NAVSEA
INDIAN HEAD
Surface Warfare Center Division

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IN SITU PERCHLORATE BIOREMEDIATION AT IHDIV NSWC

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Envirogen, Inc.

Shaw™ Shaw Environmental & Infrastructure, Inc.

Problem Statement

Perchlorate (ClO_4^-)

Use: **Perchlorate salts have been used extensively by DoD, NASA, Aerospace Contractors during last 6 decades as fuel oxidants in rockets and missiles.**

Contamination: **Groundwater contamination in at least 14 states, including CA, NV, UT, TX, MD, MA. Greater than 15 million impacted.**

Toxicology: **Perchlorate inhibits thyroid function and influences metamorphosis. Effects of low level exposure are uncertain. California action level is now 4 ppb.**

Characteristics: **Anion, low volatility, high water solubility, chemically stable, persistent in environment for years.**

Remediation: **Traditional *ex situ* technologies (e.g., air stripping, carbon adsorption, filtration) are ineffective. Biological remediation is considered the most promising approach.**

Perchlorate Biodegradation

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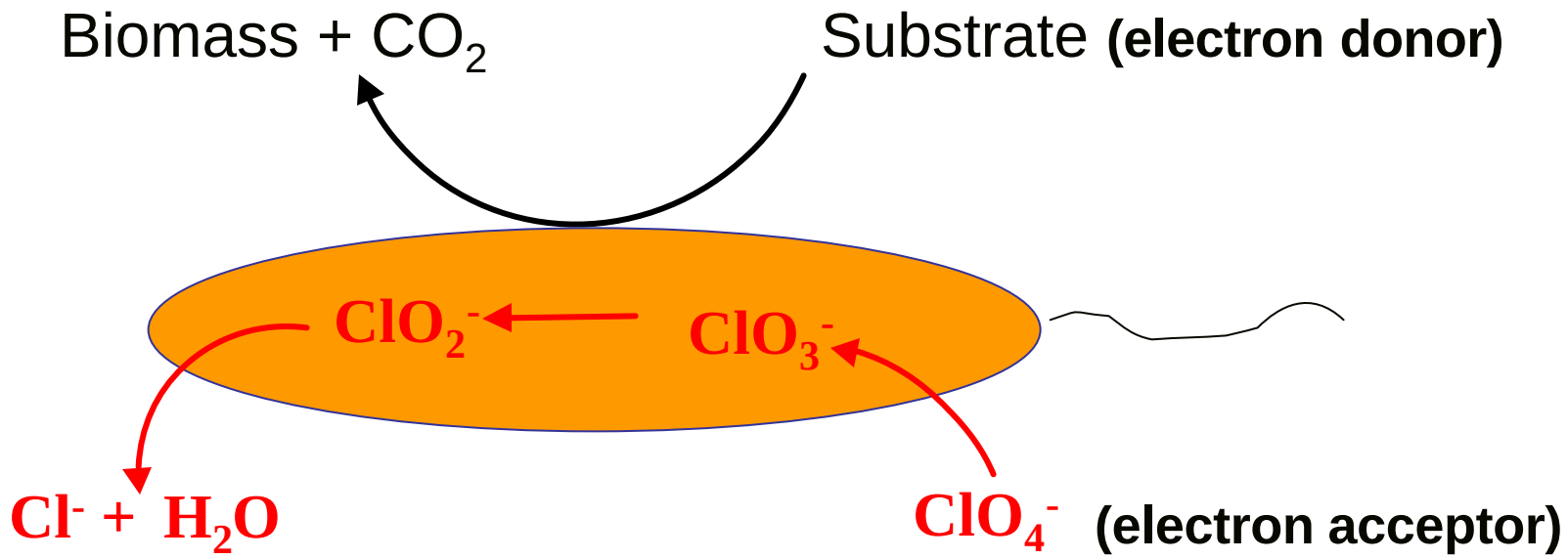

**** Highly Favorable Reaction*** *(-801 kJ/mol acetate)*

**** Several Different Genera Isolated*** *(Wolinella, Ideonella, Dechlorospirillum, Dechlorisoma, Dechlorimonas)*

Fluidized Bed Reactors

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> 7 BILLION GALLONS TREATED

Key Questions for *In Situ* Treatment

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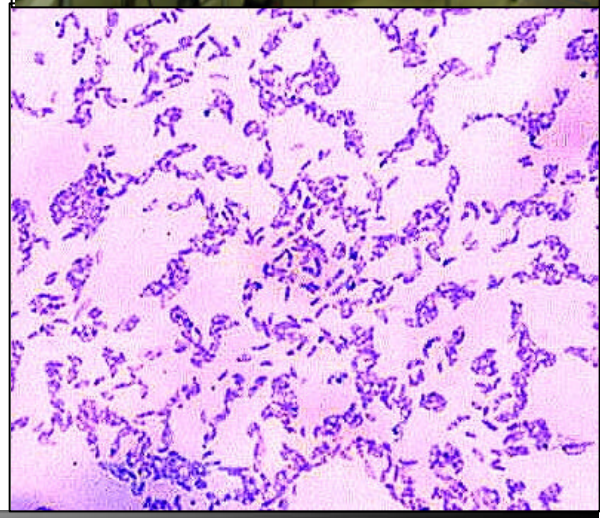
* **What is the Natural Occurrence of Perchlorate Reducers?**

* **Can They be Stimulated to Degrade Perchlorate *In Situ* Using Electron Donor Addition? - Which Donors?**

* **What are Potential Inhibitory Factors?**

DoD EPA DOE SERDP
Strategic Environmental Research and Development Program
Improving Mission Readiness Through Environmental Research

Project CU- 1163
2000 - 2002



Potential for *In Situ* Remediation

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SITES EVALUATED:

(1) JET PROPULSION LABS (CA)

(2) INDIAN HEAD NSWC (MD) *(2 Sites)*

(3) THIOKOL PROPULSION (UT)

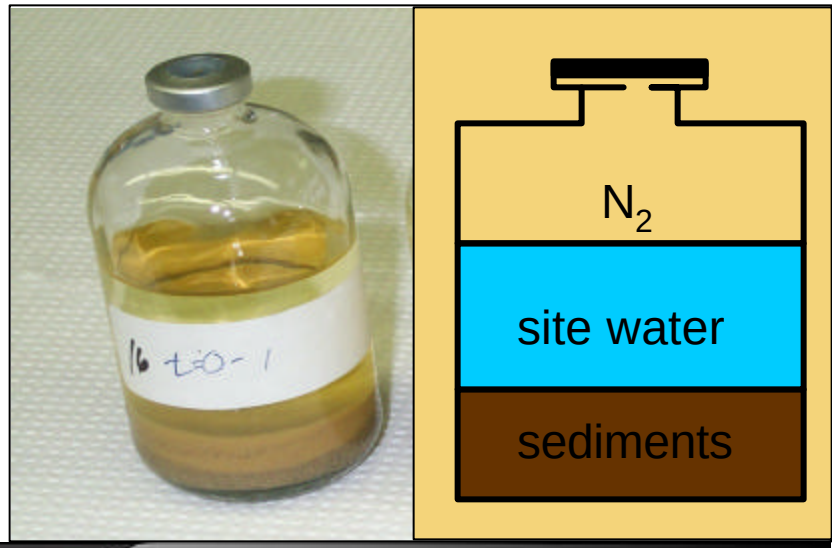
(4) SOUTH OYSTER (VA) (*Pristine Site*).

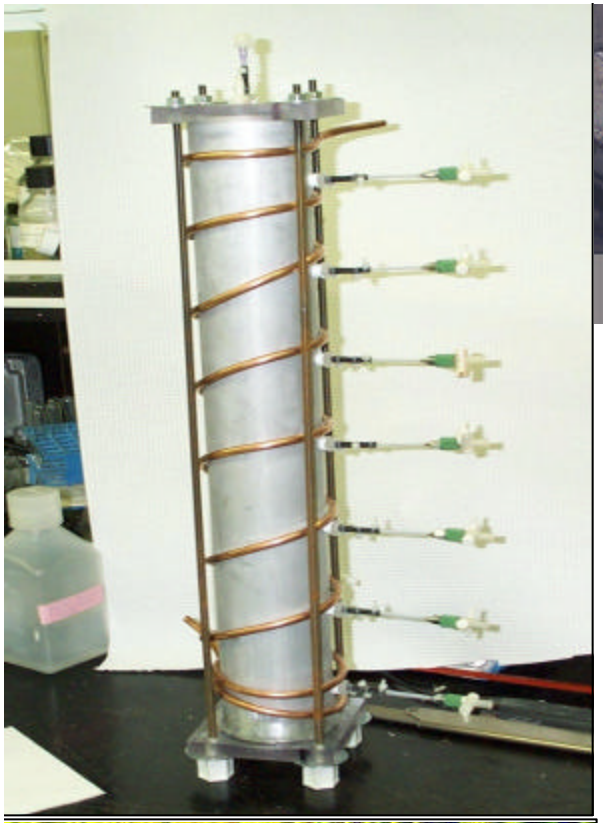
(5) LONGHORN AAP (TX) *(3 Sites)*

(6) BOEING CORP (CA) *(2 Sites)*

MICROCOSM AND COLUMN STUDIES:

Occurrence of Perchlorate Reducers
Electron Donors
Alternate Electron Acceptors
Environmental Variables
Developed Biodegradation Model





SERDP Laboratory Studies

CONCLUSIONS

- **Perchlorate-reducing bacteria are widely distributed: soils, groundwater, sewage, etc.**
- **Biostimulation is a promising *in situ* approach, but most effective electron donor is site specific.**
- **Oxygen and nitrate must be biodegraded before perchlorate reduction will occur.**
- **Low pH (< 5.5) inhibits perchlorate reduction.**
- **Other common electron acceptors such as sulfate and ferric iron do not influence perchlorate reduction.**

INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
FIELD DEMONSTRATION

January 2002 - January 2003

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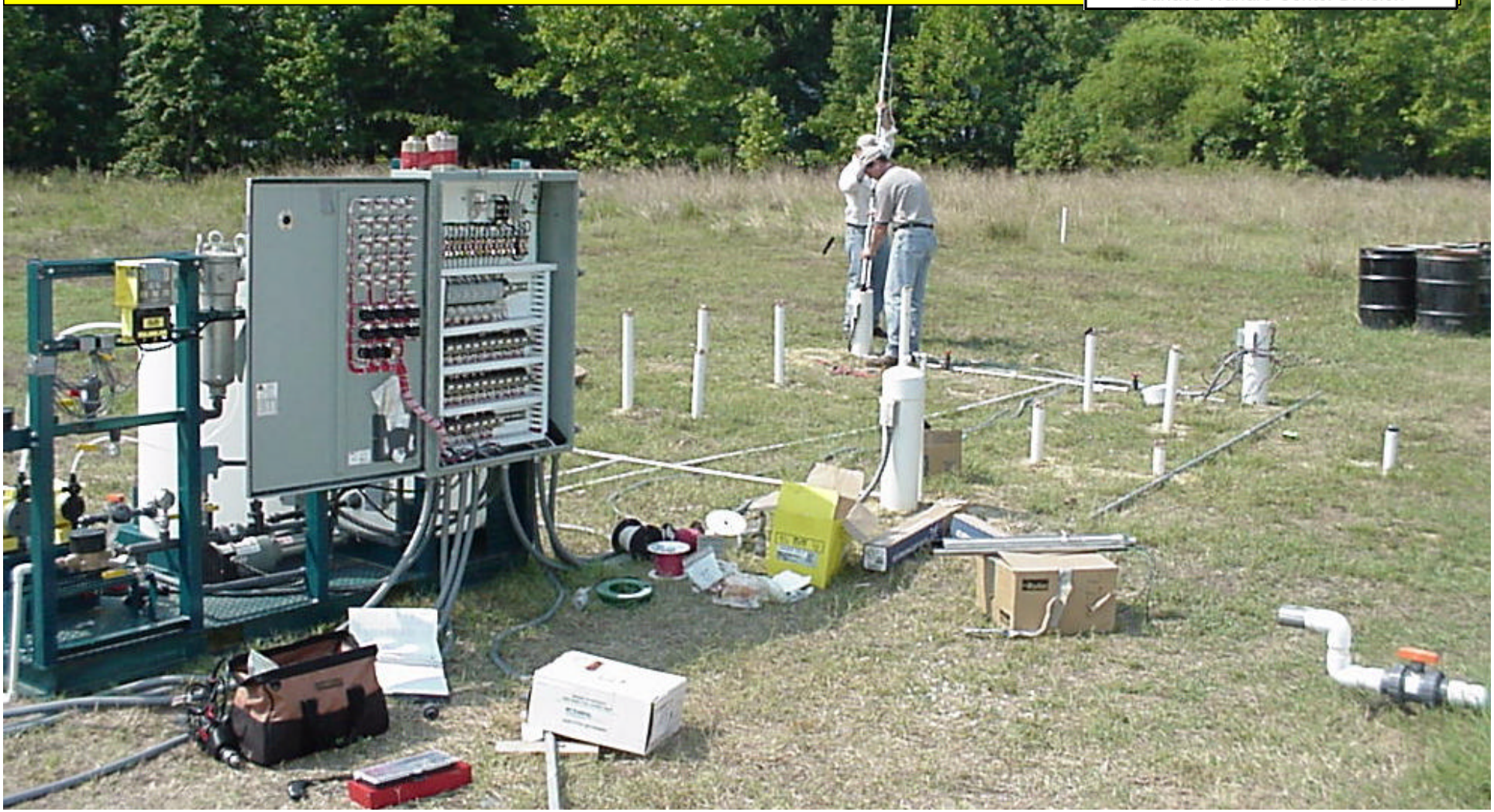


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Greenbelt
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Somerset
Woodlawn
McLean
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Belle Haven
West Springfield
Marlton
Clinton
Rosaryville
Manassas
Friendly
Newington
Mount Vernon
Lorton
Brandywine
Accokeek
Woodbridge
Dale City
Bryans Road
Waldorf
Potomac Heights
White Plains
Marbury
Dumfries
Triangle
La Plata
Hughesville
Golden Beach
Aquia Harbour
10 km
5 mi
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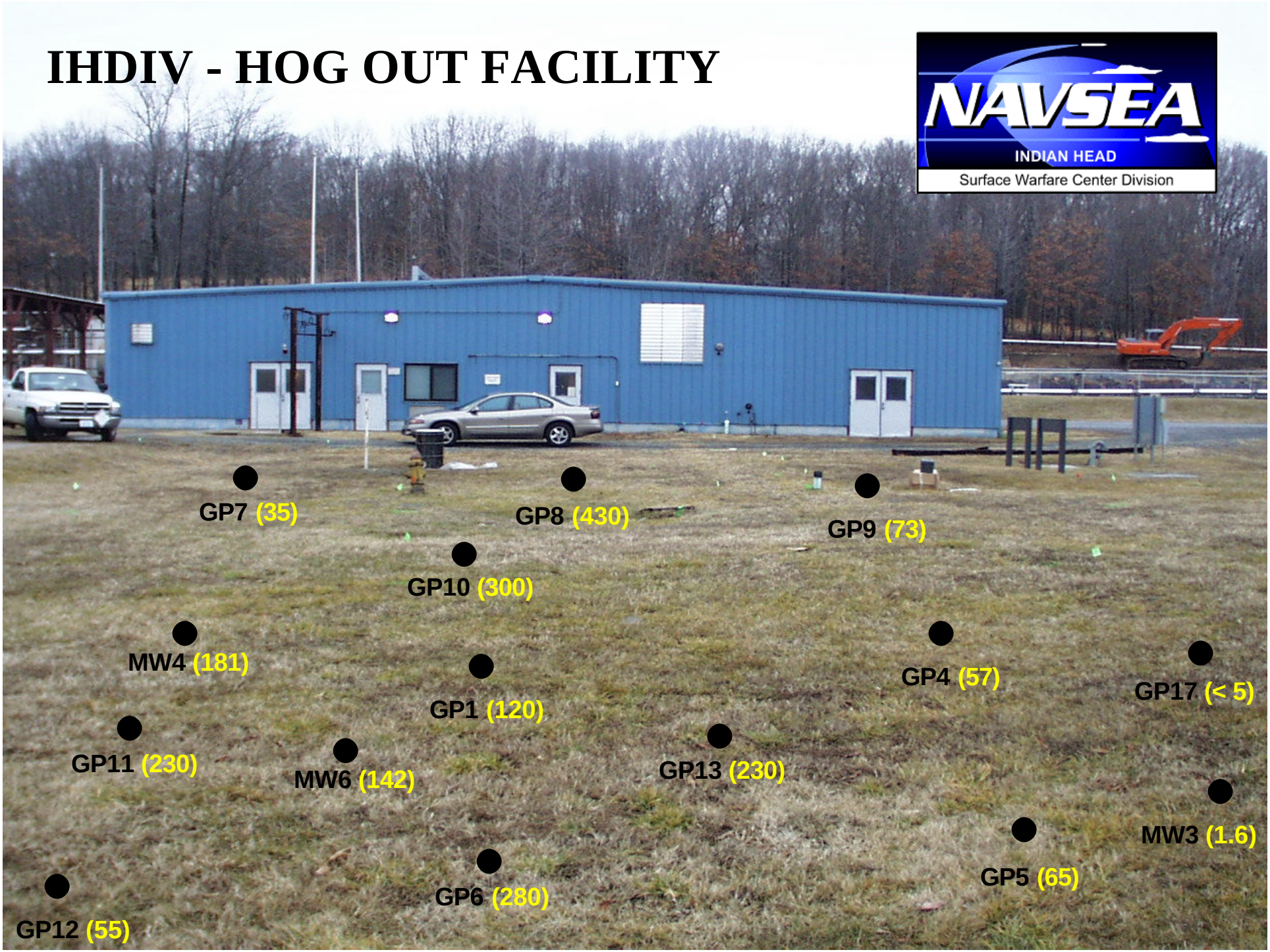
Demonstration Site

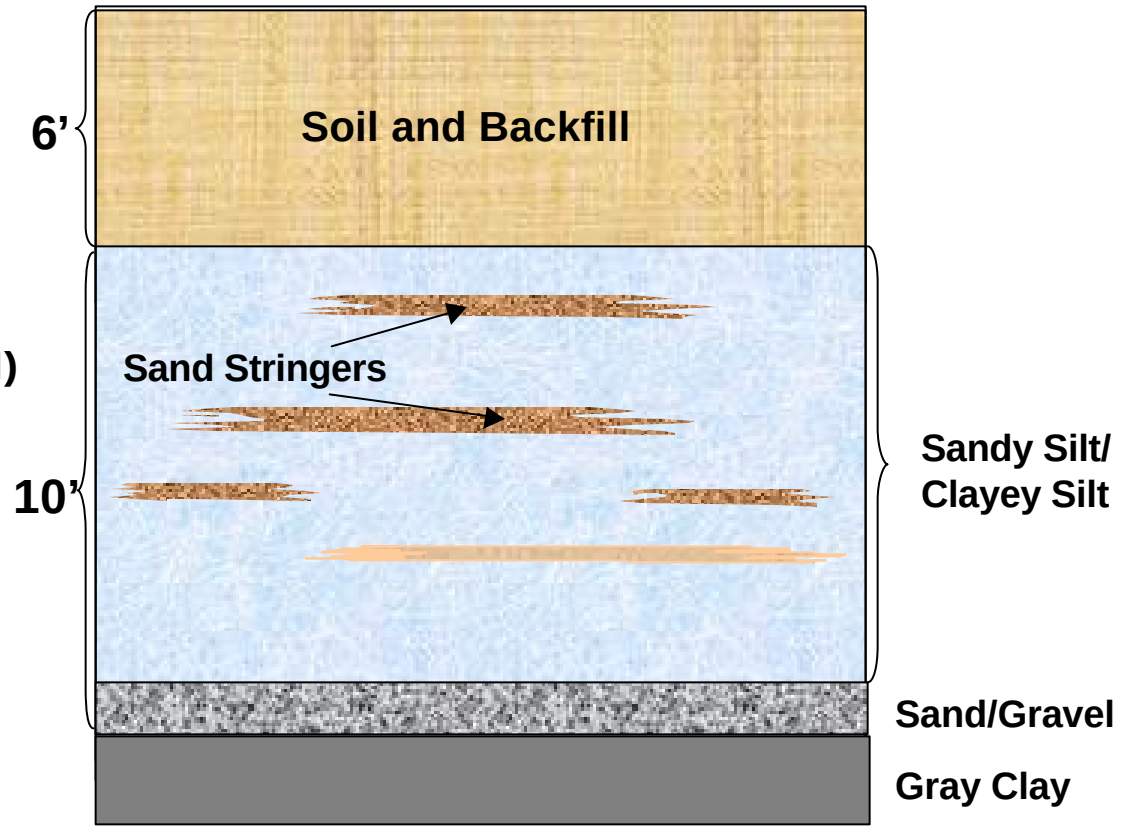
IHDIV - HOG OUT FACILITY



Site Characteristics

Groundwater Characteristics

1. Depth	6 - 16 ft (BLS)
2. Perchlorate	50-400 mg/L
3. pH	< 5.0
4. Alkalinity	~20 mg/L
5. Sulfate	50-200 mg/L
6. Nitrate	2-12 mg/L(as N)
7. Nitrite	< 0.4 mg/L
8. Oxygen	~ 1 mg/L



Laboratory Results

1. Perchlorate-Reducers Present.
2. No degradation at Site pH.
3. Degradation after Buffering.
4. Acetate, Lactate effective in Buffered Sediments.

Approach

- Amend Aquifer with Sodium Lactate as Electron Donor (~ 350 mg/L) and a Bicarbonate/Carbonate Mixture as Buffer (~ 2500 mg/L).
- Design a Recirculation System to Ensure Thorough Mixing of Amendments with Perchlorate-Contaminated Groundwater.
- Install Two Plots: A Test Plot that Receives Amendments and a Control Plot (No Amendments) to Monitor any Abiotic Decline in Perchlorate Concentrations.

Recirculation System

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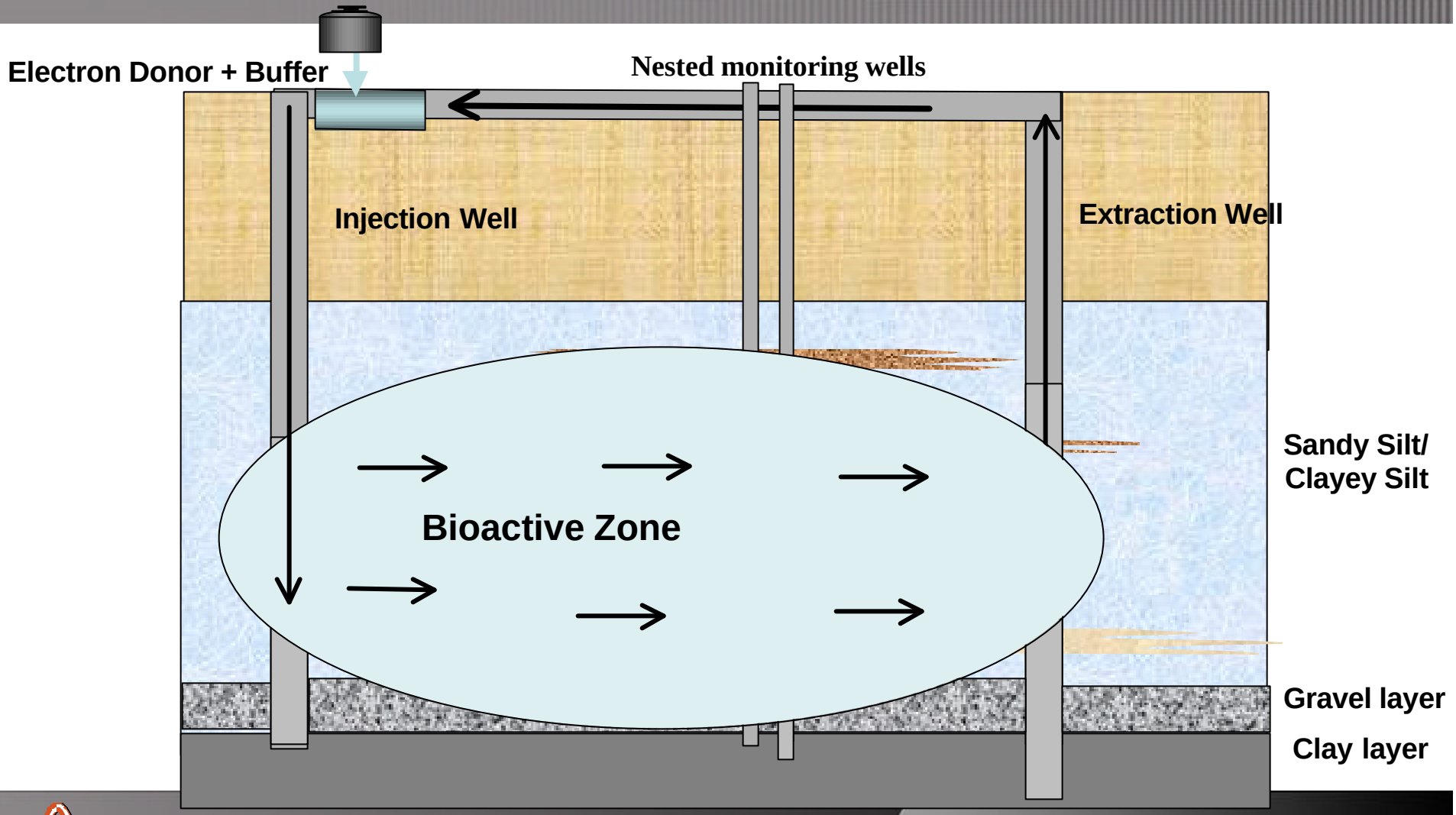

Field Pilot Design

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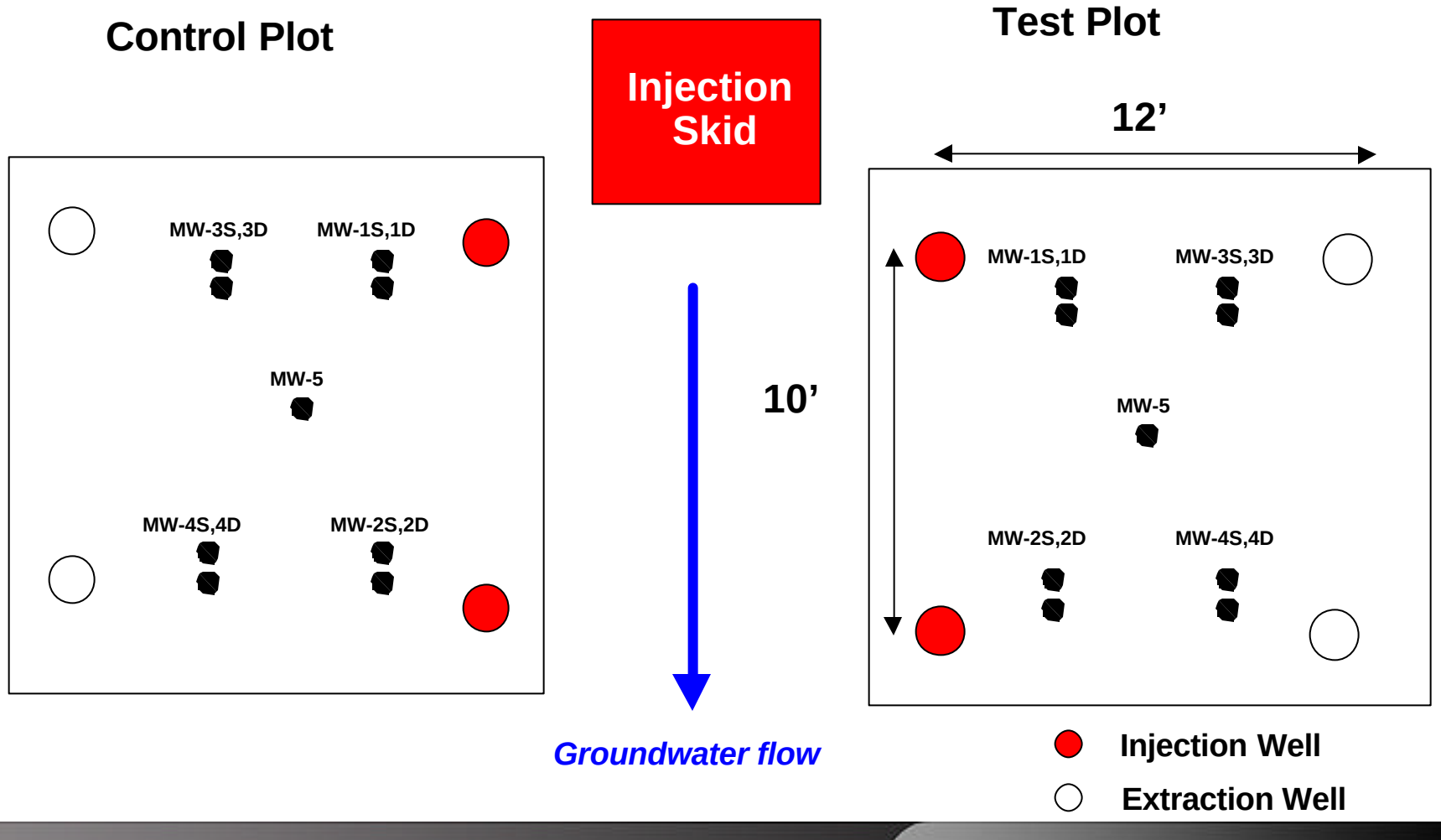

Pilot System

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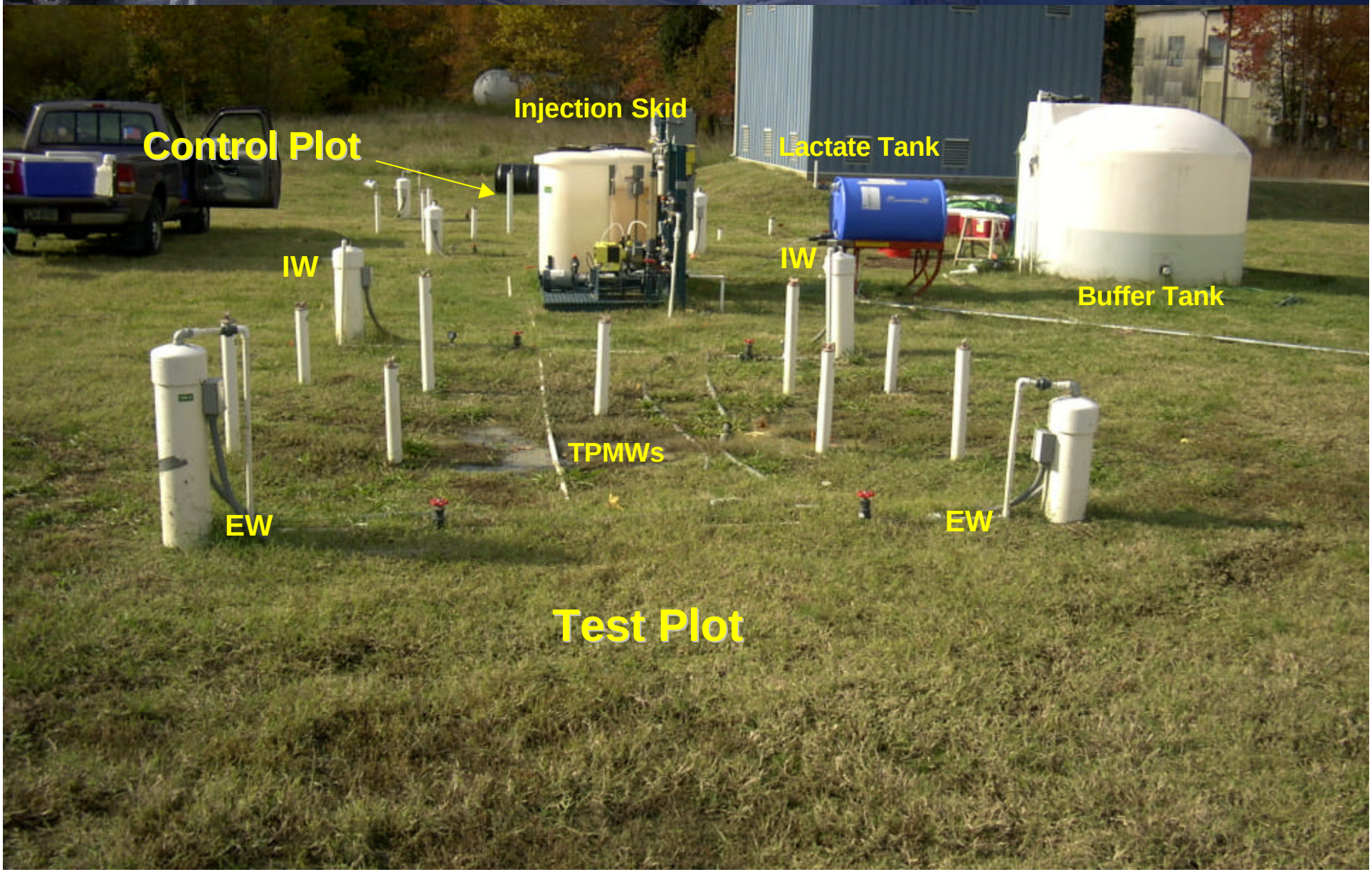

Injection Skid and Control Panel

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Injection Skid

IHDIV Field Pilot

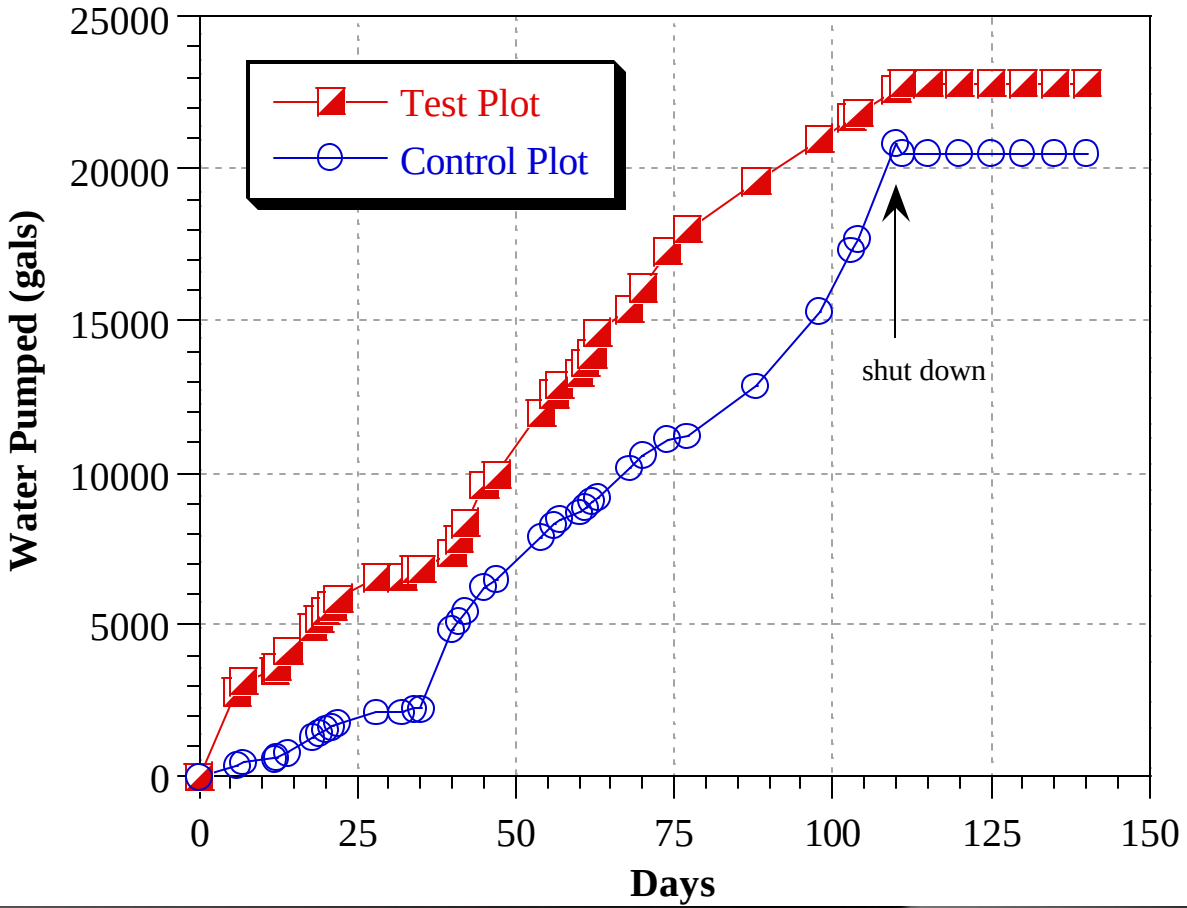
PROJECT SCHEDULE

- **Begin Adding Buffer/Electron Donor 7/25/02.**
- **Performed 2 Baseline Sampling Events (5 wks, 1 wk before)**
- **Groundwater Sampling (2, 4, 7, 10, 15, 20 wks)**
- **Completed Sampling 12/12/2002**

- **DATA** →

Water Recirculation

Water Recirculated During the Field Demonstration



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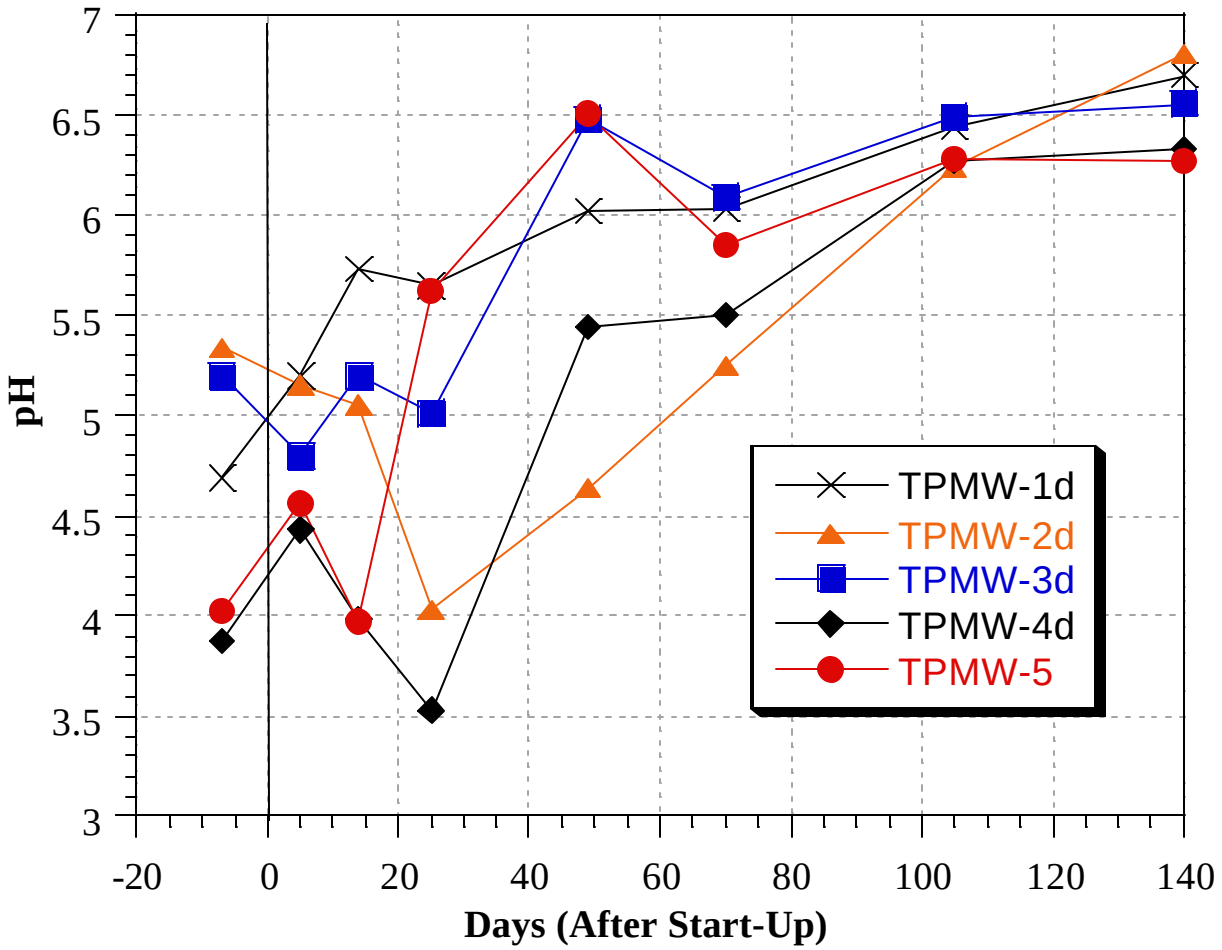
IHDIV Field Pilot - pH

Influence of Buffer Addition on pH in Deep Test Plot Wells



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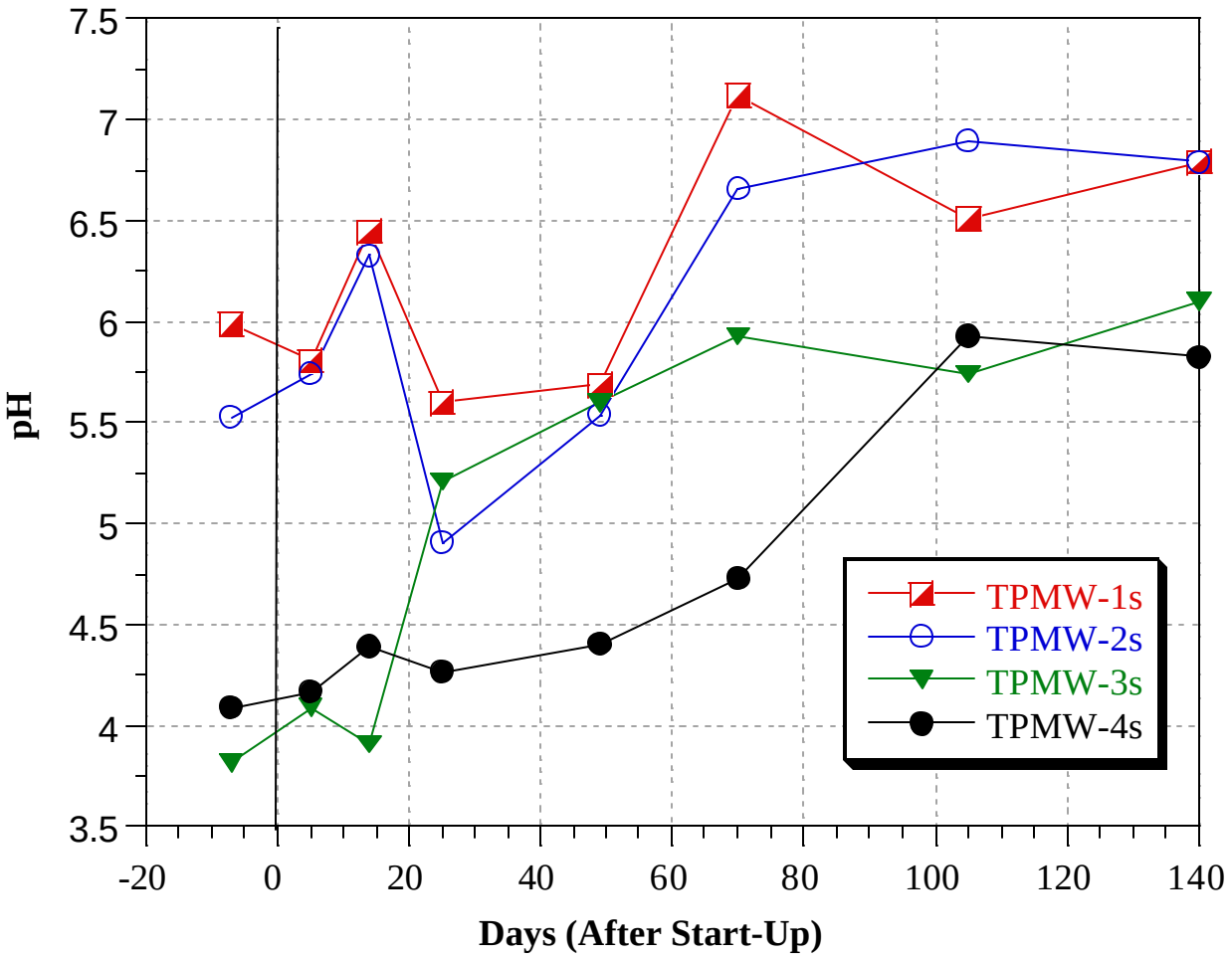
IHDIV Field Pilot - pH

pH Values in Shallow Test Plot Wells During Buffer Addition



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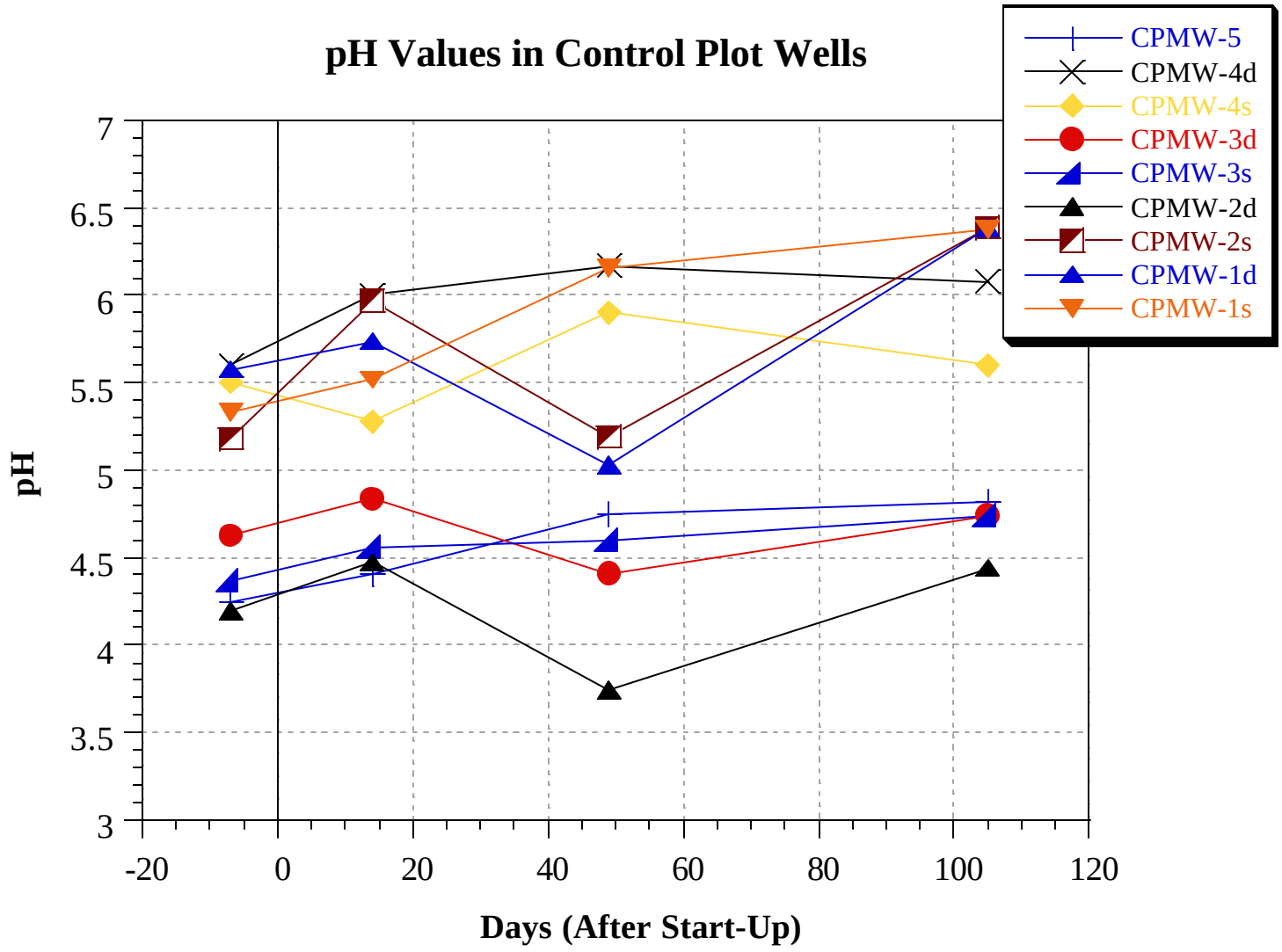
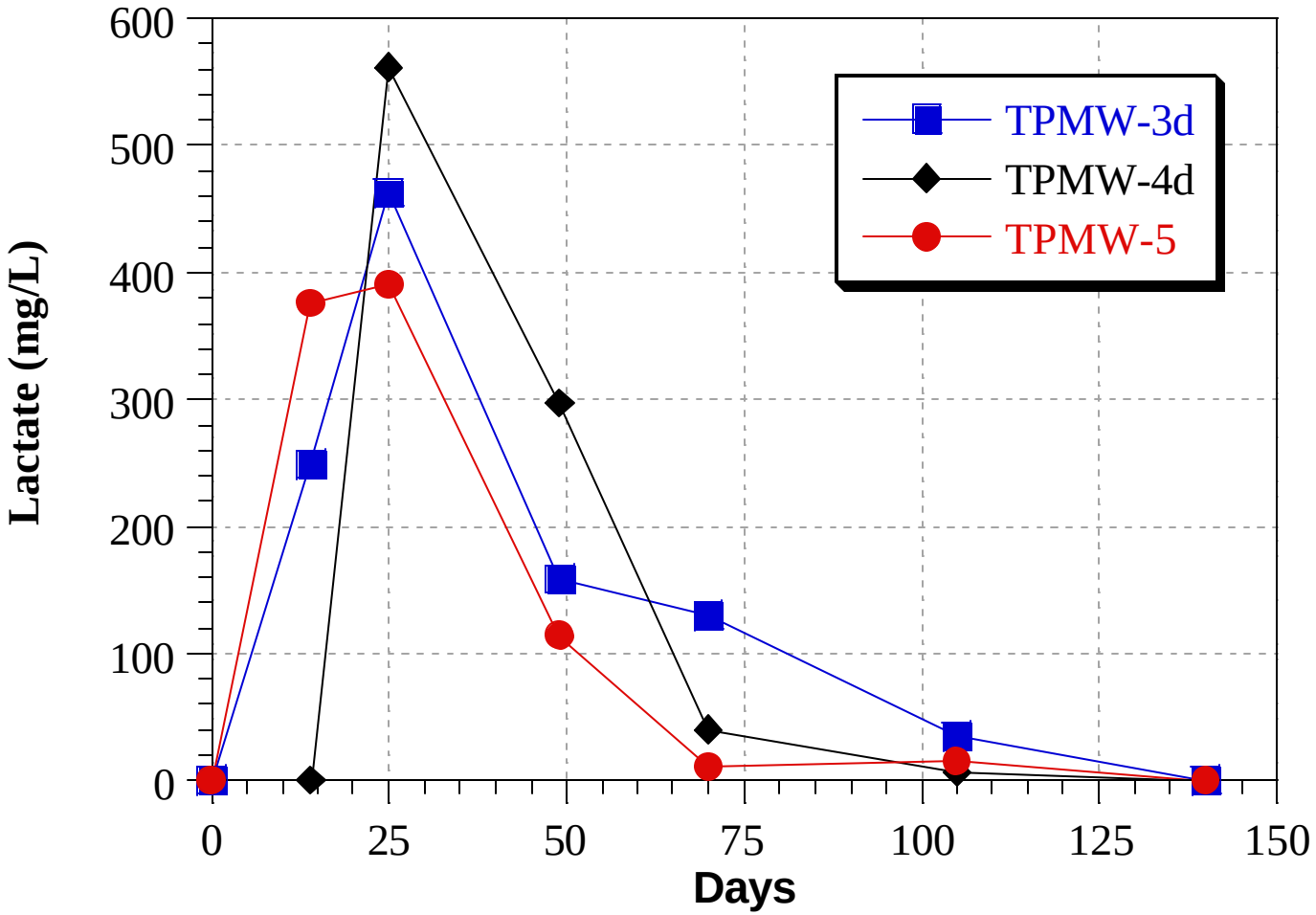
IHDIV Field Pilot - pH



IHDIV Field Pilot - Lactate

Lactate Levels in Representative TPMWs



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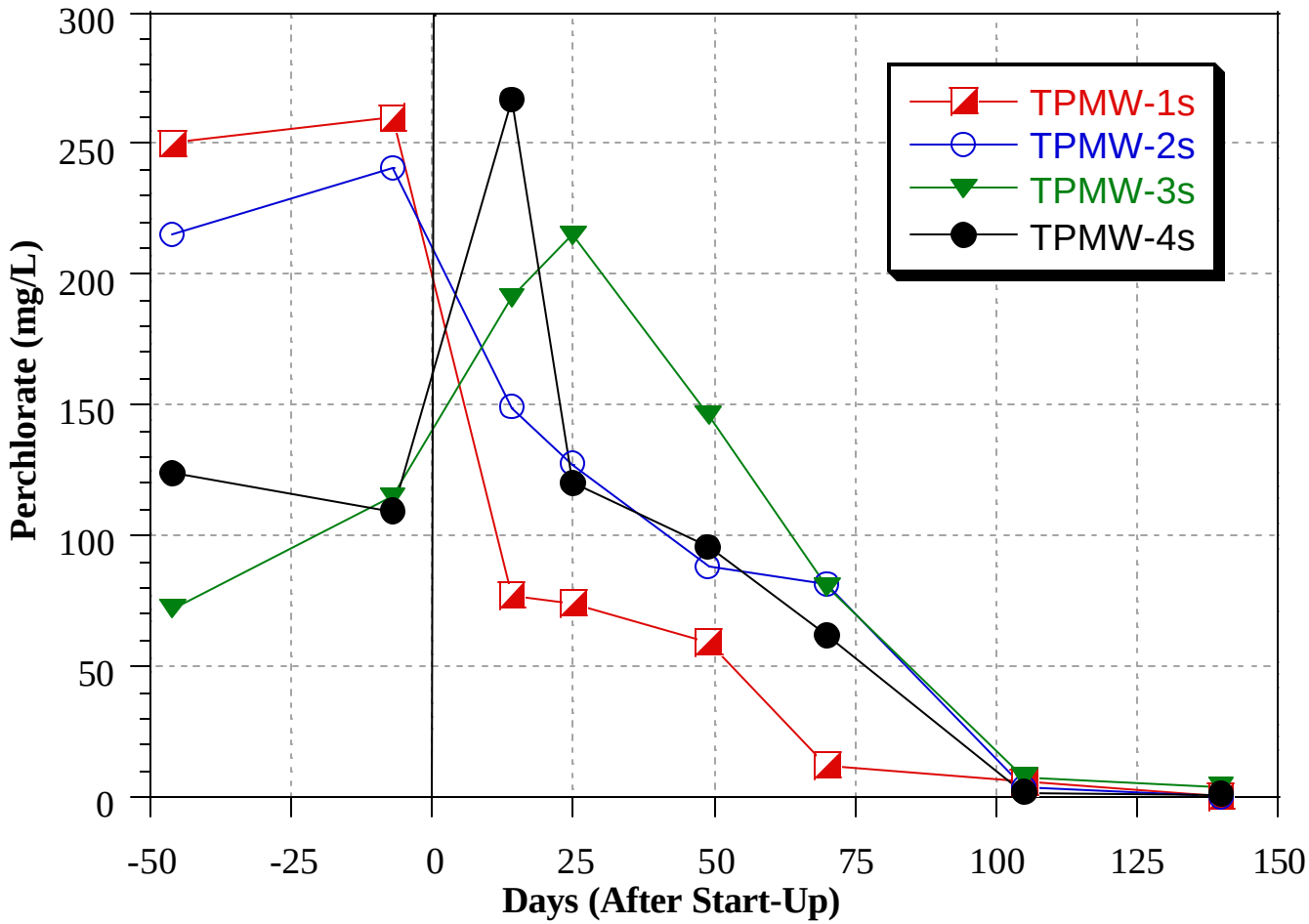
IHDIV Field Pilot - Perchlorate

Perchlorate Levels in Shallow Test Plot Wells



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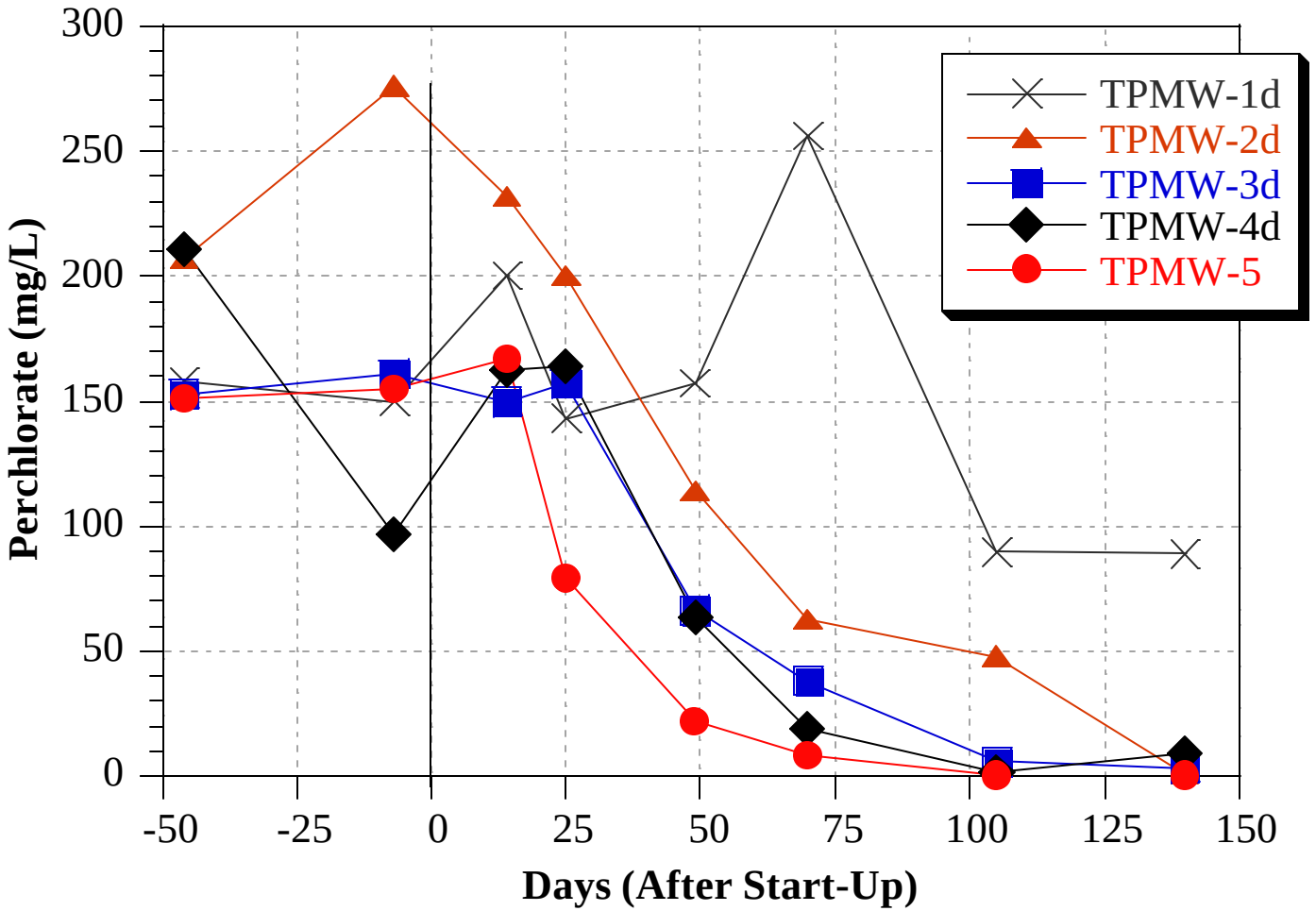
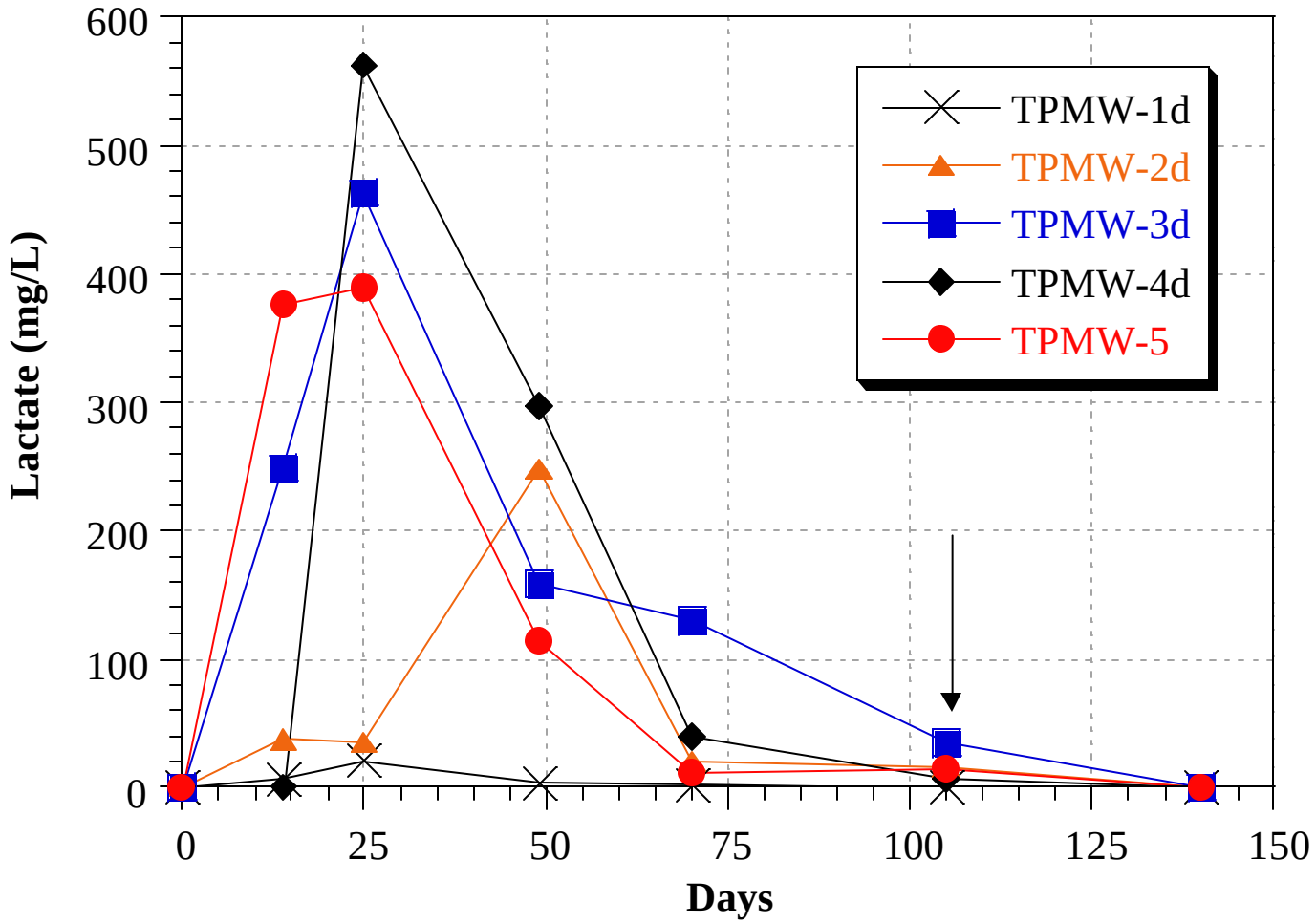
IHDIV Field Pilot - Perchlorate

Perchlorate Levels in DeepTest Plot Wells



IHDIV Field Pilot - Lactate



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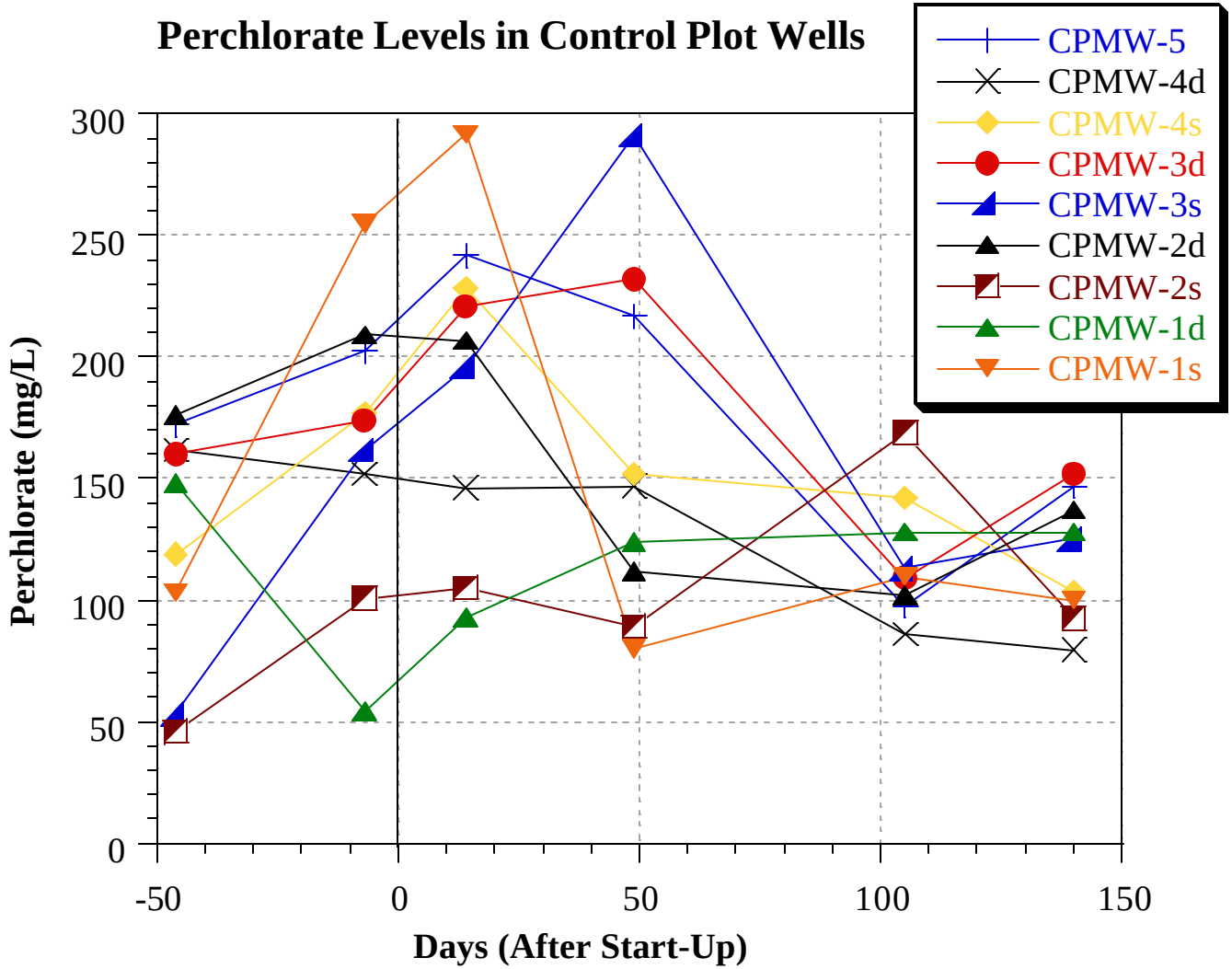
IHDIV Field Pilot - Perchlorate



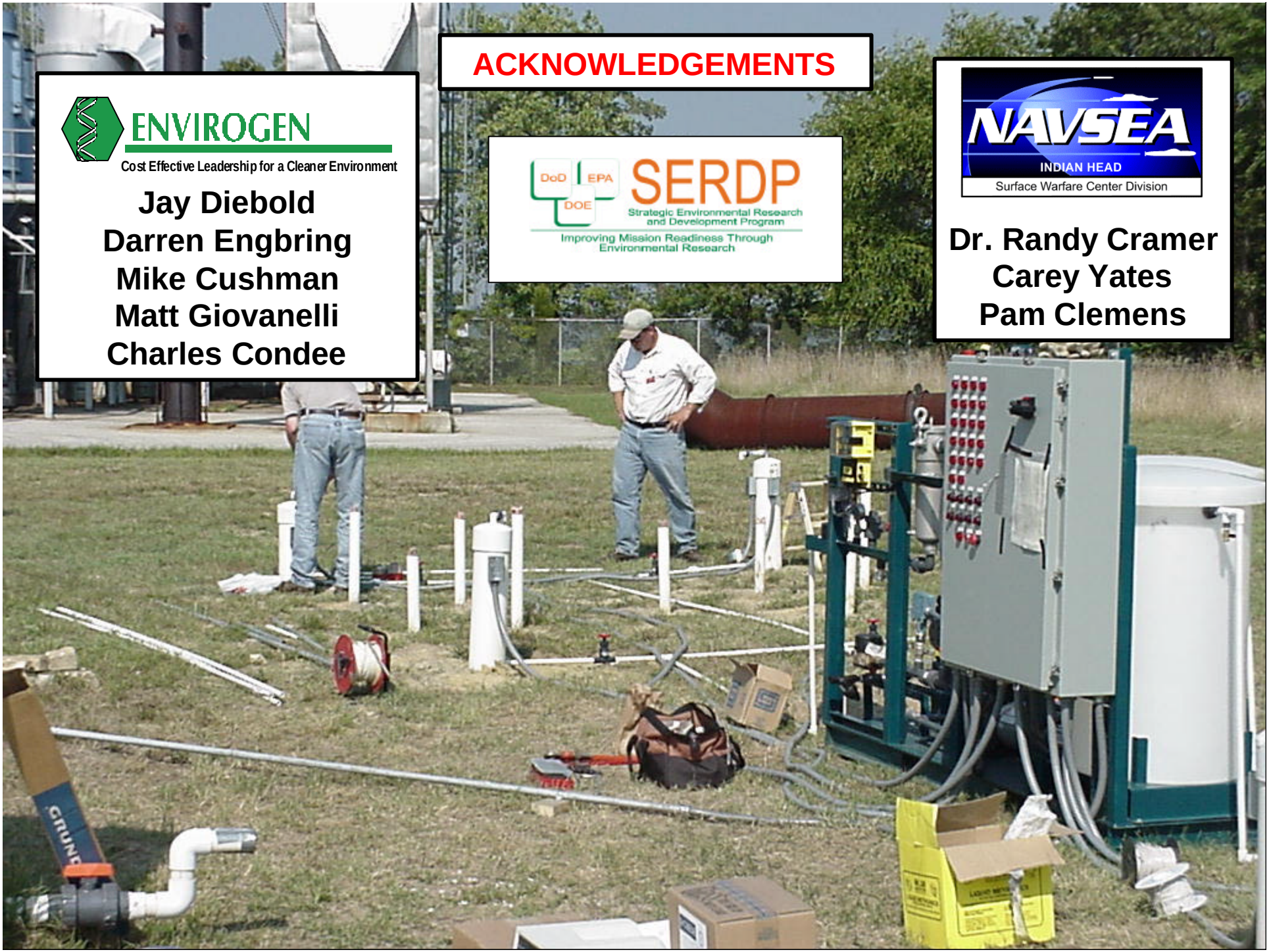
IHDIV Field Pilot

CONCLUSIONS:

1. **The Recirculation System Effectively Delivered Buffer and Electron Donor Throughout the Test Plot.**

2. **Perchlorate and Nitrate Biodegradation Occurred Rapidly After the Amendments were Applied to the Aquifer.**

3. **In Situ Treatment Using Electron Donor and Buffer Addition is a Viable Bioremediation Option for Perchlorate Treatment in Source Areas.**



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Mike Cushman
Matt Giovanelli
Charles Condee

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QUESTIONS ?

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