4.0 EROSION AND SEDIMENT PROCESS

4.1 Mechanics of Erosion

Erosion is the wearing away of material by naturally occurring agents through the detachment and transport of soil materials from one location to another, usually at a lower elevation. Natural agents are mostly responsible for this phenomenon but the extent to which erosion occurs can be considerably accelerated through human activities.

Water is the predominant agent of erosion on highway construction sites. Wind erosion is not considered a major contributing factor to erosion on highway construction projects because of the localized nature of the exposed areas and the relatively short construction time periods. Thus, methods of controlling water erosion will be the principal focus of this manual. However, many of the methods effective in reducing erosion caused by water are also effective in reducing erosion caused by wind.

4.2 Sedimentation

Sedimentation is the deposition of soil particles previously held in suspension by flowing water. The phenomenon of sedimentation takes place at those locations experiencing a reduction in the velocity of flow. Initially the larger particles settle out. As the flow velocity reduces further, the smaller particles settle, eventually, leaving only the clay sized particles, being the smallest, as the last to be deposited. Sedimentation can also occur in slower-moving, quiescent waterbodies, or in treatment facilities such as stormwater ponds. For the purpose of this document, the process of sediment control is equivalent to the control of the sedimentation process.

Suspended material, particularly fine organic material such as organic silt, can have low total suspended solids (TSS) test values but high turbidity measurements. TSS is the mass of suspended solids per volume of water whereas turbidity is an indication of the ability of light to pass through the water. Both TSS and turbidity can have detrimental effects on an aquatic environment.

Clay particles will only settle out after extended periods of time due to their fine particle size and, the potentially, elevated pH of the water. As a result, settling by gravity alone is often ineffective for clay size particles.

4.3 Types of Water Erosion

There are generally four types of erosion that result from water which are illustrated in Figure 4.1.

1. **Raindrop (Splash) Erosion:** Movement of soil particles caused by the direct impact of raindrops on unprotected exposed soil surfaces.
2. **Sheet Erosion:** Movement of soil particles by runoff flowing over the ground surface as an unconcentrated thin sheet layer. Erosion is caused by shear stresses associated with water flow.
3. **Rill and Gully Erosion**: Movement of soil particles due to concentration of runoff in the depressions (rills) in the ground surface. Erosion potential is greater than with sheet flow due to the greater velocity and depth of flow. Further increases in the

velocity and depth of flow will increase the erosion potential which may gradually enlarge the rills into gullies. Rills are 75 mm or less in depth. Once the depth exceeds 75 mm then formation of gullies occurs (Fifield, 2001).

4. **Stream and Channel Erosion:** Movement of soil particles on the bed and banks of streams and channels due to concentration of runoff. Scouring, another facet of channel erosion, occurs along channels where eddies form as a result of sudden expansion, contraction or change in flow direction. Scouring may lead to rapid soil loss from the channel bed or sideslopes.

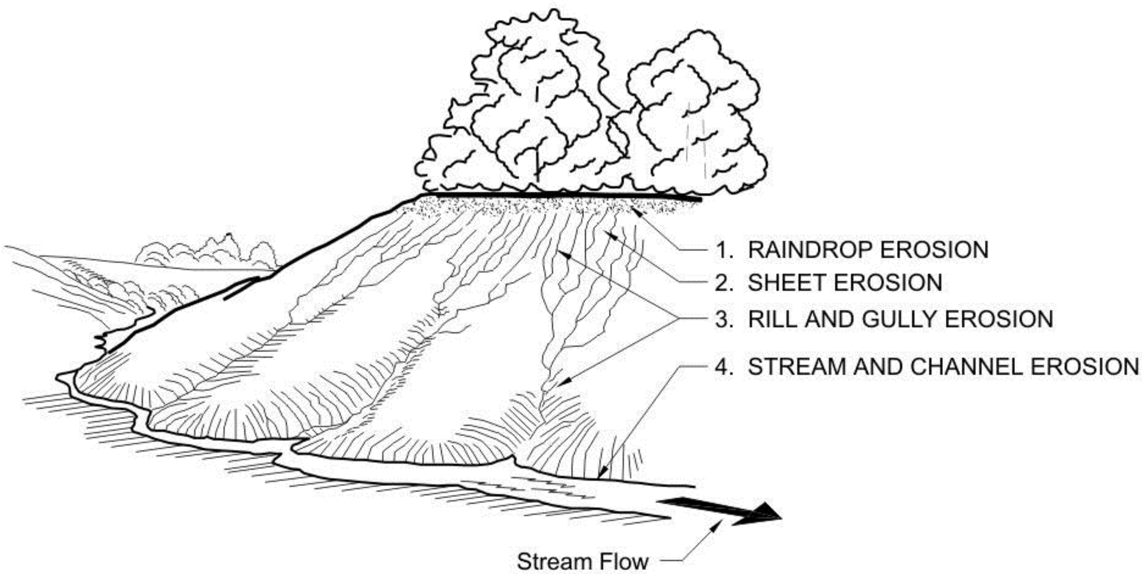


Figure 4.1: Types of Water Erosion

Erosion potential is reduced by minimizing rainfall impact and by reducing the velocity and depth of surface water flow. The erosion potential increases with increasing flow velocity and depth.

4.4 Factors Affecting Erosion

4.4.1 General

Erosion occurs as a result of a number of interacting factors and processes. Four broad factors that affect erosion are as follows:

- Climate;
- Soil characteristics;
- Vegetative cover; and
- Topography.

Each of these factors is described in the following sections.

4.4.2 Climate

The regional climate varies across the province of Alberta. As such, design rainfall event duration and intensity may vary for a given return period based on the location of the site. Rainfall events of greater duration and intensity are more likely to increase the potential for erosion on any given site.

Indirectly, the climate of a location determines the amount of annual precipitation, the length of the growing season and some other factors that affect plant growth and hence the vegetative cover. The climate may have a long term effect on topography especially in reference to wind eroded gully formation in Southern Alberta. The climate also affects soil characteristics. Arid terrain with intermittent intense rainfall events can be highly erosive environments.

4.4.3 Soil Characteristics

Soil characteristics that have been identified as primarily affecting soil erodibility are listed as follows:

- Particle Size Distribution and Texture;
- Permeability (structure); and
- Fibrous organic matter content (structure).

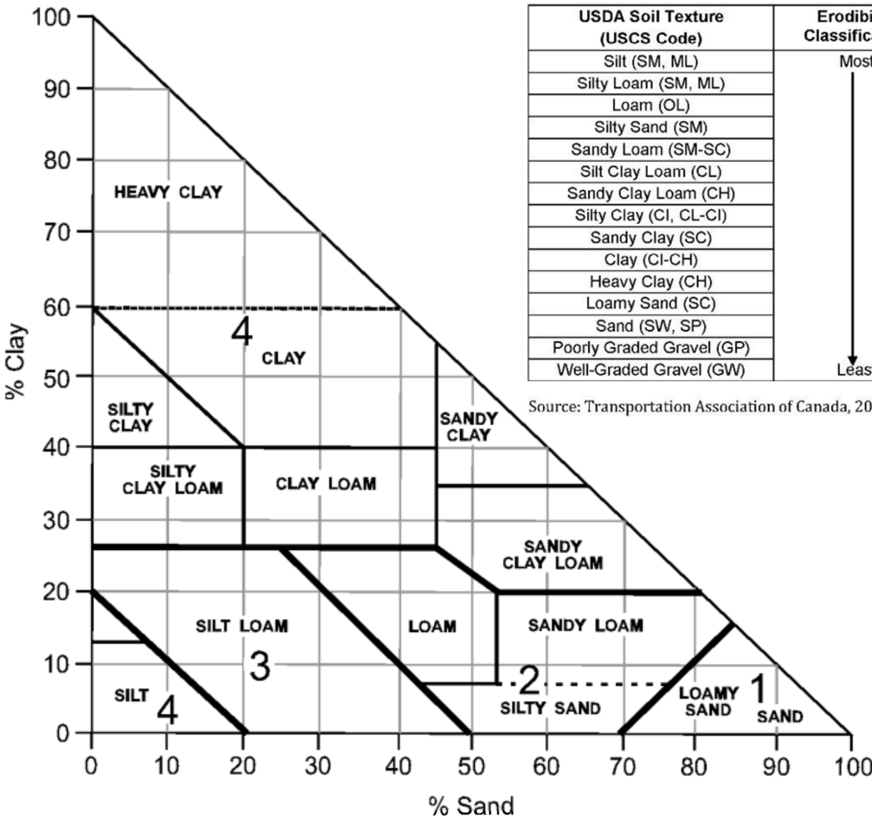
A preliminary estimate of soil erodibility in relationship to soil type is presented in Figure 4.2.

In general, soils containing high proportions of silt and very fine sand are usually the most erodible. Erodibility generally decreases as the plasticity (clay content) of the soil increases (Figure 4.2). However, once eroded, clays are readily transported. Well-graded gravel and predominantly gravel mixtures with trace amounts of silt are the least erodible soils. Soil descriptions prepared using the guidelines suggested in the Unified Soil Classification System (USCS) can be used in a preliminary assessment of soil erodibility. This classification system is presented in Figure 4.3. The various descriptions given for grain size according to various other engineering soil classification systems are presented in Figure 4.4.

The ability of a soil to absorb rainfall or surface runoff is best characterized by its permeability. The potential for erosion is reduced if the soil tends to absorb rainfall or surface runoff as this decreases the volume of water available to cause sheet or rill and gully erosion. However, after a prolonged period of hot and dry weather, there may be a lag time between the onset of rainfall and the onset of infiltration due to the unsaturated nature of the exposed surface soils. In this event, the initial amount of runoff may be significant. A general relationship between soil type and precipitation runoff is presented in Figure 4.5.

Construction site experience in Alberta indicates that topsoil can be effective in reducing or preventing erosion. This observed behaviour is mainly due to the permeability and fibrous nature of the organic material in the topsoil. An organic rich soil placed in an unsaturated condition generally has the ability to absorb a significant amount of water. Furthermore, the various rootlets and fibres present in topsoil act as reinforcement that minimizes the effect of raindrop, sheet or rill and gully erosion.

Available examples of tested data for typical Alberta soil types are presented in Appendix A to illustrate typical plasticity and gradation characteristics. This information is included for the sole purpose of illustrating the variety of soils that could be encountered on highway construction sites in Alberta. It is not intended as an exhaustive list of soil types, nor should it be used to replace or supplement soil testing data for sites near or at the locations listed.



USDA Soil Texture (USCS Code)	Erodibility Classification	Soil Erodibility Rating
Silt (SM, ML)	Most	High
Silty Loam (SM, ML)		High
Loam (OL)		High
Silty Sand (SM)		High
Sandy Loam (SM-SC)		Medium
Silt Clay Loam (CL)		Medium
Sandy Clay Loam (CH)		Medium
Silty Clay (CI, CL-CI)		Medium
Sandy Clay (SC)		Low
Clay (CI-CH)		Low
Heavy Clay (CH)		Low
Loamy Sand (SC)		Low
Sand (SW, SP)		Low
Poorly Graded Gravel (GP)		Low
Well-Graded Gravel (GW)	Least	Low

Source: Transportation Association of Canada, 2005

Figure 4.2: Soil Texture Nomograph and Erodibility Rating

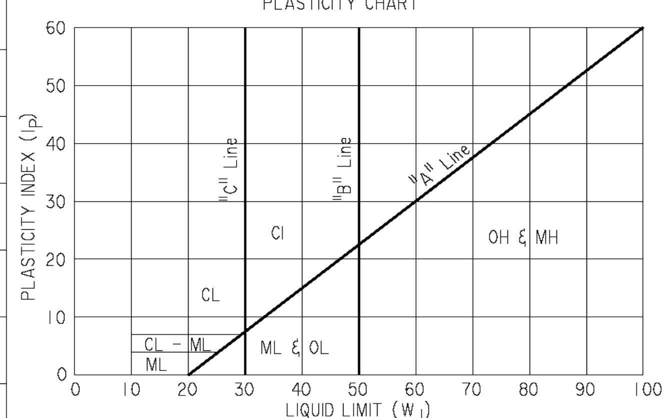
Source: Wall et al, 1997

Government of Alberta ■
Transportation

UNIFIED SOIL CLASSIFICATION SYSTEM

(Modified by PFRA)

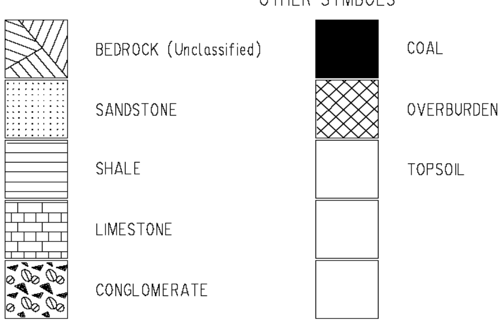
MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES	LABORATORY CLASSIFICATION CRITERIA	
COARSE GRAINED SOILS (More than half of material is larger than No. 80 sieve size)	GRAVELS (More than half of coarse fraction is larger than No. 5000 sieve size)	CLEAN GRAVELS (Little or no fines)	GW	Well-graded gavels, gravel-sand mixtures, little or no fines	Determine amount of sand and gravel from grained size curve. Depending on percent of fines (fraction smaller than No. 80 sieve size), coarse-grained soils are classified as follows: Less than 5 % ....GW, GP, SW, SP; More than 12 % ....GM, GC, SM, SC; 5 to 12 % ....Borderline cases requiring dual symbols**	$C_U = \frac{D_{60}}{D_{10}}$ is greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ is between 1 and 3
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW
		GRAVELS WITH FINES (Appreciable amount of fines)	GM* (d, u)	Silty gravels, gravel-sand-silt mixtures		Atterberg Limits below "A" Line or P.I. is less than 4 — Above "A" Line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg Limits above "A" Line with P.I. greater than 7 — Above "A" Line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
	SANDS (More than half of coarse fraction is smaller than No. 5000 sieve sze)	CLEAN SANDS (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ is greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ is between 1 and 3
			SP	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW
		SANDS WITH FINES (Appreciable amount of fines)	SM* (d, u)	Silty sands: sand-silt mixtures		Atterberg Limits below "A" Line or P.I. less than 4 — Limits plotting in hatched zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
			SC	Clayey sands: sand-clay mixtures		Atterberg Limits above "A" Line with P.I. greater than 7 — Limits plotting in hatched zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
FINE GRAINED SOILS (More than half of material is smaller than No. 80 sieve size)	CLAYS (Above "A" Line on PLASTICITY CHART; negligible organic content)	$W_L < 30\%$	CL	Inorganic clays of low plasticity, gravelly clays, sandy clays, silty clays, lean clays	PLASTICITY CHART	
		$30 < W_L < 50\%$	CI	Inorganic clays of medium plasticity, gravelly clays, sandy clays, silty clays		
		$W_L > 50\%$	CH	Inorganic clays of high plasticity, fat clays		
	SILTS (Below "A" Line, negligible organic content)	$W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity		
		$W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		
	ORGANIC SILTS AND CLAYS (Below "A" Line)	$W_L < 50\%$	OL	Organic silts and organic silty clays of low plasticity		
		$W_L > 50\%$	OH	Organic clays of medium to high plasticity, organic silts		
	HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils	Strong colour or odour and fibrous textures	



(NOTE: For soils passing No. 400 sieve & sieve size in µm)

REVISED APRIL 5, 2007

OTHER SYMBOLS



NOTE:

* Division of GM and SM groups into subdivisions of d and u are for roads and airfileds only. Subdivision is based on Atterberg Limits; suffix d is used when L.L. is 28 or less and the P.I. is 6 or less; the suffix u is used when L.L. is greater than 28.

** Borderline classifications, used for soils processing characteristics of two groups, are designated by combination of group symbols. For example: GW-GC, well-graded gravel-sand mixture with clay binder.

Figure 4.3: Unified Soil Classification System (modified by PFRA)

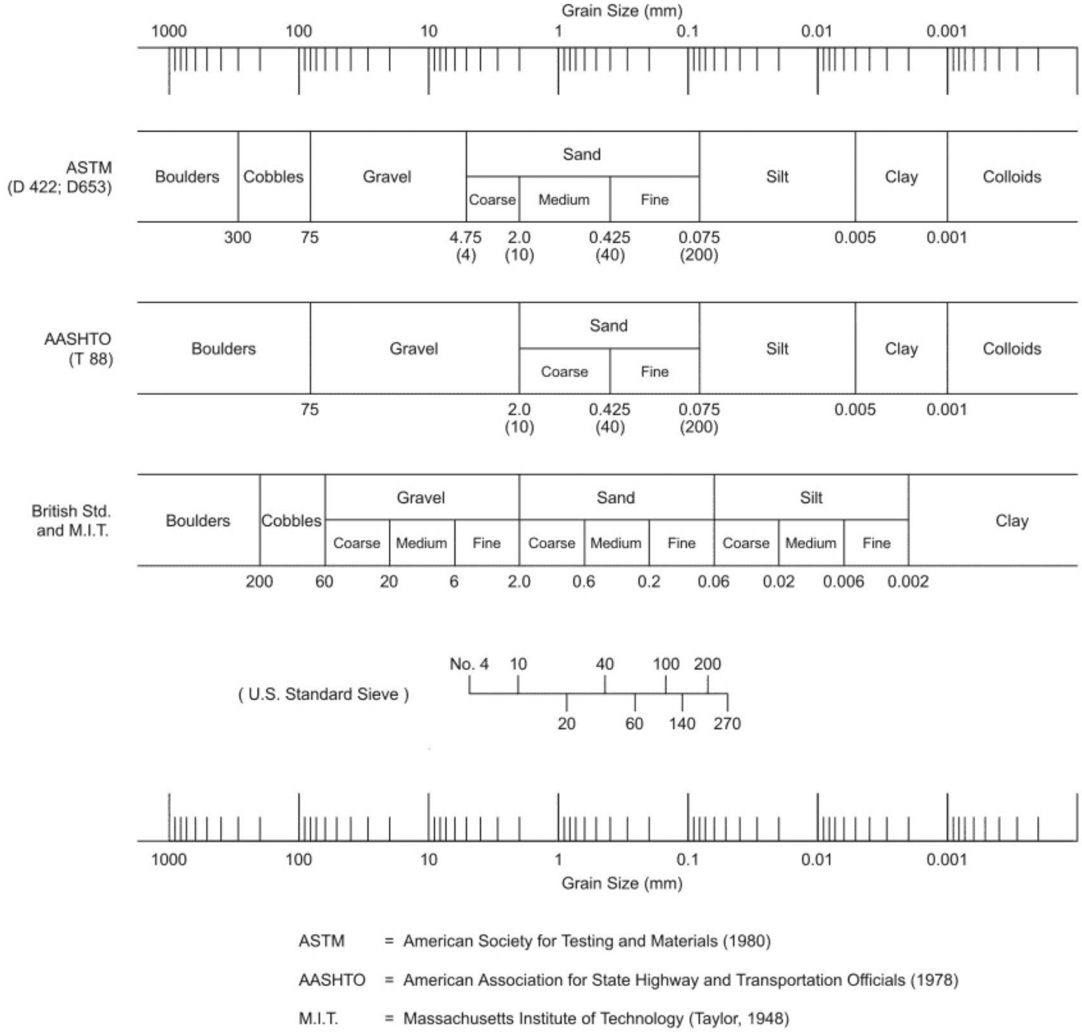


Figure 4.4: Grain Size Description According to Various Engineering Soil Classification Systems

Source: Holtz and Kovacs, 1981

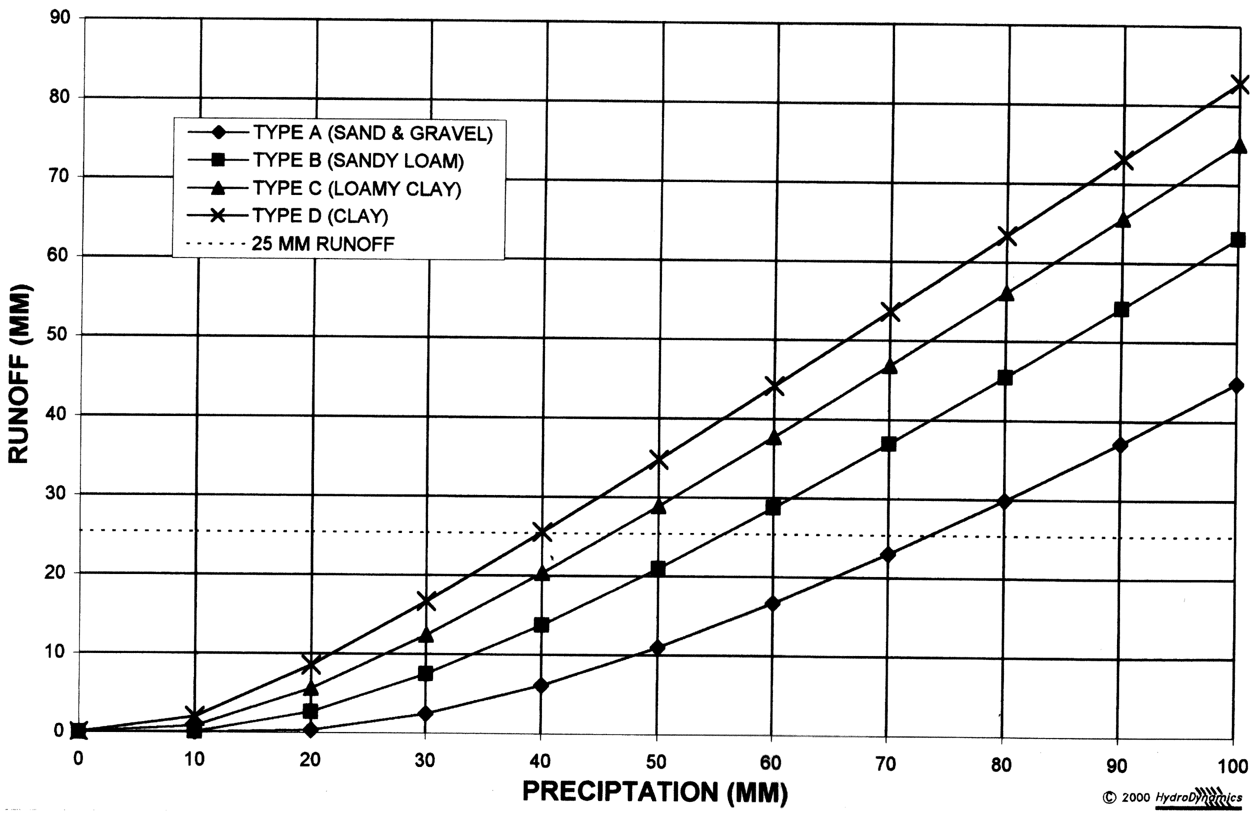


Figure 4.5: Estimated Runoff from Precipitation for Different Soil Types

Source: Fifield, 2001

4.4.4 Soil (Vegetative) Cover

In nature, the extent of vegetative cover determines to a large extent the erosion that takes place. Vegetative cover is a very durable and highly effective erosion control measure. It achieves its objective by:

- Shielding the ground from direct rainfall impact;
- Improving the soil permeability;
- Reducing velocity of runoff; and
- Holding soil particles in place with a root structure from living and dead vegetation (topsoil).

Because of the effectiveness of vegetative cover in controlling soil erosion, it is usually the primary choice for long-term erosion control unless there are reasons for doing otherwise.

4.4.5 Topography

Topography refers to the shape, length, inclination and aspect of a slope. The length and inclination are critical factors with longer and steeper slopes producing greater soil erosion. Slope aspect also affects soil erosion. For example, south-facing slopes tend to dry faster and have a better growing regime than north-facing slopes. The shape of a slope also influences the potential extent of erosion. Concave slopes with less inclination at the base are generally less erodible than convex slopes.