5.4.2 Leachate Collection and Removal System

Leachate collection and removal will be an integral part of the overall containment system to prevent contaminant migration. The system design will be of sufficient capacity and drainage capabilities to effectively and efficiently manage leachate generated by the landfill

The leachate collection and removal system (LCRS) will be designed so the maximum head pressure on the liner immediately beneath the system will be 12 inches A 12-inch layer of clean sand with a 200-foot maximum drainage length and 2 percent slope was assumed for liner evaluation with EPA's HELP Model as described in Section 5 5 1.1

A leak detection system (secondary leachate collection and removal system), similar to the LCRS will be constructed between the primary and secondary composite liner systems. It will be designed to intercept, collect, and remove any leachate that passes through the primary liner system Therefore, it will serve both as a monitoring system for performance of the primary liner system and a mechanism for removal of leachate The volume of leachate removed from this system can be measured and recorded to evaluate whether leakage through the primary liner exceeds the Action Leakage Rate (ALR)

5.4.3 Gas Management System

The generation of gases from the landfilling of RMA waste is expected to be minimal The wastes will be primarily soils and structural debris with little or no putrescible or decomposable waste material It possible that volatile organic compounds (VOC) could be released by the contaminated soils

Gases generated may be managed using a passive venting system consisting of a granular soil layer and a grid array of collection pipes that will vent gases through the final cover system Gas vents can be monitored for gas quantity and constituents, and can be fitted with VOC control devices, if necessary

5.4.4 Final Cover Systems

Cover (cap) systems include multiple layers, each selected to serve a specific function Layers include an erosion control layer, a water balance/infiltration soil layer, a drainage layer, and a barrier layer Materials that may be used for these layers include geomembranes/FML, compacted clay liners or GCL, and granular soil or geosynthetic drainage layers The cover system is designed to provide a physical barrier for containment of waste and have a low permeability The cover system is intended to minimize percolation of water into the waste, thereby reducing the amount of leachate generated

There are a variety of natural and synthetic materials that may be combined in the design of a cover system Four conceptual cover systems were evaluated using EPA's HELP Model, as shown below

Landfill Cover System Alternatives

Layer	Cover System No. 1	Cover System No. 2	Cover System No. 3	Cover System No 4
1 Erosion Control	Sandy Loam & Gravel	Sandy Loam & Gravel	Sandy Loam & Gravel	Sandy Loam & Gravel
2 Water Balance	Loam	Loam	Loam	Loam
3 Drainage	Geonet	Geonet	Geonet	Geonet
4 Geomembrane	60-mil HDPE	60-mil HDPE	60-mil HDPE	60-mil HDPE
5 Barrier	CL	GCL	CL	GCL

HDPE High-density polyethylene
CL 3 feet of compacted clay

Cross sections of each cover system are presented in Figure 5 2 The results of the evaluation are presented in detail in Section 5 5 1 2

The erosion control layer evaluated was 8 inches thick and will include 50 percent gravel mixed with the sandy loam. This layer will be seeded to produce a protective vegetative cover The water

balance layer evaluated was 52 inches thick and will include a 6- to 12-inch thick animal exclusion barrier near the top of the layer. The animal intrusion barrier will consist of rocks or aggregates large enough to prohibit burrowing animals from damaging the underlying liner system A geotextile filter fabric will be installed between the water balance and the drainage layers. The drainage layer will be geonet or gravel The drainage layer material will be selected to provide adequate removal of water. The barrier layer will be a composite of HDPE, and, either 3 feet of compacted clay or a GCL.

5.4.5 Performance and Environmental Monitoring

Monitoring systems will be used to periodically confirm facility performance This will include the monitoring observation wells around the facility, monitoring leachate collection and leak detection systems, monitoring the gas management system, and inspecting the physical plant features. Performance monitoring will be incorporated into the landfill operation and maintenance plan, as described in Section 5.9

Environmental monitoring will be performed as part of the facility performance monitoring A groundwater sampling and analysis plan will be used to establish background groundwater quality Subsequent groundwater monitoring will be compared statistically to background values to identify any significant changes

5.5 Evaluation and Screening of Alternatives

This section presents an evaluation and screening of the conceptual liner and final cover alternatives developed in Section 5 3 Two forms of evaluation are utilized First, an effectiveness evaluation is performed using the HELP Model Second, a cost evaluation is conducted by estimating the unit cost on a square foot basis for each liner and final cover alternative

The final evaluation performed in this section evaluates the overall performance of the selected liner and final cover

5.5.1 Effectiveness Evaluation

The objective of the evaluation and screening of landfill technology alternatives was to develop an appropriate range of waste management options to protect human health and the environment and analyze them in detail with respect to specific site conditions

EPA's HELP Model (Version 3), was used to assess the comparative effectiveness of various cover and liner systems and evaluate waste isolation. The model was also used to predict potential leachate production from a landfill using the best cover and liner design under both "most likely" and "worst-case" scenarios The HELP Model is a quasi-two-dimensional water balance model that predicts the movement of water across, into, through, and out of landfills (EPA, 1994) Version 3 of the model accepts various weather, soil, and landfill design data and uses solution techniques that calculate a water balance The model accounts for components such as surface storage, snowmelt, runoff, infiltration, vegetative growth, evapotranspiration, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane, or composite liners

The following sections describe the HELP Model effectiveness evaluations for the landfill liner and final cover

5.5.1.1 Landfill Liner System Effectiveness Evaluation

The HELP Model was used to evaluate the comparative effectiveness of six liner alternatives, which consisted of various configurations of double, or composite, liner systems using geomembranes, geonet, or sand drainage layers, and compacted clay or geosynthetic clay barrier layers The six alternatives are shown in Figure 5 1 To approximate conditions within a landfill, HELP Model simulations of the liners consisted of adding additional water on top of the liners until approximately 12 inches of head was built up on the upper drainage layer (leachate collection system) This was done to compare the effectiveness of the liners under maximum head conditions, not to predict

actual values of leachate generated by the landfill Thus, the conditions used in this analysis are not expected to exist during the operating, closure, or post-closure care periods of the landfill life.

To generate a consistent amount of hydraulic head in the upper layer (leachate collection system) of each conceptual design, 100 years of synthetic precipitation data were generated by inputting a consistent monthly average value for precipitation. Through iterative simulations, it was concluded that a monthly average of 3 inches (an annual average of 36 inches) was needed to generate a long-term average of approximately 11.8 inches of head in the leachate collection system Evapotranspiration was significantly reduced by setting the evaporative depth to 0 1 inches and the leaf area index to 0 This was done to promote infiltration. All other weather parameters were set consistent with the simulations of the caps

Table 5 3 presents the HELP Model input parameters for the various liner alternatives The liners were configured such that the top layer represents the leachate collection system, which is underlain by an upper liner consisting of 60-mil HDPE. Below these layers is a leak detection system consisting of a sand or geonet drainage layer, which overlies the composite bottom liner system Default HELP Model properties were used for all layers. Initial moisture contents were calculated by the HELP Model

Two simulations were run for each alternative, a most likely case and a worst-case scenario The assumptions used for these scenarios were the same as for the cover simulations, consisting of good installation of geomembranes for the most likely case and poor installation for the worst-case scenario Table 5 4 presents the results of the simulations for the various liner alternatives in terms of the amount of leachate that may pass through the liner system. For the most likely case, all liners performed approximately the same Even with 1 foot of head in the leachate collection system continuously for 100 years, only 2 5 x 10^{-6} in/yr of leachate is predicted to leak through the liners For the worst-case scenarios, leachate infiltration is predicted to range from 0.04 to 0.5 in/yr. Under

this scenario, the conceptual liner designs that included geosynthetic clay as the base layer (Liner System Nos 1 and 2) performed better than those with compacted clay or a tertiary geomembrane liner as the base

The similarity of results for conceptual designs under the most likely case indicates that final screening of the conceptual liner designs should consider cost and constructability, rather than potential performance

5.5.1.2 Landfill Cover Effectiveness Evaluation

The HELP Model was used to assess the comparative effectiveness of four cover systems The four alternatives are shown in Figure 5.2 and include various configurations of geomembrane and compacted clay or geosynthetic clay barriers and sand or geonet drainage layers Key input parameters in the HELP Model water balance approach include those associated with precipitation, evapotranspiration, and runoff The performance of each system was simulated using 100 years of weather data synthetically generated by the HELP Model using default Denver data as input. A review of the weather data generated by the HELP Model versus actual Denver data (from Stapleton Airport) from 1905 to 1993 indicates that both the mean and maximum annual precipitation are greater for the synthetic data than the actual data, resulting in a conservative analysis with respect to precipitation

Important parameters associated with evapotranspiration include evaporative zone depth, temperature, solar radiation, length of growing season, and leaf area index. One hundred years of synthetic temperature and solar radiation data were generated using default values for Denver It was assumed that "fair" grass would be maintained on all the cover systems, therefore the Denver default values of evaporative zone depth (28 inches) and leaf area index (2.0) were used Default data for the length of growing season for Denver were used.

The Soil Conservation Service (SCS) curve number, which controls the runoff calculation, was calculated with the HELP Model assuming a sandy loam surface soil with a fair stand of grass, a surface slope of 5 percent, and a slope length of 1000 feet. The final calculated value was 67 6, which limits the overall runoff and indicates significant infiltration.

Table 5 5 presents the HELP Model input parameters for the various cover systems Model default soil property data were used for all layers Each cover consisted of 8 inches of surface soil (sandy loam) underlain by 52 inches of soil (loam) to provide water storage and frost protection. These surface layers overlie either a sand or geonet drainage layer, which sits above a 60-mil HDPE geomembrane The bottom layer of each cover is a compacted clay or geosynthetic clay barrier layer Initial moisture content of each layer was calculated by the HELP Model

Two simulations were performed for each of the cover systems a "most likely" case and a "worst-case" scenario The HELP Model allows for variations in the number of defects a geomembrane liner may contain. This is the key assumption in evaluating each of the cover systems, as they all contain a 60-mil HDPE layer as the primary component. Both simulations assumed that the geomembrane liner contained one pinhole per acre as a manufacturing defect. The most likely scenario assumes that installation of the geomembrane portion of the cover is "good," with three construction defects per acre and good contact between the geomembrane and the underlying soil (better contact means less potential drainage) The worst-case scenario assumes poor construction, with ten construction defects per acre and no contact between the geomembrane and the underlying soil

Table 5 6 presents results of the simulations for the cover systems As shown on the table, all the systems were predicted to perform well for the most likely scenario, with virtually no water ($9\ 6 \times 10^{7}$ to 7.2×10^{-6} in/yr) infiltrating through any of the alternatives Landfill Cover System No 4 performed the best at limiting infiltration for the most likely scenario For the worst-case scenario, a wider range of infiltration was predicted, ranging from 0 005 in/yr for Cover System No 4 to

1 119 in/yr for Cover System No 1 A review of the worst-case results indicates that the sand drainage layer is predicted to perform better than the geonet drainage layer (Cover System No 3 versus No 1 and No 4 versus No 2) and the geosynthetic clay barrier performed better than the compacted clay Cover System No 4, which contained both a sand drainage layer above the geomembrane and a geosynthetic clay barrier below the geomembrane, performed the best in the worst-case scenario

In conclusion, the calculated infiltration results for all the cover systems evaluated are similar and very low The similarity of results for the alternatives under the most likely case indicates that final screening of the cover systems should consider cost and constructability, rather than potential performance

5.5.2 Cost Evaluation of Landfill Liner and Cover Systems

A unit cost was estimated for each liner system and cover system by estimating unit costs for each system component, and adding them together Tables 5 7 and 5 8 present the unit cost estimates for each liner system and cover system, respectively

As was noted in the previous sections, the liner and covers systems generally performed equally well and should be selected on the basis of cost and constructability The constructability of each component will also be reflected in the overall unit cost (i e., the more difficult/labor intensive it is to install, the higher the unit cost).

The total unit cost estimate for the liner systems ranged from $3.00 to $6 40 per square foot. Liner System No 1, which included a GCL instead of a compacted clay liner, was the most cost-effective

The total unit cost estimate for cover systems ranged from $3 60 to $4 55 per square foot. Similarly, the cover system that utilized the GCL was more cost-effective The sand drainage layer performed

better than the geonet for relatively the same cost, therefore, Cover System No 4 was more cost effective and efficient.

5.5.3 Overall Landfill Performance Evaluation

The analysis of potential effectiveness of the cover and liner systems indicates that, in general, the various alternatives should perform in similar fashion. Two subsequent HELP Model simulations were performed using Cover System No 4 and Liner System No 1, both of which were the most cost-effective and predicted to perform well under worst-case conditions, to estimate the potential long-term leachate production from the landfill The waste portion of the landfill was assumed to be 65 feet thick and was simulated using default characteristics for municipal refuse (HELP Model default number 19, which allows for channeling and dead zones) The simulations were performed using the same weather parameters as the cap screening simulations The most likely and worst-case scenarios were simulated as before

Results of the simulations are presented in Table 5 9 As shown in the table, extremely small rates of potential release are predicted for both the most likely ($2\ 6 \times 10^{7}$ in/yr) and worst-case ($1\ 6 \times 10^{-3}$ in/yr) scenarios

An evaluation was performed to assess whether leachate produced at these extremely small rates could potentially move through the vadose zone beneath the landfill to the water table To estimate advective travel times of unsaturated flow produced by the leachate predicted from the HELP Model, the methodology incorporated into EPA's RITZ Model (EPA, 1988) was used The equation for advective water movement in the unsaturated zone is

$$V_a = V_d/\theta$$

$$\theta = \theta_s[V_d/k_s]^{1/(2b+3)}$$

where

V_a = Advective water velocity

V_d = Infiltration or recharge rate

θ = Long-term soil water content at recharge rate V_d on a volume basis

θ_s = Saturated water content of the soil on a volume basis

k_s = Saturated hydraulic conductivity of the soil

b = Clapp and Hornberger, 1978, soil constant

General soil data collected during Task 93-03 were reviewed to estimated parameters representative of the vadose zone beneath the landfill The following parameters were used

θ_s = 0 40 (average value for clay/silt material)

k_s = ranges from 4 25 ft/day to 42 5 ft/day

b = 7 75 (Clapp and Hornberger, 1978, silty clay loam)

V_d = 0.00165 in/yr, or 3.77 x 10^{-7} ft/day (worst-case)

Using these parameters, potential travel times through the vadose zone are estimated at 8 29 x 10^{-4} ft/yr to 9 37 x 10^{-4} ft/yr, depending on saturated hydraulic conductivity At these rates, it would take from 1000 to 1200 years for soil water in the vadose zone to move downward one foot. The landfill configurations being evaluated contain at least 10 feet of vadose zone between the base of the liner and the water table

5.6 Evaluation of Facility Layout and Material Quantities

This section presents an evaluation of a conceptual facility layout and material quantities based on the three conceptual landfill volume requirements described in Section 5 1.2 and the site-specific considerations and limitations presented in Section 5.3

5.6.1 Conceptual Facility Layout

The size of the landfill facility will depend on the remedial alternative selected and the corresponding volume of waste generated for that alternative The landfill footprints for the three proposed conceptual models are shown in Figures 5 3, 5 4, and 5 5 The landfill footprint in this discussion is

the maximum lateral extent of waste, which nearly coincides with the top of the landfill's interior, below-grade slope The dimensions of each footprint are as follows

Conceptual Model No	Dimensions (feet)	Acres	Total Landfill Volume (CY)	Waste Volume (CY)
1	900 x 900	19	1,200,000	1,000,000
2	1200 x 1300	36	2,760,000	2,300,000
3	1650 x 2300	87	7,200,000	6,000,000

The excavation depth for each landfill scenario was assumed to be an average of 30 feet below the existing ground surface, with a maximum liner thickness of 5 feet, including the leachate collection and removal system Cross sections showing the approximate limits of excavations for each scenario are presented in Figures 5 6 through 5 9 Conceptual Models 1 and 2 are similar in that the base of each is placed within the alluvium and both footprints avoid areas of sand subcrops Conceptual Model 3 is a much larger footprint and the base of excavation is within the weathered Denver Formation. As illustrated in Figures 5 6 through 5 9, Conceptual Model 3 is cut into both the A sand and the IU sand Although avoidance of the subcropping sand units is preferable, it is only possible with the smaller two configurations

Excavation sideslopes were assumed to be 3 horizontal to 1 vertical (3H 1V) to calculate airspace volumes below grade A sideslope of 6H 1V and a 35-foot average waste height at the top of the sideslope was used to calculate the airspace above grade A containment dike, averaging approximately 5 feet above grade, will be initially constructed around the excavation perimeter A series of similar dikes will be constructed in a stair-step fashion as the landfilling operations proceed above grade Typical plan views of the excavation and final cover are presented on Plates 5.1 through 5 6 Plate 5 7 illustrates the depth of excavation and depth to groundwater for the three conceptual models The survey data used in these plates are based on the 1983 horizontal datum and 1988 vertical datum In all three scenarios, the depth to groundwater beneath the base of excavation is no less than 10 feet.

As is shown on Plates 5 2, 5 4, and 5 6, the 6H 1V portion of the final cover exceeds the recommended maximum top slope of 5 percent presented in EPA's Technical Guidance Document Final Covers on Hazardous Waste Landfills and Surface Impoundments (EPA, 1989) The guidance does allow for alternative designs provided that the alternative design fulfills the applicable regulatory requirement. The purpose of maintaining a final covers slope below 5 percent is to control erosion. The allowable erosion control rate listed in the guidance is less than 2 tons/ acre/year. Thus, to proceed with final design using a 6H 1V sideslope, an appropriate erosion control demonstration would be required

5.6.2 Evaluation of Slope Stability and Slippage

The slope stability evaluation described below indicates that the planned landfill can be constructed at the site if a final geotechnical investigation is performed and the recommendations contained therein are addressed in the final landfill design. The final investigation should refine and expand upon the testing and analyses presented in this report, and consider in its analyses any changes from these conceptual models

Since slope failure within the Denver Formation is not considered likely, the critical area for analysis are with the thickest alluvium deposits Boring SAB12894 was selected for the subsurface profile analysis This boring consists of 45-foot-thick interbedded strata of sandy lean clays and clayey sands Standard Penetration Test (SPT) blow counts ranged from 6 per foot to 20 per foot for these soils, which are underlain by sandstone with blow counts greater than 50 per foot.

Published information about relationships between SPT blow counts and soil strength parameters (cohesion and angle of internal friction) were used to obtain theoretical values and compare them with the limited laboratory strength test data and select input parameters for stability analyses Because of the generally dry condition of the alluvial soils, the field blow count values may indicate higher soil strengths than can be expected under wet or saturated conditions; therefore, the soil

strength parameters were conservatively interpreted The following soil parameters were selected in the slope stability analyses performed using the subsurface profile from Boring SAB12894:

Depth Interval (feet)	Cohesion (psf)	Friction Angle (Degrees)
0 to 8	500	10
8 to 26	1,500	15
26 to 45	1,000	15
Below 45	4,000	35

The conceptual design cross section consists of 3.1 cutslopes (horizontal to vertical), with the maximum landfill bottom approximately 60 to 70 feet below existing grade However, the typical average excavation depth is anticipated to be approximately 30 feet. A 5-foot-high (average) soil berm will be constructed at the top of the cutslopes Upon closure, the top of the landfill sideslope will average about 35 feet above existing grade

The cutslope cross section with the 5-foot berm in place was analyzed for stability This is a short-term condition and will occur before any waste is placed in the landfill In addition, a maximum flood elevation (to the top of the 5-foot berm) was assumed for this condition to represent flood stage The long-term condition (i.e , with the waste and cap in place) is expected to have safety factors comparable to or higher than those computed for the short-term conditions

The following factors of safety were obtained for the three conditions analyzed. Because of the small difference in computed values, they are shown in two decimal places Typically, the computed factors of safety are shown in one decimal place

Condition	Factor of Safety
Short-term without flood	2 86
Short-term with flood	2 83

These safety factors are greater than 1 5, which is commonly considered as the lowest acceptable safety factor for static conditions The landfill cross section analyzed therefore has adequate factors of safety for anticipated conditions

The cover and liner systems can be designed to avoid potential slippage along component interfaces Material such as textured geomembranes and geonet with geotextile bonded to both sides can be specified for use, if required These materials can provide friction factors in excess of 14 degrees (25 percent or 4H 1V) at all interfaces Slopes that are too steep to provide an adequate factor of safety against slippage can be constructed with proper design (i.e , use of an anchor trench)

5.7 Material Quantities and Availability of Onpost Materials

Material quantities were estimated for soils and landfill liner and cover system components The soil quantities include volume estimates for low permeability soils and structural fill soils Surface areas were calculated for the liner and cover systems Estimated quantities of soils required for landfill construction were then compared to estimated volumes of onpost materials

5.7.1 Material Quantities

Soil requirements will depend on the selected liner and cover systems developed during the design phase of the project To provide a conservative estimate of soil requirements, it is assumed that

- A 30-inch compacted clay liner will be incorporated in the final cover
- 12 inches of structural fill will be placed to achieve a suitable subgrade under the final cover
- A 12-inch protective soil layer will be placed over the LCRS
- The primary and secondary barrier layers in the liner will use 36 inches of clay
- The liner system will be underlain by a 12-inch structural fill (prepared subgrade)

Table 5 10 presents the estimated soil material requirements for each conceptual landfill model based on the above assumptions

The surface area to be lined was calculated for each conceptual landfill model assuming an excavation depth of 30 feet with sideslopes of 3H.1V The surface area that will require final cover was calculated assuming a waste height of 35 feet above grade and sideslopes of 6H 1V The estimated liner and cover surface areas are presented below

Estimated Liner and Cover Surface Areas

Conceptual Model No.	Liner Area (square feet)	Cover Area (square feet)
1	850,000	850,000
2	1,600,000	1,600,000
3	3,900,000	3,900,000

5.7.2 Availability of Onpost Materials for Landfill Construction

Ninety-eight soil borings were drilled as part of the FS Soils Support Program (HLA, 1995a) to identify potential borrow sources for low permeability and/or structural soils For the purpose of landfill liner/cap construction, low permeability soils are those that can be compacted at a specified density and moisture content to achieve a hydraulic conductivity of equal to or less than 1×10^{-7} cm/s The results of the materials feasibility study, presented in Section 3.0, indicate that soil from the two identified onpost borrow areas tested can be used to construct clay liners or caps that achieve hydraulic conductivity requirements of less than 1×10^{7} cm/s

In the FS Soils Support Report (HLA, 1995a), a total of four potential low permeability onpost soil borrow areas and two onpost structural soil borrow areas were identified The soil borrow areas and estimated volumes are presented below

Onpost Soil Borrow Areas and Estimated Soil Volumes

Area	Low Permeability Soil (cubic yards)	Structural Fill (cubic yards)	Location
Area 1	1,247,000	–	Southern half of Section 24
Area 2*	768,000	–	SE corner of Section 25 and NE corner of Section 36

Area	Low Permeability Soil (cubic yards)	Structural Fill (cubic yards)	Location
Area 3	5,454,000	--	Northern half and SE quarter of Section 29
Area 4	4,999,000	--	SW and NE quarter of Section 20
Area 5	--	8,889,000	Section 34
Storage Area	--	180,000	NE Section 31

* Area 2 is not recommended as a borrow area because of the limited volume of low permeability soil available and because the site is located in the biota exceedance area The biota exceedance area includes the top 2 inches of soil

Based on the above estimates, approximately 11,700,000 CY of low permeability soil have been identified along with 9,069,000 CY of structural fill. Additional low permeability and structural fill soils may be available from excavation of the landfill

The approximate amount of material available from each of the conceptual landfill model excavations is as follows

Conceptual Model Number	Estimated Total Excavation (CY)	Estimated Percent Low Permeability Soil % (CY)	Estimated Percent Structured Fill % (CY)
1	860,000	75 (645,000)	25 (215,000)
2	1,380,000	60 (828,000)	40 (552,000)
3	2,850,000	50 (1,425,000)	50 (1,425,000)

Based on this analysis, it appears that sufficient onpost soil from borrow areas and the landfill excavation exists to meet the construction requirements for even the largest landfill (Conceptual Model 3) Additional low permeability soil and structural fill will be required for implementing the landfill/caps remedial alternative According to the estimates provided in the Proposed Final DAA (Ebasco, 1994) and updated by RUST, E&I (1995), approximately 2,500,000 CY of low permeability soil and 13,000,000 CY of structural fill will be required to implement the preferred remedy (landfill/caps) To meet the volume of structural fill required, expansion of the proposed borrow

areas identified in the FS Soils Support Report may be required (HLA, 1995a) Further soil testing will be required to expand the proposed borrow areas

5.8 Cost Estimates and Construction Schedule

This section presents preliminary cost estimates for construction and annual operation and maintenance for the three conceptual landfill models evaluated for this site feasibility study A conceptual construction schedule was also prepared for the initial phase of landfill cell construction.

5.8.1 Construction Cost

The preliminary construction cost estimates were prepared to be accurate within the typical feasibility study range (plus 50 percent to a minus 30 percent) Table 5 11 presents a construction cost summary for each landfill model The table presents costs associated with the various elements of landfill construction. Estimated costs listed in this table reflect current present value costs to construct or install the listed items Appendix H details the estimated quantities, unit rates, and assumptions used in developing Table 5 11 Based on the total estimated costs show in Table 5 11, the estimated construction cost per cubic yard of waste disposal capacity is approximately

Conceptual Model 1 $12 50 per cubic yard

Conceptual Model 2 $10 00 per cubic yard

Conceptual Model 3 $9 00 per cubic yard

Actual landfill airspace may be constructed in a phased sequence corresponding to the estimated annual waste generation rates described in Table 5 2, in which case, landfill space would only be constructed on an annual basis, as needed If this approach is implemented, the total cost of landfill construction would increase over the estimates shown in Table 5 11 The increase would occur as a result of inflation, multiple contractor mobilization/demobilization charges, and possible increases in unit cost because of reduced volumes of materials purchased or placed at one time In addition, landfill capping cannot occur until the landfill has been filled to cap subgrade

The following discussion presents a construction sequence that reflects how construction might proceed

Initial Construction

Construct or install maintenance building, office building, access roads, perimeter security fence, parking, leachate management system, groundwater monitoring wells

Perform initial excavation (two years capacity) and construct first portions of drainage, sumps, header pipe, pumps, prepare subgrade, place liner and protective cover, construct storm-water control system, and commence waste placement.

Operational Years

Construct additional portions of drainage, sumps, header pipe, pumps, excavate soil, prepare subgrade, place liner and protective cover, construct storm-water diversion berm, and place cover on waste as cell fills

Construct cover system over areas of the landfill that are filled to capacity

Last Year

Construct remaining portions of drainage, sumps, header pipe, pumps, prepare subgrade, place liner and protective cover, construct storm-water diversion berm, and place cover on waste as cell fills

Construct remaining portion of cover system over closed landfill

5.8.2 Annual Operation and Maintenance Costs

Table 5 12 presents a summary of estimated operation and maintenance (O&M) costs for each of the landfill conceptual models under both restricted and unrestricted funding scenarios The detailed annual O&M estimate is presented in Appendix H The O&M estimates were prepared at an FS level (plus 50 percent to minus 30 percent)

Major assumptions made in preparing the O&M estimate include

1 Major heavy equipment is purchased for O&M functions and has a six-year replacement life and $0 salvage value at six years

2 Leachate and contaminated storm water is generated at a rate of 100,000 gallons per acre of open cell and is disposed at DuPont's Chambers Works in Deep Water, New Jersey

3 A 3 percent rate of inflation will occur for all labor, equipment purchase, and equipment O&M

4 The daily waste volume that must be handled is equal to the landfill volume divided by the landfill life in years, divided by 250 operating days per year. Waste inflow is uniform throughout the life of the landfill

5 The landfill life is obtained from information in the DAA that is summarized in Table 5 2

6 Borrow soil requirements for operational cover equal 20 percent of the waste volume and will be obtained from cell excavation stockpiled adjacent to the landfill

7 The CERCLA Wastewater Treatment Facility will treat water from decontamination procedures

8 Unit costs for equipment O&M include fuel, tires, trucks, and routine maintenance.

9 Groundwater monitoring costs equal $10,000 per well per year

The lowest estimated O&M costs, $7 per CY, occur for Conceptual Model 3 with unrestricted funding The highest estimated O&M costs, $18 per CY, occur for Conceptual Model 1 with restricted funding

Estimated labor costs are typically the largest component of the total estimated O&M cost over the life of the landfill However, leachate disposal costs are significant and, in the case of Conceptual Model 3, exceed labor costs

As described in the assumptions listed above, leachate is projected to be generated in portions of the landfill that have not received final cover at a rate of 100,000 gallons per acre per year This assumption is based on actual leachate production rates for 1994 at the Highway 36 Hazardous Waste Disposal Facility Leachate disposal was assumed to take place at an offsite facility. Based on the

estimated volume of leachate that will be generated and the cost of disposal, onsite treatment and disposal may be more economical and should be evaluated further

5.8.3 Construction Schedule

Figure 5.10 presents a conceptual construction schedule for cell development of an approximate 200,000 CY module that could be applied to any of the three conceptual landfill models. The schedule can be refined to be more exact once the size, operating life, and projected daily waste volumes are selected

5.9 Operation and Maintenance Plans

Operation plans should be developed for the landfill facility to help assure that operations will conform to regulatory requirements and be consistent with the engineering design of the facility These plans will provide for safe operation but, in case of accidents, the plans will include contingency plans and emergency procedures Maintenance plans should also be developed so that the facility can be properly maintained during its operating life and throughout the post-closure The specific plans that must be developed and their content and approach will depend on the final determination of applicable regulatory requirements

5.9.1 Operation Plans

A comprehensive site operating plan should be prepared for the facility Major components of the plan will include the following elements

- Construction and construction quality control (CQC) requirements
- Daily operations
- Periodic operational activities
- Specific plans

The construction and CQC section will discuss the type of future construction required throughout the life of the landfill facility This will help guide the operator from the initial construction through the completion of construction and eventual closure of the facility Specific discussion will focus on

the need to monitor waste generation and the progress of the remedial alternative Monitoring the waste generation rate is needed to predict the final quantity of waste to be received at the landfill, and when that final waste will be placed into the landfill Guidance will be provided for implementing partial closure of areas of the landfill that reach final grade, and for final closure following placement of the last quantity of waste to be received

The daily operations section of the plan will discuss accepting waste and inspection procedures, placing waste, containing or covering waste, and any other activities that are part of the daily operating routine Periodic activities will be discussed in the site operating plan including inspection, monitoring, and maintenance functions These will be developed to be specifically applicable to this landfill facility

Specific plans that should be developed are discussed in the following sections These plans are related to regulatory criteria for the operation and maintenance of a hazardous waste land disposal facility Such plans are normally prepared prior to the startup of waste management activities, and are subject to change at any time throughout the active life of the facility Changes may be made in these plans to reflect the availability of new construction materials or waste management techniques, changed conditions or operating practices at the facility, or for similar reasons

5.9.2 General Waste Analysis

Before disposing of any hazardous waste in the landfill, a representative sample of the waste stream should be obtained for chemical and physical analysis This analysis provides information necessary to properly store or dispose of the waste and is be performed on each waste stream that is to be accepted at the landfill The analysis is repeated when necessary to assure that the analysis is accurate and up-to-date Periodically, a further confirmatory sample of the waste stream being brought into the facility will be analyzed to determine its continuing conformance with the results of previous analyses

The waste analysis plan for the onpost landfill at RMA should account for the extensive sampling and site characterization that has already taken place, and minimize the amount of new sampling and analysis required prior to waste receipt.

5.9.3 Security Plan

A security plan should be developed to prevent unknowing entry and minimize the possibility of unauthorized entry of persons or livestock onto the active portion of the facility This plan will include provisions for a barrier system (e g , a security fence in good repair) and a means to control entry, such as a lockable security gate Signs will be posted at the entrance and at periodic intervals along the security fence to warn individuals about the potential danger associated with trespassing and forbidding unauthorized access to the facility The security plan should take into account the overall security system for RMA.

5.9.4 Inspection Plan

A written inspection plan should be developed to contain all the inspection requirements necessary to periodically evaluate the condition of the facility and identify need for repairs, replacement, or restoration. The inspection plan will detail the specific inspection procedures and frequency of inspecting all parts of the facility The plan will also provide for a recordkeeping system that includes an inspection form to be prepared for each inspection activity The inspection form will provide for recording adverse conditions discovered as a result of the inspection and a method of initiating appropriate followup to assure the necessary action is taken.

5.9.5 Personnel Training

A written personnel training plan should be prepared for the facility This plan will discuss, on a position-by-position basis, the training requirements for all personnel engaged in the management, operation, and maintenance of this landfill facility The plan will describe the necessary levels of pre-employment training as well as any periodic or ongoing training required for specific categories of employees Records of the personnel training program will be maintained to demonstrate compliance with these requirements

5.9.6 Preparedness and Prevention Plan

This plan will relate to the existing the RMA Contingency Plan and will focus on operations and procedures to minimize the possibility of a fire, explosion, or any unplanned sudden or non-sudden release of hazardous waste or hazardous waste constituents to the environment. This plan would provide specific information regarding equipment such as internal communications, alarm systems, external communications, fire extinguishers, spill containment, and fire control systems The plan would establish testing and maintenance requirements for related equipment. All personnel in the operations area of the facility will have access to communications, response, and alarm systems Arrangements will be made with local authorities to provide standby or backup support in case the emergency is of such magnitude that outside help is required

5.9.7 Contingency Plan and Emergency Procedures

A site-specific contingency plan will be developed as an appendix to the overall RMA Contingency Plan to minimize hazards to human health or the environment from fires, explosions, or any unplanned sudden or non-sudden release of hazardous waste or hazardous waste constituents This plan is a supplement to the Preparedness and Prevention Plan, and provides for emergency action in the event that an emergency exists in spite of efforts to prevent it. The contingency plan will contain emergency procedures to be followed in the event of any one of a number of potential emergencies that could occur at the facility The training plan described above will include provisions for training in both preparedness and prevention, and in emergency response

5.9.8 Manifest System, Recordkeeping, and Reporting

It is not anticipated that a manifest system for waste shipment will be required for this facility since it will not receive any hazardous waste from offsite sources

A full set of operating records should be routinely prepared and maintained at the landfill facility These records should be maintained at the facility until closure The records should describe the quantity and type of waste received, the date of receipt, and the location of specific wastes stored in

the landfill The records should also contain results of waste analyses, inspection results, the details of any incident requiring implementing the contingency plan, all monitoring, testing, and analytical data, and other records that are either pertinent to the facility operation or are required by federal, state, or local regulations

Reports of landfill operation should be prepared to comply with current federal or state regulations

5.9.9 Maintenance Plan

A facility maintenance plan should be prepared that requires the repair or replacement of any aspect of the landfill facility that becomes unserviceable during the operating life of the facility or during post-closure If any mechanical equipment is incorporated into the operation of the facility, such as emergency response equipment or dedicated pumps in groundwater monitoring wells, the manufacturer's recommended maintenance procedures will be obtained and incorporated into the maintenance plan. The plan would require that the specified maintenance be performed in accordance with the manufacturer's recommendations The maintenance plan should be related to the inspection plan discussed above because inspection activities may identify the need for certain maintenance operations Maintenance activity that requires repair or replacement of material or equipment will be entered into the operating record of the facility This record will enable the operator of the facility to identify maintenance activities that occur at an above average frequency This in turn could identify a need to employ different material or equipment.

5.9.10 Closure and Postclosure Care Plans

A closure plan and a postclosure care plan may be required for the landfill facility These plans will incorporate certain operation and maintenance activities These activities will become part of the overall maintenance plan at the time of landfill closure

5.10 Site Feasibility Summary and Conclusions

This section provides a summary and conclusions of the Site Feasibility Study with respect to the construction of a hazardous waste landfill at this site.

Regulatory Criteria

Regulatory criteria that apply to siting a landfill in Colorado were described in Section 4 2 and will likely form the basis for siting a facility under the various regulatory scenarios RCRA as a permitted facility, RCRA as a CAMU, or an IRA under CERCLA.

Site-Specific Considerations and Limitations

Site-specific considerations and limitations were reviewed to evaluate the potential impact on construction of a hazardous waste landfill. Site-specific climate, topography, and surface hydrology should not impact landfill construction. Based on the sand channel subcrop maps developed as part of the Area FS, areas exist in the vicinity of the landfill siting area where Denver Formation channel sand units are in contact with the alluvium The subcropping sand units should be avoided if possible The hydrogeologic site considerations include maximizing the depth to groundwater and placing the landfill away from areas where groundwater flows radially The depth to groundwater is greatest at the center of the preferred site A groundwater mound exists between Sections 25 and 36 (Figure 4 32) Siting the landfill within the central portion of western Section 25 is preferred No geologic hazard or environmentally sensitive area considerations were noted in this study, but additional study may be required for siting and design. Slope failure within competent bedrock of shale, sandstone, lignite, or claystone is unlikely considering the proposed landfill geometry The settlement resulting from a 30-foot excavation and 35-foot fill above grade may be on the order of one-half inch and should not impact construction or O&M of the landfill This estimate should be reevaluated during design.

Conceptual Landfill Design Alternatives

Conceptual design alternatives were developed for liner systems, leachate collection and removal systems, gas management systems, final cover systems, and performance of an environmental monitoring system Six liner system alternatives were developed A leachate collection and removal system consisting of 12 inches of sand with a 200-foot drainage length and 2 percent slope was proposed Gas generation from landfilling of RMA waste is expected to be minimal Gases generated

5.10.1 Summary

The Site FS included a review and evaluation of waste types, volumes, and generation rates, regulatory criteria, site considerations and limitations, conceptual landfill design alternatives, evaluation and screening of the alternatives, facility layouts, material quantities and onsite availability, construction cost estimates and schedules, and operation and maintenance requirements Three conceptual landfill models were evaluated for this Site FS to account for the potential variation of waste volumes to be generated based on the selected remedial action alternative The siting of the proposed landfill footprints was based on site-specific considerations and limitations including topographic, geologic, and hydrogeologic conditions

5.10.2 Conclusions

The objective of this Site FS was to evaluate whether a RCRA Subtitle C hazardous waste landfill of sufficient capacity could constructed at the preferred site that would meet applicable federal, state, and local regulatory requirements The site-specific requirements were reviewed and evaluated in a logical sequence

Waste Data

Review and evaluation of the waste data yielded the following conclusions

- Contaminated materials that may be landfilled can be categorized as contaminated soil, soil and debris treated by caustic washing, soil treated by thermal desorption, and structural debris
- The landfill waste volume depends on the selected remedial action alternative For purposes of this report, waste volumes of 1,000,000 CY, 2,300,000 CY (the preferred sitewide alternative in the DAA), and 6,000,000 CY were used to account for projected minimum and maximum waste volumes
- The total landfill volumes used for three conceptual models included a 20 percent volume increase over the needed waste volume to account for operational cover (1,200,000 CY, 2,760,000 CY, and 7,200,000 CY, respectively)
- Waste generation rates were estimated to be in the range of 98,000 CY to 1,100,000 CY of material per year without a funding limit, and 37,000 to 280,000 CY of material per year assuming $100 million annual funding limit.

may be managed using a passive venting system consisting of a granular soil layer and grid array of collection pipes that will vent gases through the final cover system Four final cover systems alternatives were developed Environmental monitoring will be performed as part of the facility performance monitoring

Conceptual liner and final cover alternatives were evaluated for effectiveness using the HELP model and evaluated for cost by estimating the unit cost on a square foot basis Using the HELP Model to simulate the most likely construction quality scenario, all liners performed about equally For the worst-case scenarios, leachate infiltration is predicted to range from 0 04 to 0.5 inches per year (in/yr) The conceptual liner designs that included geosynthetic clay as the base layer (Liner System Nos 1 and 2) performed better than those with compacted clay or a tertiary geomembrane liner as the base The final screening of the conceptual liner designs should consider cost and constructability rather than potential performance because performance results for conceptual liner designs are so similar

The calculated infiltration results for all the final cover systems evaluated are similar and very low All the systems are predicted to perform well for the most likely scenario, with very limited water infiltrating through the cover For the worst-case scenario, infiltration ranged from 0 005 in/yr to 1 119 in/yr Cover System No 4 performed the best in worst-case scenario The similarity of performance results for the cover alternatives indicates that final screening of the cover systems should consider cost and constructability rather than potential performance

The total unit cost estimate for the liner systems ranged from $3 00 to $6 40 per square foot. Liner System No 1, which included a GCL instead of a compacted clay liner was the most cost-effective The total unit cost estimate for the cover systems ranged from $3 60 to $4 55 per square foot. Similarly, the cover system that uses the GCL was more cost-effective The sand drainage layer

performed better than the geonet for relatively the same cost, therefore, Cover System No 4 was more cost-effective and efficient

Evaluation and Screening of Alternatives

The overall landfill performance was evaluated using the HELP Model to assess the potential effectiveness of the cover and liner systems Cover System No 4 and Liner System No 1, both of which were the most cost-effective and predicted to perform well under worst-case conditions, were used to estimate the long-term leachate production from the landfill. Extremely small rates of potential release are predicted for both the most likely (2 6 x 10^{7} in/yr) and worst-case (1.6 x 10^{-3} in/yr) scenarios EPA's RITZ Model was used to estimate advective travel times of unsaturated flow produced by the leachate predicted from the HELP Model Potential travel times through the vadose zone are estimated at 8 29 x 10^{-4} feet per year (ft/yr) to 9.37 x 10^{-4} ft/yr, depending on the saturated hydraulic conductivity The landfill configurations being evaluated contain at least 10 feet of vadose zone between the base of the liner and the water table At the estimated rates, it would take from 1000 to 1200 years for soil water in the vadose zone to move downward 1 foot

Facility Layout

Conceptual facility layouts and material quantities were based on the three conceptual landfill volume requirements (1,200,000 CY, 2,760,000 CY, and 7,200,000 CY) and the site-specific considerations and limitations The areas of each footprint are as follows 19 acres (1,200,000 CY), 35 acres (2,750,000 CY), and 87 acres (7,200,000 CY) The excavation depth for each landfill scenario was assumed to be an average of 30 feet below the existing ground surface, with a maximum liner thickness of 5 feet. Conceptual Models 1 and 2 are placed within alluvium and both footprints avoid sand subcrops The base of Conceptual Model 3 is much larger than Models 1 and 2 and is placed within the weathered Denver Formation. Conceptual Model 3 is cut into subcropping sand Units A and 1U Although avoidance of the subcropping sand units is preferable, it is only possible with Conceptual Models 1 and 2 The excavation sideslopes were assumed to be 3H.1V to calculate airspace volumes below grade A sideslope of 6H 1V was used to calculate the airspace above grade

To proceed with final design using a 6H 1V sideslope, an appropriate erosion control demonstration would be required

The slope stability evaluation indicated that the planned landfill can be constructed at the site if a final geotechnical investigation is performed and the recommendations contained therein are addressed in the final landfill design. The final investigation should refine and expand upon the testing and analyses presented in this report, and consider in its analyses any changes from these conceptual models

Material Quantities and Availability

Material quantities were estimated for low-permeability soils and structural fill soils used in landfill liner and cover system components The quantities of soils required for landfill construction were then compared to estimated volumes of onpost materials Conceptual Models 1, 2, and 3 required 270,000 CY, 510,000 CY, and 1,235,000 CY of clay soil, respectively, and 296,000 CY, 640,000 CY, and 1,635,000 CY of structural fill soil, respectively

The surface area to be lined was calculated for each conceptual landfill model assuming an excavation depth of 30 feet with sideslopes of 3H 1V The surface area for final cover was calculated assuming a waste height of 35 feet above grade and sideslopes of 6H 1V Based on these assumptions, the estimated surface area to be lined and the surface area to be covered are approximately the same Both the liner and cover areas for Conceptual Model 1 are 850,000 square feet, for Conceptual Model 2, both areas are 1,600,000 square feet, and for Conceptual Model 3, both the liner and cover areas are 3,900,000 square feet.

Approximately 11,700,000 CY of low-permeability soil and 9,069,000 CY of structural fill soil have been identified at RMA during borrow area investigations Additional low-permeability soil and structural fill soil may be available from the landfill excavation. Based on the estimated volumes of

onpost soil from borrow area and the landfill excavation, it appears that sufficient onpost soil exists to meet the construction requirements for even the largest landfill (Conceptual Model 3)

Construction Cost Estimates and Schedules

Cost estimates for construction and annual operation and maintenance for the three conceptual landfill models were prepared to be accurate within plus 50 percent to a minus 30 percent. Based on the total estimated costs (shown in Table 5.11), the estimated construction cost per cubic yard of waste disposal capacity for Conceptual Models 1, 2, and 3 are $12.50 per CY, $10.00 per CY, and $9 00 per CY, respectively The estimated total construction cost for Conceptual Models 1, 2, and 3 are $12,500,000, $22,500,00, and $52,500,000, respectively If landfill space is constructed on an annual basis as needed, then landfill construction costs would increase from the estimates presented

Annual O&M costs were prepared at a plus 50 percent to minus 30 percent range Estimates of yearly O&M costs were made for each conceptual model using both restricted and unrestricted funding The landfill life and average yearly O&M costs for restricted funding for Conceptual Models 1, 2, and 3 are 12 years and $1,487,000/yr, 10 years and $2,440,000/yr, and 16 years and $3,109,000/yr, respectively The landfill life and average yearly O&M costs for the unrestricted funding scenario for Conceptual Models 1, 2, and 3 are 4.5 years and $2,294,000/yr, 2 5 years and $5,820,000/yr, and 9 years and $4,460,000/yr, respectively

The lowest O&M costs, $7 per CY, occur for Conceptual Model 3 with unrestricted funding The highest O&M costs, $18 per CY occur for Conceptual Model 1 with restricted funding

A conceptual construction schedule for cell development of an approximate 200,000 CY module that could be applied to any of the three conceptual landfill models was prepared (Figure 5 10). The 200,000 CY module would take approximately 34 weeks to prepare

Operation and Maintenance Plans

A comprehensive site operating plan should be prepared for the facility and should include the following elements

- Construction and CQC requirements
- Daily operations
- Periodic operational activities
- Specific plans

Additional necessary plans include waste analysis, security, inspection, personnel training, preparedness and prevention, contingency and emergency procedures, manifest system, recordkeeping and reporting, maintenance, and closure and postclosure care

Based on the results of the Site FS presented in this report, it is feasible to construct a RCRA Subtitle C hazardous waste landfill of sufficient capacity at the preferred site that would meet the applicable federal, state, and local regulatory requirements

Table 5.1: Waste Volume Estimates Rocky Mountain Arsenal Site Feasibility Study

Estimated Waste Volume by Type	Remedial Action Alternative				
	Caps/Covers	Landfill/Caps	Landfill	Consolidation/Caps/ Treatment/Landfill	Caps/Treatment/Landfill
Contaminated Soil	260 000	2,100 000	3,600,000	880,000	3,100,000
Treated Soil/Debris Caustic Washing	4,000	5,000	7,000	5,000	7,000
Treated Soil Thermal Desorption	0	0	0	180,000	1,100,000
Structural Debris Landfilled	180,000	180,000	180,000	180,000	180,000
Total Volume Landfilled	440,000	2,300,000	3,800,000	1,200,000	4,400,000

All amounts are in cubic yards

Table 5.2: Waste Generation Rate Estimates Rocky Mountain Arsenal Site Feasibility Study

Estimated Waste Volume by Type	Remedial Action Alternative				
	Caps/Covers	Landfill/Caps	Landfill	Consolidation/Caps/ Treatment/Landfill	Caps/Treatment/Landfill
Total Volume Landfilled (CY)	440,000	2,300,000	3,800,000	1,200,000	4,400,000
No Funding Limit Scenario					
Remediation Time/Landfill Operations	7 years/4 5 years	6 years/2 5 years	7 years/3 5 years	9 years/6 years	14 years/9 years
Annual Generation Rate (CY/year)	98,000	920,000	1,100,000	200,000	490,000
Daily Generation Rate (CY/day)	400	3,500	4,200	800	1,900
Funding Limit Scenario*					
Remediation Time/Landfill Operation with Restriction*	17 years/12 years	16 years/10 years	22 years/16 5 years	17 years/13 years	28 years/16 years
Annual Generation Rate (CY/year)*	37,000	230,000	230,000	92,000	280,000
Daily Generation Rate (CY/day)*	100	900	900	400	1,100

CY Cubic yards

* Based on $100 million annual funding limit for overall RMA remediation activities

Table 5.3: Liner System Effectiveness Evaluation
HELP Model Input Parameters

Layer Number	HELP Model Layer Type	Layer Thickness (inches)	HELP Model Default Material Type	Porosity	Field Capacity	Wilting Point	Drainage Length (feet)	Drainage Slope (%)
Liner System 1								
1	2 (drainage)	12	1 (clean sand)	0.417	0.045	0.018	200	2
2	4 (geomembrane)	0.06	35 (HDPE)	0	0	0		
3	3 (barrier)	0.25	17 (geosynthetic clay)	0.75	0.747	0.4		
4	2 (drainage)	0.2	20 (Geonet)	0.85	0.01	0.005	200	2
5	4 (geomembrane)	0.06	35 (HDPE)	0	0	0		
6	3 (barrier)	0.25	17 (geosynthetic clay)	0.75	0.747	0.4		
Liner System 2								
1	2 (drainage)	12	1 (clean sand)	0.417	0.045	0.018	200	2
2	4 (geomembrane)	0.06	35 (HDPE)	0	0	0		
3	3 (barrier)	36	16 (compacted clay)	0.427	0.418	0.367		
4	2 (drainage)	0.2	20 (Geonet)	0.85	0.01	0.005	200	2
5	4 (geomembrane)	0.06	35 (HDPE)	0	0	0		
6	3 (barrier)	0.25	17 (geosynthetic clay)	0.75	0.747	0.4		
Liner System 3								
1	2 (drainage)	12	1 (clean sand)	0.417	0.045	0.018	200	2
2	4 (geomembrane)	0.06	35 (HDPE)	0	0	0		
3	3 (barrier)	0.25	17 (geosynthetic clay)	0.75	0.747	0.4		
4	2 (drainage)	0.2	20 (Geonet)	0.85	0.01	0.005	200	2
5	4 (geomembrane)	0.06	35 (HDPE)	0	0	0		
6	3 (barrier)	36	16 (compacted clay)	0.427	0.418	0.367		
Liner System 4								
1	2 (drainage)	12	1 (clean sand)	0.417	0.045	0.018	200	2
2	4 (geomembrane)	0.06	35 (HDPE)	0	0	0		
3	3 (barrier)	0.25	17 (geosynthetic clay)	0.75	0.747	0.4		
4	2 (drainage)	0.2	20 (Geonet)	0.85	0.01	0.005	200	2
5	4 (geomembrane)	0.06	35 (HDPE)	0	0	0		
6	1 (vert. perm.)	36	16 (compacted clay)	0.427	0.418	0.367		
7	4 (geomembrane)	0.04	35 (HDPE)	0	0	0		

Table 5.3 (continued)

Layer Number	HELP Model Layer Type	Layer Thickness (inches)	HELP Model Default Material Type	Porosity	Field Capacity	Wilting Point	Drainage Length (feet)	Drainage Slope (%)
Liner System 5								
1	2 (drainage)	12	1 (clean sand)	0.417	0.045	0.018	200	2
2	4 (geomembrane)	0.06	35 (HDPE)	0	0	0		
3	3 (barrier)	36	16 (compacted clay)	0.427	0.418	0.367		
4	2 (drainage)	0.2	20 (Geonet)	0.85	0.01	0.005	200	2
5	4 (geomembrane)	0.06	35 (HDPE)	0	0	0		
6	3 (barrier)	36	16 (compacted clay)	0.427	0.418	0.367		
Liner System 6								
1	2 (drainage)	12	1 (clean sand)	0.417	0.045	0.018	200	2
2	4 (geomembrane)	0.06	35 (HDPE)	0	0	0		
3	3 (barrier)	36	16 (compacted clay)	0.427	0.418	0.367		
4	2 (drainage)	0.2	20 (Geonet)	0.85	0.01	0.005	200	2
5	4 (geomembrane)	0.06	35 (HDPE)	0	0	0		
6	3 (barrier)	36	16 (compacted clay)	0.427	0.418	0.367		
7	4 (geomembrane)	0.04	35 (HDPE)	0	0	0		

HDPE High density polyethylene
HELP Hydrologic Evaluation of Landfill Performance
Vert Perm Vertical permeability
% Percent

Table 5.4: Landfill Liner Effectiveness Evaluation
HELP Model Results

Liners	Estimated average annual leachate passing through liner with approximately 1 foot of head on top					
	Most Likely (inches/yr)	Worst-Case (inches/yr)	Most Likely (ft^3/yr)	Worst-Case (ft^3/yr)	Most Likely (gallons/yr)	Worst-Case (gallons/yr)
System						
1	2.5×10^{-6}	0.04	0.397	5,973	2.97	44,678
2	2.5×10^{-6}	0.04	0.397	5,972	2.97	44,671
3	2.5×10^{-6}	0.51	0.398	82,073	2.98	613,906
4	2.5×10^{-6}	0.51	0.398	82,073	2.98	613,906
5	2.5×10^{-6}	0.51	0.398	81,015	2.98	605,992
6	2.5×10^{-6}	0.51	0.398	81,012	2.98	605,970

Most likely case assumes one pinhole per acre (manufacturing defect), three construction defects per acre, and good geomembrane contact

Worst-case assumes one pinhole per acre, ten constructions defects per acre, and worst-case geomembrane contact

Volume estimates (ft^3/yr and gallons/yr) were calculated assuming 44 acres as the landfill area

ft^3 Cubic feet
yr Year

Table 5.5: Final Landfill Cover Effectiveness Evaluation
HELP Model Input Parameters

Layer Number	HELP Model Layer Type	Layer Thickness (inches)	HELP Model Default Material Type	Porosity	Field Capacity	Wilting Point	Drainage Length (feet)	Drainage Slope (%)
Cover System 1								
1	1 (vert perm)	8	6 (sandy loam)	0 453	0 19	0 085		
2	1 (vert perm)	52	8 (loam)	0 463	0 232	0 116		
3	2 (drainage)	0 2	20 (Geonet)	0 85	0 01	0 005	200	2
4	4 (geomembrane)	0 06	35 (HDPE)	0	0	0		
5	3 (barrier)	30	16 (compacted clay)	0 427	0 418	0 367		
Cover System 2								
1	1 (vert perm)	8	6 (sandy loam)	0 453	0 19	0 085		
2	1 (vert perm)	52	8 (loam)	0 463	0 232	0 116		
3	2 (drainage)	0 2	20 (Geonet)	0 85	0 01	0 005	200	2
4	4 (geomembrane)	0 06	35 (HDPE)	0	0	0		
5	3 (barrier)	0 25	17 (geosynthetic clay)	0 427	0 418	0 367		
Cover System 3								
1	1 (vert perm)	8	6 (sandy loam)	0 453	0 19	0 085		
2	1 (vert perm)	52	8 (loam)	0 463	0 232	0 116		
3	2 (drainage)	12	21 (gravel)	0 85	0 01	0 005	200	2
4	4 (geomembrane)	0 06	35 (HDPE)	0	0	0		
5	3 (barrier)	30	16 (compacted clay)	0 427	0 418	0 367		

Table 5.5 (continued)

Layer Number	HELP Model Layer Type	Layer Thickness (inches)	HELP Model Default Material Type	Porosity	Field Capacity	Wilting Point	Drainage Length (feet)	Drainage Slope (%)
Cover System 4								
1	1 (vert perm)	8	6 (sandy loam)	0 453	0 19	0 085		
2	1 (vert perm)	52	8 (loam)	0 463	0 232	0 116		
3	2 (drainage)	12	21 (gravel)	0 85	0 01	0 005	200	2
4	4 (geomembrane)	0 06	35 (HDPE)	0	0	0		
5	3 (barrier)	0 25	17 (geosynthetic clay)	0.427	0 418	0 367		

HDPE High density polyethylene
HELP Hydrologic Evaluation of Landfill Performance
Vert Vertical
Perm Permeability
% Percent

Table 5.6: Landfill Final Cover Effectiveness Evaluation
HELP Model Results

Covers	Estimated Average Annual Cover Infiltration from 100 Years of Denver Weather					
	Most Likely (inches/yr)	Worst-Case (inches/yr)	Most Likely (ft^3/yr)	Worst-Case (ft^3/yr)	Most Likely (gallons/yr)	Worst-Case (gallons/yr)
System						
1	$7\ 3 \times 10^{-6}$	1 12	1 161	178,651	8 68	1,336,310
2	$2\ 8 \times 10^{-6}$	0 04	0 439	5,650	3 28	42,262
3	4.2×10^{-6}	0 08	0 664	12,836	4 97	96,013
4	$9\ 6 \times 10^{-7}$	0 005	0 154	743	1 15	5,558

Most likely case assumes one pinhole per acre (manufacturing defect), three construction defects per acre, and good geomembrane contact.

Worst-case assumes one pinhole per acre, ten constructions defects per acre, and worst-case geomembrane contact.

Volume estimates (ft^3/yr and gallons/yr) were calculated assuming 44 acres as the landfill area

ft^3 Cubic feet
yr Year

Table 5.7: Cost Evaluation of Landfill Liner Systems

Liner Component	Estimated Unit Cost $/ft²*	Unit Cost Reference
Liner System No. 1. Double Composite Liner With GCLs		
LCRS	0.50	GNRA
60-mil HDPE Primary Geomembrane	0.45	Polyflex
Geosynthetic Clay Liner	0.55	CETCO
Geonet	0.50	GNRA
60-mil HDPE Secondary Geomembrane	0 45	Polyflex
Geosynthetic Clay Liner	0.55	CETCO
Net unit cost	3.00	
Liner System No 2: Double Composite Liner with GCL and GCL		
LCRS	0.50	GNRA
60-mil HDPE Primary Geomembrane	0 45	Polyflex
3-foot-thick compacted clay/amended soil	1.80	GNRA
Geotextile	0.50	
Geonet	0.50	GNRA
60-mil HDPE Secondary Geomembrane	0 45	Polyflex
Geosynthetic Clay Liner	0.55	CETCO
Net Unit Cost	4.75	
Liner System No. 3: Double Composite Liner with GCL and GCL		
LCRS	0 50	GNRA
60-mil HDPE Primary Geomembrane	0 45	Polyflex
Geosynthetic Clay Liner	0 55	CETCO
Geonet	0.50	GNRA
60-mil HDPE Secondary Geomembrane	0 45	Polyflex
3-foot-thick compacted clay/amended soil	1 80	GNRA
Net Unit Cost	4.25	
Liner System No 4 Double Composite Liner with GCL and GCL with Tertiary FML		
LCRS	0 50	GNRA
60-mil HDPE Primary Geomembrane	0.45	Polyflex
Geosynthetic Clay Liner	0 55	CETCO
Geonet	0 50	GNRA
60-mil HDPE Secondary Geomembrane	0.45	Polyflex
3-foot-thick compacted clay/amended soil	1.80	GNRA
40-mil HDPE Tertiary Liner	0 40	
Net Unit Cost	4 65	

Table 5.7 (continued)

Liner Component	Estimated Unit Cost $/ft²*	Unit Cost Reference
Liner System No. 5: Double Composite Liner with CCLs		
LCRS	0 50	GNRA
60-mil HDPE Primary Geomembrane	0.45	Polyflex
3-foot-thick compacted clay/amended soil	1.80	GNRA
Geotextile	0 50	
Geonet	0 50	GNRA
60-mil HDPE Secondary Geomembrane	0 45	Polyflex
3-foot-thick compacted clay/amended soil	1 80	GNRA
Net Unit Cost	6.00	
Liner System No 6: Double Composite Liner with CCLs and Tertiary FML		
LCRS	0 50	GNRA
60-mil HDPE Primary Geomembrane	0 45	Polyflex
3-foot-thick compacted clay/amended soil	1.80	GNRA
Geotextile	0 50	
Geonet	0 50	GNRA
60-mil HDPE Secondary Geomembrane	0 45	Polyflex
3-foot-thick compacted clay/amended soil	1 80	GNRA
40-mil HDPE Tertiary Liner	0 40	
Net Unit Cost	6 40	

All costs are in 1995 dollars

CETCO Geosynthetic liner manufacturer
FML Flexible membrane liner
GCL Geosynthetic clay liner
GNRA G N Richardson and Associates
HDPE High-density polyethylene
LCRS Leachate collection and recovery system
Polyflex Geomembrane manufacturer

* Liner price does not include cost of 1-foot-thick prepared subgrade

Table 5.8: Cost Evaluation of Landfill Cover Systems

Cover Component		Unit Cost $/ft²*	Unit Cost Reference
Cover System No. 1			
6-foot Erosion Control Layer		1.60	GNRA
Geotextile		0 50	
Geonet		0 50	GNRA
60-mil HDPE		0 45	Polyflex
2 5-foot compaced clay/amended soil		1 50	GNRA
	Net unit cost	4 55	
Cover System No. 2			
6-foot Erosion Control Layer		1 60	GNRA
Geotextile		0.50	
Geonet		0.50	GNRA
60-mil HDPE		0 45	Polyflex
Geosynthetic Clay Liner		0 55	CETCO
	Net Unit Cost	3 60	
Cover System No. 3			
6-foot Erosion Control Layer		1 60	GNRA
Geotextile		0 50	
1-foot Sand Capillary/Drainage Layer		0 50	GNRA
60-mil HDPE		0 45	Polyflex
2 5-foot compaced clay/amended soil		1 50	GNRA
	Net Unit Cost	4 55	
Cover System No. 4			
6-foot Erosion Control Layer		1 60	GNRA
Geotextile		0 50	
1-foot Sand Capillary/Drainage Layer		0 50	GNRA
60-mil HDPE		0 45	Polyflex
Geosynthetic Clay Liner		0.55	CETCO
	Net Unit Cost	3.60	

All costs are 1995 dollars

CETCO	Geosynthetic liner manufacturer
GNRA	G N Richardson & Associates
HDPE	High-density polyethylene
Polyflex	Geomembrane manufacturer

* Cap price does not include cost of structural fill for grading

Table 5.9: Overall Landfill Cover and Liner Evaluation
Potential Leachate Release

System	Estimate Average Annual Leachate Passing Through Liner					
	Most Likely (inches/yr)	Worst-Case (inches/yr)	Most Likely (ft^3/yr)	Worst-Case (ft^3/yr)	Most Likely (gallons/yr)	Worst-Case (gallons/yr)
Cover System No 4						
Liner System No 1	$2\ 6 \times 10^{-7}$	$1\ 6 \times 10^{-3}$	0 06	260	0.3	2000

ft^3 Cubic feet
yr Year

Table 5.10: Estimated Soil Material Requirements for Conceptual Landfill Models

Soil Use	Depth (inches)	Acceptable Soil Type	Estimated Volume Required (CY) Conceptual Model No 1	Conceptual Model No 2	Conceptual Model No 3
Cover					
Vegetative layer	8	Sandy loam	21,000	40,000	100,000
Water storage/frost protection	52	Loam	140,000	260,000	630,000
Barrier	30	Clay	80,000	150,000	365,000
Subgrade	12	Structural fill	32,000	60,000	145,000
Liner					
Protective layer	12	Structural fill	32,000	60,000	145,000
Primary barrier	36	Clay	95,000	180,000	435,000
Secondary barrier	36	Clay	95,000	180,000	435,000
Subgrade	12	Structural fill	32,000	60,000	145,000
Operational Cover		Structural fill	200,000	460,000	1,200,000
Total Liner and Cover					
Sandy loam		NA	21,000	40,000	100,000
Loam		NA	140,000	260,000	630,000
Clay		NA	270,000	510,000	1,235,000
Structural fill		NA	296,000	640,000	1,635,000

CY Cubic yard
NA Not applicable

21907 703030
0403040595 RAF

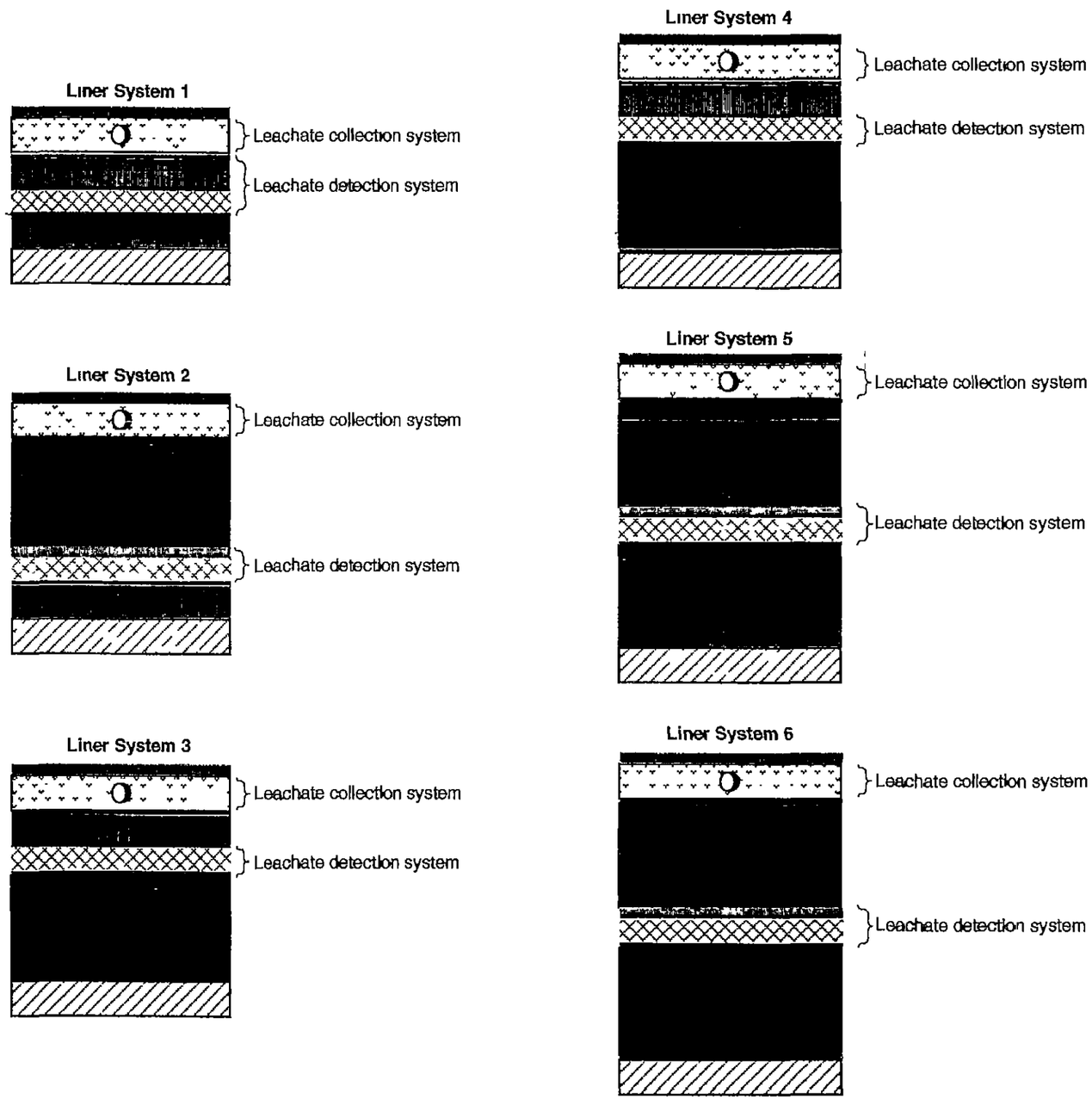
Table 5.11: Summary of Estimated Construction Cost

Item Description	Conceptual Model 1	Conceptual Model 2	Conceptual Model 3
Support Construction			
Drainage	$8,000	$13,000	$20,000
Storm-water Detention	$50,000	$100,000	$150,000
Fencing	$57,000	$77,000	$113,00
Maintenance Building	$150,000	$150,000	$150,000
Office/Decontamination Building	$30,000	$30,000	$30,000
Roads	$40,000	$40,000	$40,000
Parking	$2,000	$2,000	$2,000
Leachate Management System	$200,000	$400,000	$800,000
Groundwater Monitoring System	$120,000	$156,000	$240,000
Cell Construction			
Excavation	$1,892,000	$3,036,000	$6,270,000
Sumps, Header Pipe, and Pumps	$62,000	$68,000	$75,000
Subgrade Prep	$22,000	$42,000	$101,000
Liner System	$4,038,000	$7,600,000	$18,525,000
Protective Cover	$228,000	$427,000	$1,039,000
Embankment	$287,000	$426,000	$686,000
Cover Vent System	$855,000	$1,602,000	$3,897,000
Cover System	$3,868,000	$7,280,000	$17,745,000
Mobilization/Demobilization	$233,000	$433,000	$1,041,000
Construction QA/QC	$350,000	$650,000	$5,561,000
Total	**$12,500,000**	**$22,500,000**	**$52,500,000**

QA/QC Quality assurance/quality control

Table 5.12: Operation & Maintenance Cost Summary Table

Conceptual Model	Landfill Life In Years	Funding	Yearly O&M Costs			Total O&M Cost Per Cubic Yard
			Minimum	Maximum	Average	
1	12	Restricted	$1,150,000	$2,374,000	$1,487,000	$18
1	4 5	Unrestricted	$2,035,000	$2,991,000	$2,294,000	$11
2	10	Restricted	$1,994,000	$3,442,000	$2,440,000	$11
2	2 5	Unrestricted	$4,979,000	$7,429,000	$5,820,000	$8
3	16	Restricted	$2,364,000	$4,436,000	$3,109,000	$8
3	9	Unrestricted	$3,695,000	$6,159,000	$4,460,000	$7



Explanation

Layer	Thickness
Granular drainage with perforated collection pipe	12 inches
Compacted clay/ amended soil	36 inches
Prepared subgrade	12 inches
High-density polyethylene (HDPE)	60 mil for primary/secondary geomembrane 40 mil for tertiary geomembrane
Geonet	200 mil
Geosynthetic clay liner	250 mil
Geotextile	Variable

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Commerce City Colorado

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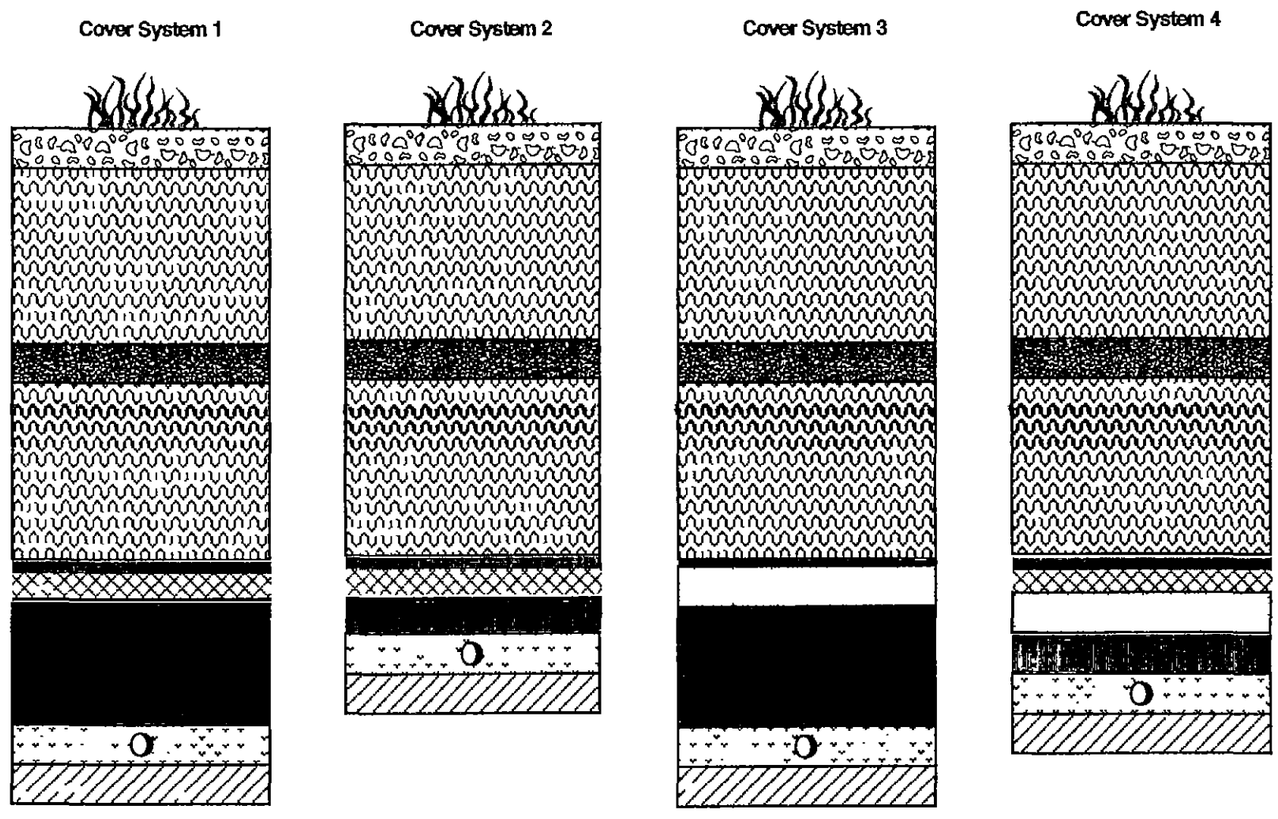
Figure 5 1

Liner System Alternatives

RMA 1245 4/95/95 NLM



Explanation

Layer Composition	Thickness
Soil/gravel admixture	8 inches
Water storage/frost protection	52 inches
Animal intrusion layer	6-12 inches
Granular/drainage layer	12 inches
Compacted clay/ amended soil	30 inches
Granular soil-gas collection with perforated vent pipe	12 inches
Intermediate cover/ grading fill	Variable
High density polyethylene (HDPE)	60 mil for primary/secondary geomembrane 40 mil for tertiary geomembrane
Geonet	200 mil
Geosynthetic clay liner	250 mil
Geotextile	Variable

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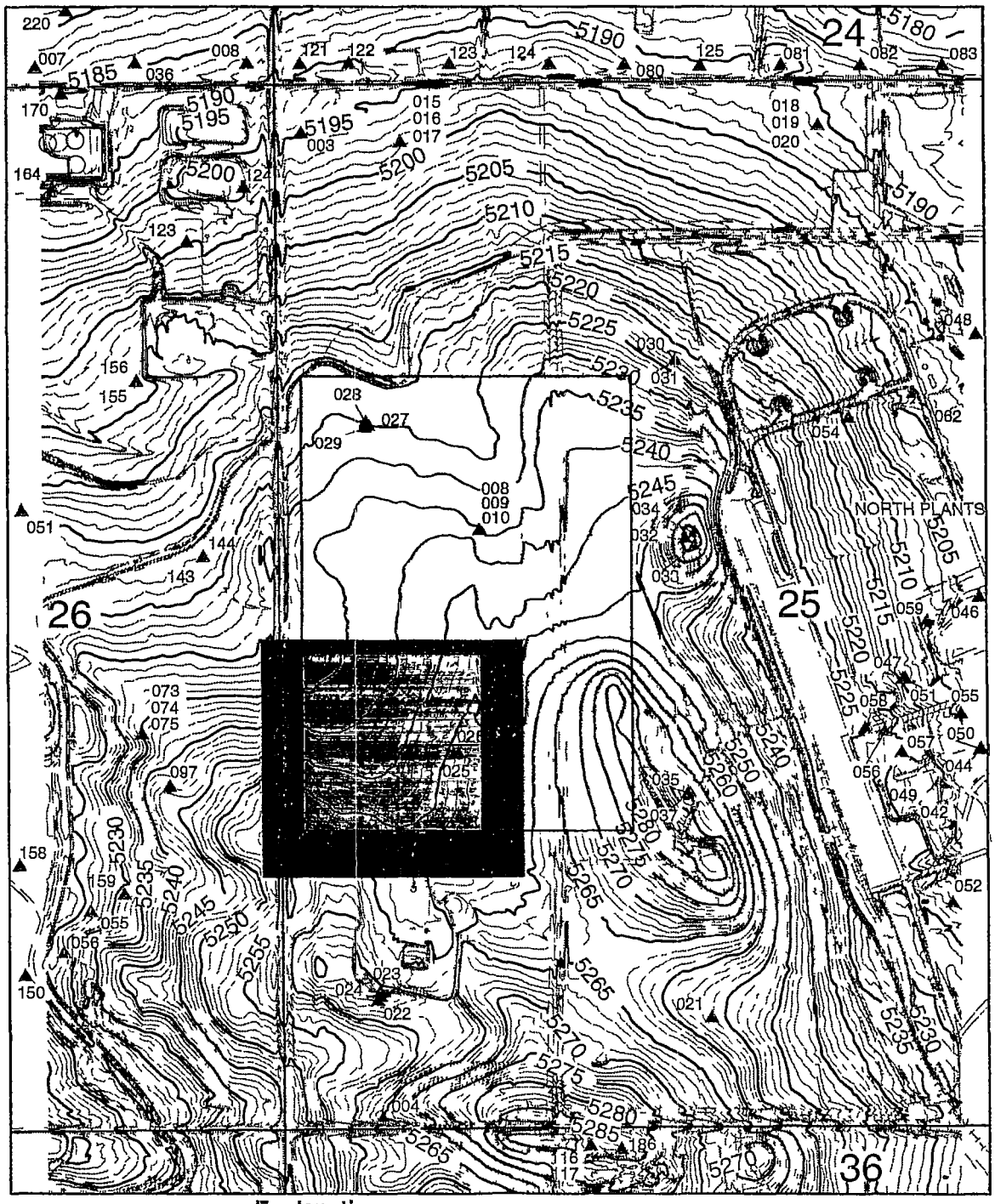
Figure 5 2

Cover System Alternatives

RMA 1245 1 3/30/9* NLM



Explanation

Approximate Waste Footprint for Conceptual Model 1
Area = 900 ft x 900 ft
Waste to be landfilled = 1 0 million cubic yards

Approximate Waste Footprint for Conceptual Model 2
Area = 1200 ft x 1300 ft
Waste to be landfilled = 2 3 million cubic yards

Approximate Waste Footprint for Conceptual Model 3
Area = 1650 ft x 2300 ft
Waste to be landfilled = 6 0 million cubic yards

038 Monitoring well

Surface Topography (1-foot contour interval)

Unpaved roadway

Surface drainage

25 Section number

N

0 400 800
Scale in feet

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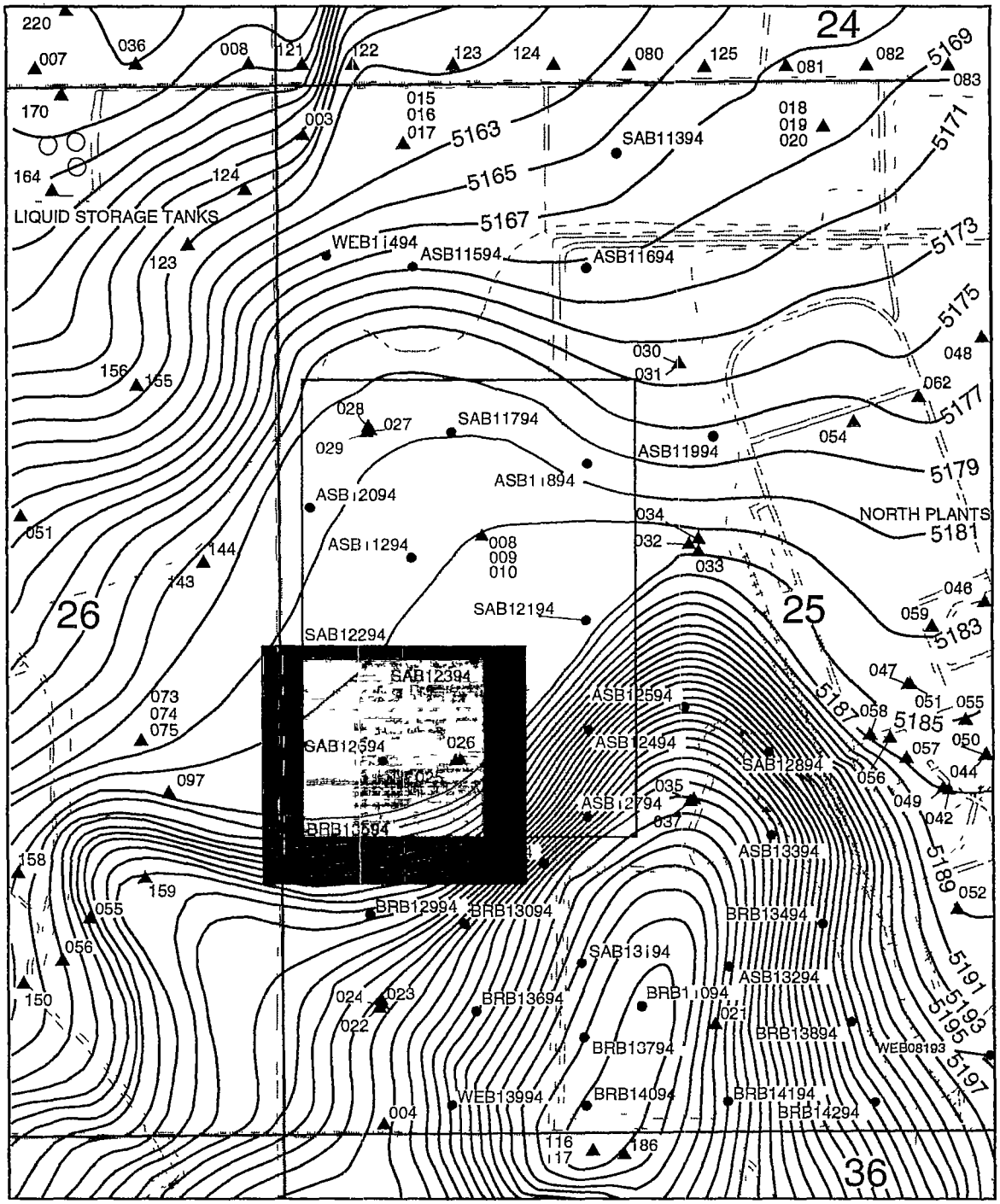
Figure 5 3

Conceptual Landfill Footprints and Surface Topography



Explanation

- Approximate Waste Footprint for Conceptual Model 1
- Approximate Waste Footprint for Conceptual Model 2
- Approximate Waste Footprint for Conceptual Model 3
- 038 — Water-level monitoring well location
- BRB11094 — Borehole location
- Water-level elevation (2-foot contour interval)
- Unpaved roadway
- Surface drainage
- 25 — Section number

N

0 400 800
Scale in feet

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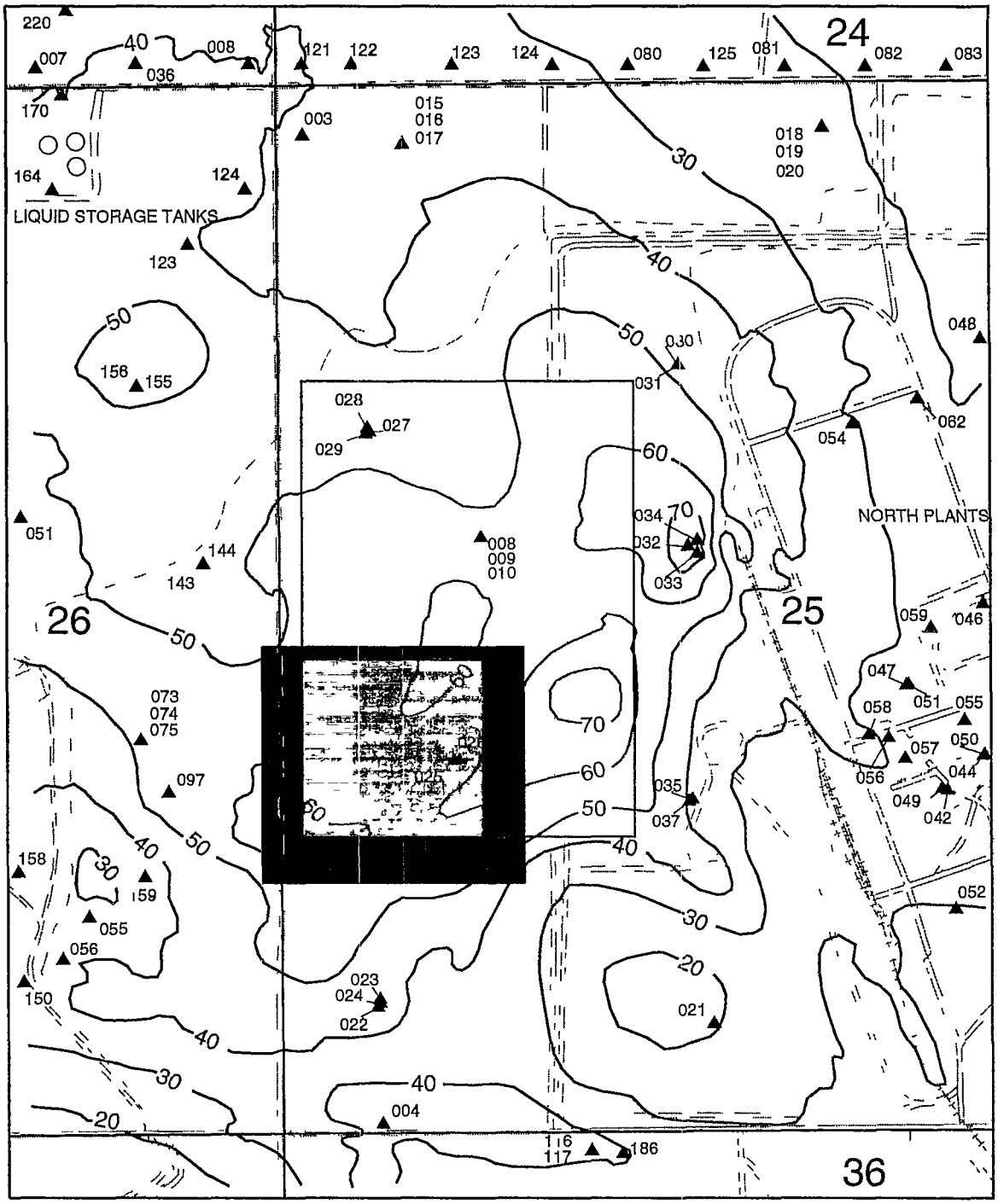
Figure 5 4

Conceptual Landfill Footprints and Groundwater Elevation Map

RMA/21907715 4/595 LDZ



Explanation

- Approximate Waste Footprint for Conceptual Model 1
- Approximate Waste Footprint for Conceptual Model 2
- Approximate Waste Footprint for Conceptual Model 3
- 038 Monitoring well
- Depth to groundwater (10-foot contour interval)
- Unpaved roadway
- Surface drainage
- 25 Section number

N

0 400 800
Scale in feet

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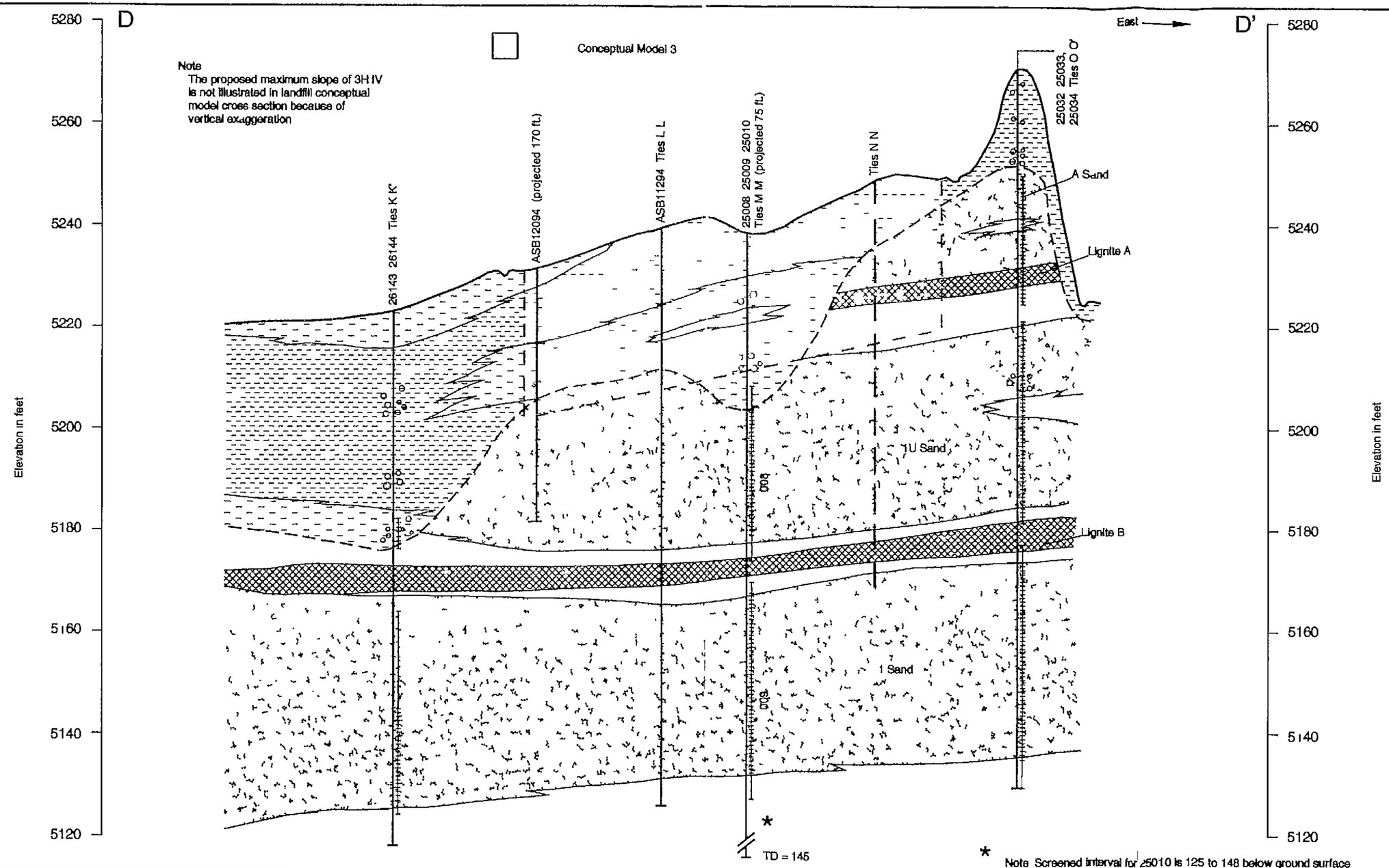
Figure 5 5

Conceptual Landfill Footprints and Depth to Groundwater



EXPLANATION

Alluvium

- Clay sandy clay (CL CH)
- Sand,silty sand clayey sand (SP SM SC SW)
- Gravel

Bedrock (Denver Formation)

- Lignite/Lignitic Claystone
- Sandstone
- Claystone with interbedded siltstone lignite and sandstone (see note)

Top of weathered bedrock

SAB-1 194 — Boring identification

29025 — Monitoring well(s) identification

Sand pack

101 — Screened interval with well number

TD = Total depth in feet

20 / 0 — 0 / 400

Scale in feet
Vertical exaggeration = 20x

Notes
1 In areas of no lithologic control lateral extent of Denver Formation sandstone lignite and claystone is unknown
2 Cross section location map illustrated in Figure 4 17

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Figure 5 6

Conceptual Model 3 through Geologic Cross Section D-D'

Note
The proposed maximum slope of 3H IV is not illustrated in landfill conceptual model cross section because of vertical exaggeration

F — F'

East →

Elevation in feet

5290, 5280, 5260, 5240, 5220, 5200, 5180, 5160, 5140, 5130

26097 Ties K K'
SAB12694 Ties L L
25025 25026 Ties M M'
ASB12794 Ties N N
25035 25037 Ties O-O
SAB12894 Ties P P
25058
25056
25055
25043
25007

Conceptual Model 1
Conceptual Model 2
Conceptual Model 3

A Sand
Lignite A?
Lignite A
1U Sand
Lignite B
1 Sand
TD = 102

EXPLANATION

Alluvium

- Clay sandy clay (CL,CH)
- Sand silty sand clayey sand (SP SM SC SW)
- Gravel

Bedrock (Denver Formation)

- Lignite/Lignitic claystone
- Sandstone
- Claystone with interbedded siltstone lignite and sandstone (see note)

Top of weathered bedrock

SAB1 194 — Boring identification

29025 — Monitoring well(s) identification
Sand pack
101 — Screened interval with well number

TD = Total depth in feet

20
0
0 400
Scale in feet
Vertical exaggeration = 20x

Notes
1 In areas of no lithologic control lateral extent of Denver Formation sandstone lignite and claystone is unknown
2 Cross section location map illustrated in Figure 4 17

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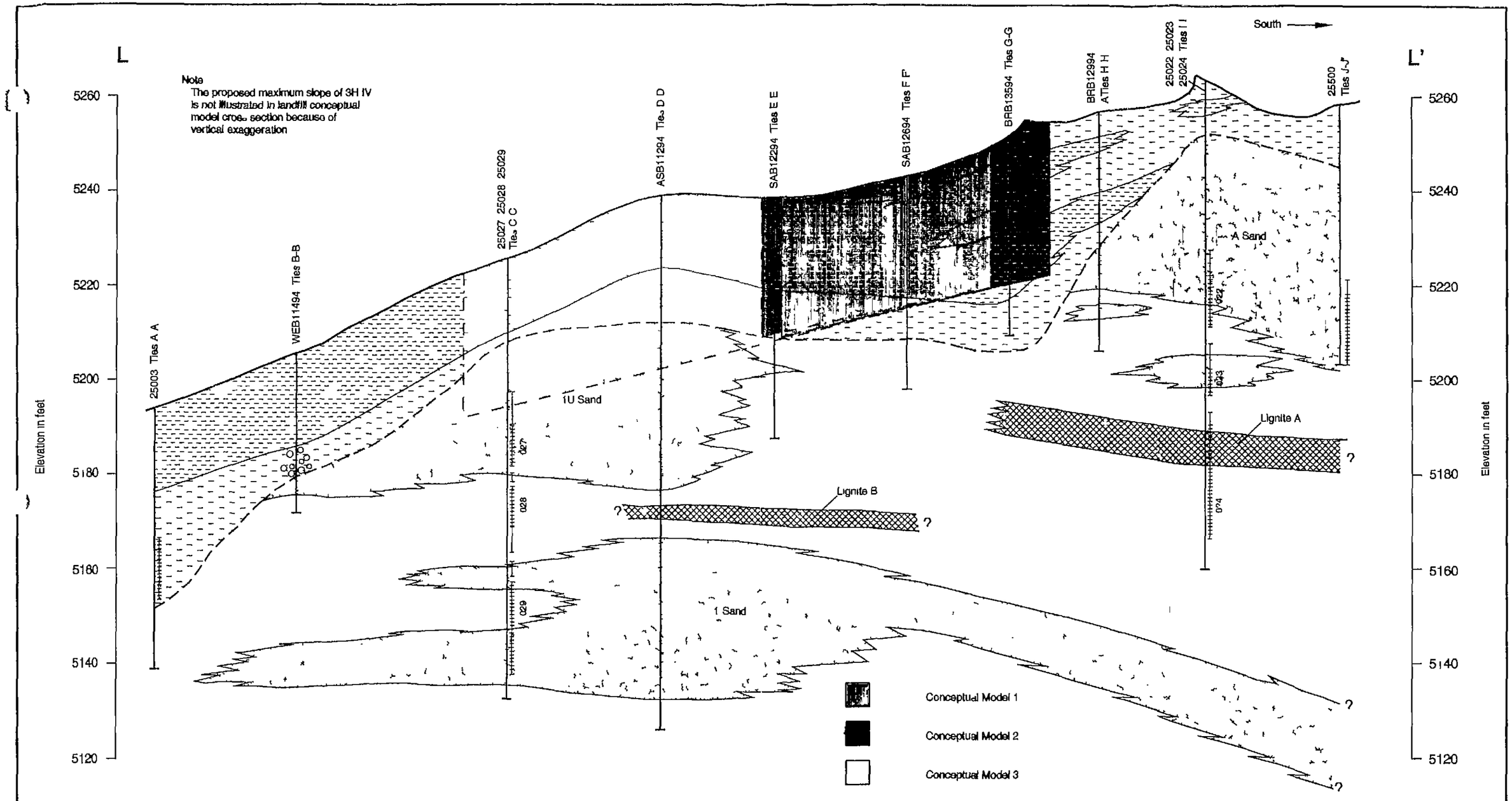
Figure 5 7

Conceptual Models 1 to 3 through Geologic Cross Section F F



EXPLANATION

Alluvium

- Clay sandy clay (CL CH)
- Sand silty sand clayey sand (SP SM SC SW)
- Gravel

Bedrock (Denver Formation)

- Lignite/Lignitic claystone
- Sandstone
- Claystone with interbedded siltstone lignite, and sandstone (see note)

Top of weathered bedrock

SAB11194 — Boring Identification

29025 — Monitoring well(s) Identification

Sand pack

Screened interval with well number

TD = Total depth in feet

20 / 0 — 0 / 400

Scale in feet
Vertical exaggeration = 20x

Notes
1. In areas of no lithologic control lateral extent of Denver Formation sandstone lignite and claystone is unknown
2. Cross section location map illustrated in Figure 4 17

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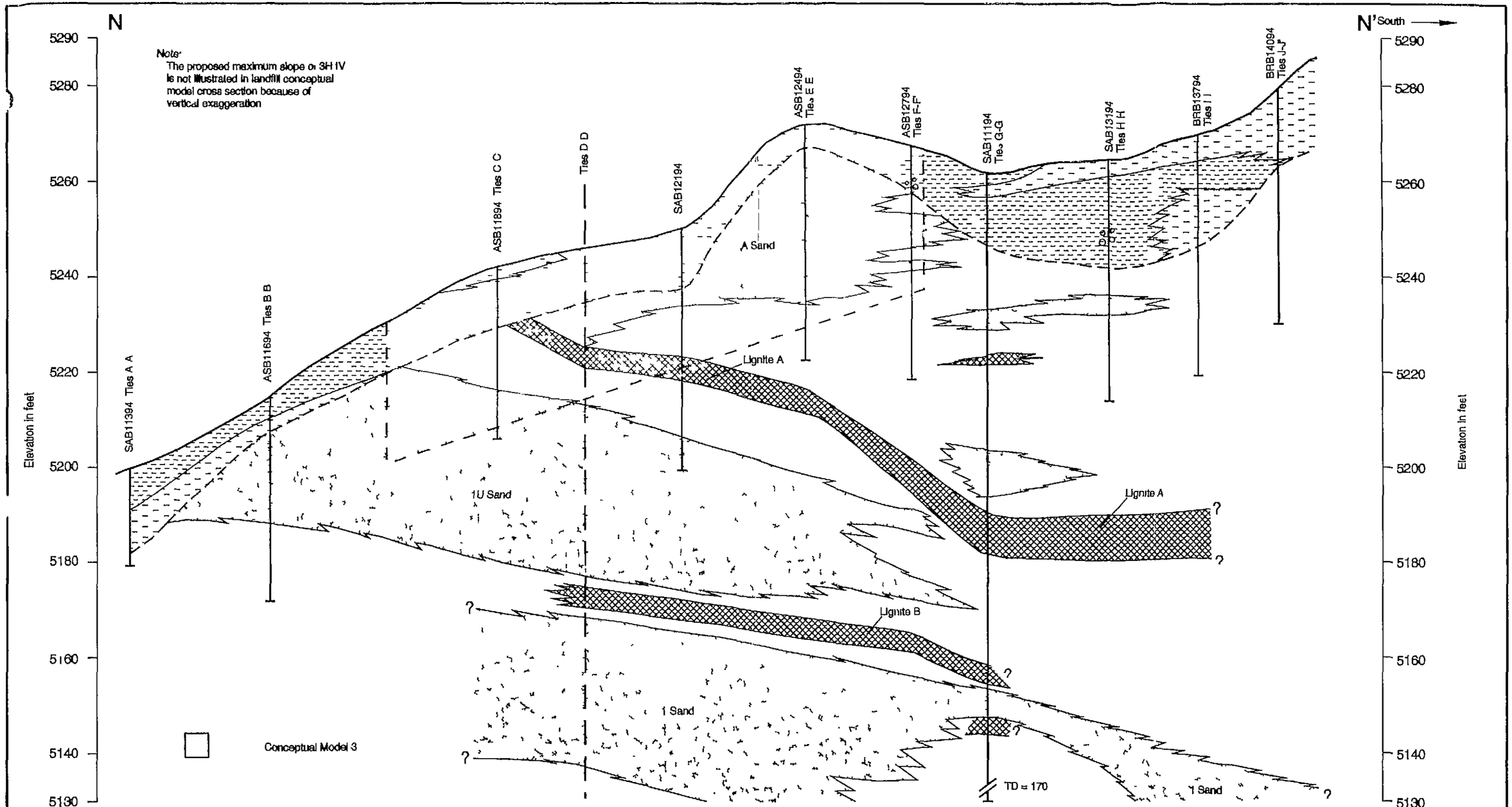
Figure 5 8

Conceptual Models 1 to 3 through Geologic Cross Section L L



EXPLANATION

Alluvium

- Clay sandy clay (CL CH)
- Sand silty sand, clayey sand (SP SM SC SW)
- Gravel

Bedrock (Denver Formation)

- Lignite/Lignitic claystone
- Sandstone
- Claystone with interbedded siltstone, lignite and sandstone (see note)

Top of weathered bedrock

SAB11194 — Boring identification

29025 — Monitoring well(s) identification

Sand pack

101 — Screened interval with well number

TD = Total depth in feet

20 / 0 — 0 / 400

Scale in feet
Vertical exaggeration = 20x

Notes
1 In areas of no lithologic control lateral extent of Denver Formation sandstone lignite and claystone is unknown
2 Cross section location map illustrated in Figure 4 17

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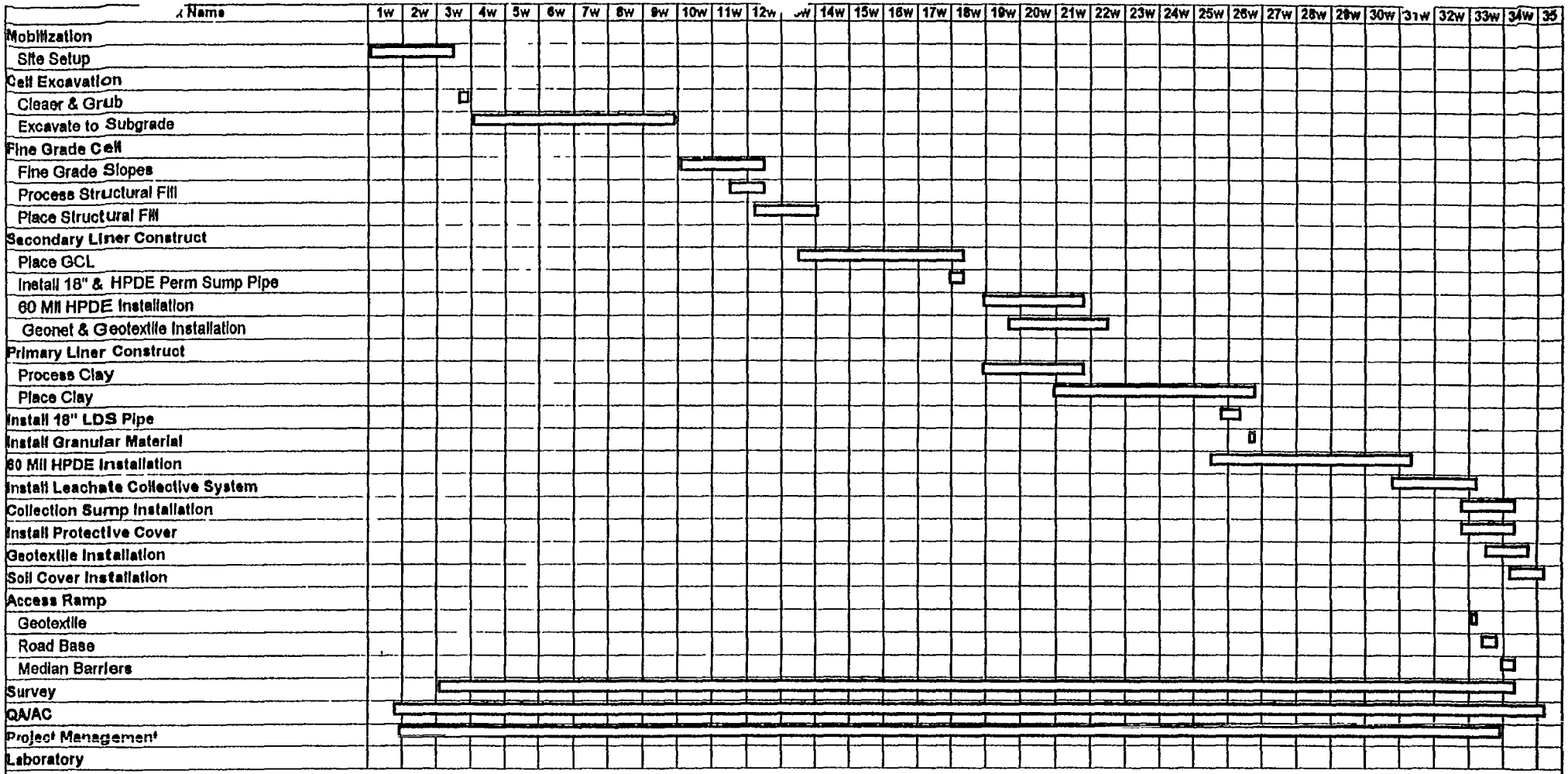
Figure 5 9

Conceptual Model 3 through Geologic Cross Section N N'



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Program Manager Rocky Mountain Arsenal

Prepared By:

Harding Lawson Associates

Figure 5.10

Typical Estimated Hazardous Waste Cell Construction Schedule for an approximately 200,000 Cubic Yard Module

6.0 CONCLUSIONS AND RECOMMENDATIONS

This section presents conclusions and recommendations based on the Material FS, Area FS, and Site FS results The Material FS evaluated whether onsite soils are suitable for use as landfill liners and capping material based on field and laboratory tests The Area FS identified an area within RMA suitable for siting a landfill based on current regulatory and institutional criteria After an area was identified, adequate geologic and geotechnical data was collected to characterize the site and evaluate the feasibility of constructing a landfill in the existing foundation materials The Site FS identified an appropriate site within the area identified in the Area FS and provided information on the overall footprint of the landfill (based on 3 different waste volumes)

6.1 Conclusions

The Material FS objectives were met The field and laboratory test results confirm that onpost soils can be used to construct caps and liners that meet regulatory-required hydraulic conductivity The construction methods employed to construct the two test fills identified the approximate lift thickness, moisture content, density, and compactive effort necessary to achieve the required permeability

The Area FS objectives were met. Landfill siting criteria and policies were used to screen RMA and identify an area suitable for potentially siting a hazardous waste landfill in the western half of Section 25 Three deep borings and thirty shallow borings were drilled and lithologically logged to characterize the geology of the area identified The three deep borings were also geophysically logged to help understand the geology across the area Three-hundred thirty-five samples were analyzed for particle size and Atterberg limits Sixty-five percent of the samples were classified as clay, and thirty percent as clayey sand Remolded permeability tests were performed on a clay soil sample from each of the 30 shallow boreholes Approximately half of the permeability tests achieved vertical permeability values less than 1×10^{-7} cm/s The results of the geologic and geotechnical characterization suggest that approximately half the soil in the identified area could potentially be

used as material for construction of caps or liner Geologic and geotechnical results indicate that the area is conducive to construction of a hazardous waste landfill with primarily clay and claystone underlying the site

The Site FS objectives were met. Appropriate landfill sites within the area identified in the Area FS were evaluated and conceptual landfill models, design elements, construction costs, operation and maintenance costs, and schedules information was developed and evaluated For the purposes of this report, waste volumes of 1,000,000 CY, 2,300,000 CY (the preferred sitewide alternative in the DAA), and 6,000,000 CY were used to account for projected minimum and maximum waste volumes The total landfill volumes used for the three conceptual models included a 20 percent volume increase over the needed waste volume to account for operational cover (1,200,000 CY, 2,760,000 CY, and 7,200,000 CY, respectively) Waste generation rates were estimated to be in the range of 98,000 CY to 1,100,000 CY of material per year without a funding limit, and 37,000 to 280,000 CY of material per year assuming a $100,000,000 annual funding limit Climate, topography, and surface hydrology should not impact landfill construction Subcropping Denver Formation sand units in contact with the alluvium should be avoided if possible Maximizing the depth to groundwater and placing the landfill away from areas where groundwater flows radially is preferred Therefore, siting the landfill within the central portion of western Section 25 is preferred No geologic hazard or environmentally sensitive area considerations were noted in this study, but additional study may be required for siting and design Slope stability and settlement from excavation should not impact construction or O&M of the landfill

Conceptual design alternatives were developed for liner systems, leachate collection and removal systems, gas management systems, final cover systems, and performance of an environmental monitoring system Six liner system alternatives were developed Four final cover systems were developed Environmental monitoring will be performed as part of the facility performance monitoring Conceptual liner and final cover alternatives were evaluated for effectiveness using EPA's HELP

Model, and evaluated for cost by estimating the unit cost on a square foot basis Using the HELP Model to simulate the most likely construction quality scenario, all liners performed about equally Liner System Nos 1 and 2 (use geosynthetic day liner) performed better than the other liner systems The final screening of the conceptual liner designs should consider cost and constructability rather than potential performance because performance results for conceptual liner designs are so similar

The calculated infiltration results for all the final cover systems evaluated are similar and very low Cover System No 4 performed the best. The similarity of performance results for the cover alternatives indicates that final screening of the cover systems should consider cost and constructability rather than potential performance

The total unit cost estimate for the liner systems ranged from $3 00 to $6 40 per square foot The total cost estimate for the cover systems ranged from $3 60 to $4 55 per square foot. Liner System No 1 was the most cost-effective Cover System No 4 was the most cost-effective

The overall landfill performance was evaluated using the HELP Model to evaluate the potential effectiveness of the cover and liner systems Cover System No 4 and Liner System No 1 were used to estimate the long-term leachate production from the landfill Extremely small rates of potential release are predicted for both the most likely ($2\ 6 \times 10^{7}$ in/yr) and worst-case ($1\ 6 \times 10^{3}$ in/yr) scenarios EPA's RITZ Model was used to estimate advective travel times of unsaturated flow produced by the leachate predicted from the HELP Model Potential travel times through the vadose zone are estimated at $8\ 20 \times 10^{-4}$ ft/yr to $9\ 37 \times 10^{-4}$ ft/yr, depending on the saturated hydraulic conductivity At the estimated rates, it would take from 1000 to 1200 years for soil water in the vadose zone to move downward 1 foot

The conceptual facility layouts and material quantities were based on the three conceptual landfill volume requirements and an excavation depth of 30 feet below the existing ground surface The

areas for each footprint are 19 acres (1,200,000 CY), 36 acres (2,760,000 CY), and 87 acres (7,200,000 CY) Conceptual Models 1 and 2 are placed within alluvium and both footprints avoid sand subcrops The base of Conceptual Model 3 is within the weathered Denver Formation and is cut into subcropping sand units

Material quantities were estimated for low-permeability soils and structural fill soils used in landfill liner and cover system components The quantities of soils required for landfill construction were then compared to the estimated volumes of onpost materials The surface area to be lined and surface area for final cover were calculated using the waste depth, height, excavation, and above grade sideslopes Based on the estimated volumes of onpost soil from borrow areas and landfill excavation, it appears that sufficient onpost soil exists to meet the construction requirements for even the largest landfill layout, Conceptual Model 3

Cost estimates for construction and annual O&M for the three conceptual landfill models were prepared to be accurate within a plus 50 percent to minus 30 percent range The estimated construction cost per cubic yard of waste disposal capacity for Conceptual Models 1, 2, and 3 are $12 50 per CY, $10 00 per CY, and $9.00 per CY, respectively The estimated total construction cost for Conceptual Models 1, 2, and 3 are $12,500,000, $22,500,000, and $52,500,000, respectively

Annual O&M costs were prepared at a plus 50 percent to minus 30 percent range The average yearly O&M costs for the restricted funding scenarios for Conceptual Models 1, 2, and 3 are $1,487,000/yr, $2,440,000/yr, and $3,181,000/yr, respectively The average yearly O&M costs for the unrestricted funding scenarios for Conceptual Models 1, 2, and 3 are $2,294,000/yr, $5,820,000/yr, and $4,460,000/yr, respectively Additionally, the lowest average O&M costs per cubic yard are associated with the largest landfill (Conceptual Model 3) at $7 per cubic yard

A conceptual construction schedule was developed for construction of an approximately 200,000 CY module Based on the estimated schedule, construction would take approximately 34 weeks

O&M plans should be prepared for the facility and should include construction and CQC requirements, daily operations, periodic operational activities, and specific plans

In conclusion, based on the evaluation performed in the Site FS, it is feasible to construct a RCRA Subtitle C hazardous waste landfill of sufficient capacity at the preferred site using onsite borrow materials that would meet the applicable federal, state, and local regulatory requirements

6.2 Recommendations

Material FS recommendations include the following

- Perform additional geotechnical testing of borrow materials concurrent with construction to assess actual specifications for cap and liner construction

Area FS recommendations include the following

- Perform a detailed hydrogeologic study to evaluate groundwater flow velocities and vertical gradients in the potential landfill area identified

Site FS recommendations include the following

- Based on completion of a hydrogeologic study in the potential landfill area, and a decision by PMRMA to pursue construction of an onsite hazardous waste landfill, a formal Subtitle C Landfill siting report should be prepared The report should rely on the information provided in this Site FS report Minimal, if any, field investigation will be required Once the ROD for the onpost operable unit is decided upon, and if the final remedy includes a landfill, a formal landfill siting report should be prepared for submittal
- Perform necessary additional geological and geotechnical drilling and testing within the landfill site concurrent with construction to prepare landfill siting report.

7.0 ACRONYMS

AHPA	Archeological and Historical Preservation Act
ALR	Action leakage rate
ARAR	Applicable or relevant and appropriate requirement
Army	U S Department of the Army
ASTM	American Society for Testing and Materials
bcy	Bank cubic yard
BEMA	Bald Eagle Management Area
bgs	Below ground surface
CCR	Code of Colorado Regulations
CEC	Cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CL	Clay liners
cm/s	Centimeters per second
CME	Central Mine Equipment
CMP	Comprehensive Monitoring Program
COC	Chain of custody
COE	U S Army Corps of Engineers
Colog	Colog, Inc
COR	Contracting Officer's Representative
CQC	Construction quality control
CRS	Colorado Revised Statute
CY	Cubic yard
DAA	Detailed Analysis of Alternatives
DSA	Development and Screening of Alternatives
Ebasco	Ebasco Services, Inc

EPA	U S Environmental Protection Agency
ESA	Endangered Species Act
ESE	Environmental Science and Engineering, Inc
FFA	Federal Facilities Agreement
FML	Flexible membrane liners
FS	Feasibility study
GCL	Geosynthetic clay liners
GIS	Geographic Information System
GMP	Groundwater Monitoring Program
HLA	Harding Lawson Associates
ID	Inside diameter
IRA	Interim response action
K	Hydraulic conductivity
K1	Time-weighted average value of Stage 1 hydraulic conductivity
K2	Time-weighted average value of Stage 2 hydraulic conductivity
K_h	Horizontal hydraulic conductivity
K_v	Vertical hydraulic conductivity
LCRS	Leachate collection and removal system
ml	Milliliter
meq/q	Milliequivalent per gram
MKE	Morrison-Knudsen Environmental Services, Inc (formerly Morrison-Knudsen Engineers, Inc)
NCP	National Contingency Plan
NHPA	National Historic Preservation Act
O&M	Operation and maintenance
OD	Outside diameter
OU	Operable unit
pcf	Pounds per cubic foot

PI	Plasticity Index
PID	Photoionization detector
PMRMA	Program Manager for Rocky Mountain Arsenal
PPE	Personal protective equipment
PRG	Preliminary remediation goal
psf	Pounds per square foot
psi	Pounds per square inch
PVC	Polyvinyl chloride
QC	Quality control
RAO	Remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial investigation
RMA	Rocky Mountain Arsenal
ROD	Record of Decision
RPO	Representative process option
RUST E&I	Rust Environment and Infrastructure
SARA	Superfund Amendments and Reauthorization Act of 1986
SCS	Soil Conservation Service
SIA	Stapleton International Airport
SM	Site Manager
SPT	Standard Penetration Test
TEG	Temperature effect gauge
USC	United States Code
USCS	Unified Soil Classification System
USFWS	U S Fish and Wildlife Service
UXO	Unexploded ordnance
VOC	Volatile organic compound

Walsh	J P Walsh and Associates, Inc
WES	Waterways Experiment Station
°F	Degrees Fahrenheit

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Appendix A

TESTFILL CONSTRUCTION SPECIFICATIONS

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SECTION 01: SUMMARY OF WORK

PART 1 GENERAL

1.01 PROJECT DESCRIPTION

A. Work of the Contract comprises construction of two (2) test fills at Rocky Mountain Arsenal, Commerce City, Colorado. Work includes, but is not limited to:

1A. Stripping and stockpiling 12 inches topsoil from the two designated borrow areas shown in Figure 2.

1B. Stripping and stockpiling 4 inches topsoil from the test fill area, and processing area.

2. Excavating approximately 500 cubic yards (yd^3) of clay from each of two (2) designated borrow areas (total of 1000 yd^3).

3. Transporting clay to soil processing area

4. Processing clay to meet moisture content and clod size specifications

5 Grading Test Fill area to a smooth, uniform surface.

6. Wetting the subgrade and placing a working layer of clay at base of each test fill.

7. Constructing the three-foot thick test fills in six (6) six-inch lifts, allowing for testing by the Engineer during construction.

8 Preparing necessary test fill surfaces and assisting with field testing, e.g , blading smooth surface for nuclear gauge, pushing Shelby tubes, excavating small test pits to check lift bonding.

9 Regrading and placing stockpiled topsoil over completed test fill, processing, and borrow areas

10 Seeding and mulching all disturbed areas.

B The Subcontractor shall furnish all labor and equipment to perform the Work outlined above The following shall be provided to the Subcontractors·

a. The Owner shall provide approved onpost borrow sources for all soil for compacted soil test fills

b The Contractor shall provide onpost water source at the Fire Station, corner of D Street and 7th Avenue, 1 1/8 miles south of test fills.

c The Contractor shall provide soil testing during processing and placement of test fill soil.

d. The Owner shall provide native grass hay mulch.

1 02 FORM OF SPECIFICATIONS

A. Term "provide" or "provided" shall mean "furnish and install in-place," except as noted.

B These Specifications are intended to be used in conjunction with the accompanying Test Fill Design Plans, hereinafter referred to as "Drawings."

C Definitions:

1. Contract - Contract documents signed by HLA and Subcontractor

2. Contractor - Harding Lawson Associates

3. Engineer - HLA's resident project engineer or designated representative

4 Subcontractor - Earthwork construction company

5 Owner - Program Manager for Rocky Mountain Arsenal

6. Work - All site work related to this project that is to be performed by the Subcontractor

D Any reference to standards of any society, institute, association or governmental agency shall be the edition in effect as of the date of this Specification, unless stated otherwise

1.03 CONTRACTS

A. Perform work as agreed to in Contract with Contractor.

1 04 WORK BY OTHERS

A. Work on project which will be performed by others during period of contract, but that is excluded from contract, is as follows

1. Construction management services.

2. Construction material testing.

3. Surveying services

4 Health and safety monitoring.

5 Owner and regulatory liaison.

1 05 SCHEDULE

A Coordinate construction schedule and operations with Engineer.

1.06 SUBCONTRACTOR'S USE OF PREMISES

A Confine construction operations to within designated work areas unless otherwise authorized by Owner. A fenced parking lot and equipment laydown area are shown in Figure 2. Some parking is also available at the test fill site.

B. Keep driveways and roads clear and available to Owner at all times. Do not use these areas for parking or storage of materials. Schedule deliveries with Engineer to minimize space and time requirements for storage and handling of materials and equipment onsite

C Subcontractor shall, at all times, conduct operations to assure least inconvenience to Owner, Contractor, other subcontractors, onpost personnel, and operations of facility.

D Do not perform any work within protected area boundaries.

E. Coordinate hours of operation with Engineer.

1.07 OWNER - FURNISHED ITEMS

A. Owner will furnish site laydown and parking facilities.

B. Owner will furnish access to construction water at the Fire Station, corner of D Street and 7th Avenue, 1 1/8 miles south of test fills.

C Owner will furnish native grass hay mulch (located in Section 29 of RMA; see Figure 2).

1 08 CONTRACTOR RESPONSIBILITIES

A. Provide construction management services.

B. Arrange for soil testing as specified in Specifications.

C. Arrange for necessary surveying.

D Coordinate construction activities with Owner.

E. Monitor site conditions for health and safety

1.09 SUBCONTRACTOR'S RESPONSIBILITIES

The Subcontractor shall furnish all labor and equipment required to perform the Work, including, but not limited to:

A. Handle material at site, including receiving, unloading, and storage in accordance with Contractor's requirements and manufacturer's recommendations

B Install materials as required by Specifications.

C. Repair or replace materials damaged by Subcontractor.

D. Arrange for replacement of damaged, defective, or missing items or materials

- END OF SECTION -

SECTION 02. GENERAL REQUIREMENTS

PART 1 GENERAL

1.01 SUMMARY

A. Two test fills shall be constructed to verify the suitability of two different local materials for use as impermeable clay liner and to verify/determine the construction procedures (i.e., moisture content range and compaction effort) required to achieve a compacted in-place permeability less than or equal to 1×10^{-7} centimeters per second (cm/sec).

B. This Specification and other Contract Documents cover the furnishing of all labor, materials, equipment, superintendence, and services necessary to construct the test fills

C. Cooperation. The Subcontractor shall cooperate with all other parties engaged in project-related activities to the greatest extent possible. Disputes or problems should be referred to the Contractor for resolution.

D Construction Water. The quality of construction water used to accomplish construction work is crucial due to the nature of the facilities being constructed. Subcontractor shall use construction water provided by Owner, which is a good quality water from an onpost source

E. Inspection All inspection, testing, and documentation procedures shall be the responsibility of the Contractor. As described in other Specification sections, Subcontractor shall assist as necessary in facilitating testing procedures

- END OF SECTION -

SECTION 03: HEALTH AND SAFETY REQUIREMENTS

PART 1 GENERAL

1.01 SUMMARY

A. SITE BACKGROUND

Rocky Mountain Arsenal (RMA) occupies approximately 27 square miles in southern Adams County, Colorado, approximately 9 miles northeast of downtown Denver (Figure 1) RMA was established by the Army in 1942 to produce chemical and incendiary munitions for World War II.

During operations at RMA, the U.S. Department of the Army's (Army's) day-to-day activities generated miscellaneous solid waste, as well as potentially contaminated tools, equipment, unwanted containers, rejected incendiaries, empty munitions casings, demilitarized munitions, explosives, burster charges, rocket propellant, rocket motors, wastes from the Mustard Plant, and wastes from the production of nerve agent (GB). These materials were decontaminated with caustic or other decontaminants and transported to burning pits to assure complete decontamination by incineration. Following World War II, the production of munitions decreased, and the Army leased selected portions of RMA to private industry.

From 1942 until 1957, chemical agents were manufactured at RMA. Levinstein mustard (H) was produced in the South Plants manufacturing area from 1942 until 1950 This area was also used to fill shells with the chemical agent phosgene or incendiary mixtures, including napalm and white phosphorous. During this period, obsolete World War II munitions were destroyed by detonation or incineration on RMA.

Section 36 was the primary area for waste disposal at RMA in the 1940s and 1950s. Potentially contaminated solid waste including metal were incinerated in pits and trenches located east and north of Basin A. The chemical nerve agent isopropylmethyl fluorophosphonate (Sarin or GB) was produced in the North Plants manufacturing area from 1953 until 1957. Munitions filling with this nerve agent continued at RMA until 1969. From 1970 to 1984, Army activities focused primarily on the demilitarization of chemical warfare materials.

In 1947, portions of RMA were leased to private industry. Early lessees included Colorado Fuel and Iron Corporation (CF&I) and Julius Hyman and Company (Hyman). CF&I produced chlorine and chlorinated benzenes and attempted to manufacture dichlorodiphenyltrichloroethane (DDT). Hyman produced several pesticides during this period. In 1950, Hyman added to its lease a number of facilities formerly operated by CF&I. In 1952, Shell Oil Company (Shell) acquired Hyman and operated it as a wholly owned subsidiary until 1954, when Hyman was integrated into the Shell corporate structure and Shell succeeded Hyman as the named lessee. From 1952 until 1982, Hyman and/or Shell produced a variety of herbicides and pesticides in the South Plants manufacturing complex.

Between 1942 and 1982, a variety of the contaminants associated with the industrial activities onsite were released to the environment at RMA. Chemical waste effluents were discharged into lined and unlined evaporation basins, and solid wastes were buried or disposed on the surface. Wastewater, raw materials, and end products were

leaked and accidentally spilled within the manufacturing complexes, storage areas, and transportation routes on RMA. Chemical products that were not manufactured to specification were commonly discharged into shallow trenches. Munitions were demilitarized and disposed in trenches and on the surface. The sites that are believed to have been the primary groundwater contamination source areas at RMA are the manufacturing complexes, the wastewater storage and evaporation basins (Basins A, C, D, E, and F), areas of solid waste disposal, and the rail classification yard.

In the early 1950s, the detrimental effects of chemical contamination on the local environment became evident. By 1951, high waterfowl mortality was suspected of being linked to the insecticide contamination of three artificial lakes on RMA (Armitage, 1951; Goodall, 1951). In 1954 and 1955, severe crop loss was reported by farmers northwest of RMA using well water for irrigation (U.S. Department of Health, Education, and Welfare, 1965). Two contaminants, diisopropylmethylphosphonate (DIMP), a manufacturing byproduct of the nerve agent GB, and dicyclopentadiene (DCPD), a chemical used to produce insecticides, were detected in offpost surface water in 1974 (R. L. Stollar and Associates, Inc. [Stollar], and others, 1991). Groundwater contaminated with dibromochloropropane (DBCP) and other compounds has been detected in samples from offpost since 1978 (Environmental Science and Engineering [ESE], 1987).

B NATURE AND EXTENT OF CONTAMINATION

Releases of a variety of contaminants to the environment at RMA have resulted in contamination of environmental media both onpost and offpost (ESE and others, 1988; HLA and ESE, 1992; Ebasco Services, Inc. [Ebasco], and others, 1991) Soil and groundwater contamination have occurred at several locations onpost. Soil contamination is in some cases fairly localized, whereas in other cases it has resulted in broader contamination as soil contaminants entered the groundwater.

The distance that a groundwater contaminant plume extends from its source area depends on numerous factors, including the contaminants' behavior in the environment, the amount and time of the release, and other factors, as noted below. Groundwater contaminant plumes at RMA may extend only a few hundred feet from their sources or may extend miles, as is the case for DIMP. Generally, the occurrence and migration of contaminants in groundwater at RMA is complicated by the following factors

- Many contaminant sources, some areally separated, some overlapping
- A variety of release scenarios, including single or repeated spills, continuous or intermittent leaks, discharges to ditches or basins, leaching from trenches, and leaching from or direct contact of groundwater with buried transport lines
- Many contaminants
- Spatial variabilities in aquifer properties
- Complex interactions between water-bearing zones
- Historical changes in the distribution and quantity of groundwater recharge

C The areas of the RMA in which the work will be performed are considered clean (nonhazardous) and no special safety measures are anticipated to be necessary beyond standard construction protective gear such as hard hats, steel-toed boots, and safety glasses or goggles.

D. However, because of the nature of the site, construction activities at the RMA could, if unexpected conditions are encountered, potentially place Subcontractor's personnel in situations where additional personal protective equipment (PPE) or other safety measures may be necessary.

E. Therefore, all Subcontractor's personnel doing work on the site shall be 40-hour trained per Occupational Safety and Health Administration (OSHA) Safety and Health Standards (29 Code of Federal Regulations [CFR] 1910) and general construction standards (29 CFR 1926).

1.02 PAYMENT

A. Subcontractor shall assume that all work shall be performed under OSHA Hazardous Waste Site "Level D" conditions, (i.e., the work is "clean" and only standard construction protective gear is necessary) Therefore, the Subcontractor shall make no allowance in time or cost in the bid for working under "Level C" or more strict conditions If results of real-time monitoring by Contractor indicates a need for additional health and safety precautions and/or protective equipment, Contractor and Subcontractor shall agree upon fair compensation for work performed under the altered circumstances.

B See also paragraph 1 06 A.

1 03 OPERATIONS AND EQUIPMENT SAFETY

A. Contractor shall be responsible for initiating, maintaining, and supervising safety precautions and programs in connection with Work. Subcontractor shall take necessary precautions for safety of employees on Project site as directed by Contractor.

B Both the Contractor and Subcontractor's duties and responsibilities for safety in connection with Work shall continue until such time as Work is complete and Contractor has issued notice to Subcontractor that Work is complete.

1 04 HEALTH AND SAFETY

A. Contractor shall prepare a site-specific Health and Safety Plan and be responsible for implementation and enforcement of health and safety requirements, and Subcontractor shall conform with this Plan, take necessary precautions, and provide protection for the following:

1. Subcontractor personnel working on or visiting Project site

2. Work and materials or equipment to be incorporated in Work area.

B Read, sign, and follow the Contractor's Health and Safety Plan.

C Hold a safety meeting prior to starting Work each day. Inform Contractor of time and location prior to meeting. Provide attendance roster to Contractor.

1.05 CONTRACTOR'S RESPONSIBILITIES

A. If Contractor determines that Subcontractor's activities do not comply with requirements of this Specification or the site-specific health and safety plan developed by the Contractor for the Subcontractor, Contractor may direct its and/or Subcontractors employees to leave Project site or implement additional safeguards for Owner's or Contractor's protection.

B. If Contractor observes situations that appear to have potential for immediate and serious injury to persons, Contractor may warn persons who appear to be affected by such situations.

1.06 DECONTAMINATION

A. Owner requires that all construction equipment be run through an onpost decontamination station. Subcontractor shall allow 1/2 hour per piece of equipment for this procedure for bidding purposes. However, payment shall be made by actual time and materials used.

- END OF SECTION -

SECTION 04: PROJECT MEETINGS

PART 1 GENERAL

1.01 SUMMARY

A. Engineer will schedule a preconstruction meeting, weekly progress meetings, and any specially called meetings throughout progress of work. Engineer will be responsible to.

1. Prepare agenda for preconstruction meeting.
2. Notify Owner and Subcontractor of location and time.
3. Make physical arrangements for meetings
4. Preside at meetings.
5. Record minutes; include significant proceedings and decisions
6. Reproduce and distribute copies of minutes to meeting participants and other parties affected by decisions made at meeting.

B. Representatives of Subcontractor attending meeting shall be authorized and qualified to act on Subcontractor's behalf.

C. Payment: Consider work specified in this section incidental and include payment as part of lump sum price in Bid Schedule

1.02 PRECONSTRUCTION MEETING

A. Purpose of meeting:

1. Review principal features of Work.
2. Environmental protection.
3. Safety requirements
4. Progress schedules.
5. Payment.
6. Address Subcontractor's questions regarding contract and Work.

1.03 WEEKLY PROGRESS MEETINGS

A. Minimum of once per week, or as requested by Engineer.

B. Attendance

1. Owner and/or Owner's representative.
2. Subcontractor's superintendent.

3 Engineer

4 Other Subcontractors as appropriate.

- END OF SECTION -

SECTION 05: CONSTRUCTION STAKING AND SURVEYING

PART 1 GENERAL

1.01 SUMMARY

A. Vertical and horizontal control staking information will be provided by Contractor at no expense to Subcontractor. Stakes will be located (by the Contractor) to set the horizontal boundaries of the test fills, and processing areas.

1. Contractor shall be responsible for reviewing and following all initial construction staking. Any restaking shall be approved by the Engineer.

2. Contractor shall be responsible for maintaining, restaking as necessary, and removing survey control stakes.

B. Payment: Consider Work specified in this section incidental (except items specifically noted as being provided by Contractor) and include cost as part of appropriate fixed prices in Bid Schedule.

1.02 CONSTRUCTION LINE AND GRADE

A. Contractor shall bear sole responsibility for correct transfer of construction lines and grades from primary vertical and horizontal control stakes and for correct alignment and grade of completed Work based on lines and grades shown on Drawings and described in these Specifications.

B Contractor shall transfer line and grade for construction from control stakes to Work utilizing the following procedures:

1. Provide qualified technician during course of construction.

2. Check line and grade as Work progresses.

C. Contractor shall

1. Review all initial construction staking.

2. Verify accuracy of line and grade by checking between stakes

3. Place stakes during test fill placement as needed to maintain specified lift thickness.

4 Assure that all elements of test fill, including subgrade, working layer, and completed lifts, slope as specified in these Specifications and on Figure 3.

5 Be responsible for protection and preservation of stakes during construction and at completion of construction.

6. Be responsible for removal of all stakes used for construction.

7. Arrange operations to avoid interference with documentation of final lines and grades.

- END OF SECTION -

SECTION 06: PROTECTION OF ENVIRONMENT

PART 1 GENERAL

1.01 SUMMARY

A. Subcontractor, in executing Work, shall maintain work areas free from environmental pollution that would be in violation of federal, state, or local regulations.

B. Subcontractor shall maintain sediment runoff within the project boundaries. Subcontractor shall take appropriate action to prevent sediment runoff beyond the designated work areas, into drainageways, or into restricted area boundaries. No significant work of this nature is anticipated.

C. Payment: Consider Work specified in this section incidental and include payment as part of lump sum price specified in Bid Schedule.

1.02 PROTECTION OF WATERWAYS

A. Observe rules and regulations of the State of Colorado and agencies of U S. government prohibiting pollution of any lakes, streams, rivers, or wetlands by dumping of refuse or debris therein.

B Divert flows, including stormwater and flows created by construction activity, to sumps, sediment traps, silt fencing, or other controls approved by Engineer to prevent excessive silting of waterways.

1.03 EROSION AND SEDIMENT CONTROL

A. Apply appropriate soil conservation measures to protect project area and adjacent lands Measures may include, but are not limited to, mulching, fabric mat, straw or hay bales, filter barriers, and sediment traps Adjust sediment control measures in field to meet conditions encountered.

B Provide erosion control measures before commencing work on project site as directed by Engineer Engineer shall direct, inspect, and approve of erosion control measures before commencing Work.

1 Maintain erosion control measures during course of construction.

2 Remove erosion control measures upon establishment of permanent, surface stabilization or as directed by Engineer.

1.04 PROTECTION OF AIR QUALITY

A. Minimize air pollution by requiring use of properly operating combustion emission control devices on construction vehicles and equipment, and encouraging shutdown of motorized equipment not actually in use.

B Trash burning is not permitted on construction site.

1.05 FUELING AND VEHICLE/EQUIPMENT LEAKAGE

A. Do not fuel or perform maintenance on equipment while within the Work area boundaries without the Engineer's permission. These activities may be performed in the test fill parking area or the designated staging/parking area. Fueling must be performed carefully to prevent spillage. Spillage or leakage of fuel, oil, or vehicle fluid must be cleaned up immediately to the satisfaction of the Engineer.

1 06 NOISE CONTROL

A. Conduct operations to cause the least annoyance to personnel and wildlife in vicinity of work, and comply with applicable local ordinances.

B. Equip equipment with mechanical devices necessary and reasonable to minimize noise and dust.

C Route vehicles carrying soil or other material over those streets that will cause the least annoyance to humans and animals, as directed by the Owner or Engineer, and do not operate on RMA roads between hours of 7.00 p.m. and 6:00 a.m., or on Saturdays, Sundays, or legal holidays, unless otherwise approved by Owner or Engineer.

1.07 DUST CONTROL

A. Due to proximity of project to sensitive onpost operations and habitats, take special care in minimizing dust generation on temporary access roadways, Owner's existing roads, and roads used for construction operation. Subcontractor shall be responsible for the control of dust by watering within the construction project area and areas utilized by Subcontractor to perform the Work. Speed limits will be followed on Owner's existing roads to minimize dust generation.

B Comply with local environmental regulations for dust control, and also with directions of Engineer and Owner If Subcontractor's dust control measures are considered inadequate by Engineer or Owner, Contractor will require Subcontractor to improve dust control measures at no cost to Contractor.

1.08 PROTECTION OF WILDLIFE

A. Due to proximity of the project to sensitive wildlife habitats, the Subcontractor shall take special care to minimize impact to these habitats. Hauling equipment will be required to stay on designated traffic routes and yield right-of-way to all wildlife. Vehicles and equipment shall proceed slowly when wildlife is present.

B No photography or harassment of wildlife is permitted.

- END OF SECTION -

SECTION 07: MATERIAL AND EQUIPMENT

PART 1 GENERAL

1.01 SUMMARY

A. Material and equipment incorporated into Work shall:

1 Conform to applicable Specifications and standards.

2. Comply with size, make, type, and quality specified or as specifically approved by Engineer.

B. Do not use material or equipment for purpose other than that for which it is designated or specified.

C. Payment Consider Work specified in this section incidental and include cost as part of lump sum prices in Bid Schedule.

1 02 SUBSTITUTIONS

A. Substitutions.

1. Subcontractor's requests for changes in equipment from those required by Contract Documents are considered "requests for substitutions" and subject to Subcontractor's representations and review provisions of Contract Documents when one of the following conditions are satisfied:

a. Where request directly related to or "equal" clause or other language of same effect in Specifications.

b Where required equipment cannot be provided within Contract Time, but not as a result of Subcontractor's failure to pursue work promptly or coordinate various activities properly.

2 Subcontractor's Options.

a. Compatibility of Options. Where more than one choice available as options for Subcontractor's selection of equipment, select option compatible with other equipment and materials already selected.

b Standards, Codes, and Regulations: Where compliance with imposed standard, code or regulation required, select from among products that comply with requirements of those standards, codes, and regulations.

c. "Or Equal": For equipment specified by naming one or more equipment manufacturer and "or equal," subcontractor shall submit request for substitution for equipment or manufacturer not specifically named.

d. Two or More Manufacturers: For equipment specified by naming several manufacturers, select one of manufacturers named. Do not provide or offer to provide unnamed manufacturer or equipment.

e. Single Manufacturer· For equipment specified by naming only one manufacturer and followed by words indicating no substitution, there is no option.

B Conditions that are not substitutions:

1. Requirements for substitutions do not apply to Subcontractor options on materials and equipment provided for in Specifications.

2 Revisions to Contract Documents, where requested by Owner or Contractor, are "changes," not "substitutions."

3. Subcontractor's determination of and compliance with governing regulations and orders issued by governing authorities do not constitute substitutions or basis for Change Orders, except as provided for in Contract Documents

1.03 TRANSPORTATION AND HANDLING

A. Arrange deliveries of equipment with Engineer and in accordance with construction schedule; coordinate to avoid conflict with Work and conditions at site.

B. Provide equipment and personnel to handle materials and equipment by methods recommended by manufacturer to prevent soiling or damage to materials or equipment, or packaging

C. Handling:

1. Handle material at Site, including receiving, unloading, and storage, in accordance with Contractor's requirements and manufacturer's recommendations. The Owner-designated staging area shown on Figure 2 or the area adjacent to the test fills shall be used for such activities.

2 Install materials as required by Specifications.

1 04 STORAGE, PROTECTION, AND MAINTENANCE

A. The designated onsite storage and staging area is shown on Figure 2. Equipment and vehicles may be stored overnight in this fenced area with Engineer's permission. No overnight parking of personal vehicles is allowed.

B Subcontractor assumes full responsibility for security and/or damage due to improper storage of materials.

C. Maintenance·

1. Repair or replace materials damaged by Subcontractor.

- END OF SECTION -

SECTION 08. SITE PREPARATION AND CLOSURE

PART 1 GENERAL

1.01 SUMMARY

A. Section includes

1. Requirements for topsoil removal and stockpiling, and protection of wells and utilities.

2. Installation of sediment and erosion control measures as necessary

3. Regrading and topsoil placement upon completion of work.

4. Temporary roads.

B Payment: Payment for items in this section is included under Bid Items A2, B1, and E1

1 02 DEFINITIONS

A. Utilities: For purposes of this section, existing gas mains, water mains, steam lines, electric lines and conduits, telephone and other communication lines and conduits, sewer pipe, cable television, other utilities, and appurtenances.

B Topsoil. For purposes of this section, the upper 12 inches of soil available from borrow areas to be disturbed during construction, or the upper 4 inches of soil available from the test fill/processing areas.

C Sediment and Erosion Control Measures: As described in Section 06 paragraph 1.03.

1.03 PROJECT/SITE CONDITIONS

A. Notification

1 Owner will identify all utilities/wells and notify Contractor, who will notify Subcontractor. No utilities are currently known to exist within the Work areas. Subcontractor bears sole responsibility for damage caused to any identified utilities or wells, or any associated damages and claims caused as a result of Subcontractor damaging such utilities or wells.

B. Protection:

1. Protect existing utilities against damage.

2. Locate existing underground utilities by hand excavation. When Work requires Subcontractor to be near or to cross known utilities, the Subcontractor shall carefully uncover, support and protect these utilities and shall not cut, damage, or otherwise disturb them without prior authorization from the Engineer.

3. If uncharted utilities are encountered during excavation, notify Engineer and wait for instructions before proceeding.

a Repair damage to utilities encountered when Work is continued without notifying Engineer or his designated representative. This work shall be done at no expense to Contractor

4. Preserve and protect groundwater monitoring wells. Damaged or destroyed monitoring wells shall be replaced at Subcontractor's expense.

PART 2 EXECUTION

2 01 PERFORMANCE

A. Site Preparation:

1 Establish sediment controls prior to disturbing project areas.

2. Cut or remove growth of tall weeds and grass greater than 6 inches high from areas to be stripped. Remove debris and boulders, within project area.

3 Strip topsoil within limits of borrow areas, processing areas, and test fill area Stripping shall not extend beyond limits of designated areas.

4 Maintain bench marks, control monuments, and monitoring wells Re-establish if disturbed, damaged or destroyed, at no cost to Contractor

B Topsoil Handling·

1 Stockpile topsoil in neat piles adjacent to each project area. Topsoil shall be kept separate from other excavated materials

C Regrading

1 The borrow areas shall be regraded and smoothed out after excavation is completed. Finished contours shall be gently sloping and blended to meet existing topography

2 The test fill and immediately surrounding area shall also be regraded and blended with existing topography. For bidding purposes, assume 1 day with a dozer to regrade test fill area.

D Topsoil Placement

1 Stockpiled topsoil shall be used to cover the completed test fills, processing areas, and disturbed borrow areas upon completion of activities in these areas The topsoil shall

a. Be placed and lightly compacted so as not to impede infiltration and subsequent plant growth.

b Be spread over the borrow areas upon completing placement of excess test fill area soil and regrading.

c. Be placed to a minimum of 1-foot thickness in all areas receiving topsoil.

E. Temporary Roads:

1. The Subcontractor shall be responsible for constructing any temporary roads that he may require in the execution of his Work. Any ditches that are filled to provide access to borrow areas or test fill area must be cleaned out and restored to original condition upon completion of Work.

- END OF SECTION -

SECTION 09· EXCAVATION, STOCKPILING, AND PROCESSING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes.

1. Excavating soil from designated borrow areas and test fill area; grading and preparation of test fill area.

2. Transporting borrow soil to processing areas.

3. Stockpiling/spreading soil as required to achieve adequate independent sources for topsoil, working layer soil, and test fill soil.

4. Processing test fill soil as needed to reduce clod size, adjust moisture content, and remove rocks.

B Payment· Payment for items in this section is included under Bid Items B2, B3, B4, C1, and C2.

1.02 PROJECT/SITE CONDITIONS

A. Locate identified existing utilities; underground utilities shall be located by hand excavation. No utilities are known to exist within the project areas

B. If uncharted utilities are encountered during excavation, notify Engineer and wait for instructions before proceeding.

C. Protect, support, and maintain monitoring wells, conduits, wires, pipes, or other features and utilities that are to remain onsite in accordance with requirements of Contractor and Owner.

D Notify Engineer if any unidentified wells or piezometers, potentially hazardous material, or other unexpected items are encountered during this work, and wait for instructions before proceeding.

E. The material borrow source for each test fill is a designated borrow area, as shown on the Drawings, Figure 2 The Engineer shall determine what borrow material is appropriate for the test fills

PART 2 EXECUTION

2.01 PREPARATION

A. Contractor shall identify to the Subcontractor acceptable independent stockpile/processing locations for topsoil, working layer material, and test fill material Areas designated for processing are shown on the Drawings, Figure 3, and shall be stripped of topsoil prior to placement of borrowed materials

B. Install, prior to construction, silt fencing or other controls approved by Contractor in areas where sediment from this construction or operations may impact wetlands, drainageways, or other sensitive areas. No or minimal activity of this type is anticipated to be done by the Subcontractor

2 02 EXCAVATION, TEST FILL AREA PREPARATION, AND STOCKPILING

A. Excavate approximately 500 yd^3 of soil from each borrow area, as directed by the Engineer, and transport soil to processing area. Borrow soil from Borrow Area A shall be taken from 1 to 4 feet in depth; borrow soil from Borrow Area B shall be taken from 4 to 7 feet in depth. Shallow soil in Borrow Area B shall be moved to the side prior to borrowing, then replaced upon completion of borrow activities.

B. Grade the test fill area to within ± 0.2 feet of the proposed grades Proposed grades are approximately 4 inches below existing grades. Subgrade shall slope at 2 percent in the direction shown on Drawings, Figure 3. Each test fill area will be approximately 40 feet wide by 100 feet long, as shown on the Drawings, Figure 3

C. The subgrade shall be compacted with 12 passes of a wedge-foot compactor, imparting a maximum of 50,000 lbs of load, or to the satisfaction of the Engineer.

D The Engineer will inspect the exposed subgrade for soft areas or other poor subgrade conditions Proofrolling is required to identify any soft areas that may require additional excavation and backfilling. After the Engineer is satisfied with the overall condition of the subgrade, the subgrade shall be scarified and recompacted uniformly with a smooth-drum roller

E. Maintain subgrade free of erosion and desiccation cracks. If necessary, rework and/or restore to be free of erosion and desiccation cracks prior to test fill construction

F Stockpile/process earthen material per category· topsoil, working layer soil, test fill soil, or other if directed by Engineer.

G Stockpile/process for proper drainage and control sediment runoff with erosion control measures as necessary

H. Notify Contractor immediately if potentially hazardous conditions or materials are encountered during construction (i e., buried drums, etc.)

2 03 PROCESSING

As part of the test fill construction, the Subcontractor will be required to adjust moisture content, reduce clod size, and remove rocks from the borrow soil prior to placement of the soil in the test fills The Engineer will evaluate the Subcontractor's methods for:

A. Moisture Conditioning. The Subcontractor shall be required to provide all necessary personnel and equipment to successfully achieve the required moisture contents as specified. The Subcontractor shall be responsible for discing, aerating, tilling, wetting, covering, or otherwise controlling the moisture content in the test fill materials using a method approved by the Engineer It is anticipated that the moisture content of the soil will need to be increased by approximately 4 to 6 percent prior to construction.

B. Clod Reduction. The Subcontractor shall be responsible for providing the necessary personnel and equipment for reduction of clod size as necessary to meet Specifications and achieve proper remolding of soil for compaction.

C Soil for the two test fills shall be stockpiled in two separate designated areas. The processing areas are designed to be large enough to process all test fill soil at one time using a depth of 1 foot. All soil processing shall be performed in the designated processing areas. The only exception is that addition of up to 2 percent moisture is allowable during placement and compaction of the test fill This exception is intended to be used only if the material dries during or between placement of lifts.

D Soil shall be blended and cured for an appropriate amount of time to allow added moisture to distribute evenly throughout processed soil. For bidding purposes, assume it will take an estimated 3 days to complete material processing. Additional curing time beyond 3 days will be paid at the unit rate quoted by the Subcontractor in the Bid Schedule. The processed soil should be kept moist during the curing process.

E. The moisture content in the processed soil immediately prior to test fill construction shall be no lower than 0.5 percent above the low end of the target moisture content range, and no higher than 1 percent above the high end of the target moisture content range.

F Processing of soil shall be done using an approximate soil thickness of 1 foot.

- END OF SECTION -

SECTION 10 WORKING LAYER

PART 1 GENERAL

1.01 SUMMARY

A. Section includes

1 Wetting of subgrade prior to working layer placement.

2. Placement of clay working layer to obtain the desired test fill subbase characteristics and elevations.

3 Requirements of completed working layer grades, prior to test fill placement.

B Subcontractor will provide all equipment, labor and supplies required to perform the work in accordance with the contract.

C Contractor will provide visual inspection and construction testing.

D. Payment. Payment for items in this section is included under Bid Item D1

1 02 REFERENCES

A. American Society for Testing and Materials (ASTM)

1 ASTM D422-63. Standard Test Method for Particle-size Analysis of Soil

2. ASTM D2487-92: Standard Classification of Soil for Engineering Purposes (Unified Soil Classification System [USCS]).

3 ASTM D2922-91: Standard Test Methods for Density of Soil and Soil-Aggregate in-Place by Nuclear Methods (Shallow Depth)

4. ASTM D3017-88. Standard Test Method for Water Content of Soil and Rock in-Place by Nuclear Methods (Shallow Depth)

5 ASTM D4318-84: Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soil.

B Section 11, 2.01A.

PART 2 PRODUCTS

2.01 WORKING LAYER

A. Onsite cohesive soil to be used for the working layer shall be substantially free of organics and other deleterious materials, and shall be approved by the Engineer Onsite cohesive soil is anticipated to typically consist of CL and SC soil per USCS

B Subcontractor shall modify working layer material (if required) to assure it meets Specification requirements. Modifications include but are not limited to, the following:

1. Removal of rocks greater than 6 inches in any dimension.

2. Removal of deleterious or unsuitable materials such as large roots, organic soil, and as otherwise determined unsuitable by the Engineer.

PART 3 EXECUTION

3.01 PLACEMENT

A. Immediately prior to placement of working layer, the subgrade shall be gently wetted by sprinkling or spraying until the soil moisture reaches a depth of at least 1 foot.

B Place working layer in accordance with the following·

1. Approximate loose lift thickness: 9 inches.

2. Soil compaction: Density not specified, as required to achieve 6-inch compacted lift thickness.

C Control lift thickness using laser-guided equipment, construction staking, manual measurement, or other method acceptable to the Engineer to assure Specification requirements are met

D Care must be used in placing the working layer over the prepared subgrade to avoid excessive tearing-up of the subgrade. A minimum of 6 inches of soil shall be maintained between the equipment and the subgrade.

E. Contractor shall examine surfaces to receive test fill material to determine existence of any unsuitable materials, including materials significantly above or below optimum moisture content. Suitable moisture content shall be obtained prior to placement of the test fill The working layer surface shall be roughened prior to placement of first test fill lift.

- END OF SECTION -

SECTION 11: CLAY TEST FILL

PART 1 GENERAL

1.01 SUMMARY

A. Section includes·

1. Requirements for placement and compaction of clay test fill, and test fill maintenance.

2. Completion of test fill with testing assistance.

B The Subcontractor will provide all equipment, labor, and supplies required to perform the Work in accordance with the Drawings and Specifications.

C. The Contractor will provide testing during construction

D Unsuitable materials include topsoil, peat, roots, organic soils, and materials containing slag, cinders, foundry sand, debris, rubble or frozen soils, and material not meeting requirements of Specifications.

E. Payment. Payment for items in this section is included under Bid Items D2 and E2.

1.02 REFERENCES

A. American Society for Testing and Materials (ASTM): (Testing to be performed by the Engineer)

1 ASTM D422-63. Standard Test Method for Particle-size Analysis of Soil.

2 ASTM D1140-54. Standard Test Method for Amount of Material in Soils Finer than the No 200 (75 Micrometer) Sieve.

3 ASTM D2216-90. Standard Test Method for Moisture Content Determination Using Oven-Drying Method.

4 ASTM D2850-87. Standard Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression.

5 ASTM D4767-88· Standard Test Method for Direct Shear Test of Soils Under Consolidated Undrained Conditions.

6 ASTM D5084-90. Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.

7. ASTM D2487-92. Standard Classification of Soil for Engineering Purposes (Unified Soil Classification System).

8. ASTM D2922-91. Standard Test Methods for Density of Soil and Soil-Aggregate in-Place by Nuclear Methods (Shallow Depth).

9. ASTM D3017-88 Standard Test Method for Water Content of Soil and Rock in-Place by Nuclear Methods (Shallow Depth).

10. ASTM D4318-84 Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soil

B The frequency, duration, and schedule for soil testing to be conducted by the Engineer during and after construction is included as Table 1.

1.03 PROJECT/SITE CONDITIONS

A. Do not block or obstruct roads with equipment or excavated materials Maintain soil stockpiles within authorized areas

B. Construction traffic shall yield right-of-way to other onpost vehicles and all wildlife

C. Schedule work in coordinated effort with Engineer and Owner.

D. Contractor and Subcontractor will notify each other immediately if delays are anticipated for any reason.

E. All placement and compaction of test fill soil shall be performed only when the Engineer or his representative is on the project site and is informed by the Contractor of intent to perform such work.

PART 2 PRODUCTS

2 01 SOURCE OF TEST FILL AND WORKING LAYER MATERIAL

A. Subcontractor shall obtain clay test fill and working layer material from the designated borrow areas; the Engineer shall observe and approve these materials prior to transport Test fill and working layer material onsite has been classified by the Engineer based on soil borings as typically CL, CH, and SC soil using the Unified Soil Classification System (USCS)

B Upon request, Subcontractor may obtain copies of pertinent boring logs and material testing results at the Contractor's offices

2 02 TEST FILL MATERIAL

A. Material - (Selected by the Engineer)

1 Soil classified as SC, CL, or CH by USCS.

2 Permeability: 1×10^{-7} cm/sec or less by ASTM 5084-90.

3 May contain no more than a negligible amount of organic or other deleterious materials

4 May contain no more than 5 percent gypsum or calcium carbonate, and all gypsum concretions and nodules shall be less than 1 inch in largest diameter.

B. Subcontractor shall modify clay test fill material to assure it meets Specification requirements. Modifications may include, but are not limited to the following.

1. Elimination of soil clods greater than 3 inches in diameter.

2. Removal of rocks larger than 3 inches in any dimension, for all lifts below final lift layer Removal of rocks larger than 1 inch in any dimension within the final lift.

3 Wetting or drying of liner soil to meet moisture requirements

4 Removal of deleterious soil and material not conforming to test fill quality clay requirements

PART 3 EXECUTION

3.01 SUBBASE (WORKING LAYER) EXAMINATION

A. Contractor shall examine surfaces to receive test fill material to determine existence of any unsuitable materials, including materials significantly above or below optimum moisture content. Suitable moisture content shall be obtained prior to placement of the test fill. The working layer surface shall be roughened prior to placement of first test fill lift.

B Unsuitable areas of the working layer shall be corrected prior to clay liner placement. Corrective action may require, but is not limited to: wetting subgrade, drying subgrade by disc harrow, drag harrow, or other means; roughening working layer to promote lift bonding, reworking and recompacting working layer; and removal and replacement of working layer soils.

C. The Subcontractor will be responsible for all costs associated with corrective actions taken to amend the working layer in preparation for test fill placement, at no additional cost to Contractor

D Do not place test fill until working layer has been surveyed, and approved by the Engineer

3.02 PLACEMENT OF TEST FILL

A. Construction of the actual test fill shall begin following placement of the working layer, and after completion of processing and moisture conditioning of the test fill soil. Place clay test fill in accordance with the following:

1 Maximum Loose Lift Thickness. 9 in., includes scarified or roughened depth of previous lift.

2 Maximum Compacted Lift Thickness 6 in. or depth of foot or tooth on compactor used, whichever is less.

3 Minimum Completed Test Fill Thickness 3 0 ft.

4 Maximum Allowable Variation from Design Thickness of Test Fill: 0 ft. to + 0.2 ft.

5. Maximum Rock Size 3 inches in all lifts below final lift. One inch in final lift surface within area designated for Sealed Double-Ring Infiltrometer (SDRI) test.

6. Maximum Soil Clod Size Prior to Compaction: 3 in., or half the lift thickness, whichever is less.

7 Allowable Soil Moisture Content Range· +1 percent to + 4 percent wet of optimum, or as directed by the Engineer.

8 Minimum Soil Compaction. 95 percent of maximum dry density as determined by the Standard Proctor ASTM D698-78.

9. Sideslopes shall be 2H:IV maximum and 3H:IV minimum on the long sides of the test fills. Sideslopes shall be 3H:IV maximum and 4H:IV minimum on the ends of the test fills

B. Material distribution and gradation throughout clay test fill shall be such that material remains free from lenses, pockets, streaks, or sections of material differing substantially in texture or gradation from designated test fill material for which prior source testing has been performed.

C Soil clods larger than specified maximum in any direction shall be broken down to size less than or equal to 3 inches prior to lift compaction.

D Place lifts of clay to form one continuous monolithic layer of material. Assure previous lift is moist and scarify surface of previously placed lifts with disc or other piece of machinery capable of penetrating into previous lift to minimum 1 in. depth to provide proper bonding between subsequent lifts of clay test fill.

E. Bonding successive lifts together shall be accomplished by penetration of the compactor feet or pads through the top lift and into the immediately underlying lift. Compactor feet shall be at least as long as the compacted lift thickness

F Compaction shall be achieved using sheepsfoot roller or similar heavy penetrating foot kneading-type compactors (e.g., CAT 825). Footed rollers towed behind a dozer shall be filled with water to assure sufficient compactive effort is exerted to test fill

G The appropriate number of passes shall be determined by performing density testing during placement and compaction of the lifts.

For the first three lifts, each test fill will be tested by the Engineer for moisture content and density in three locations after the lift has been compacted with each set of two passes of the compactor until at least 95 percent of Standard Proctor compaction has been achieved. The fourth, fifth, and sixth lifts of each test fill shall be compacted using the appropriate number of passes required to achieve a dry density at least 95 percent of Standard Proctor compaction (determined by the testing from the first three lifts)

Final density and moisture content will be verified for each of the top three lifts after the prescribed number of passes has been performed.

A visual lift bonding check using a hand shovel will be performed after each lift. Following completion of the test fill, a backhoe or excavator bucket will be used to check lift bonding of the entire test fill thickness Additionally, three laboratory permeability test samples will be obtained by the Engineer from each test fill after they are completed

For the purposes of these Specifications, a compaction pass is defined as one trip of a single-drum compactor up and back over the complete length of the test fill. If a dual-drum compactor without laterally separated front and rear drums is used, one trip up and back over the test fill would constitute two passes. If a dual-drum compactor that has the drums laterally separated by the operator's cab and differential (such as a CAT 825) is used, one trip up and a staggered trip back to cover the central portion of the roller path shall be considered one pass

H. Uniformly distribute moisture content of clay material prior to and during compaction throughout each lift of material. Clay material determined by Engineer to contain moisture outside specified range shall be adjusted by Subcontractor to provide material within specified range. Adjustment includes, but is not limited to, drying materials containing moisture in excess of specified range and adding water to materials containing moisture less than specified range. No more than 2 percent moisture may be added to the test fill during construction. If the moisture content is less than or equal to 2 percent below the low end of the target moisture content range, the select fill may be sprinkled or sprayed with water and dozed, windrowed, and/or disced to uniformly increase the moisture content. If the moisture content is greater than 2 percent below the target moisture content, the test fill soil shall be removed from the test fill, returned to the stockpile, and conditioned until the proper uniform moisture content is achieved. If the moisture content is greater than 1 percent above the target moisture content, the test fill soil shall be dozed, windrowed, and/or disced to facilitate drying.

I Maintain moisture content of clay test fill materials in previously placed lifts within specified range. Avoid drying and desiccation cracking of materials. Maintenance includes, but is not limited to, wetting surface of previously placed lifts to avoid drying and desiccation cracking of material. Prior to placement and compaction of subsequent lifts of clay material, Engineer will verify that moisture content of scarified material of previously placed lift is within specified limits. Materials determined to possess moisture content outside specified limits shall be adjusted and rechecked before subsequent lift placed.

J Control lift thickness using construction staking, or other method approved prior to construction by the Engineer to assure that requirements of Specifications are met. If grade stakes are utilized by the Subcontractor, Subcontractor should emphasize the removal of damaged stakes to work crew during daily assignments.

K. Minimum clay layer thickness will be verified and documented by Contractor. Rework or remove and replace portions of test fill not meeting Specification requirements

L. Final test fill surface shall slope at approximately 2 percent in the direction shown on the Drawings, Figure 3.

M. Lift bonding will be visually verified by excavating small test pits per the testing schedule.

N Field density and moisture content results from compaction tests shall be checked against compaction Specifications Recompact or rework and retest soil that fails field testing during construction activity Subcontractor shall recompact or rework soil area following a failed test to boundaries of passing test results, at no additional cost to Contractor.

O Precautions to minimize damage to clay test fill due to rainfall shall be taken prior to anticipated rainfall events. Precautions include, but are not limited to, grading surface to promote runoff, back-blading with dozer, sealing surface with smooth drum roller or

other means. Precautions shall be augmented by placing pump(s) in the sump or other area(s) likely to collect water, if necessary. Provide, maintain. and operate pumps; coordinate access to site with Contractor or Owner.

P After test fill or a portion thereof is complete, continue to maintain clay surface in moist condition, free of desiccation cracks. Subcontractor shall remove desiccation cracks by scarifying, wetting, and smooth-drum rolling test fill surface, or other method approved by Engineer.

Q. Repair of Penetrations: Repair of small diameter penetrations, such as those caused when taking Shelby tube samples, shall be repaired to the satisfaction of the Engineer.

R. Maintain surficial moisture content during construction by sprinkling water onto clay materials daily, or more often during hot, dry or windy conditions. Completed lifts that are left unprotected and not sprinkled for several hours or overnight must be scarified and brought to proper moisture content prior to placement of additional lifts

S. All test fill surfaces, with extra attention to areas on which SDRI test apparatus is to be placed, shall be smooth-drum rolled upon completion of clay placement to create surface free of irregularities, protrusions, loose soil, and abrupt changes in grade.

T. From completed test fill areas designated for SDRI, remove stones and soil clods greater than 1 inch in any dimension, bones, and other debris. Restore smooth surface after removal. Embedded, non-protruding smooth rocks may remain in place if approved by the Engineer. Engineer must approve of final test fill surface prior to final payment of Subcontractor.

U Place plastic sheeting or other similar material over completed areas designated for SDRI testing. Method of keeping plastic in place shall be approved by the Engineer.

V After test fill completion, topsoil from the adjacent stockpile shall be placed over the test fill, except SDRI areas, to prevent desiccation. (see Section 08)

3 03 FIELD QUALITY CONTROL

A. Notify Engineer when portions of the test fill are ready for testing.

B Provide Contractor with equipment, time, and labor necessary to support the Engineer in the completion of field testing. (Examples. blading off area for pushing Shelby tubes or nuclear gauge testing.)

C. After the test fill work has been completed, SDRI tests will be conducted by the Engineer on the surface of each test fill. The Subcontractor shall provide an equipment operator to assist the Engineer in the installation of the SDRI apparatus. It is anticipated that 30 hours of time for the operator will be required.

D Equipment to be provided by Subcontractor for installation of the SDRIs includes:

- Trencher (Ditch Witch Model 1010 or other machine capable of making a trench no more than 4 to 6 inches wide)
- Grout mixer (not cement mixer)
- Water truck

- Generator
- Small dozer or loader

This equipment will only be required for three days after completion of test fill

- END OF SECTION -

SECTION 12 SEEDING AND MULCHING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:

1. Seeding/mulching requirements for completed test fill and processing areas.

2. Seeding/mulching requirements for borrow areas.

B. Payment: Payment for items in this section is included under Bid Item E3.

PART 2 PRODUCTS

2 01 MULCH

A. Native grass hay mulch will be provided by Owner. This grass hay mulch is onpost in the southeast portion of Section 29 (See Figure 2 for location).

2.02 SEED

A. Seed shall be provided by Subcontractor to meet the requirements listed in Tables 2 and 3. If Subcontractor has difficulty in obtaining the specified seed mixture, please contact the Engineer or Bruce Hastings of the U.S Fish and Wildlife Service for assistance (303) 289-0232 .

2 03 FERTILIZER

A. No fertilizer is required for this project.

PART 3 EXECUTION

3 01 PREPARATION

A. Topsoil Grading·

1 Grade, rake, and roll with roller weighing not more than 100 lbs. per linear foot and not less than 25 lbs. per linear foot.

3 02 SEEDING

A. Sow seed at rates as described in Tables 2 and 3, dividing seed equally and sowing at 90 degree angles to produce uniform broadcast.

B Rake seed into ground and roll with roller, or use other technique approved by the Engineer

C. Do not seed on surface which has been compacted by rain.

D. Do not seed when wind velocity exceeds 6 mph.

3.03 MULCHING

A. Mulch shall be applied immediately after seeding.

B Place mulch at a rate of 2 tons/acre.

C Mulch shall be crimped immediately after application to prevent blowing away.

D. Place mulch loose or open enough to allow some sunlight to penetrate and air to circulate, but thick enough to shade ground, conserve soil moisture, and minimize erosion.

- END OF SECTION -

Table 1. Test Fill Testing Program (Per Test Fill)

Test	Method	Stockpile	Frequency During Construction	Post-Construction
Moisture Content	Oven drying ASTM D2216-90	3 initial; as needed during processing (approx 12); 3 final· estimate 18 Total	3 per lift (18 total)	---
Moisture Content	Nuclear gauge ASTM D3017	---	3 per each 2 passes per lift for first three lifts; 3 per lift for lifts 4, 5, 6; estimate 45 total	---
Atterberg Limits	Grab sample ASTM D4318-84	3	---	---
Grain Size (incl. clay content)	Sieve and Hydrometer analysis ASTM D422-63	3	---	---
		3	---	---
Optimum Moisture Content and Max Dry Density	Standard Proctor test (grab samples) ASTM D698-78	3	---	---
In-place Density (% compaction)	Nuclear gauge ASTM D2922	---	3 per each 2 passes per lift for first three lifts; 3 per lift for lifts 4, 5, 6; estimate 45 total	---
Lift Thickness (loose)	Manual	---	25-ft intervals down center-line of test fill	---
Lift Thickness (compacted)	Manual	---	25-ft intervals down center-line of test fill	---

Table 1 (continued)

Test	Method	Stockpile	Frequency During Construction	Post-Construction
Final Test Fill Thickness	Survey	---	---	3
Lift Bonding	Visual: Test Pits	---	2 per lift (Manual)	3 (Backhoe)
Laboratory Permeability	Shelby tubes, Flexible Wall Permeameter (falling-head test) ASTM D5084-90	---	---	3
Field Permeability (large-scale)	Sealed double-ring infiltrometer (SDRI)	---	---	1
Field Permeability (small-scale)	2-stage borehole (Boutwell)	---	---	5
Shear Strength	Consolidated undrained ASTM D4767-88	---	---	2
Shear Strength	Unconsolidated undrained ASTM D2850-87	---	---	2

--- Not performed

Table 2. Seed Mixture for Borrow Areas

Scientific Name	Common Name	Variety	Lbs PLS/ Acre
Seed Mix for Native Grass Species			
Bouteloua gracilis	Blue Grama	Hachita	0.9
Pascopyron smithii	Western Wheatgrass	Arriba	6.5
Buchloe dactyloides	Buffalo Grass	Sharp's	12.9
		Total	20.2
Native Forbs or Semi-shrubs (ALL 0.1 lbs. PLS/acre)			
Erysimum asperum	Wallflower		
Gaillardia aristata	Blanket Flower		
Penstemon angustifolia	Narrow-leaf Penstemon		
Linum lewisii	Blue Flax		
Helianthus annuus	Annual Sunflower		
Achillea lanulosa	Yarrow		
Arstemisia ludoviciana	Louisiana Sagewort		
Sphaeralcea coccinea	Scarlet Globemallow		
Artemisia frigida	Fringed Sage		
Dalea purpurea	Purple Prairie-clover		
Oenothera caespitosa	White Tufted Evening Primrose		
Native Shrubs and Trees (Both 0.1 lbs PLS/Acre)			
Ceratoides lanata	Winterfat		
Atriplex canescens	Fourwing Saltbush		

PLS Pure live seed

Table 3. Seed Mixture for Test Fill and Processing Area

Scientific Name	Common Name	Variety	Lbs PLS/ Acre
Seed Mix for Native Grass Species			
Bouteloua gracilis	Blue Grama	Hachita	1.1
Calamovilfa longifolia	Prairie Sandreed	Goshen	0.4
Bouteloua curtipendula	Side-oats Grama	Vaughn	0.6
Sporobolus cryptandrus	Sand Dropseed		0.1
Stipa comata	Needle-and-thread		1.9
Andropogon hallii	Sand Bluestem	Woodward	1.0
Pascopyron smithii	Western Wheatgrass	Arriba	5.0
Oryzopsis hymenoides	Indian Ricegrass	Nezpar	0.8
		Total	10.9
Native Forms or Semi-shrubs (Wildflowers) (All 0.1 lbs PLS/acre)			
Cleome serrulata	Rocky Mountain Bee Plant		
Delphinium virescens	Larkspur		
Liatris punctata	Blazing-star		
Oenothera caespitosa	Stemless Evening-primrose		
Oenothera villosa	Tall Evening-primrose		
Ipomoea leptophylla	Bush Morning Glory		
Gaillardia aristata	Blanket Flower		
Penstemon angustifolia	Narrow-leaf Penstemon		
Linum lewisii	Blue Flax		
Helianthus annuus	Annual Sunflower		
Achillea lanulosa	Yarrow		
Artemisia ludoviciana	Louisiana Sagewort		
Coreopsis tinctoria	Plains Coreopsis		
Sphaeralcea coccinea	Scarlet Globemallow		
Artemisia frigida	Fringed Sage		
Abronia fragrans	Sand Verbena		
Native Shrubs and Trees (All 0.1 lbs PLS/Acre)			
Chrysothamnus nauseosus	Rubber Rabbitbrush		
Atriplex canescens	Fourwing Saltbush		
Artemisia filifolia	Sand Sagebrush		

PLS Pure live seed

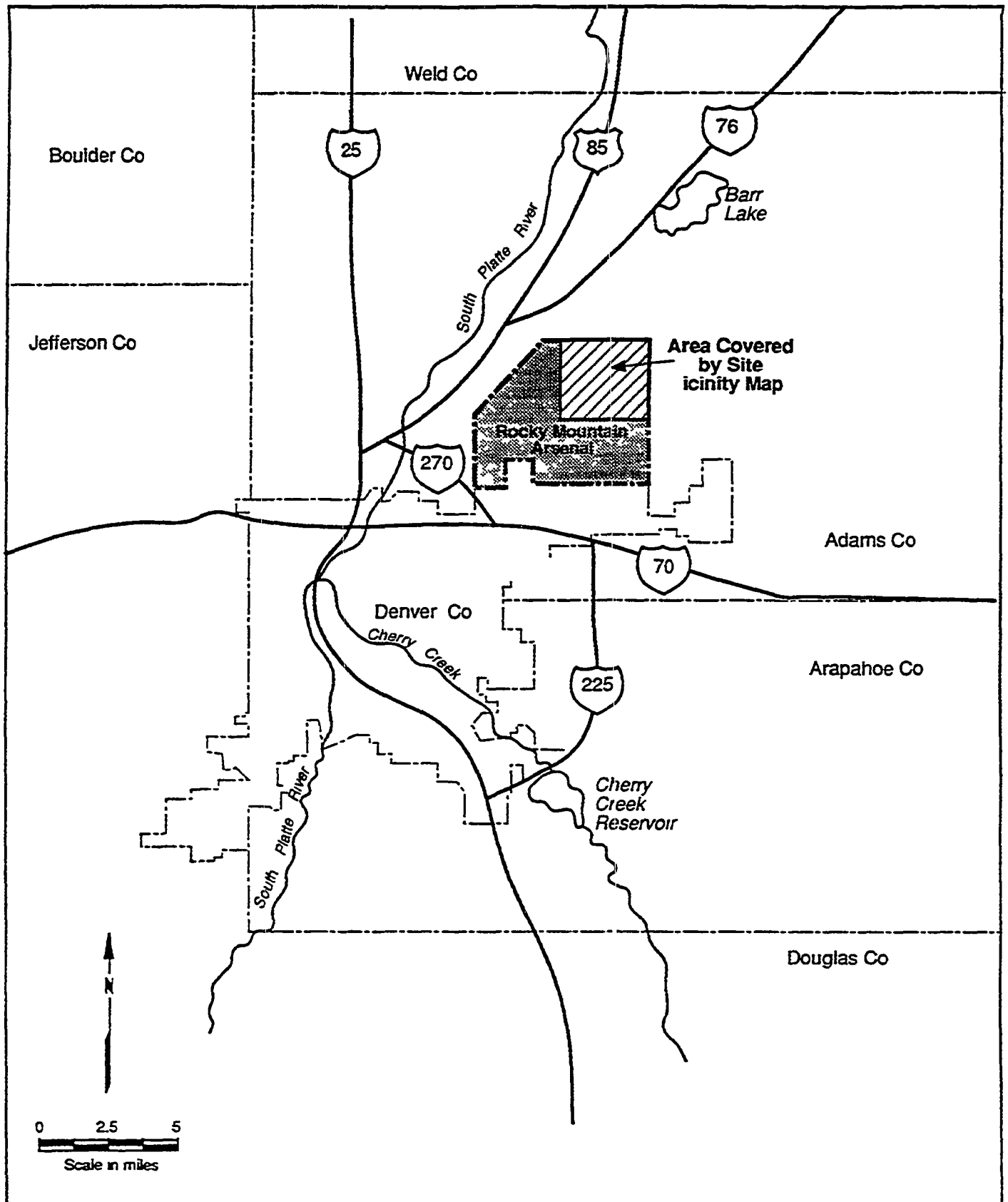

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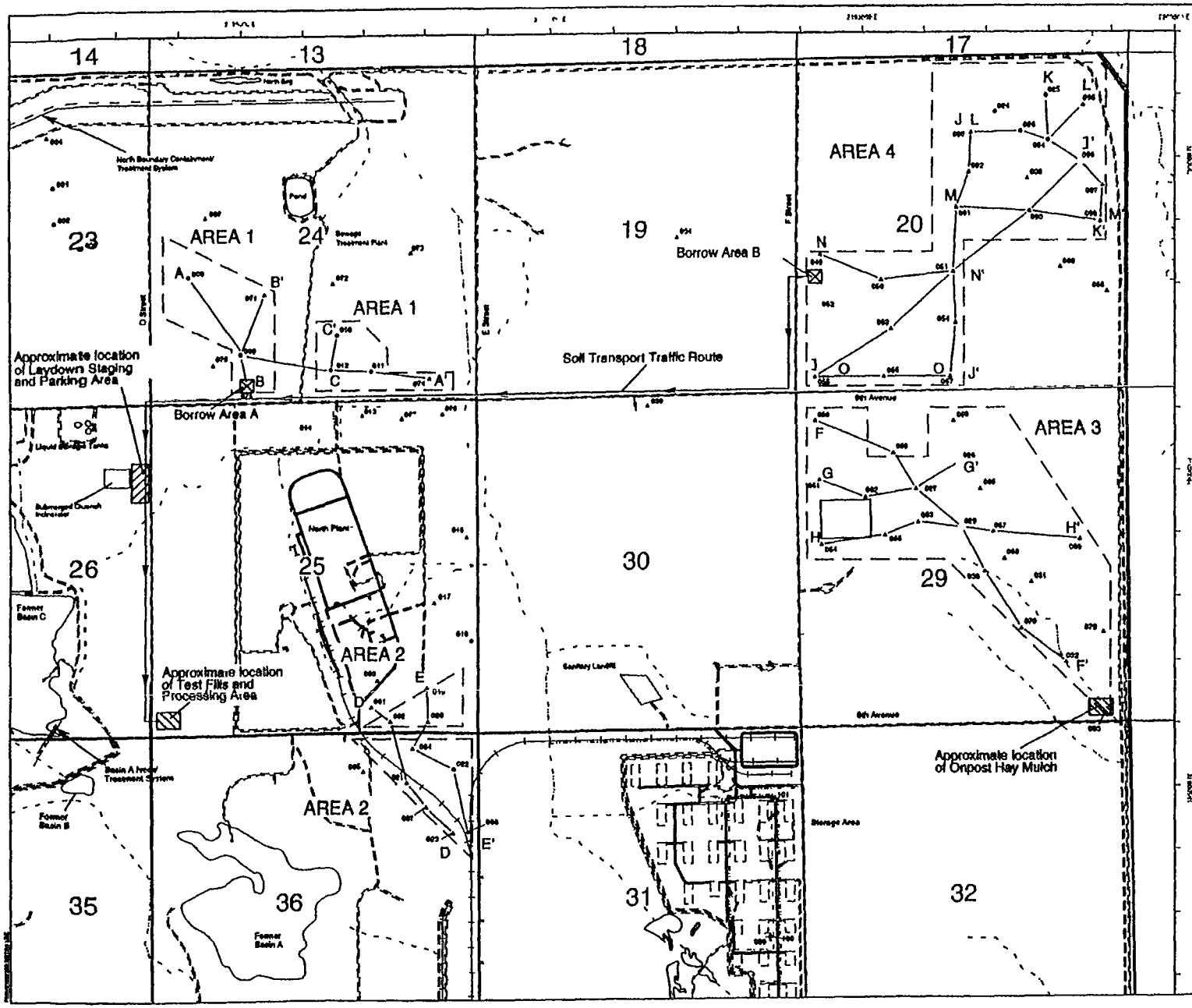
Figure A-1

Site Location Map

RMA 1232 6 3/7/95 LAM



Explanation

- Boring location for Stage 1 of Boring Program Nunn Clay
- Boring location for Stage 1 of Boring Program Weld Clay
- Boring location for Stage 1 of Boring Program Bresser Clay
- Boring location for Stage 2 of Boring Program Nunn Clay
- Boring location for Stage 2 of Boring Program Weld Clay
- Surface sample location for Stage 2 Berm Material
- A—A Line of cross sections
- Railroad
- Ditch or stream
- Paved road
- Unpaved road
- 16 Section number

Containment Systems

- Physical barrier
- Hydraulic barrier
- Recharge trenches
- Barrier wall

Note
The boring identification numbers shown have been abbreviated The full boring identification number contains the soil unit before the number and 93 for 1993 at the end For example the complete boring identification number for Boring 012 is WEB01293

Area surrounding Demolition Area not included in potential low permeability borrow area

N

0 1500
Scale in feet

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Figure A 2

Site Vicinity Map

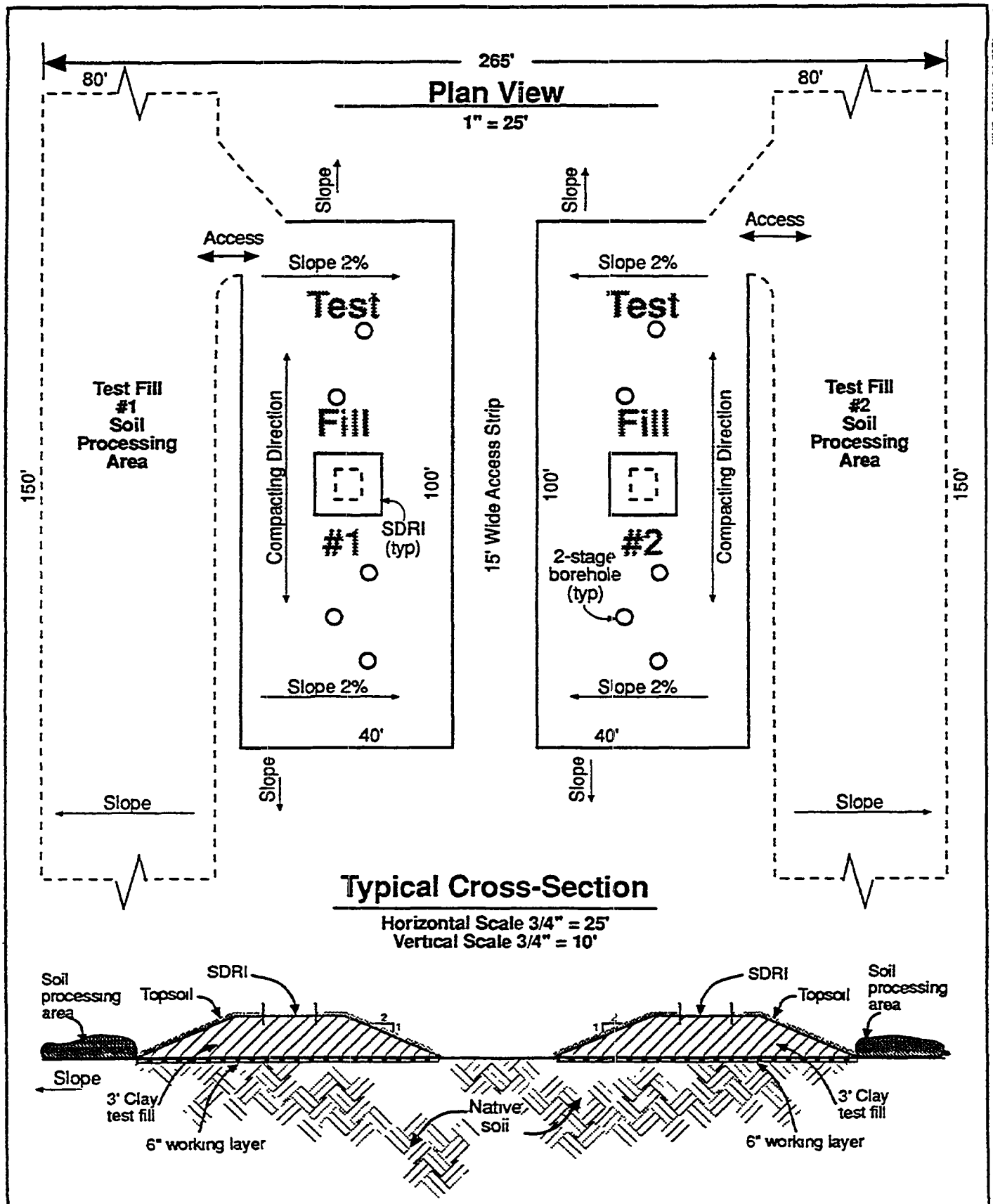

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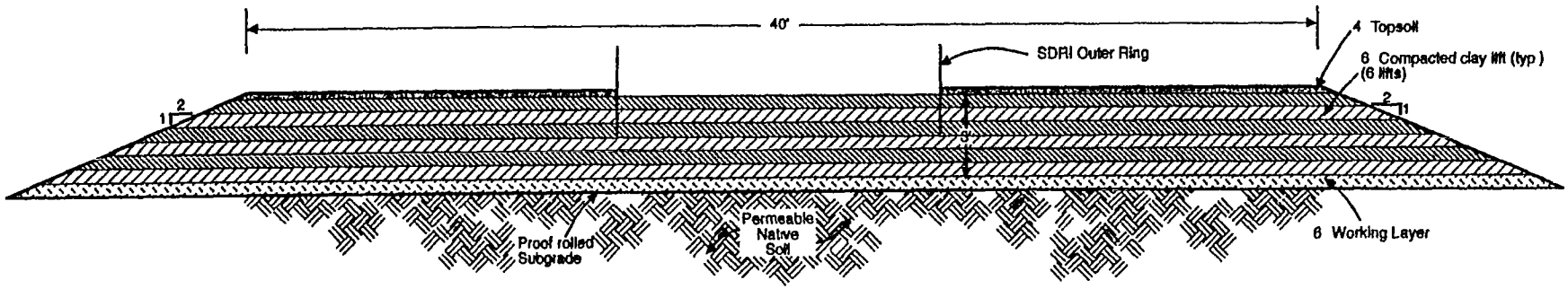
Figure A-3

Test Fill Layout

RMA 1232 to 3/7/95 LAM

Typical Test Fill Cross Section



1 25" = 5'

Note. Maximum slope shall be 2H:1V on long sides 3H:1V on ends of test fill Minimum slope shall be 3H:1V on long sides and 4H:1V on ends of test fill

0 2.5 5
Scale in feet

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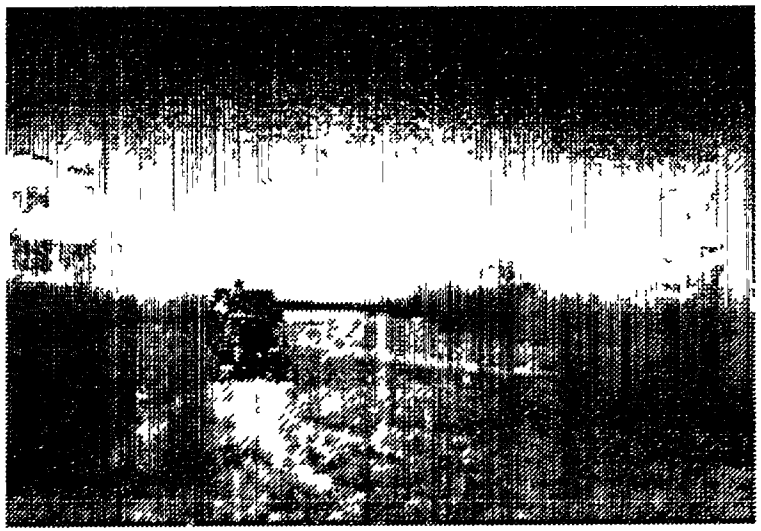
Figure A 4

Typical Test Fill Cross Section

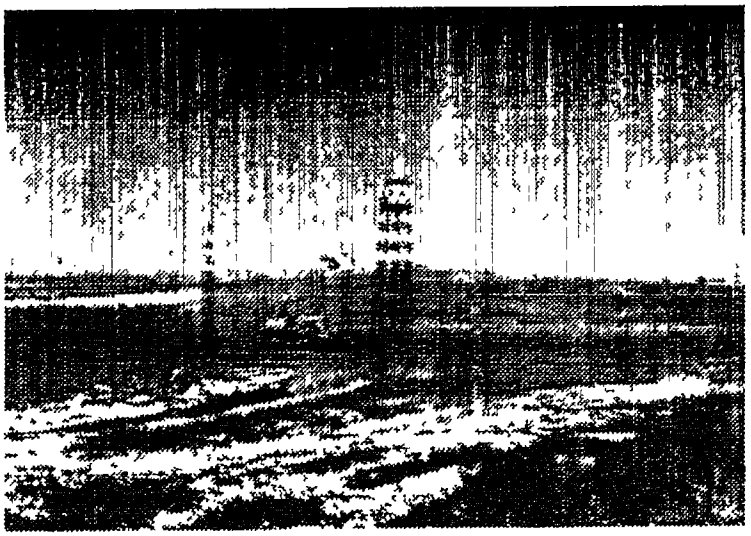
Appendix B

TESTFILL CONSTRUCTION PHOTOGRAPHS

A Excavation of Borrow Pit A in Section 24



B Hay mulching excavation pit after replacing topsoil and reseeding



C Stripping and stockpiling topsoil in test fill construction area

D Scarifying test fill subgrade after wetting and compacting native sandy soil

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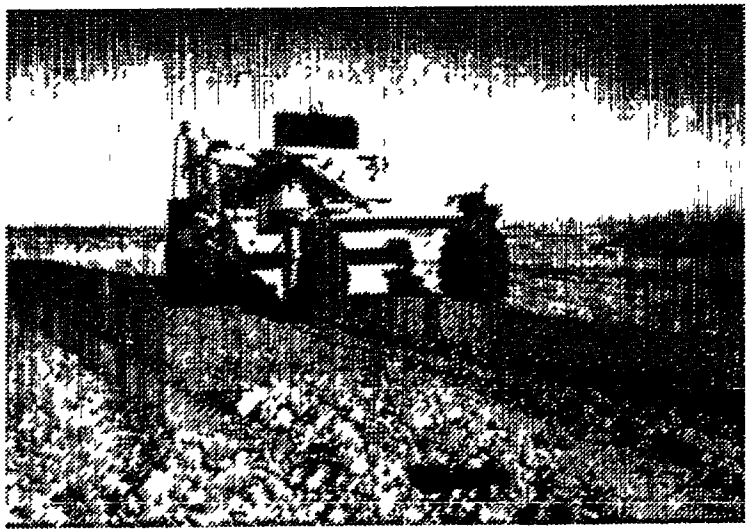
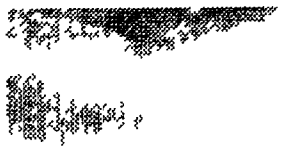
Figure B-1 (1 of 5)

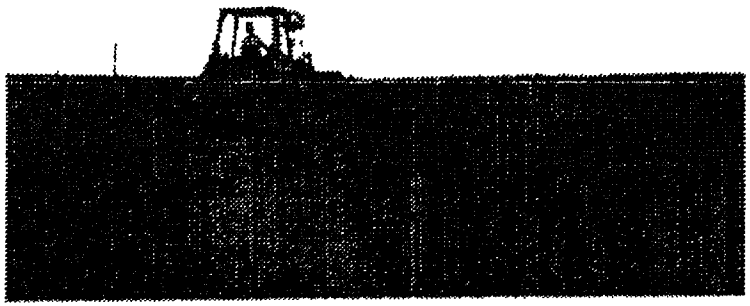
Photo Documentation of Test Fill Construction

RMA 1241 3/9/95 LAM



F Pulvamixer used to reduce clod size, moisture condition, and blend soil





G Scarifying the surface of a lift with the dozer tracks

E Soil processing using a tiller

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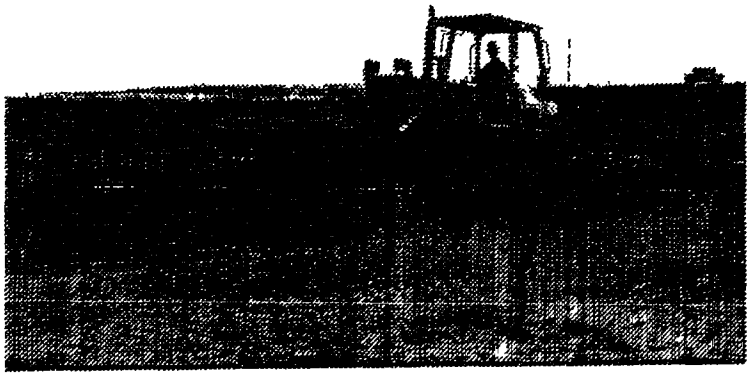
Figure B-1 (2 of 5)

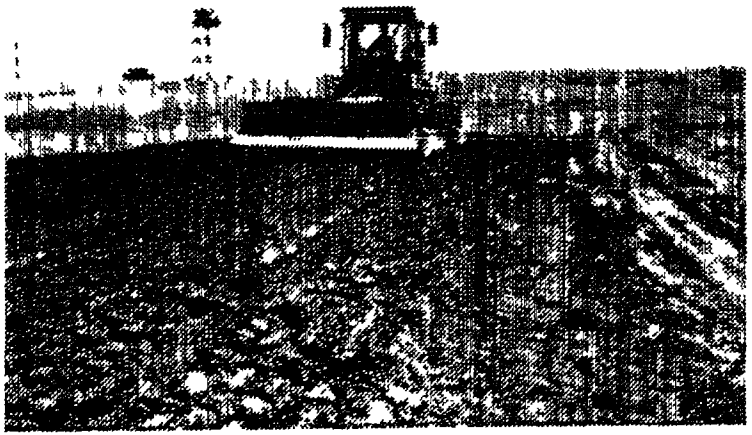
Photo Documentation of Test Fill Construction

RMA 12411 3/9/95 LAM



H Spreading a loose lift on the surface of the test fill with a dozer blade at a thickness of 8 - 9 inches

I Blending/moisture conditioning by adding water directly to drum of pulvamixer



J Compaction of the loose lift with the Caterpillar 815C compactor

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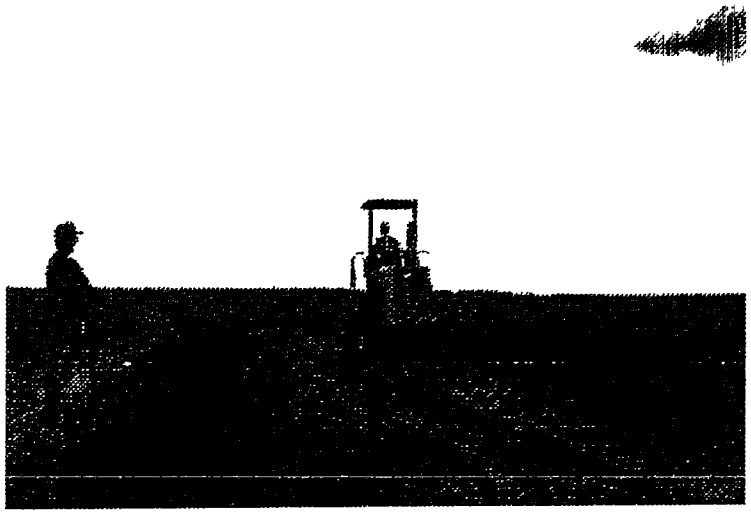
Figure B-1 (3 of 5)

Photo Documentation of Test Fill Construction



K. Smooth drum rolling test fill surface

L. Tarp covering test fill lift to prevent dessication

M To prevent desiccation of the test fill, the surface was wetted and topsoil was spread on the test pad except in the 12 x 12 foot area sealed with a tarp for solid double-ring infiltrometer installation

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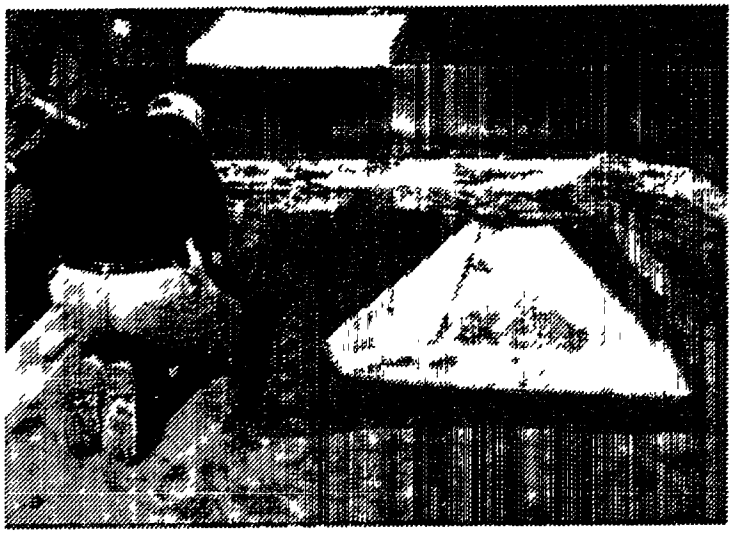
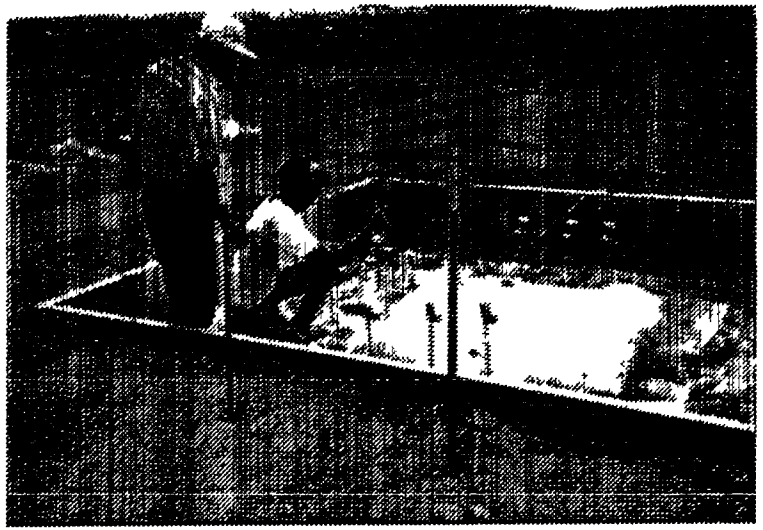
Figure B-1 (4 of 5)

Photo Documentation of Test Fill Construction

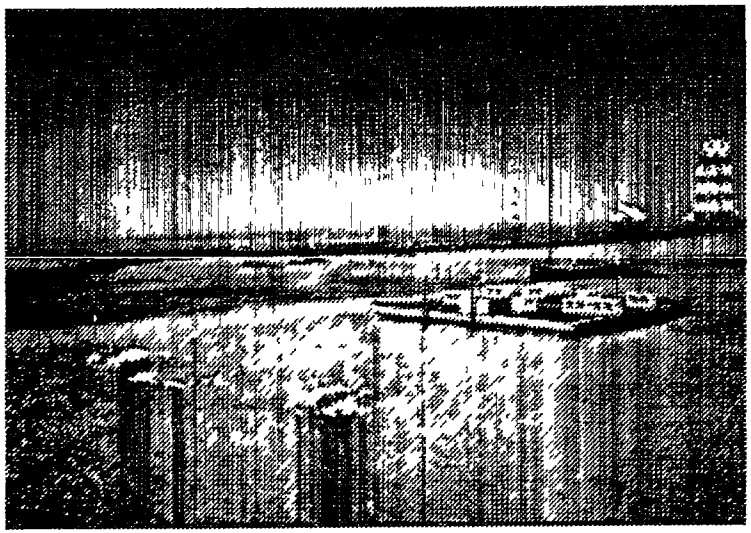
RMA 1241.3 2/1/85 LAM



N Applying grout to the inner SDRI ring installation



O Measuring the distance between the inner ring and the swell measurement guides



P Completed test fill with sealed double-ring infiltrometer and two-stage borehole installation

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Figure B-1 (5 of 5)

Photo Documentation of Test Fill Construction

RMA 1241 4 3/9/95 LAM

Appendix C

TESTFILL CONSTRUCTION EQUIPMENT

MODEL	815B		825C	
Flywheel Power	161 kW	216 hp	235 kW	315 hp
Operating Weight	20 015 kg	44 175 lb	32 400 kg	71 429 lb
Engine Model	3306		3406	
Rated Engine RPM	2200		2100	
No. Cylinders	6		6	
Displacement	10.5 L	639 in³	14.6 L	893 in³
Speeds				
Forward	4		4	
Reverse	4		4	
Turning Circle with Blade	19.3 m	40 3"	14.2 m	46 6
Fuel Tank Refill Capacity	462 L	122 U S gal	569 L	150 U S gal
TAMPING FOOT WHEELS				
Earth Drum Width	978 mm	3 2.5"	1118 mm	3 8
Diameters over feet	1.42 m	4 8	1.60 m	5 6"
over drum	1.03 m	3 4.5	1.29 m	4 3
Feet per Wheel	60		65	
Feet per Row	12		13	
Rows of Feet	5		5	
Foot Length	168 mm	6.6	220 mm	8.7
End Area Per Foot	135 cm²	21 in²	183 cm²	28.4 in²
Width of Two Pass Coverage	4.35 m	14.3	4.88 m	16.0"
GENERAL DIMENSIONS				
Height (top of ROPS)	3.53 m	11.7	3.91 m	12 10"
Height (stripped top)	2.38 m	7 10"	2.98 m	9.6"
Wheel Base	3.35 m	11.0	3.53 m	11.7"
Overall Length with Dozer	6.80 m	22.4	7.68 m	25.2
Width over Drums	3.24 m	10.8"	3.65 m	11.11
Ground Clearance	203 mm	8"	234 mm	9.2"
STRAIGHT BULLDOZER				
Width	3.76 m	12	4.53 m	14 10"
Height	0.60 m	2 10"	1.04 m	3.6"

Operating Weight includes coolant lubricants buildup hydraulics ROPS canopy full fuel tank and operator
¹Height (stripped top) — without ROPS exhaust, seat back or other easily removed encumbrances
With Compactor feet at 100% penetration

COMPACTION FUNDAMENTALS

The following discussion applies to soil compaction only For information on refuse compaction see Waste Disposal — Section 23 of this book

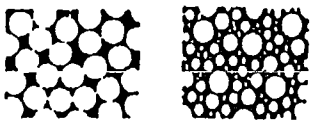
Definition

Compaction is the process of physically densifying or packing the soil resulting in an increase in weight per unit volume. It is generally accepted that the strength of a soil can be increased by densification Three important factors affect compaction

- Material gradation
- Moisture content
- Compactive effort

Material Gradation — refers to the distribution (% by weight) of the different sizes of particles within a given soil sample. A sample is described as well graded if it contains a good, even distribution of particle sizes. If a soil sample is composed of predominantly one size particle, it is said to be poorly graded In terms of compaction, a well graded soil will compact more easily than one that is poorly graded In well graded material the smaller particles tend to fill the empty spaces between the larger particles, leaving fewer voids after compaction

MATERIAL GRADATION

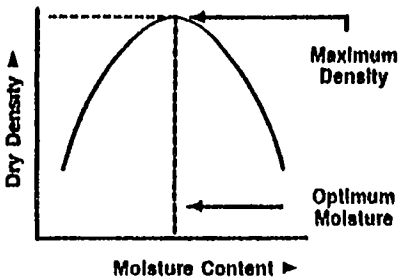


Poorly graded Well graded

Moisture Content — or the amount of water present in a soil, is very important to compaction Water lubricates soil particles thus helping them slide into the most dense position Water also creates clay particle bonding, giving cohesive materials their sticky qualities.

Experience has shown that it is very difficult, if not impossible, to achieve proper compaction in materials that are too dry or too wet Soil experts have determined that in practically every soil there is an amount of water, called optimum moisture content, at which it is possible to obtain maximum density with a given amount of compactive effort The curve below shows this relationship between dry density and moisture content It is called a compaction curve moisture density curve or Proctor curve

MOISTURE CONTENT



Compactive Effort — refers to the method employed by a compactor to impart energy into the soil to achieve compaction Compactors are designed to use one or a combination of the following types of compactive effort

- Static weight (or pressure)
- Kneading action (or manipulation)
- Impact (or sharp blow)
- Vibration (or shaking)

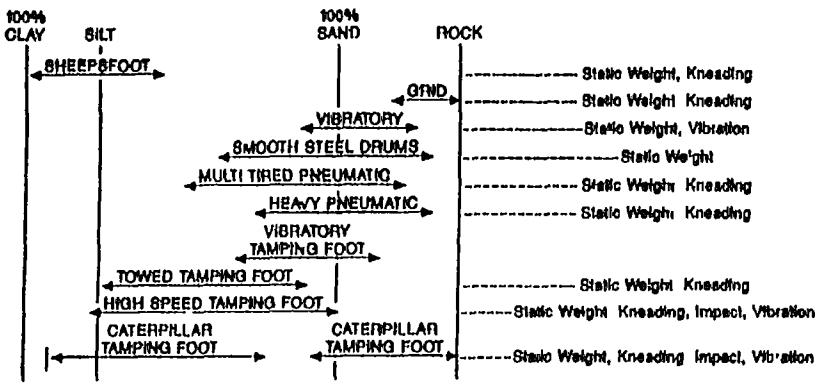
COMPACTOR TYPES

Compaction equipment can be grouped generally into nine different types or classifications
(1) sheepsfoot
(2) grid or mesh
(3) vibratory
(4) smooth steel drum
(5) multi tired pneumatic
(6) heavy pneumatic
(7) towed tamping foot
(8) high speed tamping foot
(9) chopper wheels (see Landfill Compactor section)

Combinations of these types are also available, such as a vibrating smooth steel drum

For ease of comparison, the first eight types of compactors have been placed on the Zones of Application Chart shown below This chart contains a range of material moistures from 100% clay to 100% sand, plus a rock zone Each type has been positioned in what is considered to be its most effective and economical zone of application However, it is not uncommon to find them working out of their zones. Exact positioning of the zones can vary with differing material conditions

COMPACTOR ZONES OF APPLICATION | COMPACTIVE METHOD



COMPACTOR PRODUCTION

Compactor production is expressed in compacted cubic meters (Cm^3) or compacted cubic yards (CCY) per hour Material in its natural or bank state is measured in bank cubic meters or yards (Bm^3 or BCY) When it is removed or placed in a fill, it is measured in loose cubic meters or yards (Lm^3 or LCY)

When the loose material is worked into a compacted state, the relationship of *compacted material* to *bank material* is shown as the shrinkage factor (SF)

$$SF = \frac{\text{Compacted cubic meters } (Cm^3)}{\text{Bank cubic meters } (Bm^3)}$$

$$SF = \frac{\text{Compacted cubic yards (CCY)}}{\text{Bank cubic yards (BCY)}}$$

The construction industry has developed the following formula for use in estimating compactor production. This formula gives the volume of material which a given machine can compact in a 60 minute hour

Metric Method

$$Cm^3 = \frac{W \times S \times L}{P}$$

W = Compacted width per pass, in meters (For Caterpillar Compactors it is recommended that W = Twice the width of one wheel)
S = Average speed, in kilometers per hour
L = Compacted thickness of lift, in millimeters.
P = Number of machine passes to achieve compaction (can only be determined by testing the density of the compacted material on the job).

English Method

$$CCY/Hr = \frac{W \times S \times L \times 16.3}{P}$$

W = Compacted width per pass, in feet (For Caterpillar Compactors it is recommended that W = Twice the width of one wheel)
S = Average speed, in miles per hour
L = Compacted thickness of lift, in inches.
16.3 = Conversion constant, equals 5280 feet ÷ 12 inches ÷ 27 cubic feet
P = Number of machine passes to achieve compaction (can only be determined by testing the density of the compacted material on the job)

Example problem (Metric)

Determine production for an 815B operating under the following conditions

P = 5, S = 10 km/h, L = 100 mm

Refer to 815B in the production table on the next page. Read down the first column until reaching section for 5 passes Within this section in the second column, find the speed closest to 10 km/h Read across this line to the 100 mm compacted lift Read the production figure given.

Answer: 377 Cm^3/h (Since the machine's speed of 10 km/h is slightly faster than the 9.5 of the table, production may be interpolated slightly higher — say 395 Cm^3/h)

• • •

Example problem (English)

Determine production for an 825C operating under the following conditions

P = 4, 8 S = 8 mph L = 6 inches

Refer to the production estimating table below. This table contains estimates for the 815B and 825C Compactors using various speeds, lift thicknesses and number of passes. These figures were calculated using the formula discussed on this page. The figures represent 100% efficiency. W=Twice the width of one wheel.

In the 825 portion of this table, read down the first column until reaching the section for four passes. Within this section in the second column, find the line for 8 mph. Read across this line to the lift thickness column for 6 inches. Read the production figure given.

Answer: 1444 CCY/hr

• • •

PRODUCTION TABLE

MODEL AND MACHINE PASSES*	AVERAGE SPEED km/h	AVERAGE SPEED mph	COMPACTED LIFT THICKNESS 100 mm m³/h	4 in yd³/hr	150 mm m³/h	6 in yd³/hr	200 mm m³/h	8 in yd³/hr	250 mm m³/h	10 in yd³/hr
815B 3	6.5	4	419	548	628	822	837	1095	—	
	9.5	6	628	822	942	1232	1256	1643	—	
	13.0	8	837	1095	1256	1643	1675	2191	—	
4	6.5	4	314	411	471	616	628	822	—	
	9.5	6	471	616	706	924	942	1232	—	
	13.0	8	628	822	942	1232	1256	1643	—	
6	6.5	4	251	328	377	493	502	657	—	
	9.5	6	377	493	565	739	754	986	—	
	13.0	8	502	657	754	986	1005	1314	—	
8	6.5	4	209	274	314	411	419	548	—	
	9.5	6	314	411	471	616	628	822	—	
	13.0	8	419	548	628	822	837	1095	—	
825C 3	6.5	4	488	642	731	962	975	1283	1219	1604
	9.5	6	713	962	1069	1444	1426	1925	1781	2406
	13.0	8	975	1283	1463	1925	1950	2566	2438	3209
4	6.5	4	366	481	534	722	731	962	914	1203
	9.5	6	534	722	802	1083	1069	1444	1336	1804
	13.0	8	731	962	1097	1444	1463	1925	1828	2406
6	6.5	4	293	385	439	577	585	770	731	962
	9.5	6	428	577	641	866	855	1155	1069	1444
	13.0	8	585	770	878	1155	1170	1540	1463	1925
8	6.5	4	244	321	366	481	488	642	609	802
	9.5	6	356	481	534	722	713	962	891	1203
	13.0	8	488	642	731	962	975	1283	1219	1604

The number of machine passes required is dependent on soil type, moisture content, desired compaction and machine weight.

RR 250

The RR 250 is a heavy duty single rotor cold in place reclaiming machine that utilizes a cutting mandrel that pulverizes and mixes asphaltic pavement and base materials. The machine is utilized for mechanical stabilization of deteriorated road surfaces and for complete reclamation with the addition of asphaltic emulsions or other binding agents. The RR 250 can be equipped with attachments that accurately inject liquid additives directly into the mixing hood. Optional rotors can be installed to convert the RR 250 into a soil stabilizer. The internally mounted breaker bar aids in material sizing.

SS 250

The SS-250 is a heavy duty single rotor soil stabilization machine. The machine cuts, mixes and pulverizes native in place soils or select materials, with or without additives. It modifies and stabilizes the soil obtaining a strong base.

Both the RR & SS 250 feature automatic depth control and engine load sensing.

Features.

- Full 2438 mm (8 ft) wide cutting drum delivers maximum production
- Large hood and adjustable rear door enable operator to generate most uniform mix
- Mixing depth down to 457 mm (18 in) on SS-250 and 330 mm (13 in) on RR 250
- Rotor and machine travel direction are the same. Rotor up cuts assuring maximum blending of soil materials and maximum engine and rotor drive life. Consistent mixing and blending capability reduces number of passes required to achieve specified mixing. Rotor can also be ordered in the down cut mode.
- Interchangeable rotors allow the machine to adapt to the job for best performance.
- Heavy duty mechanical rotor drive is protected with proven shear pin design
- Heavy duty chains on each side of rotor are enclosed in oil and dust tight cases.
- 3 speed hydrostatic transmission provides smooth operation and travel speeds
- 3 usable rotor speeds for matching materials and required gradation
- Automatic depth control
- Engine load sensing.
- Optional Asphalt Spray System available for RR 250
- Optional Water Spray System available for RR 250 and SS 250
- Hydraulically adjusted rear door for gradation control
- Optional rear wheel steering for a 6096 mm (20 ft) turning radius.
- Optional light package for night applications

MODEL	RR 250			SS 250		
Flywheel Power	250 kW		335 hp	250 kW		335 hp
Operating Weight	18 053 kg		39 800 lb	13 517 kg		29 800 lb
Engine Model	3406B			3406B		
Rated Engine RPM	2100			2100		
No. Cylinders	6			6		
Bore	137 mm		5.4	137 mm		5.4"
Stroke	165 mm		6.5"	165 mm		6.5
Displacement	14.6 L		893 in³	14.6 L		893 in³
Drive Systems Rotor	3 speed Mechanical			3 speed Mechanical		
Ground	3 speed Hydrostatic			3 speed Hydrostatic		
Operating Dimensions Height	2600 mm		8'6.5	2600 mm		8'6.5
Width	2921 mm		9.7"	2921 mm		9.7
Length	8560 mm		28.1	8560 mm		28.1
Width of Cut	2438 mm		8'0"	2438 mm		8.0
Depth of Cut (Max.)	305 mm		12"	457 mm		18
Rotor Speed	Trans	Drive	Speed	Trans	Drive	Speed
	Low	Low	123 rpm	Low	Low	123 rpm
	Low	High	188 rpm	Low	High	188 rpm
	High	Low	284 rpm	High	Low	284 rpm
Minimum Turning Radius: Standard	12.19 m		40.0"	12.19 m		40'0"
with optional rear steer	6.09 m		20'0"	6.09 m		20'0"
Travel Speed (Max.)	19.3 km/h		12 mph	19.3 km/h		12 mph
Gross Gradeability (will vary with conditions)	40%			30%		
Standard Tires: Front	23.5 x 25-16 ply Lug Type E 2			20.1 x 26 10 PR Lug		
Rear	16.5 x 25-8 ply Lug Type L 2			14.9 x 24 6 PR Lug		
Fuel Capacity	416 L		110 U.S. gal	416 L		110 U.S. gal
Cooling System	61 L		16 U.S. gal	61 L		16 U.S. gal
Crankcase	34 L		9 U.S. gal	34 L		9 U.S. gal

OPTIONAL EQUIPMENT

- Roll Over Protective Structure (ROPS)
- Foot per minute indicator (available in metric)
- Working light package
- Cab with heater and defroster
- Automated Asphalt Metering and Injection System (English or Metric) Includes a foot per minute indicator
- Water spray system with 76 mm (3 in) in line flow meter (English or Metric)
- Rear Wheel Steering for 6 1 m (20 ft) turning radius
- Cab with Air Conditioner

Rotor Options for RR 250 & SS 250

Rotor	Maximum Depth of Work		No. of Bits/Tools	Direction of Cut
Quick Change Tool	381 mm	15"	56	Up
Standard Mix Chopper	381 mm	15"	39 R H 39 L H	Up
Standard Mix Straight Tool	406 mm	16	78	Up
Deep Mix Chopper	457 mm	18"	39 R H 39 L H	Down
Deep Mix Straight Tool	483 mm	19	78	Down
RR 250 Reclamation Rotor				
Cone Tool Milldrum	330 mm	13	168 Quick Change Carbide Tipped	Up
Breakaway Holder Rotor	330 mm	13"	168 Carbide Bits	Up

PRODUCTION ESTIMATING

The standard Cat Soil Stabilizer and Reclaimer are capable of cutting and mixing to depths of 15 in* and 13 in respectively In addition, the cutting width of their rotors is 8 feet The following formulas allow you to determine the production in square yards (yd^2)/minute or cubic yards (yd^3)/minute

Production in square yards (yd^2) per minute

$$yd^2/min = \frac{FPM \text{ of travel speed}}{1\ 125}$$

$$\frac{9\ ft^2/yd^2}{8\ ft \text{ Cutting width}} = 1\ 125 \text{ (This is a constant value for an eight foot wide rotor)}$$

Gallons of additive (for units with pump and metering additive system)

$$\frac{GPM}{yd^2/min} = gal/yd^2$$

Or, if required additive amounts are known, you can determine necessary travel speed as shown

$$\frac{GPM}{gal/yd^2} = yd^2/min,\ yd^2/min \times 1\ 125 = ft/min$$

Production in Cubic Yards (yd^3) per minute

$$\frac{FPM \text{ of travel speed}}{1\ 125} \times \frac{\text{Cutting or mixing depth in inches}}{36} = \frac{yd^3}{min}$$

Production in Tons per Minute

$$yd^3/min \times \frac{\text{Wt of Material per yd in lbs}}{2000\ lb/ton} = tons/min$$

*Optional 18 in

Abbreviations

FPM = Foot Per Minute
GPM = Gallons Per Minute

WEIGHT OF MATERIALS

Material		lbs/yd³ (LOOSE)	lbs/yd³ (IN PLACE)
Clay	— Dry	2500	3100
	— Wet	2800	3500
Clay and Gravel	— Dry	2400	2800
	— Wet	2600	3100
Sand and Gravel	— Dry	2900	3250
	— Wet	3400	3750
Sand	— Dry	2400	2700
	— Damp	2850	3200
	— Wet	3100	3500
Earth	— Dry Packed	2550	3200
	— Wet Excavated	2700	3400
	— Top Soil	1600	2300
	— Loam	2100	2600
Bituminous Concrete	— Windrowed Chunks (25% Voids)	2925	
	— Compacted		3900

STABILIZATION/RECLAMATION PRODUCTION

To eliminate field calculations the following chart lists production in Square Yards per Minute (yd^2/min) and Cubic Yards per Minute (yd^3/min) The information is based on various travel speeds and cutting depths for the Caterpillar RR 250 and SS 250 equipped with a 2438 mm (8 ft) cutting rotor

Travel Speed FPM	6		8		10		12		13		15		18		16	
	yd^2/min	yd^3/min	yd^2/min	yd^3/min	yd^2/min	yd^3/min	yd^2/min	yd^3/min	yd^2/min	yd^3/min	yd^2/min	yd^3/min	yd^2/min	yd^3/min	yd^2/min	yd^3/min
10	0.9	1.5	0.9	2.0	0.9	2.5	0.9	3.0	0.9	3.2	0.9	3.7	0.9	4.0	0.9	4.5
20	17.8	3.0	17.8	4.0	17.8	4.9	17.8	5.9	17.8	6.4	17.8	7.4	17.8	7.9	17.8	8.9
30	26.7	4.5	26.7	6.0	26.7	7.4	26.7	8.9	26.7	9.6	26.7	11.1	26.7	11.9	26.7	13.4
40	35.6	5.9	35.6	7.9	35.6	9.8	35.6	11.9	35.6	12.8	35.6	14.8	35.6	15.8	35.6	17.8
50	44.5	7.4	44.5	9.9	44.5	12.4	44.5	14.8	44.5	16.0	44.5	18.5	44.5	19.8	44.5	22.3
60	53.4	8.9	53.4	11.9	53.4	14.8	53.4	17.8	53.4	19.3	53.4	22.2	53.4	23.7	53.4	26.7
70	62.3	10.4	62.3	13.8	62.3	17.3	62.3	20.8	62.3	22.5	62.3	25.9	62.3	27.7	62.3	31.2
80	71.2	11.9	71.2	15.8	71.2	19.8	71.2	23.7	71.2	22.7	71.2	29.6	71.2	31.6	71.2	35.6
90	80.1	13.4	80.1	17.8	80.1	22.4	80.1	26.7	80.1	28.9	80.1	33.3	80.1	35.6	80.1	40.1

Appendix D

SDRI AND TSB DATA

SDRI Data Table											
Project Title		Rocky Mountain Arsenal Task 93-03, Soils Feasibility									
Project Number		21907 207040									
Test Site		RMA Test Fill #1									
					Bag 1		Bag 2				
				Interval	Initial	Final	Initial	Final	Flow	Avg Day	Infiltr
Date On	Date Off	Time On	Time Off	(t)	weight	weight	weight	weight	(Q)	Number	(I)
				sec	gm	gm	gm	gm	ml		cm/sec
8/10/94	8/11/94	13 34	8 00	66360	3759	3578	4222	3750	653	0	4 24E-07
8/11/94	8/12/94	9 58	7 55	79020	3578	3355	3750	3578	395	2	2 15E-07
8/12/94	8/13/94	9 20	8 28	83280	3355	3301	3578	3260	372	3	1 92E-07
8/13/94	8/15/94	9 33	7 45	166320	3301	3046	3260	2974	541	4	1 40E-07
8/15/94	8/16/94	8 22	10 55	95580	3046	3015	2974	2760	245	6	1 10E-07
8/16/94	8/19/94	14 18	7 18	234000	3664	3273	3541	3332	600	8	1 10E-07
8/19/94	8/22/94	7 50	7 40	258600	3273	3273	3332	2928	404	11	6 73E-08
8/22/94	8/26/94	8 45	7 30	341100	3805	2379			1426	14	1 80E-07
8/26/94	9/2/94	7 35	12 15	621600	3900	3242			658	19	4 56E-08
9/2/94	9/28/94	12 20	15 53	2259180	3748	2197			1549	35	2 95E-08
9/28/94	10/13/94	15 56	9 55	1274340	3514	3196			318	56	1 07E-08
10/13/94	11/1/94	9 56	16 20	1664640	3568	3169			399	72	1 03E-08
	Start Water	Start Water	End Water	End Water	Avg Water	Start Water	End Water	Temp.	Est. Flow	% of	
	Reading	Depth	Reading	Depth	Depth	Temp.	Temp	Change	Due to Temp.	Total Flow	
	in	in	in	in	in	F	F	F			
	3	11 5	2 94	11 44	11 47	72	70	2	33 4	8 46	
	2 94	11 44	2 88	11 38	11 41	70	69 5	0 5	8 35	2 24	
	2 88	11 38	2 88	11 38	11 38	69 5	67	2 5	41 75	7 72	
	2 88	11 38	2 88	11 38	11 38	67	67	0	0	0 00	
	2 88	11 38	3 06	11 56	11 47	67	67	0	0	0 00	
	3 06	11 56	2 94	11 44	11 50	67	65 5	1 5	25 05	6 20	
	2 94	11 44	2 65	11 15	11 30	65 5	66	-0 5	-8 35	-0 59	
	2 65	11 15	2 94	11 44	11 30	66	65	1	16 7	2 54	
	2 88	11.38	2 5	11	11 19	65	61	4	66 8	4 31	
	2 5	11	2 82	11 32	11 16	61	52	9	150 3	47 26	
	2 82	11.32	2 5	11	11 16	52	49 5	2 5	41 75	10 46	

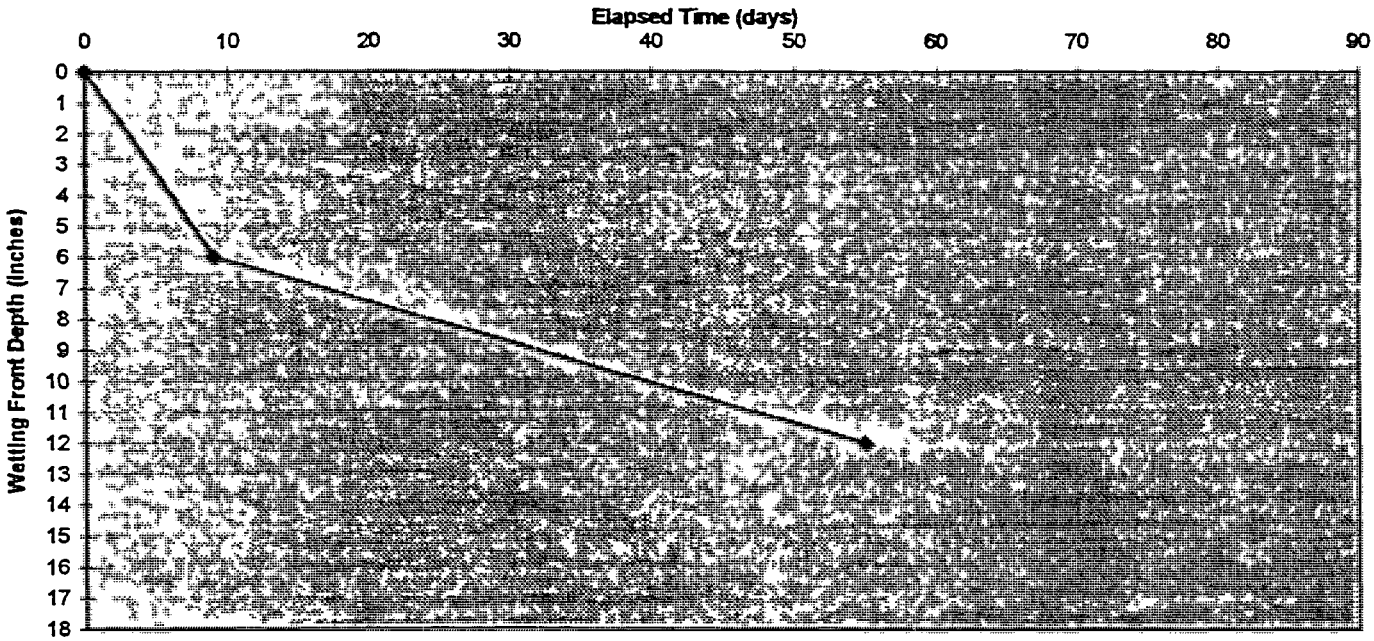
Swell data

SDRI Swell Data Table							
Project Title		Rocky Mountain Arsenal Task 93-03, Soils Feasibility					
Project Number		21907 207040					
Test Site		RMA Test Fill #1					
Date	Time	Test Day No	Swell #1	Swell #2	Swell #3	Swell #4	Ave Swell
8/10/94	9:10	0	93 4	98 4	43 7	56	0 00
8/11/94	10:20	1	92.5	97 8	43 4	55 9	0 48
8/12/94	9:37	2	93.2	98 1	43 6	56.2	0 10
8/13/94	9 37	3	93 1	97 9	43 1	55.9	0 38
8/15/94	8 30	5	93	98 3	43 5	55 7	0.25
8/16/94	13 15	6	93 1	93.2	43 3	55 8	1 53
8/19/94	8 00	9	92 7	98.2	43 1	56	0 38
8/22/94	8:50	12	92.9	98 4	43 7	56 5	0 00
8/26/94	7:35	16	91 7	97 5	42.2	55	1.28
9/2/94	7.30	22	93 5	99.2	44.3	56 6	-0 52
9/20/94	13:20	40	93.2	99 8	44.2	56 4	-0 52
9/28/94	1555	48	92.3	98 7	43.5	55	0 50
10/5/94	8 35	55	92.1	98 6	43 6	56 1	0.28
10/7/94	11 05	57	92.4	98 6	43 8	55 7	0.25
10/13/94	10:00	63	92.7	98 5	43 7	55 7	0.23
10/20/94	8 10	70	91 5	98 8	44	55 8	0 35
11/1/94	16.22	81	93.2	99 1	44.9	56 7	-0 60

Tensio data

SDRI Tensiometer Data Table														
Project Title		Rocky Mountain Arsenal Task 93-03, Soils Feasibility												
Project Number:		21907 207040												
Test Site:		RMA Test Fill #1												
	Note	All readings in Centibars												
			Depth 6 inches			Depth 12 inches			Depth 18 inches			Average Readings		
Date	Time	Day No	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
8/10/94	9:10	0	22	28	27	26	22	23	40	20	24	26	24	28
8/11/94	10.20	1	24	36	30	26	23	22	38	18	25	30	24	27
8/12/94	9 37	2	21	34	22	22	26	23	37	16	25	26	24	26
8/13/94	9 37	3	18	29	19	20	26	23	37	17	26	22	23	27
8/15/94	8 30	5	13	19	14	20	25	22	35	17	26	15	22	26
8/16/94	13 15	6	14	14	9	19	24	20	30	14	20	12	21	21
8/19/94	8 00	9	9	11	8	23	22	20	32	17	22	9	22	24
8/22/94	8:50	12	10	7	5	21	18	17	28	11	17	7	19	19
8/26/94	7 30	16	8	6	6	20	18	18	28	16	19	7	19	21
9/2/94	7 30	22	6	4	4	18	14	14	25	16	17	5	15	19
9/6/94	14:30	26	9	4	4	15	11	12	22	14	14	6	13	17
9/12/94	12.00	32	8	4	5	14	11	12	24	14	14	6	12	17
9/16/94	12:35	36	8	4	4	14	11	11	23	14	15	5	12	17
9/20/94	13 30	40	7	1	4	13	10	11	23	15	13	4	11	17
9/23/94	15:20	43	7	2	4	13	10	10	23	14	14	4	11	17
9/28/94	1555	48	6	2	3	12	10	10	23	15	12	4	11	17
10/5/94	8 35	55	4	2	2	0	10	12	26	17	0	3	7	14
10/7/94	9:45	57	4	2	2	6	9	10	25	13	0	3	8	13
10/13/94	10 00	63	4	1	2	9	8	11	26	18	18	2	9	21
10/20/94	8 10	70	2	2	2	6	8	10	26	20	20	2	8	22
11/1/94	16:22	81	3	2	2	6	9	10	25	19	20	2	8	21

Wetting Front Depth Based on Tensiometer Data



SDRI Hydraulic Conductivity Calculation Table					
Project Title.		Rocky Mountain Arsenal Task 93-03, Soils Feasibility			
Project Number		21907 207040			
Test Site		RMA Test Fill #1			
Test Day No	Infiltration	Water Depth	Wetting Front	Gradient	Hydraulic Conductivity
	(I)	Depth (H)	Depth (D)	(i)	K
	cm/sec	m	m		cm/sec
0	4.24E-07		0 75	1.00	4.24E-07
2	2.15E-07	11 47	1 75	7.55	2.85E-08
3	1.92E-07	11 41	2	6.71	2.87E-08
4	1 40E-07	11 38	2.75	5 14	2.73E-08
6	1 10E-07	11 38	4	3.85	2.87E-08
8	1 10E-07	11 47	5 5	3.09	3.58E-08
11	6 73E-08	11.50	6.5	2.77	2.43E-08
14	1 80E-07	11.30	6 75	2.67	6.73E-08
19	4.56E-08	11.30	7.5	2.51	1.82E-08
35	2.95E-08	11 19	9 9	2.13	1 39E-08
56	1 07E-08	11 16	11.2	2.00	5 36E-09
72	1 03E-08	11 16	13 5	1 83	5 65E-09

SDRI Data Table											
Project Title		Rocky Mountain Arsenal Task 93-03, Soils Feasibility									
Project Number:		21907 207040									
Test Site.		RMA Test Fill #2									
					Bag 1		Bag 2				
				Interval	Initial	Final	Initial	Final	Flow	Avg Day	Infiltr
Date On	Date Off	Time On	Time Off	(t)	weight	weight	weight	weight	(Q)	Number	(I)
				sec	gm	gm	gm	gm	ml		cm/sec
8/10/94	8/11/94	13 38	8 00	66120	3600	2701	2528	2874	553	0	3 60E-07
8/11/94	8/12/94	9 52	8 00	79680	2842	2461	3005	2874	512	2	2 77E-07
8/12/94	8/13/94	9 27	8 32	83100	3282	2892	3174	2892	672	3	3 48E-07
8/13/94	8/15/94	9 36	7 48	166320	3800	3228	3741	3269	1044	4	2 70E-07
8/15/94	8/16/94	8 26	11 00	95640	3228	2874	3269	3219	404	6	1 82E-07
8/17/94	8/19/94	9 49	7 23	164040	3282	3037	3696	3446	495	8	1 30E-07
8/19/94	8/22/94	7 55	7 47	258720	3037	2919	3446	3087	477	11	7 94E-08
8/22/94	8/26/94	8 48	7 55	342420	3895	2760			1135	14	1 43E-07
8/26/94	9/2/94	8 00	11 10	616200	3882	3105			777	19	5 43E-08
9/2/94	9/28/94	11 20	16 15	2264100	3804	1689			2115	35	4 02E-08
9/28/94	10/13/94	16 17	10 12	1274100	3528	3096			432	56	1 46E-08
10/13/94	11/1/94	10 16	16 40	1664640	3759	3314			445	72	1 15E-08
	Start Water	Start Water	End Water	End Water	Avg Water	Start Water	End Water	Temp.	Est Flow	% of	
	Reading	Depth	Reading	Depth	Depth	Temp.	Temp	Change	Due to Temp	Total Flow	
	in	in	in	in	in	F	F	F			
	2 75	10 25	2 81	11 31	10 78	70	70 5	-0 5	-8 35	-1 63	
	2 81	10 31	2 75	11 25	10 78	70 5	70	0 5	8 35	1 24	
	2 75	10 25	2 75	11 25	10 75	70	67	3	50 1	4 80	
	2 75	10 25	2 75	11 25	10 75	67	68	-1	-16 7	-4 13	
	2 63	10 13	2 5	11	10 57	68	67 5	0 5	8 35	1 69	
	2 5	10	2 38	10 88	10 44	67 5	66	1 5	25 05	5 25	
	2 38	9 88	2 06	10 56	10 22	66	66	0	0	0 00	
	2 06	9 56	3	11 5	10 53	66	66	0	0	0 00	
	3	10 5	2 65	11 15	10 83	66	61	5	83 5	3 95	
	3	10 5	2 94	11 44	10 97	61	53	8	133 6	30 93	
	2 94	10 44	2 5	11	10 72	53	50 5	2 5	41 75	9.38	

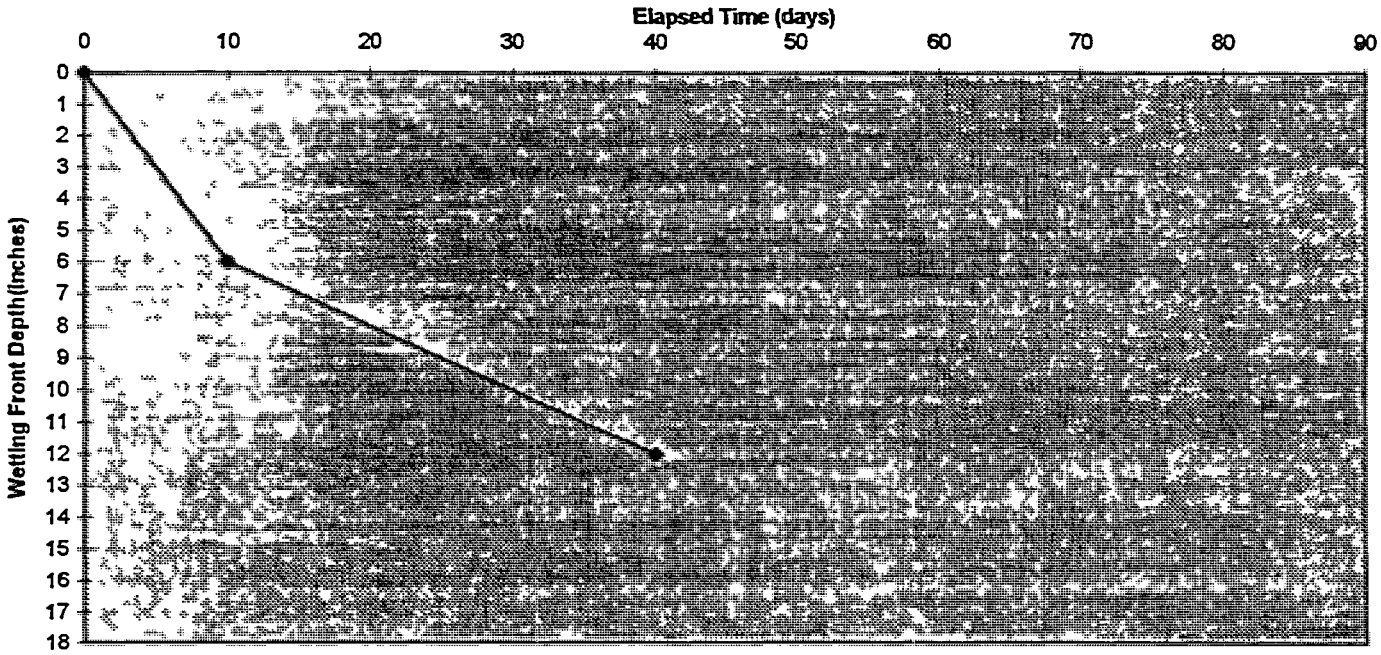
Swell data

SDRI Swell Data Table							
Project Title		Rocky Mountain Arsenal Task 93-03, Soils Feasibility					
Project Number		21907 207040					
Test Site		RMA Test Fill #2					
Date	Time	Test Day No	Swell #1	Swell #2	Swell #3	Swell #4	Ave Swell
8/10/94	10 45	0	53 8	58 5	19 8	8 6	0 00
8/11/94	10 05	1	53 3	57 4	18 1	8 1	0 95
8/12/94	9:55	2	54.2	58	18 7	8 1	0 42
8/13/94	9:50	3	54.9	58 4	19	8 6	-0 05
8/15/94	8 37	5	54.2	58.2	18 7	8 5	0.27
8/19/94	8 15	9	54 4	59.2	19 1	9 1	-0.28
8/22/94	9 00	12	54 3	58 3	19 4	9	-0 07
8/26/94	8:00	16	52.9	58 1	18 3	7.3	1 03
9/2/94	7 30	22	55 4	59 3	20.3	9 2	-0 88
9/20/94	13 50	40	54	58 9	19 7	9	-0.23
9/28/94	16:15	48	54 1	58.2	19 6	8 5	0 07
10/5/94	9 05	55	54	57 7	19.2	8 4	0 35
10/7/94	11 15	57	54.2	57 8	19	8 6	0.27
10/13/94	10:16	63	53 6	58	18.9	8 4	0 45
10/20/94	8 30	70	54 1	58 4	19.5	8.2	0 13
11/1/94	16 40	81	54 6	59 3	19 5	9 4	-0 53

Tensio data

SDRI Tensiometer Data Table														
Project Title.		Rocky Mountain Arsenal Task 93-03, Soils Feasibility												
Project Number		21907 207040												
Test Site		RMA Test Fill #2												
	Note	All readings in Centibars												
			Depth 6 inches			Depth 12 inches			Depth 18 inches			Average Readings		
Date	Time	Day No	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
8/10/94	10:45	0	43	18	46	28	0	38	38	30	35	36	22	34
8/11/94	10:05	1	40	28	49	32	26	42	30	30	32	39	33	31
8/12/94	9 55	2	38	33	42	34	26	40	30	32	30	38	33	31
8/13/94	9 50	3	31	31	38	34	27	40	32	34	30	33	34	32
8/15/94	8 30	5	22	24	24	30	26	37	35	35	33	23	31	34
8/19/94	8 15	9	10	12	11	24	22	34	37	34	37	11	27	36
8/22/94	9 00	12	9	2	7	21	19	30	36	34	38	6	23	36
8/26/94	8 00	16	8	0	4	20	18	30	35	30	38	4	23	34
9/2/94	7 30	22	6	0	0	15	15	23	33	25	35	2	18	31
9/6/94	14 30	26	7	0	2	14	13	18	32	23	35	3	15	30
9/12/94	12:00	32	6	0	4	12	11	14	30	20	34	3	12	28
9/16/94	12.37	36	6	0	1	12	10	10	29	20	33	2	11	27
9/20/94	13 50	40	6	0	1	11	9	5	27	18	32	2	8	26
9/23/94	15:30	43	6	0	0	10	9	4	27	18	32	2	8	26
9/28/94	15 15	48	6	0	2	10	8	4	26	18	32	3	7	25
10/5/94	9:05	55	2	0	0	0	6	0	24	17	26	1	2	22
10/7/94	10.35	57	2	0	0	0	5	0	22	17	24	1	2	21
10/13/94	10 16	63	3	0	0	10	3	2	22	14	22	1	5	19
10/20/94	8:30	70	1	0	0	8	3	3	20	13	32	0	5	22
11/1/94	16 40	81	2	0	0	8	1	1	18	12	32	1	3	21

Wetting Front Depth Based on Tensiometer Data



SDRI Hydraulic Conductivity Calculation Table					
Project Title.		Rocky Mountain Arsenal Task 93-03, Soils Feasibility			
Project Number:		21907 207040			
Test Site		RMA Test Fill #2			
Test Day No	Infiltration	Water Depth	Wetting Front	Gradient	Hydraulic Conductivity
	(I)	Depth (H)	Depth (D)	(i)	K
	cm/sec	m	m		cm/sec
0	3 60E-07		0 5	1.00	3 60E-07
2	2.77E-07	10 78	1	11 78	2.35E-08
3	3 48E-07	10.78	1.5	8 19	4.25E-08
4	2.70E-07	10 75	2.5	5 30	5 10E-08
6	1 82E-07	10 75	3.5	4.07	4 47E-08
8	1 30E-07	10 57	4.5	3.35	3 88E-08
11	7.94E-08	10 44	6.25	2.67	2.97E-08
14	1 43E-07	10.22	7	2.46	5.80E-08
19	5 43E-08	10.53	7 75	2.36	2.30E-08
35	4 02E-08	10 83	11	1.98	2.03E-08
56	1 46E-08	10.97	13 8	1 79	8 13E-09
72	1 15E-08	10 72	17	1 63	7 06E-09

Borehole Permeameter Stage 1 Calculations

Project RMA 93 03, 21907 207030
Test Location: RMA, Section 25, Test FM 1
Test Number: B1A

Test Dimensions and Equations:

(cm)

d = 1 27
D = 10 16
Z = 33 02
R_A = 6 92
b_1 = 58 42
$Z + R_A + b_1$ = 98 36
t_0 = 08/17/94 08 00

$K_1 = Rt\ G_1\ LN(H1/H2)/(t2 - t1)$
G_1 = 0 043

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H'2 = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/17/94	08 00	0	20 5		118 9		30 5			72 5	22 5	0 93				
08/17/94	08 02	120	9 1	118 9	107 5	30 5	30 5	0 0	107 5	72 5	22 5	0 93	1 11	3 36E-05	0 03	
08/17/94	08 04		22 1	107 5	120 5	30 5	30 5	0 0	120 5	72 7	22 6	0 93	0 89		0 07	Refill
08/17/94	08 06	120	10 6	120 5	109 0	30 5	30 5	0 0	109 0	72 7	22 6	0 93	1 11	3 34E-05	0 10	
08/17/94	08 09		24 8	109 0	123 2	30 5	30 5	0 0	123 2	72 7	22 6	0 93	0 88		0 15	Refill
08/17/94	08 13	240	12 7	123 2	111 1	30 5	30 5	0 0	111 1	72 7	22 6	0 93	1 11	1 72E-05	0 22	
08/17/94	08 15		29 0	111 1	127 4	30 5	30 5	0 0	127 4	72 7	22 6	0 93	0 87		0 25	Refill
08/17/94	08 25	600	8 0	127 4	106 4	30 5	30 4	-0 1	106 5	72 9	22 7	0 93	1 20	1 19E-05	0 42	
08/17/94	08 27		28 9	106 4	127 3	30 4	30 4	0 0	127 3	72 9	22 7	0 93	0 84		0 45	Refill
08/17/94	08 44	1020	4 0	127 3	102 4	30 4	30 4	0 0	102 4	73 2	22 9	0 93	1 24	8 54E-06	0 73	
08/17/94	08 45		29 1	102 4	127 5	30 4	30 4	0 0	127 5	73 2	22 9	0 93	0 80		0 75	Refill
08/17/94	09 06	1260	6 4	127 5	104 8	30 4	30 2	-0 2	105 0	73 4	23 0	0 93	1 21	6 16E-06	1 10	
08/17/94	09 08		29 7	104 8	128 1	30 2	30 2	0 0	128 1	73 4	23 0	0 93	0 82		1 13	Refill
08/17/94	09 36	1680	9 8	128 1	108 2	30 2	30 0	-0 2	108 4	73 9	23 3	0 93	1 18	3 98E-06	1 60	
08/17/94	10 02		27 9	108 2	126 3	30 0	30 0	0 0	126 3	74 1	23 4	0 93	0 86		2 03	Refill
08/17/94	10 37	2100	12 7	126 3	111 1	30 0	29 8	-0 2	111 3	74 3	23 5	0 91	1 13	2 36E-06	2 62	
08/17/94	10 39		28 8	111 1	127 2	29 8	29 8	0 0	127 2	74 3	23 5	0 91	0 87		2 65	Refill
08/17/94	11 38	3540	9 2	127 2	107 6	29 8	29 5	-0 3	107 9	74 7	23 7	0 91	1 18	1 82E-06	3 63	
08/17/94	11 40		29 1	107 6	127 5	29 5	29 5	0 0	127 5	74 7	23 7	0 91	0 84		3 67	Refill
08/17/94	14 37	10620	8 2	127 5	106 6	29 5	29 9	0 4	106 2	75 6	24 2	0 91	1 20	6 74E-07	6 62	
08/17/94	14 38		29 8	106 6	128 2	29 9	29 9	0 0	128 2	75 6	24 2	0 91	0 83		6 63	Refill
08/17/94	16 22	6240	21 6	128 2	120 0	29 9	30 4	0 5	119 5	75 9	24 4	0 91	1 07	4 41E-07	8 37	
08/17/94	16 24		29 8	120 0	128 2	30 4	30 4	0 0	128 2	75 9	24 39	0 91	0 94		8 40	Refill
08/18/94	08 35	58380	13 7	120 0	112 1	30 4	30 3	-0 1	112 2	74 5	23 61	0 91	1 07	4 51E-08	24 58	
08/18/94	08 40		29 4	128 2	127 8	30 4	30 3	-0 1	127 9	74 5	23 61	0 91	1 00		24 67	Refill
08/19/94	07 58	83880	17 1	127 8	115 5	30 3	30 1	-0 2	115 7	73 4	23	0 95	1 10	4 85E-08	47 97	
08/19/94	15 52	28440	14 2	115 5	112 6	30 1	29 7	-0 4	113 0	75 4	24 11	0 91	1 02	3 01E-08	55 87	

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H'2 = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/19/94	15 55		29 9	112 6	128 3	29 7	29 7	0 0	128 3	75 4	24 11	0 91	0 88		55 92	Refill
08/20/94	09·50	64500	19 7	128 3	118 1	29 7	29 1	-0 6	118 7	70 9	21 61	0 96	1 08	4 98E-08	73 83	
08/20/94	10 30	2400	19 3	118 1	117 7	29 1	29 0	-0 1	117 8	74 3	23 5	0 91	1 00	4 15E-08	74 50	
08/20/94	10 31		29 5	117 7	127 9	29 0	29 0	0 0	127 9	74 3	23 5	0 91	0 92		74 52	Refill
08/21/94	09 32	82860	21 0	127 9	119 4	29 0	29 0	0 0	119 4	71 4	21 89	0 95	1 07	3 39E-08	97 53	
08/22/94	16 09	110220	12 8	119 4	111 2	29 0	29 0	0 0	111 2	74 8	23 78	0 91	1 07	2 53E-08	128 15	
08/22/94	16 11		30 0	111 2	128 4	29 0	29 0	0 0	128 4	74 8	23 78	0 91	0 87		128 18	Refill
08/23/94	11 03	67920	22 7	128 4	121 1	29 0	28 3	-0 7	121 8	74 3	23 5	0 91	1 05	3 04E-08	147 05	
08/23/94	11 04		29 9	121 1	128 3	28 3	28 3	0 0	128 3	74 3	23 5	0 91	0 94		147 07	Refill
08/24/94	09 37	81180	23 4	128 3	121 8	28 3	28 7	0 4	121 4	74 5	23 61	0 91	1 06	2 67E-08	169 62	
08/24/94	09 38		30 0	121 8	128 4	28 7	28 7	0 0	128 4	74 5	23 61	0 91	0 95		169 63	Refill
08/26/94	14 36	190680	15 0	128 4	113 4	28 7	27 6	-1 1	114 5	75 2	24	0 91	1 12	2 35E-08	222 60	
08/26/94	14 37		28 9	113 4	127 3	27 6	27 6	0 0	127 3	75 2	24	0 91	0 89		222 62	Refill
08/27/94	09 52	69300	23 8	127 3	122 2	27 6	27 3	-0 3	122 5	75 4	24 11	0 91	1 04	2 17E-08	241 87	
08/28/94	11 05	90780	17 7	122 2	116 1	27 3	27 8	0 5	115 6	70 5	21 39	0 91	1 06	2 39E-08	267 08	
08/29/94	09 03	79080	12 4	116 1	110 8	27 8	27 9	0 1	110 7	71 2	21 78	0 98	1 05	2 54E-08	289 05	
08/30/94	07 52	82140	7 5	110 8	105 9	27 9	28 1	0 2	105 7	70 5	21 39	0 98	1 05	2 42E-08	311 87	
08/31/94	14 15	109380	1 8	105 9	100 2	28 1	28 1	0 0	100 2	72 0	22 22	0 98	1 06	2 13E-08	342 25	

Time weighted average for K1 = 8 06E-08

Borehole Permeameter Stage 1 Calculations

Project RMA 93 03, 21907 207030
Test Locat RMA, Section 25, Test Flli 1
Test Num B1B

Test Dimensions and Equations

(cm)

$d =$ 1 27 $\qquad K_1 = Rt\ G_1\ LN(H1/H2)/(t2 - t1)$

$D =$ 10 16 $\qquad G_1 =$ 0 043

$Z =$ 33 02

$R_A =$ 5 92

$b_1 =$ 58 42

$+ R_A + b_1 =$ 97 36

$t_0 =$ 8/17/94 16 30

Date	Time	Δt = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H'2 = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/18/94	08 15	56700	29 2		126 6		30 3	30 3	96 3	74 1	23	0 91	0 00		15 75	
08/18/94	08 45	1800	29 0	126 6	126 4	30 3	30 3	0 0	126 4	74 5	24	0 91	1 00	3 44E-08	16 25	
08/18/94	09 15	1800	28 7	126 4	126 1	30 3	30 3	0 0	126 1	74 7	24	0 91	1 00	5 17E-08	16 75	
08/18/94	10 15	3600	28 2	126 1	125 6	30 3	30 0	-0 3	125 9	75 6	24	0 91	1 00	1 73E-08	17 75	
08/18/94	12 15	7200	27 6	125 6	125 0	30 0	29 8	-0 2	125 2	76 3	25	0 89	1 00	1 70E-08	19 75	
08/18/94	16 15	14400	27 0	125 0	124 4	29 8	30 4	0 6	123 8	76 3	25	0 89	1 01	2 56E-08	23 75	
08/19/94	07 59	56640	17 8	124 4	115 2	30 4	30 1	-0 3	115 5	73 4	23	0 93	1 08	5 24E-08	39 48	
08/19/94	15 57	28680	14 2	115 2	111 6	30 1	29 7	0 4	112 0	75 4	24	0 91	1 03	3 84E-08	47 45	
08/19/94	16 05		30 0	111 6	127 4	29 7	29 7	0 0	127 4	75 4	24	0 91	0 88		47 58	Refill
08/20/94	09 51	63960	20 4	127 4	117 8	29 7	29 1	-0 6	118 4	70 9	22	0 95	1 08	4 68E-08	65 35	
08/21/94	09 33	85320	13 7	117 8	111 1	29 1	29 0	-0 1	111 2	71 4	22	0 95	1 06	2 76E-08	89 05	
08/21/94	09 35		29 9	111 1	127 3	29 0	29 0	0 0	127 3	71 4	22	0 95	0 87		89 08	Refill
08/22/94	16 13	110280	20 3	127 3	117 7	29 0	29 0	0 0	117 7	71 4	22	0 95	1 08	2 91E-08	119 72	
08/22/94	16 14		29 9	117 7	127 3	29 0	29 0	0 0	127 3	74 8	24	0 91	0 92		119 73	Refill
08/23/94	11 06	67920	23 6	127 3	121 0	29 0	28 3	-0 7	121 7	74 3	24	0 91	1 05	2 59E-08	138 60	
08/23/94	11 07		29 6	121 0	127 0	28 3	28 3	0 0	127 0	74 3	24	0 91	0 95		138 62	Refill
08/24/94	09 46	81540	23 4	127 0	120 8	28 3	28 7	0 4	120 4	74 5	24	0 91	1 05	2 56E-08	161 27	
08/24/94	09 47		29 9	120 8	127 3	28 7	28 7	0 0	127 3	74 5	24	0 91	0 95		161 28	Refill
08/26/94	14 38	190260	15 6	127 3	113 0	28 7	27 6	-1 1	114 1	75 2	24	0 91	1 12	2 25E-08	214 13	
08/26/94	14 39		29 8	113 0	127 2	27 6	27 6	0 0	127 2	75 2	24	0 91	0 89		214 15	Refill
08/27/94	09 53	69240	24 2	127 2	121 6	27 6	27 3	-0 3	121 9	75 4	24	0 91	1 04	2 41E-08	233 38	
08/28/94	11 05	159960	18 4	121 6	115 8	27 3	27 8	0 5	115 3	75 9	24	0 91	1 05	1 30E-08	258 58	
08/29/94	09 06	169980	13 8	115 8	111 2	27 8	27 9	0 1	111 1	71 2	22	0 95	1 04	9 96E-09	280 60	
08/30/94	07 54	82080	9 3	111 2	106 7	27 9	28 1	0 2	106 5	70 5	21	0 97	1 04	2 20E-08	303 40	
08/31/94	14 17	109380	3 2	106 7	100 6	28 1	28 1	0 0	100 6	72 0	22	0 95	1 06	2 20E-08	333 78	

Time weighted average for K1 = 2 29E-08

Borehole Permeameter Stage 1 Calculations

Project RMA 93 03, 21907 207030
Test Location: RMA, Section 25, Test Fill 1
Test Number B1C

Test Dimensions and Equations

(cm)

d = 1 27
D = 10 16
Z = 33 02
R_A = 6 02
b_1 = 58 42
$Z + R_A + b_1$ = 97 46
t_0 = 08/18/94 12 20

$K_1 = Rt\ G_1\ LN(H1/H2)/(t2 - t1)$
G_1 = 0 043

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H'2 = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/18/94	14 34	8040	20 3		117 8		30 5	30 5	87 3	78 9	26 1	0 87	0 00		2 23	
08/18/94	14 36	120	10 1	117 8	107 6	30 5	30 5	0 0	107 6	78 9	26 1	0 87	1 09	2 82E-05	2 27	
08/18/94	14 38		23 3	107 6	120 8	30 5	30 5	0 0	120 8	78 9	26 1	0 87	0 89		2 30	Refill
08/18/94	14 42	240	7 9	120 8	105 4	30 5	30 5	0 0	105 4	78 9	26 1	0 87	1 15	2 13E-05	2 37	
08/19/94	07 43		29 3	105 4	126 8	30 5	30 1	-0 4	127 2	73 4	23 0	0 93	0 83		19 38	Refill
08/19/94	08 13	1800	27 9	126 8	125 4	30 1	30 0	-0 1	125 5	73 4	23 0	0 93	1 01	2 29E-07	19 88	
08/19/94	08 44	1860	26 5	125 4	124 0	30 0	29 9	-0 1	124 1	73 6	23 1	0 93	1 01	2 24E-07	20 40	
08/19/94	09 44	3600	23 6	124 0	121 1	29 9	29 9	0 0	121 1	74 3	23 5	0 91	1 02	2 57E-07	21 40	
08/19/94	11 44	7200	18 4	121 1	115 9	29 9	29 9	0 0	115 9	74 8	23 8	0 91	1 04	2 39E-07	23 40	
08/19/94	15 44	14400	8 3	115 9	105 8	29 9	29 7	-0 2	106 0	75 4	24 1	0 91	1 09	2 43E-07	27 40	
08/19/94	16 07		29 6	105 8	127 1	29 7	29 7	0 0	127 1	75 4	24 1	0 91	0 83		27 78	Refill
08/20/94	09 52	63900	0 0	127 1	97 5	29 7	29 1	-0 6	98 1	70 9	21 6	0 95	1 30		45 53	Water drained, rodents
08/20/94	09 58		30 0	97 5	127 5	29 1	29 1	0 0	127 5	70 9	21 6	0 95	0 76		45 63	Refill
08/21/94	09:36	85080	0 0	127 5	97 5	29 1	29 0	-0 1	97 6	71 4	21 9	0 95	1 31		69 27	Water drained, rodents
08/21/94	09 37		30 4	97 5	127 9	29 0	29 0	0 0	127 9	71 4	21 9	0 95	0 76		69 28	Refill
08/22/94	16 20	110580	6 6	127 9	104 1	29 0	29 0	0 0	104 1	74 8	23 8	0 91	1 23	7 29E-08	100 00	
08/22/94	16 22		30 0	104 1	127 5	29 0	29 0	0 0	127 5	74 8	23 8	0 91	0 82		100 03	Refill
08/23/94	11 09	67620	18 2	127 5	115 7	29 0	28 3	0 7	116 4	74 3	23 5	0 91	1 10	5 27E-08	118 82	
08/23/94	11 10		29 8	115 7	127 3	28 3	28 3	0 0	127 3	74 3	23 5	0 91	0 91		118 83	
08/24/94	09 52	81720	21 1	127 3	118 6	28 3	28 7	0 4	118 2	74 5	23 6	0 91	1 08	3 55E-08	141 53	
08/24/94	09 53		30 2	118 6	127 7	28 7	28 7	0 0	127 7	74 5	23 6	0 91	0 93		141 55	Refill
08/26/94	14 40	190020	13 2	127 7	110 7	28 7	27 6	-1 1	111 8	75 2	24 0	0 91	1 14	2.74E-08	194 33	
08/26/94	14 41		30.3	110 7	127 8	27 6	27 6	0 0	127 8	75 2	24 0	0 91	0 87		194 35	Refill
08/27/94	09:54	69180	23 3	127 8	120 8	27 6	27 3	-0 3	121 1	75 4	24 1	0 91	1 06	3 05E-08	213 57	
08/28/94	11:06	90720	16 0	120 8	113 5	27 8	27 3	-0 5	114 0	75 9	24 4	0 91	1 06	2 50E-08	238 77	
08/29/94	09:07	169980	10 1	120 8	107 6	27 3	27 9	0 6	107 0	71 2	21 8	0 95	1 13	2.92E-08	280 78	

Date	Time	^t =	Test Unit			TEG		C =	H'2 =							
		t2 - t1 (sec)	R (cm)	H1 (cm)	H2 (cm)	Ro (cm)	Rf (cm)	Rf - Ro (cm)	H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/30/94	07 55	82080	5 2	107 6	102 7	27 9	28 1	0 2	102 5	70 5	21 4	0 98	1 05	4 61E 08	283 58	
08/30/94	07 56		29 5	102 7	127 0	28 1	28 1	0 0	127 0	70 5	21 4	0 98	0 81		283 60	Refill
08/31/94	14 19	109380	18 8	127 0	116 3	28 1	28 1	0 0	116 3	72 0	22 2	0 95	1 09	3 13E 08	313 98	

Time weighted average for K1 = 4 47E-08

Borehole Permeameter Stage 1 Calculations

Project RMA 93 03, 21907 207030
Test Location RMA, Section 25, Test Fill 1
Test Number B1D

Test Dimensions and Equations

(cm)

d = 1 27
D = 10 16
Z = 33 02
R_A = 5 84
b_1 = 58 42
Z + R_A + b_1 = 97 42
t_0 = 08/18/94 12 20

K_1 = Rt G_1 LN(H1/H2)/(t2 t1)
G_1 = 0 043

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H'2 = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/18/94	14 48	8880	30 1		127 5		30 5	30 5	97 0	78 9	26 1	0 87	0 00		2 47	
08/18/94	15 42	3240	28 2	127 5	125 6	30 5	30 5	0 0	125 6	76 1	24 5	0 89	1 02	1 77E-07	3 37	
08/19/94	07 46	57840	15 7	125 6	113 1	30 5	30 1	0 4	113 5	73 4	23 0	0 93	1 11	7 00E-08	19 43	
08/19/94	08 16	1800	15 6	113 1	113 0	30 1	30 0	0 1	113 1	73 4	23 0	0 93	1 00		19 93	
08/19/94	08 46	1800	15 3	113 0	112 7	30 0	29 9	-0 1	112 8	73 6	23 1	0 93	1 00	3 93E-08	20 43	
08/19/94	09 46	3600	15 0	112 7	112 4	29 9	29 9	0 0	112 4	74 3	23 5	0 91	1 00	2 90E-08	21 43	
08/19/94	11 46	7200	14 9	112 4	112 3	29 9	29 9	0 0	112 3	74 8	23 8	0 91	1 00	4 84E-09	23 43	
08/19/94	15 46	14400	13 1	112 3	110 5	29 9	29 7	-0 2	110 7	75 4	24 1	0 91	1 01	3 90E-08	27 43	
08/19/94	16 10		29 8	110 5	127 2	29 7	29 7	0 0	127 2	75 4	24 1	0 91	0 87		27 83	Refill
08/20/94	09 51	63660	22 3	127 2	119 7	29 7	29 1	-0 6	120 3	70 9	21 6	0 95	1 06	3 58E-08	45 52	
08/21/94	09 43	85920	15 4	119 7	112 8	29 1	29 0	-0 1	112 9	71 4	21 9	0 95	1 06	2 76E-08	69 38	
08/21/94	09 45		30 6	112 8	128 0	29 0	29 0	0 0	128 0	71 4	21 9	0 95	0 88		69 42	Refill
08/22/94	16 15	109800	22 0	128 0	119 4	29 0	29 0	0 0	119 4	74 8	23 8	0 91	1 07	2 48E-08	99 92	
08/22/94	16 16		29 9	119 4	127 3	29 0	29 0	0 0	127 3	74 8	23 8	0 91	0 94		99 93	Refill
08/23/94	11 14	68280	23 6	127 3	121 0	29 0	28 3	-0 7	121 7	74 3	23 5	0 91	1 05	2 58E-08	118 90	
08/23/94	11 15		29 2	121 0	126 6	28 3	28 3	0 0	126 6	74 3	23 5	0 91	0 96		118 92	Refill
08/24/94	09 49	81240	23 7	126 6	121 1	28 3	28 7	0 4	120 7	74 5	23 6	0 91	1 05	2.30E-08	141 48	
08/24/94	09 50		30 1	121 1	127 5	28 7	28 7	0 0	127 5	74 5	23 6	0 91	0 95		141 50	Refill
08/26/94	14 42	190380	17 8	121 1	115 2	28 7	27 6	-1 1	116 3	75 2	24 0	0 91	1 04	8 31E-09	194 37	
08/26/94	14 43		29 5	115 2	126 9	27 6	27 6	0 0	126 9	75 2	24 0	0 91	0 91		194 38	Refill
08/27/94	09 54	69060	24 9	126 9	122 3	27 6	27 3	-0 3	122 6	75 4	24 1	0.91	1 04	1 95E-08	213 57	
08/28/94	11 06	90720	19 6	122 3	117 0	27 3	27 8	0 5	116 5	75 9	24 4	0 91	1 05	2 10E-08	238 77	
08/29/94	09 08	79320	15 3	117 0	112 7	27 8	27 9	0 1	112 6	71 2	21 8	0 95	1 04	1 97E-08	260 80	
08/30/94	07 56	82080	11 6	112 7	109 0	27 9	28 1	0 2	108 8	70 5	21 4	0 98	1 04	1 81E-08	283 60	
08/31/94	14 20	109440	2 5	109 0	99 9	28 1	28 1	0 0	99 9	72 0	22 2	0.95	1 09	3 09E-08	314 00	

Date	Time	^t =	Test Unit			TEG		C =	H'2 =							
		t2 - t1 (sec)	R (cm)	H1 (cm)	H2 (cm)	Ro (cm)	Rf (cm)	Rf - Ro (cm)	H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks

Time weighted average for K1 = 2 45E-08

Borehole Permeameter Stage 1 Calculations

Project RMA 93 03, 21907 207030
Test Location. RMA, Section 25, Test Fill 1
Test Number : B1E

Test Dimensions and Equations:

(cm)

d = 1 27
D = 10 16
Z = 33 02
R_A = 6 02
b_1 = 58 42
$Z + R_A + b_1$ = 97 46
t_0 = 08/18/94 12 20

K_1 = Rt G_1 LN(H1/H2)/(t2 - t1)
G_1 = 0 043

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H'2 = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/18/94	14 45	8700	29 4		126 9		30 5	30 5	96 4	78 9	26 1	0 87	0 00			
08/18/94	15 23	2280	27 6	126 9	125 1	30 5	30 5	0 0	125 1	76 1	24 5	0 87	1 01	2 34E-07	3 05	
08/19/94	07 45	58920	15 7	125 1	113 2	30 5	30 1	-0 4	113 6	73 4	23	0 93	1 10	6 55E-08	19 42	
08/19/94	08 15	1800	15 6	113 2	113 1	30 1	30 0	-0 1	113 2	73 4	23	0 93	1 00	0 00E+00	19 92	
08/19/94	08 45	1800	15 3	113 1	112 8	30 0	29 9	0 1	112 9	73 6	23 1	0 93	1 00	3 93E-08	20 42	
08/19/94	09 45	3600	14 8	112 8	112 3	29 9	29 9	0 0	112 3	74 3	23 5	0 91	1 00	4 83E-08	21 42	
08/19/94	11 45	7200	14 1	112 3	111 6	29 9	29 9	0 0	111 6	74 8	23 8	0 91	1 01	3 40E-08	23 42	
08/19/94	15 45	14400	12 3	111 6	109 8	29 9	29 7	-0 2	110 0	75 4	24 1	0 91	1 01	3 93E-08	27 42	
08/19/94	16 09		29 7	109 8	127 2	29 7	29 7	0 0	127 2	75 4	24 1	0 91	0 86		27 82	Refill
08/20/94	09 52	63780	18 3	127 2	115 8	29 7	29 1	0 6	116 4	70 9	21 6	0 95	1 09	5 68E-08	45 53	
08/20/94	10 35	2580	17 9	115 8	115 4	29 1	29 0	-0 1	115 5	74 3	23 5	0 91	1 00	3 94E-08	46 25	
08/20/94	10 36		30 3	115 4	127 8	29 0	29 0	0 0	127 8	74 3	23 5	0 91	0 90		46 27	Refill
08/21/94	09 38	82920	0 0	127 8	97 5	29 0	29 0	0 0	97 5	71 4	21 9	0 95	1 31	1 33E-07	69 30	
08/21/94	09 41		29 8	97 5	127 3	29 0	29 0	0 0	127 3	71 4	21 9	0 95	0 77		69 35	Refill
08/22/94	16 17	110160	15 6	127 3	113 1	29 0	29 0	0 0	113 1	74 8	23 8	0 91	1 13	4 20E-08	99 95	
08/22/94	16 19		30 1	113 1	127 6	29 0	29 0	0 0	127 6	74 8	23 8	0 91	0 89		99 98	Refill
08/23/94	11 11	67920	21 7	127 6	119 2	29 0	28 3	-0 7	119 9	74 3	23 5	0 91	1 06	3 59E-08	118 85	
08/23/94	11 12		27 9	119 2	125 4	28 3	28 3	0 0	125 4	74 3	23 5	0 91	0 95		118 87	Refill
08/24/94	09 57	81900	20 4	125 4	117 9	28 3	28 7	0 4	117 5	74 5	23 6	0 91	1 07	3 11E-08	141 62	
08/24/94	09 58		30 0	117 9	127 5	28 7	28 7	0 0	127.5	74 5	23 6	0 91	0 92		141 63	Refill
08/26/94	14 44	189960	14 9	127 5	112 4	28 7	27 6	-1 1	113 5	75 2	24	0 91	1 12	2 40E-08	194 40	
08/26/94	14 45		30 5	112 4	128 0	27 6	27 6	0 0	128 0	75 2	24	0 91	0 88		194 42	Refill
08/27/94	09 55	69000	24 4	128 0	121 9	27 6	27 3	-0 3	122 2	75 4	24 1	0 91	1 05	2 63E-08	213 58	
08/28/94	11 07	90720	18 3	121 9	115 8	27 3	27 8	0 5	115 3	75 9	24 4	0 91	1 06	2 40E-08	239 78	
08/29/94	09 09	79320	12 8	115 8	110 3	27 8	27 9	0 1	110 2	71 2	21 8	0 95	1 05	2 43E-08	260 82	
08/31/94	14 21	191520	6 3	110 3	103 8	27.9	28 1	0 2	103 6	72.0	22 2	0 95	1 06	4 10E-08	314 02	

Time weighted average for K1 = 4 13E-08

Borehole Permeameter Stage 1 Calculations

Project: RMA 93 03, 21907 207030
Test Location: RMA, Section 25, Test Fill 1
Test Number: B2A

Test Dimensions and Equations:

(cm)

d = 1 27
D = 10 16
Z = 33 02
R_A = 6 02
b_1 = 58 42
$Z + R_A + b_1$ = 97 46
t_0 = 08/17/94 08 33

$K_1 = Rt\ G_1\ LN(H1/H2)/(t2 - t1)$
G_1 = 0 043

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H'2 = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/17/94	08 33	0	23 5		121 0		26 8		121 0	77 4	25 2		0 00		0 00	
08/17/94	08 34	60	9 9	121 0	107 4	26 8	26 8	0 0	107 4	77 4	25 2	0 89	1 13	7 61E-05	0 02	
08/17/94	08 35		30 0	107 4	127 5	26 8	26 8	0 0	127 5	77 4	25 2	0 89	0 84		0 03	Refill
08/17/94	08 37	120	6 1	127 5	103 6	26 8	26 8	0 0	103 6	77 4	25 2	0 89	1 23	6 62E-05	0 07	
08/17/94	08 38		23 6	103 6	121 1	26 8	26 8	0 0	121 1	77 4	25 2	0 89	0 86		0 08	Refill
08/17/94	08 40	120	4 5	121 1	102 0	26 8	26 8	0 0	102 0	77 4	25 2	0 89	1 19	5 48E-05	0 12	
08/17/94	08 41		26 4	102 0	125 9	26 8	26 8	0 0	125 9	77 4	25 2	0 89	0 81		0 13	Refill
08/17/94	08 48	420	11 3	125 9	108 8	26 8	26 8	0 0	108 8	77 4	25 2	0 89	1 16	1 33E-05	0 25	
08/17/94	08 49		29 1	108 8	126 6	26 8	26 8	0 0	126 6	77 4	25 2	0 89	0 86		0 27	Refill
08/17/94	08 51	120	14 3	126 6	111 8	26 8	26 0	-0 8	112 6	77 2	25 1	0 89	1 12	3 74E-05	0 30	
08/17/94	08 53		27 9	111 8	125 4	26 0	26 8	0 8	124 6	77 2	25 1	0 89	0 90		0 33	Refill
08/17/94	08 56	180	12 2	125 4	109 7	26 8	26 8	0 0	109 7	77 2	25 1	0 89	1 14	2 84E-05	0 38	
08/17/94	09 00		30 0	109 7	127 5	26 8	26 8	0 0	127 5	77 2	25 1	0 89	0 86		0 45	Refill
08/17/94	09 03	180	4 2	127 5	101 7	26 8	26 8	0 0	101 7	77 2	25 1	0 89	1 25	4 81E-05	0 50	
08/17/94	09 10		25 1	101 7	122 6	26 8	26 7	-0 1	122 7	77 2	25 1	0 89	0 83		0 62	Refill
08/17/94	09 14	240	6 5	122 6	104 0	26 7	26 7	0 0	104 0	77 2	25 1	0 89	1 18	2 62E-05	0 68	
08/17/94	09 17		24 4	104 0	121 9	26 7	26 7	0 0	121 9	77 2	25 1	0 89	0 85		0 73	Refill
08/17/94	09 20	180	9 1	121 9	106 6	26 7	26 7	0 0	106 6	77 4	25 2	0 89	1 14	2 85E-05	0 78	
08/17/94	09 33		26 6	106 6	124 1	26 7	26 7	0 0	124 1	77 4	25 2	0 89	0 86		1 00	Refill
08/17/94	09 41	480	5 6	124 1	103 1	26 7	26 7	0 0	103 1	77 2	25 1	0 89	1 20	1 48E-05	1 13	
08/17/94	10 34		27 6	103 1	125 1	26 7	26 7	0 0	125 1	77 0	25 0	0 89	0 82		2 02	Refill
08/17/94	11 28	3240	2 8	125 1	100 3	26 7	26 3	-0 4	100 7	77 0	25 0	0 89	1 24	2 56E-06	2 92	
08/17/94	12 33		23 8	100 3	121 3	26 3	26 5	0 2	121 1	76 6	24 8	0 89	0 83		4 00	Refill
08/17/94	16 33	18300	20 3	121 3	117 8	26 5	26 2	-0 3	118 1	76 6	24 8	0 89	1 03	5 59E-06	8 00	
08/17/94	16 34		29 8	117 8	127 3	26 2	26 2	0 0	127 3	76 6	24 8	0 89	0 93		8 02	Refill
08/18/94	14 17	78180	18 3	127 3	115 8	26 2	26 2	0 0	115 8	73 0	22 8	0 95	1 10	4 95E-08	29 73	
08/18/94	08 31		30 1	115 8	127 6	26 2	26 4	0 2	127 4	73 0	22 8	0 93	0 91		23 97	Refill

Date	Time	^t =	Test Unit			TEG		C =	H'2 =							
		t2 - t1 (sec)	R (cm)	H1 (cm)	H2 (cm)	Ro (cm)	Rf (cm)	Rf - Ro (cm)	H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/19/94	07 55	84240	12 6	127 6	110 1	26 4	26 0	-0 4	110 5	73 0	22 8	0 93	1 15	6 83E-08	47 37	
08/19/94	16 12	29820	9 9	110 1	107 4	26 0	25 8	-0 2	107 6	74 3	23 5	0 91	1 02	3 02E-08	55 65	
08/19/94	16 13		29 7	107 4	127 2	25 8	25 8	0 0	127 2	74 3	23 5	0 91	0 84		55 67	Refill
08/20/94	09 47	63240	18 8	127 2	116 3	25 8	25 2	-0 6	116 9	70 7	21 5	0 95	1 09	5 46E-08	73 23	
08/20/94	10 45	3480	18 4	116 3	115 9	25 2	25 0	-0 2	116 1	71 2	21 8	0 95	1 00	2 02E-08	74 20	
08/20/94	10 47		30 0	115 9	127 5	25 0	25 0	0 0	127 5	71 2	21 8	0 95	0 91		74 23	Refill
08/21/94	09 15	80880	21 2	127 5	118 7	25 0	25 1	0 1	118 6	71 4	21 9	0 95	1 08	3 66E 08	96 70	
08/22/94	16 31	1E+05	13 4	118 7	110 9	25 1	25 1	0 0	110 9	73 9	23 3	0 93	1 07	2 42E-08	127 97	
08/22/94	16 32		29 9	110 9	127 4	25 1	25 1	0 0	127 4	73 9	23 3	0 93	0 87		127 98	Refill
08/23/94	10 42	65400	23 2	127 4	120 7	25 1	24 5	-0 6	121 3	73 2	22 9	0 93	1 05	3 00E-08	146 15	
08/23/94	10 59		30 1	120 7	127 6	24 5	24 5	0 0	127 6	73 4	23 0	0 93	0 95		146 43	Refill
08/24/94	10 05	83160	23 5	127 6	121 0	24 5	24 6	0 1	120 9	74 5	23 6	0 91	1 06	2 54E-08	169 53	
08/24/94	10 06		29 8	121 0	127 3	24 6	24 6	0 0	127 3	74 5	23 6	0 91	0 95		169 55	Refill
08/26/94	14 55	2E+05	16 7	127 3	114 2	24 6	24 3	-0 3	114 5	74 8	23 8	0 91	1 11	2 18E-08	222 37	
08/26/94	14 56		29 4	114 2	126 9	24 3	24 3	0 0	126 9	74 8	23 8	0 91	0 90		222 38	Refill
08/27/94	09 57	68460	23 6	126 9	121 3	24 3	24 2	-0 1	121 4	75 9	24 4	0 91	1 05	2 53E-08	241 40	
08/28/94	11 00	90180	18 3	121 3	115 8	24 2	24 1	-0 1	115 9	75 9	24 4	0 91	1 05	1 98E-08	266 45	
08/29/94	09 11	79660	13 3	115 8	110 6	24 1	24 3	0 2	110 6	71 6	22 0	0 95	1 05	2 35E 08	288 63	
08/30/94	07 45	81240	9 2	110 6	106 7	24 3	24 7	0 4	106 3	70 9	21 6	0 95	1 04	2 09E-08	311 20	
08/31/94	14 25	1E+05	4 0	106 7	101 5	24 7	24 6	-0 1	101 6	72 3	22 4	0 95	1 05	1 81E-08	341 87	

Time weighted average for K1 = 8 20E-08

Borehole Permeameter Stage 1 Calculations

Project: RMA 93 03, 21907 207030
Test Location: RMA, Section 25, Test Fill 1
Test Number : B2B

Test Dimensions and Equations:

(cm)

d = 1 27
D = 10 16
Z = 33 02
R_A = 6 02
b_t = 58 42
$Z + R_A + b_t$ = 97 46
t_0 = 08/18/94 10 15

$K_1 = Rt\ G_1\ LN(H1/H2)/(t2 - t1)$
G_1 = 0 043

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H'2 = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/18/94	14 22	14820	25 4		122 9		26 2		122 9	74 3	23 5		0 00		4 12	
08/18/94	14 32	600	18 7	122 9	116 2	26 2	26 2	0 0	116 2	74 3	23 5	0 91	1 06	3 66E-06	4 28	
08/19/94	07 40		29 9	116 2	127 4	26 2	26 0	-0 2	127 6	73 0	22 8	0 93	0 91		21 42	
08/19/94	08 12	1920	28 1	127 4	125 6	26 0	26 0	0 0	125 6	72 9	22 7	0 93	1 01		21 95	Rodents chewed fill line
08/19/94	08 42	1800	26 6	125 6	124 1	26 0	26 0	0 0	124 1	73 0	22 8	0 93	1 01		22 45	Rodents chewed fill line
08/19/94	09 42	3600	24 4	124 1	121 9	26 0	25 8	-0 2	122 1	73 2	22 9	0 93	1 02		23 45	Rodents chewed fill line
08/19/94	11 42	7200	21 0	121 9	118 5	25 8	25 8	0 0	118 5	74 1	23 4	0 93	1 03		25 45	Rodents chewed fill line
08/19/94	15 42	14400	15 8	118 5	113 3	25 8	25 8	0 0	113 3	74 3	23 5	0 91	1 05		29 45	Rodents chewed fill line
08/19/94	18 15		29 9	113 3	127 4	25 8	25 8	0 0	127 4	74 3	23 5	0 91	0 89		30 00	Refill
08/20/94	09 47	63120	10 9	127 4	108 4	25 8	25 2	0 6	109 0	70 7	21 5	0 95	1 17		47 53	Rodents chewed fill line
08/20/94	10 48	3660	10 3	108 4	107 8	25 2	25 0	-0 2	108 0	71 2	21 8	0 95	1 00		48 55	Rodents chewed fill line
08/20/94	10 50		30 3	107 8	127 8	25 0	25 0	0 0	127 8	71 2	21 8	0 95	0 84		48 58	Refill
08/21/94	09 17		0 0	127 8	97 5	25 0	25 1	0 1	97 4	71 4	21 9	0 95	1 31		71 03	Rodents chewed fill line
08/21/94	09 19		30 5	97 5	128 0	25 1	25 1	0 0	128 0	71 4	21 9	0 95	0 76		71 07	Rodents chewed fill line
08/22/94	16 29		0 0	128 0	97 5	25 1	25 1	0 0	97 5	73 9	23 3	0 93	1 31		102 23	Rodents chewed fill line
08/22/94	16 30		30 2	97 5	127 7	25 1	25 1	0 0	127 7	73 9	23 3	0 93	0 76		102 25	Refill
08/23/94	10 47	65820	4 3	127 7	101 8	25 1	24 5	0 6	102 4	73 2	22 9	0 93	1 25	1 34E-07	120 53	
08/23/94	10 49		29 5	101 8	127 0	24 5	24 5	0 0	127 0	73 2	22 9	0 93	0 80		120 57	Refill
08/24/94	10 08	83940	5 9	127 0	103 4	24 5	24 6	0 1	103 3	74 5	23 6	0 91	1 23	9 63E-08	143 88	
08/24/94	10 09		30 3	103 4	127 8	24 6	24 6	0 0	127 8	74 5	23 6	0 91	0 81		143 90	Refill
08/26/94	14 58		0 0	127 8	97 5	24 6		-24 6	122 1		-18		1 05		196 72	Rodents chewed fill line
08/26/94	14 59		29 1	97 5	126 6	0 0	24 3	24 3	102 3	74 8	23 8	0 91	0 95		196 73	Refill
08/27/94	09 59	68400	11 0	126 6	106 5	24 3	24 2	-0 1	106 6	75 9	24 4	0 91	1 17	8 78E-08	215 73	
08/27/94	10 01		30 1	106 5	127 6	24 2	24 2	0 0	127 6	75 9	24 4	0 91	0 85		215 77	Refill
08/28/94	11 00	89940	7 7	127 6	105 2	24 2	24 1	-0 1	105 3	75 9	24 4	0 91	1 21	8 36E-08	240 75	
08/29/94	09 14		28 5	105 2	126 0	24 1	24 3	0 2	125 8	71 6	22	0 95	0 84		262 98	Refill
08/30/94	07 46	81120	8 1	126 0	105 6	24 3	24 7	0 4	105 2	70 9	21 6	0 95	1 20	9 09E-08	285 52	

Date	Time	^t =	Test Unit			TEG		C =	H'2 =							
		t2 - t1	R	H1	H2	Ro	Rf	Rf - Ro	H2 - C	T	T	Rt	(H1/H2)	K1	Cum Hrs	
		(sec)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(F)	(C)	Factor		(cm/sec)	(hrs)	Remarks
08/30/94	07 49		29 7	105 6	127 2	24 7	24 7	0 0	127 2	70 9	21 6	0 95	0 83		285 57	Refill
08/31/94	14 27	110280	4 8	127 2	102 3	24 7	24 6	0 1	102 4	72 3	22 4	0 95	1 24	8 04E-08	316 20	

Time weighted average for K1 = 8 00E 08

Borehole Permeameter Stage 1 Calculations

Project. RMA 93 03, 21907 207030
Test Location· RMA, Section 25, Test Fill 1
Test Number · B2C

Test Dimensions and Equations

(cm)

d = 1 27
D = 10 16
Z = 33 02
R_A = 6 42
b_1 = 58 42
$Z + R_A + b_1$ = 97 86
t_0 = 09/18/94 10 15

K_1 = Rt G_1 LN(H1/H2)/(t2 - t1)
G_1 = 0 043

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H'2 = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/18/94	14 13	14280	26 7		124 6	(cm)	26 2		124 6	74 3	23 5	0 91				
08/18/94	14 31	1080	10 4	124 6	108 3	26 2	26 2	0 0	108 3	74 3	23 5	0 91	1 15	5 08E-06	4 27	
08/19/94	07 39		30 0	108 3	127 9	26 2	26 0	-0 2	128 1	73 0	22 8	0 93	0 85		21 40	Refill
08/19/94	08 12	1980	28 8	127 9	126 7	26 0	26 0	0 0	126 7	72 9	22 7	0 93	1 01	1 90E-07	21 95	
08/19/94	08 43	1860	28 0	126 7	125 9	26 0	26 0	0 0	125 9	73 0	22 8	0 93	1 01	1 36E 07	22 47	
08/19/94	09 43	3600	26 8	125 9	124 7	26 0	25 8	-0 2	124 9	73 2	22 9	0 93	1 01	8 86E-08	23 47	
08/19/94	11 43	7200	25 2	124 7	123 1	25 8	25 8	0 0	123 1	74 1	23 4	0 93	1 01	7 17E-06	25 47	
08/19/94	15 43	14400	22 7	123 1	120 6	25 8	25 8	0 0	120 6	74 3	23 5	0 91	1 02	5 58E 08	29 47	
08/19/94	16 16		29 7	120 6	127 6	25 8	25 8	0 0	127 6	74 3	23 5	0 91	0 95		30 02	Refill
08/20/94	09 48	63120	19 7	127 6	117 6	25 8	25 2	0 6	118 2	70 7	21 5	0 95	1 08	4 95E-08	47 55	
08/21/94	09 20	84720	10 3	117 6	108 2	25 2	25 1	0 1	108 3	71 4	21 9	0 95	1 09	3 97E-08	71 08	
08/21/94	09 22		30 3	108 2	128 2	25 1	25 1	0 0	128 2	71 4	21 9	0 95	0 84		71 12	Refill
08/22/94	16 27	111900	19 0	128 2	116 9	25 1	25 1	0 0	116 9	73 9	23 3	0 93	1 10	3 30E-08	102 20	
08/22/94	16 28		29 9	116 9	127 8	25 1	25 1	0 0	127 8	73 9	23 3	0 93	0 91		102 22	
08/23/94	10 50	66120	22 8	127 8	120 7	25 1	24 5	-0 6	121 3	73 2	22 9	0 93	1 05	3 16E-08	120 58	
08/23/94	11 00		30 2	120 7	128 1	24 5	24 5	0 0	128 1	73 4	23 0	0 93	0 94		120 75	Refill
08/24/94	10 12	83520	23 0	128 1	120 9	24 5	24 6	0 1	120 8	74 5	23 6	0 91	1 06	2 75E-08	143 95	
08/24/94	10 13		30 1	120 9	128 0	24 6	24 6	0 0	128 0	74 5	23 6	0 91	0 94		143 97	Refill
08/26/94	15 00	190020	17 0	128 0	114 9	24 6	24 3	-0 3	115 2	74 8	23 8	0 91	1 11	2 17E-08	196 75	
08/26/94	15 01		30 1	114 9	128 0	24 3	24 3	0 0	128 0	74 8	23 8	0 91	0 90		196 77	Refill
08/27/94	10 02	68460	23 7	128 0	121 6	24 3	24 2	-0 1	121 7	75 9	24 4	0 91	1 05	2 89E-08	215 78	
08/28/94	11 02	90000	17 1	121 6	115 0	24 2	24 1	0 1	115 1	75 9	24 4	0 91	1 06	2 39E-08	240 78	
08/29/94	09 14		0 0	115 0	97 9	24 1	24 3	0 2	97 7	71 6	22 0	0 95	1 18		262 98	Rodents chewed fill line
08/29/94	09 15	60	29 8	97 9	127 7	24 3	24 3	0 0	127 7	71 6	22 0	0 95	0 77		263 00	Refill
08/30/94	07 47	81120	22 1	127 7	120 0	24 3	24 7	0 4	119 6	70 9	21 6	0 95	1 07	3 14E-08	285 53	
08/31/94	14 26	110340	12 8	120 0	110 7	24 7	24 6	-0 1	110 8	72 3	22 4	0 95	1 08	3 75E-08	316 18	

Time weighted average for K1 = 3 80E 08

Borehole Permeameter Stage 1 Calculations

Project RMA 93-03, 21907 207030
Test Location: RMA, Section 25, Test Fill 1
Test Number: B2D

Test Dimensions and Equations

(cm)

d = 1 27
D = 10 16
Z = 33 02
R_A = 6 12
b_1 = 58 42
$Z + R_A + b_1$ = 97 56
t_0 = 08/17/94 16 30

$K_1 = Rt\ G_1\ LN(H1/H2)/(t2 - t1)$
G_1 = 0 043

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H'2 = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/18/94	07 55	55500	29 5		127 1		26 5			73 0	22 8	0 93				
08/18/94	08 25	1800	26 2	127 1	123 8	26 5	26 4	-0 1	123 9	73 0	22 8	0 93	1 03	5 67E-07	15 92	
08/18/94	08 55	1800	23 2	123 8	120 8	26 4	26 3	-0 1	120 9	73 2	22 9	0 93	1 02	5 27E-07	16 42	
08/18/94	09 55	3600	18 8	120 8	116 4	26 3	26 1	-0 2	116 6	73 9	23 3	0 93	1 04	3 93E-07	17 42	
08/18/94	10 00		28 9	116 4	126 5	26 1	26 1	0 0	126 5	73 9	23 3	0 93	0 92		17 50	Refill
08/18/94	12 00	7200	15 6	126 5	113 2	26 1	25 8	-0 3	113 5	74 7	23 7	0 91	1 11	5 90E-07	19 50	
08/18/94	12 01		30 0	113 2	127 6	25 8	25 8	0 0	127 6	74 7	23 7	0 91	0 89		19 52	Refill
08/18/94	16 01	14400	16 5	127 6	114 1	25 8	26 2	0 4	113 7	74 5	23 6	0 91	1 12	3 14E-07	23 52	
08/18/94	16 03		29 8	114 1	127 4	26 2	26 2	0 0	127 4	74 5	23 6	0 91	0 90		23 55	Refill
08/19/94	07 49	56760	6 4	127 4	104 0	26 2	26 0	-0 2	104 2	73 0	22 8	0 93	1 22	1 42E-07	39 32	
08/19/94	07 53		30 1	104 0	127 7	26 0	26 0	0 0	127 7	73 0	22 8	0 93	0 81		39 38	Refill
08/19/94	16 17	30240	23 8	127 7	121 4	26 0	25 8	-0 2	121 6	74 3	23 5	0 93	1 05	6 47E-08	47 78	
08/19/94	16 18		30 2	121 4	127 8	25 8	25 8	0 0	127 8	74 3	23 5	0 93	0 95		47 80	Refill
08/20/94	09 46	62880	19 1	127 8	116 7	25 8	25 2	-0 6	117 3	70 7	21 5	0 95	1 09	5 57E-08	65 27	
08/20/94	10 42	3360	18 6	116 7	116 2	25 2	25 0	-0 2	116 4	71 2	21 8	0 95	1 00	3 13E-08	66 20	
08/20/94	10 44		30 2	116 2	127 8	25 0	25 0	0 0	127 8	71 2	21 8	0 95	0 91		66 23	Refill
08/21/94	09 24	81600	18 5	127 8	116 1	25 0	25 1	0 1	116 0	71 4	21 9	0 95	1 10	4 85E-08	88 90	
08/21/94	09 26		30 0	116 1	127 6	25 1	25 1	0 0	127 6	71 4	21 9	0.95	0 91		88 93	Refill
08/22/94	16 25	111540	15 9	127 6	113 5	25 1	25 1	0 0	113 5	73 9	23 3	0 93	1 12	4 20E-08	119 92	
08/22/94	16 26		29 9	113 5	127 5	25 1	25 1	0 0	127 5	73 9	23 3	0 93	0 89		119 93	Refill
08/23/94	10 52	66360	21 0	127 5	118 6	25 1	24 5	-0 6	119 2	73 2	22 9	0 93	1 07	4 06E-08	138 37	
08/23/94	10 56		30 3	118 6	127 9	24 5	24 5	0 0	127 9	73 4	23	0 93	0 93		138 43	Refill
08/24/94	10 14	83880	20 8	127 9	118 4	24 5	24 6	0 1	118 3	74 5	23 6	0.93	1 08	3 72E-08	161 73	
08/24/94	10:15	60	30 0	118 4	127 6	24 6	24 6	0 0	127 6	74 5	23 6	0 93	0 93		161 75	Refill
08/26/94	15:02	190080	12 5	127 6	110 1	24 6	24 3	-0 3	110 3	74 8	23 8	0 91	1 16	2.99E-08	214 53	
08/26/94	15 03		29 8	110 1	127 4	24 3	24 3	0 0	127 4	74 8	23 8	0.91	0 86		214 55	Refill
08/27/94	10:03	68400	23 5	127 4	121 1	24 3	24 2	-0 1	121 2	75 9	24 4	0 95	1 05	2 97E-08	233 55	

Date	Time	^t =	Test Unit			TEG		C =	H'2 =							
		t2 - t1 (sec)	R (cm)	H1 (cm)	H2 (cm)	Ro (cm)	Rf (cm)	Rf - Ro (cm)	H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/28/94	11 02	89940	16 9	121 1	114 5	24 2	24 1	-0 1	114 6	75 9	24 4	0 91	1 06	2 40E-08	258 53	
08/29/94	09 15	79980	11 5	114 5	109 1	24 1	24 3	0 2	108 9	71 6	22	0 95	1 05	2 56E-08	280 75	
08/30/94	07 50	81300	6 9	109 1	104 5	24 3	24 7	0 4	104 1	70 9	21 6	0 95	1 05	2 36E 08	303 33	
08/31/94	14 28	110280	1 0	104 5	98 6	24 7	24 6	0 1	98 7	72 3	22 4	0 95	1 06	2 01E-08	333 97	

Time weighted average for K1 = 4 52E-08

Borehole Permeameter Stage 1 Calculations

Project: RMA 93 03, 21907 207030
Test Location: RMA, Section 25, Test Fill 1
Test Number: B2E

Test Dimensions:

(cm)

d = 1 27
D = 10 16
Z = 33 02
R_A = 5 82
b_1 = 58 42
$Z + R_A + b_1$ = 97 26
t_0 = 08/17/94 16 30

$K_1 = Rt\ G_1\ LN(H1/H2)/(t2 - t1)$
G_1 = 0 043

Date	Time	Δt = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H'2 = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/18/94	07 45	54900	30 0		127 3		26 5	26 5	100 8	73 0	22 8	0 93	0 00			
08/18/94	08 15	1800	24 7	127 3	122 0	26 5	26 4	-0 1	122 0	73 0	22 8	0 93	1 04	9 36E-07	15 75	
08/18/94	08 45	1800	21 5	122 0	118 8	26 4	26 3	-0 1	118 9	73 2	22 9	0 93	1 03	5 72E-07	16 25	
08/18/94	09 45	3600	16 0	118 8	113 3	26 3	26 1	-0 2	113 5	73 9	23 3	0 93	1 05	5 07E-07	17 25	
08/18/94	09 50		29 3	113 3	126 6	26 1	26 1	0 0	126 6	73 9	23 3	0 93	0 89		17 33	Refill
08/18/94	11 50	7200	18 6	126 6	115 9	26 1	25 8	-0 3	116 2	74 7	23 7	0 91	1 09	4 66E-07	19 33	
08/18/94	11 55		29 4	115 9	126 7	25 8	25 8	0 0	126 7	74 7	23 7	0 91	0 91		19 42	Refill
08/18/94	15 55	14400	13 3	126 7	110 6	25 8	26 2	0 4	110 2	74 5	23 6	0 91	1 15	3 79E-07	23 42	
08/18/94	15 57		29 8	110 6	127 1	26 2	26 2	0 0	127 1	74 5	23 6	0 91	0 87		23 45	Refill
08/19/94	07 48	57060	0 7	127 1	98 0	26 2	26 0	-0 2	98 2	73 0	22 8	0 93	1 29	1 81E-07	39 30	
08/19/94	07 51		29 8	98 0	127 1	26 0	26 0	0 0	127 1	73 0	22 8	0 93	0 77		39 35	Refill
08/19/94	16 19	30480	19 6	127 1	116 9	26 0	25 8	-0 2	117 1	74 3	23 5	0 91	1 09	1 05E 07	47 82	
08/19/94	16 20		30 2	116 9	127 5	25 8	25 8	0 0	127 5	74 3	23 5	0 91	0 92		47 83	Refill
08/20/94	09 47	62820	15 6	127 5	112 9	25 8	25 2	-0 6	113 5	70 7	21 5	0 95	1 12	7 57E-08	65 28	
08/20/94	10 38	3060	15 0	112 9	112 3	25 2	25 0	-0 2	112 5	71 2	21 8	0 95	1 00	4 74E-08	66 13	
08/20/94	10 41		30 2	112 3	127 5	25 0	25 0	0 0	127 5	71 2	21 8	0 95	0 88		66 18	Refill
08/21/94	09 27	81960	15 0	127 5	112 3	25 0	25 1	0 1	112 2	71 4	21 9	0 95	1 14	6 37E-08	88 95	
08/21/94	09:29		30 3	112 3	127 6	25 1	25 1	0 0	127 6	71 4	21 9	0 95	0 88		88 98	Refill
08/22/94	16 23	111240	13 7	127 6	111 0	25 1	25 1	0 0	111 0	73 9	23 3	0 93	1 15	5 01E-08	119 88	
08/22/94	16 24		30 0	111 0	127 3	25 1	25 1	0 0	127 3	73 9	23 3	0 93	0 87		119 90	Refill
08/23/94	10 56	66720	20 3	127 3	117 6	25 1	24 5	-0 6	118 2	73 4	23 0	0 93	1 08	4 45E-08	138 43	
08/23/94	10 57		30 0	117 6	127 3	24 5	24 5	0 0	127 3	73 4	23 0	0 93	0 92		138 45	Refill
08/24/94	10:17	84000	20 5	127 3	117 8	24 5	24 6	0 1	117 7	74 5	23 6	0 91	1 06	3 65E-08	161 78	
08/24/94	10:18		30 0	117 8	127 3	24 6	24 6	0 0	127 3	74 5	23 6	0 91	0 93		161 80	Refill
08/26/94	15:04	189960	13 6	127 3	110 9	24 6	24 3	-0 3	111 2	74 8	23 8	0.95	1 14	2.91E-08	214 57	
08/26/94	15 05		29 7	110 9	127 0	24 3	24 3	0 0	127 0	74 8	23 8	0.95	0 87		214 58	Refill
08/27/94	10:03	68340	23 7	127 0	121 0	24 3	24 2	-0 1	121 1	75 9	24 4	0 91	1 05	2 72E-08	233 55	

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H'2 = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2)	K1 (cm/sec)	Cum Hrs (hrs)	Remarks
08/28/94	11 03	90000	17 8	121 0	115 1	24 2	24 1	-0 1	115 2	75 9	24 4	0 91	1 05	2 14E-08	258 55	
08/29/94	09 17	80040	0 0	115 1	97 3	24 1	24 2	0 1	97 2	71 6	22 0	0 95	1 18		280 78	Rodents chewed fill line
08/29/94	09 18		28 6	97 3	125 9	24 2	24 2	0 0	125 9	71 6	22 0	0 95	0 77		280 80	Refill
08/30/94	07 51	81180	22 8	125 9	120 1	24 2	24 7	0 5	119 6	71 1	21 7	0 95	1 05	2 46E-08	303 35	
08/31/94	14 29	110280	16 4	120 1	113 7	24 7	24 6	0 1	113 8	72 3	22 4	0 95	1 06	1 90E-08	333 98	

Time weighted average for K1 = 5 16E-08

Borehole Permeameter Stage 2 Calculations

Project: RMA 93 03, 21907 207030
Test Location: RMA, Section 25, Test Fill 1
Test Number: B1A

Test Dimensions and Equations

	(cm)				
d =	1 27	L =	15 50	G5 =	1 165
D =	10 16	1/2 L =	7 75	G4 =	3 350
Z =	33 02	b_2 =	50 67	G3 =	2 265
R_A =	6 92	$4b_2/D$ =	19 95	F =	0 948
b_1 =	58 42	L/D =	1 53	G2 =	0 016
$Z + R_A + b_1$ =	98 36	a =	-1	K2 =	$R_f G2 \, LN(H1/H2')/(t2 - t1)$
t_0 =	09/01/94 08 31				

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H2' = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2')	K2 (cm/sec)	Cum Hrs (hrs)	Remarks
09/01/94	08 31	0	30 2		128 6		27 8			68 2	20 1	1				
09/01/94	09 04	1980	29 8	128 6	128 2	27 8	27 7	-0 1	128 3	68 5	20 3	1	1 00	1 83E 08	0 55	
09/01/94	09 31	1620	29 8	128 2	128 2	27 7	27 6	-0 1	128 3	68 9	20 5	0 98	1 00			
09/01/94	10 35	3840	29 3	128 2	127 7	27 6	27 2	0 4	128 1	69 6	20 9	0 98	1 00	3 09E-09	2 07	
09/01/94	12 34	7140	28 5	127 7	126 9	27 2	27 2	0 0	126 9	70 8	21 4	0 98	1 01	1 34E-08	4 05	
09/01/94	15 34	10800	26 5	126 9	124 9	27 2	27 9	0 7	124 2	71 6	22 0	0 95	1 02	2 94E-08	7 05	
09/02/94	09 45	65460	12 0	124 9	110 4	27 9	27 4	-0 5	110 9	68 7	20 4	1	1 13	2 82E-08	25 23	
09/02/94	16 36	24660	10 8	110 4	109 2	27 4	27 1	-0 3	109 5	71 6	22 0	0 95	1 01	4 90E-09	32 08	
09/02/94	16 37		29 0	109 2	127 4	27 1	27 1	0 0	127 4	71 6	22 0	0 95	0 86			Refill
09/03/94	09 05	59280	21 7	127 4	120 1	27 1	27 8	0 7	119 4	70 9	21 6	0 95	1 07	1 61E-08	48 57	
09/03/94	09 06		30 0	120 1	128 4	27 8	27 8	0 0	128 4	70 9	21 6	0 95	0 94			Refill
09/06/94	14 43	279420	7 6	128 4	106 0	27 8	26 5	-1 3	107 3	72 0	22 2	0 95	1 20	9 48E-09	126 20	
09/06/94	14 44		30 0	106 0	128 4	26 5	26 5	0 0	128 4	72 0	22 2	0 95	0 83			Refill
09/09/94	09 37	240780	10 9	128 4	109 3	26 5	27 0	0 5	108 8	71 2	21 8	0 95	1 18	1 02E-08	193 10	
09/12/94	11 39		0 0	109 3	98 4	27 0	26 2	-0 8	99 2	72 7	22 6	0 93	1 10			Water level below scale
09/12/94	11 54	900	30 2	98 4	128 6	26 2	26 2	0 0	128 6	72 7	22.6	0 93	0 77			Refill
09/14/94	13 22	178080	14 7	128 6	113 1	26 2	26 5	0 3	112 8	72.5	22 5	0 93	1 14	1 06E-08	316 85	
09/14/94	13 27	300	28 6	113 1	127 0	26 5	26 5	0 0	127 0	72 5	22 5	0 93	0 89			Refill
09/16/94	10 50	163380	7 4	127 0	105 8	26 5	26 3	-0 2	106 0	67 1	19 5	1	1 20	1 72E-08	362 32	

Time weighted average for K2 = 1 27E-08

Borehole Permeameter Stage 2 Calculations

Project RMA 93-03, 21907 207030
Test Location. RMA, Section 25, Test Fill 1
Test Number B1B

Test Dimensions and Equations

(cm)

d =	1 27	L =	15 00	G5 =	1 157
D =	10 16	1/2 L =	7 50	G4 =	3 260
Z =	32 5	b_2 =	51 44	G3 =	2 217
R_A =	6 92	$4b_2/D$ =	20 25	F =	0 944
b_1 =	58 94	L/D =	1 48	G2 =	0 016
$Z + R_A + b_1$ =	98 36	a =	-1	K2 =	$R_1G2\ LN(H1/H2')/(t2 - t1)$
t_0 =	09/01/94 08 33				

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H2' = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2')	K2 (cm/sec)	Cum Hrs (hrs)	Remarks
09/01/94	08 33		29 6		128 0		27 8			68 2	20 1	1				
09/01/94	09 05	1920	29 7	128 0	128 1	27 8	27 7	0 1	128 2	68 5	20 3	1	1 00		0 53	
09/01/94	09 32	1620	30 0	128 1	128 4	27 7	27 6	-0 1	128 5	68 9	20 5	0 98	1 00		0 98	
09/01/94	10 37	3900	29 9	128 4	128 3	27 6	27 2	-0 4	128 7	69 6	20 9	0 98	1 00		2 07	
09/01/94	12 35	7080	29 1	128 3	127 5	27 2	27 2	0 0	127 5	70 9	21 6	0 95	1 01	1 32E-08	4 03	
09/01/94	15 35	10800	27 0	127 5	125 4	27 2	27 9	0 7	124 7	71 6	22 0	0 95	1 02	3 08E-08	7 03	
09/02/94	09 46	65460	12 8	125 4	111 2	27 9	27 4	-0 5	111 7	68 7	20 4	1	1 12	2 79E-08	25 22	
09/02/94	16 38	24720	11 6	111 2	110 0	27 4	27 1	0 3	110 3	71 6	22 0	0 95	1 01	4 93E-09	32 08	
09/02/94	16 39	60	29 2	110 0	127 6	27 1	27 1	0 0	127 6	71 6	22 0	0 95	0 86			Refill
09/03/94	09 07	59280	21 0	127 6	119 4	27 1	27 8	0 7	118 7	70 9	21 6	0 95	1 08	1 83E-08	48 57	
09/03/94	09 08	60	30 5	119 4	128 9	27 8	27 8	0 0	128 9	70 9	21 6	0 95	0 93			Refill
09/06/94	14 47	279540	6 5	128 9	104 9	27 8	26 5	-1 3	106 2	72 0	22 2	0 95	1 21	1 04E-08	126 23	
09/06/94	14 48	60	30 5	104 9	128 9	26 5	26 5	0 0	128 9	72 0	22 2	0 95	0 81			Refill
09/09/94	09 36	240600	8 9	128 9	107 3	26 5	27 0	0 5	106 8	71 2	21 8	0 95	1 21	1 17E-08	193 08	
09/12/94	11 40	266520	0 0	107 3	98 4	27 0	26 2	-0 8	99 2	72 7	22 6	0 93	1 08			Water level below scale
09/12/94	11 55	900	29 4	98 4	127 8	26 2	26 2	0 0	127 8	72 7	22 6	0 93	0 77			Refill
09/14/94	13 23	178080	0 0	127 8	98 4	26 2	26 5	0 3	98 1	72 5	22 5	0 93	1 30			Water level below scale
09/14/94	13 29	360	30 4	98 4	128 8	26 5	26 5	0 0	128 8	72 5	22 5	0 93	0 76			Refill
09/16/94	10 52	163380	0 0	128 8	98 4	26 5	26 3	-0 2	98 6	67 1	19 5	1	1 31			Water level below scale

Time weighted average for K2 = 1 34E-08

Borehole Permeameter Stage 2 Calculations

Project. RMA 93-03, 21907 207030
Test Location RMA, Section 25, Test Fill 1
Test Number . B1C

Test Dimensions and Equations

(cm)

d =	1 27	L =	17 00	G5 =	1 188
D =	10 16	1/2 L =	8 50	G4 =	3 623
Z =	33 5	b_2 =	49 44	G3 =	2 402
R_A =	6 92	$4b_2/D$ =	19 46	F =	0 959
b_1 =	57 94	L/D =	1 67	G2 =	0 015
$Z + R_A + b_1$ =	98 36	a =	-1	K2 =	$R_iG2\ LN(H1/H2')/(t2 - t1)$
t_o =	09/01/94 08 34				

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H2' = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2')	K2 (cm/sec)	Cum Hrs (hrs)	Remarks
09/01/94	08 34		29 9		128 3	29 9	27 8			68 2	20 1	1				
09/01/94	09 06	1920	30 0	128 3	128 4	27 8	27 7	-0 1	128 5	68 5	20 3	1	1 00		0 53	
09/01/94	09 33	1620	30 2	128 4	128 6	27 7	27 6	-0 1	128 7	68 9	20 5	0 98	1 00		0 98	
09/01/94	10 38	3900	30 2	128 6	128 6	27 6	27 2	-0 4	129 0	69 6	20 9	0 98	1 00		2 07	
09/01/94	12 36	7080	29 4	128 6	127 8	27 2	27 2	0 0	127 8	70 9	21 6	0 95	1 01	1 24E-08	4 03	
09/01/94	15 36	10800	27 4	127 8	125 8	27 2	27 9	0 7	125 1	71 6	22 0	0 95	1 02	2 79E-08	7 03	
09/02/94	09 47	65460	10 5	125 8	108 9	27 9	27 4	-0 5	109 4	68 7	20 4	1	1 15	3 17E-08	25 22	
09/02/94	16 40	24780	8 5	108 9	106 9	27 4	27 1	-0 3	107 2	71 6	22 0	0 95	1 02	8 96E-09	32 10	
09/02/94	16 41		29 2	106 9	127 6	27 1	27 1	0 0	127 6	71 6	22 0	0 95	0 84			Refill
09/03/94	09 09	59280	20 9	127 6	119 3	27 1	27 8	0 7	118 6	70 9	21 6	0 95	1 08	1 74E-08	48 58	
09/03/94	09 10		30 0	119 3	128 4	27 8	27 8	0 0	128 4	70 9	21 6	0 95	0 93			Refill
09/06/94	14 49	279540	9 4	128 4	107 8	27 8	26 5	-1 3	109 1	72 0	22 2	0 95	1 18	8 22E-09	126 25	
09/06/94	14 50		30 2	107 8	128 6	26 5	26 5	0 0	128 6	72 0	22 2	0 95	0 84			Refill
09/09/94	09 39	240540	7 2	128 6	105 6	26 5	27 0	0 5	105 1	71 2	21 8	0 95	1 22	1 18E-08	193 08	
09/12/94	11 40	266460	0 0	105 6	98 4	27 0	26 2	-0 8	99 2	72 7	22 6	0 93	1 06			Water level below scale
09/12/94	11 56		29 4	98 4	127 8	26 2	26.2	0 0	127 8	72 7	22 6	0 93	0 77			Refill
09/14/94	13.24	178080	12 3	127 8	110 7	26 2	26 5	0 3	110 4	72 5	22 5	0 93	1 16	1 14E-08	316 83	
09/14/94	13 31		30 0	110 7	128 4	26 5	26 5	0 0	128 4	72 5	22.5	0 93	0 86			Refill
09/16/94	10:58	163620	10 9	128 4	109 3	26 5	26 3	-0 2	109 5	67 1	19 5	1	1 17	1 45E-08	362 40	
09/16/94	10:59		29 8	109 3	128 2	26 3	26 3	0 0	128 2	67 1	19 5	1	0 85		362 42	Refill
09/20/94	14 12	357180	0 0	128 2	98 4	26 3	26 1	-0 2	98 6	69 6	20 9	0 95	1 30	1 04E-08	461 63	
09/20/94	14 13		30 0	98 4	128 4	26 1	26 1	0 0	128 4	69 6	20 9	0 95	0 77		461 65	Refill
09/25/94	15:50	437820	2.3	128 4	100 7	26 1	26 6	0 5	100 2	62 8	17 1	1 08	1 28	9 09E-09	583 27	
09/23/94	15 51		29 8	100 7	128 2	26 6	26 6	0 0	128 2	62 8	17 1	1 08	0 79		535 28	Refill
09/25/94	15 13	170520	10 0	128 2	108 4	26 6	26 3	-0.3	108 7	63 0	17.2	1 08	1 18	1 55E-08	582 65	

Time weighted average for K2 = 1 04E-08

Borehole Permeameter Stage 2 Calculations

Project RMA 93 03, 21907 207030
Test Location: RMA, Section 25, Test Fill 1
Test Number: B1D

Test Dimensions and Equations:

(cm)

d =	1 27	L =	16 50	G5 =	1 179
D =	10 16	1/2 L =	8 25	G4 =	3 531
Z =	33	b_2 =	50 19	G3 =	2 359
R_A =	6 92	$4b_2/D$ =	19 76	F =	0 956
b_1 =	58 44	L/D =	1 62	G2 =	0 015
$Z + R_A + b_1$ =	98 36	a =	-1	K2 =	$R_1G2\ LN(H1/H2')/(t2 - t1)$
t_0 =	09/01/94 08 38				

Date	Time	Δt = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H2' = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2')	K2 (cm/sec)	Cum Hrs (hrs)	Remarks
09/01/94	08 38		29 5		127 9	29 9	27 8			68 2	20 1	1				
09/01/94	09 07	1740	29 6	127 9	128 0	27 8	27 7	0 1	128 1	68 5	20 3	1	1 00		0 48	
09/01/94	09 34	1620	30 1	128 0	128 5	27 7	27 6	-0 1	128 6	68 9	20 5	0 98	1 00		0 93	
09/01/94	10 39	3900	30 2	128 5	128 6	27 6	27 2	-0 4	129 0	69 6	20 9	0 98	1 00		2 02	
09/01/94	12 37	7080	30 0	128 6	128 4	27 2	27 2	0 0	128 4	70 9	21 6	0 95	1 00	3 15E-09	3 98	
09/01/94	15 36	10740	28 7	128 4	127 1	27 2	27 9	0 7	126 4	71 6	22 0	0 95	1 02	2 09E-08	6 97	
09/02/94	09 47	65460	15 0	127 1	113 4	27 9	27 4	-0 5	113 9	68 7	20 4	1	1 12	2 53E-08	25 15	
09/02/94	16 42	24900	15 6	113 4	114 0	27 4	27 1	-0 3	114 3	71 6	22 0	0 95	0 99		32 07	
09/02/94	16 43		30 2	114 0	128 6	27 1	27 1	0 0	128 6	71 6	22 0	0 95	0 89			Refill
09/03/94	09 12	59340	23 1	128 6	121 5	27 1	27 8	0 7	120 8	70 9	21 6	0 95	1 06	1 51E-08	48 57	
09/03/94	09 13		30 3	121 5	128 7	27 8	27 8	0 0	128 7	70 9	21 6	0 95	0 94			Refill
09/06/94	14 51	279480	13 9	128 7	112 3	27 8	26 5	-1 3	113 6	72 0	22 2	0 95	1 13	6 40E-09	126 22	
09/06/94	14 52		30 0	112 3	128 4	26 5	26 5	0 0	128 4	72 0	22 2	0 95	0 87			Refill
09/09/94	09 40	240480	12 2	128 4	110 6	26 5	27 0	0 5	110 1	71 2	21 8	0 95	1 17	9 16E-09	193 03	
09/12/94	11 41	266460	0 0	110 6	98 4	27 0	26 2	0 8	99 2	72 7	22 6	0 93	1 11			Water level below scale
09/12/94	11 57		30 0	98 4	128 4	26 2	26 2	0 0	128 4	72 7	22 6	0 93	0 77			Refill
09/14/94	13 24	178020	17 9	128 4	116 3	26 2	26 5	0 3	116 0	72 5	22 5	0 93	1 11	8 00E-09	316 77	
09/14/94	13 34		28 7	116 3	127 1	26 5	26 5	0 0	127 1	72 5	22 5	0 93	0 92			Refill
09/16/94	11 02	163680	9 1	127 1	107 5	26 5	26 3	-0 2	107 7	67 1	19 5	1	1 18	1 53E-08	362 40	

Time weighted average for K2 = 8 27E-09

Borehole Permeameter Stage 2 Calculations

Project: RMA 93 03, 21907 207030
Test Location: RMA, Section 25, Test Fill 1
Test Number: B1E

Test Dimensions and Equations

	(cm)				
d =	1 27	L =	18 00	G5 =	1 200
D =	10 16	1/2 L =	9 00	G4 =	3 806
Z =	33	b_2 =	49 44	G3 =	2 491
R_A =	6 92	$4b_2/D$ =	19 46	F =	0 965
b_1 =	58 44	L/D =	1 77	G2 =	0 014
$Z + R_A + b_1$ =	98 36	a =	-1	K2 =	R_1G2 LN(H1/H2')/(t2 - t1)
t_0 =	09/01/94 08 37				

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H2' = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2')	K2 (cm/sec)	Cum Hrs (hrs)	Remarks
09/01/94	08 37		30 0		128 4	29 9	27 8			68 2	20 1	1				
09/01/94	09 08	1860	30 0	128 4	128 4	27 8	27 7	-0 1	128 5	68 5	20 3	1	1 00		0 52	
09/01/94	09 35	1620	30 4	128 4	128 8	27 7	27 6	-0 1	128 9	68 9	20 5	0 98	1 00		0 97	
09/01/94	10 40	3900	30 5	128 8	128 9	27 6	27 2	-0 4	129 3	69 6	20 9	0 98	1 00		2 05	
09/01/94	12 38	7080	29 9	128 9	128 3	27 2	27 2	0 0	128 3	70 9	21 6	0 95	1 00	9 05E-09	4 02	
09/01/94	15 37	10740	28 3	128 3	126 7	27 2	27 9	0 7	126 0	71 6	22 0	0 95	1 02	2 31E-08	7 00	
09/02/94	09 48	65460	14 0	126 7	112 4	27 9	27 4	-0 5	112 9	68 7	20 4	1	1 12	2 55E-08	25 18	
09/02/94	16 44	24960	12 7	112 4	111 1	27 4	27 1	-0 3	111 4	71 6	22 0	0 95	1 01	4 92E-09	32 12	
09/02/94	16 45		30 0	111 1	128 4	27 1	27 1	0 0	128 4	71 6	22 0	0 95	0 87			Refill
09/03/94	09 14	59340	23 5	128 4	121 9	27 1	27 8	0 7	121 2	70 9	21 6	0 95	1 06	1 34E 08	48 62	
09/03/94	09 15		29 6	121 9	128 0	27 8	27 8	0 0	128 0	70 9	21 6	0 95	0 95			Refill
09/06/94	14 53	279480	13 9	128 0	112 3	27 8	26 5	-1 3	113 6	72 0	22 2	0 95	1 13	5 87E-09	126 27	
09/06/94	14 54		30 0	112 3	128 4	26 5	26 5	0 0	128 4	72 0	22 2	0 95	0 87			Refill
09/09/94	09 41	240420	13 0	128 4	111 4	26 5	27 0	0 5	110 9	71 2	21 8	0 95	1 16	8 37E-09	193 07	
09/12/94	11 42	266460	0 0	111 4	98 4	27 0	26 2	-0 8	99 2	72 7	22 6	0 93	1 12			Water level below scale
09/12/94	11 57		30 3	98 4	128 7	26 2	26 2	0 0	128 7	72 7	22 6	0 93	0 76			Refill
09/14/94	13 25	178080	0 0	128 7	98 4	26 2	26 5	0 3	98 1	72 5	22 5	0 93	1 31	2 05E-08	316 80	
09/14/94	13 32		30 2	98 4	128 6	26 5	26 5	0 0	128 6	72 5	22 5	0 93	0 77			Refill
09/16/94	11 00	163680	13 0	128 6	111 4	26 5	26 3	-0 2	111 6	67 1	19 5	1	1 15	1 25E-08	362 38	
09/16/94	11 01		30 0	111 4	128 4	26 3	26 3	0 0	128 4	67 1	19 5	1	0 87		362 40	
09/20/94	14 01	356400	3 1	128 4	101 5	26 3	26 1	-0 2	101 7	69 6	20 9	0 98	1 26	9 27E-09	461 40	

Time weighted average for K2 = 9 42E-09

Borehole Permeameter Stage 2 Calculations

Project RMA 93 03, 21907 207030
Test Location: RMA, Section 25, Test Fill 1
Test Number: B2A

Test Dimensions and Equations.

	(cm)				
d =	1 27	L =	16 00	G5 =	1 172
D =	10 16	1/2 L =	8 00	G4 =	3 440
Z =	33	b_2 =	50 44	G3 =	2 312
R_A =	6 92	$4b_2/D$ =	19 86	F =	0 952
b_1 =	58 44	L/D =	1 57	G2 =	0 015
$Z + R_A + b_1$ =	98 36	a =	-1	K2 =	$R_1G2\ LN(H^1/H2')/(t2 - t1)$
t_0 =	09/01/94 08 30				

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H2' = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2')	K2 (cm/sec)	Cum Hrs (hrs)	Remarks
09/01/94	08 30		29 7		128 1	29 9	24 3			68 7	20 4	1				
09/01/94	09 00	1800	30 4	128 1	128 8	24 3	24 2	-0 1	128 9	69 3	20 7	0 97	0 99		0 50	Erroneous reading
09/01/94	09 30	1800	30 5	128 8	128 9	24 2	24 2	0 0	128 9	69 6	20 9	0 97	1 00		1 00	Erroneous reading
09/01/94	10 32	3720	30 9	128 9	129 3	24 2	23 8	-0 4	129 7	70 5	21 4	0 97	0 99		2 03	Erroneous reading
09/01/94	12 30	7080	31 4	129 3	129 8	23 8	23 6	-0 2	130 0	70 9	21 6	0 95	0 99		4 00	Erroneous reading
09/01/94	15 38	11280	29 7	129 8	128 1	23 6	24 3	0 7	127 4	71 2	21 8	0 95	1 02	2 41E-08	7 13	
09/02/94	09 40	64920	13 7	128 1	112 1	24 3	23 8	-0 5	112 6	69 3	20 7	0 97	1 14	2 95E-08	25 17	
09/02/94	16 47	25620	16 1	112 1	114 5	23 8	23 8	0 0	114 5	72 0	22 2	0 95	0 98		32 28	Erroneous reading
09/02/94	16 48		30 1	114 5	128 5	23 8	23 8	0 0	128 5	72 0	22 2	0 95	0 89			Refill
09/03/94	09 16	59280	19 8	128 5	118 2	23 8	24 2	0 4	117 8	72 0	22 2	0 95	1 09	2 13E-08	48 77	
09/03/94	09 17		30 3	118 2	128 7	24 2	24 2	0 0	128 7	72 0	22 2	0 95	0 92			Refill
09/06/94	14 56	279540	22 0	128 7	120 4	24 2	23 0	-1 2	121 6	72 7	22 6	0 93	1 06	2 89E-09	126 43	
09/06/94	14 57		30 1	120 4	128 5	23 0	23 0	0 0	128 5	72 7	22 6	0 93	0 94			Refill
09/09/94	09 59	241320	12 0	128 5	110 4	23 0	22 8	-0 2	110 6	73 0	22 8	0 93	1 16	8 85E-09	193 48	
09/12/94	11 47	265680	2 2	110 4	100 6	22 8	22 5	-0 3	100 9	73 4	23 0	0 93	1 09	4 82E-09	267 28	
09/12/94	11 50		29 7	100 6	128 1	22 5	22 5	0 0	128 1	73 4	23 0	0 93	0 79			Refill
09/14/94	13 38	179280	20 5	128 1	118 9	22 5	22 6	0 1	118 8	72 5	22 5	0 93	1 08	5 98E-09	317 13	
09/16/94	11 07	163740	6 0	118 9	104 4	22 6	22 3	0 3	104 7	68 5	20 3	1	1 14	1 19E-08	362 62	
09/16/94	11 08		30 0	104 4	128 4	22 3	22 3	0 0	128 4	68 5	20 3	1	0 81			Refill
09/20/94	14 14	356760	9 7	128 4	108 1	22 3	22 2	-0 1	108 2	70 7	21 5	0 95	1 19	6 98E 09	461 73	

Time weighted average for K2 = 8 00E-09

Borehole Permeameter Stage 2 Calculations

Project RMA 93 03, 21907 207030
Test Location: RMA, Section 25, Test Fill 1
Test Number: B2B

Test Dimensions and Equations:

(cm)

d =	1 27	L =	16 00	G5 =	1 172
D =	10 16	1/2 L =	8 00	G4 =	3 440
Z =	33	b_2 =	50 44	G3 =	2 312
R_A =	6 92	$4b_2/D$ =	19 86	F =	0 952
b_1 =	58 44	L/D =	1 57	G2 =	0 015
$Z + R_A + b_1$ =	98 36	a =	-1	K2 =	$R_t G2 \, LN(H1/H2')/(t2 - t1)$
t_0 =	09/01/94 08 32				

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H2' = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2')	K2 (cm/sec)	Cum Hrs (hrs)	Remarks
09/01/94	08 32		30 3		128 7	29 9	24 3			68 7	20 4	1				
09/01/94	09 01	1740	31 1	128 7	129 5	24 3	24 2	-0 1	129 6	69 3	20 7	0 97	0 99		0 48	Erroneous reading
09/01/94	09 31	1800	31 6	129 5	130 0	24 2	24 2	0 0	130 0	69 6	20 9	0 97	1 00		0 98	Erroneous reading
09/01/94	10 32	3660	31 8	130 0	130 2	24 2	23 8	-0 4	130 6	70 5	21 4	0 97	1 00		2 00	Erroneous reading
09/01/94	12 32	7200	31 7	130 2	130 1	23 8	23 6	-0 2	130 3	70 9	21 6	0 95	1 00		4 00	Erroneous reading
09/01/94	15 38	11160	30 7	130 1	129 1	23 6	24 3	0 7	128 4	71 2	21 8	0 95	1 01	1 71E-08	7 10	
09/02/94	09 40	64920	17 0	129 1	115 4	24 3	23 8	0 5	115 9	69 3	20 7	0 97	1 11	2 47E-08	25 13	
09/02/94	16 49	25740	17 0	115 4	115 4	23 8	23 8	0 0	115 4	72 0	22 2	0 95	1 00		32 28	Erroneous reading
09/02/94	16 50		29 4	115 4	127 8	23 8	23 8	0 0	127 8	72 0	22 2	0 95	0 90			Refill
09/03/94	09 18	59280	22 9	127 8	121 3	23 8	24 2	0 4	120 9	72 0	22 2	0 95	1 06	1 36E-08	48 77	
09/03/94	09 19		29 7	121 3	128 1	24 2	24 2	0 0	128 1	72 0	22 2	0 95	0 95			Refill
09/06/94	14 48	278940	17 9	128 1	116 3	24 2	23 0	-1 2	117 5	72 7	22 6	0 93	1 09	4 41E-09	126 27	
09/06/94	14 59		30 2	116 3	128 6	23 0	23 0	0 0	128 6	72 7	22 6	0 93	0 90			Refill
09/09/94	10 00	241260	14 7	128 6	113 1	23 0	22 8	-0 2	113 3	73 0	22 8	0 93	1 14	7 47E-09	193 47	
09/12/94	11 46	265560	3 7	113 1	102 1	22 8	22 5	-0 3	102 4	73 4	23 0	0 93	1 10	5 33E-09	267 23	
09/12/94	11 50		30 2	102 1	128 6	22 5	22 5	0 0	128 6	73 4	23 0	0 93	0 79			Refill
09/14/94	13 38	179280	20 4	128 6	118 8	22 5	22 6	0 1	118 7	72 5	22 5	0 93	1 08	6 36E-09	317 10	
09/16/94	11 09	163860	8 5	118 8	106 9	22 6	22 3	-0 3	107 2	68 5	20 3	1	1 11	9 60E-09	362 62	
09/16/94	11 10		30 3	106 9	128 7	22 3	22 3	0 0	128 7	68 5	20 3	1	0 83			Refill
09/20/94	14 16	356760	10 9	128 7	109 3	22 3	22 2	-0 1	109 4	70 7	21 5	0 95	1 18	6 62E-09	461 73	
09/20/94	14 17		30 2	128 7	128 6	22 3	22 2	-0 1	128 7	70 7	21 5	0 95	1 00		461 75	Refill
09/23/94	16 02	265560	10 2	109 3	108 6	22 2	21 9	-0 3	108 9	64 9	18 3	0 98	1 00	2 07E-10	535 50	

Time weighted average for K2 = 6 34E 09

Borehole Permeameter Stage 2 Calculations

Project RMA 93 03, 21907 207030
Test Location: RMA, Section 25, Test Fill 1
Test Number: B2C

Test Dimensions and Equations:

	(cm)				
d =	1 27	L =	15 75	G5 =	1 169
D =	10 16	1/2 L =	7 88	G4 =	3 395
Z =	33	b_2 =	50 57	G3 =	2 289
R_A =	6 92	$4b_2/D$ =	19 91	F =	0 950
b_1 =	58 44	L/D =	1 55	G2 =	0 015
$Z + R_A + b_1$ =	98 36	a =	-1	K2 =	$R_tG2\ LN(H1/H2')/(t2 - t1)$
t_0 =	09/01/94 08 34				

Date	Time	Δt = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H2' = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2')	K2 (cm/sec)	Cum Hrs (hrs)	Remarks
09/01/94	08 34		30 4		128 8	29 9	24 3			68 7	20 4	1				
09/01/94	09 01	1620	31 2	128 8	129 6	24 3	24 2	-0 1	129 7	69 3	20 7	0 97	0 99		0 45	
09/01/94	09 32	1860	31 6	129 6	130 0	24 2	24 2	0 0	130 0	69 6	20 9	0 97	1 00		0 97	
09/01/94	10 33	3660	31 8	130 0	130 2	24 2	23 8	-0 4	130 6	70 5	21 4	0 97	1 00		1 98	
09/01/94	12 33	7200	31 7	130 2	130 1	23 8	23 6	-0 2	130 3	70 9	21 6	0 95	1 00		3 98	
09/01/94	15 38	11100	30 0	130 1	128 4	23 6	24 3	0 7	127 7	71 2	21 8	0 95	1 02	2 46E-08	7 07	
09/02/94	09 41	64980	11 8	128 4	110 2	24 3	23 8	-0 5	110 7	69 3	20 7	0 97	1 16	3 41E-08	25 12	
09/02/94	16 51	25800	11 6	110 2	110 0	23 8	23 8	0 0	110 0	72 0	22 2	0 95	1 00	1 03E-09	32 28	
09/02/94	16 52		30 1	110 0	128 5	23 8	23 8	0 0	128 5	72 0	22 2	0 95	0 86			Refill
09/03/94	09 22	59400	22 1	128 5	120 5	23 8	24 2	0 4	120 1	72 0	22 2	0 95	1 07	1 67E-08	48 80	
09/03/94	09 23		30 2	120 5	128 6	24 2	24 2	0 0	128 6	72 0	22 2	0 95	0 94			Refill
09/06/94	15 00	279420	11 6	128 6	110 0	24 2	23 0	-1 2	111 2	72 7	22 6	0 93	1 16	7 46E-09	126 43	
09/06/94	15 01		30 0	110 0	128 4	23 0	23 0	0 0	128 4	72 7	22 6	0 93	0 86			Refill
09/09/94	10 00	241140	3 5	128 4	101 9	23 0	22 8	-0 2	102 1	73 0	22 8	0 93	1 26	1 36E-08	193 43	
09/09/94	10 02		30 0	101 9	128 4	22 8	22 5	-0 3	128 7	73 4	23 0	0 93	0 79			Refill
09/12/94	11 46	265440	7 2	128 4	105 6	22 5	22 5	0 0	105 6	73 4	23 0	0 93	1 22	1 06E-08	267 20	
09/12/94	11 51		30 4	105 6	128 8	22 5	22 6	0 1	128 7	73 4	23 0	0 93	0 82			Refill
09/14/94	13 39	179280	16 0	128 8	114 4	22 6	22 3	-0 3	114 7	72 5	22 5	1	1 12	9 97E-09	317 08	
09/14/94	13 40		30 6	114 4	129 0	22 6	22 3	-0 3	129 3	72 5	22 5	1	0 88		317 10	Refill
09/16/94	11 11	163860	0 0	129 0	98 4	22 3	22 2	-0 1	98 5	68 5	20 3	0 95	1 31	2 41E-08	362 62	

Time weighted average for K2 = 1 20E 08

Borehole Permeameter Stage 2 Calculations

Project: RMA 93 03, 21907 207030
Test Location RMA, Section 25, Test Fill 1
Test Number B2D

Test Dimensions and Equations:

(cm)

d =	1 27	L =	17 50	G5 =	1 193
D =	10 16	1/2 L =	8 75	G4 =	3 714
Z =	33	b_2 =	49 69	G3 =	2 448
R_A =	6 92	$4b_2/D$ =	19 56	F =	0 962
b_1 =	58 44	L/D =	1 72	G2 =	0 015
$Z + R_A + b_1$ =	98 36	a =	-1	K2 =	$R_t G2\ LN(H1/H2')/(t2 - t1)$
t_0 =	09/01/94 08 36				

Date	Time	^t = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H2' = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2')	K2 (cm/sec)	Cum Hrs (hrs)	Remarks
09/01/94	08 36		30 8		129 2	29 9	24 3			68 7	20 4	1				
09/01/94	09 02	1560	31 0	129 2	129 4	24 3	24 2	-0 1	129 5	69 3	20 7	0 97	1 00		0 43	
09/01/94	09 32	1800	31 4	129 4	129 8	24 2	24 2	0 0	129 8	69 6	20 9	0 97	1 00		0 93	
09/01/94	10 33	3660	31 4	129 8	129 8	24 2	23 8	-0 4	130 2	70 5	21 4	0 97	1 00		1 95	
09/01/94	12 33	7200	31 1	129 8	129 5	23 8	23 6	-0 2	129 7	70 9	21 6	0 95	1 00	1 49E 09	3 95	
09/01/94	15 39	11160	29 7	129 5	128 1	23 6	24 3	0 7	127 4	71 2	21 8	0 95	1 02	2 04E-08	7 05	
09/02/94	09 41	64920	12 4	128 1	110 8	24 3	23 8	-0 5	111 3	69 3	20 7	0 97	1 15	3 08E-08	25 08	
09/02/94	16 53	25920	14 7	110 8	113 1	23 8	23 8	0 0	113 1	72 0	22 2	0 95	0 98		32 28	Erroneous reading
09/02/94	16 53		30 0	113 1	128 4	23 8	23 8	0 0	128 4	72 0	22 2	0 95	0 88			Refill
09/03/94	09 24	59460	23 0	128 4	121 4	23 8	24 2	0 4	121 0	72 0	22 2	0 95	1 06	1 39E-08	48 80	
09/03/94	09 25		30 2	121 4	128 6	24 2	24 2	0 0	128 6	72 0	22 2	0 95	0 94			Refill
09/06/94	15 02	279420	15 9	128 6	114 3	24 2	23 0	-1 2	115 5	72 7	22 6	0 93	1 11	5 24E-09	126 43	
09/06/94	15 03		29 7	114 3	128 1	23 0	23 0	0 0	128 1	72 7	22 6	0 93	0 89			Refill
09/09/94	10 03	241200	14 2	128 1	112 6	23 0	22 8	-0 2	112 8	73 0	22 8	0 93	1 14	7 19E-09	193 45	
09/12/94	11 45	265320	0 5	112 6	98 9	22 8	22 5	-0 3	99 2	73 4	23 0	0 93	1 14	6 51E-09	267 15	
09/12/94	11 52		30 0	98 9	128 4	22 5	22 5	0 0	128 4	73 4	23 0	0 93	0 77			Refill
09/14/94	13 41	179340	19 4	128 4	117 8	22 5	22 6	0 1	117 7	72 4	22 4	0 93	1 09	6 62E-09	317 08	
09/16/94	11 14	163980	6 0	117 8	104 4	22 6	22 3	-0 3	104 7	68 5	20 3	1	1 13	1 05E-08	362 63	
09/16/94	11 15		30 4	104 4	128 8	22 3	22 3	0 0	128 8	68 5	20 3	1	0 81		362 65	Refill
09/20/94	14 20	356700	8 6	128 8	107 0	22 3	22 2	-0 1	107 1	70 7	21 5	0 95	1 20	7 20E-09	461 73	

Time weighted average for K2 = 8 14E-09

Borehole Permeameter Stage 2 Calculations

Project RMA 93 03, 21907 207030
Test Location: RMA, Section 25, Test Fill 1
Test Number B2E

Test Dimensions and Equations

(cm)

d =	1 27	L =	20 50	G5 =	1 238
D =	10 16	1/2 L =	10 25	G4 =	4 270
Z =	33	b_2 =	48 19	G3 =	2 690
R_A =	6 92	$4b_2/D$ =	18 97	F =	0 976
b_1 =	58 44	L/D =	2 02	G2 =	0 014
$Z + R_A + b_1$ =	98 36	a =	-1	K2 =	$R_t G2 \, LN(H1/H2')/(t2 - t1)$
t_0 =	09/01/94 08 38				

Date	Time	Δt = t2 - t1 (sec)	Test Unit R (cm)	H1 (cm)	H2 (cm)	TEG Ro (cm)	Rf (cm)	C = Rf - Ro (cm)	H2' = H2 - C (cm)	T (F)	T (C)	Rt Factor	(H1/H2')	K2 (cm/sec)	Cum hrs (hrs)	Remarks
09/01/94	08 38		30 2		128 6	29 9	24 3			68 7	20 4	1				
09/01/94	09 03	1500	30 6	128 6	129 0	24 3	24 2	-0 1	129 1	69 3	20 7	0 97	1 00		0 42	
09/01/94	09 33	1800	31 0	129 0	129 4	24 2	24 2	0 0	129 4	69 6	20 9	0 97	1 00		0 92	
09/01/94	10 43	4200	30 9	129 4	129 3	24 2	23 8	-0 4	129 7	70 5	21 4	0 97	1 00		2 08	
09/01/94	12 34	6660	30 3	129 3	128 7	23 8	23 6	0 2	128 9	70 9	21 6	0 95	1 00	5 99E-09	3 93	
09/01/94	15 40	11160	28 7	128 7	127 1	23 6	24 3	0 7	126 4	71 2	21 8	0 95	1 02	2 08E-08	7 03	
09/02/94	09 42	64920	15 1	127 1	113 5	24 3	23 8	0 5	114 0	69 2	20 7	0 97	1 11	2 20E-08	25 07	
09/02/94	16 54	25920	14 5	113 5	112 9	23 8	23 8	0 0	112 9	72 0	22 2	0 95	1 01	2 63E-09	32 27	
09/02/94	16 55		30 1	112 9	128 5	23 8	23 8	0 0	128 5	72 0	22 2	0 95	0 88			Refill
09/03/94	09 29	59640	22 7	128 5	121 1	23 8	24 2	0 4	120 7	72 0	22 2	0 95	1 06	1 35E-08	48 85	
09/03/94	09 30		29 9	121 1	128 3	24 2	24 2	0 0	128 3	72 0	22 2	0 95	0 94			Refill
09/06/94	15 04	279240	12 9	128 3	111 3	24 2	23 0	-1 2	112 5	72 7	22 6	0 93	1 14	5 93E-09	126 43	
09/06/94	15 05		30 2	111 3	128 6	23 0	23 0	0 0	128 6	72 7	22 6	0 93	0 87			Refill
09/09/94	10 04	241140	13 9	128 6	112 3	23 0	22 8	-0 2	112 5	73 0	22 8	0 93	1 14	6 99E-09	193 43	
09/12/94	11 43	265140	0 2	112 3	98 6	22 8	22 5	-0 3	98 9	73 4	23 0	0 93	1 14	6 04E-09	267 08	
09/12/94	11 53		29 9	98 6	128 3	22 5	22 5	0 0	128 3	73 4	23 0	0 93	0 77			Refill
09/14/94	13 42	179340	18 3	128 3	116 7	22 5	22 6	0 1	116 6	72 5	22 5	0 93	1 10	6 72E-09	317 07	
09/14/94	13 43		30 1	116 7	128 5	22 6	22 6	0 0	128 5	72 5	22 5	1	0 91			Refill
09/16/94	11 16	163980	13 4	128 5	111 8	22 6	22 3	-0 3	112 1	68 5	20 3	1	1 15	1 13E-08	362 63	

Time weighted average for K2 = 8 15E-09