Horizontal Wells for
How a technology that revolutionized the

by Garry Van Heest

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An overview of horizontal directional drilling and horizontal remediation well technology that was originally developed for the oil and gas industry, with two case studies where this technology has been applied to successfully remediate sites with impacted groundwater.

The focus of this month's issue is "water," and while many readers will likely visualize lakes, rivers, and oceans when thinking about water, this article is about groundwater, or water below the land surface in a zone of saturation.[1] Specifically, this article discusses how groundwater contaminated by chemical releases is being cleaned up (or remediated) using horizontal directional drilling (HDD) technology that was originally developed for the oil and gas industry along with specially designed horizontal remediation wells (HRWs). HDD/HRW can be combined with different treatment processes such as chemical injection to more effectively remediate groundwater.

A typical HDD drill rig.

Photo courtesy of Directional Technologies Inc.

HDD technology was developed and perfected by the oil industry in the 1980s.[2] "Horizontal drilling is the real marvel of engineering and scientific innovation" that has led to discovery and extraction of massive new shale gas and oil resources in the United States and elsewhere.[3] National and local news coverage regularly discusses how HDD coupled with hydraulic fracturing technology is increasing natural gas and crude oil production in the United States from "unconventional" sources, such as shale formations. HDD technology was also adapted for installing relatively shallow buried utility lines, such as fiber optic cables, without the need for trenching. This technique is also known as "trenchless technology."[4]

There are several key technologies that enable HDD: a specially designed drill rig, special drill pipe, a battery-operated radio transmitter located behind the specialized drill bit, and a handheld battery-powered instrument that receives/interprets the subsurface radio signal. A typical HDD drill rig is illustrated in the photo opposite. The drill rig has no vertical mast; the drill bit enters the ground at approximately a 15-degree angle. The drill pipe is constructed of high-tensile-strength steel that enables it to flex considerably without breaking, which, in turn, enables underground "steering," aided by a specially configured drill bit (see Figure 1). The drilling process uses drilling fluid, also known as "mud," to remove drill cuttings, lubricate the drill bit, and maintain borehole integrity.

HRWs consist of pipe, constructed of materials such as polyvinylchloride, high-density polyethylene (HDPE), fiberglass, and stainless steel that is inserted into the bore after the drill rig has reached the target depth and location. A portion of the pipe is slotted, to allow fluids to be injected or withdrawn from the surrounding formation (see Figure 2). The slotted section is called the well screen,[5] which keeps sediments from entering the well, and the solid section is called the riser,[6] which is the pipe extending from the screen to or above the ground surface. The screens, which can be hundreds of feet long, are specially designed to ensure uniform flow (or vacuum) across the entire screen length.[7] The screen design process uses specialized software to model (or simulate) fluid flow through the well and into the subsurface formation. This is critical in ensuring that the HRW will function as designed.

HRWs offer significant advantages over traditional vertical wells. Many remediation target zones are vertically anisotropic (the property of being directionally dependent) sedimentary systems with preferentially horizontal flow, causing vertical well screen flow distribution variability.[8] Air will preferentially flow through vertical well thin screen subsections adjacent to high permeability zones, favoring "short-circuiting," an event in which air (or fluid) finds its way to the surface, instead of the

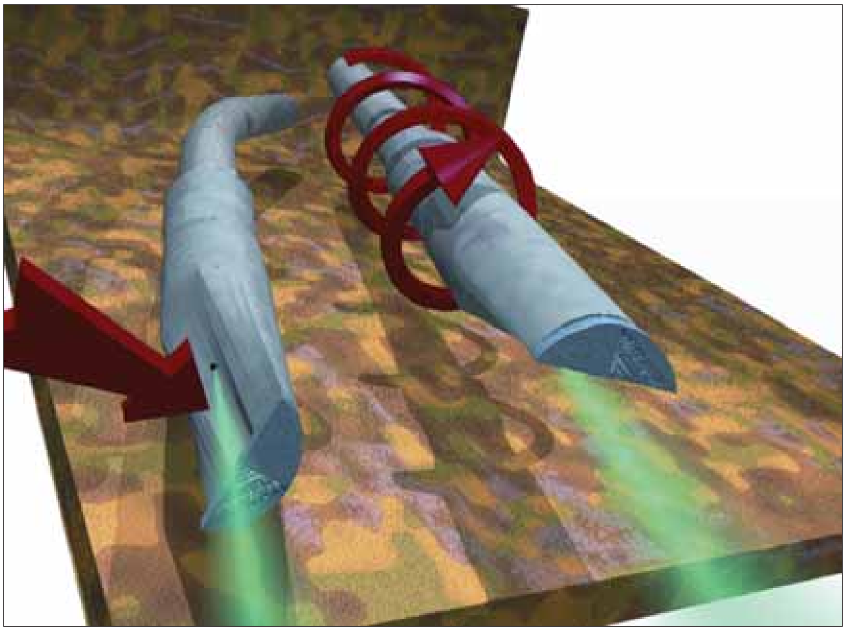

Figure 1. Underground steering is illustrated in the figure to the left. Drill bit rotation is stopped, the drill rig pushes the drill pipe and the curved drill bit tends to move, or steer, (in this instance) to the right. Straight rotational drilling is illustrated in the image to the right. The green material is drilling fluid (or "mud") used to circulate drill cuttings to the surface.

Photo courtesy of Directional Technologies Inc.

remediation target zone.[8] Conversely, a horizontal well screen in same formation is normally placed in one stratigraphic zone—air encounters the same permeability along the screen, significantly reducing the likelihood that the well will become over pressured or develop excessive vacuum buildup, making HRWs much less prone to short-circuiting. Long risers further reduce the chances of short-circuiting, due to their greater surface area in contact with surrounding soil (and greater friction).

Below are two case studies where this technology has been applied to successfully remediate sites with impacted groundwater.

Using HRWs to Remediate a Subsurface Gasoline Release

A significant gasoline release from an underground pipeline at a U.S. international airport created a multiple-acre groundwater plume that extended hundreds of feet under an active runway. After performing a remedial investigation and feasibility study, air sparge/soil vapor extraction remediation technology was employed, using a network of 600-ft long, parallel HRWs. Air sparging is an in-situ remedial technology that reduces concentrations of volatile constituents in petroleum products that are adsorbed to soils and dissolved in groundwater. This technology involves the injection of contaminant-free air into the subsurface saturated zone, enabling a phase transfer of hydrocarbons from a dissolved state to a vapor phase. The vapor is then vented through the unsaturated zone to the surface, where it is captured in vessels containing activated carbon and then transported off-site for treatment and/or regeneration.[9]

Air sparging (AS) is most often used together with soil vapor extraction (SVE), but it can also be used with other remedial technologies. When AS is combined with SVE, the SVE system creates a negative pressure in the unsaturated zone through a series of extraction wells to control the vapor plume migration. This combined system is called AS/SVE. HRWs were selected because of the magnitude and aerial extent of the plume, the severe site constraints, and the need to remediate the site quickly without interrupting runway operations. Extraordinary volatile organic compound (VOC) vapor recovery rates were achieved, ranging from 174-320 lb per day per well, with a cumulative VOC recovery of 26,687 lb over six months for a single well[8] during 2012.

Enhanced Potassium Permanganate Delivery Using HRWs

A former dry cleaner operation in Maryland experienced major perchloroethylene (PCE) subsurface releases over a period of decades. A site investigation revealed an extensive PCE groundwater plume extending more than 1,000 feet laterally under adjoining roads, buildings, and utility corridors. The site was being redeveloped into a shopping mall, there was very limited access and/or space available for drilling equipment/vertical injection wells, and remediation had to occur on an active construction site to avoid schedule delays.

In-situ chemical oxidation (ISCO) using potassium permanganate ($KMnO_4$) injection via HRWs was the selected remedy for this site (HRW-ISCO). ISCO involves the introduction of a chemical oxidant into the subsurface to transform contaminants in soil or groundwater into less harmful constituents.[10] To achieve adequate plume coverage, 10 parallel HRWs were installed perpendicular to groundwater flow; each was approximately 380-ft long overall, with screens 130- to 330-ft in length. Some of the wells were installed in pairs, with screens placed in target zones at 30-ft and 40-ft depths to ensure plume coverage. Two separate $KMnO_4$ injection events were performed during 2008: 340,000 gallons and 1,032,333 gallons, during the first and second injections, respectively, over a total of 26 days.[11]

What were the results? For source area groundwater monitoring wells: pretreatment PCE concentrations were as high as 13,000 parts per billion (ppb); post-treatment PCE concentrations ranged from non-detect (ND) to 400 ppb.[11] For downgradient groundwater monitoring wells: pretreatment PCE concentrations were as high as 8,000 ppb; post-treatment PCE concentrations ranged from ND to 1,840 ppb.[11] The use of horizontal wells resulted in a shorter injection time frame than would have occurred with vertical wells and minimized impacts to the construction schedule.

Summary

Horizontal wells have displayed several undisputed advantages over vertical wells. Horizontal well screens contact a larger surface area of contaminated media, thereby enhancing remediation of a greater volume of contaminated media per well. They also enable injections in areas where streets, utilities, and buildings are out of reach with vertical wells. Horizontal wells provide an uninterrupted zone-of-influence (ZOI) coverage versus a comparable system of vertical wells that rely on less dependable overlapping ZOI. Horizontal wells lend themselves to deployment with combinations of existing remediation technologies. For example, air sparging and soil vapor extraction and the combined technology is more efficient than vertical well implementation. Long horizontal screens enable higher volume injections than short vertical screens, resulting in a faster injection process. Importantly, for impacted sites, horizontal wells create a significantly smaller footprint and cause minimal interference with site activities and business operations. **em**

Figure 2. Typical horizontal well screen for in situ remediation. In this example, the pipe is HDPE. Note the slots, which are sized and spaced based on desired well performance parameters and to ensure uniform flow across the screen length. Screens are typically hundreds of feet long.

Photo courtesy of Directional Technologies Inc.

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