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Appendices A-F

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Plastic membranes tend to degrade in sunlight, so they would require a protective soil cover if used as a trench cover. More importantly, some question exists as to the long-term resistance to degradation at a disposal facility. In any case, special care would have to be taken during installation of a membrane as a trench cover to prevent tears or holes from occurring during installation.

Finally, concrete could be used as a trench cover material. Concrete is brittle, however, and would tend to crack over time--particularly under settling conditions. The effectiveness of a concrete trench cover by itself as a moisture barrier would be problematical. If properly supported, however, concrete could be effective as a moisture barrier, in addition to a barrier to plants, animals, and human intruders. An example of added support could be the use of grouting to fill the interstitial spaces between (stacked) waste packages.

2.3.2.1.2 Final Covers

After a cover (cap) has been placed over a disposal trench, it is important that the cap be stabilized by a final cover (Refs. 24 and 25). A lack of such a final cover leads to uncontrolled water and wind erosion of the trench caps. Two types of final covers are in general use today: natural vegetation (e.g., grass), and a hard surface cover such as cobbles or rip-rap.

A natural vegetation cover at a disposal facility can serve several functions, such as physically stabilizing earth materials, reducing erosion and infiltration of precipitation infiltration into the disposed waste, and enhancing the appearance of a site. A thick grass cover, for example, breaks the impact of falling water droplets on the earth surface, and reduces the run-off rate from the site, thereby reducing the potential for water erosion. By the same token, the plant roots help to hold the soil in place, thereby minimizing wind erosion. Reducing the rate of run-off, of course, also has the effect of increasing the amount of water infiltrating into the trench caps. However, some of the precipitating water will be caught upon leaves and other plant surfaces and will tend to evaporate rather than infiltrate into the soil. In addition, some of the water infiltrating into the trench caps will evaporate out of the soil surface. Water absorbed into plant roots may also be transpired through the plant leaves.

These processes of evaporation and transpiration--termed evapotranspiration--can result in a substantial amount of water being removed from soils. Evapotranspiration is enhanced by vegetation with dense root systems and a dense soil cover. It is important, however, that the root systems of cover grasses be of shallow depth to preclude contact with and uptake of radionuclides from the disposed waste. Examples of vegetation having shallow but dense root systems include hay, meadow grasses, and rye. Vegetation species native to the general area of the disposal site are preferable, as these species are more likely to be acclimated to the site climate.

Care needs to be taken when preparing the site for the final covering of vegetation--e.g., grading, spreading fertilizer, and mulching. If top soil removed from initial excavations is stock-piled, then this can be replaced on the completed trench cover to help promote plant growth. It has been observed that in the past at some facilities, miscellaneous fill has been used to repair cracks and sinkholes caused from trench subsidence. The fill is often devoid of essential plant nutrients. Growth of a soil cover is naturally retarded in these spots, leaving bare spots which can persist for some time. This can result in areas showing localized signs of erosion, or result in areas having concentrated point sources of infiltration.

Soil fertility is also desired in that it helps to promote evapotranspiration. First, fertile soil produces a lusher plant growth for a given crop. Second, fertile soil leads to healthier plants, which photosynthesize more rapidly and increase the water demand on the soil system.

While not as aesthetic as a vegetation cover, a layer of rip-rap or cobbles can also be effective as a final soil cover. This technique is particularly useful in arid climates, where it is more difficult to establish a vegetative cover. Such a hardened layer, in addition to preventing wind erosion, is also effective in eliminating intrusion by burrowing animals.

2.3.2.1.3 Example Alternative Trench Cover Designs

There are three principal design options which are discussed below to provide added assurance aginst infiltration of water into disposal trenches. These options are: (1) use of more densely compacted trench caps, (2) use of thicker compacted trench caps composed of low permeable clay soil, and (3) use of additional moisture barriers within a thicker trench cap. These options were selected based upon the above review of potential alternatives and improved trench covers. A number of other alternative designs could be envisioned. However, these are adequate for the purposes of this environmental impact statement.

<u>Compaction</u>

Improvements in trench cap performance can be obtained through increased attention to waste and cover compaction. Until fairly recently, little attention has been paid to compaction of disposed wastes other than the compaction that can be achieved by application of several feet of trench cover, plus driving over trench covers with waste transport and other site vehicles. This is the case assumed at the reference disposal facility. Decreased infiltration and percolation through a trench cover (by reducing porosity and thus permeability) can be inexpensively achieved, however, through use of improved compaction techniques using commercially available compacting equipment such as vibratory compactors. Within the last few years, for example, the operators of a disposal facility located in a humid environment have employed a mechanical vibratory compactor to provide additional compression of disposed waste and compaction of filled trench caps. The disposal site operators have reported that use of the vibratory compactor has greatly reduced subsequent maintenance of filled and capped trenches (Ref. 31).

Soil compaction is a standard construction technique and for a particular type of soil, a particular relationship can be developed which relates the moisture content of the soil to the amount of compaction (the dry density of the soil). These relationships can be determined and graphed using laboratory techniques. For a particular soil, an optimum moisture content can be determined which results in maximum compaction (greatest dry density). In standard construction practice, specifications for compaction require the soil to be compacted near the optimum moisture content and to a dry density specified as a percent of the standard determined in the laboratory--e.g., 90% of the standard (ASTM 1557) laboratory maximum density.

In practice, a variety of equipment types may be potentially used depending upon the type of soil. Some of these are listed in Reference 32 and include sheepsfoot rollers, rubbertire rollers, smoothwheel rollers, vibrating baseplate compactors, and crawler tractors (D8 or greater size). Soil to be compacted would be applied in 6- to 12-inch lifts and several passes made to compact each lift to the desired density. The depth of compaction available using such equipment is on the order of zero to six feet (Ref. 32).

For an example calculation of differential costs, the reference disposal facility operators are assumed to lease a vibratory compactor and employ an additional heavy equipment operator to operate the compactor. The compactor would be originally used to compact the 1 m of earthern fill down to the approximate level of the original site grade. Then, the 1 m soil cap would be applied in reasonably uniform 20 to 31 cm (8-12 in) layers and compacted to a minimum 95% of the maximum compactible density test.

Unit differential costs for this option are calculated (see Table F.15) to be about $\$1.90/m^3$ ($\$0.05/ft^3$). The resulting benefit is expected to be a decrease in trench subsidence and maintenance requirements. However, as stated above, the depth of compaction only extends for a few feet below the surface. Therefore, the potential long-term trench cap subsidence would be reduced but would not be eliminated.

Thicker Clay Cap

Another option would be to utilize low-permeability soil materials (clay) for the cap. For example, an additional 2 meters of high-grade clay soil would cost an additional $\$8.40/m^3$ ($\$0.24/ft^3$), assuming that the additional clay soil would be imported at a cost of $\$3.50/yard^3$ from a borrow pit located approximately 10 miles from the disposal facility (see Table F.16). The additional 2 m soil thicknesses would be applied in 8-12 in layers and compacted using mechanical compaction techniques. A three meter thick compacted clay cap would cost an approximate additional $\$10.90/m^3$ ($\$0.31/ft^3$). After installation and compaction, the cap would be covered with overburden and graded prior to seeding.

Moisture Barriers

Other methods may be potentially used to reduce percolation through trench caps. These include, for example, installation of single or multiple "moisture barriers" within a thicker trench cap. In this section, unit differential costs for four moisture barrier cases are briefly examined. The cases examined are shown in Figure F.5. For moisture barrier Case A, a single natural material barrier

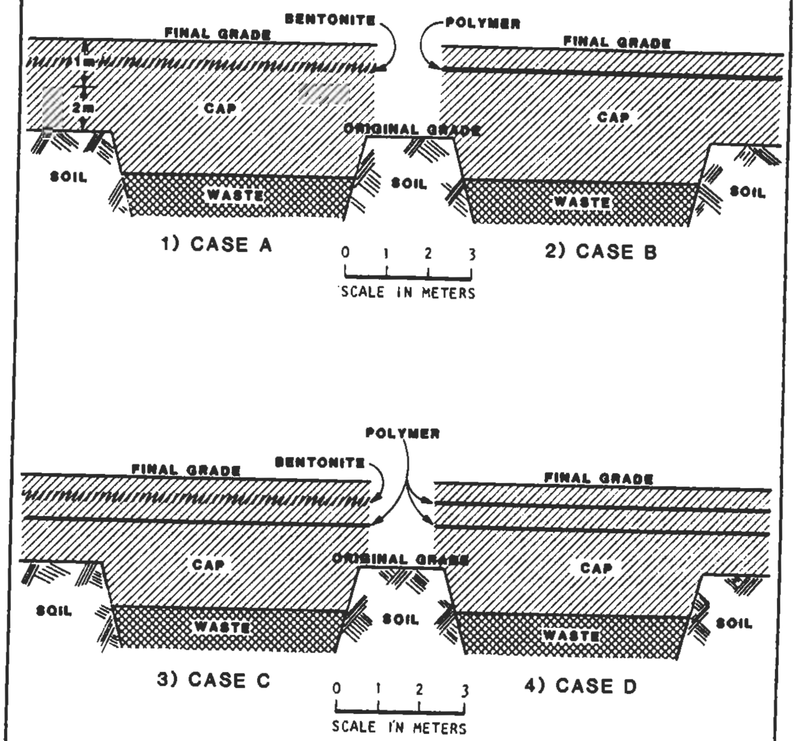

Figure F.5 Moisture Barriers

be needed to offset the lowered efficiency per unit volume expected in this type of emplacement, and additional handling equipment would be required. Increased unit costs are shown in Table F.23, and are estimated to run in the range of \$93.50 per cubic meter of waste disposed in a decontainerized manner (\$2.65/ft^3) or higher.

Radiation worker exposures would be expected to rise proportionately to the increase in work force. As discussed above, the potential for additional accidental exposures would also be expected to be greater than for the reference case.

2.3.3.4 Compaction to Greater Depths

Section 2.3.2.1.3 discussed use of standard construction techniques using heavy machinery (vibratory compactors, sheepsfoot rollers, etc.) to compact backfill into disposal trenches followed by compaction of the disposal trench cap. This compaction is expected to help compress disposed wastes and reduce voids, thus reducing settlement and subsidence problems, infiltration of water, and potential migration of radionuclides. Maintenance requirements would also be reduced. The depth of compaction achieved by these standard construction techniques is only a few feet, however. Thus, shallow compaction would not be expected to completely eliminate potential subsidence as long as a significant amount of compressible waste is disposed in the disposal trench.

Additional construction techniques, which have never been used at LLW disposal facilities but which could be considered as expensive means to achieve very deep compaction (e.g., down to the bottom of a disposal trench), include pile driving and dynamic consolidation. Both methods have been considered for potential application at the Sheffield, Illinois disposal facility (Ref. 33).

Pile driving as a means to densify deep soil deposits--particularly loose cohesionless soils--has been practiced for several years. In this technique, wood piles would be driven in a close grid pattern through the disposal trench cap and into the disposed waste. Compaction would be achieved through displacement of the soil/waste mixture by the piles as well as by vibrations generated through driving the pile. After driving, the piles could be potentially removed and holes filled with low compressive material such as cement or backfill. The piles could then be reused in another location. A problem with this would be that the piles would become contaminated as a result of contact with the waste materials. This contamination would then be available for transfer to workers or equipment or become dispersed into the air, thus becoming an occupational as well as an offsite radiation hazard. The removed piles would eventually have to be disposed as radioactive waste. As an alternative, the driven piles could be cut off at ground level and covered with a compacted cap. This would result in significantly increased expenses, however.

Dynamic consolidation (or dynamic compaction) is a relatively new (25 years) construction technique which, while not previously used at radioactive waste disposal facilities, has been used to reduce settlement problems at landfills. The technique has been developed by Menard (Refs. 37, 38) and has principally been used in Europe. In practice, a large (5-40 ton) weight is dropped from a

significant height (e.g., 20-100 ft) several times over a limited area. For an area such as a disposal trench, an optimum weight and drop height would first be determined. Then, a crane would drop the weight a number of times at several locations in a pattern across the trench cover surface. Depressions left by the weight would be filled in and additional passes over the trench surface may be made as desired and depending upon site-specific conditions.

The impact of the dropped weight is believed to cause partial liquefaction of granular and nonsaturated soil, which allows the soil mass to settle into a denser state. For saturated cohesive soils, it has been hypothesized that the shock waves and high stresses caused by repeated high energy impacts result in gradual liquefaction and consolidation of the soil. The method is reported to be effective to depths of 15 m (50 ft) and can achieve surface settlements of 5 to 15% of the deposit thickness (Ref. 33).

Other than the expense, the principal drawback to this compaction technique is the potential for expulsion of contaminated soil and waste. Depending upon the characteristics of the soil, the weight employed, and the drop height, depressions having depths of up to several feet may be produced. Care would have to be taken so that the dropped mass did not penetrate the cover material to the point that the waste is contacted and/or expelled into the air. As in the case of the piles, this would cause a contamination problem for personnel and equipment, not to mention an airborne hazard both onsite and offsite.

One way to reduce the potential for airborne spread of contamination would be to restrict the mass of the weight and the dropping height. However, this would also diminish the effectiveness of the compaction technique in that the depth of compaction would be reduced.

In any case, an example economic calculation is performed in Table F.24 for dynamic compaction of the 58 disposal trenches. As shown in Table F.24, this is estimated to result in an additional \$18.61/m^2 (\$0.51/ft^3).

2.3.3.5 Engineered Supports for Disposal Trench Covers

As discussed in the previous sections, waste stacking, waste segregation, and deep compaction all appear to offer improvements in the ability to reduce voids and to control (and possibly eliminate) subsidence. Decontainerized disposal could also be used to help reduce trench subsidence, and would be useful for such wastes as low activity bulk solids, contaminated building rubble, or occasional large pieces of machinery, provided that disposal of such wastes was carried out in an operationally safe manner. However, decontainerized disposal currently appears to be a nonviable option for general extension to all wastes.

This section discusses optional disposal methods involving construction of engineering supports for trench caps. The types of engineering supports addressed include caisson disposal, walled trench disposal, and grouting and controlled density fill. These disposal concepts were previously introduced in Section 2.2 regarding their potential use as barriers to the potential inadvertent intruder.