Resources and opportunities to better manage landslide risk

Tom Badger
WSDOT’s Initial Response Efforts

- ESF1-Transportation lead
- Science teams support
Landslide Monitoring
SR 530 Landslide

Precipitation

Inches

Date

3/2/14
4/21/14
6/10/14
7/30/14
9/18/14
11/7/14

0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

Precipitation
Landslide Monitoring
Laser Scanning
Mapping Products
Hydraulic Analyses

Q = 26,000 cfs (~10-YR) – Depth
Potential Flow Paths

- Hillshade from 2014 LiDAR
- Potential flow path through slide hummocks (green line)
- 2014 Thalweg (pink line)
- 2013 Channel
- Potential flow paths along SR 530 (orange lines)
Conceptual Geologic Section
Post-Failure Stability of Landslide Mass

<table>
<thead>
<tr>
<th>Material Name</th>
<th>Color</th>
<th>Unit Weight (lbs/ft³)</th>
<th>Cohesion (psf)</th>
<th>Phi (deg)</th>
<th>Water Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landslide Debris</td>
<td></td>
<td>115</td>
<td>0</td>
<td>24</td>
<td>Water Surface</td>
</tr>
<tr>
<td>Everson Outwash</td>
<td></td>
<td>130</td>
<td>100</td>
<td>38</td>
<td>Water Surface</td>
</tr>
<tr>
<td>Vashon Till</td>
<td></td>
<td>140</td>
<td>250</td>
<td>40</td>
<td>None</td>
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<tr>
<td>Vashon GL Siltsand</td>
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<tr>
<td>Vashon GL Clay-Silt</td>
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<td>125</td>
<td>300</td>
<td>25</td>
<td>Pleometric Line</td>
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<tr>
<td>Olympia Beds</td>
<td></td>
<td>140</td>
<td>400</td>
<td>35</td>
<td>Pleometric Line</td>
</tr>
<tr>
<td>Clay - Residual</td>
<td></td>
<td>110</td>
<td>0</td>
<td>28</td>
<td>Pleometric Line</td>
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</tbody>
</table>

2014 Ground Surface

Existing Channel
Post-Failure Stability - Migrated Channel

<table>
<thead>
<tr>
<th>Material Name</th>
<th>Color</th>
<th>Unit Weight (lbs/ft³)</th>
<th>Cohesion (psf)</th>
<th>Phi (deg)</th>
<th>Water Surface</th>
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</thead>
<tbody>
<tr>
<td>Landslide Debris</td>
<td>Pink</td>
<td>115</td>
<td>0</td>
<td>24</td>
<td>Water Surface</td>
</tr>
<tr>
<td>Everson Outwash</td>
<td>Orange</td>
<td>130</td>
<td>100</td>
<td>28</td>
<td>Water Surface</td>
</tr>
<tr>
<td>Vashon Till</td>
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<td>250</td>
<td>40</td>
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<td>Vashon GL Silt-Sand</td>
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<td>32</td>
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<tr>
<td>Vashon GL Clay-Silt</td>
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<td>125</td>
<td>300</td>
<td>25</td>
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<td>Olympia Basalt</td>
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<td>Red</td>
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<td>Piezometric Line 1</td>
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2014 Ground Surface

Migrated Channel

Existing Channel
Potential for Further Retrogression
Western Flank Stability - Local

<table>
<thead>
<tr>
<th>Material Name</th>
<th>Color</th>
<th>Unit Weight [lb/ft^3]</th>
<th>Cohesion [in]</th>
<th>Phi [deg]</th>
<th>Water Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Everson Outwash Sand - Disturbed</td>
<td>125</td>
<td>0</td>
<td>38</td>
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<td>Water Surface</td>
</tr>
<tr>
<td>Vashon GL Silt - Disturbed</td>
<td>120</td>
<td>200</td>
<td>24</td>
<td></td>
<td>Water Surface</td>
</tr>
<tr>
<td>Vashon GL Clay - Residual Strength</td>
<td>120</td>
<td>0</td>
<td>22</td>
<td></td>
<td>Water Surface</td>
</tr>
<tr>
<td>American Sand &amp; Gravel</td>
<td>140</td>
<td>400</td>
<td>35</td>
<td></td>
<td>Water Surface</td>
</tr>
<tr>
<td>Olympia Beds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

current channel
SR-530 Realignment Alternatives
Risk Exposure

HAZARD \times VULNERABILITY = RISK

- Frequency/probability of rockfall
- Magnitude/severity of rockfall
- Exposure as proportion of potential total value
- Magnitude/severity of rockfall
- Relative contribution to total annual cost
- Total annual expected cost (area under curve)
Hazard Mitigation

• Avoid
• Protect
• Stabilize
• Monitor-Warn
In support of priority programming, WSDOT launched the USMS in 1993, which includes four asset management activities:

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- Slope ranking
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- **Inventory development**
- **Slope ranking**
- **Project scoping**
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- **Inventory development**
- **Slope ranking**
- **Project scoping**
- **Prioritization**  
  - Benefit-Cost Analysis  
  - Programming Criteria
Performance Measurement
Expenditures

“...after three decades of stabilization work, the opinion of the geotechnical specialist involved since inception is that only now are the benefits clearly recognizable”.

Golder Associates (2005 WSDOT program evaluation) cited the experience of a comparable rockfall maintenance program for a railroad in British Columbia involving about 750 sites.
2 May 2014 Badakhshan Landslide
Opportunities

Emergency Response
• Rapid response geohazards team
• Interagency cooperation/responsibilities
• Discretionary immunity for betterments??

Intermediate/Long Term
• LS inventory-susceptibility-hazard maps
• Avoidance & monitor-warn strategies
• Timber harvest effects on GW recharge??
• Cumulative effects from development??
• Public engagement