Unit One

STORM WATER RUNOFF, SOIL EROSION, AND SEDIMENTATION: PROCESSES AND IMPACTS

Introduction

The effective implementation, maintenance, and monitoring of storm water runoff, soil erosion, and sedimentation control measures requires a working understanding of the basic relationships among rainfall, runoff, soils, and topography. Unless planned for and controlled, runoff will generally increase – also increasing the potential for erosion and sedimentation - during construction and after an area is developed.

Just as understanding the physical influences on runoff, erosion, and sedimentation improves the ability to effectively manage construction sites and other earth change activities, appreciating the environmental, economic, and quality of life impacts of those processes is necessary to develop the commitment to implement sound management practices.

Runoff, erosion, and sedimentation are separate, but inter-related processes. Each, if uncontrolled, cause different types of environmental or structural damage and each requires different control measures to minimize their impacts.

The Hydrologic Cycle

Water is continuously exchanged between the earth and atmosphere as depicted in the Hydrologic Cycle below (Figure 1-1). During and after a precipitation event, a portion of the water evaporates and returns directly to the atmosphere, a portion flows over the earth's surface as runoff, and a portion infiltrates into the soil. Once in the soil, the water may be taken up by plant roots and returned to the atmosphere by transpiration, become part of our drinking water supply, or seep into streams, lakes, or oceans. The amount of water cycling through a particular location is beyond our control, but human activity can significantly influence the fate and impact of that water.

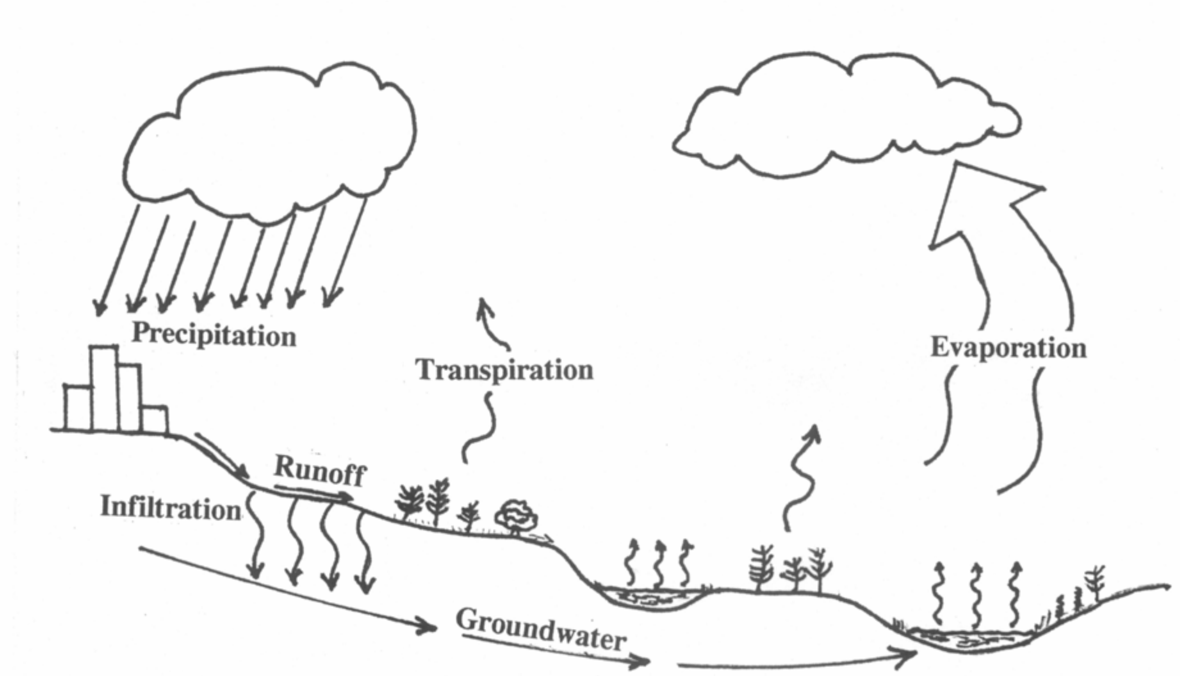

Figure 1.1 Hydrologic Cycle

At an undisturbed or well-vegetated site, the majority of rainfall either evaporates or infiltrates into the ground. Activities such as construction, agriculture, logging, or mining that remove vegetation or disturb the land surface often reduce infiltration and increase runoff. This excess runoff can create erosion and carry sediments or other pollutants into lakes, streams, wetlands, or on to adjacent properties. In addition, constructing buildings, pouring concrete, applying pavement, and compacting the soil increases the impervious area, further reducing infiltration and increasing storm water runoff rates and volumes.

Principle objectives of a properly managed construction site are to maximize infiltration, minimize runoff, and to ensure that storm water discharge during and after construction are equivalent in quantity and quality to predevelopment conditions. In other words, human disruption of the hydrologic cycle should be compensated for by implementing and maintaining effective storm water runoff, erosion, and sediment controls.

Soil Erosion

Farming, construction, logging, and mining upset the balance that has developed among rainfall, storm water runoff, and the environment. Although all the sources mentioned above increase the potential for erosion and sediment, the focus of this training is on construction.

Erosion is often increased during and after construction for two major reasons. The first is the removal of protective natural vegetation. The second is the placement of impermeable surfaces like paving and rooftops on or over the soil, preventing water infiltration and increasing storm water runoff. These two factors increase the likelihood that soil will be exposed to the erosive forces of water and wind.

Major Categories of Erosion

Soil erosion can be categorized in several ways; understanding the different categories of erosion is essential to implementing effective SESC.

Geologic erosion or natural erosion is the action of the wind, water, ice, and gravity in wearing away rock to form soil and to move existing soil downslope. Except for some stream and shore erosion, it is a relatively slow, continuous process that often goes unnoticed. Geologic erosion is reported to account for about 30 percent of all sediment in the United States each year.

Accelerated erosion is a speeding up of erosion due to human activity. Whenever we increase runoff, destroy the natural vegetation, or alter the contour of the ground without providing some sort of surface protection, we greatly increase the rate of erosion. This type of erosion is reported to account for about 70 percent of all sediment generated in this country each year. Accelerated erosion can be minimized through careful planning and by implementing appropriate control measures.

Wind erosion is common on agricultural lands and large construction sites. Soil that is stock piled and left unprotected is especially vulnerable to wind erosion. In some areas, more soil is lost from wind erosion than from water erosion. The Natural Resources Conservation Service (NRCS) estimated that wind erosion is responsible for 42 percent of the erosion damage occurring in Michigan annually. The amount of soil lost from wind erosion may not be obvious because the soil particles disperse over a large area where they are not visible. In urbanized areas, the most damaging aspect of wind erosion is dust. It can create traffic hazards, increase cleaning costs, abrade plant tissue, blight the appearance of structures and other surfaces, or create a health hazard. The problem of windborne dust is often made worse by vehicles driving through construction sites. This can be minimized by applying soil tackifiers and making sure that scraper or articulated truck haul roads are kept wet or have Calcium Chloride or other dust suppressants applied on a regular basis. This is imperative for sites with predominantly clay soils.

The effects of **water erosion** are usually more visible than wind erosion. One can readily see gullies, turbid or muddy water, and sediment build-up. Storm water runoff can cause stream channel erosion, **overland erosion**, or both. Channel erosion occurs both in intermittent and permanent waterways and streams. Three causes of channel erosion are increased storm water runoff, removal of natural vegetation along the waterway, and channel alterations resulting from construction activities. Channel erosion includes both stream bank and stream bed erosion.

Overland erosion occurs on bare slopes as a result of rain splash and storm water runoff. The predominate type of erosion and source of sediment from construction sites is overland erosion. Overland erosion is generally separated into three categories: **sheet erosion, rill erosion, and gully erosion.**

Sheet erosion is the removal of a uniform layer of soil from the land surface as a result of rain splash and storm water runoff. Erosion from rain splash occurs as a result of the impact of raindrops on an unprotected surface. The splash dislodges soil particles, making them more susceptible to movement by overland water flow. The loosened particles that are not washed away can form a muddy slick that clogs pores in the ground surface. The sealed surface further reduces infiltration and increases storm water runoff. The magnitude of soil loss resulting from rain splash can best be seen on a gravelly or stony soil (Figure 1-2).

Figure 1-2

As storm water runoff water moves down a slope, it increases in velocity and increases the potential for erosion. The volume of sediment also increases because the transported particles scour and dislodge more soil particles.

Rill erosion is another form of overland erosion. Evidence of rill erosion is the development of small grooves spaced fairly uniformly along the slope. It is caused when storm water runoff is heavy and water concentrates in rivulets (Figure 1-3). Individual rills range in depth and width up to several inches and reflect a tremendous loss of soil.

Figure 1-3

Gully erosion will develop if rilling is not corrected immediately. The depth of erosion defines the difference between rills and gullies. Although there are no formal definitions for rills and gullies, it is commonly accepted that rills can be easily obliterated by normal grading practices, whereas gullies cannot (Figure 1-4).

Figure 1-4

Gullies may form by means other than unchecked rill erosion. Gullies can form wherever the topography or paved surfaces concentrate water into an area that cannot handle the flow. Proper planning and construction practices prevent this from happening.

Gullying and rilling are more obvious than sheet erosion, but the less obvious sheet erosion often results in a greater loss of soil than either gullying or rilling. In an uncontrolled situation, sheet, rill, and gully erosion may all occur on a single site, resulting in massive soil losses and creating a situation that is very difficult to bring back under control.

Physical Factors Affecting Soil Erosion

Following is an overview of the principal physical factors affecting soil erosion:

Climate

Rainfall amount, intensity, and frequency strongly influence runoff and erosion. Rainfall amount is usually measured in inches. Rainfall intensity is the rate at which the rain falls and is measured in inches of water falling in an hour of time. The infiltration rate is the rate that water is absorbed into the soil and is also measured in inches per hour. When rainfall exceeds the infiltration rate, storm water runoff occurs. The frequency of rainfall is the number of separate rainfall events occurring during a specific period of time, such as a week or month. During periods of frequent rainfall a greater percentage of the rainfall will become storm water runoff because of high soil moisture or saturated soil conditions.

Temperature is another climatic factor influencing erosion. While frozen soil is highly resistant to erosion, rapid thawing of the soil surface brought on by warm rains can lead to serious erosion. Temperature also influences the type of precipitation. Falling snow does not cause erosion, but heavy snowmelts in the spring can cause considerable storm water runoff and erosion. In Northern areas where spring melt occurs attention should be focused in the preceding fall to ensure all controls are in place and ready to handle the particular problems associated with spring runoff. Soils thaw from the top down and if frost is in the ground this results in increased runoff quantities from saturated surface soils because infiltration cannot occur

Vegetative Cover

Vegetation is probably the most important physical factor influencing soil erosion. A good cover of vegetation shields the soil from the impact of raindrops. Roots and rhizomes bind the soil particles together creating soil structure, making the soil more resistant to storm water runoff. Soils with good structure also create pathways for infiltration between aggregated soil particles and along roots. A vegetative cover provides organic matter, slows storm water runoff, and filters sediment. Organic matter protects the soil by shielding it from the impact of falling rain and by soaking up rainfall that would otherwise become storm water runoff. Organic matter also provides essential nutrients for plant growth. More complete coverage of vegetation is found in Unit 3.

The condition of the vegetative cover determines if erosion will be stopped or only slightly decreased. A dense, robust cover of vegetation is one of the best protections against soil erosion.

Soils

The physical characteristics of soil have a bearing on erodibility, deposition rates (sedimentation), and vegetative cover. Soil properties influencing erodibility include **texture**, **structure**, **cohesion**, and **natural drainage class**.

Texture refers to the size or combination of sizes of the individual soil particles. Three broad soil size classifications, ranging from small to large, are clay, silt, and sand (Figure 1-5). Soils having a large amount of silt-sized particles are most susceptible to erosion from both wind and water. Soils with clay or sand-sized particles are less prone to erosion. Clays can become highly erodable if allowed to dry out.

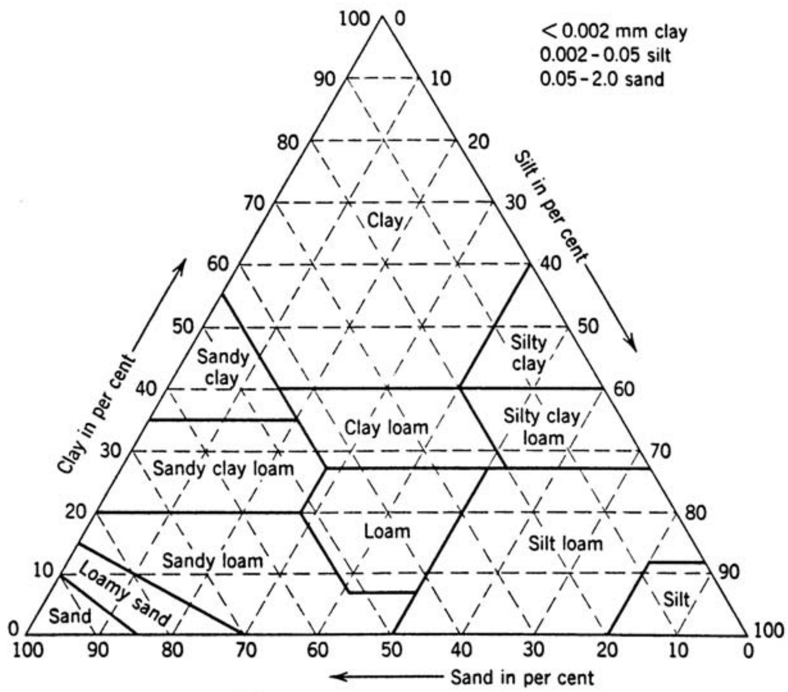

Figure 1-5 Textural Triangle

Structure refers to the degree to which individual soil particles adhere to each other, forming larger clumps and pore spaces. Structure influences the ability of the soil to absorb and infiltrate water and the physical resistance of the soil to erosion. Organic matter influences the structure of most soils. In clay soils, it loosens the structure and allows more water to infiltrate. In silty soils or granular sands, organic matter tends to bind the soil into clumps that are more resistant to erosion. Soils with organic matter absorb and store more water than soils without organic matter.

Cohesion refers to the binding force between soil particles. When moist, the individual soil particles in a cohesive soil cling together to form a doughy consistency. Clay soils are very cohesive, silts less so, and sands display little or no cohesiveness. The cohesiveness of some clay soils makes them highly resistant to erosion if their moisture content is maintained, but the same qualities that resist erosion also greatly reduce infiltration and increase runoff.

The **natural drainage class** of a soil is influenced by soil texture but is primarily a result of the depth to the water table. Soils with a high water table have less storage capacity for rainfall and may experience more runoff and erosion after becoming saturated. Natural drainage class is covered more completely in second phase of the SESC training.

Slope

The last physical factor we will discuss is slope. Slope steepness, length, and roughness affect erodibility. Generally, long, steep, smooth slopes have the greatest potential for erosion. The erosion potential is greatest at the base of the slope, where storm water runoff velocity is the greatest and storm water runoff concentrates. To avoid this problem, long slopes are often *"broken up"* by diversions, terracing, or surface roughening so they function as a series of short slopes rather than one long slope. These structures and techniques function to intercept storm water runoff and thereby reduce the flow and velocity of water over the lower portion of the slope.

Steepness of slope is expressed in several ways. The most common are as a ratio of the difference in the vertical and horizontal distance or as a percentage. For example, a slope with a 100-foot horizontal change for every 10 feet of vertical distance would be called a 10 to 1 or a 10 percent slope.

Although we have little control over soil features and other natural factors, we do have control over how we develop a site and what measures we use to prevent or minimize erosion. After every effort has been made to prevent erosion, efforts should then be directed to controlling sediment.

The Sedimentation Process

As previously explained, sedimentation is the process whereby soil particles eroded by wind or water settle out or are deposited. Deposition of sediment occurs when the wind or water slows enough to allow the different sized particles to settle out.

As is the case with erosion, the sedimentation process is strongly influenced by certain physical factors. The interaction of these factors determines how sediment is transported and deposited.

The velocity and turbulence of storm water runoff are key factors in determining the fate of sediment. The greater the velocity and turbulence of flow, the greater is the amount of sediment transported in suspension in the water or carried along the stream bottom as bedload. The lower the velocity and turbulence of flow, the greater the amount of sediment deposited.

The size, shape, and density of the transported particles also influence the rate at which they settle out. Clay particles are the smallest and have the greatest surface area to volume ratio; this makes them remain in suspension in very low water velocities or with very little turbulence. It is also very difficult or impossible to capture suspended clay particles by filtration or settling. Sand, the largest and heaviest soil particles, require more energy to keep in suspension and are the first to settle out and the easiest to capture by filtration. Silts are intermediate in size and weight between sand and clay. The finest silts can be nearly as difficult as clay to filter or take out of suspension.

It may be useful or necessary to estimate potential loss of soil. Estimates are necessary, for example, when determining maintenance schedules for removing sediment from sedimentation basins or for prioritizing sites for periodic inspections. The NRCS has equations for estimating soil loss from both wind and water erosion; the equation for water erosion is discussed in Unit 8.

Impacts of Runoff, Erosion, and Sedimentation

Over the past several decades, construction activities have increased, creating the potential for serious erosion and sedimentation problems and their associated impacts to the environment. Damage from uncontrolled storm water runoff, erosion, and sedimentation affects many aspects of the environment and, ultimately, nearly every citizen. Listed below are some specific impacts:

Loss of fertile topsoil (Figure 1-6)

Topsoil is an extremely valuable and underappreciated component of the environment. In our climate, it takes thousands of years for a few inches of topsoil to develop, but only a matter of hours or days for uncontrolled erosion to transport topsoil off-site. Topsoil contains organic matter, nutrients, and soil organisms that are beneficial for plant growth. Topsoil that is transported off-site and deposited elsewhere as sediment – often in a place where it is undesirable – is usually not recoverable. In addition, replacing topsoil is expensive, sometimes prohibitively so. It is imperative that existing topsoils be stripped and stockpiled on site for reuse in areas that need to be revegetated. Without a good topsoil base, revegetation is hard to establish and maintain.

Figure 1-6

Structural damage (Figure 1-7)

In addition to removing valuable topsoil, erosion can remove subsoil or fill material that is necessary to maintain the stability or strength of structures: paved roads can be undermined, building foundations can be exposed and weakened, and culverts and bridges can lose their stabilizing approaches and embankments.

Figure 1-7

Deposition

It is estimated that from all sources, over 4.5 billion tons of sediment pollute the rivers of this country each year. This is the equivalent to a volume the size of 25,000 football fields, 100 feet high (Figure 1-8), or nearly one cubic mile of sediment. It costs many dollars per cubic yard to remove sediment from waterways. It is estimated that **tens of billions of dollars per year are spent in the United States to correct the effects of erosion and sediment**.

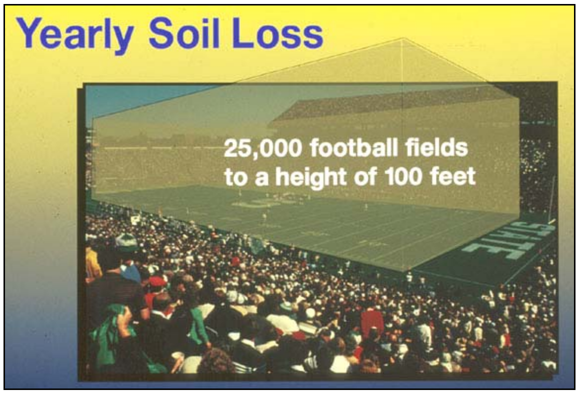

Figure 1-8
Source: John Warbach, Planning and Zoning Center, Inc.

Sediment deposition may result in any of the following:

- Reduction of fish spawning areas
- Less desirable fish communities
- Reduction of aquatic insect communities
- Impaired or destroyed wetland and terrestrial habitats
- Increased flooding due to reduced channel or storm drain capacity
- Increased costs to keep harbors and marinas navigable
- Reduced recreational opportunities

Sediment settles out in areas of relatively low slope or in the deepest or slowest moving areas of a waterbody. The deposition of sediment in a stream or lake can fill in the spawning or wintering habitat of fish. Sediment can also fill the voids created by rocks, gravel, and woody debris, which provide cover for young fish and habitat for aquatic insects on which many fish feed.

Sedimentation also affects the physical dimensions of a stream, or its morphology. The increased sediment load causes the stream to become wider and shallower, increasing streambank erosion, which further increases sediment loads. The surface area exposed to the air and sunlight also increases, temperature extremes in the stream. These temperature extremes may drive away more desirable fish species or otherwise disrupt the aquatic ecosystem, particularly in cold water trout streams.

Wetlands are extremely diverse and productive ecosystems. They provide natural flood control, filters for pollutants and naturally occurring sediments, and important habitat for wildlife, including many threatened and endangered species. Wetlands are not capable, however, of handling large concentrations or volumes of sediment produced by accelerated erosion. In order to maintain their valuable environmental functions, wetlands must be protected from sediment generated from construction site storm water runoff and erosion.

Turbidity

Turbidity is cloudiness caused by the suspension of fine soil particles in the water column (Figure 1-9). A brief episode of turbidity may be aesthetically displeasing but have little environmental impact, but persistent turbidity can significantly affect aquatic ecosystems. The suspended particles can adhere to gill structures of fish and aquatic insects inhibiting the transfer of oxygen; turbidity can impact microscopic plants and animals and interfere with photosynthesis in aquatic plants, having profound consequences for the entire aquatic ecosystem; turbidity can be detrimental to both sight feeding organisms and their prey.

Figure 1-9

Pollutant Loading

In addition to the direct impacts of transported sediment, runoff and eroded sediments can carry other pollutants, such as fertilizers, pesticides, or heavy metals into lakes, streams, or wetlands. The nutrients found in fertilizers, particularly nitrogen and phosphorous, can stimulate the growth of aquatic plants and algae, causing impediments to recreation, algae blooms, odor problems, or fish kills. Pesticides, heavy metals, oils and greases, or other hazardous materials may have significant short or long term impacts on the aquatic environment or public health.

The impacts of erosion and sedimentation are not limited to their direct effects on the environment. The economic cost of sediment removal has already been mentioned, but significant economic impacts result from the effect of erosion and sedimentation on recreation and quality of life. Boating and fishing are extremely important to the economy of Michigan and waterfront property values are strongly correlated to water quality.

Principles and Strategies

The goal of runoff, erosion, and sediment control is to protect land and water resources by eliminating or minimizing runoff, erosion, and off-site sedimentation, using the best practical combination of procedures, practices, and people. These principles and strategies include:

1. **Protect land and water resources.** Responsible people seek to be stewards of all our natural resources, including land and water. A balance must be met between resource protection and the other activities of the construction project.

2. **Minimizing erosion and off-site sedimentation.** During construction activities, everything practical should be done to prevent the erosion of soil from the site and its deposition off-site and into lakes, stream, and wetlands and on to adjacent properties.

3. **Using the best practical combination of procedures, practices, and people.** To control erosion and sediment we need workable laws, regulations, and procedures; up-to-date practices and techniques; and responsible people working together.

The effective control of runoff, erosion, and sedimentation requires the application of the following five principles of erosion and sediment control:

1. To the extent possible, plan the development to fit the topography, soils, and natural vegetation at a site. Attempts should be made in the design stage of a project to identify and preserve those areas that augment infiltration such as wetlands and woodlots. When structures and grading are designed to fit the site, less soil is exposed to erosive forces. The result can be reduced runoff rates, limited environmental damage, and savings in project costs.

2. Expose the smallest practical area of soil for the shortest possible time by scheduling and staging project activities. Stabilize soil surfaces exposed during the first phase of the project before beginning construction on the next phase. Daily seeding and mulching with permanent or temporary seeding mixtures is recommended.

3. Apply soil erosion prevention practices as a first line of defense against on-site damage. Use practices that minimize erosion on a site to prevent sediment from being produced and the need for costly controls to trap and control sediment.

4. Apply sediment control practices as a perimeter protection to prevent sediment from leaving the site. Use practices that control sediment once it is produced, and prevent it from getting off-site.

5. Implement a thorough inspection, maintenance, and follow-up program. Erosion and sedimentation cannot be effectively controlled without a thorough, periodic check of the site and continued maintenance of the control measures. An example of applying this principle would be a routine end-of-day check to be sure all control practices are working properly.

Summary

In summary, erosion and sedimentation includes the entire process whereby soil particles are detached from the ground surface, carried away, and eventually deposited. Erosion is the process by which the land surface is worn away by the action of wind, water, ice, or gravity. In simple terms, it is the process where soil particles are dislodged or detached and put in motion by the forces of wind and water.

An effective runoff, soil erosion, and sedimentation control plan addresses both erosion prevention and sediment control. Remember that it is much more effective to prevent erosion than to control or remove the sediment generated from erosion.

Specific methods of controlling runoff, erosion and sedimentation will be presented in Unit 2.

UNIT ONE REVIEW

1. Erosion is the process where soil particles are ____________ or _______________ and put in motion.

2. Sedimentation is the process whereby detached particles are _________________ elsewhere.

3. Sediment is solid __________ or __________ particulate matter that has been removed from its site of origin by ____, _____, or ______ and deposited elsewhere.

4. Accelerated erosion is a speeding up of erosion due to ____________ activity.

5. Major erosive forces are water and _________________.

6. In some areas, more soil is lost from ______ erosion than from water erosion.

7. The effects of ________________erosion are usually more visible than ______________________ erosion.

8. The three categories of overland erosion are:

    ____
    ____
    ____

9. __________________ erosion is the removal of a uniform layer of soil from rainsplash and storm water runoff.

10. The ____________ of erosion defines the difference between rills and gullies.

11. The physical factors affecting erosion are:

    ____
    ________________   _____________
    ____
    ____

12. Erosion and sedimentation may cause:
    Loss of ____________   _____________
    __________ damage to roads, buildings or bridges.
    ____________, resulting in reduction of fish ____________ ______, reduced ________ or ________ _________capacity, and __________ costs to maintain navigation,
    ____
    ___________ loading

13. The climatic factors that strongly influence erosion and runoff are _____________ amount, ____________, and ________________.

14. Soil properties influencing erodibility include:

    ____
    ____
    ____
    _________   ________   _______

15. Texture refers to the _________ or ___________ of ________ of soil particles in a soil.

16. Structure refers to the degree to which individual soil particles ________ to each other.

17. Slope _________, ____________, and ______________ affect erodibility.

18. Sediment deposition occurs when soil-laden wind or water __________ enough to allow the soil particles to settle out.

19. The ___________, ______________, and ____________ of the transported particles influence the rate at which they settle out.

20. Smaller, lighter particles such as ______ - _______ particles are easily transported and are _____________ to settle out.

21. The five principles of erosion and sedimentation control are:
    - a. _____ the development to fit the natural site conditions
    - b. Expose the ___________ practical area for the ___________ possible time
    - c. Apply ____________ ________ prevention practices as first line of defense
    - d. Apply ___________ control practices to prevent off-site sedimentation
    - e. Implement a thorough ____________, ____________, and _________________ program

22. The most effective way to prevent erosion is keep the soil covered with _____________________.

23. It is much more effective to prevent _________ than to control the ___________________ generated from erosion.

ANSWERS TO UNIT ONE REVIEW

1. Erosion is the process where soil particles are **dislodged** or **detached** and put in motion.

2. Sedimentation is the process whereby detached particles are **deposited** elsewhere.

3. Sediment is solid **mineral** or **organic** particulate matter that has been removed from its site of origin by **wind**, **water**, or **gravity** and deposited elsewhere.

4. Accelerated erosion is a speeding up of erosion due to **human** activity.

5. Major erosive forces are water and **wind**.

6. In some areas, more soil is lost from **wind** erosion than from water erosion.

7. The effects of **water** erosion are usually more visible than **wind** erosion.

8. The three categories of overland erosion are:
   Sheet
   Rill
   Gully

9. **Sheet** erosion is the removal of a uniform layer of soil from rainsplash and storm water runoff.

10. The **depth** of erosion defines the difference between rills and gullies.

11. The physical factors affecting erosion are:
    Climate
    Vegetative cover
    Soils
    Slope

12. Erosion and sedimentation may cause:
    Loss of **fertile topsoil**
    Structural damage to roads, buildings or bridges.
    Deposition, resulting in reduction of fish **spawning areas**, reduced **channel**
    or **storm drain** capacity, and **increased** costs to maintain navigation
    Turbidity
    Pollutant loading

13. The climatic factors that strongly influence erosion and runoff are **rainfall** amount, **frequency**, and **intensity**.

14. Soil properties influencing erodibility include:
   - **Texture**
   - **Structure**
   - **Cohesion**
   - **Natural drainage class**

15. Texture refers to the **size** or **combination** of **sizes** of soil particles in a soil.

16. Structure refers to the degree to which individual soil particles **adhere** to each other.

17. Slope **length**, **steepness**, and **roughness** affect erodibility.

18. Sediment deposition occurs when soil-laden wind or water **slows** enough to allow the soil particles to settle out.

19. The **size**, **shape**, and **density** of the transported particles influence the rate at which they settle out.

20. Smaller, lighter particles such as **clay**-**sized** particles are easily transported and are **slow/difficult** to settle out.

21. The five principles of erosion and sedimentation control are:
   a. **Plan** the development to fit the natural site conditions
   b. Expose the **minimum** practical area for the **shortest** possible time
   c. Apply **erosion control** prevention practices as first line of defense
   d. Apply **sediment** control practices to prevent off-site sedimentation
   e. Implement a thorough **inspection**, **maintenance**, and **follow-up** program

22. The most effective way to prevent erosion is keep the soil covered with **vegetation**.

23. It is much more effective to prevent **erosion** than to control the **sediment** generated from erosion.