Contaminated Groundwater Interception and Remediation within the Mid-Plume Constriction Area, NASA White Sands Test Facility

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Abstract

The NASA Johnson Space Center White Sands Test Facility (WSTF) is currently developing and implementing corrective measures to address a four mile long contaminant plume (halogenated solvents and N-nitrosodimethylamine). Hydrogeologic controls within a mid-section (fractured volcanic bedrock) of the plume, the mid-plume constriction area (MPCA), confine contaminated flow to a relatively narrow zone. If remediation extraction wells could be effectively placed in this area, the plume-front could be isolated from the source. Groundwater modeling simulations within the MPCA were utilized to provide the initial target flowrate required for plume interception. A 1988 site-wide seismic survey indicated some potential structural conduits within the MPCA, but lacked sufficient resolution to identify specific drill targets. A 1997 hydrostratigraphic investigation of individual volcanic units within the MPCA revealed only limited potential aquifer yields, insufficient for remediation purposes. A seismic reflection survey conducted in 1998 focused on structural targets within the MPCA. Well MPE-1, located from the 1998 seismic survey, encountered a narrow conductive fault zone that produces nearly five times the sustained volume at elevated contaminant concentrations relative to surrounding monitoring wells. Based on the success of well MPE-1, additional seismic exploration has been used to locate other structures in the MPCA that could potentially yield high volumes of contaminated water to wells.

WSTF is located on the western flank of the southern San Andres Mountains approximately 18 miles northeast of Las Cruces, New Mexico and 65 miles north of El Paso, Texas. WSTF was constructed in 1963 primarily as a propulsion systems development facility. Several important Apollo era support activities established the need for materials testing capability. WSTF's current activities in support of the space program are the development and testing of spacecraft propulsion systems and materials testing.

The groundwater contaminant plume at WSTF resulted from test area releases during the 1960s and 1970s. The plume is approximately four miles long and up to 8,000 feet wide within an alluvial aquifer at the plume-front. The MPCA is characterized by a fractured volcanic bedrock aquifer, which confines the plume to a narrow zone approximately 2,000 feet wide. Groundwater flows through the MPCA in a west-southwest direction from the San Andres recharge area, towards the regional alluvial aquifer in the Jornada del Muerto Basin (JDMB). Flow within the aquifer has been shown to follow discrete conduits comprising faults and irregular fracture systems. Within the JDMB to the west, the plume-front is hosted within an alluvial aquifer where bedrock has been down-faulted to depth along a series of northwest-trending, subparallel, half graben faults (the Western Boundary Fault Zone (WBFZ)) developed during Tertiary basin and range extension.

Groundwater model simulations using NASA's 3-dimensional site-wide bedrock model, which utilizes the Modflow-Surfact modeling code, have been used to evaluate flow interception and contaminant mass extraction within the MPCA. Simulations indicate that a limited withdrawal rate of 80 gallons per minute (gpm) sustained for three wells in the area provides significant (80%+) interception within the MPCA. The highest concentrations of N-nitrosodimethylamine (NDMA), the primary health risk contaminant at WSTF, remain upgradient of the MPCA. The potential for effective interception of this contaminant mass coupled with low extraction volumes, makes the area particularly conducive to remediation.

Fractured bedrock within the MPCA occurs at a depth between 260 and 350 feet below ground surface (bgs) and consists of Oligocene felsic volcanic rocks. Coalescing alluvial fans prograding from the mountain front have covered the bedrock, forming a westward-dipping pediment slope. The top of the aquifer is approximately coincident with the fractured bedrock surface and is unconfined to locally confined where degraded volcanics form discontinuous clay lenses. Groundwater flows at an average hydraulic gradient of 0.05 feet/feet which is elevated with respect to the plume front at 0.0002 feet/feet. The contaminant plume is confined to the north by a competent, flow banded rhyolite unit with anomalously low hydraulic conductivity. To the south, the plume is confined by low conductivity bedrock characterized by several dry boreholes. A deep multi-port monitoring well installed in 1997 within the MPCA, encountered four distinct hydrostatigraphic units within the volcanic bedrock. The most hydraulically productive unit, a series of rhyolite and rhyodacite flows (Unit 3) at a depth of 600 to 800 feet bgs, initially approximated the required flow rates needed to transport contamination to the plume-front. However, during a 1997 constant rate pumping test at well IS-1, this unit was found to be isolated from the upper contaminated aquifer, uncontaminated, and remains dewatered since testing activities.

To supplement early 1988 shallow seismic data that identified only the presence of the WBFZ to the west, an additional seismic reflection survey was conducted within the MPCA in 1998 to explore for shallow structural conduits that could transport contaminated water to the plume-front. Based on a structural drill location identified from the 1998 seismic survey, well MPE-1 was installed about 1,100 feet north-northeast of well IS-1. Well MPE-1 was completed to a depth of 523 feet. Bedrock is at 260-feet bgs and static water is 320-feet bgs. Aquifer testing indicated a hydraulically productive zone in the vicinity of a steeply dipping vertical fault. Well MPE-1 can sustain approximately 16 gpm or nearly five-times the volume as surrounding monitor wells and is characterized by rapid recharge. Contaminant concentrations are approximately two to three times higher than nearby monitor well BLM-21, which historically contains some of the highest contaminant concentrations. The rapid recovery of well MPE-1 indicates that the fault zone is connected to the San Andres mountain front recharge area to the east.

In 2000, NASA conducted a supplemental detailed 2-D seismic reflection survey across the MPCA to specifically delineate trends of potential structures from the previous survey. Results of the survey have been used to identify four additional exploration wells along favorable structural targets with the option of conversion to extraction wells.

Additional well installation and aquifer testing activities are scheduled for the MPCA between May and December 2001 with the objective of maximizing contaminant interception utilizing an estimated maximum of five wells (MPE –1 through MPE-5). If successful, water extracted from the MPCA contaminant interception system will be treated by the plume-front remediation system.

The remediation system will consist of a groundwater pump-and-treat system designed to reduce halogenated solvent and NDMA concentrations to below current applicable regulatory and health-risk-based concentrations. The extracted water from the MPCA will be piped or pre-treated in-line and routed to the plume-front remediation system for final treatment and injection. The 1,000 gpm plume-front treatment system is comprised of six extraction wells, four injection wells, HDPE subgrade piping, a treatment facility, and all associated power distribution and control logic hardware/software. The halogenated solvents will be removed via parallel sieve-tray air strippers, followed by nitrosamine destruction by ultraviolet oxidation. Treated water will be routed to four injection wells.