# RESULTS OF WASHINGTON'S PHASE TWO STUDY ON CLOSURE REQUIREMENTS FOR THE HANFORD COMMERCIAL LOW-LEVEL WASTE FACILITY: DESIGN OBJECTIVES AND COVER ALTERNATIVES

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## ABSTRACT

This paper reports on the closure design objectives and cover alternatives resulting from the state of Washington's phase two study on closure and long term care for the Hanford commercial low-level radioactive waste disposal facility. Four approaches to dealing with subsidence and two cover design alternatives are discussed in this paper, along with information on each layer of each cover. Objectives for closure of the Hanford low-level waste facility are also discussed.

Because of the presence of mixed wastes, the closure and long term care program at the facility was designed to meet both Resource Conservation and Recovery Act and Atomic Energy Act requirements.

Key issues include how to design for a 1,000 year analysis period, how to effectively accommodate long term subsidence, how to minimize deep percolation and wind erosion, how to maximize the effectiveness of both hydraulic and capillary barriers and how to address future climatic change.

## INTRODUCTION

The phase two report, Closure and Perpetual Care And Maintenance of the Commercial Low-Level Radioactive Waste Disposal Facility on the Hanford Reservation, presents the findings in response Washington State law (1), which directs the Department of Ecology (the Department) to define site closure and perpetual care and maintenance (PC&M) requirements for the Hanford low-level radioactive waste disposal facility (LLRWDF). The Department's Low-Level Radioactive Waste Management Program has been designated to perform this study.

In the latter months of 1986, the Department began preparing for these studies as mandated by the State Legislature. The extensive nature and the scope of the issues related to the site closure and long term care necessitated that the studies be addressed in two phases. The first phase collected and evaluated critical background data related to the LLRWDF including geohydrology, seismic activity, waste characterization, disposal practices, potential release mechanisms, and developed conceptual closure and perpetual care and maintenance programs for the LLRWDF. The Phase One Report was completed and presented to the Legislature in December 1987 (2).

Based upon study results provided in the Phase One Report, the Department was able to more specifically address closure and PC&M details at a level which would support a realistic assessment of the State's closure and long term care needs. The Phase Two Report addresses these specifics by providing detailed closure and PC&M options and cost projections.

## PHASE TWO ACTIVITIES

During Phase Two, the Department identified nationally acknowledged experts in the field of arid land, low-level radioactive waste burial research to provide formal peer review of the final Phase Two report. The Department then selected one person from each of the following fields: geotechnology, subsidence, hydrology, radioactive transport/chemical interaction, and commercial low-level radioactive waste site work ongoing at another commercial waste disposal facility. These national experts were asked to provide critical peer review of the study, both in terms of reviewing the Phase One work and of providing detailed, written reviews of the draft Phase Two Report.

The Department held three formal monthly progress meetings with the contractor, the site operator (US Ecology, Inc.), and state and federal representatives, including: the Department's Hanford Project; the Washington Department of Social and Health Services, Office of Radiation Protection (DSHS); the Environmental Protection Agency (EPA); the Nuclear Regulatory Commission (NRC); and the Department of Energy (DOE). In addition, regular dialogue via individual and weekly conference telephone calls between the Department and the contractor assured the study's directed progress.

Upon completion of the Draft Phase Two Report in October, 1988, copies were distributed to the five formal peer reviewers, and Departmental experts to obtain a critical, in-house review of the report. Review was also solicited from DSHS, EPA, NRC, DOE and US Ecology, Inc. Over 500 review comments were received and all comments were consolidated and sent to the contractor to be addressed. The entire Phase Two study took six months to complete, with the final report's release in March 1989.

## DESIGN OBJECTIVES

Objectives for closure of the low-level waste facility included the following:

1. to stabilize the waste and close the facility in a manner that minimizes the need for both environmental monitoring and cover maintenance;

2. to construct a cover which minimizes drainage through the waste for 1,000 years;
3. to reduce gamma radiation form buried waste to background at the site boundary; and
4. to prevent run-on from episodic climatic events.

Specific criteria to be incorporated in the cover system included the following:

1. to minimize the migration of contaminated liquid from the trenches for 1,000 years;
2. to establish vegetative and soil conditions that are consistent with criterion 1, above;
3. to minimize maintenance over the time frame given in criterion 1, above;
4. to minimize wind and water erosion of the final cover;
5. to minimize long-term waste settling and cover subsidence;

## INFILTRATION

The most important design objective was to minimize drainage through the waste over a 1,000-year time frame. If this one objective is met, nearly all other objectives can also be met. For instance, both wind erosion and biotic intrusion must be minimized if drainage through the waste is to be kept to a minimum. Similarly, subsidence of the cover must also be minimized in order to minimize drainage through the waste. Subsidence may be the single greatest problem to be faced in the attempt to minimize drainage through the cover over the 1,000 year timeframe.

## SUBSIDENCE

No cover system can be effective if steps are not taken to minimize or accommodate long-term waste settlement or cover subsidence. This is an especially difficult problem in facilities where waste has not been densified prior to or during disposal. Waste at the facility has been both placed in a low density form and stacked much greater than 24 ft. deep in many places at the facility. If one assumes at least 25% voids in the waste, then an eventual 5 ft. of subsidence can be expected, due solely to consolidation of waste solids. If at least one-third of the waste is assumed to be biodegradable organic materials, another 5 ft. of subsidence should be added to the total for eventual subsidence, giving a total subsidence of 10 ft. Anywhere near this amount of subsidence would result in complete failure of a multiple layer cover system.

Arid conditions at the site assure that both biodegradation of organic materials and consolidation of the waste may take place over as much as several hundred years. This makes the real difficulty in the situation clear; subsidence will likely continue beyond the end of institutional control.

Four solutions to the above subsidence problem have been evaluated in this paper. Each solution and both the advantages and disadvantages of each are discussed below.

### Excavation and Proper Redisposal

In hindsight, it can be seen that it was a mistake to dispose the waste in a low density form. This one management approach has made subsidence a problem for any designs that must minimize infiltration. If it is easiest to dispose of the material properly in the first instance, many would suggest that the next easiest solution would be to do it right the second time. This would involve excavating all the waste, destroying the organic materials through biodegradation or incineration, compacting the residual inorganic materials to 95% of modified Proctor density, and redisposal of this dense material.

While the above solution may be the most effective way to minimize long-term cover subsidence, it also has serious disadvantages. There can be little doubt that many of the waste containers are already partially degraded or crushed. This would have released radioactive materials into the immediate vicinity of the broken containers. This situation would greatly complicate any attempt to safely excavate the material while also substantially increasing the volume of material to be handled.

Other disadvantages to this solution of the low density waste problem would be the potential for air release of radioactivity during excavation, treatment, compaction and redisposal of the waste. This solution may actually result in greater releases of radioactivity than no action. Very intensive safety procedures and equipment would be needed to safely implement this solution. Considering also the scale and sophistication of the treatment operation, this solution could easily cost several hundred million dollars and would still require a cover system. While this expense is comparable to that encountered with some of the largest Superfund sites, it was not recommended on the grounds of the very high cost and the potential for both air releases and direct exposure of cleanup personnel.

### Dynamic Compaction and Grouting

One solution which would densify the waste while minimizing air releases, worker exposure and cost, would be dynamic compaction. This would involve a very large weight repeatedly dropped from a substantial height until there is no further consolidation of the waste. This type of operation has been considered elsewhere on the Hanford Reservation, West Valley, Maxey Flats, and has actually been implemented at the Savannah River Facility.

Disadvantages of this solution are, however, substantial. There are regulatory issues which would have to be resolved since this solution *would likely result* in the breaking open and crushing of underlying containers. However, one could argue that most of these containers do not represent secure long-term containment of the waste. In fact, where excavation of landfills has been necessary, barrels excavated were found to be either thoroughly corroded after only a few years or crushed as the result of overburden pressure. In addition, a significant portion of the waste was disposed in cardboard boxes and wooden crates. Consequently, the argument that the existing containers at the site provide containment would only be partially true even in the short-term.

Effective containment of the waste will result not from the containers but from an effective cover system. If subsidence is not prevented, the cover will fail. If the waste is not compacted, subsidence due to waste consolidation will occur. Consequently, if the waste is not densified or some other solution is not found to resist the forces of subsidence, the cover will fail. The ultimate solution is to require all future waste to be in such a form that subsidence would not occur.

It should be noted that there are two major causes for waste settlement, consolidation of solids and degradation of organic materials. Dynamic compaction would only be effective at reducing consolidation of solids. If biodegradation of organic materials proceeds, then subsidence of the cover would still occur. This could be significantly slowed, however, by keeping the waste dry. The best way to keep the waste dry would be to maintain effectiveness of the cover.

One action which could minimize the amount of subsidence due to biodegradation would be grouting of the waste. By deep injecting with a cementing material, the waste could be given sufficient strength to minimize future settling. Combining this type of in-situ stabilization with dynamic compaction may be the best long-term solution to subsidence.

**Arch Rib One-Way Slab (AROWS) Concrete Cover**

Another approach to accommodate long-term waste settlement is to construct a structure over the waste trenches. The structure would have to have sufficient strength to resist subsidence due to both settlement of the underlying waste and the overburden pressure of the overlying cover. In addition, the structure would have to have sufficient durability to provide long term support for the cover.

One structure which may be able to provide the required support would be an "Arch Rib One-Way Slab" concrete cover. All calculations and figures developed are preliminary and conceptual in nature. A more thorough design would include other concrete covering options such as vaults, domes, trusses and hyperbolic parabolas, along with different spacings and configurations for arch rib one-way slabs (AROWS).

Trench 13 was used to develop the example design of an AROWS 160 ft. wide and 880 ft. long. Arch ribs, spanning 160 ft., are 1.5 ft. to 2 ft. wide and 5 ft. deep. The rise for the ribs would be 10 ft. Ribs would be reinforced both conventionally for bending and temperature stresses, but would also be post-tensioned/pre-stressed to minimize tension stresses and cracking. The slab would be 8 to 20 inches thick. Forty-four slabs 20 ft. wide and 160 ft. long would be required for Trench 13.

Surface drainage would be accomplished by sloping the structure in both directions and draining between individual concrete trench covers with concrete troughs.

The foundation design would depend on site soil analysis. This preliminary design was based on sand with an allowable bearing pressure of 9 kg/sq. ft. and square dug footings or drilled friction shafts. Sand is normally a good bearing material if moisture content and containment are controlled. The depth at which this would be possible depends on site conditions. A 12 ft. depth would only be adequate if settlement of the waste does not result in lateral movement of sand from the areas between the trenches. If lateral movement of sand does occur, then the foundation would need to extend beneath the lowest waste elevation. In this case, costs would be significantly higher.

A 75 lb./sq. ft. superimposed load was used for this AROWS. This would allow for only 1 ft. of cover soil. If a multilayer cover system was deemed necessary to go over the AROWS, the cost would rise according to the thickness of the cover system. If construction personnel need protection from radiation, the costs would also increase.

While the AROWS does appear to deal satisfactorily with the problem of subsidence, there is a large amount of uncertainty as to the longevity of the AROWS structure.

**Periodic Replacement Of The Cover**

Another solution to dealing with subsidence would be to simply rebuild the cover periodically. How long between rebuilding and the total number of rebuilds would be very hard to define in the absence of information on the rate and total expected amount of subsidence. If it were assumed that the cover was to be rebuilt, then the requirements for a cover that would last 1,000 years could be relaxed. At the same time, however, the dollars set aside for long-term maintenance would necessarily be greatly increased.

As with the other solutions to the subsidence issue, the assumptions incorporated in this solution outnumber the hard facts. With this in mind, the solution that involves periodically readdressing the problem would have inherent advantages and reduced technical risks. By planning to rebuild the cover in 50 or 100 years, advantage could be taken of new developments in materials and cover designs.

There are several disadvantages to the periodic replacement scenario. For instance institutional control may end much sooner than predicted, leaving only a temporary cover over the facility. Subsidence may be so slow as to place much of it beyond the end of institutional control.

Uncertainty about the way or time in which institutional control will end is a strong argument to develop a permanent solution as soon as possible following closure. The fact that so many areas of uncertainty remain about how to construct a permanent cover is a strong argument for greatly accelerated research now to develop the information needed to build the permanent cover.

## COVER DESIGN ALTERNATIVES

Two cover design alternatives are discussed in this section. Cover design alternatives examined include that proposed by US Ecology, Inc. and the recommended multiple layer design. As noted earlier the designs were evaluated for their ability to minimize deep percolation, biointrusion and long-term maintenance. In addition, the multilayer cover design was required to meet all applicable NRC and RCRA regulations and guidance.

### Design Presented By US Ecology, Inc.

US Ecology, Inc. has proposed a design consisting of 10 feet of sand over a 6 inch layer of gravel. The gravel is designed to be a barrier to wind erosion while the thickness of the sand layer should reduce but not prevent biointrusion into the waste.

The cover lacks any hydraulic or capillary barrier which would divert the deep percolation of water. The presumption is that the recharge rate would be so minimal (0.2 inches per year) that the travel time to the aquifer would be sufficiently long (1420 years) so that there would be no danger of contaminating the groundwater (3).

Deep percolation rates in the Hanford area in recent years have been reported as high as 2.4 inches per year (1). If one assumes that the relationship between deep percolation and transit time to groundwater is roughly linear, then the values postulated by Bergeron et al., (3) can be used to estimate different transit times. For instance the 2.4 inches per year value on the Hanford site would be 12 times that of the 0.2 inches per year estimate by Bergeron et al. (3). Dividing the 1,420 year transit time by 12 yields a transit time estimate of 118 years for a deep percolation rate of 2.4 inches per year. It is responsible to presume that climatic changes are possible over the long post-closure period. If a long-term trend develops toward a moderately wetter climate, then the transit time may be significantly less than the 118 years.

Since the assumption of a minimal percolation rate drives this proposed cover design, its long-term performance is dependent upon such. Therefore if infiltration rates in excess of the minimum occur as they have in recent years, leachate will reach groundwater before 1,420 years. Designing a cover system for very low percolation rates ignores the potential for climatic changes over the long term.

The US Ecology, Inc. design does address wind erosion. The design does not, however, provide for minimization of deep percolation during either the relatively wet conditions optimal for performance of a hydraulic barrier or the relatively dry conditions optimal for performance of a capillary barrier.

### Multiple Layer Design

A multiple layer cover design has been developed and recommended for closure at the LLRWDF which would meet all RCRA and NRC requirements. The design has been developed to provide both a long service life and the operational flexibility to minimize deep percolation under both relatively dry and relatively wet climatic periods. In addition, the design will minimize erosion, biointrusion and long-term maintenance. Any multiple layer cover system is susceptible to performance degradation as a result of subsidence. Consequently, specific stabilization actions, such as those previously discussed should be undertaken in association with this cover design to minimize subsidence.

Each layer in a multiple layer cover design should serve specific functions, meet designated performance standards and be subjected to construction quality assurance procedures which verify that the performance standards are met. In addition, each layer in the cover should be compatible with the adjacent layers and support the overall objectives set out for the cover system. Discussions in the following pages include cover component integration and descriptions of all layers in the multiple layer cover system.

Any cover designed for the site should be developed with careful consideration of the context within which it must function. Two of the most important contextual aspects for this cover are the long lifespan and the range of potential climatic conditions. Consideration of the long half-life for many of the radionuclides disposed at the site suggests that the cover should be designed to function for 1,000 years. Such a long timeframe emphasizes the need to design the cover for a range of climatic conditions.

There are two barrier systems which have been shown to reduce deep percolation (4). Each of the barrier systems has an optimal efficiency at different water flow rates. At relatively high flow rates the optimal system is a hydraulic barrier composed of a high permeability lateral drainage layer over layers of low permeability material. At relatively low rates, the optimal system is a capillary barrier composed of a medium permeability layer, such as a loam, over a high permeability layer, such as a coarse sand or gravel.

A cover design that incorporates both a capillary barrier and a hydraulic barrier should have the ability to minimize deep percolation over the range of possible water flow rates at the site. Schulz et al., (4) noted that placing the hydraulic barrier over a capillary barrier would result in a very effective barrier system. This combination would be even more effective for this site, however, if the hydraulic barrier is placed under the capillary barrier. This is because of the need to protect the compacted soil component of the hydraulic barrier from both shrinkage cracks and biotic intrusion. When compacted soil is placed near the surface in a cover system it is susceptible

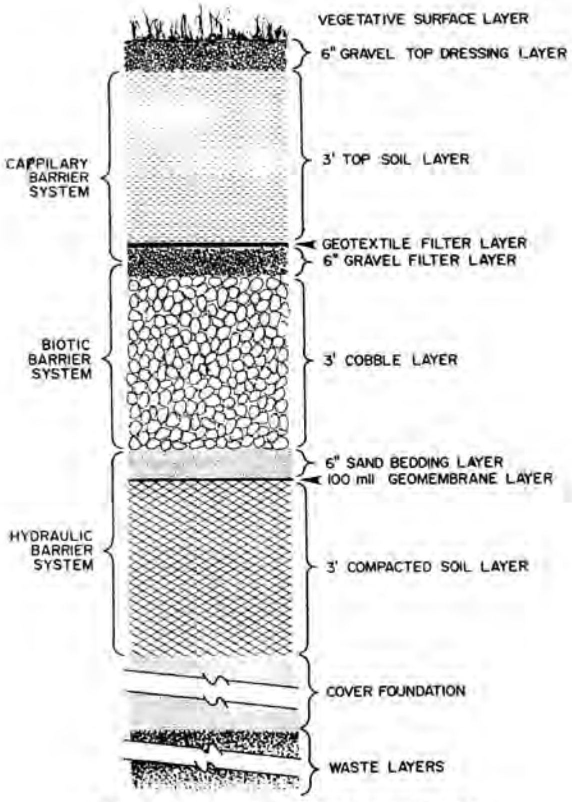


Fig. 1. Multiple Layer Cover Design.

to shrinkage cracking due to water loss from both evaporation and extraction by plant roots. In addition, near surface hydraulic barriers can be damaged by burrowing animals and holes left by penetrating plant roots. If a biotic barrier system is placed over the hydraulic barrier biotic intrusion can be prevented. By placing the capillary barrier overthe biotic barrier, additional distance is placed between the hydraulic barrier and the disruptive near-surface factors discussed above. The biotic barrier also serves as both an excellent lower component to the capillary barrier system and an efficient lateral drainage component to the hydraulic barrier system.

An illustration of the integrated hydraulic, biotic and capillary barrier systems is given in Figure 1. Equally as important as the thoughtful integration of the cover systems is the quality control activities which should be implemented during construction of the cover.

## SUMMARY

This paper provides technical and regulatory analyses and discussion of two site-specific cover design options. The first analysis evaluates the 1988 closure plan submitted to Washington State by US Ecology, Inc. The second cover design option evaluated on technical and regulatory merits was the multi-layer design. The multilayer option was designed to meet all applicable federal (NRC and EPA) and state regulations, and to ensure environmental safety and public health. Of the two closure options evaluated, the multi-layer trench cover was recommended. Recommendations were also made for further research and on-site test plots to address the numerous uncertainties associated with site conditions, such as the potential for subsidence and climatic change.

## CONCLUSIONS

The Department has not selected a time period to close the LLRWDF. Based upon site capacity and projected future waste volumes alone, site closure could be many decades away. On the other hand, should a situation arise requiring the site to close in the not so distant future, closure and long term care needs have been analyzed to some extent via the Phase One and Phase Two studies. However, there remain many unresolved questions and technical uncertainties in terms of planning for the future closure of the site. These include: The extent and nature of subsidence, probable climatic changes, nature of the buried wastes, potential for releases to the environment, wind erosion, and the costs associated with responding to these factors. To address these uncertainties, the Department and site operator are jointly evaluating the technical and fiscal implications of closure and long term care needs.

Due to requirements within the sublease agreement between the Department and US Ecology, Inc., a joint technical study (JTS) is currently in progress to reevaluate the site conditions as they relate to the adequacy of the fees for closure and long term care. The JTS is being conducted to evaluate the adequacy of the fees used to fund the LLRWDF's Closure and PC&M accounts, maintained by the State Treasurer. With the completion of the JTS, the Department will determine whether or not the current fee structure is sufficient to cover the necessary expense of protecting the environmental safety and public health in relation to closure and long term care of the LLRWDF.

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