APPENDIX E

LEAK COLLECTION AND RECOVERY SYSTEM DESIGN
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An important feature of the evaporation pond liner system is the Leak Collection and Recovery System (LCRS). The purpose of the LCRS is to provide a method to collect potential seepage should leakage develop within the pond through the primary geomembrane liner.

The LCRS layer has been designed as a high density polyethylene (HDPE) geonet. Per the requirements of 40 CFR 264.221, the transmissivity of the selected drainage layer exceeds the minimum transmissivity requirement of $3 \times 10^{-4}$ square meters per second (m$^2$/sec), and is designed with a minimum grade of one percent. Based on the geonet design presented in Appendix E-1 using the equations proposed by Giroud et al. (1997), the evaporation pond geonet is required to have a minimum transmissivity of $2 \times 10^{-3}$ m$^2$/sec and a minimum thickness of 200 mil.

Leakage through the upper geomembrane liner will be collected in the LCRS layer and routed (via gravity flow) to a LCRS sump located in each of the pond cells. Each LCRS sump is sized to contain a minimum of 48 hours of anticipated leakage in the LCRS layer (i.e., geonet) assuming one liner defect per acre for good installation (Giroud & Bonaparte, 1989), an effective porosity of 30 percent in the sump drainage gravels, and applying a factor of safety of 1.5. The LCRS sump sizing calculations is provided in Appendix E-1. Based on these calculations, a sump with base dimensions of 10 feet by 30 feet with 3H:1V (horizontal:vertical) side slopes and 5-foot depth (i.e., sump beneath all ‘flat’ portions of the pond cell) provides sufficient containment for approximately 14 days of leakage solutions.

REFERENCES


APPENDIX E-1

LEAK COLLECTION AND RECOVERY SYSTEM
SUMP CAPACITY CALCULATION
OBJECTIVE:

Evaluate the capacity of the Leak Collection and Recovery System (LCRS) sumps for the evaporation pond cells based on calculated leakage through the geomembrane in the LCRS layer.

GIVEN:

- Evaporation pond cell and LCRS sump dimensions.
  - Cell Area: 4.13 acres
  - Sump base dimensions: 30 feet by 10 feet
  - Sump depth: 5 feet
  - Sump side slopes: 3H:1V

ASSUMPTIONS:

- Because the evaporation pond LCRS sumps will not be equipped with their own dedicated pump (a mobile pump will be used), the LCRS sump should be sized to accommodate a minimum of 48 hours of the maximum leakage flow in the LCRS layer;
- Apply a factor of safety (FS) of 1.5;
- Porosity of the gravel within the LCRS sumps is assumed as 0.3;
- Assume 1 liner defect per acre;
- According to the EPA, common practice is to assume a circular defect with a diameter equal to the thickness of the geomembrane. Accordingly, these calculations assume circular defects with a diameter of 60 mil (0.005 ft, or 0.06 inches);
- The flow in the leakage collection layer is laminar;
- It is assumed that flows through various defects do not interfere with each other; and
- The maximum height of liquid above the primary geomembrane is conservatively assumed to be equal to the ultimate height of the evaporation pond (e.g. 8 ft).

MATERIAL PROPERTIES:

Table 1 summarizes the material properties considered in the analysis for the drainage geonet on the evaporation pond cells.

**Table 1. Geonet properties**

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Transmissivity gal/min ft (m²/sec)</th>
<th>Thickness mil</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSE</td>
<td>HyperNet</td>
<td>9.66 (2 x 10⁻³)¹</td>
<td>200</td>
</tr>
</tbody>
</table>

¹ see Attachment 3
CALCULATIONS:

**Flow in the LCRS Layer due to a Geomembrane Defect**

Flow in the LCRS layer for the evaporation pond cells (Attachment 1)

- Geonet: $2.67 \times 10^{-4}$ ft$^3$/sec per defect

**Required Size of the LCRS**

Flow in the LCRS layer

$Q = 2.67 \times 10^{-4}$ ft$^3$/sec = 173 gallons per defect per day

Total flow

$Q_T = Q(A) \times \left( \frac{1_{\text{defect}}}{\text{Acre}} \right)$

$Q_T = (172.6 \text{ gpd/acre}) \times (4.13 \text{ acres}) = 713 \text{ gallons per day}$

$t = 48 \text{ hr (time)}$

$n = 0.3 \text{ (porosity)}$

$FS = 1.5 \text{ (factor of safety)}$

$$\text{Required volume} = Q_T \times t \times FS$$

$$\text{Required water storage volume} = 713 \text{ gal/day} \times \frac{1 \text{ day}}{24 \text{ hr}} \times \frac{1 \text{ ft}^3}{7.48 \text{ gal}} \times 1.5 = 286 \text{ ft}^3$$

**Sump Capacity**

The designed size of the LCRS sump based on pond cell geometry (i.e., sump beneath all 'flat' portions of the cell) is:

- Sump base dimensions: 10 feet x 30 feet
- Sump top dimensions: 40 feet x 60 feet
- Sump depth: 5 feet
- Side slopes: 3H:1V

Calculations of the sump capacity are provided in Attachment 2. A sump with these dimensions has a volume capacity of 6,750 ft$^3$. The corresponding available solution volume, based on 30 percent porosity, is 2,025 ft$^3$ (15,150 gal).
RESULTS:

The calculated leakage volume to each LCRS sump due to geomembrane defects within the primary liner during a 48-hour period with a factor of safety of 1.5 is approximately 286 cubic feet. The fluid capacity (i.e. pore volume) of the LCRS sump is approximately 2,025 cubic feet, which greatly exceeds the anticipated amount of leakage accumulated in 48 hours.

CONCLUSIONS:

The LCRS sump with the designed dimensions (10 feet by 30 feet at the base, with 3H:1V side slopes and a 5 foot depth) provides sufficient capacity to accommodate approximately 14 days of leakage in the LCRS layer.

REFERENCES:

ATTACHMENT 1
FLOW CALCULATION
FLOW THROUGH LINER DEFECT CALCULATIONS

The flow rate through a defect in the geomembrane is given by the following equation (Giroud et al. 1997):

\[
d \:= \ 0.005 \ \text{ft} \quad \text{defect diameter}
\]
\[
h_{\text{prim}} \:= \ 8 \ \text{ft} \quad \text{total liquid head over primary geomembrane}
\]
\[
g \:= \ 32.2 \ \text{ft} / \text{sec}^2 \quad \text{gravity}
\]
\[
Q \:= \ \frac{2}{3} d^2 \sqrt{g \cdot h_{\text{prim}}}
\]

where the maximum flow rate through the primary liner geomembrane is:

\[
Q \ = \ 2.675 \times 10^{-4} \ \text{ft}^3 / \text{sec}
\]

The permeability of the geonet can be defined by:

\[
t_{\text{LCL}} \:= \ 0.017 \ \text{ft} \quad \text{thickness of the geonet}
\]
\[
\theta \:= \ 0.0215 \ \text{ft}^2 / \text{sec} \quad \text{geonet transmissivity}
\]
\[
k \:= \ \frac{\theta}{t_{\text{LCL}}} \quad \text{geonet hydraulic conductivity}
\]
\[
k \ = \ 1.265 \ \text{ft} / \text{sec}
\]

The maximum steady-state rate of leachate migration through a defect in the primary liner that a leakage collection layer can accommodate without being filled with leachate (Giroud et al. 1997b):

\[
Q_{\text{full}} \:= \ k \cdot t_{\text{LCL}}^2
\]
\[
Q_{\text{full}} \ = \ 3.655 \times 10^{-4} \ \text{ft}^3 / \text{sec}
\]

ATTACHMENT 1
The liquid head build-up on the secondary geomembrane liner can be calculated by using the following equation (Giroud et al. 1997b):

\[ t_{o} := \frac{\sqrt{Q}}{k} \]

\[ t_{o} = 0.015 \text{ ft} \]

Since the flow rate through a defect in the geomembrane (Q) is lower than the maximum flow rate that the leakage collection layer can accommodate (Qfull), and the estimated liquid head build-up (to) is less than the thickness of the geonet (tLCL), the calculated flow in the geomembrane is validated.

References

ATTACHMENT 2
LCRS SUMP SIZING WORKSHEET
### Attachment 2 - LCRS Sizing Worksheet

<table>
<thead>
<tr>
<th>Description</th>
<th>Upper</th>
<th>Lower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond Depth:</td>
<td>5 ft</td>
<td>1.5 m</td>
</tr>
<tr>
<td>Pond Side 1 (upper):</td>
<td>40 ft</td>
<td>12.2 m</td>
</tr>
<tr>
<td>Pond Side 2 (upper):</td>
<td>60 ft</td>
<td>18.3 m</td>
</tr>
<tr>
<td>Pond Side 1 (lower):</td>
<td>10 ft</td>
<td>3.0 m</td>
</tr>
<tr>
<td>Pond Side 2 (lower):</td>
<td>30 ft</td>
<td>9.1 m</td>
</tr>
<tr>
<td>Side Slope:</td>
<td>3 H</td>
<td>1 V</td>
</tr>
<tr>
<td>Liner Overlap per Side</td>
<td>0 ft</td>
<td>0.0 m</td>
</tr>
<tr>
<td>Dry Freeboard</td>
<td>0 ft</td>
<td>0.0 m</td>
</tr>
<tr>
<td>Pond Volume w/o freeboard:</td>
<td>6,750 ft^3</td>
<td>191 m^3</td>
</tr>
<tr>
<td></td>
<td>50,490 gal.</td>
<td>191,289 liters</td>
</tr>
<tr>
<td>Liner Area:</td>
<td>2,514 ft^2</td>
<td>234 m^2</td>
</tr>
<tr>
<td>Pond Volume w/ freeboard:</td>
<td>6,750 ft^3</td>
<td>191 m^3</td>
</tr>
<tr>
<td></td>
<td>50,490 gal.</td>
<td>191,289 liters</td>
</tr>
</tbody>
</table>
ATTACHMENT 3
GEONET PROPERTIES
GSE HyperNet geonets are synthetic drainage materials manufactured from a premium grade high density polyethylene (HDPE) resin. The structure of the HyperNet geonet is formed specifically to transmit fluids uniformly under a variety of field conditions. HDPE resins are inert to chemicals encountered in most of the civil and environmental applications where these materials are used. GSE geonets are formulated to be resistant to ultraviolet light for time periods necessary to complete installation. GSE HyperNet geonets are available in standard, HF, HS, and UF varieties.

The table below provides index physical, mechanical and hydraulic characteristics of GSE geonets. Contact GSE for information regarding performance of these products under site-specific load, gradient, and boundary conditions.

**Product Specifications**

<table>
<thead>
<tr>
<th>Tested Property</th>
<th>Test Method</th>
<th>Frequency</th>
<th>Minimum Value</th>
<th>Average Value</th>
<th>Roll Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmissivity*, gal/min/ft (m²/sec)</td>
<td>ASTM D 4716-00</td>
<td>1/540,000 ft²</td>
<td>9.66 x 10⁻²</td>
<td>14.49 x 10⁻²</td>
<td>28.98 x 10⁻²</td>
</tr>
<tr>
<td>Thickness, mil (mm)</td>
<td>ASTM D 5199</td>
<td>1/50,000 ft²</td>
<td>200 (5)</td>
<td>250 (6.3)</td>
<td>275 (7)</td>
</tr>
<tr>
<td>Density, g/cm³</td>
<td>ASTM D 1505</td>
<td>1/50,000 ft²</td>
<td>0.94</td>
<td>0.94</td>
<td>0.94</td>
</tr>
<tr>
<td>Tensile Strength (MD), lb/in (N/mm)</td>
<td>ASTM D 5035</td>
<td>1/50,000 ft²</td>
<td>45 (7.9)</td>
<td>55 (9.6)</td>
<td>65 (11.5)</td>
</tr>
<tr>
<td>Carbon Black Content, %</td>
<td>ASTM D 1603, modified</td>
<td>1/50,000 ft²</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Roll Width, ft (m)</td>
<td></td>
<td></td>
<td>15 (4.6)</td>
<td>15 (4.6)</td>
<td>15 (4.6)</td>
</tr>
<tr>
<td>Roll Length, ft (m)</td>
<td></td>
<td></td>
<td>300 (91)</td>
<td>250 (76)</td>
<td>220 (67)</td>
</tr>
<tr>
<td>Roll Area, ft² (m²)</td>
<td></td>
<td></td>
<td>4,500 (418)</td>
<td>3,750 (348)</td>
<td>3,300 (305)</td>
</tr>
</tbody>
</table>

**NOTES:**

- Gradient of 0.1, normal load of 10,000 psf, water at 70°F (20°C), between steel plates for 15 minutes.
- Please check with GSE for other available roll lengths.
- These are MARV values that are based on the cumulative results of specimens tested by GSE.

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**DS017 RO7/07/03**

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