Treatment of Chlorinated Solvents in Groundwater Beneath an Occupied Building at The Young - Rainey STAR Center (Science, Technology, and Research Center) – 16342

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ABSTRACT

Groundwater contamination, consisting of two dissolved-phase plumes originating from chlorinated solvent source areas, in the southeastern portion of the Young-Rainey Star Center (also known as the Pinellas County, Florida, Site) in Largo, Florida, has migrated beyond the property boundary, beneath the roadways, and beneath adjacent properties to the south and east. Groundwater contamination will persist as long as the onsite contaminant source remains. The origin of the contamination appears to be multiple long-term point sources beneath Building 100, a 4.5 ha (11 acre) building that housed manufacturing facilities during US DOE operations at the site.

The site is now owned by Pinellas County, and most of the space inside the building is leased to private companies, so DOE chose not to conduct characterization or remediation through the floor of the building, instead choosing to conduct all work from outside the building. Injection of emulsified soybean oil and a microbial culture has been used at other areas of the site to accelerate naturally occurring bacterial processes that degrade groundwater contaminants to harmless compounds, and that same approach was chosen for this task.

The technical approach consisted of installing horizontal wells from outside the building footprint, extending through and around the identified subsurface treatment areas, and terminating beneath the building. Two 107 m (350 ft) long wells, two 122 m (400 ft) long wells, and four 137 m (450 ft) long wells have been installed to intersect the inferred source areas and confirmed contaminant plumes beneath the building. DOE then injected emulsified vegetable oil and a microbial culture into the horizontal wells at each of several target areas beneath the building where the highest groundwater contaminant concentrations have been detected. The target areas are the northwest corner of the building between the old drum storage pad locations and monitoring well PIN12-S35B, the vicinity of former monitoring well PIN12-S57B, and hydraulically upgradient from the south plume and the east plume at the points where they exit from beneath the building.

We describe the details of designing and constructing horizontal injection wells for bioremediation beneath a large, occupied industrial production facility, including lessons learned; technical, logistical, and environmental challenges; community relations; and regulatory relations. Because of the expected lag in biological acclimation and response, distance between the treatment areas and associated monitoring points, and low groundwater velocity, it will likely be years before the full impact of the project will be realized.

INTRODUCTION

We describe an environmental remediation program underway at a Florida site formerly used to develop and manufacture weapons components for the nation's nuclear weapons program. The former Pinellas Plant, now known as the Young - Rainey Star Center (Science, Technology, and Research Center), ceased operations for US DOE in 1997, and DOE and the Pinellas County, Florida, government jointly redeveloped the site for commercial use. Upon discovery of offsite migration of groundwater contamination that originated beneath Building 100 at the site, DOE promptly completed the required notification to the Florida Department of Environmental Protection and voluntary notification to the owners of properties located hydraulically downgradient from the contaminant plume [1]. Following notifications to all stakeholders, DOE worked closely with each party to keep them informed as to potential health risks, hazard controls, and the proposed corrective actions. Subsequent efforts have focused on treatment of the groundwater contaminant sources beneath the building, as well as the dissolved-phase groundwater contamination hydraulically downgradient from the building (Fig. 1) [2].

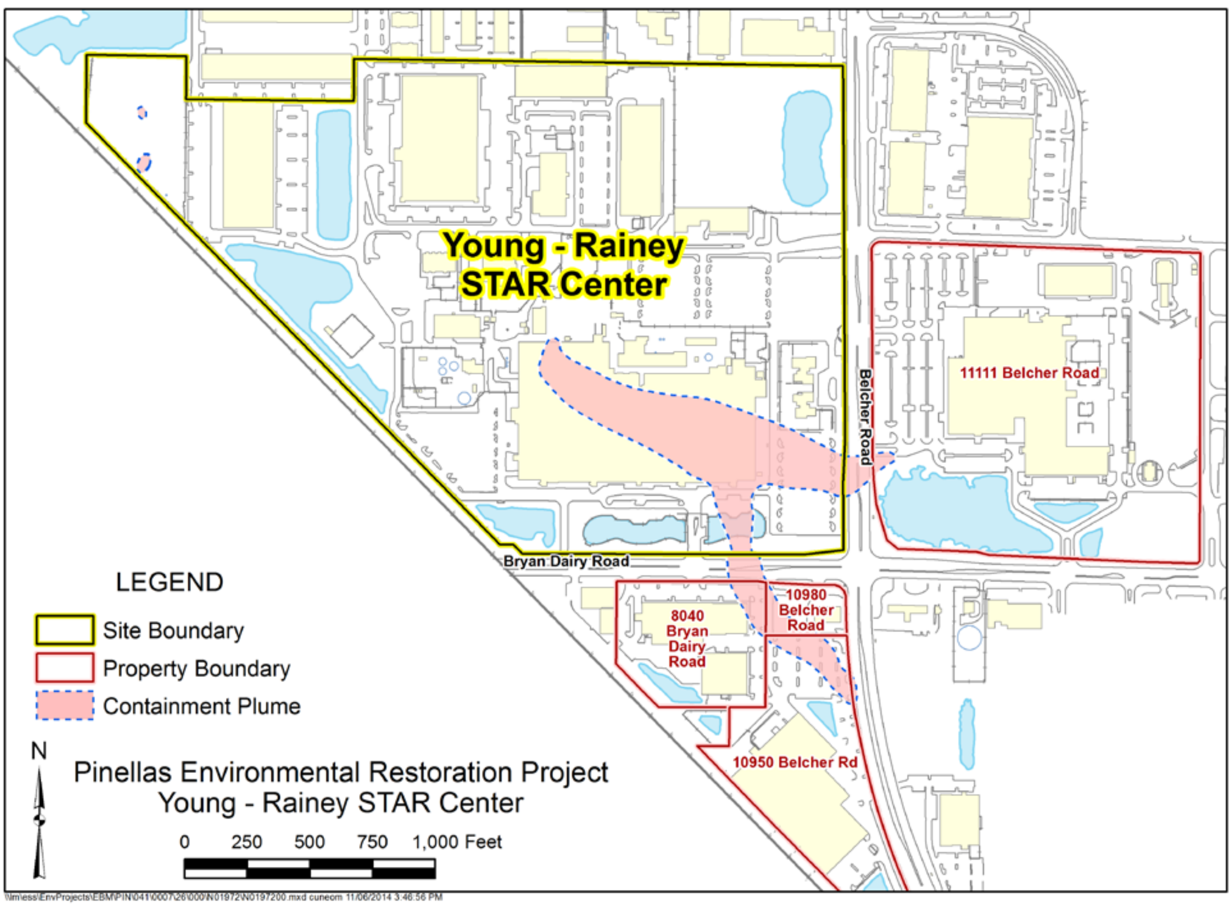

Figure. 1. Map of Groundwater Contaminant Plumes at the Young – Rainey Star Center

The most effective technology for treating the lower concentrations of chlorinated solvents at the site has proven to be the injection of soybean oil and a microbial culture to accelerate the naturally occurring biodegradation process. This treatment technology is referred to herein as “bioinjection.” Treatment consisted of four major aspects: (1) onsite vertical bioinjection, (2) offsite vertical bioinjection, (3) horizontal well installation beneath Building 100, and (4) horizontal bioinjection beneath Building 100, as discussed in the following sections. Although the vertical bioinjection activities will be briefly summarized, the focus of this paper is the installation of permanent horizontal injection wells beneath Building 100 and the subsequent bioinjection through these wells.

METHODS

Injection of emulsified vegetable oil (EVO) and the microorganism *Dehalococcoides mccartyi* (DHM; formerly known as *Dehalococcoides ethenogenes*) took place in three phases from October 2014 to November 2015 at the Building 100 Area on the Pinellas County, Florida, Site. The objective of this work was to enhance the biodegradation of contaminants in contaminant source areas beneath the building and in the downgradient contaminant plumes that extend to the south and east of Building 100.

Planning

Planning for the project included numerous critical aspects, including landlord and tenant concurrence, regulatory concurrence, and technical feasibility. The primary tenant potentially affected by the work expressed concern that electronic interference from the drill-bit navigation radio-frequency transmitters might adversely impact their sensitive electronic equipment in the building, but after a review of the radio frequencies involved, this was ruled out as a concern. Other concerns regarding sensitive or secure work in the building were eliminated by simply restricting access to these areas. By effectively addressing the tenant concerns, the landlord was also in agreement with proceeding.

Regulatory concerns with the project primarily related to documenting the work as a voluntary interim corrective measure, which also served as a mechanism to communicate the work plan to the Underground Injection Control division of the Florida Department of Environmental Protection [3]. No other well permits were required. DOE also performed a National Environmental Policy Act review to evaluate the potential for adverse impacts to human health or the environment associated with the project, but none were identified.

The remainder of the planning focused on determining the most appropriate technology for addressing the contaminant sources beneath the building and the associated logistical constraints.

Following landlord, tenant, and regulatory concurrence with the conceptual treatment approach, DOE proceeded with defining the target source areas beneath the building. Because DOE chose to avoid disrupting tenant activities, conventional contaminant characterization and delineation methods such as vertical drilling through the floor were ruled out. Instead, DOE reviewed the limited historical data sets from soil borings, monitoring wells, and subslab vapor sampling to focus on areas with high contaminant concentrations and exclude areas known to have little or no groundwater contamination. Cross sections A–A’ (Fig. 2), B–B’ (Fig. 3), and C–C’ (Fig. 4) illustrate the identified treatment target areas in each of four locations beneath the building (contaminant concentrations in micrograms per liter).

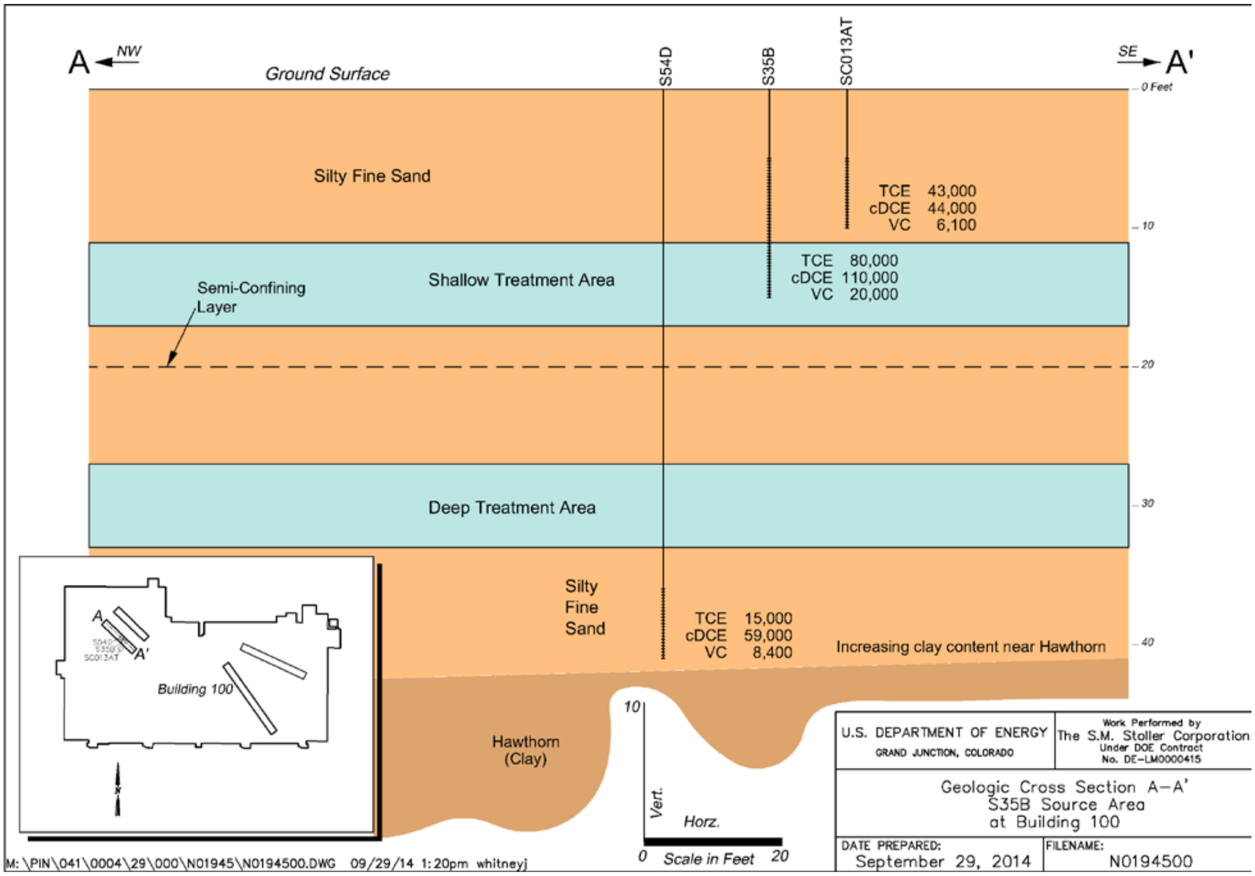

Figure 2. S35B Plume Treatment Area Cross Section A–A’ (concentration in µg/L)

The decision to install horizontal wells for bioinjection was essentially a process of elimination and was found to be the only viable option due to limited access to the subsurface beneath the building. The data analysis and treatment technology review led to the decision to install four stacked pairs of horizontal wells beneath the building (Fig. 5).

The location and orientation of the wells was primarily driven by the decision to orient the wells somewhat parallel to the long axis of the plumes for maximum contact of the slotted well intervals within the plume. Another factor in locating the wells was the availability of space in close proximity to the four target areas. The second major design consideration was the lack of space to install the wells using an entry–exit technique, which led to the decision to install using a single entry or “blind well” technique. The presence of a horizontal semiconfining layer at approximately 6 m (20 ft) below land surface drove the decision to install stacked pairs, one above and one below this zone of lower permeability (except at Area C, where the contamination was deeper).

A significant amount of time and effort was expended on identifying, locating, and mapping underground utilities and infrastructure that could have adversely impacted the drilling. This effort began long before development of solicitation packages for the drilling subcontractor and continued until the drillers arrived onsite and finalized the

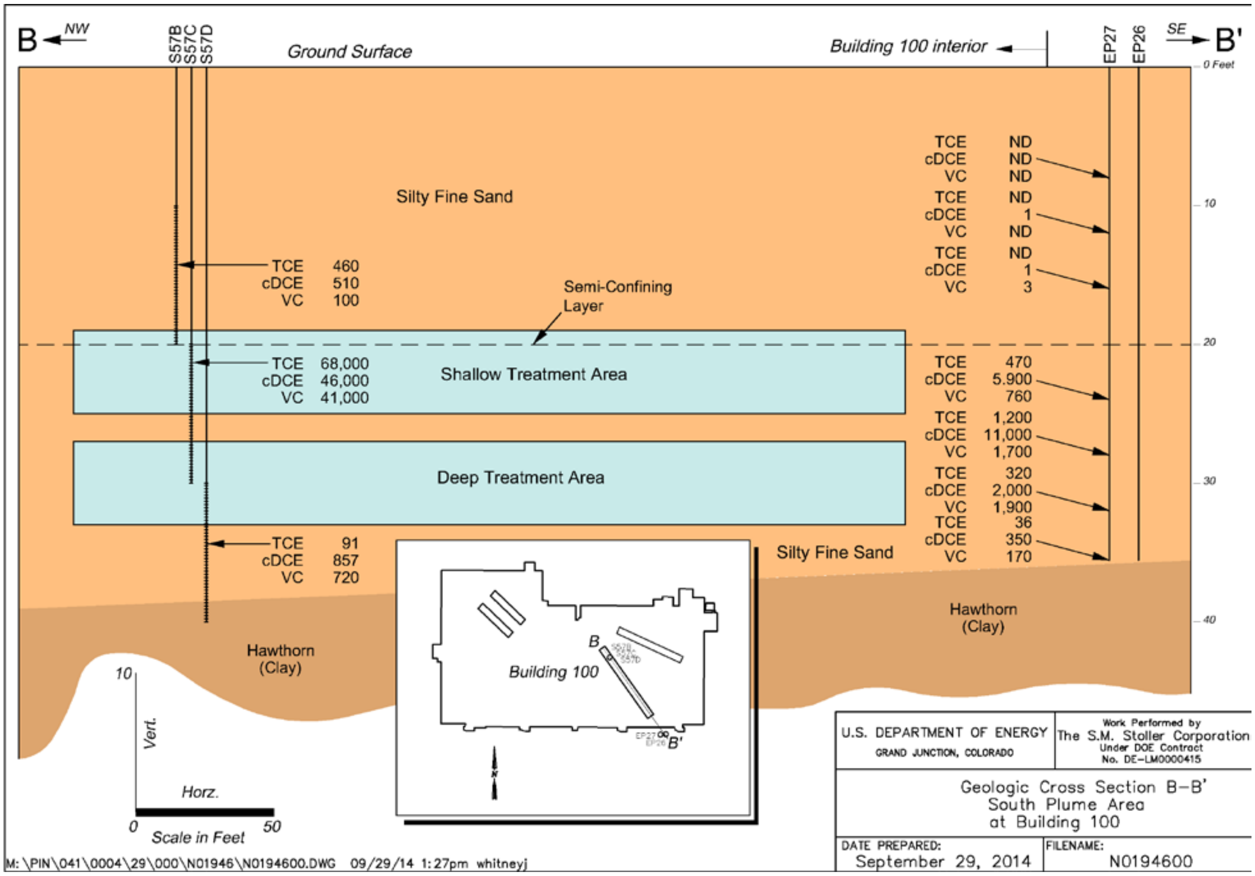

Figure 3. Plume Treatment Area Cross Section B–B' (concentration in µg/L)

borehole entry point determinations. These efforts paid dividends by precluding damages to any utilities and associated delays in the project.

Onsite Vertical Bioinjection

Terra System's SRS-SD small droplet EVO and TSI DC culture of DHM were used for injection. A drilling subcontractor (Zebra Technical Services) used direct-push rigs to inject the EVO and DHM under supervision by DOE.

EVO and DHM were injected at 62 injection points at the Building 100 Area starting on October 20 and ending on November 21, 2014. Some of the EVO and DHM was injected into groundwater recovery wells, as described later in this section. The project used 12,320 L (3,255 gallons [gal]) of concentrated (60%) emulsified soybean oil and 22 L of concentrated TSI DC. The oil was diluted with municipal tap water at a 9:1 water/oil ratio to maximize distribution in the subsurface, resulting in a total injected volume of approximately 123,200 L (32,550 gal).

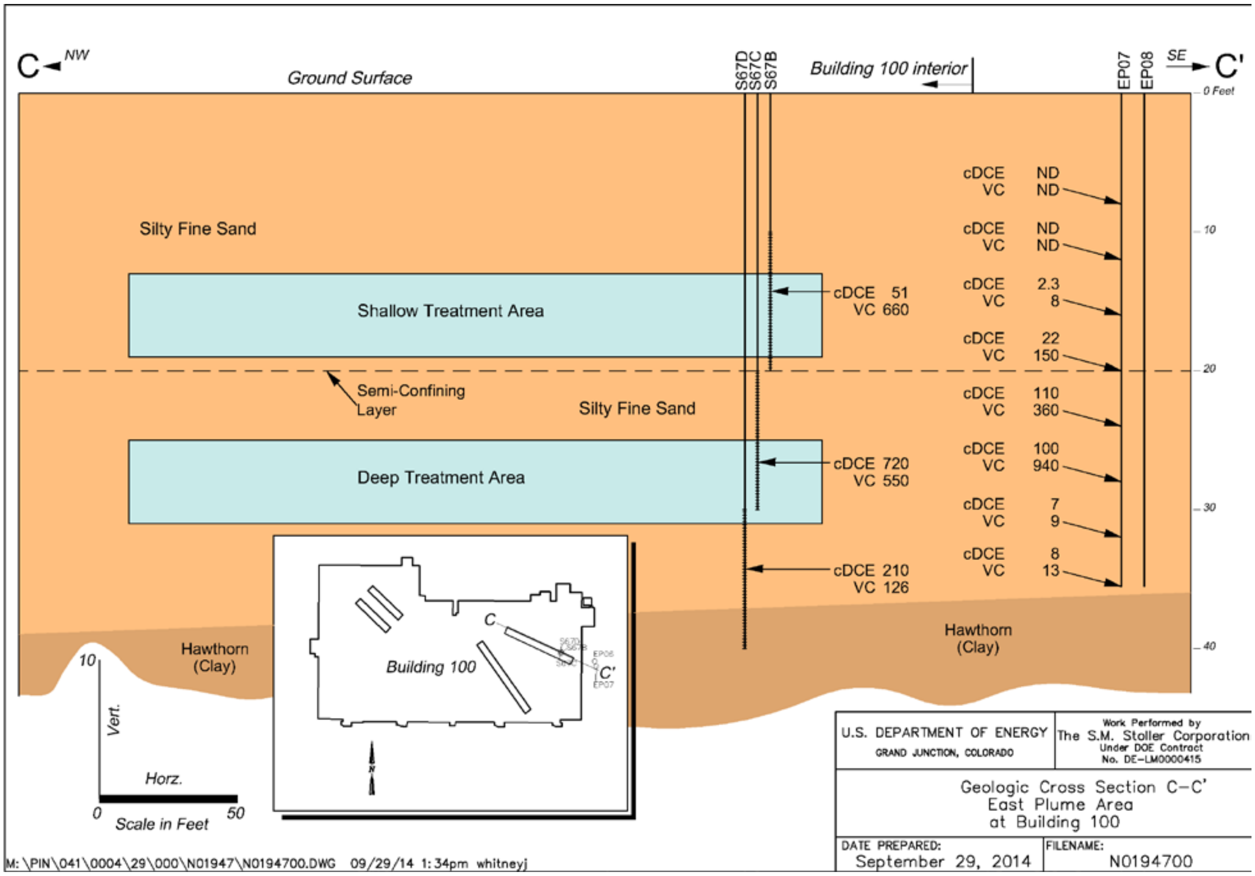

Figure 4. South Plume Treatment Area Cross Section C–C' (concentration in µg/L)

Offsite Vertical Bioinjection

DOE also selected Terra System's SRS-SD small droplet EVO and TSI DC culture of DHM for the offsite injection. The drilling subcontractor, Zebra Technical Services, used direct-push rigs to inject the EVO and DHM under supervision by DOE. EVO and DHM were injected at 33 injection points at three offsite properties starting on February 2 and ending on February 18, 2015. The project used 7,950 L (2,100 gal) of concentrated EVO and 14 L of concentrated DHM.

The total injected volume of SRS diluted at a 9:1 ratio was 13,250 L (3,500 gal), and the total volume of SRS injected at a 6.4:1 ratio was 49,200 L (13,000 gal), for a total injected volume of 62,500 L (16,500 gal) of diluted SRS. The dilution and injection were conducted using the same equipment in a manner identical to that of the onsite injection, with the exception of a slightly different dilution ratio.

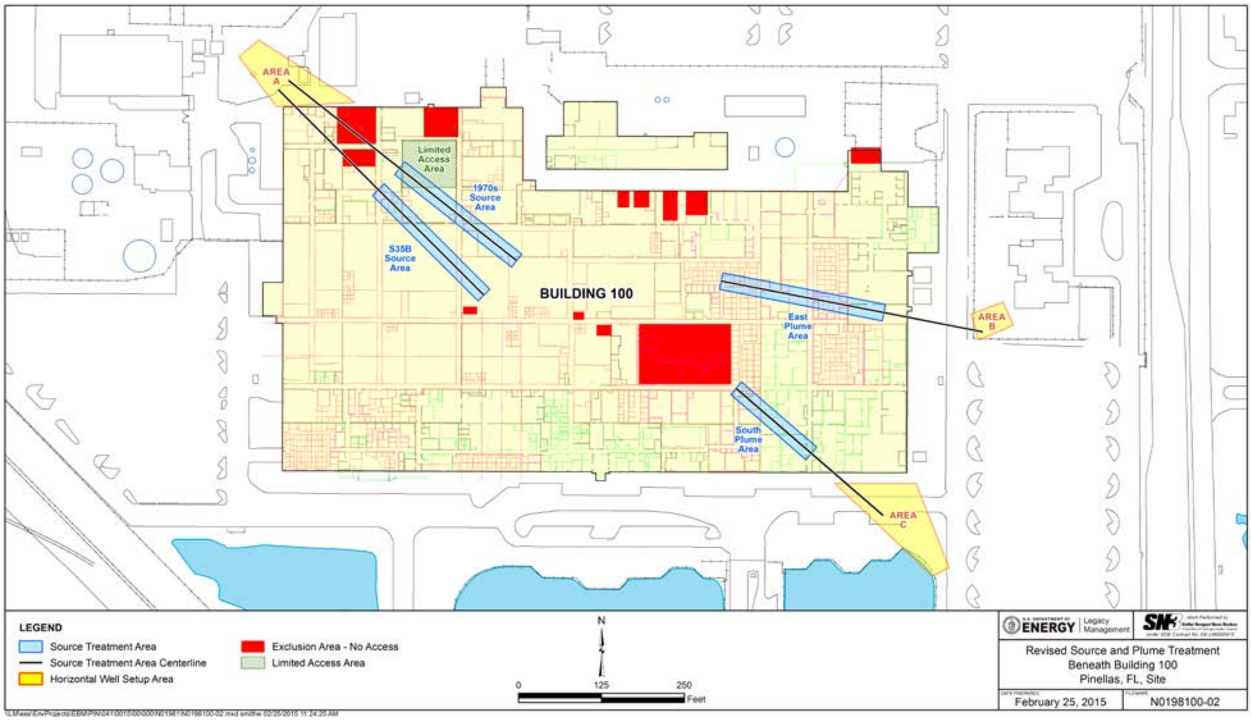

Figure 5. Building 100 Horizontal Injection Well Locations

Horizontal Well Installation

Horizontal directional drilling (HDD) is a technology that was developed in the petroleum industry and adapted for environmental remediation applications beginning in the early 1990s. This technology is typically considered only for special situations due to its higher cost and complexity relative to conventional vertical drilling. DOE solicited HDD experts to design and install the horizontal wells to ensure the success of the project. Some of the challenges during well installation included identifying and locating subsurface utilities (some of which were installed starting in the mid-1950s in undocumented locations) and other infrastructure (e.g., an elevator plunger) that had to be avoided along the bore paths of the wells, navigating the drill bit beneath inaccessible areas in the building, electromagnetic interference that disrupted the navigation equipment, heaving sands, and record rainfall.

The horizontal well installation project began on July 6, 2015, and was completed on September 28, 2015. The first half of the project was conducted during the evening and night to minimize tenant disruption. Table 1 summarizes the horizontal well information. The horizontal wells are constructed of fiberglass-reinforced epoxy. The wells have an inside diameter of 7.6 cm (3 inches) and an outside diameter of 8.9 cm (3.5 inches). The slots in the slotted sections were designed specifically for the injection of SRS over the long treatment intervals listed in Table 1 for the specific site hydrogeology. The slots are 0.33 mm (0.013 inch) wide and 3.8 cm (1.5 inches) long, with one slot per 61 cm (2 ft) section of well.

The use of an auxiliary navigation system (the SST, or short steering tool) in addition to the walkover system was critical because of large inaccessible areas inside the building, in addition to large areas where electronic interference prevented conventional walkover navigation. The SST is a geomagnetic wireline system and required more effort to use, but it was functional when the walkover system was not.

TABLE 1. Building 100 Horizontal Well Information

Well	Location	Depth (m below floor surface)	Total Well Length (m)	Slotted Interval Length (m)	Total Injected Volume (L)
PIN12-HW01	S35B Source Area	4.3	141	68.6	25,360
PIN12-HW02	S35B Source Area	9.1	143	68.6	25,360
PIN12-HW03	1970s Source Area	4.3	137	68.6	25,360
PIN12-HW04	1970s Source Area	9.1	139	68.6	25,360
PIN12-HW05	East Plume Area	4.9	126	76.2	27,630
PIN12-HW06	East Plume Area	8.5	127	76.2	27,630
PIN12-HW07	South Plume Area	6.7	105	45.7	17,300
PIN12-HW08	South Plume Area	9.1	106	45.7	17,300

Horizontal Bioinjection

As with the onsite and offsite vertical bioinjection activities, DOE selected Terra System's SRS-SD small droplet EVO and TSI DC culture of DHM for injection. Zebra Technical Services conducted the injection into the horizontal wells starting on November 2, 2015, and ending on November 18, 2015. The oil was diluted with municipal tap water at a 9:1 water/oil ratio. The project used 16,850 L (4,450 gal) of concentrated EVO and 30 L of concentrated DHM. The volumes listed in Table 1 were injected into each well; this volume includes about 3 casing volumes of clean water (no EVO or DHM) injected to flush the EVO mixture out of the wells. Injection flow rate ranged from about 64 to 95 L (17 to 25 gal) per minute.

Horizontal Well Lessons Learned

The use of an auxiliary navigation system was critical due to inaccessible areas inside the building and electronic interference.

Two different companies (or more) should be used to locate utilities. Different companies were used on this project, and the results of the utility locates were different for the two different companies (the second locate found utilities that the first one did not find). Different companies may have different brands and ages of the same type of locating equipment. This will lead to a greater chance of detecting all utilities, relative to having just one company conduct two or three locates (in the same area). Even with multiple utility locates, small, shallow PVC irrigation lines were missed.

The subcontractor's use of a surveyor using global positioning system survey equipment to spot in the horizontal well entry points and bore paths failed because the accuracy was too poor (±61 cm). Instead, regular survey equipment or more accurate GPS equipment should be used due to the high degree of accuracy. In addition to being inaccurate, the GPS approach also failed when near the two-story building because some of the GPS satellites were blocked by the building.

Abundant communication with the landlord and tenants before, during, and after field activities helped to minimize tenant concerns, misunderstanding, and rumors. This communication was initiated at least a year before the start of the project.

Problems encountered during mobilization included difficulty in unloading the initial delivery of well materials, drill-bit clogging, entry pit sidewall collapse, borehole collapse, and a steep learning curve on the use of the SST. Both the contractor and the subcontractor must have the ability to make quick adjustments to accommodate unanticipated issues.

All equipment and supplies must be ordered well ahead of the date required in order to avoid project delays.

The weather and the time of year that the work was scheduled was a factor in project progress. There was a tremendous amount of rainfall during the first 6 weeks of the project (in July and August), and it affected all aspects of the field work. Thus, if work is being conducted during the rainy season, anticipate weather issues.

The rainfall mentioned previously created extremely muddy conditions in the work area. The muddy conditions created many challenges and health and safety concerns. These problems and concerns were greatly alleviated by putting down many sheets of plywood on the ground beneath the drill rig and throughout the entire work area. Do not hesitate or wait to utilize plywood or similar ground coverage in order to make work areas safer and more manageable. This simple fix greatly improved morale.

For this project (the installation of horizontal wells), keeping a vacuum truck onsite during the work was vital. The vacuum truck was used for potholing prior to ground penetrations, to vacuum water from the roll-offs, to remove rainwater from the mud pits, for well flushing and development, and even to provide volume for temporary liquid storage.

The plan going into the project was to decant liquids from the roll-offs and treat the liquid waste with the onsite air stripper. The liquid waste was too turbid and contained too many solids to treat using the air stripper. Thus, one must have a backup plan for waste disposal.

The driller failed to show their equipment tooling trailer (a semi trailer) on the proposed site layout. Be sure to confirm with any subcontractor providing an equipment layout plan that all of their equipment is included in the plan.

There are several excellent weather “apps” available for smart phones. These apps are extremely helpful when monitoring the weather and should definitely be one of the tools used to track lightning in the area.

The excellent communication of the field management team in cooperation with the driller’s field management greatly contributed to a successful project. Keeping strong, continuous, open lines of communication with the subcontractor is absolutely critical to maintaining a safe work environment and keeping the project moving in one direction.

A nontoxic but disagreeable odor was produced by the degradation of the drilling fluid in the liquid waste storage tanks while they remained onsite awaiting the results of the waste characterization sampling. If possible, these waste tanks should be located away from parking lots and other areas where the odors can be detected. Consideration was given to adding various chemicals (e.g., chlorine) to the tanks to reduce the odor, but this would have resulted in the need to resample for waste characterization, thus, requiring the tanks to remain onsite for a longer time.

Use of the tenant’s regular security contractor significantly eased tenant concerns and greatly facilitated access to the building interior.

Subcontracting with an independent horizontal well expert was vital to ensure that the contractual requirements were realistic and sufficient.

For this procurement, the driller was given the task of designing and then installing the wells. Consideration should be given to subcontracting the well design to an expert so that the driller’s sole task is to install the wells.

Roll-offs with a lid turned out to be a special order, and this caused minor delays in tank delivery, so allow extra time for these containers. Also, ensure that the lid is functional upon delivery (broken lid springs made the cover difficult to open). Consider adding a tarp to deter rainfall entry if the lid seal is not good.

CONCLUSIONS

We described the details of designing and constructing horizontal injection wells for bioremediation beneath a large, occupied industrial production facility in Pinellas County, Florida. A determination of chlorinated solvent contaminant source areas was made using only the available historical soil, groundwater, and subslab vapor data rather than disrupt tenant operations with conventional invasive characterization methods. A dialogue with the landlord, tenants, and regulator was established early in the planning process, and for best success, timely and accurate communications with all stakeholders were maintained throughout the project.

Bioinjection was identified as the most appropriate technology to treat Building 100 Area groundwater contaminated by chlorinated solvents. Horizontal injection wells were the only viable delivery mechanism for the bioinjection mixture given the access restrictions. HDD is a relatively complex technology that is quite adaptable to environmental remediation applications and requires specialized tools and skills, best performed by experienced professionals in close cooperation with local scientists and engineers with a good understanding of site conditions.

Heavy emphasis on identifying, locating, and mapping underground utilities and infrastructure precluded damages and associated cost and delays. Because of the initial lag in biological acclimation and response, relatively slow chemical reaction time, distance between the treatment areas and associated monitoring points, and low groundwater velocity, it will likely be years before the full impact of this bioremediation will be realized.

REFERENCES

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