Engineering Manual for Mining Operations

Alan J. Bigatel, P.E.
Gary R. Camus
Douglas W. Caylor, P.E.
Alfred D. Dalberto, P.E.
William W. Hellier, P.E.

Pennsylvania Department of Environmental Protection
Bureaus of Mining Programs and District Mining Operations

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

For more information about Pennsylvania's mining program, visit Pennsylvania's website at www.state.pa.us or visit DEP directly at www.dep.state.pa.us (choose Subjects/Mining and Mineral Resources).

MANUAL UPDATES

In order to keep this manual current with the present policies and regulations of the Department, periodic updates or revisions to the appropriate sections of this manual will be issued. Please complete the following information and forward to:

Department of Environmental Protection
Bureau of Mining Programs
Division of Permits
Rachel Carson State Office Building
PO Box 8461
Harrisburg, PA 17105-8461

Request for Updates/revisions to Engineering Manual for Coal Mining Operations

Name:____

Title:____

Company:____

Street:____

City_____________________________ State:______________ Zip:______________

Phone:(___)______________

DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF MINING PROGRAMS

DOCUMENT NUMBER: 563-0300-101

TITLE: Engineering Manual for Mining Operations

EFFECTIVE DATE: January 1, 1999

AUTHORITY: Surface Mining Conservation and Reclamation Act, Noncoal Surface Mining Reclamation and Conservation Act, Clean Streams Law

POLICY:
Proper engineering principles shall be used in the review of mine permit applications, bonding increments, and bond release requests.

PURPOSE:
This manual explains the areas of permit applications which involve engineering concerns such as erosion and sedimentation control plans, water treatment plans, haul roads, stream encroachments, culverts, wetlands and areas where mining is restricted. While the permit applications for each type of mining activity are specific as to what information is required, this manual explains what is an acceptable design and when variations are acceptable.

APPLICABILITY:
This manual will apply to operators, consultants, contractors, and DEP staff who are involved in the design and operation of mining activities.

DISCLAIMER:
The policies and procedures outlined in this guidance document are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements.

The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of the Department to give these rules that weight or deference. This document establishes the framework within which the Department will exercise its administrative discretion in the future. The Department reserves the discretion to deviate from this policy statement if circumstances warrant.

PAGE LENGTH: 150

LOCATION: Volume 12, Tab 126

CONTENTS

FIGURES

TABLES

1. Introduction

The Department of Environmental Protection issues permits for anthracite and bituminous coal mining activities. These activities include underground mining, coal refuse disposal, coal refuse reprocessing, and surface mining. The Department issues one permit for each operation which covers a broad range of program areas, including air quality, water quality, and solid waste management, in addition to mining. The permit process allows for input from the public, local municipalities, and other state and federal agencies. The permit application procedure provides sufficient information for the Department to make a permitting decision.

This manual explains the areas of permit applications which involve engineering, such as erosion and sedimentation control plans, water treatment plans, haul roads, stream encroachments, culverts, wetlands, and areas where mining is restricted. While the permit applications for each type of mining activity are specific as to what information is required, this manual details the regulations that correspond to the permit application. It explains what is an acceptable design and when variations are acceptable. The manual is intended to be used by consultants, mine operators, and Department staff.

The Bureau of Mining Programs has an office in Harrisburg. District Mining Operations offices are located in Knox, Ebensburg, Hawk Run, Greensburg, Pottsville and McMurray. The District Mining Operations offices at Knox, Ebensburg, Hawk Run, and Greensburg handle bituminous coal and noncoal (industrial minerals) surface mining activities. The McMurray District Mining Office handles all bituminous underground mining, the mine subsidence program, and bituminous coal refuse disposal operations in western Pennsylvania. The Pottsville District Mining Office handles all anthracite coal mining activities, along with all industrial minerals operations in eastern Pennsylvania. The addresses and phone numbers for District Mining Operations offices are located in Appendix C.

The Bureau of Deep Mine Safety is responsible for the health and safety program for underground mines. The Bureau of Deep Mine Safety has offices in Uniontown and Pottsville. The address and phone number for Bureau of Deep Mine Safety area offices are located in Appendix C.

This manual is intended only to be a guide to persons preparing mine permit applications and to Department personnel who review permit applications. However, this manual is not intended to cover all circumstances and situations which may arise in the preparation of a permit application and design of various structures associated with surface mining operations. This manual is not a substitute for the skill and experience of the technical professional who prepared the designs and the application. In addition, this manual is not intended to establish binding legal requirements. The binding legal requirements applicable to permit applications are set forth in the various statutes and Department regulations. This manual may assist the Department and the regulated community in implementing and satisfying those requirements. References to regulations in the manual are for the convenience of the reader, and may not be a comprehensive list of applicable requirements.

This manual is derived from, and incorporates, other technical guidance that should be referenced and followed whenever that guidance is more specific or more current than the information given in this edition. These guidelines are available from the Department. They are also on the Department's website at http://www.dep.state.pa.us. They are located in the Public Participation Center.

2. Erosion And Sedimentation Control

2.1 Introduction

(25 Pa. Code §87.146)

In surface mining, large areas of soils, subsoils and overburden are exposed to the forces of erosion. Erosion is the detachment of soil particles by rainfall, flowing water or wind and the transport of these eroded particles by the runoff. Sedimentation is the deposition of those eroded particles at some point downstream. Sedimentation occurs when the water velocity and transport capacity decrease.

Undisturbed soils resist erosion in several ways. Vegetation serves to protect the land from the impact of raindrops. Root development forms an interwoven mesh which prevents soil particles from moving. Clay particles and organic matter exhibit cohesive forces which hold larger, noncohesive silt and sand-size particles together to form soil aggregates. These larger particles and aggregates are more resistant to erosion due to their size and weight.

Undisturbed soils typically exhibit higher infiltration rates than compacted soils. Therefore, the amount of runoff per unit area will be less for undisturbed soils than for compacted soils. Mining activity has a significant impact on reducing soil aggregation and structure and increases the potential for erosion.

2.1.1 Different Types of Erosion

Undisturbed and disturbed watersheds can experience various types of erosion. The main types are splash erosion, sheet erosion, rill erosion, gully erosion, and channel erosion.

2.1.2 Splash Erosion

Erosion from rainfall begins when raindrops impact the ground and dislodge soil particles. The splashed particles may reach a height of 3 feet (0.91 m) and cover a radius of as much as 5 feet (1.52 m). The kinetic energy increases directly with the mass or size of the drop and the square of its velocity. Gray (1982) reported raindrop velocities of approximately 20 miles per hour (32.19 km/hr) during cloudbursts.

2.1.3 Sheet Erosion

Sheet erosion is caused when runoff generally initially manifests itself as a thin sheet of flowing water. This occurs over uniform sloped areas and is discernible only upon close examination. Sheet erosion transports the soil particles detached due to the impact of rainfall. Sheet erosion decreases over time as the smaller particles are eroded away, leaving a coarser, more erosion resistant soil. This process of erosion of the finer soil particles is referred to as armoring. Sheet erosion can be greatly reduced by seeding at the proper time and adequate mulching immediately following the seeding operation. Mulching the area prone to erosion helps to absorb the energy of impacting precipitation and is very effective in protecting the soil (Beasley et al. 1984). Sheet erosion, though less visible than other types of erosion, is the dominant erosion process that takes place early in a reclaimed watershed. Sheet erosion can be reduced by improving soil cover, mulching, and the expeditious establishment of vegetation.

2.1.4 Rill Erosion

The next level of erosion that takes place is rill erosion, which occurs as runoff concentrates in very small channels and the shearing force of flowing water detaches additional soil particles. Rill erosion is characterized by uniform spacing of eroded parallel channels which are discernible both close up and at a distance. It is most noticeable on bare, freshly graded, or newly seeded soils. Rills can be removed with normal agricultural tillage equipment. Rill erosion can be controlled by the establishment of soil cover, seeding parallel to the contours, adequate mulching, and proper spacing of diversion ditches. The use of diversion ditches reduces the slope and overland flow path for runoff.

2.1.5 Gully Erosion

As the small rivulets present in rill erosion combine to form larger channels, the erosive force of the water increases, and gully erosion occurs. Gully erosion leaves deep defined channels that cannot be removed by agricultural tillage equipment. Gully erosion will continue to greater depths until an erosion-resistant layer is encountered in the backfill or natural soil horizon. Gully erosion can be controlled by the design and construction of adequate channels, by the regrading and reseeding of eroded areas, or by placing a lined channel in areas where gully erosion is occurring.

When a rill or gully that affects the postmining land use, forms in areas that have been re-graded and planted, the rill and gully must be filled, graded or otherwise stabilized and the area re-seeded or replanted. The Department will specify that a rill or gully of lesser size be stabilized and the area reseeded or replanted if the rill or gully is disruptive to the approved postmining land use or may result in additional erosion and sedimentation. The regrading or stabilization of a rill or gully to include the reseeding or replanting shall be completed by the first normal period for favorable planting. However, a rill or gully contributing to impacts outside the permit area or a rill or gully occurring after removal of erosion and sedimentation control structures must be stabilized immediately.

2.1.6 Channel Erosion

The last level of erosion is channel erosion, which occurs in watercourse channels and streams. Previously stable streams that have adapted to a particular peak rate of runoff can become unstable as the prevailing peak rate of runoff increases in reaction to changes to runoff rates within the upstream watershed. The instability is due to inadequate hydraulic capacity for the increased volume of runoff generated and inadequate bed and bank linings for the higher velocities encountered. Both the size and quantity of material that can be eroded and transported increase as the velocity and volume of runoff increase.

Channel erosion is reduced by decreasing the volume and peak rate of runoff leaving a site. This can be achieved by improving soil cover, reducing slope lengths, and increasing the time of concentration or retention time of the water leaving the site. Gully and channel erosion can have a significant impact for many years after reclamation has been achieved; on the other hand, the primary impact of sheet and rill erosion is through significant contributions of sedimentation immediately after reclamation.

2.1.7 Infiltration Capacity

The process of removing topsoil and subsoils, their storage for long periods, and their replacement on a site for revegetation has an impact on the infiltration capacity of a soil. Water and air infiltrate soils through void spaces present in the soil. Compaction of soil by repeated passage of heavy equipment reduces the void spaces and decreases the amount of water and air that can infiltrate into the soil. The volume of voids as a percentage of the total volume of the soil is referred to as the porosity of the soil.

The degree of compaction of a reclaimed soil is controlled by the water content of the soil when it is handled and by the ground pressure and number of passes of the equipment used in removing and replacing the topsoil. When a high level of compaction is necessary, such as in highway construction, water is added to the soil to allow the soil particles to flow together, resulting in a higher degree of compaction and a decrease in the void ratio. The natural moisture content of the soil when it is removed and replaced has a significant impact on the density and compaction of the reclaimed soil. To avoid excessive compaction, soil should not be handled during or immediately after wet periods. Care should be taken to minimize the repeated passage of equipment over the soil during the soil removal and replacement operations. The use of loaders and trucks to remove and replace soil will generally result in less compaction of the soil. The use of such equipment is necessary when prime farmland soils or other high productivity soils are involved.

In order to allow air and water to reach the soil, the voids within a soil must be interconnected. Not all void spaces within a soil are effective in allowing air and water to reach the soil. These interconnected voids are the result of decaying plant matter, earthworms, insects, groundhogs, frost action, and weathering of the soil over time. Compaction destroys the interconnected voids. While cultivation practices, such as plowing or discing, can increase the voids in a soil, the effective or interconnected voids will need time to reestablish.

The equipment used to move the soil has a significant effect on the compaction. In general the physical removal of the soil by loaders and trucks is less likely to cause compaction than the use of scrapers. Bulldozers used for topsoil handling also cause less compaction than scrapers, due to a lighter loading per unit area for bulldozers than for wheeled equipment. Maintaining the soil voids will increase the infiltration capacity. This is important as a decrease in infiltration will increase the amount of runoff and accelerate erosion and sedimentation problems.

2.2 Regulations

The statuary authority for erosion and sedimentation control is the Pennsylvania Clean Streams Law (PL 1987, passed 1937 and subsequently amended). The Erosion Control Regulations, 25 Pa. Code Chapter 102, contain specific requirements for erosion and sedimentation control plans. These regulations provide the standards for determining the runoff and sediment storage volumes required for erosion and sedimentation impoundments, conveyance of flows to a watercourse, design standards for emergency spillways, and minimum length to width ratios for impoundments.

The Chapter 102 erosion control regulations are administered by the Division of Waterways, Wetlands and Erosion, Bureau of Water Quality Protection. This Division has released a document, titled **Erosion and Sediment Pollution Control Manual** (April, 1990), that explains in detail many of the items discussed in this manual. Where appropriate, sections of the **Erosion and Sediment Pollution Control Manual** have been cited for quick and easy referencing. Copies of the **Erosion and Sediment Pollution Control Manua**l are available by contacting the local Conservation District Office. Addresses and phone numbers for each Conservation District are found in Appendix C.

Another very useful document is the Natural Resources Conservation Service's **Engineering Field Manual (EFM)**. The **EFM** covers many areas of erosion and sediment control design, including estimating runoff, hydraulics, soils, grassed waterways, diversions, culverts and impoundments. Information on purchasing the **EFM** is located in the reference section. Updates and additions to the **EFM** specific to Pennsylvania, can be obtained by contacting the local Natural Resources Conservation Service (NRCS) office (See Appendix C).

Further requirements for erosion and sedimentation control plans are contained in 25 Pa. Code Chapter 87, bituminous surface coal mining regulations; Chapter 88, anthracite coal mining regulations; Chapter 89, underground coal mining regulations; and Chapter 90, coal refuse disposal regulations. These regulations set the standards for the actual design and construction of impoundments, ditches and channels.

Incorporated by reference in the regulations are two Natural Resources Conservation Service (NRCS) standards **Sediment Basin 350** and **Pond 378**. **Pond 378** contains standards that apply to all erosion and sedimentation impoundments and treatment impoundments. **Sediment Basin 350** applies to temporary erosion and sedimentation basins whose expected life is five years or less. These two publications are part of the NRCS's **PA Field Office Technical Guide**.

2.2.1 Sediment Pollution

(25 Pa. Code §102.1)

Sediment pollution is the placement, discharge or other introduction of sediment into the waters of the Commonwealth resulting either from the failure to design, construct, implement, or maintain control measures and control facilities in accordance with the Chapter 102 regulations, or in any manner that is harmful, detrimental or injurious to the designated uses of the waters of the Commonwealth.

Sediment that is deposited on stream bottoms is detrimental to the microscopic organisms and invertebrates that are the beginning of the food chain. Particles that remain suspended are often angular and will cut and abrade gill structures of fish, causing disease and mortality. Sediment from earth disturbance activities, such as mining operations, frequently contains a high clay content. The clay sized particles are difficult to settle out and can result in higher stream turbidity. High turbidity can present problems for water withdrawn for a public water supply.

As soon as the velocity of water transporting sediment falls below the point necessary to hold the material in suspension, the sediment begins to be deposited. The particles drop out in order of size: first gravel, then sand, then silt, and finally the smaller clay-sized particles. Particles that settle to the bottom of a stream effectively fill the voids in the substrate and destroy the habitat. The cumulative effect of mining operations in a watershed can result in a significant increase in the sediment load and the potential destruction of aquatic habitat.

2.3 Predicting Sediment Yields

Sediment yields can be predicted for various soils, slopes, conservation practices and periods of time. These predictions are useful in comparing different reclamation practices that can be used on a site.

The Universal Soil Loss Equation (USLE) was developed as a means to compute expected soil losses from different watersheds. The USLE predicts the amount of sediment produced by rill and sheet erosion on field sized plots. It does not compute gully or channel erosion that occurs on larger areas. The USLE also does not compute deposition that can also occur on larger watersheds.

The Modified Universal Soil Loss Equation (MUSLE) was developed to predict deposition from larger watersheds. The MUSLE was found to overpredict sediment loads for areas with slopes steeper than 18%.

A Revised Universal Soil Loss Equation (RUSLE) has recently been developed to give a more accurate prediction of sediment yields on steep slope areas.

The USLE will give an estimate of the average annual soil loss for the reclamation phase of the mining operation. The soil loss equation is

$A = R\ K\ (LS)\ C\ P$, where

A is the computed soil loss expressed in tons/acre/year.

R is the rainfall erosion index, a measure of the erosive force and intensity of a specific rainfall or the normal yearly rainfall for specific climatic regions.

K is the soil erodibility factor, a measure of the erosion potential for a specific soil type (series) based on inherent physical properties (particle size, organic matter, aggregate stability, permeability).

LS is a combination factor for the slope length and the slope gradient.

C is the cover factor, the ratio of soil loss from a field with specific cropping relative to that from the fallow condition on which the factor K is evaluated.

P is the erosion control practice factor, the ratio of soil loss under specified soil management practices.

Soils with a K value of 0.17 or less are generally considered slightly erodible; those with a K value between 0.17 and 0.45 are moderately erodible; and those with a K value of 0.45 or higher are highly erodible (**USDA, Natural Resources Conservation Service, 1972**). Soil erodibility is affected predominantly by the particle-size composition and structure of the soil; however, during intense rain storms, even soils with low erodibility factors on steep slopes may be affected by rill and gully erosion. Soils in disturbed areas can be more easily eroded regardless of the listed K value for the soil type because the structure has been changed (Wischmeier and Smith, 1965).

To establish successful vegetation, the soil loss rate must be minimized. Keeping the soil loss rate below 15 tons/acre (6.69 t/ha) for the first year after reclamation will, if surface water controls are included, allow the establishment of successful vegetation.

The USLE can be used to determine the effect of different controls on the expected soil loss rates. The local Natural Resources Conservation Service (NRCS) office (see appendix C) can be of assistance in providing additional ways to reduce soil loss and the proper factors to use for the USLE.

2.4 Erosion And Sedimentation Control Plan

(25 Pa. Code §§ 87.70, 87.106, 88.50, 89.21, 90.37, 90.106, 102.5, 102.12)

An erosion and sedimentation (E & S) control plan is required as part of the mining permit application. The proposed sediment control measures for mining and reclamation must meet the requirements of Chapter 102. The specific requirements of Chapter 102 are found in the **Erosion and Sediment Pollution Control Manual** (April 1990) published by the Division of Waterways, Wetlands and Erosion Control, Bureau of Water Quality Protection The erosion and sedimentation control plan serves as the operator's blueprint for installing sediment control measures. In the permit application, it is the means to demonstrate the adequacy of sediment control measures that will be implemented.

The E & S plan must cover all areas to be disturbed by the mining operation within the proposed permit area during all stages of mining and reclamation. The end product of reclamation is successful revegetation that stabilizes the area against erosion. The E & S plan should address the erosion and sediment control measures that will be used from initial disturbance of the area until successful revegetation is achieved. All areas that will be disturbed or affected by the operation, including haul roads, storage areas and support areas, must be part of the plan.

The E & S plan must consider the type, depth and aerial extent of the soils found in the permit area, including surface water control on the reclaimed site and its effect on downstream watercourses, streams, culverts and bridges. The soils information can be found in the County Soil Survey Report available from the Natural Resources Conservation Service District Office located in each county. The reports are a source of information that can be used to determine expected sediment yields.

The E & S plan shall contain a narrative describing the implementation of the plan, detailed design and construction plans, and specifications for each structure or facility used in the plan.

For mining activities, the E & S design plan must be prepared by, or under the direct supervision of a qualified registered professional engineer or qualified registered land surveyor.

The erosion and sedimentation control plan must not result in an adverse effect on downstream culverts and drainage channels. This is especially important if the erosion and sedimentation control facilities will divert drainage from one area to a different area, and cause existing culverts or channels to be overloaded. It is also important to document the condition and capacity of the existing drainage system before affecting a site so that it can be established after reclamation that mining did not have an adverse effect.

For any revisions to the original E&S plan, the revised pages of the mine permit application, including the narrative, must indicate the page number and date of revision. If revisions extend beyond limitations of the original page, the revision should bear the original page number and sequential letter of the alphabet.

2.5 Control Measures That Reduce Erosion And Sedimentation

Erosion control practices are designed to prevent the detachment of soil particles, whereas sediment control practices are used to prevent the detached particles from leaving the site and entering the receiving waterways. Erosion and sedimentation can be controlled at a mining operation by proper planning and the use of erosion and sedimentation controls. The following are required practices.

2.5.1 Limiting exposed area

Limit the affected area to what is needed for coal removal planned in the near future. Expose the area for the shortest period of time. Backfilling must be concurrent with mining, and the topsoil must be redistributed and seeded during the first favorable planting season. All these practices, besides reducing erosion and sedimentation, will reduce the amount of water to be pumped from the pit and treated, limit the amount of bond on the site and allow for a quicker release of the posted bond(s).

2.5.2 Surface water diversion

All surface water shall be diverted away from the active mining area.

2.5.3 Velocity control

All ditches and watercourses shall be designed to convey flows without deterioration of the channel. Ditches and watercourses shall be stabilized to withstand anticipated flow velocities. Flow velocities in watercourses leaving the completed mining area shall be less than those calculated to initiate or accelerate erosion or scour within the receiving watercourses.

2.5.4 Permanent stabilization

All slopes, watercourses or disturbed areas shall be permanently stabilized as soon as possible after the final grade or final earth moving has been completed.

2.5.5 Interim stabilization

Until a disturbed area is permanently stabilized, the erosion and sediment pollution control measures and control facilities shall be maintained, or interim stabilization measures shall be installed, to minimize accelerated erosion and prevent sediment pollution.

2.5.6 Collection of runoff

Runoff from an earth disturbance area shall be conveyed to control measures or control facilities for removal of sediment.

2.5.7 Sediment pollution control

Runoff from the earth disturbance area shall pass through a control measure or control facility to prevent sediment pollution, including, but not limited to, sediment basins, sediment traps, filter areas and onsite erosion controls.

2.5.8 Incorporate erosion control practices as a first line of defense

The less erosion that occurs, the less sediment that will have to be handled by the sediment controls. Upslope and highwall diversion ditches divert additional runoff away from the disturbed area. On-site interceptor ditches reduce overland flow paths and carry water from the site in a non-erosive manner.

2.5.9 Perimeter Controls

Sediment controls are installed along the perimeter to prevent the sediment from leaving the site. These controls must be installed before disturbing the area. The controls must be maintained to ensure that they function properly.

2.6 Submittal Of General Erosion And Sedimentation Control Plans

(25 Pa. Code § 87.70, 87.106, 88.50, 89.21, 90.37, 90.106, 102.5, 102.12)

If the mine will be developed in separate phases over a period of time, the submittal of a general E & S plan for the entire operation and detailed plans for the initial mining phases may be used. This procedure reduces the amount of time spent designing and reviewing later stage plans which are likely to change. Prior to affecting any of the subsequent phases covered by the general E & S plan, a detailed E & S plan for that area must be approved by the Department. The detailed E & S plan must be provided to the Department prior to the request for approval of the bond increment.

The general plan must indicate the approximate location of the proposed E&S control measures and any point source discharges. The location for all proposed impoundments and discharge points, diversion and collection ditches, and haul roads must be shown on the operations map. Specific design details must be provided for those facilities to be utilized in the initial phase. When submitting subsequent detailed E & S plans for later phases, sufficient lead time must be allowed for plan approval. It should be pointed out that a major revision to the permit, such as discharging to a different watershed that was not included in the original plan, will require a permit revision and public notice of the change in accordance with 25 Pa. Code § 86.54.

2.7 Hydrology

(25 Pa. Code §§ 87.101, 88.41, 88.186, 88.291, 89.52, 90.101)

Hydrology is utilized to determine expected peak discharges and runoff volumes for different frequency storm events. This information is required to design ditches, impoundments, stream relocations, or stream crossings.

The Natural Resources Conservation Service (NRCS) has developed procedures for determining both the volume of runoff and peak rates of runoff for small watersheds across the United States. The NRCS hydrology methods are easy to apply and are the most common hydrology methods used on mining permit applications. These methods are based on anticipated rainfall amounts for various frequency 24-hour rainfall events and data collected for different soils and types of cover which is represented as a curve number. A simplified procedure is found in Chapter 2 of the NRCS **Engineering Field Manual**. A slightly more involved procedure is utilized in the NRCS **Urban Hydrology for Small Watersheds - Technical Release No. 55**. The publications differ only in the assumptions used in obtaining the time of concentration. The majority of all of the Department's requirements are based on 24-hour rainfall events. The Bureau of Mining Programs accepts and recommends the use of the NRCS hydrology methods for permit applications. The rainfall amounts listed in the regulations for each county were taken from US Weather Bureau data. Various frequency 24-hour rainfalls for counties with coal mining are shown below (Table 2-1).

The Division of Dam Safety, Bureau of Waterways Engineering and Wetlands and Wetlands published a report titled **Rainfall Duration Frequency Tables for Pennsylvania** in 1983. Techniques are presented for quick and accurate estimates of the mean annual 5, 10, 25, 50 and 100-year rainfall amounts for any location in Pennsylvania for both one-hour and twenty-four hour durations. Techniques are also presented to compute rainfall depths for shorter durations of 5, 10, 15 and 30 minutes and rainfall intensities for the desired duration. This publication is available by contacting the Division of Dam Safety, Bureau of Waterways Engineering and Wetlands and Wetlands (See Appendix C).

2.8 Upslope And Highwall Diversion Ditches

(25 Pa. Code §§ 87.105, 88.95, 89.23, 90.104, 102.12)

Surface water and shallow groundwater from upslope undisturbed areas that would drain across the mining area and into the affected area or pit must be intercepted and directed away from the disturbed area. This is done by the use of upslope diversion ditches. Upslope diversion ditches not only minimize the amount of water that contributes to the erosion and sedimentation process, but also minimize the amount of water that must be routed to a sedimentation pond. Highwall diversion ditches should be constructed immediately above all highwalls so as to minimize the volume of water that could be contaminated in the pit and would need to be pumped to the treatment facilities. In some cases the same ditch can serve both purposes.

Table 2-1: Twenty-Four Hour Rainfall Data

County	1 Year		2 Year		5 Year		10 Year		25 Year		50 Year		100 Year	
	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
Allegheny	2.3	58.4	2.6	66.0	3.3	83.8	3.9	99.1	4.4	111.8	4.9	124.5	5.2	132.1
Armstrong	2.3	58.4	2.6	66.0	3.3	83.8	3.9	99.1	4.4	111.8	4.9	124.5	5.2	132.1
Beaver	2.3	58.4	2.6	66.0	3.2	81.3	3.8	96.5	4.3	109.2	4.7	119.4	4.9	124.5
Bedford	2.4	61.0	2.8	71.1	3.6	91.4	4.5	114.3	4.9	124.5	5.5	139.7	6.0	152.4
Blair	2.4	61.0	2.8	71.1	3.6	91.4	4.3	109.2	4.8	121.9	5.3	134.6	5.8	147.3
Bradford	2.3	58.4	2.8	71.1	3.6	91.4	4.2	106.7	4.9	124.5	5.4	137.2	5.8	147.3
Butler	2.3	58.4	2.6	66.0	3.3	83.8	3.8	96.5	4.3	109.2	4.8	121.9	5.0	127.0
Cambria	2.4	61.0	2.8	71.1	3.4	86.4	4.2	106.7	4.8	121.9	5.2	132.1	5.7	144.8
Cameron	2.3	58.4	2.7	68.6	3.4	86.4	4.0	101.6	4.5	114.3	5.0	127.0	5.4	137.2
Carbon	2.5	63.5	3.0	76.2	4.0	101.6	4.8	121.9	5.3	134.6	6.0	152.4	6.7	170.2
Centre	2.3	58.4	2.8	71.1	3.6	91.4	4.3	109.2	4.8	121.9	5.4	137.2	5.8	147.3
Clarion	2.2	55.9	2.6	66.0	3.3	83.8	3.7	94.0	4.4	111.8	4.8	121.9	5.1	129.5
Clearfield	2.3	58.4	2.7	68.6	3.5	88.9	4.0	101.6	4.6	116.8	5.1	129.5	5.5	139.7
Clinton	2.3	58.4	2.8	71.1	3.6	91.4	4.2	106.7	4.8	121.9	5.3	134.6	5.7	144.8
Columbia	2.4	61.0	2.9	73.7	3.7	94.0	4.6	116.8	5.1	129.5	5.7	144.8	6.2	157.5
Crawford	2.2	55.9	2.5	63.5	3.1	78.7	3.6	91.4	4.2	106.7	4.7	119.4	4.8	121.9
Dauphin	2.5	63.5	2.9	73.7	3.9	99.1	4.8	121.9	5.2	132.1	5.9	149.9	6.5	165.1
Elk	2.3	58.4	2.7	68.6	3.4	86.4	3.9	99.1	4.5	114.3	4.9	124.5	5.3	134.6
Fayette	2.4	61.0	2.7	68.6	3.4	86.4	4.1	104.1	4.6	116.8	5.1	129.5	5.6	142.2
Forest	2.2	55.9	2.6	66.0	3.3	83.8	3.8	96.5	4.3	109.2	4.8	121.9	5.1	129.5
Franklin	2.4	61.0	2.9	73.7	3.8	96.5	4.8	121.9	5.1	129.5	5.9	149.9	6.4	162.6
Fulton	2.4	61.0	2.8	71.1	3.7	94.0	4.6	116.8	4.9	124.5	5.6	142.2	6.2	157.5
Greene	2.3	58.4	2.6	66.0	3.4	86.4	3.9	99.1	4.4	111.8	4.9	124.5	5.2	132.1
Huntington	2.4	61.0	2.8	71.1	3.7	94.0	4.6	116.8	4.9	124.5	5.5	139.7	5.9	149.9
Indiana	2.3	58.4	2.7	68.6	3.4	86.4	4.0	101.6	4.5	114.3	5.0	127.0	5.4	137.2
Jefferson	2.3	58.4	2.6	66.0	3.4	86.4	3.9	99.1	4.5	114.3	4.9	124.5	5.3	134.6
Lackawanna	2.4	61.0	2.9	73.7	3.9	99.1	4.7	119.4	5.2	132.1	5.8	147.3	6.5	165.1
Lawrence	2.2	55.9	2.5	63.5	3.2	81.3	3.7	94.0	4.2	106.7	4.7	119.4	4.8	121.9
Lebanon	2.5	63.5	3.0	76.2	4.0	101.6	4.8	121.9	5.3	134.6	6.0	152.4	6.7	170.2
Luzerne	2.4	61.0	2.9	73.7	3.9	99.1	4.7	119.4	5.2	132.1	5.8	147.3	6.4	162.6
Lycoming	2.4	61.0	2.8	71.1	3.6	91.4	4.3	109.2	4.9	124.5	5.5	139.7	5.9	149.9
McKean	2.2	55.9	2.6	66.0	3.3	83.8	3.9	99.1	4.4	111.8	4.8	121.9	5.2	132.1
Mercer	2.2	55.9	2.5	63.5	3.2	81.3	3.7	94.0	4.2	106.7	4.7	119.4	4.8	121.9
Northumberland	2.4	61.0	2.9	73.7	3.8	96.5	4.6	116.8	5.0	127.0	5.7	144.8	6.3	160.0
Potter	2.3	58.4	2.7	68.6	3.4	86.4	4.0	101.6	4.6	116.8	5.0	127.0	5.4	137.2
Schuylkill	2.5	63.5	3.0	76.2	3.9	99.1	4.7	119.4	5.3	134.6	5.9	149.9	6.5	165.1
Somerset	2.4	61.0	2.6	66.0	3.5	88.9	4.3	109.2	4.8	121.9	5.3	134.6	5.8	147.3
Sullivan	2.4	61.0	2.8	71.1	3.7	94.0	4.4	111.8	4.9	124.5	5.5	139.7	6.0	152.4
Tioga	2.3	58.4	2.7	68.6	3.5	88.9	4.2	106.7	4.7	119.4	5.1	129.5	5.6	142.2
Venango	2.2	55.9	2.5	63.5	3.3	83.8	3.7	94.0	4.2	106.7	4.7	119.4	4.9	124.5
Warren	2.2	55.9	2.5	63.5	3.2	81.3	3.8	96.5	4.3	109.2	4.8	121.9	4.9	124.5
Washington	2.3	58.4	2.6	66.0	3.3	83.8	3.9	99.1	4.4	111.8	4.9	124.5	5.2	132.1
Westmoreland	2.3	58.4	2.7	68.6	3.4	86.4	4.0	101.6	4.6	116.8	5.0	127.0	5.4	137.2

Source - NRCS Engineering Field Manual, Pennsylvania Supplement, pages 2-50.01-2-50.03; US Weather Bureau Technical Paper 40, Department of Commerce, Hershfield, D.M., 1961.

2.8.1 Design Considerations

1. The diversion ditch should be located as close as possible upslope from the disturbed area and is to extend the entire length of the disturbed area. The diversion ditch must provide positive drainage over the entire length of the disturbed area and the outlet of the diversion must be discharged in a manner that will not cause erosion. Diversion ditches that exit above previously mined areas should be continued across the mined area. The outlet for diversion ditches should be a rock-lined energy dissipater, a level spreader, or a stable existing drainageway.

2. Diversion ditches are generally triangular, trapezoidal or parabolic in cross section. Excavated material should be placed downslope of the diversion to provide additional freeboard against overtopping. The appropriate Manning's "n" value should be used for the different ditch linings. Runoff from small areas can be discharged by the use of an energy dissipater / level spreader, which spreads the concentrated ditch flow into sheet flow. An energy dissipater / level spreader should not be used when the flow would outlet onto a disturbed area.

3. The mining regulations require temporary diversion ditches (e.g., highwall diversion ditches) to have sufficient capacity to pass the 2-year, 24-hour storm event. Permanent diversion ditches (upslope diversion ditches) must have sufficient capacity for the runoff from the 10-year, 24-hour storm event. The design freeboard should be a minimum of 0.50 ft (0.15 m). Temporary diversions ditches are used during coal mining activities and not approved by the Department to remain after reclamation as part of the approved postmining land use. Permanent diversion ditches are designed to remain in place for years after surface coal mining activities are completed.

4. As the total length of a diversion ditch and the area draining to it increases the potential for breakouts and accelerated erosion increases. To ensure proper construction, diversion ditches should be surveyed and staked in the field prior to construction. The minimum preferred slope for a diversion ditch is from 1% to 2% to allow ease of construction in the field.

5. The diversion ditch must be capable of conveying the peak runoff at non-erosive velocities. When the diversion ditch slope varies or the discharge changes significantly, each segment of the ditch must be designed to meet those conditions.

   For design velocities above 4.50 ft/sec (1.37 m/sec), a synthetic or rock lining is required. The National Crushed Stone Association has published a reference titled **Quarried Stone For Erosion and Sediment Control**. This reference can be used to size riprap when a rock-lined channel is required. The permit application should indicate the size of stone to be utilized and the installation thickness. When indicating a stone size, designate the D_{50} size. The D_{50} size indicates that 50% of the rock is larger than the stated size and 50% is smaller. Only durable, non-toxic, non-acid forming stone is to be used. This eliminates the use of most types of shale.

2.9 Collection Ditches

(25 Pa. Code §§ 89.55, 102.13)

Collection ditches are used to route flow to the erosion and sedimentation impoundment. They are located around the periphery of the mining operation and prevent untreated runoff from leaving the site.

2.9.1 Design Considerations

1. The collection ditch is located downslope from the disturbed area and is to extend the entire length of the disturbed area. The ditch must provide positive drainage and outlet to a sedimentation impoundment.

2. The collection ditch must have sufficient capacity to pass the 10-year 24-hour storm event. Freeboard is to be a minimum of 0.50ft (0.15 m)

3. As the total length of a collection ditch and the area draining to it increases, the potential for breakouts and accelerated erosion increases. To ensure proper construction, collection ditches should be surveyed and staked in the field prior to construction. The minimum preferred slope for a collection ditch is from 1% to 2% to allow ease of construction and maintenance in the field.

4. The collection ditch must be capable of conveying the peak runoff at non-erosive velocities. When the collection ditch slope varies or the discharge changes significantly, each segment of the ditch must be designed to meet those conditions. The National Crushed Stone Association has published a reference titled **Quarried Stone For Erosion and Sediment Control** that can be used to help size riprap. The address of the National Crushed Stone Association is found in the reference section of this manual. The permit application should indicate the size of stone to be utilized and the installation thickness. If a percentage by weight or size is utilized it should be the D_{50} size. For velocities above 4.5 ft/sec (1.37 m/sec), a synthetic or riprap lining is required.

5. Whenever possible, a vegetated area should be left between the lower limit of mining area and the ditch construction area. This area slows down the flow prior to entering the ditch and allows sediment to filter out.

2.10 Vegetated Lining Waterways

Due to their ease of construction and low cost, vegetated lining waterways are frequently used on diversion and collection ditches. Chapter 7 of the **NRCS Engineering Field Manual** recommends the following maximum permissible velocities for individual site conditions.

1. A velocity of 3.00 ft/sec (0.91 m/sec) should be the maximum if, because of shale, soils, or climate, only a sparse cover can be established or maintained.

2. A velocity of 3.00 to 4.00 ft/sec (0.91 to 1.22 m/sec) can be used under normal conditions if the vegetation is to be established by seeding.

3. A velocity of 4.00 to 5.00 ft/sec (1.22 to 1.52 m/sec) should be used only in areas where a dense, vigorous sod is obtained quickly or if runoff can diverted out of the waterway while the vegetation is being established.

The Department recommends that vegetated lining ditches be limited to velocities of 4.50 ft/sec (1.37 m/sec). The Department will not accept design velocities above 4.50 ft/sec (1.37 m/sec). unless documentation is provided that runoff will be diverted out of the ditch while vegetation is established.

Vegetated lining waterways typically begin eroding in the invert of the channel. Once the erosion process has started, it will continue until an erosion resistant layer is encountered. If erosion of a channel bottom is occurring, rock or stone should be placed in the eroded area.

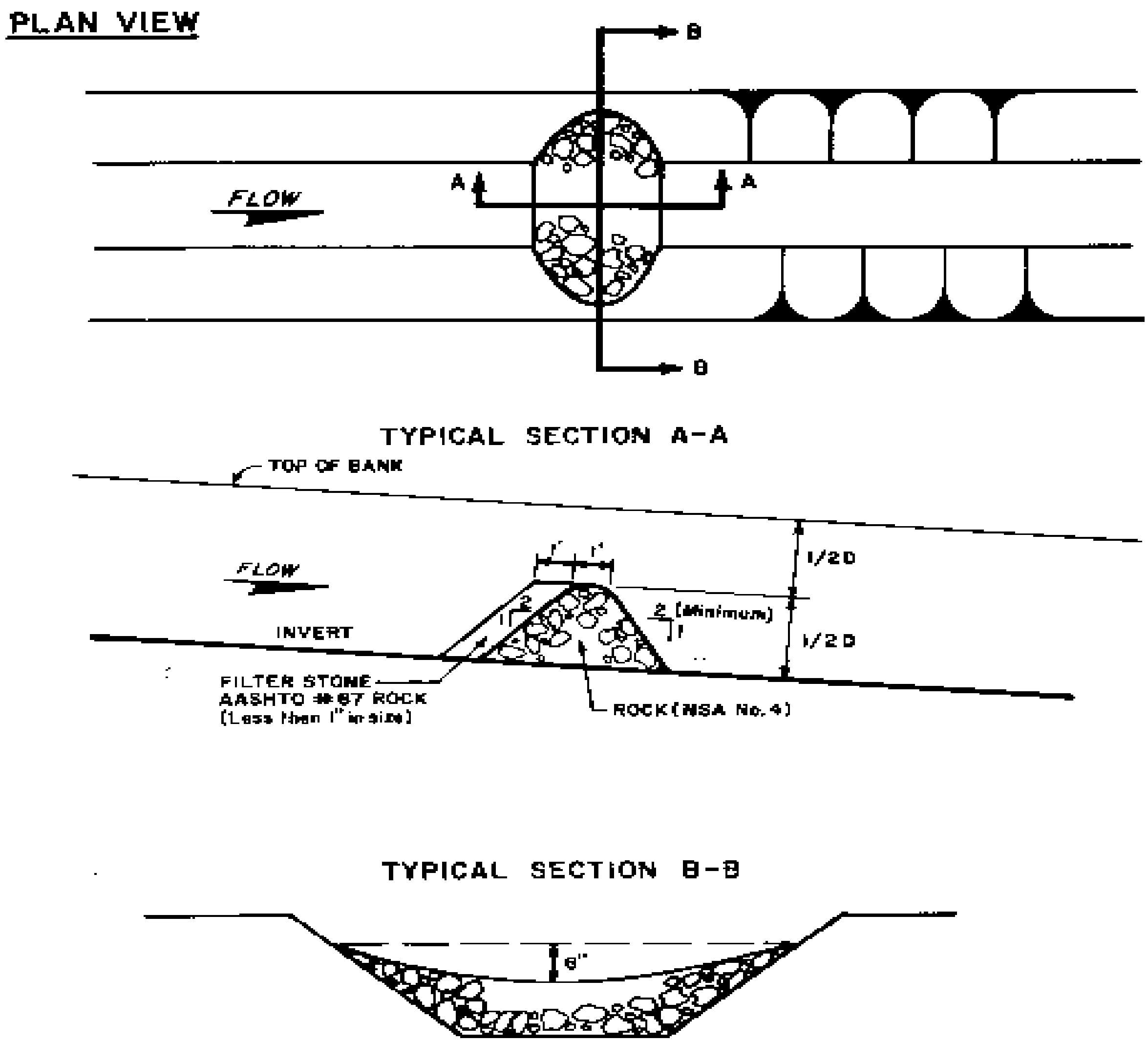
2.11 Rock Check Dams

Rock Check Dams can be constructed across collection or diversion ditches. Their purpose is to reduce the velocity of runoff in the ditch, thereby reducing erosion of the ditch. The distance between rock check dams will vary depending on the slope of the ditch, with closer spacing when the slope is steeper. The size stone used in the check dam should also vary with the expected design velocity and discharge. As velocity and discharge increase, the rock size should also increase. For most rock check dams, the National Crushed Stone Association No. R-4 stone (3 in to 12 in [7.62 to 30.46 cm], average 6 in [15.24 cm]) is a suitable stone size. To improve the sediment trapping efficiency of check dams, a filter stone can be applied to the upstream face. A well-graded coarse aggregate such as AASHTO No. 67 (less than 1 inch [2.54 cm] in size) can be used as a filter stone. The design of a rock check dam is illustrated in Figure 2-1.

Sediment that accumulates behind the check dam should be removed when it has accumulated to one-half of the original height of the dam.

Figure 2-1: Rock Check Dam

Rock Check Dam



Adapted from Erosion and Sediment Pollution Control Manual (1990)

2.12 Rock Lining Channels

When the velocity and frequency of flow increase to a point that a vegetated lining is no longer adequate, other measures such as laid sod, jute matting, and rock linings are typically used for diversion and collection ditches. All linings should be designed according to manufacturers' specifications or design standards such as those contained in the Federal Highway Administration's **Design of Roadside Channels with Flexible Linings**. The National Crushed Stone Association has a reference document titled **Quarried Stone For Erosion and Sediment Control** that contains the following design standards. This document also contains information on the sizing of filter stone. Information on the availability of these two publications is located in the reference section of this manual. The use of filter stone or a synthetic filter cloth will improve the stability of the installation. Table 2-2 shows the NSA specifications and the maximum water velocity for which the different stone sizes will be effective lining for diversion and collection ditches. Rock-lined channels are designed using the wetted perimeter, as illustrated in Figure 2-2.

Table 2-2: Graded Riprap Stone

	Maximum velocity		**Stone size**					
NSA No.	**(ft/sec)**	**(m/sec)**	**Max. (in)**	**Max. (cm)**	**Avg. (in)**	**Avg. (cm)**	**Min. (in)**	**Min. (cm)**
R-2	4.5	1.37	3	7.6	1.5	3.8	1	2.5
R-3	6.5	1.98	6	15.2	3	7.6	2	5.0
R-4	9.0	2.74	12	30.5	6	15.2	3	7.6
R-5	11.5	3.51	18	45.7	9	22.9	5	12.7
R-6	13.0	3.96	24	61.0	12	30.5	7	17.8

2.12.1 Other erosion and sedimentation controls

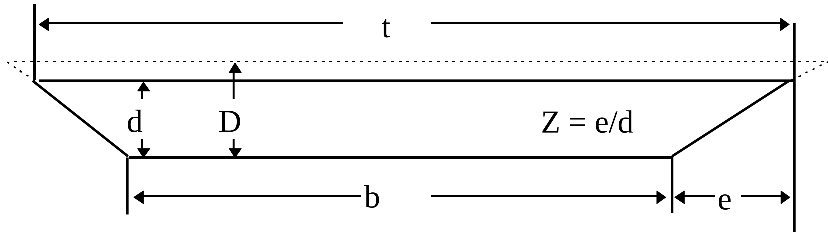
(25 Pa. Code §§ 87.108, 88.98, 102, and Erosion and Sediment Pollution Control Program Manual)

The Department has found that ditches and ponds are the most effective E & S control measures from both a cost and a functionality basis. The maintenance costs associated with ditches and impoundments are minimal, and the measures allow discharges to meet effluent standards.

The Department realizes that typical erosion controls are not always feasible to construct and other types of controls can provide an effective means of controlling erosion and sedimentation. The Department will consider the use of alternative E & S controls when there is a justification that construction of typical erosion and sedimentation controls is not feasible and/or the drainage area is ≤ 5 Ac (2.02 ha) and that the required effluent standards can be met with the proposed

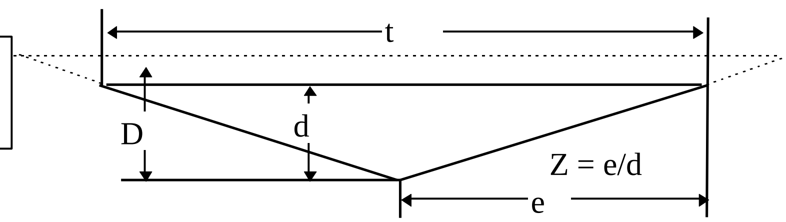
Figure 2-2: Channel Cross-Sectional Areas and Wetted Perimeters

Trapezoidal Cross - Section



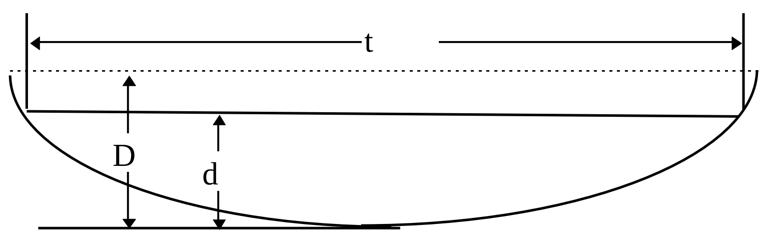
Cross-Sectional Area, a	Wetted Perimeter, P	Hydraulic Radius R = a/P	Top Width t
$Bd + Zd^2$	$B + 2d\sqrt{(Z2 + 1)}$ or $b + 2dZ$ approx.	$\frac{(bd + Zd^2)}{b + 2d\sqrt{(Z^2 + 1)}}$	$t = b + 2dZ$

Triangular Cross - Section



Cross-Sectional Area, a	Wetted Perimeter, P	Hydraulic Radius R = a/P	Top Width t
Zd^2	$2d\sqrt{(Z^2 + 1)}$ or $2dZ$ approx.	$\frac{Zd}{2d\sqrt{(Z^2 + 1)}}$ or approx. $d/2$	$t = 2dZ$

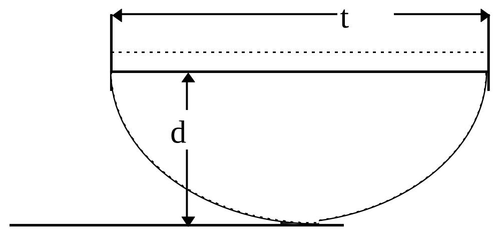
Parabolic Cross - Section



Cross-Sectional Area, a	Wetted Perimeter, P	Hydraulic Radius R = a/P	Top Width t
$(2/3)td$	$t + (8d^2)/(3t)$	$\frac{t^2d}{1.5t^2 + 4d^2}$ or approx. $2d/3$	$t = a/(0.67d)$

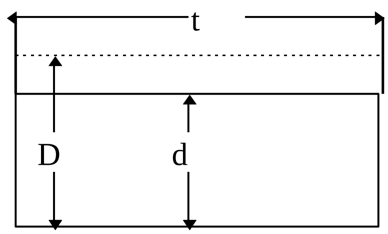
(Fig. 2-2 continued)

Semi-circular Cross - Section



Cross-Sectional Area, a	Wetted Perimeter, P	Hydraulic Radius R = a/P	Top Width t
$\pi d^2/2$	πd	d/2	t = 2d

Rectangular Cross - Section



Cross-Sectional Area, a	Wetted Perimeter, P	Hydraulic Radius R = a/P	Top Width t
dt	2d + t	(dt)/(2d + t)	t = t

controls. Examples of alternate E&S controls include filter fences, straw bale barriers and sediment traps.

When a situation arises for the potential use of alternate E & S controls, the appropriate District Mining Operations office should be consulted.

If the E & S controls are not maintained properly or are unsuccessful in controlling runoff, the Department will require the submission of a revised E & S plan to correct the problem.

2.12.2 Filter fabric fence

When used properly, a filter fabric fence can be a moderately effective erosion and sedimentation control. A filter fabric fence is illustrated in Figure 2-3. Examples of potential uses of filter fabric fence include short-term use during construction or reclamation of E & S or treatment facilities, stream crossings, stream encroachments, haul roads and as a control for small drainage areas. Filter fabric fence is frequently installed in inappropriate situations, not installed properly and not given adequate maintenance. Common problems include: placing filter fabric fence in areas of concentrated flows, and/or steep slopes and placing fence down the contours rather than along the contours.

When it is not feasible to construct typical E & S controls and filter fabric fence is used, the Department recommends the following:

1. The fence is placed at 0% grade; i.e., parallel to the contours, and follows a level alignment.

2. The filter fabric fence shall be designed to control runoff from drainage areas that do not exceed the maximum slope length to percent slope relationships shown in Table 2-3:

Table 2-3: Maximum Lengths for Filter Fabric Fences

Percent Slope	Maximum Slope Length	
	(ft)	(m)
2	500	152.4
5	250	76.2
10	200	61.0
15	135	41.1
20	100	30.5
25	80	24.4
30	65	19.8
35	60	18.3
40	50	15.2
45	45	13.7
50	40	12.2

3. The installation should be constructed in undisturbed ground. Severely disturbed or mined soils are typically too rocky and erodible to obtain a good tie-in of the bottom of the silt fence. When slope lengths are too long for one filter fabric fence installation, a second installation should not be installed in the backfilled area. In this case, more typical E & S measures should be used.

4. The tie-in at the bottom of the filter fabric fence is very important in preventing piping or blowouts of the installation. The bottom of the fence should not only be buried, but the filter cloth should be laid across the bottom of the trench to reduce piping underneath the trench and to prevent the fence from being pulled out of the ground. The bottom of the filter is "L" shaped when properly installed.

5. The excavation for the fence should not disturb any more soil area than is necessary. A small plow works well in constructing the trench. An additional advantage of using a plow is that the sod can be placed back with most of the vegetation intact.

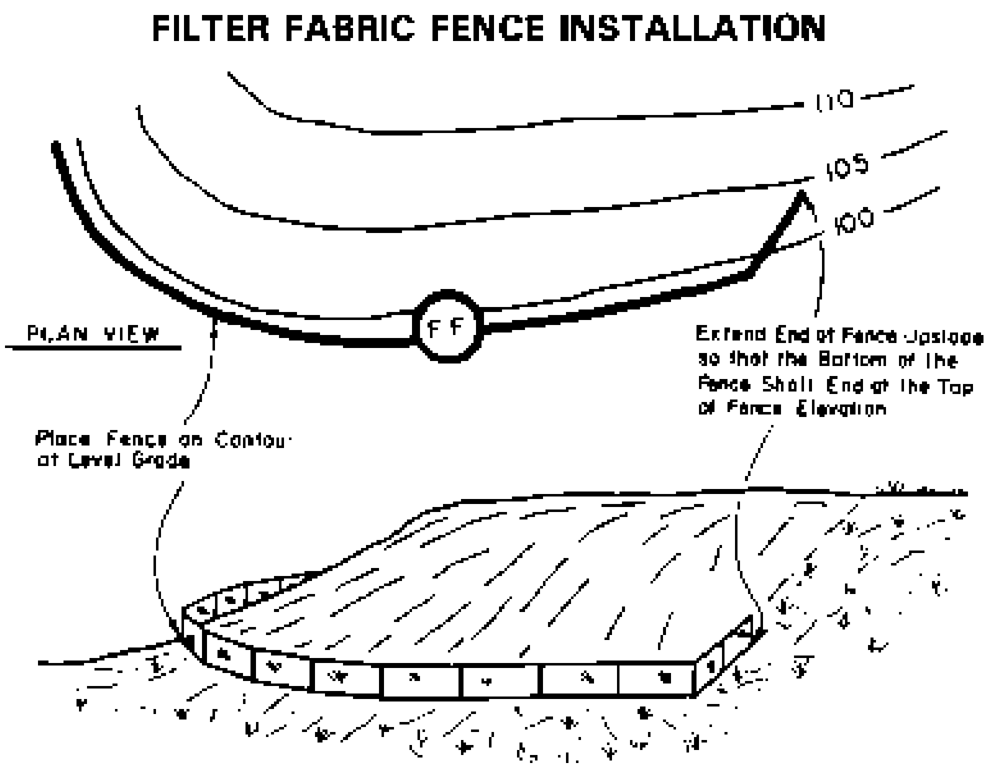
6. The disturbed area should have a temporary seed mix planted immediately after the fence is installed. This is very important in preventing washing or piping problems.

7. Pennsylvania's weather places additional burdens on silt fence installations. Wind and snow loads can have a significant effect on filter fence installations. Wind and snow can tear the filter cloth from its supports or create bows in the fence which will fail with a sediment and water load. Several manufacturers specify an 8 ft (2.44 m) post spacing. This is too long for a installation expected to last more than a single construction season. It is recommended that a 4 - 5 ft (1.22 - 1.52 m) post spacing be utilized. The posts should be a durable and large head nails should be utilized to fasten the fence to the posts.

8. The fence perimeter should be walked on a periodic basis, at least weekly and after every significant runoff event, to look for problem areas. It may be necessary to regrade eroded areas, remove accumulated sediment or repair the fence to maintain the effectiveness of the installation.

For further information on filter fabric fence, see the **Erosion and Sediment Pollution Control Program Manual**, published by the Division of Waterways, Wetlands, and Erosion Control, Bureau of Water Quality Protection.

Figure 2-3 : Filter Fabric Fence Installation



2.12.3 Filter Fabric Fence Placed Nonparallel To the Contours

Filter fabric fence works best when placed on 0% slope. When placed on a slope, the fence concentrates runoff, resulting in erosion along the toe of the fence and failure of the fence. Placing filter fabric fence at 0% slope is not always possible due to existing spoil, stream setbacks, highways or other barriers. When filter fabric fence is placed on a slope, something must be done to reduce and control the concentration of flow. This can be done by breaking the length of the installation into separate sections that will not allow a significant concentration of flow. A sediment trap is constructed at the downslope end of the fence by making a 90^{o} bend with the fence.

1. Sections of fence should be limited to maximum lengths of 30 ft (9.14 m).

2. Hay bales can be utilized to provide additional support and sediment trapping. The hay bales are to be staked on the downslope side of the silt fence. Downslope hay bales are required in the hook area of the silt fence

3. Filter fabric fence installations should be constructed with an upslope and preferably also a downslope vegetated filter strip as part of the construction. This reduces the volume of sediment and runoff that the fence must handle, and breaks up the flow before reaching the fence and increases the trapping efficiency of the installation.

4. The fence post spacing shall not exceed 5 ft (1.42 m). Posts shall be placed a minimum of 18 in (45.72 cm) into the ground.

5. Mulching shall take place immediately after topsoil placement.

2.13 Sediment Traps

Sediment traps are formed by constructing an earthen embankment across a ditch or swale. Sediment traps detain sediment-laden runoff from small disturbed areas to allow the majority of the sediment to settle out. A sediment trap is illustrated in Figure 2-4.

Sediment traps may be used to control runoff from haulroads and other support areas when the total drainage area is ≤5 ac (2.02 ha). Sediment controls for active mining areas must be designed to the normal sedimentation basin standards, requiring 7000 ft^3/acre (490 m^3/ha) total storage volume. Small areas usually contribute lesser amounts of sediment on a unit area basis than do larger areas. This is due to the decrease in the amount of gully and channel erosion that takes place on smaller areas. When a situation exists where sediment traps could be used, contact the appropriate District Mining Operations office.

Sediment traps should have a minimum length of 10 ft (3.05 m) and a minimum length-to-width ratio of 2:1. The traps must be sized at a minimum volume of 2000 cubic feet per contributory acre (140 m^3/ha) and be cleaned when the storage volume is reduced to below 1300 cubic feet per acre (91 m^3/ha). The trap must have a means to be dewatered. Sediment traps can outlet through a pipe or an overflow spillway section of the embankment. Sediment traps may be used along with normal ditches and basins. The use of sediment traps allows the E & S control to be located closer to the source. When sediment traps are utilized along with normal sedimentation basins, the capacity of a sediment trap can be used to offset the required capacity of a sedimentation pond.

The sediment trap must be part of an overall plan to control erosion and runoff on the site so that the trap is not overloaded. Measures such as mulching, and surfacing of haul roads should be part of the plan to use sediment traps.

For further information on the design of sediment traps, see pages 4.48-50 of the **Erosion and Sediment Pollution Control Program Manual**, published by the Division of Waterways, Wetlands, and Erosion Control, Bureau of Water Quality Protection.

2.14 Straw Bale Barrier

Straw or hay bale barriers can serve as an effective temporary (less than six months) erosion and sedimentation control. These are illustrated in Figure 2-5. They work best when used to control erosion and sedimentation during revegetation. Uses include construction or reclamation of E & S or treatment facilities, stream crossings, stream encroachments, and haul roads.

The following are requirements for the use of straw bales when a temporary control is needed.

1. The straw bale barrier must be placed at 0% grade. The ends of the barrier should be extended up the slope so that all runoff above the barrier will be contained in the barrier.

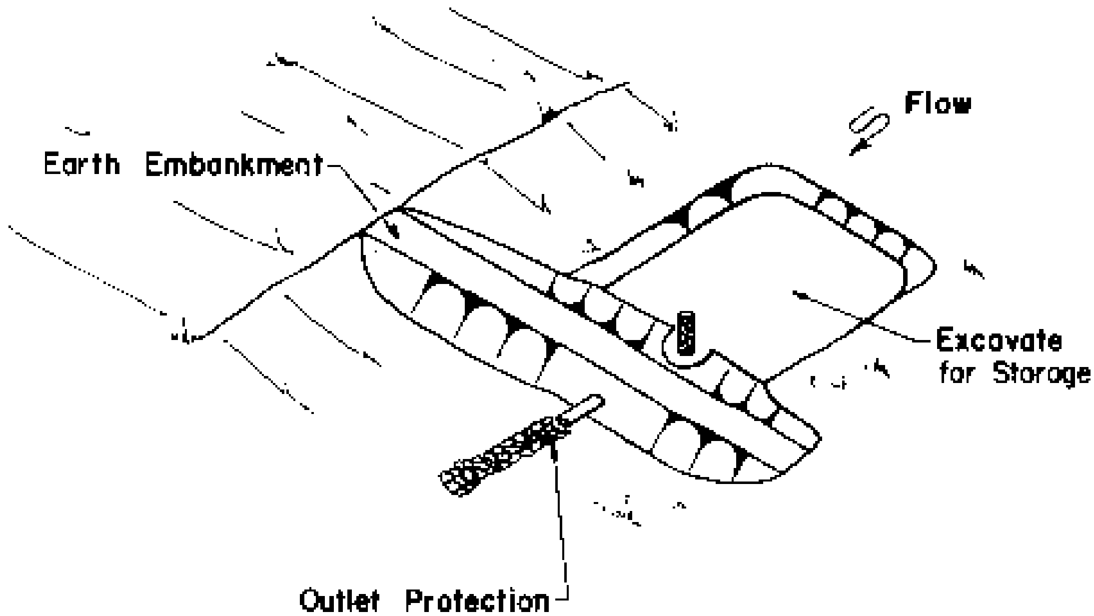
2. The straw bale barrier shall be designed to control runoff from drainage areas that do not exceed the maximum slope to slope length relationships shown in the following table from page 5-23 of the **Erosion and Sediment Pollution Control Manual** (Table 2-4):
3. The straw bale barrier must be constructed with an anchoring trench as shown in Figure 2-5. Support stakes must be used to anchor the bales.

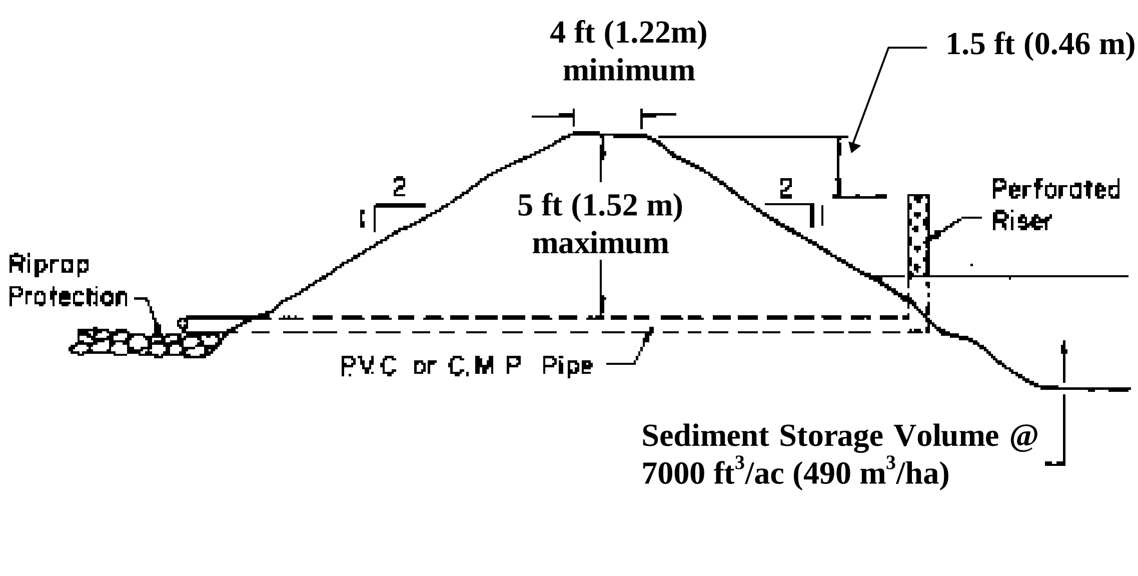
4. The straw bales may not be placed in an area where concentrated flows will develop.

5. The straw bale barriers may only be utilized in an area where permanent stabilization can be obtained in six months or less.

6. The length of the straw bale barrier should be walked on a periodic basis to look for problem areas. It may be necessary to regrade eroded areas, remove accumulated sediment or repair the barrier to maintain the effectiveness of the installation.

Figure 2-4: Sediment Trap



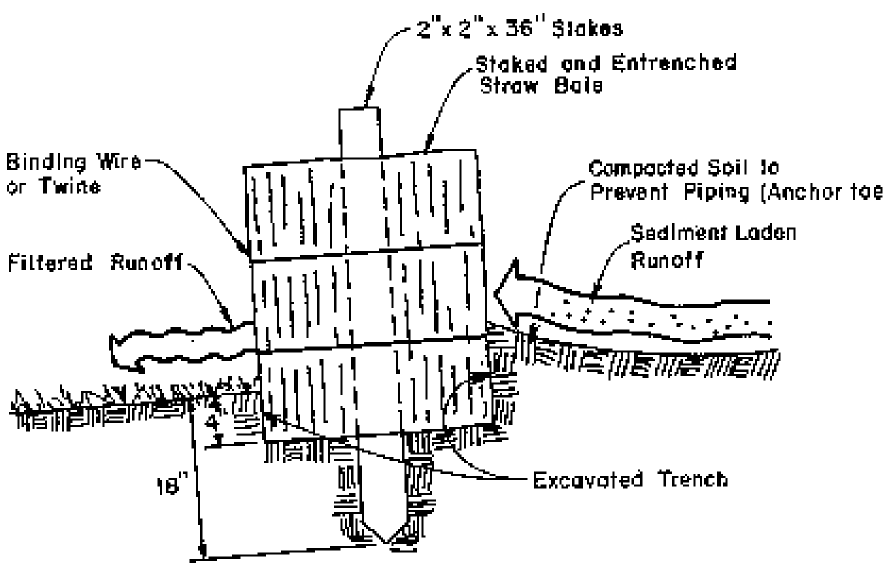


For additional information on straw bale barriers see pages 5-23 through 5-25 of **Erosion and Sediment Pollution Control Program Manual**, published by the Division of Waterways, Wetlands, and Erosion Control, Bureau of Water Quality Protection.

Table 2-4 : Maximum Slope Lengths for Straw Bale Barrier

Percent Slope	Maximum slope length above barrier	
	(ft)	(m)
2 or less	250	76.2
5	100	30.5
10	50	15.2
15	35	10.7
20	25	7.6
25	20	6.1
30	15	4.6
35	15	4.6
40	15	4.6
45	10	3.0
50	10	3.0

Figure 2-5:Cross-Section of Straw Bale Barrier



Adapted from: Michigan Soil Erosion and Sedimentation Control Guidebook (1975)

3. Sediment Control Impoundments And Coal Refuse Disposal Impoundments

3.1 Introduction

A sedimentation impoundment is a basin or pond used to provide detention time to allow for the settling of eroded particles before releasing water from the mine site. A sedimentation impoundment is illustrated in Figure 3-1. Sediment basins usually serve only during the life of the mining operation and the subsequent reclamation. The volume of the impoundment is determined according to the size of the disturbed land area (acres or hectares) draining to it.

The amount of sediment removed from the runoff is dependent upon the detention time, geometry of the impoundment and the size and weight of the sediment particles.

Coal refuse disposal impoundments are constructed for the permanent disposal of any coal, rock, shale and related materials associated with or near a coal seam which are either brought above ground or otherwise removed from a coal mine in the process of mining. Detailed plans are required for refuse impoundments.

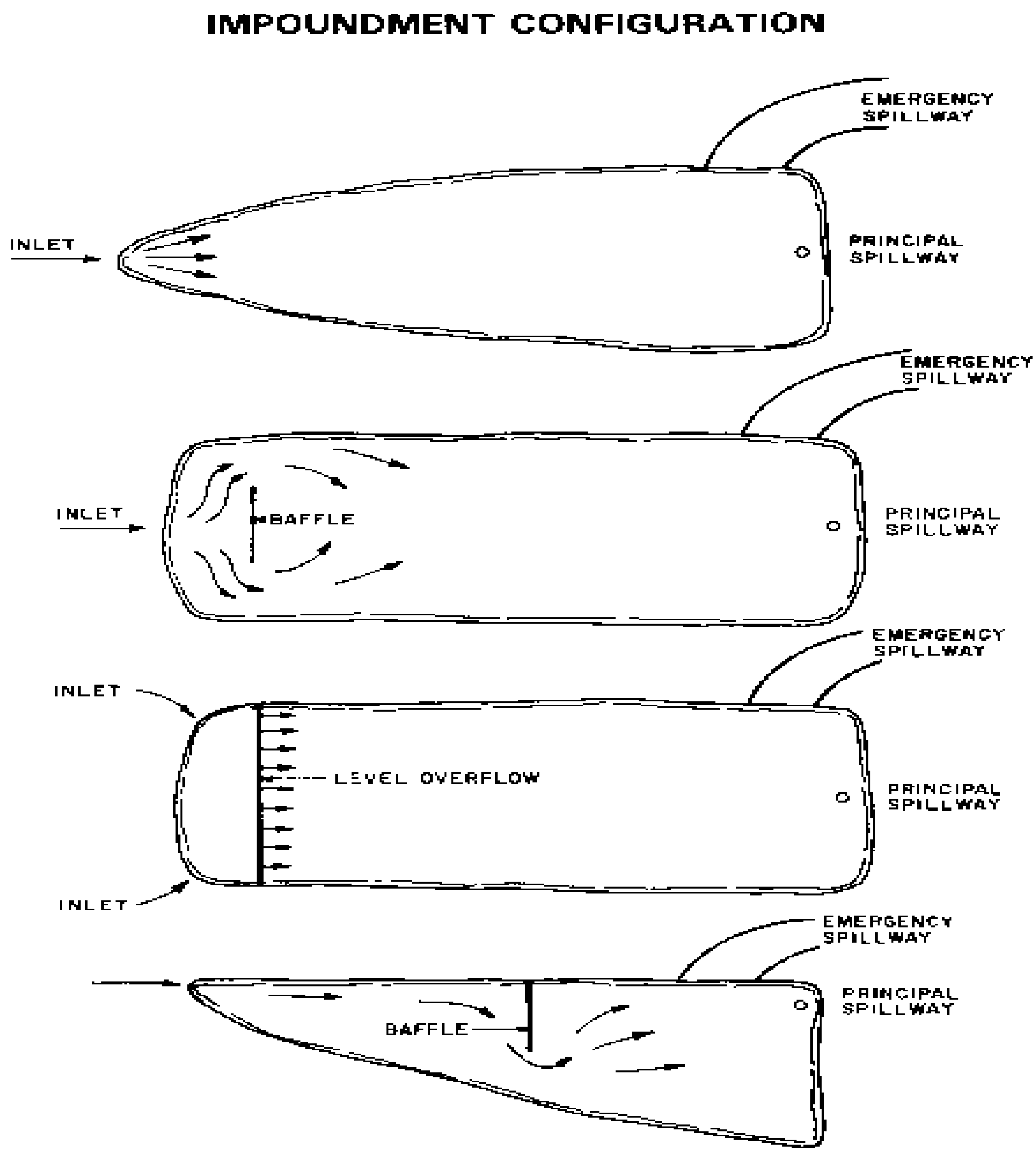
The overall size of any impoundment, taking into account the outside dimension of the embankment or cut slope, must be shown to scale on the operations map and the land use and reclamation map where appropriate. The inlet and outlet locations must also be shown on the maps. This includes the collection ditch outlets into the basin and the dewatering, principal spillway and emergency spillway outlets.

The mining regulations, Chapters 86-90, contain information on the required effluent quality and the rainfall events that apply to the different effluent standards. These regulations apply to all impoundments. The Erosion control regulations, Chapter 102, contain information on the required sediment and runoff storage capacity. Chapter 102 regulations apply to all E & S impoundments.

Chapter 105 regulations of the Division of Dam Safety, Bureau of Waterways Engineering and Wetlands apply to all impoundments over a certain size drainage area, impoundment capacity, or embankment height. The Chapter 105 regulations were enacted to protect the safety of the public. Chapter 105 regulations usually do not apply to the impoundments on most mine sites because of their small size.

The NRCS documents, **Sediment Basin 350** and **Pond 378**, apply to most impoundments. They contain the specific design requirements that control principal and emergency spillway design, embankment construction and pond configuration. Besides specific design criteria, **Sediment Basin 350** and **Pond 378** contain most of the requirements also found in Chapters 86-90, 102 and 105. In addition, for **Sediment Basin 350**, a static factor of safety of not less than 1.3 must be demonstrated.

Figure 3-1:Sediment Impoundment Configuration



While **Sediment Basin 350** and **Pond 378** apply to smaller low-hazard impoundments, NRCS **Earth Dams and Reservoirs, TR-60**, applies to high-hazard or larger impoundments. When **Earth Dams and Reservoirs** applies to a mining impoundment it is usually because the structure is located in an area where the effect of a failure on downstream property is a concern.

The federal Mine Safety and Health Administration (MSHA) is responsible for the safety of miners and the public. MSHA approval is required for impoundments over a certain size. Of particular concern to MSHA are coal waste or refuse impounding structures associated with coal preparation activities. Table 3-1 shows when different regulations or standards apply.

Table 3-1: Applicable Impoundment Regulations

Requirements	Situations Where Requirements Are Applicable
DEP Chapters 87-90	All impoundments
DEP Chapter 102	All erosion and sedimentation control (E&S) impoundments
DEP Chapter 105	Impoundments which meet any of the following: Maximum inside embankment height > 15 ft (4.57 m) Maximum storage > 50 ac ft (6.17 ha m) Maximum drainage area > 100 Ac (40.47 ha)
Review by Bureau of Waterways Engineering and Wetlands, Required.	All impoundments , Size Classification (SC) A, B, and C except for temporary SC C All impoundments, Hazard Potential Classification (HPC) 1, 2, and 3 except for temporary HPC 3
NRCS Sediment Basin 350	All temporary (< 5 years) E&S impoundments
NRCS Ponds 378	All impoundments, including permanent E&S impoundments
NRCS TR-60, Earth Dams and Reservoirs	Impoundments which meet any of the following: Maximum height > 35 ft (10.67 m) Storage (Ac ft) x height (ft) > 3000 ac ft; i.e., storage (ha m) x height (m) > 113; or All dams located in predominantly rural or agricultural areas where failure may damage isolated homes, main highways, or minor railroads or cause interruption of service for relatively important utilities
MSHA (Mine Safety and Health Administration)	Impoundments which meet any of the following: Maximum height > 20 ft (6.10 m) Maximum storage > 20 ac ft (2.47 ha m)

3.2 Chapter 105 Impoundments

(25 Pa. Code §§ 87.112, 88.102, 89.111, 90.112, 105.3)

A Dam Safety Permit is required for an impoundment if:

1. the contributory drainage area exceeds 100 acres (40 ha); or
2. the greatest depth of water measured by the upstream toe of the dam at maximum storage elevation (top of embankment) exceeds 15 feet (4.57 m); or
3. the impounding capacity at maximum storage exceeds 50 acre-feet (6.17 ha m; 61,674 m^3).

The District Mining Operations office will review the application, including processing of the additional permit fee, when the dam is classified as C-3 according to Chapter 105 criteria and the impoundment will be removed at the completion of the mining activity. For this class of impoundments, failure of the impoundment would not be expected to cause loss of life (no permanent structure for human habitation located downstream). In addition, a failure have minimal economic loss (undeveloped or occasional structures with no significant effect on public convenience downstream). Finally, this class of impoundments will not remain as permanent postmining structures.

When the mining permit includes a dam permit, the issued mining permit will have the permit face sheet checked for the Dam Safety and Encroachments Act and include any special conditions that apply to the additional activities.

If the impoundment does not have a hazard classification C-3 or is not temporary, the permit application for the impoundment will be forwarded to the Division of Dam Safety, Bureau of Waterways Engineering and Wetlands, along with comments from the District Mining Operations office, for review and processing. In these cases, the design and construction of the impoundment must comply with the NRCS document **Earth Dams and Reservoirs - Technical Release No. 60**, Revised October 1985. Impoundments that exceed the size requirements given above and that are to remain as permanent postmining impoundments, will also be forwarded to the Division of Dam Safety, Bureau of Waterways Engineering and Wetlands. If modifications to the impoundment can be achieved to reduce the size or drainage area to below the above standards, the Bureau of District Mining Operations will be the permitting agency.

3.3 Permanent Impoundments

(25 Pa. Code §§ 87.111, 88.101, 88.196, 88.301, 89.89, 90.111)

Impoundments constructed as part of the mining operation may be allowed as permanent postmining impoundments provided the following conditions are met.

1. The quality of the impounded water is suitable for the intended use and will meet the applicable 87.102, 88.92, 89.52, or 90.102 effluent standards. Examples of postmining uses include livestock management, fire protection, wildlife habitat, storm water management and recreation.

2. The constructed impoundment meets all Departmental design standards. Any proposed changes to the impoundment shall be included in the request. Proposed changes could include deletion of some of the drainage area to the impoundment, capping of the dewatering pipe and changing the principal or emergency spillway elevation or configuration.
3. The operator must provide the Department with a notarized letter from the landowner, consenting to and agreeing to maintain the impoundment after release of all bonds from the permit area. Until final Stage III bond release the operator is responsible for any maintenance that the impoundment requires.

Common uses for postmining impoundments include livestock watering, fish and wildlife habitat, or fire protection. In most cases, the dewatering pipe or valve will be capped or closed and the water elevation will be allowed to rise. As most postmining impoundments will have a permanent pool and consequently less storage volume to route the design storm, consideration should be given to reducing the drainage area to the impoundment. As in all cases the effect of postmining drainage on the existing drainage system should be considered. The local NRCS office can provide assistance in determining drainage areas and pond sizes necessary to fulfill a given function.

The Cooperative Extension Service of the Pennsylvania State University has published a document, **Fish Ponds, Construction and Management in Pennsylvania** which provides useful information on fish management. Information on obtaining this document can be found in the reference section of this manual. The Pennsylvania Fish and Boat Commission (PFBC) will answer questions concerning fish management and can provide a current list of commercial hatcheries. The addresses and telephone numbers for PFBC regional offices can be found in Appendix C.

The Department will field review all impoundments proposed to remain after mining and reclamation. Postmining impoundments that meet Chapter 105 criteria will be referred to the Division of Dam Safety, Bureau of Waterways Engineering and Wetlands for their approval, unless the impoundment or drainage area is modified such that the impoundment no longer meets Chapter 105 criteria.

3.4 Mine Safety And Health Administration Impoundments

(Title 30, Code of Federal Regulations, Sections 77.216-1 and 77.216-2, 25 Pa. Code §§ 87.112, 89.101 and 90.112)

The federal Mine Safety and Health Administration (MSHA) requires stringent design and construction standards for impoundments if the embankment, as measured from the upstream toe to top of embankment, is 20 ft (6.10 m) or more, or the total storage volume is 20 acre-feet (2.47 ha m; 24,670 m^3) or more, or the impoundment, as determined by the MSHA District Manager presents a hazard to coal miners.

All impoundments subject to these criteria as established in federal 30 CFR 77.216-1 and 77.216-2 shall have a duplicate set of the plans, with one set submitted to the district manager of the Mine Safety and Health Administration, and one set submitted to the Department. The Department will review plans for impoundments under the mining regulations; as part of its review, it will consider any review comments by MSHA.

MSHA has a reference **Design Guidelines for Coal Refuse Piles and Water, Sediment, or Slurry Impoundments and Impounding Structures** (published 1979 with a March 1983 addendum). Contact MSHA for current requirements for MSHA regulated impoundments. The addresses and phone numbers for MSHA offices are listed in Appendix C.

3.5 Pond Certification - Design

(25 Pa. Code §§ 87.73, 87.112, 89.101, 90.112)

When a permit under Chapter 105 is required, the detailed design plan for a structure shall be prepared by, or under the direction of, and certified by a qualified registered professional engineer. When a permit under Chapter 105 is not required, the detailed design plan shall be prepared by, or under the direction of, and certified by a qualified registered professional engineer or qualified registered land surveyor.

3.6 Pond Certification - Construction

(25 Pa. Code §§ 87.112, 89.101, 90.112)

Sedimentation basins and other impoundments must be constructed in accordance with the approved permit before any disturbance of the area to be drained into the impoundment. The impoundment must be inspected during construction and certified to the Department upon completion of construction by a registered professional engineer if:

1. It requires a Chapter 105 permit, or
2. The embankment, as measured from the upstream toe, is 20 ft (6.10 m) or more, or
3. The total storage volume is 20 acre-feet (2.47 ha m; 24,670 m^3)or more, or
4. The MSHA District Manager determines that it presents a hazard to coal miners.
   Impoundments that do not require a permit under Chapter 105 or do not meet or exceed MSHA requirements must be inspected by a registered professional engineer or a registered professional land surveyor. The impoundment certification form is contained in the permit application and is shown as Figure 3-2 for the reader’s reference. Additional copies are available from each District Mining Operations office. The Department will accept computer-generated reproductions of the form provided the reproduction accurately follows the original certification. When submitted as two separate sheets of paper, each page should identify the pond and be signed and dated. Each impoundment shall be certified that it is being or will be maintained as designed in the approved plan and in accordance with all applicable standards.

Figure 3-2: Impoundment Certification Form

ER-MR-311: Rev. 9/98

Commonwealth of Pennsylvania
Department of Environmental Protection
Bureau of Mining Programs

Permittee
Permit No.
Pond
Township
County
Engineer/Land Surveyor
Date

POND CERTIFICATION
INSTRUCTIONS

Complete first page and submit with permit application. Use both pages to certify completed impoundment. Sedimentation ponds and other impoundments must be constructed in accordance with the approved permit before any disturbance of the area to be drained into the pond. Impoundment must be inspected during construction under the supervision of, and certified to the Department upon completion of construction by a registered professional engineer. Any enlargement, reduction in size, reconstruction , or other modification, that may affect the stability or operation must be approved by the Department. Pond must be certified and approved prior to the start of any other mining activities. Unless otherwise specified in your permit, use this form for the sedimentation pond and other impoundment certification. Submit 1 original and 2 copies to the appropriate District Mining Office. All information must be provided, otherwise it will be returned for completion.

………………………………………………………………………………………………

U.S.G.S. Quadrangle _________________	Location (point of discharge):	Latitude __________________	Longitude ____________________
Location from Bottom Right corner of U.S.G.S. Quadrangle		________inches North	__________inches West
HYDROLOGY:	Drainage Area _________acres	Design Storm_______	Average Watershed Slope_______________
Land Use_______	Soil Type_____	Curve Number______	Peak Discharge_______

ER-MR-311:Rev. 9/98 (Fig. 3-2 continued)

Embankment	Permit Application	As Constructed
Top width (minimum)		
Outside Slope (Maximum)(___H:___V)		
Inside Slope (Maximum)		
Top Elevation		
Bottom Elevation		
Upstream Toe Elevation		
Downstream Toe Elevation		
Amount Allowed for Settlement		
Type of Cover		
Incised Slope (if any		
Inside Slope (Max.)(___H:___V)		
Top Elevation		
Bottom Elevation		

Principal Spillway	Permit Application	As Constructed
Type		
Conduit Diameter (if barrel/riser give both)		
Inlet Elevation		
Outlet Protection		
Spillway Capacity		

Dewatering Device	Permit Application	As Constructed
Type/Size		
Inlet Elevation		
Discharge Regulation (i.e., self draining or valved		
Discharge Capacity (cubic feet/second)		
Time to Dewater Full Pond		

Emergency Spillway	Permit Application	As Constructed
Type		
Width		
Depth (with 2 feet of freeboard)		
Length		
Sideslopes		
Crest Elevation		
Slope		
Type of Lining/Protection		
Spillway Capacity (providing design calculations)		

Storage Capacity	Permit Application	As Constructed
Length @ Bottom		
Width @ Bottom		
Length @ Crest of Principal Spillway		
Width @ Crest of Principal Spillway		
Length @ Crest of Emergency Spillway		
Width @ Crest of Emergency Spillway		
Volume @ Crest of Emergency Spillway		

ER-MR-311:Rev. 9/98 (Fig. 3-2 Continued)

TO BE COMPLETED AFTER CONSTRUCTION

1. Has the facility been constructed at the location shown in the approved permit?

▮ Yes ▮ No

2. Is emergency spillway constructed in original ground?

▮ Yes ▮ No

And is the type of construction adequate for the required duration and discharge of the design storm?

▮ Yes ▮ No

If "no" checked, explain.

3. Are the collection channels inlets constructed at the proper locations and located to prevent short-circuiting?

▮ Yes ▮ No

If not constructed as approved, answer the following questions.

4. Is the "as constructed" design capable of meeting the performance standards?

▮ Yes ▮ No

If "no" checked, explain.

5. Identify any conditions or deficiencies in the facility that need to be corrected.

6. Construction Inspection

Date of Inspection	Inspected By	Stage of Construction
____________	____________	____________
____________	____________	____________
____________	____________	____________

Supervising Professional Engineer________________________________
Address________________________________
Telephone Number________________________________
I certify that the above-mentioned structure is complete and has been constructed as indicated.________________________________
Signature of Professional Engineer/Surveyor Date
SEAL
____
Registration Number and Expiration Date

____
Signature of Permittee or Responsible Official Date Title

3.7 Pond Examinations And Inspections

(25 Pa. Code §§ 87.112, 89.101, 90.112)

Each impoundment shall be examined by a qualified person designated by the permittee at intervals not exceeding 7 days for structural weakness, erosion and other hazardous conditions. The examination should include checking for surface cracks, sloughing or movement of the toe, noticeable seepage, obstruction of outlet structures or riprap failures.

Impoundments with an embankment less than 20 ft (6.10 m) in height, as measured from the upstream toe of the embankment to the crest of the emergency spillway, or with a storage volume of less than 20 ac ft (2.47 ha m) shall be inspected once every 3 months unless otherwise required by the Department. The permittee shall make and retain records of such inspection, including records of actions taken to correct deficiencies found in such inspection. Copies of such records shall be provided to the Department on request.

If an examination or inspection discloses that a potential hazard exists, the person who examined the impoundment shall promptly inform the Department of the finding and provide a remedial action plan to protect the public. If adequate procedures cannot be formulated or implemented, the Department shall be notified immediately. The Department shall then notify the appropriate agencies that other emergency measures are needed to protect the public.

3.8 Impoundment Capacity

(25 Pa. Code §§ 87.108, 89.112, 90.108, 102.13)

Sedimentation impoundments shall have a capacity of 7000 ft^3/ac (489.81 m^3/ha) for each acre (0.41 ha) of disturbed area draining to it. This volume corresponds to approximately 1.9 inches (4.8 cm) of runoff from the drainage area. Of the 7000 ft^3/ac (489.81 m^3/ha) of volume, 2000 ft^3/ac (139.94 m^3/ha) shall be reserved for sediment storage. The sediment in the impoundment shall be removed when the storage capacity is less than 5000 ft^3/ac (349.86 m^3/ha).

When mining occurs within a sensitive watershed such as a High Quality (HQ) watershed as designated in 25 Pa. Code Chapter 93, the sedimentation impoundment shall have the capacity to contain the runoff from a 10-year, 24-hour precipitation event. This requires an impoundment constructed with a minimum total capacity of approximately 8600 ft^3/acre (601.76 m^3/ha).

The drainage area to an impoundment may include small areas of undisturbed ground. As these undisturbed areas can be expected to contribute only small amounts of sediment, it is not necessary to construct the impoundment for the total runoff and sediment storage volume of 7000 ft^3/ac (489.81 m^3/ha). In these cases the impoundment design can be based on 5000 ft^3/ac (349.86 m^3/ha) of runoff storage volume for the undisturbed acreage. The impoundment design need not include the additional 2000 ft^3/ac (139.94 m^3/ha) of sediment storage for the undisturbed drainage areas.

For the purpose of routing storms through an impoundment (See **Pond 378** and **Sediment Basin 350**), the normal pool shall be considered to be the sediment storage cleanout level.

For additional information of the routing of storms through a sediment basin, see page 4.51 through 4.61 of the **Erosion and Sediment Pollution Control Manual**.

Sediment traps constructed either upslope of the impoundment or in the collection ditch draining to the impoundment can be utilized on a one-for-one volumetric basis to reduce the total volume of the impoundment.

3.9 Principal Spillway

(25 Pa. Code §§ 87.112, 88.102, 89.112, 90.112, NRCS **Sediment Basin 350** and **Pond 378**)

The requirements for sizing of principal spillways are contained in the NRCS publications **Sediment Basin 350** and **Pond 378**, and are referenced in the mining regulations. The Department recommends that all E & S impoundments be designed and constructed with both a principal spillway and emergency spillway even though neither publication specifically requires a principal spillway for ponds with a drainage area less than 20 acres (8.09 ha). The use of a principal spillway reduces the frequency and duration of flow through the emergency spillway, yet allows for a controlled release of the runoff. The criteria contained in the two NRCS publications require an increase in the design storm as the drainage area to the impoundment increases. Impoundments using only an emergency spillway must have the spillway constructed in original ground and be lined with an appropriate channel lining.

These criteria for sizing principal spillways found in **Sediment Basin 350** and **Pond 378** are as follows:

1. Ponds with a drainage area between 20 and 50 ac (8.09 and 20.23 ha) shall have sufficient capacity between the sediment storage level and the emergency spillway to (1) store 2.00 inches (5.08 cm) of runoff from the watershed or (2) provide the required combination of storage and pipe discharge to accommodate the runoff from the 5-year, 24-hour storm event.

2. Ponds with a drainage area between 51 and 100 ac (20.64 and 40.47 ha) shall have sufficient capacity between the sediment storage elevation and the crest of the emergency spillway to (1) store 2.50 inches (6.35 cm) of runoff from the watershed or (2) provide the required combination of storage and pipe discharge to accommodate the runoff from the 10-year, 24-hour storm event.

3. Impoundments with a drainage area of more than 100 ac (40.47 ha) shall have sufficient capacity between the sediment and the crest of the emergency spillway to (1) store 3.00 in (7.62 cm) of runoff from the watershed or (2) provide the required combination of storage and pipe discharge to accommodate the runoff from the 25-year, 24-hour storm event.

The elevation and orientation of the principal spillway inlet is very important in determining the discharge capacity of the principal spillway and the available storage capacity and retention time. Ideally the principal spillway inlet should be placed such that full pipe flow is achieved prior to having the water elevation reach the crest of the emergency spillway, but it must not be placed too low in the structure or it will not provide sufficient storage and trapping efficiency for the runoff flowing into the impoundment.

The principal spillway design shall include the inlet elevation, pipe slope and length of the pipe. Routing procedures, such as those in NRCS **TR-55** may be used to verify a particular design.

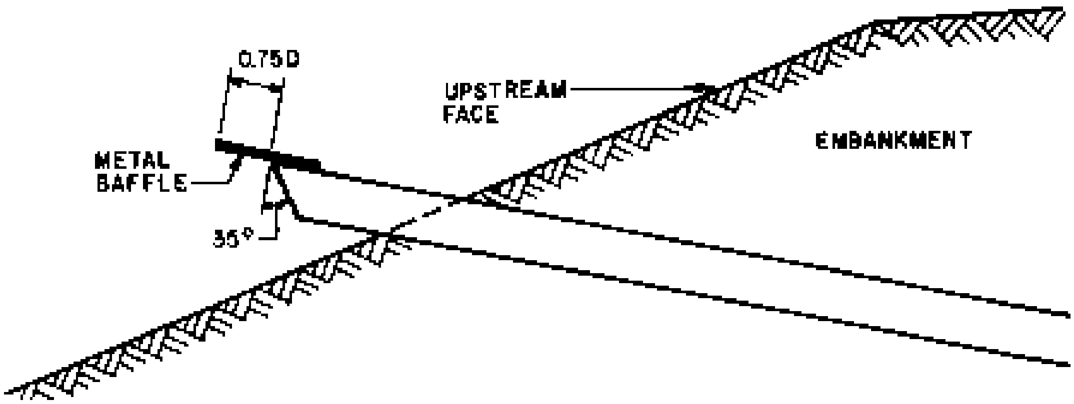
Barrel and riser principal spillways are subject to a reduction in capacity if an anti-vortex device is not used. This reduction occurs due to the swirling action that greatly reduces the capacity of the structure. A metal plate placed in the center of the riser pipe structure allows the full capacity of the pipe to develop.

On larger drainage areas, barrel and riser principal spillways should be used so that adequate storage is available in the impoundment.

Filter fence fabric should never be placed over the inlet or outlet works of a principal spillway. Doing so can cause clogging of the holes and reduces the effectiveness of the impoundment.

Straight barrel spillways are frequently used for small impoundments. If the end of the straight barrel spillway is cut off square, full flow will not develop in the pipe until a significant head is achieved. The head to develop full flow is typically greater than what is available in the ponds. To remedy this situation, the end of the pipe should be cut off diagonally and a baffle or hood placed over the end of the pipe. Figure 3-3 illustrates a straight barrel spillway design.

Figure 3-3: Principal Spillway



Hooded inlet principal spillway with metal baffle. Adapted from SCS Engineering Field Manual. (page 6-49)

3.10 Emergency Spillway

(25 Pa. Code §§ 102.13, 105.98, NRCS **Sediment Basin 350** and **Pond 378**)

Chapter 102 requires that all sedimentation impoundments be capable of safely conveying the routed 25-year frequency peak discharge. **Sediment Basin 350** and **Pond 378** require impoundments from 20 to 100 acres (8.09 and 40.47 ha) in drainage area be capable of passing the 50-year frequency peak discharge. Impoundments over 100 acres (40.47 ha) in drainage area must be able to pass the 100-year frequency peak discharge. The design events upon which drainage areas are based are listed in Table 3-2. The principal spillway capacity can be utilized in passing the design storm. The ability of a given sedimentation impoundment to safely route a given design storm is determined by developing a runoff hydrograph that takes into account the discharge capacities of both the principal and emergency spillways.

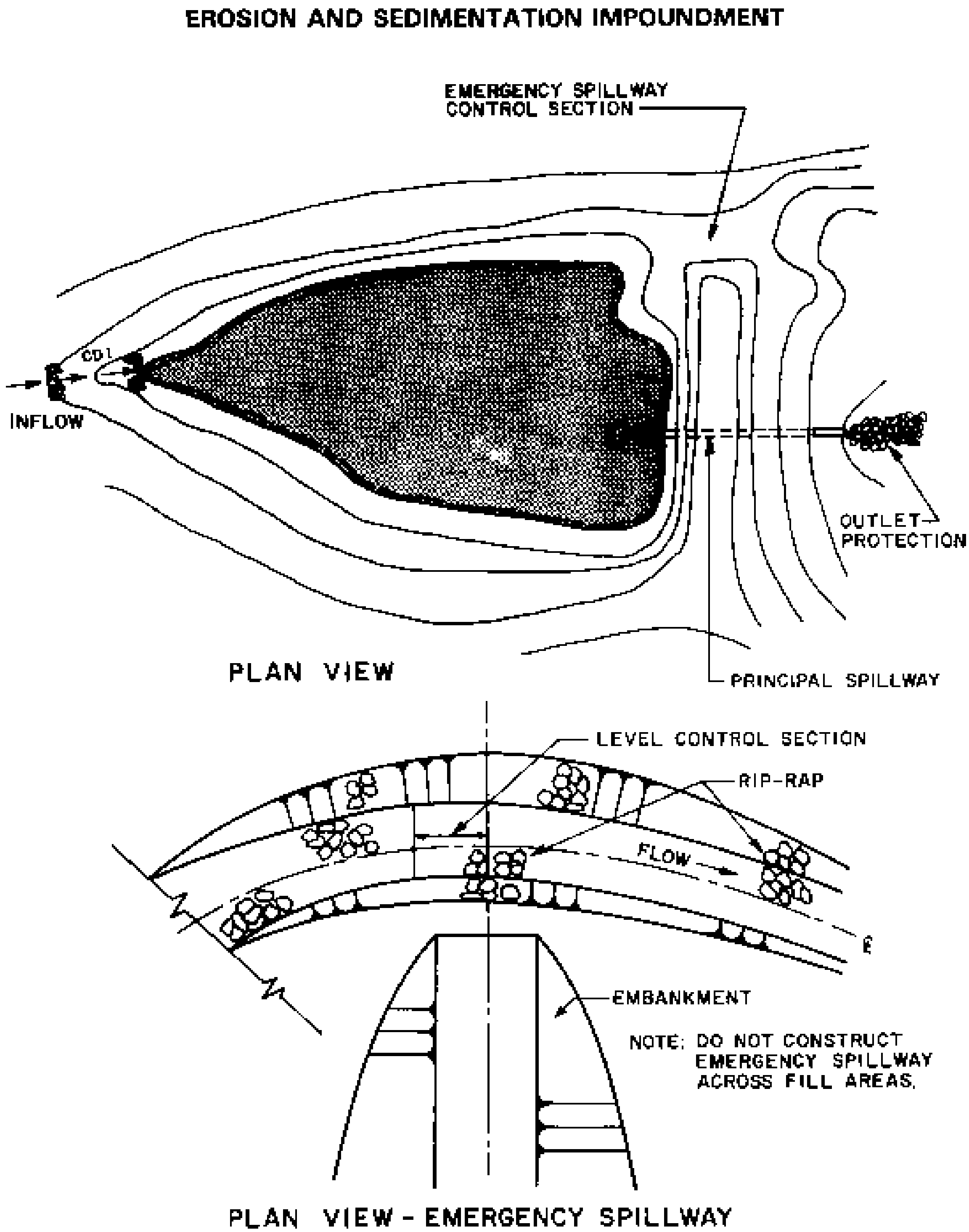
The emergency spillway should always be excavated into original ground wherever possible and protected with an appropriate channel lining. If it is physically impossible to excavate the emergency spillway in original ground, the area must be adequately compacted and lined with suitable riprap. A geotextile lining installed beneath the riprap will also be necessary. The emergency spillway outlet should convey the flow to a stable watercourse with adequate capacity for the flow.

Table 3-2: Design Area Based on Storm Events

Drainage Area	Design Event
less than 20 acres (8.09 ha)	25-year, 24-hour rainfall
20 acres to 100 acres (8.09 to 40.47 ha)	50-year, 24-hour rainfall
over 100 acres (40.47 ha)	100-year, 24-hour rainfall

The slope of the exit channel of the emergency spillway should be shown on the impoundment design sheet. A plan view of an emergency spillway is shown in Figure 3-4.

Figure 3-4: Plan View of Emergency Spillway



3.11 Freeboard

(25 Pa. Code § 102.13, NRCS **Sediment Basin 350** and **Pond 378**)

The freeboard between the design discharge elevation through the emergency spillway and the top of the embankment shall be a minimum of 2 feet (0.61 m).

3.12 Impoundment Dewatering

(NRCS **Sediment Basin 350**)

All impoundments are to be designed to dewater from the crest of the emergency spillway to the sediment storage volume in no less than two days and no more than seven days. This allows time for settling and for the impoundment to empty should a second significant rainfall event occur. Manual dewatering with a valve on the dewatering pipe is required on sensitive watersheds. All permits with manual dewatering devices must contain a narrative describing the operation of the dewatering device including operation after personnel are no longer on site.

All ponds must be designed to dewater from the crest of the emergency spillway to the sediment storage elevation in 2 to 7 days. Practice has shown that smaller pipes are prone to clogging and several small dewatering pipes in one impoundment should be avoided. When a barrel and riser principal spillway is used as a dewatering device, the riser pipe perforations should consist of 2, 3, or 4 columns of one inch (2.54 cm) holes spaced one foot (30.48 cm) vertically. To prevent clogging of the holes, one inch (2.54 cm) size is the minimum that should be used. When additional capacity is needed an additional column of holes can be added or the top one or two rows of holes can be of a larger size.

The orifice equation $Q = c(A)(2gh)^{.5}$ where c = 0.6, A is the area (ft^2), g = 32.2 ft/sec^2, and h is head in ft, can be used for pond dewatering calculations. This gives Q in ft^3/sec. In SI units, Q = m^3/day; A is the area in m^2; h is the height in m; g = 9.82 m/sec^2; 1 day = 86400 sec; and c = 2659. The impoundment dewatering calculations should be included with the permit application. Hand calculations to determine dewatering time can be done with the following information.

- Elevation
- Storage Volume
- Change in storage volume
- Discharge
- Average Discharge
- Time per unit change in storage volume
- Accumulated time

For additional information on impoundment dewatering, see pages 4.51 through 4.61 of the **Erosion and Sediment Pollution Control Manual**, published by the Division of Waterways, Wetlands, and Erosion, Bureau of Water Quality Protection.

3.13 Improving Impoundment Efficiency

There are many ways of improving the sediment trapping efficiency of a impoundment. One way of increasing the efficiency of the impoundment is to increase the flow path that the sediment laden water must travel in the impoundment. Another way is to increase the surface area of the impoundment.

Runoff enters the impoundment in a slug flow process that can result in "dead spots" in a pond that are not effective in trapping sediment. The slug flow can be reduced by placing baffles or a level overflow near the inflow to the impoundment. This permits flow to better utilize the entire cross sectional area of the impoundment.

The settling of suspended particles is a function of surface area and detention time of the impoundment. Increasing the surface area of an impoundment will decrease the flow velocity through the impoundment and increase the efficiency of the impoundment. Increasing the volume of the impoundment will increase the detention time and the efficiency of the impoundment.

The shape of the basin is another important factor in determining the efficiency of an impoundment. The impoundment must have a minimum length-to-width ratio of 2:1. The longer the distance between the inlet and the outlet, the more efficient the pond will be. Wedge shaped impoundments make better use of the impoundment area by eliminating "dead spots" within the impoundment. These areas, particularly in rectangular impoundments, can be eliminated by the use of baffles to route flow to eliminate "dead spots".

When the pond geometry is limited by site conditions, baffles can be used to increase the flow path that inflow must travel before leaving the impoundment. Baffles are required whenever inflow is coming into an impoundment from two different directions and a 2:1 flow path to pond width cannot be achieved. Baffles can be constructed of geotextile cloth, mine ventilation cloth, plywood, placed stone or a dike constructed of suitable material. Baffles work very effectively when a permanent pool can be maintained.

The outlet of the collection ditch should discharge to an area covered with riprap or other suitable protection at the invert elevation of the impoundment so that additional sediment is not deposited into the impoundment by the runoff flowing over and eroding a steep slope.

Reducing the drainage area to any one impoundment will reduce the amount of channel erosion and decrease the sediment load to the impoundment. Generally, anything which places controls close to the source will improve the overall efficiency of the plan.

Chemical treatment can be utilized to improve impoundment efficiency. In a typical impoundment, gravitational settling is used to remove suspended solids. If the runoff has a high percentage of fine-grained silts and clays, the required effluent standards will be difficult to achieve. A chemical flocculant can be added to cause the fine-grained particles to agglomerate. This agglomeration will have the settling characteristics of larger-sized particles.

3.14 Chemical Flocculation

Normal settling is gravitational and dependent on the settling velocity for the different size particles. The settling of individual particles under quiescent conditions is described in physics by Stokes' Law. Because the fall of a particle in water is due to gravity, the heavier the particle is the greater its chance of settling out. The smallest particles, clays, drop out very slowly and carry a negative electrical charge. The particles do not combine, causing them to remain in suspension for long periods of time. Flocculants and coagulants are chemicals that can be useful in increasing settling efficiency. Coagulants reduce the surface charge and allow smaller particles to combine and drop out. Flocculants promote agglomeration of suspended particles without a change in the negative surface charge. Flocculants can be utilized to increase the settling efficiency of sedimentation impoundments. Types of flocculates/coagulants include metal salts, metal hydroxides, and synthetic polymers. Salts include aluminum sulfate, ferrous sulfate, ferric chloride, and calcium sulfate. Metal hydroxides include aluminum hydroxide and iron hydroxide. Aluminum sulfate is a commonly used flocculant, as are many different synthetic polymers. Some synthetic polymers are not suitable for use when a discharge is involved due to aquatic toxicity. Specific questions as to the toxicity of a given flocculant can be directed to the Pa. Fish & Boat Commission's Division of Environmental Services, 450 Robinson Lane, Bellefonte, PA 16823, telephone (814) 359-5140.

When applied at the proper dosage, flocculants are extremely effective in reducing the suspended solids concentration of the effluent. They allow the settling of fine clay particles that can remain in suspension for days. The proper dosage rate to be used can be obtained using a jar test. Flocculants are frequently used for process water, but are not always suitable for use in treating water for discharge to a stream as the chemicals used may cause a violation of effluent standards. Chemical salespeople can be of assistance in obtaining site-specific recommendations.

Impoundments utilizing flocculants work best with manual dewatering to allow for batch treatment. A system to distribute the flocculant throughout the water to be treated is necessary. One way is to add flocculants through pumping and therefore a power source must be available. Satisfactory results have been achieved by using a hydroseeder to achieve the desired mixing effect. Flocculants are also available as "floc logs" which slowly dissolve when contacted by incoming surface water.

3.15 Impoundment Removal

Erosion and sedimentation impoundments shall remain until the vegetation is successful. Permittees must obtain Department approval before removing sedimentation controls. Removal of the impoundment should be done during the planting season so that the area can be seeded as soon as possible.

3.16 Moat Impoundments

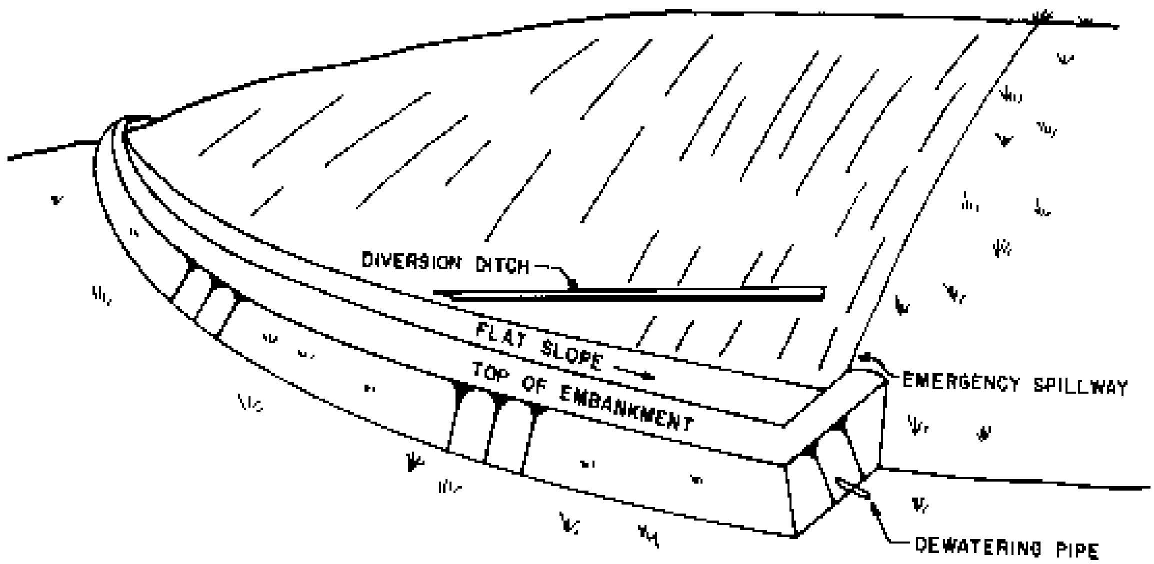
Impoundments must have a minimum length to width ratio of 2:1, but the impoundment can be very long relative to the width. Sediment ponds with a high length-to-width ratio are referred to as contour or moat impoundments, because they transverse the contours on a site and resemble a wide trench or moat. Moat impoundments, illustrated in Figure 3-5, have many advantages that favor their use in certain areas. They are well suited for use in areas of steep terrain. They take up less space due to lower embankment heights. The lower embankment height also allows for easier reclamation when the time comes to remove the impoundment. Typically a small bulldozer can be used for construction and reclamation. Moat impoundments have a lower average depth and longer flow path than more typical erosion and sedimentation impoundments.

In general, moat impoundments are treated the same as typical sediment ponds with particular emphasis on the following guidelines for the construction of moat impoundments:

1. Since runoff can enter the upslope face of the impoundment and flow directly out of the impoundment, a diversion should route runoff to the basin inlet. Another solution is the use of a pond baffle, extending along the length of the impoundment, to prevent short circuiting.
2. Moat impoundments should be constructed at a very flat or 0% slope to allow settling to occur and prevent the erosion of already settled particles.
3. Rock checks should be placed in the bottom every 400 feet (121.92 m) to reduce erosion in the bottom of the impoundment and to take into account variations in the bottom elevation.
4. Whenever possible, the emergency spillway should be constructed in original ground or in an area where the embankment is not at its highest point. Moat ponds should follow the normal criteria for the construction of principal spillways. When the principal and emergency spillways are constructed in the same area of the embankment, it is important that these areas be compacted properly. If the emergency spillway must be constructed in the embankment it is important that the spillway be lined with a riprap of adequate size. Filter cloth is recommended for placement underneath the riprap.
5. In remining situations, consideration should be given to using existing impoundments to control sediment from the new mining. This results in the eventual reclamation of the old impoundment and avoids disturbing new areas for the sole purpose of building a sediment basin.

Figure 3-5: Moat Impoundment

MOAT IMPOUNDMENT



3.17 Impoundment And Storage Area Liners

3.17.1 Introduction

(25 Pa. Code §§89.58, 90.101, 90.122, 101.3 and 101.4)

Impoundments and storage areas at underground mines, surface mines, coal preparation plants and coal refuse disposal sites must be constructed in a manner that prevents groundwater contamination. As a general rule, impoundments for the storage or treatment of mine drainage, contaminated runoff from coal or refuse sources, leachate from a coal refuse area, or water from a mineral processing operation must be equipped with a liner. In addition, coal stockpiles, pollution-forming underground development waste, spoil, and coal processing wastes must be placed on liners that are graded to drain to a collection point and are sufficiently impermeable to ensure lateral flow along the surface of the liner.

3.17.2 Regulations

The regulatory requirements pertaining to the construction and performance of impoundments and storage areas are cited in 3.17.1.

Section 89.58 requires that pollution-forming underground development waste and spoil be stored and placed on impermeable material. Section 90.101 requires coal refuse disposal activities be conducted to minimize changes to the prevailing hydrologic balance including prevention of water pollution. Section 90.122 requires coal refuse disposal areas be designed and constructed to prevent leachate and surface runoff from degrading surface waters and groundwater. Section 101.3 requires that any activity which involves the impoundment, production, processing, transportation, storage, use, application or disposal of pollution substances must include measures to prevent such substances from entering the waters of the Commonwealth; and, as such, has been applied to require lining of coal stockpiles and refuse storage areas. Section 101.4 requires that all impoundments used for the production, processing, storage, treatment, or disposal of pollution substances must be impermeable.

3.17.3 Types Of Liners (Liner Materials)

The following materials are commonly used as liners:

1. Natural clay soils in place (In-situ)
2. Hydraulic asphalt concrete
3. Concrete
4. Soil cement
5. Soil asphalt
6. Remolded clay
7. Sodium bentonite and bentonite-like materials/soil mixtures
8. Geomembranes (synthetic)

Most liners associated with mining activities may be categorized by one of four types. These are: natural clays or in-place confining layers, clays, sodium bentonite and bentonite-like materials/soil mixtures, and geomembranes. Since these types of liners appear to be most utilized by the mining industry in this state, further discussion will involve these four types of liners. The other listed liner types will be evaluated on a case-by-case basis by the Department should any operators wish to utilize them.

3.17.4 Minimum Liner Requirements

Impoundments - Specific Discharge Rates: All impoundments described in the scope of this chapter must be equipped with liners capable of achieving specific discharge rates no greater than 1.0 x 10^{-7} cm/sec under operating conditions. Specific discharge is defined by the following equation:

$$D_s = KI, \text{ or}$$
$$D_s = K(H + L)/L$$

where:

D_s = specific discharge (cm/sec)
K = hydraulic conductivity of liner (cm/sec)
I = hydraulic gradient (dimensionless)
H = height of water above liner (length in units consistent with the units for L)
L = thickness of liner (length in units consistent with the units for H)

Storage Areas - Hydraulic Conductivities: All storage areas, as outlined in the scope of this chapter must demonstrate a hydraulic conductivity of no greater than 5.0 x 10^{-5} cm/sec.

Liner Thickness: For natural clays or in-place confining layers and liners constructed of remolded clays or sodium bentonite and bentonite-like materials/soil mixtures, the minimum liner thickness is 2 ft (60.96 cm).

For liners constructed of geomembranes (synthetic) the minimum thickness required is 30 mils (0.76 mm).

Liner Material Evaluation: In order to evaluate non-synthetic liner materials and liner integrity following construction, the following items must be provided in any proposal:

1. Laboratory testing and data listing the percentage amount by volume of bentonite necessary to be mixed with the soil component to achieve the listed hydraulic conductivity value.
2. Hydraulic conductivity.
3. Liner material density/moisture content relationship.
4. Atterberg Limits - A minimum plasticity index of 10 is required for any clay soil.
5. Sieve Analysis
    - No coarse fragments greater than 1 inch (2.54 cm) in diameter.
    - 50% of the soils must pass a No. 200 mesh sieve.
    - The liner materials to be tested must be compacted to attain a minimum of 90% of the maximum dry density as determined by the Standard Proctor Test. It is imperative that field densities of constructed liners attain the laboratory test conditions regarding density.

For in-situ clay soil liners the following information is required in addition to the laboratory testing data.

1. A site plan map must be provided that shows the soil sample/test locations. These locations must be keyed to the laboratory test results.
2. Testing must be conducted at a minimum frequency of one per acre evenly spaced over the areal extent of the site.
3. Soil depths must be verified at all test locations by Shelby tube, soil probe or other suitable method and sealed immediately with bentonite.

For synthetic liners, the following information must be provided with all proposals:

1. Composition and thickness.
2. Hydraulic conductivity.
3. Seam construction.
4. Manufacturer's recommendations on uses, limitations, and installation procedures.

All plans for sites where liners will be constructed should contain information regarding groundwater elevations. If necessary, spring collector underdrains should be constructed to convey all groundwater flows away from the liner. These drains should be constructed such that the type of liner, or subbase requirements for the specific liner, do not negatively impact the drain by causing fine-grained material to migrate and block off the underdrain. In most circumstances, it is necessary to provide a geotextile covering of the underdrain itself.

All sites using liner types other than in-situ liners must include a plan for subbase or underlying ground material to be compacted to attain a minimum density of 90% of the maximum dry density as determined by the Standard Proctor Test. This action will prevent damage to liner systems from consolidation due to loading during liner construction or loading upon full utilization of the facility.

3.17.5 Quality Assurance And Testing For Liners

Non-Synthetic

1. Compaction testing must be performed for all non-synthetic liners to document that liner material has been properly compacted to correspond to the density achieved in laboratory permeability testing.
2. Liner thickness must be verified.

Synthetic - Testing shall be conducted at a minimum frequency of one per acre evenly spaced over the areal extent of the site. Synthetic liners need only be tested if installed as part of an impoundment. The testing must be done by one of the following methods:

1. Procedures recommended by manufacturer; or
2. Filling the structure with water and determining the leakage rate over a period of at least 5 days with corrections for precipitation and evaporation.

4. Haul Roads And Movement Of Mining Equipment

4.1 Introduction

(25 Pa. Code §§ 87.80, 87.160, 88.60, 89.26, 90.47)

Haul roads are a major source of sediment. The design and construction of haul roads is a very important part in controlling sediment-laden runoff from a mine site. Haul roads intercept, concentrate and direct potentially large drainage areas to receiving streams. The surface of a haul road will also have a high rate of runoff due to the compaction of the material from which the haul road is constructed. Haul roads typically cross swales and streams, a situation that can allow sediment-laden runoff to enter streams. Thus, haul roads can be a major source of sediment if they are not properly constructed and maintained.

Reed and Hainley (1989) reported that sediment yields on unimproved haul roads, that were poorly constructed and had inadequate drainage facilities, were over six times as high as sediment yields from properly constructed haul roads. The sediment yield of 148 T/ac (332 t/ha) for an unimproved haul road gave the highest sediment yield of the mine sites that were monitored by the USGS. The same USGS report indicated that sediment yields from haul roads and newly reclaimed areas were 100 to 300 times greater than the sediment load from agricultural areas planted in hay, pasture and corn.

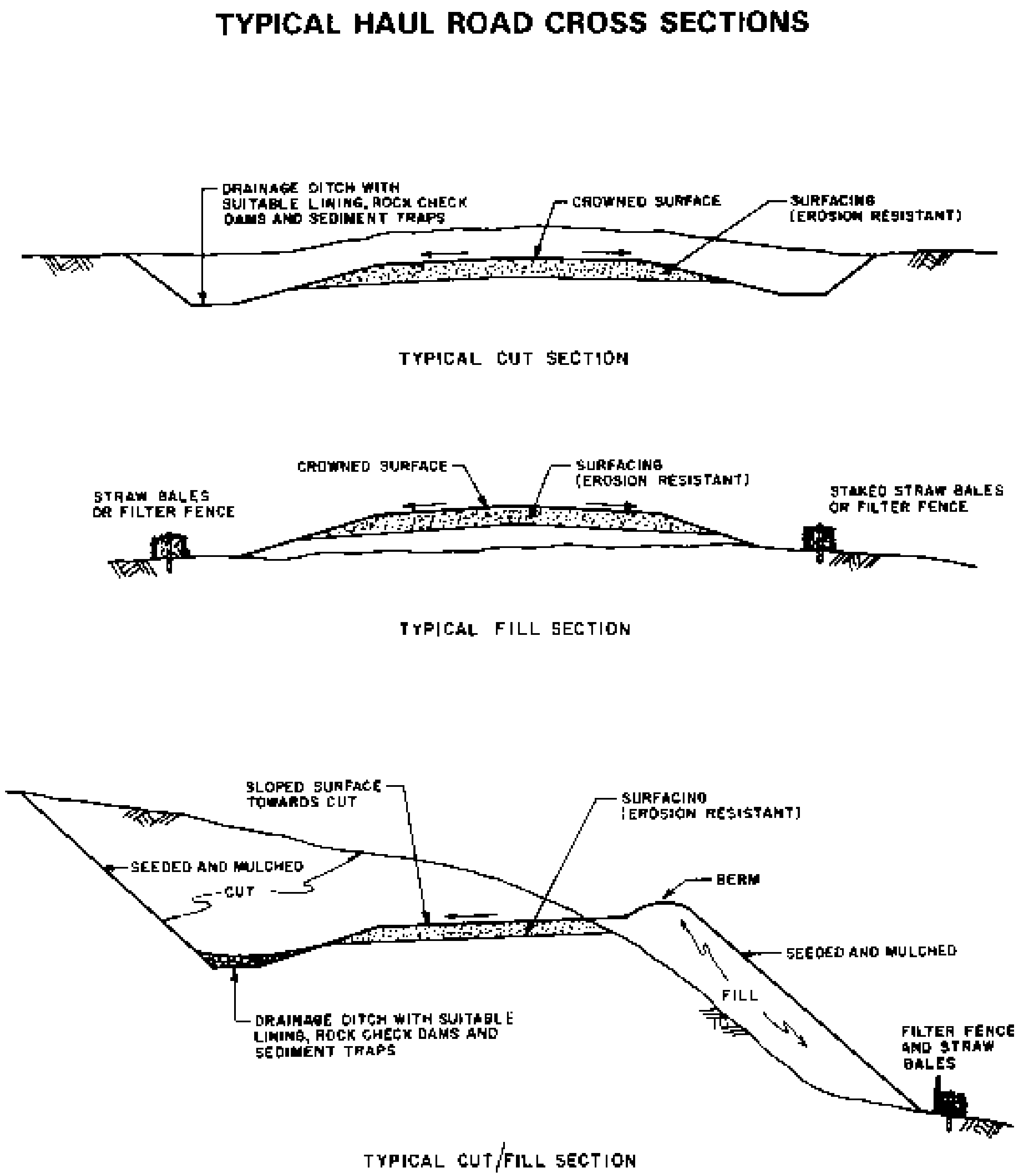
4.2 Construction

The construction of haul roads should begin with the removal of the soil at the haul road location. This serves two very important purposes: stockpiling the soil for later reclamation; and removal of organic material that would be detrimental to establishing and maintaining proper drainage. Whenever possible, haul roads should be constructed on south-facing slopes, as this reduces surface moisture and results in a safer roadway. Cut slopes for haul roads should not be constructed with slopes steeper than 1:1 (45^o), unless the slope is excavated from rock. Roads should not be constructed with coal refuse or any other acid-producing material. Geotextiles can be used to improve the stability of roads where the sub-grade is a poor quality material.

4.2.1 Location and Cross Section

The cross-section of the road is important to allow the road to drain properly and prevent accumulation of water on the road surface. To promote drainage of the road surface, the road should be sloped or crowned at about one-half inch per foot of width (41.67 mm per meter of width) . Where the road is cut into the side of a hill, it is better for safety reasons to slope the road towards the cut section and run a ditch along the cut slope. Figure 4.1 illustrates typical haul road cross-sections.

Figure 4-1: Typical Haul Road Cross-Sections



4.2.2 Culverts

Where culverts are needed to cross collection or diversion ditches, the culvert should be sized to convey the design discharge. Haul roads can intercept significant runoff, with the impervious surface of the haul road adding to the runoff volume. Culverts are needed to carry this runoff downslope of the haul road. Table 4-1 may be used as a guide for determining spacing of haul road culverts:

Table 4-1: Haul Road Culvert Spacing

Road Grade	Spacing	
	(ft)	(m)
2% to 5%	300 to 500	91.44 to 152.40
6% to 10%	200 to 300	60.96 to 91.44
11% to 15%*	100 to 200	30.48 to 60.96

*Greater than recommended road grade.
See Chapter 7, Physical Impacts on Streams, for a review of haul road crossings of streams.

4.2.3 Permit Application

The location of the haul road, including rock check dams, sediment traps, collection ditches and culverts must be shown on the Operations Map. All new or upgraded crossings of all intermittent and perennial streams that require a variance to distance limitations should be included as part of the public notice.

4.2.4 Certification

The design and construction or reconstruction of roads utilized for mining activities must be certified by a qualified registered professional engineer or land surveyor as meeting safety and performance standard requirements.

4.3 Public Highway Access

(25 Pa. Code § 86.102)

There are several issues to be considered when an access or haul road must intersect a state or township road. The intersection should be at a location were adequate sight and stopping distances can be achieved. The access or haul road should be constructed on a upgrade toward the public roadway. This is necessary to prevent the accumulation of sediment on the public road.

If the public road is a state highway, a Highway Occupancy Permit will have to be obtained from PennDOT. Applications for Highway Occupancy Permits can be obtained at any PennDOT District Office or County Maintenance Office. This permit is not part of the mining permit. It is the responsibility of the mine operator to obtain the required approval. A copy of the approved

Highway Occupancy Permit must be provided to the Department prior to activation of the mining permit. Even "existing" access roads require a new occupancy permit since conditions under which the "existing" road will be used are changing.

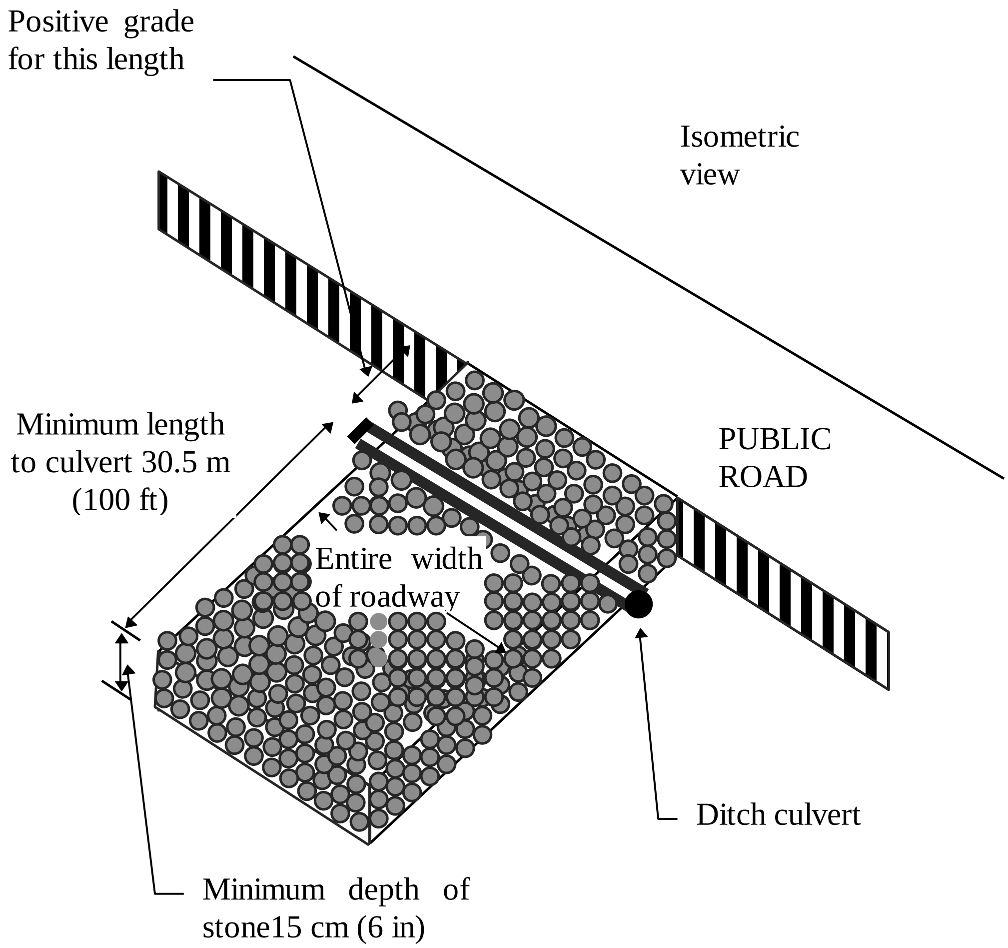
The Highway Occupancy Permit regulates the location, design, safety, construction, maintenance and drainage of the access or haul road to the state road. The main concerns that must be addressed include:

1. Placement of the access or haul road in a safe location with adequate sight and stopping distance for oncoming traffic.
2. Preventing water flowing from the access road, haul road or mining operation onto the highway, which can cause drainage problems for oncoming traffic.
3. Preventing the accumulation of mud, dirt, and coal onto the highway, which can cause hazardous driving conditions.

4.3.1 Gravel Pad

Where the access or haul road meets the public access road it is recommended that the first 100 feet of the access or haul road be lined with clean, durable, non-acidic rock to prevent the accumulation of mud, dirt and coal onto the public road. It is recommended that stone utilized be sized from 3/4 in (19.05 mm) to 3 in (76.20 mm). Alternatively, an operator could pave the first 100 feet of haul road and achieve equal or better results.

Figure 4-2: Rock Construction Entrance



4.4 Air Pollution Control Plan

(25 Pa. Code §§ 87.66, 87.137, 88.48, 89.64, 90.44)

The movement of vehicles on the mine site can be a major source of air pollution. Fugitive dust can affect human health, safety, plant and animal life, and public opinion of the mining activity. Water trucks should be utilized along with road graders to maintain haul roads and reduce fugitive dust emissions. Calcium chloride and other approved chemicals can be used as a surface application to increase moisture retention of the road surface. A fugitive dust control plan is required as part of each permit application.

For Coal Processing Facilities if the amount of minerals to be processed is greater than 200 T/day (181.60 t/day) or 50,000 T/yr (45400 t/yr), an Air Quality Permit is needed. For detailed information on the requirements for an air pollution control plan, the Air Quality Control Manager or Regional Air Pollution Control Engineer may be contacted at the appropriate DEP Regional Office. Please refer to Appendix C for locations.

Used motor oil may not be sprayed for dust control due to potential pollution from toxic substances contained in the used oil. Approved grades of virgin or processed recycled oil may be utilized for dust control. Consult the appropriate District Mining Operations office when proposing use of oil for dust control.

5. Discharge Effluent Requirements

5.1 Discharge Effluent Standards

(25 Pa. Code §§ 87.102, 88.92, 88.187, 88.292, 89.52, 90.102, 40 Code of Federal Regulation Part 434)

The regulation of discharges from coal mining activities is mandated by the federal Clean Water Act (CWA), the federal Surface Mining Control and Reclamation Act (SMRCA), and the Pennsylvania Clean Streams Law. The federal Clean Water Act establishes a program that is implemented with a National Pollution Discharge Elimination System (NPDES) permit. The discharge effluent standards for different types of discharges that are contained in the mining permit are part of the NPDES permitting system.

There are two different types of discharge limitations that apply under the Clean Water Act: the minimum federal technology-based effluent limitations, and state water quality based effluent limitations. Technology-based effluent limitations are uniform standards that apply to classes of discharges nationwide; these limits are based on the technological and economic capacity of an industry to control pollution and are referred to as Best Available Technology (BAT). As these BAT standards apply nationwide, mine operators in one state do not have an unfair economic advantage over operators in another state.

The technology-based effluent limitations for active mining discharges are set forth in 40 CFR Part 434. The effluent standards found in 25 Pa. Code Chapters 87-90, and shown in Table 5-1 are derived from 40 CFR Part 434. Table 5-2 illustrates discharge limitations for specific situations.

Table 5-1: Summary of Technology Based Effluent Limitations for Coal Mining Activities: Discharge Limitations Groupings

Group A	30-day Average	Daily Maximum	Instantaneous Maximum
Iron (total)	3.0 mg/L	6.0 mg/L	7.0 mg/L
Manganese (total)	2.0 mg/L	4.0 mg/L	5.0 mg/L
Suspended solids	35.0 mg/L	70.0 mg/L	90.0 mg/L
pH	Between 6 and 9 at all times		
Alkalinity	Greater than acidity at all times		
Group B	30-day Average	Daily Maximum	Instantaneous Maximum
Iron (total)			7.0 mg/L
Settleable solids			0.5 mL/L
pH	Between 6 and 9 at all times		
Alkalinity	Greater than acidity at all times		
Group C	30-day Average	Daily Maximum	Instantaneous Maximum
pH	Between 6 and 9 at all times		
Alkalinity	Greater than acidity at all times		

Table 5-2: Discharge Situations and Applicable Discharge Limitation Groupings

Type of Discharge	Precipitation Events	Effluent Limitations
Pit water from surface mines	All	Group A
Drainage from underground mine workings	All	Group A
Drainage from coal refuse disposal piles	Dry weather, and less than or equal to 1-year, 24-hour storm	Group A
	Greater than 1-year, 24-hour storm to less than or equal to 10-year, 24-hour storm	Group B
	Greater than 10-year, 24-hour storm	Group C
Surface runoff from active mining area and from areas where stage 2 reclamation standards have been achieved	Dry weather	Group A
	Less than or equal to 10-year, 24-hour storm	Group B
	Greater than 10-year, 24-hour storm	Group C
All other discharges	Dry weather	Group A
	Less than or equal to 10-year, 24-hour storm	Group B
	Greater than 10-year, 24-hour storm	Group C

Specific attention is called to the provision that "When a discharge without chemical or biological treatment has a pH greater than 6.0 and a total iron concentration of less than 10 mg/L, the manganese limitation does not apply." Refer to 25 Pa. Code §§ 87.102(c)(2), 88.92(c)(2), 89.52(e)(2), and 90.102(c)(2).

The technology-based limitations do not reflect the effect the mining discharges will have on the receiving stream, nor do they guarantee that the goals of the federal Clean Water Act will be met. Water quality based effluent limitations focus on the environmental effects that the discharge will have on a stream. They are designed to maintain the existing use of the stream and may result in stricter limits on additional parameters. The Best Available Technology (BAT) standards assigned to a permit cannot cause instream standards for the regulated use of the stream to be exceeded. In many instances, the receiving stream can accept additional loads without exceeding its designated criteria. In cases where the designated criteria would be exceeded, the Department, through the NPDES permitting process, is required to assign the more stringent water quality based effluent limitation.

Many times, the water quality based effluent criteria cannot be achieved with the level of treatment employed on a mining operation. In these cases, a dilution ratio may be used along with the BAT effluent standards to achieve the desired water quality.

A mass balance equation is used to determine water quality based effluent limitations. The components of the mass balance equation are background stream flow, background stream concentration of the pollutant of interest (usually Al, Mn, or Fe), design average flow of the discharge, concentration of pollutant in the discharge, and the applicable pollutant criterion. The background stream concentration is computed by averaging available stream quality data. The average design flow of the discharge is based on the information provided in the permit application. The total flow is the sum of the upstream flow and the flow of the discharge. In most cases, when the effluent limitations are being computed, the flow of both the stream and the proposed discharge are known figures. The unknown figure is the concentration of waste in the proposed discharge.

This simple mass balance procedure is only valid for chemical entities whose concentration is conserved. If the parameter in question is changed by chemical reaction, or by removal from solution in the form of a gas or a solid, a simple mass balance based only on flow and concentrations in solution will not apply.

If several instantaneous samples are taken on one or more days, they are averaged for each day, and the maximum of these averages is the daily maximum.

5.2 Precipitation Event Exemptions

(25 Pa. Code §§ 87.l03, 88.93, 88.188, 88.293, 89.53, 90.103)

The occurrence of a 24-hour rainfall exceeding certain frequency events can be used as a defense for noncompliance with the technology-based effluent standards. Runoff from active mining areas must meet the different effluent standards found in Table 5-1, depending on whether the runoff occurs from a rainfall event less than or equal to, or greater than a 10-year, 24-hour precipitation event. Where a discharge occurs during dry weather that is not result of a rainfall event, Group A effluent standards apply (See Tables 5-1 and 5-2.). Exemptions apply until 24 hours after the end of the rainfall event.

Dry-weather flow is defined as the baseflow or surface discharge from an area or treatment facility which occurs immediately before a precipitation event, and resumes 24 hours after the precipitation event ends.

Sections 87.103, 88.93, 89.53, and 90.103 of the Department's regulations explain in detail the procedure to follow when requesting a precipitation event exemption for an effluent violation. The simplest way is to provide 24-hour rainfall information from official United States Weather Bureau Stations, USGS gauging stations or published data from the National Oceanic and Atmospheric Administration. The Department will consider data from other verifiable sources such as airports, private weather stations, or individual rainfall recording stations when a precipitation event exemption is being requested.

For the permittee to demonstrate that the listed event has been exceeded or that dry-weather flow conditions did not exist, one of the following must be done:

1. Collect 24-hour rainfall information from all official United States Weather Bureau Stations within a 25-mile radius of the site, and, by appropriate interpolation of the data collected, calculate the estimated rainfall for the site.
2. Prepare a verified copy of the chart or readout from a Department-approved flow measuring device which continuously records the influent to the permitted treatment facility. Such device must be approved by the Department in writing prior to the rainfall event for which the exemption is sought and shall be secure to prevent tampering and acts of third parties. The operator shall prepare an analysis identifying the runoff area tributary to the treatment

facility, and compare the actual runoff as measured by the flow-measuring device with the runoff expected from the precipitation event.

3. Develop alternate documentation or data concerning the precipitation event. The method or system for developing such documentation or data must be approved in writing prior to the occurrence of the event for which the exemption is being sought, and shall guarantee the integrity of the information collected.

Any time the discharge from the site exceeds any effluent limit set forth in the permit, the operator must notify the Department within five days of the occurrence of the event that a precipitation event exemption is being applied for.

5.3 Special Protection Watersheds

(25 Pa. Code §93.3)

The Department has classified waters of the Commonwealth on the basis of the uses of the stream and the existing water quality in that stream. Streams classified as either High Quality waters (HQ) or Exceptional Value waters (EV) are considered sensitive and receive special protection.

High Quality waters are defined in the Chapter 93, **Water Quality Standards,** regulations, as "A stream or watershed which has excellent quality waters and environmental or other features that require special water quality protection." Exceptional Value waters are defined as "A stream or watershed which constitutes an outstanding national, State, regional or local resource, such as waters of national, State, or county parks or forests, or waters which are used as a source of unfiltered potable water supply, or waters of wildlife refuges or State Game Lands, or waters which have been characterized by the Fish Commission as 'Wilderness Trout Streams', and other waters of substantial recreational or ecological significance."

Permit applications on High Quality watersheds must contain a social and economic impact statement. The procedure to follow when proposing to mine on a HQ Watershed is contained in BMR's technical guidance titled **Review of Surface Mine Applications on High Quality Waters** (560-0700-304). Contact the appropriate District Mining Operations office for a copy of this document. If the discharge will exceed the present instream water quality, the social and economic impact statement must be approved as part of the permit application process. Two options are available for meeting the water quality standards, advanced treatment beyond Best Available Technology (BAT), or controlled discharge at a rate based on stream flow. The second option can be implemented by establishing a minimum dilution ratio below which no discharge will be allowed. Dilution ratios have been developed based on BAT effluent guidelines to assure that the stream standard is met.

A stream flow monitoring station must be established on the receiving stream above the discharge point. Existing culverts, when located nearby, can be used as a convenient flow measuring location.

The Department's *Special Protection Waters Implementation Handbook* (DER, 1992, Page A-3-4) states that in conjunction with technology-based (BAT) effluent requirements for pit water discharges, a minimum dilution ration (stream flow: discharge)of 6:1 must be provided. This dilution ratio may be increased if necessary to prevent violations of instream water quality criteria for specific pollutants of concern. If adequate dilution ratios cannot be maintained, it may be necessary to restrict the extent of surface mining in the watershed. The basis for the minimum 6:1 dilution ratio is the need to maintain a maximum instream concentration of less than 1.5 mg/L for iron and a total dissolved solids concentration of less than 500 mg/L, as required by 25 Pa Code 93.7. For example, from Table 5-1, the BAT daily maximum limit for iron is 6.0 mg/L. By applying a 6:1 dilution ratio, one part effluent mixes with six parts stream water, resulting in a 1.0 mg/L increase over the background instream concentration. The instream iron concentration will therefore be less than 1.5 mg/L as required, provided the background instream concentration is less than 0.5 mg/L. Dilution ratios are established on a case-by-case basis with the ratio based on the most limiting water quality parameter. BAT effluent limitations and dilution ratios are assigned only to those operations where social and economic statements have been approved. If a social and economic impact statement has not been approved, the operator must meet instream criteria.

If High Quality watersheds are to be mined without impacting on the water quality, the permit application and operation plan must be followed closely. This allows the operator to meet the conditions of the permit, maintain a good compliance record, and conduct mining in an environmentally sound manner.

The following are recommendations for mining in a High Quality watershed.

1. Before construction of sedimentation basins, the area downslope of the area to be disturbed should be protected with hay bales or filter fence. This protects the area while the vegetation is being established.
2. No topsoil, subsoil or spoil should be placed below the outslope of any collection ditch.
3. The sedimentation impoundment should have a capacity of 8600 cf/acre (601.76 m^3/ha) or be able to contain the 10-year, 24-hour precipitation event without flow through the emergency spillway.
4. The sedimentation impoundment should have a manual dewatering control device and a narrative explaining the operation of the dewatering device. Manual dewatering allows additional settling to occur before releasing water from the impoundment.
5. Immediately after backfilling and topsoil distribution the area should be mulched with hay or straw at a rate of 2 ½ to 3 T/ac (5.61 to 6.73 t/ha). This provides protection before vegetation is established.
6. All discharge points should be stabilized so that runoff leaving the project area will not start or accelerate erosion or scour within the receiving natural drainageway.
7. All basin inlets should be protected with a durable and stable rock lining for the last 100 feet (30.48 m) of the ditch. This lining shall extend down to the elevation of the basin's bottom.
8. The Operation Plan should provide site-specific information on the maximum area to be disturbed at any one time. This includes all areas not qualifying for Stage II Bond Release.

6. Mine Drainage Treatment Facilities

6.1 General Requirements

(25 Pa. Code §§ 87.101, 87.102, 87.107, 88.91, 88.92, 88.97, 89.52, 89.57, 90.101, 90.102, 90.107)

Surface mining activities shall be planned and conducted to prevent to the maximum extent practical the accumulation of water in the pit. All groundwater or surface runoff encountered in the pit must be collected and pumped to an appropriate treatment facility. Discharges that do not meet the water quality criteria established in the permit must be treated. Department regulations prohibit the discharge of pit water by gravity drains. Under no circumstance shall an operator drill, disrupt or blast the pit floor to avoid treating pit or surface water.

Most of the potentially toxic-forming material is found in and adjacent to the coal seam. A timely removal of the coal and backfilling of the site will reduce the potential for acid mine drainage (AMD) production.

6.2 Treatment Processes And Reagent Selection

The technology employed for treatment of acid mine drainage includes pH adjustment, chemical precipitation, aeration and settling. The first step in the process consists of the addition of an alkaline reagent to raise the pH. The increase in pH causes the solubilities of the metal ions to decrease and precipitate out of solution. These metal ions are replaced in solution by more acceptable calcium, magnesium and sodium ions (EPA 1982). In general, three types of reactions occur as a result of pH adjustments:

1. Neutralization, an ion exchange reaction that, for AMD, combines basic hydroxyl ions with acidic hydronium ions;
2. Oxidation, which, for example, converts ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}); and
3. Precipitation, which results from solubility decreases of metal ions.

The precipitates are, in most cases, metal hydroxides such as ferric hydroxide ($Fe(OH)_3$) which can be removed to a great extent by settling (EPA 1982).

Several alkaline reagents are used to neutralize acidic pit water and acid mine drainage. The different reagents can be divided into two main groups, the **sodium** compounds and the **calcium** compounds. The calcium compounds include **Hydrated Lime** (calcium hydroxide, $Ca(OH)_2$); **Limestone** (calcium carbonate, $CaCO_3$) and **Quicklime** (calcium oxide, CaO). The sodium compounds include **Caustic Soda** (sodium hydroxide, NaOH), and **Soda Ash** (sodium carbonate, Na_2CO_3). Reagents are chosen depending on the quality and volume of water to be treated and the amount of maintenance required for each neutralizing agent and treatment system.

6.2.1 Calcium versus Sodium

The calcium compounds are less expensive than sodium compounds, but they have lower solubilities in water. Therefore, calcium compounds are generally used in large treatment systems where electricity is available to improve the reactivity of the calcium material through mixing. If sulfate concentrations are above 2,000 mg/L, then the calcium products will react with the sulfate to form anhydrite or insoluble gypsum. This calcium sulfate ($CaSO_4$) precipitate may clog pipes or other structures used to convey the water to the receiving stream after treatment and discharge. (Skousen, 1990).

6.2.2 Carbonate versus Hydroxide

The pH of the water during treatment affects the types and amounts of metals that can be removed or precipitated from the water. Carbonate compounds do not raise pH of the water above 8.5, while hydroxide compounds can raise pH above 10.0. Ferric iron (Fe^{3+}) converts to the solid yellowish-orange precipitate ferric hydroxide, also referred to as yellow boy, at a pH of 5.5 or greater. Ferrous iron (Fe^{+2}) converts to the solid bluish-green ferrous hydroxide at a pH of 9.0 or greater. Soluble manganese (Mn^{2+}) changes to insoluble manganese dioxide (MnO_2) at a pH of 10.0. Therefore, the various metal concentrations in the AMD dictate the appropriate chemical reagent to be used to achieve sufficiently high pH levels. If ferric iron (Fe^{3+}) is the major problem, it is possible to remove it with sodium carbonate, while manganese generally requires the elevated pH attained by adding a hydroxide material. If ferrous iron is present, a sodium hydroxide material may be used, but it may be cost-effective to use hydrated lime in conjunction with an aerator to oxidize the ferrous to ferric iron for precipitation at a lower pH (Skousen, 1989). See Table 6-1.

Table 6-1: Factors that may Influence the Selection of a Calcium or Sodium Compound for an AMD Treatment System

Factor	**Calcium Compounds**	**Sodium Compounds**
Solubility	Slow, less soluble	Fast, more soluble
Application	Requires mixing	Diffuses well
Hardness	High	Low
Gypsum Formation	Yes	No
High Total Suspended Solids	Helps settle clay	Disperses and keeps clay particles in suspension
Chemical Cost	Lower	Higher
Installation & Maintenance Costs	High	Low

6.2.3 Hydrated lime

Hydrated lime (calcium hydroxide) is the most commonly used reagent and reacts with AMD as shown by the following equation:

$$H_2SO_4 + Ca(OH)_2 \Rightarrow Ca^{2+} + SO_4^{2-} + 2H_2O$$

Hydrated lime can be introduced dry or as an aqueous solution. One lb of sulfuric acid needs 0.76 lb of calcium hydroxide for neutralization, or equivalently, 1.00 kg of sulfuric acid needs 0.76 kg of calcium hydroxide for neutralization. Skousen (1989) reports that when neutralizing large amounts of AMD with high acidity levels for long periods of time (greater than 3 years), the more capital intensive but cheaper hydrated lime reagent is generally used. Hydrated lime treatment systems require a power source for mechanical mixing of the lime with the water and pH meters to control the application rate.

6.2.4 Crushed limestone

Crushed limestone (calcium carbonate) reacts with AMD as shown by the following equation:

$$H_2 SO_4 + CaCO_3 \Rightarrow Ca^{2+} + SO_4^{2-} + CO_2 + H_2O$$

One lb of sulfuric acid requires 1.02 lb of calcium carbonate for neutralization, or 1.00 kg of sulfuric acid requires 1.02 kg of calcium carbonate for neutralization. Limestone is the cheapest reagent, but also has a limited solubility, a low reactivity at higher pH's and its use results in the formation of gypsum. Treatment of AMD with limestone can also be limited by iron coating of the larger limestone particles which render the particles non-reactive. The efficiency of using pulverized limestone to treat AMD varies from 50% to 90% depending on the mixing method, particle size, aeration and settling characteristics (Lovell, 1973). Successful treatment with limestone usually involves the use of mixing equipment. The achievable pH ceiling for limestone treatment is approximately 7.5, which is insufficient to precipitate many metals, particularly manganese (EPA 1982). If only small concentrations of iron, manganese, and aluminum are found in the water, limestone can be utilized to precipitate these ions.

6.2.5 Quicklime

Quicklime (calcium oxide), also called burnt or pebble lime, reacts with AMD as shown by the following equation:

$$H_2SO_4 + CaO \Rightarrow Ca^{2+} + SO_4^{2-} + H_2O$$

One lb of sulfuric acid requires 0.57 lb of calcium oxide for neutralization, or 1.00 kg of sulfuric acid requires 0.57 kg of calcium oxide for neutralization. When sulfate concentrations are high (above 2000 mg/L), the calcium products will react with the sulfate to form anhydrite or insoluble gypsum. This calcium sulfate precipitate may clog pipes or other structures used to convey the water to the receiving stream after treatment. Quicklime is not frequently used as equivalent results can be achieved with the similarly priced but easier to handle hydrated lime. Quick lime is extremely caustic and can cause severe damage to the skin, eyes, and respiratory tract.

6.2.6 Caustic Soda

Caustic soda (sodium hydroxide) is frequently used to treat AMD in situations where electrical power is not available. Because caustic soda is a hydroxide compound it can be used to raise the pH of the water above 10.0 to facilitate manganese precipitation. Caustic soda is a strong base which mixes readily with and reacts with AMD as shown by the following equation:

$$H_2SO_4 \; + \; 2 \; NaOH \Rightarrow \; 2Na^+ + SO_4^{2-} + 2H_2O$$

One lb of sulfuric acid requires 0.82 lb of solid sodium hydroxide or 0.40 gallons of 20% solution for neutralization, or 1 kg of sulfuric acid requires 0.82 kg of solid sodium hydroxide or 1.51 L of 20% solution for neutralization. A 50% solution of caustic soda freezes at 54^o F (12.22^o C) (EPA 1982). To reduce the freezing problem, a 20% solution is available. When using sodium hydroxide, protective eye glasses, gloves, and clothing must be worn. A solution of 20% sodium hydroxide is particularly dangerous as it looks like water but can cause severe chemical burns and blindness. Because sodium hydroxide is such a strong base, close monitoring and control of the inflow and reagent is required to prevent over-treatment (EPA 1982). Treatment with sodium hydroxide produces a ferric hydroxide or "yellow-boy" sludge that is gel-like. Caustic soda solution is applied at the surface because the chemical moves downward into the water (Skousen, 1990).

6.2.7 Soda Ash

Soda ash (sodium carbonate) is frequently used to treat AMD discharges that are low in flow rate and acidity level. Soda ash reacts with sulfuric acid as shown by the following equation:

$$H_2\,SO_4 \; + \; Na_2CO_3 \; \Rightarrow \; 2Na^+ + SO_4^{2-} \; + H_2O + CO_2$$

One lb of sulfuric acid needs 1.08 lb of sodium carbonate or 0.40 gallons of 20% solution for neutralization, or 1 kg of sulfuric acid requires 0.82 kg of solid sodium hydroxide or 1.51 L of 20% solution for neutralization. Soda ash can be added in the form of a slurry, but it is usually added by dissolving solid soda ash briquettes. A box or barrel is used to hold the briquettes with an inlet and outlet for the water to be treated. The water flows through the inlet of the container and dissolves the soda ash. Gravity keeps the briquettes in contact with the water for continual treatment (Skousen, 1990).

6.2.8 Reagent Selection

The level of pH elevation necessary for metal precipitation is an important criterion for the selection of an AMD treatment chemical. Carbonate compounds do not raise the pH of the water above 8.5, while hydroxide compounds can raise the pH above 10.0. Soluble manganese changes to insoluble manganese hydroxide at a pH of 10.0. Thus calcium hydroxide and sodium hydroxide are suitable reagents when manganese is to be removed.

The selection of a treatment system and application method is based on the quantity of water to be treated, the use of a chemical that can adequately and economically treat the water, the detention time needed, and the mixing method. Unless power is available, the use of hydrated lime is not generally feasible. Soda ash and sodium hydroxide are soluble and can be utilized without mixing.

The volume of sludge from an AMD treatment system varies according to the chemical used and the quality of the untreated water. A precipitate consisting of mixtures of iron, manganese, and aluminum hydroxides is formed with any of the treatment chemicals used. When any of the calcium chemicals are used, a calcium sulfate or gypsum precipitate is also formed. The various lime treatment methods produce a greater quantity of sludge than the other treatment methods.

Safety of the chemicals used is also an important consideration. Limestone and sodium carbonate are relatively safe chemicals to use although they are not extremely effective neutralizers. The use of calcium hydroxide or calcium oxide can cause skin and eye irritation. Prolonged exposure will cause burns. When using sodium hydroxide, protective eyeglasses, gloves, and clothing must be worn.

6.2.9 Aeration

Aeration increases the oxygen transfer rate and therefore the oxidation reaction rate. Aeration can be accomplished by allowing the water to simply flow or cascade down a staircase trough or sluiceway. Aeration is accomplished when water flows from one impoundment to the next. On larger discharges, such as those encountered with coal preparation or underground mines, the air or oxygen may be supplied by one of the following types of aerators: diffused air systems, submerged turbine aerators and surface aerators (EPA 1982).

The oxidation system consists of a tank or basin equipped with one of the above aeration systems. The presence of dissolved oxygen supplied by the aerating technique oxidizes ferrous ions, thus enhancing the formation of essentially insoluble ferric hydroxide. The resulting sludge is more easily settled (EPA 1982). In special cases, oxidizing chemicals may be used when aeration through mechanical disturbance is not adequate or rapid enough. Chemicals which are active oxidants include hydrogen peroxide, potassium permanganate, sodium hypochlorite, calcium hypochlorite and chlorine.

6.2.10 Settling

The settling, or sedimentation, process removes the suspended solids, which includes the insoluble precipitates. Sedimentation can be accomplished in a settling basin or a clarifier. The extent of the solids removal depends on the surface area of the impoundment, flow patterns in the structure, the detention time, and the settling characteristics of the suspended solids. Clarifiers allow more control over detention time and sludge removal. In addition, problems from precipitation and short-circuiting can be avoided.

6.2.11 Flocculation

Chemical flocculation can be used to increase the efficiency of treatment basins, similar to their use in sedimentation impoundments (See Section 3.14.). The colloidal particles in AMD sludge usually carry a negative electrical charge. Consequently, a cationic flocculant must be used.

Synthetic polyelectrolytes are most frequently employed since they function best in the high ionic strength solutions encountered in AMD.

6.2.12 Sludge Disposal

The quantity of sludge formed from AMD treatment varies according to the reagent used. All treatment methods produce a precipitate consisting of a mixture of iron, manganese, and aluminum hydroxide. The calcium chemicals (e.g., limestone, hydrated lime, and burnt lime) also generate calcium sulfate or gypsum which constitutes part of the precipitate. Sodium hydroxide produces a gel-like sludge which is composed predominately of ferric hydroxide ("yellow boy") and which precipitates out in the settling ponds.

Sludge formed in the treatment process ranges from 1% to 10% of the total flow through the facility (OSM, 1988). Once the amount of precipitate accumulates to the design cleanout level, the treatment pond must be drained and the sludge removed for final disposal. Normally the sludge is simply mixed with surface mine spoil material at a location relatively high and dry in the backfill area during the reclamation process. This sludge is an alkaline material with the metals at their highest oxidation states, and it is not harmful to the environment when disposal has been accomplished in this manner.

6.3 Minimum Effluent Standards

Table 6-2 gives the minimum effluent standards for treatment basins.

Table 6-2: Minimum Effluent Standards

Parameter	Instantaneous maximum
Iron (total)	7.0 mg/L
Manganese (total)	5.0 mg/L
Suspended solids (total)	90.0 mg/L
pH	Greater than 6.0, less than 9.0
Alkalinity	Greater than acidity

As the treatment and discharge of pit water can be controlled by pumping rates there is no storm exemption allowed for exceeding the above effluent standards. Effluent limitations for aluminum will apply depending on the water quality and use of the receiving stream. The permit limitations on High Quality or other sensitive streams will be more restrictive.

Prompt dewatering of pit water accumulations will decrease the amount of reagent required to treat the water.

The application must contain a narrative describing how the treatment facility will operate. The narrative shall indicate how the accumulated sludge will be handled.

A minimum of two basins, in series, must be provided to receive water from the pit. Each basin must provide a minimum 6-hr detention time for the calculated treatment volume. Gravity flow may be used to transfer flow from the primary to the secondary basin. The basins must also provide sufficient capacity to allow settling of suspended solids.

When treatment impoundments are located in old spoils or other pervious material, a 2-ft (0.61 m) layer of clay, or synthetic lining is required. The costs of selected alkaline reagents are given in Table 6-3.

Table 6-3: Prices of Selected Alkaline Reagents

Alkaline reagent	Notes	Cost in US dollars	
		Per US Ton	Per tonne
Hydrated lime ($Ca(OH)_2$)	Bulk	59.00	64.98
	50 lb (22.70 kg) bags	100.00	110.13
Quicklime (CaO)	Bulk	57.00	62.78
	Pulverized bulk	74.00	81.50
	Pulverized - 80-lb (36.32 kg) bags	142.00	156.39
Pulverized limestone ($CaCO_3$)	Bulk	18.00	19.82
	50 lb (22.70 kg) bags	26.50	29.19
Bag house lime ($CaCO_3$)	Bulk	1.00	1.10
Caustic soda (NaOH)	50% solution" 55 gal (208.18 L) drums, 684 lb (310.54 kg) per drum. Drums cost $20.00 each	325.00	357.93
Soda ash (Na_2CO_3)	Powdered	518.00	570.48
	Briquettes - 50 lb (22.70 kg) bags	398.00	438.33
Trucking approximately $2.50 per mile			

The cost information was obtained on September 17 and 18, 1998. Costs may vary due to market conditions. The price of the calcium compounds is F.O.B. Bellefonte, Pa. The cost of caustic is F.O.B. Altoona, Pa. The cost of soda ash is F.O.B. Clearfield, Pa. The reader is cautioned that prices quoted in a given community are not necessarily representative of the prices in another.

6.4 Treatment Basin Design

Typically, more than one treatment basin is utilized. When the inflow is of relatively good quality, two parallel basins are typically used. When the sludge volume in one basin has reached capacity, flow is diverted to the second basin and the sludge in the first basin is allowed to dewater prior to removal. When the second basin has reached its sludge capacity, flow is returned to the first basin and the cycle is repeated (EPA 1982). When the inflow is of lesser quality, basins in series are generally used, the second basin acting as a polishing basin and allowing additional detention time. A third basin can be used to allow diversion of flow when the sludge volume has reached capacity. A typical treatment basis design setup is shown in Figure 6-1, and a typical neutralizing unit is given in Figure 6-2.

The design practice recommended by the Department has called for at least two treatment basins in series, each with a minimum detention time of six (6) hours. This has the following theoretical basis, from Hustwit *et al* (1992)[1], who provide also primary references to Sung and Morgan (1980)[2], Harvard University (1970)[3], and Stumm and Lee (1961)[4]. The rate of ferrous iron oxidation follows the following differential equation:

$$d[Fe^{2+}] / dt = -k\,[Fe^{2+}]\,[O_{2\,(aq)}]\,[H^+]^{-2}$$

wherein all concentrations are expressed in mol/L and the rate "constant" $k = 3 \times 10^{-12}$ mol L^{-1} min^{-1} at $T = 20^o$ C. The temperature dependence usually is approximated by an Arrhenius equation. However, for our present purpose, we shall assume that the water temperature = 20^o C. We also shall assume that the contents of the treatment unit are well aerated, so that the dissolved oxygen concentration is essentially constant at its equilibrium solubility of 9.2 mg/L, or 2.875×10^{-4} mol/L (Standard Methods, 1971)[5].

If we also assume that there is sufficient buffering capacity in the reactor to allow an assumption of constant pH, as there will be in a conventional treatment unit, the equation becomes an ordinary first-order differential equation with constant coefficients. If we design the pair of basins for the 12-hour detention time with uniform flow, the arithmetic produces a design pH of 6.32, which is lower than would be experienced in the usual conventional treatment basin. Thus, the suggested design detention time of six hours in each basin is a good conservative guideline.

---

[1] Hustwit, C.C., T.E. Ackman, and P.M. Erickson, 1992. Role of Oxygen Transfer in Acid Mine Drainage Treatment. US Department of the Interior RI 9405, US Government Printing Office, Washington DC.

[2] Sung, W., and J.J. Morgan, 1980. Kinetics and Product of Ferrous Iron Oxygenation in Aqueous Systems. *Environmental Science and Technology* v. 14, No. 5, pp. 561-568.

[3] Harvard University, 1970. Oxygenation of Ferrous Iron (US Department of the Interior, Federal Water Quality Administration, Contract PH 36-66-107), US Government Printing Office, Washington DC.

[4] Stumm, W. and F.G. Lee, 1961. Oxygenation of Ferrous Iron. *Industrial and Engineering Chemistry* v. 53 No. 2, pp. 143-146.

[5] American Public Health Association, American Water Works Association, and Water Pollution Control Federation, *Standard Methods for the Examination of Water and Wastewater, 13th ed.* p. 480.

Treatment basins are sized according to the quality and volume of runoff to be treated, the detention time that is needed to allow neutralization and settling to occur and the pumping rate that will be used to dewater the pit. While conditions encountered in the field may vary from the expected conditions, a method of sizing the treatment basin is needed prior to opening the pit. The applicant must submit information that includes the total area draining to the pit, the computed runoff volume from a 10-year, 24-hour storm event, the expected water quality and treatment method, detention time normally required and the pump size and rate for the head to be encountered. The following is an example of determining treatment basin volumes for primary and secondary treatment basins.

$$V = 1.33\ (A\ R\ C)$$

V = Volume of basin in ft^3 (or m^3 as applicable)
A = Area draining to pit in ft^2 (or m^2)
R = Total 24 hour rainfall (ft or m) x detention time (6 hours = .25 days)
C = Runoff coefficient, C = .5 for Open Pit,
1.33 = Factor to allow for sludge storage

6.5 Example

1. Maximum pit length and width of mining operation 1000 ft (304.8 m) x 250 ft. (76.20 m) = 250,000 ft^2 (23,225.76 m^2), including spoil piles that drain to pit and area below highwall diversion.

2. 10-year, 24-hour rainfall is 4.0 inches = .333 feet (0.10 m)

3. 6-hour detention time = .25 days

4. Volume calculations

   $V = 1.33\ (A\ R\ C)$
   $V = 1.33\ (250{,}000\ ft^2)\ (4.0\ inches)\ (.25\ days)\ (.5)$
   $V = 1.33\ (250{,}000\ ft^2)\ (0.333\ ft)\ (.25\ days)\ (.5)$
   $V = 1.33\ (10{,}417\ ft^3)$
   $V = 13{,}845\ ft^3$ (or $V = 392.05\ m^3$)

5. Basin size - Assuming a 6.00 ft (1.83 m) depth, the average surface area needed is 2300 ft^2 (213.68 m^2). If a 25 ft (7.62 m) bottom width is used, the basin's length would be 45 feet (13.72 m). For 2:1 side slopes the top width is 50 ft (15.24 m) and top length is 70 ft (21.34 m) and the average area of the basin is 2300 ft^2 (213.68 m^2).

6. A secondary basin of the same size will also be constructed. This will allow an additional 6 hours of detention time in the second basin. If area draining to the pit

increases, additional detention time is needed for treatment, or if effluent quality is not being met, a third basin would be constructed.

7. Computed treatment volume is 13,845 ft^3 (392.05 m^3). This may be converted to 103,561 gallons by multiplying by 7.48 gal/ft^3. The pit should be dewatered in less than 48 hours. Therefore, 10,3561 gals (392,019.4 L) divided by 48 hours equals 2157 gal/hr (8167 L/hr), or 36 gal/min (136.27 L/min), or 196.2 m^3/day.. Vertical lift from pit to treatment basin is 70 ft (21.34 m). Therefore, a pump that can discharge a minimum of 36 gal/min (136.27 L/min) against 70 ft (21.34 m) of head, or 136.2 m^3/day against 21.34 m of head, is required.

Figure 6-1: Typical Treatment Basin Design

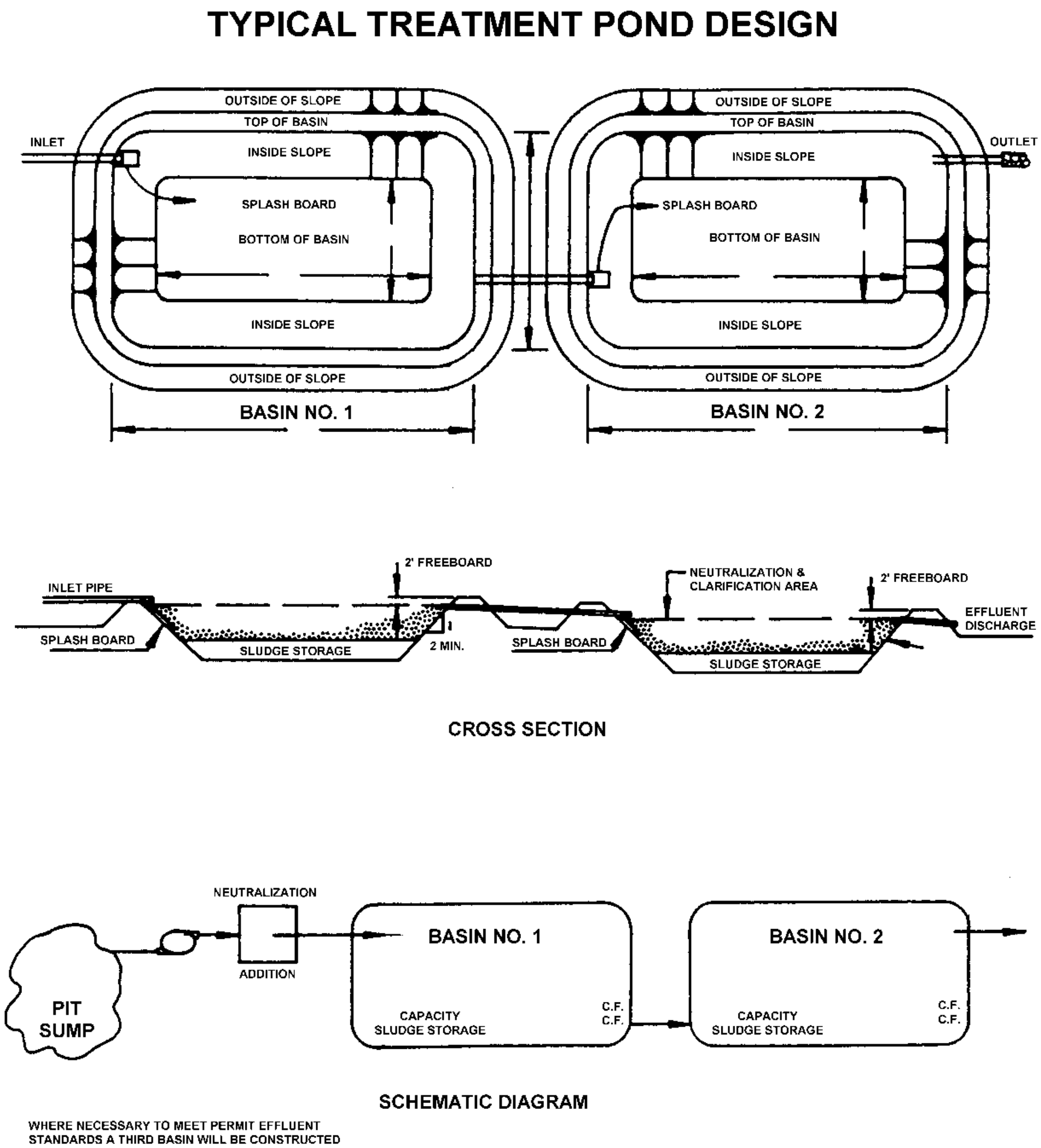
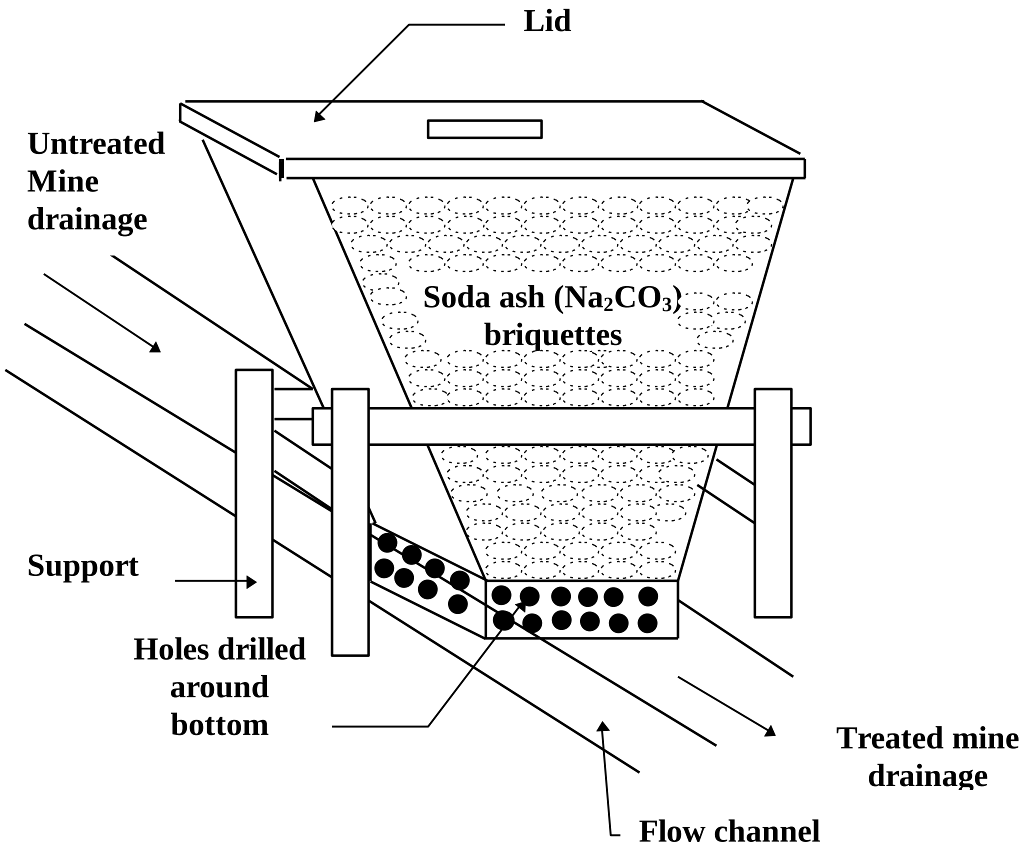


Figure 6-2: Typical Mine Drainage Neutralizer



6.6 Passive Systems For The Treatment Of Mine Drainage

Certain subcategories of postmining discharges can adequately be treated using passive treatment systems (Hellier, 1994). Accordingly, the Department has promulgated regulatory changes to §§ 87.102, 88.92, 88.187, 88.292, 89.52, and 90.102 to provide for passive treatment systems for the treatment of postmining discharges. The technical information given in the referenced regulations is the same for surface mining of coal whether bituminous or anthracite; anthracite bank removal and reclamation; coal refuse disposal whether bituminous or anthracite; underground mining of coal and coal preparation facilities.

Bonding requirements are addressed under § 86.142 and other applicable sections. The amount of bond will be calculated based on the design life of the passive system. However, should the Department find after a period of operation of the passive system that the design life is not likely to be achieved, the Department may require such bond adjustments or replacement or repair of the system as it deems necessary to prevent pollution.

6.6.1 Required information

If a postmining discharge occurs, the discharger must immediately provide interim treatment to comply with the usual effluent limitations and take whatever measures are necessary and available to abate the discharge. If the discharge continues to exist, the discharger may consider the use of a passive treatment system to abate the discharge. The discharger must provide data to categorize the discharge. Useful classes include:

- Discharges with a pH that is always greater than 6.0 and an alkalinity which always exceeds the acidity; or
- Discharges with an acidity that is always less than 100 mg/L as $CaCO_3$, an iron content that is always less than 10 mg/L, a manganese content that is always less than 18 mg/L, and a flow rate that is always less than 3.00 gal/min (16.35 m^3/day); or
- Discharges with an net acidity always less than 300 mg/L as $CaCO_3$, calculated by subtracting the alkalinity of the discharge, mg/L as $CaCO_3$, from its acidity; or
- Other discharges that the discharger demonstrates can be adequately treated with a passive system.

The discharger must demonstrate that the proposed passive system will reduce the iron concentration by at least 90% or by that percentage necessary to achieve the Group A effluent criteria given in the appropriate regulation, whichever percentage is less, and that the system will produce an effluent alkalinity which exceeds effluent acidity. The group A effluent criteria are repeated in Table 6-4 for the reader's convenience.

Table 6-4 : Group A Criteria for Mine Discharges

Parameter	30-day average	Daily maximum	Instantaneous maximum
Total iron [Fe]	3.0 mg/L	6.0 mg/L	7.0 mg/L
Total manganese [Mn]	2.0 mg/L	4.0 mg/L	5.0 mg/L
Suspended solids	35 mg/L	70 mg/L	90 mg/L
pH	Greater than 6.0 and less than 9.0		
Alkalinity	Alkalinity greater than acidity		

The proposed system must be designed to prevent discharge into the groundwater and to prevent extraneous sources of groundwater and surface water runoff from entering the passive treatment system. It must be designed to handle hydraulically the highest average monthly flow rate which occurs during a twelve-month period.

It must have inlet and outlet structures that will allow for flow measurement and water sampling.

It must be designed to prevent to the maximum extent practical physical damage and associated loss of effectiveness due to wildlife and vandalism.

It must be of such capacity that it will operate effectively and achieve the required effluent quality for 15 to 25 years before needing to be replaced.

It must be designed by, and constructed under the supervision of, a qualified professional knowledgeable in the subject of passive treatment of mine drainage

Pollution loading from mine discharges is expressed in terms of a unit mass of pollutant per unit time. The standard unit given in publications on the subject is grams per day (g/day). Pollution concentrations conventionally are reported in terms of milligrams of pollutant per liter (mg/L). Acidity and alkalinity are reported as milligrams per liter as calcium carbonate equivalent (mg/L as $CaCO_3$). To calculate the loading of a given pollutant in g/day, multiply the concentration (mg/L) by the flow Q (m^3/day).

Flows are reported in a variety of units, which are converted to cubic meters per day (m^3/day) as follows: Multiply gallons per minute (gpm, or gal/min) by 5.45, or multiply liters per minute (L/min) by 1.44 to get m^3/day.

In order to effectively design a passive treatment system, the engineer must use data representative of the pollution that is occurring. It is recommended that data from at least 12 consecutive months be evaluated to determine representative loadings. It would be even more beneficial, for statistical reasons, if data taken at 30 different times over a study period is considered.

The proposal must include the credentials of the qualified professional by whom the passive treatment system has been designed and under whose supervision it will be constructed.

6.6.2 Engineering principles

Passive treatment systems such as aerobic wetlands and horizontal flow anaerobic wetlands are usually sized on the basis of mass removed per unit area per unit time (g day^{-1} m^{-2}); i.e., grams of pollutant removed per day per square meter of wetland area. To convert square feet (ft^2) to square meters (m^2), multiply ft^2 by 0.3048^2, or 0.9290304. To convert acres to square meters, multiply acres by 4047.

Passive treatment systems must be designed to hydraulically handle the highest average monthly flow rate that occurs during a twelve-month period; this is determined from the data submitted in support of the passive treatment system proposal. Treatment system design must consider the retention time (also known as detention time, or average residence time). Treatment systems usually include some combination of the following elementary reactors: (1) Batch reactor, in which a certain amount of water is admitted, treated for the required time, and discharged; (2) Well-mixed, or continuous stirred tank, reactor (CSTR), in which the water is thoroughly mixed as it continuously flows through the treatment unit; and (3) Plug flow, or uniform flow reactor (PFR), in which the contents are not stirred. In this type of reactor, the concentrations of pollutants depend on position within the reactor. Because the average residence time is maximized (thereby increasing treatment efficiency), and because settling is encouraged by quiescent conditions (as opposed to mixed conditions), most aerobic wetlands and horizontal flow anaerobic wetlands are designed primarily as plug flow systems. However, it must be recognized that perfect plug flow conditions are impossible to achieve in the real world.

Some mixing zones, especially at the beginning of the passive treatment unit, are necessary because the system may be designed to achieve aeration. Nonuniform flow is disturbed at entrances and exits to the treatment unit. Wind and temperature effects cause mixing. With these effects taken into consideration, wetlands should be designed to achieve plug flow as nearly as possible. This can be done by maintaining a length to width ratio (aspect ratio) of at least 2:1, by planting emergent plants (such as cattails, *Typha latifolia*), and by designing a series of sub-wetlands (or cells) or by placing deflectors, or baffles, throughout the wetlands. Splash blocks, or deflectors at the influent end can be placed to dissipate turbulence. Outlet structures can be designed to minimize mixing at the effluent end.

If the medium (water or substrate) is of constant depth, specifying the surface area is equivalent to specifying the detention time. A substrate is a solid phase or phases placed at the bottom of the wetland; e.g., limestone, spent mushroom compost, peat, or even native soil. The effectiveness of the substrate in removing pollution depends on its chemical composition, its particle size and permeability, and the quality and flow rate of polluted water through it. Substrates and surface water columns do not have to be of uniform depth.

Pollution is removed principally by the mechanisms of alkalinity generation, cation oxidation, hydrolysis, and settling. Physical or chemical retention may prove important for some wetlands. Uptake by the wetlands plants is not a principal pollutant removal mechanism unless the plants are periodically harvested.

Wetlands must be designed so that their physical integrity is maintained. Surface water runoff must be excluded from the wetlands to minimize erosion damage, as well as to maximize detention time. A system of ditches or raised berms designed in a manner similar to the design of diversion and collection ditches is the usual means to accomplish this.

Exchange of the treated water with the groundwater system must be prevented, using either a clay liner or an artificial liner where necessary. The designer should be satisfied that the liner material will not itself contribute pollution to the water being treated. The principal reason for trying to eliminate groundwater exchange is to protect the groundwater from pollution, but it is also important to eliminate unmeasured effects of groundwater exchange when determining the effectiveness of the wetland.

The inlet structure should be designed so as to allow for convenient collection of water quality samples, and should be provided with a means to measure influent flow (pipe outlet for bucket and stopwatch measurements, weir, flume, etc.). The outlet structure should also be provided with a means of measuring flow and gathering samples, and should have a deflector or some other outlet device to protect the outfall from solids carry-over into the effluent. The outlet structure must be protected against structural damage from freezing, and from damage due to animals such as beavers.

The sides of the wetland must be protected from damage from such animals as muskrats; it is recommended that some structure such as chain link fence be incorporated into the sides of the wetlands to discourage burrowing animals.

The sides should be designed with a distance ratio of between 2 horizontal to 1 vertical and 3 horizontal to 1 vertical (18^o to 27^o angle measured from horizontal upward.). This maximizes stability, makes it easier for equipment that is building or maintaining the wetlands to operate, and to some degree discourages (but is not guaranteed to eliminate) mosquitoes.

The bottom should have a level to slightly upward slope in the direction from influent to effluent. If *Typha latifolia* are to be planted, surface water column depths of more than 50 cm are usually detrimental.

The wetland must be provided with a freeboard of not less than 1 meter (3.28 ft) above the free water surface. The freeboard serves a twofold purpose. It prevents overtopping of the wetland during storm events, and it provides long-term detention of the accumulated solids. The engineer should calculate how much wetland capacity will be occupied by settled solids at the end of its design life, and is strongly encouraged to design the freeboard accordingly. The wetland must be designed to operate effectively and achieve the required effluent quality for 15 to 25 years before needing to be replaced.

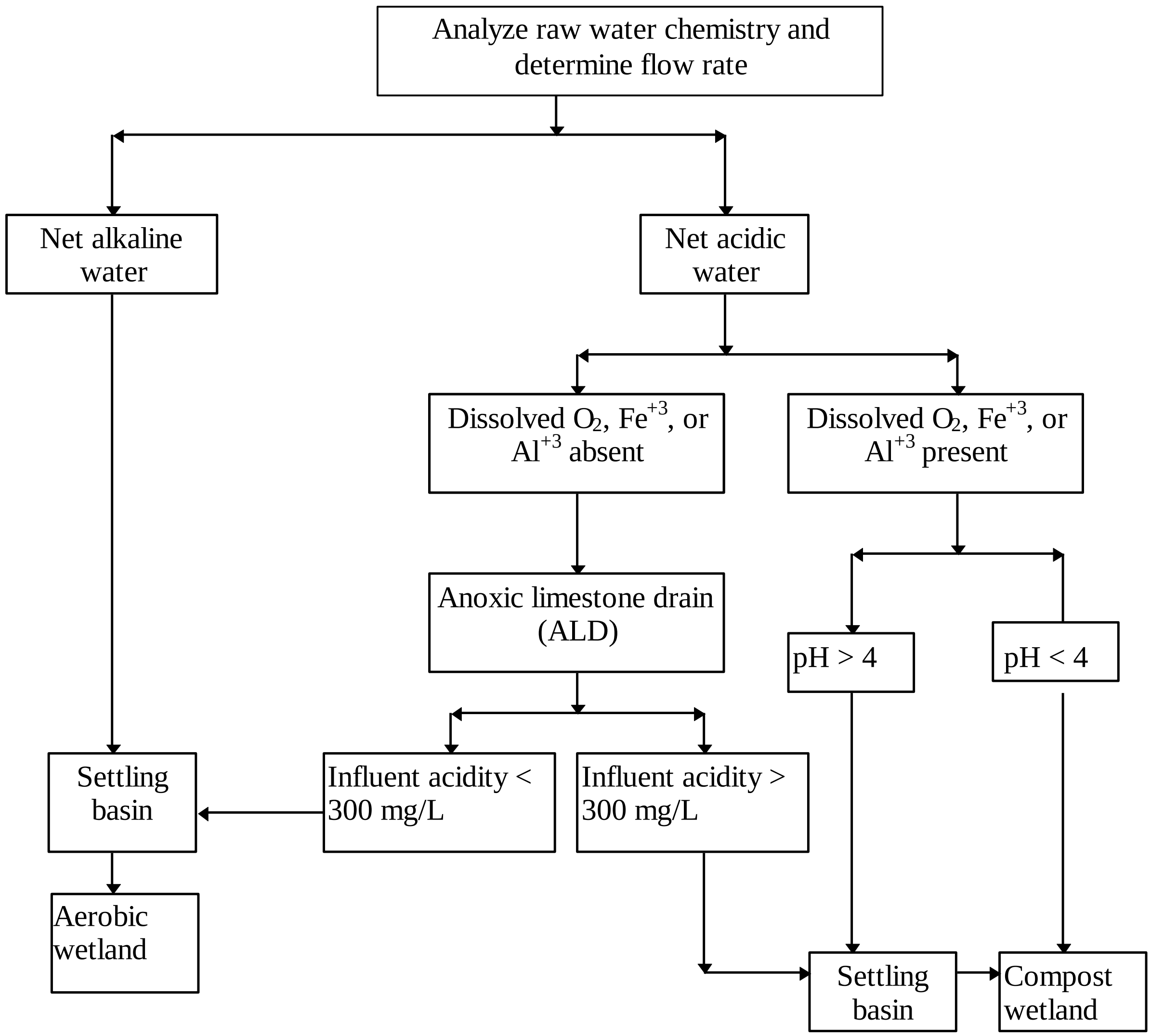
6.6.3 Chemistry

The Best Professional Judgment (BPJ) Analysis divided mine drainage which is to be the influent to treatment units into five alkalinity/acidity subcategories (Table 6-5):

Table 6-5: BPJ Subcategories for Mine Discharges

Subcategory	Description	Acidity/alkalinity range
1	Very acid:	Net acidity > 300 mg/L as $CaCO_3$
2	Moderately acid:	$100 \leq$ net acidity ≤ 300 mg/L as $CaCO_3$
3	Weakly acid:	$0 \leq$ net acidity < 100 mg/L as $CaCO_3$
4	Weakly alkaline:	Net alkalinity < 80 mg/L as $CaCO_3$
5	Strongly alkaline:	Net alkalinity ≥ 80 mg/L as $CaCO_3$

Figure 6-3: Decision Making Chart for Passive Treatment Systems



The Best Professional Judgment Analysis found that conventional treatment is usually the best available technology for discharges of Subcatergory 1. For moderately acid to strongly alkaline discharges, wetlands as a best available technology should be designed on the basis of chemistry and loading, using criteria similar to those presented by the Hedin *et al* (1994), then of the US Bureau of Mines. An adaptation of their decision-making chart[6] is presented here as Figure 6-3 for the reviewer's or designer's use. Combinations of these passive systems, such as sequential alkalinity producing systems (SAPS), can be designed and reviewed on a site-specific basis.

6.6.4 Aerobic wetlands

Aerobic wetlands and settling basins rely on the oxidation of Fe^{2+} (and to a lesser degree Mn^{2+}), hydrolysis of Fe^{3+} and Al^{3+}, and settling and retention of oxidation and hydrolysis products such

[6] Hedin, R. S.,R. W. Nairn, and R. L. P. Kleinmann, 1994. US Bureau of Mines, Information Circular 9389, "Passive Treatment of Coal Mine Drainage." US Bureau of Mines, Washingtoon DC. Figure 12, Page 26.

as FeOOH, MnO_2, and $Al(OH)_3$. These processes are only effective in water that has a net alkalinity, which may be initially present in the mine drainage or be imparted to acidic water by means of conventional treatment or by the passive systems on the right hand part of the flow chart. Aerobic wetlands or settling basins must be designed to retain the amount of solids expected to be removed, either through periodic cleaning or through the freeboards, or through a combination of both.

6.6.5 Anoxic limestone drains

Anoxic limestone drains are most effective when the influent dissolved $[O_2]$, $[Fe^{3+}]$, and $[Al^{3+}]$ approach zero. They also impart alkalinity at greater rates when dissolved $[CO_2]$ is high. They should therefore be designed to exclude oxygen and trap carbon dioxide. Groundwater exchange and invasion by roots of woody plants should be kept to a minimum. An artificial liner may be considered, and the drain should be covered by at least 1 meter (3.28 ft) of compacted earth. The limestone should be kept inundated; deflectors or dams might be necessary to achieve this inundation. The drain should not be expected to produce more than about 275 to 300 mg/L of alkalinity. It should be made from the purest limestone, $CaCO_3$, economically available; $CaMg(CO_3)_2$, or dolomite, is not as effective. The detention time should be at least 14 hours.

While some calculations have been suggested (Hedin and Watzlaf, 1994) to design the size of the anoxic limestone drain on the amount of limestone necessary to achieve the design effluent alkalinity during the expected lifespan, considerations such as interference from Fe^{3+} and Al^{3+}, physical collapse or plugging or a greater limestone removal rate at the influent (more acidic) end must be made. The proposal must specify the quantity of limestone to be used and show the calculations upon which its design life is based.

The design must also address flow velocities, detention times, and what measures will be used if the limestone becomes ineffective due to armoring with FeOOH or other material, or due to plugging with $Al(OH)_3$ or other material. The effluent of the anoxic limestone drain must be directed into an aerobic wetland or settling basin to remove the metals. The design sizing of the aerobic wetland or settling basin must be shown.

6.6.6 Anaerobic (compost) wetlands

Anaerobic, or compost, wetlands often can be used where Fe^{3+}, Al^{3+}, or O_2 are present in the influent. The compost wetlands function by reacting the mine drainage with alkalinity in the form of HCO_3^-, bicarbonate ion, generated from dissolution of limestone present in the substrate, and from the reduction of Fe^{3+} and SO_4^{2-} The iron and sulfate reducing bacteria produce bicarbonate as part of their life processes, so long as favorable pH levels are present. Beginning about 1 cm below the substrate surface, substrates tend to become anoxic, or reducing.

Some wetlands rely on diffusion of bicarbonate ion from the substrate into the aerobic surface water to impart alkalinity to water there. Others are horizontal flow systems that have a permeable compost designed to maximize contact between the substrate and the polluted water.

Still others are designed as vertical flow reactors, many with limestone or other underdrains. It is supposed that $Al(OH)_3$, FeS, and $FeCO_3$ are some of the entities retained in the substrate matrix, and studies are continuing. There are few long-term data on the performance of wetlands wherein mixing of the polluted water and the substrate was part of the design; and questions remain unanswered on how long the substrate will continue to function. The amount of carbon required and the expected life based on sulfate reduction can be used as predictive tools, but long term effects of the decrease of substrate permeability and availability of reaction surfaces due to accumulation of precipitated metal compounds are not known. For this reason, the designer is urged to be conservative in designing anaerobic wetlands, possibly considering alternating systems in parallel.

6.6.7 Sequential alkalinity producing systems (SAPS)

SAPS systems wherein alkalinity is imparted by the means described above, followed by oxidation and hydrolysis in an aerobic wetland, followed by a third system designed to generate alkalinity, followed by more aerobic wetlands and systems to generate alkalinity, as needed, are being designed and built and appear to be a very good engineering approach. The anaerobic portions of SAPS should be designed to produce alkalinity during the design life of the system. The designer should specify the quantities of organic compost and limestone or other alkaline substrate that will be incorporated to achieve the addition of alkalinity. The designer should address hydraulic gradients through the anaerobic part of the SAPS. If a series of alternating aerobic and anaerobic cells components are required, the design criteria for each component must be specified.

The former US Bureau of Mines proposed the criteria given in Table 6-5 (Their Table 19)[7], based on empirical data and some theory. Work by Dietz and Stidinger (1993) and by Hellier (1996), as well as by others, produced empirical data in harmony with these criteria. The designer should, however, consider the following:

1. Removal based solely on loading per unit area implies a zero order kinetic model. While this is very simple to understand, it may not reflect what is really occurring. The US Bureau of Mines acknowledged that in many cases, iron removal rate depends on the amount of iron present. This implies a “first-order” rate expression, a type of removal rate expression commonly used in other sanitary engineering applications. In general, removal rates are based on a set of coupled, nonlinear differential equations with variable coefficients, the solution of which may defy analysis. The designer should, if possible, consider the physical chemistry of the system in the design, making the simplifications where warranted. The reviewer should likewise respect the added effort used in the best professional engineering judgment of the engineer.
2. The effluent standards applicable to passive treatment systems are given in the Pennsylvania Bulletin, Volume 27, Number 46, pages 6041-6061, November 15, 1997. The effluent standards, such as 25 Pa. Code §87.102, do not specify a manganese standard. However, if the discharger nonetheless wishes to consider manganese removal, the following suggestions are given. The mechanism of manganese removal is not necessarily the same as that for iron, copper, nickel, or zinc. The literature points to an autocatalytic oxidation reaction at surfaces

[7] Hedin, R. S., R. W. Nairn, and R. L. P. Kleinmann (1994, op. cit.). Table 19, Page 25.

under alkaline conditions, and systems such as aerobic limestone beds for manganese removal have been proposed and built. The water entering such systems should be alkaline or easily made alkaline. Fe^{2+} tends to reduce the desired product MnO_2 and defeat the purpose of the Mn oxidation system. Certain organisms imparted to the aerobic drain seem to accelerate the rate of Mn removal. If no other information is availablewhen Mn removal is required, the US Bureau of Mines guidelines can be applied.

3. When wetlands are designed based on the US Bureau of Mines guidelines, the total design area of the wetland must be calculated by adding the design area for the removal of iron to the design area for the removal of manganese. The US Bureau of Mines guidelines do not directly account for the dependence of iron and manganese removal on pH. Iron and manganese removal rates dimish as pH decreases. The influent alkalinity will be partially or completely offset by the hydrogen ion acidity that is expected to be released by the hydrolysis of aluminum and by the oxidation and hydrolysis of iron, and manganese, thereby causing the pH within the wetland to be decreased. If the designer expects the pH to be decreased below aboout 6.2, additional wetland area should be provided to offset the expected slower iron and manganese removal rates.
4. The US Bureau of Mines criteria differentiate between “compliance” criteria and abandoned mine land reclamation criteria, but it must be recognized that “compliance” criteria could not have considered the BPJ analysis and the new rulemaking. Nonetheless, for active sites and for sites where systems are being built as part of an effort to save the bonds, the US Bureau of Mines “compliance” criteria should be applied. The abandoned mine criteria (AML criteria) should be accepted only when the areas are forfeited and/or the project is part of a reclamation effort by an agency such as the Bureau of Abandoned Mine Reclamation or the Natural Resources Conservation Service.

Table 6-6: US Bureau of Mines Sizing Criteria

	AML criteria	**AML criteria**	**Compliance criteria**	**Compliance criteria**
	g m^{-2} day^{-1}	g m^{-2} day^{-1}	g m^{-2} day^{-1}	g m^{-2} day^{-1}
	influent alkaline	influent acid	influent alkaline	influent acid
Fe	20	not applicable	10	not applicable
Mn	1.0	not applicable	0.5	not applicable
Acidity	not applicable	7	not applicable	3.5

Anoxic limestone drains and vertical flow anaerobic wetlands can also be sized on the basis of the amount of limestone or other alkaline materiel necessary to impart the design alkalinity requirement for a specified period of time. For example, the amount of limestone required to impart 300 mg/L of alkalinity to a discharge flowing at 100 m^3/day for 25 years, assuming 90% of the limestone to be composed of $CaCO_3$ and the process efficiency to be 75% would be:

(300 mg/L* 100 $m^{3/}$day * 365 days/year * 25 years)/ (0.90 * 0.75)

= 405,555,556 grams of limestone
= 406 metric tons, or tonnes (t).
= 447 US Tons (T)

This would apply, for example, to a polluted discharge with 260 mg/L of acidity for which a residual alkalinity of 40 mg/L is required.

6.6.8 References

Dietz, J.M., and D.M. Stidinger, 1993. “Evaluation of Wetlands Constructed for the Treatment of Acidic Mine Drainage, report to the Department of Environmental Resources (Now Department of Environmental Protection), Harrisburg PA.

Hedin, R.S., R.W. Nairn, and R.L.P. Kleinmann, 1994. U.S. Bureau of Mines, Information Circular IC 9389, "Passive Treatment of Coal Mine Drainage," US Bureau of Mines, Washington DC.

Hedin, R.S., and G.R. Watzlaf, 1994. “The effects of anoxic limestone drains on mine water chemistry.” Vol. 1, p. 185-194 in Proceedings: International Land reclamation and Mine Drainage Conference and International Conference on the Abatement of Acidic Drainage, US Department of the Interior, Bureau of Mines SP 06A-94, Washington DC.

Hellier, W.W., 1994. “Best Professional Judgment Analysis for the Treatment of Postmining Discharges from Surface Mining Activities.” Commonwealth of Pennsylvania, Department of Environmental Protection, Harrisburg PA.

Hellier, W.W., 1996. “The Bark Camp Run Demonstration Constructed Wetlands: Findings and Recommendations for Future Design Criteria.” Report to US EPA.

7. Physical Impacts On Streams

7.1 Mining Activities Within 100 Feet Of A Stream

(25 Pa. Code § 86.102 and Section 6.1(h)(5) of the Coal Refuse Disposal Act of 1968)

Surface mining activities and coal refuse disposal activities within 100 ft (30.48 m) of the bank of an intermittent or perennial stream are prohibited unless a variance is obtained. A request for a variance requires that the public notice requirement of the regulations be fulfilled.

Surface mining activities within 50 ft (15.24 m) of the top of bank of a watercourse or within the 100-year floodway are prohibited unless a Water Obstruction and Encroachment Permit required by the Chapter 105 regulations is obtained. Surface mining activities include mineral extraction, haulroads, E & S or treatment facilities, stream enclosures and stream crossings. These are processed as part of the variance request and the issued permit will have the Dam Safety and Encroachment Act checked on the permit face sheet.

The Chapter 105 permitting requirements are normally waived for obstructions and encroachments when the drainage area is 100 ac (40.47 ha) or less and where the Department finds that there will not be a threat to property and the environment. A permit application fee is required by the Dam Safety and Waterway Management regulations when the drainage area exceeds 100 ac (40.47 ha).

When the headwaters of a stream are within a mining area and mining around the stream would dewater it down to the crop line, the 100 ft (30.48 m) stream barrier might not be required. Downslope of the crop line, where the stream would be expected to have its usual flow characteristics, the barrier would be required. With the exception of this example, the Department will allow mining through perennial streams only in cases where environmental enhancement would result.

When several unnamed tributaries to the same stream are shown on a permit application map the application should number the different branches of each stream to distinguish one unnamed tributary from another.

7.1.1 Culverts and Bridges

(25 Pa. Code § 105.12)

If the drainage area of the stream at the culvert or bridge is over 100 ac (40.47 ha) the application for the culvert must include the Water Obstruction and Encroachment Permit application fee. The Department may waive the permit and the application fee when the drainage area is 100 ac (40.47 ha) or less.

7.1.2 Hydraulic Capacity

(25 Pa. Code § 105.161)

The Chapter 105 design criterion for culverts in rural areas is for the structure to be able to pass the 25-year flood. It is important for the proposed bridges or culverts to fit into the topography and stream bed that exists at the crossing location. The structure should be sized so that flows can enter and exit the structure without a major constriction. This is even more important on larger drainage areas were there is a continuous flow through the structure. Culverts that constrict the existing stream cross section will cause accelerated channel erosion and flooding in the vicinity of the structure. The Department may allow culverts and bridges that do not pass the 25-year frequency to be utilized when:

1. The proposed culvert or structure fits the existing stream channel and has an equivalent cross-sectional area.
2. A means of passing the 25-year frequency flow is provided. The additional flow could be handled in a rock-lined overflow channel.
3. The size structure proposed and the amount of fill over the structure will not present a hazard if the structure was blocked or over-topped.

The appropriate District Mining Office should be contacted to discuss these situations as they occur.

Typically, corrugated steel pipe and arch pipes are used. Table 7-1 is a listing of common sizes.

Table 7-1: Typical Pipe Sizes

Circular pipe		**Pipe arch**			
Diameter		Span		Rise	
(in)	(mm)	(in)	(mm)	(in)	(mm)
12	305	n/a	n/a	n/a	n/a
15	381	17	432	13	330
18	457	21	533	15	381
21	533	24	610	18	457
24	610	28	711	20	508
30	762	35	889	24	610
36	914	42	1067	29	737
42	1067	49	1245	33	838
48	1219	57	1448	38	965
54	1372	64	1626	43	1092
60	1524	71	1803	47	1194
66	1676	77	1956	52	1321

7.1.3 Permit Application Requirements

(25 Pa. Code § 105.151)

Where a culvert or bridge is proposed the following information must be provided:

1. Plans and details showing the location, type, size, and height of the structure.
2. Calculations showing the hydraulic capacity of the structure.
3. A profile of the stream for a reasonable distance above and below the proposed location. Larger structures should also show flood water surface elevations and backwater effects of the structure.
4. A cross-section at the proposed location of the structure. Larger structures should also include upstream and downstream cross-sections.
5. A narrative description and plan for the control of channel erosion above and below the structure (i.e., riprap).
6. A narrative description of the construction methods and sequence, including water handling during construction, and erosion and sedimentation controls.

7.2 Existing Stream Crossings

(25 Pa. Code §§ 87.63, 88.43, 89.37, 90.32)

Existing stream crossings are frequently utilized for access to a mine site. Information on the existing structures in the mining permit application must be provided when the applicant proposes to utilize an existing structure. This situation would not occur if the existing crossing was part of a road that met the definition of public road in § 86.1 or common use road in § 88.1 of the regulations. In these situations, the crossing would be outside of the permit area and not need to be addressed in the permit application. The following information is required when proposing to utilize an existing structure.

1. The public notice should state that an existing stream crossing of a particular stream is to be utilized as part of the mining permit operation.
2. Section 10.3 of the Surface Mining Permit Application (Module 10: Operational Information - Existing Structures) should be completed for the existing structure. Existing structures are not addressed in the anthracite or bituminous underground permit applications; but the use of existing structures is covered in the regulations, and the informational requirements would be the same. This information should include the size, type and the condition of the structure. Other information that would be necessary for a new structure, such as the stream profile, cross-sections, watershed hydrology and hydraulic analyses, should also be provided.

If an existing structure was proposed for replacement or was to be modified, the permit processing would closely follow that for a new structure. An example of an extensive modification would be increasing the length or width of a structure.

The permit application should indicate any needed work such as placement of guide rails, widening of the roadway surface or the addition of a roadway surface.

If the drainage area is greater than 100 ac (40.47 ha) and the structure is extensively modified or replaced, then a permit application fee for an obstruction would be required.

7.3 Temporary Road Crossings

(25 Pa. Code §§ 105.441)

The District Mining Office has the authority to approve general permits under Chapter 105. BMR-GP-101 and BMR-GP-102 can be used for temporary road crossings and access road crossings, respectively.

The general permit procedure does not change or impact the way in which normal obstructions and encroachments are handled and processed. The use of the general permit as approved by the District Mining Office is limited to activities that take place within the permit area and are limited to a period of time not to exceed six months unless extended in writing by the Department. The general permit procedure would be useful for the movement of surface mining equipment or for the construction of boreholes or vents.

If the proposed location for the use of the general permit under Chapter 105 is outside the mining permit area, the permittee should contact the Regional DEP Office, Bureau of Water Quality Protection, Soils and Waterways Divisions. The addresses and phone numbers for Division of Waterways, Wetlands, and Erosion, Bureau of Water Quality Protection offices are listed in Appendix C.

7.4 Stream Relocation And Channel Changes

(25 Pa. Code §§ 87.104, 88.94, 88.189, 88.294, 105.221, 105.231)

The Department may allow relocation or a change to the channel of an intermittent stream to facilitate mining. The Department will allow relocation or a change to the channel of a perennial stream when the recharge area is being mined out or it can be demonstrated that an environmental enhancement can be achieved. The procedure described in the permit application should be followed. Chapter 105 regulations require a permit application fee for intermittent and perennial stream relocations. An example of this would be a relocation and re-establishment of surface drainage to a stream that is currently lost to deep mine workings. The constructed stream channel should duplicate the original stream capacity. Trees and shrubs are required to be planted when the existing channel has such cover, to reduce the thermal effects of having a stream channel without shade.

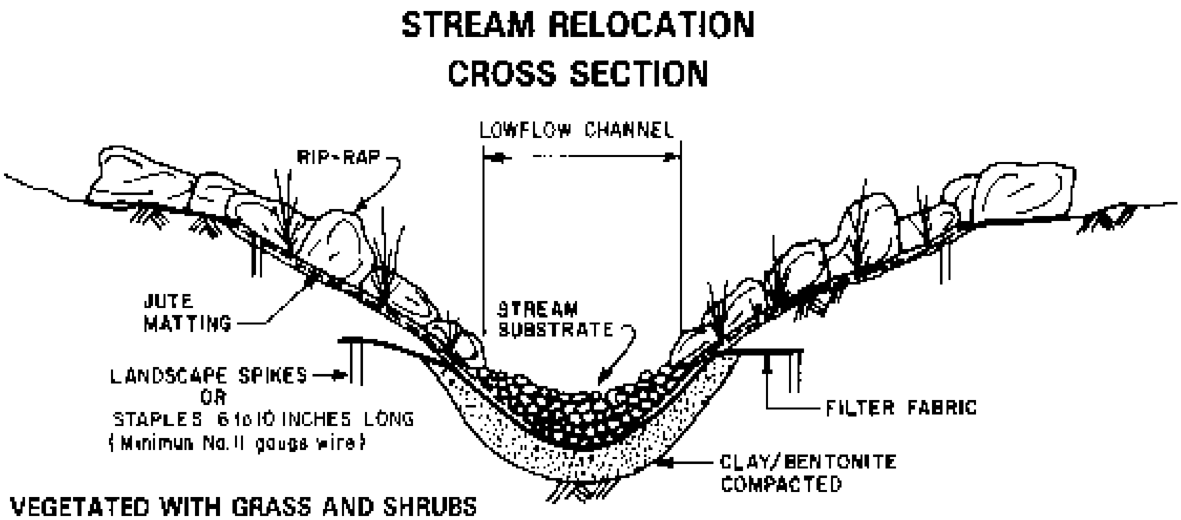
The design of stream relocations of perennial and intermittent streams must be certified by a qualified registered professional engineer.

7.5 Fish And Boat Commission Guidelines For Stream Relocations

The Pennsylvania Fish and Boat Commission has the following guidelines for perennial stream relocations for mining projects demonstrating environmental enhancement.

1. Provide the same hydraulic capacity as the present stream.
2. Approximate the original stream length by including meanders in the channel design. Meanders should not be included when the gradient exceeds 5%.
3. Limit the new average channel width to no more than 1.3 times the original channel width. Use of a low-flow channel may be necessary depending upon channel design to keep a main channel as narrow as possible. A low-flow channel provides greater water depth during periods of low flow. The greater water depth enhances fish and benthic organism survival during these critical periods.
4. Vary the channel gradient in order to establish pools and riffles. Alternate pools and riffles at distance of every 5 to 7 stream widths. Pools should be placed at the downstream end of all meanders if possible.
5. Stream banks should have a slope of 2:1 to 3:1 (horizontal to vertical).
6. Stream banks should be protected from erosion with rock rip-rap on the outside of curves and the inside of bends. Vegetative plantings restoring riparian vegetation should consist of such plant species as purple-ozier (basket) willow, tag alder, red ozier dogwood, rhododendron, autumn olive or nine-bark.
7. The stream channel should include a clay liner covered with filter cloth. Substrate material composed of the following particle sizes should be then placed upon the filter fabric preferably in the low flow channel:
   - 25% coarse rubble (6 in to 12 in diameter) (152 mm to 305 mm diameter).
   - 25% fine rubble (3 in to 6 in diameter) (77 mm to 152 mm diameter).
   - 25% coarse gravel (1 in to 3 in diameter) (25 mm to 77 mm diameter)
   - 25% fine gravel (0.12 in to 1 in diameter) (3.55 mm to 25 mm diameter).
8. Fish habitat improvement structures, in consultation with the Pennsylvania Fish and Boat Commission, should be incorporated into the final channel design plan if water quality and quantity indicates the potential for fish survival.
9. Elevated flood plains and vegetative plantings should be used when possible to control water velocities. This will keep the channel appearance as natural as possible and costs for rip-rap significantly lower. Rip-rapping, planting, or other velocity control measures are required from the edge of the low flow channel to the 25-year flood plain (Figure 7-1).

Figure 7-1: Stream Relocation Cross-Sections



7.6 Mining And Wetlands

(25 Pa. Code Chapter105)

Wetlands in Pennsylvania are considered an important aquatic resource. They provide many significant functions and values including storage of storm runoff, habitat for aquatic and terrestrial species, and recharge for groundwater and surface water systems. In the surface mine permitting process, wetlands are treated similarly to streams, with both being addressed in Module 14, Streams/Wetlands. The hydrology, vegetation, and soils of wetlands are protected from the effects of most encroachments.

In Pennsylvania wetlands are protected under both state and federal laws. Mining near wetlands is regulated at the state level under Chapter 105. At the Federal level wetlands are regulated under Section 404 of the Federal Clean Water Act (33 CFR Part 320 - 330). For non-mining programs, there is a Joint Permit Application. For coal mining, the state is the lead agency, with wetland permits being issued under a Nationwide Permit, which delegates authority to the state. For Industrial Minerals (non-coal), the federal and state permitting processes are separate and distinct. Obtaining approval under one process does not guarantee approval under the other process. On all wetlands issues, both the Pennsylvania Fish and Boat Commission and the Pennsylvania Game Commision have input to the permitting process. The following sections will discuss the laws of Pennsylvania as they pertain to mining and not the Federal laws.

7.6.1 Importance of Pre-Application Process with Wetlands

Chapter 105 requires an evaluation of all wetlands within the proposed mining permit area. The regulations distinguish between "exceptional value" wetlands and "other" wetlands. Module 14, Streams/Wetlands, of the Bituminous Surface Mine Application relates to wetlands on mine sites. It is important to identify and delineate the wetlands on the proposed permit area at the pre-application stage or even before. If wetlands exist that must be protected, then that will affect the Mining Plan and the Erosion and Sedimentation Plan. A qualified wetlands evaluator should be brought into the process at this stage. The wetlands evaluator should field delineate all of the wetlands within the proposed permit area. The applicant, the evaluator, and the Department should meet to discuss the functions and values of the delineated wetlands. If the wetlands are classified as "Exceptional Value" under Chapter 105, in general it will be very difficult to obtain permission to affect them. An example of exceptional value wetlands are those associated with a stream having a wild trout population. There are many other types of wetlands, some of which may be affected by mining, and others which are usually protected. In general, wetlands having high functions and values, such as wooded wetlands, or scrub-shrub wetlands will be protected, while other wetlands resulting from old mining pits or old sedimentation basins will probably be allowed to be affected.

7.6.2 Avoid, Minimize, Mitigate

In general it is best to avoid affecting wetlands. If that cannot be done, then the effect on the wetlands should be minimized. If neither of these is possible, then, in some instances, wetlands can be affected and then replaced at the conclusion of mining. Usually the replacement will be at a ratio of more than a one-to-one on an area basis with the same functions and values, since some replacement wetlands are not successful and even the successful ones take several years to become fully functional.

7.6.3 Protected Wetlands - Protect the Hydrology

If a wetlands must be protected and it is near the mining activity, it is necessary to protect the hydrology, or water source, to ensure that mining does not drain the wetlands. Usually a hydrogeologist will need to determine the water source and the aquitard which holds the water in the wetlands.

7.6.4 Module 14 - Streams and Wetlands

Module 14 requests information relating to wetlands that may be affected by the proposed mining activities. The information should be provided for each type of wetland. If there are several water-filled mine pits, the information may be provided for the pits as a unit. If there are wetlands along a stream, then the information required in Module 14.3 - 14.5 may be provided for that group of wetlands along the stream. The information must be provided by a qualified wetlands evaluator who will list his or her training and credentials in Module 14 and also perform the field delineation of the wetlands.

7.6.5 Replacement Wetlands

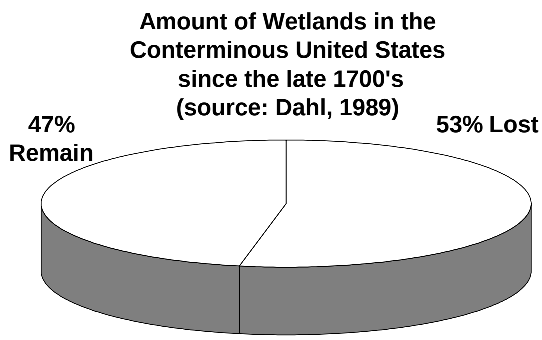
Depending upon the functions and values of the wetlands that will be, or have been, impacted by mining, the replacement wetland may be achieved by simply modifying a sedimentation pond or trying to reestablish a forested wetland or a scrub-shrub wetland. As mentioned earlier, the area of the replacement wetlands will usually be at more than a one-to-one replacement ratio. The qualified wetlands evaluator may also be used to design the replacement wetlands to assure that the functions and values closely mimic those of the wetlands that were affected by mining.

7.6.6 Facts About Wetlands

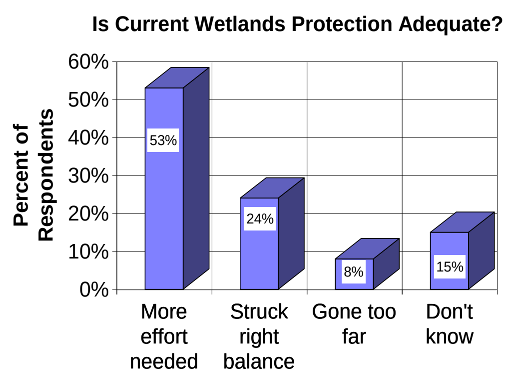
The following was adapted from "EPA Wetlands Fact Sheet #5" (Figure 7-2):

Figure 7-2: Facts About Wetlands

- Over half (53%) of the wetlands in the conterminous United States were lost between the late 1700's and mid 1970's. About 100 million acres of wetlands remain today. Source: Dahl: Status and Trends of Wetlands in the Conterminous United States.



- Coastal wetlands make up only 5% of the wetland types in the continental United States; inland wetlands such as freshwater swamps, prairie potholes, bogs, and fens make up the remaining 95% of wetland types. Source: Office of Technology Assessment, 1984.
- It has been estimated that up to forty-three percent (43%) of the threatened and endangered species listed in the United States by the US Fish and Wildlife Service rely directly or indirectly on wetlands for their survival. Source: USFWS.
- A recent survey showed that when asked whether they felt wetlands protection efforts were adequate, 53% of respondents replied more effort was needed, 24% said current efforts struck the right balance, and 8% said it had gome too far. Source: Times Mirror Magazines /Roper Survey as cited in *Popular Science* July 1992, p. 52.



- From the mid-1970's to mid-1980's, wetlands were lost at an annual rate of 290,000 acres per year. Source: Dahl and Johnson: Status and Trends of Wetlands in the Conterminous United States. Mid-970's to Mid-1980's USFWS, 1991.
- Nationally, 80% of America's breeding bird population requires bottomland hardwoods for survival; bottomland (BLH) systems are wooded swamps found predominantly in the Southeastern United States. Source: Warton and Kitchen, 1982.
- In the United States, over-logging of mature bottomland hardwood (BLH) forests is believed to have caused the extinction of the Ivory-Billed Woodpecker, North America's largest woodpecker. Source: Harris and Gosselink, Ecological Processes and Cumulative Impacts. p. 308.

7.7 High Quality And Exceptional Value Streams

(25 Pa. Code Chapter 93)

Protected water uses are listed in § 93.3, Table 1. High Quality Waters are defined as "A stream or watershed which has excellent quality waters and environmental or other features that require special water quality protection." Exceptional Value Waters are defined as "A stream or watershed which constitutes an outstanding national, State, regional, or local resource, such as waters of national, State or county parks or forests, or waters which are used as a source of unfiltered potable water supply, or waters of wildlife refuges or State game lands, or waters which have been characterized by the Fish Commission as "Wilderness Trout Streams, and other waters of substantial recreational or ecological significance." Drainage lists giving the protected water uses are given in § 93.9. The regulations refer to the former Fish Commission, which is now the Fish and Boat Commission.

Wastewater treatment requirements for High Quality Waters are found in § 95.1(b): "Waters having a water use designated as 'High Quality Waters' in §§ 93.6 and 93.9 (relating to general water quality criteria; and designated water uses and water quality criteria) shall be maintained and protected at their existing quality or enhanced, unless the following are affirmatively demonstrated by a proposed discharger of sewage, industrial wastes, or other pollutants: (1) The proposed new, additional, or increased discharge of pollutants is justified as a result of necessary economic or social development which is of significant public value. (2) The proposed discharge or discharges, alone or in combination with other anticipated discharges of pollutants to the waters, will not preclude any use presently possible in the waters downstream from the waters, and will not result in a violation of any of the numerical water quality criteria specified in § 93.9 which are applicable to the receiving waters."

Wastewater treatment requirements for Exceptional Value Waters are found in § 95.1(c): "Waters having a water use designated as 'Exceptional Value Waters' in § 93.9 shall be maintained and protected at a minimum at their existing quality. The Department will hold a public hearing on any proposed discharge into waters having a water use designated as 'Exceptional Value Waters' in § 93.9."

Whether or not a watershed has been designated as a "High Quality Watershed" or "Exceptional Value Watershed" in § 93.9, streams with naturally reproducing wild trout populations are sensitive to mining; and additional precautions are warranted to maintain the existing water quality and its uses. These additional precautions include, but are not limited to, construction of enlarged sediment ponds, addition of more haul road sediment traps, and minimizing the amount of unreclaimed acreage. The Pennsylvania Fish and Boat Commission maintains an inventory of wild trout streams.

A copy of Chapter 93 may be obtained by writing to the Bureau of Water Quality Protection, P.O. Box 8465, Harrisburg, PA 17105, or calling (717) 787-9637.

8. Mining Near Public Roads

8.1 Introduction

(25 Pa. Code §§ 86.102, 87.78, 88.57, 90.41)

Mining is prohibited within 100 ft (30.48 m) from the outside right-of-way line of any public road, except where the Department, with concurrence of the agency with jurisdiction over the road, allows the public road to be relocated or the area affected to be within 100 ft (30.48 m) of the right-of-way.

8.2 Permitting Requirements

When an application for a mining permit is submitted to the Department, a map showing the permit area is forwarded to the local municipality and the PennDOT Engineering District Office. Public notice is required where mining activities are proposed within 100 ft (30.48 m) of the right-of-way of a public road. If the mining activities include temporarily relocating a public road, the public notice should so indicate.

Prior to submitting an application for a permit to conduct surface mining activities, mine operators should contact PennDOT or the agency with jurisdiction over the road relative to plans that involve relocating roads or mining within 100 ft (30.48 m) of the right-of-way of the road. State route, segment and offset information can be obtained from the PennDOT Engineering District or the appropriate County Maintenance Department. The nearest intersection should be provided as a reference point.

Whenever surface mining activities are expected to create hazardous conditions near a state highway, PennDOT policy is to require an earthen barrier with safety barricade and warning signs. Figure 8-1 shows an example of such a barrier. In some cases a natural earthen barrier with a constructed safety barricade and warning signs will be adequate for traffic and safety protection. Figure 8-2 shows an example of such a barrier. The PennDOT District Engineering Office or the agency with jurisdiction over the road should be contacted for site specific requirements. The addresses and telephone numbers for PennDOT District Engineering Offices can be found in Appendix C.

Figure 8-1: PennDOT Requirements , Typical Cross-Section for Proposed Activities Within 100 ft (30.48 m) of the Right-of-Way Along State Routes.

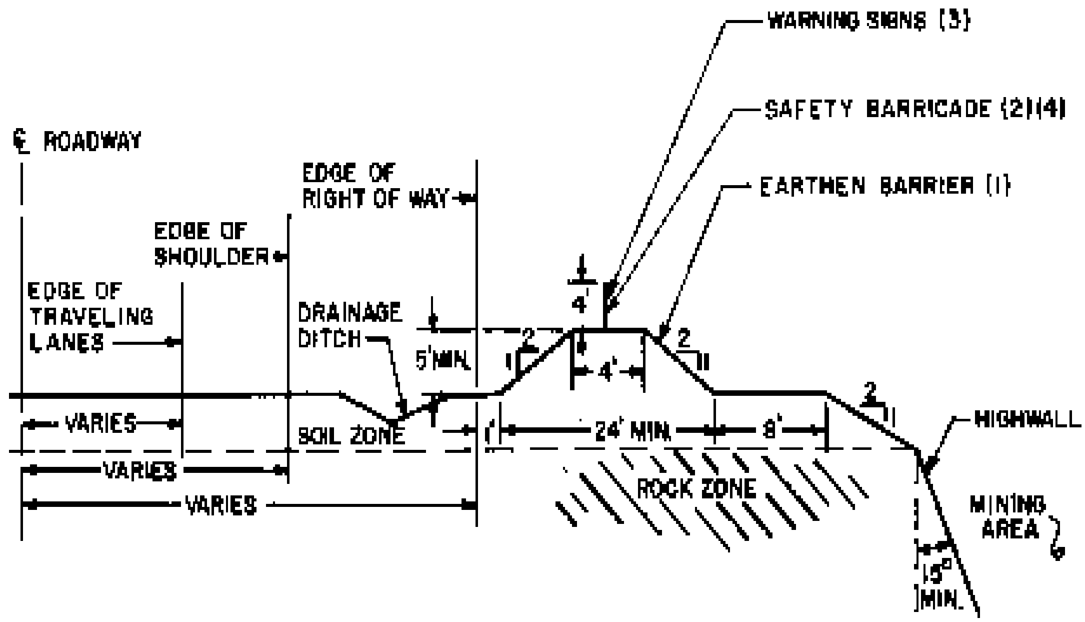
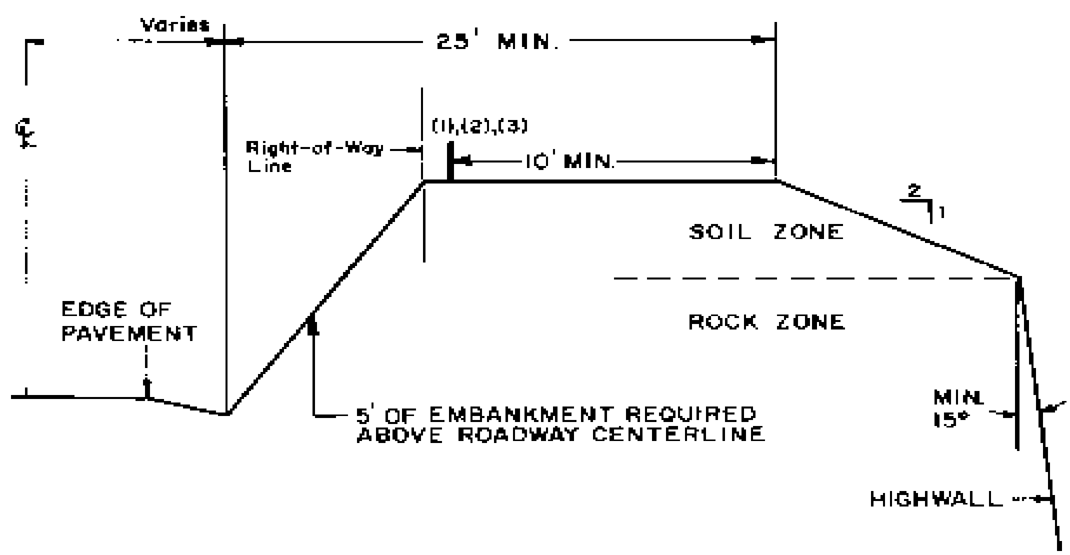


Figure 8-2: Using Natural Earthen Barrier (Compare to Figure 8.1)



9. Slope Stability

9.1 Introduction

(25 Pa. Code §§ 87.1, 87.73, 87.79, 87.81, 87.131, 87.174, 88.313, 90.39, 90.112, 90.113, 90.122)

The stability of certain structures proposed in connection with mining activities, as well as steep slope mining and reclamation activities, is a major concern regarding environmental pollution prevention and public health and safety. Rules and regulations have been promulgated to ensure certain structures associated with mining activities and certain mining and reclamation proposals are designed and constructed properly. Therefore, a "stability analysis" must be provided to the Department for evaluation and approval of these activities.

9.2 Regulations

The regulatory requirements pertaining to stability analysis are §§ 87.1, 87.73, 87.79, 87.81, 87.131, 87.174, 87.175, 88.313, 90.39, 90.112, 90.113, and 90.122. Definitions for various terms are given in §§ 87.1 and 90.1.

9.3 Stability Analysis

A stability analysis must be conducted for all proposals to:

1. Dispose of excess spoil from mining operations (§ 87.131).
2. Conduct surface mining and reclamation operations on steep slopes (§ 87.174). A steep slope is a slope of more than 20° (36%) or such lesser slope as may be designated by the Department after consideration of soil, climate and other characteristics of the region.
3. Request a variance from regrading to approximate original contour (§ 87.175).
4. Construct anthracite coal refuse banks (§ 88.313).
5. Construct impoundments or dams with a volume greater than 20 ac ft (2.47 ha m). Refer to §§ 87.73, 90.39, 90.112, 90.113, and 90.122.
6. Construct coarse coal refuse piles (§§ 90.39 and 90.122).
7. Develop coal refuse disposal sites in any location where the average slope of the coal refuse disposal area exceeds 1 vertical: 2 horizontal, or 36% (§§ 87.131 and 90.122).
8. Other structures as required by the Department to protect public health and safety. These criteria may be based on such items as the size of the facility and its proximity to public roadways, streams, and populated areas.

A stability analysis must be provided in proposals for the following coal refuse disposal facilities:

1. An impoundment or dam more than 20 ft (6.1 m) in height as measured from the upstream toe of the embankment to the crest of the emergency spillway or that has a storage volume greater than 20 ac ft (2.47 ha m).
2. A location where the average slope of the coal refuse disposal areal location exceeds 1v:2.8h or 36%.
3. Other structures as required by the Department to protect public health and safety. These criteria may be based on such items as size of the facility and proximity to public roadways, streams and populated areas.

The slope stability analysis provided for the forementioned activities should include the following:

1. Minimum required computed static and seismic factors of safety.
    - For excess spoil disposal fills, a minimum long-term static factor of safety of 1.5 and a seismic factor of safety of 1.1 is required (§ 87.131).
    - For steep-slope operations, a minimum static factor of safety for all portions of the reclaimed land of 1.3 is required. There is no minimum requirement for a seismic factor of safety on these operations (§ 87.174).
    - For coal refuse disposal sites and impoundments, a minimum long-term static factor of safety of 1.5 and a minimum seismic factor of safety of 1.2 is required (§ 90.122).
    - The lowest factors of safety for the most critical zones within and beneath the proposed structures must be listed.
2. Methodology utilized in determining factors of safety and assumptions that are the basis for calculations.
    - Utilize an acceptable computer model.
    - Provide adequate field and laboratory testing such that actual conditions and properties of materials are ascertained and utilized in computer modeling.
    - Cohesion values and internal angle of friction for each soil type and waste material associated with modeling must be verified by laboratory tri-axial testing of materials in a consolidated, undrained state at the required field density.
    - For refuse disposal operations, the computer model should include at least three zones of soil test parameters: (bedrock or base material, liner and refuse material), along with an acceptable phreatic water elevation in the pile or fill if a saturated condition is not utilized in the analysis.
3. Additional stability requirements and considerations:
    - If there are any clay horizons or known unstable units in the strata beneath the proposed structure, explain what measures will be taken to remove or stabilize these units.
    - If there are any saturated zones or layers subject to artesian pressures beneath the proposed structure, explain what measures will be taken to remove or drain these areas.

- The effect of subsidence from deep or auger mining on the stability of the proposed structure. Describe what measures will be taken to minimize subsidence beneath the proposed area to ensure stability of the area.
- The effect of blasting within the proposed area or adjacent areas on the stability of the proposed structure (seismic stability analysis).
- The presence of organic or other soft material that would jeopardize the stability of the embankment.
- If the minimum factor of safety requirements cannot be met, keyway cuts or excavation into stable bedrock or bedrock toe buttresses may be proposed and included in modeling to stabilize a fill.

4. The following are requirements to follow when surface mining occurs in steep-slope areas:
    - No material except material used to construct road embankments shall be placed downslope below the bench or mining cut.
    - The disturbed area shall be returned to approximate original contour with compacted spoil, except for approved terrace backfill on pre-act pits.
    - Material in excess of that required for backfilling and grading shall be disposed of as excess spoil.
    - Woody materials shall not be buried in the backfill unless the applicant demonstrates that the proposed method for disposal will not deteriorate the stability of the backfilled area.
    - Unlined or unprotected drainage channels shall not be constructed on the backfilled areas.

10. Special Handling Of Overburden Strata

Special handling of overburden strata is a means by which certain overburden strata are selectively placed within the mine spoil during the surface mining in order to prevent postmining water quality problems. Overburden analysis is usually used to identify which strata are to be selectively handled. Both alkaline and acidic strata can be proposed for selective, or special, handling. Special handling can include such things as placement of selected spoil in pods, clay capping of pods, constructing highwall or pit floor drains, selective placement or addition of alkaline strata.

Plans for special handling of overburden strata must include a detailed operations plan including the following information:

1. A list of the specific equipment to be used on the job and those used to special handle the selected material.
2. An overburden analysis that will identify the strata to be special handled.
3. A description of how the selected strata will be analyzed and determined in the field. The strata to be special handled must be visually identifiable in the field by color, rock type, or location adjacent to the mineable coal seams.
4. An estimate of the total weight and volume of overburden and potentially toxic strata to be handled.
5. A copy of the blast plan showing how alkaline and toxic overburden can be selectively handled.
6. A description of where toxic strata will be placed, how it will placed, and how it will be compacted. The placement of toxic material at or near the expected postmining water table shall not be allowed.
7. A representative cross-section of the final reclamation showing the location of the toxic strata in relation to the pit floor, final highwall, final reclamation and coal seams.
8. Identification of who will be responsible for identifying the strata to be selectively handled and implementing the special handling plan.

Upon approval of a special handling plan, the Department will meet with representatives of the operator to discuss implementation of the plan. The operator must notify the Department when the toxic material identified in the application is first encountered.

The following items should also be considered in planning and designing special handling plans.

1. Draglines and bulldozers are typically not effective as special handlers, since it is difficult to segregate material with them.
2. Trucks and loaders or scrapers can be effective for selective handling, since they can segregate different materials.
3. The blasting plan is very important to special handling. Material which must be selectively handled cannot be cast blast.
4. Large mining areas are needed to allow practical handling of selected zones.

5. For special handling plans to be implemented the zones to be selectively handled must be easily identifiable by the inspector, the mine foreman and the equipment operator.

11. Review Of Permit Applications By Other Agencies

The following agencies are sent general information about sections of permit applications. The comments received are considered during the permit review process.

Bureau of Abandoned Mine Reclamation - Reviews application for any effect on proposed abandoned mine reclamation projects.

Regional Office Water Supply (DEP) - Reviews application for any effect proposed activities would have on public water supplies.

Regional Office Water Management (DEP) - Provides NPDES effluent limits when requested and has responsibility under Chapter 105.

Bureau of Topographic and Geologic Survey - Uses application information to maintain database of information on coal mining.

County Conservation District/Natural Resources Conservation Service - Review all prime farmland restruction plans and comment on erosion and sediment control plans.

Fish and Boat Commission - Reviews application for impacts on aquatic resources, threatened and endangered species an d wetlands.

Game Commission - Reviews application for impacts on wildlife resources, threatened and endangered species an d wetlands.

Historical and Museum Commission - Reviews applications to determine effect on prehistoric archaeological and historical sites.

PennDOT - Reviews applications when proposed activity is within 100 ft (30.48 m) of the right-of-way of a state road or where the haul road outlets to a state road.

Local Municipality - Reviews applications to determine effect of the proposed activity on township roads or other resources.

Planning Agencies - Review applications to determine effect of proposed activity on local resources.

Water Companies - Review applications to assess potential impacts of proposed activities.

U. S. Army Corps of Engineers - Reviews applications to determine if an individual permit or authorization is needed under Section 404 of the Clean Water Act. Determines effect of proposed activities on their flood protection projects.

Mining Safety and Health Administration - Reviews applications to determine adequacy of larger mining impoundments and potential hazards to nearby underground mines.

12. References

Barfield, B. J., R. C. Warner, and C. T. Haan, 1983. Applied Hydrology and Sedimentology for Disturbed Areas. Oklahoma Technical Press, Stillwater, Oklahoma. 603 p.

Beasley, R. P., J. M. Gregory, and T. R. McCarty, 1984. Erosion and Sediment Pollution Control. Iowa State University Press, Des Moines, Iowa. 354 p.

DER, 1990. Erosion and Sediment Pollution Control Program Manual. Bureau of Soil and Water Conservation.

DER, 1992. Special Protection Waters Implementation Handbook. Bureau of Water Quality Protection.

Dietz, J. M., and D. M. Stidinger, 1993. Evaluation of wetlands constructed for the treatment of acidic mine drainage, report to the Department of Environmental Resources (Now Department of Environmental Protection), Harrisburg, Pennsylvania.

EPA, 1982. Development Document for Effluent Limitations Guidelines and Standards for the Coal Mining Point Source Category. Office of Water, Effluent Guidelines Division, Washington, DC . 408 p.

EPA, 1976. Erosion and Sediment Control, Surface Mining in the Eastern US - Planning. 102 p.

Geyer, A .R. and J. P. Wilshusen, 1982. Engineering Characteristics of the Rocks of Pennsylvania. DER, Bureau of Topographic and Geologic Survey. 300 p.

Goldman, S. J., K. Jackson, and T. A. Bursztynsky, 1986. Erosion & Sediment Control Handbook. McGraw-Hill, New York.

Gray, P. H. and A. T. Leiser, 1982. Biotechnical Slope Protection and Erosion Control. Van Nostrand, Reinhold, New York.

Hedin, R. S., 1989. Treatment of coal mine drainage with constructed wetlands. US Bureau of Mines, Pittsburgh Research Center. In: Wetlands Ecology and Conservation: Emphasis in Pennsylvania, edited by S. K. Majumdar, R .P. Brooks, F. J. Brenner, and R.W. Tiner, Jr., Pennsylvania Academy of Science, Easton, Pennsylvania.

Hedin, R. S., Nairn, R.W, and Kleinmann, R. L. P., 1994. U.S. Bureau of Mines, Information Circular IC 9389, "Passive treatment of coal mine drainage," U.S. Bureau of Mines, Washington, DC.

Hedin, R.S., and G.R. Watzlaf, 1994. The effects of anoxic limestone drains on mine water chemistry. Vol. 1, pp. 185-194 in Proceedings: International Land Reclamation and Mine

Drainage Conference and International Conference on the Abatement of Acidic Drainage, U.S. Department of the Interior, Bureau of Mines SP 06A-94, Washington, DC.

Hellier, W. W., 1989. Constructed wetlands in Pennsylvania - an overview. Department of Environmental Resources, Bureau of Mining Programs, Paper presented at International Conference on Biohydrometallurgy, Jackson Hole, Wyoming.

Hellier, W.W., 1994. "Best Professional Judgment Analysis for the Treatment of Postmining Discharges from Surface Mining Activities." Commonwealth of Pennsylvania, Department of Environmental Protection, Harrisburg, Pennsylvania.

Hellier, W.W., 1996. The Bark Camp Run demonstration constructed wetlands: findings and recommendations for future design criteria. Report to US EPA. PA Department of Environmental Protection, Harrisburg, Pennsylvania.

Hellier, W.W., 1996. The Bark Camp Run demonstration constructed wetlands: findings and recommendations for future design criteria. p 550-559 in Proceedings: Thirteenth Annual Meeting, American Society for Surface Mining and Reclamation, May 18-23, 1996, Knoxville, Tennessee.

Hersfield, D. M., 1961. Rainfall Frequency Atlas of the United States. U.S. Weather Bureau Technical Paper 40.

Loper, C. A. and K. L. Wetzel, 1988. Sediment Loads, Discharges, and Yields in the East Branch Mahoning Creek Basin, Clearfield and Jefferson Counties, Pennsylvania, June 1979 Through September 1981. US Geological Survey, Water-Resources Investigations Report 85-4213, Harrisburg, Pennsylvania. 26 p.

Lovell, H, 1973. An Appraisal of Neutralization Processes to Treat Coal Mine Drainage. EPA-670/2-73-093.

National Crushed Stone Association, 1982. Quarried Stone For Erosion and Sediment Control. National Crushed Stone Association, 1415 Elliot Place N.W., Washington, DC 20007. 32 p.

PennDOT, 1987. Specifications Publication 408.

Pennsylvania State University, Cooperative Extension Service,1987. Fish Ponds, Construction and Management in Pennsylvania, Special Circular 263, Natural Resources Series 437 Agricultural Administration Bldg., University Park, Pennsylvania.

Reed, L. A. and R. A. Hainly, 1989. Suspended-Sediment Yields From An Unmined Area and from Mined Areas Before and After Reclamation in Pennsylvania, June 1978-September 1983. U.S. Geological Survey, Water-Resources Investigation Report 88-4005. Harrisburg, Pennsylvania.. 50 p.

Sievers, D. M., G. L. Lentz, and R. P. Beasley, 1970. Movement of Agricultural Fertilizers and Organic Insecticides in Surface Runoff. Trans. American Society of Agricultural Engineers 13(3). p. 323-325.

Skousen, J., 1990. An Evaluation of Acid Mine Drainage Treatment Systems and Costs, in Proceedings: Society for Mining Engineers.

Skousen, J., 1989. Chemicals for treating acid mine drainage, Green Lands Quarterly, Vol. 18, No. 3, Fall, pp. 36-40, published by the West Virginia Mining and Reclamation Association.

OSM, 1988. Surface and Groundwater Training Course Manual.

Stares, D. J., 1989. Coal mining effluent limitations, in Proceedings: A Conference on State Surface Mining Regulation, May 1989, Richmond, Virginia. 8 p.

USDA, Natural Resources Conservation Service,1985. Earth Dams and Reservoirs. Technical Release No..60.

USDA, Natural Resources Conservation Service, 1972. Estimating Rainfall-Erosion Soil Losses On Construction Sites and Similarly Disturbed and Unvegetated Areas in Pennsylvania, 30 p.

USDA, Natural Resources Conservation Service, 1969. Engineering Field Manual For Conservation Practices.

USDI, Bureau of Reclamation, 1977. Design of Small Dams. US Government Printing Office, Washington, DC. 816 p.

USDL, Mine Safety and Health Administration, 1979. Design Guidelines for Coal Refuse Piles and Water, Sediment, or Slurry Impoundments and Impounding Structures. Informational Report IR 1109, 29 p.

USDL, Mine Safety and Health Administration, 1983. Design Guidelines for Coal Refuse Piles and Water, Sediment, or Slurry Impoundments and Impounding Structures. Amendment to Informational Report IR 1109, 6 p.

Wischmeier, W. H. and D. D. Smith, 1965. Predicting Rainfall Losses from Cropland East of the Rocky Mountains. U. S. D. A., Agricultural Handbook 282, 47 p.

The following publications are available from the National Technical Information Service; 5285 Port Royal Road, Springfield, VA 22161, Telephone: (703) 487-4650 for general information or (703) 487-4028 for orders:

Engineering Field Manual**,** USDA, NRCS PB-85-175164/As

Technical Release No. 55, PB-87-101580/As

Technical Release No. 55, PB-87-101598/As (with microcomputer program)

Design of Roadside Channels with Flexible Linings, PB-89-122584/As

Hydraulic Design of Highway Culverts, PB-86-196961/As

Hydraulic Design of Energy Dissipaters, PB-86-180205/As (Hydraulic Engineering Circular No.14)

13. Appendix A: Helpful Information

Table 0-1: Unit Weights of Different Materials (Geyer and Wilshusen, 1982)

Material	English Units	SI Units
Water	62.4 lb/ft^3	1.00 g/cm^3
Water	8.34 lb/gal	1.00 kg/L
Anthracite coal (processed)	50 to 55 lb/ft^3	0.80 to 0.88 g/cm^3
Anthracite coal (in ground)	90 to 100 lb/ft^3	1.44 to 1.60 g/cm^3
Anthracite silt	40 to 44 lb/ft^3	0.64 to 0.71 g/cm^3
Bituminous coal (loose)	68 lb/ft^3	1.09 g/cm^3
Bituminous coal (in ground)	80 lb/ft^3	1.28 g/cm^3
Fly ash (maximum dry density)	75 to 107 lb/ft^3	1.20 to 1.72 g/cm^3
Shale	134 to 165 lb/ft^3	2.15 to 2.65 g/cm^3
Silty shale	145 to 169 lb/ft^3	2.33 to 2.71 g/cm^3
Sandy shale	154 to 167lb/ft^3	2.47 to 2.67 g/cm^3
Indurated clay	131 to 170 lb/ft^3	2.10 to 2.73 g/cm^3
Claystone	148 to 164 lb/ft^3	2.37 to 2.63 g/cm^3
Siltstone	149 to 166 lb/ft^3	2.39 to 2.66 g/cm^3
Limestone	162 to 178 lb/ft^3	2.60 to 2.85 g/cm^3
Sandstone	165 to 169 lb/ft^3	2.65 to 2.71 g/cm^3

Table 0-2: Estimated Quantities

Material	Basis	English	SI
Coal	80 lb/ft^3	1750 T ac^{-1} ft^{-1}	12826 t ha^{-1} m^{-1}
Shale	167 lb/ft^3	3600 lb/ft^3	26775 t ha^{-1} m^{-1}
Sandstone	168.5 lb/ft^3	3670 lb/ft^3	27015 t ha^{-1} m^{-1}
Siltstone	172 lb/ft^3	3750 lb/ft^3	27577 t ha^{-1} m^{-1}
Limestone	113.52 lb/ft^3	9.46 lb ft^{-2} in^{-1}	18201 t ha^{-1} m^{-1}
Crushed limestone	110.19 lb/ft^3	200 T ac^{-1} in^{-1}	17667 t ha^{-1} m^{-1}

Table 0-3: Estimated Quantity of Bituminous Coal in Place (T/ac; basis 80 lb/ft^3 and t/ac, basis 1.29 g/cm^3)

ft	0	1	2	3	4	5	6	7	ft
in									in
0	0	1742	3485	5227	6970	8712	10454	12197	0
1	145	1880	3630	5372	7115	8857	10600	12342	1
2	290	2033	3775	5518	7260	9002	10745	12487	2
3	436	2178	3920	5663	7405	9148	10890	12632	3
4	581	2323	4066	5808	7550	9293	11035	12778	4
5	726	2468	4211	5953	7696	9438	11180	12923	5
6	871	2614	4356	6098	7841	9583	11326	13068	6
7	1061	2759	4501	6244	7986	9728	11471	13213	7
8	1162	2904	4646	6389	8131	9874	11616	13538	8
9	1307	3049	4792	6534	8276	10109	11761	13504	9
10	1452	3194	4937	6679	8422	10164	11906	13649	10
11	1597	3340	5082	6824	8567	10309	12052	13794	11

m	0.0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	m
cm									cm
0.0	0	3909	7819	11728	15639	19547	23456	27367	0.0
2.5	325	4218	8145	12053	15964	19873	23783	27692	2.5
5.1	651	4561	8470	12381	16289	20198	24109	28017	5.1
7.6	978	4887	8795	12706	16615	20526	24434	28343	7.6
10.2	1304	5212	9123	13032	16940	20851	24759	28670	10.2
12.7	1629	5537	9448	13357	17268	21176	25085	28996	12.7
15.2	1954	5865	9774	13682	17593	21502	25412	29321	15.2
17.8	2381	6190	10099	14010	17918	21827	25738	29646	17.8
20.3	2607	6516	10424	14335	18244	22154	26063	30375	20.3
22.9	2933	6841	10752	14660	18569	22682	26388	30299	22.9
25.4	3258	7166	11077	14986	18897	22805	26714	30624	25.4
27.9	3583	7494	11403	15311	19222	23130	27041	30950	27.9

Other useful conversions:

Temperature:

- F = 32 + 9C/5
- C= 5 (F-32)/9
- K = 273.16 + C
- R = 459.69 + F

Energy

- 1 BTU = 0.252 kcal
- 1 kcal = 3.968 BTU

14. Appendix B: Units And Conversions

The measurement system adopted for most of the world is called the International System of Units (SI, Systéme International). It is a coherent system understood readily by all, because there is only one base unit for each physical quantity. Units for all other quantities are derived from these base units by simple equations.

SI is constructed from seven base units for independent quantities plus two supplementary units for plane and solid angles. Most physicochemical quantities can be expressed in terms of these units. The units are given in Table 14-1:

Table 0-1: Base Units in Systeme International

Physical Quantity	**Unit**	**Symbol**
electric current	ampere	A
luminous intensity	candela	cd
thermodynamic temperature	kelvin	K
mass	kilogram	kg
length	meter	m
amount of substance	mole	mol
time	second	s
plane angle	radian	rad
solid angle	steradian	sr

The units are given multiplying prefixes to simplify reporting and conversation. These standard prefixes are given in Table 14-2:

Table 0-2: Multiplying Prefixes in Systeme International

Factor	**Prefix**	**Symbol**		**Factor**	**Prefix**	**Symbol**
10^{-18}	atto	a		10^{1}	deka	da
10^{-15}	femto	f		10^{2}	hecto	h
10^{-12}	pico	p		10^{3}	kilo	k
10^{-9}	nano	n		10^{6}	mega	M
10^{-6}	micro	μ		10^{9}	giga	G
10^{-3}	milli	m		10^{12}	tera	T
10^{-2}	centi	c		10^{15}	peta	P
10^{-1}	deci	d		10^{18}	exa	e

These prefixes are always combined with the unit without any spacing between the prefix and the unit; e.g., for millimeter, we write **mm**; for kilogram, we write **kg**.

SI is recognized by most of the world's population; however, the Department recognizes that most people dealing with mining operations are more familiar with the English system, and that most maps, measuring devices, price quotations, and pieces of equipment use English units. Accordingly, this Appendix provides a set of conversion tables.

Table 0-3: Length Conversions

English unit	**Symbol**		**Factor**		**SI unit**	**Symbol**
mile	mi	=	1.6093	x	kilometer	km
yard	yd	=	0.9144	x	meter	m
foot	ft	=	0.3048	x	meter	m
inch	in	=	2.5400	x	centimeter	cm
inch	in	=	25.4000	x	millimeter	mm
SI unit	**Symbol**		**Factor**		**English unit**	**Symbol**
kilometer	km	=	0.6214	x	mile	mi
meter	m	=	1.0936	x	yard	yd
meter	m	=	3.2808	x	foot	ft
meter	m	=	39.3701	x	inch	in
centimeter	cm	=	0.3937	x	inch	in
millimeter	mm	=	0.0394	x	inch	in

Table 0-4: Area Conversions

Derived unit	**Symbol**		**Factor**		**Englishunit**	**Symbol**
acre	ac	=	43560	x	square foot	ft^2
square mile	mi^2	=	640	x	acre	ac
square foot	ft^2	=	144	x	square inch	in^2
		=		x		
English unit	**Symbol**		**Factor**		**SI unit**	**Symbol**
acre	ac	=	0.4047	x	hectare	ha
acre	ac	=	4047	x	square meter	m^2
acre	ac	=	4.047×10^{-3}	x	square kilometer	km^2
square mile	mi^2	=	2.5900	x	square kilometer	km^2
square yard	yd^2	=	0.8361	x	square meter	m^2
square foot	ft^2	=	0.0929	x	square meter	m^2
square inch	in^2	=	6.4516	x	square centimeter	cm^2
SI unit	**Symbol**		**Factor**		**English unit**	**Symbol**
hectare	ha	=	2.4711	x	acre	ac
square kilometer	km^2	=	0.3861	x	square mile	mi^2
square meter	m^2	=	1.1960	x	square yard	yd^2
square meter	m^2	=	10.7639	x	square foot	ft^2
square centimeter	cm^2	=	0.1550	x	square inch	in^2
				x		
Derived unit	**Symbol**		**Factor**		**SI unit**	**Symbol**
hectare	ha	=	10^4	x	square meter	m^2

Table 0-5: Volume Conversions

Derived unit	**Symbol**		**Factor**		**Englishunit**	**Symbol**
gallon	gal	=	231	x	cubic inch	in^3
gallon	gal	=	0.1337	x	cubic foot	ft^2
acre foot	ac ft	=	3.2585×10^5	x	gallon	gal
acre inch	ac in	=	2.7154×10^4	x	gallon	gal
English unit	**Symbol**		**Factor**		**SI unit**	**Symbol**
gallon	gal	=	3.7854×10^{-3}	x	cubic meter	m^3
gallon	gal	=	3.7854	x	liter	L
quart	qt	=	0.9464	x	liter	L
cubic yard	yd^3	=	0.7646	x	cubic meter	m^3
cubic foot	ft^2	=	0.02832	x	cubic meter	m^3
cubic inch	in^2	=	16.3871	x	cubic centimeter	cm^3
acre inch	ac in	=	102.7948	x	cubic meter	m^3
acre foot	ac ft	=	0.1233	x	hectare meter	ha m
acre foot	ac ft	=	12.3348	x	hectare centimeter	ha cm
SI unit	**Symbol**				**English unit**	**Symbol**
cubic meter	m^3	=	264.1728	x	gallon	gal
liter	L	=	0.2642	x	gallon	gal
liter	L	=	1.0567	x	quart	qt
cubic meter	m^3	=	1.3080	x	cubic yard	yd^3
cubic meter	m^3	=	35.3147	x	cubic foot	ft^2
cubic centimeter	cm^3	=	0.0610	x	cubic inch	in^2
cubic meter	m^3	=	9.7286×10^{-3}	x	acre inch	ac in
hectare meter	ha m	=	8.1073	x	acre foot	ac ft
hectare centimeter	ha cm	=	0.0811	x	acre foot	ac ft
Derived unit	**Symbol**		**Factor**		**SI unit**	**Symbol**
liter	L	=	1000	x	cubic centimeter	cm^3
liter	L	=	.001	x	cubic meter	m^3

Note: we also include *application rates* for soil amendments in Table 14-7. Application rates are given as a mass per unit area, not to be confused with a *pressure*, which is a force per unit area.

Table 0-6: Mass Conversions

English unit	**Symbol**		**Factor**		**SI unit**	**Symbol**
US Tons	T	=	0.90718	x	Tonnes (metric tons)	t
pound mass	lb_m	=	0.45359	x	kilogram	kg
pound mass	lb_m	=	4.5359×10^5		milligram	mg
ounce mass	oz_m	=	28.3495	x	gram	g
ounce mass	oz_m	=	28350	x	milligram	mg
SI unit	**Symbol**				**English unit**	**Symbol**
Tonnes (metric tons)	t	=	1.1023	x	US Tons	T
kilogram	kg	=	2.2046	x	pound mass	lb_m
milligram	mg	=	2.2046×10^{-6}	x	pound mass	lb_m
gram	g	=	0.03527	x	ounce mass	oz_m
milligram	mg	=	3.5274×10^{-5}	x	ounce mass	oz_m

Table 0-7: Yield or Application Rate Conversions

English unit	**Symbol**		**Factor**		**SI unit**	**Symbol**
US Tons per acre	T/ac	=	2.2417	x	Tonnes per hectare	t/ha
US Tons per acre	T/ac	=	0.22417		kilograms per square meter	kg/m^2
pounds mass per acre	lb_m/ac	=	1.1219		kilograms per hectare	kg/ha
SI unit	**Symbol**				**English unit**	**Symbol**
Tonnes per hectare	t/ha	=	0.4461	x	US Tons per acre	T/ac
kilograms per square meter	kg/m^2	=	4.4609	x	US Tons per acre	T/ac
kilograms per hectare	kg/ha	=	0.8922	x	pounds mass per acre	lb_m/ac

Note: Weight is a force. Force is defined as the time rate of change of momentum. If mass is constant, force equals mass times acceleration. There is often confusion between mass and weight. In SI, there is less confusion, because *weight* is expressed in *newtons* (N); and represents a *mass* of 1kg *accelerated at* 9.8068 m/sec^2 when measured at average conditions at the earth's surface. The term "pound" is used interchangeably in the English system to represent both weight and mass. Technically, a pound (weight) is a *mass* of one *slug* accelerated at 32.174 ft/sec^2. Then (32.174 slug ft sec^{-2}) = 1 lb_f and 32.174 slug ft sec^{-2} lb_f^{-1} is the pure number 1. Because virtually nobody uses the technical term *slug* in everyday conversation, the term *slug* has been replaced by the term "pound mass", or lb_m. It is this lb_m which is equal to 0.454 kg. It is extremely important to keep mass and weight (force) straight when calculating pressure, which is defined as a *force* per unit area, not a mass per unit area. Use the conversion 1 = 32.174 lb_m ft lb_f^{-1} sec^{-2}, often designated as g_c. Atmospheric pressure is 14.70 lb_f/ft^2.

Table 0-8: Presure (Head) Conversions

English unit	**Symbol**		**Factor**		**SI unit**	**Symbol**
pounds per square inch	lb_f/in^2 or psi	=	6894.8	x	Pascal	Pa
pounds per square foot	lb_f/ft^2	=	47.88	x	Pascal	Pa
inches of mercury	in Hg	=	25.4		millimeters of mercury	mm Hg
feet of water	ft H_2O	=	0.3048	x	meters of water	m H_2O
SI unit	**Symbol**				**English unit**	**Symbol**
Pascal	Pa	=	1.450×10^{-4}	x	pounds per square inch	lb_f/in^2 or psi
Pascal	Pa	=	0.02089	x	pounds per square foot	lb_f/ft^2
millimeters of mercury	mm Hg	=	0.03937	x	inches of mercury	in Hg
meters of water	m H_2O	=	3.2808	x	feet of water	ft H_2O

Table 0-9: Flow Rate Conversions

English unit	**Symbol**		**Factor**		**SI unit**	**Symbol**
cubic feet per second	ft^3/sec or cfs	x	26344.72	=	cubic meters per day	m^3/day
cubic feet per minute	ft^3/min or cfm	x	439.08	=	cubic meters per day	m^3/day
gallons per minute	gal/min or gpm	x	5.45099	=	cubic meters per day	m^3/day
gallons per minute	ft^3/sec or cfs	x	5450.99	=	liters per day	L/day
million gallons per day	10^6 gal/day or MGD	x	3785.41	=	cubic meters per day	m^3/day
SI unit	**Symbol**				**English unit**	**Symbol**
cubic meters per day	m^3/day	x	3.7958×10^{-5}	=	cubic feet per second	ft^3/sec or cfs
cubic meters per day	m^3/day	x	2.2775×10^{-3}	=	cubic feet per minute	ft^3/min or cfm
cubic meters per day	m^3/day	x	0.1835	=	gallons per minute	gal/min or gpm
liters per day	L/day	x	1.8345×10^{-4}	=	gallons per minute	ft^3/sec or cfs
cubic meters per day	m^3/day	x	2.5804×10^{-4}	=	million gallons per day	10^6 gal/day or MGD

Note that 1 mg/L is the same as 1 lb per million pounds of water; i.e., 1 part of pollutant per million parts of water by weight. When the concentrations of pollutants are relatively low, we therefore often say “parts per million.” A concentration of 1000 pounds of pollutant per million pounds of *solution* would be (1000/1.001) parts per million, or 999 parts per million (999 mg/L) Thus saying “parts per million” interchangeably with “mg/L” results in a 0.1% error, which is usually less than the error involved in measurement.

Table 0-10: Density Conversions

English unit	Symbol		Factor		SI unit	Symbol
pounds per gallon	lb_m/gal	x	119934	=	grams per cubic meter equivalently, milligrams per liter	g/m^3 or mg/L
pounds per cubic inch	lb_m/in^3	x	27680	=	kilograms per cubic meter	kg/m^3
pounds per cubic foot	lb_m/ft^3	x	16.01837	=	kilograms per cubic meter	kg/m^3
pounds per cubic yard	lb_m/yd^3	x	0.5933	=	kilograms per cubic meter	kg/m^3
US tons per cubic yard	T/yd^3	x	1.1865	=	tonnes per cubic meter	t/m^3
SI unit	**Symbol**		**Factor**		**English unit**	**Symbol**
milligrams per liter	mg/L		10^{-6}		pounds per million pounds of H_2O	
grams per cubic meter equivalently, milligrams per liter	g/m^3 or mg/L	x	8.3379×10^{-6}	=	pounds per gallon	lb_m/gal
kilograms per cubic meter	kg/m^3	x	3.6127×10^{-5}	=	pounds per cubic inch	lb_m/in^3
kilograms per cubic meter	kg/m^3	x	0.06243	=	pounds per cubic foot	lb_m/ft^3
kilograms per cubic meter	kg/m^3	x	1.6856	=	pounds per cubic yard	lb_m/yd^3
tonnes per cubic meter	t/m^3	x	0.8428	=	US tons per cubic yard	T/yd^3

Table 0-11: Velocity Conversions

English unit	Symbol		Factor		SI unit	Symbol
miles per hour	mi/hr	x	0.44704	=	meters per second	m/sec
feet per second	ft/sec	x	0.3048	=	meters per second	m/sec
SI unit	Symbol		Factor		English unit	Symbol
meters per second	m/sec	x	2.2369	=	miles per hour	mi/hr
meters per second	m/sec	x	3.2808	=	feet per second	ft/sec

Slope Measurements

The slope is the change in vertical distance divided by the change in horizontal distance. This is known variously as the slope, the derivative of z with respect to x, and the *tangent* of the angle θ. The slope is often multiplied by 100 and expressed as a per cent grade.

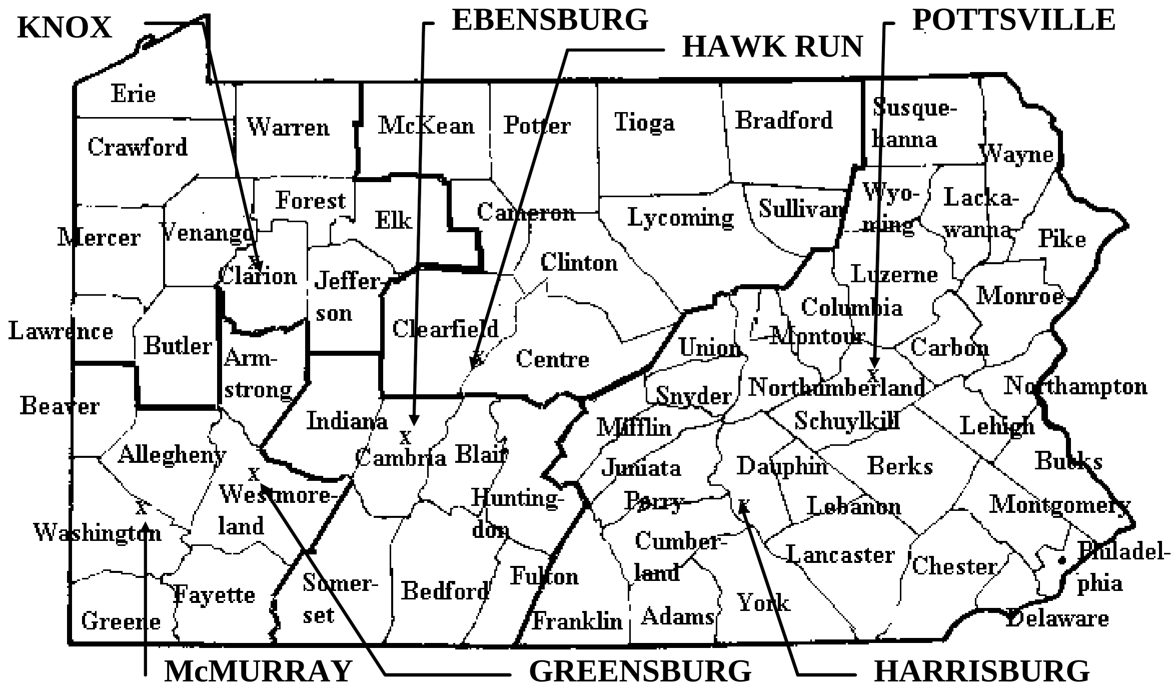
However, in discussions dealing with embankments and other civil engineering features, what is called the "slope" is actually the change in horizontal distance divided by the change in vertical distance. This is the *cotangent* of the angle θ. This is the "slope" to which we will refer in our discussions, since it is what most people with whom you will be dealing call "slope". It is usually expressed as a ratio.

Table 0-12: Slope Equivalents

Horizontal distance = x	Vertical distance = z	Tangent = z/x	Per cent Grade = 100 (z/x)	Cotangent (slope) = x/z	Angle from horizontal (degrees)	Angle from horizontal (radians)
0.5	1	2.0000	200.00	0.50	63.43	1.11
1.0	1	1.0000	100.00	1.00	45.00	0.79
1.5	1	0.6667	66.67	1.50	33.69	0.59
2.0	1	0.5000	50.00	2.00	26.57	0.46
2.5	1	0.4000	40.00	2.50	21.80	0.38
3.0	1	0.3333	33.33	3.00	18.43	0.32
3.5	1	0.2857	28.57	3.50	15.95	0.28
4.0	1	0.2500	25.00	4.00	14.04	0.24
4.5	1	0.2222	22.22	4.50	12.53	0.22
5.0	1	0.2000	20.00	5.00	11.31	0.20
5.5	1	0.1818	18.18	5.50	10.30	0.18
6.0	1	0.1667	16.67	6.00	9.46	0.17
6.5	1	0.1538	15.38	6.50	8.75	0.15
7.0	1	0.1429	14.29	7.00	8.13	0.14
7.5	1	0.1333	13.33	7.50	7.59	0.13
8.0	1	0.1250	12.50	8.00	7.13	0.12
8.5	1	0.1176	11.76	8.50	6.71	0.12
9.0	1	0.1111	11.11	9.00	6.34	0.11
9.5	1	0.1053	10.53	9.50	6.01	0.10
10.0	1	0.1000	10.00	10.00	5.71	0.10

15. Appendix C : Office Locations

Table 0-1: Mining Districts in Pennsylvania



I. Bureau of Mining Programs

P.O. Box 8461
Harrisburg PA 17105-8461

- Director — 717-787-5103
- Division of Monitoring and Compliance — 717-787-7846
- Division of Permits — 717-783-8845
- Division of Environmental Analysis and Support — 717-787-4671

II. Bureau Of District Mining Operations.

- Director — 724-942-7204
  McMurray District Office
  3913 Washington Road
  McMurray PA 15317-2532

- Ebensburg District Office — 814-472-1900
  437 South Center Street
  P.O. Box 625
  Ebensburg PA 15931-0625
- Greensburg District Office — 724-925-5500

Armburst Building
R.D. 2 Box 603-B
Greensburg PA 15601-0982

- Hawk Run District Office — 814-342-8200
  P.O. Box 209
  Empire Road
  Hawk Run PA 16840-0209

- Knox District Office — 814-797-1191
  White Memorial Building
  P.O. Box 669
  Knox PA 16232-0669

- McMurray District Office — 724-941-7100
  3913 Washington Rd.
  McMurray PA 15317-2532

- Pottsville District Office — 717-621-3118
  5 West Laurel Boulevard
  Pottsville PA 17901-2454

III. Bureau Of Deep Mine Safety
Area Offices

Anthracite and Noncoal Deep Mine Safety Division — 717-621-3140
5 West Laurel Boulevard
Pottsville PA 17901
Responsibility: Covers all underground anthracite coal mines and all metal and nonmetal mines

Bituminous Mine Safety Division — 724-439-7469
Fayette County Health Center
Room 167
100 New Salem Road
Uniontown PA 15401
Responsibility: Covers all underground bituminous coal mines

IV. Bureau Of Water Quality Protection

11th floor Rachel Carson State Office Building
P.O. Box 8465

- Harrisburg PA 17105-8465
- Division of Waterways, Wetlands, & Erosion Control (encroachments & water obstructions) 717-787-4317
- Division of Wastewater Management (biosolids) 717-787-8184
- Division of Conservation Districts/ Nutrient Management 717-783-7577

V. Regional Offices
Soils And Waterways Section
Water Management Program
Air Quality Program

Regional Offices	County Responsibility
Southcentral Regional Office One Ararat Blvd. Harrisburg PA 17110-8200 717-705-4700	Adams, Bedford, Blair, Cumberland, Dauphin, Franklin, Fulton, Huntingdon, Juniata, Lancaster, Lebanon, Mifflin, Perry, and York
Southeast Regional Office Suite 6010, Lee Park 555 North Lane Conshohocken PA 19428-2233 610-832-6000	Berks, Bucks, Carbon, Chester, Delaware, Lehigh, Northampton, Montgomery, Philadelphia, and Schuylkill
Southwest Regional Office 400 Waterfront Drive Pittsburgh PA 15222-4745 412-442-4000	Allegheny, Armstrong, Beaver, Butler, Cambria, Fayette, Greene, Indiana, Lawrence, Somerset, Washington, and Westmoreland
Northwest Regional Office 230 Chestnut St. Meadville PA 16335-3481 814-332-6945	Clarion, Clearfield, Crawford, Elk, Erie, Forest, Jefferson, Mckean, Mercer, Venango, and Warren
Northeast Regional Office 2 Public Square Wilkes-Barre PA 18701-3291 717-826-2511	Bradford, Columbia, Lackawanna, Luzerne, Monroe, Pike, Sullivan, Susquehanna, Wayne, and Wyoming

Northcentral Regional Office 208 West Third St. Williamsport PA 17701-6448 717-327-3636	Cameron, Centre, Clinton, Lycoming, Montour, Northumberland, Potter, Snyder, Tioga, and Union

VI. Bureau Of Land Recycling And Waste Management

14th floor Rachel Carson State Office Building
P.O. Box 8471
Harrisburg PA 17105-8471

- Division of Municipal and Residual Waste — 717-787-7564

VII. Pennsylvania Fish And Boat Commission

Regional Office	County Responsibility
Northwest Region Office 11528 State Highway 98 Meadville PA 16335-1528 814-337-0444	Butler, Clarion, Crawford, Erie, Forest, Lawrence, Mercer, Venango, and Warren
Southwest Region Office R,D.-2, Box 39 Somerset PA 15501-1644 814-445-8974	Allegheny, Armstrong, Beaver, Cambria, Fayette, Greene, Indiana, Somerset, Washington, and Westmoreland
Northcentral Region Office Box 187 (Fishing Creek Road) Lamar PA 16848-0187 717-726-6056	Cameron, Centre, Clearfield, Clinton, Elk, Jefferson, Lycoming, McKean, Northumberland, Potter, Snyder, Tioga, and Union
Southcentral Region Office 1704 Pine Road Newville PA 17241-9544 717-486-7087	Adams, Bedford, Blair, Cumberland, Dauphin, Franklin, Fulton, Huntingdon, Juniata, Lebanon, Mifflin, Perry, and York
Southeast Region Office Box 8 Elm PA 17521-0008 717-626-0228	Berks, Bucks, Chester, Delaware, Lancaster, Lehigh, Montgomery Northampton, Philadelphia, and Schuylkill
Northeast Region Office Box 88 Sweet Valley PA 18656-0088 717-477-5717	Bradford, Carbon, Columbia, Lackawanna, Luzerne, Monroe, Pike, Sullivan, Susquehanna, Wayne, and Wyoming

VIII. Pennsylvania Department Of Transportation

Engineering Districts	County Responsibility
Engineering District 1-0 Galena Office 1140 Liberty St. Franklin PA 16323 814-437-4200	Crawford, Erie, Forest, Mercer, Venango, and Warren
Engineering District 2-0 1924-30- Daisy Street Clearfield PA 16830 814-765-0400	Centre, Clearfield, Clinton, Cameron, McKean, Potter, Mifflin, Elk, and Juniata
Engineering District 3-0 715 Jordan Ave. Montoursville PA 17754 717-368-8686	Columbia, Lycoming, Montour, Northumberland, Snyder, Sullivan, Tioga, and Union
Engineering District 4-0 O'Neill Highway Dunmore PA 18512 717-963-4061	Bradford, Lackawanna, Luzerne, Pike,Susquehanna, Wayne, and Wyoming
Engineering District 5-0 1713 Lehigh Street Allentown PA 18103 610-821-4100 or 610-791-6000	Berks, Carbon, Lehigh, Monroe Northampton, and Schuylkill
Engineering District 6-0 200 Radnor-Chester Road St. Davis PA 19087-5178 610-964-6669	Bucks, Chester, Delaware, Montgomery, and Philadelphia
Engineering District 8-0 2140 Herr Street Harrisburg PA 17103-1699 717-787-6653 or 717-787-7464	Adams, Cumberland, Franklin, York, Dauphin, Lancaster, Lebanon, and Perry
Engineering District 9-0 1620 North Juniata Street Hollidaysburg PA 16645 814-696-7250	Bedford, Blair, Cambria, Fulton, Huntingdon, and Somerset

Engineering District 10-0
Route 286 South, Box 429
Indiana PA 15701
724-357-2800

Armstrong, Butler, Clarion, Indiana, and Jefferson

Engineering District 11-0
45 Thorns Road
Bridgeville PA 15017
412-429-5000

Allegheny, Beaver, and Lawrence

Engineering District 12-0
P.O. Box 459
North Gallatin Ave. Ext.
Uniontown PA 15401-0459
724-439-7315

Fayette, Greene, Washington, and Westmoreland

IX. County Conservation Districts

1. Adams District
57 North Fifth Street
Gettysburg PA 17325
717-334-0636

2. Allegheny District
208 Acacia Building, 875 Greentree Road
Pittsburgh PA 15220-3501
412-921-1999

3. Armstrong District
Armstrong Admin. Bldg.
R.D. #8, Box 294, Kittanning PA 16201
724-548-3425 or 3428

4. Beaver District
1000 Third Street, Suite 202
Beaver PA 15009-2026
724-774-7090

5. Bedford District
702 West Pitt Street, Fairlawn Court, Suite 4
Bedford PA 15522
814-623-6706

6. Berks District
P.O. Box 520 Agricultural Center
Leesport PA 19533-0520
610-372-4655

7. Blair District
1407 Blair Street
Hollidaysburg PA 16648
814-696-0877

8. Bradford District
Stroll Natural Resource Center, R R #5, Box 5030-C
Towanda PA 18848
717-265-5539

9. Bucks District
924 Town Center
New Britian PA 18901-5182
215-345-7577

10. Butler District
122 McCune Drive
Butler PA 16001-6501
724-285-5270 or 724-284-5271

11. Cambria District
P.O. Box 187
Ebensburg PA 15931
814-472-2120 Extension 588

12. Cameron District
416 North Broad Street
Emporium PA 15834
814-486-3350

13. Carbon District
92 Blakeslee Blvd. East
Lehighton PA 18235
610-377-4894

14. Centre District
414 Holmes Ave., Suite 4
Bellefonte PA 16823
814-355-6817/6818

15. Chester District
Government Services Center, Suite 395, 601 Westtown Road
West Chester PA 19382-4519
610-696-5126 or 610-436-9182

16. Clarion District
R R 3, Box 265
Clarion PA 16214
814-226-4070

17. Clearfield District
650 Leonard Street
Clearfield PA 16830
814-765-2629

18. Clinton District
2 State Route 150
Mill Hall PA 17751
717-726-3798

19. Columbia District
702 Sawmill Road
Suite 105
Bloomsburg PA 17815
717-784-1310

20. Crawford District
1012 Water Street, Suite 18
Meadville PA 16335
814-724-1793

21. Cumberland District
43 Brookwood Ave., Suite 4
Carlisle PA 17013
717-249-8632 or 717-240-6184

22. Dauphin District
1451 Peters Mountain Road
Dauphin PA 17018
717-921-8100

23. Delaware District
Rose Tree Park Hunt Club 1521 No. Providence Rd.
Media PA 19063
610-892-9484

24. Elk District
P.O. Box 448
Ridgway PA 15853
814-796-4203

25. Erie District
12723 Route 19, P.O. Box 801
Waterford PA 16441
814-796-4203

26. Fayette District
10 Nickman Plaza
Lemont Furnace PA 15456
724-438-4497

27. Forest District
P.O. Box 456
Tionesta PA 16353
814-755-3450

28. Franklin District
550 Cleveland Avenue
Chambersburg PA 17201
717-264-8074

29. Fulton District
216 North Second Street
McConnellsburg PA 17233
717-485-3547

30. Greene District
Ben Franklin Bldg, 22 W. High Street, Suite 203
Waynesburg PA 15370-1324
724-852-5278

31. Huntingdon District
RR# 1, Box 76
Huntingdon PA 16652-9603
814-627-1627

32. Indiana District
Ag Service Center, 251 Route 286 North
Indiana PA
15701-9203 724-463-7702

33. Jefferson District
R.D. #5, Service Center
Brookville PA 15825
814-849-7463

34. Juniata District
RR# 3, Box 302
Mifflintown PA 17059-8609
717-436-6919

35. Lackawanna District
395 Bedford Street
Clarks Summit PA 18411
717-587-2607

36. Lancaster District
Room 6, Farm and Home Center, 1383 Arcadia Road
Lancaster PA 17601
717-299-5361

37. Lawrence District
County Government Center
New Castle PA 16101
724-652-4512

38. Lebanon District
2120 Cornwall Road, Suite 5
Lebanon PA 17042-9788
717-272-3377

39. Lehigh District
Lehigh Ag. Center, Suite 102, 4184 Dorney Park Road
Allentown PA 18104-5728
610-391-9583 or 610-820-3398

40. Luzerne District
Smith Pond Road, P.O. Box 250
Lehman PA 18627-0250
717-674-7991

41. Lycoming District
Suite 6, 2130 County Farm Road
Montoursville PA 17754
717-433-3003 or 717-4333004

42. McKean District
Drawer E
Custer City PA 16725
814-368-9960

43. Mercer District
R.R.#2, Box 2055, 747 Greenville Road
Mercer PA 16137
724-662-2242

44. Mifflin District
20 Windmill Hill #4
Burnham PA 17009
717-248-4695

45. Monroe District
8050 Running Valley Road
Stroudsburg PA 18360
717-992-3060

46. Montgomery District
1015 Bridge Road, Suite B
Collegeville PA 19426
610-489-4506

47. Montour District
112 Woodbine Lane, Suite 2
Danville PA 17821
717-271-1140

48. Northampton District
R.D.#4, Greystone Building
Nazareth PA 18064
610-746-1971

49. Northumberland District
R.D.#3, Box 238-C
Sunbury PA 17801
717-988-4224

50. Perry District
31 West Main Street, Box 36
New Bloomfield PA 17068
717-582-8988

51. Philadelphia District (c/o Bucks County Conservation District)
924 Town Center
New Britian PA 18901-5182
215-345-7577

52. Pike District
HC 6, Box 6770
Hawley PA 18428-9807
717-226-8220

53. Potter District
334B Alleghany Road
Coudersport PA 16915-9501
814-274-8411

54. Schuylkill District
1206 Ag. Center Drive
Pottsville PA 17901
717-622-3742

55. Snyder District
403 West Market Street
Middleburg PA 17842
717-837-0085

56. Somerset District
North Ridge Building, 1590 North Center Ave., Suite 103
Somerset PA 15501-7000
814-445-4652

57. Sullivan District
R.R.#4, Box 4181
Dushore PA 18614
717-924-3178

58. Susquehanna District
County Office Building, 31 Public Avenue
Montrose PA 18801
717-278-4600, Extension 280

59. Tioga District
5 East Avenue
Wellsboro PA 16901
717-724-1801

60. Union District
60 Bull Run Crossing
Lewisburg PA 17837-9700
717-523-8782

61. Venango District
R.R.#2, Box 108
Franklin PA 16323
814-432-7456

62. Warren District
609 Rouse Avenue, Suite 203
Youngsville PA 16371
814-563-3117

63. Washington District
602 Courthouse Square, 100 Beau Street
Washington PA 15301
724-228-6774

64. Wayne District
Ag. Service Center, 470 Sunrise Avenue
Honesdale, PA 18431
717-253-0930

65. Westmoreland District
Donohoe Center, RR12 Box 202B
Greensburg PA 15601
724-834-3970

66. Wyoming District
Tri-County Insurance Building, RD #3
Tunkhannock PA 15657
717-836-5111

67. York District
118 Pleasant Acres Road
York PA 17402
717-771-9430

10. Natural Resources Service County Field Offices

1. Adams County Field Office
57 North Fifth Street
Gettysburg PA 17325
717-334-2317

2. Allegheny County Field Office
1000 Third Street
Beaver PA 15009-2026
724-775-6231

3. Armstrong County Field Office
Armsdale Administration Building, R.D.#8, Box 294
Kittanning PA 16201-3425
724-548-3425

4. Beaver County Field Office
1000 Third Street
Beaver PA 15009-2026
724-775-6231

5. Bedford County Field Office
702 West Pitt Street, Fair Lawn Court, Suite 4
Bedford PA 15522-8800
814-623-9616

6. Berks County Field Office
Berks County Ag. Center, P.O. Box 520
Leesport PA 19533-0520
610-372-4655

7. Blair County Field Office
1407 Blair Street
Hollidaysburg PA 16648-2468
814-695-6291

8. Bradford County Field Office
Stroll Natural Resource Center, R.R.#5, Box 5030E
Towanda PA 18848-9354
717-265-5288

9. Bucks County Field Office
530 West Butler Avenue
Chalfont PA 18914-3201
215-822-5840

10. Butler County Field Office
Zinkhann Professional Complex, Suite 102, 602 Evans City Road
Butler PA 16001-8701
724-482-2452

11. Cambria County Field Office
518 North Center Street
Ebensburg PA 15931-1153
814-472-5502

12. Cameron County Field Office
Ag Service Center, 650 Leonard Street
Clearfield PA 16830-3243
814-765-5318

13. Carbon County Field Office
92 Blakeslee Boulevard East
Lehighton PA 18235-9045
610-377-6143

14. Centre County Field Office
414 Holmes Ave, Suite 3
Bellefonte PA 16823-1401
814-355-3971

15. Chester County Field Office
601 Westown Road, Suite 381
West Chester PA 19382-4544
610-696-0398

16. Clarion County Field Office
R.R.#3, Box 265
Clarion PA 16214
814-226-4070

17. Clearfield County Field Office
Ag. Service Center, 650 Leonard Street
Clearfield PA 16830-3243
814-765-5318

18. Clinton County Field Office
2 State Route 150
Mill Hall PA 17751-1631
717-726-4928

19. Columbia County Field Office
1127 Old Berwick Road
Bloomsburg PA 17815-2913
717-784-1062

20. Crawford County Field Office
1012 Water Street, Suite 18
Meadville PA 16335-3444
814-724-1852

21. Cumberland County Field Office
43 Brookwood Avenue, Suite 3
Carlisle PA 17013-9172
717-249-1037

22. Dauphin County Field Office
1451 Peters Mountain Road
Dauphin PA 17018-9504
717-921-2380

23. Delaware County Field Office
601 Westtown Road, Suite 381
West Chester PA 19382-4544
610-691-0398

24. Elk County Field Office
R.D.#5
Brookville PA 15825-9761
814-849-5345

25. Erie County Field Office
12723 Route 19, P.O. Box 801
Waterford PA 16441-0801
814-796-6784

26. Fayette County Field Office
10 Nickman Plaza
Lemont Furnace PA 15456-9732
724-437-2264

27. Forest County Field Office (c/o Clarion County Field Office)
R.R.#3, Box 265
Clarion PA 16214
814-226-4070

28. Franklin County Field Office
550 Cleveland Avenue
Chambersburg PA 17201-3498
717-264-7013

29. Fulton County Field Office
216 North Second Street
McConnellsburg PA 17233-1157
717-485-3812

30. Greene County Field Office
93 East High Street, Room 213
Waynesburg PA 15370-1839
724-627-5821

31. Huntingdon County Field Office
R.R.#1, Box 7- C
Huntingdon PA 16652-9603
814-627-1626

32. Indiana County Field Office
Ag. Service Center, 251 Rt. 286 North
Indiana PA 15701-9011
724-463-8547

33. Jefferson County Field Office
Jefferson County Service Center, R.D.#5
Brookville PA 15825-9761
814-849-5345

34. Juniata County Field Office
R.D.#3, Box 302
Mifflintown PA 17059-9609
717-436-9531

35. Lackawanna County Field Office
395 Bedford Street
Clarks Summit PA 18411-1802
717-586-1081

36. Lancaster County Field Office
Room 4, 1383 Arcadia Road
Lancaster PA 17601-3179
717-299-1563

37. Lawrence County Field Office
1503 Old Butler Road
New Castle PA 16101-3133
724-652-5811

38. Lebanon County Field Office
2120 Cornwall Road, Suite 6
Lebanon PA 17042
717-272-4618

39. Lehigh County Field Office
4184 Dorney Park
Allentown PA 18104-4910
610-398-4910

40. Luzerne County Field Office
911 West Main Street
Plymouth PA 18651-2799
717-779-0645

41. Lycoming County Field Office
P.O. Box 68, 240 West Third Street
Williamsport PA 17703-0068
717-326-7281

42. McKean County Field Office
334-B Port Allegheny
Cloudersport PA 16915-9501
814-274-8166

43. Mercer County Field Office
559 Greenville Road, Suite B
Mercer PA 16137-9216
724-662-3740

44. Mifflin County Field Office
20 Windmill Hill #4
Burnham PA 17009-1837
717 248-9541

45. Monroe County Field Office
92 Blakeslee Boulevard
East Lehighton PA 18235-9045
610-377-6143

46. Montgomery County Field Office
1015 Bridge Road, Suite C
Collegeville PA 19426
610-489-6071

47. Montour County Field Office (c/o Columbia County Field Office)
1127 Old Berwick Road
Bloomsburg PA 17815-2913
717-784-1062

48. Northampton County Field Office
R.D.#4, Greystone Building
Nazareth PA 18064
610-746-1971

49. Northumberland County Field Office
RD #2, Box 347-1
Sunbury PA 17801
717-286-4311

50. Perry County Field Office
31 West Main Street, P.O. Box 36
New Bloomfield PA 17068
717-582-4144

51. Philadelphia County Field Office (c/o Bucks County Field Office)
530 West Butler Avenue
Chalfont PA 18914-3201
215-822-5840

52. Pike County Field Office (c/o Wayne County Field Office)
Ag Service Center, 470 Sunrise Avenue
Honesdale PA 18431-1034
717-253-1370

53. Potter County Field Office
334-B Port Allegheny Road
Coudersport PA 16915
814-274-8166

54. Schuylkill County Field Office
1108 Ag Center Drive
Pottsville PA 17901-4103
717-622-1312

55. Snyder County Field Office
401 West Market Street
Middleburg PA 17842-1038
717-837-6525

56. Somerset County Field Office
North Ridge Building, 1590 N. Center Ave, Suite 104
Somerset PA 15501-8237
814-445-6876

57. Susquehanna County Field Office
County Office Building, 31 Public Avenue
Montrose PA 18801
717-278-4600, Extension 280

58. Sullivan County Field Office
Hollowcrest Road, R.R.#3, Box 178-B
Dushore PA 18614
717-836-2490

59. Tioga County Field Office
5 East Avenue
Wellsboro PA 16901-1687
717-724-4812

60. Union County Field Office
60 Bull Run Crossing
Lewisburg PA 17837-9700
717-523-3280

61. Venango County Field Office
R.R.#2, Box 108
Franklin PA 16323
814-437-6894

62. Warren County Field Office
609 Rouse Avenue, Suite 202
Youngsville PA 16371
814-563-3125

63. Washington County Field Office
2800 North Main Street Extension, P.O. Box 329
Meadow Lands PA 15347-0329
724-222-3960

64. Wayne County Field Office
Ag Service Center, 470 Sunrise Avenue
Honesdale PA 18431-1034
717-253-1370

65. Westmoreland County Field Office
Donohoe Center, R.R.#12, Box 202- C
Greensburg PA 15601-9217
724-834-3970

66. Wyoming County Field Office
R.R.#3, Box 178-B
Tunkhannock PA 18657-9515
717-836-2490

67. York County Field Office
122 Pleasant Acres Road
York PA 17402-8987
717-755-2966