The Use of 3D Seismic Imaging in Making Groundwater Management Decisions At Hazardous Waste Sites

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Abstract: Three-dimensional (3D) acoustic imaging is a highly developed technology that has produced a detailed image of the subsurface, at over 30 hazardous waste sites. 3D imaging has been used to provide the density of data necessary to analyze the pathways for fluid transport, whether in free phase or as a dissolved plume. This information has then been used to optimally locate control or monitor points. Evaluation of chemical sampling while drilling has been combined with the seismic data to address whether the plume can be contained or remediated. In 1994 the first 3D seismic survey over a hazardous waste site was performed at Naval Air Station North Island in California. The 3D seismic information, followed by confirmatory drilling, significantly changed the site conceptual model. The seismic image saved time and costs for characterization and remediation. A seismic survey at a NASA site and confirmatory drilling showed that free product was not present and that natural attenuation could be used. At Edwards AFB in California, there was concern that contaminants could migrate off base. The seismic image demonstrated that this was unlikely. The technology can be used to help determine if groundwater problems exist and for more rapid remediation when required.

METHODOLOGY

3D seismic reflection has its origins in the oil industry, where extensive research and application of the technique has been used to locate oil reservoirs. Recent advances in equipment have made it possible to adapt this diagnostic approach for use at relatively shallow depths, which are encountered at hazardous waste sites. The 3D seismic image has provided detailed stratigraphic and structural information on the exact nature of the heterogeneous subsurface. The seismic reflection method is based on the principle that sound waves, introduced at the surface, will reflect from interfaces where there are changes in structure, such as fracture zones, or stratigraphy in the subsurface. A power assisted weight drop is used as a source for the acoustic waves, geophones are used to receive the signals, and a seismograph records the data. The use of the weight drop makes it possible to repeatedly hit the ground and stack the coherent signal, while erratic background noise is diminished. The data are processed and interpreted with oil industry software.

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2D seismic reflection data surveys are collected along a line, and show a cross section of the earth. 3D seismic reflection surveys are collected within a grid of geophones, and make it possible to analyze a site in three dimensions as a volume. After the seismic data were collected and processed it was then possible, using interpretation software (Seismic Micro-Technology Kingdom Suite 3D Pak) to examine the subsurface on a personal computer (PC) from north to south, east to west, and top to bottom or along any arbitrary azimuth.

Marine Sedimentary Site

A 3D seismic reflection survey was first performed at a hazardous waste site in 1994 at Naval Air station North Island (NASNI). NASNI is located in San Diego harbor in California. The accurate and detailed seismic image of the site significantly changed the previous site model. An estimated 120 million liters of solvents were disposed in a low-lying area at Site 9, on the western side of the island. Originally it was believed that the free product waste had collected in lows along a clay layer, which according to bore hole data was between 26 to 35 meters below ground surface (bgs). Geologically, the site was characterized by fill, which overlays alternating marine layers of sand, silt, and clay. The seismic data show that the low lying disposal area was actually a sag pond, formed by at least 3 faults. The clay layer was breached by these faults.

In the source area the acoustic signal was attenuated most likely the result of the presence of the hazardous waste. Three borings were drilled into the clay layer that confirmed the seismic interpretation. Waste solvents and oils were not pooled on a confining layer as originally thought, but were isolated within a fault zone. The accurate image of the site made it possible to better characterize the site.

Sediments Overlying a Limestone Aquifer

3D seismic imaging was used in 1997 at a NASA site at Cape Canaveral, located on the central east coast of Florida. The site is known as Wilson Corners and was a rocket engine components cleaning laboratory that had been operated from the late 1950's to the 1970's. TCE was used for degreasing and particulate matter proof testing, and discharged to the sandy surficial aquifer through grain fields and by direct release. The stratigraphy is characterized by a shallow surficial aquifer, which is underlain by a clayey confining unit below 30 meters, and then by the deep Florida limestone aquifer. In 1989 NASA installed a pump-and-treat remediation system, which had removed nearly 3000 liters of TCE by the end of 1997.

The seismic data were collected in grassy terrain, through buildings and pavement, and over dense palmatic brush. The chemical analysis of the wells drilled, based on the seismic data, and the fact that there was very little attenuation of the seismic signal, which is often seen when free product is present, led all parties concerned to the conclusion that the source had been removed and that natural attenuation was a viable option.

Sediments Overlying a Granitic Basement Site

At Edwards Air Force Base in California, there was concern that contaminated groundwater may have been flowing offsite to impact domestic water supply wells at a community to the north of the installation (3). The facility of concern had been active since the 1940's and ceased operations in the 1990's. The contaminants of concern were dissolved chlorinated solvents and perchlorate, which had been detected in the groundwater on site.

The geology at the site is characterized by Quaternary alluvium and lacustrine deposits of poorly sorted gravels, sands, silts, and clays, which overlie mainly Tertiary intrusive and extrusive volcanic, metamorphic, and sedimentary rocks. The area is actively faulted and bedrock was encountered at varied depths from less than 60 meters to greater than 150 meters. Granitic bedrock crops out to the north and west of the site and is found at the near surface to the east.

The objectives of the seismic survey were to: 1) create a bedrock surface map of over 1 million square meters; 2) characterize the 3D fracture network within the bedrock and overlying alluvial sediments to a depth of over 300 meters; 3) identify structures that may act as groundwater barriers; and 4) provide the density of data coverage that will make it possible to more accurately evaluate the groundwater management alternatives.

The bedrock surface, contoured from the seismic data, suggested groundwater would flow from a bedrock high to the west toward two small subbasins in the center of the former production area. In addition, a barrier fault zone and an upthrown block to the north would impede groundwater flow offsite.

CONCLUSION

Once an accurate and detailed seismic image of the site is available, it is often possible to better evaluate source areas and migration pathways. Fewer monitor wells can be located in the optimum place, which means that fewer wells are required and multiple phases of investigation are reduced in number. After chemical analysis has been completed, the seismic image makes it possible to better understand the structural and stratigraphic relationship to contaminant transport. As a result, it is possible to decide: 1) if remediation is required; 2) where the remedial system should be located; 3) if it is impractical to remediate the site; and 4) if natural attenuation is the most reasonable alternative.

References

Resolution Resources, Inc., 1998. *Final Report 2D and 3D High Resolution Seismic Reflection Surveys at Chemical Waste Disposal Area, Site 9 Naval Air Station North Island, San Diego, California.*

G&E Engineering, Inc., January 1989. *Contamination Assessment Report Remedial Action Plan: Wilson Corners Groundwater Remediation, Wilson Corners Site, Kennedy Space Center*, prepared for the National Aeronautics and Space Administration (NASA), Titusville, FL.

Resolution Resources, Inc., December 2000. *Final Report: 3D High Resolution Seismic Reflection Imaging at the Former NASA JPL Facility, Operable Unit 5, Edwards Air Force Base.*