Sandia National Laboratories

Environmental Program

Development of Hybrid Cost-Effective Directional Drilling Equipment

Technology Need

Directional access beneath an environmental site provides earlier access to developing contaminant plumes and less risk to water tables as compared to standard methods of drilling vertical monitoring wells at the site periphery. A grid of surface-to-surface boreholes having entry and exit portals provides access for progressive characterization, monitoring, and remediation of a site. Particularly in arid regions, this method of relatively shallow horizontal drilling reduces the risk of site contaminants being directly transported to deep waste tables by the drilling and wellbore completion processes.

A directional boring test range was established at Sandia National Laboratories (SNL), and an industrial partnership was established with Charles Machine Works, Inc., better known by their product line trademark of DITCHWITCH™, which encompasses a range of low-cost directional drilling equipment. Initial project funding was obtained from the Sandia Environmental Restoration group. Primary project support was provided by the DOE Office of Technology Development through Integrated Demonstration Programs at SNL, Westinghouse-Savannah River Site, and Westinghouse-Hanford. Charles Machine contributed similar private funding for machinery development, services-in-kind, and project management.

Objectives

The original goals of the project were: (1) minimize environmental impact of the drilling process, (2) provide a low-cost, but high-quality alternative to more expensive directional drilling methods at shallow depths, (3) provide high quality directional access as an alternative to vertical peripheral drilling, and (4) establish a technology development partnership with a world class machinery manufacturer. Manifestations of the overall goals include minimizing secondary waste, use of drilling fluid, and minimal surface impact at a site, as well as involving ultimate users of the equipment in testing and evaluation. A concurrent goal was to keep drilling costs in the range of $25 - $75/foot.

Project Description

Scoping Tests: Early testing at SNL and Charles Machine Works test ranges provided baseline evaluations of existing commercial directional boring machinery used in the underground utilities industry.

Initial Hybridization: Some of the machinery tested in the scoping phase were adapted to samplers and cone penetrometer hardware used in the soil mechanics industry.

Testing at Savannah River: This first test of X-810 test bed boring machine, using onboard electronics from the river crossing industry, new generation bits/reamers/casing pulling plugs, and several new types of environmental casing/screen materials was highly successful. The test provided preliminary data, hardware confirmation, and a 570', 40' deep, 3" diameter, fiberglass cased environmental well for

Savannah River Radio Frequency soil heating tests. The soils at this site are coastal plain sediments consisting mostly of dense clays and sands.

Testing at Hanford: This work tested the limits of the X-810 boring machine, provided additional thrust data, evaluated steering control in loose cobbles and gravels of glacial till, but did not demonstrate that the prototype machine could be steered in the glacial till. Additional testing at another Hanford location using the standard P-80TM rod pusher with soil samplers was successful from the standpoint of steering control and the ability to collect interstitial uncemented sand samples.

A Pierce Airrow™ 4" diameter pneumatic piercing tool was also relatively successful in penetrating the Hanford formation in a very qualitative test.

Testing at Sandia National Laboratories : The X-810 was tested repeatedly at the SNL test range to confirm hardware designs and drilling strategies in the alluvial fill geology. A 410', 33' deep, 4" diameter environmental well was successfully drilled and completed at a Kirtland Air Force Base buried waste site. This test provided additional data on machinery capabilities and hardware designs.

Prototype Directional Drilling machine.

Sampler Development at SNL and Charles Machine Works: Several prototype soil samplers have been proposed, fabricated, and tested on a limited basis. Eventually, these samplers will be brought to the environmental marketplace.

Drill Cuttings Containment System Development: Drill cuttings containment in air-assisted drilling operations is a current issue at some DOE sites. Current containment systems are used at ambient or slightly elevated pressures. The need for negative pressure containment of hazardous materials is a recognized problem.

SNL initiated a development program with Guzzler Manufacturing in Birmingham, Alabama, a supplier of large vacuum systems to the asbestos remediation and mining industries, to develop an appropriate negative pressure trailer-mounted vacuum system that could be coupled through a diverter box to a variety of air-assisted drilling machines. This prototype Guzzler machine has been tested at SNL and is undergoing field testing at Hanford in FY94. The machine was built by Guzzler and is being leased by SNL.

Accomplishments

- FY91 through FY94: Industry partner, Charles Machine Works, built a test bed machine capable of a minimum of 80,000 pounds of thrust, high torque, and features for thorough decontamination.

- A low cost, onboard position tracking system was adapted from the river crossing industry, permitting tracking deeper than the maximum depth of 20' available in the utilities industry with walkover equipment.
- In FY92 the prototype was successfully used at Westinghouse-Savannah River Site to emplace a 570' long, 3" diameter well at 40' depth.
- In FY93 the prototype was again used to emplace a 410' well at a depth of 33' at SNL using 4" diameter casing.
- Charles Machine Works has made a corporate decision to enter the environmental machinery market in FY94, thus transferring the project technology to the ultimate customers.
- Several patent disclosures have been made by both SNL and Charles Machine Works.

Technical Issues

The basic penetration method applied in this project was cutting and then compacting the cuttings into the wall of the borehole. Geologic materials that are not compactable are not candidates for this method, however, hard rock drilling hardware may be adapted to the equipment in the future. The following are important technical considerations for future users of the technology.

Geology Dependency: Cutting and compacting the cuttings works best in soils that are most uniform, but will work in many nonhomogenous soils. Special drilling strategies will be needed for very wet sands which are difficult to stabilize and do not buttress the steering forces very well. Widely heterogeneous formations such as alluvial fills with caliche, sand, gravel, cobbles, and boulders have been drilled in this project and require experience and patience from the driller due to the tendency for the bits and reamers to walk around obstacles.

Onboard Position Tracking: A low cost 2-axis magnetometer-accelerometer type wireline guidance package used in the river crossing industry was used in this project. This equipment is less sophisticated than systems used on larger rigs, but was adequate for development testing. Existing mechanical gyro systems are fragile and are not normally used as onboard systems. The guidance system used in this project was subjected to severe environments or frictional heating and torsional/longitudinal vibration caused by the drilling process.

Bits and Reamer Configurations: Cutting and successfully compacting the cuttings occurs over a short horizontal distance and mechanical wear is severe. A key improvement in the drilling process was obtained by adding 2-10 gal./min. of potable water to cool and lubricate the drill bits and reamers. After the wellbore is drilled at some nominal diameter, reamers are used to enlarge the borehole and then compact the cuttings in the borehole wall. Several reamer passes may be needed in certain soils and the casing pullback hardware can vary with casing type/diameter and soil conditions. Small diameter completions may not require reaming, thus significantly reducing installation costs.

Casing Materials: The material choice can be critical to installation success or failure. Site geology is again a controlling factor. Higher strength fiberglass casing has been used most effectively in this project.

Technology Transfer

Information about the project and evolving machinery, hardware, drilling strategies, and casing material options continues to be shared with sponsors, environmental restoration professionals, and at technology workshops for the user industries and regulators.

A standard procedure used by Charles Machine Works to evaluate new products includes involving selected ultimate users in the testing phase. This has been done in this project and the feedback has been beneficial.

In early 1994 Charles Machine Works made a corporate commitment to enter the world wide environmental machinery market with equipment embodying the principles developed in this project.

Advantages

The DOE and DOD have many sites where this technology could be applied. Applications of the technology benefit from lower costs compared to larger directional rigs at depths to 80', much less fluid added while boring, very little secondary waste, minimal site disturbance, and shorter mobilization and demobilization time.

Most major industries in the U.S. have environmental problem sites. Steel, aluminum, petrochemical refining, fertilizer, plastics, heavy and light manufacturing, etc., have all used and disposed of byproduct materials. The accepted disposal practices of the past are now under scrutiny, and the burden of cleanup will eventually be passed on to stockholders or the consumer. Municipalities are also facing similar cleanup problems.

Natural radon gas infiltration of inhabited structures is being encountered in certain regions of the country. This directional drilling technology could contribute to cost effective characterization and remediation/ventilation beneath occupied buildings in these regions.

The parent underground utilities installation industry will also benefit from this development work through the future availability of machinery with enhanced capabilities. Similarly, the geothermal heat pump installation industry will directly benefit from the development work.

Costs

The costs associated with the characterization and remediation of private sites could have a severe impact on financial markets, individual company survival, and stockholder earnings. Costs can be lowered by applying in situ characterization and it may be found that some sites do not need remediation, but only monitoring. Drilling costs in the range of $25 - $75/foot, excluding the cost of casing/screen materials, have been obtained in developmental testing, thus meeting the original goal for cost effectiveness.

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