# SKYLINE LANDFILL

# ATTACHMENT C1

# APPENDIX C1-D

# PERIMETER DRAINAGE SYSTEM DESIGN

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4/12/2012

Includes pages C1-D-1 through C1-D-6

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Perimeter Channel Design Calculations ........ C1-D-4

# NARRATIVE

*30 TAC §§330.303 and 330.305*

This appendix presents the design of the Skyline Landfill perimeter drainage channels and detention ponds in accordance with §330.305(a)-(d).

## PERIMETER DRAINAGE PLAN

Drawing C1-D-1 – Perimeter Drainage Plan depicts the perimeter drainage system and detention pond locations for the Skyline Landfill. The plan reflects the perimeter channel design and stationing. The perimeter channel hydraulic analysis is included for the 25-year rainfall event.

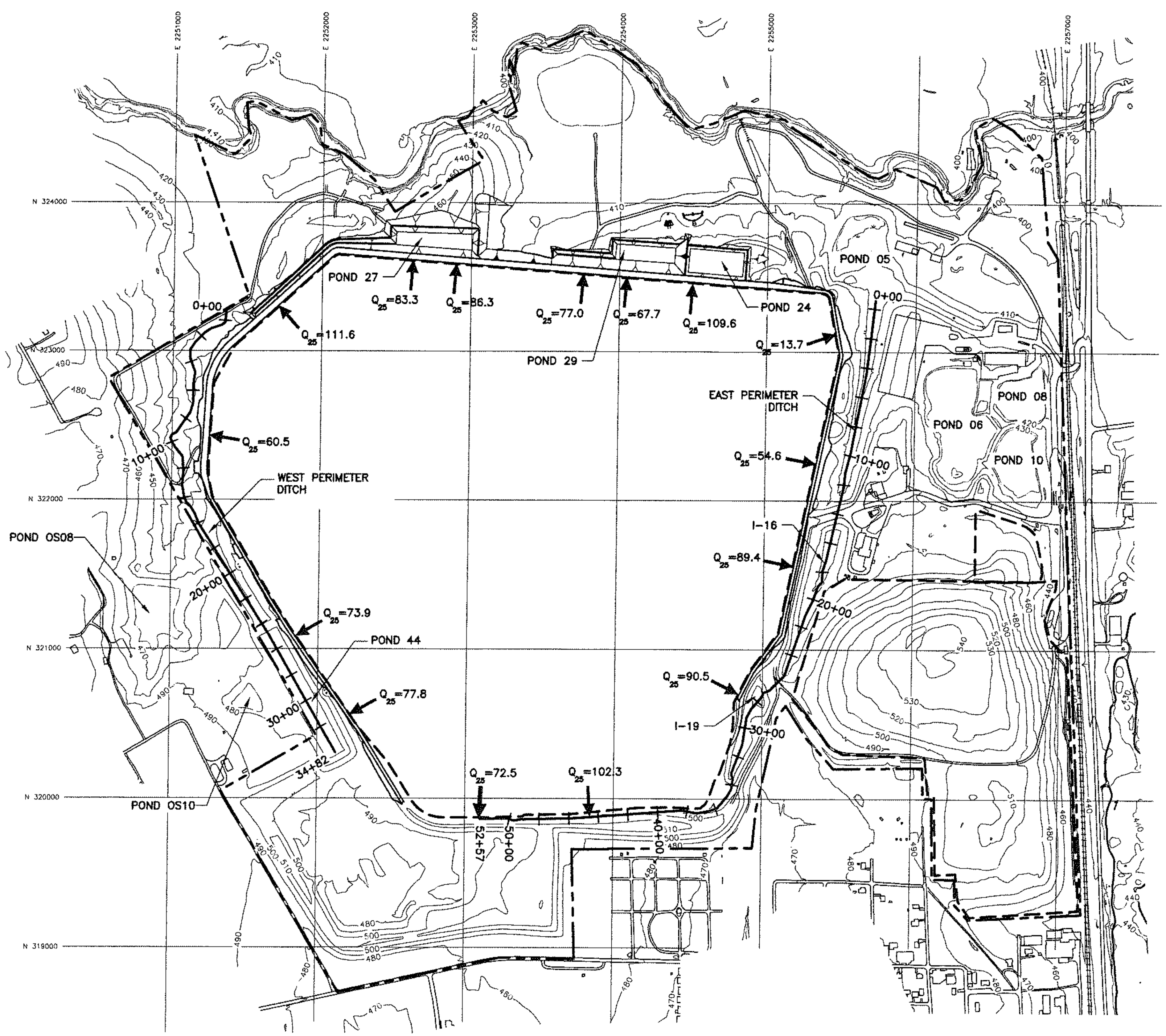
## DETENTION POND DESIGN SUMMARY

The detention ponds were designed to provide the necessary storage and outlet control to prevent an adverse alteration in the peak stormwater discharge rate off the developed site. The detention ponds were designed to closely match the current permitted peak discharges for the 25-year, 24-hour storm event. Stormwater storage is provided in earthen ponds with stormwater release controlled by concrete outfall structures. The design parameters for detention ponds 24, 27, 29 and 44 are provided on pages C1-C-22 thorough C1-C-25. The detention pond plans and details are included in Attachment C3.

## PERIMETER CHANNEL DESIGN SUMMARY

The perimeter channels are designed for the 24-hour, 25-year event and will pass the 24-hour, 100-year storm event. In several locations along the perimeter channel, the depths are much greater than necessary to convey the predicted stormwater flow rates; however, minimum channel slopes were maintained to help prevent excessive velocity and erosion. The perimeter channel design calculations are included beginning on page C1-D-4. The perimeter channel profile is included in Attachment C3.

# PERIMETER DRAINAGE PLAN

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**LEGEND**

- PERMIT BOUNDARY
- LANDFILL FOOTPRINT
- EXISTING CONTOUR
- STREAM

**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.

STATE OF TEXAS
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# PERIMETER DRAINAGE PLAN

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

BIGGS & MATHEWS ENVIRONMENTAL
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# PERIMETER CHANNEL DESIGN CALCULATIONS

# WASTE MANAGEMENT OF TEXAS, INC.
## SKYLINE LANDFILL
### Depth and Velocity Calculations for the Perimeter Channels for the 100-Year Peak Runoff

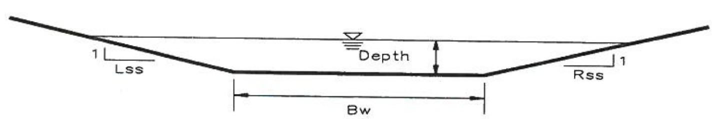
**Required:** Determine the velocity and depth for the perimeter channels and compare to the permissible non-erodible flow velocity.

**Method:** Manning's Equation for flow velocity.

**References:** 1. Texas Department of Transportation, *Hydraulic Design Manual,* March 2004.

**Solution:** Manning's Equation V = (k/n)(R^2/3)(S^1/2)

V = Velocity (fps)
k = Conversion Factor = 1.486
n = Manning's Roughness Coefficient = 0.03 Grass-lined channel
R = Hydraulic Radius = A/Pw
A = Cross-Sectional Area (ft^2)
Pw = Wetted Perimeter (ft)
S = Channel Slope (ft/ft)
Bw = Bottom Width (ft)




| Channel | Channel Station | | Q (cfs) | S (ft/ft) | BW (ft) | Rss (H:V) | Lss (H:V) | D (ft) | R (ft) | A (sf) | PW (ft) | V (fps) | Shear Stress (psf) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| East | 0+00 | 13+28 | 466.1 | 0.012 | 30 | 3 | 3 | 1.81 | 1.55 | 64.18 | 41.46 | 7.26 | 1.36 |
| East | 15+96 | 26+06 | 351.3 | 0.026 | 50 | 3 | 3 | 0.92 | 0.87 | 48.38 | 55.80 | 7.26 | 1.49 |
| East | 28+00 | 34+19 | 206.0 | 0.016 | 60 | 3 | 3 | 0.69 | 0.67 | 43.02 | 64.38 | 4.79 | 0.69 |
| East | 34+19 | 34+73 | 208.3 | 0.260 | 50 | 3 | 3 | 0.34 | 0.33 | 17.24 | 52.14 | 12.08 | 5.48 |
| East | 34+73 | 45+06 | 208.3 | 0.015 | 0 | 4 | 4 | 2.68 | 1.30 | 28.80 | 22.13 | 7.23 | 2.51 |
| East | 45+06 | 52+57 | 87.4 | 0.005 | 0 | 4 | 4 | 2.38 | 1.15 | 22.67 | 19.63 | 3.86 | 0.74 |
| | | | | | | | | | | | | | |
| West | 0+00 | 9+68 | 212.5 | 0.009 | 80 | 3 | 3 | 0.71 | 0.69 | 58.06 | 84.47 | 3.66 | 0.40 |
| West | 9+68 | 13+94 | 160.1 | 0.019 | 80 | 3 | 3 | 0.48 | 0.47 | 38.88 | 83.02 | 4.12 | 0.57 |
| West | 13+94 | 20+24 | 46.4 | 0.044 | 0 | 3 | 3 | 1.40 | 0.66 | 5.87 | 8.85 | 7.90 | 3.84 |
| West | 20+24 | 24+56 | 46.4 | 0.009 | 20 | 3 | 3 | 0.64 | 0.59 | 14.10 | 24.07 | 3.29 | 0.36 |
| West | 25+74 | 34+82 | 347.0 | 0.004 | 90 | 3 | 3 | 1.13 | 1.08 | 105.09 | 97.12 | 3.30 | 0.28 |

# WASTE MANAGEMENT OF TEXAS, INC.
## SKYLINE LANDFILL
### Depth and Velocity Calculations for the Perimeter Channels for the 25-Year Peak Runoff

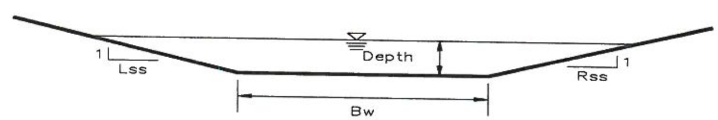
**Required:** Determine the velocity and depth for the perimeter channels and compare to the permissible non-erodible flow velocity.

**Method:** Manning's Equation for flow velocity.

**References:** 1. Texas Department of Transportation, *Hydraulic Design Manual,* March 2004.

**Solution:** Manning's Equation V = (k/n)(R^2/3)(S^1/2)

V = Velocity (fps)
k = Conversion Factor = 1.486
n = Manning's Roughness Coefficient = 0.03 Grass-lined channel
R = Hydraulic Radius = A/Pw
A = Cross-Sectional Area (ft^2)
Pw = Wetted Perimeter (ft)
S = Channel Slope (ft/ft)
Bw = Bottom Width (ft)




| Channel | Channel Station | | Q (cfs) | S (ft/ft) | BW (ft) | Rss (H:V) | Lss (H:V) | D (ft) | R (ft) | A (sf) | PW (ft) | V (fps) | Shear Stress (psf) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| East | 0+00 | 13+28 | 392.8 | 0.012 | 30 | 3 | 3 | 1.64 | 1.42 | 57.32 | 40.38 | 6.85 | 1.23 |
| East | 15+96 | 26+06 | 295.5 | 0.026 | 50 | 3 | 3 | 0.83 | 0.79 | 43.43 | 55.23 | 6.80 | 1.34 |
| East | 28+00 | 34+19 | 164.2 | 0.016 | 60 | 3 | 3 | 0.61 | 0.59 | 37.42 | 63.83 | 4.39 | 0.60 |
| East | 34+19 | 34+73 | 165.2 | 0.260 | 50 | 3 | 3 | 0.29 | 0.29 | 14.97 | 51.86 | 11.03 | 4.77 |
| East | 34+73 | 45+06 | 165.2 | 0.015 | 0 | 4 | 4 | 2.46 | 1.19 | 24.21 | 20.29 | 6.82 | 2.30 |
| East | 45+06 | 52+57 | 69.5 | 0.005 | 0 | 4 | 4 | 2.18 | 1.06 | 19.09 | 18.01 | 3.64 | 0.68 |
| | | | | | | | | | | | | | |
| West | 0+00 | 9+68 | 153.0 | 0.009 | 80 | 3 | 3 | 0.58 | 0.57 | 47.49 | 83.67 | 3.22 | 0.33 |
| West | 9+68 | 13+94 | 104.9 | 0.019 | 80 | 3 | 3 | 0.37 | 0.37 | 30.07 | 82.34 | 3.49 | 0.44 |
| West | 13+94 | 20+24 | 41.7 | 0.044 | 0 | 3 | 3 | 1.34 | 0.64 | 5.42 | 8.50 | 7.70 | 3.69 |
| West | 20+24 | 24+56 | 41.7 | 0.009 | 20 | 3 | 3 | 0.60 | 0.55 | 13.17 | 23.82 | 3.17 | 0.34 |
| West | 25+74 | 34+82 | 276.3 | 0.004 | 90 | 3 | 3 | 0.98 | 0.95 | 91.32 | 96.21 | 3.03 | 0.25 |

# SKYLINE LANDFILL

# ATTACHMENT C1

# APPENDIX C1-E

# FINAL COVER DRAINAGE STRUCTURE DESIGN

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

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# 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.

## 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.

## 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.

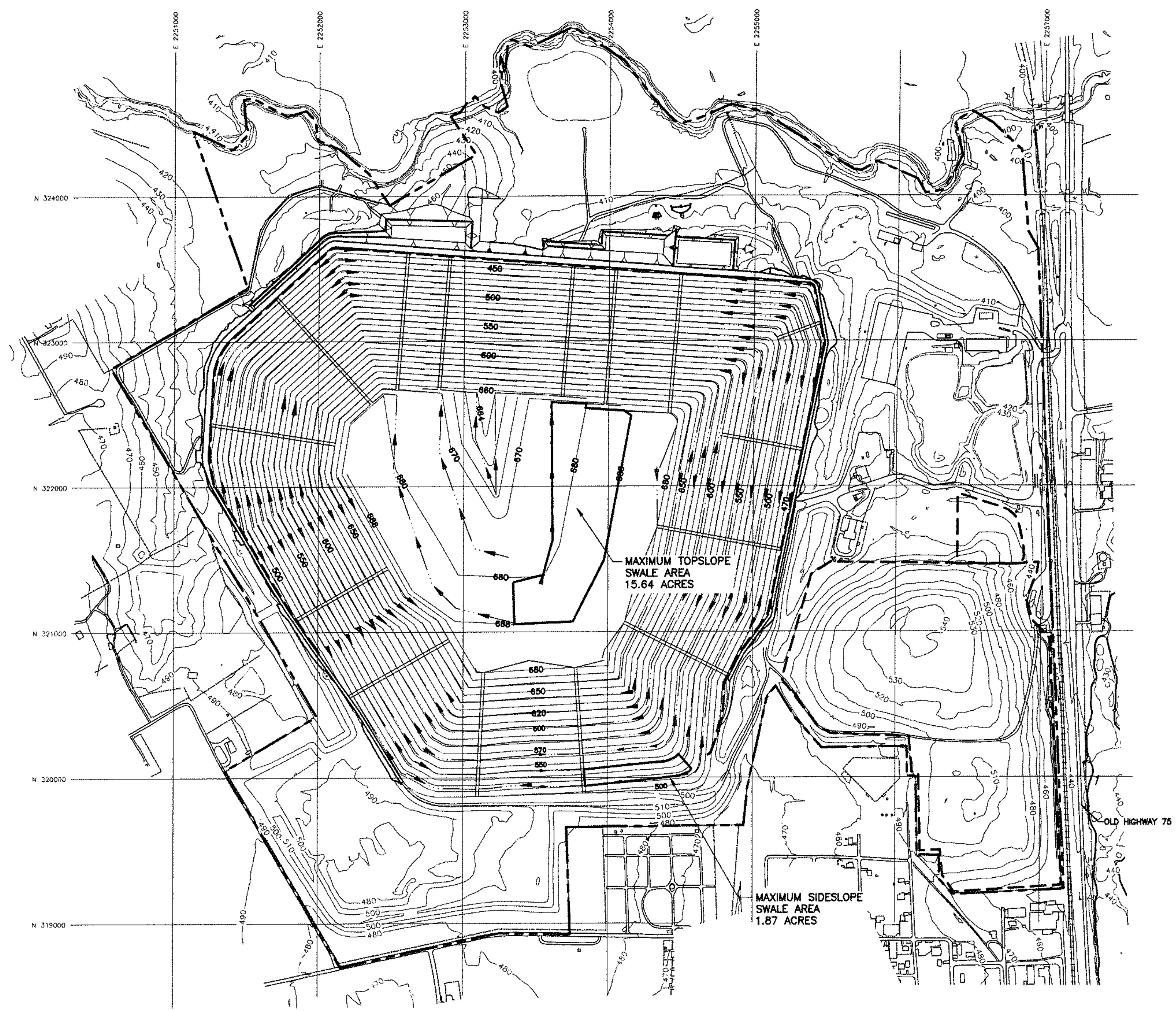
## DRAINAGE SWALE DESIGN

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.

## 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. Erosion protection within each chute is provided by 40-mil textured FML. Profiles of each drainage chute are included in Attachment C3.

# FINAL COVER PLANS

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**LEGEND**

- PERMIT BOUNDARY
- LANDFILL FOOTPRINT
- EXISTING CONTOUR
- DRAINAGE AREA BOUNDARY
- DRAINAGE AREA REACH
- STREAM

**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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C1-E-3

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# MAXIMUM SWALE AREA

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

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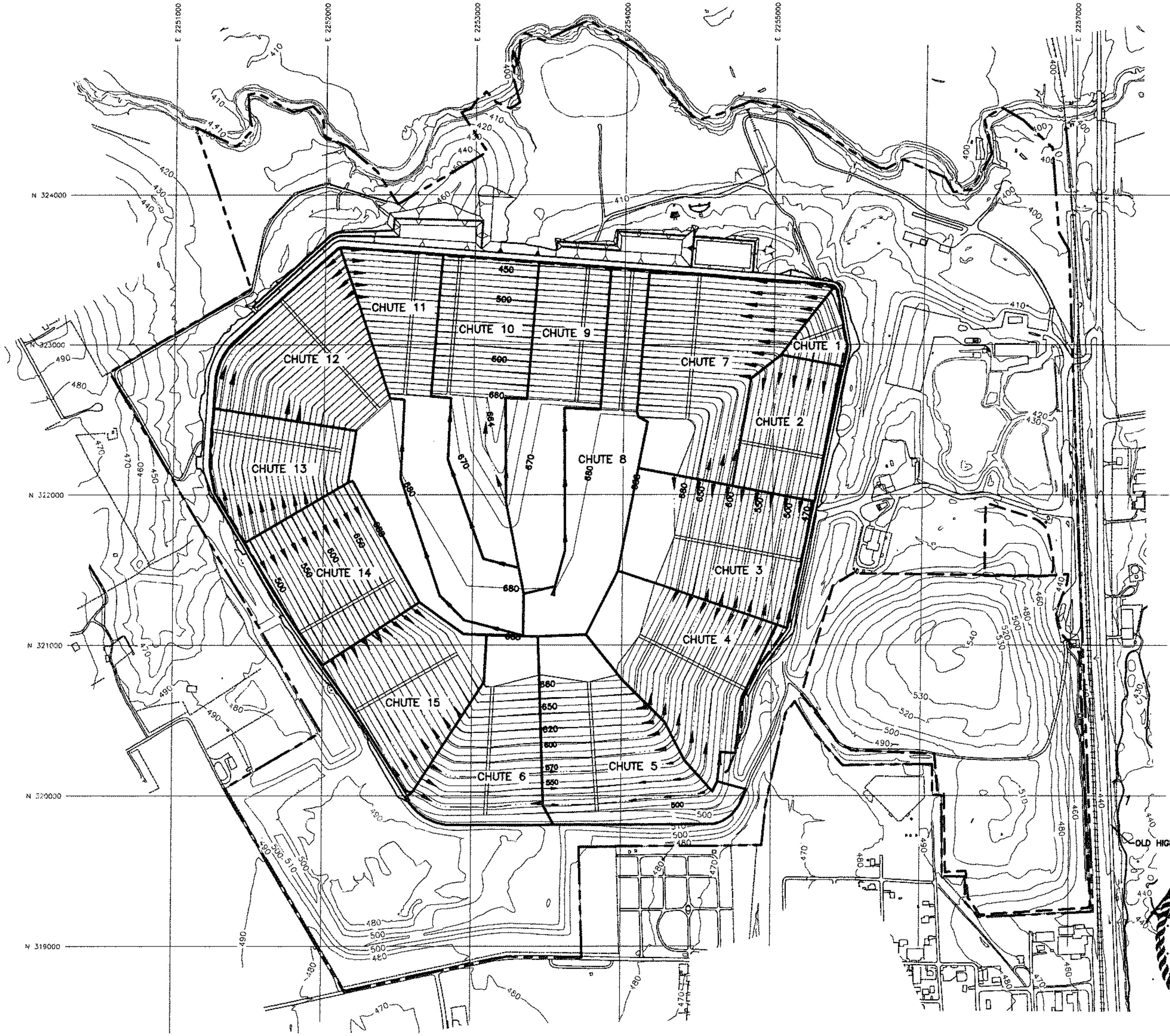


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SCALE IN FEET

LEGEND

- PERMIT BOUNDARY
- LANDFILL FOOTPRINT
- EXISTING CONTOUR
- DRAINAGE AREA BOUNDARY
- CHUTE DRAINAGE AREA
- STREAM

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 |

C1-E-4

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# CHUTE AREA

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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. The 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 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.

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.

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 (6%) | 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 = | 6 | 25 | % |
| Topographic Factor (LS) = | 1.64 | 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) = | 0.38 | 2.45 | tons/acre/yr |

**Erosion Layer Thickness Evaluation:**

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

| | Top Slope (6%) | Perimeter Slope (25%) | |
|---|---|---|---|
| Soil Loss (A) = | 0.38 | 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)** | **6.10** | **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 | 6 | 16.67 | 0.060 | 3.434 | 0.4 | 1.635 |
| 80 | 25 | 4 | 0.245 | 14.036 | 0.5 | 5.268 |

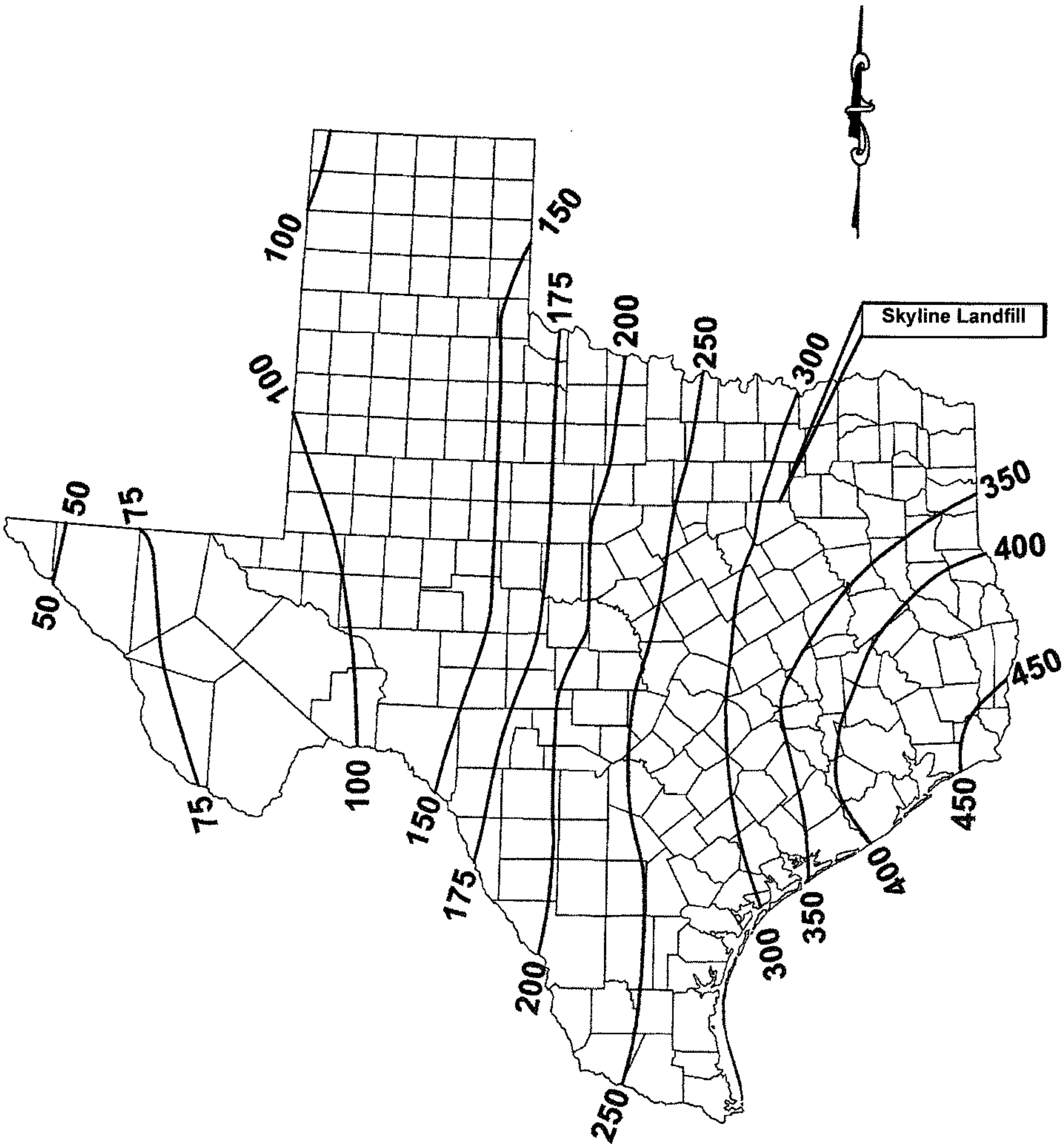



**FIGURE 1 - AVERAGE ANNUAL VALUES OF THE RAINFALL EROSION INDEX**

Prep by: FAW
Date: 2/28/2012

Chkd by: KJW
Date: 2/28/2012

## 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 (6%) | 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 = | 0.06 | 0.25 ft/ft | (final cover design slopes) |
| Depth (y) = | 0.0677 | 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** | **2.02** | **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

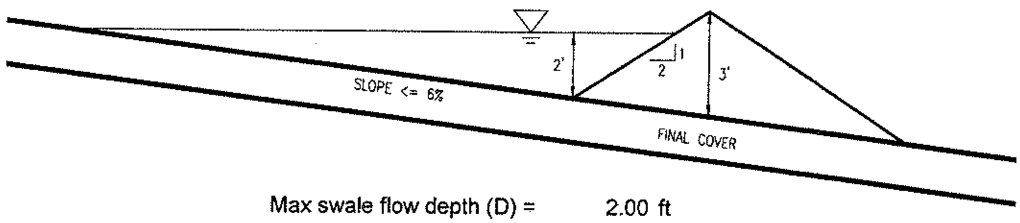
**WASTE MANAGEMENT OF TEXAS, INC.**
**SKYLINE LANDFILL**
**Drainage Swale Analysis - Topslopes**

**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) = 16.67 :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) = 37.333
Wetted Perimeter (WP) = 37.865
Hydraulic Radius (R) = 0.986

- 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) = 3.479 ft/sec

- Calculate the swale's flow capacity.
Swale capacity (Q) = V * A
Q = 129.9 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 = 21.78 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 21.78 acres for the proposed swale configuration.

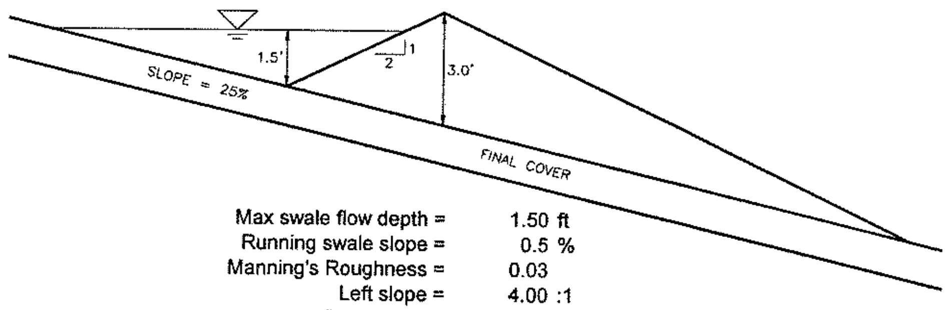
**WASTE MANAGEMENT OF TEXAS, INC.**
**SKYLINE LANDFILL**
**Drainage Swale Analysis - Sideslopes**

**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

Prep by: FAW
Date: 12/8/2010

Chkd by: KJW
Date: 12/8/2010

**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 | 33 | 12 | 0.025 | 0.28 | 13.46 |
| 4 | 91 | 20 | 25 | 4 | 0.013 | 0.22 | 20.03 | 20 | 2 | 12 | 0.020 | 0.56 | 6.11 | 20 | 33 | 12 | 0.025 | 0.29 | 13.52 |
| 5 | 102 | 20 | 25 | 4 | 0.013 | 0.23 | 20.98 | 20 | 2 | 12 | 0.020 | 0.59 | 6.35 | 20 | 33 | 12 | 0.025 | 0.31 | 14.09 |
| 6 | 73 | 20 | 25 | 4 | 0.013 | 0.19 | 18.40 | 20 | 2 | 12 | 0.020 | 0.49 | 5.70 | 20 | 33 | 12 | 0.025 | 0.25 | 12.52 |
| 7 | 110 | 20 | 25 | 4 | 0.013 | 0.24 | 21.54 | 20 | 2 | 12 | 0.020 | 0.62 | 6.49 | 20 | 33 | 12 | 0.025 | 0.32 | 14.42 |
| 8 | 68 | 20 | 25 | 4 | 0.013 | 0.18 | 17.93 | 20 | 2 | 12 | 0.020 | 0.47 | 5.58 | 20 | 33 | 12 | 0.025 | 0.24 | 12.23 |
| 9 | 77 | 20 | 25 | 4 | 0.013 | 0.20 | 18.83 | 20 | 2 | 12 | 0.020 | 0.51 | 5.81 | 20 | 33 | 12 | 0.025 | 0.26 | 12.79 |
| 10 | 86 | 20 | 25 | 4 | 0.013 | 0.21 | 19.67 | 20 | 2 | 12 | 0.020 | 0.54 | 6.02 | 20 | 33 | 12 | 0.025 | 0.28 | 13.30 |
| 11 | 83 | 20 | 25 | 4 | 0.013 | 0.21 | 19.40 | 20 | 2 | 12 | 0.020 | 0.53 | 5.96 | 20 | 33 | 12 | 0.025 | 0.27 | 13.14 |
| 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 | 33 | 12 | 0.025 | 0.26 | 12.83 |

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 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 reno mattress or articulating concrete blocks. Erosion protection at low-water crossing will be 12-inch-thick concrete.

| 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 |