Surfactant Flushing of LNAPL Contaminant

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

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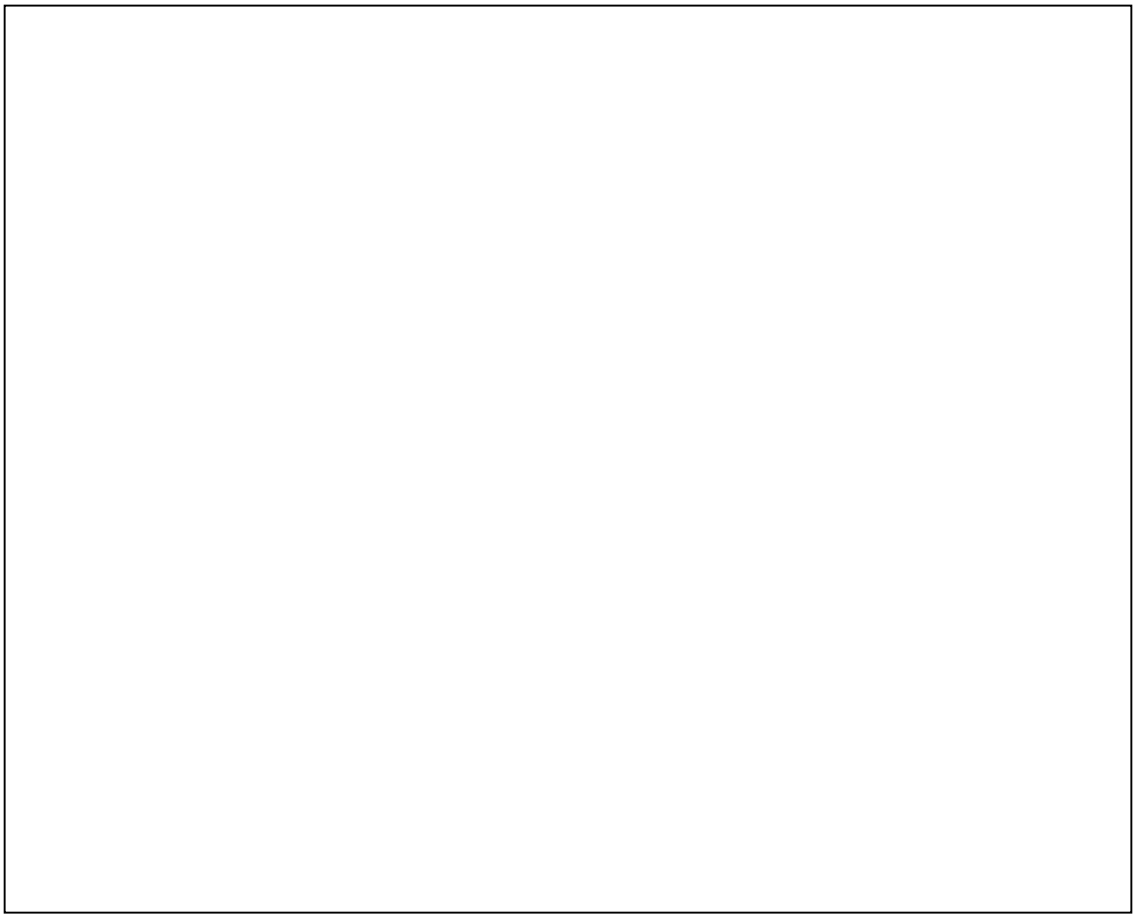

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Outline

- 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

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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

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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

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Laboratory Surfactant Screening

Surfactant system	Surfactant conc. evaluated wt%	NAPL (TPH) solubility in **Type III** microemulsion mg/L	Equilibrated time of stable **Type III** microemulsion hr
AOT/AMA/NaCl	1 to 2	440,000	1 – 2
AOT/Calfax 16L-35/NaCl*	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**

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BTEX Degradation with Oxidants

Oxidant system	Oxid. conc.	Benzene degrad.	Toluene	Ethylb enzene	Total Xylene
	mg/L	%	%	%	%
$H_2O_2/Fe^{+2}/H_2SO_4$	2,000	92	44	59	45
$KMnO_4$	5,000	8	NA*	NA	NA

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

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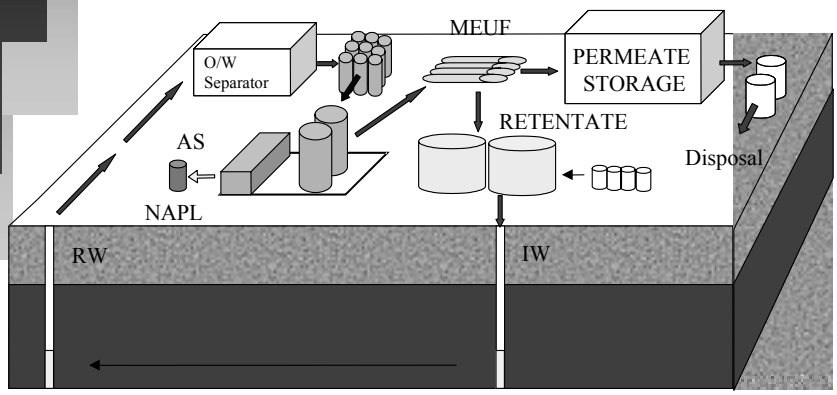
Surfactant Flushing Integrated Process



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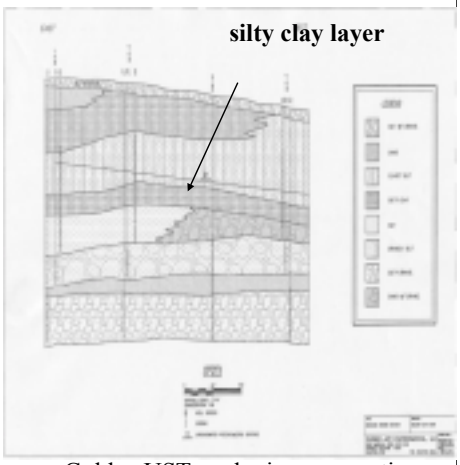
Golden, OK UST Site
Starting Point

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

Shallow zone (< 15 ft) - silt:benzene, 2,000 to 36,000 µg/L in GW; TPH, non-detect to 345 mg/L

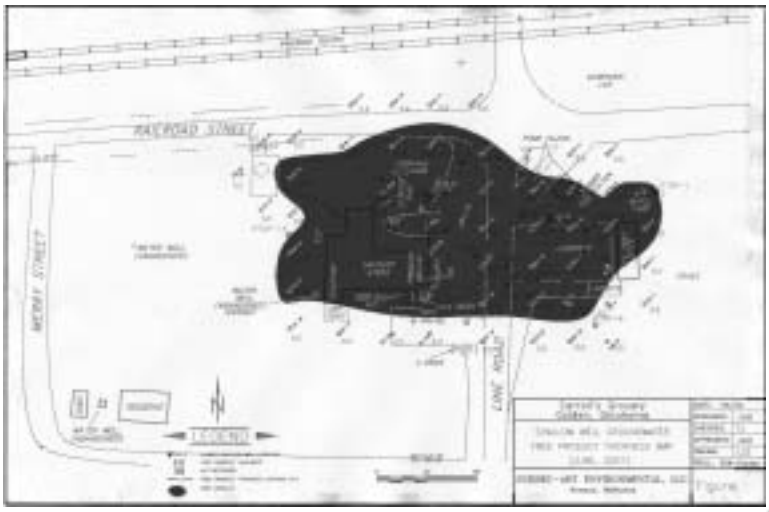
Deep zone - sand/gravel: benzene, 50 to 3,000 µg/L; TPH, non-detect to 30 mg/L

Surfactant Flushing Zone: 1.5 acres (22,300 ft^2)



Golden UST geologic cross section

Free Product Map



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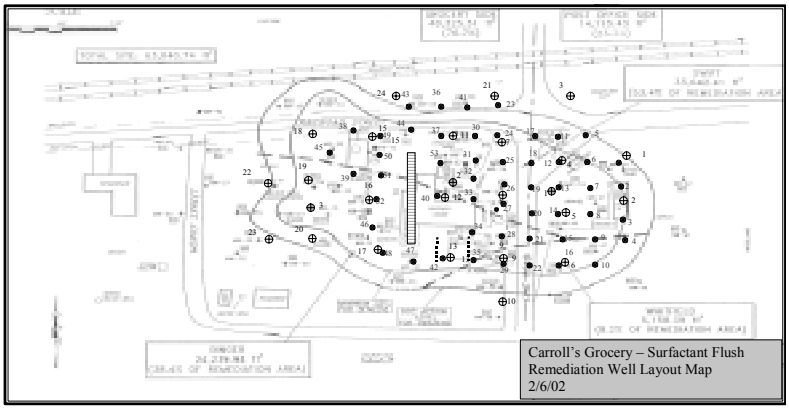
Site Well Layout



Carroll's Grocery – Surfactant Flush
Remediation Well Layout Map
2/6/02

Legend
Deep Well (DW)
Shallow Well (SW)
Horizontal Wells
MLS

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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

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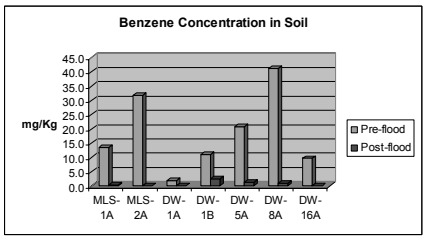
Golden, OK UST Site Approach / Results

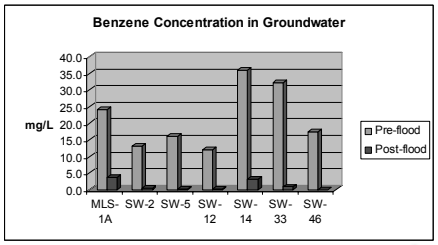
Low level (< 1 wt%) surfactant/cosurfactant mixture

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



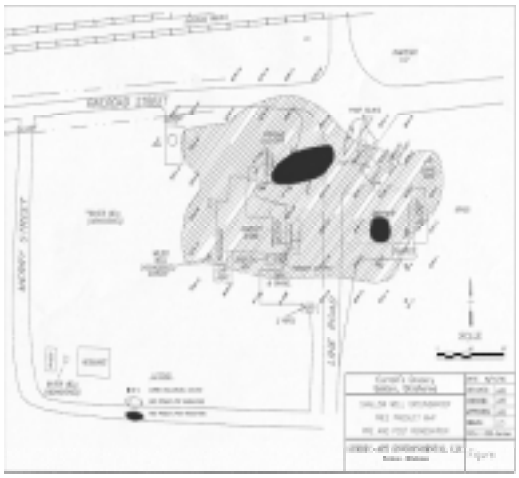


Data collected on 06/27/02

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



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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)

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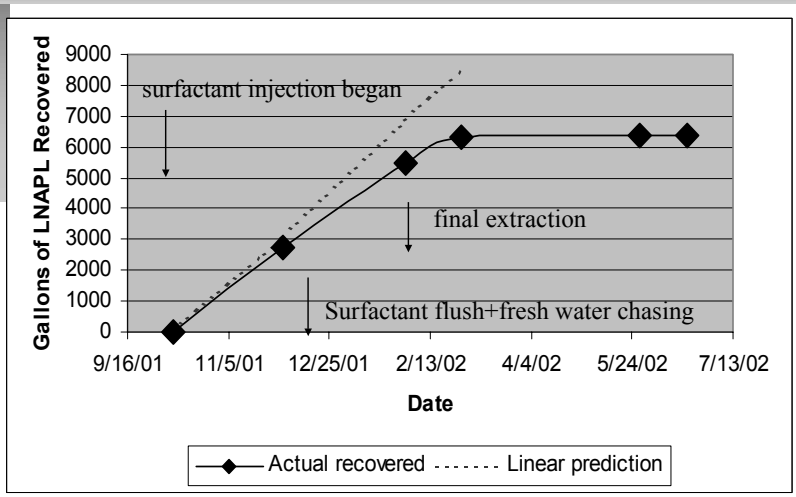
Total NAPL Recovery



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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

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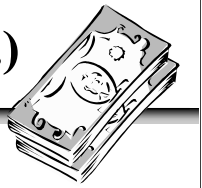
Golden UST Conclusion (cont.)



Economical Comparison

- Total project: $712 K
- Surfactant Flushing: $569 K; volume treated = 15,550 yd^3; cost = $36 / yd^3
- Total project costs (including zones area treated with chem oxid) = $14 / yd^3
- Properly designed, economical

  As low as: $25 - 30 / yd^3 (LNAPL)

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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

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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

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