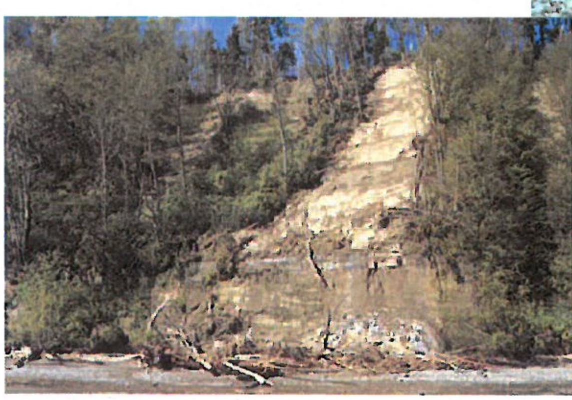
King Conservation District

Conservation Topic

Marine Shorelines:
Geological Processes, Land Use Impacts & Conservation Practices



Acknowledgment

Special acknowledgment and thanks is given to Hugh Shipman of the Washington State Department of Ecology for use of photos and text taken from Coastal bluffs and sea cliffs on Puget Sound, Washington (2004), included in the body of this information paper. Utilization of portions of the cited paper aided significantly in the timely and efficient production of this paper.

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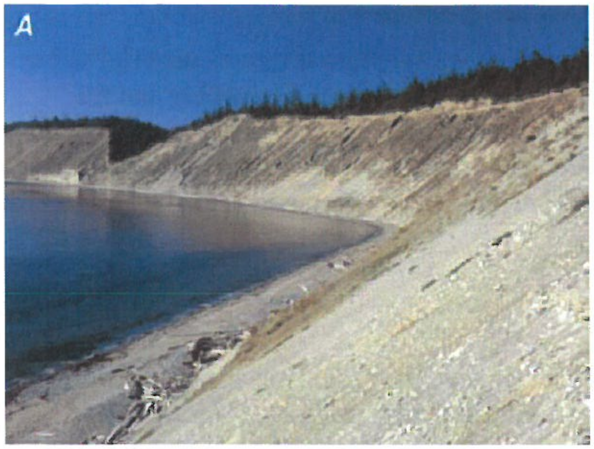
INTRODUCTION

When people think of shorelines they often think of expansive sand beaches backed by low lying lands stretching for miles behind them, sometimes with dunes and beach grasses separating the beach from the woodlands and communities which lie inland. This image, while representing much of the temperate coastal landscape including some of the Pacific Northwest Coast, does not reflect well the landscape of our Puget Sound Shoreline. In the Puget Sound region coastal bluffs and gravel beaches are the landscape most often encountered when one explores the shores of our beautiful inland marine waters.

Unfortunately, population growth in the region has significantly increased development along the shoreline. As much of the low-lying shores were already developed as ports and cities early in the last century, much of the current development is occurring along coastal bluffs. Much of this development has occurred with little awareness of the risks associated with erosion and landsliding, or the importance of these systems in maintaining the geological and biological integrity of Puget Sound's beaches and ecology with serious ramifications to public health and safety and the environment. The purpose of this text is to review some of the current knowledge of the coastal bluffs and beaches around Puget Sound, the processes that shape them, and some recently acknowledged management techniques that can aid coastal landowners in supporting and restoring their ongoing health.



Uniform slope of sand and gravel

Complex bluff profile of varied composition

In contrast, bluffs consisting solely of glacial till or marine drift may form near-vertical banks. Most bluffs, however, are cut through a sequence of sedimentary units, each with distinct slope forming properties. This can lead to complex bluff profiles containing both steep and gradual segments depending on the geologic, hydrologic, and mechanical properties of individual units. Poorly consolidated sands and gravels become slope-forming units, whereas glacial till and ancient lake bed silts and clays are often cliff-forming. The presence of distinct stratigraphic elements also impacts hydrologic characteristics that influence mass-wasting mechanisms, leading to more complex profiles. For example, many high bluffs on Puget Sound are marked by a mid-slope bench that forms at the contact between permeable advance outwash deposits and underlying impermeable lakebed clays. Saturation along this contact drives upslope failures that result in more rapid retreat of the top of the slope than the base, causing the bench to widen. These benches, which can vary from a few tens of feet to hundreds of feet in width, may exhibit highly irregular topography as a result of their origin in landslides from the upper cliff.

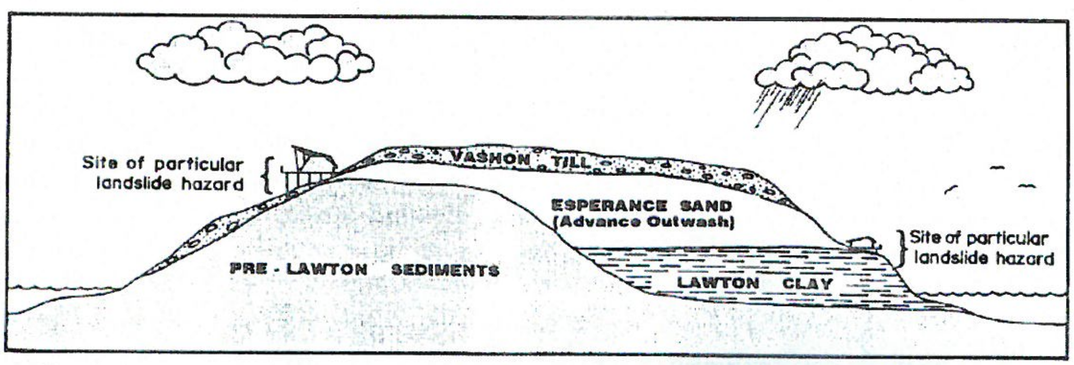


Figure 12. Sketch of a typical Seattle hill showing slope stability relations (modified from Tubbs, 1974).

Typical King County bluff profiles showing geologic composition.

HILLSLOPE AND LANDSLIDE PROCESSES

The most visible event associated with buff retreat occurs through landsliding. Slope failures can range from shallow slides a few tens of feet across to deep-seated landslides many hundreds of feet in size. It is important to realize that landsliding or "mass-wasting" is a natural part of the coastal system. Movement of material from the bluffs to the beaches is necessary for the nourishment of the beaches themselves. It is also important to realize that not all landslides are inherently hazardous. Many landslides represent the slow ongoing processes of weathering of slope sediment, and the transport of soil and woody debris to the beach where both are crucial to the existence and ecology of our unique Puget Sound shorelines.

Raveling

Poorly consolidated deposits of glacial outwash sands and gravels may erode primarily through raveling or surface erosion of the bluff face. Failures tend to be progressive, beginning with undercutting at the toe by wave action, then gradually extending upslope. Raveling tends to occur in areas where loose sediments are eroding rapidly enough so that protective soil binding vegetation cannot become established. If and when sufficient sediment moves downslope to protect and buttress the slope, vegetation can become reestablished and can protect the slope from surface erosion.

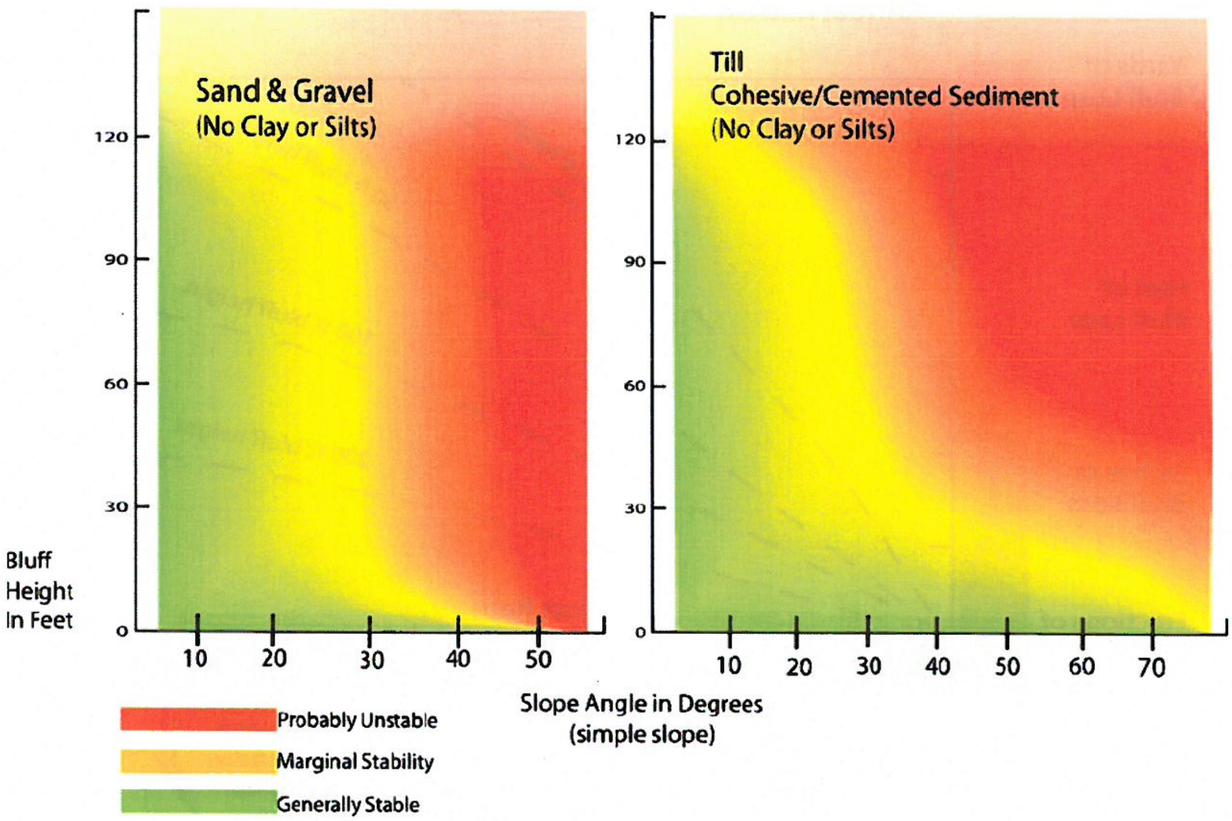
Shallow Landslides

Most landslides that occur on Puget Sound bluffs consist of shallow landslides and debris slides. Shallow landsliding is pervasive along many shoreline reaches, although any one site may slide only once every 30 or 40 years. These landslides typically involve only a thin layer of soil and associated vegetation generally involving the top 3 to 6 feet of the soil profile. Some extend the entire height of the bluff, but others only affect a portion of the slope. Shallow failures may occur as small slumps, debris slides, or as topples of overlying glacial till. Single slides may occur by several mechanisms — for example, a block failure of glacial till high on a bluff may develop into a larger landslide as it moves downslope. Shallow slides are usually triggered by heavy rainfall over a period of hours to days. They are easily caused by drainage failures or modest redirection of surface drainage.

Large Slumps and Landslides

Puget Sound is subject to occasional, much larger, landslides that may involve many thousands of cubic yards of material. These slides are much less common than shallower slides, but would be devastating if they occurred in a developed area. Understanding of the geologic conditions that give rise to these large slides is limited, but such slides seem to be associated with higher bluffs and have been triggered both by elevated groundwater levels and by earthquakes. Coherent geologic units, such as glacial till and glacial marine drift, tend to fail as blocks on near-vertical slopes. When basal support is lost, through direct undermining by waves or by erosion of underlying units, failures occur along joints or tension cracks that form parallel to the bluff face. Block failures are typically a meter or less in thickness, although faces with greater relief seem capable of generating thicker failures.

The figure shown below shows the basic relationship between bluff height, slope angle, geologic composition and general slope stability. Relating to bluffs without significant structural defects such as clay at the bluff base, this figure is provided to give the reader a basic understanding of the interplay of these elements. Due to the complexity of geotechnical evaluation techniques this figure is not meant as a alternative to consultation with qualified professionals. Always consult with your local government and qualified professional consultant before making important decisions regarding any critical area slope.



Relationships between bluff height, slope angle, geologic composition and general slope stability

RATE OF BLUFF RECESSION

Long-term bluff recession rates on Puget Sound reflect three primary factors, including wave action, bluff geology, and beach characteristics. Waves provide the energy necessary to erode the toe of the bluff and to remove eroded sediment from the site. Geology determines the resistance of the bluff to erosion and its susceptibility to landslides that deliver erodible material to the base of the slope. The width of the beach and the height of the beach berm control the frequency and intensity with which waves can reach the bluff toe. The highest erosion rates measured on Puget Sound and in the Georgia Strait occur in fairly loose sediments where wave exposure is high. Galster and Schwartz (1990) found that erosion rates of bluffs west of Port Angeles were as much as one meter per year before the shoreline was armored. Keuler (1988) determined rates of over 30 cm/yr on the western shore of Whidbey Island with significant exposures along the Strait of Juan de Fuca. These rates are not typical, however, and in most areas recession rates appear more erosion rate can give an indication of the long-term bluff recession rate.

COASTAL DEVELOPMENT

Pressure to build along coastal bluffs is rising rapidly with increasing population growth and urbanization in the Puget Sound region. Much of the shoreline lies within a short distance of the major metropolitan centers of Seattle, Tacoma, and Everett. These areas have seen a significant shift in the character of shoreline development from small seasonal retreats and retirement cabins to large primary residences. The demand for waterfront and bluff property is driven primarily by access to the water and unimpeded views of the Sound and nearby mountains. Development along bluffs most commonly occurs at the top of the bluff. The distance a building is set back from the bluff edge depends on local regulations, the history and age of the structure, the topography of the site, lot lines, and the original property owner's concept of risk and their desire for views. Property owners often build as close to the edge as allowed, in large part to maximize views in an otherwise forested area. The risk to bluff top homes is relatively low as a consequence of slow erosion rates, although a property owner's perception of danger may be greatly enhanced by periodic landslides or related bluff failures.

Since the early days of European settlement, development has occurred at the base of steep coastal bluffs. In some cases, homes are built on spits, stream deltas, or related depositional landforms waterward of the bluff toe. In other cases, development occurred on artificial fill placed across the backshore or beach. In several locales residential developments were created in the 1950s and 1960s by constructing bulkheads on the beach below a high bluff and then using hydraulic methods to wash bluff material in as landfill. The legacy of such development is rows of homes at water level, constructed on non-engineered hydraulic fill, and located at the base of unstable bluffs 100-200 feet high. In some locations, homes (and in the case of Tacoma's Salmon Beach, an entire community) were constructed on piles over the beach at the base of high bluffs. Such development would not be allowed today for many safety and environmental reasons, but where it already exists, we observe regular conversion of small cabins into large homes and periodic slide damage to homes. Although the steeper coastal bluffs largely preclude development on the slopes themselves, development can and does occur in less extreme situations. Building is common on more gradually sloping portions of complex coastal slopes, and in particular, on the mid-slope benches that characterize many bluff shorelines. These areas often appear to offer prime building sites in otherwise difficult to build areas. Unfortunately, these benched slopes often reflect unstable geologic conditions. Another circumstance where building occurs on the slopes themselves is in areas where property lines, old unregulated building practices, or modern heavily engineered development have led to homes being constructed on piles or multilevel foundations either above or into the face of steep slopes.

HUMAN IMPACTS ON SHORELANDS

Humans are in themselves an agent of bluff erosion, at least in their capacity to trigger landslides or increase erosion through careless or imprudent development practices. The occurrence of landslides and the continued erosion of coastal bluffs is a natural process, but humans, primarily through their propensity to modify natural hydrology, can easily exacerbate unstable conditions or trigger slides. Puget Lowland is a heavily forested area with high precipitation. Surface runoff and subsurface saturation are highly sensitive to the abundance and type of vegetation. Land

Bulkheads

Shoreline bulkheads are often used on Puget Sound to address wave-induced toe erosion. Numerous materials are used, including concrete, wood, and rock, and a variety of designs are employed, including gravity walls, riprap revetments, and sheet pile walls. The most commonly built structure is a steep rock bulkhead or rockery. These structures are typically less than 6 feet high and are required by regulations to be located as close to the bluff toe as possible. The effectiveness of bulkheads varies considerably. The wave environment in most of Puget Sound is sufficiently protected that structures need not be massive to address local wave conditions. Bulkheads are often seen as a panacea for coastal slope stability problems, however they are an approach that overemphasizes the role of waves in determining overall slope stability.

On many shoreline bluffs the slope is already over-steepened and more likely to fail during a heavy rainfall than during high wave conditions. Many of the landslides during the heavy rainstorms of 1996-97 occurred on slopes where bulkheads had protected the toe for many decades. Although bulkheads are commonly used to protect the toe of slopes from wave action, in some cases (for example, after a failure of a coastal bluff already protected by a bulkhead) property owners have built multiple-stage retaining walls, reinforced soil embankments, or have otherwise modified the geometry of the entire bluff. In the case of deeper sliding, larger rock toe buttresses have been constructed, but regulations preventing encroachment across the beach increasingly discourage such solutions. Biotechnical stabilization methods have received much interest in recent years, in part because of their potential for addressing slope stability problems in environmentally sensitive areas, but their actual application has been limited.

Special Foundations

Sometimes the use of deep or pile foundations can provide an additional margin of safety for structures built close to certain types of coastal bluffs. Over the last few decades pile foundations have become more frequently employed by engineers to protect structures from possible shallow slope movement and settling. It is also possible to retrofit existing homes with foundations that can lessen risks associated with the movement of bluff sediment.

Environmentally Sustainable Approaches to Bluff and Property Protection

There are a limited number of landuse and protective measures which can reduce the amount of impact we have on a bluff system, and protect both property and the environment. These measures include the following:

- Minimize impervious surfaces near bluffs
- Preserve and enhance native bluff and near-bluff trees and vegetation whenever possible
- Detain and properly convey stormwater to safe discharge point and dissipate flow energy
- Conduct risk assessment and set back buildings accordingly
- Preserve natural shoreline protection elements such as driftwood, berms, and beach grasses
- Avoid and discourage use of bulheads and groins, which can have adverse impacts on beaches
- Utilize special foundations to protect structures instead of bulkheads where practical

ATTACHMENT E -
Conservation Topic - Marine Shoreline Geological Processes