

Optimizing Fatty Acid Distribution Through Dispersion for Vegetable Oil Applications

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In Situ and On-Site Bioremediation Symposium

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- Purpose: To present a design model for neat oil applications as reductive dechlorination biobarriers
 - The key component is downgradient dispersion of fatty acids
 - Differs from emulsified oil, where key component is contact efficiency

Neat Vegetable Oil

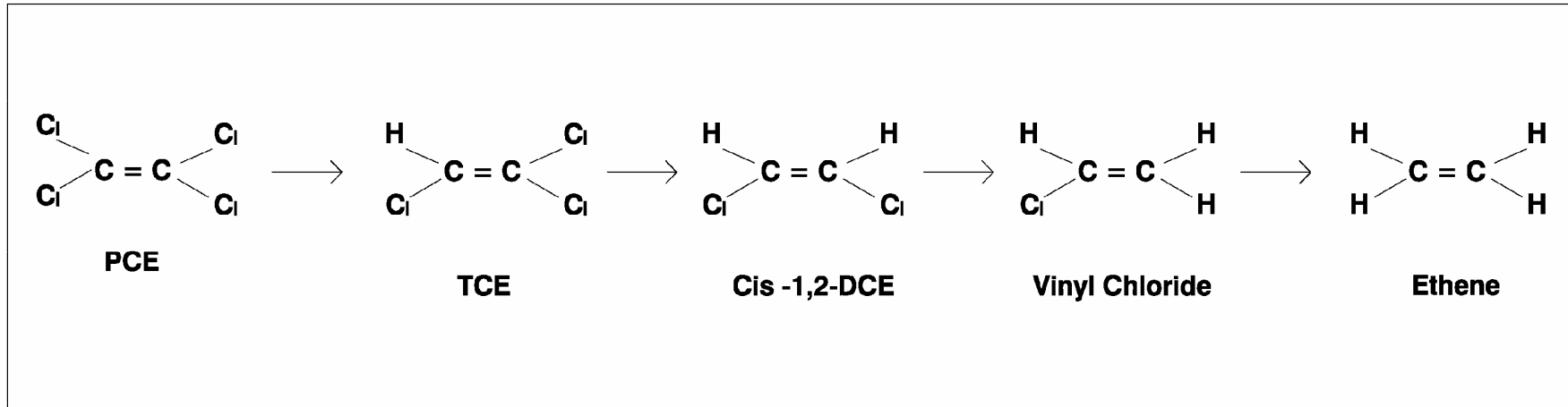
- Single phase
- Remains immobile once injected
- Lower injection volume
- Potentially more slow-release and longer lasting
- One of the least expensive electron donors available

Emulsified Vegetable Oil

- Oil mixture with water
- Oil droplets can move downgradient
- Easier to achieve high contact of oil with aquifer (larger ROI of injection)
- Faster-acting, due to larger surface area
- Higher cost

Reductive Dechlorination

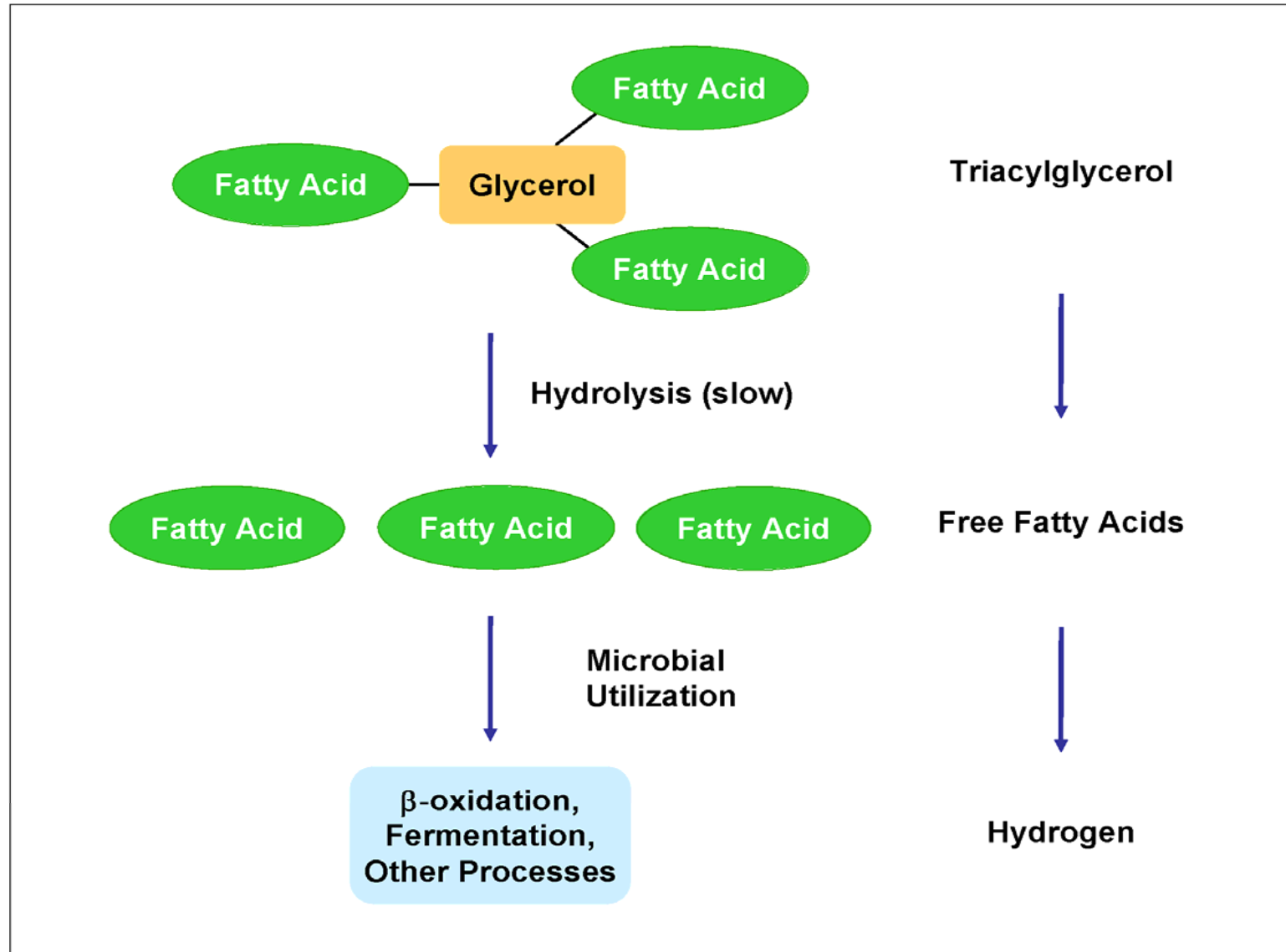
Pathway



- Degradation through transfer of electrons from fatty acids to chlorinated ethene
- Mediated by microbes, most notably *Dehalococcoides ethenogenes*

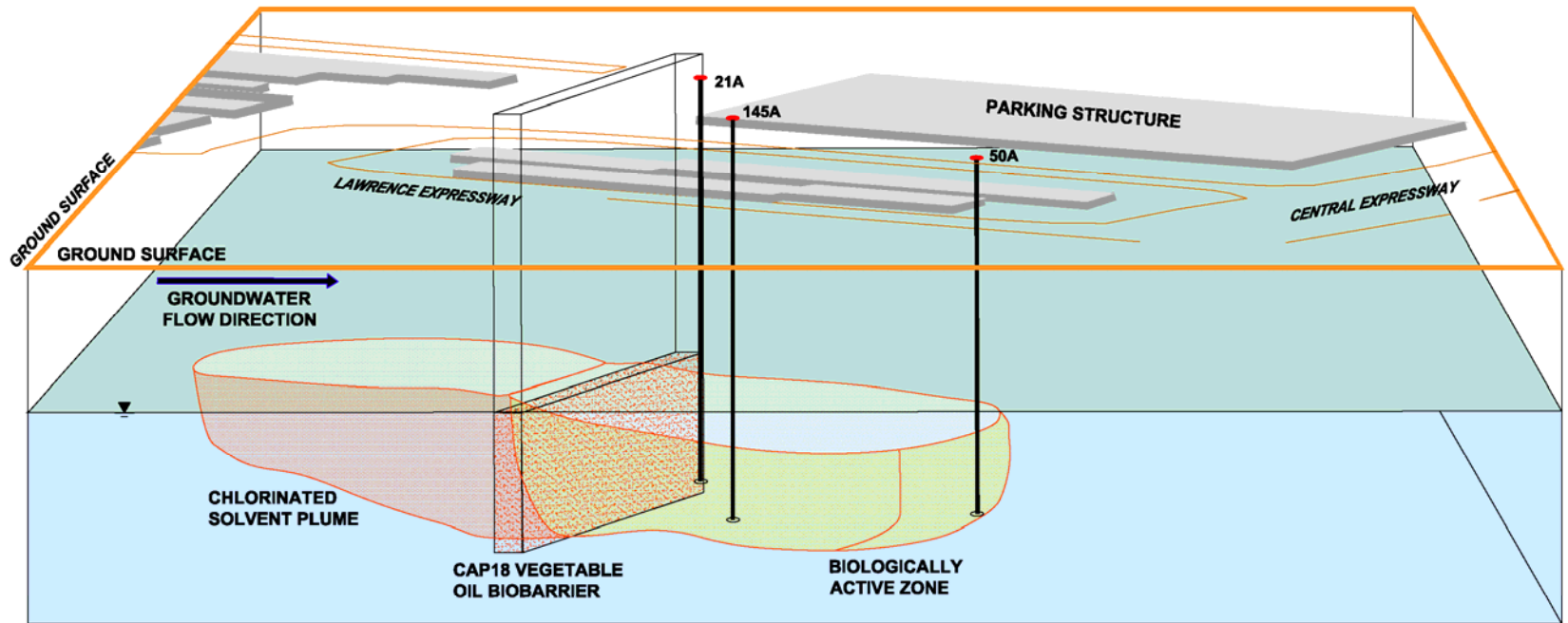
Reductive Dechlorination

H₂ Formation



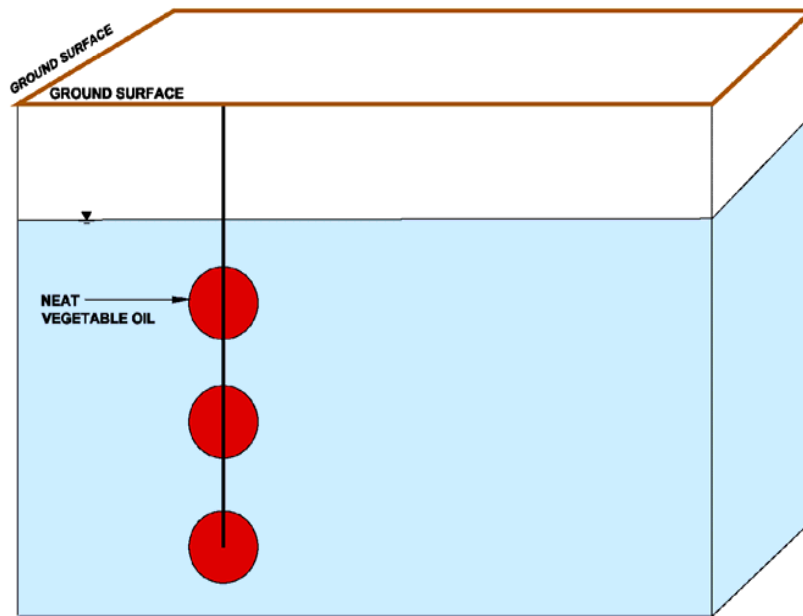
Reductive Dechlorination

Biobarrier Application

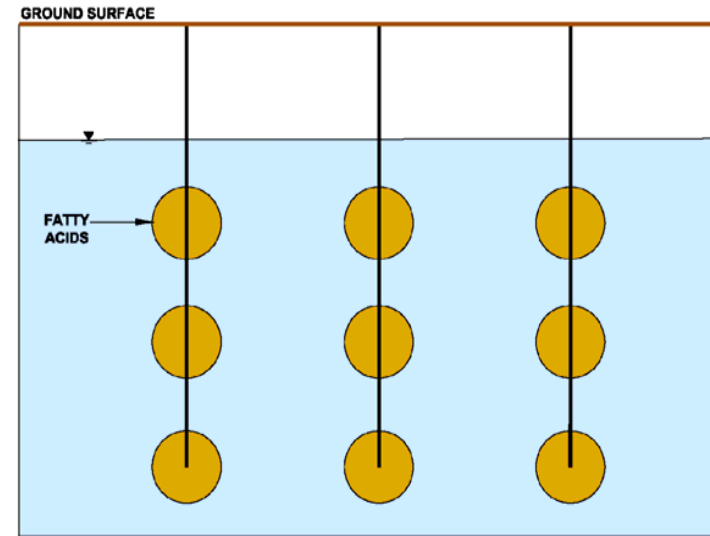


Neat Oil Injection & Dispersion

Along Biobarrier



ELEVATION VIEW

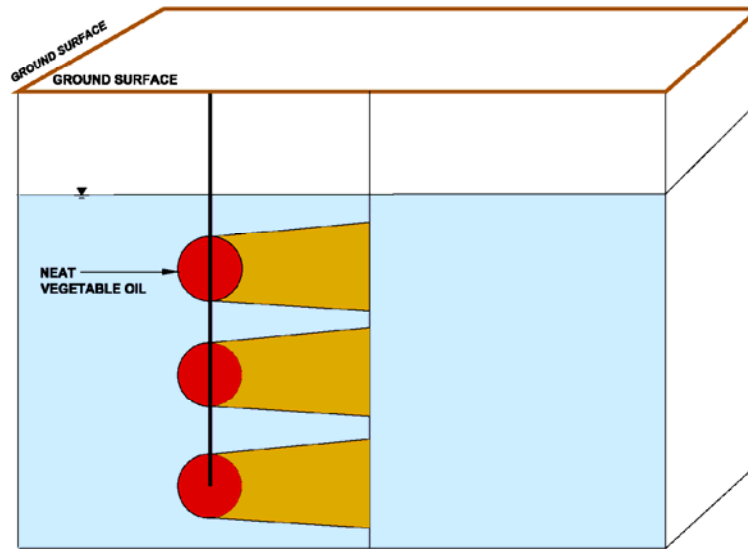


CROSS-SECTION VIEW

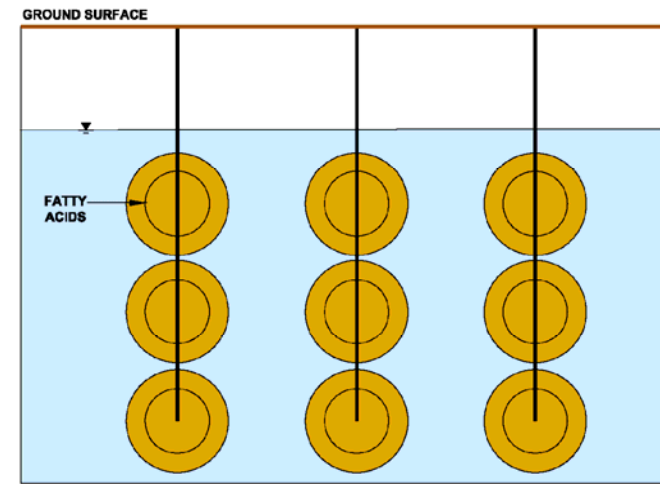
Initially: 10 to 20% coverage

Neat Oil Injection & Dispersion

Partial Mixing Zone



ELEVATION VIEW

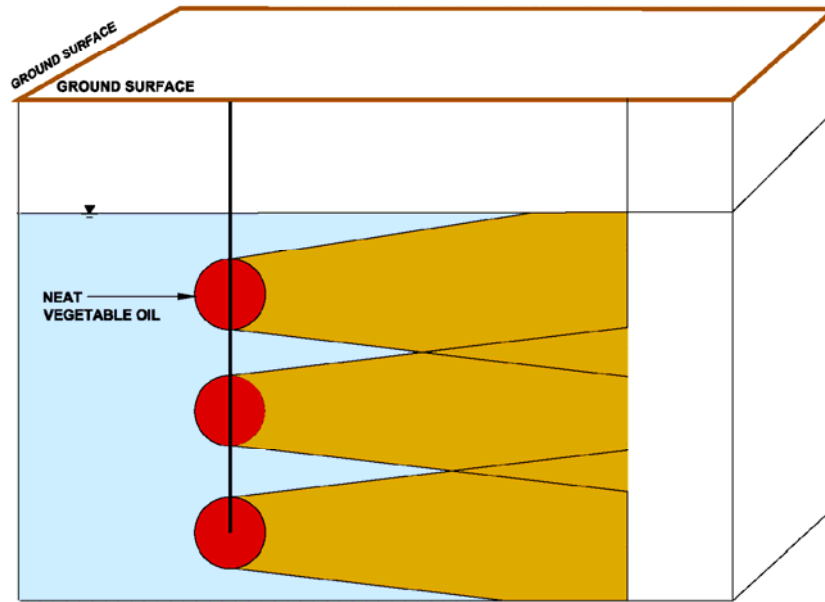


CROSS-SECTION VIEW

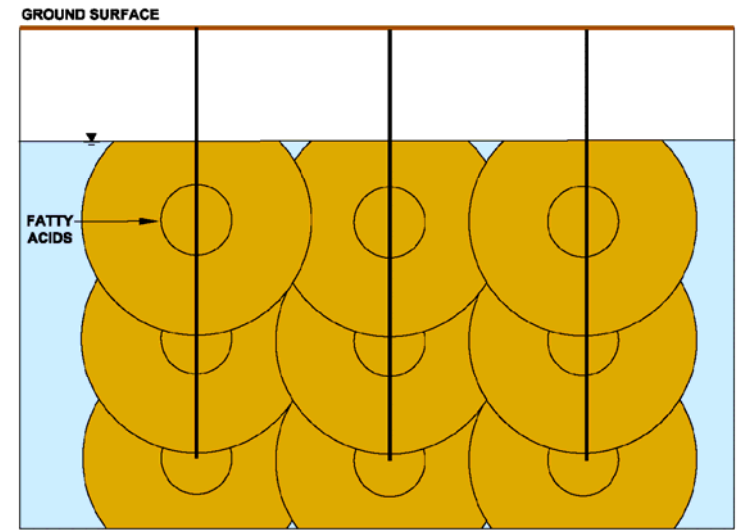
Some Time After Injection:
Increasing Coverage Due to Dispersion

Neat Oil Injection & Dispersion

Complete Distribution Zone



ELEVATION VIEW

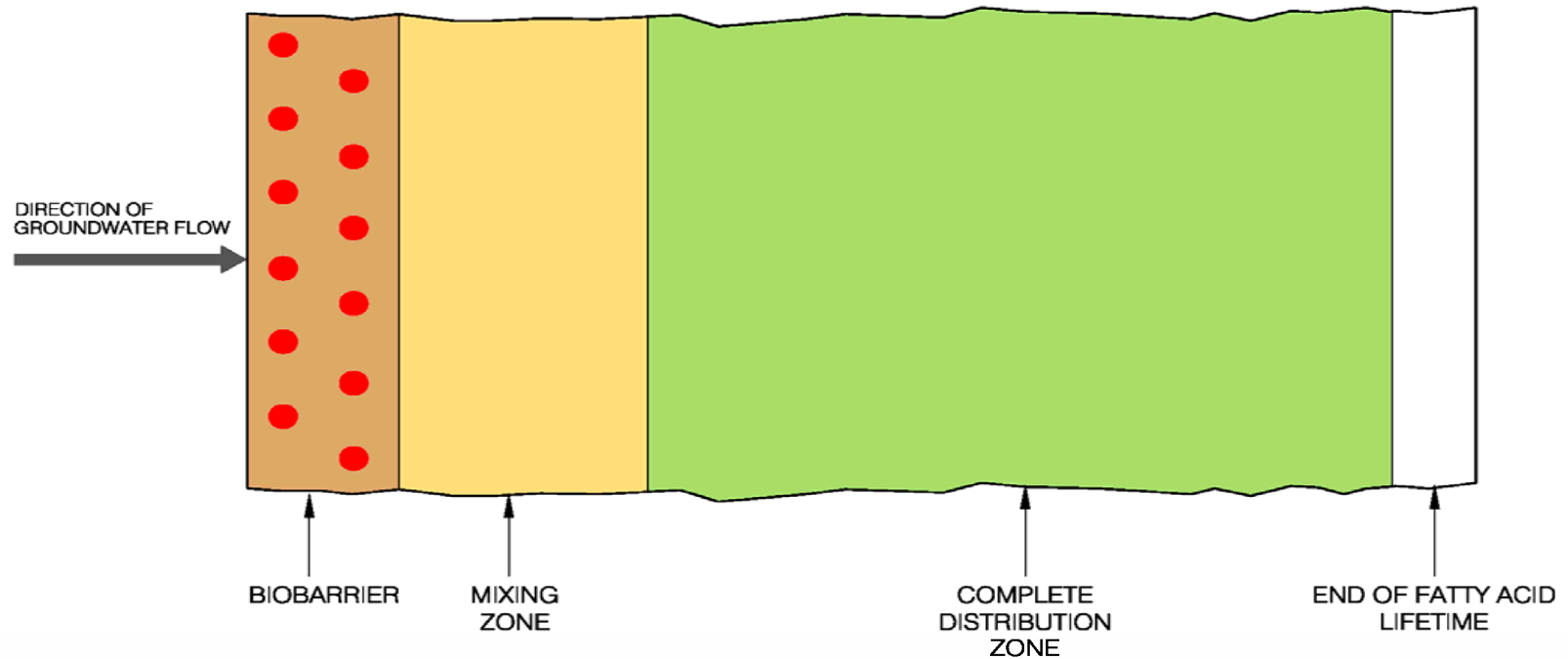


CROSS-SECTION VIEW

More Time After Injection:
Complete Coverage

Neat Oil Injection & Dispersion

Biobarrier Application



- Goal: To reach complete distribution zone with enough fatty acids remaining to complete reductive dechlorination

- Model vegetable oil as immobile NAPL that continuously releases fatty acids
- Use dispersion equation to predict spread of fatty acids
- Used adapted BioChlor model
 - To determine advection and dispersion of fatty acids
 - To locate distance downgradient where 100% coverage is reached

- Existing vegetable oil biobarrier at National Semiconductor Corporation, Santa Clara, California
 - Chlorinated ethene-impacted groundwater
 - 450-foot neat oil biobarrier
 - CAP18[®] vegetable oil (30,000 pounds)
 - Injections placed on 5-foot centers

- Cap18[®] selected based on:
 - Longevity in subsurface
 - Ease of injection
 - Low-cost donor
- Non-emulsified soybean oil
- High Concentration of 18-Carbon Chains
- Provided by DBI Remediation Products (now Carus Corporation)

Biobarrier Installation

Photos



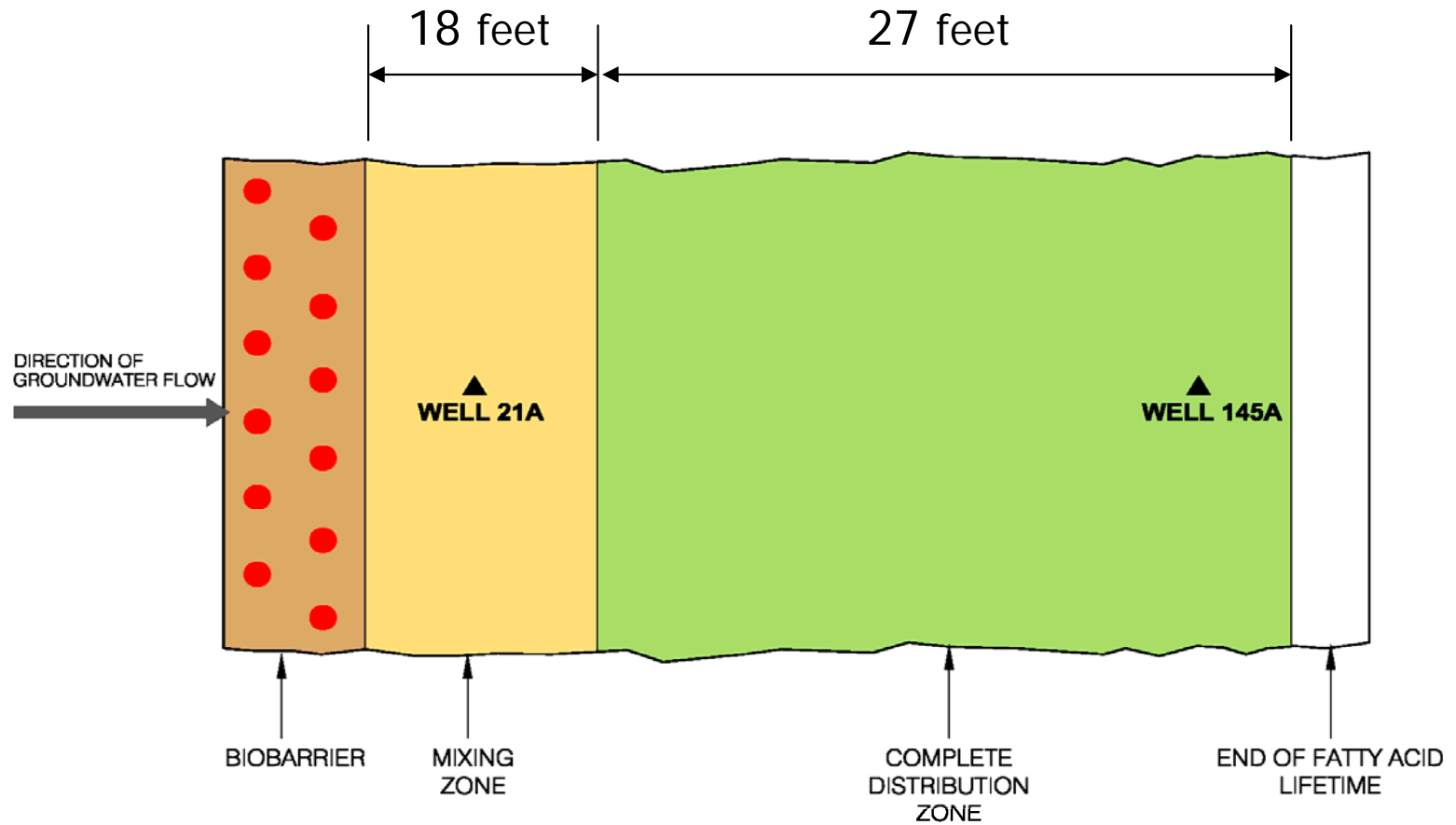
Biobarrier Installation

Photos



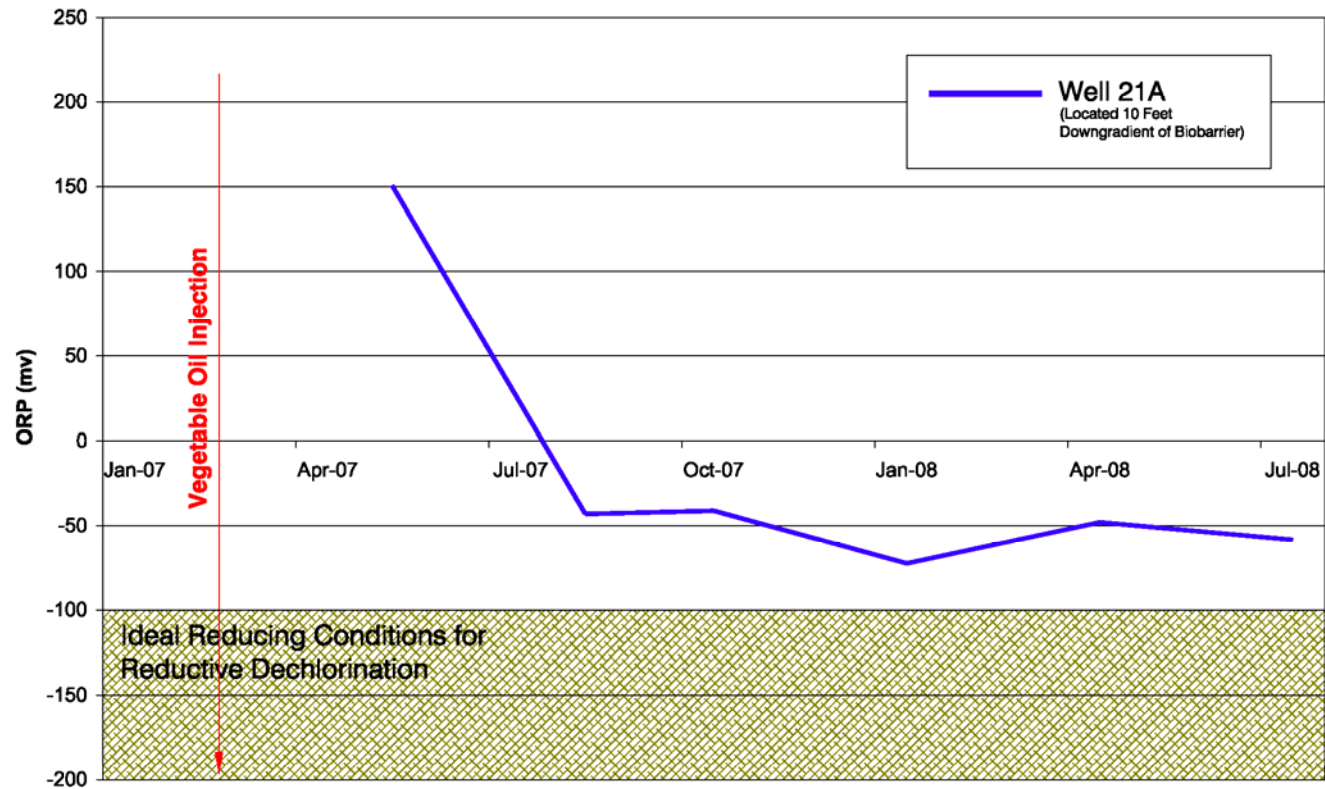
Neat Oil Design Model

Model Output



Model Output vs. Field Results

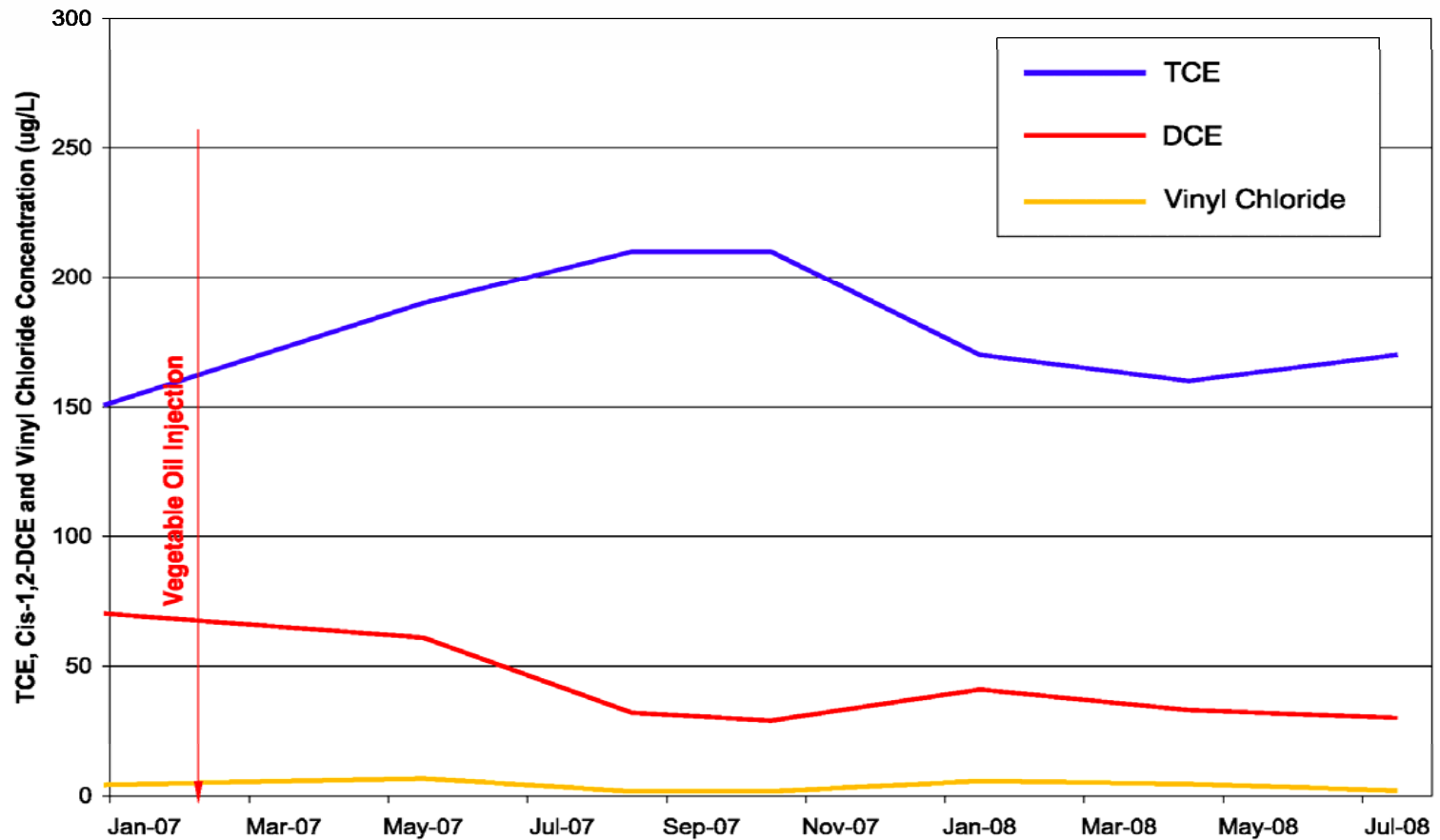
Well 21A – Mixing Zone



Moderate drop in ORP

Model Output vs. Field Results

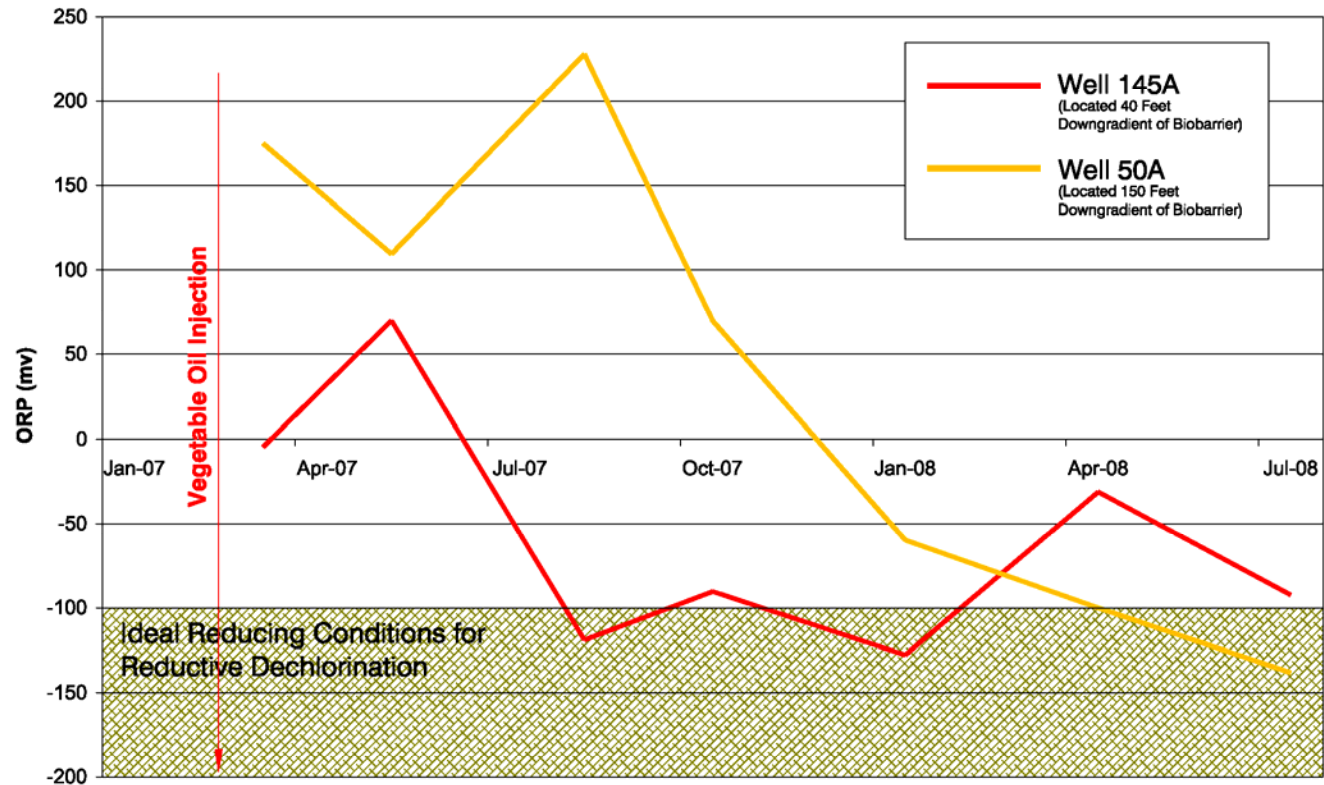
Well 21A – Mixing Zone



Very little change in VOC concentrations

Model Output vs. Field Results

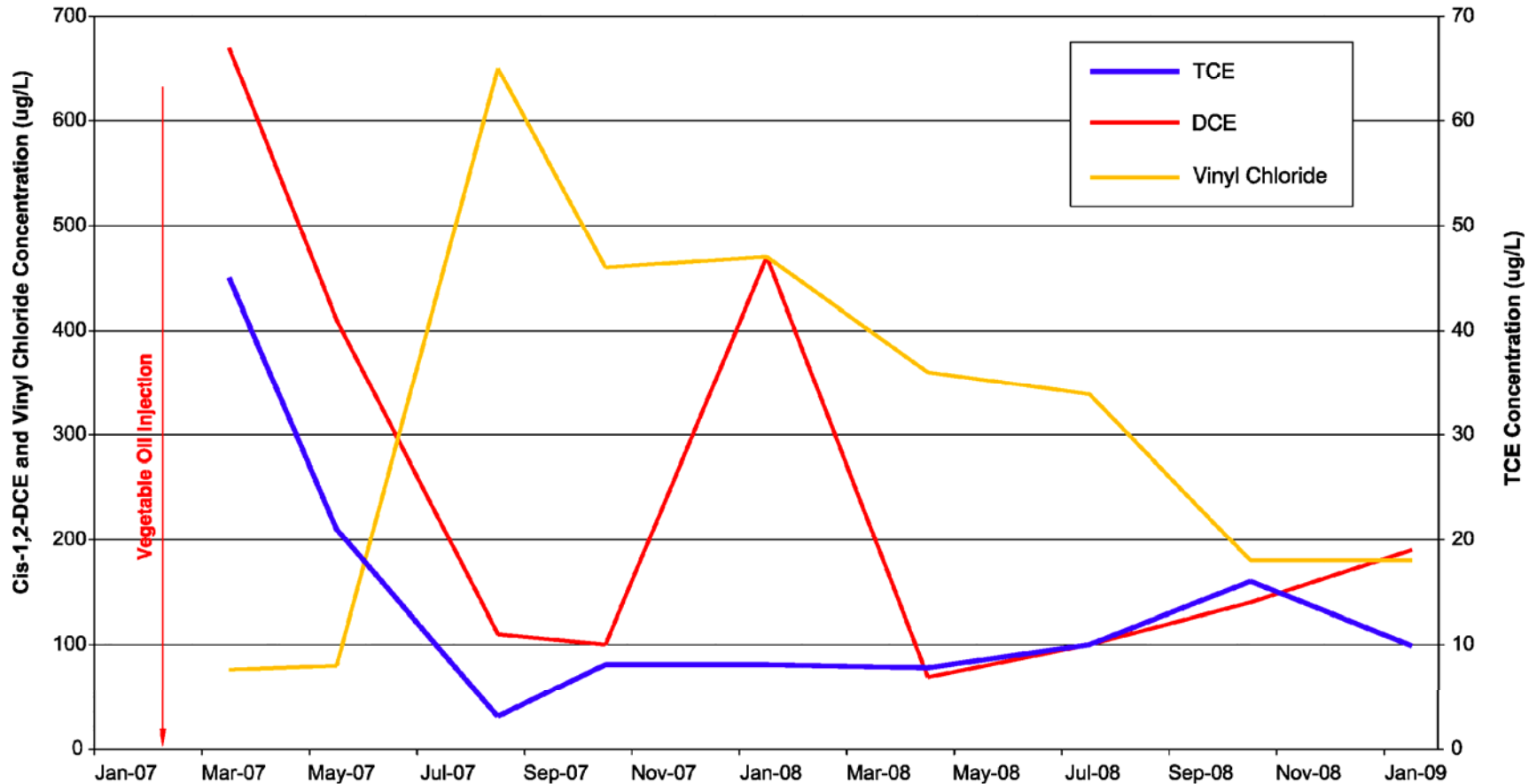
Well 145A – Complete Distribution



Excellent drop in ORP to optimal levels

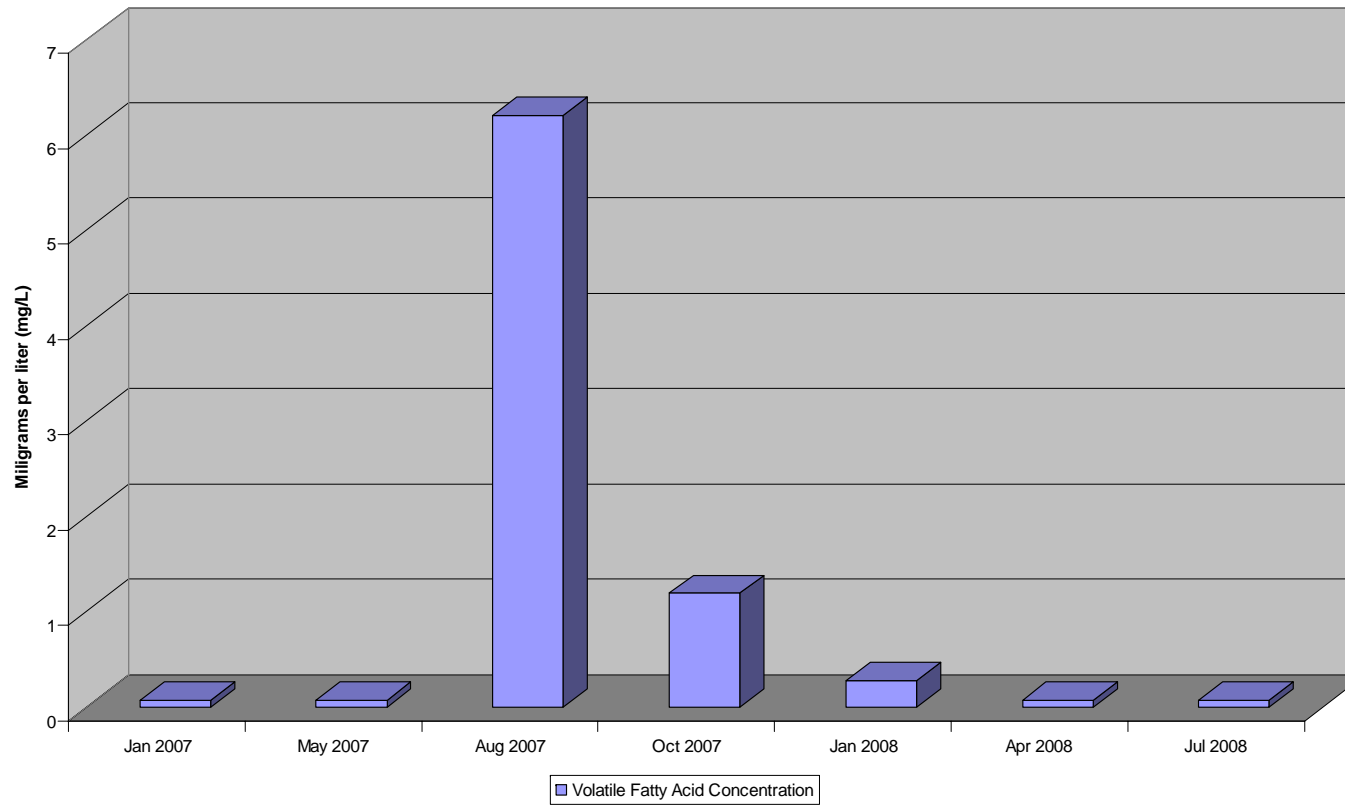
Model Output vs. Field Results

Well 145A – Complete Distribution



- 80 to 90% decrease in TCE and DCE
- Characteristic Vinyl Chloride rise and fall

VFAS

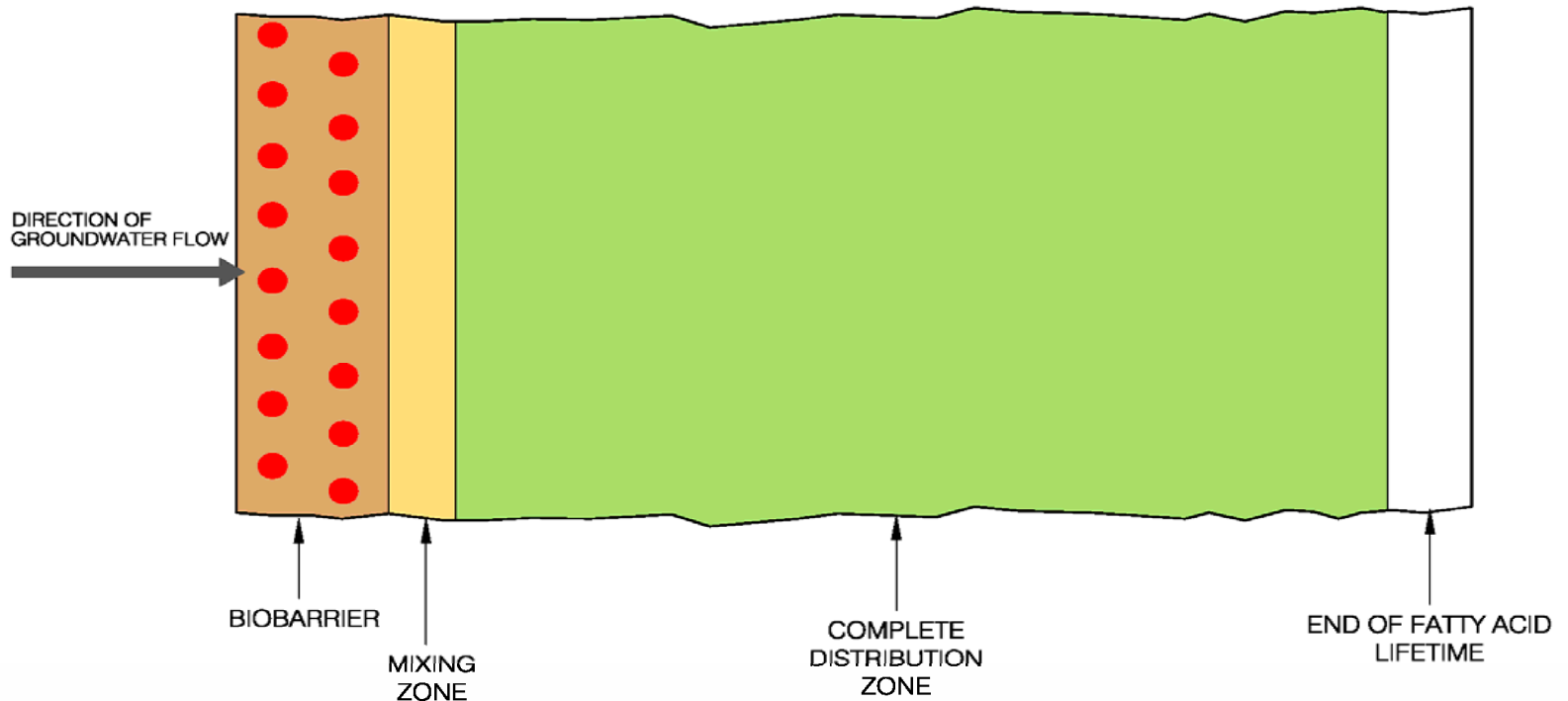


- Volatile fatty acids detected
 - Spiked 6 months following injections
 - Decreased as microbial mass grew to consume fatty acids

Treadwell & Rollo's model:

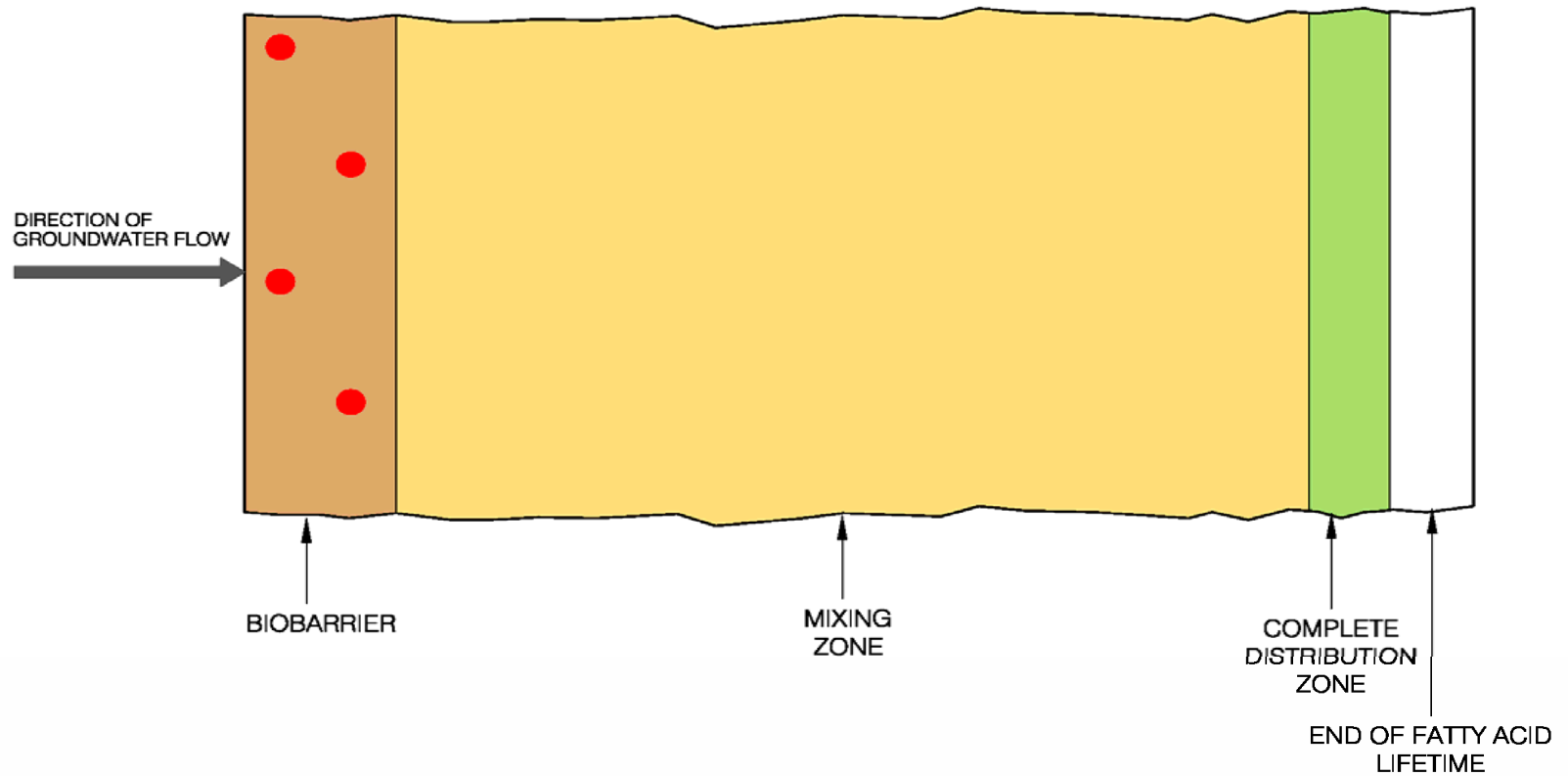
- 1) Offers a design tool for effective neat oil application
- 2) Offers a design tool for optimal placement of monitoring wells
- 3) Provides basis for ongoing neat oil vs. emulsified oil debate

Injection Spacing



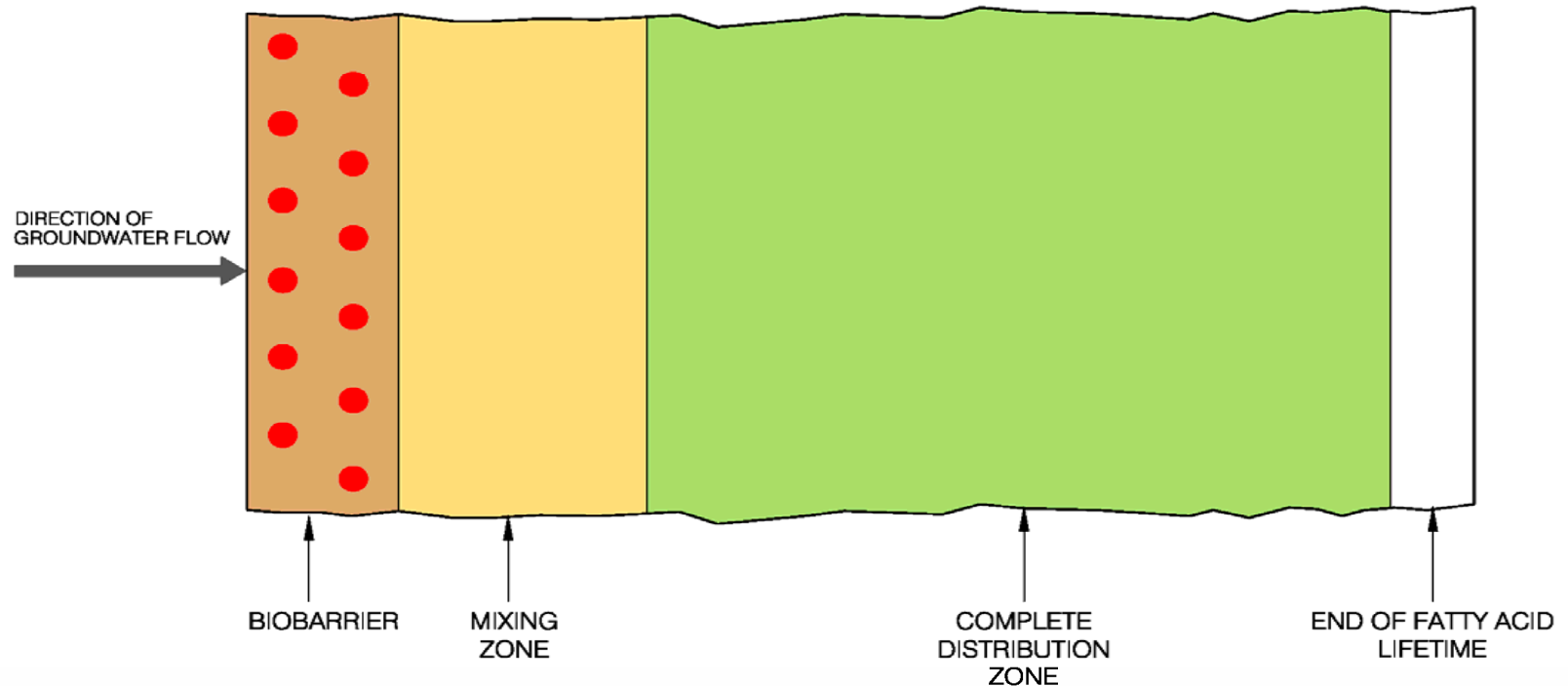
Injection Point Spacing is Too Close

Injection Spacing



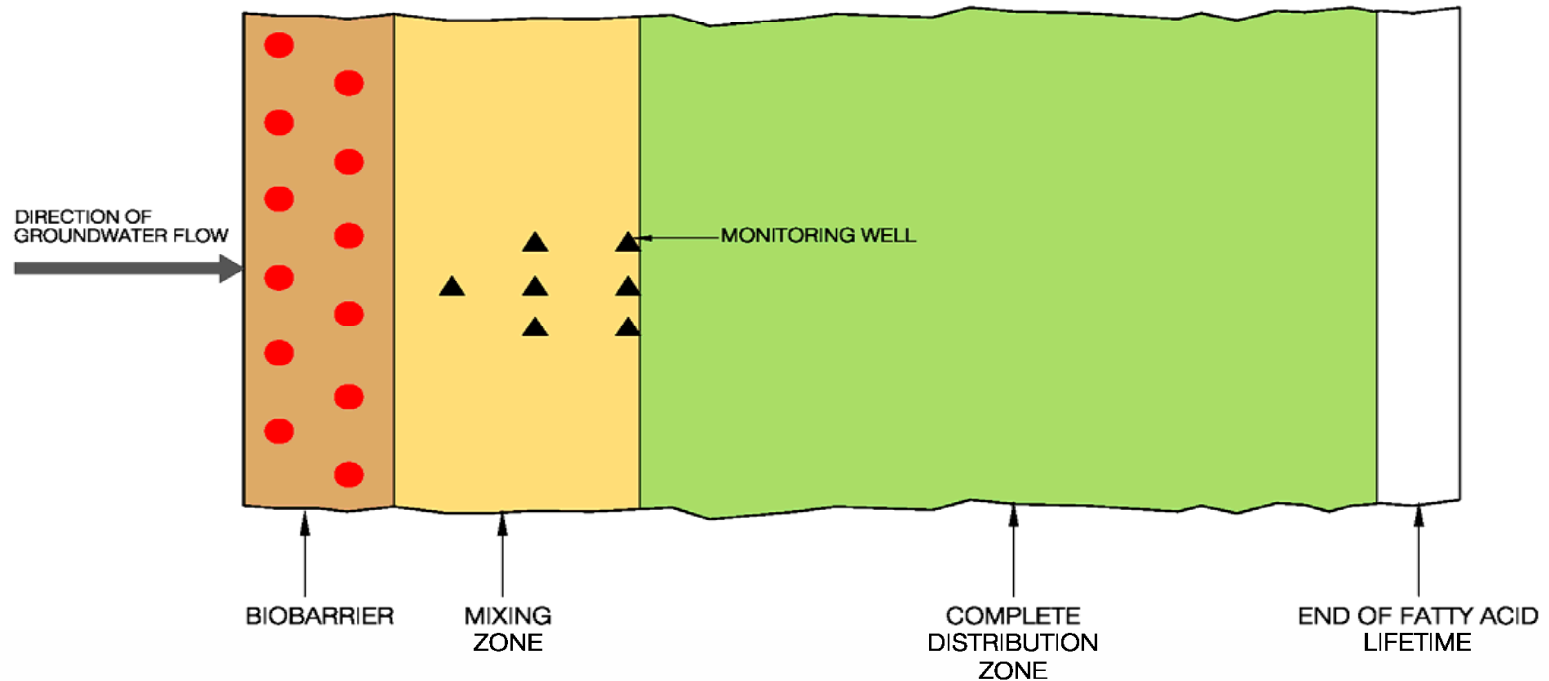
Injection Point Spacing is Too Far Apart

Injection Spacing



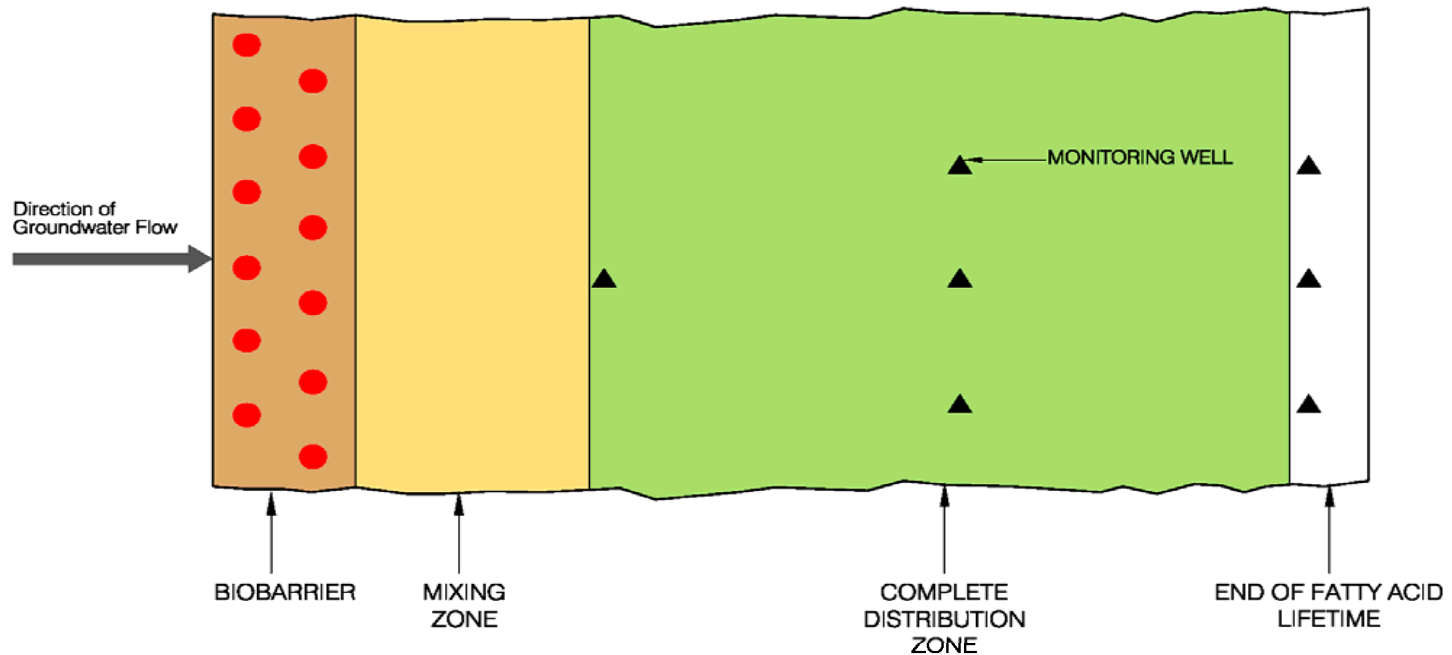
Injection Point Spacing is just right

Monitoring Point Placement



Poorly placed monitoring points

Monitoring Point Placement

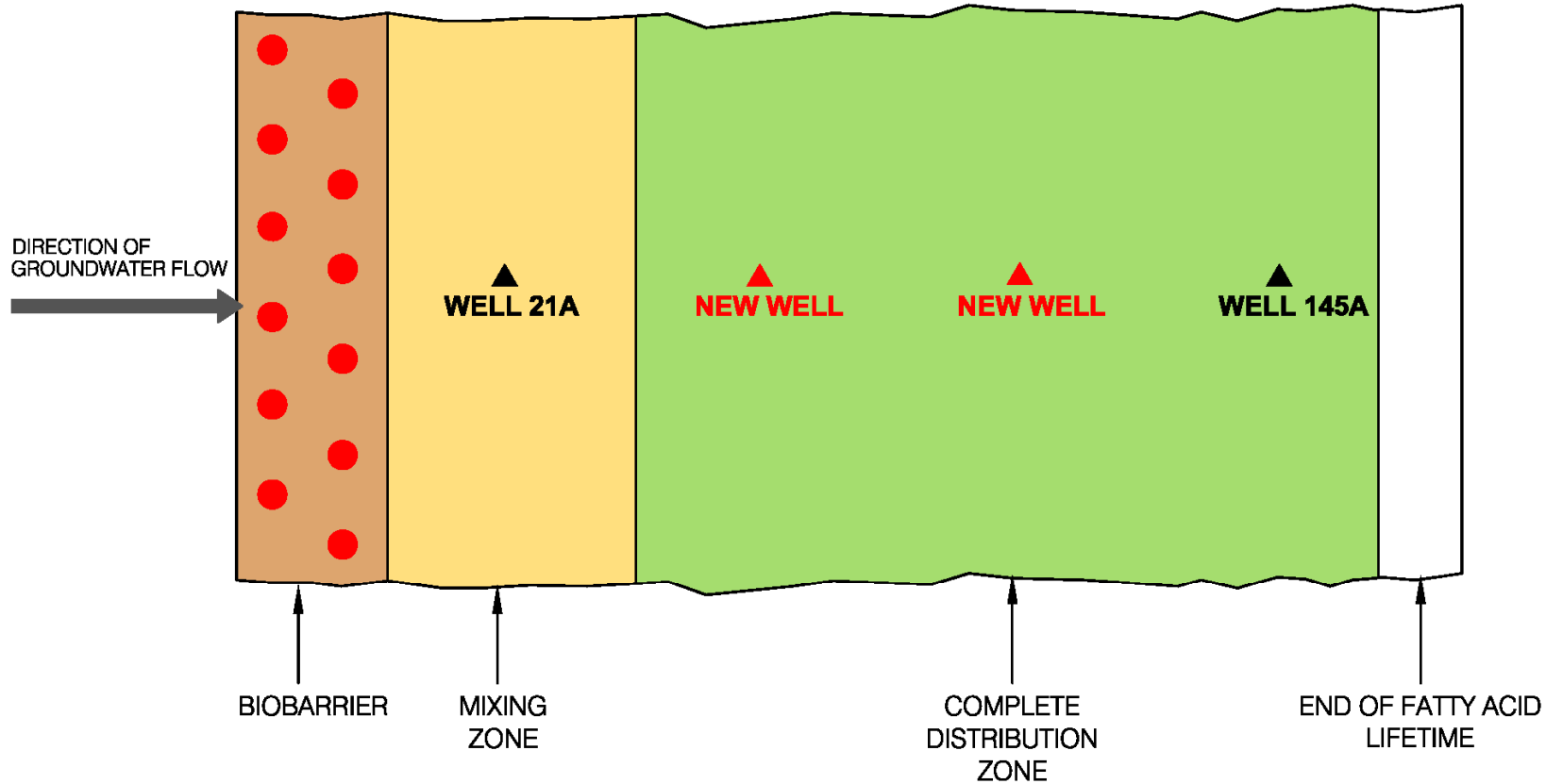


Better monitoring well network

Treadwell & Rollo is using the model to:

- 1) Install better-placed monitoring points at National Semiconductor
 - New monitoring points will further test the accuracy of the model

New Monitoring Points



Treadwell & Rollo's model:

- 1) Has been field-tested
- 2) Offers a design tool for effective neat oil application
- 3) Offers a design tool for optimal placement of monitoring wells
- 4) Provides basis for ongoing neat oil vs. emulsified oil debate

Acknowledgements

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