HYDROLOGIC CHARACTERIZATION OF A SUPERFUND SITE: REMEDIAL INVESTIGATION THROUGH REMEDIAL ACTION

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Abstract. Hydrogeologic characterization performed during the remedial investigation phase of Superfund site investigations is focused on development of the Risk Analysis and selection of a remedy. Further hydrogeologic characterization is often needed to implement cost-effective remediation of ground water. This paper describes how hydrogeologic studies have developed over time at the French Limited Site in Crosby, Texas. This case study shows how real progress in ground water remediation is achieved by a "bootstrap" learn as you remediate approach.

BACKGROUND

The French Limited site is a former sand pit (now referred to as the French Limited Lagoon) located within the alluvial plain of the San Jacinto River approximately 20 miles northeast of Houston, Texas. The site was used for liquid chemical waste disposal between 1967 and 1972. The residues formed a sludge layer at the bottom of the lagoon, containing elevated concentrations of organic constituents and metals. Leaching of the sludge and subsoils resulted in shallow groundwater contamination. In 1982, the site was put on the National Priorities List and designated for remedial action under CERCLA. The French Limited Task Group (FLTG) was formed in late 1983 by potentially responsible parties to manage the remedial investigation, feasibility study, remedial action plan (RAP), engineering design, construction and operation of the remedial system. Remedial operations began in January, 1992.

RI/FS INVESTIGATIONS

The Remedial Investigation and Feasibility Study (RI/FS) was performed from 1984 through 1986. Geologic and hydrologic interpretations were based on data from the RI boreholes and wells (Figure 1). The shallow (< 150 ft depth) sediments underlying the site were divided into three hydrostratigraphic zones: the lower silty sand

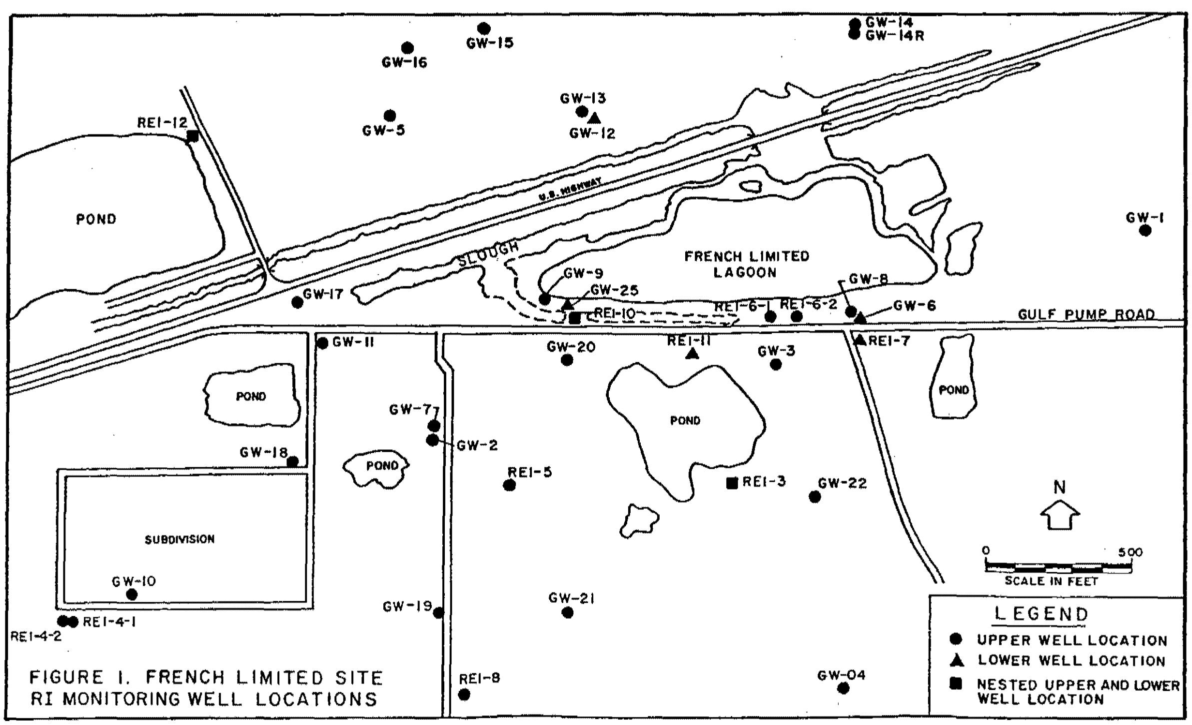

Figure 1. Monitoring well location for remedial investigations at French Limited site.

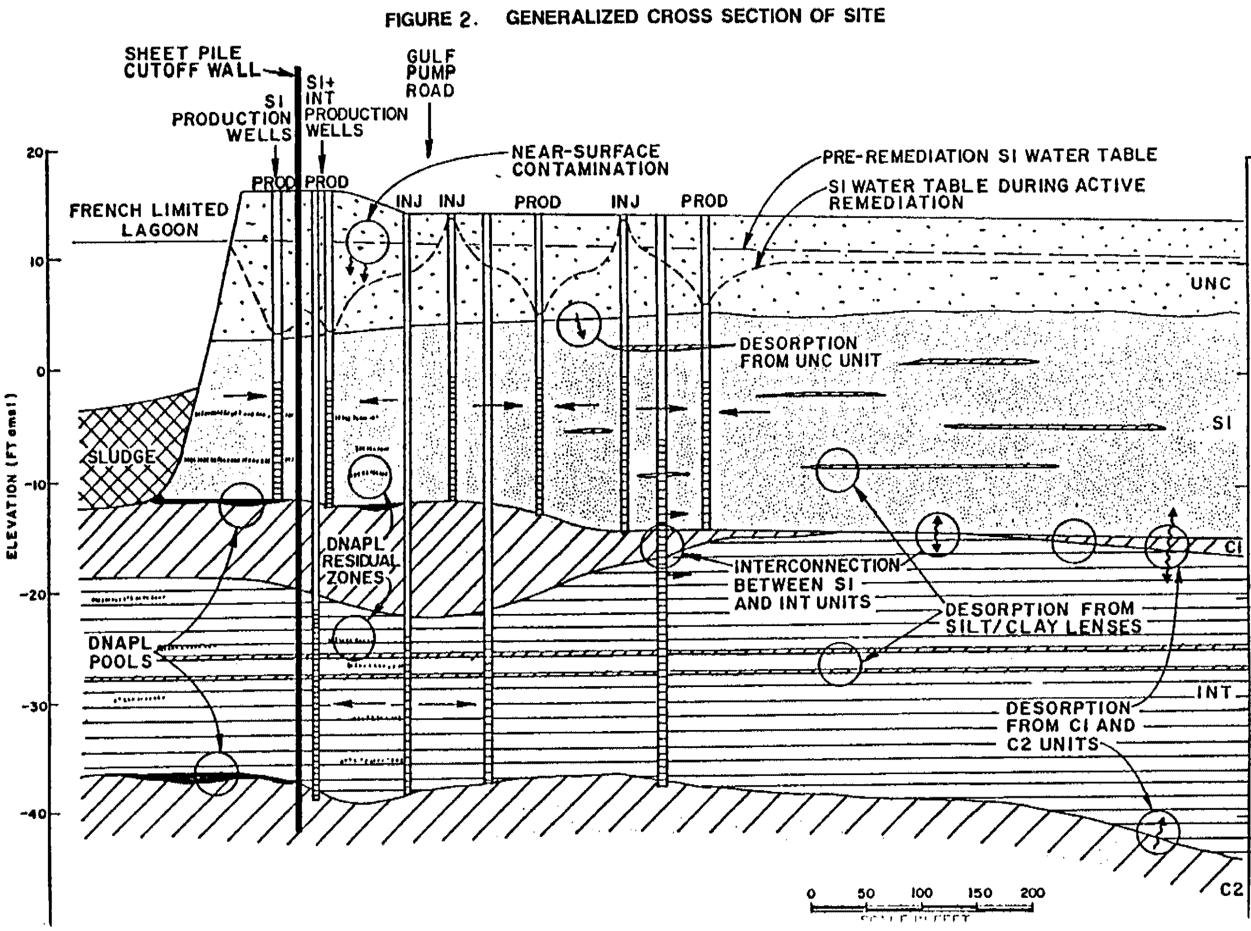

Figure 2. Generalized cross-section of site.

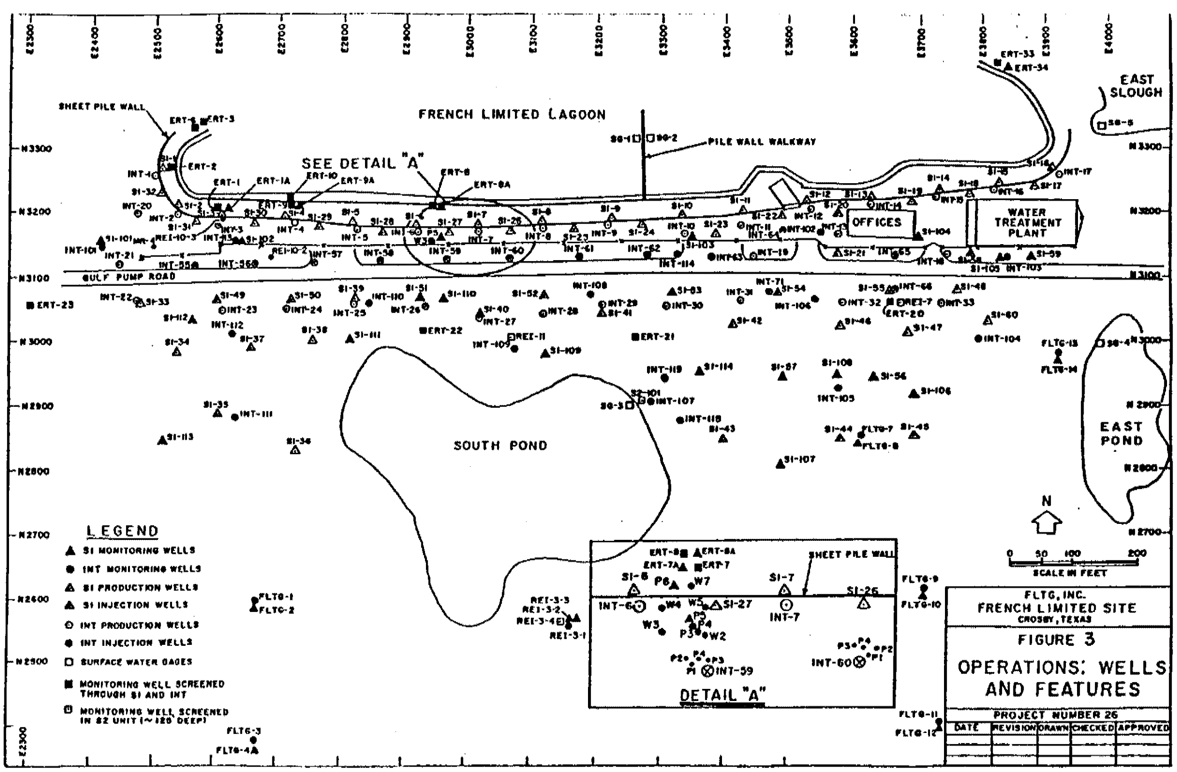

Figure 3. Wells and other features related to operation.

water had been extracted, and 30 million gallons of oxygen- and nutrient-amended potable water had been injected into the upper alluvial aquifer zone. Extraction has removed approximately 100 tons of organic carbon, of which an estimated 20 tons comprises volatile organic compounds.

In the course of operations, numerous improvements to the system were identified and implemented as refinements to the Design Report. These included conversion of extraction well pumps from pneumatic to electric submersibles; resizing production well headers to alleviate high back pressures; modifying S1 injection well controls to increase flow rates; pressure-grouting INT injection wells to allow operation at design pressures; installing automatic valves at injection wells to vent excess oxygen; and introduction of a routine preventive maintenance program for the entire well field.

Injection water currently contains 40 mg/l dissolved oxygen and 10 mg/l-N each of ammonium and nitrate. Dissolved oxygen attenuates within a short distance of injection wells, indicating relatively rapid utilization by aerobic microbial activity. Ammonium and nitrate persist over longer flow paths, the relative decline in nitrate indicating its action as an electron acceptor for enhancing microbial activity.

Within the area affected by injection, attenuation of individual compounds has been rapid (Figure 4). By using chloride content to normalize data, it appears that approximately 80% of VOC attenuation is attributable to

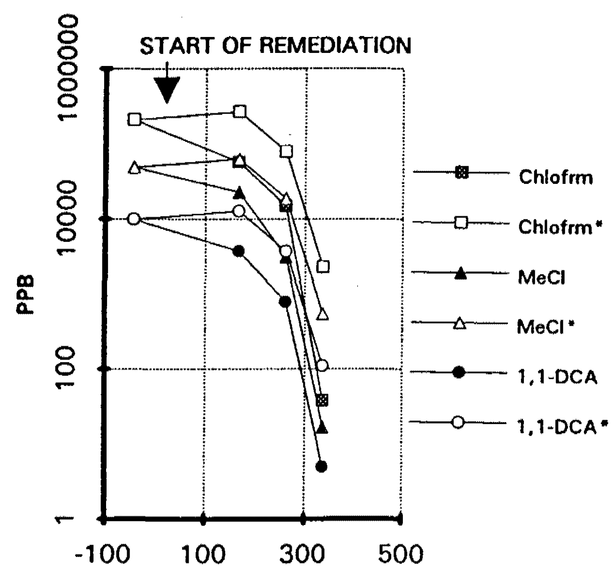

Figure 4. Volatile organics in groundwater at well #INT-102.

direct flushing, and 20% to in-situ biodegradation. Whilethe overall rate of degradation is expected to decline over time, the percentage attributable to biodegradation is expected to increase at lower VOC concentrations. In-situ microbial activity is also indicated by marked growth of biomass within wells and the onset of microbial activity within the main ground-water holding tank.

During the first few months of operation, dense non-aqueous phase liquid (DNAPL) was observed in two of the production wells, S1-16 and INT-11 (Figure 3). The Design Report acknowledged the possibility of DNAPL occurrence, but did not address DNAPL characterization or remediation except for specifying monthly extraction well inspections that were to include checks for evidence of NAPLs. Analyses of DNAPL samples show that it consists of organic constituents, primarily chlorinated solvents. Figure 2 illustrates potential mechanisms of contaminant behavior including the occurrence of DNAPL pools and residual zones. Since DNAPL may act as a continuing source of ground-water contamination which may adversely influence the effectiveness of the current ground-water remediation system, FLTG, Inc. has currently embarked on a focused remedial investigation/feasibility study for the S1-16 and INT-11 DNAPL areas.

In addition to the DNAPL RI/FS activities, routine ground-water sampling data are expected to provide an indirect indication of DNAPL occurrence. Monthly monitoring of dissolved total organic carbon (TOC) at individual production wells, and quarterly monitoring of TOC and indicator VOCs at selected monitoring wells are currently being performed. It is anticipated that locations of free or residual DNAPL occurrence will show persistently high TOC and indicator VOC concentrations, due to continued DNAPL dissolution, exceeding concentrations predicted based on a mass balance analysis that does not account for DNAPL dissolution.

CONCLUSIONS

Hydrogeologic characterization performed during the remedial investigation (RI) phase of Superfund site investigations is focused on development of the Risk Analysis and selection of a remedy. More detailed hydrogeologic characterization is typically needed to implement cost-effective remediation of ground water. Additional studies are often required in response to operational data. This is well illustrated by the discovery of DNAPL during routine operations. This case study shows how real progress in ground-water remediation is achieved by a "bootstrap", learn-as-you-remediate approach. Comparison of Figures 1 and 3 shows how the focus during remediation is narrowed and the density of wells and detail of characterization is intensified. Given the nature and localized occurrence of DNAPL contamination, RI/FS and even zone, the middle clayey zone and the upper alluvial zone. Groundwater in the site vicinity was found to be contaminated to the base of the upper alluvial zone, approximately 55 feet below grade. Principal contaminants are volatile organic constituents (VOCs). The upper alluvial zone was represented in the RI/FS as one hydrogeologic unit. This simplification did not preclude selection of the ground-water remedy, but was inadequate to design the remedy and to satisfactorily explain spatial variations in contaminant concentrations.

The middle clayey zone was confirmed to have good potential to restrict the downward migration of contaminants due to its fine-grained nature and low permeability. This was indicated by a dramatic drop in potentiometric head through this zone and by its hydraulic response to a long term pumping test in the lower silty sand zone (Day and O'Hayre, 1987).

BIOREMEDIATION DEMONSTRATION TESTS

Pilot bioremediation tests on the organic sludge and subsoils in the French Limited Lagoon were initiated on site in 1987. This work included extensive ground-water monitoring and contaminant transport modeling studies to assess possible ground water impacts expected to occur during lagoon remediation. These investigations concluded that:

1) Biological degradation results in a rapid reduction of the hydrophobic characteristics of the sludge allowing enhanced leaching of VOCs.
2) A full-scale bioremediation program for the lagoon had the potential for causing significant influx of VOCs into the surrounding shallow ground-water system.
3) A groundwater remediation program would be required to minimize the influx of VOCs to the shallow ground water during full-scale lagoon bioremediation.

Remedy Selection

On the basis of the Bioremediation Demonstration, EPA issued the Record Of Decision (ROD) in 1988, selecting in-situ bioremediation of the French Limited Lagoon as its primary remedy. To address contamination in the ground water and aquifer materials of the upper alluvial zone, both existing and potentially resulting from source removal, the remedy included ground-water pumping, treatment, and long-term monitoring.

POST-ROD INVESTIGATIONS

Pre-Design Activities. Ground-water investigations continued after the lagoon bioremediation pilot tests and included routine ground water monitoring, pumping tests and more detailed evaluation of existing geologic data. Using primarily non-subjective cone penetrometer and geophysical logs of bore holes from the RI, a post-ROD Hydrogeologic Characterization Report (AHA, 1989) determined that the upper alluvial zone could be subdivided into four distinct heterogeneous units which have appreciable lateral extent as depicted on Figure 3. The more permeable water bearing units are a lower interbedded silty (INT) unit, overlain by a coarse sand (S1) unit and a near-surface unconsolidated sand (UNC) unit. The S1 and INT units are separated by a discontinuous intervening (C1) clay, which is 2 to 8 feet thick. The additional hydrogeologic information was used to develop the remedial action plan (RAP) for design of the ground-water remediation alternative selected in the ROD.

Design Activities. The ground-water remedial system was designed to control and treat contamination in the upper alluvial zone in the vicinity of the site. As part of engineering design activities, additional hydrogeologic and soil contamination studies were performed. These included a field ground water flushing test to evaluate the potential effectiveness of a "pump and treat" system. The RI, the pre-design studies, and the design phase work all formed the basis for the *Shallow Aquifer and Subsoil Remediation Facilities Design Report* (ENSR, 1991). This includes the detailed engineering design for the following ground-water remedy components:

1) Source containment by a sheet-pile subsurface barrier completely surrounding the French Limited Lagoon and keyed into the top of the middle clay unit (C2), combined with ground-water pumping to create and maintain an inward hydraulic gradient towards the lagoon (Figures 2 and 3);
2) Extraction of contaminated ground water from the S1 and INT water-bearing zones of the upper alluvial aquifer with above-ground treatment (Figure 3); and
3) Injection of clean water (with optional amendment with nutrients and appropriate electron acceptors) to enhance flushing of soils and to promote in-situ bioremediation of organic constituents found in the shallow ground water.

Construction Activities. During construction of the ground-water remedial system, considerable additional geologic and soil contamination data was obtained during well drilling activities. Several refinements to the original design were made during this time. In-situ bioremediation was added as a component of the remedial system, using potable water (as opposed to treated water) amended with oxygen and ammonium nitrate. A complete baseline ground water sampling was conducted prior to the start of operations.

Operating Investigations. Operation of the ground-water remediation system for the S1 and INT units of the upper alluvial zone started in January 1992. By February 1993, over 71 million gallons of contaminated ground engineering design studies are rarely sufficient to detect and characterize DNAPL below the water table.

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