Landslides

What is a landslide?
A landslide is the mass movement of material (rock, earth or debris) down a slope. Landslides can be categorised into many different types depending on the antecedent conditions and triggering factors (USGS, 2013).
## Landslide Types (USGS, 2013)

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<thead>
<tr>
<th>Landslide types</th>
<th>Sub-types</th>
<th>Descriptions</th>
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<tbody>
<tr>
<td>Slides</td>
<td>Rotational</td>
<td>The surface of the slide is curved, with a rotational movement evident</td>
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<td>Translational</td>
<td>The slide occurs across a planar (i.e. straight) surface</td>
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<td>Block</td>
<td>The moving mass consists of a single unit (or very few) that moves as a coherent mass</td>
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<td>Falls</td>
<td>Rockfalls</td>
<td>Collapse of material from cliff or steep slope</td>
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<td>Topples</td>
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<td>Toppling failures are caused by the forward rotation of a unit or units about a pivotal point, below or low in the unit (at the base), under the actions of gravity and forces exerted by adjacent units or by fluids in cracks</td>
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<td>Flows</td>
<td>Debris flow</td>
<td>A debris flow is a form of rapid mass movement in which a combination of loose soil, rock, organic matter, air, and water mobilize as a slurry that flows downslope. Debris flows often occur on steep slopes, with saturation of soil the main trigger</td>
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<td>Debris avalanche</td>
<td>Rapid flow of debris</td>
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<td>Earthflow</td>
<td>The slope material liquefies and runs out, forming a bowl or depression at the head</td>
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<td>Mudflow</td>
<td>Rapid flow of mud</td>
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<td>Creep</td>
<td>Slow, steady, downward movement of slope-forming soil or rock. Caused by shear stress</td>
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<td>Lateral Spreads</td>
<td>The failure is caused by liquefaction, the process whereby saturated, loose sediments are transformed from a solid into a liquid state. Usually triggered by ground movement, e.g. earthquakes. Usually occur on very gentle slopes or flat terrain</td>
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What causes them?
The primary causes of landslides are the effect of gravitational pull on an over-steepened slope and the rapid infiltration of water into the slope material (typically, high magnitude rainfall).

Triggering factors:
- Erosion of slope material by rivers, oceans and glaciers creating over-steepened slopes
- Material weakened following precipitation (usually snow or heavy rainfall)
- Earthquakes weakening slopes
- Volcanic eruptions can produce debris flows
- Removal of vegetation can weaken slopes
- Human activity, such as mining, can cause instability
- Excess weight from man-made structures may cause stress on slope

Where do they occur?
Landslides can occur all over the world. Any area composed of weak material on a steep slope will likely experience landslides.
Case Study

Rest and Be Thankful

Scotland has a significant landslide risk at Rest and Be Thankful, a mountain pass on the A83 trunk road in the west of Scotland. Debris flow events have occurred no fewer than 10 times in the last 7 years across the following months: Oct 2007, Sept 2009, Dec 2011, Feb 2012, June 2012, Aug 2012, Oct 2013, Jan 2014, March 2014, Oct 2014.

An aerial view of the extent of the October 2014 debris flow (BEAR NW Trunk Roads (b), 2014)

Impact

Every time a debris flow event occurs the road closes for anything from a day to several weeks. This has significant socio-economic impact on local towns Inveraray and Lochgilphead, a 2½ day closure costs £130,200 in economic losses while a 13 day closure costs £676,800 (Jacobs, 2013). Closing the road also removes the main transport link, with detour routes adding significantly to journey times.

There are two diversion options, both of which cause additional complications. The Old Military Road option is a narrow undulating road which (despite being improved) is not ideal for vehicular use. This route adds an additional 15-45 minutes to each journey. Depending on the size of the event, if debris forces the closure of this route as well, the alternative is an extra 26 miles. Thankfully no deaths have occurred due to debris flows at Rest and Be Thankful, however the risk remains a major concern.
Mitigation

Current mitigation combines structural, non-structural and ecological methods. A series of options were reviewed as part of an Environmental and Engineering Assessment carried out by Jacobs (2013) for Transport Scotland. The current mitigation is ‘The Red Option’.

“The Red Option” £10million

- 440m debris flow barriers
- Improved hillside drainage
- Vegetation planting on slope

Debris flow barriers (right, Transport Scotland, 2015) have been implemented in 12 phases across 2010-2014. These catch nets are designed to contain material that is anticipated to flow in each location by absorbing energy from the flow of debris, containing it behind the barrier. Where a landslide does occur, some material might reach the road as the debris fences don’t offer complete containment, but the quantity of material is reduced, as well as the risk to road users.
Pros and cons of debris flow barriers

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<th>Pros +</th>
<th>Cons -</th>
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<td>Reduces quantity of material reaching road and therefore reduces risk (evidence of success in 2013 event holding up to 30 tonnes (Transport Scotland, 2015)).</td>
<td>Nets can only contain a certain capacity, if the event is greater than this then overflow of barriers occurs as in 2014.</td>
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<td>Light, flexible and easily installed.</td>
<td>Water is not held back by barriers so flood risk remains even if debris is caught.</td>
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<td>Cheap when compared with other options.</td>
<td>Debris needs to be removed from nets following every event.</td>
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<td>Aesthetic value not compromised.</td>
<td>Debris barriers do not extend across whole area, some gullies are unprotected. If landslide occurs then material would go onto the road.</td>
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The implementation of monitoring equipment at Rest and Be Thankful allows assessments to be made about current slope conditions and warn road users about potential risks where necessary. Monitoring is done by piezometers (measures the pressure of groundwater), inclinometers (measures angles of slopes) and weather stations (monitoring rainfall levels).

Wig-Wag signs have been implemented on the A83 as a means to warn motorists of potential landslide risk. These signs warn road users of potential landslide risk without the need for road closure in order to increase awareness of the need for cautious driving. Yellow lights flash when risk is increased as a visual indicator. Although this does not reduce the risk, it does allow motorists to be aware and take necessary precautions. In the event of an extreme risk or an actual landslide, the road is still closed to motorists.

Whilst The Red Option does not completely remove the risk of landslide in the area, it does provide a cost effective method of reducing the risk as much as possible. Despite the risk still remaining, measures that have been put in place do provide the opportunity to regularly monitor Rest and Be Thankful and warnings can be communicated easily to drivers. If necessary, the road can be closed. Although closing the road means an extended journey route and can lead to economic losses, it is better that economic losses are made than risk loss of life.
Other Mitigation Strategies

As well as the methods in place at Rest and Be Thankful there are other forms of mitigation for landslide hazards.

Examples include:

• Debris retention basins – Charles Creek, British Colombia, Canada. The idea is that the basin holds most of the debris in a landslide event. However, this needs to be emptied, which is difficult and expensive to do, and the basin could be overtopped in an extreme event.
• Landslide shelter/tunnel over roads – Arthur’s Pass, New Zealand. This can be effective but is very expensive to construct, and there is also a negative aesthetic impact.
• Realignment of critical infrastructure such as railway lines – Stromeferry, Scotland.
• Artificial drainage channels.
• Vegetation of slopes - the effectiveness of this strategy is still debated.
• Relocation of populations away from high-risk areas.

Hard engineering methods are typically expensive and will only be used where there is either significant potential for repeat events, or where there are high populations in high-risk areas. As well as hard engineering measures it is also important to monitor, model and educate. Monitoring of slopes allows antecedent conditions to be determined such that there is an awareness of when a failure may occur. As failures are often rapid it is important to give as much warning as possible to those at risk. Educating people on landslides, their associated risks and what to do in the event of a landslide allows better preparation and a reduced impact.
References


Contact
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