SKYLINE LANDFILL

ATTACHMENT C1

APPENDIX C1-E

FINAL COVER DRAINAGE STRUCTURE DESIGN

Includes pages C1-E-1 through C1-E-~~19~~20

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8/21/2012

NARRATIVE

30 TAC §§330.303 and 330.305

This appendix presents the supporting documentation for evaluation of the final cover erosion layer and drainage structures. Appendix C1-E addresses the requirements of 30 TAC §330.305(d) and (e) related to the final condition of final cover areas. The requirements of 30 TAC §330.305(d) and (e) related to intermediate phases are addressed in Appendix C1-G.

FINAL COVER PLAN

The final cover plans depict the final cover drainage system consisting of a series of swales and chutes. The drainage area for the largest area contributing to a side slope swale is shown on Drawing C1-E-1. Drainage areas for each downchute are shown on Drawing C1-E-2. Final cover details are included in Attachment C3.

EROSION LAYER EVALUATION

The erosion layer evaluation is based on the Universal Soil Loss Equation (USLE) following Soil Conservation Service (SCS) procedures. The evaluation is based on a 25-year event. The 36-inch-thick Subtitle D layer is sufficient. Calculations are included beginning on page C1-E-~~5~~6.

SHEET FLOW VELOCITY

The sheet flow velocity calculations are presented for the 6 percent top slope and the 25 percent side slope configurations. The procedures outlined in the TxDOT *Hydraulic Design Manual*, October 2011, were used to determine velocities. Maximum lengths of runoff for both final cover conditions were evaluated. Calculations are shown on page C1-E-~~13~~14.

DRAINAGE SWALE DESIGN

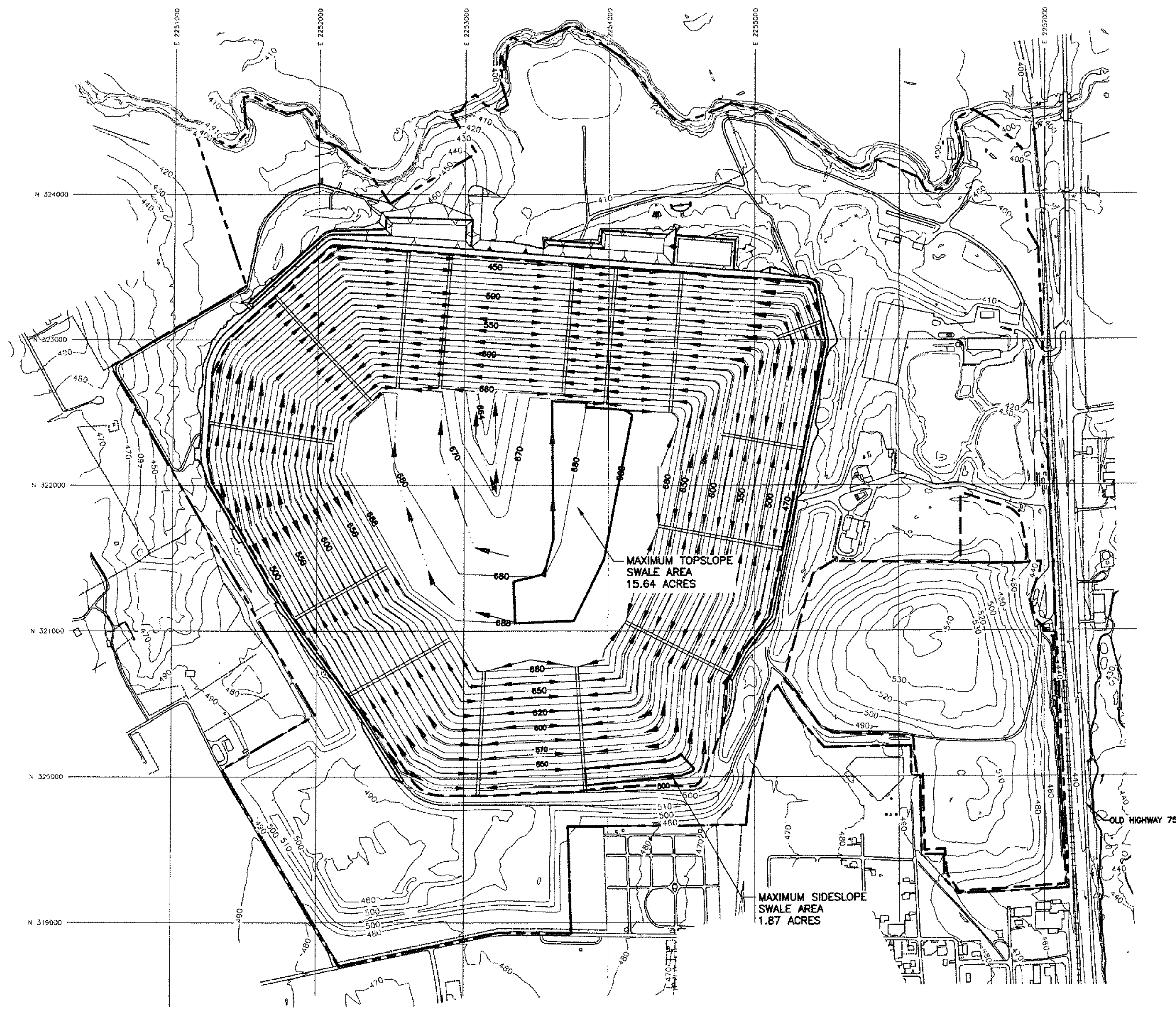
The drainage swale design calculations are presented for the typical swale flowline slope of 0.5 percent. The procedures in the TxDOT *Hydraulic Design Manual*, October 2011, were used to determine the flow depth, swale capacity, and contributing drainage area. Calculations are shown beginning on page C1-E-~~15~~16.

CHUTE DESIGN

The drainage letdown or chutes have been evaluated to determine critical velocities, flow depths in the chute, and receiving perimeter channel. Calculations are shown beginning on page C1-E-~~18~~19. Erosion protection within each chute is provided by 40-mil textured FML. Erosion protection at low-water crossings will be 12-inch-thick concrete. The erosion protection after the low-water crossings will be reno mattress (gabion) or articulating concrete blocks. Profiles of each drainage chute are included in Attachment C3.

Chutes and low-water crossings are designed to provide sufficient flow depth for the peak flow rate from the design storm. The design storm for chutes and low-water crossing is the 25-year, 24-hour rainfall event. Chutes are designed to provide 2 feet of flow depth. The maximum calculated flow depth for any chute is 0.25 feet; therefore, the chutes provide a minimum of 1.75 feet of freeboard. Low-water crossings are designed to provide 1 foot of flow depth. The maximum calculated flow depth for any low-water crossing is 0.62 feet; therefore, the low-water crossings provide a minimum of 0.38 feet of freeboard. After the low-water crossing, the flow width is initially 20-feet with 1 foot of flow depth provided and gradually transitions to a 44-foot flow width and ties into the channel sideslope. The maximum calculated flow depth after the low-water crossing is 0.32 feet which provides 0.68 feet of freeboard.

FINAL COVER PLANS



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SCALE IN FEET

LEGEND

- PERMIT BOUNDARY
- LANDFILL FOOTPRINT
- 460 — EXISTING 10' GROUND CONTOUR
- 500 — PROPOSED 10' FINAL COVER CONTOUR
- DRAINAGE AREA BOUNDARY
- DRAINAGE AREA REACH
- SWALE

NOTES:

1. EXISTING CONTOURS COMPILED BY AEROMETRIC FROM AERIAL PHOTOGRAPHY. FLOWN MARCH 6, 2011. COORDINATE SYSTEM IS BASED ON TEXAS STATE PLANE NAD 27, TEXAS NORTH CENTRAL ZONE, US FEET.
2. CONTOURS DEPICT TOP OF FINAL COVER ELEVATIONS.

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REV	DATE	DESCRIPTION	DWN BY	DES BY	CHK BY	APP BY
1	08/12	NOD NO. 1 RESPONSE	BBB	FAW	FAW	KJW

REVISIONS

MAXIMUM SWALE AREA

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
MAJOR PERMIT AMENDMENT

BIGGS & MATHEWS ENVIRONMENTAL
CONSULTING ENGINEERS
MANSFIELD
DALLAS • WICHITA FALLS
817-563-1144

TBPE FIRM NO. F-256	TBPG FIRM NO. 50222	
DSN. FAW	DATE : 04/12	DRAWING
DWN. BBB	SCALE : GRAPHIC	C1-E-1
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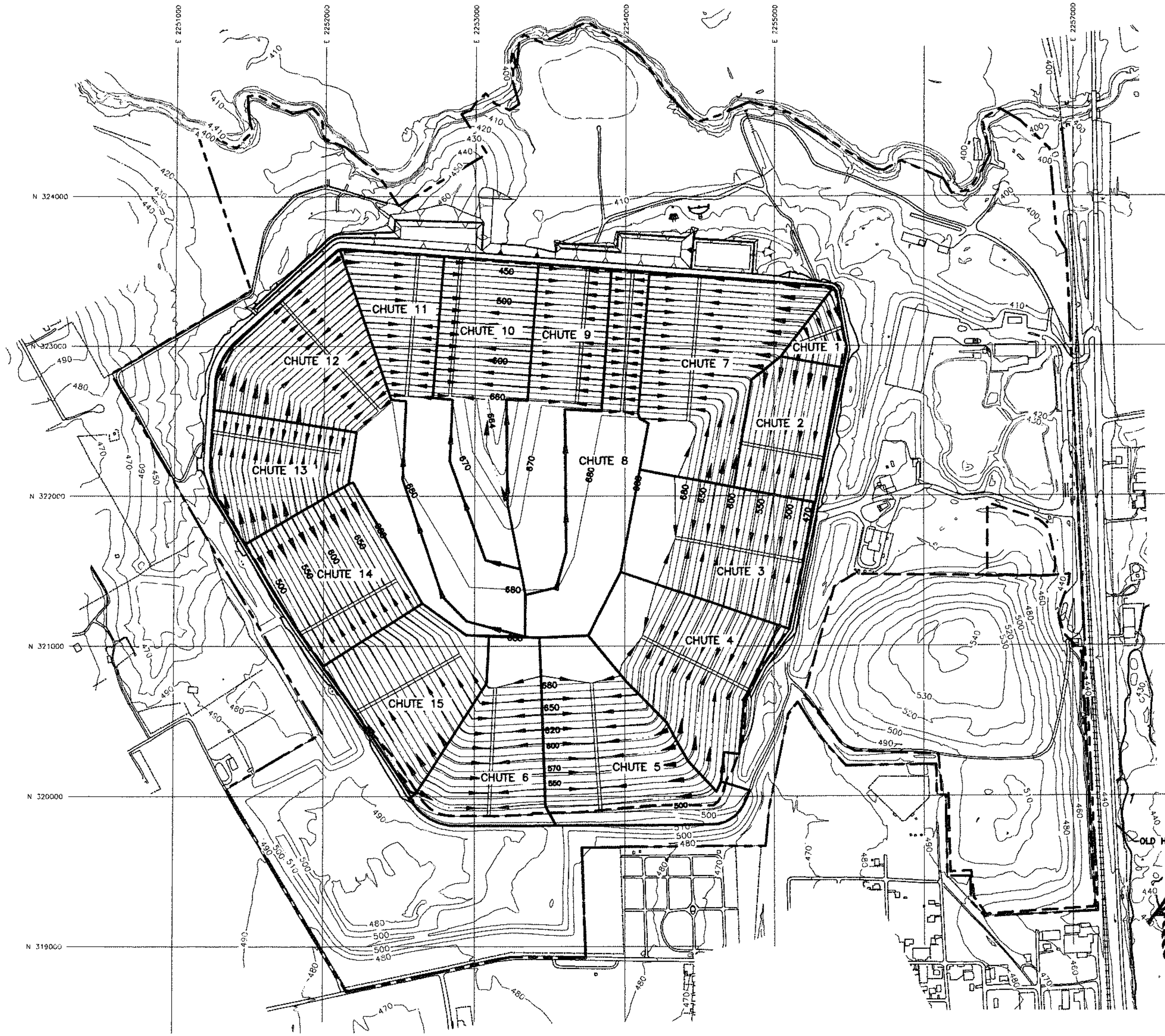

0 400 800
SCALE IN FEET

LEGEND

- PERMIT BOUNDARY
- LANDFILL FOOTPRINT
- 460 EXISTING 10' GROUND CONTOUR
- 500 PROPOSED 10' FINAL COVER CONTOUR
- DRAINAGE AREA BOUNDARY
- CHUTE DRAINAGE AREA

NOTES:

1. EXISTING CONTOURS COMPILED BY AEROMETRIC FROM AERIAL PHOTOGRAPHY. FLOWN MARCH 6, 2011. COORDINATE SYSTEM IS BASED ON TEXAS STATE PLANE NAD 27, TEXAS NORTH CENTRAL ZONE, US FEET.
2. CONTOURS DEPICT TOP OF FINAL COVER ELEVATIONS.

CHUTE DRAINAGE AREA

CHUTE DRAINAGE AREA	CHUTE AREA (AC)
CHUTE 1	2.8
CHUTE 2	11.6
CHUTE 3	21.3
CHUTE 4	21.4
CHUTE 5	24.1
CHUTE 6	17.1
CHUTE 7	26.3
CHUTE 8	21.1
CHUTE 9	20.9
CHUTE 10	21.8
CHUTE 11	24.6
CHUTE 12	28.5
CHUTE 13	13.4
CHUTE 14	17.5
CHUTE 15	17.4

STATE OF TEXAS
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REVISIONS							
REV	DATE	DESCRIPTION	DWN BY	DES BY	CHK BY	APP BY
1	08/12	NOD NO. 1 RESPONSE	BBB	FAW	FAW	KJW

CHUTE AREA

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
MAJOR PERMIT AMENDMENT

BIGGS & MATHEWS ENVIRONMENTAL
CONSULTING ENGINEERS
MANSFIELD
DALLAS • WICHITA FALLS
817-563-1144

TBPE FIRM NO. F-256 | TBPG FIRM NO. 50222

DSN. FAW	DATE : 04/12	DRAWING
DWN. BBB	SCALE : GRAPHIC	C1-E-2
CHK. KJW	DWG : C1_E_2.dwg	

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EROSION LAYER EVALUATION

EROSION LAYER EVALUATION

This appendix presents the supporting documentation for evaluation of the thickness of the erosion layer for the final cover system at the Skyline Landfill. The evaluation is based on the premise of adding excess soil to increase the time required before maintenance is needed as recommended in the EPA Solid Waste Disposal Facility Criteria Technical Manual (EPA 530-R-93-017, November 1993).

The design procedure is as follows:

1. The minimum thickness of the erosion layer is based on the depth of frost penetration, or 6 inches, whichever is greater. For Dallas and Ellis Counties, the approximate depth of frost penetration is less than 1 inch.

2. Soil loss is calculated using the Universal Soil Loss Equation (USLE) by following SCS procedures. In accordance with regulatory guidance, the calculated soil loss from final cover will not exceed 3 tons per acre per year. ~~The s~~Soil loss thickness is calculated by multiplying the soil loss by the postclosure year period (30 years), multiplying by a safety factor of 2, and then converting the soil loss to a thickness. The USLE, with a safety factor of 2, calculates the soil loss of the ~~6~~ 2.5 percent top slopes to be 0.10 inches and the side slopes to be 0.65 inches. These thicknesses are then compared to the actual soil thickness of the erosion layer, which is 36 inches. These calculations begin on page C1-E-~~7~~8.

3. Sheet flow velocities for a 25-year storm event are calculated to be less than permissible nonerodible velocities. The supporting calculations are presented on page C1-E-~~13~~15.

4. Vegetation for the site will be native and introduced grasses with root depths of 6 inches to 8 inches.

5. Native and introduced grasses will be hydroseeded with fertilizer on the disked (parallel to contours) erosion layer upon final grading. Temporary cold weather vegetation will be established if needed. Irrigation may be employed for 6 to 8 weeks or until vegetation is well established. Erosion control measures, such as silt fences and straw bales, will be used to minimize erosion until the vegetation is established. Areas that experience erosion or do not readily vegetate after hydroseeding will be reseeded until vegetation is established.

6. Slope stability information is included in Attachment D5 – Geotechnical Design.

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
Erosion Loss Evaluation

Required: Determine the sheet flow velocity for the final cover system design and compare to the permissable non-erodible flow velocity.

Method: Expected soil loss is calculated using the Universal Soil Loss Equation. Minimum erosion layer thickness is determined by adding the minimum thickness allowed by TCEQ to the expected thickness of soil loss.

References: 1. TNRCC, *Use of the Universal Soil Loss Equation in Final Cover/Configuration*

Solution: Annual Soil Loss in tons/acre/year (A) = RKLSCP

Design Parameters	Top Slope (2.5%)	Perimeter Slope (25%)	
Rainfall Factor (R) =	310	310	Ellis County
Soil Erodibility Factor (K) =	0.25	0.25	(clay)
Longest Run =	1000	80	ft
Slope =	2.5	25	%
Topographic Factor (LS) =	0.48	5.27	
Crop Management Factor (C) =	0.006	0.006	(tall grass with 85% cover)
Erosion Control Practice Factor (P) =	0.50	1.00	(Contouring)
Soil Loss (A) =	0.11	2.45	tons/acre/yr

Erosion Layer Thickness Evaluation:

Required Thickness (T) = 6 inches* + AYF/w
* - Includes required 6 inch minimum

	Top Slope (2.5%)	Perimeter Slope (25%)	
Soil Loss (A) =	0.11	2.45	tons/acre/yr
Postclosure Period =	30	30	years
Factor of Safety (F) =	2	2	
Specific Weight of Soil (w) =	125	125	pcf
Required Soil Thickness (T)	**6.03**	**6.65**	**inches**
Actual Soil Thickness	36.00	36.00	inches

Summary: As noted in the permit drawings, the erosion layer will be a minimum of 36 inches thick. As shown above, this is a conservative design considering the maximum expected soil loss for a 30 year period is 6.65 inches.

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
LS Factor Calculations

Required: Determine the length slope factor based on slope length and slope gradient.

References: 1. TNRCC, *Use of the Universal Soil Loss Equation in Final Cover/Configuration Design Procedural Handbook,* October 1993.

Solution: Length/Slope Factor (LS) = $((L/72.6)^{m})*((65.41*\sin^{2}(S))+(4.56*\sin(S))+0.065)$

LS = Length Slope Factor
L = Slope Length (ft)
S = Slope (%)
m = Exponent dependent on the slope gradient

m =	0.2	for S <= 1.0%
	0.3	for 1.0% < S <= 3.5%
	0.4	for 3.5% < S < 5.0%
	0.5	for S => 5.0%

L (ft)	S (%)	S (ft/ft)	S (radians)	S (degrees)	m	LS
1000	2.5	40.00	0.025	1.432	0.3	0.483
80	25	4	0.245	14.036	0.5	5.268

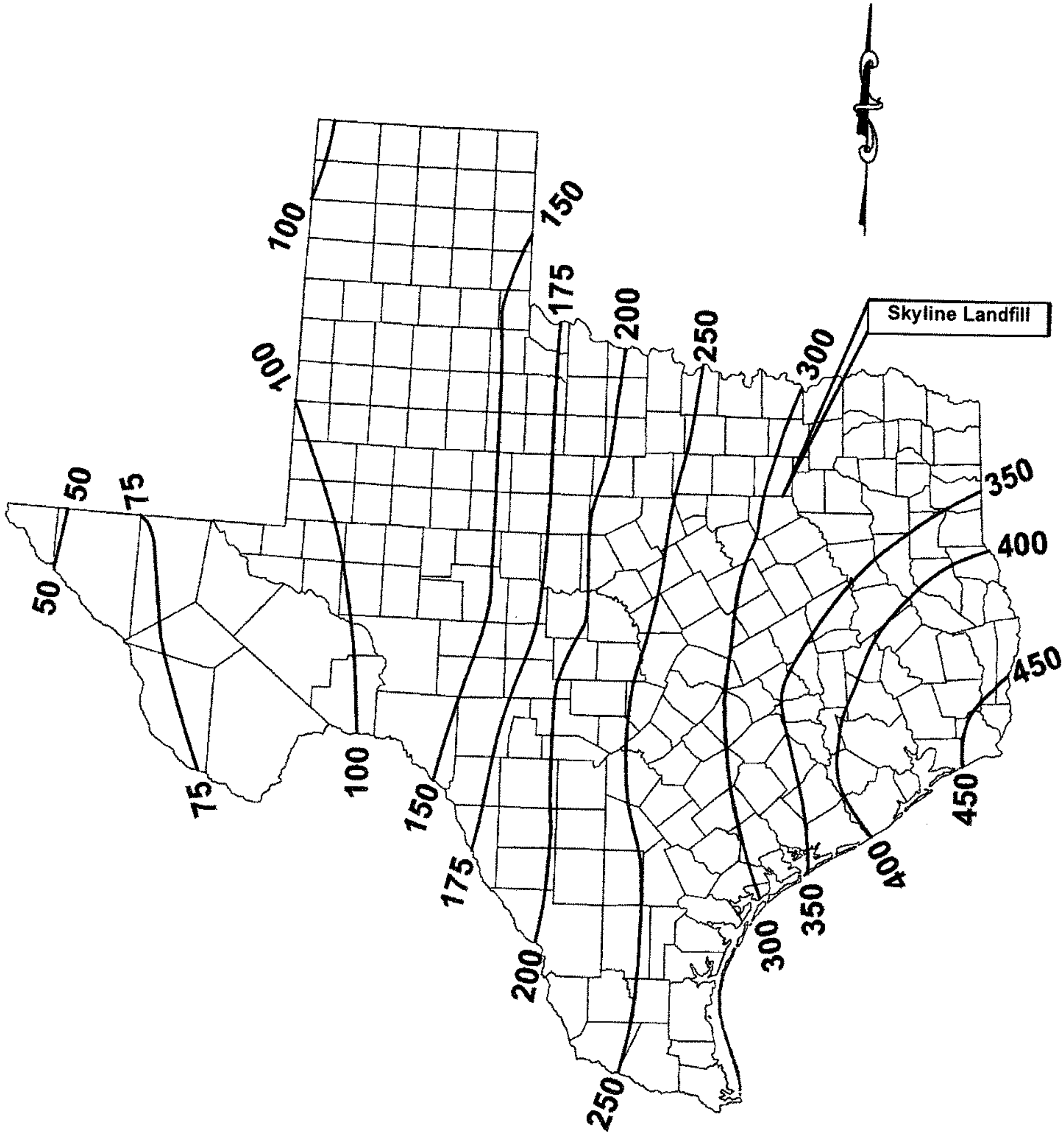


FIGURE 1 - AVERAGE ANNUAL VALUES OF THE RAINFALL EROSION INDEX

Table 1: Approximate Values of Factor K for USDA Textural Classes

Reproduced from: Texas Natural Resource Conservation Commission, Municipal Solid Waste Division, Use of the Universal Soil Loss Equation in Final Cover/Configuration Design: Procedural Handbook, 1993.

Texture Class	Organic Matter Content		
	<0.5%	2%	4%
	K	K	K
Sand	0.05	0.03	0.02
Fine Sand	0.16	0.14	0.10
Very Fine Sand	0.42	0.36	0.28
Loamy Sand	0.12	0.10	0.08
Loamy Fine Sand	0.24	0.20	0.16
Loamy Very Fine Sand	0.44	0.38	0.30
Sandy Loam	0.27	0.24	0.19
Fine Sandy Loam	0.35	0.30	0.24
Very Fine Sandy Loam	0.47	0.41	0.33
Loam	0.38	0.32	0.29
Silt Loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy Clay Loam	0.27	0.25	0.21
Clay Loam	0.28	0.25	0.21
Silty Clay Loam	0.37	0.32	0.26
Sandy Clay	0.14	0.13	0.12
Silty Clay	0.25	0.23	0.19
Clay	0.13 - 0.29		

The values shown are estimated averages of broad ranges of specific soil values. When a texture is near the borderline of two texture classes, use the average of the two K values.

Table 2: Factor C for Permanent Pasture, Range, and Idle Land[1]

Reproduced from: Texas Natural Resource Conservation Commission, Municipal Solid Waste Division, Use of the Universal Soil Loss Equation in Final Cover/Configuration Design: Procedural Handbook, 1993.

Vegetative Canopy		Cover that Contacts the Soil Surface					
Type and Height[2]	Percent Cover[3]	Percent Ground Cover					
		0	20	40	60	80	95+
No Appreciable Canopy		0.45	0.20	0.10	0.042	0.013	0.003
Tall weeds or short brush with average drop fall height of 20 in.	25	0.36	0.17	0.09	0.038	0.013	0.011
	50	0.26	0.13	0.07	0.035	0.012	0.003
	75	0.17	0.10	0.06	0.032	0.011	0.003

Extracted from: United States Department of Agriculture, AGRICULTURE HANDBOOK NUMBER 537

[1] The listed C values assume that the vegetation and mulch are randomly distributed over the entire area.
[2] Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 feet.
[3] Portions of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's eye view).

Table 3: P Factors for Contouring, Contour Stripcropping and Terracing

Reproduced from: Texas Natural Resource Conservation Commission, Municipal Solid Waste Division, Use of the Universal Soil Loss Equation in Final Cover/Configuration Design: Procedural Handbook, 1993.

Land Slope	P Values		
%	Contouring†	Contour Stripcropping	Terracing†
2.0 to 7	0.50	0.25	0.50
8.0 to 12	0.60	0.30	0.60
13.0 to 18	0.80	0.40	0.80
19.0 to 24	0.90	0.45	0.90

(This table appeared in SCS (5), p.9)

† Contouring and terracing columns are suitable for MSWLF cover. Contour stripcropping is not suitable for the type of vegetative cover normally practiced at municpal landfills.

Table 4: Guide for Assigning Soil Loss Tolerance Values (T) to Solid Having Different Rooting Depths

Rooting Depth	Soil Loss Tolerance Values Annual Soil Loss (Tons/Acre)	
Inches	Renewable Soil a/	Renewable Soil b/
0 - 10	1	1
10 - 20	2	1
20 - 40	3	2
40 - 60	4	3
60	5	4

(This table appeared in SCS (6), p.4)

a/ Soil with favorable substrata that can be renewed by tillage, fertilizer, organic matter, and other management practices. This column does not represent MSWLF final covers under normal conditions.

b/ Soil with unfavorable substrata such as rock or soft rock that cannot be renewed by economical means. Most of the MSWLF covers with constructed clay cap and/or flexible membrane should use this performance criteria.

SHEET FLOW

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
Sheet Flow Velocity

Required: Determine the sheet flow velocity for the final cover system design and compare to the permissiblenon-erodible flow velocity.

Method:
1. Determine the 25-year peak flow rate using the Rational Method.
2. Calculate flow depth using Manning's Equation.
3. Calculate sheet flow velocity and compare to permissible non-erodible velocity.

References:
1. Texas Department of Transportation, *Hydraulic Design Manual,* Revised October 2011.
2. United States Geologic Survey, *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas*, 2004.

Solution:
1. Determine the 25-year peak flow rate (Q) using the Rational Method.

25-Year Rainfall Depth (Pd) =	1.42	in	(ref 2, extrapolated for 10 minutes)
Time of Concentration (tc) =	10	min	(conservative minimum value)
Rainfall Intensity (I) =	8.5	in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70		(typical value for final cover systems)
25-Year Peak Flow Rate (Q) =	CIA	cfs	

	Top Slope (2.5%)	Perimeter Slope (25%)		
Longest Run =	1000	80	ft	(longest sheet flow distance to swale)
Width =	1	1	ft	(unit width of flow)
Area =	0.0230	0.0018	acre	
Q	0.137	0.011	cfs	

2. Calculate the flow depth using Manning's Equation.
   - Rearrange Manning's Equation for wide and shallow flow to calculate flow depth:

$$y = (Qn/1.49S^{0.5})^{0.6}$$

Manning's Roughness (n) =		0.03		(typical value for final cover systems)
Slope =	0.025	0.25	ft/ft	(final cover design slopes)
Depth (y) =	0.0881	0.0097	ft	

3. Calculate sheet flow velocity and compare to permissible non-erodible velocity.
   - A permissible non-erodible velocity of 5 ft/sec is typical for vegetated final covers.
   - Refer to page C1-E-7 for soil loss calculations.

$$V = Q / (y * width)$$

Sheet flow velocity	**1.55**	**1.13**	**ft/sec**

Summary: Permissible non-erodible velocity is 5.0 ft/sec with vegetated final cover. Therefore, the expected sheet flow velocity is acceptable on the final cover system top and side slopes with vegetation provided.

DRAINAGE SWALE DESIGN

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
Drainage Swale Analysis - Topslopes

Required: Determine the topslope drainage swale capacity.

Method:

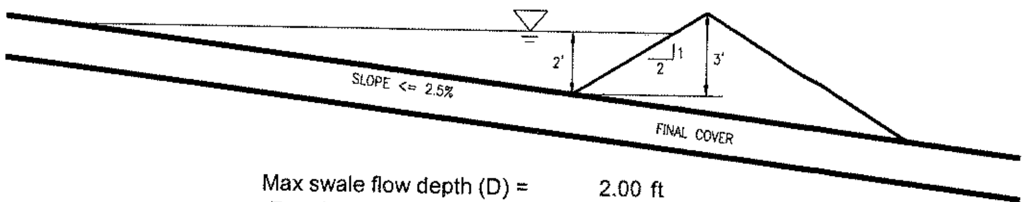
1. Calculate the topslope swale's flow capacity using Manning's Equation.
2. Determine the maximum allowable topslope drainage area using the Rational Method.
3. Provide the maximum proposed topslope drainage area for comparison.

References:

1. Texas Department of Transporation, *Hydraulic Design Manual*, Revised October 2011.
2. United States Geologic Survey, *Atlas of Depth-Duration Frequency of Precipitation Maxima for Texas*, 2004.

Solution:

1. Calculate flow capacity using Manning's Equation.
 - Swale Characteristics:



Max swale flow depth (D) = 2.00 ft
Running swale slope (S) = 0.5 %
Manning's Roughness (n) = 0.03
Left slope (LS) = 40.00 :1
Right slope (RS) = 2 :1
Flow Area (A) = ((LS+RS)*D^2)/2
Wetted Perimeter (WP) = ((LS*D)^2+D^2)^(0.5) + ((RS*D)^2+D^2)^(0.5)
Hydraulic Radius (R) = A/WP

Flow Area (A) = 84.000
Wetted Perimeter (WP) = 84.497
Hydraulic Radius (R) = 0.994

- Use Manning's Equation to determine the flow velocity in the swale.
Velocity (V) = 1.49*R^(2/3)*S^(1/2)/n
Velocity (V) = 3.498 ft/sec

- Calculate the swale's flow capacity.
Swale capacity (Q) = V * A
Q = 293.8 cfs

2. Determine the maximum allowable drainage area using the Rational Method.

25-Year Rainfall Depth (Pd) =	1.42 in	(ref 2, extrapolated for 10 minutes)
Time of Concentration (tc) =	10 min	(conservative minimum value)
Rainfall Intensity (I) =	8.5 in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70	(typical value for final cover systems)
25-Year Peak Flow Rate (Q) =	CIA cfs	

- Rearrange the Rational Formula to calculate allowable drainage area:
Drainage Area = Q / (CI)

Maximum Allowable Swale Drainage Area = 49.27 acres

3. Provide the maximum proposed topslope drainage area for comparison.

Maximum Proposed Swale Drainage Area = 15.64 acres

Summary: The maximum proposed topslope swale drainage area is 15.64 acres. This is less than the maximum allowable drainage area of 49.27 acres for the proposed swale configuration.

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
Drainage Swale Analysis - Sideslopes

Required: Determine the sideslope drainage swale capacity.

Method:

1. Calculate sideslope swale's flow capacity using Manning's Equation.
2. Determine the maximum allowable topslope drainage area using the Rational Method.
3. Provide the maximum proposed sideslope drainage area for comparison.

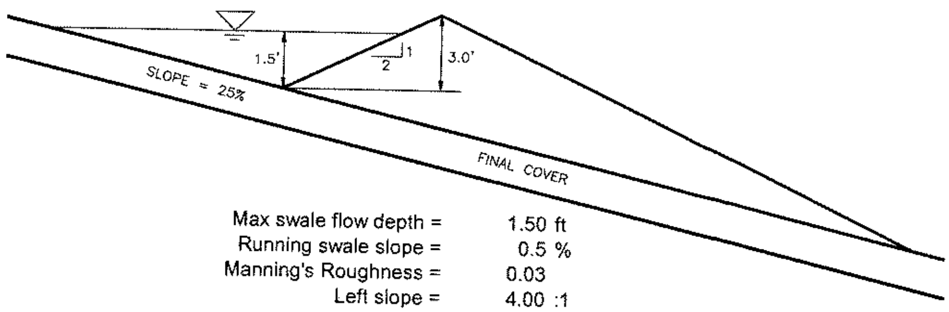
References:

1. Texas Department of Transporation, *Hydraulic Design Manual*, Revised October 2011.
2. United States Geologic Survey, *Atlas of Depth-Duration Frequency of Precipitation Maxima for Texas*, 2004.

Solution:

1. Calculate flow capacity using Manning's Equation.

- Swale Characteristics:



Max swale flow depth = 1.50 ft
Running swale slope = 0.5 %
Manning's Roughness = 0.03
Left slope = 4.00 :1
Right slope = 2 :1
Flow Area (A) = ((LS+RS)*D^2)/2
Wetted Perimeter (WP) = ((LS*D)^2+D^2)^(0.5) + ((RS*D)^2+D^2)^(0.5)
Hydraulic Radius (R) = A/WP

Flow Area (A) = 6.750
Wetted Perimeter (WP) = 9.539
Hydraulic Radius (R) = 0.708

- Use Manning's Equation to determine the flow velocity in the swale.

Velocity (V) = 1.49*R^(2/3)*S^(1/2)/n
Velocity (V) = 2.789 ft/sec

- Calculate the swale's flow capacity.

Swale capacity (Q) = V * A
Q = 18.8 cfs

2. Determine the maximum allowable drainage area using the Rational Method.

- Rainfall Intensity (I) is calculated as described in the *Hydraulic Design Manual,* I = Pd / tc.
- A minimum time of concentration (tc) of 10 minutes was used for conservatism.
- Rainfall Depth (Pd) was extrapolated for 10 minutes from the *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas.*
- A runoff coefficient (C) of 0.70 is typical for landfill final cover design.

25-Year Rainfall Depth (Pd) =	1.42 in	(ref 2, extrapolated for 10 minutes)
Time of Concentration (tc) =	10 min	(conservative minimum value)
Rainfall Intensity (I) =	8.5 in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70	(typical value for final cover systems)
25-Year Peak Flow Rate (Q) =	CIA cfs	

- Rearrange the Rational Formula to calculate allowable drainage area:

Drainage Area = Q / (CI)

Maximum Allowable Swale Drainage Area = 3.16 acres

3. Provide the maximum proposed sideslope drainage area for comparison.

Maximum Proposed Swale Drainage Area = 1.87 acres

Summary: The maximum proposed sideslope swale drainage area is 1.87 acres. This is less than the maximum allowable drainage area of 3.16 acres for the proposed swale configuration.

DRAINAGE LETDOWN (OR CHUTE) DESIGN

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
Downchute Calculations

Required: Determine the flow depth and velocity in the downchutes and low-water crossings.

Method: Calculate the flow depth and velocity using Manning's Equation.

Solution:

		Chute						Low-Water Crossing						Erosion Protection after Low-Water Crossing					
Chute	Q (cfs)	Width (ft)	Slope (%)	Side Slopes (h:v)	Manning's n	Depth (ft)	Velocity (fps)	Width (ft)	Slope (%)	Side Slopes (h:v)	Manning's n	Depth (ft)	Velocity (fps)	Width (ft)	Slope (%)	Side Slopes (h:v)	Manning's n	Depth (ft)	Velocity (fps)
1	14	20	25	4	0.013	**0.07**	**9.63**	20	2	12	0.020	**0.19**	**3.25**	20	33	12	0.025	**0.09**	**6.85**
2	55	20	25	4	0.013	**0.16**	**16.50**	20	2	12	0.020	**0.42**	**5.20**	20	33	12	0.025	**0.21**	**11.34**
3	89	20	25	4	0.013	**0.21**	**19.93**	20	2	12	0.020	**0.55**	**6.09**	20	2	12	0.025	**0.62**	**5.22**
4	91	20	25	4	0.013	**0.22**	**20.03**	20	2	12	0.020	**0.56**	**6.11**	20	10	12	0.025	**0.40**	**9.08**
5	102	20	25	4	0.013	**0.23**	**20.98**	20	2	12	0.020	**0.59**	**6.35**	20	5	12	0.025	**0.52**	**7.46**
6	73	20	25	4	0.013	**0.19**	**18.40**	20	2	12	0.020	**0.49**	**5.70**	20	2	12	0.025	**0.56**	**4.89**
7	110	20	25	4	0.013	**0.24**	**21.54**	20	2	12	0.020	**0.62**	**6.49**	20	25	12	0.025	**0.35**	**13.15**
8	68	20	25	4	0.013	**0.18**	**17.93**	20	2	12	0.020	**0.47**	**5.58**	20	25	12	0.025	**0.26**	**11.17**
9	77	20	25	4	0.013	**0.20**	**18.83**	20	2	12	0.020	**0.51**	**5.81**	20	25	12	0.025	**0.28**	**11.67**
10	86	20	25	4	0.013	**0.21**	**19.67**	20	2	12	0.020	**0.54**	**6.02**	20	25	12	0.025	**0.30**	**12.14**
11	83	20	25	4	0.013	**0.21**	**19.40**	20	2	12	0.020	**0.53**	**5.96**	20	25	12	0.025	**0.30**	**11.99**
12	112	20	25	4	0.013	**0.25**	**21.68**	20	2	12	0.020	**0.62**	**6.52**	20	33	12	0.025	**0.32**	**14.51**
13	61	20	25	4	0.013	**0.17**	**17.17**	20	2	12	0.020	**0.44**	**5.38**	20	33	12	0.025	**0.23**	**11.76**
14	74	20	25	4	0.013	**0.19**	**18.54**	20	2	12	0.020	**0.50**	**5.74**	20	33	12	0.025	**0.25**	**12.61**
15	78	20	25	4	0.013	**0.20**	**18.91**	20	2	12	0.020	**0.51**	**5.83**	20	25	12	0.025	**0.28**	**11.72**

Notes:

1. Flow rates are from HEC-HMS 25-year, 24-hour rainfall event.
2. The energy dissipation at the chute and low-water crossing confluence is accomplished via a hydraulic jump and was designed in accordance with *Hydraulic Design of Stilling Basins and Energy Dissipators*, A. J. Peterka, United States Department of the Interior, Bureau of Reclamation, 1978.
3. Erosion protection on downchute will be 40-mil textured flexible membrane liner (FML).
   Erosion protection at low-water crossing will be 12-inch-thick concrete.
4. Erosion protection after low-water crossing will be reno mattress (gabions) or articulating concrete blocks. See table below for thickness and rock fill gradation.

Erosion Protection at Perimeter Channel Entrance		
Permissible Velocity (fps)	Thickness (in)	Rock Fill Gradation (in)
6	6	3 - 6
12	6 - 10	3 - 6
15	10 - 12	3 - 6
18	12 - 18	4 - 6
22	> 18	5 - 9

SKYLINE LANDFILL

ATTACHMENT C1

APPENDIX C1-F

INTERMEDIATE COVER
EROSION AND SEDIMENTATION CONTROL PLAN

STATE OF TEXAS
KENNETH J. WELCH
60773
REGISTERED
PROFESSIONAL ENGINEER
8/21/2012

Includes pages C1-F-1 through C1-F-10

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Soil Stabilization and Vegetation Schedule C1-F-4
Stormwater System Maintenance Plan C1-F-5
Intermediate Cover Erosion Control Features C1-F-7
Temporary Erosion Control Structures C1-F-8
Temporary Erosion Control Structures C1-F-9
Temporary Erosion Control Structures C1-F-10

STATE OF TEXAS
KENNETH J. WELCH
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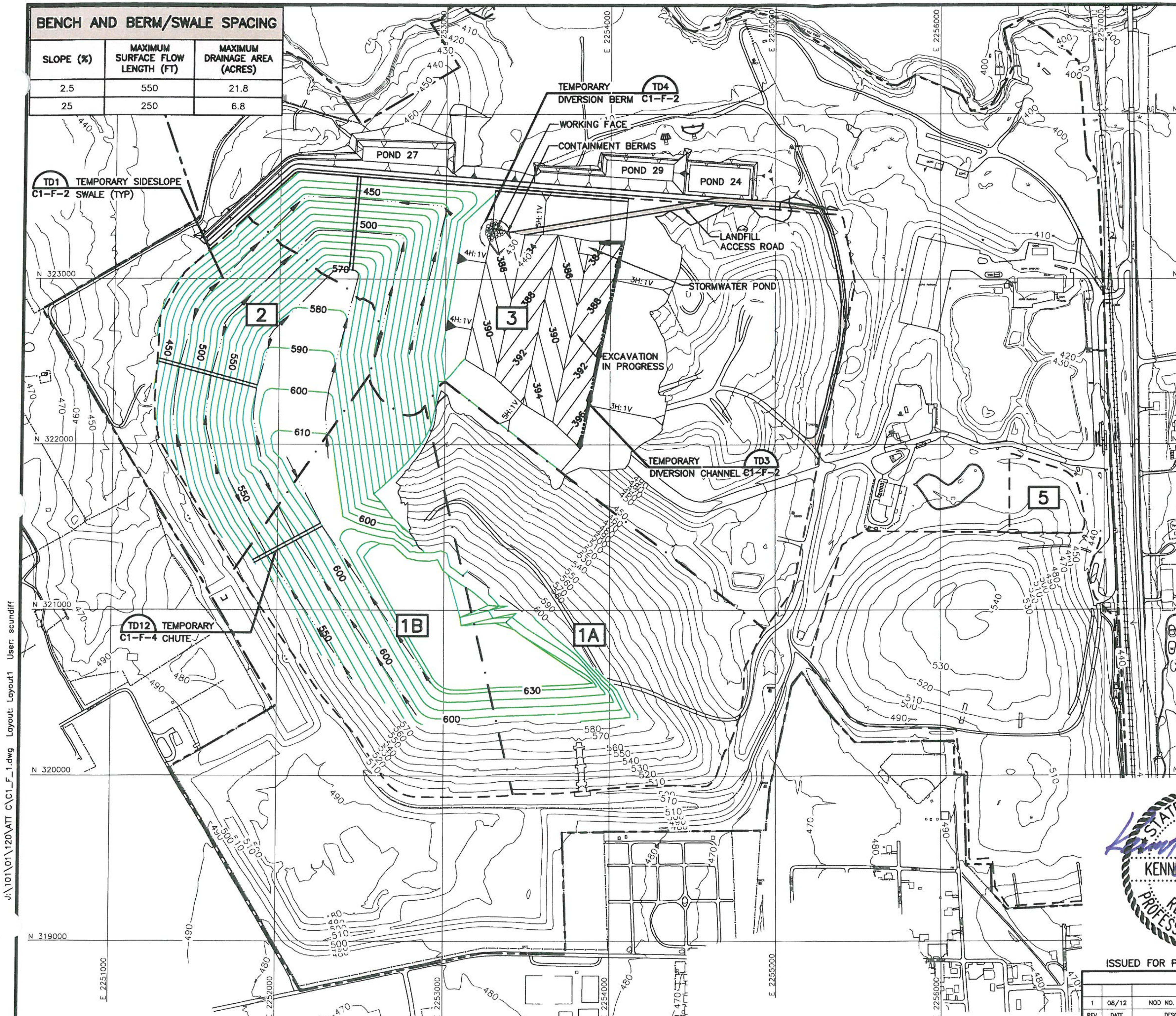
REGISTERED PROFESSIONAL ENGINEER
8/21/2012

BENCH AND BERM/SWALE SPACING

SLOPE (%)	MAXIMUM SURFACE FLOW LENGTH (FT)	MAXIMUM DRAINAGE AREA (ACRES)
2.5	550	21.8
25	250	6.8



0 300 600
SCALE IN FEET

LEGEND

— — —	PERMIT BOUNDARY
- - - -	LANDFILL FOOTPRINT
550	EXISTING 10' GROUND CONTOUR
N 323000	STATE PLANE GRID (NAD 27)
600	PROPOSED 10' CONTOUR
— · —	PHASE BOUNDARY

NOTE:

1. EXISTING CONTOURS COMPILED BY AEROMETRIC FROM AERIAL PHOTOGRAPHY. FLOWN MARCH 6, 2011. COORDINATE SYSTEM IS BASED ON TEXAS STATE PLANE NAD 27, TEXAS NORTH CENTRAL ZONE, US FEET.
2. THIS PLAN IS FOR GENERAL CONDITIONS AND MAY NOT REFLECT THE EXACT CONFIGURATION OF THE LANDFILL. THE ACTUAL SIZE OF THE INCREMENTS FOR EXCAVATION, LINING, OR FINAL COVER MAY VARY WITH SITE OPERATIONS.
3. THE LANDFILL ACCESS AND HAUL ROADS WILL BE SURFACED TO PROVIDE ALL WEATHER ACCESS. ROAD LOCATIONS TO BE DETERMINED DURING SITE OPERATIONS AND LOCATIONS WILL VARY.
4. THE STORMWATER RUN-OFF CONTROL SYSTEM WILL CONSIST OF THE PERIMETER DRAINAGE CHANNEL, AND STORMWATER DETENTION PONDS.
5. REFER TO PART III, ATTACHMENT C-DRAINAGE DESIGN REPORT FOR STORMWATER SYSTEMS AND EROSION AND SEDIMENT CONTROL PLAN. REFER TO PART III, ATTACHMENT D6-LEACHATE AND CONTAMINATED WATER MANAGEMENT PLAN FOR CONTAINMENT AND DIVERSION BERM CALCULATIONS.
6. UNCONTAMINATED STORMWATER COLLECTED IN SUMPS WILL BE PERIODICALLY REMOVED FROM EXCAVATED AREAS BY PUMPING TO PERIMETER DRAINAGE CHANNELS OR USED IN SITE OPERATIONS (DUST CONTROL, IRRIGATIONS, ROAD AND LINER CONSTRUCTION).
7. PHASE 1 AND 2 DEVELOPMENT DEPICTS ONGOING WASTE DISPOSAL OPERATIONS IN PHASES 1 THROUGH 3 TO MAXIMUM WASTE FILL ELEVATION EQUAL TO TOP OF PERIMETER BERMS. EXCAVATION AND LINER CONSTRUCTION ONGOING IN PHASE 3.
8. WASTE FILL GENERALLY NORTH TO SOUTH IN DIRECTION.

STATE OF TEXAS
KENNETH J. WELCH
60773
REGISTERED PROFESSIONAL ENGINEER
8/21/2012

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INTERMEDIATE COVER EROSION FEATURES

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
MAJOR PERMIT AMENDMENT

BIGGS & MATHEWS ENVIRONMENTAL
CONSULTING ENGINEERS
MANSFIELD • WICHITA FALLS
817-563-1144

TBPE FIRM NO. F-256 | TBPG FIRM NO. 50222

REVISIONS

REV	DATE	DESCRIPTION	DWN BY	DES BY	CHK BY	APP BY
1	08/12	NOD NO. 1 RESPONSE	BBB	FAW	FAW	KJW

DSN. SAB	DATE : 04/12	DRAWING
DWN. SRC	SCALE : GRAPHIC	C1-F-1
CHK. KJW	DWG : C1_F_1.dwg	

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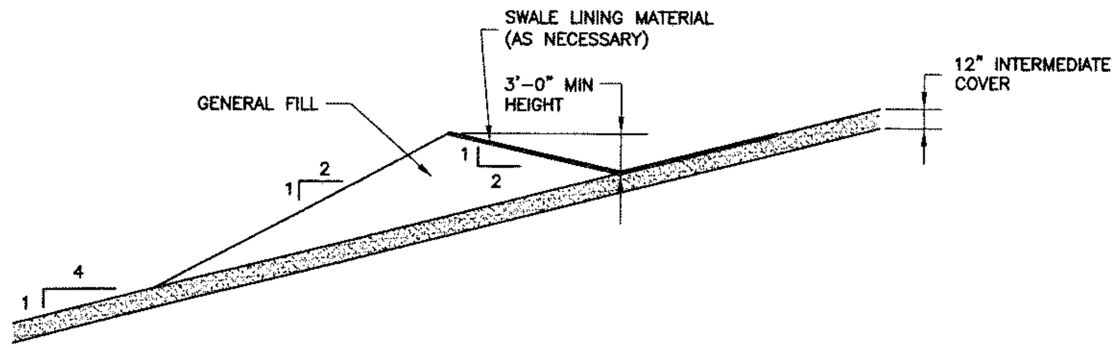
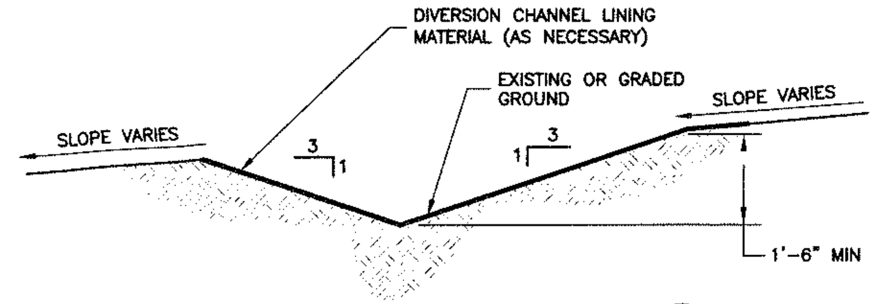


TEMPORARY SIDESLOPE SWALE (TD1 / C1-F-2)
NTS



TEMPORARY DIVERSION CHANNEL (TD3 / C1-F-2)
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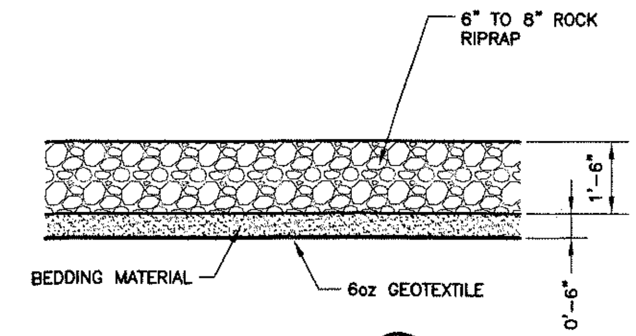
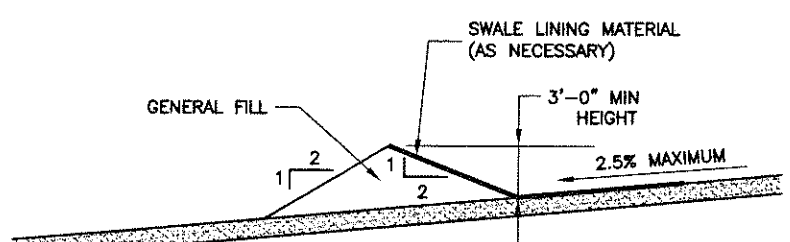


ROCK RIPRAP (TD5 / C1-F-2)
NTS



TEMPORARY TOPSLOPE SWALE (TD2 / C1-F-2)
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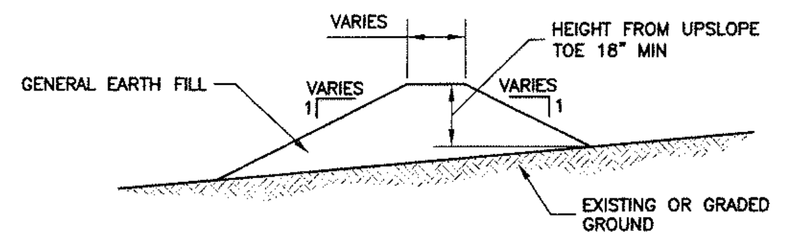
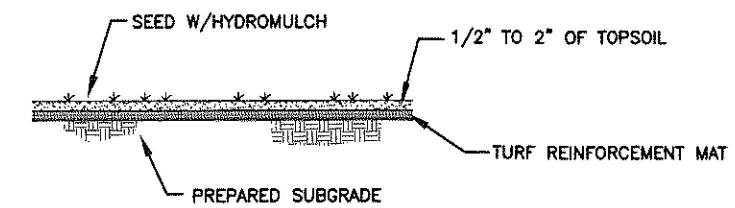


TEMPORARY DIVERSION BERM (TD4 / C1-F-2)
NTS



TEMPORARY TURF REINFORCEMENT MATTING (TD6 / C1-F-2)
NTS

NOTE:

1. LINING MATERIAL, IF NECESSARY, FOR THE TEMPORARY DRAINAGE SWALES OR THE TEMPORARY DIVERSION CHANNEL WILL BE TURF REINFORCEMENT MATTING OR OTHER SUITABLE MATERIALS.

TEMPORARY EROSION CONTROL STRUCTURES

1. TEMPORARY EROSION CONTROL STRUCTURE DETAILS DEPICT VARIOUS TYPES OF EROSION CONTROL FEATURES FOR CURRENT AND FUTURE DEVELOPMENT.
2. ALL TEMPORARY EROSION CONTROL STRUCTURES SHOWN MAY NOT BE CONSTRUCTED DEPENDING ON SITE CONDITIONS.
3. LANDFILL WILL SELECT EROSION CONTROL DETAILS TO BE USED FOR SITE SPECIFIC CONDITIONS.
4. ACTUAL DIMENSIONS OF TEMPORARY EROSION CONTROL STRUCTURES MAY VARY BASED ON SITE CONDITIONS.

ISSUED FOR PERMITTING PURPOSES ONLY

REVISIONS						
1	08/12	NOD NO.1 RESPONSE	BBB	FAW	FAW	KJW
REV	DATE	DESCRIPTION	DWN BY	DES BY	CHK BY	APP BY

TEMPORARY EROSION CONTROL STRUCTURES

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
MAJOR PERMIT AMENDMENT

BIGGS & MATHEWS ENVIRONMENTAL
CONSULTING ENGINEERS
MANSFIELD
DALLAS • WICHITA FALLS
817-563-1144

TBPE FIRM NO. F-256		TBPG FIRM NO. 50222
DSN. FAW	DATE : 04/12	ATTACHMENT
DWN. BBB	SCALE : GRAPHIC	C1-F-2
CHK. KJW	DWG : C1_F_2-4.dwg	

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SKYLINE LANDFILL

ATTACHMENT C1

APPENDIX C1-G

INTERMEDIATE COVER
EROSION CONTROL STRUCTURE DESIGN

STATE OF TEXAS
KENNETH J. WELCH
60773
REGISTERED
PROFESSIONAL ENGINEER

8/21/2012

Includes pages C1-G-1 through C1-G-27

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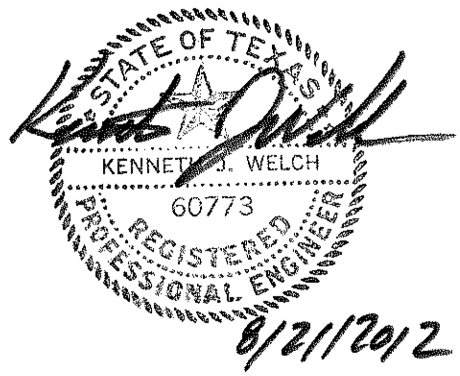
Sheet Flow C1-G-12

Temporary Drainage Swale Design C1-G-14

Temporary Diversion Channel Design C1-G-18

Temporary Drainage Letdown Design C1-G-22

Design Summary C1-G-27



NARRATIVE

This appendix presents the supporting documentation to evaluate and design temporary erosion and sediment control structures for the intermediate cover phase of landfill development.

INTERMEDIATE COVER PLAN

As intermediate cover is constructed, temporary chutes and swales will be constructed to prevent erosion and sedimentation. Erosion control features (i.e., filter berms, rock check dams, hay bales, or equivalent) may be constructed at the toe of filled areas to minimize erosion and prevent disturbance of the existing grassed slopes. Otherwise, temporary erosion and sediment control features will be installed within 180 days from when the intermediate cover is constructed. An existing conditions summary and Best Management Practices are included in Appendix C1-F. Example intermediate cover drainage calculations are included in this appendix for use in site operations.

INTERMEDIATE COVER EVALUATION

The intermediate cover evaluation is based on the Universal Soil Loss Equation (USLE) following Soil Conservation Service (SCS) procedures. The evaluation is based on a 12-inch thick intermediate cover layer with 60 percent vegetated cover. Calculations for the soil loss for intermediate cover on external ~~6~~ 2.5 percent and 25 percent slopes have been provided on pages C1-G-6 through C1-G-7.

SHEET FLOW DESIGN

The sheet flow calculations are presented for external ~~6~~ 2.5 percent and 25 percent slope configurations. The permissible non-erodible velocities should be less than 5 ft/sec (clayey soil) or 4 ft/sec (sandy soil) on vegetated intermediate cover. The Manning's Equation and Rational Method were used to calculate sheet flow velocity.

TEMPORARY DRAINAGE SWALE DESIGN

The temporary drainage swales are designed for typical drainage areas and flowline slopes. The procedures in the TxDOT Hydraulic Design Manual, October 2011, were used to determine peak flow, flow depth, flow velocity, and swale capacity. The Rational Method and the Manning's Equation were used to calculate the design parameters.

INTERMEDIATE COVER EVALUATION

SOIL LOSS

This section presents the supporting documentation for evaluation of the potential for intermediate cover soil erosion loss at the Skyline Landfill. The evaluation is based on the premise of adding excess soil to increase the time required before maintenance is needed as recommended in the EPA Solid Waste Disposal Facility Criteria Technical Manual (EPA 530-R-93-017, November 1993).

The design procedure is as follows:

1. Minimum thickness of the intermediate cover is evaluated based on the maximum soil loss of 50 tons per acre per year.

	~~2.5~~6% slope	25% slope
Maximum Sheet Flow Length	550 ft	250 ft
Soil Loss	~~2.36~~0.60 tons/acre/year	25.10 tons/acre/year

2. Soil loss is calculated using the Universal Soil Loss Equation (USLE) by following SCS procedures. The soil loss is based on 60 percent vegetative cover as recommended in the TNRCC, "Use of the Universal Soil Loss Equation in Final Cover/Configuration Design Procedural Handbook" (October 1993). These calculations are provided on pages C1-G-6 and C1-G-7.

3. Sheet flow velocities for a 25-year storm event are calculated to be less than permissible non-erodible velocities. The supporting calculations are presented on page C1-G-13.

4. Temporary vegetation for the intermediate cover areas will be native and introduced grasses with root depths of 6 inches to 8 inches.

5. Native and introduced grasses will be hydroseeded, drill seeded, or broadcast seeded with fertilizer on the disked (parallel to contours) intermediate cover layer as soon as practical following placement of intermediate cover and will be documented in the site operating record. All intermediate cover areas will be managed to control erosion and achieve a predicted soil loss of less than 50 tons per acre per year. Temporary erosion and sediment control features (including at least 60 percent vegetative cover) will be installed within 180 days from when the intermediate cover is constructed. Areas that experience erosion or do not readily vegetate will be reseeded until vegetation is established or the soil will be replaced with soil that will support the grasses.

SOIL LOSS FOR EXISTING INTERMEDIATE COVER AREAS

This section presents the supporting documentation for evaluation of the potential for intermediate cover soil erosion loss on the existing intermediate cover slopes at the Skyline Landfill. These areas have existing well established vegetation (at least 60 percent coverage), and will not be disturbed to construct temporary erosion control features.

	~~6~~2.5% slope	25% slope
Maximum Sheet Flow Length	550 ft	250 ft
Soil Loss	~~2.36~~0.60 tons/acre/year	25.10 tons/acre/year

SHEET FLOW VELOCITY

The sheet flow velocity calculations are presented for external ~~6~~2.5 percent and 25 percent slope configurations. The procedures outlined in the TxDOT Hydraulic Manual were used to determine velocities. Maximum sheet flow lengths for all three conditions were evaluated. Calculations are provided on page C1-G-13.

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
Intermediate Cover Erosion Loss Evaluation

Required: 1. Determine the erosion loss for the intermediate cover design based on a maximum soil loss of 50 tons/acre/year.

Method: Expected soil loss is calculated using the Universal Soil Loss Equation.

References: 1. TNRCC, *Use of the Universal Soil Loss Equation in Final Cover/Configuration Design Procedural Handbook,* October 1993.

Solution: Annual Soil Loss in tons/acre/year (A) = RKLSCP

Design Parameters	External Top Slope (2.5%)	External Side Slope (25%)	
Rainfall Factor (R) =	310	310	Dallas/Ellis Counties[1]
Soil Erodibility Factor (K) =	0.23	0.23	(Clay)
Longest Run =	550	250	ft
Slope =	2.5	25	%
Topographic Factor (LS) =	0.40	9.31	
Crop Management Factor (C) =	0.042	0.042	(60% vegetative cover)
Erosion Control Practice Factor (P) =	0.50	0.90	
Soil Loss (A) =	0.60	25.10	tons/acre/year

Summary: As noted in the permit drawings, the intermediate cover will be a minimum of 12 inches thick. As shown above, the maximum soil loss is 25.10 tons/acre/year, which is less than the maximum allowable soil loss of 50 tons/acre/year.

Note: [1]The Dallas/Ellis county line crosses the landfill footprint.

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
Intermediate Cover LS Factor Calculations

Required: 1. Determine the Length/Slope Factor based on slope length and slope gradient.

References: 1. TNRCC, *Use of the Universal Soil Loss Equation in Final Cover/Configuration Design Procedural Handbook,* October 1993.

Solution: Length/Slope Factor (LS) = $(L / 72.6)^m * (65.41*\sin^2 \upsilon + 4.56 * \sin \upsilon + 0.065)$

LS = Length/Slope Factor
L = Slope Length (ft)
υ = radians
m = exponent dependent on the slope gradient

m = 0.2 for S <= 1.0%
0.3 for 1.0% < S <= 3.5%
0.4 for 3.5% < S < 5.0%
0.5 for S => 5.0%

Length, L (ft)	Slope, S %	Slope, S (ft/ft)	υ (radians)	υ (degrees)	m	LS
550	2.5	40.00	0.025	1.432	0.3	0.40
250	25	4	0.245	14.036	0.5	9.31

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
Intermediate Cover Sheet Flow Velocity

Required: Determine the sheet flow velocity for the intermediate cover design and compare to the permissible non-erodible flow velocity.

Method:
1. Determine the 25-year peak flow rate using the Rational Method.
2. Calculate flow depth using Manning's Equation.
3. Calculate sheet flow velocity and compare to permissible non-erodible velocity.

References:
1. Texas Department of Transportation, *Hydraulic Design Manual*, Revised October 2011.
2. United States Geologic Survey, *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas*, 2004.

Solution:
1. Determine the 25-year peak flow rate (Q) using the Rational Method.

25-Year Rainfall Depth (Pd) =	1.42	(ref 2, extrapolated for 10 minutes)
Time of Concentration (tc) =	10 min	(conservative minimum value)
Rainfall Intensity (I) =	8.5 in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70	(typical value for intermediate cover)
25-Year Peak Flow Rate (Q) =	CIA cfs	

	External Top Slope (2.5%)	External Side Slope (25%)		
Longest Run =	550	250	ft	(longest sheet flow distance to swale)
Width =	1	1	ft	(unit width of flow)
Area =	0.0126	0.0057	acre	
Q	0.075	0.034	cfs	

2. Calculate the flow depth using Manning's Equation.
   - Rearrange Manning's Equation for wide and shallow flow to calculate flow depth:

$$y = (Qn/1.49S^{0.5})^{0.6}$$

Manning's Roughness (n) =		0.03	(typical value for intermediate cover)
Slope =	0.03	0.25 ft/ft	
Depth (y) =	0.062	0.019 ft	

3. Calculate sheet flow velocity and compare to permissible non-erodible velocity.
   - A permissible non-erodible velocity of 5 ft/sec (clayey soil) or 4 ft/sec (sandy soil) is typical for vegetated intermediate covers. Refer to page C1-G-6 for soil loss calculations.

V = Q / (y * width)

Sheet flow velocity	**1.22**	**1.78 ft/sec**

Summary: The permissible non-erodible velocity should be less than 5.0 ft/sec (clayey soil) or 4.0 ft/sec (sandy soil) on vegetated intermediate cover. Therefore, the expected sheet flow velocity is acceptable on the external intermediate cover slopes with 60% vegetative cover.

TEMPORARY DRAINAGE SWALE DESIGN

The temporary drainage swale design for intermediate cover areas is presented for the typical swale flowline of 0.5 percent. The procedures in the TxDOT Hydraulic Design Manual were used to determine peak flow, flow depth, flow velocity, and swale capacity. The temporary swales will be located on the intermediate cover to prevent erosion as follows:

Slope (%)	Maximum Sheet Flow Length (ft)	Maximum Drainage Area (acres)	Maximum Swale Length (ft)
~~6~~2.5	550	21.8	~~1,725~~3,902
25	250	6.8	1,184

All temporary swales shall be designed to minimize erosion and provide a maximum flow depth of 2 feet. The total height of the swales at the flowline is a minimum of 3 feet, as depicted in Appendix C1-F on page C1-F-2. As noted in the calculations, the velocities in the swales are less than permissible non-erodible velocities. If sustained erosion is observed, facility management will evaluate and construct additional temporary drainage swales. Example drainage swale calculations for a grassed intermediate cover are provided on pages C1-G-16 and C1-G-17.

TEMPORARY DIVERSION CHANNEL DESIGN

The temporary diversion channel design for ~~diverting~~ preventing surface water ~~runon around excavations~~from entering excavated areas is presented for three typical slopes of 0.5 percent, 1 percent and 2 percent and three typical drainage areas of 1, 5, and 10 acres. The procedures in the TxDOT Hydraulic Design Manual were used to determine peak flow, flow depth, flow velocity, and diversion channel capacity. Temporary diversion channels will be designed to minimize erosion and sedimentation.

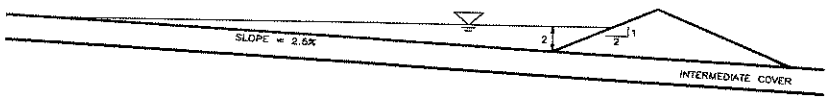
WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
Drainage Swale Analysis - External Intermediate Cover Topslopes

Required: Determine the intermediate cover topslope drainage swale capacity.

Method:
1. Calculate the intermediate cover topslope swale's flow capacity using Manning's Equation.
2. Determine the maximum allowable topslope drainage area using the Rational Method.
3. Determine the maximum swale length based on the maximum sheet flow length.

References:
1. Texas Department of Transporation, *Hydraulic Design Manual*, Revised October 2011.
2. United States Geologic Survey, *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas*, 2004.

Solution:
1. Calculate flow capacity using Manning's Equation.
- Swale Characteristics:



Max swale flow depth =	2.00 ft
Running swale slope =	0.5 %
Manning's Roughness =	0.03
Left slope =	40.00 :1
Right slope =	2 :1
Flow Area (A) =	((LS+RS)*D^2)/2
Wetted Perimeter (WP) =	((LS*D)^2+D^2)^(0.5) + ((RS*D)^2+D^2)^(0.5)
Hydraulic Radius (R) =	A/WP

Flow Area (A) =	84.000
Wetted Perimeter (WP) =	84.497
Hydraulic Radius (R) =	0.994

- Use Manning's Equation to determine the flow velocity in the swale.

Velocity (V) = 1.49*R^(2/3)*S^(1/2)/n
Velocity (V) = 3.498 ft/sec

- Calculate the swale's flow capacity.

Swale capacity (Q) = V * A
Q = 293.8 cfs

2. Determine the maximum allowable drainage area using the Rational Method.

25-Year Rainfall Depth (Pd) =	1.42	(ref 2, extrapolated for 10 minutes)
Time of Concentration (tc) =	10 min	(conservative minimum value)
Rainfall Intensity (I) =	8.5 in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70	(typical value for intermediate cover)
25-Year Peak Flow Rate (Q) =	CIA cfs	

Rearrange the Rational Formula to calculate allowable drainage area:
Drainage Area = Q / (CI)

Maximum Swale Drainage Area = 49.3 acres

3. Determine the maximum swale length based on the maximum sheet flow length.

Maximum Sheet Flow Length = 550 ft

Maximum Swale Length = Maximum Swale Drainage Area * 43560 / Maximum Sheet Flow Length

Maximum Swale Length = 3902 ft

Summary: The maximum sheet flow length will be 550 feet and maximum drainage area is 49.3 acres. The calculated velocity is less than the permissible non-erodible velocity.

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
Temporary Diversion Channel

Diversion channel drainage areas were based on the typical size that may occur during the development of the site. The diversion channels are intended to prevent surface water from entering the excavated areas. 1-, 5-, and 10-acre drainage areas were considered:

Diversion Channel Slope	Diversion Channel Area (Acres)	Flow (cfs)	Bottom Width (ft)	Side Slopes (H:V)	Manning's number (n)	Normal Depth (ft)	Flow Area (ft^2)	Velocity (ft/s)	Energy Head (ft)
0.5	1	6.0	0	3	0.03	0.98	2.86	2.10	1.05
0.5	5	29.8	0	3	0.03	1.78	9.52	3.13	1.93
0.5	10	59.6	0	3	0.03	2.31	16.01	3.72	2.52
1	1	6.0	0	3	0.03	0.86	2.21	2.72	0.97
1	5	29.8	0	3	0.03	1.56	7.34	4.06	1.82
1	10	59.6	0	3	0.03	2.03	12.35	4.83	2.39
2	1	6.0	0	3	0.03	0.75	1.70	3.53	0.95
2	5	29.8	0	3	0.03	1.37	5.66	5.26	1.80
2	10	59.6	0	3	0.03	1.78	9.52	6.26	2.39

Notes:

1. The calculations shown in the table above are normal depths from a 25-year rainfall event.
2. The required diversion channel depth will have 0.5 foot of freeboard.
3. Diversion channels shall be grassed. Erosion control features will be provided for velocities exceeding 5 fps.
4. During operation of the site different configurations of diversion channels may be used to prevent surface water from entering excavated areas. The landfill operator will determine the sizing of diversion channels if different lining materials is used.
5. The shading represents sample calculation presented on pages C1-G-20 and C1-G-21.

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
Temporary Diversion Channel
Example Calculations

Required: Determine the necessary dimensions of the temporary diversion channel for routing surface water around excavations.

Methods:

1. Calculate the 25-year peak flow rate (Q) for a 1-acre drainage area using the Rational Method.
2. Calculate the normal depth for the temporary diversion channel for a drainage area of 1 acre with a slope of 2%.

References:

1. Texas Department of Transportation, *Hydraulic Design Manual,* Revised October 2011.
2. United States Geologic Survey, *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas*, 2004.

Solution:

1. Calculate the 25-year peak flow rate (Q) for a 1-acre drainage area using the Rational Method.

25-Year Rainfall Depth (Pd) =	1.42	(ref 2, extrapolated for 10 minutes)
Time of Concentration (tc) =	10 min	(conservative minimum value)
Rainfall Intensity (I) =	8.5 in/hr	(ref 1, I = Pd/tc)
Runoff Coefficient (C) =	0.70	(ref 1, Table 4-11)
Area (A) =	1 acre	
25-Year Peak Flow Rate (Q) =	CIA cfs	
Q =	(0.7)(8.5)(1)	
Q =	6.0 cfs	

2. Calculate the normal depth for the temporary diversion channel for a drainage area of 1 acre with a slope of 2%.

List of Symbols:

- Q_d = design flow rate for channel, cfs
- R = hydraulic radius, ft
- n = Manning's roughness coefficient
- S = channel slope, ft/ft
- b = bottom width of channel, ft
- z_r = ratio of run to rise for channel sideslope for right sideslope of diversion channel
- z_l = ratio of run to rise for channel sideslope for left sideslope of diversion channel
- A_f = flow area, sf
- g = gravitational acceleration = 32.2 ft/s^2
- T = top width of flow, ft
- d = normal depth of diversion channel, ft

Design Inputs:

Q_d =	6.0	cfs
S =	0.02	ft/ft
b =	0	ft
z_r =	3	(H) : 1 (V)
z_l =	3	(H) : 1 (V)
n =	0.03	

WASTE MANAGEMENT OF TEXAS, INC.
SKYLINE LANDFILL
Temporary Diversion Channel
Example Calculations

Step A - Based on the geometry of the swale cross section, solve for R and A_f.

$$R = \frac{bd + 1/2d^2(z_r + z_l)}{b + d((z_l^2 + 1)^{0.5} + (z_r^2 + 1)^{0.5})}$$

$$A_f = bd + 1/2d^2(z_r + z_l)$$

Assume: d = 0.75 ft

R = 0.357 ft

A_f = 1.70 sf

Solve for Q: Q = 6.0

If Q is not equal to Q_d, select a new d and repeat calculations.

The program uses an iterative process to calculate the normal depth of the diversion channel to satisfy Manning's Equation.

$$Q = \frac{1.486}{n} A\, R^{0.67} S^{0.5}$$

Step B - solve for velocity, T, Froude number, velocity head, and energy head.

Q = VA => V = Q/A

V = 3.53 ft/s

$T = b + d(z_l + z_r)$

T = 4.52 ft

$$F_r = \frac{V}{(gA/T)^{0.5}}$$

F_r = 1.01

$$\text{Velocity Head} = \frac{V^2}{2g}$$

Velocity Head = 0.19 ft

Energy Head = depth + velocity head

Energy Head = 0.95 ft

TEMPORARY DRAINAGE LETDOWN DESIGN

Temporary sideslope swales will collect and route surface water runoff from intermediate cover sideslope areas to temporary drainage letdowns on the intermediate cover sideslopes. Temporary topslope swales will collect and route surface water runoff from intermediate cover top dome areas to temporary drainage letdowns on the intermediate cover sideslopes.

The temporary letdowns design is applicable for external sideslopes of the landfill with intermediate cover. Temporary letdown chutes will typically consist of channels lined with erosion control material. The temporary flow depth provided is 2-feet. The design flow depth for geomembrane and concrete lined letdowns is 0.25 feet which provide a freeboard of 1.75 feet. The design flow depth for turf reinforcement mat, gabions, riprap, crushed stone or crushed concrete lined chutes is 0.4 feet which provide a freeboard of 1.6 feet.

The flow capacity of the letdown structures was determined based on the Manning's Equation. The maximum flow calculated from the Manning's Equation is used to determine the maximum drainage area based on the Rational Method. The design calculations presented on pages C1-G-25 through C1-G-27 represent typical calculations for letdown chutes lined with different materials on a 25 percent slope. If sustained erosion is observed, facility management will evaluate the use and construction of temporary letdowns.

Temporary letdowns will discharge directly into detention ponds or perimeter ditches. If erosion protection at the discharge of the temporary letdown is required, the temporary letdown will discharge onto splash pads from gabions, crushed stone, or crushed concrete. Splash pads for 8-foot-wide temporary letdowns will be 12 feet by 12 feet. Splash pads for 30-foot-wide temporary letdowns will be 40 feet by 40 feet.

~~The flow capacity of the letdown structures was determined based on the Manning's Equation. The maximum flow calculated from the Manning's Equation is used to determine the maximum drainage area based on the Rational Method. The design calculations presented on pages C1-G-25 through C1-G-27 represent typical calculations for letdown chutes lined with different materials on a 25 percent slope. If sustained erosion is observed, facility management will evaluate the use and construction of temporary letdowns.~~