APPENDIX D

EROSIONAL STABILITY

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D.1 INTRODUCTION

This appendix presents the hydrologic analyses and evaluation of erosion protection for the cover of the disposal cell. This appendix is an update of analyses documented in the 2002 Preliminary Design Report (Reclamation Plan Appendix C). The analyses encompass the following tasks:

1. Determine the PMP event for the disposal cell area.
2. Determine the peak unit discharge from the PMP on the drainage basins of the disposal cells.
3. Evaluate erosional stability of the disposal cell cover surface using the peak unit discharge.
4. Calculate the median rock size for erosion protection materials on the disposal cell cover using the peak unit discharge.
5. Calculate the median rock size for erosion protection materials of the rock apron at the toe of the disposal cell.
6. Calculate the median rock size required for scour protection at the head of Gully 005.
7. Evaluate filter criteria between granular material and surrounding materials.
8. Evaluate wind erosion potential of disposal cell cover.

These analysis tasks are described in the following sections.

D.2 PROBABLE MAXIMUM PRECIPITATION EVENT

One of the technical criteria for the stability of the disposal cell is acceptable erosional stability from extreme storm events (Appendix A of 10 CFR 40). The NRC has interpreted this criterion to be able to safely pass the peak runoff from storms up to the Probable Maximum Precipitation (PMP) event (NRC, 1990; Johnson, 1999, Johnson, 2002). This section discusses the precipitation event used to predict the peak discharges for design of the disposal cell cover.

The depth of the PMP is derived from Hydrometerological Report 51 (HMR 51, USCOE, 1978). HMR 51 provides depths for the all-season PMP for basins with an area of 10 square miles or larger. Figure 18 from HMR 51 indicates a PMP depth of 29 inches over a duration of 6 hours for a drainage basin of 10 square miles. For this analysis, it was necessary to derive the PMP event for a smaller duration and smaller drainage area. This was accomplished by using the Hydrometerological Report 52 (HMR 52, USCOE, 1982). HMR 52 takes the PMP estimates from HMR 51 and applies them to specific drainage areas both temporally and spatially. From Figures 23 and 24 in HMR 52, the 1-hour PMP for a drainage area of one square mile is 0.65 times smaller than the 6-hour PMP for 10 square mile drainage areas. This results in a 1-hour PMP of 19 inches, which was used for this analysis. Factors for durations less than one hour where taken from Hydrometeorological Report No. 52 for durations of 5, 15 and 30 minutes. The rainfall intensity was determined by multiplying the PMP depth by its corresponding duration based on the time of concentration for that specific drainage basin.

D.3 RUNOFF FROM THE PMP (PEAK DISCHARGE)

The Rational Method was used to determine the peak discharge from the PMP for evaluation of cover erosion protection. Five drainage areas were delineated on the cover of the disposal cell; four on the side slopes (north, south, east and west), and one on the top surface, as shown in Figure D.1. The area of these drainage basins was calculated using computer-aided design (CAD) tools.

Time of Concentration. The time of concentration is computed using the Kirpich (1940) equation (give below) as recommended in the NRC STP.

$$T_c = 0.0078L^{0.77}(L/H)^{0.385}$$

Where:

T_c = time of concentration (minutes)
L = slope length (feet)
H = slope height (feet)

Table D.1 (below) shows the areas of each drainage basin, the slope, and slope length, which are used for the time of concentration calculation. As seen in Table D.1, all calculated times of concentration are less than 5 minutes except for the cover, which is 5.4 minutes. As recommended in the Urban Drainage and Flood Control District Strom Drainage Criteria Manual (UDFCD, 2001) and Nelson and others (1986), time of concentration less than 5 minutes does not lead to realistic runoff estimates, and therefore a T_c of 5 minutes was used for each basin.

Table D.1 Results of Time of Concentration Calculations

Description	Drainage Area (acres)	Slope (feet/feet)	Slope Length (feet)	Time of Concentration (minutes)
Top	7.8	0.01	500	5.4
North	2.5	0.20	190	0.9
South	1.4	0.20	110	0.6
East	1.8	0.20	100	0.5
West	3.6	0.20	225	1.0

The rainfall intensity for each basin is 75.2 inches per hour based on a T_c of 5 minutes. From Figure 36 of the Hydrometeorological Report No. 52 (Schriener and Riedel, 1978), a ratio of 0.33 is multiplied to the 1-hour PMP depth for a duration of 5 minutes. Rainfall intensities for each basin are determined as follows:

$$I = \frac{P_{pmp} \times F \times 60\,\text{min}/hr}{T_c}$$

Where:

I = intensity
P_{pmp} = 19 inches (depth of 1 hour PMP)
F = ratio of 5 minute duration to 1-hour duration = 0.33
T_c = time of concentration (minutes) = 5 minutes

Peak flow. The peak flow was calculated with the Rational Formula, as follows:

$$Q = CIA$$

Where:

Q = peak flow (cfs)
C = runoff coefficient = 0.8
I = rainfall intensity (inches/hour)
A = area (acres)

The NRC STP recommends using a conservative runoff coefficient of 0.8 when evaluating erosion protection for cover systems. Peak flow was then divided by the downstream width of the appropriate drainage area as follows:

$$q = Q/w$$

Where:

q = unit discharge (cfs/foot)
w = unit width (feet)

Table D.2 shows the results of the peak flow and unit discharge calculations for each drainage basin.

Table D.2 Results of Peak Flow and Unit Discharge for Each Drainage Basin

Description	Drainage Area (acres)	Rainfall Intensity (in/hr)	Peak Flow (cfs)	Downstream Width (feet)	Unit Discharge (cfs/acre)	Unit Discharge (cfs/foot)
Top	7.8	75.2	469.2	1200	60	0.39
North	2.5	75.2	150.4	575	60	0.26
South	1.4	75.2	84.2	600	60	0.14
East	1.8	75.2	108.3	830	60	0.13
West	3.6	75.2	216.6	850	60	0.25

For the top surface of the disposal cell, the peak flow in Table D.2 (469.2 cfs) represents the flow over the top of the east and south side slopes. The unit discharge (0.39 cfs/foot) is this flow distributed over the slope width at the top of the east and south side slopes (1,200 feet).

For sizing riprap for erosion protection on the side slopes, the unit discharge values in Table D.2 were used in evaluating the north and west side slopes. On the east and south side slopes, the unit discharge from the top surface (0.39 cfs/foot) was used, since this value was larger than the unit discharge for runoff from precipitation on the slope itself (0.13 and 0.14 cfs/foot). Due to the differences in time of concentration between the top surface and side slope runoff, the peak flows on the east and south side slopes were not added to the peak flow from the top surface.

D.4 TOP SURFACE EROSIONAL STABILITY

The top surface of the disposal cell was evaluated for erosional stability without a rock layer. As outlined in NRC (1990) and Johnson (1999), the peak discharge over the top surface (from Table D.2) was first converted to a peak velocity and depth of flow using Manning's Equation. The peak unit discharge flow (0.39 cfs/foot) was multiplied by a concentration factor of 3. Depending on surface roughness (due to vegetation conditions), peak velocities range from approximately 1.4 to 2.3 feet per second and the corresponding depths of flow are 0.87 to 0.50 feet (for Manning's roughness coefficient values ranging from 0.10 to 0.04). Permissible velocities presented in Johnson (1999) for these depths of flow range from approximately 2.0 to 2.4 feet per second. This indicates that some of the peak velocities from the PMP are less than permissible velocities, but not under all of the surface roughness conditions that were analyzed. As the next step of evaluation, procedures for vegetated surfaces outlined in Temple and others (1987) were used (as recommended in the NRC STP).

Method of Analysis. Temple and others (1987) outlines procedures for channel design, including calculation of channel velocities and depths of flow. These procedures include methods for estimating stresses on channel vegetation as well as the channel surface soils. The evaluation for the disposal cell used the peak discharge values from the PMP (summarized in Table D.2) to conservatively represent the effective stresses from runoff on the cover surface. The stresses on both the vegetation and soils were evaluated.

The erosional stability of the cover surface was evaluated by calculating a factor of safety against erosion due to the peak runoff from the PMP. Factor-of-safety values were calculated as the ratio of the allowable stresses (the resisting strength of the cover vegetation or soils) to the effective stresses (the stresses impacted by the runoff flowing over the cover). The stress calculations are summarized below.

Allowable stresses. Allowable stresses for the cover soils were calculated using the equations in Temple and others (1987). Materials planned for cover soils range from silty clays to gravelly sandy silts (depending on how much of the underlying sandstone and siltstone is present in the cover material). For cohesive soils, the resistance is based on the plastic limit and void ratio of the material. From testing of on-site silty clay in 1996 (classified as a low-plasticity clay or CL), the plastic limit was 16 and the void ratio (at 90 percent of Standard Proctor density) was 0.723. The equation for allowable shear strength for cohesive soils is:

$$\tau_a = \tau_{ab}\, C_e^2$$

Where:

τ_a = allowable shear strength (in psf)
τ_{ab} = basis allowable shear strength (for a CL) = $(1.07\,[PL]^2 + 14.3[PL] + 47.7) \times 10^{-4}$
C_e = soil parameter = 1.48 – 0.57e
PL = plastic limit = 16
e = void ratio = 0.723

For the plastic limit and void ratio values given above, τ_{ab} = 0.055, C_e = 1.07 and τ_a = 0.063 psf.

For non-cohesive soils, the resistance is based on particle size, specifically the size where 75 percent of the material is finer, or d_{75}. For a d_{75} larger than 0.05 inches (1.27 mm, No. 14 sieve size, or a medium-grained sand), the allowable shear strength is:

$$\tau_a = 0.4\, d_{75}, \text{ where } d_{75} \text{ is in inches}$$

For a soil cover d_{75} of 0.157 inches (4 mm, No. 4 sieve size, or a coarse-grained sand), the allowable shear strength is 0.063 psf.

For a vegetated surface primarily of mixed grasses, the allowable vegetation shear strength is:

$$\tau_{va} = 0.75\, C_I$$

Where:

τ_{va} = allowable vegetation shear strength (in psf)
C_I = cover index = $2.5\, [h(M)^{1/2}]^{1/3}$
h = stem length (in ft)
M = stem density factor

For average vegetation conditions, h=1.0, M=200 and C_I=6.05. For poor conditions, h=0.5, M=150, and C_I=4.57. The resulting vegetation shear stress values are 4.53 to 3.43 psf for average to poor vegetation conditions, respectively.

Effective stresses. The effective shear stress on soil due to peak runoff from the PMP was calculated as:

$$\tau_e = \gamma dS(1-C_F)(n_s/n)^2$$

Where:

τ_e = effective shear stress (in psf)
γ = unit weight of water = 62.4 pcf
d = depth of flow (in ft)
S = slope of cover surface (0.01)
C_F = cover factor (0.7 for average vegetation, 0.5 for poor vegetation)
n_s = soil grain roughness factor (0.0156 for cohesive soil, 0.018 for soil with a d_{75} of 4 mm)
n = Manning's roughness coefficient (0.10 to 0.04)

The effective shear stress on vegetation is calculated as:

$$\tau_v = \gamma dS - \tau_e, \text{ where } \tau_v = \text{effective vegetal stress (in psf)}$$

Varying the vegetation conditions and the soil grain roughness factors, the effective shear stresses for Manning's n values are summarized below.

Manning's n value	0.10	0.10	0.10	0.10	0.04	0.04	0.04	0.04
Depth of flow, d (ft)	0.87	0.87	0.87	0.87	0.50	0.50	0.50	0.50
Cover factor, C_F	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5
Soil grain roughness factor, n_s	0.0156	0.0156	0.018	0.018	0.0156	0.0156	0.018	0.018
Effective shear stress, τ_e (psf)	0.004	0.007	0.005	0.009	0.014	0.024	0.019	0.032
Effective vegetal stress, τ_v (psf)	0.539	0.536	0.538	0.534	0.298	0.288	0.293	0.280

Factors of safety. The calculated factors of safety from the shear stresses above are outlined below.

Condition	Allowable Strength (psf)	Effective Stress (psf)	Factor of Safety (allowable/effective)
Vegetation on cover surface			
(average)	4.53	0.539	8.4
(poor)	3.43	0.536	6.4
Soils on cover surface			
(cohesive)	0.0627	0.024	2.6
(granular)	0.063	0.032	2.0

The calculated factors of safety above show that for average to poor vegetation conditions, the allowable shear strengths are higher than the effective shear stresses on vegetation due to peak discharge from the PMP (with factors of safety above 6). For the conservative condition of no vegetation with the topsoil eroded away, the underlying cover soil shear strengths are higher than the effective shear strengths due to peak discharge for the PMP (with factors of safety at or above 2).

These analyses indicate that the cover on the top surface of the disposal cell can be vegetated without a riprap or rock mulch layer and meet the erosional stability criteria outlined in NRC (1990), Johnson (1999), and Johnson (2002). In the following section, riprap sizing calculations are included on the cover surface for comparative purposes.

D.5 RIPRAP SIZING FOR THE COVER SURFACES

The design unit discharge from each drainage basin was used to size riprap for the protective cover. The design unit discharge is based on the assumption of uniform sheet flow across the entire drainage basin. The NRC STP recommends using the Safety Factors Method for top surfaces (less than 10 percent). Riprap sizing on the side slopes was calculated using the Abt method, as recommended by Johnson (1999).

The equation for the Safety Factors Method (Richardson et al., 1975) is outlined in NUREG CR-4620 (Nelson et al., 1986). The key parameters used in the riprap sizing calculations are outlined below.

Flow Characteristics. The peak unit discharge values from Table D.2 were used to represent flow conditions on the cover surface. Where applicable, a concentration factor of 2 or 3 was used.

Rock Characteristics. Properties for durable rock from nearby gravel pits were used in the calculations. The rock specific gravity was 2.65, with a friction angle or angle of repose of 37 and 42 degrees (representing rounded and angular rock respectively, consistent with Table 4.8 of NUREG CR-4620), and a porosity of 0.33.

The riprap sizing results are summarized in Table D.3 below.

Table D.3 Results of Riprap Sizing Calculations for Cover Protection

Drainage Basin	Design Unit Discharge (cfs/ft)	Slope (ft/ft)	Slope Length (ft)	Flow Concentration Factor, C_f	Coefficient of Movement, C_m	Adjusted Design Unit Discharge q_f (cfs/ft)	Median Rock Size (inches) Rounded	Median Rock Size (inches) Angular
Top	0.39	0.01	500	1.0	1.35	0.47	1.2[a]	---
North	0.26	0.20	190	2.0	1.35	0.70	3.0	2.1
South	0.39[b]	0.20	110	3.0	1.35	1.42	4.7	3.4
East	0.39[b]	0.20	100	3.0	1.35	1.42	4.7	3.4
West	0.25	0.20	225	2.0	1.35	0.68	2.9	2.1

[a] - Safety Factors Method
[b] – From discharge off of top surface

Using Abt's method for the side slopes (at 20 percent) for angular rock, the median rock size ranges from 2.1 inches on the west slope to 3.4 inches on the east and south slopes of the disposal cell (based on runoff from the top surface flowing over the east and south slopes). If rounded rock is used, the median rock size ranges from 2.9 to 4.7 inches.

For the disposal cell cover design, two modifications are made from standard surface riprap design, as outlined below.

Rock mulch. A rock mulch will be used for the riprap, utilizing quarried (angular) limestone from nearby sources, with smaller materials to fill the void spaces. The median size is conservatively specified to be 2.7 inches for the north and west side slopes, and 3.4 for the south and east side slopes. This median size is for angular rock. The median size for rounded rock is 40 percent larger (with no oversizing for durability considerations). The maximum size (based on available screen size) is 9 inches. The rock mulch layer thickness (recommended to be 1.5 to 2 times the median size or at the maximum size in the NRC STP) is 9 inches.

Below-surface layer. In order to promote establishment and maintenance of vegetation on the side slopes, the rock mulch layer will not be on the cover surface. A layer of topsoil (9 inches thick) will be the top layer on the side slopes, followed by the rock mulch layer (9 inches thick). The topsoil will provide the seed bed and "A" horizon for plant establishment and growth, and the rock mulch layer will allow root penetration. The rock mulch layer will provide an erosion protection layer in the event that the topsoil is eroded.

D.6 RIPRAP SIZING FOR THE PERIMETER APRON

Additional erosion protection will be provided for runoff from the side slopes of the disposal cell with a rock apron. This perimeter apron will (1) serve as an impact basin and provide for energy dissipation of runoff, (2) provide erosion protection, and (3) transition flow from side slopes to natural ground. On the north, south, and west sides of the cell, flow will transition from the rock apron to natural ground. On the east side of the cell, the rock apron will also serve as a diversion channel as flow is received from both the east side slopes of the disposal cell and from approximately 5.4 acres of upstream ground between the property boundary and the east toe of the disposal cell.

The median rock size required in the perimeter apron was calculated using the equations derived by Abt et al. (1998) as outlined in NUREG 1623 as follows:

$$D_{50 energydissipation} = 10.46 S^{0.43} (C_f q_d)^{0.56}$$
$$D_{50 diversionchannel} = 5.23 S^{0.43} (C_f q_d)^{0.56}$$

Where S is the slope, C_f is the concentration factor, and q_d is the design unit discharge. The median rock size was increased by 40 percent to account for the use of rounded alluvial rock.

Table D.4 Results of Rock Sizing Calculations for Perimeter Apron for Energy Dissipation

Drainage Basin	Design Unit Discharge (cfs/ft)	Slope Upstream of Toe (ft/ft)	Flow Concentration Factor, C_f	Median Rock Size, Angular (inches)	Median Rock Size, Rounded (inches)
North	0.26	0.20	3.0	4.6	6.4
South	0.39	0.20	3.0	5.7	8.0
East	0.39	0.20	3.0	5.7	8.0
West	0.25	0.20	3.0	4.5	6.2

Peak flow along the east toe was calculated using the Rational Formula, as described in section D.3. Flow over the east side slope is combined with overland flow. The maximum flow in each reach of the toe/diversion is calculated using the parameters in Table D.5.

Table D.5 Results of Peak Flow along Toe of East Side Slope

Flow Area	Side Slope Unit Discharge (cfs/foot)	Linear Length of Side-Slope (ft)	Overland Flow Runoff Coef. (acre)	Rainfall Intensity (in/hr)	Overland Flow Area (acre)	Peak Flow (cfs)
A1	0.39	390	0.3	75.2	1.78	192
A2	0.39	450	0.3	75.2	3.54	255

The median rock size was calculated using equation presented by Abt et al. (1998) for embankment side slopes, as recommended in NUREG 1623. The parameters used in this calculation are shown in Table D.6.

Table D.6 Results of Riprap Sizing Calculations for Diversion Channel Along East Toe

Diversion Reach	Maximum Channel Flow (cfs)	Channel Bottom Width (ft)	Design Unit Discharge (cfs/ft)	Flow Concentration Factor, C_f	Channel Slope (ft/ft)	Median Rock Size, Angular (inches)	Median Rock Size, Rounded (inches)
North Channel	192	40	4.8	3	0.029	5.1	7.1
South Channel	255	40	6.38	3	0.024	5.5	7.7

Based on Tables D.4 and D.6, the rock apron should have a median rock size of 5.7 inches if angular rock is used, and 8.0 inches if rounded rock is used. The channel along the east side of the disposal cell should have a width of 40 feet and a minimum depth for flow of 1.0 foot. The rock apron thickness (recommended to be 3 times the median stone size) will be 18 to 24 inches.

The maximum unit flow off the toe is 0.39 cfs/ft. Using this maximum flow, and an assumed slope of the rock apron of one percent, the maximum scour depth was calculated using procedures outlined in NUREG 1623 and U.S. Department of Transportation in Hydrologic Engineering Circular 14 (calculation discussed further in Section D.7). The maximum scour depth from flow coming off the rock apron of the disposal cell is estimated to be 0.46 feet. The rock apron thickness is therefore adequate to protect against scour.

D.7 ROCK SIZING FOR SCOUR PROTECTION AT THE HEAD OF GULLY 005

On the west side of the disposal cell above the 005 drainage, runoff will be directed over the rock armor protection into the 005 drainage. The rock armor protection at the 005 drainage is shown in Figure D.2. Figure D.3 provides a plan and profile along the 005 drainage, showing depth to sedimentary rock (from available drill hole information and surface reconnaissance) and planned excavation at the toe of the disposal cell.

A rock apron to protect against headward erosion has been sized according to procedures specified in NUREG 1623. The rock apron will be constructed at the point where water discharges to natural ground at the head of Gully 005. Scour depth was estimated using the procedures presented in the U.S. Department of Transportation in Hydrologic Engineering Circular 14. These calculations indicate that the theoretical maximum depth of scour exceeds the depth of bedrock. Boring holes drilled near the head of Stream 005 (BH-42 and BH-47 from SFC FEIF, 1991) indicate that sandstone bedrock is located at a depth of less than 7 feet. Therefore, the erosion apron will be constructed by excavating the alluvial soils at a 1V:5H slope until keyed into bedrock. The median rock size is calculated by the following equation:

$$D_{50} = 5.23 S^{0.43} (C_f q_d)^{0.56}$$

Where:

> S = slope of the placed rock protection = 0.20,
> C_f = flow concentration factor = 3.0, and
> q_d = design unit discharge.

As calculated in section D.3, flow off the west slope has a unit flow of 0.25 cfs/ft. The 50-foot channel at the toe of the west side slope receives flow from approximately 200 linear feet of slope. In addition, approximately 0.13 acres of land surrounding the gully protection apron will drain past the downstream edge of the gully protection. Therefore, the design unit discharge for gully erosion protection is estimated to be approximately 1.1 cfs per foot. The median rock size for Gully 005 erosion protection should have a minimum size of 5.1 inches for angular rock, and 7.2 for rounded rock.

D.8 FILTER CRITERIA

Filter requirements between components of the disposal cell materials need to be met. Specific areas evaluated include (1) filter between disposed material, liner cover material, and leachate collection pipe, (2) rock mulch of side slope and base material, (3) rock of toe apron and base material, (4) rock of toe apron/diversion channel on the east side of the disposal cell, and (5) rock of Gully 005 erosion protection. The gradations of the various materials are shown in Figure D.2

Disposed material, liner cover material, and leachate collection pipe. Filter criteria of these materials need to meet minimum requirements to prevent clogging and to meet permeability requirements. Therefore, criteria as specified in USDA (1994) were used as follows:

Step 1: Correct base (disposed material) gradation for oversized material (>#4).
Step 2: Using Table 26-1, base soil is category 2 (sands, silts, clays, and silty and clayey sands)
Step 3: Maximum D_{15} is <=0.7 mm
Step 4: For permeability requirements, minimum D_{15}>=4*d_{15} of base soil. D_{15}>=0.012 mm
Step 5: For percentage passing of 60 or less, so ratio of maximum and minimum bands of filter are less than 5. Minimum D_{15}>=0.14 mm.
Step 6: To prevent gap-grading, set coefficient of uniformity (CU=D_{60}/D_{10}) <= 6. Maximum D_{10}=Maximum D_{15}/1.2. Maximum D_{10}=0.7/1.2=0.58 mm. Maximum D_{60}= 0.58*6=3.5 mm. Minimum D_{60}=3.5/5=0.7 mm.
Step 7: Minimum D_5=0.075 mm
Step 8: Maximum D_{100}=1 inch (protection of synthetic liner)
Step 9: Perforations in pipe <= D_{85} filter. Perforations 2-3 mm.

Rock mulch of side slope and subsoil. NUREG 1623, Appendix D, recommends a filter or bedding layer be placed under riprap when interstitial velocities are greater than 0.5 to 1.0 ft/sec. Interstitial velocities are calculated by procedures presented by Abt et al. (1991) as given in the following equation:

$$V_i = 0.23 * (g * D_{10} * S)^{\frac{1}{2}}$$

Where:

V_i = interstitial velocities in ft/s,
g = acceleration of gravity in ft/s^2,
D_{10} = stone diameter at which 10% is finer in inches, and
S = gradient in decimal form.

Using a D_{10} of ¾ in, and a side slope of 0.20, the calculated velocity is 0.5 ft/s. Therefore, a bedding layer is not required beneath the rock mulch of the side slopes. A bedding layer is not conditionally required unless D_{10} is greater than 2.9 inches.

Rock mulch of toe apron and native alluvial material. Rock sizing calculations for the toe apron specify a minimum D_{50} of 5.7 inches (assuming angular rock). The grain size distribution for the rock was determined using guidance given in NUREG 4620, Section 4.4. The toe apron serves primarily to dissipate energy of the flow coming from the slopes of the cell, and will be constructed relatively flat. Assuming a 1% slope of the toe, and using the above equation to calculate the interstitial velocities, the velocities for a D_{10} of 7.8 inches or less are below 0.5 ft/s. Therefore, no filter layer is required beneath the toe apron.

Rock of toe apron/diversion channel on the east side of the disposal cell and native alluvial material. Rock of the toe apron/diversion channel on the east side of the disposal cell will have the same gradation as the rock at the toe of the slopes on the north, west, and south of the disposal cell (minimum D_{50} of 5.7 inches). However, on the east side of the cell, water will collect at the toe and flow north and south around the east toe until it is intercepted by the diversion channels and diverted away from the disposal cell. The maximum slope along the east side of the disposal cell is approximately 2.9 percent. The calculated interstitial velocities are 0.6 ft/s. Therefore, a filter layer is not required beneath the toe apron/diversion channel along the east side of the disposal cell.

Rock of Gully 005 erosion protection and native alluvial material. The rock of Gully 005 erosion protection will have the same gradation as the rock on the toe apron (minimum D_{50} of 5.7 inches). The erosion protection will be placed by excavating at a 5:1 (horizontal:vertical) slope until keyed into bedrock. If scour were to reach the base of this protective layer, the velocities of flow into the gully would require filter between the rock protection and the native alluvial soils.

The rock protection and native alluvial soils would require two filters. The native alluvial soils would first be overlain by material meeting specifications for liner cover/liner bedding gradations. The second filter (erosion protection filter) material is designed to meet minimum requirements of

D_{15}(coarser)/D_{85}(finer)<=5 of both the liner cover/liner bedding material, and the D_{50} of 5.7-inch rock gradations, as discussed in NUREG 4620, section 4.4. In addition, the erosion protection filter is shown to have a maximum coefficient of uniformity of 6. Each filter layer should have a minimum thickness of 12 inches.

D.9 WIND EROSION

The potential for wind erosion of the top surface of disposal cell during drought conditions was evaluated using procedures given in NUREG 4620 (Nelson et al. 1986). The soil loss equation was calculated as follows:

$$A = R \times K \times LS \times VM$$

Where:

A = soil loss in tons per acre per year,
R = rainfall factor,
K = soil erodibility factor,
LS = topographic factor, and
VM = dimensionless erosion control factor relating to vegetative and mechanical factors.

The rainfall factor was conservatively modeled as 100. The soil erodibility factor was estimated based on percent silt and very fine sand to range between 26 and 36 percent, the percent sand (0,10 – 2.0 mm) to range between 5 and 22 percent. The percent organic matter was estimated at 2 percent, the soil structure was considered to be fine granular (No. 2) and the permeability was considered moderate (No. 3). Using the nomograph given in Figure 5.1 of NUREG 4620, the soil erodibility factor was estimated to be 0.12.

The topographic factor is calculated by the following equation:

$$LS = \frac{650 + 450 \times s + 65 \times s^2}{10{,}000 + s^2} \times \left(\frac{L}{72.6} \right)^m$$

Where:

s = slope steepness in percent,
L = slope length in feet, and
m = exponent dependent upon slope steepness.

For a slope of 1 percent, a length of 500 feet, LS is calculated to be 0.17. VM was set at 0.4, which is the value given for seedings, permanent 0-60 days, to represent drought conditions. During non-drought conditions, seedings older than 12 months would be represented by a VM value of 0.01.

The calculated soil loss is 0.822 tons per acre per year. Assuming a dry density of soil of 100 pcf, the soil loss is equivalent to 3.8×10^{-4} ft/year, or 0.4 feet over a 1000-year life of the disposal cell. The disposal cell has adequate topsoil depth (18 inches on the top slope) to account for wind erosion.

D.10 REFERENCES

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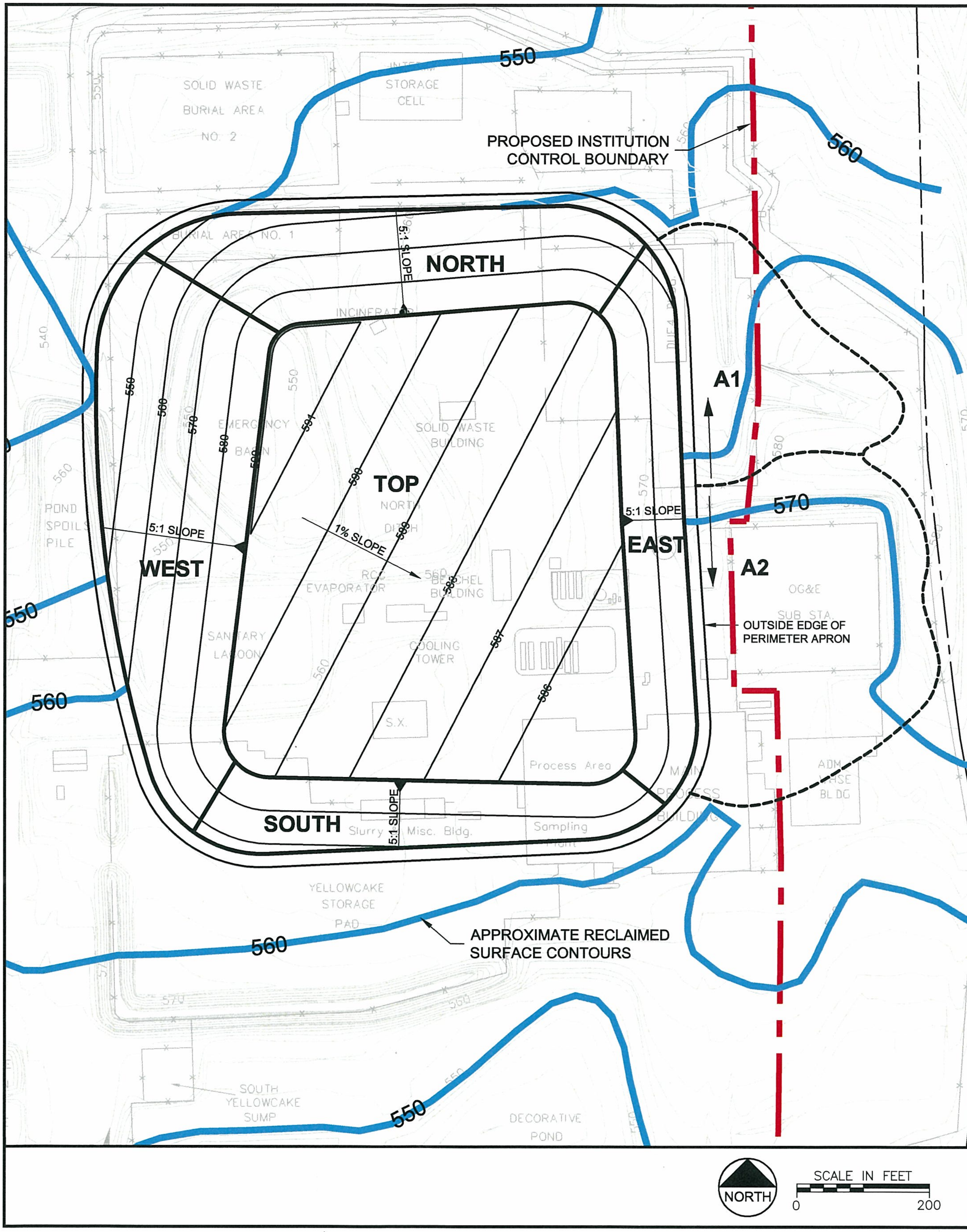

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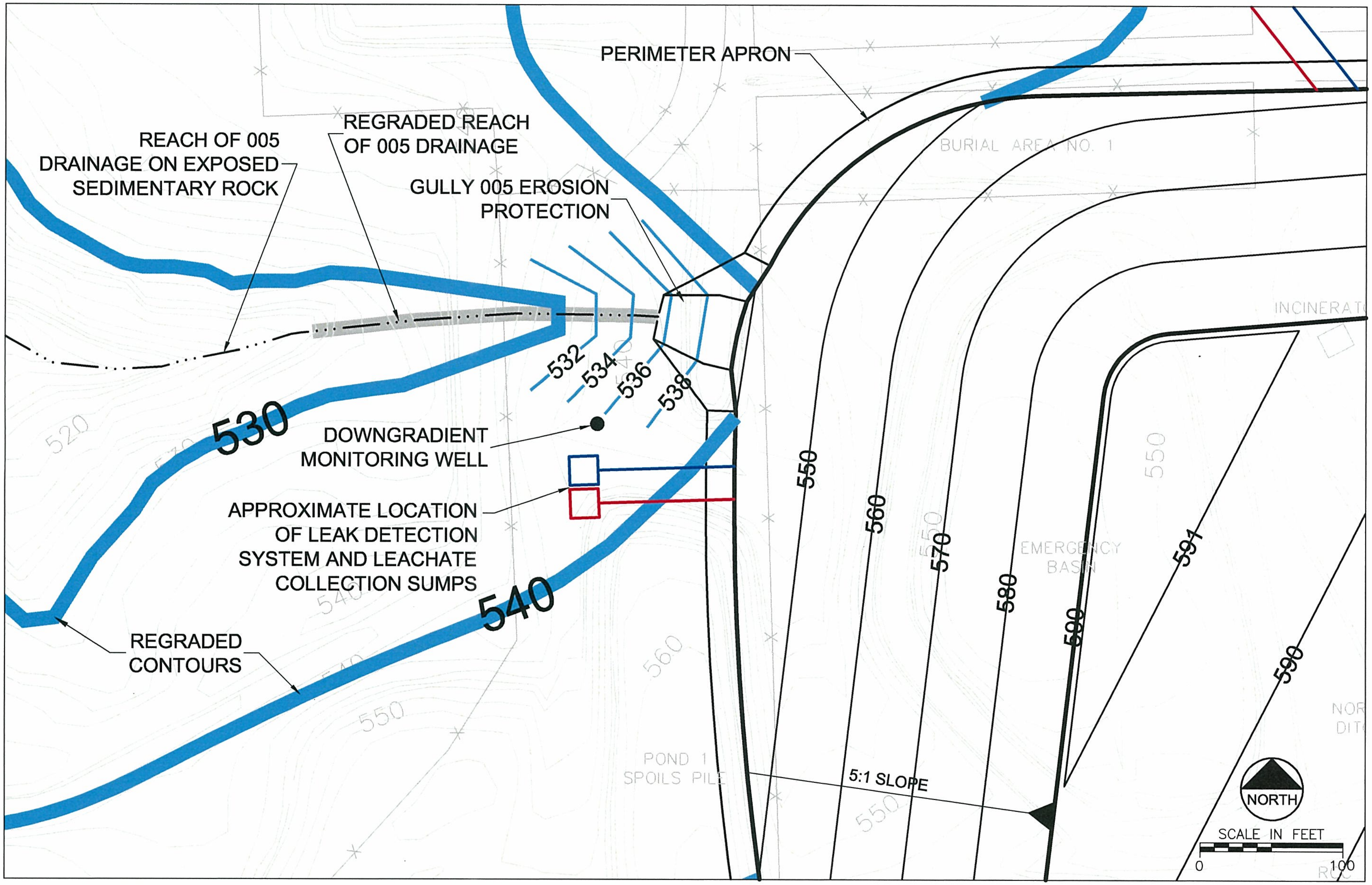
FIGURE D.1
DRAINAGE AREAS USED IN EROSIONAL STABILITY ANALYSES

Date:	OCTOBER 2007
Project:	100734
File:	SITE-12-REV-C.dwg



MFG, Inc. *consulting scientists and engineers*	FIGURE D.2 EROSION PROTECTION FACILITIES AT TOP OF STREAM 005 DRAINAGE

Date:	OCTOBER 2007
Project:	180735
File:	FIG-005-02.DWG

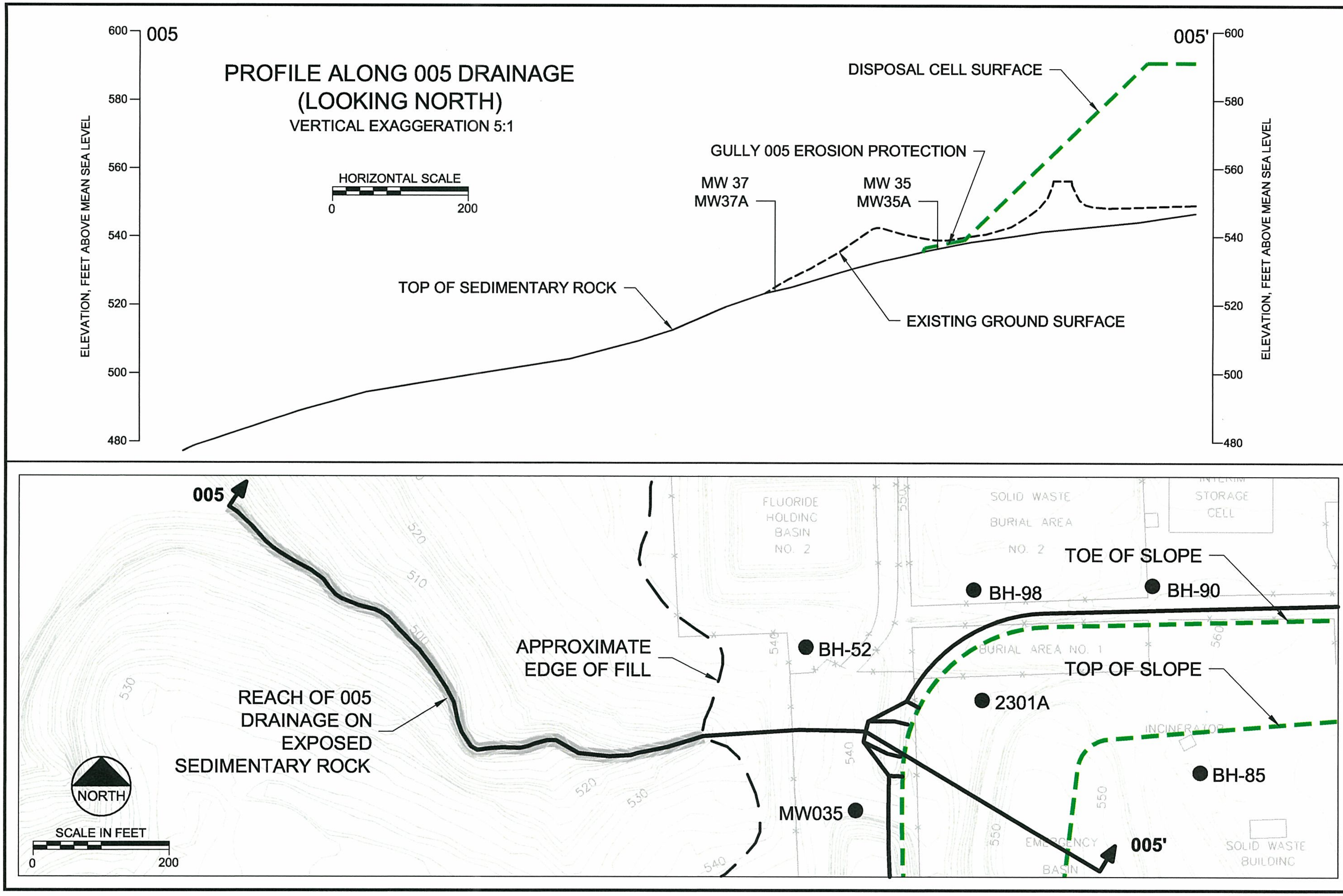


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FIGURE D.3
005 DRAINAGE PROFILE

Date:	OCTOBER 2007
Project:	180735
File:	PP-005.DWG

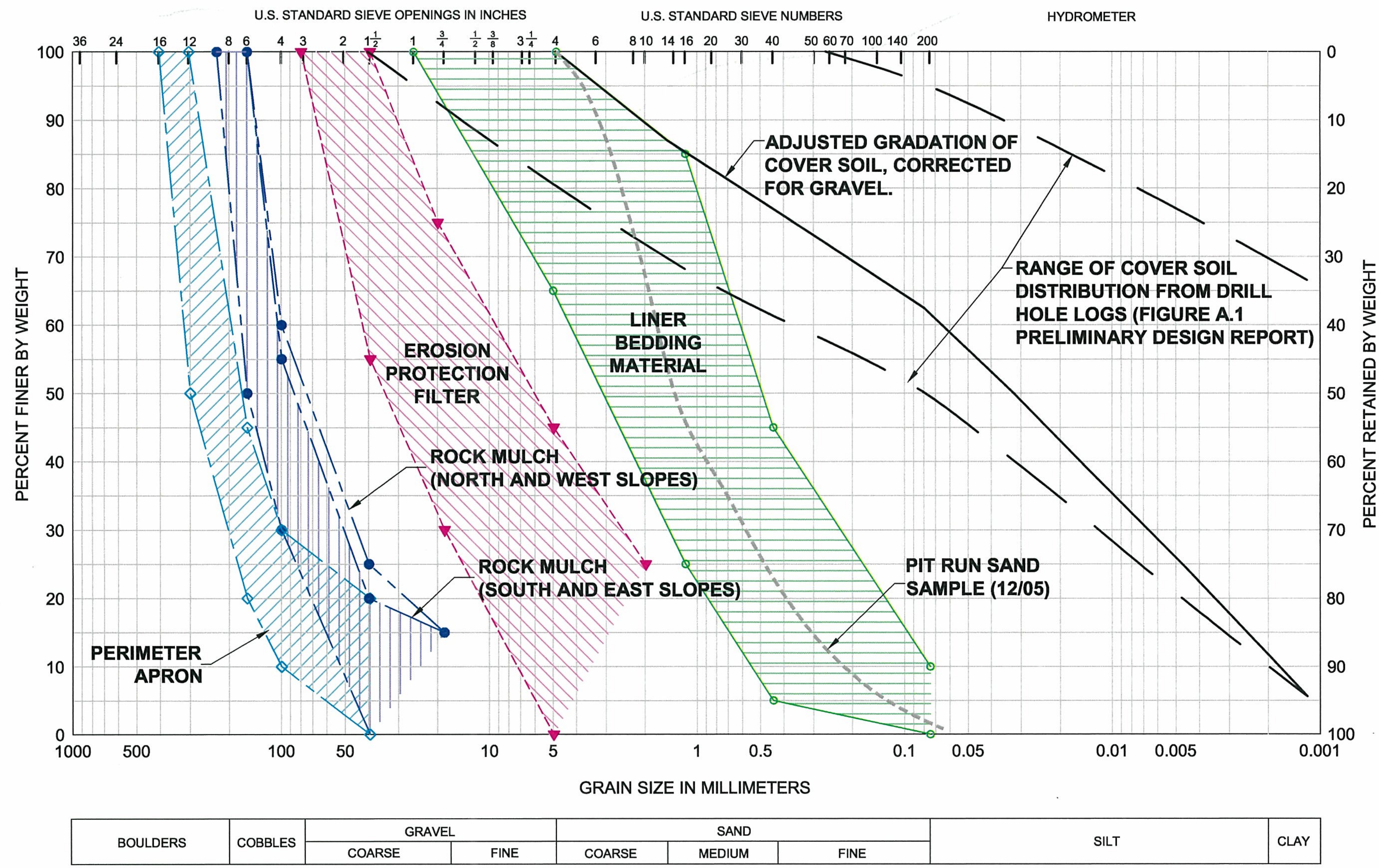

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FIGURE D.4
PARTICLE-SIZE DISTRIBUTIONS OF EROSION PROTECTION AND BEDDING MATERIALS

Date:	OCTOBER 2007
Project:	180735
File:	GSD-002.DWG