LANDFILL GAS GENERATION CURVE

Client, Project Name and Number
PROJECT NAME: Remedial Action Work Plan
PROJECT NO: 222290
LOCATION: Cranston, RI
CLIENT NAME: Ciba

Objective
Calculate the amount of landfill gas produced at this landfill on a yearly basis and generate the gas generation curve.

Method

Definitions
\[ G = \text{Methane generation rate (volume/time) for all masses of refuse in the landfill. The generation rate is for the first day of year } Y. \]
\[ G' = \text{Landfill gas generation rate (volume/time) for all masses of refuse in the landfill. Assuming methane concentration is 50%, } G' = 2 \times G \]
\[ L_w = \text{Methane potential of waste for year } t \text{ (scf/ton). Generally } L_w \text{ is assumed to be constant through all years.} \]
\[ k = \text{Rate constant (1/yr)} \]
\[ Y = \text{Year of interest} \]
\[ FY = \text{First year of waste disposal} \]
\[ t = \text{Year waste is placed} \]
\[ m_t = \text{Tons disposed during year } t \]
\[ \%CH_4 = \text{Percentage of Methane in Landfill Gas} \]
\[ r = \text{Average Annual precipitation, inches} \]

\[ k = 0.016 \times e^{0.04Y} \]

\[ G = L_w \sum m_t \times e^{-kY} / 365; \text{ from } FY \text{ to } Y-1 \]

Equations

Assumptions
\[ L_w = 5457 \text{ scf/ton} \]
\[ k = 0.04 \text{ yr}^{-1} \]
\[ \%CH_4 = 50\% \]
## Landfill Gas Generation Curve

### Calculations

<table>
<thead>
<tr>
<th>Range of $r'$s</th>
<th>$k'$s</th>
<th>m&lt;sub&gt;1&lt;/sub&gt;</th>
<th>m&lt;sub&gt;2&lt;/sub&gt;</th>
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<tr>
<td>35</td>
<td>0.06</td>
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<td>37</td>
<td>0.08</td>
<td>29823</td>
<td>9.941</td>
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<td>38</td>
<td>0.09</td>
<td>39764</td>
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<tr>
<td>39</td>
<td>0.1</td>
<td>49705</td>
<td>9.941</td>
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<tr>
<td>40</td>
<td>0.11</td>
<td>59646</td>
<td>9.941</td>
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</tbody>
</table>

Use a $k$ value of 0.07

### Total m<sub>1</sub> and m<sub>2</sub>

<table>
<thead>
<tr>
<th>Year</th>
<th>G (scf/y)</th>
<th>G (scm)</th>
<th>G' (scm)</th>
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<tbody>
<tr>
<td>1998</td>
<td>336337.5</td>
<td>48.049</td>
<td>7.087</td>
</tr>
<tr>
<td>1999</td>
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<td>2003</td>
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<td>48.049</td>
<td>7.087</td>
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<td>2005</td>
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<td>7.087</td>
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<td>7.087</td>
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</table>

Prepared By: AJM Date: 07/08/2008

Checked By: PJP Date: 28-08-08

41 Hutchins Drive
Portland, Maine 04102
207-774-2112
SECTION 4

Radius of Influence Calculations
RADIUS OF INFLUENCE CALCULATIONS

**Client, Project Name and Number**
- **PROJECT NAME:** Remedial Action Work Plan
- **PROJECT NO:** 222590
- **LOCATION:** Cranston, RI
- **CLIENT NAME:** CEBs

**Objective**

Calculate the radius of influence (R) and gas flow for each extraction well. The R represents the horizontal limit affected by a well's vacuum and is influenced by the refuse permeability, ratio of slitted to solid pipe, the applied vacuum, and refuse density. Any landfill gas generated outside the R is not collected by the extraction well.

**Method**

The ROI will be calculated using a theoretical model based on Darcy's Law.

**Definitions**

- \( q \): Landfill gas generation rate, ft\(^3\)/min
- \( Q_{well} \): Gas flow rate for each well, ft\(^3\)/min
- \( k_i \): Intrinsic Permeability of the Refuse, ft\(^2\)
- \( \phi \): Density of the Refuse, lbm/ft\(^3\)
- \( \eta \): Viscosity of Landfill Gas, lbm-ft/min/ft\(^2\)
- \( R \): Radius of influence, ft
- \( r \): Radius of well borehole, ft
- \( P_i \): Internal landfill pressure, lbm/ft\(^2\)
- \( P_{atm} \): Absolute pressure at wellhead, lbm/ft\(^2\)
- \( WD \): Well screen length, ft
- \( L \): Total well depth, ft
- \( E_s \): Efficiency of collection system, (1 = 100%)
- \( W \): Mass of Solid Waste, lbs

**Equations**

\[
q = \frac{Q_{ GENERATED}}{W}
\]

\[
k_i = \left[ \frac{p_r R^2 x \ln(R/r) x u_{par} x q x E_s}{[(P_{atm} - P_i) x (WD/L)]} \right]
\]

\[
Q_{well} = R^2 x WD x q
\]
RADIUS OF INFLUENCE CALCULATIONS

Assumptions

<table>
<thead>
<tr>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tons of waste from volume calcs</td>
</tr>
<tr>
<td>Gas Flow Rate from LandGas</td>
</tr>
<tr>
<td>Gas Generation Rate</td>
</tr>
<tr>
<td>Refuse Permeability</td>
</tr>
<tr>
<td>Refuse Density</td>
</tr>
<tr>
<td>Landfill Gas Viscosity</td>
</tr>
<tr>
<td>Borehole Radius</td>
</tr>
<tr>
<td>Atmospheric Pressure</td>
</tr>
<tr>
<td>Efficiency</td>
</tr>
</tbody>
</table>

Maximum ROI shall be set at 150 feet
RADIUS OF INFLUENCE CALCULATIONS

Client, Project Name and Number
PROJECT NAME: Remedial Action Work Plan
PROJECT NO: 220590
LOCATION: Cranston, RI
CLIENT NAME: Coba

Objective
Calculate the spacing for passive landfill gas vents based on Radius of Influence (R) calculations for an active landfill gas extraction system. The R represents the horizontal limit affected by a well’s vacuum and is influenced by the refuse permeability.

Method
The ROI will be calculated using the Waste Management/RUST design procedures as presented in MSW Management, March/April 2006 issue.

Definitions
ROI = Radius of influence, ft
Fp = Refuse Permeability Factor (typical values range from 3.5 to 6.5)
Sp = Distance from ground surface to top of slotted pipe, ft
mns = Relative layer permeability, ft/sec
Ms = Relative total cover permeability, ft/sec
d0 = Cover depth, ft
Do = Depth of Refuse (Well), ft
Qg = Unadjusted gas extraction rate, cfm
dp/dt = Gas Generation Rate (ft3/ft-year) (obtain from Gas Generation Curve for year 2009)
P = Waste Density (lb/ft3)

Equations
ROI = Fp x (Sp + mnCo)
Ms = Σ (Layer mn value) (Layer thickness) ≥ 1
Qg = ROI2 x Do x P x dp/dt

Assumptions

<table>
<thead>
<tr>
<th>Material Permeability</th>
<th>mn (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0E-03 (or more)</td>
<td>0.1</td>
</tr>
<tr>
<td>1.0E-04</td>
<td>0.4</td>
</tr>
<tr>
<td>1.0E-05</td>
<td>0.7</td>
</tr>
<tr>
<td>1.0E-06</td>
<td>0.9</td>
</tr>
<tr>
<td>1.0E-07</td>
<td>1.0</td>
</tr>
<tr>
<td>1.0E-08</td>
<td>1.1</td>
</tr>
<tr>
<td>1.0E-09 (or less)</td>
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</table>

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>Permeability</th>
<th>mn (cm/s)</th>
<th>Thickness (ft)</th>
<th>mn x t</th>
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<td>6&quot; Soil</td>
<td>5.2E-04</td>
<td>0.4</td>
<td>1.5000</td>
<td>0.60</td>
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<tr>
<td>2</td>
<td>PVC Cap</td>
<td>2.0E-11</td>
<td>1.2</td>
<td>1.0000</td>
<td>1.20</td>
</tr>
<tr>
<td>3</td>
<td>6&quot; Sand</td>
<td>5.8E-03</td>
<td>0.1</td>
<td>0.5000</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Assumptions
1. A geomembrane material shall have a soil equivalency of 1.5 feet.
2. A geocomposite clay liner shall have a soil equivalency of 8 inches.
3. The maximum ROI shall be set at 120 feet.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>Permeability</th>
<th>mn (cm/s)</th>
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<td>0.05</td>
</tr>
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2. A geocomposite clay liner shall have a soil equivalency of 8 inches.
3. The maximum ROI shall be set at 120 feet.
Solid Waste Properties

**North**

<table>
<thead>
<tr>
<th>D_i</th>
<th>d_0/d_i</th>
<th>ρ</th>
<th>F_x</th>
<th>Fs Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>See Calculations</td>
<td>0.066 ft³/ft³·yr</td>
<td>62 lbm/ft³</td>
<td>4</td>
<td>Slightly Conservative</td>
</tr>
<tr>
<td>5</td>
<td>62</td>
<td>0.066 ft³/ft³·yr</td>
<td>6.5</td>
<td>Very Aggressive, results in abnormally high ROIs</td>
</tr>
</tbody>
</table>

Note: d_0/d_i obtained from gas generation curve

**South**

<table>
<thead>
<tr>
<th>D_i</th>
<th>d_0/d_i</th>
<th>ρ</th>
<th>F_x</th>
<th>Fs Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>See Calculations</td>
<td>0.066 ft³/ft³·yr</td>
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<td>4</td>
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</tr>
<tr>
<td>5</td>
<td>62</td>
<td>0.066 ft³/ft³·yr</td>
<td>6.5</td>
<td>Very Aggressive, results in abnormally high ROIs</td>
</tr>
</tbody>
</table>

Calculations

### Inner Area

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<td>92</td>
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<tr>
<td>8</td>
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<td>90</td>
<td>10</td>
<td>6</td>
<td>4</td>
<td>0.40</td>
<td>58</td>
<td>0.82 0.54</td>
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<tr>
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<td>91</td>
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<td>6</td>
<td>5</td>
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<td>0.90 0.60</td>
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<td>90</td>
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<td>0.82 0.54</td>
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<td>0.90 0.60</td>
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### Outer Area

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<td>22.88 15.15</td>
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<td>20</td>
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<td>0.69</td>
<td>120</td>
<td>22.88 15.15</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>137.29 90.91</td>
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</table>

**Adjusted Flow Rate from Gas Generation Curve**
SECTION 5

Pipe Sizing
Header Pipe Sizing

**Objective**
The overall objective of the collection header system is to connect multiple extraction devices together for the purpose of transporting the extracted gas from the devices to the blowdown station.

**Method**
The header piping was sized using the Waste Management of North America, Inc. Landfill Gas Management System Design Procedures Manual, January 1996. The header piping calculations are based on landfill gas fill pressure drop and gas velocity. In addition the calculations include whether the landfill gas is concurent or countercurrent with condensate flow.

**Definitions**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>Gas Flow Rate (cfm)</td>
</tr>
<tr>
<td>dP</td>
<td>Pressure Drop (inches WC)</td>
</tr>
<tr>
<td>L</td>
<td>Header Pipe Length (feet)</td>
</tr>
<tr>
<td>d</td>
<td>Internal Diameter of Pipe (in)</td>
</tr>
</tbody>
</table>

**Assumptions**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>Specific Gravity of Gas (Approx. 0.86)</td>
</tr>
<tr>
<td>K</td>
<td>Sprunglass Constant = (d^2*0.1+3.64)=0.035d^0.5</td>
</tr>
</tbody>
</table>

**Equations**

SPRITZGLASS EQUATION

\[ G = 59.16TK(\text{UP/GL})^{0.5} \]

**Calculations**

<table>
<thead>
<tr>
<th>HEADER SECTION</th>
<th>PIPE LENGTH (feet)</th>
<th>FLOW RATE (cfm)</th>
<th>GAS SOURCE</th>
<th>PIPE DIAMETER (in)</th>
<th>FLOW TYPE (l or cc)</th>
<th>PRESSURE DROP (in WC)</th>
<th>PIPE DIA. CHECK (in)</th>
<th>FLOW AREA (aft)</th>
<th>GAS VELOCITY (fps)</th>
<th>PIPE DIA. CHECK (velocity)</th>
<th>SPRITZGLASS CONSTANT K</th>
</tr>
</thead>
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<td>NORTH</td>
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<td>3.97</td>
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<td>OK</td>
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<tr>
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<td>W8</td>
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<tr>
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<td>0.19</td>
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<td>0.09</td>
<td>0.19</td>
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| SOUTH          |                    |                 |            |                    |                     |                       |                     |                |                  |                           |                        | 0.80                   |

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<th>GAS SOURCE</th>
<th>PIPE DIAMETER (in)</th>
<th>FLOW TYPE (l or cc)</th>
<th>PRESSURE DROP (in WC)</th>
<th>PIPE DIA. CHECK (in)</th>
<th>FLOW AREA (aft)</th>
<th>GAS VELOCITY (fps)</th>
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**MAIN TRUNK TO BLOWER**

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0.20

**TOTAL PRESSURE DROP SYSTEM:** 1.15 MEETS DESIGN REQUIREMENT (<2.0 in WC) OK
DRAINAGE CALCULATIONS
Drainage Diagram for Cranston Landfill
HydroCAD® 8.00 s/n 004337 © 2006 HydroCAD Software Solutions LLC
### Area Listing (all nodes)

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<th>Area (acres)</th>
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<th>Description (subcats)</th>
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</table>
Subcatchment 1S: Watershed 1

Runoff = 8.45 cfs @ 12.09 hrs, Volume= 0.605 af, Depth= 1.56"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-year Rainfall=3.40"

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<td><strong>Sheet Flow,</strong> Grass: Short n= 0.150 P2= 3.40&quot;</td>
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<td><strong>Shallow Concentrated Flow,</strong> Short Grass Pasture Kv= 7.0 fps</td>
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<td><strong>Shallow Concentrated Flow,</strong> Short Grass Pasture Kv= 7.0 fps</td>
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4.2 320 Total, Increased to minimum Tc = 6.0 min

Subcatchment 2S: Watershed 2

Runoff = 8.09 cfs @ 12.09 hrs, Volume= 0.579 af, Depth= 1.56"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-year Rainfall=3.40"

<table>
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4.2 320 Total, Increased to minimum Tc = 6.0 min

Subcatchment 3S: Watershed 3

Runoff = 10.38 cfs @ 12.09 hrs, Volume= 0.743 af, Depth= 1.56"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-year Rainfall=3.40"
Plan Area

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4.2 320 Total, Increased to minimum Tc = 6.0 min

**Subcatchment 4S: Watershed 4**

Runoff = 6.44 cfs @ 12.09 hrs, Volume= 0.461 af, Depth= 1.56"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-year Rainfall=3.40"

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4.2 320 Total, Increased to minimum Tc = 6.0 min

**Reach 1R: Swale 1**

Inflow Area = 4.658 ac, Inflow Depth = 1.56" for 2-year event
Inflow = 8.45 cfs @ 12.09 hrs, Volume= 0.605 af
Outflow = 6.68 cfs @ 12.15 hrs, Volume= 0.605 af, Atten= 21%, Lag= 3.8 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.14 fps, Min. Travel Time= 6.8 min
Avg. Velocity = 0.63 fps, Avg. Travel Time= 22.8 min

Peak Storage= 2,721 cf @ 12.15 hrs, Average Depth at Peak Storage= 0.85'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 41.07 cfs
Cranston Landfill
Type III 24-hr 2-year Rainfall=3.40"

Prepared by Woodard & Curran
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Page 5 11/23/2009

2.00' x 2.00' deep channel, n= 0.035  Earth, dense weeds
Side Slope Z-value= 2.0 '/' Top Width= 10.00'
Length= 870.0'  Slope= 0.0057 '/'
Inlet Invert= 110.00', Outlet Invert= 105.00'

Reach 2R: Swale 2

Inflow Area = 4.459 ac, Inflow Depth = 1.56" for 2-year event
Inflow = 8.09 cfs @ 12.09 hrs, Volume= 0.579 af
Outflow = 6.43 cfs @ 12.15 hrs, Volume= 0.579 af, Atten= 21%, Lag= 3.7 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.41 fps, Min. Travel Time= 6.7 min
Avg. Velocity = 0.72 fps, Avg. Travel Time= 22.3 min

Peak Storage= 2,578 cf @ 12.15 hrs, Average Depth at Peak Storage= 0.76'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 49.25 cfs

2.00' x 2.00' deep channel, n= 0.035  Earth, dense weeds
Side Slope Z-value= 2.0 '/' Top Width= 10.00'
Length= 968.0'  Slope= 0.0083 '/'
Inlet Invert= 113.00', Outlet Invert= 105.00'

Reach 3R: Swale 3

Inflow Area = 5.722 ac, Inflow Depth = 1.56" for 2-year event
Inflow = 10.38 cfs @ 12.09 hrs, Volume= 0.743 af
Outflow = 8.15 cfs @ 12.15 hrs, Volume= 0.743 af, Atten= 21%, Lag= 3.8 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.72 fps, Min. Travel Time= 7.0 min
Avg. Velocity = 0.81 fps, Avg. Travel Time= 23.5 min

Peak Storage= 3,409 cf @ 12.15 hrs, Average Depth at Peak Storage= 0.82'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 53.24 cfs
2.00' x 2.00' deep channel, n= 0.035  Earth, dense weeds
Side Slope Z-value= 2.0 '/'  Top Width= 10.00'
Length= 1,139.0’  Slope= 0.0097 '/'
Inlet Invert= 113.00', Outlet Invert= 102.00'

Reach 4R: Swale 4

Inflow Area = 3.549 ac, Inflow Depth = 1.56'' for 2-year event
Inflow = 6.44 cfs @ 12.09 hrs, Volume= 0.461 af
Outflow = 5.80 cfs @ 12.13 hrs, Volume= 0.461 af, Atten= 10%, Lag= 2.4 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.68 fps, Min. Travel Time= 3.6 min
Avg. Velocity = 0.85 fps, Avg. Travel Time= 11.5 min

Peak Storage= 1,261 cf @ 12.13 hrs, Average Depth at Peak Storage= 0.65'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 59.31 cfs

2.00' x 2.00' deep channel, n= 0.035  Earth, dense weeds
Side Slope Z-value= 2.0 '/'  Top Width= 10.00'
Length= 584.0’  Slope= 0.0120 '/'
Inlet Invert= 110.00', Outlet Invert= 103.00'

Reach 5R: 30" Culvert

Inflow Area = 9.271 ac, Inflow Depth = 1.56'' for 2-year event
Inflow = 13.86 cfs @ 12.14 hrs, Volume= 1.203 af
Outflow = 13.86 cfs @ 12.14 hrs, Volume= 1.203 af, Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 12.44 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 3.95 fps, Avg. Travel Time= 0.1 min

Peak Storage= 28 cf @ 12.14 hrs, Average Depth at Peak Storage= 0.70'
Bank-Full Depth= 2.50', Capacity at Bank-Full= 82.03 cfs
30.0" Diameter Pipe,  n= 0.013  Corrugated PE, smooth interior
Length= 25.0'  Slope= 0.0400 '/'
Inlet Invert= 99.00', Outlet Invert= 98.00'

Reach 6R: 30" Culvert

Inflow Area = 9.117 ac, Inflow Depth = 1.56" for 2-year event
Inflow = 13.11 cfs @ 12.15 hrs, Volume= 1.183 af
Outflow = 13.11 cfs @ 12.15 hrs, Volume= 1.183 af, Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 12.24 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 3.91 fps, Avg. Travel Time= 0.1 min

Peak Storage= 27 cf @ 12.15 hrs, Average Depth at Peak Storage= 0.68'
Bank-Full Depth= 2.50', Capacity at Bank-Full= 82.03 cfs

30.0" Diameter Pipe,  n= 0.013  Corrugated PE, smooth interior
Length= 25.0'  Slope= 0.0400 '/'
Inlet Invert= 101.00', Outlet Invert= 100.00'

Reach 7R: Existing Riprap Drainage Swale (regraded)

Inflow Area = 9.271 ac, Inflow Depth = 1.56" for 2-year event
Inflow = 13.86 cfs @ 12.14 hrs, Volume= 1.203 af
Outflow = 13.43 cfs @ 12.17 hrs, Volume= 1.203 af, Atten= 3%, Lag= 1.8 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.29 fps, Min. Travel Time= 2.2 min
Avg. Velocity = 1.01 fps, Avg. Travel Time= 7.1 min

Peak Storage= 1,756 cf @ 12.17 hrs, Average Depth at Peak Storage= 0.88'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 84.19 cfs
Cranston Landfill
Prepared by Woodard & Curran
HydroCAD® 8.00 s/h 004337 © 2006 HydroCAD Software Solutions LLC 11/23/2009

Type III 24-hr 2-year Rainfall=3.40"

2.00' x 2.00' deep channel, n= 0.110
Side Slope Z-value= 3.0 '/' Top Width= 14.00'
Length= 430.0' Slope= 0.1349 '/'
Inlet Invert= 98.00', Outlet Invert= 40.00'

Reach 8R: Existing Riprap Drainage Swale (regraded)

Inflow Area = 9.117 ac, Inflow Depth = 1.56" for 2-year event
Inflow = 13.11 cfs @ 12.15 hrs, Volume= 1.183 af
Outflow = 12.91 cfs @ 12.18 hrs, Volume= 1.183 af, Atten= 2%, Lag= 1.3 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.56 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 1.04 fps, Avg. Travel Time= 5.6 min

Peak Storage= 1,267 cf @ 12.18 hrs, Average Depth at Peak Storage= 0.71'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 114.15 cfs

3.00' x 2.00' deep channel, n= 0.110
Side Slope Z-value= 3.0 '/' Top Width= 15.00'
Length= 350.0' Slope= 0.1829 '/'
Inlet Invert= 100.00', Outlet Invert= 36.00'

‡

Pond 9P: Plunge Pool #1

Inflow Area = 9.117 ac, Inflow Depth = 1.56" for 2-year event
Inflow = 12.91 cfs @ 12.18 hrs, Volume= 1.183 af
Outflow = 12.90 cfs @ 12.18 hrs, Volume= 1.180 af, Atten= 0%, Lag= 0.4 min
Primary = 12.90 cfs @ 12.18 hrs, Volume= 1.180 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 27.33' @ 12.18 hrs Surf.Area= 529 sf Storage= 482 cf

Plug-Flow detention time= 3.2 min calculated for 1.180 af (100% of inflow)
Center-of-Mass det. time= 1.4 min ( 857.1 - 855.6 )
Cranston Landfill

<table>
<thead>
<tr>
<th>Volume</th>
<th>Invert</th>
<th>Avail.Storage</th>
<th>Storage Description</th>
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<tbody>
<tr>
<td>#1</td>
<td>26.00'</td>
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<td>Custom Stage Data (Prismatic) Listed below (Recalc)</td>
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<td>(cubic-feet)</td>
<td>(cubic-feet)</td>
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<td>27.00</td>
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<tr>
<td>28.00</td>
<td>706</td>
<td>575</td>
<td>899</td>
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</tbody>
</table>

Device Routing Invert Outlet Devices

#1 Primary 26.50' 6.0' long x 1.0' breadth Broad-Crested Rectangular Weir

Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00
2.50 3.00

Coef. (English) 2.69 2.72 2.75 2.85 2.98 3.08 3.20 3.28 3.31
3.30 3.31 3.32

Primary OutFlow Max=12.89 cfs @ 12.18 hrs HW=27.33' (Free Discharge)

↑→1=Broad-Crested Rectangular Weir (Weir Controls 12.89 cfs @ 2.60 fps)

Pond 10P: Plunge Pool #2

Inflow Area = 9.271 ac, Inflow Depth = 1.56" for 2-year event

Inflow = 13.43 cfs @ 12.17 hrs, Volume= 1.203 af
Outflow = 13.43 cfs @ 12.17 hrs, Volume= 1.201 af, Atten= 0%, Lag= 0.1 min
Primary = 13.43 cfs @ 12.17 hrs, Volume= 1.201 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 41.14' @ 12.17 hrs Surf.Area= 267 sf Storage= 232 cf

Plug-Flow detention time= 2.0 min calculated for 1.201 af (100% of inflow)
Center-of-Mass det. time= 0.7 min ( 855.3 - 854.6 )

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<td>41.00</td>
<td>248</td>
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</tr>
<tr>
<td>42.00</td>
<td>378</td>
<td>313</td>
<td>509</td>
</tr>
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</table>

Device Routing Invert Outlet Devices

#1 Primary 40.50' 10.0' long x 2.0' breadth Broad-Crested Rectangular Weir

Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00
2.50 3.00 3.50

Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88
2.85 3.07 3.20 3.32

Primary OutFlow Max=13.42 cfs @ 12.17 hrs HW=41.14' (Free Discharge)

↑→1=Broad-Crested Rectangular Weir (Weir Controls 13.42 cfs @ 2.09 fps)
Subcatchment 1S: Watershed 1

Runoff = 15.80 cfs @ 12.09 hrs, Volume= 1.123 af, Depth= 2.89"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-year Rainfall=5.00"

<table>
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<th>Area (sf)</th>
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<td>Pervious Area</td>
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<table>
<thead>
<tr>
<th>Tc (min)</th>
<th>Length (feet)</th>
<th>Slope (ft/ft)</th>
<th>Velocity (ft/sec)</th>
<th>Capacity (cfs)</th>
<th>Description</th>
</tr>
</thead>
</table>
| 2.1      | 30            | 0.0800        | 0.24              |                | **Sheet Flow**, Grass: Short n= 0.150  P2= 3.40"
| 1.6      | 190           | 0.0800        | 1.98              |                | **Shallow Concentrated Flow**, Short Grass Pasture Kv= 7.0 fps |
| 0.5      | 100           | 0.2000        | 3.13              |                | **Shallow Concentrated Flow**, Short Grass Pasture Kv= 7.0 fps |

4.2 320 Total, Increased to minimum Tc = 6.0 min

Subcatchment 2S: Watershed 2

Runoff = 15.13 cfs @ 12.09 hrs, Volume= 1.075 af, Depth= 2.89"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-year Rainfall=5.00"

<table>
<thead>
<tr>
<th>Area (sf)</th>
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<th>Length (feet)</th>
<th>Slope (ft/ft)</th>
<th>Velocity (ft/sec)</th>
<th>Capacity (cfs)</th>
<th>Description</th>
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</table>
| 2.1      | 30            | 0.0800        | 0.24              |                | **Sheet Flow**, Grass: Short n= 0.150  P2= 3.40"
| 1.6      | 190           | 0.0800        | 1.98              |                | **Shallow Concentrated Flow**, Short Grass Pasture Kv= 7.0 fps |
| 0.5      | 100           | 0.2000        | 3.13              |                | **Shallow Concentrated Flow**, Short Grass Pasture Kv= 7.0 fps |

4.2 320 Total, Increased to minimum Tc = 6.0 min

Subcatchment 3S: Watershed 3

Runoff = 19.41 cfs @ 12.09 hrs, Volume= 1.379 af, Depth= 2.89"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-year Rainfall=5.00"
Cranston Landfill

Type III 24-hr 10-year Rainfall=5.00"

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<table>
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<tr>
<th>Area (sf)</th>
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<tr>
<td>2.1</td>
<td>30</td>
<td>0.0800</td>
<td>0.24</td>
<td></td>
<td><strong>Sheet Flow</strong>&lt;br&gt;Grass: Short n= 0.150 P2= 3.40&quot;</td>
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<tr>
<td>1.6</td>
<td>190</td>
<td>0.0800</td>
<td>1.98</td>
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<td><strong>Shallow Concentrated Flow</strong>&lt;br&gt;Short Grass Pasture Kv= 7.0 fps</td>
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<td>0.5</td>
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<td><strong>Shallow Concentrated Flow</strong>&lt;br&gt;Short Grass Pasture Kv= 7.0 fps</td>
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</tbody>
</table>

4.2 320 Total, Increased to minimum Tc = 6.0 min

Subcatchment 4S: Watershed 4

Runoff = 12.04 cfs @ 12.09 hrs, Volume= 0.856 af, Depth= 2.89"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-year Rainfall=5.00"

<table>
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<td>2.1</td>
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<td>0.24</td>
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<td><strong>Sheet Flow</strong>&lt;br&gt;Grass: Short n= 0.150 P2= 3.40&quot;</td>
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<tr>
<td>1.6</td>
<td>190</td>
<td>0.0800</td>
<td>1.98</td>
<td></td>
<td><strong>Shallow Concentrated Flow</strong>&lt;br&gt;Short Grass Pasture Kv= 7.0 fps</td>
</tr>
<tr>
<td>0.5</td>
<td>100</td>
<td>0.2000</td>
<td>3.13</td>
<td></td>
<td><strong>Shallow Concentrated Flow</strong>&lt;br&gt;Short Grass Pasture Kv= 7.0 fps</td>
</tr>
</tbody>
</table>

4.2 320 Total, Increased to minimum Tc = 6.0 min

Reach 1R: Swale 1

Inflow Area = 4.658 ac, Inflow Depth = 2.89" for 10-year event
Inflow = 15.80 cfs @ 12.09 hrs, Volume= 1.123 af
Outflow = 13.09 cfs @ 12.14 hrs, Volume= 1.123 af, Atten= 17%, Lag= 3.3 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.55 fps, Min. Travel Time= 5.7 min
Avg. Velocity= 0.74 fps, Avg. Travel Time= 19.6 min

Peak Storage= 4.464 cf @ 12.14 hrs, Average Depth at Peak Storage= 1.18'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 41.07 cfs
2.00' x 2.00' deep channel, n= 0.035  Earth, dense weeds
Side Slope Z-value= 2.0  '/' Top Width= 10.00'
Length= 870.0'  Slope= 0.0057  '/'
Inlet Invert= 110.00', Outlet Invert= 105.00'

Reach 2R: Swale 2

Inflow Area = 4.459 ac, Inflow Depth = 2.89" for 10-year event
Inflow = 15.13 cfs @ 12.09 hrs, Volume= 1.075 af
Outflow = 12.59 cfs @ 12.14 hrs, Volume= 1.075 af, Atten= 17%, Lag= 3.2 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.89 fps, Min. Travel Time= 5.6 min
Avg. Velocity = 0.84 fps, Avg. Travel Time = 19.1 min

Peak Storage= 4,220 cf @ 12.14 hrs, Average Depth at Peak Storage= 1.06'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 49.25 cfs

2.00' x 2.00' deep channel, n= 0.035  Earth, dense weeds
Side Slope Z-value= 2.0  '/' Top Width= 10.00'
Length= 968.0'  Slope= 0.0083  '/'
Inlet Invert= 113.00', Outlet Invert= 105.00'

Reach 3R: Swale 3

Inflow Area = 5.722 ac, Inflow Depth = 2.89" for 10-year event
Inflow = 19.41 cfs @ 12.09 hrs, Volume= 1.379 af
Outflow = 16.00 cfs @ 12.14 hrs, Volume= 1.379 af, Atten= 18%, Lag= 3.3 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.26 fps, Min. Travel Time= 5.8 min
Avg. Velocity = 0.94 fps, Avg. Travel Time = 20.1 min

Peak Storage= 5,594 cf @ 12.14 hrs, Average Depth at Peak Storage= 1.14'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 53.24 cfs
Cranston Landfill

2.00' x 2.00' deep channel, n= 0.035  Earth, dense weeds
Side Slope Z-value= 2.0 '/' Top Width= 10.00'
Length= 1,139.0'  Slope= 0.0097 '/'
Inlet Invert= 113.00', Outlet Invert= 102.00'

Reach 4R: Swale 4

Inflow Area = 3.549 ac, Inflow Depth = 2.89" for 10-year event
Inflow = 12.04 cfs @ 12.09 hrs, Volume= 0.856 af
Outflow = 11.11 cfs @ 12.12 hrs, Volume= 0.856 af, Atten= 8%, Lag= 2.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.20 fps, Min. Travel Time= 3.0 min
Avg. Velocity = 0.99 fps, Avg. Travel Time= 9.8 min

Peak Storage= 2,025 cf @ 12.12 hrs, Average Depth at Peak Storage= 0.91'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 59.31 cfs

2.00' x 2.00' deep channel, n= 0.035  Earth, dense weeds
Side Slope Z-value= 2.0 '/' Top Width= 10.00'
Length= 584.0'  Slope= 0.0120 '/'
Inlet Invert= 110.00', Outlet Invert= 103.00'

Reach 5R: 30" Culvert

Inflow Area = 9.271 ac, Inflow Depth = 2.89" for 10-year event
Inflow = 26.95 cfs @ 12.13 hrs, Volume= 2.235 af
Outflow = 26.95 cfs @ 12.13 hrs, Volume= 2.235 af, Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 14.97 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 4.54 fps, Avg. Travel Time= 0.1 min

Peak Storage= 45 cf @ 12.13 hrs, Average Depth at Peak Storage= 0.99'
Bank-Full Depth= 2.50', Capacity at Bank-Full= 82.03 cfs
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Type III 24-hr 10-year Rainfall=5.00"

30.0" Diameter Pipe, n= 0.013  Corrugated PE, smooth interior
Length= 25.0'  Slope= 0.0400 '/'
Inlet Invert= 99.00', Outlet Invert= 98.00'

Reach 6R: 30" Culvert

Inflow Area = 9.117 ac, Inflow Depth = 2.89"  for 10-year event
Inflow = 25.68 cfs @ 12.14 hrs, Volume= 2.198 af
Outflow = 25.68 cfs @ 12.14 hrs, Volume= 2.198 af, Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 14.78 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 4.49 fps, Avg. Travel Time= 0.1 min

Peak Storage= 43 cf @ 12.14 hrs, Average Depth at Peak Storage= 0.96'
Bank-Full Depth= 2.50', Capacity at Bank-Full= 82.03 cfs

30.0" Diameter Pipe, n= 0.013  Corrugated PE, smooth interior
Length= 25.0'  Slope= 0.0400 '/'
Inlet Invert= 101.00', Outlet Invert= 100.00'

Reach 7R: Existing Riprap Drainage Swale (regraded)

Inflow Area = 9.271 ac, Inflow Depth = 2.89"  for 10-year event
Inflow = 26.95 cfs @ 12.13 hrs, Volume= 2.235 af
Outflow = 26.29 cfs @ 12.16 hrs, Volume= 2.235 af, Atten= 2%, Lag= 1.4 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.91 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 1.17 fps, Avg. Travel Time= 6.1 min

Peak Storage= 2,889 cf @ 12.16 hrs, Average Depth at Peak Storage= 1.20'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 84.19 cfs
Cranston Landfill

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2.00' x 2.00' deep channel, n= 0.110
Side Slope Z-value= 3.0 '/' Top Width= 14.00'
Length= 430.0' Slope= 0.1349 '/'
Inlet Invert= 98.00', Outlet Invert= 40.00'

Reach 8R: Existing Riprap Drainage Swale (regraded)

Inflow Area = 9.117 ac, Inflow Depth = 2.89'' for 10-year event
Inflow = 25.68 cfs @ 12.14 hrs, Volume= 2.198 af
Outflow = 25.37 cfs @ 12.16 hrs, Volume= 2.198 af, Attn= 1%, Lag= 1.1 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.28 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 1.21 fps, Avg. Travel Time= 4.8 min

Peak Storage= 2,072 cf @ 12.16 hrs, Average Depth at Peak Storage= 0.99'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 114.15 cfs

3.00' x 2.00' deep channel, n= 0.110
Side Slope Z-value= 3.0 '/' Top Width= 15.00'
Length= 350.0' Slope= 0.1829 '/'
Inlet Invert= 100.00', Outlet Invert= 36.00'

‡

Pond 9P: Plunge Pool #1

Inflow Area = 9.117 ac, Inflow Depth = 2.89'' for 10-year event
Inflow = 25.37 cfs @ 12.16 hrs, Volume= 2.198 af
Outflow = 25.34 cfs @ 12.17 hrs, Volume= 2.195 af, Attn= 0%, Lag= 0.3 min
Primary = 25.34 cfs @ 12.17 hrs, Volume= 2.195 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 27.73' @ 12.17 hrs Surf.Area= 635 sf Storage= 718 cf

Plug-Flow detention time= 2.2 min calculated for 2.195 af (100% of inflow)
Center-of-Mass det. time= 1.1 min ( 836.2 - 835.1 )
Cranston Landfill

Type III 24-hr 10-year Rainfall=5.00"  
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Volume | Invert | Avail.Storage | Storage Description
---|---|---|---
#1 | 26.00' | 899 cf | **Custom Stage Data (Prismatic)** Listed below (Recalc)

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<tr>
<td>26.00</td>
<td>204</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>27.00</td>
<td>444</td>
<td>324</td>
<td>324</td>
</tr>
<tr>
<td>28.00</td>
<td>706</td>
<td>575</td>
<td>899</td>
</tr>
</tbody>
</table>

Device | Routing | Invert | Outlet Devices
---|---|---|---
#1 | Primary | 26.50' | **6.0' long x 1.0' breadth Broad-Crested Rectangular Weir**  
Head (feet) | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.20 | 1.40 | 1.60 | 1.80 | 2.00 | 2.50 | 3.00  
Coef. (English) | 2.69 | 2.72 | 2.75 | 2.85 | 2.98 | 3.08 | 3.20 | 3.28 | 3.31 | 3.30 | 3.31 | 3.32 |

**Primary OutFlow**  
Max=25.32 cfs @ 12.17 hrs  
HW=27.73' (Free Discharge)  
†=1=Broad-Crested Rectangular Weir  
(Weir Controls 25.32 cfs @ 3.43 fps)

**Pond 10P: Plunge Pool #2**

Inflow Area = 9.271 ac, Inflow Depth = 2.89" for 10-year event  
Inflow = 26.29 cfs @ 12.16 hrs, Volume= 2.235 af  
Outflow = 26.29 cfs @ 12.16 hrs, Volume= 2.233 af, Atten= 0%, Lag= 0.1 min  
Primary = 26.29 cfs @ 12.16 hrs, Volume= 2.233 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3  
Peak Elev= 41.49' @ 12.16 hrs  
Surf.Area= 312 sf, Storage= 333 cf

Plug-Flow detention time= 1.2 min calculated for 2.233 af (100% of inflow)  
Center-of-Mass det. time= 0.6 min ( 834.8 - 834.3 )

Volume | Invert | Avail.Storage | Storage Description
---|---|---|---
#1 | 40.00' | 509 cf | **Custom Stage Data (Prismatic)** Listed below (Recalc)

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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>41.00</td>
<td>248</td>
<td>196</td>
<td>196</td>
</tr>
<tr>
<td>42.00</td>
<td>378</td>
<td>313</td>
<td>509</td>
</tr>
</tbody>
</table>

Device | Routing | Invert | Outlet Devices
---|---|---|---
#1 | Primary | 40.50' | **10.0' long x 2.0' breadth Broad-Crested Rectangular Weir**  
Head (feet) | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.20 | 1.40 | 1.60 | 1.80 | 2.00 | 2.50 | 3.00 | 3.50  
Coef. (English) | 2.54 | 2.61 | 2.61 | 2.66 | 2.66 | 2.70 | 2.77 | 2.89 | 2.88 | 2.85 | 3.07 | 3.20 | 3.32 |

**Primary OutFlow**  
Max=26.29 cfs @ 12.16 hrs  
HW=41.49' (Free Discharge)  
†=1=Broad-Crested Rectangular Weir  
(Weir Controls 26.29 cfs @ 2.65 fps)
Cranston Landfill
Type III 24-hr 25-year Rainfall=6.20"

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11/23/2009

Subcatchment 1S: Watershed 1

Runoff = 21.53 cfs @ 12.09 hrs, Volume= 1.538 af, Depth= 3.96"
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-year Rainfall=6.20"

<table>
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4.2 320 Total, Increased to minimum Tc = 6.0 min

Subcatchment 2S: Watershed 2

Runoff = 20.61 cfs @ 12.09 hrs, Volume= 1.472 af, Depth= 3.96"
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-year Rainfall=6.20"

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4.2 320 Total, Increased to minimum Tc = 6.0 min

Subcatchment 3S: Watershed 3

Runoff = 26.45 cfs @ 12.09 hrs, Volume= 1.889 af, Depth= 3.96"
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-year Rainfall=6.20"
### Cranston Landfill

**Type III 24-hr 25-year Rainfall=6.20"**

**Prepared by Woodard & Curran**

**HydroCAD® 8.00 s/h 004337 © 2006 HydroCAD Software Solutions LLC**

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4.2 320 Total, Increased to minimum Tc = 6.0 min

**Subcatchment 4S: Watershed 4**

Runoff  = 16.41 cfs @ 12.09 hrs, Volume= 1.172 af, Depth= 3.96"  

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs  
Type III 24-hr 25-year Rainfall=6.20"

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4.2 320 Total, Increased to minimum Tc = 6.0 min

**Reach 1R: Swale 1**

Inflow Area = 4.658 ac, Inflow Depth = 3.96" for 25-year event

Inflow = 21.53 cfs @ 12.09 hrs, Volume= 1.538 af

Outflow = 18.20 cfs @ 12.14 hrs, Volume= 1.538 af, Atten= 15%, Lag= 3.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.78 fps, Min. Travel Time= 5.2 min
Avg. Velocity= 0.80 fps, Avg. Travel Time= 18.1 min

Peak Storage= 5,696 cf @ 12.14 hrs, Average Depth at Peak Storage= 1.38'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 41.07 cfs
Cranston Landfill

Type III 24-hr 25-year Rainfall=6.20"

Prepared by Woodard & Curran
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11/23/2009

Reach 2R: Swale 2

Inflow Area = 4.459 ac, Inflow Depth = 3.96" for 25-year event
Inflow = 20.61 cfs @ 12.09 hrs, Volume = 1.472 af
Outflow = 17.49 cfs @ 12.14 hrs, Volume = 1.472 af, Atten= 15%, Lag= 3.0 min
Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.15 fps, Min. Travel Time= 5.1 min
Avg. Velocity = 0.91 fps, Avg. Travel Time = 17.7 min

Peak Storage = 5,379 cf @ 12.14 hrs, Average Depth at Peak Storage = 1.24'
Bank-Full Depth = 2.00', Capacity at Bank-Full= 49.25 cfs

2.00' x 2.00' deep channel, n= 0.035 Earth, dense weeds
Side Slope Z-value= 2.0 '/' Top Width= 10.00'
Length= 870.0' Slope= 0.0057 '/'
Inlet Invert= 110.00', Outlet Invert= 105.00'

Reach 3R: Swale 3

Inflow Area = 5.722 ac, Inflow Depth = 3.96" for 25-year event
Inflow = 26.45 cfs @ 12.09 hrs, Volume = 1.889 af
Outflow = 22.24 cfs @ 12.14 hrs, Volume = 1.889 af, Atten= 16%, Lag= 3.1 min
Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.55 fps, Min. Travel Time= 5.3 min
Avg. Velocity = 1.02 fps, Avg. Travel Time = 18.6 min

Peak Storage = 7,139 cf @ 12.14 hrs, Average Depth at Peak Storage = 1.34'
Bank-Full Depth = 2.00', Capacity at Bank-Full= 53.24 cfs
Reach 4R: Swale 4

Inflow Area = 3.549 ac, Inflow Depth = 3.96" for 25-year event
Inflow = 16.41 cfs @ 12.09 hrs, Volume = 1.172 af
Outflow = 15.28 cfs @ 12.12 hrs, Volume = 1.172 af, Atten = 7%, Lag = 1.9 min

Routing by Dyn-Stor-Ind method, Time Span = 0.00-72.00 hrs, dt = 0.01 hrs / 3
Max. Velocity = 3.49 fps, Min. Travel Time = 2.8 min
Avg. Velocity = 1.07 fps, Avg. Travel Time = 9.1 min

Peak Storage = 2,561 cf @ 12.12 hrs, Average Depth at Peak Storage = 1.06'
Bank-Full Depth = 2.00', Capacity at Bank-Full = 59.31 cfs

Reach 5R: 30" Culvert

Inflow Area = 9.271 ac, Inflow Depth = 3.96" for 25-year event
Inflow = 37.33 cfs @ 12.13 hrs, Volume = 3.061 af
Outflow = 37.33 cfs @ 12.13 hrs, Volume = 3.061 af, Atten = 0%, Lag = 0.0 min

Routing by Dyn-Stor-Ind method, Time Span = 0.00-72.00 hrs, dt = 0.01 hrs / 3
Max. Velocity = 16.32 fps, Min. Travel Time = 0.0 min
Avg. Velocity = 4.88 fps, Avg. Travel Time = 0.1 min

Peak Storage = 57 cf @ 12.13 hrs, Average Depth at Peak Storage = 1.18'
Bank-Full Depth = 2.50', Capacity at Bank-Full = 82.03 cfs
30.0" Diameter Pipe, n= 0.013 Corrugated PE, smooth interior
Length= 25.0'  Slope= 0.0400 '/'
Inlet Invert= 99.00', Outlet Invert= 98.00'

Reach 6R: 30" Culvert

Inflow Area = 9.117 ac, Inflow Depth = 3.96" for 25-year event
Inflow = 35.69 cfs @ 12.14 hrs, Volume= 3.010 af
Outflow = 35.69 cfs @ 12.14 hrs, Volume= 3.010 af, Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 16.13 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 4.83 fps, Avg. Travel Time= 0.1 min

Peak Storage= 55 cf @ 12.14 hrs, Average Depth at Peak Storage= 1.15'
Bank-Full Depth= 2.50', Capacity at Bank-Full= 82.03 cfs

30.0" Diameter Pipe, n= 0.013 Corrugated PE, smooth interior
Length= 25.0'  Slope= 0.0400 '/'
Inlet Invert= 101.00', Outlet Invert= 100.00'

Reach 7R: Existing Riprap Drainage Swale (regraded)

Inflow Area = 9.271 ac, Inflow Depth = 3.96" for 25-year event
Inflow = 37.33 cfs @ 12.13 hrs, Volume= 3.061 af
Outflow = 36.53 cfs @ 12.15 hrs, Volume= 3.061 af, Atten= 2%, Lag= 1.3 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.26 fps, Min. Travel Time= 1.7 min
Avg. Velocity = 1.26 fps, Avg. Travel Time= 5.7 min

Peak Storage= 3,689 cf @ 12.15 hrs, Average Depth at Peak Storage= 1.39'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 84.19 cfs
2.00' x 2.00' deep channel, n= 0.110
Side Slope Z-value= 3.0 '/' Top Width= 14.00'
Length= 430.0'  Slope= 0.1349 '/'
Inlet Invert= 98.00', Outlet Invert= 40.00'

Reach 8R: Existing Riprap Drainage Swale (regraded)

Inflow Area = 9.117 ac, Inflow Depth = 3.96" for 25-year event
Inflow = 35.69 cfs @ 12.14 hrs, Volume= 3.010 af
Outflow = 35.30 cfs @ 12.15 hrs, Volume= 3.010 af, Atten= 1%, Lag= 1.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.68 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 1.31 fps, Avg. Travel Time= 4.4 min

Peak Storage= 2,641 cf @ 12.15 hrs, Average Depth at Peak Storage= 1.16'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 114.15 cfs

3.00' x 2.00' deep channel, n= 0.110
Side Slope Z-value= 3.0 '/' Top Width= 15.00'
Length= 350.0'  Slope= 0.1829 '/'
Inlet Invert= 100.00', Outlet Invert= 36.00'

Pond 9P: Plunge Pool #1

Inflow Area = 9.117 ac, Inflow Depth = 3.96" for 25-year event
Inflow = 35.30 cfs @ 12.15 hrs, Volume= 3.010 af
Outflow = 35.26 cfs @ 12.16 hrs, Volume= 3.007 af, Atten= 0%, Lag= 0.3 min
Primary = 35.26 cfs @ 12.16 hrs, Volume= 3.007 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 27.99' @ 12.16 hrs  Surf.Area= 703 sf  Storage= 891 cf

Plug-Flow detention time= 1.8 min calculated for 3.007 af (100% of inflow)
Center-of-Mass det. time= 1.0 min ( 826.0 - 825.0 )
### Cranston Landfill

**Type III 24-hr 25-year Rainfall=6.20"**

Prepared by Woodard & Curran
HydroCAD® 8.00 s/h 004337 © 2006 HydroCAD Software Solutions LLC

#### Volume

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**Custom Stage Data (Prismatic)** Listed below (Recalc)

**Device** | **Routing** | **Invert** | **Outlet Devices**
--- | --- | --- | ---
#1 | Primary | 26.50' | 6.0' long x 1.0' breadth Broad-Crested Rectangular Weir
Head (feet) | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.20 | 1.40 | 1.60 | 1.80 | 2.00
2.50 | 3.00 | Coef. (English) | 2.69 | 2.72 | 2.75 | 2.85 | 2.98 | 3.08 | 3.20 | 3.28 | 3.31
3.30 | 3.31 | 3.32 |

**Primary OutFlow** Max=35.25 cfs @ 12.16 hrs HW=27.99' (Free Discharge)
↑−1=Broad-Crested Rectangular Weir (Weir Controls 35.25 cfs @ 3.95 fps)

### Pond 10P: Plunge Pool #2

Inflow Area = 9.271 ac, Inflow Depth = 3.96" for 25-year event
Inflow = 36.53 cfs @ 12.15 hrs, Volume= 3.061 af
Outflow = 36.52 cfs @ 12.15 hrs, Volume= 3.059 af, Attenu= 0%, Lag= 0.1 min
Primary = 36.52 cfs @ 12.15 hrs, Volume= 3.059 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 41.72' @ 12.15 hrs Surf.Area= 342 sf Storage= 408 cf

Plug-Flow detention time= 1.1 min calculated for 3.059 af (100% of inflow)
Center-of-Mass det. time= 0.5 min (824.7 - 824.2)

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**Custom Stage Data (Prismatic)** Listed below (Recalc)

**Device** | **Routing** | **Invert** | **Outlet Devices**
--- | --- | --- | ---
#1 | Primary | 40.50' | 10.0' long x 2.0' breadth Broad-Crested Rectangular Weir
Head (feet) | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.20 | 1.40 | 1.60 | 1.80 | 2.00
2.50 | 3.00 | 3.50 | Coef. (English) | 2.54 | 2.61 | 2.61 | 2.60 | 2.66 | 2.70 | 2.77 | 2.89 | 2.88
2.85 | 3.07 | 3.20 | 3.32 |

**Primary OutFlow** Max=36.48 cfs @ 12.15 hrs HW=41.72' (Free Discharge)
↑−1=Broad-Crested Rectangular Weir (Weir Controls 36.48 cfs @ 2.99 fps)
Subcatchment 1S: Watershed 1

Runoff = 34.59 cfs @ 12.09 hrs, Volume= 2.513 af, Depth= 6.47"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-year Rainfall=8.90"

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4.2 320 Total, Increased to minimum Tc = 6.0 min

Subcatchment 2S: Watershed 2

Runoff = 33.12 cfs @ 12.09 hrs, Volume= 2.405 af, Depth= 6.47"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-year Rainfall=8.90"

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4.2 320 Total, Increased to minimum Tc = 6.0 min

Subcatchment 3S: Watershed 3

Runoff = 42.50 cfs @ 12.09 hrs, Volume= 3.087 af, Depth= 6.47"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-year Rainfall=8.90"
Cranston Landfill

Type III 24-hr 100-year Rainfall=8.90"

Prepared by Woodard & Curran

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**Subcatchment 4S: Watershed 4**

Runoff  = 26.36 cfs @ 12.09 hrs, Volume= 1.915 af, Depth= 6.47"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-year Rainfall=8.90"

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<td>30</td>
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<td><strong>Sheet Flow,</strong> Grass: Short  n= 0.150  P2= 3.40&quot;</td>
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<td>1.6</td>
<td>190</td>
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<tr>
<td>0.5</td>
<td>100</td>
<td>0.2000</td>
<td>3.13</td>
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<tr>
<td>4.2</td>
<td>320</td>
<td>Total, Increased to minimum Tc = 6.0 min</td>
<td></td>
<td></td>
<td></td>
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**Reach 1R: Swale 1**

Inflow Area = 4.658 ac, Inflow Depth = 6.47" for 100-year event
Inflow  = 34.59 cfs @ 12.09 hrs, Volume= 2.513 af
Outflow  = 30.01 cfs @ 12.13 hrs, Volume= 2.513 af, Atten= 13%, Lag= 2.8 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.16 fps, Min. Travel Time= 4.6 min
Avg. Velocity= 0.90 fps, Avg. Travel Time= 16.0 min

Peak Storage= 8,263 cf @ 12.13 hrs, Average Depth at Peak Storage= 1.74'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 41.07 cfs
2.00' x 2.00' deep channel, n= 0.035  Earth, dense weeds
Side Slope Z-value= 2.0 '/'  Top Width= 10.00'
Length= 870.0'  Slope= 0.0057 '/'
Inlet Invert= 110.00', Outlet Invert= 105.00'

Reach 2R: Swale 2

Inflow Area = 4.459 ac, Inflow Depth = 6.47" for 100-year event
Inflow = 33.12 cfs @ 12.09 hrs, Volume= 2.405 af
Outflow = 28.83 cfs @ 12.13 hrs, Volume= 2.405 af, Attn= 13%, Lag= 2.7 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.58 fps, Min. Travel Time= 4.5 min
Avg. Velocity = 1.03 fps, Avg. Travel Time= 15.6 min

Peak Storage= 7,795 cf @ 12.13 hrs, Average Depth at Peak Storage= 1.57'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 49.25 cfs

2.00' x 2.00' deep channel, n= 0.035  Earth, dense weeds
Side Slope Z-value= 2.0 '/'  Top Width= 10.00'
Length= 968.0'  Slope= 0.0083 '/'
Inlet Invert= 113.00', Outlet Invert= 105.00'

Reach 3R: Swale 3

Inflow Area = 5.722 ac, Inflow Depth = 6.47" for 100-year event
Inflow = 42.50 cfs @ 12.09 hrs, Volume= 3.087 af
Outflow = 36.71 cfs @ 12.13 hrs, Volume= 3.087 af, Attn= 14%, Lag= 2.8 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.04 fps, Min. Travel Time= 4.7 min
Avg. Velocity = 1.15 fps, Avg. Travel Time= 16.5 min

Peak Storage= 10,359 cf @ 12.13 hrs, Average Depth at Peak Storage= 1.69'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 53.24 cfs
2.00' x 2.00' deep channel, n= 0.035  Earth, dense weeds  
Side Slope Z-value= 2.0 '/'  Top Width= 10.00'  
Length= 1,139.0'  Slope= 0.0097 '/'  
Inlet Invert= 113.00', Outlet Invert= 102.00'

Reach 4R: Swale 4

Inflow Area = 3.549 ac, Inflow Depth = 6.47" for 100-year event  
Inflow = 26.36 cfs @ 12.09 hrs, Volume= 1.915 af  
Outflow = 24.87 cfs @ 12.11 hrs, Volume= 1.915 af, Atten= 6%, Lag= 1.7 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3 
Max. Velocity= 3.96 fps, Min. Travel Time= 2.5 min 
Avg. Velocity = 1.22 fps, Avg. Travel Time= 8.0 min

Peak Storage= 3,670 cfs @ 12.11 hrs, Average Depth at Peak Storage= 1.34'  
Bank-Full Depth= 2.00', Capacity at Bank-Full= 59.31 cfs

2.00' x 2.00' deep channel, n= 0.035  Earth, dense weeds  
Side Slope Z-value= 2.0 '/'  Top Width= 10.00'  
Length= 584.0'  Slope= 0.0120 '/'  
Inlet Invert= 110.00', Outlet Invert= 103.00'

Reach 5R: 30" Culvert

Inflow Area = 9.271 ac, Inflow Depth = 6.47" for 100-year event  
Inflow = 61.30 cfs @ 12.12 hrs, Volume= 5.001 af  
Outflow = 61.30 cfs @ 12.12 hrs, Volume= 5.001 af, Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3 
Max. Velocity= 18.32 fps, Min. Travel Time= 0.0 min 
Avg. Velocity = 5.48 fps, Avg. Travel Time= 0.1 min

Peak Storage= 84 cfs @ 12.12 hrs, Average Depth at Peak Storage= 1.61'  
Bank-Full Depth= 2.50', Capacity at Bank-Full= 82.03 cfs
30.0" Diameter Pipe, \( n = 0.013 \) Corrugated PE, smooth interior
Length= 25.0' Slope= 0.0400 '/'
Inlet Invert= 99.00', Outlet Invert= 98.00'

Reach 6R: 30" Culvert

Inflow Area = 9.117 ac, Inflow Depth = 6.47" for 100-year event
Inflow = 58.85 cfs @ 12.13 hrs, Volume= 4.918 af
Outflow = 58.85 cfs @ 12.13 hrs, Volume= 4.918 af, Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, \( dt = 0.01 \) hrs / 3
Max. Velocity= 18.17 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 5.42 fps, Avg. Travel Time= 0.1 min

Peak Storage= 81 cf @ 12.13 hrs, Average Depth at Peak Storage= 1.57'
Bank-Full Depth= 2.50', Capacity at Bank-Full= 82.03 cfs

30.0" Diameter Pipe, \( n = 0.013 \) Corrugated PE, smooth interior
Length= 25.0' Slope= 0.0400 '/'
Inlet Invert= 101.00', Outlet Invert= 100.00'

Reach 7R: Existing Riprap Drainage Swale (regraded)

Inflow Area = 9.271 ac, Inflow Depth = 6.47" for 100-year event
Inflow = 61.30 cfs @ 12.12 hrs, Volume= 5.001 af
Outflow = 60.20 cfs @ 12.14 hrs, Volume= 5.001 af, Atten= 2%, Lag= 1.1 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, \( dt = 0.01 \) hrs / 3
Max. Velocity= 4.83 fps, Min. Travel Time= 1.5 min
Avg. Velocity = 1.41 fps, Avg. Travel Time= 5.1 min

Peak Storage= 5,355 cf @ 12.14 hrs, Average Depth at Peak Storage= 1.73'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 84.19 cfs
2.00' x 2.00' deep channel, n= 0.110
Side Slope Z-value= 3.0 '/' Top Width= 14.00'
Length= 430.0' Slope= 0.1349 '/'
Inlet Invert= 98.00', Outlet Invert= 40.00'

Reach 8R: Existing Riprap Drainage Swale (regraded)

Inflow Area = 9.117 ac, Inflow Depth = 6.47" for 100-year event
Inflow = 58.85 cfs @ 12.13 hrs, Volume= 4.918 af
Outflow = 58.31 cfs @ 12.15 hrs, Volume= 4.918 af, Atten= 1%, Lag= 0.8 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.33 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 1.49 fps, Avg. Travel Time= 3.9 min

Peak Storage= 3,826 cf @ 12.15 hrs, Average Depth at Peak Storage= 1.47'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 114.15 cfs

3.00' x 2.00' deep channel, n= 0.110
Side Slope Z-value= 3.0 '/' Top Width= 15.00'
Length= 350.0' Slope= 0.1829 '/'
Inlet Invert= 100.00', Outlet Invert= 36.00'

‡

Pond 9P: Plunge Pool #1

Inflow Area = 9.117 ac, Inflow Depth = 6.47" for 100-year event
Inflow = 58.31 cfs @ 12.15 hrs, Volume= 4.918 af
Outflow = 59.07 cfs @ 12.14 hrs, Volume= 4.915 af, Atten= 0%, Lag= 0.0 min
Primary = 59.07 cfs @ 12.14 hrs, Volume= 4.915 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 28.57' @ 12.14 hrs Surf.Area= 706 sf Storage= 899 cf

Plug-Flow detention time= 1.2 min calculated for 4.914 af (100% of inflow)
Center-of-Mass det. time= 0.8 min (810.5 - 809.6)
Cranston Landfill

Prepared by Woodard & Curran

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Type III 24-hr 100-year Rainfall=8.90"

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<th>Storage Description</th>
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<td>6.0' long x 1.0' breadth Broad-Crested Rectangular Weir</td>
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Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00
Coef. (English) 2.69 2.72 2.75 2.85 2.98 3.08 3.20 3.28 3.31 3.30 3.31 3.32

Primary OutFlow Max=58.92 cfs @ 12.14 hrs HW=28.57’ (Free Discharge)

1=Broad-Crested Rectangular Weir (Weir Controls 58.92 cfs @ 4.75 fps)

Pond 10P: Plunge Pool #2

Inflow Area = 9.271 ac, Inflow Depth = 6.47" for 100-year event
Inflow = 60.20 cfs @ 12.14 hrs, Volume= 5.001 af
Outflow = 60.36 cfs @ 12.14 hrs, Volume= 4.999 af, Attenuation= 0%, Lag= 0.0 min
Primary = 60.36 cfs @ 12.14 hrs, Volume= 4.999 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-72.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 42.13' @ 12.14 hrs Surf.Area= 378 sf Storage = 509 cf

Plug-Flow detention time= 0.7 min calculated for 4.999 af (100% of inflow)
Center-of-Mass det. time= 0.4 min (809.4 - 809.0)

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<th>Volume</th>
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<td>Primary</td>
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<td>10.0' long x 2.0' breadth Broad-Crested Rectangular Weir</td>
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</table>

Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50
Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88 2.85 3.07 3.20 3.32

Primary OutFlow Max=60.27 cfs @ 12.14 hrs HW=42.13’ (Free Discharge)

1=Broad-Crested Rectangular Weir (Weir Controls 60.27 cfs @ 3.69 fps)
RIPRAPH CALCULATIONS
Riprap Channel Design
(Federal Highway Administration Hydraulic Engineering Circular Number 15, Third Edition, Chapter 6)

Trapezoidal Channel

Step 1
Given:

\[ Q = 37.33 \text{ cfs} \]
\[ B = 3 \text{ ft} \] (bottom width of channel)
\[ Z = 3 \] (side slope)
\[ S = 0.18 \] (Slope of channel)

Step 2
Available riprap sizes include:
Class 1: \( D_u = 5 \text{ in.} \)
Class 2: \( D_u = 6 \text{ in.} \)
Class 3: \( D_u = 10 \text{ in.} \)

Specific weight for all \( (v) = 165 \text{ lb/ft}^3 \)

Try class 3 riprap for initial trial; \( D_{up} = 10/12\) = 0.83 ft

Step 3
Assume an initial trial depth of 1.5 ft

Maximum and average flow depth (Using geometric properties of a trapezoid):

\[ A = B_d + 2Z(1.5) + 3(1.5)^2 = 11.3 \text{ ft}^2 \]
\[ P = B_d + 2(1.5) + 3(1.5)^2 = 12.49 \text{ ft} \]
\[ T = B_d + 2Z(3) + 3(1.5)^2 = 12 \text{ ft} \]
\[ d_{avg} = A/T = 11.3/12.0 = 0.94 \text{ ft} \]

Step 4
Calculate Manning’s n (roughness coefficient) with relative depth ratio, \( d_d/D_u = 1.13 \)

\[ n = \frac{0.023D_u^{1/6}}{2.25+5.23\log(d_d/D_u)} = \frac{0.026(0.84)^{1/6}}{2.25+5.23\log(0.83)} = 0.103 \]

Calculate \( Q \) using Manning’s equation

\[ Q = (1.49n)^2AR^{2/3} = (1.49(0.103))(11.3)(0.901)^{2/3}(1.18)^{1/3} = 64.43 \text{ cfs} \]

Step 5
Estimated flow (64.43 cfs) is more than 5% from the design discharge (37.33 cfs), therefore estimate new depth in Step 3

Step 3 (2nd Iteration)

Estimate new depth estimate

\[ d_{new} = d_d/(Q/Q_{design})^{1/4} = 1.23 \text{ ft} \]

Maximum and average flow depth (Using geometric properties of a trapezoid):

\[ A = B_d + 2Z(3)(1.23) + 3(1.23)^2 = 8.23 \text{ ft}^2 \]
\[ P = B_d + 2(3)(1.23) + 3(1.23)^2 = 10.76 \text{ ft} \]
\[ R = A/P = 9.23/10.78 = 0.873 \text{ ft} \]
\[ T = B_d + 2Z(3)(1.23) = 10.38 \text{ ft} \]
\[ d_{avg} = A/T = 9.23/10.38 = 0.93 \text{ ft} \]
Step 4 (2nd iteration)
Calculate Manning's n (roughness coefficient) with relative depth ratio, d/Do = 0.95

\[
\frac{d}{D_o} = 2.25 + 3.23 \log 0.95 = 2.25 + 3.23 \log 0.79 = 0.118
\]

Calculate Q using Manning's equation

\[
Q = (1.49 n^2) A R^{3/2} (1 + 0.01 U) = 36.83 \text{ cfs}
\]

Step 5 (3rd iteration)
Estimated flow (36.83 cfs) is less than 5% from the design discharge (37.33 cfs), therefore proceed to step 6

Step 6
Calculate shear velocity and Reynolds number to determine Shield’s parameter and SF

Shear velocity \( V_s = \frac{Q}{A} = 2.870 \text{ ft/s} \)

Reynolds number \( Re = \frac{V_s D_o}{4} = 1.8 \times 10^6 \) where \( v = 1.217 \times 10^{-6} \text{ (kinematic viscosity)} \)

Since \( R_s 54 \times 10^3, F^* = 0.139 \) and SF = 1.44 (See Table 6.1)

Table 6.1. Selection to Shields’ Parameter and Safety Factor

<table>
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<th>Reynolds Number</th>
<th>F*</th>
<th>SF</th>
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<tr>
<td>( 54 \times 10^3 )</td>
<td>0.047</td>
<td>1.0</td>
</tr>
<tr>
<td>( 4 \times 10^4 )</td>
<td>linear interpolation</td>
<td>linear interpolation</td>
</tr>
<tr>
<td>( 32 \times 10^5 )</td>
<td>0.15</td>
<td>1.5</td>
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</table>

Since channel slope is more than 10%, calculate minimum stable \( D_o \)

\[
D_o = \frac{SF}{\sqrt{K_2}}
\]

where,

\[
S_2 = \frac{y}{v} \text{ (specific gravity of stone)} = 165/82.4 = 2.04
\]

\[
\Delta = \text{function of channel geometry and riprap size} = 2 \cos \tan \theta \sin \phi \tan \theta
\]

\[
\phi = \angle \text{angle of the channel side slope}
\]

\[
\theta = \angle \text{angle of the riprap}
\]

(See Figure 1 for \( \phi \) and \( \theta \))

\[
\beta = \tan^{-1} \left( \frac{\tan \phi \sin \phi}{\cos \theta} \right)
\]

where, \( \theta = -1.812552 \) radians

\[
\eta = \tan^{-1} \left( \frac{\sin \beta}{\cos \beta} \right)
\]

where, \( \beta = 10.3 \) degrees

(See Figure 2)

\[
\Delta = (62.4)(0.79)(1.18) = 8.90 \text{ ft}^2
\]

\[
\eta = 7.73(1.39)(62.4)(0.83) = 0.651
\]

\[
\alpha = 10.3 \text{ degrees}
\]

\[
\beta = 61.13 \text{ degrees}
\]

\[
\theta = 18.43 \text{ degrees}
\]

\[
\phi = 40 \text{ degrees}
\]
\[ \Delta = \frac{K(1 + \sin(\alpha))\tan \theta}{2(\cos(\alpha) - S \sin(\alpha))} \]

\[ \sin(\alpha) = 0.735653553 \text{ radians} \]
\[ \tan \theta = -1.11721493 \text{ radians} \]
\[ \cos \theta = 0.913269928 \text{ radians} \]
\[ \sin \theta = -0.40735493 \text{ radians} \]
\[ \cos \beta = -0.1306819 \text{ radians} \]

\[ \Delta = 0.767 \]

\[ D_{20} = \frac{SF^dSA}{F(xG-1)} \quad \frac{SF^dSA}{F(xG-1)} = 0.69 \quad r = 8.28" \]

Therefore, OK.

Use Class 3 riprap $D_{20}=10$ in.
Riprap Channel Design
(Federal Highway Administration Hydraulic Engineering Circular Number 15, Third Edition, Chapter 6)

Figure 1. Hydraulic Forces Acting on a Riprap Element

Figure 2. Angle of Repose of Riprap in Terms of Mean Size and Shape of Stone
APPENDIX E: MATERIALS MANAGEMENT PLAN
DISCLAIMER: This Materials Management Plan is an updated version of the October 2007 version written by Weston & Sampson Engineers, Inc. This Plan has been revised to reflect the contract documents (design plans and specifications) developed for the Cranston Sanitary Landfill Closure Project. This Plan incorporates RIDEM comments since October 2007.
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<td>2-1</td>
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<tr>
<td>2.1 Material Chemical Characteristics</td>
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1. INTRODUCTION

This document provides the Materials Management Plan (MMP) for the Cranston Sanitary Landfill (CSL) grading and shaping component for the Cranston Landfill Closure Project (see Figure 1). The MMP has been developed to provide specific guidelines under which beneficial use determination (BUD) materials will be received and utilized for grading and shaping of the CSL in anticipation of final landfill closure. The top portion of the CSL, consisting of approximately twenty (20) acres, must be shaped and regraded with BUD materials in order to establish proper design grades prior to installation of a new final cover system over this area.

Strict materials management will be employed at the CSL site during all grading and shaping activities. The BUD materials proposed for achieving closure design grades will provide several benefits. These grading and shaping materials will improve the overall integrity and long-term post-closure performance of the final cover system (cap) by providing a solid foundation layer for the landfill cap construction and by providing a positive slope to promote precipitation runoff and prevent infiltration. In addition, these materials will minimize the potential differential settlement of the cap, thereby improving long-term performance of the final cover system to ensure proper stormwater management.

This MMP provides general and specific requirements for the receipt and handling of all BUD materials that will be maintained and utilized for the duration of grading and shaping activities at the CSL closure project.
2. GRADING AND SHAPING MATERIALS

The use of suitable grading and shaping BUD materials is essential to implementing final closure of the Cranston Sanitary Landfill. Consequently, the BUD materials to be utilized for grading and shaping activities must meet certain applicable physical and chemical criteria. This section outlines the selection criteria and the physical and chemical characteristics necessary for grading and shaping materials.

Materials anticipated to be utilized for grading and shaping activities are as follows:

- Urban fill (impacted soil)
- Construction and demolition (C&D) fines
- C&D residuals
- Incineration ash (coal and wood)
- Street sweepings
- Catch basin cleanings
- Other acceptable materials in accordance with this MMP

Prior to accepting any BUD material at the CSL Site, the RIDEM-approved pre-characterization information will be reviewed by the Cranston Landfill PRP Group and/or their consulting engineer, Woodard & Curran. The goal is to ensure that the specific physical and chemical properties of the BUD materials adhere to this MMP and the BUD application. This process is accomplished through review of material origin, facility processing operations, physical and chemical characteristics of the material, and general compliance with this MMP. Pre-characterization of materials is discussed further in Section 4.1.

2.1 MATERIAL CHEMICAL CHARACTERISTICS

The allowable contaminant levels for grading and shaping materials are listed at the end of Section 4. Allowable contaminant levels have been defined based on risk assessment data and correspondence with RIDEM. Materials that comply with the contaminant levels at the end of Section 4 may be reused as grading and shaping materials at the CSL provided the materials managed are consistent with all of the provisions of this MMP.

2.2 MATERIAL PHYSICAL CHARACTERISTICS

Grading and shaping materials will have the following aggregate physical characteristics.

- By the nature of these materials, they will be easy to spread and compact and will not readily decompose and cause settlement, or result in significant gas generation when managed in accordance with this MMP.
- Particle size of the material will adhere to a maximum size where no more than 10 percent of the material, by weight, exceeds 6 inches (nominal) in size with a maximum of 12 inches in any dimension.
- The aggregate material or total material quantity utilized to accomplish the grading and shaping activities will have an organic content less than 25% by weight in order to minimize the potential for settlement and generation of gas.
2.3 TRUCK ROUTES

The CSL project site is conveniently located off Pontiac Avenue within close proximity to the intersections of Route 95/Route 37 and Route 295/Route 2. Truck traffic should follow the subsequent general directions whenever possible:

From Interstate 295:
- Trucks traveling north or south on Interstate 295 will exit onto Route 37 east bound.

From Interstate 95:
- Trucks traveling north or south on Interstate 95 will exit onto Route 37 west bound.

From Route 37:
- Trucks traveling east on Route 37 will exit at Exit 3 and turn right off the exit ramp and onto Pontiac Avenue.
- Trucks traveling west on Route 37 will exit at Exit 3 and turn left onto Pontiac Avenue.

All sources of BUD materials will be informed of the preferred truck route to the CSL site prior to delivery of any materials. The CSL site entrance road from Pontiac Avenue will be accessed via an entrance shown on the final closure design plans (see Appendix B of the Remedial Action Work Plan (RAWP)). Egress from the CSL site will be onto Pontiac Avenue, turning right.
3. ON-SITE MATERIALS MANAGEMENT

This section describes the procedures and protocols for on-site materials management.

3.1 SEDIMENT AND EROSION CONTROLS

Sediment and erosion controls will be installed and maintained throughout the duration of grading and shaping activities. Sediment and erosion control measures will adhere to the EPA Stormwater Pollution Prevention Plan, the Rhode Island Pollution Discharge Elimination System (RI PDES) and other applicable permits required for this project.

Perimeter controls will be installed after the vegetation clearing and grubbing necessary for the installation of the controls. Erosion and sediment controls will be actively maintained until final stabilization is achieved on portions of the site upgradient of the control. All controls will be removed after final stabilization. Final closure design plans provide necessary installation details and location of these sediment and erosion controls (see Appendix B of the RAWP).

Stabilization practices will be implemented concurrent with the initiation of on-site construction activities. Stabilization practices may include silt fences, hay bales, temporary seeding, permanent seeding, mulching, geotextiles, vegetative buffer strips, preservation of mature vegetation, and other vegetative and non-structural measures.

Structural practices will be used to divert run-on to the active grading and shaping area, or will otherwise limit runoff and erosion of BUD materials from the site. Drainage swales, culverts, and riprap will be implemented as needed.

Maintenance of erosion and sedimentation structures will be performed to protect the waters of the State of Rhode Island from pollution. All erosion and sediment control measures, including vegetation, and all other protective measures will be maintained in operating condition during the grading and shaping construction activities.

3.2 SITE ACCESS AND WEIGHING PROCEDURES

Site access will be located off Pontiac Avenue. Access onto the CSL will be restricted using a locking entrance gate at the perimeter of the CSL. Access by vehicles delivering BUD materials at this location will allow for truck queuing without impacting other vehicle movements on public streets. Egress from the site will be via Pontiac Avenue. Signage will be placed at the entrance stating the project name, the types of materials that are accepted, the types of materials that are banned, the name of the construction contractor and project representative, a 24-hour emergency telephone number, and the hours for receipt of BUD materials.

Weight slip records of the BUD material loads will be submitted to the gate attendant. Information shall include the date and time, hauler and a classification of the material delivered. These weight slips will be maintained on file.
3.3 ON-SITE MATERIALS INSPECTION

Materials will be placed within a designated stockpile area or placed and compacted in accordance with closure design grades as they are delivered to the site. The site equipment operator will view each load prior to spreading and grading the material, to check the material for compliance with the material requirements for this project. Documenting non-conforming loads will include the type of material delivered, the hauler, and the date and time of the delivery. Unacceptable waste will be isolated for removal. Records of unacceptable materials will be included in the quarterly reporting to the Rhode Island Department of Environmental Management (RIDEM); discussed in Section 5.0. All segregated unacceptable materials will be transported off-site to a permitted solid waste handling facility for further processing or disposal.

3.4 MATERIAL STOCKPILING

Stockpiling of BUD materials may be necessary to ensure there is an adequate quantity of inert material on-site to blend with C&D debris fines and residuals to ensure a homogeneous mixture is maintained in order to comply with the organic content threshold (i.e. less then 25%) on an aggregate basis. It is anticipated that a total of approximately 20,000 tons of BUD materials may be stockpiled within the grading and shaping area at any time and will not be placed on any area previously final capped as a result of the grading and shaping. In addition, it may be necessary to stockpile C&D fines and residuals in the same manner to ensure adequate quantities and proper blending with inert materials over the duration of the project.

Stockpiling of BUD materials will be performed only within the grading and shaping area, and these activities will be conducted utilizing appropriate sediment and erosion controls identified under Section 3.1. The stockpile area is anticipated to be within relatively close proximity to the active grading and shaping area to ensure an efficient construction operation, since this material will be used on a daily basis to blend with other BUD materials placed directly at the active construction grading area. In any event, the stockpiling of BUD materials will be conducted in a manner consistent with sound environmental practices and in accordance with this MMP.

3.5 DAILY COVER

Daily cover material is intended to control potential nuisance conditions such as the potential for odors and windblown dust. By utilizing specific BUD materials in accordance with this MMP, the grading and shaping activities are not conducive to generation of nuisance conditions; therefore the application of daily cover soil is not required. Controls for dust generation are discussed in Section 3.7. Odor control is discussed in Section 4.3.

3.6 SEQUENCING

Construction sequencing is intended to minimize the total disturbed area associated with the grading and shaping activities and to expedite the completion of landfill final cap construction. In year one, filling shall occur such that the gas extraction and treatment system operation is not disturbed.
3.7 DUST AND VEHICLE NOISE CONTROLS

During construction, vehicles traveling on unpaved and paved roads may create dust during dry weather conditions. Dust may also result from wind blowing over surfaces of bare soils. These potential conditions will be controlled by applying water to gravel roadway surfaces and by sweeping any paved surfaces. Wood chips will be applied to un-vegetated areas to control dust as required.

To minimize noise impacts, the sequencing (discussed in Section 3.6) will help create a buffer between landfill closure activities and the residential neighborhood. In addition, receipt of grading and shaping materials will be limited to the following operating hours: 7:00 A.M. to 4:30 P.M. Monday through Friday and 7:00 A.M. to 12:00 P.M. on Saturday.

3.8 GRADING AND SHAPING MATERIALS PLACEMENT

The equipment proposed for use at the CSL site may include a front-end loader, a track dozer, a dump truck, and a water truck. Other types of equipment will be made available as needed.

Materials shall be placed in lifts not to exceed 2 feet in depth, and should be compacted with a minimum of 5 passes with a D-6 dozer or equivalent. The grading and shaping materials will be layered or mixed so that the aggregate product contains an organic content less than 25% by weight.

C&D BUD materials will be placed in with inert BUD materials during the grading and shaping activities. Throughout the duration of the project, stockpiling of grading and shaping materials will be necessary to ensure that a composition of the materials can be maintained during grading and shaping activities. As discussed in Section 3.4, stockpiles will only be located within the re-grading area, and will not be placed on any area previously final capped as a result of this grading and shaping project.
4. MATERIALS TESTING AND TRACKING

All incoming grading and shaping materials will be weighed using a certified scale and the necessary information will be recorded using an appropriate logging system. Specifically, the following information will be recorded: vehicle identification, company delivering the material, the origin location (facility) of the material, tonnage, date and time. All materials will be pre-characterized in accordance with the procedures below before they arrive at the site.

In addition to this comprehensive logging system, records will be maintained for all necessary parameter testing of approved grading and shaping materials (see Tables A, B, and C at the end of Section 4). For example, any urban fill (impacted soil) to be accepted at this site will be sampled and analyzed in accordance with Section 4. In addition, materials shipping records must be completed for all urban soil loads that are delivered to the site for use as grading and shaping material.

4.1 PRE-CHARACTERIZATION

Pre-characterization of each BUD material source will be completed prior to approval and acceptance at the CSL site. Pre-characterization information will be obtained and reviewed by the Cranston Landfill PRP Group and/or their environmental consultant to ensure compliance with the BUD requirements for use as grading and shaping material at the CSL closure project. Material specific review requirements are outlined below:

**All materials**

- All materials must comply with Table A requirements of this MMP (end of Section 4).
- Under no circumstance will the material delivered to the site be classified as a hazardous material under the Federal Resource Conservation and Recovery Act (RCRA) or under RIDEM hazardous materials regulations.
- Each source must attach a letter from a qualified environmental professional that has the following certification:

  "In my opinion, the analyses performed and submitted for review are sufficient to adequately characterize the identity and concentrations of contaminants in the [identify BUD Material] proposed at the Cranston Sanitary Landfill in Cranston, Rhode Island.

  Based on my review of the attached data, it is my opinion as a Qualified Environmental Professional that the [identify BUD Material] is appropriate as pre-capping grading and shaping material for the Cranston Sanitary Landfill Closure Project."

**Incinerator Ash (coal and wood)**

- Historic physical and analytical data from the facility will be reviewed for compliance with Table B of this MMP (end of Section 4). In the event historical data from the facility is insufficient (e.g. not all parameters of this MMP have been analyzed), the generator will be required to provide additional analytical data from a representative composite sample for compliance with Table B parameters. In addition, confirmatory sampling will be conducted for the parameters and
the frequency outlined in Table B that includes a minimum frequency of 1 confirmation sample per 10,000 tons of material for Total Metals and Total TCLP Metals on an on-going basis. The sampling shall be completed prior to delivery to the site. In the event RIDEM requires split sample collection of suspect material, the PRP group shall reimburse RIDEM for sampling and laboratory analysis.

- Materials identified within this category will include ash generated from coal and wood incineration facilities. These materials have widely been utilized in beneficial use applications (i.e., daily landfill cover material and structural backfill) throughout New England and the United States. As a result, these materials are considered to be able to meet the physical and analytical requirements identified within this document.

- A description of facility processing operations to include feedstock and stabilization processes.

- The generator may be required to perform additional analyses to verify that the material adheres to this MMP in the event of a change in processes at the facility that would potentially alter the chemical or physical characteristics of the material.

**Urban Fill (Impacted Soil)**

- Each source of urban fill (i.e., impacted soil) must provide representative composite sample and analytical data for compliance with Table B of this MMP.

- Each source must provide a description of site history and activities that resulted in the generation of the impacted fill. The information will include all available historical data relevant to the physical and chemical properties of the source, including a statement that the material meets the requirements identified under Table A and Table B of this MMP.

**C&D Residuals/C&D Fines**

- Each C&D processing facility must provide representative composite sample and analytical data for compliance with Table B of this MMP.

- Each C&D processing facility must provide the applicable regulatory permit that governs the associated processing operation. The facility must provide a description of the material processing activities (i.e. equipment utilized to process C&D material and associated recycling activities) and gypsum removal program.

**Dredge Spoils**

- Each source of dredge spoils must provide a representative composite sample and analytical data for compliance with Table B of this MMP.

- Each source must provide a description of site history and activities that resulted in the generation of the dredge spoils. The information will include all available historical data relevant to the physical and chemical properties of the source, including a statement that the material meets the requirements identified under Tables A ,B and C of this MMP.
Other Materials (i.e. catch basin cleanings, street sweepings, etc.)

- Each source of other inert materials must provide representative composite sample and analytical data for compliance with Table B of this MMP.
- Other information to describe the nature and origin of the material, as appropriate.

Given the detailed process to pre-characterize, review, approve and document each BUD material source, no sampling and analysis of BUD materials will be performed upon receipt at the CSL.

4.2 ORGANIC CONTENT TESTING PROGRAM FOR GRADING AND SHAPING MATERIAL

The purpose for organic content testing is to provide an engineering control on both potential odor generation and differential settlement by ensuring that the aggregate in-place organic carbon content of the shaping and grading layer is less than twenty-five percent (25%) by weight (see Tables A and C). Of the BUD materials listed in Section 2, only C&D fines and residuals can contain significant organic carbon, primarily in the form of wood content. The other BUD materials are considered inert relative to C&D fines and residuals, and for the purposes of this analysis are assumed to contain on the order of one percent (1%) organic carbon. Thus, organic carbon content testing will only be performed on C&D fines and residuals and that result will be used to determine the required blending rate with the inert BUD materials containing 1% organic carbon to meet the objective of less than 25% in-place organic carbon content.

The following sampling and testing program will be implemented to monitor and determine the organic content of C&D fines and residuals as received at the CSL. Data obtained from this monitoring program will be utilized to determine the total aggregate in-place organic content on a quarterly basis.

- The C&D generator will be responsible for collecting and analyzing a representative sample from each source as per the schedule set forth below.
- Samples frequency shall be:
  - 1 sample/5,000 tons per source
- The percent organic content of a sample will be determined using the Loss on Ignition Test (Modified ASTM 2974).
- The results of each organics test will be applied to the next 5,000 tons emanating from that facility or source. Assuming an average of 25 tons per truck, the frequency is approximately one test per 200 trucks/source for C&D BUD material.
- The organic content monitoring data for the C&D material will be compiled and presented with quarterly report information on the quantity (i.e. tonnage) of each BUD material delivered to the site in order to determine the aggregate in place percent organic content. The data from this on-going monitoring program will be reviewed on a quarterly basis to determine consistency with the 25% organic content requirement for all BUD materials placed. For calculation purposes, due to their inert nature all BUD materials other than C&D fines and residuals will be assumed to have a 1% organic content; no testing of these materials will be performed.
An organic content tracking form will be used to compile organic content results from each C&D fines and residuals source, and a summary form of all sources will be used to calculate the aggregate in-place organic content. These forms are located at the end of Section 4. The first form titled “Monthly Summary Log for C&D Organic Testing” is a monthly summary sheet for each C&D source, and it presents the daily record of tonnage and the weighted organic content. The second form titled “Monthly Summary Log for Aggregate, In-Place, Organic Content” is a monthly summary sheet for all BUD Materials that presents the total record of tonnage from all sources and the monthly average in-place percent of organic carbon by weight given the measured organic carbon content of the C&D materials and the generic 1% content of the other inert materials. Note that these forms will not be prepared if C&D fines or residuals are not accepted at the site. However, once these materials are accepted the forms will be prepared for the remainder of the project.

4.3 ODOR ASSESSMENT AND CONTROL PLAN

Because the existing landfill cap will not be removed and because the organic carbon content of the BUD materials used for shaping and grading will be limited in magnitude (see Section 4.2), significant odor issues are not anticipated. To ensure that this is the case, an odor assessment and control plan will be implemented for the project. Assessment will include weekly odor surveys, documentation, and response to odor complaints. If odor issues do arise, then odor mitigation procedures will be implemented, as discussed below.

4.3.1 Weekly Odor Survey

The landfill closure construction staff will conduct an odor survey one day per week as part of their normal operational procedures. The survey will include olfactory and instrument-driven data collection along the site perimeter, as detailed below. The day of each survey will be identified by reviewing the upcoming weekly forecast, using the days most indicative to odor causing conditions (e.g., low wind speed, high temperatures, wet conditions, wind direction toward residential receptors, etc.). Once the day is determined, the survey will be conducted in the early morning because surveyor olfactory sensitivity is high and atmospheric dispersion tends to be low.

The survey will be conducted along the site perimeter by recording hydrogen sulfide levels at prescribed locations along the perimeter of the landfill using a multi-gas meter. The prescribed locations are identified on the Weekly Odor Survey form (see example provided at the end of Section 4). In addition, while walking the perimeter of the site, the surveyor will record odors based on olfactory sense. If odors are detected, the surveyor will stop to record hydrogen sulfide levels at those locations in addition to the fixed locations. The surveyor will identify and record conditions at each location (prescribed and detected) on the Weekly Odor Survey form. The following information will be recorded at each location:

- Location;
- Description of odor character and intensity (if any);
- Measured value of hydrogen sulfide (using a multi-gas meter with a <10 ppb detection limit);
- Wind speed and direction; and
- Closure construction activity.