Accelerated Anaerobic Bioremediation Treatment Strategy For Dover Air Force Base, West Management Unit, Area 6

Oak Ridge National Laboratory's (ORNL) Environmental Sciences Division (ESD) in conjunction with Dover Air Force Base and URS has initiated final remedial action plans for Area 6 in the West Management Unit of Dover Air Force Base (DAFB), DE. Contaminants from the 7 identified sites (Fig. 1-1. and Table 1.) have entered the soil column and migrated into the shallow groundwater (Columbia Aquifer). Natural Biodegradation is occurring in all of Area 6 but the rate of bio-degradation within the target areas appears to be sufficient to prevent migration beyond the Base boundary at levels exceeding EPA's Maximum Concentration Levels (MCL's).

Contaminants of Concern for Area 6

Contaminant	WP21	WP31	ST34	OT41/ Bldg 719	OT48	SS59	OT28	Area 6	RAO* (ug/L)
Benzene		X	X		X			X	5
1,1,1-TCA	X							X	200
1,1-DCE	X							X	7
1,2-DCA	●		X					X	5
Cis-1,2-DCE	X	●	X	X	●		●	X	70
PCE	X		X	X				X	5
TCE	X	X	X	X	X		X	X	5
Carbon tetrachloride							X	X	5
Vinyl Chloride	●	●	●	X	X		●	X	2
Lindane	X		X			X		X	0.2

X - COC present at this site
● - Potential COC due to the breakdown of other COCs
*RAO is the federal MCL

Contamination is greatest in Target Area 1,2,3 and Target Area 6 (Figure 1-1). Both of these areas have a chlorinated aliphatic hydrocarbon (CAH contour greater than 1000 ug/L (Figure 1-1).

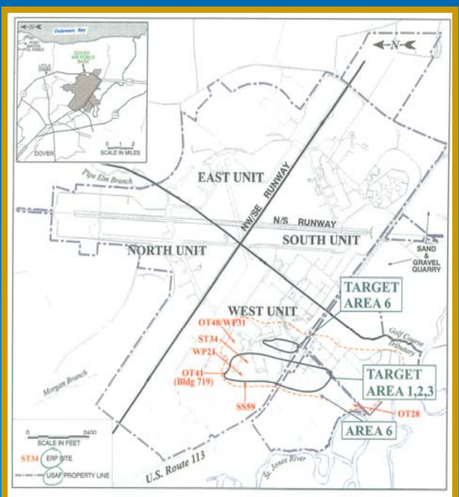
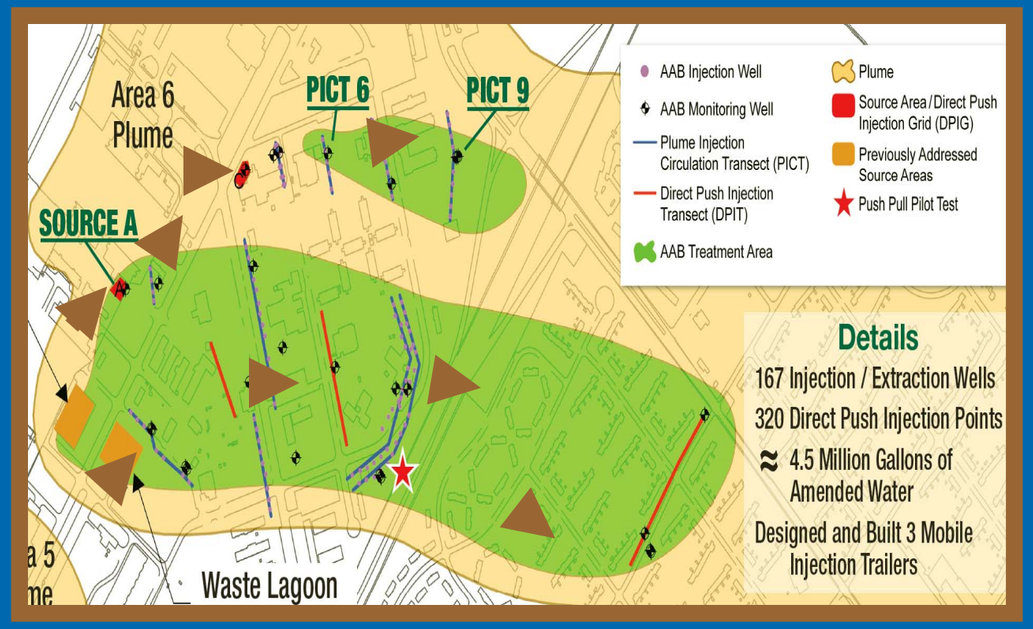


FIGURE 1-1. LOCATION OF AREA 6 AND ASSOCIATED SITES



Target Area 6, AAB Treatment Area

A direct-push rig and a pump truck was used to inject the substrate into temporary boreholes on an approximate 10 ft grid pattern within the source areas (A, B and C) at specific depths (fig 2).

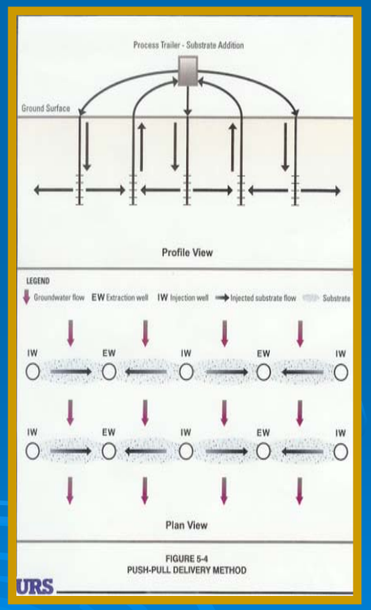
Permanent Injection Circulation Transects (PICTs) were installed down gradient of source areas A, B and C (figure 2).

Direct push injection transects (DPIT's) were installed with a direct push rig where Utilities, infrastructure or construction inhibited the installation of PICTs (fig. 2).

Direct Push Injection Grids (DPIGs) were set up in three source areas Two that were on the up gradient side Target Area 1,2,3 and one that was on the up gradient side of Target Area 6 organic contour. Three source areas (A,B and C) were injected with a 50/50 mixture of water and emulsified vegetable oil and lactate to provide approximately 2000 mg/L of total organic carbon. Injection in the source areas reduces contaminants and mobilizes shallow contaminants into the groundwater aquifer .

A second barrier was created by the Plume Injection/circulation transects (PICTs) and DPITs. These were installed relatively perpendicular to the groundwater flow and down gradient of the DPIGs to reduce and stop the flow of any remaining contaminants in the groundwater.

The PICTs use push-pull technology. Along each transect groundwater pumped from alternating wells was amended with the carbon substrate (2000 mg/L) and then returned to the aquifer under pressure (< 5 psi). Mobile process trailers were outfitted to deliver the push- pull technology. The push pull technology attempts to spread TOC uniformly along the transects by re-circulating amended water between extraction and injection wells. DPITs were used instead of PICTs where Utilities, infrastructure or construction prohibited the installation of PICTs.



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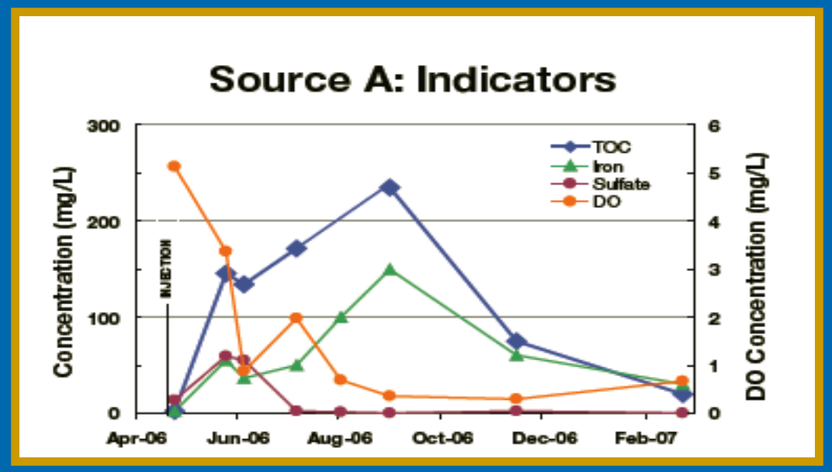
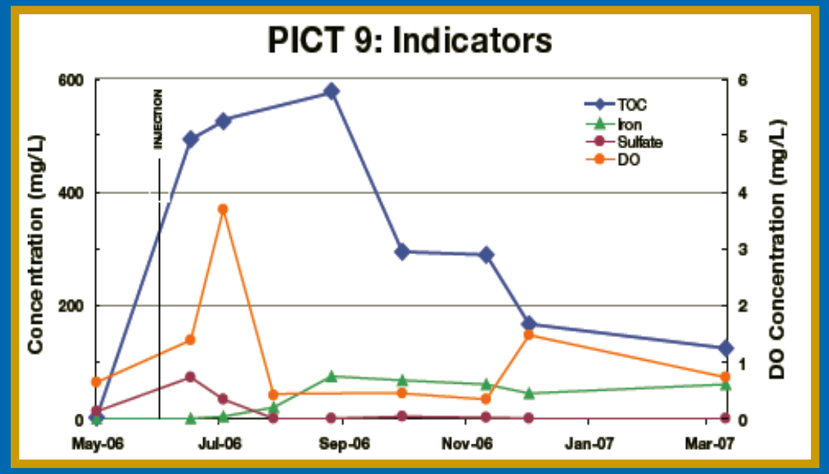
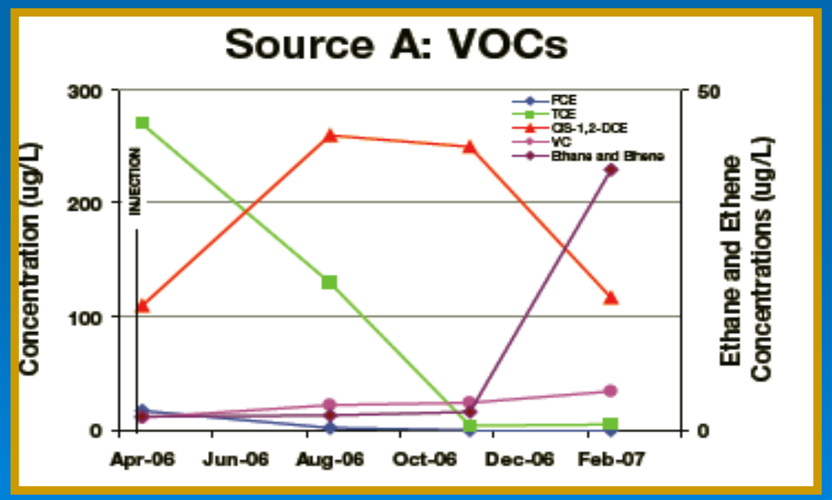
A Carbon source is pumped into the Aquifer providing a boost in the food supply for microbes. → **Conditions become increasingly anaerobic encouraging anaerobes.** → **Reductive de-chlorination occurs breaking down TCE and PCE and eventually DCE to vinyl chloride and ethenes.**



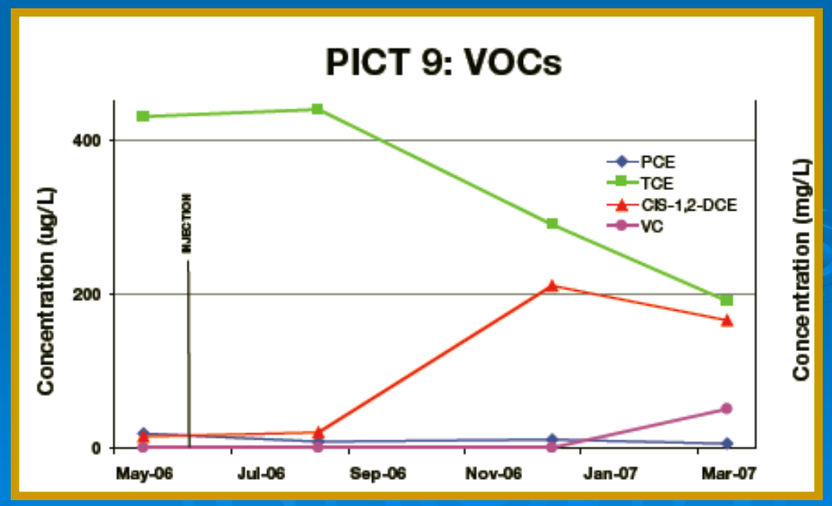
Indications of Conditions favorable to AAB

- **Organic Carbon quickly increases after injection**
- **Do quickly decreases in areas with elevated to and generally below 1mg/L indicating anaerobic conditions.**
- **Sulfate concentration generally declines in the wells with elevated TOC**
- **Dissolved Iron increases when Total Organic Carbon increases. Iron increases in response to TOC indicating reducing conditions.**





- **Daughter contaminate concentrations, including cis-1,2-DCE, vinyl chloride, 1,1-DCE, and 1,1-DCA appear to be increasing.**
- **Trend charts for DM3001S and DM3007D are good examples that demonstrate the early development of reductive dechlorination as a result of injections.**
- **Reductive De-chlorination is occurring in most wells with elevated dissolved Organic Carbon concentrations. Primary contaminate concentrations including PCE are decreasing.**



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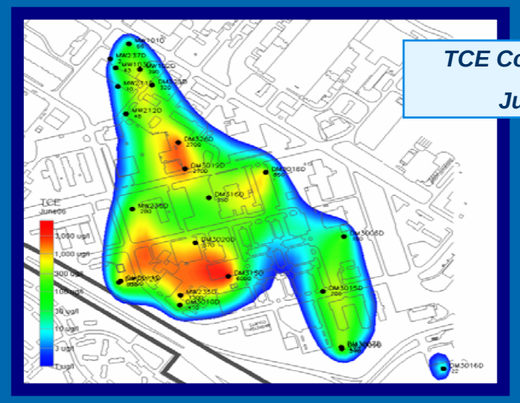
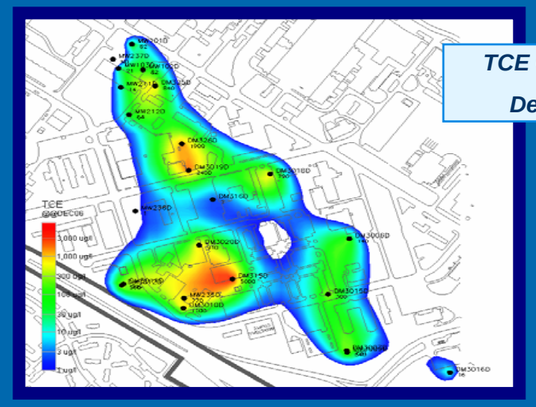


TCE Concentrations

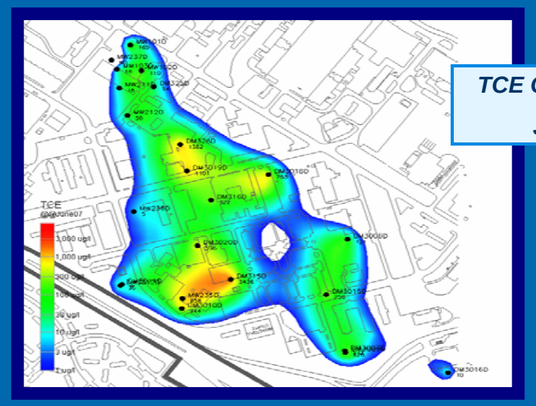
June 2006



TCE Concentrations

December 2006

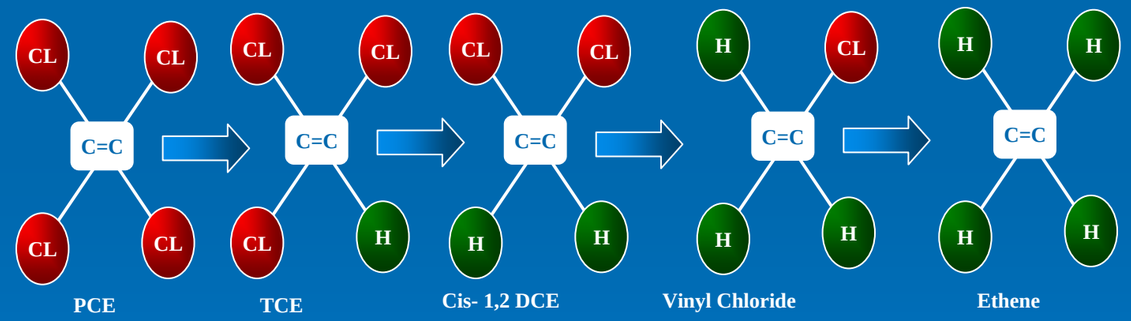
Concentrations of TCE were modeled over time to see the extent of contamination in the Area 6, AAB source area. The time modeled were 4 periods, June 2006, December 2007, June 2007, and December 2007. Over a period of 18 months TCE concentrations dropped dramatically demonstrating degradation of TCE. Concentrations decreased from 3,000 ug/l to as little as 300 ug/l in a period of approximately 1½ years exhibiting reductive dechlorination.

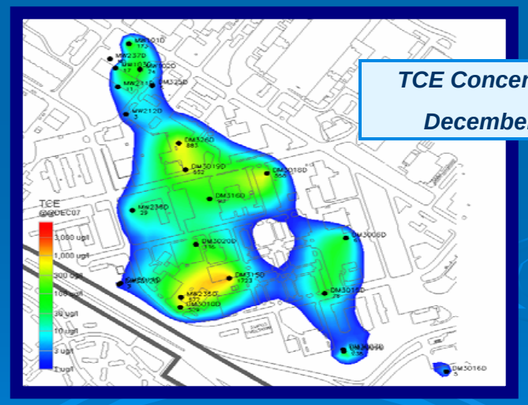


TCE Concentrations

June 2007

Indications of Reductive Dechlorination





TCE Concentrations

December 2007

Cis-1,2-DCE - cis-1,2-dichloroethene
TCE - trichloroethene
VC - vinyl chloride
PCE - tetrachloroethene
TOC – total organic carbon

The Accelerated Anaerobic Bioreduction (AAB) objective is to reduce and maintain the CAH concentrations below or at 500 ug/l, thus reducing overall time required to reach MCLs within the area 6 plume. A carbon source is injected into temporary or permanent boreholes to encourage anaerobic biodegradation. Reductive dechlorination of contaminants is a stepwise process of chlorine atom replacement with hydrogen via oxidation-reduction (redox) reactions. PCE degrades to TCE, which degrades to DCE which degrades to VC which degrades to ethene.

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