Forest Sciences

Prince Rupert Forest Region

Extension Note # 04
March, 1995

The Mink Creek Earthflow

Figure 1. The Mink Creek earthflow retrogressed about 600 meters.

Background

We generally associate slope failures with steep, mountainous areas. Flat to rolling, subdued terrain is thought of as having a relatively low risk of landslide occurrence. This is not always the case. Sometime, between mid-December, 1993 and early January, 1994, approximately 23 hectares of glaciomarine sediments (sediments of glacial origin deposited in the sea) flowed and slid rapidly into Mink Creek, near Terrace, BC. Spoil from the earthflow crater filled the incised channel of Mink Creek, extending downstream approximately one kilometer. The debris dammed the creek, raised the water level by 10 meters and backed water upstream 1200 meters.

Research Issue Groups:

- Forest Biology
- Forest Growth
- Soils
- Wildlife Habitat
- Silviculture
- Timber Harvesting
- Ecosystem Inventory and Classification
- Biodiversity
- Ecosystem Management
- Hydrology
- Geomorphology
- Extension
- Forest Engineering

Figure 2. Exposed failure plane in centre of flowbowl. Spoil lineation in the centre of photo parallels the direction of flow.

Cause

A helicopter pilot, who followed dirty water in the Lakelse River to its source in Mink Creek, first observed the earthflow site January 9, 1994. What specifically triggered the earthflow at Mink Creek is not known. No earthquakes occurred or were felt in the vicinity of Mink Creek during the months preceding the failure. Factors contributing to the failure were probably: 1) sensitive marine parent material; 2) high stream flows (observed November, 1993); and 3) high pore water pressures due to a wet, mild fall and early winter.

The failure probably started at the site of a small bank failure in the down-cutting Mink Creek when a zone of sensitive clay suddenly liquefied, causing a complex sequence of flowing and sliding along gently dipping failure planes. The headscarp (upper edge of the failure) rapidly retrogressed away from the initiation point, filling and damming Mink Creek with landslide debris.

While the conditions that led to the failure took thousands of years to develop, the entire event may have occurred in a few minutes. For example, the time elapsed from the initial failure to the final expulsion of debris of the 1962 Lakelse Lake earthflows was estimated between one and ten minutes.

Deglaciation

The Mink Creek earthflow occurred in rolling to flat, gullied glaciomarine terrain in sediments that were deposited approximately 10,000 years ago during deglaciation (glacial retreat). The weight of the glacier depressed the ground below sea level, such that when it retreated ocean water filled the valley, creating a fjord. Glacial retreat up the Kitsumkalum-Kitimat Trough was relatively rapid, although there were several periods when the ice front was stable. During one such period, the snout of the stable, calving glacier was situated near the present location of Thornhill. Sediment-laden meltwaters poured from the ice front. Gravels and sands were deposited near the snout of the glacier forming a large *sandur*, or outwash plain (Terrace Airport). Smaller clay and silt particles remained suspended in the sea much longer and were deposited further from the ice front, forming silty-clay deposits such as those found at Mink Creek.

How Marine Sediments Become Sensitive

Isostatic rebound (uplift of the earth's surface in response to a decreased load) following deglaciation elevated the fjord floor approximately 200 meters near present day Mink Creek. Elevated sediments that had settled in a saline, marine environment, underwent leaching by freshwater which gradually lowered the material's salinity.

Clay particles are plate-like, and in most freshwater situations, settle face down as individual particles. In a saline solution, however, clays form aggregates where individual particles are randomly aligned. This aggregated structure gives the material a higher than normal ratio of pore space to solids. This high void ratio enables the soil to have an abnormally high water content.

Figure 3. Ridge with horizontal bedding slid towards trees along a slightly dipping failure plane.

Interparticle bonds in marine clays are relatively strong at high salinities. These sediments become "sensitive" when the salinity falls below a certain threshold. At low salinities, interparticle bonds weaken, leaving clay aggregates prone to collapse.

Sensitivity is simply a ratio of the strength before and after structural collapse of the clay aggregates. The greater the difference between the undisturbed and the remoulded strength of a material, the greater its sensitivity will be.

The sensitive sediments of Mink Creek are relatively strong when undisturbed, but become nearly liquid when disturbed, as in the failure process.

Marine sediments become sensitive under leached conditions due to decreasing salinity. It is the low salinity that allows the soil to lose so much strength that it changes into a slurry, enabling the earthflow at Mink Creek to occur.

Material Description

A stiff, fissured, weathered crust, 3 - 4 m thick, overlies sensitive gray silty-clay. Bands of silty-clay are separated by thin (generally less than 1 mm thick) silt seams and an occasional sand seam. The sensitivity of the material beneath the crust decreases with depth. The decrease in sensitivity probably coincides with increasing salinity. Marine shells are common in the material.

Description of Flowbowl

The crater left by the earthflow is shaped like a cloverleaf and is bounded by gullies to the east, and to the west. Some of these gullies are scars of older earthflows.

There are two distinctive areas in the main flowbowl. The eastern section of the failure contains a relatively small amount of landslide debris. Extensive areas in its center reveal an exposed failure plane (Figure 2). Where the failure plane is exposed, bedding dips down-flow at about 3°. Debris sliding along a dipping slip-surface travels more rapidly than debris on a horizontal slip-surface. Lineations of spoil on a clean surface, trending parallel to the flow direction, are possibly indicators of rapid, high energy debris transport. These features may be the result of flakesliding (where a large mass of material slides simultaneously rather than retrogressively). Ridges and intervening wedges, indicating retrogressive failure, are more common in the western part of the failure (Figure 3). Generally ridges trend perpendicular to flow direction.

The flowbowl contains numerous ridges, and remarkable pyramidal structures (Figure 4) - portions of ridges - that have slid along a failure plane. Bedding in these structures is horizontal, or nearly so, indicating there was no rotational failure. Between ridges, intervening wedges of debris collapsed under their own weight. In some cases wedge material rotated off ridge flanks.

There are multiple slip-surfaces within the earthflow. This is significant because it demonstrates there are many zones of weakness and potential slip surfaces in the material. Failures possibly occurred along silty, or coarser textured seams. At one location an exposed slip-surface was littered with small pebbles.

Figure 4. Remarkable, horizontally banded prism slid along a nearly level, to slightly dipping, failure plane. Prism is approx. 4.5 m high.

Post-Failure Erosion

Post-failure erosion of the crater and spoil is significant. Nine months after the failure, 5-cm high pedestals were common in exposed deep material such as on the failure plane and gray spoil surfaces. Spoil from the stiff upper crust appeared to be less erodible than the deeper material. Near the snout of the debris, Mink Creek had re-routed a course through the adjacent forest. The creek had cut a channel more than 2 m deep, and in one location, had eroded a 3 m deep hole.

Regional Significance

Sensitive glaciomarine sediments are extensive in the Terrace-Kitimat area, and in other uplifted fiords (now fiordal valleys) of the middle and north coast. Two similar earthflows occurred in 1962 at Lakelse Lake. Smaller flows have been triggered in recent years through construction activities, generally with the loading of materials and vibration by equipment (Kitsault, Kitkiata, Crow Lagoon). Drill records indicate that sensitive sediments also occur near Alwyn Creek. Older, undated earthflow scars have been identified on airphotos at a variety of locations in the Kitsumkalum-Kitimat trough.

Flowbowls in clearcut areas are relatively easy to pick out on air photos, but they are very difficult to distinguish in forested terrain. In many cases earthflow headscarps are merely 1/lOth the height of surrounding forest.

Perhaps the rolling nature of the terrain can be attributed, not only to underlying bedrock hillocks, but also to a long history of earthflow activity.

Research To Date

Morphological features in the earthflow have been extensively examined to determine mechanisms of failure. In addition, detailed pre- and post-failure topographical maps have been prepared for the site. Shear strengths were measured at two locations in the crater, and also above the headscarp. Drill hole samples were collected above the headscarp. Samples were analyzed for strength, particle size, morphology, and other geotechnical properties. Mineralogical and chemical analysis is currently underway. Measurements from two piezometers, installed in the drill hole, are being recorded on a regular basis.

Management Implications

The Mink Creek and Lakelse earthflows were significant events. Just because an area has already failed, is no reason to conclude it won't fail again. Further downcutting of Mink Creek, for example, could set up the conditions for another earthflow.

Activities that accelerate stream erosion can also accelerate earthflow occurrence. Similarly, loading of slopes near erosional waterbodies may trigger earthflows. Channelization of water may also increase the likelihood of earthflow occurrence through local increase of pore water pressures.

Poor logging and road building practices could contribute to the above, and, hence, ripen the requisite conditions for earthflow occurrence.

Construction of permanent structures and dwellings should be avoided in earthflow-prone terrain. Only detailed geotechnical investigations can determine if conditions are safe.

Future Research Requirements

Sensitive marine clays are extensive in the Terrace-Kitimat area and other uplifted fjordal valleys. Serious study is required, not only in the Terrace-Kitimat area, but also in other fjordal valleys.

Preparation of regional hazard maps of earthflow-prone terrain is necessary. Four steps must be undertaken: 1) surficial and buried glaciomarine deposits have to be located (terrain map); 2) earthflow scars (flowbowls) need to be identified through a combination of airphoto interpretation and field reconnaissance; 3) an attempt should be made to determine the relative retrogression of these earthflows; and 4) stream erosion should be investigated in earthflow-prone terrain. Steps 3 and 4 are important because they may help predict the size and location of future failures.

Drilling should be conducted at strategic locations (it's expensive) to examine material properties. In most cases a portable instrument, such as the Swedish Vane Borer, is sufficient to record soil shear strengths at depth.

Earth resistivity measurements may also be used to indirectly determine material salinity. This could prove useful since salt content is strongly linked with clay sensitivity.

Suggested Reading

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