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II. PRELIMINARY CONSIDERATIONS FOR APPLICATION AND USE OF SEDIMENTATION PONDS FOR SURFACE MINING

2.1 Office of Surface Mining Regulations and Environmental Protection Agency Water Quality Standards

Design criteria for sedimentation ponds are established through federal and state regulations. OSM sedimentation pond design criteria are intended to prevent, to the extent possible, additional contributions of suspended solids to stream flow or runoff outside the permit area and to achieve applicable federal and state water quality standards. These minimum water quality standards include effluent limitation guidelines for coal mining point sources established by the Environmental Protection Agency (EPA). Therefore, the requirements of the EPA are directly tied to the performance standards for the design criteria of sedimentation ponds.

OSM considers sedimentation ponds in conjunction with alternative control measures as the best practical technology (BPT) currently available, as established by the EPA, for the control of sediment. A sedimentation pond is specifically defined by OSM to include any barrier, dam, or excavated depression which slows water runoff allowing sediment to settle.

OSM sedimentation pond design criteria must enable compliance with the effluent limitations, water quality standards, and the safety requirements of state and federal governments. The determination of sedimentation pond design criteria is left up to the operators and the registered professional engineers designing the ponds and reviewed by the regulatory authorities.

Currently, the requirements of the EPA effluent limitations are the result of the Federal Water Pollution Control Act Amendments of 1972. In summary, point source water discharges are required to meet effluent limitations requiring the application BPT currently available by July 1, 1977, and best available technology (BAT) economically achievable by July 1, 1983. The Clean Water Act of 1977 revised the control program for nontoxic pollutants. For detailed discussion of applicable effluent limitations, see Section 3.3. Suggested design criteria for sedimentation ponds are based on the current effluent limits found in many states. Exact requirements for each agency vary; however, the state agency requirements must be taken into account by the design engineer.

2.2 Watershed Characteristics

The location, design, construction, and methods of treatment used in sedimentation ponds are dependent on the characteristics of the watershed where mining activity takes place. Preliminary consideration for the climatology, geology, soils, vegetation, topography, and hydrology of the watershed will help facilitate the design of efficient sedimentation ponds that meet water quality standards and regulations. These characteristics do vary on a watershed-by-watershed basis; proper consideration of this must be made in order to design sedimentation ponds properly.

2.2.1 Climatology

Climatological elements in sedimentation pond design include temperature and precipitation. In general, temperature can affect the amount of runoff to be treated as well as how effectively it is treated in a pond. Variation in ambient temperature changes the viscosity of water which changes the settling velocity of sediment particles. Consequently, the detention time required to settle out a waterborne particle of a given size changes. Ambient temperature also influences the magnitude and seasonal distribution of runoff. Precipitation in the form of snow causes little or no erosion. However, snow melting in the Spring on partially frozen ground is a source for higher rates of runoff and erosion. If low temperatures exist for a significant period of time, ice formations in sedimentation ponds may be a problem. If not taken into consideration in pond design, ice formations may cause failure of embankments or damage energy dissipators such as baffles or riprap. Low temperatures for a significant period of time may disrupt, damage, or halt chemical treatment processes that may be used as part of water treatment in sedimentation ponds.

Precipitation is the most important element of climate in determining the rate of erosion. The magnitude of annual precipitation, in addition to the frequency, intensity, duration, and seasonal distribution of precipitation events affect the magnitude of runoff and erosion. Precipitation characteristics also effect the type of outlet and operation of a sedimentation pond. For example, gated outlets are normally used to store all of the runoff from an event. The gates are opened to discharge the runoff after sediments have sufficiently settled to meet water quality standards. This would be

difficult to design for a pond on a watershed in the eastern region of the United States where annual precipitation is much greater and precipitation events that occur are characteristically of a longer duration, lower intensity, and more frequent. Gated outlets are much more suitable for ponds in the western region where annual precipitation and water yield are much lower and precipitation events are of high intensity but for a relatively short duration.

Seasonal distribution of precipitation results in a seasonal distribution of annual erosion potential. The erosion potential is greater during the high precipitation period such as Spring than it is during Winter. This is important in estimating the yield and concentration of sediment in the runoff. For further consideration of seasonal erosion potential refer to "Surface Water Hydrology and Sedimentology Manual" (OSM, 1982).

2.2.2 Geology

The geology of a watershed interacts somewhat with all hydrologic characteristics of the watershed. The geology has a significant effect on the topography. Topography is a major consideration in the location and shape of a sedimentation pond.

An important consideration of the geology is to evaluate the different types of overburden material that will be exposed during the mining process. Overburden erosion characteristics should be considered when estimating sediment yields and runoff concentrations.

2.2.3 Soils

Watershed soil characteristics depend to a large extent on the parent geologic materials and the predominant weathering processes. These soil characteristics of the watershed determine runoff and erosion from the watershed. The magnitude of runoff and erosion is a function of soil infiltration, soil permeability, moisture content, structure, texture, and content of organic matter.

The sediment size distribution of the runoff is the main design criteria in sizing a sedimentation pond. As the size of particle to be removed becomes smaller the size of a sediment pond required becomes larger. Often times, the size of pond is impractical and chemical treatment may be necessary to remove

the fine particles and alleviate the high cost of constructing a very large pond.

2.2.4 Vegetation

Vegetation plays an important role in the water balance and soil stability in a watershed. Through interception, transpiration, and evaporative processes, vegetation can substantially reduce water yield from a watershed. Vegetation plays an important part in protecting the soil from erosion. Vegetation can reduce the amount of erosion through: interception, reduced rainfall intensities by providing an energy-absorbing cover, reduced landslide hazards through binding and lowering soil water content, and reduced overland and channel erosion by providing added roughness which retards water velocity. Removal of vegetation exposes underlying soils to greatly increased erosive forces. Thus, one of the more critical periods during the mining process is when reclaimed area soils have not developed significant vegetation.

2.2.5 Topography

Topography, including land and channel slopes, aspect, and surface and channel geometry, is an expression of the morphological, geologic, and other erosive forces that have acted on the watershed. In turn, these factors are modified by the topography they have created. For example, channel slope governs water discharge rate and sediment transport rate. Conversely, the discharge rate and the sediment transport can alter the channel form to produce a new slope. Channel and surface geometry affect the depth and velocity of water flow, thus altering sediment transport. Primary topographic considerations in controlling erosion are slope and length of slope. An increase in slope increases the transport capacity of surface runoff, thus increasing erosion. An increase in length of slope allows for concentration of sheet flow. This concentration of sheet flow forms rills and gullies by erosion (see Figure 2.1).

The watershed shape or geometry can also be considered part of watershed topography. The geometry of the watershed determines the amount of area of the watershed where flow concentrates and the time required for flow concentration.

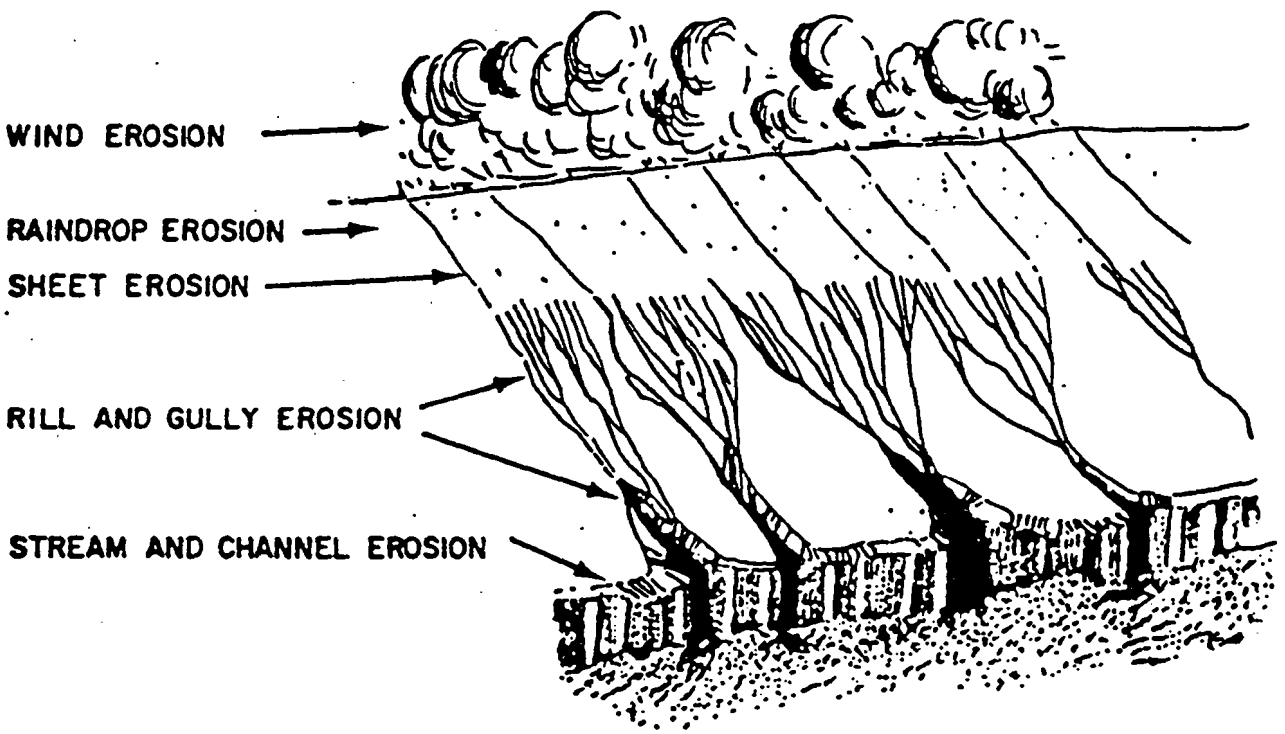

FIGURE 2.1 EXAMPLE OF RILL AND GULLY EROSION (SCS, 1980)

Many times topography controls the location of a sedimentation pond or the type of pond that is constructed. Regulations state that sedimentation ponds should be located as close to the source of sediment as possible. Normally the only factor that limits locating a pond is steep terrain; ponds are usually constructed in valleys or hollows a short distance downstream to facilitate construction.

2.2.6 Hydrology

Runoff that reaches a sedimentation pond is the result of complex interaction of all the previously discussed watershed characteristics; climatology, geology, soils, vegetation, and topography interact to make up the hydrologic process that includes runoff from a precipitation event. Climate includes the intensity, frequency, duration, distribution of precipitation events, and how that precipitation occurs, either in the form of snow or rain depending on temperature. Vegetative cover intercepts a fraction of this precipitation by evapotranspiration. The existence and degree of vegetative cover increases with favorable climate and soil conditions. Of the remaining fraction of precipitation, soil conditions determine what fraction will infiltrate and what fraction will become surface runoff. The remaining fraction that becomes surface runoff will concentrate in a watershed according to the geologic and topographic features of the watershed. In this manner the interaction of watershed characteristics governs the magnitude and distribution of runoff from precipitation and the sediment yield. Consequently, the quality of runoff from the disturbed area is affected by the dynamic equilibrium of the watershed.

2.3 Location of Major Sources of Sediment

There are four categories for sources of sediment from surface mining activities in a watershed. These are the unmined portion of the watershed, the mined or mining portion of the watershed, spoil banks or areas where spoil is stockpiled, and haul or access roads necessary for mining activities. Of these four categories, the unmined portion of the watershed generally yields the least amount of sediment and is not considered a major source of sediment yield. The remaining three categories are a direct consequence of mining operations. Of these three, haul or access roads and spoil banks commonly

generate the greatest sediment yield per unit area. For example, a study done on a monitored watershed in Appalachia (EPA, 1976) gave the following comparison for rates of erosion:

Area	Yield (tons/square mile)
Unmined watershed	28
Mined watershed	1,930
Spoil bank	27,000
Haul road	57,600

However, due to the much larger percentage of the total watershed covered by the mined or mining portion of the watershed, these areas generally yield the most sediment.

2.3.1 Haul and Access Roads

Both haul roads and access roads to mine sites constitute a major source of sediment. In addition, roadways generally remain as a main source throughout the life of the mine. Roadways yield larger amounts of sediment due to an increased rate of runoff resulting from a relatively impermeable surface, and steep cut or fill slopes associated with roadways. Roads intercept sheet runoff and act as a transport mechanism via roadside ditches. Roadways occasionally require clearing and steepening of side slopes which increase slope erosion. Other factors which contribute to a greater sediment yield from roadways include:

- Poor location of roads.
- Improper construction/maintenance of roads and side slopes.
- Improper planning/construction of road drainage systems.

2.3.2 Areas of Active Mining

The nature and extent of sediment yield from areas of active mining are dependent on the mining method or procedure utilized. Four common methods of surface mining are: area mining, contour mining, boxcut mining, and mountain

top removal. In general, area mining is a lesser source of sediment than contour mining due to containment of runoff on disturbed areas. Contour mines have a long, narrow geometry with more spoil and bench area potentiality, draining off the disturbed area directly into an off-site drainage system. In addition, the receiving waters are generally closer to the mining operations for contour mining than for area mining.

Boxcut mining is a form of contour mining used in steeper terrain that reduces spoil dumped downhill by moving it laterally along the boxcut and placing it in areas where coal has been removed. This facilitates maintaining the original grade of the hill. Boxcut mining falls somewhere between area and contour mining as a source of sediment.

Mountain top removal is another form of contour mining used when the economics of overburden removal and coal seam thickness facilitate removing the entire hilltop. Mountain top removal is also considered a lesser source of sediment than contour mining. This is due to the regional nature of, and the reduction in, relief due to mountain top removal. This generalization is true only if the surface drainage is controlled internally.

The mining methods could be ranked from the largest contributor of sediment to the least as contour mining, boxcut mining, mountain top removal, and area mining. This is an over generalization since the sediment yield from a mined area is site specific and is dependent on the amount of on-site erosion control measures that are taken.

2.3.3 Areas Being Cleared for Mining Activities

The areas being cleared and grubbed as pretreatment for surface mining activities are one of the major sources of sediment yield. Clearing and grubbing expose soil on steep slopes and can create a soil surface that impedes infiltration and/or concentrates runoff. Other factors that increase sediment yield are: failure to install perimeter control measures, overclearing or clearing too far ahead of the pit exposing the area for a longer period, and improper placement of the salvaged topsoil.

2.3.4 Areas in Process of Reclamation

This last major source occurs from the start of grading operations and lasts until stabilization of the soil occurs by vegetative and/or structural

measures. Other factors in the reclamation process that can increase sediment yield include constructing excessively steep, long slopes or structurally unstable drainage channels. Also, improper tillage practices, plant material selection, seedbed preparation, and maintenance can increase sediment yield from reclamation areas. The potential for erosion is greater just after reclamation than at any other time during mining operations; therefore, reclamation practices such as tilling, mulching, and revegetation are very important in the control of erosion.

2.4 Types and Applications of Sedimentation Ponds

Sedimentation ponds can be an effective way to control sediment from leaving the mine permit area. On-site erosion protection measures can be taken to reduce the sediment yield from the mine site, but such measures rarely control the sediment to the extent that effluent requirements can be met. Sedimentation ponds are typically the last sediment control measure that an operator uses before the runoff leaves the mine permit area and enters natural drainageways downstream. Improper control of the sediment leaving the mine permit area may cause severe off-site damages.

Sedimentation ponds are generally constructed with embankments, by excavation, or a combination of both. The sedimentation ponds presented in the following sections categorize the types of ponds that are currently used by the mining industry. However, several combinations of the various types ~~due~~ to exist and may be used in the sediment control plan. There are many factors which must be considered at each site to determine which basic type of sedimentation pond, or variation, will provide the maximum control of sediment. The following sections give a description of the various types of sedimentation ponds and where their application is most practical.

2.4.1 Excavated Sedimentation Pond

Excavated sedimentation ponds are constructed by excavating a pit or "hole" in the ground with the use of a bulldozer or backhoe. Generally, these types of sedimentation ponds are limited to contain surface runoff from disturbed areas at surface mines located in rolling to flat terrain and from small drainage areas. Sedimentation ponds which are constructed strictly by excavation are not used in steep sloped terrain due to the large amount of

excavation that would be required to achieve the applicable storage volume requirements. These types of ponds are generally located off a natural drainageway.

The excavated sedimentation pond has been used in conjunction with the mine pit which serves as a preliminary settling basin. The runoff from disturbed areas within the mine site is directed into the mine pit where settling of the larger size particles occurs. From the pit, the mine drainage is pumped into the excavated sedimentation pond where final settling occurs. Using pumps to control the inflow into the excavated sedimentation pond allows control of the detention time within the sedimentation pond. Additionally, the storage volume within the pit can be utilized, thereby reducing the sedimentation pond storage requirements as long as the storage volume within the mine pit does not interfere with mining operations.

There are many disadvantages with the excavated sedimentation pond. It is limited to applications in relatively flat terrain and controlling surface runoff from small drainage areas. Installation of dewatering devices in these types of ponds is generally very expensive and therefore, they are rarely installed. This leads to the pond storing water for a long period of time thus reducing the available storage volume when a storm event occurs. The result of this will be decreased detention times and therefore, decreased effluent quality. In addition, it is difficult to provide separate principal and emergency spillways. For these reasons, applications of the excavated sedimentation pond are very limited.

2.4.2 Embankment and Combination Embankment/Excavated Sedimentation Ponds

An embankment sedimentation pond can be used in any type of terrain. Generally, these types of ponds are located on a drainageway. An embankment is constructed across the drainageway to form the sedimentation pond. When the drainageway bed is excavated upstream of the embankment, a combination embankment/excavated sedimentation pond is formed. Excavation upstream of the embankment provides additional storage volume capacity to an embankment sedimentation pond.

A variety of outlets may be used with the embankment and combination embankment/excavated sedimentation pond. The most common method is to use a pipe outlet for the principal spillway and a channel cut into the top of the embankment as the emergency spillway. Although, several other types of outlets are used and are presented in Section 3.9.

As previously mentioned, embankment sedimentation ponds are generally constructed on drainageways. The topography often dictates that this type of pond be constructed. However, this type of pond has some disadvantages. There is a possibility of embankment failure due to poor construction or the use of poor construction materials. Bank sloughing may occur that can decrease the sediment removal efficiency of the pond by adding sediment to the pond. Bank sloughing reduces the storage volume capacity and therefore, increases the maintenance requirements. The shape of the embankment sedimentation pond is generally controlled by topography.

The combination embankment/excavated sedimentation pond has the advantage of providing additional storage volume without increasing the height or size of the embankment. However, exposure of the side slopes due to upstream excavation may require that the slopes be stabilized.

2.4.3 Sedimentation Pond Spillway Type

Sedimentation ponds have often been classified according to the type of principal and emergency spillway used. OSM regulations require that a combination of principal and emergency spillways be provided to safely pass the runoff from a 25-year, 24-hour precipitation event or larger event specified by the regulatory authority. In addition, the elevation of the crest of the emergency spillway shall be at least one foot above the crest of the principal spillway. Therefore, separate outlets must be provided for the principal and emergency spillways.

Principal spillways are usually constructed by using some type of pipe outlet. Emergency spillways are generally constructed by excavating an exit channel through the embankment or natural ground. Other types of outlets may be used for the emergency spillway but due to the costs involved, the excavated exit channel is the most feasible. A complete discussion of spillways is presented in Section 3.9.

2.4.4 Multiple Pond Systems

A multiple pond system is considered to be the use of two or more sedimentation ponds in a series (one downstream of the other). The concept of multiple ponds is also accomplished through compartmentalization of a single pond. The concept of multiple ponds is the occurrence of staged settling. Solids with higher settling velocities will settle in the first pond or compartment and the finer sediments will be settled in the final pond or compartment. One particular advantage to this type of system is that most of the maintenance (i.e., sediment removal) is limited to the first settling pond or compartment. Also, field applications have shown that multiple sediment ponds in a series are more efficient in removing finer particles than a single pond of equal surface area. One disadvantage in the use of multiple ponds is that more area is disturbed due to the construction of additional ponds. A detailed discussion on the application and design of multiple pond systems is given in Section 4.3.

2.4.5 Physical/Chemical Treatment Ponds

Physical/chemical treatment identifies the process of adding chemicals to enhance the physical settling characteristics of the sediment particles to be removed by gravity settling. The chemicals added are generally referred to as coagulants or flocculant aids. Chemicals are added to the influent of the sedimentation pond, where proper mixing must occur, and then the sediment is flocculated and settled in the pond. Coal fines may not be flocculated when chemicals are added due to the electrical nature of the coal fines. Other treatment measures may be required to remove the coal fines.

Physical/chemical treatment is a standard practice in the treatment of water for domestic use. More recently it has been applied in the mining industry for the removal of sediment to meet effluent limitations. To meet the existing and proposed effluent limitations will sometimes require removal of very fine clay and silt sediments. The volume and surface area of a sedimentation pond required for removal of very fine sediments are unreasonably large. Therefore, physical/chemical treatment measures are required for removal of fine sediments.

Physical/chemical treatment measures have been used in the field in conjunction with multiple ponds in a series. In this type of application, the

large sediment is settled in the first pond, reducing the sediment load to the second pond where it is only used for settling of the finer sediments. The chemical dose required for settling is generally directly related to the concentration of solids. Therefore, by reducing the solids concentration in the first pond, the amount of chemical required is reduced below the amount that would be required using only one sedimentation pond. Detailed discussion on the actual physical/chemical treatment process and types of coagulants is given in Section 4.3.

Some disadvantages do exist in the application of physical/chemical treatment. The use of chemicals in settling solids adds to the volume of material settled in the sedimentation pond; therefore, consideration must be given to sediment storage volume and/or frequency of maintenance. Another consideration is final disposal of the settled sediment. It should be realized that the sediment contains the chemicals used for coagulation. The type and/or difficulty of final disposal will depend on the type of coagulation chemicals and flocculant aids used.

2.4.6 Dry Basin versus Permanent Pool

The dry basin is characterized as a basin which has a dewatering device such that the sedimentation pond does not store the water runoff from any one precipitation event indefinitely. Examples of dewatering devices include trickle tubes and perforated riser pipe outlets that dewater to the sediment storage level in the pond.

Dry basins may be located either on or off drainageways. For dry basin ponds, the dewatering device is designed to dewater the sediment pond at a rate which achieves and maintains the required detention time to achieve applicable effluent limitations. Between precipitation events this type of pond is either dewatering or dry.

The permanent pool sedimentation pond is designed to provide a permanent storage volume of water after the principal spillway has stopped discharging. The maximum permanent pool elevation is the elevation of the principal spillway crest. These types of ponds are often located on small drainageways and perennial streams when approval of the regulating authority is given. Permanent pool sedimentation ponds can also be located off drainageways.

The main difference between dry basins and permanent pool basins is that the permanent pool provides a constant storage volume for water while the dry basin does not. The advantages of the permanent pool basin are that it provides a water supply for dust control on haul and access roads during dry periods and the permanent pool helps minimize resuspension of sediment that has already settled. The disadvantage of the permanent pool basin is that it needs to be designed for the additional permanent storage volume of water.

The advantage of the dry basin pond is that it does not have to be designed for an additional storage volume and therefore, the entire storage volume of the basin can be utilized during large runoff events. The disadvantage of dry basins is that resuspension of the settled sediment may occur if control measures at the inlet are not taken.

2.5 Summary of Preliminary Considerations

Preliminary consideration for the application and use of a sedimentation pond in a surface mining operation is based on the pertinent regulations and standards that outline the level of performance required. With a working knowledge of the watershed characteristics, sediment transport mechanisms, and major sediment source locations, the type of sedimentation pond and its application can be chosen and designed to facilitate meeting regulations and standards for pond performance.

The criteria for design of sedimentation ponds is established federally through regulations by the Office of Surface Mining, Environmental Protection Agency, and the Mine Safety and Health Administration (MSHA). OSM design criteria are intended to prevent, to the extent possible, additional contributions of suspended solids outside of the permit area and achieve water quality standards. Sedimentation ponds are also required to meet inspection and large dam criteria of the MSHA (30 CFR 77.216) and requirements of state and local agencies with jurisdiction over the design, construction, or discharge of sedimentation ponds.

The climate, geology, soils, vegetation, topography, and resultant hydrology of a watershed affect the magnitude and rate of erosion and sediment transport that must be treated by a sedimentation pond. Climatological factors include the seasonal variation and range of temperature and the magnitude, intensity, frequency, duration, and seasonal distribution of

precipitation. Geological processes creating long- and short-term land surface adjustments affect watershed climate and hydrology. Erosion-resistant rocks, large-scale erosive forces, and bed structure dictate the general topography. Thus, the geology of a watershed is important because it affects all of the other watershed characteristics.

The magnitude of runoff and erosion is a function of soil permeability, moisture content, structure, texture, and content of organic matter. The amount of vegetative cover, which is a function of climate and soil characteristics, affects the stability of the soil and water yield from a watershed. Primary factors of topography are the length and steepness of slopes and the geometry of the watershed. The complex interaction of all these watershed characteristics determines the magnitude and distribution of runoff from a precipitation event, which is the element of the hydrologic process of concern.

There are four categories of sediment sources from surface mining activities in a watershed. These are the unmined portion of the watershed, the mined or mining portion of the watershed, spoil banks or areas where spoil is stockpiled, and haul or access roads necessary for mining activities. Of these four categories, the unmined portion of the watershed generally yields the least amount of sediment and is not considered a major source of sediment yield. The remaining three categories are a direct consequence of mining operations.

The type of pond can be classified into one of three general categories: excavated ponds; embankement ponds; and combination excavated/embankment ponds. The major factor in the selection of the type of pond is the topography of the proposed site.

When conditions for treatment of runoff from the disturbed area warrant, chemical treatment systems or multiple pond configurations are used. Normally, chemical treatment systems are utilized when high concentrations of colloidal size particles are present in runoff from the disturbed area and gravity-settling methods are not sufficient. Multiple ponds are normally used when the cost of constructing a single pond is high because of topographic constraints, or the gravity-settling method of treatment in a single pond is not sufficient to meet effluent limitations.

With sufficient knowledge of the preliminary considerations discussed previously, the type and application of a sedimentation pond which will be effective in sediment control can be selected.