

## High Resolution Sampling and Surgical Injection of BOS 200® to Successfully Eliminate LNAPL and Treat Large Hydrocarbon Plume

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**Background/Objectives.** The site is located south of Copenhagen, Denmark. Site characterization (SI) activities following the release identified: residual petroleum contaminant mass from ~23 to 45 feet below ground surface (bgs) spread over 13,000 ft<sup>2</sup>, and LNAPL observed in 5 monitoring wells within a 1,200 ft<sup>2</sup>. Extensive remedial efforts (> \$1 million spent by client) conducted from 2003 until 2012 by means mechanical systems resulted in no significant improvements to site conditions. LNAPL remained in the 5 monitoring wells and single and double digit mg/l concentrations of Benzene and other gasoline constituents remained in the groundwater monitoring wells. Local geology consists of glacial till overlain weathered and competent limestone at approximately 45 ft bgs. Groundwater is found at approximately 25 ft bgs. The heterogeneity of the geology is believed to be the reason for poor performance during historical remedial efforts.

**Approach/Activities.** In November 2011, a Remedial Alternatives Analysis (RAA) was prepared by the primary consultant identifying the Trap & Treat® BOS 200® Technology as a feasible remediation approach at the site. The owner and primary consultant decided to complete the project in a two phased approach: first conducting an in-situ pilot test in the former UST area and second Implementing full scale, dependent on the results of the pilot test. The goal of the pilot was to verify that distribution of the BOS 200® slurry could be achieved in the difficult geology and confirm that the technology could treat LNAPL and residual mass. Prior to injection of the BOS 200®, a Remedial Design Characterization (RDC) high density sampling event was conducted throughout the impacted area. The sample results from the RDC were used to develop a three dimensional high density conceptual site model of the hydrocarbon mass distribution within the pilot and overall impacted site. Based on the supplemental analytical data generated from over 250 soil and 50 groundwater samples an optimized surgical injection strategy was designed. The strategy was implemented using innovative injection techniques. The full scale injection was completed under a performance base contract.

Pilot Test - March 2012, approximately 8,800 lbs of BOS 200® including 20 gallons of facultative bacteria was injected in 18 Injection points spaced 7.5 feet apart.

Full Scale - October 2014, approximately 160,000 lbs of BOS 200® and 320 gallons of facultative bacteria was injected in 285 injection pints spaced 7.5 feet apart. Full Scale injections required 5 months to complete (finished May 2015).

**Results/Lessons Learned.** The pilot test injections were deemed successful based on 1-year post injection groundwater sampling and gauging demonstrating: no significant accumulation of LNAPL in monitoring wells within or surrounding the injection area, and a minimum 50% reduction in groundwater concentrations within the injection area. Six (5) post full scale injection monitoring events have verified the elimination of LNAPL in all performance monitoring wells, including wells within the pilot area, and an average of 90% reduction in Benzene concentrations within groundwater across the site. The vertical migration of impacted groundwater to competent limestone aquifer has been eliminated and verified based downward trend in groundwater concentrations within bedrock monitoring wells (420 ug/l reduced to 8.5 ug/l benzene). Currently six of eight performance based contractual milestones have been achieved for the project.