OHIO STREAM MANAGEMENT GUIDE

An Introduction to Stream Management

Guide No. 01

STREAMS ARE CONNECTED TO THE LAND

The character of Ohio's rivers, streams and ground water has changed greatly over the last 200 years due to human activities. Forests and prairie lands once kept our streams narrow and deep by holding the banks intact. Stream water was cooler, cleaner and clearer, with a greater diversity of species than is found today.

Over the years agricultural production has increased through artificial land drainage. Crops are often planted up to streambanks, eliminating a crucial forested buffer zone for streams. Many of Ohio's streams were straightened to allow water to flow faster. Urbanization increases watertight surfaces (streets, roofs, and parking lots), and our streams receive greater amounts of runoff and the pollution it carries from crossing land surfaces. The increased runoff resulted in streambanks and beds being scoured and nearby cropland being lost. Downstream flood damage also increases as streams carry more water at a faster rate.

The changes we make to each watershed or drainage basin's land use, changes the character of our streams. The loss of trees and their streambank root structures allow streams to run wider and shallower, allowing sediment to fall out, silting-over important biological habitats within the stream. Sediments and pollutants must be filtered from raw water before it is used for industry and drinking. And millions of dollars are spent each year dredging sediment from channels, harbors and reservoirs.

Few people realize the overall importance of watershed-based land use practices, such as increasing the ability of surface areas to absorb water and retaining streamside forested buffer zones. Suitable streamside and in-stream habitat is the single most important factor determining the existence of diverse fish and wildlife populations. Healthy aquatic populations indicate good water quality which results in fewer external costs to society. The quality and productivity of our rivers and lakes can be improved if we retain and restore their natural characteristics.

During the 1960's and 1970's people started to see that our prosperous and productive life style was seriously impacting the quality of the environment around us, including the resource-base which supports that life style. As a society we have started to make choices to alter our land use practices in order to preserve and restore habitat that are critical for the survival of plants and animals whose continued existence we once took for granted.

Each year new information and practices help us stay productive and prosperous while protecting the natural environment. This series of Ohio Stream Management Guides is designed to make practical advice available to landowners and others responsible for land use decisions involving streams.

WHAT IS STREAM MANAGEMENT?

Stream management includes all land use activities which affect stream environments, particularly their physical structure. Streams and their watershed lands should be managed in ways that work toward finding and maintaining healthy balances between our various land uses and the needs of fish and wildlife. The Ohio Stream Management Guides will focus on the physical structure of streams and management practices which support the search for healthy balances.

More intensive land use and development tends to disrupt natural processes which protect and preserve water resources. Therefore, land uses and the design and maintenance of stream modifications and storm water structures must be managed responsibly. This means minimizing the disruption of those natural processes, and mitigating necessary disruptions as much as possible.

STREAMS ARE PART OF THE HYDROLOGIC CYCLE

Stream systems drain the land as a key part of nature's water cycle. The water cycle contains the following elements:

1. precipitation of all forms of water which falls from the atmosphere to the earth's surface;
2. infiltration and percolation of precipitation deep into the ground, replenishing the ground water supply;
3. overland flow or runoff of precipitation across land surfaces and through drainageways to streams, lakes and eventually, the ocean;
4. evaporation from surface water, soil and vegetation, returning water vapor to the atmosphere; and
5. transpiration by plants through their roots to their leaves, returning water vapor to the atmosphere.

The cycling of water from the earth's surface to the atmosphere and then returning to the earth, is called the hydrologic cycle. Hydrology is the study of the various waters of the earth, their occurrence, circulation, distribution, chemical and physical properties and reaction with the environment, including their relationships with living things.

STREAMS AND OTHER WATER RESOURCE FEATURES

Stream systems are related to other water resource features such as watersheds, lakes and reservoirs, wetlands, ground water, floodplains, riparian zones and fish and wildlife habitats.

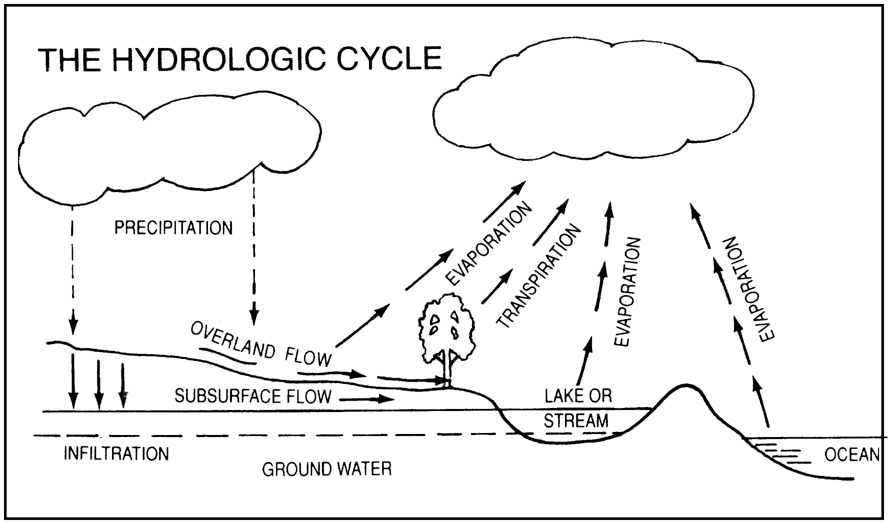
Watersheds, or drainage basins, are areas of land which drain to a single outlet. The term watershed is also used for the outline of the drainage basin. Precipitation falling on one side of a watershed line will drain to one outlet while precipitation falling on the other side of the line will drain to another outlet. The peak of a roof functions in the same way, dividing which direction runoff will flow off the roof. A watershed area may be as small as a farm field draining toward a gully, or as big as the Ohio River drainage basin, which is a combination of thousands of smaller watersheds across several states. Every river, stream and tributary is part of a watershed. The geography, geology and land uses in a watershed greatly influence a stream's character.

Lakes are naturally occurring impoundments of water, while reservoirs are made by humans. Lakes and reservoirs both serve as sinks where the sediment load that streams carry are deposited. These areas can provide water supply, flood control, fish and wildlife habitat, recreational opportunities and other benefits.

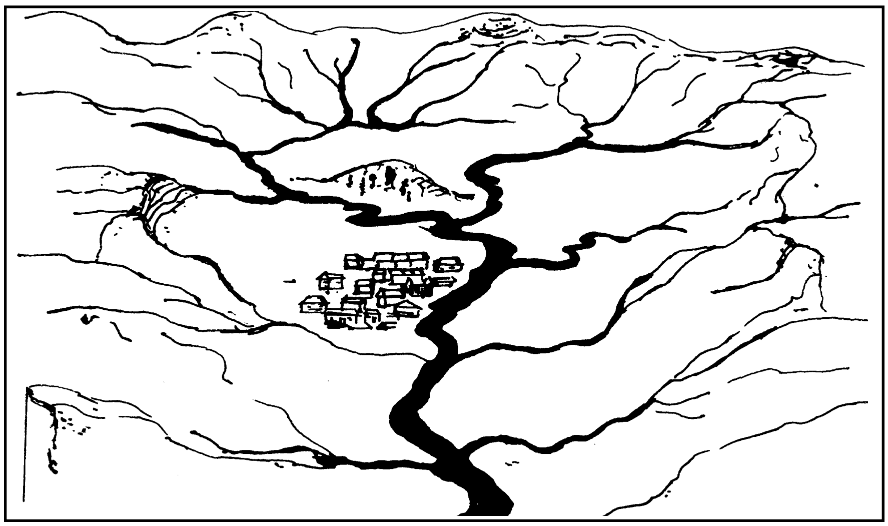
Wetlands are transitional areas between dry land and streams, ponds or lakes. Bogs, fens, marshes and swamps are examples of different types of wetlands. Wetlands are one of nature's ways of managing water quantity and quality. Wetlands provide a variety of no-cost, maintenance-free benefits such as, cleaning water, storing and slowing flood waters, providing ground water recharge and discharge, and providing wildlife habitat. Wetlands also have recreational, educational and aesthetic values which are enjoyed by more and more people.

Ground water, a valuable source of drinking water, is water stored underground in porous, permeable layers of sedimentary rock or unconsolidated sand and gravel deposits, known as aquifers. Replenishment, or recharge, of the ground water supply occurs when precipitation penetrates deep into the subsurface and becomes part of the ground water system. Shallow ground water discharges into streams where water tables intersect stream channels, providing base flow to the stream. Streams may also exist as areas of discharge for deeper ground water aquifer systems.

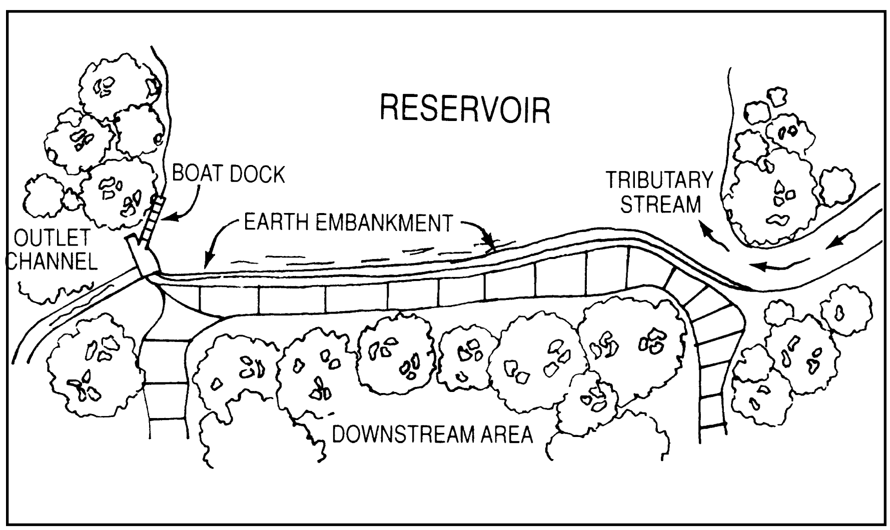
Floodplains are the valley floors adjacent to stream channels which may be inundated during flood events. Flooding is a natural and unavoidable characteristic of all streams. Floodplains function as nature's safety valve by providing a place for floodwater to spread out, thus slowing the speed of floodwater discharge. Floodplains provide other valuable functions too, including



Hydrologic Cycle



Watershed



Reservoir

wildlife habitat, ground water recharge, water quality maintenance and sediment control. They also have recreational, aesthetic and scientific values.

Riparian zones are lands immediately adjacent to streams, sometimes called stream corridors, usually within floodplains. The term riparian zone is often used to mean a streamside forested buffer area, particularly in water quality programs and local ordinances. The width of the zone is then defined according to the program's purpose. Indeed, one of the best uses of stream side land is as a forested buffer area between the stream and other land uses. Retaining or restoring riparian land to forest provides many water quality and floodplain benefits. The riparian area provides a transition between aquatic habitat and upland habitat and may contain wetlands. The relative health of the riparian zone, or stream corridor, directly affects fish and wildlife survival.

The quality of fish and wildlife habitat is a function of the physical, chemical, and biological features of the entire watershed as well as the stream corridor. It indicates the capacity of the stream to support viable, diverse populations of both aquatic and terrestrial organisms.

HOW LAND USE AFFECTS WATER QUANTITY AND QUALITY

Land use changes affect the hydrology of an area in three ways:

1. Peak Flow Characteristics

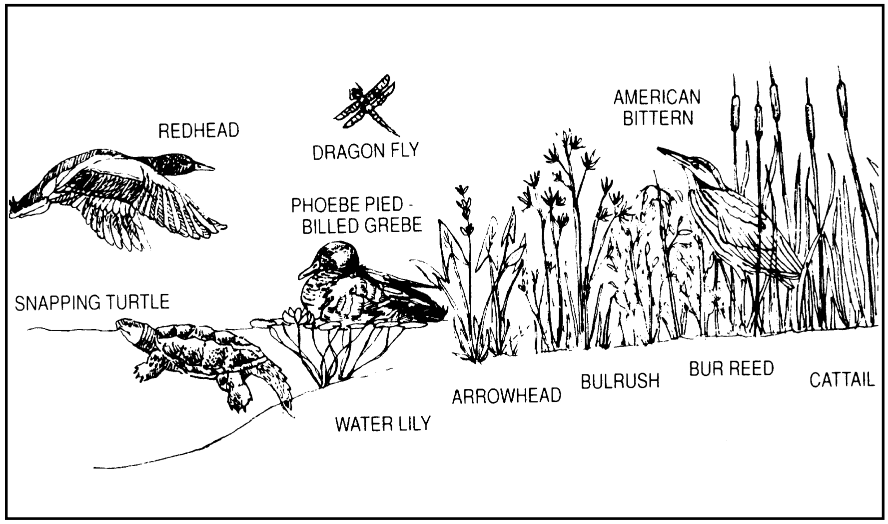
After rainfall events, runoff reaches streams and rises to reach a peak before subsiding. As land uses change from natural to agricultural or urban, the total amount of flow, peak flow height and stream flow speed increases. Streams rise higher, flow faster, and reach peak flows more quickly than under natural conditions. These effects are due to an increase in impervious area (streets, parking lots, roofs, etc.); a reduction in the opportunity for infiltration, evaporation, transpiration and depression storage; and the modification of surface drainage patterns.

2. Water Quality

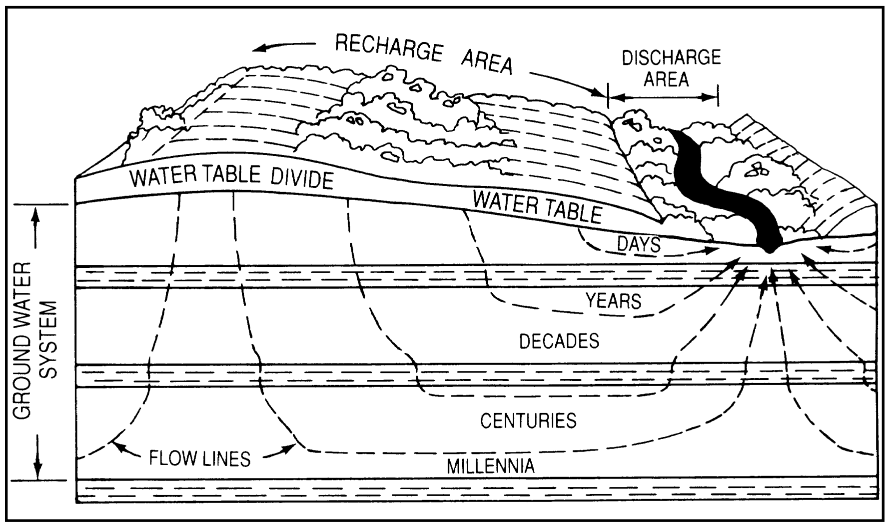
As the human use of land intensifies, the naturally occurring physical, chemical and biological activities which normally interact to recycle most of the materials found in runoff are disrupted. Human activities add pollutants such as pesticides, fertilizers, animal wastes, oil, grease and heavy metals to the land surface. Construction activities expose soil directly to precipitation. Soil and pollutant particles are washed downhill by rainfall and runoff, and increase the pollutant and sediment loads carried by receiving streams.

3. Stream Amenities

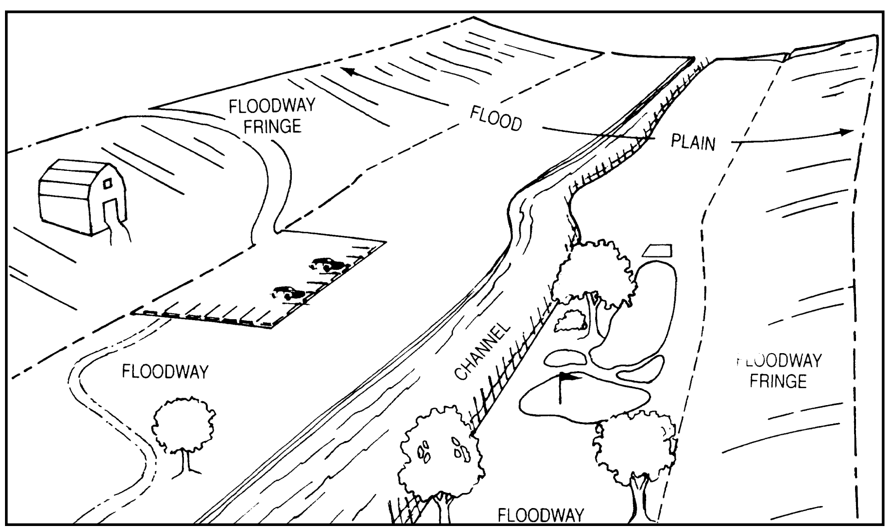
The value of natural stream corridors, as both a public and private good, reflects a higher land value near wooded stream corridors. A channel which has gradually enlarged due to increased flooding tends to possess unstable and un-vegetated banks, scoured or muddy channel beds, and accumulations of sediment and debris. In addition to being unsightly, these factors disrupt the natural balance in stream organisms. The addition of nutrients, organics and sediment caused by changes in hydrology tend to increase algae growth and turbidity (green- and brownish water),



Wetland



Ground Water



Floodplain

lower the oxygen content of the water and thereby reduce the variety of organisms supported by the stream. The beauty and value of the stream corridor is negatively affected when the stream channel is unstable, trash accumulates, and fish and wildlife communities are disrupted.

We are all land managers, so we are all stream managers. How we handle that responsibility — directly or indirectly — affects our neighbors in the watershed and along our stream. Our actions both reflect and change the society and environment around us. We should seek to improve the balance between aquatic organisms, water quality, water quantity, and land development in our Ohio watersheds and streams.

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This Guide is one of a series of Ohio Stream Management Guides covering a variety of watershed and stream management issues and methods of addressing stream related problems. The first several guides in the series are overview guides intended to give the reader an understanding of the functions and values of streams. For more information about stream management programs, issues and methodologies, see Guide 05 Index of Titles or call the ODNR Division of Soil and Water Resources at 614/265-6739. All Guides are available from the Ohio Department of Natural Resources. Single copies are available free of charge and may be reproduced. Please contact:

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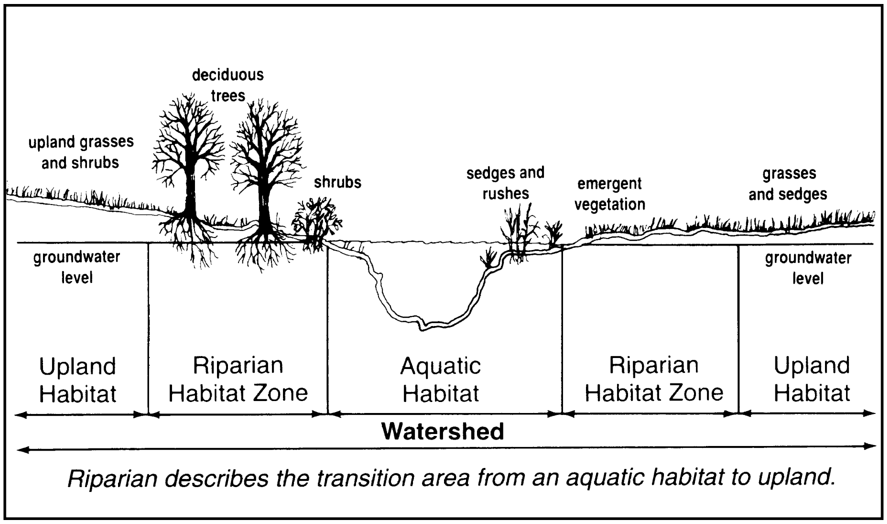

Riparian Zone

Wildlife Habitat

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OHIO STREAM MANAGEMENT GUIDE

"Who Owns Ohio's Streams?"

Guide No. 02

Over the years, Ohio citizens have frequently contacted the Department of Natural Resources seeking assistance in the resolution of problems they have encountered related to water resources. Many of the questions posed have concerned the authorities and duties of government, as well as the rights and responsibilities of individuals, with regard to surface water. This fact sheet poses some of the more frequently-asked questions, and provides the responses which have been passed along. It is intended to assist the lay person in understanding the basic legal concepts involved with some of Ohio's more common water rights issues. A more comprehensive analysis can be obtained through review of the references cited, which is strongly recommended. For those persons involved in water rights conflicts, this fact sheet is intended as a prelude to consultation with an attorney, not as a substitute for it.

Who owns Ohio's streams? Ohio's Constitution does not address this question, nor has there been a statute enacted in Ohio to address it. So the answer must be derived from the common law.

What is "the common law"? The common law, in this context, is the system of law initially developed in England by the higher courts and stated in the written opinions of these courts based on general customs or on reason and fixed principles of justice.[1&2] English common law had been adopted in the American colonies prior to the Revolutionary War, and those parts of it that were consistent with the Constitution of the United States were retained. Since then, opinions of federal and state courts in this country have modified, refined, and added to the common law of the United States and the State of Ohio.

What if the federal or state government passes a law that contradicts the common law? This type of law, called a statute, overrides the common law. Common law is used by the courts to interpret statutes and to determine the outcome of cases in which statutes are not controlling.

Are there situations not addressed by the common law? Yes, but because the common law is founded on the "laws of nature and the dictates of reason", even in the absence of a precedent it is adaptable to new situations and circumstances.[1&2] A precedent is a past decision of a higher court (an appeals court or supreme court) which serves as an example for other courts to follow in similar cases. In situations where there is no clear precedent to follow, it is difficult to predict how the common law may be adapted or modified. Even in situations where there is a clear precedent, it still may be modified or reversed by a new court decision and a new precedent established. Significant changes to the common law, which normally are the result of Ohio or U.S. Supreme Court decisions, occur due to changing circumstances, an expanding knowledge base, and changing attitudes in society and in the courts.

So what does the common law say about who owns Ohio's streams? There are two components to a stream, the water flowing in it and the land beneath the water. The nature of flowing water makes it impossible for a landowner to exercise the kind of control over it that is essential for it to be considered private property. Despite a landowner's efforts to retain it, the water will inevitably seep into the ground or evaporate into the air or flow downhill onto the next property. Water is a "public good" and not ownable as private property. Landowners do have rights to make use of the water flowing through their property including the right to withdraw it and otherwise control it to the extent that nature permits, so long as the rights of others are not infringed upon.[3] Such rights are known as "riparian rights", meaning they are derived through the ownership of streamside property.

As to who owns the land beneath a stream, under Ohio common law the owner of the land beside the stream also owns the land beneath it. If the land on each side is owned by two different owners, then each owns to the center of the stream unless otherwise specified by the landowners' deeds. On navigable streams there is a public right of navigation, spelled out originally in the Northwest Ordinance, which states that navigable waters shall be common highways, forever free to the people of the United States. On such streams, boaters have the right to navigate on the stream, regardless of who owns the land beside it. Because of this, some have claimed that the owners of land beside a navigable stream do not own the land beneath it. But Ohio courts have long held that the owners of the land on the banks of a navigable stream are also owners of the beds to the middle of the stream, as in the common law.[4] One exception is the submerged land beneath the Ohio portion of Lake Erie, which is owned and held in trust for the public by the State of Ohio.

Does a landowner who owns the land on both sides of a stream (and, therefore, beneath the stream as well) have the right to construct a dam across it? There are no constitutional provisions and, in most instances, no statutes that address this type of action. Under the common law, dam construction is allowed so long as it doesn't infringe on the rights of others. If a dam is constructed so that the water retained behind it backs up onto an upstream landowner's property and causes harm, the dam owner may be held liable in court for an unreasonable interference with the flow of surface water.[5] If the dam curtails the flow of water downstream and prevents reasonable uses by downstream property owners, the dam owner may also be held liable in court. If the dam collapses during a normal flood and causes harm to downstream landowners, the dam owner may likewise be held liable.[6] On navigable streams, the construction of a dam may interfere with the public's right to navigate the stream. This could result in a court decision disallowing a dam because it is an impediment to the public's right of navigation.[7]

There are also both state and federal statutes which are, in some instances, relevant to construction of a dam. Depending on the size of the dam and the amount of water it would retain, it may fall under the jurisdiction of Ohio's dam safety statute which requires a construction permit from the Ohio Department of Natural Resources, Division of Soil and Water Resources.[8] The purpose of the dam safety program is to require that dams are designed and constructed according to appropriate specifications to assure their structural integrity and the public safety. On a few large rivers in Ohio, construction of dams and other impediments to navigation is regulated by the U.S. Army Corps of Engineers. Impediments to navigation on these streams are generally not permitted.[9] Construction of a dam may also constitute placement of fill into waters of the United States, which may require a federal permit, also from the U.S. Army Corps of Engineers.[10] The federal and state statutes which are relevant to dam construction are outlined in Guide 06 Permit Checklist for Stream Modification Projects.

Whether or not a stream is navigable seems to affect landowner rights in Ohio. What is a navigable stream and how can I find out if a particular stream is navigable? Under Ohio common law, navigability cannot be determined by a precise formula which fits every stream under all circumstances and at all times. This means that the courts must decide the navigability of streams one at a time, on a case-by-case basis. Factors provided as guidelines for the courts include the stream's capacity for boating in its natural condition, its capacity for boating after the making of reasonable improvements and its accessibility to public destinations.[11] A natural temporary obstruction to navigation, such as a logjam or sandbar, does not destroy the otherwise navigable nature of a stream.

Traditionally, a test of navigability has been whether a stream is used or could be used as a highway for commerce, over which trade and travel are or may be conducted in the customary modes of trade and travel on water. Recently, the definition of navigability has been broadened to include a stream's capacity for recreational navigation as well. The modern view is that navigation for pleasure and recreation is as important in the eyes of the law as navigation for commercial purposes.[12] At any rate, under Ohio common law it is not possible to know with certainty whether or not a specific stream is subject to the public's right of navigation until a court has made such a determination.

Navigability is also defined in different ways by several federal and state statutes based upon the regulatory jurisdictions of the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency. These definitions are relevant only within the context of the statutes in which they appear. More information about these statutes and their applicability can be found in Guide 06 Permit Checklist for Stream Modification Projects. Fact sheets explaining Section 404 permits and Section 401 water quality certifications are available from the Ohio Environmental Protection Agency by calling (614) 644-2001.[13]

Do landowners along a stream have the right to improve drainage on their land and route the drainage outlets into the stream? Again, there are no constitutional provisions or statutes which address this concern. Under the common law in Ohio, landowners have the right to make a reasonable use of their land, even though altering the flow of surface water may cause harm to others. Landowners incur liability only when their harmful interference with the flow of surface water is unreasonable.[14]

But if the outlet is a "natural watercourse," aren't property owners allowed to discharge drainage water into it even if it does cause damage downstream? Yes, but only if their actions are reasonable. Historically, the courts in Ohio maintained that upstream landowners could place surface water above and beyond the natural flow into natural watercourses without being liable to downstream owners.[15] However, more recent court decisions have applied a "reasonable use" rule instead. Under this rule, landowners are neither permitted to dispose of surface water any way they wish nor are they prohibited from interfering with the natural flow of surface water to the detriment of others. Landowners are liable for damages caused by their interference with the natural flow of surface water only when their actions are "unreasonable".[14]

Who determines when the harmful interference with the flow of surface water is unreasonable? The reasonability of an alteration of the flow of surface water is decided by the courts on a case-by-case basis. A landowner along a stream who believes he or she has been harmed by another streamside landowner's actions must seek relief through court action. The court determines whether or not the harm is significant and material, whether it is unreasonable, and what the appropriate remedy should be. If the court determines that the harm is significant and material and that it is unreasonable, it may require that the action causing the harm be discontinued by granting an injunction against it. The court may also allow the action causing the harm to continue, but specify that compensation for damages be paid.

If a drainage improvement diverts water into a stream from land that does not naturally drain into that stream, isn't that illegal? Not necessarily. Historically, when the courts in Ohio allowed upstream landowners to place surface water above and beyond the natural flow into natural watercourses without being liable to downstream owners, one of the conditions was that none of the additional water could come from outside the watershed.[15] However, since the courts have been applying the reasonable use rule, the prohibition on diversion may no longer apply.[16] Under the reasonable use rule, such a diversion may be allowed unless a court determines that it constitutes a harmful interference with the flow of surface water that is unreasonable.

It is important to note that a state statute overrides the common law for diversions of water out of either the Lake Erie or Ohio River Basins in quantities greater than 100,000 gallons per day. A permit from the Ohio Department of Natural Resources is required for such diversions.[17] And under federal statute, diversions out of the Lake Erie Basin, regardless of quantity, must have the approval of all the Great Lakes States' Governors.[18]

Who is responsible for clearing natural obstructions, such as logjams and sandbars, from streams to keep them free flowing? It is not clear than anyone has such a responsibility. Governmental entities at the municipal, county, state, and federal levels have the statutory **authority** to undertake stream clearing and drainage improvement projects, but no governmental entity at any level has been assigned by statute the **responsibility** for such activities. The common law also does not specify that property owners must keep the streams flowing through their property clear of natural obstructions. Natural obstructions in a stream on one property may cause harm to upstream property owners by reducing the stream's capacity for conveying runoff, resulting in flooding or reducing the effectiveness of artificial drainage systems. If these problems were caused by a landowner's actions, such as the construction of a dam across the stream, this harm would be actionable in court. It is unclear whether or not a landowner's inaction in failing to remove natural obstructions from the stream is similarly actionable.

On watercourses where drainage improvements have been made under authority of County Ditch[19] statutes, there are requirements for maintenance that may include removal of logjams, sandbars, and other natural obstructions. A county ditch project doesn't change a streamside landowner's basic rights to the use of the watercourse and, in fact, improves its capacity for carrying away excess water. The county (or a joint county board for multi-county drainage projects) retains a maintenance easement along the stream, and is required by the statute to maintain the original drainage project.[20] Landowners pay an annual maintenance assessment for these services. There are similar maintenance provisions on streams where water management improvement projects have been undertaken by one of Ohio's Conservancy Districts.[21]

Municipal governments also have the authority to undertake stream clearing and drainage improvement projects, and some cities and villages have enacted ordinances requiring that streams be maintained in their free-flowing states within the municipal boundaries.

The statutory authorities available for removing obstructions are discussed in Guide 04, A Catalog of Contacts for Stream Topics. The Ohio Department of Natural Resources recommends that, before an obstruction removal project is begun, consultation be made with the applicable local, state, and federal agencies listed in Guide 06, Permit Checklist for Stream Modification Projects. The extent of permit requirements will depend on the location and design of the particular project.

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2 P.B. Gove, editor in chief, 1966, Webster's Third New International Dictionary of the English Language Unabridged, G.&C. Merriam Company, Springfield, Massachusetts.

3 3 Kent Comm. 439 (3d, 1836); VI-A Amer. L. of Prop. § 28.55 (1954); Cooper v. Williams, (1831), 4 Ohio St. 253, 287; Salem Iron Co. v. Hyland, (1906), 74

Ohio St. 160, 165. An excellent discussion on this topic and on water rights generally can be found in: Callahan, C.C. & J.R. Hanson, 1979, Principles of Water Rights Law in Ohio, 2nd edition, Ohio Department of Natural Resources, Division of Soil and Water Resources, Columbus, Ohio. Additional information specific to water withdrawal rights can be found in: Hanson, J.R., A.F. Woldorf, & L.P. Black, 1991, Water Rights—An Overview of Ohio Water Withdrawal Law, 2nd edition, Ohio Department of Natural Resources, Division of Soil and Water Resources, Columbus, Ohio.

4 Gavit v. Chambers, (1828), 3 Ohio St. 496.

5 Fox v. Fostoria, (1897), 14 OCC 471, rev. on other grounds, 60 Ohio St. 340; Neff v. Sullivan, 9 OD Repr. 765.

6 East Liverpool City Ice Company v. Mattern, (1920), 101 Ohio St. 62.

7 State ex rel. Brown v. Newport Concrete Company, (1975), 44 Ohio App. 2d 121.

8 Ohio Revised Code, § 1521.06.

9 Federal River and Harbor Act of 1899, Section 10.

10 Federal Water Pollution Control Act Amendments of 1972, Section 404.

11 Coleman v. Schaeffer, (1955), 163 Ohio St. 202.

12 Mentor Harbor Yachting Club v. Mentor Lagoons, (1959), 170 Ohio St. 193.

13 Section 404 Permits and Section 401 Water Quality Certifications, Ohio Environmental Protection Agency fact sheets.

14 McGlashan v. Spade Rockledge Corp., (1980), 62 Ohio St. 2d 55. See also: Myotte v. Mayfield, (1977), 54 Ohio App. 2d 97; Chudzinski v. Sylvania, (1976), 53 Ohio App. 2d 151; Masley v. Lorain, (1976), 48 Ohio St. 2d 334. An excellent discussion on this and related topics can be found in: Brown, L.C. and J.L. Stearns, Ohio's Drainage Laws—An Overview, Bulletin 822, OSU Extension, Columbus, Ohio.

15 Munn v. Horvitz, (1964), 175 Ohio St. 521.

16 Joseph, v. Wyss, (1991), 72 Ohio App. 3d 199.

17 Ohio Revised Code, §1501.32.

18 Federal Water Resources Development Act of 1986, Section 1109.

19 Ohio Revised Code, Chapters 6131, 6133, 6135, and 6137.

20 The maintenance requirement applies only to county ditch projects done after 1957.

21 Ohio Revised Code, Chapter 6101.

This Guide is one of a series of Ohio Stream Management Guides covering a variety of watershed and stream management issues and methods of addressing stream related problems. All Guides, including an **Index of Titles**, are available from the Ohio Department of Natural Resources Division of Soil and Water Resources at:

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OHIO STREAM MANAGEMENT GUIDE

Natural Stream Processes

Guide No. 03

Streams in their natural state are dynamic ecosystems that perform many beneficial functions. Natural streams and their flood plains convey water and sediment, temporarily store excess flood water, filter and entrap sediment and pollutants in overbank areas, recharge and discharge groundwater, naturally purify instream flows, and provide supportive habitat for diverse plant and animal species. The stream corridors wherein these beneficial functions occur give definition to the land and offer "riverscapes" with aesthetic qualities that are attractive to people.

Human activities that impact stream ecosystems can and often do cause problems by impairing stream functions and beneficial uses of the resource. Solving stream management problems requires knowledge and understanding of the stream's natural processes, and since many problems originate beyond the banks, a watershed approach.

This Ohio Stream Management Guide provides an overview of the stream's natural processes and of the human impacts on stream ecosystems. The information provided here can be used by land managers, watershed groups, river conservationists, public agency officials, and others to start a thoughtful inquiry into the true source of local stream management problems. The material contained in this guide makes evident that the source of many stream problems is in the watershed, far from the main stream channel. Landowners, local officials, and others concerned with streams need to work together across property lines and jurisdictional boundaries to find suitable solutions to stream problems and to implement practices to protect, restore and maintain healthy stream ecosystems.

STREAMS ARE DYNAMIC ECOSYSTEMS

Streams in their natural condition typically exist in a state of dynamic equilibrium. When a stream is in dynamic equilibrium, the amount of sediment delivered to the channel from the watershed is in long-term balance with the capacity of the stream to transport and discharge the sediment. A balance also exists between communities of aquatic organisms inhabiting a stream and the biochemical processes that recycle nutrients from natural pollution sources, such as leaf fall, to purifying the water. The natural stream tends to maintain itself through the flushing flows of annual floods that clear the channel of accumulated sediments, debris, and encroaching vegetation. Extreme floods may severely disrupt the stream on occasion, but the natural balance of the stream ecosystem is restored rapidly when it is in a state of dynamic equilibrium.

CHANNEL FORMING AND RECONDITIONING PROCESSES

Flowing water contributes significantly to erosion and the shaping of most land masses. During the evolution of a landscape, stream characteristics develop including: drainage density, stream order, and longitudinal profile (Figure 1). Erosion in watersheds unaffected by human disturbances takes place at geologic rates. During any given year, the majority of waterborne sediment is redeposited within the watershed as colluvium at the base

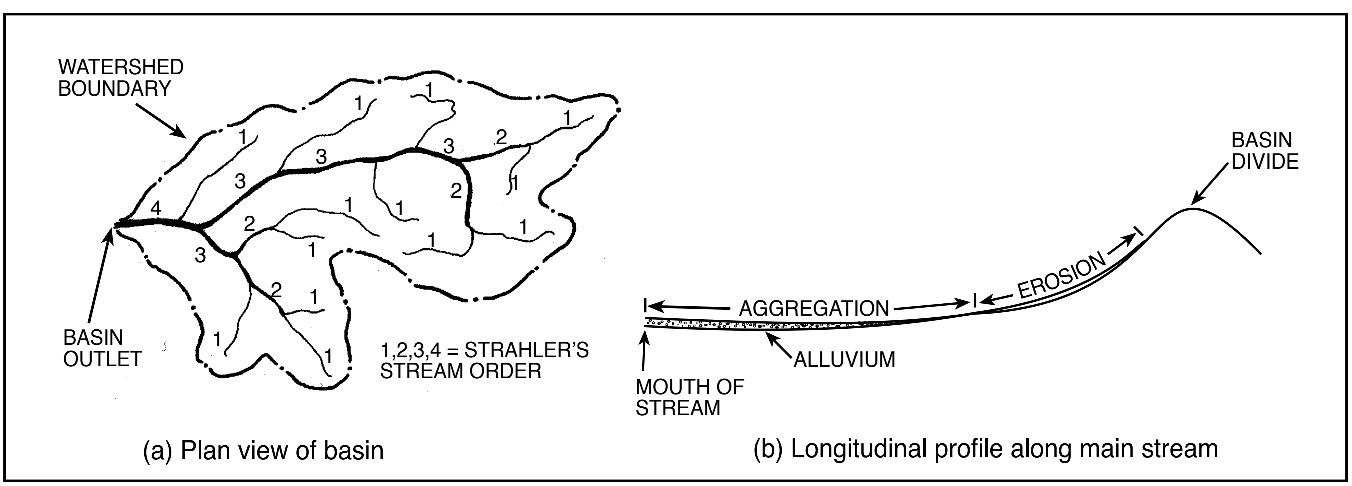


Figure 1. Drainage Basin and Longitudinal Profile Along Stream

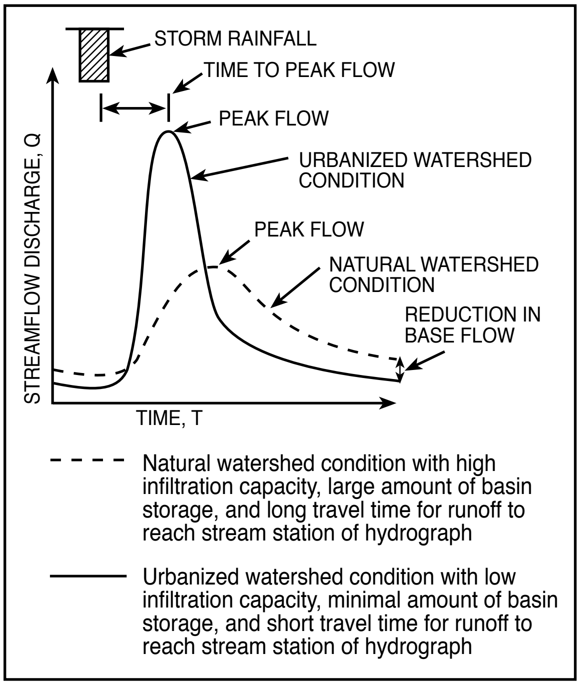


Figure 2. Hydrographs of Streamflow Discharge Before and After Urbanization

of slopes or as alluvium and sediment bars along streams. The amount of sediment discharged from the basin generally represents a small percentage of the gross erosion occurring in the watershed. Longitudinal profiles of channel bottom elevation from stream mouth to headwater divide typically exhibit upward concavity with steepest gradients in headwater areas and flattest gradients toward the mouth. This concave shape is the end result of erosion and deposition as the stream matures.

Down cutting or incising of a stream by erosion is ultimately controlled by its base level, that is, the elevation of a grade control such as resilient bedrock or the confluence with a larger, stable stream of the channel network. A stream that has adjusted its longitudinal profile to a local base level, sediment load and flow regime, and is no longer degrading (down cutting) or aggrading (rising due to sediment deposition) is referred to as a poised or graded stream. Under these conditions, the amount of sediment delivered to the stream is in balance with the capacity of the stream to discharge it. During periods of medium and low flow, tributaries may deliver sediment to the main channel where it is deposited as bars at the confluence until a flood occurs giving the main stream sufficient energy to dislodge and transport the sediment downstream.

Bankfull flows play a primary role in forming and reconditioning channels. Bankfull flows in natural watersheds of humid areas, like Ohio, occur about every 1.5 years on average. The full range of rising and falling discharges associated with these runoff events is involved in the channel forming and reconditioning processes. The frequency of bankfull flows may increase significantly with changes in land use, disrupting stream stability. Flood flows along streams in response to precipitation are a function of many factors including: basin area, infiltration capacity, and time of travel of flows (figure 2). Basins with high infiltration capacity and a long time of travel, tend to generate peak flood flows of lesser magnitude than those in similarly sized drainage areas with lower infiltration capacities and shorter time of travel.

CHANNEL TYPES AND PATTERNS

General features of natural streams are the result of physical, chemical and biological processes reflecting a long-term regime of climate, landform, geology (including soils) and resultant vegetation. Each channel reach has its own unique history of flow conditions and regime factors giving rise to its general features. A river system may contain many different channel types each transitioning from one to another.

Natural channels can be broadly grouped into alluvial channels and hard-bed or rock-bed channels. The bed and banks of alluvial channels consist of riverine deposits that allow for relatively rapid adjustment of channel geometry in response to changes in flow conditions and sediment load. Hard-bed or rock-bed channels are relatively resistant to down cutting but may have alluvial banks that allow for rapid lateral adjustments. Sediment deposits may cover portions of a hard-bed or rock-bed channel giving it the appearance of an alluvial channel. Alluvial channels in a given drainage basin tend to share similarity in their hydraulic geometry, that is, the mean depth, top width and velocity relationships for typical cross sections. Coarse materials characterize alluvial channel beds in headwater areas; fine materials dominate the lower channel reaches.

Natural channels in plan view can be considered to be either straight, meandering or braided. The distinction between straight and meandering channels depends on the degree of sinuosity, that is, the ratio of channel length to valley length. Channels with

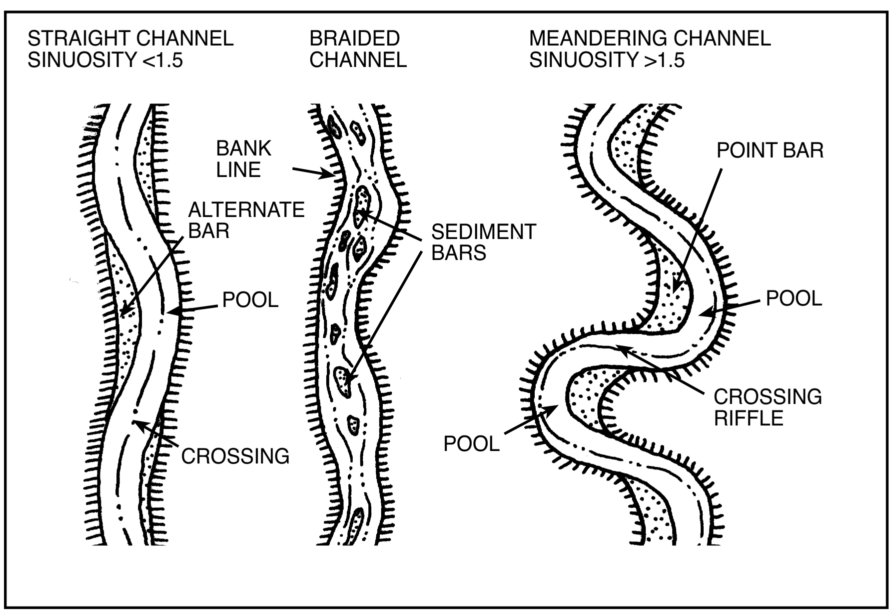


Figure 3. Plan View of Staright, Braided and Meandering Channel Forms.

sinuosity greater than 1.5 are generally considered to be meandering. Braided channels contain sediment bars that cause multiple channels to form during low-flow conditions. Straight, meandering or braided channels may change from one form to another over time such that a continuum exists between the three channel patterns (Figure 3).

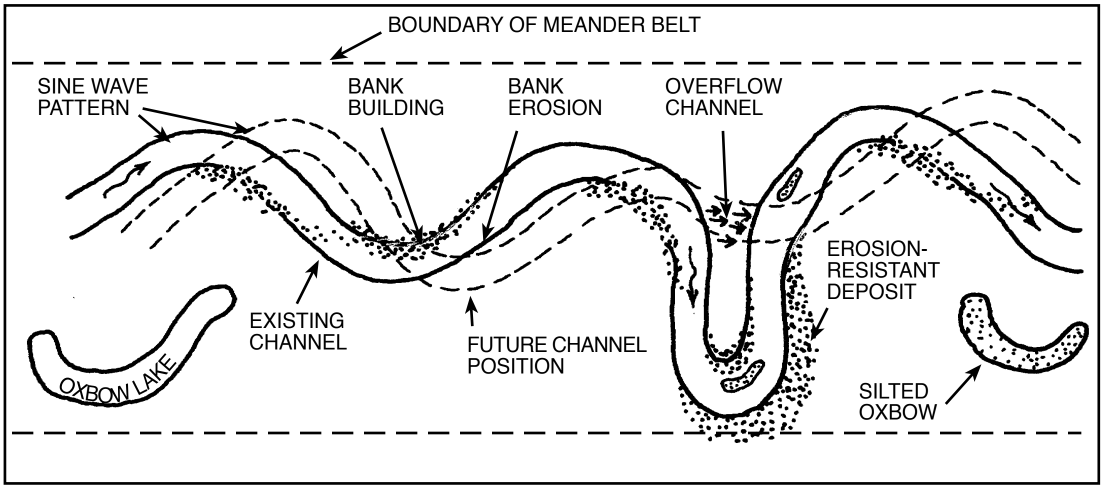


Figure 4. Meandering Stream in an Alluvial Floodplain

Meander forms of alluvial streams tend to exhibit sine wave patterns of predictable geometry, but non-uniformities in the alluvial deposits along streams and flood plains generally disrupts the regular pattern. Nonuniformities consisting of erosion resistant materials can slow the progression of bank erosion at meander bends causing cutoffs and oxbow channels to form making the stream develop an irregular winding pattern. All of the various positions that a meandering stream occupies over time defines a meander belt with outer boundaries at the extreme meander positions (Figure 4). The meandering pattern typical of many alluvial streams is an adjustment of the stream to its most stable form. Meanders lengthen a stream's course and decrease its gradient thereby effecting a balance between stream energy and sediment load.

It is possible to make qualitative predictions of stream response to changes in discharge, sediment load, base level and stream bank condition. For example, a sudden increase in sediment load to a stream typically causes an alluvial channel to widen, and with sufficient loading the stream may become braided. Lowering of the base level of an alluvial stream is typically followed by channel down cutting upstream along the main stem and its tributaries. Removal of streamside vegetation from a meandering alluvial channel generally accelerates the meandering process.

STREAM FLOW DYNAMICS

Flow in natural channels normally occurs as turbulent, gradually-varied flow. Under conditions of gradually-varied flow, the stream's velocity, cross-section, bed slope, and roughness vary from section to section, but the changes occur gradually enough that formulae for steady-uniform flow can be applied in analysis. Steady-uniform flow occurs when conditions at any given point in the channel remain the same over time and velocity of flow along any streamline (line of flow) remains constant in both magnitude and direction. Basic formulae used to analyze flow in natural channels, as discussed below, include: the continuity equation, the energy equation, and Manning's equation.

The continuity equation expresses one of the fundamental principles of stream flow dynamics. It states that the discharge passing a channel cross section is equal to the cross-sectional area multiplied by the average velocity of flow. Average velocity is used in the equation because velocity is not uniformily distributed in a channel cross sections due to boundary shear resistance and other factors. Velocity distribution at channel bends is significantly affected by deflection of faster moving water to the outside of the bend due to centrifugal force (Figure 5). This redistribution of velocity and energy is an essential part of meander formation.

Stream flow involves expenditure of energy wherein potential energy of

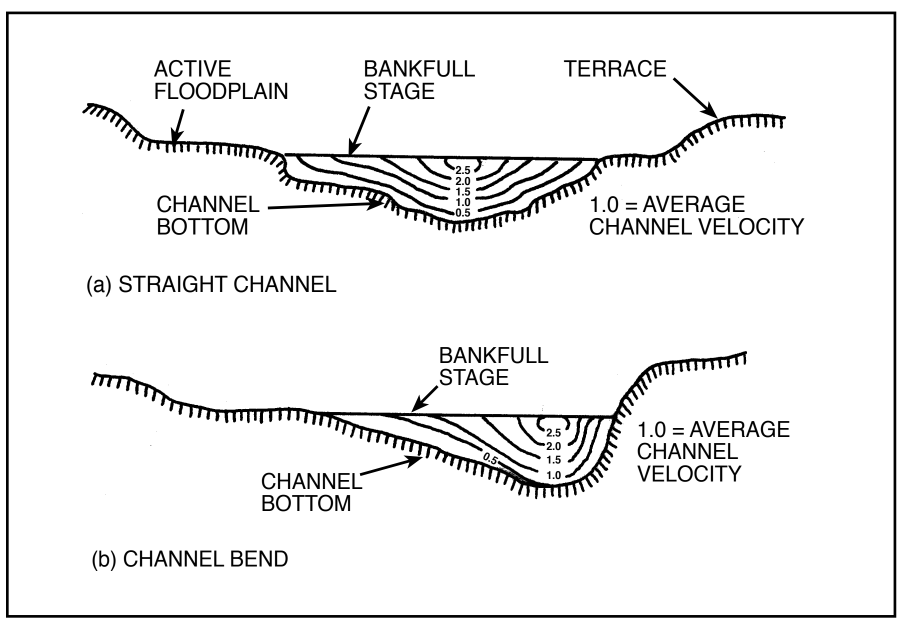
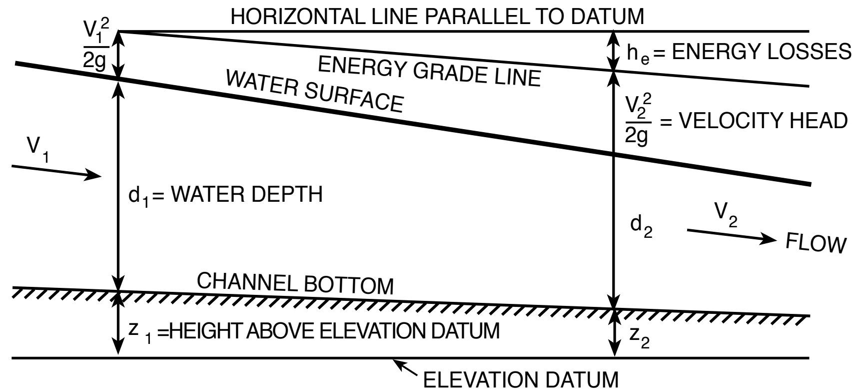


Figure 5. Cross Sections of Natural Channels Showing Velocity Distributions

the water due to position and force of gravity is converted to kinetic energy of motion. The energy equation expresses the relationship between the elevation head, velocity head and energy disipation required to move water and sediment. Energy losses include those due to friction and expansion or contraction of flow. Friction losses are determined by applying the Manning equation. Simultaneous solution of the continuity equation, energy equation and Manning equation allows for calculation of water surface profiles and average velocities of flow (Figure 6).

Flow disturbances caused by channel obstructions, sinuosity, and channel roughness, create different forms of large-scale turbulence that are important because of their connection to channel erosion and sediment transport processes. All forms of turbulence originate with boundary roughness, the most important being sinuosity and alternation of pools and bars. The strength of turbulence varies with stream stage, increasing with each rising stage to a peak when streams develop maximum energy. Forms of large-scale turbulence include: rhythmic surges, bottom rollers, bank eddies, vortex action, transverse oscillation, helicoidal flow, standing waves, sand ripple waves, and antidunes.

Boils are a form of large-scale turbulence that play a significant role in the bank caving process. Boils develop when stream flow encounters obstructions or irregularities along the stream bed causing water to surge vertically to the surface. Stream bed material adjacent to banks may be moved upward into the current by boils causing deepening of the channel bed and increasing bank height. This leads to instability and slumping of banks when flow recedes, thus removing hydrostatic support from the bank (Figure 7). Scouring of stream banks by fast moving water can cause "pop-outs" and slab-type failures of material from near vertical banks as well as undercutting and toppling of streamside trees. Dense root masses of streamside trees tends to armor banks and create flow retarding roughness that protects banks from scour.



Continuity Equation

$Q = (V)(A)$

where: Q = discharge; V = velocity; A = cross-sectional area of channel

Energy Equation

$$\frac{V_1^2}{2g} + d_1 + z_1 = \frac{V_2^2}{2g} + d_2 + z_2 + h_e$$

where: g = gravity constant

h_e= energy losses (friction losses + expansion and contraction losses)

z = elevation head

Manning's Equation

$Q = (1.5/n)(A)(R^{2/3})(S^{1/2})$ and $R = A/P$

where: n = Manning's roughness coefficient, R = hydraulic radius

P = wetted perimeter, and S = friction slope

Energy Dissipation

$$h_e = (S)(L) + C \left| \frac{V_1^2}{2g} - \frac{V_2^2}{2g} \right|$$

where L = reach length

and C = coefficient of expansion or contraction

Figure 6. Stream Channel Profile: Slope Relationships for Gradually Varied Flow

SEDIMENT LOAD IN STREAMS

Sediment production in watersheds is generated by sheet, rill and gully erosion including mass wasting at gully headcuts. Mass movement of

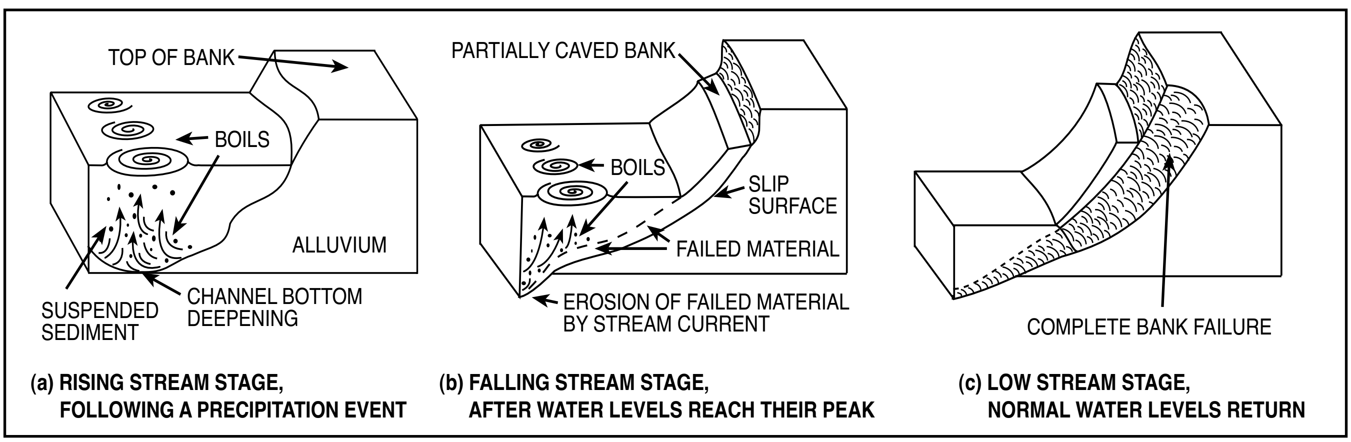


Figure 7. Stream Boil Turbulence Resulting in Bank Failure

material by slow, down slope creep and landslides may also contribute to sediment production. Eroded material that reaches streams combines with material eroded from channel bed and banks to create the sediment load—boulders, cobbles, gravels, sand, silt, and clay particles. The sediment load, dissolved minerals, and organic matter in streams constitutes the total solids load.

Dissolved minerals and suspended sediment (material kept in suspension by fluid turbulence) are important factors affecting the water quality of a stream and often comprise a disproportionately large amount of the total solids load, but it is the bed load sediment that is of primarily significance for channel stability. Bed load consists of material that is moved by sliding, rolling or bouncing along the bed. Tractive force developed by the stream acts in the direction of flow on the channel bed and banks, dislodging and moving material downstream. Calculations can be made to determine allowable tractive forces and permissible velocities for stable channels.

Stream power is the energy expended by the stream in discharging water and sediment. The more energy the stream has, the more sediment it can carry. During floods, when a stream has higher energy levels, it may erode the bed and banks of the channel to balance the energy and sediment load. Straightening a meandering channel generally increases stream energy and the potential for erosion. Over a long period of time, the majority of sediment transported by a stream is carried by the bankfull flows. Stream competence refers to the sediment load a stream can carry at bankfull flow.

When flood flows recede, stream energy is dissipated and sediment is deposited. The deposits are of predictable form and location such as the point bars and crossing bars of meandering alluvial streams. These depositional features may undergo considerable disturbance during the passage of floods as sediment is eroded, transported, and redeposited. In a stable sinuous channel, straightening of the axis of flow occurs during floods so that material on crossing bars and point bars may be eroded, transported and redeposited downstream leaving depositional features with new material but largely unchanged in form, size, and location (Figure 8).

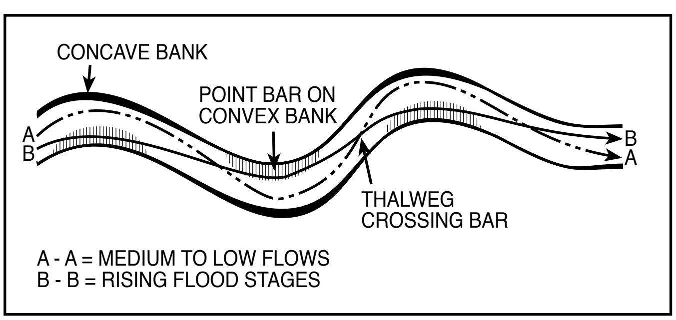


Figure 8. Axis of Main Current Along a Sinuous Channel

BASE-FLOW CHARACTERISTICS OF STREAMS

During dry weather periods, flow in natural streams is sustained primarily by ground water discharging from quifers (water bearing formations) intercepted by the channels. These dry weather flows, or base flows, typically exhibit the chemical properties of the groundwater. Streams flowing on bedrock generally have relatively low sustained base flows, whereas streams formed in glacial outwash material consisting of sands and gravel have relatively high base flows. Streams flowing across glacial till and along end moraines may receive moderate contributions of ground water to sustain base flows from sand and gravel lenses in the glacial deposits. The natural base-flow regime of many streams is significantly altered by regulation caused by reservoirs, stream intakes, well fields, wastewater treatment plants and other facilities.

The amount of ground water contributing to stream flow varies along the channel and according to the hydraulic gradient in the contributing aquifer. When stream level is below the bordering ground water table, a positive gradient exists and ground water flows into the stream. If the bordering water table declines below stream level, seepage may flow from the stream into the aquifer. Water that seeps into stream banks during passage of floods is referred to as bank storage and returns relatively quickly to the stream after high flows recede.

Alluvial flood plains and riparian wetlands are significant ground water source areas that are effective in sustaining stream flows during dry weather periods. Good sustained base flow is highly beneficial to many forms of aquatic life. It lessens the impact of water quality problems caused by concentration of pollutants and depletion of dissolved oxygen during dry weather periods. In addition, a stream with good base-flow characteristics that ceases flowing during drought may continue to discharge water along its course through porous bed material. This subsurface flow is important for survival of many aquatic animals that normally inhabit the stream bed or burrow into it during drought.

STREAM ECOLOGY AND NATURAL PURIFICATION PROCESSES

Natural streams are dynamic systems that convey, store, and transform water, sediment, and organic matter. The transformations involve: physical processes—aeration, dispersion currents, sedimentation; chemical processes—photosynthesis, metabolism; and biological processes—biological flocculation and precipitation that act in concert to naturally purify the water. Aerobic purification processes require free oxygen and are dominant in natural streams, although important anaerobic processes occur as well where free oxygen is absent.

Organic matter and nutrients in streams are decomposed and resynthesized through chemical reactions in association with aquatic organisms. The material is transformed by the cycles of nitrogen, phosphorus, carbon and sulfur in aerobic decomposition. These processes create biochemical oxygen demand that depletes dissolved oxygen in the water. Reoxygenation is effected through aeration, absorption and photosynthesis. Riffles and other natural turbulence in streams enhance aeration and oxygen absorption. Aquatic plants add oxygen to the water through transpiration. Oxygen production from photosynthesis of aquatic plants, primarily blue-green algae, slows down or ceases at night creating a diurnal or daily fluctuation in dissolved oxygen levels in streams. The amount of dissolved oxygen a stream can retain increases as water temperatures cool and concentration of dissolved solids diminish.

Fish and other aquatic organisms that utilize the dissolved oxygen in water for respiration may suffocate if oxygen levels are severely depleted. Excessive loading of streams with organic matter and nutrients from point and nonpoint-source discharges can create significant biochemical oxygen demand and reduce dissolved oxygen to critical levels. Nutrient enrichment of streams may cause algae to rapidly multiply, bloom, die and decompose during low-flow periods resulting in severe oxygen depletion and fish kills.

Aquatic organisms that inhabit natural streams may be grouped (from Fair, Geyer, and Okun, 1968) as follows:

AQUATIC PLANTS

- **seed bearing plants**
  - plants attached to stream bed or banks
  - free floating plants (duckweed)
- **mosses and liverworts**
- **ferns and horsetails**
- **primitive plants (algae)**

AQUATIC ANIMALS

- **vertebrates**
  - fish
  - amphibians
- **invertebrates**
  - mollusks (mussels, snails, slugs)
  - arthropods (crustaceans, insects, spiders, mites)
  - worms
  - protozoa

AQUATIC MOLDS, BACTERIA, VIRUSES

- **true fungi** (phycomycetes, fungi imperfecti)
- **bacteria**(streptococcus, escherichia coli, nitrosomanas, nitrobacter, beggiatoa)
- **viruses** (poliomyelitis)

Streams in their natural state tend to maintain a dynamic balance between populations of aquatic organisms and available food. The population dynamics of the communities of aquatic organisms in stream ecosystems involve: substrate utilization, the food web, nutrient spiraling, and the growth curve.

Waste organic substances in streams form the substrate on which microorganisms grow and become part of the food web. Growth of microorganisms follows sequent portions of the growth curve including: nutriently unrestricted exponential growth, nutriently restricted growth, and stationary or declining growth due to environmental conditions. Population growth of the microorganisms is a metabolic response to food under specific stream conditions.

Streams that are physically complex and healthy have a relatively high nutrient assimilative capacity, which is needed to maintain good water quality.

Nutrients circulate from surface to substrate as they flow downstream and are continuously available to bacteria, algae, fungi, invertebrates, fish and other aquatic organisms. The circulation, capture, release and recapture of nutrients is termed nutrient spiraling. The ability of a stream to assimilate nutrients and store them in the living tissue of plants and animals is termed its assimilative capacity. Streams that are physically complex and healthy have a relatively high nutrient assimilative capacity, which is needed to maintain good water quality.

The quality of water in a stream is manifest by its physical and chemical properties, and by the composition and health of the aquatic organisms that live in the stream. The presence of larvae of stoneflies, caddisflies, and dragonflies, for example, generally indicates good quality water; whereas, large populations of rat tail maggot, blood worm, and sewage fungus indicate polluted water. Ecological interpretations can be made based on what associations of organisms should be in the stream, and recognition of abnormal numbers, associations, and conditions of living things. In other words, the condition or health of a stream ecosystem is reflected by its biological integrity. Biological integrity has been defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitats of the region." (Karr and Dudley, 1981)

Survival of the many species of organisms found in natural streams depends on the integrity of the water resource. Five principal factors and some of their important chemical, physical and biological components that influence and determine the integrity of surface water resources (from Yoder and Rankin, 1995) are as follows:

FLOW REGIME
precipitation and runoff, high- or low-flow extremes, velocity of flow, ground water component, land use.

HABITAT STRUCTURE
channel morphology, pool-riffle sequence, bed material, gradient, instream cover, canopy, substrate, current, sinuosity, siltation, riparian vegetation, channel width/depth ratio, bank stability.

ENERGY SOURCE
sunlight, organic matter inputs, nutrients, seasonal cycles, primary and secondary production.

CHEMICAL VARIABLES
dissolved oxygen, temperature, pH, alkalinity, solubilities, adsorption, nutrients, organics, hardness, turbidity.

BIOTIC FACTORS
reproduction, disease, parasitism, feeding, predation, competition.

The status of factors determining the integrity of the stream resource depend in large measure on the condition of riparian zones, flood plains, valleys and watersheds. Vegetated riparian zones filter overland runoff, trap sediment, and utilize phosphorus adhering to sediment particles. Ground water near the surface in riparian areas creates conditions that support cyclical transformations of nitrogen, phosphorus, carbon and sulfur. Denitrification of nitrates is one of these important transformations. Vegetated riparian zones, vital to the health of streams, may nevertheless be overwhelmed by accelerated runoff, sediment, and pollution from mismanaged watersheds. The health of stream ecosystems and the condition of riparian zones, flood plains, valleys, and watersheds are interdependent.

HUMAN IMPACTS ON STREAM SYSTEMS

Planned and unplanned changes in one or more features of a stream ecosystem by human activity generally triggers additional changes in other stream features that can disrupt the stream's natural processes, impair natural functions and result in loss of beneficial uses. These negative consequences are often unanticipated by people in the watershed community.

Stream systems are impacted by human activities that make use of stream resources, and by human occupancy and use of flood plains and uplands. Impacts can result from direct disturbance of natural streams through such things as channelization and point discharge of pollutants to receiving waters. Impacts may also arise more indirectly through damaging land management practices and nonpoint-source pollution in watersheds. In many situations, streams are responding in a complex manner to multiple disturbances and sources of pollution that have occurred over a long period of time.

The most damaging impacts result from changes in the basic structure and functioning of the stream ecosystem. (Doppelt, et al., 1993) These impacts include the following:

- changes in water quantity and flow regime by diversions, drainage projects and land use changes (see Figure 2);
- modification of channel and riparian ecosystem morphology by channelization, damming, and removal of streamside vegetation;
- degradation of chemical water quality by addition of contaminants;
- excessive nonpoint-source pollution including siltation and nutrient enrichment;
- deterioration of stream substrate quality and stability;
- destabilization of stream banks and channel bottom directly by such things as livestock grazing and instream mining or indirectly by land use changes and damaging land management practices;
- separation of streams from their normal ground water table and elimination of riparian wetlands by dredging and induced down cutting of streams;
- modification of normal water temperature regime by removal of tree canopy or alteration of base flow regime;
- introduction of exotic species that disrupt the dynamic balance of the riverine ecosystem.

The cumulative results of damaging human impacts on stream systems include the following:

- degradation of the physical, chemical and biological integrity of the water resource;
- reduction of life-supporting complexity and diversity of the riverine ecosystem, that is, ecosystem simplification;
- impairment of beneficial functions and natural stream processes;
- loss of beneficial uses of stream resources, that is, water supply, recreation, fish consumption and aquatic life uses.

STREAM MANAGEMENT OBJECTIVES

The overall objective of stream management coincides with the principal objective of the Clean Water Act—to restore and maintain the physical, chemical and biological integrity of the water resource and achieve full attainment for designated uses. Achieving this overall objective will require that attention be given to all of the principal factors influencing and determining the integrity of the water resource, that is, flow regime, habitat structure, energy source, chemical variables and biotic factors. An important first step in the stream management process is defining specific management objectives. Stream management objectives that will apply in most situations include the following:

- to increase public awareness of the value of natural stream corridors and their beneficial functions;
- to promote acceptance of streams as dynamic systems that inherently flood and meander;
- to effect wide-spread adoption of best management practices in watersheds in order to minimize human impacts on stream ecosystems;
- to protect existing stream resources from unnecessary degradation and restore stream resources where appropriate and feasible;
- to work with the stream in an environmentally sensitive manner consistent with the stream's natural processes;
- to have active citizen involvement in stream monitoring, protection, and restoration efforts.

WATERSHED APPROACH TO STREAM MANAGEMENT

When trying to understand the stream's natural processes and how stream management problems might be addressed, it is generally useful to take a watershed perspective and look at the stream as a system, both spatially and in time. Stream restoration measures are more likely to succeed if formulated with a good knowledge of the past history of the stream, and an accurate assessment of its current status and likely future tendencies. Factors affecting stream processes that can be changed, such as land management practices, must be distinguished from factors that generally cannot be changed—geology and climate. In most cases, it is more practical and advisable to work with the stream, rather than against it.

Management of stream resources requires multi-disciplinary knowledge of: (1) the climatic environment; (2) geologic factors, including soil conditions; (3) surface water and ground water hydrology; (4) stream channel hydraulics; (5) sedimentation; (6) fluvial geomorphology; (7) stream ecology; (8) watershed management; and (9) social, cultural, economic and political constraints. A team of knowledgeable individuals is generally needed to accurately assess the factors contributing to stream problems and to find suitable solutions. Stream management depends upon bringing together people with a great diversity of interests, knowledge, and background of experience.

There are many stream management techniques and remedial action measures for addressing specific problem areas. Management initiatives, however, must do more than simply treat symptoms of problems; they must address the root causes of the problems to be of lasting effect. Success in stream management requires a strategy for protecting existing stream resources from further degradation by addressing the causes of problems while selectively restoring impaired channel reaches to the extent feasible and appropriate. Implementation of such basin-wide strategies may best be accomplished through community-based, watershed-ecosystem approaches. Above all, to be effective, stream management activities and supportive public policies and programs must be connected to how streams actually function.

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This Guide is one of a series of Ohio Stream Management Guides covering a variety of watershed and stream management issues and methods of addressing stream related problems. The overview Guides listed below, are intended to give the reader an understanding of the functions and values of streams. For more information about stream management programs, issues and methodologies, see Guide 05 Index of Titles or call the ODNR Division of Soil and Water Resources at 614/265-6739. All Guides are available from the Ohio Department of Natural Resources. Single copies are available free of charge and may be reproduced. Please contact:

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Division of Soil and Water Resources
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Columbus, Ohio 43229-6693

The guides are also available online as web pages and PDF files so you may print high quality originals at your location. You will find the guides on-line at:

http://www.ohiodnr.gov/soilandwater/

Prepared by the Ohio Department of Natural Resources, Michael Schiefer, P.E., Division of Soil and Water Resources, principal author. Input from staff of several ODNR divisions, and local, state and federal agencies are used in the development of the Ohio Stream Management Guides. Funding for the production of the Ohio Stream Management Guides is provided in part through a grant under Section 319 of the federal Clean Water Act.

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OHIO STREAM MANAGEMENT GUIDE

Index of Titles

Guide No. 05

The Ohio Stream Management Guides are fact sheets prepared by the Ohio Department of Natural Resources. The series of Guides covers a variety of watershed and stream management issues and methods of addressing stream related problems. The first several Guides present broad-based information and should be used in conjunction with those Guides which provide details about specific management practices. Input from staff of several ODNR divisions and from local, state and federal agencies is used in the development of the Guides. Funding for the production of the Ohio Stream Management Guides was provided in part through a federal grant under Section 319 of the Clean Water Act, Project #95 (h) EPA-2.

All of the Stream Management Guides, including an Index of Titles, are available from the Ohio Department of Natural Resources. Contact the ODNR, Division of Soil and Water Resources at, 614/265-6739, e-mail: water@dnr.state.oh.us, web site: http://www.dnr.state.oh.us/water/. Each Guide is designed to be easily and clearly reproduced and can be bound in a notebook. Single copies are available free of charge. When distributing guides at meetings or in mailings, please use the printed editions as a master for reproducing the number of copies you need, or you may print high quality orignals from PDF files available online at: http://www.ohiodnr.gov/soilandwater/pubs/fs_st/streamfs.htm.

The Ohio Department of Natural Resources would appreciate hearing from you about the usefulness of this series of Guides. If you would like to provide us with your opinions, or input to be considered when we update the Guides, please contact us at ODNR Division of Soil and Water Resources, 2045 Morse Road, Building B-3, Columbus, Ohio 43229-6693, or water@dnr.state.oh.us.

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01 An Introduction to Stream Management
An overview of streams as a water resource and the inter-actions between land uses and stream resources.

02 Who Owns Ohio's Streams?
Questions and answers regarding the rights and responsibilities of landowners and the authorities and duties of government with regard to surface water.

03 Natural Stream Processes
An overview of stream ecosystems, processes, and terms.

04 A Catalog of Contacts for Stream Topics:
(CANCELED)

05 Ohio Stream Management Guides: Index of Titles
This guide contains a listing of all stream management guides with a brief description of each and availability information.

06 Permit Checklist for Stream Modification Projects
Overview and contact information for permits, requirements and consultations, which may be necessary for completion of projects in or adjacent to streams.

07 Restoring Streambanks with Vegetation
Construction guidelines for planting dormant cuttings of willow (or other rapidly-rooting species) to quickly establish living erosion barriers.

08 Trees for Ditches
Guidelines on species selection, planting locations and maintenance to achieve environmental and economic benefits while maintaining drainage capacity.

09 A Stream Management Model
A walk-through guide to a the stream management display and demonstration at the Ohio Farm Science Reviews Gwynne Conservation Area.

10 Biotechnical Projects in Ohio
Biotechnical practices using vegetation and other natural materials are defined, and several projects using these techniques are described and mapped. Contacts for on-site visits to some of these sites are listed.

11 Tree Kickers
Construction guidelines for using hardwood logs anchored to a streambank at an angle to diivert stream flow energy away from undercutting the streambank.

12 Evergreen Revetments
Construction guidelines for creating a buffer system made of cut evergreen trees attached to each other and anchored into an eroding streambank.

13 Forested Buffer Strips
NNBenefits of vegetation left or restored along streams.
14 Live Fascines

Continued on back.

NNConstruction guidelines for protecting streambanks with long bundles of live woody vegetation placed in shallow entrenchments parallel to the flow of the stream.

15 Gabion Revetments

NNConstruction guidelines for protecting submerged streambanks by placing stone-filled wire baskets in shallow entrenchments along the stream.

16 Riprap Revetments

NNConstruction guidelines for protecting streambanks by layering various size rocks along a sloping bank.

17 Live Cribwalls

NNDefinition, use, and guidelines for constructing cribwalls to aid in the establishment of willow cuttings on streambanks.

18 Stream Debris and Obstruction Removal

NNQuestions and answers to assist landowners in maintaining a free flowing stream without logjams.

19 Deflectors

NNA description of the procedures and materials necessary to stabilize streambanks by directing the current away from the outside of a stream meander.

20 Eddy Rocks

NNConstruction guidelines for placing groupings of large rocks in small streams or modified channels to help restore natural stream features and enhance in-stream habitat.

21 Large Woody Debris in Streams

NNGuidelines for managing a spectrum of stream debris situations to the benefit of the stream while minimizing the hazards to personal property and the public.

22 Gravel Riffles

NNConstruction guidelines for the procedure of placing gravel and cobble-sized stones at intervals in a modified or heavily impacted stream in order to stabilize the substrate.

~

Stream Management Guides and Authors

01 An Introduction to Stream Management Margo Fulmer & Michele Willis

02 Who Owns Ohios Streams? Lenn Black

03 Natural Stream Processes Mike Shiefer

04 A Catalog of Contacts for Stream Topics: Programs, Information, Authorities, Regulations and Funding Margo Fulmer & Jason Remich

05 Ohio Stream Management Guides: Index of Titles Margo Fulmer & Jason Remich

06 Permit Checklist for Stream Modification Projects Kim Baker

07 Restoring Streambanks with Vegetation Dan Kush

08 Trees for Ditches Dave Bergman

09 A Stream Management Model Jim Lynch

10 Biotechnical Projects in Ohio Margo Fulmer

11 Tree Kickers Margo Fulmer & Roger Barber

12 Evergreen Revetments Margo Fulmer et al.

13 Forested Buffer Strips Dan Mecklenburg

14 Live Fascines Mark Ervin

15 Gabion Revetments Tara Lee & Jason Remich

16 Riprap Revetments Tara Lee

17 Live Cribwalls Mark Ervin

18 Obstruction Removal Lenn Black & Jason Remich

19 Deflectors Dan Mecklenburg

20 Eddy Rocks Dan Mecklenburg

21 Large Woody Debris in Streams Jason Remich

22 Gravel Riffle Dan Mecklenburg, Lenn Black & Jason Remich

Prepared by the Ohio Department of Natural Resources, Division of Soil and Water Resources, principal author. Input from staff of several ODNR divisions, state and federal agencies are used in the development of the Ohio Stream Management Guides.

Guides are available on-line at: http://www.ohiodnr.gov/soilandwater/

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OHIO STREAM MANAGEMENT GUIDE

Permit Checklist for Stream Modification Projects

Guide No. 06

This Ohio Stream Management Guide serves as a planning tool to assist you in obtaining information and the applicable permits for projects within a stream environment. Many of the requirements apply to projects proposed in wetlands, too. The size of the stream and your project design will affect your permit requirements. This checklist may not contain all of the permits necessary for your project, but will guide you in the procurement of most of the necessary permits.

The purpose of the project, a map showing the entire project and an identified contact person in your organization need to be included in your letter to the regulatory/resource agency in most cases.

LOCAL PERMITS

1. Special flood hazard area development permit (contact the local governmental official designated as local floodplain administrator). Nearly 700 Ohio communities (counties, cities and villages) participate in the National Flood Insurance Program. The communities agree to review all development, structural and nonstructural, proposed in a federally identified special flood hazard area (SFHA). The SFHA is that area subject to inundation in the event of a 100-year flood. The 100-year flood has a one percent chance of occurring in any given year.

In most cases, the regulations enforced by each participating community address development in floodway and fringe locations. The floodway portion of the floodplain is the area of strongest current during a flood. **Any** proposed **action** in the **floodway** must be supported by hydrologic and hydraulic analysis to demonstrate that there will be no impact on the water surface elevations during the discharge of a 100-year flood. In fringe areas (that portion of the 100-year floodplain not identified as floodway), regulations will require development to meet certain standards to ensure its protection.

OHIO DEPT. OF NATURAL RESOURCES (ODNR) PERMITS/REQUIREMENTS

1. If **instream blasting** is necessary, **written permission** from the Chief of the Division of Wildlife if required prior to blasting (O.R.C. 1533.58). Individuals should contact the Division of Wildlife's Environmental Section (614/265-6300).

2. If **dewatering in the project area** is anticipated during the course of project construction, and a **loss of aquatic life** is anticipated, **monetary compensation** is required for loss of those animals according to O.R.C. 1531.02. Contact the Division of Wildlife's Environmental Section (614/265-6300) for information.

3. If **dewatering** a site with a pump(s) that has the **capacity to withdraw 100,000 gallons per day** or more (70 gal./minute), a **temporary water withdrawal facility registration form** will need to be filed with the Division of Soil and Water Resources under O.R.C. 1521.16. For more information contact the Water Resources Section of the Division of Soil and Water Resources (614/265-6740).

4. If spoil from the project is placed in such a way as to **create a dike or levee** (as defined by the Division of Soil and Water Resources), a **permit** from the Division of Soil and Water Resources may be required (O.R.C. 1521.06). Contact the Division of Soil and Water Resources's Water Engineering Group (614/265-6731).

5. If the project involves an area located near a **State Scenic River,** authorization under the **Director's Approval Authority** may be needed before project commencement according to O.R.C. 1501.17. Those areas include portions of the Maumee, Sandusky, Chagrin, Grand, Upper Cuyahoga, Stillwater, Kokosing, Olentangy, and Little Miami rivers and the Little Beaver, Greenville and Big & Little Darby creeks. Contact the Division of Natural Areas and Preserves' Scenic Rivers staff at 614/265-6453 for more information.

6. To aid the project planning process, submit a request to the Division of Natural Areas and Preserves' **Natural Heritage Database** staff to locate any **endangered, threatened, or special interest species** found on or near your project site. Contact the Division of Natural Areas and Preserves' staff at 614/265-6453 for a request form.

OTHER STATE AGENCY PERMITS/REQUIREMENTS

1. Since the project involves work in a stream, a **401 Water Quality Certification** from the **Ohio Environmental Protection Agency** (Ohio EPA) may be required. The U.S. Army Corps of Engineers is the lead agency for coordinating the Clean Water Act permit application process (see Federal Agency Permits, below.) However, you should contact the Ohio EPA early, during project planning. They can identify water quality factors that should be considered in project design. This early coordination generally results in a faster process once you submit a Section 404 permit application. The Ohio EPA has fact sheets available which explain the certification and permit process. Ask for the fact sheets Section 401 Water Quality Certification and Section 404 Permits. The Ohio EPA also has a series of flow charts on Section 404 Nationwide Permits which will help you know whether your project falls within certain pre-authorized permit categories or whether you must apply for an individual permit. The Division of Surface Water should be contacted for more information at 614/644-2001.

2. If the proposed project may **impact a public water supply through dewatering**, the Ohio EPA's Division of Drinking and Ground Waters should be contacted at 614/644-2752.

3. The **Ohio Historic Preservation Office** (OHPO), pursuant to the National Historic Preservation Act of 1966, Public Law 89-665 as amended, should be consulted on specific archaeological, prehistorical, or historical sites or structures which might be affected by the proposed project. The applicant **must**

consult with the OHPO under the federal Clean Water Act permitting process explained below. Submission of a letter to them requesting a OHPO consultation will suffice. Send correspondence to: Ohio Historic Preservation Office, Attn: Department Head, Technical & Review Services, 1982 Velma Avenue, Columbus, OH, 43211-2497, phone 614/297-2300.

FEDERAL AGENCY PERMITS/CONSULTATIONS

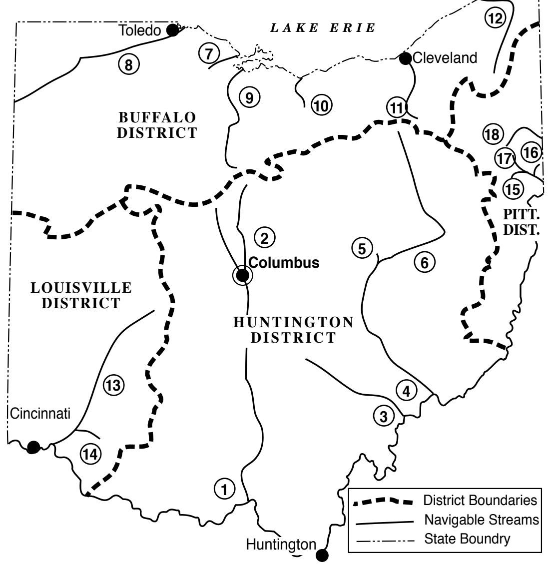
1. According to federal law, anyone who wishes to **dredge or place fill in waters of the United States** must obtain a **Section 10 Permit (Rivers & Harbors Act) and/or a Section 404 Permit (Clean Water Act) from the U.S. Army Corps of Engineers (COE)**. Waters of the United States include lakes, streams and wetlands. Note: The COE cannot permit an activity until the **Section 401 Water Quality Certification** is approved by the **Ohio EPA** (see above information regarding Ohio EPA).

Items that will need to be submitted to the COE for Clean Water Act permits include a COE application, project description and project drawings (both plan and cross sectional views). If the project is likely to impact a wetland area, include a delineation (identification of wetland and other water resources in the project vicinity) and an alternatives analysis (a summary of why the project must constructed in the proposed location and as proposed).

Four COE Districts possess jurisdiction in Ohio (depicted on the map): Buffalo (Lake Erie Basin), Pittsburgh (Mahoning River Basin), Huntington (Muskingum, Hocking & Scioto river basins) and Louisville (Little & Great Miami river basins) districts. For more information contact the district in which your project is located:

- Buffalo District COE, Attn: Regulatory Branch, 1776 Niagara St., Buffalo, NY, 14207-3199, phone 716/879-4330
- Huntington District COE, Attn: Regulatory Branch, 502 Eighth St., Huntington, WV, 25701-2070, phone 304/529-5210
- Louisville District COE, Attn: Regulatory Branch, 600 Federal Place, P.O. Box 59, Louisville, KY, 40201-0059, phone 502/582-5607
- Pittsburgh District COE, Attn: Regulatory Branch, William S. Morrhead Federal Building, 1000 Liberty Ave., Pittsburgh, PA, 15222-4186, phone 412/395-7154

Navigable Streams Under Section 10



HUNTINGTON DISTRICT
1. Scioto River
2. Olentangy River
3. Hocking River
4. Muskingum River
5. Walhinding River
6. Tuscarawas River

BUFFALO DISTRICT
7. Portage river
8. Maumee River
9. Sandusky River
10. Cuyahoga River
11. Grand River

LOUISVILLE DISTRICT
13. Little Miami River
14. East Fork Little Miami River

PITTSBURBURG DISTRICT
15. Little Beaver Creek
16. Middle Fork Little Beaver Creek
17. North Fork Little Beaver Creek
18. Mahoning River

2. Additionally, the COE will require that an applicant **consult** with the **U.S. Fish and Wildlife Service** (U.S. FWS) regarding the **presence of federally listed threatened and endangered plants and wildlife** located in the project area (Endangered Species Act). Submission of a letter to the U.S. FWS requesting an endangered species consultation will suffice. Send correspondence to: U.S. Fish and Wildlife Service, Ecological Services, 6950-H Americana Parkway, Reynoldsburg, OH, 43068-4115, phone 614/469-6923.

Not all projects will require the same permits or same level of project documentation. By contacting agencies in the project planning stages, your time, resources and frustration can be reduced. Getting input prior to permit application can avoid costly changes required by the various agencies protecting our natural resources. Plan ahead...to avoid confusion later!

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This Guide is one of a series of Ohio Stream Management Guides covering a variety of watershed and stream management issues and methods of addressing stream related problems. The overview Guides listed below, are intended to give the reader an understanding of the functions and values of streams. For more information about stream management programs, issues and methodologies, see Guide 05 Index of Titles or call the ODNR Division of Soil and Water Resources at 614/265-6739. All Guides are available from the Ohio Department of Natural Resources. Single copies are available free of charge and may be reproduced.

For copies please contact:

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Division of Soil and Water Resources
2045 Morse Road, Bldg B
Columbus, Ohio 43229-6693

The guides are also available on-line as web pages and PDF files so you may print high quality originals at your location. You will find the guides on-line at:

http://www.ohiodnr.gov/soilandwater/

Prepared by the Ohio Department of Natural Resources, Kim Baker, Division of Real Estate and Land Management, principal author. Input from staff of several ODNR divisions, state and federal agencies are used in the development of the Ohio Stream Management Guides.

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OHIO STREAM MANAGEMENT GUIDE

Restoring Streambanks with Vegetation

Guide No. 07

Woody vegetation planted along streams can be extremely useful in controlling soil erosion, providing wildlife habitat and improving water quality. Dormant woody stakes and posts can be used to stabilize eroding banks and bare-root or transplanted trees can be used on top of the bank in the riparian/ flood plain area. Properly selected and planted vegetation can withstand flooding and high velocity water and often can be used instead of costly structural practices.

SPECIES SELECTION

The best tree species and planting methods will depend greatly upon amount of bank erosion, stream size and planting location. Among the most successful woody vegetation for dormant cuttings are: black willow (Salix nigra), white willow (Salix alba), sandbar willow (~Salix interio~ and eastern cottonwood (Populus deltoides). Other bottomland species used for dormant cuttings include: green ash (Fraxinus pennsylvanica), eastern sycamore (Plantanus occidentalis), and box elder (Acer negundo); while these species live longer, they are more difficult to establish and are slower growing. Root hormone treatment at planting is suggested to improve their survival. Trees and shrubs available from commercial nurseries generally as barefoot stock and suitable for streamside planting include Bankers willow (Salix cottet/) and Streamco willow (Salix purpurea)' red-osier dogwood (Comus stolonifera), bristly locust (Robinia fertilis).

Commonly used sources for cuttings are native species (like some of those listed above) taken from a nearby site similar to the proposed planting site. Suitable trees and shrubs should be marked when the leaves are on (for best identification) for cutting and planting later.

STREAMBANK PLANTING

Post, stake and whip-sized dormant cuttings can be use for streambank erosion control. Use the larger sized cuttings for the worst bank erosion problems. To prevent moisture loss and possible washing away due to high water flow, dormant cuttings must be anchored deep in the soil from the toe of the eroding bank to the highest point where moisture is available. (See figure 1) Start the first row one foot above the low water elevation then stagger successive rows of stakes or posts. Most sites require a minimum of three rows of stakes or posts starting just upstream of the eroded site. Whips can be planted in between or above rows of stakes and posts. For all dormant or seedling plantings, ample sunlight and root moisture are necessary for successful growth. Planting in shaded or low light areas results in poor survival rates.

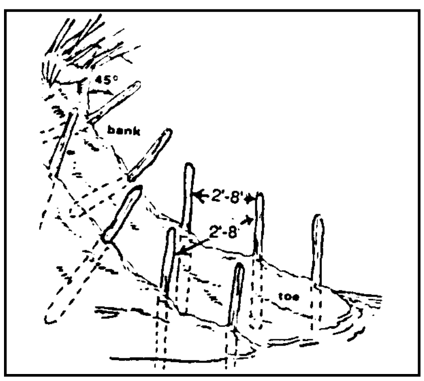

Figure 1. Stake spacing and angles.

Cuttings should be made after leaf drop when trees become dormant (December) and before the buds swell and leaf out, (late March). February to early March is a good time for planting dormant cuttings in Ohio. When storing or transporting cuttings or plants, keep them cool and moist. Planting should take place within 24 hours of cutting.

Stakes are used on small to medium sized streams with steep or eroding banks. Stakes may also be planted in between and above rows of posts.

1. Use straight branches or main stems. Cut one to three inch diameter stems into 18 to 36 inch lengths with shears, a hand or chain saw and remove all lateral stems. (Note: try to cut the branches and stems cleanly; ripped or jagged cuts may damage the plant.)

2. Make a horizontal cut on the top end which will remain exposed after planting and a 45 degree angle cut on the butt end to be planted. This will mark the correct side to plant into the ground.

3. Use a tree planting dibble bar, pry bar or drive the stake with a mallet until approximately three to six inches remain exposed or until meeting solid resistance. Do not force and split the stake or scrape the bark off.

4. Space stakes two to four feet apart in staggered rows parallel to the water elevation.

Posts are used on medium to large streams to stabilize the bank and toe of very steep or severely eroding slopes.

1. Cut three to six inch diameter trees into straight eight to twelve foot lengths with a chain saw and remove all lateral branches. Like stakes, cut the top end horizontal and cut the bottom end at an angle to ease planting. (See figure 2)

2. Set posts in pre-dug holes or drive with post driver so that half of the post is buried. Posts must be set deep enough to maintain contact with moist soil from the water table but

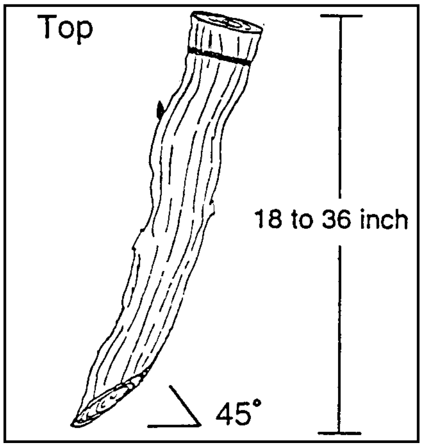

Figure 2. Stake size and shape.

not completely submerged in water year-round. Obtaining proper hole depth may require use of manual or tractor-operated augers or preferably an excavator operated ram.
For the row nearest water, the bottom of the post should be a least one foot below the deepest part of the stream bed.

3. Soil should be tamped into any holes around the post. This will provide good soil-post contact, prevent washing out and conserve plant moisture for better growth.

4. The damaged top few inches of each post should be cut off after planting if posts were driven. This will minimize insect and disease damage and conserve plant moisture.

5. Space posts four to eight feet apart in staggered rows parallel to the water elevation. The distance apart depends on the severity of erosion and site access conditions. (See figure 3)

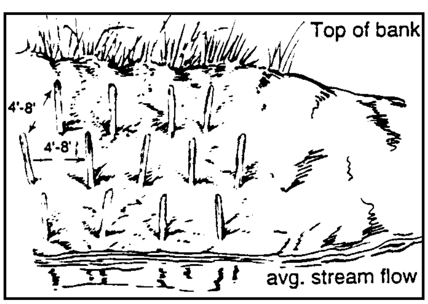

Figure 3. Post spacing on stream bank.

A combination of posts, stakes and other practices may be needed to control bank stability depending upon the site conditions. Some sites may need regrading to a 1:2 slope for planting access.

BERM PLANTING

Planting the tops of banks or berms with trees, shrubs, and grasses provides additional erosion control, buffering from agricultural and urban activities and helps filter polluted runoff before it enters the stream. Berms may extend from the top of each bank a minimum distance of two and one half times the channel width or 50 feet. For areas with severe bank erosion or in environmentally sensitive areas such as scenic rivers, 120 feet is recommended. Trees can be planted bare-root or transplanted from other sites. Plant spacings depend upon size and type of stock and soil conditions. Trees and shrubs which provide food as well as cover for wildlife should be considered for planting.

MAINTENANCE

Vegetative plantings should be inspected frequently for disease, insect infestation, wildlife damage (i.e., beavers, deer, rabbits) and high water damage. Willow sawflies, for example, may strip leaves of dormant planted willows in mid-June and late August. If sawflies are detected, immediate insecticide control is recommended. Inspections are particularly vital during the project's initial year and following periods of severe rain and/or flooding. If stakes and posts are dislodged or removed, replanting is necessary until the bank stabilizes.

Protect young trees and shrubs from livestock and drift applications of herbicides. Fencing and posting signs can help prevent these problems.

SUMMARY

Planting woody vegetation in stream corridors effectively protects soil, water, terrestrial and aquatic wildlife and recreational resources. These plantings are often used in conjunction with other conservation practices in order to effectively manage and restore stream corridors. Use of woody vegetation may not always solve slope stability problems but can often compliment other structural practices like rock rip rap or excavation. Furthermore, plantings can protect slopes from erosion until native vegetation reestablishes itself and the stream channel stabilizes.

Additional specifications can be found in the SCS Woodland Conservation Technical Note OH#13 (1992) and Technical Guide Engineering Standard No. 580 (1992).

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OHIO STREAM MANAGEMENT GUIDE

Trees for Ditches

Guide No. 08

Trees along ditches? What was once seldom recommended is now considered a responsible approach to drainage management and, when done properly, very compatible with drainage objectives. Trees planted or maintained along ditches can: 1) save money, 2) meet environmental regulations, 3) improve water quality and 4) provide wildlife habitat.

SAVE MONEY

When constructing a new ditch or maintaining an existing one, clearing and grubbing costs can be reduced substantially by leaving at least one side vegetated. Leaving woody vegetation minimizes wind and water erosion' which affects crop yields and reduces the accumulation of sediment in the channel. Where one or both sides remain vegetated, shading inhibits nuisance cattail growth, thereby reducing dip-out or spraying maintenance costs. Ditch berms can grow marketable trees or firewood if selected and managed properly and provide income in later years. If land adjacent to ditches is already out of crop production and taxed at a lower rate trees are a bonus.

MEET ENVIRONMENTAL REGULATIONS

When ditch construction must meet environmental protection standards or require a Section 401 or 404 permit under the Clean Water Act, preserving or planting trees will help mitigate water quality and wildlife damages, often making permit issuance easier.

IMPROVE WATER QUALITY

Tree cover, especially on the south or west side of a ditch, shades the water, keeping water temperatures cooler which increases oxygen levels needed for fish and other aquatic life. Shading also controls nuisance algae growth, which often results in fish kills and other water quality problems. Tree leaves and leaf litter help reduce soil erosion and resulting sedimentation. Tree roots also provide some erosion control by protecting ditch banks from high velocity water.

PROVIDE WILDLIFE HABITAT

Upland and aquatic wildlife benefit from trees. Upland wildlife benefits from cover, food, access to travel lanes and greater number of species which habitat diversity supports. In-stream, leaf litter is the base of the aquatic food chain. Leaves are eaten by aquatic insects which in turn feed minnows and fish. Fallen branches provide cover for fish and smaller aquatic life. Undisturbed vegetation, like that found on one-sided construction, provides better wildlife food and cover than leaving selected trees growing among planted grass.

TREE USE

Trees are suitable for all drainage projects constructed under Ohio Drainage Law (Sections 61 31, 6133, 6135 or 6137 of the Ohio Revised Code), Conservation Works of Improvement (Section 1515 of the Ohio Revised Code), mutual group process, by developers or by individual landowners. With proper tree selection and maintenance, both drainage and environmental benefits can often be achieved.

The recommended width of woody vegetation on "berms" of natural or unmodified channels is two and one-half times the width of the ditch or fifty feet, whichever is less. However, for ditches constructed under Ohio Drainage Law, a minimum of four feet or a maximum of 25 feet width may be "constructed and maintained" and not subject to typical property taxes.

TREE SELECTION

When preserving trees along a ditch, protect those with hardwood, minimal branching, deep rooting and non-brittle characteristics. Where possible, protect trees and their adjacent vegetation from root and soil compaction from heavy equipment for a 10 foot radius around the trunk. When spreading dredged material near trees, never spread more than one inch of soil per year over the roots to avoid feeder root suffocation. The feeder roots are mostly within the tree canopy drip line. When planting trees, choose those that are suitable to the soil drainage and pH conditions. Dredged sediment and compaction from construction access may drastically alter pH and drainage conditions; soil testing may be helpful. Native trees may be a first choice for planting or preserving as listed below, but many other species may be suitable as listed in most county soil survey reports or nursery catalogs.

If future income is desired, select trees with expected high market value. If wildlife management is a goal, select a species with food and cover characteristics. The following table lists recommended trees in Ohio for use along drainage ditches. These trees can withstand periodic flooding and are less likely to cause maintenance problems. High market value trees like Black Walnut (Juglans nigra), White Oak (Quercus alba), Red Oak (Quercus rubra borealis), Sugar Maple (Acer saccharum), White Ash (Fraxinus americana), and Basswood (Tilia americana) are not listed since they are typically found on better drained soils or upland sites. The table also illustrates their suitability to different soil/climate conditions and desirable characteristics. Short lived, brittle and shallow rooted species like Willow (Salix species) are not listed, with the exception of Box Elder (Acer negundo) and Silver Maple (Acer saccharinum) which are common and less problematic trees.

Planted shrubs are fast growing and provide more immediate erosion control and habitat than planted trees. Shrubs may complement tree planting well by establishing a dense vegetative planting. Shrubs and bank erosion control species like Bankers Willow (Salix X cotteti) or

Dogwoods (Cornus species) have beneficial uses in ditch management, but are not covered in this publication.

Common/Scientific Name	Average Mature Height	pH Preferance	Specific Characteristics
			Highly Flood Tolerant Tress
American Sycamore Platanus occidentalis	100+	6.6-8.0	Adaptable to many soils, streambanks, bottomlands, windfirm, long-lived, fast growth, urban tolerant.
Swamp White Oak Quercus bicolor	60-70	6.0-6.5	Lowlands, stream edges, swamps, long-lived, fast growth, wildlife food, sprouts, timber, firewood.
Bur Oak Quercus macrocarpa	70-80	4.6-8.0	Adaptable to many soils, very drought resistant, deep-rooted long-lived, sprouts, wildlife food, timber, firewood.
Pin Oak Quercus palustris	70-80	5.5-6.5	Bottomlands or moist uplands, tolerant of urban stresses, moderately long-lived (100-150 years), firewood, wildlife food,sprouts, fast growth.
Bald Cypress Taxodium distichum	60-80	6.1-6.5	Highly flood tolerant, grows on flooded, poorly drained to upland soils, extensive root system, very windfirm slow-growing. longlived, sensitive to drought and heat, loses leaves in winter, not native although wideiy planted in Ohio.
Red Maple Acer rubrum	50-70	4.5-6.5	Adaptable to many soil types, some susceptibility to ice and snow damage, moderately long-lived (100-150 years), sprouts, resistant to herbicides, wildlife food, firewood, brilliant fall color
Silver Maple Acer saccharinum	60-80	4.5-6.5	Bottomlands, streambanks, alluvial floodplains, moist sites, drought resistant, branches are somewhat brittle, susceptible to ice damage, can tolerate temporary flooding, sprouts.
Box Elder Acer negundo	30-40	6.5-7.5	Adaptable to many soils, tolerant to drought and cold, short-lived (60-80 years), fibrous root system provides good erosion control, susceptible to wind/ice damage
Honey Locust Gleditsia triacanthos	70-80	6.1-7.5	Alluvial floodplains, bottomlands, drought resistant, shelter-belt series, windfirm, used to pioneer strip-mine spoils, initially fast growing, thorns.
			Moderately Flood Tolerant Tress
Shellbark Hickory Carya laciniosa	80-100	6.1-6.5	Bottomlands & alluvial floodplains, sprouts, long-lived, slow growing, some susceptibility to frost damage, wildlife food, firewood.
Green Ash Fraxinus pennsylvanica	50-70	6.1-7.5	Bottomlands, strip-mine reclamation species, windfirm, alluvial soils along streams, wildlife food, firewood, sprouts, timber
Hackberry Celt/s occ/dentalis	30-50	6.6-8.0	Bottomland, limestone outcrops or soils, drought resistant, fast growing, long-lived (150-200 years), wildlife food.
Slippery Elm Ulmus rubra	60-70	6.6-8.0	Moist, rich soils of lower slopes, streambanks, terraces, and bottomlands, moderately fast growing, fairly long-lived, sprouts. Dutch Elm disease, urban tolerant.
Black Tupelo (Gum) Nyssa sy/vatica	40-60	6.1-6.5	Adaptable to many soil types, alluvial stream bottoms, shade tolerant, wildlife food, wildlife den tree, moderateiy long-lived.
River Birch Betula nigra	60-80	<6.5	Alluvial soils, stream bottoms, highly tolerant of acid soils, sprouts, firewood, most common in South/Central Ohio.

TREE MAINTENANCE

Wooded ditch berms require maintenance. Regular inspections are needed, especially after ice storms to locate and remove damaged trees which may become water flow obstructions. When dead, leaning or other trees susceptible to breakage are removed, future maintenance costs can be reduced. While the listed species are not likely to cause problems, certain weather damages are not preventable. Trees should be kept away from subsurface drainage outlets so that roots do not plug the drainage pipes and outlets can be located for inspection and maintenance. Trees affected by insects or disease should be treated or removed before problems spread to other trees or they die, fall in and become obstructions.

When trees are managed properly they can provide income, benefit water quality and wildlife, protect crops from wind erosion and beautify the landscape. For more information on tree selection or site suitability contact your local Soil and Water Conservation District (SWCD), ODNR Divisions of Forestry or Wildlife, Ohio State University Extension, or qualified private consultant. For more information on drainage laws and standards contact your County or City Engineer, City Manager, Township Trustee or SWCD.

TreeSource—Ohio's Greenprint for the Future— is a strong new partnership between state and local government, private businesses and citizen volunteers renewing Ohio's commitment to planting and nurturing trees across the state.

For more information on TreeSource, contact the Ohio Department of Natural Resources, Division of Forestry (614) 265-6694.

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This Guide is one of a series of Ohio Stream Management Guides covering a variety of watershed and stream management issues and methods of addressing stream related problems. The overview Guides listed below, are intended to give the reader an understanding of the functions and values of streams. For more information about stream management programs, issues and methodologies, see Guide 05 Index of Titles or call the ODNR Division of Soil and Water Resources at 614/265-6739. All Guides are available from the Ohio Department of Natural Resources. Single copies are available free of charge and may be reproduced. Please contact:

ODNR
Division of Soil and Water Resources
2045 Morse Road, Bldg B
Columbus, Ohio 43229-6693

The guides are also available on-line as web pages and PDF files so you may print high quality originals at your location. You will find the guides on-line at: http://www.ohiodnr.gov/soilandwater/

Creation of this guide was partially funded by Nonpoint Source Programs under Section 319 of the Clean Water Act.

Prepared by the Ohio Department of Natural Resources, Dave Bergman, Division of Real Estate and Land Management, principal author. Input from staff of several ODNR divisions, state and federal agencies are used in the development of the Ohio Stream Management Guides.

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OHIO STREAM MANAGEMENT GUIDE

Demonstration at Gwyne Conservation Area

A Stream Management Model

Guide No. 09

The character of Ohio's rivers, lakes, and streams has changed greatly over the past three centuries, since the state's earliest pioneer settlements. Each year, in both agricultural and urban settings, precious soil is lost to erosion. The result is increasingly costly damage to our waterways and other natural resources.

Over the past several years, the Ohio Department of Natural Resources and The Ohio State University have developed a 35-acre demonstration site to illustrate some of the most effective practices used to solve streambank erosion. The Gwynne Conservation Area, named after the previous land owners, is located at the Farm Science Review in Madison County. This site features a variety of natural and constructed stream management practices along the banks of Deer Creek. The demonstration site offers dramatic comparisons between traditional and nontraditional stream restoration techniques.

Major features of the demonstration site include:

Stream Corridor

From the observation tower, the entire stream corridor is visible, although Deer Creek itself may be hidden behind the tree cover. Notice the setback which separates the stream corridor from farming, mowing and other land use activities. Due to the threat of flooding, it is recommended to avoid development in the floodplain area. The resulting permanent vegetation (grass, shrubs and trees) is one of the best means for bank protection. This vegetation provides several benefits: a filter strip which cleans sediment and nutrients from water runoff; shade to keep the water cool and increase oxygen content; food for aquatic wildlife; and habitat for many upland wildlife species.

Wetland

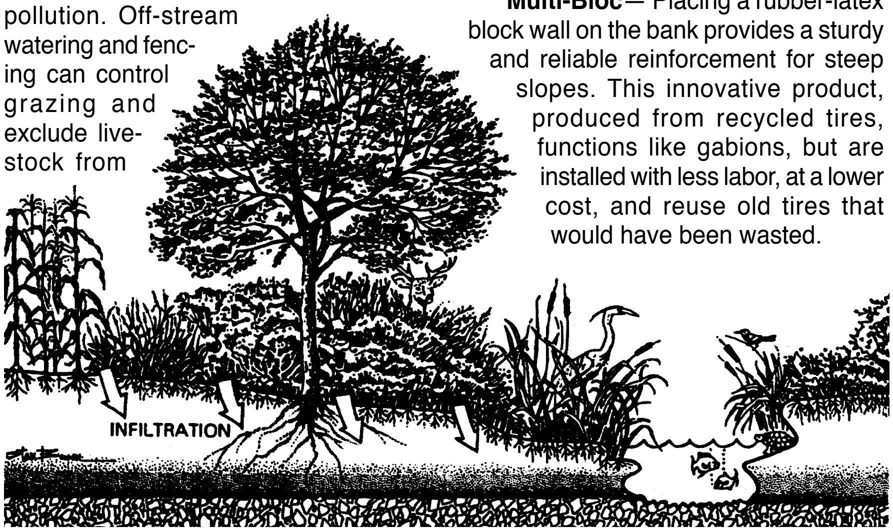
A 3.2 acre wetland area can also be seen from the observation tower. Constructed in 1989, this area demonstrates the ways in which wetlands may be built on farmland to serve as habitat for water fowl, provide food for upland wildlife and offer an effective filter for pollutants from runoff and water discharge. The wetland's average depth is two feet and is typically found in low-lying areas.

Stream Tree Planting

The forested area next to Deer Creek serves important water quality functions. The tree roots hold the soil in place, keeping the stream from "wandering", eroding the streambank and consuming crop field or pasture. Trees also serve as a filter for sediment and pollutants from water runoff.

Livestock Watering Areas

Uncontrolled livestock access to streams can result in bank erosion, damage streamside vegetation and degrade water quality with solid waste pollution. Off-stream watering and fencing can control grazing and exclude livestock from stream channels. Furthermore, good off-stream watering practices can facilitate rotational grazing, reduces livestock injuries and increases production. A typical livestock watering tank, which is fed from an existing pond, costs between $300-$500. Government cost-sharing is often available for this purpose.



BANK PROTECTION - SITE 1

Site 1 provides a streambank protection demonstration which compares eight techniques to help prevent erosion.

Tree Revetment or Kicker— By placing and securing a tree deflector on the stream's bank, this practice reduces erosion by deflecting high-velocity water away from the eroding streambank while allowing natural stream sedimentation to fill in the eroded area. Trees in the water also add fish habitat.

Gabions—Through this approach, wire baskets are filled with rocks then stacked into the streambank to stabilize steep banks and provide erosion control protection from high velocity water. Although labor intensive and somewhat unsightly, gabions work well in urban areas where little excavation is possible and low risk protection is needed.

Multi-Bloc— Placing a rubber-latex block wall on the bank provides a sturdy and reliable reinforcement for steep slopes. This innovative product, produced from recycled tires, functions like gabions, but are installed with less labor, at a lower cost, and reuse old tires that would have been wasted.

Rock Rip Rap—This traditional bank protection approach places rock, typically measuring eighteen inches in depth, on the bank's slope to keep banks in place and to deflect water away from the eroded section of the streambank.

Dormant Willow Post —Willow posts (5-6 feet long and 2-4 inches in diameter) were cut and driven into the eroding bank. These posts have rooted and sprouted new growth to stabilize the bank and form a dense vegetative barrier against erosion. This low-cost method also provides shade and habitat for fish and wildlife.

Dwarf Willow—Two varieties of Dwarf Willow, Bankers Willow and Streamco Willow, offer excellent erosion control. The result is a fast growing erosion control technique without the threat of breakage causing logjams. This practice is best used on relatively small streams or ditches, with lower velocity stream flow.

Native Vegetation—Most streambanks are best protected by leaving the native vegetation on the berm or top of the bank alone. Native trees, shrubs and grasses will form a protective barrier of roots for controlling bank erosion as the leaves serve as protection from rainfall.

Grassed Slope—Streambanks are typically excavated to a 1:2 side slope on non-erosive soils. The slopes are then seeded, fertilized and mulched to an erosion resistant grass like Kentucky31 Tall Fescue.

BANK PROTECTION - SITE 2

In the years ahead, Site 2 will stop bank erosion by using instream and streambank deflectors to redirect water flow away from an eroding bank and back into the center of the stream's channel. Through the use of Instream Stone Flow Deflectors, rocks or logs are placed along the streambank to deflect the flow of water away from the eroding bank, allowing it to stabilize naturally by the settlement of suspended sediments. Tree kickers also serve the same purpose.

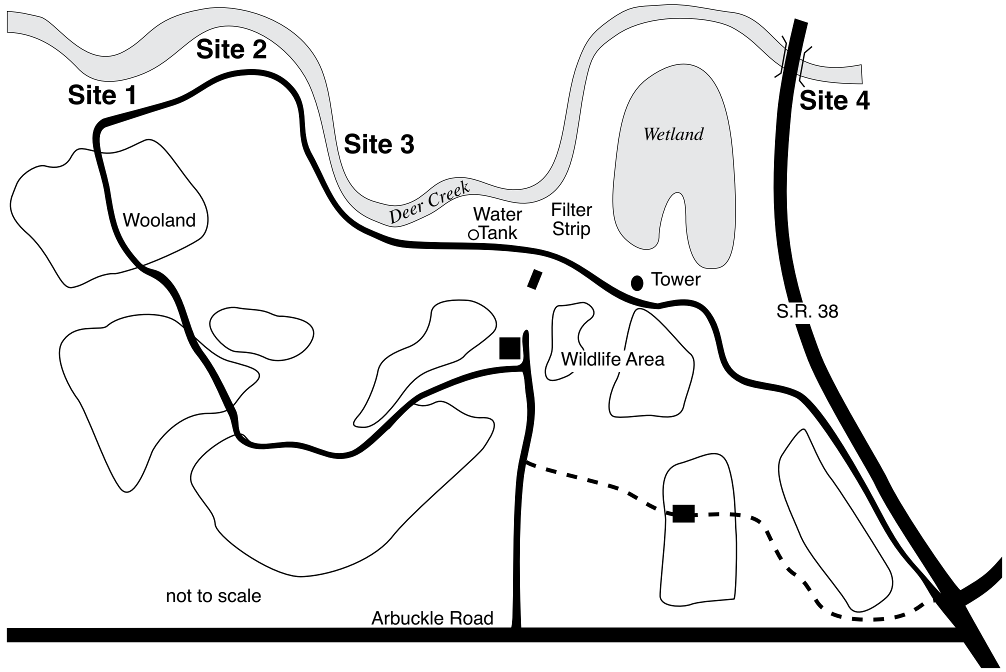
BANK PROTECTION - SITE 3

On severely eroded banks, sometimes a combination of bank protection techniques are needed to stabilize and restore the streambank. For example, the bank's vertical slope must be pulled back in order for willow posts to be planted. Planting trees on the berm further stabilizes the banks.

BANK PROTECTION - SITE 4

This proposed site will focus on vegetative streambank protection research by constructing a new conservation practice each year. Research conducted at this site will include the experimentation with planting dormant cuttings such as Cottonwood, Green Ash or Dogwood next to willow. Other instream and bank practices will also be used.

Farm Science Review
Gwynne Conservation Area
Streambank Erosion Demo Site Locations



As stewards of Ohio's natural resources we must all take an active role in helping preserve and protect Ohio's rivers, lakes and streams. If you are interested in learning more about the streambank management practices demonstrated at the Gwynne Conservation Area, please contact your county Soil and Water Conservation District V Soil Conservation Service office. Additional information can also be obtained through the Ohio Department of Natural Resources (ODNR) Divisions of Soil and Water Conservation, Water, Wildlife, Forestry, or Natural Areas and Preserves, Fountain Square, Columbus, Ohio, 43224, or by calling (614) 265-6585.

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Prepared by the Ohio Department of Natural Resources, Jim Lynch, Division of Media Relations, principal author. Input from staff of several ODNR divisions, state and federal agencies are used in the development of the Ohio Stream Management Guides.

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OHIO STREAM MANAGEMENT GUIDE

Biotechnical Projects in Ohio

Guide No. 10

This Ohio Stream Management Guide maps and briefly describes some of the many projects that have been constructed in Ohio using biotechnical practices. If you want to investigate using biotechnology to solve a stream problem or improve stream habitat on your property, you can locate sites close to you and contact the person listed to arrange for a visit. Installation dates are given so you can estimate the amount of change to the environment since the practices were installed. Names and phone numbers for the contacts are listed following the project descriptions. Additional Guides are or will be available that describe construction methods for several of these practices.

Biotechnical practices use vegetative or other natural materials to achieve stream management objectives, usually erosion control. One of the chief advantages of biotechnical practices is that they help restore natural stream features, like in-stream habitat and streambank vegetation. The materials used for biotechnical practices are generally less expensive than for more traditional approaches, but installation is more labor intensive and they may require more frequent maintenance.

BIOTECHNICAL PRACTICES

Biotechnical practices can be used alone or with other practices to accomplish management objectives. Installing biotechnical practices has been described as more art than science, that is, you may need to experiment with their use to get a feel for what will work in a given situation. When these practices are combined with surveying, engineering and horticultural sciences, their professional design and installation is called bioengineering.

Some site conditions and/or project objectives will require use of more traditional, structurally engineered solutions. This is particularly true where high stream flows can be expected. In other situations, a combination of structural and biotechnical practices may provide both strength and habitat. See Guide No. 03, Natural Stream Processes for an overview of stream mechanics.

The following is a brief overview of the practices used in the projects listed below:

Willow posts - Large branches of willow or Red Osier Dogwood cut in four to six-foot lengths and installed in the dormant season (Nov. - Mar.). These plants quickly reestablish root structure on streambanks exposed to sunlight. Construction details are given in Guide No. 07, Restoring Streambanks with Vegetation.

Native hardwood tree plantings on top of the streambank supplements willow postings, eventually shading out the willows and establishing a wooded corridor.

Fascines - Thin branches of dormant willow or red osier dogwood bundled together into long bundles and laid in trenches dug parallel to the shoreline or streambank. The trenches capture runoff, enabling the willows to sprout roots and leaf.

Brush layering - Thin branches of dormant willows, etc., are placed sideby- side in alternate layers of soil and branches to fill in an eroded or excavated area of streambank. Each layer runs parallel to the water line. The top third of branches are exposed and leaf out while the bottom two-thirds establish roots. Also called Branch packing.

Evergreen revetments - Cedars, firs or Christmas trees anchored into an eroded bank to armor the bank by absorbing stream energy and trapping sediments. Usually used with willow posts to establish needed root structure.

Log revetment - hardwood logs anchored against the streambank to buffer stream energy. Brush is tied behind the log to prevent scour and capture sediments.

Tree kickers - Felled streambank trees or hardwood logs found in streams which are anchored to the bank at an angle to kick the stream flow away from an erosion point and back toward the center of the stream. Brush is tied in behind the log to prevent scour.

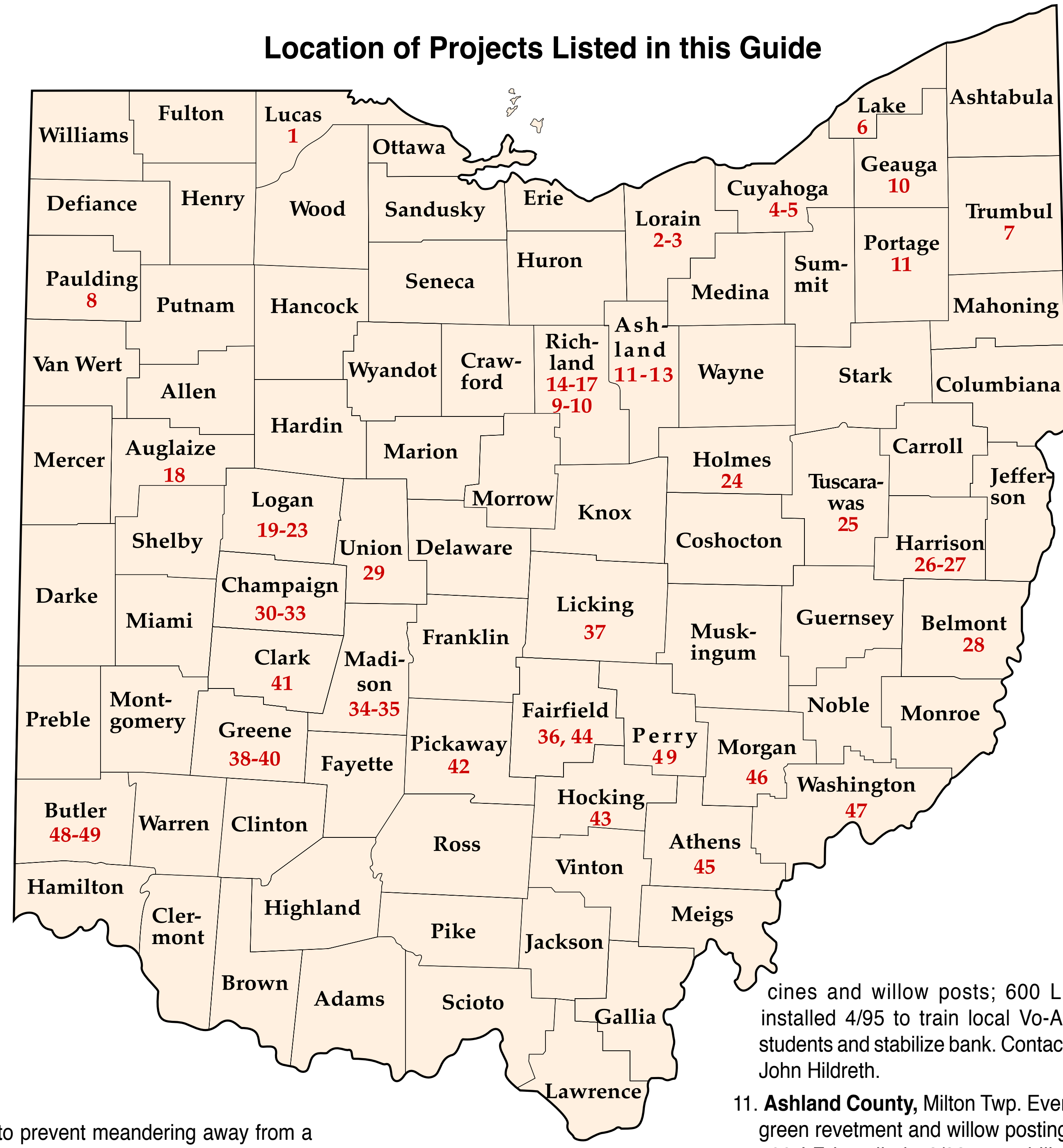
Lunker structure - A wooden, box-like frame placed into the streambank at or near channel bottom and covered with rock and soil fill. Lunkers provide shelter for fish from predators and strengthen the toe of the bank slope to prevent undercutting. Excavation of the bank is required.

Placed rocks - Stones or boulders are strategically placed in a stream channel which lacks natural structural features. They can create eddies and scour holes, which are important elements of fish habitat.

BIOTECHNICAL PROJECTS

1. **Swan Creek, Lucas County**, in Toledo's Swan Creek MetroPark. Evergreen revetment, fascines, willow posts, log revetments and native hardwood tree plantings; 200 linear feet (LF) installed 12/95 & 3/96 to train volunteers. Contact: Cherie Blevins.
2. **Black River, Lorain County**, in the Black River Reservation, Elyria. Fascines in swale area and evergreen revetment on streambank; 75 LF installed 3/96 to prevent gully erosion into the streambank and train volunteers. Contact: Linda Lagunzad.
3. **East Branch Black River, Lorain County,** LaGrange Twp. Evergreen revetment, willow posts, fascines, and hardwood tree plantings; 432 LF installed 12/95 to prevent bank erosion and train volunteers. Contact: Linda Lagunzad.
4. **Sagamore Creek, Cuyahoga County,** Valley View. Root wads, fascines, and brush mat; 200 LF installed 6/95

Location of Projects Listed in this Guide



to prevent meandering away from a bridge. Contact: Jim Storer.

5. **Tinkers Creek, Cuyahoga County**, Independence. Evergreen revetment; 102 LF installed 5/96 to protect base of a electric transmission tower and train volunteers. Contact: Kelvin Rogers.

6. **East Branch Chagrin River, Lake County**, Chardin Twp. Brush layering with rip-rap; 1,500 LF installed 1/96 to stabilized streambank. Contact: Cindy Paschke.

7. **Grand River, Trumbull County**, Farmington Twp. Lunker structure and evergreen revetment; 30 LF installed in 1992 to provide in-stream structure and shelter while stabilizing the streambank. Contact: John Golz.

8. **Flatrock Creek, Paulding County.** Tree kickers, log revetments, and willow plantings; 300 LF installed 7/ 94 to reestablish stable channel and control erosion. Contact: Tim Franklin.

9. **Black Fork of the Mohican River, Richland County**, Cass Twp. Emergency storm water bypass; 1,000 ft. installed 8/91 to improve stormwater discharge near a series of oxbows. Contact: John Hildreth.

10. **Black Fork of the Mohican River, Richland County,** Cass Twp. Fascines and willow posts; 600 LF installed 4/95 to train local Vo-Ag students and stabilize bank. Contact: John Hildreth.

11. **Ashland County,** Milton Twp. Evergreen revetment and willow posting; 400 LF installed 12/93 to stabilize bank. Contact: Jim Bishop.

12. **Ashland County**, Village of Mifflin. Evergreen revetment; 350 LF installed 11/94 to stabilize a streambank. Contact: Jim Bishop.

13. **Ashland County,** Mohican Twp. Willow posting; 350 LF installed 3/93 to revegetate an eroded area. Contact: Jim Bishop.

14. **Clear Fork of the Mohican River, Richland County**, Washington Twp. Bankers Willow planting and top-of-bank tree planting; 400 LF installed 4/96 to stabilize bank and reestablish river corridor. Contact: John Hildreth.

15. **Richland County,** Monroe Twp. Evergreen revetment; 400 LF installed 5/93 to stabilize a streambank. Contact: Jim Bishop.

16. **Rocky Fork of the Mohican River, Richland County,** Monroe Twp. Evergreen revetment and willow posting; 300 LF installed 4/93 to stabilize bank and train staff. Contact: John Hildreth.

17. **Clear Fork of the Mohican River, Richland County**, Jefferson Twp. River corridor tree planting, including Buckeye and Black Walnut seedlings; 1,800 LF planted 4/96 to train Vo-Ag students. Contact: John Hildreth.

18. **Pusheta Creek, Auglaize County,** Clay Twp. Willow posts, evergreen revetment, river corridor tree plantings; 400 LF installed 1/96 to control field erosion. Contact: Randy Hoover.

19. **Logan County,** Richland Twp. Willow posts and dwarf willow plantings; 150 LF installed Spring, 1996, to control bank erosion. Contact: Richard Neff.

20. **Logan County,** Richland Twp. Branch packing, "biologs", tree kickers, willow wattles (fascines), willow posts, dwarf willow plantings, evergreen revetments; 580 LF installed Spring, 1996, to control streambank erosion. Contact: Richard Neff.

21. **Logan County,** Richland Twp. Evergreen revetment; 350 LF installed Summer, 1994 to control streambank erosion. Contact: Richard Neff.

22. **Logan County,** Richland Twp. Evergreen revetment, tree kickers, willow posting; 300 LF installed Summer, 1995 to control bank erosion. Contact: Elmer Heyob.

23. **New Richland tributary to S. Fork Great Miami, Logan County**, Richland Twp. Evergreen revetments, tree kickers, log revetments, large willow posts, river corridor tree plantings, livestock fencing; approximately (-) 400 LF installed 12/94 to control field erosion. Contact: Randy Hoover.

24. **Doughty Creek, Holmes County,** Berlin Twp. Evergreen revetment; 75 LF installed 4/93 to stabilize streambank. Contact: Darla DiFabio.

25. **Tuscarawas County,** Franklin Twp. Evergreen revetment, dormant posts; 800 LF installed 9/94 to stabilize streambank. Contact: Jim Bishop.

26. **Buxton Bay of Tappan Lake, Harrison County, Franklin** Twp. Lakeside forest buffer, wildlife structures, livestock exclusion, shoreline watering facilities; 2,500 LF installed 4/94 to prevent shoreline erosion. Contact: Jim Bishop.

27. **Clendening Lake, Harrison County,** Nottingham Twp. Fascines; 1,665 LF installed 12/95 to stabilize the shoreline. Contact: Cindy Couts.

28. **Crabapple Creek, Belmont County,** Wheeling Twp. Willow posting; 1,600 LF installed 3/93 to revegetate a reconstructed mine land stream channel. Contact: Jim Bishop.

29. **Big Darby Creek, Union County,** Allen Twp. Evergreen revetment and willow posting; 400 LF installed 3/95 and 7/95. Contact: Kathy Smith.

30. **Mad River, Champaign County**, Mad River Twp. Tree Kickers, evergreen revetment, willow posts; - 800 LF installed 2/93 to curtail field erosion. Contact: Randy Hoover.

31. **Mad River, Champaign County**, Mad River Twp. Rocks placed for in-stream structure; 100 LF installed in Summer, 1994, for habitat improvement in a channelized stream. Contact: Elmer Heyob.

32. **Mad River, Champaign County**, Urbana Twp. Rocks placed for instream structure; - 100 LF installed in Summer, 1994, for habitat improvement in a channelized stream. Contact: Elmer Heyob.

33. **Treacle Creek, Champaign County**, Goshen Twp. Fascines, willow posts, tree kickers; 200 LF installed 3/95 to stabilize a bank and prevent field erosion. Contact: Kathy Smith.

34. **Little Darby Creek, Madison County,** Pike Twp. Willow posts and evergreen revetment; 800 LF installed 2/91 to demonstrate streambank erosion control. Contact: Kathy Smith.

35. **Spring Fork, Madison County,** Monroe Twp. Evergreen revetments; 350 LF (several sites) installed 4/96 to stabilize a streambank. Contact: Kathy Smith.

36. **Walnut Creek, Fairfield County,** Liberty Twp. Brush layering, fascines, willow posts, riprap toe protection, fascine toe protection, willow posts, seedlings and geo-textile materials; 1,000 LF installed 3/96 to demonstrate streambank stabilization techniques. Contact: Art Brate.

37. **Licking County,** Madison Twp. Tree kickers and willow posts; approx 500 LF installed 9/95 as an erosion control demonstration. Contact: Daniel Blatter.

38. **Little Miami River, Greene County,** Beavercreek Twp. Tree kickers and willow posts; 400 ft. (in two locations) installed 3/91 to protect electric transmission towers. Contact: Doug Maloney.

39. **Paintey Run, Greene County**, Caesar Creek Twp. Evergreen revetments, river corridor hardwood tree plantings; - 200 LF installed Summer, 1995, to establish vegetation on a stream channel relocated due to bridge work (required as a special condition of a federal water quality permit). Contact: Randy Hoover.

40. **North Fork Massies Creek, Greene County**, Cedarville Twp. Willow posts, river corridor hardwood tree plantings; 12 sites along one-half mile installed 3/91 as a training demonstration to reduce bank erosion and improve habitat. Contact: Doug Maloney.

41. **Clark County,** Green Twp. Willow posts; 150 LF installed 2/92 to control streambank erosion and train volunteers. Contact: Kathy Smith.

42. **Big Darby Creek, Pickaway County,** Jackson Twp. Evergreen revetment, willow posts; 900 LF installed 2/94 and 6-7/96 to protect a newly constructed levee. Contact: Kathy Smith.

43. **Salt Creek, Hocking County,** Salt Creek Twp. Tree Kickers, willow posts, evergreen revetments, hardwood plantings and livestock fencing; - 700 LF installed 2/94 to control field erosion. Contact: Mike Greenlee.

44. **Clear Creek, Fairfield County**, Madison Twp. Brush layering, evergreen revetment, willow posting, fascines, hardwood plantings and other seedlings; - 1,000 LF installed 3-4/96 to demonstrate erosion control methods and improve habitat. Contact: Chad Hermandorfer.

45. **Hocking River, Athens County**, York Twp. Evergreen revetment, willow posts, hardwood plantings; - 650 LF installed 2/91 to demonstrate erosion control methods and improve habitat. Contact: Mike Greenlee.

46. **Morgan County,** Meigsville Twp. Evergreen revetment and willow posts; 2 sites, 250 and 100 LF, respectively, installed 3-4/96 to demonstrate erosion control methods. Contact: Lori Ryan-Griffin.

47. **Muskingum River, Washington County,** in a Marietta City Park. Tree kickers and willow posts; - one-quarter mile, installed 5/94 to stabilize a steep bank. Contact: Michael Mullens.

48. **Indian Creek, Butler County,** Reilly Twp. Log revetments; - 300 LF installed 7-8/95 to curtail erosion into a field and forest area. Contact: Dave Carter.

49. **Indian Creek, Butler County**, Reilly Twp. Evergreen revetment, tree kicker, willow posts; - 200 LF installed 6-7/95 to protect a park road from erosion. Contact: Dave Carter.

CONTACTS

- Jim Bishop, Watershed Forester, Ohio Department of Natural Resources (ODNR) Division of Forestry, 330/339- 2205.
- Daniel Blatter, District Engineer, Licking Soil & Water Conservation District (SWCD) , 614/349-6920.
- Cherie Blevins, Ohio Environmental Protection Agency (Ohio EPA), Coordinator for the Maumee River Remedial Action Plan (RAP), 419/373-3010.
- Art Brate, State Conservation Engineer, U.S.D.A. Natural Resource Conservation Service (NRCS), 614/469- 6942.
- Dave Carter, Program Administrator, Butler SWCD, 513/887-3720.
- Cindy Couts, Muskingum Watershed Conservancy District, 330/343-6647.
- Darla DiFabio, District Technician, Holmes SWCD, 330/674-2811.
- Tim Franklin, District Technician, Paulding SWCD, 419/399-4771.
- John Golz, Aquatic Biologist, ODNR Division of Wildlife District 3, 216/644-2293.
- Mike Greenlee, Aquatic Biologist, ODNR Division of Wildlife District 4, 614/594-2211.
- Chad Hermandorfer, Engineer Technician, Fairfield SWCD, 614/653-8154.
- Elmer Heyob, Aquatic Biologist, ODNR Division of Wildlife District 1, 614/644- 3925.
- John Hildreth, Program Administrator, Richland SWCD, 419/589-2712.
- Randy Hoover, Aquatic Biologist, ODNR Division of Wildlife District 5, 513/372-9261.
- Linda Lagunzad, Ohio EPA, Black River RAP Coordinator, 216/963-1169.
- Doug Maloney, Fish Management Supervisor, ODNR Division of Wildlife District 5, 513/372-9261.
- Michael Mullen, Development Director, City of Marietta, 614/373-9354 .
- Richard Neff, NRCS Water Quality Coordinator, at the Logan SWCD, 513/ 593-2946.
- Cindy Paschke, HRZ Environmental Consultants, Inc., 216/357-1260.
- Kelvin Rogers, Ohio EPA, Cuyahoga River RAP Coordinator, 216/963-1117.
- Lori Ryan-Griffin, NRCS Soil Conservationist, at the Muskingum SWCD, 614/454-2767.
- Kathy Smith, Watershed Forester, ODNR Division of Forestry, 513/653-4106.
- Jim Storer, NRCS District Conservationist, at the Cuyahoga SWCD, 216/524-6580

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This Guide was developed using information from a centralized file on biotechnical project sites in Ohio. To find out about other project sites or contribute information about projects you know about, please contact the Ohio department of Natural Resources, Division of Soil and Water Resources, at 614/265-6610 or by e-mail at: water@dnr.state.oh.us.

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OHIO

STREAM MANAGEMENT GUIDE

Tree Kickers

TREE KICKERS

Tree "kickers" are hardwood logs which are used to deflect stream flow away from an unstable bank area. One or more logs are anchored to the streambank on an outside curve and placed at an angle to "kick" stream flow away from the bank and toward the middle of the stream. Brush is tied between the log and the bank to prevent scour erosion. Kickers are often used with other practices such as evergreen revetments (see Guide No. 12 Evergreen Revetments) which further protect streambanks from eroding forces, and with dormant cuttings and hardwood plantings which reestablish root systems in the bank. See Guides No. 07 Restoring Streambanks with Vegetation, No. 08 Trees for Ditches, and No. 13 Forested Buffer Strips for detailed information on these practices.

A kicker is one of several biotechnical practices described in the Ohio Stream Management Guides. These practices use vegetative or other natural materials to achieve stream management objectives, usually erosion control. One of the chief advantages of biotechnical practices is that they help restore natural stream features, like in-stream habitat and streambank vegetation. Guide No. 10, Biotechnical Projects in Ohio, provides an overview of biotechnical practices. It also maps over 50 project sites and lists contacts who can arrange for site visits.

Some site conditions and/or project objectives (such as protecting existing structures on the streambank) will require use of more traditional, structurally engineered solutions. This is particularly true where high velocity flows can be expected. In other situations, a combination of structural and biotechnical practices may provide both strength and habitat. No project should be undertaken without an understanding of the functions of stream energy and the source of any problem to be corrected. Guide No. 03, Stream Management and the Stream's Natural Processes, will provide an overview of stream dynamics and the impacts land and channel management practices have on streams. Technical assistance about stream dynamics can also be obtained at your local Soil & Water Conservation District. The phone numbers are listed under county government in your local phone directory.

The purpose of this Ohio Stream Management Guide is to describe the generally suitable site conditions and the design, installation and maintenance steps for tree kickers. The guidelines provided are based on years of field experience in Ohio, particularly on Scenic Rivers. As with any construction project in a stream, the Ohio Department of Natural Resources recommends you consult with the applicable local, state and federal authorities listed in Guide No. 06, Permit Checklist for Stream Modification Projects, prior to construction. The extent of permit requirements will depend on the location and design of your project.

WHERE TO USE KICKERS

Tree kickers are most often used to correct bank undercutting, especially where the crest of the cut bank is five feet (ft.) or more above normal water levels. A kicker deflects the concentration of stream energy away from the bank. In addition, kickers help rebuild the bank by providing an area for sediments to deposit and provide underwater structure for fish and aquatic insects. The construction guidelines in this Guide apply to this use of the kicker practice. Tree kickers are occasionally used to deflect flows into a point bar on an opposite bank to erode sediment deposits. The sediments will then redeposit downstream where stream velocity slows.

Always look for the cause of erosion when considering how to solve it. If the bank is eroded from flow coming over the bank from adjacent land, kickers are not applicable. If the stream is just naturally meandering, protection measures should not be installed unless really necessary. Tree kickers will not correct erosion due to lack of root structure. In that case, new vegetation should be planted. However, banks which lack vegetation and root structure are vulnerable to undercutting, so a kicker might be needed in addition to the new vegetation.

Channel depth at the construction site needs to be shallow enough for a person to safely stand and work during low flows. Kickers work best where there are trees, preferably live ones, on the bank onto which one or more logs can be anchored. Since the kicker practice alone does not include planting vegetation, it can be used in shady areas. Kickers are most often installed in streams where the channel width is less than 100 ft. but wide enough so that deflected stream flows do not cause erosion on the opposite bank.

DESIGN AND CONSTRUCTION GUIDELINES

Choosing a Kicker Log — Any available tree can be used for the deflecting log, including those found in the channel. In fact, woody debris found in stream channels can be put to good use in constructing kickers. Excess debris (that which is causing an obstruction) should be removed from both the channel and the floodplain. The best species for kicker logs are hardwood trees, which deteriorate slowly, and/or trees with dense branches, which slow stream flow and catch sediments. The size of the log(s) should be compatible with the channel width and stream flow at the site. Of course, the anchor trees should be as large or larger than the kicker log.

Brush or evergreen trees should be cabled to the kicker log in the area between the log and the bank (see Figure 1). Small trees with crowns intact can also be used. This prevents bank scour and traps sediments in the slower, "backwater" area. If the kicker log still has its root wad attached, extra care should be taken to tie brush around the wad on the side toward the bank. Root wads are excellent for in-stream habitat structure but increase the likelihood of bank scour.

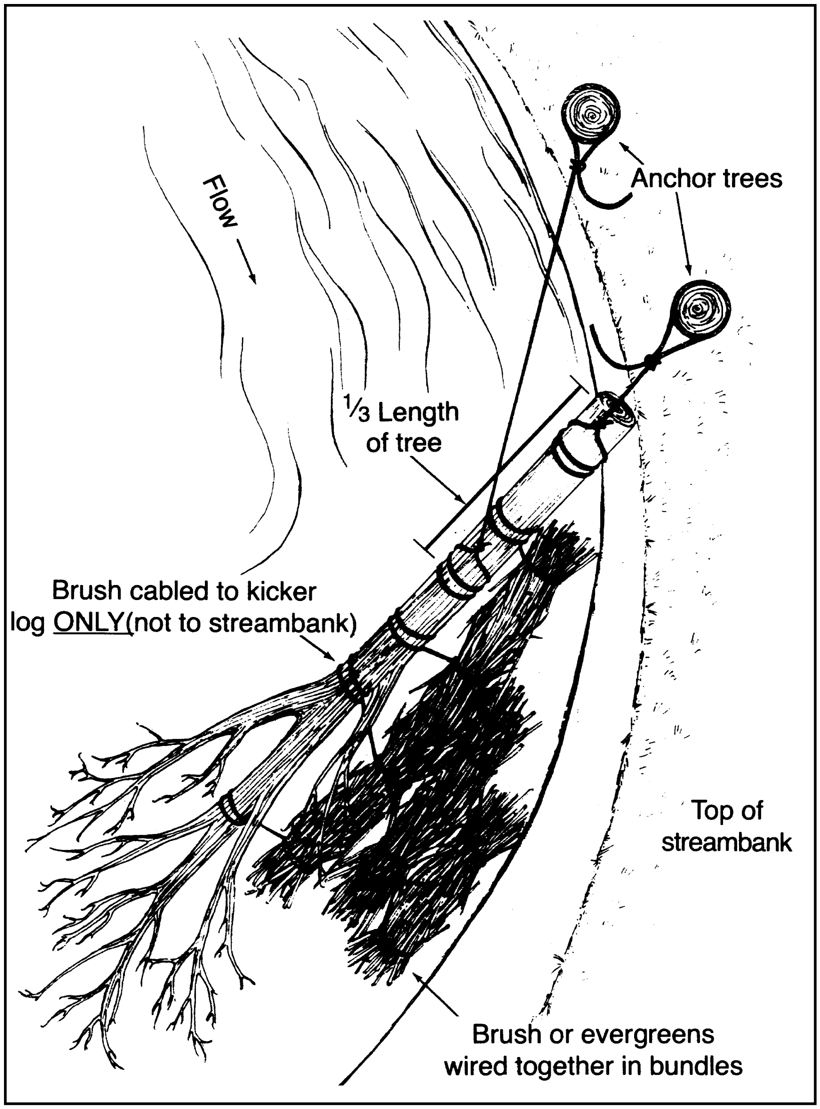

Figure 1. Tree Kicker Construction

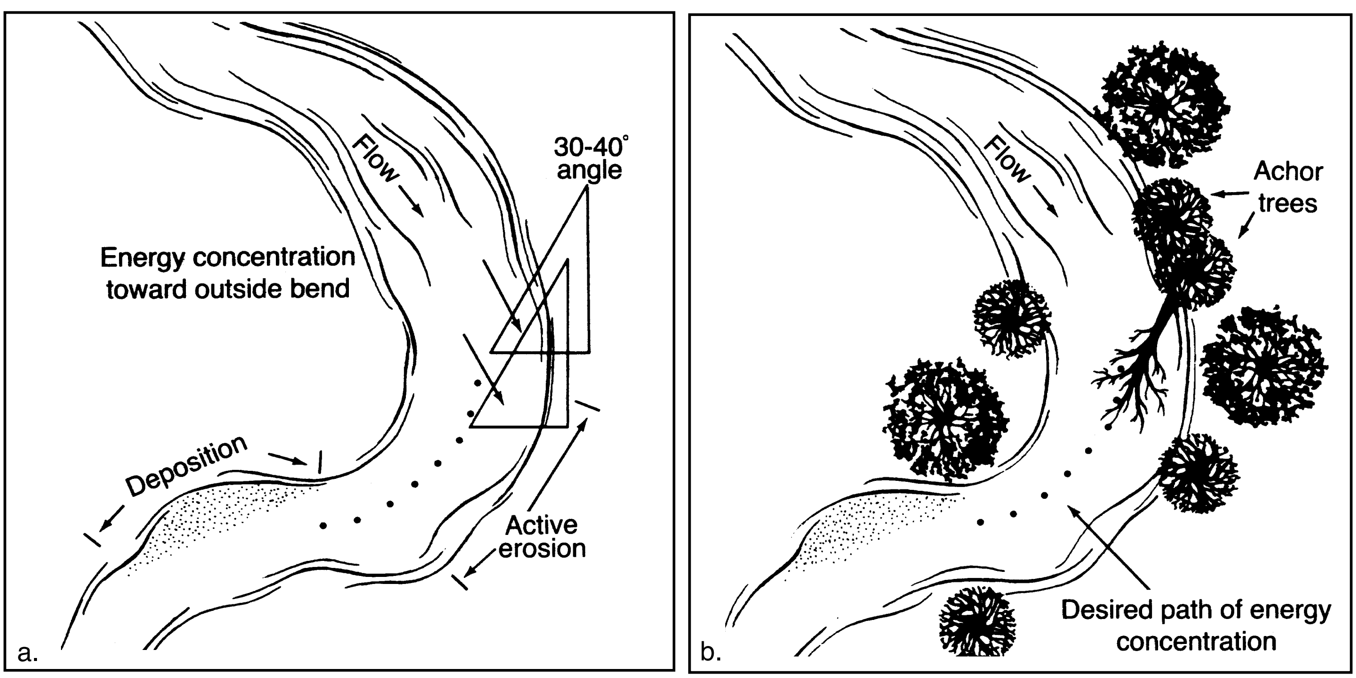

Figure 2. Placement of Kickers

Do not anchor the kicker log or the brush to the streambank. During high flows the log and attached brush need to be able to rise with the water. If high velocity flows occur before sediments have a chance to build up and "attach" the kicker log to the bed and bank, those flows may scour under the kicker structure. Choosing logs with large and dense branches helps prevent this scour. Repair or replacement may, however, be necessary. If this is a concern, and the stream size and project design allows the kicker log diameter to be about 6 inches or less, you can try anchoring the top end of the kicker log into the stream bed or bank to prevent it from floating. Anchoring methods are discussed in Guide No. 12, Evergreen Revetments.

Placement of the Kicker(s) — Each stream channel and erosion problem is different. The decision about where to start and stop placing kickers will depend on the site conditions, especially the location of trees onto which the kicker log can be anchored. Install the first kicker upstream of the eroded area at a 30-40° angle to the streambank (see Figure 2-a). Afterward, toss some small, floatable debris in the stream and observe where the current takes it. If the current is now deflected toward the center of the channel and avoids the eroded area, one kicker will suffice (see Figure 2-b). If not, adjust the angle or install another kicker downstream of the first. Be careful not to deflect the flows all the way over to the opposite bank.

Anchoring a Kicker — Kickers need to be securely anchored to the streambank. Anchoring it to two live anchor-trees on the stream bank is best. The root structure of a dead tree may or may not be dense enough to hold a kicker in place during high flows, and there is no way to find out prior to construction. To secure the kicker log to the anchor trees, cable needs to be amply wrapped around both the log and the trees. As shown in Figure 3, cable should be wrapped two full circumferences around the log or anchor tree beyond what is needed to simply clamp the cable together.

When attaching cable to live an-

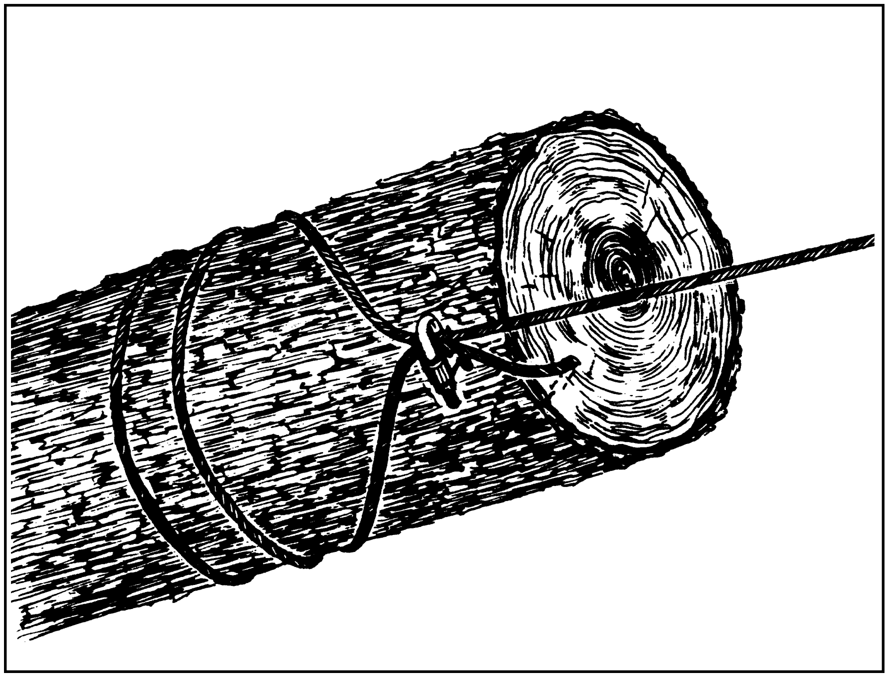

Figure 3. Securing Cables: Use two full wraps of cable around the kicker log and the anchor trees in addition to what is needed for clamping.

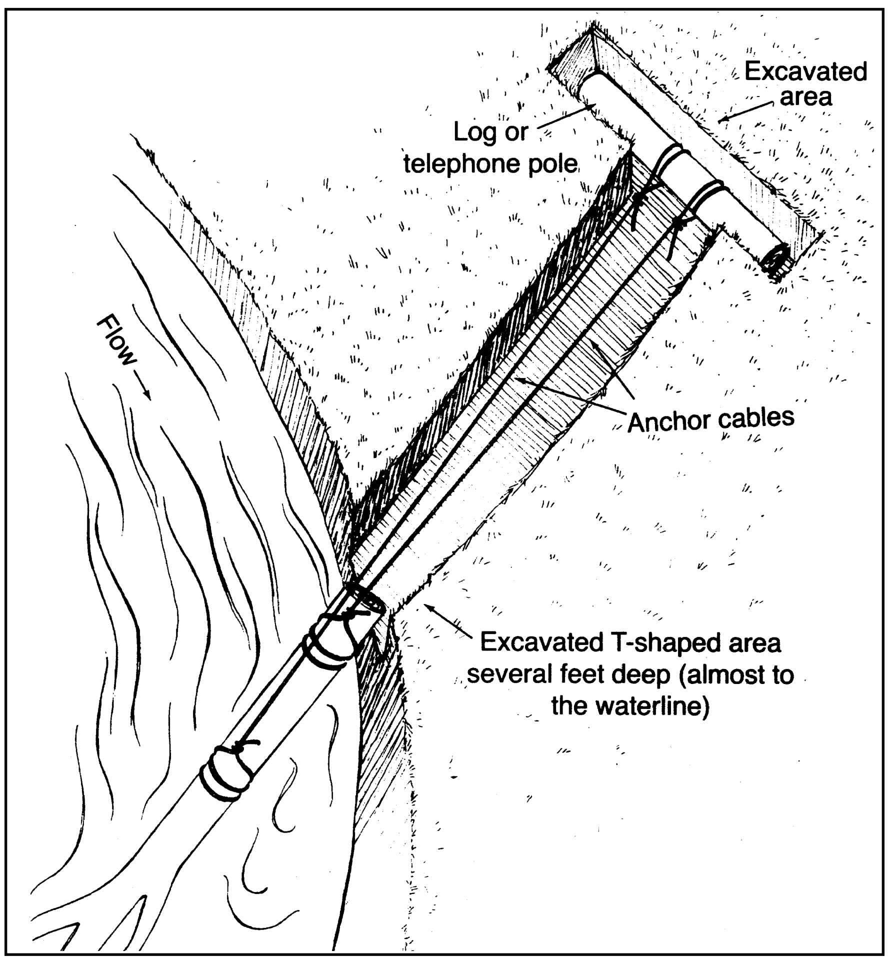

Figure 4. Dead Man Anchor

chor trees, three feet or more extra cable should be left loose, beyond the clamp (see Figure 1). Use this during maintenance improvements as the tree grows to loosen the tightness of the cable's wrap around the live tree and prevent girdling. Placing about 6 blocks of wood (1 to 2 inch squares) between the cable and the tree bark also reduces stress on the trees as they grow.

If no anchor trees are available, and a tree kicker is the most practical solution to the problem, consider installing a dead man anchor, as shown in Figure 4. The same 30-40˚ angle is used for placing the kicker log. Excavate a T-shaped trench and cable the kicker log to a large log or telephone pole placed in the cross bar of the "T." The anchor log or pole should be placed several feet below the ground surface, just above normal water elevation. The excavated soil should be replaced and tightly compacted over the anchor and cable lines.

It is important to avoid hitting any utility lines during excavation and it is easy to be safe by using the "Call Before You Dig" service (1-800/362-2764) 48 hours prior to digging. They will contact local utility companies and have them flag any lines located near your project.

Kicker Construction — A four-wheel drive truck or small tractor can be used to pull the kicker logs into place. Cable and two or three snatch block pulleys can be used to angle the logs without moving the truck more than necessary. A manual come-along can be used if the logs are not too large. At least two people should work together to safely place and angle the logs correctly. Secure the logs with cables and clamps as shown in Figures 1 and 3. After construction, be sure to reseed any areas disturbed by the vehicle.

Equipment — In addition to the items mentioned above, you will need:

- A first aid kit
- Chain saw and appropriate safety equipment: hard hat and goggles, chaps and gloves
- Saw or loppers for harvesting brush
- Steel aircraft cable, 3/8, 1/2 or 5/8 inch, depending on the kicker log's size.
- Clamps sized to match the cable; bring extra to replace any lost in the water. Some lost clamps can be recovered with a large magnet.
- Standard deep well 3/8 drive socket set with 9/16, 1/2, 5/8 inch extensions - or
  Open end wrench set, 5 pieces including 9/16, 1/2, 5/8 inch sizes
- Wire and/or 1/4 inch cable to tie the brush together and secure it to the deflector log
- Pliers and wire cutters, if using wire
- Sledge hammer and sledge-type cable cutter
- Chest waders
- A back hoe if excavating trench for a dead man anchor

Maintenance — During the first year or two after construction at least two people should inspect the kicker(s) after high water events and make any necessary repairs. Check the angle of the kicker and adjust it as necessary. Make sure the cable on the deflector logs and brush is wrapped tight, add more brush if you find evidence of scouring, and tighten any loose clamps. Inspect and maintain the kicker annually after that.

An important factor in every maintenance check is to make sure the cable around the live trees is not too tight. If the bark on the trunk is expanding beyond the cable, the tree is being girdled and its life is being threatened. Use the extra cable which you left loose during the installation to ease the wrapped cable as the tree grows. Use the wooden blocks, too, to ease pressure on the live trees. After several years it may be possible to eliminate the cable on the anchor trees altogether. This is only possible where enough new sediment has settled in to solidly reestablish the bank so that the kicker is secure without it being anchored to the trees.

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This Guide is one of a series of Ohio Stream Management Guides covering a variety of watershed and stream management issues and methods of addressing stream related problems. The overview Guides listed below, are intended to give the reader an understanding of the functions and values of streams. For more information about stream management programs, issues and methodologies, see Guide 05 Index of Titles or call the ODNR Division of Soil and Water Resources at 614/265-6740. All Guides are available from the Ohio Department of Natural Resources. Single copies are available free of charge and may be reproduced. Please contact:

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Division of Soil and Water Resources
2045 Morse Road, Bldg. B
Columbus, Ohio 43229-6693
614/265-6740

The guides are also available online as web pages and PDF files so you may print high quality originals at your location. You will find the guides on-line at:

http://www.ohiodnr.gov/soilandwater/

Prepared by the Ohio Department of Natural Resources, Roger Barber, Division of Natural Areas and Preserves and Margo Fulmer, Division of Soil and Water Resources, co-authors. Input from staff of several ODNR divisions, and local, state and federal agencies are used in the development of the Ohio Stream Management Guides.

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OHIO

STREAM MANAGEMENT GUIDE

Evergreen Revetments

EVERGREEN REVETMENTS

An evergreen revetment is a protective "wall" made of freshly cut cedars, pines, firs or recycled Christmas trees which are anchored into an eroded streambank. It absorbs stream energy and traps sediments. This buffer system, shown in Figure 1, slows or halts active erosion, creates a place for sediments to deposit and allows vegetation to re-establish on the streambank. An evergreen revetment alone may not be sufficient to hold soils in place after the evergreens decay. For long-term stability, dormant cuttings of willow or other rapidly-rooting species should be planted within the revetment and above it on the bank face to accelerate the re-establishment of root structure (see Guide No. 07 Restoring Streambanks with Vegetation). A buffer strip of native hardwoods should also be planted, if absent, along the top of the bank (see Guides No. 08 Trees for Ditches and No. 13 Forested Buffer Strips).

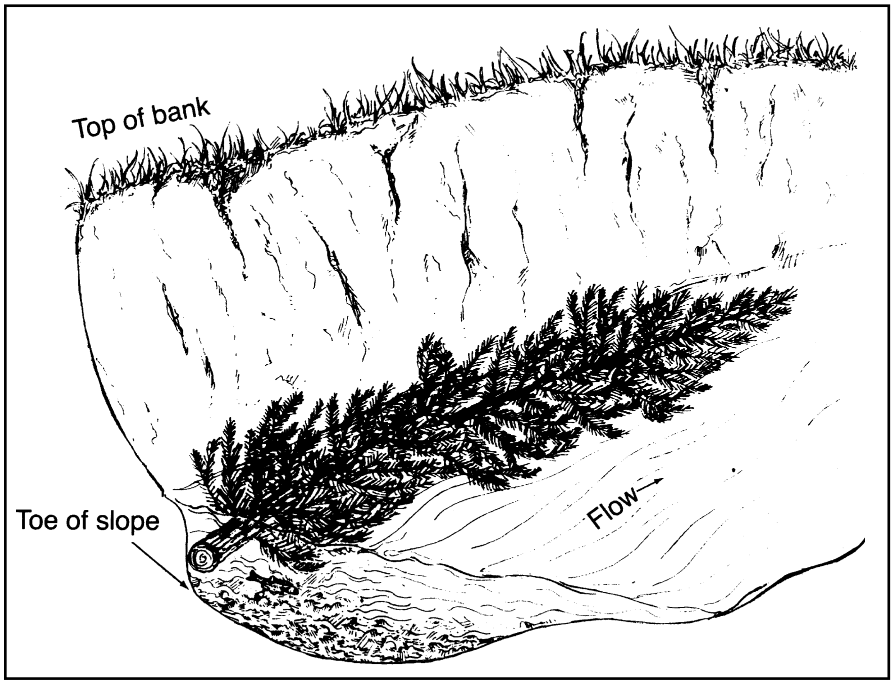

Figure 1. Evergreen Revetment

An evergreen revetment is one of several biotechnical practices described in the Ohio Stream Management Guides. These practices use vegetative or other natural materials to achieve stream management objectives, usually erosion control. One of the chief advantages of biotechnical practices is that they help restore natural stream features, like in-stream habitat and streambank vegetation. Guide No. 10, Biotechnical Projects in Ohio, provides an overview of biotechnical practices. It also maps over 50 project sites and list contacts who can arrange for site visits.

Some site conditions and/or project objectives (such as protecting existing structures on the streambank) will require use of more traditional, structurally-engineered solutions. This is particularly true where high velocity flows can be expected. In other situations, a combination of structural and biotechnical practices may provide both strength and habitat. No project should be undertaken without an understanding of the functions of stream energy and the source of any problems to be corrected. Guide No. 03, Stream Management and the Stream's Natural Processes will provide an overview of stream dynamics and the impacts land and channel management practices have on streams. Technical assistance about stream dynamics can also be obtained at your local Soil and Water Conservation District. Its number is listed under county government in the local phone directory.

The purpose of this Ohio Stream Management Guide is to describe the generally suitable site conditions, design, installation and maintenance steps for evergreen revetments. The guidance provided is based on guidelines from Missouri and on field experience here in Ohio. As with any construction project in a stream, the Ohio Department of Natural Resources recommends you consult with the applicable local, state and federal authorities listed in Guide 06, Permit Checklist for Stream Modification Projects, prior to construction. The extent of permit requirements will depend on the location and design of your project.

WHERE TO USE EVERGREEN REVETMENTS

Evergreen revetments work best on medium to small streams which have erosion problems due to inadequate tree cover on the streambanks. This lack of tree cover usually means there is adequate sunlight to supplement the revetment by planting dormant cuttings and hardwood trees. Always look for the cause of erosion when considering how to solve it. If the stream is just naturally meandering, protective measures should not be installed unless really necessary. A bank that is well covered with trees but still eroding indicates that the channel is undergoing adjustments due to changes in land use or channel configuration in the upper watershed, and an evergreen revetment will probably not stabilize it. Biotechnical practices are not likely to stabilize an eroded area if streambank erosion is very prevalent in your stream, an indication that the stream is undergoing a systematic change (e.g. deepening or widening).

If the water depth at the toe of the slope is less than three feet, a revetment should stabilize the bank. Channel depth at the site needs to be shallow enough to safely stand and work during low flows. Generally, if the target streambank is over 12 feet (ft.) high, an evergreen revetment may not be adequate to stabilize it. However, revetments have been successfully built on higher banks. If the water depth at the toe of the slope is more than three feet, the revetment alone may not be able to protect the toe and stabilize the bank. The toe of the slope is where the bank slope turns and becomes the channel bottom. Consider using a tree kicker upstream to deflect flows if they are undercutting the bank (see Guide No. 11, Tree Kickers).

DESIGN AND CONSTRUCTION GUIDELINES

Enclosed is a reproducible Evergreen Revetment Worksheet which takes you through the calculations needed for designing a revetment and estimating the amount of materials needed for construction. Many hands make constructing a revetment "light" work, but a minimum of 3 to 5 people in good physical condition should be on site to build even a one-row revetment on a small site. Since the revetment itself does not use live vegetation, construction can take place in any season. Construction in late winter or early spring will allow the revetment to catch silt from spring floods while it still has most of its needles and fine branches in tact. In addition, February and early March are good months for planting dormant cuttings to supplement the revetment with new root structure in the bank.

Regrading the slope — Evergreen revetments are generally used as an alternative to expensive regrading, so they are most often used in locations were regrading is not necessary. Providing safe working conditions is a key factor in determining if a revetment should be built at all or if the bank needs regraded before construction. Regrading loosens soil and increases the chance of revetment blow-out, so regrade only if absolutely necessary.

Some eroded banks have a slumped area at the base and a more vertical section toward the top. If the soils in the slump are stable and there is enough area to safely work, regrading the base area may not be necessary, but the top should be regraded after construction. If there is an overhang, for safety's sake it should be taken off first, before construction takes place lower on the bank.

Tree Selection — Freshly cut cedars, firs or pines work best. Cedars resist decay the best, but are not available in all parts of Ohio. It is often possible to work with Christmas tree farms to help cull their stock and put the culled trees to good use. Christmas trees gathered for recycling in January have also been successfully used. But trees which have been dead for some time are more brittle and lose needles and branches during construction.

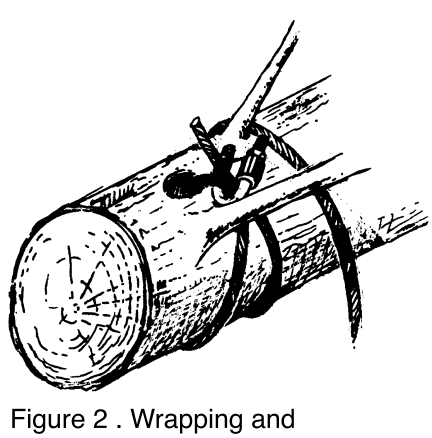

Figure 2 . Wrapping and Clamping Cable to Tree Trunks

The more limbs and fine branches a tree has the more it will continue to slow the stream's current after the needles are gone, allowing sediments to accumulate within the anchored trees. Both time and money can be saved by using the largest trees available as long as they are compatible with the stream's size (see worksheet calculations). Cut the trunk near the lowest limbs; anything below that is excess weight to carry. Trees cut prior to construction and stored on site should be placed above the floodplain. This will prevent them from floating downstream should a storm occur before construction begins.

Some of those with field experience prefer to drill holes in the butt end of each tree trunk (Figure 2). During construction, cable is threaded through the hole first, then wrapped around the trunk above the bottom limbs. When using this method be sure to size the hole appropriately for the cable you are using (see Equipment, below). Others prefer wrapping cable twice around the trunks above the lower limbs and have found this method adequate for resisting stream flow velocities, especially in lower gradient streams.

Anchoring Methods — Anchoring the trees into the streambank in a manner that will resist the force of water is imperative. There are several different types of anchors available, and they vary in availability, cost, ease of use and effectiveness in different soils.

- Disk anchors (Figure 3-a) are available at most hardware or farm supply stores. They are often used to tie down mobile homes. Use a model with at least a four-foot arm. Since they are screwed into the bank they are used in soils, preferably clays, where there are no rocks. At-

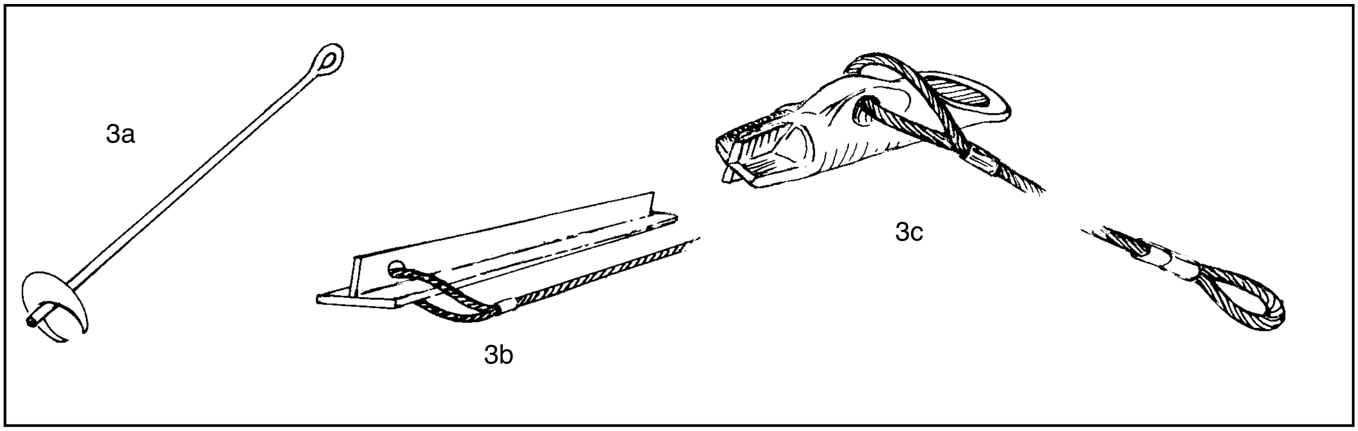

Figure 3. (a, b &c) Types of Anchors

tach the wrapping cable with a saddle clamp after screwing in the anchor.

- T-posts (Figure 3-b) can also be purchased at farm supply stores. These fenceposts are best used on small streams. They can be driven all the way into even rocky banks with a sledge hammer or a T-post driver. Metal caps are available which make driving posts with a sledge hammer easier. Attach a cable to the end below the flange before driving it in.
- Duckbill earth anchors (Figure 3-c) are available from fencing vendors, and nursery and forestry suppliers. Duckbill anchors come in two sizes and are available with or without a cable attachment. The anchors are installed with a drive rod or rebar and can be driven into even rocky soils (see Figure 4). When the anchor is driven most of the way in, thread the wrapping cable through the cable attachment's top loop. Finish driving the anchor far enough into the streambank so that the cable attachment is no longer visible, generally about 2.5 feet. Then jerk the cable with a handyman jack or other type of lever system. This turns the anchor from the vertical to the horizontal underground. Many of the evergreen revetments built in Ohio are anchored with duckbills.

Any of several types of wire or cable can be attached to the anchors and used to tie the trees together. The strength of the materials used should be based on expected stream flows and project size. Choose from cable with saddle clamps, high tensile wire with crimping sleeves (attached with crimping pliers), or use number nine fencing wire which can be twisted tight with pliers. These materials are available at local hardware stores, farm supply stores, and some construction suppliers. The construction suppliers generally keep larger supplies of cable in stock.

Tree Placement — Depending on the bank height and tree size, the trees may be manually lowered over the bank crest for placement. If using large trees on a tall bank, it may be best to lower the cut trees using cable or push them over the bank with a vehicle and front-end loader. All vehicles should stay as far away from the bank crest as possible to prevent soil damage or collapse. Workers in the stream should stay clear of cables and trees as they come down the bank.

In order to adequately protect the area of active erosion, an evergreen revetment needs to extend beyond the area of exposed soils on the streambank. Start downstream of the exposed soil anchoring each tree in place with the butt end of the trunk pointing upstream. Work upstream laying each tree so that it overlaps the previously laid tree until the revetment extends beyond the exposed soils.

Figure 4. Driving a Duckbill Earth Anchor

This usually means the entire length of the outside bend must be covered by the revetment. The first row of trees needs to be placed so that the tree crown (the widest part of the tree, i.e., the bottom of the foliage area for evergreens) rests on the toe of the bank slope as shown in Figure 1.

Anchor the trees near the toe of the slope (where the bank slope turns and becomes the channel bottom), which is usually below the water line. Banks often become unstable when stream energy cuts into the bank toe and undermines the strength of the bank. Protecting the toe of the slope is a primary objective in revetment construction. The branches underwater must be located where they will stop the undercutting action of the water around the curve. In the process they provide excellent cover for fish and other aquatic life.

It is very important to wrap the cable more than once around each trunk and to pull the cable together as tight as you can before you clamp the ends firmly. If cables are loose or too much cable is stretched between the anchors and the trees, flood waters will cause the trees to move violently and either break free or allow the bank behind them to erode. Loose cable and not setting the anchors properly are two major reasons for revetment failure.

Construction procedures — The following construction steps are

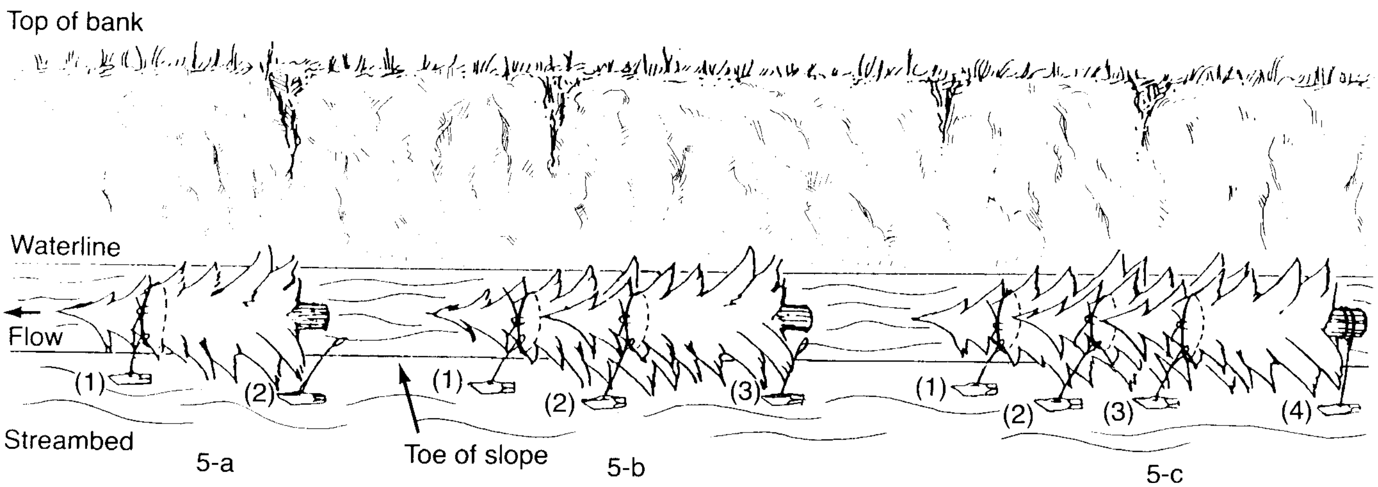

Figure 5. Constructing a One-Row Revetment - Figure shows the general placement of cable. Cable should be wrapped around trunks only and not the outside branches. Pull cable together as tight as possible and clamp tightly.

provided in a logical order to give you a concept of how each element fits together. Once you understand the concept, you will establish a sequence of steps which suits you best. The description assumes holes are drilled in the trunks and that duckbill anchors with pre-assembled cable attachments and cable with clamps are used. Directions are found on the worksheet for estimating the length of cable needed in total and for wrapping each tree or set of trees.

Constructing Revetment — When complete, a revetment made with one row of overlapping trees has anchors with cable wrapped around the trunks of both trees on the ends. In the middle section, anchors with wrapping-cable attach the top of each of the middle trees to the trunk of the previously laid tree. Depending on the size of the trees used, it is sometimes possible to construct a revetment with two rows of trees using one row of anchors like a one-row revetment. The following construction steps are illustrated in Figure 5.

- Start at the downstream stable point and position the first tree tight against the bank, with the butt end of the trunk upstream and low enough for the tree crown to rest on the bank toe. Drive and set anchor #1 near the top end of the tree leaving at least 1/5 of the tree height beyond the anchor, and drive anchor #2 by the butt end of the trunk. Set each anchor as described in "Anchoring Methods - Duckbill earth anchors", above.
- Thread a length of cable through anchor #1's cable attachment and wrap it around the trunk near the top of the tree. Pull the two ends of the cable together as tight as you can and clamp the ends of the "loop" together firmly (Figure 5-a).
- Place the second tree slightly upstream with its top overlapping the butt end of the first tree so that no gap exists between them. Drive anchor #3 at the butt end of the second tree.
- Thread a length of wrapping-cable through anchor #2's cable attachment and through the hole drilled in the first tree's trunk; then wrap it around the trunk. (If no holes are drilled, wrap it more than once around the trunk above the bottom branches.) Wrap the same cable around the top end of the second tree's trunk. Pull the cable tight and clamp the loop of cable together near the first tree's trunk (Figure 5-b) linking the top of the second tree to the butt end of the first.
- Thread cable through anchor #3's attachment and the hole in the trunk of the second tree. Position the third tree to overlap the second and repeat the process of threading, wrapping and clamping cable to attach the top of the third tree to the butt end of the second (Figure 5-c).
- Follow this overlapping process until trees cover beyond the eroded area. Anchor the butt of the last tree on the upstream end very tightly and low against the bank to prevent it from breaking loose when flows hit it.

Constructing Revetment — A revetment with more than one row is made of "sets" with each set of trees anchored and cabled together as a unit up the bank slope. The sets of trees overlap each other as in a one-row revetment. Each set has an anchor at the bottom (near the toe of the slope) and at Each set has an anchor at the bottom (near the toe of the slope) and at the the top (on the bank). Cable is threaded through both anchor assemblies and wrapped around each trunk in the stack of trees, making a loop of cable with the ends clamped together. The number of trees in a set is equal to the number of rows in the revetment. Use the worksheet to calculate the number of rows needed. The rows of trees should cover the eroded area of the bank about 1-2 feet higher than the elevation where storm flows will spread out across the low bank into

EVERGREEN REVETMENT WORKSHEET

For use with Ohio Stream Management Guide No. 12

1. Determine water depth at toe of bank slope under normal water level conditions:
   A. If more than 3 feet, then revetments may not stabilize bank.
   B. If 3 feet or less, then revetments should work.

2. Determine streambank soil type and anchoring method by using 3/4" steel rod (scrap rebar) to probe at least 4 feet into channel bottom and streambank:
   A. If bedrock is less than 4 feet below streambank, anchors won't hold.
   B. If bedrock is more than 4 feet below surface, and soils are rocky, use T-post or duckbill anchor.
   C. If bedrock more than 4 feet below surface, and soils are sand, silt, or clay, use T-post, duckbill, or screw-in anchors.

3. Determine size of channel constriction the revetment will cause, and optional approaches:
   A. Difference in elevation (in feet) from top of eroded bank to toe of bank slope = _____ ("3A").
   B. Tree crown diameter (in feet) needed = answer to 3A x 0.67 = _____ (3B).
   C. Tree crown radius = answer to 3B x 0.5 = _____ (3C).
   D. Measure stream width (average) in feet at revetment site = _____ feet (3D).
   E. Percent constriction caused by revetment = (3C ÷ 3D) x 100 = _____ % (3E).
   F. If answer to 3E is less than 15%, then one row of anchored trees should work. Use of at least two rows is recommended if bank height will accommodate it.
   G. If 3E is greater than 15%, a second row is needed, but with smaller diameter tree crowns. Also, the narrower the stream width, the greater the likelihood water will overtop one row.

4. Determine total length (in feet) of trees needed:
   A. Length of bank needing coverage by the revetment (measure beyond area of exposed soils) = ______ feet (4A).
   B. Total length of trees needed, accounting for tree overlap during construction = 4A x 1.2 = ______ feet (4B).

5. Determine number of **trees** needed:
   A. Number of trees needed for one row = total length of trees needed (4B) ÷ estimated aver age height of trees available = _____ trees for one row (5A).
   B. Height of revetment = height of area needing protection, measured vertically from the toe of the slope up to a point 1-2 feet above where flows will spread out across the low bank into the floodplain = _______ feet (5B).
   C. Number of rows up the bank = 5B ÷ estimated average *compressed* tree crown diameter [cedar & arbor vitae compress more than fir trees] = ____ rows (5C).
   D. The number of rows up the bank is also the number of trees in a "set"; the number of trees needed for one row = the number of sets needed. 5A = ___ sets (5D).
   E. Estimated total number of trees needed for the revetment = 5A x 5C = _____ trees (5E).
   F. *If height or diameter of trees found available is different than the estimate, re-calculate number of trees, anchors, clamps and cable length needed, and adjust purchases.*

6. Determine the number of **anchors** needed
   A. For a one-row revetment, the number of anchors = 1 + number of trees in one row = _____ _______ anchors.
   B. For a multiple-row revetment, the number of anchors = 2 x the number of sets + 2 = _____ _______ anchors.

7. Determine the number of **cable clamps** (sized for cable) needed = 2 x number of anchors. Bring extra clamps to replace any lost in the water. Some lost clamps can be retrieved with a *large* magnet.

8. Estimating the amount of **cable or wire** needed, especially for multiple row revetments, is difficult considering the difference between tree species on how much they compact when wrapped with cable. The following are principles to follow:
   A. When using cable, 1/4" steel aircraft cable is flexible and adequate in most circumstances. If in real doubt, double it, but washouts rarely happen due to a 1/4" cable breaking.
   C. When the revetment will have **one row of trees**, the amount of cable/wire needed to wrap around the trees = [4 ft. x the number of anchors (6A)] + 20% = _____ feet of cable or wire (8C).
   D. When the revetment design is for **multiple rows**, the amount of cable needed = [2 x revetment height (5B)] x (the number of sets + 1) + 20% = _____ feet of cable or wire (8D).
   E. *If you are using* ***anchors without pre-attached cable*** *for sinking into the soil, you must estimate the depth of your anchor installations, add 0.5 - 1.0 ft. more for a loop to clamp the cable onto the anchor, multiply that sum times the number of anchors, and add that total to your results for 8C or 8D, whichever is applicable.*

Example:

A revetment covering 200 ft. of eroded bank needs 240 ft. of trees to cover the first row [200 x 1.2 = 240] (see worksheet items 4A&B). If using 8 ft. trees, 30 trees are needed for a one-row revetment [240 ÷ 8 = 30] or 30 sets of trees are needed for a multiple row revetment (item 5D). If the revetment needs to cover an eroded area 5 ft. high, and the average tree crown diameter is 2 ft., then the revetment needs to have 3 rows [5 ÷ 2 = 2.5 ‘ 3] (item 5C). Three rows x 30 sets = 90 trees are needed (item 5E). Sixty-two anchors are needed [2 x 30 sets + 2 = 62] (item 6B) and 124 clamps (item 7) are needed. Each set needs 10 ft. of cable for wrapping [2 x 5 ft. eroded area height], so 10 ft./ set x (30 sets + 1) = minimum 310 ft of cable needed (item 8D). Purchase an additional 20% for a margin of error. Cut the cable in lengths of 10 ft. per set at first. If you find less cable is needed for wrapping, reduce that length, saving cable for its next use.

If using anchors without pre-attached cable, and they are to be sunk 3 ft. into the stream-bank, add [3 ft. + 0.5-1.0 ft. for the loop] x [30 sets +1] to the 310 ft. minimum before calculating the 20% extra and cut the cable in 13.5-14 foot lengths at first (item 8E).

The source of the original worksheet, on which this edition is based, is unknown. Its development and availability are appreciated by the authors of Guide No. 12.

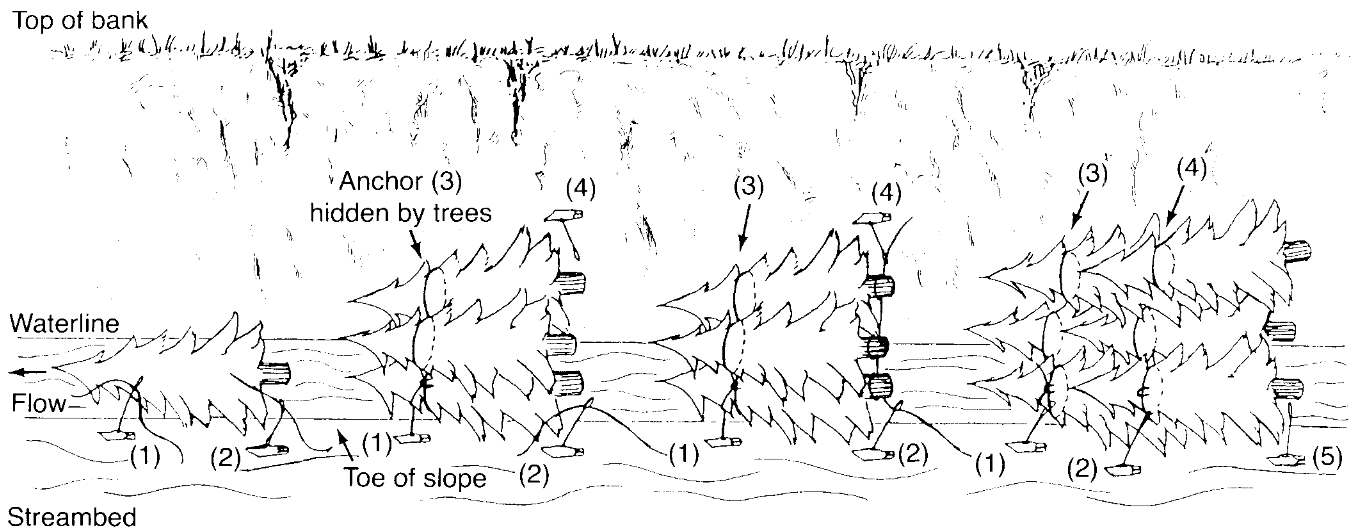

Figure 6. Constructing a Multiple-Row Revetment - Figure shows the general placement of cable. Cable should be wrapped around trunks only and not the outside branches. Compress the trees, pull the cable together as tight as possible and clamp tightly.

the floodplain. Once storm flows are high enough to spread outside of the channel, velocities slow down and the protection of dense branches is no longer needed. The following construction steps are illustrated in Figure 6.

- Start at the downstream stable point and position the first tree tight against the bank, with the butt end of the trunk upstream and low enough for the tree crown to rest on the bank toe. Drive anchor #1 near the top end of the tree, leaving at least 1/5 of the tree height beyond the anchor and drive anchor #2 by the butt end of the trunk. Set each anchor as previously described in “Anchoring Methods - Duckbill earth anchors”.
- Thread a length of wrapping-cable through each of the anchors' cable attachments. There should now be a length of wrapping cable threaded through each of the two driven anchor assemblies, one near the trunk and one near the tree top, both placed underwater (See Figure 6-a).
- Lay the trees for the first set up the bank. Drive another two anchors into the bank at the upper end of the set, under where the top tree lies. Keep in mind when you position these upper anchors that you will be compressing the trees in the set together so that they will not shift in high flows. Place anchor #3 near the top end of the trees and #4 in line with the butt ends.
- Take the wrapping-cable from anchor #1 and wrap it around each trunk near the tree tops to link the trees together. Thread the cable through anchor #3's cable attachment. Compress the trees and pull the two ends of the cable together tightly, wrapping and weaving some more as you go. Clamp the two ends of the cable loop together. More than one clamp may be used. As shown in Figure 6-b, the first set of trees is now linked together near their tops.
- Thread the wrapping-cable from anchor #2 through the holes drilled in the first set's trunks. Wrap the cable around the trunk once as you thread it through each hole. Thread the same cable through anchor #4 at the upper end of the set, then let it lie loose (see Figure 6-c).
- Lay the second set of trees in place with the tops of the second set overlapping the butt ends of the first set so that no gap exists between them. At the same time, so you can position it correctly, drive in anchor #5 at the butt end of the second set. Place anchor #5 where the butt end of the second set's bottom tree trunk will lie in the overlapping formation.
- While compressing the trees, weave the cable from the first set (which has been threaded through the trunks then lying loose) around the trunks of the second set's top-end. Pull tightly and clamp the ends of the second cable loop together. As shown in Figure 6-d, the top of the second set is now linked to the butt end of the first set.
- Follow this process, overlapping each set, until trees cover beyond the eroded area. Anchor the butts of the last trees on the upstream end very tightly and low against the bank to prevent them from breaking loose when flows hit them.

Equipment — You will need a first aid kit and the following items.

For harvesting evergreens and dormant cuttings to supplement the revetment:

- Chain saw and appropriate safety equipment: hard hat, goggles, chaps, and gloves
- Tree pruning saw, long handled loppers, hand-held pruners if volunteers help in the harvest
- Pick-up truck, flat-bed truck or

tractor and trailer for transporting vegetation
- A garden tractor or golf cart can be used to drag or maneuver trees if working conditions, (number of workers available, distance from site) warrant it

For drilling holes in the trunks of cut evergreen trees, if desired:
- Drill, 1/2 or 3/4 chuck, variable speed if possible
- Drill bits for wood, appropriate chuck size:
  1/2" diameter bit if using 1/4" cable; 3/4" diameter bit if using 3/8" cable

For cutting wire or cable and tightening clamps:
- Cable cutter (1/2" dia. max) for use with a sledge hammer is a good investment if you will be constructing many revetments; hand-held cable cutters do not have replacement blades
- Electrician's tape may be used to wrap cut ends of cable
- Crimping sleeves and crimping pliers when using high tensile wire
- Wire cutters when using No. 9 fencing wire or high tensile wire
- Standard deep well 3/8 inch drive socket set, including extension, 9/16, 1/2, 5/8 sizes or a five-piece open-end wrench set, including 9/16, 1/2, and 5/8 sizes

For driving various types of anchors into the bank:
- Sledge hammers
- T-post drivers
- If using duck bill earth anchors, use a cold-roll 3/4" steel rod or rebar shaped on the end for the size earth anchor to be used (either # 68 DBI or # 88 DBI). Rods can be purchased and shaped at a local steel supplier.

Maintenance — Inspect the revetment after high water events during the first year and once a year thereafter. Replace any blown out sections. Look for any additional erosion and add more trees as necessary.

Reference: Gough, S., "Tree Revetments for Streambank Stabilization," Missouri Department of Conservation, Fisheries Division.

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614/265-6740

The guides are also available on-line as web pages and PDF files so you may print high quality originals at your location. You will find the guides on-line at:

Prepared by the Ohio Department of Natural Resources, Jim Bishop and Kathy Smith, Division of Forestry, Randy Hoover, Division of Wildlife, and Margo Fulmer, Division of Soil and Water Resources, co-authors. Input from staff of several ODNR divisions, and local, state and federal agencies are used in the development of the Ohio Stream Management Guides.
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Video Available

A copy of the video "How to Build a Stream Revetment" is available at each Division of Wildlife district office. This 20 minute video was developed by the Missouri Department of Conservation and is available by permission. To borrow or view a copy, contact any of the following staff.

District 1	(Central Ohio)	Elmer Heyob	614/644-3925
District 2	(NW Ohio)	Larry Getty	419/424-5000
District 3	(NE Ohio)	John Golz	330/644-2293
District 4	(SE Ohio)	Mike Greenlee	614/594-2211
District 5	(SW Ohio)	Randy Hoover	937/372-9261

OHIO STREAM MANAGEMENT GUIDE

Forested Buffer Strips

Guide No. 13

Trees along streams are so vital to the integrity of streams in climates like Ohio's, they are given the name "forested buffer strips." This Ohio Stream Management Guide is designed to give landowners, land managers and volunteer groups general guidance on the creation, protection and enhancement of forest areas along streams.

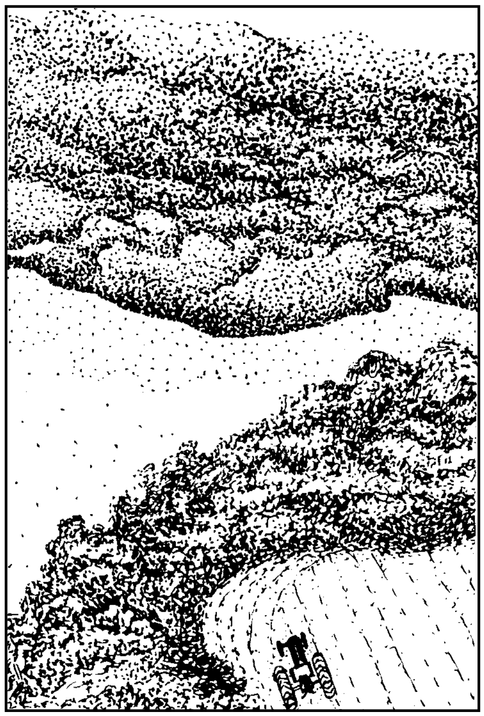

Figure 1. A forested buffer strip as seen from the air.

BENEFITS PROVIDED BY FORESTED BUFFER STRIPS

Streamside forests nurture Ohio's streams. The stream and it's adjacent land (riparian area) together form the most vital and diverse feature of Ohio's landscape. Without trees in this land-water transition zone, streams typically become wide and shallow, habitat is degraded and water quality drops.

Riparian ecosystems with forest vegetation:

- remove pollutants from stream flows during periods of over-bank flow;
- reduce water temperatures by sheltering and shading;
- provide wildlife habitat and protect and create aquatic habitat;
- provide detritus (leaves and woody debris), which is the basic source of energy for the stream ecosystem; and
- reduce streambank erosion through the high durability of tree root mass.

THREATS TO FORESTED STREAM BUFFERS

Encroachment — Meandering ribbons of trees often show up on aerial photos. Clearing trees has historically occurred last along streams and rivers leaving forested riparian strips winding through farm fields and suburbs. From a stream management perspective, we are fortunate that these areas are rough, steep and subject to flooding, making them generally less desirable for intensive land uses. However, most forested buffer strips only remain today because of decisions made independent of stream benefits. Until the importance of riparian areas is understood, forested buffer strips will be extremely vulnerable to encroachment as adjacent land uses become more intense. In fact, a major cause of buffer strip loss and stream degradation continues to be encroachment.

Overuse — Stream-side areas are often popular recreation areas, but overuse can reduce the integrity of the buffer through soil compaction and vegetation loss. High use can coexist with water quality objectives and damage limited by establishing trails and stabilized access points to the stream. Trails parallel to a stream should be set away from the banks. Provide viewing and lounging access to the stream through branches of trail which access the inside of meander bends.

Figure 2. A forested buffer between a stream and other land uses

This will minimize impacts and leave the critical vegetation on the outside banks undisturbed.

Grazing — Forested buffers are degraded by livestock. Not only is vegetation and soil damaged on the banks and uplands areas, but livestock trample and degrade the stream channel. Typical impacts include wide shallow channels with less cover, less shade, increased nitrates, increased turbidity, compacted soils and poor ground cover and understory. One Ohio study cited a 40% reduction in soil loss after livestock were fenced from a stream.

PROTECTING STEAMSIDE FORESTS

Define the Buffer Strip Width — Riparian areas are definitive land forms. They are transition zones between channels and uplands where the land influences the stream and the stream influences the land. It is in this zone that 'buffer strips' of forest vegetation have special importance for the quality of streams. Riparian areas correspond very well with the active flood plain. The active floodplain is the area that would become flooded if stream levels rose above the maximum bankfull depth (see Figure 3). Estimations of riparian area boundaries may also be based on floodplains identified on federal Flood Insurance Rate Maps. Lastly, county soil survey reports list soils 'subject to frequent flooding' which may help delineate some riparian areas.

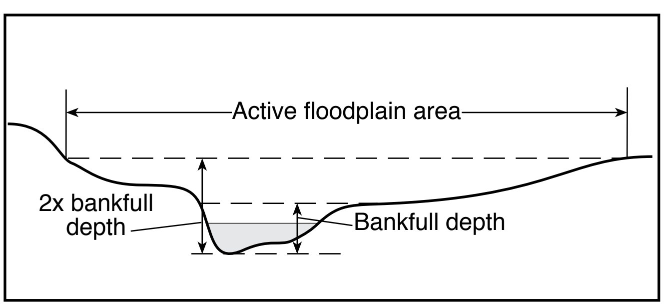

Figure 3. Buffer strip width defined by the active floodplain

It is not always feasible to base buffer strip width on the riparian area. For example, highly entrenched channels may have a riparian area hardly wider than the channel itself and in other places floodplains and riparian areas may be so extensive that encroachment is inevitable. For these conditions a generic minimum standard may be useful. One such standard is based on a dimension equal to two and one-half times the bankfull channel width or 50 feet, whichever is less (see Figure 4). This distance is then measured away from the bankfull channel to arrive at the standard buffer width.

Fence livestock from the stream — Stream fencing is a practice which keeps livestock away from the stream channel. Stream fencing projects often include stock tanks and water lines. Assistance for fencing livestock from streams may be sought through:

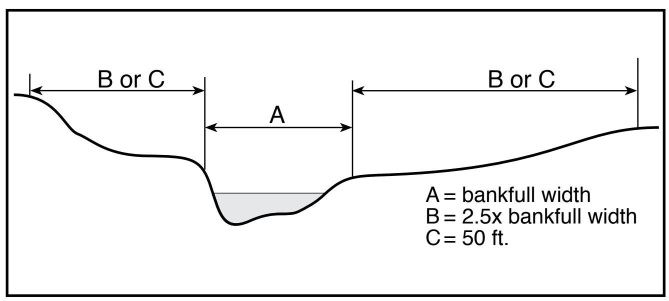

Figure 4. Buffer strip width defined by a minimum standard

- Ohio State University Extension, Grazing Coordinator, 614/ 397-0401.
- USDA-Natural Resources Conservation Service (NRCS), Grazing Coordinator, 614/ 653-1559.
- County offices for the NRCS and local Soil & Water Conservation Districts, listed under County Government in local phone directories.

Establish a Legal Easement — One of the best ways to protect riparian areas is to establish legal easements, also known as conservation easements. Easements allow you to protect your streamside forests without giving up ownership. An easement is a legal agreement that protects a land's conservation value by restricting certain actions which can be taken, even by future owners. Among other things, riparian protection easements can prohibit or restrict timber harvesting, pesticide spraying and development in the buffer strip. The landowner may receive or waive compensation. The easement is held by a legally qualified conservation organization (such as a land trust) or a government agency. Conservation easements can be tailored for each landowner and situation, so may differ from property to property.

The following private organizations and public agencies are among those who can provide you information or assistance in creating a legal easement:

- The Trust for Public Land, 612/ 338-8494
- American Farmland Trust, 202/ 659-5170
- Land Trust Alliance, 202/ 638-4725
- The Nature Conservancy, 614/ 717-2770
- Ohio Department of Natural Resources, Division of Natural Areas and Preserves, 614/265-6460
- Ohio Department of Natural Resources, Division of Soil and Water Conservation, 614/265-6637
- Soil and Water Conservation Districts, listed under County Government in local phone directories

Erect Visual Barriers — Easements alone are only lines on paper which have proven to be ineffective against encroachment. One study found that 90% of easement protected forested buffers had been encroached upon to some extent, with 45% severely degraded. Visual barriers such as fences or signs appeared to be most effective at stopping encroachment.

REFORESTATION METHODS

Allow Natural Regeneration — Simply establishing a preservation area or "no-mow" zone may be enough to allow natural forest regeneration if there are some trees nearby to provide a seed source. This may not work in areas without trees which have been farmed or have managed turf. Areas with intrusive species or dense turf may require some site preparation to improve regeneration potential.

Transplant Woody Plants — A number of sources for trees exist including commercial nurseries, the ODNR Division of Forestry, and compatible sites where you obtain permission to harvest plants. A list of flood tolerant tree species is found in Guide No. 08,Trees for Ditches. Planting dormant cuttings such as willow posts and stakes is discussed in Guide No. 07, Restoring Streambanks with Vegetation.

A combination of tree planting and natural regeneration may be a good choice for certain areas. For example, natural regeneration may be adequate for the majority of a buffer strip but trees may need to be planted adjacent to the stream to expedite streambank stabilization or to restore a tree canopy over the stream.

Species Selection:

- It is best to use a diverse mix of tree and shrub species with an emphasis on native species.
- Species should be mixed randomly across the site.
- In areas of partial shade, use a large proportion of shade-tolerant species.
- Ideally a mix of dominant tree species, understory trees and shrubs, and herbaceous plants should be planted.
- In open areas, it may be useful to mix hardier pioneer species (two-thirds) with later successional species (one-third) in recognition of the difficult environment for new plants.

Pioneer Species	Later Successional Species
Cottonwood	Swamp white oak
Box elder	Pin oak
Red maple	Black walnut
Ash (green)	Silver maple
Red osier dogwood	Hawthorn
Gray dogwood	Black haw viburnum
Silkey dogwood	Maple leaf viburnum
Sycamore	

Stocking Rates — Common reforestation stocking rates are 600 -1,000 seedlings per acre or 500 containerized stock per acre. If planting in the fall or in high use areas, seedlings are generally not recommended. Seedlings are best planted after the ground thaws and before April 14.

Soil Preparation — Depending on soil conditions, the site may benefit from pre-planting preparation, including lime and/or fertilizer, and disking or plowing.

Stabilization — A cover of annual grains such as wheat, rye or oats at 1 to 1 1/2 bushel per acre may need to be planted to temporarily stabilize soil during the establishment period. Perennial grasses are not recommended because of their competition with woody vegetation.

Maintenance — Within the first two years, monitor at least monthly during the spring and summer. Once per month in the fall and winter should be adequate. On these monitoring visits check the planted sites for soil moisture, competing vegetation, mulch and pruning needs; maintain as needed. Fertilizing is not recommended during the first two years of plant growth.

Competing Vegetation — Competing vegetation is a critical factor to monitor for during the first two years. Minimize competition from weeds and grasses through hand weeding where feasible, or mowing, mulching and use of selected herbicides.

References:

Mecklenburg, Dan, 1996, "Rainwater and Land Development, Ohio's Standards for Stormwater Management, Land Development and Urban Stream Protection," Ohio Department of Natural Resources.

Lewis, S., J. Kopec, D. Rice, 1991, "Ohio's Streamside Forests: The Vital, Beneficial Resource," The Ohio Department of Natural Resources, Division of Natural Areas and Preserves.

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Prepared by the Ohio Department of Natural Resources, Dan Mecklenburg, Division of Soil and Water Conservation, principal author. Input from staff of several ODNR divisions, and local, state and federal agencies are used in the development of the Ohio Stream Management Guides. Funding for the production of the Ohio Stream Management Guides is provided in part through a federal grant under Section 319 of the Clean Water Act.

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OHIO STREAM MANAGEMENT GUIDE

Live Fascines

Guide No. 14

Live fascines (fa-sheens) are long bundles of live woody vegetation buried in a streambank in shallow trenches placed parallel to the flow of the stream (Figure 1). The plant bundles sprout and develop a root mass that will hold the soil in place and protect the streambank from erosion. For optimum success in Ohio, fascines are constructed of thin live cuttings of willow or red-osier dogwood. These cuttings are bound together in bundles 6-8 inches in diameter and 4-20 feet in length. The name fascine comes from the Latin for 'bundle of sticks.'

The purpose of this Ohio Stream Management Guide is to describe the generally suitable site conditions, design, installation and maintenance steps for live fascines. The guidelines listed herein are a compilation of specifications from a number of sources (see References) and from field experience in Ohio. As with any construction project in a stream, the Ohio Department of Natural Resources recommends you consult with the applicable local, state and federal authorities listed in Guide 06, Permit Checklist for Stream Modification Projects, prior to construction. The extent of permit requirements will depend on the location and design of your project.

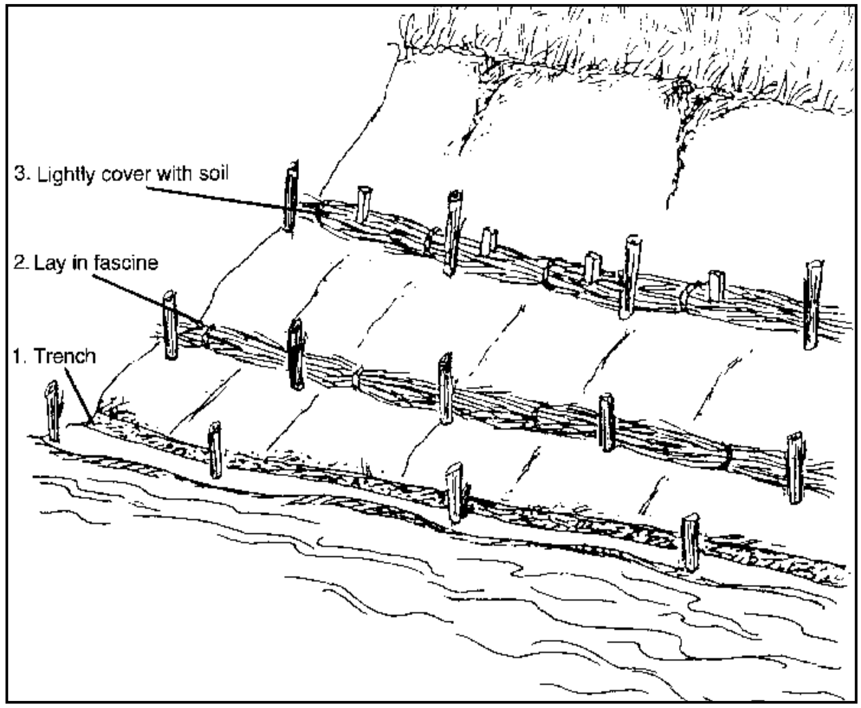

Figure 1. Live fascine construction

WHERE TO USE LIVE FASCINES

Fascines are useful in controlling erosion problems associated with over-bank run off, prior to the formation of deep gullies, and are most often used to stabilize fairly long slopes. The plant-filled trenches break up the length of the bank face, shortening each slope segment and reducing the energy available for erosion. The trenches act as a water retention system when placed horizontally or can serve as a drainage system if installed at a slight angle.

Fascines also help protect slopes from shallow slides and can be used to soak up ground water seepage which can de-stabilize a bank. Live fascines are best applied on small, headwater streams, or can be placed above the line of bank-full discharge on larger streams. They are also used to stabilize lake shorelines with shallow slopes. The lines of vegetation placed parallel to the contour of the shore can break up the erosive force of small waves since the plants grow in lines perpendicular to the source of energy.

Some site conditions and/or project objectives (such as protecting existing structures on the streambank) will require use of more traditional, structurally engineered solutions. This is particularly true where high velocity flows can be expected. In other situations, a combination of structural and biotechnical practices, like live fascines, may provide both strength and habitat. Biotechnical practices are not likely to stabilize an eroded area if streambank erosion is very prevalent in your stream, an indication that the stream is undergoing a systematic change (e.g. deepening or widening). Consulting other Stream Management Guides will help in this planning effort.

No project should be undertaken with out an understanding of the functions of stream energy and the source of any problem to be corrected. Guide No. 03, Natural Stream Processes will provide an overview of stream dynamics. Technical assistance about stream management can also be obtained at your local Soil & Water Conservation District. Its phone number is listed under County Government in local phone directories.

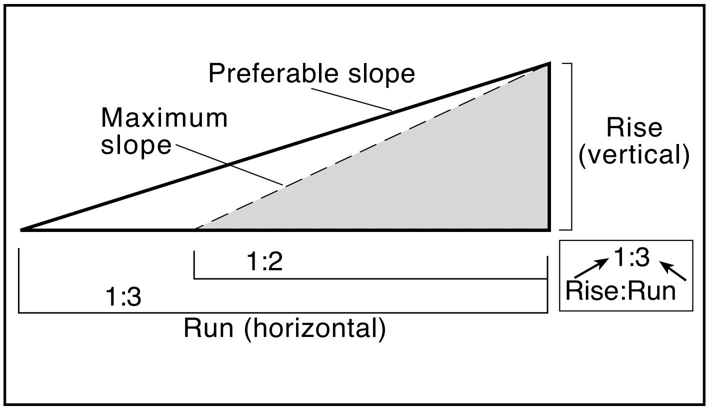

Figure 2. Rise to Run relationship

Site Requirements

For a successful installation of the practice, the bank face should be a maximum of 15 feet long. The streambank should have a slope no steeper than 1:2, that is, a one foot rise per two feet horizontal distance (see Figure 2). A slope of 1:3, that is a one foot rise to three feet horizontal distance, is preferable. Steeper banks should be excavated to this slope. The bank needs to be composed of a material that can easily be trenched and that can hold moisture to support growing vegetation; the presence and predominance of fine soil particles and organic matter will meet this requirement while banks composed of sand or gravel will not. The site will need to receive full sunlight since the live fascine is composed of tree/shrub species that are intolerant of shade.

Check the toe of the slope to see if it is stable and not threatened by scour action that will undermine it. In addition to installing the fascines, the toe of the bank slope may need to be stabilized through the use of another practice such as a revetment made from evergreen or deciduous trees (see Guide 12 Evergreen Revetments). Riprap should be used when stream flow velocities are high enough to erode the toe of the slope. Guide No. 16 Riprap Revetments describes the use of broken rock, or riprap.

INSTALLATION AND MAINTENANCE

Design

Additional project design considerations include the spacing between rows of live fascines up the face of the bank and location of the project in relation to stable portions of the streambank. The live fascine bank stabilization project must be anchored to non-eroding portions of the streambank; if it is not, the bank will erode behind the fascine rendering it useless.

The spacing of the live fascine bundles up the bank face depends on the soil type the bank is composed of. If it is a loose erosive soil, the spacing should be 3-5 feet between rows. If the soil is cohesive and less subject to erosion, the spacing can be 5-7 feet between rows. Place a row at any ground water seepage line or spring.

The bundles themselves, as previously noted, are composed of cuttings of willow or red-osier dogwood. The bundles need to contain at least five cuttings, each being a minimum of 1/2 inch in diameter. These bundles can contain some dead cuttings as long as they are in the center of the bundle leaving the live cuttings on the outside in direct contact with the soil. The cuttings must be in a dormant condition cut between mid-November and mid-March. They must be installed into the streambank within 48 hours of being cut. The cuttings must not be allowed to dry out. They must be kept moist or soaked in water before being formed into bundles and installed in the streambank.

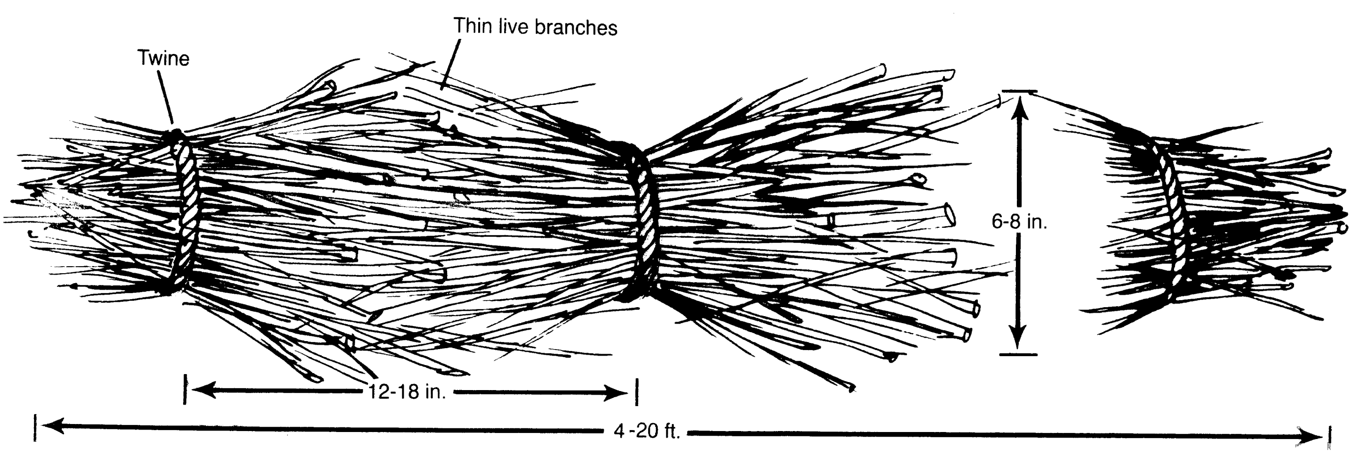

Figure 3. Fascine bundle

All the butt ends of the cuttings should point towards the same end of the bundle with the bundle ends tapered to form a cigar shape. The ends of the cuttings may be staggered along the length of the bundle to facilitate the construction of a long bundle with a maximum length of 15 feet to 20 feet. Ultimately, the bundle should be 6-8 inches in diameter. The cuttings are then bound together every 12-18 inches with untreated/un-dyed bailing twine (see Figure 3). It is helpful to make a saw-horse type frame to support the bundles at waist height as they are being tied together. The frame can be constructed of lumber or cuttings from the site. Each set of legs should extend beyond the crossbar into a "V" shape so that the cuttings can lay inside the V's while being tied together.

Construction

Excavate the bank to the appropriate slope, if needed, according to design specifications (see Table 1). Starting at the toe of the slope, dig or excavate trenches into the exposed slope at the designated spacing, parallel to the stream course. The trenches should be 10-15 inches wide and deep to accommodate the live fascines. Lay the fascines into the trench and backfill soil loosely, leaving the top of the fascine partially exposed (Figure 4). When more than one fascine bundle is used to fill the length of a trench, a slight overlap (6-12 inches) of the ends of the bundles should be used.

Drive stakes 2-3 feet in length through the live fascine to anchor the bundle into the trench. The stakes can be made of live or dead willow or untreated lumber. Live stakes 2-4 inches in diameter and 2-3 feet long, are driven into the soil immediately below the installed live fascine. These live stakes will stabilize the fascine in the bank and will also sprout to enhance the bank stabilization. Cut the ends of live stakes that will go into the earth at a 45° angle and cut the tops flat. They should be cut and installed so that the buds and branches point up.

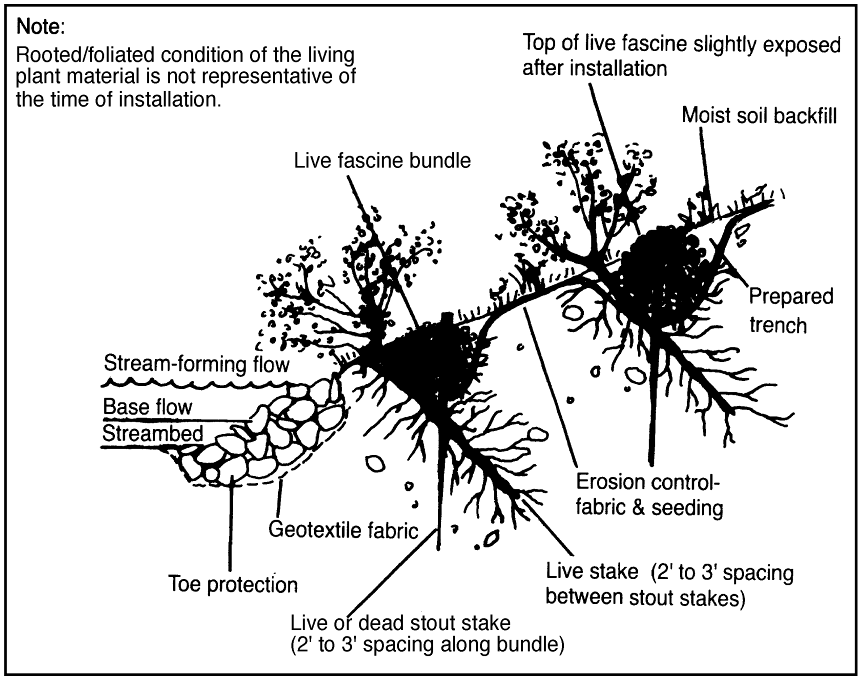

Figure 4. Live fascine cross section

Table 1. Timing of Construction and Resources

Activity	Time Frame	Sample Schedule
Stabilize bank if necessary	Period of low flow prior to live fascine installation	September 1
Bank excavation to 1:2 or 1:3 slope	December to March (but just prior to fascine installation)	November 25-30
Cut willows for fascines, keep moist at project site	December to March	December 1
Construct fascine at project site, keep moist at project site	December to March	December 2
Entrench and install fascines	December to March	December 3

Table 2 . Materials and Equipment

Activity	Required Materials	Required Equipment
Bank excavation, if needed		Backhoe. Alternately: hand tools (shovels, mattock) & wheel barrow.
Excavate trenches		Hand tools (shovels, mattock), wheel barrow, & measuring tape. Alternately: backhoe.
Construct live fascine bundle	willow (Salix spp.) or red-osier dogwood (Cornus stolonifera) cuttings, bailing twine	Saws, loppers, knives, & saw-horse type frame.
Install fascine	Live willow stakes, dead stakes	Sledge hammers & hand tools (shovels, mattock).

Materials & Equipment

The type of equipment required to install a live fascine streambank stabilization project will vary depending on the size and scope of the project, the labor available and the condition of the streambank itself (see Table 2). The tall, steep banks requiring excavation will probably need a backhoe. A backhoe may also be handy to dig the trenches for the live fascines on projects that effect longer stretches of streambank. If plenty of hand labor is available and the site permits, hand tools may be all that is required.

Maintenance

When properly designed and installed, maintenance of live fascines should be minimal. Inspect the fascine installation after high water events during the first year and once a year thereafter. Small washouts should be dealt with as soon as practicable and can be stabilized using the same or related biotechnical practice. Remove any accumulated debris which would threaten the health of the plants.

Streambank stabilization with a live fascine is achieved through live plant material. As with any live plant, health, growth and form need to be evaluated periodically to assure its continued function. As willows grow and mature, they lose their vigor and become subject to insect and disease problems. They also become brittle with age causing them to break, fall into the stream and contribute to channel obstructions. These problems can be avoided by periodic pruning of the willows to a convenient height, or down to a stump. The willows will re-sprout and the function of the stabilization practice will be maintained.

References:

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Gabion Revetments

Streambank erosion is a natural process that occurs in streams. Depending on the soil type and land use, streambank erosion can account for 40 percent or more of total soil loss in some watersheds (Farm Journal, 1992). The major factor accounting for streambank erosion is the velocity of the flowing water. Velocity is affected by the stream cross section, stream bed gradient, bank cover, depth of flow and degree of meander. Water flowing at two feet per second can move a cobblestone weighing half a pound, but an increase to ten feet per second can move a stone that weighs one hundred and fifty pounds.

There are numerous methods of controlling streambank erosion. When a streambank requires protection from high velocity flows, structural methods should be considered. Two structural methods commonly used are riprap revetments and gabion revetments. Structural methods are also used when infrastructure, such as utility lines, roads or buildings, are endangered by the eroding stream. When installing streambank protection, the velocities during everyday flows as well as the velocities during large storm events should be considered in the design process.

This Ohio Stream Management Guide describes the basic uses for gabion revetments, their installation and maintenance. Depending on the skill, equipment and labor force available to a landowner, the services of a land improvement contractor may be needed to install the revetment. Projects on larger streams and projects protecting structures or utilities should be designed by a professional engineer. Design advice and limited assistance on smaller projects may be obtained at your local Soil and Water Conservation District. Prior to purchasing materials, check the stream's water quality against the manufacturer's recommendations. If the water quality would cause premature deterioration of the baskets, other bank protection measures need to be considered.

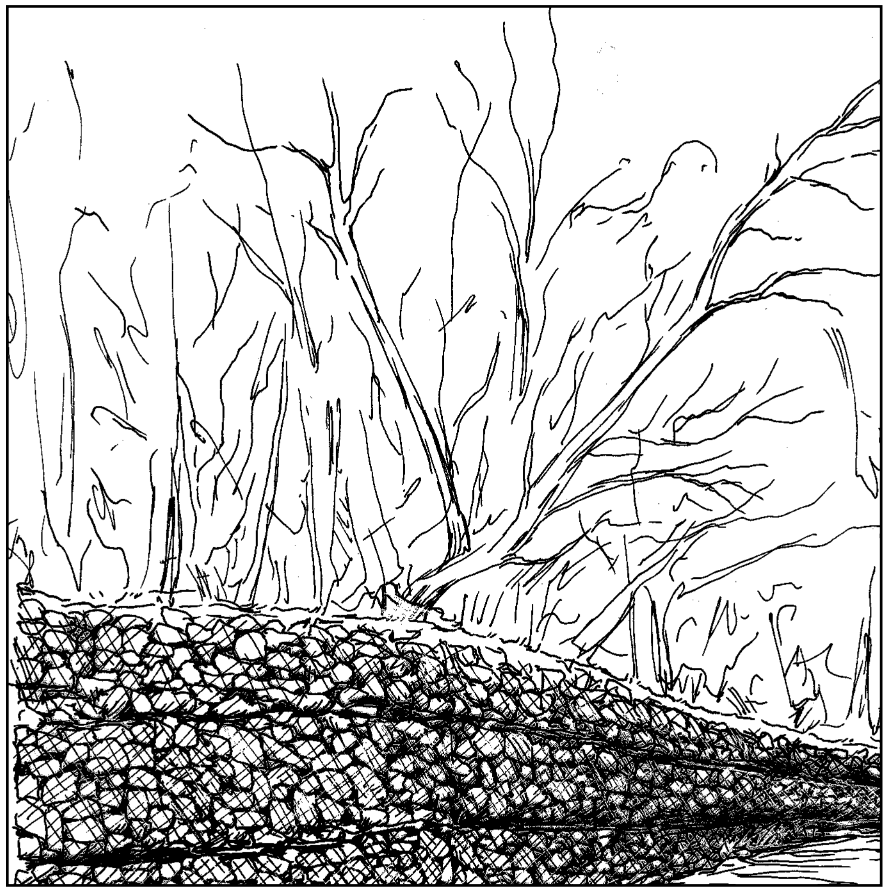

Figure 1. Gabion revetment on streambank

As with any project in a stream environment, the Ohio Department of Natural Resources recommends that you consult with the applicable local, state and federal authorities listed in Guide 06, Permit Checklist for Stream Modification Projects, prior to construction. The extent of permit requirements will depend on the location and design of your project.

GABION REVETMENTS

Gabions are stone-filled galvanized or coated wire baskets placed along a streambank. Gabions are particularly effective for protecting the submerged part of the streambank. They provide the same basic protection as riprap, but can be utilized when the streambank slope cannot be cut back due to physical constraints (e.g., roads, utilities or buildings) or when larger rock is not readily available.

SIZING

The typical size of a wire basket is three feet wide by three feet high per cell purchased in the desired length. Wire baskets can be purchased prefabricated or requiring assembly. Stone size diameter should be a minimum of four inches to prevent the stone from washing through the mesh of the wire basket.

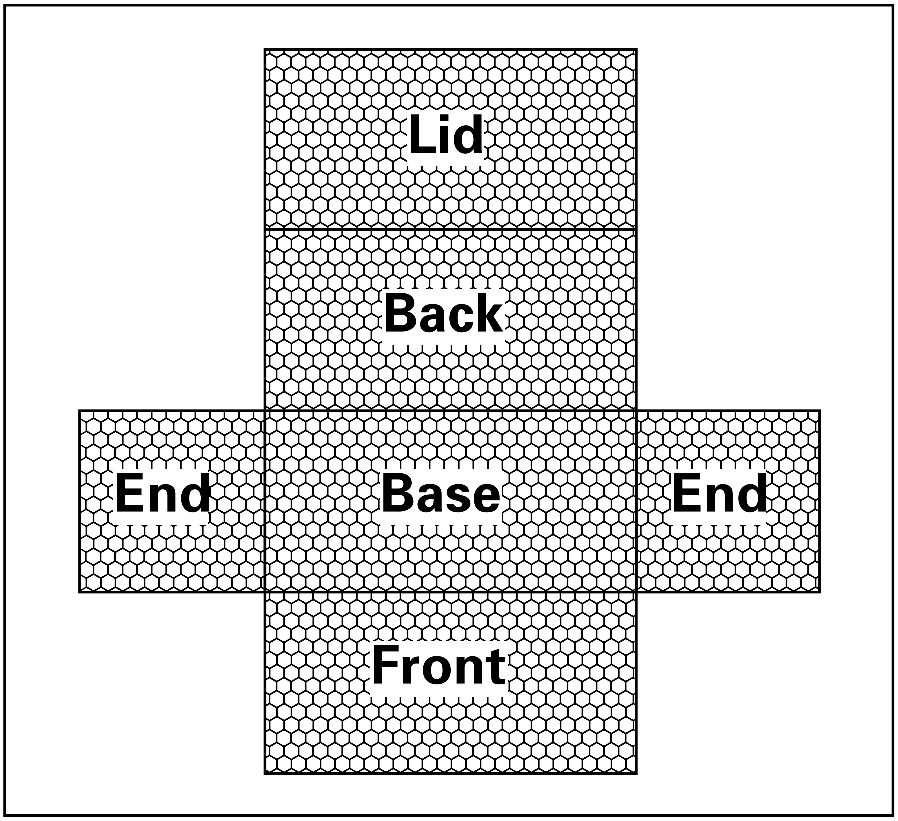

Figure 2. Gabion basket as it arrives from manufacturer for assembly

INSTALLATION PROCEDURE

Basic installation consists of the following steps; detailed installation specifications, provided by the manufacturer, should be reviewed and followed during installation. Improper installation can lead to collapse of the gabion revetment.

1. Place appropriately sized geotextile filter fabric on the streambank slope following the manufacturer's recommendations. Caution should be taken not to tear the filter fabric. A highly permeable fabric should be used.

2. Make an entrenchment into the stream bed at least one foot deep and large enough to hold the bottom row of baskets. The trench floor should be level along the project length. Pin the empty baskets into the stream bed with several steel rods that are three to four feet long.

3. Fill the wire baskets with stone. Tight layers, free of voids, should be formed when the stone is in place. A tight layer can be obtained by varying the size of the stone and may require some hand manipulation.

4. As the baskets are filled with stone, place wire reinforcements in each direction every twelve inches to retain the shape of the basket (see Figure 3).

5. Secure the tops of the baskets with a galvanized wire and

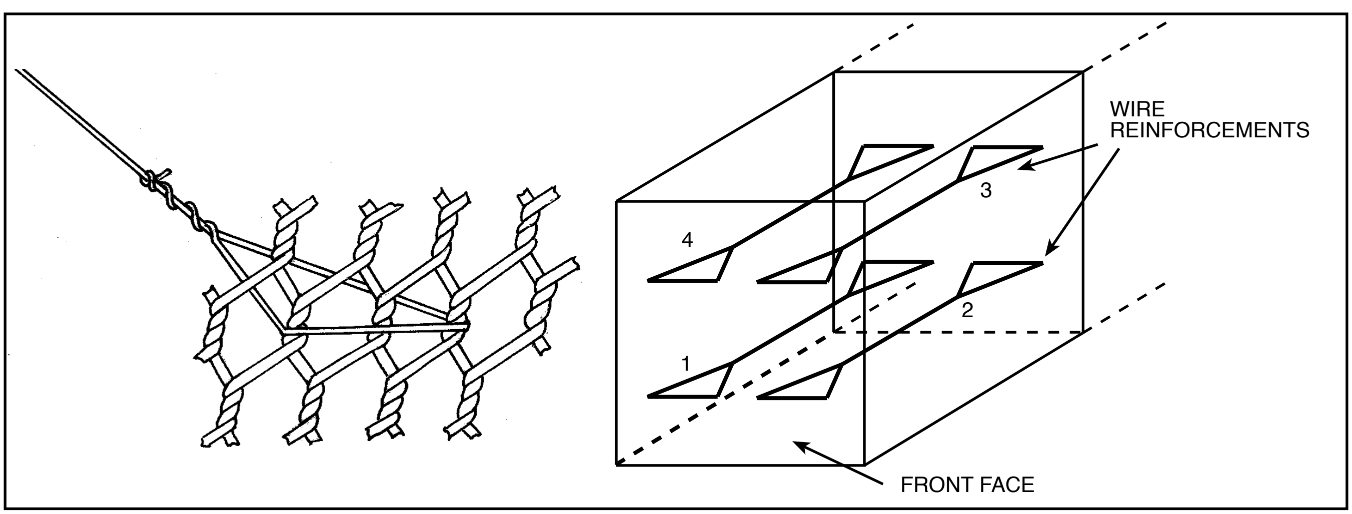

Figure 3. Use wire reinforcements to retain rectangular shape and increase stability

lace the baskets to each other (see Figure 4). The length of wire needs to be about 1.5 times the length to be laced. Wire longer than 5 feet is difficult to handle. Secure one end at a corner, and lace the wire by alternating single and double loops at 5 inch intervals. Secure the wire again at the end.

6. Stagger the joints of the wire baskets during construction to make the structure stronger and more stable. Each row should be stair-stepped back from the previous row.

7. Any open area between the filter fabric and baskets should be backfilled with gravel to provide positive drainage. Open areas should be minimal if gabions are properly installed.

8. Where sunlight is available, dormant cuttings of willow or other rapidly-rooting species may be placed between the layers of baskets during construction (Figure 5). The branches must be long enough to reach the undisturbed soil. Make sure the buds point out, toward the sunlight. See Guide 07 for information on harvesting and using plant materials.

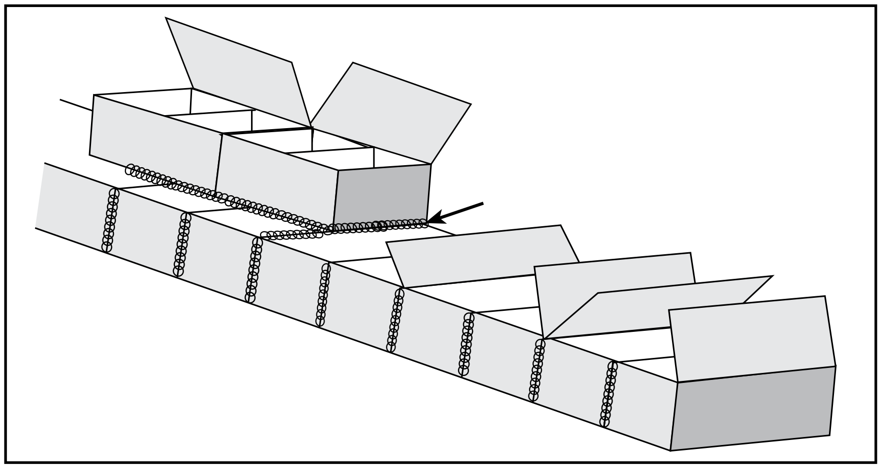

Figure 4. Wire the baskets shut and wire them to each other

MAINTENANCE REQUIREMENTS

The primary factor in maintaining a gabion revetment is in the durability of the wire used in the basket. A gabion revetment is susceptible to wire deterioration. The stream's water quality should be within the manufacturer's recommendations. Broken wire needs to be replaced with galvanized or coated wire.

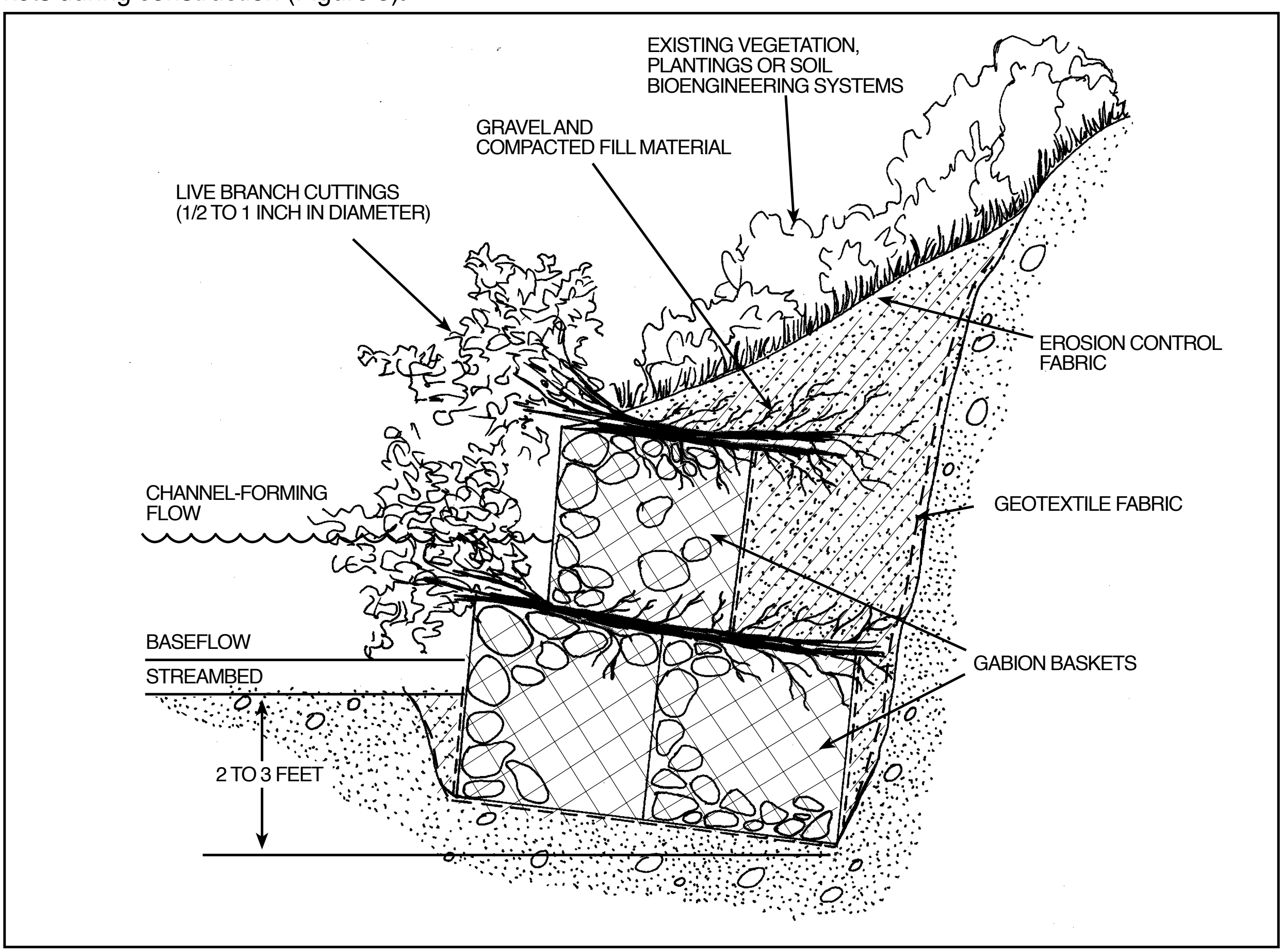

Figure 5. Cross section of vegetated gabion revetment

A gabion revetment needs to be inspected annually and after high flow events. Any displacement or shifting of the wire baskets needs to be corrected immediately.

ADVANTAGES

- Designed for high velocity flows
- Can be installed where tight physical constraints exist
- Easily fits contours of streambank
- Openings provide positive drainage of streambank
- Freeze & thaw sequences shift stones with minimal impact to structure
- Heavy machinery may not need to be used
- Minimal maintenance costs

DISADVANTAGES

- Wire baskets are susceptible to deterioration
- Labor intensive
- Installation cost may be expensive

REFERENCES:

Iowa Department of Water, Air and Waste Management. How To Control Streambank Erosion, 1984.

Smith, Darrell. "Raging Waters." Farm Journal, May 1992.

State of Ohio, Department of Transportation. Construction and Material Specifications, 1995.

U.S. Army Corps of Engineers, North Central Division. Help Yourself, 1978.

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OHIO STREAM MANAGEMENT GUIDE

Riprap Revetments

Streambank erosion is a natural process that occurs in streams. Depending on the soil type and land use, streambank erosion can account for 40 percent or more of total soil loss in some watersheds (Farm Journal, 1992). The major factor accounting for streambank erosion is the velocity of the flowing water. Velocity is affected by the stream cross section, stream bed gradient, bank cover, depth of flow and degree of meander. Water flowing at the rate of two feet per second can move a cobblestone weighing half a pound, but an increase in velocity to ten feet per second can move a stone that weighs one hundred and fifty pounds.

There are numerous methods of controlling streambank erosion. When a streambank requires protection from high velocity flows, structural methods should be considered. Two structural methods commonly used are riprap revetments and gabion revetments. Structural methods are also used when infrastructure, such as utility lines, roads or buildings, are endangered by the eroding stream. When installing streambank erosion protection, the velocities during everyday flows as well as the velocities during large storm events should be considered in the design process.

Table 1. (From Ohio Department of Transportation, Construction & Material Specifications, 1997)

Velocity of Stream During High Flows	Size Range Largest Diameter of Rock	
2 - 6 feet/second	4” - 12”; average 6”	(ODOT Type D)
6 - 8 feet/second	6” - 18”; average 12”	(ODOT Type C)
8 - 10 feet/second	12” - 24”; average 18”	(ODOT Type B)
10 - 12 feet/second	18” - 30”; average 24”	(ODOT Type A)

RIPRAP REVETMENTS

Riprap revetments are a very effective and popular method of controlling streambank erosion. A revetment is a facing of stone or other armoring material to protect a streambank or shoreline. A riprap revetment consists of layered, various-sized rocks placed on a sloping bank (Figure 1). The most commonly used material for riprap in Ohio is broken limestone, dolomite or quartzite. The type of stone used is usually determined by what is locally available. The variance in size and the rough angular surfaces of the rock allow the revetment to absorb the impact of the flowing water instead of deflecting the flow which could cause erosion to an adjacent streambank area. The rough angular surfaces of the broken rocks also allows them to fit together to form a dense layer of protection over the eroding bank.

STONE SIZE

The size of riprap to use for a given stream depends on the velocity of the water when the stream is at a bank full stage. Table 1 provides minimum size ranges for given stream flow velocities.

INSTALLATION PROCEDURE

1. Reshape the streambank to a maximum slope of two feet of horizontal distance for one foot of vertical rise.
2. Place a highly permeable and appropriately sized geotextile filter fabric on the prepared slope following the manufacturer’s recommendations. Take care not to tear the filter fabric during installation.
3. Place a layer (six inch minimum) of gravel or small rock on the geotextile filter fabric. The underlayer stone needs to be sized appropriately so it will not wash through any gaps between the riprap stones.
4. Place the layer of riprap, 1.5 times the thickness of the largest stone, on top of the gravel. The heaviest rocks should be placed along the

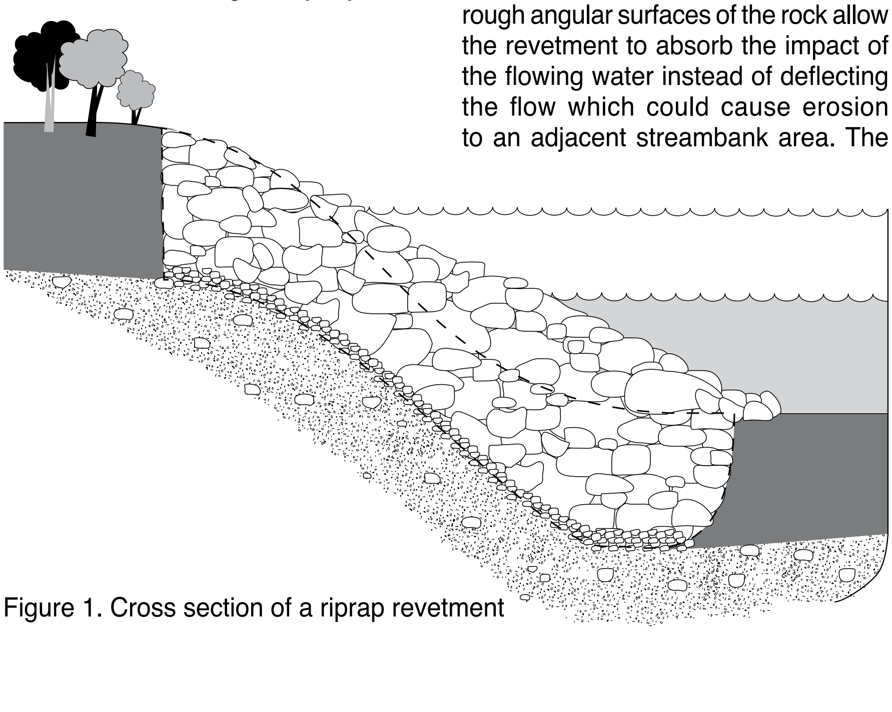


Figure 1. Cross section of a riprap revetment

bottom of the bank. Riprap should be placed into position, not dumped over the streambank edge.

5. Extend the rock layer out into the channel four to six feet or entrench the bottom row of stone into the stream bed to prevent undercutting.
6. Extend the revetment beyond the area of active erosion to prevent further erosion behind the ends of the structure.

MAINTENANCE REQUIREMENTS

A riprap revetment is susceptible to displacement and deterioration of the rock. When displacement and deterioration occur the effectiveness of the structure is greatly reduced. A riprap revetment needs to be inspected periodically and after high flow events. Any displaced or deteriorated rock should be replaced as needed.

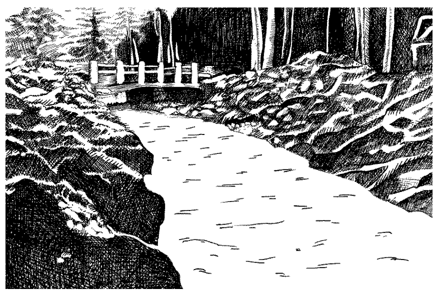
MATERIALS TO AVOID

Stones that appear to have a smooth and rounded surface should be avoided if possible. The surface of these stones does not allow the rocks to interlock which decreases resistance to movement. Broken asphalt should not be used because it has a low density and contains toxic chemicals which can leach out into the water. Items such as refrigerators, mattresses, wood and plastics should never be used because they can increase the rate of erosion and degrade the water quality of the stream. Slab concrete should only be used as an underlayer material and then only if it is broken and free of rebar.

USE OF DORMANT CUTTINGS IN RIPRAP REVETMENTS

Dormant stakes of willow (or other rapidly-rooting species) may be installed between the placed rock. The stakes must be installed perpendicular to the bank, and be long enough for the base ends to reach back-filled or undisturbed soil. Over time, dormant cuttings create a living root mat in the base soil underlying the revetment. The roots reinforce the soil particles and prevent wash out of fine materials between and under the rocks. The roots also improve drainage by removing soil moisture. The willow branches and leaves will dissipate additional energy along the streambank and may produce a more aesthetically pleasing view of the bank, as opposed to riprap alone.

As willows grow and mature, they lose their vigor and become subject to insect and disease problems. They also become brittle with age, causing them to break, fall into the stream and contribute to channel obstructions. These problems can be avoided by periodic pruning of the willows to a convenient height or down to a stump. They will re-sprout and maintain the function of the dormant cuttings.



ADVANTAGES OF RIPRAP AS AN EROSION TREATMENT

- •Designed for high velocities
- •Provides high degree of protection
- •Relative ease of installation
- •Low maintenance
- •Provides immediate long-term protection

DISADVANTAGES OF RIPRAP AS AN EROSION TREATMENT

- •Limited access to the site can make construction difficult
- •Heavy machinery may be required to position rock
- •Material costs (including transportation) may be expensive
- •Often used to hold stream in an unstable configuration
- •May pass erosion problems downstream

REFERENCES:

Iowa Department of Water, Air and Waste Management, 1984. How To Control Streambank Erosion

Smith, Darrell, May, 1992. "Raging Waters." Farm Journal.

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OHIO STREAM MANAGEMENT GUIDE

Live Cribwalls

Guide No. 17

WHAT IS A LIVE CRIBWALL?

A live cribwall is a wooden log cabin-type structure built into a streambank which is filled with rock, soil and cuttings of willow. The cuttings will sprout and develop a root mass that, in conjunction with the log structure, will armor the stream bank and protect it from erosion. The submerged rocks and logs provide excellent aquatic habitat. Well built cribwalls can last for decades as the live materials take over the structural function of the logs.

The purpose of this Ohio Stream Management Guide is to describe the applicable site conditions and design, installation and maintenance guidelines for live cribwalls. The specifications listed herein are gleaned from literature sources and not based on field experience here in Ohio. As with any construction project in a stream, it is recommended you consult with the applicable local, state and federal authorities listed in Guide 06, Permit Checklist for Stream Modification Projects, prior to construction. The extent of permit requirements will depend on the location and design of your project.

Live cribwalls are often used in conjunction with other practices that further protect streambanks from eroding forces. Compatible practices, described in other Ohio Stream Management Guides, may be selected by finding similar site requirements and applications.

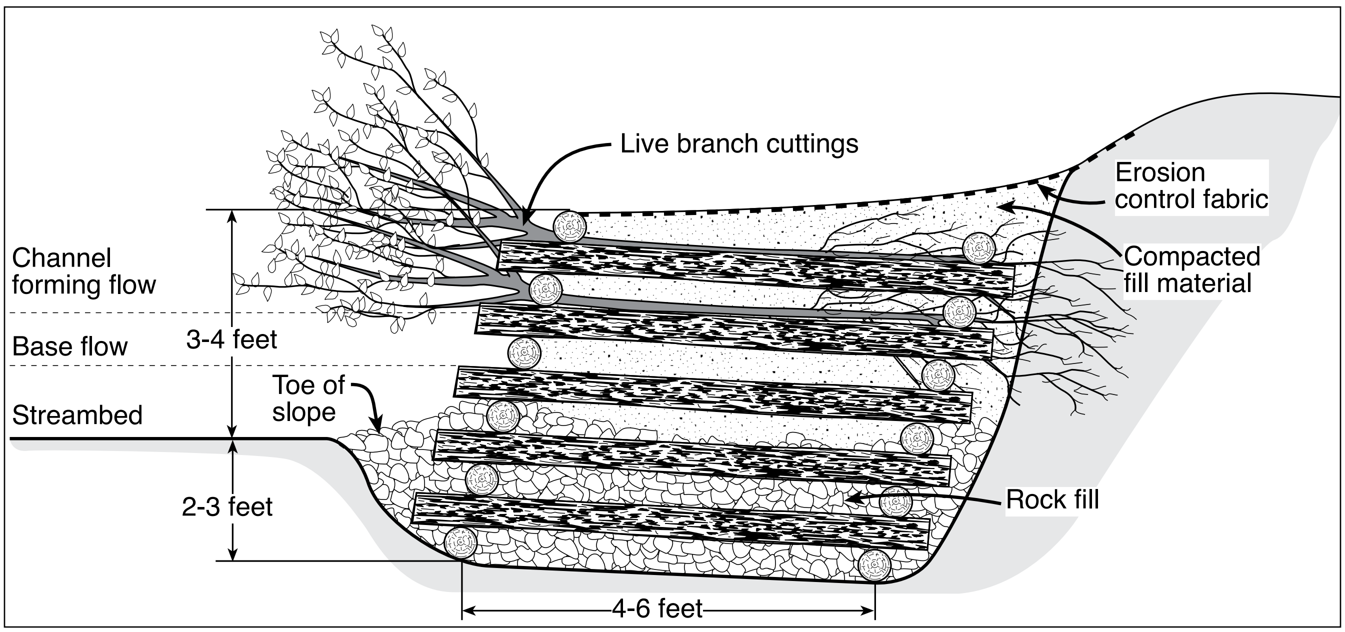

Figure 1. Cross section of a live cribwall.

WHERE TO USE LIVE CRIBWALLS

Live cribwalls are effective at reducing erosion and streambank instability on: the outside bends of streams with strong currents; where a there is a steep streambank with an unstable toe of the slope; and where immediate protection from erosion is needed while vegetation becomes established. (The toe is where the stream bed meets the bank slope.) They can be used to reduce the steepness of a slope by building a low wall to protect the toe and grading the soil above it back at a gentler grade. Live cribwalls have also been successfully used to prevent the development of a split channel in a stream. If used to protect roads, structures or utilities, a professional engineer should be involved in the design process.

These structures are not effective in locations where the stream is down cutting because the base of the structure will be undermined. The major disadvantage of live cribwalls is that it is labor and equipment intensive. They are therefore used only where the expected benefit warrants the investment.

SITE REQUIREMENTS

Live cribwalls are effective for streambank stabilization on streams up to 75 feet wide. The structures are placed along scoured or excavated areas of the bank. Therefore the streambank must have adequate room between what is to be protected and the edge of the water (existing or as designed) to allow for the placement of log cabins' that are six feet deep. To anchor the structure the channel bed must be excavated, so this practice is not applicable for sites on bedrock. The live cuttings of willow or other rapidly-rooting species require full sunlight for part of the day during the growing season to grow properly. Therefore, the site will need full sun for the cribwall to be effective.

DESIGN

The length of the eroding streambank can be treated with a number of cribwall structures each of which should not exceed 20 feet in length. The series of structures must be designed to start at and end at areas of the bank where there is no active erosion. If it is not anchored to the bank this way, the stream will scour into the soil around the ends of the cribwall, rendering it useless.

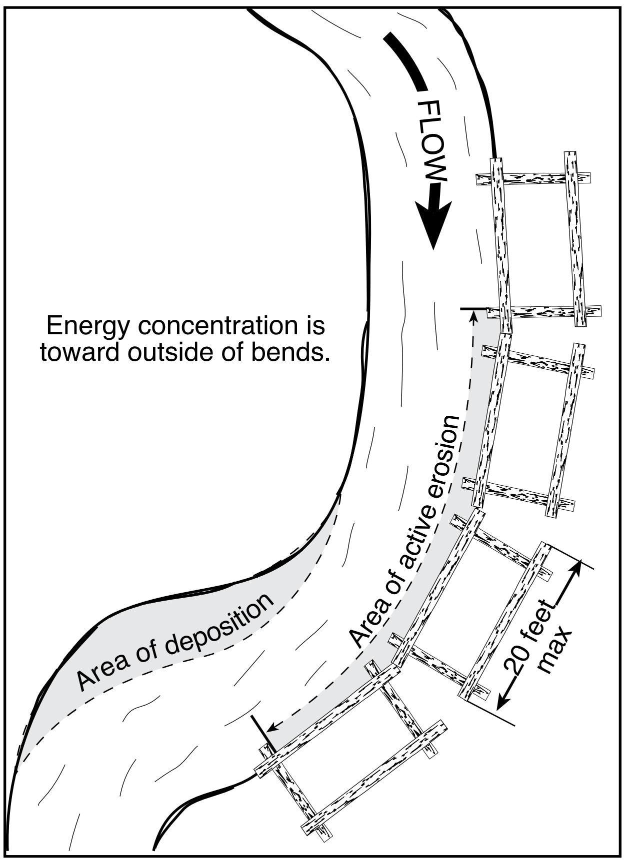

Figure 2. Placement of cribwall structures.

The structure's height depends on the elevation of channel-forming flows. The elevation at which water will flow over the low bank into the floodplain is called the bankfull flow and is considered the channel-forming flow. The bankfull flows are the most critical because they have enough energy to carry solid materials and happen frequently enough (on average every 1.5 years) for their impact to add up.

The cribwall needs to be somewhat higher than the elevation of the channel-forming flow in order to protect the outside bank (see Figure 1), but it should not exceed seven feet measured from the excavated base. If the existing bank is significantly higher than the cribwall's design height, the bank area above the live cribwall needs to excavated to a slope of 1 foot rise for every 2 foot of horizontal distance.

CONSTRUCTION AND INSTALLATION

Step 1

Collect cuttings from willow, red-osier dogwood or other rapidly-rooting species (listed in Guide 07). These cuttings must be taken from live trees during their dormancy (approximately between mid-November and late March). The cuttings can be 0.5 to 2 .5 inches in diameter at the butt end and need to be six to eight feet long. The harvest should be made no more than 48 hours prior to installation. If not using them immediately keep the cuttings moist by wrapping them in wet cloth or blankets and do not allow them to dry out.

Step 2

Construction begins with the excavation of the bank. This excavation should be done during times of low stream flow and just prior to the installation of the live cribwall. Excavation should be about six feet into the bank measured from the water's edge (either existing or as designed) at low flow. Excavation should also extend two to three feet below the existing streambed. The floor of the excavated area should be sloped so that it is one to two feet lower in the back, toward the bank. As shown in Figure 1, this will tilt the weight of the cribwall away from the water's edge, adding to its stability.

Step 3

Use untreated logs or timber members. Place two logs, four to six inches in diameter, parallel to the stream edge four to five feet apart within the excavated area. Place the second two logs perpendicular to and at the ends of the first course of logs. As in a log cabin, allow about 6 inches of overhang in each direction. The four logs should be spiked together with long nails or re-bar. Each successive course of logs parallel to the stream flow should be set back six to nine inches from the log beneath it creating a stair-step effect (see Figure 1). Continue building the log cabin-like structure with alternating courses of logs up to the level of the stream's low flow. Build the remaining number of rectangular structures along the project's length, up to the same level.

Step 4

Place rock fill material in and around the bottoms of the structures up to the existing stream bed level. The weight of the rock will counteract against the log's buoyancy, securing the structures in place. Make sure that the excavated area between the stream bed and the structures is filled with rock to protect the toe of the slope. Fill the remaining area of the crib structures with soil up to the low flow level, i.e., up to the level constructed so far. Compact the soil.

Step 5

Before adding the next course of logs, lay a row of live dormant cuttings on the compacted backfill soil. Lay the cuttings perpendicular to the flow of the stream with the bud ends protruding one to two feet out of the open face of the cribwall. The butt ends must extend into the area behind the structure so their roots will eventually grow beyond the backfilled soil into the undisturbed soil. Repeat this step until the cribwall reaches the designed height.

MAINTENANCE

As with any structure, maintenance is important to the proper and continued function of the live cribwall. During the first year after construction the structure should be inspected for maintenance needs after high flow events; it should be inspected at least annually thereafter. Check the logs for proper alignment and evidence of rot to ensure the structural integrity of the cribwall. The health of the willow cuttings growing in the cribwall is also important; should significant mortality of the willows occur, supple-

Activity	Equipment Needed
Excavate bank	Backhoe
Compact backfill	Power tamper/compactor or hand tamper/compactors
Cut and construct log cribwall: Untreated logs four to six inches in diameter and 4.5 to 20 feet long;	Chain saw & safety equipment, drill, sledge hammer; spikes or re-bar
Harvest live cuttings 0.5 to 2.5 inches in diameter at butt end; 6 to 8 feet long.	Chain saw or loppers

mental cuttings should be inserted as replacements.

Periodic inspections will also reveal cribwall failures or new areas of unstable streambank that could affect the live cribwall. Should inspection reveal either of these conditions, action to deal with the problems should be taken as soon as practicable.

USING BIOTECHNICAL PRACTICES

A live cribwall is one of several bio-technical practices described in the Ohio Stream Management Guides. Biotechnical practices use vegetative or other natural materials to achieve stream management objectives, usually erosion control. One of the chief advantages of biotechnical practices is that they help restore natural stream features, like in-stream habitat and streambank vegetation. In some situations, a combination of structural and biotechnical practices, such as a live cribwall, may provide both needed strength and habitat. The materials used for biotechnical practices are generally less expensive than for more traditional approaches, but installation is more labor intensive and may require more frequent maintenance.

Some site conditions and/or project objectives will require use of more traditional, structurally engineered solutions. This is particularly true where high velocity stream flows can be expected. Projects built to protect roads, utilities or buildings should be designed by a professional engineer. No project should be undertaken with out an understanding of the functions of stream energy and the source of any problem to be corrected. Read Guide No. 03, Natural Stream Processes for an understanding of how streams function and consult with staff at your local Soil and Water Conservation District for help in deciding which practice would be the best solution in your situation.

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OHIO STREAM MANAGEMENT GUIDE

Stream Debris and Obstruction Removal

A Proactive Landowner's Guide to Maintaining a Free-Flowing Stream

Guide No. 18

PREFACE

Over the years, Ohio citizens have frequently contacted the Department of Natural Resources seeking assistance in the resolution of problems they have encountered related to water resources. One of the most common concerns raised by private landowners involves the situation in which trees and other debris accumulate in stream channels and obstruct streamflow through their properties. These obstructions, sometimes referred to as logjams, may become large enough to disrupt existing drainage patterns and contribute to flooding. In-stream debris often gets lodged behind bridge and culvert openings, which can cause higher flood levels and result in additional land inundation and property damage. Some streams also serve as recreational boating resources, and logjams may interfere with canoeing or other small watercraft navigation. This fact sheet poses some of the frequently raised questions regarding logjams, and provides responses from the Ohio Department of Natural Resources.

WHAT IS A LOGJAM?

A logjam is any woody vegetation, with or without other debris, which obstructs a stream channel and creates a backwater condition. Logjams occur naturally, providing beneficial stream structure and cover for fish and wildlife and allowing nutrient-rich sediment to be deposited on adjacent floodplains. However, Ohio's streams are also expected to function as efficient drainage outlets, conveying water off the land in a timely manner. Logjams may inhibit this drainage function.

DO LOGJAMS CONTRIBUTE TO FLOODING?

Yes, especially during small-scale floods. Since a logjam and the backwater pool created behind it take up volume in the stream channel or floodplain, less natural storage is available when a flood event occurs. This can elevate the level of small-scale flood events, those that occur several times a year. Such impacts can be significant to farm fields and residences in the floodplain and to particularly low-lying, flood-prone areas. A logjam can also lengthen the duration of inundation during these floods, which can have a significant impact on crops planted in floodplain fields.

The amount by which a logjam reduces the floodplain's natural storage capacity is inadequate to make a significant difference in flood elevation during large-scale flood events. Thus, removing logjams is generally not considered an effective measure to mitigate large-scale floods. Large-scale flood events can create, relocate, or enlarge logjams, though, by carrying debris from the floodplain into the stream channel and blocking bridge and culvert openings, resulting in localized impacts.

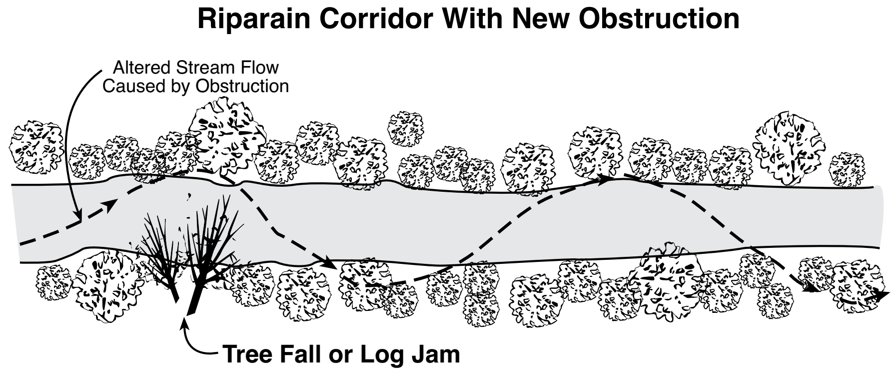
HOW DOES A LOGJAM FORM?

A logjam most commonly forms when a relatively large object, often a tree that has fallen into a stream channel, becomes wedged or blocked across the streambed. Sometimes human activities induce stream obstructions, like when trimmings from tree pruning or large appliances and other litter are dumped in a stream or left in a floodplain and subsequently are carried into the stream by high water. When an object obstructs the channel, it slows the flow and creates a pool of water behind it. As the water slows or stops behind the object, sediment suspended in the water settles out. The deposited sediment adds to the obstruction and causes additional debris to be trapped on and behind it. As more sediment and debris accumulate around and behind the obstruction, the logjam becomes larger and more tightly packed, forming a natural dam across the stream.

WHY SHOULD LOGJAMS BE REMOVED?

The formation of a logjam is a natural phenomenon and there are beneficial as well as detrimental impacts. A logjam provides structure and cover for fish and other aquatic organisms. The pool created behind the logjam provides critical aquatic habitat during low flow conditions, and the stirring and mixing oxygenates the water as it cascades over, around, and through the logjam.

A logjam may also negatively impact the stream. A tightly packed stream obstruction can act as a barrier to fish migration. Other problems caused by logjams are more insidious. A stream's energy is naturally channeled toward the route of least resistance, which is often around the obstruction. As the stream's flow is directed around an obstruction, it scours away the stream bank until a new channel is created. As the stream flows in its new channel around the logjam, it is re-directed toward the opposite bank. This begins a process, depicted in Figure 1, in which the stream's energy is directed subsequently from one bank to the other as the water flows downstream, eroding the stream banks and undercutting riparian vegetation as it creates a series of meanders. In an undeveloped watershed, where the streamside vegetation on a newly cut channel is similar to the vegetation on the original channel, such meandering and channel relocation is not really a problem. In a developed watershed, where the streamside vegetation consists of a narrow corridor with adjacent farm fields and housing tracts, stream meandering and relocation can inflict considerable riparian property damage and also degrade the quality of the stream habitat as the limited riparian habitat is destroyed.



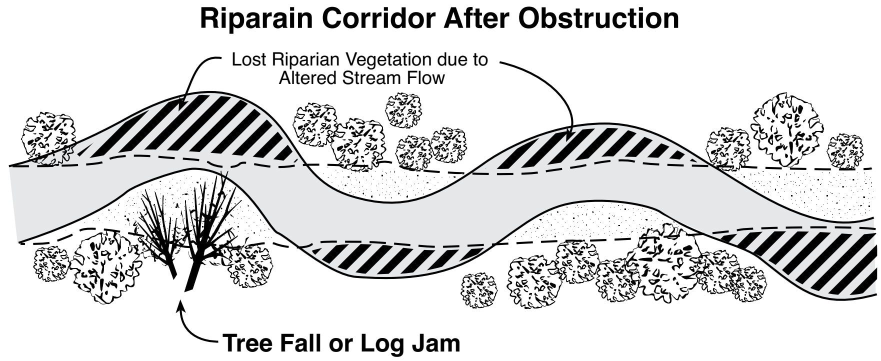


Figure 1. Effects of Obstruction on Riparian Corridor

IS THERE A GOVERNMENT AGENCY RESPONSIBLE FOR REMOVING LOGJAMS IN ORDER TO KEEP OHIO STREAMS FREE FLOWING?

No. Governmental entities at the municipal, county, state, and federal levels have the statutory authority to undertake stream clearing and drainage improvement projects, but no governmental entity at any level has been assigned by statute the responsibility for such logjam removal activities. For more information on legal responsibilities regarding logjams see Guide 02, Who Owns Ohio Streams? The Ohio Department of Natural Resources recommends that, before an obstruction removal project is begun, there should be consultation with the applicable local, state, and federal regulatory agencies listed in Guide 06, Permit Checklist for Stream Modification Projects. The extent of permit requirements will depend on the location and design of the particular project.

Technical, educational, and other assistance may be available for obstruction removal projects. Township trustees, county engineers, soil & water conservation districts, conservancy districts, local emergency management agency and floodplain management coordinators, and staff with The Ohio State University Extension may all be possible sources of information or assistance to individuals. State agencies (e.g., the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency) and federal agencies (e.g., the USDA Natural Resource Conservation Service) may also provide assistance to organized groups. Successful logjam removal projects have been undertaken in Ohio on many streams, some by volunteers and others using state and local appropriations and/or landowner assessments.

ARE RIPARIAN PROPERTY OWNERS REQUIRED TO REMOVE LOGJAMS FROM STREAMS ON THEIR PROPERTY?

Landowners generally are not required by statute to remove logjams from streams on their properties. Statutes do exist that grant county commissioners (Ohio Revised Code ß 6151.14) and township trustees (Ohio Revised Code ß 505.82) the authority to remove stream obstructions on private property and charge the costs of removal back to the property owner; however, these statutes are rarely used. The common law also does not specify that landowners must keep the streams flowing through their properties clear of natural obstructions. An obstruction to streamflow on one property can result in damages to upstream properties by reducing the stream's capacity for conveying runoff, contributing to flooding, or reducing the effectiveness of artificial drainage systems. Landowners have the right to pursue civil litigation for damages to their property caused by the unreasonable actions of others, but it is unclear whether a landowner's inaction in failing to remove natural stream obstructions could be successfully litigated. For more information on this subject, see Guide 02, Who Owns Ohio Streams?

While they are not required to remove logjams, landowners can contribute to the stability and overall health of their streams by proactively removing obstructions to flow. Such activities, especially on streams with limited riparian habitat, help maintain the multiple use nature of streams for fish and wildlife, drainage, recreation, and other purposes. A regular program for stream maintenance and obstruction removal may alleviate the need for a large, expensive channel restoration project later on.

HOW SHOULD IT BE DETERMINED WHAT ACTIVITIES ARE NEEDED ON A STREAM?

The easiest way to deal with logjams is to remove them before significant sediment and debris has been deposited. Riparian landowners should conduct routine stream inspections twice a year to identify fallen trees and other debris on their properties that need to be removed from the stream and floodplain. Special inspections should be made following large storm events, during which debris is commonly deposited. A volunteer organization could be formed to undertake annual stream walks or canoe trips of the entire stream (with landowner permission and support) to identify obstructions that need to be removed, develop a work plan of needed activities, and perhaps even assist landowners in the obstruction removal. Such a group can serve a valuable function to riparian landowners by building support throughout the watershed for a regular inspection and maintenance program.

HOW SHOULD STREAM OBSTRUCTIONS BE REMOVED AND WHAT TOOLS ARE NEED?

Fallen trees and other debris in the floodplain should be removed, buried, or secured as soon as possible. Fallen trees and other debris encountered in the stream should be removed at the earliest appropriate time. Standing trees should be left as they are. All debris should be buried, secured, or removed from the floodplain so that it won't be re-deposited during the next flood. Debris removal should be conducted only during low flow periods, which typically occur during late summer, autumn, and winter. Small debris can be removed from the channel without any tools or equipment. Larger logs and trees across the channel will need to be cut into manageable pieces and dragged out of the stream. Accumulated sediment can be raked and grubbed to remove vegetation. Large equipment should not be placed within the stream channel. Any disturbed areas along the stream channel should be seeded immediately to avoid unnecessary streambank erosion. If stream bank erosion has already occurred where a logjam has been removed, bank stabilization may be appropriate. For more information on bank stabilization methods, see Guide 07, Restoring Stream Banks With Vegetation, Guide 08, Trees for Ditches, Guide 11, Tree Kickers, Guide 12, Evergreen Revetments, Guide 13, Forested Buffer Strips, Guide 14, Live Fascines, Guide 15, Gabion Revetments, Guide 16, Rip Rap Revetments, and Guide 17, Live Cribwalls.

The following equipment is typically used for logjam removal projects: hand tools to facilitate removal of small debris; articulated log skidders with cable winches to remove larger logs; a chain saw or reciprocating saw to cut large logs and trees to manageable size; an adequate length of cable, chain, or rope to attach to the logs to facilitate their removal; a tractor, truck, or team of draft horses on the top of the stream bank to pull the logs out of the stream; and a wagon or truck on which to load the debris for subsequent removal from the floodplain.

Large logjams that are already well established need to be left for properly trained and equipped crews to remove. Specialized power equipment and explosives should never be used by anyone other then highly trained experts. The use of expensive and elaborate equipment is often not necessary when landowners take the time to perform routine maintenance and upkeep on their properties.

WHAT PRECAUTIONS SHOULD BE TAKEN BEFORE AND DURING AN OBSTRUCTION REMOVAL PROJECT?

The Ohio Department of Natural Resources recommends a consultation with the county engineer and local floodplain coordinator prior to initiation of an obstruction removal project. All tractors and other wheeled or tracked vehicles need to be kept out of the stream channel and well away from the top of the bank. Logjam removal activities should never be attempted alone, and a crew leader should be appointed to keep visual contact with everyone on the crew. The utmost caution should be taken to protect the personal safety of all workers. To avoid unnecessary damage to the streambank or riparian corridor, a single route to and from the project site should be utilized.

REFERENCES

Mecklenburg, Dan, Rainwater and Land Development—Ohio's Standards for Stormwater Management, Land Development, and Urban Stream Protection, 2nd edition, 1996, the Ohio Department of Natural Resources in cooperation with the USDA Natural Resources Conservation Service and the Ohio Environmental Protection Agency.

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For more information about the project call ODNR, Division of Soil and Water Resources at 614/265-6740. Each Guide is designed to be easily and clearly reproduced and can be bound in a notebook. Single copies are available free of charge. When distributing guides at meetings or in mailings, please use printed editions as a master for reproducing the number of copies you need, or you may print high quality originals from PDF files available on-line at: http://www.ohiodnr.gov/soilandwater/

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OHIO STREAM MANAGEMENT GUIDE

Deflectors

Guide No. 19

DESCRIPTION

Deflectors, also called hard points or wing deflectors, are spurs of rocks, logs or gabions that extend from the bank into the stream. They stabilize streambanks by directing current away from the banks, which creates slack water adjacent to the banks and dissipates the stream's energy. They also add diversity to the channel by concentrating the flow and creating deep pools. Alternating deflectors in a straight channel can encourage a meandering pattern with a narrower, deeper flow. Double deflectors, spaced opposite each other, can cause a long, deep scour hole to form downstream.

CONDITIONS WHERE PRACTICE APPLIES

Deflectors are described here for use in modified channels having uniform shape and little cover or in small streams with unstable banks. There is a much wider range of applications for deflectors but they are beyond the scope of these standards.

DESIGN CRITERIA

Materials:

Rock--The best materials for deflectors are often large rocks, preferably angular in shape to allow interlocking. The larger rocks should be arranged near the point of the deflector. Soil may be filled around the rocks and willow post may then be planted.

Logs--Logs and timber also may be used for deflectors. Because the logs, which are not continually submerged, will eventually decay, the design should incorporate live plant material to take over the deflectors' function.

Effect on Direction of Flow--All deflectors direct the flow toward the opposite bank at low-stream stages; however, during high stages, their effect may be different as shown in Figure 1. When deflectors are submerged the flow will be directed perpendicular from the downstream edge. If the downstream edge of a deflector faces the streambank, it will force the current into the bank immediately downstream and cause erosion or "back-cutting." To avoid erosion of the adjacent bank, the downstream edge of deflectors must always face directly downstream. This can be achieved with triangular or wedge-shaped deflectors. It can also be achieved with linear deflectors but only if it is angled upstream. These are sometimes called vanes and should form a 20-degree angle with the upstream bank.

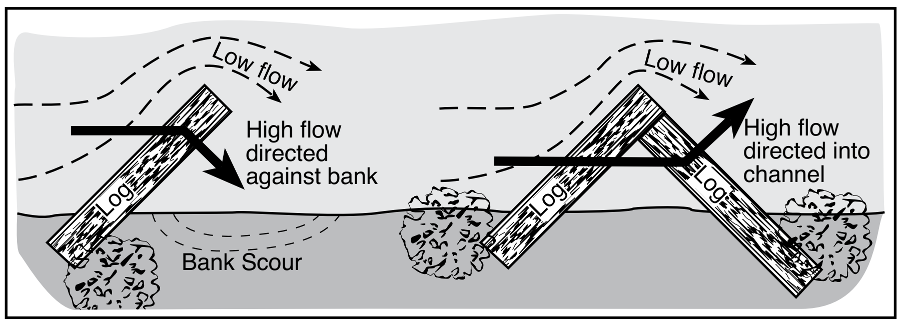
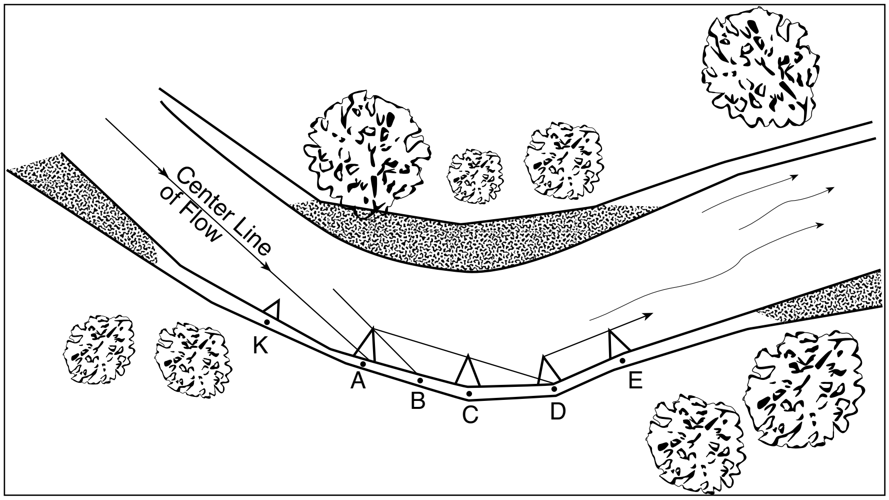


Figure 1: Deflector design to avoid directing high flow against streambank

Planting--Live plantings should be incorporated into current deflectors. Some of the best examples of current deflectors are the ones that old sycamore trees have formed naturally where the streambank has eroded slightly and the remaining lattice of roots acts as an anchor to the soil. Live plantings are not only beneficial in decreasing streambank erosion but also restore a more natural biotic habitat and moderate temperature regimes in streams.

Riprap—To prevent erosion of the streambank, riprap may be needed to protect the bank upstream and downstream from the deflector. Depending on the bank configuration, riprap should extend in each direction one to two times as far as the deflector extends into the channel .

Length--The deflectors should project into the stream channel about one-fifth to one-third the width of the channel.



Fgure 2. Deflector spacing on outside of bends.

Depth--To prevent undermining, the body of the deflector should be embedded into stable streambed substrate. Where a lot of scour is anticipated, the deflector's tip may be supported with large footer rocks entrenched beneath and slightly downstream of the deflector.

Height--Deflectors should project above the water surface during low flows and be submerged during high flows or when flows are at bankfull. If less turbulence and bed scour are desired, the deflector may be sloped from the bankfull elevation at the bank, down to the elevation of normal low flow at the tip.

Configuration and Spacing--Depending on the purpose of the deflector, the following spacing criteria should be used:

1.Alternating--Deflectors used to create meanders or narrow the width of a low-flow channel should be placed on alternating banks a distance equal to five to seven stream widths apart or based on meander spacing of similar undisturbed portion of the stream. Alternating deflectors should not be used in unstable channels or where erosion is likely to be a problem on the opposite banks from the deflector. Keeping the deflectors low will lessen this potential.

2.Streambank Protection--Deflectors can be used to control streambank erosion on the outside bends of meanders. Note that deflectors constructed for this purpose usually require about the same amount of rock as armoring the bank with riprap. To position the deflectors, see Figure 2 and use the following procedure:

- First, identify the centerline of flow before it enters the eroding bend. Point A is located by extending the center line to intersect the eroding bank.
- Next, draw a line parallel to the center line of flow and through the tips of the deflector to be constructed at Point A. The intersection of this line with the bank is Point B. The distance from deflector A to the next deflector, C, is twice the distance from Point A to B.
- The location of deflector D is determined by drawing a line through the tips of deflectors A and C to the line's intersection with the eroding bank. Each successive deflector is located the same way.
- An additional deflector, K, should be constructed upstream from deflector A. The distance upstream should be the same as the spacing between deflectors A and C. Deflector K should be about half the length of the other deflectors.
- The entire section of bank instability should be protected by the deflectors. If erosion occurs upstream of point K, additional deflectors are needed.

3.Opposite--Deflectors can be constructed one on each bank opposite each other. The restricted flow will create a scour hole downstream and narrow the stream.

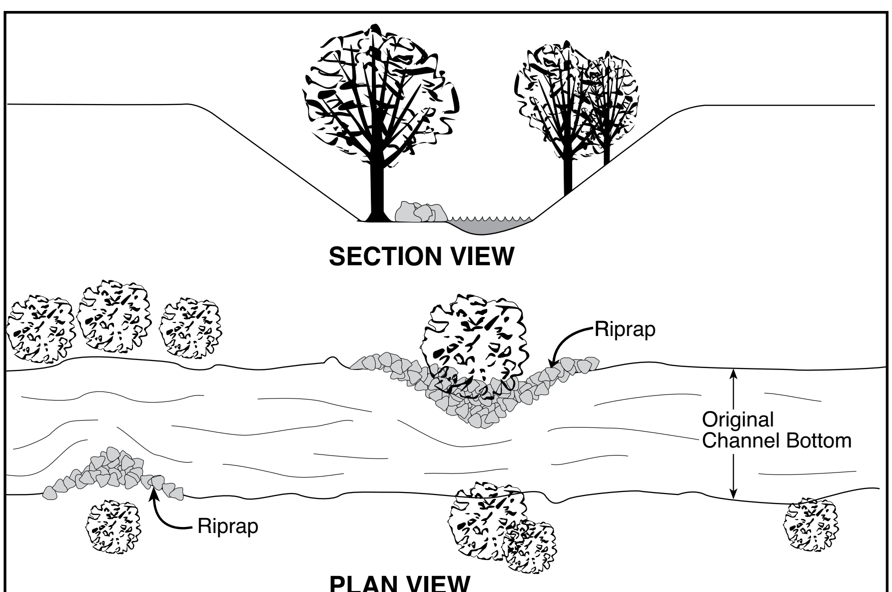


Figure 3: Alternating patterns of deflectors in straight channel

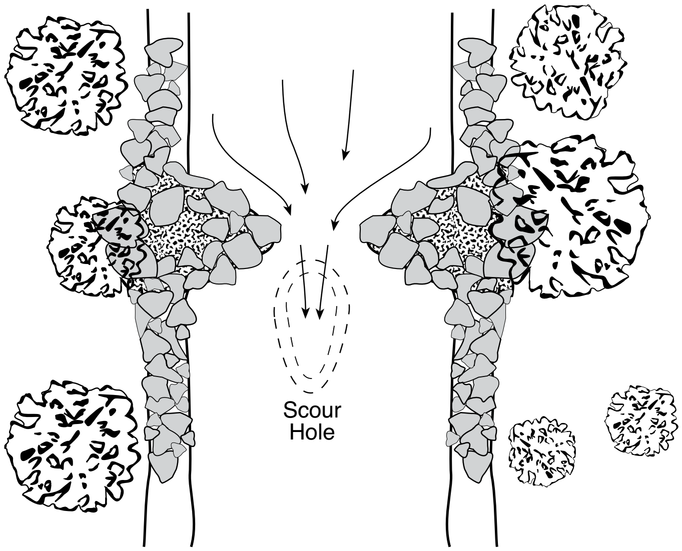


Figure 4: Opposite pattern of deflectors

SPECIFICATIONS FOR DEFLECTORS

1. Logs and timbers used in the deflector should be untreated hardwood in good condition. They should be placed in a trench cut into the channel bank so that half the log is buried and half projects into the channel. The trench shall be backfilled and compacted.

2. The height of deflectors should allow them to project above the water surface during low flows and be submerged during high flows.

3. Rock used in the deflectors should be large enough to be stable for high flows. The largest rocks should be arranged near the point of the deflector. Riprap used to protect the bank should be ODOT Type C rock. With a diameter of 6”-18” on average.

4. The voids in the rock and riprap shall be filled with soil and aquatic vegetation should be planted.

REFERENCES:

Firehock, K. and J. Doherty, 1995, A Citizen’s Streambank Restoration Handbook, Izaak waltonLeague.

Gough, S., “Tree Revetments for Streambank Stabilization,” Missouri Department of Conservation, Fisheries Division.

USDA, Natural Resource Conservation Service, 1996, “Streambank and Shoreline Protection”, Engineering Field Handbook, Chapter 16.

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This Guide is one of a series of Ohio Stream Management Guides covering a variety of watershed and stream management issues and methods of addressing stream related problems. The first several guides in the series are overview guides intended to give the reader an understanding of the functions and values of streams. For more information about stream management programs, issues and methodologies, see Guide 05 Index of Titles or call the ODNR Division of Soil and Water Resources at 614/265-6740. All Guides are available from the Ohio Department of Natural Resources. Single copies are available free of charge and may be reproduced. Please contact:

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OHIO STREAM MANAGEMENT GUIDE

Eddy Rocks and the Importance of In-Stream Structure

Guide No. 20

Eddy rocks, as illustrated in Figure 1, are groupings of large rocks placed in a stream channel to improve the habitat structure. As the stream flows over the rocks, the diversion of the current scours holes in the channel bottom, this adds oxygen to the water and creates a more diverse habitat for fish.

Many streams in Ohio have been modified to increase their capacity to convey stormwater. This has most often been achieved by straightening the channel alignment and lowering the bed to increase channel slope and velocity. An increase in velocity and in the stream's capacity to transport additional sediment and suspended load can, over time, straighten the channel and reduce its roughness. Although these practices greatly improve the efficiency with which stormwater can be carried away, this kind of channel modification degrades the stream's natural value, destroys aquatic habitat and degrades water quality.

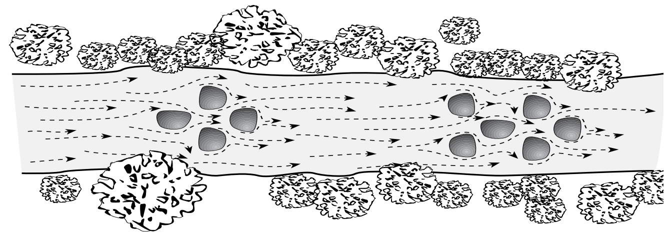

Figure 1. Eddy Rocks During Low Flow Conditions

Reducing channel roughness removes much of the in-stream structure that provides habitat for fish and other aquatic life. Reinstalling some of this structure through biotechnical practices (methods that use vegetation and natural materials to restore channel roughness) provides hiding, spawning and feeding areas for fish. This also increases the substrate suitable for benthic (bottom dwelling) organisms to become established and support a healthier, more diverse aquatic ecosystem. Other biotechnical practices, such as establishing streamside vegetation to enhance in-stream structure, can vastly improve a stream's value as an aquatic habitat while maintaining much of its ability to convey runoff.

The purpose of this Ohio Stream Management Guide is to describe the generally suitable site conditions, design and installation of eddy rocks. The guidelines listed herein are a compilation of specifications from agencies in other states and from field experience here in Ohio.

DESIGN

Eddy rocks provide substrate for benthic organisms, aerate the water and create scour holes. The scour holes provide cover for fish and serve as mini-pools to preserve aquatic life during periods of low flow. Eddy rocks also dissipate high-energy flow and improve the appearance of channels.

The rocks as described herein, are best utilized in small streams or modified channels that have a uniform shape and little canopy cover. They are useful where erosive forces should be reduced, where habitat should be enhanced, and where the appearance of a channel could be restored to a more natural condition.

The placement of the Eddy Rocks is critical for optimal results. The objective is to place each rock so that high streamflows tumble over it, creating an eddy effect as shown in Figure 2. This current will cause the water to scour a hole downstream of the rock.

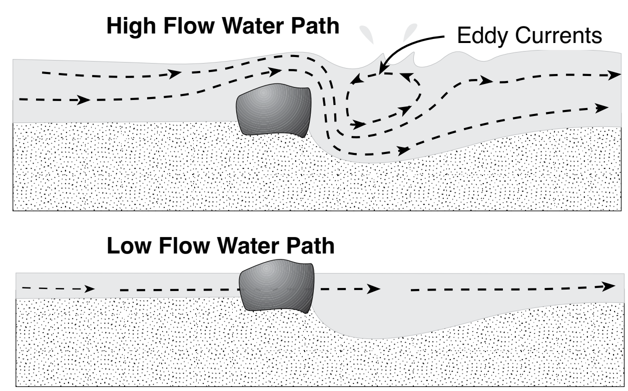

Figure 2. Effects of Flow Levels on Eddy Currents

Selecting rocks of the appropriate size is critical so that they resist being moved by high streamflows. If the channel bottom is stable, a rock two feet in diameter (about 1,000 pounds) will resist movement in streamflow velocities up to 10 feet per second. A rock four feet in diameter will be stable in velocities up to about 13 feet per second. The maximum rock size in its largest dimension should not be greater than one-fifth the width of the channel. In small channels with a gradient of more than three percent, rocks may be up to one-third the channel width. If rocks of sufficient size are not available or accessible to the site, root wads may be substituted. Root wads, however, must be anchored securely to the streambed with cable fastened to a duck bill, or other suitable anchors. Refer to Guide 12, Evergreen Revetments, for a discussion of anchors and anchoring.

INSTALLATION PROCEDURE

1. Eddy rocks should be larger than 2 ft. in diameter except in small channels where they should be no more than

one-third the width of the channel

2. Groups of three to seven rocks should be placed in a staggered pattern so current deflected around one rock then flows into another.
3. Eddy rocks should be placed in the center half of a channel in straight runs where they would be in swift current during high flow. However, they should not be placed in existing riffles.
4. Rocks should be placed with their longest dimension perpendicular to the flow, not angled to one bank or the other.
5. Rocks should be placed so they will project above the surface during low flows and be submerged during high flows. Also, they should be placed in an excavation so that they are at least one-third buried in the channel-bed.

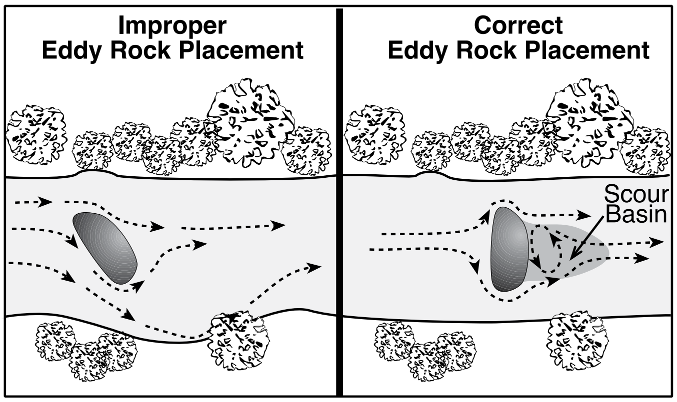

Figure 3. Effects of Eddy Rock Placement

MAINTENANCE

Inspect the eddy rocks after high water events during the first year and once a year thereafter. Displacement of a rock may require a deeper excavation into the streambed before placing it back into position. Look along the streambanks around the eddy rocks for any erosion that may be occurring. If it is determined that the rocks are redirecting the stream's energy into the adjacent bank, the rocks will need to be rearranged in order to avoid further streambank erosion.

As with any construction project in a stream, the Ohio Department of Natural Resources recommends you consult with the applicable local, state, and federal authorities listed in Guide 06, Permit Checklist for Stream Modification Projects, prior to construction. The extent of permit requirements will depend on the location and design of your project

The installation of eddy rocks is one of several biotechnical practices described in the series of Ohio Stream Management Guides available online at the Ohio Department of Natural Resources' website. These practices use vegetation or other natural materials to achieve stream management objectives. One of the chief advantages of biotechnical practices is that they help restore natural stream features such as in-stream habitat and streambank vegetation. Guide No. 10, Biotechnical Projects in Ohio, provides an overview of biotechnical practices, maps over 50 project sites, and lists contacts who can arrange site visits. No project should be undertaken without some understanding of the functions of stream energy and the source of the problem to be corrected. Guide No. 03, Stream Management and the Stream's Natural Processes, provides an overview of stream dynamics. Technical assistance about stream dynamics can also be obtained at your local Soil & Water Conservation District, which is listed under county government in local phone directories.

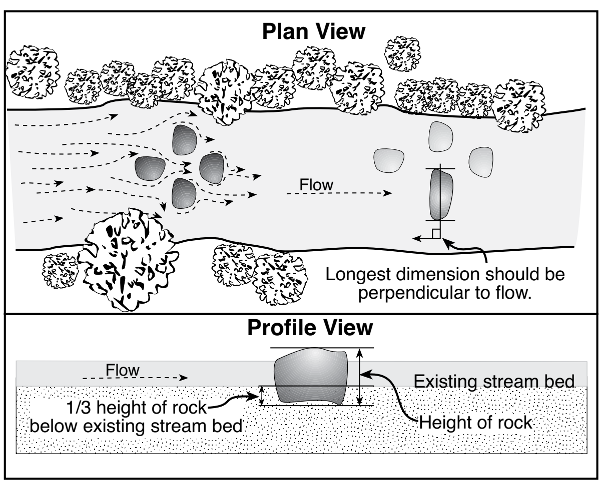

Figure 4. Placement Depth and Angle

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Mecklenburg, Dan, 1996, Rainwater and Land Development, Ohio's Standards for Storm Water Management, Land Development, and Urban Stream Protection, Second Edition, Ohio Department of Natural Resources, Division of Soil & Water Conservation in cooperation with the Natural Resources Conservation Service and the Ohio Environmental Protection Agency, Co-

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OHIO STREAM MANAGEMENT GUIDE

Large Woody Debris in Streams

Guide No. 21

Large Woody Debris (LWD) is a general term referring to all wood naturally occurring or artificially placed in streams including branches, stumps, logs and logjams. Almost all LWD in streams is derived from trees located in the riparian corridor. Streams affected by urbanization, agriculture, development, or clear cuts often lack a sufficient quantity of the LWD necessary to maintain an ecologically healthy and stable ecosystem. Streams with adequate LWD tend to have greater habitat diversity, a natural meandering shape and greater resistance against high water events. Therefore, LWD is an essential component of a healthy stream's ecology and is beneficial.

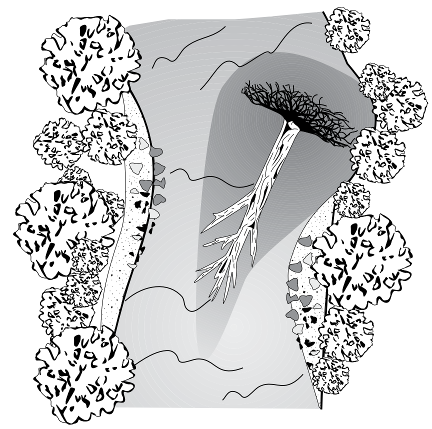
LWD is an important component of high quality streams that helps increase the diversity of biological communities and physical habitats. Certain species of fish depend on the wood in the streams to survive. However, many riparian owners and land managers traditionally treat woody material in streams as a nuisance and remove the LWD in the streams and along the banks with uncertain consequences. This is often unnecessary and perhaps harmful to high quality streams. Stream cleaning practices reduce the amount of organic materials necessary to support the aquatic food web, remove the vital in-stream habitats that fish utilize for shelter and spawning, and reduce the level of erosion resistance provided against high flows. In addition, LWD improves the stream structure by enhancing the substrate and diverting the stream current in such ways that pools and riffles are likely to develop. A stream with a heterogeneous substrate and pools and riffles is ideal for benthic (bottom dwelling) organisms as well as for spawning of desirable fish species like trout and bass.

BIOLOGICAL HABITAT DIVERSITY

In order for a stream to maintain a healthy ecosystem with a wide variety of plant and animals species, there must be structure, a variety of habitats, and a large influx of nutrients and materials. LWD is essential to macroinvertebrates for food and shelter, who break organic materials down into small particles known as detritus. Detritus is necessary for a complex food web to maintain a healthy balance. Detritus also provides habitat for bacteria and insects, which in turn are prey for fish, birds, amphibians, and riparian mammals. The leaf litter and vegetation that falls into streams are primary food sources for caddisflies, stoneflies, and mayflies. Trees that have fallen in or near the stream provide shelter and habitat for insects, birds, and small animals while certain fish utilize the shade for protection and camouflage for hunting.

TRUNKS AND ROOTWADS

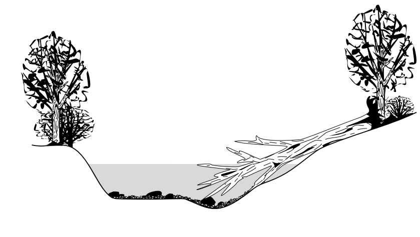
"Rootwad" is a term given for the trunk of a tree with the roots still attached and exposed either from an undercut bank or a tree that has fallen. A "rootmat" is similar to a rootwad but with a smaller root diameter and root mass area. Both provide several benefits to an aquatic ecosystem such as erosion control, substrate for invertebrates, feeding areas, and refuge for young fish. They are also a key structural component that deflect



flows in ways that induce meanders and help scour deep pools, both beneficial for fish habitats. Rootwads may act as streambank anchors against high flows and floods, holding the soil into the bank, thus reducing sedimentation downstream. Therefore, they provide a necessary resource function and should not be disturbed.

LOGS

The term "log" is commonly associated with lumber but simply means a fallen tree. Logs that fall in or along a stream are generally viewed as obstacles by land managers, but can be very beneficial to the ecosystem. Depending on its orientation, a log can protect banks from scour at high flows, enhance deposition of fine sediment, and deposit substrate for invertebrates. Logs also



provide refuge from predators and feeding areas for smaller fish and insects. A fallen tree also provides roughness to the stream channel by altering the flow pattern, which increases channel diversity (pools, riffles, meanders and undercut banks) and decreases the channel slope. A sweeper is the name for a log that has fallen perpendicular to the streambank where water flows both over and underneath it. The current flowing over the sweeper often scours a deeper hole on the downstream side of the log called a plunge pool. Plunge pools provide critical habitat for aquatic life seeking slower current and cover for fish to rest.

LOGJAMS

Logjams are obstructions occurring in streams from the accumulation of woody vegetation, with or without debris. They obstruct a stream channel, and create a backwater condition. Logjams may be positive or negative depending on the perspective and the specific site characteristics. Determining a logjam's value requires an understanding of watershed dynamics as well as the social and biological impacts in the watershed. Not all logjams need to be removed.

Leaving in LWD should be considered in high quality streams as long as water is not impounded behind the logjam. For the purposes of this Stream Management Guide, only the benefits are discussed. For information regarding the negative aspects of logjams, The Ohio Department of Natural Resources recommends Guide 06, Stream Debris and Obstruction Removal, in addition to seeking consultation from the county engineer and local floodplain coordinator before working in streams and riparian corridors.

Contrary to the negative perceptions commonly associated with logjams, they provide many benefits to fish and wildlife. Logjams in smaller streams can redirect the stream flow into multiple channels, often where it has previously been dry, creating more habitat for fish and aquatic organisms. These shifts within the floodplain are a frequent occurrence in forested streams; unfortunately, development has often limited the area in which a stream may naturally meander. In addition to the biological assets of logjams, they are often a catalyst initiating the run-riffle-pool sequence that enhances the substrate and reduces high-water forces. A balance of the advantages of logjams (biological integrity and an enhanced substrate), versus the disadvantages (floods and erosion), should be considered before any action is taken.

SUMMARY

The intent of this guide is not to suggest adding LWD or other materials into a stream channel, but rather reconsidering its removal in stream management. In some cases, adding LWD to streams may be desired for stream channel restoration to achieve bank and channel erosion protection. Other circumstances where valuable property is subject to flooding and public safety is threatened, removal may be necessary. LWD is most important in streams with a low gradient and less critical in headwater streams. The effects of LWD on a stream channel is a function of the size of both the debris and the stream as well as the land use of the adjacent watershed.

REFERENCES:

U.S. Geological Survey and Missouri Department of Conservation, 1998. Riparian-Vegetation Controls on the Spatial Pattern of Stream-Channel Instability, Little Piney Creek, Missouri

This Guide is one of a series of Ohio Stream Management Guides covering a variety of watershed and stream management issues and methods of addressing stream related problems. The first several guides in the series are overview guides intended to give the reader an understanding of the functions and values of streams. For more information about stream management programs, issues and methodologies, see Guide 05 Index of Titles or call the ODNR Division of Soil and Water Resources at 614/265-6610. All Guides are available from the Ohio Department of Natural Resources. Single copies are available free of charge and may be reproduced. Please contact:

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OHIO STREAM MANAGEMENT GUIDE

Gravel Riffles Provide In-Stream Structure

Guide No. 22

Gravel riffles consist of gravel and cobble-sized stone arranged at distinct intervals in shallow streams. Gravel riffles promote the formation of stable substrate in channels that have been modified or otherwise heavily impacted by development. Gravel substrate provides productive habitat for aquatic organisms and areas for fish to spawn.

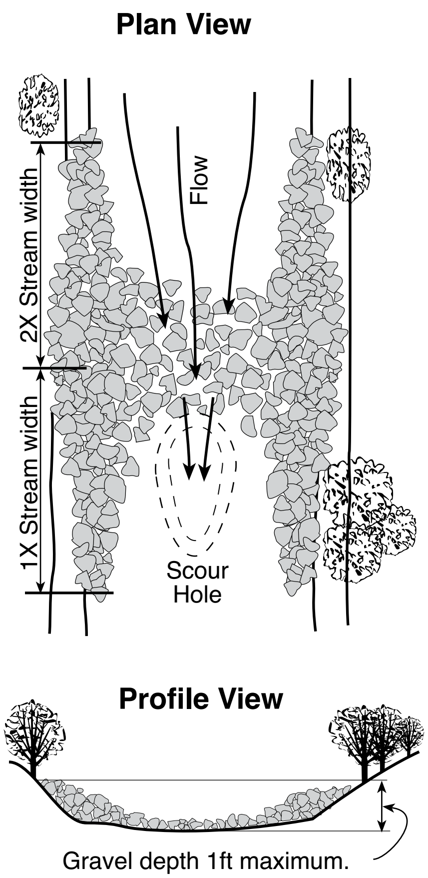

Figure 1. A gravel riffle

Many streams in Ohio have been modified to improve their capacity to convey stormwater. This has most often been achieved by straightening the channel alignment and lowering the streambed to increase channel slope and flow velocity. Although these practices greatly improve the efficiency with which stormwater can be carried away, this kind of channel modification degrades the stream's water quality and destroys aquatic habitat.

Reducing channel roughness removes much of the in-stream structure that provides habitat for fish and other aquatic life. Restoring some of this structure through biotechnical practices (methods that use vegetation and natural materials to restore channel roughness) provides additional hiding, spawning and feeding areas for fish. This also increases the substrate suitable for benthic (bottom dwelling) organisms to become established which supports a healthier, more diverse aquatic ecosystem. Other biotechnical practices, such as establishing streamside vegetation to enhance in-stream structure, can vastly improve a stream's value as an aquatic habitat while maintaining much of its ability to convey runoff.

The purpose of this Ohio Stream Management Guide is to describe the site conditions suitable for gravel riffles, their design and installation. The guidelines listed herein are a compilation of specifications from agencies in other states and from field experience here in Ohio. As with any construction project that takes place within a stream, the Ohio Department of Natural Resources recommends you consult with the applicable local, state, and federal authorities listed in Guide 06, Permit Checklist for Stream Modification Projects, prior to construction. The extent of permit requirements will depend on the location and design of your project

WHERE TO USE GRAVEL RIFFLES

The use of gravel riffles should be considered if a coarse gravel substrate was an original characteristic of the stream, but has been removed. This situation is common in deepened, modified, or relocated channels. It may also occur where the bedload sediment supply has been interrupted by the construction of an instream pond or by the enclosure of the upstream channels in a storm drain system. Constructed gravel riffles are usually of greatest value in small channels. The bedload of larger streams is more likely to supply adequate coarse material to maintain natural riffles. A stream's natural condition can further be enhanced when gravel riffles are supplemented with the addition of forested riparian corridors.

Gravel riffles should be used to augment natural channel formation. Supplies of gravel and cobble introduced into a channel will not force a channel into a desired shape but can mimic what will eventually accumulate from natural deposition of bedload sediment.

DESIGN AND INSTALLATION

The length of gravel riffles should range from one to two times the channel width. The thickness of the gravel should generally be less than one foot and not more than the depth of the water at normal stage flow so that it doesn't extend out of the water and back up a significant pool or otherwise act as a dam. To concentrate lower stream flows, the gravel should be placed so that it is slightly lower in the middle of the channel and higher along the streambanks as illustrated in figure 1.

Gravel size is best determined by examining the substrate and any gravel bars in the existing stream channel. Gravel should be sized so that it is stable at low and medium flows but erodible at high or bankfull flows. This typically ranges from one to four inches in diameter. Several methods (or criteria) can be used to determine the appropriate placement of gravel riffles as shown if figure 2 including: placing them where existing riffles are already forming; plac-

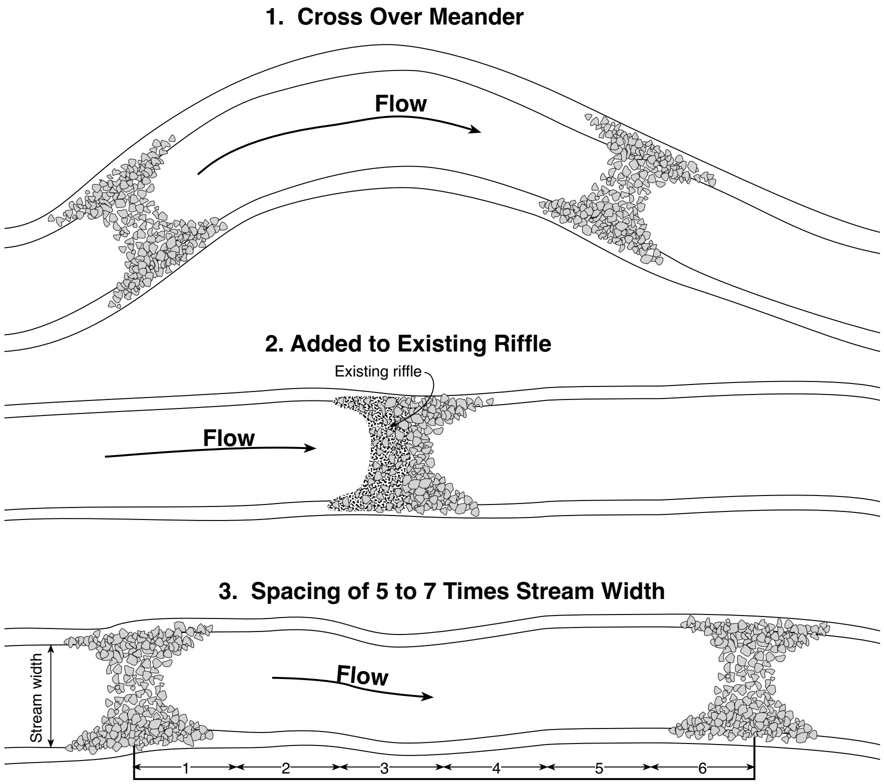

Figure 2. Gravel riffle placement and spacing

ing them to match the spacing of riffles in a similar undisturbed portion of the stream (not illustrated); placing them at the crossovers between meanders; or placing them spaced approximately five to seven stream widths apart.

EQUIPMENT NEEDED

Equipment used may vary based on the specific site's accessibility and limitations. The equipment most commonly used includes dump trucks, backhoes, waders, shovels and wheelbarrows.

MAINTENANCE

Inspect the gravel riffles after high-water events during the first year and once a year thereafter. Look along the streambanks near the gravel riffles for any erosion that may be occurring. If it is determined that the riffles are redirecting the stream's energy into the adjacent bank, the riffles will need to be modified in order to avoid further streambank erosion.

This guide is one of several biotechnical practices described in the Ohio Stream Management Guides series available online at the Ohio Department of Natural Resources' website. These practices use vegetation or other natural materials to achieve the desired stream management objectives. One of the primary advantages of biotechnical practices is how they help restore natural stream features such as in-stream habitat and streambank vegetation. Guide No. 10, Biotechnical Projects in Ohio, provides an overview of biotechnical practices, maps more than 50 project sites, and lists contacts that can arrange for site visits. No project should be undertaken without some understanding of the functions of stream energy and the source of the problem that needs to be corrected. Guide No. 03, Stream Management and the Stream Natural Processes, provides an overview of stream dynamics. Technical assistance about stream dynamics can also be obtained at your Soil & Water Conservation District, which is listed under county government in the local phone directory.

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