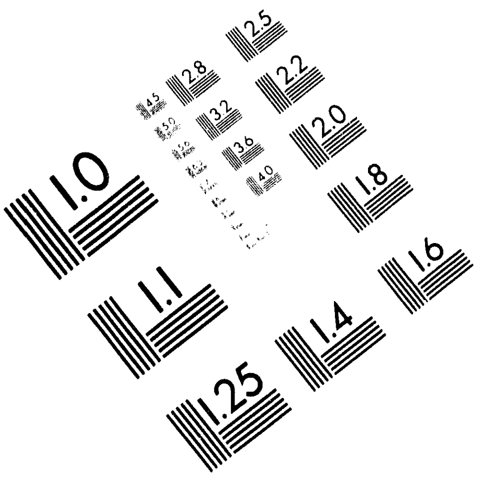

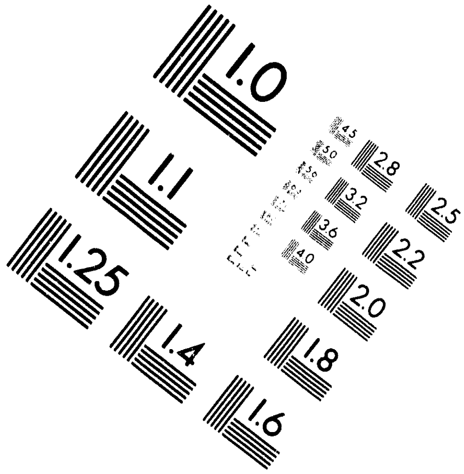

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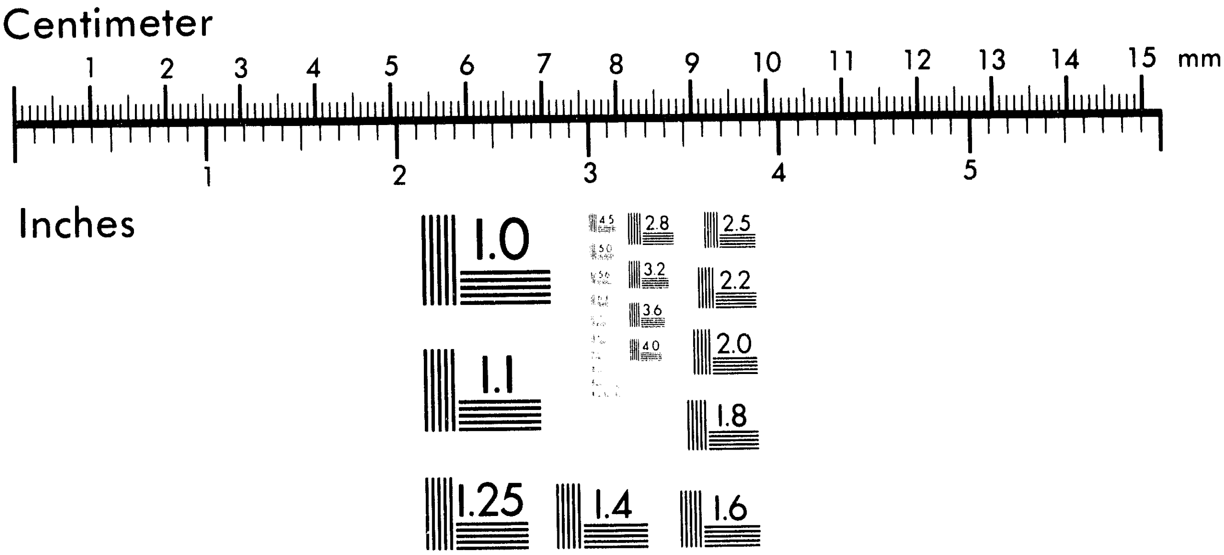

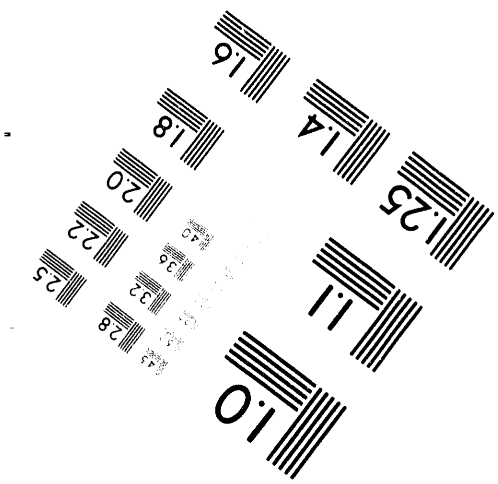

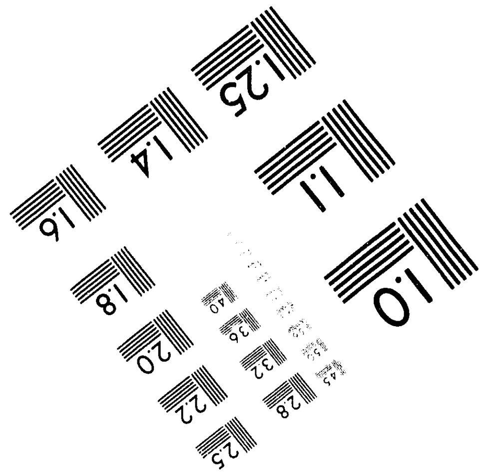

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Biointrusion Test Plan for the Permanent Isolation Surface Barrier Prototype

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Summary

This document provides a testing and monitoring plan for the biological component of the prototype barrier slated for construction at the Hanford Site. The prototype barrier is an above-ground structure engineered to demonstrate the basic features of an earthen cover system. It is designed to permanently isolate waste from the biosphere. The features of the barrier include multiple layers of soil and rock materials and a low-permeability asphalt sublayer. The surface of the barrier consists of silt loam soil, covered with plants. The barrier sides are reinforced with rock or coarse earthen-fill to protect against wind and water erosion. The sublayers inhibit plant and animal intrusion and percolation of water. A series of tests will be conducted on the prototype barrier over the next several years to evaluate barrier performance under extreme climatic conditions. Plants and animals will play a significant role in the hydrologic and water and wind erosion characteristics of the prototype barrier.

Studies on the biological component of the prototype barrier will include work on the initial revegetation of the surface, continued monitoring of the developing plant community, rooting depth and dispersion in the context of biointrusion potential, the role of plants in the hydrology of the surface and toe regions of the barrier, the role of plants in stabilizing the surface against water and wind erosion, and the role of burrowing animals in the hydrology and water and wind erosion of the barrier.

Design of the prototype was completed in September 1992. Construction began in 1993 and will be completed in 1994. Under this schedule, testing of the prototype will begin in April 1994 and will continue for a minimum of 3 years.

Acknowledgments

The biointrusion task is a component of the Testing and Monitoring Plan for the Permanent Isolation Surface Barrier Prototype document written for the prototype barrier, which is a joint effort conducted by Westinghouse Hanford Company (WHC), Kaiser Engineers Hanford (KEH), and Pacific Northwest Laboratory (PNL). We appreciate the support and help of the Barrier Design Team from WHC, KEH, and PNL, whose initial input has stimulated the development of this test plan. Funding for the development of permanent isolation barriers and the prototype has been provided by the U.S. Department of Energy's Environmental Restoration Program under Contract DE-AC06-76RLO 1830.

Contents

1.0 Introduction

Pacific Northwest Laboratory (PNL) and Westinghouse Hanford Company (WHC) are working together to develop permanent isolation barriers for the near-surface disposal of hazardous waste at Hanford. The proposed barrier design consists of a layer of fine-textured soil overlying a series of layers grading from sand to basalt riprap (USDOE 1987). This capillary-break soil layer structure will minimize infiltration into the waste by holding the water in the uppermost fine soil layer. Plants and animals significantly affect the upper fine soil layer where they reside. Thus, it is important to determine how they will affect the soil water balance, the stability of the surface subjected to wind and water erosion, and the potential they pose for biointrusion (Wing 1992; Gee et al. 1993).

This task will concentrate on three subtasks that will quantify the effect of plants and animals on the prototype barrier: 1) vegetation establishment and monitoring, 2) root intrusion/root distribution, and 3) animal intrusion.

The vegetation establishment and monitoring subtask will endeavor to establish a community of deep-rooted perennials on the surface of the barrier and a community of deeper-rooted shrubs and trees at the toe of the barrier. Monitoring includes documenting the plant community structure though time and their effects on the soil water balance of the surface and toe areas.

Revegetation in semiarid ecosystems has been most intensively studied in areas destroyed by mining operations (Allen 1988). Allen (1988) found, during a 10-year study, that Russian thistle (*Salsola kali)* dominated initially, but became rare after 4 years, and perennial grasses and shrubs such as big sagebrush (*Artemisia tridentata*) were dominant after 5 years. The effects of other introduced annuals such as cheatgrass (*Bromus tectorum)* and tumble mustard (*Sisymbrium altissimum),* common at the Hanford Site, were not investigated.

At the Hanford Site, previous revegetation efforts have focused on stabilizing the surface against erosion and preventing roots from entering buried wastes. Cline and Uresk (1979) established shallow-rooted annuals (*B. tectorum*) instead of deep-rooted perennials to stabilize soil surfaces and preclude the intrusion of *S. kali* roots into buried radioactive wastes. They successfully established *B. tectorum,* minimizing the establishment of *S. kali.* This required soil stabilization with straw, to prevent wind erosion and nitrogen fertilization and irrigation in the fall to ensure a vigorous stand of *B. tectorum.*

Other revegetation efforts at Hanford have successfully re-established deep-rooted perennial shrubs [*A. tridentata* and spiny hopsage (*Grayia spinosa*)] on disturbed Basalt Waste Isolation Project (BWIP) areas (Brandt et al. 1990; Brandt and Rickard 1990). These species were successfully established as tublings (a tubling is a seedling established in a narrow tube to facilitate transplantation). Recent efforts by Brandt et al. (1992) demonstrated successful revegetation with grasses in BWIP areas. They prepared seedbeds in the fall, testing various combinations of McGee Ranch soils, fertilizer, compost, and wood chips. They seeded Sandberg's bluegrass (*Poa sandbergii*), bottlebrush squirreltail (*Sitanion hystrix*), needle and thread grass (*Stipa comata*), and white sweet clover (*Melilotus alba*). The highest density of *P. sandbergii* occurred where seedbed treatments consisted of a control (no treatments), only fertilizer disked into the soil, and McGee Ranch soil plus compost. They also recorded the presence of *S. kali* and *B. tectorum* in the study plots.

We will endeavor to establish a perennial community of grasses (*P. sandbergii* and *S. hystrix*) and the shrub *A. tridentata* on the upper surface of the prototype. We believe we will be successful, with careful attention to seedbed preparation, composting, fertilization, irrigation, and planting time of seeds, tublings, and transplanted field-grown seedlings. The result will be a deep-rooted perennial community with the uncontrolled addition of weedy annuals such as *S. kali*, *B. tectorum*, and *S. altissimum.* Along the toe of the prototype we will establish a community of deep-rooted shrubs, such as western juniper (*Juniperus occidentalis*), antelope brush (*Purshia tridentata*), and *A. tridentata*, and trees such as black locust (*Robinia pseudoacacia*) that will take advantage of the extra water found there because of runoff (Sauer and Rickard 1982).

Once the communities have been established, we will measure them for composition and cover at least once a year thereafter. Monitoring efforts will document community dynamics after revegetation and provide data to support work done on soil water balance, root intrusion, and erosion studies.

The strong effect of plants on the soil water balance of the surface and toe areas requires significant efforts to measure the dynamics of transpiration for various species on the barrier. Because the surface will be irrigated, we will also measure the effect of irrigation on plant transpiration and the subsequent effect on soil water balance. It has been established that areas dominated by shallow-rooted annuals such as *B. tectorum* can accumulate water beneath the root zone that can, potentially, lead to recharge (Cline et al. 1977).

Variation in the rooting depth of deep-rooted perennials is associated with variation in soil water storage (Link et al. 1990). Link et al. (1990) found an increase in soil water storage below the 125-cm depth in a antelope bitterbrush (*Pseudoroegneria spicata*)-dominated community in comparison with a more deeply rooted community dominated by *A. tridentata* and *P. spicata.* The presence of deeply (200 cm) rooted shrubs such as *A. tridentata* and *G. spinosa* at McGee Ranch has been demonstrated to extract more water from the soil profile than areas dominated by sparse vegetation. Areas dominated by these shrubs were also able to extract twice normal precipitation from the soil profile (Link et al. 1994). We hypothesize that variation in plant cover and type will be closely associated with variation in soil water storage on the surface of the prototype and along the toe. We will use geostatistical tools to assess spatial autocorrelation, aid in hypothesis testing, and assess risk (Rossi et al. 1992, 1993). Risk here is defined as the probability of barrier failure.

Roots play a central role in soil water storage dynamics, as described above, in addition to binding the soil. Deeply rooted plants pose the potential threat of entering the buried wastes. Because of the overriding importance of roots, we have structured a subtask that focuses specifically on roots. This subtask will attempt to measure the dynamics of rooting depth and dispersion on the surface and along the toe as a function of depth, proximity to plant species on the surface, and the irrigation treatment on the surface.

Rooting depth and dispersion are controlling factors determining soil water dynamics. The likelihood of the accumulation of water deep in the upper profile of the prototype will depend on the depth of the rooting zone. As described above, rooting depth is highly dependent on the species. Rooting depth can be ordered from shallow to deep as follows: *P. sandbergii, B. tectorum, P. spicata, G. spinosa, A. tridentata, and S. kali.* The rooting depth of *S. hystrix* is not known on this site. More water will potentially accumulate deep in the profile if shallow-rooted plants dominate the surface than if deep-rooted plants dominate (Cline et al. 1977). A knowledge of rooting parameters is required to properly simulate soil water dynamics (Link et al. 1993).

Deep-rooted plants [*Chrysothamnus nauseosus* (Klepper et al. 1976); *S. kali* (Selders 1950)] have been observed to accumulate fission products when growing over buried radioactive wastes. The presence of fission products in the shoot is a consequence of roots penetrating the radioactive wastes. Past workers have sought to prevent the intrusion of roots into buried wastes by maintaining a loose rock layer between the waste and the surface soils (Cline et al. 1980). They were successful as long as an asphalt layer was present to prevent soils, and thus roots, from filling cracks in the rock layer. We will test for the presence of roots below the surface soil zone by using a lithium chloride tracer (Cline et al. 1980) in selected areas of the prototype barrier.

Animals have been recognized as agents that can burrow into buried waste and bring it to the surface. This was observed on the Hanford Site where an animal, most likely a badger (O'Farrell and Gilbert 1975) had tunneled into radioactive salts (^{90}Sr and ^{137}Cs), which were subsequently ingested by a black-tailed hare (Cline et al. 1980). Cline et al. (1980) demonstrated that intrusion by roots, animals, and ants into buried waste could be prevented if a layer of loose rock covered with an asphalt emulsion was placed between the buried waste and the topsoil. These authors cautioned, though, that intrusion can occur if soil is allowed to penetrate into the rock layer providing a pathway for roots and animals. Such penetration could happen over long periods of time.

Work to document the effect of burrowing animals on permanent isolation surface barrier structures has focused on preferential infiltration of water through burrows, erosion of caste material, and the potential for entering the buried wastes and bringing them to the surface (Cadwell et al. 1989; Landeen et al. 1990). These studies were done in controlled lysimeter studies (Landeen et al. 1990) and in field studies (Cadwell et al. 1989) in soils similar to those that will be placed on top of the prototype barrier. Conclusions drawn from these studies indicate that small mammal burrows have little or no impact on soil moisture content. Larger animal burrows show an increase in soil water during the winter, but the soils near the large burrows dry out during the rest of the year because of increased evaporation and transpiration from weedy annuals growing on the disturbed soils (Cadwell et al. 1993). Thus, it is not likely that animals will compromise the water relations of the barrier. It should be noted, however, that this conclusion is based on short-term studies. More conclusive evidence of the effects of burrowing animals on water relations of barriers would require long-term studies or a wide range of field studies in natural analog sites. The problems around the impact of burrowing animals on erosion characteristics and the potential for intrusion into the buried wastes have not been resolved in the context of the permanent isolation surface barrier.

Animal studies on the permanent isolation surface barrier will focus on documentation of the location and characteristics of burrows on the surface. Such information will aid in understanding the potential for change in soil water contents and erosion of the surface associated with burrows.

2.0 Scope and Objectives

The timing and duration of observations on the prototype barrier are discussed in detail by Gee et al. (1993). Observations on the effect of plants and animals on characteristics of the prototype are of central importance for documenting the success of the prototype. We plan on expending the majority of our efforts on establishing vegetation on the prototype. Thereafter we will monitor the development of the plant communities on the surface and along the toe of the prototype. Special attention will be paid to documenting the depth and dispersion of roots on the barrier. This information will support efforts to model the water balance of the surface and toe areas. Transpiration and soil evaporation measurements will be made at select times during the length of the project to develop an understanding of the role of plants on the water balance of the surface and toe areas. Finally, animal burrow occurrence will be documented yearly during the course of the project.

Several objectives have been established for testing and monitoring the effects of plants and animals on the prototype barrier:

- establishing self-sustaining deep-rooted perennial plant communities on the surface and toe areas of the barrier
- documenting the dynamics of the plant communities on the surface and toe areas and as influenced by irrigation on the surface
- measuring rooting depth and dispersion of the plant communities on the surface and toe areas and as influenced by irrigation on the surface
- measuring transpiration in the plant communities on the surface and toe areas and as influenced by irrigation on the surface
- documenting the number and dispersion of animal burrows on the surface and the effect of such burrows on soil water balance and erosion
- providing required plant variables and parameters for the operation of hydrology models of soil water balance on the prototype.

These objectives provide general guidance for testing the effect of plants and animals on the prototype barrier. How these objectives generally and specifically will be met are described in subsequent sections of this test plan.

3.0 Biointrusion Testing and Monitoring Activities

A number of tests and experiments will be conducted on the prototype barrier to assess the effect of plants and animals on the prototype's performance. The following subsections provide detailed descriptions of 1) test objectives, 2) techniques and equipment, 3) test and experiment duration, 4) expected results, and 5) any special considerations for the design of the prototype barrier. Information pertaining to costs associated with the tests is contained in Section 5.0.

3.1 Vegetation Establishment and Monitoring

Under this task, the surface and toe areas of the prototype barrier will be revegetated and the dynamics and transpiration of the resulting communities will be monitored.

3.1.1 Revegetation

Vegetation will function as an important component of the permanent isolation barrier design. For the prototype barrier, a preferred vegetation cover must be determined and established as quickly as possible to ensure that other tests of water infiltration and surface erosion mimic expected barrier conditions as closely as possible. Successful vegetation establishment strongly depends on the careful reconstruction of the ecosystem. The techniques we will use for revegetation will follow those described by Waugh and Link (1988) and Brandt et al. (1992).

3.1.1.1 Objective

Objectives of this subtask are to determine a preferred vegetation cover for the prototype that will represent the vegetation expected to develop on fine soils under climate conditions on the 200 Area Plateau and to establish this fully functional vegetation cover as quickly as possible. Issues that must be addressed to successfully establish this vegetation cover include seed collection, seedbed preparation, planting, and irrigation.

3.1.1.2 Technique(s)/Equipment

The revegetation task was initiated with the acquisition of seeds beginning in fall 1993 and continuing through summer 1994. We will attempt to collect seed from plants growing at McGee Ranch or in the local area, in the 200 Areas, and on the Fitzner/Eberhardt Arid Lands Ecology (ALE) Reserve. It is better to use local seed because these plants are already adapted to the local environment and should be successful on the prototype. If adequate local seed is not available, we will acquire seed from local commercial seed sources and/or the Soil Conservation Service's Plant Material Center in Pullman, Washington.

Collected seed will be vernalized using refrigerators at the ALE laboratory. A germination test will be conducted using petrie plates to determine if the local seed is germinable. If seed is considered good, then it will be stored dry until planting time.

Seedbed preparation includes surface manipulation, manipulation of soil microorganisms, fertilization, and irrigation. We will consider two possible surface conditions that will strongly influence seedbed preparation. If the topsoil (top 30 cm) from the borrow pit area is separated, stored, and placed on top of the prototype we can minimize seeding, tubling insertion, surface manipulation, manipulation of soil microorganisms, and fertilization, but will have to expend significant efforts to control weeds. If a barren soil surface is used for the seedbed, then we will have to maximize efforts to manipulate the surface, manipulate soil microorganisms, and fertilize. Weeds will be less of a problem under these conditions, but cannot be ignored. Weeds can be controlled by the carefully timed application of a pre-emergence herbicide. This work will be done by a registered herbicide applicator. Irrigation will most likely be needed for both conditions to ensure establishment if the spring after planting is dry.

Surface manipulation for the prototype concerns microtopographical modifications to create microsites conducive to germination and establishment (Waugh and Link 1988). If a topsoil with admix gravel is applied, then an adequate microtopography will most likely already exist. This is because the inclusion of substantial amounts of dead material will roughen the surface along with admix gravels. If a barren surface is used, then a rough microtopography will have to be created. This will be done with a soil imprinting device, which has been shown to be superior to simply drilling seed (Dixon and Carr 1993).

Soil microorganisms and mycorrhizae are needed for nutrient (nitrogen and phosphorus for example) cycling, which makes nutrients available for adequate plant growth (Waugh and Link 1988). The use of a topsoil treatment will maintain the soil microflora naturally present as long as the topsoil storage time is short. If a barren surface is used, then we will add an organic mulch or compost. Well-cured composts provide nutrients and soil microflora needed for adequate establishment of plants. Such a compost can be added as a hydromulch, as described by Brandt et al. (1992).

Fertilization with nitrogen is generally considered necessary because of the low nutrient contents of these soils (Waugh and Link 1988). More nitrogen will be available with a topsoil treatment than with a barren soil surface. If a topsoil treatment can be added, then we will add little or no fertilizer. It has been demonstrated that weedy annuals respond more strongly to fertilization than do shrub-steppe perennials (Waugh and Link 1988). If a barren soil surface is used, then we will consider the addition of fertilizer. Brandt et al. (1992) observed significant increases in the cover of *P. sandbergii* with nitrogen fertilizer or control soil conditions compared with more complex soil amendments such as the combination of soil, compost, fertilizer, and wood chips, which suggests that nitrogen is not critical for the establishment of *P. sandbergii*. We will conduct a simple pot study to determine if the addition of nitrogen will have a positive effect on the establishment of perennials compared with a barren soil surface characteristic of the prototype.

We will need to be prepared to irrigate the prototype barrier surface to ensure plant establishment. This can be done with drip irrigation system or a pop-up sprinkler system. A drip irrigation system will allow greater control over the location of added water and will minimize the possibility of runoff. In addition, we will establish a drip irrigation system along the toe area to ensure the establishment of the shrubs and trees until runoff water adequately irrigates the toe.

Planting will be done by two methods on the prototype barrier surface. The first method will apply seed directly to the prototype surface with a Brillion seeder using a revegetation contractor such as Bentz Fence Co., as described by Brandt et al. (1992). A redundant seeding method will be used in addition to direct seeding to ensure vegetation establishment in case direct seeding fails. The second method will germinate seeds in a greenhouse to produce tublings, which can then be planted on the prototype barrier surface by hand. The production of tublings will be done by a contractor offsite. Plants for the toe will be obtained from local nurseries and planted by hand.

3.1.1.3 Duration

Vegetation establishment will begin immediately after the construction of the prototype and continue during the following year. The prototype construction schedule calls for completion of the prototype barrier during FY 1994. Because of the seasonality associated with most effective plant establishment, it is important that all construction activities be completed on schedule so that vegetation establishment work can begin promptly in early fall of the year that the barrier is completed. The production of tublings will require enough lead time to establish a contract and to grow the plants to an adequate size for transplanting in fall 1994.

3.1.1.4 Expected Results

We expect to establish a self-sustaining plant community consisting of deep-rooted shrubs and perennial grasses, shallow-rooted perennial grasses, and annual weeds. The long-term composition of the community cannot be predicted. We will monitor the community dynamics of the prototype barrier surface and toe areas for as long as neecessary. The plant community composition will have a strong impact on the hydrology and stability of the upper surface of the prototype barrier.

3.1.1.5 Special Design Considerations

During construction of the prototype barrier, four things are important in establishing vegetation: 1) the top meter of the fine-soil layer may not exceed soil bulk densities of 1.4 g/cm^3, 2) nutrient amendments (yet to be determined) can be added to the top 15 cm of the fine-soil layer on the barrier (before vegetation establishment), 3) a source of water will be required for light irrigation during plant establishment, and 4) a layer of topsoil must be included on top of the upper surface.

3.1.2 Community Dynamics and Transpiration

3.1.2.1 Objective

The objective of this subtask is to monitor vegetative structure, community dynamics, and transpiration characteristics of vegetation on the barrier surface and along the toe. This will help us determine the effectiveness of vegetation to recycle water out of the barrier surface and aid in developing hydraulic models.

3.1.2.2 Technique(s)/Equipment

Instrumentation required to monitor and test the vegetation cover includes point frames for community description, plant growth monitors, and water relations monitoring devices (pressure bombs, porometers, and gas exchange equipment). Stem flow gauges and dendrometers will be used to measure transpiration and growth on trees and shrubs in the toe area.

3.1.2.3 Duration

Monitoring of vegetation for community structure will be conducted annually after construction of the barrier and should continue throughout the testing of the prototype barrier. Monitoring efforts for transpiration will be conducted monthly. Stem flow gauges and dendrometers will be used to measure transpiration and growth continuously.

3.1.2.4 Expected Results

Success of the vegetation establishment task will be monitored by observation and measuring the vegetative cover established on the prototype barrier. Standard quantitative measures of canopy cover will be used. The results will be used to support modeling and erosion evaluations of the prototype surface and will be compared with similar measures in comparable native vegetation stands and other vegetation establishment efforts on the Hanford Site. The expected direction of community dynamics will be toward a community dominated by *A. tridentata* with an understory of perennial grasses and annual weeds. Transpiration measures will document the amount of water each species takes out of the profile and will help in defining patterns of soil water profile variability on the surface. Transpiration measurements in the toe area will indicate the amount of water withdrawn from this water accumulation area and will help assess the success of this vegetation in preventing drainage along the toe.

3.1.2.5 Special Design Considerations

No special design considerations are involved.

3.2 Root Intrusion/Root Distribution

Vegetation will function as an important component of the permanent isolation barrier design, both to stabilize the soil surface and to extract soil moisture from the soil and recycle it to the atmosphere through evapotranspiration. For the prototype barrier design, in which fine soils overlie graded layers, we believe the optimal root distribution for barrier function will be one in which roots fully exploit the fine-soil layer. However, the establishment and growth of deep-rooted plants on the barrier presents the possibility of intrusion of plant roots into the wastes and subsequent biotic transport of hazardous materials. Knowledge of root growth, root/soil interactions, and water uptake patterns is needed to model and predict the removal of soil water through evapotranspiration.

3.2.1 Objective

The main objectives of this subtask are to 1) evaluate the extent to which plant roots exploit the depth of the fine-soil layer under actual barrier construction conditions and 2) determine whether the roots of established vegetation penetrate the various biointrusion control layers.

3.2.2 Technique(s)/Equipment

To monitor root distribution on the prototype barrier, the following instrumentation will be required: set of standard mini-rhizotrons will be placed in each moisture treatment to monitor plant root development and growth rates. These mini-rhizotrons will not penetrate past the fine-soil layer and will be augered into the fine-soil layer at a 45° angle after construction of the prototype. A field-portable downhole video camera will be required to record root distributions within the mini-rhizotrons. To determine whether roots of established vegetation penetrate below the fine-soil layer, a layer of nonhazardous tracer will be required.

3.2.3 Duration

Root distributions in the fine-soil layer will be monitored for at least 2 years after prototype construction. Depending on the success of plant establishment and rooting depths observed at that time, monitoring of root growth and development will continue as deemed necessary to document exploration of the fine-soil layer.

Most root intrusion testing will be conducted during FY 1994, 1995, and 1996. During FY 1996, data will be compiled, analyzed, and summarized in a final report on plant root distributions and intrusion in the barrier system.

3.2.4 Expected Results

Data from these endeavors will be used to construct a clear understanding of root distribution within the barrier under different moisture conditions and will be correlated with the aboveground vegetation structure. Analysis of leaf material sampled annually will determine whether tracer materials have been taken up by roots growing beyond the fine-soil layer. These data will be valuable in proving that anti-biointrusion layers prevent plant root intrusion into wastes, as well as providing information necessary for adequate model predictions of plant water uptake from barrier systems.

3.2.5 Special Design Considerations

During construction, placing a tracer layer will require a break in construction activities.

3.3 Animal Intrusion

The prototype barrier is not a convenient vehicle for testing the effectiveness of barrier components as deterrents to animal burrowing. (This should be done through independent testing where burrow stress can be maximized.) Nevertheless, evaluations of animal burrowing impacts on the prototype are desirable to parameterize the extent and nature of burrowing that occurs during the test life of the prototype barrier.

3.3.1 Objective

The objective of these tests is to document the extent of colonization of the barrier surface through the years when exposed naturally to burrowing animals of the Columbia Basin.

3.3.2 Technique(s)/Equipment

Periodic surveys of the barrier surface will record the types and locations of natural burrowing. Mapping of burrowing activity will be greatly facilitated by use of accurate, automated position-finding and recording instrumentation that key to a reference location.

3.3.3 Duration

This activity will be initiated only after completion of the prototype but should continue for many years at a low level. Measurements should be made quarterly at first and then less frequently if the development of new burrows is found to be low. Measurements should continue to be made for the duration of the prototype testing and observation period, which is expected to be from 3 to 10 years.

3.3.4 Expected Results

Data collected will document burrowing animal invasion of the prototype barrier subsurface during the first several years after construction. Records of the animal species, numbers of burrows, the extent of burrowing disturbance, and specific locations of burrows will aid in overall evaluations of barrier performance. The records will aid in assessing results from other barrier performance measurements, such as water infiltration, should accelerated or enhanced infiltration occur in the vicinity of or as a result of animal burrowing. It is also expected that soil disturbances caused by burrowing activities will influence the plant community by creating a seedbed that will aid in the establishment of weedy annuals (Cadwell et al. 1989). This expected result will be a strong determining factor in plant community dynamics and associated soil water storage patterns.

3.3.5 Special Design Considerations

No special design considerations are involved.

4.0 Relationships with Other Tasks

Plants and animals will affect the hydrologic, water erosion, and wind erosion characteristics of the surface of the prototype barrier. This section describes how tests of each of these characteristics relate.

4.1 Water Infiltration Tests

The objective of the water infiltration task is to measure the complete water balance on the prototype barrier, including the soil-covered surface and the rock-covered side slopes of the barrier under current and possible future climatic conditions (Gee et al. 1993).

Vegetation has a strong effect on soil water budgets, and a clear understanding of the prototype water budget will require a thorough analysis of the vegetation. This will need to include, at least, documentation of spatial and temporal variation in the vegetation as associated with measurement points and times for soil water content. The spatial and temporal role of plants in controlling soil water budgets has been demonstrated for McGee Ranch soils (Link et al. 1994).

Rooting depth and distributions will account for a significant amount of the variation in the soil water budget patterns in space and time. Shallow-rooted plants will allow more water to accumulate in the surface soil layer of the prototype barrier than will deep-rooted plants. Increases in deep soil water content associated with shallow-rooted plants compared with deep-rooted plants has been demonstrated on the Hanford Site (Cline et al. 1977; Link et al. 1990). Observations of rooting characteristics need to be made in association with soil water observations.

The role of vegetation in the recycling of runoff water at the toe of the barrier will be significant. It is anticipated that more mesic vegetation will be established in this wet zone, and it is hypothesized that this vegetation will recycle all runoff water to the atmosphere (Gee et al. 1993). This will ensure that no water seeps under the edge of the barrier. Observations on the water use of these plants will aid in the quantification of the water balance in the runoff area.

Large animal burrows have been shown to increase soil water content compared to undisturbed areas on site (Cadwell et al. 1989). Documentation of animal burrows in space and time on the prototype barrier will aid in assessing results from water infiltration measurements if enhanced infiltration occurs as a result of animal burrowing.

4.2 Water Erosion Tests

The degree of water erosion will be strongly related to the type and density of vegetation on the prototype barrier. As a consequence, spatial patterns of vegetation will need to be assessed in association with the measurement of surface water erosion patterns.

Water erosion will also be influenced by the effects of burrowing animals. Soils deposited on the surface by animals will create a three-dimensional surface that will cause channeling of water runoff. A clear understanding of water erosion patterns will require the documentation of topography patterns caused by burrowing animals.

4.3 Wind Erosion Tests

The degree of wind erosion will be strongly related to the type and density of vegetation on the prototype barrier. As a consequence, spatial patterns of vegetation will need to be assessed in association with the measurement of surface wind erosion patterns.

Wind erosion will also be influenced by the effects of burrowing animals. Soils deposited on the surface by animals will lead to increased wind erosion. This is because excavated soils are less dense than undisturbed soils, and because the three-dimensional surface created by the excavated soils will increase erosion compared to a flat surface (Ligotke 1993). A clear understanding of wind erosion patterns will require the documentation of topography patterns caused by burrowing animals.

5.0 Costs and Timeline

Testing and monitoring of the performance of the prototype barrier is a critical element of the Barrier Development Program. The estimated costs of this effort are based on the most current personnel and overhead rates available.

The prototype project has been funded by both the Office of Technology Development (OTD) and the Environmental Restoration (EM) program of the U.S. Department of Energy. Funding of prototype construction is expected to be available from the EM program. It is anticipated that both OTD and EM will support the testing and monitoring cost for the prototype barrier over the next 4 years. Table 5.1 provides a cost summary by task for the testing and monitoring of the prototype barrier.

Table 5.1. Cost Summary By Task ($ Thousands)

Activity	FY 93	FY 94	FY 95	FY 96	FY 97	Total
Vegetation establishment and monitoring	30	70	70	30	30	230
Root intrusion	0	65	65	65	40	235
Animal intrusion	0	20	30	30	20	100
Total	30	155	165	125	90	565

A projected timeline for subtasks described in this test plan is shown below.

Task	FY 94	FY 95	FY 96	FY 97
Revegetation	--------	--------		
Community dynamics		--------	--------	--------
Transpiration		--------	--------	--------
Root studies	--------	--------	--------	--------
Animal intrusion		--------	--------	--------

6.0 Quality Assurance

All the testing and monitoring tasks supported by the prototype barrier project will be performed in such a manner that Quality Assurance (QA) Impact Level 2 program requirements are met. Throughout the testing and monitoring of the prototype barrier, various types of engineering and scientific information will be generated. This information will be analyzed, reviewed, and documented in status reports or other documents. The documentation will be cleared for public release (as applicable) and placed in archives according to approved QA procedures.

Data management for testing and monitoring the prototype will be under PNL Quality Assurance control. Data from the revegetation, community dynamics, transpiration, root intrusion, root distribution, and animal intrusion subtasks will be collected and recorded in laboratory record books and on data loggers. Detailed records will be kept, and laboratory record books will be reviewed as specified in the PNL-MA-70 Quality Assurance Manual and as specified in the QA plan (OHE-002, Rev. 4) for the barriers program.

Data analysis will focus on quantifying barrier performance with respect to the influence of plants and animals. Water balance of the test areas will be evaluated annually (or more frequently as necessary). Hypothesis testing will be done at the 95% confidence level where appropriate. There are limitations to the hypotheses that can be tested because there will only be one prototype barrier. We cannot replicate the prototype barrier because of costs. Observational data from the tasks will be used in model validation testing and verification.

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