

- Cohesive material is more resistant to surface erosion and has low permeability, which reduces the effects of seepage, piping, frost heaving, and subsurface flow on the stability of the banks. However, when undercut and/or saturated, such banks are more likely to fail due to mass wasting processes. Failure mechanisms for cohesive banks are illustrated in Figure 2.9(b).
- Composite or stratified banks consist of layers of materials of various sizes, permeability, and cohesion. The layers of noncohesive material are subject to surface erosion, but may be partly protected by adjacent layers of cohesive material. This type of bank is also vulnerable to erosion and sliding as a consequence of subsurface flows and piping. Typical failure modes are illustrated in Figure 2.9(c).

Piping. Piping is a phenomenon common to alluvial streambanks. With stratified banks, flow is induced in more permeable layers by changes in stream stage and by waves. If flow through the permeable lenses is capable of dislodging and transporting particles, the material is slowly removed, forming “pipes” which undermine portions of the bank. Without this foundation material to support the overlying layers, a block of bank material drops down and results in the development of tension cracks as sketched in Figure 2.9(c). These cracks allow surface flows to enter, further reducing the stability of the affected block of bank material. Bank erosion may continue on a grain-by-grain basis or the block of bank material may ultimately slide downward and outward into the channel, with bank failure resulting from a combination of seepage forces, piping, and mass wasting.

Mass Wasting. Local mass wasting is another form of bank failure. If a bank becomes saturated and possibly undercut by flowing water, blocks of the bank may slump or slide into the channel. Mass wasting may be caused or aggravated by the construction of homes on river banks, operation of equipment adjacent to the banks, added gravitational force resulting from tree growth, location of roads that cause unfavorable drainage conditions, agricultural uses on adjacent floodplain, saturation of banks by leach fields from septic tanks, and increased infiltration of water into the floodplain as a result of changing land-use practices.

Various forces are involved in mass wasting. Landslides, the downslope movement of earth and organic materials, result from an imbalance of forces. These forces are associated with the downslope gravity component of the slope mass. Resisting these downslope forces are the shear strength of the materials and any contribution from vegetation via root strength or engineered slope reinforcement activities. When the toe of a slope is removed, as by a stream, the slope materials may move downward into the void in order to establish a new equilibrium. Often, this equilibrium is a slope configuration with less than original surface gradient. The toe of the failed mass then provides a new buttress against further movements. Erosion of the toe of the slope then begins the process over again.

Bank Erosion and Failure. The erosion, instability, and/or retreat of a stream bank is dependent on the processes responsible for the erosion of material from the bank and the mechanisms of failure resulting from the instability created by those processes. Bank retreat is often a combination of these processes and mechanisms operating at various timescales. While the detailed analysis of bank stability is, primarily, a geotechnical problem (see for example, FHWA publications on soil slope stability),<sup>(18,19)</sup> insight on the relationship between stream channel degradation and bank failure, for example, can be important to the hydraulic engineer concerned with bank instability. The processes responsible for bank erosion and bank failure mechanisms are discussed in more detail in Appendix B.