CONTROL OF WATER INFILTRATION INTO NEAR SURFACE LLW DISPOSAL UNITS

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ABSTRACT

NRC is investigating means for controlling deepwater percolation through LLW disposal unit covers. The covers fall into two groups--surface and subsurface. Bioengineering management is an example of the former. It promises to be particularly effective at poorly drained sites or those subject to subsidence. The terms resistive layer barrier and conductive layer barrier refer to subsurface structures. The resistive layer barrier depends on compaction of permeable porous material to achieve low flow rates. The conductive layer barrier is a special case of the capillary barrier and it requires: 1) a conductive layer to conduct water and 2) a capillary break to keep water from waste. Because the resistive layer barrier is most efficient at high flow rates and the conductive layer barrier at low flow rates an effective barrier system could be constructed by placing a resistive layer barrier over a conductive layer barrier. A note of caution: such a system must fail if there is appreciable subsidence.

INTRODUCTION

The principal pathway for water entry into LLW disposal units in the humid eastern United States is through their covers. Most of that water is derived from precipitation. On a long term basis, precipitation has three possible fates: (1) some water will be returned to the atmosphere by evaporation and plant transpiration; (2) some water may run-off laterally; and (3) some may percolate below the root zone of the vegetation. Since deep percolation is undesirable in a waste isolation system, it is required that the sum of run-off plus evapotranspiration approach or equal precipitation. It should be noted that the run-off can be surface or sub-surface so long as the lateral transport occurs before the water can contact the waste.

If deep percolation is to be close to zero, then only two parameters are left for possible control, evapotranspiration and run-off. Evapotranspiration, however, has a very definite maximum. The energy available for evapotranspiration is incident solar radiation and is not subject to control. Thus only *run-off* is subject to unlimited management.

Two types of sub-surface features that may be constructed to enhance run-off are: (1) the "resistive layer" barrier, and (2) the "conductive layer" barrier. The theoretical basis for these barriers is described in Schulz et al., (1). The "resistive layer" barrier is the well known compacted soil or compacted clay layer (Fig. 1) and it depends on compaction of permeable porous material to obtain low flow rates. The "conductive layer" barrier (Fig. 2) is a special case of the capillary barrier. Use is made of the capillary barrier phenomenon not only to increase the moisture content above an interface but to divert water away from the waste. During such diversion the water is at all times at negative capillary potential or under tension in the "flow layer". The use of the capillary barrier concept is perhaps most readily apparent upon consideration of Richards' "outflow law" (2) which explains the existence of dry caves present in porous materials and also why gopher holes do not fill up during a rainstorm. This is because, that as long as the soil moisture has a path to follow so that water pressure remains negative (less than atmospheric) no water will enter the cavity. That is, outflow from a soil to a cavity or rock layer occurs if the pressure in the soil water exceeds atmospheric. A conductive layer barrier has a theoretical efficiency approaching 100%. But on both a theoretical and practical basis, such a barrier can work only under relatively low water flows. On the other hand, the resistive layer barrier works most efficiently at higher precipitation rates. Based on these two considerations, a very effective barrier system might be constructed by placing a "resistive layer" barrier over a "conductive layer" barrier (Fig. 3). A note of caution: such a system must fail if appreciable subsidence takes place.

An alternate procedure, called "bioengineering management"(Fig. 4), utilizes engineered features at the surface (as opposed to the subsurface) to ensure adequate run-off. It is described in detail in Schulz et al. (3). This procedure is applicable to shallow land burial as well as above ground disposal (e.g. Tumulus). In essence, the technique combines engineered or positive control of run-off, along with a vegetative cover, and is named "bioengineering management". To investigate control of infiltration, lysimeters are being used to make complete water balance

RESISTIVE LAYER BARRIER

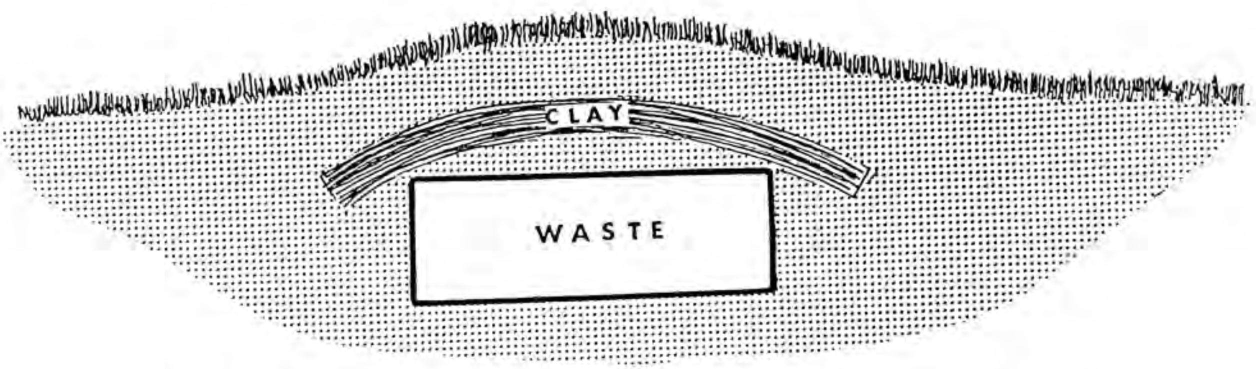

Fig. 1. Resistive Layer Barrier. Although Shown Here as Being Below Grade Such a Barrier Could be Constructed Above Grade as Well.

CONDUCTIVE LAYER BARRIER

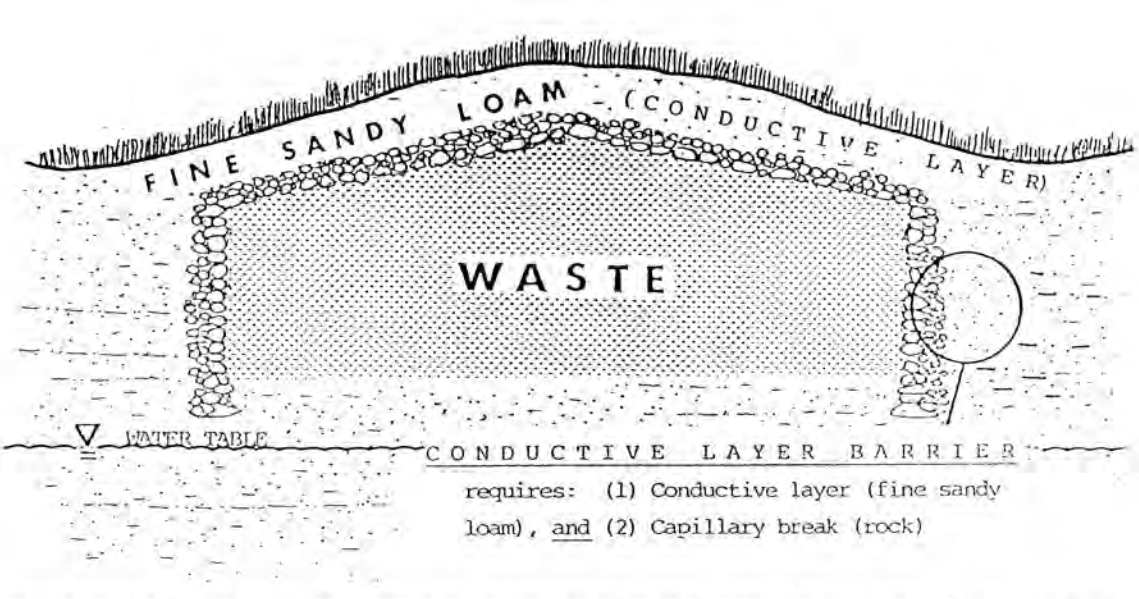

Fig. 2. Conductive Layer Barrier. For a Well Drained Soil, the Soil Itself Will Act as a Conductor. As Long as the Soil is Unsaturated Water Will Not Enter a Drain (Large Voids in the Rock Layer). This System Will Work Best When There are Slow Percolation Rates. Water Drains (Not Shown) Which Should be Located Below the Waste. If Percolation Rates are High, a Resistive Layer Barrier Should be Placed Above the Conductive Layer Barrier as Shown.

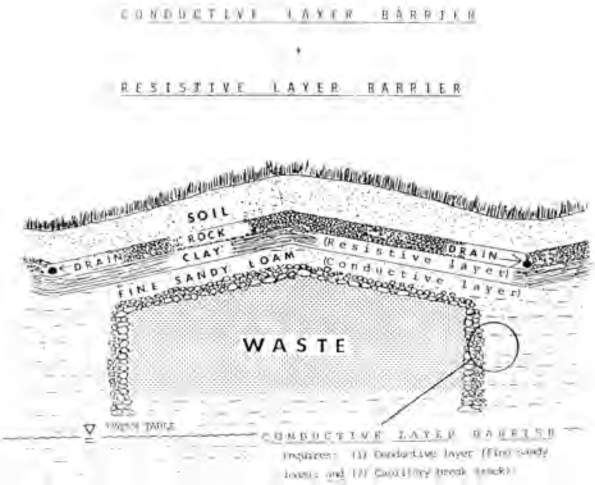

Fig. 3. Conductive Layer Barrier Used in Conjunction With a Resistive Layer Barrier. The Resistive Layer Barrier Functions Best With High Percolation Rates. It's Purpose Here is to Reduce the Amount of Water That Reaches the Conductive Layer Barrier. As Noted in Fig. 2, the Conductive Layer Barrier Functions Most Efficiently With Slow Percolation Rates. As Long as the Conductive Layer Remains Unsaturated Water Will Not Enter the Voids in the Rock Layer. Under Unsaturated Conditions Water Will be Conducted Around the Rock Layer to the Water Table or to Drains (Not Shown) Which Should be Located Below the Waste.

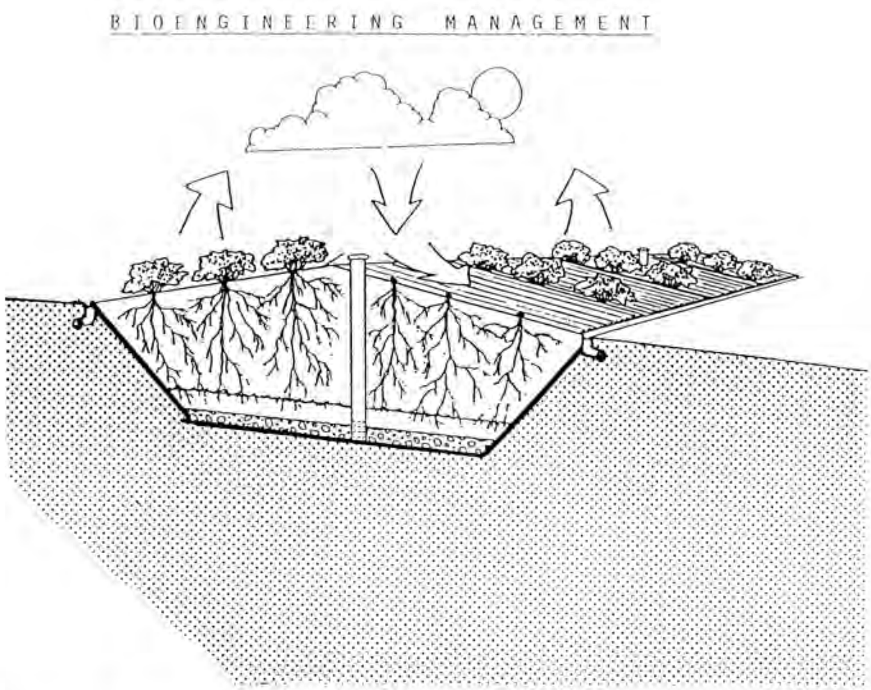

Fig. 4. Bioengineering Management. Shown Above is a Schematic View of the Large Scale Lysimeters (14 m x 21 m x 4 m) Constructed at Beltsville, Maryland. The Lysimeters Give Complete Water Balance Measurements. Ninety Percent of their Surface is Covered With Impermeable Panels to Enhance Run-Off. Pfizer Juniper, a Woody Plant Tolerant of Both Wet and Very Dry Soil Conditions is Planted in Openings Between the Panels. The Juniper is in a Stressed, That is, Overdraft Condition. It Actively Seeks the Small Amount of Water That Passes Through the Panel Openings and Removes it From the Lysimeters by Evapotranspiration.

measurements. The studies have been underway at the Maxey Flats, Kentucky Low Level Waste Disposal Facility for the past three seasonal years. When the original Maxey Flats site closure procedure is followed, it is necessary to pump large amounts of water out of the lysimeters to prevent the water table from rising closer than 2 meters from the surface. When the bioengineering management procedure is used, no pumping is required (Fig. 5). As a result of the encouraging initial findings in the rather small-scale lysimeters at Maxey Flats, a large scale facility for demonstration of the bioengineering management technique has been constructed at Beltsville, Maryland. This facility is now operational with the demonstration and data collection underway.

REFERENCES

1. ROBERT K. SCHULZ, ROBERT W. RIDKY, and EDWARD O'DONNELL, "Control of Water *Infiltration* into Near Surface LLW Disposal Units A Discussion", NUREG/CR 4918, Vol. 2, (1988).

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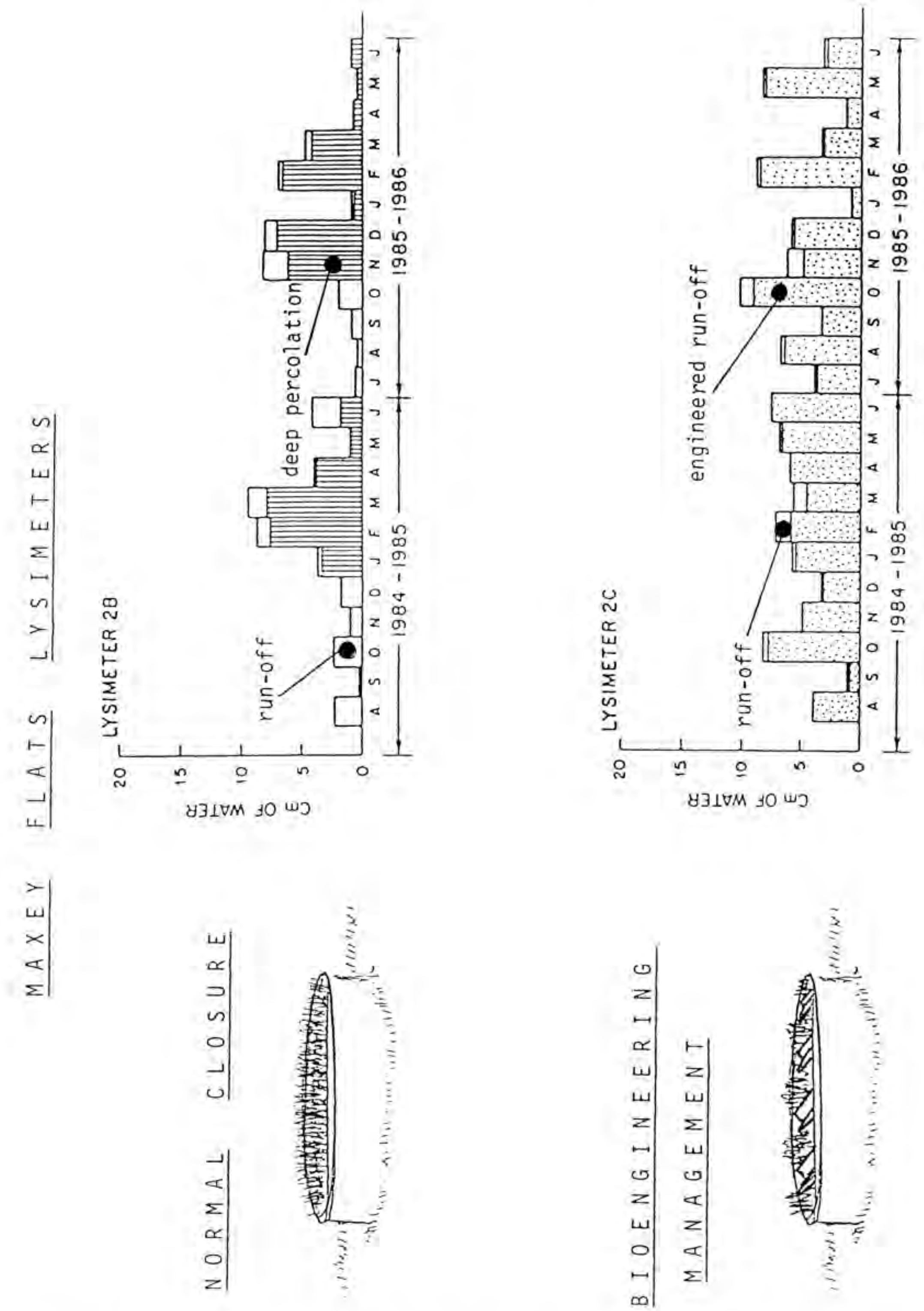

Fig. 5. Results of Lysimeter Experiments at Maxey Flats (Ref. 3). Both Lysimeters Were Planted With Kentucky Fescue Grass. No Pumping was Required at any Time During the 2 Year Period in the Case of Bioengineering Management, but Substantial Pumping was Required to Prevent the Water Table from Rising Higher than -2 Meters in the "Normal Closure" Lysimeter.