Module 2: Defining erosion and it's impacts

Module 2 Objectives

After completing this module, you will be able to:

- Define erosion and sediment control
- List and explain:
    - Two sources of erosion
    - Five types of erosion
    - Four factors influencing erodibility
- Describe the environmental and socioeconomic benefits of erosion and sediment control

Module 2 Content

2a. Erosion Defined

2b. Erosion: The Source of Sediment

2c. Five Stages of Erosion

2d. Four Factors Influencing Erodibility

2e. Impacts of Erosion and Sedimentation

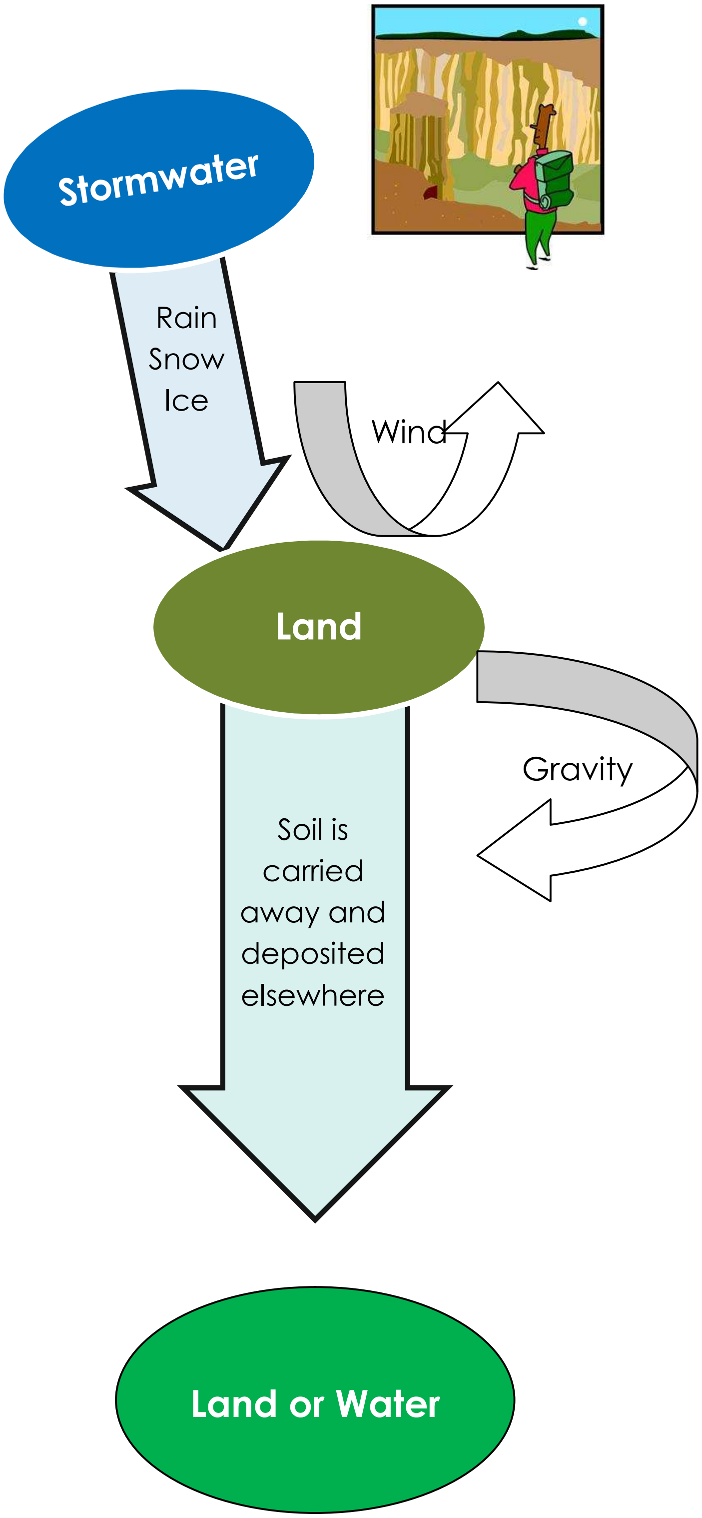
2f. The Principles of Erosion and Sediment Control

Introduction

This module provides the some scientific foundation for understanding erosion and sediment control (ESC) in Virginia, and the consequences of ineffective control on our natural waterways. This module defines what is erosion is and how it occurs. Also discussed here is how erosion and sedimentation causes impacts on the environment, society as a whole, and economic impacts which we don't often realize.

Figure 1. Results of poor erosion and sediment controls.

2a. Erosion Defined



Soil erosion is defined as the removal of the land surface by erosive forces such as water, wind, ice, and gravity.

Erosion processes carry away soil particles from one location and deposit them on another location. Erosion is an important contributor to landscape formation by wearing away mountains; filling valleys; and creating sandbars, islands and coastal planes. Erosion is a natural process, but in many places it is increased by human land activities that disturb the soil.

Figure 2. Bryce Canyon (UT)

2b. Sources of Sediment

Erosion can be divided into geologic (natural) and accelerated (human induced) erosion. In Virginia, our primary concern is with accelerated erosion or erosion arising from exposed soils during land-disturbing activities. For example, during construction, land clearing, grading, and cut and fill operations leave soil vulnerable to erosion, which result in the movement of soil across a construction site and potentially onto down gradient properties and into waterways. As Virginia's population continues to grow and the demand for development increases, proper implementation of erosion and sediment controls during construction remains highly important for protecting downstream properties and the state's water quality and resources.

Geologic erosion results from the detachment and transportation of soil by water, wind, ice, and gravity. It is a natural process that has been occurring since the beginning of time. Mountain ranges have eroded down, leaving sediment deposits several miles thick. In fact, Virginia's mountains have been greatly affected by erosion. In geologic time, the Appalachian Mountains used to be the tallest mountains in the world, taller than today's Himalayan Mountains. Over time, erosion wore these mountains down and the rivers from the mountains carried sediment to the oceans. As a result, the Virginia Coastal Plain is underlain by a thick wedge of sediment that is more than 600 feet deep in some locations. The Grand Canyon is another spectacular example of geologic erosion.

Geologic erosion accounts for 30% of total sediment production, accelerated erosion accounts for 70%.

A slowly moving process, geologic erosion accounts for **thirty percent (30%)** of the total sediment deposited in the United States.

Accelerated erosion results from human land-disturbing activity which causes the detachment and transportation of soil onto adjacent properties and/or waterways. This form of erosion occurs at a much faster pace than geologic erosion. In the United States, accelerated erosion dates back to the first European settlers who cleared land fields to plant crops during the pre-revolutionary days. Accelerated erosion accounts for **70%** of the sediment deposited in the United States. *Minimizing the impact of accelerated erosion is the primary objective of Virginia's Erosion and Sediment Control Program.*

Figure 3. Agriculture, is one of the contributors to accelerated erosion

Major Activities Contributing to Accelerated Erosion

Agriculture, construction, surface mining, and forestry are the major contributors of accelerated erosion. Agricultural activities account for ~72% of the total sediment generated by accelerated erosion in Virginia. Sedimentation from construction accounts for most of the remaining 28%.

On a per acre basis, construction accounts for 10 to 20 times more sediment production than agriculture.

However, on a per acre basis, when comparing a construction site with an agriculture field of the same size, construction sites contribute ten to twenty times higher sediment rates than those found from cropland or naturally vegetated areas. This trend is illustrated in Table 2-1 which shows the yearly sediment rates for the four major land uses contributing to accelerated erosion.

Table 2-1.
Sediment Volume per Square Mile by Year & Activity

Land Use	Sediment production	
	(Tons/mile^2/year)	(Tons/acre/year)
Forest	24	0.04
Grassland	240	0.38
Cropland	4,800	7.5
Construction	48,000	75

The potential for erosion is not necessarily reduced after construction is complete. Increased stormwater runoff from impervious surfaces such as roofs and parking lots still has the potential to degrade property, streams and downstream receiving waters.

2c. Five Stages of Soil Erosion

As mentioned in Section 2a, the major factors of erosion are water, ice, wind, and gravity. While the first three factors are considered to be climatic, gravity is a physical factor responsible for the movement of soil particles to the lowest elevations on a landscape. In a general sense, **climate is the most significant force in the erosion process.**

In Virginia, water is the primary and most damaging erosive force. During a rainfall event, water strikes the soil's exposed surface in the form of raindrops, which dislodges soil particles. This is the beginning of the five stages of erosion.

Raindrop impact is the first effect which dislodges soil particles and splashes them into the air. Once dislodged soil particles can be easily transported by water flowing over a site and become sheet erosion.

Of the five types of erosion, raindrop erosion is the most significant in the erosion process. The action of falling rain on disturbed or denuded soil is responsible for **90%** or more of total soil erosion.

Raindrop impact produces two damaging effects:

- The detachment of soil particles
- Sealing of the soil's surface

Figure 4. Raindrops impact the soil as little bombs.

Raindrop impact is responsible for 90% of the soil loss on denuded soil.

How can a raindrop be responsible for so much damage?

Observation of intense rain on bare soil attests to the destructive power of raindrop impact. Raindrops hit the surface like tiny bombs, shattering soil granules and splashing the detached material back and forth. The erosive capacity of rainfall comes from the energy of its motion, or *kinetic energy*. The magnitude of this energy is dependent on the amount and intensity of rainfall, raindrop diameter, and raindrop velocity.

Raindrop sizes range from the finest mist to 1/3 inch or nearly 8 millimeters in diameter. All rain events contain drops of various sizes. An intense rain has a much higher proportion of large drops than a light rain. Raindrop velocity is closely tied to drop size. Fine mists with droplets of about 1/100 inch (.25 mm) in diameter fall at a rate of about 1 inch per second (25 mm per second). Conversely, large drops may attain a velocity of 30 feet per second (10 meters per second). The damaging effects from rain falling as large drops in an intense thunderstorm has many times more erosive energy than rain falling as a fine drizzle over a longer period of time. In an intense rain event, splashed soil particles may be moved more than two feet (61 cm) high and five feet (150 cm) horizontally. Often times, splashed soil particles can be seen clinging to fences, walls or the foundation of buildings that are adjacent to bare soil. Soil particles can also be seen on the stems and leaves of plants that are growing in a partially vegetated field. Pedestals of soil, capped with protective stones, can be seen where raindrop splashes carried away unprotected material (see photo below).

Figure 5. These rocks protected the soil from raindrop impact, in places where there were no rocks the soil was loosened and washed away.

On level surfaces, the horizontal and vertical effects of splashed soil are self- cancelling. However, on sloping land, the net movement is downhill. For example, on a 10% slope, 75% of the soil movement is down-slope.

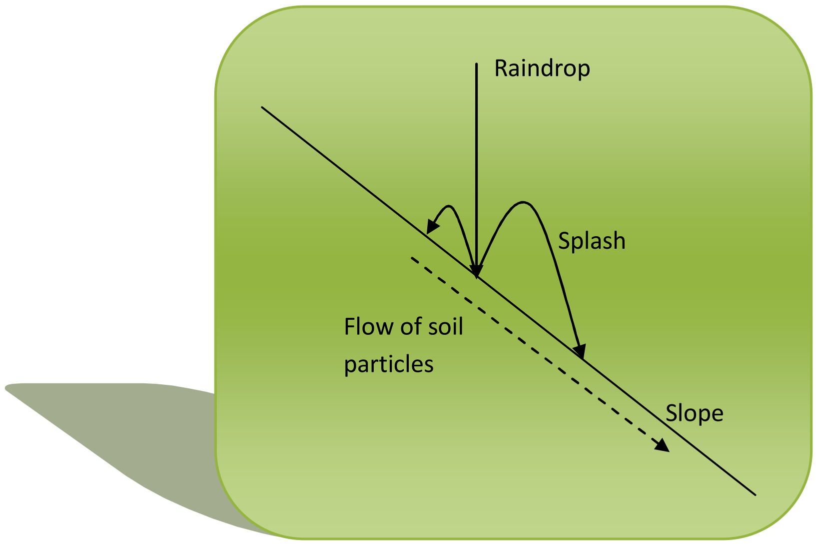


Figure 6. On exposed slopes, the impact of raindrops moves the majority of the soil down the slope.

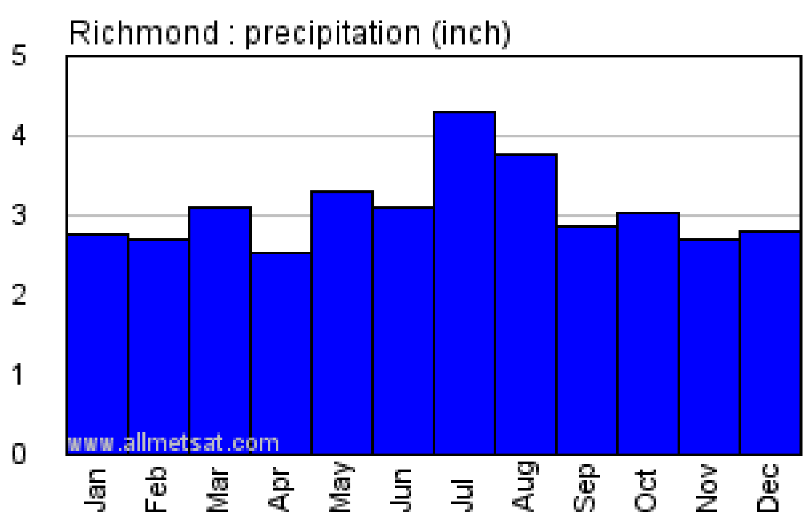
Another damaging effect of raindrops is the **compacting, puddling, and sealing of the soil surface.** Repeated strikes churn the surface into a slurry. This viscous mass effectively seals the pore spaces in the soil preventing water infiltration. As they continue to pound the land, raindrops will also compact the bare soil, forming an almost complete seal. Even on coarse sandy soil, this action reduces the infiltration of water into the soil and leads to increased runoff and erosion.

Figure 7. Sediment-laden water and raindrop impact are slowly sealing the soil in this agricultural field

As mentioned above, the erosive impact of raindrops is influenced by the size of the drops and the speed by which they hit the soil. Drop size and speed are often seasonally influenced. In Virginia, the most erosive rains are concentrated during the months of June through September when rainfall events occur as thunderstorms and tropical systems. This is also the period when land-disturbance is most active. Precipitation in the winter generally is less intense and falls as a finer mist.

Table 2-2 below indicates some significant differences between storms occurring during the spring and summer and those occurring during the fall and winter.

TABLE 2-2
Precipitation Characteristics by Seasons (Richmond, VA)



As rain continues to fall, the soil's ability to infiltrate water is exceeded and water starts to run across the surface of the soil (sheet flow). The dislodged soil particles are transported in sheet flow in the form of sheet erosion (second type of soil erosion). Rill erosion begins when the sheet erosion starts to cut small channels into the soil's surface and turns into shallow, concentrated flow, which is due to the increase depth of the runoff and the energy contained in the runoff (third type of soil erosion). When the rill deepens due to even more runoff and energy, gully erosion begins to occur (fourth type of soil erosion). As gullies continue to increase in size from even more runoff and energy, channel erosion begins to occur (fifth type of erosion). Channel erosion also occurs in existing channels when the frequency and amount of water that flows through these channels increase as a result of increased imperviousness caused by development.

Figure 8. Sheet Erosion

Sheet erosion is caused by a shallow sheet of rainwater that runs across the land. These very shallow moving sheets of water seldom detach soil but rather pick up and transport soil particles already detached by raindrop impact, splash or soil disturbances. Sheet erosion generally only moves a short distance before concentrating in surface irregularities.

Rill erosion develops as the shallow (sheet) flow begins to concentrate in low spots. As the flow changes from sheet flow to deeper flow in these low areas, the velocity and turbulence increases. The energy of this concentrated flow detaches and transports soil material, cutting tiny channels or rills that are only a few inches deep. At this stage, hand tools or other surface treatments will usually repair erosion damage.

Figure 9. Rill erosion

Gully erosion occurs when rills converge to form larger channels or gullies. The major difference between gully and rill erosion is size. Gullies are too large to be restored with conventional tillage equipment and may require heavy equipment to repair.

Figure 10. Gully erosion

Figure 11. Channel erosion

Channel erosion can occur in two ways:

1: When gullies are not repaired in time and large volumes of water increase the size of the gully, or

2: In existing streams or drainage ways when the volume and velocity of flow destroys the structural integrity of stream beds and banks.

Runoff occurs when the rate of rainfall exceeds the infiltration capacity of the soil. Runoff on unprotected soil begins a few minutes after the start of rainfall. While raindrops have a lot of (kinetic) energy when they hit the soil, water collecting on the land has no kinetic energy. Water on the soil gains energy as it begins to run down slopes as runoff.

In this early stage, the major potential for damage caused by stormwater runoff is the ability to transport loose soil particles.

The amount of runoff depends upon:

- The amount and intensity of the rainfall, and
- The character of the soil surface impacted by rainfall.

Runoff initially presents itself as **sheet flow**, a shallow layer of water flowing more or less uniformly over the land. As we learned earlier, sheet erosion primarily refers to the transport of soil particles that have already been detached and suspended by raindrop impact. Runoff contains the energy that carries those suspended soil particles. Although it is sometimes difficult to estimate, total soil loss by sheet flow may be large but can be observed as muddy water. Sheet erosion can very effectively transport the particles that are kept in suspension by the action of falling raindrops on an area.

Concentrated flow starts as a result of irregularities in the soil surface such as low spots, depressions, rocks, plant stems, and roots and the depth of the sheet flow. As the volume of water increases, the velocity and turbulence also increases. Runoff concentrated in tiny rills may then expand into larger gullies, acquiring more energy to detach and to transport soil particles.

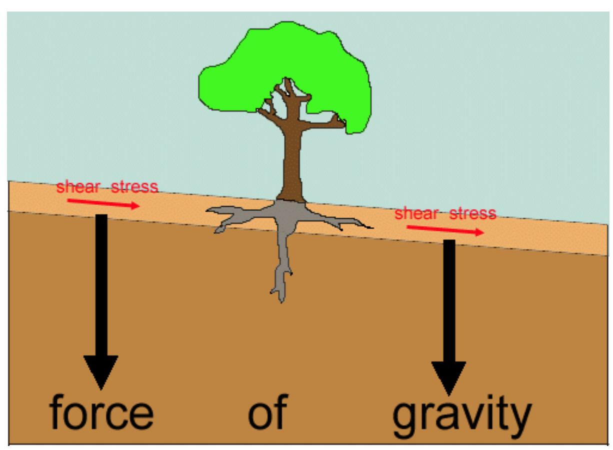


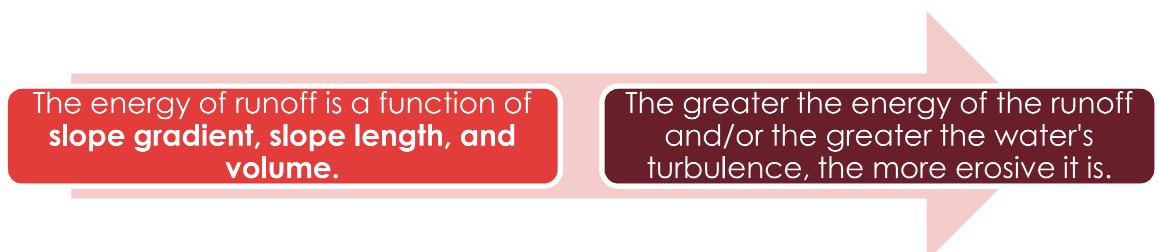
Figure 12. The combined effect of water, suspended sediment and its abrasive effect, and gravity is also known as sheer stress.

The rolling, lifting, and abrasive action of concentrated/channelized flow on the land surface results in soil detachment and leads to rill and gully erosion as discussed earlier. At first, the force of channelized flow is horizontal in the direction of the flow of water. As the velocity and turbulence of channelized flow increases, vertical currents and eddies develop that dislodge, suspend and transport soil particles. These entrained soil particles strike and abrade the soil's surface and channel beds like sandpaper, which then causes more soil particles to detach and mobilize. The turbulent flow of sediment laden water will start scouring the sides of the rills, gullies and channels. More soils particles will become suspended in the flowing water further increasing its abrasive force. The amount of additional sediment detached by abrasive action is determined by the amount and abrasiveness of the suspended particles.

In summary, the erosive capacity of flowing water is based on its:

- Velocity
- Turbulence
- Amount and type of abrasive material conveyed by the flow
- Surface or channel roughness
- Slope gradient

As slope length and steepness increases, the depth of runoff increases and hence the velocity also increases.



2d. Four Factors Influencing Erodibility of soil

As we have previously discussed, runoff starts when the soils infiltration capacity is exceeded, water flows over the land. Examples of when this happens include:

Erodibility is the vulnerability of a material to erosion.

- Site gets more precipitation than it can handle
- Soil is frozen
- Soil has a low infiltration rate or high runoff potential
- Site has steep slopes
- Soil surfaces on a site are graded smooth or compacted
- Groundcover is sparse or non-existent
- A combination of all these factors

These conditions along with the four factors we will discuss influence erosion:

(1) Climate
(2) Soil Properties
(3) Topography
(4) Groundcover

While these factors are often interrelated, they need to be discussed individually.

1) **Climatic Factors** influencing erosion include precipitation type (rain, snow, etc.); rainfall intensity and raindrop size; snow melt; and temperature extremes (freezing, excessive heat, etc.). In Section 2c we discussed that raindrops are responsible for 90% of the erosion that occurs on a site and that summer storms are generally more intense and more erosive. In discussing precipitation, we often refer to: amount and intensity. A two inch precipitation event in the winter is very different than a two inch precipitation event in the summer. Winter rains tend to have smaller raindrops and might last hours. Summer rains are usually associated with thunderstorms and the same two inches of rain could fall in a matter of minutes.

Rainfall (precipitation) intensity equals the amount of rain that falls over a certain time period (i.e. 2 inches/hour or 3.5 inches in 24 hours).

Temperature can also be an important factor. Freezing temperatures in winter can destroy the soil structure and destabilize the soil when the water in the soil expands and soil particles lose the ability to adhere to each other. The loose particles can then be picked up as sediment in the melting water and transported from the site. Warm temperatures can bake the soil, which also destroys the structure of the soil. In addition, hot temperatures and wet soils can lead to excessive crusting of the soil which results in a host of issues including poor infiltration, increased runoff and poor germination of seeds (due to soil moisture loss and the inability of germinating seeds to penetrate the crust).

Wind can also be an influence on erosion as we learned in Module 1. Wind blowing across soil can dry out the soil and reduce the cohesiveness allowing loose or detached particulates of soil to be transported.

2) **Soil properties** are also important factors when looking at the erodibility of soil. Soil structure or the way soil particles adhere to each other is an important factor. Additional properties include soil texture (or the size of the particles in the soil), bulk density (or how tightly those particles are packed together), the percent organic matter, infiltration rate (the speed by which water enters the soil) and permeability rate (the speed by which water moves through the soil).

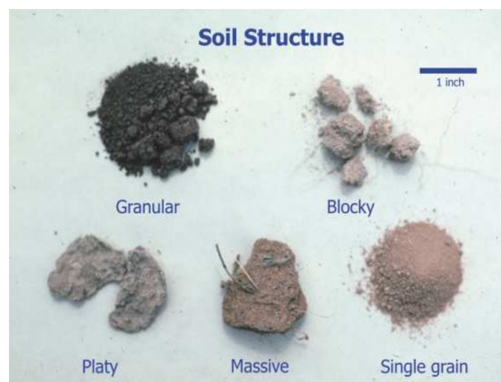


Figure 13. Typical soil structures.

Particle size distribution or the composition of the soil in its three components sand, silt and clay influence the *infiltration rate*, or the rate at which waters enters the soil, and *permeability* or the rate at which water will move through the soil. Organic matter influences characteristics such as *cohesiveness, structure and permeability* of the soil. Soil structure is determined by how individual soil particles clump or bind together and aggregate,

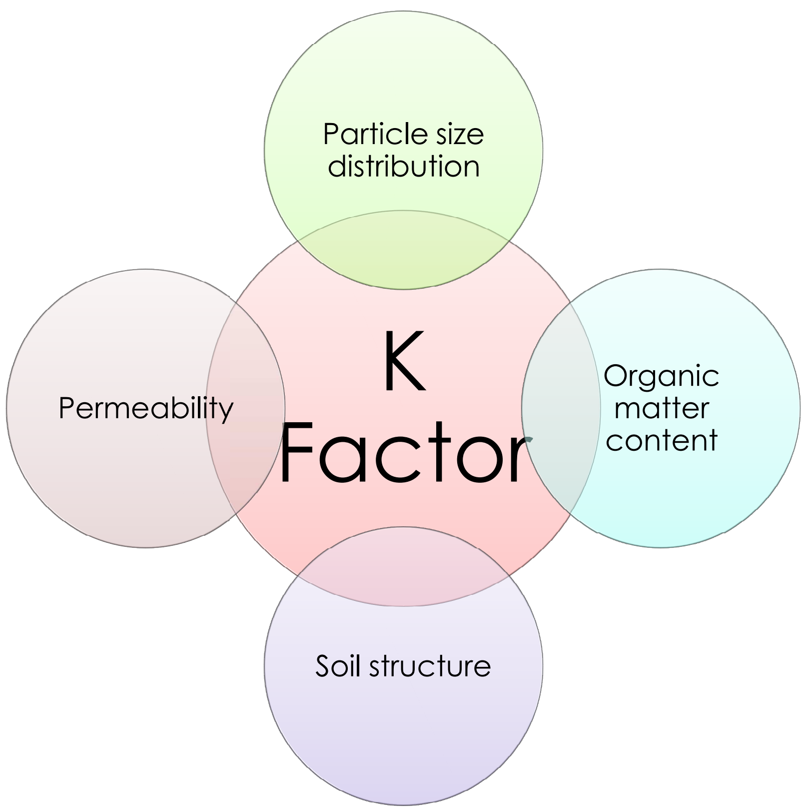
Soil Structure: the arrangement of soil particles in various aggregates differing in shape, size, stability, and degree of adhesion to one another and therefore, the arrangement of soil pores between them. Soil structure has a major influence on water and air movement, biological activity, root growth and seedling emergence.

Generally, erodibility increases with silt size particles (.002-.05mm) and very fine sand (.05-0.1 mm) and decreases with larger sand (0.1 to 2 mm) and clay (< or = to .002 mm) and organic matter content. High clay soils are more resistant to detachment, but once detached they are easily transported and stay suspended in solution. Organic material makes soils more permeable- improves structure & stability of soil.

The Soil Erodibility K Factor

Under similar climatic, topographic and vegetative conditions, different soils may erode at different rates. This difference in erosion rates may be tenfold, and is caused by differences in soil characteristics. The susceptibility of a particular soil to erosion is called its **erodibility factor or K factor**. In addition to susceptibility of the soil to erosion, the soil erodibility factor (K) represents the rate of runoff.

Soil properties used to develop a K factor for soils include:



Chapter 6 of The Virginia Erosion and Sediment Control Handbook contains K factors of all the soil types listed in Virginia.

Erodibility is highest in soils with increased silt particles and very fine sand content; and lower with larger sand particles, clay particles and organic matter content (Figure 14). Soils with high clay content are generally more resistant to detachment, although once detached, the clay particles are easily transported. Clay soils also usually have poor infiltration, which will increase runoff. Increased organic matter reduces erodibility by:

- Serving as an adhesive to hold particles together, and
- Improving the permeability and stability of the soil structure.

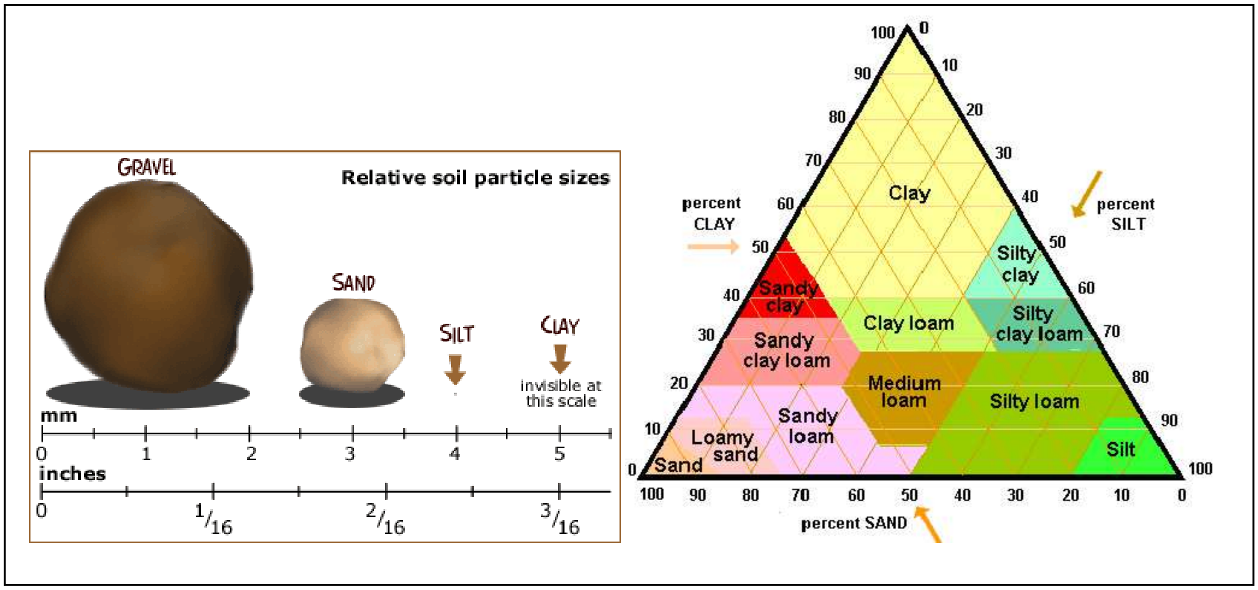


Figure 14. Soils are made up of different particle sizes (left), and these particles can be found in various combinations in the different soil types.

Soil properties that influence erodibility:

- Infiltration rate-rate at which water enters soil
- Permeability-rate at which water moves through soil
- Total water holding capacity
- Detachment rate by raindrop impact & flowing water impacts
- Ability to resist transporting forces

The higher the K factor value, the more susceptible the soil is to erosion.

K factors can be grouped into three general ranges:

0.23 and lower	-	Low erodibility
0.24 to 0.36	-	Moderate erodibility
0.37 and higher	-	High erodibility

For the plan preparer/reviewer, job superintendent and inspector who are likely to be laymen in the field of soil science, the K factor is a good indicator of a soil's susceptibility to erosion. The K factor of a soil can be found in various sources, including a county soil survey, on line at the web soil survey (http://websoilsurvey. nrcs.usda.gov/app/HomePage.htm), and in Appendix 6C of the 1992 Virginia Erosion and Sediment Control Handbook.

Topographic features that influence erodibility include *slope steepness, slope length, slope shape.*

Slope steepness or grade influences erosion in several ways. Physics and hydrologic principles teach us that water will flow faster with the increased length and angle of a slope. Moreover, there is more turbulence and energy in the runoff over steeper slopes. These principles are the reason for the grouping of slope gradient into three general ranges of erodibility potential (Table 2.3).

Table 2.3.
Relation between slope steepness and erosion hazard

Slope gradient	Erosion hazard
0-7%	Low
7-15%	Moderate
15% & over	High

In the case of Erosion and Sediment Control, slope length is defined as the distance from the point where overland flow begins to the point where it enters a well-defined channel, waterway or the point where deposition may occur because of a decrease in slope gradient. The same principles tell us that increasing slope length will increase the water accumulated in the runoff. Therefore, using these principles, there will be a point on a slope where water volume and velocity will start to result in rill and gully formation (where the slope becomes critical). The primary topographic considerations for erosion potential of a slope are its length and steepness. Table 2.4 provides the critical slope length for different slope steepness ranges.

Table 2.4.
Slope steepness and Length Combinations at Which the Erosion Hazard Will Become Critical

Slope gradient	Slope length
0-7%	300 feet (100 meters)
7-15%	150 feet (50 meters)
15% & over	75 feet (25 meters)

Slope shape also impacts erosion potential

- *Convex slopes (are slopes that are steeper at the lower end).*
- *Concave slopes (are slopes which flatten at the lower end).*

The potential for erosion will be more on convex slopes and less on concave slopes than what would be expected if the effect is calculated on the basis of an average grade.

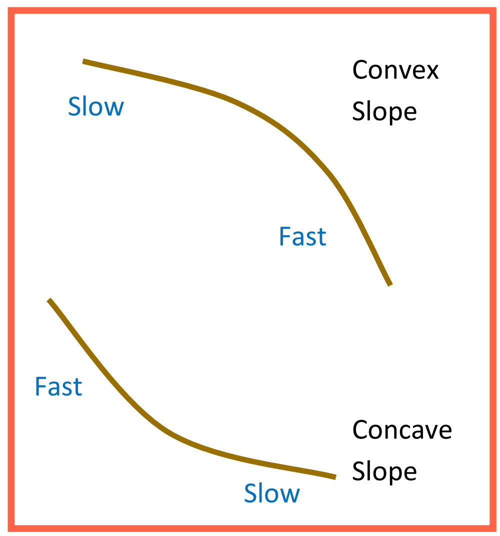


Figure 15. Slope shape impacts runoff speed and erodibility of the slope

Ground cover is the last of the four major factors influencing erosion. As was discussed earlier in this chapter; the size of raindrops and the speed by which they hit the soil are among the most important factors influencing erosion. Ground cover such as vegetation or mulches slow down the speed of raindrops by intercepting them on leaves, branches, and stalks, thus breaking up raindrops into smaller drops and reducing the effect of raindrop impact. Research has shown that erosion potential is directly proportional to the amount of bare soil exposed to raindrop impact. Therefore, surface cover is the most important factor for controlling erosion. Vegetative cover provides the best protection; however, the use of any surface cover material, including vegetation and mulches, offers an excellent range of control options.

Research has shown that the amount of erosion depends on how much of the land surface is exposed to erosive forces such as raindrop impact and scouring. Vegetation of the right type and density provides excellent protection for soil that is exposed to the unimpeded impact of falling rain. Moreover, roots and litter also resist scouring. In a controlled experiment involving identically sized plots seeded at significantly differing density rates (i.e. 9,000 plants per acre on one plot & 14,500 plants per acre on the other plot), soil loss over a 10-year period was four times greater on the less densely populated plot. In the above study, soil exposure was measured from aerial photographs.

Table 2-5 below provides the protection and percent effectiveness of various grasses and additional ground covers when compared to the erosion rate for an identical plot of bare soil.

Table 2.5.
Effectiveness of Various Ground Covers In Preventing Soil Erosion

Type of Ground Cover	Percent Reduction
Permanent grass	99
Perennial ryegrass	95
Annual ryegrass	90
Small grains	95
Millet or Sudan grass	65
Field bromegrass	97
Grass sod	99
Hay or straw (@2 tons/acre)	98

(This table compares fully established stands of groundcover with bare soil)

Although Table 2.5 does not contain values for woodchips, wood cellulose fiber, and similar mulching materials, when applied according to specifications these controls are usually 90% effective (application rate: Woodchips 6 tons/acre, and Wood cellulose fiber 1 $^{3}/_{4}$ tons/acre).

In this section we discussed the factors that influence erosion. To prevent these other forces from having a large impact on erosion the most important influence which helps prevent or control erosion is ground cover.   Protecting exposed soil from the raindrop impact is critical to preventing erosion. The most common methods of providing ground cover is either establishing vegetation or the use of mulches which we will discuss in Module 6. Vegetation not only minimizes splash erosion, but also prevents puddling and sealing of the soil surface. In addition, a good vegetative cover (or mulch) significantly reduces runoff. This was shown in studies on plots composed of different soil types demonstrate that protected plots offer higher *water intake rates* than the water intake rates found on bare soil even when exposed to high rates of sustained rain. Similarly, *water infiltration rates* on plots protected by vegetative cover are significantly higher than the rates measured for unprotected plots subjected to identical rainfall conditions. This result was similarly observed on plots of dune sand that were protected and unprotected.

One additional value of vegetation is its use as a protective lining along shallow waterways and channels, where its use can reduce the flow velocity near the bed of the channel. Vegetation with a dense uniform growth near the soil surface and a strong fibrous root system is most effective in reducing erosion. Good uniform stands of sod-forming grasses meet these requirements by providing good surface cover even after mowing. With good management these grasses will retain their density indefinitely. Additionally, the roots of vegetation used in waterway improve soil structure and increase organic matter content. In some instances, a solid root structure minimizes erosion to the banks and bed of the channel, providing some protection against the mud flows which occur on thawed, saturated surface layers above frozen soil.

2e. Impacts of Erosion and Sedimentation

Erosion is a natural process, and in the previous section we have seen that there are two types of erosion: geologic or natural erosion and accelerated or man-made erosion along with the four factors that influence erosion. Over geologic time the Appalachian Mountains eroded away and the sediment was deposited off the coast, forming the coastal plain.

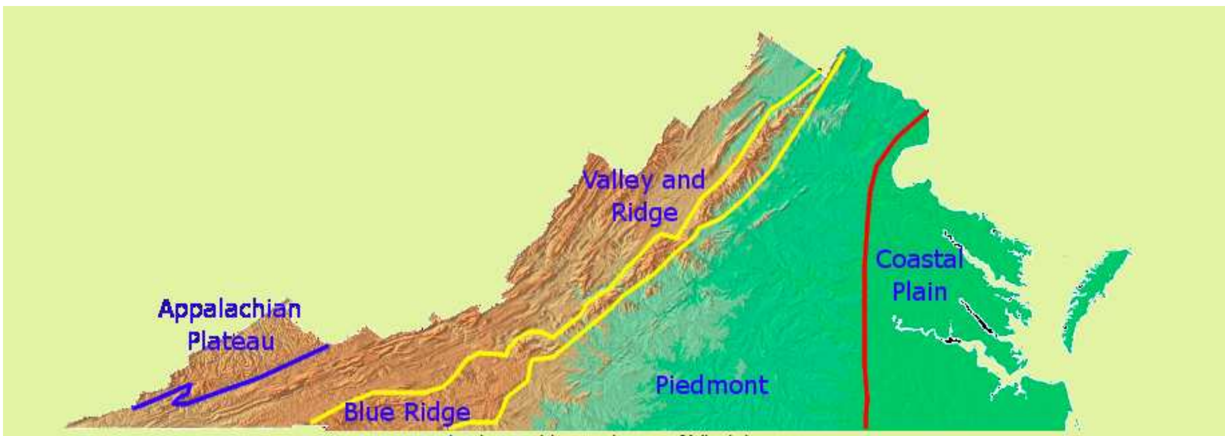


Figure 16. The physiographic provinces of Virginia

While geologic erosion has stayed relatively steady over the past thousand years, accelerated erosion has gradually increased with the growing human population and the resulting increasing pressure on the land. The soil particles loosened up by erosion are called sediment. These soil particles may have heavy metals and other contaminants attached to them. Some of the negative impacts of sediment released into the environment are shown as part of Figures 17 and 18.

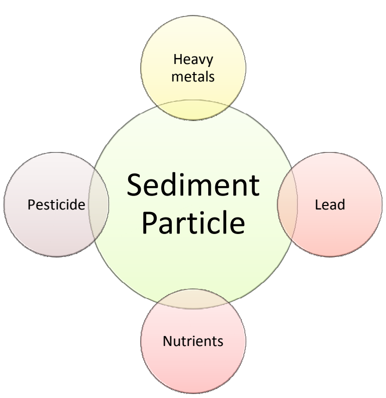


Figure 17. Sediment particles have various other elements, metals and other contaminants stuck on them which can be released into the environment.

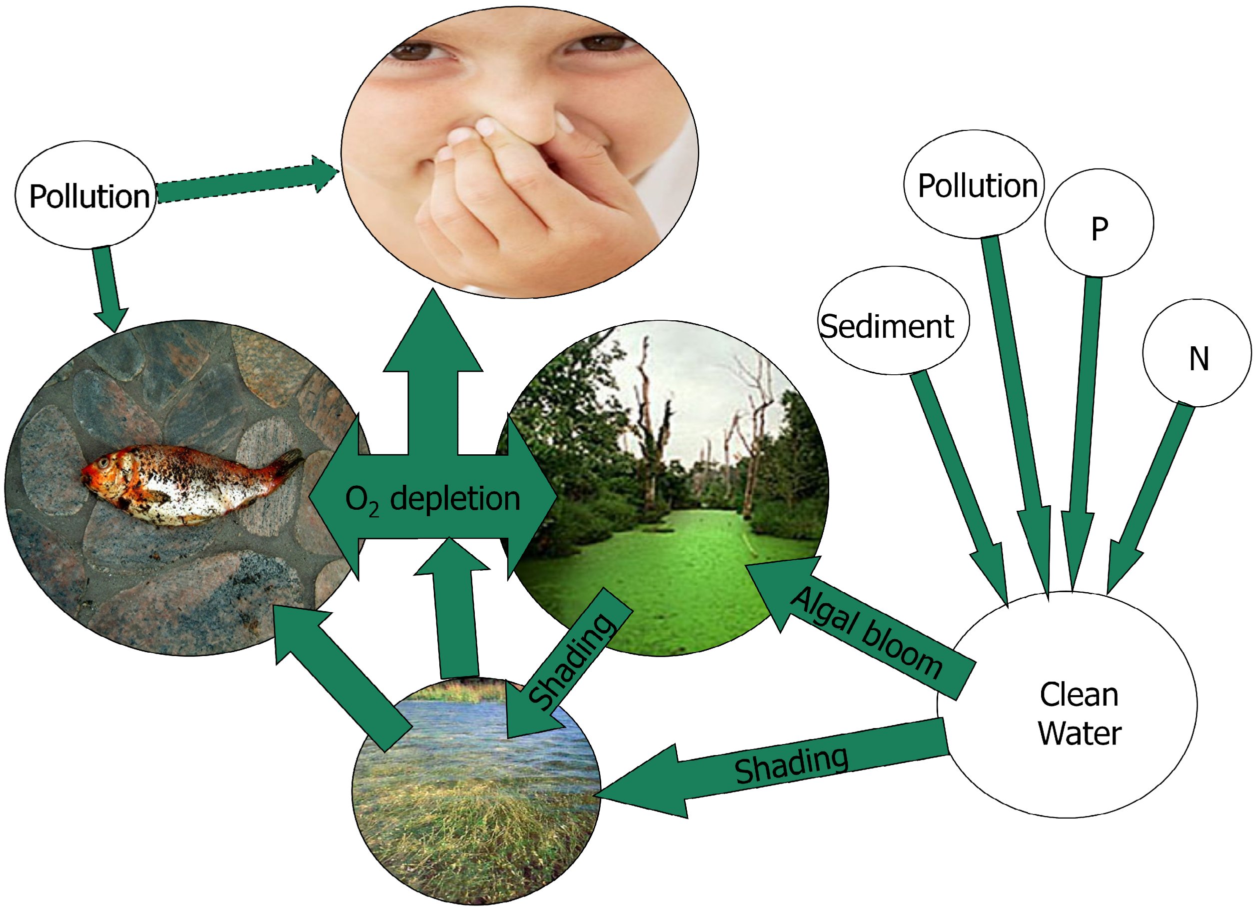


Figure 18. When sediment and associated/attached contaminants and nutrients (Phosphorus and Nitrogen) enter waterways a cascade of issues can occur:

(1) Sediment shades the bottom of the waterway and weakens or kills the aquatic vegetation, which oxygenate the water and serve as cover for young fish and other aquatic organisms;
(2) Nutrients stimulate algae to grow resulting in algal blooms. This algal growth shades native aquatic vegetation and decaying algae and native vegetation depletes oxygen in the water;
(3) Sediment and contaminants in the water plugs gills of fish and other aquatic organisms thus weakening and/or killing them;
(4) Sediment settles in waterways and smothers spawning beds, oyster reefs, crab habitat, etc;
(5) Stocks of fish, oysters and crabs decline and reduce the income of commercial watermen and sports fishermen, , thereby hurting the economy of the region; and
(6) Shipping lanes, reservoirs, harbors, marinas, and other waterways may require dredging, at considerable cost (Tables 2.6 and 2.7).

Figure 19. Out-of-Bank Flooding Endangers Human Life and Property
(Source: ARC, 2001)

The financial loss to the commercial water men and the commercial sports fishing industry whether it is in the bay, its tributaries, lakes, or mountain streams as a result of erosion and sedimentation cannot be estimated.

Examples of anadromous fish of Virginia: Fish that live in salt water but migrate to fresh water (up rivers) to spawn (source VDGIF). They and many other fish need clean water to spawn. A lot of fish species will also will need a gravel bed to lay their eggs in, while immature fish may need hiding places such as aquatic vegetation to stay out of the way of predators.

American shad

Blueback herring

Alewife

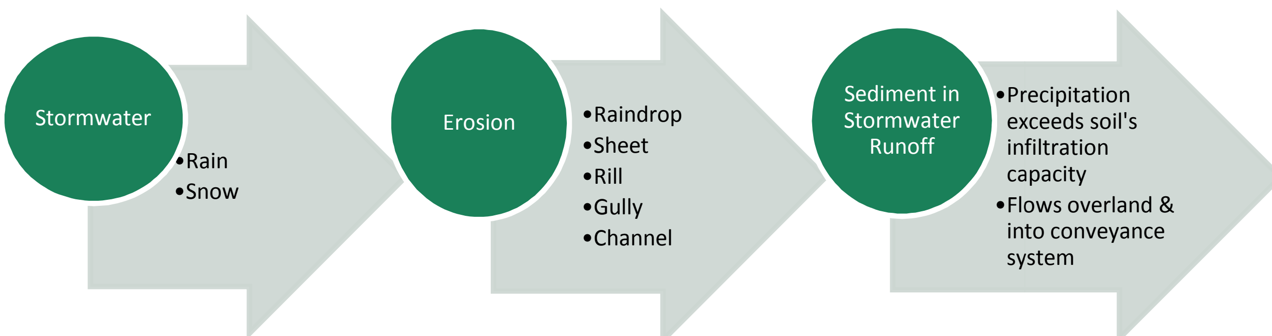
Striped bass

Other species such as blue crab, oysters and trout are also dependent on clean water with low turbidity. While small crabs also hide in aquatic vegetation, oysters need a hard surface to grow on and will choke in mud and muddy water.



Blue crab Oyster Trout

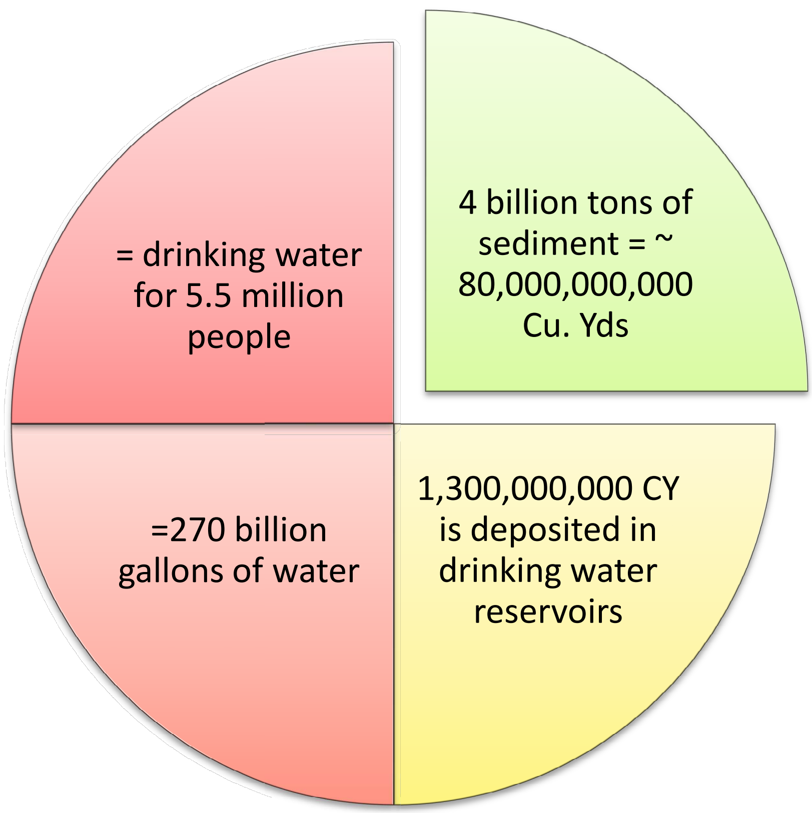
All of the forces of erosion, sources of sediment and increases in stormwater runoff have an economic effect that reaches all of us.



Let’s see what some of the cost are.

Quantifying Erosion and Sediment Control

It has been estimated that the total sediment production in the U.S. is 4 billion (4,000,000,000) tons per year. The average annual sewage load in the U.S. is 8,000,000 tons per year.



In addition to filling up reservoirs, sediment will also block shipping channels. Considering that **46%** of our imported goods come via the water ways, we can see that sediment accumulation in our shipping channels is costly to remove and maintain as well as create safety hazards to the vessels and the public.

Figure 20. Dredging our waterways.

The following tables illustrate the cost of sediment removal through dredging in the U.S. (Table 2.6) and in Virginia (Table 2.7) as conducted by the U.S. Army Corps of Engineers. Note that nation-wide removal has been consistently between 0.20 and 0.27 billion cubic yards. These figures do not include the private dredging done by property owners, neighborhood associations, and marinas.

Table 2.6. Amount Of Sediment Removed By Dredging in the US and Associated Cost From 2001 To 2009 (Source U.S. Army Corps Of Engineers).

Year	Sediment Removed (CY)	Total Cost	Cost per CY
2001	268,468,100	$ 867,758,200	$ 3.23
2002	248,579,800	$ 1,850,096,400	$ 7.44
2003	233,804,500	$ 887,345,900	$ 3.80
2004	265,240,900	$ 903,132,300	$ 3.41
2005	255,079,800	$ 956,490,700	$ 3.75
2006	204,281,000	$ 966,187,600	$ 4.73
2007	206,872,900	$ 996,193,800	$ 4.81
2008	216,450,200	$ 1,011,725,200	$ 4.67
2009	263,625,000	$ 1,344,107,100	$ 5.10

Table 2.7. Amount Of Sediment Removed by Dredging in Virginia and Associated Cost From 2004 to 2009 (Source U.S. Army Corps Of Engineers).

Year	No. of Contracts	Sediment Removed (CY)	Total Cost	$t per CY
2004	12	5,919,790	$ 27,757,785	$ 4.69
2005	6	2,394,600	$ 9,217,654	$ 3.85
2006	7	2,133,950	$ 10,453,199	$ 4.90
2007	6	3,510,000	$ 26,046,734	$ 7.42
2008	7	1,226,100	$ 8,245,203	$ 6.73
2009	17	2,659,600	$ 18,031,070	$ 6.78

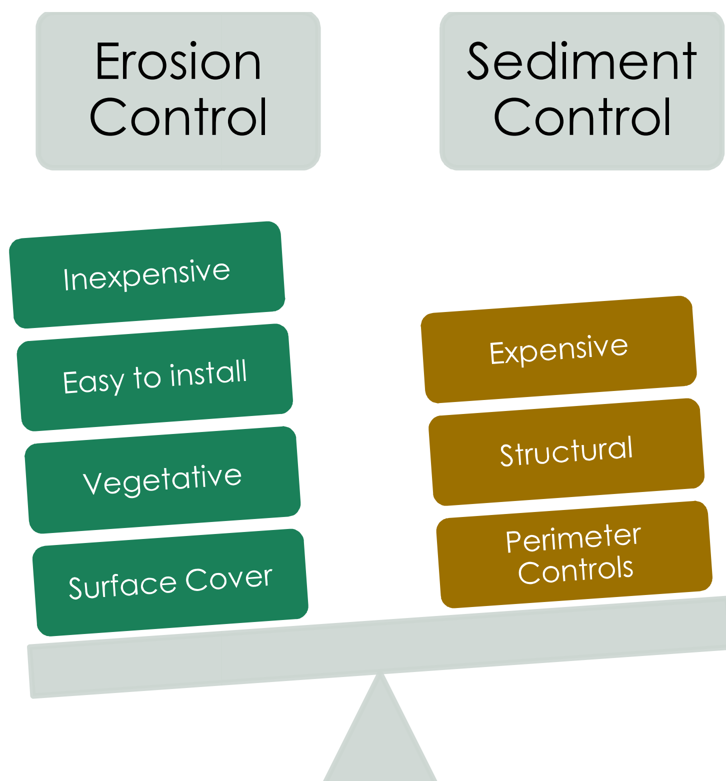
Additional impacts from erosion and sedimentation include:

- The cost to clean-up water for use as drinking water,
- The loss of fertile topsoil with a resulting loss in productivity of the land,
- Sediment deposition on land,
- In-stream erosion,
- Flooding resulting in property damage,
- Increases in turbidity in the water and habitat loss for aquatic organisms.

2f. Principles of Erosion and Sediment Control

If we can control erosion we can effectively control sediment

*The Virginia Erosion and Sediment Control Program targets accelerated erosion***.** More specifically, as the title indicates, it addresses (1) erosion control and (2) sediment control. The order, *erosion* and *sediment* control was chosen for a reason: erosion control is often considered a first line of defense, if we can control erosion efforts to control sediment can be reduced. Sediment control is considered a second line of defense, it catches the sediment from areas where erosion controls could not be installed or where they failed to work properly. Sediment control is always necessary on land disturbance projects since by definition a site can never be completely stabilized when land disturbance takes place. Erosion control is generally less costly that installing sediment control measures, and therefore erosion control generally minimizes the cost of the E&S program on a project. In addition, by trying to minimize erosion we can greatly reduce the number of sediment control measures on a site and minimize the maintenance of sediment control structures, saving additional funds.



Universal Soil Loss Equation

Applying the principles of erosion control can be illustrated through use of the *Universal Soil Loss Equation* (USLE) which is a mathematical model for a particular site.

This equation describes long-term average soil losses expected from sheet and rill erosion for agricultural land uses and illustrates how the implementation of erosion and sediment control measures may reduce the potential for erosion. This method of describing soil loss is a good indicator of the potential for erosion problems based on soil properties. The USLE does not provide an accurate means for estimating sediment yield (actual soil lost from a particular site). In the development of this equation, several of the soil factors discussed above were used.

$$A = RKLSCP$$

Where:

A = average annual soil loss in tons per acre
LS = topographic factor (L = slope length, S = slope grade)
C = cropping factor
R = rainfall index
K = soil erodibility factor
P = conservation practice (i.e., BMP) factor

It is recommended that a soil inventory be conducted on a site before beginning land-disturbance in order to identify areas with highly erodible soils. Assistance in soil identification is available from the local USDA-Natural Resources Conservation Service office, Soil and Water Conservation District, or Cooperative Extension Office. Soil maps can be viewed on NRCS' web soil survey site. Below are some resources to get soil information.

http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/contact/local/

http://www.vaswcd.org/

http://www.ext.vt.edu/offices/index.html

Knowledge Check

1. On a per acre basis, which NPS contributes the most sediment?

a. Agriculture
b. Mining
c. Construction
d. Forestry

2. Which water erosion process accounts for the highest erosion percentage?

a. Rill
b. Raindrops
c. Sheet flow
d. Gully

3. In which month would precipitation intensity have the greatest impact on soil?

a. Oct.
b. July
c. Feb.
d. About the same

4. The higher the K-factor, the less likely a soil will erode.

a. True
b. False

5. Vegetative controls are _______ costly then structural controls?

a. More
b. Less