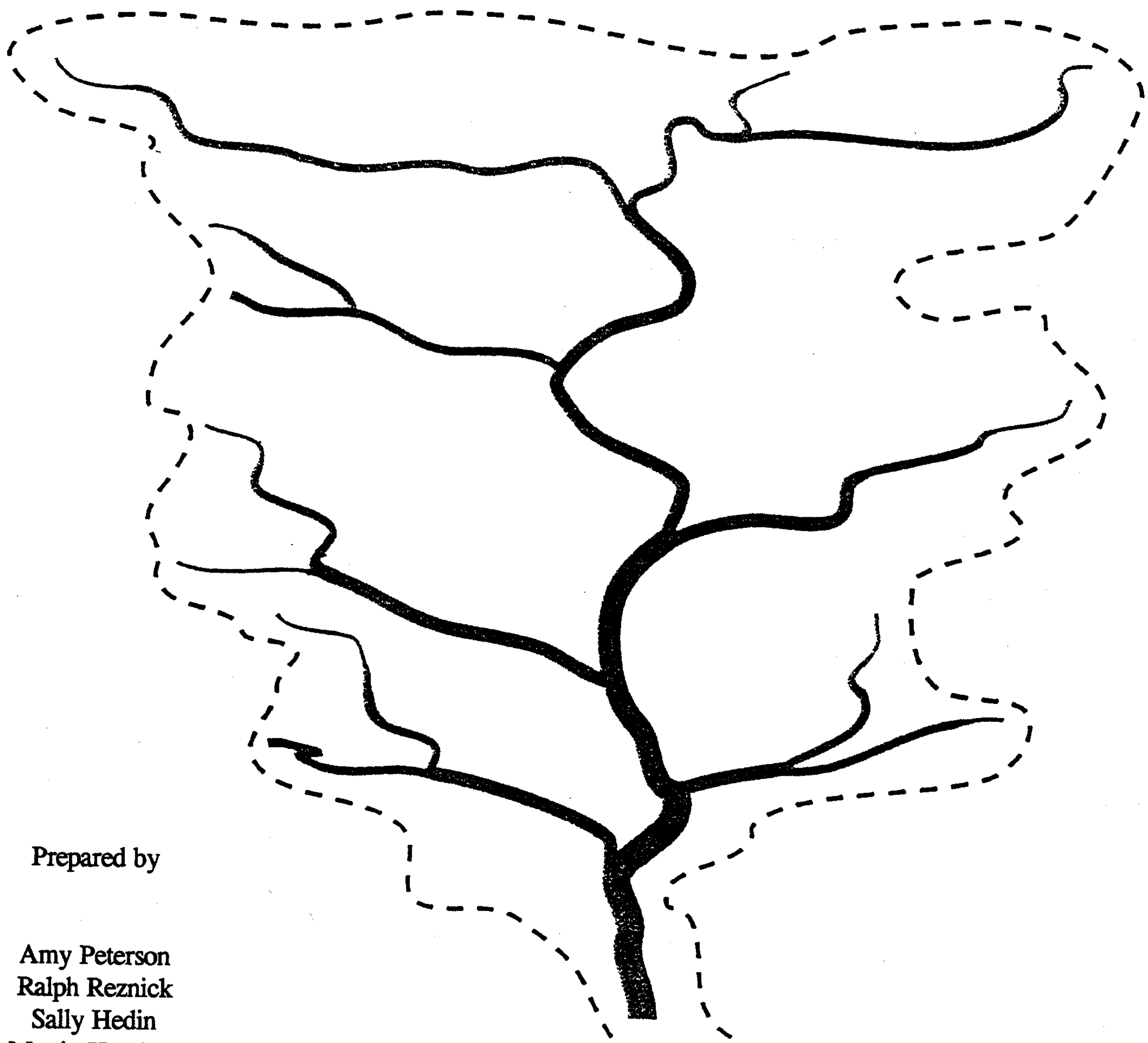
Guidebook of Best Management Practices for Michigan Watersheds

Reprinted October, 1998



Prepared by

Amy Peterson
Ralph Reznick
Sally Hedin
Martin Hendges
Dennis Dunlap

Michigan Department of Environmental Quality,
Surface Water Quality Division
Russell J. Harding, Director
John Engler, Governor

DEQ

ACKNOWLEDGMENTS

Staff of the Michigan Department of Environmental Quality (MDEQ), Nonpoint Source Program, would like to thank everyone who helped in the development of this manual. The Appendices contain a list of the members of three technical committees which were instrumental both in developing and reviewing the various Best Management Practices (BMPs) and the Guidebook. In addition to these people, numerous other individuals offered support and assistance. Special thanks are extended to: Dave Bastian, MDEQ, Land and Water Management Division; Steve Davis, USDA, Soil Conservation Service; Jerry Fulcher, MDEQ, Land and Water Management Division; Dick Mikula, MDEQ, Land and Water Management Division; Dave Hamilton, MDEQ, Land and Water Management Division; Greg Lyman, Michigan State University, Cooperative Extension Service; Mike O'Malley and Doug Proper, Michigan Department of Transportation; Gary Rinkenberger, USDA, Soil Conservation Service; Frank Rossi, Michigan State University, Cooperative Extension Service; John Price, Price and Company, Inc.

Special thanks also go to MDEQ secretarial staff which made this project possible: Penny Stockel, Barb Wilcox, and Veronica Willard.

GUIDEBOOK CONTENTS

FOREWORD

This manual was prepared to help developers, contractors, city and township planners, engineers, architects and local citizens to control runoff* from construction sites, urban areas, and large recreational areas. Our goal is to provide people with a tool which can be used to help plan development projects in a way which will maintain the integrity of lakes, streams, wetlands and groundwater, and to reduce the pollutant loads to these waters. The concepts in this manual may also be used in developed areas to protect or improve water quality.

The manual was written in response to a need to address runoff and wind-generated pollution in Michigan. This diffuse, intermittent pollution is called nonpoint source pollution, and is usually contrasted with point sources which come from pipes (i.e. from areas such as waste water treatment plants, large businesses, etc.). Since point sources have been addressed nationally since the early 1970s, nonpoint sources remain the most significant challenge in protecting and preserving our surface and groundwaters. Other nonpoint sources which are being addressed in the state include agricultural operations, and forest harvesting activities.

The primary mechanism used to prevent nonpoint sources from impacting watersheds is Best Management Practices (BMPs). These are structural, vegetative or managerial practices used to protect and improve our surface waters and groundwaters. BMPs for urban areas, construction sites and golf courses were written in conjunction with this guidebook. BMPs will be updated as often as deemed necessary and when funding is available. A separate supplement for golf courses is available from the MDEQ, Nonpoint Source Unit.

If you have comments or questions on the concepts presented in this manual, or on the Best Management Practices, feel free to contact the Nonpoint Source Unit at 517-373-2867, or any of the district staff listed in Figure 1.

We look forward to working with you to continue protecting and preserving our surface waters.

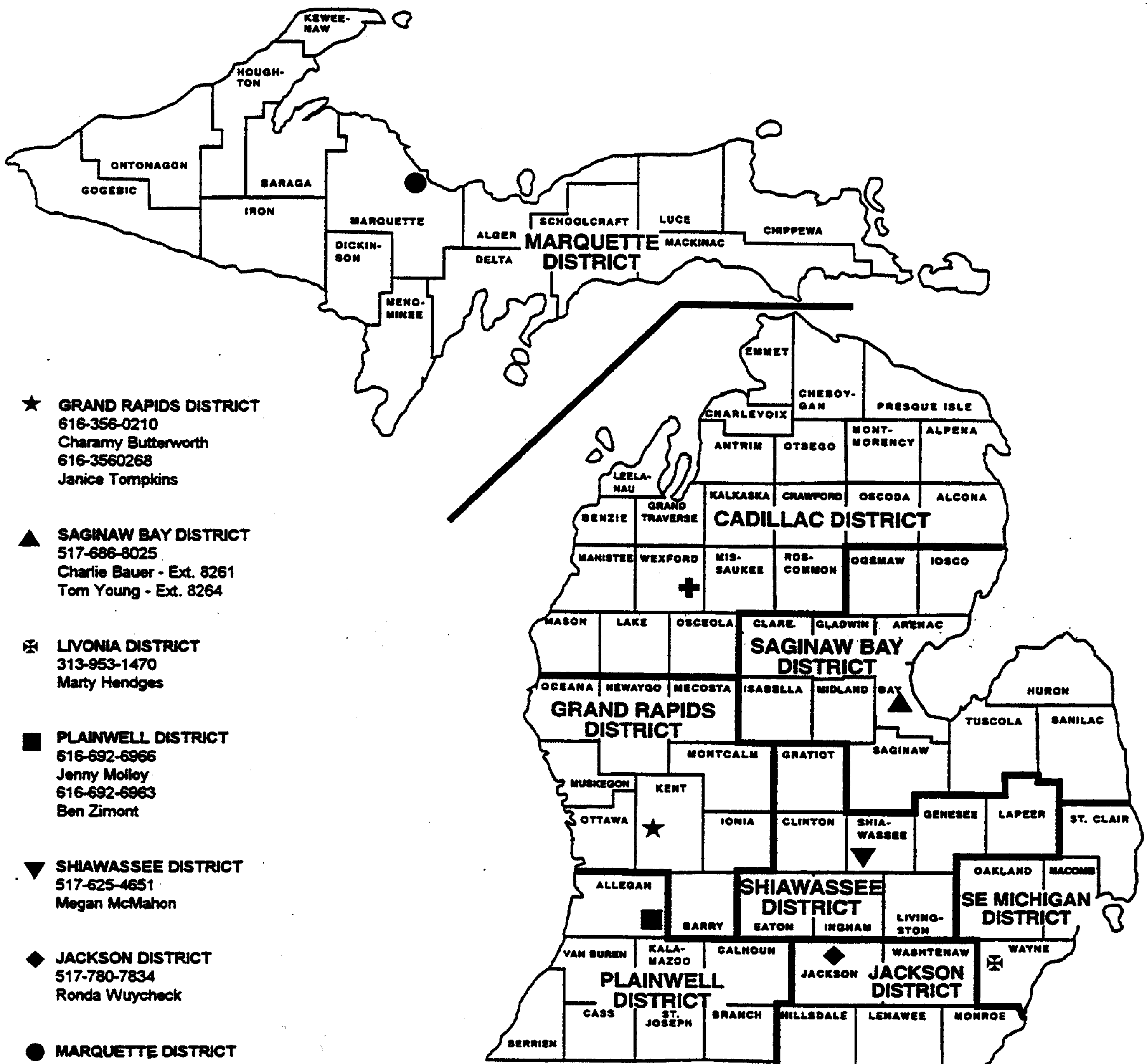
Note: For the purpose of this manual, a "surface water" is any body of water, including lakes, streams, rivers, and wetlands.

---

*Runoff: Rainwater, snow melt or irrigation which does not infiltrate into the ground and runs over or "off' the land, picking up soil particles and other pollutants as it goes and carrying them to surface waters.

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
District Boundaries and Offices

John Engler, Governor ♦ Russell J. Harding, Director



★ **GRAND RAPIDS DISTRICT**
616-356-0210
Charamy Butterworth
616-3560268
Janice Tompkins

▲ **SAGINAW BAY DISTRICT**
517-686-8025
Charlie Bauer - Ext. 8261
Tom Young - Ext. 8264

✠ **LIVONIA DISTRICT**
313-953-1470
Marty Hendges

■ **PLAINWELL DISTRICT**
616-692-6966
Jenny Molloy
616-692-6963
Ben Zimont

▼ **SHIAWASSEE DISTRICT**
517-625-4651
Megan McMahon

◆ **JACKSON DISTRICT**
517-780-7834
Ronda Wuycheck

● **MARQUETTE DISTRICT**
906-226-1375
Kristie Sitar

✚ **CADILLAC DISTRICT**
616-775-3960
Mike Stifler - Ext. 6260

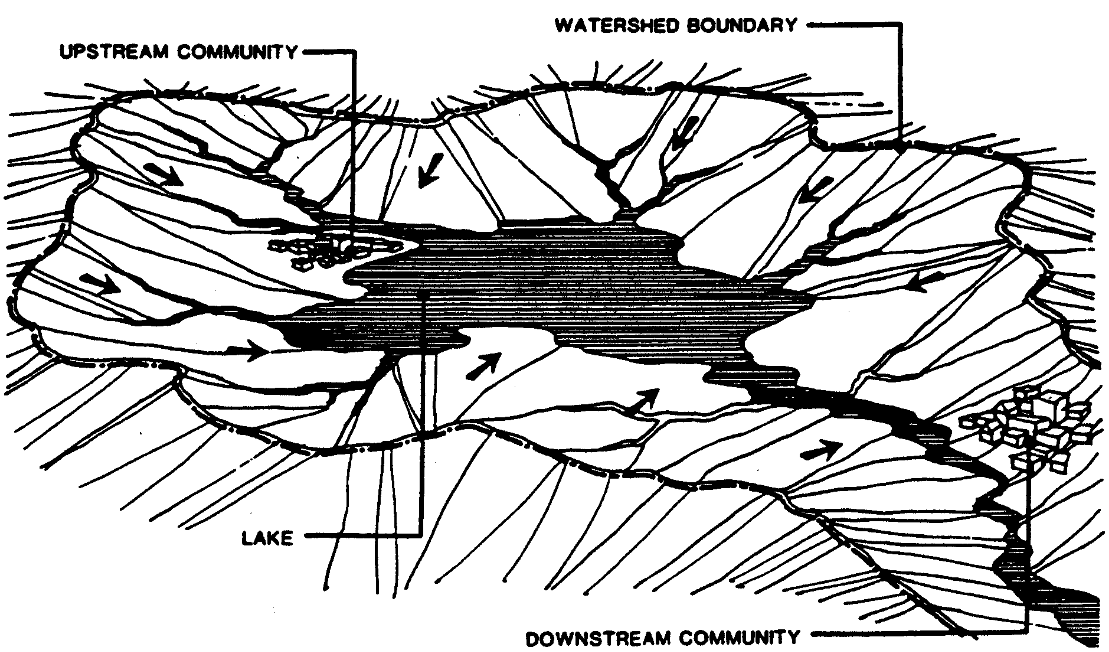
SURFACE WATER QUALITY DIVISION
NONPOINT SOURCE
DISTRICT CONTACTS

The 1987 Amendments to the Clean Water Act were written with the recognition that most point sources were being controlled and that nonpoint sources were causing most of the remaining water quality problems. The Amendments required all states to conduct an assessment of nonpoint sources in their state and develop a strategy to address the identified problems.

An assessment of Michigan's nonpoint sources was conducted in 1987. It involved distributing survey forms to agency personnel who had information on nonpoint source problems in their watershed. As shown in Figure 2, a watershed is all the land which drains into a body of water, such as a lake or river. The results of the assessment are available in "Michigan's 1988 Nonpoint Pollution Assessment Report, " with some information provided in the next two sections.

Figure 2

A Watershed



Source: Stormwater Management: A Guide for Floridians. Florida Department of Environmental Regulations.

"Michigan's Nonpoint Pollution Control Management Plan" was developed in 1988, and contains the specific programs that are necessary to prevent and reduce nonpoint sources in Michigan. Many of the program elements identified in the strategy are currently being implemented. One program, the Nonpoint Source Watershed Initiative, promotes the identification of nonpoint sources at the watershed level, and the implementation of best management practices to address the problems identified in the watershed. A list of Best Management Practices is included in the strategy for each of the major sources of nonpoint pollution. The BMP list has been revised, and the detailed BMPs for urban areas and construction sites are included in this binder. BMPs for golf courses have also been completed and are available from the Surface Water Quality Division of the Department of Natural Resources.

Best Management Practices:
BMPs are any structural, vegetative or managerial practice used to treat, prevent or reduce water pollution. Such practices include temporary seeding on exposed soils, detention and retention basins for stormwater control, and scheduling the implementation of all BMPs to ensure their effectiveness.

Michigan' s BMPs include specifications which will provide the user with information to help design and implement the BMP. This is an important concept, in that: 1) no BMP can be used at every site; and 2) no BMP can include so many specifications that all possible uses and all possible conditions are included. Each site must be evaluated, and specific BMPs can be selected which will perform under the site conditions.

Michigan's BMPs were developed for use in Michigan. BMPs developed for other states may not necessarily work in Michigan. For example, vegetative BMPs should emphasize the use of grasses which have adapted to Michigan. Vegetation which has adapted to Michigan is not necessarily going to adapt to other states.

We acknowledge that Michigan's set of BMPs is not all-inclusive. There are several BMPs that nonpoint staff still plans to develop specifications for. There are also other innovative BMPs being used for which there are no specifications. These and other lesser known BMPs should also be considered on a site-specific basis.

We encourage creativity and innovation, but provide potential users with our BMPs because they have been proven to work when designed, installed and maintained correctly. It is important to follow all specifications when designing and installing practices. It is also pertinent that the BMP be maintained. Maintenance is most often the shortcoming of BMP performance.

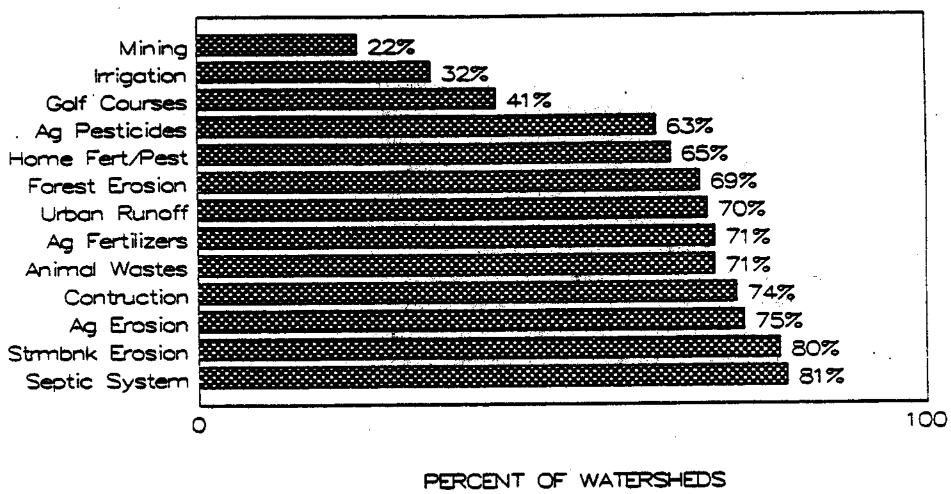
Following a section on the sources and impacts of nonpoint source pollution, the rest of this manual is devoted to identifying the type of BMPs to consider, both at the watershed level and the site level.

SOURCES OF NONPOINT POLLUTION

The sources of nonpoint pollution in Michigan are shown in Figure 3, a bar graph from the 1987 Nonpoint Source Assessment Report. The graph shows that 81% of Michigan's 297 watersheds are perceived to be impacted by failed septic systems, and 80% by stream bank erosion. Other nonpoint sources and the percentage of watersheds impacted by each major source are also shown in Figure 3.

Figure 3

Perceived Sources of Nonpoint Pollution



RURAL AREAS:

The most common nonpoint source problems in rural areas are septic systems, stream bank erosion, agricultural soil erosion, improper agricultural fertilizer and pesticide applications, improper animal manure management, and mining.

Failed sewage disposal systems are widespread throughout the state. Septic tanks should be pumped at least once every three years, and more often depending on the size of the family or group using the tank. Replacing sewage disposal systems is much more costly than routine maintenance.

Some rural **stream bank erosion** problems are due to historic logging practices. During the logging boom, some Michigan rivers were used to transport logs down to the mouth. Early forestry practices also included clear cutting (cutting all trees instead of selective species) and clearing trees right down to the edge of the lake or stream. Proper forestry practices include leaving a natural buffer/filter strip adjacent to surface waters and constructing temporary bridges to cross from one stream bank to another.

Soil erosion is caused by raindrops detaching soil particles and carrying the soil away. Soil erosion in agricultural areas occurs mostly in the spring, before crops develop adequate canopy.
Agricultural soil erosion is particularly problematic in row crops such as corn, because the soil can move easily between the rows. Practices such as no-till planting--which leaves the residue from the

previous year's crop on the surface--are effective in reducing soil erosion. Buffer/filter strips of vegetation along waterways are also effective in reducing soil erosion.

Soil erosion can also be caused by cattle and other livestock, anglers and recreational vehicles entering the water. This tramples banks and destroys stabilizing vegetation. Limiting access to the river and stabilizing the banks with vegetation or other means will prevent additional sediment from going into the water.

Forest erosion occurs mostly as a result of improperly sited, constructed or maintained roads that are needed for forestry operations. Forest erosion also occurs when buffer/filter strips are removed from the waters edge.

Improper use of pesticides and fertilizers is another source of nonpoint pollution. Landowners often apply fertilizers in excess of what is needed by the plant. Numerous agencies are trying to encourage landowners to apply only the amount of fertilizer needed based on an analysis of soil samples collected from their land. Landowners are also encouraged to apply only the amount of pesticides needed to control the pests to the economic threshold level of the plant.

Improper pesticide and fertilizer use can also impact local water bodies. Winter applications of fertilizers will likely run off the soil because plants only absorb fertilizers during the growing season. Applicators sometimes apply pesticides and fertilizers without consideration to weather forecasts or wind conditions. When properly stored, handled and applied, pesticides and fertilizers can be used in a way which will result in very little impact to the water resource. Separate BMPs are dedicated solely to pesticide and fertilizer management.

Improper animal manure management is also a nonpoint source problem in many of Michigan's watersheds. Tons of animal waste can be produced on a single farm, and if improperly stored or applied, nutrients can run off the land and enter surface waters. Proper animal manure management includes proper collection, storage, transport, and land application or other appropriate utilization methods.

Irrigation is used on golf courses, agricultural areas and by homeowners. Many irrigators apply fertilizers and pesticides using the irrigation system (called chemigation). There is a potential for groundwater contamination of nitrates and pesticides using chemigation.

Mining operations are most commonly a problem in Michigan’s Upper Peninsula where copper mines were abandoned without efforts to stabilize the area. Mine tailings containing trace amounts of copper and other elements can and have contaminated water resources. Mining operations in the Lower Peninsula include salt mining operations, many which are still active. Mining for gravel and sand is done throughout the state. Stabilization and restoration with vegetative and sometimes structural means is the best defense against nonpoint problems from mining operations.

URBAN AND URBANIZING AREAS:

Urbanizing areas are those areas which are in the transition between rural and urban--they are essentially experiencing expansion and development. Nonpoint source problems in urbanizing areas are problems which can be minimized with proper local planning and by implementing BMPs. Ordinances are also very effective in promoting development practices that protect the natural environment.

A common nonpoint source problem in urbanizing areas is soil erosion from **construction** sites. Bare soil is easily eroded, especially on sites which do not maintain a natural buffer/filter strip between the construction area and the water resource, and in areas which are not temporarily or permanently seeded. Natural buffer/filter strips, temporary seeding, sediment basins, and other best management practices can reduce the amount of soil that leaves the site and entering waterbodies. Access roads to construction sites can be designed and constructed to reduce the amount of sediment that is tracked off the site by vehicles.

Urban runoff occurs because the natural filtration system is covered with impervious surfaces such as roads and buildings. Before urbanization, most rainwater is infiltrated into the ground through wetlands and depressions. The rainwater was either stored there as groundwater or slowly found its way to a lake or stream. The majority of the land area was vegetated, keeping most soil in place and filtering the runoff which did occur. Stream flows were more stable causing less stream bank erosion and habitat destruction. Once the land is urbanized, very little water is able to infiltrate into the ground, and instead, is rapidly conveyed via storm drains to the nearest water resource. This results in significant changes in stream flow and wetland hydrology, which may result in stream bank erosion and loss of aquatic habitat. Some areas, such as the lower Rouge River in Detroit, have been channelized because alterations in flow have been so significant and destructive.

In addition to the problems caused by changes in hydrology, storm runoff in urban areas can collect a variety of pollutants and carry them to the nearest storm drain. For example, a parking lot constructed of concrete will collect pollutants such as oil and grease that drip off cars in the lot, as well as any sediment that washes off cars or blows onto the lot. A rainstorm washes the parking lot and carries these pollutants to the storm drain and directly to the water body. BMPs which could be implemented include: parking lot or rooftop storage to reduce peak discharge of stormwater, oil/grit separators to remove pollutants, and porous pavement, or infiltration trenches to increase infiltration.

Many homeowners also may unknowingly over-apply or misuse fertilizers and pesticides. Homeowners should read product labels on both pesticides and fertilizers because the labels include information on the use, storage, and disposal of the chemical. Riparian property owners should consider using fertilizers without phosphorus, where possible. Over fertilization may lead to accelerated eutrophication of the lake.

All property owners--including homeowners, farmers, golf course managers, etc.--are encouraged to have their soil tested for nutrient (e.g. phosphorus, nitrogen) and organic content, and only apply fertilizers when soil tests indicate fertilizers are needed. In some situations there is already elevated nutrient concentrations and no additional nutrients from fertilizers are needed.

Homeowners cause other nonpoint source problems. Some riparian homeowners improperly dispose of their organic debris* by raking them right into the lake, river, or wetland. Each year, over 11 million gallons of used motor oil are dumped down Michigan storm drains, in backyards or on driveways. In addition, hundreds of tons of household hazardous waste are dumped into Michigan landfills, some of which can leach out and contaminate groundwater and/or surface waters. Included in the BMPs are practices which homeowners can use to address lawn maintenance and the proper disposal of used oil and household hazardous wastes.

Golf courses are common in Michigan's urban and urbanizing areas. Like other large construction projects, golf courses under construction can result in soil erosion and sedimentation if a natural buffer/filter area isn't left in place and if other BMPs are not implemented. Both new and existing golf courses should have pesticide, fertilizer, and irrigation management programs. Proper disposal of organic debris, including grass clippings and leaves, is needed to prevent impact on local water resource. BMPs have been developed for pesticide management, fertilizer management, lawn maintenance, and organic debris disposal.

---

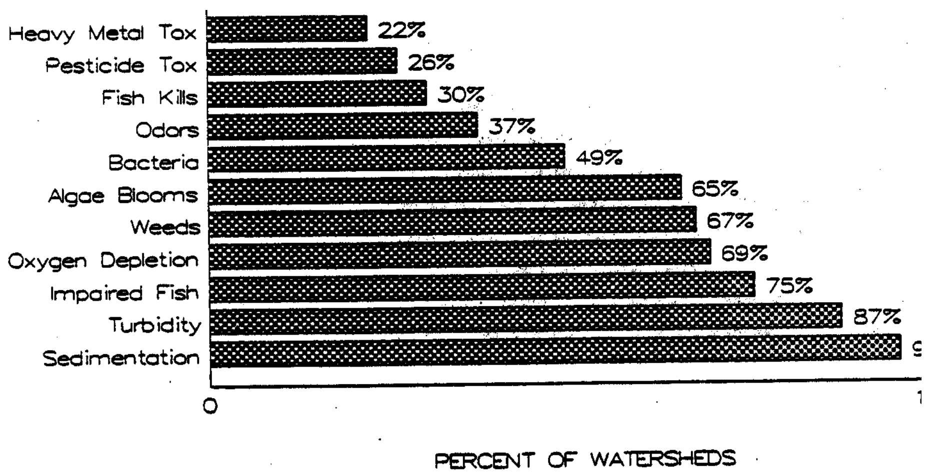
*As organic debris decomposes, the micro-organisms breaking down the debris consume oxygen. As the oxygen level decreases, fish and other aquatic life become stressed and can die. Also, nutrients are released from the organic debris which stimulates plant growth. Ideally, organic debris should be composted in upland areas away from water resources.

IMPACTS OF NONPOINT SOURCES ON SURFACE WATERS

The sources of nonpoint pollution have varying impacts on the environment. Results of Michigan's nonpoint source assessment indicated that the impacts of the various nonpoint sources include sedimentation (affecting 95% of Michigan's watersheds) and turbidity (affecting 87% of Michigan's watersheds). The perceived effects identified by the Assessment are shown in Figure 4.

Figure 4

Perceived Impacts of Nonpoint Sources on Surface Waters



SPECIFIC IMPACTS OF NONPOINT SOURCES

Sedimentation occurs when soil particles which are carried off the land enter surface waters and settle out. When the soil particles settle out, they fill in streams, lakes and wetlands, and cover up habitat needed by fish and other aquatic organisms. Sedimentation occurs as a result of stream bank erosion, excessive hydrologic fluctuation, agricultural soil erosion and construction site erosion.

Turbidity occurs in conjunction with sedimentation. Turbidity is basically a cloudy, muddy condition in the water which occurs when eroded soil is suspended in the water (i.e. before it settles out). Turbid water can stress or kill fish by clogging their gills and making it hard for them to see food sources.

Impacted Fish Habitat is directly associated with many other nonpoint source effects. Decreased habitat can be caused by sedimentation, increases in temperature, and alterations in stream hydrology.

Oxygen Depletion occurs in nutrient-enriched waters because excessive plant growth causes nighttime dissolved oxygen losses during plant respiration. Under severe situations oxygen concentrations may be almost entirely used up for short periods, stressing or killing fish. Excessive large deposits of organic debris also result in oxygen depletion. The microorganisms which break down the organic material use up the oxygen needed by other aquatic life. Common sources of organic material include improperly disposed leaves and grass clippings, raw sewage from "improper (illicit) connections" to storm sewers, and failing septic systems. Improper connections occur when sanitary sewers or industrial discharge pipes are connected to storm sewers, and concentrated waste is discharged directly into the surface water.

Algae Blooms also occur as a result of phosphorus and nitrogen loadings to surface waters. Algae blooms are those green mats of (sometimes slimy) vegetation which often float on top of the water. Like weeds, algae use up the same oxygen other aquatic life needs. Thick beds of algae can also block out sunlight to the aquatic life below.

Bacteria such as fecal streptococci and fecal coliform are found in human and other animal waste and are a natural by-product of the digestive process. The continued presence of bacteria in surface waters is usually indicative of combined sewer overflows or leaking sewer pipes in urban areas, or leaking animal waste storage ponds or other animal waste management problems in rural areas.

Odors can result from animal waste, sewage, and/or decomposing organic debris.

Fish Kills can be caused by sudden oxygen depletion, acute toxicity and excessive turbidity. (See pesticide toxicity below). "Winter kill" occurs when fish die under ice cover as a result of oxygen depletion. Winter kill occurs mostly in shallow lakes where oxygen-depleting weeds "use up" the oxygen. Winter kill is far less common in larger, deeper lakes.

Pesticide Toxicity is caused by exposure to herbicides, insecticides, fungicides or other chemical agents. Both acute and chronic toxicity are of concern. Acute toxicity is expressed in a relatively short period of time and may occur after exposure to a single dose of the pesticide. An example of acute toxicity would be a fish kill as a result of a pesticide spill. This "acute" action usually results from the biologically active ingredients of the pesticide, which shuts down or blocks some critically important life function of an organism.

Chronic toxicity is expressed over a long period of time, and results when an organism is exposed to repeated or continual sublethal concentrations of a pesticide. Chronic toxicity is difficult to assess because one species may gradually disappear from the aquatic environment over a long period of time. Examples of chronic toxicity would include reproductive impairment of aquatic organisms due to low-level herbicide concentrations in the water. All pesticides have certain exposure levels which can result in acute and chronic toxicity to aquatic organisms.

Like pesticides, heavy metals can cause acute and/or chronic toxic effects to aquatic organisms. Zinc, copper and lead are heavy metals, among others, that have many private, industrial, municipal and commercial uses and, as a result, are often found elevated in urban stormwater runoff. Atmospheric loadings of metals also serve as a substantial source to the urban area. The toxic effects of some heavy metals are often mitigated by chemical conditions of the receiving stream.

Wetland Degradation from nonpoint sources of pollution can also occur. In general terms, wetlands are areas where land and water meet. They are comprised of water, hydric soils, and plant species adaptable to fluctuating land/water conditions. Disturbance to these elements can potentially alter the natural functions that wetlands provide.

Improper land practices may result in soil erosion and sedimentation problems, pesticide and fertilizer runoff, excess flow, and other nonpoint problems which can significantly alter the wetland and its ability to remove pollutants. These problems can be manifested in the watershed quickly or over a long period of time.

The proper selection and application of Best Management Practices can control the sources, and therefore the effects, of nonpoint sources on the aquatic environment.

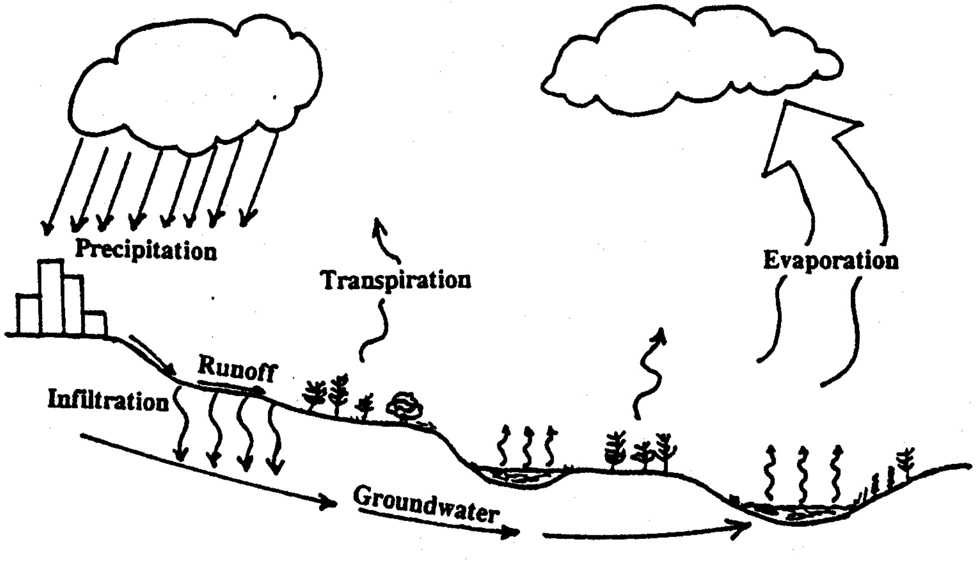
CHANGES IN WATERSHED HYDROLOGY

The impacts of nonpoint sources go above and beyond what was included in our assessment. For example, the hydrology of a surface water may be altered by increased imperviousness (i.e. paved areas) or by other changes in the watershed.

The most basic concept of watershed management is to try to maintain the natural hydrologic balance. Water is transported to the atmosphere from the surface primarily by evaporation, where it condenses and falls back to the land as precipitation. Precipitation either infiltrates the ground, or runs off the surface and is collected in lakes, streams and other water bodies. The collected water evaporates and the cycle starts all over. Figure 5 shows the relationship between surface and groundwaters and how altering any aspect of the **hydrologic cycle** will alter the hydrology of the watershed. In practice it is much more complicated than explained here, but this is the basic concept.

If land is developed, areas of infiltration decrease, transpiration decreases (because vegetation is removed) and runoff increases. Increased runoff results in increased flood flows, higher in-stream velocity, and alterations in wetlands. These and other changes in hydrology are discussed more technically below, as modified from "Mitigating the Adverse Impacts of Urbanization on Streams: A Comprehensive Strategy for Local Government," Metropolitan Washington Council of Governments (Schueler, 1987).

Figure 5



Generalized Hydrologic Cycle

Source: Stormwater Management Guidebook, MDEQ, Land and Water Management Division, 1992.

<u>The magnitude and frequency of severe flood events increases.</u> In extremely developed watersheds (impervious surface area > 50%), the peak discharge after development may increase by as much as five times the pre-development rate. More severe floods reshape the dimensions of the stream channel and its floodplain and wetlands.

In addition, watershed development increases the frequency of bankfull and sub-bankfull flooding events. Bankfull floods are defined as floods that completely fill the stream channel to the top of its banks, but do not spill over into the floodplain. Schueler (1987) estimated that the number of bankfull floods increases from one every other year prior to development, to over five each year for a 50% impervious watershed. In practical terms, this means that a short but intense summer thunderstorm that had scarcely raised water levels prior to development may turn an urban stream into a raging torrent. The greater number of bankfull floods subject the stream to continual disturbance by channel scour and erosion.

Increasing flood frequency or water level fluctuations in wetlands can kill certain wetland plant species while favoring the productivity of others. The character of riparian wetland areas is primarily governed by the flooding regime, with periodic inundation promoting richer and more abundant species composition than either predominantly dry or predominantly flooded conditions. Wetlands located along flowing waters generally receive high nutrient loads from these waters. Floodwaters distribute pollutants extensively through wetlands. Changes in velocity of flow through wetlands will cause changes in deposition as well as erosion.

More of the stream's annual flow is delivered as surface storm runoff rather than base flow or interflow. In undeveloped watersheds, anywhere from 5 to 15% of the annual stream flow is delivered during storm events, depending on watershed vegetative cover, soils and geology. By contrast, in developed watersheds, the majority of annual stream flow occurs as surface runoff. As a general rule, the amount of storm runoff increases in direct proportion to the amount of watershed imperviousness. For example, surface runoff typically comprises half the annual stream flow in a watershed that is 50% imperviousness.

Consequently, the amount of base flow and interflow available to support stream flow during extended periods of dry weather is greatly reduced. In smaller headwater streams, the reduction in dry weather flow can cause a perennial stream and adjacent wetlands to become seasonally dry .In larger urban streams, the reduced dry weather flow can significantly restrict the wetted perimeter of the stream or adjacent wetlands, thereby reducing the usual habitat available to aquatic life.

Reduction in groundwater base flows has the potential effect of extending the length of dry periods in wetlands which are seasonally affected by groundwater sources. This extended length of dry periods will impact the life cycles of the wetland species dependent on the water column.

The velocity of flow during storms becomes more rapid. This is due to the combined effect of greater discharge (flow), rapid time of concentration, and smoother hydraulic surfaces. In a 50% impervious watershed, post-development runoff velocities exceed thresholds for erosivity, requiring channel protection measures. In addition, stream flow becomes extremely flashy, with sudden and sharp increases in discharge, followed by an equally abrupt return to pre-storm discharge levels.

Increased flows can increase the velocity of water entering adjacent wetlands which can result in biotic disturbances. Changes in average water levels, or duration or frequency of flooding, will also alter the species composition of wetland plant and animal communities.

CHANGE IN WATERSHED MORPHOLOGY (Structure and Form)

As the flow of a surface water increases, the shape of the watercourse also changes. The channel generally widens to accommodate the additional flow, and stream bank erosion often occurs.

As sediment enters the system from stream bank erosion and runoff, pools within the stream, and lakes and wetlands within the watershed become filled with sediment and other types of pollutants. Stream channels and riparian wetlands also must respond and adjust to the altered hydrologic regime that accompanies urbanization. The severity and extent of stream adjustment is a function of the degree of watershed imperviousness. Generally, the impact to wetlands will vary depending upon the wetland type and size.

These and other ways the surface water may change are discussed in more detail below, as modified from "Mitigating the Adverse Impacts of Urbanization on Streams: A Comprehensive Strategy for Local Government".

The primary adjustment to increased storm flow is channel widening, and to a lesser extent, down-cutting. Stream channels in moderately developed watersheds may become four times wider than before development. The channel widening process is primarily accomplished by lateral cutting of the stream banks. As a consequence, the riparian zone adjacent to the channel is severely disturbed by undercutting, tree-fall and slumping. Disrupted flow patterns and channeling in wetlands can result in decreased natural pollutant removal efficiencies.

Sediment loads to the stream increase sharply due to stream bank erosion and upland construction site runoff. The coarser grained sediments are deposited in the new wider channels and may reside there for years until the stream can export them from the watershed. Much of the sediment remains in temporary storage, in the form of constantly shifting sandbars and silt deposits. The shifting bars often accelerate the stream bank erosion process by deflecting runoff into sensitive bank areas. Excessive suspended sediment loads through wetlands result in increased deposition of silts and debris. Over time, the deposited silts and debris become the new, higher ground surface. Wetland plants then receive less surface or groundwater. Eventually plants become stressed and replaced by plants more adaptable to dryer conditions.

Together, the massive sediment load and channel widening produce a major change in the morphology of urban streams. The series of pools and riffles so characteristic of natural streams is eliminated, as the gradient of the stream adjusts to accommodate the frequent floods. In addition, the depth of the flow in the channel becomes shallower and more uniform during dry weather periods. The loss of pool and riffle structure in urban streams greatly reduces the availability and diversity of habitat for the aquatic community.

The nature of the streambed is also modified by the urbanization process. Typically, the grain size of the channel sediments shifts from coarse grained particles towards a mixture of fine and coarse grained particles. This results in a phenomena known as imbedding, whereby sand, silt and even clay fill up the interstitial voids between larger cobbles and gravels. Imbedding reduces the circulation of water, organic matter and oxygen to the filter-feeding aquatic insects that live among and under the bed sediments. These insects are the basic foundation of the stream food chain. In addition, imbedding of the stream sharply limits the quality and availability of fish spawning areas, particularly for trout.

In intensively urbanized areas, many streams are totally modified by people to “improve” drainage and reduce flooding risks. Headwater streams tend to suffer disproportionately from enclosure in pipes. When enclosed, the headwater stream is entirely destroyed, and is replaced by an underground network of storm drain pipes. In the past, larger urban streams have been engineered and channelized to more efficiently and safely convey floodwaters. As a result of such channelization and storm drain construction, flooding problems are simply passed on to downstream communities and property owners. Although large-scale stream channelization is now discouraged, some form of future channel "improvement" is inevitable if development is allowed to continue without some form of stormwater management.

Another inevitable consequence of urbanization are stream crossings by roads and pipelines. These structures must be heavily armored to withstand the down-cutting power of stormwater. Many engineering techniques utilized for this purpose (e.g. drop structures, culverts, etc.) create barriers to the migration of both resident and anadromous fish. Even a six-inch drop can block the upstream movement of many fish species.

Additionally , pollutants in storm water can accumulate in wetlands. Urban stormwater input has the potential to change the pH and redox potential of soils, making many toxins in the storage pool available so that they can have an immediate effect on wetland soils, both in-situ and potentially downstream. The rate of metal accretion and the degree of burial in the sediments are critical factors in determining the loadings which can be endured by wetlands without damage.

CHANGES IN WATERSHED HABITAT AND ECOLOGY

The ecology of urban streams is shaped and molded by the extreme shifts in hydrology, morphology and water quality that accompany the development process. Changes within the aquatic community of urbanizing watersheds are both subtle and profound, and include a reduction in the habitat available and the number and kinds of species. The impacts of urbanization and stormwater discharge on wetland systems are interactive and are not always clearly understood. These changes are discussed in technical detail below, as modified from "Mitigating the Adverse Impacts of Urbanization on Streams: A Comprehensive Strategy for Local Government".

Shift from external to internal stream production. In natural streams, the primary energy source driving the entire aquatic community is the import and decomposition of leaf litter, woody debris and other organic matter. However, in many urban streams, internal benthic algal production becomes a major energy source supporting the aquatic community, due to the combined effect of increased light penetration and nutrients (and the rapid washout of organic matter through the stream system). This shift is often manifested in changes in the mix of species found in the stream community. For example, environmental conditions are more favorable for species that graze algae from rocks (e.g., snails) than for species that shred leaves or filter coarse grained detritus (e.g. caddisflies, stone flies etc.).

Reduction in Diversity in the Wetland and Stream Communities. The cumulative impact of the loss of habitat structure (pools/riffles), the imbedding of the stream bed, greater flooding frequency, higher water temperatures, extreme turbidity, lower dry weather flows, eutrophication, and toxic pollutants is to greatly reduce the diversity and richness of the urban stream and wetland communities. In intensively developed areas, streams support only a fraction of the fish and macroinvertebrates that exist in natural streams.

In wetlands, species richness is affected by increases in water level fluctuation, with decreased species richness associated with higher water level fluctuations than are found in natural systems. Wetland mammal populations may potentially be affected by change in hydroperiod because of loss of vegetative habitat and the increased potential for disease organisms and parasites due to shallower, warmer, base flow conditions. Changes in wetland water level may alter the quantity and quality of amphibian habitat triggering changes in breeding patterns and species composition.

Destruction of Stream Ecosystems, Freshwater Wetlands, Riparian Buffers and Springs. In the past decade, it has been necessary to abandon the notion that a watershed is defined solely by the stream ecosystem. It is now understood that extensive freshwater wetlands, floodplains, riparian buffers, seeps, springs, the stream ecosystem, and ephemeral channels are linked to the watershed. In varying ways, these areas contribute many of the ecological functions and processes upon which the watershed and its features depend. Unfortunately, these areas are subject to destruction during indiscriminate clearing and grading.

Lakes within urban watersheds are particularly sensitive to urbanization and stormwater discharge since lake water quality is critically linked to the quality of the incoming water from the watershed. Generally, lake eutrophication is a natural, usually irreversible process resulting from the gradual accumulation of nutrients, increased productivity, and a slow filling in of the basin with accumulated sediments, silt and organic matter from the watershed. However, human-induced disturbances in the watershed which dramatically increases nutrient, soil or organic matter loads will accelerate the natural eutrophication process. A lake's resource value can be reduced drastically by activities such as forest clearing, road building, cultivation and residential development because these activities increase soil and nutrient loads that eventually move to the lake. Once a lake has been degraded, restoration, if at all possible, will be difficult and costly.

STEPS TO TAKE TO ADDRESS URBAN/URBANIZING NONPOINT SOURCES AT THE WATERSHED LEVEL

It is important to remember that Best Management Practices are just some of the tools used to reduce nonpoint source impacts to surface and groundwaters. Other more long-lasting tools such as ordinances should be implemented to prevent unsound practices and encourage good practices throughout the watershed.

In order for BMPs to be effective, a systematic approach must be taken which evaluates the existing conditions in the watershed, determines the water quality goals of the watershed, and determines the steps needed to reach those goals. Randomly installed BMPs may provide the desired loca1 treatment, but when considering the overall effects in the watershed, they can actually increase nonpoint source problems.

The steps to developing a watershed plan are given in the following text, and are summarized in the flow chart on the next page. **The Department is encouraging the development of watershed plans because the hydrologic and water quality changes which occur in one portion of the watershed will impact the entire watershed.** In addition, watershed planning will allow the use of regional BMPs, which are often less expensive to install and maintain than several on-site BMPs. (See the section on "Detention and Infiltration.")

After a watershed plan is developed, specific individual site plans within the watershed can then be designed to meet the objectives of the watershed plan. The steps to developing a site plan are discussed in a separate section.

Watershed Evaluation: There are two major activities which need to be undertaken in order to develop a watershed plan (see Figure 6). The first major activity is conducting a watershed evaluation. A watershed evaluation is essentially an inventory of the existing natural, cultural and aesthetic features of the watershed, as well as the water quality goals of the community. Where logical, this information should be presented in map form.

Developing a watershed evaluation has been divided up into the following steps:

STEP 1: Delineate Watershed Boundaries

The first step in developing a watershed plan is to use topographic maps to delineate watershed boundaries. For planning purposes, and to help in prioritizing areas, if a watershed is larger than 100,000 acres in size, it is recommended that the watershed be divided into smaller, more manageable sections (sub-watersheds).

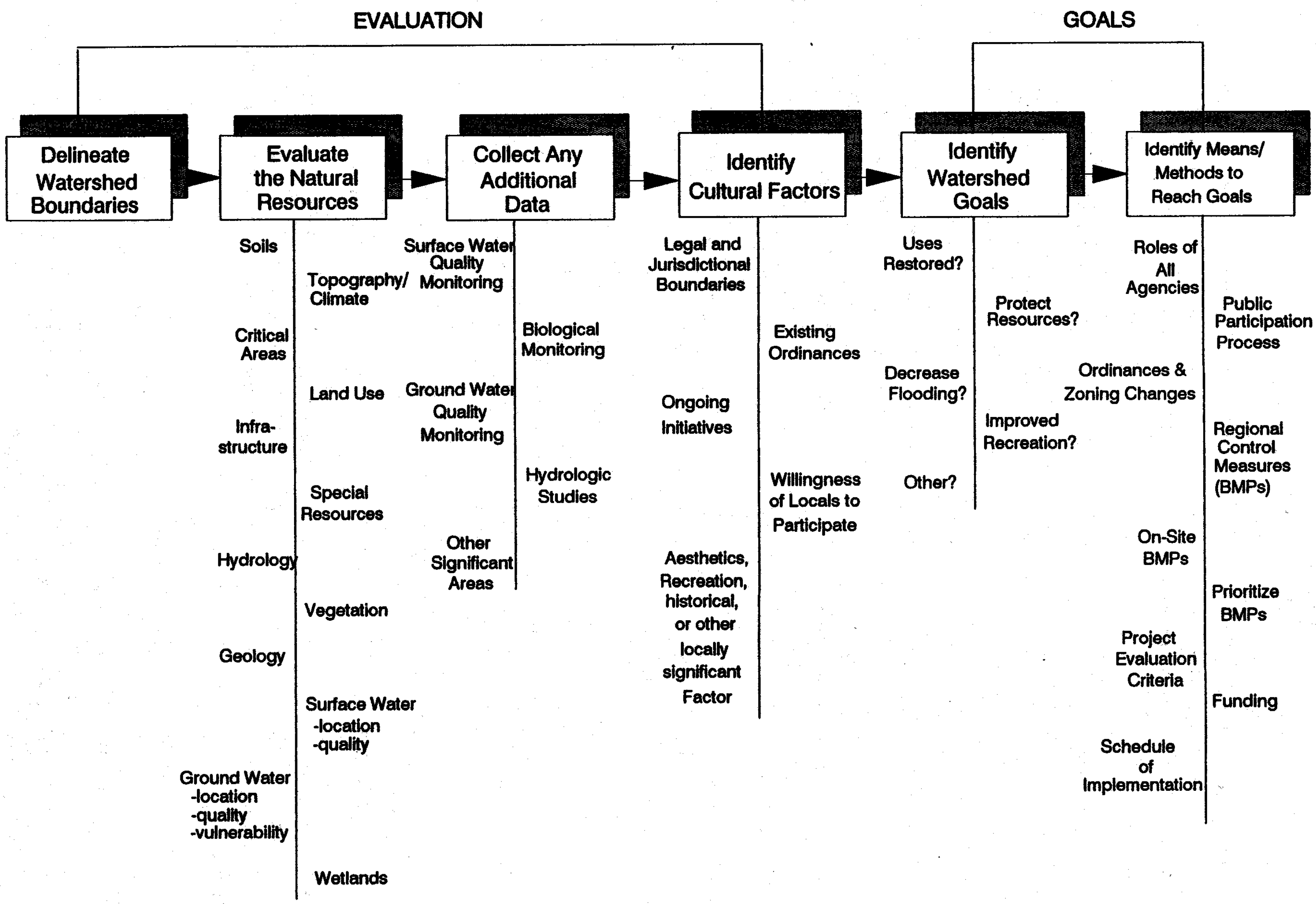
STEP 2: Evaluate the Natural Resources

When looking at the natural resources, include the following:

- **Soils.** It will be necessary to know the soil characteristics in the watershed, including permeability, erodibility and the hydrologic soil group. Soils information for most counties is contained in soil surveys which are available at local Soil Conservation District Offices. See the "Soils" section in the Appendix for additional information on soils.

Figure 6

How to develop a Watershed Plan



- **Topography and Climate.** Identify slopes, contours, natural depressions and elevations. Note rainfall distribution, areas which could be affected by wind and solar orientation, and freeze-thaw patterns.

- **Critically Eroding Areas.** These are areas which are likely to erode, including steep slopes, raw (i.e. exposed) areas, and other areas in which runoff has or will cause erosion and sedimentation. Include shorelines, natural drainageways, steep slopes, porous soils and wetlands. (These areas are discussed in further detail in STEP 3 of the "Step by Step method to Develop a Site Plan", below.) The recommended procedure for identifying wetlands is that established by the State's Goemaere-Anderson Wetland Protection Act and Administrative Rules. Contact county or regional planning agencies, or the MDEQ, Land and Water Management Division, Wetland Management Program, for land use information.

- **Land Use.** Land use is simply how the land is used. It is often indicative of the amount of impervious surface. (Impervious surfaces include all paved surfaces and buildings, and are a critical component of runoff calculations, pollutant load estimations, and hydrology).Typical land uses include rural, urbanizing or urban, commercial, industrial, residential, parks/recreational, and transportation. Each type of land use will generate different types of runoff .

  The choice of BMPs may be limited in order to fit in to existing land use. Therefore, determine both the existing land use and projected or known land use changes. Land use maps for many parts of the State are available from the MDEQ, Land and Water Management Division.

- **Infrastructure.** Identify location and all connections to storm drains. Start by identifying major storm outlets to waterbodies, including established county drains, road drains, and direct outlets from streamside/lakeside developments. Note the location of utilities, water mains and sanitary sewers.

- **Hydrology.** Determine the exact location of all surface waters, including lakes, streams, rivers, wetlands, drainage ditches, floodplains and groundwater recharge areas. Determine the flow patterns of all surface waters and the monthly 95% and 50% exceedance flows. Indicate areas which have been channelized and where dredging may occur in the next several years. Other hydrologic modifications such as dams should also be noted. Depending on the county , some of this information can be obtained from the MDEQ, Land and Water Management Division.

- **Special Resources.** Identify any special resources within the watershed, including endangered species, natural areas, and wild and scenic rivers. The list of Wild and Scenic Rivers is included in the Appendix. Information on endangered species can be obtained through the assistance of the Natural Heritage Program, MDNR, Wildlife Division. Note that the Department will not permit the development of land which contains endangered species.

- **Vegetation.** Note the types and locations of existing vegetation. Note areas where vegetation has been disturbed (i.e. clear cutting, excessive grazing) and where replacing indigenous vegetation would be beneficial. Also note significant woodlands.

- **Geology.** Note the location of bedrock and mineral deposits, and groundwater level.

- **Surface Water Quality.** Identify water quality and quantity problems. Look for any of the "Sources and Impacts of Nonpoint Sources", as well as any "Changes in Hydrology", "Changes in Stream Morphology" , or "Changes in Stream Habitat and Ecology" , as discussed previously. Document existing water quality .

  The water quality and quantity impacts in a watershed are best described in terms of designated uses. **All** waters of the state of Michigan are to meet the following seven designated uses:

  - Agriculture
  - Navigation
  - Industrial water supply
  - Public water supply at the point of intake
  - Warmwater fish
  - Other indigenous aquatic life and wildlife
  - Partial body contact recreation and total body contact recreation between May 1 and October 31

  Those are the **minimum** uses that should be met for all waters of the state. Additional protection is given to high quality waters and other sensitive resources. Specific local uses should also be identified.

  When identifying if problems exist in a watershed, refer to the list of designated uses. If any uses are impaired, the Watershed Plan should include a map with prioritized activities which will restore those uses .

  An important part of identifying the impacts and sources is to walk, canoe or drive the entire watershed. Take notes as you investigate the watershed, noting all potential problems that can be seen and their possible sources. Local agencies such as the Soil Conservation District, health department, drain commissioners and others are also good sources of information.

- **Groundwater Quality.** Determine groundwater characteristics, including its vulnerability. Groundwater vulnerability information may be available from the county health department, MDEQ, Waste Management Division, or local universities. Also, contact the local health department to see if any groundwater samples have been collected.

  The watershed plan should also include the location and activities occurring at Act 307, LUST and Superfund sites. This information is available from the MDEQ, Environmental Response Division.

- **Wetlands.** Identify the location of all wetlands. The "Michigan Wetlands: Yours to Protect," published by the Tip of the Mitt Watershed Council, includes information on how to identify and delineate wetlands. Other sources of information include MlRIS, the Michigan Resource Inventory System, and the "Federal Wetlands Delineation Manual." MIRIS information may be available from the MDEQ, Land and Water Management Division. The federal manual can be obtained from the U.S. Environmental Protection Agency, wetlands and watersheds Section, at 312-886-0243.

Unless exempted, wetlands permits will be needed from the MDEQ Land and Water Management Division for activities that occur within 500 feet of an inland lake, stream or pond and 1,000 feet from a Great Lakes. These are contiguous wetlands. Non-contiguous wetlands are regulated only if they are greater than five acres in size and in counties with populations of 100,000.

STEP 3: Collect Any Additional Water Quality/Quantity Information

A monitoring plan should be developed to document existing (baseline) water quality and to determine changes in water quality as changes occur in the watershed. Water quality monitoring is especially important where there are concerns for heavy metals (such as zinc, lead and copper), conventional pollutants (such as dissolved oxygen, nutrients and suspended solids), and organics (such as PCBs).

Biological surveys are good indicators of water quality and should be considered, especially in areas where aquatic habitat is known or suspected to be impacted.

Also consider: hydrologic studies to determine hydrologic regimes, and to get baseline information to determine hydrologic changes in the watershed; and collecting groundwater samples to get background information on groundwater quality.

It is important to tailor your monitoring plan to the goals of the watershed, and to sample often enough and over a long enough period of time to show results. If the goal is to reduce nutrient inputs, then at a minimum the monitoring plan should include nutrient monitoring. If the goal is to restore eroded banks, then hydrologic monitoring should be done in conjunction with either biological surveys or monitoring for suspended solids. MDEQ staff may be able to provide assistance in developing a water quality sampling or monitoring program suitable for your site. Many Michigan streams and lakes have already been surveyed by MDEQ biologists.

STEP 4: Identify the Cultural Factors Affecting the Watershed

- **Legal and Jurisdictional Boundaries.** Identifying the legal and jurisdictional boundaries will help eliminate confusion as to who-does-what.

- **Ordinances.** What ordinances currently impact water quality or quantity? Include land use (zoning) restrictions, wetlands ordinances, stormwater ordinances, etc.

- **Ongoing Initiatives.** Determine the federal, state and local initiatives in the watershed or project area. How do these initiatives relate to the proposed project?

- **Willingness of Locals to Participate.** Survey all the local agencies and residents in the area to determine their awareness and willingness to assist with the project.

- **Aesthetics, Recreational Value, and Other Significant Areas.** Determine the aesthetic value of the watershed, including rolling hills, scenic views, beaches. Recreational areas, including access points to the water should be noted. Also note historically or archaeologically significant areas.

Once the watershed evaluation has been completed, display as much of the information as possible on maps. Geographic Information Systems (GISs) can be used to graphically show the interrelationship between various types of information. For example, areas with highly erodible soils can be compared with the locations of eroded stream banks to help prioritize stream bank erosion sites for stabilization .

Determining the Goals and How to Achieve Them. The second major activity in developing the watershed plan is determining the goals of the watershed and the means of obtaining the goals.

STEP 5: Determine the Goals and Desired Uses of the Watershed.

What does the community want from its watershed: improved recreation, water supply, fisheries, or aesthetics? Does the community wish to try to return the hydrology of the stream to its pre-development state? Describe the primary benefits of the project, such as meeting water quality standards, return of uses and protection of water resources. Describe the secondary benefits of the project, such as flood control, improved air quality, aesthetics, habitat protection, or soil erosion control. Each goal should be specific and given a specific time frame for implementation.

The section below on the "Step by Step Process for Developing a Site Plan. " This contains a set of goals which can be used at the watershed level, including such things as keeping hydrology to pre-development levels, etc.

STEP 6: Identify Methods/Means to Obtain the Goals. Do this by including in the watershed plan the following:

- **Identify Participating Agencies and Their Roles.** Since a watershed plan is a comprehensive, intensive effort, it is recommended that one agency take the lead in writing the plan and other agencies assist in its development by providing technical assistance or other types of expertise. Soil Conservation Districts, Soil Conservation Service, Cooperative Extension Service, county drain commissioners, road commissions, local health departments, and planning agencies can all be of assistance in developing the plan, or can take the lead role. MDEQ, Surface Water Quality staff is knowledgeable in designing sampling plans which may be needed to pinpoint nonpoint sources. Spell out who is responsible for the various aspects of the plan and be sure each agency agrees with its role. Include the municipalities, county and township governments, drain commissioners, health departments, state and federal agencies, citizen groups, developers, local universities, and all other interested groups. Each group should be tied to the implementation of one of the goals mentioned above.

- **Develop a Public Participation Process.** A process should be established for involving the local public in the planning and implementation activities (e.g. group meetings, public meetings, newsletters, news releases, tours, field days, demonstrations, etc.). Estimate the percentage of local participation needed to ensure the established goals are met.

- **Develop the Necessary Ordinances and Zoning Requirements.** Ordinances can be developed which provide wetland or flood plain protection, green belt requirements or site drainage specifications. Existing ordinances should be reviewed during the development of the watershed plan. Zoning can be used to protect critical areas or to promote cluster developments. For this and the identification of BMPs, see the section on "Developing a Site Plan," Step 3.

Also consider the possibility of conservation easements and trusts.

- **Identify Regional Control Measures.** Regional control measures are those measures (BMPs) applied over large parts of the watershed under some central control. Generally, regional BMPs are much more efficient to install, operate and maintain than on-site BMPs. It is easier to predict the effect of regional BMPs on a watershed, they are less expensive to build and maintain, and may provide uses beyond their use as nonpoint source controls, such as sports fields or parks.

  Regional control measures and on-site detention are discussed in the section below entitled "Detention and Infiltration to Address Urban Nonpoint Sources of Pollution. "

- **Maps.** If data is available on a geographic information system (GIS), overlays can be made of the soils information, land use, groundwater vulnerability, etc. If Geographic Information Systems are not available, use topographic maps to delineate the watershed boundaries and make continual references to soil surveys (where available) when making decisions about the watershed. Identify on the map all regional BMPs (see below).

- **Identify Other BMPs.** The implementation of certain BMPs could be encouraged throughout the watershed. For example, in areas with permeable soils, sites could be required to replace permeable areas lost during the course of development with infiltration practices. Also, in areas of the watershed that are particularly sensitive or have a special use, such as a wildlife preserve, special practices could be required.

- **Prioritize BMPs and Other Actions.** Resources are generally not available to tackle all the identified problems at once. Prioritizing BMPs and other actions will help get the greatest water quality/quantity benefit for your money. If fecal coliform is elevated throughout the watershed, priority will probably be given to considering more intensive water quality sampling to identify specific sources. Once the sources of bacteria are identified and corrective measures underway, begin tackling the next most significant water quality/quantity project. Always determine priority based on the desired goals of the watershed.

- **Project Evaluation Criteria.** Describe the criteria that will be used to evaluate the success of the project toward meeting the objectives (i.e. stream monitoring, BMP training, participation rate, modeling, etc.).

- **Funding Sources.** Identify all potential funding sources, from re-directing existing funds to address water quality , to cost-share monies, to low-interest loans and grants. See the section on "Funding. "

- **Schedule of Implementation.** A timeline needs to be developed to keep the local communities on target in the implementation of the BMPs.

STEP 7: Writing the Watershed Management Plan: The watershed plan is developed with information obtained from the Watershed Evaluation steps and the Goals. The plan may be for a very small sub-watershed and therefore relatively simple, or it may be for a large watershed crossing multiple jurisdictions or including multiple tributaries, making the plan more complex. The watershed plan will be a type of blueprint for how local communities want to manage their watershed.

The final watershed plan should contain a compilation of:

*A summary of all the data collected during the evaluation, including information on:
- the natural resources
- cultural factors

*The goals of the watershed
*The means of achieving the goals

STEP BY STEP METHOD TO DEVELOP A SITE PLAN

The types of activities which need to be undertaken to develop a site plan are similar to those needed for a watershed plan. The site plan should detail the practices that will be implemented on a particular site to protect the natural resources in the watershed. The goals of a site plan should be consistent with the goals of the watershed plan. If no watershed plan exists, the site plan should include the practices and strategies which will reduce adverse impacts on the hydrology and water quality of the watershed.

For the purposes of this document, an acceptable site plan should include, at a minimum, a grading plan, a soil erosion and sedimentation control plan, and a stormwater plan. A grading plan is a short-term plan which contains all existing structures, all cut and fill areas, and the elevations before and after construction will take place. A soil erosion/sedimentation control plan includes all temporary and permanent structures which are needed to keep soil from leaving a construction site. A stormwater management plan is a long-term plan which includes all the practices that will be used to manage stormwater. These three components of the site plan are discussed in detail in STEP 5.

We encourage a three-component site plan to ensure that the short-term soil erosion/sedimentation control (SE/SC) plan and the long-term storm water plan follow one another logically. For example, if a sediment basin is included in the SE/SC plan, then its location and eventual fate as a stormwater control practice should be logical. We also encourage including the grading plan so that all initial and final elevations are consistent with the SE/SC and stormwater plans.

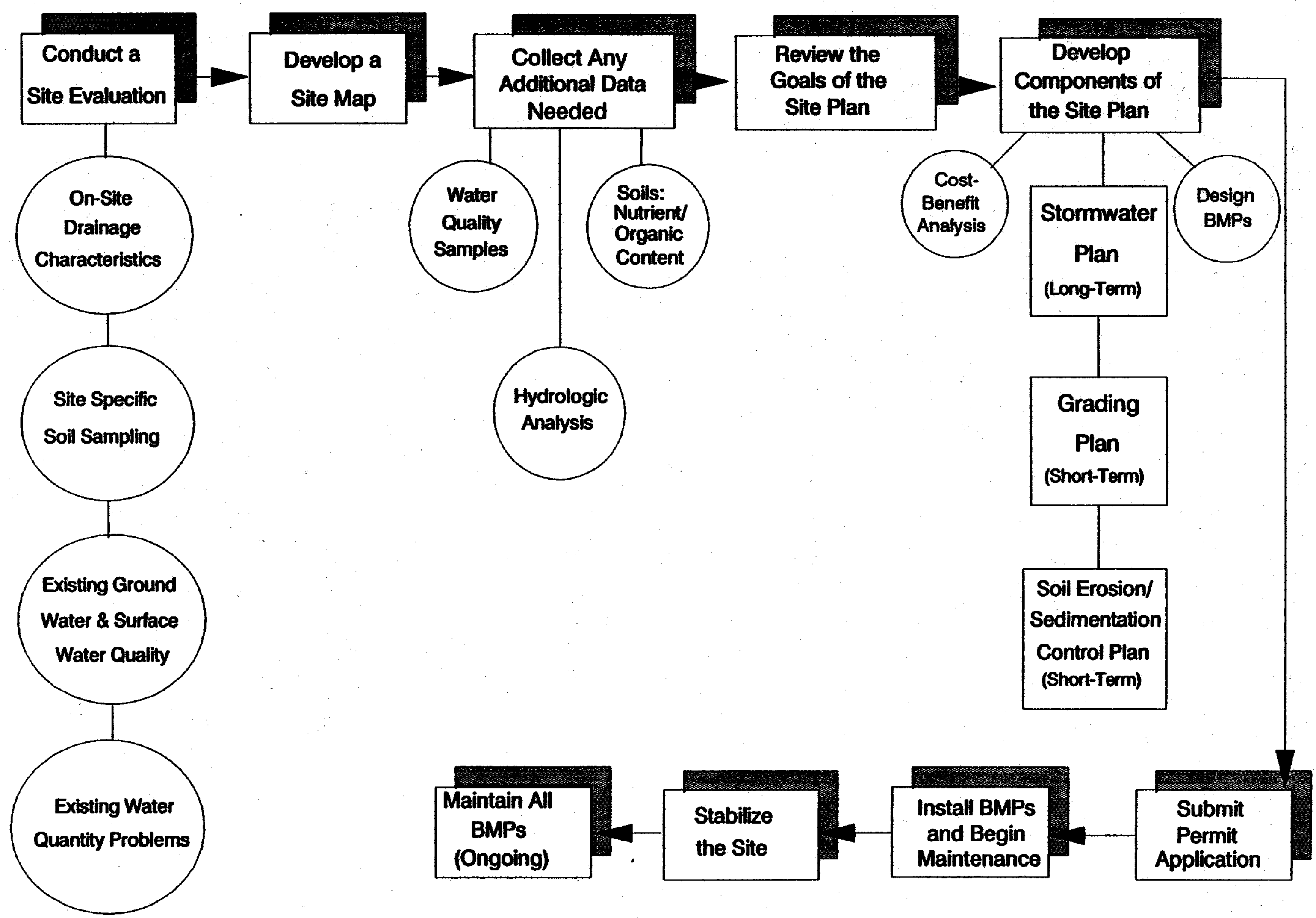
The following are steps which can be followed to develop a site plan and identify the BMPs needed at the site. These steps are summarized in Figure 7.

A note on Legal Implications of the Site Plan:

Under Act 347, the Michigan Soil Erosion and Sedimentation Control Act, a soil erosion/sedimentation control plan is a requirement of all construction sites of one acre or more in size or within 500 feet of a lake or stream. Under the recently promulgated stormwater regulations, all construction sites which expose five or more acres of land will also require a National Pollution Discharge Elimination System (NPDES) permit. Michigan's recently approved rule amendments (part 21 Rules) state that if you are permitted under Act 347, you are deemed to have a NPDES permit, "unless the Commission has required an individual national permit pursuant to the provisions...of this rule. " The rules state that for all construction sites of five or more acres, the construction permittee must file to the MDEQ a notice of coverage under this rule before commencing with construction activities. The rules also require maintenance of all soil erosion control structures to comply with the Act 347 permit, and inspections of the site once a week and within 24 hours after every precipitation event. There are also provisions for certified stormwater operators, proper waste disposal, reporting requirements and inspection requirements. See the appendices for the Part 21 Rule amendments.

Figure 7

How to Develop a Site Plan



STEP 1: Conduct a Site Evaluation. A site evaluation is basically a more focused version of a watershed evaluation. Some of the information needed here can be obtained from the watershed plan. Note information from the watershed evaluation, as well as the site conditions upstream and downstream of the site, and on-site conditions. Maps of the site should be produced detailing the various characteristics of the site. Use professional surveys when possible. Make the maps as large as possible because eventually you will want to identify and locate specific BMPs which will be needed. Be sure to include on your map the names of all surface waters, the location of trees and other vegetation that will be preserved, the approximate slopes after grading, areas of soil disturbance, the direction of drainage patterns, and:

- **on-site drainage characteristics,** including:

    *the **size of the drainage area.** This will be needed in the design of almost all BMPs.

    ***runoff calculations** for the design storm(s) needed per each BMP. Where possible, obtain either from direct measurement or determine by estimate the expected pollutant loadings from the watershed.

- Determine **site-specific soils information**. Soil tests will provide the most accurate information for the proper selection of BMPs. If soil tests cannot be done, use soil surveys, as available from the local Soil Conservation District. See also the Appendix text on "Soils".

Determine Existing or Potential Ground and Surface Water Quality Problems.

- Determine the cause of the problems identified. For example, if banks are sloughing, it may be necessary to look at upstream areas to see if development upstream is adding to flow velocities in your part of the watershed. It may be necessary to work with upstream users to control the sources of nonpoint pollution.

- Identify sites of potential problems so that problems may be reduced before they occur. Such problems areas may include sites which may result in increased hydrology or soil erosion, either during or after construction.

Where known problems exist or when retrofitting existing BMPs, the following information is also needed:

- Work with engineers or environmental consultants, MDEQ staff, Drain Commissioners, Soil Conservation District staff, Soil Conservation Service staff, the Cooperative Extension Service, or other appropriate professionals to discuss options for remediating the problem.

    Note: All structural BMPs should be designed by professional engineers experienced in the design of such BMPs. Structural BMPs include all runoff conveyances and outlets, sedimentation control structures, and runoff storage structures.

- Don't overlook the nonpoint problems that can be remediated by simple measures such as leaving existing woody vegetative buffers, re-seeding exposed soils, proper household hazardous waste disposal, and proper lawn maintenance. Include these measures as part of the site plan.

STEP 2: Develop a Site Map.

A site map should be developed which, at a minimum, contains the soil textures, elevation, the location of surface waters (including wetlands), and the location of vegetative buffers and any other resource in need of protection (such as endangered plants). This map should be used as a basis for all other components of the site plan.

STEP 3: Collect Any Additional Information Needed.

If little information is available on water quality, then a water quality sampling program may need to be developed to establish baseline data. Consider biological surveys and/or collecting water samples. If little information is available on the hydrologic regime, then a hydrologic study is recommended. MDEQ staff may be able to provide assistance in developing a water quality sampling or monitoring program suitable for your site.

Site-specific soil sampling should always be done, even in areas where there are soil surveys. The soil surveys are good tools for general planning purposes, but they don't provide the detail necessary for site-specific design.

STEP 4: Review the Goals of the Site Plan.

The goals of a site plan should be consistent with the goals of the watershed plan. If no watershed plan exists, identify goals that would help direct the choice of practices and strategies for site development toward those that will reduce adverse impacts on the hydrology and water quality of the watershed. The following goals provide such direction. (The following is modified from "Protecting Water Quality in Urban Areas", Minnesota Pollution Control Agency, Division of Water Quality.)

A. Reproduce pre-development hydrological conditions. This is a goal that can only be addressed comprehensively at the site planning level. It means trying to reproduce the full spectrum of hydrologic conditions: peak discharge, runoff volume, infiltration capacity, base flow levels, groundwater recharge, existing detention, and maintenance of water quality. A comprehensive approach is difficult and involves the whole context of site planning. Runoff volume, infiltration recharge and water quality must take into consideration the amount of paved surfaces in the watershed, its configuration in terms of its relationship to drainage paths, and vegetative cover.

B. Confine development and construction activities to the least sensitive areas. Protecting critical areas during construction and after development is extremely difficult and costly. It is best to avoid construction in critical areas and plan development around them. In this way the watershed is more easily protected at a much lower cost. The major types of sensitive areas are discussed below:

- **Avoid construction in and adjacent to natural drainageways.** Construction in natural drainageways destroys natural vegetation and often results in channelized streams. Once natural vegetation in drainageways is destroyed, it is very difficult to reestablish. Since natural drainageways contribute large amounts of water directly to receiving lakes or streams, once disturbed, they can become high-energy, high-volume conduits for moving pollutants to receiving waters. Site plans that call for disturbing natural drainageways are unlikely to be able to meet the goal of keeping the waterbody within pre-development hydrologic conditions. Therefore, protect the existing vegetation to the extent possible.

- **Avoid developing on steep slopes.** Generally, the steeper the slope, the greater the soil erosion potential. This is because the effects of gravity and reduced friction between soil particles on steep slopes means it takes less energy for water to dislodge and transport soil particles. In addition, steep slopes also limit the area in which buildings can be located. Good site planning avoids placing houses and roads on steep slopes (1:2 slopes or less).

- **Maintain and protect dense vegetation and buffer/filter strips.** Leaving a dense vegetative cover adjacent to surface waters is the most important factor in preventing erosion. Disturbance of areas with a well established dense vegetative cover will yield the greatest change or impact in terms of erosion. Wooded areas with understory are the most runoff-absorbent types of cover in the landscape. Destruction of such vegetation adds significant expense to the construction budget for clearing, and destroys the aesthetic and economic attributes of the site. A good site plan preserves large areas of existing dense vegetation.

- **Preserve porous soils.** Site planning should include avoiding development on highly porous soil areas. This will make porous soils available for infiltration and significantly reduce the land area that must be committed to detention facilities required to control peak discharges.

- **Avoid disturbing erodible soils.** When denuded of vegetation during construction, areas with easily eroded soils can yield great volumes of transported soils. If site planning can be done to avoid disturbing erodible soils, large erosion and sedimentation problems will also be avoided.

- **Protect wetlands.** Wetlands provide many water quality functions such as nutrient retention, filtration, and the storage and delay of flood and runoff waters. Wetlands also serve as habitat for fish and wildlife. Approximately 30% of Michigan's threatened and endangered plants, and approximately 60% of the 65 threatened and endangered animals, are wetland species. It is therefore vital to protect them. Their use in stormwater control is discussed in section E, the "treatment train. "

Through careful site planning, sensitive areas can be set aside as natural open space areas to meet open space area requirements. Other areas can be used to preserve views from homesites, and to provide privacy between homesites.

C. **Fit the development to the terrain.** Choose road patterns to provide access schemes which match land form. For example, in rolling or dissected terrain use strict street hierarchies with local streets branching from collectors in short loops and cul-de-sacs along ridge lines. This approach results in a road pattern which resembles the branched patterns of ridge lines and drainageways in the natural landscape, facilitating the development of plans which control the landform and minimize disruption of existing grades and the natural drainage.

D. **Preserve and "more wisely" use the natural drainage system.** Keep pavement and other impervious surfaces out of low areas such as swales and valleys. This means keeping the roads and parking areas high in the landscape and along ridges wherever possible. Unfortunately, most existing development standards and approaches implicitly encourage developing roads and parking areas in low areas. However, this traditionally accepted practice does, in fact, cause nonpoint and point pollution problems.

The best example of this is the use of curbing on streets and parking areas in low- and medium-density subdivisions. Curbs are widely held to be the signature of quality development; they provide a neat, "improved" appearance and also help delineate roadway edges. Because curb-and-gutter streets trap runoff on the roadway, storm inlets and drains are logical solutions to providing good drainage for the roadway. As a result of such thinking, many municipalities require the use of storm drains and curb and gutter streets.

Unfortunately, this solution can create significant storm water management problems when looked at in the broader context of devising an environmentally sound land development scheme. The problem scenario goes something like this. Because storm drains operate on gravity flow principles, their efficiency is maximized if they are located in the lowest areas of the site. Since storm drains are the preferred technology for providing drainage for the curb and gutter streets, it is natural to locate the streets where the storm drains are best located--in the valleys and low areas which comprise the natural drainageways of any site. In this way, natural drainageways can become unintended targets for destruction: the natural vegetative cover in the most hydrologically critical areas of the landscape is replaced by impervious pavement. Natural filtration capacity is lost in the most strategic locations.

Further, in most locations, storm drains are designed only for short duration, high frequency storms with flood flows handled by street and gutter flows after the storm drain capacity is exceeded. This often means that the natural floodways have been converted from slow- moving, permeable, vegetated waterways to impermeable streets and gutters which move water at an increased velocity. The combination of storm drain and paved overland flow areas result in a watercourse that is "flashy", has an increased peak discharge, and, to some extent, a higher runoff volume. As natural waterways become paved and specifically designed to be quickly drained by storm drain, channel storage time is minimized and base flow and groundwater recharge are sharply reduced. The net effort of a seemingly beneficial decision to use curb and gutter can inadvertently cause nonpoint source pollution in water resources.

This scenario also has important effects on water quality. Trace metals, hydrocarbons and fuel spills from automobile are directly deposited on the now paved surfaces of the site's waterways. A certain amount of these pollutants, which might have settled out in the natural waterway, are now kept in suspension by the storm drain system during rainfall events.

In curb-and-gutter areas, pollutants are delivered via runoff to receiving waters where changes in velocity permit them to settle out. Pollutants such as nutrients from area lawns are quickly moved through the paved system with no opportunity to come in contact with plant roots and soil surfaces. The result is quick delivery of these pollutants to lakes, streams, and wetlands.

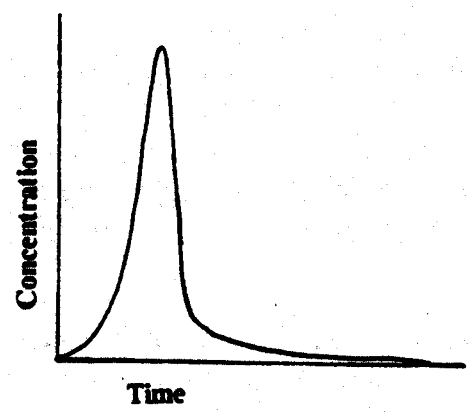
Note: Wetlands, like lakes and streams, are surface waters. They may in some cases act as natural drainageways. In these situations, wetlands must be protected from excessive point and nonpoint pollution loads. This is accomplished through maintaining the pre-development characteristics of wetland hydrology, and providing adequate pre-treatment of stormwater.

If natural vegetated drainageways are strictly preserved in the site planning process, flood volumes, peak discharges, and base flows will be held closer to their pre-development levels. Trace metals, hydrocarbon and other pollutants will have a much greater opportunity to become bound to the extent allowable through natural processes, with underlying soil. The infiltration which would occur along the entire drainageway would not only contribute to the reduction of runoff volumes, but would also allow nutrients to be taken up by the vegetation lining the drainageway.

E. All BMPs should be chosen using a **"treatment train"** concept. A treatment train is a series of BMPs used in conjunction with one another to "treat" runoff. Each BMP is chosen for its ability to remove or limit specific pollutants, and/or its ability to help regulate changes in hydrology. An example of a treatment train is parking lot runoff which outlets through a riprapped outlet, to a wet detention pond, which discharges to an infiltration basin. The riprapped outlet decreases the velocity of the water. The wet detention pond allows for settling of particles and biological uptake of nutrients. The infiltration basin removes some of the finest particles and provides infiltration.

Figure 8

Plot of Pollutant Concentration Versus Time



Source: Stormwater Management Guidebook, MDEQ, Land and Water Management Division, 1992.

The first flush is the term given to the fact that the majority of pollutants that enter surface waters during a rain event do so during the first part of the storm. This is shown graphically in Figure 8. The reason for this phenomenon is that during the first few minutes of a storm, the rain water picks up oil, grease and other pollutants that have accumulated on paved areas or roadways and transports them to the surface water or storm drain. After the first few minutes of the storm, there are fewer pollutants on the ground available for the rainwater to pick up. Because of this first flush effect, BMPs that capture the first ½ inch of runoff in Michigan would capture a higher percentage of pollutants. Our basin BMPs (detention and retention basins, for example) include a recommendation to design to capture at least the first ½ inch of runoff.

STEP 5: Develop Components of the Site Plan Based on the Goals.

General Considerations:

Since a site plan (which, again, consists of a grading plan, a soil erosion/sedimentation control plan, and a stormwater plan) will contain BMPs, it is important that the selection of site-specific BMPs takes into consideration the BMPs included in the watershed plan, especially in the case of regional controls. Again, this is important because the changes that occur on an individual site can affect the water quality and quantity of the entire watershed.

Design:

All BMPs which are identified for use on the site should be designed based on the specific site characteristics--soil type, slope, topography, climate, etc. The design of all structural practices should be done by engineers or other professionals qualified in the design of the BMPs needed. Persons designing BMPs should use the specifications in the attached BMPs as a basis for which to design the BMP for the specific location. It is important to remember that the specifications in the BMPs are not so inclusive as to be applicable to anyone particular site.

Whenever possible, design the BMPs with secondary uses in mind, particularly where large areas of land are needed to construct the BMP. Athletic fields and playgrounds are most often considered but fountains, waterfalls and aesthetics should also be considered. Wherever possible, the BMP should be designed to be aesthetically pleasing.

Maintenance procedures must be considered during the design phase to be sure the BMP can be easily maintained.

Cost and Time Comparisons:
When developing the components of the site plan, keep in mind that every BMP costs money to install, and many require design by professionals. Money will also be needed for the operation of the project, as well as for the maintenance of the control measures. Careful planning can minimize construction costs.

Before deciding on the use of a particular BMP, be sure to compare its cost effectiveness and the time that will be involved in its implementation with other similar BMPs. For example, although sodding may cost more money than seeding, establishing vegetation immediately to protect a sensitive area may outweigh the difference in cost. Temporary operations don't require the same expenses as long-term operations.

A. Developing the Grading (earth change) Plan:
(Note that earth change plans are required for all development sites under Act 347, the Soil Erosion and Sedimentation Control Act). The purpose of the earth change plan is to find the most harmonious fit between the natural characteristics of the site and its intended uses.

The site analysis done in Step 1 will help you determine which areas are best for development and which should remain undisturbed. An earth change plan consists of:

1. a written plan, which should include:

    - the site's proximity to surface waters
    - the severity of topography
    - the erodibility of soils
    - a description of existing woody vegetation
    - BMPs, including a planting program and other measures that will be used to control erosion and collect sediment during the grading operation.

2. a schematic earth change plan, which should include the location of:

    - all man-made structures, including buildings, vehicular and pedestrian routes, parking areas, open space areas, other site facilities, etc.
    - all cut and fill areas
    - the grades (elevation) both before and after development
    - all BMPs
    - all former and remaining woody vegetation

B. Developing the Soil Erosion and Sedimentation Control Plan:
The General Rules of the Soil Erosion and Sedimentation Control Act require the submission of an erosion and sedimentation control plan which includes both a graphic and written submission.

1. The **graphic submission** should include:

   - a description and location of the limits of all proposed earth changes.
   - a description and location of all existing and proposed on-site drainage. Plans should also take into account an estimate of the volume of water and the rate water runs off the site. These factors can be determined from field surveys, topographic maps, soil surveys, aerial photographs, and/or hydrologic computer models. Computer models can be used to determine runoff conditions on proposed earth changes in the land use and physical conditions of the watershed. Models can also be used to incorporate both water quality and water quantity considerations and to determine the effectiveness of selected BMPs. See the Appendix for two methods to calculate runoff.

   - a description and location of all proposed temporary erosion and sediment control measures. Using the Unified Keying System (UKS) during this part of the plan development can be very helpful. The UKS is a numbered listing of temporary and permanent soil erosion control measures, detailed with a simplified graphic and description. The keying numbers can be used by the planner to identify the type and location of the measures to be used on the site.

   - a description and location of all proposed permanent erosion and sediment control measures. Each permanent control measure should be documented and recorded with the county register of deeds and the enforcing agency prior to final approval of the project, or prior to occupancy, or use.

   - a description and location of all existing and remaining vegetation.

   - a schedule of the BMPs. Follow the Staging and Scheduling BMP .

   Plans should also take into account an estimate of the amount of soil that may erode during an earth change. The Universal Soil Loss Equation (USLE) is the most commonly used equation for estimating soil loss. The USLE can be used to estimate the annual average soil loss (in tons) from a site. It is used extensively for determining soil loss associated with farming activities, and is also a viable method for determining potential soil loss from construction activities. See the "Soils" Section in the Appendix for further explanation on the USLE.

2. The **written submission** should include a program proposal for the maintenance of all erosion and sedimentation control facilities which will remain after the project is completed, including the designation of a responsible party. Proper maintenance should include visual inspections of structures and vegetation for undercutting, erosion and failure. Particular attention should be given after each rain to ensure the measure will be effective during the next rain. Time should also be scheduled to allow for mowing, fertilizing, seeding and other non-structural maintenance.

   To ensure an effective means of controlling soil erosion and sedimentation, the soil erosion and sedimentation control plan should also include the following:

   - a site location map
   - a topographic map showing existing vegetation, predominant land features, and a description of existing site drainage patterns and facilities
   - a soil surveys and interpretation

- a site analysis to determine critically eroding areas
- an earth change plan to show how erosion and sedimentation will be controlled
- an erosion and sedimentation control plan to specify the schedule and control measures proposed

Source: Section 3 of "Michigan's Soil Erosion and Sedimentation Guidebook, " which contains several graphic illustrations and examples of soil erosion and sedimentation control plans.

C. Developing the Stormwater Control Plan:
A stormwater control plan should indicate the **existing drainage** characteristics of the site, including floodplains, wetlands, swales and conveyance systems. This information should be included on a map, with arrows denoting the direction of drainage.

The map should also indicate the practices or infrastructure that will alter the existing drainage patterns. Indicate on the map the **drainage changes** that will occur due to the proposed development.

Indicate the **BMPs** which will be used to prevent drainage from causing erosion or other water quality or quantity problems. BMPs to control runoff include check dams, stabilized outlets, grassed waterways, lined waterways, etc. Practices should be indicated on the map, and their general design (i.e. minimum storm design) indicated in writing. Be sure to keep in mind the goals of the waterbody being protected--extra precautions may be needed depending on the goals for the waterbody. All practices should be listed in writing. All practices should be shown on the construction blueprints.

In urban and industrial areas, **pre-treatment** of stormwater may be needed. Indicate in writing how pre-treatment will occur and indicate on the map the location where pre-treatment will occur.

D. Putting it All Together:
An example of how to incorporate BMPs into a site plan is given below, based on the types of practices that might be included in both the soil erosion/sedimentation control plan and the stormwater plan. These plans should then be checked against the grading plan to ensure all grades and elevations make sense.

1. **For the soil erosion/sedimentation control plan:**
   a. Using the map(s) made during the site investigation, identify the construction site preparation BMPs. These include things like Construction Barriers, Tree Protection devices, and Buffer/Filter Strips. These should be installed before any other earth changes occur.

   b. Identify the soil erosion and sedimentation control structures which should be used and include these on the map:

      - Remember, it is always easier (and usually cheaper) to prevent soil erosion using techniques such as mulching and seeding than it is to remove sediment from storm water.

      - Consider using filter fences at the downstream end of all sites which are adjacent to surface waters or wetlands. (See the Filters BMP).

- Consider using a Sediment Basin to allow sediment to settle out before water is released to a waterbody or wetland.

- When work must be done "in the dry", consider using cofferdams as part of the Dewatering operation.

- When applicable, identify where Watercourse Crossings are needed to safely and most feasibly cross a watercourse.

c. Based on the drainage characteristics identified during the site investigation, identify the runoff conveyance structures needed and include these on the map:

- Consider Diversions to direct water away from critically eroding areas.

- Water diverted via Diversions should be directed to Stabilized Outlets such as Grassed Waterways. Sediment Basins, Filters, and the runoff storage structures listed below can also serve as outlets.

- Consider Grade Stabilization Structures to move water from one grade to another without causing erosion. These include downdrains, drop control structures, flumes, etc.

- Consider using Check Dams in ditches, (especially those which will not be seeded) to decrease flow velocities.

- Determine whether Subsurface Drains are needed to remove ponding water that would inhibit establishment of desired vegetation.

d. Use the Staging and Scheduling BMP at all work sites both for installation of BMPs and during the general construction process. This BMP promotes conducting development operations in stages, and scheduling the implementation and maintenance of all BMPs. As each area is developed it should be temporarily seeded and mulched, or sodded to prevent erosion.

e. Determine the appropriate managerial BMPs. These include Dust Control, Fertilizer Management, Pesticide Management and the proper location of Spoil Piles. This should always include the Equipment Maintenance and Storage Area BMP, which includes the proper location, storage and use of all hazardous substances. Spill prevention of these substances should also be included in a separate spill prevention plan.

f. Consider the housekeeping BMPs and incorporate them into your maintenance efforts. Housekeeping BMPs include Street Sweeping and Household Hazardous Waste Disposa1.

All structural practices which will be used should be indicated on the construction blueprints.

2. **For the stormwater plan:**

a. Identify the runoff storage structures which should be used, based on the site or watershed hydrology. Include these on the map:

- Consider the use of Porous Asphalt Pavement or Modular Pavement in place of standard pavement. Porous/modular pavement allows water to infiltrate into the ground.

- Specialized detention basins such as Rooftop Storage or Parking Lot Storage can be used in developed areas where little land is available.

- Infiltration practices such as Infiltration Trenches or Infiltration Basins are encouraged in areas where soils are such that water can infiltrate easily, and where pollutants are such that they will not impact groundwater.

- Extended Detention Basins should be used in those areas where water quantity must also be controlled.

- BMPs which should be considered to "treat" runoff before it leaves a site include Oil/Grit Separators, Catch Basins and Wet Detention Basins.

b. Review all managerial BMPs. These include Fertilizer Management, Pesticide Management and proper Household Hazardous Waste Disposa1. Be sure to review the Equipment Maintenance and Storage Area BMP, which includes the proper location, storage and use of all hazardous substances. Spill prevention of these substances should also be included in a separate spill prevention plan.

c. Review the housekeeping BMPs and incorporate them into your maintenance efforts. Housekeeping BMPs include Organic Debris Disposa1 and Street Sweeping.

All structural practices which will be used, should be indicated on the construction blueprints.

The soil erosion/sedimentation control plan and stormwater plan should then be checked against the grading plan. Again, the schematic part of the grading plan should include all man-made structures, (including buildings, vehicular and pedestrian routes, parking areas, open space areas, other site facilities, etc.), all cut and fill areas, and the grades (elevation) both before and after development.

Upon completion of the site plan:
Once the three components of the site plan are complete, we recommend that a pre-construction meeting occur with all persons who will be involved in the construction project. This will ensure that there is no confusion about what is being done and at what time. This will also ensure that all three components of the plan correspond logically with each other.

STEP 6: Submit Permit Applications to the Appropriate Agency

As described in the "Legal Implications" section, above, under Act 347, Michigan's Soil Erosion and Sedimentation Control Act, all construction activities which disturb l or more acres of land or within 500 feet of a lake or stream will require a permit from the Act 347 agency. An Act 347 agency is a local or county agency that is authorized by the MDEQ to approve soil erosion control plans, pursuant to Act 347. Also, construction activities which disturb five or more acres of land need to meet the federal requirements of the National Pollution Discharge Elimination System (NPDES) permit for construction sites. In Michigan, this coverage can be obtained under the permit-by-rule for construction activities. The construction permittee will need to submit to the MDEQ a notice of coverage, certifying that they have an approved plan or permit under Act 347.

For storm water activities in industrial areas, a storm water application will need to be submitted to the MDEQ, Surface Water Quality Division. We encourage industries to get involved in watershed management, because what is done at your industrial site affects the water quality and quantity of the entire watershed.

Use the "State/County Environmental Permits Check List" on pages 39 and 40 to decide which other permits are needed for your site plan. This state/county checklist is not a permit application form, but a means of determining which permits must be obtained. Keep in mind that you will also need to follow any local requirements.

STEP 7: Construct/Install BMPs

Construction should be done following the scheduling sequence outlined in the Staging and Scheduling BMP. All earthwork should follow specifications in the Land Clearing and Grading Practices BMPs. No other earthwork should be done until BMPs which protect the natural resources are in place--including such practices as Tree Protection, Construction Barriers, Filter (fences) and Sediment Basins. Begin the maintenance program.

STEP 8: Stabilize the Site

Procedures after construction include removing temporary BMPs (such as Construction Barriers and temporary Sediment Basins) and stabilizing the area with vegetation. Under the Part 17 Rules of the Michigan Soil Erosion and Sedimentation Control Act (1972, P.A. 347), permanent soil erosion control measures for all slopes, channels, ditches or any disturbed land area shall be completed within 15 calendar days after final grading or the final earth change has been completed. When it is not possible to permanently stabilize a disturbed area after an earth change has been completed or where significant earth change activity ceases, temporary soil erosion control measures shall be implemented within 30 calendar days. All temporary soil erosion control measures shall be maintained until permanent soil erosion control measures are implemented. Once the site is stabilized, managerial and housekeeping BMPs should be followed to prevent nonpoint source pollution from occurring.

STEP 9: Maintain BMPs

Ongoing maintenance of all BMPs will assure the continued protection of the natural resources from nonpoint sources. All temporary and permanent control measures must be periodically checked to ensure that they are functioning according to the original design. Some BMPs may require an end-of-day check, whereas others may need to be checked only during and after a storm. Weekly checks should be made on any BMPs which can be damaged by heavy equipment or other local traffic. Each BMP includes the maintenance procedures which should be followed, including frequency of inspections and problems to be aware of. For permanent BMPs, a mechanism must be agreed upon and in place to ensure the long-term maintenance of the practice.

CHANGING THE PLAN

We recommend that site inspections be done at least weekly, and following any precipitation events which can result in runoff from the site. Look at the stream for impacts from your activities. If the BMPs selected and approved for a site are not effective in protecting the resource, or if there are significant changes in the design, construction, operation, maintenance or scheduling of BMPs, the plan will need to be modified. For example, if the group of BMPs on a large construction site is not adequate to keep soil on the site, then additional practices may be needed. If additional structural practices are needed that require engineering, the revised plan should be submitted to the appropriate agency for review and approval.

Emergency changes to the plan--those that are required to take immediate action to prevent further soil erosion or sedimentation, flooding, or the contamination of surface or groundwaters--do not require agency pre-approval and should be undertaken as necessary to prevent additional damage to the water resources. The permitting agency should be notified of the emergency changes.

STATE/COUNTY ENVIRONMENTAL PERMITS CHECKLIST
FOR
(name & address of municipality)

This checklist has been prepared to alert businesses to state and county environmental permit requirements which may apply to new or existing facilities. Applicants are requested to complete this form and submit it to the municipal office with the proposed site plan. Upon receipt, the township will forward the information to the permit coordinator, MDEQ.

This checklist is not a permit application form; businesses are responsible for obtaining information and permit application forms from appropriate state and county offices. Please not that this checklist pertains only to state and county environmental permits. Additional permits and approvals may be required by the municipality or other government agencies.

<u>Circle the regulations which you think may apply to your business:</u>

1. Y N Will the project involve the discharge of any type of wastewater to a storm sewer, drain, lake, stream or other surface water?
   Contact: *MDEQ, Surface Water Quality Division.*
   District office telephone: ________________

2. Y N Will the project involve the discharge of liquids, sludges, wastewater and/or wastewater residuals into or onto the ground?
   Contact: *MDEQ, Waste Management Division.*
   District office telephone: _________________

3. Y N Will the project or facility store or use hazardous substances, oil or salt? Depending on the type of substance, secondary containment and a Pollution Incident Prevention Plan (or a material storage permit) may be required.
   Contact: *MDEQ, Waste Management Division.*
   District office telephone: _________________

4. Y N Will the facility use underground storage tanks? Existing tank must be registered with the State Police Fire Marshall Division. Tanks must be installed and operated in accordance with state regulations.
   Contact: *Michigan State Police Fire Marshall Division, Hazardous Materials Section, Lansing, (517) 322-1935 or 1-800 MICH UST.*

5. Y N Will the facility involve the transport, on-site treatment, storage or disposal of hazardous waste generated in quantities of 1000 kilograms (250 gallons or 2200 pounds) or more per month? If yes, one or more permits may be required.

   Will the facility generate between 100 kilograms/month (25 gallons or 220 pounds) and 1000 kilograms/month (250 gallons or 2200 pounds) of hazardous waste? If yes, the facility may be a small quantity generator, subject to federal and state regulations. An EPA identification number should be obtained from the MDEQ (special forms are available) and a manifest (shipping paper) should be used to transport waste off-site.
   Contact: *MDEQ, Waste Management Division.*
   District office telephone: ___________________

6. Y N Will the project involve bumming, landfilling, transferring or processing any type of solid non-hazardous wastes on-site?
   Contact: *MDEQ, Waste Management Division.*
   District office telephone: ___________________

7. Y N Will the project involve the installation, construction, reconstruction, relocation, or alteration of any process or process equipment (including air pollution control equipment) which has the potential to emit air contaminants?
   Contact: *MDEQ, Air Quality Division, Permit Section.*
   District office telephone: ____________________

8. Y N Will the project involve any man-made change in the natural cover or topography of land, including cut and fill activities which may contribute to soil erosion and sedimentation? Will the earth change disturb an area of one acre or more, or occur within 500 feet of a lake or stream? If the answer to both of these questions is yes, a soil erosion and sedimentation control permit is required.
   Contact: *Local Enforcing Agent or County Enforcing Agent for soil erosion/sedimentation control*______________________

9. Y N Will the project involve any work (dredging, filling, construction) in a river, stream, creek, ditch, wetland or floodplain, or within 500 feet of an inland lake, stream, creek or ditch? Or will it impact special management areas such as dunes or wild and scenic rivers?
   Contact: *MDEQ, Land* & *Water Management Division.*
   District office telephone: _______________________

10. Y N Will an on-site wastewater treatment system or septic system be installed? Will septage be stored on-site prior to off-site disposal?
    Contact: *For* ***sanitary sewage*** *-County or District Environmental Health*______________
    For ***industrial/commercial wastewater in any quantity*** *or more than* ***10,000 gallons/day of sanitary sewage*** *-MDEQ, Waste Management Division.*
    District office telephone: _________________________

11. Y N Is this facility (or any facility under your ownership) currently involved in any compliance discussions with the MDEQ or the Michigan Attorney General's office?
    Contact: *MDEQ, Office of Environmental Enforcement.*
    Telephone: (517) 373-3503.

12. Y N If this facility/property (or any facility/property under your ownership) included on the Act 307 Priority List, "Michigan Sites of Environmental Contamination" or subject to corrective action under the Leaking Underground Storage Tank (LUST) program?
    Contact: *MDEQ, Environmental Response Division.*
    District office telephone: __________________________

13. Y N Will the project involve any work in an established county or inter-county drain or in the right-of-way of an established drain, or discharge to an established drain?
    Contact: *County Drain Commissioner.*

NOTE: For assistance with permits and approvals from the MDEQ, including permit coordination among MDEQ divisions, contact the Permit Coordinator, Lansing Central office (517) 335-4235.

Business Name:	Mailing Address:
Street Address:	Telephone:
Facility Owner or Manager:	Type of Business:

DETENTION AND INFILTRATION TO ADDRESS URBAN NONPOINT SOURCES OF POLLUTION

The terms detention and retention have been used throughout this guidebook. The difference between the two is important. *Detention* practices are those practices which store stormwater for some period of time before discharging to a surface waterbody. *Retention* practices capture stormwater and release it through infiltration to the ground. Many people will use "retention" and "infiltration" interchangeably.

LOCATION OF DETENTION STORAGE

In the past, communities have passed ordinances that require peak runoff rates after development to be less than or equal to peak runoff rates before development. The criteria may change from community to community, however the goal is to maintain the current peak runoff rates through the use of on-site storage. While the concept may be honorable, in some instances, the result of the ordinance is the construction of a number of detention basins throughout the community for which the combined effects actually increase downstream flooding.

The size and location of detention storage has been shown to impact the peak flood flows. Basin-wide planning is essential to result in properly sized basins, and to prevent flood discharges from being increased.

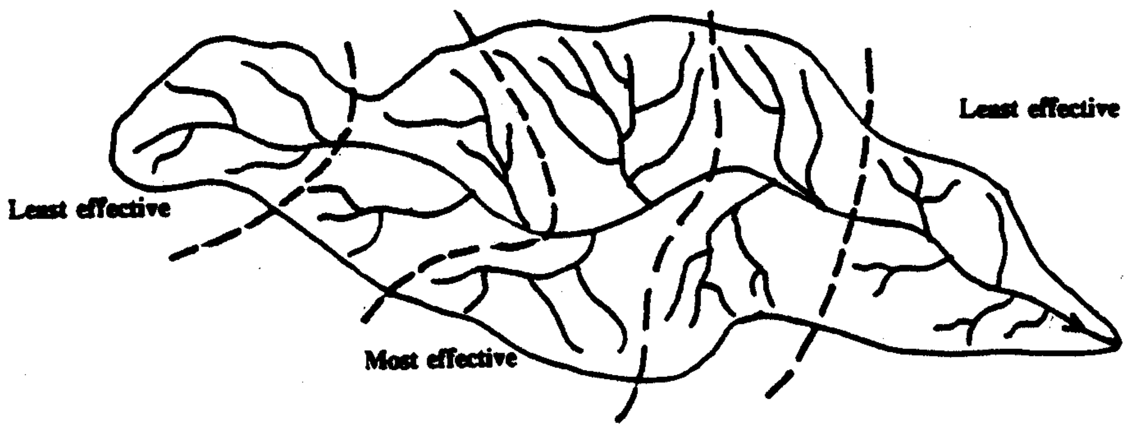
In 1986, the MDEQ studied the Sargent Creek Watershed, in Oakland County, to determine the impact detention has had on the flood flows of this urbanized basin. As the watershed was urbanizing, on-site stormwater detention was required. The study looked at the impact that the on-site detention basins had on the flood flows, as compared to a regional detention basin, or a series of detention basins. It was found that an in-line detention basin would need about one-half of the amount of land that the on-site detention basins needed to accomplish the same impact on flood discharges. The study also indicates that in some instances, regulated on-site detention ponds have increased peak flows downstream by delaying outlet peaks to the extent that all of the flood peaks combine simultaneously.

Figure 9 illustrates the most effective locations for detention ponds. At the extreme upper and lower ends of the watershed, detention ponds will have little beneficial impact on peak flows.

The installation of detention facilities at the lower end of the watershed, may hold water that would normally have been gone, and release it at the same time as the flood peak on the main channel reaches the site. As a result, a detention basin at such a location may actually increase the flood peak. For this reason, it is essential that the entire watershed be considered when the stormwater management plan is being developed. In addition to the volume of runoff, an effective detention pond design must be based on the timing of the flood hydrographs of the entire watershed.

Figure 9

Effectiveness of Detention Locations Within a Watershed



Source: Stormwater Management Guidebook, MDEQ, Land and Water Management Division, 1992.

ON-SITE DETENTION

There is quite a bit of information available for the design of individual detention ponds, which primarily deal with the volume and rate of runoff. However, there is not much information on the impacts of on-site detention ponds as opposed to a regional detention pond.

Another concern with on-site detention is the long-term maintenance requirements. Since the detention pond will likely be placed on private property, it will be necessary to have a maintenance agreement to clearly identify responsibility for maintenance, and easements to ensure that the ponds are maintained. If they are not maintained, the basins will not be as effective as intended, and will likely turn into "eye-sores". Because of the maintenance requirements and potential problems, the landowner may not readily accept a pond being placed on their property.

On-site stormwater management facilities should be designed to replicate the natural, pre-development runoff conditions to the greatest extent possible. This principle underlies detention requirements, which attempt to restrict the peak rate of stormwater discharge to pre-development conditions.

REGIONAL FACILITIES

As with on-site detention, the placement of a regional detention facility will require a hydrologic analysis of the watershed. Since a regional facility will likely be placed on a public land, the problem with easements and responsibility of maintenance will be minimized. However, there will still be the problem of providing adequate maintenance.

A regional facility will usually require less land than would be required to achieve the same effects from numerous on-site facilities. There will also be savings on construction and maintenance costs associated with a regional facility, as opposed to many on-site facilities.

Regional facilities can be more readily accepted by the public, if designed and maintained properly. Since regional facilities will be larger than on-site facilities, it is possible to incorporate multi-purpose uses into the design, such as soccer fields, football fields, fishing ponds, and parks.

BENEFITS OF INFILTRATION

When urban development takes place, pavement and buildings block the natural infiltration of stormwater into the ground. Groundwater base flow, which sustains small streams, wetlands, and lakes may be depleted, while surface water runoff increases. Infiltration helps maintain the natural flow of runoff into the ground, while still providing for both quantity and quality control of stormwater.

In addition to water quality and quantity control benefits, infiltration systems reduce the downstream bank erosion problems which may result from other types of stormwater detention structures. Even when discharge from detention ponds is restricted, the discharge comes from a single point, sometimes resulting in downstream channel erosion. Infiltration of stormwater helps to minimize the potential for downstream erosion and other adverse impacts. From an environmental protection standpoint, infiltration of stormwater is the optimal approach, provided that systems can be made to function.

It is important to note, however, that infiltration practices should be the last step in the treatment train. Soluble organic substances, oil and grease and coarse sediment must be removed by other management practices prior to infiltration in order to prevent groundwater contamination, and prevent clogging of the infiltration area. Infiltration could be used to simply return "clean" water to the ground to maintain the hydrologic regime. Infiltration practices must be properly designed, constructed and maintained to prevent groundwater contamination.

PREFERRED APPROACHES TO ON-SITE DETENTION AND RETENTION

To protect Michigan's water resources, stormwater management for both quantity and quality control purposes are essential. With these two objectives in mind, stormwater detention and retention facilities can be ranked in order of preference. The following was derived from "Stormwater Management Guidebook for Michigan Communities," Clinton River Watershed Council, 1987.

First Priority: Infiltration systems, provided that soil and groundwater conditions are suitable, and provided that groundwater supplies will not become contaminated. By directing stormwater runoff into the soils, downstream impacts are minimized.

Second Priority: Wet detention basins with a fixed water level between runoff events. This type of basin holds stormwater long enough for sediment and attached pollutants to settle out.

Third Priority: Extended dry detention basins which hold stormwater for 24 to 72 hours before completely draining to become a dry basin. This extended detention time allows for some sediments to settle out before stormwater is released.

Lowest Priority: Dry detention basins which completely dewater within 3-4 hours after the end of the storm. Although dry basins can effectively reduce downstream flood peaks, they rarely provide substantial water quality benefits. The stormwater (carrying sediment and pollutants) reaches the basin, but the stormwater (with pollutants) is then discharged into the waterway after a short holding period.

SPILL RESPONSE PLAN

A spill response plan should be developed in conjunction with all stormwater facilities to deal with accidental spills into the system. These facilities can be a key in preventing environmental damage in the event of a spill, or they may provide a conduit for concentrated pollutants to get to sensitive areas depending on how they are managed. The spill response plan should describe in detailed steps who is responsible for what actions in the event of a spill and how they are contacted, particularly during off- duty hours.

Speed is often the most important aspect of reacting to a spill. If an outlet can be closed in time, pollutants can be contained in a basin and cleaned out there instead of being released to the watershed. Cleanup of downstream areas significantly increases the cleanup cost. Where infiltration is used, spills must be contained within the smallest area possible and cleaned up before groundwater is contaminated.

ORDINANCES

LOCAL ORDINANCE DEVELOPMENT

Ordinances provide a means by which county and municipal governments can assure that site planning and development take potential erosion and stormwater problems into account and include effective measures for their control. Ordinances can also be implemented which prohibit indiscriminate land clearing, or which require leaving natural buffer/filter areas around all surface waters. While the principal intent of the ordinances is preventative, they also include provisions for the enforcement action where this becomes necessary.

Listed below are elements that would typically be included in local stormwater management zoning ordinances.

1. **Statement of Authority to Regulate** (What statute gives the community the authority to enact the ordinance).

2. **Goals and Objectives** of the Stormwater Management Program.

3. **Definitions of terms** used in the ordinance.

4. Relationship between current and existing legislation should be included to avoid conflict.

5. **Stormwater Management Plan Review**

    a. Specifications (Descriptions, standard format and certifications that are required.)

    b. Evaluation of Plans (The agencies that will evaluate the plans, and the criteria that will use for the evaluation.)

    c. Zoning Approval (The proposal must meet current zoning requirements.)

    d. Review Fees (The fee schedule for review and evaluation should be included.)

6. **Permits**

    a. When permits are required (The situations that will require permits should be specifically described.)

    b. Waivers (Circumstances in which permit requirements are waived should be listed.)

    c. Appeals (An appeal procedure must be present to handle denials of a permit or waiver.)

    d. Expiration and renewal (The permit should be given an expiration date. There should also be a method to apply for an extension or renewal.)

e. Suspension or Revocation of Permit (It is necessary to have an enforcement section to ensure that the construction and implementation of the stormwater management plan is completed in accordance with the approved plans).

f. Fees (Any permit fees should be listed.)

g. Performance Bonds (To ensure the completion of the project.)

h. Compliance **and Enforcement** (The responsibility of completing the project should be clearly designated to the owner.)

i. Liability Insurance (An alternative to a performance bond, the liability insurance would allow the project to be completed even if the developer is not financially able.)

7. **Design Criteria**

a. Acceptable Methods of Stormwater Management

b. Performance Standards (List the amount of protection or control that is expected. Such as no increase the l00-year peak runoff.)

c. Acceptable Methods of Evaluating Stormwater Management Facilities

d. Reference List (Stormwater management technical references.)

e. Safety and Aesthetics (When the use of fencing and other safety devices is required.)

f. Emergency Spillways (When design conditions are exceeded, how the emergency spillway will function.)

8. **Maintenance and Inspection**

a. Access to Site (Access to the site must be guaranteed during construction and for the entire design life of the facility.)

b. Inspection During and After Construction

c. Responsibility of Maintenance (The responsibility should be noted in the ordinance. If given to landowner, the property title must indicate that the responsibility will transfer if the land is sold.)

d. How Funds for Maintenance will be Collected

9. **Severability** (If one portion of the ordinance is found to be unenforceable, the other provisions will remain in effect.)

EXAMPLE ORDINANCES

<u>Grand Traverse County Soil Erosion and Stormwater Runoff Control Ordinance:</u>

The drain commissioner is the county's designated enforcing agency to issue permits to control soil erosion and stormwater runoff.

Some of the purposes of the ordinance include the following:

* To ensure that property owners control the volume and rate of stormwater runoff originating from their property so that groundwater quality is protected, and soil erosion and flooding potential are minimized.

* To preserve the use of the natural drainage system for receiving and conveying stormwater runoff and to minimize the need to construct enclosed, below-grade storm drain systems.

* To preserve natural infiltration and the recharge of groundwater and to maintain subsurface flows which replenish lakes, streams and wetlands.

Earth changes which require permits from the Drain Commissioner include some of the following:

* Earth changes proposed for environmentally sensitive residential sites.

* Industrial or commercial development sites, regardless of size, location, or environmental sensitivity.

Standards for the review and approval of permit applications are specified in the ordinance. Examples of the some of the standards are as follows:

* Removal of vegetation and tree roots within 50 feet of the ordinary high water mark of any lake or stream shall be discouraged unless approved for recreation uses by the drain commissioner. Additional buffer areas may also be required.

* Removal of vegetation and tree roots within 25 feet of the ordinary high water mark of any protected wetland shall be discouraged unless approved for recreation uses by the drain commissioner. Additional buffer areas may also be required.

* Drainage wells (dry wells) shall be discouraged as a stormwater control method.

* A two-stage design for detention and retention basins shall be used on sites where parking lots and other impervious services exceed five acres in size, as well as other sites identified by the drain commissioner or the MDEQ as requiring special protection for water quality purposes.

* A 25-foot undeveloped buffer area shall be provided around the perimeter of all detention, retention, and infiltration basins which are 112 acre or more in size.

Maintenance:

All soil erosion and stormwater runoff control facilities must be maintained in working order. Options for maintenance responsibilities include: (a) the property owner; (b) a property owners association; or (c) drain commissioner.

The Oakland Township and Orion Township Stormwater Management and Erosion Control Ordinances:

The purpose of these ordinances is to protect against floods and water pollution. These dual goals are affirmed in many specific sections of the ordinances.

Legal authority for the ordinances is drawn from several state laws including the Township Ordinance Act, the Wetlands Protection act, the Soil Erosion and Sedimentation Control Act, and the Michigan Environmental Protection Act.

The stormwater management and erosion control ordinances reaffirm the common law principle that stormwater runoff control is the responsibility of the landowner. The requirements help to insure that new development projects will not adversely affect adjoining property owners and other township residents. The ordinances clarify township requirements and assure equitable application and benefits for residents and landowners.

The stormwater management and erosion control ordinances include the following major provisions:

* Each developer must submit a stormwater management plan for the site (in addition to a site plan and/or subdivision plat).

* Stormwater management plans are reviewed by the Planning Commission at the same time that the other aspects of the development proposals are reviewed.

* The stormwater management plan must include site data on water resources, topography, and natural drainage patterns, as well as a general description and locations for the proposed stormwater management system.

* The stormwater management plan must identify the primary stormwater management system designed to control the 10-year frequency storm as well as the secondary stormwater management system (a 100-year frequency storm event).

* Erosion control regulation is included in the ordinance. The Orion Township Ordinance will provide a Township with authority to issue erosion control permits in accordance with state law. The Oakland Township Ordinance will allow for a substantive erosion control review of the development plans, prior to the required county-level erosion permit review.

* Wetlands can be used for stormwater detention in selected locations, while ensuring that the natural functions and quality of wetlands throughout the township are protected to the maximum feasible extent. If wetlands are the primary detention area for stormwater, they must be set back at least 100 feet from the edge of any lake or stream. Wetlands with significant wildlife habitat or ecological values which would likely be impaired may not be used. To protect wetlands from excessive siltation, erosion control in upland areas near the wetland must be provided.

* On-site retention of stormwater is required, in accordance with standards in the ordinance and engineering design specifications of the consulting engineer.

* The requirement for on-site detention may be waived if a suitable off-site, shared stormwater detention area is identified.

* Through township agreements, arrangements for stormwater and erosion control facility maintenance must be made. In Orion Township, the Township will enter into the agreements and establish an inspections program through the Department of Public Works. In rural Oakland Township, agreements between the Drain Commissioner and landowner will be required for subdivisions.

* Engineered grading plans for individual lot development will be required and reviewed by township staff, separate from the more extensive stormwater management plan review outline.

The City of Ann Arbor's Stormwater Utility and Soil Erosion and Sedimentation Control Ordinances:

A note on stormwater utilities: A stormwater utility is a fee charged to property owners, attached to their monthly or quarterly utility bill. The fees are used for stormwater system planning and ongoing maintenance. Property owners are charged in relation to the actual cost of planning or maintaining facilities serving their properties.

Ann Arbor's Stormwater Utility: Chapter 33

All owners of real property in the City of Ann Arbor shall be charged for the use of a stormwater system based on the amount of stormwater and rate of flow of stormwater which is determined to be entering the stormwater system from the property. The impact of the stormwater from the property on the system shall be determined on the basis of the flat rates or the measurements contained within Chapter 33.

The quarterly charges for single-family or two-family dwellings shall be $6.09 per dwelling unit. However, if adequate stormwater retention is provided (see Section 5:673 of Chapter 63 of Title V of the Code of the City of Ann Arbor - Stormwater Retention Facilities), the charge shall be $5.15 per dwelling unit.

The quarterly charges for properties other than described above shall be computed in the following manner: $65.25 per acre multiplied by the following factors for the acreage of the following types of land area:

> 0.20 for pervious area;
> 0.95 for impervious area without adequate retention;
> 0.30 for impervious area with adequate retention.

All funds collected for stormwater service shall be placed in a separate account and shall be used solely for the construction, operation and maintenance of the stormwater system.

Soil Erosion and Sedimentation Control: Chapter 63

Fees. Fees shall be paid to the City of Ann Arbor in accordance with the following provisions:

1. The fee for a grading permit shall be at a rate of $60.00 per acre, computed to the nearest tenth of an acre, with a minimum fee of $30.00.

2. A monthly inspection fee shall be assessed, except in the subdivision or lot development which disturbs less than one acre of land, at a rate of $60.00 per acre subject to the accelerated soil erosion, computed to the nearest tenth of an acre, with a $30.00 minimum.

3. An additional inspection fee of $60.00 per acre of site area subject to accelerated soil erosion shall be assessed with a $60.00 minimum for each inspection following the issuance of a correction notice for work to be performed in less than one month.

4. Inspection fees are to be paid prior to the issuance of a Certificate of Occupancy.

5. Should construction activities begin prior to the issuance of a grading permit, the applicant is subject to double the plan checking and inspection fees, as determined by the Building Official.

For additional information:

The "Stormwater Management Guidebook for Michigan Communities," published by the Clinton River Watershed Council, includes ways local governments can address stormwater at the local level. The guidebook discusses on-site detention, infiltration, ordinances, soil erosion control, and maintenance. Several funding options are also discussed.

"Local Zoning to Protect Designated Natural Rivers: A Guide for Citizens and Local Officials," MDEQ, Land and Water Management Division, 1978, includes the "how-to" of local zoning regulations. Although it was written primarily for the protection of rivers which fall under Natural Rivers designation, the manual includes many basic zoning principles that can be applied to general water quality protection efforts at the local level.

The PEARL "Design Manual," Livingston County Planning Department, November, 1991, provides the basis for understanding rural clustering and how it can fit into a master plan. The manual promotes cluster development as a means to preserve wildlife habitat and vegetation, environmentally sensitive areas, scenic views, agricultural areas, and open space.

APPLICABLE STATE AND FEDERAL REGULATIONS

The following section briefly describes the federal, state, and local laws currently in effect which have some impact on the management of nonpoint source pollution. The purpose of this section is not to give a detailed analysis of each law, but to provide a brief description of the laws which affect land and water construction activities in Michigan. Figure 10 at the end of this section graphically illustrates these laws.

Federal Clean Water Act

Section 405 of the Water Quality Act of 1987 amended Section 402 of the Clean Water Act of 1972 by requiring EPA to develop regulations requiring permit applications for stormwater discharges associated with industrial activity, and storm sewers from municipalities with populations of 100,000 people or more (medium and large size municipalities). The requirements would eventually include small municipalities, those with populations of less than 100,000 people. These regulations were published on November 16, 1990.

There are a large number of industries that will be required to apply for permits under the regulation. One notable industry is the construction industry, for activities that will disturb more than five acres of land. The second phase of the regulations (effective 2002) will require construction sites greater than one acre to apply for a permit. Agricultural activities are exempted.

As a result of the amendments to the Water Quality Act, there will be an increased effort to eliminate non-storm water discharges into storm sewers. Requiring permits for discharges of storm water runoff from municipalities and industries is an attempt to reduce the discharge of pollutants through management, controls, education and engineering methods. Permits must require medium and large size municipalities to control pollutants in their storm water runoff to the Maximum Extent Practicable (MEP).

Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 P.A. 451 (formerly the Water Resources Act, Act 245).

Part 31 of Act 451 empowers the Director of DEQ to protect and conserve the water resources of the state. This includes the prohibition of pollution of the state's waters, and to prohibit the obstruction and occupation of floodways, and prohibit activity that would harmfully interfere with the stage discharge characteristics of the rivers and streams of the state.

Part 91, Soil Erosion and Sedimentation Control, of the Natural Resources and Environmental Protection Act. 1994 P.A. 451 (formerly Soil Erosion and Sedimentation Control Act. Act 347)

Part 91 of Act 451 provides for the control of soil erosion, and protects the waters of the state from sedimentation. Part 91 is applicable to all earth changes of one acre or greater or to any earth change within 500 feet of a lake or stream.

Part 91 is enforced at three different levels of government: Local (City, village, or charter township), County, or State. Counties are given the primary responsibility for administration of this Part. In some instances, public agencies, such as road commissions and drain commissions are self-enforcing.

The methods for minimizing erosion have a significant impact on the amount of runoff as well as controlling sediments. Since sedimentation is estimated to be a pollutant in about 95% of the watersheds in Michigan, this Part is very important in controlling a high percentage of the nonpoint source pollution problems.

Part 301, Inland Lakes and Streams, of the Natural Resources and Environmental Protection Act, 1994 P.A. 451, (formerly Inland Lakes and Streams Act, Act 346).
Part 301, as amended was enacted to regulate activities occurring within inland lakes and streams; and to protect riparian rights and the public trust in inland lakes and streams.

One of the environmental concerns that is addressed by the Part includes regulating dredge or fill projects (within the banks of a watercourse). In one way, the Inland Lakes and Streams Act could be thought of as a "bottomland " version of the Soil Erosion and Sedimentation Act. Whenever bottomlands are dredged or filled, a permit must be obtained, and adequate soil erosion control measures are a condition of the permit. As noted above, the control of erosion and sedimentation is essential to begin to solve nonpoint source pollution.

Part 303, Wetland Protection, of the Natural Resources and Environmental Protection Act, 1994 P.A. 451, (formerly Goemaere-Anderson Wetland Protection Act, Act 203).
Part 303 provides for the preservation, management, protection, and use of wetlands. A permit is required for the alteration or use of a wetland. This Part applies to wetlands that are contiguous (a ground or surface water connection) to a lake, pond, river, or stream; to many isolated wetlands that are greater than 5 acres in size; in counties having a population in excess of 100,000 or to any wetland determined to be essential to the preservation of the natural resources of the state from pollution, impairment, or destruction.

Part 303, in part, indicates that some or all of the following benefits are derived from a wetland:

1. Flood and storm control by the hydrologic absorption and storage capacity.

2. Pollution treatment by serving as a biological and chemical oxidation basin.

3. Erosion control by serving as a sedimentation area and filtering basin, absorbing silt and organic matter.

It is imperative that wetlands not be exploited as the solution to all stormwater treatment problems. Wetlands must be recognized and protected against excessive point and nonpoint stormwater pollution loads just as any other surface water (lake or stream) would be protected. This can be accomplished by maintaining the pre-development hydrologic characteristics of the wetland. If use of a wetland area is considered as part of a stormwater management project, the District Office of the Land and Water Management Division, MDEQ, should be contacted for advice and guidance on permit requirements.

Part 17, Michigan Environmental Protection Act, of the Natural Resources and Environmental Protection Act, 1994 P.A. 451, (formerly Michigan Environmental Protection Act (MEPA), Act 127)
Act 127, P.A. of 1970 is an extremely important piece of legislation, as it provides protection of the air, water, and other natural resources, and the public trust associated with these resources. The Act provides the right to any person in the State to bring action against another person, agency, corporation, or political subdivision for conduct that may pollute, impair, or destroy the air, water, or natural resources.

Within Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 P.A. 451, (formerly Flood Plain Control Act (1929 P.A. 245 as amended by Act 167 of P.A. 1968)
The purpose of this Part is to control encroachments, occupations and alterations of floodways. This would include bridges and culvert construction, fills and stream modifications.

Part 315, Dam Safety, of the Natural Resources and Environmental Protection Act, 1994 P.A. 451, (formerly Michigan Dam Safety Act, Act 300, P.A. of 1989).

This Act requires a Dam construction permit for the construction of a structure that will be six feet more in height and will impound five surface acres or more at the design flood elevation. Depending on size, some detention ponds may fall under the authority of this Act.

The Act requires dams to have a specified spillway capacity, based on the hazard rating of the dam. As an example, low hazard potential dams must have a spillway capacity that is capable of passing the 100-year flood, or the flood of record whichever is greater. (Low hazard potential dams are located in areas where failure would pose little to no danger to individuals, and damage would be limited to agriculture, uninhabited buildings, structures, or township or county roads). Other dam classifications with a height of less than 40 feet of height would require a spillway that is capable of passing the 200-year flood, or the flood of record whichever is greater.

Subdivision Control Act, Act 288, P.A. of 1967.

This Act was passed to regulate the subdivision of land; and to promote the public health, safety, and general welfare. Among the provisions of the Act (Section 192) is the review by the county drain commissioner, or the governing municipality for adequate storm water facilities within the proposed subdivision. At this time, there is no statewide standard that is being used in regard to quality and quantity issues. As a result, a standard--if one exists--will vary between communities and counties.

Part 305, Natural Rivers, of the Natural Resources and Environmental Protection Act, 1994 P.A. 451 (formerly Natural River Act, Act 231, P.A. of 1970).

The purpose is to establish a system of outstanding rivers in Michigan, and to preserve, protect, and enhance the wildlife, fisheries, scenic, historical, recreational, and other values associated with those river environments. A list of designated rivers is included in the Appendices.

Most activities within an established Natural River District (usually all land within 400 feet of the river's edge on both sides of the river) require state or local zoning permits. These include:

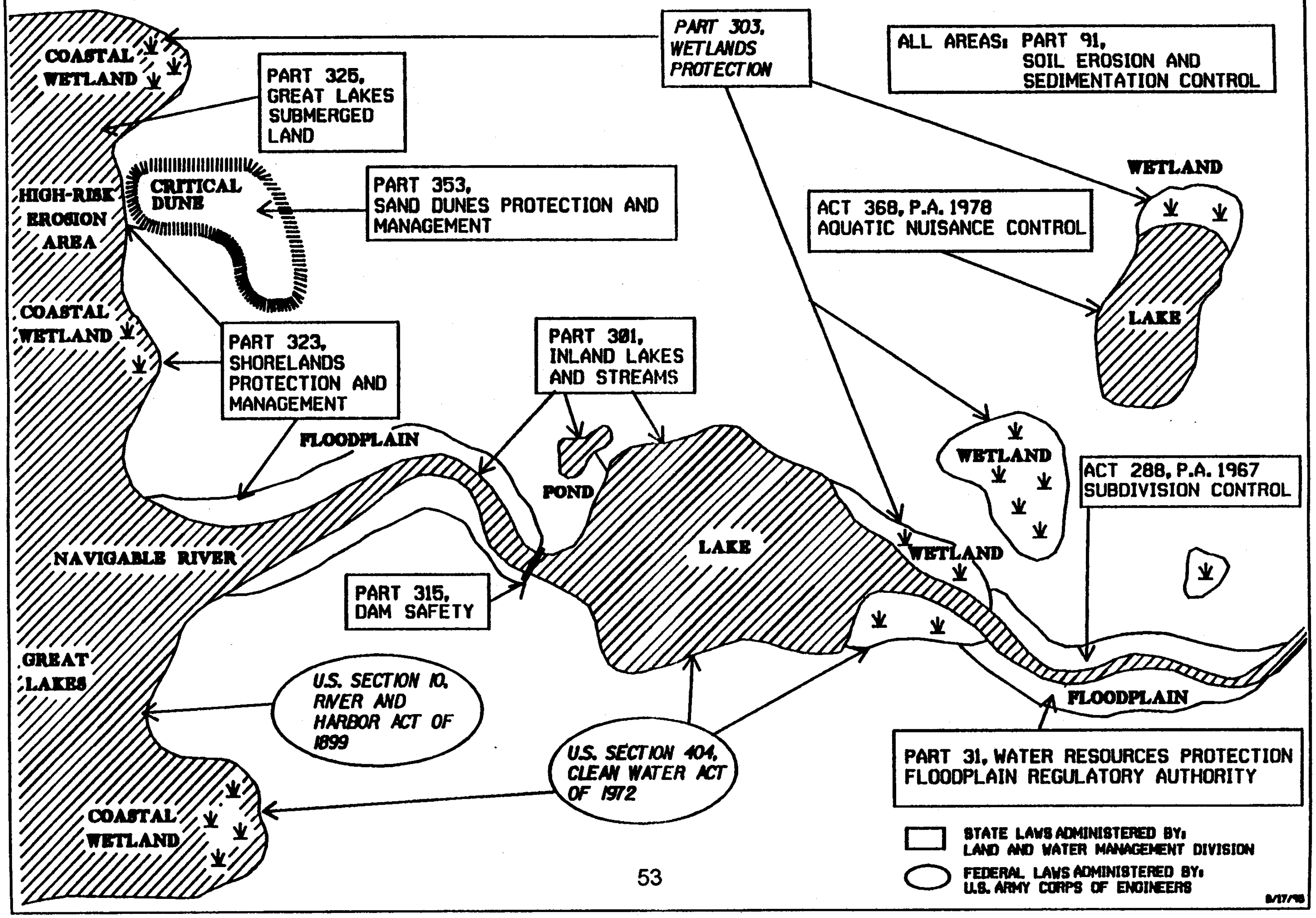
1. Building construction
2. Platting of lots
3. Cutting of vegetation within an established natural vegetation strip
4. Land alteration
5. Bridge construction

Michigan Drain Code, Act 40

Act 40, P.A. of 1956, as amended was passed with the primary objective of improving the drainage of agricultural lands. Over the years as these areas have become developed, the flooding problems faced by the county drain commissioner have increased.

The establishment of drains or improvements on existing drains are initiated by petition from landowners in the drainage district, or two or more public bodies. Once drainage districts are established, assessments may be levied to finance drain improvements. In the past, county drain projects have typically consisted of drain enclosures and clean-outs. However, in recent years, stormwater management has become a primary focus in various counties around the State.

LAND/WATER RELATED LAWS IN MICHIGAN
NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION ACT
ACT 451 OF THE PUBLIC ACTS OF 1994 & RELATED STATUTES



FUNDING

The key to a successful project is not to count on anyone source of funding but to tap into as many different sources of funding as you can. Since very limited funding is available for nonpoint sources controls through federally funded programs--such as Sections 319, 604(b)(1) and 314 of the Federal Clean Water Act, and the State Revolving Fund (SRF)--local communities will have to be creative in generating funding for reducing nonpoint sources. Some local funding sources which various Michigan communities have tried are given below.

Ordinances can be developed at the local level to ensure that developers put in the BMPs needed to meet the goals of the watershed. Several townships have ordinances which require submitting fees as part of the soil erosion/sedimentation control permitting process. The fee system in Grand Traverse County funds all or most of their soil erosion control staff.

The fee system in the city of Ann Arbor charges developers for the amount of soil exposed. This has encouraged staging on development projects so that only certain portions of the area are exposed at any given time. Their fee system also includes a monthly inspection fee and an additional inspection fee if correction notices are issued. Ann Arbor's construction fee system is described in the "Example Ordinances" section, above.

Various funding sources can also be explored for funding stormwater activities. Stormwater utilities provide services of flood control, drainage, and stormwater management, and are financed with user charges. The user fees are typically based upon the runoff that would be anticipated from the property--a commercial property with paved parking lots would be required to pay more than a residential development, due to the greater runoff potential. Ann Arbor's stormwater users fees are described in the "Example Ordinances" section.

In urbanizing areas, sewer tap fees can be used to generate additional funds for stormwater. The city of Novi charges developers tap fees for maintaining stormwater basins. The tap fee is based on the percentage of impervious area and is charged if the development is to drain to a regional basin. (All regional basins are designed for the 100-year storm). If no regional basin is in place, the developer is required to put in an on-site detention basin (based on the 10-year storm). Once the regional basin is constructed, the on-site basin is put off-line and the developer is charged the tap fee. The design and construction of basins in Novi is funded through their millage.

BMP FORMAT AND ORGANIZATION WITHIN DOCUMENT

INDIVIDUAL BMP FORMAT:

Except for the " Specifications " section of the BMP, all BMPs are set up in the same format:

- The first section is a "Description" which gives a general definition and purpose of the BMP.

- The second section is "Other Terms Used to Describe" which lists the other names or terms which are used to describe the BMP. For example, fertilizer management may also be referred to as nutrient management.

- The third section is the "Pollutants Controlled and Impacts". This describes the pollutants which the BMP is designed to control and the positive impacts the BMP will have on the environment.

- The next section is "Application". This is broken down into several subsections:

- "Land Use" describes the types of land uses the BMP applies to. A land use is simply how the land is being used-- for recreation, transportation, agriculture, forestry, etc.

- "Soil/Topography/Climate" describes certain soils, topographic or climatic conditions which may affect the use of the BMP.

- "When to Apply" gives the time in which the BMP should (and sometimes should not) be applied.

- "Where to Apply" describes the types of locations the BMP is applicable to.

- The next section is "Relationship With Other BMPs". This includes the BMPs which can be implemented in conjunction with this BMP.

BMP SPECIFICATIONS:

The "Specifications" sections differ depending on whether the BMP is managerial, structural or vegetative:

In most cases, the "Specifications" section **for vegetative BMPs** contains the following:

  - "Planning Considerations", including the specific time in which the practice should be implemented, species selection, etc.

  - "Site Preparation", including actions which can be taken on the site to prepare the soil and site for vegetation.

  - "Application", including how to apply the seed, sod, mulch, etc.

In most cases, the "Specifications" section **for structural BMPs** contains the following:

- "Planning Considerations", including conducting a site evaluation, determining soil types, and other factors which need to be determined before structural BMPs can be properly designed.

- "Design", including general design considerations such as proper slope length, sizing, material type, etc. per each aspect of the structure. In many cases, there is also a design example problem.

- "Construction", including the step-by-step method for installing the designed structure.

- "After Construction", including stabilizing the surrounding area and other post-construction activities.

The "Specifications" section **for managerial BMPs** varies depending on the specific BMP.

All BMPs also have a "Maintenance" section which describes the activities which must be done to ensure the BMP continues to function as it was designed.

Some BMPs also have an "Additional Considerations" section which includes information which does not fit into any of the above categories.

Note: Where needed in the BMP text, other BMPs will be underlined. For example, the Riprap BMP will include references to Lined Waterway and other BMPs.

BMP ORGANIZATION:

BMPs are organized in the binder by:

1. Housekeeping BMPs. These are managerial type BMPs which should be incorporated into your planning efforts.

2. Managerial BMPs. These are the BMPs which should be considered both during and after construction.

3. Construction Site Preparation BMPs. These BMPs should be considered on every construction site prior to the onset of land clearing.

4. Runoff Conveyance and Outlets. These BMPs convey runoff from eroding areas to more stabilized outlets.

5. Sedimentation Control Structures. These BMPs help reduce sedimentation. They are usually put in when it is not possible to keep the soil on-site.

6. Runoff Storage. These are structural BMPs which contain runoff, allowing it to infiltrate, evaporate or be treated before it is allowed to be released downstream.

7. Vegetative Establishment BMPs. These are practices which are usually used in conjunction with one another when establishing vegetation, including grasses, trees and ground covers.

8. Wetland BMPs. These BMPs help protect wetlands, or allow the least impact on wetlands.

    - All pertinent BMPs include specifications which serve as starting point for BMP selection, design and construction.

    - All BMPs include maintenance procedures which should be followed.

BEST MANAGEMENT PRACTICES FOR CONSTRUCTION SITES, URBAN AREAS AND GOLF COURSES

The BMPs are categorized in one of eight categories. The abbreviation listed in parentheses after the BMP name corresponds with the BMP page numbering system.

Construction Site Preparation:

- Access Road (AR)
- Construction Barriers (CoB)
- Grading Practices (GP)
- Land Clearing (LC)
- Spoil Piles (SP)
- Staging and Scheduling (S&S)
- Tree Protection (TP)

Housekeeping:

- Household Hazardous Waste Disposal (includes used oil disposal) (HHHW)
- Street Sweeping (SW)
- Community Car Wash (Car). New BMP, September, 1997.

Managerial:

- Critical Area Stabilization (CAS)
- Dune/Sand Stabilization (D/SS)
- Dust Control (DC)
- Equipment/Maintenance Storage Area (EMS)
- Fertilizer Management (FM)
- Lawn Maintenance (LM)
- Organic Debris Disposal (ODD)
- Pesticide Management (PM)
- Pond Construction and Management (PCM)
- Pond Sealing and Lining (PS)
- Slope/Shoreline Stabilization (S/SS)
- Stream Bank Stabilization (SBS). Updated September, 1997.
- Winter Road Management (WRM)

Runoff Conveyance and Outlets:

- Check Dams (CD)
- Diversions (DIV)
- Grade Stabilization Structures (GSS)
- Grassed Waterways (GW)
- Riprap (RIP). Updated September, 1997.
- Stabilized Outlets (SO)
- Stormwater Conveyance Channels (SCC)
- Subsurface Drain (SD)

Runoff Storage:

- Catch Basins (CaB)
- Extended Detention Basin (EDB)
- Infiltration Basin (IB)

Infiltration Trench (IT)
Modular Pavement (MP)
Oil/Grit Separators (O/GS)
Parking Lot Storage (PLS)
Porous Asphalt Pavement (PAP)
Roof Top Storage (RTS)
Wet Detention Basins (WDB)

Sedimentation Control Structures:

Buffer/Filter Strips (B/F). Updated September, 1997.
Dewatering (DW)
Filters (includes filter fencing) (FIL)
Sediment Basins (SB)
Watercourse Crossings (WaC)

Vegetative Establishment BMPs:

Mulching (MUL)
Seeding (includes Dormant Seeding) (SEE)
Sodding (SOD)
Soil Management (includes pH Control) (SM)
Trees, Shrubs and Ground Covers (T,S)

Wetland BMPs:

Wetland Crossings (WeC)
Constructed Wetland Use in Stormwater Control (ConW). New BMP, September, 1997.

CONSTRUCTION SITE PREPARATION BMPs

Access Road

Description

Access roads are graveled areas or pads which allow construction equipment and workers to enter and leave the work site from a public right-of-way, street, alley, sidewalk or parking area. This practice provides for the delivery and removal of construction equipment and materials in a manner which will protect vegetative cover, prevent erosion, and protect water quality. Access roads should be used on all construction sites and in forestry and mining to allow the mud on tires to fall off onto the access road before vehicles enter the main (primary road). In urban and urbanizing areas, this practice may reduce the frequency in which street sweeping is done.

Other Terms Used to Describe

Ingress Road
Egress Road
Driveway
Haul Road
Stabilized Construction Entrance

Pollutants Controlled and Impacts

Access roads effectively confine construction equipment to one or more specific area(s), thereby minimizing the amount of vegetation disturbed and reducing the potential for soil erosion.

Application

Land Use
Use anywhere equipment or vehicular access is necessary, including, but not limited to: transportation (highway construction, drain work); urban (private development, commercial and industrial development); forestlands (forest management,); mining (drilling and mining); and recreation (development of recreational facilities).

Soil/Topography/Climate
Access roads are particularly important in areas that have highly erodible soils, soft soils, or steep slopes, including areas subject to rainy conditions or heavy winds.

When to Apply
The location and construction of the access road should be determined during the planning stage of the project. Construction and stabilization of the access road should be completed prior to initiating construction on the project site.

Where to Apply
The road should be located in such a way that it can provide limited and confined access to any construction project. The road should *not* be placed in wetlands, flood plains, rivers, streams, or drains.

Relationship With Other BMPs

Drainage from the road should be diverted to vegetated areas. (See Diversion BMP). Use Seeding and Mulching or Sodding if vegetation is needed alongside the road. Use Watercourse Crossings where access roads cross rivers or other water bodies.

Specifications

Planning Considerations:

1. Select a site which provides for maximum use by all construction vehicles and equipment. Keep a natural Buffer/Filter Strip between the road and all watercourses and wetlands.

2. Determine soil types in the area selected for the access road and tailor the design to the soil type.

3. Access roads that lead to isolated project areas, such as drilling sites or mining activities, commonly cross streams or wetlands. State permits for these crossings will generally be needed, and special precautions may be required to be taken to protect the streams and wetlands.

4. Provide drainage adequate to carry water to a Sediment Basin or other suitable outlet.

Design Considerations:

The information below assumes that the access road will not be turned into a permanent secondary road upon completion of the rest of the project.

1. Roads which will be located in wetlands should be designed with no shoulders, to accommodate one-way traffic only, and have a minimum top width. Slopes should be 2:1.

2. Roads which will not impact wetlands should be designed based on the following specifications.

   a. The road should be a minimum of 10 feet wide, or wide enough to accommodate the width of the largest piece of equipment. Design the road with no shoulders.

   b. Side slopes should be 2:1 or less.

   c. To be effective, the length of the aggregate portion of the road should not be less than 50 feet.

   d. Except on single family resident lots, all other access roads should be underlain with geotextile fabric appropriate for the soil and drainage conditions. Geotextile material improves the stability of the road.

e. Stone size should be 2 inches. Reclaimed or recycled concrete of an equivalent diameter may also be used.

f. The road should consist of not less than 6 inches of the 2-inch aggregate. Aggregate should be placed in uniform, compacted layers of not more than 6 inches, nor less 3 inches.

g. Where access to the construction site is limited in length (such as in urban areas), daily street sweeping may be needed to keep soil that is tracked onto primary roads from reaching sewers.

Construction Considerations:

1. Remove and dispose of all unwanted trees and other vegetation from the area and grade according to Grading Practices specifications.

2. Apply geotextile fabric.

3. Apply the stone and compact it.

After Construction:

If the mud and soil attached to truck tires does not fall off onto the gravel, truck tires should be washed on an area stabilized with crushed stone. The wash area should drain into a Sediment Basin or other suitable outlet. Wash racks may also be used.

Maintenance

Proper maintenance may include adding additional layers of stone when the original stone becomes covered with mud. After each storm event, inspect the road for erosion and make any necessary repairs. It is also important to check and maintain any BMPs which are used in conjunction with this BMP, especially those for drainage. All sediment dropped or eroded onto public rights-of-way should be removed immediately by sweeping.

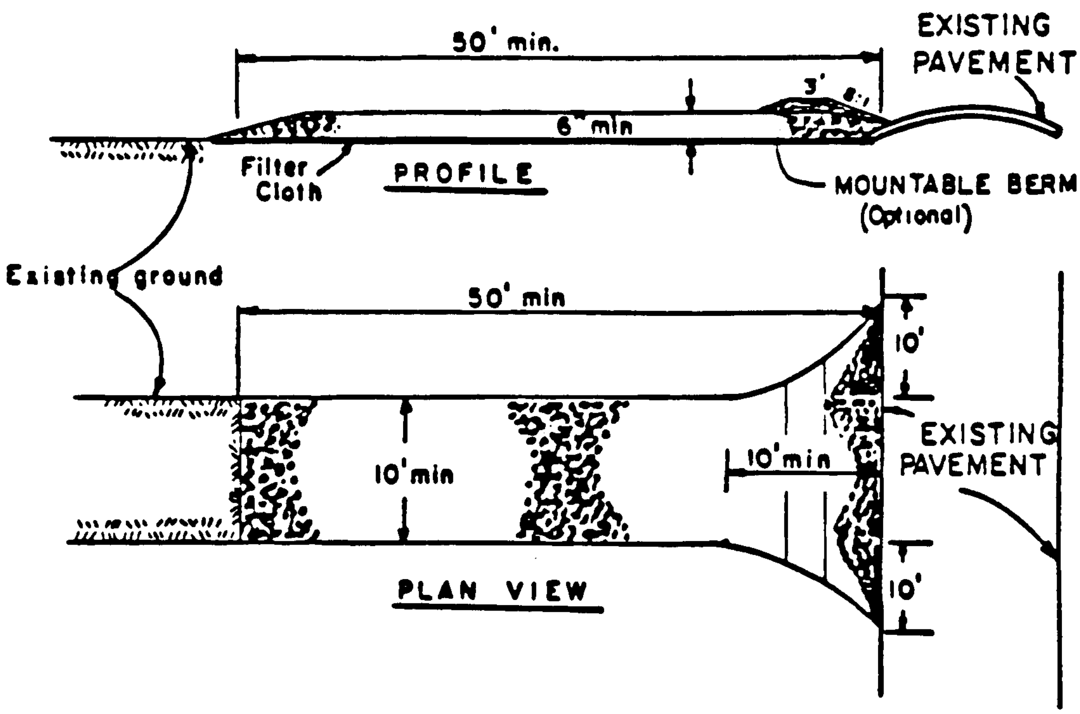
Exhibits

Exhibit 1: Stabilized Construction Entrance. USDA, Soil Conservation Service, College Park, Maryland.

Exhibit 1

Access Road

not to scale



Source: Modified from USDA,Soil Conservation Service, College Park, MD.

Construction Barriers

Description

Construction barriers are fences, signs and other means used on a construction site to:

-confine equipment and personnel to the immediate construction area, thus minimizing the destruction of vegetation and reducing the potential for erosion and compaction.

-protect trees and their root zones against abrasion and soil compaction. It takes 20-30 years for newly planted trees to provide the benefits of mature trees.

-prevent unnecessary access to structural BMPs

-protect sensitive areas, such as water bodies and newly seeded areas

-restrict access of unauthorized persons and vehicles.

Other Terms Used to Describe

Fencing

Pollutants Controlled and Impacts

Confining construction activities to a specific site will limit the amount of soil exposed to wind and rain. Effective confinement may also eliminate unnecessary or excessive regrading or revegetation of slopes or raw areas.

Application

Land Use
Use at all construction areas where earth changes are taking place. Land uses include transportation (highway work), urban (drain work, private, commercial and industrial developments), and golf courses.

Soil/Topography/Climate
This practice can be used anywhere, but is particularly important on erodible soils and steep slopes.

When to Apply
Apply this practice prior to the start of construction and as needed throughout the duration of the project. Some barriers, such as vehicle deterrent barriers, may remain in place after project completion.

Where to Apply
Apply anywhere confinement or protection of persons, property or natural resources is needed.

Relationship With Other BMPs

Construction barriers are used to protect critical erosion areas (see Critical Area Stabilization) and to prevent unwanted access by vehicles, equipment and people. It is a component BMP used with many other soil erosion control practices.

Specifications

Planning Considerations:

1. Barriers used to separate the construction area from pedestrian thoroughfares, or used to alert personnel about the existence of hazardous conditions, should be stable and easily discernible.

2. Keep barriers outside the drip line of any trees which will remain intact during and after the construction project. (The drip line is the area from the trunk outward to the a point at which there is no longer any overhanging vegetation). Pounding barriers into the ground within the drip line of trees may cause root damage and weaken the tree. Follow specifications in the Tree Protection BMP.

3. Signs should *not* be nailed or otherwise posted on trees.

4. In large open areas susceptible to wind, consider protecting sprigged or seeded areas with fencing.

5. Barriers are particularly important around detention, retention, and Sediment Basins, and dams (including cofferdams). At a minimum, barriers in these areas should include signs which warn people of potential dangers. Fencing may also be needed, depending upon the slope steepness, outlet flows, depth of water, etc.

   Select appropriate structures for the intended use:

   Temporary structures:
   Temporary fences can be made out of snow fence or the orange plastic fencing which is commonly used in construction areas. Silt fences can also be used as temporary barriers where safety is not a consideration. (See the Filters BMP).

   Permanent structures:
   Permanent fences may be constructed of wood, plastic, synthetic fabric, plastic or any other appropriate material.

   Cyclone-type fences with secure gates and locks should be used around dangerous areas such deep basins.

   Snow fences can be used to prevent pedestrian access and to control wind erosion.

Construction Considerations:

1. Signs should be constructed out of durable materials and printed legibly.

2. Construct the fence following specifications for the type of fence being installed. Be sure all posts are sturdy, and all material is suitable for the intended use. One source of specifications for standard wire, suspension, electric and permanent power fences is the Soil Conservation Service Technical Guide, specifications for Fencing (#382).

3. All fences used as filters should be implemented following specifications in the Filters BMP.

After Construction:

1. Remove all temporary construction barriers. Before leaving the site, inspect all permanent barriers to ensure they are in good working order, and repair where necessary.

2. When removing tree protection barriers, check to make sure the tree is still in good health. Trees which are severely damaged should be removed and replaced. See the Tree Protection BMP for information on replacing trees, and techniques on how to properly repair damaged roots and limbs.

Maintenance

Barriers should be inspected and maintained on a regular basis. Damaged signs and fences should be repaired or replaced immediately.

Grading Practices

Description

Grading is reshaping the ground surface to planned grades determined by engineering survey evaluation and layout. This BMP includes basic grading concepts, as well as specific types of grading practices that can be used to reduce erosion. Grading plans are discussed in the BMP Guidebook.

Other Terms Used to Describe

Rough Grading
Contour Grading
Special Grading Practices
Land Smoothing

Pollutants Controlled and Impacts

Proper grading practices help to improve surface drainage and reduce the amount of soil which erodes from a site.

Application

Land Use
Construction sites

Soil/Topography/Climate
Grading should compliment the natural configuration of the landscape. Where possible, the depth of grading should be controlled to prevent exposing extensive amounts of subsoil. Topsoil should be removed, stockpiled and re-spread over the graded area.

When to Apply
Apply whenever earth moving or construction activities produce grades which may increase erosive velocities or off-site sedimentation.

Where to Apply
This practice applies on any areas which require grading.

Relationship With Other BMPs

Diversions should be considered to prevent runoff from causing erosion on the exposed soil. To prevent off-site sedimentation, control measures such as Filters (filter fences), Grade Stabilization Structures and Sediment Basins may need to be installed at the lower perimeter of the site. Staging should be done to reduce the size of the area being exposed. (See the Staging and Scheduling BMP).

Specifications

The following is modified from the "North Carolina Erosion and Sediment Control Planning and Design Manual."

Planning Considerations:

1. Develop a **grading plan** to help establish drainage areas, direct drainage patterns, and decrease runoff velocities. The grading plan should follow the guidance in the BMP Guidebook, including coordinating the grading plan with the soil erosion/sedimentation control plan and the stormwater plan.

2. Slopes which will be mowed should not be steeper than 3:1.

3. Grading should be done in stages according to the implementation schedule. See the Staging and Scheduling BMP.

4. Protect spoil piles following specifications in the Spoil Piles BMP.

5. To ensure even settling, any fill to be used should be free of objectionable material such as logs, rocks and stumps. Do not use frozen or mucky material for fill.

6. Do not place fill adjacent to a channel bank where it can create bank failure or result in deposition of sediment downstream.

7. The exposed area should be stabilized with vegetation, crushed stone, riprap or other ground cover as soon as grading is completed or when work is interrupted for 30 working days or more. Use mulch (see Mulching BMP) to stabilize areas temporarily where final grading must be delayed. Slopes in excess of 2:1 should be stabilized following the specifications in the Critical Area Stabilization BMP.

During Grading:

1. Following the grading plan, construct all erosion and sedimentation control practices.

2. Remove vegetative matter in accordance with Land Clearing specifications. Remove topsoil and store in temporary Spoil Piles until final grading. Temporary spoil piles adjacent to wetlands or streams should be protected to prevent erosion.

3. Do not grade to the edge of watercourses. If a natural Buffer/Filter Strip cannot be left, construct a berm or place filter fencing adjacent to the watercourse/wetland. (See Filters BMP).

4. Divert runoff to stabilized areas, according to the grading plan.

5. Where possible, contour the grade to follow the natural contour of the land.

6. Finish grade and compact according to the intended use of the area. See the appropriate BMP for additional information on the finish grading procedures and the degree of compaction needed.

7. Except on roadway side slopes, use one of the surface roughening techniques described below to retain water, increase infiltration and facilitate vegetative growth. See Exhibit 1.

   Stair-step grading. This method should be done on slopes steeper than 3:1 which have material soft enough to be bulldozed and which will not be mowed. The vertical cut should be less than the horizontal distance and should not exceed 2 feet in soft material and 3 feet in rocky material. The horizontal position of the "step" should be sloped toward the vertical up-hill wall.

   Grooving. This method can be done on any area which can safely accommodate disks, tillers, spring harrow, or the teeth of a front-end loader bucker. In areas which will not be mowed, use equipment to create grooves perpendicular to the slope. Grooves should not be less than 3 inches deep, nor more than 15 inches apart. In cuts, fills, and areas that will be mowed, grooves should be less than 10 inches apart and not less than 1 inch deep.

   Tracking. This method is done by running tracked machinery (such as bulldozers) up and down slopes to leave horizontal depressions in the soil. To avoid undue compaction of the soil, this method should only be done on sandy soils. Back-blading should not be done during the final grading operation.

8. Use proper <u>Tree Protection</u> techniques to maintain the health and integrity of the trees. Excavate as far away from the drip line as possible.

   When **raising the grade** around an existing tree:

   1. A well can be created around the tree(s) just outside the drip line to retain the natural soil in the area of the feeder roots

   2. A dry well can be constructed around the trunk with space to allow the trunk to grow. The well should be designed to allow drainage within the well and around the root system inside the drip line. See exhibit 2.

   When **lowering the grade:**

   Protect trees by constructing a tree wall made of large stones, brick, building tile, or concrete block or cinder block. The wall should be designed to provide for drainage through the wall. See exhibit 3.

   See the <u>Tree Protection</u> BMP for specifications on how to repair damaged tree roots and limbs.

<u>After Construction:</u>
Stabilize all areas with vegetation (See vegetative BMPs) or <u>Slope/Shoreline Stabilization</u> structures, where appropriate.

Maintenance

Desired gradients will have to be maintained until the proposed land use is established with a structure, pavement, or vegetation. In addition, maintenance should be done on any BMPs installed in association with the grading.

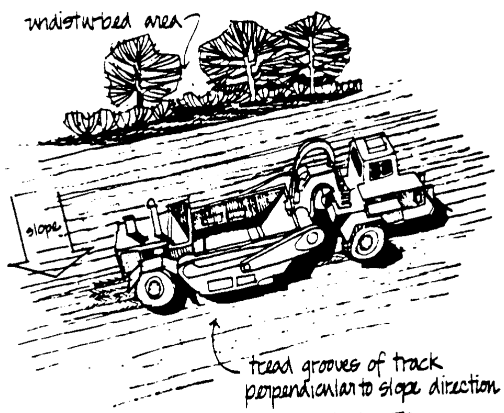
Exhibits

Exhibit 1: Surface Roughening Techniques. Includes two diagrams from the Michigan Soil Erosion and Sedimentation Control Guidebook. Also, grooving, as modified from the Virginia SWCC (copied from the North Carolina Erosion and Sedimentation Control Planning and Design Manual).

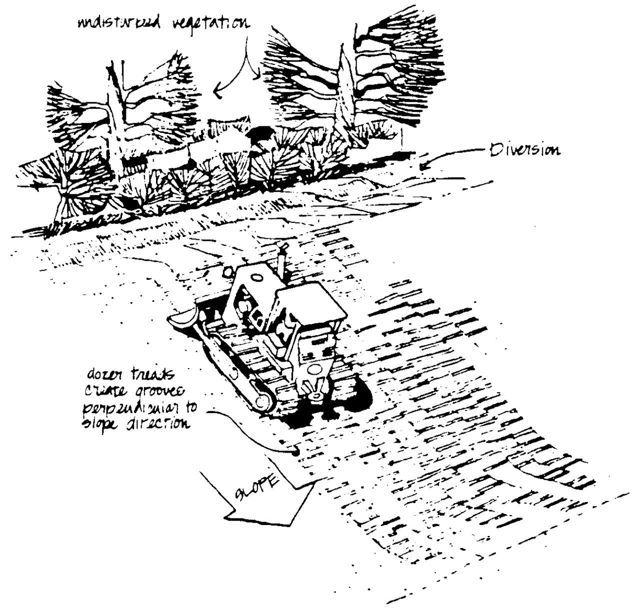
Exhibit 2: Tree Well. Adapted from the Virginia Erosion and Sediment Control Handbook. Copied from Connecticut Guidelines for Soil Erosion and Sediment Control.

Exhibit 3: Tree Wall. Originally from the Virginia Erosion and Sediment Control Handbook. Copied from Connecticut Guidelines for Soil Erosion and Sediment Control.

Exhibit 1
Surface Roughening Techniques

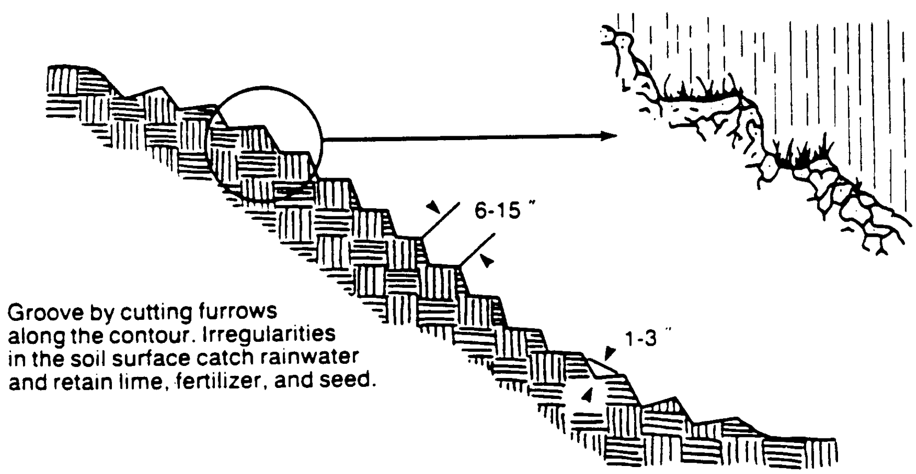


HEAVY EQUIPMENT CAN BE USED TO
MECHANICALLY SCARIFY SLOPES



UNVEGETATED SLOPES SHOULD BE TEMPORARILY
SCARIFIED TO MINIMIZE RUNOFF VELOCITIES

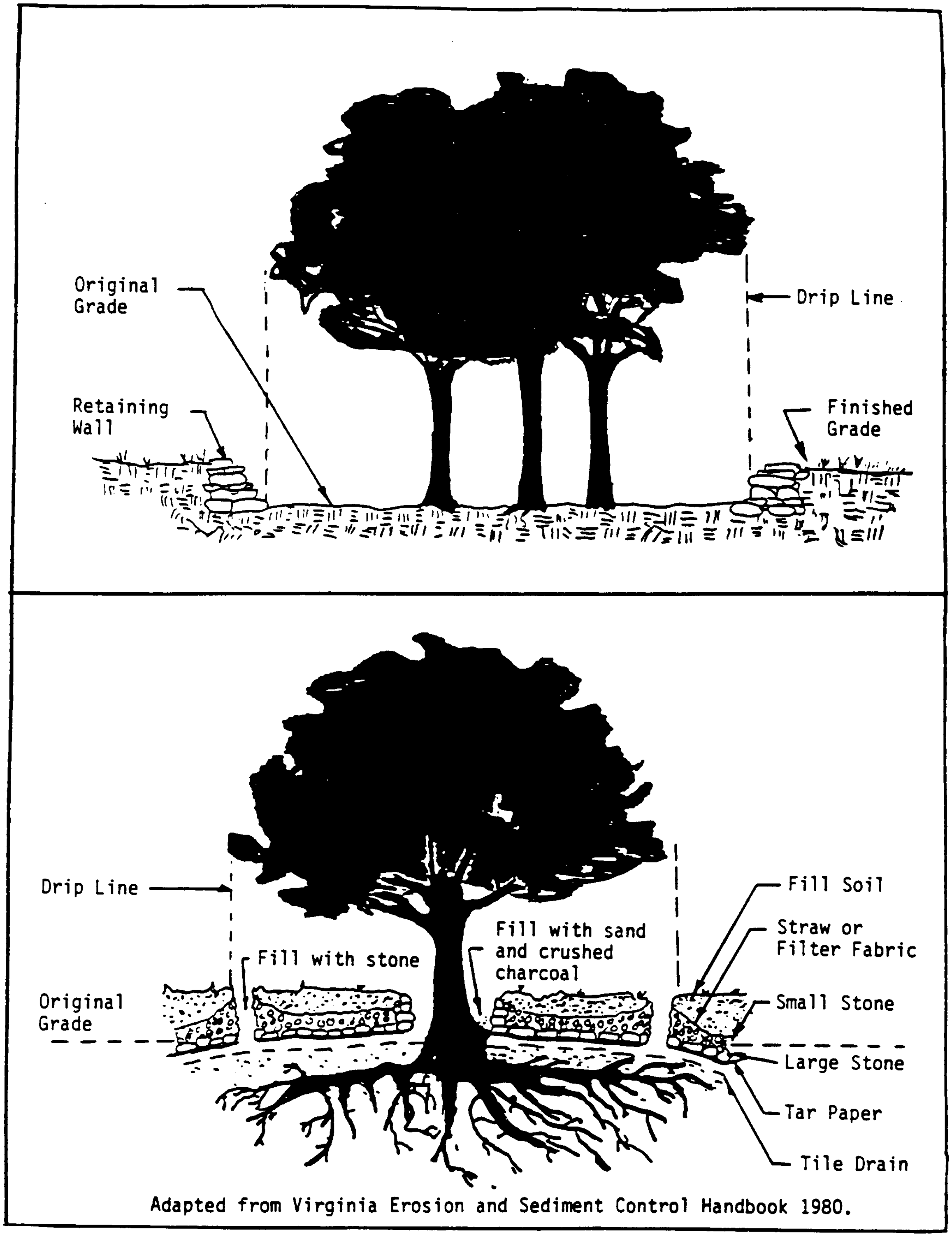
Source: Michigan Soil Erosion and Sedimentation Control Guidebook



Grooving slopes (modified from Va SWCC).

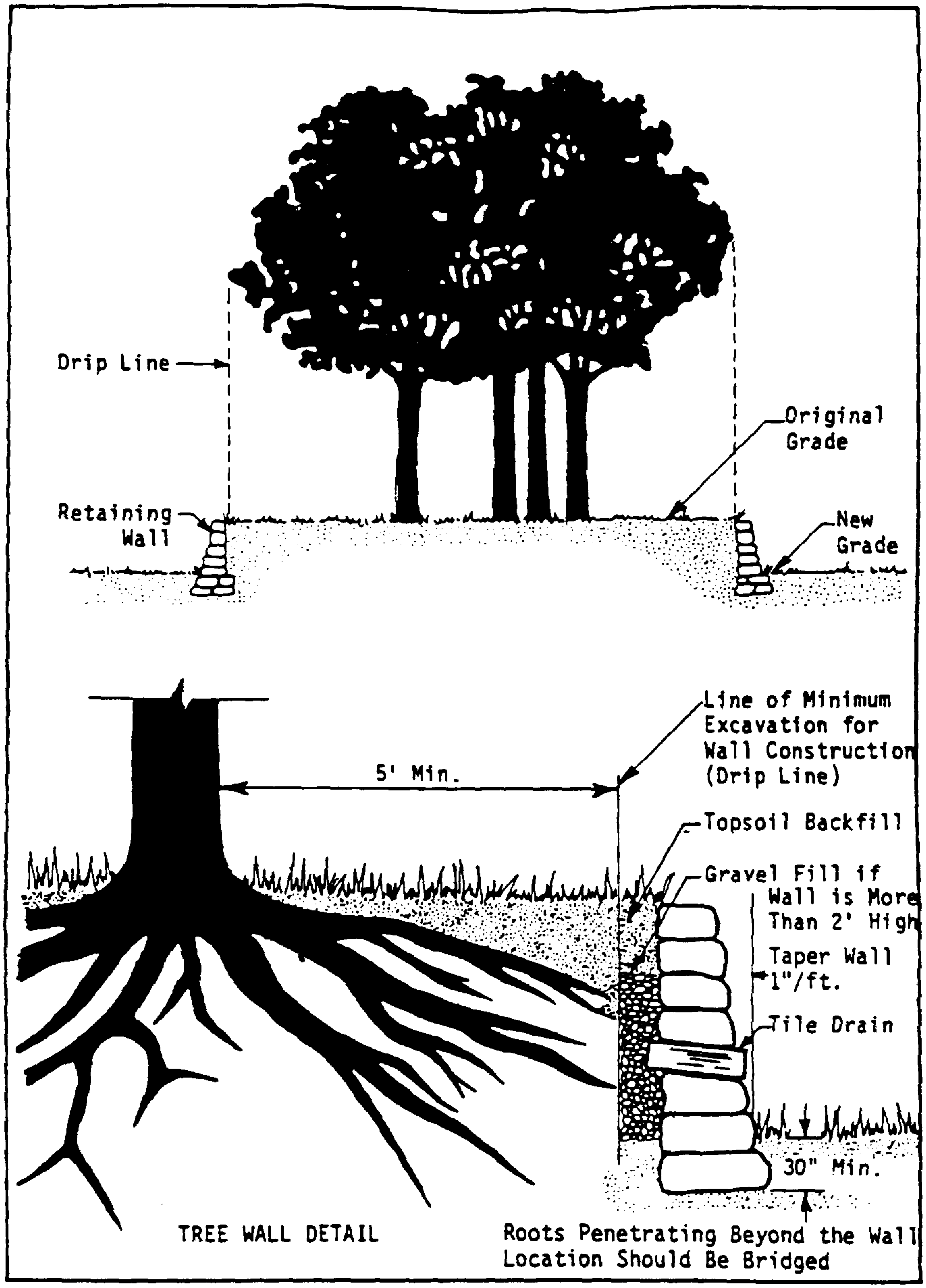
Source: North Carolina Erosion & Sediment Control Planning & Design Manual

Exhibit 2
Tree Well



Source: Connecticut Guidelines for Soil Erosion and Sediment Control

Exhibit 3
Tree Wall



Source: Virginia Erosion and Sediment Control Handbook, as copied from Connecticut Guidelines for Soil Erosion & Sediment Control.

Dec. 1, 1992

Land Clearing

Description

Land clearing is the removal of all woody and herbaceous plant material from a site to develop the site for other uses. Land clearing is divided up into two components, grubbing--which is removing roots and stumps by digging--and tree removal.

In regulated wetlands, clearing trees and shrubs with heavy equipment is not allowed without a permit from the State. Trees and shrubs can be cut by hand without a permit, but stump removal requires a permit.

Other Terms Used To Describe

Grubbing
Tree Removal

Pollutants Controlled and Impacts

Due to the nature of the activity, land clearing will expose soil to erosive forces. BMPs which help prevent erosion should be used in conjunction with proper land cleaning practices to keep soil on-site. One essential BMP is the Buffer/Filter Strip, which includes the minimum width of natural vegetation that should be left in place to protect water bodies. This is important because vegetation provides shade for rivers and other water bodies. When land clearing is done immediately adjacent to a water body, shade is reduced, resulting in increased stream temperatures. For some fish species such as trout, even slight changes in stream temperatures can be lethal.

In some instances, land clearing removes over-age, high canopy forest cover and opens up new land to reforestation or other land uses. Proper land clearing practices may increase the amount of sunlight and allow for a greater diversity of plant and animal associations.

Application

Land Use
Applicable to all land uses.

Soil/Topography/Climate
Cleared sites on heavy soils and steep slopes are more subject to erosion and may require additional BMPs to keep the soil in place. See the Critical Area Stabilization BMP for information on how to protect steep slopes.

When to Apply
Land clearing activities should not begin until the site has been assessed and the trees which have been selected for cutting have been tagged. Except on highway projects, large-scale sites should be cleared in phases to allow second phase work to proceed in the initally cleared area while clearing

proceeds in other areas on-site. Land clearing during dry or frozen times will decrease compaction and potential water quality problems from runoff.

Where to Apply
This BMP applies to all construction sites.

Relationship With Other BMPs

BMPs that may be needed in conjunction with land clearing include:

Access Roads
Critical Area Stabilization
Slope/Shoreline Stabilization
Buffer/Filter Strip
Filters (Filter Fencing)
Staging and Scheduling

Specifications

Planning Considerations:
Forestry operations. The MDNR is currently developing BMPs for forestry operations. Upon their availability, any land clearing done as part of a forestry operation should be done following the guidance in the forestland BMP manual. As interim guidance: a plan should be developed which specifies the kinds and location of timber which will be salvaged, the location of haul roads and skid trails, the width of the natural buffer zone which remains around all water bodies, and the method (where applicable) proposed to cross any water bodies. The method of disposing of all material which will not be salvaged should also be specified. The plan should also include the BMPs which will be used to protect the cleared area from erosion.

When clearing land **for golf courses**, the golf course architect should take full advantage of opportunities to establish clearing edges so that natural tree specimens and vegetative edges create visually attractive golf holes. Selecting the final edge of the fairway should be dependent upon species size, age condition, design intent and visual impact. It is not uncommon to shift golf holes to preserve a single key tree.

Other non-forestry land clearing activities should be done so that valuable, healthy and aesthetically pleasing trees are kept in place. Leaving standing trees is also economically advantageous to the developer. Healthy trees should be identified and protected following specifications in the Tree Protection BMP. Where possible, preserve a natural Buffer/Filter Strip above and below the graded area and adjacent to all water bodies. Always try to avoid clearing to the water's edge.

1. Where it is necessary to develop to the water's edge, filter fencing should be used. See Filters BMP.

2. Stage the construction site so that only part of the site is being cleared at any given time. This will reduce the amount of time soil is exposed to erosive forces. Follow examples in the Staging and Scheduling BMP.

3. Diversions may be needed to intercept and divert runoff to Stabilized Outlets.

4. All debris should be kept out of surface water. If possible, leave some debris on the ground to decrease runoff and increase shade for seedlings. See the "Disposal Options" section, below.

5. Exposed soil should be temporarily seeded to prevent further erosion from the site. Follow specifications in the Spoil Piles and Seeding BMPs. Other BMPs may also be necessary to keep soil on the site.

Grubbing:

Grubbing is removing roots and stumps by digging. Grubbing is done to remove grasses, shrubs and small trees.

Grubbing should be carefully monitored near lakes and streams to protect the water's edge. Where possible, it is recommended that total clearing not take place to the water's edge. If it is necessary to clear to the edge, clear by hand cutting to preserve the bank.

Tree Removal:

1. The preferred method of tree removal is to cut the tree and remove the stump in a separate operation. This allows the tree to be used for commercial purposes such as lumber, firewood, or mulch. All stumps that need to be removed from a site should be removed at the same time to decrease the time soil is exposed.

2. The less preferred option is to remove the entire tree (including stump) in one operation.

3. The operation of heavy equipment too close to the tree may result in possible tree loss later because of soil disruption, compaction and trunk damage. It is recommended that, within reasonable limits, all heavy equipment operations be limited to outside the drip line of all trees to be preserved. (The drip line is the area from the trunk of the tree outward to a point at which there is no longer any overhanging vegetation).

4. In forested wetlands, shallow-rooted species are protected by each other from potential wind damage. Whenever trees are removed from a forested wetland, the possibility of blow downs or windthrow increases. Shallow rooted species are also protected by edge trees, which shield the prevailing wind side of the woodlot. It is helpful to leave as many edge trees as possible on the prevailing wind side of the cleared area.

Disposal Options:
Where possible, all stumps, roots, logs, brush, limbs, tops and other debris resulting from the clearing or thinning operation should be disposed of by reducing the material by processing through a chipping machine. The chips should be disposed of as mulch (see the Mulching BMP), as part of a landscaping plan (where applicable), outside the right-of-way, or in other approved areas. Organic material may also be composted. See the Organic Debris Disposal BMP for more information on organic debris disposal options.

Note that tree tops, stumps and field stone which are cleared and piled in suitable areas can improve habitat for wildlife such as rabbits, raccoons, snakes, salamanders, toads and frogs.

Maintenance

Land clearing itself requires no maintenance except maintenance of the equipment used in the land clearing operation. Tree Protection, which is an important part of land clearing, should be done throughout the clearing stages. It is also important to maintain all other temporary and permanent BMPS which are used in conjunction with the land clearing BMP to prevent soil erosion and sedimentation. This includes maintaining appropriate Buffer/Filter Strip widths.

Dec. 1, 1992

Spoil Piles

Description

Spoil piles are excavated materials consisting of topsoil or subsoils that have been removed and temporarily stored during the construction activity. This BMP addresses spoils which will be stored during most of the construction phases, as well as spoils which will be spread to blend into the natural topography. Specifications for dredged spoils are also included.

Other Terms Used to Describe

Soil Piles
Stock Piles
Storage Piles

Pollutants Controlled and Impacts

Properly placed and stabilized spoil piles will reduce soil erosion.

Application

Land Use
Construction sites and anywhere dredging is done.

Soil/Topography/Climate
All stockpiled soils need to be stabilized because of their highly erodible nature. Even soils subject to quick freezing need to be protected since they will eventually thaw.

When to Apply
Stripping and stockpiling topsoil should be done early in the excavation stage of the project to save all the fertile soil on-site. Subsoils should not be mixed with topsoil and should be stockpiled in stages to minimize the exposure time.

Where to Apply
Apply in all areas where spoil piles are created during grading operations. Also apply in all areas which are dredged.

Relationship With Other BMPs

Spoil piles are usually created during Land Clearing operations. Filter fencing is usually put in at the base of the storage pile to prevent soil from leaving the site. Spoil piles should be stabilized following specifications in the Seeding BMP.

Specifications

For Spoil From Dredging Operations:

1. Spoil collected during dredging should be placed in a manner which will not endanger the stability of any ditch bank. Locate piles a minimum of eight feet from the top of the bank and slope landward to prevent direct drainage from the spoil pile back into the waterway.

2. To prevent both wind and water erosion, piles should not exceed three feet in height above the natural ground surface, except as otherwise approved. Make the piles no steeper than 4:1 (h:v) on the land side, and 3:1 on the channel side if a berm is established. If the spoil is spread to the edge of the channel, side slopes of the spoil should be no steeper than 4:1 and shaped to join the side slope of the ditch bank so loose spoil will not roll or wash into the channel or ditch.

3. Spoil piles should be seeded daily as an area is dredged. Follow the specifications for temporary seeding in the Seeding BMP.

4. Where runoff from the pile may occur, place filter fence at the base of the spoil pile (between the pile and the ditch bank) to help retain soil until vegetation is established. This is especially important on subsoils where vegetation may not grow readily. See the Filters BMP.

For Spoil From Construction Sites:

1. Spoil piles may be located around the perimeter of the project away from the construction activity, or located in the immediate vicinity of the construction. Do not locate spoil piles in or immediately adjacent to wetlands and watercourses, or such that any runoff from the spoil pile will end up in wetlands and watercourses. Include the location of the spoil piles(s) on the soil erosion/sedimentation control plan.

2. Where it is not possible to move the spoil pile upland, place the spoil pile behind a bench or berm to prevent erosion. This is especially important on steep slopes.

3. If runoff can occur, place filter fencing at the base of the spoil pile to help retain soil until vegetation is stabilized. See the Filters BMP.

4. Seed all spoil piles (temporary and permanent) following specifications in the Seeding BMP.

5. Consider placing Construction Barriers around the spoil pile to prevent access by people and equipment.

Excess Stockpiled Soil:
Excess stockpiled soil which is not used as fill or in the preparation of seedbeds or sodbeds should be disposed of in a manner which will not result in the soil running off and impacting surface waters or wetlands. The manner in which this excess soil is disposed of should be included on the soil erosion control plan.

Maintenance

When vegetative stabilization is promptly and effectively applied, very little maintenance is required. The guidelines below should be followed on all sites:

1. Periodic inspections should be done to ensure excessive erosion hasn't occurred. If runoff or wind erosion has occurred, reduce the side slopes of the spoil pile, or stabilize the spoil pile with pieces of sod laid perpendicular to the slope, and staked.

2. When filter fencing is used around a spoil pile, periodic checks should be made to ensure that piping has not occurred under the fencing, and to ensure the fence has not collapsed due to soil slippage or access by construction equipment. Repair any damaged fencing immediately.

3. Berms at the base of the spoil pile which become damaged should be replaced.

Staging and Scheduling

Description

Staging is dividing a construction area into two or more areas to minimize the area of soil that will be exposed at any given time. It is done to ensure that as much of the site as possible is stabilized.

Scheduling is a planning process which provides a basis for implementing other BMPs in a timely and logical fashion. In any one development, not all BMPs should be implemented at the same time.

Other Terms Used to Describe

Construction Sequence
Phasing
Sequencing

Pollutants Controlled and Impacts

Staging reduces the likelihood of soil erosion and off-site sedimentation by exposing an area for the shortest time possible. Scheduling reduces water quality impacts by ensuring that BMPs are implemented at the most appropriate time.

Application

Land Use
Use on all construction sites.

Soil/Topography/Climate
Staging and scheduling should be done in all areas, regardless of soil, topography and climate.

When to Apply
Staging and scheduling should begin during the planning phase and continue throughout the construction and stabilization phases. All BMPs which will be implemented on-site should be incorporated into the staging and scheduling process.

Where to Apply
Apply on all projects. This BMP is especially important in areas adjacent to watercourses and on steep slopes, or areas which are susceptible to heavy rains, snowmelt, or strong winds.

Relationship With Other BMPs

The implementation of all temporary and permanent best management practices should be coordinated via staging and scheduling until final stabilization of the site has been accomplished

Specifications

1. Divide the construction site into the number of areas which will be actively developed at any given time. Keep the area and duration of exposure to a minimum. Plan the development phases so that only areas which are actively being developed are exposed. All other areas should be left undeveloped or stabilized with temporary vegetation or mulch.

2. Develop a scheduling sequence for each staged area. The scheduling sequence should list each BMP which will be used on the area, and when the BMP will be implemented, and, if, appropriate, when it will be removed. Follow the example given in the attached exhibit.

The Exhibit: The purpose of staging and scheduling is to install soil erosion and sedimentation control structures, as well as any stormwater structures, in a way which prevents pollutants from leaving the construction site. Exhibit 1 shows the construction sequence of a shopping center in southern Michigan. It is assumed that site plans have been developed. (A site plan should consist of a grading plan, soil erosion/sedimentation control plan, and stormwater control plan). This exhibit also assumes that a pre-construction meeting has taken place, and that MISS DIG has been contacted regarding underground utilities.

Step 1 is to install underground utilities. Step 2 is to stake building sites.

The next several steps should be taken **before** any grading or land clearing: use the Critical Area Stabilization BMP to protect areas prone to erosion; and install soil erosion/sedimentation control measures, including measures such as Diversions, Sediment Basins and silt fences (Filters). All such practices should be on the site plan.

Step 7 is Land Clearing and installing an Access Road.

Following land clearing, topsoil will be removed and stored in Spoil Piles.

Step 9 is grading the area using the Grading Practices indicated on the grading plan.

Next, the schedule calls for installing other temporary erosion control measures. This includes temporary seeding of all areas not under active development, possibly including storage piles.

The next several steps (11-14) are outlined in sequence for the shopping center structure.

Step 15 is establishing a final grade according to Grading Practices, and again, following the grading plan.

The next step is to install permanent stormwater structures, including vegetative controls such as permanent vegetation.

Step 17 calls for removing temporary structures such as silt fences, but **only after the area is stabilized**.

Step 18 is the **ongoing maintenance of all structures.**

Maintenance

Follow the maintenance procedures for each of the BMPs that are used in the construction process. See the individual BMPs.

Exhibits

Exhibit 1: An example Construction Schedule for a Subdivision. Detail CS-1, as modified from MDNR, Soil Erosion and Sedimentation Control Unit.

EXHIBIT 1
Sample Construction Schedule For A Shopping Center
SOIL EROSION AND SEDIMENTATION CONTROL IN SOUTHERN MICHIGAN

CONSTRUCTION ACTIVITY	MONTHS												
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1. Install underground utilities			X	X									
2. Stake building sites		X	X	X									
3. Protect, stabilize critical areas using Critical Area Stabilization	X	X		X	X								
4. Identify and protect Buffer/Filter Strips	X												
5. Implement Tree Protection; Install Construction Barriers	X												
6. Install erosion/sediment control measures (temp/perm.)													
a. Diversions	X		X										
b. Sediment Basins	X		X										
c. Other (Temp. Seeding, Silt Fence, etc.)	X	X	X	X	X								
7. Remove trees, shrubs, etc. using Land Clearing. Install Access Road	X	X											
8. Remove topsoil and store in Soil Piles	X	X											
9. Grade using proper Grading Practices	X												
10. Install other temporary erosion control measures													
a. Seeding/Sodding/Mulching Temporary-Stagging		X		X	X	X							
b. Other													
11. Excavate footings/basement		X	X	X	X						X	X	
12. Construct footings/foundations		X	X	X	X	X					X	X	
13. Construct superstructure			X	X	X	X	X	X	X	X	X		
14. Apply aggregate base to driveways, parking lots, etc.				X	X	X							
15. Final grade according to Grading Practices				X	X	X						X	
16. Implement permanent stormwater control measures:													
a. Vegetative Controls				X	X	X						X	X
b. Others													
17. Remove temp. struct. (upon comp. stabilization) or dormant seeding													X
18. Maintenance of all erosion/sediment measures	X	X	X	X	X	X	X	X	X	X	X	X	X

APPROPRIATE BOXES TO BE DATED BY APPLICANT FOR APPROVED BY ENFORCING AGENCY

Estimated Potential Soil Loss in Tons______________________________

Tree Protection

Description

Protecting trees during construction activities is done to preserve their health and ensure their vitality after construction.

Other Terms Used to Describe

Tree Preservation

Pollutants Controlled and Impacts

Trees should be considered for preservation because:

- -They stabilize the soil and prevent erosion
- -They reduce stormwater runoff by intercepting rainfall and promoting infiltration
- -They moderate temperature changes, promote shade, and reduce the force of wind
- -They provide buffers and screens against noise and visual disturbance, and provide some privacy
- -They filter pollutants from the air and produce oxygen
- -They provide a habitat for animals and birds
- -They increase property values and improve site aesthetics

Application

Land Use
This practice is used most often on construction sites.

Soil/Topography/Climate
This practice is especially important in areas subject to windthrow, where trees removed in the upland area may cause a domino effect in the lower area. It is also important on highly erodible soils, where tree roots help stabilize soils and prevent erosion.

When to Apply
Apply during site evaluation before any construction is done on the site. During site evaluation, note where valuable trees are located and incorporate them into the overall construction design.

Where to Apply
Apply anywhere trees are in need of protection.

Relationship With Other BMPs

Tree protection should be done before any Land Clearing or Grading Practices are done. Construction Barriers are often used in conjunction with tree protection.

Specifications

Note that much of the information below was derived from the North Carolina Erosion and Sediment Control Planning and Design Manual.

Planning Considerations:
When selecting trees to be protected, consider:

1. Tree vigor. Preserve healthy trees. Sick trees or those damaged beyond repair can be left for wildlife, or removed. Trees lacking vigor include those with dead branches, small annual twig growth, stunted leaf size, sparse foliage, and pale foliage color. Trees with hollow or rotten trunks also should be removed.

2. Tree age. Older trees are usually more aesthetically pleasing, but often require more maintenance than younger trees.

3. Tree species. Protect trees which are most suitable for the site development.

4. Tree aesthetics. Protect trees which are aesthetically pleasing.

5. Wildlife benefits. Protect trees which are preferred by wildlife for food, cover or nesting. Evergreens are important for cover during the winter months. Hardwoods are more valued for food. A mix of evergreens and hardwoods is usually most beneficial.

Design Considerations:
When designing a construction site in wooded areas, consider:

1. Leaving critical areas (such as floodplains, steep slopes and wetlands) with as many desirable trees as possible in their natural condition.

2. Locating roadways, storage areas and parking areas away from valuable trees.

3. Selecting trees to be preserved before siting roads, buildings, or other structures.

4. Minimizing trenching in areas with trees. Multiple utilities should be placed in the same trench.

5. Equipment, structural materials, topsoil and fill dirt should never be stored in the drip line of the tree.

6. When the construction plan calls for lowering or raising the grade around trees, see the specifications for tree wells and tree walls in the Grading Practices BMP.

Implementation:
See Exhibit 1 for examples of several types of tree protection methods.

1. Never excavate, traverse, or fill closer than the drip line of trees to be saved.

2. Trees which will be preserved should be marked with a bright color paint or surveyor's ribbon applied in a band circling the tree at a height visible to equipment operators.

3. (Construction) Barriers for tree protection should never be placed within the drip line of the tree.

4. Don't cut roots in the drip line.

5. Never nail boards or wire to the trees, as this will make them more susceptible to disease, insect damage and decay. As a last resort, a tree trunk can be armored with burlap wrapping and 2-inch studs wired vertically no more than two inches apart to a height of five feet encircling the trunk.

After Construction:

Once construction is complete, you can remove all temporary tree protection devices. Inspect all trees to ensure they are in good health. Repair all damaged roots and branches:

1. Repair roots by cutting off the damaged areas and painting them with tree paint. Spread peat moss or moist topsoil over exposed roots.

2. Repair damaged bark by trimming around the damaged area (as shown in Exhibit 2). Taper the cut to provide drainage. Paint with tree paint.

3. Cut off all damaged tree limbs above the tree collar at the trunk or main branch. Use three separate cuts to prevent bark from peeling off healthy areas of the tree. (See Exhibit 2).

4. Trees which are severely damaged should be removed and replaced with similar species, with trunk diameters at least 2 inches.

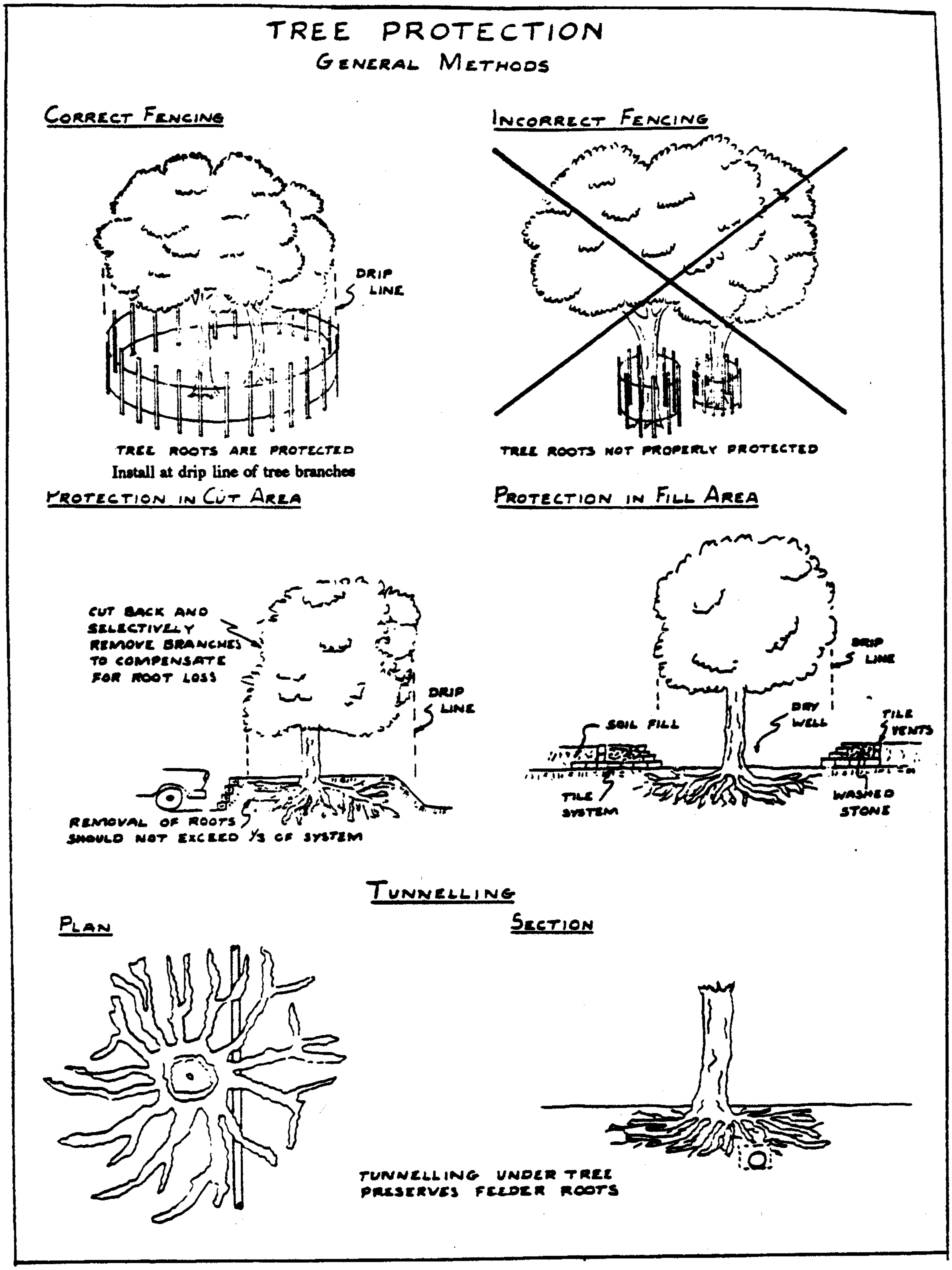
5. Soil over the root zone which has become compacted should be aerated by punching holes in it with suitable equipment.

Exhibits

Exhibit 1: Tree Protection, General Methods, Detail TP-1. Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

Exhibit 2: Repairing Damaged Tree Limbs. North Carolina Erosion and Sediment Control Planning and Design Manual.

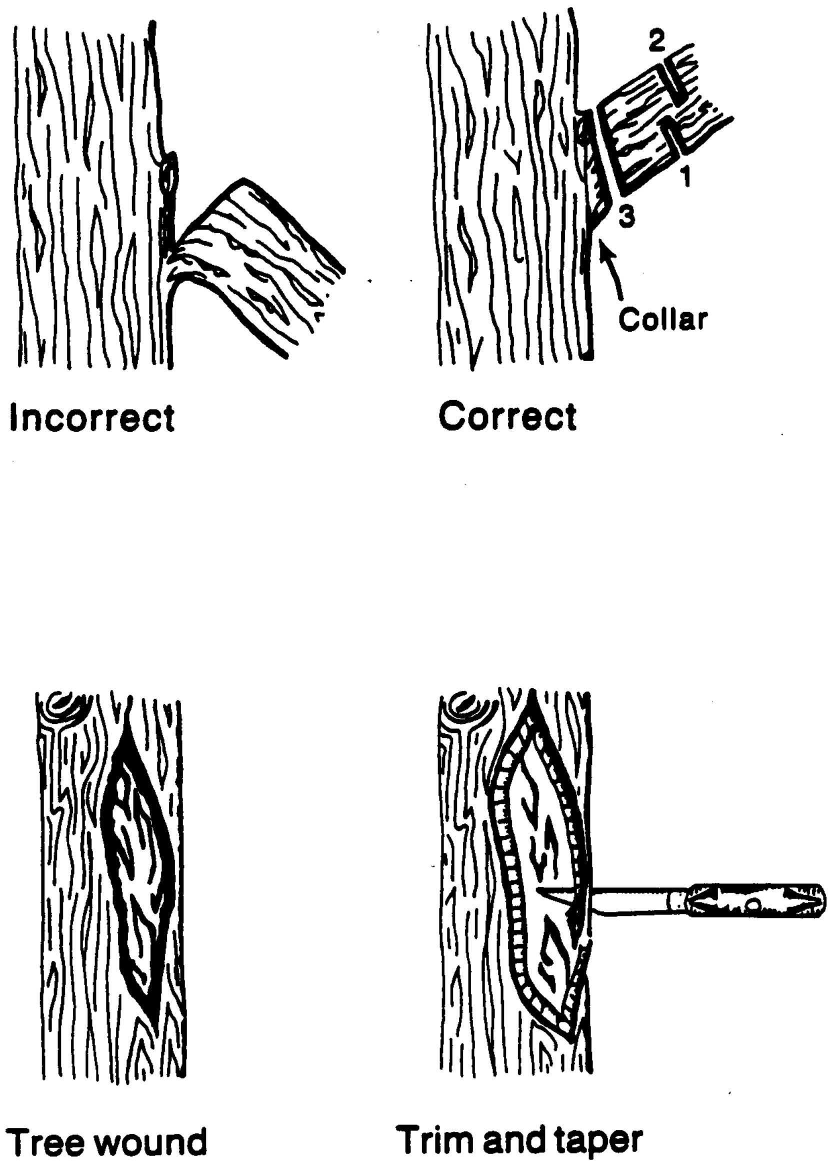
Exhibit 1



Source: Construction Project Evaluation Manual. Michigan Department of Natural Resources, Land and Water Management Division.

Exhibit 2

Repairing Damaged Tree Limbs



Trim bark wounds with a tapered cut, then apply tree paint.

Prune damaged branches with three cuts to avoid peeling bark from the tree trunk when limb falls.

Source: North Carolina Erosion and Sediment Control Planning and Design Manual

HOUSEKEEPING PRACTICES

Dec. 1, 1992

Household Hazardous Waste Disposal

Description

The average American house contains three to ten gallons of hazardous chemicals, including items such as automotive wastes, cleaners and paint. Proper buying, using, storing and disposal of hazardous materials will prevent these types of wastes from entering the environment, and will minimize exposure risks to humans.

This practice addresses the proper disposal of household hazardous wastes.

Wastes which are considered to be hazardous are waste materials that are any of the following:

IGNITABLE = burn readily or have a low flashpoint
REACTIVE = potential to explode or give off poisonous gases
CORROSIVE = corrode steel or alter skin tissue
TOXIC = harmful to human or aquatic life

For the proper disposal of quantities of hazardous waste over 1 gallon, contact the Michigan Department of Natural Resources (MDNR), Waste Management Division at 517-373-2730.

Pollutants Controlled and Impacts

The proper disposal of hazardous materials will minimize the amount of hazardous materials that will enter surface waters and contaminate groundwater supplies.

Application

Land Use
This BMP is applicable to all land use areas where household hazardous materials are present.

Soil/Topography/Climate
This BMP is applicable to all soil types, topography and climates.

When to Apply
This practice should be applied at all times.

Where to Apply
This should be applied in all households.

Specifications

General Considerations:
Improper disposal methods, such as pouring wastes into septic tanks or sewers, burying them in the back yard, may allow the hazardous waste to enter the ground or surface waters where they can

migrate to the water supplies we use for our drinking water. Some hazardous wastes which are discarded in landfills have leached out of the landfill and into the ground water. It is therefore important to dispose of hazardous wastes properly. Follow the guidelines below.

Buying, Storing and Using Household Hazardous Wastes:

1. Use alternative household products which are not toxic. See the attached Exhibit for some ideas.

2. Where alternative household products are not available, buy non-toxic products. Look for "non-toxic" on the label.

3. Always read labels carefully before buying and using hazardous products. Be aware of their uses and dangers. If directions are unclear, contact the manufacturer before using.

4. If your area is served by septic systems, make sure you buy products which are safe for septic systems. Most products include this type of information on the label.

5. Reduce your waste and save money by purchasing only the materials you need and will use.

6. Use the product according to the directions on the label, and in a well-ventilated area, where possible. Special care should be taken to avoid eye and skin contact, inhalation or ingestion of these materials. Many hazardous products have dangerous fumes that can burn your skin or irritate your eyes, so consider using gloves and protective eyewear.

7. Avoid mixing different products that can cause explosive or poisonous chemical reactions.

8. Keep unused portions in their original containers with labels intact and readable. Keep out of the reach of children and pets. Knowing the contents could be a lifesaver in case of accidental poisonings.

9. Store out of direct sunlight, in a cool, dry area.

10. Place all containers in a second container to contain any accidental spills.

11. Look up the phone number of the poison control center and place it near or on your phone in case of actual or suspected poisonings.

*You may also want to post the following numbers:

Center for Environmental Toxicology
(517) 353-6469

Center for Environmental Health Science
(517) 335-8350

MDNR Waste Management Division
(517) 373-2730

Disposing of Household Hazardous Wastes:

1. Identify materials needing special disposal consideration by key words on the label: POISON, CORROSIVE, CAUSTIC, VOLATILE, FLAMMABLE, EXPLOSIVE.

2. Whenever possible, reuse and recycle household hazardous wastes. For example:

   *Used motor oil can be recycled.

   *Paint thinners can be reused. (Let used solvents and paint thinners set for a while in a closed jar. The dirt and paints will settle to the bottom. The top portion can be reused. The amount of actual waste for disposal will be much less.)

   *Offer surplus portions of products that are usable and safely packaged to others, such as pesticides to nurseries, and paint to theater groups.

   Consult the attached Exhibit for information on disposing several other common household hazardous wastes.

3. Some hazardous materials that are no longer usable may need to be taken to a household hazardous waste collection center. A list of collection days and centers scheduled around the state is available from the Michigan Department of Natural Resources, Waste Management Division at (517)- 373-2730.

Getting the Community Involved:
Local communities can organize collection programs in their areas for household hazardous wastes. A public information and education program held prior to a collection day will help inform citizens of the hazards and risks associated with the products used in their homes. In a collection program, citizens bring their wastes to a common collection point. A licensed hazardous waste transporter sorts and packages the waste, and takes it to a hazardous waste facility that has been licensed to operate by the MDNR. Contact the MDNR Waste Management Division for information on starting a household hazardous waste collection day in your community.

<u>Maintenance</u>

Maintain the area in which the household hazardous wastes are stored by ensuring that product labels are legible, and that the products are being stored in a secondary container.

<u>Exhibits</u>

Exhibit 1: <u>Does Your House `Hold' Hazardous Waste?</u> (brochure). Michigan Department of Natural Resources, Waste Management Division.

Exhibit 1

DOES YOUR HOUSE "HOLD" HAZARDOUS WASTE?

KEY:  poisonous  corrosive  flammable  reactive

PRODUCT	HAZARD	OPTIONS
	key: see above	key: ● no alternative ★ alternative
AUTO		
Antifreeze		● Take to a collection day or pour down drain to a sewage treatment plant. If you have a septic tank, don't pour more than 1 gallon per week down the drain. Greatly dilute the coolant.
Car Batteries		● Take to local service station or battery collection site for recycling.
Waste Motor Oil		● Take to local service station or oil collection site for recycling.
Gasoline/Kerosene		● Use uncontaminated gasoline or kerosene. Take contaminated fuel to a collection day.
CLEANERS		
Floor Polish		★ Use those without petroleum distillates. Take to a collection day.
Furniture Polish		★ Lemon oil beeswax. Take to a collection day.
Drain Cleaner		★ Plunger, plumber's snake. Mix one cup each vinegar, baking soda, salt, pour into drain, let stand 15 minutes, flush with boiling water. Rinse them down drain with lots of water to a sewage treatment plant. If connected to a septic tank, give to someone who can use them or take to a collection day.
Oven Cleaner		★ Baking soda and salt — sprinkle on spills and wipe. Rinse them down drain with lots of water to a sewage treatment plant. If connected to a septic tank, give to someone who can use it or take to a collection day.

Exhibit 1

(con't.)

Toilet Bowl Cleaner	★ ½ cup chlorine bleach, let stand 30 minutes, brush and flush. Flush down drain with lots of water. If connected to a septic tank and you have a large amount of cleaner to get rid of, take to a collection day.
Chlorine Bleach	Flush down drain with lots of water. Never mix with ammonia-containing products.
PAINT	
Latex Paints	● Allow paints to solidify and dispose of in the trash.
Oil Base Paints	★ Use latex paints whenever possible. Take to household collection day.
Lead Base Paints	★ Use latex paints whenever possible. Take to collection day.
Paint Thinners/Turpentine Mineral Spirits/Solvents	★ Sandpaper, sander. Let sit in a closed jar and contaminants will settle to the bottom. Pour off liquid on top and reuse. Wrap paint sludge in newspaper, place inside a closed container in the trash. Take to a collection day.
PESTICIDES	
Wood Preservatives	★ Use Wolmanized™ lumber rather than wood treated with pentachlorophenol. Take to a collection day.
Weed Killer	★ Pull weeds, keep grass short. Take to a collection day.
Insecticides: Roach & Ant Killer	★ Boric Acid. Take to a collection day.

DNR WASTE MANAGEMENT DIVISION (517) 373-2730

PRINTED ON RECYCLED PAPER

Street Sweeping

Description

Street sweeping involves the use of specialized equipment to remove litter, loose gravel, soil, pet waste, vehicle debris and pollutants, dust, de-icing chemicals, and industrial debris from road surfaces. Street sweeping equipment can consist of a truck or truck-like vehicle equipped with multiple brushes, pick-up deflector, holding bin, water sprayer, vacuum nozzle and filter, or a combination of some or all of these features.

Pollutants Controlled and Impacts

When done regularly, street sweeping can remove 50-90% of street pollutants that potentially can enter surface water through storm sewers. Street sweepers will also make road surfaces less slippery in light rains, improve aesthetics by removing litter, and control pollutants which can be captured by the equipment.

Application

Land Use
Transportation, urban

Soil/Topography/Climate
Street sweeping is not effective on snow covered roads.

When to Apply
Street sweeping is typically done in the early morning hours when traffic is light. It is sometimes necessary to control parking by placing signs which limit the hours or the side of the street in which parking is allowed.

Where to Apply
Street sweeping is applicable on urban streets with curb and gutter, or paved drainageways.

Relationship With Other BMPs

Sweeping is recommended at least four times per year on all Porous Asphalt Pavement. Street sweeping in some areas may decrease the frequency in which Catch Basins need to be cleaned.

Specifications

General Considerations:

1. Approximately 90% of the contaminants will accumulate within 12 inches of the curb, therefore, only one sweep is generally necessary to remove contaminants.

2. When replacing gutters or constructing new ones in urban areas, consider installing broader concrete gutters to increase street cleaning efficiency.

3. Damaged pavement is not possible to clean effectively and should be resurfaced in areas where street cleaning is done.

4. Use vacuum sweepers on dry pavement only.

Frequency of Sweeping:
The frequency in which street sweeping should be done is very controversial, and the schools of thought range from "not at all" to "every other day." Some studies have shown that street sweeping may have a negative effect by breaking down aggregated particles (clumps of particles) into fine particles which can be carried more easily by runoff. We feel that the goal of street sweeping should be to keep the larger-sized pollutants from entering storm sewers.

We recommend street sweeping:

-after heavy rain storms in which sediment is present on the streets; and

-adjacent to construction sites where sediment has left the site and entered the street; and

-at least once during the fall to collect leaves and keep them out of the sewer system; and

-at least once during the spring to collect garbage and coarse sediment left behind during snow melt.

The effectiveness of street sweeping appears to be primarily dependent upon the frequency of sweeping and the interval between storms. Additional considerations are operator skill and the number of cars parked at the curb. Other factors in order of importance are: total mass of the area to be swept and its relation to loadings on other areas not accessible to sweepers; the efficiency of sweepers compared to the storm runoff of the pollutant of interest; and local storm characteristics.

Types of Sweepers:
Street sweeping effectiveness is a function of sweeping frequency, number of passes per sweeping, equipment speed and pavement conditions. Below are two types of street sweepers. Keep in mind that street sweeping equipment is manufactured by more than one company and each company competes for design efficiency.

Mechanical broom street sweepers are effective in removing larger particles, but are not effective in removing fine, pollutant-laden dust and dirt (smaller than 400 microns). These small particles contain the majority of pollutants found on the streets (i.e. oxygen demanding substances, nutrients, metals, oils). The removal efficiency for these machines is 50%, assuming a smoothly paved surface, particles greater than 400 microns, and the absence of parked vehicles. These are less expensive to operate than vacuum sweepers.

Vacuum-type street sweepers are more efficient in removing dust and dirt particles (about 90%) than mechanical broom sweepers. However, vacuum sweepers are ineffective when the pavement is wet.

Maintenance

In order to increase the effectiveness of street sweeping, roads should be kept well-surfaced.

Community Car Washes

New BMP: September, 1997

Description

This BMP applies to community car washes, that is, fund raising events for non-profit organizations where numerous vehicles are washed at one location over a short period of time. It also applies to individual car washing done at home. This BMP does *not* apply to do-it-yourself (coin) or drive-thru car washes, or the commercial cleaning of cars, trucks and equipment by private contractors. Commercial operations—including coin-operated, drive-thru and mobile washes—may need a permit from the MDEQ, Surface Water Quality Division.

Community Car Washes Done In Parking Lots:
Community car washes are often conducted outside on parking lots and other impervious areas. Wash water from the hoses carries away the dirt, oil, grease, salt and any soap or other cleaner the washers use. This dirty, soapy water works its way to either a grate near the curb (where it enters a sewer), or it collects somewhere off the parking lot (and infiltrates into the ground). Therefore, before you consider doing a community car wash, know where the water from your washing activities will go.

If the wash water from your community car wash will make its way to a sewer, the sewer will be either a storm sewer or a combined sanitary/storm sewer (see Exhibit 1):

- If the sewer is a storm sewer, then the "dirty" water will be carried by the storm sewer pipes and discharge to a lake or stream. Any "dirt" that settles out in the lake or stream will cover habitat needed by fish and aquatic insects. Any soaps (or detergents) that enter the lake or stream may make the water look foamy, and may harm aquatic life. Even soaps or detergents labeled "biodegradable" can be harmful because they contain surfactants—substances which may be lethal to sensitive organisms in low concentrations.

- If the sewer is a sanitary sewer or combined sanitary/storm sewer, the water will be piped to a wastewater treatment plant where the "dirty" water is treated.

Discharge to a sanitary sewer or combined sanitary/storm sewer is preferred over discharge to a separate storm sewer, if there is an option.

Community Car Washes Done On Grass:
When community car washes are done on large grassed areas, it is important that the grass is dense (thick). Do not wash cars on bare soil. Conduct the car wash away from wells and wellheads, especially if soap/detergent is being used. If you don't know where the wells and wellheads are, contact the local health department. Be sure to get permission from the landowner.

If the water will run off the grassed area or parking lot, or concentrate in a small area and infiltrate into the ground, you should contact the MDEQ, Waste Management Division to discuss the potential for contamination and ways to prevent it.

Pollutants of Concern

Soil ("dirt"), surfactants (soap/detergents), oil and grease.

Application

Land Use
This practice is applicable to any areas where cars are washed for community fund-raising purposes, or by individuals at home.

Soil/Topography/Climate
Cars should not be washed on bare soil.

When to Apply
Apply before washing cars for community fund raising purposes.

Where to Apply
Anywhere community car washes are done.

Relationship With Other BMPs

Community car washes should not be done on Buffer/Filter Strips.

Specifications

Planning Considerations:

If washing outside on parking lots or other impervious areas:

- Determine where the wash water will drain.

- If water drains to a sanitary sewer or combined/sanitary sewer, you should obtain permission from the wastewater treatment plant operator before beginning your community car wash.

- If wash water drains to a storm sewer, wash vehicles using water alone, without soap. Not using soap will leave only the “dirt” and attached pollutants, which can be trapped before entering the sewer. To trap these pollutants, cover the storm sewer with a filter fabric and pea stone (see Exhibit 2).

If washing on thickly grassed areas:

- Obtain permission from the landowner to use the land for community car washing purposes.

- Make sure the wash area isn’t near wells or wellheads.

- Use water alone, without soap/detergents, if possible. This will reduce the potential for ground water contamination.

- If you do use soaps/detergents, use those that are biogradable.

Other Tips:

- Consider working with local commercial car wash operators. In some cases, the commercial operators will give community organizations some of the profits in exchange for the organization’s “campaigning” efforts.

- To preserve water, use a bucket and wash from it instead of leaving the hose running. In 60 seconds, a 5/8 inch diameter hose left on can use 14 gallons of water. For a ten-minute car wash, that's 140 gallons for one car. If using a bucket is not practical, attach a spray nozzle onto the hose to restrict the flow of water when it's not needed.

After the Car Wash:
If a filter fabric and pea stone structure is used, shovel off the pea stone and the pollutants (dirt, oil/grease, etc.) it captured, and remove the filter fabric. The filter fabric, pea stone and pollutants attached to the pea stone should be disposed of in the trash.

Exhibit 1

Exhibit 1: Sanitary Sewers versus Storm Sewers.

Exhibit 2: Geotextile-Stone Inlet Filters, modified from Virginia Sediment Control Manual.

Exhibit 1

Sanitary Sewers versus Storm Sewers

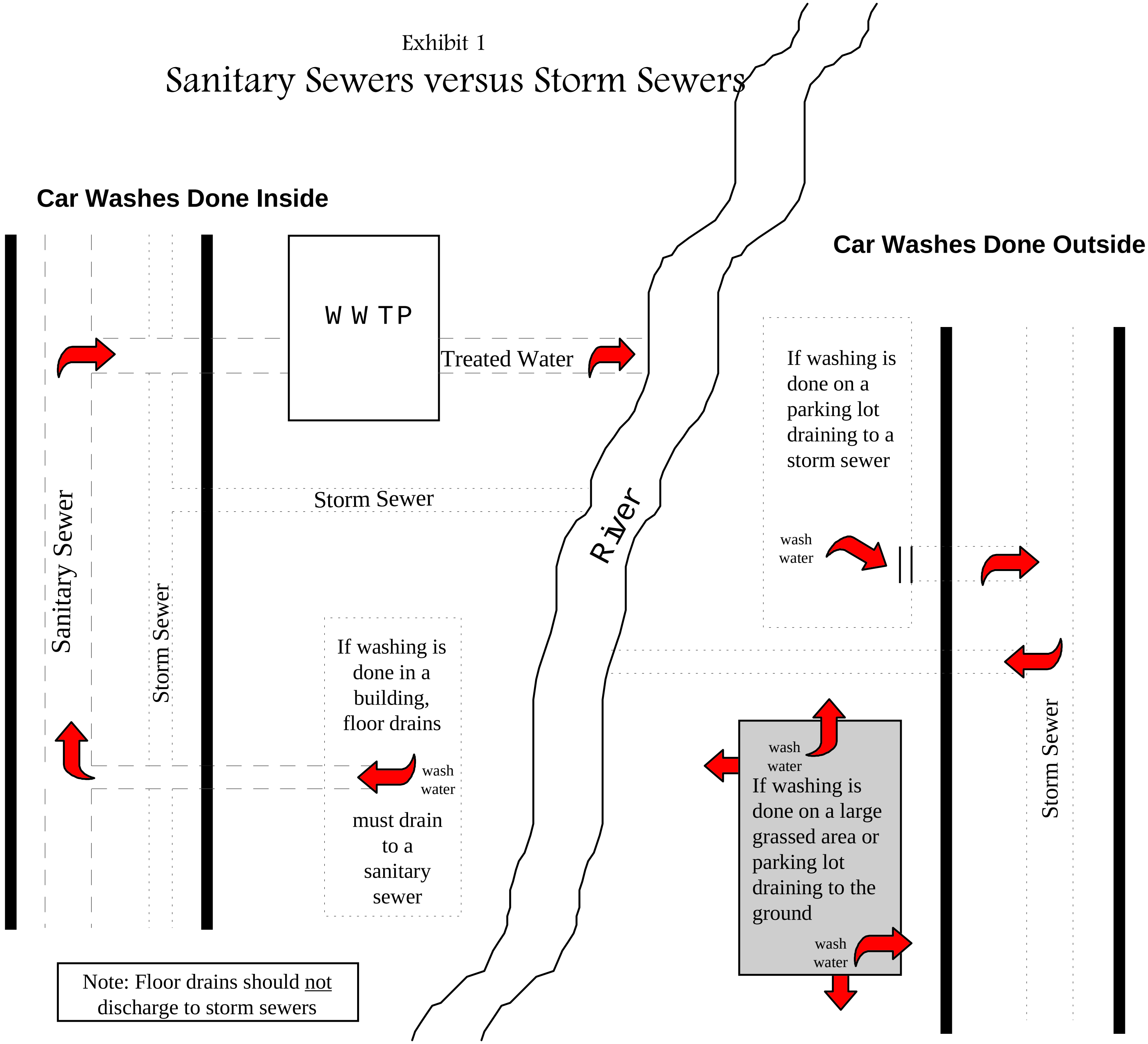


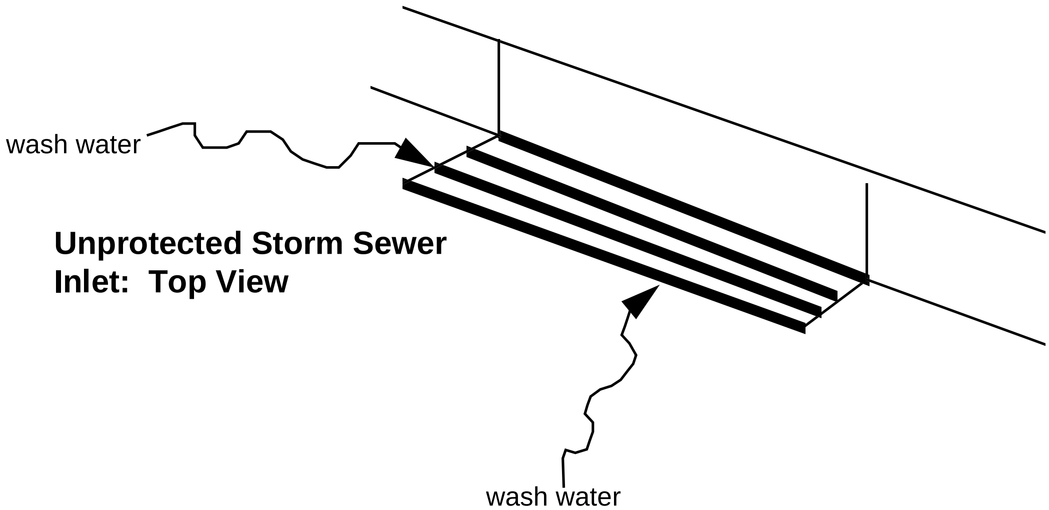
Exhibit 2

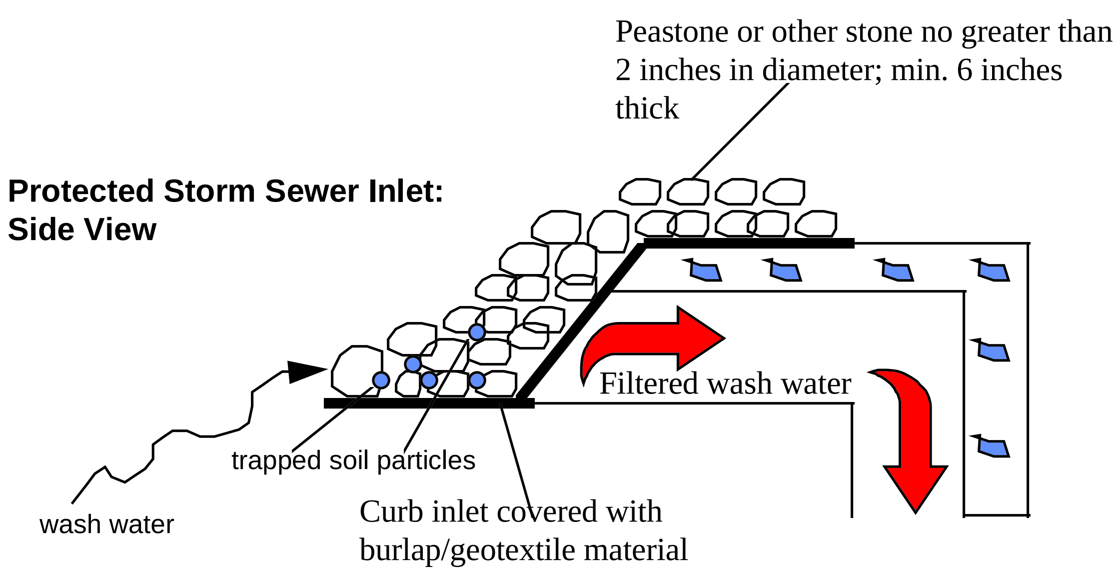
A Simple Way to Protect Storm Sewers during Community Car Washes

Simple stone filters can be used to prevent "dirt" and other pollutants from entering storm sewers. The purpose of the filter is to trap the pollutants in the stone and filter fabric.

Below is a simple way to make a stone filter to protect storm sewer inlets:

Take hardware cloth, geotextile filter fabric, burlap, or wire mesh with mesh size no larger than 1/2 inch, and wrap it around the storm sewer inlet. Allow extra cloth/wire to extend beyond the perimeter of the inlet. Lay six inches of peastone or small gravel (no larger than 2 inches in diameter) on top of the fabric/wire mesh. Upon completion of the car wash, remove all parts of the filter and dispose in the trash.





Modified from Vigrinia Sediment Control Manual

MANAGERIAL PRACTICES

Critical Area Stabilization

Description

Critical area stabilization is stabilizing areas which are highly susceptible to erosion by implementing one or more vegetative or structural BMPs. For the purposes of this BMP, critical areas include areas with highly erodible soils, long or steep slopes, droughty soils, excessively wet soils, soils that are very acidic or alkaline, slopes immediately adjacent to waterbodies or wetlands, fill areas and areas subject to concentrated flows.

Other Terms Used to Describe

High-Risk Erosion Areas
Critical Area Seeding

Pollutants Controlled and Impacts

Protecting critical areas is one of the most effective means of preventing sediment from entering surface waters. Properly established vegetation used to protect critical areas will also help absorb nutrients and reduce flows from steep slopes.

Application

Land Use
Applicable to all land uses.

Soil/Topography/Climate
This practice is particularly important on soils that are excessively wet, droughty, or which are subject to erosion even during a light to moderate rainfall.

When to Apply
Critical erosion areas should be identified during the planning stages of the project or proposed earth change activity. All possible measures should be taken not to disturb these areas. If it is necessary to disturb these areas, attention should be given to protecting them immediately.

Where to Apply
Apply on any area which is difficult to stabilize.

Relationship With Other BMPs

See the "Specifications" section, below.

Specifications

Planning Considerations:

For vegetative practices:

1. All critical areas should be protected from pedestrian access using Construction Barriers.

2. If possible, divert concentrated flows away from critical areas, at least until the vegetation is established. Follow specifications in the Diversions BMP.

3. Select and apply seed and legumes according to specifications in the Seeding BMP. Be sure to select plant species which are tolerant to the site condition.

4. Mulching should be done on seeded areas according to specifications in the Mulching BMP.

5. Sodding should be done according to the Sodding BMP to stabilize areas quickly. Rows of sod can be alternated with rows of seeded areas to stabilize the area more quickly.

6. Dune/sand areas should be stabilized following specifications in the Dune/Sand Stabilization BMP.

7. Trees, shrubs and ground covers should be selected and planted based on the Trees, Shrubs and Ground Covers BMP. Note that Soil Conservation Service soil surveys include species of trees, shrubs and ground covers that work well in each soil texture.

For structural practices:

1. Consider using Grade Stabilization Structures to take concentrated flows from one elevation to the other.

2. Consider using Riprap on slopes adjacent to watercourses and wetlands, and Slope/Shoreline Stabilization on steep slopes and slopes adjacent to cut and fill slopes. The Slope/Shoreline Stabilization BMP includes information on seawalls/retaining walls, revetments, and gabions.

3. Consider using terraces or benches to slow runoff velocities.

4. Consider using Buffer/Filter Strips to control erosion resulting from sheet flow.

5. Subsurface Drains may be needed where water movement may cause seeps or soil slippage. Grassed Waterways may need to be tiled to ensure the vegetation is established.

Site Preparation:

For vegetative practices:

1. Soil tests should be done to determine the nutrient and pH content of the soil. Depending on the results of soil tests, Soil Management may be necessary to adjust the soil pH to between 6.5 and 7.0 (for most conditions). All soil deficiencies should be addressed following the Soil Management specifications.

2. Follow the site preparation sections in the BMPs being used for vegetative establishment.

For structural practices:
Follow the procedures in the selected BMP.

Design and Implementation:
The proper design and implementation of all BMPs used to stabilize critical areas should be done according to the specifications in the selected BMPs.

Maintenance

For vegetative practices:
Periodic inspections should be scheduled to ensure the vegetation is maturing correctly and staying in place.

Once the vegetation is well established:

1. Consideration should be given to removing Construction Barriers. In some areas, it may be beneficial to leave the barriers in place.

2. Vegetation should continue to be watered, when appropriate, to a depth of 1 inch into the sod bed. Water uniformly. See the Lawn Maintenance BMP.

3. Vegetation should be mowed according to its intended use. Follow the mowing specifications in the Lawn Maintenance BMP.

4. Soil testing should be done periodically to determine if the soil requires additional fertilizer or lime. Follow specifications in the Soil Management BMP.

5. Pesticides should only be used following specifications in the Pesticide Management BMP.

6. Spot Seeding should be done as needed on small damaged areas.

For structural practices:
Follow maintenance procedures in the "Maintenance" section of each structural BMP.

Dune/Sand Stabilization

Description

Dune/sand stabilization involves using structural controls and native vegetation to stabilize, build, or repair dunes. This BMP is used to stabilize sandy areas disturbed by construction activities, and to protect roads, buildings and valued areas from encroachment by blowing sand.

There are 275,000 acres of designated dune areas in Michigan, 70,000 acres of which are critical dunes. Critical dunes are unique, sensitive and easily erodible dunes which are protected under the amendments (P.A. 146 and 147) to the Sand Dune Protection and Management Act. Almost all activities conducted in critical dunes will require permits from the Michigan Department of Natural Resources, Land and Water Management Division.

Other Terms Used to Describe

Live clumps of grasses are also referred to as sprigs. Planting these clumps of grasses can be referred to as sprigging, plugging, or wattling.

Pollutants Controlled and Impacts

Stabilization of dunes and other sandy areas can prevent shoreline and stream bank erosion. In areas subject to strong winds, this BMP will also keep soil from blowing off the ground and potentially being deposited in nearby wetlands, watercourses, roads, and sewers.

Application

Land Use
This BMP is most applicable to recreation areas, open areas, transportation, golf courses and construction sites.

Soil/Topography/Climate
Only certain plant species may be used to stabilize dunes. See the "Specifications" portion of this BMP.

When to Apply
When possible, this BMP should be applied before serious dune/sand erosion problems occur.

Where to Apply
Apply on coastal foredunes and any other areas where stabilization of sand is necessary.

Relationship With Other BMPs

Slope/Shoreline Stabilization and Trees, Shrubs and GroundCovers are used to stabilize dune/sand. Fences (see Construction Barriers BMP) are also useful in protecting dunes.

Specifications

Planning Considerations:

It is important to remember that dunes are unique and sensitive ecosystems. While stabilizing a dune, every effort should be made to protect the integrity of the natural dune ecology.

Below are several practices which can be used to stabilize dunes. Refer to the underlined BMP for additional information.

1. Vegetative establishment can be done by planting native grasses, trees, shrubs or ground covers.

   American beech grass is the most commonly used dune grass in Michigan and has proved to be the best plant for initial stabilization of moving sand. It and any other **native species** should be purchased commercially from a reputable Michigan supplier. Dune grass should be planted after September 1 and before the ground becomes frozen. Spring plantings before May 1 are also possible. Planting procedures are discussed below.

   Select appropriate trees, shrubs, and ground covers following the guidance provided in county soil surveys. If soil surveys are not available, follow the general guidance below:

   > In loamy sand, plant Red pine, White pine and Jack pine. In sand, use Jack pine.
   >
   > Trees and shrubs that can be used on wet spots of shifting sands are: Cottonwood, Shrub willow, and Dogwoods.
   >
   > Tree species adapted to sand dune plantings adjacent to large lakes are: Cottonwood, Birch, White pine, White oak, and bigtooth aspen.

   Select individual trees, shrubs and ground covers following specifications in the Trees, Shrubs and Ground Covers BMP. Plants and protective material should be kept moist and protected from drying until the time of planting. Each plant should have at least one live rhizome and sufficient root stock to ensure continued growth following transplanting. Planting procedures are discussed below.

2. Stabilization using revetments, seawalls, groins and breakwalls should be done following specifications in the Slope/Shoreline Stabilization BMP.

3. Snow fencing or other similar fences may be used to help protect eroding areas, either alone or in conjunction with vegetative and other structural controls. Fences are also used to protect newly sprigged areas. Follow specifications in the Construction Barriers BMP.

Planting Dune Grasses:

1. Except for smoothing areas which have been impacted by construction activities, no other ground preparation is usually required. Liming and other soil amendments are also not usually needed prior to planting.

2. A narrow tile spade, planting bar, or tree planter may be used for planting trees in large areas. Sand must be moist enough that it will not run back into the hole before the plant is set.

3. Grass should be planted in a staggered or diamond pattern for maximum erosion control. Holes should be spaced 18" apart in areas where wind velocities and sand movement are high. This equates to about 40,000-60,000 culms per acre. (A culm is a single stem with roots attached). Space culms 24" apart in areas not directly exposed to strong wind (about 22,000-33,000 culms per acre).

4. The holes for plants should be between 8-10 inches deep. This depth is important to prevent the base of the stem from drying out, and to prevent the entire plant from blowing out. The plant should be placed in the resulting opening, with the crown slightly below the surrounding ground. (See Exhibit 1). Be sure dry surface sand doesn't enter the freshly opened hole.

5. Plant 2-3 culms per hole. On large areas which will be planted over several years, start plantings on the windward side.

6. Once the plant is placed in the hole, tamp the soil as shown in Exhibit 1. Sand should be firm and moist around roots, with no air pockets near the base of the plants.

7. Do not trim freshly planted plants.

8. Mulch between plants to protect plantings against rain and wind. Mulch should be applied and anchored following specifications in the Mulching BMP.

Planting Dune Trees and Shrubs:

1. Trees can be hand planted in beachgrass after it has controlled sand movement, but before the grass becomes too dense. This may be done about 2 years after planting beachgrass. Space trees 6'x 6' to 8'x 8'.

2. When planting trees in open blow areas without beachgrass, apply a brush mulch. Lay the brush with the butts to the wind and the tops over the butts. Space trees as above.

3. Blowing areas can also be controlled by planting two or more rows of trees each year, beginning on the windward side and progressing across the area as it is stabilized. Space trees at 4'x 6', staggered in rows.

For the installation of structural dune stabilization techniques, refer to the appropriate BMP.

Maintenance

If any of the cover is lost or destroyed, replant immediately. Replace dead plants with native species following the procedures above. Do not mulch or mow dune vegetation. Keep pedestrians and traffic off the area being stabilized.

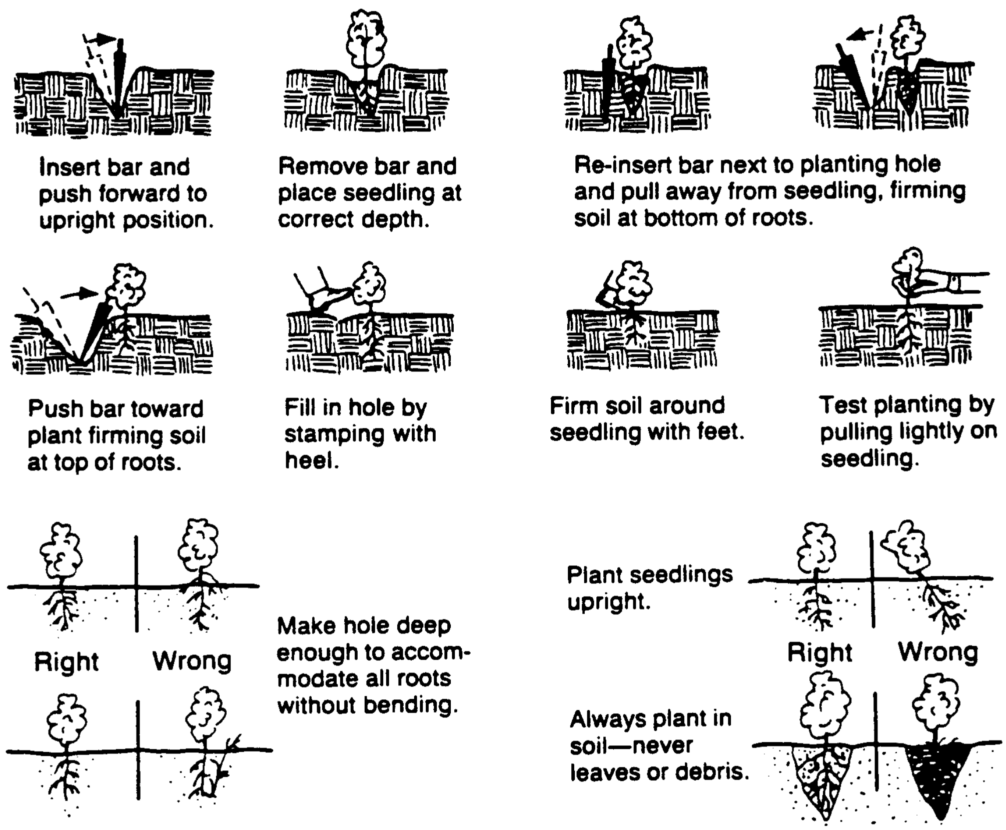
Exhibits

Exhibit 1: A Method for Planting Bare-Root Seedlings and Sprigs of Grasses. North Carolina Erosion and Sediment Control Planning and Design Manual.

Exhibit 1

A Method for Planting Bare-Root Seedlings and Sprigs of Grasses

A method of hand planting bare-root seedlings and sprigged grasses is shown below. With a planting bar/iron or shovel/spade, make a notch in the soil no less than 8 inches deep. Place the roots in the notch to the same depth as the plant was in its original growing container. Firm soil around the roots by pressing the notch closed. Water immediately, and mulch, where necessary, within 2 feet of the plant. Since fertilizers tend to dry out young seedlings, do not fertilize bare-root seedlings until the end of the first year.



Source: North Carolina Erosion and Sediment Control Planning and Design Manual, as modified from the Va. Div. of Forestry.

Dec. 1, 1992

Dust Control

Description

Dust is generated when vegetation is removed and soil is exposed to wind. Light winds can pick up and transport silty soils, fine sands and clays. Course sands can also become erodible when winds are strong. Soil particles and any attached chemicals such as fertilizer and pesticides may settle out in surface waters. Airborne particles can scour leaves and tender shoots of vegetation. Clouds of dust can create a traffic hazard.

Dust control measures should be implemented to prevent the soil and attached pollutants from leaving the site. Acceptable dust control practices include watering, snow fencing (see the Construction Barriers BMP), using mulch (see the Mulching BMP), establishing vegetation, and using spray-on adhesives.

Pollutants Controlled and Impacts

Maintaining an effective dust control program helps keep the lighter soils (silt, clay) on the site and sustains the textural qualities necessary for good vegetative growth. It also prevents sediment and attached chemicals such as fertilizer and pesticides from entering surface waters.

Application

Land Use
Rural, urbanizing and transportation

Soil/Topography/Climate
Special attention needs to be given to dust control during the drought months of the year when the ground is dry. Less severe conditions usually exist during the fall and winter months when the ground is frozen or covered with snow.

When to Apply
Dust control measures should be applied any time dust is generated on a construction site or road.

Where to Apply
Apply this practice on any area subject to wind erosion; especially construction sites and roads.

Relationship With Other BMPs

Dust control is an alternative control measure for temporary and permanent vegetation on areas that are to be surfaced with impervious materials. Mulching is another method of dust control.

Specifications

1. Use seeding, mulching and sodding to cover bare soil and prevent dust. Follow specifications in the Seeding and Mulching or Sodding BMPs.

2. On larger areas, consider planting trees and shrubs as wind breaks. Follow specifications in the Trees, Shrubs and Ground Covers BMP.

3. Watering should be done at a rate which prevents dust but does not cause soil erosion.

4. Any snow fencing that is used should be installed following manufacturer's specifications.

5. Use spray-on adhesives according to Table 1, below. **We recommend using these adhesives only if other methods cannot be used. Many of these adhesives are messy, sticky and form fairly impenetrable surfaces.**

Table 1

Type of emulsion	Water dilution	Nozzle type	Apply Gal/Acre
Anionic asphalt emulsion	7:1	Coarse spray	1,200
Latex emulsion	12.5:1	Fine spray	235
Resin-in-water emulsion	4:1	Fine spray	300

Source: Excerpted from the Maryland Erosion and Sediment Control Planning and Design Manual.

Maintenance

To prevent dust from becoming a public nuisance and causing off-site damages, dust control should be ongoing during earth change activities.

Equipment Maintenance and Storage Areas

Description

The maintenance, repair, cleaning, and storage of construction machinery, vehicles, and equipment should be confined to areas specifically designed and designated for that purpose. This practice includes both open and covered equipment maintenance and storage areas, and emphasizes the importance of controlling runoff from both kinds of storage areas. It is applicable to construction sites as well as existing permanent storage facilities.

Other Terms Used to Describe

Service Area
Shop Area

Pollutants Controlled and Impacts

Equipment storage areas which properly control runoff will prevent oil, grease, solvents, hydraulic fluids, sediment, wash water, and other pollutants from being carried off the area and entering surface waters. Proper use of this practice will also prevent pollutants from filtering into the ground.

Application

Land Use
This BMP applies to all land uses.

Soil/Topography/Climate
Where possible, maintenance/storage areas should be placed on flat areas to prevent surface runoff from entering or leaving the area.

When to Apply
This practice should be implemented at all existing equipment maintenance and storage areas, and whenever construction will be ongoing long enough that construction equipment will need to be stored, serviced, maintained, or repaired on a construction site. Appropriate equipment maintenance/storage sites should be identified before any actual construction begins.

Where to Apply
Apply anywhere equipment is maintained and/or stored.

Relationship With Other BMPs

Where possible, the identification of an appropriate maintenance/storage area should be done before any construction is done on the site. Diversions should be considered to keep runoff from entering the storage area. Pesticides stored and used in the area should be handled, stored and disposed of according to specifications in the Pesticide Management BMP. Smaller quantities of hazardous wastes (i.e. quantities of approximately 1 gallon or less) should be disposed of following the specifications in the Household Hazardous Waste Disposal BMP. Larger quantities of hazardous waste should be disposed of by consulting the MDNR, Waste Management Division at 517-373-2730.

Specifications

Planning Considerations for New Areas:
Determine site selection based on the following considerations.

If equipment is to be maintained and stored in an open area (i.e. **temporary storage**):

-The site should not be within the drip line of trees.

-The site should not be within 100 feet of a watercourse or wetland. Runoff should be diverted away from watercourses and wetlands.

If equipment is to be maintained and stored in a **permanent structure** (i.e. building):

-The building should not be located within 100 feet of a watercourse

-When possible, the building should not be constructed on or within 100 feet of a wetland.

Under no circumstances should buildings or equipment be located in floodplains, stream beds, or the channel of any watercourse.

General Considerations for All Equipment Maintenance/Storage Areas:

1. Runoff from equipment maintenance/storage areas should be directed to stabilized outlets designed to assimilate the volume and type of pollutants discharged to them. See the Stabilized Outlets BMP.

2. Heavy equipment should be well-maintained to prevent leaks.

3. Vehicles and other equipment should *not* be washed at locations where the runoff will flow directly into a watercourse or storm sewer.

4. Store, cover and isolate construction materials, including topsoil and chemicals, to prevent runoff of pollutants and contamination of groundwater, following the design guidance below.

5. A spill response plan should be developed which includes the procedures which will be taken in the case of a spill. This is discussed further in "Proper Storage, Use and Disposal of Chemicals," below.

6. A waste management plan should be developed. Empty canisters, cans or other chemical containers (i.e. from hydraulic fluids, etc.), scrap wood, scrap metal, and all other waste materials are to be disposed of daily or kept in sealed waste containers until they can be disposed of off-site in a landfill. Waste materials are *not* to be buried on-site.

7. Specific areas should also be designated and maintained for employee parking.

Equipment Maintenance and Storage in Structures (buildings):

1. All floor drains which discharge to storm sewers should be sealed/plugged. New floor drains should discharge to a sanitary sewer.

2. All floors should be constructed of cement or other impervious materials to prevent contaminants from leaching into the soils or groundwater.

3. Equipment wash areas should discharge into a sanitary sewer line. Depending on the amount of oil, grease and other pollutants, pre-treatment of wastewater may be needed before it enters the sanitary sewer.

4. Trucks and other equipment with large quantities of mud should be washed outside on designated wash areas, so as not to clog sanitary sewer lines.

Equipment Maintenance and Storage in Maintenance in Open Areas:

1. Ideally, all maintenance should be done on impervious areas surrounded with impervious berms. Where this is not possible, use pads designed to contain the pollutants which may leak or spill during maintenance operations. Impervious pads are particularly important on sandy and other course soils where spilled materials can easily leach into the groundwater.

2. Wash areas should be constructed out of 2-3" stone or other approved material, with a minimum 6-inch base. They should be underlain with geotextile materials, and protected using berms or Diversions to prevent the runoff water from leaving the site. See the Appendices for manufacturers of geotextile materials.

3. Equipment should never be stored within the drip line of trees.

4. Topsoil should be stored following specifications in the Spoil Piles BMP.

5. Follow the guidance below for the "Proper Storage, Use and Disposal of Chemicals."

Proper Storage, Use and Disposal of Chemicals:

1. Follow all federal, state and local laws regarding the storage of hazardous materials. In general:

    -All hazardous chemicals should be stored in sealed containers. Secondary containment should be incorporated into the design of the maintenance/storage facility to contain spills from all hazardous materials.

    -Pesticides should be stored according to the guidelines in the Pesticide Management BMP.

    -Keep labels on all products so that they are readable. Do not use a product without a label.

    -Maintain records of the use and application of all products stored on site.

    -Maintain proper ventilation. Post "no smoking" and other signs to warn of potential dangers. Keep the area locked.

2. Develop a spill response plan. This should include the steps that will be taken to contain and cleanup spills. All persons working with chemicals should be familiar with the spill response plan. For spills of hazardous materials which cannot be contained on-site, or when there is a known or potential impact to surface or ground water or soils, contact the Pollution Emergency Alert System (PEAS) line at 1-800-292-4706.

3. Absorbent materials such as hay bales, cat litter and absorbent pads should be kept on-site to prevent the migration of pollutants which are spilled on imperious areas.

4. Dispose of small quantities of material (i.e. less than 1 gallon) based on the type of pollutant absorbed:

   -Dispose of pesticides following specifications in the Pesticide Management BMP; and

   -Follow specifications in the Household Hazardous Waste Disposal BMP for small quantities of hazardous wastes (1 gallon or less);

   For other hazardous wastes, or wastes in excess of 1 gallon, contact the MDNR, Waste Management Division at 517-373-2843 for additional information.

5. Contact the MDNR, Environmental Response Division at 517-373-4823 for information on the Right-to-Know Law and for information on underground storage tanks.

Maintenance

Outside equipment/maintenance storage areas should be inspected daily to ensure equipment isn't being stored within the drip line of trees and to ensure the vehicles and equipment aren't leaking. Also make sure waste materials are being properly disposed of. Periodic checks of the equipment wash area should also be done to ensure it is not failing. Additional stone may be needed to maintain the wash area.

Ongoing maintenance of structural equipment maintenance/storage areas should include periodic inspections of the structure to check for cracks in the floor, and for other structural flaws. In existing buildings, be sure to inspect the floor drains to make sure they are not discharging to storm drains.

Additional Considerations

Draft revisions to Part 21 Rules of the Water Resources Commission (Act 245) will require construction permittees to provide facilities for containing any accidental losses of oil or other polluting substances, and comply with reporting procedures for on-land facilities under Part 5 rules. Approved equipment maintenance and storage areas must meet these Part 21 Rules.

Fertilizer Management

Description

Nitrogen, phosphorus, potassium and other nutrients are necessary to maintain optimum growth and stress tolerance of most vegetation. This BMP addresses the proper selection, use, application, storage, and disposal of fertilizers.

Although most of the information in this BMP applies to trees, shrubs and ground covers, as well as turf, the *application* of fertilizer on trees, shrubs and ground covers should be done following the procedures given in the Trees, Shrubs and Ground Covers BMP. All storage, mixing and disposal of fertilizers should be done in accordance with this fertilizer management practice.

Other Terms Used to Describe

Nutrient Management
Nitrogen/Phosphorus Management

Pollutants Controlled and Impacts

Nutrients applied at appropriate times and rates will minimize the potential for pollution of surface and ground waters. Nutrients are also essential in order for vegetation to stay healthy. Healthy plants require fewer inputs.

Application

Land Use
This practice is applicable to all land uses--wherever fertilizers are used.

Soil/Topography/Climate
Fertilizer programs will vary from site to site, partially due to varying soil characteristics, topography and climate. For example, sandy soils are more prone to nitrogen leaching than finer-textured soils.

When to Apply
A fertilizer program for lawns should begin in the fall (as opposed to spring) to promote deep, healthy root systems and hardy lawns. This, in turn, will help grass compete with unwanted grass species and weeds. Spring applications of fertilizer will help the grass start growing, but may promote more top (leaf) growth than root growth. Shallow root systems are unable to sustain lawns through a drought or harsh winter.

Fertilizers should not be applied to turf when the soil is frozen because turf cannot utilize the nutrients and runoff rates are high. Fertilizers should also not be applied before significant intensive rainfall events.

Where to Apply
Fertilizer management practices should be applied in all areas where vegetation is managed.

Relationship With Other BMPs

A sound fertilizer management program is just one of the elements needed to maintain healthy vegetation. Healthy vegetation also requires proper irrigation management, Pesticide Management, Soil Management, and, in the case of turf grasses, using the proper mowing frequency and height. Many of these principles are mentioned in the Lawn Maintenance BMP, with additional specifications in individual BMPs.

Specifications

General Information:

Plants need a certain amount of nutrients (nitrogen, phosphorus, etc.) to grow and stay healthy. Nutrient deficiency may result in weaker plants, which may make them more susceptible to disease. This, in turn, may increase the amount of pesticides or other inputs needed. Proper fertilization will help plants stay healthy and reduce other inputs.

Excess nutrients which are applied beyond that needed by the plant may get washed off the soil and end up in lakes, streams and wetlands, or leach into ground water. When nutrients such as nitrogen and phosphorus run off into surface waters (i.e. rivers, lakes), they can cause algae blooms and nuisance aquatic plant growth.

Ground water can be impacted by excess nitrogen, which readily converts to nitrates. When nitrate leaches to ground water, it can contaminate drinking water supplies. Phosphorus generally doesn't affect groundwater since it binds readily with the soil.

Application rates for fertilizers should always be based on soil tests. To take soil samples, follow the directions in the Soil Management BMP.

The recommendations below are given to ensure healthy vegetation, while maintaining water quality. It includes the proper application, storage and disposal of fertilizers. **Always follow directions on the label**. If the label is not legible, contact the distributor for proper application and storage information.

General Considerations:

A fertilizer management plan should be developed for each of the vegetative species in the managed area, and for each use of that species. All vegetative species should be chosen following guidance in the Pesticide Management BMP, which includes integrated pest management (IPM) principles. The first step in any IPM program is selecting disease-resistant species. Proper species selection also depends on the use of the vegetation. For example, if the purpose of the vegetation is to give a natural appearance and prevent erosion, then fertilizer needs will be far less than for a turf used for golf course greens.

Fertilization rates will differ depending on the existing nutrient needs of the soil. Collect soil tests to determine existing nutrient needs, following specifications in the Soil Management BMP. Soils should be analyzed for nitrogen, phosphorus, potassium and any micro-nutrients of concern. Soil tests should be conducted regularly, such as every three years on low-maintenance turfs and every year for high-maintained turfs.

Types of Fertilizers:

Many liquid and solid fertilizers are available. The characteristic of common materials used in fertilizers are summarized in Table 1, below. The material used in a fertilizer determines the rate nutrients are released into the soil. For example, *water-soluble* nitrogen such as urea is readily available to turf roots and provides a quick response after application. These materials are the least expensive forms of nitrogen. However, water-soluble N fertilizers have a high potential for chemically burning turf. Again, select the type of fertilizer based on the intended use of that vegetation.

Table 1

Characteristics of Fertilizer Materials for Turf

Material	Type	Nutrient Content %	Soil Reaction	Rate of N Release	Burn Potential
Ammonium sulfate $(NH_4)_2SO_4$	inorganic	21 (N)	strong acidifier	water soluble	moderately high
Ammonium nitrate	inorganic	33.5-34 (N)	acidifier	water soluble	high
Urea $CO(NH_2)_2$	synthetic organic	45-46 (N)	acidifier	water soluble	moderately high
Activated sewer sludge	natural organic	5-6 (N)	no change	slowly soluble	low
Urea-formaldehyde	synthetic organic	38 (N)	no change	slowly soluble	low
IBDU	synthetic organic	31 (N)	no change	slowly soluble	low
Sulfur-coated urea	synthetic organic	31 (N)	acidifier	slow release	low
Triple super-phosphate $Ca(H_2PO_4)_2$	inorganic	45-46 (P_2O_5)	no change	–	low
Muriate of potash KCL	inorganic	60-62 (K_2O)	no change	–	high
Potassium sulfate K_2SO_4	inorganic	50-53 (K_2O)	no change	–	moderate
Ferrous sulfate monohydrate	inorganic	31.5 (Fe)	acidifier	–	high

Adapted from *Landscape Management* by J.R. Feucht and J.D. Butler.

Source: "Turfgrass Pest Management: A Training Manual for Commercial Pesticide Applicators". Michigan State University, Cooperative Extension Service, Bulletin E-2327.

Slow-soluble forms of N include natural and synthetic organic fertilizers. *Slow-release* products are formulated so that elements are released relatively slowly over time. Slow-release products are more expensive than water-soluble fertilizers, but fewer applications at higher rates are possible with less chance of burn.

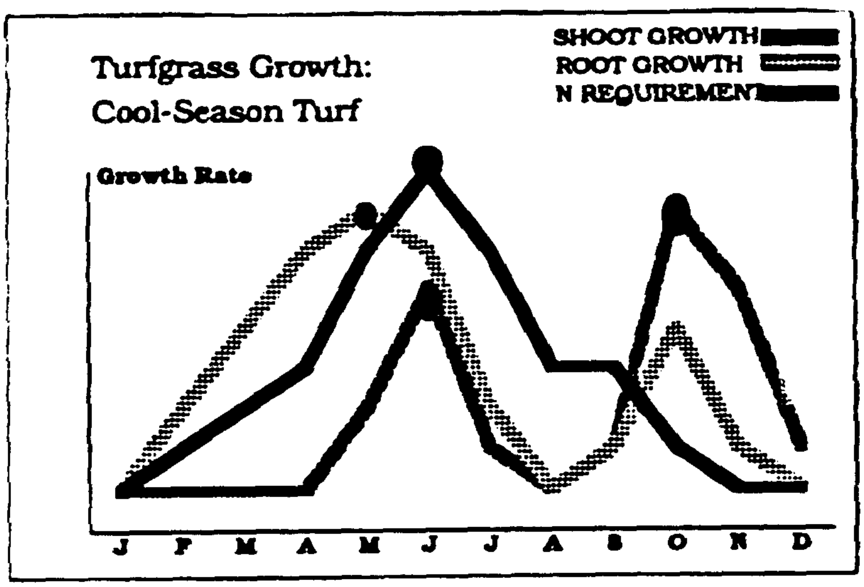
Complete fertilizer contains nitrogen, phosphorus and potassium. As a rule, turf fertilizers have a high ratio of nitrogen to phosphorus and potassium. The ratio of these three nutrients ($N:P_2O_5:K_2O$) is called the fertilizer analysis. Common turf fertilizer analyses include 20-10-5, 20-5-10, and 21-3-7. One hundred pounds of 20-10-5 fertilizer contains 20 pounds of nitrogen, 10 pounds of phosphorus and 5 pounds of potassium. The rest is inert material.

Before Applying Fertilizers:

Take soil tests and have them analyzed by Michigan State University or other approved laboratory for nitrogen, phosphorus, potassium, and any other nutrient of concern. Follow procedures in the Soil Management BMP.

Determine Appropriate Application Rates. Fertilizer applications should be based on a number of factors, including previous fertilizations, turf quality, environmental conditions, weather conditions, use of the turf, type of turf, and soil conditions. Be sure to give credit for leaving grass clippings on lawns--this can reduce fertilizer needs by 25-50%. What follows are general considerations for nutrient applications in all areas except gardens, which are discussed in the Lawn Maintenance BMP.

Table 2



Source:"Truth and Consequences: Turfgrass Environmental Management", Michigan State University, 1991.

The appropriate number of fertilizer applications is dependent upon the rate of application, and the growth stage of the plant. As shown in Table 2, turfgrass root and shoot growth occurs primarily in the spring, with another burst in the fall. Where only one application of fertilizer is needed (again, based on the results of soil tests), apply in the fall because strong root systems will make the plants more able to compete against weeds in the spring.

Appropriate Nitrogen Rates:

-may prevent turf susceptibility to moisture stress.

-may prevent foliar burn. Note that when applying fertilizers which can cause foliar burn, the turf should be watered immediately after application.

-should be coordinated with proper irrigation rates to provide the moisture needed by the turf, yet prevent over-watering which could result in leaching.

-is especially important where there are sandy soils and/or a high water table because leaching of nitrates may occur. This may impact drinking water supplies.

i. **Application rates and the number of applications should be based on the results of soil tests**, modified only to meet the use of that turf. Where needed based on soil tests and the intended use, consider split applications.

ii. When turf roots are very short, nitrogen applications should be done at lighter rates and at shorter intervals. An example would be a golf course green.

iii. Application rates and the number of applications may also need to be adjusted, depending on turf conditions and any unique problems which may exist. An example might be significant thinning of turf by disease, which may necessitate increased nitrogen fertilization to regain the desired turf density.

Appropriate Phosphorus Rates:
Phosphorus is necessary to maintain a dense, healthy turf. Phosphorus applied in excess of what the plant needs may enter water bodies if the soil to which it attaches is eroded.

i. **Application rates should be based on the results of soil tests.**

ii. Consider split applications in areas where runoff or soil erosion is likely to occur.

Appropriate Potassium Rates:
Potassium is important for maintaining a healthy, stress-tolerant turf. Although it can be leached readily from sandy soils, potassium and the associated anions in most of the carriers used on turf (i.e. chloride and sulfate) are not considered harmful to ground or surface waters at the rates being utilized for most turfs.

Application rates should be based on the results of soil tests.

Other Nutrients:
While other nutrients may be applied to turfs, the rates and frequencies of use are low. Sulfur is not known to be deficient in Michigan turf, so no sulfur applications are routinely made. Iron is a micronutrient that is commonly deficient in alkaline soils. It will normally produce a temporary "greening" effect on the turf when applied foliarly. Such applications are often made to enhance turf color when additional nitrogen is not needed. However, since the iron deficiency is due to soil alkalinity, long-term treatment requires modifying the soil pH. Other micronutrients, such as

manganese, copper and zinc may be used on turf occasionally, but rates and frequencies of application are very low and these nutrients are tied up quickly by soils.

Equipment Calibration:

Calibrate your equipment as needed to ensure the desired application rate. Follow the calibration procedures in Appendix 4 of the BMPs, entitled "Application Calculations and Calibration." Make sure all components of your equipment are in good working order. Do not use the equipment if you are not familiar with it. Contact the equipment supplier if you have questions.

Mixing the Fertilizer:

Before mixing fertilizers, determine the size of the area which needs fertilizing. Appendix 4 includes methods for measuring the area needing fertilization. After determining the area needing treatment, and using the amount of fertilizer needed based on soil test results, mix the appropriate amount using the "Common Measuring Equivalents for Pesticides and Fertilizers", which is Exhibit 2 of Appendix 4. The equivalents allows you to mix only the amount of fertilizer or pesticide needed for your application.

Pour/mix the fertilizer into the bin/spreader/sprayer over an impervious area such as cement, so that if the fertilizer is spilled it can be easily cleaned up. Never pour fertilizers into bins/spreaders/sprayers on the turf because large concentrations of fertilizer can kill the turf, and potentially impact surface and ground waters. Avoid back-siphoning of liquid fertilizers by keeping the end of the fill hose above the water level, or by installing devices which prevent back-siphoning.

Applying the Fertilizer:

1. Never apply fertilizers to frozen soils, before storms, or under real windy conditions. Except where fertilizers are being applied to surface waters to increase productivity (as is done in walleye pond management, for example), **never apply fertilizers directly in or adjacent to streams, rivers, lakes, or wetlands.**

2. Select the most appropriate method of applying the fertilizer. Follow fertilizer label directions, or discuss potential options with the grain elevator, local fertilizer store, or the local Cooperative Extension Service office. Hand application of fertilizers is not recommended because it is tedious and usually does not result in an even distribution of fertilizer. Improperly applied fertilizers can "burn" and destroy turf.

   For granular forms of fertilizers, the centrifugal (rotary) type of spreaders usually distribute the material more rapidly and with minimal overlapping compared to gravity (drop-type) spreaders. The latter are safer if herbicide-fertilizer mixtures are applied around susceptible shrubs and trees.

3. Make sure the equipment has been calibrated.

4. Adjust the application equipment to fit the application rates determined above.

5. Check equipment occasionally throughout the application to ensure it is delivering the appropriate amount of fertilizer to the turf.

6. Keep equipment well-maintained to ensure it functions as designed.

7. When establishing new grass by Seeding, mix the fertilizer into the top 3 inches of soil. This will encourage better rooting and reduce the amount of fertilizer nutrients which could be lost by erosion of topsoil from the site before the turf becomes well established.

After the Initial Fertilization:

A healthy turf requires a deep rooting system. A deep rooting system can remove nitrates further down in the soil, thereby reducing leaching potential. Several management variables can influence rooting of the turf, including:

1. Irrigation. A light irrigation immediately after fertilization can be helpful in moving fertilizer down into the thatch and the surface layer of soil. Do not apply water in excess of what can be taken up by the soil. Remember, most established turfs require about one inch of water per week. See the Lawn Maintenance BMP.

2. Mowing height. Mow according to specifications in the Lawn Maintenance BMP.

3. Diseases, insects and other pests. These should be controlled following specifications in the Pesticide Management BMP.

Storage and Disposal of Fertilizers:

1. **Always follow the storage and disposal directions on the label.**

2. Most fertilizers should be kept in a cool, dry place. Be sure to store granular fertilizers separate from any pesticide that can cause contamination of the fertilizer.

3. Liquid fertilizers, like pesticides, should be stored inside another container (i.e. **secondary containment**) in case the chemicals leak from the original containers.

4. For additional guidance, or where labels do not indicate proper storage and disposal, follow the specifications in the Pesticide Management BMP.

Spill Cleanup:

A **spill response plan** should be developed for all sites which contain fertilizers. The spill response plan should include the steps which will be taken to contain and cleanup any spilled fertilizers. In general:

> Small quantities of spilled liquid fertilizers should be cleaned up by applying kitty litter or sawdust, then sweeping it, wrapping it in newspaper and disposing in the trash. Small quantities of powdered fertilizers should be swept and disposed of in the trash. Never wash fertilizer spills down floor drains or driveways--the concentrated runoff will likely either go to storm sewers (and consequently directly into the local river or stream) or could leach into the ground water.
>
> For large spills, contact the Pollution Emergency Alert System (PEAS) system at 1-800-292-4706. Where possible, use any spilled fertilizer according to appropriate rates and methods.

Record Keeping:
It is advisable to keep records of the amount and type of fertilizer used (including percentages of nitrogen, phosphorus and other nutrients), type of equipment used, date of the last calibration, weather conditions, type of soil, specific area where applied, and the name of the applicator. This will help the manager in adjusting the application rates. The Pesticide Use Record sheet in the Pesticide Management BMP can be modified for fertilizers.

Maintenance

Proper fertilizer management is an ongoing practice, starting at the onset of the first fertilization, and ending when fertilizers are no long used or stored on the site. Ongoing maintenance includes a minimum annual check to ensure:

1. Applicators are applying fertilizers based on annual soil tests.

2. Equipment is calibrated for optimal use and is well-maintained.

3. The continued proper storage and handling of fertilizers. An annual check of all fertilizer labels should be made. Illegible labels should be replaced, where possible, or the fertilizers disposed of according to the disposal procedures above. There should be secondary containment for all fertilizers.

4. Information is being recorded on the application rates, etc., as listed above.

Lawn Maintenance

Description

Lawn maintenance includes mowing, irrigating, pesticide and fertilizer management, soil management, and the disposal of organic debris such as lawn clippings, leaves and pruned branches and twigs. This BMP also briefly discusses home gardens. For the purposes of this BMP, "lawn" and "turf" are used interchangeably.

Other Terms Used to Describe

Urban Lawn Care
Rural Lawn Care

Pollutants Controlled and Impacts

Proper maintenance results in healthy lawns. Healthy lawns will:

- -help keep soil on the site, thereby preventing erosion
- -take up nutrients
- -reduce the volume and rate of runoff and increase groundwater recharge
- -decrease the need for pesticides

Application

Land Use
This practice is applicable to all land uses.

Soil/Topography/Climate
Lawn maintenance practices will differ, depending upon the soils, topography and climates.

When to Apply
Apply this BMP throughout the year.

Where to Apply
Apply on all lawns and gardens.

Relationship With Other BMPs

The Pesticide Management BMP walks users through the proper selection of turf species (the first and most important part of an integrated pest management program), as well as the proper use, storage and disposal of pesticides. Establishment of turf by seeding is discussed in the Seeding and Mulching BMPs. Establishment of turf by sodding is discussed in the Sodding BMP. This Lawn Maintenance BMP assumes turf is already in place.

<u>**Specifications**</u>

The following specifications are provided **to maintain healthy turf areas.** Much of the information, including both tables, is extracted from "Turfgrass Pest Management: A Training Manual for Commercial Pesticide Applicators", Michigan State University, Cooperative Extension Service, Bulletin E-2327.

Mowing:

Different types of grasses have different mowing requirements, based on the turf species and the intended use of that species. When you lower the mowing height, you reduce the root system. Root reduction decreases the amount of water available to support the turf stand. In addition, since close mowing weakens cool-season grasses, it invites weed invasion. Crabgrass, in particular can be reduced by the shading effects of the taller, denser growth of plants.

The chart below shows the proper cutting heights for typical cool-season grasses. Use this chart as a general guide. Where the mowing height is not dictated by the turf's use, mow at the "preferred height" listed in the chart.

Table 1

Cutting Heights for Cool-Season Grasses

Grass Type	Low Cut (inches)	Preferred Cut (inches)	High Cut (inches)
Kentucky bluegrass common types	1¼	2 to 3	4
Kentucky bluegrass improved types	¾	2	3
Perennial ryegrass common types	1½	2 to 3	4
Perennial ryegrass turf types	¾	1½ to 2	3
Fine fescue	1	1½ to 3	4
Tall fescue pasture types	2	2½ to 3½	4
Tall fescue turf types	1¼	1½ to 3	3
Creeping bentgrass	¼	½ to ¾	1
Colonial bentgrass	½	¾ to 1	2
Annual bluegrass	¼	½ to 1	2
Smooth bromegrass	2	3 to 4	5

From *Landscape Management* by J.R. Feucht and J.D. Butler.

During hot, dry periods turf stands need more water. Where uses don't limit mowing height, and to conserve water in grass plants experiencing drought, consider mowing less frequently and at a higher height of cut.

Grass clippings should be left on the grass because they offer a "free" source of nitrogen, and will decompose without affecting the quality of the grass. When clippings are regularly removed, fertilization must be increased by 25-50%. Grass clippings do *not* contribute to thatch. Mulching mowers can be used to cut the grass into tiny pieces which degrade faster.

Watering (Irrigation):

Too much water is as damaging to turf as drought. When turf is saturated, transpiration is slowed and infectious diseases encouraged.

Proper irrigation depends on weather conditions, soil type, grass variety preference, and turf use and maintenance practices. Generally, most turfs require about 1 inch of water per week. For site-specific water requirements, it is important to use a rain gauge to measure rainfall and determine the amount of irrigated water needed. Computer models are also available which can help determine watering requirements.

An irrigation system is complex and should be designed only by professionals experienced in their design. Each irrigation system should be custom designed to fit the site conditions--soils, availability of water, vegetation needing irrigating, etc.

For many purposes, the crude, but effective "footsteps" method can be used. With this method, you need to irrigate when turf begins to wilt and does not spring back when crushed (footsteps linger in turf). Other watering guidelines are discussed below.

In general:

1. The total precipitation and irrigated water should amount to about an inch of water per week. To determine how much water small sprinklers deliver, place a coffee can in a straight line from your sprinkler to the edge of the watering area. Turn the water on for 15 minutes and measure the average depth of the water that collects in the can. Multiply this number by four to determine the amount of water that would cover your lawn in one hour. Then calculate the amount of time (in hours) that it would take to apply an inch of water.

   With sprinkler systems, the uniformity of water application depends on the spacing, choice of sprinkler, water pressure, and wind velocity. System efficiency and effectiveness, in turn, is dependent on uniform application of water.

2. Do not apply water faster than it can soak into the soil. Any water running off the lawn indicates that the application rate is too high.

3. Many sources recommend applying supplemental water once a week during the early morning hours. However, during hot, droughty periods, turf may benefit from daily, light, afternoon waterings. Water during the heat of the day cools grass plants and replaces evaporated water. In addition, research conducted at Michigan State University found that injury due to patch diseases, including necrotic ring spot, was reduced on susceptible turf that received light, frequent waterings during the summer.

4. When a groundwater well is used, the well should be sited and constructed to avoid potential contamination of the groundwater supply. Locate the well on high ground to exclude the entrance of surface and near-surface water that may contain potential sources of contamination; such as drainage fields, and fertilizer and chemical storage and preparation areas. Adequate ground protection should include extending the well casing above grade, using a sanitary well seal or pitless adaptor at the well head, and sealing or grouting between the well casing and borehole. All wells must comply with state water laws and regulations.

   Any discharge pipe from the well or to the system must be protected against backflow in the well by installing backflow prevention devices.

5. By law, all abandoned wells must be sealed. Contact the local health department for assistance in sealing abandoned wells.

Dethatching:

A layer of thatch exists in all turf between the green vegetation and the soil surface. Thatch is composed of tightly intermingled living and dead stems, leaves and roots. A small amount of thatch in turf is beneficial in that it reduces soil compaction, moderates soil temperature, and limits evaporation of soil water.

Turf-inhabiting organisms such as earthworms break down thatch. In areas which are highly managed, excess fertilizer and routine pesticide applications significantly reduce these organisms. To keep beneficial organisms in turf, apply fertilizers and pesticides according to BMP specifications.

Because production of thatch is increased and break-down decreased, excessive thatch can be a problem of intensively-managed turf. Too much thatch restricts the movement of water, air, fertilizers and pesticides into the soil, encourages disease and insect pests, and reduces cold and heat tolerance. To determine if a stand has excessive thatch, cut a pie-shaped wedge out of the turf and measure the thickness of the thatch layer. If it is greater than one-half inch thick, take steps to reduce thatch.

To reduce thatch:

Practices that relieve soil compaction also help break down thatch. Vigorous hand-raking will remove thatch on small turf areas. Machines equipped with vertical knives or tines can remove thatch on larger areas. Dethatching machines cut and extract organic debris from turf. Because dethatching thins turf stands, thatch removal should be done during cool, moist periods when turf can recover quickly.

Organic Debris Disposal:

The following is summarized from the Organic Debris Disposal BMP. Refer to that BMP for the disposal of all leaves, grass and pruned branches:

1. Leave grass clippings on the grass.

2. Where it is necessary to remove grass clippings or leaves, dispose of them by composting. Information on how to construct and maintain a composting pile is discussed in the Organic Debris Disposal BMP.

3. Pruned branches should be disposed of either by chipping or by composting. Wood chips can be used as part of the landscaping.

4. Do *not* dispose of organic debris by dumping it in or near water bodies. Do not dump or sweep leaves, grass (or anything else) into sewers--storm sewers discharge into waterbodies. Do not put debris in the floodplains of rivers or streams. Follow all other Organic Debris Disposal specifications.

Fertilizers:

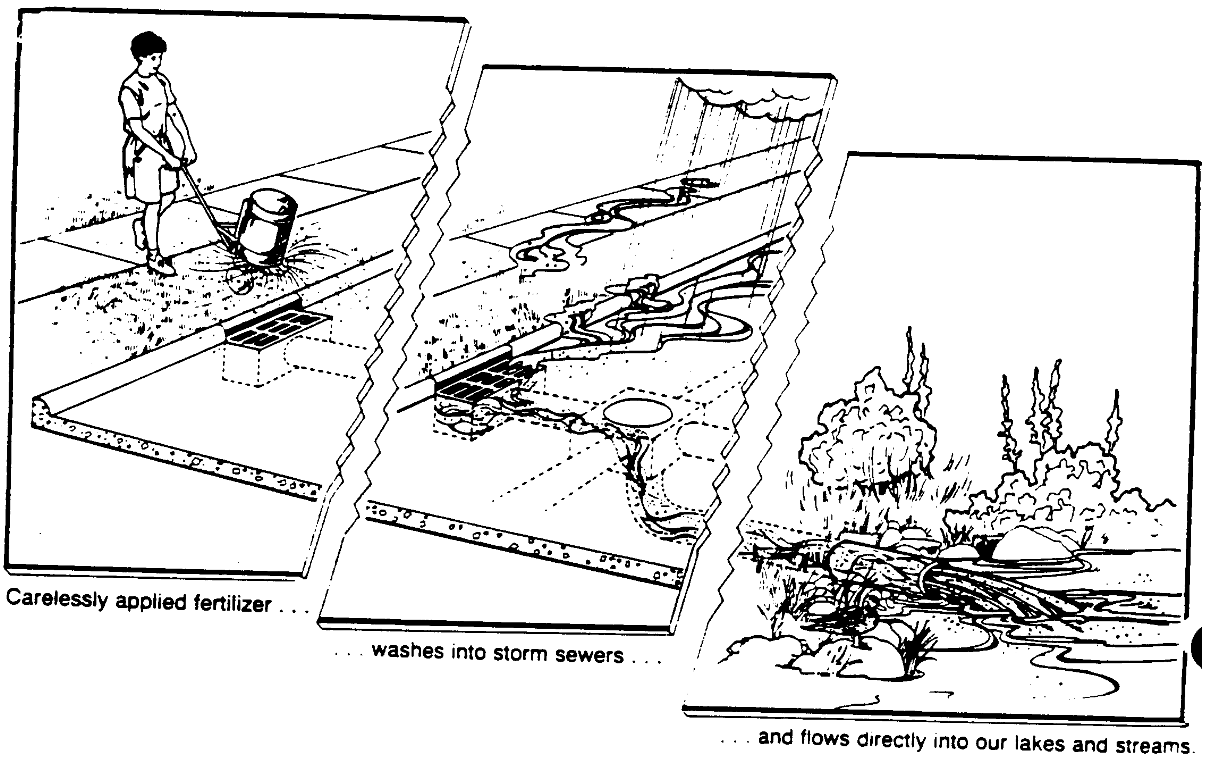
Plants require a certain amount of nutrients (nitrogen, phosphorus, etc.) to grow, thrive and stay green. Nutrients which are applied beyond that needed by the plant can be either washed off the soil and into lakes, streams and wetlands, or leach into groundwater. Nutrients such as nitrogen and phosphorus which enter surface waters can result in algae blooms and nuisance aquatic plant growth.

Groundwater can also be impacted by nutrients. Nitrogen readily converts to nitrate which, when leached to groundwater, can contaminate drinking water supplies. Coarse soils such as sands and loamy sands are more susceptible to leaching than fine-textured soils such as silts or clays. Phosphorus generally does not leach into groundwater because it binds readily with soil.

Complete fertilizers contain nitrogen, phosphorus, and potassium. The ratio of the three nutrients is called the fertilizer analysis. Common turf fertilizer analyses include 20-10-5, 20-5-10, and 21-3-7. A 100 pound bag of complete fertilizer with an analysis of 20-10-5 contains 20 pounds nitrogen, 10 pounds phosphorus and 5 pounds potassium.

Slow-release fertilizers are formulated so that elements are released relatively slowly over time. Fertilizers are also available that do not contain one of the three common nutrients. For example, in areas where soil tests indicate phosphorus levels are adequate for turf growth, you can use fertilizers which contain no phosphorus.

A fertilizer program for lawns should begin in the fall (as opposed to the spring) to promote deep, healthy root systems and hardy lawns. This, in turn, will help grass compete with unwanted grass species and weeds in the spring. Spring applications of fertilizer will help the grass start growing, but may promote more top (leaf) growth than root growth. Shallow root systems are unable to sustain lawns through a drought or a harsh winter.



Source: University of Wisconsin - Extension bulletin: Lawn and Garden Fertilizer.

Application rates for fertilizers should always be based on soil tests. To take soil samples, follow directions in the Soil Management BMP. Where soil samples cannot be taken, follow the "Nitrogen guidelines" in the attached exhibit.

Fertilizers should *not* be applied to turf when the soil is frozen because turf cannot utilize the nutrients, and runoff rates are high. Fertilizers should *not* be applied before significant intensive rainfall events.

Always follow all specifications in the Fertilizer Management BMP for the proper handling, storage, use and application of fertilizers. Calibration procedures are also included in that BMP.

Pesticides:

Pesticides are a family of chemicals which kill insects (insecticides), weeds (herbicides), fungus (fungicides) and rodents (rodenticide). Over-application of pesticides can results in fish kills in lakes and streams, contaminated groundwater, and damaged turf.

When most people identify a weed or insect problem, the most common response is to buy pesticides to eliminate the problem. However, in some situations, hand removing weeds and large insects will be as effective as spot spraying them. It is also possible to interfere with the pests' habitat by altering the landscaping in a way which will not attract the pest. Using biological controls, such as the pests' predators, should also be considered. Keep in mind that not all pests are "bad". Many insects, for example, are natural predators of more harmful insects.

The Pesticide Management BMP discusses integrated pest management techniques, and the proper handling, application, storage and disposal of pesticides. Always follow the specifications in the Pesticide Management BMP whenever a pest is encountered.

The local Cooperative Extension Service (CES) office or a reputable private consultant can also be contacted for information on the best way to get rid of your problem pest. These professionals may ask you to bring in sample weeds, leaves or small branches to help identify the specific pest. CES staff and reputable consultants will then suggest ways to eliminate the problem, following the principles in the Pesticide Management BMP.

Gardens and Other Bare Soils:
Ideally, gardens and other bare soils in and around lawns should be covered with a light layer of organic material (such as grass clippings or leaves) to keep soil on-site. Organic material will reduce the impact of raindrops and allow rain to soak into the ground. Sweep any soil off paved areas (i.e. sidewalks and driveways) to prevent the soil from entering the storm sewer system.

For Unhealthy Turf:
The turf manager must first determine the reason for the unhealthy turf, then take steps to address the problem. The Pesticide Management BMP contains a section on monitoring techniques for turf. It may be necessary to take soil samples, following specifications in the Soil Management BMP to help determine the problem. Make soil amendments, including liming and sulfur additions for pH, and coring for compaction problems following BMP specifications. If soil tests indicate nutrients are lacking, add fertilizers following the Fertilizer Management BMP. If pests are the problem, determine the threshold of the pest, then use the Pesticide Management BMP to control or reduce the pest population. Sometimes unhealthy turf may benefit simply from adjusting irrigation schedules and/or raising mowing heights.

Shade may also be a problem for turf. The Pesticide Management BMP contains turf species which do better in shade than others. If trees which provide shade are hindering the growth of the turf, it may be beneficial to prune lower branches and thin out the crowns of shade-producing trees and shrubs. This increases the amount of light and air movement to the turf. It may also be necessary to aerate or adjust the pH of soils underneath trees, especially in areas where decomposing leaves may turn the soil acid. If all efforts to improve the turf fail, you may want to consider using mulch or shade-tolerant ground covers such as periwinkle, pachysandra, purple winter creeper, and English ivy in the place of turf.

To **irrigate** diseased turf: Managers of diseased turf should replace only the water lost in evapotranspiration (the amount of water that evaporates from turf stands plus the amount of water used in transpiration). Do not saturate the thatch. During hot, dry periods, apply daily a small amount of water (one-two tenths inch) during the heat of the day. Since this practice will not deliver a full inch of water per week, regularly check the moisture of deeper soil and apply additional water when necessary.

Exhibits

Exhibit 1: Nitrogen for New Lawns and Vegetable Gardens: Modified from Protecting Water Quality in Urban Areas, State of Minnesota. Table: Modified from University of Wisconsin-Extension.

Exhibit 1

Nitrogen Guidelines if Soil Tests Are Not Possible

New Lawns:
Apply 0.5 pounds nitrogen per 1,000 square feet before planting. Incorporate the nitrogen 0.5 to 1 inch into the soil, and mulch on top. (See the Mulching BMP).

Existing Lawns:
Several bulletins for lawn fertilizer applications recommend applying fertilizer two-four times a year, with a maximum of 1 pound N per 1,000 square feet. To save money and prevent excess nutrients from entering surface waters, we recommend starting with an application of 0.5 - 1.0 pounds (8 - 16 ounces) nitrogen per 1,000 square feet two times a year, once in May and once in October. Grass clippings left on your lawn is a source of nitrogen for your lawn and, if evenly distributed, can be equal to one fertilizer application per year.

If your lawn is not staying healthy with these rates, then use the chart below to increase your fertilizer use. Never apply more than 1.0 pound per 1,000 square feet in any one application. (Example: 20-5-10 is 20% nitrogen, so 5 lbs. of 20-5-10 is applied per 1,000 square feet in order to apply 1 lb. of actual nitrogen).

Nitrogen Application Guidelines for 4 Times/ Year Application
Pounds of Nitrogen per 1,000 square feet

Time of Application	Grass Clippings Removed	Grass Clippings Not Removed
October 1	1.50	1.50
Late May	1.5	1.00
Late June	0.75	0.50
Late August	0.75	0.50

Source: Modified from University of Wisconsin-Extension

Vegetable and Flower Gardens:
Apply 0.2 pounds (3.2 ounces) nitrogen per 100 square feet. An additional 0.18 pound (2.9 ounces) nitrogen per 100 square feet may be needed for corn, tomatoes and pole crops (beans).

To avoid nitrogen loss **on sandy soils** (and to protect groundwater supplies from nitrate contamination) apply nitrogen at one-half the rate but twice as often. Another option is to use slow-release nitrogen or natural organic nitrogen sources.

Source: "Protecting Water Quality in Urban Areas," State of Minnesota.

Organic Debris Disposal

Description

For the purposes of this BMP, organic debris includes grass, leaves, pruned branches and any other vegetative material. This BMP discusses water quality concerns surrounding organic debris disposal methods.

Proper management of organic debris will likely become crucial as laws limiting the disposal of such waste in landfalls go into effect. As of March 27, 1993, yard waste collected or generated in Michigan on public property is banned from land fills and incinerators.

Other Terms Used to Describe

Composting
Yard Waste Management

Pollutants Controlled and Impacts

One significant impact of proper organic debris disposal is the reduction of organic debris in landfills. Since organic debris may contain pesticides and/or fertilizers, this may help reduce the amount of leachate that can impact groundwater.

Additional benefits include:

-compost and mulch contribute nutrients back into the soil. This reduces the amount of fertilizer needed.

-keeping compost piles and other organic debris out of surface waters and away from floodplains will help prevent the depletion of oxygen in surface waters. During decomposition, biological organisms deplete dissolved oxygen supplies in water.

-leaf composting prevents drains and sewers from clogging and reduces leaf burning by residents.

-increased organic material in soil results in improved water and nutrient holding capacity of the soil, better drainage, resistance to insects and diseases, easier cultivation, and better aeration.

<u>Land Use</u>
Although this BMP applies to all land uses, it is particularly important in urban and urbanizing areas where available land is limited. This practice is also important on golf courses and other large recreational areas.

Soil/Topography/Climate
Soils, topography and climate will all affect the types of organic debris disposal options available. These are discussed in more detail in the "Specifications" section, below.

When to Apply
For newly developed areas, an organic debris management plan should be incorporated into the overall site plan. All areas which currently require the disposal of organic debris should evaluate ongoing disposal practices and modify them based on the contents of this BMP.

Where to Apply
Apply in urban and urbanizing backyards, on golf courses, recreation areas and any other place where organic debris needs to be disposed of.

Relationships With Other BMPs

The Lawn Maintenance BMP includes information on the proper mowing heights of the most common turfgrasses, and the basics of irrigating grass. It also briefly discusses concepts derived from the Pesticide Management and Fertilizer Management BMPs, and refers to this BMP for organic debris disposal specifications.

The end product of organic debris disposal may be of use in Soil Management.

Diversions may be needed to prevent excess stormwater from entering a composting area.

Specifications

Grass Clippings:
The Michigan State University publication "Turfgrass Pest Management: A Training Manual for Commercial Pesticide Applicators" (Extension Bulletin, E-2627) indicates that each year, degrading clippings provide 4 pounds of nitrogen, 1 pound of phosphorus and 2 pounds of potassium per 1,000 square feet. When clippings are regularly removed, fertilization must be increased by 25-50%. Grass clippings in plastic bags increase the cost of commercial composting efforts.

Clippings are routinely removed from high-maintenance areas to improve appearance and texture. Managers also routinely remove clippings with the belief that doing so prevents excessive thatch build-up. **Grass clippings do not cause thatch.** Wherever possible, leave grass clippings on lawns.

Mulching mowers can be used to chop grass clippings into smaller pieces. This will increase the rate in which the clippings are broken down. Use mulching mowers on lawns which are not overly wet and where the grass height has not been left too long between cuttings. The height of the grass should be somewhat higher than typical settings for bagging mowers: the lawn is best cut when the grass is one-third higher than the height of the blade. For example, if the grass if left at two inches following mowing, the grass would be cut when it reaches three inches.

Although lawns cut by mulching mowers must be cut more frequently (every 5-6 days as opposed to once per week), the time actually spent in the yard is less because there is no need to continually stop and empty the grass catcher. In addition, since grass clippings return nutrients to the soil, fewer fertilizer applications will be needed.

The only times clippings *should* be removed is when doing so will limit the inoculum of some diseases.

When clippings are removed, use proper composting procedures. Some of the basics of composting are discussed below.

Leaves:
Like grass, leaves can also be mulched. Mulched leaves left on the ground over the winter will not harm grass, because grass goes dormant in the Michigan climate. Winter puts leaves through a "freeze-thaw" cycle that helps soften them for decomposition. Winter snow and spring rains provide needed moisture for the subsequent breakdown.

Leaves can be gathered and placed in wooded areas for mulching, as long as the wooded area is not a forested wetland, surface water or in a floodplain. Spread the leaves evenly so that they can decompose properly. To aid decomposition, moisten each layer lightly. If possible, spread leaves over the garden, in flower beds and wherever there is open soil.

Leaf mulching can be assisted by chopping, shredding, or mowing the leaves before using them as mulch. Make sure the machine selected for this is rated to handle leaves.

If it is not practical to mulch leaves, follow proper composting procedures, some of which are summarized below.

Tree Branches, Limbs, etc.
Ideally, tree branches should be chipped and the chipped material used in landscaping. The use of wood chips as mulch is discussed in the Mulching BMP.

Inclusion of brush and tree trimmings in a composting program will require a chipper or other device such as a tub grinder to reduce particle size and volume. Co-mingling brush with leaves and grass clippings is not advised prior to chipping, because leaves and grass clog chippers and brush will clog shredders and screens. Because brush breaks down more slowly than leaves and grass, chipped brush should not exceed 10% of the volume of materials being composted. Some people add wood chips to compost to increase aeration of the pile.

Composting:
Composting is the biological decomposition of organic matter. The micro-organisms which break down organic matter need food, air and water. Food is the organic waste. Air is provided by mixing and aerating. Water comes from rainfall and the garden hose. With the proper balance of food, air and water, coupled with sufficient volume to hold heat, micro-organisms will thrive and generate heat to initiate and sustain the composting reaction. The finished product--called compost or humus--can be a valuable mulch or soil conditioner if proper care is taken to avoid contaminants and if aerobic conditions are maintained during composting. See "Land Application," below.

The following is provided as a summary of the water quality concerns surrounding composting operations. Most of the information was extracted from two publications, both of which are available from the Michigan Department of Natural Resources, Waste Management Division. These publications are: "Mulching and Backyard Composting Guidebook," and "Yard Waste Composting Guidebook for Michigan Communities."

The Type of Composting System:
The type of composting system required will vary depending on the amount of material expected. For backyard operations, small bins or a series of bins will work. For larger operations, organic debris should be put into several piles.

Land Application of Compost:
Compost is considered a soil amendment, not a fertilizer. Compost can be added into the soil to provide more organic matter, but only after the compost is cured. A cured compost is free from objectionable odors, has little oxygen demand, is dark and crumbles in the hand. Compost can also be spread around shrubs, trees or in the garden in 1-3 inch layers as concentrated **mulch**.

Direct land application of organic matter should not exceed 40 tons per acre, which would be approximately 400 cubic yards of yard waste at a density of 200 pounds per cubic yard spread to a 3-inch depth. Debris can be applied via a manure spreader or other methods, and can be incorporated into the soil 4-12 inches using a chisel plow or rototiller. Shredding leaves during collection makes soil incorporation easier and spreading rates more uniform. One of the best times to rototill compost is before seeding or sodding a new lawn.

Composting in Windrows (Rows of Piles):
As a rule of thumb, 3,500 to 5,000 lightly compacted cubic yards of incoming leaves requires about one acre of land. For bigger quantities of waste, or where large amounts of land are not available for direct land application, push thick layers of leaves into windrows. Windrows can be anywhere from 3-10 feet high and up to 18 feet wide. Leave space between windrows to allow air to circulate amongst the piles, and to allow access by equipment. Water lightly between layers. Mix and reform the windrow one or more times per year.

Decomposition time of large piles which sit on the ground and are mixed only once per year will not likely result in compost for several years. To increase decomposition time, more frequent mixing should be done, and watering should be done to prevent the piles from getting too dry. By increasing the rate of decomposition, yard waste can be stabilized in as little as 3-6 months. Follow all mixing, watering and aerating procedures in the guidebooks listed above.

Location of Composting Piles:
Soil type will help dictate the proper location of the bins or windrows. Natural soils should have a high enough percolation rate to move water away quickly so that standing ponds of water don't form. In bigger operations, the need for the soil to provide sufficient stability for heavy equipment must be balanced by the ability of the surface to drain off excessive rainwater.
To lessen the chances of ponding water, do not locate organic debris piles in areas with high water tables. Also avoid steep slopes. Soil surveys providing information on soil types, percolation rates, and depth to ground water are available for most counties in the local Soil Conservation District offices.

Never locate composting piles in wetlands or other surface waters, or in floodplains.

To reduce potential odor problems, the Department recommends a minimum 500-foot buffer zone between large, active compost operations and residences, with a 50-foot setback from compost windrow edges. Curing piles can be placed so as to create a berm around the perimeter of the site to serve as a visual and sound barrier.

The ideal composting site for most homes is a clear area, away from trees and landscaping. An area somewhere between 6' x 6' and 12' x 9' will suffice. Avoid tight and crammed corner spots. Provide plenty of room to access the working area with a pitchfork from all directions.

The Processes Involved in Composting:
It is beyond the scope of this BMP to discuss all the principles of composting. Composting requires proper aeration, watering and mixing in order to result in a useable end-product. Refer to the guidebooks listed at the beginning of this section for additional information. Those guidebooks also discuss various types of machinery that can be used, frequency of mixing, various types of bins, and the biological processes involved in composting. The purpose of this BMP was to encourage users to incorporate organic debris disposal in their overall site management scheme, and to locate their mulching and composting operations in a manner which will not impact surface waters.

Exhibits

Exhibit 1: "Compost Bin Manufacturers." Mulching and Backyard Composting Guidebook. Michigan Department of Natural Resources, Waste Management Division.

Exhibit 1

Compost Bin Manufacturers

This partial list was derived through a review of resource recovery magazines, lawn and garden catalogs, vendors at the 1990 National Hardware Association Annual Hardware Show, and lawn and garden product distributors. Some of these firms may not sell directly to consumers. No recommendation is made for any model, style, or manufacturer. Check with your local hardware, department store, or lawn and garden retailer for availability in your area. Many gardening and specialty magazines and catalogs advertise compost bins, aerators, mixers, and inoculants that can be purchased through the mail.

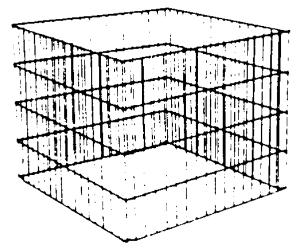
Wire Bins

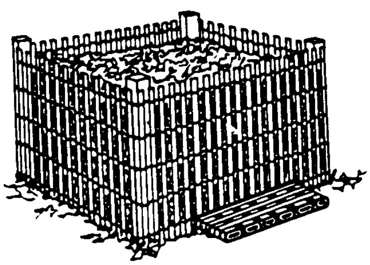
Keystone Steel and Wire
7000 SW Adams St.
Peoria Illinois 61641

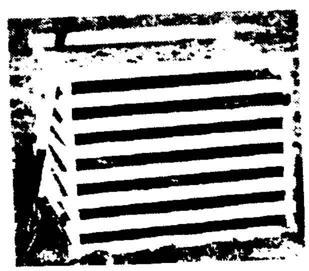
Spread All Manufacturing
2237 Marshaltown Blvd.
Marshaltown, IA 50158
800-383-5601

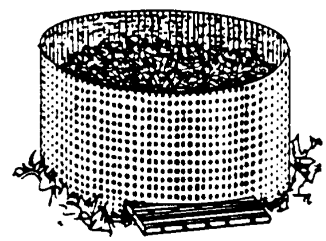
Vision Sales Inc.
Bartlett, Il. 60103
708-837-2967

Southwestern Products, Inc.
PO Box 421
Joplin, MO 64802
800-624-3800









Cedar Bins

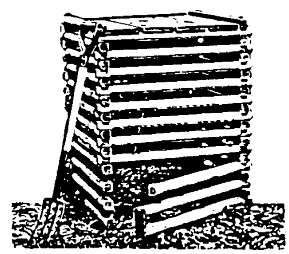
Evergreen Bins
PO Box 70307
Seattle, WA 98107
206-783-7095

The Natursoil Company
1015 W. St. Germain, #400
St. Cloud, MN 56301
612-253-6153

R.C. Sales
Box 427
Shaftsbury, VT 05262
802-442-2071

BioBin
8407 Lightmoor Court
Bainbridge Island, WA 98110
206-842-6641

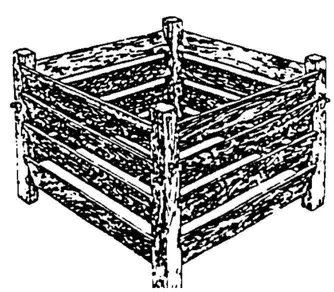
Zema Corporation
PO Box 12803
Research Triangle Park, NC 27709
800-334-5530



Treated Wood Bins

K-D Wood Products
PO Box 645
Bingham, ME 04920
207-672-4333

Al-ko Kober
25784 Borg Road
Elkhart, IN 46514
219-264-0631

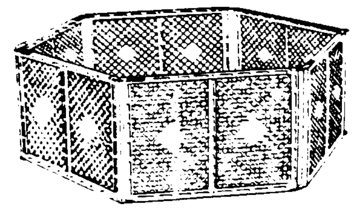


(Continued)

Compost Tumblers

Plant Right
7201 Rawson Road
Victor, NY 14564
800-752-6802

Green Magic Tumbler
Gardener's Supply
128 Intervale Road
Burlington, VT 05401
800-548-4784

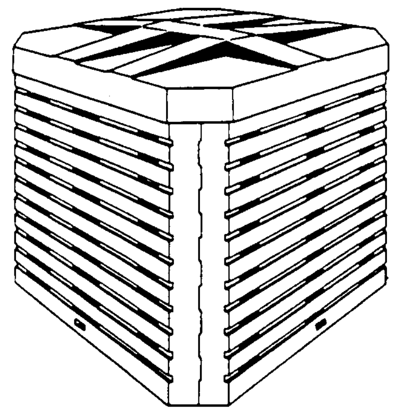


Kemp Compos-Tumbler
160 Koser Road
Lititz, PA 17543

Plastic Bins

North States Industries
1200 Mendelssohn Ave. Suite 210
Minneapolis, MN 55427
612-541-9101

Ringer
9959 Valley View Road
Eden Prairie, MN 55344
612-941-4180



Brave Industries, Inc.
115 E. Front Street
Annawan, IL 61234
800-627-1280

Plastigone Technologies
10700 N. Kendall Drive
Miami, FL 33176
305-274-8497

Kompost Industries Inc.
1640 Superior Avenue
Costa Mesa, CA 92627
714-548-8531

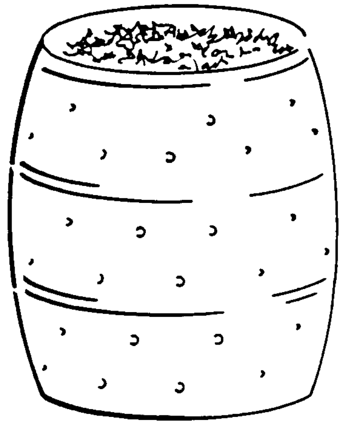
Bio Industries, Inc.
450 S. Lombard Rd.
Addison, IL 60101
708-953-9040

Compost Systems
16 Hillview
Barrington, IL 60010
800-848-3829

Barclay Recycling, Inc.
75 Ingraham Rd.
Toronto, Ontario M6M 2M2
416-240-8227

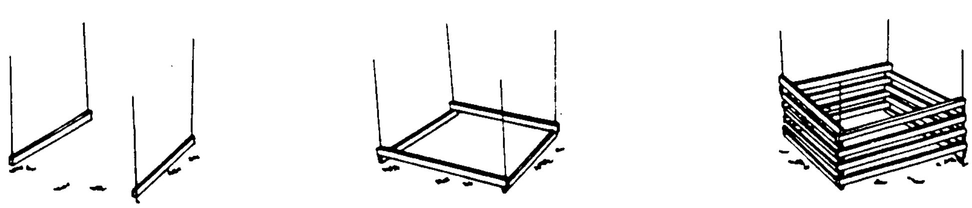
Shape Plastics
PO Box 1037
Crystal Lake, IL 60012
815-455-6310

Solar Cone, Inc.
Box 67
Seward, IL 61077
815-247-8454



A Plastic 55 gallon drum can be turned into an effective compost bin in a few simple steps. Merely cut off the top and bottom of the barrel with a sabre saw and cut a series of 2" to 3" holes in the sides for aeration.

A lid can be formed by cutting off the top of the barrel 6" to 10" down along the side. The barrel is then inverted and the lid placed over what was the bottom of the drum. For more information on barrel and other composters, contact Wayne Koser through the Resource Recovery Section of the Waste Management Division at 517-373-4741.



Source: Mulching and Back Yard Composting Guidebook, Michigan Department of Natural Resources, Waste Management Division.

Pesticide Management for Turfgrass and Ornamentals

Description

Pesticides are a family of chemicals used to manage pests. Common pesticides include herbicides, insecticides, and fungicides. This BMP offers guidance in the selection, use, storage and disposal of pesticides, with an emphasis on using integrated pest management principles. Much of the information included in this BMP is extracted from "Turfgrass Pest Management: A Training Manual for Commercial Pesticide Applicators", Michigan State University, Cooperative Extension Service, Bulletin E-2627.

Integrated pesticide management (IPM) is the use of all available strategies to manage pests so that an acceptable yield and quality can be achieved economically with the least disruption to the environment. The goal of IPM is to reduce and maintain pest populations at levels where aesthetic and economic losses are tolerable. The strategies used in IPM incorporate a wide range of pest controls, such as using resistant turf varieties, cultural controls, biological controls, mechanical controls, and the use of pesticides. IPM should not be considered "anti-pesticide." Pesticides are one of several management components within an IPM system. Knowledge of the pest and cultural requirements of the vegetation are keys to a successful IPM program.

This BMP addresses pesticide use in upland areas. It does not address pesticide use in aquatic resources, such as herbicides used to control nuisance aquatic weeds. Aquatic herbicides should be applied according to Act 368 of 1968 (Section 333.12561 - 333.12563, Public Health Code) and the rules promulgated thereunder. Permits for aquatic herbicide applications are not needed if the waterbody is a pond and is less than 10 acres **and** has one owner and no outlet. Contact the MDNR, Land and Water Management Division at (517)-373-1170 for information on aquatic herbicide use. The information contained in this BMP on pesticide storage, handling, transporting and record keeping are pertinent to aquatic pesticides.

Other Terms Used to Describe

Pest Management
Integrated Pest Management (IPM)
Integrated Turf Management (ITM)
Integrated Crop Management (ICM) See the Department of Natural Resource's Agricultural BMPs for ICM applications.

Pollutants Controlled and Impacts

The proper use of IPM principles will promote healthy vegetation, which require fewer inputs. (According to "Turfgrass Pest Management: A Training Manual for Commercial Pesticide Applicators", Michigan State University, Cooperative Extension Service, E-2327, some lawn care companies that implement IPM report a 40-60% reduction in pesticide usage). The proper storage, handling, application and disposal of pesticides will reduce the amount of pesticides available to contaminate surface waters and/or groundwater.

Application

Land Use
This practice is applicable to all land uses where pests are encountered or where pesticides are used or stored.

Soil/Topography/Climate
Soil adsorption, which is the tendency of the pesticide to be attached to soil, varies from one soil texture to the next. The higher the soil adsorption capacity, the greater the pesticide will attach to the soil and move off the land with soil erosion. This is discussed further in the "Specifications" Section, below.

It is particularly important to divert runoff from waterbodies and wetlands when pesticides are used on hilly terrain. Depending on the topography involved, certain application procedures may not be possible.

Climatic factors such as rainfall and temperature are discussed in the "Specifications" section, below.

When to Apply
For new development projects where pesticides will likely be used (such as parks/recreation areas, golf courses, etc.), a pesticide management program should be developed during the site planning process. On all existing sites where pesticides are applied, it may be appropriate to review the practices and adjust them based on specifications in this BMP.

Where to Apply
Apply this practice in all areas where pesticides are stored or applied.

Relationship With Other BMPs

Trees, Shrubs and Ground Covers should be used to select disease or insect-resistant varieties of trees, shrubs and ground covers, and to maintain healthy vegetation. To maintain healthy turf, use this BMP in conjunction with proper watering and mowing (see the Lawn Maintenance BMP), as well as Fertilizer Management and Soil Management.

Specifications

General Considerations:
Use Integrated Pest Management (IPM). IPM is a pest management system that uses all suitable techniques in a total management system to prevent pests from reaching unacceptable levels, or to reduce existing pest populations.

It is important to remember that vegetation cannot be both pest-free and benefit from biological control. For example, there are "good" insects which feed on pests. Accidently killing these insects through indiscriminate pesticide applications may cause more problems than if the pesticide hadn't been applied. Do not attempt to wipe out a pest population; take time and care to use only the management practices which will prevent unacceptable injury to the plant.

<u>Plant Selection:</u>
To **reduce pest problems**, the first step in any IPM program is to **select plants or materials that are resistant to pests and diseases**. Other considerations include selecting materials that provide food, moisture, or habitat to predators, parasitoids, and pathogens of pests. Selection should also be based on the soil characteristics, or with the intention of modifying that soil using the <u>Soil Management</u> BMP. Managers who choose well-adapted species are usually capable of minimizing management inputs while maintaining high quality vegetation.

Native plant species usually require fewer pest controls than introduced species. Choose adapted varieties based on environmental conditions, management level desired, and the intended use.

Species should also be selected based on where they will be planted. For example, most turf grasses generally do best in full to partial sun. The following lists turf performance in shady sites:

Satisfactory: rough bluegrass, fine fescue
Fair: tall fescue, perennial ryegrass
Poor: Kentucky bluegrass

Once the proper plant species is selected, **become knowledgeable in the management of that species**. Every species and every use of that species will involve different water requirements, mowing heights and frequency, and fertilizer rates. All of these factors can affect the health of that plant species.

<u>Identify the Pest:</u>
An organism should not be classified and treated as a pest until it is proven to be one. There are species of insects, fungi, nematodes, and bacteria that are harmless or beneficial to vegetation. Eliminating them with unnecessary pesticide applications often causes greater or additional pest problems. You cannot make appropriate management decisions until you identify the pest. Consider using reference books, the County Extension Service, and/or reliable consultants to help you identify pests.

Understanding pest life cycles and behavior allows applicators to effectively target pest control activities. Regular monitoring will allow you to determine when the pest is in the life stage that is susceptible to controls. See the attached exhibit for various monitoring techniques applicable to grasses.

<u>Determine the Action Threshold:</u>
The action threshold is the pest density at which action must be taken to prevent the pest from reaching the economic injury level. The economic injury level is defined as the density of pests at which the cost to manage the pest is equal to the losses that pest causes. This definition was developed for cash crops, where pest injury is easily converted into monetary losses. For turfgrass management, replacing damaged turf (for example) is an obvious cost of pest activity. However, damaged turf also reduces the aesthetic value of an area.

Action thresholds are usually set based on the judgement of the scout or applicator and reflect the level of treatment desired by the individual. Always take action before unacceptable injury occurs.

Select the Pest Control Strategy:

The best pest control strategy is one that most effectively controls the target pest and minimizes the potential for any adverse effect on the environment. This may include:

Cultural Controls. These include devising ways to change the conditions which are favorable to the pest to conditions that are not favorable to the pest, conditions which favor the pests' natural enemies, or conditions which encourage growth. Review the irrigation schedule, fertilizer rates, soil management, and, for turf, the mowing height and frequency, etc. All of these factors will affect the health of vegetation.

Consider modifying habitats, including components of the landscape and buildings, to enhance the environment required by the pests' predators. Crabgrass is a weed which out-competes turf in sunny, compacted areas. Aerating compacted soils will help desirable turf compete in this area.

Biological controls. Biological controls are living organisms which are used to control other living organisms. They include predators, bacteria, fungi and nematodes. Use of biological controls should only be done by professionals.

Mechanical controls. These include cultivating to control weeds, hand-picking weeds from turf and pests from plants, and screening living space to limit access by mosquitos and flies.

Traps/baits. If the pest is an insect, consider using pheromones (insect hormones) or other attractants to lure or confuse the pest; and use traps to capture pests.

Monitor pest populations using one or more of the following:

-detection kits
-computer models
-disease models
-traps
-knowledgeable (trained) scouts

Pest activity is predicted more accurately by monitoring weather conditions which influence pest development. Both plant and pest development depend on the amount of heat that surrounds the organisms. Turf pest development and their activity is best predicted with **degree days**. Degree days are figured in several ways, but are all based on a common principal: the development of plants and pests begins when the air temperature reaches a certain level, and usually continues until the temperature falls below that threshold. Degree days precisely measure the occurrence of above-threshold temperatures. The threshold is called the base temperature and is between 40-60 degrees F for most organisms.

The Crop Advisory Team (CAT) of Michigan State University (MSU) reports degree days with base temperatures of 42 degrees and 50 degrees F for several areas in Michigan. Pest management references, such as the CAT Alert, Landscape Edition (MSU, Cooperative Extension Service) identify what stage of pest development occurs at specific degree day totals. There are also many commercially-available weather monitoring devices and computer programs to help you predict pest development.

Turf managers: When selecting monitoring equipment, keep in mind that climatic information that most accurately measures the conditions affecting turf is gathered at the crown level of turfgrass. Consider using one of the monitoring techniques listed in Exhibit 1.

Pesticides. Choose the most appropriate pesticide after considering pest resistance, human exposure, and environmental impact (including impact or surface and ground water). (See the next section for additional information). Follow the "Applications" section, below.

Educate all persons who will be involved in the use of pesticides. Inform them of potential pest problems (i.e. what to look for). Review irrigation and mowing schedules. Review pesticide and fertilizer management practices, including integrated pest management practices.

Selecting Pesticides:

Selection of the appropriate pesticide should first be based on the type of pest which needs to be controlled: either a plant (use a herbicide), insect (use an insecticide), rodent (use a rodenticide) or fungus (use a fungicide). If more than one pesticide can be used to control the pest, choose the pesticide that will yield the desired control results and have the lowest potential to cause any adverse environmental impacts. Choose the pesticide that fits into your pest management strategy and is the least toxic alternative. Ideally, you would want to choose a chemical with low leachability, low runoff potential, a low persistence value, low water solubility, and high soil adsorption capacity. (See the discussion below on the specific compound).

Where more than one formulation can be used (e.g. powder, gas, liquid, etc.), consult Exhibit 2.

Buy only the amount needed to give the desired results.

Selection of the specific compound should be based on the following considerations:

1. Persistence (Half-life). This is the term given to the days required for the pesticide in soil to degrade to one-half of its previous concentration. In general, the longer the half-life, the greater the likelihood the pesticide will be able to move into surface or ground waters and cause environmental impacts. **A pesticide with a half-life greater than 21 days may persist long enough to leach or move with surface runoff before degrading**.

2. Water solubility. The degree to which a pesticide can dissolve in water is given in parts per million (ppm). Solubility affects how easily a pesticide can runoff or leach. In general, pesticides with solubilities of 1 ppm or less tend to remain at the soil surface, tend not to leach, but may move off-site with soil. **Pesticides with solubilities greater than 30 ppm are more likely to leach**.

3. Soil adsorption capacity. Each soil type has a soil adsorption property, which is the tendency of the pesticide to become attached to soil. The higher the soil adsorption capacity, the greater the pesticide will attach to the soil and move off the land with soil erosion. The lower the adsorption capacity, the less likely the pesticide will bind with the soil, but the more likely the pesticide will have the potential to runoff or leach to groundwater. In general, soils with adsorption numbers greater than 1,000 strongly attach to soil, and those with number less than 300-500 are more readily available to run off or leach. See the

appendices to these BMPs for specific soil adsorption values.

4. Leaching and runoff potential. These characteristics are directly related to the soil adsorption and water solubility characteristics. Quite often a trade-off must be made between two pesticides, and the final selection of that pesticide should be based on the soil and groundwater conditions. If one pesticide has a low leachability and another a high leachability factor, then the low leachable one should be chosen to protect the groundwater.

5. Toxicity. After considering all other aspects of pest management, the applicator should choose the least toxic pesticide that is capable of producing the desired effect. Applicators need to remember that pesticides are inherently toxic by their nature, and utilize appropriate protective equipment to minimize their exposure.

   In selecting the appropriate pesticides, applicators need to be aware of the potential for pest resistance. To reduce pest resistance potential, applicators should choose alternative control measures in their pest management strategies.

Pesticide labels contain the following information:

a. Name of the chemical, including trade name, common name, chemical name and formulation

b. EPA registration number

c. Amount of active ingredient per unit, and net contents of the package

d. Information on how to store, mix, apply and dispose of the product and container

e. Manufacturer or formulator name, address and telephone number, and EPA establishment number

f. Use classification. Certain chemicals have restricted use which requires applicator certification to purchase and use.

g. Use recommendations, including timing and the minimum number of days between applications.

h. Pest(s) controlled by the pesticides.

i. Precautionary statements pertaining to physical and environmental hazards. Includes information such as keeping out of reach of children.

j. Persistence (half-life), which is the duration it takes the pesticide to break down to one-half its previous concentration. See "Selecting Appropriate Pesticides," below.

k. Statements regarding the toxicity of the pesticide. Pesticides are categorized based on toxicity:

   Class I- Danger-Poison. Includes skull and crossbones; poisonous if swallowed. Do not breathe vapor. Do not get in eyes, on skin, or on clothing.

Class II- <u>Warning</u>. May be fatal if swallowed. Do not breathe vapors. Do not get in eyes, on skin, or on clothing.

Class III- <u>Caution</u>. Harmful if swallowed. Avoid breathing vapors. Avoid contact with skin.

Class IV- <u>Caution</u>. No caution statement required.

Never purchase a pesticide that doesn't contain a label.

Review the pesticide label prior to mixing. **Follow label directions**.

Note that if you choose a **restricted use pesticide**, by law, you MUST have the credentials to use it. Restricted use pesticides are usually toxic or environmentally persistent chemicals which can cause significant health or environmental damage if misused. See the "Applicator Certification/Registration" section, below.

<u>Pesticide Applications:</u>
Read the label before application.

1. Application techniques include everything from hand-spraying to aerial spraying. Follow the application procedures on the label.

2. If the label lists more than one acceptable application procedure, use Exhibit 3 to apply the pesticide using the most target-specific method that effectively controls the pest. It is essential that the pesticide be applied in a manner to maximize the percentage of material on-target, and minimize any potential off-target effects.

3. Purchasers and applicators of restricted-use pesticides are required to pass an examination administered by the Michigan Department of Agriculture. See "Additional Considerations," below.

4. Equipment should be in sound mechanical condition, free of leaks and other defects or malfunctions which might cause a pesticide to be deposited off-site, or in a manner inconsistent with its label.

5. Application equipment should be **calibrated** frequently enough to ensure proper and safe application and comply with label directions. All pesticide applicators must follow label directions when using pesticides. Appendix 4 of these BMPs contains calibration procedures for the most common types of chemical application equipment. **Follow calibration procedures in the Appendix for all pesticide applications.**

<u>Mixing and Loading:</u>
Read the label before mixing and loading.

1. Always wear protective clothing when mixing and applying pesticides.

2. Mix the chemicals away from people and animals, on an impermeable surface, preferably a sealed concrete pad. Ideally, the pad should drain to a sump which can contain any spilled pesticides until they are pumped back into the sprayer and used according to label directions.

3. Never leave the filling operation unattended.

4. Have material available to contain any potential spill (see information on spills, below).

5. Fill the tank (or sprayer) approximately half full with water before adding pesticides.

6. Accurately measure chemicals in accordance with label directions. If measuring in teaspoons, use level spoonfuls, not heaping spoonfuls. Never use the same measuring device for food preparation.

   Appendix 4, entitled "Supplemental Fertilizer and Pesticide Applications" includes a list of "Common Measuring Equivalents for Pesticides and Fertilizers." The equivalents allow users to mix only the amount of pesticide (or fertilizer) needed for a single, specific application.

7. If the tank is used to mix two or more chemicals, make sure the two chemicals are compatible with each other. When mixing two or more chemicals in a tank, be sure to mix them according to the sequence below:

   a. Wettable powders
   b. Flowables
   c. Water solubles
   d. Emulsifiable concentrates

8. Pesticide application equipment designed to draw water must have a properly functioning **anti-siphoning device**. Avoid back-siphoning by keeping the end of the fill hose above the water level, or by installing devices which prevent back-siphoning. For additional information, see Michigan State University, Cooperative Extension Service bulletin E-2349, "Protect Water Supplies from Back-Siphoning of Ag Chemicals."

Application Procedures:

1. Prior to an application of pesticides, the applicator should identify any sensitive areas (i.e. wetlands, lakes, streams, etc.) within and adjacent to the target area.

2. Pesticide applications should be made in a way which will prevent direct discharge of pesticides and reduce drift to the lowest extent possible. To do this:

   - Avoid applying pesticides prior to a rain storm, in heavy winds, or during any other weather conditions which may result in runoff. Do not apply on frozen ground.

   - When spraying pesticides, leave an unsprayed buffer strip around surface waters or near other sensitive areas (such as wetlands). Where possible, **leave a minimum 30-35-foot buffer between the edge of the spray area and the watercourse to avoid drift and/or runoff into surface waters**.

3. Where possible, apply pesticides only to those areas which are known to be impacted by the pest. Avoid applying to areas not affected by the pest.

4. **Always spray at the rate recommended on the label**. On the advice of experts, you may be able to apply less than the label recommended rate.

5. All applicators should apply pesticides during the most vulnerable or appropriate stage in the pests' life cycle. Insects, for example, have several life stages, some of which make them more vulnerable than others. The pesticide label may indicate the best time of year to apply the pesticide based on the type of pest being controlled.

6. Special precautions should be implemented in areas where the groundwater is high or where soils are coarse and groundwater could be easily impacted. Routine applications of pesticides that have the potential to impact groundwater should be avoided.

7. Pesticides should be applied in a manner which minimizes exposure to humans, livestock, domestic animals and non-target wildlife.

8. Use up excess pesticide mixtures according to label directions.

<u>Pesticide Storage:</u>
Read the label to determine appropriate storage procedures

1. Store all pesticides away from food products, seeds, fertilizer, and protective equipment.

2. Store all pesticides in a cool dry location, out of direct sunlight. Ideally, pesticides should be stored in a secure room/building. Buildings should be located no closer than 150 feet from a well and no closer than 200 feet from surface water (i.e. lake, river, stream, wetland). Where these restrictions are not being adhered to, additional water source protection methods should be used.

   The following applies to the room/building where pesticides are stored:

   *Post the room/building with highly visible warning and "NO SMOKING" signs.

   *The room/building should be properly ventilated with an exhaust fan.

   *The room/building should contain a sealed cement floor that will prevent spilled pesticides from leaking through cracks.

   *Where possible, the room/building should be fireproof and explosion proof.

   *The room/building should be locked when not in use. Keep all pesticides out of the reach of children, pets and unauthorized persons.

   *If pesticides are stored in a separate building, there should be a containment dike around the building to prevent potential runoff.

*The pesticide storage room/building should contain metal shelves for smaller containers and pallets on the floor for large drums.

3. Store pesticides in their original container. **Secondary containment should be provided for all pesticide containers.**

4. Store all pesticides by classification (herbicide, fungicide, etc.) to prevent misuse or contamination.

5. Mark the date of purchase on each container so older material can be used first.

6. Have supplies for the clean-up of pesticide spills readily available. These include kitty litter, sawdust, and buckets. A fire extinguisher approved for chemical fires should also be readily accessible.

7. Have emergency telephone numbers visibly posted, and first aid equipment readily available.

8. Store protective clothing in a location separate from the pesticides.

9. Store equipment for measuring and mixing pesticides in the pesticide storage room/building.

10. Do not store pesticides in underground tanks.

11. MSU Cooperative Extension Service bulletin E-2335, "On-Farm Agri-Chemical Storage and Handling," contains additional information on pesticide storage.

<u>Pesticide Disposal:</u>
Read the label for specific disposal instructions.

1. Do not discard partially-filled pesticide containers in the trash.

2. Before disposing of empty pesticide containers, triple rinse or power rinse the container. If conducted at a common site, the rinsing operation should be performed over an impervious pad, otherwise the operation should occur in the field at the time of application. To triple rinse, follow the steps below:

    a. Allow concentrate to drain into the tank for 30 seconds.

    b. Add water to the container (10% of the tank volume), replace lid and rotate container.

    c. Dump rinse water into tank and drain for 30 seconds.

    d. Repeat twice more.

    e. Use the rinseate according to label directions.

It is critical that pesticide containers are rinsed immediately after they are emptied. Once pesticide residues become dry in the containers, they are difficult to remove.

3. Puncture the container so it is not used for other purposes.

4. Where possible, recycle plastic containers.

5. Dispose of glass containers in a sanitary landfill.

6. Never reuse a pesticide container.

7. Open burning of pesticide containers is prohibited by law.

8. For additional information on pesticide disposal, contact the Michigan Department of Natural Resources, Waste Management Division at (517)-373-2730, or the Michigan Department of Agriculture, Pesticide and Plant Pest Management Division, (517)-373-1087.

Spill Cleanup:
Develop a spill response plan to identify the procedures which will be followed to contain and clean up spills.

Below are guidelines for spill cleanup if a pesticide is spilled indoors and if the area drains to a sanitary sewer. For all outdoor spills, and indoor spills with areas which drain to storm sewers, contact the Michigan Department of Natural Resources at the Pollution Emergency Alert System (PEAS) number: 1-800-292-4706.

1. If the pesticide is a liquid, surround the area with an absorbent material to keep the pesticide from moving.

2. If the pesticide is a liquid, sprinkle sawdust, kitty litter or other absorbent materials over the spill. Wear gloves and rubber boots.

3. Collect the absorbent material and read label directions for the proper disposal of the waste. If in doubt as to the proper disposal of the waste material, contact the MDNR, Waste Management Division at (517)-373-2730, or your local Cooperative Extension Service office.

4. After removing the waste material, contact the wastewater treatment plant operator. Upon their approval, wash the area down with water, again, only **if the area drains to a sanitary sewer. Do not wash into a storm sewer.**

Record Keeping:
The Michigan Pesticide Control Act (Act 171) requires that all commercial applications of pesticides be recorded by the applicator. Records are useful when runoff, drift or leaching occurs. Records should include:

-Date of application
-Chemical applied (trade name and formulation)

-Rate per acre (acres or square feet)
-Method of application
-Area treated with pesticides
-Purpose of application (target pest(s))
-Weather and soil conditions at time of application
-Most recent date of calibration
-Name of applicator

Exhibit 4 is a Pesticide Use Record form which can be used for each pesticide application.

Maintenance

Proper pesticide management is an ongoing practice, beginning on or before the first pesticide is brought onto the site, and ending only when pesticides are no longer stored or used on the site. Ongoing maintenance should include a minimum annual check to ensure that:

1. Applicators are applying pesticides according to label directions.

2. Equipment is calibrated so that pesticides are applied at the appropriate rate.

3. Labels on the pesticide containers are legible.

4. Pesticides are being stored according to the label directions, and that there is secondary containment for all pesticides.

5. Records are being kept which accurately document the use and application of the pesticide.

Transporting Pesticides:

Proper transporting of pesticides should include:

-Securing containers to avoid breakage and leakage

-Packaging containers to avoid contamination with other chemicals, seed, fertilizer, animal feed and human food

Additional Considerations

Wildlife:

Bees and amphibians such as toads, frogs and salamanders, are sensitive to pesticides. Avoid spraying near wetlands used by breeding amphibians, especially during the breeding season of April, May and June.

Applicator Certification/Registration:

Anyone purchasing and applying restricted use pesticides in Michigan must be certified by the Michigan Department of Agriculture via a testing procedure. Recertification is required every three years.

For persons employed by **commercial certified applicators**: The Pesticide Control Act of 1976 was amended in 1988 to create a new classification of pesticide applicators called "registered technicians." Under this amendment all commercial applicators must be either "certified" or "registered" in order to apply any pesticide.

Notification and Posting:
Commercial applications on golf courses, lawns, community rights-of-way, as well as all indoor applications, should be indicated on a placard visible to employees and visitors, stating that pesticide applications do occur from time to time. On golf courses, signs should also be placed on the first and tenth tees at the time of application, noting the date and time of application and product information, until label reentry requirements have been fulfilled.

Right-of-way applications will likely only be posted at multiple use areas. Persons that want notification should be aware that notification may occur via newspaper advertisement in the legal section of a community paper.

Exhibits

Exhibit 1: Monitoring Techniques for Turf. "Turfgrass Pest Management: A Training Manual for Commercial Pesticide Applicators", Bulletin E-2627.

Exhibit 2: Pesticide Formulations. USDA, Soil Conservation Service (Michigan), 1992.

Exhibit 3: Pesticide Application Equipment and Methods. USDA, Soil Conservation Service (Michigan), 1992.

Exhibit 4: Pesticide Use Record. "Turfgrass Pest Management: A Training Manual for Commercial Pesticide Applicators", Bulletin E-2627.

Exhibit 1

Monitoring Techniques for Turf

There are a number of ways to monitor turfgrass for information used in a pest management program. One of the most common detection methods is the actual sighting of pests and their damage. The following describes turf pest detection methods.

1. Visual inspection. Get down on your hands and knees and part the grass with your fingers. Concentrate on the edge of the damaged area where fungal disease and insects are likely to be abundant. Watch for insect movement and check grass blades and thatch for insect cases or excrement (grass), or for fungal fruiting bodies.

2. Coffee can technique. Use this technique to flush turf insects out of grass crowns and thatch. First cut both ends out of a 2-pound coffee can. Drive one end a couple of inches into the turf, then fill the can with water. Wait a few minutes for insects to float to the surface.

3. White paper test. Use a sod lifter, cup cutter, sturdy knife, or a trowel to remove a small piece of sod. Slowly peel the sample including soil, thatch, and grass plants apart over a sheet of white paper. Against the white background, living organisms will be easily detected.

4. Turf roll-back. Cut a section of turf one foot square and roll it back to expose root-feeding grubs.

To be useful in turf management, detection information should include detailed information such as the specific area of turf showing injury, level of injury, or number of pests present per sample area. To keep detection information uniform, develop a system to rank turf condition. Use a standardized monitoring sheet.

Source: "Turfgrass Pest Management: A Training Manual for Commercial Pesticide Applicators", Michigan State University, Cooperative Extension Service, Bulletin E-2627.

Exhibit 2

Pesticide Formulations

Pesticide Formulations	Water Quality Hazard		Potential Environmental Hazard
	Med	Low	
Aerosol		X	Drift
Aqueous suspension	X		Runoff, Drift, Leach
Bait		X	Runoff, Leach
Controlled release formulation		X	Runoff, Leach
Dry flowable (water dispersable granule)	X		Drift, Runoff, Leach
Dry soluble	X		Drift, Runoff, Leach
Emulsifiable concentrate	X		Drift, Runoff, Leach
Emulsifiable solution	X		Drift, Runoff, Leach
Encapsulated	X		Runoff, Leach
Flowable	X		Drift, Runoff, Leach
Gas		X	Drift
Granule		X	Runoff, Leach
Liquid	X		Drift, Runoff, Leach
Pellet		X	Runoff, Leach
Soluble powder		X	Drift, Runoff, Leach
Ultra low volume		X	Drift
Wettable powder	X		Drift, Runoff, Leach

The pesticide formulation is a product of the pesticide's active ingredient and the inert carrier. The inert carrier and any additives--such as surfactants, stickers, defoaming agents, etc.--determine how easily and effectively the active ingredient is applied to the target pest. The formulation strongly influences the pesticide's potential for drift during application.

The runoff and leaching potentials of pesticides are strongly influenced by the pesticide's chemistry. The pesticide chemistry (i.e. the composition, structure and properties of the active ingredient and transformations it undergoes) becomes a potential environmental hazard after the pesticide is applied.

Exhibit 3

Pesticide Application Equipment and Methods

Pesticide Application Method	Potential Drift Hazard To Surface Water Quality		
	High	Med	Low
Airplane and helicopter (aerial spraying)	X		
Air assisted applicator (band application)			X
Airblast sprayer (broadcast application)	X		
Backpack sprayer, duster		X	
Controlled droplet applicator			X
Dips and drenches			X
Fogger	X		
Fumigation equipment			X
Granular application			X
Hand gun			X
Hand sprayer			X
Hopper box application			X
Impregnated fertilizer		X	
Incorporation into asphalt			X
Injector			X
Irrigation equipment (chemigation)		X	
Low volume applicator		X	
Mister		X	
Recycling sprayer			X
Roller			X
Seed treatment			X
Spreader		X	
Transplanter and seeder			X
Wick			X
Wiper			X

This Exhibit provides the user a comparison of pesticide application methods. Each method is ranked as having a high, medium, or low potential to drift from the target pest and affect surface water quality.

Exhibit 4

Pesticide Use Record	
Name of applicator: Certification or Registered Technician number:	Date of application: Time of application:
Name of client and address of target area: Specific area(s) treated:	Target pest or purpose: Life stage of pest:
Air temperature: Windspeed and direction:	Soil moisture and texture: Sunny/cloudy: Rain before/after application? When?
Pesticide product name: Pesticide EPA registration number:	Pesticide rate: Amount applied:
Sprayer or spreader used: Date of last calibration:	Nozzle or gun size: Spray pressure or spreader setting:

Source: "Turfgrass Pest Management: A Training Manual for Commercial Pesticide Applicators", Michigan State University, Cooperative Extension Service, Bulletin E-2627.

Pond Construction and Management

Description

This BMP addresses two types of ponds, both of which can serve multiple purposes. This BMP does not address Sediment Basins, nor detention/retention basins or ponds. There are separate BMPs for Sediment Basins, Extended Detention Basins, Wet Detention Basins, and Infiltration Basins.

Excavated ponds are constructed by digging a pit in a nearly level area. They are made for conditions which require a small supply of water such as a golf course hazard. These ponds may require a permit from the MDNR, Land and Water Management Division.

Embankment ponds are made by constructing an embankment or dam across a stream or watercourse where the stream is such that 6 or more feet of water can be stored. Larger volumes of water can be stored using embankment ponds rather than excavated ponds. The Department will require an extensive assessment and justification to support the construction of a pond or dam in a natural stream. MDNR Act 346 permits will be required.

Note: Act 300, the Dam Safety Act, 1989, P.A. 300, states that a dam with a height of six feet or more and impounding five or more surface acres, requires a permit from the Michigan Department of Natural Resources. A permit is also required to repair, alter, reconstruct, enlarge, remove and abandon a dam. Inspection reports are also required under the Act, either every three, four or five years, depending on the hazard potential rating.

Pollutants Controlled and Impacts

Ponds can be used for stormwater management, to attract wildlife, to revitalize landscapes of poor quality, offer recreational opportunities and aesthetics, and offer water hazards on golf courses.

Surface water runoff provides a source of water to maintain the level in the **excavated pond**. If water quantity is more critical than quality, the runoff can be used to maintain higher pond levels.

Properly designed and maintained **embankment ponds** provide a safe, reliable means of water supply, and may become the settling area for sediment and contaminants in the drainage area.

Application

Land Use
This practice is applicable to all land uses.

Soil/Topography/Climate
Embankment ponds should be developed on soils which have the ability to hold water. Clays and silt clays are most suitable; sands and gravels less suitable. In less suitable soils, embankment ponds can be "treated" or sealed with materials such as clay or bentonite to make them suitable. Determine the suitability of the soil by soil surveys or soil testing.

When to Apply
Ponds should be developed during the growing season to allow rapid revegetation along the shoreline. Although pond development during winter months should be avoided (since spring runoff may result in the greatest amount of soil erosion back into the pond), in certain soil types development may be limited to the winter months. Development should occur during periods of low precipitation.

Where to Apply
Build ponds in areas where the water supply is adequate for the intended use and where water can be stored and accessed easily. Also, site ponds where dam failure would not result in significant downstream flooding. Avoid areas where pollutant sources from other land use activities could reach the pond. Except when developing wildlife ponds, avoid rich, organic soils, when possible.

Relationship With Other BMPs

The best way to extend the life of a pond is via proper site selection, and by implementing erosion controls in the drainage area. Slope/Shoreline Stabilization may be needed to protect slopes from erosion and wave action.

Vegetation should be established as soon after the pond is developed as possible using Seeding and Mulching or Sodding and other related BMPs.

Specifications

Planning Considerations:

1. Conduct a site evaluation to determine the best location for the type of pond needed.

   For embankment ponds, consider upstream drainage characteristics and how the pond will affect downstream flows, temperatures, etc. Also consider **hazard potential ratings**. All dams have a hazard potential rating, (either high, significant or low, depending on downstream impacts in the event of a dam failure). Ratings are based on the U.S. Army Corps of Engineers 1977-1981 National Dam Safety Program Inventory of Dams.

   For excavated ponds, consider drainage characteristics, including depth to the water table. All excavated ponds should be constructed in low-erosion areas to blend in with the surrounding topography. Where possible, native vegetation should be preserved to give the pond a natural look, and to provide shade.

2. Determine soil type, and rainfall amounts and expected frequencies.

Design Considerations:
Ponds should be designed by registered professional engineers.

1. The overall design of the pond should be based on the site characteristics and the intended use of the pond.

2. If the pond is to be used for irrigation, determine irrigation needs and design the pond accordingly.

3. Consider using a more irregular pond shape to provide more edge effect. A shallow ledge 10-20 feet wide or wider along the pond perimeter can be created to promote wildlife usage.

4. Install wildlife nesting islands if they can be placed more than 200 feet from shore, and if the intended use of the pond is not jeopardized. Water depth between the shore and island should be a minimum of 2 feet to discourage predation. These will need to be approved as part of the permit review process.

Embankment ponds:

1. If embankment ponds are to be sealed or lined to prevent groundwater infiltration, follow specifications in the Pond Sealing or Lining BMP.

2. All ponds should be developed to accommodate the runoff from a one percent or 0.5% chance flood event, depending on the hazard potential rating.

Excavated ponds:

1. Water in excavated ponds usually heats up to temperatures exceeding those of most streams at the inlet or outlet. Warmer water released from the pond may be harmful to the downstream water body. To allow cooling, ponds which will eventually release water to trout streams should be discharged over rock-lined (Riprap) and/or Grassed Waterways before releasing to the stream. The length of the waterway should be such that the water released to the river is within a few degrees of the stream temperature. (Note that for trout, water temperatures over 70 degrees F are considered to be stressful, and those above 77 degrees are lethal).

2. Consider using "bottom draw" outlet structures so that cooler water from the bottom of the pond enters the stream.

3. Upon completion of excavation, a six-inch layer of topsoil that is seeded and mulched will assist in the re-vegetation of shoreline and shallow water areas.

Slope and Depth:

For fish ponds: the slope should be 3:1, average depth should be 8-10 feet, and the maximum depth 12 feet or greater. Consider flatter slopes or a fence for safety. For wildlife ponds: the slope should be 10:1 or greater, average depth should be 2-3 feet, and the maximum depth 6 feet or less.

Construction Considerations:

Embankment ponds:

1. Construction should be done in accordance with all pertinent Michigan laws, including the Wetlands Act.

2. Install upland BMPs to prevent sedimentation of the pond. Coordinate BMPs using the Staging and Scheduling BMP.

3. Construct the pond according to design.

4. Install pond liners following specifications in the Pond Sealing and Lining BMP.

5. Dredge spoils from construction of ponds, including those permitted in or adjacent to wetland areas, must be placed on an upland site, and stabilized to prevent erosion. Permits will not generally be issued for the disposal of spoils in wetland locations.

6. For ponds with dams. Trees and brush shouldn't be allowed to grow on the dam embankment. Remove trees for a distance of 30-50 feet from the edge of the pond to prevent organic matter from accumulating in the pond. Establish a windbreak of evergreens or bushes. See the Tree Protection BMP for information on how to protect trees which will not be cut, as well as to determine which trees to cut. Use Garlon or other suitable herbicides to control brush, following specifications in the Pesticide Management BMP.

Excavated ponds:

1. Install upland BMPs to prevent sedimentation of the pond. Coordinate these BMPs using the Staging and Scheduling BMP.

2. Use proper Land Clearing and Grading Practices, and, where possible, leave a natural Buffer/Filter Strip around the pond.

3. Construct the pond according to design.

4. Spoil Piles should be removed from the site, smoothed back gradually to provide an even slope to the pond, or used as Diversions or berms around the pond to divert nutrient-rich surface water away from the pond. If the spoils come from a wetland, replacing them in or on the shore of the pond will help establish wetland vegetation.

After Construction:

1. Areas around the pond should be stabilized following specifications in the Seeding and Mulching or Sodding BMPs.

2. A Buffer/Filter Strip should be left around the pond. No fertilizers or pesticides should be applied in the buffer/filter strip except where necessary. When using fertilizers and pesticides in the drainage area around ponds, follow specifications in the Fertilizer Management and Pesticide Management BMPs.

3. Where appropriate, a safety station, equipped with a long pole or flotation device, should also be placed around the pond for personal safety.

Maintenance

Ponds are small ecosystems and as such are easily impacted and change quickly. Consequently, continuous management of the pond may be necessary to maintain it for its desired uses. Maintenance of upland BMPs can prevent pollutants from entering the pond and shortening its lifespan.

Routine **mowing** around embankment ponds should be done to keep unwanted vegetation from growing on the impoundment. Mowing makes the embankment less attractive to burrowing animals, prevents development of seepage paths along roots, and helps prevent dam failure.

If wildlife benefits are desirable, only mow once every three years, between July 15 and September 1. This will discourage woody vegetation while maintaining nesting and winter cover.
For pond treatment of **weeds**, start by reviewing your fertilizer management plan to ensure you are following specifications in the Fertilizer Management BMP. Weed control can be done via harvesting, altering the water levels and chemical treatment. Contact the Soil Conservation Service, local Cooperative Extension Service or the MDNR, Land and Water Management Division for weed removal options. Note that any natural or artificial lake, pond or impoundment which has a surface area five acres or greater, has definite banks, bed and continued or recurrence of water, will require an Act 346 permit for weed removal.

Purple loosestrife (Lythrum salicaria) is an undesirable, exotic perennial which often becomes established in disturbed sites. Eradicate purple loosestrife before plants become established and develop a large seed bank. Eradicate by hand pulling or digging, if feasible. Otherwise, cut stems and paint with a 50% solution of Roundup or Rodeo during July or August. Only **spot treatment** of Rodeo or Roundup should be done because these are broad-spectrum herbicides which will kill virtually all vegetation (including trees) in the sprayed area. Garlon 3A is also effective on the weed. Apply all pesticides following specifications in the Pesticide Management BMP.

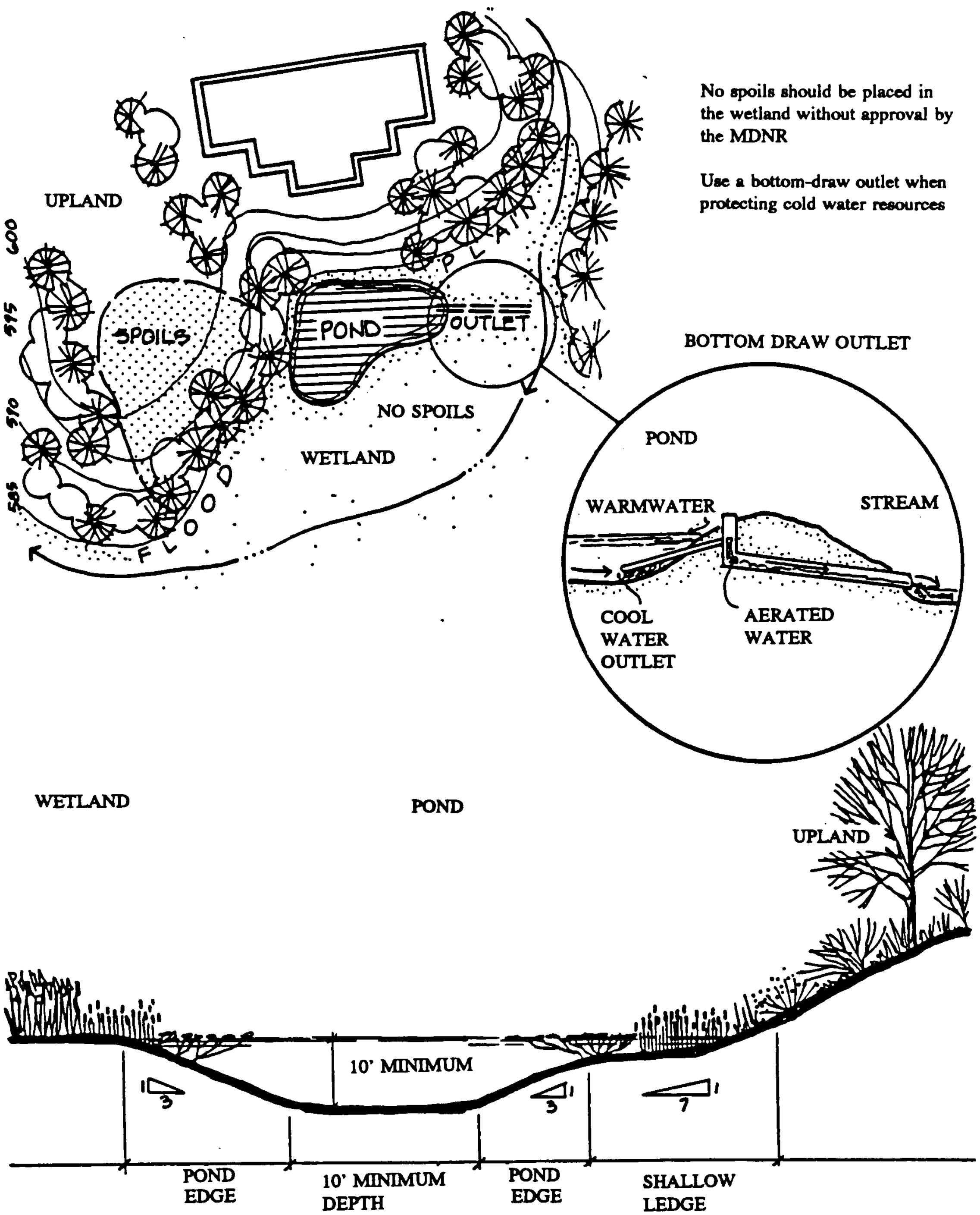
Permits from the MDNR, Land and Water Management Division, are required for herbicide treatment if standing water is present.

Ponds with **dams** require extra attention, since a break in the dam may affect the downstream riparian. Maintain barriers to prevent animals from accessing the pond. Fill any wash-outs that form and reestablish vegetation where erosion occurs. Maintain bank slopes and repair any muskrat damage.

Exhibits

Exhibit 1: Typical Pond Construction. Construction Project Evaluation Manual. Michigan Department of Natural Resources. 1987.

Exhibit 1
Pond Construction



Source: Construction Project Evaluation Manual. Michigan Department of Natural Resources, Land and Water Management Division.

Pond Sealing or Lining

Description

Pond sealing or lining is the process of installing a fixed lining of impervious material, or mechanically treating the soil in a pond to impede or prevent water loss. Ponds can serve as stormwater management detention facilities, add visual aesthetics, create an environment for wildlife, and serve as golf course hazards.

Pollutants Controlled and Impacts

Properly sealed ponds help prevent pollutants from infiltrating into the ground water and provide water storage in soils with high infiltration rates.

Application

Land Use
This practice applies to all land uses, but may be most important in areas where there are vulnerable aquifers, such as on sandy soils.

Soil/Topography/Climate
Soils at the site determine whether a pond needs to be sealed, and what type of material is needed in order to result in an effective seal.

When to Apply
Apply when soils are such that water cannot be retained, or in areas where groundwater is in need of protection.

Where to Apply
Apply on sites where soil types dictate an impervious liner is needed to retain water, or where possible leaching of unwanted pollutants or fine soil particles may adversely affect ground water.

Relationship With Other BMPs

Development of the pond should follow specifications in the Pond Construction and Management BMP. Spoil Piles should be properly stabilized during the pond lining process.

Specifications

General Considerations:

1. Site selection, construction and management of a pond should be consistent with specifications listed in the Pond Construction and Management BMP.

2. Soil samples should be collected from sites under consideration to help determine the type of pond sealer or liner that is needed.

Design Considerations:

1. Ponds designed with liners that exceed low-head dams in height or receive high volumes of surface water runoff, should be designed by a certified engineer.

2. Pond liners should be incorporated into the overall design of the pond. Refer to the specifications in the Pond Construction and Management BMP.

3. Maintain a slope of 4:1 or less on the bank of the pond.

Choose from the following types of liners:

Compaction: Areas containing a high percentage of coarse grained material can be made relatively impervious by compaction without any other treatment methods. However, the material must be well graded and consist of small gravel or coarse sand to fine sand, clay, and silt. This method of sealing is the least expensive, but it can only be used on the soil types described.

1. Clear the pond area of all trees following specifications in the Land Clearing BMP. Fill all stump holes, crevices and similar areas with relatively imperious soils.

2. Scarify the soil (see Grading Practices BMP) to a depth of 8-10 inches with a disk, roto-tiller, pulverizer, or similar equipment. Be sure to remove all rocks and tree roots.

3. Under optimum moisture conditions, roll the soil under to a tight layer making 4-6 passes with a sheepsfoot roller to compact the soil. The soil should be compacted to a minimum of 8 inches for impoundments up to 10 feet in depth. In cases where the depth of the water will exceed 10 feet, remove the top layers of soil and compact the bottom two or more layers. Each layer should be no more than 8 inches thick. Once the bottom layers are compacted, replace the topsoil and compact it like the other layer(s).

Clay: Areas dominated by coarse grained materials and lacking sufficient amounts of clay to prevent seepage can be sealed by adding material containing at least 20% clay:

1. The clay material should be a minimum of 18 inches thick for all depths of water up to 10 feet. Increase the minimum thickness by 2 inches for each additional foot of water.

2. Properly compact the clay according to the design to ensure a good seal.

3. Do not use in areas where drawdowns will be done. The exposed clay may crack and the seal therefore rendered ineffective. If drawdowns will be done, cover the clay with 12-18 inches of gravel.

4. Protect the clay and/or clay/gravel seal area by constructing a cantilevered pipe or rock Riprap at the intake point.

Bentonite: Bentonite is a fine-textured colloidal clay that will absorb several times its own weight of water. When Bentonite is mixed with coarse grained materials, then thoroughly compacted and saturated, it will fill pores in the material and make it virtually impervious.

1. Soil tests should be collected and analyzed to determine the percentage of Bentonite needed. Rates range from 1 to 3 pounds per square foot, depending on the soil content.

2. Do not use Bentonite in areas where the water level fluctuates significantly. When dry, Bentonite returns to its original volume and will leave cracks in the pond.

3. Excavate soil, mix Bentonite thoroughly with the soil in a pug mill, and apply to a depth of at least 6 inches.

4. Compact the area with a minimum of 4-6 passes of a sheepsfoot roller, or equivalent, to achieve required density. Pay special attention to moisture content.

5. If enough time will elapse before the Bentonite is covered with water for it to dry out, cover the treated area with a mulch of straw or hay anchored to the surface by the final passes of the sheepsfoot roller.

6. Protect the inflow to the treated area with Riprap or other appropriate measures.

Flexible Membranes: Flexible membranes include polyethylene, PVC, vinyl, and butyl rubber. Although structurally weak, these materials are water-tight if kept from puncture and properly sealed.

1. Choose from:

    a. Vinyl, which is more resistant to damage from impact than other flexible membranes, and is easily sealed and patched with a solvent cement.

    b. Polyethylene, which can only be sealed or patched by heat sealing.

    c. Butyl rubber, which can be joined and patched with rubber cement.

2. All polyethylene and vinyl membranes should be covered with no less than 12 inches of soil that is free from rocks and other injurious materials. The bottom 3 inches of soil/gravel should be coarser than silty sand.

3. Because certain plants can penetrate the membrane liners, it may be necessary to sterilize the subgrade. Sterilization is not needed on butyl rubber membranes.

4. Anchor the top edge of the lining in a trench at the planned water level. The anchor should be buried 8-12 inches in a trench and secured with compacted backfill.

Chemical Treatment: The two types of chemical treatment discussed below can be used to line ponds if the specific products selected are chemically stable (i.e. are not leached into the water column) once they are applied.

1. Dispersing Agents. Dispersing agents are used to "seal" the porous holes that form between fine-grained clay particles. To be effective, the soils in the pond area should contain more than 50% of the fine-grained material (silt and clay finer than .074 mm diameter) and at least

15% of clay finer than .002 mm diameter). Soils should contain less than 0.5% soluble salts based on dry soil weight.

a. Mix the dispersing agent into the top 6-inch layer of soil using a disk, roto-tiller, pulverizer or similar equipment. The thickness of the layer for depths of water up to 8 feet should be 6 inches. For water depths exceeding 8 feet, the layer should be 12 inches thick, treated in two 6-inch layers. For the best results, operate the mixing equipment in two different directions.

b. Compact each treated layer with 4-6 passes of a sheepsfoot roller, or equivalent.

2. Cationic Emulsion. In order to use cationic emulsion, the top 2 inches of soil should be sandy, very fine through very coarse, or loamy sands and sandy loams.

a. Use sealants that are emulsions of suitable bituminous, resinous, or polymeric bases, with infinite dilutability and good stability after dilution.

b. Apply only when air and water temperatures are above 40-degrees F.

c. Minimum application should be 1 gallon per square yard. Follow manufacturer's directions.

Construction Considerations:
Follow construction specifications included in the Pond Construction and Management BMP. Install the liner promptly upon completion of the excavation processes. In the case of plastic liners, the pond should be filled immediately with water to stabilize the liner and cover the soil layer.

After Construction:
Stabilize the slope with vegetation to minimize erosion.

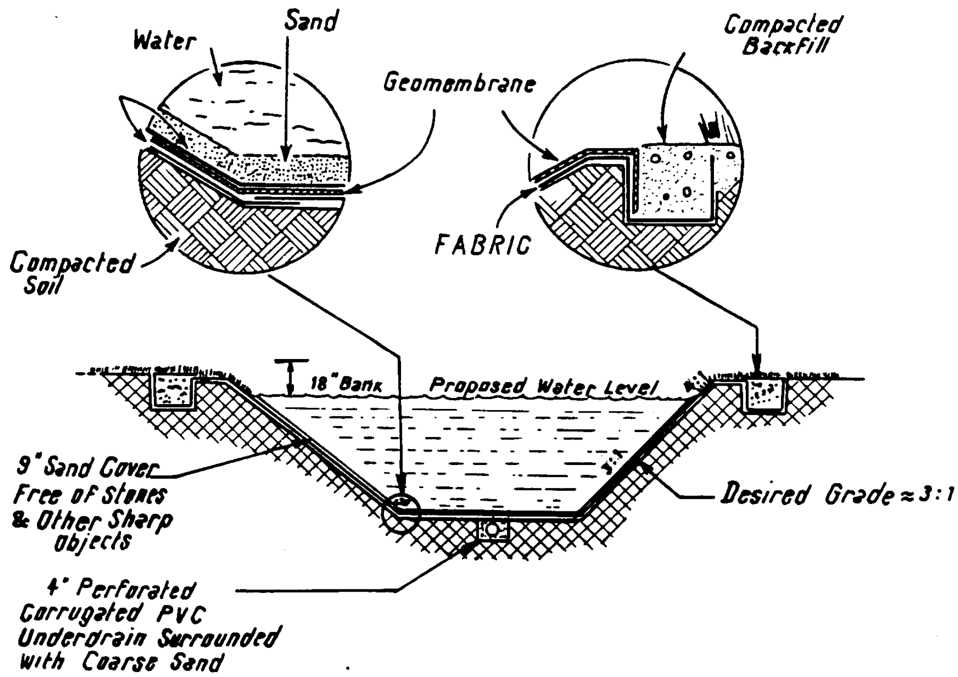
The water level of the pond should be kept at a sufficient level to minimize erosion of earth material covering the pond liner.

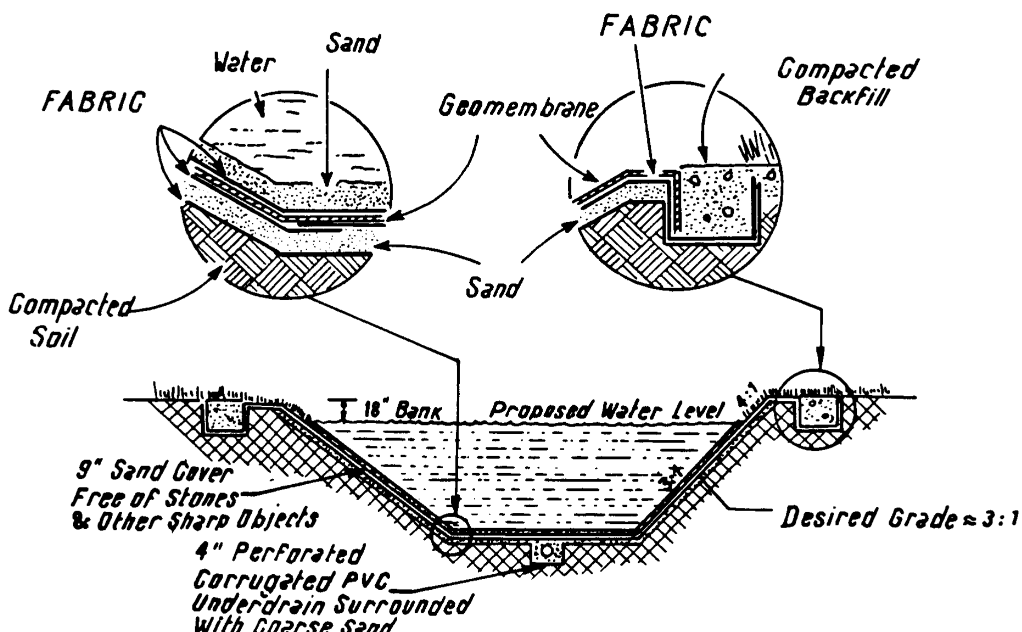
Exhibits

Exhibit 1: Pond Sealing Methods. Warren's - TerraBond Field Manual and Specification Guide.

Exhibit 1

Pond Sealing Methods





SOURCE OF DETAILS
WARREN'S - TerraBond
Field Manual and Specification Guide

MATTHEWS & ASSOCIATES P.C
GOLF COURSE ARCHITECTS
Lansing...Grand Haven, Michigan

Slope/Shoreline Stabilization

Description

This BMP addresses structures which stabilize shorelines and slopes that cannot be stabilized with vegetation. Structures included in this BMP are: revetments, gabions, seawalls, bulkheads, groins, breakwaters and retaining walls. Typical applications of each of these structures are included in this BMP. Note that some of these structures are also used to stabilize stream banks. For additional information on these and other practices which can be used to stabilize stream banks, see the Stream Bank Stabilization BMP.

Permits for the construction of slope/shoreline stabilization practices will be required by the Department of Natural Resources, Land and Water Management Division if the structure is below the ordinary high water mark of a lake (or stream), floodplain or wetland. In some situations, both MDNR and U.S. Army Corps of Engineer permit requirements will need to be met.

Other Terms Used to Describe

Breakwalls
Bulkheads
Gabions
Groins
Retaining Walls
Revetments
Seawalls

Pollutants Controlled and Impacts

These practices protect the shorelines of watercourses by stabilizing embankments, thus limiting the erosion of soils and their associated particles into a watercourse.

Application

Land Use
This practice is applicable to all land uses.

Soil/Topography/Climate
The type of shoreline stabilization method used will vary depending upon the soils, slope of the land, groundwater characteristics, and the climatic conditions of the area. Their use is very important in areas where there are steep slopes, highly erodible soils, and where conditions can significantly increase or create erosion (i.e. areas of flash floods, strong winds and lake shorelines).

Special consideration should be given to the design and use of structures that will be susceptible to the forces of ice movement. Ice action has been shown to weaken, dislocate, and destroy improperly designed and installed structures.

When to Apply
Slope/shoreline stabilization structures should be installed prior to or immediately after disturbing erodible soils. Seasonal limitations exist for the construction of several of these structures, some of which are included in the specifications.

Where to Apply
Apply this BMP in areas where there is active or foreseeable erosion of the soils adjacent to a watercourse or wetland, and/or on steep slopes. Note that the construction and installation of these structures should not result in encroachment into the watercourse or wetland.

Relationship With Other BMPs

Areas up-slope of these structures should be stabilized with vegetation following the Seeding and Mulching or Sodding BMPs. In some instances, Diversions can be used to divert water away from these structures while they are being developed. Geotextile Filters are often used under these structures to filter sediment.

Specifications

General Considerations:
All slope/shoreline stabilization structures should be designed by licensed professional engineers, or other persons trained and experienced in their design.

1. All slope/shoreline stabilization structures should be free of sharp edges and protruding metals.

2. All structures require a site visit to determine the appropriate structure. During a site visit:
   - determine the soil texture and its inherent stability
   - determine the normal and storm surge water elevations
   - measure the length and (where appropriate) height of the area
   - consider the elevation of the proposed location for the new structure in comparison to the elevation of the existing shoreline

3. When designing structures, always try to follow the contour of the existing shoreline.

Revetments:
Revetments are stone, rock, interlocking blocks, gabions (see below), stacked bags (filled with sand or grout), or special mats, which are placed at the toe of a bluff to protect against storm/wave action. Revetments are cost effective, beneficial to the affected property owner, and do little or no harm to a lake environment *provided* the revetment material is clean, stable, and tied to existing structures and/or the shore.

General Considerations:
1. The three basic components of a revetment are the armor layer which absorbs the wave energy, the underlying filter layer supporting the armor layer, and the toe protection to prevent displacement of the armor units. All components should be designed simultaneously.

2. The stability of a revetment depends on the underlying soil conditions and should therefore be constructed on a stabilized slope. Erosion may continue or accelerate on an adjacent shore if it was formerly supplied with material eroded from the now protected area.

3. Slopes steeper than two horizontal to one vertical (2:1) are generally not suitable for revetments.

Design and Construction:

1. Riprap design and installation should be done following specifications in the Riprap BMP. Upon Department approval, consider installing fish habitat structures in conjunction with rock rip-rap to both stabilize an embankment and improve fish habitat.

2. Inter-locking blocks and honeycomb-shaped plastic sections which are backfilled with soil have been used successfully on steep slopes. The manufacturer's/suppliers listing in the Appendix of the "Guidebook to Best Management Practices for Construction Sites and Urban Areas" includes companies which carry these type of products.

Gabions:

Gabions are flexible woven-wire or plastic baskets composed of two to six rectangular cells filled with stone. They can be used in lakes and steep shorelines (or where river flow is such that riprap will not hold). The following is modified from "Guidelines for Soil Erosion and Sediment Control," Connecticut, 1985.

General Considerations:

Since gabions are used where erosion potential is high, construction must be sequenced so that the gabions are put in place with the minimum possible delay. Disturbance of areas where gabions are to be placed should be undertaken only when final preparation and placement of the gabions can follow immediately behind the initial disturbance. Always work at the low lake level (or low stream flow level).

Design:

Gabions may be used when all the following conditions are met:

a. The design storm, riprap size and location, filter and quality criteria for riprap are met.

b. The design water velocity does not extend beyond that given in Table 1, below.

Table 1

Design Water Velocity

Gabion Thickness (ft.)	Maximum Velocity* (ft./sec.)
1/2	6
3/4	11
1	14

*Maximum velocity is the velocity at the gabion (not, for example, the mean stream velocity.

Source: U.S. Department of Agriculture, Soil Conservation Service, Storrs, Connecticut.

c. The Manning's "n" value used for gabions shall be 0.025.

d. The pH of the soil and water is above 5, and the soil water resistivity is more than 4,000 ohms/cm, or plastic coated gabions shall be used.

e. A filter is required unless the gabion has a thickness of at least three times the D_{50} size of the rock used to fill the gabions.

f. The rock used to fill the gabions shall be larger than the gabion mesh opening.

g. Manufacturer's specifications are followed.

<u>Construction:</u>

1. Each gabion should be assembled by binding together all vertical edges with a continuous piece of connecting wire looped twice around the vertical edges with a coil approximately every four inches, except the mattress type where the coil should be approximately every three inches. Empty gabion units should be set to line and grade as shown on the plans. Connecting wire should be used to join the units together in the same manner as described above for assemble. Internal tie wires should be uniformly spaced and securely fastened in each outside cell of the structure. When gabions are being placed as slope protection or channel lining, the internal tie wires may be deleted.

2. Care should be taken when placing aggregate to assure that the sheathing on PVC-coated gabions will not be broken or damaged.

3. A standard fence stretcher, chain fall, or iron rod may be used to stretch the wire baskets and to maintain an alignment. After a gabion has been filled, the lid should be bent over until it meets the sides and edges. The lid should then be secured to the sides, ends and diaphragms with the connecting wire in the manner described above for assembling.

4. When the mattress type gabions are placed on 1.5:1 (or steeper) slope, steel stakes should be driven through the gabion along the top edge, as necessary, to hold the structure in place. Manufacturer's directions should be followed closely.

Seawalls and Bulkheads:

A seawall is a structure that is built to protect the landward side of a slope from damaging wave action or currents. Seawalls may be constructed with concrete, steel sheet piles or wood. Bulkheads have two functions. The first is to retain or prevent sliding of material seaward, and the second, to protect the upland against damage from wave action. The effects of seawalls and bulkheads on the entire reach of shoreline (or stream edge) must be evaluated.

General Considerations:

1. If the adjacent property has a seawall, a similar seawall in height and location should be used. It should tie into existing adjacent walls.

2. If the adjacent property is not seawalled, the proposed wall should tie into the shoreline and include tie backs into the upland. Tie backs should be riprapped at the shoreline to prevent erosion of adjacent properties.

Design:

1. The structure should be located and designed such that the structure will not create navigation safety hazards, debris traps, accelerated erosion of adjacent property, or any other problems.

2. The design should be appropriate for the site. Consider using materials similar to adjacent property owners. This will make the water line look more aesthetically pleasing.

3. Tie-backs must be designed to prevent erosion from water flow around the sides. Typical tie-backs extend 10 feet into the upland.

4. Bulkheads and seawalls that rise vertically well above a water or wetland surface may need to be equipped with ladders or escape measures in case of accidental falls by users.

Construction:

In general, for proper installation of steel or timber bulkheads, one-third of the wall should be above the lake bottom and two-thirds of the wall should be into the lake bottom.

Groins:

A groin is a shoreline protection structure which is usually situated perpendicular to the shore to trap soil for creating a beach on the up-drift side of the groin. These structures may consist of a single groin, or be combined with several groins to form a groin field. Careful design is needed to avoid adverse erosional effects on the down-drift side of a project.

General Considerations:

1. Groins by themselves will usually not provide adequate protection to the backshore area during a large storm. A wood retaining wall at the toe of the bluff may also be necessary to provide adequate protection.

2. Since groins may affect the "down-drift" area, the groin should be located and designed such that any erosion caused by the groin does not affect unprotected shoreline. Determine the new littoral transport direction by visual inspection of other groins in the vicinity, or review aerial photographs.

3. Spacing of groins depends on local wave energy and the amount of littoral drift. Groins should be spaced so that drift accumulates along the entire distance between the structures. (If the groins are too far apart, part of each compartment will be unprotected due to lack of accumulation. If the groins are too close together, not enough littoral material will accumulate in the compartments). As a rule of thumb, space groins from 1 - 1.5 times their effective length apart.

Design:

1. The proposed groin should not be longer than other groins in the vicinity.

2. Groins must be:
   - designed to cause the least damage to the down-drift side of the project
   - designed with no more than one foot above the current water level at the lakeward end
   - designed to extend into the face of the bluff or upland area
   - designed so that it is at least one-half of its length away from the property line. If this is not possible, then written consent must be obtained from the adjacent land owner.
   - constructed perpendicular to the shore

Groins constructed of wood or steel should extend 2/3 of the length of the material below the beach or lake bottom.

Construction:
Construction should be perpendicular to shore and should be done according to the design.

Breakwaters:
The function of breakwaters is to intercept incoming waves, dissipate their energy, and thus form a low-energy zone on the landward side. This reduction in wave energy reduces the ability of sediment transport. Sand moving along the shore is therefore trapped behind the structures and accumulated. Breakwaters are often placed as segmented structures that allow for the protection of longer reaches of shoreline for less cost.

Design:
The design and construction of breakwaters is usually done by or with the supervision of the U.S. Army Corps of Engineers.

Retaining Walls:
Retaining walls are used to stabilize steep slopes. They may made using riprap, railroad ties, gabions or other appropriate materials.

Maintenance

Annual inspections are important to check and re-align structures for functionability and safety. Check for hazardous materials or conditions which may have resulted from flooding, ice, or other weather conditions (i.e. look for sharp metal objects, signs of piping around structures, animal burrows, shifted and/or damaged materials within the structure, etc.).

Exhibits

Exhibit 1: Typical Revetment. Michigan Department of Natural Resources, Land and Water Management Division. Construction Project Evaluation Manual.

Exhibit 2: Gabions. Virginia Soil Erosion and Sediment Control Handbook. 1980.

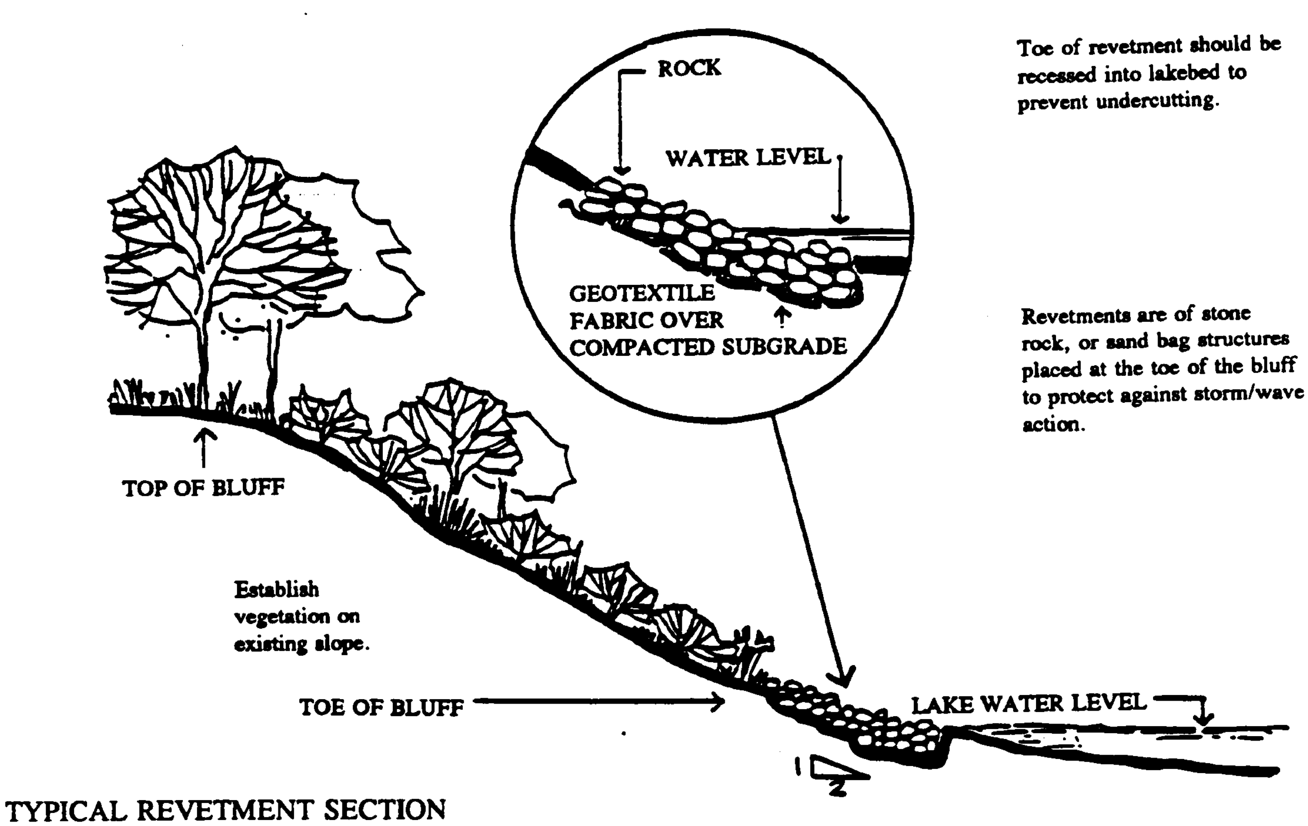
Exhibit 3: Seawalls: Four Situations and the Type of Structures Required. Michigan Department of Natural Resources, Land and Water Management Division. Construction Project Evaluation Manual.

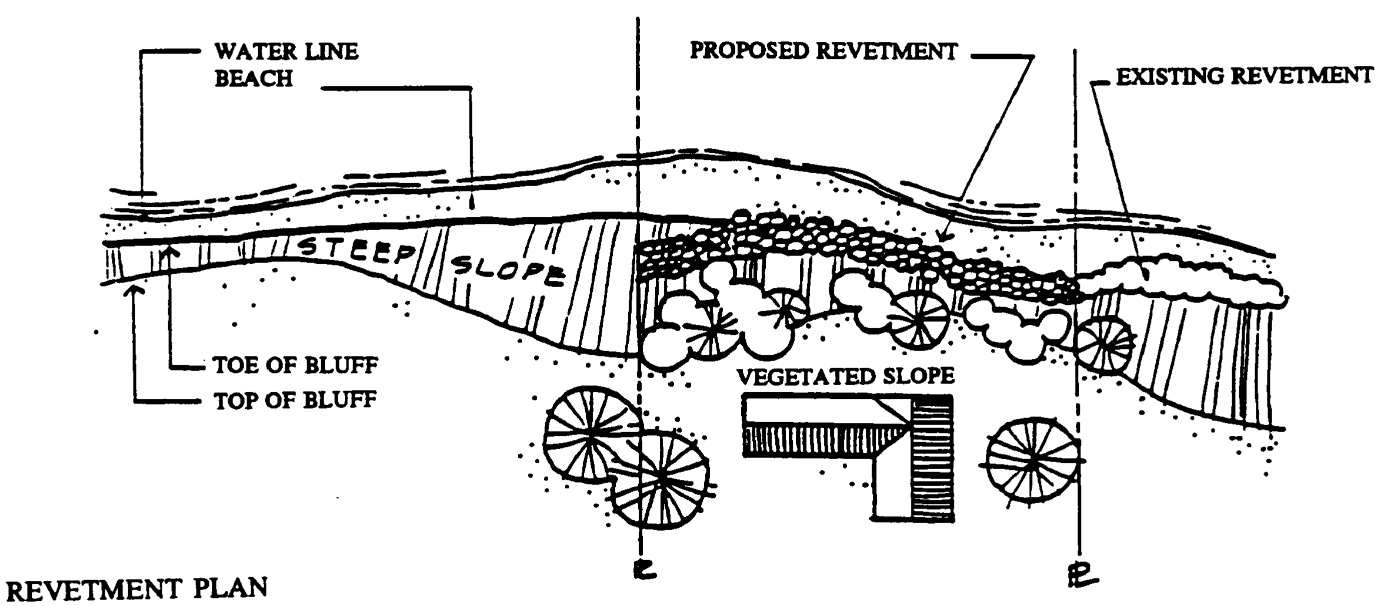
Exhibit 4: Groins. Michigan Department of Natural Resources, Land and Water Management Division. Construction Project Evaluation Manual.

Exhibit 5: Retaining Wall. Michigan Soil Erosion and Sedimentation Control Guidebook. 1975.

Exhibit 1

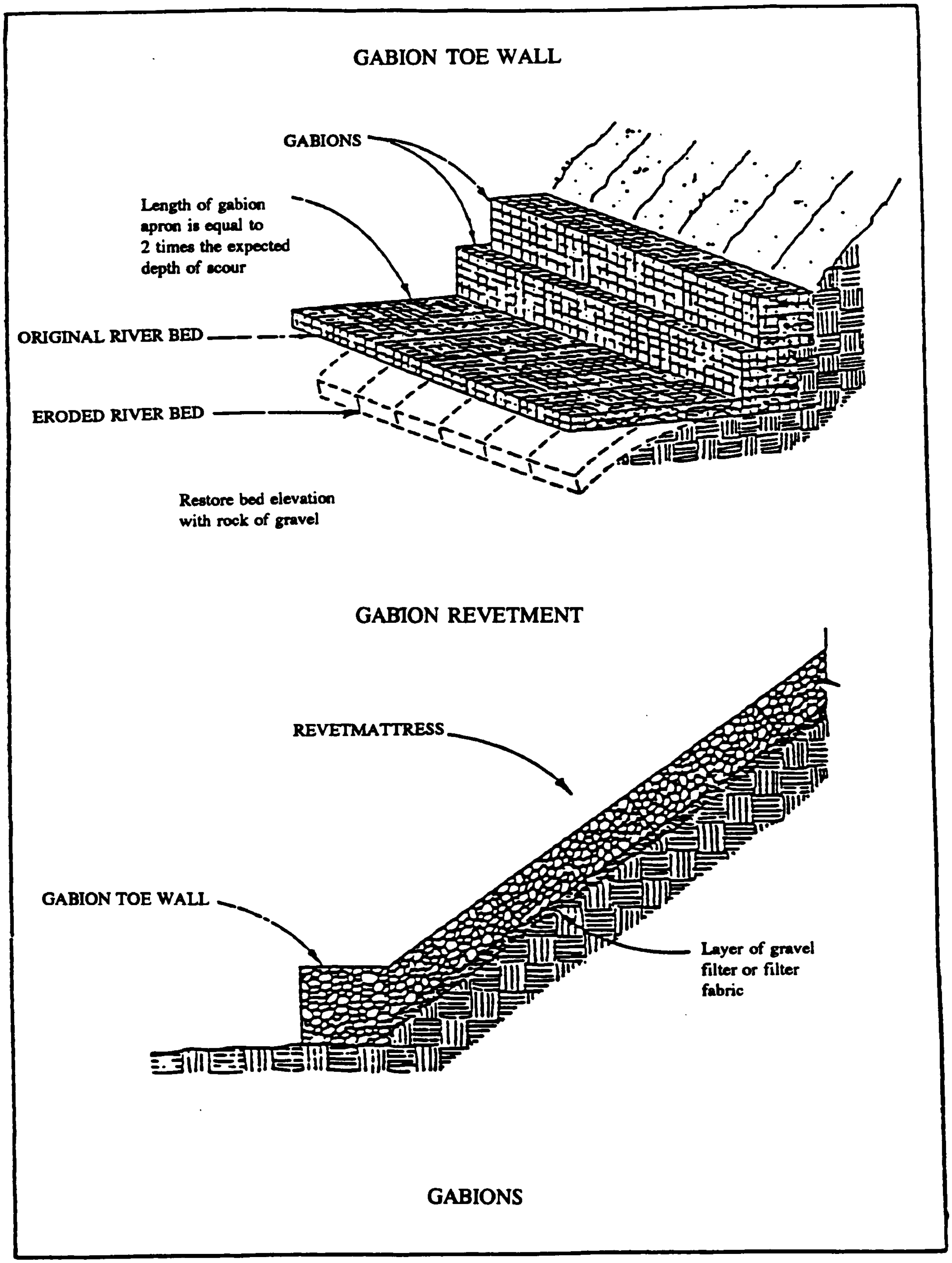
Typical Revetment





Source: Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

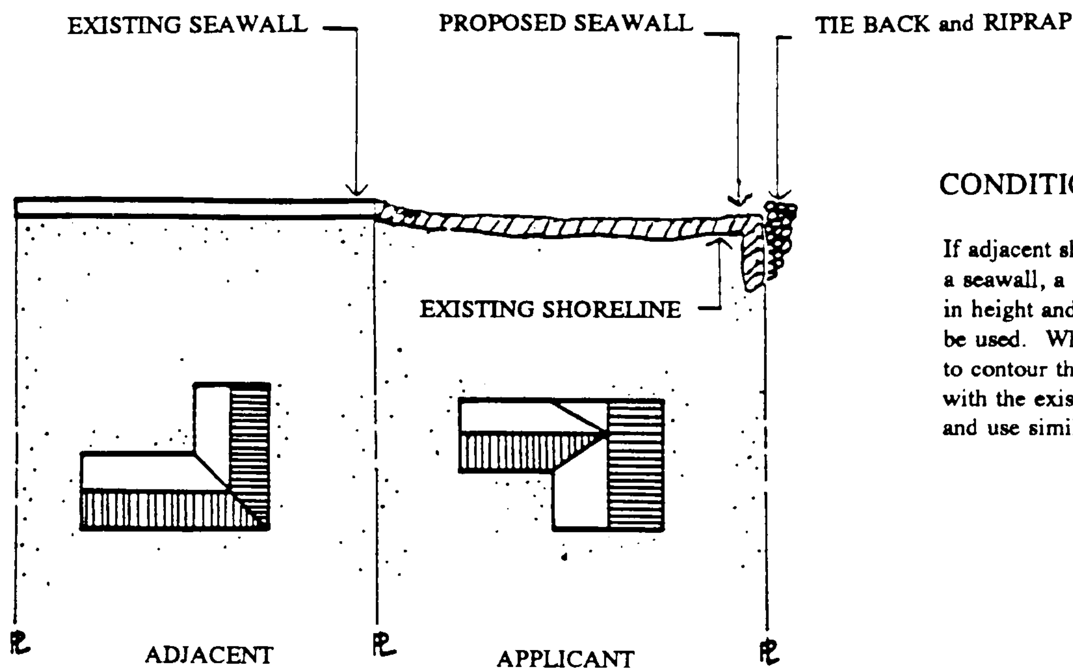
Exhibit 2
Gabions



Source: Virginia Soil Erosion and Sediment Control Handbook, 1980.

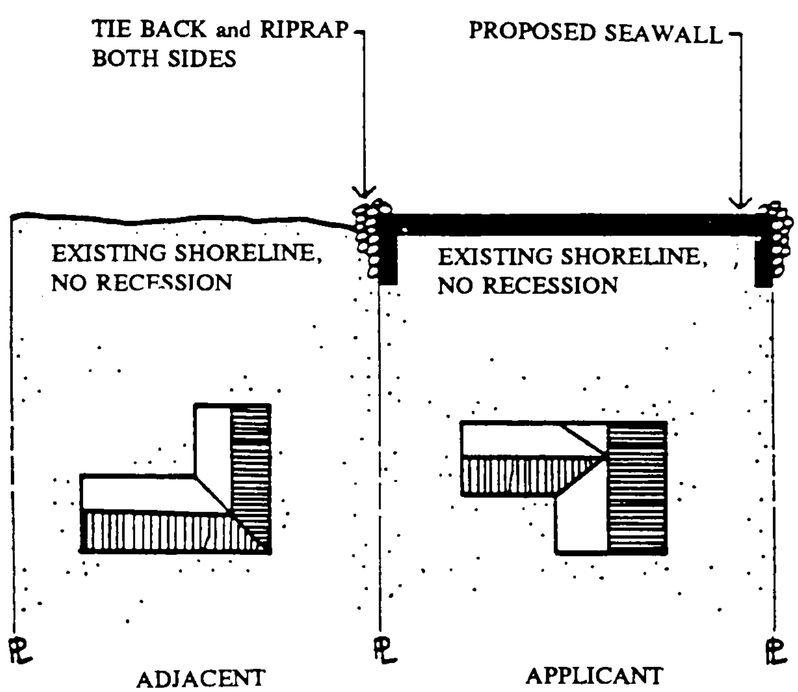
Exhibit 3

Seawalls: Four Situations and the Types of Structures Required



CONDITION ONE

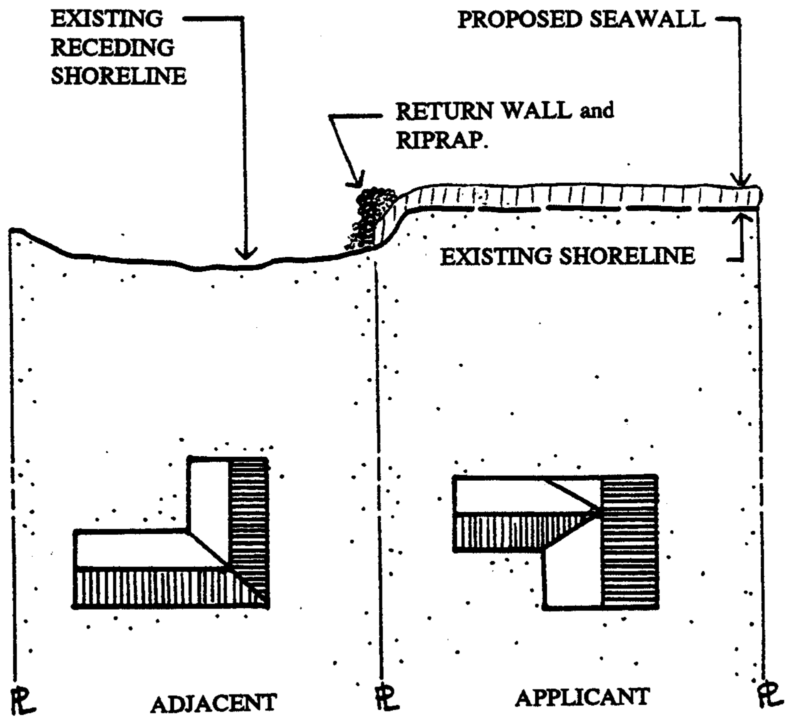
If adjacent shoreline has a seawall, a similar seawall in height and location should be used. Where possible, try to contour the new seawall with the existing shoreline, and use similar materials.



CONDITION TWO

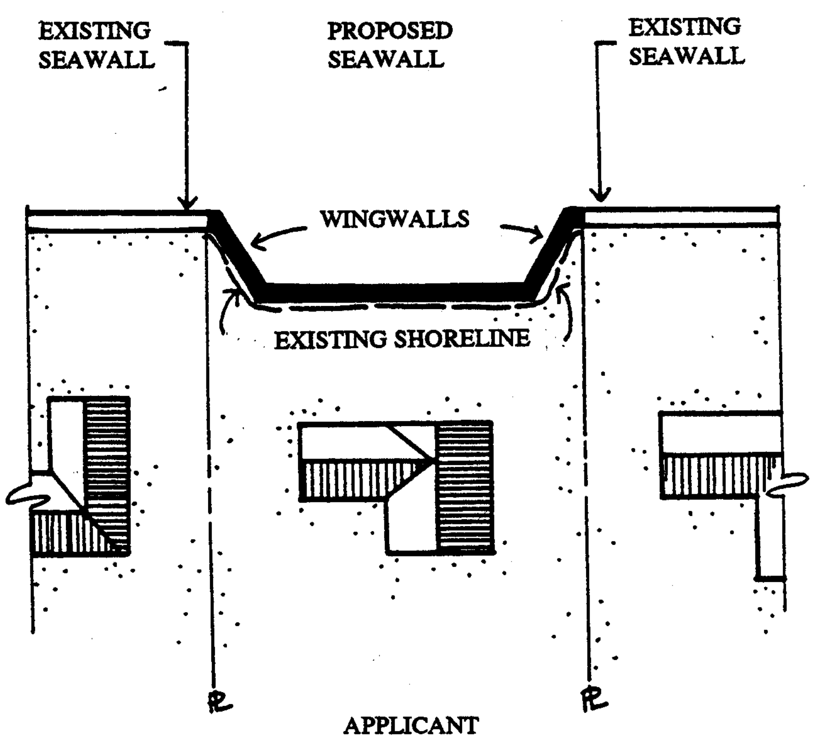
If adjacent shoreline has not recessed, a seawall parallel to the shoreline is required.

Exhibit 3 (Con't)



CONDITION THREE

If adjacent shoreline is recessed, a return wall is required.



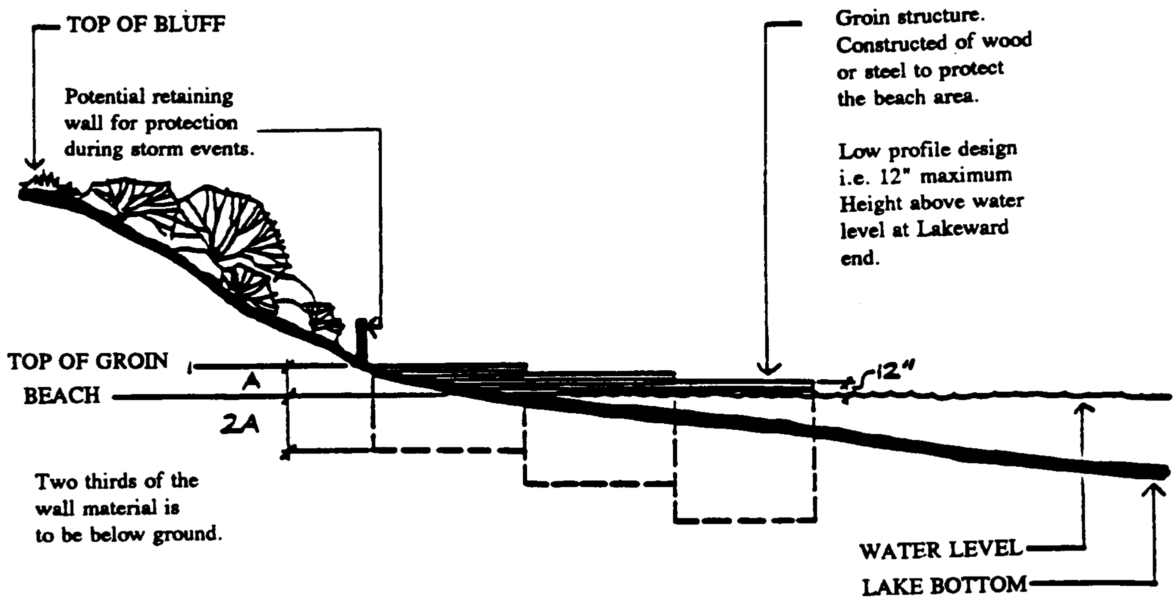
CONDITION FOUR

If adjacent shorelines have seawalls and existing shoreline has recessed significantly, a seawall with wingwalls is required.

Source: Modified from the Construction Project Evaluation Manual, Michigan Department of Natural Resources, 1987.

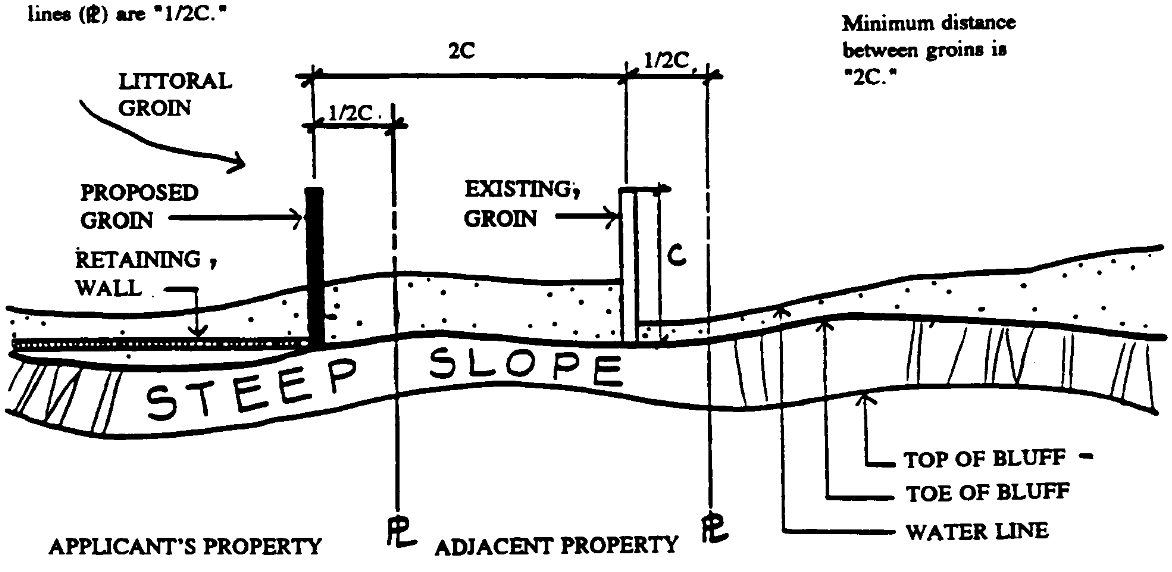
Exhibit 4

Typical Groin



TYPICAL GROIN SECTION

A proposed groin may be no longer than other groins in the vicinity (C). Unless authorized by adjacent landowners, minimum distances between groins and property lines (℄) are "1/2C."

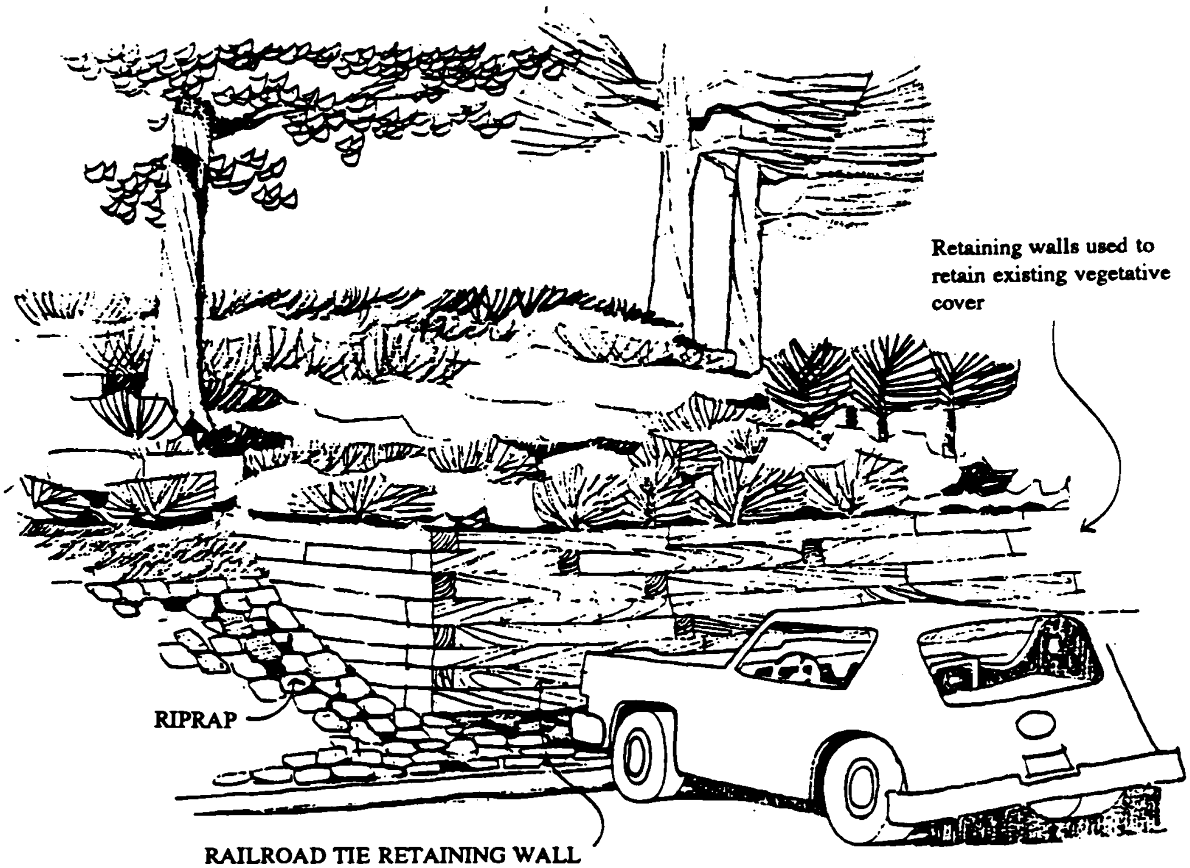


GROIN PLAN

Source: Construction Project Evaluation Manual, MDNR, Land and Water Management Division.

Exhibit 5

Retaining Wall



Source: Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

Stream Bank Stabilization

updated September, 1997

Description

This BMP discusses the thought process that should be used when eroding stream banks are deemed in need of stabilization. Emphasis is placed on stabilization at the watershed level first, then individual sites. Several systems of BMPs are discussed, with reference to specific BMPs. Emphasis is given to "softer", less rigid structures.

In all aspects of stream bank erosion—from source and cause identification to design and implementation of BMPs—people are encouraged to work with Department of Environmental Quality (DEQ) Nonpoint Source staff in Surface Water Quality Division, or with other stream bank experts.

Note that all stream bank stabilization activities will require permits from the Department of Environmental Quality, Land and Water Management Division. For a discussion on the use of gabions, seawalls and retaining walls, groins, shoreline revetments, and breakwalls, see the <u>Slope/Shoreline Stabilization</u> BMP.

Other Terms Used to Describe

Armoring
Revetments
Riprapping (Note that <u>Riprap</u> is a separate BMP)
Soil Bioengineering/Bioengineering
Stream Bank Protection

Pollutants Controlled and Impacts

Stabilizing stream banks can:

* Prevent the loss of land or damage to utilities, roads, buildings or other facilities adjacent to a watercourse, and prevent the loss of stream bank vegetation,
* Reduce sediment loads to streams,
* Maintain the capacity of the stream channel,
* Improve the stream for recreational use or as habitat for fish and wildlife, and
* Control unwanted meander of a river or stream.

Application

<u>Land Use</u>
This practice is applicable to all land uses.

<u>Soil/Topography/Climate</u>
The site-specific stream bank practices used will be partially dependent upon the types of soils present, the slope of the bank, gradient of the river, flow, and uses of the watercourse.

<u>When to Apply</u>
The appropriate time to apply stream bank erosion controls is dependent upon the method used. Some seasonal limitations are included in the specifications of referenced BMPs.

Where to Apply
Apply this practice in areas where stream banks are eroding.

Relationship With Other BMPs

Geotextile materials (Filters) are often used underneath Riprap.

Specifications

Since each reach of a watercourse is unique, stream bank protection techniques must be selected on a site-by-site basis; the specifications for each technique differ. The following is guidance which can be used to determine appropriate stream bank erosion control practices.

Planning Considerations:
It is important to remember that streams are dynamic. Even without human influence streams may meander, and in the process, cause banks to erode. Therefore, not all eroding banks are “bad” and in need of repair. In fact, the wrong system of BMPs installed in the wrong place may cause more damage downstream (and therefore to the entire stream system) than leaving the stream in its natural state. For example, “hard structures” like large riprap or gabions, placed on one eroding bank, can displace the stream’s energy downstream to a previously stable bank, causing the downstream bank to erode. If this downstream bank is also stabilized with a hard structure, the stream’s energy may be moved further downstream to another previously stable bank, and so on.

So before stabilizing stream banks, consider the cause of the stream bank erosion. If the banks are eroding due to a natural meander, then it may be best to leave the bank alone. If the banks are eroding due to fluctuations in hydrology, the hydrologic fluctuations should be addressed before the banks are stabilized.

Once the cause of erosion is addressed, determine the goal in stabilizing the stream banks. Some banks are stabilized to protect buildings and land. Others are stabilized to keep soil from entering the stream and to allow angler access to the stream. The purpose for stabilizing the banks and the users of the stream will help determine the type of structures needed.

Once the above concerns have been addressed, then it is important to work with agencies with expertise in stream bank erosion techniques to address stream bank erosion at the watershed level. Looking at the entire watershed will help prioritize bank stabilization efforts. If you are only interested in site-specific alternatives, please turn to “Methods” on page 5.

1) compile land use data on the watershed to determine if there is a direct link between land use and soil erosion. For example, land in livestock production can be a source of sediment if the livestock have direct access to the stream. If land uses are being converted from agriculture to urban, the increased impervious areas may cause increased flows to the stream, which may scour stream banks and cause erosion. Put simply, land uses can help pinpoint potential sources of erosion.

The DEQ, Land and Water Management Division’s Michigan Resource Information System (MIRIS) database contains information on the soils, land uses, streams, roads and other features in watersheds throughout the state. Keep in mind that as of the date of this printing, MIRIS data was based mostly on 1978 land use data. Many Soil Conservation District offices also have land use data (often based in part on the MIRIS). Several universities have sophisticated land use decision-making capabilities (which may include MIRIS data), as well as the capabilities to determine future land uses based on current trends.

Other important sources of land use information include topographic maps of the area, soil maps (if available), and aerial photos. These will show the pattern of the river as it meanders through the watershed. Comparing recent aerial photos to historic photos will also help determine if the river is widening, meandering or otherwise in a state of change.

2) Field verify the data. Because land uses change, it is important to field verify land use data in order to ensure decisions are made based on current and accurate information. This is particularly important in rapidly developing areas. Field verify data by walking or canoeing the entire river, or, if granted permission by property owners, by walking the stream banks. If you're not familiar with the river or stream, contact the DEQ, Surface Water Quality Division or Land and Water Management Division, or DNR, Fisheries Division to find out if the stream is wadable. In National Forest Service lands, contact the US Forest Service. These and other agencies will likely have some information on the stream you're interested in.

When you go out in the field, take a measuring tape, clipboard, pencil or waterproof pen, and multiple copies of the attached worksheet (Exhibit 1). A camera is also important when discussing site-specific conditions with other people. On wadable streams, take hip boots or waders. Use the attached worksheet while noting the specific areas of stream bank erosion. Note soil type and any log jams, construction activities, eroding road crossings, and improper stream access (e.g. cows in the water, areas where people have accessed the river for recreational opportunities, etc.). Where possible, measure the length and height of the eroded stream banks.

Back in the office, incorporate your visual observations with the land use data. Ideally, this will be done by incorporating your notes into the land use database.

3) Estimate the magnitude of the erosion and all potential sources of erosion. Sources of sediment to the stream may include angler access, livestock access, or poorly maintained or improperly designed road crossings. The magnitude of the erosion can be determined by ranking each site as severe, moderate or minor, using the attached field sheet (Exhibit 1). Use of the Universal Soil Loss Equation is discussed in an appendix of the Guidebook of BMPs.

4) Rank the sites. At its simplest, ranking sites can be based on addressing the most severe sites first and working from upstream to downstream, including tributaries. Another alternative is to rank sites based on four criteria: 1) degree of impact (severe, moderate, minor); 2) the cost of installing the system of BMPs needed; 3) landowner willingness to cooperate; and 4) "demonstration-ability." (i.e. amount of public visibility). "Demonstration-ability" is important if you plan to solicit volunteers or funding for stabilization efforts. This site ranking method was used in the Bear Creek watershed, Kent County.

5) Determine appropriate options for the high priority sites. Use the information gathered on land use and from visual observations (including photos) to evaluate stream bank stabilization alternatives. The BMPs selected should also help to achieve the overall goals for the watershed (such as improving fish habitat or providing greater recreational access). Review the scenarios below, the various <u>Methods</u> on page 5, and then contact stream bank experts to discuss site-specific options.

Stream Bank Stabilization Scenarios:
The following hypothetical scenarios illustrate various alternatives for stream bank stabilization:

Scenario 1: Visual observations show several minor stream bank erosion sites. Erosion was determined to be caused by stream flow. The amount of human influence on flow is low (i.e. it is naturally "flashy" versus flashiness caused by increased flow from urbanization). The decision in this case is to leave the eroding banks alone.

Scenario 2: Comparing aerial photos from 1938 and 1990 shows that the stream hasn't meandered much, yet there are hundreds of banks along the stream that are bare, mostly due to angler and canoeist access. The stream is a high quality trout stream and local people hold the river in high esteem. Since sediment is detrimental to trout habitat, the decision was made to stabilize stream banks in this watershed, providing access via stairways and canoe landings, and restricting access via practices such as fencing and brush mulch. Since the greatest reduction in sediment load will be gained by stabilizing severe sites, the most severe banks will be stabilized first, going from upstream areas, downstream. If more money becomes available, then moderate sites would be stabilized, again, starting upstream.

Scenario 3: The predominant land use is urban. Severe erosion is observed downstream of the urban area. In this hydrologically unstable area a stormwater management plan will be developed in conjunction with or prior to stream bank stabilization to reduce extreme hydrologic fluctuation and velocities. In this example, the decision was also made to work on an ordinance which would address stormwater practices to prevent additional flows to the stream.

Scenario 4: The predominant land use is agricultural. Moderate and severe bank erosion is occurring at several livestock access areas. In this example, cattle exclusion systems, including fencing and alternative watering areas, were designed and implemented in conjunction with stream bank stabilization techniques.

Scenario 5: Visual observations and historical aerial photographs show the stream to be relatively stable. Most of the adjoining land is rural/agricultural but is expected to experience 35% growth in the next 15 years: therefore, additional flows to the stream are expected. Two new road crossings are causing severe erosion downstream of the crossings. The decision was made to stabilize the banks downstream of the new crossings with structures which help absorb some of the energy from stream flow (see soil bioengineering structures, below). The decision was also made to work with the road commission so that future road designs would be done such that downstream areas are not impacted. An ordinance to provide on-site detention/retention of stormwater from the newly constructed area was also proposed.

Other Things to Consider
In selecting site-specific options to stabilize eroding stream banks, consult the Michigan Department of Environmental Quality (Surface Water Quality Division or Land and Water Management Division), local Conservation District, or other agencies or consultants experienced in stream bank erosion control. Also, be sure to check Exhibit 2 to see if your river is included on the list of Natural or Wild and Scenic Rivers. These rivers have special restrictions, depending on their designation. Contact the MDEQ, Natural Rivers Program staff for further information on the types of stream bank practices that can be used in Natural Rivers.

It is also important to get input from the people who may use the watercourse at the specific site in need of stabilization, (i.e. river boat guides, anglers, canoeists, etc.). Consider working through a local watershed steering committee, if available. These committees include representatives from a variety of backgrounds and interests.

NOTE: While considering BMP options, remember that no removal of sediment bars, snags, stumps, debris drifts, trees, brush or similar material should be done unless absolutely necessary, and upon approval by the MDEQ, Land and Water Management Division. This in-stream cover is necessary for channel diversity and aquatic habitat.

Methods:

There are numerous methods available to stabilize stream banks. Rather than discuss all of them or any of them in detail, below is a discussion of the most common practices.

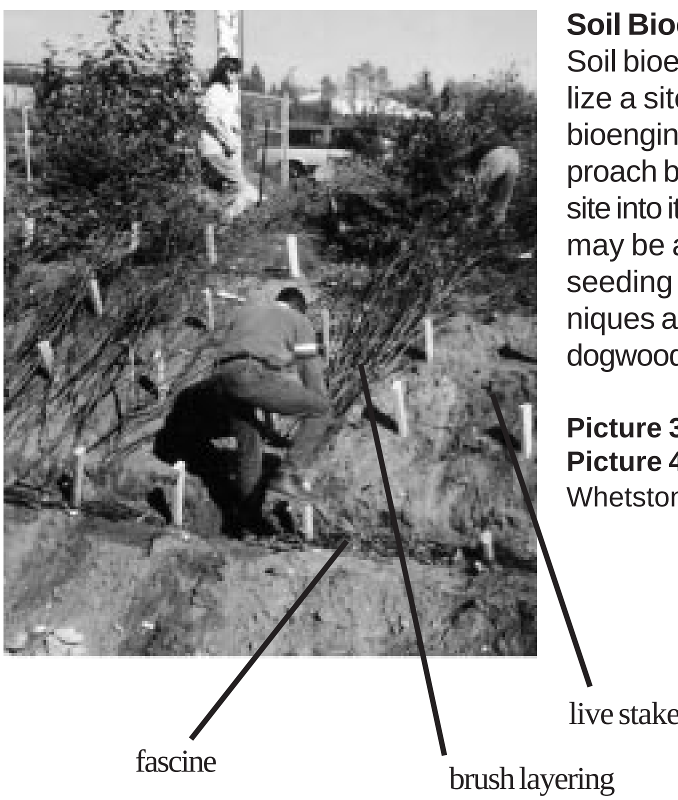
Riprap:

Riprap is one of the more commonly used stream bank stabilization techniques. It is a permanent cover of rock used to stabilize stream banks, provide in-stream channel stability, and provide a stabilized outlet below concentrated flows. It is generally used on stream banks at the toe (bottom) of the slope, with other structures placed up-slope to prevent soil movement. It is often a component of many soil bioengineering techniques. Specifications for riprap used in stream bank stabilization is discussed in the Riprap BMP.

Picture 1, above: The bank was stabilized with rock riprap from the toe (bottom) of the bank to the top of bank. This may be needed on streams with unstable hydrology (i.e. “flashy” streams), and where banks have groundwater seeps. Source: North Branch Chippewa River Nonpoint Source Project.

The Department supports the use of natural fieldstone for riprap; only natural fieldstone is allowed in rivers designated under the Natural Rivers program. The use of vegetation in conjunction with riprap is encouraged to "soften" stream bank structures.

Picture 2, right: Riprap was placed to 3 feet above the ordinary high water mark and a portion back-filled with soil. Log terraces were placed on the bank and the bank was seeded. This approach can be used on top of fish lunker structures and on banks where stream flows are relatively stable. Also note the fence and stairway to direct recreationist access. Source: Boardman River Nonpoint Source Project.



Soil Bioengineering:
Soil bioengineering is a method of using vegetation to stabilize a site with or without structural controls. Some refer to bioengineering as softening the traditional rock-the-bank approach because non-invasive vegetation is used to blend the site into its surrounding landscape. Bioengineering techniques may be as simple as using stop-logs to form terraces, then seeding exposed soil to help prevent soil movement. Techniques also include using fascines (long bundles of willow or dogwood), with layers of brush, along with individual plantings.

Picture 3, left, shows a fascine, brush layering and live stakes. **Picture 4, below,** shows new growth from a live stake. Source: Whetstone Creek Nonpoint Source Watershed Project.

Chapter 18 of the USDA Soil Conservation Service (now Natural Resource Conservation Service (NRCS)) Engineering Field Handbook is one of the most comprehensive sources of information on soil bioengineering. Chapter 18 describes soil bioengineering as a combination of biological and ecological concepts to arrest and prevent shallow slope failures and erosion. Rather than duplicate NRCS' efforts to describe soil bioengineering techniques here, people interested in exploring soil bioengineering are encouraged to work with the NRCS, MDEQ, and other agency staff familiar with bioengineering practices.

As another example of a system of practices used to stabilize a bank, refer to Picture 2. In addition to riprap, seed and log terraces, the system of BMPs on the bank in Picture 2 included fencing to direct foot traffict, and a set of stairs.

Maintenance

A maintenance plan should be included with all site plans. The maintenance plan should indicate when inspections of the site will be made and who will be responsible for needed maintenance. Site inspections, conducted to ensure the stream bank structures are staying in place, are particularly important within the first few months of installation, and following storm events which result in bank-full streams. More specific maintenance procedures can be found in the referenced BMPs.

Exhibits

Exhibit 1: Field Data-Entry Form which can be used in the stream bank erosion inventory, Northwest RC&D Council. (This type of approach has been used to identify and rank eroding sites on the Muskegon, Au Sable, Pine and Betsie Rivers).

Exhibit 2: Michigan's Natural Rivers System. List of rivers designated or proposed under the Natural Rivers program.

Field Data-Entry Form for Stream Bank Erosion Inventory

This form is intended to be used to compare the severity of eroding stream banks within a watershed. Results can be used to help prioritize stream bank stabilization efforts. Fill in all known information. Where provided, fill in the appropriate number per each category, then total the "points" on the last page.

Date: ___________________
County: ____________________
Stream: _____________________
Observer: _____________________

SITE LOCATION:
Township Name: _______ No. _____ Range ____ Sec. ____
Bank (right or left, looking downstream): _______________
Property Owners: ________________________________
Other info re: location: _____________________________
Accessibility for machinery/materials (good/bad)
Access Problems:________________________________

SITE NUMBER: _______

MEAN WIDTH OF RIVER: _____
(no points)

CONDITION OF BANK:

	5	Toe and upper bank eroding
	3	Toe undercutting
_____	1	Toe stable, upper bank eroding
	5	Length of eroding bank > 50 ft.
	3	Length of eroding bank 20-50 ft.
_____	1	Length of eroding bank < 20 ft.
	5	Side slope vertical 1:1
	3	Side slope 2:1, 3:1
_____	1	Side slope 4:1 or flatter

PROBLEM TREND

	5	Increasing
_____	1	Decreasing or stable

(continued, next page)

DEPTH OF RIVER

1 > 3 feet
______ 2 < 3 feet

VEGETATIVE COVER

5 Vegetative cover 0-50%
3 Vegetative cover 50-80%
______ 1 Vegetative cover 80-100%

MEAN HEIGHT OF BANK

5 Mean height of bank > 20 ft.
3 Mean height of bank 10-20 ft.
______ 1 Mean height of bank < 10 ft.

SOIL TYPE OR TEXTURE

3 Sand
2 Gravel
2 Stratified
______ 1 Clay or loam

APPARENT CAUSE OF EROSION

1-Light access traffic
1-Obstruction in river
1-Bank seepage
1-Gullying by side channels
2-Bend in river
3-Road-stream crossing, grade/shoulder runoff
3-Moderate access traffic
5-Heavy access (foot, horse, etc.) traffic
______ 5-Construction site erosion

______ TOTAL POINTS: more than 36 — severe
30-36 — moderate
less than 30 — minor

RECOMMENDED TREATMENT

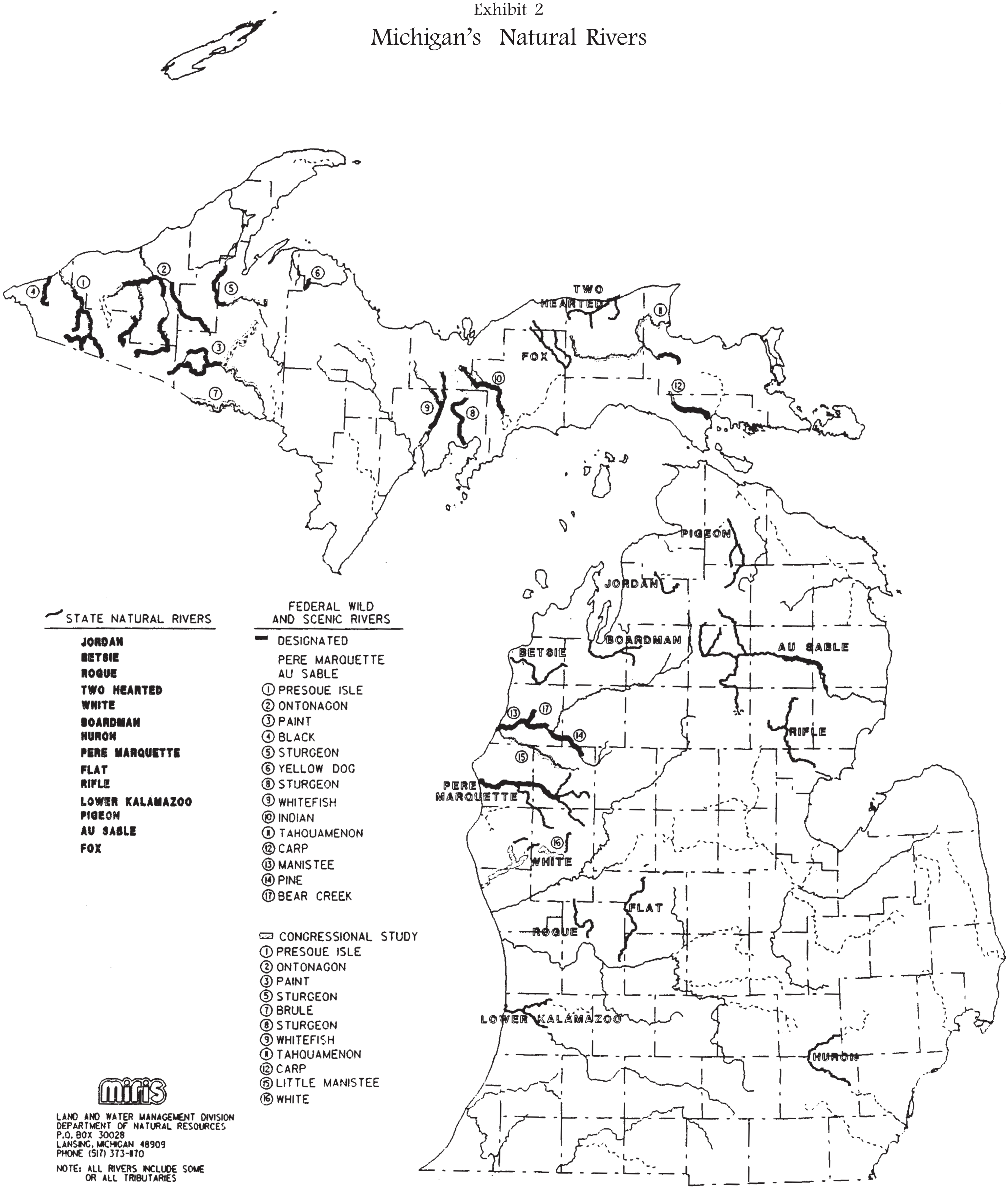
Describe a potential system of BMPs for the site:

NOTE: Sketch location on a separate sheet, showing any unusual circumstances. Also, provide black-and-white or color photograph, if possible.

Source: Modified from the inventory sheet used in the Upper Manistee Stream Bank Erosion Inventory.

Exhibit 2

Michigan's Natural Rivers



MUCC
DISTRIBUTED BY THE MICHIGAN UNITED CONSERVATION CLUBS

Dec. 1, 1992

Winter Road Management

Description

This BMP addresses the proper use and storage of road salt, and discusses alternatives to road salt.

Road salt, also called rock salt, is known chemically as sodium chloride. Use of road salt has been implicated in the elevation of chloride and sodium levels in surface and groundwater as well as in the surrounding environment, and causes corrosion to roads, cars, and bridges. Sources of road salt runoff are roads and parking lots, drains, ditches, salt storage piles, loading areas, truck garages, truck washing areas, and sites where snow is piled. It is estimated that Michigan uses 0.5 million tons of road salt per year, and nationally, 10-11 million tons are used.

Salt can enter surface and ground waters due to the fact that it is soluble. Elevated levels of chlorides entering the Great Lakes and tributaries can have a negative impact on the fresh-water ecosystem. At high levels, salt is toxic to fresh-water organisms adapted to a narrow range of salinity. High levels of chloride can also lead to density stratification in ponds and lakes, which can result in oxygen depletion and fish kills. High sodium levels in ground water can cause health problems such as hypertension, and can aggravate cardiac-related diseases.

Other Terms Used to Describe

De-icing Chemical Use

Pollutants Controlled and Impacts

A reduction in the application rate of salt may result in an improvement of surface water quality by reducing chloride and sodium concentrations. Reductions in salt application will also help protect ground water supplies used for drinking water.

Other benefits that may occur by reducing salt application rates and encouraging proper salt storage include:

-reducing density stratification in ponds and lakes
-reducing corrosion of vehicles and bridges
-reducing damage to roadside vegetation, and
-reducing the deterioration of soil structure.

By properly storing road salt, runoff from salt storage piles can be prevented.

Application

<u>Land Use</u>
Urban, transportation

Soil/Topography/Climate
Winter precipitation comes in the form of sleet, hail, freezing rain and snow, each of which produces different road conditions. All maintenance personnel should know the basic kinds of weather conditions and how to adjust their application procedures to result in the desired road condition. Weather information should be carefully monitored using the most reliable sources available. Some maintenance departments hire private forecasters to get the most reliable local weather information.

When To Apply
Apply this BMP when weather and road conditions require salt spreading for road safety.

Where To Apply
Apply this BMP on any roads which require the application of salt to maintain safe driving conditions, or wherever salt is stored in storage piles.

Relationship With Other BMPs

Street Sweeping can be used to eliminate salt residues on street curbsides.

Specifications

Proper road salt management includes protecting sensitive areas, determining appropriate areas to dump snow, proper salt storage, exploring alternatives to road salt, using proper salt application practices, supervising and training staff, and maintaining equipment.

Protecting Sensitive Areas:
Planning should be made to protect sensitive areas. Sensitive areas include surface waters, drinking water wells and vegetation. Ideally, direct discharges of storm drains to lakes and streams should be avoided in areas where road salt is used in high quantities. Where possible, these drains should be directed to detention basins. Protect ground water supplies by locating salt storage piles away from wells.

Planting salt-resistant vegetation and diverting drainage away from important vegetative areas will help minimize the effect road salt may have on vegetation. Consider installing barriers to protect roadside vegetation from road splash.

Determining Areas to Dump Snow:
When piling snow, do not place directly in or immediately adjacent to surface waters (including wetlands), nor in the vicinity of wellheads. Ideally, snow piles should be directed to detention basins so that the soil and other debris attached to the snow can settle out before the water is discharged to surface waters.

Salt Storage:
Some of the basic elements of a good salt storage policy are as follows:

1. Salt should be covered, preferably in a permanent, roofed structure, to prevent rain and snow from reaching it. If this is not feasible, the next best solution is a waterproof covering weighted and tied down.

2. Salt should be stored on an impermeable pad, not on the ground. Asphalt is the most widely used material for pads, since salt has little effect on it. However, concrete is sometimes used. Concrete must be high quality, air-entrained and treated with linseed oil or asphalt-type coatings to reduce chloride penetration, and prevent scaling or spalling (i.e. flaking).

3. Any runoff that might occur should be contained within the storage site through an appropriate drainage design. Storage pads should slope to let water drain away, and the water channeled to a collection point via ditches, pipes or tile. This brine can then be reapplied to the stockpile during dry seasons, or applied to spreader loads prior to street applications.

4. Any salt storage areas existing in sensitive areas (i.e. zone of influence of water supply wells, significant recharge areas, lakes and wetlands) should be relocated.

Advantages of Using Salt:
Although the use of road salt has many drawbacks, the advantages of using it are:

-it is effective in increasing vehicle traction and achieving the "bare pavement" policy which is currently desired in various parts of the country
-transportation time delays and work time losses are minimized
-it facilitates emergency response in adverse weather
-it doesn't clog drains (like sand might)
-it is relatively inexpensive, costing between $25-50/ton

Application Rate:
It is important to use only the amount of salt necessary to result in safe driving conditions. Rates should be tailored to local conditions.

Application Pattern:
The proper spreading pattern is dependent upon the traffic density and highway design. The type of storm dictates frequency of application, the type of de-icing compound, and the total amount of de-icing compound necessary. The following is given for salt applications:

1. Windrow application is typical of two-lane pavements with low to medium traffic. A 4 to 8 foot application down the center line allows for good traction under at least two wheels.

2. Traffic flow will move the brine toward the shoulders, gradually melting the entire road width. Full-width spreading should be done on multiple-lane pavements with medium to high traffic volumes. Care must be used in the full width spreading not to waste salt.

3. A strong wind blowing across a street or highway can cause salt to drift into gutters or shoulders as it comes out of the spreader. Operators should be aware of wind conditions and spread accordingly on the upwind side.

4. Salt brine will flow down and across a banked curve. Spreading salt on the high side of the road will allow gravity to pull the brine to the low side of the road.

Proper calibration of spreading equipment should be done to accurately apply the proper amount of salt.

<u>Alternatives to Salt:</u>
Some reports have estimated that the damage done by salt ranges from 6-30 times the initial cost of the salt, with 90% of the damage due to corrosion. With the corrosive damage to bridges, highways, and vehicles factored in, one study concluded that the actual cost of salt may be closer to $775/ton. The total annual national cost of salt-related damage is estimated at approaching $5.5 million.

Alternatives to road salt include calcium magnesium acetate (CMA), calcium chloride, urea, sand, natural brines, potassium chloride, magnesium chloride (Freeze Guard), sodium formate, and regular salt such as Quik Salt, TCI, and CG-90.

CMA (ICE-B-GON) is manufactured from dolomitic limestone and acetic acid. The cost of this material ($650-700/ton) is related to the expense of producing acetic acid. At this time, CMA seems to be the alternative of choice. It is reported to be 10-15 times less corrosive than salt, with little or no effects on terrestrial vegetation or soil physical properties. However, it can result in significant organic loadings to receiving waters caused by chemical oxygen demand. During significant runoff events, this may deplete oxygen in surface waters, causing harmful effects to fish and other aquatic organisms. It can also cause increased organic loadings to wastewater treatment plants which serve combined sewers.

Four main obstacles to switching from salt to CMA are:

1. Inadequate understanding of the extent of salt damage

2. Subsidy of infrastructure repair by the federal government

3. Corrosion and environmental costs are external to the typical highway maintenance decision-process

4. Tendency by political decision-makers to heavily discount future cost savings when confronted by the need to increase current outlays in the near term

Other alternatives cause various types of environmental damage. Calcium chloride is an effective deicer but contains chloride and costs $250/ton. Urea costs $250/ton and may result in nitrogen contamination. Sand costs only $3/ton but can clog drains and settle out in streams. Alternatives such as ethylene glycol, diethylene glycol, methanol, and propylene glycol have a high chemical oxygen demand. The former two chemicals are also toxic to humans and wildlife if ingested, and methanol is toxic if ingested or absorbed through the skin.

Other proposed methods to remove snow are listed below. These may or may not be practical according to specific circumstances:

1. The use of external and/or in-slab melting systems

2. Mobile thermal "snow melters"

3. Use of compressed air in conjunction with snowplows or sweepers

4. Inclusion of snow and ice adhesion-reducing substances in the pavement itself (i.e hydrophobic materials such as silicone rubber or silicone resin)

5. Pavement substances that store and release solar energy for melting

6. Road and drainage design modifications to enhance runoff

7. Salt retrieval or treatment possibilities enhanced by the addition of chelating agents

8. Improved tire and/or vehicular design so as to reduce deicing requirements

Supervising and Training Staff:
The following principles should be included in staff training programs:

1. The application of salt and salt alternatives should not be substituted for plowing.

2. The best designed spreader equipment should be employed to avoid scatter and waste.

3. On and off ramps should be addressed as quickly as possible--safe roads are of little use if access ramps are hazardous.

4. All equipment should be calibrated before use.

Ideally, the same crews should be assigned to the same road sections in each storm, and monitor the amounts dispersed from each spreader route.

Maintenance

Ongoing maintenance includes keeping equipment properly calibrated to ensure the salt or other substance is distributed at the proper rate and in the proper pattern. Another important part of the maintenance program is keeping good spare parts available.

RUNOFF CONVEYANCE
AND OUTLETS

Dec. 1, 1992

Check Dam

Description

Check dams are constructed across drainageways to reduce concentrated flows in the channel and protect vegetation in the early stages of growth. They can consist of stones, sandbags or gravel, and are most commonly used in the bottom of channels that will be stabilized at a later date. Although check dams also collect sediment and hence act as filters, their primary purpose is to reduce erosive velocities.

Other Terms Used to Describe

In-Stream/Channel Energy Dissipators

Pollutants Controlled and Impacts

By reducing runoff velocities in drainageways, check dams reduce the potential for erosion to occur. Although they also help filter sediment, they should in no way replace other Filters, or Sediment Basins.

Application

Land Use
This practice is most commonly used on construction sites and transportation and urban projects.

Soil/Topography/Climate
The proper spacing between check dams is dependent upon the topography (i.e. slope) of the drainageway.

When to Apply
Check dams are to be used when it is not practical to divert flow to a stabilized outlet, or where weather conditions prevent the timely installation of vegetation or non-erosive liners. Apply during the construction of ditches and diversions, and before vegetation is established.

Where to Apply
Apply this practice across drainagways as needed to reduce concentrated flows to non-erosive velocity.

Relationship With Other BMPs

Check dams are often used to help stabilize channels until in-channel vegetation (for Grassed Waterways) is established. They are used during the establishment of other Stormwater Conveyance Channels as well.

Specifications

Design:

1. Check dams are usually used in a series. They should be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam. See exhibit 1.

2. The side slope of the dam should be 2:1 or flatter.

3. The middle of the dam should be 9 inches lower then the outer edges at natural ground elevation. This allows water to flow over the center of the check dam, as opposed to around the sides where it would erode the banks. In areas of heavy flows, additional stone may be needed immediately below the check dam to help dissipate energy and to prevent undercutting of the check dam.

4. Stone size should be increased with increased slope and velocity. The stone should be big enough to stay in place during anticipated high flows. When larger sizes of stone are used, place smaller stones immediately downstream of and adjacent to the check dam to prevent undercutting of the dam.

5. Straw bales are not recommended for use as check dams.

Construction Considerations:

1. Place the stone in the ditch banks and extend it beyond the banks a minimum of 18 inches above the anticipated flow, to avoid washouts from overflow around the dam.

2. The area downstream of the last check dam should be stabilized, or the flow diverted to a Stabilized Outlet.

After Construction:

Temporary check dams may only be removed after the vegetation or permanent lining has been established. Some check dams may remain as permanent structures.

Maintenance

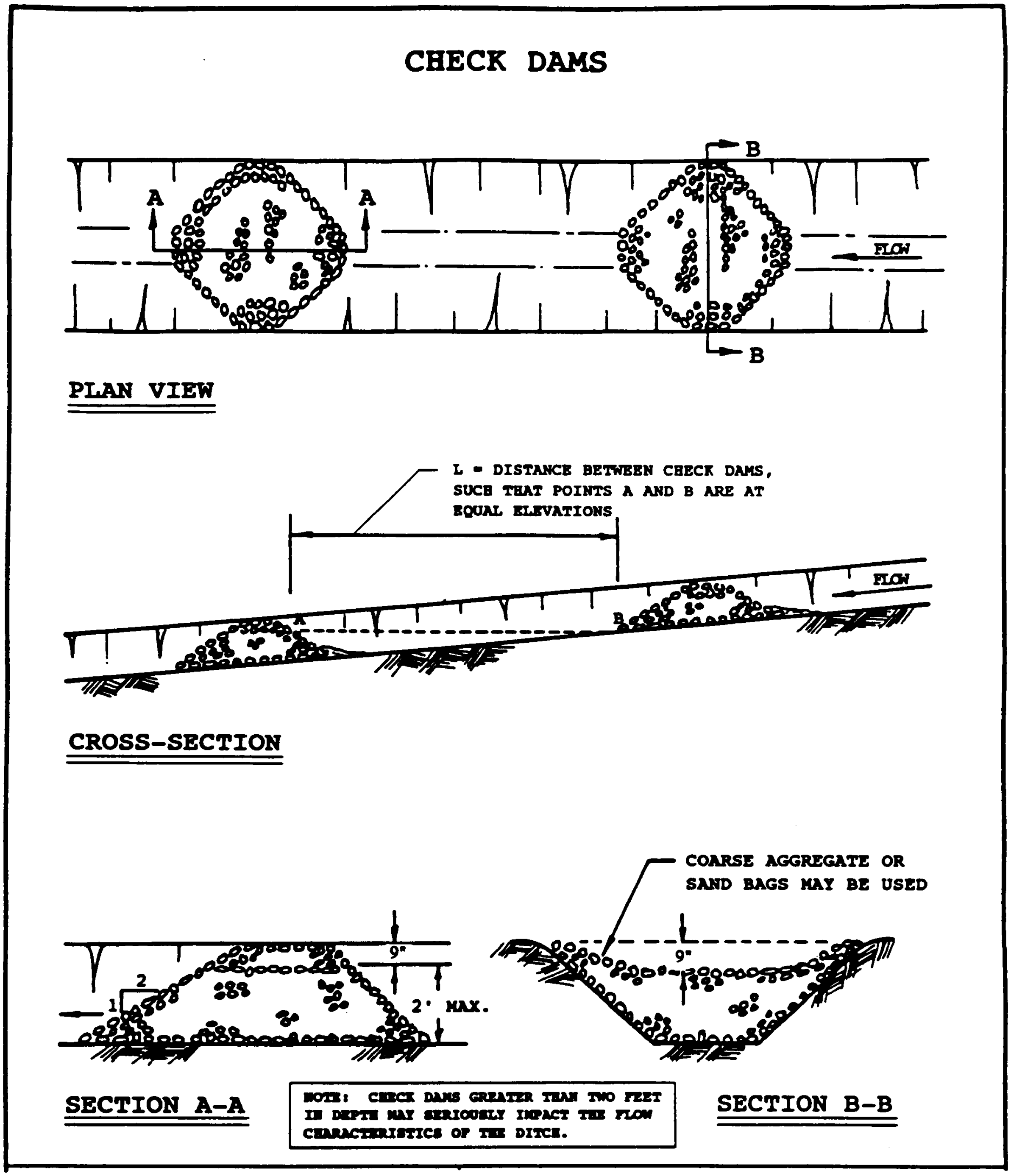
Check dams should be inspected after each rain to ensure there is no piping under the structure or around its banks. Correct all damage immediately. If banks are severely eroded, consider Critical Area Stabilization options. Sediment should be removed when it accumulates to 1/2 the height of the dam, to ensure water can flow through the dam and to prevent large flows from carrying sediment over the dam. That sediment should be placed in the Spoil Pile or other approved upland area.

Add stones as needed to maintain design height and cross section. Also, be sure that culverts and other structures below the check dams are not damaged or blocked due to any displaced stone.

Exhibits

Exhibit 1: Check Dams. Oakland County (Michigan) Soil Erosion Manual.

Exhibit 1



Source: Modified from the Erosion Control Manual, Oakland County, Michigan.

Dec. 1, 1992

Diversions

Description

A diversion is a graded channel and ridge constructed across a slope, perpendicular to the direction of runoff. It functions to protect other BMPs and sensitive areas by intercepting and diverting runoff and carrying it to a stabilized area. Diversions can be bare channels, vegetated channels or channels lined with a hard surface material.

Other Terms Used to Describe

Interceptors

Pollutants Controlled and Impacts

Diversions located down-gradient of a site will intercept sheet flow carrying sediment, and if diverted to a sediment basin or other stabilized area, will help minimize off-site sedimentation. Diversions can also be used to direct runoff away from highly erodible areas or other sensitive areas such as wetlands.

Diversions that direct runoff to vegetative areas, detention/retention basins, or Sediment Basins may promote groundwater recharge.

Application

Land Use

Diversions should be used on all land use activities that will generate erosive runoff velocities, or as may be needed to divert runoff to stabilized areas.

Soil/Topography/Climate

Diversions should be used to direct runoff away from highly erodible soils and other critical areas.

When to Apply

Diversions should be installed and stabilized prior to excavation of the area to be protected.

Where to Apply

Diversions should be used:

-where it is necessary to prevent off-site drainage from crossing over into excavated areas

-where it is necessary to protect adjoining properties from excessive runoff

-to break up concentration of water on long gentle slopes and on undulating land surfaces generally considered too flat or irregular for terracing.

-to divert water away from buildings and other permanent structures.

-to intercept and channel runoff to other areas to prevent on-site erosion.

Relationship With Other BMPs

Diversions are often used to protect critical areas (see the Critical Area Stabilization BMP). Diverted runoff should outlet to a stabilized area such as a Sediment Basin, detention or retention basin, or other Stabilized Outlet. Closed conduit outlets (see Subsurface Drains) may be suitable on steep slopes where ordinary outlets are unacceptable. When movement of sediment into a diversion channel is a significant problem, consider installing a vegetated Buffe/Filter Strip upgradient of the diversion.

Specifications

Planning Considerations:

1. High sediment-producing areas above a diversion should be controlled by Critical Area Stabilization and other good land use management practices to prevent excessive sediment accumulation in the diversion channel.

2. Diversions must not be substituted for terraces on land requiring terracing for erosion control. Consider using terraces and benches on slopes greater than 15%.

3. It is important that channel dimensions be adapted for the equipment that will be used to maintain the diversion. For example, in urban areas the diversion should be such that municipal mowers can be used. In utility right-of-way, the diversion should be designed to accommodate utility maintenance equipment.

4. Diversions should not be used as an area to deposit plowed snow.

5. The length of a diversion is often fixed by the availability of Stabilized Outlets. To prevent channel scour or excessive seepage that would damage lower lying land, the length may be reduced, or Subsurface Drains or a stone filter can be constructed at the outlet. Consideration should be given to outletting diversions at both ends into Stabilized Outlets, thus dividing the flow and possibly eliminating or reducing outlet problems.

Design Considerations:

NOTE: All structural best management practices should be designed by a registered professional engineer.

Grade:

Grades should be determined by the general lay of the land following a field survey. A profile and cross section survey will determine the design grade profile. Variable grades may be needed to obtain more uniform cross sections and best possible alignment.

Capacity:

Diversions should be designed to have sufficient capacity to carry the peak runoff expected from the storm frequency consistent with the hazard involved and the area to be protected. Use Exhibit 2 to determine the minimum design storm.

As shown in Exhibit 2, at a minimum, diversions should have a capacity to carry the peak runoff from a 10-year frequency storm. Peak runoff can be computed using the Appendix or any other acceptable method. Retardance factors should be determined following Exhibit 3.

Where the drainage area of the diversion varies appreciably along the length of the diversion, the capacity should be adjusted in reaches proportional to the change in the drainage area.

Permissible Velocities (Maximum Allowable Velocities):
The diversion designer will select two permissible velocities (V_1 and V_2) based on soil texture. V_1 is the permissible velocity when the channel has been constructed and the vegetation is short (1 inch or less) and not well-developed. This condition is more susceptible to erosion. V_2 is the permissible velocity when the channel is fully functioning, (i.e., the grass has formed a protective sod and the vegetation is being maintained at design length). Use Exhibit 3 and 4 to select permissible velocities.

The diversion designer will base the V_2 on three criteria: soil texture, V_1, and planned length of vegetation. For example, if the diversion is in a remote area, the designer chooses a V_2 of 5.0 fps for a silty clay loam with V_1 of 2.0 fps and vegetal managed length of 11 to 24 inches. Or if the diversion is in a school playground, then the designer would select a V_2 of 4.0 fps for silty clay loam with a V_1 of 2.0 fps and vegetal managed length of 2 to 6 inches.

The retardance is a function of the species of vegetation and the managed vegetal length. Exhibit 5 classifies the vegetation cover as to the degree of retardance. Generally, B retardance is optimal for erosion control and channel velocity. However, in urban areas where vegetal lengths of less than 10 inches will be maintained, retardance C and D can be used for V_2 as long as vegetation species and length is within the maximum permissible velocity.

Cross Section:
The cross-section of the channel may be parabolic o trapezoidal. The minimum constructed cross section should meet the design dimensions. See Exhibit 1.

Ridge Design:
top width: 4 foot minimum
freeboard: 0.5 foot minimum
settlement: 10% of total fill height minimum
back slope: 3:1 or flatter

The top of the constructed ridge should not be lower at any point than the design elevation plus the specified overfill for settlement.

Outlets:
Diversions should outlet into a stable area. See the Stabilized Outlets BMP. The outlets should be established prior to outletting runoff from the diversion.

Outlet selection should be appropriate for the soil type. In soils which do not facilitate vegetative growth, use structural outlets.

The design elevation of the water surface in the diversion should not be lower than the design elevation of the water surface in the outlet at the junction when both are operating at design flow.

Materials:
The earth material used in constructing the basin should be obtained from the basin channel, designated borrow areas or other excavation.

Fill material should contain no frozen particles, rock particles greater than 6 inches in diameter, sod, brush or other objectionable material.

The fill material should have a moisture content sufficient to secure compaction. When kneaded in the hand, it will form a ball which does not readily separate when struck sharply with a pencil, and will not extrude out of the hand when squeezed tightly. Any fill used in the creation of the diversion should be compacted in layers not exceeding 9 inches.

Diversions which will be located at vehicle crossings should be designed according to the anticipated vehicular traffic, such that the vehicles do not damage it.

Top Soil:
Topsoil should be stockpiled following specifications in the Spoil Piles BMP. Topsoil should be spread on the diversion flow area to a depth of not less than three inches. The final cross section with the topsoil in place must meet the design cross-section.

Vegetative Cover:
Vegetation should be established immediately after construction, following specifications in the Seeding and Mulching , or Sodding. Vegetative cover should be consistent with the retardance value used in the design.

Step-by-Step Process:
The following is a step-by-step process which can be followed to design a diversion. Steps 1-4 should be followed for all diversions. Steps 5-8 are steps which can be followed when using the Soil Conservation Service charts (attached).

1. Complete a profile and cross section survey of the site to identify the percentage slope.

2. Identify soil textures. Use Soil Conservation Service soil maps, where available, or have soil surveys done by qualified soil scientists.

3. Determine the size of the drainage area using a topographic map or other appropriate reference. Also determine the watershed slope.

4. Determine the peak runoff from the drainage area. The Appendices includes one acceptable method.

5. Determine the storm design based on the area in need of protection and the degree of hazard, using Exhibit 2.

6. Determine the vegetal retardance using Exhibit 2 of this BMP.

7. Determine the permissible velocity (V_1) using Exhibit 4 of this BMP.

8. Determine the appropriate dimensions using the design charts in Exhibits 6 and 7 of this BMP. There are two cross sections available: parabolic and trapezoidal.

9. Using Exhibit 5, select a vegetative cover that corresponds with the design.

Design Example:

Situation:

In Ingham County, there is a 54 acre watershed consisting of a grassed community park and woods that drains into a residential area. A diversion is needed to prevent excess runoff from the park and woods from causing septic system fields to fail in the residential area (due to saturated soil). As indicated in Figure 1, the soils in the watershed are Morley loam (MoC), Blount loam (BbB) and Fox sand loam (FoD). The Ingham County Soil Survey book indicates that soil textures are loam and sandy loam. For areas in which there is lawn, the parks department will keep a healthy (i.e. “good”) turf, cut to 2-6 inches. The peak runoff was determined to be 99 cfs and the grade is 1%. Design a parabolic diversion.

1. Determine the storm design based on the area in need of protection and the degree of hazard. For this example, given that a residential area is in need of protection, and using Exhibit 2 of this BMP, the diversion should be designed for a 50-year, 24-hour storm.

2. Determine the appropriate vegetal retardance using Exhibit 3 of this BMP. Given that the grass will be maintained to between 2-6 inches, the degree of retardance is D.

3. Determine the permissible velocity (V_1) using Exhibit 4 of this BMP. Given that the soil textures are loam and sandy loam, assuming “good” channel vegetation, and having determined a retardance of D, the permissible velocity is 3.0 feet per second (fps).

4. Determine the appropriate design using the Parabolic Diversion Design Chart in Exhibit 6. In our example the peak discharge was determined to be 99 cfs, the permissible velocity (V_1) 3.0 fps, and the given grade is 1%. According to Exhibit 6, the diversion design has a top width (T) of 47 feet and a depth (D) of 2.4 feet.

5. Using Exhibit 5, select a vegetative cover that corresponds with the design. In our example, we need a grass that can be maintained at 2-6 inches. Exhibit 5 includes as options lespedeza sericea, or a grass-legume mixture of orchard grass, redtop, Italian ryegrass and common lespedeza.

Construction Considerations:

1. Use proper Land Clearing practices and grade according to the grading plan (see Grading Practices BMP).

2. Excavate the diversion according to the design.

3. Compact any fill material to prevent uneven settlement and to provide stability against seepage.

4. Vegetate the area according to the design, and following specifications in the Seeding and Mulching or Sodding BMPs.

5. Remove temporary Construction Barriers when the area is stabilized.

Maintenance

Before final stabilization, the diversion should be inspected after every rainfall. Sediment should be removed from the diversion channel and repairs made as necessary. Seeded areas which fail to establish a vegetative cover should be reseeded as necessary. Maintain a vigorous sod by applying lime and fertilizer as needed, in accordance with specifications in the Soil Management and Fertilizer Management BMPs.

Once the diversion is established, remove excess growth of woody vegetation by mowing. Mowing other than to control woody vegetation should be done according to the diversion design.

Keep vehicular traffic off the diversion except for maintenance.

The contractor is responsible for maintenance and inspection until construction is completed or until responsibility is accepted by the owner. The owner is responsible thereafter.

Exhibits

Exhibit 1: Typical Parabolic and Trapezoidal Diversions. Modified from Va. SWCC, draft 1/80.

Exhibit 2: Minimum Design Storm for Diversions. Modified from the North Carolina Erosion and Sediment Control Planning and Design Manual.

Exhibit 3: Guide to the Selection of Vegetal Retardance. USDA Soil Conservation Service, Engineering Field Manual.

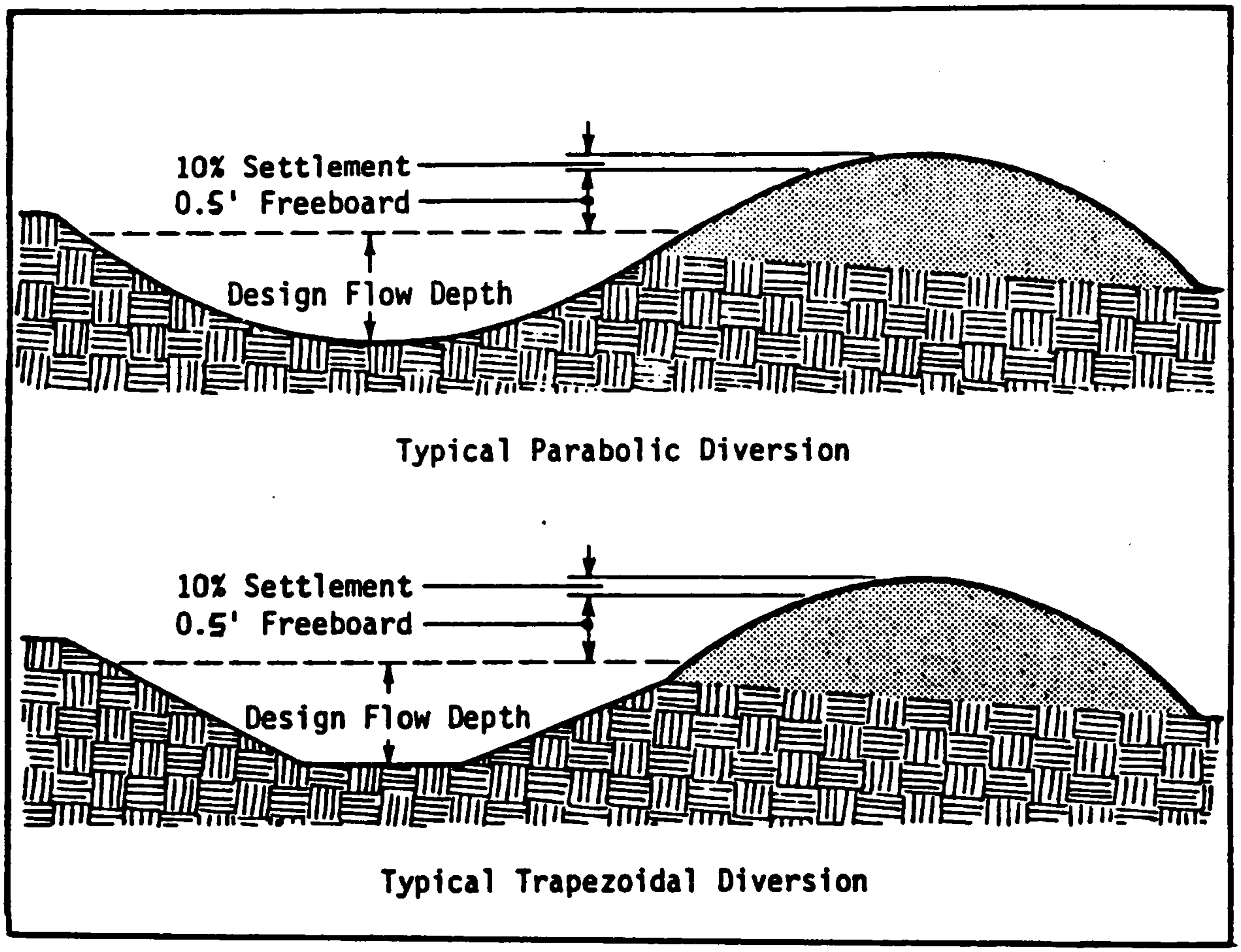
Exhibit 4: Permissible Velocities. USDA Soil Conservation Service, Engineering Field Manual.

Exhibit 5: Classification of Vegetation Cover as to Degree of Cover. USDA Soil Conservation Service.

Exhibit 6: Diversion Design Charts. USDA Soil Conservation Service, Engineering Field Manual.

Exhibit 1

Typical Parabolic and Trapezoidal Diversions



Source: Modified from Va. SWCC, draft, 1/80.

Exhibit 2

Minimum Design Storm for Diversions

Level of Protection	Area to be Protected	Minimum Desing Storm
Low	All erosion control facilities, open areas, parking lots, minor recreation areas	10-year, 24-hour
Medium	Recreation development low-capacity roads and minor structures	25-year, 24-hour
High	Major structures, homes schools, high-capacity roads	50-year, 24-hour

Source: Modified from the North Carolina Erosion and Sediment Control Planning and Design Manual.

Exhibit 3

Guide to Selection of Vegetal Retardance

Stand	Average Length Of Vegetation	Degree Of Retardance	Stand	Average Length Of Vegetation	Degree Of Retardance
	Longer than 30”	A		Longer than 30”	B
	11 to 24”	B		11 to 24”	C
Good	6 to 10”	C	**Fair**	6 to 10”	D
	2 to 6”	D		2 to 6”	D

Source: Modified from USDA Soil Conservation Service, Engineering Field Manual

Exhibit 4

Permissible Velocities

Permissible velocity – (fps)			
SOIL TEXTURE	Channel Vegetation		
	Retardance	Fair (V_1)	Good (V_2)
Loam, Sand, Silt	B	3.0	4.0
Sandy Loam and	C	2.5	3.5
Silty Loam	D	2.0	3.0
	B	4.0	5.0
Silty Clay Loam	C	3.5	4.5
Sandy Clay Loam	D	3.0	4.0
	B	5.0	6.0
Clay	C	4.5	5.5
	D	4.0	5.0

Source: Modified from USDA Soil Conservation Service, Engineering Field Manual.

Exhibit 5

Classification of Vegetation Cover as to Degree of Retardance

(See the Seeding BMP for appropriate seeding mixtures)

Retardance	Cover	Condition
A	Red canarygrass	Excellent stand, tall (avg. 36")
B	Smooth Bromegrass....................................	Good stand, mowed (avg. 12-15")
	Native grass mixture (Smooth Bromegrass, tall Fescue and other long and short midwest grasses..........	Good stand, unmowed (avg. 16-18")
	Tall Fescue..	Good stand, unmowed (avg. 18")
	Lespedeza sericea....................................	Good stand, not woody, tall (avg. 19")
	Grass-legume mixture--Timothy, smooth Bromegrass, or orchard grass....................................	Good stand, uncut (avg. 20")
	Reed canarygrass.....................................	Good stand, mowed (avg. 12 to 15")
	Tall Fescue, with bird's foot trefoil or lodino......	Good stand, uncut (avg. 18")
C	Redtop...	Good stand, headed (15 to 20")
	Grass-legume mixture--summer (orchard grass, redtop, Italian ryegrass and common lespedeza)............	Good stand, uncut (6 to 8")
	Grass-legume mixture--smooth Bromegrass, perennial rye, all Fescue.................................	Good stand, head (6 to 12")
D	Red Fescue...	Good stand, headed (12 to 18")
	Grass-legume mixture--fall, spring (Orchard grass, redtop, Italian ryegrass, and common lespedeza)....	Good stand, uncut (4 to 5")
	Lespedeza sericea....................................	After cutting to 2" height. Very good stand before cutting.

Source: Modified from USDA Soil Conservation Service.

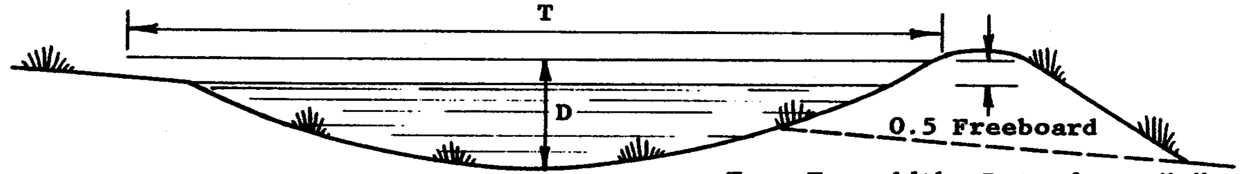
Exhibit 6

V_1 Based on Permissible Velocity of the Soil With Retardance "D"

Top Width, Depth & V_2 Based on Retardance "B"

Grade = 0.25%

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15																											
20																											
25	12	3.8	1.0																								
30	14	3.6	1.1																								
35	17	3.5	1.1																								
40	19	3.5	1.2	13	4.1	1.4																					
45	21	3.4	1.2	14	4.0	1.4																					
50	23	3.4	1.2	16	3.9	1.5																					
55	26	3.4	1.2	17	3.9	1.5																					
60	28	3.4	1.2	19	3.9	1.5																					
65	30	3.4	1.2	20	3.8	1.6																					
70	32	3.4	1.2	22	3.8	1.6	15	4.5	1.8																		
75	34	3.4	1.2	23	3.8	1.6	16	4.4	1.9																		
80	37	3.4	1.2	25	3.8	1.6	17	4.4	1.9																		
90	41	3.4	1.2	28	3.8	1.6	19	4.3	1.9																		
100	46	3.4	1.2	31	3.7	1.6	21	4.3	2.0																		
110	50	3.4	1.2	34	3.7	1.6	23	4.2	2.0																		
120	55	3.4	1.3	37	3.7	1.6	26	4.2	2.0	18	5.0	2.3															
130	59	3.4	1.3	40	3.7	1.6	28	4.2	2.0	19	4.9	2.4															
140	64	3.3	1.3	43	3.7	1.7	30	4.2	2.0	21	4.9	2.4															
150	68	3.3	1.3	46	3.7	1.7	32	4.2	2.0	22	4.8	2.5															
160	73	3.3	1.3	49	3.7	1.7	34	4.2	2.0	24	4.8	2.5															
170	77	3.3	1.3	52	3.7	1.7	36	4.2	2.1	25	4.8	2.5	20	5.5	2.8												
180	82	3.3	1.3	55	3.7	1.7	38	4.2	2.1	26	4.7	2.6	21	5.4	2.8												
190	86	3.3	1.3	58	3.7	1.7	40	4.2	2.1	28	4.7	2.6	22	5.4	2.8												
200	91	3.3	1.3	61	3.7	1.7	42	4.2	2.1	29	4.7	2.6	23	5.3	2.9												
220				67	3.7	1.7	46	4.2	2.1	32	4.7	2.6	25	5.3	2.9												
240				73	3.7	1.7	50	4.1	2.1	35	4.7	2.6	27	5.2	3.0												
260				79	3.7	1.7	54	4.1	2.1	38	4.7	2.6	29	5.2	3.0	22	6.0	3.3									
280				85	3.7	1.7	59	4.1	2.1	40	4.6	2.6	31	5.1	3.1	24	5.9	3.4									
300				91	3.7	1.7	63	4.1	2.1	43	4.6	2.7	33	5.1	3.1	26	5.9	3.4									



T = Top width, Retardance "B"
D = Depth, Retardance "B"
V_2 = Velocity, Retardance "B"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Parabolic diversion design chart (Sheet 1 of 6)

Continued

Exhibit 6

V_1 Based on Permissible Velocity of the Soil With Retardance "D"

Top Width, Depth & V_2 Based on Retardance "B"

Grade = 0.5%

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	12	2.8	1.0																								
20	15	2.7	1.0																								
25	18	2.7	1.1	12	3.1	1.4																					
30	22	2.6	1.1	14	3.0	1.4	10	3.4	1.6																		
35	25	2.6	1.1	16	3.0	1.5	12	3.3	1.7																		
40	29	2.6	1.1	18	2.9	1.5	13	3.2	1.8																		
45	33	2.6	1.1	20	2.9	1.5	15	3.2	1.8																		
50	36	2.6	1.1	22	2.9	1.5	17	3.1	1.9	12	3.7	2.1															
55	40	2.6	1.1	24	2.9	1.6	18	3.1	1.9	13	3.6	2.2															
60	43	2.6	1.1	27	2.9	1.6	20	3.1	1.9	14	3.6	2.2															
65	47	2.6	1.1	29	2.9	1.6	21	3.1	1.9	15	3.5	2.3															
70	50	2.6	1.1	31	2.9	1.6	23	3.1	1.9	16	3.5	2.3															
75	54	2.6	1.1	33	2.9	1.6	25	3.1	1.9	17	3.5	2.3	14	4.0	2.5												
80	58	2.6	1.1	35	2.9	1.6	26	3.1	1.9	18	3.5	2.4	15	3.9	2.6												
90	65	2.6	1.1	40	2.9	1.6	29	3.1	2.0	21	3.5	2.4	16	3.9	2.6												
100	72	2.6	1.1	44	2.8	1.6	32	3.1	2.0	23	3.4	2.4	18	3.8	2.7	14	4.3	3.0									
110	79	2.6	1.1	48	2.8	1.6	36	3.1	2.0	25	3.4	2.4	20	3.8	2.8	16	4.2	3.1									
120	86	2.6	1.1	52	2.8	1.6	39	3.1	2.0	27	3.4	2.5	21	3.7	2.8	17	4.1	3.1									
130	93	2.6	1.1	57	2.8	1.6	42	3.1	2.0	30	3.4	2.5	23	3.7	2.8	18	4.1	3.2									
140				61	2.8	1.6	45	3.1	2.0	32	3.4	2.5	25	3.7	2.8	19	4.1	3.2									
150				65	2.8	1.6	48	3.1	2.0	34	3.4	2.5	26	3.7	2.9	21	4.1	3.2	17	4.6	3.5						
160				70	2.8	1.6	52	3.0	2.0	36	3.4	2.5	28	3.7	2.9	22	4.0	3.3	18	4.5	3.6						
170				74	2.8	1.6	55	3.0	2.0	39	3.4	2.5	30	3.7	2.9	24	4.0	3.3	19	4.5	3.6						
180				78	2.8	1.6	58	3.0	2.0	41	3.4	2.5	31	3.7	2.9	25	4.0	3.3	20	4.5	3.7						
190				83	2.8	1.6	61	3.0	2.0	43	3.4	2.5	33	3.7	2.9	26	4.0	3.3	21	4.5	3.7						
200				87	2.8	1.6	64	3.0	2.0	45	3.4	2.5	35	3.7	2.9	27	4.0	3.3	22	4.4	3.8	18	5.0	4.0			
220				95	2.8	1.6	71	3.0	2.0	50	3.4	2.5	38	3.7	2.9	30	4.0	3.4	24	4.4	3.8	19	4.9	4.1			
240							77	3.0	2.0	54	3.4	2.5	42	3.7	2.9	33	4.0	3.4	26	4.4	3.8	21	4.9	4.1			
260							83	3.0	2.0	59	3.4	2.5	45	3.7	3.0	36	4.0	3.4	28	4.3	3.9	23	4.8	4.2			
280							90	3.0	2.0	63	3.4	2.5	48	3.7	3.0	38	4.0	3.4	30	4.3	3.9	24	4.8	4.2	20	5.4	4.5
300							96	3.0	2.0	68	3.4	2.5	52	3.6	3.0	41	4.0	3.4	32	4.3	3.9	26	4.8	4.3	21	5.3	4.6

T = Top width, Retardance "B"
D = Depth, Retardance "B"
V_2 = Velocity, Retardance "B"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Parabolic diversion design chart (Sheet 2 of 6)

Continued

Exhibit 6

V_1 Based on Permissible Velocity of the Soil With Retardance "D"

Grade = 0.75%

Top Width, Depth & V_2 Based on Retardance"B"

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2
15	16	2.3	0.9	10	2.7	1.2			
20	21	2.3	0.9	12	2.6	1.4			
25	26	2.2	1.0	14	2.5	1.4	11	2.8	1.7
30	31	2.2	1.0	17	2.5	1.4	12	2.8	1.8
35	36	2.2	1.0	20	2.5	1.5	14	2.7	1.8
40	41	2.2	1.0	23	2.5	1.5	16	2.7	1.8
45	46	2.2	1.0	26	2.5	1.5	18	2.7	1.9
50	51	2.2	1.0	28	2.5	1.5	20	2.7	1.9
55	56	2.2	1.0	31	2.5	1.5	22	2.7	1.9
60	61	2.2	1.0	34	2.5	1.5	24	2.7	1.9
65	66	2.2	1.0	37	2.5	1.5	26	2.6	1.9
70	71	2.2	1.0	39	2.5	1.5	28	2.6	1.9
75	76	2.2	1.0	42	2.5	1.5	30	2.6	1.9
80	81	2.2	1.0	45	2.5	1.5	32	2.6	1.9
90	91	2.2	1.0	50	2.5	1.5	36	2.6	1.9
100				56	2.5	1.5	40	2.6	1.9
110				61	2.5	1.5	44	2.6	1.9
120				67	2.5	1.5	48	2.6	2.0
130				72	2.5	1.5	52	2.6	2.0
140				78	2.5	1.5	56	2.6	2.0
150				83	2.5	1.6	60	2.6	2.0
160				89	2.5	1.6	64	2.6	2.0
170				94	2.5	1.6	68	2.6	2.0
180							72	2.6	2.0
190							76	2.6	2.0
200							80	2.6	2.0
220							87	2.6	2.0
240							95	2.6	2.0
260									
280									
300									

Q	V_1 = 3.5			V_1 = 4.0			V_1 = 4.5		
cfs	T	D	V_2	T	D	V_2	T	D	V_2
15									
20									
25									
30	10	3.1	1.9						
35	11	3.0	2.1						
40	13	2.9	2.1						
45	14	2.9	2.2						
50	16	2.9	2.2	12	3.3	2.5			
55	17	2.9	2.2	13	3.3	2.5			
60	19	2.9	2.2	14	3.2	2.6			
65	20	2.8	2.3	15	3.2	2.6	12	3.5	2.8
70	22	2.8	2.3	16	3.2	2.7	13	3.5	2.9
75	23	2.8	2.3	17	3.2	2.7	14	3.5	2.9
80	25	2.8	2.3	18	3.2	2.7	15	3.4	3.0
90	28	2.8	2.3	20	3.1	2.8	16	3.4	3.1
100	31	2.8	2.3	22	3.1	2.8	18	3.4	3.1
110	34	2.8	2.3	25	3.1	2.8	20	3.3	3.2
120	37	2.8	2.3	27	3.1	2.8	22	3.3	3.2
130	40	2.8	2.3	29	3.1	2.9	23	3.3	3.2
140	43	2.8	2.3	31	3.1	2.9	25	3.3	3.2
150	46	2.8	2.3	33	3.1	2.9	27	3.3	3.2
160	49	2.8	2.3	35	3.1	2.9	29	3.3	3.3
170	52	2.8	2.3	38	3.1	2.9	31	3.3	3.3
180	55	2.8	2.3	40	3.1	2.9	32	3.3	3.3
190	58	2.8	2.3	42	3.1	2.9	34	3.3	3.3
200	61	2.8	2.3	44	3.1	2.9	36	3.3	3.3
220	68	2.8	2.3	48	3.1	2.9	39	3.3	3.3
240	74	2.8	2.4	53	3.1	2.9	43	3.3	3.3
260	80	2.8	2.4	57	3.1	2.9	46	3.3	3.3
280	86	2.8	2.4	62	3.1	2.9	50	3.3	3.3
300	92	2.8	2.4	66	3.1	2.9	53	3.3	3.3

Q	V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2
15									
20									
25									
30									
35									
40									
45									
50									
55									
60									
65									
70									
75									
80									
90	13	3.8	3.3						
100	15	3.7	3.4						
110	16	3.7	3.5						
120	18	3.6	3.5	14	4.0	3.8			
130	19	3.6	3.6	16	4.0	3.8			
140	20	3.6	3.6	17	4.0	3.9			
150	22	3.6	3.7	18	3.9	4.0			
160	23	3.6	3.7	19	3.9	4.0	15	4.3	4.4
170	24	3.5	3.7	20	3.9	4.1	16	4.3	4.4
180	26	3.5	3.7	21	3.8	4.1	17	4.2	4.5
190	27	3.5	3.7	22	3.8	4.1	18	4.2	4.5
200	29	3.5	3.7	23	3.8	4.2	19	4.2	4.5
220	32	3.5	3.7	26	3.8	4.2	21	4.2	4.6
240	34	3.5	3.8	28	3.8	4.2	23	4.1	4.6
260	37	3.5	3.8	30	3.8	4.2	25	4.1	4.7
280	40	3.5	3.8	32	3.8	4.3	26	4.1	4.7
300	43	3.5	3.8	35	3.8	4.3	28	4.1	4.7

T = Top width, Retardance "B"
D = Depth, Retardance "B"
V_2 = Velocity, Retardance "B"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Parabolic diversion design chart (Sheet 3 of 6)

Continued

Exhibit 6

V_1 Based on Permissible Velocity of the Soil With Retardance "D"

Grade = 1.0%

Top Width, Depth & V_2 Based on Retardance "B"

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	18	2.1	0.9	11	2.3	1.2																					
20	24	2.0	0.9	15	2.2	1.3	10	2.5	1.7																		
25	30	2.0	0.9	19	2.2	1.3	12	2.5	1.7	10	2.7	1.9															
30	36	2.0	0.9	22	2.2	1.4	15	2.4	1.8	12	2.6	2.0															
35	42	2.0	0.9	26	2.2	1.4	17	2.4	1.8	14	2.6	2.1	10	2.9	2.4												
40	48	2.0	1.0	29	2.2	1.4	19	2.4	1.8	15	2.5	2.1	12	2.8	2.5												
45	54	2.0	1.0	33	2.2	1.4	22	2.4	1.8	17	2.5	2.1	13	2.8	2.5												
50	59	2.0	1.0	37	2.2	1.4	24	2.4	1.9	19	2.5	2.2	14	2.8	2.5	11	3.1	2.9									
55	65	2.0	1.0	40	2.2	1.4	26	2.4	1.9	21	2.5	2.2	16	2.8	2.6	12	3.1	2.9									
60	71	2.0	1.0	44	2.2	1.4	29	2.4	1.9	23	2.5	2.2	17	2.7	2.6	13	3.0	3.0									
65	77	2.0	1.0	47	2.2	1.4	31	2.4	1.9	25	2.5	2.2	18	2.7	2.6	14	3.0	3.0	11	3.4	3.2						
70	83	2.0	1.0	51	2.2	1.4	33	2.4	1.9	26	2.5	2.2	20	2.7	2.6	15	3.0	3.0	12	3.3	3.3						
75	88	2.0	1.0	54	2.2	1.4	36	2.4	1.9	28	2.5	2.2	21	2.7	2.7	16	3.0	3.1	13	3.3	3.4						
80	94	2.0	1.0	58	2.2	1.4	38	2.4	1.9	30	2.5	2.2	23	2.7	2.7	17	3.0	3.1	14	3.2	3.4						
90				65	2.2	1.4	43	2.4	1.9	34	2.5	2.2	25	2.7	2.7	19	3.0	3.1	16	3.2	3.5	13	3.5	3.8			
100				72	2.2	1.4	47	2.4	1.9	38	2.5	2.2	28	2.7	2.7	21	3.0	3.1	17	3.2	3.6	14	3.4	3.9			
110				79	2.2	1.4	52	2.4	1.9	41	2.5	2.3	31	2.7	2.7	23	2.9	3.2	19	3.2	3.6	16	3.4	3.9	13	3.7	4.1
120				86	2.2	1.4	57	2.4	1.9	45	2.5	2.3	34	2.7	2.7	25	2.9	3.2	21	3.2	3.6	17	3.4	4.0	15	3.7	4.2
130				94	2.2	1.4	61	2.4	1.9	49	2.5	2.3	36	2.7	2.7	27	2.9	3.2	22	3.1	3.6	18	3.4	4.0	16	3.6	4.3
140							66	2.4	1.9	52	2.5	2.3	39	2.7	2.7	29	2.9	3.2	23	3.1	3.6	20	3.4	4.1	17	3.6	4.3
150							71	2.4	1.9	56	2.5	2.3	42	2.7	2.7	31	2.9	3.2	26	3.1	3.7	21	3.4	4.1	18	3.6	4.4
160							75	2.4	1.9	60	2.5	2.3	45	2.7	2.7	33	2.9	3.2	27	3.1	3.7	22	3.4	4.1	19	3.6	4.4
170							80	2.4	1.9	63	2.5	2.3	47	2.7	2.7	35	2.9	3.3	29	3.1	3.7	24	3.4	4.1	20	3.6	4.5
180							84	2.4	1.9	67	2.5	2.3	50	2.7	2.7	38	2.9	3.3	31	3.1	3.7	25	3.3	4.1	21	3.5	4.5
190							89	2.4	1.9	71	2.5	2.3	53	2.7	2.7	40	2.9	3.3	32	3.1	3.7	26	3.3	4.2	22	3.5	4.5
200							94	2.4	1.9	74	2.5	2.3	55	2.7	2.7	42	2.9	3.3	34	3.1	3.7	28	3.3	4.2	24	3.5	4.6
220										82	2.5	2.3	61	2.7	2.7	46	2.9	3.3	37	3.1	3.7	30	3.3	4.2	26	3.5	4.6
240										89	2.5	2.3	66	2.7	2.8	50	2.9	3.3	41	3.1	3.7	33	3.3	4.2	28	3.5	4.6
260										96	2.5	2.3	72	2.7	2.8	54	2.9	3.3	44	3.1	3.8	36	3.3	4.2	30	3.5	4.7
280													77	2.7	2.8	58	2.9	3.3	47	3.1	3.8	38	3.3	4.2	33	3.5	4.7
300													83	2.7	2.8	62	2.9	3.3	50	3.1	3.8	41	3.3	4.2	35	3.5	4.7

T = Top width, Retardance "B"
D = Depth, Retardance "B"
V_2 = Velocity, Retardance "B"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Parabolic diversion design chart (Sheet 4 of 6)

Continued

Exhibit 6

V_1 Based on Permissible Velocity of the Soil With Retardance "D"

Top Width, Depth & V_2 Based on Retardance "B" Grade = 1.5%

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	24	1.8	0.9	15	1.9	1.2	10	2.2	1.5																		
20	32	1.8	0.9	20	1.9	1.2	14	2.1	1.6																		
25	39	1.8	0.9	25	1.9	1.2	17	2.1	1.6	11	2.3	2.1															
30	47	1.8	0.9	31	1.9	1.2	20	2.1	1.6	13	2.3	2.2	11	2.4	2.4												
35	55	1.8	0.9	36	1.9	1.2	23	2.1	1.7	16	2.2	2.2	13	2.4	2.5	10	2.6	2.7									
40	63	1.8	0.9	41	1.9	1.2	27	2.1	1.7	18	2.2	2.2	14	2.3	2.6	12	2.5	2.8									
45	70	1.8	0.9	46	1.9	1.2	30	2.1	1.7	20	2.2	2.2	16	2.3	2.6	13	2.5	2.8	10	2.8	3.2						
50	78	1.8	0.9	51	1.9	1.2	33	2.1	1.7	22	2.2	2.2	18	2.3	2.6	15	2.5	2.9	11	2.8	3.3						
55	86	1.8	0.9	55	1.9	1.2	36	2.1	1.7	24	2.2	2.3	20	2.3	2.6	16	2.5	2.9	12	2.7	3.4	10	3.0	3.5			
60	93	1.8	0.9	60	1.9	1.2	40	2.0	1.7	26	2.2	2.3	21	2.3	2.6	17	2.5	2.9	13	2.7	3.4	11	3.0	3.6			
65				65	1.9	1.2	43	2.0	1.7	29	2.2	2.3	23	2.3	2.6	19	2.5	3.0	14	2.7	3.4	12	2.9	3.7			
70				70	1.9	1.2	46	2.0	1.7	31	2.2	2.3	25	2.3	2.6	20	2.5	3.0	15	2.7	3.4	13	2.9	3.8	11	3.1	4.0
75				75	1.9	1.2	49	2.0	1.7	33	2.2	2.3	26	2.3	2.7	22	2.5	3.0	16	2.7	3.5	14	2.9	3.8	12	3.1	4.0
80				80	1.9	1.2	52	2.0	1.7	35	2.2	2.3	28	2.3	2.7	23	2.5	3.0	18	2.7	3.5	15	2.9	3.8	13	3.1	4.2
90				90	1.9	1.2	59	2.0	1.7	39	2.2	2.3	32	2.3	2.7	26	2.5	3.0	20	2.7	3.5	16	2.8	3.9	14	3.0	4.2
100							65	2.0	1.7	44	2.2	2.3	35	2.3	2.7	29	2.4	3.0	22	2.7	3.5	18	2.8	4.0	15	3.0	4.3
110							72	2.0	1.7	48	2.2	2.3	39	2.3	2.7	31	2.4	3.0	24	2.7	3.5	20	2.8	4.0	17	3.0	4.4
120							78	2.0	1.7	52	2.2	2.3	42	2.3	2.7	34	2.4	3.0	26	2.6	3.6	22	2.8	4.0	18	3.0	4.4
130							85	2.0	1.7	57	2.2	2.3	45	2.3	2.7	37	2.4	3.0	28	2.6	3.6	23	2.8	4.0	19	3.0	4.4
140							91	2.0	1.7	61	2.2	2.3	49	2.3	2.7	40	2.4	3.1	30	2.6	3.6	25	2.8	4.0	21	3.0	4.5
150							97	2.0	1.7	65	2.2	2.3	52	2.3	2.7	43	2.4	3.1	32	2.6	3.6	27	2.8	4.0	22	2.9	4.5
160										69	2.2	2.3	56	2.3	2.7	45	2.4	3.1	34	2.6	3.6	29	2.8	4.1	24	2.9	4.5
170										74	2.2	2.3	59	2.3	2.7	48	2.4	3.1	37	2.6	3.6	30	2.8	4.1	25	2.9	4.5
180										78	2.2	2.3	63	2.3	2.7	51	2.4	3.1	39	2.6	3.6	32	2.8	4.1	27	2.9	4.6
190										82	2.2	2.3	66	2.3	2.7	54	2.4	3.1	41	2.6	3.7	34	2.8	4.1	28	2.9	4.6
200										86	2.2	2.3	69	2.3	2.7	56	2.4	3.1	43	2.6	3.7	36	2.8	4.1	30	2.9	4.6
220										95	2.2	2.3	76	2.3	2.7	62	2.4	3.1	47	2.6	3.7	39	2.8	4.1	33	2.9	4.6
240													83	2.3	2.7	68	2.4	3.1	51	2.6	3.7	43	2.8	4.1	35	2.9	4.6
260													90	2.3	2.7	73	2.4	3.1	55	2.6	3.7	46	2.8	4.1	38	2.9	4.6
280													97	2.3	2.7	79	2.4	3.1	60	2.6	3.7	50	2.8	4.1	41	2.9	4.6
300																84	2.4	3.1	64	2.6	3.7	53	2.8	4.1	44	2.9	4.7

T = Top width, Retardance "B"
D = Depth, Retardance "B"
V_2 = Velocity, Retardance "B"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Parabolic diversion design chart (Sheet 5 of 6)

Continued

Exhibit 6

V_1 Based on Permissible Velocity of the Soil With Retardance "D"

Top Width, Depth & V_2 Based on Retardance "B" Grade = 2.0%

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	30	1.6	0.8	18	1.8	1.2	13	1.9	1.4	9	2.1	1.8															
20	39	1.6	0.8	24	1.8	1.2	17	1.9	1.5	12	2.0	1.9															
25	49	1.6	0.8	30	1.7	1.2	21	1.9	1.5	15	2.0	2.0	11	2.2	2.4												
30	59	1.6	0.8	35	1.7	1.2	25	1.9	1.5	18	2.0	2.0	13	2.1	2.5	10	2.3	2.8									
35	68	1.6	0.8	41	1.7	1.2	29	1.9	1.5	21	2.0	2.0	15	2.1	2.5	12	2.2	2.9	10	2.4	3.0						
40	78	1.6	0.8	47	1.7	1.2	34	1.9	1.5	23	2.0	2.0	17	2.1	2.5	14	2.2	2.9	11	2.4	3.2						
45	88	1.6	0.8	53	1.7	1.2	38	1.9	1.5	26	2.0	2.0	19	2.1	2.5	15	2.2	2.9	13	2.4	3.2	10	2.6	3.5			
50	97	1.6	0.8	59	1.7	1.2	42	1.9	1.6	29	2.0	2.0	21	2.1	2.6	17	2.2	2.9	14	2.4	3.2	11	2.5	3.6			
55				64	1.7	1.2	46	1.8	1.6	32	2.0	2.0	23	2.1	2.6	19	2.2	2.9	15	2.4	3.3	12	2.5	3.7	10	2.7	4.0
60				70	1.7	1.2	50	1.8	1.6	35	2.0	2.0	25	2.1	2.6	20	2.2	3.0	17	2.4	3.3	13	2.5	3.7	11	2.7	4.0
65				76	1.7	1.2	54	1.8	1.6	38	2.0	2.0	27	2.1	2.6	22	2.2	3.0	18	2.3	3.4	15	2.5	3.7	12	2.7	4.1
70				81	1.7	1.2	58	1.8	1.6	41	2.0	2.1	29	2.1	2.6	24	2.2	3.0	19	2.3	3.4	16	2.5	3.8	13	2.7	4.1
75				87	1.7	1.2	62	1.8	1.6	43	2.0	2.1	31	2.1	2.6	25	2.2	3.0	21	2.3	3.4	17	2.5	3.8	14	2.7	4.1
80				93	1.7	1.2	68	1.8	1.6	46	2.0	2.1	33	2.1	2.6	27	2.2	3.0	22	2.3	3.4	18	2.5	3.8	15	2.6	4.2
90							74	1.8	1.6	52	2.0	2.1	37	2.1	2.6	30	2.2	3.0	25	2.3	3.4	20	2.5	3.8	17	2.6	4.2
100							83	1.8	1.6	58	2.0	2.1	41	2.1	2.6	34	2.2	3.0	27	2.3	3.4	22	2.5	3.9	18	2.6	4.3
110							91	1.8	1.6	63	2.0	2.1	45	2.1	2.6	37	2.2	3.0	30	2.3	3.4	24	2.5	3.9	20	2.6	4.3
120							99	1.8	1.6	69	2.0	2.1	49	2.1	2.6	40	2.2	3.0	33	2.3	3.4	26	2.4	3.9	22	2.6	4.3
130										75	2.0	2.1	53	2.1	2.6	44	2.2	3.0	35	2.3	3.4	29	2.4	3.9	24	2.6	4.3
140										80	2.0	2.1	57	2.1	2.6	47	2.2	3.0	38	2.3	3.5	31	2.4	3.9	26	2.6	4.4
150										86	2.0	2.1	61	2.1	2.7	50	2.2	3.0	41	2.3	3.5	33	2.4	3.9	27	2.6	4.4
160										91	2.0	2.1	65	2.1	2.7	53	2.2	3.0	43	2.3	3.5	35	2.4	3.9	29	2.6	4.4
170										97	2.0	2.1	69	2.1	2.7	57	2.2	3.1	46	2.3	3.5	37	2.4	4.0	31	2.6	4.4
180													73	2.1	2.7	60	2.2	3.1	49	2.3	3.5	39	2.4	4.0	33	2.6	4.4
190													77	2.1	2.7	63	2.2	3.1	51	2.3	3.5	41	2.4	4.0	34	2.6	4.5
200													81	2.1	2.7	66	2.2	3.1	54	2.3	3.5	44	2.4	4.0	36	2.6	4.5
220													89	2.1	2.7	73	2.2	3.1	59	2.3	3.5	48	2.4	4.0	40	2.6	4.5
240													97	2.1	2.7	79	2.2	3.1	65	2.3	3.5	52	2.4	4.0	43	2.6	4.5
260																86	2.2	3.1	70	2.3	3.5	56	2.4	4.0	47	2.6	4.5
280																92	2.2	3.1	75	2.3	3.5	61	2.4	4.0	50	2.6	4.5
300																99	2.2	3.1	81	2.3	3.5	65	2.4	4.0	54	2.6	4.

T = Top width, Retardance "B"
D = Depth, Retardance "B"
V_2 = Velocity, Retardance "B"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Parabolic diversion design chart (Sheet 6 of 6)

Continued

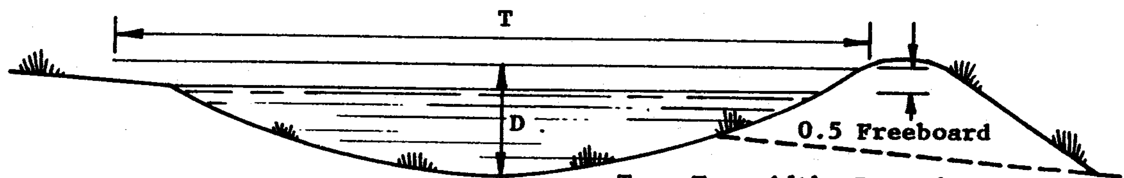
Exhibit 6

V_1 Based on Permissible Velocity of the Soil With Retardance "D"

Top Width, Depth & V_2 Based on Retardance "C"

Grade = 0.25%

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15																											
20																											
25	11	2.9	1.6																								
30	13	2.8	1.7																								
35	15	2.8	1.7																								
40	17	2.8	1.8	11	3.2	2.1																					
45	19	2.7	1.8	13	3.1	2.2																					
50	21	2.7	1.8	14	3.1	2.2																					
55	23	2.7	1.8	15	3.1	2.3																					
60	25	2.7	1.8	17	3.0	2.3																					
65	27	2.7	1.8	18	3.0	2.3																					
70	29	2.7	1.9	19	3.0	2.3	14	3.6	2.7																		
75	31	2.7	1.9	21	3.0	2.3	15	3.5	2.8																		
80	33	2.7	1.9	22	3.0	2.4	16	3.5	2.8																		
90	37	2.7	1.9	25	3.0	2.4	17	3.5	2.8																		
100	41	2.7	1.9	28	3.0	2.4	19	3.5	2.9																		
110	45	2.7	1.9	30	3.0	2.4	21	3.4	2.9																		
120	49	2.7	1.9	33	3.0	2.4	23	3.4	2.9	16	4.1	3.3															
130	53	2.7	1.9	36	3.0	2.4	25	3.4	2.9	18	4.1	3.3															
140	57	2.7	1.9	38	3.0	2.4	27	3.4	2.9	19	4.0	3.4															
150	61	2.7	1.9	41	3.0	2.4	29	3.4	2.9	20	4.0	3.4															
160	65	2.7	1.9	44	3.0	2.4	30	3.4	3.0	21	4.0	3.4															
170	69	2.7	1.9	46	3.0	2.4	32	3.4	3.0	23	4.0	3.4	18	4.5	3.8												
180	73	2.7	1.9	49	3.0	2.4	34	3.4	3.0	24	4.0	3.5	19	4.5	3.8												
190	77	2.7	1.9	52	3.0	2.4	36	3.4	3.0	25	4.0	3.5	20	4.5	3.9												
200	81	2.7	1.9	55	3.0	2.4	38	3.4	3.0	27	3.9	3.5	21	4.4	3.9												
220	89	2.7	1.9	60	3.0	2.4	42	3.4	3.0	29	3.9	3.5	23	4.4	3.9												
240	97	2.7	1.9	65	3.0	2.5	45	3.4	3.0	32	3.9	3.6	25	4.4	4.0												
260				71	3.0	2.5	49	3.4	3.0	34	3.9	3.6	27	4.4	4.0	21	5.1	4.3									
280				76	3.0	2.5	53	3.4	3.0	37	3.9	3.6	29	4.4	4.0	22	5.1	4.3									
300				82	3.0	2.5	57	3.4	3.0	40	3.9	3.6	31	4.3	4.1	24	5.0	4.4									



T = Top width, Retardance "C"
D = Depth, Retardance "C"
V_2 = Velocity, Retardance "C"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Parabolic diversion design chart (Sheet 1 of 6)

Continued

Exhibit 6

V_1 Based on Permissible Velocity of the Soil With Retardance "D"

Top Width, Depth & V_2 Based on Retardance "C" — **Grade = 0.5%**

Q	$V_1 = 2.0$			$V_1 = 2.5$			$V_1 = 3.0$			$V_1 = 3.5$			$V_1 = 4.0$			$V_1 = 4.5$			$V_1 = 5.0$			$V_1 = 5.5$			$V_1 = 6.0$		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	10	2.1	1.6																								
20	13	2.1	1.7																								
25	16	2.1	1.7	10	2.4	2.1																					
30	20	2.1	1.7	12	2.4	2.2	9	2.7	2.5																		
35	23	2.1	1.7	14	2.4	2.3	11	2.6	2.6																		
40	26	2.1	1.7	16	2.3	2.3	12	2.6	2.7																		
45	29	2.0	1.7	18	2.3	2.3	13	2.5	2.8																		
50	32	2.0	1.7	20	2.3	2.4	15	2.5	2.8	11	2.9	3.2															
55	35	2.0	1.7	22	2.3	2.4	16	2.5	2.8	12	2.9	3.3															
60	39	2.0	1.7	24	2.3	2.4	18	2.5	2.8	13	2.9	3.3															
65	42	2.0	1.8	26	2.3	2.4	19	2.5	2.9	14	2.9	3.3															
70	45	2.0	1.8	28	2.3	2.4	21	2.5	2.9	15	2.8	3.4															
75	48	2.0	1.8	30	2.3	2.4	22	2.5	2.9	16	2.8	3.4	12	3.2	3.7												
80	51	2.0	1.8	32	2.3	2.4	23	2.5	2.9	17	2.8	3.4	13	3.2	3.8												
90	57	2.0	1.8	35	2.3	2.4	26	2.5	2.9	19	2.8	3.4	15	3.2	3.8												
100	64	2.0	1.8	39	2.3	2.4	29	2.5	2.9	21	2.8	3.5	16	3.1	3.9	13	3.5	4.1									
110	70	2.0	1.8	43	2.3	2.4	32	2.5	2.9	23	2.8	3.5	18	3.1	3.9	14	3.5	4.2									
120	76	2.0	1.8	47	2.3	2.4	35	2.5	2.9	25	2.8	3.5	19	3.1	3.9	15	3.4	4.3									
130	83	2.0	1.8	51	2.3	2.4	38	2.5	2.9	27	2.8	3.5	21	3.1	4.0	17	3.4	4.4									
140	89	2.0	1.8	55	2.3	2.4	41	2.5	2.9	29	2.8	3.5	22	3.1	4.0	18	3.4	4.3									
150	95	2.0	1.8	59	2.3	2.4	44	2.5	2.9	31	2.8	3.5	24	3.1	4.0	19	3.4	4.4	15	3.8	4.8						
160				62	2.3	2.4	46	2.5	2.9	33	2.8	3.5	25	3.1	4.0	20	3.4	4.4	16	3.8	4.8						
170				66	2.3	2.4	49	2.5	2.9	35	2.8	3.6	27	3.1	4.0	22	3.4	4.4	17	3.8	4.9						
180				70	2.3	2.4	52	2.5	2.9	37	2.8	3.6	29	3.1	4.0	23	3.4	4.5	18	3.8	4.9						
190				74	2.3	2.4	55	2.5	2.9	39	2.8	3.6	30	3.1	4.0	24	3.4	4.5	19	3.8	5.0						
200				78	2.3	2.4	58	2.5	2.9	41	2.8	3.6	32	3.1	4.0	25	3.4	4.5	20	3.8	5.0	16	4.2	5.2			
220				86	2.3	2.4	64	2.5	2.9	45	2.8	3.6	35	3.1	4.0	28	3.4	4.5	22	3.7	5.0	18	4.2	5.3			
240				93	2.3	2.4	69	2.5	2.9	49	2.8	3.6	38	3.0	4.1	30	3.4	4.5	24	3.7	5.0	20	4.2	5.4			
260							75	2.5	2.9	53	2.8	3.6	41	3.0	4.1	33	3.4	4.5	26	3.7	5.0	21	4.1	5.4			
280							81	2.5	3.0	57	2.8	3.6	44	3.0	4.1	35	3.3	4.6	28	3.7	5.0	23	4.1	5.5	19	4.6	5.8
300							87	2.5	3.0	61	2.8	3.6	47	3.0	4.1	38	3.3	4.6	30	3.6	5.0	24	4.1	5.5	20	4.6	5.8

T = Top Width, Retardance "C"
D = Depth, Retardance "C"
V_2 = Velocity, Retardance "C"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Parabolic diversion design chart (Sheet 2 of 6)

Continued

Exhibit 6

V_1 Based on Permissible Velocity of the Soil With Retardance "D"
Top Width, Depth & V_2 Based on Retardance "C" Grade = 0.75%

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	14	1.8	1.5																								
20	18	1.8	1.5	10	2.0	2.2																					
25	23	1.8	1.5	13	2.0	2.2																					
30	27	1.8	1.5	15	2.0	2.2	11	2.2	2.7																		
35	32	1.8	1.5	18	2.0	2.3	13	2.2	2.7	10	2.4	3.1															
40	37	1.8	1.5	20	2.0	2.3	15	2.2	2.8	11	2.4	3.2															
45	41	1.8	1.6	23	2.0	2.3	17	2.2	2.8	13	2.3	3.2															
50	45	1.8	1.6	25	2.0	2.3	18	2.1	2.9	14	2.3	3.3	10	2.7	3.7												
55	50	1.8	1.6	28	2.0	2.3	20	2.1	2.9	16	2.3	3.3	11	2.6	3.8												
60	54	1.8	1.6	30	2.0	2.3	22	2.1	2.9	17	2.3	3.3	12	2.6	3.8												
65	59	1.8	1.6	33	2.0	2.3	24	2.1	2.9	18	2.3	3.3	13	2.6	3.8	11	2.9	4.1									
70	63	1.8	1.6	35	2.0	2.3	25	2.1	2.9	20	2.3	3.3	14	2.6	3.9	12	2.9	4.2									
75	68	1.8	1.6	38	2.0	2.3	27	2.1	2.9	21	2.3	3.3	15	2.6	3.9	13	2.8	4.2									
80	72	1.8	1.6	40	2.0	2.3	29	2.1	2.9	23	2.3	3.3	16	2.6	3.9	14	2.8	4.3									
90	81	1.8	1.6	45	2.0	2.3	33	2.1	2.9	25	2.3	3.4	18	2.6	4.0	15	2.8	4.4	12	3.1	4.6						
100	90	1.8	1.6	50	2.0	2.3	36	2.1	2.9	28	2.3	3.4	20	2.6	4.0	17	2.8	4.4	13	3.1	4.8						
110	99	1.8	1.6	55	2.0	2.3	40	2.1	2.9	31	2.3	3.4	22	2.5	4.0	18	2.8	4.5	15	3.1	4.8						
120				60	2.0	2.3	43	2.1	2.9	34	2.3	3.4	24	2.5	4.0	20	2.8	4.5	16	3.0	4.8	13	3.4	5.2			
130				65	2.0	2.4	47	2.1	2.9	36	2.3	3.4	26	2.5	4.0	21	2.7	4.5	17	3.0	4.9	14	3.3	5.3			
140				70	2.0	2.4	50	2.1	2.9	39	2.3	3.4	28	2.5	4.1	23	2.7	4.5	19	3.0	4.9	15	3.3	5.3			
150				75	2.0	2.4	54	2.1	2.9	42	2.3	3.4	30	2.5	4.1	25	2.7	4.5	20	3.0	4.9	16	3.3	5.3			
160				80	2.0	2.4	58	2.1	2.9	45	2.3	3.4	32	2.5	4.1	26	2.7	4.5	21	3.0	4.9	17	3.3	5.4	14	3.6	5.8
170				85	2.0	2.4	61	2.1	2.9	47	2.3	3.4	34	2.5	4.1	28	2.7	4.5	22	3.0	5.0	18	3.3	5.4	15	3.6	5.8
180				89	2.0	2.4	65	2.1	2.9	50	2.3	3.4	36	2.5	4.1	29	2.7	4.5	24	3.0	5.0	19	3.3	5.5	16	3.6	5.9
190				94	2.0	2.4	68	2.1	2.9	53	2.3	3.4	38	2.5	4.1	31	2.7	4.6	25	3.0	5.0	21	3.3	5.5	17	3.6	5.9
200				99	2.0	2.4	72	2.1	3.0	55	2.3	3.4	40	2.5	4.1	33	2.7	4.6	26	3.0	5.0	22	3.2	5.5	18	3.6	5.9
220							79	2.1	3.0	61	2.3	3.4	44	2.5	4.1	36	2.7	4.6	29	3.0	5.0	24	3.2	5.5	19	3.6	5.9
240							86	2.1	3.0	66	2.3	3.4	48	2.5	4.1	39	2.7	4.6	32	3.0	5.0	26	3.2	5.5	21	3.6	6.0
260							93	2.1	3.0	72	2.3	3.4	52	2.5	4.1	42	2.7	4.6	34	3.0	5.0	28	3.2	5.5	23	3.6	6.0
280										77	2.3	3.4	56	2.5	4.1	45	2.7	4.6	37	3.0	5.0	30	3.2	5.5	24	3.5	6.0
300										83	2.3	3.5	60	2.5	4.1	49	2.7	4.6	39	3.0	5.0	32	3.2	5.5	26	3.5	6.0

T = Top Width, Retardance "C"
D = Depth, Retardance "C"
V2 = Velocity, Retardance "C"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge)

Parabolic diversion design chart (Sheet 3 of 6)

Continued

Exhibit 6

V_1 Based on Permissible Velocity of the Soil With Retardance "D"
Top Width, Depth & V_2 Based on Retardance "C" **Grade = 1.0%**

Q	$V_1 = 2.0$			$V_1 = 2.5$			$V_1 = 3.0$		
cfs	T	D	V_2	T	D	V_2	T	D	V_2
15	16	1.6	1.5	10	1.8	2.0			
20	22	1.6	1.5	13	1.8	2.1			
25	27	1.6	1.5	17	1.8	2.1	11	2.0	2.6
30	32	1.6	1.5	20	1.8	2.1	13	2.0	2.7
35	37	1.6	1.5	23	1.8	2.2	15	2.0	2.8
40	43	1.6	1.5	26	1.8	2.2	17	1.9	2.8
45	48	1.6	1.5	29	1.8	2.2	19	1.9	2.8
50	53	1.6	1.5	33	1.8	2.2	22	1.9	2.8
55	58	1.6	1.5	36	1.8	2.2	24	1.9	2.8
60	64	1.6	1.5	39	1.8	2.2	26	1.9	2.8
65	69	1.6	1.5	42	1.8	2.2	28	1.9	2.8
70	74	1.6	1.5	45	1.8	2.2	30	1.9	2.8
75	79	1.6	1.5	49	1.8	2.2	32	1.9	2.9
80	84	1.6	1.5	52	1.8	2.2	34	1.9	2.9
90	95	1.6	1.5	58	1.8	2.2	38	1.9	2.9
100				65	1.8	2.2	43	1.9	2.9
110				71	1.8	2.2	47	1.9	2.9
120				77	1.8	2.2	51	1.9	2.9
130				84	1.8	2.2	55	1.9	2.9
140				90	1.8	2.2	59	1.9	2.9
150				96	1.8	2.2	64	1.9	2.9
160							68	1.9	2.9
170							72	1.9	2.9
180							76	1.9	2.9
190							80	1.9	2.9
200							84	1.9	2.9
220							93	1.9	2.9
240									
260									
280									
300									

Q	$V_1 = 3.5$			$V_1 = 4.0$			$V_1 = 4.5$		
cfs	T	D	V_2	T	D	V_2	T	D	V_2
15									
20									
25									
30	11	2.1	3.0						
35	12	2.1	3.1						
40	14	2.1	3.1	10	2.3	3.7			
45	16	2.1	3.2	12	2.3	3.7			
50	17	2.1	3.2	13	2.3	3.7	10	2.5	4.2
55	19	2.0	3.3	14	2.3	3.8	11	2.5	4.3
60	21	2.0	3.3	15	2.2	3.8	12	2.5	4.3
65	22	2.0	3.3	17	2.2	3.8	13	2.5	4.3
70	24	2.0	3.3	18	2.2	3.9	14	2.5	4.4
75	26	2.0	3.3	19	2.2	3.9	15	2.5	4.5
80	27	2.0	3.3	20	2.2	3.9	16	2.5	4.5
90	31	2.0	3.3	23	2.2	3.9	17	2.4	4.5
100	34	2.0	3.3	25	2.2	3.9	19	2.4	4.5
110	37	2.0	3.3	28	2.2	3.9	21	2.4	4.5
120	41	2.0	3.3	30	2.2	4.0	23	2.4	4.5
130	44	2.0	3.3	33	2.2	4.0	25	2.4	4.5
140	47	2.0	3.3	35	2.2	4.0	27	2.4	4.5
150	51	2.0	3.3	38	2.2	4.0	29	2.4	4.5
160	54	2.0	3.3	40	2.2	4.0	30	2.4	4.5
170	57	2.0	3.3	43	2.2	4.0	32	2.4	4.5
180	61	2.0	3.4	45	2.2	4.0	34	2.4	4.5
190	64	2.0	3.4	48	2.2	4.0	36	2.4	4.5
200	67	2.0	3.4	50	2.2	4.0	38	2.4	4.5
220	74	2.0	3.4	55	2.2	4.0	42	2.4	4.5
240	81	2.0	3.4	60	2.2	4.0	45	2.4	4.5
260	87	2.0	3.4	65	2.2	4.0	49	2.4	4.5
280	94	2.0	3.4	70	2.2	4.0	53	2.4	4.5
300				75	2.2	4.0	57	2.4	4.5

Q	$V_1 = 5.0$			$V_1 = 5.5$			$V_1 = 6.0$		
cfs	T	D	V_2	T	D	V_2	T	D	V_2
15									
20									
25									
30									
35									
40									
45									
50									
55									
60									
65	10	2.7	4.7						
70	11	2.7	4.7						
75	12	2.7	4.7						
80	13	2.7	4.9						
90	14	2.7	4.9	12	2.9	5.2			
100	16	2.7	4.9	13	2.9	5.3			
110	17	2.6	5.0	14	2.9	5.3	12	3.1	5.7
120	19	2.6	5.0	16	2.9	5.4	13	3.1	5.7
130	20	2.6	5.0	17	2.9	5.4	14	3.1	5.8
140	22	2.6	5.0	18	2.8	5.5	15	3.1	5.8
150	23	2.6	5.0	19	2.8	5.5	17	3.1	5.8
160	25	2.6	5.0	20	2.8	5.5	18	3.0	6.0
170	26	2.5	5.0	22	2.8	5.5	19	3.0	6.0
180	28	2.6	5.0	23	2.8	5.5	20	3.0	6.0
190	29	2.6	5.0	24	2.8	5.5	21	3.0	6.0
200	31	2.6	5.0	25	2.8	5.5	22	3.0	6.0
220	34	2.6	5.0	28	2.8	5.5	24	3.0	6.0
240	37	2.6	5.0	30	2.8	5.5	26	3.0	6.0
260	40	2.6	5.0	33	2.8	5.5	28	3.0	6.0
280	43	2.6	5.0	36	2.8	5.5	30	3.0	6.0
300	46	2.5	5.0	38	2.8	5.5	32	3.0	6.0

T = Top Width, Retardance "C"
D = Depth, Retardance "C"
V_2 = Velocity, Retardance "C"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Parabolic diversion design chart (Sheet 4 of 6)

Continued

Exhibit 6

V_1 Based on Permissible Velocity of the Soil With Retardance "D"

Top Width, Depth & V_2 Based on Retardance "B" **Grade = 1.5%**

Q	$V_1 = 2.0$			$V_1 = 2.5$			$V_1 = 3.0$		
cfs	T	D	V_2	T	D	V_2	T	D	V_2
15	24	1.8	0.9	15	1.9	1.2	10	2.2	1.5
20	32	1.8	0.9	20	1.9	1.2	14	2.1	1.6
25	39	1.8	0.9	25	1.9	1.2	17	2.1	1.6
30	47	1.8	0.9	31	1.9	1.2	20	2.1	1.6
35	55	1.8	0.9	36	1.9	1.2	23	2.1	1.7
40	63	1.8	0.9	41	1.9	1.2	27	2.1	1.7
45	70	1.8	0.9	46	1.9	1.2	30	2.1	1.7
50	78	1.8	0.9	51	1.9	1.2	33	2.1	1.7
55	86	1.8	0.9	55	1.9	1.2	36	2.1	1.7
60	93	1.8	0.9	60	1.9	1.2	40	2.0	1.7
65				65	1.9	1.2	43	2.0	1.7
70				70	1.9	1.2	46	2.0	1.7
75				75	1.9	1.2	49	2.0	1.7
80				80	1.9	1.2	52	2.0	1.7
90				90	1.9	1.2	59	2.0	1.7
100							65	2.0	1.7
110							72	2.0	1.7
120							78	2.0	1.7
130							85	2.0	1.7
140							91	2.0	1.7
150							97	2.0	1.7
160									
170									
180									
190									
200									
220									
240									
260									
280									
300									

Q	$V_1 = 3.5$			$V_1 = 4.0$			$V_1 = 4.5$		
cfs	T	D	V_2	T	D	V_2	T	D	V_2
15									
20									
25	11	2.3	2.1						
30	13	2.3	2.2	11	2.4	2.4			
35	16	2.2	2.2	13	2.4	2.5	10	2.6	2.7
40	18	2.2	2.2	14	2.3	2.6	12	2.5	2.8
45	20	2.2	2.2	16	2.3	2.6	13	2.5	2.8
50	22	2.2	2.2	18	2.3	2.6	15	2.5	2.9
55	24	2.2	2.3	20	2.3	2.6	16	2.5	2.9
60	26	2.2	2.3	21	2.3	2.6	17	2.5	2.9
65	29	2.2	2.3	23	2.3	2.6	19	2.5	3.0
70	31	2.2	2.3	25	2.3	2.6	20	2.5	3.0
75	33	2.2	2.3	26	2.3	2.7	22	2.5	3.0
80	35	2.2	2.3	28	2.3	2.7	23	2.5	3.0
90	39	2.2	2.3	32	2.3	2.7	26	2.5	3.0
100	44	2.2	2.3	35	2.3	2.7	29	2.4	3.0
110	48	2.2	2.3	39	2.3	2.7	31	2.4	3.0
120	52	2.2	2.3	42	2.3	2.7	34	2.4	3.0
130	57	2.2	2.3	45	2.3	2.7	37	2.4	3.0
140	61	2.2	2.3	49	2.3	2.7	40	2.4	3.1
150	65	2.2	2.3	52	2.3	2.7	43	2.4	3.1
160	69	2.2	2.3	56	2.3	2.7	45	2.4	3.1
170	74	2.2	2.3	59	2.3	2.7	48	2.4	3.1
180	78	2.2	2.3	63	2.3	2.7	51	2.4	3.1
190	82	2.2	2.3	66	2.3	2.7	54	2.4	3.1
200	86	2.2	2.3	69	2.3	2.7	56	2.4	3.1
220	95	2.2	2.3	76	2.3	2.7	62	2.4	3.1
240				83	2.3	2.7	68	2.4	3.1
260				90	2.3	2.7	73	2.4	3.1
280				97	2.3	2.7	79	2.4	3.1
300							84	2.4	3.1

Q	$V_1 = 5.0$			$V_1 = 5.5$			$V_1 = 6.0$		
cfs	T	D	V_2	T	D	V_2	T	D	V_2
15									
20									
25									
30									
35									
40									
45	10	2.8	3.2						
50	11	2.8	3.3						
55	12	2.7	3.4	10	3.0	3.5			
60	13	2.7	3.4	11	3.0	3.6			
65	14	2.7	3.4	12	2.9	3.7			
70	15	2.7	3.4	13	2.9	3.8	11	3.1	4.0
75	16	2.7	3.5	14	2.9	3.8	12	3.1	4.0
80	18	2.7	3.5	15	2.9	3.8	13	3.1	4.2
90	20	2.7	3.5	16	2.8	3.9	14	3.0	4.2
100	22	2.7	3.5	18	2.8	4.0	15	3.0	4.3
110	24	2.7	3.5	20	2.8	4.0	17	3.0	4.4
120	26	2.6	3.6	22	2.8	4.0	18	3.0	4.4
130	28	2.6	3.6	23	2.8	4.0	19	3.0	4.4
140	30	2.6	3.6	25	2.8	4.0	21	3.0	4.5
150	32	2.6	3.6	27	2.8	4.0	22	2.9	4.5
160	34	2.6	3.6	29	2.8	4.1	24	2.9	4.5
170	37	2.6	3.6	30	2.8	4.1	25	2.9	4.5
180	39	2.6	3.6	32	2.8	4.1	27	2.9	4.6
190	41	2.6	3.7	34	2.8	4.1	28	2.9	4.6
200	43	2.6	3.7	36	2.8	4.1	30	2.9	4.6
220	47	2.6	3.7	39	2.8	4.1	33	2.9	4.6
240	51	2.6	3.7	43	2.8	4.1	35	2.9	4.6
260	55	2.6	3.7	46	2.8	4.1	38	2.9	4.6
280	60	2.6	3.7	50	2.8	4.1	41	2.9	4.6
300	64	2.6	3.7	53	2.8	4.1	44	2.9	4.7

T = Top width, Retardance "B"
D = Depth, Retardance "B"
V_2 = Velocity, Retardance "B"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Parabolic diversion design chart (Sheet 5 of 6)

Continued

Exhibit 6

V_1 Based on Permissible Velocity of the Soil With Retardance "D"

Top Width, Depth & V_2 Based on Retardance "C" **Grade = 2.0%**

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	27	1.3	1.3	16	1.4	1.9	11	1.5	2.4																		
20	35	1.3	1.3	21	1.4	1.9	15	1.5	2.4	11	1.6	3.0															
25	44	1.3	1.3	27	1.4	1.9	19	1.5	2.4	13	1.6	3.0	10	1.8	3.7												
30	53	1.3	1.3	32	1.4	1.9	23	1.5	2.5	16	1.6	3.0	11	1.7	3.7	10	1.8	4.2									
35	61	1.3	1.3	37	1.4	1.9	26	1.5	2.5	19	1.6	3.1	13	1.7	3.8	11	1.8	4.2									
40	70	1.3	1.3	42	1.4	1.9	30	1.5	2.5	21	1.6	3.1	15	1.7	3.8	12	1.8	4.3	10	2.0	4.7						
45	78	1.3	1.4	48	1.4	1.9	34	1.5	2.5	24	1.6	3.1	17	1.7	3.8	14	1.8	4.3	11	1.9	4.8						
50	87	1.3	1.4	53	1.4	1.9	38	1.5	2.5	26	1.6	3.1	19	1.7	3.8	15	1.8	4.3	13	1.9	4.8	10	2.1	5.3			
55	95	1.3	1.4	58	1.4	1.9	41	1.5	2.5	29	1.6	3.1	21	1.7	3.8	17	1.8	4.3	14	1.9	4.9	11	2.1	5.3			
60				63	1.4	1.9	45	1.5	2.5	32	1.6	3.1	23	1.7	3.9	18	1.8	4.4	15	1.9	4.9	12	2.1	5.3	10	2.2	5.7
65				68	1.4	1.9	49	1.5	2.5	34	1.6	3.1	24	1.7	3.9	20	1.8	4.4	16	1.9	4.9	13	2.1	5.4	11	2.2	5.7
70				73	1.4	1.9	52	1.5	2.5	37	1.6	3.1	26	1.7	3.9	22	1.8	4.4	18	1.9	4.9	14	2.1	5.4	12	2.2	5.8
75				78	1.4	1.9	56	1.5	2.5	39	1.6	3.1	28	1.7	3.9	23	1.8	4.4	19	1.9	4.9	15	2.1	5.4	13	2.2	5.9
80				83	1.4	2.0	60	1.5	2.5	42	1.6	3.1	30	1.7	3.9	24	1.8	4.4	20	1.9	4.9	16	2.1	5.4	14	2.2	5.9
90				94	1.4	2.0	67	1.5	2.5	47	1.6	3.2	34	1.7	3.9	28	1.8	4.4	22	1.9	4.9	18	2.1	5.5	15	2.2	5.9
100							74	1.5	2.5	52	1.6	3.2	37	1.7	3.9	31	1.8	4.4	25	1.9	5.0	20	2.1	5.5	17	2.2	6.0
110							81	1.5	2.5	57	1.6	3.2	41	1.7	3.9	34	1.8	4.4	27	1.9	5.0	22	2.0	5.5	19	2.2	6.0
120							89	1.5	2.5	62	1.6	3.2	45	1.7	3.9	37	1.8	4.4	30	1.9	5.0	24	2.0	5.5	20	2.2	6.0
130							96	1.5	2.5	67	1.6	3.2	48	1.7	3.9	40	1.8	4.5	32	1.9	5.0	26	2.0	5.5	22	2.2	6.0
140										73	1.6	3.2	52	1.7	4.0	42	1.8	4.5	35	1.9	5.0	28	2.0	5.5	23	2.2	6.0
150										78	1.6	3.2	56	1.7	4.0	46	1.8	4.5	37	1.9	5.0	30	2.0	5.5	25	2.2	6.0
160										83	1.6	3.2	59	1.7	4.0	48	1.8	4.5	39	1.9	5.0	32	2.0	5.5	27	2.2	6.0
170										88	1.6	3.2	63	1.7	4.0	51	1.8	4.5	42	1.9	5.0	34	2.0	5.5	28	2.2	6.0
180										93	1.6	3.2	67	1.7	4.0	54	1.8	4.5	44	1.9	5.0	36	2.0	5.5	30	2.2	6.0
190										98	1.6	3.2	70	1.7	4.0	57	1.8	4.5	47	1.9	5.0	38	2.0	5.5	32	2.2	6.0
200													74	1.7	4.0	60	1.8	4.5	49	1.9	5.0	40	2.0	5.5	33	2.2	6.0
220													81	1.7	4.0	66	1.8	4.5	54	1.9	5.0	44	2.0	5.5	37	2.2	6.0
240													88	1.7	4.0	72	1.8	4.5	59	1.9	5.0	48	2.0	5.5	40	2.2	6.0
260													96	1.7	4.0	78	1.8	4.5	64	1.9	5.0	51	2.0	5.5	43	2.2	6.0
280																84	1.8	4.5	69	1.9	5.0	55	2.0	5.5	46	2.2	6.0
300																90	1.8	4.5	73	1.9	5.0	59	2.0	5.5	50	2.2	6.0

T = Top width, Retardance "C"
D = Depth, Retardance "C"
V_2 = Velocity, Retardance "C"
V_1 = Velocity, Retardance "D"

(Settlement to be added to top of ridge.)

Parabolic diversion design chart (Sheet 6 of 6)

Continued

Exhibit 7

(Based on Handbook of Channel Design, SCS-TP-61)

● 3:1 Side Slopes
"C" Retardance

6' bottom

Grade Q	0.2 d	0.2 A	0.3 d	0.3 A	0.4 d	0.4 A	0.5 d	0.5 A
20	1.9	22	1.7	19	1.5	16	1.4	14
30	2.0	24	1.8	21	1.7	19	1.5	16
40	2.2	28	2.0	24	1.9	22	1.7	19
50	2.3	30	2.1	26	2.0	24	1.8	21
60	2.5	34	2.3	30	2.1	26	1.9	22
80			2.5	34	2.3	30	2.1	26
100					2.5	34	2.3	30
120							2.5	34
140								
160								
180								
200								
220								

8' bottom

Grade Q	0.2 d	0.2 A	0.3 d	0.3 A	0.4 d	0.4 A	0.5 d	0.5 A
20	1.7	22	1.5	19	1.4	17	1.3	15
30	1.9	26	1.7	22	1.5	19	1.4	17
40	2.0	28	1.8	24	1.6	21	1.5	19
50	2.2	32	2.0	28	1.8	24	1.6	21
60	2.3	34	2.1	30	1.9	26	1.8	24
80	2.5	39	2.3	34	2.1	30	1.9	26
100			2.5	39	2.3	34	2.1	30
120					2.5	39	2.3	34
140							2.4	36
160								
180								
200								
220								

10' bottom

Grade Q	0.2 d	0.2 A	0.3 d	0.3 A	0.4 d	0.4 A	0.5 d	0.5 A
20	1.6	24	1.4	20	1.3	18	1.2	16
30	1.7	26	1.5	22	1.4	20	1.3	18
40	1.9	30	1.7	26	1.5	22	1.4	20
50	2.0	32	1.8	28	1.6	24	1.5	22
60	2.2	37	2.0	32	1.8	28	1.6	24
80	2.4	41	2.2	37	2.0	32	1.8	28
100			2.4	41	2.2	37	2.0	32
120					2.3	39	2.1	34
140					2.5	44	2.3	39
160							2.4	41
180							2.5	44
200								
220								

12' bottom

Grade Q	0.2 d	0.2 A	0.3 d	0.3 A	0.4 d	0.4 A	0.5 d	0.5 A
20								
30	1.6	27	1.4	23	1.3	21	1.2	19
40	1.8	31	1.6	27	1.5	25	1.4	23
50	1.9	34	1.7	29	1.6	27	1.5	25
60	2.0	36	1.8	31	1.7	29	1.6	27
80	2.2	41	2.0	36	1.9	34	1.7	29
100	2.5	49	2.2	41	2.0	36	1.8	31
120			2.4	46	2.2	41	2.0	36
140					2.3	43	2.1	38
160					2.4	46	2.2	41
180							2.4	46
200							2.5	49
220							2.6	51

● 4:1 Side Slopes
"C" Retardance

6' bottom width

Grade Q	0.2 d	0.2 A	0.3 d	0.3 A	0.4 d	0.4 A	0.5 d	0.5 A
30	2.0	28	1.8	24	1.6	20	1.5	18
40	2.1	30	1.9	26	1.7	22	1.6	20
50	2.3	35	2.1	30	1.9	26	1.7	22
60	2.4	37	2.2	33	2.0	28	1.9	26
80			2.4	37	2.2	33	2.0	28
100			2.5	40	2.3	35	2.2	33
120					2.5	40	2.4	37
140							2.5	40
160								
180								
200								
220								

8' bottom width

Grade Q	0.2 d	0.2 A	0.3 d	0.3 A	0.4 d	0.4 A	0.5 d	0.5 A
30	1.8	27	1.7	25	1.5	21	1.4	19
40	2.0	32	1.8	27	1.6	23	1.5	21
50	2.1	34	1.9	30	1.7	25	1.6	23
60	2.3	40	2.1	34	1.9	30	1.7	25
80	2.5	45	2.3	40	2.1	34	1.9	30
100			2.5	45	2.3	40	2.0	32
120					2.4	42	2.2	37
140					2.5	45	2.3	40
160							2.5	45
180								
200								
220								

10' bottom width

Grade Q	0.2 d	0.2 A	0.3 d	0.3 A	0.4 d	0.4 A	0.5 d	0.5 A
30	1.8	31	1.6	26	1.4	22	1.3	20
40	1.9	33	1.7	29	1.5	24	1.4	22
50	2.0	36	1.8	31	1.6	26	1.5	24
60	2.1	39	1.9	34	1.7	29	1.6	26
80	2.3	44	2.1	39	1.9	34	1.8	31
100	2.5	50	2.3	44	2.1	39	1.9	34
120			2.5	50	2.3	44	2.1	39
140					2.4	47	2.2	41
160					2.5	50	2.3	44
180							2.4	47
200							2.5	50
220								

12' bottom width

Grade Q	0.2 d	0.2 A	0.3 d	0.3 A	0.4 d	0.4 A	0.5 d	0.5 A
30	1.7	32	1.6	29	1.4	25	1.2	20
40	1.8	35	1.7	32	1.5	27	1.3	22
50	1.9	37	1.8	35	1.6	29	1.4	25
60	2.0	40	1.9	37	1.7	32	1.5	27
80	2.2	46	2.0	40	1.8	35	1.7	32
100	2.3	49	2.1	43	2.0	40	1.8	35
120	2.5	55	2.3	49	2.2	46	2.0	40
140			2.5	55	2.3	49	2.1	43
160					2.4	52	2.2	46
180					2.5	55	2.3	49
200							2.4	52
220							2.5	55

Diversion design table – "C" Retardance: (Trapezoidal Section) 10-26-55 4-L-10122-1
(Sheet 1 ofe 2)

Exhibit 7

● 6:1 Side Slopes
"C" Retardance

(Based on Handbook of Channel Design, SCS-TP-61)

	6' bottom width								8' bottom width							
Grade	0.2		0.3		0.4		0.5		0.2		0.3		0.4		0.5	
Q	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A
20	1.8	30	1.7	28	1.6	25	1.4	20	1.7	31	1.6	28	1.5	26	1.3	21
30	2.0	36	1.9	33	1.7	28	1.5	23	1.8	34	1.7	31	1.6	28	1.4	23
40	2.1	39	2.0	36	1.8	30	1.6	25	2.0	40	1.9	37	1.7	31	1.5	26
50	2.2	42	2.1	39	1.9	33	1.7	28	2.1	43	2.0	40	1.8	34	1.6	28
60	2.3	46	2.2	42	2.0	36	1.8	30	2.2	47	2.1	43	1.9	37	1.7	31
80	2.5	53	2.3	46	2.1	39	1.9	33	2.4	54	2.2	47	2.0	40	1.8	34
100			2.5	53	2.3	46	2.1	39	2.5	58	2.4	54	2.2	47	2.0	40
120					2.4	49	2.2	42			2.5	58	2.3	50	2.1	43
140					2.5	53	2.3	46					2.4	54	2.2	47
160							2.4	49					2.5	58	2.3	50
180							2.5	53							2.4	54
200															2.5	58
220																

	10' bottom width								12' bottom width							
Grade	0.2		0.3		0.4		0.5		0.2		0.3		0.4		0.5	
Q	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A
20	1.6	31	1.5	29	1.4	26	1.2	20	1.5	32	1.4	29	1.3	27	1.2	22
30	1.8	36	1.7	34	1.5	29	1.3	23	1.7	37	1.6	34	1.4	29	1.3	27
40	1.9	41	1.8	38	1.6	31	1.4	26	1.8	41	1.7	37	1.5	32	1.3	27
50	2.0	44	1.9	41	1.7	34	1.5	29	1.9	45	1.8	41	1.6	34	1.4	29
60	2.1	47	2.0	44	1.8	38	1.6	31	2.0	48	1.9	45	1.8	41	1.6	34
80	2.3	55	2.1	47	1.9	41	1.7	34	2.2	55	2.1	52	1.9	45	1.7	37
100	2.4	59	2.3	55	2.1	47	1.9	41	2.3	59	2.2	55	2.0	48	1.8	41
120	2.5	63	2.4	59	2.2	51	2.0	44	2.4	64	2.3	59	2.1	52	1.9	45
140			2.5	63	2.3	55	2.1	47	2.5	68	2.4	64	2.2	55	2.0	48
160					2.4	59	2.2	51			2.5	68	2.3	59	2.1	52
180					2.5	63	2.3	55					2.4	64	2.2	56
200							2.4	59					2.5	68	2.2	55
220							2.5	63							2.3	59

4-L-10122-2

Source: Modified from USDA, Soil Conservation Service

Exhibit 7

(Based on Handbook of Channel Design, SCS-TP-61)

● 3:1 Side Slopes
"D" Retardance

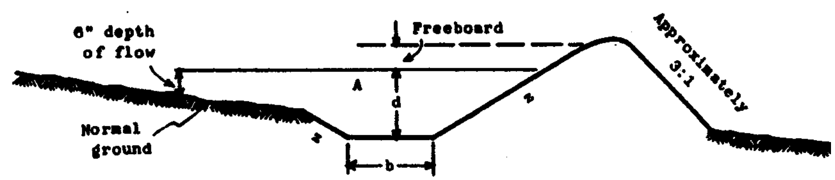
Grade	6' bottom width								8' bottom width							
	0.2		0.3		0.4		0.5		0.2		0.3		0.4		0.5	
Q-cfs	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A
10	1.3	12	1.1	10	1.0	9	0.9	8	1.2	13	1.1	11	1.0	10	0.9	9
20	1.5	16	1.4	14	1.2	12	1.1	10	1.4	17	1.3	16	1.2	14	1.1	12
30	1.8	21	1.6	17	1.5	16	1.3	13	1.7	22	1.5	19	1.4	17	1.2	14
40	2.0	24	1.8	21	1.7	19	1.5	16	1.8	24	1.7	22	1.5	19	1.4	17
60	2.3	30	2.1	26	1.9	22	1.7	19	2.1	30	1.9	26	1.8	24	1.6	21
80	2.5	34	2.3	30	2.1	26	1.9	22	2.4	37	2.2	32	2.0	28	1.8	24
100	2.8	40	2.5	34	2.3	30	2.1	26	2.6	41	2.4	37	2.2	32	2.0	28
120	3.0	45	2.8	40	2.5	34	2.3	30	2.8	46	2.5	39	2.3	34	2.1	30
140			2.9	43	2.6	36	2.4	32	2.9	48	2.7	44	2.5	39	2.3	34
160			3.0	45	2.8	40	2.6	36	3.1	51	2.9	48	2.7	44	2.5	39
180															2.6	41
200																
220																

Grade	10' bottom width								12' bottom width							
	0.2		0.3		0.4		0.5		0.2		0.3		0.4		0.5	
Q-cfs	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A
10	1.1	14	1.0	12	0.9	11	0.8	10	1.0	14	0.9	12	0.8	11	0.7	10
20	1.3	18	1.2	16	1.0	13	0.9	11	1.2	19	1.1	17	1.0	15	0.9	13
30	1.5	22	1.4	20	1.2	16	1.1	15	1.3	21	1.2	19	1.2	19	1.1	17
40	1.7	26	1.5	22	1.4	20	1.2	16	1.6	27	1.5	25	1.3	21	1.2	19
60	2.0	32	1.8	28	1.7	26	1.5	22	1.8	31	1.6	27	1.5	25	1.3	21
80	2.3	39	2.1	34	1.9	30	1.7	26	2.1	38	1.9	34	1.8	31	1.6	27
100	2.4	41	2.2	37	2.1	34	1.9	30	2.3	44	2.1	38	1.9	34	1.7	29
120	2.6	46	2.4	41	2.2	37	2.0	32	2.5	50	2.3	44	2.1	38	1.9	34
140	2.7	49	2.5	44	2.3	39	2.1	34	2.6	59	2.4	46	2.2	41	2.0	36
160	2.9	54	2.7	49	2.5	44	2.3	39	2.7	54	2.5	50	2.3	44	2.1	38
180	3.0	57	2.8	51	2.6	46	2.4	41	2.8	57	2.6	52	2.4	46	2.2	41
200							2.5	44	2.9	60	2.7	54	2.5	50	2.3	44
220									3.0	63	2.8	57	2.7	54	2.5	50

NOTE: For diversions built on slopes under 2% the available cross-sectional area above normal ground will allow a reduction in design depth as follows:

For land slopes of 1% or less reduce depth of flow (taken from Design Table) 20%.
For land slopes of 1% to 2% reduce depth of flow (taken from Design Table) 10%.
For land slopes greater than 2% use depth of flow taken from Design Table.

For Example: A diversion 6 feet wide with a 2.5 foot depth of flow is required to remove 120 c.f.s. on a 0.4% grade. If this is built on a 1% slope the depth may be reduced 20% thus obtaining a flow depth of 2.0 feet. The required cross-sectional area of the channel plus that above normal ground line will be 34 square feet corresponding to the 2.5 foot depth. The overall height of diversion will be 2.0 feet plus 0.5 foot freeboard or 2.5 feet, instead of the original 3.0 feet.



d = depth of flow, feet
b = bottom width of channel, feet
A = channel capacity, sq. ft., including area below 0.5' freeboard and excluding any area less than 0.5' depth of flow
z = side slope of channel (horizontal to vertical)

IMPORTANT: To all designed depths of flow add freeboard required by State Standards and Specifications to obtain overall height of terrace above bottom of channel. For final check on cross-sectional area subtract required freeboard from settled height of diversion and provide for cross-sectional area shown in table.

Diversion design table - "D" Retardance (Trapezoidal Section) 3/27/53 4-L-8618-1
(Sheet 1 of 2)

Exhibit 7

(Based on Handbook of Channel Design, SCS-TP-61)

● 4:1 Side Slopes
"D" Retardance

	6' bottom width								8' bottom width								10' bottom width								12' bottom width							
Grade	0.2		0.3		0.4		0.5		0.2		0.3		0.4		0.5		0.2		0.3		0.4		0.5		0.2		0.3		0.4		0.5	
Q-cfs	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A
10	1.2	13	1.1	11	1.0	10	0.9	9	1.1	14	1.0	13	0.9	11	0.8	10	1.1	14	1.0	13	0.9	12	0.8	11	1.0	15	0.9	14	0.8	13	0.7	12
20	1.5	18	1.4	16	1.2	13	1.1	11	1.4	19	1.3	17	1.2	15	1.1	14	1.3	20	1.2	18	1.0	14	0.9	12	1.2	20	1.1	18	1.0	16	0.9	14
30	1.8	24	1.6	20	1.5	19	1.3	15	1.7	25	1.5	21	1.4	19	1.2	15	1.5	24	1.4	22	1.2	18	1.1	16	1.3	22	1.2	20	1.2	20	1.1	16
40	1.9	26	1.8	24	1.6	20	1.5	18	1.8	27	1.7	25	1.5	21	1.4	19	1.6	26	1.5	24	1.3	20	1.2	18	1.6	29	1.5	27	1.3	22	1.2	20
60	2.2	33	2.0	28	1.9	26	1.7	22	2.0	32	1.9	30	1.7	25	1.6	23	1.9	33	1.8	31	1.6	26	1.5	24	1.7	32	1.6	29	1.4	25	1.3	22
80	2.4	37	2.2	33	2.1	30	1.9	26	2.3	40	2.1	34	2.0	32	1.8	27	2.2	41	2.0	36	1.8	31	1.6	26	2.0	40	1.9	37	1.7	32	1.6	29
100	2.7	45	2.5	40	2.3	35	2.1	30	2.5	45	2.3	40	2.1	34	1.9	30	2.3	44	2.1	39	2.0	36	1.8	31	2.2	46	2.0	40	1.9	37	1.7	32
120	2.9	51	2.7	45	2.4	37	2.2	33	2.7	51	2.5	45	2.3	40	2.1	34	2.5	50	2.3	44	2.2	41	2.0	36	2.4	52	2.2	46	2.0	40	1.8	35
140	3.0	54	2.8	48	2.6	43	2.4	37	2.8	54	2.6	48	2.5	45	2.3	40	2.6	53	2.4	47	2.3	44	2.1	39	2.5	55	2.3	49	2.2	46	2.0	40
160	3.1	57	2.9	51	2.8	48	2.6	43	3.0	60	2.8	54	2.6	48	2.4	42	2.8	59	2.6	53	2.5	50	2.3	44	2.7	62	2.5	55	2.3	49	2.1	43
180															2.5	45	2.9	63	2.7	56	2.6	53	2.4	47	2.8	65	2.6	58	2.4	52	2.2	46
200																							2.5	50	2.9	68	2.7	62	2.5	55	2.3	49
220																									3.0	72	2.8	65	2.6-	58	2.4	52

● 6:1 Side Slopes
"D" Retardance

	6' bottom width								8' bottom width								10' bottom width								12' bottom width							
Grade	0.2		0.3		0.4		0.5		0.2		0.3		0.4		0.5		0.2		0.3		0.4		0.5		0.2		0.3		0.4		0.5	
Q-cfs	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A	d	A
10	1.2	16	1.1	14	1.0	12	0.9	10	1.1	16	1.0	14	0.9	13	0.8	11	1.1	17	1.0	15	0.9	13	0.8	12	1.0	17	0.9	15	0.8	14	0.7	12
20	1.5	23	1.4	20	1.2	16	1.1	14	1.4	23	1.3	21	1.1	16	1.0	14	1.3	21	1.2	20	1.1	19	1.0	16	1.3	25	1.2	23	1.0	17	0.9	16
30	1.7	28	1.5	23	1.4	20	1.2	16	1.6	28	1.5	26	1.3	21	1.2	18	1.4	26	1.3	23	1.2	20	1.1	18	1.4	29	1.3	27	1.1	20	1.0	18
40	1.8	30	1.7	28	1.5	23	1.4	20	1.7	31	1.6	28	1.4	23	1.3	21	1.5	29	1.4	26	1.3	23	1.2	20	1.5	32	1.4	29	1.3	27	1.2	22
60	2.0	36	1.9	33	1.7	28	1.6	25	1.9	37	1.8	34	1.6	28	1.5	26	1.8	38	1.7	34	1.5	29	1.4	26	1.6	34	1.5	32	1.4	29	1.3	27
80	2.2	42	2.1	39	1.9	33	1.8	30	2.1	43	2.0	40	1.9	34	1.7	31	2.0	44	1.9	41	1.7	34	1.6	31	1.8	41	1.7	37	1.6	34	1.5	32
100	2.4	49	2.2	42	2.1	39	1.9	33	2.3	50	2.1	43	2.0	40	1.8	34	2.2	51	2.0	44	1.9	41	1.7	34	2.1	51	1.9	45	1.8	41	1.6	34
120	2.6	56	2.4	49	2.3	46	2.1	39	2.5	58	2.3	50	2.2	47	2.0	40	2.3	55	2.2	51	2.0	44	1.9	41	2.2	55	2.0	48	1.9	45	1.7	37
140	2.7	61	2.6	56	2.4	49	2.3	46	2.6	61	2.5	58	2.3	50	2.2	47	2.5	63	2.3	55	2.2	51	2.0	44	2.4	64	2.2	55	2.1	51	1.9	45
160	2.9	68	2.8	64	2.6	56	2.5	53	2.8	67	2.6	61	2.5	58	2.3	50	2.7	71	2.5	63	2.4	59	2.2	51	2.6	70	2.4	64	2.3	59	2.1	51
180									2.9	71	2.7	64	2.6	61	2.4	54	2.8	75	2.6	67	2.5	63	2.3	55	2.7	76	2.5	68	2.4	63	2.2	55
200									3.0	72	2.8	67	2.6	61	2.4	54	2.9	79	2.7	77	2.6	67	2.4	59	2.8	81	2.6	72	2.5	66	2.3	59
220															2.5	58							2.4	59	2.9	85	2.7	76	2.5	68	2.3	59
240																							2.5	63							2.4	64
260																															2.5	68

4-L-8618-2

Diversion design table - "D" Retardance (Trapezoidal Section)
(Sheet 2 of 2)

Source: Modified from USDA, Soil Conservation Service.

Dec. 1, 1992

Grade Stabilization Structures

Description

Grade stabilization structures (GSSs) are permanent structures which stabilize grades in natural or artificial channels by carrying runoff from one grade to another. These structures include vertical drop structures, chutes, pipe drop structures and downdrains. They may be made of rock riprap, concrete, metal, wood and/or heavy plastic. Note that Riprap is a separate BMP.

Note that GSSs located in or adjacent to streams or other water courses will need a permit from the MDNR.

In natural stream, every effort should be made to reduce stormwater inputs which may increase stream velocities.

Other Terms Used to Describe

Chute
Downdrain
Drop Box
Drop Control Structure
Drop Inlet Spillway
Drop Pipe
Earth Embankment Structure
Enclosed Side Drain
Flume
Spillway
Straight-pipe
Toewall

Pollutants Controlled and Impacts

Grade stabilization structures are designed to prevent banks from slumping, reduce the velocity with which water runs off the land, and prevent erosion of a channel that results from excessive grade in the channel bed. Proper grade stabilization, combined with adequately protected outlet structures, can reduce the likelihood that soil will be detached and transported to surface water.

Application

Land Use
This practice is applicable to all land uses, but is most often used in agricultural, urban/urbanizing and transportation areas.

Soil/Topography/Climate
The foundation material at the site should be stable, relatively homogeneous, mineral soil with sufficient strength to support the structure without uneven settling. The soils should have low piping potential.

When to Apply
Implementation of this practice should occur early in the construction sequence. Use the Staging and Scheduling BMP to help coordinate its implementation with other BMPs.

Where to Apply
Applications include areas where the concentration and velocity of water are such that head cutting or gully erosion is occurring, where beds of intersecting channels are at different elevations, and where a flatter grade is needed for stability in a proposed channel.

Relationship With Other BMPs

Check Dams, Diversions and other BMPs may be required upstream of GSSs to reduce the velocity of incoming runoff, and to prevent undercutting, piping or scouring. Grassed Waterways are often used in conjunction with a GSS to control erosion in unstable areas. The outlets for GSSs should be stable and included in the design.

Specifications

Planning Considerations:
An on-site evaluation should be done to ensure that the channel upstream and downstream from the structure will be stable for the design flow conditions. A site evaluation should include:

1. An evaluation of the entire drainage area, including the size of the drainage area. GSSs are often built in conjunction with other BMPs, some of which also control drainage. By looking at the entire drainage area, the appropriate type and design of all BMPs needed in the drainage area can be determined.

2. Determine soil textures. Use soil surveys, where available. Soils should be stable and able to support the planned structure, with no piping.

3. The drainage area above the structure should be protected against erosion.

4. For most structures, the channel below the selected site must be stable for the design flow.

5. Consideration should be given in the planning phases as to how water will be diverted if Dewatering will be done.

6. Selection of the appropriate type of grade stabilization structure should be based on actual site conditions. Exhibits 1-3 show some of the more commonly used GSSs.

The design criteria which follows applies to most grade stabilization structures. The actual design should be based on sound engineering principles.

Design Considerations:

Note: The design of a GSS should be done by a registered professional engineer.

The information provided below consists of guidelines which will help in deciding if the site is appropriate for consideration of a GSS, and what things need to be considered in the design and construction of a GSS.

1. Design considerations should include the following:

   -the differences in channel depths and widths

   -the effect on the water table

   -the need for an emergency bypass and the effect the bypassed water may have on the areas downstream

   -the stability of side slopes

   -outlet velocities and the need for a stabilized outlet below the GSS.

In general, shallow channels stabilized with riprap are preferred to deeper earth channels that require GSSs.

2. Grassed Waterways are often used in conjunction with GSSs and should be designed in conjunction with the GSS.

3. When GSSs are designed to stabilize head cutting in an existing channel, make sure that the channel upstream and downstream of the proposed structure will be stable for the design flow conditions. Make the stability evaluation based on clean water flow, since another head cut may begin below the structure once sediment sources are controlled. Side slopes on the site should also be stable.

4. Structures which include an emergency bypass/spillway should be designed so that the overflow enters the channel below the grade stabilization structure. The emergency bypass should be designed to prevent structural failure from larger storms, based on the expected structure life and frequency of failure.

5. Consideration should also be given to incorporating some type of foundation drainage to reduce hydrostatic loads on drop spillway structures.

6. All grade stabilization structures should complement their surroundings, both visually and functionally. Excavated material and cut slopes should be shaped to blend with the natural topography, or excess material removed from the site.

Grade Elevation:

The crest of the structure's inlet should be set at an elevation that will stabilize the grade of the upstream channel. To assure stability, set the outlet at an elevation that will provide a stable grade downstream.

Capacity:
The hydraulic capacity of all structures should be adequate to pass the frequency of storm determined based on the type of structure selected. At a minimum, structures other than "island type structures," defined below, should pass the peak runoff from the 24-hour design storm shown in Table 1, below.

Table 1

Drainage Area Acres	Design Storm Frequency - Years Principal Spillway	Principal Spillway + Emergency Spillway
< 20	2[1]	10
20-100	5	25
>100	10	25

[1]At the designer's option, a 10-inch minimum diameter pipe with at least 1.5 feet stage may be used in lieu of designing for the 2-year frequency design storm.

Source: USDA, Soil Conservation Service, Technical Guide, #410

Box inlets on road structures should meet the above hydraulic capacity requirements and should not have less capacity than 1.25 times the road structure capacity.

"Island type structures" consist of a drop spillway in the channel with auxiliary earth spillways for carrying excess flows around the structure. Either the straight drop spillway or the box inlet drop spillway can be used. This type of structure can only be used where there is a sufficient area of nearly level land on either side of the dam, for use as an earth spillway. Its use in urban areas is primarily limited to recreation areas and other open spaces. The minimum hydraulic capacity of these structures should be equal to or greater than the capacity of the downstream channel at bank full stage.

Earth Embankment:
The minimum top width of the embankment should be 6 feet if the total height of the embankment is 10 feet or less, and 8 feet if the total height of the embankment is 11-15 feet. The maximum effective height of the embankment should be 15 feet.

When the embankment top is to be used as a public road, guardrails or other approved safety devices should be used following the guidelines of the local transportation authority.

Emergency Bypass/Spillway:
Locate the emergency bypass/spillway so flood flows in excess of the spillway capacity enters the channel below the structure without serious erosion or damage to the structure.

Embankment Side Slopes:
The sum of the upstream and downstream side slopes of the settled embankment should not be less

than five horizontal to one vertical, with neither slope steeper than 2:1. Slopes must be designed to be stable in all cases, even if flatter side slopes are required.

Freeboard:
The minimum elevation of the top of the settled embankment should be 1.0 feet above the water surface with the emergency spillway flowing at design depth. The minimum difference in elevation between the crest of the emergency spillway and the settled top of the dam should be 2.0 feet. For surface water inlet pipe structures, the above dimensions may be reduced to 0.5 and 1.0 feet respectively.

Settlement:
The design height of the dam should be increased by the amount needed to insure that after all settlement has taken place the height of the dam will equal or exceed the design height. This increase shall not be less than five percent.

Foundation Drainage:
Foundation drainage may be needed on drop spillways and similar structures to reduce hydrostatic pressure.

Pipe Conduits:

1. In most cases, the diameter of the pipe should not be less than 6 inches.

2. The following pipe materials may be used: cast-iron, steel, corrugated steel or aluminum, plastic, or reinforced concrete. Plastic pipe that will be exposed to direct sunlight must be made of ultraviolet resistant materials or protected by coating or shielding.

3. Pipe appurtenances. Inlets and outlets should be structurally sound and made from materials compatible with the pipe. All pipe joints are to be made watertight in accordance with the manufacturer's specifications.

4. Pipe strength should not be less than that of the grades indicated in Table 2, below, for plastic pipe and Table 3, below, for corrugated aluminum and galvanized steel, or in accordance with other industry-accepted standards.

Concrete Chutes or Flumes:
Concrete chutes or flumes should be trapezoidal or rectangular in shape, with a minimum thickness of 4 inches. A well-graded aggregate gravel at least 6 inches thick can be used for the base material.

Table 2

Acceptable PVC* Pipe for use in Grade Stabilization Structures

Nominal Pipe Size	Schedule or Standard Dimension Ratio (SDR)	Maximum Depth of Fill Over Pipe (Feet)
8, 10, 12	Schedule 40	10
	Schedule 80	15
	SDR 26	10

* Polyvinyl chloride pipe, PVC 1120 or PVC 1220, conforming to ASTM D 1785 or ASTM D 2241

Source: USDA, Soil Conservation Service, Technical Guide, #410

Table 3

Gage or Thickness Required: Corrugated Metal Pipe for Fill Heights Above Pipe not to exceed 15 feet

Pipe Diameter Inches	Steel [1]/ Minimum Gage	Aluminum [2]/ Minimum Thickness (Inches)
21 & less	16	0.06
24	16	0.06
30	16	0.075
36	14	0.075
42	12	XXX
48	10	XXX

[1]/ For steel CMP, maximum allowed pipe diameter is 48 inches.

[2]/ For aluminum CMP:

a. Pipe may be riveted or helical fabrication.
b. Pipe shall not be placed in soils having a pH less than 4 nor greater than 9.
c. Maximum allowed pipe diameter is 36 inches.

Source: USDA, Soil Conservation Service, Technical Guide, #410

Concrete used should be plastic enough for thorough consolidation and stiff enough to stay in place on side slopes. It should have a minimum strength of at least 3,000 lbs./square inch. Cement can be Portland Types I or II, or if required, Types IV or V. Aggregate used should have a minimum size of 1.5 inches.

If contraction joints are necessary, they should be formed transversely to a depth of about 1/3 the thickness of the cement at a uniform spacing of 10-15 feet. Uniform support should be provided to the joint to prevent unequal settlement.

Antivortex Devices:
Closed conduit spillways designed for pressure flow are to have adequate antivortex devices.

Emergency Spillways or Bypass Channel:
An emergency spillway must be constructed for all closed conduit structures. Other structures such as chute or drop spillway structures do not require an emergency spillway if the principal spillway has sufficient capacity to pass the emergency spillway design storm discharge.

Dimensions:
The **cross section** of the emergency spillway should be trapezoidal and located in undisturbed or compacted earth. The side slopes should be 2.5:1 or flatter. The emergency spillway should have a bottom width of not less than 8 feet.

The breadth of **earth** emergency spillways should be a minimum of 20 feet. The inlet channel may be curved to fit existing topography. The grade of the exit channel of a constructed spillway must fall within the range established by discharge requirements, existing topography and soil erodibility conditions. The exit channel should provide for passage of the design flow at a safe velocity to a point downstream of where the embankment will not be endangered.

Inlets:

1. To minimize future maintenance, field stone or riprap should be placed around the crest of drop inlet structures. Riprap should be placed 1 foot deep and extend 2 feet upstream from the inlet structure.

2. Where it is necessary to prevent clogging of the conduit, an appropriate **trash guard** should be installed at the inlet or riser. Trash guards are especially important in urban areas. Install trash guards immediately after the pipes are in place.

3. **Seepage Control** along a pipe conduit spillway should be provided if either of the following conditions exist:

   -the conduit is of smooth pipe larger than 8 inches in diameter, or
   -the conduit is of corrugated pipe larger than 12 inches in diameter.

   Seepage along pipes extending through the embankment should be controlled by use of a **filter or drainage diaphragm**, unless it is determined that antiseep collars will adequately serve the purpose.

The drainage diaphragm should consist of sand, meeting fine concrete aggregate requirements (at least 15% passing the No. 40 sieve but no more than 10% passing the No. 100 sieve). If unusual soil conditions exist, a special design analysis should be made.

The drainage diaphragm should be a minimum of 2 feet thick and extend vertically upward and horizontally at least three times the pipe diameter, and vertically downward at least 18 inches beneath the conduit invert. The drainage diaphragm should be located immediately downstream of the cutoff trench, approximately parallel to the centerline of the dam.

The drainage diaphragm should be outletted at the embankment downstream toe, preferably using a drain backfill envelope continuously along the pipe to where it exits the embankment. Protecting drain fill from surface erosion will be necessary.

When **antiseep collars** are used in lieu of a drainage diaphragm, they should have a watertight connection to the pipe. Maximum spacing should be approximately 14 times the minimum projection of the collar measured perpendicular to the pipe. Collar material should be compatible with pipe materials. The antiseep collar(s) should increase by 15% the seepage path along the pipe.

Outlets:

1. Where possible, grade stabilization structures should not outlet directly into a watercourse, but should be placed at a distance allowing for dissipation of water velocity.

2. The velocity of flow at the outlet should be within the permissible velocity for the receiving stream.

3. Outlet structures should be part of the design and should be stable. See the Stabilized Outlets BMP for some potential options.

Construction Considerations:

1. Divert all surface runoff around the structure during construction so that the site can be properly dewatered for foundation preparation, construction of headwalls, apron drains, and other structures. Follow specifications in the Dewatering BMP.

2. Ensure that the concrete is stable. To be stable, concrete should conform to Michigan Department of Transportation standards, ASCI or other appropriate standards for reinforced structural concrete.

3. Hand-compact backfill in 4-inch layers around the structure to a density consistent with the design.

4. If riprap is used to stabilize outlets, it should be underlain by geotextile filter fabric. Make the end of the riprap section as wide as the receiving channel, and make sure the transition section of the riprap between the structure end sill and the channel is smooth. Ensure that there is no overfall from the end sill along the surface of the riprap to the existing channel bottom, unless it is part of the design. Follow Riprap specifications.

5. Stabilize all disturbed areas following specifications in the Seeding and Mulching or Sodding BMPs.

Maintenance

Because grade stabilization structures are subject to high flow conditions, periodic inspections should be performed to ensure that erosion is not occurring, and that vegetation is adequately established. These structures should also be inspected after storm events which exceed the design storm. The discharge point should be investigated to ensure that the concentrated flows are not causing erosion downstream. Check the emergency bypass/spillway for erosion. Check the structure itself for cracked concrete, uneven or excessive settling, piping and proper drain functioning. Repair or replace failing structures immediately. Address vegetation and erosion problems as soon as weather permits.

Additional Considerations

Open structures should be signed or marked to alert people in the vicinity about potential dangers.

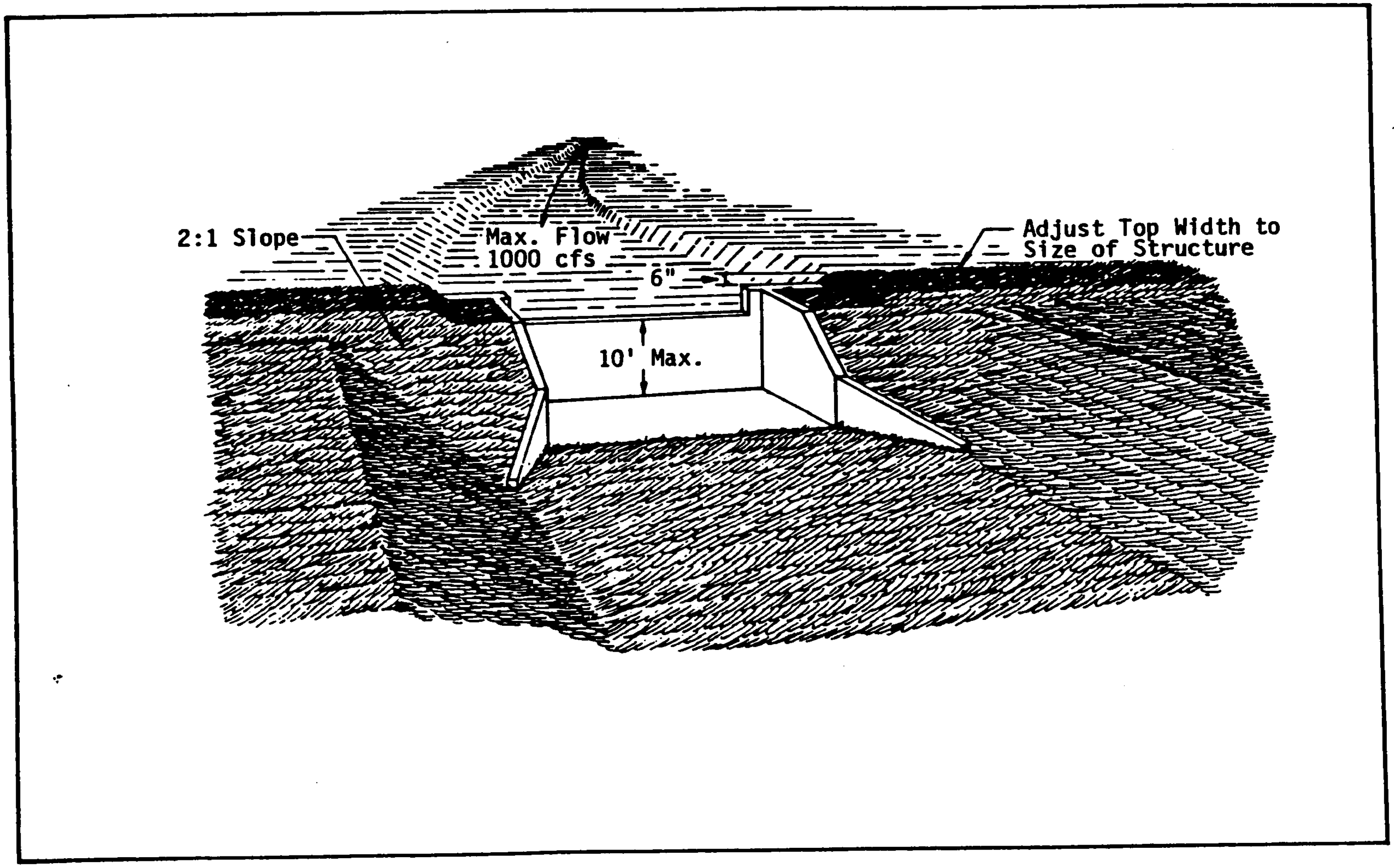
Exhibits

Exhibit 1: Waterway Drop Structure. USDA, Soil Conservation Service. 1980.

Exhibit 2: Rock Chute. USDA, Soil Conservation Service. 1983.

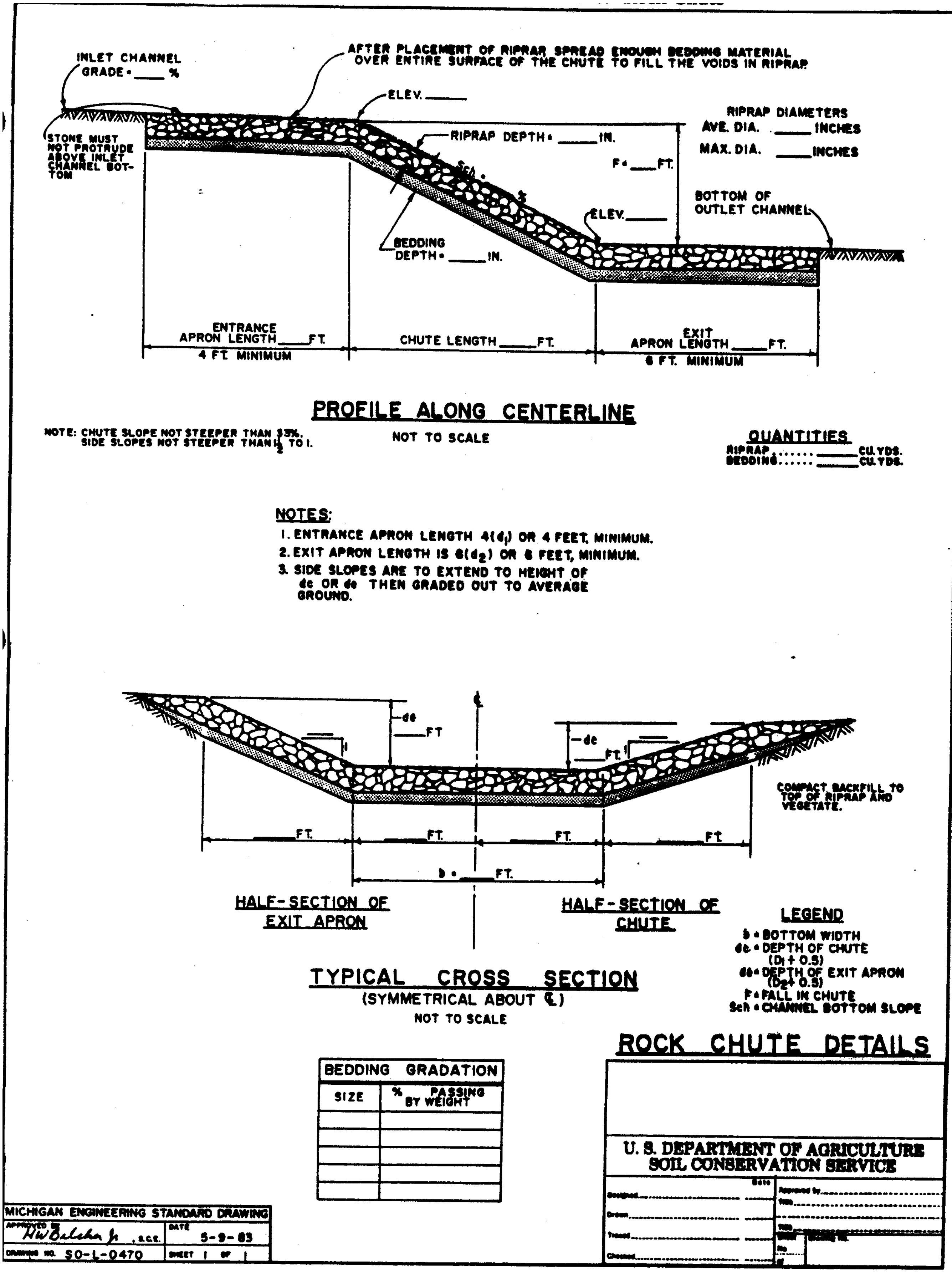
Exhibit 3: Earth Emergency Spillway. USDA, Soil Conservation Service.

Exhibit 1
Grade Stabilization Structure:
Waterway Drop Structure



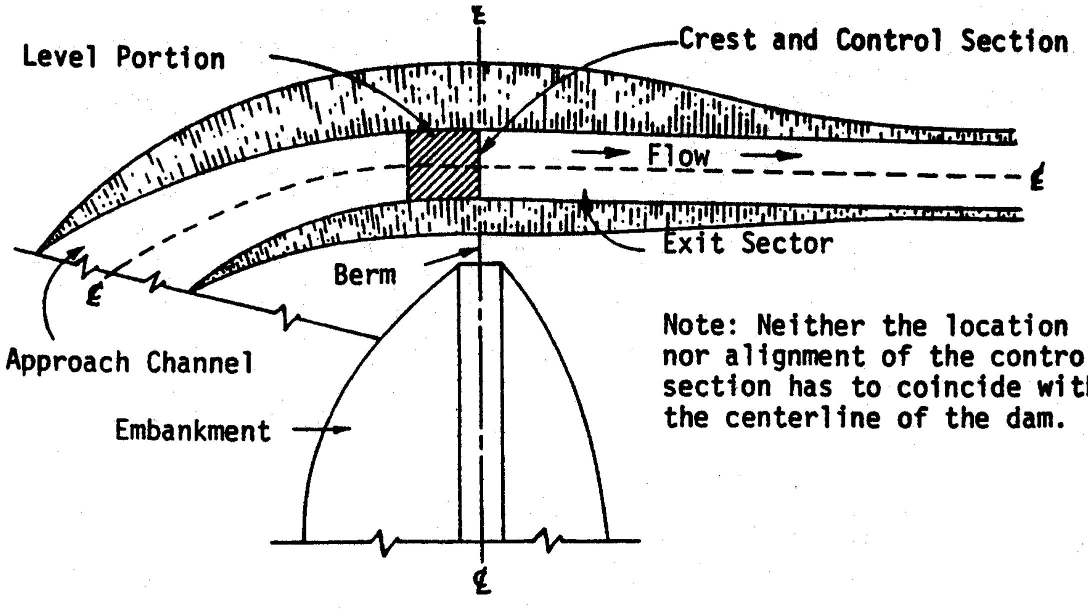
Source: USDA-Soil Conservation Service

Exhibit 2 - - Grade Stabilization Structure: Rock Chute

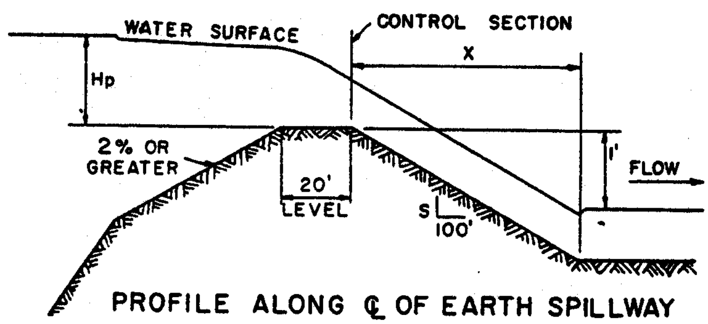


BEDDING GRADATION	
SIZE	% PASSING BY WEIGHT

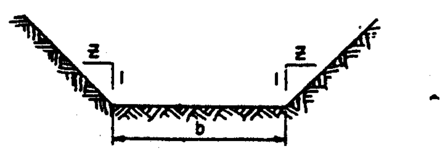
Exhibit 3
Grade Stabilization Structure:
Earth Emergency Spillway (showing level section and control section)



Plan



PROFILE ALONG ℄ OF EARTH SPILLWAY



CROSS SECTION OF EARTH SPILLWAY AT CONTROL SECTION

LEGEND

n	Manning's Coefficient of Roughness.
Hp	Difference in Elevation between Crest of Earth Spillway at the Control Section and Water Surface in Reservoir, in Feet.
b	Bottom Width of Earth Spillway at the Control Section, in Feet.
Q	Total Discharge, in cfs.
V	Velocity, in Feet Per Second, that will exist in Channel below Control Section, at Design Q, if Constructed to Slope (S) that is shown.
S	Flattest Slope (S), in %, allowable for Channel below Control Section.
X	Minimum Length of Channel below Control Section, in Feet.
z	Side Slope Ratio

Source: USDA, Soil Conservation Service

Dec. 1, 1992

Grassed Waterway

Description

A grassed waterway is a natural or constructed watercourse consisting of vegetation and designed to accommodate concentrated flows without erosion. Grassed waterways are capable of sustaining higher in-channel velocities than bare areas because the vegetation protects the soil by covering it and retarding water velocity. They also provide for the disposal of excess surface water from Diversions and natural drainage.

Other Terms Used to Describe

Grassed Channel
Sod Waterway
Swale

Pollutants Controlled and Impacts

Grassed waterways reduce runoff velocity, filter sediment and absorbed chemicals from sheet erosion, and deliver intermittent flows to streams. Grassed waterways may also provide grazing or habitat opportunities for wildlife.

Application

Land Use
This practice can be used in rural areas, and in urban and urbanizing areas where flows meet design criteria. The limitation of this practice is usually flow-dependent.

Soil/Topography/Climate
This practice is usually used in natural depressions where intermittent water flows concentrate to cause gullies. The depth to the groundwater table, climatic factors, and vegetative retardance will be used to determine the species of vegetation needed.

When to Apply
Limit construction to enable the establishment of vegetative cover. (See the Seeding and Sodding BMPs). Avoid using dormant seedings because of their high risk of failure. Keep in mind that the effectiveness of the waterway is reduced on snow-covered ground.

It is important that this practice be established before periods of high runoff (i.e. the spring and fall) to prevent gullies from displacing soils and transporting them to the water system.

Where to Apply
This practice applies to all sites where additional vegetative protection or capacity, or both, is needed to control erosion resulting from concentrated runoff. Grassed waterways are used to prevent erosion and transport runoff to stable outlets from golf courses, parks, subdivision lawns, and parking lots.

Grassed waterways are not applicable to watercourses where construction of a waterway would destroy important woody wildlife cover. Waterways which do not usually require additional vegetation are usually recognized by a meandering condition, with side slopes which are stabilized by woody plants or herbaceous vegetation.

Relationship With Other BMPs

Grassed waterways should be established in accordance with specifications for Seeding and Mulching or Sodding. They should be designed to be consistent with the retardance value that will control runoff and prevent erosion. Grade Stabilization Structures usually provide adequate outlets for grassed waterways. Subsurface Drains should be used in wet soils to promote thick sod growth and soil stability by draining excess internal water.

Specifications

Planning Considerations:

1. Channels should generally be designed to conform with the natural runoff system. A channel should therefore not be such that there are significant changes in direction or grade. Use natural depressions rather than reshaping the land.

2. Protect upland areas from eroding prior to constructing the waterway. Grass-lined channels are quickly rendered ineffective if they are subject to sedimentation.

3. Consider Diversions to divert water from the channel until vegetation is established. Consider using geotextile fabrics to provide stability until vegetation is fully established.

4. On sites that are subject to prolonged wet conditions due to long duration flows or high water table, or springs and seeps, use either Riprap-lined channels or Subsurface Drains. Subsurface drains will remove excess internal water. Riprap will provide a non-erosive surface in the channel that is too wet to sustain grass.

5. Surface inlets into Subsurface Drains are necessary for continuous surface flows. There are many commercial products on the market that provide proper inlets for continuous surface flows.

6. Outlets below grassed waterways must be stable. Outlets may be Grade Stabilization Structures, Infiltration Basins, or other water courses. Discharges to other water courses must be such that scouring does not occur.

Design Considerations:

Grassed waterways should be designed by registered professional engineers.

This practice should only be used in areas where permissible velocities (see below) are less than 6 fps, assuming good vegetative cover, or 4 fps, assuming poor vegetative cover. Refer to the Stormwater Conveyance Channel BMP if permissible velocities exceed these criterium.

The procedure is to design first for stability, then capacity.

Stability (V_1):
Stability is achieved by designing for a safe velocity. It is recommended that when designing the channel for a safe velocity, a retardance not greater than "D" be used.

Capacity (V_2):
Minimum capacity should be that required to confine the peak runoff expected from a 10-year, 24-hour rainfall event, without eroding. Where flood hazards exist, capacity should be increased according to the hazard involved. On slopes less than 1 percent, where out-of-bank flow will not cause erosion or property damage, the minimum capacity should be 50 percent of a 10-year, 24-hour storm. Capacity is to accommodate the peak flow under conditions where vegetation gives the highest retardance. The retardance corresponds to the vegetal cover. Capacity should be designed on a "C" or "B" retardance.

Permissible Velocity:
The permissible velocity depends on the retardance, which in turn depends largely on the height and density of cover, particularly the height. Generally, after the cover is selected, the retardance with a good stand condition will be the criteria to determine capacity. However, since a condition offering less protection exists at least during the establishment period, it is advisable to use at least the next lower degree of retardance when designing for stability. Again, the procedure is to design first for stability, then, capacity. We recommend using a retardance of "D" for V_1 (stability) and a retardance of "B" or "C" for V_2 (capacity), where V_1 is the permissible velocity during establishment and V_2 is the permissible velocity after establishment. Exhibits 5 and 6 incorporate the D-C, or D-B retardance with the V_1-V_2 relationship.

The permissible velocity (V_1) should be determined using Exhibit 4.

Liner:
Since the permissible velocity (V_1) of a channel is equal to or exceeds 2 ft/sec, a temporary geotextile liner should be used in the channel to prevent loss of the seed, fertilizer and mulch and control erosion. See the Appendices for some suppliers of geotextile filter fabric.

Cross-Section:
Use a parabolic or trapezoidal cross section. V-shaped channels are not recommended since they readily form gullies and are more erosive. The cross-sectional area should be large enough, relative to the design flow, soil type and vegetation, to maintain runoff velocities below erosive levels.

Dimensions:
Channel dimensions may be determined by using design tables with a retardance based on the type and height of vegetation selected, or by using Manning's formula with an appropriate "n" value. The bottom width of trapezoidal waterways should not exceed 100 feet unless multiple or divided waterways, riprap center, or other means are provided to control meandering flows. All grassed waterways should have a depth of 0.8 feet or more.

Side Slopes:
To aid in the establishment of vegetation and for maintenance, the side slopes of a grassed channel should be 3:1 or flatter.

Outlet:
Design the outlet to accommodate the flows expected from the grassed waterway such that no scouring occurs.

Elevation:
The surface water elevation of a grassed waterway receiving water from Diversions or other tributaries, should be equal to or less than the surface water elevation in the diversion or tributaries.

Step-by-Step Process:

1. Complete a profile and cross section survey to determine the design gradient for the waterway.

2. Identify soil resistance to erodibility using Exhibit 1. To determine the soil texture on your site, use Soil Conservation Service soil maps, where available, or have soil investigations done by qualified soil scientists.

3. Determine the size of the watershed area using a topographic map, by visual inspection of the watershed, or using aerial photography in stereo. Also, determine the average watershed slope. This is the average slope of the land, not the watercourse.

4. Determine the peak runoff (Q) expected from a 10-year, 24-hour frequency storm using Appendix 1 or any other accepted method.

5. Determine the appropriate vegetal retardance using Exhibit 2. The appropriate retardance is dependent primarily on the management of the grassed waterway. For example, in an urban area, the grassed waterway may need to be kept short, 2-6 inches. It is important to determine the final, managed length of vegetation and to select the proper retardance. Always aim for a "good" stand of vegetation.

   Remember that the retardance in Exhibit 2 is for capacity (V_2). The design for stability is always based on "D" retardance.

6. Use Exhibit 3 to determine the types of grasses that can be used to establish the waterway. This is based on the retardance and the height of vegetation desired. Seeding rates are found in the Seeding BMP.

7. Determine the permissible velocity (V_1) in Exhibit 4.

8. Use the appropriate table in Exhibits 5 or 6 to select an appropriate top with, depth and maximum permissible velocity at the determined retardance. Exhibit 5 is for parabolic design and Exhibit 6 is for trapezoidal design.

9. Use Exhibit 7 to select an appropriate method of establishing the vegetative cover based on the site conditions.

Design Example:

Situation:

In Oakland County, there is an intermittent watercourse that is bordered on one side by an agricultural field and on the other by a county park. Because of recent development in the park, runoff has increased to the intermittent watercourse, creating a gully. Determine the safe velocity for stability (V_1) and the dimensions for capacity for a grassed waterway with a parabolic cross section.

1. Complete a profile and cross section engineering survey to determine design gradient for the waterway. Use 2.0% for this example.

2. Identify soil resistance to erodibility from Exhibit 1. Assume loam and sandy loam (easily erodible) for this example.

3. Determine the size of the watershed and average slope found in the watershed. For this example, assume the watershed is 100 acres and has an average slope of 4%.

4. Determine peak runoff for a 10-year, 24-hour frequency storm. Assume 55 cfs for this example.

5. Determine the appropriate retardance from Exhibit 2 based on the desired vegetative cover and planned management. In this example, the county park maintenance staff will mow the waterway to maintain it between 6-10 inches. A good grass legume stand is desired for the waterway and will be managed for 6 to 10 inch length. According to Exhibit 2, this is a "C" retardance. This is the design retardance for capacity. The design for stability is based on "D" retardance for all waterway designs.

6. Use Exhibit 3 to find that one possible grass with a "C" retardance and between 6-10" is a grass legume mixture of smooth bromegrass, perennial rye, and tall fescue.

7. Use Exhibit 4 to determine the permissible velocity (V_1). Previous data includes grass mixture, slope of 2.0% and easily erodible soils. This gives a permissible velocity (V_1) of 3.5 fps.
8. Exhibit 5, sheet 8 of 14, indicates design criteria for the waterway:

V_1	3.5 fps
Top (T)	23.9 ft.
Depth (D)	1.09 ft.
V_2	3.12 fps

9. Using Exhibit 7, vegetative cover on slopes <2%, a velocity less than 5 fps and (moderately) erodible soils can be established by seeding with a straw mulch and jute mesh or erosion netting.

Construction Considerations:

1. Apply upland practices prior to waterway construction to prevent sedimentation from occurring in the proposed channel. Be sure to divert runoff away from the channel area until the vegetation is established. Follow design specifications in the Diversions BMP.

2. Any Subsurface Drains that are needed should be installed before shaping the waterway.

3. Use proper Land Clearing practices and grade according to the grading plan.

4. Excavate the channel according to the design.

5. Earth which is removed and not needed in the grassed waterway should be disposed of according to specifications in the Spoil Piles BMP.

6. Compact fill to prevent unequal settlement along the watercourse.

7. Plant seed or sod according to the design. Protect the channel with mulch or a temporary liner sufficient to withstand anticipated velocities during the establishment period. Follow specifications in the Mulching BMP.

Maintenance

Once established, grassed waterways should have dense, mature grass at all times to prevent erosion and effectively serve as a filter. During the establishment period, check the channel after every rainfall. Repair eroded areas immediately. Be sure to check channel outlets and any BMPs implemented up-slope of the channel. Remove any sediment which ends up in the channel and re-evaluate upland BMPs accordingly.

Mowing should be scheduled to keep the grass within the range of design retardance for capacity. Mow regularly to maintain dense sod and vegetative vigor.

Exhibits

Exhibit 1: Soil Resistance to Erodibility.

Exhibit 2: Guide to the Selection of Vegetal Retardance. USDA, Soil Conservation Service, Engineering Field Manual.

Exhibit 3: Classification of Vegetation Cover as to Degree of Retardance. Modified from USDA, Soil Conservation Service.

Exhibit 4: Permissible Velocity Table.

Exhibit 5: Parabolic Waterway Dimensions for "D-B" Retardance. USDA, Soil Conservation Service.

Exhibit 6: Parabolic Waterway Dimensions for "D-C" Retardance. USDA, Soil Conservation Service.

Exhibit 7: Establishment Methods Based on Permissible Velocities (V_1). Modified from Virginia SESC.

Exhibit 1

Soil Resistance to Erodibility

Soil Texture	Easily Eroded Soils	Erosion Resistant Soils
Loam, Sand, Silt, Sandy loam, Silty loam	X	
Silty clay loam Sandy clay loam		X
Clay		X

Exhibit 2

Guide to the Selection of Vegetal Retardance

Stand	Average Length Of Vegetation	Degree Of Retardance	Stand	Average Length Of Vegetation	Degree Of Retardance
Good	Longer than 30"	A	Fair	Longer than 30"	B
	11 to 24"	B		11 to 24"	C
	6 to 10"	C		6 to 10"	D
	2 to 6"	D		2 to 6"	D

Source: USDA Soil Conservation Service, Engineering Field Manual.

Exhibit 3

Classification of Vegetative Cover as to Degree of Retardance

(See the Seeding BMP for appropriate seeding mixtures)

Retardance	Cover	Condition*
A	Red canarygrass	Excellent stand, tall (avg. 36”)
B	Smooth Bromegrass………………………………………	Good stand, mowed (avg. 12-15”)
	Native grass mixture (Smooth Bromegrass, tall Fescue and other long and short midwest grasses……………	Good stand, unmowed (avg. 16-18”)
	Tall Fescue………………………………………………	Good stand, unmowed (avg. 18”)
	Lespedeza sericea………………………………………	Good stand, not woody, tall (avg. 19”)
	Grass-legume mixture—Timothy, smooth Bromegrass, or orchard grass………………………………………	Good stand, uncut (avg. 20”)
	Reed canarygrass………………………………………	Good stand, mowed (avg. 12 to 15”)
	Tall Fescue, with bird’s foot trefoil or lodino…………	Good stand, uncut (avg. 18”)
C	Redtop……………………………………………………	Good stand, headed (15 to 20”)
	Grass-legume mixture—summer (orchard grass, redtop, Italian ryegrass and common lespedeza)……………….	Good stand, uncut (6 to 8”)
	Grass-legume mixture—smooth Bromegrass, perennial Rye, Tall Fescue……………………………………….	Good stand, head (6 to 12”)
D	Red Fescue………………………………………………	Good stand, headed I12 to 18”)
	Grass-legume mixture—fall, spring (Orchard grass, Redtop, Italian, ryegrass, and common lespedeza)…	Good stand, uncut (4 to 5”)
	Lespedeza sericea………………………………………	After cutting to 2” height. Very good stand before cutting.
	Kentucky bluegrass, red Fescue, perennial rye………..	3-6”

*These “conditions” are defined in the Appendix.

Exhibit 4

Permissible Velocity (V_1)*

		Erosion Resistant		Easily Eroded
	Slope Range	Established by Seeding	Established by Sod	
Kentucky bluegrass Smooth brome Tall fescue	0- 5 5-10 over 10	4 3 3	6 5 5	3.5 2.5 2.5
Grass mixtures Reed canarygrass Orchard grass	0- 5** 5-10**	4 3	6 5	3.5 2.5
Lespedeza Redtop Alfalfa Red fescue	0-5***	4	6	2.5

* Use velocities between 5 and 6 feet per second only where good covers and proper maintenance can be obtained.

** Do not use on slopes steeper than 10 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.

*** Do not use on slopes steeper than 5 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.

Exhibit 5

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 0.25 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15																											
20																											
25	11.3	3.27	1.00																								
30	13.2	3.09	1.09																								
35	15.2	3.01	1.13																								
40	17.3	2.99	1.15	12.1	3.61	1.36																					
45	19.3	2.94	1.18	13.4	3.49	1.42																					
50	21.4	2.93	1.18	14.7	3.41	1.48																					
55	23.5	2.92	1.19	16.1	3.38	1.50																					
60	25.5	2.89	1.21	17.5	3.35	1.52																					
65	27.6	2.89	1.21	18.8	3.30	1.56																					
70	29.7	2.89	1.21	20.2	3.28	1.57	14.4	3.98	1.81																		
75	31.7	2.87	1.23	21.6	3.27	1.58	15.3	3.91	1.86																		
80	33.8	2.87	1.23	23.0	3.26	1.58	16.3	3.90	1.87																		
90	38.0	2.87	1.23	25.8	3.25	1.60	18.1	3.80	1.94																		
100	42.1	2.85	1.24	28.6	3.23	1.61	20.0	3.76	1.98																		
110	46.3	2.85	1.24	31.4	3.22	1.62	21.9	3.73	2.01																		
120	50.4	2.84	1.25	34.1	3.20	1.64	23.9	3.73	2.00	17.0	4.47	2.34															
130	54.6	2.85	1.24	36.9	3.19	1.64	25.8	3.70	2.02	18.3	4.42	2.39															
140	58.7	2.84	1.25	39.7	3.19	1.65	27.7	3.68	2.04	19.6	4.37	2.43															
150	62.9	2.85	1.25	42.5	3.19	1.65	29.6	3.67	2.06	20.9	4.33	2.47															
160	67.0	2.84	1.25	45.3	3.18	1.65	31.6	3.68	2.05	22.2	4.30	2.50															
170	71.1	2.84	1.26	48.1	3.18	1.65	33.5	3.66	2.07	23.5	4.27	2.53	18.5	4.95	2.76												
180	75.3	2.84	1.25	50.9	3.18	1.66	35.4	3.65	2.08	24.8	4.24	2.55	19.5	4.90	2.80												
190	79.4	2.84	1.26	53.7	3.18	1.66	37.4	3.66	2.07	26.1	4.22	2.57	20.5	4.87	2.84												
200	83.5	2.84	1.26	56.5	3.18	1.66	39.3	3.65	2.08	27.5	4.23	2.56	21.5	4.83	2.87												
220	91.8	2.84	1.26	62.1	3.18	1.66	43.2	3.65	2.08	30.1	4.19	2.60	23.5	4.77	2.92												
240	100.0	2.83	1.26	67.6	3.17	1.67	47.0	3.63	2.10	32.7	4.15	2.64	25.5	4.72	2.97												
260	108.3	2.84	1.26	73.2	3.17	1.67	50.9	3.63	2.10	35.4	4.15	2.64	27.5	4.68	3.01	21.4	5.50	3.29									
280	116.6	2.84	1.26	78.8	3.17	1.67	54.8	3.63	2.10	38.1	4.14	2.64	29.5	4.64	3.05	22.9	5.44	3.35									
300	124.8	2.84	1.26	84.4	3.17	1.67	58.6	3.62	2.11	40.8	4.14	2.65	31.5	4.61	3.08	24.5	5.42	3.37									

Parabolic waterway design
(Retardance "D" and "B")

(Sheet 1 of 14)

Exhibit 5

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 0.50 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	10.2	2.28	0.95																								
20	13.3	2.18	1.02																								
25	16.5	2.15	1.05	10.5	2.60	1.35																					
30	19.7	2.12	1.06	12.4	2.51	1.42	9.5	2.91	1.60																		
35	22.8	2.09	1.09	14.3	2.45	1.48	10.9	2.81	1.69																		
40	26.0	2.08	1.09	16.3	2.44	1.49	12.3	2.74	1.76																		
45	29.2	2.08	1.10	18.2	2.41	1.52	13.7	2.69	1.81																		
50	32.4	2.08	1.10	20.2	2.40	1.53	15.1	2.64	1.86	11.1	3.22	2.07															
55	35.6	2.08	1.11	22.1	2.38	1.55	16.6	2.64	1.86	12.0	3.11	2.18															
60	38.8	2.08	1.11	24.1	2.38	1.55	18.0	2.61	1.90	13.0	3.07	2.23															
65	42.0	2.08	1.11	26.0	2.36	1.57	19.5	2.61	1.89	14.0	3.03	2.27															
70	45.2	2.08	1.11	28.0	2.36	1.57	20.9	2.59	1.92	15.0	3.01	2.31															
75	48.4	2.08	1.11	29.9	2.35	1.59	22.4	2.59	1.92	16.0	2.98	2.34	12.7	3.48	2.52												
80	51.6	2.08	1.11	31.9	2.36	1.58	23.8	2.58	1.94	17.0	2.96	2.36	13.4	3.41	2.60												
90	57.9	2.07	1.12	35.8	2.35	1.59	26.7	2.56	1.96	19.1	2.95	2.37	15.0	3.37	2.64												
100	64.3	2.07	1.11	39.7	2.34	1.60	29.6	2.55	1.97	21.1	2.92	2.42	16.5	3.31	2.72	13.3	3.77	2.96									
110	70.7	2.08	1.11	43.6	2.34	1.61	32.6	2.56	1.96	23.2	2.92	2.42	18.1	3.29	2.75	14.5	3.70	3.05									
120	77.0	2.07	1.12	47.5	2.33	1.61	35.5	2.56	1.97	25.2	2.89	2.45	19.6	3.24	2.81	15.7	3.64	3.12									
130	83.4	2.08	1.12	51.5	2.34	1.61	38.4	2.55	1.98	27.3	2.90	2.45	21.2	3.23	2.82	16.9	3.60	3.18									
140	89.7	2.08	1.12	55.4	2.34	1.61	41.3	2.55	1.98	29.3	2.88	2.47	22.8	3.22	2.84	18.1	3.56	3.23									
150	96.0	2.08	1.12	59.3	2.34	1.61	44.2	2.55	1.99	31.4	2.88	2.47	24.3	3.19	2.88	19.4	3.56	3.23	15.5	4.09	3.52						
160	102.3	2.08	1.12	63.2	2.34	1.61	47.1	2.54	1.99	33.5	2.89	2.47	25.9	3.19	2.88	20.6	3.53	3.27	16.4	4.02	3.60						
170	108.6	2.08	1.12	67.1	2.34	1.62	50.0	2.54	1.99	35.5	2.87	2.48	27.5	3.19	2.89	21.9	3.54	3.27	17.4	4.01	3.62						
180	114.9	2.08	1.12	70.9	2.33	1.62	52.9	2.54	1.99	37.6	2.88	2.48	29.1	3.19	2.89	23.1	3.51	3.30	18.3	3.96	3.69						
190	121.2	2.08	1.12	74.8	2.33	1.62	55.8	2.54	2.00	39.6	2.87	2.49	30.6	3.16	2.92	24.3	3.49	3.34	19.3	3.96	3.70						
200	127.4	2.08	1.13	78.7	2.33	1.62	58.7	2.54	2.00	41.7	2.87	2.49	32.2	3.16	2.93	25.6	3.50	3.33	20.2	3.91	3.77	16.8	4.48	3.96			
220	140.0	2.08	1.13	86.5	2.33	1.62	64.5	2.54	2.00	45.8	2.87	2.50	35.4	3.16	2.93	28.1	3.49	3.35	22.1	3.87	3.83	18.3	4.39	4.08			
240	152.6	2.08	1.13	94.3	2.33	1.63	70.3	2.54	2.01	49.9	2.86	2.51	38.6	3.16	2.93	30.6	3.48	3.36	24.1	3.87	3.84	19.9	4.36	4.12			
260	165.2	2.08	1.13	102.1	2.33	1.63	76.1	2.54	2.01	54.0	2.86	2.51	41.7	3.15	2.95	33.1	3.47	3.38	26.0	3.84	3.88	21.5	4.34	4.15			
280	177.7	2.08	1.13	109.8	2.33	1.63	81.9	2.54	2.01	58.2	2.87	2.50	44.9	3.15	2.95	35.6	3.46	3.39	28.0	3.84	3.88	23.0	4.28	4.24	19.0	4.88	4.50
300	190.3	2.08	1.13	117.6	2.33	1.63	87.7	2.54	2.01	62.3	2.86	2.51	48.0	3.14	2.97	38.1	3.45	3.40	29.9	3.82	3.92	24.6	4.27	4.26	20.2	4.80	4.61

USDA-SCS-FORT WORTH, TEX. 1969

4-28467 5-69

Parabolic waterway design
(Retardance "D" and "B")

(Sheet 2 of 14)

Exhibit 5

4-28467 5-68

V_1 for <u>RETARDANCE "D"</u>. Top Width (T), Depth (D) and V_2 for <u>RETARDANCE "B"</u>.

Grade 0.75 Percent

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2
15	13.7	1.76	0.92	8.0	2.22	1.24			
20	18.2	1.75	0.93	10.4	2.10	1.35			
25	22.6	1.73	0.95	12.8	2.03	1.42	9.5	2.33	1.66
30	27.1	1.73	0.95	15.3	2.02	1.44	11.2	2.25	1.76
35	31.5	1.72	0.96	17.8	2.01	1.45	13.0	2.23	1.79
40	36.0	1.72	0.96	20.2	1.98	1.48	14.8	2.21	1.81
45	40.4	1.71	0.96	22.7	1.98	1.49	16.5	2.17	1.86
50	44.9	1.72	0.96	25.2	1.98	1.49	18.3	2.16	1.87
55	49.3	1.72	0.96	27.6	1.96	1.51	20.1	2.16	1.88
60	53.7	1.72	0.97	30.1	1.96	1.51	21.9	2.16	1.89
65	58.1	1.72	0.97	32.5	1.95	1.52	23.6	2.14	1.92
70	62.5	1.72	0.97	35.0	1.96	1.52	25.4	2.14	1.92
75	66.9	1.72	0.97	37.4	1.95	1.53	27.2	2.14	1.92
80	71.2	1.71	0.97	39.9	1.95	1.53	29.0	2.14	1.92
90	80.0	1.71	0.97	44.8	1.95	1.53	32.5	2.12	1.94
100	88.8	1.72	0.98	49.7	1.95	1.54	36.1	2.13	1.94
110	97.6	1.72	0.98	54.7	1.95	1.53	39.7	2.13	1.94
120	106.3	1.72	0.98	59.6	1.95	1.54	43.2	2.12	1.95
130	115.0	1.72	0.98	64.5	1.95	1.54	46.8	2.12	1.95
140	123.7	1.72	0.98	69.4	1.95	1.54	50.3	2.12	1.96
150	132.4	1.72	0.98	74.2	1.95	1.55	53.9	2.12	1.95
160	141.1	1.72	0.98	79.1	1.95	1.55	57.4	2.12	1.96
170	149.7	1.72	0.98	84.0	1.95	1.55	60.9	2.12	1.97
180	158.3	1.72	0.98	88.8	1.95	1.55	64.5	2.12	1.96
190	166.9	1.72	0.98	93.7	1.95	1.55	68.0	2.12	1.97
200	175.5	1.72	0.99	98.5	1.95	1.55	71.5	2.12	1.97
220	192.8	1.72	0.99	108.3	1.95	1.55	78.6	2.12	1.97
240	210.1	1.72	0.99	118.0	1.95	1.56	85.6	2.12	1.98
260	227.3	1.72	0.99	127.7	1.95	1.56	92.7	2.12	1.98
280	244.5	1.72	0.99	137.4	1.95	1.56	99.7	2.12	1.98
300	261.7	1.72	0.99	147.1	1.95	1.56	106.8	2.12	1.98

Q cfs	V_1 = 3.5 T	D	V_2	V_1 = 4.0 T	D	V_2	V_1 = 4.5 T	D	V_2
15									
20									
25									
30	8.9	2.56	1.94						
35	10.2	2.47	2.05						
40	11.6	2.44	2.09						
45	12.9	2.39	2.16						
50	14.3	2.38	2.18	10.6	2.82	2.47			
55	15.7	2.37	2.19	11.6	2.80	2.51			
60	17.1	2.36	2.20	12.5	2.73	2.61			
65	18.4	2.33	2.25	13.5	2.71	2.63	11.2	3.04	2.83
70	19.8	2.33	2.25	14.4	2.66	2.71	12.0	3.01	2.87
75	21.2	2.33	2.26	15.4	2.65	2.73	12.8	2.99	2.91
80	22.5	2.31	2.29	16.4	2.65	2.74	13.5	2.92	3.01
90	25.3	2.31	2.29	18.4	2.63	2.76	15.1	2.89	3.07
100	28.1	2.31	2.29	20.4	2.62	2.78	16.7	2.86	3.11
110	30.8	2.30	2.31	22.4	2.61	2.79	18.3	2.84	3.15
120	33.6	2.30	2.31	24.4	2.61	2.81	19.9	2.82	3.18
130	36.4	2.30	2.31	26.3	2.58	2.85	21.5	2.81	3.20
140	39.1	2.29	2.33	28.3	2.58	2.85	23.1	2.80	3.22
150	41.9	2.30	2.32	30.3	2.58	2.86	24.7	2.79	3.24
160	44.6	2.29	2.33	32.3	2.58	2.86	26.3	2.78	3.26
170	47.4	2.30	2.33	34.3	2.58	2.86	28.0	2.80	3.24
180	50.1	2.29	2.34	36.3	2.58	2.86	29.6	2.79	3.25
190	52.8	2.29	2.34	38.3	2.58	2.86	31.2	2.78	3.26
200	55.6	2.29	2.34	40.2	2.57	2.89	32.8	2.78	3.27
220	61.1	2.29	2.34	44.2	2.57	2.89	36.0	2.77	3.29
240	66.6	2.29	2.35	48.2	2.57	2.89	39.2	2.76	3.31
260	72.1	2.29	2.35	52.2	2.57	2.89	42.5	2.77	3.30
280	77.6	2.29	2.35	56.2	2.57	2.89	45.7	2.76	3.31
300	83.0	2.29	2.36	60.1	2.57	2.90	48.9	2.76	3.32

Q cfs	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15									
20									
25									
30									
35									
40									
45									
50									
55									
60									
65									
70									
75									
80									
90	12.4	3.26	3.30						
100	13.7	3.22	3.36						
110	14.9	3.15	3.48						
120	16.2	3.13	3.52	13.4	3.49	3.81			
130	17.5	3.11	3.55	14.5	3.49	3.82			
140	18.7	3.07	3.63	15.5	3.44	3.91			
150	20.0	3.06	3.65	16.5	3.39	3.98			
160	21.3	3.05	3.67	17.6	3.39	3.98	14.4	3.77	4.37
170	22.6	3.04	3.68	18.6	3.36	4.05	15.3	3.77	4.38
180	23.9	3.04	3.69	19.6	3.33	4.11	16.1	3.73	4.46
190	25.2	3.03	3.70	20.7	3.33	4.10	17.0	3.73	4.45
200	26.5	3.03	3.71	21.7	3.31	4.15	17.8	3.70	4.52
220	29.1	3.02	3.73	23.8	3.29	4.18	19.5	3.67	4.58
240	31.7	3.01	3.75	25.9	3.28	4.22	21.2	3.64	4.63
260	34.3	3.01	3.76	28.0	3.26	4.24	22.9	3.62	4.67
280	36.9	3.00	3.77	30.1	3.25	4.26	24.7	3.63	4.65
300	39.5	3.00	3.78	32.2	3.25	4.28	26.4	3.62	4.68

Parabolic waterway design
(Retardance "D" and "B")

(Sheet 3 of 14)

Exhibit 5

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 1.0 Percent

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2	V_1 = 3.5 T	D	V_2
15	15.7	1.55	0.91	9.9	1.80	1.24						
20	20.9	1.54	0.92	13.0	1.74	1.31	8.8	2.04	1.65			
25	26.0	1.53	0.93	16.2	1.73	1.32	10.9	1.99	1.70	8.9	2.21	1.87
30	31.1	1.52	0.94	19.3	1.70	1.35	12.9	1.94	1.78	10.5	2.14	1.98
35	36.2	1.52	0.94	22.5	1.70	1.36	15.0	1.93	1.80	12.1	2.08	2.06
40	41.3	1.52	0.95	25.7	1.70	1.36	17.1	1.92	1.81	13.7	2.04	2.12
45	46.4	1.52	0.95	28.8	1.69	1.37	19.2	1.91	1.82	15.4	2.04	2.12
50	51.5	1.52	0.95	32.0	1.70	1.37	21.2	1.89	1.85	17.0	2.02	2.16
55	56.5	1.51	0.95	35.1	1.69	1.38	23.3	1.89	1.86	18.7	2.02	2.16
60	61.6	1.52	0.95	38.3	1.69	1.37	25.4	1.89	1.86	20.3	2.00	2.19
65	66.6	1.52	0.96	41.4	1.69	1.38	27.5	1.89	1.86	22.0	2.01	2.19
70	71.6	1.51	0.96	44.6	1.70	1.38	29.5	1.88	1.88	23.6	1.99	2.21
75	76.6	1.51	0.96	47.7	1.69	1.38	31.6	1.88	1.88	25.3	2.00	2.21
80	81.6	1.52	0.96	50.8	1.69	1.38	33.7	1.88	1.88	26.9	1.99	2.22
90	91.7	1.52	0.96	57.1	1.69	1.39	37.8	1.88	1.89	30.2	1.98	2.24
100	101.7	1.52	0.96	63.4	1.69	1.39	42.0	1.88	1.89	33.5	1.98	2.24
110	111.7	1.52	0.97	69.6	1.69	1.39	46.1	1.87	1.90	36.8	1.98	2.25
120	121.7	1.52	0.97	75.8	1.69	1.39	50.2	1.87	1.90	40.1	1.98	2.26
130	131.6	1.51	0.97	82.1	1.69	1.39	54.4	1.87	1.90	43.4	1.97	2.26
140	141.5	1.51	0.97	88.3	1.69	1.39	58.5	1.87	1.90	46.7	1.97	2.26
150	151.4	1.52	0.97	94.5	1.69	1.40	62.6	1.87	1.91	50.0	1.98	2.26
160	161.3	1.52	0.97	100.7	1.69	1.40	66.7	1.87	1.91	53.3	1.98	2.26
170	171.1	1.52	0.97	106.8	1.69	1.40	70.8	1.87	1.91	56.5	1.97	2.28
180	180.9	1.52	0.98	113.0	1.69	1.40	74.9	1.87	1.91	59.8	1.97	2.27
190	190.6	1.52	0.98	119.1	1.69	1.40	79.0	1.87	1.91	63.1	1.98	2.27
200	200.4	1.52	0.98	125.3	1.69	1.40	83.0	1.87	1.92	66.3	1.97	2.28
220	220.1	1.52	0.98	137.6	1.69	1.41	91.2	1.87	1.92	72.9	1.97	2.28
240	239.8	1.52	0.98	150.0	1.69	1.41	99.4	1.87	1.93	79.5	1.98	2.28
260	259.4	1.52	0.98	162.3	1.69	1.41	107.6	1.87	1.93	86.0	1.97	2.28
280	279.0	1.52	0.98	174.6	1.70	1.41	115.8	1.87	1.93	92.5	1.97	2.29
300	298.5	1.52	0.98	186.9	1.70	1.41	123.9	1.87	1.93	99.1	1.98	2.29

Q cfs	V_1 = 4.0 T	D	V_2	V_1 = 4.5 T	D	V_2	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15															
20															
25															
30															
35	9.2	2.37	2.37												
40	10.4	2.32	2.45												
45	11.7	2.32	2.46												
50	12.9	2.28	2.52	9.9	2.61	2.86									
55	14.1	2.25	2.57	10.8	2.57	2.93									
60	15.3	2.23	2.61	11.7	2.54	3.00									
65	16.6	2.24	2.60	12.7	2.55	2.98	10.6	2.88	3.16						
70	17.8	2.22	2.63	13.6	2.52	3.03	11.3	2.82	3.26						
75	19.0	2.21	2.66	14.5	2.50	3.08	12.0	2.77	3.35						
80	20.3	2.22	2.64	15.4	2.48	3.11	12.7	2.73	3.43						
90	22.8	2.21	2.65	17.3	2.47	3.13	14.2	2.69	3.49	11.8	2.99	3.78			
100	25.2	2.19	2.69	19.2	2.47	3.14	15.7	2.67	3.55	13.0	2.94	3.88			
110	27.7	2.19	2.70	21.0	2.44	3.20	17.3	2.68	3.53	14.3	2.94	3.88	12.4	3.23	4.07
120	30.2	2.19	2.70	22.9	2.44	3.20	18.8	2.66	3.57	15.5	2.91	3.96	13.4	3.17	4.19
130	32.7	2.19	2.70	24.8	2.44	3.20	20.3	2.64	3.61	16.7	2.88	4.03	14.4	3.12	4.30
140	35.2	2.19	2.70	26.6	2.42	3.24	21.8	2.63	3.64	17.9	2.85	4.08	15.5	3.12	4.31
150	37.6	2.18	2.72	28.5	2.42	3.23	23.3	2.62	3.66	19.2	2.86	4.07	16.5	3.08	4.39
160	40.1	2.18	2.72	30.4	2.43	3.23	24.8	2.61	3.68	20.4	2.84	4.11	17.6	3.08	4.39
170	42.6	2.19	2.72	32.2	2.41	3.26	26.3	2.60	3.70	21.7	2.85	4.10	18.6	3.05	4.46
180	45.0	2.18	2.73	34.1	2.42	3.25	27.9	2.61	3.68	22.9	2.83	4.14	19.6	3.02	4.52
190	47.5	2.18	2.73	35.9	2.41	3.27	29.4	2.61	3.69	24.1	2.81	4.17	20.7	3.03	4.51
200	49.9	2.18	2.74	37.8	2.41	3.27	30.9	2.60	3.71	25.4	2.82	4.15	21.7	3.00	4.57
220	54.9	2.18	2.74	41.5	2.41	3.28	33.9	2.59	3.73	27.9	2.82	4.17	23.8	2.99	4.61
240	59.8	2.18	2.75	45.3	2.41	3.28	37.0	2.60	3.72	30.4	2.81	4.18	25.9	2.97	4.64
260	64.8	2.18	2.74	49.0	2.41	3.29	40.0	2.59	3.75	32.9	2.81	4.20	28.0	2.96	4.67
280	69.7	2.18	2.75	52.7	2.40	3.30	43.0	2.58	3.76	35.3	2.79	4.24	30.2	2.97	4.65
300	74.6	2.18	2.75	56.4	2.40	3.30	46.1	2.59	3.75	37.8	2.79	4.24	32.3	2.97	4.67

Parabolic waterway design
(Retardance "D" and "B")

(Sheet 4 of 14)

Exhibit 5

4-28467 5-68

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 1.25 Percent

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2
15	18.1	1.40	0.88	11.5	1.59	1.21	7.7	1.85	1.55
20	24.0	1.38	0.89	15.2	1.56	1.25	10.1	1.79	1.64
25	30.0	1.38	0.89	19.0	1.56	1.25	12.5	1.75	1.69
30	35.9	1.38	0.90	22.7	1.55	1.27	14.9	1.73	1.73
35	41.8	1.38	0.90	26.4	1.54	1.28	17.3	1.71	1.75
40	47.7	1.38	0.90	30.1	1.54	1.28	19.7	1.70	1.77
45	53.6	1.38	0.90	33.9	1.54	1.28	22.1	1.69	1.78
50	59.4	1.38	0.91	37.6	1.54	1.28	24.5	1.69	1.79
55	65.3	1.38	0.91	41.3	1.54	1.28	26.9	1.69	1.80
60	71.1	1.38	0.91	44.9	1.53	1.29	29.3	1.68	1.81
65	76.9	1.38	0.91	48.6	1.54	1.29	31.7	1.68	1.81
70	82.7	1.38	0.91	52.3	1.54	1.29	34.1	1.68	1.81
75	88.4	1.38	0.91	55.9	1.53	1.30	36.5	1.68	1.82
80	94.2	1.38	0.91	59.6	1.54	1.30	38.9	1.68	1.82
90	105.8	1.38	0.91	66.9	1.53	1.30	43.7	1.68	1.82
100	117.3	1.38	0.92	74.3	1.54	1.30	48.5	1.68	1.83
110	128.9	1.38	0.92	81.6	1.54	1.31	53.3	1.68	1.83
120	140.4	1.38	0.92	88.9	1.54	1.31	58.1	1.68	1.83
130	151.8	1.38	0.92	96.1	1.53	1.31	62.9	1.68	1.83
140	163.2	1.38	0.92	103.4	1.54	1.31	67.6	1.68	1.84
150	174.6	1.38	0.92	110.6	1.53	1.31	72.4	1.68	1.83
160	186.0	1.38	0.92	117.8	1.53	1.32	77.1	1.68	1.84
170	197.3	1.39	0.92	125.0	1.54	1.32	81.9	1.68	1.84
180	208.5	1.38	0.93	132.2	1.54	1.32	86.6	1.68	1.84
190	219.8	1.39	0.93	139.3	1.54	1.32	91.3	1.68	1.84
200	231.0	1.39	0.93	146.5	1.54	1.32	96.0	1.68	1.84
220	253.7	1.39	0.93	160.9	1.54	1.32	105.5	1.68	1.84
240	276.3	1.39	0.93	175.3	1.54	1.33	115.0	1.69	1.84
260	298.9	1.39	0.93	189.7	1.54	1.33	124.4	1.68	1.85
280	321.3	1.39	0.93	204.0	1.54	1.33	133.9	1.69	1.85
300	343.7	1.39	0.93	218.2	1.54	1.33	143.3	1.69	1.85

Q cfs	V_1 = 3.5 T	D	V_2	V_1 = 4.0 T	D	V_2	V_1 = 4.5 T	D	V_2
15									
20	7.7	2.03	1.89						
25	9.5	1.97	1.97	7.8	2.19	2.16			
30	11.2	1.90	2.09	9.2	2.11	2.28			
35	13.0	1.88	2.12	10.5	2.02	2.44	8.3	2.36	2.64
40	14.8	1.87	2.15	12.0	2.02	2.44	9.4	2.32	2.72
45	16.6	1.86	2.17	13.4	1.99	2.50	10.5	2.28	2.78
50	18.4	1.85	2.18	14.9	1.99	2.50	11.5	2.22	2.90
55	20.2	1.84	2.19	16.3	1.97	2.54	12.6	2.20	2.94
60	22.0	1.84	2.20	17.7	1.96	2.57	13.7	2.19	2.97
65	23.7	1.82	2.24	19.2	1.97	2.56	14.8	2.18	2.99
70	25.5	1.82	2.24	20.6	1.95	2.58	15.9	2.17	3.01
75	27.3	1.82	2.24	22.1	1.96	2.57	17.0	2.16	3.03
80	29.1	1.82	2.24	23.5	1.95	2.59	18.1	2.16	3.05
90	32.7	1.82	2.25	26.4	1.95	2.60	20.3	2.14	3.07
100	36.3	1.82	2.25	29.3	1.95	2.61	22.5	2.14	3.10
110	39.8	1.81	2.27	32.2	1.95	2.61	24.7	2.13	3.11
120	43.4	1.81	2.27	35.0	1.94	2.64	26.9	2.12	3.13
130	47.0	1.82	2.27	37.9	1.94	2.64	29.1	2.12	3.14
140	50.5	1.81	2.28	40.8	1.94	2.64	31.3	2.12	3.14
150	54.1	1.81	2.28	43.7	1.94	2.64	33.5	2.12	3.15
160	57.6	1.81	2.29	46.5	1.93	2.65	35.7	2.12	3.16
170	61.2	1.81	2.28	49.4	1.94	2.65	37.9	2.12	3.16
180	64.7	1.81	2.29	52.2	1.93	2.66	40.1	2.12	3.16
190	68.2	1.81	2.29	55.1	1.94	2.65	42.3	2.12	3.16
200	71.8	1.82	2.29	57.9	1.93	2.66	44.5	2.12	3.17
220	78.9	1.82	2.29	63.7	1.94	2.66	48.9	2.12	3.17
240	85.9	1.81	2.30	69.4	1.94	2.66	53.3	2.11	3.18
260	93.0	1.81	2.30	75.1	1.93	2.67	57.6	2.11	3.19
280	100.1	1.82	2.30	80.8	1.93	2.67	62.0	2.11	3.19
300	107.1	1.81	2.30	86.5	1.94	2.67	66.4	2.11	3.19

Q cfs	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15									
20									
25									
30									
35									
40									
45									
50	9.4	2.49	3.16						
55	10.3	2.47	3.20						
60	11.2	2.45	3.23						
65	12.0	2.40	3.34	9.8	2.76	3.55			
70	12.9	2.39	3.36	10.5	2.74	3.61			
75	13.8	2.39	3.38	11.1	2.67	3.76			
80	14.7	2.38	3.39	11.8	2.65	3.80	10.3	2.92	3.94
90	16.4	2.34	3.48	13.2	2.62	3.87	11.4	2.83	4.14
100	18.2	2.34	3.49	14.6	2.59	3.92	12.6	2.80	4.21
110	20.0	2.34	3.50	16.0	2.58	3.97	13.8	2.77	4.27
120	21.7	2.31	3.56	17.4	2.56	4.00	15.0	2.75	4.32
130	23.5	2.31	3.56	18.8	2.55	4.04	16.2	2.74	4.36
140	25.3	2.31	3.56	20.2	2.54	4.06	17.4	2.72	4.39
150	27.0	2.30	3.60	21.6	2.53	4.08	18.6	2.71	4.42
160	28.8	2.30	3.60	22.9	2.50	4.16	19.8	2.70	4.45
170	30.6	2.30	3.59	24.3	2.50	4.17	21.0	2.69	4.47
180	32.3	2.29	3.62	25.7	2.49	4.18	22.2	2.69	4.49
190	34.1	2.30	3.62	27.1	2.49	4.19	23.4	2.68	4.51
200	35.8	2.29	3.64	28.5	2.49	4.20	24.6	2.68	4.52
220	39.4	2.29	3.63	31.3	2.48	4.22	27.0	2.67	4.55
240	42.9	2.29	3.65	34.1	2.48	4.23	29.4	2.66	4.57
260	46.5	2.29	3.64	36.9	2.48	4.24	31.8	2.65	4.59
280	50.0	2.29	3.65	39.7	2.47	4.25	34.2	2.65	4.61
300	53.5	2.28	3.66	42.5	2.47	4.26	36.6	2.65	4.62

Parabolic waterway design
(Retardance "D" and "B")

(Sheet 5 of 14)

Exhibit 5

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 1.50 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	20.1	1.29	0.86	13.2	1.43	1.17	8.9	1.65	1.51																		
20	26.8	1.29	0.86	17.5	1.42	1.19	11.7	1.60	1.58	8.1	1.86	1.95	6.7	2.09	2.10												
25	33.4	1.28	0.86	21.8	1.41	1.21	14.5	1.57	1.63	9.9	1.78	2.10	8.1	1.95	2.34												
30	40.0	1.28	0.87	26.2	1.42	1.20	17.4	1.57	1.63	11.8	1.75	2.15	9.6	1.90	2.43	8.0	2.13	2.60									
35	46.5	1.28	0.87	30.5	1.41	1.21	20.2	1.56	1.65	13.7	1.74	2.18	11.1	1.86	2.50	9.2	2.06	2.72									
40	53.1	1.28	0.87	34.8	1.41	1.21	23.0	1.55	1.67	15.6	1.73	2.20	12.6	1.84	2.56	10.4	2.02	2.82	8.2	2.38	3.03						
45	59.6	1.28	0.88	39.0	1.40	1.22	25.9	1.55	1.66	17.5	1.72	2.22	14.2	1.85	2.55	11.7	2.02	2.82	9.1	2.31	3.16						
50	66.1	1.28	0.88	43.3	1.41	1.22	28.7	1.55	1.67	19.4	1.71	2.24	15.7	1.83	2.58	12.9	1.99	2.89	10.0	2.26	3.27						
55	72.6	1.28	0.88	47.6	1.41	1.22	31.5	1.55	1.68	21.3	1.71	2.25	17.2	1.82	2.61	14.2	1.99	2.89	10.9	2.22	3.36	9.3	2.47	3.54			
60	79.0	1.28	0.88	51.8	1.41	1.22	34.3	1.54	1.69	23.2	1.70	2.25	18.8	1.82	2.60	15.4	1.97	2.94	11.9	2.22	3.36	10.1	2.45	3.59			
65	85.5	1.28	0.88	56.0	1.40	1.23	37.1	1.54	1.69	25.1	1.70	2.26	20.3	1.82	2.62	16.6	1.95	2.98	12.8	2.19	3.43	10.8	2.39	3.73			
70	91.9	1.28	0.88	60.3	1.41	1.22	39.9	1.54	1.69	27.0	1.70	2.26	21.8	1.81	2.64	17.9	1.96	2.96	13.8	2.20	3.42	11.6	2.38	3.76	9.8	2.62	4.03
75	98.2	1.28	0.89	64.5	1.41	1.23	42.7	1.54	1.69	28.9	1.70	2.27	23.3	1.80	2.66	19.1	1.95	3.00	14.7	2.18	3.48	12.4	2.37	3.79	10.5	2.62	4.04
80	104.6	1.28	0.89	68.7	1.41	1.23	45.5	1.54	1.70	30.8	1.70	2.27	24.9	1.81	2.64	20.4	1.95	2.98	15.7	2.18	3.46	13.2	2.36	3.81	11.1	2.58	4.15
90	117.5	1.28	0.89	77.1	1.41	1.23	51.1	1.54	1.70	34.6	1.70	2.28	27.9	1.80	2.67	22.9	1.95	3.00	17.6	2.17	3.50	14.7	2.31	3.93	12.4	2.54	4.24
100	130.3	1.28	0.89	85.6	1.41	1.23	56.7	1.54	1.70	38.3	1.69	2.30	31.0	1.80	2.66	25.4	1.94	3.02	19.5	2.16	3.53	16.3	2.30	3.96	13.7	2.51	4.32
110	143.0	1.28	0.89	94.0	1.41	1.24	62.3	1.54	1.71	42.1	1.69	2.30	34.0	1.79	2.68	27.9	1.94	3.03	21.4	2.15	3.56	17.9	2.30	3.98	15.0	2.49	4.38
120	155.8	1.28	0.89	102.4	1.41	1.24	67.9	1.54	1.71	45.9	1.69	2.30	37.1	1.80	2.68	30.4	1.94	3.03	23.3	2.14	3.57	19.5	2.29	3.99	16.3	2.47	4.43
130	168.4	1.28	0.90	110.7	1.41	1.24	73.4	1.54	1.71	49.7	1.69	2.30	40.1	1.79	2.69	32.9	1.94	3.04	25.2	2.14	3.59	21.1	2.29	4.01	17.6	2.45	4.48
140	181.0	1.28	0.90	119.1	1.41	1.24	79.0	1.54	1.71	53.4	1.69	2.31	43.2	1.80	2.68	35.3	1.93	3.07	27.1	2.14	3.60	22.7	2.29	4.02	18.9	2.44	4.51
150	193.6	1.28	0.90	127.4	1.41	1.24	84.5	1.54	1.72	57.2	1.69	2.31	46.2	1.79	2.70	37.8	1.93	3.07	29.0	2.13	3.61	24.2	2.27	4.07	20.2	2.43	4.54
160	206.2	1.28	0.90	135.7	1.41	1.24	90.0	1.54	1.72	60.9	1.69	2.32	49.3	1.80	2.69	40.3	1.93	3.07	30.9	2.13	3.62	25.8	2.27	4.08	21.6	2.45	4.51
170	218.6	1.28	0.90	144.0	1.41	1.24	95.6	1.54	1.72	64.7	1.69	2.31	52.3	1.80	2.69	42.8	1.93	3.07	32.8	2.13	3.62	27.4	2.27	4.08	22.9	2.44	4.53
180	231.1	1.28	0.90	152.2	1.41	1.25	101.0	1.54	1.72	68.4	1.69	2.32	55.3	1.80	2.70	45.3	1.93	3.07	34.7	2.13	3.63	29.0	2.27	4.08	24.2	2.43	4.56
190	243.5	1.28	0.90	160.4	1.41	1.25	106.5	1.54	1.72	72.1	1.69	2.32	58.3	1.80	2.71	47.7	1.92	3.08	36.5	2.12	3.66	30.6	2.27	4.08	25.5	2.42	4.58
200	255.8	1.28	0.91	168.6	1.41	1.25	112.0	1.54	1.72	75.9	1.69	2.32	61.3	1.79	2.71	50.2	1.93	3.08	38.4	2.12	3.66	32.1	2.26	4.12	26.8	2.42	4.60
220	280.9	1.28	0.91	185.2	1.41	1.25	123.0	1.54	1.73	83.4	1.69	2.32	67.4	1.80	2.71	55.2	1.93	3.08	42.2	2.12	3.67	35.3	2.26	4.12	29.5	2.42	4.58
240	305.8	1.28	0.91	201.7	1.41	1.25	134.1	1.54	1.73	90.9	1.69	2.32	73.5	1.80	2.71	60.1	1.92	3.09	46.0	2.12	3.67	38.5	2.26	4.12	32.1	2.41	4.62
260	330.7	1.28	0.91	218.2	1.41	1.26	145.1	1.54	1.73	98.3	1.69	2.33	79.5	1.80	2.72	65.1	1.93	3.09	49.8	2.12	3.68	41.7	2.26	4.12	34.7	2.41	4.64
280	355.5	1.28	0.91	234.7	1.41	1.26	156.0	1.54	1.73	105.8	1.69	2.33	85.5	1.79	2.72	70.0	1.93	3.10	53.6	2.12	3.68	44.8	2.25	4.14	37.4	2.41	4.63
300	380.2	1.28	0.91	251.1	1.41	1.26	167.0	1.54	1.73	113.2	1.69	2.33	91.6	1.80	2.72	74.9	1.92	3.11	57.4	2.12	3.68	48.0	2.25	4.14	40.0	2.41	4.65

Parabolic waterway design
(Retardance "D" and "B")

Exhibit 5

4-26467 5-68

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B"

Grade 1.75 Percent

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2
15	21.8	1.21	0.84	14.2	1.33	1.17	10.0	1.50	1.48
20	29.0	1.20	0.85	18.9	1.33	1.18	13.2	1.46	1.53
25	36.2	1.20	0.85	23.5	1.32	1.20	16.4	1.45	1.56
30	43.4	1.21	0.85	28.2	1.32	1.20	19.6	1.44	1.58
35	50.5	1.20	0.85	32.8	1.31	1.21	22.8	1.43	1.59
40	57.6	1.20	0.85	37.4	1.31	1.21	26.0	1.43	1.60
45	64.6	1.20	0.86	42.0	1.31	1.21	29.2	1.43	1.61
50	71.6	1.20	0.86	46.6	1.31	1.21	32.4	1.43	1.61
55	78.6	1.20	0.86	51.2	1.31	1.22	35.6	1.43	1.61
60	85.6	1.20	0.87	55.8	1.31	1.22	38.8	1.43	1.61
65	92.6	1.20	0.87	60.3	1.31	1.22	41.9	1.42	1.62
70	99.5	1.20	0.87	64.9	1.32	1.22	45.1	1.42	1.62
75	106.4	1.20	0.87	69.4	1.31	1.22	48.2	1.42	1.63
80	113.3	1.20	0.87	73.9	1.31	1.22	51.4	1.43	1.62
90	127.2	1.20	0.87	83.0	1.31	1.23	57.7	1.42	1.63
100	141.0	1.20	0.87	92.1	1.32	1.23	64.0	1.42	1.64
110	154.9	1.21	0.87	101.2	1.32	1.23	70.4	1.43	1.63
120	168.6	1.20	0.88	110.2	1.32	1.23	76.6	1.42	1.64
130	182.3	1.21	0.88	119.2	1.32	1.23	82.9	1.42	1.64
140	196.0	1.21	0.88	128.1	1.32	1.23	89.2	1.43	1.64
150	209.6	1.21	0.88	137.1	1.32	1.23	95.4	1.42	1.64
160	223.1	1.21	0.88	146.0	1.32	1.24	101.6	1.42	1.65
170	236.6	1.21	0.88	154.9	1.32	1.24	107.9	1.43	1.64
180	250.0	1.21	0.89	163.7	1.32	1.24	114.0	1.43	1.65
190	263.4	1.21	0.89	172.6	1.32	1.24	120.2	1.43	1.65
200	276.7	1.21	0.89	181.4	1.32	1.24	126.4	1.43	1.65
220	303.8	1.21	0.89	199.2	1.32	1.24	138.8	1.43	1.65
240	330.8	1.21	0.89	217.0	1.32	1.24	151.2	1.43	1.66
260	357.7	1.21	0.89	234.7	1.32	1.25	163.6	1.43	1.66
280	384.5	1.21	0.89	252.3	1.32	1.25	176.0	1.43	1.66
300	411.2	1.21	0.90	269.9	1.32	1.25	188.3	1.43	1.66

Q cfs	V_1 = 3.5 T	D	V_2	V_1 = 4.0 T	D	V_2	V_1 = 4.5 T	D	V_2
15	6.9	1.74	1.84						
20	9.0	1.66	1.98	7.6	1.83	2.12			
25	11.2	1.64	2.01	9.3	1.75	2.27	7.6	1.93	2.51
30	13.3	1.60	2.08	11.1	1.72	2.32	9.0	1.88	2.62
35	15.5	1.60	2.09	12.8	1.68	2.40	10.4	1.84	2.70
40	17.6	1.58	2.13	14.6	1.68	2.42	11.8	1.81	2.77
45	19.8	1.58	2.13	16.4	1.68	2.43	13.2	1.79	2.82
50	21.9	1.57	2.16	18.2	1.67	2.44	14.7	1.80	2.80
55	24.1	1.58	2.15	19.9	1.66	2.48	16.1	1.79	2.83
60	26.2	1.57	2.17	21.7	1.66	2.48	17.5	1.78	2.86
65	28.4	1.57	2.16	23.5	1.66	2.48	18.9	1.77	2.88
70	30.5	1.57	2.18	25.2	1.65	2.50	20.3	1.76	2.90
75	32.7	1.57	2.17	27.0	1.65	2.50	21.8	1.78	2.88
80	34.8	1.57	2.18	28.8	1.66	2.50	23.2	1.77	2.90
90	39.1	1.57	2.18	32.3	1.65	2.52	26.0	1.76	2.93
100	43.4	1.57	2.18	35.8	1.64	2.53	28.9	1.76	2.92
110	47.7	1.57	2.19	39.4	1.65	2.52	31.7	1.76	2.94
120	51.9	1.57	2.20	42.9	1.64	2.53	34.6	1.76	2.93
130	56.2	1.57	2.20	46.4	1.64	2.54	37.4	1.76	2.95
140	60.4	1.57	2.21	49.9	1.64	2.55	40.2	1.75	2.96
150	64.7	1.57	2.20	53.4	1.64	2.55	43.1	1.76	2.95
160	68.9	1.57	2.21	56.9	1.64	2.55	45.9	1.76	2.96
170	73.1	1.57	2.21	60.4	1.64	2.55	48.7	1.76	2.96
180	77.4	1.57	2.21	63.9	1.64	2.55	51.5	1.75	2.97
190	81.6	1.57	2.21	67.4	1.64	2.55	54.3	1.75	2.97
200	85.7	1.57	2.22	70.8	1.64	2.56	57.1	1.75	2.98
220	94.2	1.57	2.22	77.8	1.64	2.57	62.8	1.76	2.97
240	102.7	1.57	2.22	84.8	1.64	2.57	68.4	1.75	2.98
260	111.1	1.57	2.22	91.8	1.64	2.57	74.1	1.76	2.98
280	119.5	1.57	2.23	98.7	1.64	2.58	79.7	1.76	2.98
300	127.9	1.57	2.23	105.7	1.64	2.57	85.3	1.76	2.99

Q cfs	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15									
20									
25									
30									
35	8.2	2.11	2.98						
40	9.3	2.08	3.06						
45	10.3	2.01	3.21	8.6	2.26	3.41			
50	11.4	2.00	3.25	9.5	2.24	3.48			
55	12.5	1.99	3.28	10.3	2.17	3.64	8.6	2.51	3.77
60	13.6	1.98	3.31	11.2	2.16	3.67	9.2	2.41	4.00
65	14.7	1.97	3.33	12.1	2.15	3.70	9.9	2.38	4.08
70	15.8	1.96	3.35	13.0	2.14	3.73	10.6	2.35	4.15
75	16.9	1.96	3.36	13.9	2.13	3.75	11.4	2.37	4.11
80	17.9	1.94	3.43	14.8	2.13	3.77	12.1	2.35	4.17
90	20.1	1.93	3.45	16.6	2.12	3.81	13.5	2.31	4.28
100	22.3	1.93	3.46	18.4	2.11	3.83	14.9	2.28	4.37
110	24.5	1.92	3.47	20.1	2.08	3.91	16.4	2.29	4.36
120	26.7	1.92	3.48	21.9	2.08	3.93	17.8	2.26	4.43
130	28.9	1.92	3.49	23.7	2.07	3.93	19.2	2.25	4.48
140	31.1	1.92	3.49	25.5	2.07	3.94	20.7	2.25	4.47
150	33.3	1.92	3.49	27.3	2.07	3.95	22.1	2.24	4.51
160	35.4	1.91	3.52	29.1	2.07	3.95	23.6	2.25	4.49
170	37.6	1.91	3.52	30.9	2.07	3.95	25.0	2.24	4.53
180	39.8	1.92	3.52	32.6	2.06	3.99	26.4	2.23	4.56
190	42.0	1.92	3.52	34.4	2.06	3.99	27.9	2.23	4.54
200	44.1	1.91	3.54	36.2	2.06	3.99	29.3	2.23	4.57
220	48.5	1.91	3.53	39.8	2.07	3.99	32.2	2.22	4.58
240	52.9	1.92	3.53	43.3	2.06	4.02	35.1	2.22	4.58
260	57.2	1.91	3.54	46.9	2.06	4.01	38.0	2.22	4.59
280	61.6	1.92	3.54	50.5	2.06	4.01	40.9	2.22	4.59
300	65.9	1.91	3.55	54.0	2.06	4.03	43.7	2.21	4.62

Parabolic waterway design
(Retardance "D" and "B")

(Sheet 7 of 14)

Exhibit 5

V_1 for **RETARDANCE "D"**. Top Width (T), Depth (D) and V_2 for **RETARDANCE "B"**.

Grade 2.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	24.7	1.14	0.79	15.0	1.25	1.18	11.0	1.40	1.43	7.8	1.56	1.81															
20	32.8	1.14	0.79	20.0	1.25	1.18	14.5	1.37	1.49	10.3	1.53	1.88	7.5	1.71	2.29	6.3	1.91	2.44									
25	41.0	1.14	0.79	24.9	1.24	1.20	18.1	1.37	1.50	12.7	1.48	1.96	9.3	1.68	2.36	7.7	1.82	2.62									
30	49.0	1.14	0.80	29.8	1.24	1.20	21.6	1.35	1.52	15.2	1.48	1.98	11.0	1.63	2.47	9.1	1.77	2.76	7.6	1.97	2.95						
35	57.1	1.14	0.80	34.7	1.24	1.21	25.1	1.35	1.54	17.7	1.47	1.99	12.8	1.62	2.50	10.5	1.73	2.86	8.8	1.94	3.03						
40	65.1	1.14	0.80	39.6	1.24	1.21	28.7	1.35	1.53	20.2	1.47	2.00	14.6	1.62	2.51	12.0	1.73	2.86	9.9	1.88	3.18	8.2	2.13	3.38			
45	73.1	1.14	0.80	44.5	1.24	1.21	32.2	1.35	1.54	22.6	1.46	2.03	16.4	1.61	2.52	13.5	1.73	2.86	11.1	1.87	3.21	9.1	2.08	3.52			
50	81.0	1.14	0.81	49.3	1.24	1.22	35.7	1.35	1.55	25.1	1.46	2.03	18.1	1.59	2.57	14.9	1.71	2.92	12.3	1.86	3.24	10.0	2.03	3.64	8.6	2.29	3.76
55	88.9	1.14	0.81	54.2	1.24	1.21	39.2	1.34	1.55	27.6	1.46	2.03	19.9	1.60	2.57	16.4	1.71	2.91	13.5	1.85	3.26	11.0	2.03	3.65	9.3	2.21	3.96
60	96.8	1.14	0.81	59.0	1.24	1.22	42.7	1.34	1.55	30.0	1.45	2.05	21.7	1.60	2.57	17.8	1.69	2.95	14.7	1.85	3.28	11.9	2.00	3.74	10.1	2.19	4.01
65	104.6	1.14	0.81	63.8	1.24	1.22	46.2	1.35	1.55	32.5	1.46	2.04	23.4	1.58	2.60	19.3	1.70	2.94	15.8	1.82	3.36	12.9	2.00	3.73	10.9	2.18	4.06
70	112.4	1.14	0.81	68.6	1.24	1.22	49.7	1.35	1.56	34.9	1.45	2.05	25.2	1.59	2.60	20.7	1.69	2.98	17.0	1.82	3.36	13.8	1.98	3.81	11.7	2.16	4.10
75	120.2	1.14	0.81	73.4	1.24	1.22	53.1	1.34	1.56	37.3	1.45	2.06	27.0	1.59	2.60	22.2	1.69	2.96	18.2	1.82	3.37	14.8	1.98	3.79	12.5	2.15	4.14
80	127.9	1.14	0.82	78.1	1.24	1.23	56.6	1.35	1.56	39.8	1.45	2.06	28.7	1.58	2.62	23.6	1.69	2.99	19.4	1.82	3.37	15.8	1.99	3.78	13.3	2.14	4.17
90	143.6	1.14	0.82	87.8	1.24	1.23	63.5	1.34	1.57	44.7	1.45	2.06	32.3	1.59	2.61	26.5	1.68	3.00	21.8	1.82	3.38	17.7	1.97	3.83	14.9	2.12	4.22
100	159.2	1.14	0.82	97.4	1.24	1.23	70.5	1.34	1.57	49.6	1.45	2.07	35.8	1.58	2.63	29.4	1.68	3.01	24.1	1.80	3.43	19.6	1.96	3.87	16.5	2.11	4.26
110	174.8	1.14	0.82	106.9	1.24	1.23	77.4	1.34	1.57	54.5	1.45	2.07	39.3	1.58	2.64	32.3	1.68	3.02	26.5	1.80	3.43	21.5	1.95	3.90	18.1	2.10	4.30
120	190.3	1.14	0.82	116.5	1.24	1.23	84.3	1.34	1.58	59.4	1.45	2.07	42.8	1.58	2.65	35.2	1.68	3.02	28.9	1.80	3.43	23.4	1.94	3.92	19.7	2.09	4.33
130	205.7	1.14	0.82	126.0	1.24	1.23	91.2	1.34	1.58	64.2	1.45	2.08	46.4	1.58	2.64	38.1	1.68	3.03	31.3	1.80	3.43	25.4	1.95	3.90	21.3	2.09	4.35
140	221.0	1.14	0.82	135.4	1.24	1.24	98.0	1.34	1.58	69.1	1.45	2.08	49.9	1.58	2.64	41.0	1.68	3.03	33.6	1.80	3.46	27.3	1.95	3.92	22.9	2.08	4.37
150	236.3	1.14	0.83	144.9	1.25	1.24	104.9	1.34	1.58	73.9	1.45	2.08	53.4	1.58	2.65	43.9	1.68	3.03	36.0	1.80	3.45	29.2	1.95	3.93	24.5	2.08	4.38
160	251.5	1.14	0.83	154.3	1.25	1.24	111.7	1.34	1.59	78.7	1.45	2.09	56.9	1.58	2.65	46.7	1.67	3.05	38.3	1.79	3.47	31.1	1.94	3.94	26.1	2.08	4.40
170	266.6	1.14	0.83	163.7	1.25	1.24	118.5	1.34	1.59	83.6	1.45	2.08	60.3	1.58	2.66	49.6	1.68	3.05	40.7	1.80	3.46	33.0	1.94	3.95	27.7	2.07	4.41
180	281.7	1.14	0.83	173.0	1.25	1.24	125.2	1.34	1.59	88.4	1.45	2.09	63.8	1.58	2.66	52.5	1.68	3.04	43.0	1.79	3.48	34.9	1.94	3.96	29.3	2.07	4.41
190	296.7	1.14	0.83	182.3	1.25	1.24	132.0	1.34	1.59	93.2	1.45	2.09	67.3	1.58	2.66	55.3	1.68	3.06	45.4	1.80	3.47	36.8	1.94	3.97	30.8	2.06	4.46
200	311.7	1.14	0.83	191.6	1.25	1.24	138.7	1.34	1.60	97.9	1.45	2.10	70.7	1.58	2.67	58.2	1.68	3.05	47.7	1.79	3.49	38.7	1.94	3.97	32.4	2.06	4.47
220	342.1	1.14	0.83	210.4	1.25	1.25	152.4	1.35	1.60	107.6	1.45	2.10	77.7	1.58	2.67	63.9	1.68	3.06	52.5	1.80	3.47	42.5	1.93	3.99	35.6	2.06	4.48
240	372.4	1.14	0.84	229.2	1.25	1.25	165.9	1.34	1.60	117.2	1.45	2.10	84.7	1.58	2.67	69.7	1.68	3.06	57.2	1.80	3.48	46.4	1.94	3.97	38.8	2.06	4.49
260	402.5	1.14	0.84	247.9	1.25	1.25	179.5	1.34	1.60	126.8	1.45	2.10	91.7	1.58	2.67	75.4	1.68	3.07	61.9	1.80	3.49	50.2	1.94	3.99	42.0	2.06	4.49
280	432.6	1.14	0.84	266.5	1.25	1.25	193.0	1.34	1.61	136.4	1.45	2.10	98.6	1.58	2.68	81.1	1.68	3.07	66.6	1.80	3.49	54.0	1.94	3.99	45.2	2.06	4.49
300	462.5	1.14	0.84	285.1	1.25	1.25	206.5	1.35	1.61	146.0	1.46	2.10	105.5	1.58	2.69	86.8	1.68	3.07	71.2	1.79	3.51	57.8	1.94	4.00	48.4	2.06	4.50

Parabolic waterway design
(Retardance "D" and "B")

(Sheet 8 of 14)

Exhibit 5

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 3.0 Percent

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2
15	28.1	0.98	0.80	19.2	1.05	1.10	13.4	1.15	1.44
20	37.4	0.98	0.80	25.6	1.05	1.10	17.8	1.14	1.46
25	46.7	0.99	0.80	31.9	1.05	1.11	22.2	1.14	1.47
30	55.9	0.99	0.81	38.2	1.05	1.11	26.6	1.14	1.47
35	65.0	0.99	0.81	44.4	1.04	1.12	31.0	1.14	1.47
40	74.1	0.99	0.81	50.6	1.04	1.12	35.3	1.14	1.48
45	83.2	0.99	0.81	56.8	1.04	1.13	39.7	1.14	1.48
50	92.2	0.99	0.81	63.0	1.04	1.13	44.0	1.14	1.48
55	101.1	0.99	0.82	69.1	1.04	1.13	48.3	1.14	1.49
60	110.1	0.99	0.82	75.3	1.05	1.13	52.6	1.14	1.49
65	118.9	0.99	0.82	81.4	1.05	1.13	56.9	1.14	1.49
70	127.8	0.99	0.82	87.4	1.04	1.14	61.1	1.14	1.50
75	136.6	0.99	0.82	93.5	1.05	1.14	65.4	1.14	1.50
80	145.3	0.99	0.83	99.5	1.05	1.14	69.6	1.14	1.50
90	163.1	0.99	0.83	111.7	1.05	1.14	78.2	1.14	1.50
100	180.8	0.99	0.83	123.8	1.05	1.15	86.7	1.14	1.51
110	198.3	0.99	0.83	135.9	1.05	1.15	95.2	1.14	1.51
120	215.8	0.99	0.83	148.0	1.05	1.15	103.7	1.14	1.51
130	233.3	0.99	0.83	160.0	1.05	1.15	112.1	1.14	1.51
140	250.6	0.99	0.84	171.9	1.05	1.15	120.5	1.14	1.52
150	267.8	0.99	0.84	183.8	1.05	1.16	128.9	1.14	1.52
160	285.0	0.99	0.84	195.7	1.05	1.16	137.2	1.14	1.52
170	302.0	0.99	0.84	207.5	1.05	1.16	145.5	1.14	1.52
180	319.0	0.99	0.84	219.2	1.05	1.16	153.8	1.14	1.53
190	335.9	0.99	0.85	231.0	1.05	1.16	162.1	1.14	1.53
200	352.7	0.99	0.85	242.6	1.05	1.16	170.3	1.14	1.53
220	387.1	0.99	0.85	266.3	1.05	1.17	187.0	1.14	1.53
240	421.2	0.99	0.85	289.9	1.05	1.17	203.6	1.14	1.53
260	455.2	0.99	0.85	313.4	1.05	1.17	220.2	1.14	1.54
280	489.0	0.99	0.85	336.9	1.05	1.17	236.7	1.14	1.54
300	522.6	0.99	0.86	360.2	1.05	1.17	253.2	1.15	1.54

Q cfs	V_1 = 3.5 T	D	V_2	V_1 = 4.0 T	D	V_2	V_1 = 4.5 T	D	V_2
15	10.3	1.24	1.74	7.6	1.37	2.12	5.8	1.56	2.44
20	13.7	1.23	1.76	10.0	1.33	2.22	7.6	1.50	2.59
25	17.0	1.21	1.80	12.5	1.33	2.23	9.4	1.46	2.69
30	20.3	1.20	1.82	14.9	1.31	2.27	11.2	1.44	2.75
35	23.7	1.21	1.81	17.3	1.30	2.30	13.0	1.43	2.80
40	27.0	1.20	1.83	19.7	1.29	2.33	14.8	1.42	2.83
45	30.3	1.20	1.84	22.1	1.29	2.34	16.6	1.41	2.85
50	33.6	1.20	1.84	24.6	1.30	2.32	18.4	1.40	2.87
55	36.9	1.20	1.84	27.0	1.30	2.34	20.2	1.40	2.88
60	40.2	1.20	1.85	29.4	1.29	2.34	22.0	1.40	2.89
65	43.4	1.20	1.86	31.8	1.29	2.35	23.8	1.40	2.90
70	46.7	1.20	1.86	34.2	1.29	2.35	25.6	1.40	2.90
75	49.9	1.20	1.87	36.6	1.29	2.35	27.4	1.40	2.91
80	53.1	1.20	1.87	38.9	1.29	2.37	29.2	1.40	2.91
90	59.7	1.20	1.87	43.7	1.29	2.38	32.7	1.39	2.94
100	66.2	1.20	1.88	48.5	1.29	2.38	36.3	1.39	2.95
110	72.7	1.20	1.88	53.3	1.29	2.38	39.9	1.39	2.95
120	79.2	1.20	1.88	58.1	1.29	2.38	43.5	1.39	2.95
130	85.7	1.20	1.88	62.8	1.29	2.39	47.0	1.39	2.96
140	92.1	1.20	1.89	67.6	1.29	2.38	50.6	1.39	2.96
150	98.5	1.20	1.89	72.3	1.29	2.39	54.1	1.39	2.97
160	104.9	1.20	1.89	77.0	1.29	2.39	57.7	1.39	2.96
170	111.3	1.20	1.89	81.7	1.29	2.40	61.2	1.39	2.97
180	117.7	1.20	1.89	86.4	1.29	2.40	64.7	1.39	2.98
190	124.0	1.20	1.90	91.1	1.30	2.40	68.2	1.39	2.98
200	130.3	1.20	1.90	95.7	1.29	2.40	71.7	1.39	2.99
220	143.1	1.20	1.90	105.1	1.29	2.41	78.8	1.39	2.99
240	155.9	1.20	1.90	114.5	1.29	2.41	85.9	1.39	2.99
260	168.6	1.20	1.91	123.9	1.30	2.41	92.9	1.39	2.99
280	181.3	1.20	1.91	133.3	1.30	2.41	99.9	1.39	3.00
300	193.9	1.20	1.91	142.6	1.30	2.42	106.9	1.39	3.00

Q cfs	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15									
20	6.8	1.58	2.74						
25	8.4	1.54	2.85	6.9	1.68	3.18			
30	9.9	1.48	3.02	8.2	1.64	3.28	6.7	1.88	3.50
35	11.5	1.47	3.07	9.5	1.62	3.36	7.7	1.82	3.68
40	13.1	1.46	3.10	10.8	1.60	3.42	8.7	1.78	3.82
45	14.7	1.45	3.12	12.1	1.59	3.46	9.7	1.75	3.92
50	16.3	1.45	3.14	13.4	1.58	3.50	10.7	1.72	4.01
55	17.9	1.45	3.15	14.7	1.57	3.53	11.7	1.70	4.09
60	19.5	1.45	3.16	16.0	1.57	3.55	12.7	1.69	4.15
65	21.1	1.45	3.16	17.3	1.57	3.56	13.8	1.70	4.11
70	22.7	1.45	3.17	18.5	1.55	3.63	14.8	1.69	4.16
75	24.2	1.44	3.21	19.8	1.55	3.64	15.8	1.68	4.20
80	25.8	1.44	3.21	21.1	1.55	3.64	16.9	1.69	4.16
90	29.0	1.44	3.21	23.7	1.54	3.66	18.9	1.67	4.23
100	32.2	1.44	3.21	26.3	1.54	3.67	21.0	1.67	4.23
110	35.4	1.44	3.21	28.9	1.54	3.67	23.1	1.68	4.22
120	38.5	1.43	3.23	31.5	1.54	3.68	25.1	1.67	4.27
130	41.7	1.44	3.23	34.1	1.54	3.68	27.2	1.67	4.26
140	44.8	1.43	3.24	36.7	1.54	3.68	29.3	1.67	4.25
150	48.0	1.44	3.24	39.3	1.55	3.68	31.3	1.67	4.28
160	51.1	1.44	3.25	41.8	1.54	3.70	33.4	1.67	4.27
170	54.3	1.44	3.24	44.4	1.54	3.70	35.4	1.67	4.29
180	57.4	1.44	3.25	47.0	1.55	3.69	37.5	1.67	4.28
190	60.5	1.44	3.25	49.5	1.54	3.71	39.5	1.67	4.30
200	63.6	1.44	3.26	52.1	1.55	3.70	41.6	1.67	4.28
220	69.9	1.44	3.26	57.2	1.54	3.71	45.7	1.67	4.29
240	76.2	1.44	3.26	62.3	1.54	3.72	49.8	1.67	4.30
260	82.4	1.44	3.27	67.5	1.55	3.72	53.9	1.67	4.31
280	88.6	1.44	3.27	72.6	1.55	3.72	58.0	1.67	4.31
300	94.9	1.44	3.27	77.7	1.55	3.73	62.0	1.67	4.33

Parabolic waterway design
(Retardance "D" and "B")

(Sheet 9 of 14)

Exhibit 5

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 4.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	33.1	0.87	0.77	23.6	0.93	1.01	16.3	1.00	1.36	12.1	1.08	1.69	9.2	1.15	2.08	7.4	1.27	2.34	5.7	1.43	2.69						
20	44.0	0.87	0.77	31.4	0.93	1.01	21.7	1.00	1.37	16.1	1.08	1.70	12.3	1.16	2.08	9.7	1.23	2.48	7.4	1.35	2.94	6.4	1.47	3.12			
25	54.9	0.87	0.77	39.1	0.93	1.02	27.1	1.00	1.37	20.1	1.08	1.71	15.3	1.15	2.11	12.1	1.22	2.50	9.2	1.33	3.01	7.9	1.43	3.26	6.5	1.56	3.62
30	65.7	0.87	0.78	46.8	0.93	1.02	32.4	0.99	1.38	24.0	1.07	1.73	18.3	1.14	2.13	14.4	1.20	2.57	11.0	1.32	3.05	9.3	1.38	3.46	7.7	1.52	3.78
35	76.4	0.87	0.78	54.5	0.93	1.02	37.7	0.99	1.39	27.9	1.07	1.74	21.3	1.14	2.14	16.8	1.20	2.57	12.7	1.30	3.14	10.9	1.39	3.42	8.9	1.49	3.90
40	87.1	0.87	0.78	62.1	0.93	1.03	43.0	0.99	1.39	31.9	1.07	1.74	24.3	1.14	2.15	19.2	1.21	2.56	14.5	1.30	3.15	12.4	1.38	3.47	10.2	1.50	3.87
45	97.7	0.87	0.78	69.7	0.93	1.03	48.3	0.99	1.39	35.8	1.07	1.74	27.2	1.13	2.17	21.5	1.20	2.59	16.3	1.30	3.16	13.9	1.37	3.51	11.4	1.48	3.95
50	108.3	0.87	0.78	77.3	0.93	1.03	53.5	0.99	1.40	39.7	1.07	1.75	30.2	1.13	2.17	23.9	1.20	2.58	18.1	1.30	3.16	15.4	1.36	3.54	12.6	1.46	4.01
55	118.8	0.87	0.78	84.7	0.93	1.04	58.7	0.99	1.40	43.6	1.07	1.75	33.2	1.13	2.17	26.2	1.20	2.60	19.8	1.29	3.21	16.9	1.36	3.56	13.8	1.45	4.06
60	129.2	0.87	0.79	92.2	0.93	1.04	63.9	0.99	1.40	47.4	1.07	1.76	36.1	1.13	2.18	28.5	1.19	2.62	21.6	1.29	3.20	18.4	1.36	3.57	15.1	1.46	4.02
65	139.6	0.87	0.79	99.6	0.93	1.04	69.1	0.99	1.41	51.3	1.07	1.76	39.0	1.13	2.19	30.9	1.20	2.61	23.4	1.29	3.19	19.9	1.35	3.58	16.3	1.46	4.06
70	149.9	0.88	0.79	107.0	0.93	1.04	74.2	0.99	1.41	55.1	1.07	1.77	42.0	1.13	2.19	33.2	1.20	2.62	25.1	1.28	3.23	21.4	1.35	3.59	17.5	1.45	4.09
75	160.2	0.88	0.79	114.3	0.93	1.05	79.3	0.99	1.42	58.9	1.07	1.77	44.9	1.13	2.19	35.5	1.20	2.62	26.9	1.29	3.22	22.9	1.35	3.60	18.7	1.45	4.12
80	170.4	0.88	0.79	121.6	0.93	1.05	84.4	0.99	1.42	62.7	1.07	1.77	47.8	1.13	2.20	37.8	1.20	2.63	28.6	1.28	3.24	24.4	1.35	3.60	20.0	1.46	4.08
90	191.1	0.88	0.80	136.5	0.93	1.05	94.8	0.99	1.42	70.4	1.07	1.78	53.7	1.13	2.20	42.4	1.19	2.65	32.1	1.28	3.26	27.4	1.35	3.62	22.4	1.45	4.13
100	211.8	0.88	0.80	151.2	0.93	1.05	105.1	0.99	1.42	78.1	1.07	1.78	59.6	1.13	2.20	47.1	1.20	2.64	35.7	1.29	3.24	30.4	1.35	3.63	24.9	1.45	4.12
110	232.3	0.88	0.80	165.9	0.93	1.06	115.3	0.99	1.43	85.8	1.07	1.78	65.4	1.13	2.21	51.7	1.19	2.65	39.2	1.29	3.25	33.4	1.35	3.63	27.3	1.44	4.16
120	252.7	0.88	0.80	180.5	0.93	1.06	125.5	0.99	1.43	93.4	1.07	1.78	71.2	1.13	2.22	56.3	1.19	2.66	42.7	1.28	3.26	36.3	1.34	3.66	29.8	1.45	4.14
130	273.0	0.88	0.80	195.1	0.93	1.06	135.6	0.99	1.43	101.0	1.07	1.79	77.0	1.13	2.22	60.9	1.19	2.66	46.2	1.29	3.26	39.3	1.34	3.66	32.2	1.44	4.16
140	293.2	0.88	0.80	209.5	0.93	1.06	145.7	0.99	1.44	108.5	1.07	1.79	82.8	1.13	2.22	65.5	1.20	2.66	49.6	1.28	3.28	42.3	1.35	3.66	34.6	1.44	4.18
150	313.3	0.88	0.81	223.9	0.93	1.07	155.8	0.99	1.44	116.0	1.07	1.80	88.6	1.13	2.22	70.1	1.20	2.66	53.1	1.28	3.28	45.3	1.35	3.66	37.1	1.45	4.17
160	333.2	0.88	0.81	238.2	0.93	1.07	165.8	1.00	1.44	123.5	1.07	1.80	94.3	1.13	2.23	74.6	1.20	2.67	56.6	1.28	3.28	48.2	1.35	3.67	39.5	1.44	4.18
170	353.1	0.88	0.81	252.4	0.93	1.07	175.8	1.00	1.44	131.0	1.07	1.80	100.0	1.13	2.23	79.2	1.20	2.67	60.0	1.28	3.29	51.2	1.35	3.67	41.9	1.44	4.19
180	372.8	0.88	0.81	266.5	0.93	1.07	185.7	1.00	1.45	138.4	1.07	1.80	105.7	1.13	2.24	83.7	1.20	2.68	63.5	1.28	3.29	54.1	1.35	3.68	44.3	1.44	4.20
190	392.4	0.88	0.81	280.6	0.93	1.08	195.6	1.00	1.45	145.8	1.07	1.81	111.4	1.13	2.24	88.2	1.20	2.68	66.9	1.28	3.30	57.0	1.34	3.69	46.7	1.44	4.21
200	411.9	0.88	0.82	294.6	0.93	1.08	205.4	1.00	1.45	153.2	1.07	1.81	117.1	1.14	2.24	92.7	1.20	2.68	70.3	1.28	3.30	60.0	1.35	3.68	49.1	1.44	4.21
220	451.9	0.88	0.82	323.2	0.93	1.08	225.4	1.00	1.46	168.2	1.07	1.81	128.6	1.14	2.24	101.9	1.20	2.68	77.2	1.28	3.31	65.9	1.35	3.69	54.0	1.44	4.21
240	491.6	0.88	0.82	351.6	0.93	1.09	245.3	1.00	1.46	183.2	1.07	1.81	140.0	1.14	2.25	110.9	1.20	2.69	84.1	1.28	3.32	71.8	1.35	3.70	58.8	1.44	4.22
260	531.0	0.88	0.82	379.9	0.93	1.09	265.2	1.00	1.46	198.0	1.07	1.82	151.5	1.14	2.25	120.0	1.20	2.69	91.0	1.28	3.32	77.7	1.35	3.70	63.7	1.44	4.21
280	570.3	0.88	0.82	408.0	0.93	1.09	284.9	1.00	1.47	212.9	1.08	1.82	162.8	1.14	2.25	129.0	1.20	2.70	97.9	1.28	3.32	83.5	1.35	3.71	68.5	1.44	4.22
300	609.3	0.88	0.83	436.0	0.93	1.09	304.6	1.00	1.47	227.6	1.08	1.83	174.2	1.14	2.25	138.1	1.20	2.69	104.8	1.29	3.32	89.4	1.35	3.71	73.3	1.44	4.23

Parabolic waterway design
(Retardance "D" and "B")

Exhibit 5

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 5.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	34.8	0.80	0.79	25.2	0.86	1.02	17.7	0.92	1.36	14.3	0.96	1.61
20	46.3	0.80	0.79	33.5	0.86	1.02	23.5	0.92	1.37	19.0	0.96	1.62
25	57.7	0.80	0.80	41.7	0.86	1.03	29.3	0.92	1.38	23.7	0.96	1.63
30	69.0	0.80	0.80	49.9	0.86	1.04	35.0	0.91	1.39	28.3	0.95	1.65
35	80.3	0.80	0.80	58.1	0.86	1.04	40.8	0.91	1.39	33.0	0.95	1.65
40	91.5	0.81	0.80	66.2	0.86	1.04	46.5	0.91	1.40	37.6	0.95	1.66
45	102.6	0.81	0.81	74.2	0.86	1.05	52.2	0.91	1.40	42.2	0.95	1.66
50	113.7	0.81	0.81	82.3	0.86	1.05	57.9	0.92	1.40	46.8	0.95	1.66
55	124.7	0.81	0.81	90.2	0.86	1.05	63.5	0.91	1.41	51.4	0.96	1.66
60	135.7	0.81	0.81	98.2	0.86	1.05	69.1	0.91	1.41	56.0	0.96	1.66
65	146.5	0.81	0.81	106.1	0.86	1.05	74.7	0.92	1.41	60.5	0.96	1.67
70	157.3	0.81	0.82	113.9	0.86	1.06	80.2	0.91	1.42	65.0	0.96	1.67
75	168.1	0.81	0.82	121.7	0.86	1.06	85.8	0.92	1.42	69.5	0.96	1.67
80	178.8	0.81	0.82	129.4	0.86	1.06	91.3	0.92	1.42	74.0	0.96	1.67
90	200.5	0.81	0.82	145.2	0.86	1.07	102.4	0.92	1.43	83.0	0.96	1.68
100	222.2	0.81	0.82	160.9	0.86	1.07	113.5	0.92	1.43	92.1	0.96	1.68
110	243.7	0.81	0.82	176.5	0.86	1.07	124.6	0.92	1.43	101.0	0.96	1.69
120	265.0	0.81	0.83	192.0	0.86	1.07	135.6	0.92	1.43	110.0	0.96	1.69
130	286.3	0.81	0.83	207.5	0.86	1.08	146.6	0.92	1.43	118.9	0.96	1.69
140	307.4	0.81	0.83	222.8	0.86	1.08	157.5	0.92	1.44	127.8	0.96	1.69
150	328.4	0.81	0.83	238.1	0.87	1.08	168.3	0.92	1.44	136.6	0.96	1.70
160	349.3	0.81	0.83	253.2	0.86	1.08	179.1	0.92	1.44	145.4	0.96	1.70
170	370.0	0.81	0.84	268.3	0.87	1.09	189.9	0.92	1.45	154.1	0.96	1.70
180	390.7	0.82	0.84	283.3	0.87	1.09	200.6	0.92	1.45	162.9	0.96	1.70
190	411.2	0.82	0.84	298.2	0.87	1.09	211.2	0.92	1.45	171.5	0.96	1.71
200	431.6	0.82	0.84	313.0	0.87	1.09	221.8	0.92	1.46	180.2	0.96	1.71
220	473.3	0.82	0.84	343.4	0.87	1.10	243.4	0.92	1.46	197.8	0.97	1.71
240	514.8	0.82	0.84	373.6	0.87	1.10	264.9	0.92	1.46	215.3	0.97	1.72
260	556.1	0.82	0.85	403.6	0.87	1.10	286.3	0.92	1.46	232.7	0.97	1.72
280	597.1	0.82	0.85	433.5	0.87	1.10	307.6	0.92	1.47	250.1	0.97	1.72
300	638.0	0.82	0.85	463.1	0.87	1.11	328.7	0.92	1.47	267.4	0.97	1.73

Q cfs	V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	10.6	1.04	2.00	8.4	1.12	2.34	6.7	1.23	2.67	5.4	1.36	3.00			
20	14.1	1.04	2.02	11.1	1.10	2.41	8.8	1.19	2.81	7.0	1.28	3.29	6.1	1.40	3.44
25	17.5	1.03	2.06	13.8	1.09	2.46	10.9	1.17	2.90	8.7	1.26	3.37	7.5	1.35	3.64
30	21.0	1.03	2.06	16.6	1.10	2.44	13.0	1.15	2.96	10.4	1.25	3.41	8.9	1.32	3.78
35	24.4	1.02	2.08	19.3	1.09	2.46	15.2	1.16	2.94	12.1	1.24	3.45	10.3	1.30	3.87
40	27.8	1.02	2.09	22.0	1.09	2.47	17.3	1.15	2.97	13.8	1.24	3.47	11.8	1.30	3.85
45	31.3	1.03	2.08	24.7	1.09	2.48	19.4	1.15	2.99	15.4	1.22	3.55	13.2	1.29	3.91
50	34.7	1.03	2.08	27.3	1.08	2.51	21.5	1.15	3.01	17.1	1.22	3.55	14.7	1.30	3.88
55	38.0	1.02	2.11	30.0	1.08	2.51	23.7	1.15	2.98	18.8	1.22	3.55	16.1	1.29	3.93
60	41.4	1.02	2.11	32.7	1.08	2.51	25.8	1.15	3.00	20.5	1.22	3.55	17.5	1.28	3.97
65	44.8	1.02	2.10	35.3	1.08	2.53	27.9	1.15	3.00	22.1	1.22	3.59	18.9	1.28	4.00
70	48.1	1.02	2.11	38.0	1.08	2.53	30.0	1.15	3.01	23.8	1.22	3.58	20.4	1.29	3.96
75	51.4	1.02	2.12	40.6	1.08	2.54	32.0	1.15	3.04	25.4	1.21	3.62	21.8	1.28	3.98
80	54.8	1.02	2.12	43.3	1.09	2.53	34.1	1.15	3.04	27.1	1.22	3.61	23.2	1.28	4.00
90	61.5	1.02	2.12	48.6	1.08	2.54	38.3	1.15	3.05	30.4	1.21	3.63	26.1	1.28	4.00
100	68.2	1.02	2.13	53.9	1.08	2.54	42.5	1.15	3.05	33.8	1.22	3.61	28.9	1.28	4.03
110	74.8	1.02	2.14	59.2	1.09	2.55	46.7	1.15	3.05	37.1	1.22	3.63	31.8	1.28	4.02
120	81.4	1.02	2.15	64.4	1.08	2.56	50.8	1.15	3.07	40.4	1.21	3.64	34.6	1.28	4.04
130	88.1	1.02	2.14	69.7	1.09	2.56	55.0	1.15	3.06	43.7	1.21	3.65	37.5	1.28	4.03
140	94.6	1.02	2.15	74.9	1.08	2.57	59.1	1.15	3.07	47.0	1.21	3.65	40.3	1.28	4.04
150	101.2	1.02	2.15	80.1	1.08	2.57	63.2	1.15	3.08	50.2	1.21	3.67	43.1	1.28	4.05
160	107.7	1.02	2.16	85.3	1.09	2.57	67.3	1.15	3.09	53.5	1.21	3.67	45.9	1.28	4.06
170	114.2	1.02	2.16	90.4	1.08	2.58	71.4	1.15	3.09	56.8	1.21	3.67	48.7	1.28	4.07
180	120.7	1.02	2.17	95.6	1.09	2.58	75.5	1.15	3.09	60.0	1.21	3.69	51.5	1.28	4.07
190	127.1	1.02	2.17	100.7	1.08	2.59	79.6	1.15	3.09	63.3	1.21	3.68	54.3	1.28	4.07
200	133.5	1.02	2.18	105.8	1.09	2.59	83.6	1.15	3.10	66.5	1.21	3.69	57.1	1.28	4.08
220	146.6	1.02	2.18	116.2	1.09	2.60	91.9	1.15	3.10	73.1	1.22	3.69	62.7	1.28	4.09
240	159.6	1.02	2.18	126.5	1.09	2.60	100.1	1.15	3.10	79.6	1.21	3.70	68.3	1.28	4.09
260	172.6	1.03	2.19	136.8	1.09	2.61	108.2	1.15	3.11	86.1	1.21	3.71	73.9	1.28	4.10
280	185.5	1.03	2.19	147.1	1.09	2.61	116.4	1.15	3.11	92.6	1.21	3.71	79.5	1.28	4.10
300	198.4	1.03	2.19	157.3	1.09	2.61	124.5	1.15	3.12	99.1	1.22	3.71	85.1	1.28	4.10

Parabolic waterway design
(Retardance "D" and "B")

(Sheet 11 of 14)

Exhibit 5

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 6.0 Percent

4-28467 5-68

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2	V_1 = 3.5 T	D	V_2	V_1 = 4.0 T	D	V_2
15	40.5	0.72	0.76	26.9	0.81	1.02	19.6	0.85	1.34	14.8	0.90	1.66	11.7	0.96	1.97
20	53.9	0.72	0.76	35.7	0.81	1.03	26.1	0.85	1.34	19.6	0.89	1.69	15.6	0.96	1.97
25	67.1	0.72	0.76	44.5	0.81	1.03	32.5	0.85	1.35	24.5	0.90	1.69	19.4	0.95	2.00
30	80.3	0.72	0.76	53.2	0.80	1.04	38.9	0.85	1.35	29.3	0.89	1.70	23.3	0.96	1.99
35	93.4	0.72	0.76	61.9	0.81	1.04	45.3	0.85	1.35	34.1	0.89	1.70	27.1	0.96	2.00
40	106.4	0.73	0.77	70.6	0.81	1.04	51.6	0.85	1.36	38.9	0.89	1.71	30.9	0.95	2.01
45	119.3	0.73	0.77	79.2	0.81	1.04	57.9	0.85	1.36	43.7	0.90	1.71	34.6	0.95	2.03
50	132.1	0.73	0.77	87.7	0.81	1.05	64.1	0.84	1.37	48.4	0.89	1.71	38.4	0.95	2.03
55	144.9	0.73	0.77	96.2	0.81	1.05	70.4	0.85	1.37	53.1	0.89	1.72	42.2	0.95	2.03
60	157.5	0.73	0.77	104.6	0.81	1.05	76.5	0.84	1.38	57.8	0.89	1.72	45.9	0.95	2.04
65	170.1	0.73	0.78	113.0	0.81	1.06	82.7	0.85	1.38	62.5	0.90	1.72	49.6	0.95	2.04
70	182.6	0.73	0.78	121.3	0.81	1.06	88.8	0.85	1.38	67.2	0.90	1.72	53.3	0.95	2.05
75	195.1	0.73	0.78	129.6	0.81	1.06	94.9	0.85	1.39	71.8	0.90	1.73	57.0	0.95	2.05
80	207.4	0.73	0.78	137.8	0.81	1.06	100.9	0.85	1.39	76.4	0.90	1.73	60.6	0.95	2.06
90	232.6	0.73	0.78	154.5	1.81	1.07	113.2	0.85	1.40	85.8	0.90	1.73	68.1	0.95	2.06
100	257.7	0.73	0.78	171.2	0.81	1.07	125.5	0.85	1.40	95.1	0.90	1.74	75.5	0.95	2.06
110	282.6	0.74	0.78	187.8	0.81	1.07	137.7	0.85	1.40	104.4	0.90	1.74	82.8	0.95	2.07
120	307.3	0.74	0.79	204.2	0.81	1.08	149.8	0.85	1.40	113.6	0.90	1.74	90.2	0.95	2.07
130	331.9	0.74	0.79	220.6	0.81	1.08	161.9	0.85	1.41	122.8	0.90	1.75	97.5	0.95	2.08
140	356.3	0.74	0.79	236.8	0.81	1.08	173.9	0.85	1.41	131.9	0.90	1.75	104.7	0.95	2.09
150	380.5	0.74	0.79	253.0	0.81	1.09	185.8	0.85	1.41	141.0	0.90	1.75	112.0	0.96	2.09
160	404.6	0.74	0.79	269.0	0.81	1.09	197.7	0.85	1.42	150.1	0.90	1.76	119.2	0.96	2.09
170	428.6	0.74	0.79	285.0	0.81	1.09	209.5	0.85	1.42	159.1	0.90	1.76	126.4	0.96	2.09
180	452.4	0.74	0.79	300.8	0.81	1.09	221.3	0.85	1.42	168.1	0.90	1.76	133.5	0.96	2.10
190	476.1	0.74	0.80	316.6	0.81	1.10	233.0	0.85	1.42	177.0	0.90	1.77	140.6	0.96	2.10
200	499.6	0.74	0.80	332.3	0.81	1.10	244.6	0.85	1.43	185.9	0.90	1.77	147.7	0.96	2.11
220	547.7	0.74	0.80	364.5	0.81	1.10	268.4	0.85	1.43	204.1	0.91	1.77	162.1	0.96	2.11
240	595.6	0.74	0.80	396.5	0.81	1.11	292.1	0.85	1.43	222.1	0.91	1.78	176.5	0.96	2.11
260	643.2	0.74	0.80	428.3	0.81	1.11	315.7	0.85	1.43	240.1	0.91	1.78	190.7	0.96	2.12
280	690.5	0.75	0.81	459.9	0.81	1.11	339.1	0.85	1.44	258.0	0.91	1.78	205.0	0.96	2.12
300	737.5	0.75	0.81	491.4	0.81	1.11	362.4	0.85	1.44	275.8	0.91	1.78	219.1	0.96	2.13

Q cfs	V_1 = 4.5 T	D	V_2	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15	9.4	1.02	2.31	7.6	1.09	2.67	6.1	1.18	3.05	5.0	1.32	3.33
20	12.5	1.01	2.33	10.1	1.08	2.71	8.0	1.14	3.23	6.5	1.24	3.63
25	15.5	1.00	2.39	12.5	1.06	2.80	10.0	1.14	3.24	8.1	1.23	3.69
30	18.6	1.00	2.39	15.0	1.06	2.80	11.9	1.12	3.32	9.6	1.20	3.84
35	21.6	0.99	2.42	17.4	1.05	2.84	13.9	1.13	3.31	11.2	1.20	3.84
40	24.7	1.00	2.41	19.9	1.05	2.83	15.8	1.12	3.36	12.7	1.19	3.93
45	27.7	1.00	2.42	22.3	1.05	2.86	17.7	1.11	3.40	14.3	1.19	3.92
50	30.7	0.99	2.43	24.7	1.05	2.87	19.7	1.12	3.38	15.8	1.18	3.98
55	33.7	0.99	2.44	27.1	1.04	2.89	21.6	1.11	3.40	17.4	1.18	3.96
60	36.7	1.00	2.44	29.6	1.05	2.87	23.5	1.11	3.42	18.9	1.18	4.01
65	39.7	1.00	2.44	32.0	1.05	2.88	25.4	1.11	3.43	20.5	1.18	3.98
70	42.7	1.00	2.44	34.4	1.05	2.88	27.4	1.11	3.41	22.0	1.18	4.01
75	45.6	1.00	2.46	36.7	1.04	2.91	29.3	1.11	3.42	23.6	1.18	3.99
80	48.6	1.00	2.45	39.1	1.05	2.91	31.2	1.11	3.42	25.1	1.18	4.02
90	54.6	1.00	2.45	43.9	1.05	2.92	35.0	1.11	3.44	28.2	1.18	4.02
100	60.5	1.00	2.46	48.7	1.05	2.92	38.8	1.11	3.46	31.3	1.18	4.03
110	66.4	1.00	2.47	53.5	1.05	2.92	42.6	1.11	3.47	34.4	1.18	4.03
120	72.3	1.00	2.47	58.3	1.05	2.92	46.4	1.11	3.47	37.4	1.18	4.06
130	78.2	1.00	2.48	63.0	1.05	2.93	50.2	1.11	3.48	40.5	1.18	4.05
140	84.0	1.00	2.48	67.7	1.05	2.94	54.0	1.11	3.48	43.5	1.18	4.07
150	89.9	1.00	2.48	72.5	1.05	2.93	57.8	1.11	3.48	46.6	1.18	4.06
160	95.7	1.00	2.49	77.2	1.05	2.94	61.5	1.11	3.49	49.6	1.18	4.08
170	101.5	1.00	2.49	81.8	1.05	2.95	65.3	1.11	3.49	52.7	1.18	4.07
180	107.2	1.00	2.50	86.5	1.05	2.95	69.0	1.11	3.49	55.7	1.18	4.08
190	113.0	1.00	2.50	91.1	1.05	2.96	72.7	1.11	3.50	58.7	1.18	4.08
200	118.7	1.00	2.50	95.8	1.05	2.96	76.4	1.11	3.51	61.7	1.18	4.09
220	130.3	1.00	2.51	105.2	1.05	2.96	83.9	1.11	3.51	67.8	1.18	4.09
240	141.9	1.00	2.51	114.5	1.05	2.97	91.4	1.11	3.52	73.8	1.18	4.11
260	153.4	1.00	2.52	123.9	1.05	2.97	98.9	1.11	3.52	79.9	1.18	4.10
280	164.9	1.00	2.52	133.2	1.05	2.97	106.3	1.11	3.53	85.9	1.18	4.11
300	176.3	1.00	2.52	142.4	1.05	2.98	113.7	1.11	3.53	91.9	1.18	4.12

Parabolic waterway design
(Retardance "D" and "B")

(Sheet 12 of 14)

Exhibit 5

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "B".

Grade 8.0 Percent

4-25467 5-68

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2	V_1 = 3.5 T	D	V_2
15	43.1	0.64	0.80	31.6	0.71	0.98	22.2	0.76	1.31	18.0	0.79	1.56
20	57.3	0.64	0.80	42.0	0.71	0.99	29.5	0.76	1.32	24.0	0.79	1.56
25	71.4	0.65	0.80	52.3	0.71	0.99	36.7	0.76	1.33	29.9	0.79	1.57
30	85.4	0.65	0.80	62.6	0.71	0.99	43.9	0.76	1.33	35.8	0.79	1.57
35	99.3	0.65	0.80	72.8	0.72	0.99	51.1	0.76	1.34	41.6	0.79	1.58
40	113.1	0.65	0.81	82.9	0.72	1.00	58.2	0.76	1.34	47.4	0.79	1.59
45	126.8	0.65	0.81	93.0	0.72	1.00	65.3	0.76	1.34	53.2	0.79	1.59
50	140.4	0.65	0.81	102.9	0.72	1.01	72.3	0.76	1.35	59.0	0.79	1.59
55	153.9	0.65	0.81	112.8	0.72	1.01	79.3	0.76	1.35	64.7	0.79	1.60
60	167.3	0.65	0.81	122.7	0.72	1.01	86.2	0.76	1.36	70.4	0.79	1.60
65	180.6	0.65	0.82	132.4	0.72	1.01	93.1	0.76	1.36	76.0	0.79	1.61
70	193.9	0.65	0.82	142.2	0.72	1.01	100.0	0.76	1.37	81.7	0.79	1.61
75	207.0	0.65	0.82	151.8	0.72	1.02	106.8	0.76	1.37	87.2	0.79	1.62
80	220.1	0.66	0.82	161.4	0.72	1.02	113.6	0.76	1.37	92.8	0.79	1.62
90	246.8	0.66	0.82	180.9	0.72	1.02	127.4	0.76	1.38	104.1	0.79	1.62
100	273.3	0.66	0.82	200.3	0.72	1.03	141.1	0.76	1.38	115.4	0.79	1.62
110	299.6	0.66	0.83	219.6	0.72	1.03	154.8	0.76	1.38	126.5	0.79	1.63
120	325.7	0.66	0.83	238.8	0.72	1.03	168.4	0.76	1.39	137.7	0.79	1.63
130	351.7	0.66	0.83	257.9	0.72	1.04	181.9	0.76	1.39	148.7	0.79	1.64
140	377.5	0.66	0.83	276.8	0.72	1.04	195.3	0.76	1.39	159.7	0.79	1.64
150	403.1	0.66	0.83	295.6	0.72	1.04	208.6	0.76	1.40	170.7	0.80	1.64
160	428.5	0.66	0.83	314.2	0.72	1.04	221.9	0.76	1.40	181.5	0.79	1.65
170	453.8	0.66	0.84	332.8	0.72	1.05	235.1	0.76	1.40	192.4	0.80	1.65
180	478.9	0.66	0.84	351.2	0.72	1.05	248.2	0.76	1.41	203.1	0.80	1.65
190	503.9	0.66	0.84	369.5	0.72	1.05	261.2	0.77	1.41	213.8	0.80	1.66
200	528.5	0.67	0.84	387.7	0.73	1.05	274.1	0.77	1.42	224.4	0.80	1.66
220	579.5	0.67	0.84	425.1	0.73	1.06	300.7	0.77	1.42	246.2	0.80	1.66
240	630.1	0.67	0.84	462.2	0.73	1.06	327.0	0.77	1.42	267.9	0.80	1.67
260	680.4	0.67	0.85	499.1	0.73	1.06	353.3	0.77	1.42	289.4	0.80	1.67
280	730.4	0.67	0.85	535.6	0.73	1.07	379.3	0.77	1.43	310.8	0.80	1.68
300	780.0	0.67	0.85	572.1	0.73	1.07	405.2	0.77	1.43	332.1	0.80	1.68

Q cfs	V_1 = 4.0 T	D	V_2	V_1 = 4.5 T	D	V_2	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15	13.7	0.84	1.92	11.0	0.89	2.26	9.2	0.95	2.54	7.4	0.99	3.00	6.2	1.09	3.26
20	18.2	0.84	1.94	14.7	0.89	2.25	12.2	0.93	2.59	9.8	0.98	3.08	8.1	1.04	3.49
25	22.7	0.84	1.95	18.3	0.89	2.28	15.2	0.93	2.62	12.2	0.97	3.12	10.1	1.04	3.53
30	27.2	0.84	1.95	21.9	0.89	2.29	18.1	0.92	2.67	14.6	0.97	3.15	12.1	1.03	3.55
35	31.7	0.84	1.95	25.5	0.89	2.30	21.1	0.92	2.67	17.0	0.96	3.16	14.0	1.02	3.64
40	36.1	0.84	1.96	29.0	0.88	2.32	24.1	0.92	2.67	19.4	0.96	3.17	16.0	1.02	3.63
45	40.5	0.84	1.97	32.6	0.88	2.32	27.0	0.92	2.69	21.8	0.97	3.17	18.0	1.02	3.62
50	44.9	0.84	1.97	36.1	0.88	2.33	30.0	0.92	2.68	24.2	0.97	3.17	19.9	1.02	3.67
55	49.3	0.84	1.97	39.6	0.88	2.34	32.9	0.92	2.70	26.5	0.96	3.20	21.9	1.02	3.65
60	53.7	0.84	1.97	43.1	0.88	2.34	35.8	0.92	2.70	28.9	0.97	3.19	23.8	1.02	3.69
65	58.0	0.84	1.98	46.6	0.88	2.35	38.7	0.92	2.71	31.3	0.97	3.18	25.7	1.01	3.71
70	62.3	0.84	1.98	50.1	0.88	2.35	41.6	0.92	2.71	33.6	0.97	3.20	27.7	1.02	3.69
75	66.6	0.84	1.99	53.5	0.88	2.36	44.5	0.92	2.72	35.9	0.96	3.22	29.6	1.02	3.71
80	70.9	0.84	1.99	56.9	0.88	2.37	47.3	0.92	2.73	38.2	0.96	3.23	31.5	1.01	3.72
90	79.5	0.84	2.00	63.9	0.88	2.37	53.1	0.92	2.74	42.9	0.96	3.23	35.4	1.02	3.72
100	88.1	0.84	2.00	70.8	0.88	2.38	58.9	0.92	2.74	47.6	0.97	3.24	39.2	1.01	3.75
110	96.7	0.84	2.01	77.7	0.88	2.38	64.7	0.92	2.74	52.3	0.97	3.23	43.1	1.02	3.74
120	105.3	0.84	2.01	84.6	0.88	2.39	70.4	0.92	2.75	56.9	0.97	3.25	46.9	1.01	3.75
130	113.8	0.84	2.01	91.4	0.88	2.40	76.1	0.92	2.75	61.6	0.97	3.24	50.7	1.01	3.76
140	122.2	0.84	2.02	98.2	0.88	2.40	81.8	0.92	2.76	66.2	0.97	3.25	54.5	1.01	3.77
150	130.6	0.84	2.02	105.0	0.88	2.40	87.4	0.92	2.77	70.8	0.97	3.25	58.3	1.01	3.78
160	139.0	0.85	2.02	111.7	0.88	2.41	93.1	0.92	2.77	75.3	0.97	3.27	62.1	1.01	3.78
170	147.3	0.85	2.03	118.4	0.88	2.42	98.7	0.92	2.77	79.9	0.97	3.27	65.9	1.02	3.78
180	155.6	0.85	2.03	125.1	0.88	2.42	104.3	0.93	2.78	84.4	0.97	3.28	69.6	1.02	3.79
190	163.9	0.85	2.03	131.8	0.89	2.42	109.8	0.92	2.79	89.0	0.97	3.27	73.4	1.02	3.79
200	172.1	0.85	2.04	138.4	0.89	2.43	115.3	0.92	2.79	93.5	0.97	3.28	77.1	1.02	3.80
220	188.8	0.85	2.04	151.8	0.88	2.44	126.6	0.93	2.80	102.6	0.97	3.29	84.7	1.02	3.80
240	205.5	0.85	2.05	165.2	0.89	2.44	137.8	0.93	2.80	111.8	0.97	3.29	92.2	1.02	3.81
260	222.1	0.85	2.05	178.6	0.89	2.45	149.0	0.93	2.80	120.8	0.97	3.30	99.7	1.02	3.82
280	238.6	0.85	2.05	191.9	0.89	2.45	160.1	0.93	2.81	129.9	0.97	3.30	107.2	1.02	3.82
300	255.0	0.85	2.06	205.1	0.89	2.46	171.2	0.93	2.81	138.9	0.97	3.31	114.7	1.02	3.82

Parabolic waterway design
(Retardance "D" and "B")

(Sheet 13 of 14)

Exhibit 5

V_1 for **RETARDANCE "D"**. Top Width (T), Depth (D) and V_2 for **RETARDANCE "B"**.

Grade 10.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	51.4	0.56	0.77	38.3	0.63	0.92	27.2	0.69	1.18	19.6	0.73	1.56
20	68.2	0.55	0.78	50.9	0.63	0.92	36.2	0.69	1.18	26.1	0.73	1.56
25	85.0	0.56	0.78	63.4	0.63	0.92	45.1	0.69	1.19	32.5	0.73	1.57
30	101.6	0.56	0.78	75.8	0.63	0.92	53.9	0.69	1.20	38.8	0.72	1.58
35	118.1	0.56	0.78	88.1	0.63	0.93	62.7	0.69	1.20	45.2	0.73	1.58
40	134.4	0.56	0.79	100.3	0.64	0.93	71.3	0.69	1.21	51.5	0.73	1.59
45	150.7	0.56	0.79	112.5	0.64	0.93	80.0	0.69	1.21	57.7	0.72	1.60
50	166.8	0.56	0.79	124.5	0.64	0.93	88.5	0.69	1.21	63.9	0.72	1.60
55	182.8	0.56	0.79	136.4	0.64	0.93	97.1	0.69	1.21	70.1	0.73	1.60
60	198.6	0.56	0.79	148.2	0.64	0.94	105.5	0.69	1.22	76.2	0.72	1.61
65	214.3	0.57	0.79	160.0	0.64	0.94	113.9	0.69	1.22	32.3	0.73	1.62
70	229.9	0.57	0.79	171.6	0.64	0.94	122.2	0.69	1.23	88.4	0.73	1.62
75	245.4	0.57	0.80	183.2	0.64	0.94	130.5	0.69	1.23	94.4	0.73	1.62
80	260.7	0.57	0.80	194.6	0.64	0.95	138.6	0.69	1.24	100.3	0.73	1.63
90	292.1	0.57	0.80	218.1	0.64	0.95	155.4	0.69	1.24	112.5	0.73	1.64
100	323.3	0.57	0.80	241.5	0.64	0.95	172.1	0.69	1.24	124.6	0.73	1.64
110	354.3	0.57	0.80	264.6	0.64	0.96	188.6	0.69	1.25	136.7	0.73	1.64
120	385.0	0.57	0.80	287.6	0.64	0.96	205.0	0.69	1.25	148.7	0.73	1.65
130	415.5	0.57	0.81	310.3	0.65	0.96	221.3	0.69	1.26	160.6	0.73	1.65
140	445.7	0.57	0.81	333.0	0.65	0.96	237.5	0.69	1.26	172.5	0.73	1.65
150	475.7	0.58	0.81	355.4	0.65	0.97	253.6	0.69	1.26	184.2	0.73	1.66
160	505.5	0.58	0.81	377.7	0.65	0.97	269.5	0.69	1.27	195.9	0.73	1.66
170	535.0	0.58	0.81	399.7	0.65	0.97	285.3	0.69	1.27	207.6	0.73	1.66
180	564.3	0.58	0.81	421.7	0.65	0.97	301.0	0.70	1.28	219.1	0.73	1.67
190	593.4	0.58	0.82	443.4	0.65	0.98	316.6	0.70	1.28	230.6	0.73	1.67
200	622.2	0.58	0.82	465.0	0.65	0.98	332.1	0.70	1.28	242.1	0.73	1.68
220	681.9	0.58	0.82	509.6	0.65	0.98	364.1	0.70	1.29	265.5	0.73	1.68
240	741.1	0.58	0.82	553.8	0.65	0.99	395.9	0.70	1.29	288.8	0.73	1.68
260	799.9	0.58	0.82	597.7	0.65	0.99	427.4	0.70	1.29	312.0	0.73	1.69
280	858.2	0.58	0.83	641.3	0.65	0.99	458.7	0.70	1.30	335.0	0.73	1.69
300	916.0	0.59	0.83	684.6	0.65	0.99	489.8	0.70	1.30	357.9	0.73	1.69

Q cfs	V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	15.7	0.76	1.86	12.6	0.81	2.18	10.6	0.85	2.45	8.7	0.90	2.83	7.2	0.94	3.26
20	20.9	0.76	1.87	16.8	0.81	2.18	14.0	0.84	2.53	11.5	0.88	2.91	9.5	0.92	3.39
25	26.1	0.76	1.87	20.9	0.80	2.20	17.5	0.84	2.52	14.3	0.87	2.96	11.9	0.92	3.37
30	31.2	0.76	1.88	25.0	0.80	2.22	20.9	0.83	2.55	17.1	0.87	2.98	14.2	0.91	3.42
35	36.3	0.76	1.88	29.1	0.80	2.22	24.3	0.83	2.57	19.9	0.87	3.00	16.5	0.91	3.46
40	41.3	0.76	1.90	33.2	0.80	2.22	27.7	0.83	2.58	22.7	0.87	3.00	18.9	0.91	3.43
45	46.4	0.76	1.90	37.2	0.80	2.24	31.1	0.83	2.58	25.5	0.87	3.01	21.2	0.91	3.45
50	51.3	0.76	1.91	41.3	0.80	2.23	34.5	0.83	2.58	28.3	0.87	3.01	23.5	0.91	3.46
55	56.3	0.76	1.92	45.3	0.80	2.24	37.8	0.83	2.60	31.1	0.87	3.00	25.8	0.91	3.47
60	61.2	0.76	1.92	49.3	0.80	2.25	41.1	0.83	2.61	33.8	0.87	3.02	28.1	0.91	3.47
65	66.2	0.76	1.92	53.2	0.80	2.26	44.4	0.83	2.62	36.5	0.87	3.04	30.3	0.91	3.51
70	71.0	0.76	1.93	57.2	0.80	2.26	47.7	0.83	2.63	39.3	0.87	3.03	32.6	0.91	3.50
75	75.9	0.76	1.94	61.1	0.80	2.27	51.0	0.83	2.63	42.0	0.87	3.04	34.9	0.91	3.50
80	80.7	0.76	1.94	65.0	0.80	2.27	54.3	0.83	2.63	44.7	0.87	3.04	37.1	0.91	3.52
90	90.5	0.76	1.95	73.0	0.81	2.27	60.9	0.83	2.64	50.1	0.87	3.06	41.7	0.91	3.52
100	100.3	0.76	1.95	80.9	0.81	2.28	67.5	0.83	2.65	55.6	0.87	3.06	46.2	0.91	3.53
110	110.0	0.76	1.96	88.7	0.81	2.29	74.1	0.83	2.65	61.0	0.87	3.07	50.7	0.91	3.54
120	119.6	0.76	1.97	96.5	0.81	2.29	80.6	0.83	2.66	66.4	0.87	3.08	55.2	0.91	3.55
130	129.3	0.76	1.97	104.3	0.81	2.30	87.1	0.83	2.67	71.8	0.87	3.08	59.7	0.91	3.55
140	138.8	0.76	1.97	112.1	0.81	2.30	93.5	0.83	2.68	77.1	0.87	3.09	64.2	0.91	3.55
150	148.4	0.76	1.97	119.8	0.81	2.30	100.0	0.83	2.68	82.5	0.88	3.09	68.6	0.91	3.57
160	157.8	0.76	1.98	127.4	0.81	2.31	106.4	0.83	2.69	87.8	0.88	3.10	73.0	0.91	3.58
170	167.2	0.76	1.98	135.0	0.81	2.32	112.8	0.83	2.69	93.0	0.87	3.11	77.5	0.91	3.57
180	176.6	0.76	1.99	142.6	0.81	2.32	119.1	0.83	2.70	98.3	0.88	3.11	81.8	0.91	3.59
190	185.9	0.76	1.99	150.1	0.81	2.33	125.4	0.83	2.71	103.5	0.88	3.12	86.2	0.91	3.59
200	195.2	0.76	1.99	157.6	0.81	2.33	131.7	0.83	2.71	108.7	0.88	3.13	90.6	0.92	3.59
220	214.1	0.76	2.00	173.0	0.81	2.33	144.6	0.83	2.71	119.3	0.88	3.13	99.4	0.91	3.60
240	233.0	0.76	2.00	188.2	0.81	2.34	157.4	0.84	2.72	129.9	0.88	3.13	108.3	0.92	3.60
260	251.7	0.77	2.01	203.4	0.81	2.34	170.1	0.84	2.72	140.4	0.88	3.14	117.0	0.92	3.61
280	270.4	0.77	2.01	218.5	0.81	2.35	182.7	0.84	2.73	150.9	0.88	3.15	125.8	0.92	3.62
300	289.0	0.77	2.01	233.5	0.81	2.35	195.4	0.84	2.73	161.3	0.88	3.15	134.5	0.92	3.62

Parabolic waterway design
(Retardance "D" and "B")

Exhibit 6

4-28467 5-88

V_1 for **RETARDANCE "D"**. Top Width (T), Depth (D) and V_2 for **RETARDANCE "C"**.

Grade 0.25 Percent

Q	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
cfs	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15																											
20																											
25	9.6	2.36	1.63																								
30	11.4	2.31	1.68																								
35	13.2	2.27	1.73																								
40	15.0	2.25	1.76	10.4	2.67	2.13																					
45	16.8	2.23	1.78	11.6	2.62	2.19																					
50	18.6	2.21	1.80	12.8	2.59	2.24																					
55	20.4	2.20	1.82	14.0	2.56	2.28																					
60	22.2	2.19	1.83	15.2	2.53	2.31																					
65	24.0	2.18	1.84	16.5	2.54	2.30																					
70	25.8	2.18	1.85	17.7	2.52	2.33	12.6	3.05	2.70																		
75	27.6	2.17	1.86	18.9	2.51	2.35	13.4	3.00	2.76																		
80	29.4	2.17	1.87	20.1	2.50	2.37	14.3	3.01	2.76																		
90	33.1	2.17	1.86	22.6	2.49	2.38	16.0	2.97	2.81																		
100	36.7	2.17	1.87	25.1	2.49	2.38	17.7	2.95	2.85																		
110	40.3	2.16	1.88	27.5	2.47	2.41	19.4	2.93	2.88																		
120	43.9	2.16	1.89	30.0	2.47	2.41	21.1	2.91	2.91	15.2	3.58	3.28															
130	47.6	2.16	1.88	32.5	2.48	2.41	22.8	2.89	2.93	16.4	3.55	3.32															
140	51.2	2.16	1.88	34.9	2.46	2.43	24.6	2.91	2.91	17.6	3.53	3.35															
150	54.8	2.16	1.89	37.4	2.47	2.42	26.3	2.90	2.93	18.8	3.51	3.39															
160	58.4	2.16	1.89	39.9	2.47	2.42	28.0	2.89	2.95	20.0	3.49	3.41															
170	62.0	2.16	1.89	42.3	2.46	2.43	29.7	2.88	2.96	21.2	3.47	3.44	16.7	4.03	3.75												
180	65.6	2.16	1.90	44.8	2.47	2.43	31.4	2.87	2.97	22.4	3.46	3.46	17.6	4.00	3.81												
190	69.2	2.16	1.90	47.2	2.46	2.44	33.1	2.87	2.98	23.6	3.45	3.48	18.5	3.97	3.85												
200	72.8	2.16	1.90	49.7	2.46	2.44	34.9	2.88	2.97	24.8	3.44	3.49	19.4	3.94	3.90												
220	80.0	2.16	1.90	54.6	2.46	2.44	38.3	2.87	2.99	27.2	3.42	3.53	21.3	3.92	3.92												
240	87.3	2.16	1.90	59.5	2.46	2.45	41.7	2.86	3.00	29.6	3.40	3.55	23.1	3.88	3.99												
260	94.5	2.16	1.90	64.5	2.46	2.44	45.2	2.86	3.00	32.1	3.41	3.54	25.0	3.87	4.01	19.5	4.57	4.34									
280	101.7	2.16	1.90	69.4	2.46	2.45	48.6	2.85	3.01	34.5	3.40	3.56	26.9	3.86	4.02	21.0	4.57	4.34									
300	108.9	2.16	1.90	74.3	2.46	2.45	52.1	2.86	3.00	36.9	3.39	3.58	28.7	3.83	4.07	22.4	4.53	4.40									

Parabolic waterway design
(Retardance "D" and "C")

(Sheet 1 of 14)

Exhibit 6

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "C".

Grade 0.50 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0		
	T	D	V_2	T	D	V_2	T	D	V_2
15	8.6	1.63	1.58						
20	11.3	1.58	1.66						
25	14.1	1.57	1.67	9.0	1.91	2.14			
30	16.9	1.56	1.68	10.7	1.87	2.21	8.2	2.18	2.48
35	19.6	1.55	1.71	12.4	1.85	2.26	9.4	2.10	2.62
40	22.4	1.55	1.71	14.1	1.83	2.30	10.7	2.08	2.66
45	25.1	1.54	1.73	15.8	1.82	2.33	11.9	2.03	2.76
50	27.9	1.54	1.73	17.5	1.80	2.35	13.2	2.02	2.78
55	30.7	1.54	1.72	19.2	1.80	2.37	14.5	2.02	2.79
60	33.4	1.54	1.74	20.9	1.79	2.38	15.8	2.01	2.80
65	36.1	1.53	1.75	22.7	1.80	2.36	17.0	1.99	2.86
70	38.9	1.54	1.74	24.4	1.80	2.37	18.3	1.99	2.86
75	41.6	1.54	1.75	26.1	[illegible]	2.38	19.6	1.99	2.86
80	44.3	1.53	1.75	27.8	[illegible]	2.39	20.9	1.99	2.86
90	49.8	1.53	1.75	31.2	1.78	2.41	23.5	1.99	2.87
100	55.3	1.53	1.75	34.6	1.78	2.42	26.0	1.97	2.90
110	60.8	1.54	1.75	38.1	1.78	2.41	28.6	1.97	2.90
120	66.3	1.54	1.75	41.5	1.78	2.42	31.2	1.98	2.90
130	71.7	1.53	1.76	44.9	1.78	2.42	33.7	1.97	2.92
140	77.2	1.54	1.76	48.3	1.78	2.43	36.3	1.97	2.92
150	82.6	1.54	1.76	51.7	1.78	2.43	38.9	1.97	2.91
160	88.0	1.53	1.76	55.1	1.78	2.44	41.4	1.97	2.93
170	93.4	1.53	1.77	58.5	1.78	2.44	44.0	1.97	2.92
180	98.8	1.53	1.77	61.9	1.78	2.44	46.5	1.96	2.94
190	104.2	1.54	1.77	65.3	1.78	2.44	49.1	1.97	2.93
200	109.6	1.54	1.77	68.7	1.78	2.44	51.6	1.96	2.94
220	120.5	1.54	1.77	75.5	1.78	2.44	56.8	1.97	2.93
240	131.3	1.54	1.77	82.3	1.78	2.45	61.9	1.97	2.94
260	142.1	1.54	1.77	89.1	1.78	2.45	67.0	1.97	2.94
280	152.9	1.54	1.78	95.9	1.78	2.45	72.1	1.97	2.95
300	163.7	1.54	1.78	102.6	1.78	2.46	77.2	1.97	2.95

Q cfs	V_1 = 3.5			V_1 = 4.0			V_1 = 4.5		
	T	D	V_2	T	D	V_2	T	D	V_2
50	9.6	2.42	3.19						
55	10.5	2.39	3.25						
60	11.4	2.37	3.30						
65	12.3	2.35	3.34						
70	13.2	2.33	3.38						
75	14.1	2.32	3.41	11.2	2.71	3.66			
80	15.0	2.31	3.43	11.8	2.65	3.80			
90	16.9	2.31	3.42	13.3	2.65	3.78			
100	18.7	2.29	3.47	14.7	2.63	3.85	11.9	3.02	4.13
110	20.5	2.28	3.50	16.1	2.60	3.90	13.0	2.98	4.22
120	22.4	2.29	3.49	17.5	2.58	3.94	14.1	2.94	4.30
130	24.2	2.28	3.51	18.9	2.57	3.98	15.2	2.91	4.36
140	26.0	2.27	3.54	20.4	2.58	3.95	16.4	2.93	4.34
150	27.9	2.28	3.52	21.8	2.57	3.98	17.5	2.90	4.39
160	29.7	2.27	3.54	23.2	2.56	4.01	18.6	2.88	4.44
170	31.5	2.26	3.55	24.6	2.55	4.03	19.8	2.89	4.41
180	33.3	2.26	3.57	26.1	2.56	4.01	20.9	2.88	4.45
190	35.2	2.27	3.55	27.5	2.56	4.03	22.0	2.86	4.49
200	37.0	2.26	3.56	28.9	2.55	4.04	23.1	2.85	4.52
220	40.7	2.26	3.56	31.8	2.55	4.04	25.4	2.85	4.53
240	44.3	2.26	3.58	34.6	2.54	4.07	27.7	2.85	4.53
260	48.0	2.26	3.58	37.5	2.55	4.06	30.0	2.85	4.54
280	51.6	2.25	3.59	40.3	2.54	4.08	32.2	2.83	4.58
300	55.3	2.26	3.59	43.2	2.54	4.08	34.5	2.83	4.58

Q cfs	V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2
150	14.0	3.34	4.77						
160	14.9	3.33	4.80						
170	15.7	3.27	4.92						
180	16.6	3.26	4.94						
190	17.5	3.26	4.96						
200	18.4	3.25	4.98	15.3	3.72	5.23			
220	20.2	3.24	5.01	16.7	3.66	5.36			
240	22.0	3.23	5.04	18.2	3.65	5.38			
260	23.8	3.22	5.06	19.7	3.64	5.39			
280	25.6	3.21	5.08	21.1	3.61	5.48	17.5	4.14	5.75
300	27.3	3.18	5.15	22.6	3.60	5.49	18.7	4.12	5.80

Parabolic waterway design
(Retardance "D and "C")

(Sheet 2 of 14)

Exhibit 6

V_1 for **RETARDANCE "D"**. Top Width (T), Depth (D) and V_2 for **RETARDANCE "C"**.

Grade 0.75 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	11.7	1.29	1.47	6.8	1.61	2.02																					
20	15.5	1.27	1.51	8.9	1.54	2.15																					
25	19.3	1.26	1.52	11.0	1.50	2.23	8.2	1.74	2.58																		
30	23.1	1.25	1.54	13.2	1.50	2.24	9.7	1.69	2.70	7.7	1.92	2.99															
35	27.0	1.26	1.53	15.3	1.48	2.29	11.3	1.68	2.72	8.9	1.88	3.08															
40	30.8	1.26	1.53	17.5	1.49	2.28	12.8	1.65	2.80	10.1	1.86	3.16															
45	34.5	1.25	1.55	19.6	1.47	2.31	14.4	1.65	2.80	11.3	1.84	3.21															
50	38.3	1.25	1.55	21.8	1.48	2.30	15.9	1.63	2.85	12.5	1.82	3.26	9.3	2.18	3.65												
55	42.1	1.25	1.55	24.0	1.48	2.29	17.5	1.64	2.85	13.7	1.81	3.30	10.1	2.12	3.80												
60	45.9	1.25	1.55	26.1	1.48	2.31	19.1	1.64	2.84	15.0	1.82	3.26	11.0	2.12	3.82												
65	49.6	1.25	1.56	28.2	1.47	2.33	20.6	1.63	2.88	16.2	1.81	3.29	11.9	2.11	3.84	9.9	2.38	4.08									
70	53.4	1.25	1.56	30.4	1.48	2.32	22.2	1.63	2.87	17.4	1.80	3.31	12.8	2.11	3.85	10.6	2.35	4.15									
75	57.1	1.25	1.56	32.5	1.47	2.33	23.7	1.62	2.90	18.6	1.80	3.34	13.6	2.07	3.95	11.3	2.33	4.22									
80	60.9	1.25	1.56	34.7	1.48	2.32	25.3	1.63	2.89	19.8	1.79	3.35	14.5	2.07	3.95	12.0	2.31	4.28									
90	68.4	1.25	1.56	38.9	1.47	2.34	28.4	1.62	2.91	22.2	1.78	3.39	16.3	2.07	3.97	13.4	2.28	4.38	11.1	2.62	4.59						
100	75.9	1.25	1.56	43.2	1.47	2.34	31.5	1.62	2.92	24.7	1.79	3.37	18.1	2.07	3.98	14.9	2.28	4.37	12.2	2.56	4.75						
110	83.4	1.25	1.57	47.5	1.47	2.34	34.7	1.63	2.90	27.1	1.78	3.40	19.8	2.04	4.04	16.3	2.26	4.45	13.4	2.55	4.78						
120	90.8	1.25	1.57	51.8	1.47	2.34	37.8	1.62	2.91	29.6	1.79	3.38	21.6	2.05	4.04	17.8	2.26	4.43	14.6	2.54	4.80	12.1	2.85	5.16			
130	98.3	1.25	1.57	56.0	1.47	2.35	40.9	1.62	2.92	32.0	1.78	3.40	23.4	2.05	4.04	19.2	2.24	4.49	15.7	2.51	4.91	13.0	2.81	5.29			
140	105.7	1.25	1.57	60.3	1.47	2.35	44.0	1.62	2.92	34.4	1.78	3.41	25.1	2.03	4.09	20.7	2.25	4.48	16.9	2.51	4.92	14.0	2.81	5.29			
150	113.1	1.25	1.58	64.5	1.47	2.36	47.1	1.62	2.93	36.8	1.77	3.43	26.9	2.04	4.08	22.1	2.23	4.52	18.1	2.50	4.92	15.0	2.81	5.30			
160	120.5	1.25	1.58	68.8	1.47	2.35	50.2	1.62	2.93	39.3	1.78	3.41	28.7	2.04	4.07	23.6	2.24	4.50	19.3	2.50	4.93	15.9	2.77	5.40	13.1	3.13	5.80
170	127.9	1.25	1.58	73.0	1.47	2.36	53.3	1.62	2.93	41.7	1.78	3.42	30.4	2.03	4.11	25.0	2.23	4.54	20.4	2.48	5.00	16.9	2.78	5.39	13.9	3.12	5.83
180	135.2	1.25	1.58	77.2	1.47	2.36	56.4	1.62	2.93	44.1	1.78	3.43	32.2	2.03	4.10	26.5	2.24	4.52	21.6	2.48	5.00	17.8	2.75	5.48	14.7	3.11	5.85
190	142.6	1.25	1.58	81.5	1.47	2.36	59.5	1.62	2.93	46.5	1.77	3.43	34.0	2.04	4.09	27.9	2.23	4.56	22.8	2.48	5.00	18.8	2.75	5.46	15.5	3.11	5.87
200	149.9	1.25	1.58	85.7	1.47	2.36	62.5	1.62	2.95	48.9	1.77	3.44	35.7	2.03	4.12	29.4	2.23	4.54	24.0	2.49	4.99	19.7	2.73	5.54	16.3	3.10	5.88
220	164.7	1.25	1.58	94.2	1.47	2.36	68.7	1.62	2.95	53.8	1.78	3.43	39.3	2.03	4.11	32.3	2.23	4.55	26.3	2.47	5.05	21.7	2.74	5.52	17.9	3.09	5.92
240	179.4	1.25	1.59	102.6	1.47	2.37	74.9	1.62	2.95	58.6	1.77	3.44	42.8	2.03	4.12	35.2	2.23	4.56	28.7	2.47	5.04	23.6	2.72	5.57	19.4	3.05	6.04
260	194.1	1.25	1.59	111.1	1.47	2.37	81.1	1.62	2.95	63.5	1.78	3.44	46.3	2.02	4.14	38.1	2.23	4.57	31.0	2.46	5.09	25.5	2.71	5.61	21.0	3.05	6.05
280	208.8	1.25	1.59	119.5	1.47	2.37	87.3	1.62	2.95	68.3	1.77	3.44	49.9	2.03	4.12	41.0	2.22	4.58	33.4	2.46	5.08	27.4	2.70	5.65	22.6	3.04	6.07
300	223.5	1.26	1.59	127.9	1.47	2.37	93.4	1.62	2.96	73.1	1.77	3.45	53.4	2.03	4.13	43.9	2.22	4.58	35.8	2.47	5.07	29.4	2.71	5.62	24.2	3.04	6.08

Parabolic waterway design
(Retardance "D" and "C")

(Sheet 3 of 14)

Exhibit 6

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "C".

Grade 1.0 Percent

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2
15	13.4	1.13	1.47	8.4	1.30	2.03			
20	17.8	1.12	1.49	11.1	1.27	2.10	7.6	1.52	2.55
25	22.2	1.11	1.50	13.9	1.27	2.09	9.4	1.49	2.64
30	26.6	1.11	1.50	16.6	1.26	2.13	11.2	1.46	2.71
35	30.9	1.11	1.52	19.3	1.25	2.15	13.0	1.45	2.75
40	35.3	1.11	1.52	22.1	1.26	2.13	14.8	1.44	2.79
45	39.7	1.11	1.52	24.8	1.25	2.15	16.7	1.45	2.76
50	44.0	1.11	1.52	27.5	1.25	2.16	18.5	1.44	2.79
55	48.3	1.11	1.53	30.2	1.25	2.16	20.3	1.43	2.80
60	52.7	1.11	1.52	32.9	1.25	2.17	22.1	1.43	2.82
65	57.0	1.11	1.53	35.6	1.25	2.17	23.9	1.43	2.83
70	61.3	1.11	1.53	38.3	1.25	2.17	25.7	1.43	2.84
75	65.6	1.11	1.53	41.0	1.25	2.18	27.5	1.42	2.85
80	69.8	1.11	1.54	43.7	1.25	2.18	29.3	1.42	2.85
90	78.5	1.11	1.54	49.1	1.25	2.18	32.9	1.42	2.87
100	87.1	1.11	1.54	54.5	1.25	2.18	36.6	1.43	2.85
110	95.6	1.11	1.54	59.9	1.25	2.18	40.2	1.42	2.86
120	104.2	1.11	1.54	65.2	1.25	2.19	43.8	1.42	2.87
130	112.7	1.11	1.55	70.6	1.25	2.19	47.4	1.42	2.87
140	121.2	1.11	1.55	76.0	1.25	2.19	51.0	1.42	2.87
150	129.7	1.11	1.55	81.3	1.25	2.19	54.6	1.42	2.87
160	138.1	1.11	1.55	86.6	1.25	2.20	58.2	1.42	2.88
170	146.6	1.11	1.55	91.9	1.25	2.20	61.7	1.42	2.89
180	155.0	1.11	1.55	97.2	1.25	2.20	65.3	1.42	2.89
190	163.4	1.11	1.55	102.5	1.25	2.20	68.9	1.42	2.89
200	171.7	1.11	1.56	107.8	1.25	2.20	72.4	1.42	2.90
220	188.7	1.11	1.56	118.4	1.25	2.21	79.6	1.42	2.89
240	205.5	1.11	1.56	129.0	1.25	2.21	86.7	1.42	2.90
260	222.4	1.11	1.56	139.6	1.25	2.21	93.9	1.42	2.90
280	239.1	1.11	1.56	150.2	1.25	2.22	101.0	1.42	2.91
300	255.9	1.11	1.56	160.8	1.25	2.22	108.1	1.42	2.91

Q cfs	V_1 = 3.5 T	D	V_2	V_1 = 4.0 T	D	V_2	V_1 = 4.5 T	D	V_2
15									
20									
25	7.6	1.62	2.99						
30	9.1	1.61	3.03						
35	10.5	1.57	3.14	8.0	1.80	3.59			
40	12.0	1.57	3.14	9.1	1.78	3.65			
45	13.4	1.55	3.21	10.2	1.76	3.70			
50	14.9	1.55	3.21	11.3	1.75	3.74	8.7	2.02	4.20
55	16.3	1.54	3.26	12.4	1.75	3.76	9.5	1.99	4.30
60	17.8	1.54	3.25	13.5	1.74	3.79	10.4	2.01	4.26
65	19.2	1.53	3.29	14.6	1.73	3.81	11.2	1.98	4.33
70	20.7	1.53	3.27	15.6	1.71	3.90	12.0	1.96	4.40
75	22.1	1.53	3.31	16.7	1.71	3.90	12.8	1.95	4.46
80	23.6	1.53	3.29	17.8	1.71	3.91	13.7	1.96	4.42
90	26.5	1.53	3.31	20.0	1.70	3.93	15.3	1.93	4.52
100	29.4	1.52	3.32	22.2	1.70	3.94	17.0	1.93	4.52
110	32.3	1.52	3.33	24.4	1.70	3.94	18.7	1.93	4.52
120	35.2	1.52	3.33	26.6	1.70	3.95	20.3	1.92	4.59
130	38.1	1.52	3.34	28.8	1.70	3.95	22.0	1.92	4.58
140	41.0	1.52	3.34	30.9	1.69	3.99	23.7	1.92	4.57
150	43.9	1.52	3.34	33.1	1.69	3.99	25.3	1.91	4.62
160	46.8	1.52	3.34	35.3	1.69	3.99	27.0	1.91	4.61
170	49.7	1.52	3.34	37.5	1.69	3.99	28.7	1.92	4.60
180	52.5	1.52	3.36	39.6	1.69	4.01	30.3	1.91	4.63
190	55.4	1.52	3.36	41.8	1.69	4.01	32.0	1.91	4.62
200	58.3	1.52	3.35	44.0	1.69	4.00	33.6	1.91	4.65
220	64.0	1.52	3.37	48.4	1.70	4.00	37.0	1.91	4.63
240	69.8	1.52	3.37	52.7	1.69	4.01	40.3	1.91	4.65
260	75.5	1.52	3.38	57.1	1.69	4.01	43.6	1.91	4.66
280	81.3	1.52	3.37	61.4	1.69	4.02	46.9	1.90	4.68
300	87.0	1.52	3.38	65.7	1.69	4.03	50.3	1.91	4.66

Q cfs	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15									
20									
25									
30									
35									
40									
45									
50									
55									
60									
65	9.3	2.22	4.66						
70	10.0	2.21	4.69						
75	10.7	2.21	4.71						
80	11.3	2.16	4.85						
90	12.7	2.16	4.87	10.6	2.42	5.20			
100	14.1	2.15	4.89	11.7	2.39	5.31			
110	15.4	2.12	5.00	12.9	2.40	5.28	11.1	2.59	5.67
120	16.8	2.12	5.00	14.0	2.37	5.36	12.1	2.59	5.69
130	18.2	2.13	5.00	15.1	2.35	5.44	13.0	2.55	5.83
140	19.6	2.13	5.00	16.2	2.34	5.50	14.0	2.55	5.83
150	20.9	2.11	5.07	17.4	2.35	5.46	15.0	2.55	5.84
160	22.3	2.11	5.06	18.5	2.33	5.51	15.9	2.52	5.95
170	23.7	2.11	5.05	19.6	2.32	5.56	16.9	2.52	5.94
180	25.0	2.10	5.10	20.7	2.31	5.60	17.9	2.52	5.93
190	26.4	2.10	5.09	21.9	2.32	5.56	18.8	2.50	6.02
200	27.8	2.11	5.08	23.0	2.32	5.59	19.8	2.50	6.01
220	30.5	2.10	5.12	25.3	2.32	5.59	21.7	2.48	6.08
240	33.3	2.10	5.11	27.5	2.30	5.65	23.6	2.47	6.13
260	36.0	2.10	5.14	29.8	2.30	5.64	25.6	2.48	6.11
280	38.8	2.10	5.12	32.1	2.31	5.63	27.5	2.47	6.15
300	41.5	2.10	5.14	34.3	2.30	5.68	29.5	2.48	6.12

Parabolic waterway design
(Retardance "D" and "C")

(Sheet 4 of 14)

Exhibit 6

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "C".

Grade 1.25 Percent

4-26467 5-68

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	15.3	1.00	1.45	9.8	1.15	1.95	6.6	1.37	2.44																		
20	20.4	1.00	1.45	12.9	1.12	2.04	8.7	1.33	2.55	6.6	1.49	2.98															
25	25.4	0.99	1.47	16.1	1.12	2.05	10.8	1.31	2.61	8.2	1.47	3.06	6.7	1.62	3.38												
30	30.5	1.00	1.46	19.3	1.12	2.06	12.9	1.30	2.66	9.7	1.43	3.20	7.9	1.56	3.58												
35	35.5	0.99	1.47	22.5	1.12	2.06	15.0	1.29	2.68	11.3	1.42	3.22	9.2	1.55	3.62	7.2	1.78	4.02									
40	40.5	0.99	1.47	25.7	1.12	2.06	17.1	1.28	2.70	12.9	1.42	3.24	10.5	1.55	3.64	8.2	1.77	4.07									
45	45.5	0.99	1.48	28.8	1.11	2.08	19.2	1.28	2.72	14.4	1.40	3.31	11.7	1.52	3.75	9.1	1.72	4.25									
50	50.4	0.99	1.49	32.0	1.12	2.08	21.3	1.28	2.73	16.0	1.40	3.31	13.0	1.52	3.75	10.1	1.71	4.27	8.3	1.95	4.57						
55	55.4	0.99	1.48	35.1	1.11	2.09	23.4	1.28	2.74	17.6	1.40	3.31	14.3	1.52	3.75	11.1	1.71	4.29	9.1	1.93	4.63						
60	60.3	0.99	1.49	38.3	1.12	2.09	25.5	1.28	2.74	19.1	1.39	3.36	15.6	1.52	3.75	12.1	1.71	4.30	9.9	1.92	4.67						
65	65.2	0.99	1.49	41.4	1.11	2.10	27.6	1.28	2.74	20.7	1.39	3.35	16.8	1.51	3.81	13.0	1.68	4.41	10.6	1.88	4.84	8.7	2.18	5.06			
70	70.1	0.99	1.50	44.6	1.12	2.09	29.7	1.28	2.75	22.3	1.39	3.35	18.1	1.51	3.80	14.0	1.68	4.41	11.4	1.87	4.86	9.3	2.15	5.18			
75	75.0	0.99	1.50	47.7	1.12	2.09	31.8	1.28	2.75	23.8	1.39	3.38	19.4	1.51	3.80	15.0	1.68	4.40	12.2	1.87	4.88	9.9	2.12	5.28			
80	79.9	0.99	1.50	50.8	1.12	2.10	33.8	1.27	2.77	25.4	1.39	3.37	20.6	1.50	3.84	16.0	1.69	4.40	13.0	1.87	4.89	10.5	2.10	5.37	9.2	2.33	5.51
90	89.7	0.99	1.50	[illegible]	1.12	2.10	38.0	1.27	2.77	28.5	1.38	3.39	23.2	1.51	3.83	17.9	1.67	4.48	14.6	1.86	4.92	11.8	2.09	5.40	10.3	2.31	5.60
100	99.6	0.99	1.50	63.3	1.11	2.11	42.2	1.27	2.77	31.7	1.39	3.38	25.7	1.50	3.86	19.9	1.67	4.47	16.2	1.85	4.94	13.1	2.09	5.42	11.4	2.29	5.68
110	109.4	0.99	1.50	69.6	1.12	2.11	46.4	1.27	2.77	34.8	1.39	3.39	28.3	1.50	3.85	21.9	1.67	4.46	17.8	1.85	4.96	14.4	2.09	5.43	12.4	2.24	5.88
120	119.1	0.99	1.51	75.8	1.12	2.11	50.5	1.27	2.78	37.9	1.38	3.41	30.8	1.50	3.87	23.8	1.66	4.51	19.3	1.83	5.05	15.6	2.06	5.55	13.5	2.23	5.91
130	128.9	1.00	1.51	82.0	1.12	2.11	54.7	1.27	2.78	41.1	1.39	3.39	33.3	1.49	3.89	25.8	1.67	4.50	20.9	1.83	5.05	16.9	2.06	5.55	14.6	2.22	5.95
140	138.6	1.00	1.51	88.2	1.12	2.12	58.8	1.27	2.79	44.2	1.39	3.40	35.9	1.50	3.87	27.8	1.67	4.48	22.5	1.83	5.06	18.2	2.06	5.55	15.7	2.22	5.97
150	148.2	1.00	1.51	94.4	1.12	2.12	63.0	1.27	2.78	47.3	1.39	3.41	38.4	1.50	3.88	29.7	1.66	4.52	24.1	1.83	5.06	19.4	2.04	5.63	16.8	2.21	6.00
160	157.9	1.00	1.51	100.6	1.12	2.12	67.1	1.27	2.79	50.4	1.39	3.41	40.9	1.50	3.89	31.7	1.67	4.51	25.7	1.83	5.06	20.7	2.05	5.62	17.9	2.21	6.01
170	167.5	1.00	1.51	106.7	1.12	2.12	71.2	1.27	2.79	53.5	1.39	3.41	43.4	1.49	3.90	33.6	1.66	4.53	27.3	1.83	5.06	22.0	2.05	5.62	19.0	2.21	6.03
180	177.1	1.00	1.51	112.9	1.12	2.12	75.3	1.27	2.80	56.6	1.39	3.42	46.0	1.50	3.88	35.6	1.67	4.52	28.9	1.84	5.05	23.3	2.05	5.61	20.1	2.21	6.04
190	186.6	1.00	1.52	119.0	1.12	2.12	79.4	1.27	2.80	59.7	1.39	3.42	48.5	1.50	3.89	37.5	1.66	4.54	30.4	1.83	5.10	24.5	2.04	5.67	21.2	2.20	6.05
200	196.1	1.00	1.52	125.1	1.12	2.13	83.5	1.27	2.80	62.8	1.39	3.42	51.0	1.50	3.90	39.5	1.67	4.52	32.0	1.83	5.09	25.8	2.04	5.66	22.3	2.20	6.06
220	215.4	1.00	1.52	137.4	1.12	2.13	91.8	1.27	2.80	69.0	1.39	3.42	56.0	1.50	3.91	43.4	1.67	4.53	35.2	1.83	5.09	28.3	2.03	5.70	24.5	2.20	6.08
240	234.7	1.00	1.52	149.8	1.12	2.13	100.0	1.27	2.81	75.2	1.39	3.43	61.1	1.50	3.90	47.3	1.67	4.54	38.4	1.83	5.09	30.9	2.04	5.68	26.7	2.20	6.10
260	253.8	1.00	1.52	162.0	1.12	2.13	108.2	1.27	2.81	81.4	1.39	3.43	66.1	1.50	3.91	51.2	1.66	4.55	41.5	1.83	5.12	33.4	2.03	5.72	28.8	2.18	6.18
280	273.0	1.00	1.52	174.3	1.12	2.13	116.4	1.27	2.81	87.6	1.39	3.43	71.1	1.50	3.92	55.1	1.67	4.55	44.7	1.83	5.11	36.0	2.03	5.70	31.0	2.18	6.18
300	292.0	1.00	1.53	186.5	1.12	2.14	124.6	1.27	2.82	93.7	1.39	3.44	76.2	1.50	3.91	59.0	1.67	4.55	47.8	1.82	5.13	38.5	2.03	5.73	33.2	2.18	6.19

USDA SCS-FORT WORTH, TEX. 1968

Parabolic waterway design
(Retardance "D" and "C")

(Sheet 5 of 14)

Exhibit 6

V_1 for **RETARDANCE "D"**. Top Width (T), Depth (D) and V_2 for **RETARDANCE "C"**.

Grade 1.50 Percent

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2
15	17.0	0.92	1.42	11.3	1.05	1.86	7.6	1.20	2.41
20	22.7	0.92	1.41	14.9	1.03	1.93	10.0	1.17	2.53
25	28.3	0.92	1.42	18.6	1.03	1.94	12.4	1.15	2.59
30	33.9	0.92	1.43	22.3	1.03	1.94	14.9	1.15	2.59
35	39.5	0.92	1.43	26.0	1.03	1.95	17.3	1.14	2.62
40	45.0	0.92	1.44	29.7	1.03	1.94	19.8	1.15	2.61
45	50.5	0.92	1.44	33.3	1.02	1.96	22.2	1.14	2.63
50	56.1	0.92	1.44	37.0	1.03	1.95	24.6	1.14	2.65
55	61.5	0.92	1.45	40.6	1.02	1.96	27.1	1.14	2.64
60	67.0	0.92	1.45	44.2	1.02	1.97	29.5	1.14	2.65
65	72.5	0.92	1.45	47.8	1.02	1.98	31.9	1.14	2.66
70	77.9	0.92	1.45	51.4	1.02	1.98	34.3	1.14	2.66
75	83.3	0.92	1.46	55.0	1.02	1.98	36.7	1.14	2.67
80	88.7	0.92	1.46	58.6	1.02	1.98	39.1	1.14	2.67
90	99.6	0.92	1.46	65.8	1.02	1.99	44.0	1.14	2.66
100	110.5	0.92	1.46	73.0	1.02	1.99	48.8	1.14	2.67
110	121.4	0.92	1.46	80.2	1.02	1.99	53.6	1.14	2.68
120	132.2	0.92	1.46	87.3	1.02	2.00	58.4	1.14	2.68
130	142.9	0.92	1.47	94.5	1.02	2.00	63.2	1.14	2.68
140	153.6	0.92	1.47	101.6	1.02	2.00	68.0	1.14	2.69
150	164.3	0.92	1.47	108.7	1.03	2.00	72.8	1.14	2.68
160	175.0	0.92	1.47	115.7	1.02	2.01	77.6	1.14	2.68
170	185.6	0.92	1.48	122.8	1.03	2.01	82.3	1.14	2.69
180	196.2	0.92	1.48	129.8	1.02	2.01	87.1	1.14	2.69
190	206.7	0.92	1.48	136.8	1.03	2.02	91.8	1.14	2.69
200	217.2	0.92	1.48	143.8	1.03	2.02	96.5	1.14	2.70
220	238.5	0.92	1.48	157.9	1.03	2.02	106.0	1.14	2.70
240	259.7	0.92	1.49	172.0	1.03	2.02	115.6	1.15	2.70
260	280.9	0.92	1.49	186.1	1.03	2.03	125.0	1.15	2.71
280	302.0	0.92	1.49	200.1	1.03	2.03	134.5	1.15	2.71
300	323.0	0.93	1.49	214.1	1.03	2.03	143.9	1.15	2.71

Q cfs	V_1 = 3.5 T	D	V_2	V_1 = 4.0 T	D	V_2	V_1 = 4.5 T	D	V_2
15									
20	7.0	1.40	3.01	5.7	1.52	3.39			
25	8.6	1.35	3.19	7.0	1.46	3.60			
30	10.3	1.34	3.22	8.4	1.46	3.62	6.9	1.59	4.03
35	11.9	1.31	3.32	9.7	1.43	3.74	8.0	1.56	4.13
40	13.6	1.31	3.32	11.1	1.43	3.73	9.1	1.55	4.20
45	15.2	1.30	3.39	12.4	1.41	3.81	10.2	1.54	4.25
50	16.9	1.30	3.38	13.7	1.39	3.88	11.3	1.53	4.29
55	18.6	1.30	3.37	15.1	1.40	3.86	12.4	1.52	4.32
60	20.2	1.29	3.41	16.4	1.39	3.91	13.5	1.52	4.35
65	21.9	1.30	3.40	17.8	1.40	3.88	14.6	1.51	4.37
70	23.5	1.29	3.43	19.1	1.39	3.92	15.7	1.51	4.39
75	25.2	1.29	3.42	20.5	1.40	3.89	16.8	1.51	4.40
80	26.8	1.29	3.44	21.8	1.39	3.93	17.9	1.50	4.41
90	30.1	1.29	3.46	24.5	1.39	3.93	20.1	1.50	4.43
100	33.4	1.29	3.47	27.2	1.39	3.94	22.3	1.50	4.45
110	36.7	1.28	3.47	29.9	1.39	3.94	24.5	1.50	4.46
120	40.0	1.28	3.48	32.6	1.39	3.95	26.7	1.49	4.47
130	43.3	1.29	3.48	35.3	1.39	3.94	28.9	1.49	4.48
140	46.6	1.29	3.48	37.9	1.38	3.97	31.1	1.49	4.48
150	49.9	1.29	3.48	40.6	1.39	3.97	33.3	1.49	4.49
160	53.2	1.29	3.48	43.3	1.39	3.97	35.5	1.50	4.49
170	56.4	1.29	3.49	45.9	1.38	3.99	37.7	1.50	4.49
180	59.7	1.29	3.49	48.6	1.39	3.98	39.8	1.49	4.52
190	62.9	1.29	3.50	51.3	1.39	3.97	42.0	1.49	4.52
200	66.2	1.29	3.49	53.9	1.39	3.99	44.2	1.49	4.51
220	72.7	1.29	3.50	59.3	1.39	3.98	48.6	1.50	4.51
240	79.3	1.29	3.50	64.6	1.39	3.99	53.0	1.50	4.51
260	85.8	1.29	3.51	69.9	1.39	3.99	57.3	1.49	4.53
280	92.3	1.29	3.51	75.2	1.39	4.00	61.7	1.50	4.53
300	98.8	1.29	3.51	80.5	1.39	4.00	66.0	1.49	4.54

Q cfs	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15									
20									
25									
30									
35									
40	7.1	1.79	4.64						
45	8.0	1.79	4.63						
50	8.8	1.75	4.78						
55	9.6	1.73	4.91	8.2	1.93	5.14			
60	10.5	1.73	4.88	8.9	1.91	5.23			
65	11.3	1.71	4.97	9.6	1.89	5.30			
70	12.2	1.72	4.94	10.3	1.88	5.36	8.8	2.12	5.55
75	13.0	1.70	5.02	11.0	1.87	5.41	9.4	2.10	5.61
80	13.9	1.71	4.98	11.7	1.86	5.46	9.9	2.05	5.83
90	15.6	1.71	5.02	13.2	1.87	5.42	11.1	2.04	5.90
100	17.3	1.70	5.05	14.6	1.85	5.50	12.3	2.03	5.95
110	19.0	1.70	5.07	16.0	1.84	5.56	13.5	2.02	6.00
120	20.7	1.69	5.09	17.5	1.85	5.52	14.7	2.01	6.03
130	22.4	1.69	5.10	18.9	1.84	5.57	15.9	2.00	6.06
140	24.0	1.68	5.18	20.3	1.83	5.61	17.1	2.00	6.08
150	25.7	1.68	5.18	21.7	1.82	5.64	18.3	2.00	6.10
160	27.4	1.68	5.19	23.2	1.83	5.60	19.5	1.99	6.12
170	29.1	1.68	5.19	24.6	1.83	5.63	20.7	1.99	6.13
180	30.8	1.68	5.19	26.0	1.82	5.66	21.9	1.99	6.14
190	32.5	1.68	5.18	27.4	1.82	5.68	23.1	1.99	6.15
200	34.2	1.68	5.18	28.9	1.83	5.64	24.3	1.99	6.16
220	37.6	1.68	5.19	31.7	1.82	5.68	26.7	1.99	6.18
240	40.9	1.67	5.23	34.6	1.82	5.67	29.1	1.98	6.19
260	44.3	1.68	5.22	37.4	1.82	5.70	31.5	1.98	6.20
280	47.7	1.68	5.22	40.3	1.82	5.69	33.9	1.98	6.21
300	51.1	1.68	5.21	43.1	1.82	5.71	36.3	1.98	6.21

Parabolic waterway design
(Retardance "D" and "C")

(Sheet 6 of 14)

Exhibit 6

V_1 for **RETARDANCE "D"**. Top Width (T), Depth (D) and V_2 for **RETARDANCE "C"**.

Grade 1.75 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	18.5	0.87	1.38	12.1	0.97	1.89	8.5	1.08	2.40	5.9	1.28	2.92															
20	24.5	0.86	1.41	16.1	0.96	1.91	11.3	1.07	2.43	7.8	1.25	3.03	6.5	1.34	3.38												
25	30.6	0.86	1.41	20.1	0.96	1.91	14.1	1.07	2.45	9.7	1.23	3.09	8.1	1.33	3.43	6.6	1.46	3.81									
30	36.7	0.86	1.40	24.1	0.96	1.92	16.8	1.06	2.50	11.6	1.22	3.13	9.6	1.29	3.57	7.8	1.41	4.01									
35	42.7	0.86	1.41	28.1	0.96	1.92	19.6	1.06	2.50	13.4	1.20	3.23	11.2	1.29	3.58	9.1	1.41	4.02	7.1	1.59	4.57						
40	48.7	0.86	1.42	32.0	0.96	1.93	22.4	1.06	2.50	15.3	1.20	3.24	12.7	1.27	3.67	10.3	1.38	4.15	8.1	1.58	4.61						
45	54.7	0.86	1.42	36.0	0.96	1.93	25.1	1.05	2.53	17.2	1.20	3.24	14.3	1.28	3.66	11.6	1.39	4.14	9.1	1.57	4.64	7.5	1.73	5.12			
50	60.7	0.86	1.42	39.9	0.96	1.94	27.9	1.06	2.52	19.1	1.20	3.25	15.8	1.26	3.72	12.8	1.37	4.22	10.0	1.54	4.80	8.3	1.71	5.20			
55	66.6	0.86	1.42	43.8	0.96	1.94	30.6	1.05	2.53	21.0	1.20	3.25	17.4	1.27	3.70	14.1	1.37	4.21	11.0	1.54	4.80	9.1	1.70	5.25	7.5	1.91	5.65
60	72.5	0.86	1.43	47.7	0.96	1.95	33.3	1.05	2.55	22.8	1.19	3.29	18.9	1.26	3.75	15.4	1.38	4.19	12.0	1.54	4.81	9.9	1.69	5.30	8.2	1.92	5.63
65	78.4	0.86	1.43	51.6	0.96	1.95	36.1	1.06	2.54	24.7	1.19	3.28	20.5	1.26	3.73	16.6	1.37	4.25	12.9	1.52	4.92	10.7	1.68	5.34	8.8	1.88	5.79
70	84.3	0.86	1.43	55.5	0.96	1.95	38.8	1.05	2.54	26.6	1.19	3.28	22.0	1.26	3.76	17.9	1.37	4.23	13.9	1.52	4.91	11.5	1.68	5.38	9.5	1.89	5.76
75	90.2	0.86	1.43	59.4	0.96	1.95	41.5	1.05	2.55	28.5	1.20	3.27	23.6	1.26	3.74	19.1	1.36	4.28	14.9	1.52	4.90	12.3	1.67	5.40	10.1	1.87	5.89
80	96.0	0.86	1.43	63.2	0.96	1.96	44.2	1.05	2.56	30.3	1.19	3.30	25.1	1.26	3.77	20.4	1.37	4.25	15.9	1.53	4.89	13.1	1.67	5.43	10.8	1.88	5.85
90	107.8	0.86	1.44	71.0	0.96	1.96	49.7	1.05	2.55	34.1	1.19	3.29	28.2	1.26	3.78	22.9	1.37	4.28	17.8	1.51	4.96	14.7	1.66	5.47	12.1	1.86	5.93
100	119.5	0.86	1.44	78.8	0.96	1.96	55.1	1.05	2.56	37.8	1.19	3.31	31.3	1.26	3.79	25.4	1.36	4.30	19.8	1.52	4.94	16.3	1.65	5.51	13.4	1.85	5.99
110	131.2	0.86	1.44	86.5	0.96	1.97	60.5	1.05	2.57	41.5	1.19	3.32	34.4	1.26	3.79	27.9	1.36	4.31	21.7	1.51	4.99	17.9	1.65	5.53	14.7	1.84	6.05
120	142.9	0.86	1.44	94.2	0.96	1.97	65.9	1.05	2.58	45.3	1.19	3.31	37.5	1.26	3.79	30.4	1.36	4.32	23.7	1.51	4.97	19.5	1.65	5.55	16.0	1.83	6.09
130	154.5	0.86	1.45	101.9	0.96	1.97	71.3	1.05	2.58	49.0	1.19	3.31	40.6	1.26	3.79	32.9	1.36	4.33	25.6	1.51	5.01	21.1	1.65	5.57	17.3	1.82	6.12
140	166.1	0.87	1.45	109.6	0.96	1.97	76.7	1.05	2.58	52.7	1.19	3.32	43.7	1.26	3.79	35.4	1.36	4.33	27.6	1.51	4.99	22.7	1.64	5.58	18.6	1.82	6.15
150	177.6	0.87	1.45	117.2	0.96	1.98	82.1	1.05	2.58	56.4	1.19	3.32	46.8	1.26	3.79	37.9	1.36	4.33	29.5	1.51	5.02	24.3	1.64	5.59	19.9	1.82	6.17
160	189.1	0.87	1.45	124.8	0.96	1.98	87.5	1.06	2.58	60.1	1.19	3.33	49.8	1.26	3.81	40.4	1.36	4.33	31.4	1.50	5.04	25.9	1.64	5.60	21.3	1.83	6.10
170	200.5	0.87	1.45	132.4	0.96	1.98	92.8	1.05	2.58	63.7	1.19	3.34	52.9	1.26	3.80	42.9	1.36	4.33	33.4	1.51	5.02	27.5	1.64	5.60	22.6	1.83	6.13
180	211.9	0.87	1.46	140.0	0.96	1.98	98.1	1.05	2.59	67.4	1.19	3.34	55.9	1.26	3.82	45.4	1.36	4.33	35.3	1.51	5.04	29.1	1.64	5.61	23.9	1.83	6.14
190	223.3	0.87	1.46	147.5	0.96	1.99	103.4	1.05	2.59	71.1	1.19	3.34	59.0	1.26	3.81	47.8	1.36	4.36	37.2	1.50	5.06	30.7	1.64	5.61	25.2	1.82	6.16
200	234.6	0.87	1.46	155.1	0.97	1.99	108.7	1.06	2.60	74.7	1.19	3.35	62.0	1.26	3.82	50.3	1.36	4.35	39.2	1.51	5.03	32.3	1.64	5.61	26.5	1.82	6.17
220	257.6	0.87	1.46	170.3	0.96	1.99	119.4	1.06	2.60	82.1	1.19	3.35	68.1	1.26	3.83	55.3	1.36	4.35	43.1	1.51	5.03	35.5	1.64	5.62	29.1	1.82	6.20
240	280.4	0.87	1.47	185.5	0.97	1.99	130.1	1.06	2.60	89.5	1.19	3.35	74.3	1.26	3.82	60.3	1.36	4.35	46.9	1.51	5.06	38.7	1.64	5.62	31.7	1.81	6.22
260	303.2	0.87	1.47	200.6	0.97	2.00	140.8	1.06	2.60	96.9	1.19	3.35	80.4	1.26	3.82	65.2	1.36	4.37	50.8	1.51	5.06	41.9	1.64	5.63	34.3	1.81	6.24
280	326.0	0.87	1.47	215.7	0.97	2.00	151.4	1.06	2.61	104.2	1.19	3.36	86.5	1.26	3.83	70.2	1.36	4.36	54.7	1.51	5.05	45.1	1.64	5.63	36.9	1.81	6.25
300	348.6	0.87	1.47	230.8	0.97	2.00	162.0	1.06	2.61	111.5	1.19	3.36	92.5	1.26	3.84	75.1	1.36	4.37	58.5	1.51	5.07	48.3	1.65	5.63	39.5	1.81	6.26

Parabolic waterway design
(Retardance "D" and "C")

(Sheet 7 of 14)

Exhibit 6

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "C".

Grade 2.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	20.8	0.81	1.32	12.8	0.91	1.90	9.3	1.00	2.37	6.7	1.15	2.85															
20	27.6	0.80	1.33	17.1	0.91	1.89	12.3	0.99	2.43	8.8	1.12	3.00	6.5	1.29	3.51	5.4	1.41	3.84									
25	34.5	0.81	1.33	21.3	0.91	1.91	15.4	0.99	2.43	11.0	1.11	3.01	8.0	1.25	3.69	6.7	1.38	3.96									
30	41.3	0.81	1.34	25.5	0.91	1.92	18.4	0.98	2.46	13.2	1.11	3.02	9.6	1.24	3.71	7.9	1.33	4.20	6.6	1.49	4.48						
35	48.0	0.80	1.35	29.7	0.91	1.93	21.5	0.99	2.44	15.3	1.10	3.08	11.1	1.22	3.82	9.2	1.33	4.23	7.6	1.45	4.68						
40	54.8	0.80	1.34	33.9	0.91	1.93	24.5	0.98	2.46	17.5	1.10	3.07	12.7	1.22	3.81	10.5	1.32	4.26	8.7	1.45	4.67	7.2	1.65	4.96			
45	61.5	0.80	1.35	38.1	0.91	1.93	27.5	0.98	2.47	19.6	1.10	3.11	14.3	1.23	3.80	11.8	1.32	4.27	9.7	1.43	4.80	8.0	1.61	5.16			
50	68.2	0.80	1.35	42.3	0.91	1.93	30.5	0.98	2.48	21.8	1.10	3.09	15.8	1.22	3.86	13.1	1.32	4.28	10.8	1.43	4.78	8.8	1.57	5.33	7.5	1.74	5.64
55	74.9	0.81	1.35	46.4	0.91	1.94	33.5	0.98	2.48	23.9	1.09	3.12	17.4	1.22	3.84	14.4	1.32	4.29	11.8	1.42	4.87	9.7	1.58	5.30	8.2	1.72	5.75
60	81.5	0.81	1.36	50.6	0.91	1.93	36.5	0.98	2.49	26.1	1.10	3.10	18.9	1.21	3.89	15.6	1.30	4.38	12.9	1.42	4.84	10.6	1.59	5.28	9.0	1.74	5.65
65	88.1	0.81	1.36	54.7	0.91	1.94	39.5	0.98	2.49	28.2	1.10	3.12	20.5	1.22	3.87	16.9	1.30	4.38	13.9	1.41	4.92	11.4	1.56	5.40	9.7	1.73	5.74
70	94.7	0.81	1.36	58.8	0.91	1.94	42.5	0.98	2.49	30.3	1.09	3.14	22.0	1.21	3.90	18.2	1.31	4.37	15.0	1.42	4.89	12.3	1.57	5.37	10.4	1.71	5.82
75	101.2	0.81	1.36	62.9	0.91	1.94	45.5	0.99	2.49	32.4	1.09	3.15	23.6	1.22	3.88	19.5	1.31	4.37	16.0	1.41	4.95	13.1	1.55	5.46	11.1	1.70	5.89
80	107.8	0.81	1.36	67.0	0.91	1.95	48.4	0.98	2.50	34.6	1.10	3.13	25.1	1.21	3.91	20.7	1.30	4.42	17.1	1.41	4.91	14.0	1.56	5.43	11.8	1.69	5.95
90	121.0	0.81	1.37	75.2	0.91	1.95	54.4	0.98	2.50	38.8	1.09	3.15	28.2	1.21	3.92	23.3	1.30	4.41	19.2	1.41	4.94	15.7	1.55	5.48	13.3	1.69	5.92
100	134.2	0.81	1.37	83.4	0.91	1.96	60.4	0.99	2.50	43.1	1.10	3.15	31.3	1.21	3.93	25.9	1.30	4.40	21.3	1.41	4.96	17.4	1.55	5.52	14.7	1.68	6.02
110	147.3	0.81	1.37	91.6	0.91	1.96	66.3	0.98	2.51	47.4	1.10	3.15	34.4	1.21	3.93	28.4	1.30	4.44	23.4	1.40	4.98	19.1	1.54	5.55	16.2	1.68	5.99
120	160.3	0.81	1.38	99.8	0.91	1.96	72.2	0.98	2.51	51.6	1.10	3.16	37.5	1.21	3.93	31.0	1.30	4.42	25.5	1.40	4.99	20.8	1.54	5.58	17.6	1.67	6.06
130	173.3	0.81	1.38	107.9	0.91	1.96	78.1	0.98	2.51	55.8	1.09	3.17	40.6	1.21	3.93	33.5	1.30	4.45	27.6	1.40	5.00	22.5	1.53	5.60	19.1	1.68	6.03
140	186.3	0.81	1.38	116.0	0.91	1.97	84.0	0.99	2.52	60.1	1.10	3.16	43.6	1.21	3.96	36.0	1.29	4.47	29.7	1.40	5.00	24.2	1.53	5.62	20.5	1.67	6.08
150	199.2	0.81	1.38	124.1	0.91	1.97	89.9	0.99	2.52	64.3	1.10	3.16	46.7	1.21	3.96	38.6	1.30	4.45	31.8	1.40	5.00	25.9	1.53	5.63	21.9	1.66	6.13
160	212.0	0.81	1.38	132.1	0.91	1.97	95.7	0.99	2.52	68.5	1.10	3.17	49.8	1.21	3.95	41.1	1.30	4.47	33.8	1.40	5.05	27.6	1.53	5.64	23.4	1.67	6.09
170	224.8	0.81	1.39	140.2	0.91	1.97	101.6	0.99	2.52	72.7	1.10	3.17	52.8	1.21	3.97	43.6	1.30	4.48	35.9	1.40	5.05	29.3	1.53	5.65	24.8	1.66	6.13
180	237.5	0.81	1.39	148.2	0.91	1.98	107.4	0.99	2.53	76.8	1.10	3.18	55.9	1.21	3.96	46.2	1.30	4.46	38.0	1.40	5.04	31.0	1.53	5.65	26.3	1.67	6.10
190	250.2	0.81	1.39	156.1	0.91	1.98	113.2	0.99	2.53	81.0	1.10	3.18	58.9	1.21	3.97	48.7	1.30	4.47	40.1	1.40	5.04	32.7	1.53	5.65	27.7	1.67	6.13
200	262.8	0.81	1.39	164.1	0.91	1.98	119.0	0.99	2.53	85.2	1.10	3.18	61.9	1.21	3.98	51.2	1.30	4.48	42.2	1.40	5.03	34.4	1.53	5.66	29.1	1.66	6.16
220	288.5	0.81	1.40	180.2	0.91	1.99	130.7	0.99	2.54	93.6	1.10	3.18	68.1	1.21	3.97	56.3	1.30	4.48	46.3	1.40	5.06	37.8	1.53	5.67	32.0	1.66	6.16
240	314.1	0.81	1.40	196.2	0.91	1.99	142.4	0.99	2.54	102.0	1.10	3.19	74.2	1.21	3.98	61.3	1.30	4.50	50.5	1.40	5.06	41.2	1.53	5.68	34.9	1.66	6.16
260	339.5	0.81	1.40	212.2	0.91	1.99	154.0	0.99	2.54	110.3	1.10	3.20	80.3	1.21	3.98	66.4	1.30	4.49	54.7	1.40	5.05	44.6	1.53	5.68	37.8	1.66	6.16
280	364.9	0.81	1.40	228.2	0.92	1.99	165.6	0.99	2.55	118.7	1.10	3.19	86.3	1.21	4.00	71.4	1.30	4.50	58.8	1.40	5.07	48.0	1.53	5.68	40.6	1.66	6.20
300	390.2	0.81	1.40	244.1	0.92	2.00	177.2	0.99	2.55	127.0	1.10	3.20	92.4	1.21	4.00	76.4	1.30	4.51	63.0	1.40	5.06	51.4	1.53	5.68	43.5	1.66	6.19

Parabolic waterway design
(Retardance "D" and "C")

(Sheet 8 of 14)

Exhibit 6

V_1 for **RETARDANCE "D"**. Top Width (T), Depth (D) and V_2 for **RETARDANCE "C"**.

Grade 3.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	23.6	0.69	1.35	16.3	0.76	1.80	11.4	0.83	2.33	8.8	0.90	2.77	6.5	1.01	3.37	5.0	1.16	3.78									
20	31.4	0.69	1.36	21.7	0.76	1.81	15.2	0.83	2.34	11.7	0.90	2.81	8.6	0.99	3.48	6.6	1.13	3.94	5.9	1.19	4.17						
25	39.2	0.69	1.36	27.0	0.75	1.83	19.0	0.83	2.33	14.6	0.90	2.83	10.8	0.99	3.44	8.1	1.09	4.18	7.3	1.16	4.33	6.0	1.27	4.80			
30	46.9	0.69	1.37	32.4	0.75	1.82	22.7	0.83	2.36	17.4	0.88	2.89	12.9	0.98	3.49	9.7	1.08	4.22	8.7	1.15	4.44	7.1	1.24	5.03	5.8	1.41	5.37
35	54.6	0.69	1.37	37.7	0.75	1.83	26.4	0.83	2.38	20.3	0.89	2.88	15.0	0.98	3.53	11.3	1.08	4.25	10.1	1.13	4.51	8.3	1.24	5.02	6.7	1.38	5.55
40	62.2	0.69	1.37	43.0	0.75	1.83	30.2	0.83	2.37	23.2	0.89	2.88	17.1	0.98	3.55	12.9	1.08	4.26	11.5	1.13	4.57	9.4	1.22	5.17	7.6	1.36	5.70
45	69.9	0.70	1.37	48.3	0.75	1.83	33.9	0.83	2.37	26.0	0.88	2.90	19.2	0.97	3.57	14.5	1.08	4.27	12.9	1.12	4.61	10.6	1.22	5.14	8.5	1.34	5.81
50	77.4	0.69	1.38	53.5	0.75	1.84	37.6	0.83	2.38	28.9	0.89	2.89	21.3	0.97	3.58	16.0	1.06	4.36	14.3	1.12	4.63	11.7	1.21	5.24	9.4	1.33	5.90
55	85.0	0.70	1.38	58.7	0.75	1.85	41.2	0.83	2.40	31.7	0.89	2.91	23.4	0.97	3.58	17.6	1.06	4.35	15.7	1.11	4.66	12.9	1.21	5.20	10.4	1.35	5.80
60	92.5	0.70	1.38	64.0	0.75	1.84	44.9	0.83	2.40	34.5	0.88	2.92	25.5	0.97	3.59	19.2	1.07	4.35	17.1	1.11	4.67	14.0	1.20	5.28	11.3	1.34	5.87
65	99.9	0.69	1.39	69.1	0.75	1.85	48.6	0.83	2.39	37.3	0.88	2.93	27.6	0.97	3.59	20.8	1.07	4.34	18.5	1.11	4.69	15.2	1.21	5.24	12.2	1.33	5.93
70	107.3	0.69	1.39	74.3	0.75	1.86	52.2	0.83	2.40	40.1	0.88	2.93	29.7	0.98	3.59	22.3	1.06	4.39	19.9	1.11	4.69	16.3	1.20	5.30	13.1	1.32	5.98
75	114.7	0.70	1.39	79.4	0.75	1.86	55.8	0.83	2.41	42.9	0.88	2.94	31.8	0.98	3.59	23.9	1.06	4.38	21.3	1.11	4.70	17.5	1.21	5.26	14.0	1.32	6.02
80	122.1	0.70	1.40	84.5	0.75	1.87	59.4	0.83	2.42	45.7	0.88	2.94	33.9	0.98	3.58	25.5	1.07	4.36	22.7	1.11	4.70	18.6	1.20	5.31	15.0	1.33	5.94
90	137.0	0.70	1.40	94.9	0.75	1.87	66.7	0.83	2.42	51.4	0.89	2.93	38.0	0.97	3.61	28.6	1.06	4.40	25.5	1.11	4.72	20.9	1.20	5.33	16.8	1.32	6.01
100	151.8	0.70	1.40	105.2	0.75	1.87	74.0	0.83	2.42	57.0	0.89	2.94	42.2	0.98	3.61	31.7	1.06	4.42	28.3	1.11	4.73	23.2	1.20	5.34	18.6	1.31	6.08
110	166.6	0.70	1.41	115.5	0.75	1.87	81.3	0.83	2.42	62.6	0.89	2.95	46.4	0.98	3.61	34.9	1.06	4.40	31.0	1.10	4.78	25.5	1.20	5.34	20.5	1.32	6.04
120	181.3	0.70	1.41	125.7	0.75	1.88	88.5	0.83	2.43	68.2	0.89	2.95	50.5	0.98	3.62	38.0	1.06	4.42	33.8	1.11	4.78	27.7	1.19	5.40	22.3	1.32	6.08
130	195.9	0.70	1.41	135.9	0.76	1.88	95.7	0.83	2.43	73.7	0.89	2.96	54.6	0.98	3.63	41.1	1.06	4.43	36.6	1.11	4.77	30.0	1.19	5.40	24.2	1.32	6.04
140	210.5	0.70	1.41	146.1	0.76	1.88	102.8	0.83	2.44	79.3	0.89	2.96	58.8	0.98	3.62	44.2	1.06	4.44	39.4	1.11	4.77	32.3	1.20	5.39	26.0	1.32	6.08
150	225.0	0.70	1.42	156.2	0.76	1.89	110.0	0.83	2.44	84.8	0.89	2.96	62.9	0.98	3.63	47.3	1.06	4.44	42.1	1.11	4.80	34.6	1.20	5.38	27.8	1.31	6.11
160	239.4	0.70	1.42	166.2	0.76	1.89	117.1	0.83	2.45	90.3	0.89	2.97	67.0	0.98	3.63	50.4	1.06	4.45	44.9	1.11	4.79	36.8	1.19	5.42	29.6	1.31	6.13
170	253.7	0.70	1.42	176.2	0.76	1.90	124.2	0.83	2.45	95.8	0.89	2.97	71.1	0.98	3.64	53.5	1.06	4.45	47.7	1.11	4.78	39.1	1.20	5.41	31.5	1.32	6.09
180	268.0	0.70	1.43	186.2	0.76	1.90	131.2	0.83	2.46	101.3	0.89	2.97	75.2	0.98	3.64	56.6	1.06	4.45	50.4	1.11	4.80	41.3	1.19	5.44	33.3	1.32	6.11
190	282.2	0.70	1.43	196.1	0.76	1.90	138.3	0.83	2.46	106.7	0.89	2.98	79.2	0.98	3.65	59.7	1.07	4.45	53.1	1.11	4.81	43.6	1.20	5.42	35.1	1.32	6.12
200	296.3	0.70	1.43	206.0	0.76	1.90	145.3	0.83	2.46	112.2	0.89	2.98	83.3	0.98	3.65	62.7	1.06	4.47	55.9	1.11	4.80	45.8	1.19	5.45	36.9	1.32	6.14
220	325.1	0.70	1.44	226.1	0.76	1.91	159.5	0.83	2.47	123.2	0.89	2.98	91.5	0.98	3.65	68.9	1.06	4.47	61.4	1.11	4.81	50.4	1.20	5.43	40.6	1.32	6.12
240	353.8	0.70	1.44	246.2	0.76	1.91	173.7	0.83	2.47	134.2	0.89	2.99	99.7	0.98	3.65	75.1	1.07	4.47	66.9	1.11	4.81	54.9	1.20	5.44	44.2	1.32	6.15
260	382.4	0.70	1.44	266.1	0.76	1.92	187.8	0.83	2.48	145.1	0.89	2.99	107.8	0.98	3.67	81.3	1.07	4.47	72.4	1.11	4.82	59.4	1.20	5.45	47.8	1.31	6.17
280	410.8	0.70	1.45	286.0	0.76	1.92	201.9	0.83	2.48	156.0	0.89	3.00	116.0	0.98	3.66	87.4	1.07	4.48	77.9	1.11	4.82	63.9	1.20	5.46	51.5	1.32	6.15
300	439.0	0.70	1.45	305.8	0.76	1.92	215.9	0.83	2.49	166.9	0.89	3.00	124.1	0.98	3.67	93.6	1.07	4.47	83.3	1.11	4.83	68.4	1.20	5.46	55.1	1.32	6.17

Parabolic waterway design
(Retardance "D" and "C")

(Sheet 9 of 14)

Exhibit 6

V_1 for **RETARDANCE "D"**. Top Width (T), Depth (D) and V_2 for **RETARDANCE "C"**.

Grade 4.0 Percent

Q cfs	V_1 = 2.0 T	D	V_2	V_1 = 2.5 T	D	V_2	V_1 = 3.0 T	D	V_2
15	27.9	0.62	1.29	19.9	0.66	1.68	13.9	0.73	2.20
20	37.1	0.62	1.29	26.5	0.66	1.69	18.5	0.72	2.21
25	46.2	0.62	1.30	33.0	0.66	1.70	23.0	0.72	2.24
30	55.3	0.62	1.30	39.5	0.66	1.70	27.6	0.72	2.23
35	64.3	0.62	1.31	46.0	0.66	1.71	32.1	0.72	2.25
40	73.3	0.62	1.31	52.4	0.66	1.71	36.6	0.72	2.25
45	82.2	0.62	1.32	58.8	0.66	1.72	41.1	0.72	2.26
50	91.1	0.62	1.32	65.2	0.66	1.72	45.6	0.72	2.26
55	99.9	0.62	1.32	71.5	0.66	1.73	50.1	0.72	2.26
60	108.7	0.62	1.32	77.8	0.66	1.73	54.5	0.72	2.26
65	117.4	0.62	1.33	84.1	0.66	1.73	58.9	0.72	2.27
70	126.1	0.62	1.33	90.3	0.66	1.74	63.3	0.72	2.27
75	134.7	0.62	1.33	96.5	0.66	1.74	67.7	0.72	2.28
80	143.3	0.62	1.34	102.7	0.66	1.74	72.1	0.72	2.28
90	160.8	0.62	1.34	115.2	0.66	1.75	80.9	0.72	2.28
100	178.2	0.62	1.34	127.7	0.66	1.75	89.7	0.72	2.29
110	195.4	0.62	1.35	140.1	0.66	1.76	98.5	0.72	2.29
120	212.6	0.62	1.35	152.5	0.66	1.76	107.2	0.72	2.30
130	229.6	0.62	1.35	164.8	0.66	1.76	115.9	0.72	2.30
140	246.6	0.62	1.36	177.0	0.66	1.77	124.5	0.72	2.30
150	263.5	0.62	1.36	189.1	0.66	1.77	133.2	0.73	2.30
160	280.3	0.62	1.36	201.2	0.66	1.78	141.7	0.73	2.31
170	296.9	0.62	1.37	213.3	0.67	1.78	150.3	0.73	2.31
180	313.5	0.62	1.37	225.3	0.67	1.78	158.8	0.73	2.32
190	330.0	0.62	1.37	237.2	0.67	1.79	167.3	0.73	2.32
200	346.4	0.62	1.37	249.1	0.67	1.79	175.7	0.73	2.32
220	380.0	0.62	1.38	273.3	0.67	1.79	192.9	0.73	2.33
240	413.3	0.62	1.38	297.4	0.67	1.80	209.9	0.73	2.33
260	446.5	0.62	1.39	321.4	0.67	1.80	227.0	0.73	2.33
280	479.5	0.62	1.39	345.3	0.67	1.80	243.9	0.73	2.34
300	512.3	0.62	1.39	369.0	0.67	1.81	260.8	0.73	2.34

Q cfs	V_1 = 3.5 T	D	V_2	V_1 = 4.0 T	D	V_2	V_1 = 4.5 T	D	V_2
15	10.3	0.79	2.73	7.9	0.85	3.28	6.3	0.92	3.78
20	13.7	0.78	2.76	10.5	0.84	3.33	8.4	0.92	3.81
25	17.1	0.78	2.77	13.1	0.84	3.35	10.5	0.92	3.82
30	20.4	0.77	2.82	15.7	0.84	3.36	12.5	0.91	3.92
35	23.8	0.78	2.81	18.3	0.84	3.37	14.6	0.91	3.90
40	27.1	0.77	2.83	20.8	0.83	3.42	16.6	0.90	3.96
45	30.4	0.77	2.85	23.4	0.84	3.41	18.7	0.91	3.94
50	33.7	0.77	2.86	26.0	0.84	3.40	20.7	0.90	3.97
55	37.0	0.77	2.86	28.5	0.84	3.43	22.8	0.91	3.95
60	40.3	0.77	2.87	31.0	0.83	3.45	24.8	0.90	3.97
65	43.6	0.77	2.87	33.6	0.84	3.43	26.8	0.90	3.99
70	46.9	0.77	2.86	36.1	0.84	3.44	28.8	0.90	4.01
75	50.1	0.77	2.88	38.6	0.84	3.45	30.9	0.91	3.98
80	53.3	0.77	2.89	41.1	0.84	3.46	32.9	0.91	3.99
90	59.9	0.77	2.89	46.2	0.84	3.46	36.9	0.90	4.01
100	66.4	0.77	2.90	51.2	0.84	3.47	41.0	0.91	4.00
110	72.9	0.77	2.90	56.2	0.84	3.48	45.0	0.90	4.02
120	79.4	0.77	2.90	61.2	0.84	3.49	49.0	0.90	4.03
130	85.9	0.77	2.91	66.2	0.84	3.49	53.0	0.90	4.03
140	92.3	0.77	2.91	71.2	0.84	3.49	57.0	0.90	4.04
150	98.7	0.77	2.92	76.2	0.84	3.49	61.0	0.91	4.04
160	105.1	0.77	2.92	81.1	0.84	3.50	65.0	0.91	4.04
170	111.5	0.78	2.92	86.0	0.84	3.51	68.9	0.91	4.05
180	117.8	0.78	2.93	90.9	0.84	3.52	72.9	0.91	4.05
190	124.2	0.78	2.93	95.8	0.84	3.52	76.8	0.91	4.06
200	130.5	0.78	2.93	100.7	0.84	3.52	80.7	0.91	4.07
220	143.3	0.78	2.93	110.6	0.84	3.53	88.7	0.91	4.07
240	156.0	0.78	2.94	120.4	0.84	3.53	96.6	0.91	4.07
260	168.7	0.78	2.94	130.2	0.84	3.54	104.5	0.91	4.08
280	181.3	0.78	2.95	140.0	0.84	3.54	112.3	0.91	4.09
300	193.9	0.78	2.95	149.8	0.84	3.55	120.2	0.91	4.09

Q cfs	V_1 = 5.0 T	D	V_2	V_1 = 5.5 T	D	V_2	V_1 = 6.0 T	D	V_2
15	4.9	1.06	4.21						
20	6.4	1.01	4.52	5.5	1.09	4.88			
25	8.0	1.01	4.55	6.8	1.06	5.09	5.7	1.20	5.34
30	9.5	0.99	4.71	8.2	1.07	5.03	6.7	1.15	5.71
35	11.1	0.99	4.70	9.5	1.06	5.15	7.8	1.15	5.77
40	12.7	1.00	4.68	10.8	1.04	5.24	8.9	1.14	5.81
45	14.2	0.98	4.77	12.2	1.05	5.17	10.0	1.14	5.83
50	15.8	0.99	4.74	13.5	1.05	5.24	11.1	1.14	5.85
55	17.3	0.98	4.80	14.8	1.04	5.28	12.2	1.14	5.87
60	18.9	0.99	4.77	16.1	1.04	5.32	13.3	1.14	5.88
65	20.4	0.98	4.81	17.5	1.05	5.26	14.3	1.12	6.00
70	21.9	0.98	4.85	18.8	1.04	5.29	15.4	1.12	6.00
75	23.5	0.98	4.82	20.1	1.04	5.31	16.5	1.13	5.99
80	25.0	0.98	4.84	21.4	1.04	5.33	17.6	1.13	5.98
90	28.1	0.98	4.85	24.0	1.04	5.38	19.7	1.12	6.07
100	31.2	0.98	4.85	26.7	1.04	5.35	21.9	1.12	6.05
110	34.3	0.98	4.85	29.3	1.04	5.37	24.1	1.12	6.03
120	37.3	0.98	4.88	31.9	1.04	5.40	26.2	1.12	6.09
130	40.4	0.98	4.87	34.6	1.04	5.36	28.4	1.12	6.07
140	43.4	0.98	4.90	37.2	1.04	5.38	30.5	1.12	6.10
150	46.5	0.98	4.88	39.8	1.04	5.39	32.7	1.12	6.08
160	49.5	0.98	4.90	42.4	1.04	5.40	34.8	1.12	6.11
170	52.5	0.98	4.91	45.0	1.04	5.40	36.9	1.12	6.13
180	55.6	0.98	4.90	47.6	1.04	5.40	39.1	1.12	6.11
190	58.6	0.98	4.90	50.2	1.04	5.40	41.2	1.12	6.12
200	61.6	0.98	4.91	52.7	1.04	5.43	43.3	1.12	6.14
220	67.6	0.98	4.93	57.9	1.04	5.44	47.6	1.12	6.14
240	73.7	0.98	4.93	63.1	1.04	5.44	51.9	1.12	6.14
260	79.7	0.98	4.94	68.3	1.04	5.44	56.2	1.12	6.13
280	85.8	0.99	4.93	73.5	1.04	5.44	60.4	1.12	6.15
300	91.8	0.99	4.94	78.6	1.04	5.46	64.7	1.12	6.14

Parabolic waterway design
(Retardance "D" and "C")

Exhibit 6

V_1 for **RETARDANCE "D"**. Top Width (T), Depth (D) and V_2 for **RETARDANCE "C"**.

Grade 5.0 Percent

4-28467 5-68

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	29.3	0.57	1.33	21.1	0.60	1.74	15.0	0.66	2.23	12.2	0.70	2.58	9.0	0.75	3.25
20	39.0	0.57	1.33	28.1	0.61	1.74	19.9	0.66	2.26	16.2	0.70	2.62	12.0	0.75	3.26
25	48.6	0.57	1.34	35.1	0.61	1.73	24.8	0.66	2.28	20.3	0.70	2.59	15.0	0.75	3.27
30	58.1	0.57	1.34	42.0	0.61	1.74	29.7	0.66	2.28	24.3	0.70	2.61	18.0	0.76	3.26
35	67.6	0.57	1.35	48.8	0.61	1.75	34.6	0.66	2.28	28.2	0.70	2.64	20.9	0.75	3.30
40	77.0	0.57	1.35	55.7	0.61	1.75	39.5	0.66	2.28	32.2	0.70	2.64	23.9	0.75	3.29
45	86.4	0.57	1.35	62.5	0.61	1.75	44.3	0.66	2.29	36.1	0.70	2.65	26.8	0.75	3.31
50	95.7	0.57	1.36	69.2	0.61	1.76	49.1	0.66	2.30	40.1	0.70	2.64	29.7	0.75	3.32
55	105.0	0.57	1.36	75.9	0.61	1.77	53.9	0.66	2.30	44.0	0.70	2.65	32.6	0.75	3.33
60	114.2	0.57	1.36	82.6	0.61	1.77	58.7	0.66	2.30	47.9	0.70	2.66	35.5	0.75	3.34
65	123.4	0.57	1.36	89.3	0.61	1.77	63.4	0.66	2.31	51.8	0.70	2.66	38.4	0.75	3.34
70	132.4	0.57	1.37	95.9	0.61	1.77	68.2	0.66	2.31	55.6	0.70	2.67	41.3	0.75	3.34
75	141.5	0.57	1.37	102.4	0.61	1.78	72.9	0.66	2.31	59.4	0.70	2.68	44.1	0.75	3.36
80	150.5	0.57	1.37	109.0	0.61	1.78	77.5	0.66	2.32	63.3	0.70	2.68	47.0	0.75	3.36
90	168.8	0.57	1.38	122.3	0.61	1.79	87.0	0.66	2.33	71.0	0.70	2.69	52.8	0.75	3.36
100	187.0	0.57	1.38	135.5	0.61	1.79	96.5	0.66	2.33	78.7	0.70	2.70	58.5	0.75	3.37
110	205.1	0.57	1.38	148.7	0.61	1.79	105.9	0.66	2.33	86.4	0.70	2.70	64.3	0.75	3.37
120	223.1	0.57	1.39	161.8	0.61	1.80	115.3	0.66	2.33	94.1	0.70	2.70	70.0	0.75	3.38
130	240.9	0.57	1.39	174.8	0.61	1.80	124.6	0.66	2.34	101.7	0.70	2.71	75.7	0.76	3.38
140	258.7	0.57	1.40	187.7	0.61	1.81	133.9	0.66	2.34	109.3	0.70	2.71	81.3	0.75	3.39
150	276.4	0.58	1.40	200.6	0.61	1.81	143.1	0.66	2.35	116.8	0.70	2.72	87.0	0.76	3.39
160	293.9	0.58	1.40	213.4	0.61	1.81	152.3	0.66	2.35	124.3	0.70	2.72	92.6	0.76	3.40
170	311.4	0.58	1.40	226.1	0.61	1.82	161.5	0.66	2.35	131.8	0.70	2.73	98.2	0.76	3.41
180	328.7	0.58	1.41	238.8	0.61	1.82	170.6	0.66	2.36	139.2	0.70	2.73	103.8	0.76	3.41
190	346.0	0.58	1.41	251.4	0.61	1.83	179.7	0.67	2.36	146.6	0.70	2.74	109.4	0.76	3.41
200	363.1	0.58	1.42	263.9	0.61	1.83	188.7	0.67	2.37	154.0	0.70	2.74	114.9	0.76	3.42
220	398.3	0.58	1.42	289.6	0.62	1.83	207.1	0.67	2.37	169.0	0.70	2.75	126.1	0.76	3.43
240	433.2	0.58	1.42	315.0	0.62	1.84	225.4	0.67	2.37	184.0	0.70	2.75	137.4	0.76	3.43
260	467.9	0.58	1.43	340.4	0.62	1.84	243.7	0.67	2.38	198.9	0.70	2.76	148.5	0.76	3.44
280	502.5	0.58	1.43	365.6	0.62	1.84	261.8	0.67	2.38	213.7	0.70	2.76	159.7	0.76	3.44
300	536.7	0.58	1.43	390.7	0.62	1.85	279.9	0.67	2.38	228.5	0.71	2.77	170.7	0.76	3.45

Q cfs	V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	7.2	0.83	3.70	5.8	0.93	4.09	4.6	0.99	4.81			
20	9.5	0.81	3.84	7.6	0.89	4.35	6.1	0.97	4.95	5.3	1.06	5.21
25	11.9	0.81	3.82	9.5	0.89	4.37	7.6	0.96	5.03	6.5	1.02	5.56
30	14.2	0.80	3.89	11.3	0.87	4.49	9.1	0.96	5.08	7.8	1.01	5.59
35	16.6	0.81	3.86	13.2	0.88	4.47	10.5	0.94	5.26	9.1	1.01	5.60
40	18.9	0.80	3.90	15.1	0.88	4.46	12.0	0.94	5.26	10.3	0.99	5.77
45	21.3	0.81	3.87	16.9	0.87	4.52	13.5	0.94	5.25	11.6	1.00	5.75
50	23.6	0.81	3.89	18.8	0.88	4.50	15.0	0.94	5.25	12.9	1.00	5.73
55	25.9	0.81	3.90	20.6	0.87	4.54	16.5	0.94	5.24	14.1	0.99	5.84
60	28.2	0.81	3.92	22.4	0.87	4.57	17.9	0.93	5.32	15.4	0.99	5.81
65	30.5	0.81	3.92	24.3	0.87	4.54	19.4	0.94	5.30	16.7	1.00	5.78
70	32.8	0.81	3.93	26.1	0.87	4.56	20.8	0.93	5.36	17.9	0.99	5.85
75	35.1	0.81	3.93	27.9	0.87	4.58	22.3	0.93	5.34	19.2	1.00	5.82
80	37.4	0.81	3.92	29.7	0.87	4.60	23.8	0.94	5.32	20.4	0.99	5.88
90	42.0	0.81	3.93	33.4	0.87	4.59	26.7	0.94	5.35	22.9	0.99	5.91
100	46.5	0.81	3.96	37.0	0.87	4.62	29.6	0.93	5.38	25.5	0.99	5.86
110	51.1	0.81	3.96	40.7	0.87	4.61	32.5	0.93	5.39	28.0	0.99	5.88
120	55.7	0.81	3.96	44.3	0.87	4.62	35.4	0.93	5.41	30.5	0.99	5.89
130	60.2	0.81	3.97	47.9	0.87	4.64	38.3	0.93	5.41	33.0	0.99	5.90
140	64.7	0.81	3.98	51.5	0.87	4.64	41.2	0.93	5.42	35.5	0.99	5.91
150	69.3	0.81	3.97	55.1	0.87	4.65	44.1	0.93	5.42	37.9	0.99	5.96
160	73.7	0.81	3.99	58.7	0.87	4.65	47.0	0.94	5.42	40.4	0.99	5.95
170	78.2	0.81	3.99	62.3	0.87	4.65	49.9	0.94	5.41	42.9	0.99	5.95
180	82.7	0.81	3.99	65.9	0.87	4.65	52.7	0.93	5.44	45.4	0.99	5.94
190	87.1	0.81	4.00	69.4	0.87	4.67	55.6	0.94	5.43	47.8	0.99	5.97
200	91.6	0.81	4.00	73.0	0.87	4.66	58.4	0.94	5.45	50.3	0.99	5.96
220	100.6	0.81	4.00	80.1	0.87	4.68	64.2	0.94	5.45	55.2	0.99	5.99
240	109.5	0.81	4.01	87.3	0.87	4.68	69.9	0.94	5.46	60.2	0.99	5.98
260	118.5	0.81	4.01	94.4	0.87	4.69	75.6	0.94	5.47	65.1	0.99	5.99
280	127.4	0.81	4.02	101.5	0.87	4.70	81.4	0.94	5.46	70.0	0.99	6.01
300	136.2	0.81	4.03	108.6	0.87	4.70	87.0	0.94	5.48	74.9	0.99	6.01

Parabolic waterway design
(Retardance "D" and "C")

(Sheet 11 of 14)

Exhibit 6

V_1 for **RETARDANCE "D"**. Top Width (T), Depth (D) and V_2 for **RETARDANCE "C"**.

Grade 6.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	34.6	0.53	1.22	22.6	0.57	1.72	16.6	0.61	2.20	12.6	0.65	2.68	10.0	0.70	3.15	8.1	0.76	3.59	6.6	0.82	4.05	5.3	0.90	4.61	4.3	0.98	5.19
20	46.0	0.53	1.22	30.0	0.57	1.73	22.1	0.61	2.20	16.8	0.66	2.68	13.2	0.69	3.25	10.7	0.74	3.71	8.7	0.80	4.22	7.0	0.88	4.79	5.7	0.96	5.36
25	57.2	0.52	1.23	37.4	0.57	1.74	27.6	0.61	2.20	21.0	0.66	2.68	16.5	0.69	3.25	13.3	0.73	3.78	10.8	0.79	4.32	8.7	0.86	4.90	7.0	0.92	5.69
30	68.5	0.53	1.23	44.7	0.57	1.75	33.0	0.61	2.22	25.1	0.66	2.70	19.8	0.69	3.24	16.0	0.74	3.75	13.0	0.80	4.29	10.4	0.86	4.97	8.4	0.92	5.71
35	79.6	0.53	1.24	52.0	0.57	1.76	38.4	0.61	2.22	29.2	0.65	2.71	23.0	0.69	3.28	18.6	0.74	3.78	15.1	0.79	4.34	12.1	0.85	5.01	9.8	0.92	5.72
40	90.6	0.52	1.24	59.3	0.57	1.76	43.8	0.61	2.22	33.3	0.65	2.72	26.3	0.69	3.26	21.2	0.74	3.80	17.2	0.79	4.37	13.8	0.85	5.04	11.2	0.92	5.72
45	101.6	0.53	1.25	66.5	0.57	1.76	49.1	0.61	2.24	37.4	0.66	2.72	29.5	0.69	3.28	23.8	0.73	3.81	19.4	0.79	4.33	15.5	0.85	5.05	12.5	0.91	5.85
50	112.5	0.53	1.25	73.6	0.57	1.77	54.4	0.61	2.24	41.5	0.66	2.72	32.7	0.69	3.29	26.4	0.74	3.82	21.5	0.79	4.35	17.2	0.85	5.06	13.9	0.91	5.83
55	123.3	0.53	1.25	80.8	0.57	1.77	59.7	0.61	2.25	45.5	0.66	2.73	35.9	0.69	3.29	29.0	0.74	3.82	23.6	0.79	4.37	18.8	0.84	5.15	15.3	0.92	5.82
60	134.1	0.53	1.26	87.8	0.57	1.78	65.0	0.61	2.25	49.5	0.66	2.74	39.1	0.69	3.30	31.6	0.74	3.82	25.7	0.79	4.38	20.5	0.84	5.14	16.6	0.91	5.90
65	144.7	0.53	1.26	94.9	0.57	1.78	70.2	0.61	2.26	53.5	0.66	2.75	42.2	0.69	3.32	34.1	0.73	3.85	27.8	0.79	4.38	22.2	0.85	5.14	18.0	0.91	5.87
70	155.3	0.53	1.27	101.9	0.57	1.79	75.4	0.61	2.26	57.5	0.66	2.75	45.4	0.69	3.31	36.7	0.74	3.84	29.9	0.79	4.39	23.9	0.85	5.13	19.3	0.91	5.94
75	165.8	0.53	1.27	108.8	0.57	1.80	80.6	0.61	2.26	61.5	0.66	2.75	48.5	0.69	3.33	39.2	0.73	3.86	31.9	0.79	4.43	25.5	0.84	5.18	20.7	0.91	5.91
80	176.3	0.53	1.27	115.7	0.57	1.80	85.8	0.61	2.27	65.4	0.66	2.76	51.7	0.69	3.32	41.8	0.74	3.85	34.0	0.79	4.42	27.2	0.85	5.16	22.0	0.91	5.96
90	197.6	0.53	1.28	129.8	0.57	1.80	96.2	0.61	2.28	73.4	0.66	2.77	58.0	0.69	3.33	46.9	0.74	3.87	38.2	0.79	4.43	30.5	0.84	5.20	24.8	0.91	5.91
100	218.8	0.53	1.28	143.8	0.57	1.81	106.6	0.61	2.28	81.4	0.66	2.77	64.3	0.69	3.34	52.0	0.74	3.88	42.4	0.79	4.42	33.9	0.85	5.18	27.5	0.91	5.93
110	239.9	0.53	1.28	157.7	0.57	1.81	117.0	0.61	2.28	89.3	0.66	2.78	70.6	0.69	3.35	57.1	0.74	3.88	46.5	0.79	4.45	37.2	0.84	5.20	30.2	0.91	5.95
120	260.8	0.53	1.29	171.5	0.57	1.82	127.3	0.61	2.29	97.2	0.66	2.79	76.9	0.69	3.35	62.2	0.74	3.89	50.7	0.79	4.44	40.5	0.84	5.22	32.9	0.91	5.96
130	281.5	0.53	1.29	185.3	0.57	1.82	137.6	0.61	2.29	105.1	0.66	2.79	83.1	0.69	3.36	67.2	0.74	3.90	54.8	0.79	4.46	43.8	0.84	5.23	35.6	0.91	5.96
140	302.1	0.53	1.30	199.0	0.57	1.83	147.8	0.61	2.30	112.9	0.66	2.80	89.3	0.69	3.36	72.3	0.74	3.90	58.9	0.79	4.46	47.1	0.84	5.24	38.3	0.91	5.97
150	322.6	0.53	1.30	212.6	0.57	1.83	157.9	0.61	2.30	120.7	0.66	2.80	95.5	0.69	3.37	77.3	0.74	3.91	63.0	0.79	4.47	50.4	0.84	5.24	40.9	0.91	6.01
160	342.9	0.53	1.30	226.1	0.57	1.84	168.0	0.61	2.31	128.5	0.66	2.80	101.7	0.69	3.37	82.3	0.74	3.91	67.1	0.79	4.47	53.7	0.85	5.24	43.6	0.91	6.00
170	363.1	0.53	1.31	239.6	0.57	1.84	178.0	0.61	2.32	136.2	0.66	2.81	107.8	0.69	3.37	87.3	0.74	3.91	71.2	0.79	4.47	56.9	0.84	5.27	46.3	0.91	5.99
180	383.1	0.53	1.31	253.0	0.57	1.84	188.0	0.61	2.32	143.9	0.66	2.81	113.9	0.69	3.38	92.2	0.74	3.93	75.2	0.79	4.49	60.2	0.85	5.26	48.9	0.91	6.02
190	403.0	0.53	1.32	266.3	0.57	1.85	197.9	0.61	2.33	151.5	0.66	2.82	120.0	0.70	3.38	97.1	0.74	3.94	79.3	0.79	4.49	63.4	0.84	5.28	51.6	0.91	6.01
200	422.7	0.53	1.32	279.5	0.57	1.85	207.8	0.61	2.33	159.1	0.66	2.82	126.1	0.70	3.39	102.1	0.74	3.93	83.3	0.79	4.50	66.7	0.85	5.27	54.2	0.91	6.03
220	463.4	0.53	1.32	306.6	0.57	1.86	228.0	0.61	2.33	174.6	0.66	2.83	138.4	0.70	3.39	112.0	0.74	3.95	91.5	0.79	4.50	73.2	0.85	5.29	59.6	0.91	6.02
240	503.8	0.53	1.33	333.6	0.57	1.86	248.1	0.61	2.34	190.1	0.66	2.83	150.7	0.70	3.40	122.0	0.74	3.95	99.7	0.80	4.50	79.8	0.85	5.28	64.9	0.91	6.04
260	543.8	0.53	1.33	360.4	0.57	1.86	268.1	0.61	2.34	205.4	0.66	2.84	162.9	0.70	3.40	131.9	0.74	3.96	107.8	0.80	4.51	86.3	0.85	5.29	70.2	0.91	6.05
280	583.6	0.53	1.34	387.0	0.57	1.87	287.9	0.61	2.35	220.7	0.66	2.85	175.1	0.70	3.41	141.8	0.74	3.96	115.9	0.80	4.51	92.8	0.85	5.30	75.5	0.91	6.05
300	623.2	0.53	1.34	413.5	0.58	1.87	307.7	0.61	2.36	235.9	0.66	2.85	187.2	0.70	3.41	151.6	0.74	3.97	123.9	0.80	4.53	99.3	0.85	5.30	80.8	0.91	6.06

Parabolic waterway design
(Retardance "D" and "C")

(Sheet 12 of 14)

Exhibit 6

V_1 for RETARDANCE "D". Top Width (T), Depth (D) and V_2 for RETARDANCE "C".

Grade 8.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	37.0	0.47	1.26	26.6	0.51	1.65	18.7	0.54	2.19	15.3	0.57	2.54	11.7	0.61	3.08
20	49.2	0.47	1.26	35.3	0.50	1.66	24.9	0.54	2.19	20.4	0.57	2.54	15.6	0.61	3.08
25	61.2	0.47	1.27	44.0	0.50	1.67	31.0	0.54	2.21	25.4	0.57	2.56	19.4	0.61	3.12
30	73.2	0.47	1.28	52.6	0.50	1.67	37.2	0.54	2.19	30.4	0.57	2.57	23.3	0.61	3.10
35	85.1	0.47	1.28	61.2	0.50	1.68	43.2	0.54	2.21	35.3	0.57	2.59	27.1	0.61	3.12
40	96.9	0.47	1.28	69.7	0.50	1.68	49.3	0.54	2.21	40.3	0.57	2.59	30.9	0.61	3.13
45	108.6	0.47	1.29	78.2	0.51	1.68	55.3	0.54	2.22	45.2	0.57	2.60	34.6	0.61	3.16
50	120.2	0.48	1.29	86.5	0.50	1.69	61.2	0.54	2.23	50.0	0.57	2.62	38.4	0.61	3.15
55	131.8	0.48	1.30	94.9	0.51	1.70	67.1	0.54	2.24	54.9	0.57	2.62	42.1	0.61	3.17
60	143.2	0.48	1.30	103.1	0.51	1.70	73.0	0.54	2.24	59.7	0.57	2.62	45.9	0.61	3.16
65	154.6	0.48	1.30	111.4	0.51	1.71	78.9	0.54	2.24	64.5	0.57	2.63	49.6	0.61	3.16
70	165.9	0.48	1.31	119.5	0.51	1.71	84.7	0.54	2.25	69.3	0.57	2.63	53.2	0.61	3.19
75	177.1	0.48	1.31	127.6	0.51	1.72	90.5	0.54	2.25	74.1	0.57	2.63	56.9	0.61	3.19
80	188.2	0.48	1.32	135.6	0.51	1.72	96.2	0.54	2.26	78.8	0.57	2.64	60.5	0.61	3.20
90	210.9	0.48	1.32	152.1	0.51	1.73	108.0	0.55	2.26	88.4	0.57	2.65	67.9	0.61	3.21
100	233.5	0.48	1.32	168.4	0.51	1.73	119.6	0.55	2.27	98.0	0.57	2.65	75.3	0.61	3.21
110	255.9	0.48	1.33	184.6	0.51	1.74	131.2	0.55	2.28	107.5	0.57	2.66	82.6	0.61	3.22
120	278.1	0.48	1.33	200.7	0.51	1.74	142.7	0.55	2.28	116.9	0.57	2.67	89.9	0.61	3.22
130	300.2	0.48	1.34	216.6	0.51	1.75	154.1	0.55	2.29	126.4	0.57	2.67	97.1	0.61	3.24
140	322.1	0.48	1.34	232.5	0.51	1.76	165.5	0.55	2.29	135.7	0.57	2.67	104.4	0.62	3.23
150	343.9	0.48	1.34	248.3	0.51	1.76	176.8	0.55	2.30	145.0	0.57	2.68	111.5	0.61	3.25
160	365.5	0.48	1.35	264.0	0.51	1.76	188.1	0.55	2.30	154.3	0.57	2.68	118.7	0.62	3.25
170	386.9	0.48	1.35	279.6	0.51	1.77	199.3	0.55	2.31	163.5	0.57	2.69	125.8	0.62	3.26
180	408.2	0.48	1.36	295.1	0.51	1.77	210.4	0.55	2.31	172.7	0.57	2.69	132.8	0.62	3.27
190	429.3	0.48	1.36	310.5	0.51	1.78	221.4	0.55	2.32	181.8	0.57	2.70	139.9	0.62	3.27
200	450.2	0.48	1.36	325.7	0.51	1.78	232.4	0.55	2.32	190.8	0.57	2.71	146.9	0.62	3.28
220	493.4	0.48	1.37	357.1	0.51	1.79	254.9	0.55	2.33	209.4	0.58	2.71	161.1	0.62	3.29
240	536.2	0.48	1.37	388.3	0.51	1.79	277.3	0.55	2.34	227.8	0.58	2.71	175.4	0.62	3.29
260	578.8	0.48	1.38	419.3	0.51	1.80	299.5	0.55	2.34	246.2	0.58	2.72	189.5	0.62	3.30
280	621.1	0.48	1.38	450.1	0.51	1.80	321.6	0.55	2.35	264.4	0.58	2.72	203.6	0.62	3.31
300	663.1	0.48	1.39	480.7	0.51	1.81	343.6	0.55	2.35	282.6	0.58	2.73	217.6	0.62	3.31

Q cfs	V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	9.4	0.65	3.61	7.9	0.70	3.99	6.4	0.74	4.62	5.3	0.80	5.18
20	12.5	0.65	3.65	10.4	0.68	4.17	8.5	0.74	4.70	7.1	0.80	5.16
25	15.6	0.65	3.67	13.0	0.68	4.17	10.6	0.73	4.75	8.8	0.79	5.32
30	18.7	0.65	3.67	15.6	0.68	4.17	12.7	0.73	4.77	10.5	0.78	5.41
35	21.7	0.64	3.72	18.1	0.68	4.23	14.8	0.73	4.78	12.2	0.77	5.48
40	24.8	0.64	3.71	20.7	0.68	4.20	16.9	0.73	4.78	13.9	0.77	5.53
45	27.8	0.64	3.73	23.2	0.68	4.24	19.0	0.73	4.78	15.7	0.78	5.45
50	30.9	0.65	3.71	25.8	0.68	4.21	21.0	0.73	4.84	17.4	0.78	5.48
55	33.9	0.65	3.73	28.3	0.68	4.23	23.1	0.73	4.83	19.1	0.78	5.50
60	36.9	0.65	3.73	30.8	0.68	4.24	25.1	0.73	4.87	20.8	0.78	5.51
65	39.9	0.65	3.74	33.3	0.68	4.25	27.2	0.73	4.85	22.5	0.78	5.52
70	42.8	0.64	3.76	35.8	0.68	4.26	29.2	0.73	4.88	24.1	0.77	5.59
75	45.8	0.65	3.76	38.2	0.68	4.29	31.2	0.73	4.90	25.8	0.77	5.59
80	48.7	0.64	3.78	40.7	0.68	4.29	33.3	0.73	4.87	27.5	0.77	5.58
90	54.7	0.65	3.78	45.7	0.68	4.29	37.4	0.73	4.88	30.9	0.77	5.59
100	60.7	0.65	3.78	50.6	0.68	4.32	41.4	0.73	4.92	34.2	0.77	5.64
110	66.6	0.65	3.79	55.6	0.68	4.32	45.5	0.73	4.91	37.6	0.77	5.63
120	72.5	0.65	3.79	60.5	0.68	4.33	49.5	0.73	4.93	40.9	0.77	5.66
130	78.3	0.65	3.81	65.4	0.68	4.34	53.6	0.73	4.92	44.3	0.77	5.64
140	84.2	0.65	3.81	70.3	0.68	4.34	57.6	0.73	4.93	47.6	0.77	5.66
150	90.0	0.65	3.82	75.2	0.68	4.35	61.6	0.73	4.94	50.9	0.77	5.67
160	95.8	0.65	3.82	80.0	0.68	4.36	65.6	0.73	4.94	54.2	0.77	5.68
170	101.6	0.65	3.82	84.8	0.68	4.37	69.5	0.73	4.97	57.5	0.77	5.69
180	107.3	0.65	3.84	89.7	0.68	4.36	73.5	0.73	4.96	60.8	0.77	5.69
190	113.0	0.65	3.84	94.4	0.68	4.38	77.4	0.73	4.98	64.0	0.77	5.71
200	118.7	0.65	3.85	99.2	0.68	4.39	81.4	0.73	4.97	67.3	0.77	5.71
220	130.3	0.65	3.85	108.9	0.68	4.39	89.3	0.73	4.99	73.9	0.77	5.72
240	141.8	0.65	3.86	118.6	0.68	4.40	97.3	0.74	4.99	80.5	0.77	5.72
260	153.3	0.65	3.87	128.2	0.68	4.40	105.2	0.74	5.00	87.0	0.77	5.74
280	164.8	0.65	3.87	137.8	0.68	4.41	113.1	0.74	5.00	93.5	0.77	5.76
300	176.1	0.65	3.88	147.4	0.69	4.41	120.9	0.74	5.02	100.1	0.78	5.75

4-28,467 5-68

USDA-SCS-FORT WORTH, TEX 1968

' Parabolic waterway design
(Retardance "D" and "C")

(Sheet 13 of 14)

Exhibit 6

V_1 for **RETARDANCE "D"**. Top Width (T), Depth (D) and V_2 for **RETARDANCE "C"**.

Grade 10.0 Percent

Q cfs	V_1 = 2.0			V_1 = 2.5			V_1 = 3.0			V_1 = 3.5			V_1 = 4.0			V_1 = 4.5			V_1 = 5.0			V_1 = 5.5			V_1 = 6.0		
	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2	T	D	V_2
15	45.2	0.43	1.14	32.5	0.45	1.50	22.9	0.49	1.98	16.6	0.52	2.56	13.4	0.55	2.99	10.7	0.58	3.55	9.0	0.61	3.99	7.4	0.65	4.57	6.2	0.70	5.08
20	60.1	0.43	1.14	43.2	0.45	1.50	30.4	0.49	2.00	22.1	0.52	2.56	17.8	0.55	3.02	14.3	0.59	3.52	12.0	0.61	4.00	9.9	0.65	4.55	8.3	0.70	5.06
25	74.8	0.43	1.15	53.8	0.45	1.51	37.9	0.49	2.00	27.5	0.52	2.59	22.3	0.55	2.99	17.8	0.58	3.56	14.9	0.61	4.08	12.3	0.65	4.63	10.3	0.69	5.18
30	89.3	0.43	1.15	64.2	0.45	1.52	45.3	0.49	2.01	33.0	0.52	2.58	26.6	0.55	3.03	21.3	0.58	3.58	17.9	0.61	4.05	14.7	0.64	4.68	12.4	0.70	5.13
35	103.7	0.43	1.16	74.6	0.45	1.53	52.6	0.48	2.03	38.3	0.52	2.60	31.0	0.55	3.02	24.8	0.58	3.59	20.8	0.61	4.09	17.2	0.65	4.63	14.4	0.69	5.19
40	118.0	0.43	1.16	85.0	0.46	1.53	59.9	0.48	2.04	43.7	0.52	2.60	35.3	0.55	3.04	28.3	0.58	3.59	23.8	0.61	4.06	19.6	0.65	4.66	16.4	0.69	5.24
45	132.2	0.43	1.17	95.2	0.45	1.53	67.2	0.49	2.04	49.0	0.52	2.61	39.6	0.55	3.05	31.7	0.58	3.62	26.7	0.61	4.08	22.0	0.65	4.68	18.4	0.69	5.27
50	146.3	0.43	1.17	105.3	0.45	1.54	74.4	0.49	2.04	54.3	0.52	2.61	43.9	0.55	3.05	35.2	0.58	3.61	29.6	0.61	4.09	24.4	0.65	4.68	20.4	0.69	5.28
55	160.2	0.43	1.17	115.4	0.46	1.55	81.5	0.49	2.06	59.5	0.52	2.63	48.2	0.55	3.05	38.6	0.58	3.62	32.4	0.61	4.13	26.7	0.64	4.74	22.4	0.69	5.29
60	174.0	0.43	1.18	125.3	0.46	1.55	88.6	0.49	2.06	64.7	0.52	2.63	52.4	0.55	3.07	42.0	0.58	3.63	35.3	0.61	4.12	29.1	0.65	4.73	24.4	0.69	5.30
65	187.6	0.43	1.18	135.2	0.46	1.56	95.6	0.49	2.07	69.9	0.52	2.64	56.6	0.55	3.08	45.4	0.58	3.64	38.2	0.61	4.12	31.5	0.65	4.72	26.4	0.69	5.30
70	201.2	0.43	1.19	145.0	0.46	1.57	102.6	0.49	2.08	75.1	0.52	2.64	60.8	0.55	3.08	48.7	0.58	3.66	41.0	0.61	4.14	33.8	0.65	4.75	28.4	0.69	5.29
75	214.6	0.43	1.19	154.7	0.46	1.57	109.6	0.49	2.08	80.2	0.52	2.65	65.0	0.55	3.08	52.1	0.58	3.66	43.8	0.61	4.15	36.2	0.65	4.74	30.3	0.69	5.34
80	227.9	0.43	1.20	164.3	0.46	1.58	116.4	0.49	2.09	85.3	0.52	2.65	69.1	0.55	3.09	55.4	0.58	3.67	46.6	0.61	4.16	38.5	0.65	4.76	32.3	0.69	5.33
90	255.2	0.43	1.20	184.1	0.46	1.58	130.5	0.49	2.10	95.6	0.52	2.67	77.5	0.55	3.11	62.1	0.58	3.69	52.3	0.61	4.17	43.2	0.65	4.78	36.3	0.69	5.33
100	282.4	0.43	1.20	203.7	0.46	1.59	144.5	0.49	2.10	105.9	0.52	2.67	85.9	0.56	3.11	68.8	0.58	3.70	58.0	0.61	4.18	47.9	0.65	4.78	40.2	0.69	5.36
110	309.2	0.43	1.21	223.2	0.46	1.60	158.4	0.49	2.11	116.2	0.52	2.68	94.3	0.56	3.11	75.5	0.58	3.71	63.7	0.61	4.18	52.6	0.65	4.79	44.2	0.69	5.34
120	335.9	0.43	1.21	242.4	0.46	1.60	172.2	0.49	2.12	126.4	0.52	2.68	102.5	0.56	3.12	82.2	0.58	3.71	69.3	0.61	4.19	57.3	0.65	4.79	48.1	0.69	5.36
130	362.3	0.43	1.22	261.6	0.46	1.61	185.9	0.49	2.12	136.5	0.52	2.69	110.8	0.56	3.13	88.8	0.58	3.72	74.9	0.61	4.20	61.9	0.65	4.81	52.0	0.69	5.37
140	388.4	0.44	1.22	280.5	0.46	1.61	199.5	0.49	2.13	146.5	0.52	2.70	119.0	0.56	3.13	95.4	0.58	3.73	80.5	0.61	4.20	66.5	0.65	4.82	55.9	0.69	5.38
150	414.4	0.44	1.23	299.3	0.46	1.62	213.0	0.49	2.13	156.5	0.52	2.71	127.1	0.56	3.14	101.9	0.58	3.74	86.0	0.61	4.22	71.1	0.65	4.83	59.7	0.69	5.41
160	440.1	0.44	1.23	318.1	0.46	1.62	226.5	0.49	2.14	166.4	0.53	2.71	135.2	0.56	3.15	108.4	0.58	3.75	91.6	0.62	4.21	75.7	0.65	4.83	63.6	0.69	5.41
170	465.5	0.44	1.24	336.7	0.46	1.63	239.8	0.49	2.14	176.3	0.53	2.72	143.3	0.56	3.15	114.9	0.58	3.76	97.1	0.62	4.22	80.3	0.65	4.83	67.4	0.69	5.42
180	490.8	0.44	1.24	355.1	0.46	1.63	253.1	0.49	2.15	186.1	0.53	2.73	151.3	0.56	3.16	121.3	0.58	3.77	102.5	0.62	4.24	84.9	0.65	4.83	71.3	0.69	5.42
190	515.7	0.44	1.25	373.5	0.46	1.64	266.3	0.49	2.15	195.9	0.53	2.73	159.3	0.56	3.17	127.7	0.58	3.78	108.0	0.62	4.24	89.4	0.65	4.84	75.1	0.69	5.43
200	540.5	0.44	1.25	391.6	0.46	1.64	279.4	0.49	2.16	205.6	0.53	2.74	167.2	0.56	3.17	134.1	0.58	3.79	113.4	0.62	4.25	93.9	0.65	4.85	78.9	0.69	5.43
220	592.0	0.44	1.26	429.2	0.46	1.65	306.3	0.49	2.17	225.4	0.53	2.75	183.5	0.56	3.18	147.1	0.58	3.80	124.4	0.62	4.26	103.1	0.65	4.85	86.6	0.69	5.45
240	643.0	0.44	1.26	466.4	0.46	1.65	333.1	0.49	2.17	245.2	0.53	2.75	199.6	0.56	3.19	160.0	0.58	3.81	135.4	0.62	4.27	112.2	0.65	4.87	94.3	0.69	5.45
260	693.6	0.44	1.27	503.4	0.46	1.66	359.6	0.49	2.18	264.8	0.53	2.76	215.6	0.56	3.19	172.9	0.58	3.82	146.4	0.62	4.27	121.3	0.65	4.87	101.9	0.69	5.47
280	743.7	0.44	1.27	540.0	0.46	1.66	386.0	0.49	2.18	284.4	0.53	2.77	231.6	0.56	3.20	185.8	0.59	3.82	157.3	0.62	4.28	130.4	0.65	4.88	109.6	0.69	5.47
300	793.4	0.44	1.28	576.4	0.46	1.67	412.3	0.49	2.19	303.8	0.53	2.77	247.5	0.56	3.21	198.6	0.59	3.83	168.1	0.62	4.29	139.4	0.65	4.89	117.2	0.69	5.48

Parabolic waterway design
(Retardance "D" and "C")

(Sheet 14 of 14)

Source: USDA, Soil Conservation Service

Exhibit 7

Establishment Methods Based on Permissible Velocities (V_1)

Establishment Technique	Conditions
1a.Seeding with straw mulch and Tack coat. 2. Establishing bermudagrass by sprigging	1. Slopes less than 5% 2. Velocity less than 3 feet per second. 3. Majority of drainage can be diverted from channel during establishment. 4. Erosion-resistant soils
3.Seeding with straw mulch and jute mesh or erosion netting.	1. Slopes less than 5% 2. Velocity less than 5 feet per second 3. Majority of drainage cannot be diverted away from channel during establishment. 4. Moderately erodible soil.
4.Sodding	1. Slopes greater than 5% 2. Velocity between 5 fps and 6 fps 3. Majority of drainage cannot be diverted away from channel during establishment. 4. Highly erodible soils.

1. Seeding with straw mulch and tack coat. Seeding should be done in accordance with Seeding specifications. Mulching should be done in accordance with the Mulching specifications.

2. Sprigging with Bermuda grass. Sprigging is described in the Trees, Shrubs and Ground Covers BMP. Divert as much runoff away from the drainageway as possible until the grass is established.

3. Seeding with straw mulch and or erosion netting. Seed according to Seeding specifications. Mulch and apply an erosion control blankets following specifications in the Mulching BMP.

4. Sodding. Sodding should be done in accordance with Sodding specifications.

Source: Modified from the Virginia SESC.

Riprap

Definition

Riprap is a permanent cover of rock used to stabilize streambanks, provide in-stream channel stability, and provide a stabilized outlet below concentrated flows.

This BMP addresses using riprap to stabilize streambanks, line channels and provide stable outlets. For purposes of this BMP, "rock" can be used interchangeably with "stone". For information on designing various types of stream liners (including vegetation and riprap), see the Stormwater Conveyance Channel BMP.

All work conducted below the ordinary high water mark of a lake or stream, or in a floodplain or wetland will require permits from the Michigan Department of Environmental Quality, Land and Water Management Division. This includes the placement of riprap. (See Exhibit 1 for a definition of ordinary high water mark).

Other Terms Used to Describe

Armoring
Energy Dissipator

Pollutants Controlled and Impacts

The use of riprap in channels and below concentrated flows protects stream banks and discharge channels from higher erosive flow velocities. This reduces downcutting and lateral cutting, which in turn decreases sediment input to a watercourse.

Application

Land Use
All land uses.

Soil/Topography/Climate
The rock to be used as riprap must be capable of withstanding freezing and thawing and the flow or wave action of the water where it is used. The soil texture on the site and whether seepage is occurring are factors in determining the need and thickness of filters beneath the riprap.

When to Apply
Riprap used at outlets should be in place before the outlet is discharging. Streambank grading should be done when it is most feasible to bring stone to the site. Riprap should be placed as soon after grading as possible.

Where to Apply
Riprap is most often used in streambanks, on slopes, and at outlets.

Relationship With Other BMPs

Riprap is often used in making Stabilized Outlets, in Streambank Stabilization (including bioengineering techniques), and Slope/Shoreline Protection. Filters should be used underneath riprap to help stabilize the soils.

Specifications

General Considerations:

Riprap structures should be designed by licensed professional engineers or other persons qualified in the design of such structures.

Stone Type

The material used for riprap should be fieldstone or rough unhewn quarry stone. Stone should be hard, angular, and of such quality that it will not disintegrate on exposure to water or weathering. It should also be chemically stable, capable of withstanding freezing and thawing, and suitable in all other respects for the intended use.

Because it is not as aesthetically pleasing as rock, broken concrete is a less favorable riprap alternative. If concrete is used, it should be clean and otherwise meet design criteria. Asphalt should *not* be used as riprap.

Riprap Size

Riprap comes in a variety of sizes. The appropriate size to use primarily depends on the intended use of the structure. For example, the size of riprap used to stabilize streambanks depends on the velocity of the water.

Structural design is usually based on the diameter of stone in the mixture for which a percentage, by weight, will be smaller. For example, D_{50} indicates a mixture of stones in which 50 percent of the stone by size would be larger than the diameter specified, and 50% would be smaller than the stone size specified. In other words, the design is based on the average size of stone in the mixture.

Table 1 lists some typical riprap by weight, spherical diameter and corresponding rectangular dimensions. These stone sizes are based on an assumed specific weight of 165 lbs./ft^3.

Table 1
Size of Typical Riprap Stones

	Mean Spherical	Typical Rectangular Shape	
Weight (lbs)	Diameter (in)	Length (in)	Width, Height (in)
50	10	18	6
100	13	21	7
150	14	24	8
300	18	30	10
500	22	36	12
1000	27	45	15
1500	31	52	17
2000	34	57	19
4000	43	72	24
6000	49	83	28
8000	54	90	30

Source: USDA Soil Conservation Service

Gradation

Riprap should be composed of a well-graded mixture down to the one-inch size particle such that 50 percent of the mixture by weight is larger than the D_{50} size as determined from the design procedure. For the purposes of this BMP, a well-graded mixture is defined as a mixture composed primarily of the larger stone sizes but with a sufficient mixture of other sizes to fill the progressively smaller voids between the stones. The diameter of the largest stone size in such a mixture should not be more than 1.5 times the D_{50} stone size.

After determining the riprap size that will be stable under the flow conditions, the designer should consider that size to be a minimum size and then, based on riprap gradations actually available in the area, select the size or sizes that equal or exceed the minimum size.

Riprap structures for **streambank stabilization** should be designed to be stable for bank-full flows in the reach of the channel being stabilized.

Thickness

For both streambank stabilization and outlets, the minimum thickness of the riprap layer should be 1.5 times the D_{50} diameter, or 6 inches, whichever is greater. **A geotextile or stone filter must be placed under the riprap to prevent water from removing the underlying soil material through the voids in the riprap.** (Removal of the soil material leaves cavities behind the riprap and failure of the riprap may result). The filter may consist of smaller sized stone (usually 2"), a geotextile material, or a combination of both. Stone filters should be a minimum of 6 inches thick, and greater if the area has high seepage pressures. Follow the specifications below.

Granular (Stone) Filter Blanket. For dumped riprap, a filter ratio of 5 or less between successive layers will result in a stable condition. The filter ratio is defined as the ratio of D_{15} size of the coarser layer to the D_{85} size of the finer layer. An additional requirement for stability is that the ratio of the D_{15} size of the coarse material to the D_{15} size of the fine material should exceed 5 and be less than 40. A further requirement is that the ratio of the D_{50} size of the coarse material to the D_{50} size of the fine material not exceed 40. These requirements can be stated as follows:

$$\frac{D_{15}\text{ (coarser layer)}}{D_{85}\text{ (finer layer)}} < 5 < \frac{D_{15}\text{ (coarser layer)}}{D_{15}\text{ (finer layer)}} < 40$$

$$\frac{D_{50}\text{ (coarser layer)}}{D_{50}\text{ (finer layer)}} < 40$$

The filter requirements apply between the bank material and the filter blanket, between successive layers of filter blanket material if more than one layer is used, and between the filter blanket and the stone cover.

If a single layer of filter material will not satisfy the filter requirements, one or more additional layers of filter material must be used. In addition to the filter requirements, the grain size curves for the various layers should be approximately parallel to minimize the infiltration of the fine material into the coarser material. Not more than 5 percent of the filter material should pass the No. 200 sieve.

The minimum thickness of each layer of granular filter material shall be 6 inches, or 3 times the D_{50} size of the filter, whichever is greater.

Synthetic (Geotextile) Filter Fabric. The Filters BMP includes information on geotextile materials which may be used may be used in place of or in conjunction with granular filters. Always check manufacturer's specifications to ensure that the filter fabric selected meets the tensile strength and

durability requirements for the determined rock size. Some guidance in selecting filter fabric is given below.
The following particle size relationships must exist:

For filter fabric adjacent to granular materials containing 50 percent or less (by weight) of fine particles (less than 0.075 mm):

a) $\frac{D_{85} \text{ base (mm)}}{\text{EOS* filter fabric (mm)}} > 1$

b) Total open area of filter fabric is less than 36 percent.

For filter fabric adjacent to all other soils:

a) EOS less than U.S. Standard Sieve No. 70.

b) Total open area of filter is less than 10 percent.

*Equivalent Opening Size to a US Standard Sieve Size

No filter fabric should be used with less than 4 percent open area or an EOS smaller than U.S. Standard Sieve No. 100.

Stream Bank Protection and Channel Lining

See Exhibit 1 for applications.

General Planning Considerations:

1. Slopes on which riprap is used to stabilize streambanks should be no steeper than 1.5:1.

2. All bare soil on the slope above the riprap should be stabilized with seed and mulch, or sod. See the Vegetative BMPs.

3. When riprap is used in conjunction with other vegetative practices or bioengineering, the riprap should extend 1 foot above the ordinary high water mark. When only riprap is being used for bank stabilization, the top of the riprap should extend 3 feet above the ordinary high water mark. See Exhibit 1 for an explanation of the ordinary high water mark.

4. Determine a means of accessing the site before designing any riprap structure.

5. Determine how the riprap will be placed on the site. If the rock is to be dumped, it must be done in a manner which will not cause separation of the small and large stones. If rock is to be dumped over a bank and placed by hand, it must be done so that it does not create more erosion. Consider using aluminum or wooden shutes to roll rock down a bank to the waters' edge.

6. If riprap placement requires re-configuring banks or slopes, the filter should be placed as soon after the banks are prepared as possible. Placement of riprap should follow immediately after the placement of the filter.

7. The finished surface should not have pockets of finer materials which would flush out and

weaken the structure. Some hand placing should be done to provide a stable surface.

8. Riprap used both at the outlet of storm sewers <u>and</u> to protect an eroding bank, should be designed to accommodate both uses. Riprap used as outlet protection should be constructed before the pipe or channel begins to operate.

Design:

Stone Size Selection for Streambank Stabilization:

The design method described below is adapted from *Design of Stable Channels with Flexible Linings, Hydraulic Engineering Circular No. 15* of the Federal Highway Administration. It is applicable to both straight and curved sections of channel where the flow is not perpendicular to the bank of the channel.

A. Straight Sections of Channel.

This design method determines a stable rock size for straight and curved sections of channels. It is assumed that the shape, depth of flow, and slope of the channel are known. A stone size is chosen for the maximum depth of flow. If the sides of the channel are steeper than 3:1, the stone size must be increased accordingly. The final design size will be stable on both sides of the channel and the bottom.

1. Enter Exhibit 3 with the maximum depth of flow (feet) and channel slope (feet/foot). Where the two lines intersect, choose the d_{50} size of stone.

2. If channel side slopes (z) are steeper than 3:1, continue with step 3, if not, the procedure is complete.

3. Enter Exhibit 4, with the side slope and the base width to maximum depth ratio (B/d). Where the two lines intersect, move horizontally left to K1. Record K1.

4. Determine from Exhibit 5, the angle of repose (Ar) for the d_{50} size of stone. The angle of repose is the angle in which the rocks will lay in relation to the bank. Banks should be designed so that the natural angle of repose of the stone mixture is greater than the slope of the bank being stabilized. (Use Ar=42° for d_{50} greater than 1.0 ft. Do not use riprap on slopes steeper than the angle of repose for the size of stone.)

5. Enter Exhibit 6, with the side slope (z) of the channel and the angle of repose (Ar) for the d_{50} size of stone. Where the two lines intersect, move vertically down to read K2. Record K2.

6. Compute $d'_{50} = d_{50} \times K1/K2$, where d'_{50} is to determine the correct size stone for the bottom and side slopes of straight sections of channel.

B. Curved Sections of Channel

1. Compute the radius of the curve (Ro), measured at the outside edge of the bottom.

2. Compute the ratio of the top width of the water surface (Bs) to the radius of the curve (Ro), Bs/Ro.

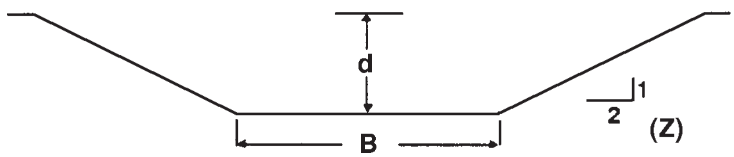
3. Enter Exhibit 7, with the ratio Bs/Ro. Move vertically until the curve is intersected.

Move horizontally left to read K3.

4. Compute $d_{50c} = d'_{50} \times K3$, where d_{50c} is the correct size stone for bottom and side slopes of curved sections of channel.

C. <u>Design Example Problems</u>:

Problem #1
Given: A trapezoidal channel 3 feet deep (d), with an 8-foot bottom (B), 2:1 side slopes (z), and a 2 percent slope. **Calculate**: A stable riprap size for the bottom (B) and side slopes (z) of the channel.



Solution:

1. From Exhibit 3, for a 3-foot deep channel on a 2 percent grade: $d_{50} = 0.75$ feet or 9 inches.

2. Since the side slopes (z) are steeper than 3:1, continue with Step 3.

3. From Exhibit 4 for B/d = 2.67 and z = 2; K1 = 0.8

4. From Exhibit 5 for $d_{50} = 9$ inches; Ar = 41°

5. From Exhibit 6 for z = 2 and Ar = 41°; K2 = 0.75

6. $d'_{50} = d_{50} \times K1/K2 = 0.75 \times 0.8/0.75 = 0.8$ feet

   0.8 ft x 12 inches = 9.6 inches

   Use $d'_{50} = 10$ inches

Problem #2
Given: The preceding channel in Problem #1 has a curved section with a radius of 50 feet at the outside edge of the bottom. **Calculate**: A stable riprap size for the bottom and side slopes of the curved section of channel.

Solution:

1. Radius of curvature, Ro = 50 feet

2. Top width at water surface,

   Bs = 8 +(2 x 3 x 2) = 20 feet

   Bs/Ro = 20/50=0.40

3. From Exhibit 7 for Bs/Ro = 0.40; K3 = 1.1

4. $d_{50c} = d'_{50} \times K3 = 0.84 \times 1.1 = 0.92$ feet

   Use d_{50c} = 1.0 ft = 12 inches

Length/Thickness/Height of Streambank Area to be Riprapped
Refer back to page RIP-3 for specifications on the proper thickness.

Length: The appropriate length of channel in which rock should be placed should be at least the entire eroded section that is being protected, plus a minimum of 10 feet upstream and downstream of the eroded area. Be sure that the stone on the upstream and downstream ends are trenched in to prevent dislodging.

Where riprap is used only for slope or bank protection and does not extend across the bottom at the channel, riprap should be "keyed in" as shown in Exhibit 2.

Height: Install riprap to a height of three feet above the ordinary high water mark, or 1 foot above the ordinary high water mark if used in conjunction with bioegineering techniques. All exposed soil above the riprap should be stabilized according to the vegetative BMPs.

Design Example Problem:
A streambank has an ordinary high water mark of 3 feet, an 8 foot bottom width, 2:1 side slopes and a two percent slope. There is a 75 foot long curved bank that is eroding. Determine the proper rock size, appropriate stone gradation, and dimensions of the riprap.

1. Refer to example Problems #2 to solve for the proper stone size. Use a D_{50} stone size of 12 inches.

2. This riprap will be placed to a height of 6 feet (3 feet above the ordinary high water mark). The depth will be 24 inches: [1.5 x (stone size of 12 inches) = 18 inches + 0.5 foot granular stone = total of 24 inches].

3. The length of area covered with riprap will be the eroded area (75 feet) + 10 feet upstream and downstream = 95 feet.

4. A geotextile fabric will be installed beneath the riprap.

Construction:

1. Where grading is required, grade the site according to the grading plan. Grade only when stone is ready to be placed.

2. Compact gravel subgrades according to design. Any fill that is used should be compacted to a density approximating that of the surrounding undisturbed area.

3. Install geotextile filter fabrics according to the manufacturer's specification. Always bury both the upper-most and toe of the geotextile fabric to prevent unravelling. (Basic installa-

tion techniques are discussed in the Filters BMP. Spread granular filters in uniform layers according to the design.

4. Install riprap. If riprap is dumped, hand place any rocks that need to be moved to fit the design.

Maintenance of Riprap on Stream Banks

Inspections should be made of all sites immediately after the first rainfall following installation of riprap. This is particularly important in areas where riprap that is displaced during the storm would impact culverts. Thereafter, riprapped sites should be checked following large storms, especially those which are near or exceed the storm frequency used in the design. Displaced riprap should be removed from its downstream location and new riprap placed according to the specifications above.

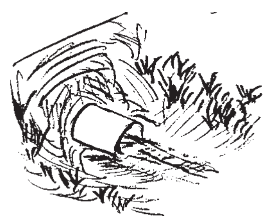
Outlets

General Considerations for Outlets

1. How and when to use a riprapped outlet should be made based on criteria given in the Stabilized Outlets BMP.

2. The outlet structure should be designed in conjunction with the conveyance system (i.e. pipe, outlet of a Sediment Basin, etc.) from which the water is outletted. There should be no overfall from the end of the pipe/outlet to the outlet structure (i.e. the pipe/outlet should not be suspended above the outlet structure).

overfall



no overfall

3. The outlet structure should be in place before water is released from the conveyance system.

4. Additional protection may be required on the opposite bank or downstream to prevent instream erosion.

5. There should be no overfall from the end of the apron to the receiving channel streambed.

Stone Size Selection for Outlets

1. The median stone diameter, d_{50}, in feet, shall be determined from the formula:

$$d_{50} = \frac{0.02}{TW}\left(\frac{Q}{D_o}\right)^{4/3}$$

Where TW is tailwater depth above the invert of the culvert in feet, Q is the pipe discharge in cfs for the conduit design storm, or the 25-year storm, whichever is greater, and

D_o is the maximum inside culvert width in feet.

2. Fifty percent by size of the riprap mixture should be larger than the median size stone designated as d_{50} and 50% should be smaller. The largest stone size in the mixture should be 1.5 times the d_{50} size. The riprap should be reasonably well-graded.

<u>Outlet Dimensions</u>
Refer to Exhibit 8.

1. **Length**: The length of the apron, L, should be determined using the following formula:

$$L_a = \frac{1.7\,Q}{D_o^{3/2}} + 8D_o \quad \text{for culverts flowing up to 1/2 full.}$$

$$L_a = \frac{3.0\,Q}{D_o^{3/2}} \quad \text{for culverts flowing at or above 1/2 full}$$

Where Q and D_o are as described above.

2. **Width**: Where there is a well-defined channel downstream of the apron, the bottom width of the apron should be at least equal to the bottom width of the channel. The structural lining should extend at least one foot above the tailwater elevation, but no lower than two-thirds of the vertical conduit dimension above the conduit invert.

Where there is *no* well-defined channel immediately downstream of the apron (i.e. as may apply to <u>Sediment Basins</u>) width, W, of the outlet end of the apron should be as follows:

For tailwater elevation greater than or equal to the elevation of the center of the pipe:

$$W = 3D_o + 0.4L_a$$

For tailwater elevation less than the elevation of the center of the pipe:

$$W = 3D_o + L_a$$

Where L_a is the length of the apron determined from the formula above and D_o is the culvert width.

The width of the apron at the culvert outlet should be at least three times the culvert width.

3. The side slopes should be 2:1 or flatter.

4. The bottom grade should be level (0.0%).

5. There should be no overfall from the end of the apron to the receiving channel streambed.

6. There should be no overfall at the end of the apron or at the end of the culvert.

7. There should be no bends or curves at the intersection of the conduit and apron.

Stone Size and Gradation

1. The median stone diameter, D_{50}, in feet shall be determined from the formula,

$$D_{50} = \frac{0.02}{TW}\left(\frac{Q}{D_o}\right)^{4/3}$$

   Where Q and D_o are as defined under apron dimensions and TW is tailwater depth above the invert of culvert in feet.

2. The largest stone size in the mixture shall be 1.5 times the D_{50} size. The riprap shall be reasonably well graded.

3. Gabions or precast cellular blocks may be substituted for riprap if the D_{50} size calculated above is less than or equal to the thickness of the gabions or concrete revetment blocks. See the Shoreline/Slope Stabilization BMP.

Design Example Problem:

Given: a maximum inside culvert width, D_o of 1.5 ft., a flow (Q) of 14/5 cfs, and a tailwater elevation, TW, of 0.7 feet, determine the appropriate design dimensions of the apron (h_a and W), and the D_{50} stone size.

Solution:

Using $L_a = \frac{1.7Q}{D_o^{3/2}} + 8D_o$

$$= \frac{1.7\,(14.5)}{(1.5)^{3/2}} + 8(1.5)$$

L_a = 25.4 feet, rounded up = 26 feet

Since TW < 0.5 D_o , use W = $3D_o + L_a$

$$= 3(1.5) + 26$$

W = 30.5 feet, rounded up = 31 feet

Using $D_{50} = \frac{0.02}{TW}\left(\frac{Q}{D_o}\right)^{4/3}$

$$= \frac{0.02}{0.7}\left(\frac{14.5}{1.5}\right)^{4/3}$$

D_{50} = 0.58 feet, converted and rounded = 7 inches

Maintenance

Inspections should be made of all sites immediately after the first rainfall following installation of riprap. This is particularly important in areas where riprap that is displaced during the storm would impact culverts. Thereafter, riprapped sites should be checked following large storms, especially those which are near or exceed the storm frequency used in the design. Displaced riprap should be removed from its downstream location and new riprap placed according to the specifications above.

Exhibits

Formulas included in this BMP were taken from the Rhode Island Soil Erosion and Sediment Control Handbook, Rhode Island Dept. of Env. Mgt., 1989.

Exhibit 1: Streambank stabilization using Riprap. MDNR Construction Project Evaluation Manual, 1987, and Rhode Island Soil Erosion and Sediment Control Handbook, as adopted from Connecticut Guidelines for Soil Erosion and Sediment Control, Connecticut Council on Soil and Water Conservation, 1985.

Exhibit 2: Length and Height of Riprap. MDEQ, Surface Water Quality Division.

Exhibit 3: Maximum depth of Flow for Riprap-lined Channels. "Design of Stable Channels with Flexible Linings", Hydraulic Engineering Circular No. 15, Federal Highway Administration, 1975.

Exhibit 4: Distribution of Boundary Shear Around Wetted Perimeter of Trapezoid Channels. "Design of Stable Channels with Flexible Linings", Hydraulic Engineering Circular No. 15, Federal Highway Administration, 1975.

Exhibit 5: Angle of Repose for Riprap Stone. Virginia Erosion and Sediment Control Handbook, Virginia Soil and Water Conservation Commission, 1980.

Exhibit 6: Ratio of Critical Shear on Sides to Critical Shears on Bottom. "Design of Stable Channels with Flexible Linings", Hydraulic Engineering Circular No. 15, Federal Highway Administration, 1975.

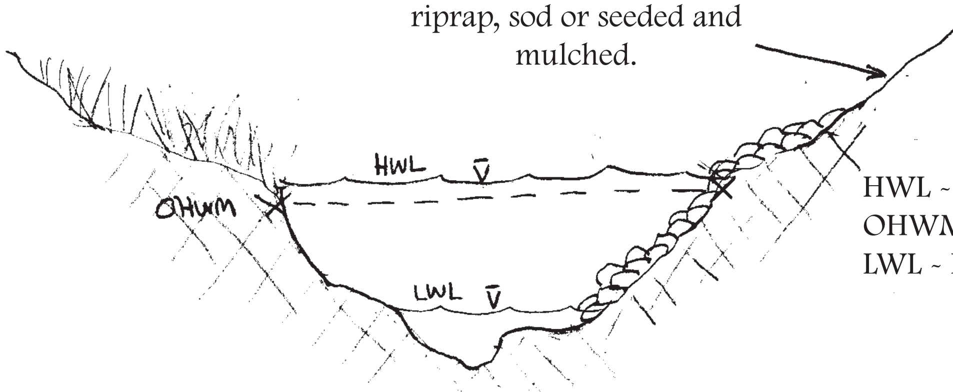
Exhibit 7: Ratio of Maximum Boundary Shear in Bends to Maximum Bottom Shear in Straight Reaches. Virginia Erosion and sediment Control Handbook, Virginia Soil and Water Conservation Commission, 1980.

Exhibit 8: Configuration of Conduit Outlet Protection where there is no well defined channel downstream. Standards for Soil Erosion and Sediment Control in New Jersey, New Jersey Soil Conservation Committee, 1980.

Exhibit 1

Ordinary High Water Mark

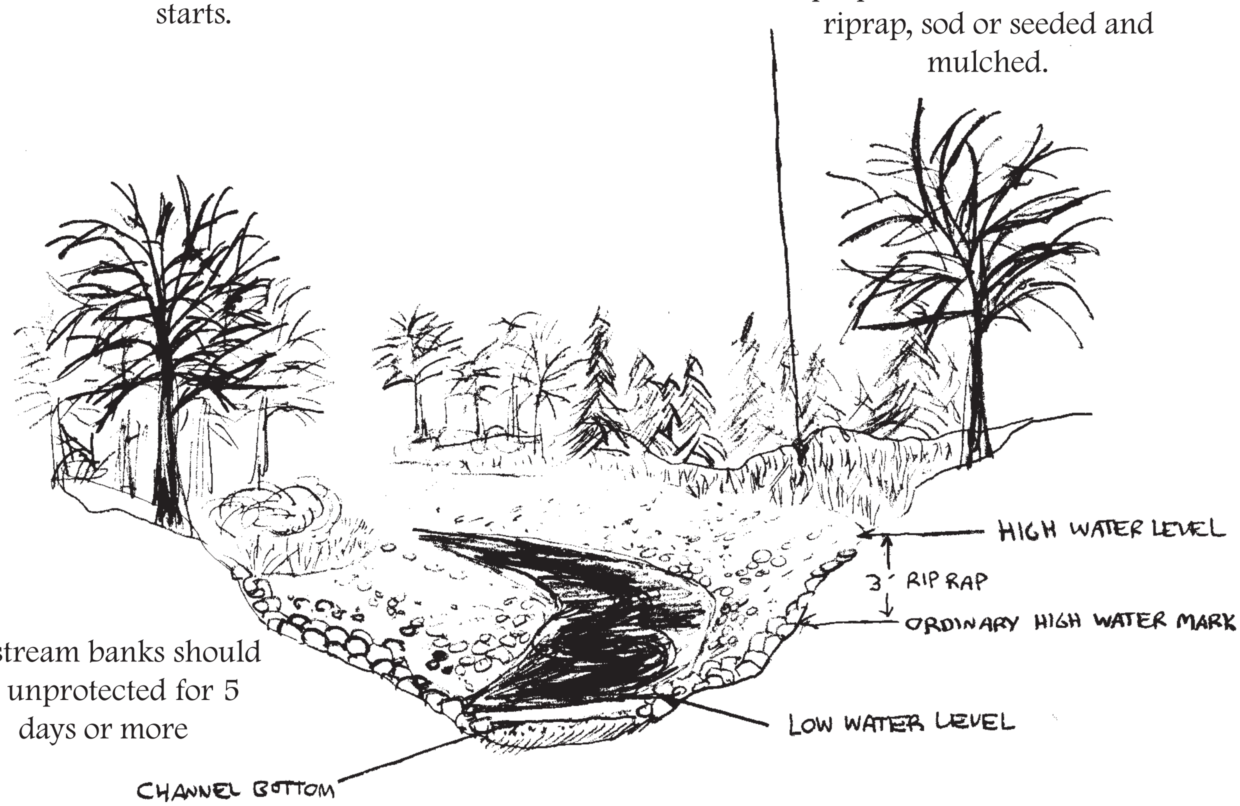
All raw soil above permanent riprap should be covered with riprap, sod or seeded and mulched.



HWL - High Water Level
OHWM - Ordinary High Water Mark
LWL - Low Water Mark

The ordinary high water mark is the normal water level, which on a river is where the grass stops and the bare soil starts.

All raw soil above permanent riprap should be covered with riprap, sod or seeded and mulched.

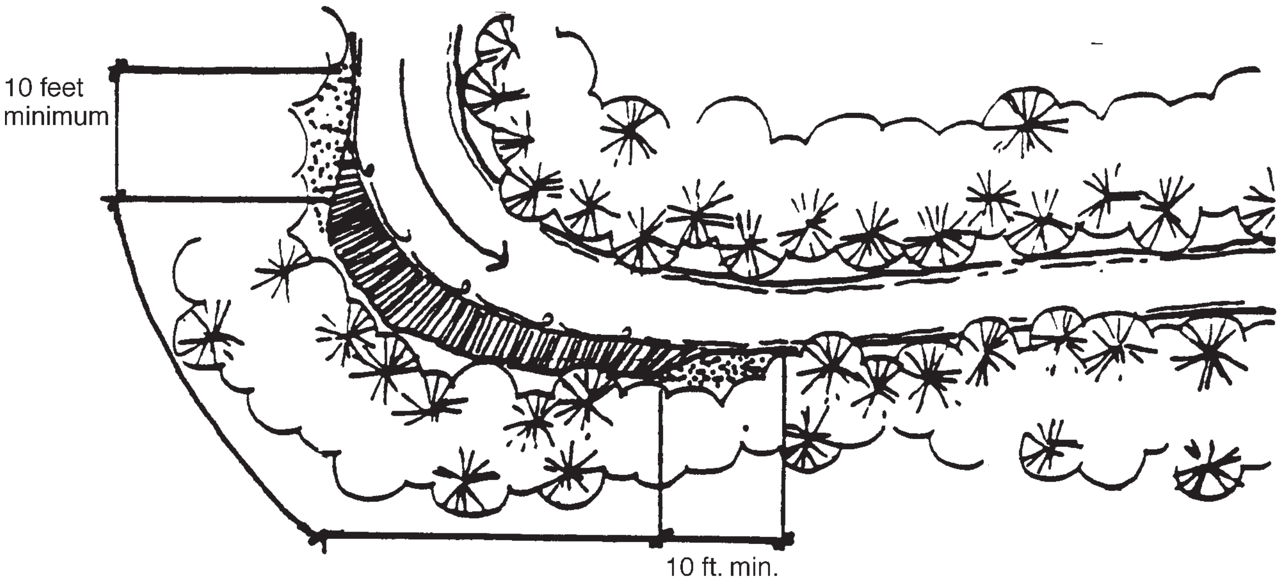


No stream banks should be unprotected for 5 days or more

Source: Michigan Department of Environmental Quality, Land and Water Management Division, 1997.

Exhibit 2

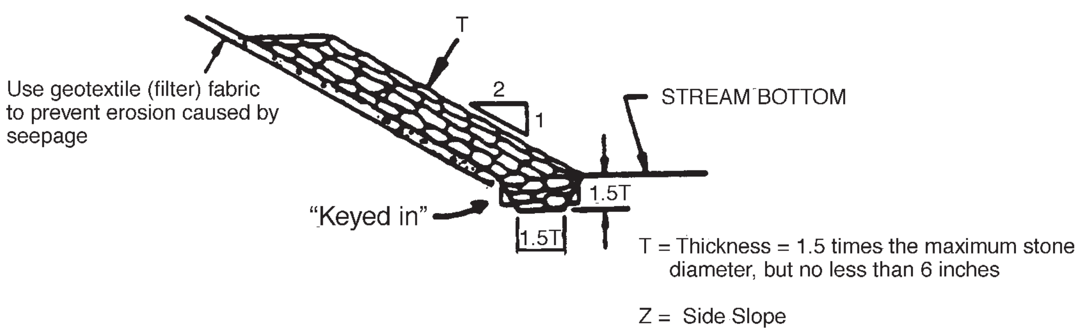
Riprap Placement: Length, Thickness, Height



Length to stabilize: cut bank, plus a minimum of 10 feet on both sides.

Height to stabilize: usually three feet above the Ordinary High Water Mark; can be less on hydrologically stable streams.

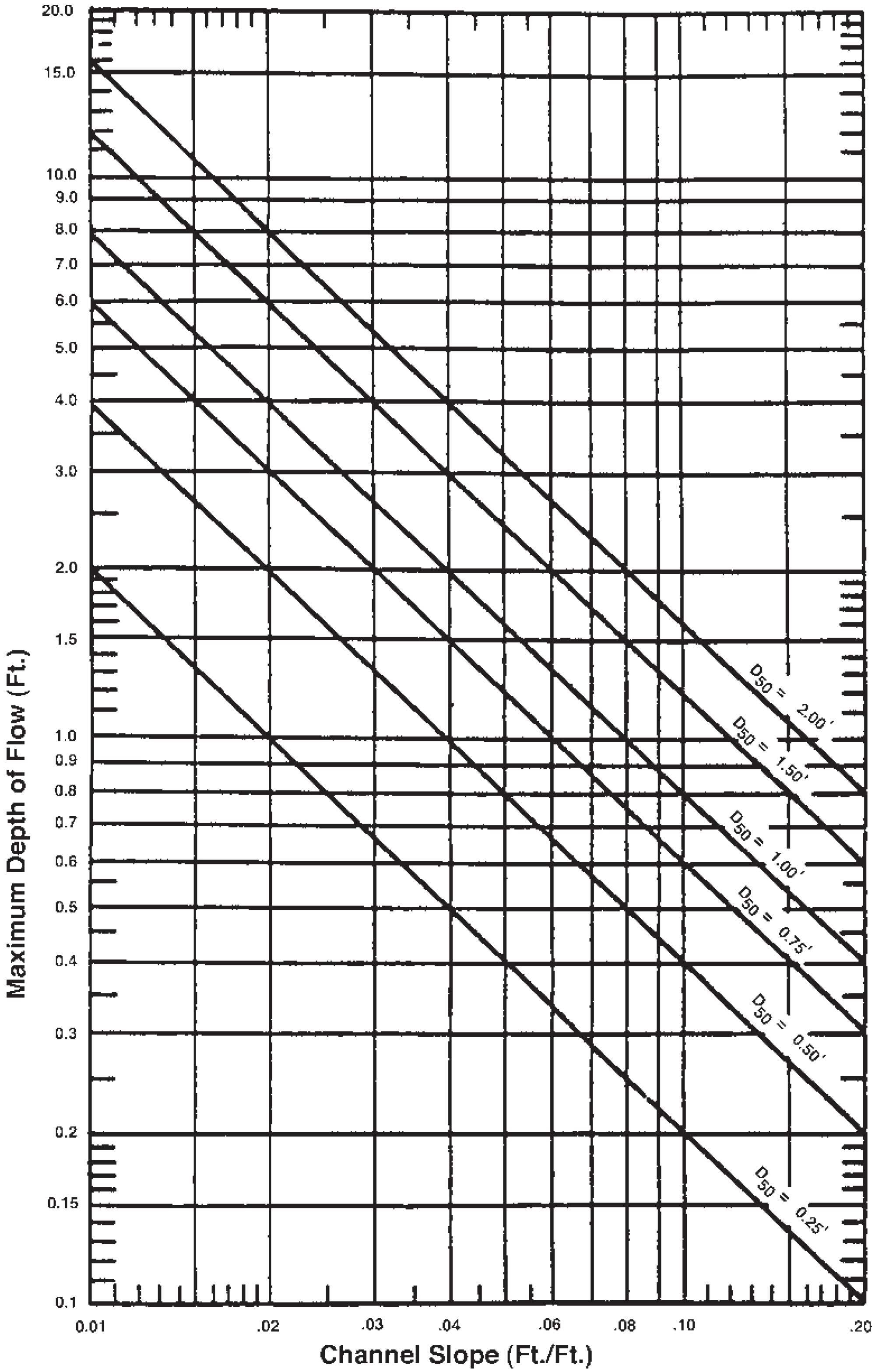
"Keying in"



Sources: Top: Construction Project Evaluation Manual. Michigan Department of Environmental Quality, Land and Water Mangement Division. Redrawn 1997. Bottom: Rhode Island Soil Erosion and Sediment Control Handbook, as adopted from the Connecticut Guidelines for Soil Erosion and Sediment Control, Connecticut Council of Soil and Water Conservation, 1985. Redrawn 1997 by MDEQ.

Exhibit 3

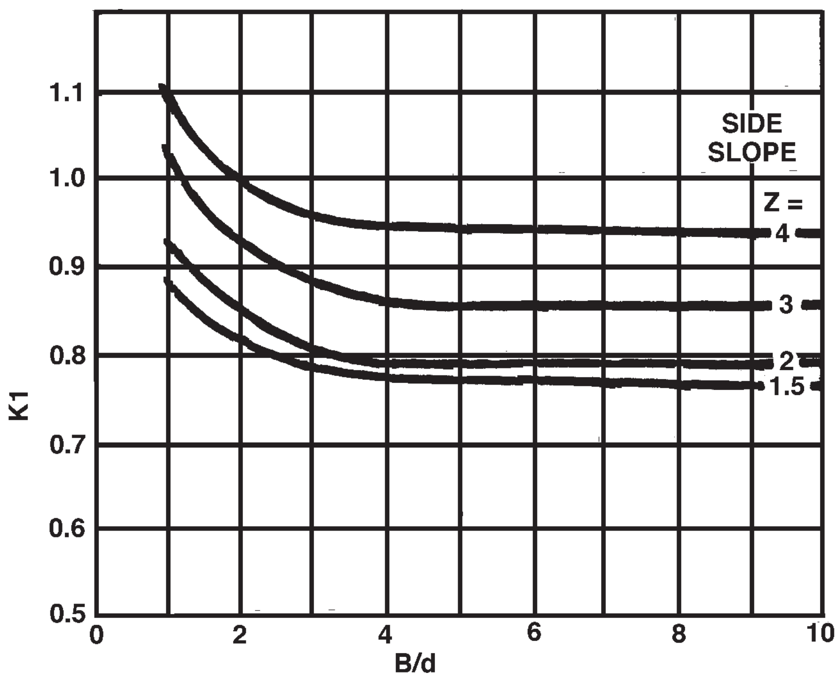
Maximum Depth of Flow for Riprap-Lined Channels



Source: Design of Stable Channels with Flexible Linings, Hydraulic Engineering Circular No. 15, Federal Highway Administration, 1975, as copied from the Rhode Island Soil Erosion and Sediment Control Handbook.

Exhibit 4

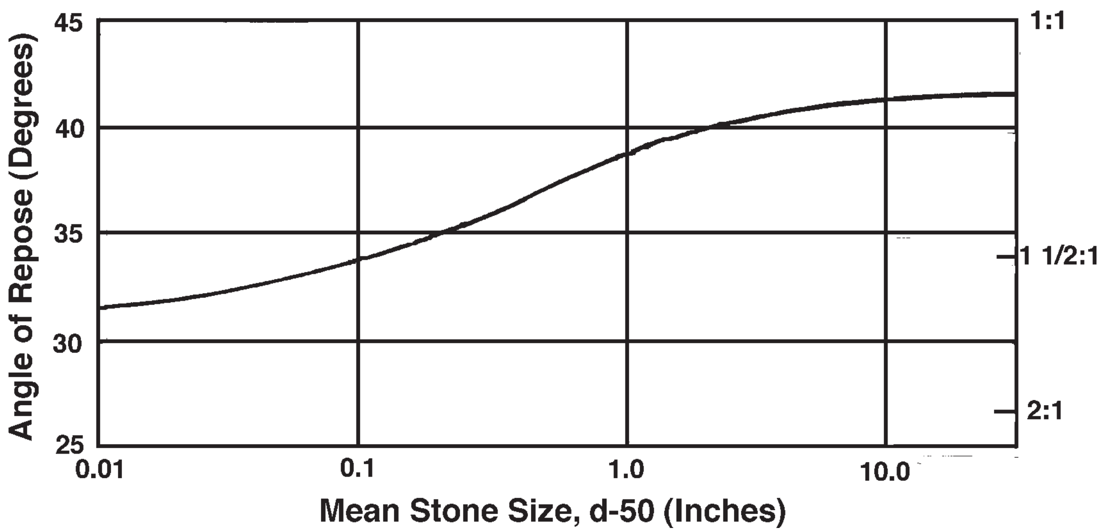
Distribution of Boundary Sheer Around Wetted Perimeter of Trapezoidal Channels



Source: Design of Stable Channels with Flexible Linings, Hydraulic Engineering Circular No. 15, Federal Highway Administration, 1975, as copied from the Rhode Island Soil Erosion and Sediment Control Handbook.

Exhibit 5

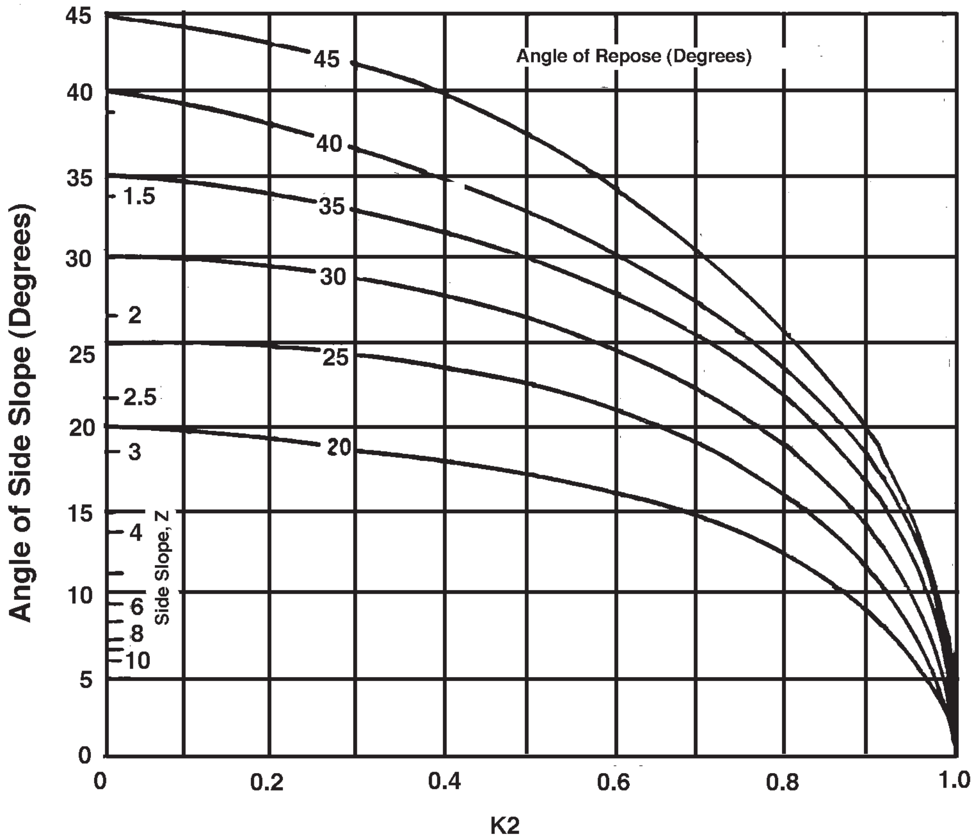
Angle of Repose for Riprap Stones



Source: Virginia Erosion and Sediment Control Handbook, Virginia Soil and Water Conservation Commission, 1980, as copied from the Rhode Island Soil Erosion and Sediment Control Handbook.

Exhibit 6

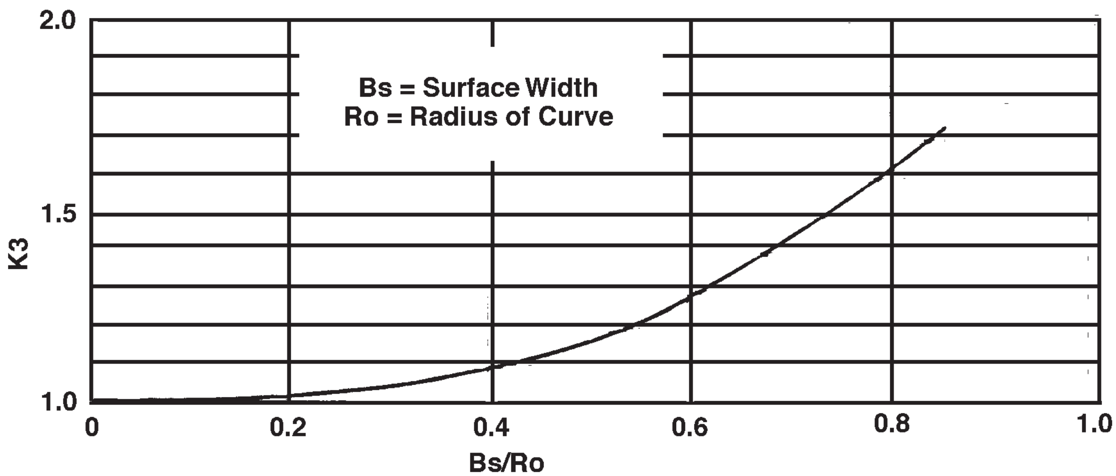
Ratio of Critical Shear on Sides to Critical Shear on Bottom



Source: Design of Stable Channels with Flexible Linings, Hydraulic Engineering Circular No. 15, Federal Highway Administration, 1975, as copied from the Rhode Island Soil Erosion and Sediment Control Handbook.

Exhibit 7

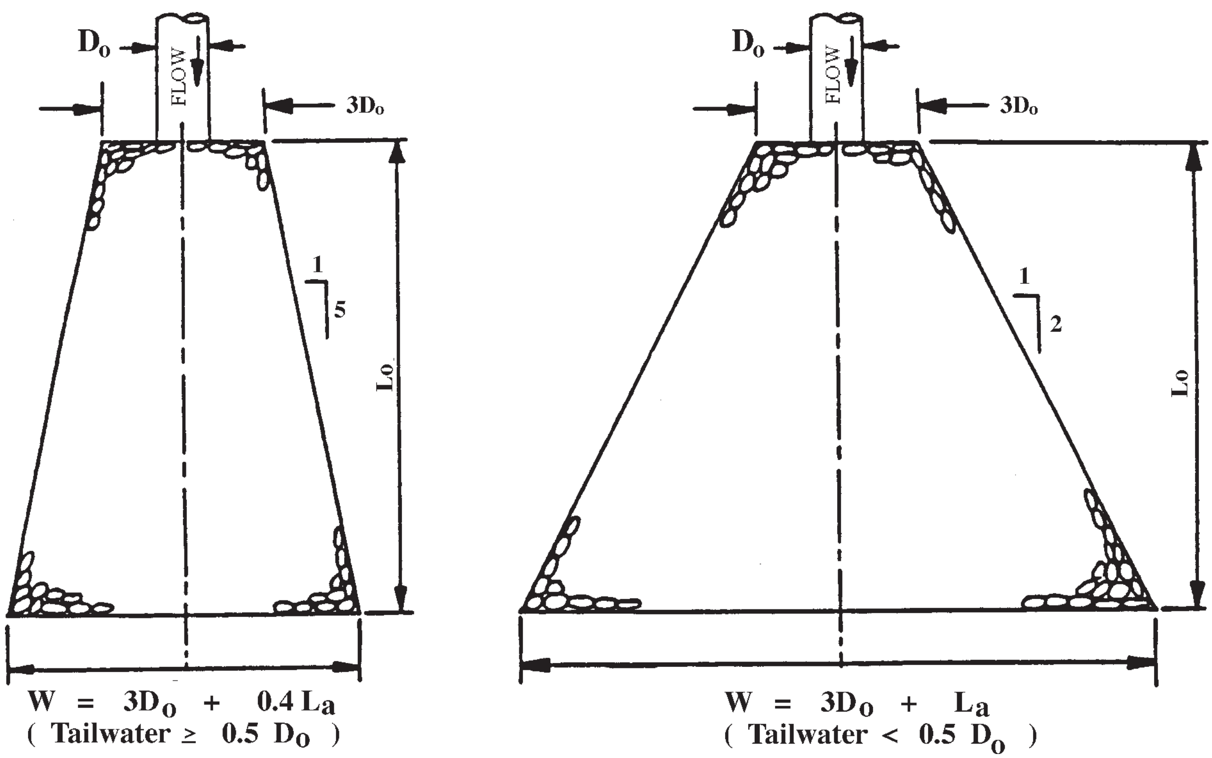
Ratio of Maximum Boundary Shear in Bends to Maximum Bottom Shear in Straight Reaches



Source: Virginia Erosion and Sediment Control Handbook, Virginia Soil and Water Conservation Commission, 1980, as copied from the Rhode Island Soil Erosion and Sediment Control Handbook.

Exhibit 8

Configuration of Conduit Outlet Protection Where There is no Well-Defined Channel Downstream



Source: Standards for Soil Erosion and Sediment Control in New Jersey, New Jersey Soil Conservation Committee, 1980, as copied from the Rhode Island Soil Erosion and Sediment Control Handbook.

Stabilized Outlets

Definition

Outlets are areas which receive discharge water. Stabilized outlets are outlets which reduce the velocity of discharge water to non-erosive velocities.

Other Terms Used to Describe

Outlet Protection
Energy Dissipators

Pollutants Controlled and Impacts

Stabilized outlets help reduce erosion in the area in which the water is released. Some outlets may also provide treatment of various types of pollutants. See the "Specifications" section for the type of pollutants controlled per each type of outlet.

Application

Land Use
This practice is applicable to all land uses.

Soil/Topography/Climate
Each type of outlet has limitations based on soil and topography. See the "Specifications" section.

When to Apply
Stabilized outlets should be installed before runoff is directed to them.

Where to Apply
Apply at the down-slope end of all areas in which runoff is directed.

Relationship With Other BMPs

See the "Specifications" section.

Specifications

Planning Considerations:
If the outlet is a county or inter county drain, permission to discharge must be obtained from the drain commissioner or drain board. The actual structure may require a MDNR permit if the outlet is in a watercourse or if wetlands are impacted.

Design Considerations:
Stabilized outlets should be designed by registered professional engineers.

The specific type of outlet needed depends on the velocity of the water being discharged, the pollutants in the water and the type of soil. The following is a brief discussion of several types of outlets, most of which are BMPs.

Conveyance Outlets:

1. Grassed Waterway or swale. Used most often in rural areas where flows are 6 cfs or less and water is not laden with sediment or other pollutants.

2. Stone Filters. Used at the outlets of small Sediment Basins and other areas where flows are maintained at low velocities.

3. Stormwater Conveyance Channels. Used in both urban and rural areas to contain flows at non-erosive velocities.

Water Storage Outlets:

1. Sediment Basins are used on construction sites where water is laden with sediment. They can serve as outlets for Diversions and areas of bare soils and concentrated runoff.

2. Infiltration Basins are used in areas where the water is such that it would not contaminate groundwater, and where soils are such that water will infiltrate into the ground. They should be used as one of the final stops in a "treatment train."

3. Detention/Retention Basins are used on many development sites, as well as in-stream, to obtain an in-stream hydrology that is similar to the pre-construction conditions.

4. Oil/Grit Separators are used in urban areas and industrial sites where oil and grit is contained in the runoff.

5. Wet ponds and wetlands. Like infiltration basins, these are used as the "final treatment" in a series of BMPs, where water up-slope/up-stream has been treated with other BMPs.

Conduits:
Outlets from stormwater basins, sediment basins and any other conduit structures which release water to watercourses, should be designed as part of the structural BMP. Conduits which release water into watercourses should be stablilized with riprap to three feet above the ordinary high water mark. Follow specifications in the Riprap BMP.

Outlet Protection:
The maximum allowable velocity at the outlet should be determined using Table 1, below. When the velocity at the outlet exceeds the allowable velocity given in Table 1, riprap outlet protection should be used to dissipate energy. Follow specifications in the Riprap BMP.

Maintenance

All of the BMPs cited in the section above require regular maintenance. Follow the maintenance sections in the outlet (BMP) selected.

Table 1

Maximum Allowable Velocities for Various Soils

Soil Texture	Maximum Allowable Velocity (ft/sec)
Sand and sandy loam	2.5
Silt loam	3.0
Sandy clay loam	3.5
Clay loam	4.0
Clay, fine gravel, graded loam to gravel	5.0
Cobbles	5.5
Shale	6.0

Source: Connecticut Guidelines for Soil Erosion and Sediment Control, Connecticut Council for Soil and Water Conservation, 1985.

Stormwater Conveyance Channel

Definition

A stormwater conveyance channel is a permanent waterway, designed to convey stormwater runoff. The channel is lined with vegetation or riprap, or, in limited cases, gabions, which extend up the side slopes to design flow depth. This practice provides a means of transporting concentrated surface runoff without causing erosion or flooding. Channels, including road ditches, that are constructed as part of a development to transport surface runoff, generally are included in this practice. This practice does *not* apply to natural waterways.

Pollutants Controlled and Impacts

Properly designed storm water conveyance channels are effective in preventing erosion caused by concentrated flows. They can significantly reduce or eliminate sediment loads originating in the channel area.

This practice has limited ability to remove pollutants such as nutrients, bacteria, biological oxygen demand, and sediment. These pollutants should be controlled with other BMPs.

Application

Land Use
This BMP potentially applies to all land uses where channels are constructed, but is most common in urban and urbanizing areas, and along roads.

Soil/Topography/Climate
Channel design and stability will differ depending on the soil type and topography. On hilly terrain, for example, velocities may most often be such that grass-lined channels won't work effectively and riprap will be needed instead. If deep cuts are required on hilly terrain, an above-ground channel may be impractical. In such a situation, you may want to consider downdrains or some other type of Grade Stabilization Structure.

When to Apply
Apply whenever stormwater runoff is resulting in erosive channels or gullies.

Where to Apply
Apply where it is necessary to construct channels for stormwater management purposes, including:

- where steep grades, wetness, prolonged base flow, seepage, or piping would cause erosion.

- where high property values or adjacent facilities warrant extra cost to contain design runoff in a limited space.

- in recreational areas, along road sides or in other areas where gullies have occurred. See Exhibit 1 for an example of an application in roadside ditches.

Relationship With Other BMPs

This BMP addresses the proper way to design channels which will be used for stormwater conveyance. The key BMPs which will be referred to for lining the channel are Grassed Waterways and Riprap. Gabions are included in the Slope/Shoreline Stabilization BMP. For concrete flumes and downdrains, refer to the Grade Stabilization Structures BMP. All channels should discharge through a Stabilized Outlet.

Specifications

Planning Considerations:

1. The design of a channel is based primarily on the volume and velocity of flow expected in the channel. The intent is to design the waterway so that it has adequate capacity and sufficient erosion resistance. Use Appendix 1 or other acceptable methods to determine the peak runoff.
2. Determine the slope of the channel.
3. Determine the soil type using field soil tests or soil surveys. Knowledge of soil type is important in completing the design.

Design Considerations:

The design of stormwater conveyance channels should be done by registered professional engineers.

Shape:

There are two types of channels to choose from: parabolic and trapezoidal (see Exhibit 2). Parabolic channels are more similar to the shape of natural channels and are often used where space is available for a wide, shallow channel to allow low velocities. Trapezoidal channels are normally used where deeper channels are needed to carry large flows. Trapezoidal design works well with riprap or other structural linings, and tends to revert to a parabolic shape over time. **V-shaped channels are not to be used** because they are similar to the shape of gullies.

Side Slopes:

Vegetated slopes in urban areas should be 4:1 or flatter for maintenance reasons. Slopes can be steeper for structurally lined channels as long as they are within the capability of the soil and structural lining. For trapezoidal channels with a bottom width greater than 15 feet, the center should be lowered 0.5 foot to prevent meandering during low flows.

Capacity:

Unless local stormwater requirements indicate otherwise, all stormwater channels should be designed to contain at least the peak flow from a 10-year frequency storm. In areas where flooding of the channel will cause damage to property owners, the channel capacity should be increased. The capacity of the channel should not exceed the capacity of the outlet area. Property damage or safety hazards may result if channel capacity is exceeded.

Extra capacity may be needed for areas where sediment is expected to accumulate. An extra 0.3 to 0.5 foot of depth is recommended.

Velocity:
Channels should be designed so that the velocity of flow expected from the design storm does not exceed the permissible velocity for the type of lining used. Permissible velocities for grass-lined channels are given in the Grassed Waterways BMP. Information on selecting the proper stone size and gradation for riprap-lined channels is given in the Riprap BMP. Design velocities should be appropriate for the type of liner selected. See "Channel Linings," below.

Depth:
The design water surface elevation of a channel receiving water from Diversions or other tributary channels should be equal to or less than the design water surface elevation of the diversion or other tributary channel at the point of intersection.

Cross Sections:
The top width of parabolic and grass-lined channels should not exceed 30 feet, and the bottom width of trapezoidal, grass-lined channels should not exceed 15 feet unless multiple or divided waterways, riprap center, or other means are provided to control meandering of low flows.

Freeboard:
Where good vegetative cover cannot be grown adjacent to the lined side slopes, a minimum freeboard of 1 foot above design flow depth should be incorporated into the lined waterway.

Channel Linings:
If flows are expected to be 6 cfs or less, consider using Grassed Waterways. If flows are expected to be over 6 cfs, consider using Riprap. If flows or slopes are such that riprap cannot be used, consider using gabions (see the Slope/Shoreline Stabilization BMP). Concrete applications, including flumes and downdrains are included in the Grade Stabilization Structures BMP.

It is important to follow the design and installation procedures for the type of liner selected--follow the specifications in the chosen BMP.

Outlet:
All channels should discharge through a Stabilized Outlet. The outlet should be designed so that it will handle the expected runoff velocities and volumes from the channel without resulting in scouring. An energy dissipator may be needed if it is determined that flow velocities exceed the allowable velocity of the receiving channel.

Upstream Areas:
If the channel is below a high sediment-producing area, sediment should be trapped before it enters the channel (see Sediment Basin) or the area stabilized with vegetation.

Design Procedures:
The following information is needed to design lined waterways:

* Expected runoff volume (see Appendix 1)
* Desired channel capacity
* Slope of the channel
* The type of cross-sectional design of channel (trapezoidal or parabolic)
* The type of lining

* Design depth or design cross sectional area

1. Based on the expected peak runoff, determine which type of liner is best for the waterway. Use the table below:

peak flow < 6 cfs	consider Grassed Waterways and refer to that BMP for design specifications.
peak flow > 6 cfs	use Riprap wherever possible. Only use gabions where riprap is not feasible. See the Slope/Shoreline Stabilization BMP for information on gabions. If it is necessary to use concrete, refer to the Grade Stabilization BMP for design specifications. Concrete is not the preferred material for stormwater conveyance.

2. Choose a channel shape and approximate design dimensions. Use the dimensions in the formulas in Exhibit 2 to determine cross sectional area, A, and hydraulic radius, R, based on the expected design flow. In the formulas that we provided, all units are in feet.

3. Determine the appropriate Manning's "n" value for the chosen liner. Use the table below:

   Riprap -- Select the D_{50} stone size first and use Exhibit 3 to determine "n" for use in the Manning's formula in Exhibit 4.

   Gabions -- use 0.30

   Where two or more channel slopes occur at the site, choose the appropriate "n" value and bottom width for each slope and provide a smooth transitional section at least 15 feet long between the various design sections.

4. Use Exhibit 4 and solve the Manning formula for velocity.

5. Multiply the velocity found in step 4 times the cross sectional area, A, found in step 2 to determine design flow, Q.

6. Compare the design flow to the calculated runoff. The design flow should be greater than the calculated runoff by no more than 10%. If the design flow is not within this range, modify the shape of the channel to obtain a better cross sectional area and try this procedure again.

Example Problem for Riprap-lined Channels:

Situation:

A city engineer is designing a riprap-lined channel that will flow through a city park. The calculated runoff capacity is 15 cubic feet per second. A trapezoidal channel with a 3:1 side slope and a bottom width of 2 feet is desired. The channel slope will be 2%. The size of stone to be used has a D_{50} value of 4 inches. This means that 50% of the stone to be used (by weight) is smaller than 4 inches in diameter.

i. In order to calculate cross-sectional area (A) and the hydraulic radius (R), either the depth (d) or top width (T) must be determined. Choose a depth of 1 foot to start. Then from Exhibit 2, b= 2, d= 1, and Z= 3. Using these values A= 5 square feet, and R= 0.60 feet.

ii. Use Exhibit 3 to find the "n" value for D_{50} = 4-inch stone. Since depth of flow equals 1 foot, the "n" value is 0.041 from the chart.

iii. Use Exhibit 3 to find the velocity (V), or calculate V using the formula. In our example, using "n", R and S, this is 3.6 feet per second.

iv. To find the flow (Q) for this design, multiply the area (5) by the velocity (3.6). This gives 18.2 cubic feet per second, which is adequate capacity for the expected flow, but because the design flow is much less, velocities may be extremely low. Choose a smaller depth and try to get within 10% of the design flow. In this case, a depth of 0.95 feet would correspond to a flow of 16.3 cfs, which is within 10% of the design flow and therefore a better design.

Construction Considerations:

1. Excavate the channel using proper Grading Practices, and following the design.

2. Compact all fills to prevent unequal settlement. Any soil that is removed and not used as part of the waterway should be disposed of following specifications in the Spoil Piles BMP.

3. Install the channel liner based on specifications in the appropriate BMP.

Maintenance

At a minimum, check all constructed channels after each storm which meets or exceeds the design storm. On riprap-lined waterways, check for scouring below the riprap layer, and be sure the stones have not been dislodged by the flow.

Particular attention should be paid to the outlet of the channel. If erosion is occurring at the outlet, appropriate energy dissipation measures should be taken.

Sediment should be removed from riprap-lined channels if it reduces the capacity of the channel.

Exhibits

Exhibit 1: Roadside Ditch with Armored Channel. Connecticut Guidelines for Soil Erosion and Sediment Control, 1985.

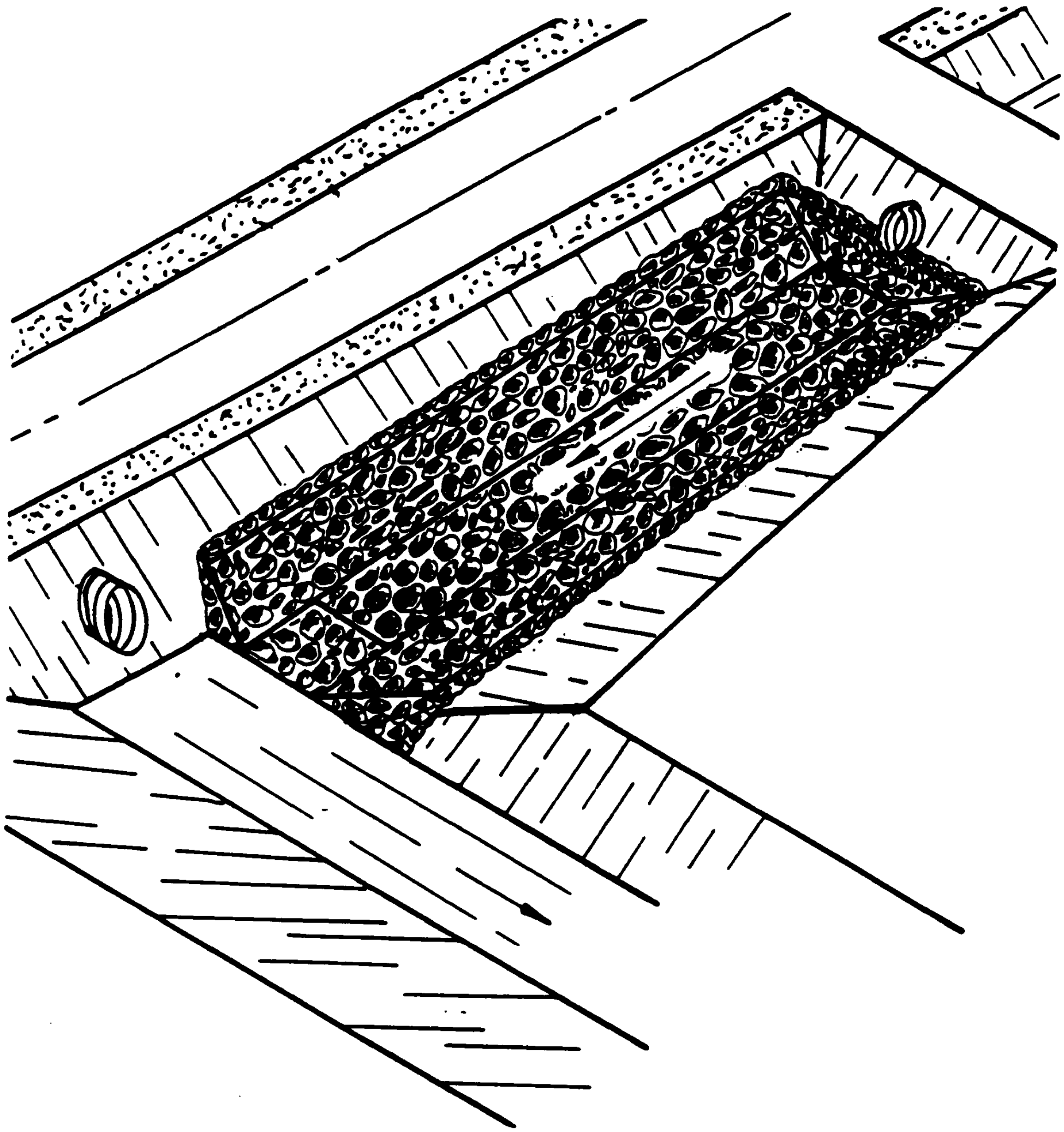
Exhibit 2: Channel Geometry. Modified from Connecticut Guidelines for Soil Erosion and Sediment Control, 1985, as copied from USDA, SCS, Storrs, Conn.

Exhibit 3: Values of n for Riprap-Lined Channels, D_{50} vs. depth of flow. Protecting Water Quality in Urban Areas. Minnesota Pollution Control Agency, Division of Water Quality. 1989.

Exhibit 4: Solution of the Manning Formula. Protecting water Quality in Urban Areas. Minnesota Pollution Control Agency, Division of Water Quality, 1989.

Exhibit 1

Roadside Ditch with Armored Channel

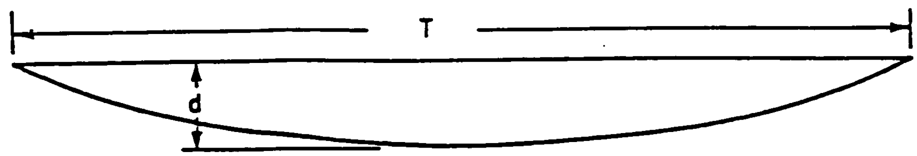


Source: Connecticut Guidelines for Soil Erosion and Sediment Control, 1985.

Exhibit 2

Channel Geometry

Parabolic Shape

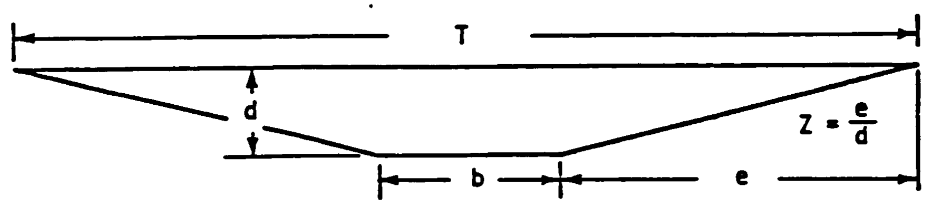


Cross-Sectional Area (A) $= \frac{2}{3}Td$

Top Width (T) $= \frac{1.5\ A}{d}$

Hydraulic Radius $= \frac{T^2d}{1.5T^2 + 4d^2}$

Trapezoidal Shape



Cross-Sectional Area (A) $= bd + Zd^2$

Top Width (T) $= b + 2dZ$

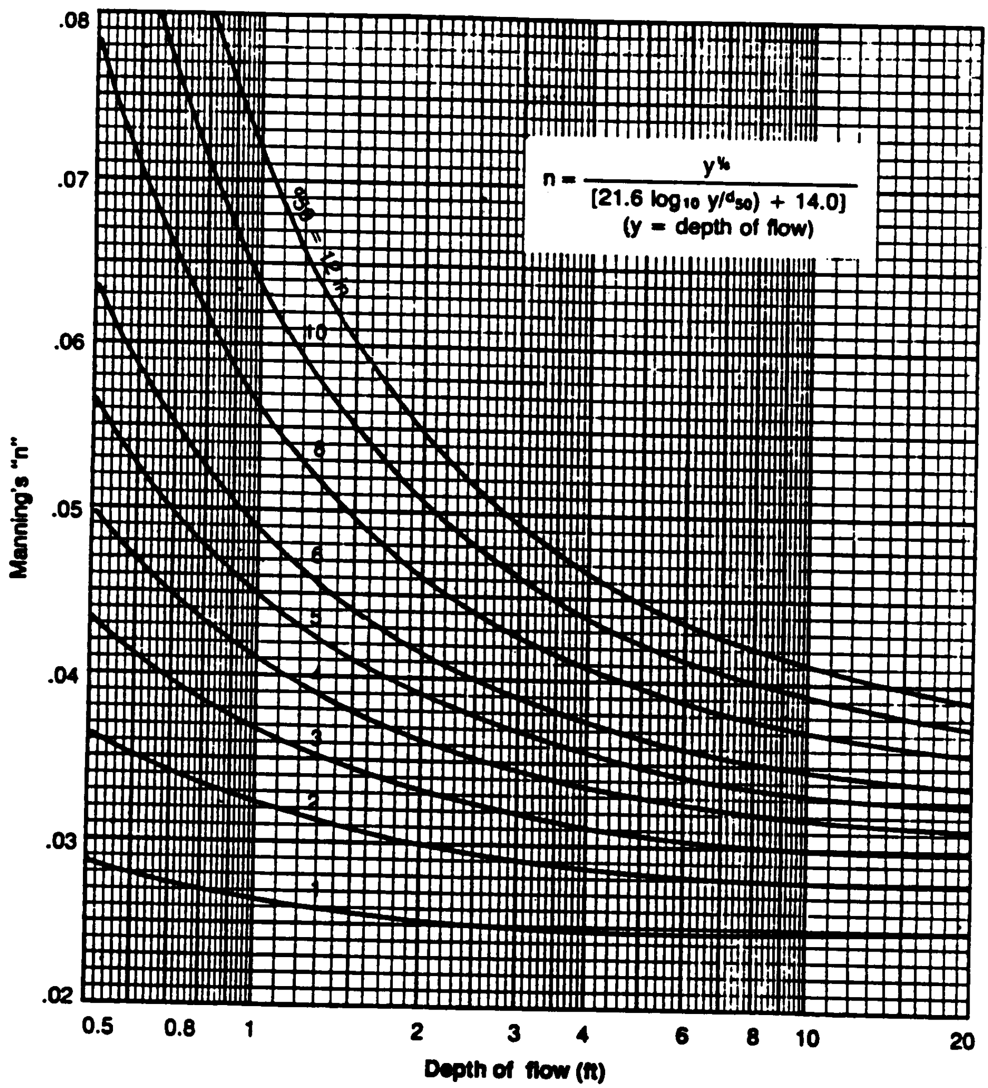
Hydraulic Radius $= \frac{bd + Zd^2}{b + 2d\sqrt{Z^2 + 1}}$

Z = slope

Adapted from: U.S. Department of Agriculture, Soil Conservation Service, Storrs, Connecticut.

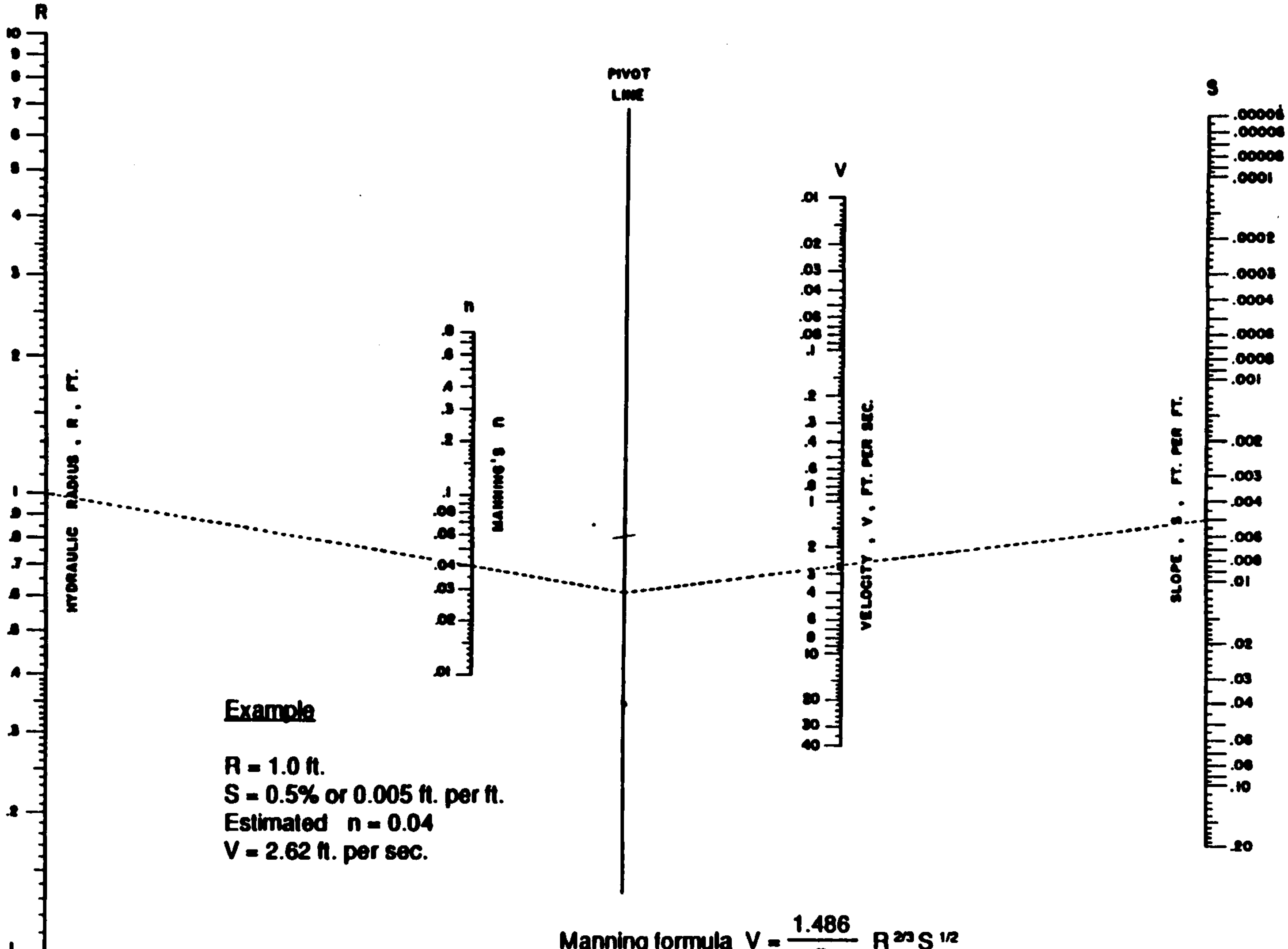
Exhibit 3

Values for n for Riprap-lined Channels, d_{50} vs. Depth of Flow



Source: Protecting Water Quality in Urban Areas, Minnesota Pollution Control Agency, Division of Water Quality, 1989.

Exhibit 4
Solution of the Manning Formula



Manning formula $V = \frac{1.486}{n} R^{2/3} S^{1/2}$

Source: Protection Water Quality in Urban Areas, Minnesota Pollution Control Agency, Division of Water Quality, 1989.

Dec. 1, 1992

Subsurface Drain

Description

A subsurface drain is a perforated conduit, such as tile, pipe or tubing, installed below the ground surface to intercept, collect, and/or convey drainage water. Subsurface drains are designed to remove excess water from soil. Uses include:

- improving the soil environment for vegetative growth by regulating the water table and ground water flow
- intercepting and preventing water movement into a wet area
- serving as an outlet for other subsurface drains
- regulating and controlling ground water for subirrigated areas or waste disposal areas
- removing surface runoff and ponded water around buildings, roads, airports, recreational fields and physical improvements

Subsurface drains are most beneficial in providing internal drainage of slopes to improve their stability and reduce erosion.

Other Terms Used to Describe

Drainage Tile
Interceptor Drain
Relief Drain
Tile
Underground Drain

Pollutants Controlled and Impacts

Subsurface drains are effective, although expensive, means of controlling stormwater or lowering a water table.

It is important to note that soluble phosphorus may be transported to surface water through subsurface drainage tiles. In addition, the ground water table may be depleted due to the installation of subsurface drains. This may jeopardize water supply needs, and may cause serious damage to wetlands.

Application

Land Use
Applicable to all land uses.

Soil/Topography/Climate
The soil should have enough depth and permeability to permit installation of an effective and economically feasible system.

When to Apply
Subsurface drains are used when it is necessary to remove excess water form soil, or to improve infiltration or percolation characteristics of soil in stormwater management facilities. Sometimes it is also necessary to use subsurface drains because the topography is not suitable to direct water to design locations. Subsurface drains will also be used when the topography would require a very deep "cut" through a hill or ridge in order to direct stormwater to a desirable outlet.

Where to Apply
Apply in areas: where it is necessary to intercept groundwater so slopes can be stabilized; where it is necessary to relieve hydrostatic pressure behind retaining walls and other similar structures; to provide a stable base for construction; or where lowering the water table justifies the installation of such a system.

Relationship With Other BMPs

Subsurface drains provide internal drainage behind bulkheads, seawalls, retaining walls and other Slope/Shoreline stabilization Structures.

They also provide drainage for dry storm water management structures and infiltration BMPs.

Specifications

Planning Considerations:

1. Conduct a site inspection to ensure that the site is suited for the proposed use(s). All potential impacts should be assessed prior to the onset of construction, with particular attention given to the potential impact of altering the water table.

   Where possible, do not install drain lines within 50 feet of trees to avoid tree roots that may clog the line. Use solid pipe with water-tight connections where tree roots cannot be avoided.

2. Evaluate soils to determine the appropriate method of installation. Certain soils necessitate using an envelope of granular drain material to maximize effectiveness.

3. Determine the appropriate **type** of subsurface drain needed. There are three types of drains:

   A. **Relief drains** (tile systems). These are used to lower the water table in large, relatively flat areas that frequently become too wet to support desirable vegetation. Although surface water may also be carried through relief drains, it is generally better to install a separate drain for this purpose.

   Relief drains may be installed in one of three patterns, as shown in Exhibit 1. Relief drains drain in the same direction as the slope.

   B. **Under drains.** These are type of relief drain used to improve infiltration characteristics in stormwater management facilities when permeability is restricted to soil texture or high water table conditions, or to specifically filter a portion of stormwater runoff contained in detention facilities prior to discharge.

C. **Interceptor drains.** These are used to remove excess groundwater from a slope, stabilize slopes, and lower the water table immediately below a slope. They also may be used to stabilize shallow foundations such as paved channels or construction Access Roads. They usually consist of a single pipe or a series of single pipes buried perpendicular to the slope on the upstream side of wet areas.

Design Considerations:
Subsurface drains should be designed by registered professional engineers.

All materials (i.e. perforated, continuous closed-joint conduits of concrete, corrugated plastic, corrugated metal) used in the construction of subsurface drains should be strong and durable enough to meet the requirements of the site.

Capacity:

A. **Relief drains** must be designed to remove at least 1 inch of groundwater per hour over the area served, or 0.042 ft^3/sec/acre. However, when the relief drain empties into an existing stormwater system, local design standards must also be met. The design capacity must be increased accordingly to accommodate any surface water which enters the system directly.

B. **Under drains.** The capacity of underdrains should be determined in conjunction with the corresponding stormwater treatment system to achieve treatment of a minimum 0.5 inches of runoff over the entire drainage area, and insure proper operations of the facility.

C. **Interceptor drains** should be designed to remove a minimum of 1.5 cfs/1000 ft. of length. As land slope increases, capacity should be increased according to the following table:

Land Slope	Capacity
2-5%	1.65 cfs/1000 ft.
6-12%	1.80 cfs/1000 ft.
> 12%	1.95 cfs/1000 ft.

As with relief drains, additional capacity must be included in the drain if surface or flowing spring water enters the drain.

Velocity:
The minimum velocity that should be used in all subsurface drains is 2.0 feet per second. Lower velocities will allow sediment to accumulate in the drain. Maximum allowable velocities are listed in Table 1, below, based on soil texture.

Table 1

Maximum Allowable Velocities for Various Soils

Soil Texture	Maximum Allowable Velocity (fps)
Sand and sandy loam (non-colloidal)	2.5
Silt loam (also high lime clay)	3.0
Sandy clay loam	3.5
Clay loam	4.0
Stiff clay, fine gravel, graded loam to gravel	5.0
Graded silt to cobbles (colloidal)	5.5
Shale, hardpan and coarse gravel	6.0

Size:
Subsurface drains should be designed to carry the required capacity without pressure flow. It is important to consider changes in upland land uses, particularly in urbanizing areas. Changes in land uses could result in increased flows, which may significantly alter the design of the drain. The minimum diameter for a subsurface drain is 4 inches.

Depth and Spacing:

1. **Relief drains.** Relief drains should be installed in a uniform pattern, with equal spacing between the drains. All drains should be the same depth. Spacing between drains depends on soil hydraulic conductivity (i.e. permeability) and the depth of the drain. A spacing of 50 feet is adequate.

   The maximum depth is limited by the allowable load for the type of pipe, depth to an impervious layer, and outlet conditions. (The depth to an impervious layer can be determined by soil borings). In no case should the relief drain be less than 24 inches deep, and in most cases a depth of 4 feet will be adequate.

   Design equations are available which may permit a more economic design.

2. **Interceptor drains.** The depth of an interceptor drain is determined primarily by the depth to which the water table is to be lowered or the depth to a permeability-restricting layer. The maximum depth is limited by the allowable load for the type of pipe used and the depth to an impermeable layer. For practical reasons, the maximum depth is usually limited to 6 feet, with a minimum cover of 2 feet to protect the conduit. Install close to the impermeable layer to ensure stability.

Outlet:
The outlet should be designed in conjunction with the conveyance system and should be in place before water is released from the conveyance system. The outlet should empty into a channel or other watercourse such that there is no overfall from the end of the apron to the receiving channel streambed.

Outlet protection using Riprap or other approved materials should be provided if the outlet velocity exceeds the permissible velocity of the stream. Specifications for riprap as outlet protection is given in the Riprap BMP.

The soils above and around the outlet should be compacted and stabilized to prevent piping around the structure. Riprap placed 3 feet above the ordinary high water mark is recommended for all outlets.

The outlet should be constructed of corrugated metal, cast iron, steel, concrete, or heavy-duty plastic without perforations.

Bedding Conditions:
The recommended method of bedding a rigid ditch conduit is to construct an earth foundation shaped to fit the lower part of the conduit for a width of at least 50% of the conduit breadth, and in which the remainder of the conduit is surrounded to a height of at least 1 foot above its top by clean, granular materials that are shovel-placed and shove-tamped to completely fill all spaces under and adjacent to the conduit.

When sand and gravel filter or envelopes are used, the foundation need not be shaped since the filter and envelope material are placed entirely around the conduit and provide for lateral pressures on the conduit. See “Envelopes and Envelope Materials”, below.

Bedding Conditions for Flexible Drainage Tubing:
A flexible conduit has relatively little inherent load-bearing strength, and its ability to support soil loadings in a trench must be derived form pressures induced as the sides of the conduit deflect and move against the soil. This inability of a flexible conduit to deform and use the soil pressure to support it is the main reason that light-weight plastic drainage tubing can support soil loadings in drainage trenches.

A flexible tubing must be installed in a trench in a way which insures good soil support from all sides. There must be no voids remaining which would permit the soil pressure from backfill to cause deflection of the tubing to the point of buckling. Most installations will be made with machinery, without requiring a person in the trench to position the tubing or place the bedding. Some modification of machinery designed for installation of rigid conduit usually is necessary to install flexible conduits efficiently.

Envelopes and Envelope Material:
Envelopes should be used around drains where proper bedding of the conduit is required, or as necessary to improve the characteristics of ground water flow into the conduit. They are most often used with flexible drain tubing.

Materials used for envelopes should not contain materials which will cause an accumulation of sediment in the conduit, or render the envelope unsuitable for bedding of the conduit. Envelopes should be a minimum of 4 inches thick, and be comprised of gravel no larger than ¾ inches in diameter.

Filter fabric can be used to encase the gravel envelope. If soil is used for the backfill, place filter cloth over the top of the gravel before backfilling to prevent soil from moving into the gravel.

Materials For The Drain:
The conduit should meet strength and durability requirements of the site. Do not use crushed or otherwise damaged materials.

Pipe Size:
Pipe size is determined based on the volume of water to be removed (Q, in cfs), slope of the pipe (s) and the velocity when flowing full (v, in ft/sec). The volume of water to be removed is the drainage coefficient (inches of water removed/day) times the entire drainage area served by the subsurface drain (square feet).

The drainage charts in the attached exhibits can be used to determine the appropriate pipe size, or the expected flow may be determined and used in the Mannings equation to determine the correct pipe size. The design example below demonstrates how the exhibits can be used.

Design Example:
Situation:
An athletic field constructed on a silt loam is experiencing wet conditions that are unsatisfactory to the athletic club. The field has a 0.4% grade and is 1,000 feet long and 750 feet wide. The subsurface drain should extend the length of the field, plus an additional 50 feet to a suitable outlet. The surrounding area is adequately drained. Determine the appropriate tubing diameter assuming plastic tubing will be used. Assume a drainage coefficient of ½” (1/2 inch of water drained in 24 hours).

1. Refer to the Maximum Allowable Velocity (MAV) table (Table 1 of this BMP) to determine the MAV for silt loam. That value is 3.0 ft/sec. Choose a pipe size that will be adequate for this velocity.

2. Determine the number of acres drained. We know that the total length equals 1,050 feet and the width of the field is 750 feet, so the area 750,000 ft^2. One acre equals 43,560 ft^2, so 750,000 ft^2 is 17.2 acres.

3. Determine the pipe size using Exhibit 3, the Plastic Drainage Chart. Align a ruler with one end on the 0.4% grade (on the bottom of the chart) and the other end on 17 acres (with a ½” coefficient). The line created by connecting these two points crosses the V = 3.0 ft/sec. line within the 4” pipe size.

Construction Considerations:
1. Install Construction Barriers to prevent unwanted access to the construction site.

2. For work which must be done in the dry, use cofferdams to divert the waterbody temporarily. Use proper Dewatering techniques.

3. Overfill the trench a few inches allow for settlement.

4. Consider installing trash racks, rodent guards, and other protective outlet devices to gather debris and keep children and animals from accessing the drain.

5. Cap the upper end of each drain with a standard cap made for this purpose, or with concrete or other suitable material to prevent soil from entering the open end.

After Construction:
Stabilize all adjacent areas following specifications for Seeding and Mulching or Sodding.

Remove Construction Barriers.

Maintenance

Properly installed drains usually require very little maintenance unless trees such as willow are permitted to grow above a subsurface drain. In this case, it may be necessary to remove root obstructions.

Maintenance may also be necessary under the following conditions:

1. If piping occurs. This may result if the drain was not constructed with a good bond with the soil. Piping can cause a complete washout of the drain.

2. On outlets which begin to capture sediment, trash or other debris. These should be cleaned and the trash racks re-installed.

3. In wet areas where the soil has caved in due to vehicle traffic, blockage by roots, or other problems. Repair the site immediately.

Note: In some cases (especially in large urban areas) maintenance may require entering the enclosed drain. All staff which enter such drains should be trained in safety techniques for entering enclosed spaces.

Exhibits

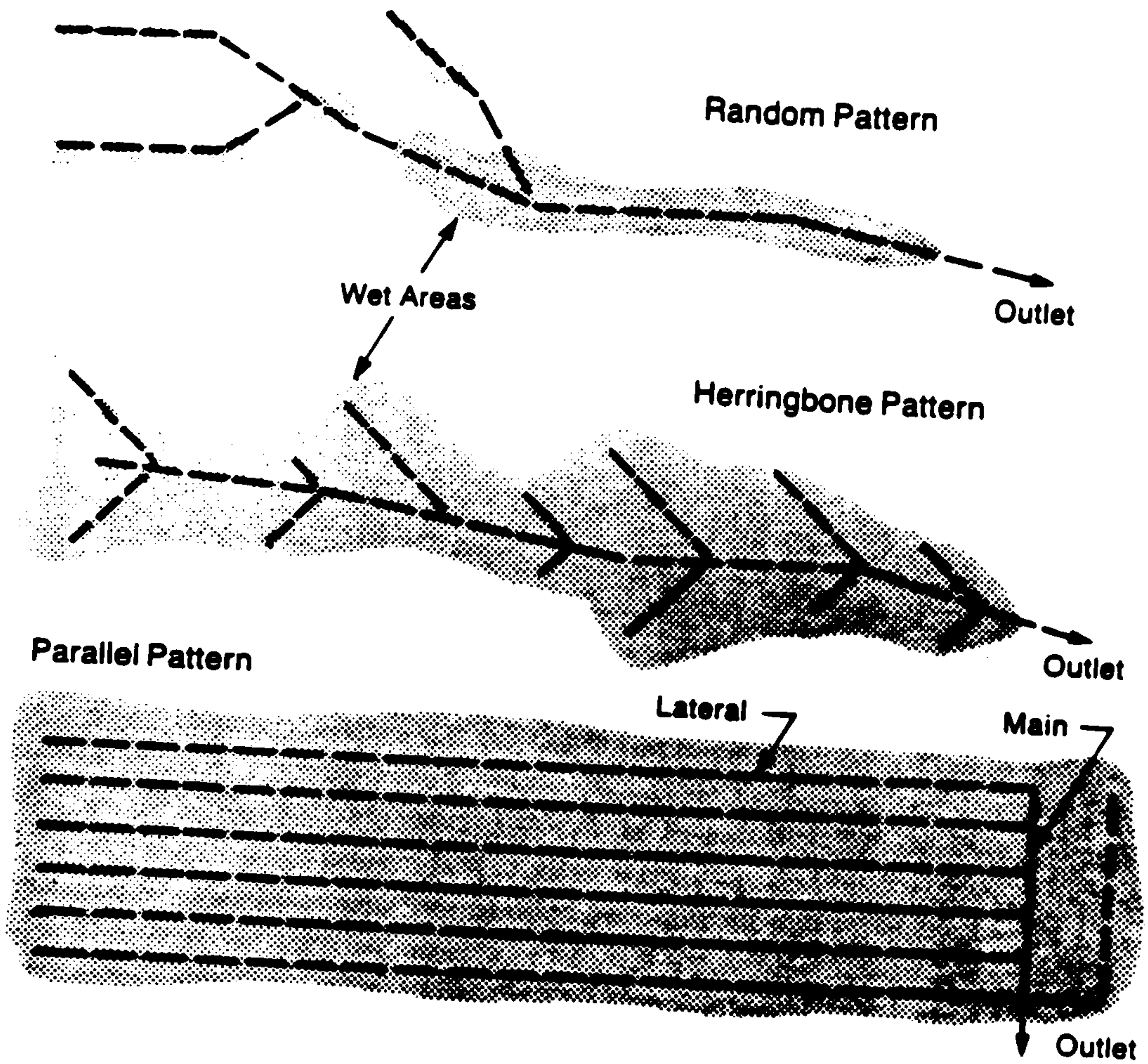
Exhibit 1: Subsurface Relief Drain Layouts. USDA, Soil Conservation Service.

Exhibit 2: Drainage Chart for Concrete Tile. USDA, Soil Conservation Service.

Exhibit 3: Drainage Chart for Plastic Pipe. USDA, Soil Conservation Service.

Exhibit 1

Subsurface Relief Drain Layouts



Source: USDA Soil Conservation Service.

Exhibit 2

Concrete Tile Drainage Chart
Acres Drained by Various Sizes of Tile

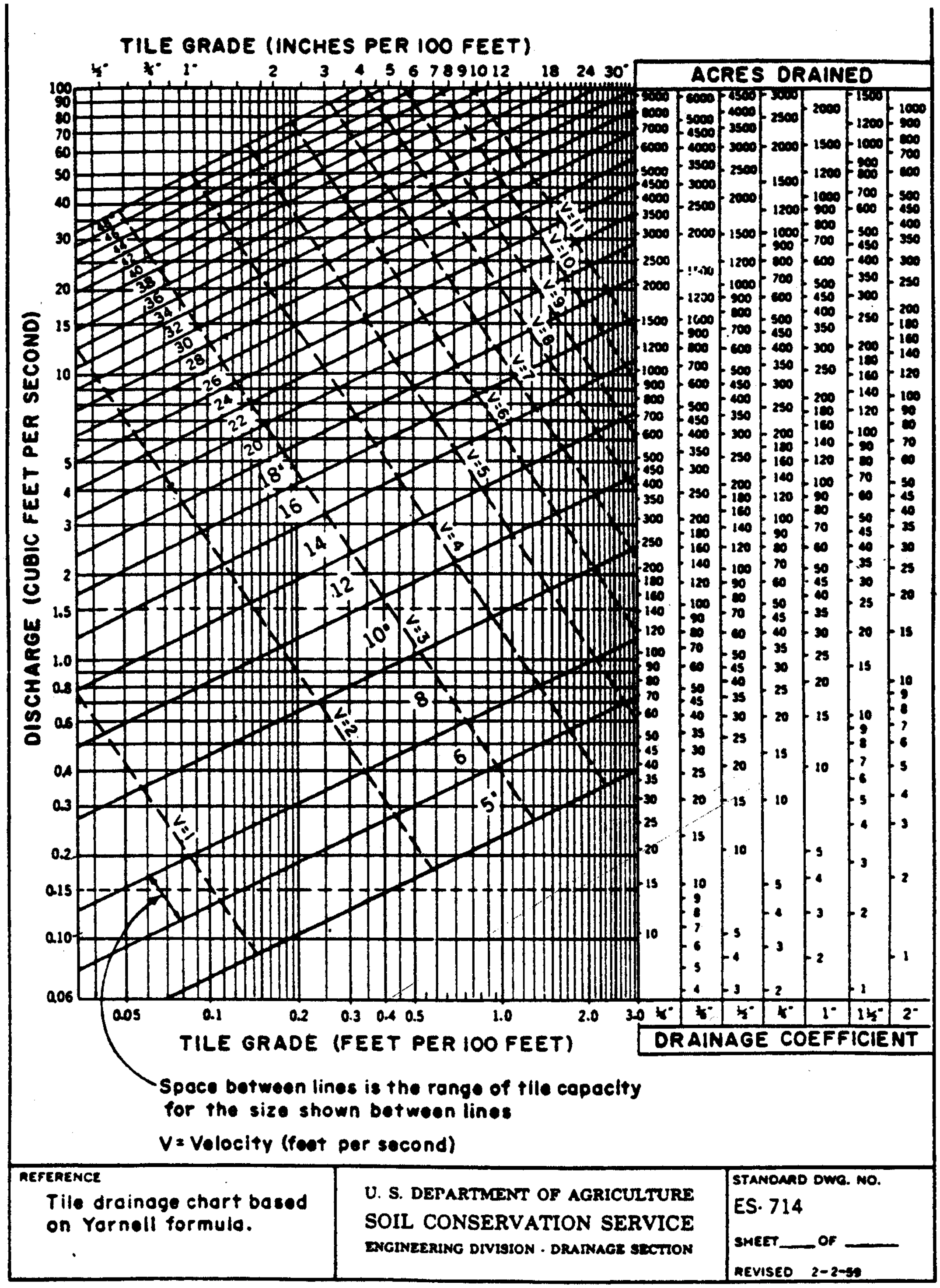
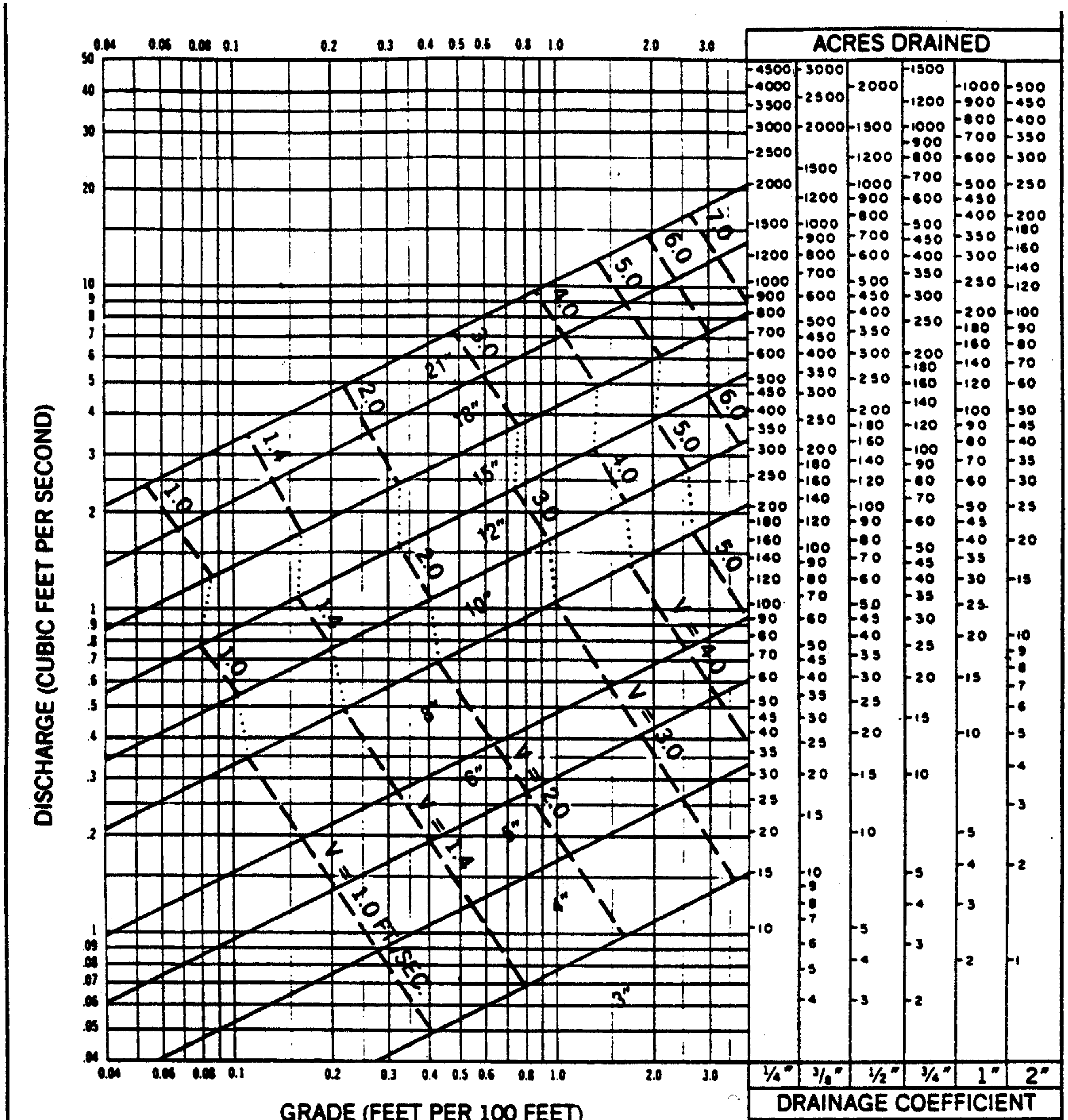


Exhibit 3

Plastic Tubing Drainage Chart



SIZE (DIA.)	"n"
3" - 8"	0.015
10" - 12"	0.017
> 12"	0.020

Source: USDA Soil Conservation Service

Dec. 1, 1992

Catch Basin

Description

Catch basins are stormwater inlets to the sewer system which contain a sump to capture solids and thereby prevent sewer blockages.

Note: This BMP should not be implemented unless a regular maintenance program is adhered to. Uncleaned catch basins may contribute loads of biological oxygen demand (BOD) and sediment to the receiving stream. If regular maintenance cannot be done, use an alternative to catch basins such as simple inlets (without sediment traps), Street Sweeping, sewer cleaning, off-line storage, or flow attenuation.

Pollutants Controlled and Impacts

Catch basins are reasonably effective in protecting sewers from receiving loads of coarse solids greater than 0.04 inches in diameter. They are not very effective in capturing fine particles such as clays or silt.

The trapped liquid flushed from catch basins during the "first-flush" from storm events may have a high pollutant loading (e.g. BOD). This liquid can be displaced to the sewer by a rainfall of as little as 0.02 in/hr, lasting four hours.

Application

Land Use
This BMP is most commonly used in urban areas, but may have rural applications along roads.

Soil/Topography/Climate
This BMP is most effective in capturing coarse soils.

When to Apply
Apply this BMP following the stabilization of up-slope areas.

Where to Apply
Apply in locations where large solids need to be removed and where strict maintenance schedules can be adhered to. Catch basins are typically built at the curbline of streets, although they may be built entirely below ground. The inflow is typically through a grating at the curbline. In locations where clay, silt, nutrients, or other pollutants may pass through the catch basin, direct discharges to surface waters should be avoided.

Relationship With Other BMPs

In urban areas, use with Street Sweeping. To avoid direct discharge to surface waters, use with Sediment Basins, Extended Detention Basins, or Wet Detention Basins.

Specifications

Planning Considerations:

1. Evaluate the site for potential pollutant loadings. If pollutant loadings will be high, avoid direct discharge to surface waters by using another BMP, or by using this BMP with another BMP.

2. Evaluate the hydrology of the site to prevent flooding and erosion problems.

Design Considerations:

The design of a catch basin should be done by a registered professional engineer.

Storage basin **depth** is the primary control for performance. Deeper basins that have longer water retention times and less hydraulic turbulence are more efficient. Solids removal becomes impaired when 40-50% of the storage depth is filled. Once this level is reached, solids begin to be washed out of the basin.

See Exhibits 1 and 2 for catch basin designs. Also included are designs for catch basin covers (Exhibits 4, 5, and 6). Exhibit 3 is an optional sewer trap design used to prevent large solids from entering the outlet pipe. It may also function as an odor control device and serve as an oil and water separator.

Exhibit 1 also includes designs for a leaching basin. The leaching basin has a porous sump bottom as opposed to the concrete sump of the catch basin. The leaching basin should only be used where soils will allow infiltration, and where potential groundwater contaminants will not be introduced through stormwater.

Construction Considerations:

Install Construction Barriers around the area to prevent access by pedestrians.

Consider using Diversions and other soil erosion practices up-slope of the catch basin to prevent runoff from entering the site before catch basins are complete.

Filter cloth may be placed over catch basins in construction areas until soil is stabilized. See the Filters BMP.

After Construction:

Stabilize the surrounding area and any established outlet following specifications in the Seeding and Mulching or Sodding BMPs.

Remove temporary structures after vegetation is established.

Maintenance

Proper maintenance of catch basins includes vacuum or adductor cleaning to remove accumulated solid material. Frequent vacuum or adductor cleaning of catch basins removes the accumulated pollutant material and maintains the removal efficiency of catch basins. **Cleaning should be done**

before basins are half full.

Additional Considerations

Solids removed from catch basins may be high in pollutants such as oil and grease, metals, organic and inorganic chemicals, and nutrients. Proper handling of this material includes disposal so as to not contaminate surface water and groundwater. This material may need to be landfilled.

Exhibits

All six attached exhibits are from the Michigan Department of Transportation, Bureau of Highway Planning.

Exhibit 1

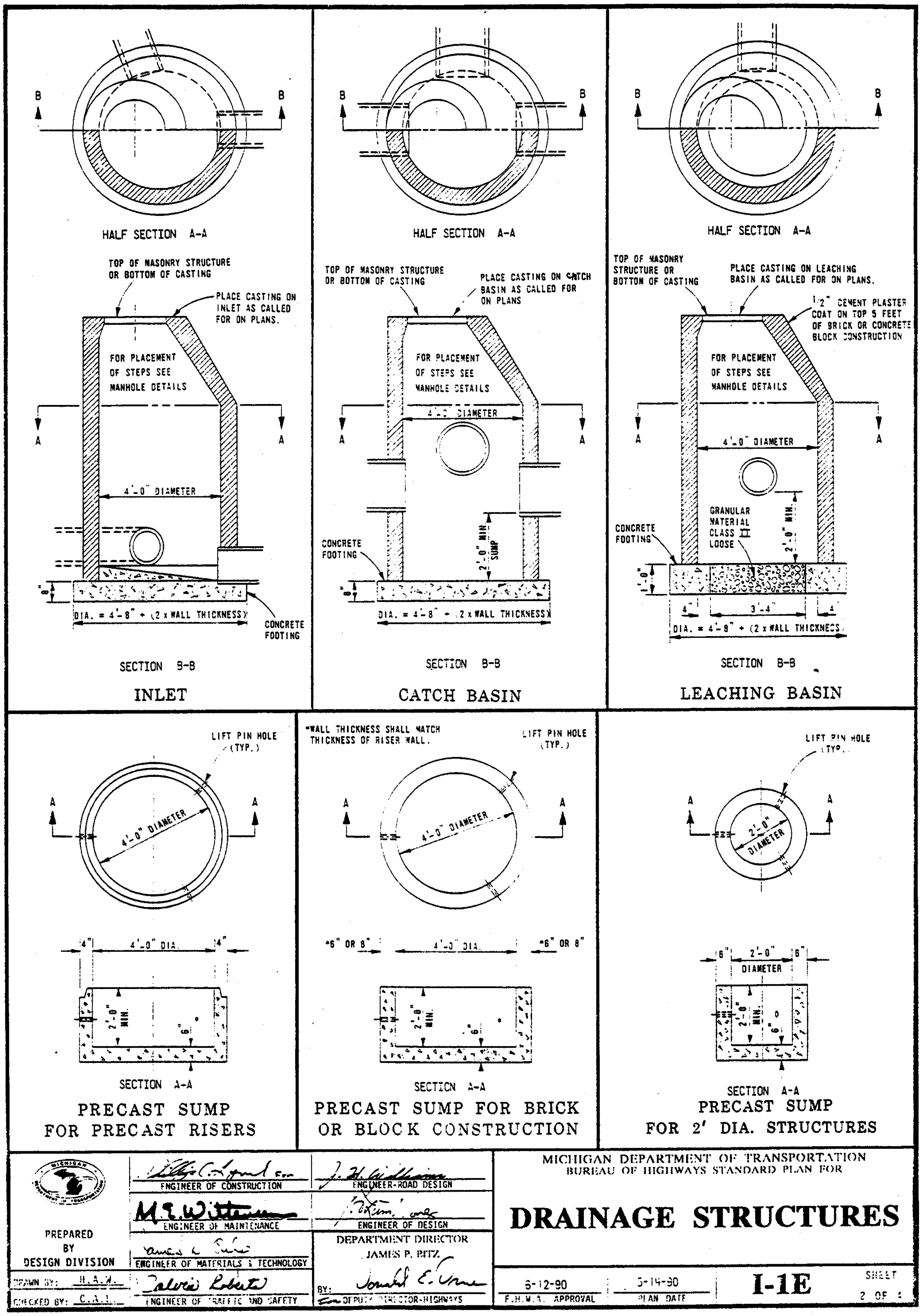
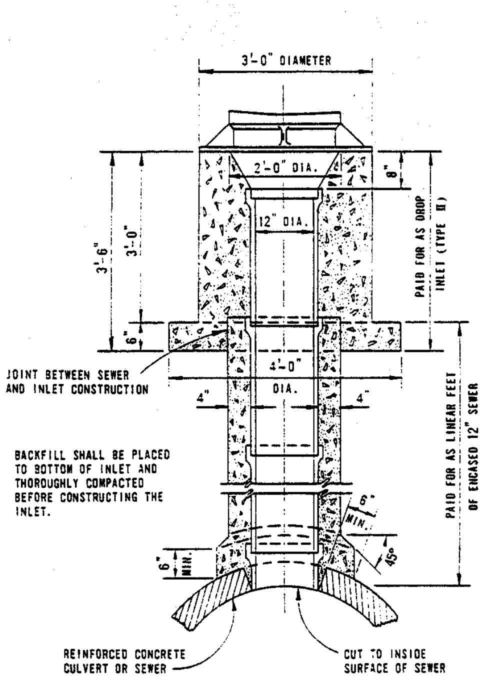
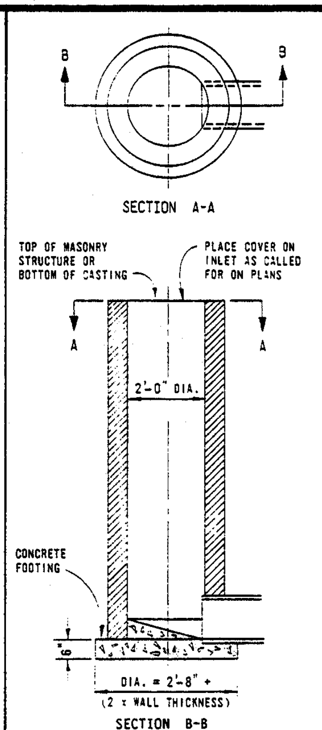

HALF SECTION A-A
TOP OF MASONRY STRUCTURE OR BOTTOM OF CASTING
PLACE CASTING ON INLET AS CALLED FOR ON PLANS.
FOR PLACEMENT OF STEPS SEE MANHOLE DETAILS
4'-0" DIAMETER
DIA. = 4'-8" + (2 x WALL THICKNESS)
CONCRETE FOOTING
SECTION B-B
INLET
PLACE CASTING ON CATCH BASIN AS CALLED FOR ON PLANS
2'-0" MIN. SUMP
CATCH BASIN
PLACE CASTING ON LEACHING BASIN AS CALLED FOR ON PLANS.
1/2" CEMENT PLASTER COAT ON TOP 5 FEET OF BRICK OR CONCRETE BLOCK CONSTRUCTION
GRANULAR MATERIAL CLASS II LOOSE
3'-4"
LEACHING BASIN
LIFT PIN HOLE (TYP.)
SECTION A-A
PRECAST SUMP FOR PRECAST RISERS
*WALL THICKNESS SHALL MATCH THICKNESS OF RISER WALL.
*6" OR 8"
PRECAST SUMP FOR BRICK OR BLOCK CONSTRUCTION
2'-0" DIAMETER
PRECAST SUMP FOR 2' DIA. STRUCTURES
PREPARED BY DESIGN DIVISION
ENGINEER OF CONSTRUCTION
ENGINEER-ROAD DESIGN
ENGINEER OF MAINTENANCE
ENGINEER OF DESIGN
ENGINEER OF MATERIALS & TECHNOLOGY
DEPARTMENT DIRECTOR JAMES P. PITZ
ENGINEER OF TRAFFIC AND SAFETY
DEPUTY DIRECTOR-HIGHWAYS
MICHIGAN DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS STANDARD PLAN FOR
DRAINAGE STRUCTURES
6-12-90
F.H.W.A. APPROVAL
3-14-90
PLAN DATE
I-1E
SHEET 2 OF 2

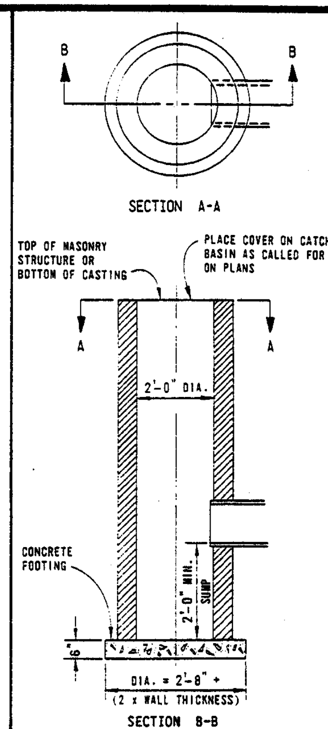
Exhibit 2



DROP INLET (TYPE II)



INLET



CATCH BASIN

NOTES:

ALL COVERS ARE INTERCHANGEABLE ON ANY STRUCTURE BY MODIFYING THE STRUCTURE TOP. COVERS FOR STRUCTURES ON THIS STANDARD ARE SHOWN ON STANDARD PLANS IN DIVISION I.

TOP OF MASONRY STRUCTURES SHALL BE SUFFICIENTLY LOW TO PERMIT PROPER ADJUSTMENT OF COVER TO GRADE WITH MORTAR OR BRICK AS DIRECTED BY THE ENGINEER.

THE TOP PORTION OF 4' DIAMETER AND LARGER PRECAST REINFORCED UNITS SHALL BE ECCENTRIC IN DESIGN.

PREMIUM JOINTS ARE REQUIRED ON ALL SANITARY MANHOLES. SEE A.S.T.M. DESIGNATION C-923.

GRANULAR MATERIAL CLASS III SHALL BE USED IN BACKFILLING AROUND ALL STRUCTURES THAT FALL WITHIN THE 1 ON 1 INFLUENCE LINES FROM THE EDGE OF PAVEMENT OR BACK OF CURB.

A STRIP OF SOD THREE FEET WIDE SHALL BE PLACED AROUND THE TOP OF EACH STRUCTURE LYING OUTSIDE OF SURFACED PORTIONS OF THE HIGHWAY.

STEPS SHALL BE OF AN APPROVED DESIGN. MADE OF CAST IRON. ALUMINUM OR PLASTIC COATED STEEL. RUNGS SHALL BE A MINIMUM OF 10" CLEAR LENGTH. DESIGNED TO PREVENT THE FOOT FROM SLIPPING OFF THE END AND CAPABLE OF SUPPORTING 300 POUNDS.

THE BELL SHALL BE REMOVED FOR THE FIRST LENGTH OF OUTLET PIPE PROJECTING THROUGH THE WALL OF THE MANHOLE.

PRECAST CONCRETE SECTIONS, SUMPS, AND FLAT TOP SHALL BE BUILT IN ACCORDANCE WITH A.S.T.M. C-478. THE WALLS OF THE PRECAST UNITS MAY HAVE A SLIGHT TAPER TO ALLOW FOR FORM REMOVAL. PRECAST CONCRETE 2' DIAMETER DRAINAGE STRUCTURES SHALL HAVE A MINIMUM 3" WALL THICKNESS WITH A 6" MINIMUM BEARING SURFACE ON TOP. SEE PRECAST RISER RING FOR 2' DIAMETER STRUCTURE.

PIPES ENTERING OR LEAVING PRECAST STRUCTURES SHALL NOT HAVE AN INSIDE DIAMETER GREATER THAN 2' LESS THAN THE INSIDE DIAMETER OF THE STRUCTURE, EXCEPT PIPES ENTERING OR LEAVING 2' INSIDE DIAMETER STRUCTURES MAY HAVE PIPES 1' INSIDE DIAMETER OR LESS.

THE NUMBER OF PIPE OPENINGS IN A RISER SHALL BE DETERMINED BY THE DESIGNER. SPACING BETWEEN OPENINGS SHALL BE 6" MINIMUM. OPENINGS MAY BE CONSTRUCTED BY CASTING, REMOVING THE GREEN CONCRETE, OR BY DRILLING THE OPENINGS IN CURED CONCRETE.

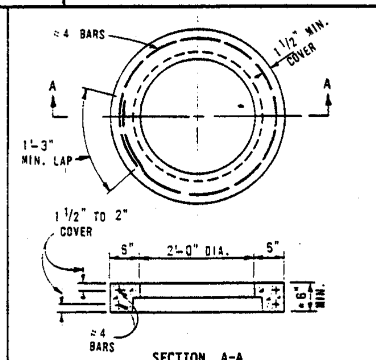
A SEWER TRAP AS SHOWN ON STANDARD PLAN I-19 SERIES SHALL BE PLACED WHERE CALLED FOR IN THE OUTLET SEWER LINE OF CATCH BASINS. SEWER TRAPS WILL BE PAID FOR SEPARATELY AT THE CONTRACT UNIT PRICE EACH.

PRECAST CONCRETE FOOTINGS OR BASES SHALL BE REINFORCED WITH #4 STEEL BARS SPACED AT 1' BOTH WAYS OR WITH TWO LAYERS OF WELDED WIRE FABRIC OF EQUIVALENT CROSS SECTIONAL AREA LAID AT RIGHT ANGLES AND WIRED TOGETHER. REINFORCEMENT SHALL BE PLACED IN TOP OF FOOTING AND SHALL BE MARKED. STEEL REINFORCEMENT MAY BE OMITTED IN CAST-IN-PLACE CONCRETE FOOTINGS.

PRECAST CONCRETE FOOTINGS SHALL BE SUPPORTED BY A COMPACTED 6" GRANULAR SUBBASE.

THE MINIMUM WALL THICKNESS FOR ALL 2', 4', AND 5' DRAINAGE STRUCTURES USING CONCRETE BLOCK, BRICK, OR CAST-IN-PLACE CONCRETE SHALL BE AS SHOWN IN TYPICAL WALL SECTIONS.

THE CONICAL SECTION OF MANHOLES OR CATCH BASINS CONSTRUCTED OF BLOCK OR BRICK WILL BE SHROUDED WITH GEOTEXTILE FABRIC FROM THE TOP DOWN 5' MINIMUM OR THROUGH THE FROST ZONE. ENOUGH GEOTEXTILE MATERIAL WILL BE LEFT ON THE TOP (8" OR MORE) TO ROLL OVER THE TOP OF THE CONE.



* WHEN RISER TONGUE LENGTH GREATER THAN 3", USE 2 TIMES TONGUE LENGTH.

NOTE: PRECAST RISER RING SHALL FULLY ENGAGE THE TONGUE OF THE RISER PIPE.

PRECAST RISER RING
FOR 2' DIAMETER STRUCTURE

PREFORMED HIGH DENSITY POLYSTYRENE FILLER PIECES MAY BE USED TO CHANNEL FLOW IN THE BOTTOM OF MANHOLES PROVIDED THEY HAVE AT LEAST 2" OF CONCRETE COVER. THE USE OF THIS MATERIAL FOR CHANNEL FLOW IS RESTRICTED TO MANHOLES WHERE THE BOTTOM SECTION IS NOT SUBJECT TO FREEZING. THE USE OF THIS MATERIAL MUST BE APPROVED BY THE ENGINEER.

PREPARED BY DESIGN DIVISION

DRAWN BY: H.A.W.
CHECKED BY: C.A.L.

ENGINEER OF CONSTRUCTION
ENGINEER OF MAINTENANCE
ENGINEER OF MATERIALS & TECHNOLOGY
ENGINEER OF TRAFFIC AND SAFETY

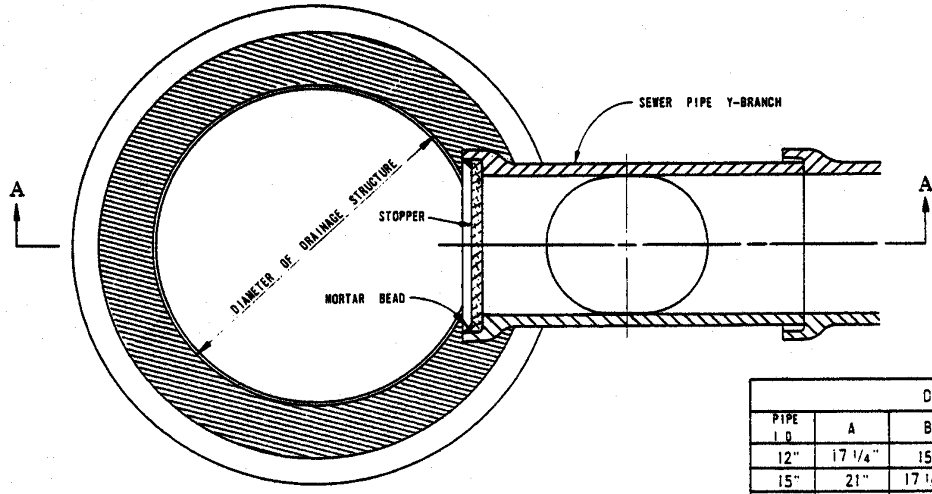
ENGINEER-ROAD DESIGN
ENGINEER OF DESIGN
DEPARTMENT DIRECTOR
JAMES P. PITZ
BY:
DEPUTY DIRECTOR-HIGHWAYS

MICHIGAN DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS STANDARD PLAN FOR

DRAINAGE STRUCTURES

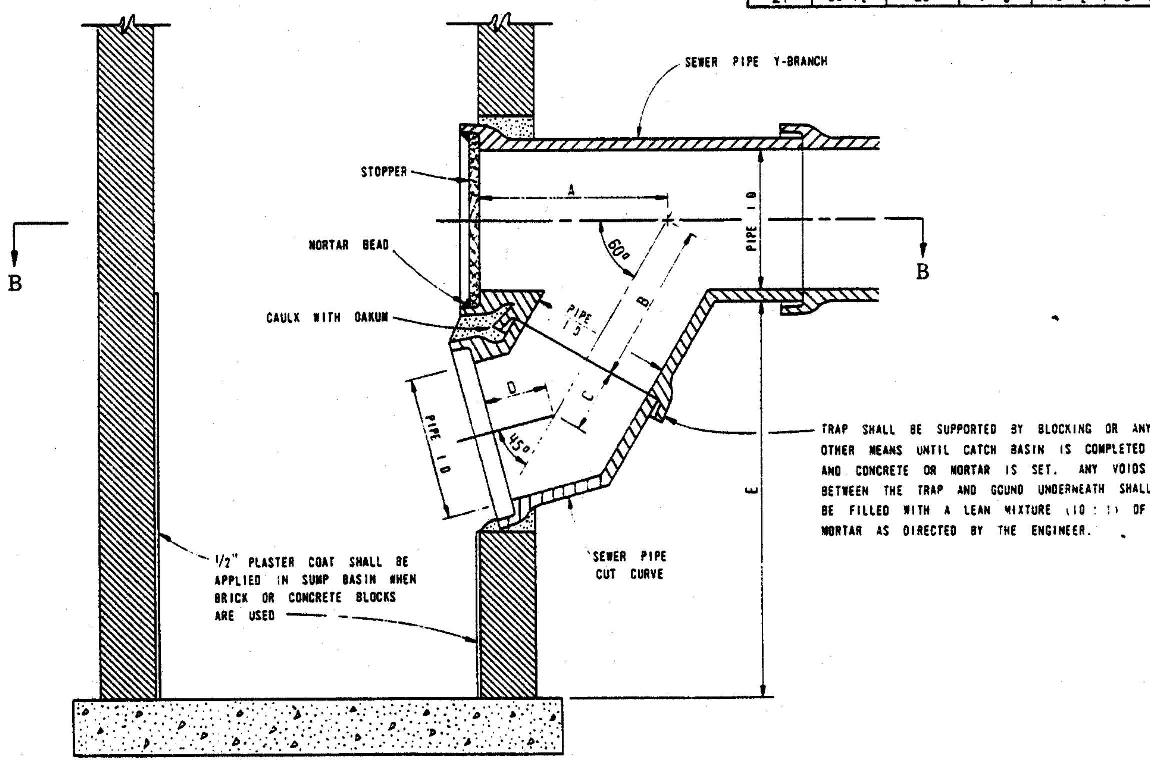
6-12-90	5-14-90	I-1E	SHEET 4 OF 4
F.H.W.A. APPROVAL	PLAN DATE		

Exhibit 3



SECTION B-B

DIMENSIONS					
PIPE I.D.	A	B	C	D	E
12"	17 1/4"	15"	5 7/8"	5 7/8"	3'-0"
15"	21"	17 1/2"	7 1/8"	7"	3'-0"
18"	25 1/2"	21 1/2"	8 3/8"	8 3/8"	4'-0"
21"	28"	24"	9 1/2"	9 1/2"	5'-0"
24"	30 1/2"	28"	9 [illegible]/8"	10 [illegible]/2"	5'-0"



SECTION A-A

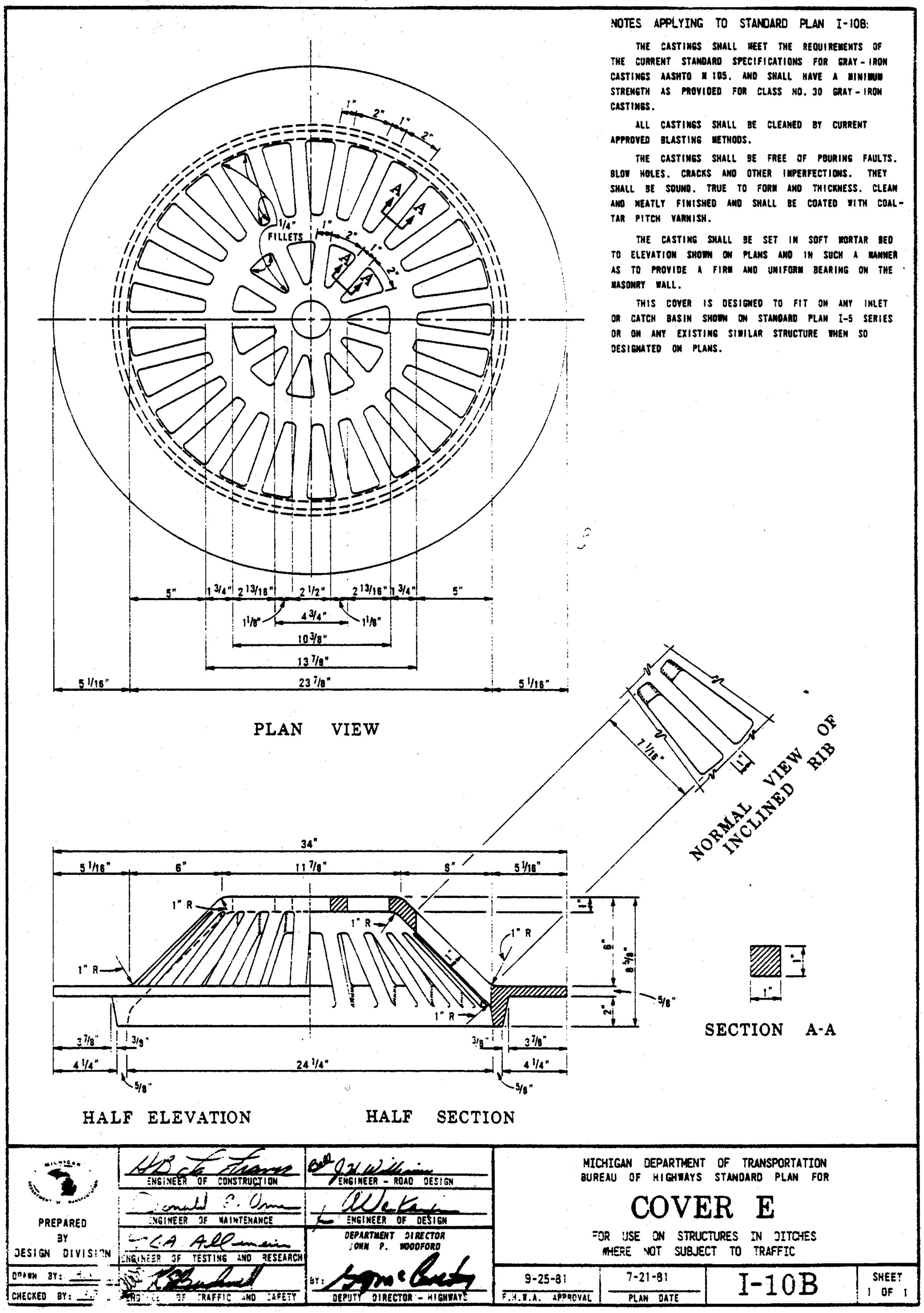
NOTES:

A CATCH BASIN, WHERE A SEWER TRAP IS TO BE PLACED, SHALL BE CONSTRUCTED IN ACCORDANCE WITH STANDARD PLAN I-5 SERIES EXCEPT AS SHOWN ON THIS PLAN.

SEWER TRAP SHALL BE MADE OF THE SAME MATERIAL AND HAVE THE SAME STRENGTH AS INLET SEWER PIPE.

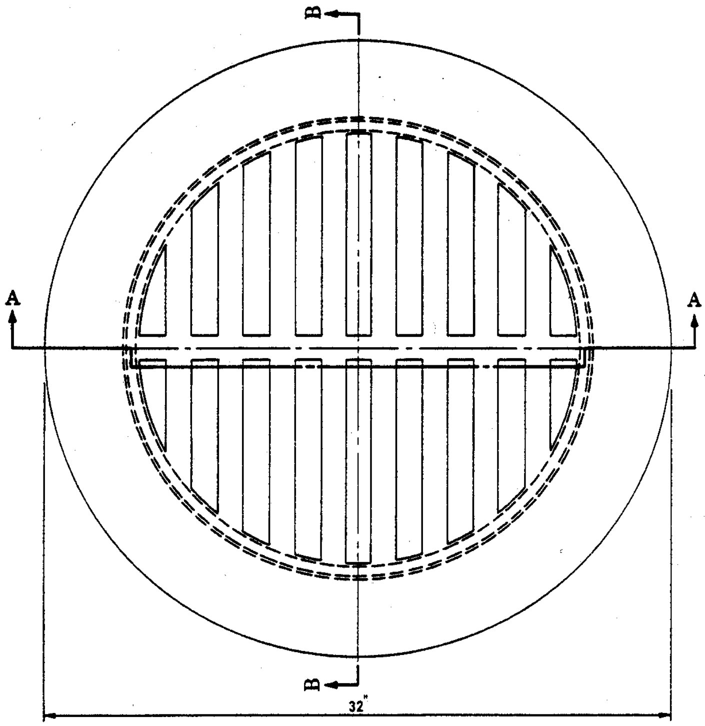
PREPARED BY DESIGN DIVISION	C. J. Zajac — ENGINEER OF ROAD DESIGN	for ENGINEER OF DESIGN	MICHIGAN DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAYS STANDARD PLAN FOR SEWER TRAP
DRAWN BY M.A.W. / CHECKED BY V.H.	K. A. Allemeier — ENGINEER OF TESTING AND RESEARCH	DEPARTMENT DIRECTOR JOHN P. WOODFORD	F.H.W.A. APPROVAL 3-4-80 DATE; 12-20-79 PLAN DATE; I-19B; SHEET 1 OF 1
	ENGINEER OF CONSTRUCTION	BY — DEPUTY DIRECTOR - HIGHWAYS	

Exhibit 4

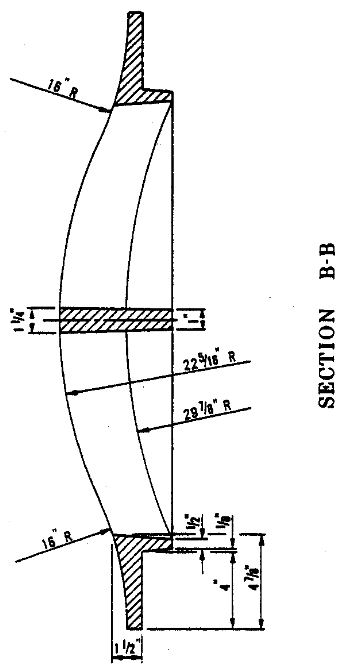


NOTES APPLYING TO STANDARD PLAN I-10B:
THE CASTINGS SHALL MEET THE REQUIREMENTS OF THE CURRENT STANDARD SPECIFICATIONS FOR GRAY-IRON CASTINGS AASHTO M 105, AND SHALL HAVE A MINIMUM STRENGTH AS PROVIDED FOR CLASS NO. 30 GRAY-IRON CASTINGS.
ALL CASTINGS SHALL BE CLEANED BY CURRENT APPROVED BLASTING METHODS.
THE CASTINGS SHALL BE FREE OF POURING FAULTS, BLOW HOLES, CRACKS AND OTHER IMPERFECTIONS. THEY SHALL BE SOUND, TRUE TO FORM AND THICKNESS, CLEAN AND NEATLY FINISHED AND SHALL BE COATED WITH COAL-TAR PITCH VARNISH.
THE CASTING SHALL BE SET IN SOFT MORTAR BED TO ELEVATION SHOWN ON PLANS AND IN SUCH A MANNER AS TO PROVIDE A FIRM AND UNIFORM BEARING ON THE MASONRY WALL.
THIS COVER IS DESIGNED TO FIT ON ANY INLET OR CATCH BASIN SHOWN ON STANDARD PLAN I-5 SERIES OR ON ANY EXISTING SIMILAR STRUCTURE WHEN SO DESIGNATED ON PLANS.
1/4" FILLETS
PLAN VIEW
NORMAL VIEW OF INCLINED RIB
SECTION A-A
HALF ELEVATION
HALF SECTION
PREPARED BY DESIGN DIVISION
ENGINEER OF CONSTRUCTION
ENGINEER - ROAD DESIGN
ENGINEER OF MAINTENANCE
ENGINEER OF DESIGN
ENGINEER OF TESTING AND RESEARCH
DEPARTMENT DIRECTOR JOHN P. WOODFORD
ENGINEER OF TRAFFIC AND SAFETY
DEPUTY DIRECTOR - HIGHWAYS
DRAWN BY:
CHECKED BY:
MICHIGAN DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS STANDARD PLAN FOR
COVER E
FOR USE ON STRUCTURES IN DITCHES WHERE NOT SUBJECT TO TRAFFIC
9-25-81
F.H.W.A. APPROVAL
7-21-81
PLAN DATE
I-10B
SHEET 1 OF 1

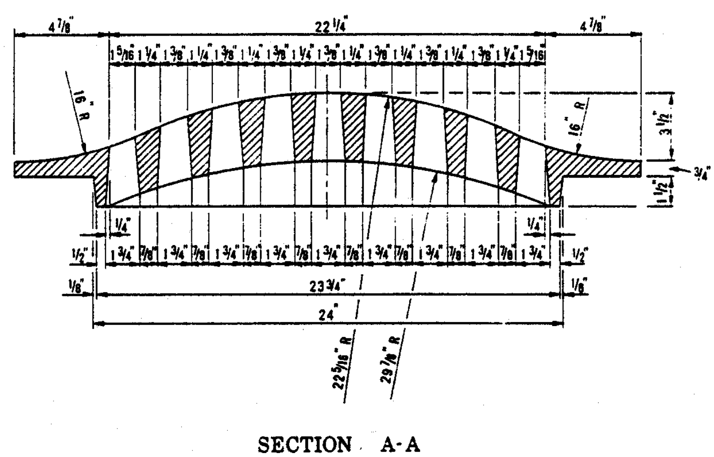
Exhibit 5



PLAN VIEW



SECTION B-B



SECTION A-A

NOTES APPLYING TO STANDARD PLAN I-12B:

THE CASTINGS SHALL MEET THE REQUIREMENTS OF THE CURRENT STANDARD SPECIFICATIONS FOR GRAY - IRON CASTINGS AASHTO M 105, AND SHALL HAVE A MINIMUM STRENGTH AS PROVIDED FOR CLASS NO. 30 GRAY - IRON CASTINGS.

ALL CASTINGS SHALL BE CLEANED BY CURRENT APPROVED BLASTING METHODS.

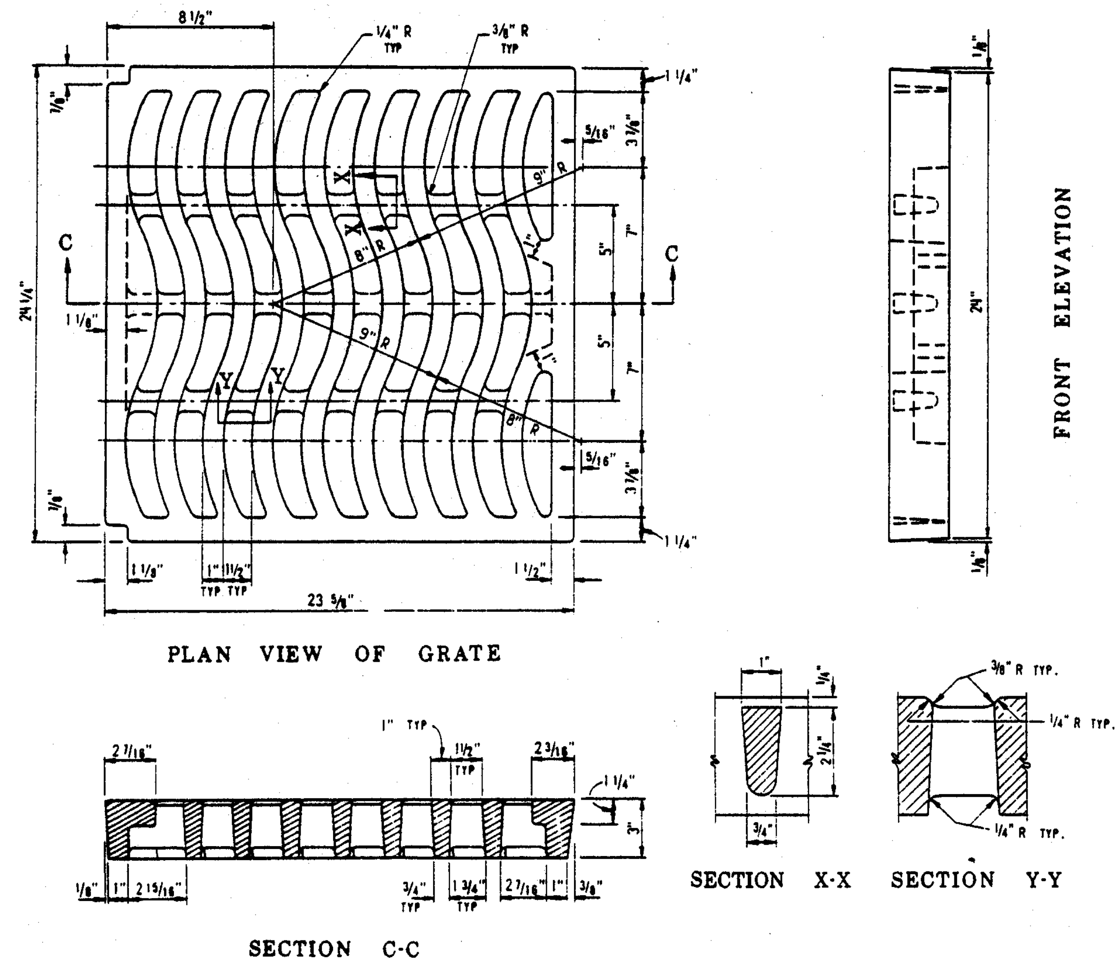
THE CASTINGS SHALL BE FREE OF POURING FAULTS, BLOW HOLES, CRACKS AND OTHER IMPERFECTIONS. THEY SHALL BE SOUND, TRUE TO FORM AND THICKNESS, CLEAN AND NEATLY FINISHED, AND SHALL BE COATED WITH COAL - TAR PITCH VARNISH.

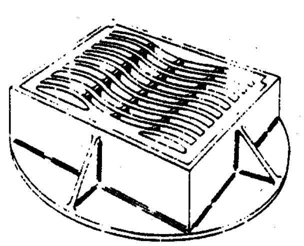
THE CASTING SHALL BE SET IN SOFT MORTAR BED TO ELEVATION SHOWN ON PLANS AND IN SUCH A MANNER AS TO PROVIDE A FIRM AND UNIFORM BEARING ON THE MASONRY WALL.

THIS COVER IS DESIGNED TO FIT ON ANY INLET OR CATCH BASIN AS INDICATED ON STANDARD PLAN I-5 SERIES OR ON ANY EXISTING SIMILAR STRUCTURE WHEN SO DESIGNATED ON PLANS.

PREPARED BY DESIGN DIVISION	ENGINEER OF CONSTRUCTION	ENGINEER - ROAD DESIGN	MICHIGAN DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAYS STANDARD PLAN FOR **COVER G** FOR USE IN DITCHES AND AREAS SUBJECT TO MINOR TRAFFIC
	ENGINEER OF MAINTENANCE	ENGINEER OF DESIGN	
	ENGINEER OF TESTING AND RESEARCH	DEPARTMENT DIRECTOR JOHN P. WOODFORD	
DRAWN BY: H.A.W. CHECKED BY: J.H.	ENGINEER OF TRAFFIC AND SAFETY	BY: DEPUTY DIRECTOR - HIGHWAYS	9-25-81 F.H.W.A. APPROVAL | 7-21-81 PLAN DATE | I-12B | SHEET 1 OF 1

Exhibit 6





NOTES APPLYING TO STANDARD PLAN I-20C:

THE CASTINGS SHALL MEET THE REQUIREMENTS OF CURRENT STANDARD SPECIFICATIONS FOR GRAY-IRON CASTINGS AASHTO M 105, AND SHALL HAVE A MINIMUM STRENGTH AS PROVIDED FOR CLASS NO. 30 GRAY-IRON CASTINGS.

ALL CASTINGS SHALL BE CLEANED BY CURRENT APPROVED BLASTING METHODS.

THE CASTINGS SHALL BE FREE OF POURING FAULTS, BLOW HOLES, CRACKS AND OTHER IMPERFECTIONS. THEY SHALL BE SOUND, TRUE TO FORM AND THICKNESS, CLEAN AND NEATLY FINISHED, AND SHALL BE COATED WITH COAL-TAR PITCH VARNISH.

THE SEATING FACE OF THE GRATE AND THE SEAT FOR THE SAME ON THE FRAME SHALL BE GROUND OR MACHINED SO THAT THE GRATE WILL HAVE AN EVEN BEARING ON ITS SEAT TO PREVENT ROCKING OR TILTING.

THIS COVER IS DESIGNED TO FIT ON ANY INLET OR CATCH BASIN SHOWN ON STANDARD PLAN I-5 SERIES OR ON ANY EXISTING SIMILAR STRUCTURE WHEN SO DESIGNATED ON PLANS.

PREPARED BY DESIGN DIVISION	ENGINEER OF CONSTRUCTION	ENGINEER ROAD DESIGN	MICHIGAN DEPARTMENT OF TRANSPORTATION BUREAU OF HIGHWAYS STANDARD PLAN FOR **COVER R**
	ENGINEER OF MAINTENANCE	ENGINEER OF DESIGN	
	ENGINEER OF TESTING AND RESEARCH	DEPARTMENT DIRECTOR JOHN P. WOODFORD	
DRAWN BY: H.A.W. CHECKED BY: V.R.	ENGINEER OF TRAFFIC AND SAFETY	DEPUTY DIRECTOR HIGHWAYS	9-25-81 F.H.W.A. APPROVAL · 7-21-81 PLAN DATE · I-20C · SHEET 2 OF 2

Extended Detention Basin

Description

Extended detention basins are designed to receive and detain stormwater runoff for a prolonged period of time, typically up to 48 hours. Extended detention is achieved by use of an outlet device regulating the flow from the basin at a rate which minimizes downstream erosion, reduces flooding, and provides for enhanced pollutant removal.

Extended detention basins may be designed as either single-stage or two-stage. Single-stage basins are normally used strictly for flood control and are not usually recommended where water quality benefits are needed. A two-stage basin contains water from small, frequent storms and the first flush of large storms in a lower second stage, with a normally dry upper stage for detention of larger storms for flood control. Managing a second stage as a shallow marsh increases the effectiveness of the basin to remove pollutants. All designs should be developed with multiple uses in mind.

Other Terms Used to Describe

Single-Stage Detention Basin
Two-Stage Detention Basin
Dual Purpose Basins

Pollutants Controlled and Impacts

A single-stage detention basin can be effective at removing sediment, nonsoluble metals, organic matter and nutrients through settling. Up to 90% of particulates may be removed if the stormwater is held for 24 hours or more.

A two-stage detention basin is also effective at settling out nonsoluble pollutants and sediment. Additional pollutant removal is gained when the second stage is managed as a shallow marsh. The marsh area helps prevent resuspension of sediment and provides some removal of soluble pollutants through plant uptake and bacterial activity. Still greater pollutant removal would be expected from a single-stage basin, followed by a Wet Detention Basin.

Extended detention basins also reduce peak discharges of storm runoff, thereby reducing flooding and stream bank erosion. They may actually help increase low flows, and reduce the peak discharge rate from urbanized areas.

Since extended detention basins can significantly warm the water in the marsh area over a short period of time, if the receiving stream is sensitive to increases in temperature, such as a trout stream, this BMP may not be appropriate.

Application

Land Use
Urbanized, urbanizing and agricultural areas

Soil/Topography/Climate
Soils with low infiltration rates may cause standing water problems. Extremely permeable soils may prohibit the establishment of a marsh area.

When to Apply
Extended detention basins may be applied to new or existing developments, and are usually considered permanent, year-round control measures. If used as a sediment basin during construction, the accumulated sediment must be removed at the end of the project and the banks stabilized.

Where to Apply
Basins should be sited as a result of a hydrologic analysis of the watershed. Too small a drainage area (less than 10 acres) may not provide sufficient volume to support wetlands, or may require a release orifice smaller than is practical.

A single-stage basin uses approximately 5% of a site, as opposed to 10% for a two-stage basin. This may be important where land prices are high or where little land is available.

Relationship With Other BMPs

Riprap is used to protect side slopes and inlet and outlet areas. Grassed Waterways are used to direct water from the inlet or to the outlet. Sediment Basins can be used upstream of the extended detention basin to remove large sediment particles. This technique will increase the pollutant removal efficiency and reduce the maintenance of the extended detention basin.

Specifications

Planning Considerations:
The **location** of basins must be determined through a hydrologic analysis of the watershed. If the peak discharge from a particular basin is delayed to coincide with the peak discharge from an upstream tributary or release from an upstream basin, the actual stream discharge peak can increase.

The location of any Sediment Basin should logically correspond with the location of any stormwater basins, including extended detention basins.

Adequate **access** right-of-way must be assured. The access should be a minimum of ten feet wide and stabilized to provide for passage of heavy equipment.

A **spill response plan** must be developed which clearly defines the emergency steps to be taken in the event of an accidental release of large quantities of harmful substances to the basin at any time. As a result of this plan, design changes such as shut-off valves or gates may be needed.

Design Considerations:

NOTE: All structural best management practices should be designed by a registered professional engineer.

The design of extended detention basins can be quite different depending on whether the primary function of the basin is flooding/erosion control or water quality enhancement. Each issue should be evaluated and a design developed which meets both requirements (as closely as possible).

An example of a typical two-stage extended detention basin is shown in Exhibit 1.

Buffer Strip:

A minimum 25-foot buffer from the basin to any adjoining property should be provided. This buffer should be landscaped to improve the appearance for local residents, provide wildlife habitat and meet any other local design considerations.

Volume:

The minimum volume of the basin to address water quality should be equal to 0.5 inches of runoff from the entire contributing watershed. Greater pollutant removal is gained with larger basin volumes. Additional capacity should be considered, especially in two-stage basins, to account for five to ten years of sediment accumulation. Additional volume up to the 100-year storm is recommended for flooding and erosion control.

Holding Time:

For optimum pollutant removal, the basin should be designed to hold the design volume for a minimum of 24 hours. Longer holding times may be necessary in large watersheds to prevent stream bank erosion. Storms smaller than design should be held a minimum of six hours. The hydrologic analysis of the receiving stream should be used to determine the optimum release rate.

Outlets:

The basin outlet will control the release rate from the basin. It must control both the design storm and lesser storms. Multiple outlets may be necessary to control discharge from a range of storms. Example outlets for normally dry basins are shown in Exhibit 2. Example outlets for basins with marsh areas or permanent pools are shown in Exhibit 3. A hydraulic analysis of the outlet structures at the low flow and design storm will be necessary to size the outlets to achieve the desired release rate. All outlets should have an accessible, above-ground cap to allow easy cleaning.

Outlet design can be extremely complex. A detailed design method can be found in the "Stormwater Management Guidebook" by Bruce Menerey and published by the Michigan Department of Natural Resources, Land and Water Management Division.

A stabilized outlet structure must be used to prevent scouring at the discharge point. Stabilized Outlets are normally constructed using Riprap, corrugated pipe or concrete.

Basin Configuration:

The length of the basin should be at least three times the width. Baffles may be used to increase the length of the basin. The basin should be narrow at the inlet and wide at the outlet.

Side Slopes:
Berm side slopes should not be more than 3:1 and not less than 20:1. The basin floor of the dry portion should have a slope of 2% toward the outlet.

Emergency Spillway:
An emergency spillway must be included to handle storms greater than design. The spillway must be designed and installed to protect against erosion problems.

The banks should be constructed such that two feet of freeboard is above the emergency spillway.

Low-flow Channel:
A low flow channel should be provided through the dry portion of the basin. This channel should be lined with riprap to prevent scouring. The remainder of the basin should drain toward this channel. Where recreational uses are desired, the low-flow channel should be placed to one side instead in the middle of the basin.

Anti-seep Collars:
Anti-seep collars should be installed on any piping passing through the sides or bottom of the basin.

Construction Considerations:
At the conclusion of construction, stabilize the surrounding area following the guidance in the Seeding and Mulching, or Sodding BMPs.

Maintenance

Regular maintenance includes mowing the buffer/filter strip and removing debris from the basin. Follow mowing specifications in the Buffer/Filter Strip BMP. If properly designed, sediment removal from an extended detention basin will be necessary every five to ten years.

The basin should be inspected regularly during wet weather. Particular attention should be given to the outlet structure and low-flow channel.

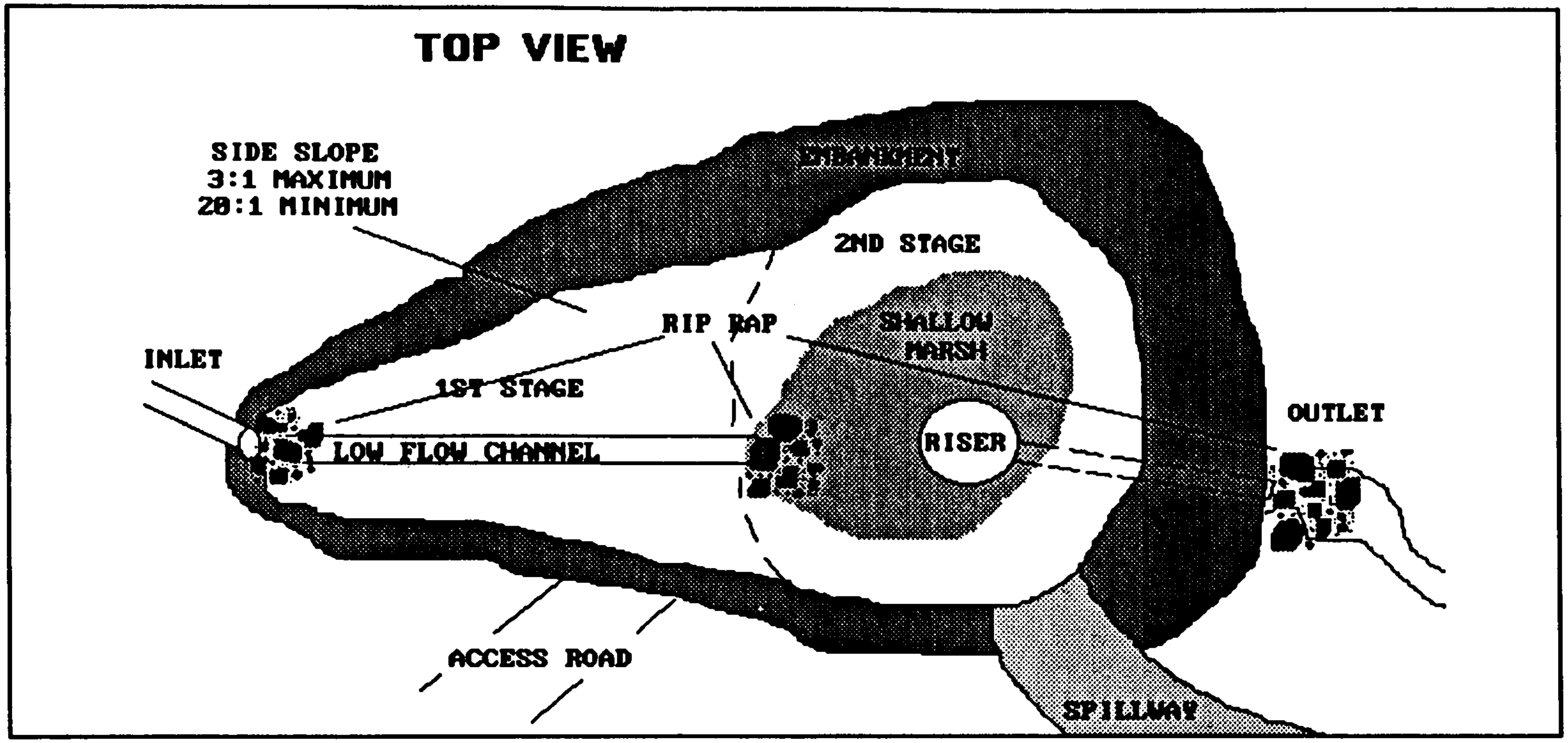
Exhibits

Exhibit 1: Typical 2 Stage Detention Basin. Michigan Department of Natural Resources. Surface Water Quality Division.

Exhibit 2: Examples of Outlets Used in Dry Detention Basins. "Controlling Urban Runoff: a Practical Manual for Planning and Designing Urban BMPs." Metropolitan Washington Council of Governments (Schueler). 1987.

Exhibit 3: Examples of Outlets Used in Wet Detention Basins. "Controlling Urban Runoff: a Practical Manual for Planning and Designing Urban BMPs." Metropolitan Washington Council of Governments (Schueler). 1987.

Exhibit 1
Typical 2 Stage Extended Detention Basin



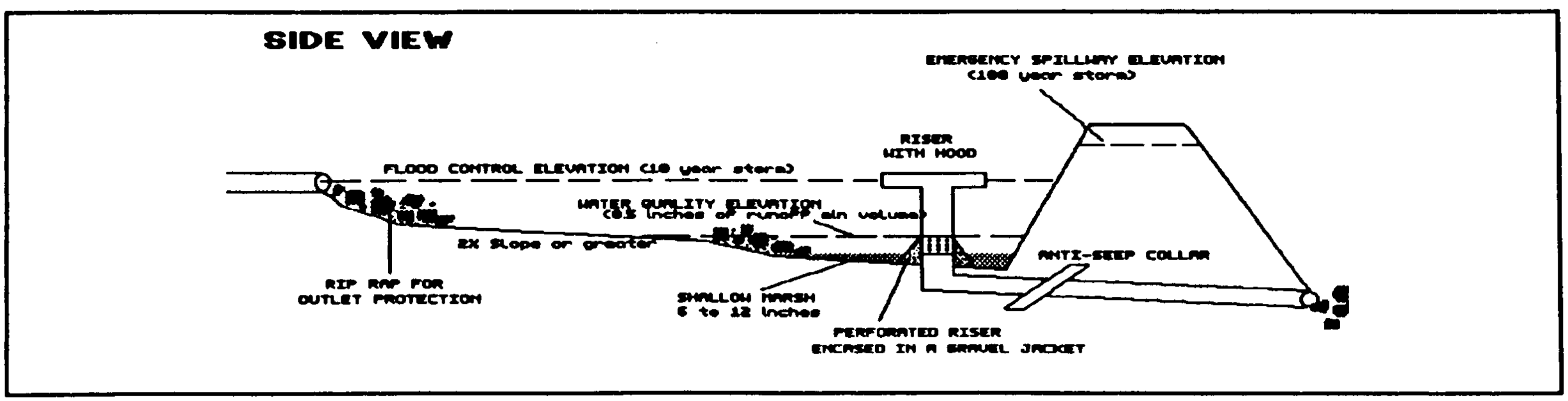
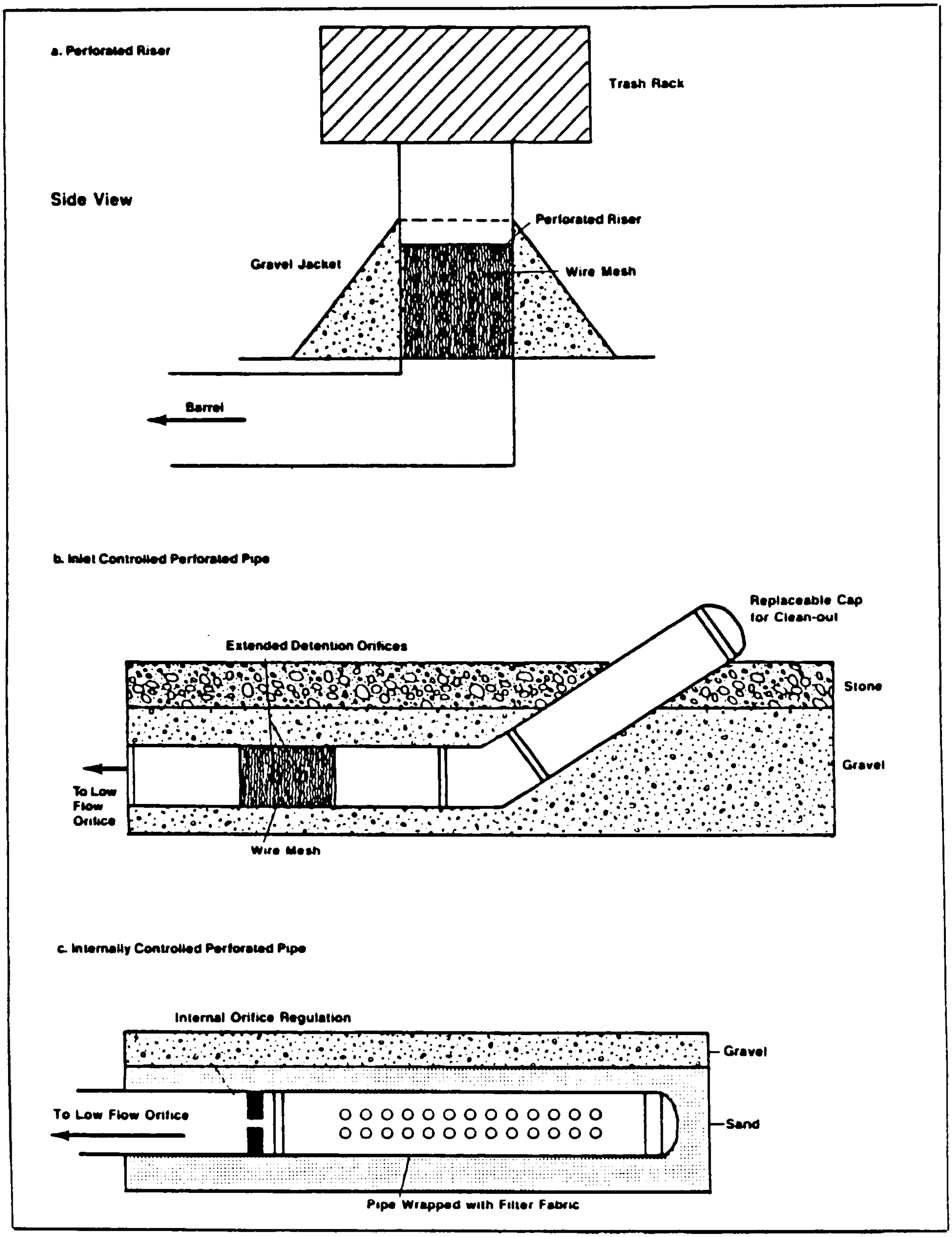
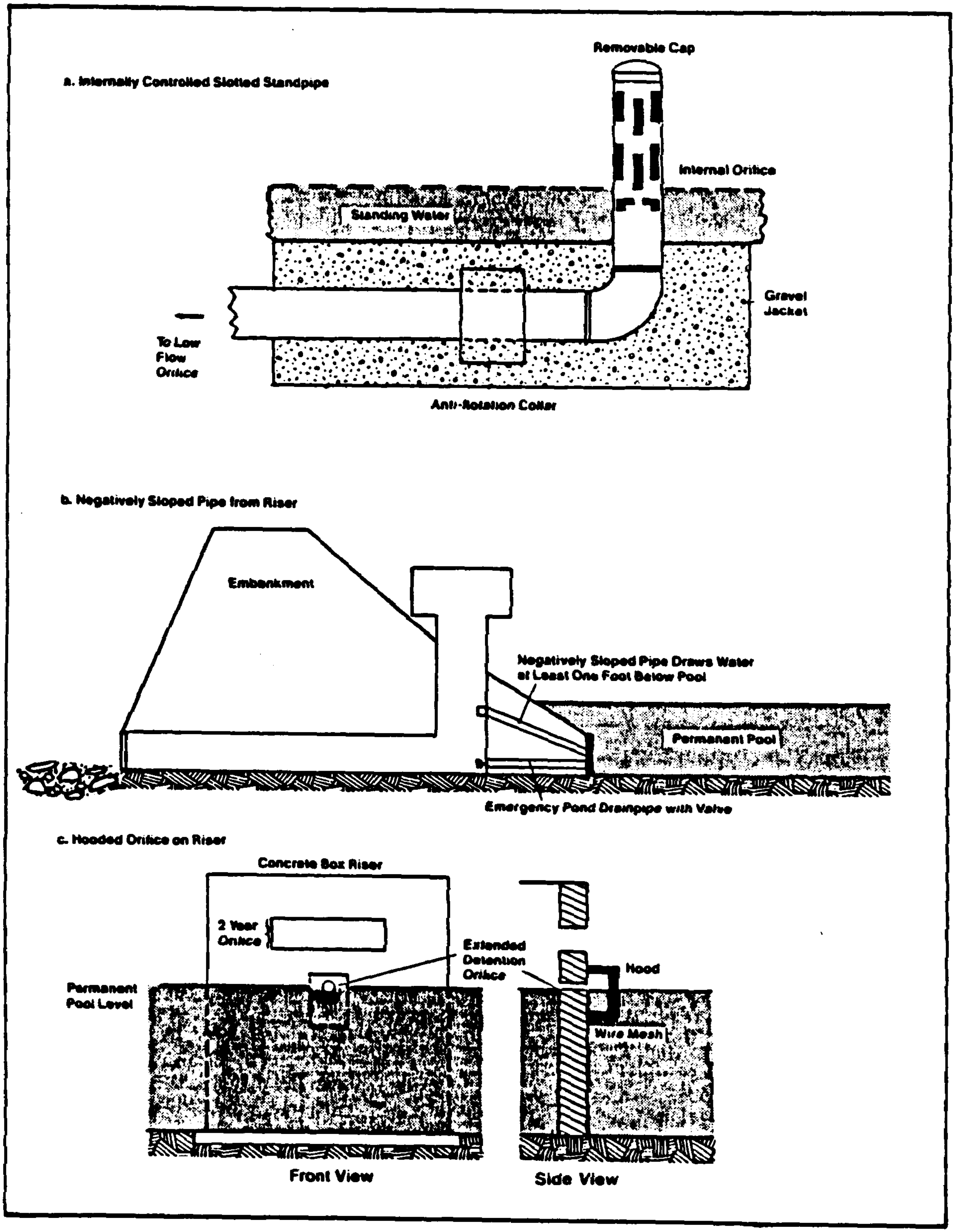


Exhibit 2 – Examples of Outlets Used In Dry Detention Basins



Source: Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Council of Governments (Scheuler). 1987.

Exhibit 3 – Examples of Outlets Used In Wet Detention Basins



Source: Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Council of Governments (Scheuler). 1987.

Infiltration Basin

Description

An infiltration basin is a water impoundment over permeable soils which receives stormwater runoff and contains it until it infiltrates the soils. These basins remove *fine* sediment and the pollutants associated with them. *Coarse* sediment must be removed from the stormwater by other methods prior to entering the basin. This BMP serves drainage areas up to 50 acres in size.

Although use of infiltration practices is encouraged, if not properly designed, constructed, and maintained, contamination of groundwater can occur. Infiltration basins should only be used as part of a "treatment train," where soluble organic substances, oils, and course sediment are removed by other management practices prior to stormwater entering the infiltration basin. This practice should *not* be used in industrial parks, high density or heavy industrial areas, chemical or pesticide storage areas, or fueling stations.

Infiltration basins can provide recreational, wildlife habitat or aesthetic benefits in addition to stormwater control. Multiple uses of these basins are recommended whenever possible.

Other Terms Used to Describe

Exfiltration Basin
Infiltration Pond
Recharge Basin
Retention Basin
Seepage Basin

Pollutants Controlled and Impacts

Infiltration basins are effective at removing fine sediment and the pollutants associated with them. Coarse sediment and oils will plug the basin and must be removed prior to entering it (i.e. pretreated). Some soluble pollutants can be effectively removed if proper vegetation is planted and managed, and detention time is maximized. The degree to which soluble pollutants are removed is dependent primarily on uptake by vegetation in the basin, degree of bacterial transformation, bonding to soils, and holding time.

Infiltration basins can provide full control of peak discharges for large design storms. They provide groundwater recharge and may augment base stream flow. They are effective at replacing infiltration lost due to the addition of impervious areas, and may be used strictly as a means to maintain the hydrologic balance after stormwater runoff has been treated by other means.

It is important to remember that if stormwater runoff contains high amounts of soluble contaminants, groundwater contamination can occur. If soluble contaminants are known to be present, source elimination of the contaminants should be pursued.

Application

Land Use
Primarily urban and urbanizing

Soil/Topography/Climate
The soil at the site selected for the basin is extremely important. Acceptable soils are those with infiltration rates greater than 0.52 inches per hour, and a clay content less than 30%. Basins should not be constructed in areas where fill has been used.

Infiltration basins are not feasible where the slope of the contributing watershed is greater than 20%.

When to Apply
Normally, the basin would not be put into use until after the work site is stabilized. If the basin will also serve as a Sediment Basin during construction, it should only be excavated down to two feet above the design floor. Sediment which accumulates in the basin can then be excavated when the basin is constructed and after all other construction is complete.

Where to Apply
Infiltration basins may be used for sites five to 50 acres in size.

Randomly sited basins with regular discharges to a surface water may add to peak discharges at some points in the receiving stream. Basin placement and discharge rates should be determined based on a hydrologic analysis of the watershed.

Basins can be designed for multiple uses, such as playgrounds or parks. This is particularly attractive in urban areas where available land is limited.

Relationship With Other BMPs

Sediment Basins and Buffer/Filter Strips are needed to remove larger particles from stormwater prior to entering the basin. Riprap is used at inlets and outlets to prevent scouring, reduce flow velocities, and trap sediment. Oil/Grit Separators are used to remove oil, grease and large solids from stormwater before it enters the basin. Extended Detention Basins and Wet Detention Basins are often used in a treatment train prior to the infiltration basin.

Specifications

Planning Considerations:
The **location** of basins must be determined through a hydrologic analysis of the watershed. If the peak discharge from a particular basin is delayed to coincide with the peak discharge from an upstream tributary, or release from an upstream basin, the actual stream discharge peak can increase.

The location of any Sediment Basins should logically correspond with the location of any stormwater basins, including infiltration basins.

Basins should be sited a minimum 100 feet from drinking water wells.

Basins should be sited a minimum 100 feet up-gradient and 20 feet down-gradient from building foundations.

A minimum of four feet from the basin bottom to the seasonally high water table is recommended in order to insure proper basin operation. A minimum of four feet from the basin bottom to bedrock is also recommended.

Take **soil tests** to ensure that the soils meet the minimum infiltration capacity. (See below).

Adequate **access** right-of-way must be assured. The access should be a minimum 10 feet wide and stabilized to provide for passage of heavy equipment.

A **spill response plan** must be developed which clearly defines the emergency steps to be taken in the event of an accidental release of large quantities of harmful substances to the basin. Response time is critical in order to prevent groundwater contamination. As a result of this plan, design changes such as shut-off valves or gates may be needed.

<u>Design Considerations</u>:
NOTE: All structural best management practices should be designed by a registered professional engineer.

Infiltration basins may be designed several ways:

On-Line Basin: The basin is a part of the stormwater conveyance system. That is, all runoff that reaches the conveyance system will be retained in, or pass through the infiltration basin. A protected low-flow channel and outlet structure are necessary parts of this design.

Off-Line Infiltration Basins: Flow is diverted from a storm sewer or surface channel by a device such as a weir, to an infiltration basin. At some determined volume, additional flows are directed to the receiving stream by means of a spillway.

Exhibits 1 through 3 are diagrams of different types of infiltration basin design.

Watershed Size:
Infiltration basins should not be used on sites greater than 50 acres.

Soil Infiltration Capacity:
The infiltration capacity of the soil must be greater than 0.52 inches/hour to insure that the basin operates properly. This corresponds to soils classified A or B by the Soil Conservation Service. It is prudent to multiply the actual soil infiltration capacity in the design by 0.5, as a margin of safety in order to account for lowered basin efficiency by sediment accumulation or soil compaction between maintenance visits.

Buffer Strip:
At a minimum, a 25-foot grass buffer strip should surround the infiltration basin.

Pretreatment:
As with any BMP, this practice should be used as part of a treatment train. A treatment train is a series of BMPs used in conjunction with each other, such that each BMP removes certain pollutants. Infiltration practices should be considered to be the final stop in the treatment train because they can become clogged by oils and course solids, and because of the possibility of pollutants leaching to groundwater. BMPs which precede these infiltration practices should remove oils and course solids at a minimum.

Volume:
Minimum design volume should be no less than 0.5 inches of runoff from the entire contributing watershed. Larger volumes will provide more effective treatment and are recommended. If some portion of the volume is to release directly to a receiving water, as in a detention facility, the design of the outlet can be very complex. An outlet design method is discussed in the "Stormwater Management Guidebook" by Bruce E. Menerey, which is available from the Department of Natural Resources, Land and Water Management Division.

Holding Time:
The basin should hold water for not less than six hours nor greater than 72 hours. Less than six hours of holding time provides little treatment, while greater than 72 hours can create nuisance problems and capacity problems for back-to-back storms.

Basin Configuration:
The basin floor should be as flat as possible, with no significant depressions. Side slopes should be no more than 3:1 (h:v) to allow for mowing and bank stabilization.

Infiltration is enhanced with increasing surface area of the basin floor. Therefore, maximize basin floor surface area and reduce depth.

Emergency Spillway:
An emergency spillway must be provided in order to direct overflows from storms larger than the design storm.

Vegetation:
Vegetation on the basin bottom and sides must be capable of surviving up to 72 hours under water. Tall fescues or bermuda grass are often used. **Native** vegetation is most desirable. The vegetation can maintain and possibly improve infiltration, prevent erosion, and remove soluble nutrients in the stormwater.

Access:
Adequate access to the basin floor for maintenance must be provided.

Construction Considerations:
To prevent soil compaction, avoid the use of heavy equipment on the bottom of the basin.

At the conclusion of construction, stabilize the surrounding area following the guidance in the Seeding and Mulching, or Sodding BMPs.

Maintenance

Existing infiltration basins have the highest failure rate of any BMP. The primary reasons are lack of pretreatment for removal of substances which can clog the basin, and lack of maintenance. Maintenance is essential for the long-term use of this practice.

The most critical maintenance item for this BMP is the periodic removal of accumulated sediment from the basin bottom. If sediment is allowed to accumulate, surface soils will become clogged and the basin will cease to operate as designed. Sediment should be removed only when the surface is dry and "mud-cracked." Light equipment must be used in order to avoid compacting soils. After removal of sediment, the infiltration area should be deep tilled to restore infiltration rates. Normally, sediment should be removed at least once a year. More frequent tilling may be necessary in areas with soils that are only marginally permeable.

Other maintenance items include mowing buffer/filter strips, side slopes, and the basin floor. Debris and litter accumulated in the basin must be removed. Eroding or barren areas must be revegetated as soon as possible.

Exhibits

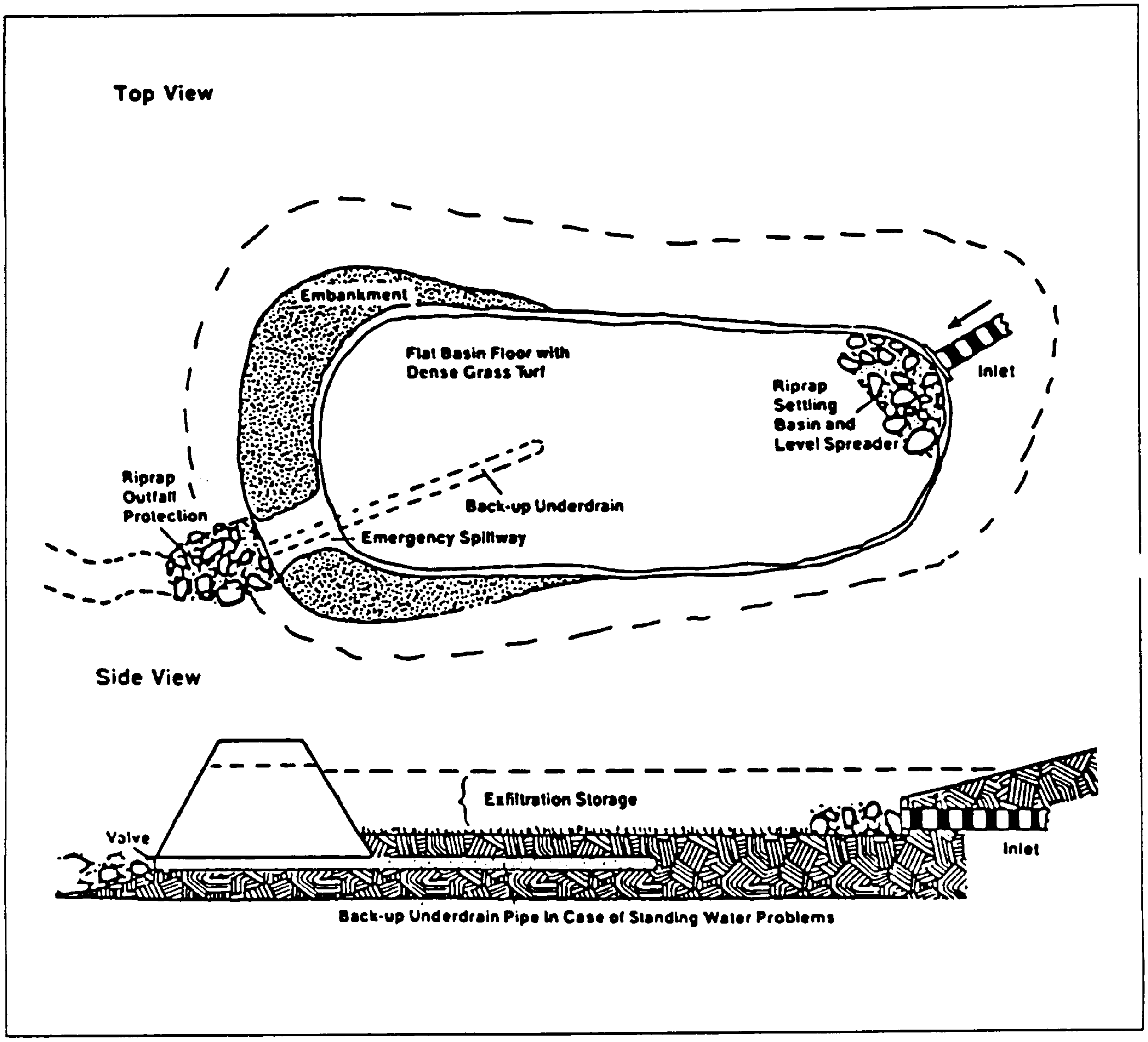
All three exhibits were taken from: Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments (Schueler). 1987.

Exhibit 1: Full Infiltration Basin.

Exhibit 2: Combined Infiltration/Detention Basin.

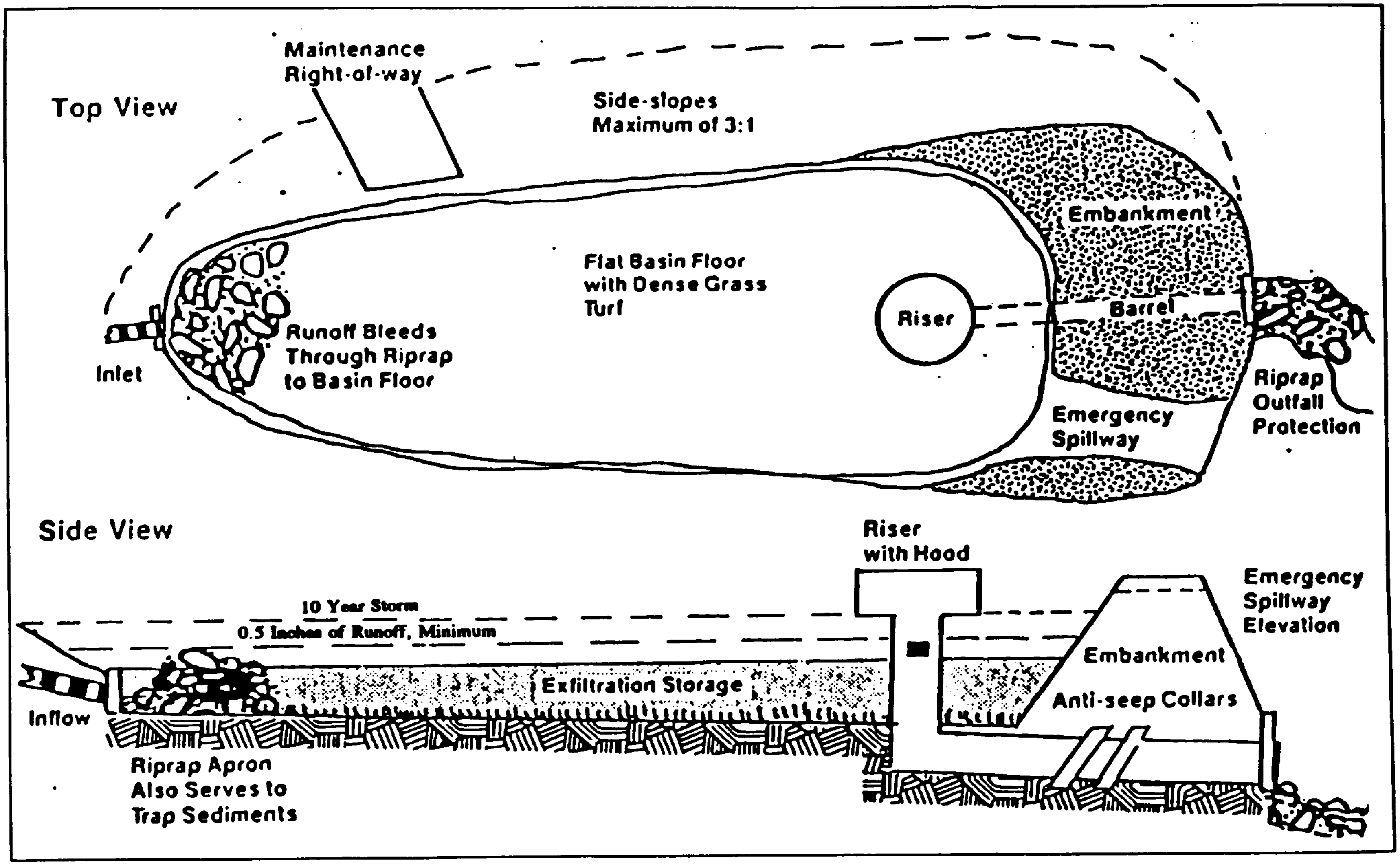
Exhibit 3: Off Line Infiltration Basin.

Exhibit 1 – Full Infiltration Basin



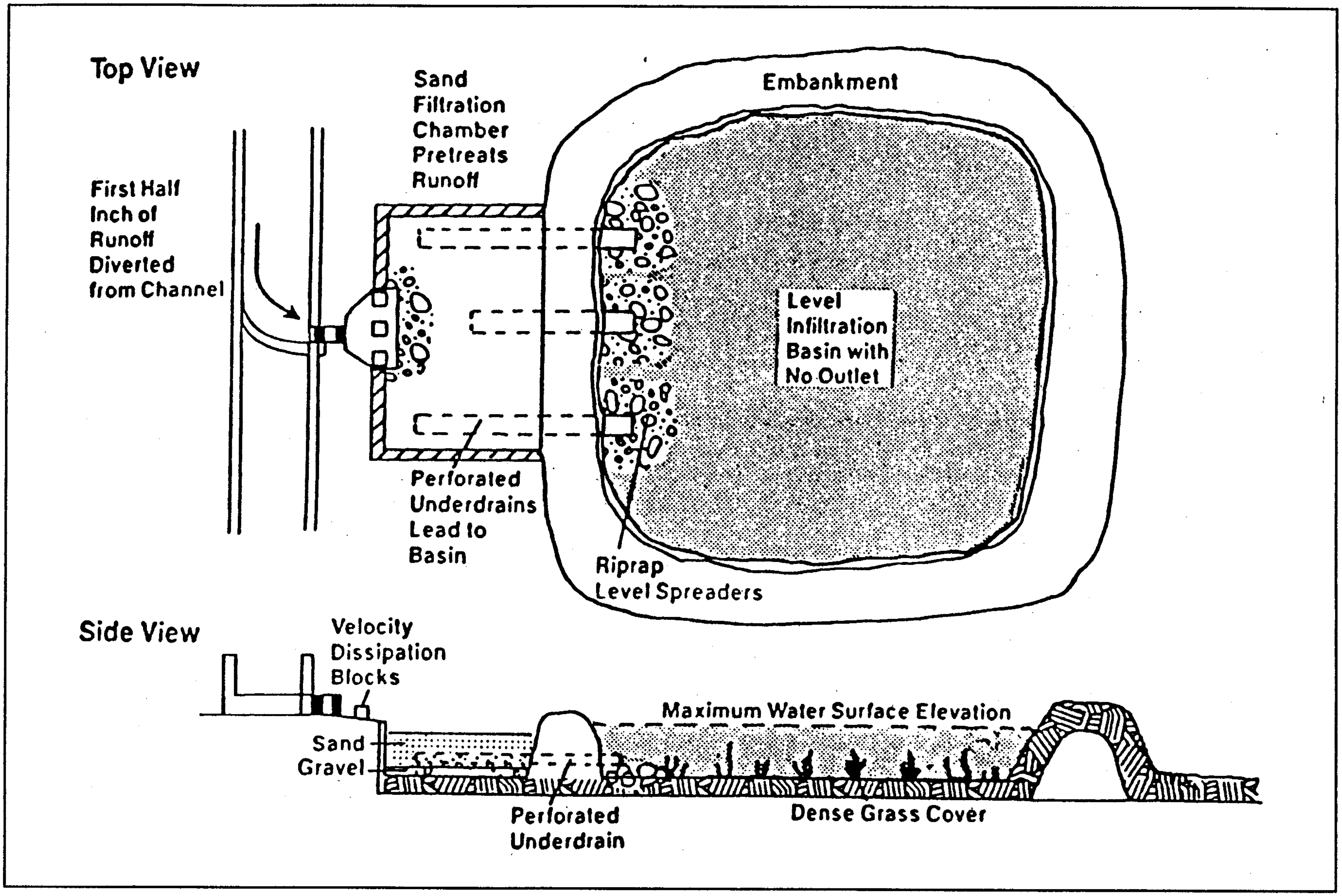
Source: Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments (Scheuler). 1987.

Exhibit 2 – Combined Infiltration/Detention Basin



Source: Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments Ischeuler). 1987.

Exhibit 3 – Off-Line Detention Basin



Source: Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments (Scheuler). 1987.

Dec. 1, 1992

Infiltration Trench

Description

An infiltration trench is a long, narrow, shallow excavation located over porous soils and back-filled with stone to form a subsurface reservoir to hold stormwater and allow it to infiltrate the soil. It can be used on small sites up to five acres in size. Infiltration trenches remove fine sediment and the pollutants associated with them.

Trenches may be "open" to the surface or enclosed below ground. Open trenches receive sheet flow of stormwater from surrounding sources. The sheet flow enters the trench through a layer of vegetated porous soil on the top of the trench. Grass filter strips remove coarse sediments which would plug the spaces between the stones and make the trench ineffective.

Below-ground trenches may receive higher concentrations of flow than above-ground trenches. With below-ground trenches, stormwater enters the basin through an inlet and pipe from the surface. The stormwater entering the trench must be pre-treated using a combination of buffer strips and multi-chambered catch basins to remove coarse sediments and oils.

Although use of infiltration practices is encouraged, if not properly designed, constructed, and maintained, contamination of groundwater can occur. Infiltration trenches should only be used as part of a "treatment train," where soluble organic substances, oils, and coarse sediment are removed by other management practices prior to stormwater entering the infiltration trench. This practice should not be used in industrial parks, high density or heavy industrial areas, or chemical or pesticide storage areas, or fueling stations.

Pollutants Controlled and Impacts

Infiltration trenches remove fine sediment and the pollutants associated with them. Coarse sediment may prevent the trench from operating properly and must be removed prior to entering it.

Soluble pollutants can be effectively removed if detention time is maximized. The degree to which soluble pollutants are removed is dependent primarily on holding time, the degree of bacterial activity, and chemical bonding with the soil. It is important to remember that if stormwater runoff contains high amounts of soluble contaminants, groundwater contamination can occur. If soluble contaminants are known to be present, either pretreatment or source elimination of the contaminants must be pursued.

The efficiency of the trench to remove pollutants can be increased by increasing the surface area of the trench bottom. Infiltration trenches can provide full control of peak discharges for small sites. They provide groundwater recharge and may augment base stream flow. They are effective at replacing infiltration lost due to the addition of impervious areas, and may be used strictly as a means to maintain the hydrologic balance after stormwater runoff has been treated by other means.

Application

Land Use
Urban, urbanizing, transportation, and agricultural

Soil/Topography/Climate
Soil infiltration rates at the site selected for the basin are extremely important. Acceptable soils are those with infiltration rates greater than 0.52 inches per hour, with clay content less than 30%. Trenches should not be constructed in areas which have been filled in.

Infiltration trenches are not feasible where the slope of the site is greater than 20%, unless proper energy dissipation devices are installed. Infiltration trenches are not recommended where the slope of the contributing watershed is greater than 5%.

When to Apply
Infiltration trenches should not be constructed until after the entire work site is stabilized. The trenches or the area where they will be constructed must not be used as a sediment basin during construction. Heavy equipment must be kept off the site where the trenches are to be constructed to prevent compacting the underlying soils.

Where to Apply
Infiltration trenches should only be used for sites five acres or less in size. Examples include parking lot drainage, roof drainage and highway drainage.

Infiltration trenches are a good alternative at small sites where little land is available. Trenches can easily be incorporated into the existing landscape, causing no negative aesthetic impacts.

This practice should not be used in industrial parks, high density or heavy industrial areas, areas with chemical or pesticide storage, and fueling stations in order to reduce the risk of groundwater contamination from substances which may not be removed by this practice.

Relationship With Other BMPs

Sediment Basins and Buffer/Filter Strips are needed to remove larger soil particles from stormwater prior to entering the trench.

Oil/Grit Separators are constructed inlets used to provide settling of coarse sediments and skimming of oils prior to entering the infiltration trench. Primarily used for below-ground trenches.

Filter Fabric is used to line the sides and sometimes bottom of the trench. Filter fabric placed 6 to 12 inches below the surface of an open trench can prevent major rehabilitation.

Specifications

Planning Considerations:

Take **soil tests** to ensure that the soils meet the minimum infiltration capacity. (See below).

Determine the **site location**. Trenches should be sites:

> a minimum 100 feet from drinking water wells; and
>
> a minimum 100 feet up-gradient and ten feet down-gradient from building foundations.

A minimum of four feet from trench bottom to the seasonally high water table is recommended in order to insure proper operation. A minimum of four feet from trench bottom to bedrock is also recommended.

In order to remain operative in freezing weather, infiltration trenches need to be placed three feet below the frost line.

Develop a **spill response plan**. The plan should clearly define the emergency steps to be taken in the event of an accidental release of large quantities of harmful substances to the basin. Response time is critical in order to prevent groundwater contamination. As a result of this plan, design changes such as shut off valves, or gates may be needed.

Design Considerations:

NOTE: All structural best management practices should be designed by a registered professional engineer.

Exhibit 1 is a diagram of a recommended infiltration trench design.

Watershed Size:

Drainage of a single infiltration trench should be less than five acres.

Soil Infiltration Capacity:

The infiltration capacity of the soil must be greater than 0.52 inches/hour to insure that the trench operates properly. This corresponds to soils classified A or B by the Soil Conservation Service. It is prudent to multiply the actual soil infiltration capacity in the design by 0.5, as a margin of safety in order to account for lowered trench efficiency by sediment accumulation or soil compaction between maintenance visits.

Buffer/Filter Strip:

At a minimum, surface trenches should have a 25 foot wide grass buffer/filter strip approaching the trench. Water should be directed through the buffer strip in sheet flow, rather than as concentrated flow. An example of such a configuration is shown in Exhibit 2.

Pretreatment:
As with any BMP, this practice should be used as part of a treatment train. A treatment train is a series of BMPs used in conjunction with each other, such that each BMP removes certain pollutants. Infiltration practices should be considered to be the final stop in the treatment train because they can become clogged by oils and course solids, and because of the possibility of leaching pollutants to groundwater. BMPs which precede these infiltration practices should remove oils, and coarse solids at a minimum.

Volume:
Minimum design volume should be based on infiltration of 0.5 inches runoff over the entire drainage basin. Larger volumes will provide more effective treatment and are recommended.

To calculate the storage volume in the trench the void space between the aggregate must be determined. For the aggregate specified, assume a void space of 40% and use the formula:

$$\text{Storage Volume} = 0.4\ WHL\ Ft^3$$

Where W = Width
H = Depth
L = Length

Storage volume may be increased and trench length decreased if a perforated pipe is used in the trench design. The pipe must be placed a minimum of one foot above the bottom of the trench and six inches from either side. This pipe should be equipped with a solid overflow pipe for storms larger than design. In order to calculate storage volume of a trench with a perforated pipe, the above formula becomes:

$$\text{Storage Volume} = \text{Pipe Volume} + [0.4*(WHL\text{-Pipe Volume})]$$

This method is a conservative method which does not take into account infiltration, water depth, or soil saturation. More complex methods are available which more accurately describe the storage characteristics of the basin during a storm.

Holding Time:
The basin should hold water for a minimum of six hours and a maximum of 72 hours. Holding water for less than six hours provides little pollutant removal. Holding water for greater than 72 hours can create nuisance problems and capacity problems for back-to-back storms.

Overflow Pipe:
Where an overflow pipe is provided for flows in excess of design, the pipe should be placed near the surface of the trench and discharge to a non-erosive channel which leads to a surface water.

Underground trenches should receive water directed through a Oil/Grit Separator, or similar device which will remove both coarse solids and oils from the waste stream. An underground infiltration trench configuration is shown in Exhibit 3.

Filter:
Filter fabric must be used to line the sides of the trench. Either filter fabric or six inches of sand is used on the trench bottom. Cleaned, washed stone aggregate, 1.5 to 3 inches in diameter should be used as fill.

Observation Well:
An observation well, consisting of a perforated vertical pipe within the trench, should be installed in every trench to monitor performance.

Construction Considerations:
Avoid the use of heavy equipment which would compact the soil in the trench.

Do not construct the trench until the entire construction area is stabilized. Construct a diversion berm around the perimeter of the trench. Remove excavated soils to outside the berm.

The trench floor should be as flat as possible.

Maintenance

A very high failure rate occurs with infiltration trenches if they are not maintained. The most critical maintenance item for this BMP is the periodic removal of accumulated sediment. If sediment is allowed to accumulate, the storage volume of the trench for wastewater will become reduced as the space between rocks is filled with sediment. Surface soils can become clogged and the trench will cease to operate as designed. Normally, total rehabilitation of the trench will be needed if it becomes clogged.

Total rehabilitation can be avoided if filter fabric is placed 6 to 12 inches below the surface of the trench. If failure occurs, only the portion of the trench above the filter fabric will require replacement. This is most useful where systems to remove course sediment have a high probability of failure.

The observation well should be checked several times within the first few months of operation to be sure the trench is operating correctly. The well should be checked annually thereafter to determine when rehabilitation is needed.

Where Catch Basins or Oil/Grit Separators are used, the sediment and oil accumulated within them must be periodically removed. Follow the maintenance schedule in the BMP. Debris which can clog the inlets or outlets must also be removed.

Other maintenance items include mowing Buffer/Filter Strips. Follow specifications in the Buffer/Filter Strip BMP.

Eroding or barren areas must be revegetated as soon as possible.

Exhibits

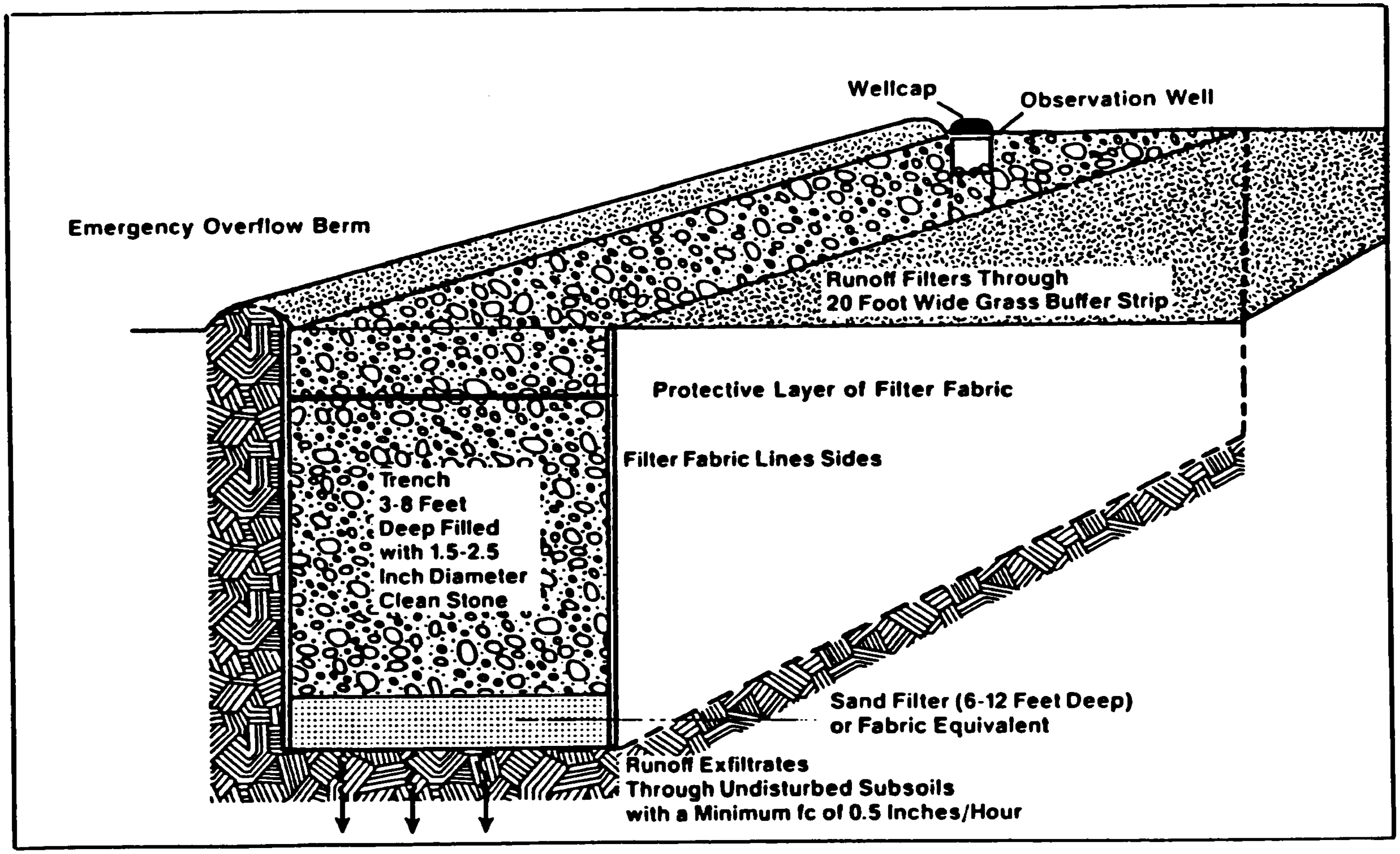
All three exhibits were taken from: Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments (Schueler). 1987.

Exhibit 1: Typical Infiltration Trench.

Exhibit 2: Example Surface Trench Configuration.

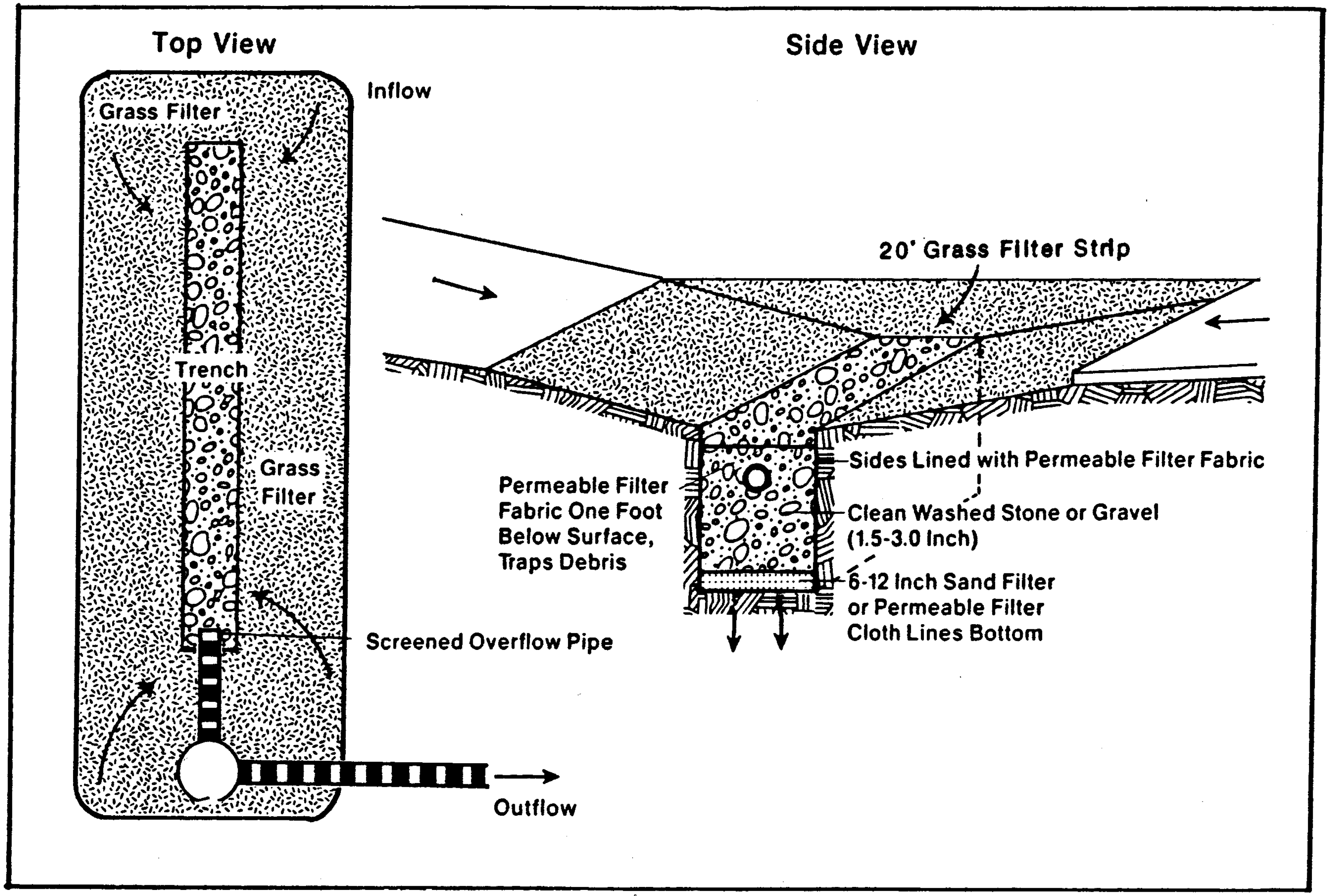
Exhibit 3: Example Underground Trench Configuration.

Exhibit 1 – Typical Infiltration Trench



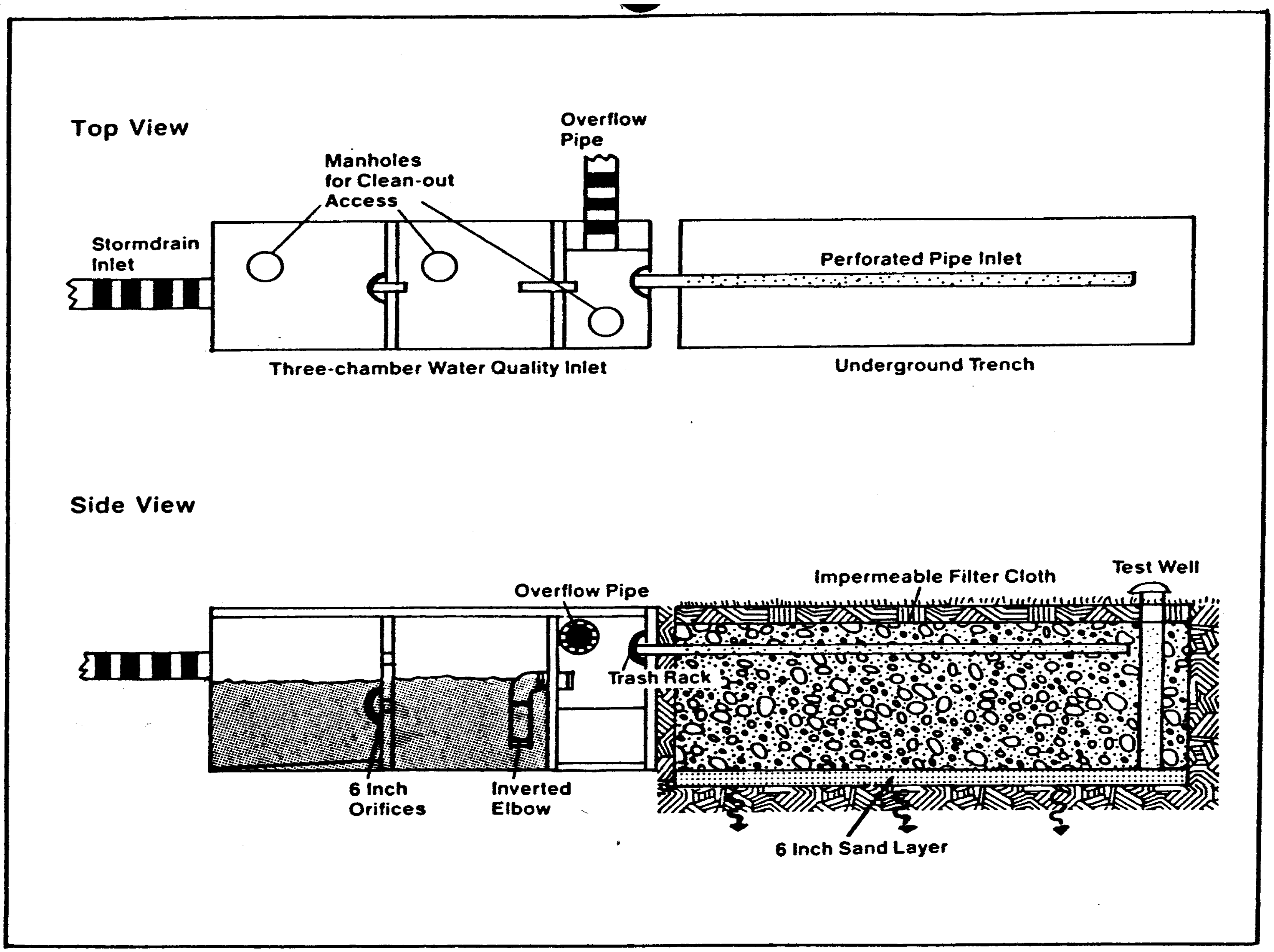
Source: Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments (Scheuler). 1987.

Exhibit 2 – Highway Median Strip Trench Design



Source: Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments (Scheuler). 1987.

Exhibit 3 – Underground Infiltration Trench Design



Source: Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments (Scheuler). 1987.

Dec. 1, 1992

Modular Pavement

Description

Modular pavement comes in pre-formed modular pavers of brick and concrete. When the brick or concrete is laid on a permeable base, water will be allowed to infiltrate. Grass can be planted between the pavers, allowing structural support in infrequently used parking areas.

Other Terms Used to Describe

Lattice concrete blocks
Monoslab concrete blocks
Modular brick or concrete pavers
Pre-cast concrete
Perforated pavers laid over pre-cast concrete

Pollutants Controlled and Impacts

Some of the possible benefits of this practice include: removal of fine particulates and soluble pollutants through soil infiltration; attenuation of peak flows; reduction in the volume of runoff leaving the site and entering storm sewers; reduction in soil erosion; and groundwater recharge. The degree of pollutant removal is related to the amount of runoff which exfiltrates the subsoils. It may also help reduce land consumption by reducing the need for traditional stormwater management structures.

There is a potential risk to groundwater due to oils, greases, and other substances that may leak onto the pavement and leach into the ground. Pre-treatment of stormwater is recommended where oil and grease or other potential groundwater contaminants are expected.

Application

Land Use
Urban, urbanizing, rural

Soil/Topography/Climate
This practice should only be used on sites with soils which are well or moderately well drained. Since subgrade soils will differ in their capacity to infiltrate and percolate water, the design of modular pavement will vary slightly based on soil type. See the "Specifications" section of this BMP.

Weather conditions will also affect frost penetration depth. This practice is not recommended for barren areas with expected wind erosion.

When to Apply
Apply when the soil, topography and climatic conditions listed above can be met.

Where to Apply
Apply in low-volume parking lots and roads, and in high activity recreational areas like basketball and tennis courts or playground lots. The area is generally limited to 0.25 to 10.0 acres and generally serves only a small section of the watershed. This BMP can also accept rooftop and adjacent parking lot runoff.

Relationship With Other BMPs

Subsurface Drains may collect water infiltrating the subbase of the modular pavement and route it to an Extended Detention Basin or Infiltration Basin. This may be necessary for soils having marginal infiltration capabilities. The use of subsurface drains may diminish the pollutant removal efficiency of this BMP by not allowing the water to fully exfiltrate the soil. Subsurface drains may also be installed but allowed to remain capped, acting as a backup system if the modular pavement becomes clogged.

Specifications

Planning Considerations:
Soil tests should be conducted to determine permeability, load bearing capacity, resistance to frost heaving, swell and shrink. Soils with a permeability rating of A or B (higher permeability) are more suitable than soils with a permeability rating of C (lower permeability). Evaluate the soils and drainage area to estimate the amount of water that may enter the modular pavement, and how fast this water will percolate through the soil. Underlying soils should have a minimum infiltration rate of 0.27 in/hr, or 0.52 in/hr for full exfiltration systems.

Diversions should be placed around the perimeter of the modular pavement to keep runoff and sediment completely away from the site both before and during construction. Plan to design Diversions in conjunction with the modular pavement.

Design Considerations for Various Types of Modular Paving:
As discussed below, modular pavement comes in a variety of materials, from lattice concrete blocks to modular brick or concrete pavers. This information was derived from "Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development," the Urban Land Institute (Tourbier and Westmacott).

Lattice concrete blocks are used for infrequent parking use, for lining grass swales, and for grass ramps. In parking areas, blocks should be laid on a bed of gravel or crushed aggregate (to give a sufficient capacity), and a 2-inch layer of fines and gravel. Interstices of blocks should be filled by screening with coarse sand. Spaces between blocks should be filled with coarse sand. Where the only purpose is for erosion control, blocks may be laid directly on soil and screened with topsoil. On driveways under lawns, blocks may be covered with 1-2 inches of topsoil

Monoslab concrete blocks result in a surface which is 25% concrete and 75% permeable soil. Blocks are of high-strength freeze/thaw resistant concrete, with both a rough and a smooth side. Lay the smooth side down for driveways, parking lawns, construction roads, erosion control, slopes banks, and waterways. Lay the rough side down for footpaths, sidewalks, bike trails, patios, malls and tree grilles.

Modular brick or concrete pavers are perforated bricks, or bricks with lugs to control spacing. The brick or concrete pavers are made to a variety of specifications depending on the intended use, usually with a compressive strength of between 7,500-10,000 psi for use in areas where more wear is expected than for lattice blocks. Uses include paving around trees and dividing strips between impermeable paved surfaces. It is generally not conduce for walking. Interstices and perforations are usually kept free of vegetation.

Lay on a bed of gravel topped with 2 inches of coarse sand. The depth of the gravel will depend on the required stormwater storage capacity.

Pre-Cast Concrete Perforated Pavers Laid over Pre-cast Concrete Lattice Blocks can be made to a variety of specifications. A "web" opening may be in the order of 5" x 5" and 4.5" deep. The entire slab may be only 2.5 inches thick, with 0.75 inch diameter holes. These are laid on a base course of gravel of the necessary depth to provide storage capacity and 2 inches of coarse sand. This type of system is used in formal areas, especially where "warping" of large impermeable surfaces would be unsightly; also as a strip cover for French drains between areas of impermeable surface. Concrete blocks may be lifted and the web and sand filter cleaned out if the percolation rate falls.

Construction Considerations:

Where necessary, install a temporary Diversion to prevent runoff from entering the site during construction.

Install all modular pavement following manufacturer's specifications. The requirement for skilled labor for laying modular pavement may be reduced if mechanical vibrators are used for levelling uneven surfaces.

After Construction:

1. Stabilize the surrounding area and any established outlet following specifications in the Seeding and Mulching or Sodding BMPs. This will prevent sediment from entering the modular pavement.

2. Where applicable, remove temporary Diversions after vegetation is established.

3. Although snow and ice tends to melt more quickly on modular pavement, it may still be necessary to apply de-icing compounds to melt snow and ice. Do not use sand or ash because they may cause clogging of the pavement.

Maintenance

All modular pavement should be inspected several times in the first few months after construction, and at least annually thereafter. Inspections should be conducted after large storms to check for surface ponding that might indicate local or widespread clogging. If severe clogging occurs, the entire structure may have to be removed and old (clogged) filtering material replaced with new material.

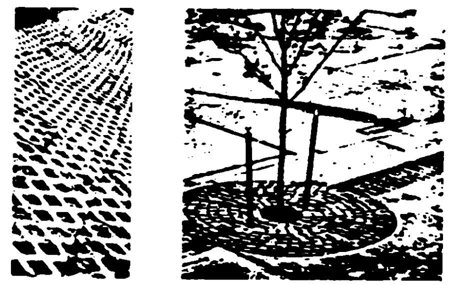
Additional maintenance requirements will differ depending on the type of modular pavement selected. Follow the manufacturer's recommendations.

Exhibits

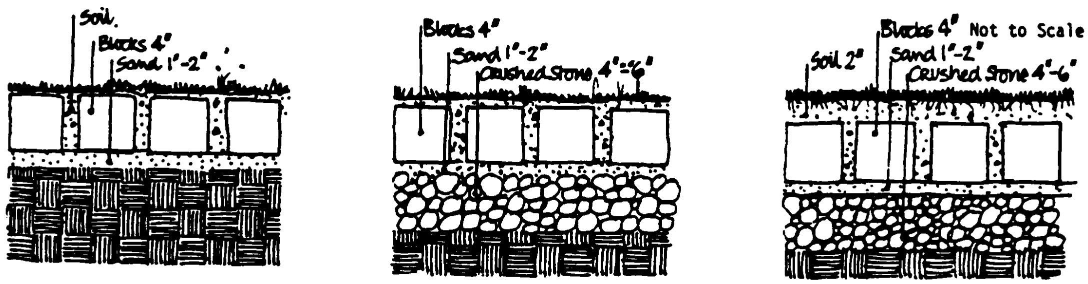
Exhibit 1: Examples of Modular Pavement. Source: "Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development," the Urban Land Institute.

Exhibit 1

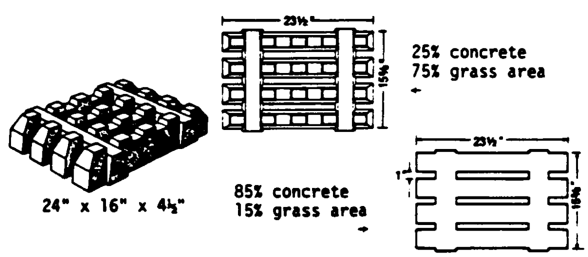
Examples of Modular Pavement



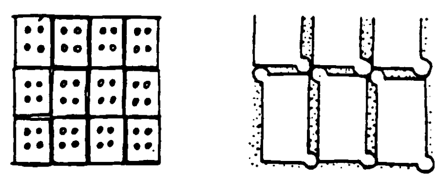
Concrete Blocks



Monoslab Concrete

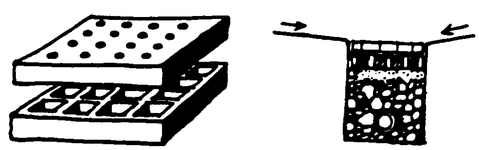


Modular Brick or Concrete Pavers



Pre-cast Concrete Lattice Block

Perforated Paver Laid Over Pre-Cast Concrete



Source: "Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development," the Urban Land Institute.

Oil/Grit Separators

Description

Oil/Grit Separators are multi-chambered structures designed to remove course sediment and oils from stormwater prior to delivery to a storm drain network, the ground, or other treatment. Separators are often used as pretreatment for infiltration BMPs such as Porous Asphalt Pavements, Modular Pavement or Infiltration Trenches. They are generally used on parking lots, streets or other areas which receive vehicular traffic. Each separator would generally receive runoff from a drainage area of less than 1 acre.

Other Terms Used to Describe

Water Quality Inlets
Oil/Grit Traps

Pollutants Controlled and Impacts

Oil/grit separators provide removal of course sediment and oil and grease. They provide little or no treatment of fine sediments and soluble pollutants. Separators have limited storage capacity and therefore very little impact on stream flow. Pollutant removal is enhanced by maximizing storage capacity of the basin.

Pollutants are permanently removed only after the separator chambers are cleaned. Therefore, routine clean-outs are essential in order to gain any benefit from this practice. Without routine cleaning, collected sediment may resuspend and be flushed out during the next storm. The chances of this may be reduced by placing baffles in the chambers to prevent the upward movement of collected sediment.

Application

Land Use
Urban, urbanizing, transportation and rural

Soil/Topography/Climate
Special precautions such as energy dissipation may be necessary to reduce incoming velocities if the incoming sewer is set on a steep slope.

When to Apply
Oil/grit separators should be put into service at the completion of the project. They should not be used as sediment basins during the course of construction. They are considered permanent control structures.

Where to Apply
Oil/grit separators are most appropriate for small areas which produce heavy loads of hydrocarbons and sediment, such as roads, parking lots, gas stations and convenience stores.

Each separator is generally designed to be used on sites 1 acre or less in size.

Relationship With Other BMPs

Oil/grit separators are often used in conjunction with infiltration BMPs such as Infiltration Basins, Infiltration Trenches, Porous Asphalt Pavement and Modular Pavement.

Specifications

Planning Considerations:

Individual separators should serve impervious areas of no more than 1 acre. Multiple separators may be used on larger sites, each one receiving runoff from up to approximately 1 acre. Single separators designed for larger areas would be so large as to be cost prohibitive.

Either the inlet or outlet of the separator must be connected to a storm drain network.

Design Considerations:

As shown in Exhibit 1, oil/grit separators consist of three chambers. The first chamber is used to trap sediment (sediment chamber), the second traps oil & grease (oil chamber), and the third is the discharge chamber. A manhole must be provided to each chamber for maintenance.

Volume:

The separator should be designed to pass the two-year design storm without hydraulic interference. An overflow weir installed between the chambers is recommended to accomplish this. The minimum distance between the crest of the weir and the top of the chamber must be 12 inches. The minimum distance between the weir and the water surface of the permanent pool is 12 inches.

All but the last chamber should be designed to hold a permanent pool of at least 400 cubic feet of stormwater. The permanent pool in each chamber should be a minimum 4 feet deep. A permanent pool in the final chamber is desirable, but not possible if the outlet from the separator is at the bottom of the chamber.

Conveyance:

A recommended conveyance between the first and second chambers consists of two 6-inch orifices protected by a trash rack. The orifices should be placed a minimum of 4 feet above the floor of the separator. The trash rack should be inspected at each cleaning and cleared of debris.

The recommended conveyance between the second and third chambers is an inverted elbow designed to be a least 3 feet in length and 1 foot from the bottom of the separator. The elbow should be a minimum of 18 inches in diameter.

The floor of the separator should be either level or slope only slightly toward the outlet of each chamber.

Construction Considerations:

If oil/grit separators are installed prior to completion of the project, use the necessary soil erosion BMPs or other barrier to prevent sediment from entering the separator. Do not use this BMP as a sediment basin during construction.

At the conclusion of construction, stabilize the surrounding area and any established outlet following the guidance in the Seeding and Mulching or Sodding BMPs.

Maintenance

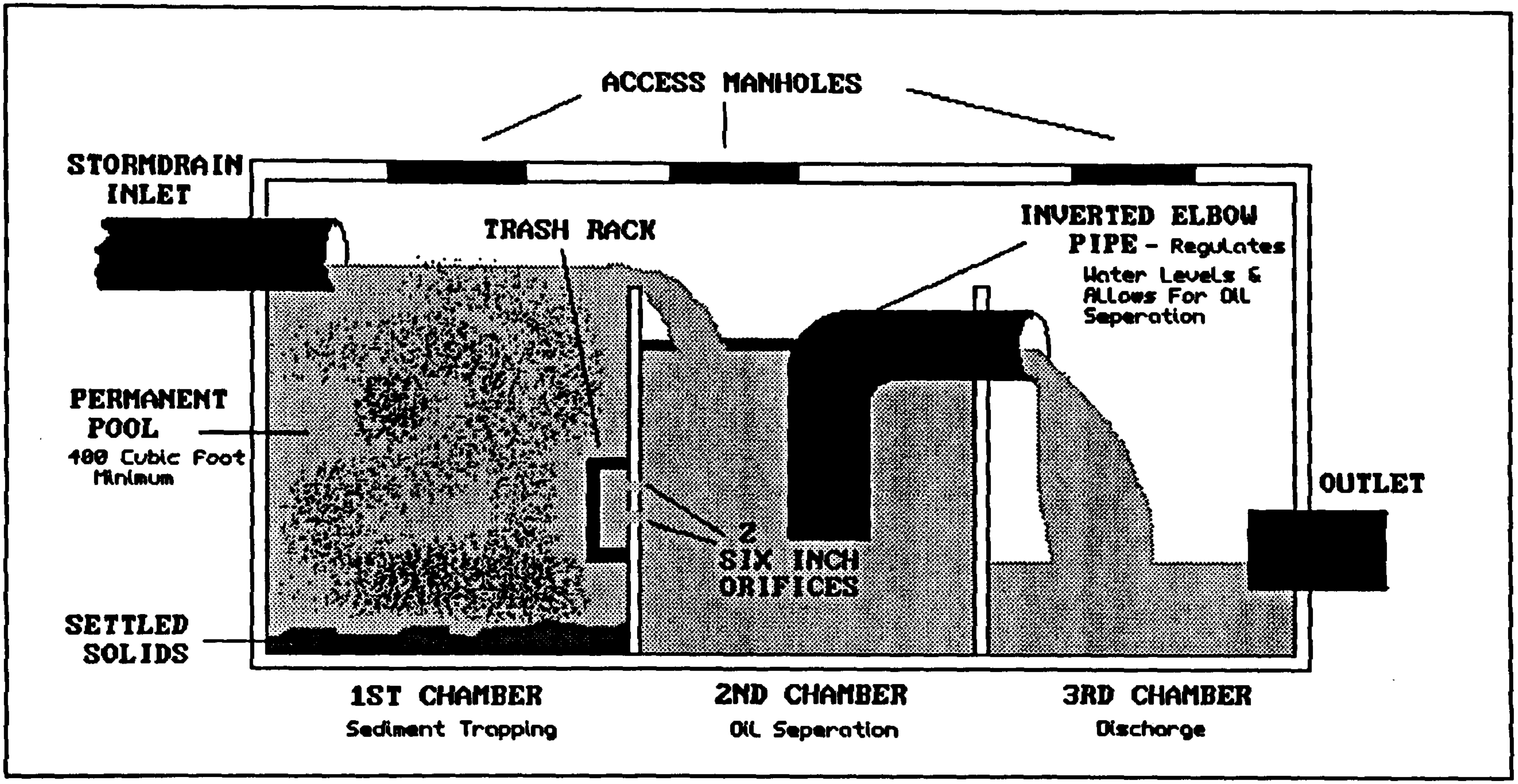
In order to receive any water quality benefit from these structures, it is critical to regularly clean each chamber. The separators should be inspected after several rain events in the first year after construction to observe the amount of residue collected and determine an appropriate cleaning schedule. Separators should not be cleaned less than twice a year. After a cleaning schedule is implemented, inspections should continue to determine the adequacy of the schedule. Inspections should always be done following storms larger than design.

Oil/grit separators are normally cleaned by pumping out the contents of each chamber to a tanker trunk. The collected material is then hauled to an approved disposal site.

Exhibits

Exhibit 1: Typical Oil/Grit Separator. Michigan Department of Natural Resources, Surface Water Quality Division. 1992.

Exhibit 1
Typical Oil/Grit Separator



Parking Lot Storage

Description

Storage of stormwater on parking lots is used primarily to reduce the peak discharge of stormwater from the surrounding area during moderate storms. This method may provide a limited amount of treatment by allowing settling of the largest particles. Modular Pavement and grass areas may be used to promote infiltration. Care must be taken to either restrict use of the parking lot during storms or insure that vehicles won't be damaged and are accessible. Parking lot storage is most attractive in highly urbanized areas where there are few alternatives for stormwater detention.

Other Terms Used to Describe

Parking Lot Storage is essentially a specialized detention basin.

Pollutants Controlled and Impacts

The primary purpose of parking lot storage is to reduce peak runoff from small sites and provide some flood storage. This helps reduce stream bank erosion and flooding.

Some large solids may be removed by settling, but because detention time is small it is unlikely to result in significant improvement. Where settling does occur, the settled solids must be removed often to prevent resuspension in future runoff events. In order to gain any significant pollutant removal, other BMPs will need to be used in conjunction with this one to form a "treatment train."

Application

Land Use
Predominately urban, but can be used anywhere.

Soil/Topography/Climate
This BMP will work best in areas that do not have a steep slope. Parking lot slope should be 1% or less. Detention time will be important in climates where freezing may occur. As an additional use, intentional freezing for ice rinks may be desired in parking lots that are not otherwise used in winter.

When to Apply
This BMP may be applied at any time in the construction project, however, it is primarily designed for use when the project is complete. If used during the construction phase, special measures may have to be taken to prevent excess solids from being discharged through the outlet and overflow.

Where to Apply
This BMP is most applicable in urbanized or urbanizing areas where there are few alternatives available for stormwater detention. The parking lot should be under utilized, such as overflow lots, or have special uses, such as for special events.

Relationship with other BMPs

This BMP is most effective when used in conjunction with other BMPs that allow for infiltration or sediment trapping. These BMPs include: Grassed Waterway, Modular Pavement, Infiltration Trench, Buffer/Filter Strip, Catch Basin, and Street Sweeping.

Specifications

Planning Considerations:

This is a permanent BMP and should be included in the initial design of the project, especially when multiple BMPs will be used which will affect the landscaping and parking lot configuration. Parking lot use must be properly managed during storm events. Overflow lots or other lots which are not normally used work best for parking lot storage. In some cases, parking lot use may have to be restricted during storm events.

A **spill response plan** must be developed which clearly defines the emergency steps to be taken in the event of an accidental release of large quantities of harmful substances to the parking lot at any time. As a result of this plan, design changes such as shut off valves or gates may be needed.

Design Considerations:

NOTE: All structural best management practices should be designed by a registered professional engineer.

A possible configuration of parking lot detention is shown in Exhibit 1.

Watershed Size:
Watershed size should be kept small. The contributing watershed should normally be no more than the runoff from the parking lot and nearby buildings.

Slope:
The parking lot should slope toward the outlet(s) by not less than 0.5% and not more than 1%.

Water Depth:
If the parking lot is in use during storm events, then the maximum water depth can be no more than 6 inches.

Volume:
At a minimum, storage volume should be sufficient to detain 0.5 inches of runoff from the surface of the parking lot and adjacent impervious area draining to the parking lot. Larger storage volumes will provide better treatment. Discharge to the receiving stream should be at the pre-development rate or at a rate determined by ordinance or law. The release rate is controlled by the outlet structure which is therefore the most critical part of the design. The outlet should be chosen to achieve the desired release rate, while maintaining less than 6 inches of water in the parking lot. Unlike other detention basins, in parking lot storage the parking lot should be drained as quickly as possible, while at the same time meeting the minimum detention necessary to reduce peak flows in the receiving stream. It is critical to analyze the hydrology of the entire receiving stream to insure that the peak release from the parking lot does not coincide with the arrival of peak flows from upstream in the watershed.

Often it is not possible to meet the desired storage volume or discharge criteria without the use of additional BMPs such as Infiltration Trenches or Grassed Waterways (or swales) in conjunction with parking lot storage.

Spillway:
A spillway for flows larger than design must be included. Proper care must be taken to protect the discharge channel of the spillway from erosion problems.

Construction Considerations:
Construction should not begin until up-slope areas are stabilized and all necessary soil erosion BMPs are in place.

At the conclusion of construction, stabilize the surrounding area outlet following the guidance in the Seeding and Mulching, or Sodding BMPs.

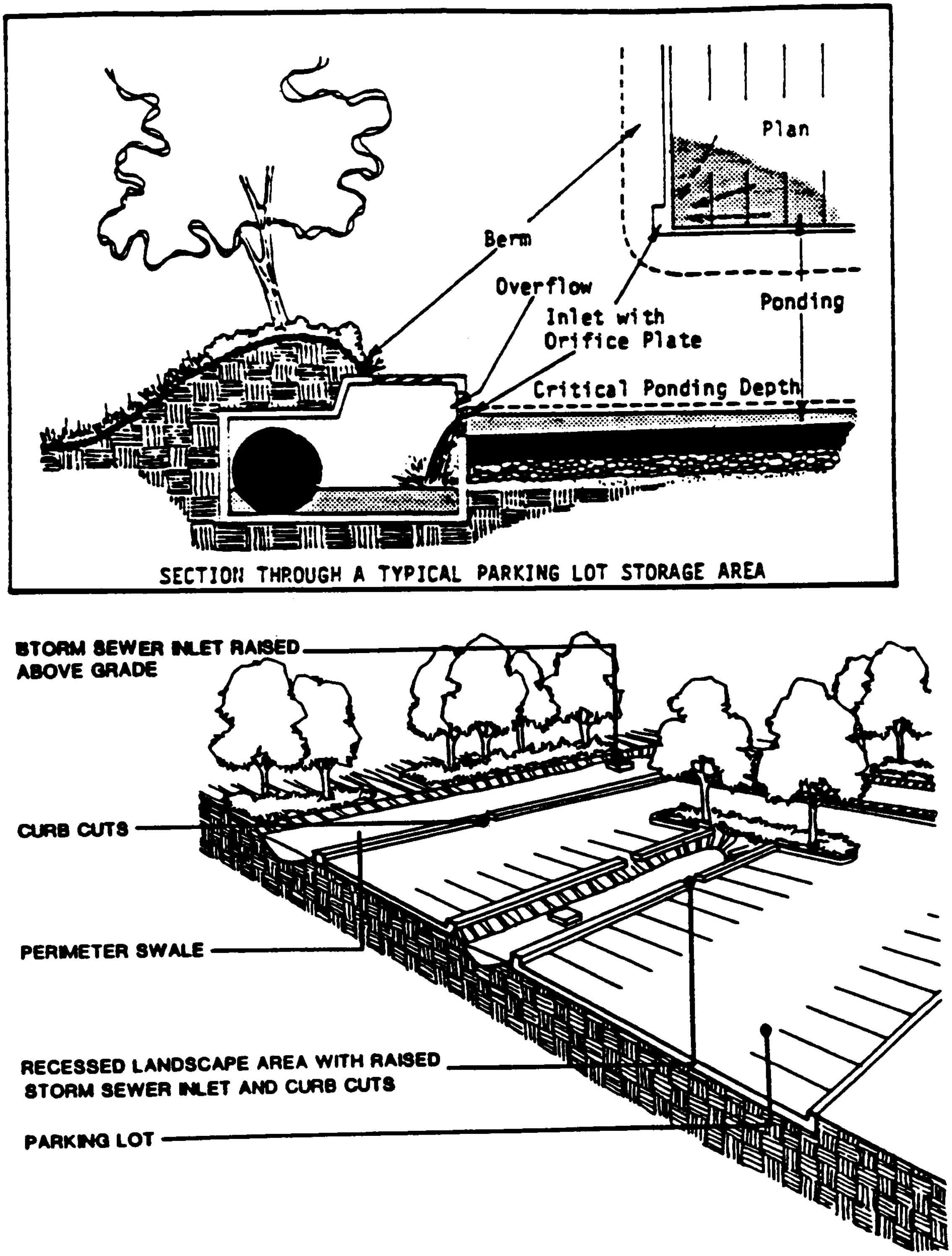
Maintenance

Sweep and clear debris from the parking lot after storms. Regularly inspect and clean the release drain.

Exhibits

Exhibit 1: Typical Parking Lot Configuration. The Florida Development Manual: A Guide to Sound Land and Water Development. State of Florida, Department of Environmental Regulation. 1988.

Exhibit 1: Typical Parking Lot Detention Configuration



Source: Florida Development Manual: A Guide to Sound Land and Water Development. State of Florida, Department of Environmental Regulation. 1988.

Porous Asphalt Pavement

Description

Porous asphalt pavement is a paved surface and subbase comprised of asphalt, gravel, and stone, formed in a manner resulting in a permeable surface. The various layers, called "courses," have the potential for stormwater detention. Stormwater which passes through the pavement may completely or partially infiltrate the underlying soil, the excess being collected and routed to an overflow facility through perforated underdrain pipes. The pavement may also be designed to receive off-site runoff.

Other Terms Used to Describe

Pervious Pavement
Permeable Pavement

Pollutants Controlled and Impacts

When properly designed and carefully installed, porous pavement has load bearing strength, longevity, and maintenance requirements similar to conventional pavement. Some of the possible benefits over conventional pavement include: removal of fine particulates and soluble pollutants through soil infiltration; attenuation of peak flows; reduction in the volume of runoff leaving the site and entering storm sewers; reduction in soil erosion; and groundwater recharge. The degree of pollutant removal is related to the amount of runoff which exfiltrates the subsoils. This practice may also help reduce land consumption by reducing the need for traditional stormwater management structures.

There is a potential risk to groundwater due to oils, greases, and other substances that may leak onto the pavement and leach into the ground. Pre-treatment of stormwater is recommended where oil and grease or other potential groundwater contaminants are expected.

Application

Land Use
Mostly urban, urbanizing and transportation

Soil/Topography/Climate
This practice should only be used on sites with gentle slopes, permeable soils, and relatively deep water table and bedrock levels. Soils should be well or moderately well drained. Since subgrade soils will differ in their capacity to infiltrate and percolate water, the design of porous pavement will vary slightly based on soil type. See the "Specifications" section of this BMP.

Meteorological conditions will affect the design infiltration rate for the top pavement course, and the volume necessary in the reservoir course. Meteorological conditions will also affect frost penetration depth.

This practice is not recommended for barren areas subject to wind erosion.

When to Apply
Apply when the soil, topography and climatic conditions listed above can be met.

Where to Apply
Apply in low-volume parking lots and roads, and in high activity recreational areas like basketball and tennis courts or playground lots. The area is generally limited to 0.25 to 10.0 acres and generally serves only a small section of the watershed. This BMP can also accept rooftop and adjacent parking lot runoff.

Relationship With Other BMPs

Subsurface Drains may collect water infiltrating the reservoir course of porous asphalt pavement and route it to an Extended Detention Basin or Infiltration Basin. This may be necessary for soils having marginal infiltration capabilities. The use of subsurface drains may diminish the pollutant removal efficiency of this BMP by not allowing the water to fully exfiltrate the soil. Subsurface drains may also be installed but allowed to remain capped, acting as a backup system if the porous pavement becomes clogged.

Specifications

General Considerations:
As shown in Exhibit 1, a typical porous asphalt pavement consists of a top porous asphalt course, a filter course, a reservoir course (designed for runoff detention and frost penetration), and existing soil or subbase material.

> The **top porous asphalt course** is an open-graded asphalt concrete surface course approximately 2-4 inches thick. This course consists of porous asphalt concrete containing little sand or dust, with a pore space of approximately 16% (as compared to 2-3% for conventional asphalt concrete). Strength and flow properties of porous asphalt concrete are similar to conventional asphalt concrete.
>
> The **filter course** is a 1-2-inch thick layer of 0.5-inch crushed stone aggregate. In addition to providing some filtration (limited by the relatively large pore space), the filter course also provides stability for the reservoir course during application of the asphalt mix.
>
> The **reservoir course** is a base of 1.5-3-inch stone of a depth determined by the storage volume needed. In addition to transmitting mechanical loads, the reservoir course stores runoff water until it can infiltrate into the soil. On slopes, reservoir courses at the higher end are not credited with storage capability due to lateral drainage.
>
> Where soils have low permeability, the reservoir course thickness should be increased to provide additional storage. With soils composed primarily of clay or silt, the infiltration capacity may be so slow that the soil is unacceptable as a subgrade, necessitating replacement by suitable borrow material. If the natural material beneath is relatively impermeable, drainage may have to be provided. The drainage may take the form of subsurface drains, french drains or dutch drains.

Another 2-inch **filter course** can be applied below the reservoir course to allow additional infiltration. Below the filter course, we recommend a Filter fabric.

Under the filter fabric is the undisturbed soil.

Planning Considerations:

Soil tests should be conducted to determine permeability, load bearing capacity, resistance to frost heave, swell and shrink. Soils with a permeability rating of A or B are probably more suitable than soils with a permeability rating of C. Evaluate the soils and drainage area to estimate the amount of water that may enter the porous pavement, and how fast this water will percolate through the soil. Underlying soils should have a minimum **infiltration rate** of 0.27 in/hr, or 0.52 in/hr for full exfiltration systems.

Plan to design any necessary Diversions in conjunction with the porous pavement. Diversions should be placed around the perimeter of the porous pavement to keep runoff and sediment completely away from the site both before and during construction.

Do *not* store heavy equipment on the area in which porous asphalt pavement will be laid. Heavy equipment will compact soils and reduce the soil's infiltration.

Design Considerations:

Porous asphalt pavement systems should be designed by registered professional engineers.

Slope:

The slope of porous asphalt pavement should not exceed 5% and is best when as flat as possible. If low spots do develop in the parking lot, it may be advisable to install drop inlets to divert runoff into the stone reservoir more quickly.

Depth:

The depth of the stone reservoir should be such that it drains completely within 72 hours. This allows the underlying soils to dry out between storms (improving pollutant removal) and also preserves capacity for the next storm. If the site has marginal soils for infiltration (e.g. loams, silt loams), or covers a wide area, it may be prudent to design the reservoir to drain within 48 hours.

Residence Time:

Care should be taken in spacing the underdrain network in partial exfiltration systems. If perforated underdrains are too close together, runoff may be collected too efficiently to provide the exfiltration needed for high pollutant removal. As a general design rule, a minimum residence time of 12 hours should be a target for the design storm.

Effects of Frost:

If frost penetrates deeper than the thickness of the pavement and reservoir courses, and the subgrade soil has potential for frost heaving, it is recommended that additional material be added to the reservoir course to below the frost zone. If the subsurface freezes, the effectiveness of this BMP is diminished.

Construction Considerations:

1. Before the entire development site is graded, the planned area for the porous pavement should be roped off by Construction Barriers to prevent heavy equipment from compacting the underlying soils.

2. Install Diversions as needed to keep runoff off the site until the porous pavement is in place.

3. Excavate the subgrade soil using equipment with tracks or over-sized tires. Narrow rubber tires should be avoided since they compact the soil and reduce its infiltration capabilities.

4. After excavation is complete, the bottom and sides of the stone reservoir should be lined with filter fabric to prevent upward piping of underlining or underlying soil. The fabric should be placed flush with a generous overlap between rolls. Follow manufacturer's specifications.

5. Clean, washed 1.5-3-inch aggregate should be placed in the excavated reservoir in lifts, and lightly compacted with plate compactors to form the reservoir or base course. Unwashed stone has enough sediment to pose a clear risk of clogging at the soil/filter cloth interface. The minimum depth of this layer is usually 9 inches.

6. A 1-2-inch thick layer of 0.5-inch stone should be placed over the reservoir or base course, and manually graded to plan specifications.

7. Add the porous asphalt layer (2-4 inches thick), but only when the air temperature is above 50^{o}F and the laying temperature is between 230-260^{o}F. Failure to follow these guidelines can lead to premature hardening of the asphalt and subsequent loss of infiltration capacity.

8. Asphalt used in porous asphalt concrete ranges from a 50% to 100% penetration grade, depending upon the ambient temperatures and viscosity characteristics desired. Generally, the grades used in a given locality for conventional asphalt concretes will suffice for porous asphalt as well. However, the porous product is more subject to scuffing, which occurs when the front wheels of stationary vehicles are turned. It is therefore suggested that for porous asphalt, an 85 to 100% penetration grade be used.

9. The percent of asphalt should be specified between 5.5 and 6, based on the total weight of the pavement. The lower limit is to assure adequately thick layers of asphalt around the stones, and the upper limit is to prevent the mix from draining asphalt during transport.

10. To avoid damage due to photo-oxidative degradation of the asphalt, the asphalt coatings on the aggregate surfaces should be thicker than usual. In this case, the asphalt can form skins or otherwise be mildly degraded without significant loss of cementing properties.

11. Roll the asphalt when it is cool enough to withstand a ten-ton roller. Normally, only one or two passes of the roller are necessary. More frequent rolling can reduce the infiltration capabilities on the open-graded asphalt mix.

12. After rolling is complete, all traffic should be kept out of the porous pavement area for a minimum of one day to allow proper hardening.

After Construction:

1. Stabilize the surrounding area and any established outlet following specifications in the Seeding and Mulching or Sodding BMPs. This will prevent sediment from entering the porous pavement.

2. Where applicable, remove temporary Diversions after vegetation is established.

3. Post signs to prevent vehicles from entering the area with muddy tires. If muddy vehicle access cannot be prevented, a temporary Access Road should be installed.

4. Although snow and ice tends to melt more quickly on porous pavement, it may still be necessary to apply de-icing compounds to melt snow and ice. Do not use sand or ash because they may cause clogging of the pavement.

Maintenance

All porous pavement should be inspected several times in the first few months after construction, and at least annually thereafter. Inspections should be conducted after large storms to check for surface ponding that might indicate local or widespread clogging. If severe clogging occurs, the entire structure may have to be replaced.

The porous pavement surface should be vacuum swept at least four times per year, followed by high-pressure jet hosing to keep the asphalt pores open.

Spot clogging of the porous pavement layer can be relieved by drilling half-inch holes through the porous asphalt layer every few feet. In cases where clogging occurs in a low spot in the pavement, it may be advisable to install a drop inlet to route water into the stone reservoir.

Potholes and cracks can be repaired using conventional, non-porous patching mixes as long as the cumulative area repaired does not exceed 10% of the parking lot area.

Additional Considerations

Safety:

Porous pavement overlays on conventional surfaces prevent many wet skidding or hydroplaning accidents. For safety application, a 3/4-1-inch layer over normal dense pavement is used to provide rapid lateral surface drainage.

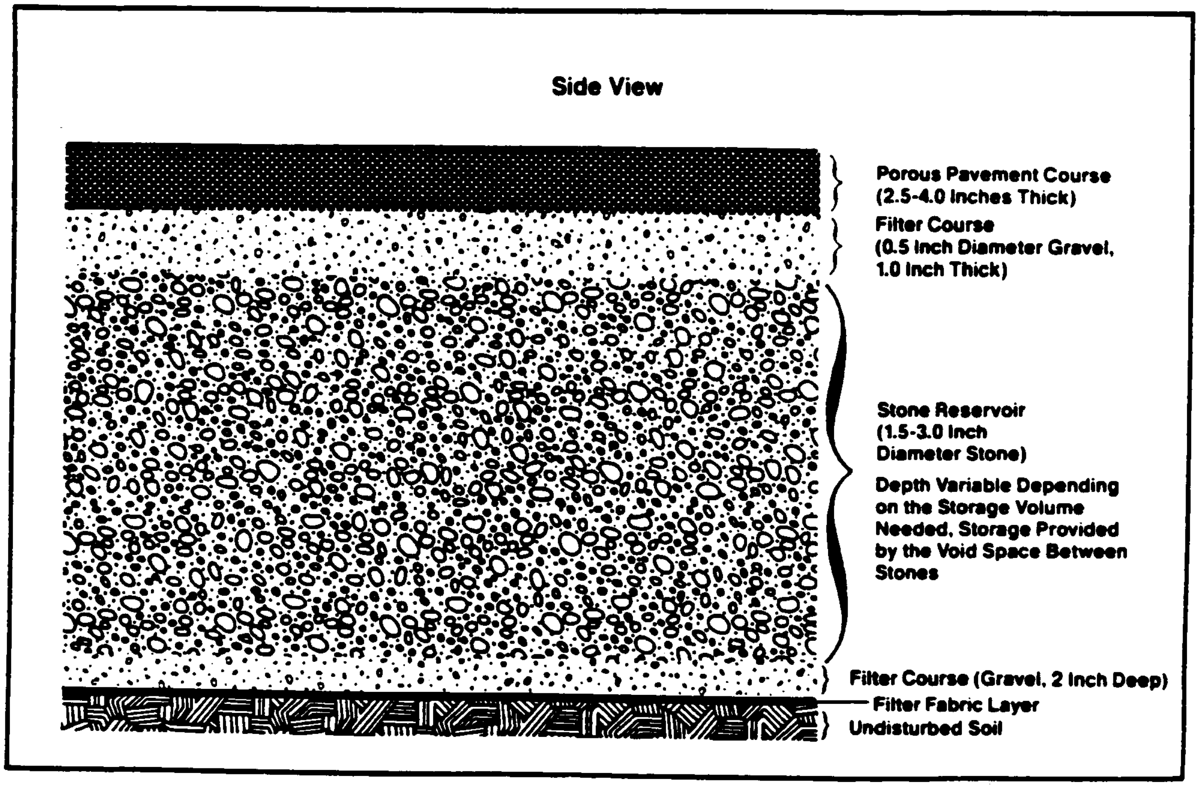
The visibility of pavement markings is improved on porous/modular pavement because of the rapid removal of water, and because the marking material penetrates the voids to present an oblique view. The enhanced visibility of pavement markings would be an important factor in preventing accidents during storms.

Exhibits

Exhibit 1: Design Schematic for Porous Pavement. Source: City of Rockville, Md., as copied from "Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development." The Urban Land Institute. 1981.

Exhibit 1

Schematic of Typical Porous Pavement Section



Source: City of Rockville, Md., as copied from "Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development." The Urban Land Institute. 1981.

Roof Top Storage

Description

Roof top storage is used to reduce the peak discharge of stormwater from roof tops, thereby reducing storm sewer loadings, stream bank erosion and flooding. This method is most often used in densely developed areas where other means of stormwater detention are no longer available or have become very expensive to implement. Where water quality benefits are desired, this BMP is used in conjunction with other BMPs.

Other Terms Used to Describe

Roof top storage is essentially a specialized detention basin. Findams and roof top detention barriers are devices used to detain water on rooftops.

Pollutants Controlled and Impacts

The primary purpose of roof top storage is to reduce the peak discharge rate from roof tops. This helps reduce stream bank erosion and storm sewer hydraulic loadings. The majority of pollutant removal is accomplished when this BMP is used in conjunction with other BMPs, normally infiltration BMPs such as Infiltration Trenches or dutch drains.

Application

Land Use
Urban and urbanizing areas

Soil/Topography/Climate
This BMP can be used under almost any condition. If used in conjunction with infiltration BMPs, soils with a high infiltration rate will be necessary. Where the discharge is to the ground in an area with steep slopes, special erosion protection should be used.

When to Apply
This BMP can be applied on new or existing structures at any time.

Where to Apply
Apply in highly urbanized or urbanizing areas where storm sewer capacity is a concern. Roof top storage can be very effective in helping to maintain the pre-development flow rate from a site if it is required of all buildings constructed in a new development.

Relationship With Other BMPs

Where possible, roof top storage should be used in conjunction with infiltration BMPs such as dutch drains or Infiltration Trenches. Riprap should be used where erosion protection is needed at the discharge. Runoff can be directed to a Grassed Waterway (or swale) rather than the storm sewer.

Specifications

Planning Considerations:

This BMP is most effective if required of an entire development prior to beginning construction. A hydrologic study should be performed by a competent professional engineer. Roof top storage would be required where the volume of runoff exceeds the rate of infiltration, or where storm sewer capacity is a problem.

Design Considerations:

Roof top storage design should be done by registered professional engineers.

Weight:

The most important design consideration is the ability of the roof to hold the weight of the water being detained. In most cases, roofs designed to carry snow weight in the winter will be sufficient to hold the weight of large rain events. An overflow must be considered for very large rain events which may exceed the capacity of the roof.

Storm Design:

At a minimum, the roof storage and other necessary BMPs should reduce the peak flow of the runoff from the storm frequency used to design the local stormwater collection system to pre-development levels. It may be desirable or required to also design for larger, less frequent storms.

Outlets:

The desired release rate is achieved through the use of orifices or weirs around the outlet.

There are two alternatives for the discharge of water from the roof:

1. **Surface Drainage:** The roof drains directly to the ground surface. The surface outlet must be protected with some sort of Stabilized Outlet. Adequate drainage away from the structure must be assured. It is desirable to discharge the water over the land surface as a sheet flow rather than a concentrated flow. Avoid surface ponding.

2. **Subsurface Infiltration:** Downspouts are directed to an infiltration BMP such as an Infiltration Trench or dutch drain. The permeability of the soils must be adequate to use this technique (see the Infiltration Trench BMP for specifications). A surface overflow from the downspout is necessary for flows greater than design. This is not recommended where pollutant loadings from stormwater are such that they may infiltrate to the groundwater.

Maintenance

Periodic inspection and maintenance is essential in keeping outlets free from debris. Inspection and repair of waterproofing should occur frequently.

Wet Detention Basin

Description

Wet detention basins maintain a permanent pool of water which is completely or partially displaced by stormwater received from the serviced watershed. Of the detention/retention basins, this management practice may be the most effective in removing pollutants. Wet detention basins also require more planning, maintenance and land to construct than most other BMPs. As in other detention management practices, wet detention basins help minimize downstream erosion and reduce flooding.

Other Terms Used to Describe

Wet Pond

Pollutants Controlled and Impacts

Wet detention basins are effective at removing sediment, nonsoluble metals, organic matter and nutrients through settling. Soluble nutrients and organic matter are removed through plant uptake and bacterial activity in the permanent pool of water, and by rooted plants in the littoral (shallow) zone.

Wet detention basins provide full control of peak discharges for large design storms. Wet detention basins reduce flooding, stream bank erosion, and may actually help increase low flows.

Wet detention basins can significantly warm the water in the permanent pool. When the receiving stream is sensitive to increases in temperature, wet detention basins may not be appropriate.

Application

<u>Land Use</u>
Urbanized, urbanizing and agricultural areas

<u>Soil/Topography/Climate</u>
Ponds generally will not work in soils with high infiltration rates. In order to maintain a permanent pool of water, six inches of compacted clay or an impermeable geotextile liner are recommended for the sides and bottom of the basin.

<u>When to Apply</u>
This BMP may be applied to new or existing developments. These basins would be considered permanent, year-round control measures. They normally will not be placed into service until all other construction is complete.

Where to Apply
Basins should be sited based on a hydrologic analysis of the watershed. Improperly sited basins may actually increase flooding problems.

Wet detention basins can be used on very large watersheds. Too small a drainage area (less than ten acres) may not provide sufficient volume to support a permanent pool of sufficient size to be effective, unless the pool is also fed by springs.

Relationship With Other BMPs

Riprap may be needed to protect side slopes and inlet and outlet areas. A Sediment Basin may be used to pretreat incoming stormwater in areas receiving particularly high sediment loads, such as from construction sites. Filter fabric is often used to protect small outlets.

Specifications

Planning Considerations:

The **location** of basins must be determined through a hydrologic analysis of the watershed. If the peak discharge from a particular basin is delayed to coincide with the peak discharge from an upstream tributary or release from an upstream basin, the actual stream discharge peak can increase.

A minimum 25-foot **buffer** from the basin to any adjoining property should be provided. This buffer should be landscaped to improve the appearance for local residents, provide wildlife habitat and meet any other local design considerations.

Adequate **access** right-of-way must be assured. The access should be a minimum of ten feet wide and stabilized to provide for passage of heavy equipment.

A **spill response plan** must be developed which clearly defines the emergency steps to be taken in the event of an accidental release of large quantities of harmful substances to the basin. As a result of this plan, design changes such as shut-off valves or gates may be needed.

Design Considerations:

NOTE: All structural best management practices should be designed by a registered professional engineer.

A diagram of an example wet detention basin is shown in Exhibit 1.

Volume:
The minimum volume of the permanent pool should be equal to 0.5 inches of runoff from the entire contributing watershed, with two to four weeks of detention. Additional capacity to receive at least 0.5 inches of runoff during storm events must also be included. The basin is designed to displace the water in the permanent pool with water from storm events. Greater pollutant removal is gained with larger basin volumes. The basin must also be designed with adequate capacity to treat stormwater delivered from existing stormwater collection systems designed according to local criteria.

The basin should be designed to release the water displaced by the design storm over 24 to 48 hours, in order to provide for settling and to prevent stream bank erosion. The hydrologic analysis of the receiving stream and desired settling of particulates should be used to determine the optimum release rate. Several outlet structures may be used to provide extended detention of the design storm (see Extended Detention Basin BMP).

Several other methods can be used to determine pool size effectively.

Basin Depth:
The depth of the permanent pool should normally be between three to eight feet deep. A shallow zone one to two feet deep and approximately ten feet wide around the edge of the basin is critical to optimize pollutant removal and provide for safety. Aquatic plants must be established in this shallow area. Settling of particulates is dependent on particle size, surface area and discharge rate, and is not affected by depth.

Outlets:
The basin outlet will control the release rate from the basin. It must control both the design storm and lesser storms. Multiple outlets may be necessary to control discharge from a range of storms. Example outlets for wet detention basins are shown in Exhibit 3 of the Extended Detention Basin BMP. A hydraulic analysis of the outlet structures at the low flow and design storm will be necessary to size the outlets to achieve the desired release rate. All outlets should have an accessible, above-ground cap to allow easy cleaning. The outlet should be designed so that trapped trash and debris can be easily removed.

A stabilized outlet structure must be used to prevent scouring at the discharge point. Stabilized outlets are normally constructed using Riprap, corrugated pipe or concrete. Outlet design can be extremely complex. A detailed design method can be found in the "Stormwater Management Guidebook" by Bruce Menerey and published by the Michigan Department of Natural Resources, Land and Water Management Division.

Basin Shape:
The basin should be wedge shaped, and narrow at the inlet and wide at the outlet to promote good circulation and reduce the chance of short circuiting. The length of the basin should be at least threes times the width.

Side Slopes:
Side slopes of not more than 3:1 and not less than 20:1 are recommended. Gentle side slopes are recommended for safety, particularly in the shallow zone along the edge of the basin.

The banks should be constructed such that two feet of freeboard is above the emergency spillway.

Anti-seep Collars:
Anti-seep collars should be installed on any piping passing through the sides or bottom of the basin.

Emergency Spillway:
An emergency spillway must be included to handle storms greater than design. It is recommended that the spillway be placed such that the basin has sufficient volume to detain the 100-year storm.

Construction Considerations:
At the conclusion of construction, stabilize the surrounding area following the guidance in the Seeding and Mulching or Sodding BMPs.

Maintenance

Regular maintenance includes mowing the buffer/filter strip and removing debris from the basin. The side banks must be mowed regularly to prevent woody plant growth. If maintained as a lawn, mowing is much more frequent. If maintained as a meadow, mowing can be reduced to twice a year.

The basin should be inspected regularly during wet weather. Particular attention should be given to the inlet and outlet structures.

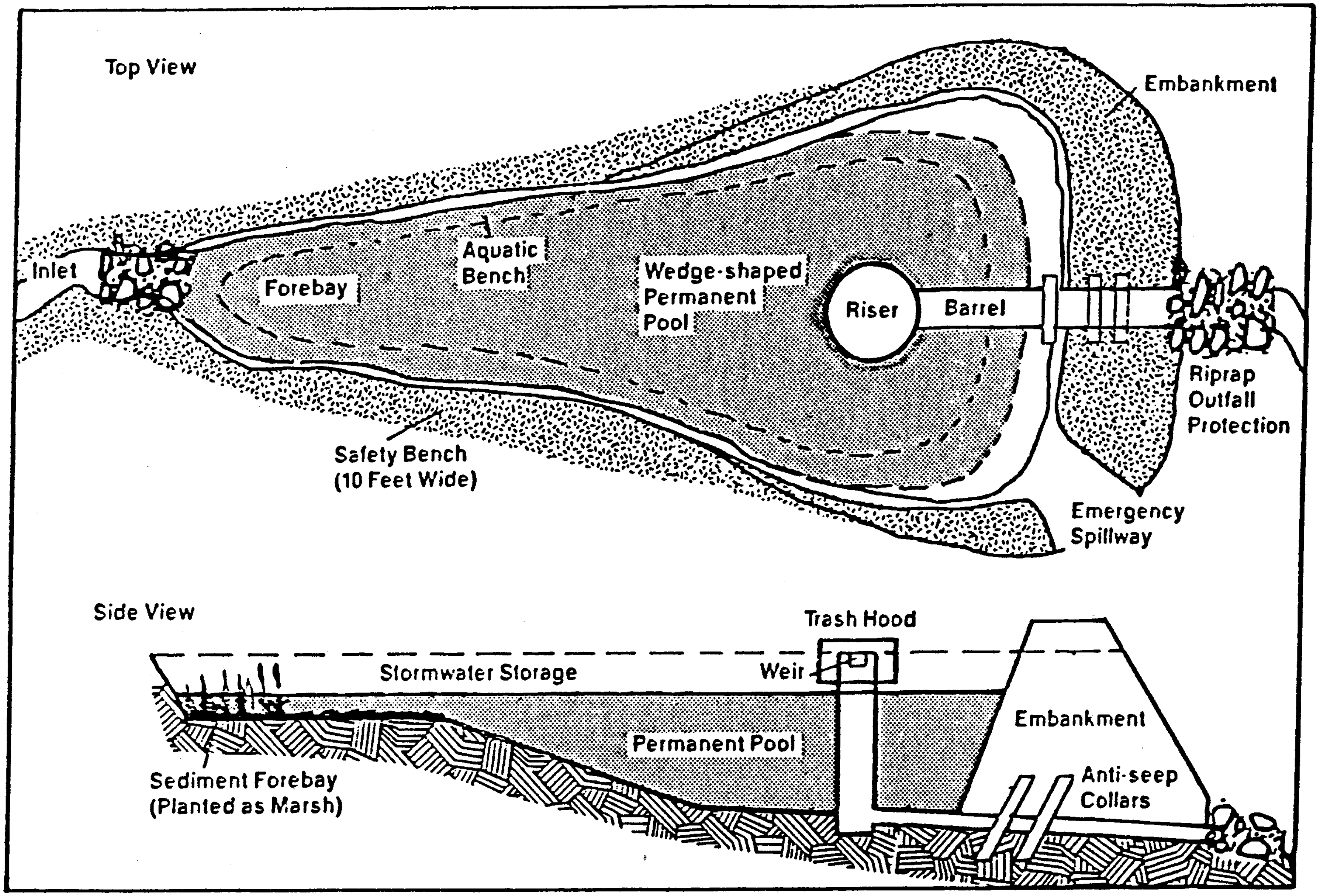
If properly designed, sediment removal from the basin will only be necessary every five to ten years. Excessive algae must be removed to prevent odors and to maintain nutrient removal capacity.

Any eroded banks must be stabilized as soon as possible.

Exhibits

Exhibit 1: Typical Wet Detention Basin. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments (Schueler). 1987.

Exhibit 1
Typical Wet Detention Basin



Source: Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Council of Governments (Scheuler). 1987.

SEDIMENTATION CONTROL STRUCTURES

Buffer/Filter Strips

Updated September, 1997

Description

A buffer/filter strip is a vegetated area adjacent to a waterbody (i.e. river, stream, wetland, lake). The buffer/filter area may be natural, undeveloped land where the existing vegetation is left intact, or it may be land planted with vegetation. Its purpose is to protect streams and lakes from pollutants such as sediment, nutrients and organic matter, prevent erosion, provide shade, leaf litter, and woody debris. Buffer/filter strips often provide several benefits to wildlife, such as travel corridors, nesting sites and food sources.

For the purposes of this BMP, a buffer/filter strip is a combination of 1) a *buffer* of vegetation between human land use and a stream, and 2) a *filter*, to trap sediment and absorb sheet flow. The buffer is usually comprised of trees, the buffer provides shade, leaf litter, woody debris, erosion protection, and often serves as wildlife habitat. The filter strip is an area of dense grass at least 20 feet wide designed specifically to remove pollutants from stormwater runoff from sheet flow off adjacent land, through filtering and infiltration. Although vegetative filters designed as specified in this BMP can be expected to provide significant pollutant removal, overall water quality will not be protected if a filter stirp is not used in conjunciton with a buffer along the stream corridor.

To protect water quality, a buffer/filter at least 100 feet wide should be preserved or created around all waterbodies and wetlands, with strip widths increasing with increasing slope. Research shows that when the buffer is less than 100 feet, stream quality begins to diminish. If a 100-foot buffer/filter strip is not feasible, or if wildlife habitat is of interest, refer to the specifications section of this BMP for additional information.

Special Considerations: Natural or Wild and Scenic Rivers may have special buffer/filter strip restrictions, depending on their designation (see Exhibit 1). Contact the MDNR, Forest Management Division, Natural Rivers Program staff for further information.

Other Terms Used to Describe

Vegetative Filter

Pollutants Controlled and Impacts

Several researchers have measured >90% reductions in sediment and nitrate concentrations; buffer/filter strips do a reasonably good job of removing phosphorus attached to sediment, but are relatively ineffective in removing dissolved phosphorus (Gilliam, 1994).

Application

Land Use

Applicable to all land uses adjacent to waterbodies.

Soil/Topography/Climate

This practice is especially important on and adjacent to steep slopes. Natural buffer strips are essential in maintaining the shade and stream temperatures of coldwater streams.

When to Apply
Natural buffer/filter strips should be identified and protected before any development occurs on a site. At the watershed level, buffer/filter strips could be identified during community land use planning (i.e. during master plan development, development of parks, or greenways, etc.) or as part of efforts to identify and protect specific land uses, such as prime farm land. At the site level, buffer/filter strips should be incorporated into the overall plan for the site, and protected during construction.

Where to Apply
Adjacent to all watercourses and wetlands.

Relationship With Other BMPs

Natural buffer/filter strips should be identified prior to any Land Clearing operations.

BMPs may be needed upslope of a buffer/filter strip if: 1) runoff directed to the buffer/filter cannot enter as sheet flow, or 2) protection of the buffer from excess sediment is needed to maintain the integrity of the buffer.

Specifications

Planning Considerations to Preserve Buffer/Filter Strips:

Buffer/filter strips which are able to remain as undisturbed native vegetation should be delineated on preliminary and final site plans. *To protect water quality*, preserve natural buffer areas a total *minimum width of 100 feet* along all water courses and wetlands, with widths increasing with increasing slope. This is recommended to maintain shade, uptake pollutants and absorb sheet flow (i.e. stormwater that is not concentrated at a single point and causes erosion). While the 100-foot width is consistent with stream research studies (see Exhibit 6) and is the policy of most forest managers as a means to protect water quality, if wildlife habitat is of particular interest, see the Exhibit 1 for information on buffer/filters which protect water quality and wildlife habitat.

Management of the Buffer: The Three-Buffer Zone System

Scheuler (1995) promotes the use of a buffer/filter system made up of three zones, each of which has a different width, function and management scheme. The total minimum width of the three zones is 100 feet and includes the floodplain.

- The *streamside zone* is usually made up of mature trees which provide shade, leaf litter, and woody debris to the stream, as well as erosion protection. The minimum width of this zone is 25 feet. Land uses allowed in this zone are limited to footpaths, and well-designed watercourse crossings (for utilities, roads, etc.). See the Watercourse Crossings BMP to help in designing sound watercourse crossings.
- The *middle zone* extends from the outer edge of the streamside zone and protects the stream's ecosystem by providing a larger protective area between the stream and upland development. Ideally, this zone will also be made of mature trees and will be a minimum of 50 feet, with widths increasing to ensure the 100-year floodplain, adjacent steep slopes and protected wetlands are included. The width of this zone may also increase as the stream order increases. Uses allowed in this zone include bike paths and other low-impact recreational uses and stormwater BMPs.
- The *outer zone* is the zone between the middle zone and the nearest permanent structure (e.g. house or building). This is the filter part of the buffer/filter system. In residential areas, this

zone is usually a grassy backyard. The zone is a minimum of 20 feet in width, with widths increasing with increasing slopes and with the amount of sediment and/or nutrients the filter is expected to treat. Septic systems and permanent structures are restricted in this zone. In urban areas or areas directly adjacent to pavement, this area should be a managed filter strip to maximize pollutant removal.

Incorporating Stormwater BMPs in the Buffer/Filter:
Buffer/filter strips are not capable of treating all stormwater generated in a watershed. (Schueler states that a buffer/filter system can treat runoff from less than 10% of the contributing watershed). Therefore, stormwater BMPs must be used to protect the streamside buffer zone and the stream itself.

The designer should evaluate all the possible paths of flow into the buffer/filter strip. If any flow paths are expected to exceed sheetflow or otherwise cause erosion, then BMPs are needed upslope. If land is limited, the BMPs may need to be installed in the upper or middle zones.

Example problem: A designer determined that stormwater would enter the buffer/filter strip from a new development at three points: 1) a parking lot curb cut draining half of a parking lot, 2) parking lot overland flow draining the other half of a parking lot; and 3) building roof drains. The designer determined that the water leaving the parking lot would do so as sheet flow and cause no erosion in the buffer/filter strip.

Example Solution: Since the parking lot curb cut would cause concentrated flow into the buffer/filter strip, the designer added two more curb cuts to the design to break up the flow. He designed the parking lot so that the buffer/filter would be located 3 to 6 inches lower than the pavement to prevent sediment deposits from blocking inflow to the filter strip. He also included installing a layer of stone at the outlets of the curb cuts to slow the water. To address the concentrated flow from the building roof drains, he included a rock-lined splash apron below the drains, and below it, some dense vegetation. Due to limitations in the land available, these BMPs were installed in the outer zone of the buffer/filter strip.

Planning Considerations for Creating Buffer/Filter Strips:
Re-establishment of buffer/filter strips is possible if urban land is being reclaimed, if sites of environmental contamination are being cleaned up, or if greenways are being established as part of a greenways program or recreation enhancement program. Under these and other re-establishment conditions:

1. Conduct a site evaluation to determine:
   - the drainage characteristics. Depending on drainage, it may be necessary to use other BMPs. Note that concentrated flows can be minimized by limiting the drainage area to less than 5 acres.
   - percentage slope and length of slope.
   - type of soil and soil stability. Sloughing soils, will require additional BMPs to ensure stability of the slope.

2. Determine all of the possible uses of the newly developed buffer strip and incorporate those uses into the design. For wildlife considerations, see Exhibit 1.

3. Select vegetation based on the site characteristics determined uses and the three-zone

concept. For vegetative mixtures for the outer zone, see Exhibit 2.

4. **Buffer/filter strips are not effective methods for treating concentrated flow.** Determine flow patterns onto the buffer/filter strip and incorporate BMPs to ensure stormwater enters the buffer/filter strip as **sheet flow**.

Installing Buffer/Filter Strips:

1. Install any BMPs needed upland.

2. Prepare the site. If it is necessary to clear and grade land, follow specifications in the Land Clearing and Grading Practices BMPs. *Never grade to the edge of a watercourse without using filter fencing or other BMPs to protect the watercourse.* Any use of soil amendments such as fertilizer should be based on soil tests and follow the Soil Management specifications.

3. Refer to the Seeding, Sodding, Mulching and Trees, Shrubs and Ground Covers BMPs, as appropriate to the vegetation selected.

4. Maintain any temporary upland BMPs until vegetation "takes." Grass should be a minimum height of 4 inches and 90 percent ground cover before temporary upland BMPs are removed (i.e. the site should be stable).

5. Consider using mulch between trees and shrubs to keep soil on site.

6. Avoid spraying the buffer strip with pesticides; consider alternatives in the Integrated Pest Management BMP.

7. Protect the buffer/filter from damage by equipment and traffic. Do not use the buffer/filter strip as a roadway.

Maintenance

All Zones:

Periodic inspections should be done to ensure that concentrated flows have not developed, and to make sure the vegetative cover is maintaining its effectiveness. If the integrity of the buffer/filter strip is jeopardized by upland erosion, or if concentrated flows are creating rills or gullies up-slope of the strip, additional BMPs may need to be installed. If the buffer strip is being jeopardized by stream bank erosion, then the cause of the bank erosion needs to be investigated and actions taken to address the causes. Damaged strips should be repaired as soon as possible. Strips damaged due to construction upslope of the buffer/filter should be replanted, as necessary, after the cause of the damage is assessed and any other BMPs needed are implemented.

In buffer/filter strips used by wildlife—but especially in the streamside zone—avoid using herbicides to control weeds. Refer to the Pesticide Management BMP for other options.

Streamside Zone and Middle Zone:

Natural woody buffer/filter strips should be left undisturbed, except for the uses listed in the management section of this BMP (pages 2 and 3). Do not use heavy equipment in this area.

To replace or repair damaged trees, refer to the Tree Protection and Trees, Shrubs and Ground Covers BMP.

The Outer Zone:

- If sediment enters the filter strip in amounts which cannot be removed by hand, or in amounts which damage the filter strip, additional upland BMPs will likely need to be installed.
- Remove sediment in this zone when sediment begins to build up. Reseed if necessary.
- If the filter was designed for nutrient removal, remove any harvested vegetation (grass clippings, leaves, etc.) and dispose of outside the buffer/filter strip.
- If grass fails to grow in newly established filter strips, determine the reasons for failure before reseeding. The Lawn Maintenance BMP includes information on unhealthy turf. Spot seed applications when only small areas are affected. If insects are damaging the filter strip, explore integrated pest management techniques in the Pesticide Management BMP to protect any wildlife using the filter strip.
- Mowing should be done to help control weed growth, prevent the growth of woody plants, and help the filter maintain its effectiveness. Mow no lower than six inches to allow vegetation to provide filtering of sediment, organic matter, nutrients, and pesticides. If the strips are used by nesting birds, do not mow until after July 15. To maintain winter cover for wildlife, do not mow after September 1.
- *During the establishment year,* clip to control undesirable plants such as Canadian thistle and milkweed. Clip high (6 inches) to prevent damage to the permanent seeding. Clip between July 15 and August 15. If needed, clip twice during the summer. Use chemical controls only after all non-chemical methods have been considered.
- *After the establishment year*, only spot clipping (or spot chemical treatment, if necessary) should be done, rather than clipping or otherwise treating the entire strip. If noxious weeds develop, clip in the spring to prevent weed seeds from dispersing. Otherwise, clip between July 15 and August 15 to protect any nesting wildlife.

Exhibits

Exhibit 1: 1997 Literature Review of Buffer/Filter Strips for Wildlife and Water Quality. MDEQ, Surface Water Quality Division.

Exhibit 2: Vegetative Widths for the Outer Zone. USDA Soil Conservation Service Technical Guide.

Exhibit 3: Vegetative Mixtures for the Outer Zone. USDA Soil Conservation Service Technical Guide.

Exhibit 4: 1993 Literature Review on Buffer/Filter Strip Widths. MDEQ, Surface Water Quality Division.

Exhibit 5: References used in developing the BMP.

Exhibit 6: Michigan's Natural Rivers System. List of rivers designated or proposed under the Natural Rivers program.

Exhibit 1

For Wildlife Corridors That Also Protect Water Quality

For wildlife corridors that also protect water quality, consider the following:

- Rudolf and Dickenson (1990) found that reptiles and amphibians were more abundant in buffers 99-313 feet than 0-82 feet.
- Dicken and Huntly (1987) found abundant signs of squirrels in buffers greater than 165 feet, but virtually none in zones narrow than 99 feet.
- Dicken and William (1988) found small mammals to be more abundant in narrower streamside areas with well developed herbaceous vegetation compared to wider zones with sparse vegetation.
- Burk et al (1990) found that turkeys were significantly less when buffers were less than 150 feet.
- Premo (1995) found that a 50-foot zone of intact vegetation is too narrow to support most breeding species of birds. He also found that in hardwood riparian buffers/filters, mammal use was heaviest closest to the river and decreased out to 400 feet and leveled off; in conifer riparian buffer/filters, mammal use was fairly high near the river but peaked at 400 feet, and therefore, sections of 400-foot buffer/filter may be needed in coniferous riparian zones to optimize use by mammals.

Exhibit 2

The Outer Zone: Grass/Sod Filter Widths

Length of Slope	Percent Slope															
	0.2	0.3	0.4	0.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0
	Width - Feet															
100	20	20	20	20	20	20	20	20	30	40	50	50	50	60	60	60
200	20	20	20	20	20	20	20	30	40	40	50	50	60	60	60	60
300	20	20	20	20	20	20	30	40	40	50	50	60	60	60	60	60
400	20	20	20	20	20	20	30	40	50	50	50	60	60	60	60	60
500	20	20	20	20	20	20	30	40	50	50	60	60	60	60	60	60
600	20	20	20	20	20	20	30	40	50	50	60	60	60	60	60	60
700	20	20	20	20	20	20	30	40	50	50	60	60	60	60	60	60
800	20	20	20	20	20	20	30	40	50	50	60	60	60	60	60	60
900	20	20	20	20	20	20	30	40	50	50	60	60	60	60	60	60
1000	20	20	20	20	20	20	30	40	50	60	60	60	60	60	60	60
1100	20	20	20	20	20	30	30	40	50	60	60	60	60	60	60	60
1200	20	20	20	20	20	30	40	40	50	60	60	60	60	60	60	60
1300	20	20	20	20	20	30	40	50	50	60	60	60	60	60	60	60
1400	20	20	20	20	20	30	40	50	50	60	60	60	60	60	60	60
1500	20	20	20	20	20	30	40	50	50	60	60	60	60	60	60	60
1600	20	20	20	20	20	30	40	50	60	60	60	60	60	60	60	60
1700	20	20	20	20	20	30	40	50	60	60	60	60	60	60	60	60
2000	20	20	20	20	20	30	40	50	60	60	60	60	60	60	60	60

Source: USDA Soil Conservation Service Technical Guide, #326.

Exhibit 3

Vegetative Mixtures for the Outer Zone

Soils: Well and moderately well drained sand and loamy sand (coarse textured soils)

Seeding Mixtures	Rates Lbs./Acre	Suitability Sediment Filter Wind	Water
Red Fescue Ryegrass	20 5		X
Smooth Brome	15		X
Switchgrass	8	X	
Switchgrass Tall or Intermediate Wheatgrass	4 8	X	
Tall or Intermediate Wheatgrass	15	X	

Soils: Well and moderately well drained, moderately coarse to moderately fine textured soils (sandy loam, loam, silt loam, and clay loam)

Seeding Mixtures	Rates Lbs./Acre	Suitability Sediment Filter Wind	Water
Reed Canarygrass	6		
Reed Canarygrass Tall Fescue	4 8		X
Smooth Brome	15	X	X
Smooth Brome Tall Fescue	8 12	X	X
Switchgrass	8	X	
Switchgrass Tall or Intermediate Wheatgrass	4 8	X	
Tall Fescue	20	X	X
Tall or Intermediate Wheatgrass	15	X	

1/ Double seeding rates.

(continued)

Exhibit 3 (Continued)

Vegetative Mixtures for the Outer Zone

Soils - Well and moderately well drained clay and silty clay (fine textured soils)

Seeding Mixtures	Rates Lbs./Acre	Suitability Sediment Filter Wind	Water
Reed Canarygrass	6	X	X
Reed Canarygrass Tall Fescue	4 8	X	X
Smooth Brome	15	X	X
Smooth Brome Tall Fescue	8 12	X	X
Switch Grass	8	X	
Tall Fescue	20	X	X
Tall or Intermediate Wheatgrass	15	X	X

Soils - Somewhat poorly drained or poorly drained soils without artificial drainage.

Seeding Mixtures	Rates Lbs./Acre	Suitability Sediment Filter Wind	Water
Reed Canarygrass	6	X	X
Switchgrass 2/	8	X	
Tall Fescue	20	X	X

* The following legumes may be added to the grass mixtures:
6#-8# alfalfa or 3#-4# of birdsfoot trefoil and/or 2# of sweet cover.

1/ Double seeding rates.

2/ Use species tolerant of wetter soils.

Source: USDA Soil Conservation Service Technical Guide #393

Exhibit 4

1993 Literature Review of Buffer/Filter Widths

SOURCE	FACTORS REVIEWED	FINDINGS/RECOMMENDATIONS
Aubertin West Virginia	turbidity, nutrients	Used 10-20M (32.8 feet - 65.6 feet) buffers in study. Both turbidity & nutrients increased during and after logging.
Brazier Oregon	temperature	80' Buffer was necessary to maintain temperature and 55' was necessary for 90% of that temperature or angular canopy density
Erman California	stream invertebrates	Streams with a buffer strip less than 30M (98.4') showed same response as stream logged without buffers. Changes were caused by decreased canopy density, increased primary production, increased stream flows, increased temperature and increased sediment.
Graynoth New Zealand	stream invertebrates	Streams with buffer strip less than 30M showed same response as stream logged without buffers. Changes were caused by decreased canopy density, increased primary production, increased stream flows, increased temperature and increased sediment.
Corbett Pennsylvania	turbidity, sedimentation	1978 Report recommended 23-30M (75.4'-98.4') Buffers 1981 Report recommended 30M (98.4') Buffers 1990 Report recommended 100 feet or 1 1/2 times the average tree length
Farrish Louisiana	soil erosion	**Buffers did not stop gully erosion** that was initiated upslope of buffer. All 1,584 sites reviewed had developed gullies.
Verry 1986 Minnesota	stream flow	Clearcutting hardwoods increased annual stream flow 9 to 20 cm (a 30 to 80 percent increase). It took 12 to 15 years to return to preharvest levels
Verry 1992 Minnesota	large woody debris, temperature, water depth, cover, stream flow	Recommend 2 tree lengths, typically 150 feet, as a leave zone beginning at the top of the bank. Cut only 25% of basal area in second tree length.
Oklahoma State University	Habitat	
-Rudolph & Dickenson, 1990	reptiles/amphibians	More abundant in buffer 99 - 313' than 0-82 feet.
-Dicken & William 1988	small mammals	More abundant in narrower streamside areas with well developed herbaceous vegetation compared to wider zones with spare vegetation
-Dicken & Huntly 1987	squirrels	Abundant signs of squirrel in buffers wider than 165' but virtually none in zone narrower than 99'
-Burk et. al. 1990	turkeys	Turkeys were significantly less when buffers were less than 150'
Hesser Pennsylvania	trout production, sedimentation, temperature	A recommendation of one and one-half chains (100') on both sides of river was made from a literature review. Increased zones may be necessary for sensitive areas.

Exhibit 5

References

Aubertin, G.M. and J.C Patrick. 1974. Water Quality after Clearcutting a Small Watershed in West Virginia. J. Environ. Quality. Vol 3 (3): 243-761.

Brazier, J.R. and G. W. Brown. 1973. Buffer strips for stream temperature control. Research Paper 15, Forest Research Laboratory, School of Forestry, Oregon State University, Corvallis, OR: pp. 1-9.

Erman, D.C., J.D. Newbold, and K.B. Roby. 1977. Evaluation of streamside bufferstrips for protecting aquatic organisms. California Water Resources Center, Contribution No. 165, Davis, CA: pp. 1-48.

Farrish, K.W., J.C. Adams, and C.V. Thompson. 1993. Soil Conservation Practices on Clearcut Forestlands in Louisiana. J. Soil and Water Conservation 48 (2): 136-139.

Gilliam, J.W., Reparian Wetlands and Water Quality. J. Envionrmental Quality. 23:896-900 (1994).

Graynoth, E. 1979. Effects of logging on stream environments and faunas in Nelson, New Zealand. Journal of Marine and Freshwater Research 13: 79-100.

Hesser, Robert , R. Hoopes, C. Weirich, J. Selcher, B. Hollender and R. Snyder. Clear Cutting in Pennsylvania, The Aquatic Biota, Chapter 2, pp. 9-20.

Lynch, J. A. and E.S. Corbett. 1981. Effectiveness of Best Management Practices in Controlling Nonpoint Pollution from Commercial Clearcuts. Reprinted from: Nonpoint Pollution - Tools and Techniques for the Future, Interstate Commission on the Potomac River Basin: 213-224.

National Council of the Paper Industry for Air & Stream Improvement, Inc., (NCASI), 1992. Effectiveness of Buffer Strips for Ameliorating offsite Transport of Sediment, Nutrients, and Pesticides from Silvicultural Operations, Technical Bulletin No. 631, pp. 1-48.

Oklahoma State University, 1993. Riparian Forest Buffers, OSU Extension Facts, Water Quality series. pp. 1-6.

Premo, Dean, 1995. The Proceedings of Five Regional Citizen Education Workshops on Lake Management. USEPA, Region 5, citizen education grant. Pages, 47-50.

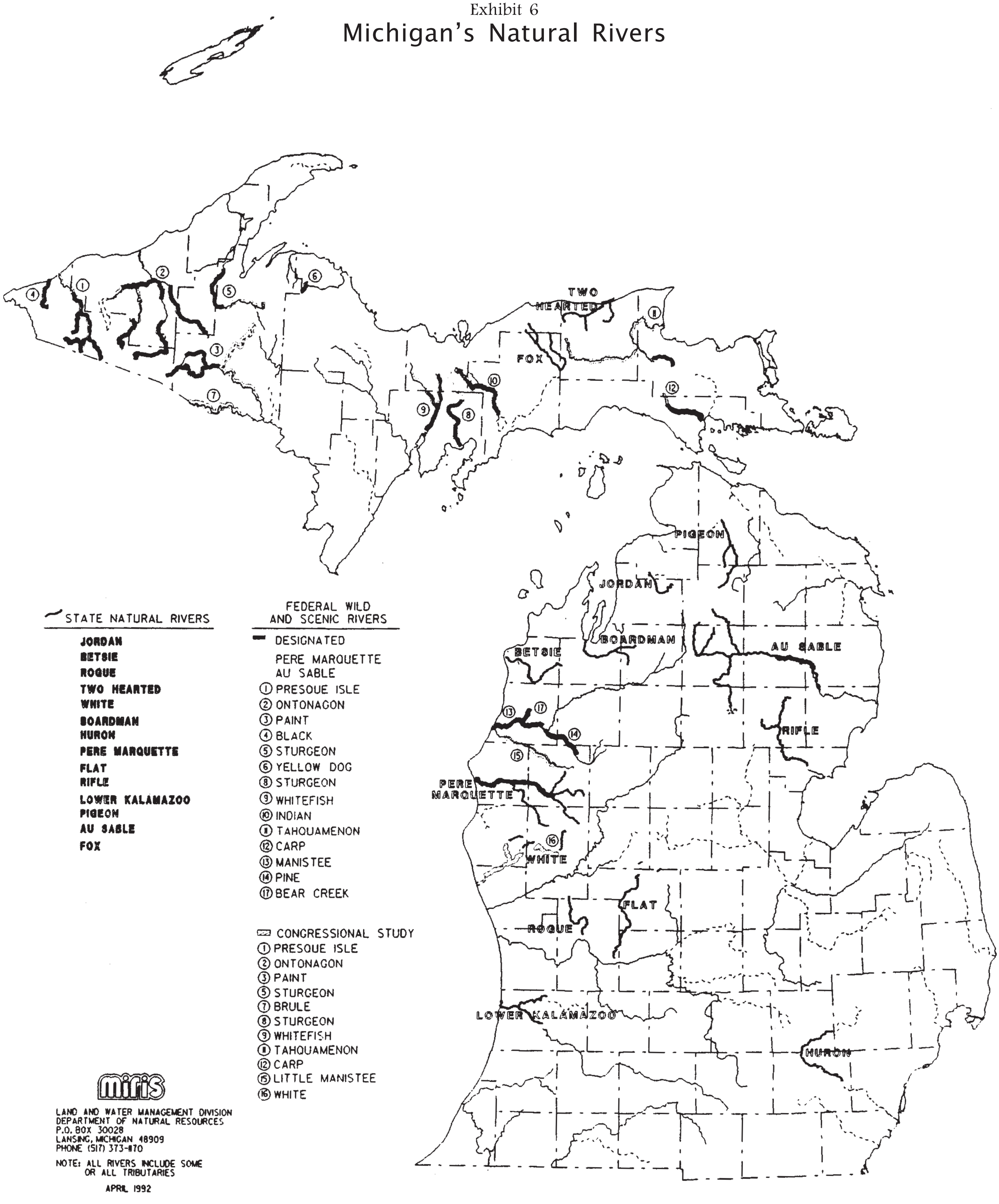
Schueler, Tom, 1995. The Architecture of Urban Stream Buffers. Watershed Protection Techniques, Vol. 1, No.4.

Verry, Elon S., 1986. Forest Harvesting & Water: The Lake States Experience. Water Resources Bulletin, Vol. 22, No. 6.

Verry, Elon S., 1992. Riparian Systems and Management. Forest Practices and Water Quality Workshop, Green Bay, Wisconsin, B1 - B24.

Exhibit 6

Michigan's Natural Rivers



DISTRIBUTED BY THE MICHIGAN UNITED CONSERVATION CLUBS

Dewatering

Description

Dewatering is the removal of ground or surface water from a construction site to allow construction to be done "in the dry" (as opposed to under wet conditions). Water is usually removed using well points and power driven pumps. Dewatering of cofferdams and trenches is a common practice during the construction of bridges, culverts and public utilities (see the Watercourse Crossings BMP).

Other Terms Used to Describe

Pumping

Pollutants Controlled and Impacts

Proper dewatering techniques will filter water of sediment, oils, and other chemicals, thus preventing these pollutants from entering the surface waters.

Application

Land Use
Transportation (highway construction), urban (utility construction, and commercial development), and construction sites.

Soil/Topography/Climate
Dewatering is important in areas that have high ground water tables, or which do not have adequate drainage.

When to Apply
Apply at the beginning of and during construction when it is necessary to lower the ground water table. Pumping needs to be maintained to keep utility ditches and cofferdams dry until all underground work is completed.

Where to Apply
Apply on construction sites, where appropriate, or anywhere else dewatering is done.

Relationship With Other BMPs

Dewatering is often implemented in conjunction with Watercourse Crossings. Sediment Basins and Filters should be considered to help filter the dewatered water before it is discharged to a surface water.

Specifications

1. Dewatering must be done so that the velocity of the discharged water doesn't cause scouring of the receiving area. If the receiving area is a structural BMP (i.e. basin or sump), the design of the BMP should be based on the anticipated flow from the dewatered area.

2. Sediment-laden water from cofferdams, trenches and other areas which need to be dewatered, should be pumped through a geotextile material before the water is discharged to a watercourse. See the Filters BMP. The filter bag should be disposed of by the contractor at an upland site.

3. If the dewatered water is discharged through a filter to a county or inter county drain, permission must be obtained from the drain commissioner or drain board.

Maintenance

The dewatering site should be inspected several times daily to ensure that the pumping procedure is adequately controlling the excess water, to ensure the filter bag is not clogged, and that the vegetative filter, where used, is still retaining sediment. If the filter bag becomes clogged, replace with a new one. If sediment basins are used, be sure to follow maintenance procedures included in the Sediment Basin BMP.

Dec. 1, 1992

Filters

Description

Filters are mechanical methods of removing sediment from storm water before the water leaves a construction site. The filter may consist of pea stone, various grades of washed crushed stone, straw, or one of many types of geotextile materials. This BMP includes specifications for filter fences (silt fences), storm drain inlet protection devices, and several other less common types of filtering mechanisms.

This BMP does not address filter or buffer strips. Buffer/Filter Strips is a separate BMP which contains specifications for preserving and establishing vegetation between erodible areas and water courses to filter sediment. This Filters BMP discusses structural filtering devices.

Other Terms Used to Describe

Filter Fence
Flotation Curtain
Geotextile Fabric
Sewer Inlet Protection
Silt Curtain
Silt Fence
Storm Drain Inlet Protection

Pollutants Controlled and Impacts

All filters help retain sediment and attached chemicals, including phosphate, nitrates, metals, and pesticides. The effectiveness of each type of filter is dependent upon the type of material used, design, flow, and proper maintenance. Most filters have limited capacity to control silts and clays, and are most effective in filtering larger sand-sized particles.

By collecting sediment, filters will help reduce the maintenance of storm sewers and other underground piping systems.

Application

Land Use
The filters discussed in this practice are most applicable to construction sites.

Soil/Topography/Climate
Most filters are suitable for retaining sand. Only specialized geotextile materials are suitable for retaining clay, silt and other fine soils. Geotextile materials used to control fine soils clog up quickly, and should be replaced frequently.

When to Apply
Filters used in conjunction with Check Dams, Sediment Basins, Diversions and areas subject to runoff, should be installed prior to or in conjunction with major earth change activities. Storm sewer inlet filters should be installed as soon as the manhole is capable of receiving storm water.

Geotextile filters should be implemented according to their intended use, and following manufacturer's specifications.

Where to Apply
The location for installing these practices is site-specific and material-specific. See the "Specifications" section, below.

Relationship With Other BMPs

The following is a list of BMPs and the type of filter most often used in conjunction with them. Refer to the underlined BMP for additional information.

Sediment Basins. Stone is placed around the perforated riser pipe to filter sediment-laden water from runoff, or at the outlet of the sediment basin.

Dewatering operations. Geotextile materials are used to filter soil from water pumped during dewatering.

Diversions. Stone is placed at the hydraulic outlet point.

Check Dams. Although the primary purpose of a check dam is to reduce velocity, it may also be used to filter sediment. Burlap or geotextile bags filled with sand, pea stone or washed crushed stone may be added to the check dam design to provide filtering benefits in addition to reducing the flow velocity.

Specifications

General Considerations:
The filters below are listed according to the specific purpose for which they were intended. Note that straw bales are not recommended as filters, since upon becoming saturated, they swell and act as dams. If straw bales are used, they must be trenched in and replaced before they become water-logged.

Many of the practices below rely on the use of **geotextile materials**. These materials are manufactured to control the rate of storm water flow, and to cause deposition up-slope of the material. They are constructed like a sieve to prevent certain sizes of soil particles from passing through the system, yet allowing water to pass through.

Geotextile fabrics come in a variety of materials. All fabric materials come with permeability, strength and durability ratings. In all cases, follow the manufacturer's recommendations for the specific product application, installation and maintenance. Suppliers of geotextile fabrics are listed in the Appendices.

1. **Protecting storm sewer and catch basin inlets.** Filters are used around catch basins and storm sewer inlets to filter sediment-laden water and maintain the integrity of the storm sewer and/or catch basin. All inlet protection practices should be constructed so that the structure can be easily cleaned out and maintained, and so that any resulting ponded stormwater will not cause excessive inconvenience or damage to adjacent areas or structures. These inlet protection practices are most effective in small drainage areas.

A. Excavated Drop Inlet Sediment Trap. Where the storm sewer can be left below the final grade, a depression in the ground adjacent to the manhole can be an effective way of protecting the sewer. The runoff water is directed to the depression and the sediment allowed to settle out in the pre-fabricated filter. See Exhibit 1 for specifications on this practice.

B. Sod Inlet Filter. This practice should only be used to filter sheet flow in areas which have been final graded and seeded. It is designed to protect the inlet from sediment while all other permanent vegetation is being established. (See Exhibit 2).

C. Geotextile Inlet Filter. This method consists of placing filter fence around the perimeter of the storm inlet. Apply this method where the inlet drains gentle slopes and sheet or overland flow. See Exhibit 3.

D. Geotextile-Stone Filters. These are used both on storm inlets and in street curbs and gutters. Exhibit 4 is simply constructed of geotextile materials over the inlet, with stone on top. The geotextile-stone inlet device may be used when flows in the street are such that if the geotextile filter fabric becomes clogged during a typical storm, the ponded water would not cause damage or inconvenience. Because burlap rots rapidly when it is exposed to sunlight and moisture, use burlap in place of geotextile material only if it is replaced frequently.

E. Exhibit 5, the Modified Geotextile-Stone Filter is used only on curb and gutter inlets. This practice makes use of wire mesh, wood, filter cloth and stone, and should be used to prevent larger volumes of water from ponding in the street. If the geotextile-stone inlet device in Exhibit 4 isn't adequate, modify it according to Exhibit 5 to accommodate greater flows.

F. Block and Gravel Drop Inlet Filter. This practice is used around storm sewers in areas where heavy flows are expected and where an overflow capacity is necessary to prevent excessive ponding around the structure. See Exhibit 6.

G. Block and Gravel Curb and Gutter Inlet Filter. This is similar to the geotextile-stone inlet filters, except that concrete blocks are used. Follow the specifications in Exhibit 7.

2. **Filter Fences.** *When properly installed and maintained*, filter fences are very effective filtering devices adjacent to streams and wetlands. They are most effective on slopes that are not very steep or long. Place at the base of the slope and only in areas of sheet flow. **Do not use in areas of concentrated flow.** Follow the installation and maintenance specifications in Exhibits 8 and 8a.

3. **Filter bags used as part of a dewatering operation.** Geotextile filter bags are often used as part of a Dewatering operation. Water which is pumped from construction activities should be pumped through filter bags, a grass Buffer/Filter Strip, or a Sediment Basin before it enters a water course.

i. The filter bag should be constructed with a needle-punched, non-woven fabric.

ii. The seams of the filter bag may be sewn, nailed between 2" x 4"s, or connected by some positive method of closure. The seams should be strong enough to withstand pumping pressures, sediment loads, and transportation by the contractor to an upland site for disposal.

4. **Floatation silt (turbidity) curtains.** These are silt barriers used in non-flowing water such as a lake or pond. The silt curtain consists of a filter fabric curtain weighted at the bottom and attached to a floatation device at the top. Its purpose is to isolate an active construction area within a lake or stream to prevent silt-laden water from migrating out of the construction area. See Exhibit 9 for specifications for this practice.

5. **Filters as additional protection under structures** and similar practices. Filter fabric can be used under Riprap, and seawalls/retaining walls and other Slope/Shoreline Stabilization structures. Lay filter fabric underneath these structures to allow groundwater seepage and retain soil particles. Consult the "Supplies of Geotextile Filter Fabric," Appendix 6, for specific applications.

6. **Filters as detention berms.** On sites which may benefit from temporary terracing, the developer may opt instead to construct a series of large rock piles (which also act as check dams) along a slope to filter sediment-laden water. See the Check Dams BMP for this application.

7. **Stone filters as outlets for sediment basins and diversions.** The area between a Sediment Basin and a stabilized outlet should consist of stone with or without geotextile material under it. The outlet for a Diversion can also be a stone filter. See also the Stabilized Outlets BMP.

Maintenance

Effective filters will collect sediment, particularly when the soil is sandy. Filters must be cleaned periodically so they don't become clogged and cause flooding conditions, piping, or overtopping of the control structures. Filter fencing which sags, falls over, or is not staked in, should be promptly repaired or replaced.

Exhibits

Exhibit 1: Excavated Drop Inlet Sediment Trap. Michigan Soil Erosion and Sedimentation Control Guidebook, and USDA Soil Conservation Service.

Exhibit 2: Sod Inlet Filter. Modified from Virginia Erosion and Sediment Control Manual.

Exhibit 3: Geotextile Inlet Filter. Modified from Virginia Erosion and Sediment Control Manual.

Exhibit 4: Geotextile-Stone Inlet Filter. Virginia Erosion and Sediment Control Manual.

Exhibit 5: Modified Geotextile-Stone Filters for Storm Inlets and Catch Basins. Text: Modified from 1983 Maryland Standards and Specifications for Soil Erosion and

Sediment Control. Graphic: USDA, Soil Conservation Service, College Park, Md.

Exhibit 6: Block and Gravel Drop Inlet Filter. Modified from Virginia Erosion and Sediment Control Manual.

Exhibit 7: Block and Gravel Curb and Gutter Inlet Filter. Modified from Virginia Erosion and Sediment Control Manual.

Exhibit 8: Silt Fence (Filter Fence). Text: Several sources.

Exhibit 8a: Filter Fences. Oakland County, Michigan, Erosion Control Manual.

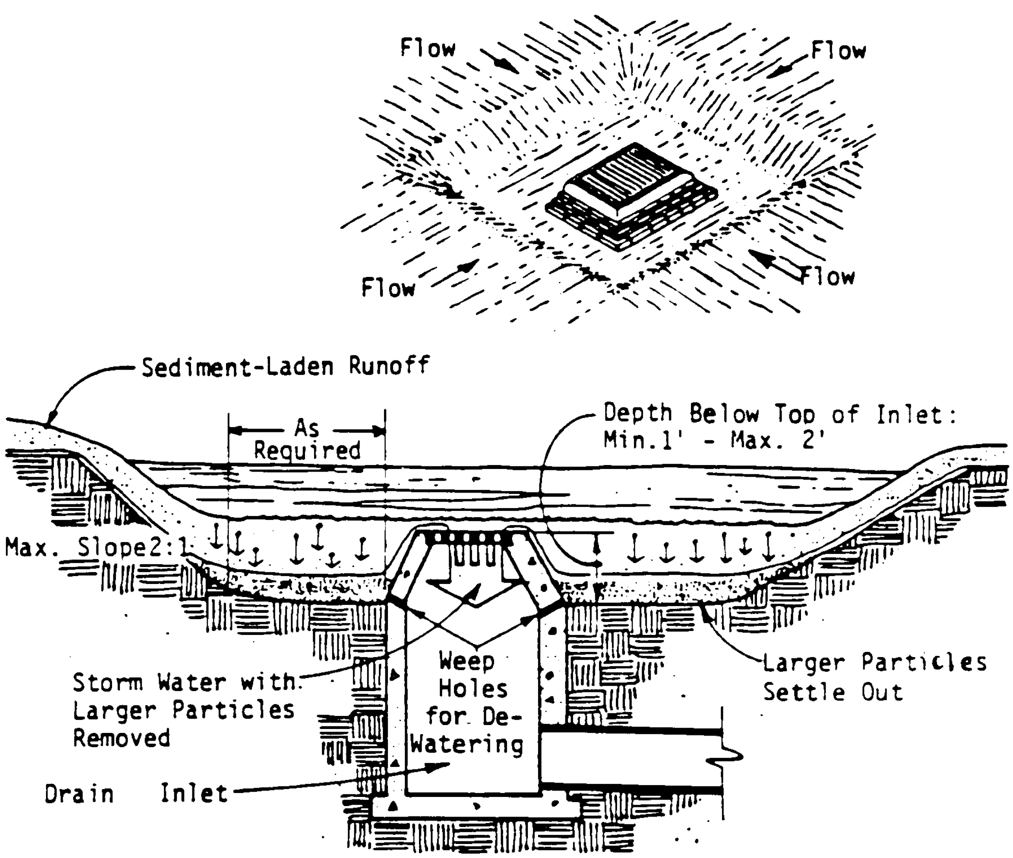
Exhibit 9: Silt (Turbidity) Curtains. Protecting Water Quality in Urban Areas: Best Management Practices for Minnesota.

Exhibit 1

Excavated Drop Inlet Sediment Trap

Use:
Use in areas where heavy flows are anticipated.

1. The excavated trap should be sized to provide a minimum storage capacity calculated at the rate of 135 cubic yards for 1 acre of drainage area. A trap should be no less than 1 foot, nor more than 2 feet deep measured from the top of the inlet structure. Side slopes should not be steeper than 2:1.
2. The slopes of the basin may vary to fit the drainage area and terrain. Observations should be made as necessary to ensure satisfactory trapping of the sediment.
3. Where an inlet is located so as to receive concentrated flows, such as in a highway median, it is recommended that the basin have a rectangular shape in a 2:1 ratio, with the length oriented in the direction of the flow.
4. Sediment should be removed and the trap restored to the original dimensions when the sediment has accumulated to 40% the design depth of the trap. Place any removed sediment in a manner consistent with the Spoil Piles BMP.
5. During final grade, the inlet should be protected with a geotextile-stone filter. Once final grading is achieved, a sod inlet filter should be implemented to protect the inlet until permanent vegetation is established.



Source: Modified from the Virginia Erosion and Sediment Control Manual.

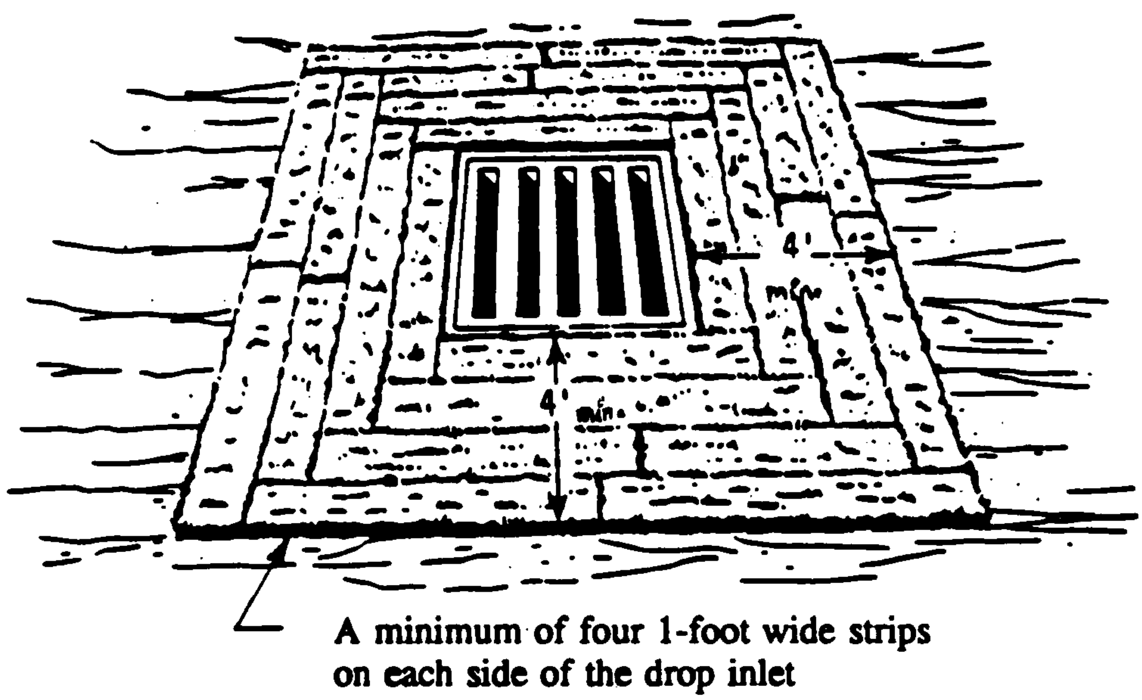
Exhibit 2

Sod Inlet Filter

Use:

Use in areas which are not stable on any and all sides. An alternative method to the Burlap or Geotextile Inlet Filter.

1. Use only to filter sheet flow and in areas which have been final graded and seeded for vegetative cover.
2. This practice may be used in conjunction with a stone filter around the inlet.
3. The minimum sod requirement is 4 feet on each side of the inlet. The width of the sodded area should increase based on the slope of the drainage area.
4. Sod should be laid so that the anticipated runoff does not flow directly into the inlet between the pieces of sod. This is best done by laying the sod like masonry bricks (i.e. off-setting every other row.) See Exhibit 3 for the proper placement of the sod.
5. Select sod type, prepare sodbed, lay, and stake sod following the specifications in the Sodding BMP.
6. Maintenance should be done following each rain to ensure the sod is adequately filtering the runoff. Stone filters around the inlet may be added, as necessary.



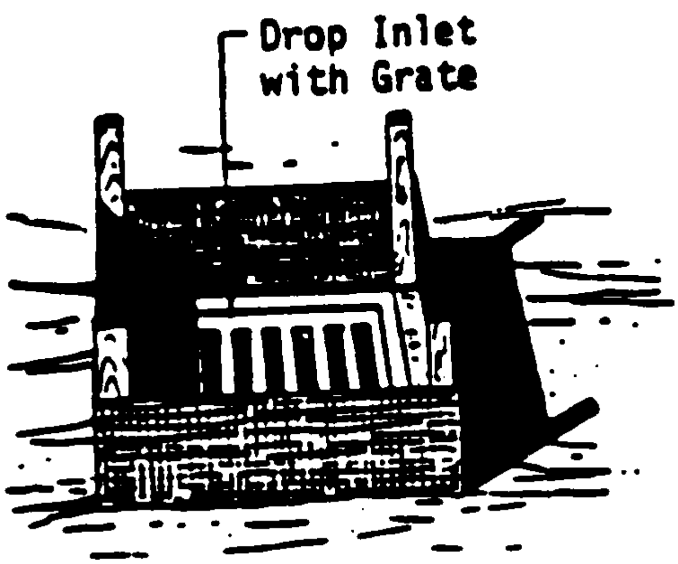
Source: Modified from Virginia Erosion and Sediment Control Manual.

Exhibit 3

Geotextile Inlet Filter

Use:
Use around the perimeter of inlets in areas which are not stabilized on any or all sides.

1. Filter fabric should have ultraviolet protection and be strong enough to maintain effectiveness under anticipated flows. It should come from a continuous roll and otherwise meet the specifications for filter fabric.
2. Stakes should be 1 1/8" x 1 3/8" finished wood or equivalent metal with a minimum length of 3 feet (36 inches).
3. Staples should be of heavy duty wire at least 1/2-inch long.
4. Stakes should be spaced around the perimeter of the inlet a maximum of 3 feet apart and driven into the ground a minimum of 8 inches.
5. A trench should be excavated around the perimeter of the inlet and the fencing materials placed in the trench. The trench should be 4" wide and 6" deep.
6. Staple the material to the stakes.
7. After lowering the bottom of the material into the trench, backfill with soil and make a small ridge on the up-slope side of the filter material. The geotextile material above the soil should be approximately 16 inches, minimum.
8. The material in the last corner to be completed should overlap with the material from the first one by six inches. Wrap the ends and staple to both posts.



Source: Modified from Virginia Erosion and Sediment Control Manual.

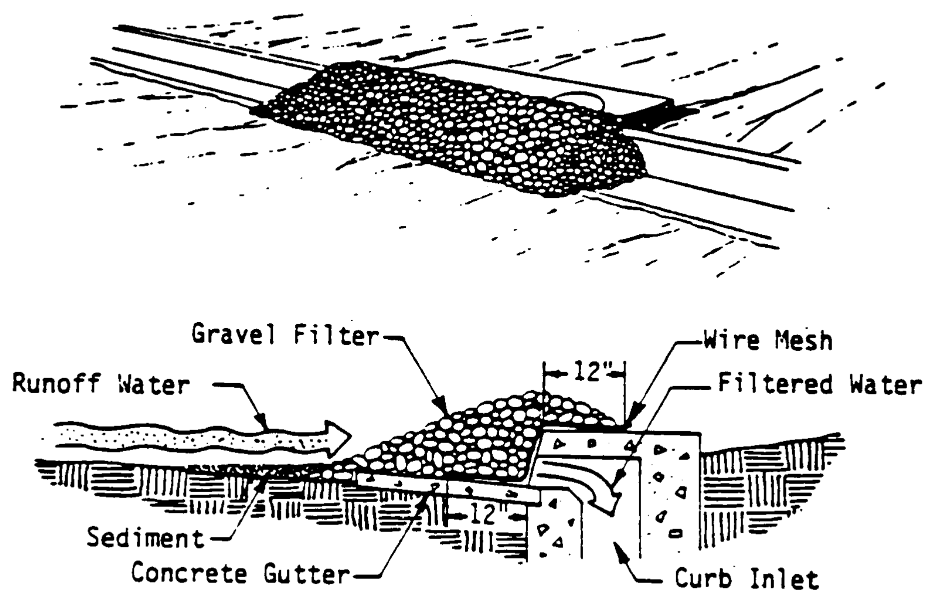
Exhibit 4

Geotextile-Stone Inlet Filters

Use:
Simple stone filters can be used on storm inlets where flows are minimal. They can consist of laying geotextile or wire material on top of the storm sewer and laying approximately six inches of 2-inch clean aggregate on top. This method can also be used on curb and gutters, though the method in Exhibit 5 is preferred.

Maintenance must be done regularly, especially after storms. When clogging occurs, remove the old geotextile material and stone and replace with new material and either clean stone.

Extra support can be provided by placing hardware cloth or wire mesh across the inlet cover. The wire should be no larger than 1/2" mesh and should extend an extra 12 across the top and sides of the inlet cover. See the diagram below.



Specific Application

This method of inlet protection is applicable at curb inlets where ponding in front of the structure is not likely to cause inconvenience or damage to adjacent structures and unprotected areas.

Source: Modified from Virginia Sediment Control Manual.

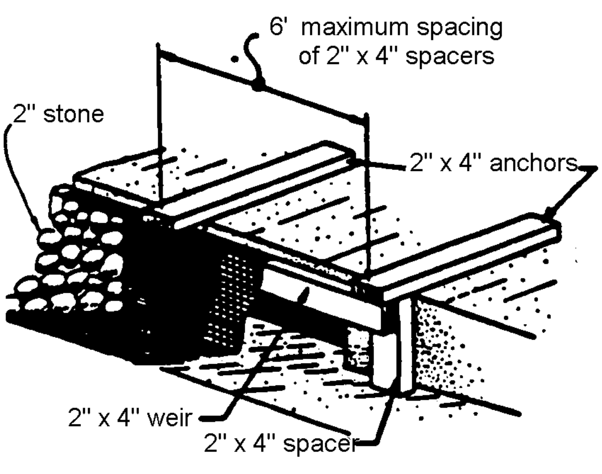
Exhibit 5

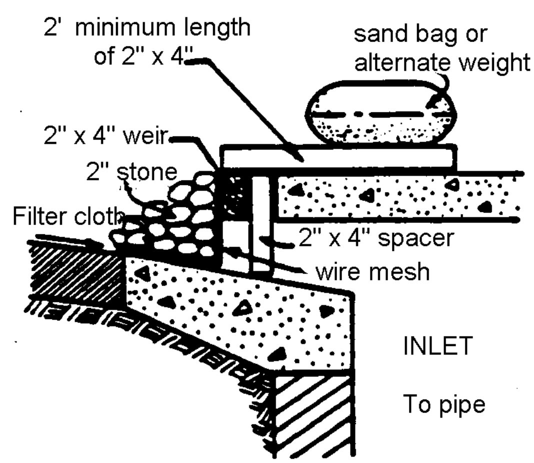
Modified Geotextile-Stone Filter
For Storm Inlets and Catch Basins

<u>Use</u>:
Use this method on curb and gutter inlets and storm sewer inlets where overflow capability is needed to prevent excessive ponding in front of the structure.

1. The wire mesh must be of sufficient strength to support filter fabric, and stone for the curb inlets, with water fully impounded against it.
2. The filter cloth must be of a type approved for this purpose, resistant to sunlight, and a sieve size sufficient enough to allow passage of water and the removal of sediment.
3. Use 2" stone. It must be clean.
4. Attach a continuous piece of wire mesh (30" minimum width by throat length plus 4') to the 2" X 4" weir (measuring throat length plus 2') as shown on the drawing.
5. Place a piece of approved filter cloth (40-85 sieve) of the same dimensions as the wire mesh over the wire mesh and securely attach to the 2" X 4" weir.
6. Securely nail the 2" X 4" weir to 9" long vertical spacers to be located between the weir and inlet face (maximum 6' apart).
7. Place the assembly against the inlet throat and nail minimum 2' lengths of 2" X 4" to the top of the weir at spacer locations. These 2" X 4" anchors should extend across the inlet top and be held in place by sandbags or alternate weight.
8. Place the assembly so that the end spacers are a minimum 1' beyond both ends of the throat opening.
9. Form the wire mesh and filter cloth to the concrete gutter and against the face of curb on both sides of the inlet. Place clean 2" stone over the wire mesh and filter fabric in such a manner as to prevent water from entering the inlet under or around the filter cloth.
10. This type of protection must be inspected frequently and the filter cloth and stone replaced when clogged with sediment.
11. Assure that storm flow does not bypass inlet by installing temporary earth or asphalt dikes directing flow into the inlet.

Modified from 1983 Maryland Standards and Specifications for Soil Erosion and Sediment Control.





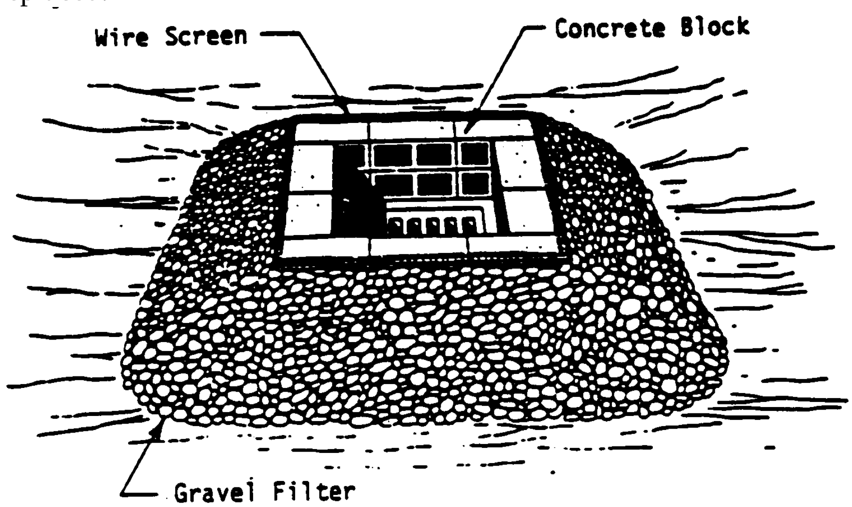
Source: USDA, Soil Conservation Service, College Park, Md.

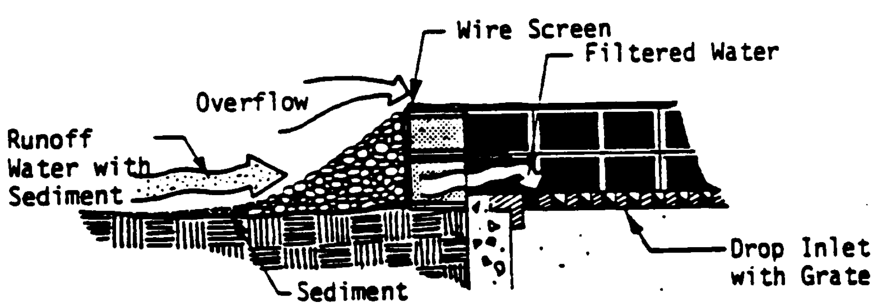
Exhibit 6

Block and Gravel Drop Inlet Filter

Use:
Use where heavy flows are expected and where an overflow capacity is necessary to prevent excessive ponding around the structure.

1. Place 4" X 8" X 12" concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, with the ends of adjacent blocks abutting. The height of the barrier can be varied, depending on design needs, by stacking combinations of the same size blocks. The barrier of blocks should be at least 12 inches high and no greater than 24 inches high.
2. Wire mesh should be placed over the outside vertical face (webbing) of the concrete blocks to prevent stone from being washed through the holes in the blocks. Hardware cloth or comparable wire mesh with 1/2-inch openings should be used.
3. Two-inch stone should be piled against the wire to the top of the block barrier, as shown in the diagram.
4. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the blocks, cleaned and replaced, or new stone replaced.





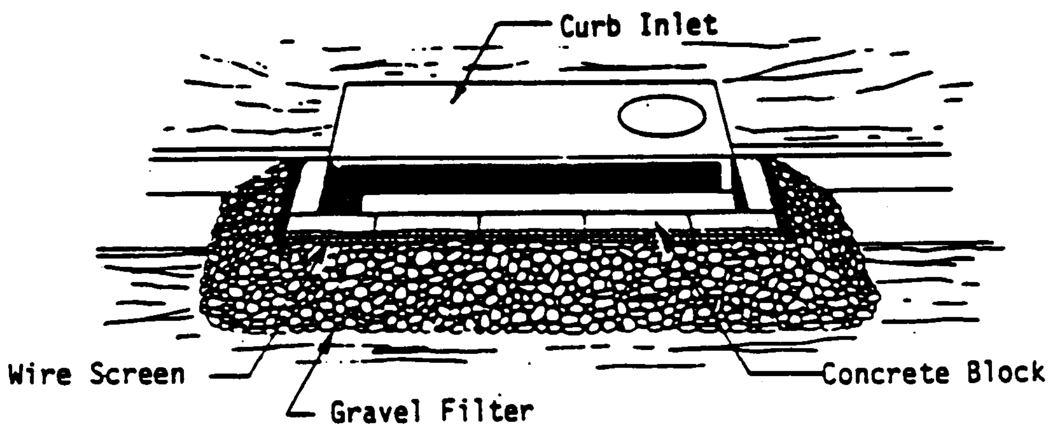
Source: Modified from Virginia Erosion and Sediment Control Manual

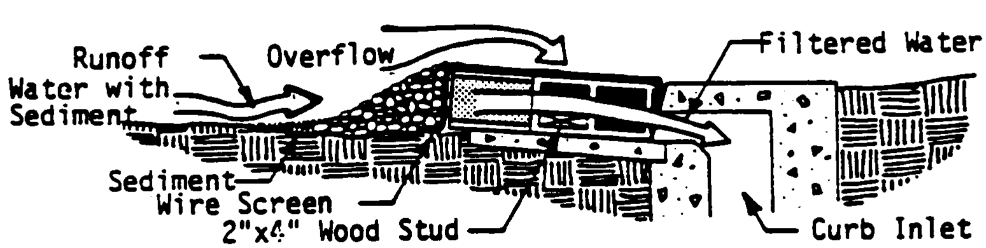
Exhibit 7

Block and Gravel Curb and Gutter Inlet Filter

Use:
Use this method on curb and gutter inlets and storm sewer inlets where overflow capability is needed to prevent excessive ponding in front of the structure.

1. Place two concrete blocks on their sides abutting the curb at either side of the inlet opening. These blocks provide a space between the filtering stone and the inlet.
2. Cut a 2" X 4" stud and place it through the outer holes of each spacer block to keep the front blocks in place.
3. Place additional concrete blocks on their sides across the front of the inlet and abutting the spacer blocks. Refer to the diagram above.
4. Place wire mesh over the outside vertical face (webbing) of the concrete blocks to prevent stone from being washed through the holes in the blocks. Use chicken wire or hardware cloth with 1/2-inch opening.
5. Pile 2" stone against the wire to the top of the barrier, as shown in the diagram.
6. If the stone filter becomes clogged with sediment so that it no longer performs as a filter, the stone must be removed and either cleaned and replaced, or a clean set of aggregate placed.





Source: Modified from Virginia Erosion and Sediment Control Manual.

Exhibit 8

Filter Fences

Use:
Use to control sheet flow only (not concentrated flow). Use adjacent to critical areas, wetlands and watercourses and at the base of slopes. Slopes should be no steeper than 2:1. Drainage should be 1/2 acre per 100 feet of fence.

Do not use in live streams, ditches or swales.

Specifications:
The fabric should be non-woven and composed of at least 95% propylene or ester polymers. It should be certified by the manufacturer or supplier as conforming to the specifications below. Because of the potential for clogging, non-woven materials are not to be used.

The following criteria will meet the requirements of Michigan Department of Transportation 1990 Standard Specifications, Section 8.09.06, and should be used as guidance in selecting geotextile filter fencing.

Physical Characteristics	
Typical fence length:	100 ft.
Fabric width	24" minimum
Post length	36" minimum
Post size	1 1/8" x 1 3/8" finished
Post pointing	Rotary (pencil style)
Post composition	No. 1 common hardwood
Geotextile/post connection	Stapled or pocketed

Mechanical/hydraulic Characteristics:		Testing Procedure
Grab tensile strength	100 lbs.	ASTM D-4632
Trapezoid Tear Strength	45 lbs.	ASTM D-4533
Mullen Burst Strength	280 psi	ASTM D-3786
U.V. Resistance	70%	ASTM D-4355
Water Flow Rate	30 gpm/sf	ASTM D-4491
AOS	0.6 mm minimum	ASTM D-4751

Source: Price and Company, Inc., Grand Rapids, Michigan.

Installation:
In most situations, pre-fabricated materials (i.e. those with posts already attached) can be used. However, on rolling terrain, pre-fabricated fences are difficult to install. On rolling terrain, fences should be assembled in the field.

Install along a contour line of equal elevation.

1. Dig a 6-inch trench along the area in which the fence is to be located.
2. Place 6 inches of the bottom of the fabric into the trench. Some manufacturer's include lines on the bottom of the fabric to indicate the approximate 6-inch line. Make sure the fence is taught.

(Con't.)

Exhibit 8a (Con't.)

3. Backfill the trench and compact the soil on both sides. Make a small ridge on the up-slope side. (See the Exhibit).
4. Place wooden stakes or metal re-rod a maximum of 7'8" apart. The stakes' re-rod should be pounded into the ground, on the down-slope side, a minimum of 8 inches.
5. Staple the geotextile material onto the wooden stakes using metal staples recommended by the manufacturer (minimum 1/2-inch long). Tie metal posts to the fence with wire.
6. Stabilize the area down-slope of the site with grass and/or sod.

For Reinforcement:

Filter fences can be reinforced with 1/2"-inch mesh wire placed on the down-slope side and supported with 2 X 4s. Use a minimum 14 gage wire and a maximum mesh spacing of 6 inches.

Maintenance

1. Silt fences should be inspected immediately after each rainfall and several times during prolonged rainfalls.

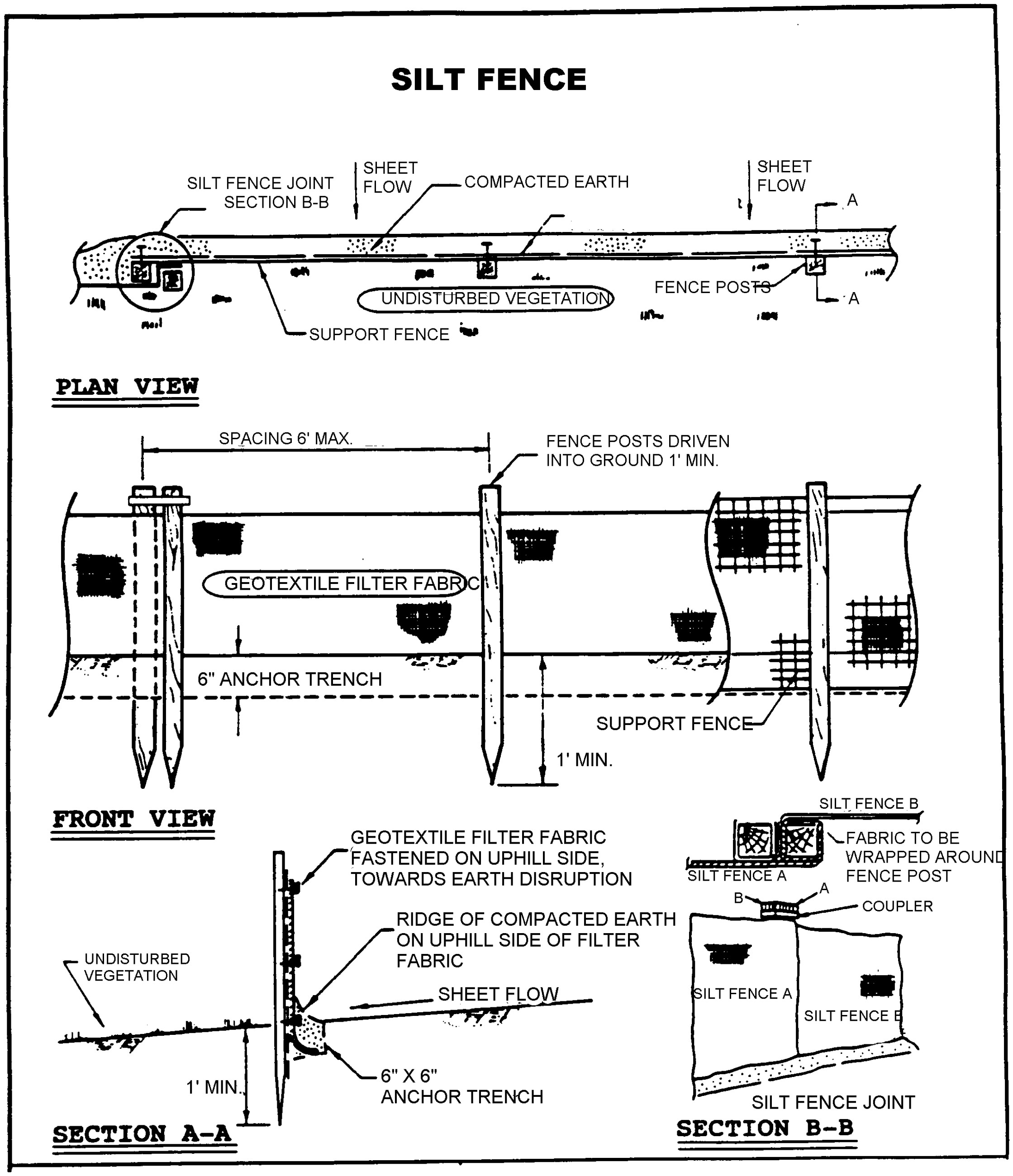
2. If the fence is sagging or the soil has reached one half the height of the fabric, the soil behind the fabric must be removed and disposed of in a stable upland site. The soil can be added to the spoil pile. (See the Spoil Piles BMP).

3. If the fabric is being undercut (i.e. if water is seeping under the fence), the fence should be removed and reinstalled following the procedures given above.

4. Fabric which decomposes or otherwise becomes ineffective should be removed and replaced with new filter fabric immediately.

5. Filter fences should be removed once vegetation is well established and the up-slope area is fully stabilized.

Exhibit 8a



Source: Oakland County (Michigan) Erosion Control Manual.

Exhibit 9

Silt (Turbidity) Curtains

Use:
In lakes adjacent to construction areas and in-stream parallel to the streambank. Used to prevent in-stream sedimentation.

The following specifications are minimum performance standards for suspended solids applications. The following assumptions were made:

-that the primary pollutant is suspended solids (i.e. sand, clay and/or silt). Other types of silt curtains must be used to control other types of pollutants.
-that the silt curtain will be used for no more than one full construction season, (or less, depending on the severity of exposure)

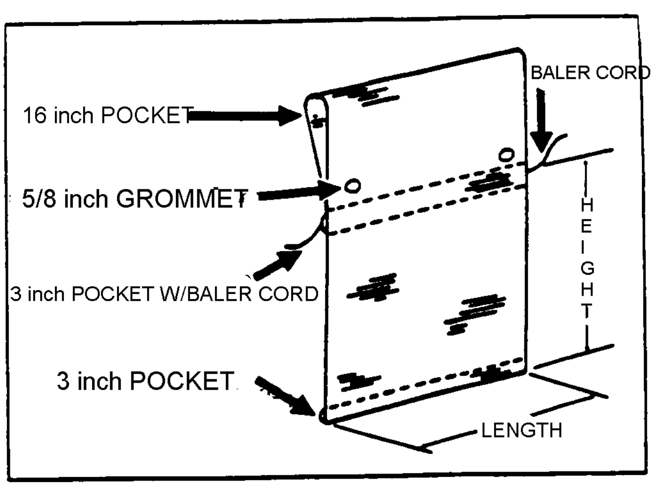
1. The turbidity curtain should be a pre-assembled system including floatation mechanisms, geotextile/geomembrane, bottom weights, securing/tie-off mechanism and joining mechanism.

2. The curtain should be constructed of mechanically-bound, non-woven material consisting of long-chain polymeric fibers. The fibers must be composed of at least 95% propylene or ester polymers. The fibers should be produced in a manner which achieves a stable network.

3. Use Table 1 to determine the appropriate specifications based on the wave height expected in the project area. This table delineates product requirements for a given set of conditions. In no way should a turbidity curtain be extended across or around the flow-path of any inlet structure or waterway without due regard to piping potential, water conveyance needs and clogging potential. If used in streams, the curtain must be placed parallel to the flow of water.

4. Requirements for tie-down locations are site-specific. The number of locations is dependent on the desired shape of the ensuing containment, exterior currents, size of project, etc.

5. Maintain the silt curtain until the construction is stabilized and turbidity is reduced to acceptable levels.



(Con't.)

Exhibit 9 (Con't)
Table 1

Specifications for Wave Heights Less than 6 Inches:

Property	Required[1] Value	Unit	Test Procedure
Tensile Strength	200	lbs	ASTM D-4632
Tensile Elongation	50	%	ASTM D-4632
Mullen Burst	350	psi	ASTM D-3786
Trapezoidal Tear Strength	75	lbs	ASTM D-4533
Puncture Strength	100	lbs	ASTM D-3787[2]
Apparent Opening Size (max)	0.210	mm	ASTM D-4751
Permittivity	1.3	1/sec	ASTM D-4491
U.V. Resistance (150 hrs.)	70	%	ASTM D-4355

Specifications for Wave Heights of 6 - 12 Inches:

Property	Required[1] Value	Unit	Test Procedure
Tensile Strength	360	lbs	ASTM D-4632
Tensile Elongation	50	%	ASTM D-4632
Mullen Burst	650	psi	ASTM D-3786
Trapezoidal Tear Strength	160	lbs	ASTM D-4533
Puncture Strength	225	lbs	ASTM D-3787[2]
Apparent Opening Size (max)	0.210	mm	ASTM D-4751
Permittivity	0.7	1/sec	ASTM D-4491
U.V. Resistance (150 hrs.)	70	%	ASTM D-4355

Specifications for a Minimum Curtain Height of 10 Feet:

Property	Required[1] Value	Unit	Test Procedure
Tensile Strength	400	lbs	ASTM D-4632
Tensile Elongation	50	%	ASTM D-4632
Mullen Burst	700	psi	ASTM D-3786
Trapezoidal Tear Strength	160	lbs	ASTM D-4533
Puncture Strength	180	lbs	ASTM D-3787[2]
Apparent Opening Size (max)	0.210	mm	ASTM D-4751
Permittivity	0.7	1/sec	ASTM D-4491
U.V. Resistance (150 hrs.)	70	%	ASTM D-4355

[1] The Required Value refers to the average minimum value associated with the geotextile's weaker principal direction (when directional difference is possible).

[2] Tension testing machine with ring clamp; steel ball replaced with a 5/16" diameter solid steel cylinder with flat tip centered within the ring clamp.

Source: Price and Company, Inc. Grand Rapids, Michigan.

Dec. 1, 1992

Sedimentation Basin

Description

Sediment basins are man-made depressions in the ground where runoff water is collected and stored to allow suspended solids to settle out. They are used in conjunction with erosion control measures to prevent off-site sedimentation. They may consist of a dam, barrier or excavation, a principal and emergency outlet structure, and water storage space. Their primary purpose is to trap sediment and other course material. Secondary benefits can include runoff control and preserving the capacity of downstream reservoirs, ditches, canals, diversions, waterways and streams.

Sediment basins are often converted to stormwater basins after the completion of the construction project. It is therefore important to determine from the onset what the ultimate fate of the basin will be and design accordingly.

Other Terms Used to Describe

Settling Basins
Sumps
Debris Basins
Dewatering Basins

Pollutants Controlled and Impacts

Properly designed and maintained sediment basins can be very effective in preventing sedimentation of downstream areas. Coarse and medium size particles and associated pollutants will settle out in the basin. Suspended solids, attached nutrients, and absorbed non-persistent pesticides may break down before proceeding downstream. Because sediment basins also retain water, they may help recharge the ground water.

Sediment basins are not as effective in controlling fine particles (i.e. silt, clay) as sand and other coarse particles.

Application

<u>Land Use</u>
Applicable to all land uses where construction is being done.

<u>Soil/Topography/Climate</u>
Sediment basins are most effective in trapping sandy soils. They are not very effective in areas dominated by clay soils. Therefore, soil tests should be conducted to determine whether a sediment basin will be a feasible means of preventing off-site sedimentation.

As shown in Table 1, below, sand has a low erosion potential, high settlement rate in basins and therefore a low potential for off-site sedimentation in surface waters. Clay has moderate and low erosion potential, low settlement rate in basins, and therefore a high potential for off-site sedimentation.

Table 1

	ERODIBILITY	RUNOFF POTENTIAL	SETTLEMENT RATE
SILTY SOILS silt, silt loam	H	M	L
CLAYEY SOILS clay, clay loam	M	H	L
LOAMY SOILS loam, sandy loam	M	M	M
SANDY SOILS sand	L	L	H

HIGH H MODERATE M LOW L

Source: "Soils and Runoff". Michigan Department of Natural Resources, Land and Water Management Division.

<u>When to Apply</u>
Sediment basins should be one of the first sedimentation control measures to be installed. Apply prior to the start of land clearing on the rest of the construction project and in conjunction with erosion control measures.

<u>Where to Apply</u>
Although erosion control should always be considered first, in those situations where physical conditions or land ownership prevents implementation of erosion control measures, sediment basins offer the most practical solution to the problem.

It is practical and economical to locate sediment basins where the largest storage capacity can be obtained with the least amount of earth work, such as in natural depressions and drainage ways. Do *not* place sediment basins in or immediately adjacent to wetlands.

Relationship With Other BMPs

In general, this practice should be used to help prevent off-site sedimentation. Flow in Diversions and Grassed Waterways are often directed to sediment basins. Dewatering operations may require the use of sediment basins. Energy dissipators should be included at all outfalls to prevent erosion and/or scouring. See the Stabilized Outlets BMP.

Specifications

Planning Considerations:

1. Conduct a site investigation to determine the size of the drainage area and the best location for the basin or basins. Determine soil types. (If the soils are predominantly clay, the basin size required may be larger than practical. With clay soils it is particularly important to make the best use of soil erosion control measures, because sedimentation measures—including sediment basins—do not readily retain clays).

2. Select the site for the sediment based on the natural drainage of the area and the soil type.

   A. Determine the number of basins needed. In some cases, it is more effective to have a number of smaller basins rather than one large basin. This is particularly important in areas with large-grained sediments. In addition, the damage caused by one small basin which fails is much less than the damage caused by one large basin which fails.

   B. The area(s) chosen should be such that runoff can be easily diverted to the basin. The most logical location is usually at the lower end of a drainage area.

   C. The discharge from basins should approximate the pre-development runoff from the site.

   D. Where necessary, the site(s) should also easily accommodate periodic clean-outs.

   E. Do not locate sediment basins in perennial streams or wetlands. In-stream sediment basins are only allowed upon permit by the MDNR, Land and Water Management Division.

3. Determine the ultimate fate of the basin. If the basin is to be a temporary structure which will be filled and stabilized upon completion of the project, then proceed with the design criteria below. If the basin is to become part of a stormwater runoff “treatment train” upon completion, then the design of the basin must be coordinated with the design of the “future use” of the basins. For example, if upon completion of the project the sediment basin will be dredged, stabilized and used as an infiltration basin, then the design criteria in the Infiltration Basin BMP must also be followed. *When two BMPs differ in their design criteria, always use the more conservative of the two designs.*

   If the ultimate fate of the basin is an infiltration basin, avoid using heavy equipment in the area so as not to compact the soils. Soil compaction will decrease the ability of the soil to infiltrate water.

4. Select the appropriate type of basin based on the information below.

There are three classes of sediment basins, as described by the Soil Conservation Service Standards and Specifications. Classification is based on: 1) the maximum drainage area a basin serves; 2) the height of the dam; and 3) the extent of mechanical control devices provided with a basin. While reading the descriptions below, keep in mind the ultimate fate of the basin. If the basin is to be a temporary structure, choose between Class 1 and Class 2 basins. If the structure is to be permanent, then choose between the Class 2 and Class 3 basin and remember that the design criteria for both the sediment basin and the stormwater basin must be met.

<u>Class 1</u> – This is a simple temporary basin, frequently used on construction sites. This basin consists of an excavated area of an earth embankment or dam less than 3 feet high constructed of the soil or stone which is available on the site. These basins can be quickly located and constructed with equipment available on most construction sites. Stabilization of the embankment with vegetation or paving is necessary. Maximum drainage is 20 acres.

<u>Class 2</u> – This is a carefully constructed temporary or permanent sediment basin. It consists of an embankment of selected soil materials constructed under controlled procedures, with provisions for an emergency discharge for stormwater to prevent embankment failure. A class 2 basin is most applicable in situations where significant damage can result to downstream and off-site areas if the basin should fail. Maximum drainage is 30 acres.

<u>Class 3</u> – Class 3 basins have carefully engineered, sophisticated controls and are usually permanent. Both the spillways and embankments are intended to serve as grade stabilization structures which will continue to function as stormwater control measures after construction activities are completed. A Class 3 basin should always be constructed if a basin is to be converted to a permanent stormwater detention site. The maximum drainage is 200 acres.

5. The basins should be stabilized before the upstream area is cleared.

6. Disposal sites for the sediment removed from the basin should be incorporated into the overall site plan. Follow specifications in the Spoil Piles BMP.

7. Sediment basins with dams over six feet in height or more and impounding five or more surface acres, are regulated under the Dam Safety Act, (P.A. 1989, Act 300). Other permits may also be needed.

<u>Design Considerations:</u>
Sediment basins should be designed by registered professional engineers.

The effectiveness in reducing in-stream velocity and allowing suspended solids to settle out depends on the:

A. Surface area of the basin. In general the greater the area, the greater the detention time and the less the flow velocity

B. Size of particles coming into the basin

C. Concentration of particles coming into the basin

D. Rate of flow into the basin

E. Volume. As sediment accumulates, the volume decreases (as does the effectiveness of the basin)

F. Travel distance

Temporary structures should be designed with an expected life of no more than 3 years. Structures which will be in place longer than that should be designed as permanent structures (i.e. have emergency spillways).

Side Slopes:
For safety reasons, the side slopes of sediment basins should be no greater than 2:1 (horizontal to vertical). Use flatter slopes in urban or urbanizing areas for safety and liability.

Shape:
The basin shape should be greater than 2:1 (length to width), and preferably 4:1 to improve trapping efficiency. Baffles can be used to modify the effective flow distance.

Basin Capacity:
At minimum, the sediment capacity of a sediment basin should be equal to the volume of sediment expected to be trapped at the site during the life of the structure, plus additional volume to contain 1 inch of runoff from the entire drainage area. This is equivalent to 3,630 ft^3/acres. For example, if the drainage area is 50 acres, then the basin should be sized to accommodate the soil which can be expected to erode from the 50 acres, plus a volume of 1 inch of runoff from the entire drainage area. For a 50-acre watershed, this would equate to:

The soil expected from the drainage area, plus:

$$50 \text{ acres} \times 1 \text{ inch} \times \frac{1 \text{ foot}}{12''} \times \frac{3{,}630 \text{ ft}^2}{\text{acre}} = 181{,}500 \text{ ft}^3$$

To determine the soil loss expected from the drainage area, use the Universal Soil Loss Equation (USLE) in the Appendix.

If sediment is to be removed periodically, the capacity of the structure can be reduced to not less than a one-year debris accumulation.

Dimensions:
The longer the basin is, the more settling will occur. Therefore, at a minimum, the length of the basin should be no less than 2 times the width, or:

Area of the basin = depth X width X 2 (width)

The length can be effectively “extended” by adding a baffle in the basin perpendicular to the direction of the incoming sediment/water.

Design Problem:
<u>Situation:</u>
Given a drainage area of 50 acres, and having determined that the basin volume needed to control the runoff from this 50 acres is 181,500 ft^3, and having determined—using the USLE—that the volume of soil expected from the site is 7,833 ft^3, determine the appropriate dimensions of the basin. Assume an average depth of 5 feet.

1. First determine that the total volume needed is the volume needed to contain both the sediment and the water. This equates to:

   $181{,}500\ ft^3 + 7{,}833\ ft^3 = 189{,}249\ ft^3$

2. Given that the area of the basin = depth (5 ft.) X W X 2W,

   $189{,}249\ ft^3 = 5 \text{ X } 2W^2$

   $189{,}249\ ft^3 = 10W^2$

   $18{,}924.9\ ft^3 = W^2$

   $137.57\ ft = W$

   and length = 2W = 275.14 ft.

The dimensions are therefore:

a depth of 5 ft, a width of 138 ft, and a length of 275 ft.

Spillway System:
The spillway system should carry the peak runoff from the sediment basin design storm allowing for a 2 foot freeboard. The velocity of the flow discharged from the basin should not exceed that allowable for the receiving water body.

Principle Spillway (Mechanical Spillway):
Class 2 and 3 basins include the design of a principle spillway to allow a controlled discharge of water. The principle spillway normally consists of a vertical pipe (or riser) located at the deepest part of the basin, connected to a horizontal pipe which outlets through the dam or lower slope.

The top of the riser should be at least 3 feet below the top of the dam or crest of the emergency spillway.

The **riser** may be solid or perforated. Perforated risors are surrounded by filter fabric, wire mesh and a mound of well-graded gravel. A trash rack over the top of the riser prevents debris from entering and clogging the spillway.

The horizontal pipe should be provided with **anti-seep collars** to prevent piping along the outside of the pipe.

The **outlet** of the principle spillway for Class 2 and Class 3 basins should be stabilized with riprap. Follow specifications in the Riprap BMP. Although riprap is also recommended for the principle spillway on a Class 1 basins, in most cases a simple filter at the outlet will be adequate. See the Filters BMP.

The **size** of the principle spillway should be large enough to pass 80% of the calculated peak discharge from the drainage area. For Class 1 basins, the peak discharge should be based on the storm frequency equivalent to the lifetime of the project in years, and the Class 2 and Class 3 basins should be designed on a 10-year and 25-year storm frequency, respectively. If the sediment basin will also be used as a stormwater basin then be sure to design the spillway using the appropriate stormwater basin procedure.

Emergency Spillway:
Class 2 and 3 basins require an emergency spillway to protect the embankment by providing an outlet from the basin for runoff volumes which exceed the capacity of the principle spillway. The emergency spillway should be sized to pass the difference in discharge between the design storm frequency and the capacity of the principle spillway. If the basin will be used as a stormwater basin, the emergency spillway should be designed to pass the 100-year storm.

Emergency spillways can be as simple as a slope drain constructed of a half section of corrugated metal pipe, or a riprap channel constructed down the dam slope. The **crest** of the spillway should be three feet above the crest of the mechanical riser and a minimum of two feet above the expected water level for the design storm.

The **cross-section** should be trapezoidal, with side slopes 3:1 or flatter.

The **outlet** of the emergency spillway for Class 2 and Class 3 basins should be stabilized with riprap. Follow specifications in the Riprap BMP. The emergency spillway for a Class 1 basin can consist of a simple berm alongside the outlet to channel water to a stabilized area.

Riser and Barrel:
To facilitate installation and reduce the potential for failure from blockage, the minimum barrel size for corrugated metal pipe should be 8 inches, and 6 inches for smooth wall pipe. The cross-sectional area of the rise at least 1.5 times that of the barrel to improve the efficiency of the principal spillway system.

Embankments:
The embankment should always be constructed with the most stable fill material available. For permanent embankment, selected material may have to be hauled in. Where possible, use soils other than sand. Sandy soils tend to “shift”.

Construction Considerations:
Never build a sediment basin in a perennial stream.

1. Construct the sediment basin before any other land clearing or grading is done. Construct according to the design and following the guidelines below.

2. The natural ground under any proposed embankment or dam should be cleared and stripped of trees, other vegetation and roots following the specifications in the Land Clearing BMP.

The remainder of the basin area should be cleared of trees and larger vegetation to allow easy periodic removal of sediment. Natural grasses and ground cover, however, should be retained to provide stabilization. Also leave a natural Buffer/Filter Strip between the edge of the sediment basin and the sediment basin.

3. Disk or scarify the area where the embankment fill will be placed to allow a good bond between the fill and the existing soil. The placement of fill should be in controlled, uniform layers, and should be compacted using a compacting, or by driving hauling equipment over the area.

4. Dispose of spoils taken from the excavation following procedures in the Spoils Pile BMP. The location of the spoil pile should have been included in the overall design.

5. Stabilize all exposed areas of the embankment by Seeding and Mulching or Sodding. Stabilization of the embankment is particularly important with Class 1 basins since the embankment functions as the spillway.

After Construction:

1. Immediately after the sediment basin is constructed, the top banks of the basin and all surrounding areas should be stabilized with vegetation.

2. If basin size was limited and sediment removal is necessary, it should be done when the sediment has accumulated to no more than 50% of the design depth. It is possible to mark the riser pipe or place a bench mark in the basin to indicate when the basin is half full.

3. Dispose of the sediment in an upland site a way which will not cause erosion, such as in accordance with the Spoils Pile BMP. It is important to test the sediment in areas where toxics are or have been stored, or where toxics can in any way get into the sediment basin. Toxic sediment will have to be disposed in an approved landfill.

4. After the entire construction project is completed, temporary sediment basins should be dewatered following Dewatering BMP, then filled in to conform with the contours of the area. The bulkhead and structures should be removed. Stabilized the area following the Seeding and Mulching or Sodding BMPs.

Maintenance

The property owner is responsible for the maintenance of any sediment basins constructed on their property. Maintenance should be done following any storm and should include:

1. Checking the depth of sediment deposit to ensure the capacity of the basin is adequate for stormwater and sediment deposition, and removing sediment when it has accumulated to no more than 50% of the design depth.

2. Checking the basin for piping, seepage, or other mechanical damage.

3. Checking for the presence of soil caking around the perforated riser pipe, which would prevent proper drainage from the basin.

4. Checking the outfall to ensure drainage is not causing erosive velocities, and to ensure the outlet is not clogged.

Any problems discovered during the maintenance checks should be addressed immediately.

Sediment removed during cleaning should be placed at an upland area and stabilized so that it does not re-enter the drainage course.

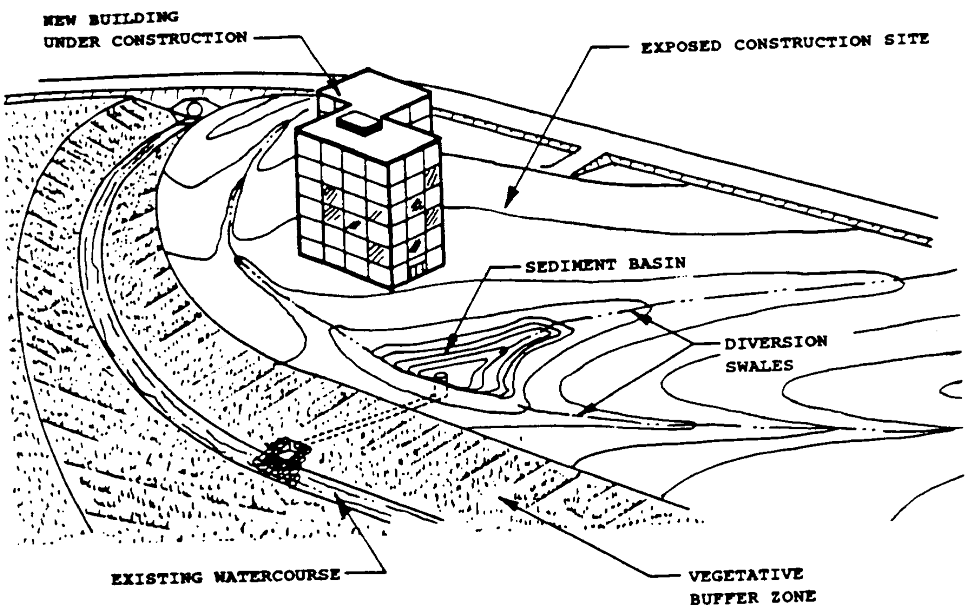
Exhibits

Exhibit 1: Use of Sediment Basins on Construction Sites. Top: Oakland County Soil Erosion Control Manual, Oakland County, Michigan. January 1, 1990. Bottom: "Sediment Basins" (brochure). Michigan Department of Natural Resources, Land and Water Management Division.

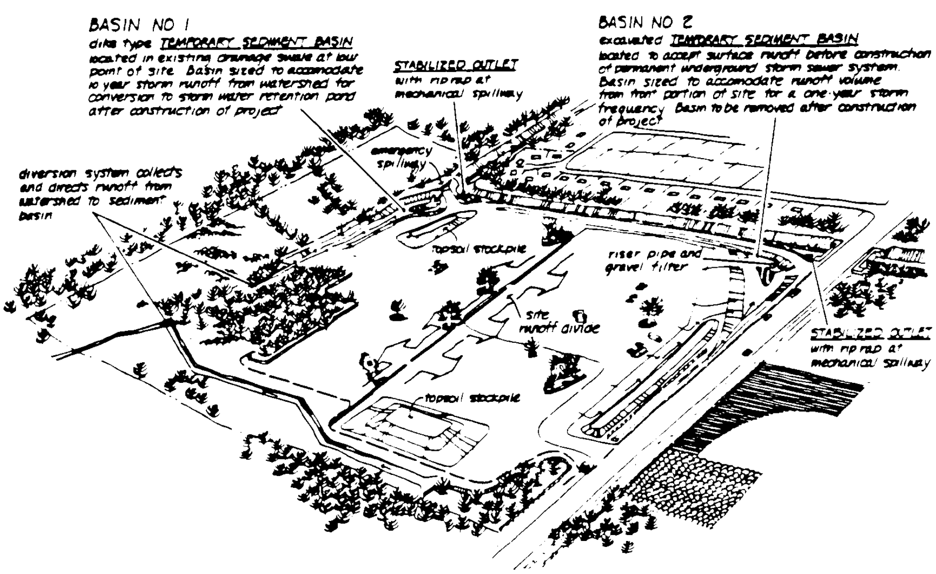
Exhibit 2: Side View of a Sediment Basin. "Sediment Basins" (brochure). Michigan Department of Natural Resources, Land and Water Management Division.

Exhibit 1

Use of Sediment Basins on Construction Sites



Source: Oakland County Erosion Control Manual. Oakland County, Michigan. 1990.

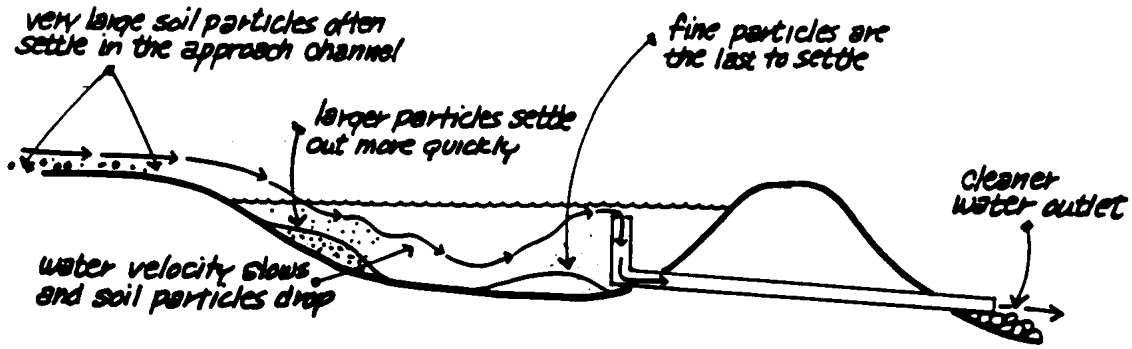


USE OF SEDIMENT BASINS ON CONSTRUCTION SITES
" to collect sediment from storm water runoff "

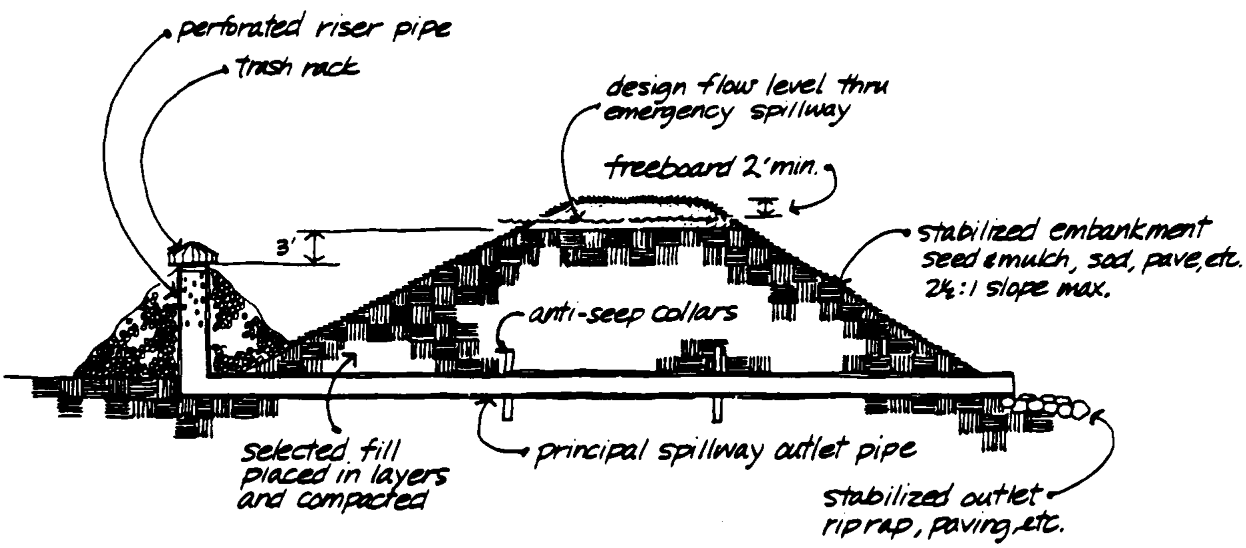
Source: Sediment Basins (brochure). Michigan Department of Natural Resources, Land and Water Management Division.

Exhibit 2

Side View of a Sediment Basin



HOW A SEDIMENT BASIN WORKS



SECTION THRU EMBANKMENT & BASIN CONTROLS

Source: Sediment Basin (brochure). Michigan Department of Natural Resources, Land and Water Management Division.

Watercourse Crossings

Descriptions

For the purpose of this BMP, structures which cross creeks, streams, ponds, or other surface areas of running or open water are defined as watercourse crossings. Watercourse crossings are typically used to provide a more confined, safer, and environmentally sensitive means for crossing from one side of a watercourse to the other.

Watercourse crossings may be either above or below the water surface. The type of crossing may vary with respect to length, width, height, and construction design, depending on the purpose of the crossing and the environmental and physical characteristics of the watercourse.

All watercourse crossings require a permit from the Michigan Department of Natural Resources and the local soil erosion enforcing agency, and some may require permits from the U.S. Army Corps of Engineers or the Michigan Department of Transportation (MDOT). Crossing a county or inter-county drain requires a permit from the drain commissioner or inter-county drain board, as well as the MDOT.

Other Terms Used to Describe

Bridges (Bridge Crossings)
Culverts (Culvert Crossings)
Stream Crossing
Temporary Crossing
Utility Crossing
Wetland Crossings are discussed in the Wetlands Crossing BMP

Pollutants Controlled and Impacts

Confining and consolidating watercourse crossings to less sensitive areas eliminates random crossings and allows greater protection of the water resource.

Application

Land Use
Transportation, recreation areas, golf courses.

Soil/Topography/Climate
Methods of installation and materials for the crossing will vary depending on the soils, topography, and climatic conditions during installation and throughout the expectant life of the crossing. Because the chemical and physical attributes of the soils may shorten the life expectancy of certain materials when they are placed underground or when the materials are periodically saturated, it is important to use soil tests or soil survey books or soil tests to determine the suitability of the soils for the structures being considered.

When to Apply
Watercourse crossings are used when there is a dependency for their use at a given location and when there are no other feasible and prudent alternatives to accessing the desired location without the use of a crossing.

Construction should be restricted to periods of low water levels when impacts to aquatic resources within the watercourse can be minimized. State permit conditions may restrict installation during time periods critical to various aquatic life (i.e. fish migrations, spawning, etc.).

Where to Apply
Apply in areas where there is a dependency for the crossing, where there are no other feasible and prudent alternatives, where impacts to the resources associated with the watercourse are minimal, and where adjacent wetland and watercourse resources would be adversely impacted if a bridge or culvert were not installed. See attached Exhibits for typical installation methods.

Relationship With Other BMPs

Construction of some watercourse crossings may require using a cofferdam and Dewatering to work "in the dry." The areas around bridges and culverts may need to be stabilized using Slope/Shoreline Stabilization structures.

The areas up-slope and adjacent to the crossings should be stabilized using Seeding, Sodding, Mulching, Critical Area Stabilization and other appropriate BMPs.

Specifications

Note: **All watercourse crossings should be designed by registered professional engineers.**

Planning Considerations for All Watercourse Crossings:

The following are general items to consider during the planning of any watercourse crossing. Specific items for each type of crossing follow.

1. Perform a site evaluation to determine where the crossing should be located. Site selection should consider:

   -Using areas which would provide minimal impact to wetlands, floodplains, floodways, sensitive areas, or protected species associated with the watercourse. Check the list of known occurrences of threatened and endangered species--available at MDNR, Wildlife Division.

   -Using areas where the potential for erosion of the disturbed land cover is minimal.

   -Using areas where clearing and disturbance of surrounding vegetative cover can be minimized.

-Avoiding areas where the watercourse bends.

-Avoiding stretches with the highest velocity.

2. Determine the type of structure needed. There are basically two types of structures--above-ground structures and below-ground structures. Above-ground structures include culverts and bridges. Below-ground structures include the pipelines and utilities.

3. Determine the soil textures at the selected site. The soil survey maps produced by the Soil Conservation Service include information on the suitability of each soil type for various types of structures. Make sure the soil type will support the structure you are proposing.

4. Design the structure, following the general guidelines below. The design of all watercourse crossings should be done by licensed professional engineers.

Permanent Below-Ground Crossings:
Utility crossings, cables and/or pipelines are all possible methods of below-ground crossings. The specifications listed directly below apply to below-ground crossings. See Exhibits 1-4

Planning Considerations for Below-Ground Crossings:

1. The MDNR prefers the use of drilling and boring utility lines over the plow-in and trenching methods. Drilling and boring reduces the likelihood of erosion, as well as disturbance of the banks and bottom substrates which typically occurs with both the plow-in and trenching methods.

2. Localize utility crossings to one location, and/or encase several utilities into one casing.

3. If a utility line cannot be bored or drilled under the watercourse, the plow-in method should be used, where possible. A "dry run" with the plow is usually done prior to attaching the cable or pipe to clear out any possible stumps, logs, or other obstructions.

4. If the open-trench method must be used, consider constructing a Sediment Basin downstream to collect sediment during construction.

5. Backfill all excavated substrates from a utility crossing with clean, washed fieldstone or clean, washed gravel.

Construction Considerations for Below-Ground Crossings:
The construction of underground utilities should be done in one operation to minimize the impacts on the environment. To do this, follow the guidelines below and refer to Exhibits 1-4.

1. Bring both sides of the utility within 10 feet of the crossing on either side. The ten-foot unexcavated area should remain as such until both sides are within 10 feet and until the rest of the crossing process occurs.

2. When using the trenching method, install a temporary Sediment Basin downstream to collect sediment from the project area, or follow the procedures in Exhibit 3 to construct a flume so that work can be done "in the dry."

3. For the trenching method, dig out the remainder of the fill area to excavate the trench.

   Note that the depth to which the utility pipe should be laid is dependent upon the waterbody which is being crossed. For example, on county and inter-county drains, you may be required to maintain 3 to 5 feet below the last established bottom elevation, depending on the requirements of the drain commissioner or the inter-county drain board. A minimum of 3 feet of cover should be maintained at all locations.

4. Backfill, as needed, with washed stone or gravel, according to the design. You may use the original material if it is not erodible.

5. Upon completion of the project, Sediment Basins should be filled and stabilized or converted into a stormwater basin. Follow specifications in the Sediment Basin BMP.

6. Stabilize the up-slope area with vegetation following the Seeding and Mulching or Sodding BMPs. Consider using Diversions to divert runoff from the project area.

Permanent Above-Ground Crossings:
Culverts and bridges are the two primary means of crossing a watercourse above-ground. The Department of Natural Resources recommends the following structures, in order of preference.

1. Clear span bridge
2. Multi-span bridge
3. Single box, arch or pipe culvert
4. Multiple box, arch or pipe culvert

Clear-span bridges are preferred for crossing a watercourse over other methods because they can provide adequate hydraulic capacity without restricting normal or above normal flows within a watercourse. Other types of structures, including multi-span bridges and culverts, tend to restrict or obstruct the normal flow of a watercourse via their related fill materials or support pilings, by reducing the area in which the watercourse normally would flow. These restrictions typically lead to increased erosion both upstream and downstream of the structures, collection of debris on these structures, and possible navigational hazards. These structures also cover up and reduce the amount of natural bottom substrate available as habitat.

Above-ground crossings can be made of timber, concrete or metal. In areas designated as Natural Rivers the applicant may be required to soften the aesthetic impact of the material used. See the Appendices for the list of Natural Rivers in Michigan.

Note on Wood Preservatives: There are three classes of common timber treatment: creosote, pentachlorophenol, and inorganic arsenicals. These "preservatives" are restricted use pesticides. Lumber treated with these products is allowable for use in direct incidental contact with surface water uses as drinking water supplies.

The Department does not recommend the use of creosote and pentachlorophenol due to the leachability, persistence, bioaccumulation and hazards of their constituents. The Department supports the use of inorganic arsenicals for use in watercourse crossings.

General Considerations for All Above-Ground Crossings:

1. A flood flow analysis should be done for all types of above-ground crossings and are required under Act 167 for drainage areas greater than 2 square miles.

2. Consider using existing (old) crossings and existing (old) grades instead of creating new crossings.

3. Roadway approach fills should be minimized in temporary crossings and must be removed after use.

4. Consider installing devices along the roadway itself to control runoff from the roadway. These devices can include Grade Stabilization Structures and water turnouts, both of which are discussed under "Bridges: Design," below.

5. Adequate vegetative cover must be established on all disturbed areas upon completion of finish grading.

Bridges:

Planning Considerations for Bridges:

1. Obtain hydraulic clearances from the Land and Water Management Division.

   -Locate the structure at the narrowest point in the floodplain/wetland.

   -Indicate any alterations or reconstruction that is needed in the channel to accommodate the proposed structure.

   -For bridges which will be used as part of a roadway, indicate how stormwater runoff from the roadway will be managed to prevent erosive velocities. Alternatives are discussed below in number 6.

2. A cofferdam may be used to create a dry work site, or water may be flumed or pumped around the work site. Follow specifications in the Dewatering BMP.

3. Consider installing a sediment trap downstream of the road crossing if filter fences, floatation curtains, cofferdams and other practices won't be able to keep soil from moving downstream. These are temporary in-stream basins which will only be used to trap excess sediment from this particular project. Once the project is completed, the sediment basin will be removed and the channel bottom restored. You will need a permit from the MDNR, Land and Water Management Division for any in-stream sediment basin.

4. Disruption of the natural vegetation should be kept to a minimum.

5. Avoid the use of pentachlorophenol-treated wood in timber bridges. Use inorganic arsenicals.

Design Considerations:

1. Bridge crossings (including bridges and roadways) must be designed to pass the 100-year flood flow without causing a harmful interference, as determined by the MDNR, Land and Water Management Division.

2. Bridge abutments should be parallel to the direction of flow. Exceptions may occur during the engineering review as a result of flood flow direction.

3. The bridge should span the entire width of the stream, leaving the stream bed beneath the structure undisturbed. The vertical clearance should not obstruct wading, boating, or other types of free passage.

4. If cofferdams are used, locate them to isolate the construction work site from the stream flow. Alternatives include:

    -Constructing a temporary run around the channel
    -Pumping water around the site to provide a dry work site

    Follow proper Dewatering operations.

5. Riprap should be installed beneath bridges on all fill slopes or exposed banks. Follow specifications in the Riprap BMP.

6. Stormwater runoff from roadways should be directed away from the crossing using one of the methods below:

    a. Water turnouts. These are small chutes or depressions constructed on roadways to direct water to stabilized outlets. The stabilized outlets can consist of sod, or with higher velocities, rock or concrete. In sandy soils, excavations alongside the road may be adequate to retain water and allow it to percolate to the groundwater without running directly into the watercourse.

    b. Grade Stabilization Structures, which include down drains, pipe drop structures and chutes, can be used to take water from one elevation to the next, either above-ground or underground. GSSs can be used along roadways to take the water from the road to the watercourse, or to a stabilized area.

    c. Curb and gutter should only be used where it is absolutely necessary. The areas adjacent to the curb and gutter should be stabilized with seed or sod, and the outlets from the gutters should not be such that they cause erosive velocities.

    d. Concentrated runoff can be directed to a detention or retention basin and either released slowly to the watercourse or allowed to infiltrate the soil. Refer to one of the detention/retention BMPs for more guidance.

7. Provide stabilization of bridge abutments and all fill slopes using Riprap and other Critical Area Stabilization practices.

Construction Considerations:
The construction of a bridge should be done with the least amount of impact on the natural resources. To do this, the operation must be done in steps which will decrease the amount of water crossings that occur. Follow the guidelines below and refer to Exhibits 5-8 for permanent structures. See the section on "Temporary Above-Ground Crossings" for information on using bridges, culverts and other materials for temporary crossings.

1. Where depth allows, place filter fences in the water adjacent to the bridge abutment which will be removed first. If filter fences will not work in water because of water depth, consider using floatation curtains. These are suspended in the water and help settle out larger particles so that they are not carried downstream. Filter fences and floatation curtains are both discussed in the Filters BMP.

2. If flows or banks are such that filter fences cannot be used, consider using cofferdams alongside the channel.

3. Where applicable, install the approved sediment trap.

4. Where applicable, remove the first bridge abutment and replace with a new one.

5. Stabilize the first side with vegetation and riprap following the Riprap and Critical Area Stabilization BMPs.

6. Install riprap alongside the new abutment and on either side of the new abutment. Follow specifications in the Riprap BMP to determine the size stone needed, the filter required, and the installation procedures for riprap.

7. Place filter fences and/or floatation curtains on the opposite site and repeat the sequence above for the second side.

8. Complete the rest of the bridge using as few crossings with equipment as possible.

9. Clean out the sediment trap upon completion. Restore the natural channel bottom.

10. During construction, keep loose boards, nails and other debris on-site and in a way which will not result in them entering the waterway. Wash buckets, wheel barrows and shovels upland away from the water course.

Culverts:
Culverts may be permitted by the MDNR, drain commissioner or drain board where there is a shown dependency for the crossing, where the installation of a bridge is not a feasible and prudent alternative, and where aquatic impacts are minimal. The MDNR, Land and Water Management Division must be contacted regarding any culvert construction, repair, etc.

Planning Considerations:

1. Obtain hydraulic clearances from the MDNR, Land and Water Management Division.

2. The structure should be located at the narrowest point of the floodplain/wetland.

3. If the proposed crossing will require reconstructing or relocating the stream, you must contact the MDNR, Land and Water Management Division to obtain the necessary permit.

4. A cofferdam may be used to create a dry work site, or water may be flumed or pumped around the work site. Follow specifications in the Dewatering BMP.

5. A sediment trap may be required for installation downstream of the crossing prior to any other construction work. These are in-stream temporary basins which will only be used to trap excess sediment from this particular project. Once the project is completed, the sediment basin will be removed and the channel bottom restored. You will need a permit from the MDNR, Land and Water Management Division for any in-stream sediment basin.

6. Disruption of the natural vegetation must be kept to a minimum.

7. Consideration should be given to the amount of development occurring in the upstream reaches so that culverts can be sized to account for potential increases in flow.

Design Considerations:

1. Culverts and weir flow over the road must be designed to pass the 100-year flow of a watercourse with no harmful interferences, as determined by the MDNR, Land and Water Management Division.

2. The bottoms of these structures must be recessed to a depth based on the natural downcutting rate of the stream over the expected lifespan of the structure, or at least 12 inches below the existing streambed, if no data is available to support a deeper recess.

3. The diameter of the culvert should approximate the width of the watercourse. Stream width should not be changed.

4. The culvert should be installed so that it maintains the existing stream gradient.

5. The culvert must provide for proper road width and side slopes.

6. The culvert should not obstruct navigation if the watercourse is deemed navigable.

7. The use of multiple culverts is discouraged. If multiple culverts are needed then the design should be changed to a bridge.

Construction Considerations:

1. When depth allows, place filter fences in the water adjacent to the area in which the culvert will be placed or replaced. If filter fences will not work because of water depth, consider using floatation curtains. These are suspended in the water and help settle out larger particles so that they are not carried downstream. Filter fences and floatation curtains are

both discussed in the Filters BMP.

2. If flows or banks are such that filter fences cannot be used, consider using cofferdams along the channel.

3. Where approved, install an in-stream sediment trap downstream of the road crossing.

4. Remove the old culvert and install the new one. The new culvert should line up with the watercourse at both the inlet and outlet ends. Recess the culvert at least 12 inches into the bottom of the watercourse, or to the anticipated scour depth of the natural channel.

5. Backfill on either side of the culvert. Compact following the design.

6. Install riprap on all fill in contact with the watercourse, and a minimum of two rows on either side, or at least three feet above the ordinary high water mark. Follow specifications in the Riprap BMP to determine the size stone needed, the filter required, and the installation procedures for riprap.

7. Stabilize the area up-slope of the culvert with vegetation, following the Critical Area Stabilization BMP.

8. Clean out the in-stream sediment trap upon completion. Restore the natural channel bottom.

Temporary Above-Ground Crossings:
Temporary above-ground crossings are utilized to provide access for larger equipment for construction purposes, forestry operations and similar uses. These structures are removed upon completion of the needed work and the crossing is restored to its original condition. All temporary crossings require a permit from the MDNR.

Exhibits 9-11 include examples of three different types of temporary roads.

Additional Considerations

Safety:
All structures should be free of protruding objects and sharp edges. Guard and hand rails should be installed, where appropriate. (See the Michigan Department of Transportation/OSHA Construction and Safety Manual).

Inadequately sized culverts have the potential to create strong suction at their upstream ends during peak flows, thus creating public safety hazards and liability concerns. They may also cause upstream flooding, as well as excessive velocities at the outlet.

Maintenance

Maintenance of **culverts** should include inspections to determine if:

-piping has occurred around the culvert. Note any erosion adjacent to the culvert

-the culvert has collapsed or is otherwise inoperable
-the culvert is clogged or otherwise obstructed

These and any other problems should be addressed immediately. Failure of a culvert can severely impact surface waters and/or threaten the safety of people and structures downstream. Replace collapsed culverts. Stabilize eroded areas using vegetative BMPs. Do *not* dump new sediment and leave exposed soil. Remove debris which is clogging culverts.

Bridge maintenance should include checking the structural integrity of the structure and making sure the banks on either side are stabilized. Stabilize all exposed soils.

Exhibits

Exhibit 1: Stream Crossing--Pipelines/Cables. MDNR, Land and Water Management Division, Bridge/Culvert Program.

Exhibit 2: Stream Crossing--Pipeline, Detail SC-1. Same as Exhibit 1.

Exhibit 3: Stream Crossing--Flume Construction, Detail SC-3. Same as Exhibit 1.

Exhibit 4: Stream Crossings--Pipelines/Cables, Detail SC-4. MDNR, Land and Water Management Division, Construction Project Evaluation Manual.

Exhibit 5: Bridges--Typical Bridge Placement, Detail B-1. Same as Exhibit 4.

Exhibit 6: Bridges--Typical Rip-Rap Section, Detail B-2. Same as Exhibit 4.

Exhibit 7: Culverts--Typical Culvert Sections and Placement, Details C-1 and C-2. Same as Exhibit 4.

Exhibit 8: Streambank Stabilization--Permanent Rip-Rap, Detail SBS-2. Same as Exhibit 1.

Exhibit 9: Stream Crossing--Temporary Haul Road, Detail SC-2. Same as Exhibit 1.

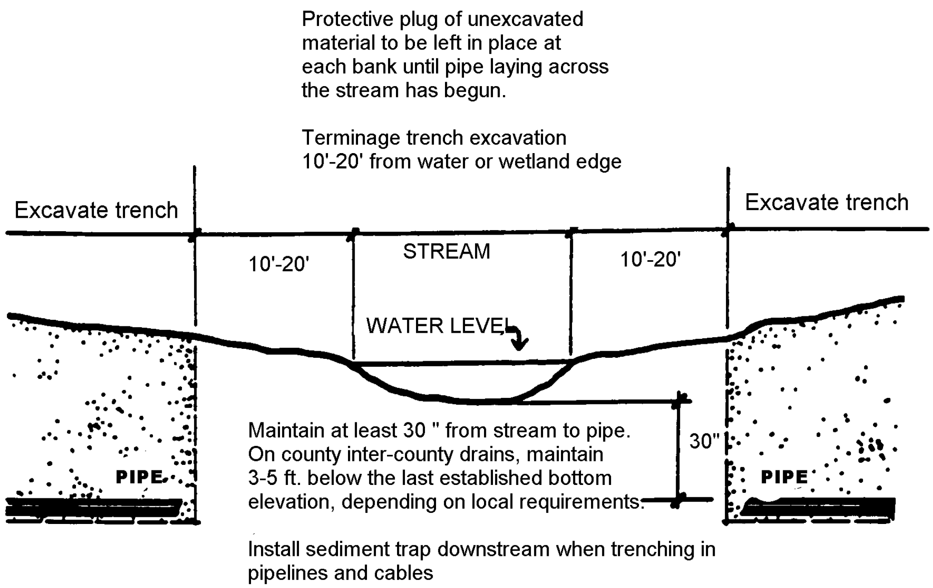
Exhibit 10: Temporary Stream Crossing--Culvert, Detail TSC-1. Same as Exhibit 4.

Exhibit 11: Temporary Stream Crossing--Preferred and Unacceptable, Detail TSC-2. Same as Exhibit 4.

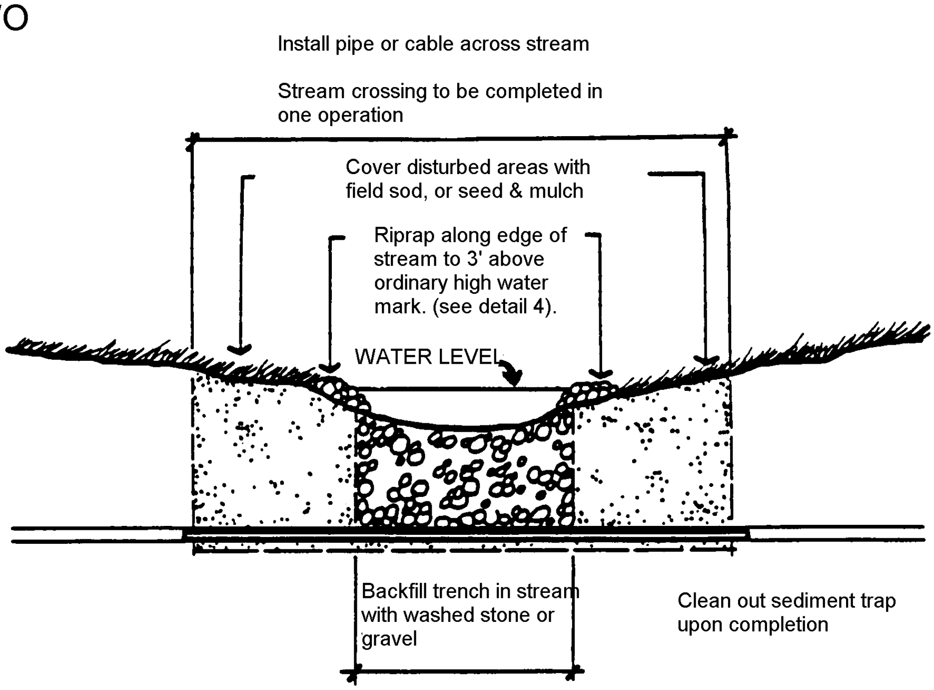
Exhibit 1

Stream Crossing (Pipelines/Cable)

STEP ONE



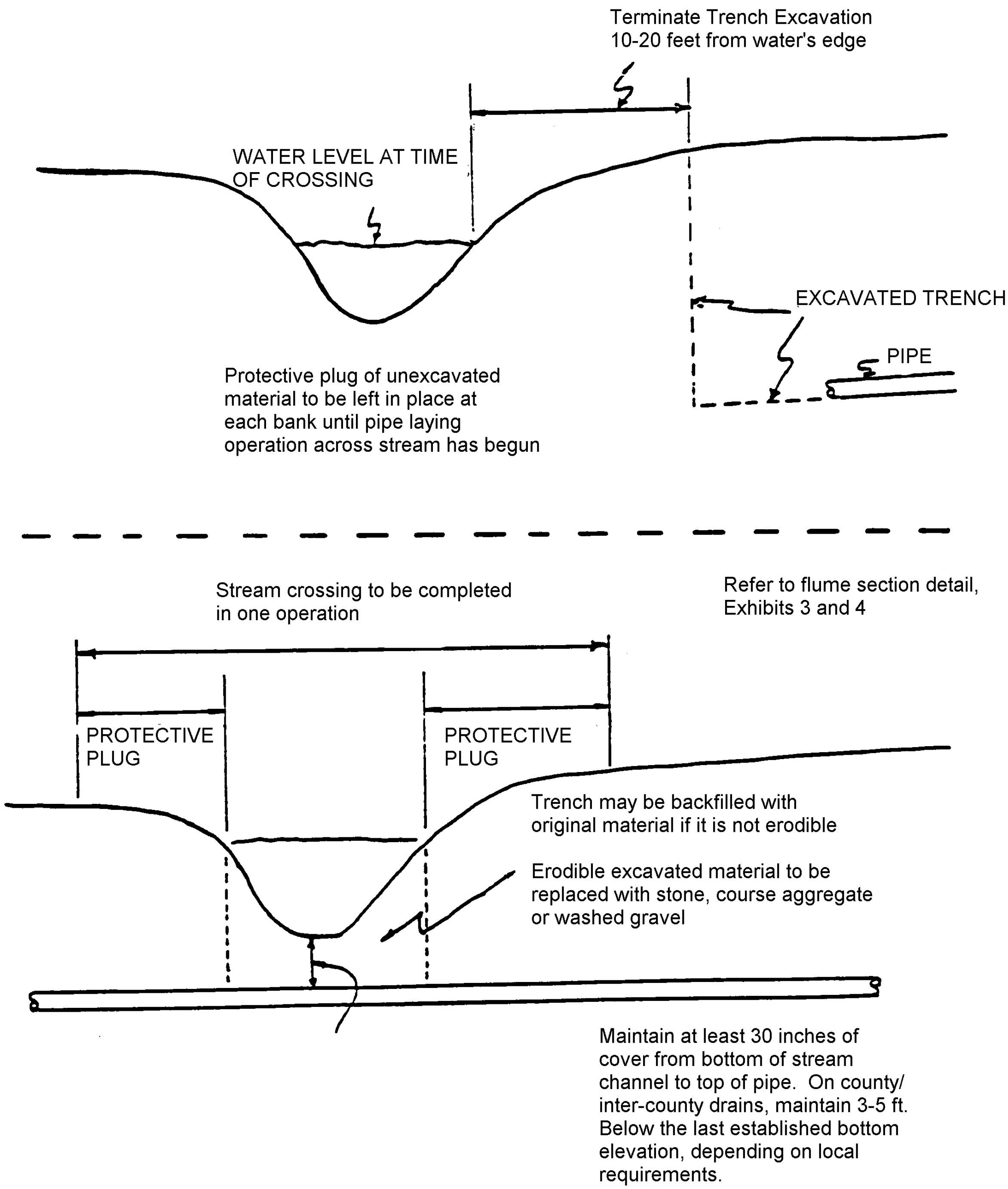
STEP TWO



Source: Modified from Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

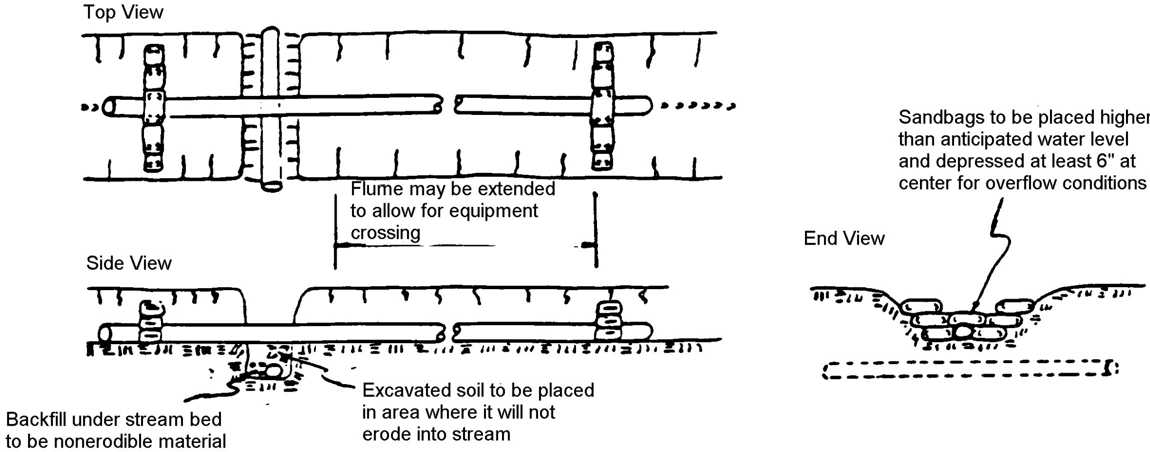
Exhibit 2

Stream Crossing
Pipelines



Source: Modified from Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

Exhibit 3
Stream Crossing
Flume Construction



Notes: Contractor to notify department when crossing will be made. Notify drain commissioner if working in a county or inter-county drain.

Only sandbags will be used for damming unless other materials are approved by the department.

Sandbags to be filled no more than 75% capacity of the bag to allow effective stacking and molding of bags around flume.

Sediment control practices downstream of flume may be required subject to extent of stream disturbance caused by construction.

Sequence of Construction:

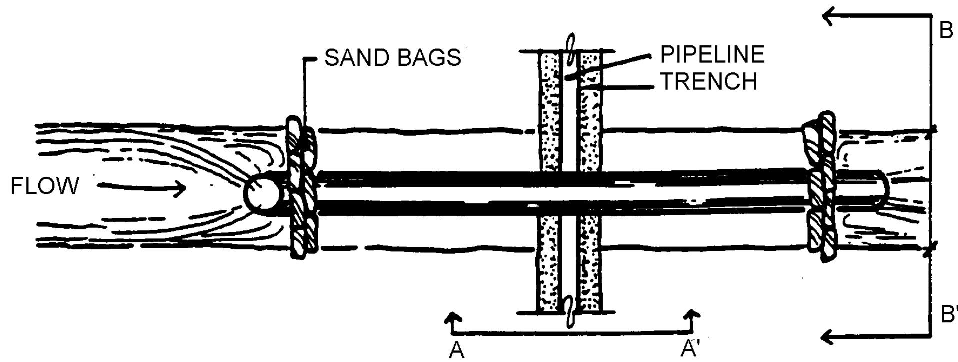
1. Lay flume along bottom of stream.
2. Place sandbags at upper end of flume and then at lower end of flume to lower water level.
3. Dewater crossing at discretion of contractor. Discharge water following <u>Dewatering</u> specifications.
4. Begin trenching and placement of pipe.

Sequence of Stabilization:

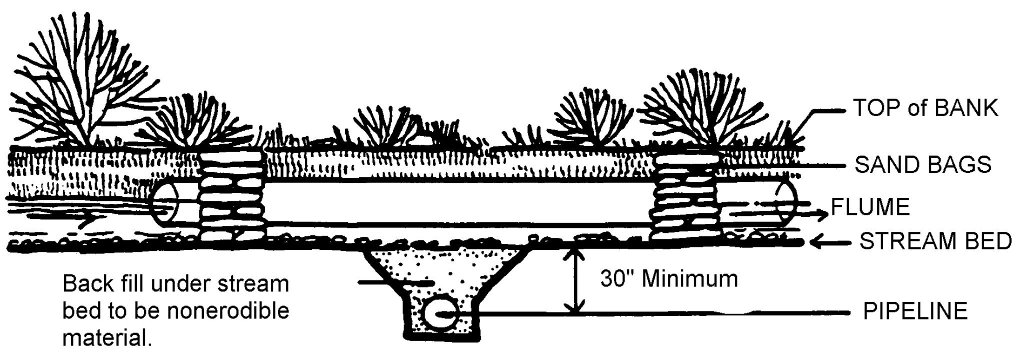
1. Backfill trench under stream bed with nonerodible material.
2. Stabilize disturbed stream banks and bed.
3. Remove sandbags. Dispose of in upland site.
4. Remove flume without disturbing bottom of stream.

Source: Modified from Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

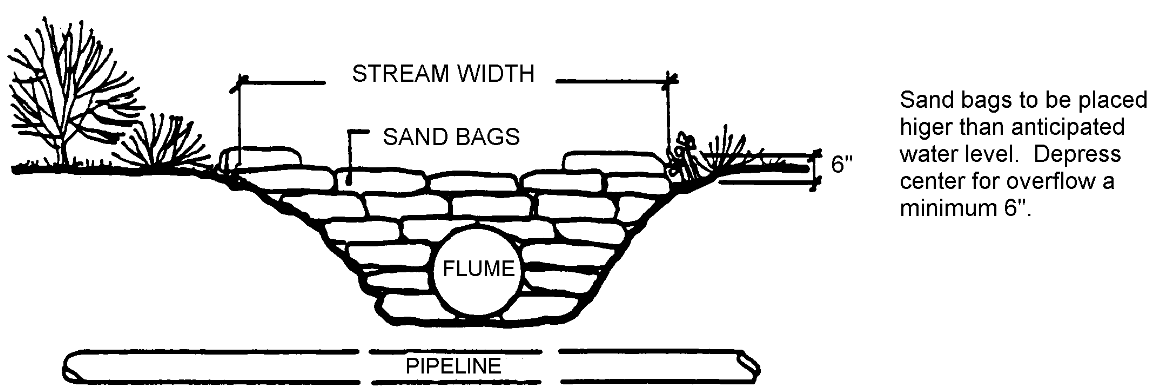
Exhibit 4
Stream Crossings (Pipelines/Cable)



FLUME PLAN VIEW



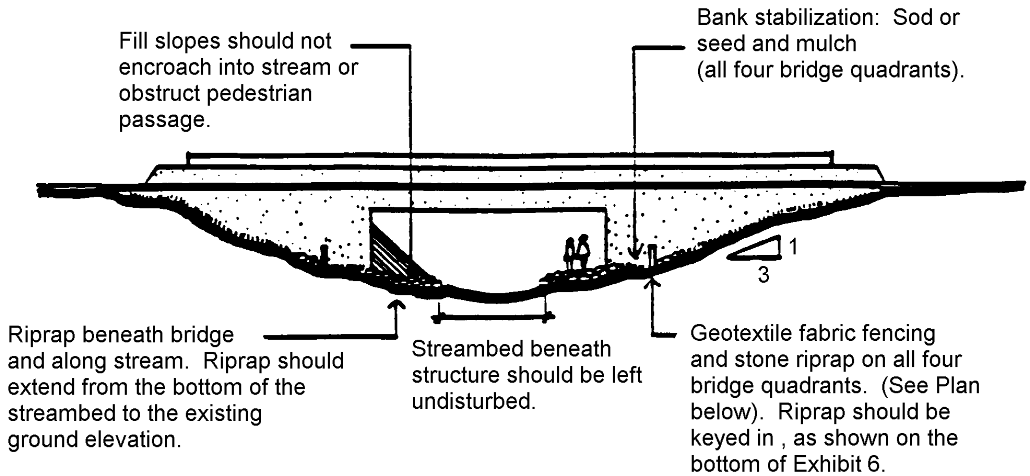
FLUME SECTION A-A'



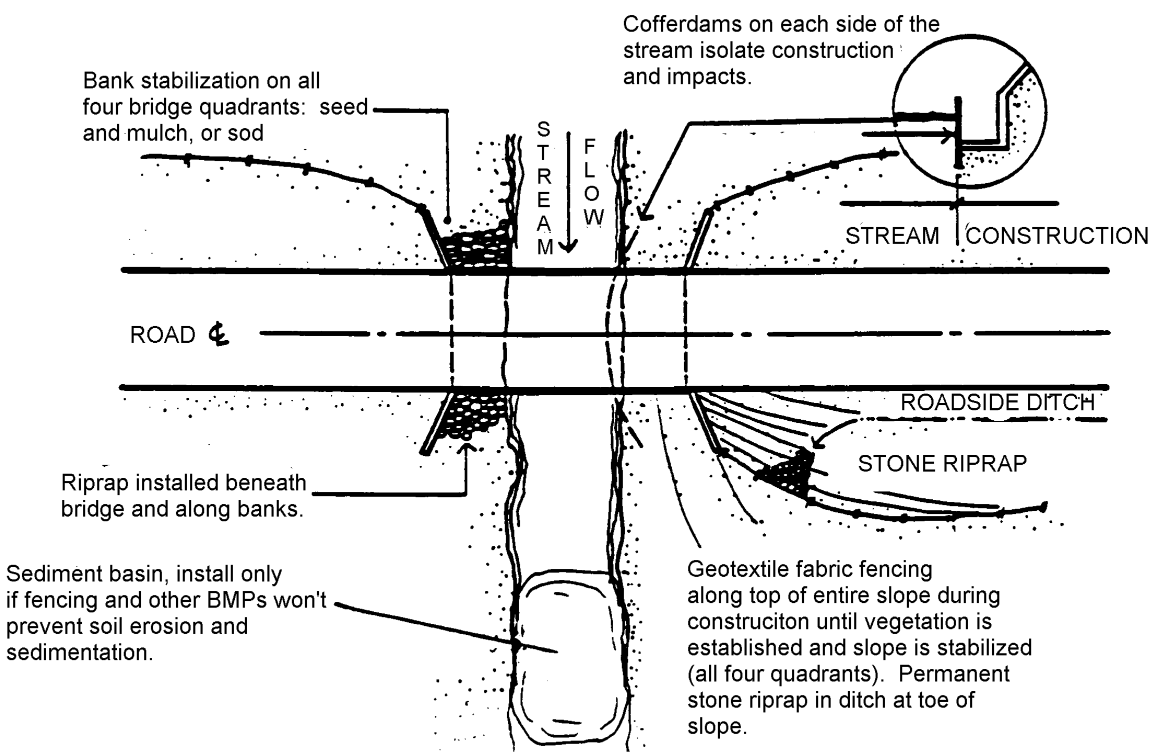
FLUME SECTION B-B'

Source: Modified from Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

Exhibit 5
Bridges

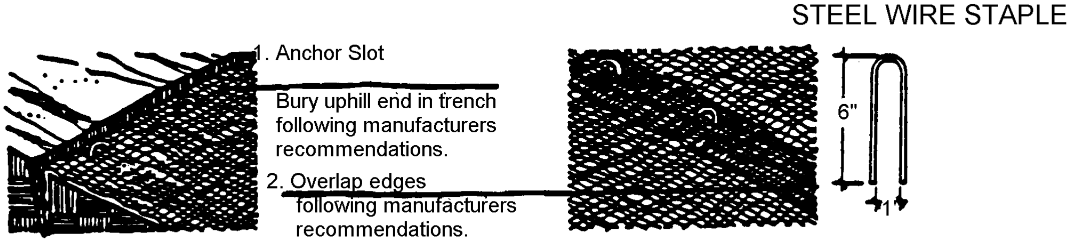


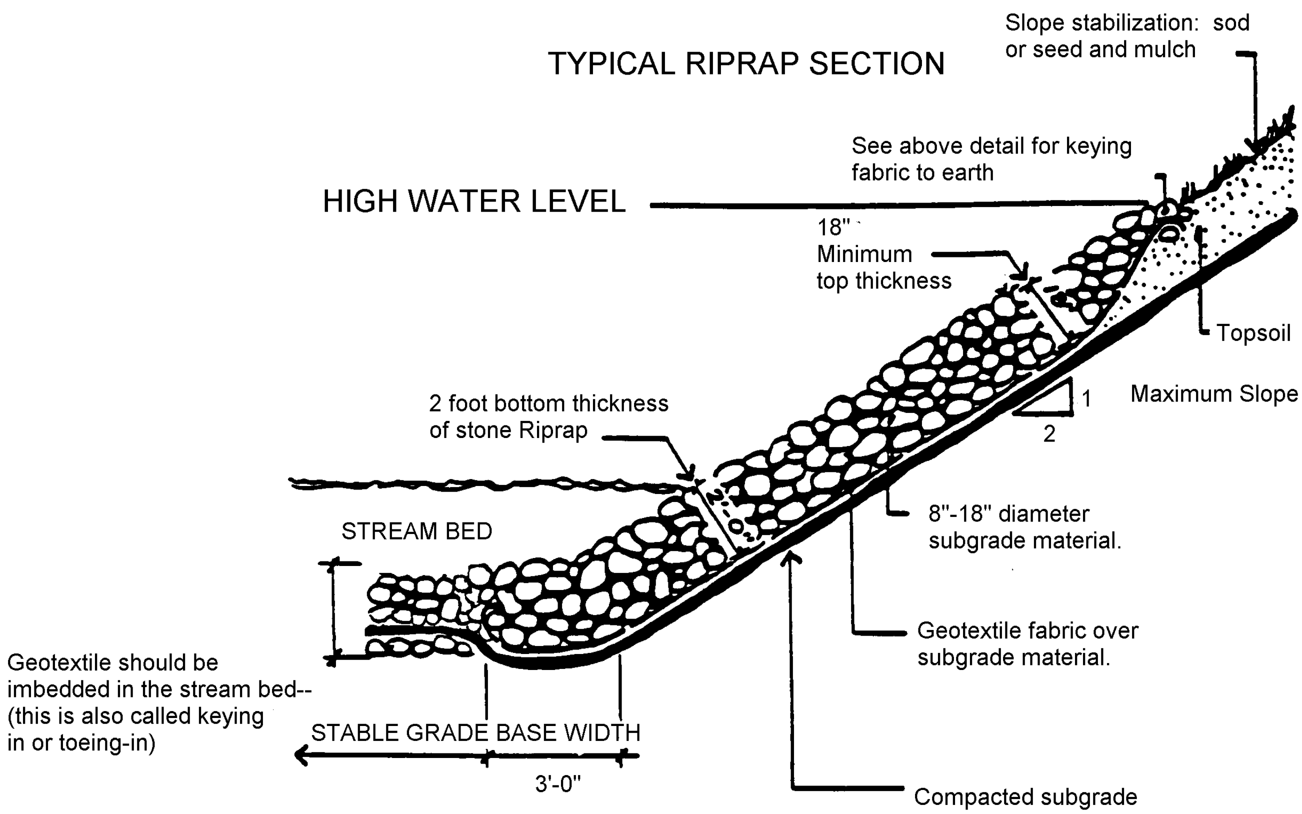
TYPICAL BRIDGE PLACEMENT



Source: Modified from Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

Exhibit 6
"Keying In" Filter Fabric



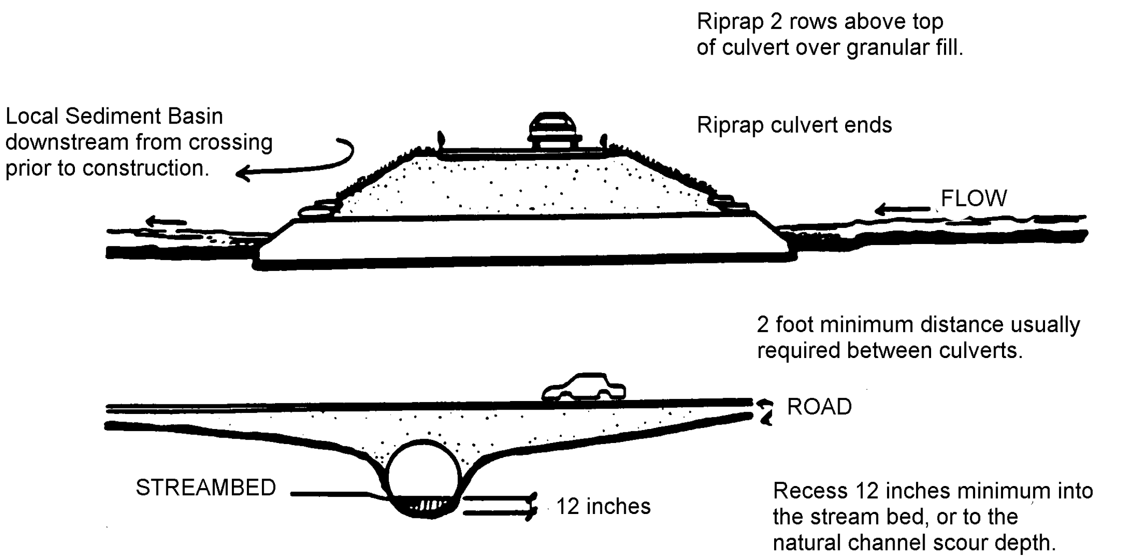


Source: Modified from Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

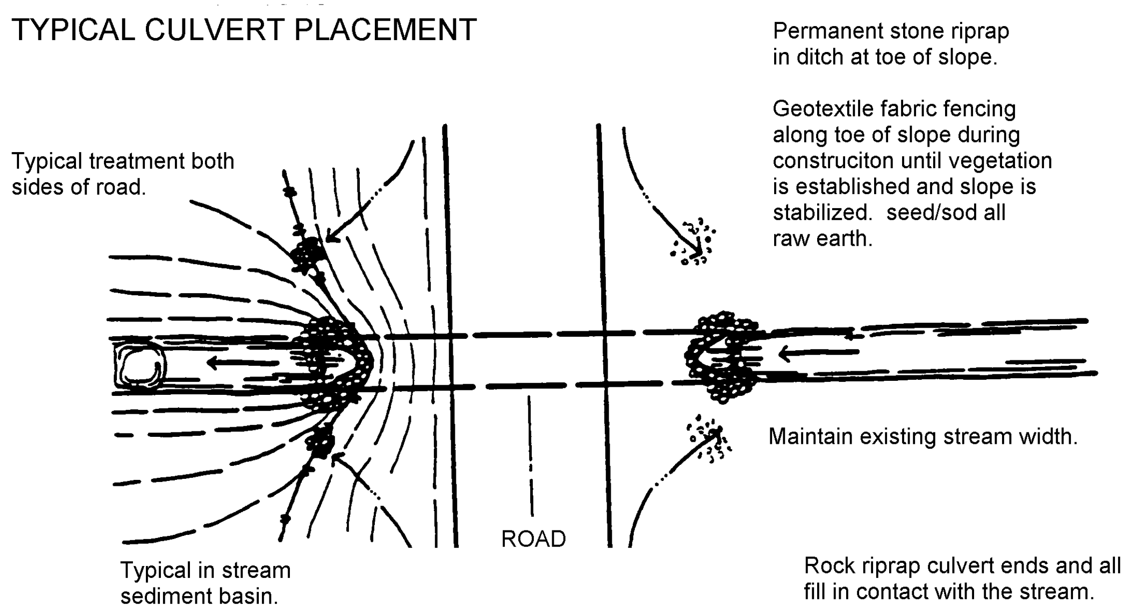
Exhibit 7

Culverts

Culvert length should allow for proper road width and shoulders, and gradual side slopes, 2:1 (horizontal: vertical) maximum.



TYPICAL CULVERT PLACEMENT



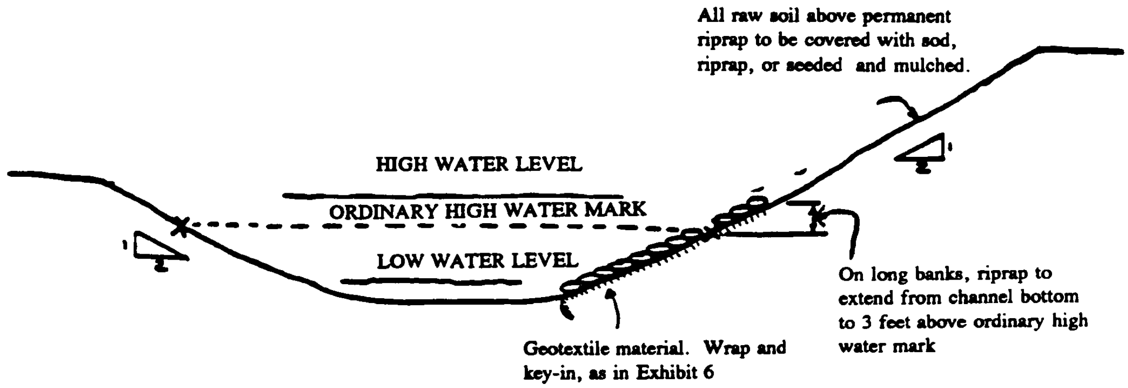
TYPICAL CULVERT PLACEMENT

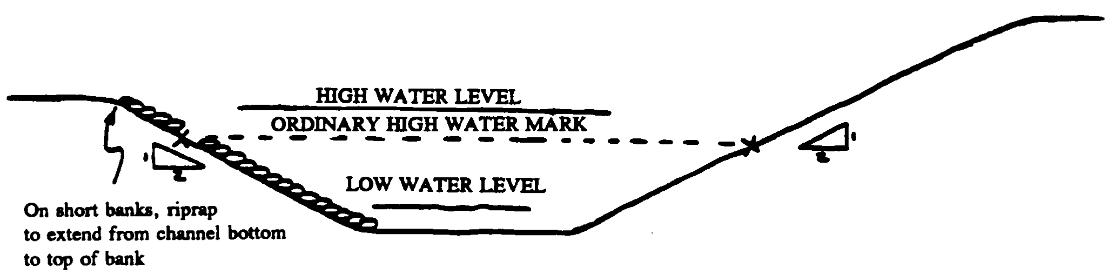
Source: Modified from Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

Exhibit 8

Streambank Stabilization:

Permanent Riprap





Notes: Stream banks shall not be left unprotected for any period of time. Temporary or permanent protection must be applied immediately.

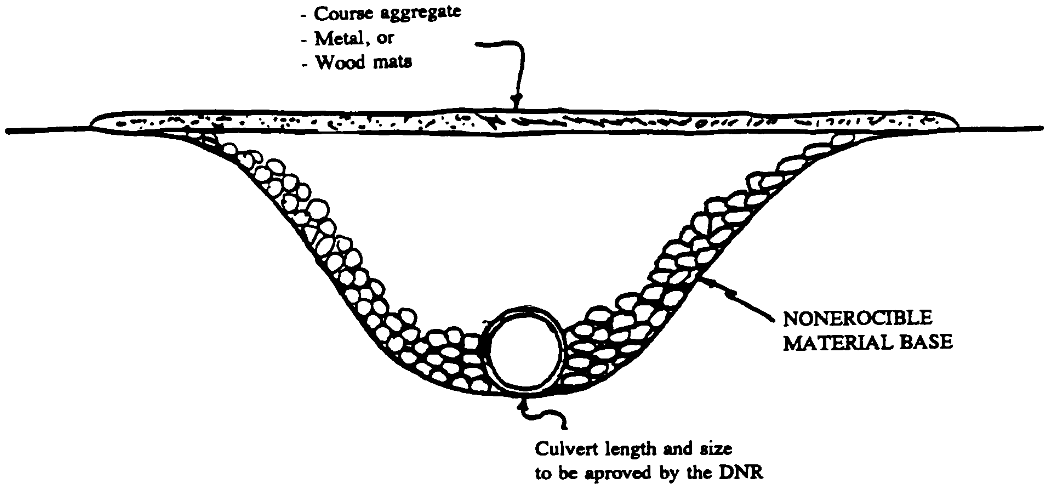
Riprap following Riprap specifications

Source: Modified from Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

Exhibit 9

Temporary Haul Roads

Running surface materials should be placed on the surface, to a depth of 1 foot. The material should be capable of sustaining the anticipated load. Use:



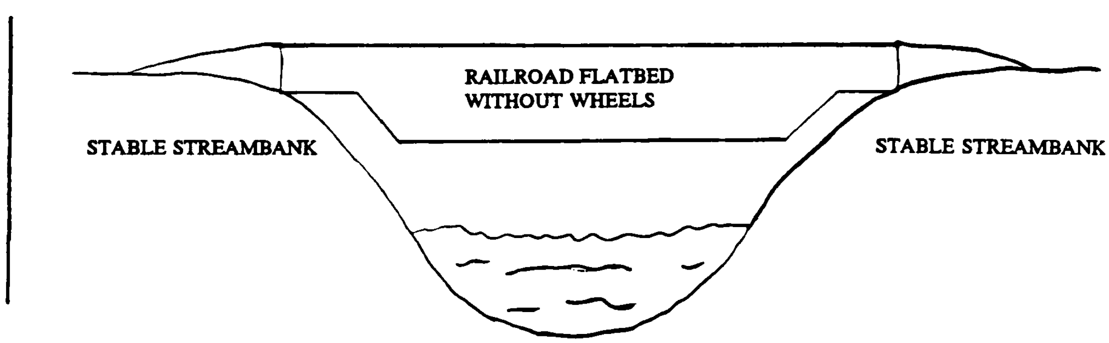
* Streambanks are to be left in a stable condition when temporary structures are removed.

* Construction and removal of temporary haul road may require sediment control measures downstream.

Other possible temporary crossings which may be used upon approval include:

* Crossings constructed with a culvert with snow packed around it. In the spring when the snow melts, the culvert is removed.

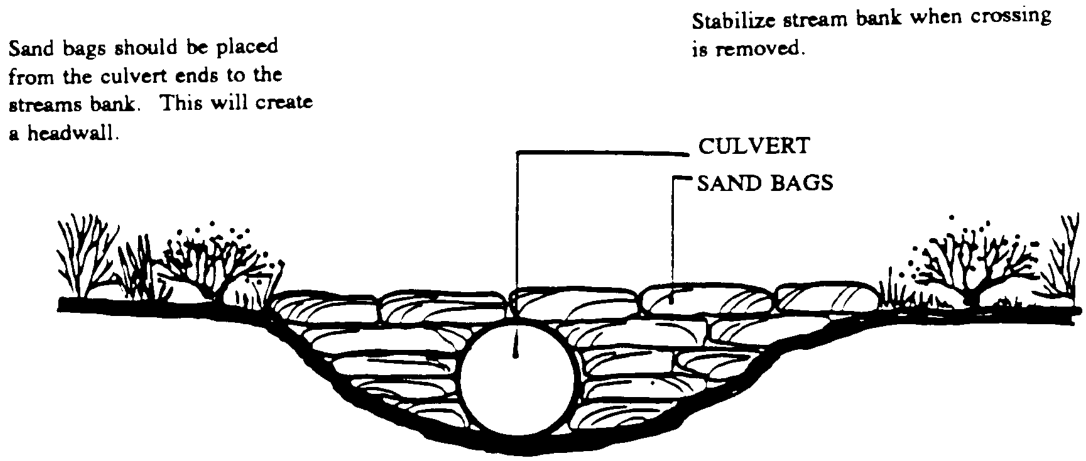
* Crossings constructed of a flatbed railroad with its wheels removed. This structure can be moved easily on logging trucks, etc.



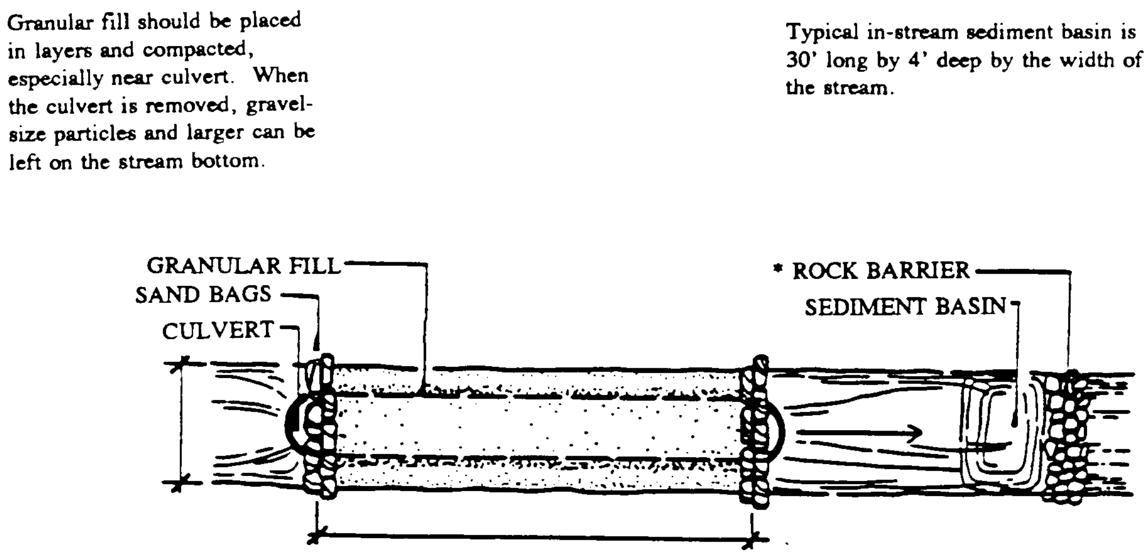
Source: Modified from Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

Exhibit 10

Temporary Stream Crossing



SECTION VIEW at Culvert End



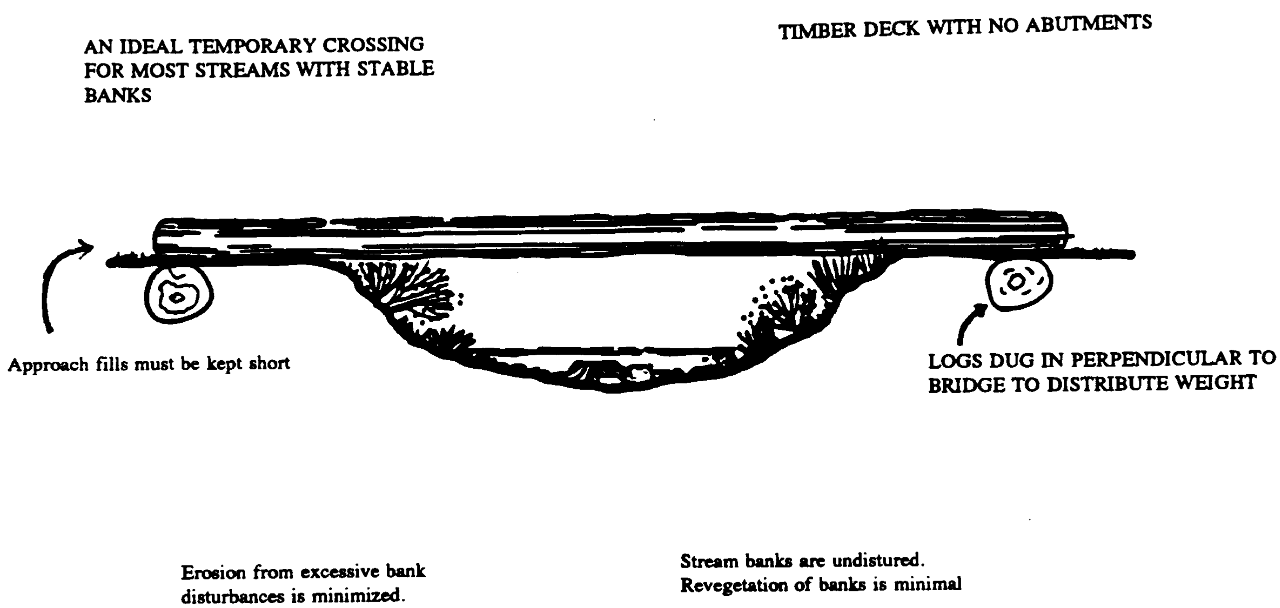
PLAN VIEW

*The rock barrier should be designed following specifications in the Check Dam BMP.

Source: Modified from Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

Exhibit 11

Temporary Stream Crossing



Source: Modified from Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

VEGETATIVE ESTABLISHMENTS BMPs

Mulching

Definition

Mulching is the process of placing a uniform layer of straw, wood fiber, wood chips or other acceptable materials over a seeded area to allow immediate protection of the seed bed. Mulch offers a moist, shaded growing zone which reduces plant burn-off. The proper and timely application of mulch can save entire seeded areas and minimize the amount of raw soil exposed to the elements. This BMP includes the use of erosion control blankets.

Mulch is also used for temporary stabilization of exposed soils which have not been seeded.

Pollutants Controlled and Impacts

Mulching done as a part of vegetative establishment will help keep soil particles and their associated attached chemicals (including phosphorus and pesticides) from entering surface waters. Mulch will also help suppress weed growth, provide a moist area for vegetative growth, reduce evaporation, and prevent crusting and sealing of the soil surface.

Application

Land Use
This BMP applies to any and all areas made bare of vegetation, either by human-induced or natural forces.

Soil/Topography/Climate
Although this practice should be used on all seeded areas, it is especially important on sloping or hilly terrain, and on wind-erodible soils.

When to Apply
Mulch should be applied immediately after each small segment of the area is seeded. Mulch may also be placed as temporary erosion control on exposed areas, and is especially important on exposed areas adjacent to streams and wetlands. Anchoring of the mulch should be done immediately after the mulch is applied.

Where to Apply
Mulch is necessary:

- on new seedings used to stabilize raw areas, especially slopes, droughty sands, and clayey soils

- on unseeded raw areas which need temporary protection from wind or rain

- on any other areas subject to erosion

Relationship With Other BMPs

To ensure an area has a strong vegetative cover, mulching should be done in conjunction with proper Seeding, Soil Management, Fertilizer Management and Grading Practices.
Concentrated flows should be directed away from mulched areas following specifications in the Diversions BMP.

Specifications

Mulch should be applied immediately after seeding has occurred.

Planning Considerations:

1. All seeded areas (see Seeding BMP) should be mulched using one of the mulching techniques below. Hydroseeding is discussed in the Seeding BMP.

2. Organic mulches are more effective and less likely to impact the environment than manufactured mulches, and are therefore recommended for most uses.

3. Choose from the following types of mulch. Application rates are given for each type of mulch.

   Straw. Straw is the most commonly used type of mulch, is readily available in most areas, and is effective when applied properly. Use small grain straw (wheat or oat) that is reasonably free of grain and weed seeds or mold. Straw of winter rye is preferable to spring-seeded grains, since fewer weed seeds generally are present. On critically eroding areas, spread uniformly at the rate of 2.5 to 3 tons per acre (2-3 bales per 1,000 square feet). Under normal applications, use 1.5 to 2 tons per acre. Hay should only be used if straw is not available.

   Straw rates for hydroseeding operations should be 2 tons/acre for most applications, and 3 tons/acre for dormant seeding.

   Straw Mulch Blankets. Straw mulch blankets should be made of a uniform layer of straw and should have a net covering on only one side. The straw and net should be securely stitched together to create a uniform mat. The straw should be clean wheat straw free of weeds and weed seeds. All components, including the stitching, should break down within the first growing season after placement.

   Excelsior Blankets. Excelsior blankets are made up of coarse wood fibers reinforced by netting. They are most commonly used in drainageways and other critical areas which will be exposed to concentrated flows during storms. The excelsior should consist of evenly distributed wood fibers. The top of the blanket should be covered with netting.

   Blankets should be applied with the netting side of the blanket on the top side (i.e. exposed). Lay the downstream or down-slope blankets first, working upstream or up-slope. Follow manufacturer's specifications.

   Where more than one width is required, and on ends, provide a minimum 4-inch overlap (or more based on the manufacturer's recommendations). Blankets should be secured with U-shaped wire staples of a size and length suited to the soil condition. Follow the manufacturer's specifications. Apply fertilizer and seed before the blankets are laid.

Wood Chips. Wood chips are suitable for areas which will not be mowed, and around landscaped areas. Wood chips should not be used in areas which are drained by storm sewers, areas subject to flooding, or any other place where they would cause problems if they floated away.

Wood chips do not require anchoring, but need to be applied evenly to be effective as an erosion control measure. Ten or more tons of wood chips per acre should be applied. (The average weight per cubic yard is about 400 pounds. Thus, about 5 cubic yards equals 1 ton.) Several sources recommend applying nitrogen (N) when wood chips are used, in order to have N available for plant growth. If grass doesn't grow without N applications, apply 10-12 lbs. of N per ton of mulch.

Bark Chips and Shredded Bark. Bark chips and shredded bark are bi-products of timber processing and are often used in landscaping. They may also serve as mulch for areas planted to grasses which are not mowed, and on slopes which are not steep. Apply with a blower. Bark chips and shredded bark do not require nitrogen applications, and are less likely to leave the site than wood chips (because of their rough edges).

Compost. Compost (humus) can be used as mulch. See the Organic Debris Disposal BMP.

Note that the mulching application rates given above can be increased for dormant seeding.

Note also that wood materials should be fairly fine-textured when spread over seed.

4. **Anchoring should be done at the time of or immediately following the application of the mulch**. The appropriate type is dependent upon the type of mulch selected:

Mulch Blankets.
Below are some generic types of mulch blankets, (also called nets and mats) which are effective in preventing erosion on both raw and seeded areas. Their specific applications differ depending on the soil type and the slope of the area being protected. See the attached exhibit for additional information on installing and stapling blankets.

a. Mulch netting. This is a light-weight, fibrous material used to secure straw mulch where heavy flow is expected (i.e. in waterways and on steep slopes). Except when wood fiber slurry is used, the netting should be rolled on top of the mulch and secured to the ground with metal pins or wooden stakes. Wood fiber may be sprayed on top of an installed net. In areas which will be regularly mowed, netting may not be recommended. Use bio- or photo-degradable products.

b. Mulch with netting in combination. Several manufacturers make rolls of mulches bound on either side by netting. Because the mulch and netting are in one roll, installation is much easier than applying mulch and then securing a netting in a separate step. These must be anchored with staples or wooden pegs.

c. Mulch, netting and seed in combination. Some manufacturers also make rolls of mulch bound on either side by netting, with seed mixed in. This would allow the user to merely prepare the seedbed and install the blanket. These must also be anchored with staples or wooden pegs.

All mulch nettings should be made of a polypropylene mesh that will gradually decompose with exposure to sunlight.

Recycled Newsprint. Recycled newspapers should consist of a minimum 96% shredded high-grade newsprint fibers with a maximum 8% moisture context. The recycled newsprint should consist of a wetting agent, defoaming agent, and non-toxic dyestuff that will impart a bright green color. The dyestuff should adhere tightly to the fiber to minimize leaching of the dye after application. The mulch should contain a minimum 0.8 percent by weight of guargum tackifier. This material should come packaged in a waterproof material so it may by stored outside.

Application: Apply recycled newsprint mulch at a rate of 750 lbs/acre, placed over the straw mulch.

Mulch Crimper. This consists of a series of flat, notched discs that punch the mulch into the soil. Crimping is usually done on straw. When pulled over the mulch, the crimper punches some of the mulch into the soil.

Application: To use the crimper, the soil must be moist, free of stones, and loose enough to permit disc penetration to a depth of 3 inches. When using a crimper, seed and mulch by working across the slope. This method is limited to slopes where equipment can operate safely.

Emulsified Asphalt. This is a liquid chemical that has been used as a mulch binder. We do not recommend its use because: of the potential for the chemical to drift; it forms a fairly impenetrable layer; and it is sticky and therefore a potential nuisance to children.

Implementation:

1. Follow seedbed preparation in the Seeding BMP. Add any needed lime or fertilizer based on the results of soil tests. (See the Soil Management BMP).

2. Apply the seed before mulching except when the seed is applied as part of a hydroseeder slurry containing wood fiber mulch, or when a mulch blanket is used which already contains seed.

3. Apply the mulch uniformly according to the rates determined above. In hydroseeding operations, a green dye added to the slurry assures a uniform application.

4. Secure the mulch using the anchoring method selected above.

Maintenance

Mulched areas should be checked following each rain to ensure the mulch is staying in place. Additional tacking materials or netting may need to be applied to hold the mulch in place.

Maintenance procedures should also be followed for the BMPs which were implemented to keep eroded soil or concentrated runoff away from the mulched area. Follow maintenance procedures in the appropriate BMPs.

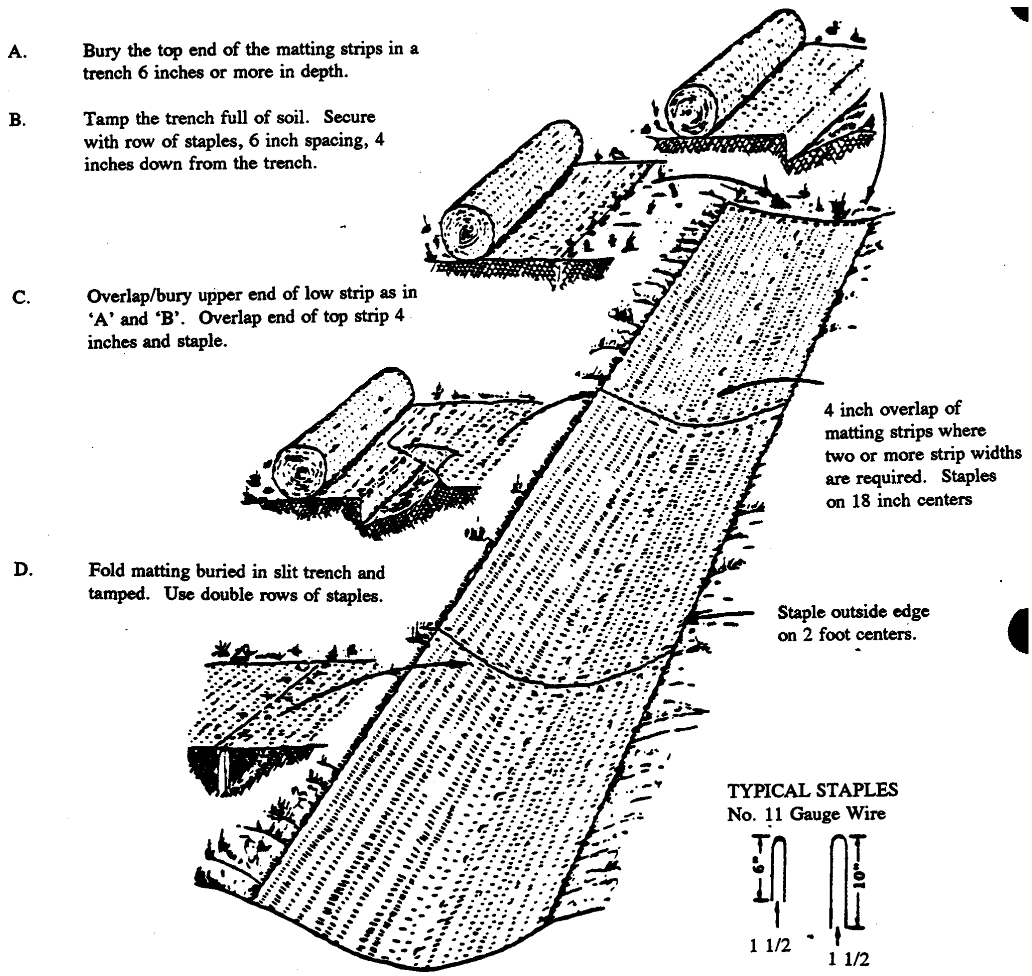
Exhibits

Exhibit 1: Installation of Netting and Matting for Erosion Control. Modified from the 1983 Maryland Standards and Specifications for Soil Erosion and Sediment Control.

Exhibit 1

Installation of Netting and Matting for Erosion Control

Below are general principles for installing netting and matting. Always follow the manufacturer's recommendations.



1. Bury top ends of matting in a trench. As the blankets are unrolled down slope, the matting must be on top with the wood fibers, seed, etc. in contact with soil. Butt snugly at the ends and side before stapling.

2. Staple, following manufacturer's recommendations.

3. Make sure matting is uniformly in contact with the soil.

4. Make sure all lap joints are secure.

5. Make sure all staples are flush with the ground.

Source: Modified from 1983 Maryland Standards and Specifications for Soil Erosion and Sediment Control.

Seeding

Description

Seeding is the establishment of a temporary or permanent vegetative cover by planting seed. For the purposes of this BMP, "grass" and "turf" will be used interchangeably.

This BMP does not address planting individual sprigs of grasses or other vegetation. See the Trees, Shrubs, and Ground Covers BMP for information on planting sprigs.

Other Terms Used to Describe

Hydroseeding
Vegetative Cover

Pollutants Controlled and Impacts

Once established, turf helps keep soil on site, absorbs nutrients, and allows groundwater recharge.

Application

Land Use
This BMP is applicable to all land uses.

Soil/Topography/Climate
Vegetative establishment is important on all exposed areas, but particularly on sloping terrain and areas adjacent to waterbodies or wetlands. It is also important in areas which frequently flood or which are impacted by spring runoff or strong winds.

When to Apply
Seed should be applied immediately after grading and preparation of the seed bed is finished on each small segment of a construction project. Mulch and/or soil erosion control blankets should be used to keep seed in place until the vegetation is established.

Where to Apply
Apply on all construction or earth change sites which require temporary or permanent vegetative stabilization.

Relationship With Other BMPs

Seeding can be used in conjunction with almost all temporary and permanent soil erosion and sedimentation control measures. Any fertilizer or lime that is applied should be done based on the results of soil tests. See the Soil Management BMP. Mulching should be used in conjunction with seeding to ensure establishment of an effective vegetative cover.

Proper grading is needed to ensure the seed bed is adequate for seed application. See the "Site Preparation" section, below.

Specifications

Planning Considerations:

1. The proper **species** of seed should be selected following basic integrated pest management practices (see the Pesticide Management BMP). To reduce the amount of fertilizer, pesticides and other inputs needed, choose adapted varieties based on environmental conditions, management level desired, and the intended use. Consider mixes because they are more adaptable than single species.

2. The proper **time to seed** is dependent upon the climate of the area. In Michigan, there are three different climatic areas which determine when seeding should occur. These are included in Exhibits 1 and 2.

   Seeding dates for permanent cover and dormant seeding are given in Exhibit 1. Dormant seeding is done after the normal growing season, using seed which will lay dormant in the winter but start growing as soon as soil conditions are favorable. Note that perennial grasses should be used for all permanent cover.

   To determine seeding dates for temporary cover use Exhibit 2. Note that the seeds listed here are annual grasses. Be sure to use annual grasses for all temporary cover. Seed mixtures for temporary seeding usually consist of rye or wheat. These species grow better after over-wintering (via a process called vernalization).

3. **Seeding mixture** for permanent cover. For permanent cover, the appropriate seeding mixture is determined in a two-step process. First, consult Exhibit 3, which lists various land uses and site conditions. Determine conditions at your site and use the table to come up with an appropriate seeding mixture number. Exhibits 4 and 5 indicate the various species and seeding rates associated with the selected seeding mixture number on a pound per acre and 1,000 square foot basis, respectively.

   Seeding mixtures for dormant seedings. Use Exhibits 3, 4, and 5 to determine proper seeding mixtures. Dormant seedings are completed in the late fall after the soil temperature remains consistently below 50^{o}F. Perennial grasses are to be used with all dormant seedings.

   Seeding mixtures for temporary cover. Temporary vegetative cover is provided to protect Spoil Piles and larger areas which are staged. Seeding mixtures for temporary vegetative cover are given in Exhibit 2.

4. Subsurface Drains may be needed where water movement may cause seeps or soil slippage. Wet waterways should be tiled to ensure the vegetation is established.

5. Note: Some wildflower seed packages contain seeds of plant species which will compete with native plants. For example, some packages contain purple loosestrife, which is detrimental to cattail populations. The Department therefore does not recommend wildflower plantings unless the seed can be certified as being native to Michigan and is appropriate to the soil and other site conditions.

Site Preparation:

1. Consider protecting seeded areas from pedestrian access using the Construction Barriers BMP.

2. Where possible, divert concentrated flows away from the seeded area at least until the vegetation is established. Follow specifications in the Diversions BMP.

3. Soil tests should be done to determine the nutrient and pH content of the soil. Depending on the results of soil tests, Soil Management may be necessary to adjust the pH to between 6.5 and 7.0 (for most conditions). All lime, fertilizer and other soil amendments should be addressed following the Soil Management specifications. Note that sandy loam, loam, and silt loam are the preferred soils for seeding. Consideration should be given to incorporating these soils into the seedbed.

4. Prepare a 3-5-inch deep seedbed, with the top 3-4 inches consisting of topsoil. Note that the earth bed upon which the topsoil is to be placed should be at the required grade.

5. The seedbed should be firm but not compact. The top three inches of soil should be loose, moist and free of large clods and stones. For most applications, all stones larger than 2 inches in diameter, roots, litter and any foreign matter should be raked and removed. The topsoil surface should be in reasonably close conformity to the lines, grades and cross sections shown on the grading plans.

6. Slopes steeper than 3:1 should be roughened.

Planting:

1. Seed should be applied as soon after seedbed preparation as possible, when the soil is loose and moist. If the seedbed has been idle long enough for the soil to become compact, the topsoil should be harrowed with a disk, a spring tooth drag, a spike tooth drag, or other equipment designed to condition the soil for seeding. Harrowing should be done horizontally across the face of the slope.

2. Always apply seed before mulch.

3. Apply seed at the rates specified in the attached Exhibits using calibrated spreaders, cyclone seeders, mechanical drills, or hydroseeders.

4. Ideally, broadcast seed should be incorporated into the soil by raking or chain dragging, or otherwise floated, then lightly compacted to provide good seed-soil contact.

5. For hydroseeding operations:

    - Seed should be applied at recommended rates. If no rates are given, use 150-200 lbs/acre.

    - Use 2 tons/acre straw mulch, unless otherwise recommended. Use 3 tons/acre when dormant.

- If recycled newsprint is used, follow specifications in the Mulching BMP.

6. All newly seeded areas should be protected from erosive forces by mulch. See the Mulching BMP.

7. Species of grasses which cannot be planted with seed should be planted by sprigging or sodding. See the Trees, Shrubs and Ground Covers BMP for information on sprigging, and the Sodding BMP for information on sodding.

8. Excess topsoil should be disposed of following specifications in the Spoil Piles BMP.

Maintenance

Newly seeded areas need to be inspected frequently for the first few months to ensure the grass is growing. If the seeded area is damaged due to runoff, additional stormwater measures may be needed. Spot Seeding can be done on small areas to fill in bare spots where grass didn't grow properly.

Once the vegetation is well established:

1. Construction Barriers may be removed.

2. Water the grass following specifications in the Lawn Maintenance BMP.

3. If the grass is to be mowed, keep it to a height appropriate for the species selected and the intended use. Follow mowing specifications in the Lawn Maintenance BMP.

4. Occasional soil tests should be collected and analyzed to determine if the soil is appropriately fertilized. Follow the procedures in the Soil Management BMP.

5. Control pests following specifications in the Pesticide Management BMP.

6. Refer to the Lawn Maintenance BMP for determining the steps which can be taken to improve unhealthy turf.

Exhibits

Exhibit 1: Seeding Dates for Permanent Cover. Modified from the Soil Conservation Service Technical Guide, #342.

Exhibit 2: Seeding Dates for Temporary Vegetation. USDA Soil Conservation Service Technical Guide, #342.

Exhibit 3: Determining the Appropriate Seed Mixture. Extracted from USDA Soil Conservation Service Technical Guide, #342.

Exhibit 4: Seeding Mixture (in pounds/acre). Extracted from USDA Soil Conservation Service Technical Guide, #342.

Exhibit 5: Seeding Mixture (in pounds/1,000 ft^2). Extracted from USDA Soil Conservation Service Technical Guide, #342.

Exhibit 1

Seeding Dates for Permanent Cover

Zones	Normal Seeding Dates	Dormant* Seeding Dates
Lower Peninsula, South of U.S. 10	May 1 to October 10	Nov. 1 to freeze up
Lower Peninsula, North of U.S. 10	May 1 to October 1	Oct. 25 to freeze up
Upper Peninsula, entire area	May 1 to Sept. 20	Oct. 20 to freeze up

* Dormant seeding may be done in the late fall after the soil temperature remains consistently below 50^{o}F. This is appropriate if construction on a site is completed in the fall but seed was not planted prior to Normal Seeding Dates. Since the initial temperature for seed germination is approximately 50 degrees F (soil temperature), this practice intends germination will not occur until spring. Extra cereal rye, a cool season annual grass, may be added to attempt to get some fall growth.

- Mulching must be used on any dormant seed. This is particularly important on erosive sites.

- Do not seed when the ground is frozen or snow covered.

- Do not use a dormant seeding on Grassed Waterways.

Source: Modified from USDA Soil Conservation Service Technical Guide.

Exhibit 2

Seeding Dates for Temporary Vegetation Cover

Planting Zones:

1. Lower Peninsula, South of US 10.
2. Lower Peninsula, North of US 10.
3. Upper Peninsula.

Zone			Kind of Seed	Amount	
1	2	3		Per 1,000 Sq. Feet	Per Acre
Apr. 1 to Sept. 15	Apr. 15 to Aug. 1	May 1 to Aug. 1	Oats*, barley*	2 lbs.	3 bu.
June-July	June-July	Not. rec.	Sudangrass	1 lb.	30-40 lbs.
Aug. 1 to Oct. 15	Aug. 1 to Oct. 10	Aug. 1 to Oct. 1	Rye*	3 lbs.	2-3 bu.
Sept. 20 to Oct. 15	Sept. 10 to Oct. 10	Sept. 1 to Oct. 1	Wheat	3 lbs.	2-3 bu.

* Indicates species best suited for wildlife food.

Immediately after seeding, mulch:
- -all slopes
- -unstable soils, and
- -heavy clay soils

with unweathered small grain straw or hay spread uniformly at a rate of 1.5 to 2 tons per acre, or 100 pounds (2-3 bales) per 1,000 square feet. Other suitable materials may be used, according to specifications in the Mulching BMP.

Source: USDA Soil Conservation Service Technical Guide #342

Exhibit 3

Determining Appropriate Seeding Mixture Numbers Based on Site Conditions.

Site	Rough Areas	Steep Areas Ditch Banks Cuts Fills	Utility Rights-of way	Pond Edges[b]	Grassed Waterways Diversions[b]
Well and moderately well drained sand and loamy sand (coarse textured soils)	sunny-1, shady-2 or 4	4 or 6	15	4	4
Well and moderately well drained, moder-ately coarse to moderately fine textured soils (sand loam, loam, silt loam, and clay loam)	sunny-1, shady-2 or 5	4, 7, 8, 9, or 19	15	11 or 14	11, 13 17, 20
Well and moder-ately well drained clay and or 5 silty clay (fine texture soils)	sunny-1 shady-2	7, 8, 9, 13 or 19	15	11, 12 or 14	11, 13, 17, 20
Somewhat poorly drained or poorly drained soils without artificial drainage[a]	3 or 5	8, 10, 13 or 16	15	12 or 13	17, 18
Organic soils[a]	3	10, 16 or 18	16	11 or 12	

[a] With artificial drainage, use the appropriate site condition in the well-drained groups above.

[b] Mixtures one and two can be used on grassed waterways that are to be given care and management as lawn.

Source: USDA Soil Conservation Service Technical Guide #342

Exhibit 4

Seeding Mixtures (in pounds per acre) Corresponding with Seeding Mixture Number

Under the seed mixture number selected in Exhibit 3, use all species shown in that column. For example: for Exhibit 3, seeding no. 6, the correct seeding mixture is 25 lbs. of creeping red fescue plus 5 lbs. of perennial ryegrass and 20 lbs. of tall fescue. These are minimum rates for ideal conditions. Use judgement to increase rates for less than ideal conditions.

Seeds Per Pound	Species	Seed Mixtures From Exhibit 3*																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
615000	Creeping red fescue**	20	30	10	40		25		20						20	20					
227000	Perennial ryegrass	(a)	(a)		(a)		5					5	5			5		5	5		
2177000	Kentucky bluegrass	20	10	25					5						15						
4990000	Redtop**								1							1	1	2	2		
533000	Reed canarygrass**										10						10				
8700000	Seaside bentgrass											1	1	1	1						
136000	Smooth bromegrass**											30		15		10		25			20
227000	Tall fescue					50	20		20	10			40	15		15			30	15	20
1230000	Timothy**							3	2								4				
375000	Birdsroot trefoil (b)**							10	10											10	
110000	Crownvetch (b)**									15											
TOTAL POUNDS		40	40	35	40	50	50	13	58	25	10	36	46	31	36	51	15	32	37	25	40

Seed per square foot at the recommended seeding rate

(a) Five pounds of ryegrass may be added to this mixture on erodible sites or other areas where quick cover is essential

(b) Inoculate all legume seeds with correct inoculant.

* Seeding rates have been rounded off.

** Indicates species best suited for wildlife cover.

Source: USDA Soil Conservation Service Technical Guide #342

Exhibit 5

Appropriate Seeding Mixtures (in pounds/sq. ft.) Corresponding with Seeding Mixture Number

Under the seed mixture number selected in Exhibit 3, use all species shown in that column. For example, for Exhibit 3, seeding no. 6, the correct seeding mixture is .6 lbs. of creeping red fescue plus .2 lbs. of perennial ryegrass and .5 lbs. of tall fescue. These are minimum rates for ideal conditions. Use judgement to increase rates for less than ideal conditions.

Seeds Per Pound	Species	Seed Mixture From Exhibit 3*																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
515000	Creeping red fescue**	.5	.7	.3	1.0		.6		.5						.75	.75					
227000	Perennial ryegrass	(a)			(a)		.2					.2	.2			.2		.2	.2		
2177000	Kentucky bluegrass	.5	.3	.6					.2						.4						
4990000	Redtop**								.03						.03	.03	.05	.05			
533000	Reed canarygrass**										.3						.3				
8700000	Seaside bentgrass											.03	.03	.03	.03						
136000	Smooth bromegrass**											.7		.4		.3		.6			.5
227000	Tall fescue					1.2	.5		.5	.3			1	.4		.4			.7	.4	.5
1230000	Timothy**							.1	.05								.1				
375000	Birdsroot trefoil[b] **							.3	.3											.3	
110000	Crownvetch[b] **									.4											

[a] 0.15 pounds of cereal ryegrass may be added to this mixture on erodible sites or other areas where quick cover is essential.

[b] Inoculate all legume seeds with correct inoculant.

*Seeding rates have been rounded off.

**Indicates species best suited for wildlife cover.

Source: USDA Soil Conservation Service Technical Guide #342

Sodding

Description

Sodding is transplanting vegetative sections of plant materials to promptly stabilize areas that are subject to erosion. Sod may be field sod, or commercial sod which is a cultured product utilizing specific grass species.

Other Terms Used to Describe

Vegetative Establishment

Pollutants Controlled and Impacts

A sodded area provides one of the best filtering methods for preventing soil particles and associated attached chemicals from leaving the site. Sod provides immediate protection against soil erosion caused by water and wind, helps minimize runoff, and allows groundwater recharge.

Application

Land Use
Applicable to all land uses.

Soil/Topography/Climate
On all slopes greater than 3:1 (h:v), or where high water velocities are expected, sod should be held in place with wooden stakes.

When to Apply
Sod should be placed as soon as possible after the ground surface has been graded, to take advantage of the ground moisture. Sod may be laid any time from May 1 until October 20 if it can be irrigated as needed. Sod should not be laid between June 10 and September 10 without irrigation.

Where to Apply
Apply at all construction sites or earth change activities which require vegetative stabilization sooner than can be established by seeding. Sodding is particularly beneficial along steep slopes where seeding may be difficult to establish and maintain.

Relationship With Other BMPs

Sodding is sometimes used to develop Grassed Waterways and Buffer/Filter Strips, and is often used as a part of Critical Area Stabilization. Sod can also be used as Filters around storm drain inlets.

Specifications

Planning Considerations:
Sod selection:
Species. The proper sod species should be selected following basic integrated pest management principles (see the Pesticide Management BMP). To reduce the amount of fertilizers, pesticides and

other inputs needed, choose adapted varieties based on environmental conditions, management level desired, and the intended use. For example, consider using bluegrass sod on areas where an attractive appearance is desired and maintenance will include regular mowing and intensive care. Natural fieldgrass of bluegrass and associated perennial grasses may be used in areas where maintenance will be less intensive.

Size. Sod should be live grass in uniform width strips, taken from thick-growing stands free of weeds. Cultured sod should be cut approximately 0.5 inches thick. Other grass sods should be cut at least 2 inches thick.

Length. Cultured strips should not be less than 30 inches in length. Other grass sods shall be in strips at least 10 inches by 18 inches.

Sod strips should be cut with smooth clean edges and square ends to facilitate laying and fitting.

When to Sod. Although sod can be laid any time from May 1 until October 20 if it can be irrigated as needed, survival is greatly increased if sod is placed during months other than July and August. Sod should never be laid between June 10 and September 10 without irrigation.

Sod should never be frozen, nor should sod ever be applied on frozen ground.

Sod should not be permitted to dry out. Lay sod within 24 hours after cutting. Sod should also be protected from wind and rain until it is laid.

Site Preparation:

1. Consider protecting sodded areas from pedestrian access using the Construction Barriers BMP.

2. Where possible, divert concentrated flows away from the sodded areas at least until the sod is attached to the soil through rooting. Follow specifications in the Diversions BMP.

3. Soil tests should be done to determine the nutrient and pH content of the soil. Depending on the results of soil tests, Soil Management may be necessary to obtain a pH of between 6.5 and 7.0 (for most conditions). All lime, fertilizer and other soil amendments should be addressed following the Soil Management specifications.

4. Prepare a 3-5-inch deep sodbed, with the top 3-4 inches consisting of topsoil. Note that the earth bed upon which the topsoil is to be placed should be at the required grade.

5. The sodbed should be firm but not compact. The top three inches of the soil should be loose, moist and free of large clods and stones. All stones larger than 2 inches in diameter, roots, litter and any foreign matter should be raked and removed. The topsoil surface should be in reasonably close conformity to the lines, grades and cross sections shown on the grading plans.
6. Subsurface Drains may be needed where water movement may cause seeps or soil slippage. Wet waterways should be tiled to ensure the vegetation is established.

7. Immediately before placing the sod, the soil surface should be loosened to a depth of 1 inch

and thoroughly dampened if not already moist.

Applying the Sod:

1. Apply the sod by hand in rows at right angles to the direction of the slope, starting at the base of the area to be sodded and working upward. Do not use pitch forks to handle sod and don't dump the sod from vehicles, as this will ruin the integrity of the sod. Place the strips together tightly so that no open joints are left between strips or between the ends of strips. Stagger the joints between the ends of strips.

2. Always lay sod perpendicular to the flow of water on slopes and in ditches and waterways.

3. The edges of the sod at the top of the slopes should be tucked slightly under. A layer of soil should be compacted over the edge to conduct surface water over and onto the top of the sod.

4. Fill any spaces between the joints and all sod edges with at least 2 inches of topsoil.

5. Sod should be firmly tamped or rolled immediately after it is placed.

6. On slopes steeper than 3:1, or areas of concentrated flows, sod should be secured with wooden pegs, or other approved techniques. Wooden pegs should be a minimum of 10 inches long, spaced 2 feet apart in any direction, and driven flush with the surface of the sod.

   In areas of concentrated flows, you may also want to consider installing Check Dams to decrease the velocity in the channel.

7. Water sod immediately after it is installed. Water to a depth of 1 inch into the sod. Additional watering should be done based on soil moisture, and following specifications in the Lawn Maintenance BMP.

8. See the Filters BMP for the use of sod as filters.

9. Excess top soil should be disposed of following specifications in the Spoil Piles BMP.

Maintenance

Newly sodded areas need to be inspected frequently for the first few months to ensure the sod is maturing. Failures may be due to improper conditioning of the subsoil, lack of irrigation, improper staking, or improper placement of the sod pieces. New pieces of sod, and fertilizer, lime or other constituents may need to be applied. Spot Seeding can be done to small damaged areas. Follow specifications in the Fertilizer Management and Soil Management BMPs to identify appropriate options.

Once the sod is well established:

1. Construction Barriers may be removed.

2. Water the sod following specifications in the Lawn Maintenance BMP.

3. Protruding stakes should either be pounded flush to the ground or removed before mowing.

Follow mowing specifications in the Lawn Maintenance BMP.

4. Occasional soil tests should be collected and analyzed to determine if the soil is appropriately fertilized.

5. Control pests following specifications in the Pesticide Management BMP.

6. Refer to the Lawn Maintenance BMP for information on determining the steps which can be taken to improve unhealthy turf.

Soil Management

Description

Soil management is managing soil to provide the best growing conditions for turf and other vegetation. It may include adding lime, fertilizer, topsoil or other constituents to the existing soil to address low fertility, abnormal moisture content or inappropriate pH. It also includes cultivation and drainage techniques.

All soil additions (amendments) should be based on the results of **soil tests**. Soil samples should be taken following procedures in the attached Exhibit.

Other Terms Used to Describe

Liming
Soil conditioning
Soil preparation

Pollutants Controlled and Impacts

Proper soil treatment applied in conjunction with proper vegetative establishment will help prevent erosion and promote the filtering of runoff water. Soil treatment will also reduce the potential of groundwater contamination by providing a better environment for vegetative growth.

Application

Land Use
The BMP is applicable to all land uses where soils will be used for vegetative establishment.

Soil/Topography/Climate
Soil management varies based on soil classification and the use of that soil.

When to Apply
Certain aspects of this BMP will need to be applied at various times throughout the year. For example, when establishing new turf areas, liming materials should be incorporated into the soil before or during final seedbed or sodbed preparation.

Where to Apply
Apply to all soils.

Relationship With Other BMPs

This BMP is used in conjunction with all vegetative BMPs, as well as the Pesticide Management and Fertilizer Management BMPs.

Specifications

General Considerations:
Naturally existing soils are divided into layers called horizons (see Exhibit 1). These horizons may differ by pH, organic content, moisture, texture, etc. For the purposes of providing good soils for vegetation, only the top two soil layers are of concern. Exhibit 2 shows typical plants which can survive at various pHs.

Changes to the characteristics of the soil may be needed if the soil is not suitable for its intended use (e.g. if the soil is to support a building, its composition will be completely different than if its purpose is to grow grass). Therefore, first determine what the intended use of that soil is.

Since many land uses involve the establishment of grasses and other vegetation, the remaining text of this BMP is devoted to soil amendments for improving vegetative growing conditions. Refer to Exhibit 3, the USDA Soil Texture Classification, to determine soil texture based on the percentage of clay, silt or sand. This chart helps clarify what soils like "loam" and "clay loam" are comprised of.

All soil additions should be done based on the results of soil tests. Exhibit 4 is a step-by-step procedure for collecting soil samples. The Michigan State University, Cooperative Extension Service (MSU, CES) lab can analyze the samples, and staff can offer suggestions on the appropriate amount of fertilizer and other additives that are needed. Exhibit 5 lists the MSU CES laboratory fees.

The discussion below includes possible treatments which will be needed based on the results of the soil test. Much of the information was derived from "Turfgrass Pest Management," Michigan State University, Cooperative Extension Service, Bulletin E-2327.

pH:
pH is a measure of acidity. Soils with a pH less than 7 are considered acid, while soils with pH greater than 7 are considered alkaline. A pH of 7.0 is considered to be neutral.

Although most turf grasses grown in Michigan will grow well under a wide range of soil pH conditions, the optimum pH range for turf grasses is 5.0 to 7.5, depending on the turf species selected. Some acid-loving plants such as blueberries and rhododendrons prefer pHs between 4.0 and 7.0. Again, the type of plant to be grown in the soil will determine the pH requirements. Determine pH by soil test.

If the pH is too low:
Soils that are too acidic for the plant type should be treated with **lime** to raise the pH. This is particularly important because as the soil becomes more acidic, metals become more soluble. As metals become soluble they can be more easily transported to surface and ground waters. Lime should be mixed into the soil to a depth of at least 3 inches before seeding or sodding.

If the pH is too high:
pH levels higher than the optimum range (to 7.5) are generally not encountered in Michigan. Where necessary, sulfur or sulfur compounds may be added to lower the pH to the optimum range.

In droughty soils:
Droughty soils may be caused by a lack of irrigation, or because of a lack of organic material. Determine the cause of the droughty condition, then adjust the irrigation schedule, or add organic matter, loamy material, or preferably, topsoil to increase the moisture holding capacity of the soil.

Nutrients (Phosphorus and Nitrogen):
Nutrients in a soil are in constant flux, becoming more or less available as soil conditions change. Fertilizers sold commercially contain varying amount of the 16 mineral elements essential for turf growth and development, nitrogen, phosphorus and potassium being the three most common elements. Remember that only a soil sample will tell you how much of each nutrient is available in your soil.

Nitrogen:
Nitrogen is an essential element for plant growth. Because nitrogen makes grass "green," it is often used in excess of what the plant needs. Nitrogen which is not absorbed by vegetation can leach through the soil and into the groundwater. During this leaching process, nitrogen is converted into nitrate, which can contaminate drinking water supplies and cause health problems. The Environmental Protection Agency limits the acceptable level of nitrate in drinking water to 10 ppm (parts per million).

Nitrogen is often unavailable to turf roots because it leaches through the soil rapidly. Turf deficient in nitrogen may have poor color, decreased elasticity, and is less able to compete with weeds. Apply nitrogen based on soil tests. Do not apply any more than one pound of actual nitrogen per 1,000 square feet during a single application.

Phosphorus:
Phosphorus is important for root development, maturation, and seed production. This element is found chemically bound to oxygen; two particles of phosphorus are bonded to five oxygen particles (P_2O_5). Since this molecule is practically immobile in soil, few soils are deficient in phosphorus. Soils that are deficient show purpling of grass blades. Note that this symptom can be confused with the color change induced by cold weather.

Many Michigan soils have been historically over-applied with phosphorus. Since phosphorus binds readily with soil, excessive applications of phosphorus which are carried off in eroded soil can result in algae blooms and nuisance aquatic plant growth. This, in turn, results in eutrophication.

Phosphorus fertilizer must be delivered directly to turf roots. This can be done by fertilizing after aeration or by liquid fertilizer injection. Apply all phosphorus amendments based on the results of soil tests.

Potassium:
Turf uses potassium in quantities second only to nitrogen. This element is important for rooting, and wear and climatic stress tolerance. While rarely visually evident, turf deficient in potassium has yellowing and dead blade tips.

Potassium generally does not cause water quality problems, nor is it over-applied in the same manner as phosphorus and nitrogen. Apply potassium amendments on the basis of soil test results.

For all Nutrient-Deficiencies:
If soils are nutrient-deficient, follow specifications in the Fertilizer Management BMP.

Micro-Nutrients:
Micronutrients are elements used by plants in relatively small amounts. They include manganese, boron, copper, and zinc. Typically, micronutrients required by turf are naturally present in Michigan soils in adequate amounts. High soil pH, however, can render these elements insoluble, making them unavailable to turf roots. Iron is an example of a micronutrient that is commonly deficient in alkaline soils (i.e. those soils with a pH greater than 7). Iron is required for chlorophyll production, and therefore the green coloring of plants. It is also important for root and shoot development and drought resistance. Iron-deficient turf usually has blotchy yellow patches. Severe iron deficiencies may result in white grass blades or the death of plants. Application of iron fertilizer will provide temporary green-up of turf. Since the deficiency is due to soil alkalinity, long-term treatment requires modifying the soil pH.

Soil Organisms:
Living and decaying soil organisms contribute greatly to a soil's organic matter and fertility. As they burrow, organisms break down organic matter, making nutrients available for absorption by turf roots.

Earthworms are the best known of soil organisms, but a great number of microorganisms also occupy the soil. One teaspoon of soil can contain a billion bacteria, a million fungi, and several thousand algae. Most of these organisms improve soil conditions for plants.

Turf managers who appreciate the benefits of soil life are careful not to destroy it with unnecessary soil amendments. Again, make amendments to the soil based on the result of soil tests.

Managing for Compacted Soils:
Compacted and heavy clay soils contain less air and have a hard surface that drains poorly. Turf growing in such soils lack air and beneficial micro-organisms, and suffer from poor drainage. Root development and turf quality declines.

Mechanical aerators create holes in compacted and heavy soils. This practice increases the movement of air in the soil and improves drainage. Machines that remove cores from the soil are generally more efficient aerators than those that spike or slit the soil. Coring machines remove a quarter to one-inch diameter cores and deposit them on the surface of the turf. Fall is the best time to aerate turf, when weed seed germination is at a minimum.

When practical, break up deposited cores by dragging chain-linked fence or similar material over them. Cores of poor quality soil should be discarded. Holes will more rapidly be covered by turf if the area is top dressed, seeded and fertilizer is applied directly after aeration. Follow this with a light watering. Fall is the best time to aerate turf, when weed seed germination is at a minimum.

Site Preparation:
For established areas:

1. Collect soil samples following the procedures in the attached Exhibit.

2. Discuss the soil test results with the local Soil Conservation District or Cooperative

Extension Service staff, and buy the recommended amount of fertilizers, lime, or other needed amendments. Apply fertilizers following specifications in the Fertilizer Management BMP. Lime should not be spread using a hydroseeder. It can be blown onto steep slopes in dry form. For the application of compost, see the Organic Debris Disposal BMP.

For a typical seeding or sodding operation as part of a construction project:

1. Collect soil samples following the procedures in the attached Exhibit.

2. Discuss the soil test results with the local Soil Conservation District or Cooperative Extension Service staff and buy the recommended amount of fertilizers, lime, or other needed amendments.

3. In large areas, topsoil should be removed and stored in storage piles according to specifications in the Spoil Piles BMP.

4. Where appropriate, grade following specifications in the Grading Practices BMP. Complete all cut and fill activities. Use Diversions and other BMPs to prevent soil erosion and sedimentation. Follow the site plan.

5. The earth bed upon which the topsoil is placed for seedbed and sodbed preparation should be at the required grade.

6. Work lime, fertilizer and other additives into the topsoil, either before or during final seedbed preparation, or before sod is laid. Lime should be mixed into the soil to a depth of at least 3 inches before seeding or sodding. Lime should not be spread using a hydroseeder. It can be blown onto steep slopes in dry form. For all seeding applications, follow specifications in the Seeding BMP.

   For all sodding applications, follow specifications in the Sodding BMP. For the application of compost, see the Organic Debris Disposal BMP.

7. Inoculate all legume seed in accordance with the manufacturer's recommendations.

Maintenance

If the vegetation doesn't grow according to its intended use, additional soil tests may need to be taken and analyzed for other parameters. Additional soil samples should also be taken as new areas are developed.

Once vegetation is established, additional soil amendments, including fertilizers, should only be made based on the results of soil tests.

Additional Considerations

Treating soils on-site is less expensive than importing soils from off-site. Existing soils are also usually compatible with the lower horizons.

Exhibits

Exhibit 1: Soil Horizons. Michigan Department of Natural Resources, Soil Erosion Control Unit.

Exhibit 2: pH Toxicity Chart. Michigan Department of Natural Resources, Soil Erosion Control Unit.

Exhibit 3: USDA Soil Texture Classification.

Exhibit 4: How to Collect a Soil Sample. Compiled from several sources.

Exhibit 5: Michigan State University Testing Laboratory Fee Schedule. Lists prices effective July 1, 1990.

Exhibit 1:

Soil Horizons

Horizon O - This uppermost horizon consists of detritus, leaf litter, and other organic material lying on the surface of the soil. This layer is dark because of the decomposition that is occurring, and is usually 0" to 2" deep, or it may be as deep as 16" for poorly drained, unclassified soil.

Horizon A - The second layer of soil, called topsoil, is darker than the lower layers. It is loose and crumbly with varying amounts of organic matter. In cultivated fields, the plowed layer is topsoil. As water moves down through the topsoil, many soluble minerals and nutrients dissolve. The dissolved materials leach from the topsoil. This is generally the most productive layer of soil, and ranges from 2" to 10" in depth.

Horizon B - The third layer is commonly called subsoil. This layer is usually light colored, dense, and low in organic matter. The subsoil is a zone of accumulation since most of the materials leached from the topsoil accumulate here. This zone ranges from 10" to 30" in depth.

Horizon C - This layer is beneath the subsoil. It is lighter in color than the subsoil. It is typically described to a depth of 60" in soil survey reports, but may be many feet thick. It may or may not be like the material from which the A and B horizons have formed. If it is dissimilar, it is designated as 2C or IIC.

Horizon R - This layer represents bedrock.

Source: Michigan Department of Natural Resources, Soil Erosion Control Unit.

Exhibit 2

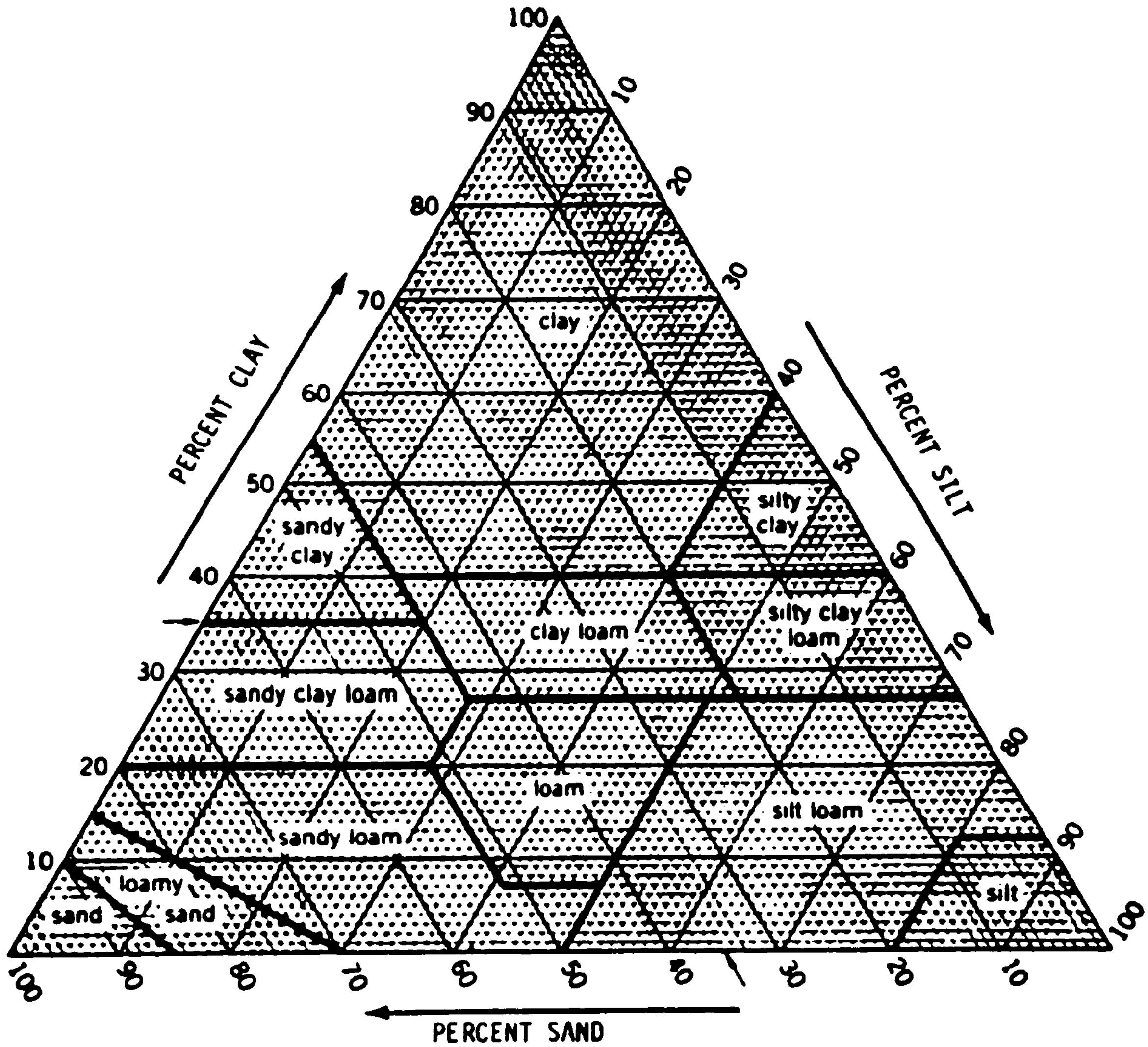
pH Toxicity Chart

	pH		
	14		
B	13		
A	12	Typical Basic Soils	Typical Plants Tolerant of Basic Soils
S	11	Alpena, Aurelius, Barry, Belleville	Willow, American Elm, Poison Sumac, Poison Ivy
I	10		
C	9		
	8		
	7	Neutral	Vegetation grows best when it is within the range of 5.5 and 8.0
	6		
	5		
A	4		
C	3	Typical Acid Soils	Typical Plants Tolerant of Acid Soils
I	2	Burt, Champion, Gogebic, Isabella	Red Maple, Balsam Fir, Bunchberry
D	1		
	0		

Source: Michigan Department of Natural Resources, Soil Erosion Control Unit.

Exhibit 3

USDA Soil Texture Classification



Source: USDA, Soil Conservation Service

Exhibit 4:

How To Collect a Soil Sample

Soil tests are generally collected and analyzed for nitrate-nitrogen, phosphorus, and pH. As discussed in the Lawn Maintenance BMP and above, BMP, nitrogen and phosphorus are two of the three primary nutrients which make up commercial fertilizers. Fertilizers put on the soil in excess of that which is needed by the plant may 1) run off the soil into lake, rivers and streams, causing algae blooms; or 2) leach through the soil and impair groundwater supplies.

Generally, a representative sample should be taken. This may mean only a few samples, as in the case of an average one-acre yard, or a dozen or more, as in the case of a large field. The more variety of soil textures in the area to be vegetated, the more samples that should be taken. Turf areas that differ significantly in grass type, use, or growing conditions should be analyzed separately.

Remember that there are three primary types of soil textures are sands, silts and clays. Soil which is comprised of a mixture of sand, silt and clay is called loam. Use Exhibit 3, the USDA Soil Texture Classifications, to determine the soil textures of your soils.

Step by step process:

For Yards/Lawns Less than 1 Acre:

1. Take a spade or trowel and stick it in the soil to a depth of 4-5 inches at a 45-degree angle (to make a V-shaped cut). Take the spade out and move it 1/2-inches away from the first cut and dig out a 1/2-inch chunk of soil. Then, trim off from each side of the spade all but a thin ribbon of soil down the center of the spade face. Place this in a clean bucket, plastic container or paper bag. Do not contaminate samples by mixing them in a metal container.

2. Take additional samples, as needed for different textures of soils, and for the different ways turf can differ--by grass type, use, or growing conditions. Add the soil to the bucket/container and mix thoroughly.

3. Air dry the sample by spreading the soil out in the bottom of the bucket/container, or, if a lot of soil is collected, in the bottom of a flat pan.

4. When the soil is dry, mix it thoroughly. Then take out about a half-pint, and put it in a jar for testing.

5. Take the soil test to the county Cooperative Extension Service (CES) office or a private lab experienced in the analysis of soils. Be prepared to answer questions about the amount of fertilizer you've used in the past, the spreading/spraying technique used, and the type of grass or sod the fertilizer will be applied to. Also indicate to the CES staff any problems which have been encountered on the lawn: look for thin spots, brown spots, etc.

Exhibit 4 (Con't)

6. The CES staff will have the soil test analyzed and present you with the results, along with a recommendation for the amount of fertilizer needed, the application rate, the best time to apply the fertilizer, and frequency of applications. By tailoring fertilizer applications to your lawn, you will put on only what is needed, thus saving money and protecting surface and ground waters, and will likely save money.

7. Homeowners should have their soil tested once every three or four years, unless additional problems arise.

<u>For Yards Larger than 1 Acre, Including Parks, Cemeteries, etc.</u>

1. Get a copy of a soils map from the Soil Conservation District or the Cooperative Extension Service to identify the number and types of soils on your property.

2. Collect soil tests to a depth of 4-5 inches and 1/2-inch thick using a spade, soil auger or soil sampling tube.

3. Trim off from each side of the spade all but a thin ribbon of soil down the center of the spade face. Place this in a clean bucket.

4. Take additional samples, as needed for each different type of soil identified on the soil map. If you were unable to access the soil map, at least take additional samples for each soil texture (sand, silt, or clay). Add the additional soil samples to the bucket.

5. Follow steps 3 - 6 in the above section.

6. People with large acres to manage should collect soil samples annually.

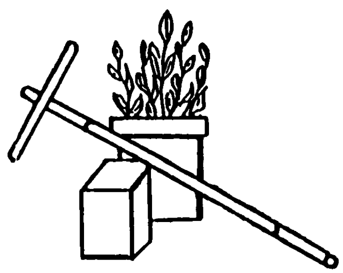
Compiled from several sources.

MICHIGAN STATE UNIVERSITY
SOIL TESTING LABORATORY

FEE SCHEDULE

For
SOIL ANALYSIS
And OTHER MATERIALS

(EFFECTIVE JULY 1, 1990)



Cooperative Extension Service
Crop and Soil Sciences Department
A81 Plant and Soil Sciences Building
East Lansing MI 48824-1325

Telephone (517) 355-0?18
FAX (517) 355-1732

Exhibit 5

PRICES EFFECTIVE July 1, 1990

1a. REGULAR FIELD SOIL TEST. . . . . $ 6.00*
pH, lime requirement, P, K, Ca, Mg & recommendations

1b. REGULAR FIELD TEST PLUS ZN & MN $10.00*

*Samples coming into the lab not in pre-paid boxes add $.50 per sample for boxing

2. MICRONUTRIENT TESTS (Zn, Mn, Cu, & Fe) .$ 3.00/EA
(price is per micronutrient per sample)

3. GREENHOUSE TEST $14.00
(For artificial growth media) pH, Nitrate-N, P, K, Ca, Mg, soluble salts, Na, Cl and nutrient balance

4. SUPPLEMENTAL SOIL TESTS

a. Nitrate - Nitrogen . . . . $ 3.00
b. Nitrate - N + Ammonium - N . . . . . . $ 4.00
c. Sodium . . . . $ 3.00
d. Chloride . . . . $ 3.00
e. Soluble Salts . . . .$ 3.00
f. Organic Matter . . . . $ 3.00
g. pH . . . . $ 2.00
h. Total Nitrogen $12.00
i. C.E.C. by ammonium saturation $15.00
j. Boron (analysis by U. Of Wisconsin). $ 5.50
Sulfur . . . . $ 5.50

5. PARTICLE SIZE ANALYSIS $10.00
(percent sand, silt and clay)

6. GOLF COURSE ANALYSIS Sand Classification $15.00
(USGA size limits by wet sieving)

7. PEAT FOR SALE . . . .$ 7.00
(pH, organic matter, moisture content, peat type)

PRE-PAYMENT IS ENCOURAGED - OTHERWISE A SERVICE FEE OF $6.00 WILL BE ADDED

Exhibit 5 (con't.)

8. LIMESTONE ANALYSIS

a. Neutralizing Value, Sieve Analysis…………….$18.00
% $MgCO_3$ and Moisture

b. Neutralizing Value only………………………...$ 6.00

c. Sieve Analysis only……………………………..$ 6.00

d. Percent $MgCO_3$ only……………………………$ 6.00

9. MARL ANALYSIS

a. Neutralizing Value, $CaCO_3$ equivalent per cubic yard, % $MgCO_3$, % moisture………………………...$18.00

b. Neutralizing Value, $CaCO_3$ equivalent per cubic yard and % moisture………………………………...$12.00

c. Percent $MgCO_3$ only……………………………$ 6.00

10. WATER TESTS

a. **COMPLETE…**……………………………….$12.00
(soluble salts, alkalinity, pH, Nitrate-N, P, K, Ca, Mg, Na and chloride)
b. Total Soluble Salts…...………………………….$ 2.00
c. Alkalinity………………………………………..$ 2.00
d. Nitrate-N…..…………………………………….$ 2.00
e. Nitrate-N + Ammonium-N………………..……$ 3.00
f. Any single soluble element……………………...$ 2.00

11. PLANT TISSUE ANALYSIS

COMPLETE tissue analysis includes N, P, K, Ca, Mg, Zn, Mn, Cu, Fe, B, Al and Mo.

a. Field Crop & Vegetable tissue…………………$16.00
(includes interpretation of results)

b. Fruit trees, grapes, strawberries,……………….$18.00
blueberries & raspberries (includes interpretation of results & computerized fertilizer recommendations)
c. Complete analysis <u>without N</u>………………..….$12.00
d. N alone..………………………………………...$ 8.00

12. SUPPLIES

a. Soiltex pH kits…………………………………..$ 3.00

b. Hoffer Soil Sampling Probes…………………...$20.00

13. DISCOUNT INFORMATION
(on purchases of soil sample boxes only)

a. 0-99…………..…………………………………..No discount
100-199…………………………………………………4%
200-399…………………………………………………8%
400 +…………………………………………………...10%

TURNAROUND TIME for Regular Soil Tests is one week, turnaround time for Greenhouse tests is two (2) days from receipt. A 20% surcharge will be added for Rush samples.

MSU SOIL TESTING LABORATORY
A81 Plant & Soil Sciences Building
Michigan State University
East Lansing, MI 48824
Phone: (517) 355-0218
FAX: (517) 355-1732

Dec. 1, 1992

Trees, Shrubs and Ground Covers

Description

This BMP addresses the selection and maintenance of woody plant materials, including trees, shrubs, and ground covers. Seed selection is discussed in the Seeding BMP, and sod selection in the Sodding BMP.

Trees, shrubs and ground covers can be used on steep or rocky slopes where mowing is not feasible. Once trees, shrubs and ground covers are well established they:

-help stabilize the soil, reducing both wind and water erosion
-reduce stormwater runoff by intercepting rainfall and promoting infiltration
-filter pollutants from the air and produce oxygen
-moderate temperature changes and provide shade
-provide some privacy
-improve aesthetic values and increase property values

In addition, ground covers can provide stabilization in areas which are heavily shaded.

Other Terms Used to Describe

Landscape Planting
Landscaping

Pollutants Controlled and Impacts

Tree, shrub and ground cover plantings: protect the soil from wind and water erosion, thereby reducing sedimentation in surface waters; utilize nutrients, thereby minimizing nutrient loading to surface water and nitrate leaching to groundwater; and filter soil that has eroded.

Application

Land Use
The BMP is applicable to all land uses.

Soil/Topography/Climate
Soils, topography and climate will all be considerations in selecting the appropriate trees, shrubs and ground covers for the site.

When to Apply
Plantings are usually done in the spring or fall, based on the following dates and depending on the type of vegetation.

Spring: April 15 - May 30
Fall: September 1 - October 30

Winter and summer plantings are generally not as successful.

Where to Apply
Apply at all sites where landscape planting will minimize soil erosion and/or enhance aesthetic values.

Relationships With Other BMPs

This BMP should also be used when trees, shrubs or ground covers are accidently damaged during Land Clearing operations. Trees, shrubs and ground covers are often incorporated into sites which need Critical Area Stabilization.

Specifications

Planning Considerations:
Wherever possible, **preserve existing woody vegetation.** Existing vegetation is more aesthetically pleasing, costs less than purchasing new species, and provides immediate shade, canopy and habitat. The identification of trees which should be preserved is discussed in the Tree Protection BMP.

For New Plantings:
1. Selection of appropriate species should be based on the following:

Soil texture. Some species will grow best in certain soil textures. Information on soils for many counties is available from the local Soil Conservation District office. The Appendices include an update of the soils information that has been entered in the Department's land resources database.

Soil tests may be needed to determine if nutrients or fertilizers need to be added to the site. All additions to the soil should be based on the results of soil tests. Follow the specifications in the Soil Management BMP.

Exhibit 1 can be used as a starting point for selecting trees and shrubs based on soil conditions.

Exhibit 2 can be used as a starting point for selecting ground covers based on soil conditions.

Drainage classification. Drainage classification is reflective of the soil moisture condition of the soil. For example, species such as white birch will grow best if soil moisture is high. Other species such as Jack pines will "drown" and die in soils of high water content. Be sure to take the drainage classification of soils into consideration when selecting tress and shrubs.

Native species. The type of vegetation which exists in the area is a good indicator of plants which will likely have good survival rates. These indicator species provide information on soil texture, drainage class, and fertility. Native vegetation or plant materials with similar requirements can then be used.

Purpose (Use). The purpose for which the plant is being used should also be considered. If the plant is being added for shade, trees with fuller canopies should be selected. If the plant is being added to control soil erosion, then its rate of growth, type of root system, ground covering characteristics, and spacing between plants are important factors.

2. Because of the spacing required between many shrubs and trees, and because it takes time for most woody species to "take hold," soil erosion between plants may occur. To prevent erosion, mulch all sites which will be planted with woody species. See the Mulching BMP.

3. On steep slopes, stagger plantings and consider using erosion control mats or netting prior to placing to keep soil from eroding. Mats and netting should be slit to accommodate the shrubs. See the Filters BMP for information on the proper selection of nets and mats.

4. For areas in which trees or shrubs will be planted, any seeding that is done to help stabilize the area should consist of the least competitive plant species. Species such as tall fescue, which produces vigorous early growth, is highly competitive with tree seedlings and therefore should not be used. Species such as annual lespedezas, which starts growing relatively late in the spring, is much less competitive.

5. Any pruning that needs to be done should be completed before planting occurs and should be done by persons experienced in pruning.

   For deciduous trees: Prune to balance the loss of roots so as to retain the natural form of the plant type. The height ratio of the crown to the trunk after pruning should be approximately one-third crown to two-thirds trunk. The primary leader should not normally be cut back. Branches to be removed should be cut off flush with the trunk or main branch.

   For deciduous shrubs: Prune by removing all dead wood and broken branches, thinning out entire canes where they are too thick, cutting back or removing unsymmetrical branches and sufficient other growth to ensure healthy and symmetrical growth of new wood. Shrubs should be pruned so that they form a loose outline conforming to the general shape of the shrub type.

   Evergreen trees and shrubs: Evergreens should be pruned only to remove broken or damaged limbs.

6. In windy areas or where plantings will be done in stages, always begin planting on the windward side and progress across the area as it is being stabilized. Stagger trees in rows.

Trees:

Selecting Individual Trees:
Large nursery trees usually come with the roots and attached soil wrapped in burlap. As a rule of thumb, the soil ball of containerized and burlapped trees should be 12 inches in diameter for each inch of trunk diameter. Keep the soil around the roots moist until the tree is planted. Bind branches with soft rope to

prevent damage during transport.

Smaller nursery trees are usually sold in plastic containers as balled and burlapped stock, or as bare-root stock (seedlings):

Container-grown plants should have grown in the container for at least one growing season. If plants have been in the container too long they will show "pot-bound" root ends.

Balled and burlapped plants should be planted prior to "bud break." If planted in the fall, balling operations should not begin until after the plants have begun to "harden off." All plants should be dug and transported so that the ball is moist, and protected from rain or sudden changes in the weather.

Bare-root plants should only be handled in early spring, late fall or late winter. These plants should meet the following criteria to prevent a high rate of mortality:

Seedlings should be fresh smelling. Sour odor indicates that the seedlings have been stored too long and have begun to rot. Trees stored at correct temperatures will be free of mold.

The roots must be moist and glistening white when stripped of bark. Using a knife or fingernail, strip the bark off the root, working from base to tip. If the roots appear yellow, brown or have brown spots, the stock is badly damaged and has little chance of survival. Check the roots of several seedlings.

Buds must be firm, with no evidence of new growth.

Seedlings should be packed and shipped in wet moss or other medium, and kept cool (less than 34 degrees F) and moist prior to and throughout the planting process. Moss-packed seedlings should be kept in their container and kept moist. Clay-packed seedlings should not be watered, but should be covered with burlap if they are not to be planted soon after they are purchased.

Store packages of seedlings in a shaded location out of the wind.

Seedlings should be planted as soon as possible after they are received. If planting is delayed longer than four days after seedlings are received, "heel" the seedlings in a shaded area and keep moist. To heel in seedlings, dig a trench in soil that is shaded or in a well-ventilated enclosure. Place seedlings in the trench and cover the roots with soil. Replant when planting conditions allow.

<u>Site Preparation:</u>
Dig a hole at least deep enough and wide enough to hold the entire root ball. The final level of the root ball's top should be level with the ground surface. Keep topsoil separate from the subsoil. If the soils are clay, dig a deeper hole and backfill with some of the topsoil.

<u>Planting:</u>
Although the planting seasons for deciduous plants is between March 1 and October 1 or until the prepared soil becomes frozen, spring and fall are the best times to plant. Planting of evergreens should occur between March 1 and June 1, before new growth occurs.

Trees in containers and burlap will need to be planted individually. See Exhibit 3 and follow the steps below:

> Trees in containers should be removed carefully so that all roots and soil remain attached. It may be easiest to cut the container. On balled and burlapped trees, loosen the twine and burlap at the top and check to make sure no other wrapping is present before planting.
>
> Depending on the type of subsoil, it may be beneficial to mix a little peat moss into the soil.
>
> The dug hole should be such that the plant is planted at the same depth as the original container.
>
> Add water to settle the soil and eliminate air pockets. Once the water is drained off, lower the tree into the hole, backfill half way, and pat firm. Water again. Once the water is drained again, remove the burlap from ball and burlapped trees from around the trunk and the upper half of the ball. Fill the hole so that it is filled even with the ground line.
>
> Backfill the hole and pat the soil firm. Leave a small depression around the tree so that water can run into the depression.
>
> Add mulch around the tree to reduce competition from unwanted vegetation and to help prevent roots from drying out.

Bare-root seedlings should not be pruned prior to planting, except for broken or damaged roots. Plants can be planted either by hand or by machine. On large sites where slopes do not prohibit machinery, bare-root seedlings can be planted in furrows using a tree-planting machine.

A method of hand planting bare-root seedlings is shown in Exhibit 4. Plants should be set at a depth equal to the depth in their original location. The exposed roots should be held firmly in the proper position, with the roots spread out. The prepared soil should be watered around the roots and thoroughly firmed at intervals during the process of backfilling. Sufficient water should be used to ensure the soil is thoroughly saturated.

<u>Spacing and Rates of Planting:</u>
The proper spacing and rates of planting various tree species are shown in Exhibit 5.

Tree seedlings should *not* be fertilized during the first 12 months following planting because fertilizer tends to dehydrate newly planted trees.

Mulch between plants to prevent soil from eroding. Follow specifications in the <u>Mulching</u> BMP.

<u>Plants Located on Slopes:</u>
For plants located on slopes, a berm of prepared soil should be constructed halfway around each plant on the down-slope side. The berm of prepared soil should have an inside diameter equal to that of the planting hole, and a maximum height of 6 inches. Soil should not spill down-slope more than 18 inches.

Wrapping trees:
Trees should be wrapped within one week following planting. Trunks should be carefully wrapped beginning at the base of the trunk just above the roots and below the normal ground line, and should extend upward in a spiral with an overlap of one-half the width of the strip. The portion of the wrapping below the finished grade should be covered with soil. The paper should be held securely in place with masking tape.

Staking trees:
Newly planted trees often need to be staked for support. Trees which need to be staked should be secured with stakes and guy wires. Cushion the tree against the wire by placing old garden hose or equivalent between the tree and wire. See Exhibit 3.

Shrubs:

Selecting Shrubs:
For erosion control purposes, and when more than one species can be used, make the final species selection using the following characteristics:

-fast growing
-easy to establish
-have large lateral spread or prostrate growth (i.e. will grow outwardly to provide more cover)
-disease and insect resistant
-ability of the roots to fix nitrogen
-adaptation to a broad range of soil conditions

Like small trees, nursery shrubs usually come in plastic containers or as bare-root stock.

Site Preparation and Planting:
Follow the tree planting procedures for "Trees in containers and burlap," above. See Exhibit 3. Space shrubs approximately three feet apart.

It is important to mulch the entire area to keep other plants from competing with the desired plant and to cover exposed soil. See the Mulching BMP for mulching specifications.

Ground Covers:

Selecting Ground Covers:
When ground covers are to be used to help stabilize soils, select fast-growing, evergreens that require little maintenance.

Site Preparation:
The dense growth of ground covers requires that they have good soil. Well-drained soils high in organic matter work best. Make soil additions based on the results of soil tests. See the Soil Management BMP.

On steep slopes, till the soil in contour rows, or dig individual holes for each plant. Blend soil additions into the soil.

Planting:
Most ground covers are planted from container-grown nursery stock. Transplanting to the seedbed can be done using a small trowel or spade. Dig a hole large enough to accommodate the roots and soil. Backfill and firm the soil around the plant. Water immediately.

Space between plants based on how quickly full cover is achieved, usually between 1 and 3 feet apart.

Like with trees and shrubs, ground covers will be better protected from competitive species if the area is mulched. See the Mulching BMP for mulching specifications.

Maintenance

For New Plantings:

1. Check survival the first and second year and replant where survival is poor.

2. Where needed, control competing vegetation the first 2 or 3 years, preferably by mulching or cultivating.

3. Exclude livestock from all plantings.

For All Trees, Shrubs and Ground Covers:

Trees:

Seedlings are subject to competition with invading grasses and other vegetation. For hardwoods, vegetation must be controlled for at least three growing seasons. For conifers, vegetation must be controlled for at least two growing seasons. Mulch to prevent competition, or mow or clip competitive vegetation, where possible. Use herbicides only where mulching has failed and mowing and clipping are not possible. Follow guidelines in the Pesticide Management BMP.

Where soil tests indicate fertilizers are needed, fertilize in late fall or early spring before leaves emerge. For evergreens, use only 1/2 the recommended amount of fertilizer. Use a punchbar, crowbar or auger. Make holes about 18 inches deep and about 2 feet apart around the drip line of each tree. Distribute fertilizer evenly among the holes to bring it in contact with trees roots. Store and mix fertilizers following specifications in the Fertilizer Management BMP.

Ideally, newly planted trees should receive an inch of water each week for the first two years after planting. When rain does not supply this need, and where possible, the tree should be watered deeply but not more often than once per week.

Trees should be protected and unhealthy limbs cut following procedures in the Tree Protection BMP. Train and prune black walnut and other hardwoods to produce straight, single stemmed trees.

Christmas tree shearing should begin after the third year. Refer to the Soil Conservation Service Technical Guide, #660, Woodland Pruning.

Shrubs:

Maintenance of shrubs, including watering and fertilizing, depends upon the species. Maintain mulch around the base of each plant to reduce weed competition and retain moisture. See the Mulching BMP. Fertilizers are usually needed only once every 3 years or so, depending on the results of soil tests.

Pruning should be done as needed to remove dead limbs.

Ground Covers:
Most ground covers need yearly trimming to promote growth. Trim back from trees, flower beds, fences, and buildings. Add additional mulch as needed until the area is completely stabilized. Like shrubs, fertilizers may only be needed once every 3-4 years, depending on the results of soil tests.

Organic Debris Disposal:
Any organic debris which results from pruning, trimming or any other vegetative maintenance should be disposed of following specifications in the Organic Debris Disposal BMP.

Exhibits

Exhibit 1: Selecting Trees and Shrubs. USDA Soil Conservation Service Technical Guide, #342.

Exhibit 2: Selecting Ground Covers. USDA Soil Conservation Service Technical Guide, #342.

Exhibit 3: Planting Balled-and-Burlapped and Container-Grown Shrubs and Trees. North Carolina "Soil Erosion and Sediment Control Planning and Design Manual," as modified from the Virginia Division of Forestry.

Exhibit 4: A Method for Planting Bare-Root Seedlings and Sprigs of Grasses. Modified from the North Carolina "Erosion and Sediment Control Planning and Design Manual."

Exhibit 5: The Proper Spacing and Rates of Planting. USDA Soil Conservation Service Technical Guide, #612.

Exhibit 1
Selecting Trees and Shrubs

Soil Condition	Trees[1]	Shrubs[2]
1. Well and moderately well drained sand and loamy sand (coarse textured soils)	Austrian pine Jack pine* Red pine White pine* Black locust Cottonwood	Autumn olive Hawthorn Crabapple Tatarian honeysuckle Staghorn sumac Serviceberry
2. Well and moderately well drained, moderately coarse to moderately fine textured soils (sandy loam, loam, silt loam and clay loam)	Red pine White pine* Cottonwood Norway spruce* Jack pine* White spruce* Black locust Sugar maple*	Gray dogwood Autumn olive Crabapple
3. Well and moderately well drained clay and silty clay (fine textured soils)	White pine* Norway spruce* Black locust White spruce* Sugar maple* Red pine Cottonwood	Silky dogwood Tatarian honeysuckle Autumn olive Crabapple
4. Excessively wet (poorly drained) organic soils	Northern white cedar* White spruce* Red maple Silver maple Green ash Swamp white oak* Pin oak**	American cranberry bush Redosier dogwood Gray dogwood "Indigo" silty dogwood Nannyberry Viburnum
5. Excessively wet (poorly drained) mineral soils	Northern white cedar* Silver maple Green ash**	Nannyberry Viburnum "Indigo" silky dogwood Redosier dogwood American cranberry bush
6. Excessively wet (poorly drained) pH>7.4	Northern white cedar* White spruce* Green ash**	Nannyberry Viburnum

[1]For other species, refer to section II-H of the SCS Technical Guide, or the appropriate county soil survey, as available from the USDA Soil Conservation Service.
[2]Indicates species best suited for wildlife food or cover.
*Indicates species best suited for wildlife food or cover.
**Tamarack and willow may also be used, where available.

Source: USDA, Soil Conservation Service Technical Guide #342

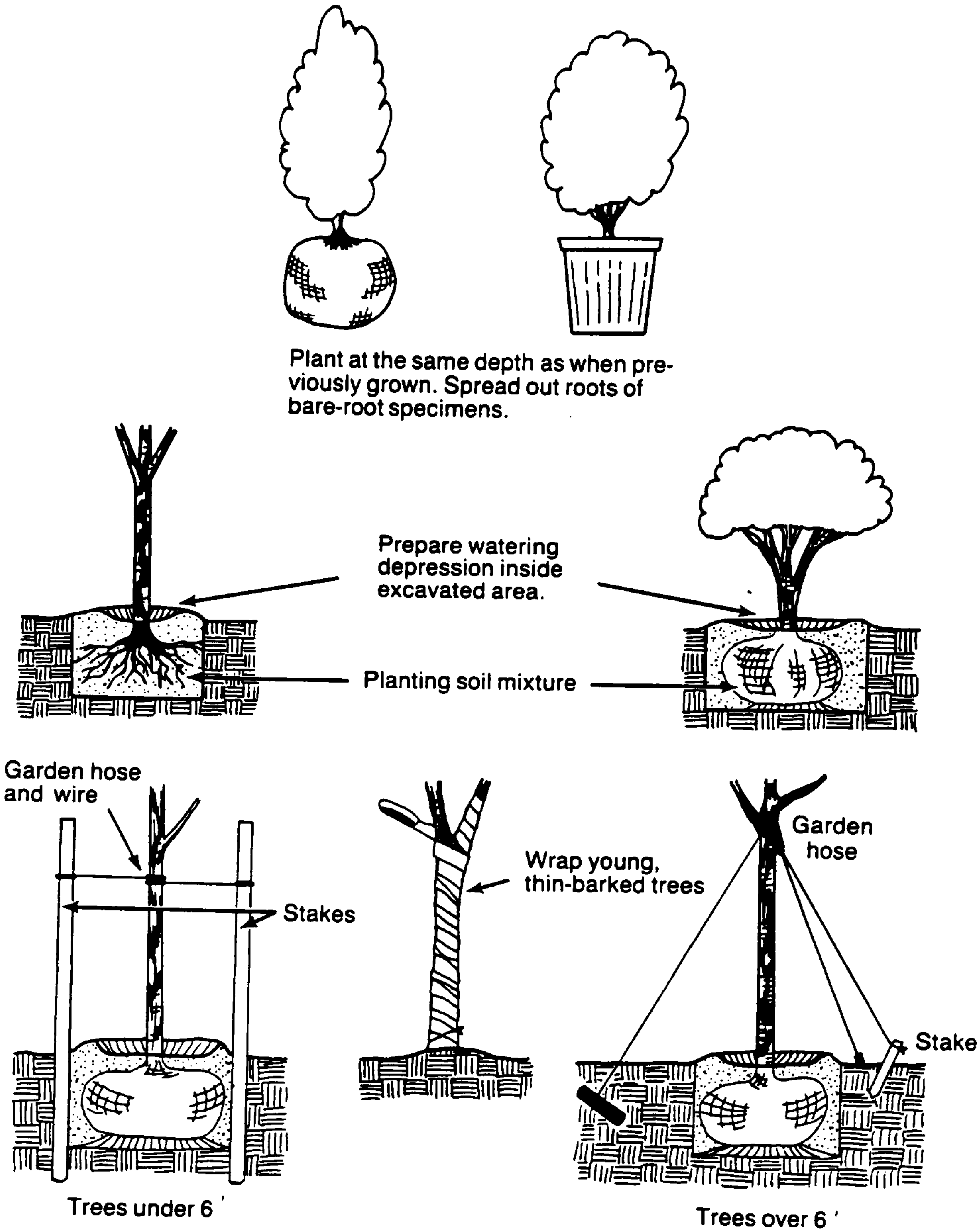
EXHIBIT 2
SELECTING GROUND COVERS

Plant	Height (inches)	Sun	Partial Shade	Shade	Soil	
Buglewood (carpet bugle) (Ajuga reptans)	4 to 8	X	X	X	most soils	One of the best perrenials; spreads rapidly. Parent plant has deep deep green foliage, blue flowers. Gaiety and Metallica Crispa varieties have bronze-purple leaves. Silver Beauty's foliage is cream and light green. Alba is white-flowered.
English Ivy (Hedera helix)	6 to 8	X	X	X	rich, well-drained	Semievergreen to evergreen; covers large or small areas. Look for improved varieties: Baltic, Thornapple, Wilson and others.
Japanese Spurge (Pachysandra terminalis)	up to 6		X	X	fertile, moist	Universally popular evergreen herb. Some plants have small, spiked white flowers sometimes followed by white berries in the fall. Improved forms Green Carpet, Silver Edge.
Juniper* (Juniperus hortizontalis)	12 to 18	X	X		dry areas	Creeping, soft-textured plant; light green to steel blue needles frequently turn purple in winter. Waukegan variety is good. Japanese garden variety is very compact.
Juniper* (J. sabina tamariscifolia)	up to 24	X	X		dry areas	Sometimes called Tamarix Savin juniper. Needle-like silver-green leaves. A good spreader for slopes; use as foreground for deciduous trees or complete ground cover.
Lily-of-the-Valley (Convallaria majalis)	6 to 10		X	X	rich, moist	Fragrant white bell-like flowers; Rosea variety has purplish-pink flowers.
Periwinkle (myrtle) (Vinca minor)	up to 6		X	X	moist, well-drained	Almost universally used. Dislikes humid conditions. Good on slopes, level land or as a backdrop for bulbs. Bowles, a superior variety, has glossier leaves, larger blue flowers. Golden Bowles has gold and yellow foliage with white flowers.
Stonecrop, Goldmoss (Sedum acre)	up to 4	X	X		stony, sandy, dry	Mats of tiny foliage, good between stepping stones and in crevices. Spreads rapidly and can become a weed in grass. The sedum variety, Dragon's Blood, is known for its reddish-brown inch-high foliage and carmine flowers.
Sedum album	up to 4	X	X		sandy, well-drained	Forms mats of attractive dark-green to red foliage on creeping stems. Not as likely to invade grass areas as stonecrop.

* Indicates species best suited for wildlife cover.
Source: USDA, Soil Conservation Service Technical Guide #342.

Exhibit 3

Planting Balled-and Burlapped and Container-Grown Shrubs and Trees

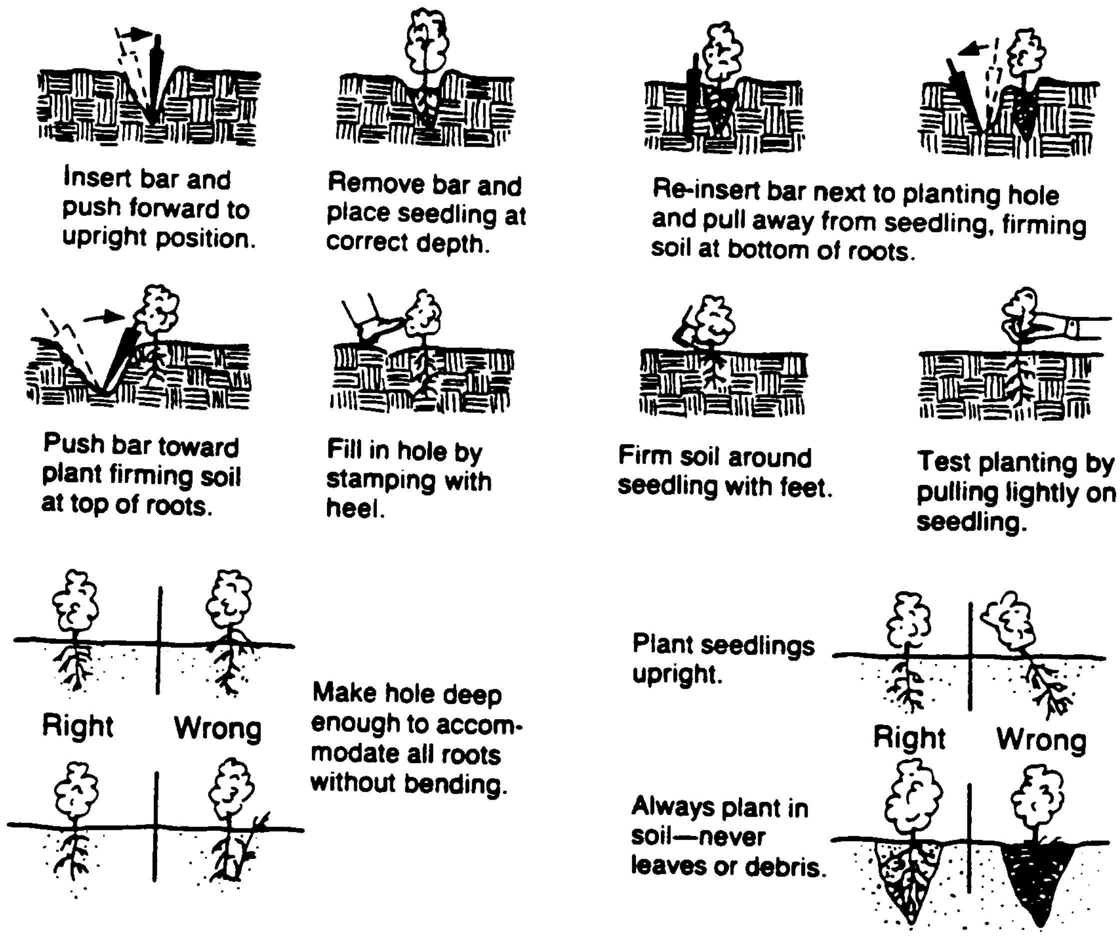


Source: North Carolina Erosion & Sediment Control Planning & Design Manual, as modified from the Virginia Division of Forestry.

Exhibit 4

A Method for Planting Bare-Root Seedlings and Sprigs of Grasses

A method of hand planting bare-root seedlings and sprigged grasses is shown below. With a planting bar/iron or shovel/spade, make a notch in the soil no less than 8 inches deep. Place the roots in the notch to the same depth as the plant was in its original growing container. Firm soil around the roots by pressing the notch closed. Water immediately, and mulch, where necessary, within 2 feet of the plant. Since fertilizers tend to dry out young seedlings, do not fertilize bare-root seedlings until the end of the first year.



Source: North Carolina Erosion and Sediment Control Planning and Design Manual, as modified from the Va. Div. of Forestry.

Exhibit 5

Spacing and Rates of Planting Several Tree Species

Species	Recommended Spacing (Open Planting)		Approx. No. Trees Needed	Acceptable Range
	Between Rows	In Rows	Per Acre	In Rate Per Acre
Jack Pine	8 feet	5 feet	1,050	900-1,200
Spruce & N. White-Cedar	8 feet	6 feet	900	800-1,000
Red Pine	8 feet	7 feet	800	700-950
White Pine	8 feet	7 feet	800	700-950[1]
Hardwood Trees (including black walnut)	10 feet	10 feet	430	400-500[2]
Hardwood Shrubs	6 feet	5 feet	1,450	1200-1800

----

[1]Planting white pine is recommended primarily for understocked wooded areas from Jackson County north because of the white pine weevil. The number of seedlings required for interplanting on a per acre basis will usually be less in a wooded area. Most seedlings should be planted in the small openings where they will have significant amounts of sunlight. From Jackson County south, planting white pine in open fields is an acceptable practice, as well as interplanting.

[2]The spacing for hardwood trees depends upon several factors. Hardwood trees will not grow and develop well when spaced as closely together as conifers; however, competing vegetation is much more detrimental to hardwood plantations particularly in the establishment period. The closer spacing is recommended where the vegetation will only be controlled for approximately 3 years. The close spacing will enable the hardwood crowns to close more quickly and shade out the competing vegetation. Closer spacing will, however, require thinning at an earlier date. Wider spacing requires controlling the vegetation more than 3 years or until the crowns close, which may take up to 6 years. The closer spacing is an alternative to controlling the vegetation for longer periods of time.

Source: USDA Soil Conservation Service Technical Guide #612

WETLANDS BMPs

Wetland Crossings

Description

For the purpose of this BMP, wetland crossings are structures or methods used to cross a wetland. Wetland crossings may be above or below the surface of the wetland. The type of crossing may vary with respect to length, width, height, and construction design, depending on the purpose of the crossing and the environmental and physical attributes of the wetland.

Wetland crossings generally require a permit under the Goemaere-Anderson Wetland Protection Act. Wetland crossings may be permitted where: there is a dependency on their use at a given location; there are no feasible and prudent upland alternatives or less damaging wetland alternatives to crossing at the desired location; and where the crossing will not result in adverse impacts to the wetland.

Other Terms Used to Describe

Boardwalk
Car Path/Foot Path
Decking
Fill Path
Platforms
Wood Chip Paths

Pollutants Controlled and Impacts

These structures minimize soil disturbances and reduce the potential for erosion to occur. In addition, structures which do not impede surface or ground water movement (i.e. boardwalks or equalization culverts) will reduce: the potential for creating backwater areas; the likelihood that the installed structure will fail; and impacts to groundwater recharge and discharge areas.

Application

Land Use
Use this BMP whenever wetlands need to be crossed.

Soil/Topography/Climate
Methods of installation and materials for the crossing will vary depending upon the soils, topography and climatic conditions during installation and throughout the expectant life of the crossing.

Chemical and physical attributes of the wetland soils may shorten the life expectancy of various materials when placed underground and when periodically saturated. Saturated and sometimes unstable/unconsolidated soils may also dictate the use of alternate installation methods.

When to Apply
Construction should be undertaken and completed during drier periods of the wetland. If the area is constantly saturated, installation and construction activities may be required to be done on equipment mats to prevent compaction of the soils.

Conditions of State of Michigan permits may restrict construction during time periods critical to various wildlife or aquatic resources associated with the wetland.

Where to Apply
Wetland crossings will be authorized only in those areas where a crossing is needed to gain access, where there are no feasible and prudent alternatives (potentially including easements across uplands on adjacent parcels), and where the crossing will not unacceptably impact the wetland resource. Generally speaking, crossings should be made at the narrowest possible point of the wetland or in the area of the wetland determined by the MDNR to be least environmentally damaging.

Relationship With Other BMPs

The areas around bridges and culverts may need to be stabilized using Slope/Shoreline Protection.

Specifications

Wetland crossings should normally be designed by registered professional engineers.

General Planning Considerations:
A site evaluation should be conducted to determine the best site for constructing the crossing.

1. The area should have a minimal potential for erosion of the disturbed land cover.

2. The area should be such that various types of crossings can be consolidated into a lesser number of crossings.

3. Avoid areas which have highly saturated wetland soils or habitat deemed important or critical to wildlife.

Above-Ground Crossings:
For most uses, crossing a wetland can be done above-ground. The MDNR prefers the use of **open-pile boardwalks** to cross wetlands, not only because they provide access from one upland area to another (or to a watercourse) with minimal impact to the wetland, but also because they allow users to come into better contact with wetlands. Boardwalks provide for free water movement and require a minimal amount of disturbance to the surface of the wetland. See Exhibit 1.

Unlike boardwalks, fill paths and roadways tend to impede the natural surface flows in a wetland and act as dam-like structures. Fill paths and roadways are not recommended for use by the Department unless absolutely necessary. See Exhibit 2.

1. Use open-pile structures to minimize impacts to the wetland resources. See the Watercourse Crossings BMP for the use of wood preservatives, where applicable.

2. Use structures that do not impede surface or groundwater flow.

3. Use structures that do not require placement of fill within the wetland or sensitive areas.

4. Use structures that do not require placement of fill within floodplains or floodways of a watercourse.

5. Provide proper stabilization of all fill slopes.

6. In the past, fill paths and roadways required removal of the unstable wetland soils before placement of additional fill. The placement of geotextile fabrics over the wetland surface can eliminate the need for excavation of these wetland soils and related additional fill into the wetland.

Temporary Above-Ground Crossings:
Temporary crossings may be authorized to provide access for larger equipment needed for the initial construction of the project area. These temporary structures must be removed upon completion of the needed work, and the crossing site must be restored to its original condition. Permits are required for temporary crossings in jurisdictional wetlands.

1. If possible, plan to work when the ground is frozen to decrease impacts to the wetland area.

2. If it is necessary to work when the ground is not frozen, utilize construction mats or similar measures to minimize impacts, including compaction.

3. Post project restoration should reverse soil compaction, and should include stabilizing and replanting the site if vegetation has been destroyed.

Below-Ground Crossings:
Utility crossings, above ground lines, cables and/or pipelines are all possible methods of below-ground crossings. The MDNR prefers the use of drilling and boring utility lines. This method reduces the likelihood of erosion, as well as disturbance of the bottom substrates which typically occurs with both the plow-in and trenching methods.

1. Localize utility crossings to one location, and/or encase several utilities into one casing. (See Exhibit 3).

2. Below-ground crossings must be designed and installed so as not to drain or adversely impact the wetland.

<u>Maintenance</u>

Annual inspections following spring runoff are important to ensure that there is no erosion, nor deterioration or failure of the structures associated with the crossing.

Exhibits

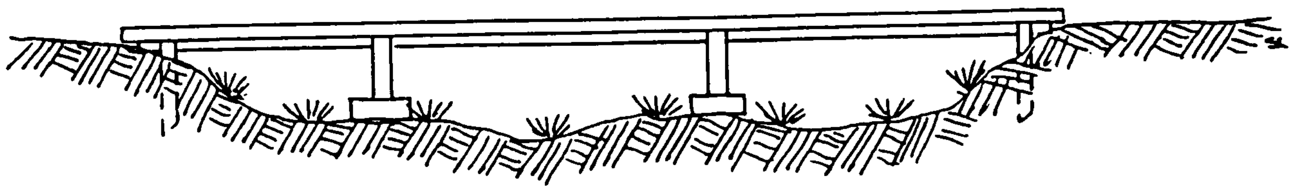
Exhibit 1: Typical Boardwalk. Construction Project Evaluation Manual. Michigan Department of Natural Resources, Land and Water Management Division.

Exhibit 2: Fill Path/Road. Construction Project Evaluation Manual. Michigan Department of Natural Resources, Land and Water Management Division.

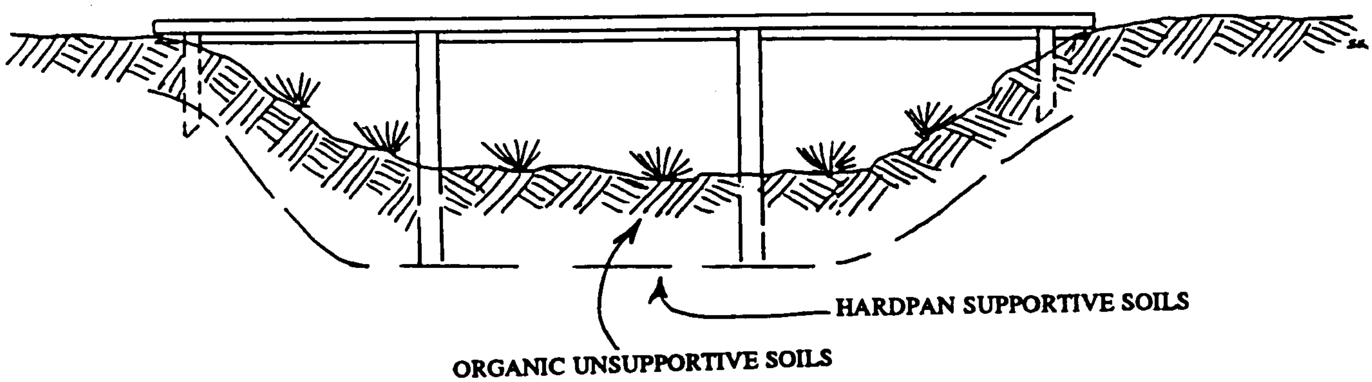
Exhibit 3: Utility Crossing. Construction Project Evaluation Manual. Michigan Department of Natural Resources, Land and Water Management Division.

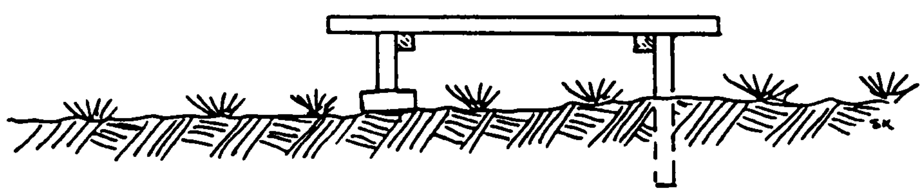
Exhibit 1

Typical Boardwalk



CROSS SECTIONAL VIEW (no scale)



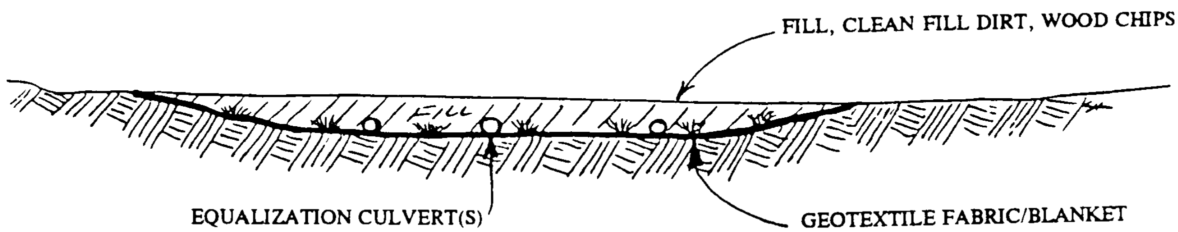


END VIEW--BOTH STYLES SHOWN (no scale)

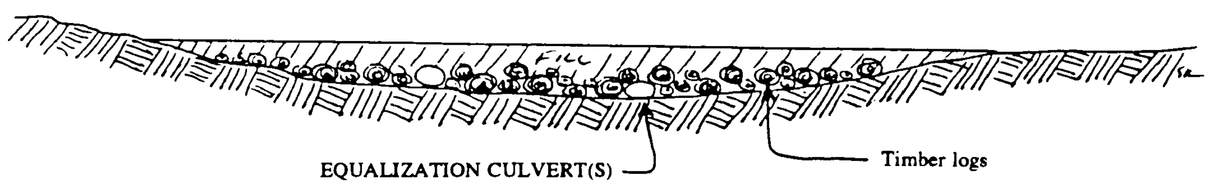
Source: Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

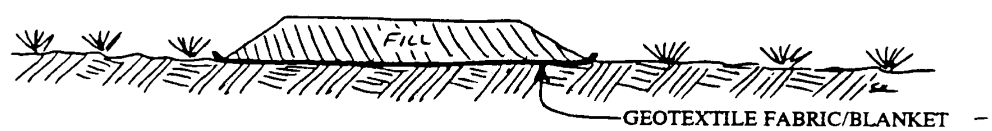
Exhibit 2

Fill Path/Road

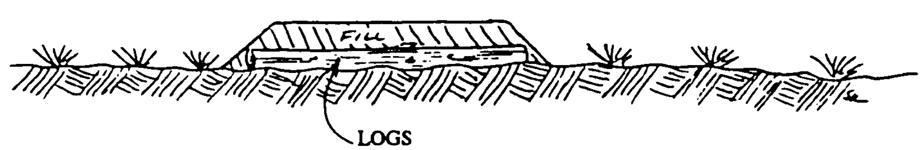


CROSS-SECTIONAL VIEW (no scale)





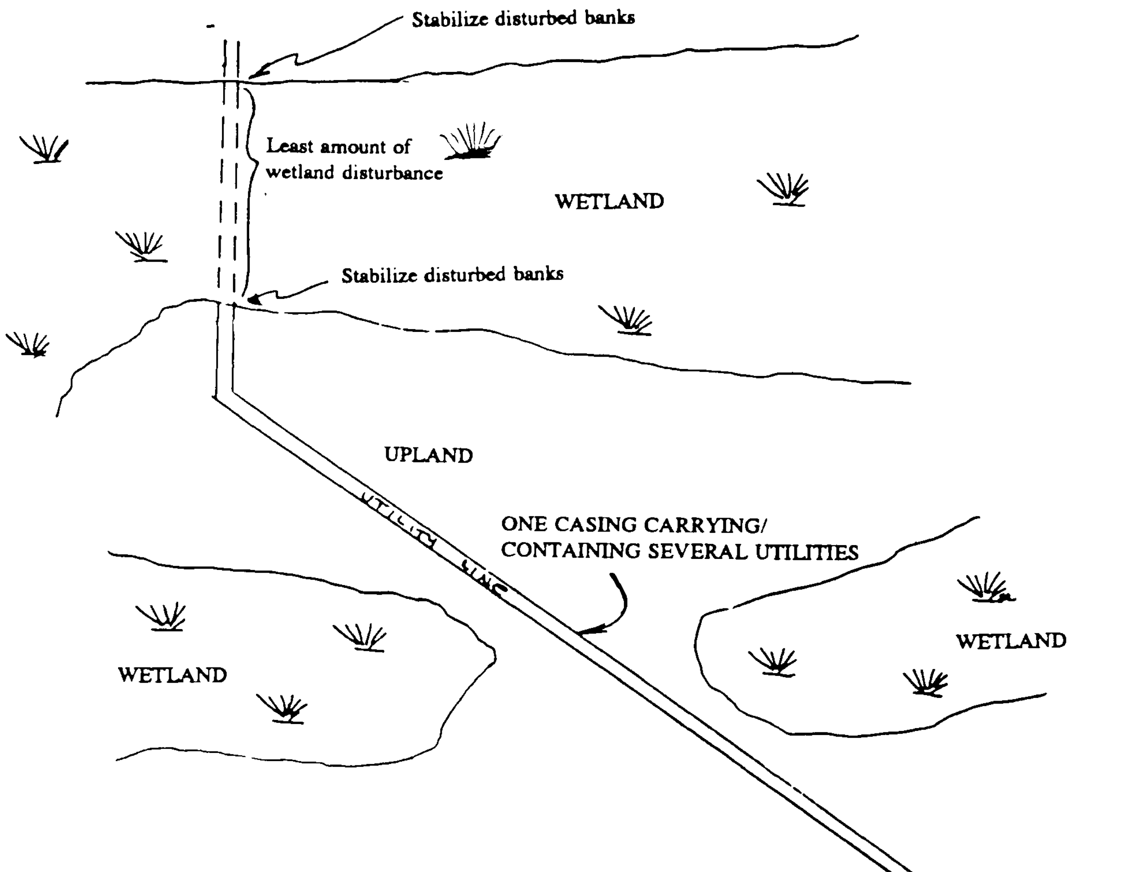
END VIEWS (no scale)



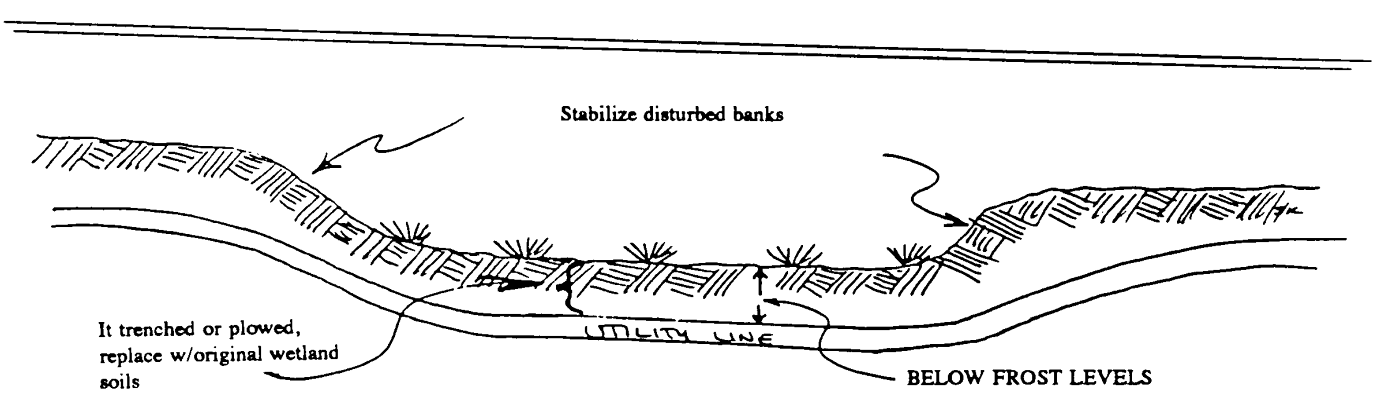
Source: Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

Exhibit 3

Utility Crossing



TOP VIEW (no scale)



CROSS SECTIONAL VIEW (no scale)

Source: Construction Project Evaluation Manual. MDNR, Land and Water Management Division.

Constructed Wetland Use in Nonpoint Source Control

New BMP, September, 1997

Description

Constructed wetlands are excavated basins with irregular perimeters and undulating bottom contours into which wetland vegetation is purposely placed to enhance pollutant removal from stormwater runoff. Stormwater enters a constructed wetland through a forebay where the larger solids and course organic material settle out. The stormwater discharged from the forebay passes through emergent vegetation which acts to filter organic materials and soluble nutrients. The vegetation can also remove some dissolved nutrients. Constructed wetlands can also be designed to reduce peak stormwater flows.

The use of constructed wetlands can be looked at from two ways. First, a constructed wetland may be used primarily to maximize pollutant removal from stormwater runoff and also help to control stormwater flows. Or, it may be used primarily to control stormwater flows, with increased pollutant removal capabilities.

Secondary benefits of constructed wetland include preservation and restoration of the natural balance between surface waters and ground waters, increased wildlife habitats, and higher property values than if the same area was turned into a rectangular stormwater basin.

The following criteria dictate the feasibility of using a constructed wetland for stormwater treatment: 1) the type of wetland designed and its characteristics; 2) the hydrologic characteristics of the designed wetland; 3) the vegetation planted within the wetland (to utilize and lower nutrients and pollutants); 4) the type and volume of nutrients and pollutants entering the wetland prior to treatment; and 5) soil texture.

Note: **This BMP should never be used during the construction phase of any project or for sedimentation control.** Runoff from construction sites is typically very sediment-laden. Such runoff will choke the constructed wetland and may render it useless in a short amount of time. **Existing natural wetland systems should *never* be destroyed to construct another wetland habitat for stormwater treatment.**

Other Terms Used to Describe

Wetlands include fens, bogs, swamps and marshes.

Pollutants Controlled and Impacts

In addition to trapping sediment, nutrients and soluble pollutants may be taken up and assimilated into the plant tissues where they are held until harvesting or the annual fall die-back.

Application

Land Use

Numerous land uses can benefit from the use of created wetlands for the treatment of stormwater. Land uses include agriculture, transportation, recreational areas such as golf courses, and urban and urbanizing areas.

Soil/Topography/Climate

Soil at the site proposed for a created wetland must be suitable to allow for sufficient water retention, infiltration and wetland plant growth. For wetland vegetation, soils must be suitable, from the ground surface to below the static water level. It may be necessary to stockpile topsoil during construction and later overlay it along the wetland bottom and side slopes.

The topography of the site proposed for a created wetland must also be considered. Steep side slopes surrounding the wetland should be avoided since they will deter the growth of wetland vegetation, which in turn increases problems with harvesting and maintenance problems (which may raise potential safety concerns). Minimal excavation is preferred to reduce constructions costs and to produce a more natural looking wetland.

It is also important to know the location of the water table. This information will aid in designing areas that will have standing water.

Climate may be a factor if the wetland will receive large amounts of stormwater during the winter months. Shallow wetland zones may freeze solid in the northern temperate area, thereby decreasing the overall effectiveness of the wetland. The lack of vegetation during the winter will also lower the amount of nutrients and pollutants that can be assimilated into plant tissues. Without aquatic vegetation, the sediment may move through the wetland quickly unless the detention time is long enough for the particles to settle out. Therefore, if the wetland will receive large amounts of stormwater during freezing weather, it may be necessary to provide deep pools that will not freeze solid.

When to Apply

This BMP must not be placed into service until all other construction activities are complete and the wetland and contributing area are stabilized. Again, this prevents overloading the wetland with sediment from unstabilized areas. Wetlands should be considered permanent year-round practices.

Where to Apply

Apply in areas where nutrients and sediment are the primary pollutants of concern. Pre-treatment of toxic contaminants must be assured.

There are some locations where wetlands were historically drained for agricultural and other purposes and *may* no longer meet the scientific and legal definition of a wetland; these sites may provide an excellent opportunity for the re-establishment of wetland habitat for stormwater storage and treatment.

Relationship With Other BMPs

Depending on the quality of the stormwater to be treated by the wetland, it may be necessary to provide some pre-treatment to the water. This follows the "treatment train" concept presented in the Guidebook. It may be necessary to consider the constructed wetland as the last step in a system of BMPs. To provide pre-treatment, consider using Oil/Grit Separators or Catch Basins to remove oil and grease. The following BMPs can be used upstream of a wetland to remove sediment and other solids: Buffer/Filter Strips; Check Dams; Grassed Waterway; Sediment Basins; Extended Detention Basins and Wet Detention Basins. Refer to each BMP for its uses and limitations.

Specifications

Planning Considerations:

Determine if the site selected for the constructed wetland:

- meets the soil/topography/climate and other conditions above. Prior to seeding/planting a wetland, test the soil to determine if the soil will support wetland vegetation, or if a soil enhancement plan should be developed.

- meets the legal definition of a wetland. An existing wetland cannot be destroyed to create another wetland for nonpoint source control. The area must also not contain any threatened or endangered plant or animal species, as these will be impacted upon construction. If any of these conditions exist, the site is not appropriate for a constructed wetland BMP. A qualified wetland scientist should perform the necessary wetland delineation and plant/animal survey prior to design.

- meets sizing requirements. The total surface area of the created wetland should be a minimum of 1% of the area draining into the wetland.

Determine the need the wetland will fulfill. This may include one or more of the following: hydrologic benefits, nutrient uptake, sediment trapping. The design of the constructed wetland will differ depending on its intended use. This BMP discusses four constructed wetland designs.

The construction of a wetland may require local, state and federal permits, depending on the specific circumstances. All relevant laws should be investigated prior to plans being developed to determine the legality of constructing a wetland for stormwater treatment and to ensure that necessary permits are obtained.

Again, it may be necessary to know the location of the water table.

It is essential to establish the emergent and upland plant communities as soon as possible following construction. This should be included in the construction sequence schedule.

Design Considerations:

Several examples of constructed wetland design are shown in Exhibits 1 through 4. Throughout this document the following plant community "zones" will be used to describe constructed wetlands.

These zones are shown in Exhibit 5.

Deep Marsh	18 to 72 inches in depth.
Low Marsh	6 to 18 inches in depth.
High Marsh	0 to 6 inches in depth.
Semi-wet	0 to 24 inches above the normal water level.

Wetland Configuration:
The wetland should be irregular in shape, with a length to width ratio of at least 2:1 preferably 4:1. Inlets and outlets must be placed far apart to avoid short circuiting (in other words, inlet water going directly into the outlet without receiving the treatment of the wetland). The length to width ratio can be increased by using high marsh areas or islands to cause incoming water to meander back and forth on its way through the system. With the proper design characteristics these wetlands can have a natural appearance and still provide all the desired functions for stormwater treatment.

All constructed wetlands should contain a *forebay* at the inlet and *micropool* at the outlet. The forebay at the inlet allows for sediment and other solids to settle out of the stormwater before entering the wetland. This forebay should be located in such a way that sediment can be removed with machinery as it fills up. The micropool at the outlet allows for the collection of all the water in the system at one common point. It also provides for cooling of the water before discharge.

In some cases the “Pocket Wetland” design shown in Exhibit 4 may not lend itself to the use of a properly designed forebay. A smaller “cattail” forebay may be useful at least to trap trash and oil.

The following are guidelines for the size ratios in percent of total surface area of each plant community: Deep Marsh (Forebay) 20%-45%, Low Marsh 25%-40%, High Marsh 30%-40%, Semi-wet (the size of this area depends on the topography surrounding the wetland; steep slopes will produce less semi-wet habitat and shallow slopes will produce more semi-wet habitat). A variety of different depths must be present within the wetland to meet the growing requirements of diverse emergent wetland plants.

Surface Area:
The total surface area of the created wetland should be a minimum of 1% of the area draining into the wetland. The pollutant removal capability of the wetland is increased as the surface area to volume ratio is increased. This ratio can be increased by a) increasing the overall area of the wetland , or b) creating a complex microtopography within the wetland of various pools, shoals and islands.

Volume:
The wetland should be able to contain a treatment volume capable of capturing the runoff generated by 90% of the runoff-producing storms in the region on an annual basis. The forebay should have a minimum treatment volume of 10% of the total wetland treatment volume. The micropool should also have a minimum treatment volume of 10% of the total treatment volume.

Water Depth:
The normal water depth in the forebay and micropool areas should be 3.0 to 6.0 feet. Be sure to allow sufficient capacity for 3 to 5 years of sediment accumulation in the forebay. The depth of the

standing water for the remaining surface area, where the wetland vegetation is installed, should vary between 6 to 18 inches. The depth/area allocation of the wetland should be designed to produce the desired plant communities at maturity.

If the wetland is also used for hydraulic detention, the temporary increase in water depth above the normal water level of the wetland should be no more than 3 feet and should not occur for more than 24 hours. Some wetland vegetation cannot survive inundation for extended periods of time. A wetland specialist can provide detailed information about specific species.

Side Slopes:
Side slopes leading into the wetland should be not more than 3:1 and not less than 10:1. Shallower slopes will promote better establishment and growth of wetland plant species, and will produce a more natural wetland appearance. Shallower slopes also allow for easier mowing and maintenance activities. It is recommended to include in the design a vegetated ten-foot wide shelf, one foot deep, leading to any deeper waters (forebay and micropool) to reduce the hazard potential.

Outlets:
The wetland outlet will control the release rate from the wetland. The outlet must maintain the desired water level in the wetland and provide the desired release rate for a range of storm events. Wetlands which are designed for extended detention may need to use multiple outlets. Outlet design and flow routing through the wetland are complex procedures which should be done by licensed professional engineers. A detailed design method can be found in the "Stormwater Management Guidebook," published by the Michigan Department of Environmental Quality, Land and Water Management Division.

If an outlet pipe is used, it should be designed to draw water from one foot below the water surface. This will decrease clogging from floating vegetative material and will also draw cooler water from the bottom of the wetland.

The outlet should be designed so that trapped trash and debris can be easily removed.

An additional valved outlet should be provided to drain the wetland for maintenance.

A stabilized outlet structure must be used at the discharge of the forebay and at the outlet from the wetland. This will prevent erosion within the wetland and at the discharge point. See the Stabilized Outlets and Riprap BMPs for more detail regarding proper design.

An example outlet structure is shown in Exhibit 5 of this BMP and in the exhibits of the Extended Detention Basin BMP.

Emergency Spillway:
An emergency spillway must be provided to safely discharge from the wetland during storms which exceed design. A common design condition of an emergency spillway is the 50 to 100-year storm event. However, in wetland design the emergency spillway should be placed to limit the extended detention of stormwater to a maximum of 3 feet or the 50 to 100-year design storm, whichever is less.

Water Balance:
An adequate dry weather water balance for the wetland must be maintained throughout the year. This entails the measurement of the incoming base flow to the wetland as well as using soil borings to determine the elevation of the water table and soil permeability rates. This data can then be used to determine if the water inputs (runoff, precipitation, and groundwater) are greater than the water losses (discharge, infiltration, and evaporation). To maintain the water level during the dry season, it may be necessary to install a clay or plastic semi-permeable or impermeable liner. The need for a liner shall be determined by the examination of the preceding information. Some liners are discussed further in the Pond Sealing and Lining BMP (although this should not be treated as an exclusive source of information).

Vegetation:
A qualified wetland scientist should prepare the portion of the design that relates to vegetation (plant species) selection, installation, and harvesting procedures. The wetland should contain a high diversity and density of wetland plant species. The plant communities should be designed by creating a functional pondscape within and around the wetland. This planning will increase the wetland's ability to remove nutrients and pollutants and will provide habitat diversity within the created wetland.

Establishing the emergent and upland plant communities as soon as possible following construction will allow the wetland to begin stormwater treatment and will provide erosion control during the first growing season.

Periodic harvesting of the vegetation is essential in stimulating the growth of many plant species, thereby allowing them to remove more of the nutrients flowing into the wetland. Periodic harvesting also may remove accumulated nutrients and excess organic material and thereby extend the life of the constructed wetland.

Wildlife Enhancement:
Measures to further enhance habitat for wildlife are encouraged. Wildlife enhancement, however, is a secondary concern. For the purposes of this BMP, pollutant removal and hydraulic detention are the primary concern. Additional wildlife elements may be added to increase the use of the wetland by wetland-dependent animal species. This becomes even more important in areas which are predominantly urban and have lost much of their natural habitat. For example, maximizing vegetation density around the wetland will attract numerous waterfowl and other species while discouraging the entry of domestic animals that would prey on wildlife. Wildlife use should not be encouraged if toxic or harmful pollutants are expected to accumulate within the water, soil or plants.

Construction Considerations:
Wetlands contain areas of deep water and muck soils which may present a safety hazard for those persons working or playing in and around them. Depending on local regulations, wetland areas may need to be fenced during and after construction for increased safety. Special care should always be taken during the initial seeding/planting and at harvesting times to minimize potential problems.

Maintenance

A detailed maintenance plan must be developed which specifies short and long-term maintenance of the wetland. The complexity of the plan is dependent on the complexity of the design. For simple structures the plan may only need to specify how often to mow and inspect the banks, when to inspect inlet and outlet structures for signs of clogging and when to remove sediment. More complex structures with mechanical devices such as valves or pumps may require much more detail, including manufacturer's maintenance recommendations. It is a good idea to develop a checklist for maintenance items which includes the schedule for the maintenance or inspection and a date and signature for when it was completed.

The maintenance plan should include the following at a minimum:

- Specify what individual or agency is responsible for which maintenance items. If several agencies are involved each must agree to do their portion of the maintenance.
- Inspect the wetland twice a year and after major storm events. Initially, determine if it is working according to design, look for signs of eroding banks or excessive sediment deposits and insure that plant growth is occurring as expected. Routine inspections should include looking for clogged outlets, dike erosion and nuisance animals. Be sure to specify what measures to take to correct any defects.
- Determine what the maximum sediment accumulation in the forebay and micropool can be from the design. Sediment accumulation should not reduce the treatment volume to less than 10% of the total wetland treatment volume. Specify how to measure the sediment accumulation, how to remove excess sediment and where to dispose of it.
- Remove floatables and trash as necessary.
- Inspect structures such as riprap or concrete for signs of damage. Inspect and test any mechanical structures such as gates, valves or pumps.
- Mow the banks and access roads at least twice per year to prevent the growth of woody vegetation.
- Harvesting (the periodic annual or semiannual cutting and removal of wetland vegetation) is necessary to maintain the capability of the wetland to remove soluble nutrients and pollutants. Harvesting the vegetation promotes plant growth and thereby the uptake of soluble nutrients and pollutants from stormwater. A written harvesting procedure should be prepared by a qualified wetland scientist. The plan should include how to dispose of harvested material.
- Harvesting vegetation within a natural wetland is often difficult due to the topography and thick organic soils present. However, a constructed wetland can be designed in a manner that decreases harvesting and maintenance practices and associated costs.

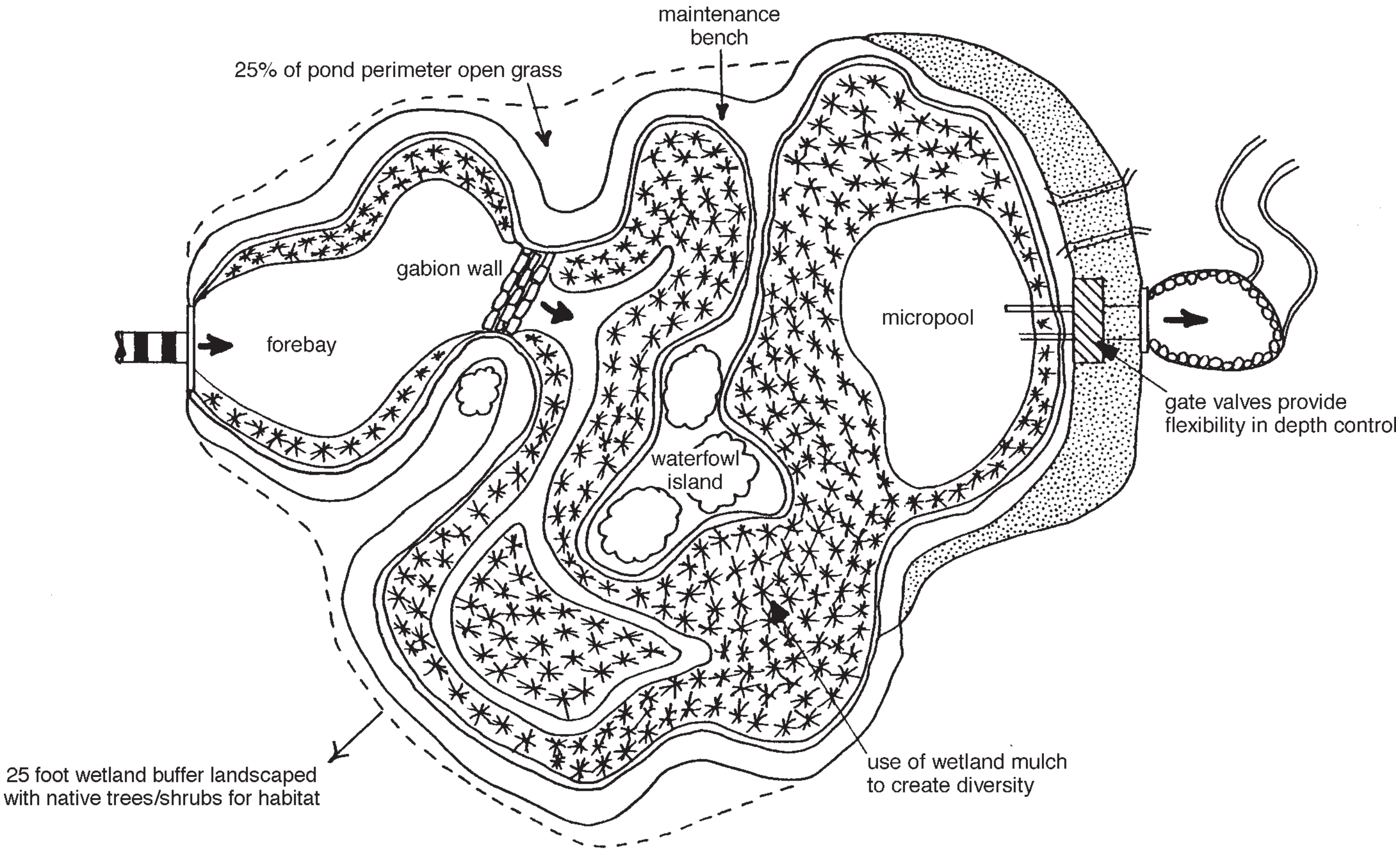
Exhibits

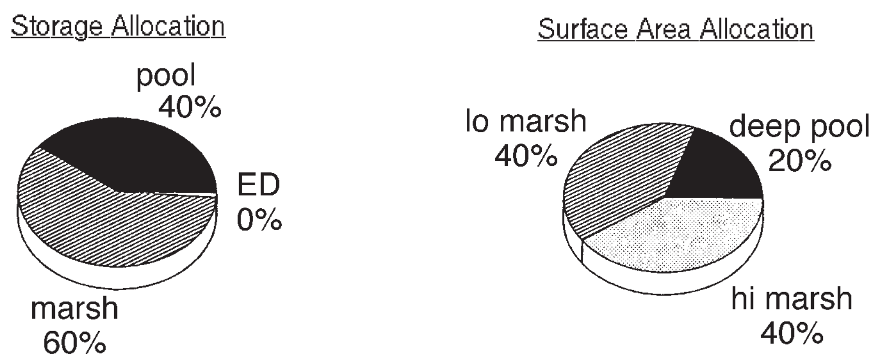
All five exhibits were taken from "Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region." Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Council of Governments.

Exhibit 1: The Shallow Marsh System
Exhibit 2: The Pond Wetland System
Exhibit 3: The Extended Detention Wetland
Exhibit 4: The Pocket Stormwater Wetland
Exhibit 5: Extended Detention Wetland Outlet Structure

Exhibit 1

The Shallow Marsh System



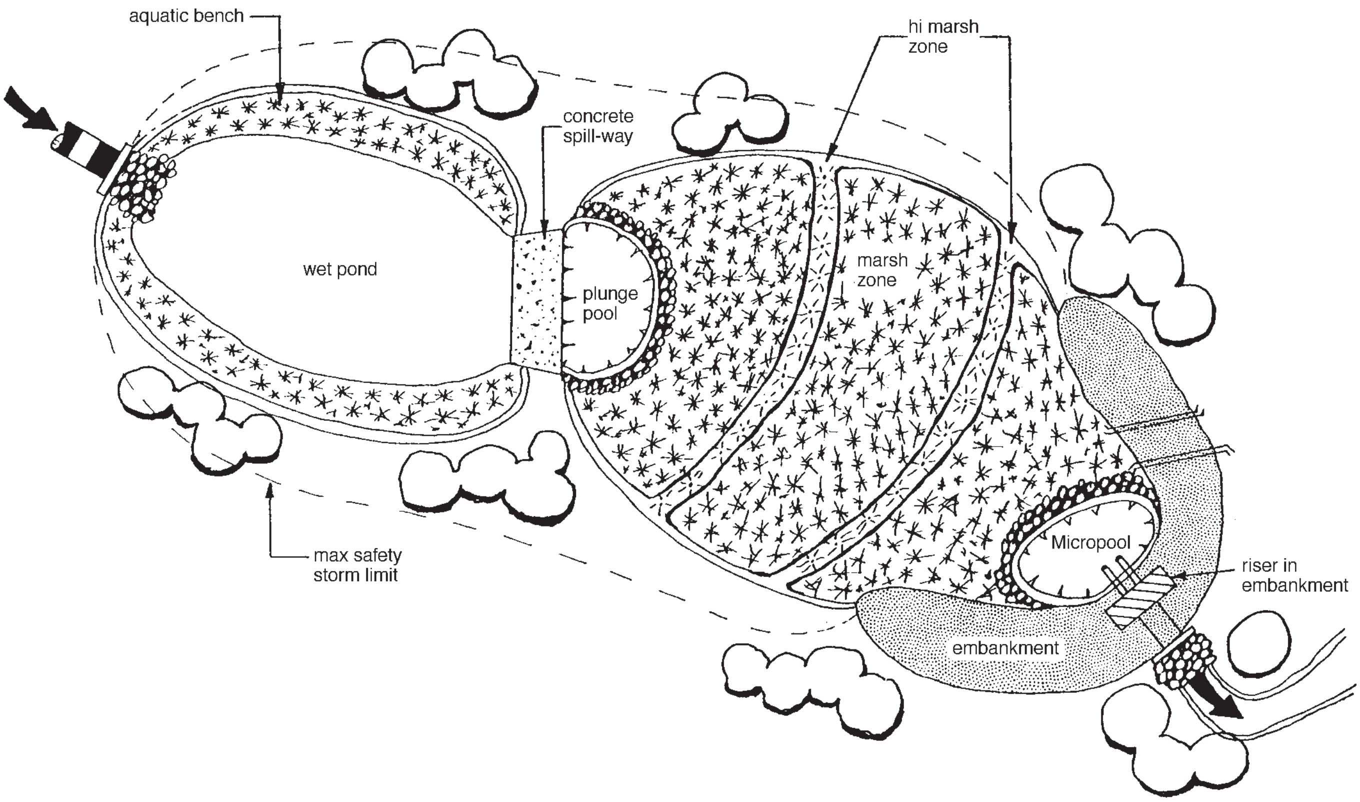


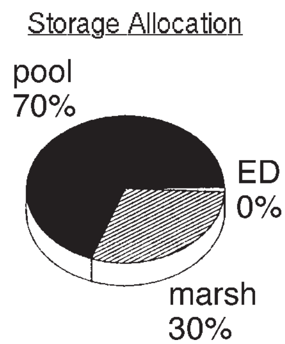
The majoriy of the shallow marsh system is zero to eighteen inches deep, which creates favorable conditions for the growth of emergent wetland plants. A deeper forebay is located at the major inlet, and a deep micropool is situated near the outlet.

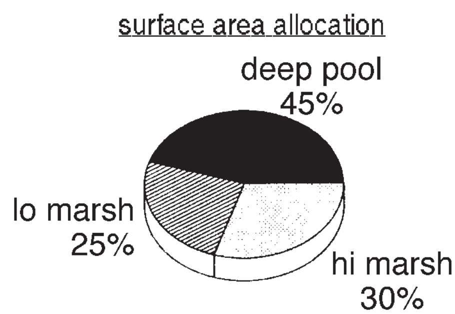
Source: "Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region." Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Council of Governments.

Exhibit 2

The Pond/Wetland System





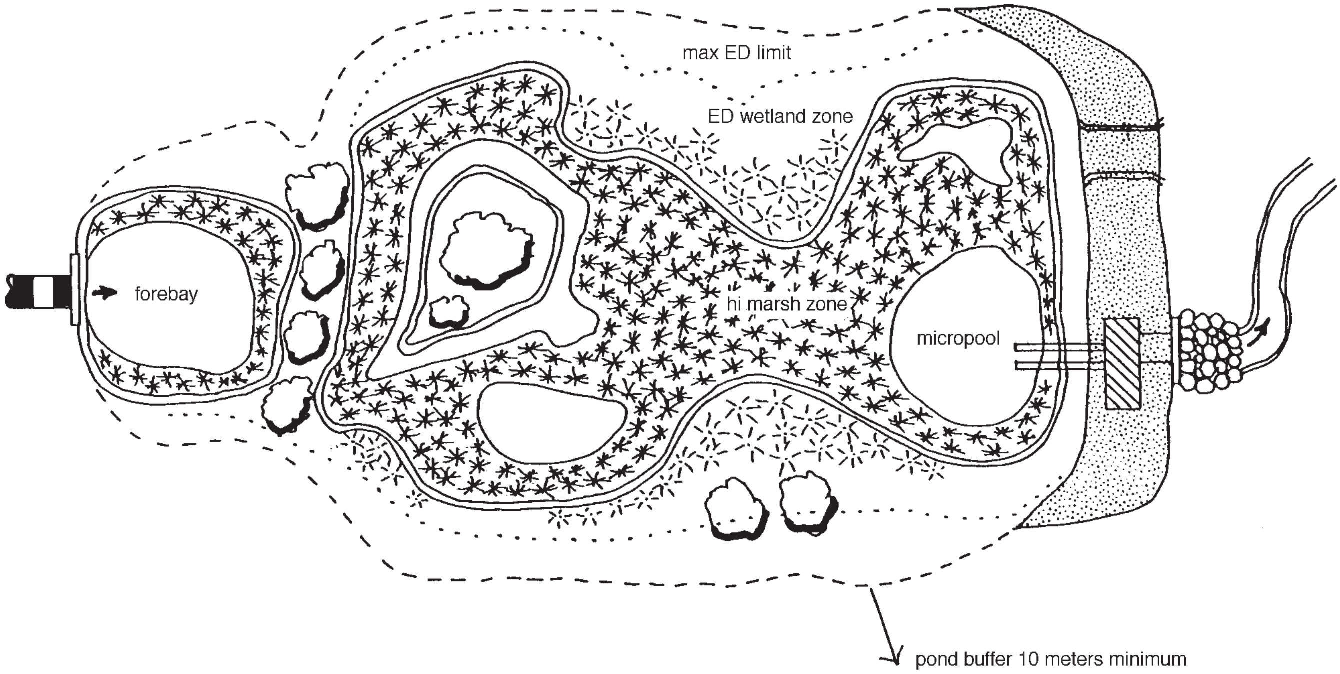


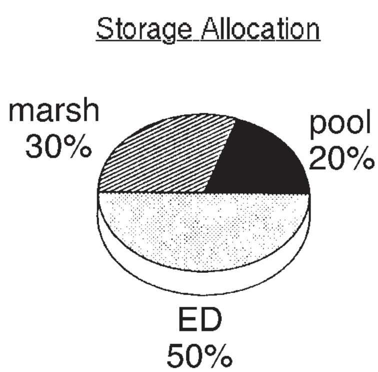
The pond/wetland system consists of two separate cells — a deep pond leading to a shallow wetland. The pond removes pollutants, and reduces the space required for the system.

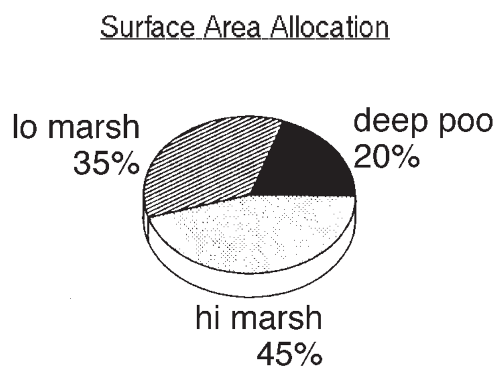
Source: "Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region." Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Council of Governments.

Exhibit 3

The Extended Detention Wetland





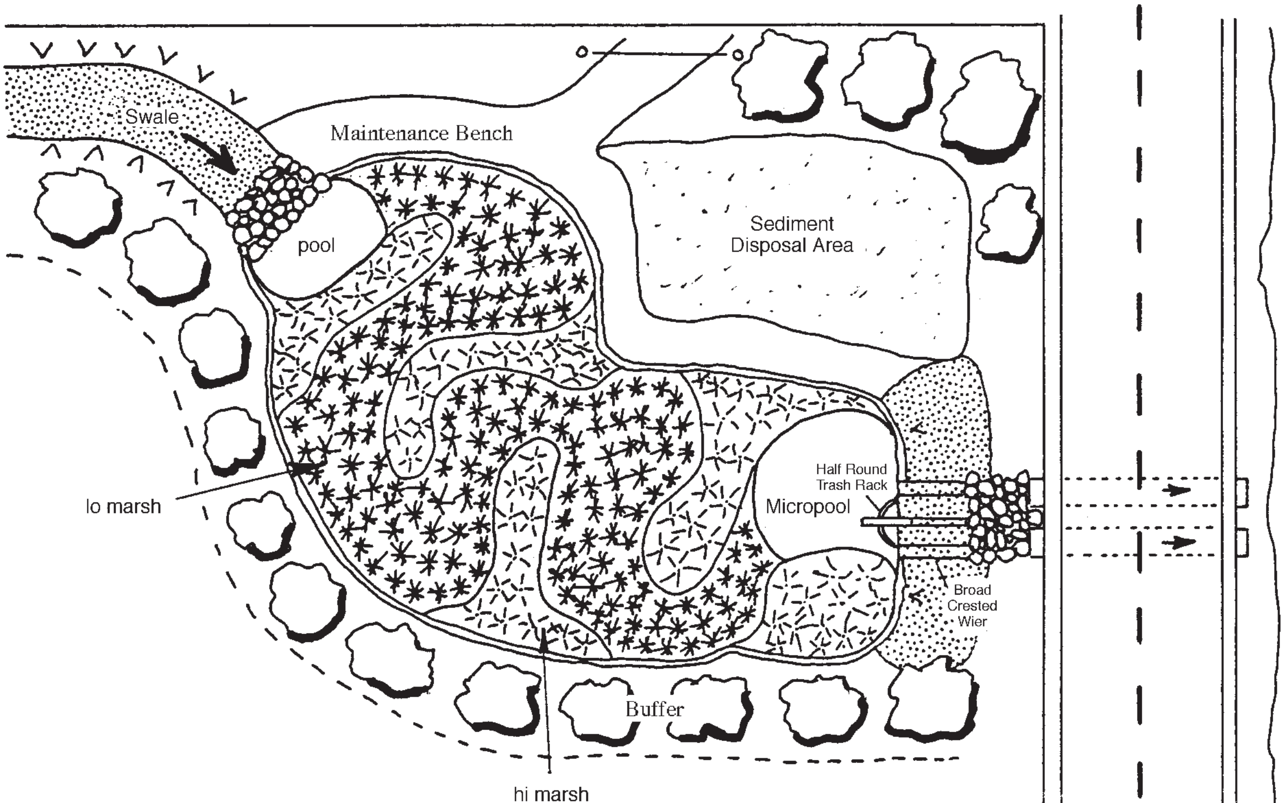


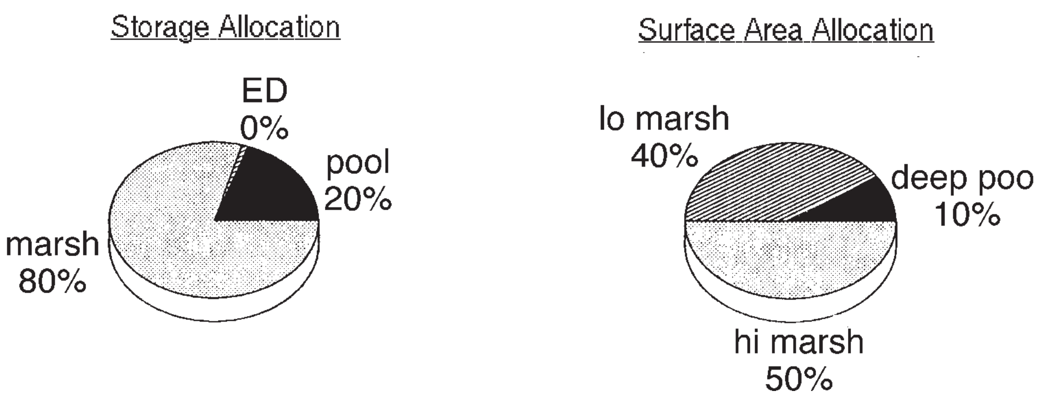
The water level within an ED wetland can increase by as much as three feet after a storm event, and then returns to normal levels within 24 hours. As much as 50% of the total treatment volume can be provided as ED storage, which helps to protect downstream channels from erosion, and reduce the wetland's space requirement.

Source: "Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region." Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Council of Governments.

Exhibit 4

The Pocket Stormwater Wetland



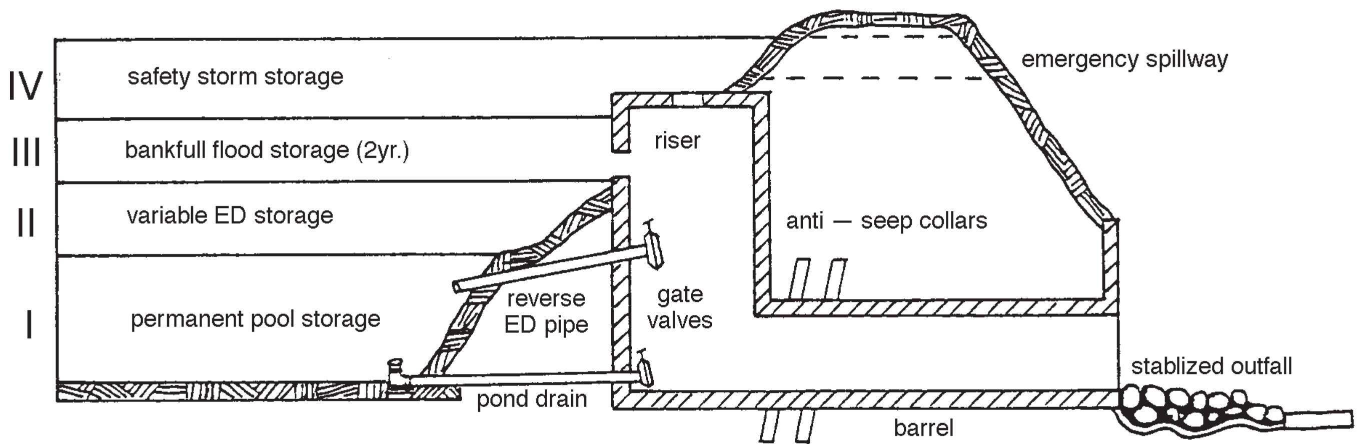


Pocket wetlands seldom are more than a tenth of an acre in size, and serve development sites of ten acres or less. Due to their size and unreliable water supply, pocket wetlands do not possess all of the benefits of other wetland designs. Most pocket wetlands have no sediment forebay. Despite many drawbacks, pocket wetlands may be an attractive BMP alternative for smaller development situations.

Source: "Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region." Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Council of Governments.

Exhibit 5

Extended Detention Wetland Outlet Structure



The micropool of an ED wetland system is 4 to 6 feet deep, and helps protect the orifice of the reverse slope pipe extending from the riser. The pipe withdraws water within one foot of the normal pool, and is equipped with a gate valve to adjust detention times. The pond drain pipe is also equipped with a gate valve, and is used to drain the entire wetland for planting or sediment cleanout.

Source: "Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region." Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Council of Governments.

APPENDICES

APPENDIX 1

ONE METHOD OF CALCULATING RUNOFF

Appendix 1

Computing Flood Discharges

For Small Ungaged Watersheds

Richard C. Sorrell, P.E.
and
David A. Hamilton, P.E.

Michigan Department of Natural Resources
Land and Water Management Division
October, 1991

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1. INTRODUCTION

Concern for potential flooding is needed to safely design water-related projects. The magnitudes of floods are described by flood discharge, flood elevation, and flood volume. This report will detail a procedure that can be used to estimate both the discharge and volume of a flood given a design rainfall and a physical description of the watershed.

There are a variety of methods for estimating design floods. They can be grouped into three general categories.

1. Statistical analysis of gage data

   This method is used for streams which have a number of years of recorded flood data. It involves fitting a probability distribution to the data (usually the log-Pearson Type III) and using the parameters of the distribution to estimate large floods. Since this method utilizes actual flood data, it is generally regarded as the best estimator of design floods and should be used whenever possible.

2. Regression analysis

   This method involves correlating watershed characteristics to streamflow using data from a number of gaged streams. The predicting equation derived from this type of analysis usually expresses flood discharge as a function of multiple watershed characteristics. These equations almost always include drainage area as the most significant factor and may also include channel slope, precipitation intensity, and other characteristics related to land uses, soil types, and geologic formations in the watershed. This method can be used for ungaged stream locations.

3. Unit hydrograph techniques

   This method involves determining the peak rate of runoff Q_p expressed in cfs per inch of runoff from a given drainage area. This factor is primarily a function of the time it takes for runoff to travel through the basin to the design point. Once this rate of runoff is determined, it can be multiplied by the amount of runoff to produce a discharge. The versatility of this method is that it can account for changes in watershed travel time, and subsequently Q_p, which are caused by alterations in the hydraulic capacity of the stream, such as channel maintenance operations, flood control structures, etc. The volume of runoff from a given amount of rainfall can also be adjusted to reflect changing land use within a watershed. This method is also suitable for ungaged watersheds.

This report presents a method for computing flood discharges using unit hydrograph (UH) techniques. The procedure is similar to that developed by the U.S. Soil Conservation Service (SCS) and described in National Engineering Handbook, Hydrology: Section 4 (1972).

The advantage of this method is that it is straightforward to apply and the physical parameters are easily determined. The primary disadvantage is that the method presented here is only valid for use with a 24-hr rainfall. For other rainfall durations, one should follow the full procedure in the SCS reference. This method should also be limited to watersheds with a drainage area of approximately 20 mi^2 or less. The reason for this limit is that UH theory assumes uniform runoff from the entire basin. This assumption is less reliable if the drainage area becomes too large. If a large watershed is being analyzed, it should be divided into subbasins and the flows from the individual subareas routed to the design location.

The physical description of the watershed includes drainage area, soil types, land uses, and time of concentration. These are discussed in subsequent sections of this report.

A comprehensive application of this method is presented in Appendix A.

2. THE UNIT HYDROGRAPH

First proposed by Sherman (1932), the unit hydrograph of a watershed is defined as a surface runoff hydrograph (SRH) resulting from one inch of excess rainfall generated uniformly over the drainage area at a constant rate for an effective time duration. Sherman originally used the word "unit" to denote a unit of time, but since then it has often been interpreted as a unit depth of excess rainfall. Sherman classified streamflow into surface runoff and groundwater runoff or baseflow. The UH is defined for use only with surface runoff. When analyzing a recorded flood hydrograph, the baseflow contribution should be subtracted from the total flow before deriving the UH. Likewise, when using an UH to compute a design flow, a baseflow should be added to obtain the total design discharge.

The following basic assumptions are inherent to the UH:

1. The excess rainfall has a constant intensity within the unit duration.
2. The excess rainfal1 is uniformly distributed throughout the whole drainage area.
3. The base time of the SRH (the duration of surface runoff) resulting from an excess rainfall of a given duration is constant.
4. The ordinates of all SRH's of a common base time are directly proportional to the total amount of surface runoff represented by each hydrograph.
5. For a given watershed, the hydrograph resulting from a given excess rainfall reflects the unchanging characteristics of the watershed.

Assumption 3 implies that all 24-hr rainfalls will produce a SRH where the time to peak and base time of the SRH remain constant. Assumption 4 implies that if the ordinates of the UH represent one inch of runoff, then a hydrograph representing two inches of runoff is obtained by simply multiplying each ordinate of the UH by 2. If all unit hydrographs conform to a constant shape, that is, a constant amount of volume under the rising limb of the UH, then both the time and discharge ordinates can be normalized to produce a dimensionless UH. SCS has examined many hydrographs nationwide and computed a standard dimensionless UH which has 37.5 percent of the volume under the rising limb. This volume has been known to vary, according to SCS, in the range of 23 to 45 per cent.

Over the years, use of the SCS dimensionless hydrograph consistently overestimates discharges when compared to recorded gage flows for Michigan streams. To partially compensate for this, the SCS Type I rainfall distribution has been used in place of the recommended, but more intense, Type II distribution. A review of hourly rainfall data shows, however, that the Type II distribution is the appropriate one to use. Therefore, a study has been done to evaluate whether the shape of the standard SCS dimensionless UH is applicable to Michigan streams.

This study involved 24 gaged streams with drainage areas less than 50 mi^2. Seventy-four different flood events were analyzed. The results from this study demonstrate that the recorded floods are best reproduced if the SCS UH has 28.5 per cent of the volume under the rising limb. This value is within SCS's acknowledged range for this parameter.

3. DESIGN RAINFALL

Atlases are available from various governmental agencies which provide design rainfall amounts for durations from 30 minutes to 24 hours and recurrence intervals from 1 to 100 years. Normal practice in Michigan has been to use 24 hours as the design rainfall duration. The rainfall amounts have been taken almost exclusively from Hershfield (1961), commonly known as the U.S. Weather Bureau's technical paper TP-40.

Rainfall amounts in excess of the 100-year values from TP-40 have been occurring in Michigan regularly for a number of years. Part of the reason may be that TP-40 only utilized data through 1958. Sorrell and Hamilton (1991) analyzed 24-hour rainfall data from Michigan gages in order to update the TP-40 information. Figures 3.1 to 3.6 are from that study and should be used with the design method presented in this report. Areas unbounded by two contour lines should use a constant value equal to the nearest rainfall contour.

The design rainfalls obtained from the figures may be used for drainage areas up to 10 square miles. For larger watersheds, the rainfall should be adjusted to account for areal distribution. This adjustment is shown in Table 3.1. These factors are taken from Table 21.1 in the SCS National Engineering Handbook reference. Values for intermediate drainage areas may be interpolated in the table.

Table 3.1 Ratios for areal adjustment of point rainfalls

Area (mi^2)	Ratio
= 10	1.00
15	.978
20	.969
25	.964
30	.960
35	.957
40	.953

Figure 3.1 2-year, 24-hour rainfall

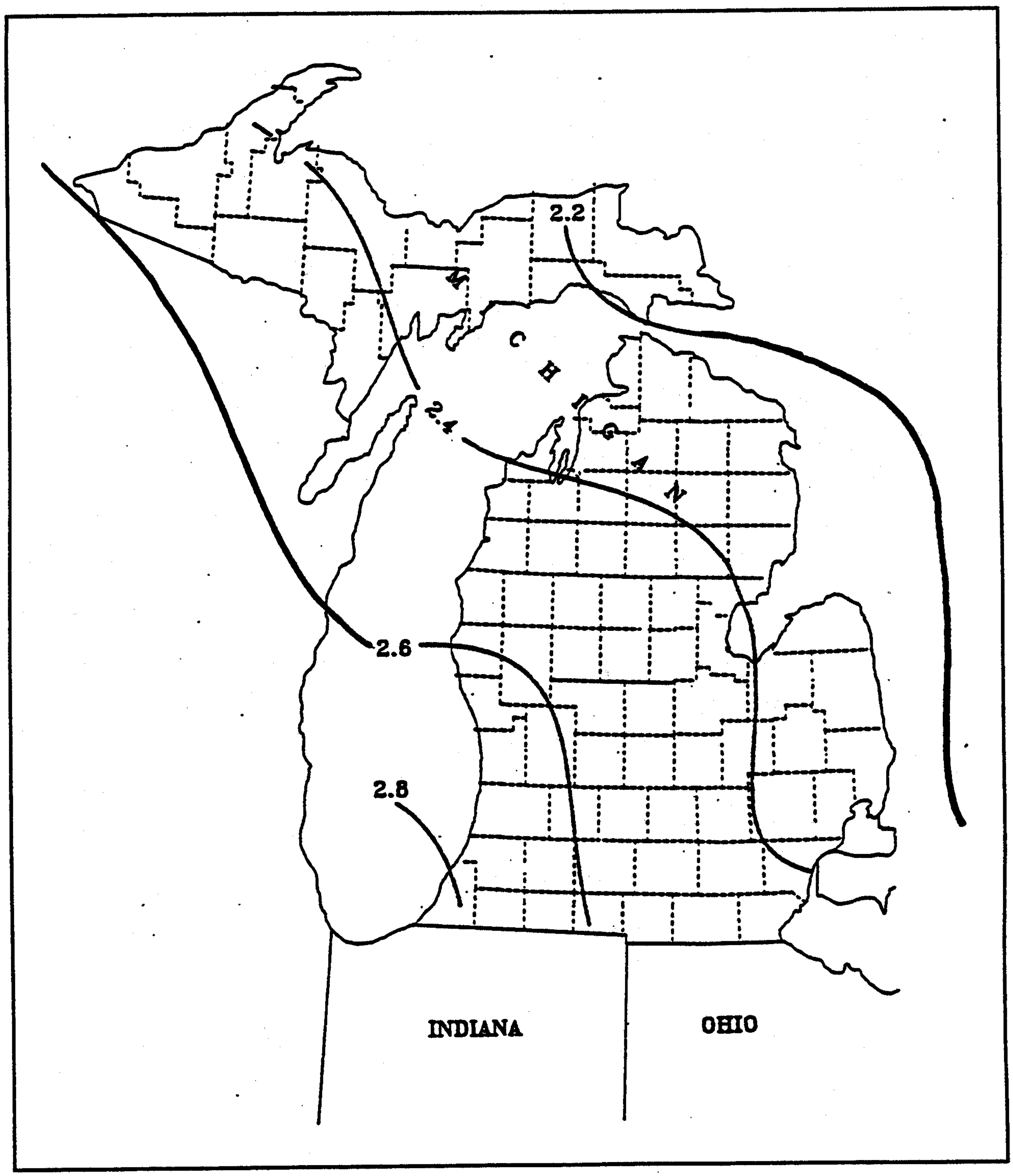


Figure 3.2 5-year, 24-hour rainfall

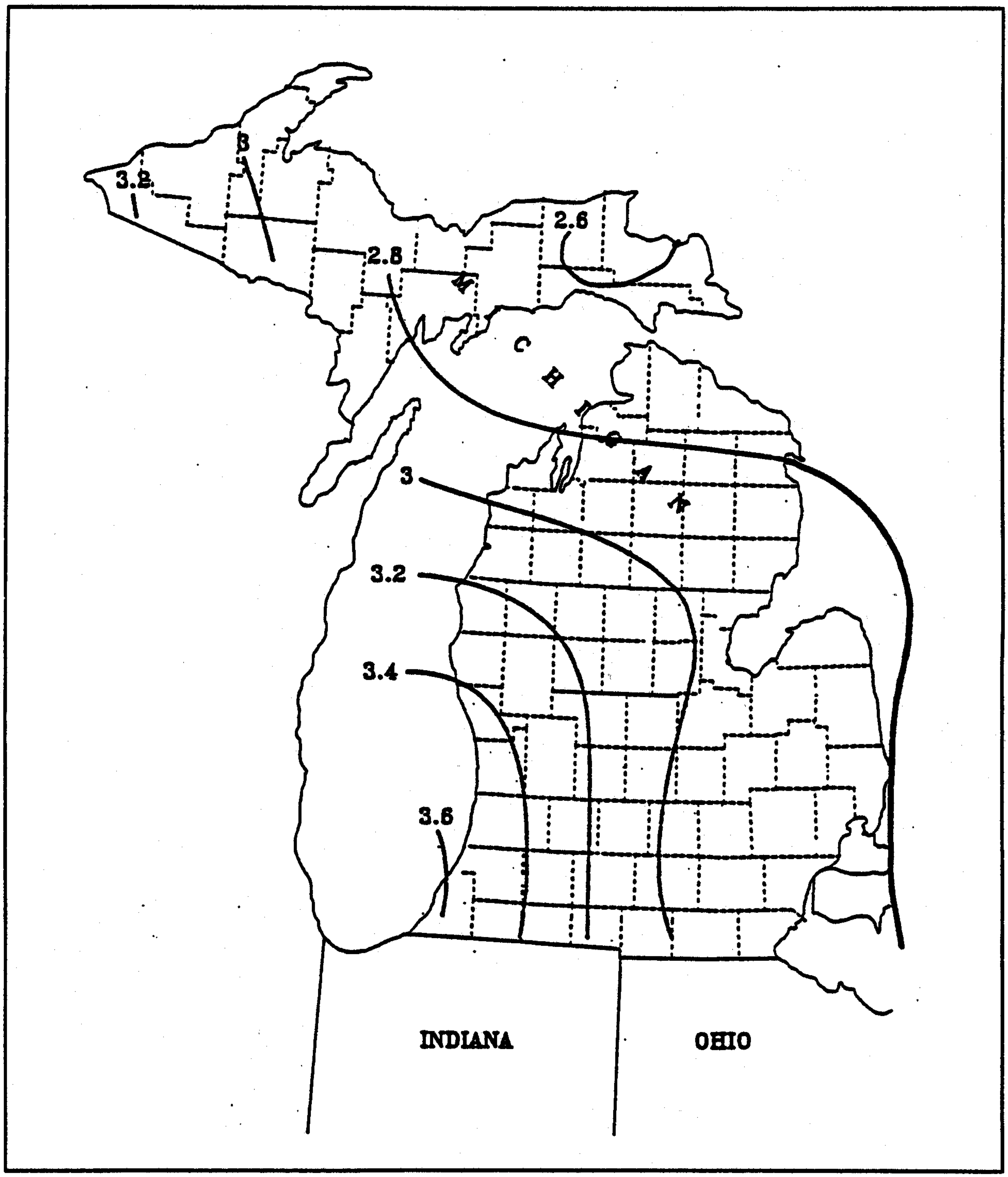


Figure 3.3 10-year, 24-hour rainfall

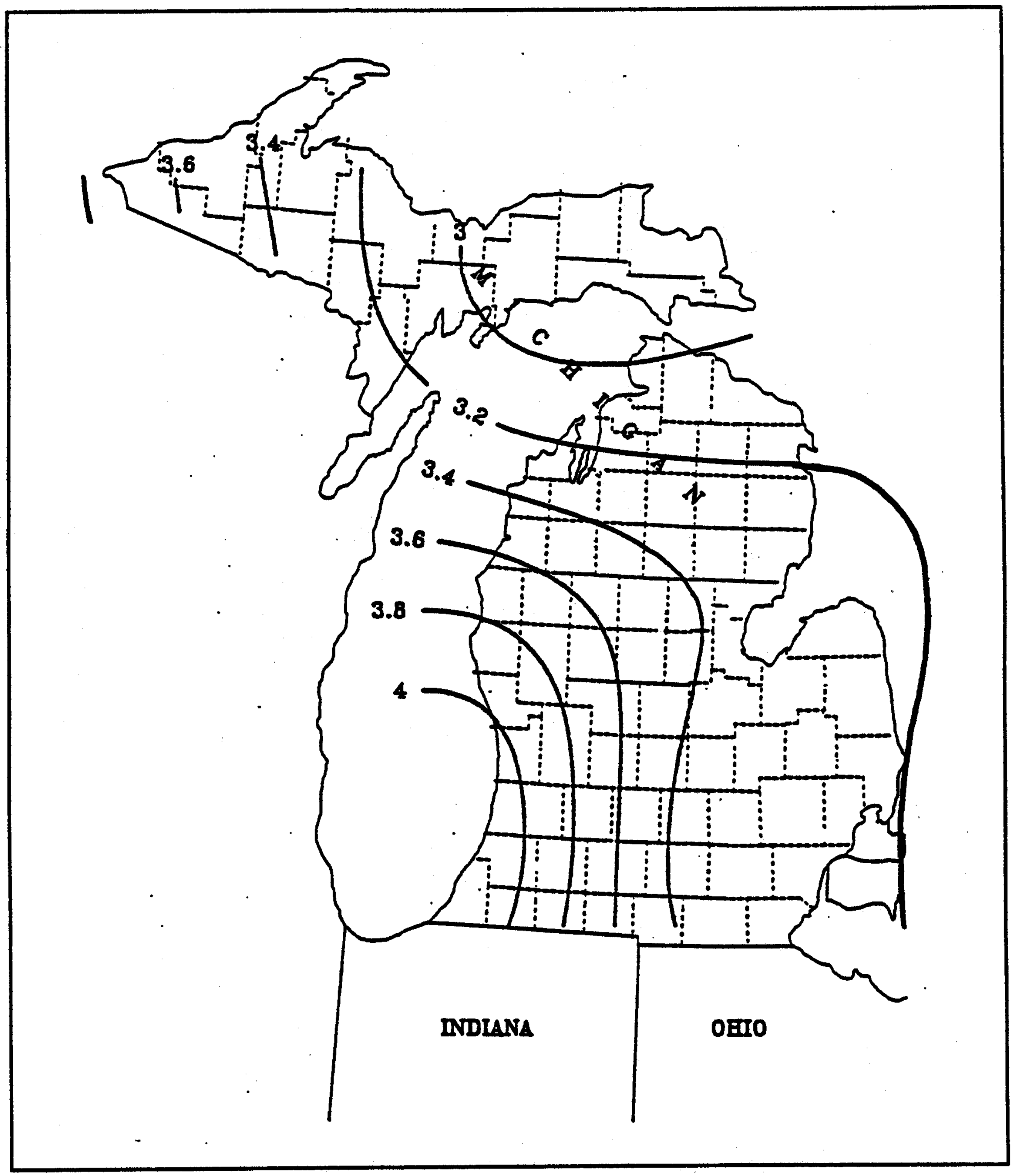


Figure 3.4 25-year, 24-hour rainfall

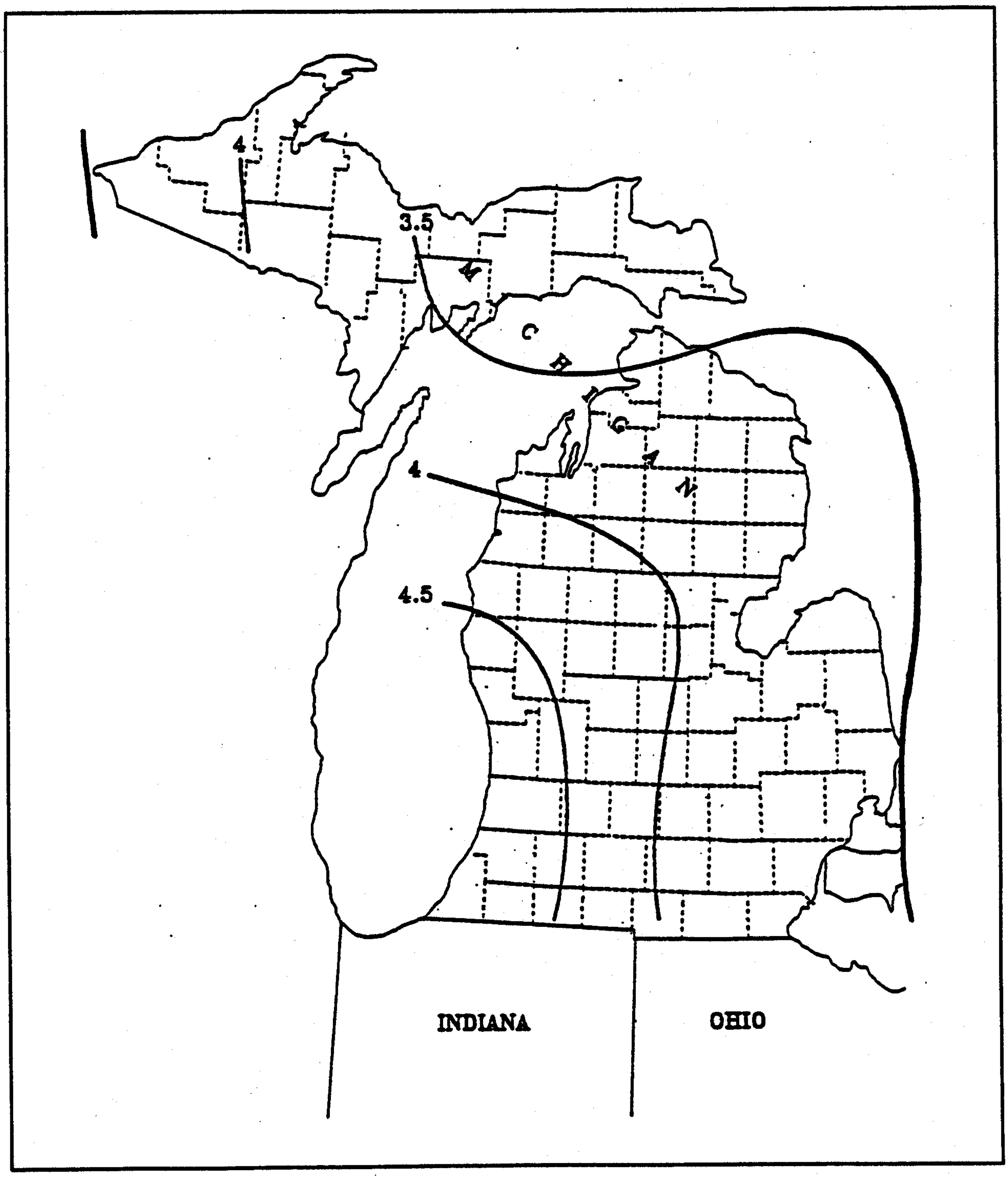


Figure 3.5 50-year, 24-hour rainfall

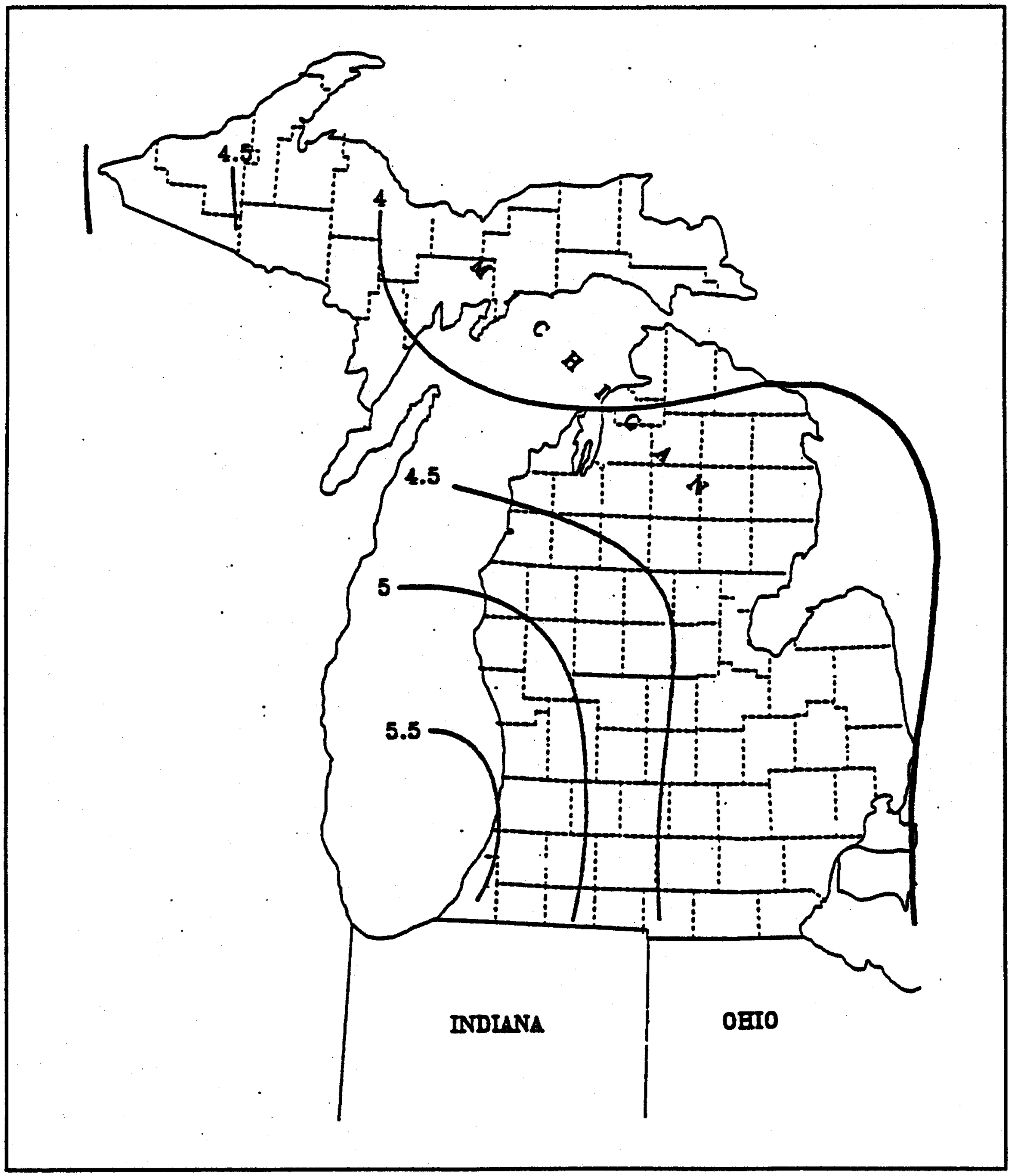
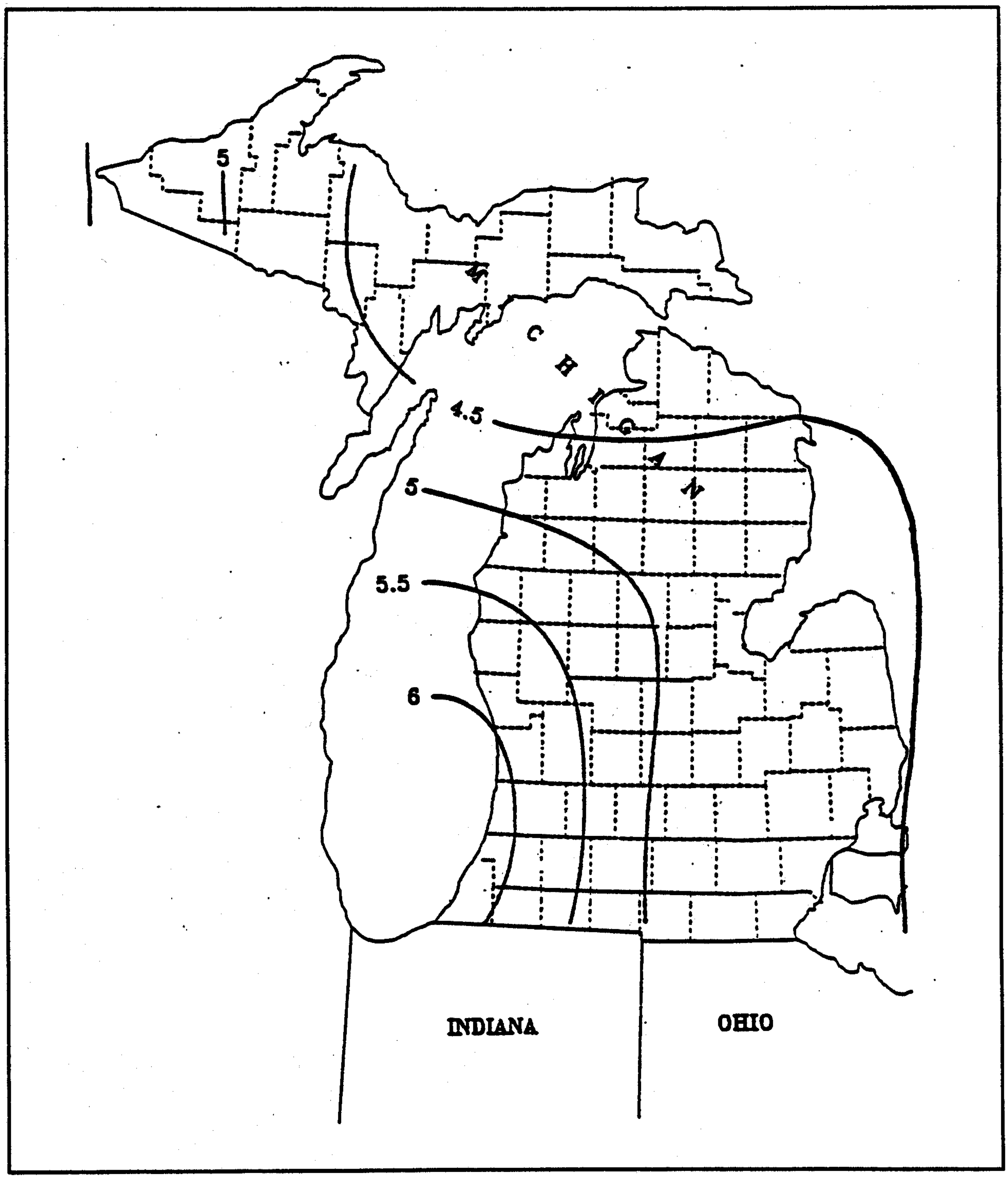


Figure 3.6 100-year, 24-hour rainfall



4. SOIL TYPE

Soil properties influence the process of generating runoff from rainfall and must be considered in methods of runoff estimation. When runoff from individual storms is the major concern, the properties can be represented by a hydrologic parameter which reflects the minimum rate of infiltration obtained for a bare soil after prolonged wetting. The influences of both the surface and the horizons of the soil are therefore included.

Four hydrologic soil groups are used. The soils are classified on the basis of water intake at the end of long-duration storms occurring after prior wetting and an opportunity for swelling and without the protective effects of vegetation. In the definitions to follow, the infiltration rate is the rate at which water enters the soil at the surface and which is controlled by surface conditions. The transmission rate is the rate at which the water moves in the soil and is controlled by the horizons. The hydrologic soil groups, as defined by SCS soil scientists, are:

A. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

B. Soils having moderate infiltration rates when thoroughly wetted and consisting of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes the downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Appendix B tabulates the hydrologic soil group for each soil series and, in some cases, may list several possible hydrologic soil groupings for a series. In using this table, the first hydrologic group shown is the native or natural group that the soil series is usually classified under when its water intake characteristics have not been significantly changed by artificial drainage, land use, or other factors. The second group shown is the probable maximum improvement that can be made through artificial drainage and the maintenance or improvement of soil structure. For example, the Adrian soil series is classified as D/A. This means that the natural hydrologic soil group is D. If a field inspection shows that drains and tiles have been constructed to improve the drainage, then the hydrologic soil group may be lowered to A. In general, those soils having several possible classifications are those with relatively high water tables so that artificial drainage measurably improves their ability to absorb rainfall and thus reduce runoff.

Soil surveys have been performed by SCS and are published in book form. Surveys published since 1970 show the soil type delineations superimposed on an aerial photograph. This format allows for determining land use at the same time the soil determinations are made.

5. LAND USE

In the SCS method of runoff estimation, the effects of the surface conditions of a watershed are evaluated by means of land use and treatment classes. Land use is the watershed cover and it includes every kind of vegetation, litter and mulch, fallow (bare soil), as well as nonagricultural uses such as water surfaces (lakes, swamps, etc.) and impervious surfaces, such as roads, roofs, etc. Land treatment applies mainly to agricultural land uses and includes mechanical practices such as contouring and terracing and management practices like grazing control and crop rotation. The classes consist of use and treatment combinations actually to be found on watersheds. The following is a brief description of various land uses.

Pasture or range is grassed land that is used for grazing animals. The hydrologic condition is characterized by the degree of grazing and plant cover. Poor condition is that which is heavily grazed that has plant cover on less than half of the area. Fair condition has a moderate amount of grazing with plant cover on ½ to 3/4 of the area. Good condition refers to light grazing with plant cover on more than 3/4 of the area.

Meadow is a field on which grass is continuously grown, protected from grazing, and generally mowed for hay.

Woods or **forest** are characterized by their vegetative condition. Poor condition refers to those woods which are either heavily grazed, regularly burned, or have had the undergrowth cleared for recreational uses. Litter, small trees, and brush are absent in this condition. Woods in fair condition may still be grazed but have not been burned. In a good condition, the woods are protected from grazing and litter, small trees, and shrubs cover the soil.

Fallow is the agricultural land use and treatment with the highest potential for runoff. The land is kept as bare as possible to conserve moisture for use by a succeeding crop. The loss due to runoff is offset by the gain due to reduced transpiration.

Row crop is any field crop (corn, soybeans, sugar beets) planted in rows far enough apart that most of the soil surface is exposed to rainfall impact through the growing season.

Small grain (wheat, oats, barley) is planted in rows close enough that the soil surface is not exposed except during planting and shortly thereafter.

Close-seeded legumes or rotation meadow (alfalfa, sweetclover) are either planted in close rows or broadcast. This cover may be allowed to remain for more than a year so that year-round protection is given to the soil.

The four preceding agricultural land uses are also characterized by the farming practice employed. Straight row fie1ds are those farmed in straight rows either up and down the hill or across the slope. Where land slopes are less than about two percent, farming across the slope in straight rows is equivalent to contouring. Contoured fie1ds are those farmed as nearly as possible to conform to the natural land contours. The hydrologic effect of contouring is due to the surface storage provided by the furrows because the storage prolongs the time during which infiltration can take place. Terracing refers to systems containing open-end level or graded terraces, grassed waterway outlets, and contour furrows between the terraces. The hydrologic effects are due to the replacement of a low-infiltration land use by grassed waterways and to the increased opportunity for infiltration in the furrows and terraces.

The four agricultural land uses are further characterized by the crop rotation. Hydrologically, rotations range from "poor" to "good" in proportion to the amount of dense vegetation in the rotation. Poor rotations are generally one-crop land uses such as continuous corn or wheat or combinations of row crops, small grains, and fallow. Good rotations generally contain alfalfa or other close-seeded legume or grass to improve tilth and increase infiltration.

6. RUNOFF CURVE NUMBER

In 1954, SCS developed a unique procedure for estimating surface runoff from rainfall. This procedure, the Runoff Curve Number (RCN) technique, has proven to be a very useful tool for evaluating effects of changes in land use and treatment on surface runoff. It is the procedure most frequently used within SCS and by hydrologists nationwide to estimate surface runoff from ungaged watersheds.

The combination of a hydrologic soil group and a land use and treatment class is a hydrologic soil-cover complex. Each combination is assigned a RCN which is an index to its runoff potential on soil that is not frozen. A list of these values is shown in Table 6.1. The tabulated RCN values are for normal soil moisture conditions which is referred to as Antecedent Moisture Condition II (AMC-II). AMC-I has the lowest runoff potential and the watershed soils are dry. AMC-III has the highest runoff potential as the watershed is practically saturated from antecedent rainfall or snowmelt. The AMC can be estimated from the 5-day antecedent rainfall by using Table 6.2. In this table, the "growing" season in Michigan is assumed to be June through September. The limits for "dormant" season apply when the soils are not frozen and there is no snow on the ground.

Although the RCN in Table 6.1 is for AMC-II conditions, an analysis of a specific storm event may require an equivalent RCN for AMC-I or AMC-III. They may be computed by the following equations

$$RCN(I) = \frac{4.2 * RCN(II)}{10 - 0.058 * RCN(II)} \tag{6.1}$$

and

$$RCN(III) = \frac{23 * RCN(II)}{10 + 0.13 * RCN(II)} \tag{6.2}$$

A typical watershed is comprised of many different combinations of soil types and land uses. In using the method presented here, the runoff characteristic of the watershed is represented using an average or composite RCN for the entire watershed. The most practical way to determine this is to tabulate each of the four hydrologic groups as a percentage of the total drainage area. Land uses should then be tabulated as a percentage within each specific group along with the appropriate RCN. Multiplying the RCN by the two percentages and summing over all the different soil-cover complexes yields the average watershed RCN. This is illustrated in the following example.

Hydrologic Soil group	% of total Drainage area	Land Use	% of soil Group	RCN	Partial RCN
A	30	Meadow	100	30	9.0
B	50	Woods (good cover)	25	55	6.9
		Fallow	75	86	32.3
C	10	Pasture (fair condition)	80	79	6.3
		Woods (poor cover)	20	77	1.5
D	10	Meadow	100	78	7.8
					63.8

In this instance, an average RCN of 64 would be used for this watershed. Tabulating in this manner makes it easier to estimate how a change in land use will alter runoff. Here the bulk of the RCN is contributed by the fallow land use. If all of this land were developed into 1.4 acre residential lots (RCN 75), the composite RCN for the watershed would decrease to 60. On the other hand, if all of the fallow land were developed into an industrial area (RCN 88), the average watershed RCN would increase to 65, thereby increasing surface runoff.

This method of computing a composite RCN works very well if all of the individual RCN's are at least 45 or above, where the correlation between RCN and SRO is virtually linear. This method also works well if all of the individual RCN's are less than 45. But there may be an occasion where the watershed has a significant amount of very low RCN's and a large amount of very high ones. Since the RCN/SRO relationship becomes less linear for the very low RCN's, proportioning the RCN to compute a composite value as described above will produce a RCN which underestimates the correct amount of runoff. In this instance, a more accurate runoff estimate is made by computing the

Table 6.1 Runoff curve numbers for hydrologic soil-cover complexes
(AMC-II conditions)

Land use	Treatment or practice	Hydrologic condition	Hydrologic soil group			
			A	B	C	D
Fallow	Straight row		77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Contoured and terraced	Poor	66	74	80	82
	Contoured and terraced	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
	Straight row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
	Contoured and terraced	Poor	61	72	79	82
	Contoured and terraced	Good	59	70	78	81
Close-seeded legumes or rotation meadow	Straight row	Poor	66	77	85	89
	Straight row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Contoured and terraced	Poor	63	73	80	83
	Contoured and terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79
Meadow			30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Residential						
1/8 acre or less lot size			77	85	90	92
¼ acre			61	75	83	87
1/3 acre			57	72	81	86
½ acre			54	70	80	85
1 acre			51	68	79	84
Open spaces (parks, golf courses, cemeteries, etc.)						
Good condition: Grass cover > 75% of area			39	61	74	80
Fair condition: Grass cover 50-75% of area			49	69	79	84
Commercial or business area (85% impervious)			89	92	94	95
Industrial district (72% impervious)			81	88	91	93
Farmsteads			59	74	82	86
Paved areas (roads, driveways, parking lots, roofs)			98	98	98	98
Water surfaces (lakes, ponds, reservoirs, etc.)			100	100	100	100
Swamp	At least 1/3 is open water		85	85	85	85
Swamp	Vegetated		78	78	78	78

incremental SRO for each land use and summing these to obtain the total runoff. Equations 6.1 and 6.2 may then be solved to yield the composite RCN, if desired. This method of weighting the runoff requires more work than simply proportioning the RCN's. It should only be needed if more than 20 per cent of the watershed has RCN's less than 45 with most of the remaining RCN's at the higher end of the scale.

Table 6.2 Seasonal rainfall limits for AMC

AMC group	Total 5-day antecedent rainfall (inches)	
	Dormant season	Growing season
I	< 0.5	< 1.4
II	0.5 – 1.1	1.4 – 2.1
III	> 1.1	> 2.1

7. SURFACE RUNOFF

The total precipitation (P) in a storm can be divided into three paths that the water will follow in the hydrologic cycle. There is some initial amount of rainfall (I_a) for which no runoff will occur. This quantity is the initial abstraction and consists of interception, evaporation, and the soil-water storage that must be satisfied before surface runoff may begin. After this initial abstraction is met, the soil has a continuing abstraction capacity (F) depending on the type of soil. A rainfall rate greater than this continuing abstraction is surface runoff (SRO). These quantities can be described by the equation

$$P = SRO + I_a + F \tag{7.1}$$

While F is a continuing abstraction, there is a potential maximum retention S characteristic to each RCN. The hypothesis of the SCS method is that the ratio of F to S is equal to the ratio of the actual runoff SRO to the potential maximum runoff, $P - I_a$. This is expressed as

$$\frac{F}{S} = \frac{SRO}{P - I_a} \tag{7.2}$$

Combining (6.1) and (6.2) to solve for SRO:

$$SRO = \frac{(P - I_a)^2}{P - I_a + S} \tag{7.3}$$

An empirical relation was developed by studying many small experimental watersheds:

$$I_a = 0.2 * S \tag{7.4}$$

Substituting this into (6.3) produces

$$SRO = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{7.5}$$

The curve number and S are related by

$$S = \frac{1000}{RCN} - 10 \tag{7.6}$$

where S is in inches. Therefore, given RCN for a watershed and a design rainfall, equations (7.5) and (7.6) can be solved to compute the surface runoff.

8. TIME OF CONCENTRATION

Time of concentration (T_c) is the time it takes for runoff to travel from the hydraulically most distant point in the watershed to the design point. In hydrograph analysis, T_c is the time from the end of rainfall excess to the inflection point on the falling limb of the hydrograph. This point signifies the end of surface runoff and the beginning of baseflow recession. T_c may vary between different storms, especially if the rainfall is nonuniform in either areal coverage or intensity. However, in practice, T_c is considered to be constant.

Measuring from a recorded hydrograph provides the most accurate estimate of T_c. For ungaged watersheds, T_c is calculated by estimating the velocity through the various components of the stream network. There are many methods used to estimate the velocity. The method presented in this report expresses velocity in the form

$$V = K * S^{0.5} \qquad (8.1)$$

where K is a coefficient depending on the type of flow, S is the slope of the flow path in percent, and V is the velocity in feet per second.

Three flow types are used based on their designation on U.S. Geological Survey topographic maps.

Small tributary: Permanent or intermittent streams which appear as a solid or dashed blue line on the topo maps. This also applies to a swamp that has a defined stream channel.

Waterway: This is any overland route which is a well-defined swale by elevation contours but does not have a blue line denoting a defined channel. This also applies to a swamp that does not have a defined channel flowing through it.

Sheet Flow: This is any overland flow path which does not conform to the waterway definition.

An illustration of each of these flow types is included in the example in Appendix A. The coefficients for each of these in equation (8.1) are

Flow type	K
Small tributary	2.1
Waterway	1.2
Sheet flow	.48

These coefficients were derived by Richardson (1969) as a means of estimating velocities when detailed stream hydraulic data are unavailable.

Once the velocity is determined, time of concentration can be computed as

$$T_c = \frac{L}{V * 3600} \qquad (8.2)$$

where L is the length in feet of the particular flow path and the factor 3600 converts T_c from seconds to hours.

In most watersheds, all three flow types will be present. Starting at the basin divide, the runoff may proceed from sheet flow to waterway, back to sheet flow, then waterway again, then small tributary, etc. The T_c for each segment should be computed and then summed to give the total T_c.

It is important that the length used to compute T_c has a uniform slope. As an example, assume a 5000 foot length of small tributary has a change in elevation of 10.4 feet. This slope of 0.208% produces a T_c of 1.45 hours. However, if it is known that the upper 1000 feet of this stream falls 10 feet and the lower 4000 feet only falls 0.4 feet, then this would produce a total T_c of 5.42 hours. Therefore, it is best to sum T_c over the smallest possible contour interval which is usually 5 or 10 feet on most topo maps. This interval can be enlarged if a visual examination of the topo map shows a uniform spacing between successive contour crossings.

9. UNIT HYDROGRAPH PEAK

The unit hydrograph peak (Q_p) is a function of travel time through the stream system or T_c. An expression relating Q_p to T_c was developed in the following manner.

Discharges were computed for a hypothetical watershed having a drainage area of 1 mi^2, a RCN of 75, and a 24-hour design rainfall of 5 inches using the SCS Type II rainfall distribution. The discharges were computed using the TR-20 computer program developed by SCS. However, in lieu of using the standard dimensionless UH in TR-20, these simulations used the UH determined from the gage analysis discussed in Section 2 of this report.

The T_c for this hypothetical basin was varied from 1 hour to 40 hours. The peak discharge for each different T_c was divided by the amount of surface runoff to obtain Q_p which has the units of cfs per inch of runoff per square mile of drainage area. The data set of Q_p versus T_c was analyzed using a log-linear regression to obtain

$$Q_p = 270.9 * T_c^{-0.81} \qquad (9.1)$$

10. ADJUSTMENTS FOR SURFACE PONDING

Peak flows determined in this method assume that the topography is such that surface flow into ditches, drains, and streams is approximately uniform. In areas where ponding or swampy areas occur in the watershed, a considerable amount of surface runoff may be retained in temporary storage. The peak rate of runoff should be reduced to reflect this condition. Table 10.1 provides adjustment factors to determine this reduction based on the ratio of ponding or swampy area to the total drainage area for a range of flood frequencies. The three sections of this table provide different adjustment factors depending on where the ponding occurs in the watershed. These values were determined by SCS (1975) from experimental watersheds of less than 2000 acres. These factors may still be used for larger basins until newer data become available. For percentages beyond the range in the tables, the data may be extrapolated on semi-log paper with the reduction factor on the log scale.

In some cases, it is appropriate to apply the ponding adjustment more than once. For example, assume a watershed has two per cent ponding scattered throughout and a lake that is one per cent of the drainage area located at the design point. If the 100-year frequency flood is being determined, the peak flow should be multiplied by 0.87 for the scattered ponding and further reduced by 0.89 for the lake. This produces a total reduction factor of 0.77. However, if the inflow to the lake is to be analyzed using a reservoir routing procedure, then only the reduction factor of 0.87 representing the scattered ponding should be applied.

Table 10.1 Adjustment factors where ponding occurs in central parts of the watershed or is spread throughout

Percentage of ponding and swampy area	Storm frequency (years) 2	5	10	25	50	100
0.2	.94	.95	.96	.97	.98	.99
0.5	.88	.89	.90	.91	.92	.94
1.0	.83	.84	.86	.87	.88	.90
2.0	.78	.79	.81	.83	.85	.87
2.5	.73	.74	.76	.78	.81	.84
3.3	.69	.70	.71	.74	.77	.81
5.0	.65	.66	.68	.72	.75	.78
6.7	.62	.63	.65	.69	.72	.75
10	.58	.59	.61	.65	.68	.71
20	.53	.54	.56	.60	.63	.68
Ponding occurs only in upper reaches of watershed						
0.2	.96	.97	.98	.98	.99	.99
0.5	.93	.94	.94	.95	.96	.97
1.0	.90	.91	.92	.93	.94	.95
2.0	.87	.88	.88	.90	.91	.93
2.5	.85	.85	.86	.88	.89	.91
3.3	.82	.83	.84	.86	.88	.89
5.0	.80	.81	.82	.84	.86	.88
6.7	.78	.79	.80	.82	.84	.86
10	.77	.77	.78	.80	.82	.84
20	.74	.75	.76	.78	.80	.82
Ponding occurs at the design point						
0.2	.92	.94	.95	.96	.97	.98
0.5	.86	.87	.88	.90	.92	.93
1.0	.80	.81	.83	.85	.87	.89
2.0	.74	.75	.76	.79	.82	.86
2.5	.69	.70	.72	.75	.78	.82
3.3	.64	.65	.67	.71	.75	.78
5.0	.59	.61	.63	.67	.71	.75
6.7	.57	.58	.60	.64	.67	.71
10	.53	.54	.56	.60	.63	.68
20	.48	.49	.51	.55	.59	.64

11. SUMMARY OF METHOD

This section summarizes the steps needed to compute discharges using the procedures in this report.

1. Delineate the watershed boundaries on a topographic map and measure the drainage area. If there are areas within this boundary which are either deep depressions or otherwise do not contribute any runoff, then measure these and delete them from the total drainage area. The area remaining is termed the 'contributing drainage area' and is the portion of the watershed which will be used in subsequent calculations.

   [Note: Some judgement needs to be used when defining noncontributing areas. If a topo map with a five foot contour interval shows two nested depression contours, then we know that portions of the entire depression are at least five feet deep. The volume of the depression can be calculated and compared to the volume of runoff which drains into it. If it can contain all of the runoff, the entire area draining into the depression may be deleted as 'noncontributing area'. However, if the topo map only shows a single depression contour, it could be anywhere from a few inches deep to just under five feet deep. In this case, there is no definitive way to tell how much runoff this depression can store. In this instance, it may be necessary to conduct a field inspection of the watershed to ascertain the storage potential of the depression areas.]

2. Overlay the boundaries of the contributing drainage area on soil and land use maps and tabulate the hydrologic soil-cover complexes in the watershed. Assign curve numbers using Table 6.1 and calculate the average RCN as outlined in section 6.

3. Starting at the design point and working upstream, tabulate incremental times of concentration using the procedure in section 8. When reaching a junction of two or more streams, follow the one which has the largest contributing drainage area. After reaching the most upstream point (as defined by a blue line on topo maps), determine any

additional contribution to T_c due to overland flow paths. Add all of the incremental times of concentration to determine the watershed T_c. Compute Q_p using equation 9.1.

4. Select a design frequency and determine the 24-hour rainfall from Figures 3.1 through 3.6. If the contributing drainage area is greater than 10 square miles then adjust the rainfall using Table 3.1.

5. Using the average RCN computed in step 2, calculate the surface runoff for the selected design event using equations 7.5 and 7.6.

6. Compute the design discharge by multiplying Q_p (step 3) times the contributing drainage area (step 1) times SRO (step 5). If there are ponding or swampy areas in the watershed, adjust this computed discharge as outlined in section 10.

REFERENCES

Hershfield, D.M., Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years, Tech. Paper 40, U.S. Dept. of Commerce, Weather Bureau, Washington, D.C., May 1961.

Richardson, Harvey, unpublished document, Massachusetts Soil Conservation Service, 1969.

Sherman, L.K., Streamflow from rainfall by the unit-graph method, *Eng. News Rec*., Vol. 108, pp. 501-505, April 7, 1932.

Soil Conservation Service, Hydrology, Sec. 4 of *National Engineering Handbook*, U.S. Dept. of Agriculture, Washington, D.C., 1972.

Soil Conservation Service, Urban Hydrology For Small Watersheds, Technical Release No.55, U.S. Dept. of Agriculture, Washington, D.C., January, 1975.

Sorrell, R.C. and D.A. Hamilton, Rainfall frequency for Michigan 24-hour duration with return periods from 2 to 100 years, Michigan Dept. of Natural Resources, September 1990.

Appendix A Sample application

The bridge at the Brocker Road crossing of the example watershed needs to be replaced. The watershed which contributes runoff to this point, which is depicted in Figure A.1, is undergoing urbanization. All of the areas which are currently either pasture or meadow will be developed into ¼ acre residential subdivisions. What effect will this have on the design flood produced by the 100-year, 24-hour rainfall?

Figure A.1 is an enlargement of a USGS topographic map. The contour interval for this map is 10 feet. In this figure, a thick black line is used to denote the watershed boundary while the prominent, but thinner, black line inside the boundary shows the small tributaries in the basin. The irregularly shaped black areas show the locations of lakes and ponds while the lighter gray patches show the wooded portions of the watershed.

The following table shows the different soil groups and associated land uses as they currently exist in the watershed.

Hydrologic Soil group	% of total Drainage area	Land use	% of soil Group	RCN	Partial RCN
A	7	Meadow	25	30	.5
		Pasture (fair)	15	49	.5
		Row crop (cont./good)	60	65	2.7
B	84	Small grain (cont./good)	60	73	36.8
		Pasture (fair condition)	25	69	14.5
		Woods (poor cover)	10	66	5.5
		Meadow	5	58	2.4
D	9	Meadow	35	78	2.5
		Woods (good cover)	5	77	.3
		Lakes and ponds	15	100	1.4
		Swamps (vegetated)	35	78	2.5
		Swamps (open water)	10	85	.8
					70.4

Deleting the contribution from meadows and pastures and replacing them with the RCN's for the residential lots changes the composite RCN to 73.4. Common practice is to round off the computed

RCN so this watershed would have curve numbers of 70 and 73 to represent existing and proposed development conditions, respectively.

The time of concentration is computed along the stream which flows in a northeastward direction from the headwaters in section 36. There is also a small portion of waterway and sheet flow upstream from the end of the small tributary .The small tributary portions were generally divided into lengths which correspond with the contour interval of the topo map. The following table shows the computations:

Type of flow	Length (ft)	Δ Ele (ft)	Slope (%)	V (fps)	Incremental T_c (hr)
Small trib	1640	12	.73	1.80	.25
Small trib	1380	10	.73	1.79	.21
Small trib	1970	10	.51	1.50	.37
Small trib	1520	10	.66	1.70	.25
Small trib	6870	8	.12	.72	2.66
Waterway	1840	2	.11	.40	1.29
Sheet	150	22	14.86	1.85	.28
					5.31

Summing the incremental T_c's produces a total T_c of 5.3 hours. Substituting this into equation (9.1) produces a peak discharge of 70 cfs per square mile per inch of runoff. The table shows that the slope of the small tributary is not uniform over its entire length. If the slope is calculated as a 50 foot drop over the 13,400 foot length, the resulting total T_c is 4.46 hours. This produces a Q_p of 80.7 cfs/mi^2-in. Thus, the design discharge would have been 15 per cent higher because of an error in calculating T_c. This illustrates the importance of using the most refined data available, in this case, the distance between successive 10-foot contours.

The 100-year, 24-hour rainfall obtained from Figure 3.6 is 4.8 inches. Using this value and the previously computed RCN's, the runoff can be determined using equations (7.5) and (7.6). For existing conditions (RCN=70), the runoff is 1.89 inches. The runoff for proposed development conditions (RCN =73) is 2.12 inches.

The design discharge is obtained by simply multiplying the computed Q_p by the drainage area and the computed runoff. These results are:

Existing: $Q = 70.06\ cfs/mi^2\text{-}in * 2.43\ mi^2 * 1.89\ in$

$= 322\ cfs$

Proposed: Q = 361 cfs

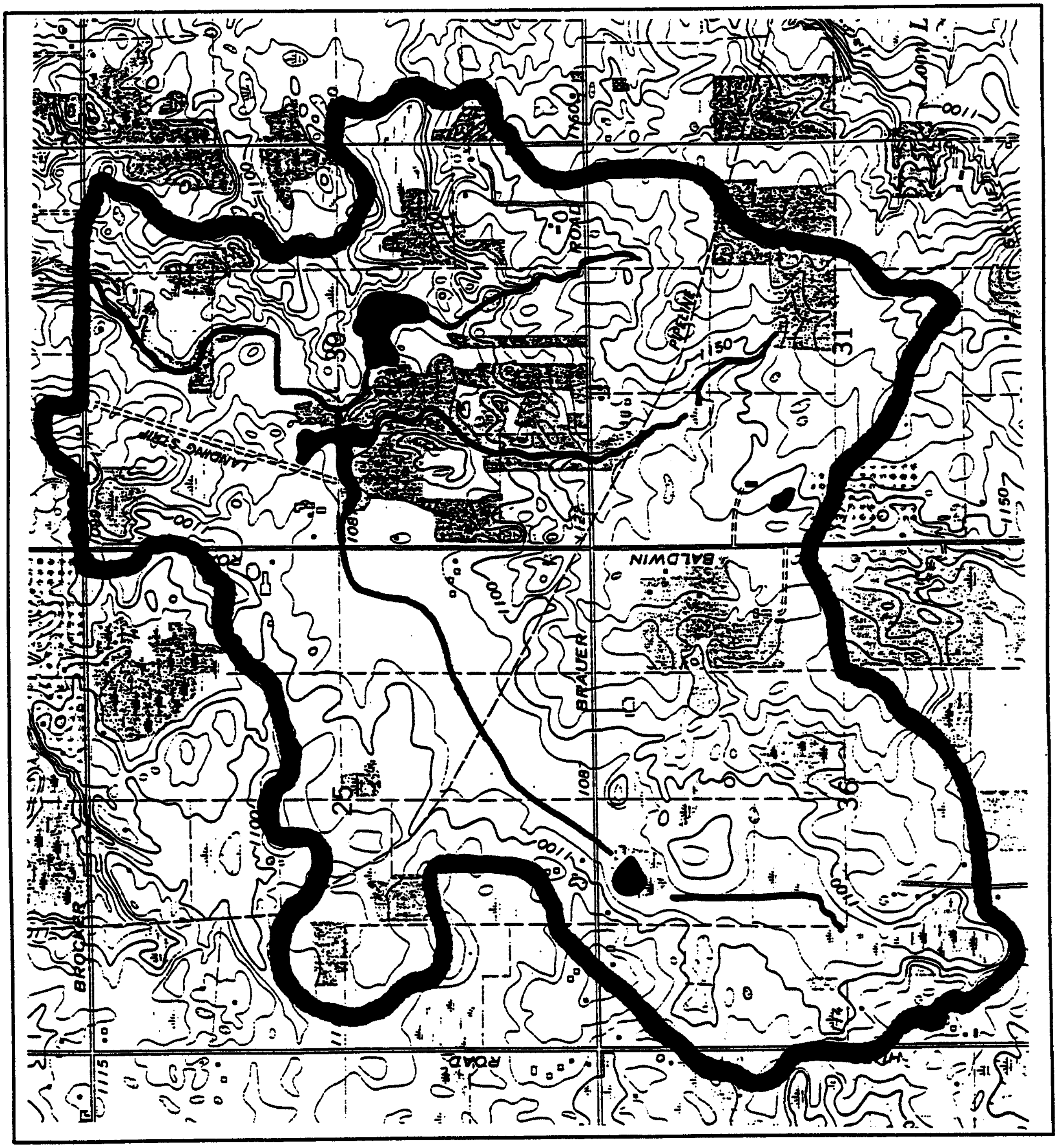
These numbers need to be adjusted for ponding. The land use table shows that 5.4 per cent of the watershed is either open water or swamps. These areas are spread uniformly throughout the basin. An adjustment factor of 0.77 can be interpolated from Table (10.1). The final design discharges are:

Existing: Q = 322 * 0.77

= 248 cfs

Proposed: Q = 278 cfs

Figure A.l Example watershed



Appendix B Hydrologic soil groups for Michigan soils

Soil series	Hyd. Group	Soil series	Hyd. Group	Soil series	Hyd. Group
Abbaya	B	Brassar	C	Dighton	B
Abscota	A	Breckenridge	D/B	Dixboro	B
Adrian	D/A	Brems	A	Dora	D/B
Alcona	B	Brevort	D/B	Dowagiac	B
Algansee	B	Brimley	B	Dresden	B
Allendale	B	Bronson	B	Dryburg	B
Allouez	B	Brookston	D/B	Dryden	B
Alpena	A	Bruce	D/B	Duel	A
Alstad	C	Burleigh	D/A	Dungridge	B
Amasa	B	Burt	D	East Lake	A
Angelica	D/B	Cadmus	B	Eastport	A
Arkona	B	Capac	C	Edmore	D
Arkport	B	Carbondale	D/A	Edwards	D/B
Arnheim	D	Carlisle	D/A	Eel	B
Ashkum	D/B	Caasopolis	B	Eleva	B
Assinins	B	Cathro	D/A	Elmdale	B
Aubarque	D/C	Celina	C	Elston	B
Aubbeenaubbee	B	Ceresco	B	Elvers	D/B
Au Gres	B	Champion	B	Emmet	B
Aurelius	D/B	Channahon	D	Ensign	D
Avoca	B	Channing	B	Ensley	D/B
Bach	D/B	Charity	D	Epoufette	D/B
Badaxe	B	Charlevoix	B	Epworth	A
Banat	B	Chatham	B	Ermatinger	D/B
Barry	D/B	Cheboygan	B	Esau	A
Battlefield	D/A	Chelsea	A	Escanaba	A
Beavertail	D	Chesaning	B	Essexville	D/A
Beechwood	C	Chestonia	D	Evart	D
Belding	B	Chippeny	D	Fabius	B
Belleville	D/B	Cohoctah	D/B	Fairport	C
Benona	A	Coloma	A	Fence	B
Bergland	D	Colonville	C	Fibre	D/B
Berville	D/B	Colwood	D/B	Filion	D
Biscuit	D/B	Conover	C	Finch	C
Bixby	B	Coral	C	Fox	B
Bixler	C	Corunna	D/B	Frankenmuth	C
Blount	C	Coupee	B	Frechette	B
Blue Lake	A	Covert	A	Freda	D
Bohemian	B	Crosier	C	Froberg	D
Bonduel	C	Croswell	A	Fulton	D
Bono	D	Cunard	B	Gaastra	C
Boots	D/A	Cushing	B	Gagetown	B
Borski	B	Dawson	D/A	Gay	D/B
Bowers	C	Deer Park	A	Genesee	B
Bowstring	D/A	Deerton	A	Gilchrist	A
Boyer	B	Deford	D/A	Gilford	D/B
Brady	B	Del Rey	C	Gladwin	A
Branch	B	Detour	B	Glawe	D/B

Two soil groups such as D/B indicates the undrained/drained condition

Soil series	Hyd. Group	Soil series	Hyd. Group	Soil series	Hyd. Group
Glendora	D/A	Keowns	D/B	Miami	B
Glynwood	C	Kerston	D/A	Michigamme	C
Gogebic	B	Keweenaw	A	Millsdale	D/B
Gogomain	D/B	Kibbie	B	Milton	C
Goodman	B	Kidder	B	Minoa	C
Gorhan	D/B	Kilmanagh	C	Minocqua	D/B
Grace	B	Kingsville	D/A	Minong	D
Granby	D/A	Kinross	D/A	Misery	C
Grattan	A	Kiva	A	Mitiwanga	C
Graveraet	B	Klacking	A	Moltke	B
Graycalm	A	Kokomo	D/B	Monico	C
Grayling	A	Koontz	D	Monitor	C
Greenwood	D/A	Krakow	B	Montcalm	A
Grindstone	C	Lacota	D/B	Moquah	B
Grousehaven	D	Lamson	D/B	Morley	C
Guardlake	A	Landes	B	Morocco	B
Guelph	B	Lapeer	B	Mudsock	D/B
Gutport	D	Latty	D	Munising	B
Hagensville	C	Leelanau	A	Munuscong	D/B
Halfaday	A	Lenawee	D/B	Mussey	D/B
Hatmaker	C	Leoni	B	Nadeau	B
Henrietta	D/B	Liminga	A	Nahma	D/B
Hessel	D/B	Linwood	D/A	Napoleon	D/A
Hettinger	D/C	Locke	B	Nappanee	D
Hillsdale	B	Lode	B	Nester	C
Hodenpyl	B	Londo	C	Net	C
Houghton	D/A	Longrie	B	Newaygo	B
Hoytville	D/C	Loxley	D/A	Newton	D/A
Huntington	B	Lupton	D/A	Nottawa	B
Ingalls	B	Mackinac	B	Nunica	C
Ingersoll	B	Macomb	B	Oakville	A
Ionia	B	Mancelona	A	Ockley	B
Iosco	B	Manistee	A	Oconto	B
Isabella	B	Manitowish	B	Ocqueoc	A
Ishpeming	A	Markey	D/A	Ogemaw	D/C
Ithaca	C	Marlette	B	Okee	B
Jacobsville	D	Martinsville	B	Oldman	C
Jeddo	D/C	Martisco	D/B	Olentangy	D/A
Jesso	C	Matherton	B	Omega	A
Johnswood	B	Maumee	D/A	Omena	B
Kalamazoo	B	McBride	B	Onaway	B
Kalkaska	A	Mecosta	A	Onota	B
Kallio	C	Melita	A	Ontonagon	D
Karlin	A	Menagha	A	Ormas	B
Kawbawgam	C	Menominee	A	Oshtemo	B
Kakkawlin	C	Mervin	D/A	Otisco	A
Kendallville	B	Metamora	B	Ottokee	A
Kent	D	Metea	B	Owosso	B

Two soil groups such as D/B indicates the undrained/drained condition

Appendix B Hydrologic soil groups for Michigan soils (cont'd)

Soil series	Hyd. Group	Soil series	Hyd. Group	Soil series	Hyd. Group
Paavola	B	Saganing	D/A	Thomas	D/B
Padus	B	Sanilac	B	Tobico	D/A
Palms	D/A	Saranac	D/C	Toledo	D
Parkhill	D/B	Sarona	B	Tonkey	D/B
Paulding	D	Satago	D	Toogood	A
Pelkie	A	Saugatuck	C	Trenary	B
Pella	D/B	Saylesville	C	Trimountain	B
Pemene	B	Sayner	A	Tula	C
Pence	B	Scalley	B	Tuscola	B
Pendleton	C	Schoolcraft	B	Tustin	B
Pequaming	A	Sebewa	D/B	Twining	C
Perrin	B	Selfridge	B	Tyre	D/A
Perrinton	C	Selkirk	C	Ubly	B
Pert	D	Seward	B	Velvet	C
Peshekee	D	Shebeon	C	Vestaburg	D/A
Petticoat	B	Shelldrake	A	Vilas	A
Pewamo	D/C	Shelter	B	Volinia	B
Pickford	D	Shiawassee	C	Wainola	B
Pinconning	D/B	Shinrock	C	Waiska	B
Pinnebog	D/A	Shoals	C	Wakefield	B
Pipestone	B	Sickles	D/B	Wallace	B
Plainfield	A	Sims	D	Wallkill	D/C
Pleine	D	Sisson	B	Warners	D/C
Ponozzo	C	Skanee	C	Wasepi	B
Posen	B	Sleeth	C	Washtenaw	D/A
Poseyville	C	Sloan	D/B	Watton	C
Potagannissing	D	Solona	C	Waucedah	D
Poy	D	Soo	D/C	Wauseon	D/B
Proctor	B	Sparta	A	Wautoma	D/B
Randolph	C	Spinks	A	Wega	B
Rapson	B	Springlake	A	Westbury	C
Remus	B	St. Clair	D	Whalan	B
Rensselaer	D/B	St. Ignace	D	Wheatley	D/A
Richter	B	Stambaugh	B	Whitaker	C
Riddles	B	Steuben	B	Whitehall	B
Rifle	D/A	Sturgeon	B	Willette	D/A
Riggsville	C	Sugar	B	Winneshiek	B
Rimer	C	Summerville	D	Winterfield	D/A
Riverdale	A	Sundell	B	Wisner	D/B
Rockbottom	B	Sunfield	B	Witbeck	D/B
Rockcut	B	Superior	D	Wixom	B
Rodman	A	Tacoosh	D/B	Wolcott	D/B
Ronan	D	Tallula	B	Woodbeck	B
Rondeau	D/A	Tamarack	B	Yalmer	B
Roscommon	D/A	Tappan	D/B	Ypsi	C
Roselms	D	Tawas	D/A	Zeba	B
Rousseau	A	Teasdale	B	Ziegenfuss	D
Rubicon	A	Tedrow	B	Zilwaukee	D
Rudyard	D	Tekenink	B	Zimmerman	A
Ruse	D	Thetford	A		

Two soil groups such as D/B indicates the undrained/drained condition

APPENDIX 2

SOILS

APPENDIX 2A

SOILS: GENERAL INFORMATION

Appendix 2A

Soils: General Information

The proper selection and installation of Best Management Practices cannot be done anywhere without some basic knowledge of the soils on the site. The information below discusses the basics of soils and their importance in BMP selection and development.

There are three major soil textures: clay, silt and sand. Clay soils are composed of fine particles and can contain a high percentage of water. Sandy soil consists of coarse particles and holds very little water. Silt consists of particles intermediate in size between sand and clay. Pure sand, silt or clay seldom exists in nature--generally soil is a mixture of the three textures. Exhibit 1A of this appendix shows the relationships between the different soil classifications.

Soil texture influences infiltration rate, transmission rate*, and the tendency of the soil to shrink and swell as it is alternately dried and moistened. For example, a clay soil will result in more storm water runoff than a sand because the particles are small and more condense, which greatly limits infiltration. Sand, on the other hand, is ideal for infiltration purposes.

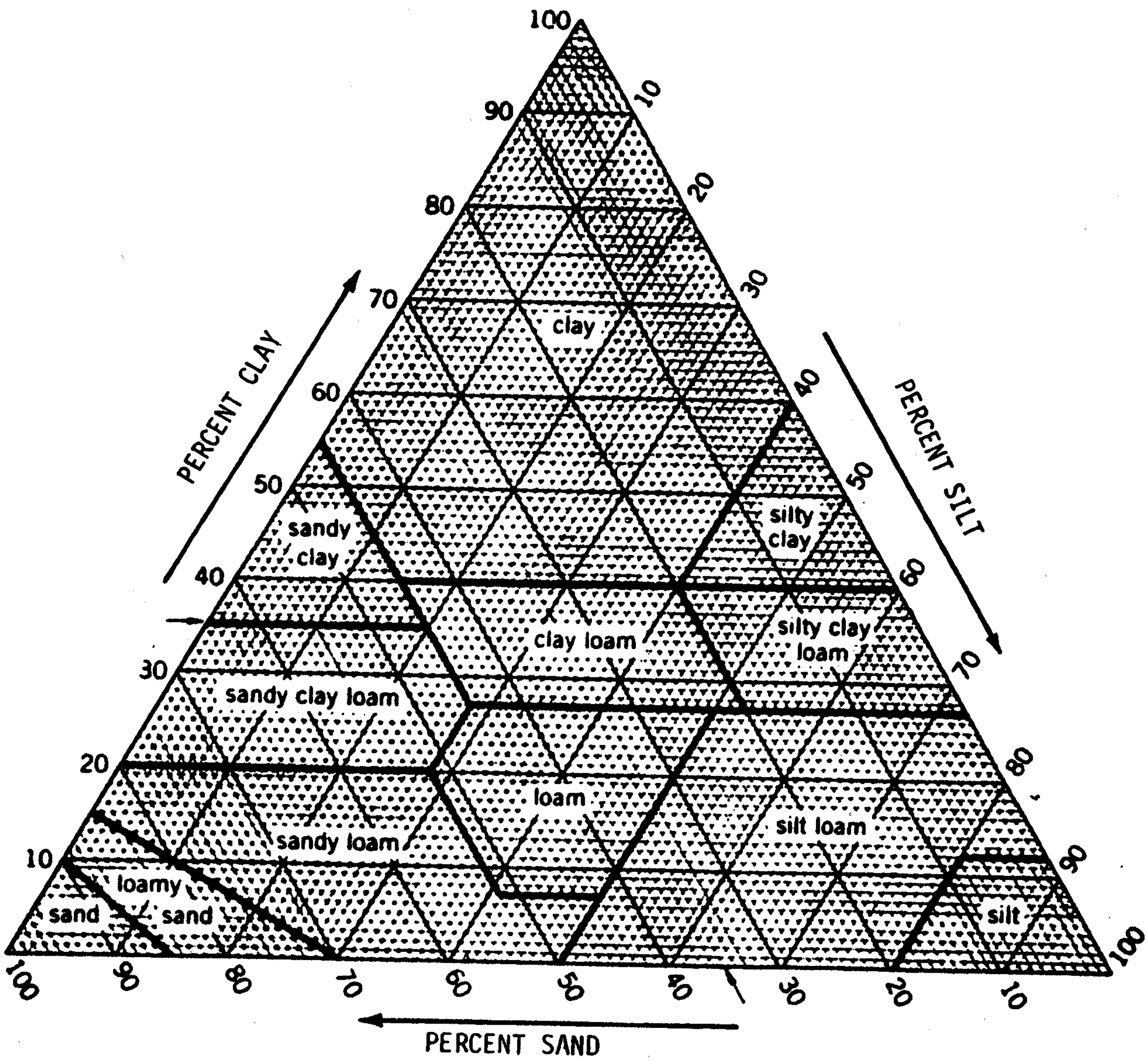
All soils are classified into one of four hydrologic soil groups which denote the runoff potential. Exhibit 2 is the list of hydrologic soil groups for all Michigan soils.

The best way to get general information on the soils in a given area is by consulting Soil Conservation Service soil surveys. Each survey contains maps with polygons of each of the soil textures found in the area, and a description of that soil. The surveys also contain information on the use and management of that soil for such things as recreation, wildlife habitat, engineering, woodland management and productivity, and appropriate types of vegetation. Exhibit 3 contains a status of soil surveys for each Michigan county.

Although a soil survey will provide general information, including soil texture, drainage classification and soil hazards for the soil textures indicated in the polygons, site specific sampling should be done. Soil scientists should be hired to identify site-specific textures. Soil sampling procedures are discussed in the Soil Treatment BMP.

Appendix 2A

USDA Soil Textural Classification



APPENDIX 2B

SOILS: HYDROLOGIC SOIL GROUPS

Appendix 2B

Hydrologic Soil Groups for Michigan Soils

Soil properties influence the process of generation of runoff from rainfall and must be considered in methods of runoff estimation. When runoff from individual storms is the major concern, the properties can be represented by a hydrologic parameter which reflects the minimum rate of infiltration obtained for a bare soil after prolonged wetting. The influences of both the surface and the horizons of a soil are therefore included.

Four hydrologic groups are used. The soils are classified on the basis of water intake at the end of the long-duration storms occurring after prior wetting and after an opportunity for swelling, and without the protective effects of vegetation. In the definitions to follow, the infiltration rate is the rate at which water enters the soil at the surface and which is controlled by surface conditions, and the transmission rate is the rate at which the water moves in the soil and which is controlled by the horizons. The hydrologic soil groups, as defined by SCS soil scientists, are:

A. (Low runoff potential) Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

B. Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D. (High runoff potential) Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

The following table gives the hydrologic soil group for each soil series and, in some instances, gives several possible hydrologic soil group classifications for a series. In using this table, the first group shown (capital letter) is the native or natural group that the soil series is usually classified under when its water intake characteristics have not been significantly changed by artificial drainage, land use, or other factors. The second group shown is the probable maximum improvement that can be made through artificial drainage and the maintenance or improvement of soil structure. Generally speaking, those series having several possible classifications are soils with relatively high water tables so that artificial drainage measurably improves their ability to absorb rainfall and thus reduce runoff.

Appendix 2B

Soil Series	Hydrologic Group	Soil Series	Hydrologic Group	Soil Series	Hydrologic Group
Abbaya	B	Bono	D	Colwood	D/B
Abscota	A	Boots	D/A	Conover	C
Adrian	D/A*	Borski	B	Coral	C
Alcona	B	Bowers	C	Corunna	D/B
Algansee	B	Bowstring	D/A	Coupee	B
Allendale	B	Boyer	B	Covert	A
Allouez	B	Brady	B	Crosier	C
Alpena	A	Branch	B	Croswell	A
Alstad	C	Brassar	C	Cunard	B
Amasa	B	Breckenridge	D/B	Cushing	B
Angelica	D/B	Brems	A	Dawson	D/A
Arkona	B	Brevort	D/B	Deer Park	A
Arkport	B	Brimley	B	Deerton	A
Arnheim	D	Bronson	B	Deford	D/A
Ashkum	D/B	Brookston	D/B	Del Rey	C
Assinins	B	Bruce	D/B	Detour	B
Aubarque	D/C	Burleigh	D/A	Dighton	B
Aubbeenaubbee	B	Burt	D	Dixboro	B
Au Gres	B	Cadmus	B	Dora	D/B
Aurelius	D/B	Capac	C	Dowagiac	B
Avoca	B	Carbondale	D/A	Dresden	B
Bach	D/B	Carlisle	D/A	Dryburg	B
Badaxe	B	Cassopolis	B	Dryden	B
Banat	B	Cathro	D/A	Duel	A
Barry	D/B	Celina	C	Dunbridge	B
Battlefield	D/A	Ceresco	B	East Lake	A
Beavertail	D	Champion	B	Eastport	A
Beechwood	C	Channahon	D	Edmore	D
Belding	B	Channing	B	Edwards	D/B
Belleville	D/B	Charity	D	Eel	B
Benona	A	Charlevoix	B	Eleva	B
Bergland	D	Chatham	B	Elmdale	B
Berville	D/B	Cheboygan	B	Elston	B
Biscuit	D/B	Chelsea	A	Elvers	D/B
Bixby	B	Chesaning	B	Emmet	B
Bixler	C	Chestonia	D	Ensign	D
Blount	C	Chippeny	D	Ensley	D/B
Blue Lake	A	Cohoctah	D/B	Epoufette	D/B
Bohemian	B	Coloma	A	Epworth	A
Bonduel	C	Colonville	C	Ermatinger	D/B

* Two soil groups, such as D/A, indicates the undrained/drained situation.

Appendix 2B

Soil Series	Hydrologic Group	Soil Series	Hydrologic Group	Soil Series	Hydrologic Group
Esau	A	Guelph	B	Kiva	A
Escanaba	A	Gutport	D	Klacking	A
Essexville	D/A	Hagensville	C	Kokomo	D/B
Evart	D	Halfaday	A	Koontz	D
Fabius	B	Hatmaker	C	Krakow	B
Fairport	C	Henrietta	D/B	Lacota	D/B
Fence	B	Hessel	D/B	Lamson	D/B
Fibre	D/B	Hettinger	D/C	Landes	B
Filion	D	Hillsdale	B	Lapeer	B
Finch	C	Hodenpyl	B	Latty	D
Fox	B	Houghton	D/A	Leelanau	A
Frankenmuth	C	Hoytville	D/C	Lenawee	D/B
Frechette	B	Huntington	B	Leoni	B
Freda	D	Ingalls	B	Liminga	A
Froberg	D	Ingersoll	B	Linwood	D/A
Fulton	D	Ionia	B	Locke	B
Gaastra	C	Iosco	B	Lode	B
Gagetown	B	Isabella	B	Londo	C
Gay	D/B	Ishpeming	A	Longrie	B
Genesee	B	Ithaca	C	Loxley	D/A
Gilchrist	A	Jacobsville	D	Lupton	D/A
Gilford	D/B	Jeddo	D/C	Mackinac	B
Gladwin	A	Jesso	C	Macomb	B
Glawe	D/B	Johnswood	B	Mancelona	A
Glendora	D/A	Kalamazoo	B	Manistee	A
Glynwood	C	Kalkaska	A	Manitowish	B
Gogebic	B	Kallio	C	Markey	D/A
Gogomain	D/B	Karlin	A	Marlette	B
Goodman	B	Kawbawgam	C	Martinsville	B
Gorham	D/B	Kawkawlin	C	Martisco	D/B
Grace	B	Kendallville	B	Matherton	B
Granby	D/A	Kent	D	Maumee	D/A
Grattan	A	Keowns	D/B	McBride	B
Graveraet	B	Kerston	D/A	Mecosta	A
Graycalm	A	Keweenaw	A	Melita	A
Grayling	A	Kibbie	B	Menagha	A
Greenwood	D/A	Kidder	B	Menominee	A
Grindstone	C	Kilmanagh	C	Merwin	D/A
Grousehaven	D	Kingsville	D/A	Metafora	B
Guardlake	A	Kinross	D/A	Metea	B

Appendix 2B

Soil Series	Hydrologic Group	Soil Series	Hydrologic Group	Soil Series	Hydrologic Group
Miami	B	Onaway	B	Rensselaer	D/B
Michigamme	C	Onota	B	Richter	B
Millsdale	D/B	Ontonagon	D	Riddles	B
Milton	C	Ormas	B	Rifle	D/A
Minoa	C	Oshtemo	B	Riggsville	C
Minocqua	D/B	Otisco	A	Rimer	C
Minong	D	Ottokee	A	Riverdale	A
Misery	C	Owosso	B	Rockbottom	B
Mitiwanga	C	Paavola	B	Rockcut	B
Moltke	B	Padus	B	Rodman	A
Monico	C	Palms	D/A	Ronan	D
Monitor	C	Parkhill	D/B	Rondeau	D/A
Montcalm	A	Paulding	D	Roscommon	D/A
Moquah	B	Pelkie	A	Roselms	D
Morley	C	Pella	D/B	Rousseau	A
Morocco	B	Pemene	B	Rubicon	A
Mudsock	D/B	Pence	B	Rudyard	D
Munising	B	Pendleton	C	Ruse	D
Munuscong	D/B	Pequaming	A	Saganing	D/A
Mussey	D/B	Perrin	B	Sanilac	B
Nadeau	B	Perrinton	C	Saranac	D/C
Nahma	D/B	Pert	D	Sarona	B
Napoleon	D/A	Peshekee	D	Satago	D
Nappanee	D	Petticoat	B	Saugatuck	C
Nester	C	Pewamo	D/C	Saylesville	C
Net	C	Pickford	D	Sayner	A
Newaygo	B	Pinconning	D/B	Scalley	B
Newton	D/A	Pinnebog	D/A	Schoolcraft	B
Nottawa	B	Pipestone	B	Sebewa	D/B
Nunica	C	Plainfield	A	Selfridge	B
Oakville	A	Pleine	D	Selkirk	C
Ockley	B	Ponozzo	C	Seward	B
Oconto	B	Posen	B	Shebeon	C
Ocqueoc	A	Poseyville	C	Shelldrake	A
Ogemaw	D/C	Potagannissing	D	Shelter	B
Okee	B	Poy	D	Shiawassee	C
Oldman	C	Proctor	B	Shinrock	C
Olentangy	D/A	Randolph	C	Shoals	C
Omega	A	Rapson	B	Sickles	D/B
Omena	B	Remus	B	Sims	D

Appendix 2B

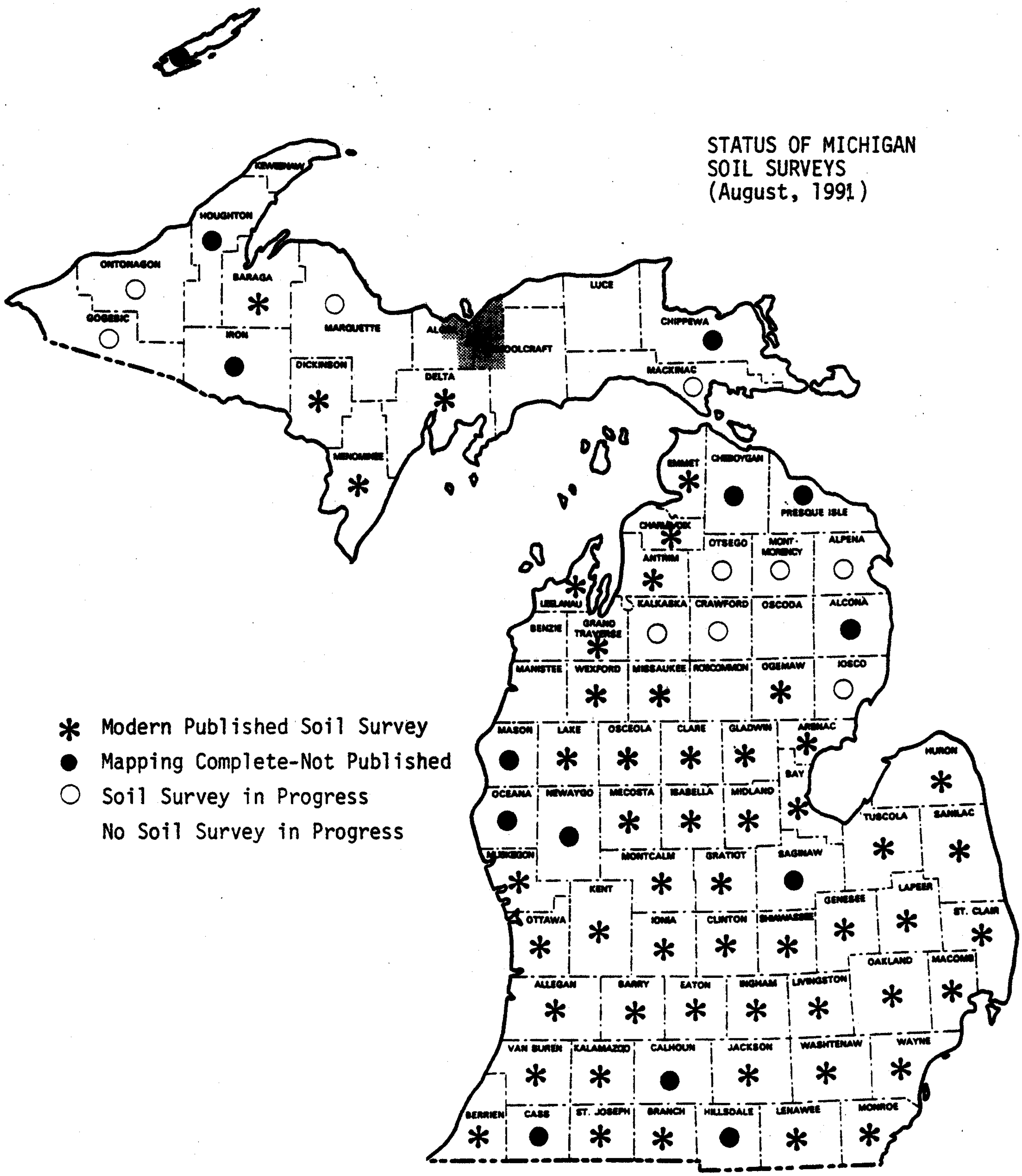
Soil Series	Hydrologic Group	Soil Series	Hydrologic Group
Sisson	B	Ubly	B
Skanee	C	Velvet	C
Sleeth	C	Vestaburg	D/A
Sloan	D/B	Vilas	A
Solona	C	Volinia	B
Soo	D/C	Wainola	B
Sparta	A	Waiska	B
Spinks	A	Wakefield	B
Springlake	A	Wallace	B
St. Clair	D	Wallkill	D/C
St. Ignace	D	Warners	D/C
Stambaugh	B	Wasepi	B
Steuben	B	Washtenaw	D/C
Sturgeon	B	Watton	C
Sugar	B	Waucedah	D
Summerville	D	Wauseon	D/B
Sundell	B	Wautoma	D/B
Sunfield	B	Wega	B
Superior	D	Westbury	C
Tacoosh	D/B	Whalan	B
Tallula	B	Wheatley	D/A
Tamarack	B	Whitaker	C
Tappan	D/B	Whitehall	B
Tawas	D/A	Willette	D/A
Teasdale	B	Winneshiek	B
Tedrow	B	Winterfield	D/A
Tekenink	B	Wisner	D/B
Thetford	A	Witbeck	D/B
Thomas	D/B	Wixon	B
Tobico	D/A	Wolcott	D/B
Toledo	D	Woodbeck	B
Tonkey	D/B	Yalmer	B
Toogood	A	Ypsi	C
Trenary	B	Zeba	B
Trimountain	B	Ziegenfuss	D
Tula	C	Zilwaukee	D
Tuscola	B	Zimmerman	A
Tustin	B		
Twining	C		
Tyre	D/A		

Source: USDA Soil Conservation Service, March, 1990.

APPENDIX 2C

SOILS: STATUS OF MICHIGAN SOIL SURVEYS

Appendix 2C


STATUS OF MICHIGAN
SOIL SURVEYS
(August, 1991)
Modern Published Soil Survey
Mapping Complete-Not Published
Soil Survey in Progress
No Soil Survey in Progress
KEWEENAW
HOUGHTON
ONTONAGON
BARAGA
GOGEBIC
IRON
MARQUETTE
DICKINSON
DELTA
MENOMINEE
LUCE
CHIPPEWA
MACKINAC
EMMET
CHEBOYGAN
PRESQUE ISLE
OTSEGO
MONT-MORENCY
ALPENA
ANTRIM
LEELANAU
KALKASKA
CRAWFORD
OSCODA
ALCONA
BENZIE
GRAND TRAVERSE
MANISTEE
WEXFORD
MISSAUKEE
ROSCOMMON
OGEMAW
IOSCO
MASON
LAKE
OSCEOLA
CLARE
GLADWIN
ARENAC
HURON
BAY
OCEANA
NEWAYGO
MECOSTA
ISABELLA
MIDLAND
TUSCOLA
SANILAC
MUSKEGON
MONTCALM
GRATIOT
SAGINAW
KENT
LAPEER
GENESEE
ST. CLAIR
OTTAWA
IONIA
CLINTON
SHIAWASSEE
OAKLAND
MACOMB
ALLEGAN
BARRY
EATON
INGHAM
LIVINGSTON
VAN BUREN
KALAMAZOO
CALHOUN
JACKSON
WASHTENAW
WAYNE
BERRIEN
CASS
ST. JOSEPH
BRANCH
HILLSDALE
LENAWEE
MONROE

APPENDIX 2D

SOILS: EROSION CAUSED BY WATER

-USE OF THE UNIVERSAL SOIL LOSS EQUATION

-USE OF THE GULLY EROSION EQUATION

Appendix 2D

Use of The Universal Soil Loss Equation

In Developing Areas

WATER EROSION--SHEET

The following procedure is commonly used to estimate soil loss from construction sites and other developing areas. It is a method adopted from the Universal Soil Loss Equation as presented in Agricultural Handbook No. 282, Rainfall-Erosion Losses from Cropland East of the Rocky Mountains. A more precise computation can be made by using the full procedures given in the publication. This method is used to calculate soil eroded by water and causing sheet erosion. Use Exhibit 5 of this Appendix to calculate soil eroded by gullies. Contact the Soil Conservation Service for information on calculating soil lost by wind erosion.

To predict soil losses in developing areas, the simplified form of the equation is: A = RCKLS

A - is the computed soil loss per acre per year in tons. This quantity may be converted to cubic yards by using the conversion factors found in Exhibit 4A. (See attached example problem). All soil loss computations will be made using full years as the unit of time, that is l-year, 2-year, etc.

R - is the average annual rainfall erosion index which is a measure of the erosive force of rainfall. The "R" value for urban areas is the same as that for agricultural lands and should be used in predicting annual soil losses on construction sites. Exhibit 4B gives "R" values for each county in Michigan.

C - is the ratio of soil loss from land cropped under specified conditions to the corresponding loss from tilled, continuous fallow. For developing areas the following three values will represent conditions in most cases:

Well established grass or grass-legume cover	C = 0.006
Weeds and wild grass cover	C = 0.120
Bare or disturbed area	C = 1.000

If more than one condition exists on a site, more than one C value will need to be used per each length-slope ration (see "LS" and the example problem, below).

K - is the soil erodibility factor. On construction sites, substrata materials are often exposed to water erosion so that appropriate "K" values must be used. Exhibit 4C (attached) gives "K" values for the surface soil and for the substrata material if it differs significantly from the surface.

Limited research data show that infiltration rates and erosion losses from compacted fills do not differ greatly from those on "cuts" when slopes and surface materials are the same.

Loose fills may lose less soil and water than compacted fills. Since research has not yet determined the rates of soil loss on loose fills, the same "K" values that are used for cuts or compacted fills may be used for loose fills. Compaction, in this sense, refers to that which occurs from normal grading and hauling operations.

LS - These two factors are closely interrelated and have been combined into one value known as the "LS" value. LS values are given in Exhibit 4D. Their individual significance is:
L - the slope-length factor
S - the slope-gradient factor

Example:
Assume Ypsilanti, Michigan, as the locale of the construction site. The disturbed area is 10 acres in size, with an additional 15 acres under good grass cover in the watershed. The average slope is 8% and the average slope length is 500 feet. The soil is Blount Clay Loam. Compute the annual soil loss from this area.

A = RCKLS

1. First, find the "R" value (annual rainfall erosion index) from Exhibit 4B. The R value for Washtenaw County is 100.

2. Find the "K" (erodibility) factor using Exhibit 4C. A Blount Clay Loam has K of 0.43.

3. Find the "LS" value in Exhibit 4D. With an 8% slope and an average slope length of 500 feet, the LS is 2.2.

4. Find the C value. The disturbed area "C" value is 1.000. The undisturbed grass area "C" value is 0.006.

5. "A" for the disturbed area (C = 1.000):

   A = 100 X 1.00 X 0.43 X 2.2 X 10 acres = 946 tons
   946 tons x .98 (Exhibit 4A) = 927 cubic yards

6. " A " for the grassed area (C = 0.006):

   A = 100 X 0.006 X 0.43 X 2.2 X 15 = 8.5 tons
   8.5 tons X 0.98 = 8.3 cubic yards

7. Total annual soil loss = 927 + 8.3 = 935.3 cubic yards

See also the example practice problem work sheet at the end of this appendix.

Appendix 2D

While sediment yields are not always exactly equal to soil losses (due to the deposition of some soil, materials enroute), for the design of sediment basins covered by this standard, the two values will be assumed to be equal.

Factors For Converting Soil Losses (air-dry) From Tons Per Acre (T/ac) To Cubic Yard Per Acre (cu.yds./ac.)

Sands & loamy sands	- multiply soil loss in T/Ac. by 0.67	(110)[1]
Sandy loam	- multiply soil loss in T/Ac. by 0.70	(105)
Fine sandy loam	- multiply soil loss in T/Ac. by 0.74	(100)
Loam	- multiply soil loss in T/Ac. by 0.82	(90)
Silt loam	- multiply soil loss in T/Ac. by 0.87	(85)
Clay loam	- multiply soil loss in T/Ac. by 0.98	(75)
Silty clay loam	- multiply soil loss in T/Ac. by 0.92	(80)
Silty clay	- multiply soil loss in T/Ac. by 1.06	(70)

[1] The number in parentheses is the air-dry weight of the soil in pounds per cubic foot and from which the conversion factors were calculated.

Appendix 2D

Example Practice Problem:
Sheet Erosion

Site: Twelve acre parcel in Cheboygan County where all vegetation has been removed to build a shopping center.

Soil: Boyer Sandy Loam

Slope: 6% average slope; 800 feet average length

Problem: Calculate the annual potential soil loss (in tons and in cubic feet) from the construction site using the Universal Soil Loss Equation.

Solution: A = RCKLS

R = Rainfall erodibility factor = 75

C = Cropping management factor = 1

K = Soil erodibility factor = .24

LS = Length/Slope factor = 1.9

A = 34.2 tons/acre/year
= 34.2 tons/acre/yr x 12 acres = 410.4 tons/yr

Refer to Exhibit 1 to convert tons to cubic feet. Exhibit 1 indicates that for sandy loam soils, multiply by 0.7 to convert tons to cubic yards:

410 tons x 0.7 = 287 cu. yds.

287cu. yds. x 27 cu. ft./cu. yd. = 7,749 cu. ft.

Importance of Calculation

* Evaluate sizing of (sediment) basin.

* Schedule cleaning of basin.

* Consider need for Staging and Scheduling.

* Establish inspection priorities

*Help persuade others for need of staging and implementing best management practices.

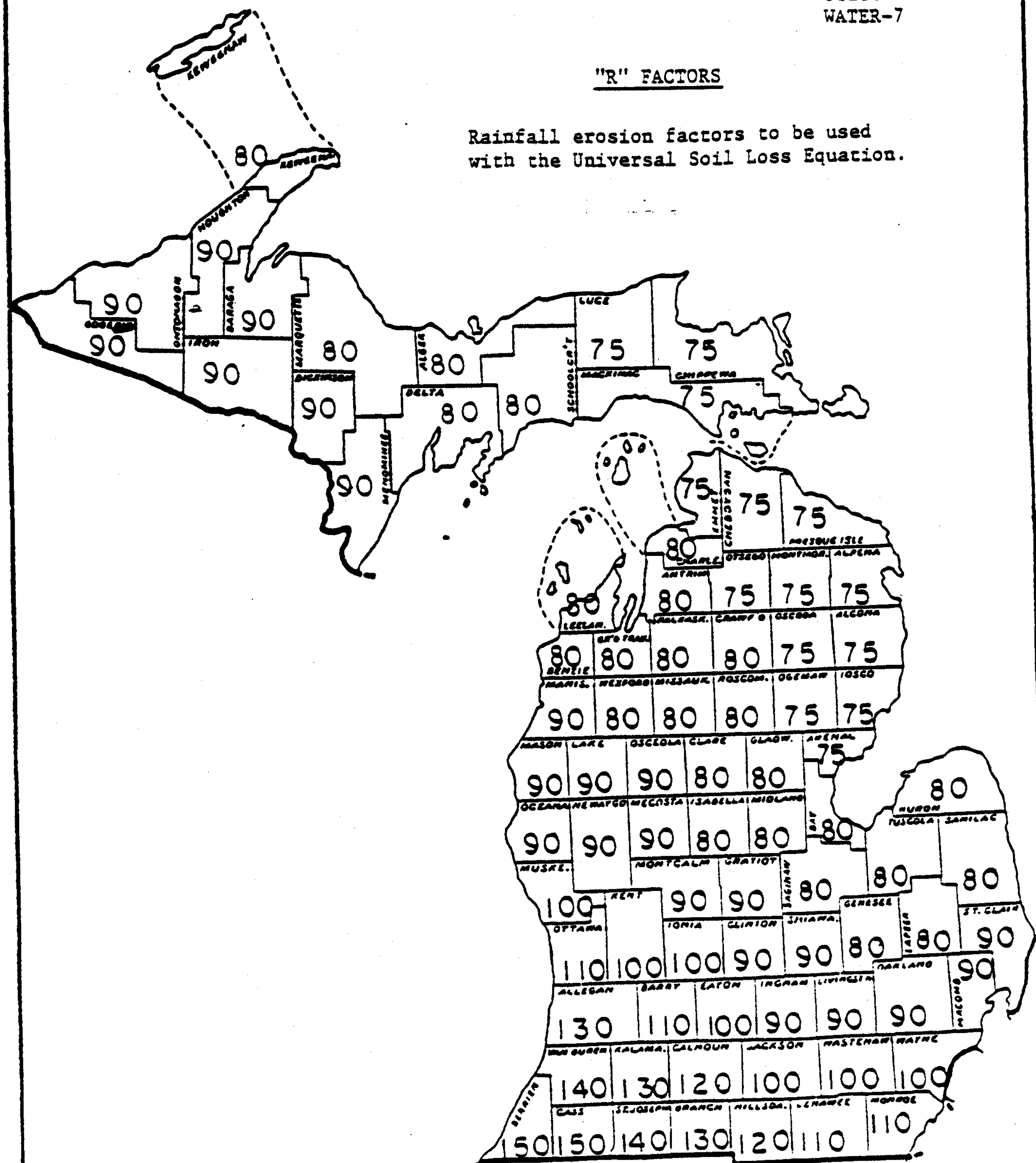
"R" FACTORS

Rainfall Erosion Factors To Be Used
With The Universal Soil Loss Equation

TECHNICAL GUIDE
SECTION I-C
State-wide
WATER-7

"R" FACTORS

Rainfall erosion factors to be used
with the Universal Soil Loss Equation.



USDA-SCS-MICH

(Notice 69 - 9/87)

Soil Erodibility and Soil Loss Tolerance
Water Erosion K and T Factors and T/K Values

Soil Series		Depth (in.)	K	T	T/K	WEG
Abbaya	SL.	0-11	.24	4	17	3
MI0411*	LS	0-11	.17	4	24	2
Abscota	LS, LFS	0-5	.17	5	29	2
MI0082	L	0-5	.32	5	16	5
Moderately Wet	SL, FSL	0-5	.24	5	21	3
Abscota	S	0-6	.15	5	33	1
MI0374	LFS, LS	0-6	.17	5	39	2
Well Drained	FSL	0-6	.24	5	21	3
Adrian	SP, MUCK	0-34	-	4	-	2
MI0028						
Ahmeek	L, SIL	0-2	.32	3	9	5
MN0157	FSL, VFSL	0-2	.24	3	13	3
Alcona	SL, FSL, VFSL	0-8	.24	5	21	3
MI0177	LFS, LVFS	0-8	.17	5	29	2
MI0333						
Algansee	LS, LFS	0-10	.17	5	29	2
MI0123	SL, FSL	0-10	.24	5	21	3
	S, FS	0-10	.15	5	33	1
Allendale	LS, LFS	0-10	.17	4	24	2
MI0185	S, FS	0-10	.15	4	27	1
	SL	0-10	.24	4	17	3
Allendale Variant	S	0-9	.15	4	27	1
MI0301						
Allouez	GR-SL, GR-FSL,	0-4	.17	3	18	8
MI0071	GR-COSL					
	GR-SIL, GR-L	0-4	.24	3	12	8
Alpena	SL, LS	0-7	.17	2	12	3
MI0126	GR-SL, GR-LS	0-7	.10	2	20	8
	GRV-SL, GR-L	0-7	.10	2	20	8
Alpena Variant	SL	0-6	.17	3	18	3
MI0435	GR-SL, GR-L	0-6	.10	3	30	8
Alstad	SIL, L	0-9	.37	5	14	5
WI0218	FSL, SL	0-9	.24	5	21	3
WI0464						
Alstad Variant	MK-SL	0-4	.20	5	25	8
MI0367						
Amasa	VFSL, FSL	0-3	.24	4	17	3
MI0125	SIL	0-3	.37	4	11	5
MI0446						
Angelica	L, SIL, MK-SIL	0-6	.32	5	16	5
MI0065	SL, MK-SL	0-6	.24	5	21	3
MI0446						
Antigo	SIL	0-14	.37	4	11	5
WI0142						
Arkona	S, FS	0-12	.15	4	27	1
MI0264	LS, LFS	0-12	.17	4	24	2
	SL	0-12	.24	4	17	3
Arkport	VFSL, LVFS, FSL	0-9	.28	3	11	-
NY0110	LFS, FS	0-9	.17	3	18	-
Arnheim	MK-SIL, SIL,	0-5	.37	5	14	8
MI0348	LVFS					
Ashkum	SICL, SIC	0-16	.28	5	18	4
IL0031	SIL	0-16	.28	5	18	6
Assinins	S	0-20	.15	4	27	1
MI0338	LS	0-20	.17	4	24	2
Assinins Variant	MUCK	0-4	-	2	-	8
MI0380						

Soil Series		Depth (in.)	K	T	T/K	WEG
Aubarque	L, SIL	0-12	.32	3	9	5
MI0204	SL	0-12	.24	3	12	3
Aubbeenaubbee	SL, FSL	0-15	.24	5	21	3
IN0009						
Au Gres	S	0-13	.15	5	33	1
MI0109	LS	0-13	.17	5	29	2
Aurelius	SP, MUCK	0-9	-	1	-	2
MI0219						
Avoca	LS, LFS	0-10	.17	5	29	2
MI0057	S, FS	0-10	.15	5	33	1
Bach	VFSL	0-8	.32	5	16	3
MI0058	FSL	0-8	.20	5	25	3
	SIL	0-8	.32	5	16	5
Badaxe	SL, FSL	0-10	.24	4	17	3
MI0205	LS	0-10	.17	4	24	2
	CB-SL	0-10	.17	4	24	8
Banat	SIL, L	0-9	.37	3	8	5
MI0427	FSL, SL	0-9	.24	3	13	3
Barry	L, SIL	0-11	.28	5	18	5
MI0035	SL, FSL	0-11	.20	5	25	3
Beechwood	SIL, L	0-2	.37	5	14	5
MI0402						
Belding	SL, FSL	0-8	.24	5	21	3
MI0181	LS	0-8	.17	5	29	2
Belleville	LFS, LS	0-11	.17	5	29	2
MI0054	FS, S	0-11	.15	5	33	1
	SL	0-11	.24	5	21	3
Bergland	SICL	0-8	.37	3	8	4
MI0127	C, SIC	0-8	.32	3	9	4
	SIL	0-8	.37	3	8	6
Berville	L	0-11	.24	5	21	5
MI0128	SL	0-11	.20	5	25	3
	GR-L	0-11	.17	5	29	8
Biscuit	VFSL	0-11	.37	4	11	3
MI0302	VFS, LVFS	0-11	.17	4	24	2
Bixby	L, SIL	0-9	.32	4	13	6
MN0123						
Bixler	LFS	0-10	.17	5	29	2
OH0184	FS	0-10	.15	5	33	1
Blount	SICL	0-10	.43	3	7	7
IL0014	SIL, L	0-10	.43	3	7	6
Blue Lake	LS	0-9	.17	5	29	2
MI0102	S	0-9	.15	5	33	1
Bohemian	SIL, L	0-9	.37	5	14	5
MI0178	VFSL, FSL	0-9	.24	5	21	3
MI0434	LFS	0-9	.17	5	29	2
Bohemian Variant	LVFS	0-7	.24	5	21	2
MI0287	VFS	0-7	.17	5	29	1
	VFSL	0-7	.37	5	14	3
Bonduel	L, SIL	0-8	.32	4	13	5
WI0129						

* The number(s) listed with the soil name is the soil record number, which identifies the SCS-SOI-5 for that particular soil. For soils that are phases of soils such as flooded, ponded, substratum, etc., use the SCS-SOI-5 interpretation record listed on the order form (MI-SOI-4) for T, K and WEG information.

Soil Series		Depth (in.)	K	T	T/K	WEG
Bono	SICL	0-9	.28	5	18	4
OH0111	SIC	0-9	.28	5	18	4
	MK-SIC	0-9	.28	5	18	4
Boots	SP	0-10	-	5	-	2
WI0045						
Borski	SL, FSL	0-5	.24	4	17	3
MI0403						
MI0278						
Bowers	SL, FSL	0-7	.24	4	17	3
MI0105	L, SIL	0-7	.32	4	13	6
Bowstring	MUCK	0-32	-	5	-	8
MN0336						
Boyer	LS, LFS	0-7	.17	4	24	2
MI0032	SL, FSL	0-7	.24	4	17	3
	L	0-7	.32	4	13	5
Boyer	GR-SL	0-7	.17	3	18	8
MI0528	SL, FSL	0-7	.24	3	13	3
Severely Eroded	L	0-7	.15	3	20	2
Brady	SL, FSL	0-9	.20	5	25	3
MI0025	LS, LFS	0-9	.17	5	29	2
	L, SIL	0-9	.28	5	18	5
Branch	LFS, LS	0-28	.17	5	29	2
MI0379	FS, S	0-28	.15	5	33	1
Breckenridge	SL, FSL	0-8	.20	5	25	3
MI0129	L	0-8	.28	5	18	5
Brems	LS, LFS	0-9	.17	5	29	2
IN0022	S, FS	0-9	.15	5	33	1
Brevort	LS, LFS	0-8	.17	5	29	2
MI0055	SL, FSL	0-8	.20	5	25	3
	S	0-8	.15	5	33	1
Brevort	MK-S	0-8	.15	5	33	1
MI0503	MK-LS	0-8	.17	5	29	2
Mucky Surface						
Brimley	FSL, VFSL	0-8	.32	5	16	3
MI0221	SIL, L	0-8	.32	5	16	5
Bronson	SL	0-20	.24	4	17	3
MI0060	LS	0-20	.17	4	24	2
Brookston	SIL, L, MK-SIL	0-14	.28	5	18	6
IN0002	SICL, CL	0-14	.28	5	18	7
Bruce	SIL, MK-L, L,	0-7	.28	5	18	5
MI0222	MK-SIL					
	VFSL, FSL	0-7	.28	5	18	3
Burleigh	S, FS	0-9	.15	5	33	1
MI0531	LS, LFS	0-9	.17	5	29	2
Burleigh	MK-S, MK-FS	0-9	.15	5	29	1
MI0111						
Mucky Surface						
Burt	MK-S, MK-FS	0-5	.15	2	12	1
MI0235	MK-LS	0-5	.17	2	12	2
	MK-SL	0-5	.24	2	8	3
Burt Variant	GRV-S, GRV-LS	0-13	.10	2	20	8
MI0362						
Cadmus	L	0-12	.32	5	16	5
MI0130	SL	0-12	.24	5	21	3
Capac	L, SIL	0-8	.32	5	16	5
MI0091	SL, FSL	0-8	.24	5	21	3
	GR-SL	0-8	.17	5	29	8
Capac Variant	CB-SL	0-14	.17	5	29	8
MI0248						
Carbondale	SP, MUCK	0-5	-	5	-	2
MI0089	HM, MPT	0-5	-	5	-	5
	FB, PEAT	0-5	-	5	-	7

Soil Series		Depth (in.)	K	T	T/K	WEG
Carlisle	SP, MUCK	0-66	-	5	-	2
MI0020						
Casco	L, SIL	0-8	.32	3	9	5
WI0074	SL, FSL	0-8	.24	3	13	3
	GS-SL	0-8	.17	3	18	5
Cassopolis	SL, FSL	0-11	.24	5	21	3
MI0523	L	0-11	.32	5	16	5
Cathro	SP, MUCK	0-11	-	5	-	2
MI0031						
Celina	FSL	0-8	.28	5	18	3
OH0005	SIL, L	0-8	.37	5	24	6
Ceresco	SL, FSL, L	0-12	.20	5	25	3
MI0015	LS, LFS	0-12	.17	5	29	2
	L, SIL	0-12	.24	5	21	5
Champion	SIL	0-4	.37	4	11	5
MI0131	VFSL	0-4	.37	4	11	3
MI0297	SL, FSL	0-4	.24	4	17	3
Champion	CB-VFSL, CB-SIL,	0-4	.28	4	14	8
MI0354	CB-FSL					
Well Drained						
Channahon	L, SIL	0-8	.37	2	5	6
IL0106						
Channing	FSL, SL, VFSL	0-5	.24	4	17	3
MI0132						
Charity	FSL	0-8	.24	3	13	3
MI0486	SICL	0-8	.37	3	8	4L
Charlevoix	SL, FSL	0-10	.24	5	21	3
MI0175	LS	0-10	.17	5	29	2
	L	0-10	.32	5	16	5
Chatham	FSL, SL	0-13	.24	4	17	3
MI0067	L	0-13	.32	4	13	5
Cheboygan	LS	0-6	.17	4	24	2
MI0294	S	0-6	.15	4	27	1
Chelsea	LFS, LS	0-4	.17	5	29	2
IA0119	FS, S	0-4	.15	5	33	1
Chestonia	SICL	0-9	.37	3	8	7
MI0261	L	0-9	.32	3	9	6
Chippeny	SP	0-20	-	4	-	2
MI0133						
Cohoctah	FSL, SL, MK-VFSL	0-13	.24	5	21	3
MI0040	LFS	0-13	.17	5	29	2
	L, SIL	0-13	.28	5	18	5
Coloma	LS	0-4	.17	5	29	2
WI0181	S	0-4	.15	5	33	1
Colonville	FSL, SL	0-17	.20	3	15	3
MI0262	LFS	0-17	.17	3	18	2
	L, SIL	0-17	.20	3	15	5
Colwood	SIL, L	0-12	.28	5	18	5
MI0036	FSL, VFSL	0-12	.20	5	25	3
	SICL	0-12	.28	5	18	7
Conover	SL	0-11	.20	5	25	3
MI0044	L	0-11	.28	5	18	5
	SIL	0-11	.32	5	16	5
Coral	FSL, SL	0-12	.24	5	21	3
MI0186						
Corunna	SL, FSL	0-11	.20	4	20	3
MI0088	L	0-11	.24	4	17	5

Soil Series		Depth (in.)	K	T	T/K	WEG
Corwin	L, SIL	0-15	.28	5	18	5
IN0037	GL	0-15	.28	5	18	5
Coupee	L, SIL	0-14	.32	4	13	5
IN0024	SL	0-14	.24	4	17	3
Covert	LS	0-8	.17	5	29	2
MI0272	S	0-8	.15	5	33	1
Crosby	SIL, L	0-14	.43	3	7	5
IN0023	FSL	0-14	.24	3	13	3
Crosier	L, SIL	0-11	.32	5	16	5
IN0019	SL, FSL	0-11	.24	5	21	3
Croswell	S	0-12	.15	5	33	1
MI0187	LS	0-12	.17	5	29	2
Cunard	FSL, SL	0-4	.24	4	17	3
MI0428	L	0-4	.32	4	13	5
	GR-L, GR-FSL, GR-SL	0-4	.17	4	24	8
Dawson	SP, MUCK	0-8	-	4	-	2
MI0134	FB, PEAT	0-8	-	4	-	7
	HM, MPT	0-8	-	4	-	5
Deer Park MI0188	FS, S	0-24	.15	5	33	1
Deerton	S	0-8	.15	4	27	1
MI0209	LS	0-8	.17	4	24	2
Deerton Variant (Huron Co.) MI0209	GR-LS	0-6	.10	3	30	8
Deerton Variant	S	0-5	.15	4	27	1
(Baraga Co.) MI0361	LS	0-5	.17	4	24	2
Deford	MUCK	0-5	-	5	-	2
MI0112	LFS, FS	0-5	.15	5	33	2
	MK-LS, MK-LFS, MK-FS	0-5	.17	5	29	2
Del Rey	SIL, L	0-9	.43	3	7	6
IL0022	SICL	0-9	.43	3	7	7
Demontreville	LFS, LS	0-24	.17	5	29	2
MN0242	S, FS	0-24	.15	5	33	1
Detour	SL, FSL	0-6	.24	3	13	3
MI0135	CB-L, CB-SL	0-6	.24	3	13	8
	L	0-6	.32	3	9	5
Dighton	L	0-11	.32	4	13	6
MI0176	SL	0-11	.24	4	17	3
	CL	0-11	.32	3	9	6
Dixboro	FSL, SL	0-11	.20	5	25	3
MI0115	LFS, LVFS	0-11	.20	5	25	2
	VFSL	0-11	.32	5	16	3
Dora Variant	SP, MUCK	0-12	-	4	-	2
MI0277	MPT, HM	0-12	-	4	-	5
Dowagiac	L, SIL	0-11	.28	4	14	5
MI0006	SL	0-11	.20	4	20	3
Dresden	SL	0-11	.20	4	20	3
IL0013	SIL, L	0-11	.28	4	14	6
Dryburg MI0136	SL, FSL	0-18	.24	4	17	3
Dryden	SL	0-8	.24	5	21	3
MI0062	L	0-8	.32	5	16	5
Duel	LS	0-6	.17	4	24	2
MI0137	S	0-6	.15	4	27	1
Dunbridge	FSL, SL	0-8	.17	4	24	3
OH0130	LFS, LS	0-8	.17	4	24	2
	GR-FSL, GR-LFS GR-LS	0-8	.15	4	27	8
East Lake	S	0-4	.15	4	27	1
MI0101	LS	0-4	.17	4	24	2
	GR-LS, GR-S	0-4	.10	4	40	8
Eastport MI0095	S	0-3	.15	5	33	1
Eastport MI0431 Well Drained	S, FS	0-24	.15	5	33	1
Edmore	SL	0-9	.24	5	21	3
MI0225	LS	0-9	.17	5	29	2
Edwards MI0016	SP, MUCK	0-32	-	4	-	2
Eel	CL	0-8	.37	5	14	6
IN0021	SIL, L	0-8	.37	5	14	5
	SICL	0-8	.37	5	14	7
Eleva	SL, FSL	0-5	.24	4	17	3
WI0011	L	0-5	.32	4	12	5
Eleva Variant MI0280 (Ingham Co.)	CN-SL	0-6	.17	3	18	8
Eleva Variant MI0317 (Jackson Co.)	CN-FSL	0-6	.17	3	18	8
Elmdale	SL, FSL	0-9	.24	5	21	3
MI0019	L	0-9	.32	5	16	5
Elo MI0138	FSL, L, SIL	0-17	.24	3	13	5
Elston	SL, FSL	0-20	.20	4	20	3
IN0029	L	0-20	.28	4	14	5
Elvers WI0054	SIL	0-35	.37	5	18	5
Emmet	LS	0-8	.17	5	29	2
MI0190	SL, FSL	0-8	.24	5	21	3
	L	0-8	.32	5	16	5
Emmet	LS	0-8	.17	5	29	2
MI0480	SL, FSL	0-8	.24	5	21	3
Mod. Slow Perm.	L	0-8	.32	5	16	5
Emmet	SL, FSL, L	0-8	.24	5	21	3
MI0487	GR-SL	0-8	.17	5	29	8
Moderately Wet	LS	0-8	.17	5	29	2
Ensign	FSL	0-5	.24	2	8	3
MI0070	L, SIL	0-5	.32	2	6	6
	GR-FSL, GR-L	0-5	.17	2	12	5
Ensley	SL, FSL	0-10	.24	5	21	3
MI0189	L, SIL	0-10	.32	5	16	5
	MK-L, MK-SIL, MK-SL	0-10	.24	5	21	5
Epoufette	LS, MK-LS, LFS	0-8	.17	4	24	2
MI0214	SL, COSL, MK-SL	0-8	.20	4	20	3
	MK-S	0-8	.15	4	27	1
Ermatinger	MK-SIL, MK-VFSL	0-8	.37	5	14	5
MI0276	SIL, VFSL	0-8	.37	5	14	5
	LVFS	0-8	.24	5	21	2
Escanaba	LFS, LS	0-6	.17	5	29	2
MI0442	FS	0-6	.15	5	33	1
Essexville	LS, LFS	0-11	.17	5	29	2
MI0230	FS, S	0-11	.15	5	33	1
	SL	0-11	.20	5	25	3

Soil Series		Depth (in.)	K	T	T/K	WEG
Evart	S	0-10	.15	5	33	1
MI0226	LS	0-10	.17	5	29	2
	L, SIL	0-10	.28	5	18	5
Fabius	SL	0-10	.20	3	15	3
MI0008	L	0-10	.24	3	13	5
	SIL	0-10	.28	3	11	5
Fairport	SIL	0-9	.37	4	11	5
MI0139	L	0-9	.32	4	13	5
	FSL	0-9	.24	4	17	3
Fairport	SIL, L	0-9	.37	4	11	5
MI0285	FSL	0-9	.24	4	17	3
Moderately Wet						
Fence	SIL	0-4	.37	5	14	5
WI0009	VFSL	0-4	.37	5	14	3
WI0405						
Fibre	SP, MUCK	0-5	-	3	-	2
MI0457	S, FS	0-5	.15	3	20	1
Filion	ST-L, ST-SL	0-14	.24	5	21	8
MI0292						
Finch	S	0-12	.15	2	13	1
MI0260	LS	0-12	.17	2	12	2
Fox	SIL, L	0-11	.37	4	11	5
WI0026	SL, FSL	0-11	.24	4	17	3
	CL, SCL	0-11	.32	3	9	6
Frechette	LVFS	0-9	.24	5	21	2
MI0026	VFSL	0-9	.37	5	14	3
	SIL	0-9	.37	5	14	5
Froberg	SIL	0-7	.37	3	8	6
MI0140	SICL	0-7	.37	3	8	7
MI0414						
Fulton	SIL, L	0-9	.43	3	7	6
OH0080	SICL	0-9	.43	3	7	7
	FSL	0-9	.24	3	12	3
Gaastra	SIL	0-18	.37	5	14	5
MI0069	VFSL	0-18	.37	5	14	3
Gagetown	SIL	0-12	.32	5	16	5
MI0208	VFSL	0-12	.32	5	16	3
	FSL	0-12	.20	5	15	3
Gay	SP, MUCK	0-7	-	-	-	2
MI0141	SL, FSL	0-7	.24	5	29	3
	MK-SL, MK-FSL	0-7	.24	5	29	3
Gay Variant	MK-SL, MK-FSL,	0-6	.17	4	24	8
MI0363	MK-LS					
Genesee	FSL, SL	0-8	.24	5	21	3
IN0115	SIL, L	0-8	.37	5	14	5
Gilchrist	LS, LFS	0-5	.17	5	29	2
MI0068	S	0-5	.15	5	33	1
MI0259						
Gilford	FSL, MK-FSL,	0-14	.20	4	20	3
IN0003	SL, MK-SL	0-14	.20	4	20	3
	L	0-14	.28	4	14	5
Gladwin	LS	0-11	.17	4	24	2
MI0142	SL	0-11	.24	4	17	3
	S	0-11	.15	4	27	1
Gladwin Variant	S	0-5	.15	5	33	1
MI0401	LS	0-5	.17	5	29	2
Glendora	LS, LFS	0-8	.17	5	29	2
MI0094	L	0-8	.24	5	21	5
	SL, FSL	0-8	.20	5	25	3
Glynwood	SIL, L	0-9	.43	3	7	6
OH0040	SICL, CL	0-9	.43	2	5	7
	SIC	0-9	.32	2	6	4

Soil Series		Depth (in.)	K	T	T/K	WEG
Gogebic	VFSL	0-18	.37	3	8	3
MI0077	SL, FSL	0-18	.24	3	13	3
Moderately Wet	L	0-18	.32	3	9	5
Gogebic	VFSL	0-5	.37	3	8	3
MI0373	VFSL, SL, FSL	0-5	.24	3	13	3
Well Drained						
Gogomain	VFSL	0-6	.37	4	11	3
MI0122	SIL	0-6	.37	4	11	5
	LVFS	0-6	.24	4	17	2
Goodman	SIL	0-6	.37	5	14	5
WI0014						
WI0210						
Granby	LS, LFS	0-10	.17	5	29	2
MI0029	FSL, SL	0-10	.20	5	25	3
MI0118	S, FS	0-10	.15	5	33	1
Granby Variant	LS	0-10	.17	5	29	2
MI0310						
Grattan	S	0-12	.15	5	33	1
MI0322						
Graveraet	SIL, L	0-2	.37	3	8	5
MI0493	FSL, VFSL	0-2	.24	3	13	3
MI0496	GR-FSL, GR-L, GR-SIL	0-2	.28	3	11	8
Graycalm	S	0-3	.15	5	33	1
MI0180	LS, LCOS	0-3	.17	5	29	2
MI0429						
Grayling	S	0-15	.15	5	33	1
MI0097						
Greenwood	FS, PEAT	0-6	-	5	-	7
MI0143	HM, MPT	0-6	-	5	-	5
	SP, MUCK	0-6	-	5	-	3
Grindstone	L	0-9	.32	4	13	5
MI0202	SL	0-9	.20	4	20	3
	CB-L	0-9	.24	4	17	8
Grousehaven	SP, MUCK	0-7	-	-	-	2
MI0051						
Grousehaven Variant	SP, MUCK	0-7	-	1	-	8
MI0482						
Guardlake	SL, FSL	0-3	.24	3	13	3
MI0439	L	0-3	.32	3	9	5
	VFSL	0-3	.37	3	8	3
Guelph	SL	0-8	.24	5	21	3
MI0046	L	0-8	.32	5	16	5
Well Drained	SIL	0-8	.37	5	14	5
Guelph	L	0-8	.32	5	16	5
MI0307	SL	0-8	.24	5	21	3
Moderately Wet	SIC	0-8	.37	5	6	5
Halfaday	S	0-7	.15	5	33	1
MI0441						
Hatmaker	FSL, SL	0-15	.24	5	21	3
MI0336	L	0-15	.32	5	16	5
Henrietta	SP, MUCK	0-12	-	5	-	2
MI0306						
Hessel	L, MK-L	0-8	.32	3	9	5
MI0144	CB-L	0-8	.24	3	13	8
MI0445	GR-L	0-8	.24	3	13	8
Hessel Variant	SP	0-8	-	3	-	8
MI0108						
Hettinger	CL	0-8	.32	3	9	6
MI0107	SICL	0-8	.32	3	9	7
	MK-L, SIL, L	0-8	.32	3	9	6

Soil Series		Depth (in.)	K	T	T/K	WEG
Hillsdale	SL, FSL	0-15	.24	5	21	3
MI0012	LS	0-15	.17	5	29	2
	L	0-15	.32	5	16	5
Hodenpyl	FSL, SL	0-10	.24	5	21	3
MI0327	L	0-10	.32	5	16	5
Houghton MI0024	SP, MUCK	0-66	-	5	-	2
Hoytville	C	0-9	.24	5	21	6
OH0007	SICL, CL	0-9	.28	5	18	7
	SIL	0-9	.28	5	18	6
Huntington WV0005	SIL, L, SICL	0-11	.28	5	18	-
Ingalls	S, FS	0-11	.15	5	33	1
MI0113	LS, LFS	0-11	.17	5	29	2
Ingersoll	SIL	0-9	.37	5	14	5
MI0244	FSL	0-9	.24	5	21	3
	VFSL	0-9	.37	5	14	3
Ionia	SL	0-11	.24	4	17	3
MI0043	SIL, L	0-11	.32	4	13	5
Iosco	LS, LFS	0-11	.17	5	29	2
MI0096	S, FS	0-11	.15	5	33	1
Iron River	VFSL, FSL	0-20	.28	3	11	3
MI0076	SIL, L	0-20	.37	3	8	5
Isabella	L	0-3	.32	5	16	5
MI0179	SL, FSL	0-3	.24	5	21	3
MI0074						
Ishpeming	S, FS	0-14	.15	4	27	1
MI0288	LS, LFS	0-14	.17	4	24	2
Ithaca	L	0-9	.32	3	9	5
MI0266	SIL	0-9	.37	3	8	5
	SL	0-9	.24	3	13	3
Jeddo MI0143	SIL, L	0-8	.43	3	7	5
Jesso	FSL, SL	0-2	.24	3	13	3
MI0396	L, SIL	0-2	.32	3	9	5
MI0397	VFSL	0-2	.37	3	8	3
Johnswood	CB-L, GR-L	0-5	.20	3	15	8
MI0146	CB-SL	0-5	.15	3	20	8
Kalamazoo	L	0-11	.32	4	13	5
MI0007	SL	0-11	.24	4	17	3
	SIL	0-11	.37	4	11	5
Kalkaska	S	0-9	.15	5	33	1
MI0098	LS	0-9	.17	5	29	2
Kallio MI0347	CB-SIL, CB-VFSL, CB-FSL	0-5	.28	4	14	8
Karlin	LFS	0-3	.17	4	24	2
MI0182	FSL, SL	0-3	.24	4	17	3
Karlin Variant	FSL, SL	0-4	.24	5	21	3
MI0284	L	0-4	.32	5	16	5
Kawbawgam	SL	0-6	.24	4	17	3
MI0236	LS	0-6	.17	4	24	2
Kawkawlin	L	0-11	.32	3	9	5
MI0147	SL, FSL	0-11	.24	3	13	3
	SIL	0-11	.37	3	8	5
Kawkawlin Variant MI0404	SL	0-8	.24	4	17	3

Soil Series		Depth (in.)	K	T	T/K	WEG
Kendallville	SIL, L	0-7	.37	5	14	6
OH0067	CL	0-7	.37	5	14	6
	SL	0-7	.24	5	13	2
Kent	SIL, L	0-9	.37	3	8	6
MI0174	FSL, SL	0-9	.24	3	13	3
MI0472						
Keowns	SIL, L	0-16	.28	5	18	5
WI0131	SL, FSL, VFSL	0-16	.24	5	21	3
Kerston MI0022	SP	0-22	-	5	-	2
Keweenaw	LS, LFS	0-8	.17	5	29	2
MI0148	SL	0-8	.24	5	21	3
MI0241						
Kibbie	L, SIL	0-11	.28	5	18	5
MI0041	LFS	0-11	.17	5	29	2
	FSL, SL, VFSL	0-11	.20	5	25	3
Kidder	SIL, L	0-11	.37	5	14	5
WI0049	SL, FSL	0-11	.24	5	21	3
Well Drained	CL, GR-CL	0-11	.32	4	13	6
Kidder	SIL, L	0-11	.37	5	14	5
WI0192	SL, FSL	0-11	.24	5	21	3
Moderately Wet						
Kilmanagh	L	0-9	.32	4	13	5
MI0203	CB-L	0-9	.24	4	17	8
	SL	0-9	.24	4	17	3
Kingsville	FS	0-8	.15	5	33	1
OH0070	LFS, LS	0-8	.17	5	29	2
	MK-LFS	0-8	.17	5	29	2
Kinross	S, FS	0-10	.15	5	33	1
MI0106	LS, LFS	0-10	.17	5	29	2
Kiva	SL, FSL	0-6	.24	3	13	3
MI0066	L	0-6	.32	3	9	8
	LS	0-6	.17	3	18	8
Klacking	S	0-2	.15	5	33	1
MI0351	LS	0-2	.17	5	29	2
Kokomo	SICL, CL	0-16	.32	5	16	7
IN0086	SIL, L	0-16	.32	5	16	6
	MK-SIL	0-16	.32	5	16	6
Kolberg	SIL, L	0-13	.37	4	11	5
WI0132	FSL	0-13	.24	4	17	3
Lacota	CL	0-8	.32	4	13	6
MI0149	SL	0-8	.24	4	17	3
	SIL, L	0-8	.37	4	11	6
Lamson	VFSL, FSL, SIL	0-15	.28	5	18	3
NY0041	LVFS, LFS	0-15	.20	5	25	2
	MK-VFSL, MK-FSL, MK-L	0-15	.28	5	18	3
Landes	FSL, VFSL, SL	0-14	.20	4	20	3
IL0021	L, SIL	0-14	.32	4	13	5
Well Drained	LS, LVFS, LFS	0-14	.17	4	24	2
Landes	FSL, SL	0-13	.20	4	20	3
IL0265	LS	0-13	.17	4	24	2
Moderately Wet	L, SIL	0-13	.28	4	14	5
Landes Variant MI0318	SIL	0-10	.32	5	16	5
Lapeer	SL, FSL	0-12	.24	5	21	3
MI0017	L, SIL	0-12	.32	5	16	5
	LFS	0-12	.17	5	29	2
Latty	SICL	0-7	.28	5	18	4
OH0082	C, SIC	0-7	.28	5	18	4
Leelanau	S	0-8	.15	5	33	1
MI0191	LS	0-8	.17	5	29	2
Lenawee	MK-SICL, SICL	0-9	.28	3	11	7
MI0002	CL	0-9	.24	3	13	6
	SIC	0-9	.28	3	11	4

Soil Series		Depth (in.)	K	T	T/K	WEG
Lenawee	L	0-9	.24	3	13	5
MI00519	SIL	0-9	.28	3	11	5
Med. Tex. Surface						
Lenawee	SICL, MK-SICL	0-9	.28	3	11	7
MI0540	CL	0-9	.24	3	13	6
Slow Permeability	SIC	0-9	.28	3	11	4
Lenawee	L	0-9	.24	3	13	5
MI0541	SIL	0-9	.28	3	11	5
Med. Tex. Surface						
Slow Permeability						
Lenawee Variant	SICL, CL, SIL	0-10	.24	5	21	4
MI0425						
Leoni	GR-SL	0-13	.17	5	29	8
MI0253	GR-LS	0-13	.10	5	50	8
Liminga	FS	0-10	.15	5	33	1
MI0492						
Linwood	SP, MUCK	0-9	-	4	-	2
MI001	MK-SIL	0-9	.28	4	14	5
Locke	SL, FSL	0-15	.20	5	25	3
MI0063	L	0-15	.24	5	21	5
Lode	L, SIL	0-7	.32	5	16	5
MI0398	FSL	0-7	.24	5	21	3
Londo	L	0-8	.32	5	16	5
MI0192	FSL	0-8	.24	5	21	3
	SIL	0-8	.37	5	-	5
Longrie	FSL, SL	0-9	.24	4	17	3
MI0150	L, SIL	0-9	.32	4	13	5
Loxley	SP, MUCK	0-13	-	5	-	2
MI0080	HM, PT	0-13	-	5	-	5
	FP, PEAT	0-13	-	5	-	7
Lupton	SP, MUCK	0-10	-	5	-	2
MI0090	HM, MPT	0-10	-	5	-	5
Mackinac	L	0-8	.32	5	16	5
MI0064	CB-L	0-8	.24	5	21	8
Macomb	L	0-11	.28	4	14	5
MI0003	SL, FSL	0-11	.20	4	20	3
Mancelona	LS, LFS	0-10	.17	4	24	2
MI0210	SL	0-10	.24	4	17	3
	S	0-10	.15	4	27	1
Manistee	LS, LFS	0-11	.17	4	24	2
MI0183	S, FS	0-11	.15	4	27	1
MI0256	FSL	0-11	.24	4	17	3
Manistee Variant	VFS, LVFS	0-3	.24	4	17	2
MI0459	VFSL, SIL	0-3	.32	4	13	3
MI0460						
Manitowish	SL, FSL	0-4	.24	3	13	3
WI0388	L	0-4	.32	3	9	5
Markey	SP, MUCK	0-32	-	4	-	2
MI0030						
Mariette	L	0-9	.32	5	16	5
MI0083	SL, FSL	0-9	.24	5	21	3
MI0084						
Mariette	L	0-9	.32	5	16	5
MI0359	CL	0-9	.32	4	13	6
Eroded	SL	0-9	.24	5	21	3
Martinsville	L, SIL	0-13	.37	5	14	5
IN0018	FSL, SL	0-13	.24	5	21	3
Martisco	SP, MUCK	0-13	-	3	-	2
NY0106						

Soil Series		Depth (in.)	K	T	T/K	WEG
Matherton	L	0-11	.28	4	14	5
MI0037	SIL	0-11	.32	4	13	5
	SL	0-11	.20	4	20	3
Maumee	LFS, LS	0-23	.17	5	29	2
IN0012	MK-LS, MK-S, WK-LFS	0-23	.17	5	29	2
	S	0-23	.17	5	29	1
McBride	SL, FSL	0-8	.24	3	13	3
MI0213	LS	0-8	.17	3	18	2
MI0467						
Macosta	S	0-10	.15	5	33	1
MI0324	LS, GR-LS	0-10	.17	5	29	2
Melita	S, FS	0-10	.15	5	33	1
MI0215	LS, LFS	0-10	.17	5	29	2
Menagha	LCOS, LS	0-4	.15	5	33	2
MN0057	COS, S	0-4	.15	5	33	1
Menominee	S, FS	0-9	.15	5	33	1
MI0193	LS, LFS	0-9	.17	5	29	2
MI0300	GR-S, GR-LS, GR-LFS	0-9	.10	5	50	8
Metamora	SL, FSL	0-13	.20	5	25	3
MI0087	LS	0-13	.17	5	29	2
Metea	LS, LFS	0-9	.17	5	29	2
IN0016	S, FS	0-9	.17	5	29	1
Metea Variant	CB-LS	0-31	.10	5	50	8
MI0249						
Miami	SIL, L	0-8	.37	4	11	5
IN0013	FSL, SL	0-8	.24	4	17	3
	CL, SICL	0-8	.37	3	8	6
Michigamme	SIL	0-4	.37	4	11	5
MI0073	SL, FSL	0-4	.20	4	20	3
	VFSL	0-4	.37	4	11	3
Millsdale	SICL	0-9	.28	4	14	7
OH0018	SIL, L	0-9	.32	4	13	6
	CL	0-9	.24	4	17	6
Milton	SIL, L	0-8	.37	4	11	6
OH0011	SICL	0-8	.37	3	8	7
	CL	0-8	.32	4	13	6
Minoa	VFSL, SIL, LVFS,	0-10	.32	4	13	-
NY0046	L, FSL	0-10	.28	4	13	-
Misery	VFSL	0-7	.37	3	8	3
MI0491	SIL	0-7	.37	3	8	5
	FSL	0-7	.28	3	11	3
Mitiwanga	SIL, L	0-11	.32	4	13	6
OH0055	CN-L	0-11	.24	4	17	8
Monico	L, SIL	0-7	.37	5	14	5
WI0344	SL, FSL	0-7	.24	5	21	3
	GR-L, GR-SL, CB-SL	0-7	.28	5	18	8
Monitor	L, SIL	0-13	.32	5	16	5
IN0093	SL	0-13	.20	5	25	3
Montcalm	LS	0-9	.17	5	29	2
MI0217	GR-LS	0-9	.10	5	50	8
	SL	0-9	.24	5	21	3
Moquah	FSL, SL, VFSL	0-5	.24	5	21	3
WI0322	L, SIL	0-5	.32	5	16	5
Morley	SIL, L	0-9	.37	4	11	6
IL0017	SICL	0-9	.37	3	8	7
Moderately Wet	CL	0-9	.32	3	9	6
Morley	SIL, L	0-9	.43	4	9	6
IL0270	CL	0-9	.32	4	13	6
Well Drained	SICL	0-9	.37	4	11	7

Soil Series		Depth (in.)	K	T	T/K	WEG
Morocco	LFS, LS	0-8	.17	5	29	2
IN0079	FS, S	0-8	.15	5	33	1
Munising	SL, FSL	0-9	.24	4	17	3
MI0151	LS	0-9	.17	4	24	2
MI0355						
Munuscong	FSL, SL	0-8	.24	4	17	3
MI0114						
Mussey	MK-SL	0-9	.20	3	15	3
MI0227	L	0-9	.24	3	13	5
	SL	0-9	.20	3	15	3
Nadeau	L	0-3	.32	3	9	5
MI0382	FSL, SL	0-3	.24	3	13	3
	GR-L, GR-SL, GR-FSL	0-3	.17	3	18	8
Nahma	SP, MUCK	0-4	-	4	-	2
MI0152	MK-SL, MK-FSL	0-4	.24	4	-	3
	MK-L	0-4	.32	4	13	5
Napoleon	SP, MUCK	0-10	-	5	-	2
MI0218	HM, MPT	0-10	-	5	-	5
	FS, PEAT	0-10	-	5	-	7
Nappanee	L, SIL	0-8	.37	3	8	6
MI0014	SICL	0-8	.43	3	7	7
	CL	0-8	.37	3	8	6
Nester	L, SIL	0-9	.32	3	9	5
MI0153	SL, FSL	0-9	.24	3	13	3
MI0299	LS	0-9	.17	3	18	2
Nester	CL	0-8	.32	2	6	4
MI0242	C	0-8	.32	2	6	4
Severely Eroded	SICL	0-8	.32	2	6	7
Net	ST-SIL, ST-VFSL, ST-FSL	0-3	.28	4	14	8
MI0376						
Newaygo	L	0-7	.32	4	13	5
MI0154	SL	0-7	.24	4	17	3
Newton	LFS, LS	0-16	.17	5	29	2
IN0085	S	0-16	.17	5	29	1
	FSL	0-16	.17	5	25	3
Nottawa	SL	0-11	.20	4	20	3
MI0313	L	0-11	.28	4	14	5
Munica	SIL, L	0-6	.37	5	14	5
MI0194	VFSL	0-6	.37	5	18	3
Munica Variant	SICL	0-7	.43	5	12	7
MI0483						
MI0490						
Oakville	LS, LFS	0-7	.17	5	29	2
MI0038	FS, S	0-7	.15	5	33	1
MI0323						
Ockley	SL	0-12	.24	5	21	3
IN0034	SIL	0-12	.37	4	11	6
	L	0-12	.24	5	21	3
Oconto	SL, FSL	0-9	.24	4	17	3
WI0016	L	0-9	.32	4	13	5
Ocqueoc	LS, LFS	0-8	.17	4	24	2
MI0237	S, FS	0-8	.15	4	27	1
MI0255						
Odell	SIL, L	0-13	.28	4	14	6
IN0036	SICL	0-13	.28	4	14	7
Ogemaw	LS	0-10	.17	2	24	2
MI0231	S	0-10	.15	2	27	1
	SL	0-10	.24	2	17	3
Okee	LFS, LS	0-3	.17	4	24	2
WI0064						
Olentangy	MK-SIL	0-14	-	5	-	6
OH0144	SIL	0-14	-	5	-	6
	SP	0-14	-	5	-	2

Soil Series		Depth (in.)	K	T	T/K	WEG
Omega	LS, LFS	0-10	.17	5	29	2
MN0120	S, FS	0-10	.15	5	33	1
Omena	SL, FSL	0-8	.24	3	13	3
MI0196						
Onaway	FSL, SL	0-4	.24	4	17	3
MI0195	L	0-4	.32	4	13	5
	STV-FSL, STV-L	0-4	.20	4	20	8
Onaway	FSL, SL	0-13	.24	5	21	3
MI0304	L	0-13	.32	5	16	6
Moderately Wet	STV-FSL, STV-L	0-13	.24	5	21	8
Onota	LS	0-7	.17	4	24	2
MI0155	SL	0-7	.24	4	17	3
Onota Variant	CN-S, CN-LS, CRV-S	0-15	.10	2	20	8
MI0360						
Ontonagon	SIC, C	0-3	.28	3	11	4
MI0075	SICL	0-3	.43	3	7	4
	SIL, L	0-3	.43	3	7	6
Ormas	LS, LFS	0-24	.17	5	29	2
IN0158	S	0-24	.15	5	33	1
Oshtemo	SL, FSL	0-14	.24	5	21	3
MI0033	LS, LFS	0-14	.17	5	29	2
Otisco	S	0-9	.15	5	33	1
MI0156	LS	0-9	.17	5	29	2
	SL	0-9	.24	5	21	3
Ottokee	LFS, LS	0-8	.17	5	29	2
OH0010	FS	0-8	.15	5	33	1
Ottokee Variant	FS, S	0-9	.15	4	27	1
MI0315						
Owosso	SL, FSL	0-12	.24	5	21	3
MI0047						
Padus	SL, FSL	0-4	.24	4	17	3
WI0015	SIL, L	0-4	.32	4	13	5
WI0369						
Palms	SP, MUCK	0-14	-	5	-	2
MI0023	HM, MPT	0-14	-	5	-	5
Parkhill	L	0-8	.24	5	21	5
MI0092	CL	0-8	.24	5	21	6
	MK-L	0-8	.24	5	21	5
Paulding	C, SIC	0-6	.28	5	18	4
OH0068	SICL	0-6	.28	5	18	4
Pelkie	LVFS, LFS	0-8	.17	5	29	2
MI0337	VFSL, FSL	0-8	.24	5	21	3
	FS	0-8	.15	5	33	1
Pella	CL	0-13	.28	5	18	6
IL0130	SICL	0-13	.28	5	18	7
	SIL	0-13	.28	5	18	6
Pemene	LS, LFS	0-21	.17	5	29	2
MI0378	FSL, SL	0-21	.24	5	21	3
Pence	SL, FSL	0-8	.24	3	13	3
WI0179	L	0-8	.32	3	9	5
Pendleton	FSL	0-2	.24	3	13	3
MI0400	SIL, L	0-2	.37	3	8	5
Pequaming	LS	0-11	.17	5	29	2
MI0293						
Perrin	GR-LS	0-14	.10	4	40	8
MI0056	LS	0-14	.17	4	24	2
	SL	0-14	.24	4	17	3

Soil Series		Depth (in.)	K	T	T/K	WEG	Soil Series		Depth (in.)	K	T	T/K	WEG
Perrinton	CL, SICL	0-8	.32	2	6	6	Richter Variant	FSL, VFSL	0-10	.24	5	21	3
MI0265	L	0-8	.37	3	8	5	MI0368	LFS	0-10	.17	5	29	2
	SIL	0-8	.43	3	7	5		LS	0-10	.17	5	29	2
Perrinton	L	0-8	.37	3	8	5	Riddles	L, SIL	0-8	.32	5	16	5
MI0325	SIL	0-8	.43	3	7	5	IN0015	SL, FSL	0-8	.24	5	21	3
Moderately Wet													
Pert	SICL	0-7	.37	3	8	7	Rifle	FB, PEAT	0-4	-	5	-	7
(Perth)	L, SIL	0-7	.37	3	8	6	MI0021	SP, MUCK	0-4	-	5	-	2
MI0197	CL	0-7	.37	3	8	6		HM, MPT	0-4	-	5	-	5
Peshekee	VFSL, FSL, SL	0-5	.24	2	8	3	Riggsville	LS	0-9	.17	4	24	2
MI0286	SIL	0-5	.37	2	5	5	MI0484	LFS	0-9	.17	4	24	2
Peshekee Variant	FSL-VFLS	0-3	.28	2	7	8	Rimer	LFS, LS	0-9	.17	4	24	2
MI0381							OH0078	FS	0-9	.15	4	27	1
Petticoat	CB-SIL, CB-L	0-10	.28	4	14	8	Riverdale	LS	0-8	.17	4	24	2
MI0412	CB-L	0-10	.24	4	17	8	MI0268	SL	0-8	.24	4	17	3
								S	0-8	.15	4	21	1
Pewamo	CL, MK-CL	0-13	.24	5	21	6	Rodman	GR-L, L	0-7	.20	3	15	8
MI0042	SICL, MK-SICL	0-13	.28	5	18	7	IN0006	GR-SL, SL, GR-LS	0-7	.15	3	20	8
	SIC, C	0-13	.28	5	18	4		GR-S	0-7	.10	3	30	8
Pewamo	L	0-13	.24	5	21	6	Rondeau	SP, MUCK	0-44	-	5	-	2
MI0516	SIL	0-13	.28	5	18	6	MN0148						
Med. Tex. Surface													
Pickford	SIL, L, MK-SIL	0-10	.43	3	7	5	Roscommon	LS, MK-LS	0-4	.17	5	29	2
MI0157	SIC, C	0-10	.32	3	9	4	MI0159	S, MK-S	0-4	.15	5	33	1
	SICL, MK-SICL	0-10	.43	3	7	7		SP, MUCK	0-4	-	5	-	2
Pinconning	S, FS	0-8	.15	4	27	1	Roscommon Variant	MK-S	0-5	.15	4	27	8
MI0110	LS, LFS	0-8	.17	4	24	2	MI0389						
Pinnebog	SP, MUCK	0-34	-	5	-	2	Roselms	CL	0-9	.37	3	8	6
MI0282							OH0137	SIL, L	0-9	.43	3	7	6
								SICL	0-9	.43	3	7	7
Pipestone	S, FS, COS	0-11	.15	5	33	1	Rousseau	FS	0-8	.15	5	33	1
MI0257	LS, LFS, LCOS	0-11	.17	5	29	2	MI0099	LFS	0-8	.17	5	29	2
							MI0308						
Plainfield	LS, LFS	0-7	.17	5	29	2	Rubicon	S	0-6	.15	5	33	1
WI0116	S, FS	0-7	.15	5	33	1	MI0050	LS	0-6	.17	5	29	2
Pleine	SP, MUCK	0-6	-	5	-	8	Rudyard	SIC	0-6	.37	3	8	4
MI0158							MI0078	SIL, L	0-6	.37	3	8	5
								SICL	0-6	.37	3	8	4
Ponozzo	SL, FLS	0-7	.24	3	13	3	Ruse	L	0-7	.32	2	6	5
MI0399	L	0-7	.32	3	9	5	MI0072	SIL	0-7	.37	2	5	5
								GR-L	0-7	.24	2	8	8
Posen	CB-FSL, GR-SL,	0-6	.17	5	25	8	Ruse	SP, MUCK	0-7	-	2	-	2
MI0436	FL-FSL						MI0510	MK-L	0-7	.32	2	6	5
	CB-LS, FL-LS	0-6	.10	5	50	8	Mucky Surface	MK-S	0-7	.15	2	13	1
	CB-L, CB-SIL,	0-6	.20	5	18	8							
	FL-L												
Poseyville	S, FS	0-16	.15	5	33	1	Saganing	SL, FSL	0-8	.20	4	17	3
MI0245	LS, LFS	0-16	.17	5	29	2	MI0233	MK-SL	0-8	.20	4	17	3
Poy	SICL, SIC	0-12	.28	3	11	4	Sanilac	VFSL, FSL	0-13	.37	5	14	3
WI0411	SIL, L	0-12	.28	3	11	6	MI0086	SIL	0-13	.37	5	14	4L
WI0012	CL	0-12	.24	3	17	6							
Randolph	SIL, L	0-8	.37	4	11	6	Saranac	CL	0-11	.24	5	21	6
OH0013							MI0160	SICL	0-11	.28	5	18	7
								C, SIC	0-11	.28	5	18	4
Rapson	S	0-25	.15	5	33	1	Saranac	L	0-11	.24	5	17	5
MI0275	LS, LFS	0-25	.17	5	29	2	MI0516	SIL	0-11	.28	5	14	5
							Med. Tex. Surface						
Remus	SL, FSL	0-6	.24	3	13	3	Sarona	SL, FSL	0-6	.24	5	21	3
MI0326	LS	0-6	.17	3	18	2	WI0280	LS	0-6	.17	5	29	2
Rensselaer	SIL, L	0-15	.32	5	16	5	Satago	SIL, L	0-4	.37	5	14	4L
IN0008	SICL, CL	0-15	.32	5	16	7	MI0437	VFSL	0-4	.37	5	14	3
	SL, FSL	0-15	.24	5	21	3							
Rib	SIL, MK-SIL	0-11	.28	4	14	5	Satago Variant	L, SCL	0-8	.32	5	16	5
WI0144							MI0438	VFSL	0-8	.37	5	14	3
Richter	L	0-6	.32	5	16	5	Saugatuck	S	0-10	.15	2	13	1
MI0184	SL	0-6	.24	5	21	3	MI0045	LS, LFS	0-10	.17	2	12	2
	LFS, LS	0-6	.17	5	29	2							

Soil Series		Depth (in.)	K	T	T/K	WEG
Saylesville	SIL, L	0-12	.37	5	14	5
WI0082	SICL	0-12	.37	5	14	7
WI0300						
Sayner	LS	0-4	.17	3	18	2
WI0334	S	0-4	.15	3	20	1
Scalley	SL, FSL	0-18	.24	4	17	3
MI0342	L	0-18	.32	4	13	5
Schoolcraft	L	0-12	.28	4	14	5
MI0289	SIL	0-12	.32	4	13	5
	SL	0-12	.20	4	20	3
Sebewa	L, MK-L	0-14	.24	4	17	5
MI0039	SL	0-14	.20	4	20	3
	SIL	0-14	.28	4	14	5
Sebewa	CL	0-14	.24	4	17	6
MI0511	SCL	0-14	.24	4	17	5
Mod. Fine Surface	SICL	0-14	.28	4	14	7
Selfridge	S, FS	0-8	.15	5	33	1
MI0081	LS, LFS	0-8	.17	5	29	2
Selkirk	SIL, L	0-12	.37	3	8	5
MI0234	SL	0-12	.24	3	13	3
	SICL	0-12	.37	3	8	7
Seward	FS	0-10	.17	4	24	1
OH0079	LFS, LS	0-10	.17	4	24	2
Shawano	FS	0-4	.15	5	33	1
WI0134	LFS	0-4	.17	5	29	2
Shebeon	SL	0-11	.24	4	17	3
MI0201	L	0-11	.32	4	12	5
	CB-L, CB-SL	0-11	.24	4	17	8
Shelldrake	S	0-60	.15	5	33	1
MI0100						
Shelter	CBV-L, GRV-L, CBV-SIL	0-6	.24	3	13	8
MI0334						
	CB-L, GR-L, CB-SIL	0-6	.24	3	13	8
Shinrock	SIL, L	0-10	.37	3	8	5
OH0124	FSL	0-10	.24	3	13	3
	SICL	0-10	.37	2	5	7
Shoals	SIL, L	0-9	.37	5	14	6
IN0116	SICL	0-9	.37	5	14	7
	CL	0-9	.37	5	14	6
Sickles	SL	0-9	.24	4	17	3
MI0269	S, FS	0-9	.15	4	27	1
	LS, LFS	0-9	.17	4	24	2
Sims	SL	0-7	.20	3	15	3
MI0093	L	0-7	.24	3	13	5
	LS	0-7	.17	3	18	2
Sims	CL	0-7	.24	3	13	6
MI0502	SICL	0-7	.28	3	11	7
Mod. Fine Surface						
Sisson	FSL, SL, VFSL	0-14	.24	5	21	3
MI0011	LFS	0-14	.17	5	29	2
	L, SIL	0-14	.32	5	16	5
Skanee	SL, FSL	0-5	.24	3	13	3
MI0161	LS	0-5	.17	3	18	2
Sleeth	L, SIL	0-11	.32	5	16	5
IN0026	SL	0-11	.32	5	16	3
Sloan	SIL, L	0-15	.28	5	18	6
OH0132	SICL	0-15	.28	5	18	7
	CL	0-15	.24	5	21	6
Solona	L, SIL	0-9	.32	5	16	5
WI0135	SL, FSL	0-9	.24	5	21	3
Sparta	LFS, LZ	0-15	.17	5	29	2
WI0041	S, FS	0-15	.15	5	33	1
Spinks	LS, LFS	0-10	.17	5	29	2
MI0005	S, FS	0-10	.15	5	33	1
Spirit	SIL	0-14	.37	5	14	5
WI0018						
Springlake	LS	0-4	.17	5	29	2
MI0433	S	0-4	.15	5	33	1
St. Clair	L, SIL	0-9	.37	3	8	6
MI0010	SICL	0-9	.43	3	7	7
	CL	0-9	.37	3	8	6
St. Clair	SICL	0-9	.37	2	5	7
MI0515	C	0-9	.32	2	6	4
Severely Eroded	SIC	0-9	.32	2	6	4
St. Ignace	STV-SL, STV-L	0-4	.20	2	10	8
MI0198						
Stambaugh	VFSL	0-18	.32	4	13	3
MI0085	SIL	0-18	.32	4	13	5
MI0330						
Steuben	FSL, SL	0-6	.24	3	13	3
MI0163	LS	0-6	.17	3	17	2
Sturgeon	SIL	0-8	.37	4	11	5
MI0335	FSL	0-8	.24	4	17	3
	VFSL	0-8	.37	4	11	3
Sugar	LVFS	0-3	.24	4	17	2
MI0459	VFSL	0-3	.32	4	13	3
MI0460						
Summerville	FSL, SL, VFSL	0-2	.24	2	8	3
MI0164	L, SIL	0-2	.32	2	6	5
Sundell	SL, FSL	0-7	.24	4	17	3
MI0165	L	0-7	.32	4	13	5
Sunfield	L	0-11	.32	4	13	5
MI0079	SL	0-11	.24	4	17	3
Superior	FSL, SL	0-6	.24	3	13	3
WI0019	LFS, LS	0-6	.17	3	18	2
WI0154	L	0-6	.32	3	9	5
Tacoosh	SP, MUCK	0-8	-	5	-	2
MI0166	HM-MPT	0-8	-	5	-	5
			-			
Tallula	SIL	0-15	.32	5	16	5
IL0200						
Tappan	L	0-13	.28	5	18	5
MI0220	SL	0-13	.20	5	25	3
	MK-L	0-13	.32	5	16	5
Tawas	SP, MUCK	0-4	-	4	-	2
MI0027	HM, MPT	0-4	-	4	-	5
	FB, PEAT	0-4	-	4	-	7
Teasdale	FSL, SL	0-13	.24	5	21	3
MI0018	L	0-13	.32	5	16	5
Tedrow	LFS, LS	0-8	.17	5	29	2
OH0026	FS	0-8	.15	5	33	1
Tekenink	LFS, LS	0-11	.17	5	29	2
MI0343	FSL, SL	0-11	.24	5	29	3
Thetford	LS, LFS	0-6	.17	5	29	2
MI0049	S, FS	0-6	.15	5	33	1
Thomas	SP	0-9	-	5	-	2
MI0199	MK-SIL, MK-L	0-9	-	5	-	5
	MK-SL	0-9	-	5	-	3
Tobico	S, FS, MK-S	0-7	.15	5	33	1
MI0167	LS, MK-LS, LFS	0-7	.17	5	29	2
	SP, MUCK	0-7	-	5	-	2

Soil Series		Depth (in.)	K	T	T/K	WEG	Soil Series		Depth (in.)	K	T	T/K	WEG
Toledo	SICL, CL	0-9	.28	5	18	7	Wasepi Variant	SL	0-9	.20	3	15	3
OH0081*	SIC, C	0-9	.28	5	18	4	MI0104						
	SIL	0-9	.28	5	18	6							
Tonkey	SL, MK-SL	0-8	.24	4	17	3	Washtenaw	SIL, L	0-10	.37	5	14	5
MI0224	L, MK-L	0-8	.32	4	12	5	IN0004						
	LFS, LS, MK-LS	0-8	.17	4	21	2							
Tracy	L	0-9	.32	5	16	5	Watton	SIL, L	0-6	.37	5	14	5
IN0001	SL	0-9	.24	5	21	3	MI0004						
Trenary	FSL, VFSL	0-17	.24	5	21	3	Waucedah	MK-SL, MK-FSL	0-11	.20	5	25	3
MI0168							MI0426	MK-L	0-11	.24	5	21	5
MI0329													
Tula	L	0-14	.32	5	16	5	Wauseon	L, SIL	0-13	.28	4	14	5
MI0169	SIL	0-14	.37	5	14	5	OH0077	FSL, SL	0-13	.20	4	20	3
	SL, FSL	0-14	.24	5	21	3		LFS, LS	0-13	.17	4	24	2
Tuscola	FSL, SL, VFSL	0-9	.24	5	21	3	Whalan	SIL, L	0-9	.32	4	13	6
MI0009	SIL, L	0-9	.32	5	16	5	MN0112	SL	0-9	.24	4	17	3
	LFS	0-9	.17	5	29	2							
Tustin	LFS, LS	0-9	.17	4	24	2	Wheatley	MK-LS, LS, LFS	0-7	.17	3	18	2
WI0069	FS, S	0-9	.15	4	27	1	MI0211	MK-SL, SL	0-7	.24	3	13	3
							MI0497	S	0-7	.15	3	20	1
Twining	SL	0-16	.24	5	21	3	Whitaker	L, SIL	0-17	.37	5	14	5
MI0223	L	0-16	.32	5	16	5	IN0010	FSL, SL	0-17	.24	5	21	3
Tyre	LS	0-5	.17	4	24	2	Wilette	SP, MUCK	0-32	-	4	-	2
MI0207	S	0-5	.15	4	27	1	MI0034						
Ubly	SL	0-8	.24	5	21	3	Winneshiek	FSL	0-11	.20	3	15	3
MI0200	LS	0-8	.17	5	29	2	IA0115	L, SIL	0-11	.28	3	11	6
MI0298													
Ubly Variant	FSL	0-5	.28	4	14	3	Winterfield	FSL, SL	0-7	.24	5	21	3
MI0447	VFSL	0-5	.37	4	11	3	MI0263	LS, LFS	0-7	.17	5	29	2
								S, FS	0-7	.15	5	33	1
Vestaburg	LS	0-8	.17	4	24	2	Wisner	CL, L	0-8	.37	5	14	4L
MI0270	S, FS	0-8	.15	4	27	1	MI0229	SL	0-8	.24	5	21	3
	SL	0-8	.24	4	17	3							
Vestaburg	MK-LS	0-8	.17	4	24	2	Witbeck	STV-MUCK	0-6	-	5	-	8
MI0494	MK-S	0-8	.15	4	27	1	MI0172						
Mucky Surface													
Vilas	LS	0-4	.17	5	29	2	Wixom	LS, LFS	0-9	.17	5	29	2
WI0242	S	0-4	.15	5	33	1	MI0267	S, FS	0-9	.15	5	33	1
Wainola	FS	0-10	.15	5	33	1	Wolcott	CL	0-10	.28	5	18	6
MI0212	LFS	0-10	.17	5	29	2	IN0142	L	0-10	.28	5	18	6
								SICL	0-10	.28	5	18	7
Waiska	LS	0-3	.17	2	12	2	Woodbeck	SIL	0-12	.37	4	11	6
MI0170	S	0-3	.15	2	13	1	MI0350	L	0-12	.32	4	12	6
	SL	0-3	.24	2	8	3		SL	0-12	.24	4	17	3
Waiska Variant	CNV-S, CNX-S	0-60	.10	2	20	8	Worcester	L, SIL	0-8	.32	4	13	5
MI0358							WI0022	SL, FSL	0-8	.24	4	17	3
Wakefield	SIL, L	0-18	.37	3	8	5	Yalmer	LS, LFS	0-23	.17	4	24	2
MI0171							MI0173	S, FS	0-23	.15	4	27	1
							MI0357						
Wallace	S	0-7	.15	1	7	1	Ypsi	SL	0-9	.24	4	17	3
MI0103							MI0048	LS	0-9	.17	4	27	2
Wallkill	SIL, L, FSL	0-8	.37	5	14	-	Zeba	LS, LFS	0-5	.17	4	24	2
NY0053	SICL	0-8	.37	5	14	3	MI0413	SL, FSL	0-5	.24	4	17	3
	GR-SIL, GR-L, GR-FSL	0-8	.32	5	16	-							
Warners	SIL, L, SICL, MK-SIL	0-8	.43	5	12	6	Ziegenfuss	L	0-6	.28	3	11	5
NY0077							MI0346	SICL	0-6	.32	3	9	7
Wasepi	SL, FSL	0-13	.20	4	20	3	Zimmerman	LFS	0-10	.17	5	29	2
MI0059	LS, LFS	0-13	.17	4	24	2	MN0512	FS	0-10	.15	5	33	1

Slop-Effect Table (Topographic Factor, LS)

Slope Length in feet	LS Value (% Slope)														
	4	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
50	.3	.5	.7	1.0	1.3	1.6	2.0	2.4	3.0	4.3	6.0	7.9	10.1	12.6	15.4
100	.4	.7	1.0	1.4	1.8	2.3	2.8	3.4	4.2	6.1	8.5	11.2	14.4	17.9	21.7
150	.5	.8	1.2	1.6	2.2	2.8	3.5	4.2	5.1	7.5	10.4	13.8	17.6	21.9	26.6
200	.6	.9	1.4	1.9	2.6	3.3	4.1	4.8	5.9	8.7	12.0	15.9	20.3	25.2	30.7
250	.7	1.0	1.6	2.2	2.9	3.7	4.5	5.4	6.6	9.7	13.4	17.8	22.7	28.2	34.4
300	.7	1.2	1.7	2.4	3.1	4.0	5.0	5.9	7.2	10.7	14.7	19.5	24.9	30.9	37.6
350	.8	1.2	1.8	2.6	3.4	4.3	5.4	6.4	7.8	11.5	15.9	21.0	26.9	33.4	40.6
400	.8	1.3	2.0	2.7	3.6	4.6	5.7	6.8	8.3	12.3	17.0	22.5	28.7	35.7	43.5
450	.9	1.4	2.1	2.9	3.8	4.9	6.1	7.2	8.9	13.1	18.0	23.8	30.5	37.9	46.1
500	.9	1.5	2.2	3.1	4.0	5.2	6.4	7.6	9.3	13.7	19.0	25.1	32.1	39.9	48.6
550	1.0	1.6	2.3	3.2	4.2	5.4	6.7	8.0	9.8	14.4	19.9	26.4	33.7	41.9	50.9
600	1.0	1.6	2.4	3.3	4.4	5.7	7.0	8.3	10.2	15.1	20.8	27.5	35.2	43.7	53.2
650	1.1	1.7	2.5	3.5	4.6	5.9	7.3	8.7	10.6	15.7	21.7	28.7	36.6	45.5	55.4
700	1.1	1.8	2.6	3.6	4.8	6.1	7.6	9.0	11.1	16.3	22.5	29.7	38.0	47.2	57.5
750	1.1	1.8	2.7	3.7	4.9	6.3	7.9	9.3	11.4	16.8	23.3	30.8	39.3	48.9	59.5
800	1.2	1.9	2.8	3.8	5.1	6.5	8.1	9.6	11.8	17.4	24.1	31.8	40.6	50.5	61.4
900	1.2	2.0	3.0	4.1	5.4	6.9	8.6	10.2	12.5	18.5	25.5	33.7	43.1	53.5	65.2
1000	1.3	2.1	3.1	4.3	5.7	7.3	9.1	10.8	13.2	19.5	26.9	35.5	45.4	56.4	68.7

Example Practice Problem
Sheet Erosion

Site: Twelve acre parcel in Cheboygan County where all vegetation has been removed to build a shopping center.

Soil: Boyer Sandy Loam

Slope: 6% average slope; 800 feet average length

Problem: Calculate the annual potential soil loss (in tons and in cubic feet) from the construction site using the Universal Soil Loss Equation.

Solution: A = RCKLS

R = Rainfall erodibility factor = 75

C = Cropping management factor = 1

K = Soil erodibility factor = .24

LS = Length/Slope factor = 1.9

A = 34.2 tons/acre/year
= 34.2 tons/acre/yr x 12 acres = 410.4 tons/yr

Refer to Exhibit 1 to convert tons to cubic feet. Exhibit 1 indicates that for sandy loam soils, multiply by 0.7 to convert tons to cubic yards:

410 tons x 0.7 = 287 cu. yds.

287 cu. yds. x 27 cu. ft./cu. yd. = 7,749 cu. ft.

Importance of Calculation

*Evaluate sizing of (sediment) basin.

* Schedule cleaning of basin.

*Consider need for Staging and Scheduling.

* Establish inspection priorities

* Help persuade others for need of staging and implementing best management practices.

Use or the Universal Soil Loss Equation

In Developing Areas

WATER EROSION--GULLY

The soil loss from concentrated flow, gullies, and other similar types of erosion will be determined by calculating the annual volume of soil removed from the eroded area. The annual tons of soil loss can then be determined by multiplying volume by unit weight of the soil. If the time period of the erosion exceeds 1 year, the quantity should be divided by the number of years the gully has existed to get an annual rate. The following table provides a guide for approximate unit weight of various soils that can be used in the absence of better data.

Approximate Unit Weight [1]/

Soil Textural Class	Dry Density lbs./ft.^{3}
Sands, loamy sands	110 lbs.
Sandy loam	105 lbs.
Fine sandy loam	100 lbs.
Loams, sandy clay loams, sandy clay	90 lbs.
Silt loam	85 lbs.
Silty clay loam, silty clay	80 lbs.
Clay loam	75 lbs.
Clay	70 lbs.
Organic	22 lbs.

[1]/ Data and estimates from published soil surveys, laboratory data, and soil interpretation results are to be used where available. Parent materials, soil consistency, soil structure, pore space, soil texture, and content of coarse fragments all have influence on unit weight.

Gully formula:

$$\frac{(T + B) \times D \times L \times SW}{4000 \times yr. \times acres} = tons / yr$$

Source: USDA Soil Conservation Service

Example Practice Problem:
Gully Erosion

An eroded silty clay channel has the following dimensions: 10 ft. top, 2 ft. bottom, 1 ft. deep, 600 ft. long. It was formed in 2 years in a field that was 10 acres in size. Find the soil loss in tons of soil/acre/year.

Using the Gully Formula:

$$\frac{(T+B)\times D\times L\times SW}{4000\times yr.\times acres}=tons/yr$$

where:

T = top width of gully (ft.)

B = bottom width of gully (ft.)

D = channel depth (ft.)

L = length of gully (ft.)

SW = soil weight (lbs/ft^3)

Yr = number of years to produce gully

Then $$\frac{(10+2)\times 1.0\times 600\times 80\#/\ ft^3}{4000\times 2\times 10}=7.2 tons/acre/year$$

Severe gullies such as this example should be considered as part of the overall erosion from a site. If the gully is controlled by a grassed waterway, then its future contribution is zero. But if it is controlled by a sediment basin, its erosion contribution must be considered.

APPENDIX 3

CONVERSION FACTORS

AND

SLOPE/PERCENT CHART

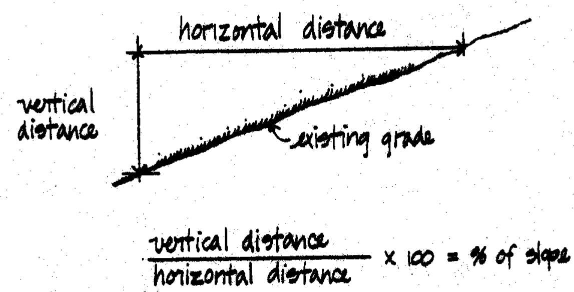
Appendix 3

Conversion Factors, Slope/Percent Ratios

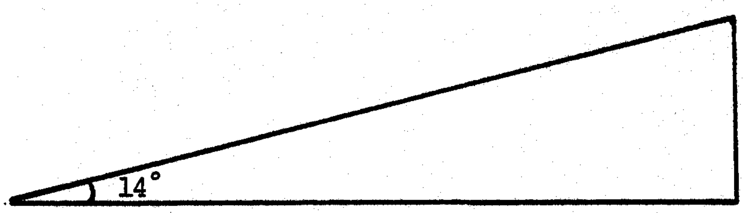
Conversion Factors
1 acre = 43,560 square feet
1 hectare = 2.471 acres
1 square mile = 640 acres
1 cubic yard = 27 cubic feet
1 ton = 0.907 metric tons
1 foot = 12 inches

Conversion Factors

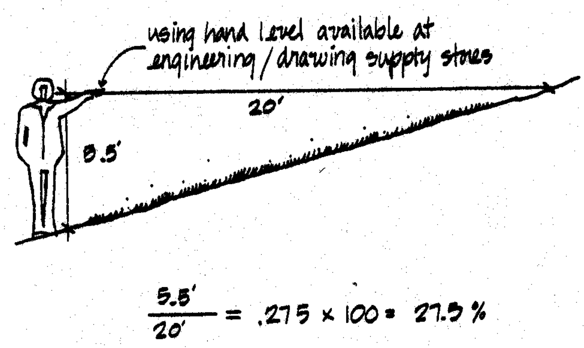
1 acre = 43, 560 square feet
1 acre = 2.471 hectares
1 square mile = 640 acres
1 cubic yard = 27 cubic feet
1 ton = 0.907 metric tons
1 foot = 12 inches



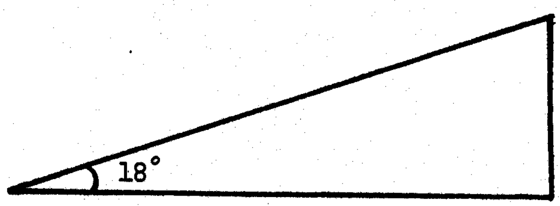
Slope/Percent



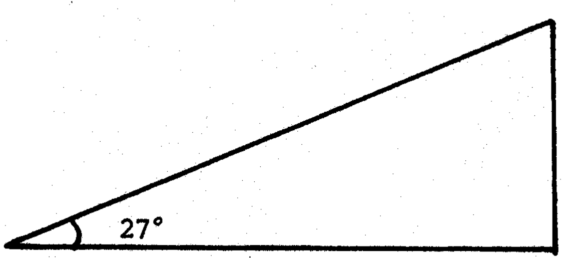
4:1



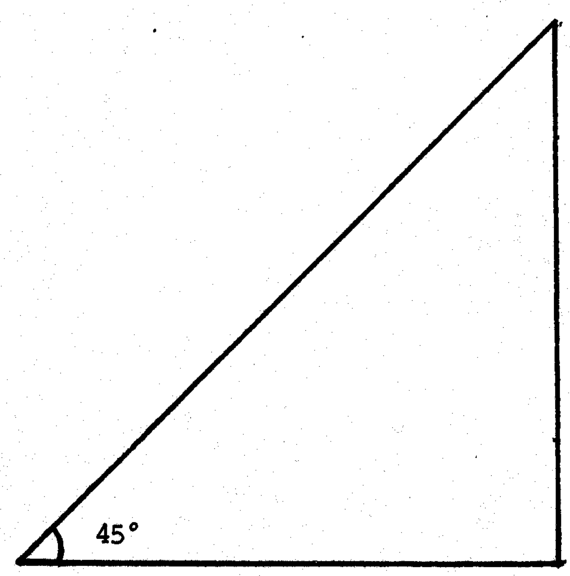
CALCULATING SLOPE GRADIENT



3:1



2:1



1:1

APPENDIX 4

SUPPLEMENTAL FERTILIZER

AND

PESTICIDE APPLICATION PROCEDURES

APPENDIX 4A

SUPPLEMENTAL FERTILIZER

AND

PESTICIDE APPLICATION PROCEDURES:

APPLICATION CALCULATIONS & CALIBRATION

Appendix 4A

APPLICATION CALCULATIONS AND CALIBRATION

(Copied directly from "Turfgrass Pest Management: A Training Manual for Commercial Pesticide Applicators", Michigan State University, Cooperative Extension Service, Bulletin E-2627.)

Accurately mixing pesticides and calibrating equipment is critical to successful pest management. As important as these activities are, applicators frequently do not obtain the desired application rate simply because their equipment was not calibrated properly. A study over 100 farmers conducted in North Dakota found a number of problems that diminished spray application accuracy.

Percent of Sprayers With Problems	Problem
60%	Calibration error greater than + or – 10% from the applicator's prediction.
43%	Greater than + or – 10% variation in discharge from individual nozzles.
32%	Inaccurate travel speed from that predicted by applicator.
27%	Improper boom height for the nozzle spacing and nozzle discharge angle.
13%	Inaccurate pressure gauges. Many gauges indicate pressure lower than the actual pressure.
8%	Inadequate hose size to supply nozzles.

Note that 60% of the farmers tested did not achieve delivery rates from their equipment within10% of the desired rate. Under-applying pesticides may not provide adequate control, while an over application could cause plant injury or compromise environmental safety. Both are a waste of time, money and resources.

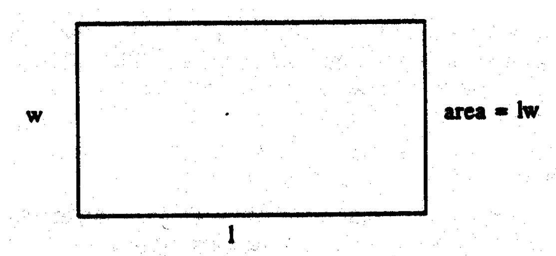
Area Measurement

While the importance of accurate area measurement to an application is obvious, easily measuring irregularly shaped areas can be a challenge. The methods listed here provide a system for easy and accurate area measurement. Method 1 (Divide and Conquer) breaks an area into smaller, more common shapes that are easier to work with. The procedures to determine the area of several common shapes are described in this section. Method 2 (Offset Lines), and Method 3 (Average Radius) are alternative methods for measuring these areas.

Method 1: Divide and Conquer

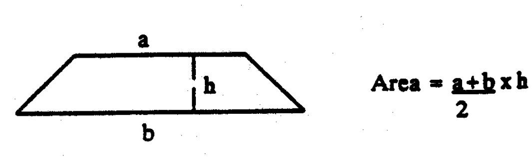
With this method the irregular-shaped area is divided into a group of simple geometric shapes which can be easily added together. The area of geometric figures can be readily calculated using these formulas:

Rectangle: The area of a rectangle is the length multiplied by the width.



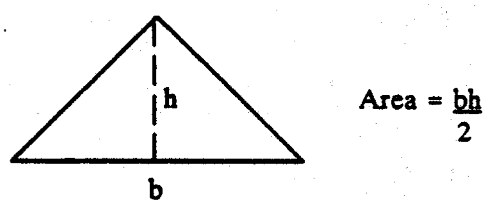
Example 1: The length of a rectangular yard is 100 ft. Its width is 50 ft. The area of this yard is: 100 ft x 50 ft = 5,000 sq ft.

Trapezoid. A trapezoid is a four-sided figure with two parallel sides. The area is the average length of the parallel sides multiplied by its height.



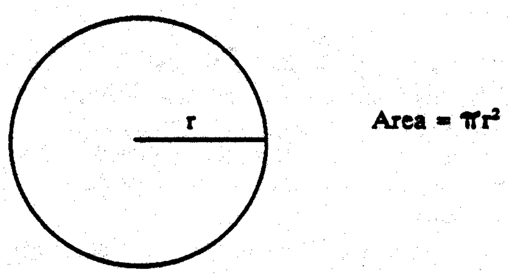
Example 2: One parallel side of a trapezoid is 200 ft, and the other is 300 ft. The distance between the two parallel lines (height) is 50 ft. The area is $\frac{200+300}{2}\times 50\,ft = 12{,}500\,sq.ft$

Triangle. The area of a triangle is one-half the base of the triangle multiplied by the height.



Example 3: The base of a triangular area measures 200 ft and the height is 400 ft. The area is $\frac{200\,ft}{2}\times 400\,ft = 40{,}000\,sq.ft$

Circle. The radius of a circle is one-ha1f the diameter. The area of a circle is the radius squared multiplied by 3.14 (pi).



Example 4: What is the area of a circle with a diameter of 200 ft? The radius is half of the diameter, or 100 ft. The area of the circle is:
$(100\text{ ft})^2$
or X 3.14 = 31,400 sq ft
100ft x 100 ft

Example 5: This irregularly-shaped turfgrass area has been broken up into a group of geometric shape. The area of the shapes can readily be determined and added together to give the total area of turf stand.

Area A is a circle with a 70 ft radius.
$(70\text{ ft})^2$ x 3.14 = 15,386 sq ft

Area B is a rectangle:
170 ft x 90 ft = 15,300 sq ft

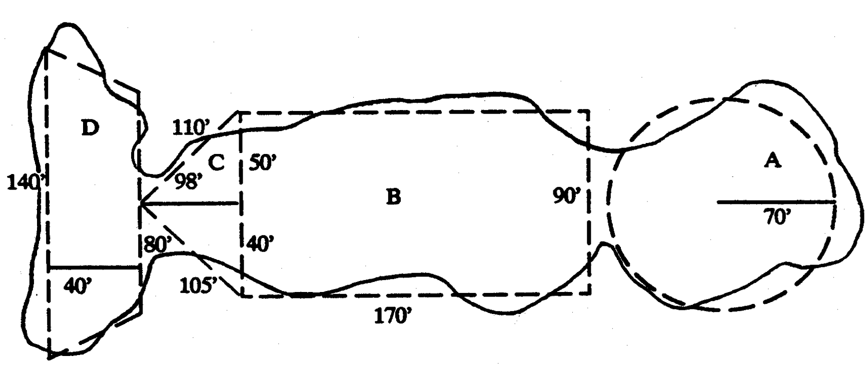
Area C is a triangle
$\frac{90\,ft\times 98\,ft}{2} = 4{,}410\,sq.ft$

Area D is a trapezoid. The parallel sides are 80 ft and 140 ft long.
$\frac{80\,ft+140\,ft}{2}\times 40\,ft = 4{,}400\,sq.ft$

The total area of the irregular turf stand is Area A + Area B + Area C + Area D:
15,386 + 15,300 + 4,410 + 4,400 = 39,496
sq ft sq ft sq ft sq ft sq ft

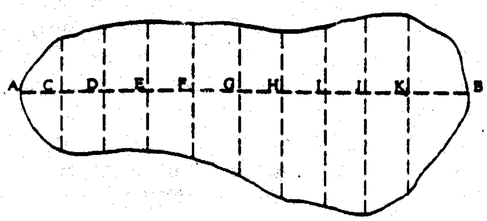
Method 2: Offset Lines

The "offset line" method is another way to figure the area of irregular turf stands. An irregular area is broken up into a series of trapezoids. Lines are drawn at right angles (90^o) at regular intervals along a pre-measured line drawn down the middle of the area (points A and B in Example 6.) The uniformity of the turf stand will determine how may offset lines are needed. A fairly uniform-shaped area will require fewer offset lines. Remember, the more offsets used, the greater the accuracy of the calculation.



Example 6:

First establish and measure the distance

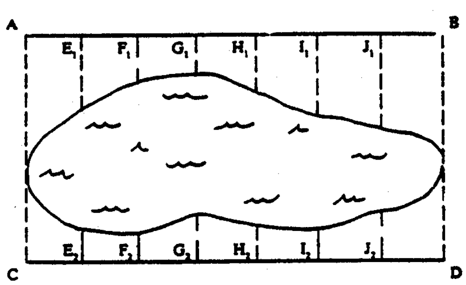


between Points A and B. The fairway of Example 6 (distance between A and B) is 900 feet long. Mark and measure the offsets at regular intervals (the same distance from one another.) The shape of this fairway is relatively uniform, so offsets every 90 feet is adequate. Should a fairway be more irregular, use offsets at least every 45 feet. The offsets are marked in the diagram as lines C through K. The lengths of the offsets in this example are:

A = 0 ft	D = 75 ft	G = 120 ft	J = 210 ft
B = 0 ft	E = 75 ft	H = 150 ft	K = 195 ft
C = 60ft	F=90ft	I=l80ft	1,155ft

The total area is found by adding up the lengths of the offset lines and multiplying by the distance between offset lines. The sum of the area into a circle. From a central point in the turf area offset lines in our example is 1,155 ft.
1,155 ft x 90 ft = 103,950 sq ft

Example 7:



You may need to subtract the area of a pond from the total area of a target turf stand. Pond areas can be measured using the offset method. First, mark a rectangle around the pond with two opposite sides touching the pond edge (lines A-C and B-D.) The distance between A and B should be the same as between C and D. Measure offset lines at regular intervals from the outside lines to the edge of the pond. In this example, the offsets are 10 feet apart. There are actually two lines and the pond distance making up each line (e.g. El and E2, and the distance across the pond at that point.)

El = 14 ft	Fl = 8 ft	Gl = 7 ft	H1 = 10 ft	I1 = 14 ft	J1 = 17 ft
+	+	+	+	+	+
E2 = 6 ft	F2 = 4ft	G2= 8 ft	H2= 4 ft	I2 = 4 ft	J2 = 6 ft
20 ft	12 ft	15 ft	14ft	18ft	23ft

Subtract line set totals from the distance between A and C (50 ft) to find the length of the pond at that point. These are the offset lines.

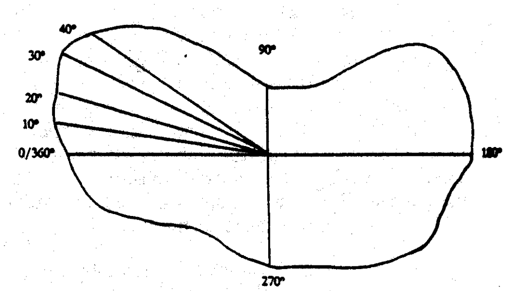
A-C distance		**line set totals**		**offset length**
50 ft	-	20 ft	=	30 ft
50 ft	-	12 ft	=	38 ft
50 ft	-	15 ft	=	35 ft
50 ft	-	14 ft	=	36 ft
50 ft	-	18 ft	=	32 ft
50 ft	-	23 ft	=	27 ft
		offset total	=	198 ft

Now multiply the offset total by the distance between offset lines to find the area of the pond.
198 ft x 10 ft = 1,980 sq ft

Method 3: Average Radius

This method converts the irregularly-shaped, measure the distance to the edge of the area. Mark distances at 10° increments so that there are 36 radius measurements. Use the average radius to figure the area.

Example 8:



If the 36 measurements taken from Example 8 totaled 1,731 ft, then the average radius is:

$$\frac{1{,}731.6 \text{ ft}}{36} = 48.1$$

The area of this turf stand is:

$3.14 \times (48.1)^2 = 7{,}264.7$ sq ft

Calibrating Application Equipment

Turfgrass professionals use a variety of pesticide application equipment in their operations. The following sections outline methods to calibrate drop and rotary granular spreaders, plus several sprayers including small hand pump (hand can), backpack, power sprayers, and boom systems.

There are several factors involved in applying pesticides that can be manipulated to achieve the intended rate of application. They are ground speed, output from the machine, and concentration of the solution. With each piece of equipment or material, one of these items may be easier to change than another. The following methods and examples will explain these concepts and provide a reliable system for calibration.

Granular Spreaders

Drop and rotary spreaders are the most common granular spreaders used by turf managers. Changing the orifice size of either type directly changes the flow of material and is the most important factor in calibrating these devices. Altering the ground speed of granular spreaders may be difficult for the applicator and only slightly affects the rate of application. The concentration of pesticide in the granular material is set by the manufacturer and is not possible to manipulate.

Output. The size of the meter opening determines the flow of the material from the spreader. The rate in which granules flow from the hopper through the meter openings is affected by granule weight, size, shape, and the carrier material (clay, ground corncob, etc.). Do not attempt to mix granules with different characteristics. You must recalibrate your equipment whenever you change from one material to another. High humidity may cause some granules to clump, resulting in uneven distribution. Suggested settings to achieve specific application rates may be listed in the operator's manual or on the product label. These are a good reference to begin the calibration process. For accurate application, each piece of equipment must be calibrated for every type of material.

Ground Speed. As with any manually operated equipment, the speed you wa1k must be consistent throughout calibration and applications. Pick a speed that is comfortable for you on the application area. Equipment that is bouncing over rough terrain will result in inconsistent coverage. The speed of the spreader agitator roughly corresponds to ground speed. However, the flow of granules through the orifice is not necessarily proportional to ground speed. *Doubling the ground speed does not always double the application rate.*

Calibration. First, determine the swath width of the spreader. The swath of a drop spreader is simply the width between the wheels, or the width of the bottom of the hopper. The swath created by rotary spreaders will be different with each material because some types of granules will travel farther than others. Approximate the correct orifice opening for your rotary spreader, make a small test run, and measure the swath width. Next, determine the rate of the material to be applied on the target area. Most product labels refer to the rate as pounds of material per thousand square feet.

Method 1: The easiest way to calibrate granular spreaders is to use a pan or shroud to catch and weigh the output. Pans for drop spreaders and shrouds for rotary spreaders are available from some manufacturers.

1. Measure a test course approximately 50 feet long. A shorter test course is acceptable, but remember that the longer the course the more accurate your calibration. The test area should have terrain similar to that of application areas.

2. After putting some material in the hopper, select an orifice opening and install the catch pan or shroud. The spreader can then be taken over the test course making sure the material is caught in the pan or shroud.

3. Remove the capture material and weigh it in pounds.

4. Figure the square feet of the test course by multiplying the spreader swath width by the length of the test course. Divide the amount of delivered material (pounds) by the square feet of the test course to determine the amount of material you have applied per square foot. Simply multiply this figure by 1,000 to determine the amount you applied per 1,000 sq ft.

5. Compare the rate delivered by the test run (your application rate) with the label rate. Make appropriate changes in the orifice size and repeat the procedure until your application rate is within plus or minus 5% of the recommended rate.

Method 2: A precise measuring scale is required for this method because a small amount of material is used. Start by laying a pre-measured sheet of plastic over a portion of the test course or mark off a measured area on a sweepable surface such as concrete or asphalt. Make certain the plastic sheet or the surface is clean and is wider than the swath width of the spreader.

1. After putting some material in the hopper, select an office opening. Mark the surface or lay the plastic down on the test course. Take the spreader over the test course making sure the spreader is delivering material well before the test area.

2. Carefully recover the material from the test area and weigh it in pounds.

3. Determine the square feet of the plastic or marked surface. Divide the amount of material (pounds) by the square feet of this test area to determine the amount of material you have applied per square foot. Simply multiply this figure by 1,000 to determine the amount you applied per 1,000 sq ft.

4. Compare the rate delivered by the test run with the target rate. Make appropriate changes in the orifice size and repeat the procedure until the delivery rate is consistent with the target rate.

Example 9: You recover 4.75 pounds of granules over the test course as described in Method 1. Your rotary spreader has a swath width with this material of 8 feet, and the course is 40 feet long. What is your application rate per 1,000 sq ft?

test course area is 40 ft x 8 ft = 320 sq ft

your application rate is (per one sq ft) $\frac{4.75}{320 \text{ sq ft}}$ = .01484lb per sq ft

your application rate is (per 1,000 sq ft) .0151b x 1,000 sq ft = 15lb per l,000 sq ft

If the label states that this product should be applied at the rate of 9 pounds per 1,000 sq ft, is your application rate acceptable? First, find what 5% of 9 pounds is:
.05 x 9 lb = .45 lb
To be within plus or minus 5% of the label rate, your application rate must be within the range of 8.55 lb to 9.45 lb. You are applying over 5 pounds too much per 1,000 sq ft. You must adjust the orifice size and recalibrate.

Sprayers

Turf managers use a variety of sprayers for pesticide applications. The key factors involved in proper delivery and calibration are ground speed, pressure, and output or orifice size. Understanding how to manipulate these factors will allow applicators to perform successful spray applications.

Ground Speed. The speed at which an applicator walks or operates the spray vehicle is directly related to the rate of application. If the forward speed is doubled, nozzles pass over the target area for only half of the original time, which cuts the application rate in half. Therefore, it is critical to successful applications to maintain a constant speed whether traveling uphill or downhill, on soft or hard terrain, or over bumps. When using backpack or vehicle-driven sprayers, be sure to calibrate on the same terrain as the target area so that a comfortable speed is selected. Traveling at high speeds over rough terrain with a full tank can damage the frame of a sprayer or "whiplash" a boom out of shape. Booms that are bouncing up and down or swinging from side to side produce application rates that vary as much as 50%.

Pressure. Maintaining consistent pressure is also critical for proper application, but changes in pressure do not have the direct influence on application rate as described for speed. For example, in order to double the spray output, the pressure must be increased by four times. All pumps and nozzles have a range of acceptable operating pressures. Check the manufacturer specifications and work within the guidelines. Excessive pressure produces inconsistent output and smaller droplets that are more likely to drift. Low pressure results in weak spray patterns and poor coverage. Any time an applicator changes the pressure or modifies the sprayer (changes hoses or couplings), the sprayer must be recalibrated. Because of friction, the pressure is reduced as the spray solution flows through a hose. The longer the hose, and the more couplings in the hose, the greater the reduction in pressure.

Output. The output of a sprayer is determined by the pressure and the type of nozzle used to deliver the solution. There are nozzles available that produce a wide range of application rates and changing the nozzle is the most effective way to modify the output. An applicator must determine the desired output for each application and choose the nozzle(s) that best correspond to those specifications. Manufacturers of nozzles and guns supply a chart of their products and the output at given pressures. Once the nozzle and pressure have been determined, the calibration process can begin.

Calibration. There are many methods used to calibrate sprayers; find one you are comfortable with and use it often. The following is only a sample of procedures that can be used to calibrate single-nozzle manual and power sprayers, and boom systems.

Take care to accurately calculate target area size, figure pesticide rates and calibrate equipment.

Small Manual Sprayers (Hand Can): The flow of material from a hand can sprayer is difficult to regulate, because the pressure changes dramatically each time the applicator pumps the sprayer. Applications requiring a consistent flow are not recommended for this sprayer. Products appropriate for hand cans are mixed as a specific "percent solution" and sprayed on the foliage until wet. For example, a product label may specify to mix 2.0-3.0 ounces of product per gallon of water and spray to wet. The applicator then only needs to estimate how much material is required to complete the job. Check the product label for suggested hand can applications.

Showerhead Nozzles: A showerhead nozzle delivers a relatively wide pattern (2-3 feet) through multiple streams as the name implies. Many applicators move this pattern from side to side as they walk to cover as much area as possible in one pass. This technique requires a great deal of practice so that walking speed and hand motion is smooth and consistent, and the material is uniformly applied. Once this technique is perfected, then the sprayer can be calibrated. First, set the pressure of the sprayer making sure it is within manufacturer guidelines for the pump and nozzle. Then proceed with step one.

1. Determine the output per 1,000 sq ft or per that is appropriate for the job based on the product label, type of application, and equipment used.

2. Mark off a test course at least 40 feet long and determine your swath width. Calculate the area in square feet of your test course.

3. Fill the tank with water and spray the test course using the technique you will be using during the actual application. Always begin spraying before you enter the test course.

4. Record the number of seconds required to spray the test course. To increase your accuracy, spray test course at least three times and use the average number of seconds for all the tests.

5. Determine the volume of water applied to the test course by spraying into a bucket the exact number of seconds it took to cover the test course. Measure this amount in gallons.

6. Divide the gallons collected in Step 4 by the square feet of your test course. This is the gallons of solution applied per square foot. Multiply by 1,000 to determine the gallons per 1,000 sq ft or multiply by 43,560 to determine the gallons per acre. This is your output.

7. Compare your output with Step 1. Make any necessary changes in nozzles, walking speed, or pressure and recalibrate, to achieve an acceptable output.

8. Refer to the pesticide ca1culation section to determine the amount of pesticide needed for the job and to add to each tank.

Once an acceptable output is achieved, be sure to record the pressure, area of the test course, time and volume. Take care not to change your walking speed or spray swath width. Recalibrate often: weekly or daily. Also be sure to recalibrate if you change nozzles or hose length, or otherwise modify your spray system.

Example 10: You want to determine the output of a power sprayer with a showerhead nozzle. You choose a 40-foot long test strip and your swath width is 6 feet wide. You sprayed the 240 square foot course in 45, 41, and 48 seconds. What is your output per 1,000 square feet and per acre if the amount of spray delivered into the measuring bucket in 45 seconds is 1.25 gallons?

your output is (per one sq ft) $= \dfrac{1.25 \text{ gal}}{240 \text{ sq ft}} = .0052$ gal per sq ft

your output is (per 1,000 sq ft) .0052 gal x 1,000 sq ft = 5.2 gal per 1,000 sq ft

your output is (per acre) .0052 gal per sq ft x 43,560 = 226.5 gal per acre

Backpack Sprayers: For backpack sprayers to be used most effectively they should be fitted with a gauge at the hand valve or have a pressure regulator so the operator can maintain a constant pressure during application. The "ounce method" calibration process can be used to calibrate backpack sprayers. First, determine the desired output, select an appropriate nozzle, and set the pressure at a level that is within the manufacturer specifications for the nozzle and pump. Then proceed with step one of the "ounce method". If your backpack sprayer is fitted with a boom system, follow the instructions for boom sprayers.

Boom sprayers: The biggest challenge of boom sprayers is to deliver a consistent output from all nozzles throughout the spray operation. As with backpack sprayers, first determine the desired output and select the appropriate nozzles. Set the pressure at a level that is within the manufacturer specifications for the nozzles and the pump. Before calibrating the output, using the "ounce method", make sure all nozzles are delivering the same rate by catching the spray of all nozzles and determine the average output. Replace any nozzles that are not delivering within plus or minus 5% of the average output or do not have uniform patterns.

Ounce Method

1. Determine the band width (backpack) or distance between nozzles (boom system) and select the length of the test course from the chart provided here.

Band Width or Distance Between Nozzles (inches)	Test Course Length (feet)
10	408
12	340
14	291
16	255
18	227
20	204
22	185
24	170
26	157
28	146
30	136
32	127
34	120
36	113
38	107
40	102

2. Clearly mark the test course in terrain that is the same as the treatment area.

3. Walk or drive the sprayer through the test course using a speed that is comfortable for the terrain. Precisely time the seconds it takes to complete the test course. Make sure not to start the timing from a dead stop. Repeat this procedure several times and use the average time.

4. With the sprayer running, catch the output from one nozzle for exactly the same number of seconds it took to run the test course. *The nozzle output in fluid ounces is equal to the gallons per acre output of the sprayer*. For example, it took an average of 37 seconds to walk/drive the test course. In 37 seconds you collected an average of 45 ounces of water. The sprayer's output is 45 gallons per acre. To determine your output in gallons per 1,000 sq ft, simply divide your final answer by 43.56 (the number of 1,000 sq ft units per acre). For the example above, the output per 1,000 sq ft is 45 divided by 43.56, or 1.03 gallons per 1,000 sq ft.

5. If your sprayer's output does not match the desired output, then adjust the speed, pressure, or nozzle(s) and start again with Step 1.

Example 1: You are using a boom system to apply a pesticide that has 12 inches between nozzles. It took you 75, 77, and 73 seconds to travel the 340 foot test course. You collected 53 ounces of water during the averaged (75 sec) travel time. What is the volume of water in gallons applied per acre and per 1,000 sq ft?

Your output per acre using the "ounce method" is 53 gallons per acre. To convert this into gallons per 1,000 sq ft, divide the answer by 43.56.

$$\frac{53 \text{ gal per acre}}{43.56} = 1.21 \text{ gal per 1,000 sq ft}$$

The answers are 53 gallons per acre and 1.21 gallons per 1,000 square feet output.

Pesticide Calculations

Once the output of the sprayer has been determined, the actual amount of material required for the spray operation can be easily calculated. The steps listed below will determine the amount of water and pesticide needed to complete the job, and the amount of water and pesticide to add to each tank load. To complete these steps you need to know the recommended rate of the pesticide, the total area to be treated, and the capacity of the spray tank. Each step contains a procedure for areas measured in acres and areas measured per 1,000 square feet. Be careful to consistently use acres *or* 1,000 square feet throughout your calculations.

1. To determine the **total amount of water** and pesticide needed for the job:

   If area is measured in **acres -**

   A. Multiply the sprayer output (gallons per acre) by the total acreage of the treatment area. This is equal to the total amount of solution (water plus pesticide) required.

   B. Multiply the recommended rate per acre of the pesticide by the total acreage. This is the total amount of pesticide required.

   If area is measured per **1,000 square feet** –

   A. Multiply the sprayer output (gallons per 1,000 square feet) by the units of 1,000 square feet of the treatment area. For example, an area of 1,600 square feet has 1.6 units of 1,000 square feet. This is equal to the total amount of solution (water plus pesticide) required.

   B. Multiply the recommended rate per 1,000 square feet of the pesticide by the units of 1,000 square feet of the target area. This is the total amount of pesticide required.

2. To determine **the amount of pesticide** for each tank load:

   If area measured in **acres** –

   A. Divide the spray tank capacity (in gallons) by the gallon per acre output to determine the acreage covered by one tank load.

   B. Multiply the acreage covered by one tank load by the recommended rate per acre to determine the amount of pesticide needed in each full tank load.

   If area measured per **1,000 square feet** –

   A. Divide the spray tank capacity (in gallons) by the gallons per 1,000 square feet output to determine the units of 1,000 square feet covered by one tank load.

   B. Multiply the units of 1,000 square feet covered by one tank load by the recommended rate per 1,000 square feet to determine the amount of pesticide needed for each full tank load.

Example 12: You need to spray 10 acres of turf. Your boom sprayer has a 100 gallon tank and is calibrated to provide an output of 75 gallons per acre. The recommended rate for the liquid pesticide is 2 quarts per acre. How much spray mix will be needed for a 10 acre target area, and how much pesticide is added to each tankful?

total spray mix for the job	is	75 gal per acre x 10 acres = 750 gal
area covered by one tankful (acres)	is	100 gal / 75 gal per acre = 1.33 acres
pesticide added per tankful	is	.1.33 acres per tankful x 2 quarts per acre = 2.66 quarts per tankful

Example 13: Your backpack sprayer has a capacity of 3 gallons and is calibrated to deliver an output of 1.5 gallons per 1,000 square feet. You need to spray a turf area that is 4,000 square feet. The label of the pesticide you wish to apply specifies that 6 fluid ounces of the pesticide be applied per 1,000 sq ft. How much total spray mix will you need and how much pesticide must be added to a full tank load?

total spray mix for the job	is	1.5 gal per 1,000 sq ft x 4.0 sq ft l,000 sq ft units = 6.0 gal
area covered by one tankful (1,000 sq ft)	is	3 gal / 1.5 gal per 1,000 sq ft = 2.0 1,000 sq ft units
pesticide added per tankful	is	2.0 1,000 sq ft units x 6 fl oz = 12.00 fl oz

APPENDIX 4B

SUPPLEMENTAL FERTILIZER

AND

PESTICIDE APPLICATION PROCEDURES:

COMMON MEASURING EQUIVALENTS

FOR PESTICIDES AND FERTILIZERS

Appendix 4B

Common Measurements Measuring Equivalents for Pesticides and Fertilizers

As stated in exhibit 2, if you need to determine the size **(area)** of a square or rectangular area, such as a lawn for herbicide application, measure and multiply the length and width. For example, an area 10 feet long by 8 feet wide contains 80 square feet. Common area measurements may involve square yards or square feet:

1 square yard = 9 square feet
1 square foot = 144 square inches

If you need to determine the **volume** of a space such as a room, measure and multiply the room's length, width, and height. For example, a space 10 feet long, 8 feet wide, and 8 feet high contains a volume of 640 cubic feet. You would use this procedure for instance, for an aerosol release to control cockroaches.

Most residential-use pesticides are measured in terms of volume. Some common equivalents are:

1 gallon (gal.)	= 128 fluid ounces (fl. oz.)
	= 4 quarts (qt.)
	= 8 pints (pt.)
	= 16 cups
1 qt.	= 32 fl. oz.
	= 2 pt.
	= 4 cups
1 pt.	= 16 fl. oz.
	= 2 cups
1 cup	= 8 fl. oz.
1 tablespoon	= 1/2 fl. oz.
	= 3 teaspoons
1 teaspoon	= 1/6 fl. oz.

A practical use of these equivalents:
If the product label says: "for the control of aphids on tomatoes, mix 8 fluid ounces of pesticide into 1 gallon of water and spray until foliage is wet." Your experience has been that your six tomato plants require only one quart of pesticide to wet all the foliage. Therefore, only 2 fluid ounces of the pesticide should be mixed into 1 quart of water. Reasoning: one quart is one-fourth of a gallon, and 2 fluid ounces mixed into 1 quart make the same strength spray recommended by the label, but in a quantity that can be used up all at once.

Derived from "Citizen's Guide to Pesticides." U.S. Environmental Protection Agency, April, 1990.

APPENDIX 5

PART 21 RULE REVISIONS OF ACT 245

OF THE MICHIGAN WATER RESOURCES ACT

MICHIGAN'S PERMIT-BY-RULE FOR CONSTRUCTION ACTIVITIES

Effective November 13, 1992

R 323.2190. National permit for storm water discharge from construction activity; effective date of subrule (2)(d).

Rule 2190. (1) Unless the commission has required an individual national permit pursuant to the provisions of subrule (3) or (4) of this rule, a point source discharge of storm water from a construction activity will be deemed to have a national permit if both of the following criteria are met:

(a) The construction permittee has filed, with the executive secretary, on a form approved by the commission, notice of coverage pursuant to the provisions of this rule before the initiation of construction activity. The notice of coverage shall include all of the following:

(i) Certification that an individual soil erosion and sedimentation control permit for the site has been issued to the construction permittee or, if the construction activity is to be carried out by an authorized public agency, that an approved control plan exists.

(ii) Acknowledgement by the construction permittee that any discharge that is made pursuant to the provisions of this rule shall be in compliance with the commission act and the rules promulgated thereunder.

(iii) A location map and a description of the nature of the construction activity.

(iv) The location of the proposed discharge and identification of the receiving water.

(v) The total area of the site and the area of the site that is expected to undergo construction activity during the life of the project.

(vi) Site-specific soil erosion control measures that will be used to control waste in storm water discharges during construction activity.

(vii) Site-specific measures to control waste in storm water discharges that occur after construction activities have been completed.

(viii) An estimate of the runoff coefficient of the site and the increase in impervious area after the construction activities are completed, the nature of any fill material used, and existing data that describe the soil or the quality of the discharge.

(b) The notice of coverage has a valid signature. If the construction permittee is a partnership, association, corporation, industry, municipality, state agency, or interstate body, the valid signatory for the notice of coverage shall be determined in accordance with the provisions of R 323.2114.

(2) A construction permittee that has authorization to discharge pursuant to this rule shall comply with all of the following provisions:

(a) Not directly or indirectly discharge any substance into the waters of the state in violation of the commission act or rules promulgated thereunder.

(b) Be in compliance with the soil erosion and sedimentation control permit for the site or, if the construction activity is carried out by an authorized public agency, the approved control plan, including the selected control measures that are applicable to the site.

(c) Properly maintain and operate the soil erosion control measures.

(d) Have the soil erosion control measures under the specific supervision and control of a storm water operator who has been certified by the director as properly qualified to operate the soil erosion control measures. The certification shall be done in accordance with the requirements of R323.1251 et seq. of the Michigan Administrative Code. This requirement shall take effect 2 years after the effective date of this rule.

(e) Cause the construction activity to be inspected by a certified storm water operator once per week, and within 24 hours after every precipitation event that results in a discharge from the site and ensure that any needed corrective actions are carried out. A log of the inspections and corrective actions shall be maintained on file by the construction permittee for review and shall be retained by the construction permittee for a period of 3 years from the date of the inspection or corrective action.

(f) In accordance with the requirements for on-land facilities as set forth in spillage of oil and polluting materials, being part 5 of these rules, provide facilities and comply with reporting procedures for containment of any accidental losses of oil or other polluting materials.

(g) Dispose of solids, sediment, filter backwash, or other waste that is removed from or results from the treatment or control of storm water in compliance with applicable state laws and regulations and in a manner that prevents any waste from entering waters of the state.

(h) Allow the director or authorized representative to enter upon the site at any reasonable time before the expiration of the authorization to discharge as set forth in subrule (5) of this rule, upon presentation of credentials and other documents as may be required by law, for the purpose of inspecting conditions relating to the pollution of any waters or determining compliance with the provisions of this rule.

(i) Upon request, make available for public inspection or provide to the executive secretary all reports or logs prepared pursuant to the provisions of this rule.

(j) File a revised notice of coverage in compliance with the provisions of subrule (1) of this rule before any expansion of the construction activity or change in the soil erosion control measures that requires a change in the soil erosion and sedimentation control permit.

(3) The commission may require that discharges from a construction activity be authorized by an individual national permit if it has been determined by the commission that unlawful pollution cannot be adequately guarded against and there is or may be water quality degradation that will violate the commission act unless requirements in addition to those in the soil erosion and sedimentation control permit are imposed. Such a determination by the commission constitutes grounds for revocation of the authorization to discharge pursuant to the provisions of this rule.

(4) The commission may require that discharges from a construction activity be authorized by an individual national permit if it has been determined by the director that the responsible act 347 permitting entity or authorized public agency is not carrying out a program that is adequate to ensure that the requirements of act 347 are complied with.

(5) The authorization to discharge pursuant to the provisions of this rule expires as follows:

(a) When the soil erosion and sedimentation control permit expires or is revoked or terminated by the act 347 permitting entity in accordance with the provisions of act 347 and Act No.306 of the Public Acts of 1969, as amended, being §24.20l et seq. of the Michigan Compiled Laws, or when the authorized public agency determines that the project has been completed by the stabilization of earth change activity.

(b) 5 years from the date of the notice that is filed pursuant to the provisions of subrule (1)(a) of this rule, if the authorization to discharge has not previously expired pursuant to the provisions of subdivision (a) of this rule. This authorization may be extended by filing a new notice in compliance with the provisions of subrule (1)(a) of this rule. The construction permittee shall file a notice of termination with the executive secretary on a form approved by the commission when authorization to discharge expires as set forth in accordance with subdivision (a) of this rule. The notice of termination shall include the name and address of the construction permittee, the location of the construction site and the mailing address, if available, and certification that stabilization of earth change activity has been completed or, if such certification cannot be made, the reason why the authorization to discharge has expired.

(6) The commission may revoke authorization to discharge pursuant to the provisions of this rule if an individual national permit is required pursuant to the provisions of subrule (3) of this rule or in compliance with the provisions of R 323.2159.

(7) Nothing in this rule shall be construed to preclude the institution of any legal action or relieve the construction permittee from any responsibilities, liabilities, or penalties to which the construction permittee may be subject pursuant to the commission act or rules promulgated thereunder.

(8) The provisions of this rule are severable, and if any provision of this rule or the application of any provisions of this rule to any circumstances is held invalid, the application of such provision to other circumstances and the remainder of this rule shall not be affected by the invalidity.

(9) The construction permittee shall take all reasonable steps to minimize any adverse impact to the surface or ground waters of the state that result from noncompliance with any of the conditions specified in this rule.

(10) If, for any reason, the construction permittee does not comply with, or will be unable to comply with, any of the conditions that are specified in this rule, the construction permittee shall provide the executive secretary with the following information, in writing, within 5 days of becoming aware of such condition:

(a) A description of the noncompliance and its cause.

(b) The period of noncompliance, including exact dates and times, or, if the noncompliance is not corrected, the anticipated time that the noncompliance is expected to continue and the steps taken to reduce, eliminate, and prevent recurrence of the noncompliance.

(11) The provisions of this rule do not convey any property rights in either real or personal property or any exclusive privileges, authorize any pollution, impairment, or destruction of the natural resources of the state or the violation of any federal, state or local laws or regulations, or obviate the necessity of obtaining permits or approvals from other units of government as may be required by law.

(12) The provisions of this rule do not exempt the construction permittee from giving notice to public utilities and complying with each of the requirements of Act No.53 of the Public Acts of 1974, as amended, being §460.701 et seq. of the Michigan Compiled Laws.

(13) This rule shall not provide authorization to discharge storm water from construction activity which is mixed with non-storm water or which is subject to an existing national permit or general permit.

DEFINITIONS AS USED IN THE PERMIT-BY-RULE

"Act 347" means Act No.347 of the Public Acts of 1972, as amended, being §282.101 et seq. of the Michigan Compiled Laws, and the rules promulgated thereunder.

"Act 347 permitting entity" means an agency that is designated by a county board of commissioners pursuant to the provisions of section 6 of act 347, an agency that is designated by a city, village, or charter township in accordance with the provisions of section 7 of act 347, or the director if the construction activity overlaps more than 1 permitting entity.

"Approved control plan" means the plan which is prepared by an authorized public agency, which is approved by the director pursuant to the provisions of section 11 of act 347, and which contains the soil erosion and sedimentation control procedures that govern all construction activities normally undertaken by the authorized public agency.

"Authorized public agency" means a state, local, or county agency that is designated pursuant to the provisions of section 11 of act 347 to implement soil erosion and sedimentation control requirements with regard to construction activities undertaken by the agency.

"Certified storm water operator" means an individual who has been certified by the department pursuant to the provisions of section 6(a) of the commission act as properly qualified to operate treatment or control facilities for storm water discharges.

"Commission" means the water resources commission.

"Commission act" means Act No.245 of the Public Acts of 1929, as amended, being §323.1 et seq. of the Michigan Compiled Laws, and the rules promulgated thereunder.

"Construction activity" means a man-made earth change or disturbance in the existing cover or topography of land that is equal to or more than 5 acres in size for which a national permit is required pursuant to the provisions of 40 C.F.R. §122.26(a) and which is defined as a construction activity pursuant to the provisions of 40 C.F.R. §122.26(b)(14) (x). The term includes clearing, grading, and excavating activities. The term does not include the practices of clearing, plowing, and tilling soil and harvesting for the purpose of crop production.

"Construction permittee" means a person who is deemed to have a national permit pursuant to the provisions of R 323.2190 and who owns or holds a recorded easement on the property where a construction activity is located, is constructing in a public right-of-way in accordance with the provisions of sections 13, 14, 15, and 16 of Act No.368 of the Public Acts of 1925, as amended, being §§247.183, 247.184, 247.185, and 247.186 of the Michigan Compiled Laws, or is the authorized public agency if a construction activity is carried out by the authorized public agency.

"National permit" means an NPDES permit, or equivalent document or requirements, issued by the commission to a discharger pursuant to sections 5 and 7 of the commission act for discharges into surface waters.

"NPDES" means the national pollutant discharge elimination system established by the federal act.

"Point source discharge" means a discharge that is released to the waters of the state by a discernible, confined, and discrete conveyance, including any of the following from which wastewater is or may be discharged:

(i) A pipe.

(ii) A ditch.

(iii) A channel.

(iv) A tunnel.

(v) A conduit.

(vi) A well.

(vii) A discrete fissure.

(viii) A container.

(ix) A concentrated animal feeding operation.

(x) A vessel or other floating craft.

The term does not include a legally established county or intercounty drain, except for a county or intercounty drain that has a POTW designated as part of the drain or a discharge otherwise required to be authorized by a national permit.

"Runoff coefficient" means the fraction of total rainfall that will appear at a conveyance as runoff.

"Site" means the area where a construction activity is physically located or conducted, including adjacent land that is used in connection with the construction activity.

"Soil erosion and sedimentation control permit" means a permit that is issued pursuant to the provisions of act 347 by an act 347 permitting entity.

"Soil erosion control measures" means the measures or procedures to prevent or reduce the pollution of waters of the state that are required in the soil erosion and sedimentation control permit for the site or the selected control measures from the approved control plan that are applicable to the site.

"Stabilization of earth change activity" means the proper placement, grading, or covering of soil or rock at a construction activity to insure subsequent resistance to soil erosion, sliding, or other earth movement.

"Storm water" means storm water runoff, snowmelt runoff, and surface runoff and drainage.

OTHER RULES REFERENCED IN THE PERMIT-BY-RULE

R323.2114. Permit application and other NPDES forms; valid signatories.

Rule 2114. A state or national permit application form or any other NPDES form submitted to the executive secretary pursuant to these rules shall be signed as follows:

(1) For a corporation, by a principal executive officer of at least the level of vice president, or his designated representative, if the representative is responsible for the over-all operation of the facility from which the discharge described in the permit application or other NPDES form originates.

(2) For a partnership, by a general partner.

(3) For a sole proprietorship, by the proprietor.

(4) For a municipal, state or other public facility, by either a principal executive officer, the mayor, village president, city or village manager or other duly authorized employee.

R 323.2159. State and national permits; modification or revocation by the commission.

Rule 2159. (1) The commission may modify any term or condition, including a schedule of compliance, of a permit or may revoke a permit upon its finding of any of the following:

(a) There is a change in any condition that requires a temporary or permanent reduction or elimination of a permitted discharge or constituent thereof.

(b) The administrator of EPA issues a regulation prescribing a restriction or prohibition of a waste or wastewater constituent which is not covered by the terms and conditions of a permit or the regulation is more stringent than any limitation imposed on a wastewater constituent in a permit.

(c) A modification of the terms and conditions of a permit or a time schedule thereon is necessary because of an act of God or other conditions beyond the control of the permittee.

(d) In the case of discharges from publicly owned treatment works, federal treatment works grant funds are not available or are not sufficient to allow construction of the treatment works in a time schedule set forth in the permit.

(e) There is a violation of any term or condition of the permit.

(f) The permittee has obtained a permit by misrepresentation or has failed to disclose all relevant facts to the commission.

(g) A toxic effluent standard or prohibition, including any schedule of compliance specified therein, is established pursuant to section 307(a) of the federal act for a toxic waste or wastewater constituent which is present in the permittee's discharge and the standard or prohibition is more stringent than any limitations upon the waste or wastewater constituent in the permit.

(h) The POTW receives wastewater from a nondomestic source and the development of a pretreatment program is necessary to control the introduction of regulated pollutants.

(i) When a request for removal credits is approved in accordance with R 323.2162(3).

(2) The commission shall notify the regional administrator of any change in status or condition of a permit and he or she shall have an opportunity to object thereto, in writing, within 45 days before the effective date of the modification. If the regional administrator objects in writing, the objection shall be resolved before the modification is approved by the commission, unless the right to object is waived, in writing, by the regional administrator.

(3) A permittee who is affected by a modification of a permit by the commission shall be notified not less than 90 days before the effective date of the modification and, upon petition therefore, shall have a hearing thereon pursuant to section 8(a) of the commission act and R 323.1031 to R 323.1036.

(4) If the commission modifies an effluent limitation or a schedule of compliance in a permit, notice of the modification shall be mailed to all persons on the commission mailing list for public notices and fact sheets as prescribed by R 323.2124, and any interested person may comment thereon within 30 days following the date of notification.

APPENDIX 6

SUPPLIERS OF GEOTEXTILE FILTER FABRIC

Appendix 6
Suppliers of Geotextile Filter Fabric

* This is a list of known suppliers of geotextile fabric.

The Michigan Department of Natural Resources neither endorses nor recommends any contractor or supplier.

Advanced Drainage Systems, Inc.
770 S. Chestnut Street
P.O. Box 100 (517) 725-7893
Owosso, MI 48867 (800) 237-7659
Corrugated PE pipe including ADS N-12tm storm sewer and fittings as well as typar geotextiles.

Almac Plastics Inc.
4320 Airwest SE
Grand Rapids, MI 49508 (800) 632-9596
Plastic film, sheet, rod, tube, pipe, including PE tarps, and visqueen.

American Excelsior Co.
1210 Manufacturers Drive
Westland, MI 48185 (313) 722-4540
Construction fabrics, erosion control.

American Excelsior Company
6730 Lonyo Avenue
Dearborn, MI 48126 (313) 491-1717
Curles excelsior.

The Boomer Company
1940 E. Forest Avenue
Detroit, MI 48207 (313) 832-5050
Mirafi fabric, construction materials, concrete and drywalls.

American Enka Company (704) 667-7713
Enka, NC 28728 (704) 667-7668
Enkamat matting, stabilenka fabric.

Burlap Bag
5346 Ivanhoe
Kalamazoo, MI 49002 (616) 345-4289

Burlap Bag
5421 W. Saginaw
Lansing, MI 48933 (517) 321-5834

Carthage Mills
Erosion Control Division
124 West 66th Street
Cincinnati, OH 45216 (513) 242-2740
Poly-filter fabric.

Century Rain Aid
3400 Jefferson SE
Grand Rapids, MI 49508 (616) 452-3373
Warrens Terrabond & Terra Flow, geotextile landscape 9 filter fabrics for erosion control, separation filter.

Century Rain Aid
31691 Dequindre
Madison Hts, MI 48071 (313) 588-2990

Century Rain Aid
22159 Telegraph
Southfield, MI 48034 (313) 358-2994

Construction Supply, Inc.
1500 Alloy Parkway
P.O. Box 668 (313) 887-6767
Highland, MI 48031 (800) 621- 7007
Corrugated polyethylene pipe, drainage, fabric, stabilization fabric, and silt control fences.

Detroit Concrete Products Corp.
4900 McCarthy Dr.
Milford, MI 48042 (313) 685-9590
Asphalt mixtures and asphalt construction.

E.I. DuPont DeNemours & Company
Suite 301
9800 McKnight Road
Pittsburgh, PA 15237 (412) 367-2003
Typar fabric.

Earthbase Construction Products
24635 Halsted
Farmington Hills, MI 48018 (313) 474-6580

L.T. Elsey & Son, Inc.
18538 Mack Avenue
Grosse Pointe Farms, MI 48236 (313) 886-9700
Corrugated plastic and steel pipe. Construction fabrics.

Environmental Protection Inc.
111 West Park Drive
Kalkaska, MI 49646 (616) 258-9501
Construction fabric, soil stabilization and erosion control fabric.

Environmental Protection Inc.
9939 US 131 South, NE (616) 258-9108
Mancelone, MI 49646 (800) 221-2535
Construction fabric, soil stabilization and erosion control fabric.

Don Ellis & Co.
945 S. Milford Road
Highland, MI 48031 (313) 887-6767

Erosion Control Systems, Inc.
3349 Ridgelake
Suite 101-B
Metaire, LA 70002 (504) 834-5650
Gobimat concrete cells.

Ersco Corp.
22750 W. Eight Mile Road
Southfield, MI 48034 (313) 353-8202
Cures, epoxies, grouts, precast trench drain, mesh, rebar, hand tools, forming, concrete restoration products.

Ersco Corp.
3232 W. St. Joseph
Lansing, MI 48917 (517) 372-0232

Ersco Corp.
6666 Bay Road
Saginaw, MI 48604 (517) 790-8001

Geotextile Systems, Inc.
N15 W24817 Highway
Pewaukee, WI 53072 (414) 542-5523
Grass Pavers Limited
3807 Crooks Road
Room 4
Royal Oak, MI 48073 (313) 549-4046
Monoslabs concrete grids.

Gulf States Paper Corporation
P.O. Box 3199
Tuscalousa, AL 34501 (205) 553-6200
Hold-gro fabric

R.M. Hunter Co.
207 Carroll SE
Grand Rapids, MI 49506 (616) 774-0414

Jensen Bridge & Supply
400 Stoney Creek Drive
P.O. Box 151
Sandusky, MI 48471 (313) 648-3000
Culvert pipe and construction fabrics.

LaFayette Farm and Industry
Wisconsin (800) 221-4699
Agri-fabric

Linwood Tile Company
205 S M-13
Linwood, MI 48634 (517) 697-4491
Farm drainage tile and pump stations, septic field tile, plastic culvert pipe, steel culverts.

Maccaferri Gabions, Inc.
Radisson Center
Suite 1421
44 South Seventh Street
Minneapolis, MN 55402 (612) 341-3924
Wire gabions.

Miller Product & Supply Co.
P.O. Box 548
Iron Mountain, MI 49801 (906) 774-1243

Monsma Lumber Co.
1409 Buchanan S. W. (616) 245-8714
Grand Rapids, MI 49507 (800) 632-4673

Mt. Pleasant Central Concrete
W. High Street
Mt. Pleasant, MI 48858 (517) 772-3695
Ready mixed concrete, sand/gravel excavating.

Napoleon Lumber
120 Depot
Napoleon, MI 49203 (517) 536-8623

Appendix 6 (Cont.)

National Construction Special
7742 Greenfield Fld.
Dearborn, MI 48126 (313) 846-2277
Construction Fabric

Price & Company, Inc.
425 36th Street, SW
Wyoming, MI 49508 (616) 530-8230
Erosion control & soil reinforcement products; installation guidance, design assistance.

St. Regis Culvert, Inc.
202 Morrell
P.O. Box 69
Charlotte, MI 48813 (517) 543-3430
Manufacturer of corrugated metal pipe & accessories, supply blades, filter fabric, and plaster pipe.

S.P. Streicher Co.
3644 Marine Drive
Toledo, OH 43609 (419) 382-9041

Trammel Brothers
152 Valley Drive
Metamora, MI 48455 (313) 678-2653

Vanderlind & Son
1649 Century S.W.
Grand Rapids, MI 49509 (616) 247-0307
Clow Ductile iron pipe, mirafi geotextiles, armco construction products.

Wolohan Lumber
1740 Midland Road
Saginaw, MI 48603 (517) 793-3880

Supac
Phillips Fibers Corp.
P.O. Box 66 (803) 242-6600
Greenville, SC 29602 (800) 845-5737
Drainage, soil stabilization, protective membrane, sedimentation control, embankment stabilization, and railroad trackbed stabilize.

Amoco Fabrics and Fibers Company
900 Circle 75 Parkway
Suite 550
Atlanta, GA 30339 (404) 956-9025
Ground stabilization for paved and unpaved surfaces, embankment/ erosion control, and sediment control.

APPENDIX 7

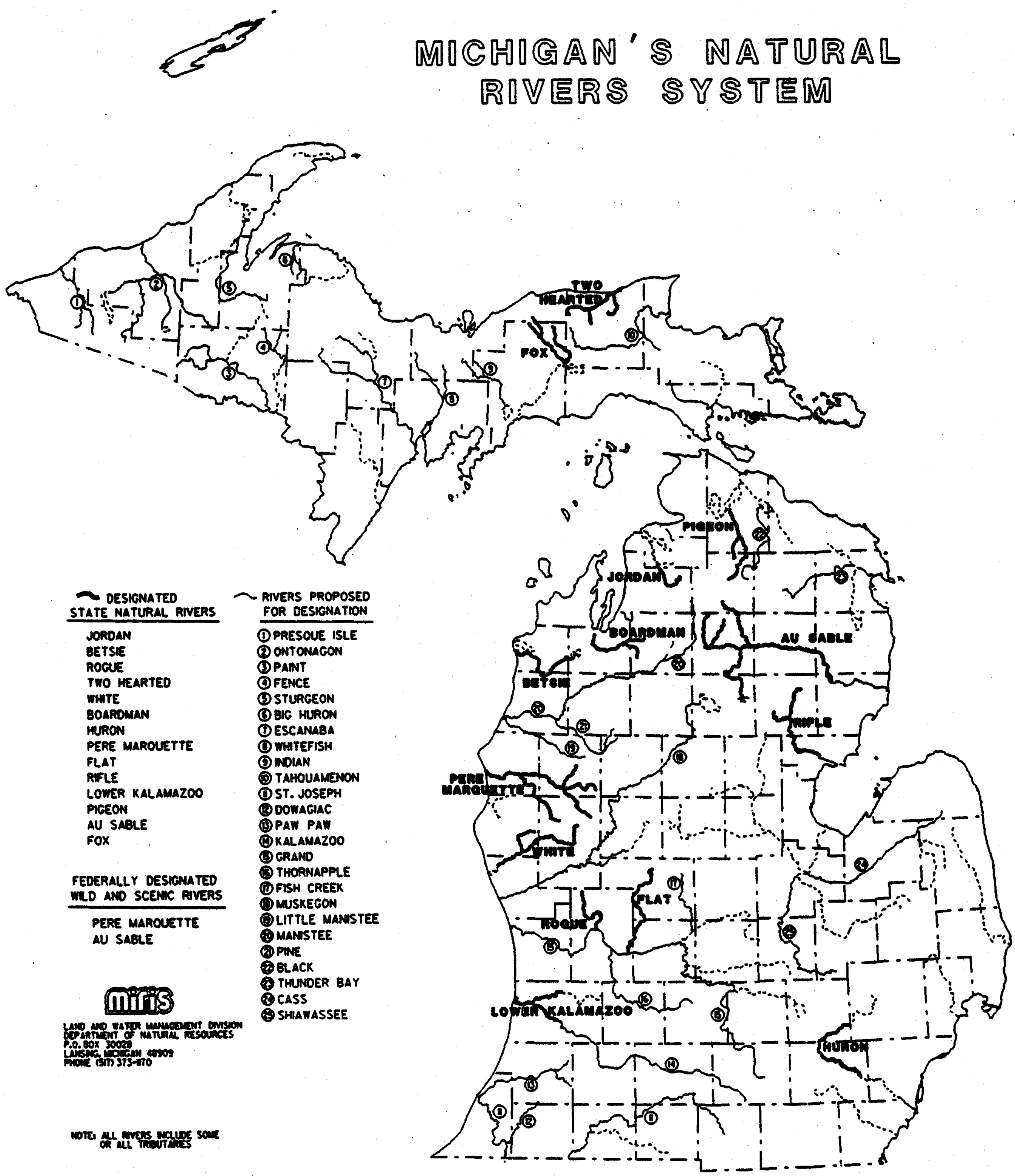
MICHIGAN'S NATURAL RIVERS SYSTEM:

THE LIST OF DESIGNATED AND PROPOSED

NATURAL RIVERS AND

WILD AND SCENIC RIVERS

Appendix 7


MICHIGAN'S NATURAL RIVERS SYSTEM
TWO HEARTED
FOX
PIGEON
JORDAN
BOARDMAN
AU SABLE
BETSIE
RIFLE
PERE MARQUETTE
WHITE
FLAT
ROGUE
LOWER KALAMAZOO
HURON
DESIGNATED STATE NATURAL RIVERS
JORDAN
BETSIE
ROGUE
TWO HEARTED
WHITE
BOARDMAN
HURON
PERE MARQUETTE
FLAT
RIFLE
LOWER KALAMAZOO
PIGEON
AU SABLE
FOX
RIVERS PROPOSED FOR DESIGNATION
1 PRESQUE ISLE
2 ONTONAGON
3 PAINT
4 FENCE
5 STURGEON
6 BIG HURON
7 ESCANABA
8 WHITEFISH
9 INDIAN
10 TAHQUAMENON
11 ST. JOSEPH
12 DOWAGIAC
13 PAW PAW
14 KALAMAZOO
15 GRAND
16 THORNAPPLE
17 FISH CREEK
18 MUSKEGON
19 LITTLE MANISTEE
20 MANISTEE
21 PINE
22 BLACK
23 THUNDER BAY
24 CASS
25 SHIAWASSEE
FEDERALLY DESIGNATED WILD AND SCENIC RIVERS
PERE MARQUETTE
AU SABLE
miris
LAND AND WATER MANAGEMENT DIVISION
DEPARTMENT OF NATURAL RESOURCES
P.O. BOX 30028
LANSING, MICHIGAN 48909
PHONE (517) 373-1170
NOTE: ALL RIVERS INCLUDE SOME OR ALL TRIBUTARIES

APPENDIX 8

GLOSSARY

Appendix 8

Glossary

Absorption: To take up or receive by chemical or molecular action.

Adsorption: To gather a gas, liquid, or dissolved substance on a surface.

Armoring: Installation of a rigid protective shield to prevent erosion or washouts. Common types of armors are rock, concrete, steel sheeting and timber.

Acre-foot: A volume of water one foot deep and one acre in area, or 43,560 cubic feet.

Aerator: A device that sprays water into the air, bubbles air through the water, or agitates the water, to incorporate oxygen into the water.

Backfill: Earth refilling a trench or an excavation.

Backwater: The increased depth of water upstream of an obstruction, such as a dam or bridge, in the stream channel.

Baffles: Fin-like devices installed vertically on the inside walls of liquid waste transport vehicles that are used to reduce the movement of the waste inside the tank.

Base Flow: The part of the stream flow that is not due to direct runoff from precipitation; it is usually supported by water draining from natural storage in ground water bodies, lakes or wetlands.

Baseline General Permit: A permit applicable to a number of classes or categories of discharges.

Bedload: The sediment in a stream channel that moves by sliding, rolling, or skipping on or near the stream bottom.

Benthic macroinvertebrates: Organisms that live in, crawl upon, or attach themselves to the bottom (substrate).

Bentonite: A fine-textured clay.

Berm: An earthen mound used to direct the flow of runoff around or through a structure.

Best Management Practice (BMP): Structural devices or non-structural practices that are designed to prevent pollutants from entering into storm water flows, to direct the flow of storm water or to treat polluted storm water flows.

Biochemical Oxygen Demand (BOD): Measures the amount of organic material in water.

Biodegradable: The ability to break down or decompose under natural conditions and processes.

Booms: 1. A floating device used to contain oil on a body of water. 2. A piece of equipment used to apply pesticides from the ground equipment such as a tractor or truck.

Borrow Area: Areas where soils, sand, gravel, and rock are excavated for use as fill at a construction site.

Bottomland: The land of a lake or stream which lies below the ordinary high water mark of the lake or stream.

Buffer Strip or Zone: Strips of grass or other erosion-resistant vegetation between a waterway and an area of more intensive land use. For the purposes of this document, buffer strips and filter strips have been combined into one Buffer/Filter Strip BMP.

Bulkhead: A structure or partition placed on a bank or bluff to retain or prevent sliding of the land and protect the inland area against damage from wave action. See the Slope/Shoreline Protection BMP.

By-Products: Material, other than the principal product that is generated as a consequence of an industrial process.

CERCLA: Comprehensive Environmental Responsibility Compensation and Liabilities Act.

Calibration: To check the precision and accuracy of measuring equipment.

Cofferdam: A temporary watertight enclosure built in the water and pumped dry to expose the bottom so that construction, as of piers, may be undertaken.

Concentrated Flow: Water which flows in a channel and causes erosion which ranges from a large rill to a gully.

Concrete Aprons: A pad of nonerosive material designed to prevent scour holes developing at the outlet ends of culverts, outlet pipes, grade stabilization structures, and other water control devices.

Conduit: Any channel or pipe for directing the flow of water.

Conveyance: Any channel or pipe for directing the flow of water.

Corridor Projects: Construction activities that are conducted along strips of land (i.e. roads, drains, utilities, pathways and streams).

Corrosion: The dissolving and wearing away of metal caused by a chemical reaction such as between water and the pipes that the water contacts, chemicals touching a metal surface, or contact between two metals.

Crimped: Mulch that has been pressed or folded into the soil into regular folds or ridges. Mulch can be crimped using a gang or coultors.

Culvert: A covered channel or a large diameter pipe that directs water flow below the ground level.

Curve Number: See runoff curve number.

Denuded: Land stripped of vegetation such as grass, or land that has been worn down due to impacts from the elements or humans.

Detention Basin: Temporarily stores water before discharging into a surface water body. Primarily used to reduce flood peaks. Can be classified into three groups:

Dry Detention Basin - usually dry except for short periods following large rainstorms or snow melt events. Not effective at removing pollutants. Pollutants that may settle in the basin, will be "picked up" by future floods.

Extended Dry Detention Basin - is a dry detention basin that has been modified to increase the time which the stormwater will be detained in the basin. The typical detention time is 24 to 48 hours. Not effective at removing nutrients such as phosphorus and nitrogen, unless a shallow marsh at the outlet is incorporated into the design.

Wet Detention Pond - a detention basin that contains a permanent pool of water that will effectively remove nutrients in addition to other pollutants.

Detention Time: The amount of time that a volume of water will remain in the detention basin.

Dike: An embankment to confine or control water, often built along the banks of a river to prevent overflow of lowlands; a levee.

Discharge: A release or flow of storm water or other substance from a conveyance or storage container. It is usually expressed as cubic feet per second (CFS).

Dissolved Solids: That portion of material in water which passes through a filter.

Drainage Area: The area of a watershed usually expressed in square miles or acres.

Drip Line: The area from the trunk of a tree outward to a point at which there is no longer any overhanging vegetation.

Drainage Divide: The line which follows the ridges and high points of the ground surface that separates one drainage area from another.

Droughty Soils: Sandy or gravelly soils that are not able to retain water to support vegetational growth without applying irrigation. .

Emergency Spillway: A depression in the embankment of a pond or basin which is used to pass peak discharges in excess of the design storm.

Energy Dissipater: Concrete blocks, large stones, or check dams installed to reduce water flow and prevent erosive velocities.

Erosion: The wearing away of land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices related to farming, residential or industrial development, road building, or timber cutting.

Eutrophication: The process of enrichment of water bodies by plant nutrients, which may lead to increased growth of algae or rooted plants.

Excavation: The process of removing earth, stone, or other materials.

Excelsior: Slender, curved wood shavings that are formed in variable width rolls for covering seeded areas.

Fertilizer: Materials such as nitrogen and phosphorus that provide nutrients for plants. Commercially sold fertilizers may contain other chemicals or may be in the form of processed sewage sludge.

Filter Fabric: Textile of relatively small mesh or pore size that is used to (a) allow water to pass through while keeping sediment out (permeable), or (b) prevent both runoff and sediment from passing through (impermeable).

Filter Strip: Usually long, relatively narrow area of undisturbed or planted vegetation used to retard or collect sediment for the protection of watercourses, reservoirs, or adjacent properties. For the purposes of this document, buffer strips and filter strips have been combined into one BMP.

First Flush: Highly concentrated pollutant loading during the early portion of stormwater runoff, due to the rapid runoff of accumulated pollutants.

Flange: A rim extending from the end of a pipe; can be used as a connection to another pipe.

Flowmeter: A gauge that shows the speed of water moving through a conveyance.

Forebay: An extra storage area provided near the inlet to a detention basin to trap incoming sediments before they accumulate in the basin.

General Permit: A permit applicable to a class or category of dischargers.

Grading: The cutting and/or filling of the land surface to a desired slope or elevation.

Gully Erosion: The erosion process whereby water accumulates in narrow channels and removes soil from a narrow area with depths exceeding four inches.

Hazardous Substance: (1) Any material that poses a threat to human health and/or the environment. Typical hazardous substances are toxic, corrosive, ignitable, explosive, or chemically reactive. (2) Any substance named by EPA to be reported if a designated quantity of substance is spilled in the waters of the United States of if otherwise emitted into the environment.

Hazardous Waste: By-products of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Possesses at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity), or appears on special EPA lists.

Head Cutting: Stream channel grade line that is comprised of "steps" rather than a consistent decline, and is subject to water erosion.

Herbaceous Vegetation: Plants that are leafy and non-woody with characteristics similar to herbs.

Horizon (Soil Horizon): Natural layers of soil. Each layer has characteristics unlike any of the other layers.

Hydraulic Capacity: Measure of the volume of water which a structure can pass; measure of the volume and flow of water within a watercourse.

Hydraulic Radius: The area of the culvert or stream section divided by wetted perimeter (A/WP).

Hydrograph: A graph, usually of discharge or stage versus time, at a given point along a stream.

Hydrologic Cycle: The continuous process of the exchange of water between the earth and the atmosphere.

Illicit Connection: Any discharge to a municipal separate storm sewer that is not composed entirely of storm water except discharges authorized by an NPDES permit (other than the NPDES permit for discharges from the municipal separate storm sewer) and discharges resulting from fire fighting activities.

Impervious: A surface through which little or no water will move. Impervious areas include paved parking lots and roof tops.

Infiltration: The penetration of water through the ground surface into sub-surface soil or the penetration of water from the soil into sewer or other pipes through defective joints, connections, or manhole walls.

Infiltration Capacity: The maximum rate at which the soil can absorb falling rain or melting snow. Usually expressed in inches/hour, or centimeters/second.

Inlet: An entrance into a ditch, storm sewer, or other waterway.

In-Line Detention: The detention is provided within the flow carrying network (stream).

Irrigation: Human application of water to agricultural or recreational land for watering purposes.

Jute: A plant fiber used to make rope, mulch, netting, or matting. See the Mulching BMP.

Lagoon: A shallow pond where sunlight, bacterial action, and oxygen work to purify wastewater; also used for storage of wastewaters or spent nuclear fuel rods.

Land Application: Discharge of wastewater onto or into the ground for treatment or reuse.

Land Form: A discernable natural landscape that exists as a result of geological activity , such as a plateau, plain, basin, mountain, etc.

Landfills: (1) Sanitary landfills are land disposal sites for Non-hazardous solid wastes at which the waste is spread in layers, compacted to the smallest practical volume, and cover material applied at the end of each operating day.
(2) Secure chemical landfills are disposal sites for hazardous waste. They are selected and designed to minimize the chance of release of hazardous substances into the environment.

Leaching: The process by which soluble constituents are dissolved in solvent such as water and carried down through the soil.

Liming: Treating soil with lime to neutralize acidity levels.

Manning's roughness Coefficient ("n"): A coefficient used in Manning's equation to describe the resistance to flow due to the roughness of a culvert of stream channel.

Mean Storm: Over a long period of years, the average rainfall event, usually expressed in inches.

Mean Storm Volume: The runoff volume produced by the "mean storm".

Moisture Content: See antecedent moisture content.

Mulch: A natural or artificial layer of plant residue or other materials covering the land surface which conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Parabolic: A round bottom ditch, channel, waterway or stream that blends into the banks.

Non-Point Source Pollution: Pollution that is not identifiable to one particular source, and is occurring at locations scattered throughout the drainage basin. Typical sources include erosion, agricultural activities, and urban runoff.

Notice of Intent: An application to notify the permitting authority of a facility's intention to be covered by a general permit; exempts a facility from having to submit an individual or group application.

100-Year Flow: Measurable flow of water within a watercourse with a magnitude which has a 1% chance of occurring or being exceeded in any given year; also referred to as l00-year flood.

100-Year Flood: A flow of water within a watercourse with a magnitude which has a l% chance of occurring or being exceeded in any given year; also referred to as 100-year flow.

Off-Line Detention: Detention placed outside of the natural watercourse or storm sewer system.

Off-Site Detention: Detention is provided at a regional detention facility as opposed to storage on- site.

Oil and Grease Traps: Devices that collect oil and grease, removing them from water flows.

Oil Sheen: A thin, glistening layer of oil on water.

Oil/Water Separator: A device installed, usually at the entrance to a drain, which removes oil and grease from water flows entering the drain.

On-Site Detention: Stormwater is detained on the property as opposed to a regional site.

Ordinary High Water Mark: On an inland lake which has a level established by law, it means the high-established level. Where water returns to its natural level as the result of the permanent removal or abandonment of a dam, it means the natural ordinary high water mark. On a river that is where the grass stops and the bare soil starts.

Organic Pollutants: Substances containing carbon which may cause pollution problems in receiving streams.

Organic Soils: Soils with a high percentage of organic matter, often referred to as muck or peat.

Organic Solvents: Liquid organic compounds capable of dissolving solids, gases, or liquids.

Orifice: An opening in a wall or plate.

Outfall: The point, location, or structure where wastewater or drainage discharges from a sewer pipe, ditch, or other conveyance to a receiving body of water.

Overburden: Soil that must be removed to reach a desired final elevation.

Overfalls: Abrupt changes along the grade line causing the water to tumble.

Overtopping: Drainage over the top of dikes, diversions, or other embankments because of high water conditions.

Peak Discharge: The maximum instantaneous rate of flow during a storm.

Permeability: The quality of a soil that enables water or air to move through it. Usually expressed in inches/hour or inches/day.

Permit: An authorization, license, or equivalent control document issued by EPA or an approved State agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.

Permit Issuing Authority: The State agency or EPA Regional office which issues NPDES or other environmental permits to regulated facilities.

Pervious: A surface that will allow water to infiltrate into the ground.

Pesticides: A family of chemicals used to kill pests. Pesticides include herbicides, insecticides, fungicides and rodenticides.

Piping: Removal of soil material through subsurface flow channels "pipes" developed by seepage water along the outside of a structure.

Point Source: Any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.

Pollutant: Generally, any substance introduced into the environment that adversely affects the usefulness of a resource.

Porous Pavement: A surface that will allow water to penetrate and percolate into soil (porous asphalt pavement). Pavement is comprised of irregular shaped crush rock precoated with asphalt binder. Water seeps through into lower layers of gravel for temporary storage, then filters naturally into the soil.

Precipitation: The supply of water received from the atmosphere, such as rain, snow, and hail.

PVC (Polyvinyl Chloride): Used in pipes because of its strength; does not dissolved in most organic solvents.

Reportable Quantity (RQ): The quantity of a hazardous substance or oil that triggers reports under CERCLA or the Clean Water Act. If a substance is released in amounts exceeding its RQ, the release must be reported to the National Response Center, the State Emergency Response Commission, and community emergency coordinators for areas likely to be affected.

Retardance Value: Classification ratings for vegetative materials based on their ability to reduce water from velocities. Short stands of grass (up to two inches) provide less resistance to flows than a tall stand of grass (up to 36 inches).

Retention Pond: A stormwater management practice that captures stormwater runoff, and does not discharge directly to a surface water body. The water is" discharged" by infiltration or evaporation.

Retrofit: To modify an existing structure to improve the pollutant removal or flood peak reduction capability .A retrofit can consist of the construction of a new BMP in the developed area, the enhancement of an older storm water management structure, or a combination of improvement and new construction.

Rill Erosion: The formation of numerous, closely spread small channels caused by the removal of surface soils by storm water or other water.

Riparian Habitat: Areas adjacent to rivers and streams that have a high density, diversity, and productivity of plant and animal species relative to nearby uplands.

Riser: A vertical pipe extending from the bottom of a basin that is used to control the discharge from the basin.

Runoff: That part of precipitation, snowmelt, or irrigation water that does not infiltrate or evaporate and runs off the land into streams or other surface water. It can carry pollutants form the air and land into the receiving water.

Runoff Curve Number: Indicates the runoff potential of a parcel, and is based on soil group and land use. The higher the runoff curve number, the higher the runoff potential.

Revetment: A facing of stone placed on a bank or bluff to protect a slope, embankment, or shore structure against erosion by wave action or currents. See Detail R-l.

Sanitary Sewer: A system of underground pipes that carries sanitary waste or process wastewater to a treatment works plant.

Sanitary Waste: Domestic or industrial sewage.

Scour: The clearing and digging action of flowing water, especially the downward erosion caused by stream water in sweeping away mud and silt from the stream bed and outside bank of a curved channel.

Seawall: A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action.

Secondary Containment: Structures, usually dikes or berms, surrounding tanks or other storage containers and designed to catch spilled material from the storage containers.

Sediment: Soil, sand and minerals transported from its site of origin by water. May be in form of bedload (along the bed), by bouncing along the bed, suspended, or dissolved.

Sediment Trap: A device for removing sediment from water flows; usually installed at outfall points. See the Sediment Basin BMP.

Sedimentation: The process of depositing soil particles, clays, sands, or other sediments that were picked up by runoff.

Sheet Erosion: Erosion of thin layers of surface materials by continuous sheets of running water.

Sheetflow: Runoff which flows over the ground surface as a thin, even layer, not concentrated in a channel.

Shelf Life: The time for which chemicals and other materials can be stored before becoming unusable due to age or deterioration.

Significant Materials, as defined at 122.26(b)(12) include, but not limited to:

- raw materials; fuels; materials such as solvents, detergents and plastic pellets; finished materials such as metallic products; raw materials used in food processing or production; hazardous substances designated under Section 101(14) of the Comprehensive Environmental Response, Compensation, and Liability act (CERCLA); any chemical the facility is required to report pursuant to Section 313 of Superfund Amendments and Reauthorization Act (SARA); fertilizers; pesticides; and waste products such as ashes, slag, and sludge that have a potential to be released with storm water discharges.

Soil: The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

Soil Erosion: The wearing away of land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices related to farming, residential or industrial development, road building, or timber-cutting.

Source Control: A practice or structural measure (such as covering) to prevent pollutants from entering storm water runoff or other waste materials.

Spill Prevention Control and Countermeasures Plan (SPCC): Plan consisting of structures, such as curbing, and action plans to prevent and respond to spills of hazardous substances as defined in the Clean Water Act.

Sprigged Vegetation: Vegetation that is planted as individual plants, such as trees, shrubs, and dune grass. Spacing between plants is critical for effective growth.

Staged: Staging is dividing a construction area into two or more areas to minimize the area of soil that will be exposed to erosion.

Storm Drain (Storm Sewer): a slotted opening leading to an underground pipe or an open ditch for exclusively carrying surface runoff.

Storm Water: Runoff from a storm event, snowmelt runoff, and surface runoff and drainage.

Stormwater Utility: A source of funding the construction and maintenance of stormwater management facilities. User fees are typically charged based on the amount of runoff that may be anticipated from a property.

Stream Biota: Plant and animal life that is unique to a given stretch of the stream, or a lake.

Subsoil: The bed or stratum of earth lying below the surface soil.

Sump: A pit or tank that catches liquid runoff for drainage or disposal.

Surface Water: All water naturally open to the atmosphere (rivers, lakes, reservoirs, streams, wetlands impoundments, seas, etc.); also refers to springs, wells, or other collectors which are directly influenced by surface water .

Suspended Solids: That portion of material which is retained by a filter.

Swale: An elongated depression in the land surface that is at east seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales direct storm water flows into primary drainage channels and allow some of the storm water to infiltrate into the ground surface.

Time of Concentration: The time it takes for runoff to travel from the hydraulically farthest point of the watershed to the design point.

Topography: The physical features of a surface area including relative elevations and the position of natural and man-made features.

Toxic Pollutants: Materials contaminating the environment that cause death, disease, and/or birth defects in organisms that ingest or absorb them. The quantities and length of exposure necessary to cause these effects can vary widely.

Transpiration: The process of passing water, in vapor form, through the pores of a plant (usually in the leaves) to the atmosphere. Temp & Perm. Wetland Alt.

Treatment: The act of applying a procedure or chemicals to a substance to remove undesirable pollutants.

Tributary: A river or stream that flows into a larger river or stream.

Underground Storage tanks (USTs): Storage tanks with at least 10 percent or more of its storage capacity underground (the complete regulatory definition is at 40 CFR Part 280.12).

Turbidity: Results from suspended solids in water; the opposite of clarity.

Undulating Terrain: Land that has a rolling characteristic, in contrast to land that is flat. .

Volatilization: The loss of gaseous components, such as ammonium nitrogen, from animal manures.

Water Table: The depth or level below which the ground is saturated with water.

Waterway: A channel for the passage or flow of water.

Weir: A device that has a crest and some side containment, and is used to measure, regulate, or restrict flow. The amount of flow that may pass over the weir is a function of the weir geometry and upstream height of water above the cres.

Well Points: Pipes driven into the ground for pumping out water to lower the water table.

Wet Well: A chamber used to collect water or other liquid, and to which a pump is attached.

Wetlands: An area that is regularly saturated by surface or ground water and subsequently is characterized by a prevalence of vegetation that is adopted for life in saturated soil conditions. Examples include: swamps, bogs, fens, and marshes.

Wetted Perimeter: The wetted surface of a stream (culvert) cross section which causes resistance to flow. The water to surface interface is a distance, usually expressed in feet.

Wind Break: Any device designed to block wind flow and intended for protection against any ill effects of wind.

Windthrow: Loss of trees due to the wind causing the trees to fall, usually due to shallow root systems not providing sufficient support from the wind' s force. Often there is a "domino" effect, that once trees start to fall, the wetland becomes more vulnerable for additional tree loss.

Woody Plants: Woody, tree-like plants, including trees and shrubs.

APPENDIX 9

REFERENCES/PUBLICATIONS

Appendix 9

References

The following references were used most often in developing Michigan's BMPs and the "Guidebook to Best Management Practices for Construction Sites and Urban Areas":

Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, Metropolitan Washington Council of Governments, July 1987.

Engineering Field Manual for Conservation Practices, including Michigan supplements, USDA Soil Conservation Service.

Erosion and Sediment Control Planning and Design Manual, State of North Carolina, 1988.

Erosion Control Manual, Oakland County, Michigan, 1990.

Guidelines for Soil Erosion and Sediment Control, Connecticut Council on Soil and Water Conservation, 1985.

The Florida Development Manual: A Guide to Sound Land and Water Management – Stormwater Management, State of Florida, Department of Environmental Regulation, June, 1988.

Michigan Soil Erosion & Sedimentation Control Guidebook, Land and Water Management Division, Soil Erosion Control Unit. 108 pages. (This document is available on a very limited basis, or for loan).

National Handbook of Conservation Practices, Washington, D.C., USDA Soil Conservation Service, October 1987.

Protecting Water Quality in Urban Areas: Best Management Practices for Minnesota. Minnesota Pollution Control Agency, Division of Water Quality, 1989.

A Training Manual for Commercial Pesticide Applicators (Category 3a), Michigan State University, Cooperative Extension Service, January 1992.

Water Resources Protection Technology: A Handbook of Measures to Protect Water Resources in Land Development. Urban Land Institute. Washington, D.C (Tourbier, J. T. and R. Westmacott), 1981.

1990 Standard Specifications for Construction, Michigan Department of Transportation.

Additional References

The following is a list of materials that are provided for additional information:

Michigan Department of Natural Resources publications:

Dam Safety Guidebook: Michigan Edition. Land and Water Management Division, Dam Safety Unit.

Map Interpretation and Plan Review (pamphlet), Land and Water Management Division, Soil Erosion Control Unit. 15 pages. (This publication is available on a limited basis).

Michigan Inland Lakes and Streams Act (pamphlet). Inland Lakes and Streams Section. April 1972. 25 pages.

Vegetation and Its Role in Reducing Great Lakes Shoreline Erosion: A Guide for Propety Owners, Michigan Sea Grant Communications and MDNR Land and Water Management Division, Coastal Zone Management Section.

Vegetative Erosion Control (pamphlet), Land and Water Management Division, Soil Erosion and Sedimentation Control Unit. 16 pages. (This is available on a limited basis).

Wetland Protection Guidebook.

Michigan Department of Transportation publications:

Bureau of Highway Standard Plan for Soil Erosion and Sedimentation Control Measures – V-96C, 1981.

U.S. Department of Agriculture publications, Soil Conservation Service:

Assistance Available from the Soil Conservation District. Program Aid No.1352, 1988.

Clean Water: Our Conservation Commitment. Program Aid No.1475, 1991.

Grassed Waterways in Soil Conservation Leaflet No.477, 1971.

How to Control Sheet and Rill Erosion, E2315.

Hydric Soils of the United States. Publication No.1491.

Maintaining Subsurface Drains. Leaflet No.557, 1972.

Maintaining Watercourses. Leaflet No.562, 1975.

Plant Materials for Conservation. Program Aid Number 1219, 1979.

Soil Erosion by Water. Bulletin No.513, 1987.

Soil Erosion by Wind. Bulletin No.555, 1989.

Soil Surveys Can Help You. Program Aid No.1054, 1991.

What is a Watershed? Program Aid No.420. (1988--revision pending).

Wind Erosion and Its Control.

Miscellaneous publications:

Ecologistics Ltd., Critical Review of the Cost-Effectiveness of Various Erosion & Sediment Control Techniques, Ontario Ministry of Natural Resources, 1981.

APPENDIX 10

BMP CROSS REFERENCE GUIDE

Appendix 10

Cross Reference Guide

ALTERNATE NAME	SEE THE BMP CALLED:
ARMORING	STREAM BANK STABILIZATION; RIPRAP
BOARDWALKS	WETLAND CROSSINGS
BREAKWALLS	SLOPE/SHORELINE STABILIZATION
BRIDGES (BRIDGE CROSSINGS)	WATERCOURSE CROSSINGS
BUFFER AREA	BUFFER/FILTER STRIP
BULKHEADS	SLOPE/SHORELINE STABILIZATION
CART PATHS	WETLAND CROSSINGS
CATCH BASIN INLET PROTECTION	FILTER
CHUTES	GRADE STABILIZATION STRUCTURE
COMPOSTING	ORGANIC DEBRIS DISPOSAL
CONCRETE PAVERS	MODULAR PAVEMENT
CONSTRUCTION SEQUENCE	STAGING & SCHEDULING
CONTOUR GRADING	GRADING PRACTICES
CRITICAL AREA SEEDING	CRITICAL AREA STABILIZATION
CULVERTS (CULVERT CROSSING)	WATERCOURSE CROSSINGS
DEBRIS BASIN	SEDIMENT BASIN
DECKING	WETLAND CROSSINGS
DE-ICING CHEMICAL USE	WINTER ROAD MANAGEMENT
DEWATERING BASIN	SEDIMENT BASIN
DETENTION BASIN	WET DET. BASIN; EXTENDED DET. BASIN; PARKING LOT STORAGE; ROOFTOP STORAGE
DOWNDRAINS	GRADE STABILIZATION STRUCTURES
DRAINAGE TILE	SUBSURFACE DRAIN
DRIVEWAY	ACCESS ROAD
DROP BOXES	GRADE STABILIZATION STRUCTURES
DROP CONTROL STRUCTURES	GRADE STABILIZATION STRUCTURES
DROP INLET SPILLWAYS	GRADE STABILIZATION STRUCTURES
DROP PIPES	GRADE STABILIZATION STRUCTURES
DUAL PURPOSE BASIN	EXTENDED DETENTION BASIN
EARTH EMBANKMENT STRUCTURES	GRADE STABILIZATION STRUCTURES
EGRESS ROAD	ACCESS ROAD
EMBANKMENT POND	POND CONSTRUCTION AND MGT.
ENERGY DISSIPATORS	STABILIZED OUTLETS; RIPRAP
EROSION CONTROL BLANKETS	MULCHING
EXCAVATED PONDS	POND CONSTRUCTION AND MGT.
EXCELSIOR BLANKETS	MULCHING
EXFILTRATION BASIN	INFILTRATION BASIN
FENCES	CONSTRUCTION BARRIERS
FILL PATHS	WETLAND CROSSINGS
FILTER FENCES	FILTERS
FINDAMS	ROOFTOP STORAGE

Appendix 10 (con't.)

ALTERNATE NAME	SEE THE BMP CALLED:
FLUMES	GRADE STABILIZATION STRUCTURES
FOOTPATH	WETLAND CROSSINGS
GABIONS	SLOPE/SHORELINE STABILIZATION
GEOTEXTILE FABRIC	FILTERS; MULCHING
GRASSED CHANNEL	GRASSED WATERWAY
GROINS	SLOPE/SHORELINE STABILIZATION
GRUBBING	LAND CLEARING
HAUL ROAD	ACCESS ROAD
HIGH RISK EROSION AREAS	CRITICAL AREA STABILIZATION
HYDROSEEDING	SEEDING
INGRESS ROAD	ACCESS ROAD
INFILTRATION POND	INFILTRATION BASIN
IN-CHANNEL ENERGY DISSIPATOR	CHECK DAM
INTEGRATED PEST MANAGEMENT	PESTICIDE MGT.; LAWN MAINTENANCE
INTEGRATED TURF MANAGEMENT	PESTICIDE MGT.; LAWN MAINTENANCE
INTERCEPTORS	DIVERSIONS
INTERCEPTOR DRAIN	SUBSURFACE DRAIN
LANDSCAPE PLANTING	TREES, SHRUBS & GROUND COVERS
LANDSCAPING	TREES, SHRUBS & GROUND COVERS
LAND SMOOTHING	GRADING PRACTICES
LATERAL DRAIN	SUBSURFACE DRAIN
LATTICE CONCRETE BLOCKS	MODULAR PAVEMENT
LIMING	SOIL MANAGEMENT
LOG JAM STRUCI'URES	STREAM BANK STABILIZATION
MONOSLAB CONCRETE BLOCKS	MODULAR PAVEMENT
MODULAR BRICK	MODULAR PAVEMENT
NATURAL AREA	BUFFER/FILTER STRIP
NUTRIENT MANAGEMENT	FERTILIZER MANAGEMENT
NITROGEN/PHOSPHORUS MGT.	FERTILIZER MANAGEMENT
OIL/GRIT TRAPS	OIL/GRIT SEPARATORS
OUTLETS	STABILIZED OUTLET
OUTLET PROTECTION	STABILIZED OUTLET
PALMITER METHOD	STREAM BANK STABILIZATION
PERFORATED PAVERS	MODULAR PAVEMENT
PERVIOUS PAVEMENT	POROUS ASPHALT PAVEMENT
PERMEABLE PAVEMENT	POROUS ASPHALT PAVEMENT
PHASING	STAGING & SCHEDULING
PLATFORMS	WETLAND CROSSINGS
PRE-CAST CONCRETE	MODULAR PAVEMENT
PUMPING	DEWATERING
RELIEF DRAIN	SUBSURFACE DRAIN
RETAINING WALLS	SLOPE/SHORELINE STABILIZATION
REVETMENTS	SLOPE/SHORELINE STABILIZATION; STREAM BANK STABILIZATION; RIPRAP

Appendix 10 (con't.)

ALTERNATE NAME	SEE THE BMP CALLED:
ROADWAYS (HAUL ROAD)	ACCESS ROAD
ROADWAYS (SECONDARY ROAD)	ACCESS ROAD
ROADWAY (INGRESS/EGRESS)	ACCESS ROAD
ROOFTOP DETENTION BARRIERS	ROOFTOP STORAGE
ROUGH GRADING	GRADING PRACTICES
RURAL LAWN CARE	LAWN MAINTENANCE
SALT PILES	WINTER ROAD MANAGEMENT
SEAWALLS	SLOPE/SHORELINE STABILIZATION
SEEPAGE BASIN	INFILTRATION BASIN
SEQUENCING	STAGING & SCHEDULING
SERVICE AREA	EQUIPMENT MAINTENANCE/STORAGE AREA
SETTLING BASIN	SEDIMENT BASIN
SHOP AREA	EQUIPMENT MAINTENANCE/STORAGE AREA
SILT FENCES	FILTERS
SILT FLOATATION CURTAINS	FILTERS
SINGLE STAGE DETENTION BASIN	EXTENDED DETENTION BASIN
SOD WATERWAY	GRASSED WATERWAY
SOIL ADDITIVES/AMENDMENTS	SOIL MANAGEMENT
SOIL CONDITIONING	SOIL MANAGEMENT
SOIL PILES	SPOIL PILES
SOIL TEST	SOIL MANAGEMENT
SPECIAL GRADING PRACTICES	GRADING PRACTICES
SPILLWAYS	GRADE STABILIZATION STRUCTURES
SPRIGGING	TREES, SHRUBS & GROUND COVERS; DUNE/SAND STABILIZATION
STABILIZED CONSTR. ENTRANCE	ACCESS ROAD
STOCK PILES	SPOIL PILES
STORAGE PILES	SPOIL PILES
STORM DRAIN INLET PROTECTION	FILTERS
STRAIGHT-PIPES	GRADE STABILIZATION STRUCTURES
STREAM CROSSINGS	WATERCOURSE CROSSINGS
STREAM BANK PROTECTION	STREAM BANK STABILIZATION; RIPRAP
SUMP	SEDIMENT BASIN
SWALE	GRASSED WATERWAY
TACKING	MULCHING
TEMPORARY CROSSING	WATERCOURSE CROSSINGS
TILE	SUBSURFACE DRAIN
TOEWALLS	GRADE STABILIZATION STRUCI'URES
TREE PRESERVATION	TREE PROTECTION
TREE REMOVAL	LAND CLEARING
TURBIDITY CURTAIN	FILTERS
TURF ESTABUSHMENT	SEEDING; SODDING
TWO-STAGE DETENTION BASIN	EXTENDED DETENTION BASIN
UNDERGROUND DRAIN	SUBSURFACE DRAIN

Appendix 10 (con't.)

ALTERNATE NAME	SEE THE BMP CALLED:
URBAN LAWN CARE	LAWN MAINTENANCE
USED OIL DISPOSAL	HOUSEHOLD HAZARDOUS WASTE DISPOSAL
UTILITY CROSSINGS	WATERCOURSE CROSSINGS; WETLAND CROSSINGS
VEGETATIVE SWALES	GRASSED WATERWAYS
VEGETATIVE ESTABLISHMENT	SEEDING; SODDING
WATER QUALITY INLETS	OIL/GRIT SEPARATORS
WET POND	WET DETENTION BASIN
WOOD CHIP PATHS	WETLAND CROSSING
YARD WASTE MANAGEMENT	ORGANIC DEBRIS DISPOSAL

APPENDIX 11

TECHNICAL COMMITTEE MEMBERS:

URBAN TECHNICAL COMMITTEE

CONSTRUCTION SITE EROSION COMMITTEE

GOLF COURSE COMMITTEE

Appendix 11

Technical Committee Members

Construction Site Erosion Technical Committee:
John Kennaugh, Chair, MDNR, Land and Water Management Division, retired
Gaylord Alexander, MDNR, Fisheries Division
Everett E. Bailey, City of Novi, Building Department
Dave Bastian, MDNR, Land and Water Management Division
Lynn Egbert, Michigan Association of Home Builders
Dave Fisher, Department of Public Works
Shirley Gammon, USDA, Soil Conservation Service
Wendell Haag, Van Buren County Road Commission
David E. Jordan, Newaygo County Drain Commission
Tom Killingsworth, Michigan Department of Transportation
William McCurdy, Department of Military Affairs, Engineering and Facilities
Tom McNulty, Wayne County Department of Health
Dick Mikula, MDNR, Land and Water Management Division
Mike O'Malley, Michigan Department of Transportation
Charles R. Page, Associated General Contractors of America, the Christman Company
Amy Peterson, MDNR, Surface Water Quality Division
John T. Price, Price and Company, Inc.
Dwight Quisenberry, USDA, Soil Conservation Service
Vern Rounds, Huron County Deputy Drain Commissioner
Marc Soles, Wayne County Health Department
Warren Studley, retired, Soil Conservation Service

(continued)

Appendix 11

Technical Committee Members

Urban Technical Committee:
Dennis Dunlap, Martin Hendges, Ralph Reznick, co-chairs, MDNR, Surface Water Quality Division
Deb Allen, MDNR, Surface Water Quality Division
Janis Bobrin, Washtenaw County Drain Commissioner
Jack Brodhagen, City of Portage
Lillian Dean, Planning and Management Consultant
Dave Drullinger, MDNR, Surface Water Quality Division
George Griffiths, Ingham County Drain Commissioner
Dave Hamilton, MDNR, Land and Water Management Division
Dick Hinshon, Wade, Trim and Assoc.
Peggy Johnson, Clinton River Watershed Council
Mike O'Malley, Michigan Department of Transportation
Jeana Paluzzi, Wayne County Department of Public Works
Amy Peterson, MDNR, Surface Water Quality Division
Ronda Phillips-Scales, MDNR, Surface Water Quality Division
Shari Shaftlein, West Michigan Environmental Action Council
Ron VanTil, MDNR, Office of the Great Lakes
Nancy Watkins, Wayne County Department of Public Services

(continued)

Appendix 11

Technical Committee Members

Golf Course Technical Committee:
Amy Peterson, Chair, MDNR, Surface Water Quality Division
James Bogart, Turfgrass, Inc.
Bruce Branham, Michigan State University
Doug Carter, MDNR, Land and Water Management Division
Carol Colein, Colein & Associates, Inc.
David Cozad, Mainstream Flow Group
Tim Doppel, Atwood Lawn Care, Inc.
Elwin Evans, MDNR, Surface Water Quality Division
Jim Karas, Department of Commerce, Travel Bureau
Stu Kogge, MDNR, Land and Water Management Division
Jacque Korn, USDA, Soil Conservation Service
Jerry Matthews, Matthews & Associates
Fritz McMullen, Forest Lake Country Club
Dave Morris, Department of Commerce, Travel Bureau
Jessica Ratliff, Deparment of Public Health
Paul Rieke, Michigan State University
Frank Rossi, Michigan State University
Bill Roberts, Lochmoor Club
Kurt Thelen, Department of Agriculture, Environmental Division
Kurt Thuemmel, Walnut Hills Country Club
Joe Vargas, Michigan State University
Chuck Wolverton, Resource Management Group