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Debris flows and debris avalanches in Clayoquot Sound

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23.1 INTRODUCTION

Clayoquot Sound on the west coast of Vancouver Island is rich in natural resources. The watersheds in Clayoquot Sound are heavily forested with a variety of conifers, and five species of salmon spawn in the streams of the area. Both aboriginal and western cultures harvest the abundance of resources that these streams and watersheds supply. The area supports a major tourist industry as well as commercial fishing and logging operations.

Clayoquot Sound is rugged, with steep mountains rising directly from the ocean, or from a narrow coastal plain that lies in front of the mountains (Figure 23.1). The winter months are wet due to cyclonic storms that originate in the northern Pacific Ocean and track eastward towards the coast of British Columbia (BC). Intense precipitation frequently occurs as the storm fronts rise over the coastal mountains. Debris flows and debris avalanches are common as a result of this intense precipitation.

Until the 1960s, most forest harvesting in Clayoquot Sound occurred at low elevations on the coastal plain and along the valley bottoms. As logging moved onto steeper slopes, landslides became more common; a result of changes in hillslope stability due to both clearcut harvesting and road-building practices that failed to address landslide concerns.

In the 1980s and 1990s, environmentalists began to direct criticism against the forest industry on Vancouver Island and, particularly, in Clayoquot Sound. One of their strongest criticisms was directed towards the effects of forest harvesting on steep slopes that led to debris avalanches and debris flows that delivered large quantities of sediment into fish streams. The visual effect of logged hillslopes scarred with landslides was a potent image (Figure 23.2), and photographs of clearcuts and landslides on west-coast mountainsides were featured in environmental

publications and in mainstream journals such as the *National Geographic* magazine (September, 1990).

During this time, the BC government and the forest industry began studies to improve their understanding of the effects of logging and road construction on steep slopes. Research was also directed at developing methods that better identified landslide-prone terrain and that minimized landslide hazards and the risks of operating in steep terrain. Much of this research occurred on the west coast of Vancouver Island, with some research centered in Clayoquot Sound. At the same time, extension efforts intensified in the form of workshops, conferences, and handbooks on the management of landslide-prone terrain (e.g., Chatwin et al., 1994).

In 1995 the BC government passed the Forest Practices Code Act of British Columbia (FPC), which contained strict requirements for the assessment and management of landslide-prone terrain. Even greater restrictions were incorporated with the implementation of recommendations from the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound (SPSFP, 1995). Many of the slope stability regulations in the FPC are based on studies that were conducted in Clayoquot Sound, on the west coast of Vancouver Island and elsewhere in coastal BC.

Government and the logging industry recognized the damage caused by logging-related landslides. Shortly before the FPC was introduced, the BC Watershed Restoration Program was implemented to mitigate and minimize further logging-related landslide damage to watersheds throughout BC. An important aspect of this program was the deactivation (or de-building) of old roads that were associated with landslides. In 1996, a particularly long and intense storm in the central and northern portion of Clayoquot Sound as well as widespread areas in Washington, Oregon, and northern California (Robinson et al., 1999) reinforced the need for a watershed restoration program. In the Clayoquot Sound region alone 273 landslides initiated within a four-day period. Of these, two-thirds were related to logging, with landslides from roads accounting for 25% of the total number of landslides.

The west coast of Vancouver Island continues to be difficult terrain in which to conduct forest harvesting. For example, by 1994, more than 80% of the remaining old-growth forest in Clayoquot Sound was located on slopes steeper than 30° (SPSFP, 1995). The industry relies on the advice of terrain specialists to identify the landslide hazards and risks their operations may present. In turn, these experts rely on a locally developed body of research on which to base their assessments.

The remainder of this chapter discusses debris flows and debris avalanches, the most common landslide types in Clayoquot Sound. To a lesser extent, other landslide types are also discussed. Finally, the effects of logging on hillslope stability, and how current forest operations manage landslide risks in Clayoquot Sound are presented.

23.2 LOCATION AND SETTING

Clayoquot Sound is located within the central portion of the Vancouver Island Mountains, a major north-west to south-east-trending physiographic unit that