Any gravity-assisted movement of loose material (rock or sediment) at the surface is called a mass movement. Clearly, this is a force that reshapes what various areas look like. Landslides are one type of mass movement that are significant earth hazards. Lahars are a type of landslide that is a specific hazard in parts of the Puget Sound Lowland; the Osceola Mudflow was a lahar that extended from Mt. Rainier to Kent.

A landslide, or, more properly, a mass wasting event occurs when earth materials, under specific pre-existing conditions, move downslope comparatively rapidly after some event (called a trigger).

Landslides are triggered simply when the force acting to pull the material down a slope (gravity) overcomes the forces holding the slope in place. The force acting to pull the material down the slope increases as

- the slope steepens, as when it is undercut by waves or bulldozers
- the weight of the material on the slope increases, due to sedimentation or construction
- the density of the material on the slope increases, as when sediment grain pores are filled with water after rainfall

A landslide also becomes more likely if the forces holding the material in place decrease. This occurs if

- the cohesion (stickiness) of the material decreases, as during an earthquake or if deep-rooted plants are killed or removed
- the internal friction between grains in the material decreases, as happens when water enters a plane of weakness
- the pore water pressure increases, as after rainfall, with the water wedging grains apart

Note the connection between groundwater and landslide potential; some groundwater increases the cohesion of the sediment grains and therefore decreases landslide potential, but too much groundwater increases the weight on the slope as well as increases lubrication (lowers friction) between grains and increases landslide potential.

1. Where (what neighborhoods in the city or what geographical setting) would you expect most landslides to occur in Seattle? Why?

On the next page is a figure from a Department of Natural Resources publication titled *Landslides in Seattle* by Donald W. Tubbs (1974).
2. a. From the graph, **what time of year** do you expect most landslides to occur in Seattle?

b. Why isn’t the large amount of precipitation in **January** accompanied by a similarly large number of landslides?

3. a. Why didn’t the rains in **April** result in a lot of landslides?

b. Now look at figure 1 of *Puget Sound Bluffs: The Where, Why and When of Landslides Following the Holiday 1996/97 Storms* by Gerstel et al (1997) on the next page. The gray shaded areas represent Tubbs' hazard zones; the dots are actual slides during 1996/97. **How accurately** did Tubbs predict the location of the slides?
Sediments and landslides

Though mass movements can occur in any type of sediment (soil creep to mudflows), landslides in the Seattle area tend to occur at the contact between two sediment units (recall that a unit, or a formation, is a lithologically distinct layer of sediment — it does not mean that there cannot be any layers within the unit!). Examine the four tubs of sediment — each represents a unit found in the cross-section in Figure 20 of Puget Sound Bluffs: (except I don’t have a soil sample). The "Olympia Beds" is another name for the "pre-Lawton sediments" shown in the cross-section.

4. a. Given the factors which affect landslide potential (see first page), which factor would a sediment with high porosity most affect?

b. Which factor would a sediment with high permeability most affect?
5. Assess the following characteristics of each sediment. For **grain size**, choose the **average** grain size from one of the following: pebble, sand, silt, clay. For **grain sorting**, choose one of the following: well-sorted, moderately-sorted, poorly-sorted. For **porosity**, choose either high or low.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Grain size</th>
<th>Grain sorting</th>
<th>Porosity</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vashon Till</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(consider the tub’s entire contents)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esperance Sand</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lawton Clay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olympia Beds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Look again at the cross-section and recall that water will lubricate the **slide plane** (the surface along which the landslide occurs). At the **contact** of which two units is the slide plane most likely to be?

7. a. Orient the *North Seattle Surface Geology* raised relief geological map such that you can locate the same area on Tubbs’ Zone of Particular Landslide Hazard map (the mouth of Thornton Creek at Matthews Beach should help). Find the only landslide hazard zone in this part of Seattle; what **geological contact** seems to coincide with this hazard zone?

b. How would you **test** this correlation (in other words, if you go to this zone and are unable to see the sediments, what would you look for besides sediments?)? Hint: you can see a lot of these after a good steady rainfall, sometimes in driveways of homes.
8. Look at the Landslide Hazard Areas criteria from the King County Sensitive Areas Map Folio (1990). This folio, incidentally, contains all sorts of other hazard assessments so you may wish to consult it when buying land in this county! But, to return to landslides, suppose a piece of land you’re buying is situated on a slope from the front to the back of the property. If the property line in that direction is 400 feet long, how much elevation change (relief) can there be on your property before King County would classify it as a hazardous area? Hint: set up a proportion.

9. What could you do to mitigate this hazard? List at least two possibilities. Are they permanent solutions?

Earth hazards summary

10. To summarize earthquake, volcano and landslide hazards: Examine the tall map of the Puget Sound area on the easel. Suppose you bought land in each of the following towns; give at least one hazard from the three listed above that would affect you and how you could minimize (or avoid) being affected.

a. Sunlight Beach (Whidbey Island — 48°N 122°30’W)

b. Sumner (Pierce County — 47°15’N 122°15’W)

c. Sunset Beach (Vashon Island — 47°25’N 122°30’W)