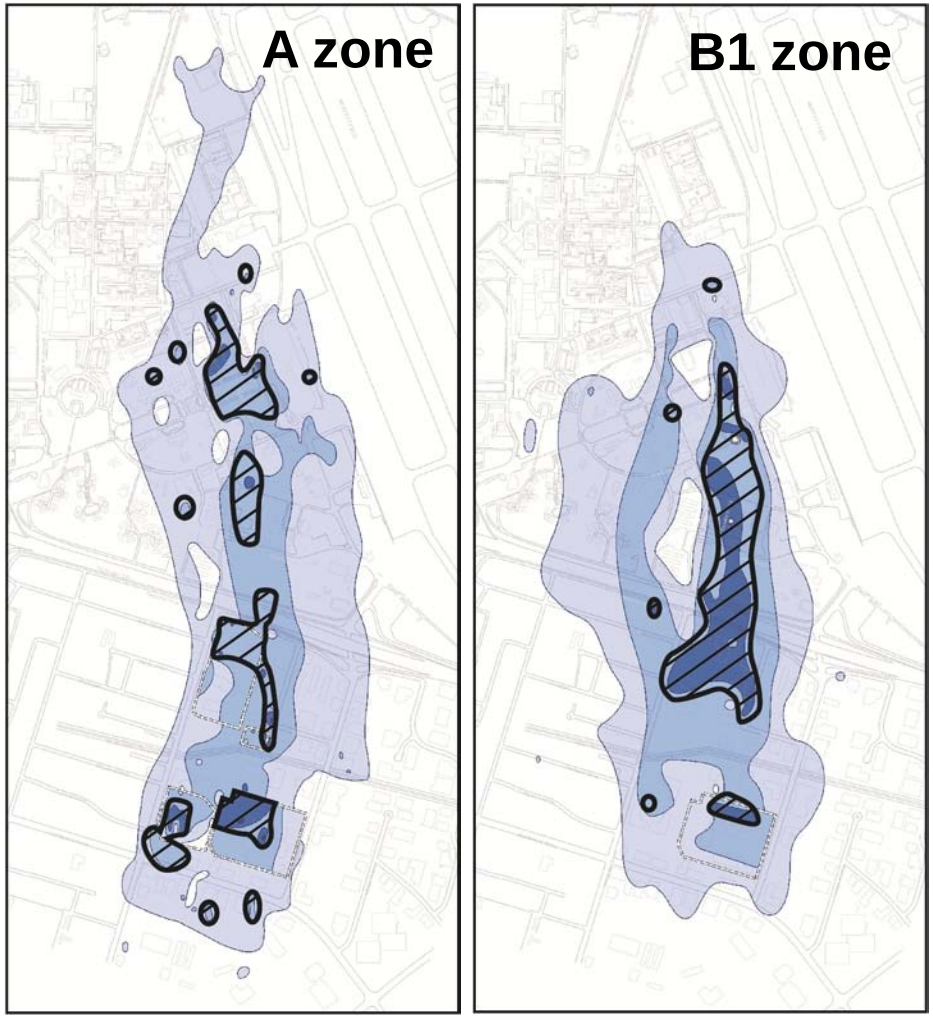
Navy Pilot Test Areas



Intel Pilot Area

Challenge of Large Scale Plume

- Cost of in-situ treatment of remaining areas with > 1,000 µg/L would be more than $1 billion
- With no evidence that the plume would be reduced to 5 µg/L in reasonable time



Matrix Diffusion in GWFS

- Needed to consider matrix diffusion impacts on:
  - conceptual site model,
  - alternative remedy effectiveness,
  - cleanup times, and therefore,
  - cost
- To allow for the development and comparison of realistic alternatives with realistic timeframes and costs
- Dispel the misconception that: “ … once we get the sources cleaned up, the rest of the plume will clean-up quickly.”

GWFS Alternatives

Alternatives Evaluated:

1. Existing P&T
2. Optimized P&T
3. Optimized P&T + MNA
4. Optimized P&T + MNA + source treatment
5. Optimized P&T + MNA + PRBs

Cleanup targets considered:

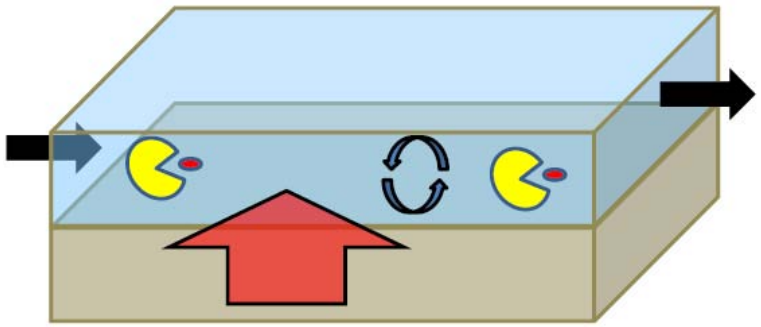
- 5 µg/L
- 200 µg/L
- 90% concentration reduction

Clean-Up Time Evaluation

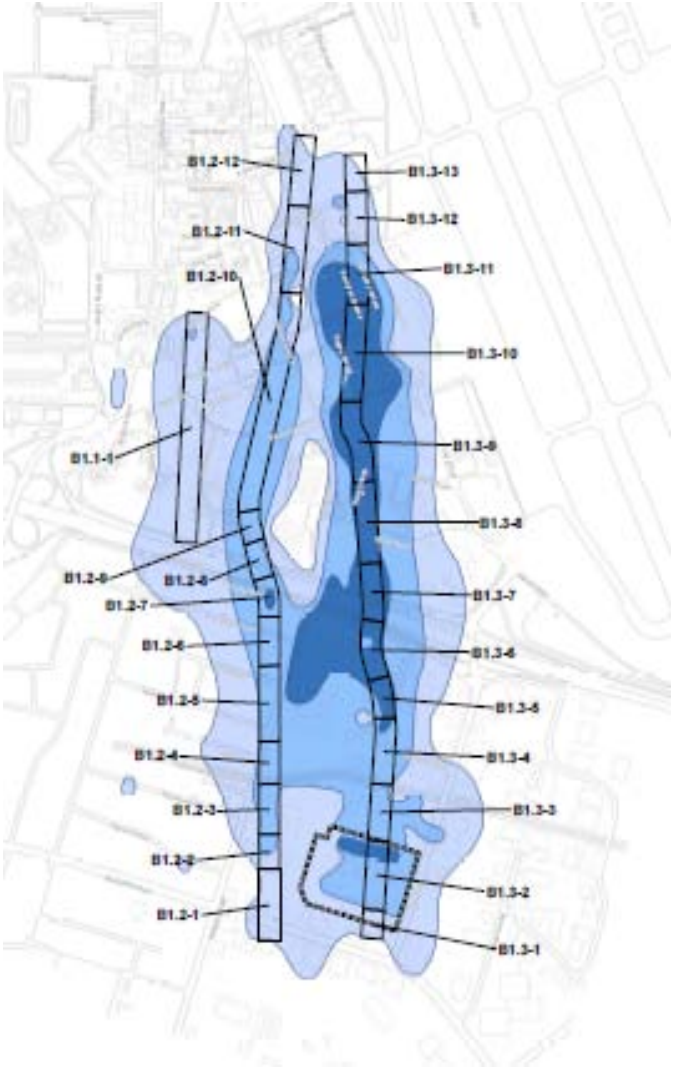
- Used a simple “box model” to evaluate clean-up times
- Reasons for this approach:
  - Tight schedule: Clean-up time estimates generated within 3 months of start of FS process
  - Complex site: Calibration of a solute transport model would need to account for very complex history, including many sources, multiple depth intervals, 100 extraction wells
  - Decision making: Simple analysis tool allows discussion of clean-up time issues to remain accessible to stakeholders and not become hidden within the realm of expert modelers

Box Model Incorporating Matrix Diffusion

- Two component box model
  - Transmissive zone
  - Low permeability zone
- Mass balance on VOCs in transmissive zone
  - Partitioning between groundwater and soil
  - Removal via advection
  - Removal via degradation
  - Matrix diffusion from low permeability zone as secondary source
- Models change in concentration with time for both transmissive and low permeability zones

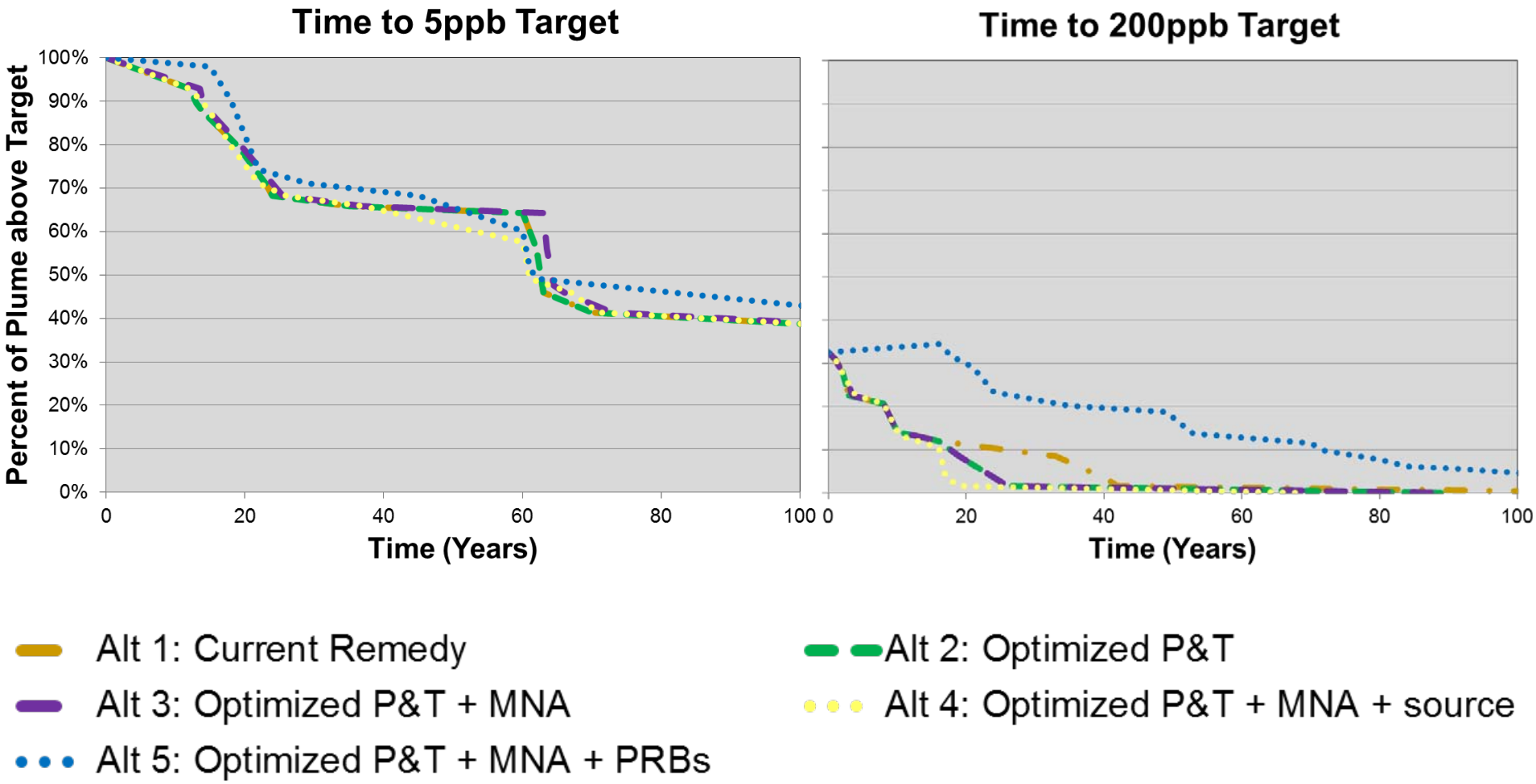


Application of Box Model to Cleanup Time Evaluation



- Concentration over time in sample portions of the plume calculated using the spreadsheet-based “box model”
- Modeling results representative of entire plume footprint
- A few selected results compared with Remchlor (source zone)

Cleanup Time Evaluation Results



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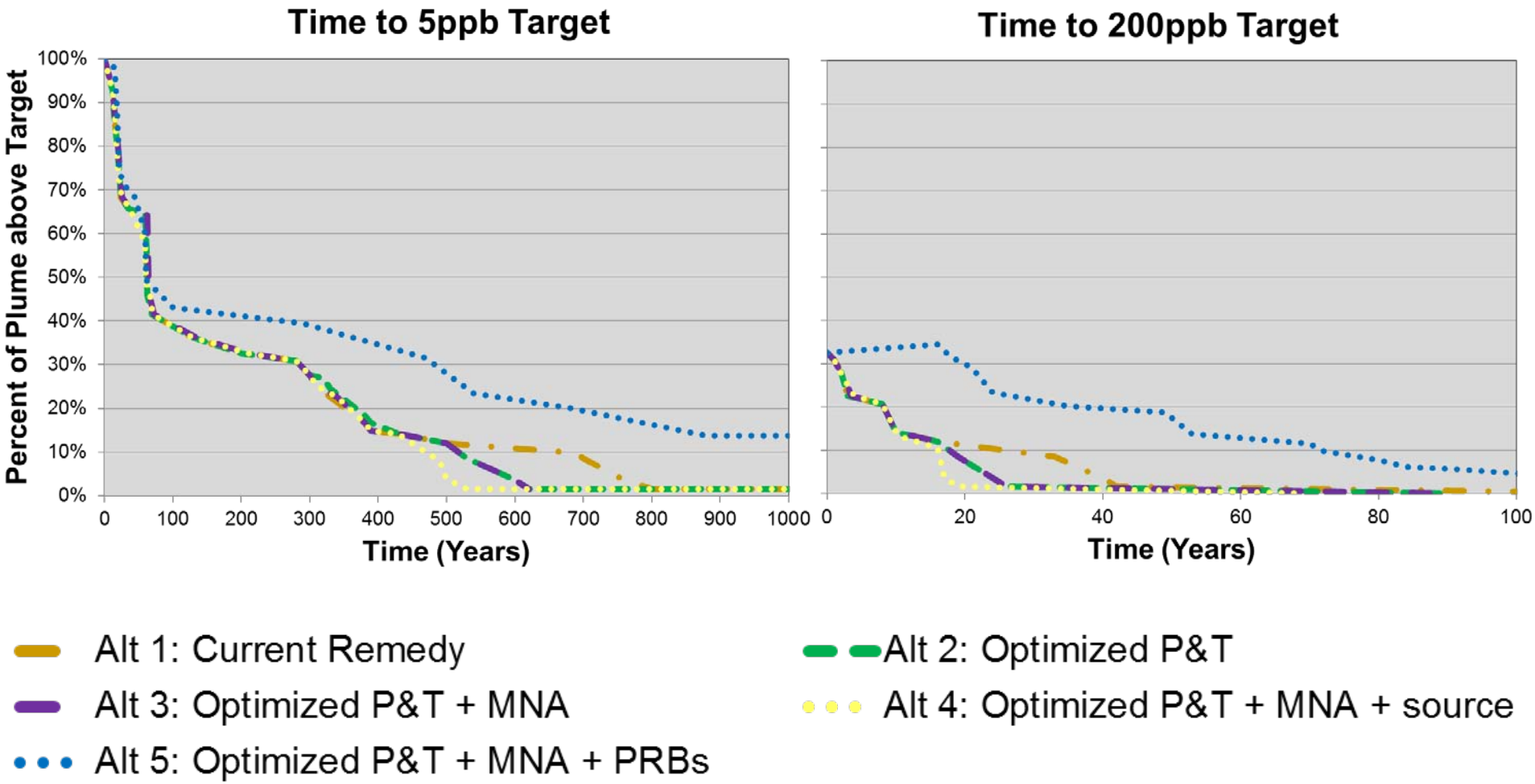
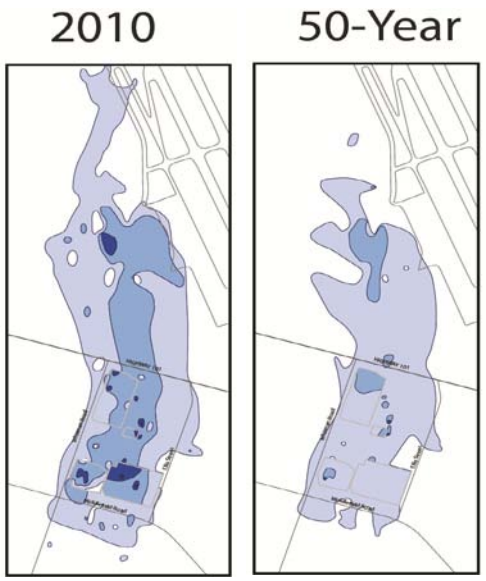
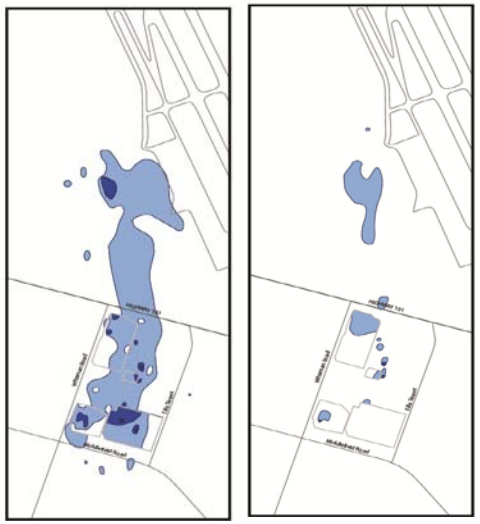


Cleanup Time Evaluation Results

Plume footprint – 5ppb target



Plume footprint – 200 ppb target



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Conclusions

- 25 years of P&T has been effective in reducing concentrations in the dissolved plume - 90% reduction in dissolved plume mass, however, plume footprint is not shrinking
- 2,500 lbs/yr of VOC mass removal by P&T systems, but estimated that only 20% is from reducing VOC concentrations in mobile groundwater, remaining 80% is coming out of storage
- Matrix diffusion is source of VOCs in storage, based on site geology and observed trends outside of contained source areas

Conclusions

- Feasibility study needed to account for challenge of large plume scale and matrix diffusion
- Simple box model developed for cleanup time evaluation
- Centuries to reach 5 µg/L under all alternatives
- Decades to reach 200 µg/L - may allow for MNA as remedy

Acknowledgements

- Dave Major, Geosyntec
- Jim McDade, and Shahla Farhat, GSI