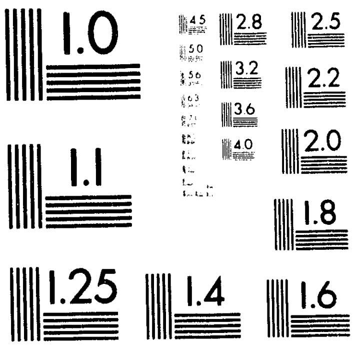
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The Development of Permanent Isolation Surface Barriers: Hanford Site, Richland, Washington, U.S.A.

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and Waste Management

Westinghouse Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the U.S. Department of Energy under Contract DE-AC06-87RL10930

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The development of permanent isolation surface barriers: Hanford Site, Richland, Washington, U.S.A.

Le développement des barrières de surface pour isolation permanente: Hanford, Richland, Washington, Etats Unis

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ABSTRACT: Permanent isolation surface barriers are being developed to isolate wastes disposed of in situ (in place) at the U.S. Department of Energy's Hanford Site in Washington State (U.S.A.). The current focus of development efforts is to design barriers that will function in a semiarid to subhumid climate, limit infiltration and percolation of water through the waste zone to near-zero amounts, be maintenance free, and last up to 1,000 years or more. A series of field tests, experiments, and lysimeter studies have been conducted for several years. The results of tests to date confirm that the Hanford barrier concepts are valid for both present and wetter climatic conditions. The data collected also have provided the foundation for the design of a large prototype barrier to be constructed later in 1993. This paper presents the results of some of the field tests, experiments, and lysimeter studies.

RESUME: Les études des barrières de surface pour l'isolation permanente des déchets toxiques sont en cours de développement à Hanford, dans l'Etat de Washington, sous la direction du Département de l'Energie. Le développement des barrières se prêtant à un climat variant du semi-aride à sous-humide, réduisant à près de zéro toute possibilité d'infiltration et d'égouttement d'eau à travers la zone des déchets, et ne demandant aucun entretien pour au moins un millenaire, constituent le but principal de ces efforts. Un nombre d'études utilisant les lysimetres et les autres appareils ont été executés sur plusieurs années. Les résultats de ces études jusqu'à maintenant confirment que les concepts des barrières développés à Hanford sont valables sous les conditions climatiques actuelles aussi bien que sous des conditions plus extrêmes. Les données obtenues ont permis d'établir une base d'étude pour le développement d'une large barrière prototypique qui sera construit plus tard en 1993. Ce texte présente les résultats de quelques unes de ces études utilisant les lysimetres et les autres appareils.

1 INTRODUCTION

The exhumation and treatment of wastes may not always be the preferred alternative in the remediation of a waste site. In-place disposal alternatives, under certain circumstances, may be the most desirable alternative to use in the protection of human health and the environment. The implementation of an in-place disposal alternative will likely require some type of protective covering that will provide long-term isolation of wastes. (Also, even if wastes are exhumed, treated, and subsequently disposed of, a long-term barrier may still be needed to isolate the wastes adequately.) Currently, no "proven" long-term barrier and marker system is available. The Hanford Site Permanent Isolation Surface Barrier Development Program (BDP) was organized in 1985 to develop the technology needed to provide a long-term surface barrier capability for the U.S. Department of Energy's (DOE) Hanford Site near Richland, Washington, U.S.A. (Adams and Wing 1986). The BDP is supported by DOE and consists of a team of engineers and scientists from the Pacific Northwest Laboratory (PNL) and Westinghouse Hanford Company (WHC). The permanent isolation barrier technology also could be used at locations other than the Hanford Site.

2 FUNCTIONAL REQUIREMENTS OF THE BARRIER AND MARKER SYSTEM

Permanent isolation barriers and warning marker systems use engineered layers of natural materials to create an integrated structure with redundant protective features. The natural construction materials (e.g., fine soil, sand, gravel, riprap, asphalt, and clay) have been selected to optimize barrier performance and longevity. The objective of current designs is to use natural materials to develop a permanent isolation barrier and warning marker system with these features:

- maintenance-free
- functions in a semiarid to subhumid climate
- isolates wastes for a minimum of 1,000 years
- limits water drainage to near-zero amounts (<0.5 mm/yr)
- minimizes the likelihood of plant, animal, and human intrusion
- limits the exhalation of noxious gases
- minimizes erosion-related problems.

The permanent isolation barrier consists of a variety of different materials placed in layers to form an above-grade mound directly over the waste zone (Figure 1). The barrier design consists of a fine-soil layer overlying other layers of coarser materials such as sands, gravels, or basalt riprap. Each of these layers serves a distinct purpose. The fine-soil layer acts as a medium in which moisture is stored until the processes of evaporation and transpiration can recycle any excess water back to the atmosphere. The fine-soil layer also supports plants necessary for transpiration. The coarser materials placed directly below the fine-soil layer create a capillary break that inhibits the downward percolation of water through the barrier until the fine-soil layer nearly saturates. The placement of the fine-soil layer directly over the underlying coarser materials also creates a favorable environment for containing the biological cycles in the upper portion of the barrier, thereby reducing biointrusion into the lower layers. The coarser materials also help to deter inadvertent human intruders from digging deeper into the barrier profile. Low-permeability layers, placed in the barrier profile below the capillary break, also are used in the protective barriers. The purposes of the low-permeability layers are to (1) divert any percolating water that gets through the capillary break away from the waste zone and (2) limit the upward movement of noxious gases from the waste zone.

3 HANFORD SITE PERMANENT ISOLATION SURFACE BARRIER DEVELOPMENT PROGRAM

The goal of the BDP is to provide defensible evidence that final barrier design(s) will meet the performance objectives identified above. Evidence of barrier performance will be obtained by conducting laboratory experiments, field tests, computer modeling, and other studies that establish confidence in the barrier's ability to meet its 1,000-year design life. The stability and performance of natural analogs that have existed thousands of years and the prediction of future climatic conditions based on the reconstruction of past climatic changes will serve to focus experimental designs and increase confidence in the barrier's ability to meet its design life.

The BDP has organized 14 groups of tasks to resolve technical concerns and complete the development and design of permanent isolation barrier and warning marker systems. These task groups are listed below:

1. Project management
2. Biointrusion control
3. Water infiltration control
4. Erosion/deposition control
5. Physical stability testing
6. Human interference control
7. Barrier construction materials procurement
8. Prototype barrier designs and testing
9. Model applications and validation
10. Natural analog studies
11. Long-term climate change effects
12. Interface with regulatory agencies
13. Technology integration and transfer
14. Final design.

This paper focuses on several significant results of tests conducted over the past 7 years in the BDP. It should be noted that over 60 publications have resulted from the BDP's efforts conducted to date. The authors can be contacted for copies of these publications.

4 WATER INFILTRATION CONTROL: RESULTS OF THE FIELD LYSIMETER TEST FACILITY

As mentioned above, protective barriers will be designed and constructed with a fine-soil layer overlying a layer of coarser materials (e.g., silt over sands and/or gravels). The differences in textures between the barrier materials at this interface provide a capillary barrier for percolating water.

In an unsaturated system, the capillary pressures are much less than atmospheric pressure. For significant quantities of water to flow into and through the coarser sublayers, the water pressure must be raised to nearly equal atmospheric pressure. The overlying fine-textured soils must become nearly saturated for the water pressure to approach atmospheric and allow water to flow into the sublayers. This resistance to drainage explains the large storage capacity of the overlying fine-textured soil. Keeping the water in the fine-textured layer provides time for evaporation and transpiration to remove it.

The critical component of the capillary barrier is the fine-soil layer. The fine-soil layer must be able to retain infiltrating precipitation until evaporation and transpiration can recycle the water back to the atmosphere. The results of computer simulations suggested that using a 1.5-m thick layer of suitable fine soils in the design of the barrier would prevent drainage under Hanford Site climatic conditions (Fayer 1987). A large deposit of fine soils that possess suitable moisture retention characteristics has been located on the Hanford Site.

The capillary barrier concept has been tested for over 5 years at the Field Lysimeter Test Facility (FLTF). Results from these tests indicate that the capillary barrier functions as designed. During the first 3 years of testing, twice the annual average precipitation (320 mm/yr) was added to lysimeters simulating a wetter climate. Over the last 2 years, three times the annual average precipitation (480 mm/yr) was added to the same lysimeters. During this entire 5-year testing period, water losses by evaporation and transpiration have exceeded water gains by precipitation and irrigation--even for the lysimeters receiving treatments representative of wetter climatic conditions. (Soil water storage decreased in the lysimeters during the 5-year test period, and no drainage occurred.) Annual water losses by evapotranspiration create a soil storage capacity adequate to accommodate estimated 1,000-year storm events at the Hanford Site. In two of the drainage lysimeters at the FLTF, enough water was added to force water to break through the capillary barrier. As expected, it was determined that water does not pass through the capillary barrier in the liquid phase until the soil approaches saturation and pore pressure becomes positive. Once breached, the capillary barriers in the lysimeters drained only slowly until they reached a stable water content almost twice as high as that normally held by that soil against gravity (Campbell et al. 1990, Campbell and Gee 1990). Vapor flow, an artifact of thermal fluctuations in the lysimeter facility, has caused minor amounts (<0.5 mm/yr) of water condensation in some of the lysimeters. Issues regarding vapor-phase transport past the capillary break are currently being studied. A prototype barrier, planned for construction in late 1993, will enable tests to be performed to determine the effectiveness of the capillary barrier on a much larger scale than that provided by lysimeters.

5 THE EFFECTS OF BURROWING ANIMALS ON WATER INFILTRATION

Tests have been conducted to assess the impact of burrowing animals on the infiltration and percolation of water through protective barriers. Early in the BDP, concerns were raised that the presence of animal burrows may provide preferential conduits through which infiltrating water could bypass the fine-soil layer of the permanent isolation barrier and subsequently migrate deeper into the barrier and possibly into the waste zone below. The results of the tests that have been conducted to date for small mammals are provided below.

An Animal Intrusion Lysimeter Facility (AILF) was constructed in FY 1988 to assess the effects of small-mammal burrows on the infiltration of meteoric water through protective barriers. The following trends have been observed from the tests conducted to date with small mammals at the AILF (Landeen 1991).

- During the summer months, more water is lost from plots with animal burrows than from the control plots (no animal burrows).
- During the winter months, both the plots with animal burrows and the control plots gained water.
- There is no indication of water infiltration below 1 m even though burrow depths always exceed 1.3 m.

The lack of significant water infiltration at depth and the overall water loss in the lysimeter plots is occurring despite the following worst-case conditions:

- No vegetative cover (no water loss through transpiration) existed.
- No water runoff occurred (all incipient precipitation/irrigation is contained).
- The burrow densities in the lysimeters were greater than the burrow densities found in "natural" settings.
- Extreme rainfall events were applied frequently (three 100-year storm events in 3 months).
- Animals burrow deeper in the lysimeters than in "natural" settings.

Three preliminary conclusions have been drawn from the tests conducted to date at the AILF. Overall water loss appears to be enhanced by a combination of (1) soil turnover and subsequent drying, (2) ventilation effects from open burrows, and (3) high ambient temperatures. From the results of the testing performed to date, the presence of small-mammal burrows does not appear to have a significant effect on the deep percolation of water through the barrier.

6 EROSION PROTECTION FEATURES

Throughout the majority of a barrier's design life, vegetation will be growing on its surface. The presence of vegetation on the barrier surface will significantly reduce the amount of fine soil lost from the barrier by wind and water erosion. However, to protect the barrier surface during periods of time when the vegetative cover is disturbed by range fires, drought, disease, or some other phenomenon, surface gravels will be admixed into the surface of the protective barrier--similar to a desert pavement.

Studies conducted in the PNL Aerosol Wind Tunnel Research Facility have shown that field wind erosion stresses and surface conditions can be replicated in the wind tunnel. These studies have provided significant input for the design of the permanent isolation barriers (Ligotke and Klopfer 1990). For example, wind tunnel tests have demonstrated that admixtures and layers of 0.3 to 0.7 cm gravels provided superior surface protection. The best gravel admixtures reduced surface deflation rates by 97% to 98% (compared to unprotected soil). In addition, it was determined that rounded river rock and angular crushed-rock gravel provided equal surface protection--thereby expanding the possibilities of finding adequate source materials for the least cost.

Wind tunnel studies also determined that erosion rates increased five times as the sand content of silt loam fine soil was increased from 40% to 80%. This finding suggests that sandy areas surrounding the prototype barrier need to be stabilized to minimize the possibility that sand will be eroded from surrounding areas and deposited onto the barrier surface.

The amount of gravel used to stabilize the surface of the protective barrier is a critical design consideration from a water infiltration perspective as well. At the Small-Tube Lysimeter Facility (STLF), the water storage and evapotranspiration in a permanent isolation barrier were determined to be significantly affected by the types of materials used on the barrier surface (Relyea et al. 1989). The lysimeters at the STLF were backfilled with materials to test how various erosion control surface treatments affect soil moisture balance. Data collected at the STLF show that when gravel is spread onto a fine-soil surface instead of being tilled into it, plant transpiration and surface evaporation are significantly reduced, thereby increasing the amount of water available for drainage through the barrier. Similar results were observed for lysimeters with a layer of dune sand overlying fine-textured soils. It should also be noted that drainage has occurred only in irrigated gravel- and sand-covered lysimeters. Because of the results stated above, from a water infiltration standpoint, the use of admix gravels rather than gravel mulches is recommended.

7 CONCLUSIONS

The study of surface barriers at the Hanford Site is progressing well. The results of field tests, experiments, and lysimeter studies are providing a defensible foundation upon which barrier designs can be based. Test results show that for the Hanford Site's arid climate, a well-designed capillary barrier limits drainage to imperceptible amounts. A subsurface asphalt layer provides additional redundancy. The data collected under extreme events (excess precipitation) are building confidence in the barrier's ability to meet its performance objectives over the 1,000-year design life. A prototype barrier, planned for construction in late 1993, will add to the understanding of barrier performance.

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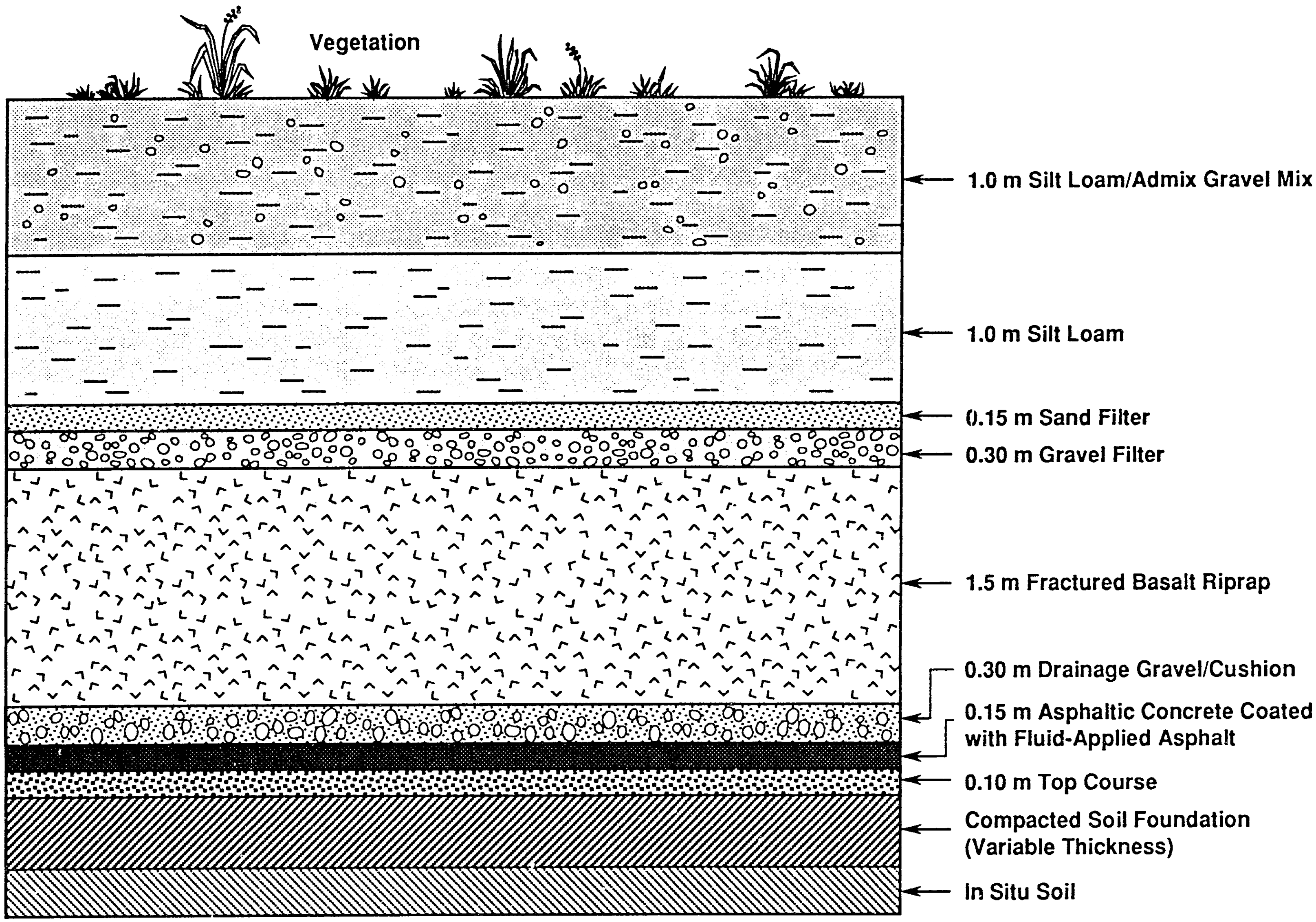
Typical Barrier Cross Section



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