

# Surfactant Flushing of LNAPL Contaminant

## Full-Scale Source and Plume Remediation of Golden UST Site: Treatment-Train Approach

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## Outline

Recent Surfactant Flushing  
Development  
Laboratory Study  
Field Test  
Conclusions  
Future Development



## Recent Surfactant Flushing Development

Low Surfactant Concentration  
Integrated Low Surfactant/  
Chemical Oxidation and/or  
Bioamendment for Complete Site  
Closure



## Low Surfactant Concentration

Why this approach? Most site owners, especially USTs and industries, have limited resources for site clean-up efforts

Improve economics by using low surfactant concentrations (0.1 to 1 wt% versus 3 to 8 wt% in earlier Surfactant Flushing projects)

Low surfactant challenges: formation of microemulsion (volume reduction, significant change of IFT), greater sorption impact



## Integrated Low Surfactant/Chemical Oxidation or Bioamendment Approach

Surfactant Flushing is not suitable for dilute plume remediation

Polishing step: injection of low chemical oxidant (< 1 wt%) and/or bioamendment to polish remaining residual / dilute NAPL plume

Selection of chemical oxidants and/or nutrients depend on site-specific NAPL and soil properties



## Laboratory Surfactant Screening

Surfactant system	Surfactant conc. evaluated wt%	NAPL (TPH) solubility in <b>Type III</b> microemulsion mg/L	Equilibrated time of stable <b>Type III</b> microemulsion hr
AOT/AMA/NaCl	1 to 2	440,000	1 – 2
<b>AOT/Calfax 16L-35/NaCl*</b>	0.2 to 1	450,000	1 – 2
Lubrizol DP/AMA/NaCl	0.2 to 1	400,000	8 - 12

\*selected for Golden UST site



## BTEX Degradation with Oxidants

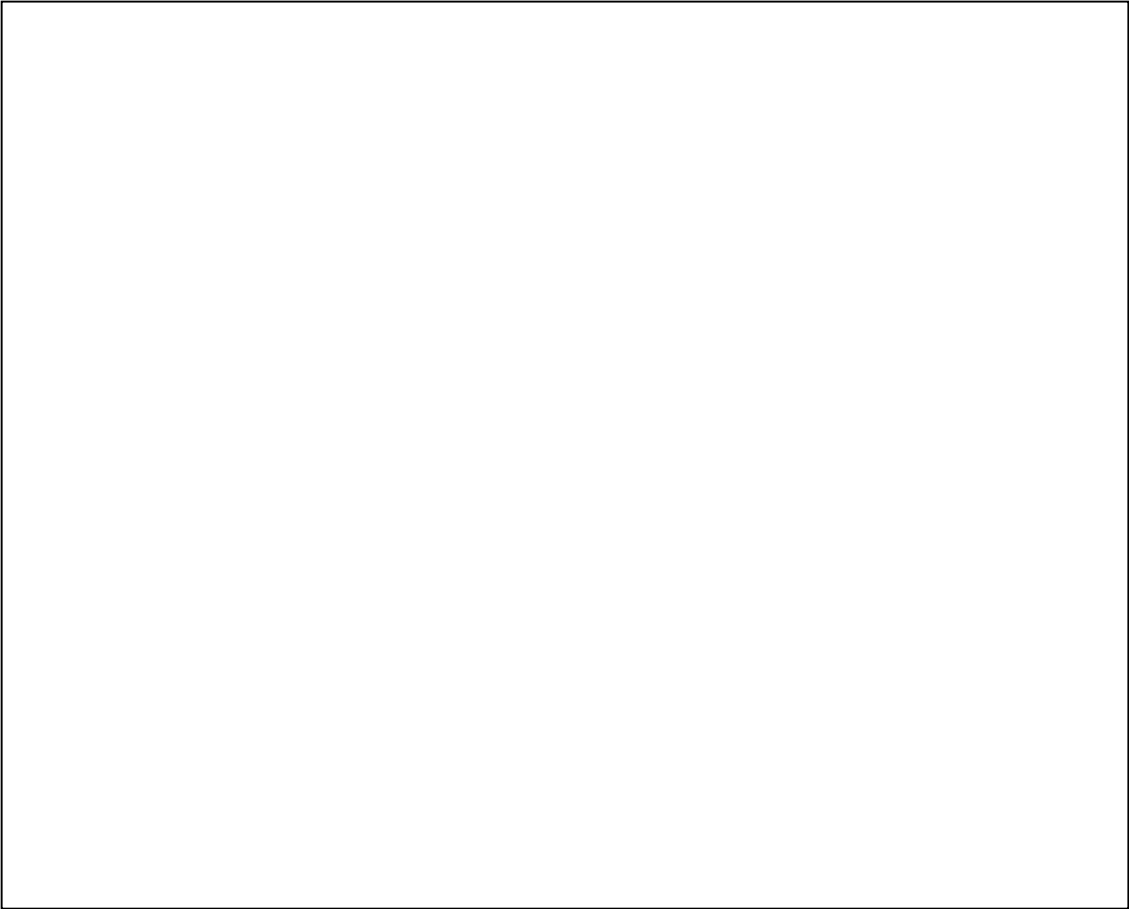
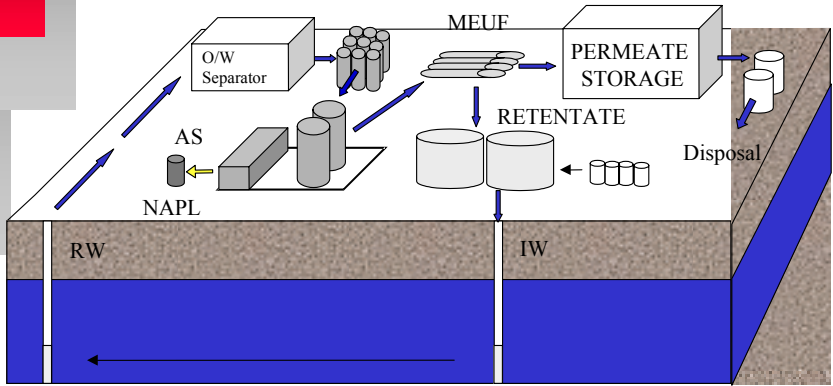
Oxidant system	Oxid. conc.	Benzene degrad.	Toluene	Ethylbenzene	Total Xylene
	mg/L	%	%	%	%
$\text{H}_2\text{O}_2/\text{Fe}^{+2}/\text{H}_2\text{SO}_4$	2,000	92	44	59	45
$\text{KMnO}_4$	5,000	8	NA*	NA	NA

\*Benzene only system; **Fenton's Reagent** was used at Golden UST site





# Surfactant Flushing Integrated Process



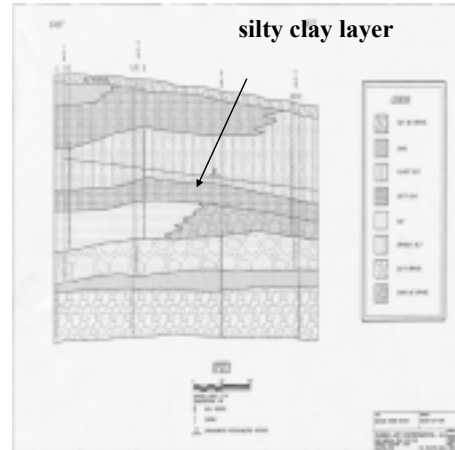
# Golden, OK UST Site Starting Point

Gasoline free phase:  
thickness on water table 2.7  
to 3.3 ft

Shallow zone (< 15 ft) -  
silt:benzene, 2,000 to 36,000  
 $\mu\text{g/L}$  in GW; TPH, non-  
detect to 345 mg/L

Deep zone - sand/gravel:  
benzene, 50 to 3,000  $\mu\text{g/L}$ ;  
TPH, non-detect to 30 mg/L

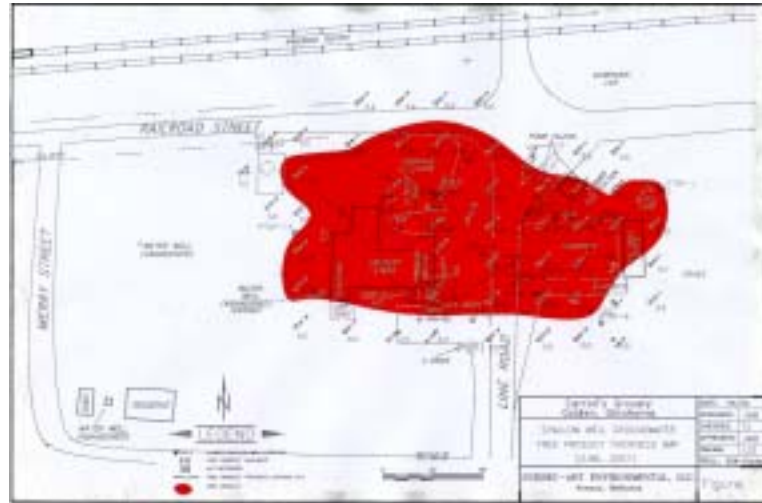
Surfactant Flushing Zone:  
1.5 acres (22,300  $\text{ft}^2$ )



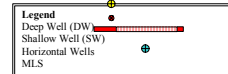
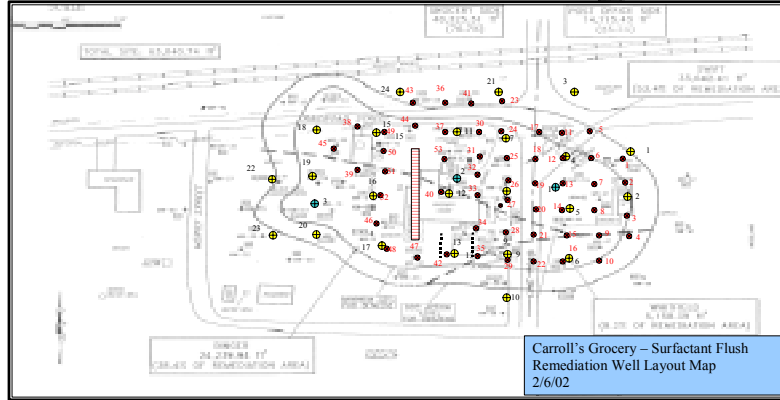
Golden UST geologic cross section



# Free Product Map



# Site Well Layout



## Golden UST Site, Oklahoma

### Project Goals

Primary: Remove all free phase gasoline

Secondary: Significant decrease in soil and groundwater concentrations (one to two order magnitude)

Tertiary: Soil and groundwater concentrations to primary drinking water standard

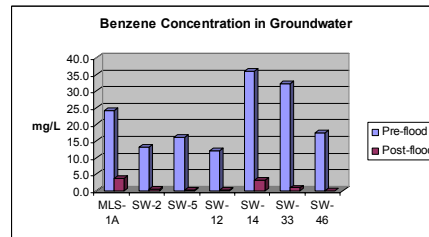
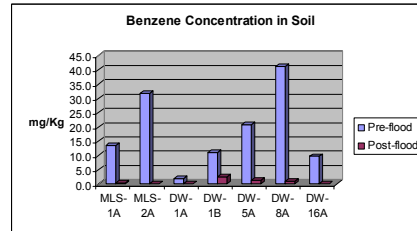


Golden UST Site, OK



# Golden, OK UST Site Approach / Results

Low level (< 1 wt%) surfactant/cosurfactant mixture  
 1 PV (190,000 gallons) – 60 days flushing  
 Polishing: shallow -- low level chemical oxidation;  
 deep – bioammendments (Phase I); chemical oxidation (Phase II-ongoing)  
 Soil and ground water concentrations reduced by one to three orders of magnitude



Data collected on 06/27/02



# Golden, OK UST Site Results vs Goals

Primary: no visible or instrumental evidence of free phase gasoline in 22 wells after three-month shut-down (3 had trace levels of NAPL)  
> 6,500 gallons gasoline extracted



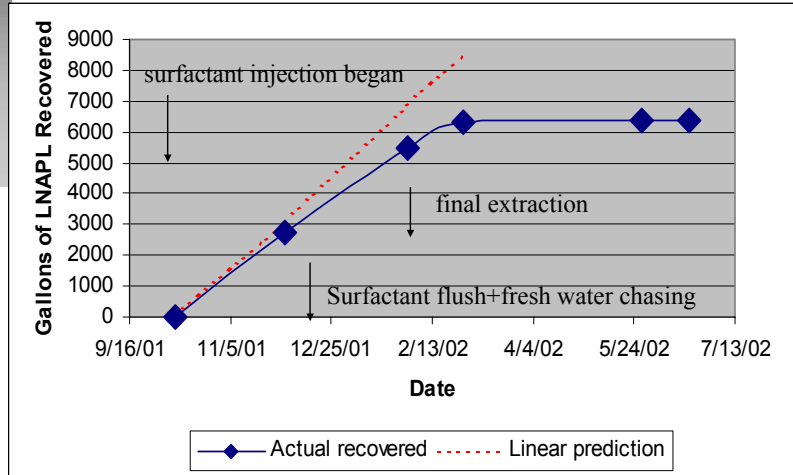
# Golden, OK UST Site Results (cont.)

Secondary: GW--  
70% to 99%  
reduction in  
benzene  
concentration  
Final Polishing  
(Chem Oxid-Phase  
II) to approach  
MCL (12/02-  
expected)





# Total NAPL Recovery



## Golden UST Conclusion

Surfactant Flushing appears technically and economically favorable compared with other technologies

Significant NAPL mass removal can be achieved by low surfactant concentration approach

Treatment-train approach -- combination of Surfactant Flushing (source removal) with chemical oxidation and/or bioamendments (contaminant plume polishing) to expedite site closure



## Golden UST Conclusion (cont.)



### Economical Comparison

- Total project: \$712 K
- Surfactant Flushing: \$569 K; volume treated = 15,550 yd<sup>3</sup>; cost = \$36 / yd<sup>3</sup>
- Total project costs (including zones area treated with chem oxid) = \$14 / yd<sup>3</sup>
- Properly designed, economical  
As low as: \$25 - 30 / yd<sup>3</sup> (LNAPL)



# Current & Future Surfactant Flushing Development

Potential UST Sites for Low Surfactant Flushing:  
Oklahoma (2), Arkansas (1), Missouri (1), New Jersey (1)

Tank Pit Flushing:

Free phase removal  
(gasoline & diesel pits)

Love's Country Store  
(OKC, Completed--  
10/02)

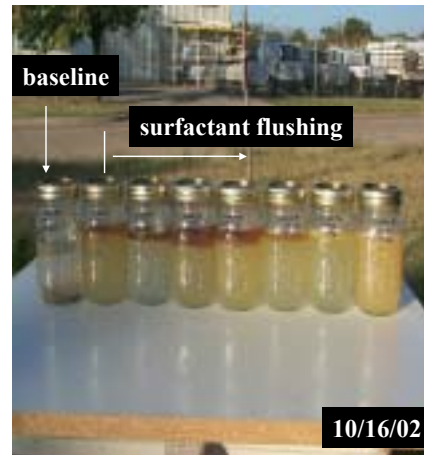


Love's Tank Pit



# Current & Future Surfactant Flushing Development (cont.)

Approach: low surfactant conc. (1PV)  
Different surfactant systems for gasoline and diesel pits  
Low cost (\$10K-20K)  
Recycling/ reuse of recovered water  
Compact design without interrupting the routine activity



Tank Pit Effluent

