Geomembrane Barriers
In Bottom Liner and Cover Applications
At Landfill Sites

Presented to:
B.C. MEND Metal Leaching / Acid Rock
Drainage Workshop

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Prepared by
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Agenda

1. Geomembrane Applications
2. Materials and Engineering Properties
3. Subgrade Suitability
4. Friction Angle and Stability
5. Installation
6. Landfill Gas and Air Intrusion
7. Drainage Control
8. Costs
Selected Geomembrane Projects completed by SHA

- Hartland South Face Closure
- Knockholt Lagoon
- Hartland North Face Lagoon
- Norampac Lagoon
- Iona Grit Landfill Closure
- Nanaimo Progressive Closure
- Nanaimo Phase 3 Geogrid Berm and Liner
- Gibraltar Mine Landfill Bottom Liner and Closure
- Bailey Chilliack - Bottom Liner
- Minnies Pit – Mission, Bottom Liner and Closure
- Highland Valley Copper – Centre for Waste Management
- Skimikin Landfill Closure
- Fernie Landfill Closure
- Vancouver Phase 1 Closure
- 7 Mile Phase 3 Liner & Treatment Pond
Objectives of Liners and Covers

In landfill applications geomembranes are used in three ways:

1. Impervious bottom liner
   - Contain leachate
   - Prevent landfill gas migration

2. Impervious final cover
   - Prevent infiltration of rainfall
   - Contain fugitive landfill gas emissions
   - Control odours

3. Leachate treatment pond liner
   - Contain leachate for treatment
Bottom Liner at Whistler
HDPE Aeration Pond at 7 Mile Landfill
Value of Landfill Air Space $75 to $100/m$^3$

Extra lift provides additional 60,980 m$^3$ (42,076 tonnes) of Airspace
This equates to $2,734,953 in tipping fee revenue
Liner Materials

• **Compacted Clay Liner**
  – 1 m thick (consumes air space)
  – $K < 1 \times 10^{-7}$ cm/s – clay or silty clay (hard to come by)
  – Good compaction required
  – Subject to desiccation cracking

• **Geosynthetic Clay Liner (GCL)**
  – Bentonite clay between two geotextiles
  – Wet dry cycles - dessication
  – Ion exchange with divalent cations can lead to collapse of double layer
  – Hydration is tricky
  – Need good confining pressure
Liner Materials (cont.)

• **HDPE**
  - Very low permeability
  - Requires knowledgeable installer
  - Seams must be welded
  - Antioxidant depletion (function of $T$)
  - Textured Sheet adds stability

• **LLDPE**
  - Slightly lower density than HDPE
  - More flexible than HDPE
  - Material of choice for cover systems
Liner Materials (cont.)

• **PVC**
  - *Can be welded or solvent seamed*
  - *More flexible than HDPE*
  - *Can be installed in large panels*
  - *Subject to plasticizer loss over time (material can become brittle)*
Critical Properties

- Permeability (transmissivity)
- Yield strength
- Friction angle (interface)
- Longevity
  - Thermal
  - Ultraviolet
  - Chemical
  - Stress
- Price
- Installation Cost (ease of installation)
- Air Space Consumption !!!
Permeability

- **Clay Liners** $1 \times 10^{-7}$ cm/s or less
- **GCL** $1 \times 10^{-9}$ to $5 \times 10^{-9}$ cm/s
- **Geomembrane** depends on defects
### Lifespan a Function of Antioxidant Depletion

<table>
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<tr>
<th>Temperature °C</th>
<th>Service Life (years)</th>
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<tbody>
<tr>
<td>20</td>
<td>565 - 900</td>
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<tr>
<td>30</td>
<td>205 - 315</td>
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<tr>
<td>35</td>
<td>130 - 190</td>
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<td>40</td>
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<td>35 - 50</td>
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After Rowe (2005)
## Shear Strength Summary

<table>
<thead>
<tr>
<th>Material</th>
<th>Friction Angle</th>
<th>Slope</th>
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<tbody>
<tr>
<td></td>
<td>Minimum</td>
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<td>Textured</td>
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<td>Non Woven Geotextile</td>
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<td>32</td>
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<tr>
<td>Sand</td>
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<td>1.9:1</td>
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<tr>
<td>Clay</td>
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<td>HDPE Membrane Smooth</td>
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<tr>
<td>Sand</td>
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<td>23</td>
<td>3.4:1</td>
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<tr>
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<td>LLDPE</td>
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<td>Non Woven Geotextile</td>
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<tr>
<td>PVC Membrane</td>
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<td>Non Woven Geotextile</td>
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<td>GCL</td>
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<tr>
<td>Sand</td>
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<tr>
<td>GCL</td>
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<td>Non Woven Geotextile</td>
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<td>3.3:1</td>
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<td>Agru Super Grip</td>
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<tr>
<td>Non Woven Geotextile</td>
<td>41</td>
<td></td>
<td>1.15:1</td>
</tr>
</tbody>
</table>

- **Textured liners can support covers at slopes to 2.5H:1V**
Textured Liner on 2H:1V Slope - Chilliwack
Training for the 2010 Olympic Skeleton Team
GCL – Nu-drain interface resulted in failure
Nanaimo Geogrid Berm – Test Pad
Preparing Subgrade

• **Base must be smooth and firm**
• **No sharp rocks or objects**
• **Stones finer than 25 mm**
• **Proof roll smooth with smooth drum roller**
• **Use cushion geotextile to protect liner unless soil cushion first class**
  - Sand is great cushion
  - Clay is great cushion
• **Deal with leachate breakouts before hand**
Gib East ARD Waste Dump
Deployment Methods

• **State-of-art is evolving**
  – *Excavator to spool liner out*
  – *Quads or “buggies” pull liner*
  – *Labour can pull liner out*
  – *Velcro effect can be significant*
  – *Slip sheet may be needed*
  – *Skilled crew can install 5,000 m²/day*
Spooling out geomembrane with spreader bar
Pulling sheet with Quad at Whistler
Crew pulling geotextile – note sandbags
Seaming Geomembrane

• **Double Wedge Welder is standard**
  – Provides double seam
  – QA/QC easy with pressure test

• **Extrusion Weld for patches, “T” junctions and boots**
  – Test with vacuum box
Wedge Welder melts fuses two sheets together
Extrusion welding custom boot at Knockholt
Vacuum Box testing extrusion weld
Managing Penetrations

• **Penetrations need to occur for:**
  – Landfill gas wells
  – LFG horizontal and headers
  – Leachate clean-outs

• **Key issues are:**
  – Differential settlement
  – Membrane displacement during construction
  – Pond liner freezing
Well head stressed from liner creep
Designing For Settlement

Settlement from May 2006 (m)

van hub 5
van hub 4
van hub 3
van hub 2
van hub 1
Covering Geomembrane

- Covering liner is the most critical step and requires strict QA/QC
- Cushion geotextile improves liner survival
- Must avoid “pushing wave”
- Preferred approach is to push uphill (not always possible due to access)
- Must maintain minimum thickness (depends on equipment)
- Cones work best for layer thickness control
### Minimum Cover Thickness to avoid damage

<table>
<thead>
<tr>
<th>Backfill Thickness</th>
<th>Placement Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Backfill</td>
<td>Foot Traffic or Quad ATV Only</td>
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<tr>
<td>150 mm or less</td>
<td>Hand Placement or Stone Slinger</td>
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<tr>
<td>200 – 300 mm</td>
<td>D3 – D4 LGP Cat</td>
</tr>
<tr>
<td>300 mm</td>
<td>Bobcat (Skid-Steer)</td>
</tr>
<tr>
<td>300 mm</td>
<td>D4 – D6 LGP Style Cat</td>
</tr>
<tr>
<td>600 mm</td>
<td>D7 – D9 Style Cat</td>
</tr>
<tr>
<td>900 mm</td>
<td>Loaded Scrapers, Motor Graders</td>
</tr>
<tr>
<td>900 – 1200 mm</td>
<td>Loaded Tandem Axle Trucks</td>
</tr>
</tbody>
</table>
Articulated Rock Truck – More versatile, but requires double handling
Using small LGP dozer – avoid “wave”
Survivability Testing of Geomembrane
No Damage with 5 to 25 mm Crushed Gravel and Glass
Numerous Punctures with Coarse Concrete
Managing Air Intrusion

• **Air intrusion is a risk factor at landfills**
  – Reduces methane concentration in LFG
  – Inhibits methanogenic bacteria
  – Increases risk of landfill fire

• **Key design factors**
  – Boots that can accommodate settlement
  – Air intrusion seals at edges of liner
  – Air intrusion seals on leachate lines
Landfill Gas Well at Hartland
Air Entry Seal on leachate outlet
Major Fire at Yellowknife Landfill
Providing Drainage

- Sand Layers
- Gravel Layers
- Geonet
- Drain Tube
- Agru Liner
Leachate Collection System and Drainage Layer
Drainage Tube Replaces Gravel
Healthy Vegetation
- Top Soil: ensures a healthy and sustainable vegetation
- Subsoil: provides a deep soil horizon for root establishment
- Drainage Layer: quickly conveys water passing through the topsoil horizon
- Barrier Layer: prevents infiltration, reduces leachate production
- Leachate/Gas Collection Layer: pathway for leachate-breakouts and gas
- Intermediate Cover: Existing
Geomebranes in Final Closure
## Costs

- **Textured Membrane** $8 - $12/m²
- **GCL** $10 – 12/m²
- **Geotextile** $2 - $3.50/m²
- **Closure System** $40 - $50/m²
- **Liner / Leachate Collection** $40 - $60/m²
THANK YOU FROM SHA

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