EVALUATION OF ALTERNATIVE DRILLING TECHNOLOGIES AND SUBSURFACE CONFINEMENT BARRIERS FOR SINGLE SHELL TANKS AT HANFORD

Willard P. Acheson, Terri A. Towers and Kendrick W. Wentzel
K&M Engineering and Consulting Corporation
Harry R. Johnson and William K. Overbey
BDM International, Inc.

ABSTRACT

Many of the tanks in the Hanford tank farm are well beyond design life and are perceived as being in imminent danger of failure. Some of the tanks have already failed. Over the years, tank leaks and spills have contaminated the soils; the soil contamination raises issues about the characterization of the tanks, closure of the tanks, and the safety of the tank farms. This study investigated the application of conventional and innovative drilling techniques to the problems of soil characterization, monitoring, and barrier installation beneath the Hanford 241-C tank farm.

An evaluation and ranking of twenty four types of drilling technologies included horizontal and directional drilling techniques developed by the oil and gas industry, the mining and minerals extraction industry, and others. The drilling technologies were evaluated for their ability to drill in unconsolidated soils, provide good horizontal and vertical position control, their potential use for subsurface characterization and monitoring, and their potential for use to install subsurface barriers beneath individual tanks or beneath a tank farm.

Another facet of the study included investigation and concept development of barrier systems which could be installed beneath and around the tank farms with a minimum of excavation. The barrier concepts, existing, commercially available technologies, had to be suitable for the variety of soil conditions found beneath the Hanford tank farms. The barriers were also investigated for their ability to withstand chemical attack and seismic deformations, and for their ability to have the barrier integrity verified remotely.

The best barrier technologies and drilling systems were combined into seven integrated barrier systems which were evaluated and ranked for their suitability to the Hanford site, their ability to meet environmental constraints, the safety of personnel working on the site, and the ability of the barrier to withstand large and small tank leaks. Each of these seven systems were then evaluated in terms of relative amounts of material extracted, deployment time, and costs.

The two highest ranked barrier systems developed were a circulating air barrier and a cone grouting barrier. Both are candidates for quick deployment, and either can be applied to single or multiple tank systems. Both systems are candidates for demonstration at a cold test at the Hanford site. Two other potentially applicable barrier systems evaluated, permeation grouting from horizontal wells and fracture grouting, are candidates for continued development and demonstration, and may be included in the cold test at the Hanford site.

INTRODUCTION

Westinghouse Hanford Company has initiated numerous activities focusing on the final disposition of Hanford's single-shell tanks (SSTs). Characterization of contaminated sediments resulting from past tank leaks, continued safe operations of SSTs, total confinement of leaking materials, secondary waste minimization, and final closure of SSTs are five of the many facets of the SST issue at Hanford and elsewhere in the nation. The application of horizontal and directional drilling techniques and integrated subsurface barrier systems may provide additional options for the cost effective remediation of Hanford's SSTs. A comprehensive evaluation was undertaken on methods that may be used to access the area under leaking single shell tanks or tank farms located at Hanford, WA. Such access will permit direct sampling of the conditions under the tank, the installation of monitoring equipment, and/or the injection of barrier materials to prevent downward movement of contaminant plumes. In addition, subsurface barriers are one option being considered to protect the soil column and water table in the likely event of leakage occurring during high water volume retrieval (sluicing) of the tanks, currently scheduled to begin in 1997. The study explores the possibility of cross-deployment of commercially available technologies found in the oil and gas industries, and well as the coal mining sector to accomplish these objectives. At this time, the greatest uncertainty is the technical feasibility of using directional drilling and verifiable subsurface barrier technology in Hanford's unconsolidated sands, gravels, and cobbles.

The study focus is the 200-E area, particularly the C tank farm. Special emphasis is given to tank 106-C, which has a high heat generation capacity. One of the contingency plans associated with this tank includes creation of a confinement barrier system, should the tank suddenly develop a leak.

The site is semi-arid; water contained in the soil matrix is low, averaging 20%. The geology is complex; sediments in the near surface and at depth vary rapidly, both vertically and horizontally. Average porosity is relatively high, about 24%. The ground water table is found approximately 244 feet below the surface of the C tank farm area. This complex geology presents significant technology issues associated with safe and effective drilling in and around the tank farm.

SUBSURFACE DRILLING REQUIREMENTS AND APPROACHES

The planning of vertical or horizontal drilling operations within the C Tank Farm area at the Hanford Site is difficult, primarily due to the complex geologic setting, site logistics, and the need to minimize adverse health and safety effects caused by bringing subsurface materials to the surface.

The initial horizontal wells should be targeted to the intervals in the sediments which minimize the number of boulders which could be encountered. The horizontal wells should be drilled from outside of the tank farm to avoid disturbing the tanks during well construction and to avoid drilling initially into or through contaminated sediments. A horizontal well beneath the tank farm will require a total measured length of approximately 850 feet, with a horizontal section approximately 550 feet in length and a curved section approximately 300 feet in length. Based on the analysis of the available geologic and contaminant plume movement data, a target depth for drilling beneath the C Tank Farm was selected to be 150 feet subsurface or about 100 feet below the bottom of the tanks. This target drilling depth was selected to minimize drilling into zones which are potentially contaminated, but shallow enough to protect the integrity of the water table. The most significant concerns that must be addressed in relation to the drilling operations and the ability to cope with the rapid changes in drilling conditions from the surface to the final depth.

Established drilling technologies were researched, analyzed, and ranked for their applicability and usefulness at the Hanford site. No technology was judged to be directly applicable to drilling the formations likely to be encountered under the C Tank Farm without further testing and improvement to meet the rigorous demands imposed by the drilling conditions and restrictions on what is acceptable to use at the Hanford site. The screening evaluation of 24 drilling technologies was based on the current capabilities of the technology to perform under the geologic and environmental constraints that exist at the Hanford Site to characterize, monitor, remediate, and/or install barriers. Each higher ranked approach was further evaluated for its ability to drill through cobbles, to control the position of the well bore, to minimize health and safety risks, to achieve maximum environmental control, and to place a well that will increase the efficiency of the injection or withdrawal of fluids.

Of these approaches, cable tool drilling, slant wells using air rotary or sonic, and air drilled horizontal wells have the highest probability of successful application to the C tank farm. Microtunneling from caissons and compaction thrust boring from the surface were also identified as a technologies with potential for special application in highly contaminated soils. Microtunneling is rated lower due to the greater volume of material extracted and less ability to minimize health and safety and maximize environmental controls. Thrust systems are currently depth and length limited, but evolving technology could enhance this approach enough to be a viable access candidate. Each of these technologies is discussed below with specific reference to the applicability of the method for use at the C tank farm at the Hanford site.

Cable Tool Drilling: Cable tool drilling methods are currently utilized at Hanford for drilling wells in and around the tank farms. The cable tool wells are usually drilled very straight, and deviate only slightly when encountering cobbles or bolders. Health and safety requirements are relatively easy to control using this drilling process. When drilling in contaminated terrain, samples are checked for radiation while still in the bailer or core barrel. Protocols relating to handling of radioactive samples are implemented if radioactive materials are detected. This methodology produces only very minor, short term environmental impacts relative to cuttings, noise, and fugitive dust. In addition, no water is used while drilling in contaminated areas at the Hanford Site. Cable tool drilling is the method choice at Hanford for these reasons.

Slant Wells - Air Rotary Drilled: Many mineral exploration drilling rigs are top drive rigs that are designed to initiate drilling operations at inclinations of up to 70 degrees from vertical. Coring operations can be conducted with these rigs as easily as drilling operations. Air-rotary rigs equipped with large diameter drill pipe and tungsten carbide button bits can drill through most cobbles and boulders, but a downhole motor will likely be required to maintain the drilling angle. Health and safety effects from air drilling operations have been greatly reduced in recent years. Drilling effluents can be handled in a closed system to minimize problems associated with fugitive dust that may be contaminated. Drill cuttings are removed by a cyclone and the air with minor particles can then be passed through a HEPA filter to remove all other particles including any airborne radioactive material. Access at the surface is not a problem because the rig can be located outside of the tank farm.

Slant Wells - Sonic Drilled: Sonic drilling methods were developed in Canada more than 25 years ago for use in the Canada's Athabasca Tar Sands deposits. Sonic drilling is a method of drilling whereby a vertical oscillation is imparted to the drill by two counter rotating eccentric weights mounted in a unit placed on top of the hydraulic pull down rig. The unit also has a rotary bushing that provides a rotary motion in conjunction with the vertical oscillation. This allows a relatively easy penetration of unconsolidated sand and cobble formations, but the drilling of boulders is more difficult. The cuttings remain inside the drill pipe and are removed by bailing or by auguring. Collecting samples at a specific depth is best accomplished by bailing the material inside the drill pipe. Special control units for handling cuttings need to be developed for application at the C tank farm.

Horizontal Wells - Air Drilled: Horizontal wells can be drilled with either mud or air as the circulating medium using either oil field type rigs or with river crossing rigs. These rigs may have problems where cobbles and boulders in unconsolidated sediments are dislodged and roll around under the tri-cone button bit. Methods of immobilizing cobbles and boulders will need to be developed and tested at the site, including cementing the formation in advance of drilling. Horizontal wells can be steered using downhole motors for azimuth and inclination deviation corrections. Directional control must be perfected if parallel horizontal boreholes are to be placed beneath the Hanford tank farms. Health and safety effects can be reduced and environmental control enhanced by using a closed air drilling system to separate the drill cuttings from the air stream for subsequent filtration and contaminant removal. Horizontal wells can be drilled from outside of the C Tank Farm to minimize surface access problems. Because the wells can access practically any point under the single shell tanks, horizontal wells have the highest process efficiency of the various methods under consideration.

Compaction Thrust Boring Systems (with Caissons): Compaction boring systems use hydraulic rams to thrust a boring device through the soil, compacting the particles into the available pore space. The bits are guiding devices that allow directional control of the drill rods within a limited range. Modifications to the equipment may allow the units to drill to depths of 75 feet, in which case this unit could be used to install 4 inch diameter bore holes for jet grouting beneath the single shell tanks. Otherwise, a rotary percussion unit might be required to drill the series of holes required to install a cement grout barrier. Compaction boring devices are not good at drilling cobbles but probably are more adroit at maneuvering around them if a tortuous drill path is acceptable. This equipment may require some modifications to handle any returned materials in an environmentally safe manner. The equipment must be launched from an area that is at least 15 feet wide to be able to handle the drill pipe, so a twenty foot diameter caisson must be sunk to the target depth to allow launching of the grout holes in the proper orientation. Engineering design will have to address the problem of snubbing the well bore access through the caisson shield to prevent blow back during the grouting process.

SUBSURFACE BARRIER REQUIREMENTS AND APPROACHES

In conjunction with the horizontal/directional drilling study, an evaluation of the technical feasibility of the placement of subsurface barriers, designed for interim confinement of any leaked material from Hanford's SSTs, has been undertaken. The evaluation includes both lateral and underlying barriers placed both under single tanks and under an entire tank farm. Lateral barriers (oriented vertically, preventing horizontal flow) evaluated are: slurry walls, drilled piers/piles, sheet piling, jet grouting, permeation grouting, and freeze barriers. Underlying barriers (oriented horizontally, preventing downward flow) evaluated are: circulating air barrier (CAB), permeation grouting, fracture grouting, longwall mining, and microtunneling from caissons.

Thickness and Hydraulic Conductivity

Bounds can be established for the most important parameters required of the confinement barriers through use of the following expression which relates the four basic parameters of the system:

$$H\,Tc + \frac{S^2}{K}$$

where S is the thickness of the barrier, Tc is the projected confinement time, K is the hydraulic conductivity and H is the hydraulic head which drives the flow. Assuming a maximum hydraulic head of 15 feet of water (H = 4.5m) and a confinement time of 30 years (Tc = E+09 seconds), the barrier thickness and its hydraulic conductivity must satisfy:

$$\frac{S^2\,[m^{2}]}{K\,[m/s]} \geq 4.5\,E + 9\,[meter/sec]$$

A plot of this relation can be used to quickly determine whether, for example, a barrier 0.2 meters thick with a conductivity of less than 1 E-11 would satisfy the assumed time and hydraulic head specifications.

The twelve large SSTs in this area have an outside diameter of 80 ft, including the footing, and are located 104 ft apart, center-to-center on a square grid. Assuming that the lateral barriers must be at least 1 tank diameter away from any tank in order to avoid any appreciable mechanical disturbance to the tanks during construction, a 520 ft x 550 ft (159 m x 168 m) area is defined as the zone to be enclosed. Different specifications for these parameters will substantially affect the costs, but not necessarily the feasibility of a given process.

Ranking Criteria

The criteria applied to each barrier include: Capability of installation to depths up to 200 feet; currently available technology; ability to drill through the formation; position (placement) control; minimize health and safety effects; maximize environmental control; barrier integrity; minimize tank stress; resistance to chemical attack; resistance to seismic disturbance; and ability to verify barrier integrity.

The top ranked lateral barriers were slurry walls, drilled piers and piles, jet grouting and permeation grouting. Slurry walls are a standard construction technique where a trench is filled with bentonite slurry for stabilization, which is then displaced with the material that is to form the barrier. For the second type of lateral barriers, drilled pilings, a continuous barrier of interlocking cylinders is formed by grouting holes that are successively drilled partially into the previous piling. A jet grouted barrier, the third type, is similar to one constructed of drilled piles, except that a high pressure jet grouting head is used in construction to form interlocking cylinders approximately 36" in diameter. Finally, permeation grouted barriers are constructed by pumping viscous grouting fluid through a grouting pipe as it is slowly withdrawn from the formation. The grout fills the voids in the soil, creating interlocking cylinders.

The top ranked underlying barriers are the circulating air barrier (CAB), permeation grouting, and fracture grouting. The CAB concept involves the circulation of air through a subsurface interval in order to lower and then maintain the water saturation below the saturation required for liquids to flow. The barrier can be installed using either vertical wells drilled in and around the tank farm or using horizontal wells which are drilled beneath the tank farm from locations outside of the tank farm. In either case, a pattern of air injection and production wells is established so that the injected air moves from the injection wells through the formation to the production wells. The interval targeted for drying is ideally located above the water table and below heavily contaminated strata. The moving air vaporizes the water and carries the water vapor to the production wells. The air and water vapor are collected at the surface, dehydrated to remove the water vapor, and then filtered to remove any contaminants or particulate matter. The dry air is then compressed and reinjected. In time, the circulating air reduces the water saturation in the swept interval to a level that prevents the flow of liquids through the interval. In other words, this dehydrated interval acts like a sponge, and any liquids that move into the interval are absorbed into the pore space and subsequently removed by the air circulation process. No liquids can flow through this interval until a critical saturation is achieved, a saturation level that is well above the initial liquid saturation. In the event that a large leak occurs, the production wells serve as early leak detectors and as a method of remediation.

The second type of underlying barrier, a permeation grout barrier, is emplaced by injecting grout into the formation at less than fracturing pressure from an array of horizontal boreholes. The holes should be directionally drilled starting from outside the tank farm, parallel to each other at a spacing such that grout from adjacent holes will overlap and form a continuous barrier.

The third type, a fracture grouting barrier, is emplaced by injecting grout at greater than fracture pressure from vertical fracture wells. The fracture wells (relatively few) are placed such that the radial ("penny-shaped") fractures will overlap and cover the entire area below the tanks. These sheet-like fracture barriers can then be used to direct the flow of subsequent permeation grouting from horizontal boreholes drilled above the fractures. Better control of the permeation grout zone results in the need for fewer wells.

INTEGRATED SUBSURFACE BARRIER SYSTEMS

The highest ranked drilling technologies and barrier systems were combined to create seven integrated barrier systems for consideration at the Hanford site. These systems are: Circulating Air Barrier (CAB); Subsurface Cone Grouting (ConeGrout); Permeation Grout Barrier Using Horizontal Wells (PermGrout); Fracture Grouting and Permeation Barriers using Horizontal and Vertical Wells (FracGrout); Horizontal Pressure Grouting (HorGrout); Trenchless Excavation - Microtunneling (MicroGrout); and Longwall Mining (LongGrout). Each of these systems, with the exception of the CAB, consists of underlying and lateral barrier components for confinement of potential tank leaks. The CAB system does not require lateral barriers and is the only system that provides for ongoing monitoring and remediation possibilities.

The CAB system is a confinement system which can be immediately installed using existing, commercially available technologies. The system can be installed by using either horizontal or vertical wells. A schematic for the horizontal well configuration is shown in Fig. 1. The barrier forms both underlying and a lateral barrier as it "absorbs" liquids that may enter the dried area. An adequately sized barrier will prevent lateral escape of water and waste liquids.

Subsurface Cone Grouting may be used to place a barrier under a single tank or under an entire tank farm (Fig. 2). A group of slant wells will be drilled to a depth approximately 200 feet below the bottom of the tank or farm in order to minimize drill through contaminated areas. The barrier developed from the slant wells can be permeation grout barriers or jet grouted barriers or both, depending upon properties of the barrier materials. In the case of a barrier for the entire tank farm, the end lateral barriers can be vertically drilled and grouted or of slurry wall construction.

In the PermGrout system, a horizontal permeation grout barrier is used in conjunction with slurry walls to form a complete lateral and underlying barrier system for the tank farm. Lateral barriers are constructed on one side by grouting the horizontal wells to the surface; the other three lateral barriers would be constructed by drilling and permeation grouting vertical wells or by constructing slurry walls.

In the FracGrout system, a lateral barrier would be placed around a tank farm by slurry walls. A dual underlying barrier system would be placed by using fracture grouting from vertical wells. A second, thicker barrier would be placed on top of the fracture grouts from horizontal wells. In this manner, the fracture grout barriers would serve as an underlying barrier for an overlying, thicker, permeation grout barrier which would seal the spaces between the fracture planes.

The remaining systems ranked relatively low in the comparative analysis. HorGrout involves jet grouting horizontal holes thrust-bored radially from caissons beneath a tank. The MicroGrout barrier system would be constructed as follows: large-diameter vertical caissons will be installed and large diameter tunnels installed between caisson pairs. microtunnels will then be bored between the horizontal tunnels and subsequently jet grouted to form the horizontal barrier. Lateral barriers will be constructed of slurry walls. For the final system, LongGrout, automated longwall mining equipment would excavate an interval beneath the tanks, backstowing with excavated materials, concrete and other additives to form the underlying barrier. The lateral barriers will be constructed of permeation-grouted vertical wells or slurry walls.

COMPARATIVE ANALYSIS RESULTS

Criteria used in the comparative analysis of the seven integrated systems are of two types: 1) criteria that can be quantified (material extracted, deployment time, and costs); and 2) criteria that are subjective (regulatory acceptance, minimize environmental, health and safety (EH&S) effects, confidence that the approach will work as designed, and ability to verify barrier integrity).

Quantified criteria (material extracted. deployment time, and costs) are presented on a relative basis that reflect the current level of investigation. That is, while materials extracted and costs were estimated for this study, none of the barrier systems has been subjected to the detailed conceptual design required to firmly establish costs and schedules. Therefore, relative values are used to establish an overall view of the seven barrier systems relative to each other.

Subjective criteria involve judgements concerning the regulatory acceptance of the barrier system, confidence that the barrier approach will work as designed, ability to minimize EH&S effects during construction and operation, and ability to verify barrier integrity. Each of these criteria are graded at three levels, low, medium, or high (Table I).

Relative values are computed as a ratio of estimates used to prepare the process descriptions. For example, the CAB system will require a minimum extraction of 1,700 cubic feet of material, while the LongGrout system requires extraction of 1,357,000 cubic feet of material. The ratio of the material extraction estimates is 798. Stated in a different manner, 798 units of material will need to be extracted using the LongGrout method for every one unit extracted using the CAB barrier system. Relative values for each criteria and for each barrier system are computed in a similar manner. As shown in Fig. 3, the (CAB) system is the baseline process for this analysis with a relative value of one for each criteria. That is, this process has the least material extracted, is the fastest to deploy, and is the lowest in costs as compared with each of the other barrier systems evaluated.

The CAB system's lowest relative ranking reflects the fundamental difference between this system as compared with

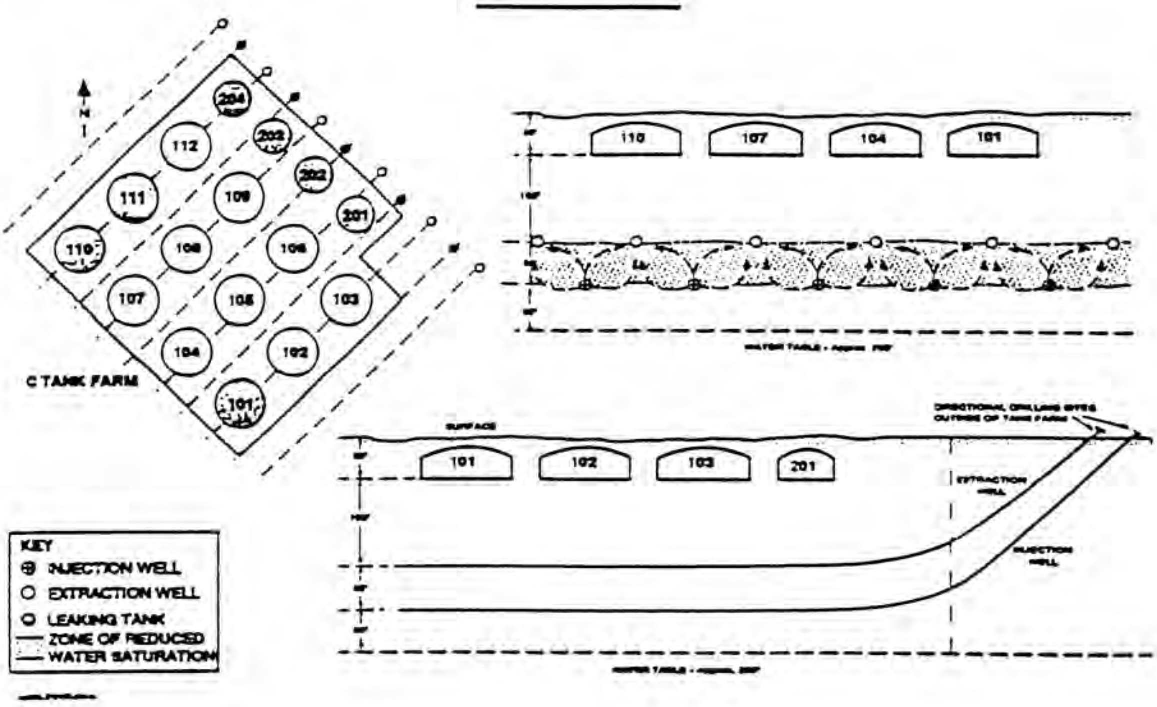

Fig. 1. Circulating air barrier (CAB) system utilizing horizontal wellbores.

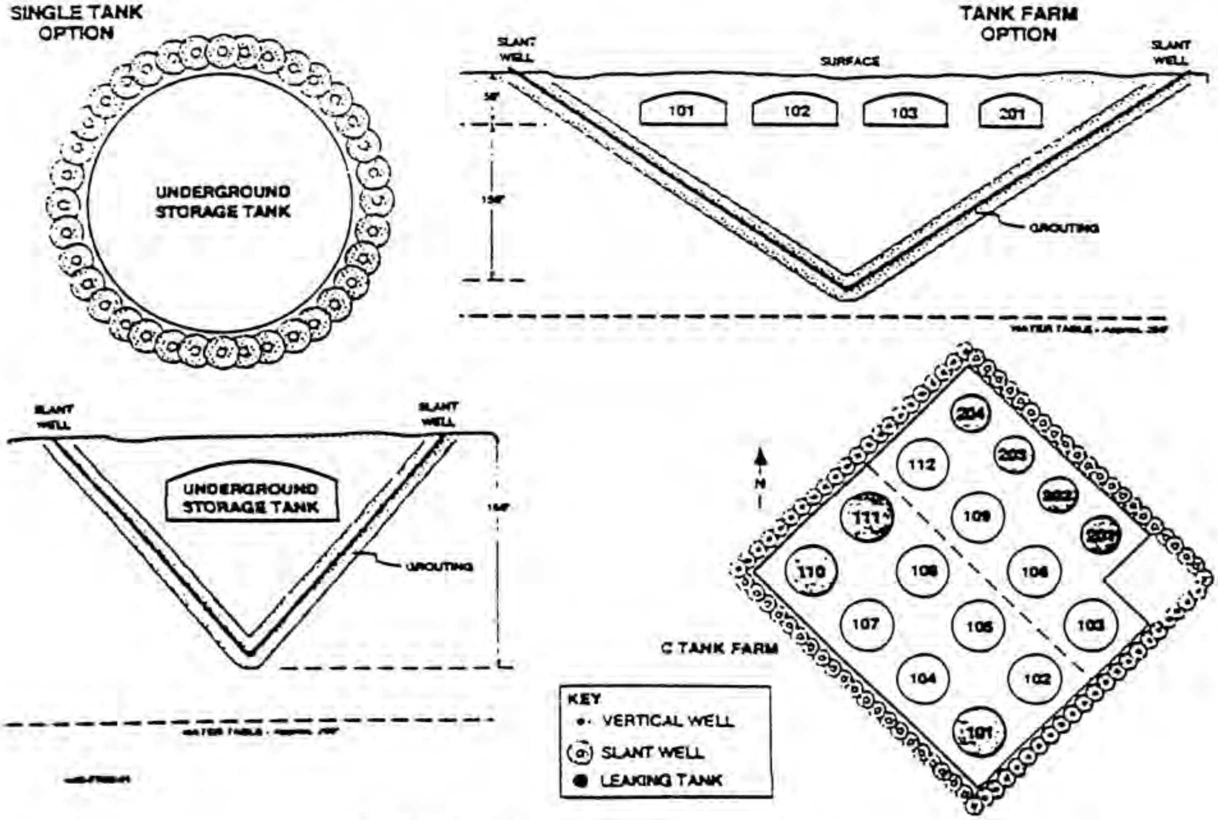

Fig. 2. Subsurface cone grouting system.

TABLE I
Comparative Analysis of Barrier Systems

	CAB	ConeGrout	PermGrout	FracGrout	HorGrout	MicroGrout	LongGrout
Quantified Comparative Evaluation							
Relative Material	1	10	9	8	46	600	798
Relative Time	1	5	6	7	3	9	10
Relative Costs	1	4	4	3	2	2	2
Subjective Comparative Evaluation							
Confidence in Approach	high	high	med	med	high	high	high
Regulatory Acceptance	med	med	low	low	high	high	high
Minimize EH&S Effects	med	high	high	high	low	low	low
Verify Barrier Integrity	high	low	low	low	med	med	high

Note: The relative values are normalized to the CAB System, which has the least material extracted, the fastest deployment time, and the lowest cost as compared with the other barrier systems. Thus, the CAB system is the baseline with a relative value of 1 for each criteria.

each of the other barrier options. Each of the other options involve the injection of grout to form a solid barrier.

The CAB system does not require grout, but operates on the basis of air drying the formation, in effect creating an underground sponge to absorb liquids that may enter the area that has been dried. Since air is highly mobile in the Hanford formations under the C tank farm, fewer vertical and/or horizontal wells will be required as compared with the other barrier systems. Fewer wells translate directly to less cost and less time required to deploy the CAB system, as reflected in the analysis.

The CAB system is developed from the surface by drilling, as are each of the first four barrier approaches presented in Table I (CAB, ConeGrout, PermGrout, and FracGrout). Each of the remaining three barrier systems (HorGrout, MicroGrout, and LongGrout) depend on underground access methods that require significantly more extracted materials.

Each of the barrier systems will provide information needed to characterize the area accessed by the process. The inherent design of the CAB system provides additional advantages over the grout based systems: 1) monitoring of the contaminants that enter the swept zone and are produced, and 2) lowering, by production, the contaminants in solution contained in the subsurface. The study team has high confidence in its ability to establish the CAB system and the Cone Grouting system, but judges each system to have medium probability for regulatory acceptance. The CAB system, while based on

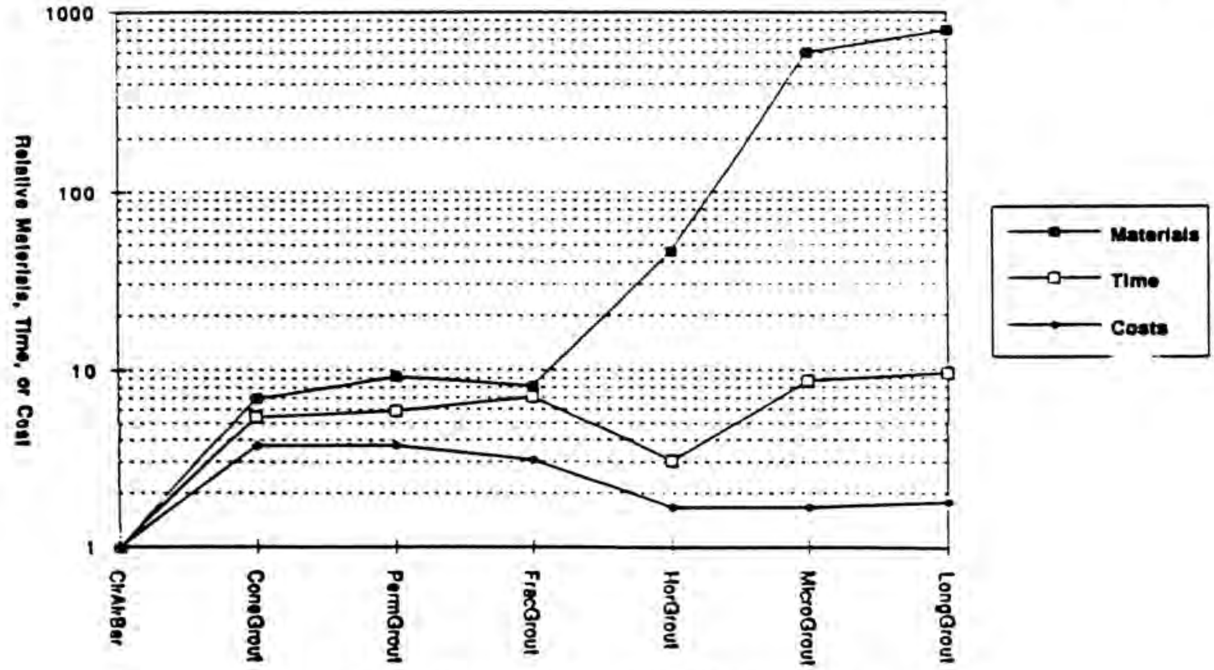

Fig. 3. Comparative analysis of barrier systems.

solid petroleum engineering principles, has not been proven for its application as a barrier. In contrast, the barrier systems developed by underground access methods are judged by the study team to be high in both regulatory acceptance and in confidence in the system working as planned. This high confidence and acceptance is based on the ability to place grout materials in the earth at the desired location using the desired quantity of materials. Placement of grouting materials required by the PermGrout and FracGrout methods is not as certain, leading to less confidence in these approaches and, consequently, to a probable low regulatory acceptance. These uncertainties can be resolved with targeted research and demonstration of the higher ranked barrier systems.

The EH&S effects of barrier construction and operation were subjectively evaluated. The CAB system will return materials to the surface and therefore has a lower ES&H subjective rating than do the other three surface-based systems that use grout as a stationary barrier. However, each of the surface-based barrier systems are inherently less risky from a health and safety standpoint than those that require underground access. While the underground access approaches would seek to employ equipment operated from the surface, mechanical equipment will ultimately fail. Correction of the problem or problems will bring personnel in close proximity to large quantities of extracted materials that are potentially heavily contaminated with radionuclides. Protection of underground workers will need to be solved before any of the underground access methods are deployed.

Ability to verify barrier integrity was also evaluated. Due to its design, the CAB system will provide continuous information (moisture, pressure and radioactive counts) that would be plotted to show changes in the barrier integrity. Similarly, each of the engineered barrier systems developed from a subsurface location would be equipped to verify barrier integrity. The ConeGrout, PermGrout, and FracGrout barrier systems are each rated low in the ability to verify barrier integrity since each system will require the proper placement of monitoring wells.

Resolution of Key Drilling Issues

During the course of evaluating the various drilling alternative methods, each was weighed against the dominant drilling issues identified from examination of the geologic media beneath the tank farms in 200 East area.

The following are a list of the most pressing issues relative to drilling slant or directional horizontal wells beneath the tank farm:

1. Drilling Boulders and Cobbles
2. Borehole Stability
3. Directional Control
4. Mobilization of Contaminants
5. Control of Drilling Effluents
6. Completion of the Borehole

The study team, in examining the various drilling problems, compiled potential solutions which should be investigated during the technology demonstration. The following is a recommended list of potential solutions which the study team recommends for consideration:

- Drilling of Boulders and Cobbles
    - Test tungsten carbide bits
    - Test special short barrel diamond coring bit/air motor
    - Test indexing horizontal air hammer bit
- Borehole Stability
    - Test pre-stabilization of the borehole in place
- Directional Control
    - Test pre-conditioning with acceptable materials
- Mobilization of Contaminants
    - Test feasibility of air drilling
    - Test pre-conditioning of borehole with acceptable materials
- Drilling Effluent Control
    - Test of a closed handling system for air and liquids
- Completion of the Borehole
    - Test the installation and operation of steel casing and ported collars for formation access
    - Test of pre-ported and screened plastic casing

The team recommends that two types of horizontal drilling rigs be tested during the technology demonstration, an Eastman Christensen type drilling rig (as modified for drilling at Savannah River), and a slimhole drilling system utilizing a coiled tubing drilling unit especially designed for operation at Hanford site. The team also recommends testing of a sonic rig configured to drill a slant hole at inclinations of either 15 or 20 degrees from the horizontal. For applications at shallow depths, the team recommends testing of the several types of compaction boring devices including a guided thrust boring rig and a pneumatic thrust boring device. The team also recommends testing of logging and measurement while drilling devices for use with several of the drill rig types.

Recommendations Regarding Potential Barrier Systems

The CAB system and Cone Grouting offer two alternative methods of placing a barrier from the surface with a high confidence of success. Each of these systems is a candidate for quick deployment in an emergency situation. However, each of these methods will need to be demonstrated to develop data need to gain regulatory acceptance from both the U.S. Environmental Protection Agency and the Washington State Department of Ecology. To move toward a cold test of these barrier approaches, it is recommended that a more detailed conceptual design be undertaken for each system, possibly with technical staff participation from relevant regulatory agencies.

Permeation *Grouting* and Fracture Permeation *Grouting* will require additional research and development before either can be considered viable candidates for use in the C tank farm area. To test these concepts, it is recommended that research be initiated at the subsurface test facility recently constructed at the Hanford site by Westinghouse Hanford Company. This test facility, with installed monitoring devices, is an excellent test bed for cost-effective testing of these two subsurface barrier systems in the unconsolidated soils, cobbles and boulders present.

Underground access methods (HorGrout, MicroGrout, and LongGrout) have an excellent chance of serving as engineered underlying barriers. However, use of underground approaches will be constrained by concerns associated with placing people in close proximity to large amounts of potentially radioactive material; issues associated with the health and safety of workers is must addressed.

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