Section 2
Erosion and Sedimentation Processes

2.1 Concepts of Erosion and Sedimentation

Each year the Montana Department of Transportation (MDT) completes numerous highway construction projects where soils are disturbed. This disturbance can increase the potential for excess erosion if not properly addressed. Excess soil erosion from construction projects removes the soil surface layer rich in nutrients and transports the sediments into surface waters contributing to sediment loading and contamination from contaminants transported with the sediments. The excess sediment collects in reservoirs, lakes, rivers, and streams reducing their water holding capacity and quality; consequently being detrimental to aquatic life. While erosion and sedimentation are natural processes that help shape Montana's rivers and valleys, intrusive activities such as highway construction can greatly accelerate these natural processes causing serious and costly problems. The implementation of BMPs to prevent soil erosion and the resulting sedimentation from entering the waterways during the early stages of planning can significantly reduce serious and costly problems in the future.

The principles of erosion and sedimentation, and the associated pollutants that can accompany sedimentation, are provided in this section as a background to understanding how to prevent excess erosion from occurring during construction projects and how to best contain the sediments that are released.

2.1.1 Types of Erosion

Erosion is often described as the detachment of soil particles from the ground surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Once detachment occurs, the particles are transported by agents like water or wind. Principles of water and wind erosion are discussed below.

2.1.1.1 Water Erosion

The types of erosion associated with the flow or movement of water can be categorized as follows:

- **Splash Erosion:** This type of erosion is caused by the impact of raindrops on bare or sparsely vegetated soil. The soil particles are detached and transported by runoff creating a water/soil solution. The pouring action destroys the soil structure forming a hard crust once the soil dries. The crust prevents future water from infiltrating, hindering plant establishment which can cause further erosion.

- **Sheet Erosion**: As the name implies, this type of erosion is caused by sheet type flows over soil surfaces. True sheet flow is uncommon because water most often concentrates in surface depressions. Soil particles dislodged or loosened by splash erosion are entrained in the runoff water and transported down gradient. This type of erosion is characterized by the uniform removal of material from the ground surface.

- **Rill/Gully Erosion:** This type of erosion occurs when water flows over the surface of the soil and accumulates in depressions. Once the water reaches sufficient velocity to cut into the depression, it creates channels (rills) which transport sediment. As the scouring action of the water intensifies, larger channels (gullies) are created. This action releases large amounts of sediments.

- **Stream Bank Erosion:** This type of erosion occurs in natural drainage channels and occurs naturally in all streams. Stream bank erosion can be accelerated by upstream development or disturbances to the stream banks. This type of erosion can begin with erosion of the toe of the stream bank that may lead to bank sloughing into the creek.

- **Shoreline Erosion:** This type of erosion occurs at lakeshores and ocean coastlines. It is characterized by sloughing of banks and mass wasting of material in to the water body. It is caused by high-energy wave action.

- **Snow Melt Erosion:** This type of erosion occurs when large volumes of snow allowed to accumulate in disturbed areas cause significant erosion. As moisture accumulates in the soils, the soil expands during freezing causing the soil particles to detach. The snow melts and becomes runoff transporting detached sediment downstream. Also, water stored in structures like sediment ponds tend to freeze, reducing their holding capacity and subsequently leading to flooding and concentrated flow.

2.1.1.2 Wind Erosion

The second main type of erosion is wind erosion. This type of erosion usually occurs in flat poorly vegetated areas. As the soil particles dry and loosen, the wind lifts the particles and transports them to other locations. Although this is a natural process, construction activities create temporary bare areas which are receptive to erosion. A minimum velocity is required to move the particle. The velocity, called threshold velocity, is related to the particle size, the cloddiness of particles, and the surface conditions.

There are three main types of wind erosion which are described below:

- **Suspension Erosion:** This type of erosion is attributed to the movement of very fine particles due to impact with other particles or due to the wind itself. The particles are suspended in the air and transported long distances at high altitudes.

- **Saltation Erosion:** This type of erosion is when large quantities of soil particles are lifted into the air by the wind forces and moved mainly horizontally across the surface. The particles bounce onto the surface lifting other particles and causing damage to the surface and to the vegetation.

- **Surface Creep Erosion:** This type of erosion is caused when heavy particles roll across the soil surface after they come in contact with smaller particles that moved by saltation or by suspension.

2.1.2 Sediments and Pollutants

Erosion is the predominant source of suspended material; however, erosion is a naturally occurring process. As such, attention should focus on erosion rates above those occurring naturally or prior to development. Although erosion rates are difficult to determine, every effort should be made to reduce erosion caused by construction projects and existing facilities. This can be accomplished by implementing BMPs.

A wide variety of constituents exist in the environment and may be found in runoff from highways and highway-related facilities. A constituent becomes a pollutant if it enters receiving waters in a quantity sufficient to impair a beneficial use (e.g. aquatic habitat, water supply, recreation). Each receiving waterway or water body is unique as to the characteristics that contribute to this beneficial use and the type and quantity of constituents that would impair its use.

Suspended sediment material (i.e., soil, gravel, etc.) in storm water runoff is considered a pollutant of primary importance. Excess suspended particles, or high turbidity in waterways and water bodies have environmental and economic implications. The quality of aquatic life habitats degrade as the quantity of sediments increase. The high turbidity prevents the sunlight from reaching the lower sections of the water bodies; therefore, reducing photosynthesis and consequently reducing food production. The sunlight is absorbed in the water, increasing the temperature, which changes the natural aquatic habitats. The sediment settles on the bottom of the water bodies, creating a smooth crust that harms fish spawning habitats. Excess sediments can also be costly because they can affect adjacent properties and clog catch basins and storm drains, causing flooding and resulting in higher maintenance costs. When sediments enter streams and lakes, they create cloudy or turbid water conditions as well as reducing the flow capacity of the water bodies. These conditions can interfere with industrial and recreational activities. In addition, sediments can transport many other pollutants, including metals, and other organic pollutants.

Contaminated sediments affect small creatures such as worms, crustaceans, and insect larvae that inhabit the bottom of a water body, known as the benthic environment. Some kinds of toxic sediments kill benthic organisms, reducing the food available to larger animals such as fish. EPA lists five major types of pollutants found in sediments. These include nutrients, bulk organics, halogenated hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), and metals. EPA's description of these major pollutants is provided below:

- **Nutrients:** Nutrients, including phosphorous and nitrogen compounds such as ammonia, can be toxic to benthic organisms. Elevated levels of phosphorous can promote the unwanted growth of algae. This can lead to depletion of oxygen in the water causing the algae to die and to decay. Decomposition of vegetation can generate unpleasant odors and tastes, as well as unsightly conditions. Elevated nutrient levels can be encountered where channels and storm drains are disturbed and where sewer lines and fertilized vegetated areas are excavated.

- **Bulk Organics:** A class of hydrocarbons that includes oil and grease. Construction activities require the present of hydrocarbons as fuels, solvent, lubricants, and many other applications. If these compounds are released into the environment they might work they way into the water bodies via erosion. Hydrocarbons can be toxic to aquatic and faunal habitats as well as consume oxygen during their decay process resulting in fish kill and unsightly conditions. On construction sites, the storage, transfer, and usage of these compounds should be performed following all federal, state, and local regulations.

- **Halogenated Hydrocarbons or Persistent Organics:** A group of chemicals that are very resistant to decay. Organochlorine compounds such as (DDT) and (PCBs) are in this category. These compounds bioaccumulate in the food chain becoming toxic to aquatic life, wildlife, and humans. The main sources of these compounds are atmospheric deposition, urban, industrial, and municipal discharges from past and ongoing activities. When encountered, these compounds should be treated as hazardous waste and the appropriate governmental agencies should be contacted, as well as all the federal, state, and local regulations shall be followed.

- **PAHs:** A group of organic chemicals that includes several petroleum products and their by products. These compounds are very toxic and most of them are carcinogens. They tend to be persistent in the environment, absorbent in soil particles, bioaccumulative in living tissue, and lethal to several organisms. Urban runoff from industrial, urban, and municipal sources is suspected to be a major contributor of PAH in water bodies, as well as atmospheric deposition.

- **Metals:** The main metals of concern are iron, manganese, lead, cadmium, zinc, mercury, arsenic, and selenium. The major sources of metals are inactive and active mines, and atmospheric deposition from urban, industrial, and municipal discharges.

In Montana, many areas have been mined for precious metals. The mining areas typically exhibit high metal concentrations in the ore, waste rock, and tailings presenting a threat to human health and the environment. Erosion and sedimentation of these materials can be dangerous to the environment and should be avoided. Mining waste is often characterized by oxidation zones which results in soils or wastes having a very uniform texture and colors such as gray, red, or yellow. Special care should be taken when construction activities disturb areas affected by mining activities. The appropriate MDT and DEQ environmental departments should be contacted and the federal, state, and local regulations should be followed.

Contaminated sediments do not always remain at the bottom of a water body. Any activity that stirs up the water, such as a storm or a boat's propeller, can resuspend sediments. Resuspension may result in the direct exposure of animals in the water and not just the bottom-dwelling organisms, to toxic contaminants.

2.2 Impacts of Erosion and Sedimentation

2.2.1 Economical Impacts

Montana incurs significant direct and indirect costs as a result of excess erosion and sedimentation caused by construction activities. Improper BMP use or uncontrolled construction sites cause excess erosion which can lead to soil loss and flooding. The direct costs of excess erosion and sedimentation are readily seen, such as the cost to repair and revegetate a side slope, and dredging of navigational waterways. Indirect costs associated with excess erosion and the resulting sedimentation are not as easy to see and can be overlooked at construction sites. For example, a loss of water storage capacity in reservoirs and lakes due to accumulation of sediments can lead to flooding, downstream damage to streams or private property due to increased stream velocities, and the need to build new reservoirs to increase the water storage capacity. Another example is the loss of soils that are capable to support plant growth, requiring the addition of fertilizers and nutrients. Every year, approximately 230 million cubic meters (300 million cubic yards) of sediment are dredged to deepen harbors and clear shipping lanes in the United States. Roughly 2 to 9 million cubic meters (3 to12 million cubic yards) of these sediments are so contaminated that they require special, and sometimes costly, handling and disposal (EPA, 2002). All these items can be extremely expensive.

Wind erosion can also have economic impacts including: increased highway maintenance and repair; frequent cleaning of personal property; damage to personal property; damage to crops and landscape vegetation; as well as related health problems.

2.2.2 Environmental Impacts

Damage to Montana's environment from excess erosion and sedimentation is most readily seen in the rivers and streams. High turbidity from sedimentation, deposition of excess sediments, and steam bank erosion are a few examples. Loss of valuable topsoil also limits the quality and quantity of vegetation in areas impacted by excessive erosion. Reclamation of some of Montana's steep slopes experiencing excess erosion is very expensive.

Pollutants contained within the sediments are also damaging to the environment. The EPA estimates that approximately 10 percent of the sediment underlying our nation's surface water is sufficiently contaminated with toxic pollutants to pose potential risks to human health and to the environment.

2.3 Principles of Erosion and Sediment Control

Erosion control practices during construction activities protect the soil surface by using soil stabilization BMPs. Erosion control treats soil as a valuable resource that needs to be protected from erosion mechanisms. Sediment control practices trap soil particles after they have been dislodged and prevent or minimize their movement off site. Sediment controls are generally passive systems that rely on filtering and/or settling soil particles before they leave the site.

The understanding of the nature of the contaminants, the basic erosion and sedimentation processes, and the erosion and sedimentation control principals provide the basis for selection and design of storm water quality controls. The principal types of controls to be considered are source controls and treatment controls. Source controls prevent pollutants from being generated at the source. The primary example of source controls is soil stabilization measures. Treatment controls capture and remove particles suspended in runoff that were eroded despite implementation of source control measures. Examples of temporary treatment controls are silt fences and hay bale dikes. The purpose of temporary BMPs used during construction activities is to limit the detachment and subsequent transport of sediment as close to the source as practicable. For example, it is more desirable to minimize erosion from a construction zone by establishing vegetation than to trap sediment below the construction zone with silt fencing.

Planning considerations for runoff control are also very important. A site must be evaluated for drainage patterns. External flows originating offsite should be temporarily (or permanently) diverted around the work area. Runoff controls internal to the site usually divert and direct sediment-laden water to collection and trapping facilities prior to discharge from the site. When management practices for erosion control and storm water management are designed, two components of surface runoff need to be predicted: runoff volume and peak rate of discharge.

In order to address the requirements of pollution reduction at construction sites, a variety of techniques should be employed to reduce soil erosion, reduce site sediment loss and manage construction-generated waste and construction related toxic materials. EPA stresses that a management systems approach should be used that addresses numerous individual practices and evaluates the overall cost and effectiveness of the entire storm water control system. In other words, no single BMP should be used. All of the BMP tools provided in Section 3 should be considered in combination for each construction site in order to develop an erosion and sediment control plan that is protective of Montana residents' health and the environment.

2.3.1 Vegetation

Vegetation is the key to long-term soil stability. Sediment controls are dependent on the reestablishment of vegetation on disturbed areas. Vegetation serves to physically impede runoff by the presence of stems and leaves which retard runoff shear stress and protect the soil surface. Vegetation also greatly increases water infiltration into the soil by facilitating the development of soil structure, macropores, and roughness. A vegetated soil surface might exhibit 80-99% less runoff compared to a barren soil surface depending on the soil texture and vegetation cover. Rapid establishment of vegetation is a critically important component of long-term stability. A number of construction practices are available which promote successful vegetation development.

- **Minimize the extent of vegetation disturbance:** Fewer acres of disturbed soil equate to lower sediment yield and lower BMP cost. Vegetation removal should be avoided in all areas where disturbance is not required. Stands of existing vegetation within the right-of -way may be left undisturbed. Surface Soil Stablization BMP SS-2 describes techniques for preservation of existing vegetation. Particular attention should be paid to preservation of vegetation in wet areas, on stream banks, and on steep slopes where revegetation is difficult. In areas where vegetation is not removed, care should be taken to avoid parking vehicles, staging, developing haul roads, and other activities that lead to soil compaction and vegetation trampling.

- **Salvage of topsoil during construction:** This measure is highly desirable for promotion of robust plant growth. Topsoil is differentiated from subsoil by the presence of soil structure, nutrients, microorganism, and organic matter. Soil development in Montana proceeds very slowly requiring hundreds of years for each inch of topsoil development. Therefore, salvage of topsoil provides a significant resource to the seeded plants improving the probability of rapid and robust plant growth in the short-term.

- **Direct haul of topsoil:** To have topsoil directly from salvage areas to replacement areas without intermediate stockpiling is desirable for vegetation establishment. Conversely, soil quality diminishes when stored in topsoil stockpiles, especially over long periods of time. If topsoil must be stockpiled, effort should be made to minimize the amount of time that soil is stored prior to replacement. Since topsoil is essentially a living material, loss of plant propagules, nutrients, and beneficial soil organisms are expected after prolong stockpiling of topsoil resulting in the loss of vegetation productivity.

- **Minimize compaction of replaced topsoil:** To promote water infiltration and root development, compaction of replaced topsoil shall be minimized. Compacted soil is a leading cause of runoff and poor vegetation establishment that can be caused by excessive vehicle traffic.

- **Minimize the spread of weeds in disturbed areas:** To minimize the spread of weeds, only weed free seed shall be used. Noxious weeds are a significant problem in Montana and at construction sites. Construction equipment and vehicles should not be parked in weed infested areas and vehicles brought onsite should be free of weed seeds.