Comparison of Biofouling Control Methods for an In Situ Chlorinated Solvent Bioremediation System

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presented by

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Project Background

- Past maintenance activities at Dover AFB, DE, resulted in release of chlorinated solvents to the environment.
- Source area is in soil *beneath* building foundation.
- Contaminated soil is inaccessible by conventional remedial technologies.
- Groundwater plume extends ≈ 1 mile downgradient.

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Project Background (continued)

- Limited soil data/source delineation.
- Soil concentrations:
  TCE up to 280,000 µg/kg.
- Groundwater concentrations:
  TCE up to 21,000 µg/L.

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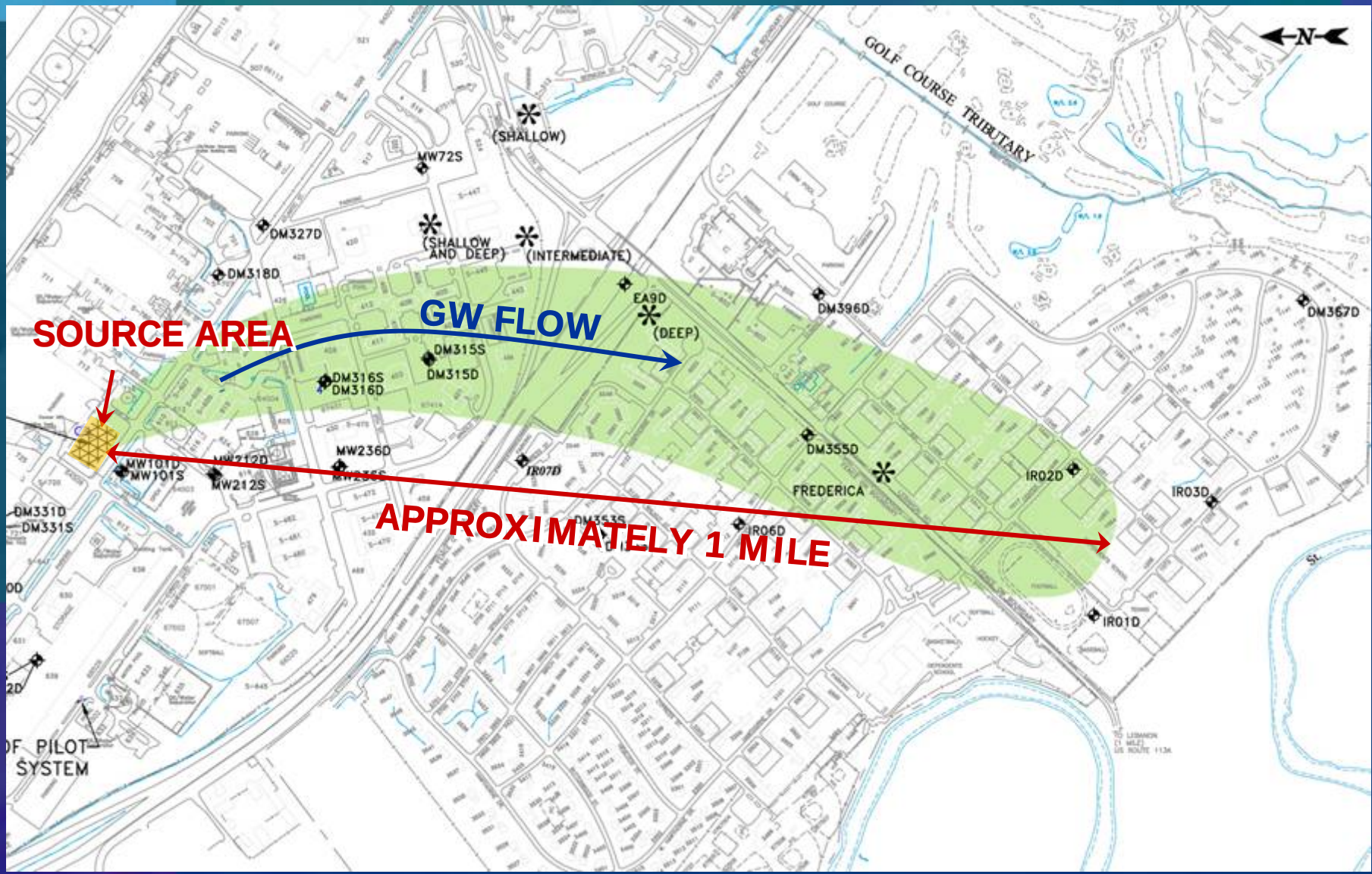
Source Area vs. Downgradient Plume



Remediation Approach

- Establish hydraulic control of contaminated groundwater
  - Recirculate groundwater under facility.
  - 4 Extraction Wells/12 Injection Wells.
- Accelerate anaerobic biodegradation of chlorinated solvents
  - Substrate: Sodium Lactate.
  - Metabolic Nutrients: Dibasic Ammonium Phosphate (DAP).

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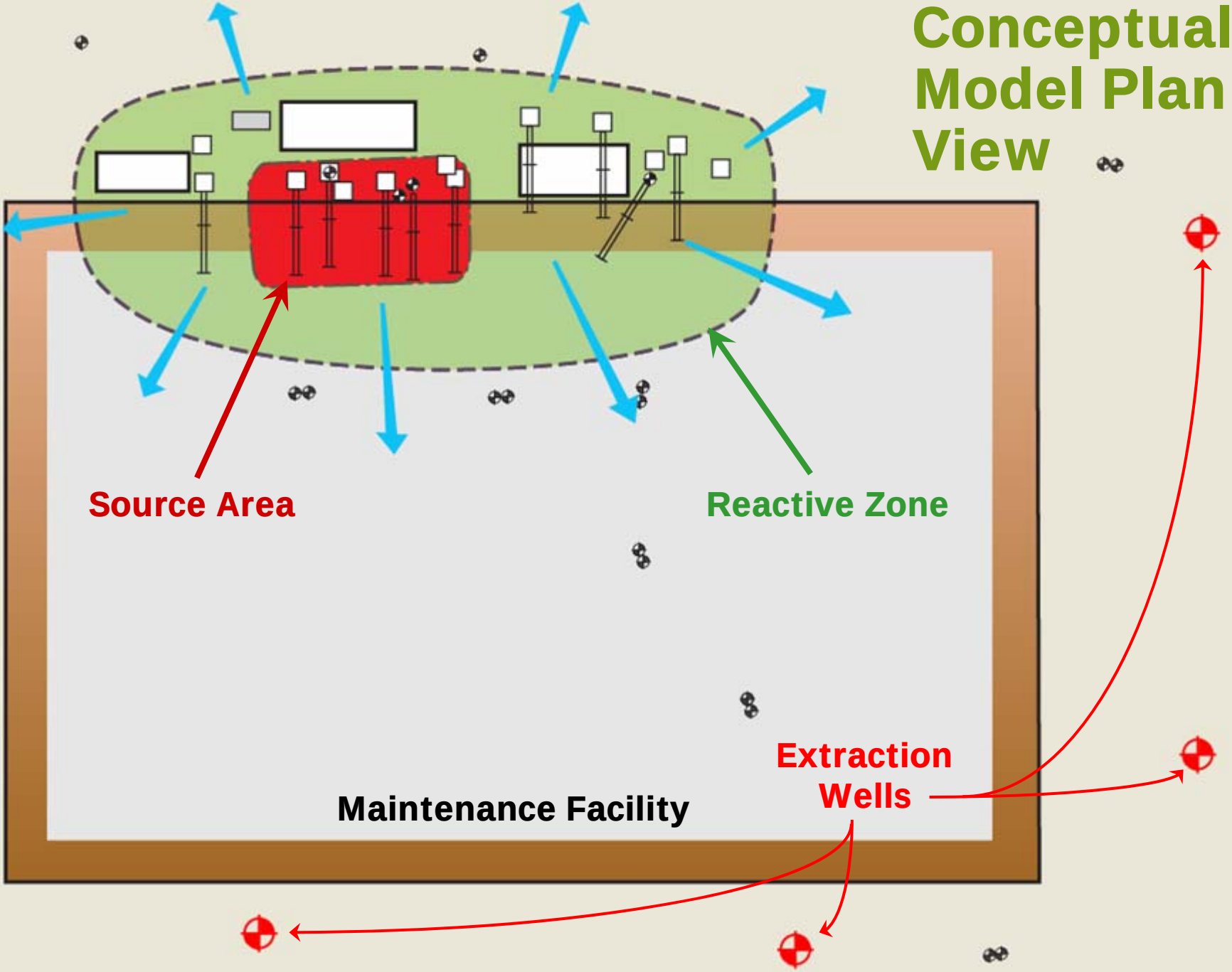
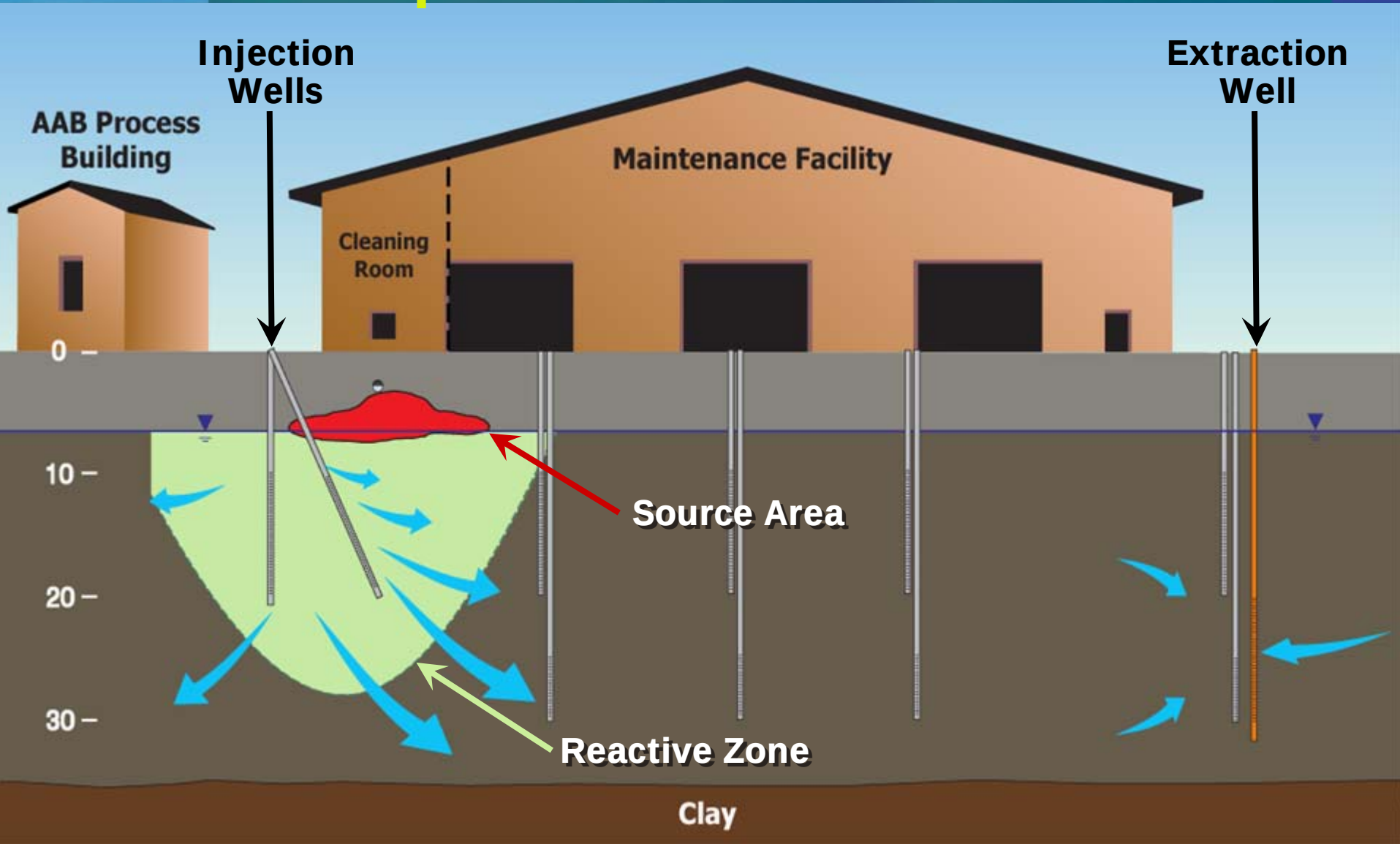
Conceptual Model Plan View



Conceptual Model Cross Section View



Process Building Recirculation Plumbing

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O&M Challenge

- Prevent biological activity in the system components.
- Enhance biological activity in the Reactive Zone.

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System Efficiency Indicators

- Groundwater Recirculation System – total flow from extraction wells.
- Reactive Zone – percent chlorinated ethene degradation.

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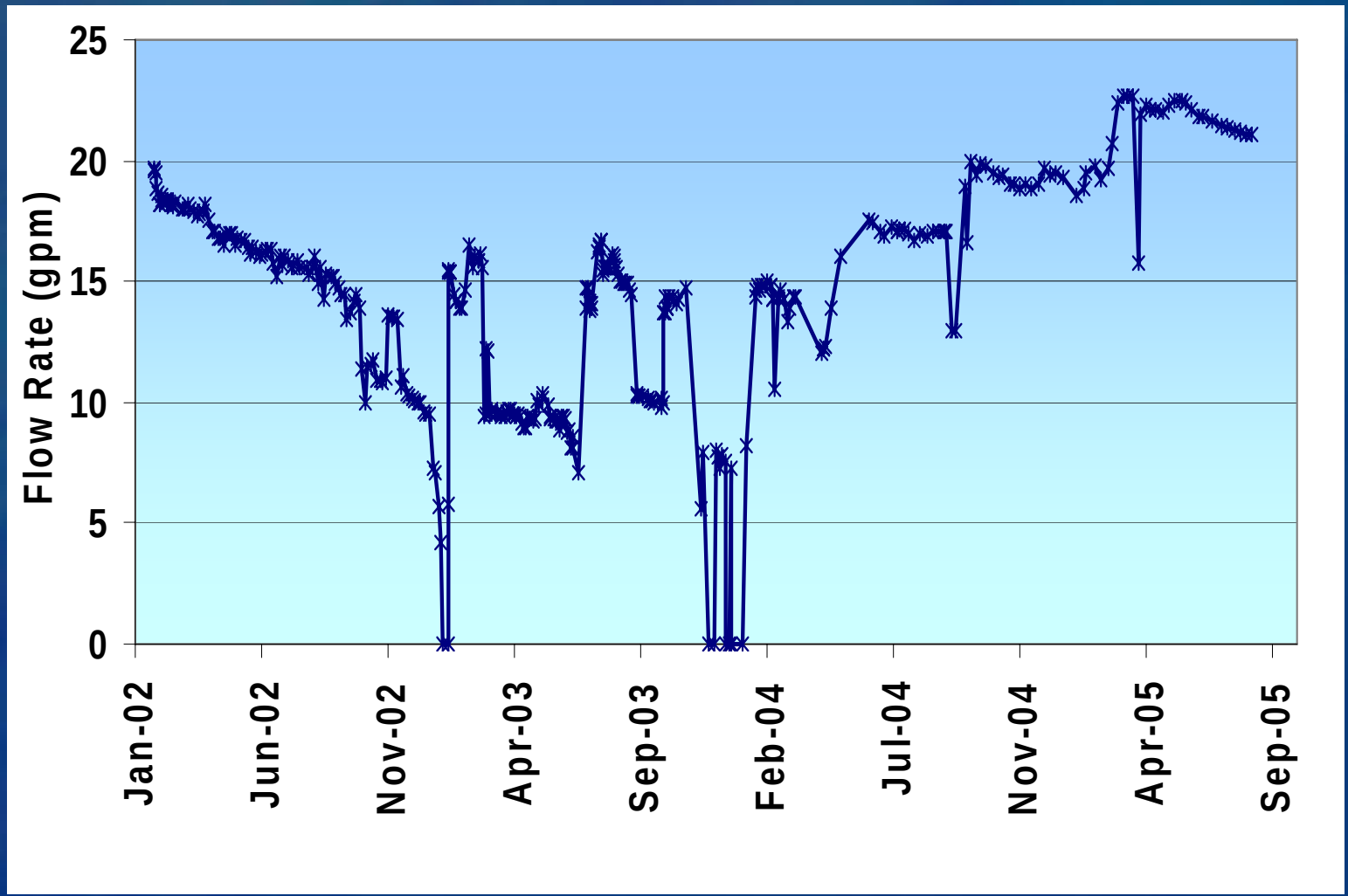
System Flow Rate



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Biological Fouling Control Methods

- Pulsed Substrate and Nutrient Injection
- Physical Redevelopment
- Hydrogen Peroxide Treatment
- Pressure Injection
- Acid Treatment
- Anaerobic Biocide
- Iron Sequestering Agent

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Pulsed Substrate and Nutrient Injection

- → Injected separately into recirculated groundwater for 4 to 6 hours every 2 to 4 days.
- \+ Limits availability of substrate and nutrients in injection wells.
- \- Creates substrate fluctuations in subsurface.
- = Minimizes biological fouling in injection wells.

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Physical Redevelopment

- → Physical removal of biological mass and precipitated solids from injection wells.
- \+ Effective for bulk removal of fouling.
- \- Labor intensive.
- = Not effective for long-term biological fouling.

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H_2O_2 Treatment

- → 35 percent solution added to severely fouled injection wells. Combined with physical redevelopment.
- \+ Disassociates organic mass.
- \- Labor intensive, introduces O_2, precipitation of dissolved metals, H&S concerns.
- = Effective for restoring permeability to severely fouled wells. Last resort option.

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Pressure Injection

- → > 3.0 psi at injection well heads.
- \+ Allows increased recirculation rates, especially during increased biofouling and high-water table conditions.
- \- Does not eliminate biological fouling.
- = Increases time between required treatments.

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Acid Treatment

- ➔ Used to treat biological and iron precipitate fouling in extraction wells and piping.
- \+ Effectively removes fouling.
- \- Labor intensive. Acid detrimental to Reactive Zone if reinjected.
- = Effective at high acid concentrations for severe fouling.

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Anaerobic Biocide

- ➔ "Green" biocide used to control biological fouling in injection wells.
- \+ May be recirculated. Does not oxidize Reactive Zone. H&S concerns easily addressed w/ safe handling practices.
- \- Registered pesticide, requires USEPA SLN permit. Requires frequent system monitoring for best results. Can affect reductive dechlorinators.
- = Highly effective if it can be applied appropriately.

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Iron Sequestering Agent

- → Dripped into extraction wells with measurable dissolved iron.
- \+ Dissolved iron unavailable for IRB. Glycolic acid is biodegradable.
- \- May lower pH in Reactive Zone. Corrosive nature complicates product delivery.
- = Appears to minimize biological and iron precipitate fouling associated with IRB.

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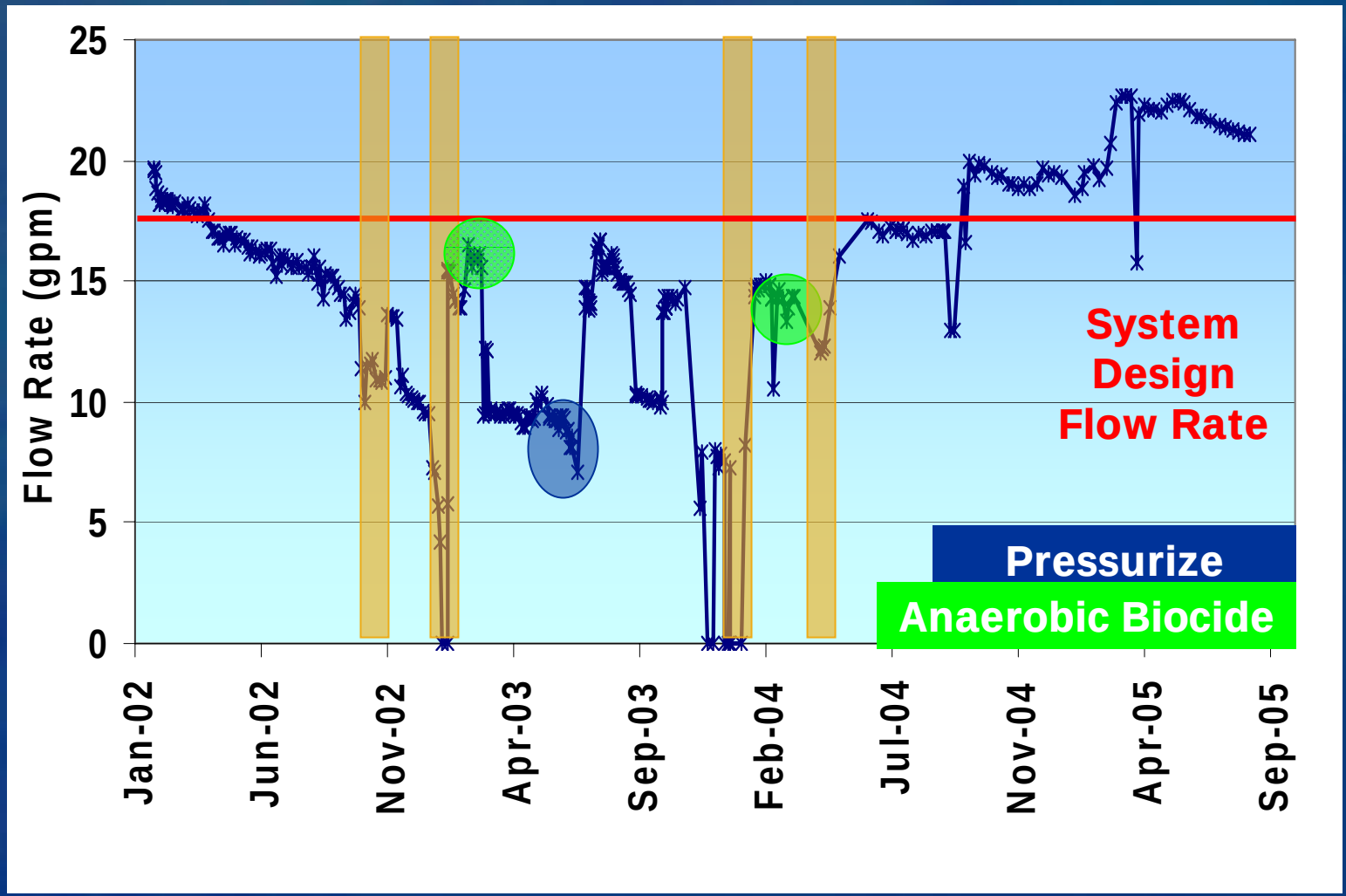
Effects of Biofouling Controls on Flow Rates



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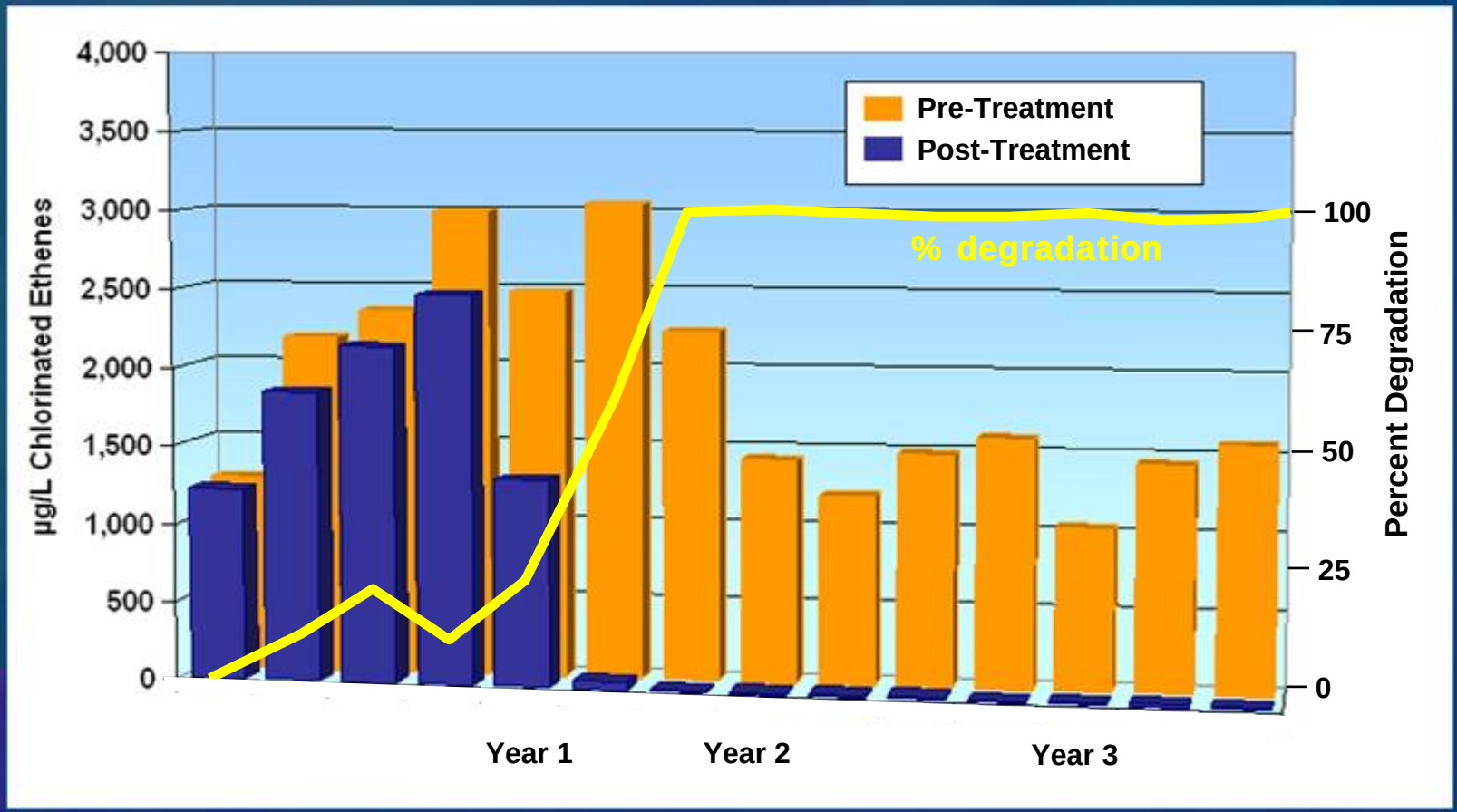
Effects of Biofouling Controls on Reactive Zone



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Conclusions

- Integrated and thoughtful application of multiple control methods required.
- Long-term/cost effective controls
  - Pulsed feeding, pressure injection, anaerobic biocide, iron sequestering agent.
- Labor/cost intensive, "Last Resort" controls
  - H_2O_2 and acid treatments with physical redevelopment.
- Reduced level of effort in system O&M means reduced O&M costs.
- System flow rate increased 30% over design with no observed impact to Reactive Zone efficiency.

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Biofouling Photos – A picture is worth 1,000 words

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