Ohio Drainage Manual

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1. Introduction

1.1 Purpose of the Ohio Drainage Manual

The Ohio Drainage Manual is to provide a reference guide for drainage work to County Commissioners, County Engineers, Soil & Water Conservation District Staff and Supervisors, contractors, and private landowners involved in the construction or maintenance of drainage improvements. This manual was developed as a result of recommendations developed by ODNR Division of Soil and Water Conservation and the Ohio Federation of Soil and Water Conservation District Rural Drainage Advisory Committee. The committee suggested ODNR-DSWC and partnering agencies develop this manual by which the aforementioned stakeholders could use it as a guide to construct and maintain drainage improvement projects.

The Manual is not intended to propose additional regulation, but rather identifies methods and procedures that communities and/or landowners may follow to protect the integrity of Ohio's drainage infrastructure in a socially, environmentally, and economically acceptable manner.

This manual reviews the applicability of current regulations and laws to construction and excavation operations within existing ditches and streams, including the Clean Water Act and rules implemented by Ohio Environmental Protection Agency and the U.S. Army Corps of Engineers. It also provides a brief review of drainage law that is contained in Ohio Revised Code. The Ohio revised Code sections 1515, 6131, 6133, and 6137 describe the requirements and procedures by which local governments use to construct drainage projects on private lands.

The manual outlines a process by which the drainage needs can be assessed or evaluated. This assessment procedure is recommended for all drainage improvement projects. Confirming that the drainage improvement is feasible and is necessary will eliminate unnecessary projects that are costly and often have negative environmental impacts. The manual also provides a method by which the user may assess the beneficial and adverse water quality impacts of the drainage improvement project. This information may be necessary and useful when performing a cost vs. benefit analysis and when considering the social and economical impacts of the alternatives for the drainage improvement project.

The manual provides guidance for performing maintenance on constructed channels and/or conduits. The Best Management Practices listed are alternatives that should be considered as maintenance is performed. Site specific conditions, personnel availability, and environmental sensitivity are items to incorporate in determining the appropriate maintenance activities.

This manual is not meant to serve as a complete design guide for constructing new drainage improvement projects. The design approaches outlined are meant to serve as an introduction identifying the benefits and challenges with each alternative. This information will be valuable in selecting which alternatives meet the social and economic needs of the community and participating landowners. The manual provides links to design references and manuals that will assist the designer and the project sponsor.

Finally, this manual is meant to serve as a gateway for providing information to construct and maintain rural drainage improvement projects. Standardized forms and various links related to drainage improvement projects are included throughout the document.

1.2 History of Drainage

Ohio's drainage network is made up by a series of natural and man-made channels and subsurface drainage mains or conduits. Agricultural drainage improvements can be made to the soil surface, the subsurface, or a combination of both. Surface drainage is designed to remove standing water from the soil surface through land leveling and smoothing or constructing shallow ditches or grassed waterways. Subsurface drainage is designed to remove excess water from the soil profile through a series of drainage pipes (tile or tubing). Surface and subsurface drainage improvements require suitable outlets to remove excess water. It is estimated that approximately half of the cropland in Ohio relies on artificial or man made drainage improvements to remove excess water from the soil. Moreover, in a drainage study conducted across Ohio in 1972, Byron Nolte estimated two thirds of Ohio's cropland would benefit from drainage improvements.

The first land settled in Ohio drained well naturally without severe challenges to settlement and crop production due to excessive wetness. On these lands grew small communities, villages, and towns. As these areas became more populated and developed, pressure grew to develop marginal ground that had not been cleared earlier. In many areas this led to small 'farm scale' drainage projects to bring these marginal lands into agricultural production, allowing settlement and crop production on these marginal grounds.

This process resulted in growing communities across the state. However, there were large areas of the state where 'farm scale' drainage projects were not sufficient to remove excess water from the land. Many areas in the glaciated portion of the state would require landowner cooperation across hundreds to thousands of acres to remove excess water, and bring it into agricultural production.

Eventually, in order to encourage settlement in Northwest Ohio, Public Ditch Laws were enacted in the 1840's and 1850's. These laws granted local officials the authority to design and construct drainage projects, and assess local landowners for the cost of such projects. This law has come to be called the County Petition Ditch Law and is still in use today. Through these laws, marginal and poor lands were developed into productive agricultural lands. The Black Swamp is probably the largest example of such an area. The Black Swamp stretched across 11 counties in Ohio, and extended into Indiana along the Maumee River. Through drainage laws a majority of this land was drained and settled as farmland from the 1850's through the early 1900's.

Drainage proceeded in this manner until the 1940's. It was then that many county commissioners and county engineers noticed that drainage projects were being constructed for the second, third, or fourth time. While the initial project had worked well, reconstruction was needed to remove sediment or other debris that had accumulated over time. To address this, county commissioners were granted authority to establish a maintenance fund for the county. These funds were to be used to maintain channels and tiles installed through the petition ditch laws. Maintenance funds were optional until 1957, after which maintenance programs were mandated by the law.

Ohio's drainage laws have been updated many times as the state has grown and developed. Drainage systems that were originally built to enhance agricultural production have also made former wetlands suitable for communities, home sites and industrial development. Today, municipalities manage water with their own set of drainage laws, but most rural drainage projects involving multiple landowners are organized under Ohio's Petition Ditch Law (Ohio Revised Code 6131) or Conservation Works of Improvement (Ohio Revised Code 1515). While there are important differences in how these two legal processes work, both fund projects with assessments on affected landowners and require that the financial benefits of a project exceed its cost.

Several attempts have been made in recent years to document group drainage activity in Ohio. In 1884 the Ohio Society of Engineers and Surveyors reported there were approximately 20,000 miles of public ditches benefiting 11 million acres. Nolte (1972) refers to a 1964 survey, which showed an estimated 10,000 miles of county tile and 20,000 miles of county open ditches in 47 Ohio counties. In 1972, the Ohio Soil and Water Commission initiated a report (Channel Modification Task Force, 1972) that indicates 7093 miles of natural and constructed streams were being maintained in 53 counties. In a 1996 survey (Bruce Atherton, The Ohio State University), 50 counties with drainage programs were surveyed and 45 counties reported 4589 miles of ditches and waterways under maintenance. In a survey sent to all 88 of Ohio SWCDs and County Engineers by ODNR Division of Soil and Water Conservation in 2005, 6217 miles of open ditches/waterways and 5947 miles of subsurface mains were reported under maintenance with 85 counties responding.

Historically, the main reason for drainage on agricultural land has been to enhance crop production. Drainage removes excess water from the soil and helps create a well-aerated root zone that enhances plant up take of nutrients. Drainage on wet agricultural soil allows timely field operations, and helps plant growth to begin early, continue vigorously, and achieve improved levels of productivity. The major drainage periods in the U.S. occurred during the periods of 1870-1920 and 1945-1960. It is estimated that over 60% or approximately 7 million acres of Ohio's cropland has drainage improvement.

Today many villages, cities, and rural homeowners also rely on Ohio's rural drainage network to prevent flooding, wet backyards, and wet basements. Ohio's rural drainage network is facing some major challenges that include the following:

1. The useful life of many drainage systems has been exceeded,
2. The increasing number of rural landowners often do not understand or want to pay for drainage improvement projects,
3. Funding for adequately staffing rural drainage improvement projects at the county and state level has been redirected to other priorities, and
4. Agency regulation and public scrutiny are often increasing the time, effort, and cost of completing a drainage improvement project.

1.3 Value of Drainage to Ohio

It is difficult to place a dollar value on any type of infrastructure improvement. What is the value of the interstate system across Ohio? What is the economic value of Ohio's railway systems? Assessing the economic value of Ohio's drainage system is a similar challenge. The following discussion is an attempt to explain the importance and scope of the drainage systems that have been constructed in Ohio.

Agriculture is Ohio's largest industry. Crop production occurs on 45 percent of Ohio's land area and about two-thirds of Ohio's agricultural soils need drainage improvements to minimize soil erosion and enhance crop production. Nationally, drainage improvements are required on more than 20 percent of U.S. cropland (approximately 110 out of 421 million acres).

Research in Ohio has shown that agricultural drainage reduces the year-to-year variability in crop yield. Furthermore, research conducted by The Ohio State University on Hoytville silty-clay at OARDC in Wood County indicates that subsurface drainage improves annual corn yields by 20 to 30 bushels per acre and annual soybean yields by 7 to 14 bushels per acre. The increased yields result in an increase in revenue of 70 to 105 dollars per acre for corn, and 63 to 126 dollars per acre for soybeans assuming corn prices of $3.50 per bushel and soybeans prices of $9.00 per bushel. The study was conducted over an 11 year period.

This improved drainage also provides improved access of farm equipment to the field with less compaction and reduced crop damage at harvest. Improved drainage also allows the implementation of many conservation practices on soils that otherwise would require conventional tillage management.

Drainage water quality evaluated over a 14-year period on Toledo silty clay indicated that subsurface drainage reduced the losses of sediment, phosphorus and potash by 40, 50, and 30 percent respectively as compared to surface drained cropland. Over a 17-year period, runoff from land that was subsurface drained was lower than that from land that was not subsurface drained and peak runoff was reduced by approximately 32 percent.

It is estimated that over 60% of Ohio's cropland acres or over 7 million acres have artificial drainage improvements. Ohio ranks fourth in the total acres of cropland drained behind Illinois, Indiana, and Iowa. Systematic subsurface drainage systems installed in Ohio typically cost in the range of $500 to $1000 per acre.

While the benefits of drainage vary from year to year and depend heavily on the soil type, much of Ohio's most productive crop ground could not be farmed economically without man-made drainage.

Although the first drainage work was done for the improvement of agricultural land, as Ohio's economy grew, all development benefited from improved drainage of the landscape. Today most small villages and rural residents depend on this drainage network to maintain a landscape we have come to expect.

For rural homeowners, agricultural drainage systems are typically the outlet for sump pumps and roof downspouts. Household sewage treatment systems often rely on this drainage infrastructure to lower seasonal high water tables around treatment areas.

Rural homeowners often depend on these ditches and subsurface drains to carry excess water away from their property much as suburban homeowners rely on storm sewers to remove runoff from rainfall. In many parts of Ohio, residents and communities rely on the rural drainage infrastructure just as they rely on roads, bridges, and electricity.

Finally, in a survey conducted by ODNR-DSWC in 2005, county engineers and the local SWCD's were asked to estimate what percentage of their respective county benefited by man-made drainage improvements. The results were as follows:

Less than 20% of county benefited	25% of responses
20% to 39% of county benefited	16% of responses
40% to 59% of county benefited	10% of responses
60% to 80% of county benefited	24% of responses
Greater than 80% of county benefited	25% of responses

Survey results show that nearly half of the agencies reporting listed man-made drainage improvements as benefiting over 60% of the lands in their respective counties. Drainage systems have been built in Ohio since settlement started, and these systems are of vital importance to the landscape that we enjoy today.

1.4 Environmental Impacts and Water Quality

Although drainage is necessary for crop production on Ohio's poorly drained soils and many Ohioans rely on the rural drainage network, there are environmental costs associated with it. Most reports indicate that better than half of the original wetlands in the United States have been lost due to drainage improvement practices, Ohio's loss of wetlands is estimated to be 90%. The loss of wetlands has caused a decline in wildlife habitat and adverse impacts to water quality.

Both surface and subsurface drainage systems affect water quality. Subsurface drainage water monitored over a 14-year period on Toledo silty clay, indicated that subsurface drainage reduced the losses of sediment, phosphorus and potash by 40, 50, and 30 percent, respectively, compared to surface drained cropland. However, nitrate-N losses increased by 40 percent.

Drainage systems were originally designed for the efficient and economical removal of excess water; they were not installed as water quality management tools. As a result, drainage systems also efficiently deliver sediment, nutrients, and other pollutants downstream.

The export of nutrients downstream can have drastic impacts. The largest example currently being investigated is the hypoxic zone in the Gulf of Mexico. The result is a large area in the Gulf of Mexico that is essentially devoid of aquatic life. The cause of this hypoxic zone is thought to be the result of increased runoff of nitrogen fertilizers from the Mississippi River Basin.

Natural drainage systems while not as efficient hydraulically, have floodplains that trap sediment and assimilate or treat nutrients and pollutants as they are carried downstream. The assimilation of nutrients and removal of sediments on flood planes reduce the downstream impacts and improve water quality.

The characteristics of the channel and its floodplain determine the ability of the channel to assimilate nutrients. Lower flow velocities and longer contact times with flood planes will increase the treatment provided.

Natural drainage systems also have improved aquatic life. Historically man made drainage systems offered no aquatic habitat at construction. Aquatic habitat developed in some man made channels and can support a variety of aquatic species. Other channels however will never be able to develop the aquatic habitat required to support diverse aquatic life.

In order to gauge and monitor water quality current environmental standards use a variety of indicators to assess a water body. Scientists have categorized the features that affect the health of aquatic systems into three categories. These categories are described below.

1. **Physical Characteristics** – The physical characteristics of water includes such things as turbidity, stream shape, sinuosity, substrate, in stream cover, sediments, riparian and canopy, and temperature. The physical characteristics of the water body includes: stable channels, the transport of nutrients, the volume and speed of water, the streambed material and log jams

2. **Biological Characteristics** – Biological characteristics refer to the number and types of individual species that live in an aquatic community.

By evaluating the size, number, and types of organisms such as plants (algae), vertebrates (fish and frogs), and macro invertebrates (insects, snails, and worms) scientists can accurately assess the aquatic community and health of a watershed.

3. **Chemical Characteristics** – Chemicals in water determine whether or not it is safe to use or to swim in. The chemical properties of water include things like pH, hardness, dissolved oxygen, nutrients, acidity, conductivity, and fecal coliform.

By measuring these characteristics, scientists determine the overall quality of water, identify sources of pollution, and begin to plan how to improve the watershed health. Standards for water quality have also been established based on these categories.

Ohio's Water Quality Standards have been written by the Ohio Environmental Protection Agency as a result of the passing of the Federal Clean Water Act. The water quality standards help determine how clean Ohio's water bodies need to be to provide for healthy aquatic communities.

In 1990, the water quality standards were changed to include the condition of the aquatic biologic community. These aquatic life use designations include the items listed below.

1. **Limited Resource Water** – small streams that have been irretrievably altered to the extent that no appreciable aquatic communities can be supported or those which lack water year round
2. **Modified Warmwater** – incapable of supporting a well balanced community of aquatic organisms due to extensive, maintained hydromodifications which have been sanctioned by state or federal law
3. **Warmwater** – supports a balanced community of aquatic organisms expected to be found in typical Ohio streams
4. **Exceptional Warmwater** – supports and maintains an exceptional or unusual community of warmwater aquatic organisms
5. **Coldwater** – capable of supporting populations of coldwater fish and associated vertebrate and invertebrate organisms on an annual basis

As a result, design considerations must consider the design drainage goals, as well as the water quality criteria for a given channel of segment of channel.

2. Regulatory Requirements

2 Water Quality and Environmental Considerations

By their nature drainage projects have the potential to impact water quality in the short term (the construction phase) and over many decades (the permanently altered physical features of the water course). Impacts can be localized within the project area, but may also extend to downstream reaches of streams and rivers. Statewide monitoring work conducted by Ohio EPA has identified ditching and the channelization of larger streams as leading causes of impairment of water quality and the overall health of aquatic life. We are optimistic that this trend can be reversed as the information in this Manual is applied to new drainage projects and the maintenance of existing petitioned ditches.

A major goal of the Ohio Rural Drainage Manual is to assist local drainage engineers and resource agency personnel in conducting an appropriate level of environmental review when designing new drainage improvements. A pre-requisite to initiating an environmental review is a completed drainage needs assessment. This section of the Manual provides a summary of surface water quality standards and goes on to translate these standards into specific steps that should be taken to protect water quality whenever new drainage projects are undertaken. A description of permitting requirements is also provided.

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2.1 Regulatory Standards for Surface Waters

Regulatory standards that apply to surface waters are set forth in Chapter 3745-1 of the Ohio Administrative Code (OAC). Collectively, they are termed the Water Quality Standards (WQS). The rules are required by the federal Clean Water Act and Ohio's environmental and water pollution control laws (Chapters 3745 and 6111 of the Revised Code). Their overall purpose is to ensure that water quality is maintained at a level that is protective of public health and the environment. U.S. EPA regulations (40 CFR 131) set forth minimum content requirements for WQS. The three main components are described below. States have some flexibility to adopt their own standards to reflect regional and local needs so long as they comply with federal requirements and are justified as protective of human heath and aquatic life.

A brief summary of the current rule content is presented below. Also described are pending rule changes that if implemented would protect water quality while explicitly recognizing legitimate drainage needs as a beneficial use.

2.1.1 Beneficial Uses

Under State law Ohio's WQS are "…..to enable the present and planned uses of Ohio's water for public water supplies, industrial and agricultural needs, propagation of fish, aquatic life and wildlife, and recreational purposes." The beneficial uses established in the WQS rules reflect this mandate. U.S. EPA and Ohio EPA have a number of documents explaining beneficial uses and Ohio's system of tiered aquatic life uses (see list in reference section).

Drainage and agricultural needs are reflected in the current WQS in two ways:

1) Agricultural Water Supply – a beneficial use that protects water bodies for potential use for livestock watering and irrigation; and

2) Tiered aquatic life uses – two tiers of aquatic life uses (Limited Resource Water - small drainageway maintenance and Modified Warmwater Habitat) are designed to account for the permanent channel modifications necessary for agricultural drainage. Because these water bodies cannot support diverse communities of aquatic life, and those species that do inhabit these waters are tolerant of some pollutants, the biological criteria and some chemical water quality criteria are set at levels below the benchmark Clean Water Act goal. Site specific data is required for

each water body assigned one of these designations. The designation must be reviewed every 3 years.

Pending Revisions to Align with Drainage Needs

The Rural Drainage Advisory Committee discussed the requirements of the existing WQS. Most members expressed the opinion that the current rules don't fully address agricultural drainage needs. The group reached a general consensus that led to three important changes in the draft rules:

1) An Upland Drainage use for all historically channelized waters draining less than 3.1 square miles[1];
2) Eliminating the application of biological criteria for waters designated Upland Drainage[2]; and
3) A Water Conveyance use for larger waters under petition ditch maintenance provided the water has a tiered aquatic life use designation assigned.

Ohio EPA used these broad consensus points to prepare draft rule language. An "interested party review" process was initiated in August 2008. Formal rule making steps will ensue after these initial public comments are considered. New rules could be effective sometime in 2009.

2.1.2 Water Quality Criteria

The second essential component of the WQS program is to establish narrative and numerical water quality criteria. Narrative "free froms" are general water quality criteria that apply to all surface waters. They protect against public nuisance conditions and other forms of flagrant pollution.

Much of Ohio EPA's present strategy regarding water quality based permitting is based upon the narrative free from, "no toxics in toxic amounts." Ohio EPA developed its strategy based on an evaluation of the potential for significant toxic impacts within the receiving waters. Very important components of this evaluation are the biological survey program and the biological criteria used to judge aquatic life use attainment.

Biological criteria are targets for the performance of instream fish and macroinvertebrate communities. The performance expectations are calibrated for variations in geologic features, land form, land use and

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[1] Advisory committee worked under the assumption that most historically channelized waters are in the relatively flat, glaciated area of Ohio.
[2] Advisory committee discussed why exceptions must be allowed if historical data confirm attainment of one of the tiered aquatic life uses. See discussion under antidegradation.

stream size. A very important principle is that the prevailing stream habitat (and influences on habitat such as drainage maintenance) must be evaluated when assigning the "tiered" aquatic life use (i.e., Warmwater Habitiat, Modified Warmwater Habitat, etc.). To evaluate stream habitat Ohio EPA uses a standardized measurement technique called the Qualitative Habitat Evaluation Index.

Chemical numeric criteria are estimations of concentrations of chemicals allowable in a water body without adversely impacting its beneficial uses. Although numeric criteria are applied to water bodies, they primarily are used to regulate wastewater dischargers through NPDES permits.

Pending Revisions to Align with Drainage Needs

The current WQS in effect since 1997 apply both narrative and chemical numeric criteria to small ditches where drainage improvements are often sought or routine drainage maintenance is already performed. These chemical specific criteria apply to any surface water that lacks a specific aquatic life use designation.

Draft changes to the WQS under consideration continue the application of narrative and chemical criteria to small ditches and streams. To make this point clearer the draft rules establish a new beneficial use, Base Aquatic Life. It simply puts a name to the past and present practice. The Base Aquatic Life use is not considered a tiered aquatic life use and no biological criteria are associated with it. In the draft rule the Base Aquatic Life use is assigned to any surface water that does not have a tiered aquatic life use.

2.1.3 Antidegradation

The last required component of WQS is called antidegradation. Under federal regulation every state must have an antidegradation rule that sets out procedures intended to keep clean waters clean. There are three mechanisms available to achieve this end. The most direct is to classify certain waters as the "best of the best" and to impose prohibitions or restrictions on facilities and activities that would lower water quality on these selected waters. The state antidegradation rule includes # stream segments (totaling # miles) of Outstanding State Waters and Superior High Quality Waters where this kind of added protection is enforced. These waters are concentrated along the glacial boundary and in certain watersheds in southeast and northeast Ohio (see Figure __). Regardless of location, these waters are the highest quality waters in the State and drainage improvement projects located in nearby upstream locations should take precautions so that water quality is not lowered.

Another mechanism in the antidegradation rule that helps keep waters clean is the protocol that all regulated activities that propose to add pollutants to surface waters must be reviewed. The review uses a list of factors designed to assure that it is necessary to discharge and that there are benefits (e.g., jobs, taxes, etc.) associated with the project that outweigh the lowering of water quality. This would affect any rural drainage projects where it is determined that a Section 401 water quality certification is needed. However, a drainage improvement project on a historically channelized water course is eligible for a streamlined antidegradation review if the nine conditions in ORC 6111.12(C) are met.

The last provision of the antidegradation rule is that any beneficial use that is determined to be an "existing use" must be protected. An existing use is defined as " "

The prohibition against the loss of an existing use is a difficult and controversial point when considering drainage improvement projects, particularly work on natural streams and rivers on old petition ditches left for long periods of time (50 to 100 years) without regular maintenance. However, "no loss of existing use" is a matter of state and federal law and cannot be ignored. Section 3.3 discusses procedures that should be followed to comply with this regulation.

Pending Revisions to Align with Drainage Needs

Several changes in upcoming WQS rule making packages have bearing upon the existing use question. A separate rule making package for the antidegradation rule will be initiated in 2008 with an interested party review.

Figure__. Map of Outstanding State Waters and Superior High Quality Waters.

2.2 Permitting Requirements

This manual is intended to apply as voluntary guidance to be followed by contractors, landowners and governmental entities engaged in drainage improvement and maintenance work. However, there are circumstances wherein drainage improvement projects trigger the need to obtain environmental permits. Construction site storm water NPDES permits are necessary under existing federal and state laws[3] when the acreage of disturbed ground exceeds certain thresholds. See the attached fact sheet (Ohio EPA, September 2008) and Section 5 for more information.

Other permits are necessary if the drainage improvement project will result in the placement of fill material in a wetland or below the ordinary high water line of an open waterway.

> NOTE: Expanded text on Section 404 permits and Section 401 water quality certifications will be provided in the final version of the Ohio Rural Drainage Manual

2.3 Environmental Evaluation Protocols for Individual Projects

The authority and responsibility to consider significant environmental factors in the conduct of drainage improvements already exists in Ohio law.

…… *When deciding whether to grant the prayer of the petition, the board shall give consideration to the protection of environmentally significant areas when those areas could be adversely affected by the construction of the proposed improvement and, if necessary, to alternative plans providing for that protection as well as for construction of the proposed improvement.* (ORC 6131.12)

As the state agency responsible for water quality, Ohio EPA offered the Rural Drainage Advisory Committee a number of observations and suggestions for how the wealth of chemical and biological water quality data available for Ohio's streams and rivers could factor into the "consideration …. of environmentally significant areas." The material presented in this section of the Manual is the result of numerous discussion sessions with members of the committee and test applications using drainage projects in Madison and Defiance counties.

Those persons responsible for undertaking drainage improvement projects give consideration to Ohio's system of beneficial aquatic life uses and help minimize adverse water quality impacts by following the environmental review protocol laid out in Figures __, __, and __.

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[3] Add citations

Five types of information about open water courses that are the subject of proposed drainage improvements are necessary to apply the flow charts:

1) the drainage area at the downstream end of the proposed project;

2) records documenting prior drainage improvements made under petition ditch laws or the conservation works of improvement law (including the as built gradient for the last improvement);

3) locations on small drainages flagged for protection under the existing use provisions of the antidegradation rule (referred to as Table 1 in the flow chart);

4) whether or not a high quality water designation is present within 2000 linear feet from the downstream end of the proposed project; and

5) the tiered aquatic life use designation for the water course and its status as confirmed or not confirmed.

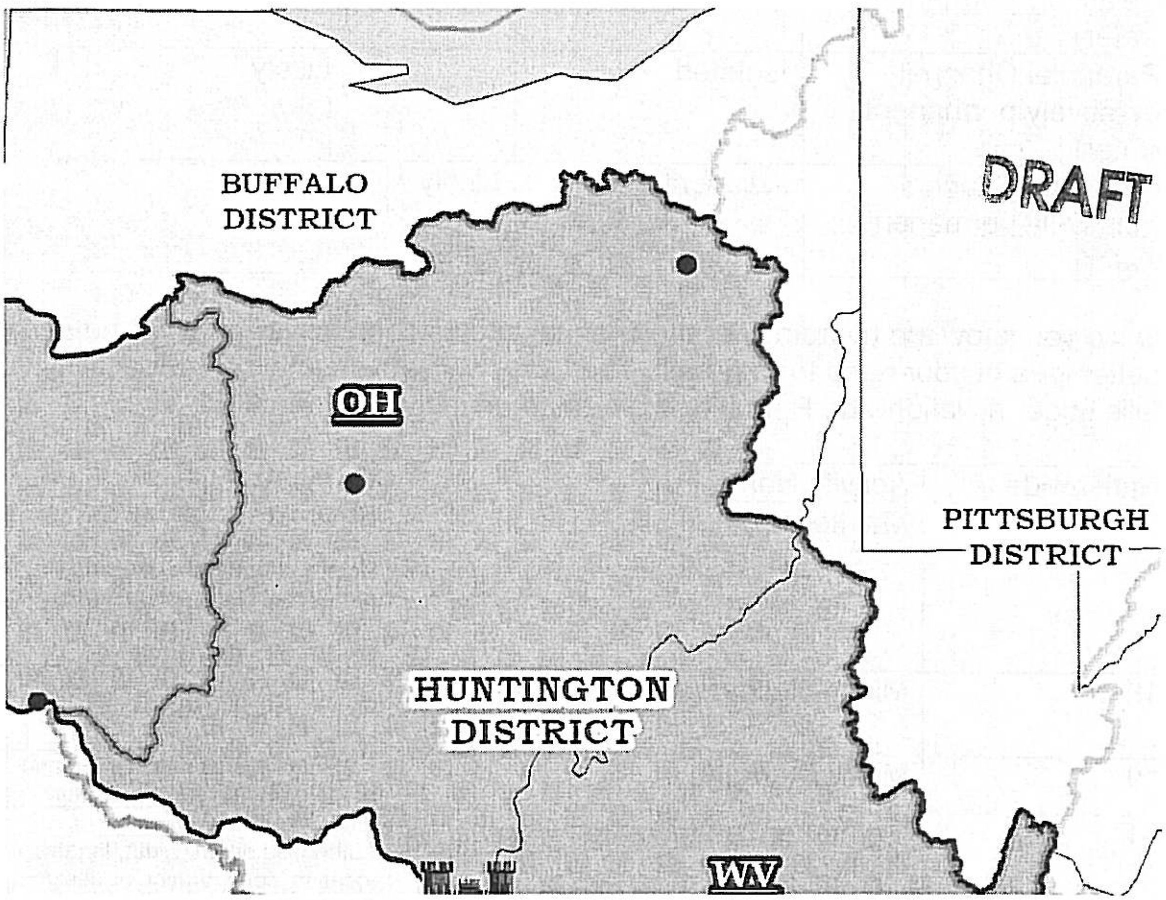
ADD THE 3 FLOW CHARTS

NOTE: Expanded text on accessing the information in items 3, 4 and 5 will be provided in the final version of the Ohio Rural Drainage Manual. Ohio EPA has posted a pilot GIS project through the Ohio Office of Information Technology web site. You can access the current working version at: http://gistest1.oit.ohio.gov/website/epa

While generally reliable, the information on this site is currently considered draft and is not represented by Ohio EPA to be accurate and complete. The Agency is working on revisions and hopes to have a fully functional version available when the final Manual is published.

3.3 Clean Water Act Sections 401 and 404 Permitting Requirements

This section is provided as guidance to Ohio contractors and landowners involved in maintaining drainage channels. The circumstances that will trigger the need to obtain a Clean Water Act Section 404 or Section 10 permit or an Ohio EPA Section 401 Water Quality Certification or isolated wetland permit for the placement of fill material in waters of the United States will vary depending on the hydrologic connection of the channel to be maintained to waters of the United States, the type of equipment to be used and the location of the placement of the dredged material. Unfortunately, it is not easy to give simple guidance, except to recommend that you contact the Army Corps of Engineers and provide them details about what you propose to do and ask them if you need a permit.



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Depending on your location in Ohio- you need to contact the district that controls the watershed where you live and explain the type of work you propose to do.
(Lake Erie- NE Ohio) Buffalo District Phone #716-879-4109
Lake Erie- NW Ohio) Buffalo District Phone # 419-898-3491
(Ohio River) Huntington District Phone # 304-399-5210
(Ohio River) Pittsburgh District Phone # 412-395-7154

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The Corps staff can tell you what the hydrology of your channel is and its connectivity to a water of the United States and whether a permit is needed.

Due to recent court cases and Supreme Court decisions, the hydrology and connectivity of the channel proposed for work is important information to know if a permit is necessary.

Type of Hydrology	**Type of Connection To Waters of the US**	**Section 404 Needed**	**Section 401 or Isolated Wetland Permit Needed**
Ephemeral Channel	Isolated		Possibly
Ephemeral Channel	Adjacent	Possibly	
Intermittent Channel (relatively permanent water)	Isolated		Possibly
Intermittent Channel (relatively permanent water)	Adjacent	Likely	
Perennial Channel (relatively permanent water)	Isolated		Likely
Perennial Channel (relatively permanent water)	Adjacent	Likely	Likely

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Once you know the hydrology of the channel and its connectivity, you will have a better idea of your need for a permit. The Corps will let you know if your activity falls under a Nationwide Permit or will require an individual permit.

Nationwide #	Activity Name	Comments
3	Maintenance	Removal of Accumulated Sediments and Debris in the vicinity of and within existing structures. Does not authorize new stream channelization or stream relocation projects.
18	Minor Discharges	< 25 cubic yards and the loss of no more than 1/10 acre of waters of the US
19	Minor Dredging	< 25 cubic yards below the plane of the ordinary high water mark.
31	Maintenance of Existing Flood Control Facilities	Limited to the previously authorized depth, width, length, location, configuration or design flood capacity.
40	Agricultural Activities	
41	Reshaping Existing Drainage Ditches	Reshaping cannot increase drainage capacity beyond the original as-built capacity nor expand the area drained. The centerline of the reshaped channel must be approximately the same as the original construction.
46	Discharges in Ditches	No discharges into ditches constructed in streams.

Activities that may require a permit

Activities	Section 10	Section 404	Section 401
Stream Relocation or Channelization		YES	YES
Conversion of Wetland Areas		Possibly	Possibly
Structures placed in navigable waters	YES	Possibly	
Material is pushed or stockpiled (even temporarily)		YES	
Section 10 Dredging	YES		
Material Sidecast in Wetlands		Possibly	Possibly
Provide USACE information and maintain to original contours (previously excavated maximum depth)		NO, after contact with the Corps	
Vegetation cutting & removing		NO, if no disruption to root systems	
Mechanized pushing, dragging or other work that deposits excavated soil		YES	
Equipment on the stream bed		YES	

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Who should apply for a permit?

A. Any person, firm, or agency (including Federal, state, and local government agencies) planning to work in navigable waters of the United States, or discharge (dump, place, deposit) dredged or fill material in waters of the United States, including wetlands, must first obtain a permit from the Corps of Engineers. Permits, licenses, variances, or similar authorization may also be required by other Federal, state and local statutes.

How can I design my project to eliminate the need for a Corps Permit?

A. The best way to avoid the need for a permit is to stay above the ordinary high water and avoid wetlands adjacent to the channel. Also, it is possible that your activity is exempt and does not need a Corps Permit. Another possibility for minor activities is that a Nationwide or a Regional General Permit may have authorized them. So, before you maintain your channel, you should contact the Corps (http://www.usace.army.mil/cw/cecwo/reg/district.htm) for your area for specific information about location, exemptions, and regional and nationwide general permits.

The geographic jurisdiction of the Rivers and Harbors Act of 1899 includes all navigable waters of the United States which are defined (33 CFR Part 329) as, "those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible to use to transport interstate or foreign commerce." This jurisdiction extends seaward to include all ocean waters within a zone three nautical miles from the coast line (the "territorial seas"). Limited authorities extend across the outer continental shelf for artificial islands, installations and other devices (see 43 U.S.C. 333 (e)). Activities requiring Section 10 permits include structures (e.g., piers, wharfs, breakwaters, bulkheads, jetties, weirs, transmission lines) and work such as dredging or disposal of dredged material, or excavation, filling, or other modifications to the navigable waters of the United States.

The Clean Water Act uses the term "navigable waters" which is defined (Section 502(7)) as "waters of the United States, including the territorial seas. " Thus, Section 404 jurisdiction is defined as encompassing Section 10 waters plus their tributaries and adjacent wetlands and isolated waters where the use, degradation or destruction of such waters could affect interstate or foreign commerce.

Activities, requiring Section 404 permits are limited to discharges of dredged or fill materials into the waters of the United States. These discharges include return water from dredged material disposed of on the upland and generally any fill material (e.g., rock, sand, dirt) used to construct fast land for site development, roadways, erosion protection, etc.

DRAFT

3. Petition Projects

3.1 Conservation Works of Improvement, ORC 1515

TO BE DEVELOPED

3.2 County Petition Ditch, ORC 6131

TO BE DEVELOPED

3.3 Drainage Needs Evaluation

A drainage needs evaluation should be conducted in order to document the watershed size and land uses, define the historic drainage capacity, determine the current drainage capacity, and develop a desired or design drainage capacity or design storm event to protect public and private property.

This evaluation should inventory the extent, location, and type of drainage problems that exist in the watershed. Drainage problems may be severe public safety issues such as flooding houses and roads, stability and safety of bridges or other public utilities. Alternatively, drainage problems may result in depressed crop yields and crop damage due to excess water in the soil profile.

A comprehensive drainage evaluation should establish clear design goals for drainage and/or flood protection for the different reaches of the proposed project. These design goals may need to be discussed or debated among the project sponsors in order to build consensus.

This evaluation should be one of the first activities completed when considering any drainage work. In the case of Petition Projects or Conservation Works of Improvement this evaluation should be used to support the preliminary report required in ORC 6131 and 1515.

3.3.1 Watershed Description

The first step to be completed for a drainage needs evaluation is a full and complete description of the watershed. At a minimum this description should include the watershed size, and a review of the current land uses. Depending on the project the description may also include future land use changes, an inventory of soils in the watershed, or other information that will be pertinent to the proposed project and the problems to be corrected through the project.

3.3.2 Define Current Drainage Issues

After the watershed has been determined and described, designers should start to define the drainage system in the watershed. It may prove necessary to describe the drainage system in the terms of surface drainage and subsurface drainage.

Surface drainage should consider the runoff from storm events or the timely removal of surface water from the landscape. Surface drainage issues may include flooded areas or flooded houses and roads, property damage due to erosion and or flooded basements, bank stability problems, erosion problems, or other concerns caused by flowing water.

The surface water problems should be identified and inventoried completely. This may include where the problems are located, the storm events that cause them or how often they occur. Damage that has occurred over time and significant public and / or private properties that could be benefited from a proposed project should also be documented.

Solutions to correct surface drainage will generally require open channels of some sort. These may include grassed waterways, surface drains, drainage ditches, or natural channels. In many cases, it is not practical to build storm sewers sized to handle the peak runoff from design storms through closed conduits. Certainly tile systems typically installed for the drainage of cropland should not be used to solve problems associated with surface drainage.

Subsurface drainage has been used for centuries to increase the agricultural production of ground that does not drain well naturally. While problems associated with inadequate or failing subsurface drainage systems are typically not as obvious as surface water problems, these problems can cost property owners substantially through lost production, additional repairs to foundations or buildings, and shortened life of septic systems.

Quantifying and determining subsurface drainage problems may require looking at the watershed throughout different times of the year. Water left standing on crop field for extended periods of time will result in crop damage. Furthermore, excess water in the soil profile can result in depressed crop yields, poor nutrient uptake, and reduces crop management options for the owner or operator.

Subsurface drainage problems can also result in failing septic systems and flooded basements. Septic problems occur in areas where a perimeter drain is required and no longer lowers seasonal high water tables in the treatment area due to an inadequate outlet. In many areas of the state, homeowners rely on sump pumps to lift water from the floor elevation to a height where the water can drain away freely through subsurface drainage systems. When these systems fail, the sump pump is left without a drain, and cannot remove the water from the area of the house.

Failing subsurface drainage systems can also delivery excess sediment to the outlet channel. As the drainage tile ages, it breaks down, and in many cases of clay and concrete tile, will crack. These tile eventually cave in and create a direct conduit for soil and sediment into the channel.

For both surface and subsurface drainage issues identified, the areas that may be improved through drainage work should be identified. In addition, a review of flood damage and the costs associated with repairs or property value lost should be evaluated.

Appurtenant structures must also be evaluated during the needs assessment. Structures such as bridges, culverts, headwalls, etc. often serve as control points that must be designed around. These structures may also require replacement as part of the project affecting the costs of the proposed project.

The location of appurtenant structures should be noted and may be used to determine the capacity needs of the channel at different locations. Structures such as bridges, culverts, and low water crossings should be studied to determine the existing capacity, and evaluated for replacement if necessary. These structures can also be used to evaluate the accumulation of sediments in the channel.

Conditions of culverts should be documented during the evaluation period. The evaluation should include the condition of the headwalls, wing walls, outlets and channels before and after the culverts, as well as the pipe itself. The amount of sediment in the culvert will need to be documented, as this will help in determining the existing capacity of the culverts.

Bridges and condition of the footings, walls, and channels should be documented. The deposition and scouring of material at bridges can give an indication of problems that may need to be addressed with a project. These problems may be alignment issues, or illustrate insufficient capacity underneath the bridge.

Notes and references to photographs should be utilized to document existing conditions as thoroughly as possible. This information can then be utilized when deciding if the project warrants additional work.

3.3.3 Estimating Historic and Current Drainage Capacity

In many cases, drainage projects are proposed in order to repair a failing system, and re-establish capacities that the system once had. In order to estimate historic and current system capacities, a fair amount of field work and investigation will be needed.

In order to determine the historic capacity of the drainage system, a detailed record of the original construction is needed. From these records calculations can be made to estimate the original capacity. If records are not available, field surveys will be needed to establish the original design grades and dimensions before calculations can be made.

In order to accurately estimate the capacity of the drainage system, it will need to be broken down into reaches that have fairly uniform properties. The capacity of each reach can be estimated through engineering calculations.

In order to estimate the historic capacity of the channel, public records are likely to be the easiest place to start. Any drainage projects that were built through the public petition process or conservation works of improvement should have extensive public records available. At a minimum the watershed and benefited properties of the original project should be listed. Depending on the age of the project and quality of records, original grade lines, elevations, and capacities may also be available.

Unfortunately, the records for these projects may not always be available. They may have been damaged or destroyed over time, or the quality of the records may not allow the estimate of capacities. In there cases, field work must be completed in order to estimate the original capacity.

Regardless of public records, field work and preliminary surveys are required to estimate the current capacity of the drainage system. Field observations of existing grade, dimensions, construction materials, and vegetation are all important in estimating flow capacities.

Observation should also be made of flow obstruction in open channels or in subsurface drains. Log jams and tiles clogged with sediment both drastically affect the capacity of the system and can cause severe drainage problems upstream.

3.3.4 Developing Design Capacity

For many rural drainage projects where the goal is to remove excess water from the soil profile, the design capacity will be based on the use of a drainage coefficient or a drainage curve. In other areas where flood protection is the goal of the project, design capacities should be based on peak runoff rates from a design storm.

When considering subsurface drainage, NRCS has developed recommendations for drainage coefficients based on system design and crop production. A drainage coefficient simply identifies the depth of water to be removed in a 24 hour period. For instance a ½" drainage coefficient requires the drainage system capacity be such that ½" of water could be removed from the entire watershed in one day. Table 14-5 in Chapter 14; Water Management of NRCS's Engineering Field Handbook gives recommendations for subsurface drainage system design.

Drainage Curves are often used in the design of open channels for rural drainage projects. NRCS has developed several drainage curves across the country. In Ohio the Q_a, Q_b, Q_c, and Q_d drainage curves have been used regularly. These drainage curves are to be used to determine the capacity required for the timely removal of surface water from rural lands. Drainage curves are not to be used to determine capacities when flood protection is a primary design goal.

The historic capacity of surface drainage systems should be considered as a major factor in the determination of the design capacity. This will re-establish the drainage capacity that the area had historically, and minimize the effects of increased flooding downstream.

When flood control or protection is determined to be the primary design goal, a design storm must be determined before design work can be started. Local zoning requirements, road and highway officials, and local leaders should all be consulted in the determination of the design storm.

Once the design storm is determined, an analysis on the watershed can be used to determine the peak discharge from the design storm. The capacity of the drainage system should meet or exceed the peak discharge from the design storm.

When developing the design capacities for drainage projects, downstream effects of the work must also be considered. Drastic increases in the channel capacity may only trade problems in one location, and move them downstream below the proposed improvement.

3.3.5 Summary

Finally, when conducting the drainage needs evaluation, full and complete documentation of the existing and historic conditions is a must. This may include photographs of the existing system, historical documentation such as aerials and ditch records, engineering calculations, inventory of problem areas, etc.

The following pages have two forms that may be used to document portions of the Drainage Needs Assessment. Any additional information and documentation should be attached and filed in the project design folder.

Drainage Needs Evaluation Form

Project Name: ____

Date of Petition: ___________________ **Watershed Acres:** __________________

Current Land Uses:

____

____

____

____

Problems To Be Solved Through Petition:

____

____

____

____

Channel History

Record all data found in public records relating to work authorized and conducted under ORC 6131, ORC 6133, ORC 1515, or similar state law that preceded any of those chapters and authorized such an improvement.

Date	**Reach**	**Grade Range** (%)	**Dimensions** (SS, BW, Etc.)	**Description of Work**	**Estimated Capacity** (cfs)

Existing Channel Condition

Record existing information on the channel in all categories listed below.

	Reach ___ to ___	**Reach** ___ to ___	**Reach** ___ to ___	**Reach** ___ to ___
Watershed *(acres)*				
Grade Range *(min% – max%)*				
Channel Bottom Material				
Shape – Bottom Width *(ft)*				
Shape – Side Slopes				
Vegetation - Banks				
Vegetation – Top of Banks				
Endangered Species (species/location relative to the channel)				
Tile Outlets Observed (estimate %, list larger ones)				
Tile Outlets >1’ Freeboard				
Tile Outlets <1’ Freeboard				
Tile Outlets at Grade				
Tile Outlets Submerged				
Culvert Rating				
Condition of culvert materials				
Condition of concrete wingwalls/headwalls/etc…				
Depth of sediment in Culvert?				
Estimated channel Capacity *(cfs)*				
Required channel Capacity *(cfs)* *(Design storm event)*				
Debris (log jams/trash) (Estimate % of Type A. B, C, D)				

General description of existing channel conditions. Include a description of whether or not the existing conditions demonstrate a need for construction. I.E. Does the channel not meet the capacity requirements needed for good drainage of the surrounding landscape? Are tile outlets submerged?

____

____

3.4 Environmental Review Process

In addition to determining the drainage needs for the watershed in question, an assessment of the existing drainage network must be conducted. This section discusses evaluation of the existing conditions from an environmental perspective. The review will be conducted primarily on open channels. Existing tile systems will not typically fall into this review process.

However, if proposed work includes replacing a channel with a closed conduit, there may be substantial permitting requirements to complete this work. These permitting issues include 404 permits from the Army Corps of Engineers, and 401 Water Quality Certification from Ohio EPA.

The assessment reviewed in this section is meant to satisfy the requirements with Ohio's Water Quality Standards and the Clean Water Act. To meet these requirements the Existing Aquatic Life Use Designation must be determined. These uses are listed in Ohio Administrative Code (OAC) 3745-1-08 through 3745-1-32. These standards can be found online at www.epa.state.oh.us/dsw/rules/3745-1.html.

Two tables are included below. These tables were developed as part of the Rural Drainage Advisory Committee in order to address conflicts between the Ohio's Drainage Laws and Ohio's Water Quality Standards. Currently, there are areas in these laws that may conflict depending on the proposed project and site conditions.

Table 1

No "existing use" complications

Framework and decision making matrix for drainage projects (part 1 of 3). Pertains to situations where there is no scientific biological field data to assign a sub-category of aquatic life use as an "existing use" which requires protection.

Position on Agricultural Landscape	Defined by watershed area (acres)	Primary Water Quality Concerns	Primary Socio – Economic Concerns	Preferred WQS Use Designations	Criteria Types Applied	Minimum Drainage Design for New Project
Upland Areas (often ephemeral)	< 2,000	Protect downstream uses; Public health	Cropland Drainage, Flooded Roads & Cropland	Drainage; General Aquatic Life	Chemical Only	Traditional Design
Transition Zone (often intermittent, sometimes ephemeral)	2,000 to 6,400	As above, plus: Increase pollutant assimilation; Feeder streams with some aquatic life	Water Conveyance Flooded Roads & Cropland	Drainage; Modified Warmwater Habitat	Chemical and Biological	One-sided Design
Lowlands	> 6,400	As above, plus: Pollutant loads; Year round aquatic habitats	Flooded Roads & Cropland	Warmwater Habitat	Chemical and Biological	Limited Snag & Clear; Natural Channel

Table 1

For the designer, projects have been classified by the watershed size on each table. Moreover, the minimum drainage design refers to the design approach to be used, and the minimum ecological expectation for the given category.

For example, in Table 1, Traditional Design is listed as the Minimum Drainage Design. This means that a traditional trapezoidal channel can be used. One-sided construction or natural channel design would have higher ecological functions for aquatic life use and could also be used for a design approach.

To determine the Aquatic Life Use Designation, refer to the Water Body Use Designation Index for the drainage basin where the project is listed. Designated uses for rivers and streams within that basin are listed within the index. If the is not listed in the Use Index, Table 1 should be used to determine the design approach.

If the designated use for the channel is listed in the Index, the designated use must be protected by the proposed design. If the designation was made based on 1978 Water Quality Standards, there is no scientific biological field data to establish the designated use. In these circumstances, refer to table 1 to determine the design approach. For any other cases Table 2 must be used.

Table 2
addressing "existing use" protection

Framework and decision making matrix for drainage projects (part 2 of 3). Pertains to typical in-field situations that do have scientific biological field data indicating a sub-category of aquatic life use (General Aquatic Life; Modified Warmwater or Exceptional) exists and requires protection.

Position on Agricultural Landscape	Defined by watershed area (acres)	Primary Water Quality Concerns	Primary Socio – Economic Concerns	Uses Attained	Existing Uses Protected	Minimum Drainage Design for New Project
Upland Areas (often ephemeral)	< 2,000	Protect downstream uses; Public health	Cropland Drainage Flooded Roads & Cropland	Drainage; General Aquatic Life	Drainage; General Aquatic Life	Traditional Design
Transition Zone (often intermittent, sometimes ephemeral)	2,000 to 6,400	As above, plus: Increase pollutant assimilation Feeder streams with some aquatic life	Water Conveyance Flooded Roads & Cropland	Drainage; Modified Warmwater	Drainage; Modified Warmwater	One-sided Design
	2,000 to 6,400		Water Conveyance Flooded Roads & Cropland	Drainage; Warmwater	Drainage; Warmwater	Over wide channel Design
Lowlands (perennial water)	> 6,400	As above, plus: Pollutant loads; Year round aquatic habitats	Flooded Roads & Cropland	Warmwater; Modified Warmwater w/ higher potential	Warmwater	Limited Snag & Clear; Natural Channel
	> 6,400		Flooded Roads & Cropland	Modified Warmwater (w/o higher potential)	Modified Warmwater	One-sided Design

Table 2

When conducting this review for proposed projects, assistance can be found with ODNR Division of Soil and Water Conservation staff members.

3.4.1 Upland Watersheds – Less Than 2,000 Acres

The following is a step by step process to conduct the environmental evaluation of proposed drainage projects with a watershed of 2,000 acres or less. This evaluation is meant to meet the requirements of Ohio's Water Quality Standards. This process is illustrated in the following flowchart.

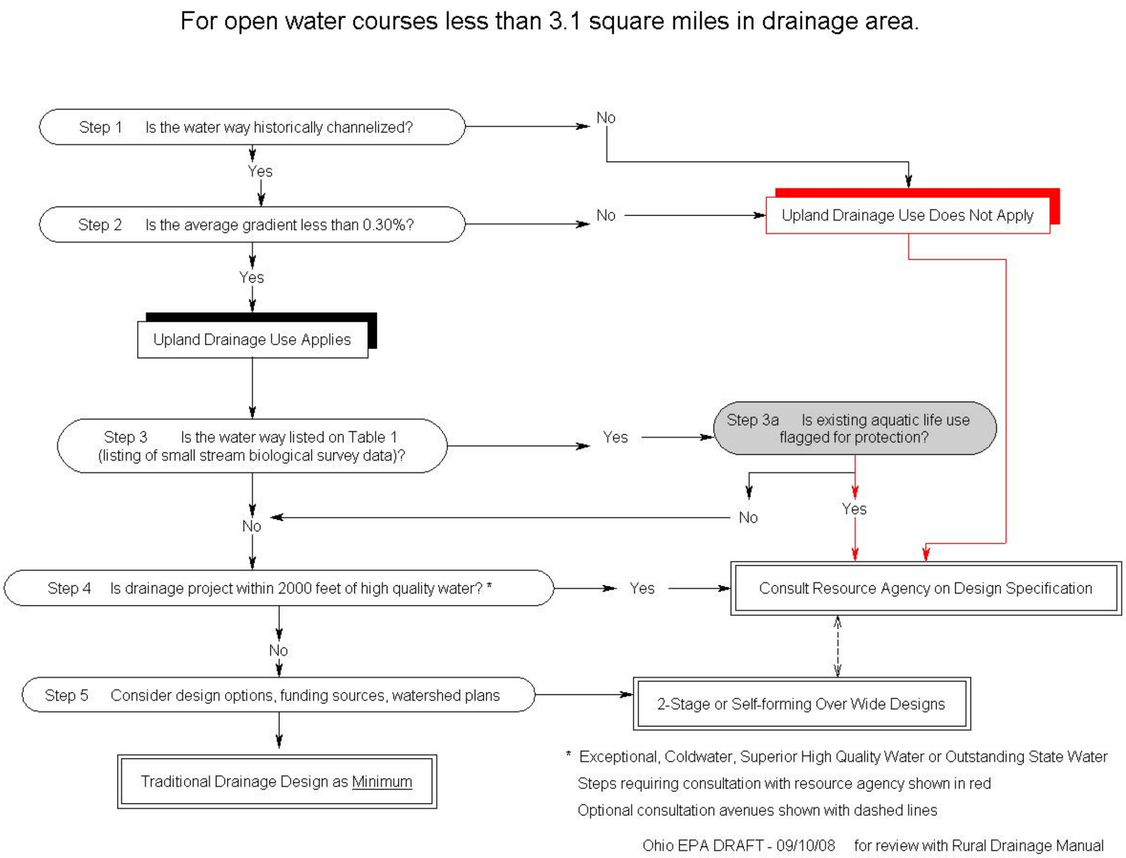

Figure 1. Environmental review flowchart for small upland watersheds

Step 1. Is the waterway historically channelized?

The Ohio Revised Code gives special consideration to watercourses that have been 'Historically Channelized'. This term is defined in ORC 6111 as:

> *'… the portion of a watercourse on which an improvement, as defined in divisions (C)(2) to (4) of section 6131.01 of the Revised Code, was constructed pursuant to Chapter 1515., 6131., or 6133. of the Revised Code or a similar state law that preceded any of those chapters and authorized such an improvement'*

In order for a watercourse to be considered 'Historically Channelized' the channel has to have had construction done to it through a public process. Documentation to support this can be found in the County Ditch Records. These records typically reside in the County Engineer's Office or at the Local Soil and Water Conservation District Office. A record of the date and name of the project should be recorded, as well as where to find the references to the project within the county records.

In some cases, county records may have been destroyed or lost over time. In these cases, evidence must be used to document the work done in the past. This evidence may be found in public documentation, such as the county commissioner's journals or records, aerial photos, physical evidence along the channel etc. Regardless of the evidence and documentation collected, the designation of historically channelized should be reviewed with Ohio EPA.

Step 2. Is the Average Channel Grade Less than 0.30%?

The average channel grade considers the existing grade on the channel. Steeper channels have more energy and ability to form aquatic habitat when compared to flatter channels. Therefore, channels with steeper grades are more likely to have higher aquatic life use values than flatter channels.

Channels with an average gradient in excess of 0.30% are not automatically required to have a higher ecological design requirement. However, additional evaluation should be conducted to determine the existing aquatic life use designation.

Upland Drainage Use Does / Does Not Apply

Upland drainage use is a classification within the Ohio Administrative Code. If the Upland Drainage Use applies to a water course, the biological requirements for water quality standards are removed. The chemical requirements of the water quality are still in effect, but the biological indicators are not considered in the water quality requirements.

Step 3. Is the waterway listed in Ohio EPA's Table 1, Small Stream Survey Data?

Ohio EPA has a listing of water quality monitoring data conducted on small streams. In general, water quality data has not been collected on streams with watersheds less than 5 to 10 square miles. Table 1 is a listing of the survey data collected on channels with watersheds less than 10 square miles. Ohio EPA is currently making this survey data available to the public through their website and should be available in the near future.

Until the information is available to the public a complete review of the existing water quality standards and consultation with ODNR; Division of Soil and Water Resources or Ohio EPA is required to determine the small stream data.

Step 3A. Is the Aquatic Life Use Flagged For Protection?

If the survey data concludes the aquatic life use designation to be 'Warmwater' habitat or above, it has been flagged for protection. Designations of Limited

Resource Water or Modified Warmwater Habitat are not flagged for protection of the aquatic habitat.

Step 4. Is the Drainage Project Within One Quarter Mile of a High Quality Water?

Any waters with an aquatic life use designation of Exceptional Warmwater or above are considered High Quality Waters. These designations include:

Exception Warmwater Habitat
Coldwater Habitat
Seasonal Salmonid Habitat
Outstanding State Waters

Any work completed in thee areas may influence the water quality downstream. When working in these areas special consideration must be given to the downstream effect of construction and how to minimize these effects.

Minimizing downstream effects may include consideration of timing of construction, pumping water around the construction site, or temporarily damming the watercourse in order to trap sediment.

Step 5. Consider Design Options, Funding Sources, and Watershed Plans.

This part of the evaluation considers the goals of project sponsors and the availability of public monies to construct a channel with a higher ecological function compared to a traditional trapezoidal channel.

3.4.2 Transition Zone watersheds – 2,000 Acres to 6,400 Acres

As watershed size increases the likelihood of a channel supporting aquatic life increases. Water is more likely to be flowing year round, and more apt to develop the habitat to support a wide variety of aquatic life.

The following is a step by step process to conduct the environmental evaluation of proposed drainage projects with a watershed of 2,000 acres to 6,400 acres. This evaluation is meant to meet the requirements of Ohio's Water Quality Standards. This process is illustrated in the following flowchart.

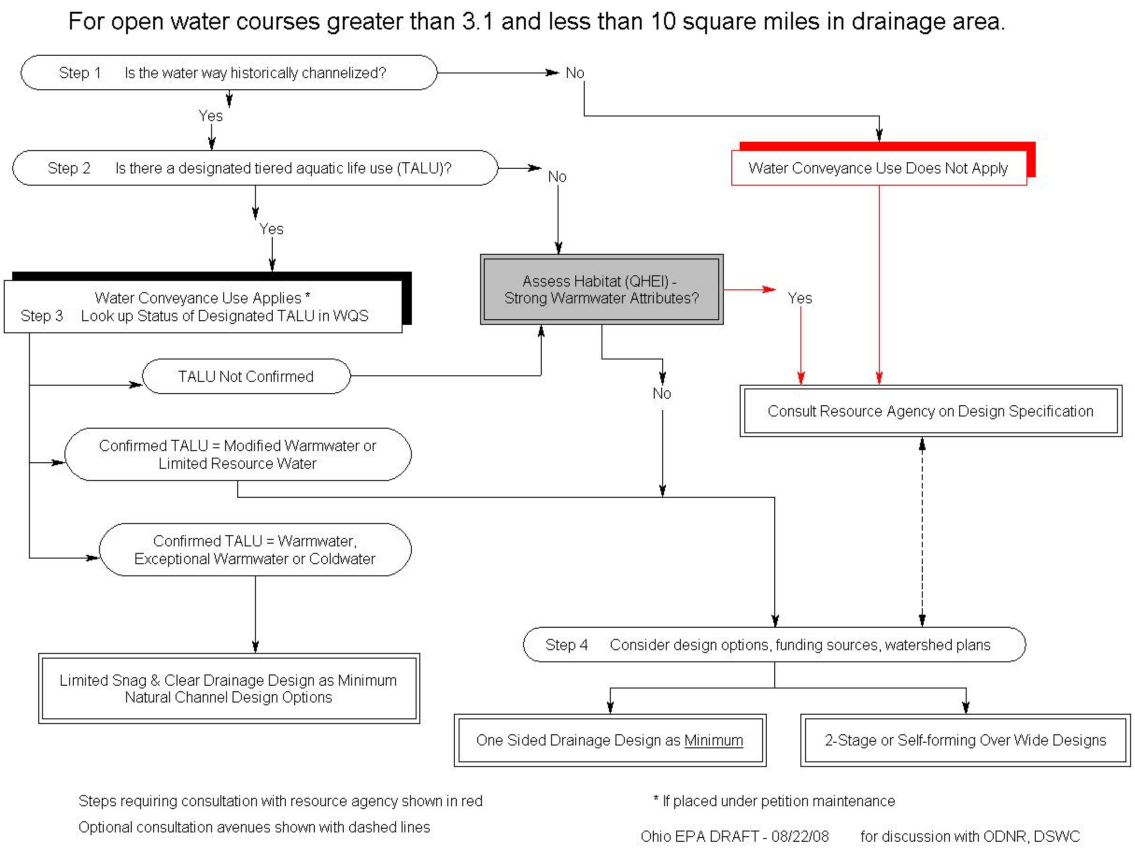

Figure 2. Environmental review flowchart for transitional watersheds

Step 1. Is the waterway historically channelized?

The Ohio Revised Code gives special consideration to watercourses that have been 'Historically Channelized'. This term is defined in ORC 6111 as:

> *'… the portion of a watercourse on which an improvement, as defined in divisions (C)(2) to (4) of section 6131.01 of the Revised Code, was constructed pursuant to Chapter 1515., 6131., or 6133. of the Revised*

Code or a similar state law that preceded any of those chapters and authorized such an improvement'

In order for a watercourse to be considered 'Historically Channelized' the channel has to have had construction done to it through a public process. Documentation to support this can be found in the County Ditch Records. These records typically reside in the County Engineer's Office or at the Local Soil and Water Conservation District Office. A record of the date and name of the project should be recorded, as well as where to find the references to the project within the county records.

In some cases, county records may have been destroyed or lost over time. In these cases, evidence must be used to document the work done in the past. This evidence may be found in public documentation, such as the county commissioner's journals or records, aerial photos, physical evidence along the channel etc. Regardless of the evidence and documentation collected, the designation of historically channelized should be reviewed with Ohio EPA.

Step 2. Is there a designated Tiered Aquatic Life Use?

In order to answer this question, the designer must look into the current water quality standards contained in the Ohio Administrative Code (OAC). Ohio EPA administers and monitors the water quality standards in Ohio, and the current standards can be found in OAC 3745-1. The standards can be found on Ohio EPA's website at:

www.epa.state.oh.us/dsw/rules/3745-1.html

The standards are divided into the major drainage basins across the state. The water quality standards for each basin can be downloaded in PDF form. The standards are written starting at the discharge point of the basin, and list the main channel and tributaries working upstream. In order to determine the tiered aquatic life use designation, the designer must locate the listed channel in the water quality standards. This usually requires knowing the names of the all of the channels downstream of the stream or ditch being considered for the project.

If the channel has an aquatic life use designated, it will be listed in the water quality standards. If the channel can not be found in the water quality standards, there is no aquatic life use designation for that channel. Moreover, if the life use is marked with an asterisk, it means that the life use has never been confirmed with biological sampling data. If the life use has never been confirmed or there is no listing, a QHEI assessment must be conducted.

The QHEI assessment is used to gauge the habitat within the channel. Assessments that show strong warmwater attributes will be required to have designs with a lighter construction footprint. These design approaches are a snag and clear to remove flow obstructions in the channel, or to design a natural channel.

Channels that show little warmwater attributes or score as a modified habitat, can use one-sided construction methods, or use an over-wide design approach to the channel.

Step 3. Look up the status of the Designated TALU in WQS.

The tiered aquatic life use designations are a measurement of the variety of aquatic life that has been found in the channel. The review process considers three different scenarios for the aquatic life use designations. The scenarios considered are TALU Not Confirmed, Confirmed Modified Warmwater Habitat, Confirmed Warmwater or above, and are described below.

As discussed earlier, if the TALU is not confirmed with biological sampling data, a QHEI must be conducted on the channel where the proposed improvement is to be constructed. TALU's that are not confirmed are marked in the water quality standards with an asterisk.

Confirmed Modified Warmwater Habitat means that the channel has had biological sampling, and that the channel has been modified to such an extent that natural recovery is very unlikely. many channel with a confirmed MWH designation are currently under county maintenance programs.

Confirmed Warmwater or Higher are channels where the aquatic life has been evaluated, and a variety of species are living in the channel. In order to protect the habitat, a higher ecological channel design, or lighter construction footprint is required.

Step 4. Consider design options, funding sources, watershed plans.

This part of the evaluation considers the goals of project sponsors and the availability of public monies to construct a channel with a higher ecological function compared to a traditional trapezoidal channel.

3.4.3 Lowland watersheds – Over 6,400 Acres

Ohio EPA's Aquatic Life Use Designations are designed for channels with watersheds of 10 square miles or more. The environmental review for this size channel assumes a tiered aquatiuc life use designation is in place for the channel, and that the channel can support a variety of aquatic life.

The following is a step by step process to conduct the environmental evaluation of proposed drainage projects with a watershed of 6,400 acres or more. This evaluation is meant to meet the requirements of Ohio's Water Quality Standards, and is illustrated in the following flowchart.

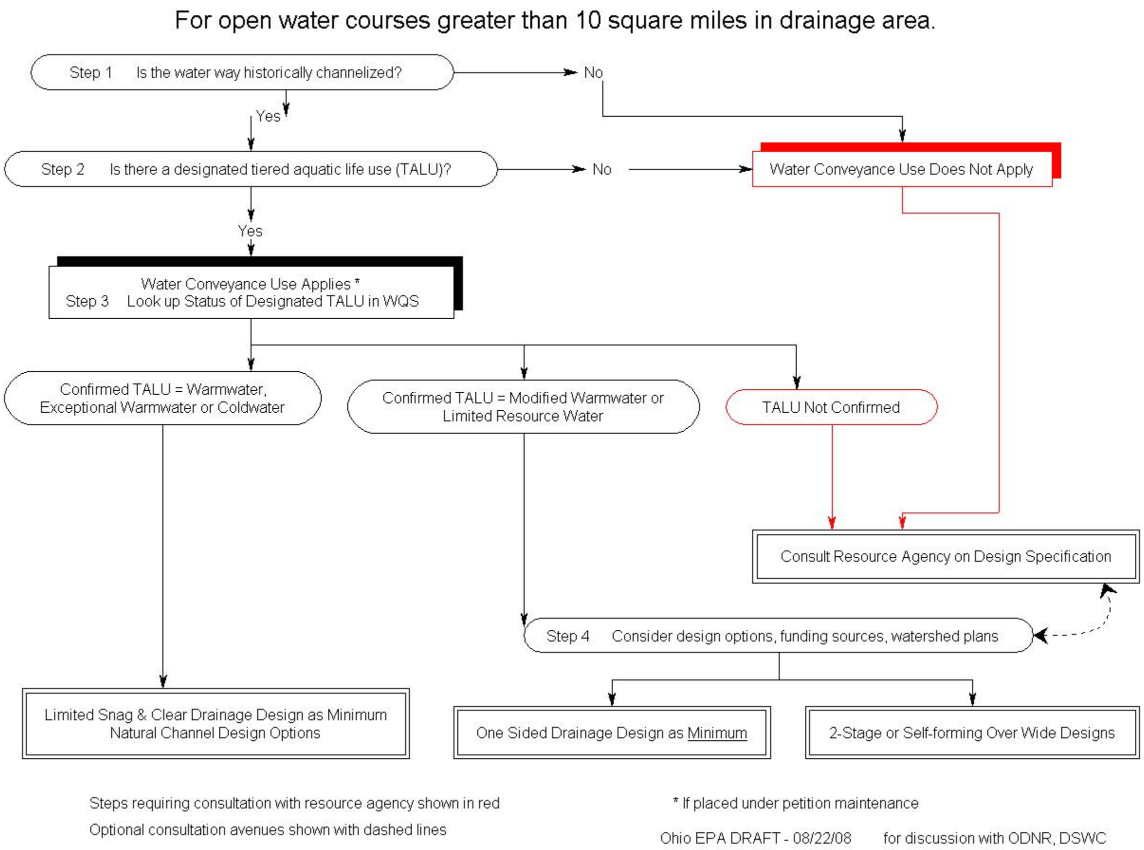

Figure 3. Environmental review flowchart for lowland watersheds

Step 1. Is the waterway historically channelized?

The Ohio Revised Code gives special consideration to watercourses that have been 'Historically Channelized'. This term is defined in ORC 6111 as:

> *'… the portion of a watercourse on which an improvement, as defined in divisions (C)(2) to (4) of section 6131.01 of the Revised Code, was constructed pursuant to Chapter 1515., 6131., or 6133. of the Revised*

Code or a similar state law that preceded any of those chapters and authorized such an improvement'

In order for a watercourse to be considered 'Historically Channelized' the channel has to have had construction done to it through a public process. Documentation to support this can be found in the County Ditch Records. These records typically reside in the County Engineer's Office or at the Local Soil and Water Conservation District Office. A record of the date and name of the project should be recorded, as well as where to find the references to the project within the county records.

In some cases, county records may have been destroyed or lost over time. In these cases, evidence must be used to document the work done in the past. This evidence may be found in public documentation, such as the county commissioner's journals or records, aerial photos, physical evidence along the channel etc. Regardless of the evidence and documentation collected, the designation of historically channelized should be reviewed with Ohio EPA.

Step 2. Is there a designated Tiered Aquatic Life Use?

In order to answer this question, the designer must look into the current water quality standards contained in the Ohio Administrative Code (OAC). Ohio EPA administers and monitors the water quality standards in Ohio, and the current standards can be found in OAC 3745-1. The standards can be found on Ohio EPA's website at:

www.epa.state.oh.us/dsw/rules/3745-1.html

The standards are divided into the major drainage basins across the state. The water quality standards for each basin can be downloaded in PDF form. The standards are written starting at the discharge point of the basin, and list the main channel and tributaries working upstream. In order to determine the tiered aquatic life use designation, the designer must locate the listed channel in the water quality standards. This usually requires knowing the names of the all of the channels downstream of the stream or ditch being considered for the project.

If the channel has an aquatic life use designated, it will be listed in the water quality standards. If the channel can not be found in the water quality standards, there is no aquatic life use designation for that channel. Moreover, if the life use is marked with an asterisk, it means that the life use has never been confirmed with biological sampling data.

If the channel can not be found in the water quality standards, Ohio EPA and ODNR should be contacted for a consultation on design requirements. This consultation should consider the history of the channel, and the existing condition of the channel.

Step 3. Look up the status of the Designated TALU in WQS.

The tiered aquatic life use designations are a measurement of the variety of aquatic life that has been found in the channel. The review process considers three different scenarios for the aquatic life use designations. The scenarios considered are Confirmed Warmwater Habitat or above , Confirmed Modified Warmwater Habitat , or TALU Not Confirmed, these scenarios are described below.

Confirmed Warmwater Habitat or higher are channels where the aquatic life has been evaluated, and a variety of species are living in the channel. In order to protect the habitat, a higher ecological channel design, or lighter construction footprint is required. These design approaches are Limited Snag and Clear, or a Natural Channel Design.

Confirmed Modified Warmwater Habitat means that the channel has had biological sampling, and that the channel has been modified to such an extent that natural recovery is very unlikely. many channel with a confirmed MWH designation are currently under county maintenance programs.

If the Water Quality Statndards show the aquatic life use with an asterisk, it means the use has never been confirmed with biological data. In the case where the TALU has not been confirmed, a consultation should be scheduled with ODNR and Ohio EPA.

Step 4. Consider design options, funding sources, watershed plans.

This part of the evaluation considers the goals of project sponsors and the availability of public monies to construct a channel with a higher ecological function compared to a traditional trapezoidal channel.

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4. Design & Construction

4 *Design and Construction Considerations*

Once the review of the existing channel has been completed, the focus must be turned to the development of design requirements and construction specifications. The following sections discuss references that can be used for design and specification development

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4.1 Design Considerations

Currently there is much debate regarding the proper design of open channels when considering the costs, functionality, and environmental impacts of channel construction both upstream and downstream. However, most of this debate concentrates on the dimensions and proportions of the channel cross section. Regardless of the outcome of environmental reviews or the existing condition of the channel, the designer should strive to design a stable channel cross section.

For the purposes of this discussion, a stable channel is defined as a channel with a flow line that neither aggrades or degrades beyond acceptable limits, and does not migrate laterally beyond acceptable limits.

4.1.1 Design References

The Natural Resources Conservation Service (NRCS) has developed many design references for open channels over the past 70 years.

The most widely used design manual for open channels in Ohio has been Technical Release 25 Design of Open Channels (TR-25). TR-25 provides a detailed stability analysis for a given channel cross-section, considering engineering properties of the materials where the channel will be constructed.

Given the variability of design possibilities, selecting correct values for variables is imperative when making engineering calculations. An important part of any open channel design is the proper selection of Manning's roughness coefficient. An informative guide to assist in the selection of a suitable roughness coefficient is also available through NRCS. In 1963 the Soil Conservation Service published the 'Guide For Selecting Roughness Coefficient "n" Values for Channels.'

Both TR-25 and the roughness coefficient guides can be found online at NRCS's website, or contact the State Conservation Engineer.

4.2 Purpose of Construction Specifications

This section provides guidelines for preparing and utilizing construction specifications.

4.2.1 Definition

"Specifications" is a general term applying to all directions, provisions, and requirements pertaining to the performance of the work and payment for the work.

4.2.2 Importance and Characteristics of Well-Written Specifications

Well-written specifications are essential to the efficient construction of a successful project. Well-written specifications inform the Contractor of the work to be performed, the conditions and restrictions on performance of the work, the expected quality of the work, and the manner in which the work will be measured for payment.

With the increased complexity and specialization in modern construction and the need for the Project Engineer to focus on legal requirements and administration, use of the phrase "as directed by the Engineer" should be minimized. Work requirements must be clearly stated in the specifications.

Well-written specifications:

- are clear, concise, and technically correct.
- do not use ambiguous words that could lead to misinterpretation.
- are written using simple words in short, easy to understand sentences.
- use technically correct terms, not slang or "field" words.
- avoid conflicting requirements.
- do not repeat requirements stated elsewhere in the Contract
- do not explain or provide reasons for a requirement.
- state construction requirements sequentially.
- avoid the use of awkward phrases such as "and/or" and "him/her." Rewriting the sentence can eliminate such phrases.

Furthermore, the phrases "approved by the Engineer" or "accepted by the Engineer" should be avoided. These should be used only when the Engineer will actually accept or approve the work. In such phrases, "approved" and "accepted" are synonymous; there is no difference in the responsibility taken by the Engineer.

4.2.3 Uniformity

Specifications from project to project should provide uniformity in the use and application of specifications. Frequent changes to specifications and differences in specifications from project to project lead to misinterpretation, inconsistent enforcement, higher bid prices, and contractor claims.

4.2.4 Materials-Methods vs. End-Result Specifications

Materials-methods and end-result are the two basic types of construction specifications. Materials-methods specifications describe in detail the materials, workmanship, and processes the Contractor is to use during construction. Materials-methods specifications restrain contractor innovation and obligate the owner to accept the work if the specified materials and processes are used. End-result specifications describe the desired result or quality of the final product to be achieved. End-result specifications encourage contractor innovation and allow the owner to accept or reject the final product. End-result specifications are preferred.

Quality Control/Quality Assurance (QC/QA) is a type of end-result specification. QC/QA specifications require the Contractor to perform all testing necessary for control of production while the owner performs the testing necessary to determine acceptance, rejection, or price adjustment of the product. Acceptance/rejection/price adjustment is usually based on a statistical analysis of the test results.

4.2.5 Materials & Construction Specifications

A detailed set of construction and material specifications has been developed by the Natural Resources Conservation Service (NRCS) over the last 40 years. These specifications can be referenced and used in the development of contract documents. These specifications can be found at the following web link:

http://www.nrcs.usda.gov/technical/ENG/construction_specs_home.html

Furthermore, the Ohio Department of Transportation has also developed detailed material and construction specifications. These specifications can be found online at:

www.dot.state.oh.us/construction/OCA/Specs/default.htm

Use of this type of contract documentation should reduce contract errors and fully describe all party responsibilities.

References:

CDOT – *Chapter 16 Construction Specifications – 2005,* Colorado State Department of Transportation

[http://www.dot.state.co.us/DesignSupport/Design%20Guide%2005/DG05%20Ch%2016%20Specifications.pdf]

4.3 Construction Storm Water Permit Requirements

As of March 10, 2003, if a construction project disturbs one or more acres of ground, then a permit to discharge storm water is required. The permitting program is mandated in the Clean Water Act and is part of the NPDES (National Pollutant Discharge Elimination System) program.

Examples of ground disturbing activities include clearing and grubbing, grading, and excavating. Projects that are routinely permitted include new building construction sites, re-development projects and road building. Normal farming practices are excluded from this permit requirement, but the ground disturbing work and storm water runoff associated with building and maintaining open ditch improvements for agricultural drainage are covered by the permitting regulations. Once constructed the performance of routine maintenance that maintains the original line and grade, hydraulic capacity, or original purpose of the open ditch does not need a construction site storm water permit unless the ground disturbance reaches five acres or more [40 CFR 122.26(b)(15)].

Ohio EPA administers the construction storm water permitting program and requires practices (BMPs) to keep pollutants out of streams and other surface waters. The person or governmental entity making drainage improvements must apply for permit coverage when it is required. Table 4.3.1 presents a summary of storm water permitting requirements for different types of drainage improvement projects.

Table 4.3.1 - A summary of storm water permitting requirements for different types of drainage improvement projects.

Type of Drainage Improvement Project	Acres of Ground Disturbed[4]	NPDES Construction Site Storm Water Permit (OHC000003)
Routine Maintenance[5] of a Surface Water Drainage Project (e.g. petition ditch or similar type project)	---	Not Required
Periodic Bottom Dipping and Shaping of Ditches under Maintenance Program	5 or more	Required
	Less than 5	Not Required
Construction of a New Surface Water Drainage Project (e.g. petition ditch or similar type project)	1 or more	Required
	Less than 1	Not Required
Sub-surface Tile Main Drainage Projects	---	Not Required
Conservation Practices such as Filter Strips and Grass Waterways	---	Not Required

[4] Refer to the text for guidance on estimating the acreage of disturbed ground for each project type. Projects subject to periodic maintenance programs may reduce the acres of ground disturbed by following recommended BMPs.

[5] Annual maintenance involving no significant ground disturbing work.

The permit requirements for each basic project type are described below along with recommended BMPs to control erosion and the discharge of sediment to surface water.

Routine Maintenance of a Surface Water Drainage Project
*No general construction site storm water permit is required***.** This work usually involves practices to manage vegetation cover along the entire project length and spot repairs of tile outlets and other structures. There may be isolated locations where ground is disturbed and re-planted but the total area disturbed each year is minimal. Estimates of ground disturbing work are not required if vegetation management is limited to mowing and herbicide spraying. General descriptions of the types and amount of routine maintenance performed should be retained as part of the petition ditch records.

Periodic Bottom Dipping and Shaping of Ditches under Maintenance Program
A general construction site storm water permit is required when ground disturbing activity exceeds 5 acres. Depending upon the rates of sediment deposition bottom dipping to maintain tile drainage outlets can occur every 10 to 20 years on low gradient open ditches. This maintenance work and the reshaping of the channel side slopes to repair bank slippage create exposed soil and storm water runoff. Therefore, prior to initiating the project the contractor, landowner or government agency is responsible for estimating the acreage of disturbed ground. Guidance for making these estimates is provided in Table 4.3.2. If the area is 5 or more acres, then a NOI should be submitted. The project should begin only after authorization for permit coverage is obtained from Ohio EPA.

Construction of a New Surface Water Drainage Project
A general construction site storm water permit is required when ground disturbing activity exceeds 1 acre. Clean outs of historically channelized water ways not currently under petition ditch maintenance are considered herein to be new drainage projects. Any drainage project on a natural stream or waterway would also be a new drainage project. These new drainage projects will typically involve considerably more land clearing, grading and bank stabilization and thus have a much greater potential to create storm water runoff and the discharge of sediment and other pollutants. The one acre threshold for permit coverage applies because the work performed is outside what can reasonably be termed routine maintenance [40 CFR 122.26(b)(15)] and a new drainage project meets the definition of small construction activity.

Prior to initiating the project the contractor, landowner or government agency is responsible for estimating the acreage of disturbed ground. Guidance for making these estimates is provided in Table 4.3.2. If the area is 1 or more acre, then a NOI should be submitted. The project should begin only after authorization for permit coverage is obtained from Ohio EPA.

Conservation Practices such as Filter Strips and Grass Waterways
No general construction site storm water permit is required, unless the project is at an Animal Feeding Operation. Construction at an AFO disturbing one or more acres of ground requires a permit. Otherwise conservation practices installed in accordance with Natural Resources Conservation Service specifications and associated with agricultural production or silviculture are exempt from the construction site storm water permit.

Sub-surface Tile Main Drainage Projects

No general construction site storm water permit is required. Storm water runoff that delivers nonpoint pollution from agricultural activities on cropland is not regulated under the Clean Water Act. The installation and maintenance of subsurface field drainage systems and large multi-farm tile mains does not require a Construction Site Storm Water permit.

Table 4.3.2 - Guidance for making estimates of acreage disturbed by construction work on open ditch or surface water drainage improvements.

Work Area Description	Area Counts Toward 1 or 5 acre Threshold	Comment on How to Comply with Permit
Side slopes & top berm where vegetation is removed	Yes	Stabilization Procedures listed in Section 4.4 of this Manual
Re-shaped side slopes	Yes	
Other areas shaped by grading	Yes	
Spoil piles & sediment (bottom dipped material) placed along or immediately adjacent to top berm prior to spreading on adjacent cropland	Yes	Spread on cropland within 21 days or, if spread after 21 days apply the temporary stabilization procedures listed in this Manual
Stockpiled soil & sediment (bottom dipped material) placed elsewhere and not destined for spoiling on adjacent cropland	Yes	Stabilization Procedures listed in Section 4.4 of this Manual
Access roads (other than existing maintained public or private roads and farm lanes)	Yes	
Area where soil & sediment (bottom dipped material) is spoiled on adjacent crop land when graded along existing contours.	No	Not applicable
Soil & sediment (bottom dipped material) immediately hauled off site	No	Not applicable

How to obtain permit coverage?

Contractors, landowners and governmental agencies involved with open ditch and larger stream drainage improvement projects are responsible for evaluating the need for NPDES construction site storm water permits. In most circumstances permit coverage may be obtained through submission of a one page Notice of Intent (NOI) application form. A small fee ($200 to a $500 maximum) is associated with the permit. In response to the NOI Ohio EPA authorizes discharges from the project under the construction storm water general permit (OHC000003) and typically responds with an approval letter within 3 weeks time[6]. An NOI form and corresponding instructions are included in sections 4.6 and 4.7 of this manual and can also be found at http://www.epa.state.oh.us/dsw/storm/stormform.html.

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[6] Three week turn around time assumes a complete NOI application; the applicant is encouraged to submit NOI application farther in advance of the 21 day processing time.

4.4 Stabilization BMPS Required in The Storm Water Permit

The applicant is responsible for following a storm water pollution prevention plan (SWP3) that is designed to minimize the delivery of sediment and other pollutants to surface waters. A storm water pollution prevention plan (SWP3) is required when a drainage improvement or maintenance projects requires a construction site storm water permit.

Ohio EPA and Ohio DNR DSWR have developed guidelines for the types of BMPs to follow and be inserted into the plan as SWP3 documentation required under the permit. Ohio's expectations for an acceptable SWP3 for drainage improvement projects are aligned with the BMPs described in this Section of the Manual. The permittee is encouraged to apply these BMPs as the SWP3. Alternatively the permittee may elect to plan and document other BMPs through a SWP3 developed for the individual project. **BMPs to be included in the engineering plan to meet Ohio's expectations for an acceptable SWP3 are shown below.**

1. **Clearing and Grubbing -** Clearing and grubbing shall not advance more than 2 working days ahead of the excavation of the channel. Unless reshaping of the bank sideslopes is necessary, the integrity of the channel shall be maintained by keeping the vegetation roots in place and bottom and bank sideslopes intact. All trees, logs, brush, and other woody material shall be disposed of in designated on-site areas or hauled off-site to an approved disposal area. The woody material may be burned, buried, piled, or chipped. All burning shall be performed outside the channel and shall conform to regulations in effect in the area. All buried material shall have adequate earth cover and mounded up to allow for settlement. Special attention shall be given to visual resources, protecting and maintaining key shade, food, and den trees and to stabilization of disturbed areas. Additional information on clearing and grubbing is located in section 6.1.3 of this manual.

2. **Seeding -** Seedbed for the grass berms and banks shall be scarified with a disc or similar tool to an approximate depth of 3 inches where accessible with equipment; a depth of 1 inch is acceptable where hand tools are required. Channel slope seeding shall be accomplished within 24 hours of excavation. Seeding rates must be determined and specified in the design stages of the project. A companion cover of wheat, oats, or cereal rye shall be used during dormant seasons of the year. Additional information on seeding and mulching is located in section 6.1.1 of this manual.

3. **Mulching -** Grass berms shall be mulched at a rate of 4,000 lbs. per acre, or approximately 130 small square bales per acre. Channel slopes do not require mulching. Mulch shall be applied to areas seeded not later than 2 working days after seeding has been performed. Straw mulch material shall be stabilized within 24 hours of application using a mulch crimper or equivalent anchoring tool or by a suitable tackifier. When the mulch crimper or equivalent anchoring tool is used, it shall have straight blades and be the type manufactured expressly for and capable of firmly punching the mulch into the soil. Where the equipment can be safely operated, it shall be operated on the contour. Hand methods shall be used

where equipment cannot safely operate to perform the work required. Additional information on seeding and mulching is located in section 6.1.2 of this manual.

4. **Placing and Spreading Spoil -** Place spoil or removed material in a location so that it cannot re-enter the ditch. Spoil piles which are not to be spread within 21 days of being excavated, shall be seeded and mulched within the first seven days after construction. If stockpiles are located adjacent to the channel where dewatering of the dredged material will occur, silt fence is recommended.

5. **Grade Stabilization Structure Installation -** Install all bank protection, grade control structures, and other related protection devices as the work progresses to permit the proper functioning of the channel. Grade stabilization structures shall be installed once the location for surface water entry points has been established and the reach has been graded to final dimensions. Grade stabilization structures shall be installed as dictated by the project plans and specifications.

6. **Channel Work in Areas Identified as High Quality Stream Resources -** Efforts shall be made to conduct work during periods when the ditch is dry. In situations where the downstream terminus of a drainage improvement project is located within 2000 feet of a high quality stream resource (defined by Ohio EPA tiered aquatic life and antidegradation categories, see Section 2.1 of this Manual), the channel should be blocked when excavation is performed to prevent sediment from moving downstream. Depending if water flow is present and the size of the drainage way, it may be necessary to divert flow or pump water around the work area until the area is stabilized.

7. **Vegetation Establishment and Monitoring -** At the completion of the project, the inspector shall identify any areas without the uniform density of at least 70 percent grass cover. Any areas not meeting the required density shall be repaired as soon as possible. County maintenance crews shall inspect new projects once a month for an entire growing season or until an acceptable seeding is established. Areas void of vegetation during non-growing seasons shall be protected by mulching or other appropriate measures.

8. **Additional SWP3 Content for <u>All</u> Open Water Drainage Projects**

   - Phase ground disturbing activities in linear increments along the water course (e.g., 200 feet, or distance covered in each days work). Complete stabilization (temporary or final) of each increment to protected from erosion at the end of each work day and prior to disturbing the next increment.

   - Perform work during low flow. Do not begin work if a large rain event is imminent.

   - Take appropriate pre-cautions with all de-watering activities associated with the project so as NOT to create turbid discharges to waters of the state. This can be accomplished by having sediment-laden water pass through a filter bag, sediment pond or similar device designed to remove sediment from a concentrated discharge

- Provide a stable working pad for equipment if working on very wet ground. If equipment is placed in the channel, make it non-erodible material

- All Stream crossing for equipment access must be constructed of a non-erodible fill utilizing appropriate sediment and erosion control

- Utilize low impact equipment to the maximum extent practical

- Install and maintain silt fencing if stockpiling or dewatering the dredged material

- Install matting or turf reinforcement mats where success of typical grass seeding practices is in doubt

- Stabilize (temporary or final) all disturbed areas within 7 days of initial disturbance. Ditch banks and areas immediately adjacent to the water course shall be stabilized daily.

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5. Channel Maintenance

5 Drainage Maintenance

Maintenance programs were not originally part of Ohio's petition process. Originally maintenance of the construction was the obligation of individual landowners. This lead to a wide range of results, but in general projects would be petitioned again after the original construction had been degraded, and the design flow-line or capacity had been lost.

To address this, county maintenance programs were mandated by the Ohio Revised Code (ORC) in 1957. Legal requirements to conduct maintenance are detailed in ORC 6137, and all projects constructed under ORC 1515, ORC 6131, or ORC 6133 are required to be maintained by the county commissioners.

Maintenance programs are obligated to maintain the original construction that was completed through whichever public process was used. This includes the channel capacity, flow line, erosion control structures, outlet pipes, and other appurtenances constructed with the project.

In maintaining the original construction, maintenance supervisors should strive to leave the smallest possible 'foot print' on the channel. Less invasive practices are encouraged, where a minimal disturbance of the channel results.

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5.1 Maintenance Programs

All projects constructed through ORC 6131, 6133, and 6135 after August 23, 1957 must be maintained in accordance to ORC 6137. Similarly, all drainage projects constructed under ORC 1515 must be maintained by the board of county commissioners, but how this maintenance is to be conducted is not specified. The following is a review of some of procedures set forth in ORC 6137.

5.1.1 Maintenance Funds

Ohio Revised Code 6131.02 requires the board of county commissioners to establish a maintenance fund for each improvement constructed under ORC 6131 and ORC 6133. A maintenance fund must also be established for improvements constructed under ORC 6135 (Interstate County Ditches), if the ability to do so has been granted by the adjoining state. For improvements constructed under ORC 1515 (Conservation Works of Improvement), establishing a separate maintenance fund for each project is recommended.

Maintenance accounts are funded by assessments paid by the owners befitting from the project. The proportion of maintenance assessments paid by each owner is based on the assessments originally developed to pay for the construction of the project. The assessments for maintenance is levied on the real estate taxes for each parcel, and are levied only once per year. Maintenance accounts are limited to an unencumbered balance of no more than twenty percent of the original construction costs of the project.

The board of county commissioners does have the authority to combine improvements within the same watershed into a Drainage District. In this case, assessments for maintenance are made in the same percentage as the original costs for each project to be maintained. However, when combining drainage projects, the commissioners and engineer must consider uniformity of topography and soil types so that maintenance activities will be uniform across the watershed.

5.1.2 Conducting Maintenance

Conducting maintenance on drainage improvements considers all activities to maintain the original flow line and capacity of the channel or tile. In order to achieve this, a permanent easement is established for maintenance purposes. For open channels the easement is limited to a maximum of 25 feet measured at right angles to the channel bank. The permanent easement is limited to one side of the channel wherever practical. When an emergency situation exists, the county engineer may extend the easement temporarily to 75 feet when approved by the county commissioners. Maintenance activities are to be conducted within the easement areas.

The county engineer has general charge and supervision of repair and maintenance activities of projects built under ORC sections 6131, 6133, and 6135. As such, the county engineer is responsible for annual inspection of the improvements and reporting the condition of the improvements to the county commissioners. The engineer’s report is to include repairs that are needed along with estimated costs. These estimates are used by the county commissioners to establish maintenance assessments to be included in real estate taxes.

In making inspections, the following table has been developed to review areas to be considered for maintenance. Moreover, the following page contains a work order to efficiently and concisely record the work to be completed.

Work Item	Items to consider
Sediment Buildup	Approximate depth to be dipped: Approximate length to be dipped:
Bank Erosion	Materials needed: Length, depth and height needed:
Outlet Pipes	Size needed (length and diameter): Animal Guard needed: Outlet toe protection needed:
Vegetation:	Noxious species present: Areas in need of reseeding:
Maintenance Berm	Locations that require notification of encroachment on berm: Areas to be reseeded: Items located in maintenance berm:
Surface Outlets	What needs repaired: Materials and quantities needed:
Culverts	Culvert needs (repaired replaced) Culvert needs cleaned (yes no)

Maintenance Work Form

Inspector: Ditch Name/Number:
Date:

Work Item	Reach/Location	Description of work to be done

5.3 Construction Storm Water Permit Requirements

How to obtain permit coverage?
Contractors, landowners and governmental agencies involved with maintaining open ditch and larger stream drainage improvement projects are responsible for evaluating the need for NPDES construction site storm water permits. In most circumstances permit coverage may be obtained through submission of a one page Notice of Intent (NOI) application form. A small fee ($200 to a $500 maximum) is associated with the permit. In response to the NOI Ohio EPA authorizes discharges from the project under the construction storm water general permit (OHC000003) and typically responds with an approval letter within 3 weeks time[7]. An NOI form and corresponding instructions are included in sections 4.6 and 4.7 of this manual and can also be found at http://www.epa.state.oh.us/dsw/storm/stormform.html.

Routine Maintenance of a Surface Water Drainage Project
No general construction site storm water permit is required unless the total ground disturbing activity exceeds 5 acres. This work usually involves practices to manage vegetation cover along the entire project length and spot repairs of tile outlets and other structures. There may be isolated locations where ground is disturbed and re-planted but the total area disturbed each year is minimal. Estimates of ground disturbing work are not required if vegetation management is limited to mowing and herbicide spraying. General descriptions of the types and amount of routine maintenance performed should be retained as part of the petition ditch records.

Periodic Bottom Dipping and Shaping of Ditches under Maintenance Program
A general construction site storm water permit is required when ground disturbing activity exceeds 5 acres. Depending upon the rates of sediment deposition bottom dipping to maintain tile drainage outlets can occur every 10 to 20 years on low gradient open ditches. This maintenance work and the reshaping of the channel side slopes to repair bank slippage create exposed soil and storm water runoff. Therefore, prior to initiating the project the contractor, landowner or government agency is responsible for estimating the acreage of disturbed ground. Guidance for making these estimates is provided in Table 4.3.2. If the area is 5 or more acres, then a NOI should be submitted. The project should begin only after authorization for permit coverage is obtained from Ohio EPA.

[7] Three week turn around time assumes a complete NOI application; the applicant is encouraged to submit NOI application farther in advance of the 21 day processing time.

6. BMPs

6.1 Vegetation Establishment & Control

6.1 Vegetation Establishment, Control, and Maintenance

The vegetation established along an open channel has a significant effect on the stability of the channel, the flow characteristics, the capacity, and the habitat within the channel itself. For these reasons vegetation selection and management is an important tool in addressing a variety of challenges within the channel.

In constructed and maintained channels grasses are often used as the primary barrier to bank erosion and scour. Grasses are used to stabilize the soils above the waterline at low flow, and reduce flow velocities at the soil surface. The upkeep of such a stand of grass may include mowing, spraying, fertilizing, and reseeding.

In a natural channel setting, vegetation selection will often include more shrubs and trees and less emphasis on grasses. In these situations the management of vegetation will be much less intense. Practices such as spot plantings, removal of log jams, and cutting dead trees and snags from the channel are used to prevent excessive erosion, and protect valuable structures such as bridges or other appurtenances.

In any case the goals and purposes for the vegetation must be clearly identified. Then proper selection of vegetation types and species can be made to meet the intended goals. Selected vegetation must be tolerant of occasional to frequent inundation, capable of withstanding anticipated flow velocities, and be cost effective through the establishment and maintenance phases of the project.

When identifying the goals and purposes for vegetation to be established or managed along the channel, additional benefits may also be incorporated for little or no cost. Additional purposes that vegetation may serve include sediment filtering, wildlife cover, shading of the water surface, provide forage for wildlife, etc. These additional benefits should be considered and included where appropriate.

The following practices are basic recommendations to meet the identified goals for the project sponsors and participants.

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6.1.1 Seeding

Description:

Preparation, placement, and establishment of permanent vegetation within or along the channel.

Purpose:

To stabilize the soil, control and reduce sheet and rill erosion, and to capture and retain sediment.

Where Applicable:

Anywhere where construction, development, or maintenance activities have left bare soils.
Areas where soils have become unstable due to active erosion.

Advantages:

Timely seeding will reduce costs of repairing erosion sites.
Reduce sediment load on the channel.

Limitations:

Proper timing required for seeding
Access to site may be limited

Design and Construction Considerations:

Species Selection – Proper selection of species is critical to the overall performance and function of the vegetation planned. Different areas may allow for selection of different species to provide additional benefits beyond erosion control.

Within the channel cross-section, selected species must be resistant to frequent inundation, and stable given the anticipated flow velocities. Moreover, where erosion control is of primary concern, species must be relatively quick to germinate and establish. Within the channel cross section seeding shall be accomplished within 24 hours of excavation.

When considering what type of vegetation to establish within the channel, the anticipated flow velocities must be calculated. The Natural Resources Conservation Service has established acceptable flow velocities for several different plant species. This information can be found in The Engineering Field Handbook, Chapter 7, Grassed Waterways. The grassed waterways design reference can be found at:

http://directives.sc.egov.usda.gov/media/pdf/H_210_650_7.pdf

Filter strips and maintenance berms along the channel, generally will not experience inundation as often or flow velocities experienced within the channel. In these areas species selection can also consider the plant's ability to filter nutrients, provide cover for wildlife, supply a food source to foraging animals, etc.

The NRCS also maintains Seeding Tables in Appendix A of Section IV of the Field Office Technical Guide. Appendix A contains recommendations and seed mixes for permanent critical area seedings, and lists the suitable purposes for different mixes. In addition

Table 3 of this reference lists several species and suitable uses for forage, filter strips, wildlife, and conservation cover. This document can be found on-line at:

http://efotg.nrcs.usda.gov/references/public/OH/Appendix_A_04-23-08.pdf

Care must also be taken when selecting different species. Species must be compatible with each other, and proper equipment for the placement of seed must be available. Local conditions may also eliminate or favor certain species over others, local Extension professionals or agronomists will be able to discuss these issues and experiences.

All seed used must conform to the current rules and regulations of the Ohio Department of Agriculture. Seed should be from the latest crop available, and meet standards for purity and germination.

Seedbed Preparation – Proper preparation of the seedbed will encourage good seed to soil contact, increasing seed germination and stand density. In addition proper preparation will reduce future costs associated with seed establishment and maintenance.

The seedbed must be firm, and prepared with a disk or similar equipment in all areas accessible. Soil should be worked to a depth of 3 inches where accessible with equipment; a depth of 1 inch is acceptable where hand tools are required. All rocks, stumps, roots, or other debris that will interfere with seeding equipment must be removed prior to seed placement.

Preparation of the seedbed within the channel must be done with caution; flowing water will flush loose material downstream very quickly. Preparation within the channel should be done immediately before seeding, and should not result in large amounts of sediment being flushed off of the banks.

Recommended fertilizers should be applied prior to tillage operations. This allows fertilizers to be mixed into the soil profile and more available for plant uptake. Fertilization recommendations may be developed from soil tests taken from the site. The Seeding Tables also give general fertilization recommendations for critical area seedings in Table 5.

Seeding Rate & Placement – Seeding rates must be determined and specified in the design stages of the project. Seeding rate recommendations are given in table 3 and table 6 of the Seeding Tables referenced above.

Different types of seed require different types of equipment. Many traditional cool season grasses can be sowed with a drill commonly used in agricultural production. Many warm season grasses will not flow through a typical drill and will require the use of a specially equipped drill.

Broadcasting seed may also be employed, but follow-up operations must be employed to increase seed soil contact. Such operations may include a smooth roller, a drag, cultipacker or similar equipment.

Depth of seed placement will depend on site conditions and species. Local experience and practices should dictate seeding depth.

References:

Ohio NRCS Design Standard 342, Critical Area Seeding
Ohio NRCS Design Standard 484, Mulching
NRCS Construction Specification 6, Seeding, Sprigging, & Mulching
NRCS Field Office Technical Guide Appendix A, Seeding Tables

6.1.2 Mulching

Description:

Application of plant residues, or other suitable materials to the soil surface

Purpose:

Help establish plant cover
Reduce runoff and erosion
Control weeds

Where Applicable:

On soils subject to erosion where permanent seeding is to be established
Construction sites where excavation and grading activities have left bare soils

Advantages:

Conserves soil moisture
Prevents surface compaction and crusting
Moderates soil temperatures

Limitations:

Proper anchoring is required to hold mulch in place
Access to site may be limited

Design & Construction Considerations:

Site Preparation – Soil surface must be prepared to achieve the desired purpose prior to mulch application. All areas to be mulched must be free of irregularities. Typically seeding must be placed prior to mulching activities.

Application – Mulch may be applied to both seeded and unseeded areas. When applied to seeded areas, mulch shall be applied immediately after the area is seeded and no later than 24 hours after the seeding has occurred. Mulches with a high carbon and nitrogen ratio can take away soil nitrogen for the plants being established. In this situation additional nitrogen may need to be applied.

When temporary erosion control is needed, mulch may be applied any time soil and site construction conditions are suitable for spreading and anchoring. Disturbed areas that will not have additional construction activity for 21 days or completed sites that will not be permanently seeded for 21 days should be mulched.

In areas of concentrated flow, mats and nets shall be laid parallel to the direction of flow. Outside edges of mats and nets shall be buried in a trench six inches deep.

Mulching Material – Many different materials are available for mulching activities. Straw from cereal grains, wood cellulose fiber, and erosion control blankets are just a few examples of mulch options. When deciding which material and method to use, cost, installation requirements, site conditions, and availability must all be considered.

Straw Mulch – Straw or grass hay mulch is the most commonly used mulch material. Straw and grass hay mulch shall be applied to areas seeded not later than 2 working days after seeding is performed. Straw mulch should be clean and free of unwanted seed, with lengths of 6 to 10 inches. Application rates should range from 2 to 2.5 ton/acre, and provide 80% to 90% cover.

Many anchoring methods can be used with straw. However, the most common is to crimp the straw with an anchoring tool. The straw anchoring tool should have straight disks with serrated edges and spaced 6 to 10 inches apart. Anchoring tools should tuck individual straw pieces 2 to 3 inches in the ground.

Straw mulching will typically last up to three months. Straw mulch is subject to blowing unless kept moist, and is very susceptible to floating when inundated.

Hydro-mulch Wood Cellulose Fiber – Hydro-mulch is made of natural wood fiber and may be applied with hydro-mulcher or hydro-seeder; completing seeding and mulching at the same time. Application rates range from 1 to 2 ton/acre, and provide 80% to 90% cover.

Hydro-mulch typically performs better than straw mulch on steeper slopes due to a tackifier mixed with the fibers from the manufacturer. Application equipment must be available for proper application, and costs are typically higher compared to straw mulch.

Erosion Control Blanket – Erosion control blankets often use straw or similar fibers woven between two polypropylene grids. Blankets work exceptionally well in conditions where concentrated flow is likely. Installation will require an overlap between roles and typically use staples or other manufactured anchors. Installation requirements should be as detailed by the manufacturer.

Many other options are available, each must be considered recognizing limitations in performance, cost differential, and expected life of the installation.

Anchoring – Proper mulching requires close observation of the requirements for the type of mulch to be used. Proper anchoring methods must be used to hold mulch in place and prevent downstream problems.

Floating mulch not only leaves the mulched area susceptible to erosion, but can also plug culverts or other structures downstream. This results not only in the cost of replacing the mulch, but also time and money spent to open plugged pipes.

<u>If flow velocities are above 4 feet per second additional Geotextile material or other protection should be considered.</u>

Plans and Specifications – Specifications for applying this practice shall be prepared for each site. Information recorded shall include: 1) type of mulch material used, 2) percent cover of mulch material, 3) timing of application, 4) site preparation, and 5) listing of netting, tackifiers, or method of anchoring.

References:

Ohio NRCS Design Standard 484, Mulching

6.1.3 Clearing and Grubbing

Description:

Consists of clearing trees and root removal, disposal of trees, brush, stumps, and rubbish from designated areas.

Purpose:

To prepare construction areas for excavation and reshaping by heavy equipment.

Where Applicable:

Designated areas where excavation or land reshaping is required and trees, shrubs, or other woody vegetation currently established.

Advantages:

Proper site preparation reduces time requirements for excavation or reshaping.
Reduces excavation costs for the project

Limitations:

Likely to have significant negative impact to channel habitat in area.
Results in unstable soils in project area that may lead to erosion.
Timing must allow for completion of planned excavation, and stabilization of soil without excessive erosion at the site.

Design & Construction Considerations:

Identifying Areas – Areas designated for clearing and grubbing must be identified and planned during the design process. Areas where excavation, equipment access, or final grading requires clearing trees or roots should also be inventoried and adequately defined.

Clearing and grubbing areas must be clearly marked on engineering plans. Identifying areas may include the stations of affected reaches along the project, or referencing landmarks or other references installed during field surveys.

Extent of Work – Another consideration for clearing and grubbing is the extent of work required to meet the final design. Some work may require the clearing of trees for equipment access, but little or no excavation is planned. In such areas, cutting trees or other vegetation flush with the ground and treating stumps with the appropriate herbicides should be considered.

Areas to be grubbed should be minimized where possible. Roots of cut trees maintain their ability to stabilize soil for years after the tree is removed. Establishing seeding in areas that have not been grubbed will be more difficult. Tillage and seeding equipment may be hindered by roots and stumps remaining at the site.

Clearing and grubbing activities should be staged to limit the size of the area open and exposed to increase erosion especially when within the channel or in areas of frequent inundation. Plans should specify a maximum reach to be opened before final grading, shaping, and seeding activities can be completed.

Timing – Clearing and grubbing should be conducted immediately prior to excavation and finishing work and shall not advance more than 2 working days ahead of the excavation of the channel. Sites should not be disturbed with clearing or grubbing activities, and then left idle for extended periods of time. If this is unavoidable, temporary seeding should be established immediately.

Seasonal weather patterns must also be considered during the planning and construction of clearing and grubbing activities. Avoid such activities when high rainfall and extended wet periods are expected.

Protection of Existing Vegetation – All vegetation that is to be preserved must be clearly identified on plans and in the field. Marking may be completed with surveyors tape, paint, or fenced off. Equipment traffic should be maintained outside the drip edge of the tree if possible. Traffic within the drip edge should be eliminated whenever possible.

Effects on Water Quality and Quantity – Prior to clearing and grubbing the following items shall be considered.

- Temporary and long term effects on visual quality of water and landscape
- Effects of discharge on the flood plain and the sediment load
- Potential downstream flooding
- Effects of on-site and downstream temperatures

Disposal of Materials – All trees, logs, brush and other woody material shall be disposed of in designated on-site areas or hauled off-site to an approved disposal area. The woody material may be burned, buried, piled, or chipped. All burning material shall be performed outside the channel and shall conform to regulations in effect in the area. All buried material shall have adequate earth cover and mounded to allow for settlement.

References:

Ohio NRCS Design Standard 326, Clearing and Snagging
NRCS Construction Specification 2, Clearing and Grubbing
NRCS Construction Specification 4, Channel Clearing and Shaping

6.1.4 Mowing

Description:

Mechanical mowing of vegetation above the waterline or along channel berms

Purpose:

To maintain stands of grass, reduce grass clumping, and control weeds or other unwanted vegetation

Where Applicable:

All areas where grass lined channels require stand maintenance

Advantages:

Positive control of unwanted vegetation
Encourage better stands of grass, reduces stand 'clumping' in susceptible species and provides a buffer for the channel

Limitations:

Expense of equipment and operation may be higher than other alternatives
Improper mowing heights can leave bare banks and thin grass stands
Improper timing of mowing can cause water temperatures to increase as vegetation that provides shading for the water is eliminated
Mowed materials or clippings left to decay in the channel may cause depletion of oxygen levels in the water

Design & Construction Considerations:

What to Mow – Mowing programs typically mow both the berm area and the channel banks. Channel mowing should be done carefully to minimize impacts on water quality within the channel.

Grass stands within the channel typically will not drastically affect the channel capacity or flow velocities. Mowing should be conducted in order to maintain desired species, and discourage unwanted species. Mowing operations should only occur above the waterline and not extend into the channel bottom. Vegetation below the waterline or within the channel bottom should be hand cut.

Grasses can be mowed to encourage better stands and reduce clumping at the ground surface. Spot mowing may also be useful in controlling noxious weeds or other unwanted species.

Berms may also require mowing to maintain selected vegetation and to maintain the prescribed berm width over time.

Mowing Heights – Care must be taken to maintain a reasonable height of grass after mowing.

In no case should mowing result in bank areas that are scalped or physically damaged due to mowing. Areas that are left scalped will reduce grass vigor and encourage establishment of unwanted species.

Equipment should be adjusted to leave a minimum grass height of 6 inches. This reduces the chance of scalping channel banks and berm areas, and allows clippings to be held in the grass rather than falling into the water surface.

Mowing heights may vary more along the channel in the berm areas depending on the land use and management requirements. Mowed material shall be kept form entering the channel as the material will reduce drainage efficiency and the decay of material will cause lower oxygen levels in the water.

Mowing Costs – County maintenance programs show that mowing programs cost $0.30 to $0.40 per lineal foot. These costs will obviously vary with equipment and other maintenance practices, and from project to project. However, compared to spraying costs of $0.05 to $0.16 per lineal foot, mowing is a more expensive method of typical vegetation management.

Mowing Schedule & Timing – Deciding when to mow will vary with programs and goals. Regular mowing for stand maintenance should consider mowing when the channel is most likely to be dry. This will reduce water quality implications within the channel. Moreover, waiting until after July 15th to mow will allow most bird species to complete nesting prior to mowing. For ditches that are wet year-round, the preferred time of year for mowing vegetation is in the fall/winter when water levels are low. This will allow the riparian vegetation to green up along the channel during summer months when shading is critical.

Spot mowing to reduce invasive species and weeds should be conducted prior to those species going to seed, and timed to encourage competition from desired grasses and other species.

References:

British of Columbia Constructed Ditch Fact Sheet No. 5

6.1.5 Spraying

Description:

Application of approved chemicals for the control of unwanted vegetation

Purpose:

To encourage the growth of preferred vegetation and eradicate unwanted species and invasive weeds

Where Applicable:

Any grass lined channels where stand maintenance is required

Advantages:

Herbicide control of weeds and other unwanted species may be less expensive than mechanical control methods
Chemical application can be completed more quickly than most mechanical control methods

Limitations:

Wind can drastically affect application rate and offsite damages
Chemicals application must be timely to avoid runoff or reduced effectiveness due to rain

Design & Construction Considerations:

Developing a Spray Program – Starting a spray program will require specialized equipment to spray both channel banks and berms along the channel. Recognizing equipment requirements, labor requirements, and registration and permitting issues will have a large influence in program costs. Moreover, application timing and rates will vary depending on chemical selection.

Registration & Permitting – All applicator's who will spray herbicides must meet all registration requirements maintained by the Ohio Department of Agriculture. A commercial applicators license must be held by anyone applying herbicides. The license requires annual renewal and recertification every third year. ODA's requirements for commercial applicator's can be found at:

http://www.agri.ohio.gov/apps/odaprs/pestfert-PRS-index.aspx

In addition to holding an applicator's license, all chemicals used within the channel must be labeled for aquatic use. The aquatic use label designates the herbicide to have no water quality effects when used at label rates.

Weather & Timing – Herbicides and spraying can be very vulnerable to weather conditions. Wind speeds can cause dramatic overspray and damage to nearby vegetation. Spraying operations should be conducted when winds are mild and will not cause sprays to drift to adjacent properties or non-targeted vegetation.

In addition to wind, rain can have a drastic impact on herbicide effectiveness. Herbicides will be labeled with a minimum required time to become ‘rainfast’. This is the minimum amount of time required without rain to assure herbicide efficacy.

Some herbicides are sold with a wider application window than others. Manufacturers produce dormant sprays for some applications. For all herbicide use, applicators must read and follow label directions.

Chemical Selection – The advancement and development of new herbicides prevents the use of a detailed list of herbicides in this document. Consultation with local agronomists and consultants can assist with proper selection and control methods. Public utilities often use chemical control and spraying for maintenance of Right –of-Ways.

Spraying Costs – Expense records from a few maintenance programs show spraying costs vary depending on the vegetation to be controlled. Spraying costs ranged from $0.06 to $0.16 per lineal foot.

References:

http://pested.osu.edu/commercial.html

6.1.6 Managing Woody Vegetation

Description:

Selective pruning, cutting, or removal of overgrown or unwanted woody vegetation that has developed along a maintained channel

Purpose:

To maintain and manage areas for desired vegetation
To maintain site access
To maintain channel capacity
To remove debris and logs from floodway prior to forming logjams

Where Applicable:

Areas where undesirable woody vegetation is prominent
Along natural channels that are on maintenance to prevent logjams
In channels where debris is causing flow blockages

Advantages:

Reduce future maintenance costs due to logjams or bank erosion problems
Maintain erosion resistant cover along banks

Limitations:

Access to site may be limited
Excessive growth may require clearing and reestablishment of desired species
May have adverse effects on channel habitat

Design & Construction Considerations:

Managing woody vegetation along a channel may have several long term implications on the channel and habitat within the channel. Maintenance practices must consider effects on aquatic life and habitat within the channel along with benefits to the maintenance program.

Woody vegetation control should be considered for the following reasons:

Vegetation Maintenance – Thick brush along a channel can shade out desired grass stands along the channel, leaving bare soil banks that are more susceptible to erosion. Maintaining grass stands may require removal of excessive brush along the channel.

Maintain Access – Brush and other woody vegetation can restrict access to a site for maintenance equipment. Most equipment will require a minimum of 8 feet of width or more to access a site.

Logjam Reduction – Trees and woody vegetation along the channel can serve as a source of material for logjams, and increase snags along the channel where logjams are initiated. Prevention of logjams is usually less expensive compared to removal of the logjams from the channel.

Protection of Outlets – Water loving trees and brush tend to clog subsurface drains with roots. To prevent this, remove these trees and brush from the vicinity of the subsurface drain for a minimum distance of 100 feet.

Tree Management – Dead trees along the channel or trees that are leaning severely over the channel may be considered for removal. These trees have the highest potential for falling into the channel, and creating snags or becoming material source for logjams. Trees selected for removal should be clearly marked for easy identification.

Trees that are selected for removal should be cut and removed from the site and disposed of. The stump should be cut flush with the ground, or as close as practical and treated with herbicide to prevent re-growth of the stump.

Removal of a single tree or other similar growth can generally be completed with small hand held equipment, and will not require heavy construction equipment. All safety precautions should be observed.

Brush Management – Control of extended areas may require the use of larger equipment such as choppers or trimmers, or the use of herbicides.

When using large equipment to remove brush, care must be taken to prevent re-growth of brush and to stabilize channel banks when work is completed. Herbicides should be applied to the stumps of cut brush to discourage re-growth. Such herbicides should have an aquatic use label if they will be applied in or near the channel cross section.

Seeding may also be necessary in cases where bare soil is left after brush removal. Brush removed from the site may be shredded to supply mulch to the site if seeding requirements will allow.

Herbicides may also be used to eliminate unwanted brush along the channel. Chemical control will take longer to control and remove brush from the site, but may be less costly over time.

References:

Ohio Stream Management Guide # 8 Trees for Ditches
Ohio Stream Management Guide # 18 Stream Debris and Obstruction Removal
Ohio Stream Management Guide #21 Large Woody Debris in Streams

6.2 Sediment Control

6.2 Sediment Control & Removal

Accumulation of sediment within the channel can pose several problems in man made and constructed channels. These sediments can reduce the capacity of the subsurface drainage systems, reduce channel capacity, increase localized flooding, impair culverts and other structures, reduce habitat, and impair water quality.

Keeping sediment out of the channel is the most cost effective method of sediment control within the channel, and is a primary focus of many of the Federal Farm Bill Programs. The use of reduced tillage and no-till crop production, installation of filter strips, cover crops, and other practices all help reduce sediment delivery to the channel.

However, even the best conservation management practices will still result in some sediment delivery to the channel. Periodic removal of sediment will be required on many extremely low gradient channels.

Conducting sediment removal operations must be done with care to avoid creating water quality problems both at the construction site and downstream. Moreover, if done incorrectly can cause erosion problems upstream as well. Careful consideration must be given to sediment transport and water quality concerns when sediment removal activities are conducted.

The following practices review sediment control practices.

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6.2.1 Vegetated Filter Strips

Description:

Permanent grasses or other vegetation established along a channel at a specified width

Purpose:

To capture and process sediment, excess nutrients and other pollutants before entering the channel

To restore, create, or enhance herbaceous habitat for wildlife or beneficial insects

Where Applicable:

In areas below cropland, grazing land, or other disturbed areas where sediment, particulate matter may enter the watercourse

Advantages:

Uptakes and transforms soluble contaminants
Can provide wildlife food and cover
Maintains buffer between adjacent land use and the channel
Easier to maintain original designed maintenance berm widths
Provide localized erosion protection

Limitations:

Cooperation of adjacent landowners required

Design & Construction Considerations:

Filter strips may be established along constructed or natural channels along the top of the channel banks. These strips are generally established in the berm area used by public maintenance programs for access to the channel. Filter strips may be established by private landowners through the use of different USDA/NRCS conservation programs. This program makes payments available to the landowner, and may assist in the establishment costs of the filer strip. Program eligibility is dependent on land use, cropping history, and owner eligibility.

Filter strip widths will vary from site to site. Typical widths range from 20 feet to a maximum of 300 feet. Wider strips will tend to filter sediment and nutrients more effectively than narrow strips. Moreover, flatter areas will be more effective than steeper filter strips. The filter strip should intercept the flow while it is still shallow and uniform. The quality of vegetation also impacts the effectiveness of the filter strip.

Establishment of filter strips with cool season grasses allows relatively quick establishment, and requires management consistent with many other hay crops in Ohio. If the area is not enrolled in a federal program, harvesting these areas may provide forage to livestock. This may also assist in harvesting nutrients collected in these areas.

Wildlife habitat is also drastically impacted by the species selection. In order to promote wildlife, other species, such as warm season grasses, may need to be considered. Wider filter strips are also recommended to encourage wildlife habitat.

Establishment of filter strips should follow the recommendations in the Natural Resources Technical Guide, Section IV, Appendix A.

References:

United States Department of Agriculture, Natural Resources Conservation Service, Grass Filter Strips, Practice Code 393

Rob Leeds, Larry C. Brown, Marc Sulc, Larry VanLieshout. *"Vegetative Filter Strips: Application, Installation and Maintenance"* AEX-467. Ohio State University Extension

6.2.2 Channel Dip-Out

Description:

Removal of accumulated sediments in constructed channels and return the channel flow-line to designed grades and elevations

Purpose:

Return the capacity of the channel to the original design capacities, and provide design free board below subsurface drain outlets

Where Applicable:

Reaches where sediment has accumulated in the bottom of the channel, reducing channel capacity below design capacity or where subsurface drain capacity has been reduced.

Advantages:

Can be completed relatively quickly without dramatic disturbance of channel banks

Limitations:

Proper sediment disposal requires cooperation with landowners
Potential impact on channel habitat

Design & Construction Considerations:

Sediment removal is often required in small, low gradient channels were flow volume and velocities are not sufficient to carry sediment downstream. Determining when sediment removal is required requires careful consideration of program supervisors.

Dip-outs should be conducted when the capacity of the channel has been reduced below acceptable values. Dip-outs should also be considered when accumulated sediments reduce the capacity or stability of subsurface drains. Accumulated sediments may also reduce bridge or culvert capacities below acceptable limits, resulting in more frequent road flooding, or damage to bridges.

Determination of when sediment removal is required should be based on field observations, surveys of accumulated sediment, and original design data. Tolerable capacity reduction limits will vary greatly from project to project; reasonable judgment must be used to determine when sediment must be removed prior to causing damage to subsurface drainage systems or adjacent land uses.

When conducting channel dip-outs, care must be taken to remove only accumulated sediments. Excavation equipment should be kept on the channel banks and remove sediment with minimal disturbance to the channel side slopes and vegetation. Excavation equipment should be equipped with a dredge bucket that has no teeth; this will leave a smooth flow line.

Figure 1 illustrates the material that should be removed from the channel cross section. Any damage to the vegetation on the banks should be repaired and reseeded as soon as possible. Extensive reseeding should not be required in most situations; the areas that are dipped will typically be too wet for a grass seeding to take root.

Care must be taken in planning a dip-out and during construction to limit the excavation to reaches where sediment has accumulated. Furthermore, excavation should return the channel to the original flow line of the channel, not to deepen the channel. Over excavation can lead to drastic erosion problems upstream and downstream from the project, and result in steeper banks that may become unstable.

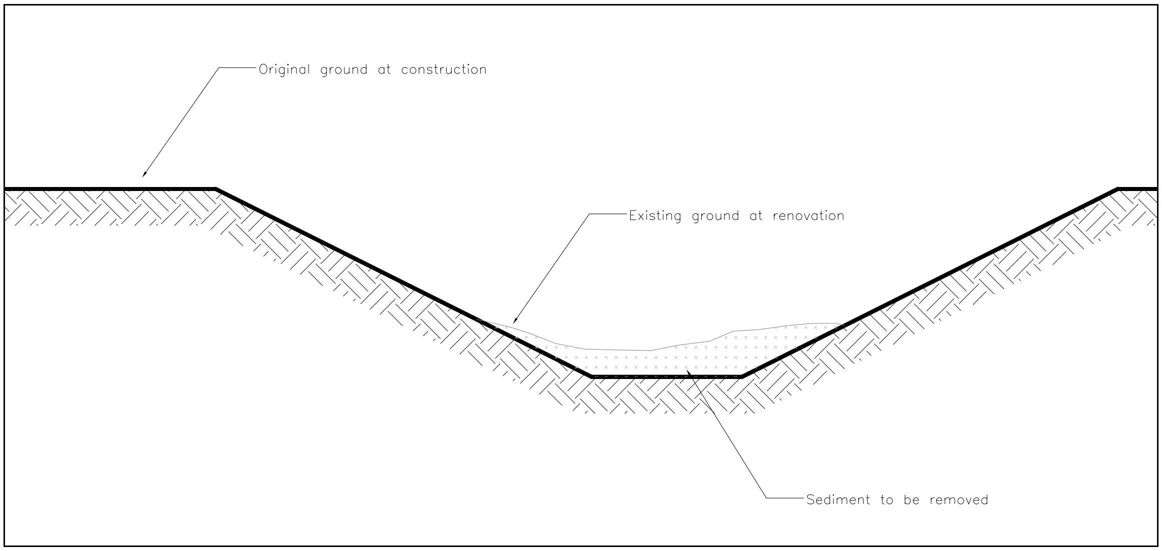

Figure 1. *Material to be removed during renovation*

Sediment removal should be completed when the channel is dry if possible. Dredging sediment from a dry channel reduces sediment transport downstream, minimizes drying time and spreading costs.

If sediment removal cannot be completed when the channel is dry, sediments will typically need to be stockpiled beyond the grass maintenance berm and allowed to dry prior to spreading or final disposal. When stockpiles are required, locate stock piles such that sediment will not re-enter the channel. In addition, temporary seeding may be necessary depending on plans for spreading or removing the material from the site.

Spoil removed from the channel should be disposed of properly. In agricultural areas, spoil is typically spread over adjacent crop fields and incorporated. When spoiling sediment, care must be taken to work with adjacent landowners to spread material in an acceptable manner. Depending on the extent of the work to be done, topsoil may need to be scalped away from the spoil area, and replaced when dredged material has been spread.

In some cases sediment may have to be moved offsite or land filled elsewhere if materials can not be spoiled adjacent to the site. If this is the case, project costs will be increased dramatically, and appropriate disposal sites must be selected.

References:

6.2.3 In-Channel Sediment Basin

Description:

Basin constructed within the channel to reduce flow velocities

Purpose:

To capture sediment from channel flow and reduce downstream export of sediment and nutrients

Where Applicable:

In channels where sediment transport downstream is a concern
Extremely flat sections of channel where additional sediment storage is needed

Advantages:

Increase period between required dip-out or renovation projects
May provide additional floodwater storage and habitat

Limitations:

Excavation and land rights costs may be prohibitive
Watershed size may reduce basin effectiveness

Design and Construction Considerations:

Description - The In Channel Sediment Basin concept is not new, but there has been little if any experience in practical application. Given the lack of experience with this type of application, caution should be used by the designer in selecting possible site and design requirements.

Design - When considering the construction of sediment storage in the channel, it is recommended to consider increasing the channel width rather than channel depth. Limited experience shows that creating deeper sections along an otherwise uniform channel tend to scour and will not fill with sediment. This results in possible erosion problems and increased turbidity downstream.

Creating a section that has a significantly wider cross section allows water to spread out, slow down and deposit sediment. This design approach also reduces potential erosion and scouring concerns compared to a deeper channel section.

Sizing - The designer must also consider the size of the watershed draining to the proposed site. Larger watersheds will require a larger basin footprint. Undersized sediment basins will be filled quickly and have little if any impact on water quality or downstream sediment deposition. General recommendations need to be developed, but watershed size to basin size ratios of 20:1 to 200:1 may be reasonable.

Basins should be sized such that maintenance and excavation equipment can be used from the top of the bank, rather than down in the basin. This will prevent the need for equipment to enter the channel during construction and during future maintenance activities.

Placement – Excavation costs and disposal of spoil will be the primary costs in construction. Selecting sites that are relatively low relative to the channel or areas that flood frequently should minimize excavation costs. Concentrating on these areas may also minimize costs if land must be obtained from private individuals or corporations.

Consider locating several basins along the channel rather than one large basin on the downstream end of the channel. Locating several small basins throughout the watershed, especially toward the top of the watershed will reduce the size of the watersheds on the basins, and should increase effectiveness.

Maintenance – In order to keep the basin effective, periodic removal of sediment will be required. Frequency of sediment removal will depend largely on the watershed size, and site specific conditions. Sediment removed from basins should be properly disposed of, and should not be permitted to re-enter the channel.

Removing sediment when the channel is dry or at low flow will minimize downstream sediment transport, and reduce any required drying time for excavated material.

References:

Drainage Management Guide, Factsheet No. 9 – Sediment Traps, British of Columbia, Ministry of Agriculture, Food and Fisheries

6.3 Bank Stability

6.3 Bank Erosion, Stability, and Repair

Bank erosion and stability problems not only affect the capacity and flow characteristics, but can also affect and diminish adjacent land uses. This may range from loss of farm fields or residential lots, to damage to roads and bridges. Moreover, excessive bank erosion can be a major source of sediment entering the channel, effecting water quality and habitat at the site of erosion and downstream.

When considering alternatives to repairing channel banks, several issues must be taken into account. Not only must the engineering design requirements be developed, but property rights and public safety issues must also be considered. Addressing bank erosion and stability problems can be done through various approaches. These approaches include flow alteration, bank stabilization, and bank armoring.

Flow alteration techniques are used to change flow characteristics in the area of the erosion problems identified. The goal of flow alteration is to reduce the flow depth and velocities in the area. This reduces the erosive potential in the area of concern, addressing erosion problems without armoring the banks. Flow alteration practices include a variety of different techniques, and may include in channel weirs, piling and slotted board revetments, floodplain excavation, etc.

Bank stabilization approaches are designed to eliminate or reduce weaknesses within the bank slope to eliminate bank sloughing or shearing failures. Bank stabilization projects may require flattening slopes or creating benches on the slope to reduce internal shear stresses. For steeper slopes or large elevation changes extensive soil borings and lab testing may be required to design acceptable slopes and internal loads.

Other bank stabilization approaches aim to increase the erosive resistance of the slope and reduces erosive forces at the surface of the slope. These activities include establishment of vegetation or woody vegetation, geo-textile or other erosion control matting, and other bio-engineering techniques.

Bank armoring creates a hardened surface that is relatively erosion proof given the anticipated flow velocities. These practices are relatively expensive, and are used in areas where additional erosion is unacceptable, or where public safety concerns require such an approach.

All of these approaches have advantages and limitations for their use. A good understanding of these limitation and advantages is required when choosing possible solutions to bank erosion and slope stability concerns.

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6.3.1 Streambank Soil Bioengineering (1 – NRCS, August 2007)

(Users of this manual should refer to the referenced NRCS document for more specifics and details of Streambank Soil Bioengineering)

Description:

The use of living and nonliving plant materials in combination with natural and synthetic support materials for slope stabilization, erosion reduction, and vegetative establishment.

Purpose:

Streambank soil bioengineering uses plants as structural components to stabilize and reduce erosion on streambanks, in an effort to create habitat, or reduce negative impacts to channel habitat.

Where Applicable:

When selecting the best-suited soil bioengineering techniques, it is important to have a clear understanding of the ecological systems of the adjacent areas. Plant selection and the techniques used will play an initial role in site stabilization and, ultimately, serve as the foundation for the ecological restoration of the site. The successful establishment and long-term sustainability of herbaceous and woody plants are extremely important to the physical and biological functions of the streams and the connected watershed system.

Advantages:

- The root system helps hold the soil together and increases the overall bank stability by its binding network structure, that is, the ability of roots to hold soil particles together.
- The exposed vegetation (stalks, stems, branches, and foliage) increases roughness, which can increase the resistance to flow and reduce the local flow velocities, causing the flow to dissipate energy against the deforming plant, rather than the soil. The vegetation acts as a buffer against the abrasive effect of transported materials.
- Close-growing vegetation can induce sediment deposition by causing zones of slow velocity and low shear stress near the bank, allowing coarse sediments to deposit.

Limitations:

Streambank soil bioengineering offers a broad-based approach to solving many stream problems. However, it is not appropriate for all sites and situations and may offer a higher level of risk than conventional structures such as sheet pile or riprap.

Considerations:

Table 1 Design modifications to account for site conditions

Issue	**Concern**	**Possible action or design modification**
Duration of inundation	Some plant species and soils cannot withstand long flooding duration	-Choose plant materials that can withstand long inundation such as willow, dogwood, or elderberry, which can withstand1 to 6 months of inundation. -Use or combine inert or soil reinforcement material in areas of prolonged inundation.
Susceptibility of plant materials to disease or insects	Loss of plants could endanger the project	-Use a diversity of species in the plant mix so that the loss of one or two species will not endanger the entire treatment area. -Monitor the installation regularly for the first year or two during the establishment period. -Apply a fungicide or insecticide as needed to promote healthier growth.
Excessive velocity	High velocities could damage or destroy the project	-Compare estimated velocity and/or shear thresholds at site to recommendations for limiting velocity and shear when selecting project type and method of repair.
Increased resistance to flood levels	Increased roughness resulting from project may result in more frequent out-of-bank flows	-Choose plant material that remains supple. Avoid plant material that will be tree-like and form an obstruction to the flow. -Install the vegetative treatment further up on the bank -Coordinate possible affects with flood plain regulatory authorities. -Excavate floodway to account for lost conveyance.

Live Staking – The insertion of dormant cuttings into the ground. The cuttings are typically 1-3 inches in diameter and approximately 18-36" in length. The cuttings are often willow or Red Osier Dogwood. S [ace stakes 2-4 feet apart in staggered rows parallel to the water elevation. The horizontal cut on the top end of the stake will remain exposed (3-6 inches) after planting and a 45 degree angle cut will be made on the butt end to be planted. February to early March is a good time for planting dormant cuttings in Ohio. Plantings should take place within 24 hours of cutting and over a period of a couple of years, the plant's roots stabilize the bank by binding soil particles together. Stakes are used on small to medium sized streams.

Posts - Three to six inch diameter trees are cut into straight eight to twelve foot lengths and inserted into the ground into pre-dug holes or driven with a post driver. Posts shall be set deep enough to maintain contact with moist soil but not placed below the water table. Any damage to the top of the posts should be cut off after placement. Space posts four to eight feet apart in staggered rows parallel to the water elevation. Like stakes, cut the top end of the post horizontal and the bottom end at an angle to ease planting. February to early March is a good time for planting posts in Ohio and all planting should occur within 24 hours of cutting the post. Posts are used on medium to large streams in Ohio.

Fascines (Wattles) – Bundles of live dormant cuttings that are staked into trenches. The cuttings are bound together in bundles 6-8 inches in diameter and 4-20 feet in length. The bundles need to contain at least five cuttings, each being a minimum of ½ inch in diameter. The bundles are placed in trenches that are 10-15 inches wide and deep enough to accommodate the bundles. The fascine is placed horizontally along the slope contour to create a terraced slope with spacing between fascines of 3-5 feet. Loose soil shall be placed over top of the fascine into the trench and stakes (2-3 feet in length) shall be driven through the fascine every 2-3 feet for anchoring purposes. Fascines can be installed on slopes up to 2H: 1V and are placed from normal water level to the top of bank. The trenches capture runoff, enabling the dormant cuttings to sprout roots and leaves. Mulch or other appropriate cover shall be placed between wattles to increase erosion protection while the vegetation is becoming established. February to early March is a good time for installing fascines in Ohio.

Brush Mattress – Interlaced layer of live dormant branches laid on the bank slope and held in place with untreated twine and live or dead stakes. The brush mattress should consist of branches that are 5-8 feet in length and with basal ends of the branches being 1-2 inches in diameter. The branches shall be placed perpendicular to the bank with the basal end placed into a trench at the top of the rock revetment. The branch density should be 20-50 branches per yard. Wedge shaped construction stakes 3 feet in length are inserted on a 3 feet grid pattern and inserted half their length. Heavy untreated twine is tied 6 inches from the top of the stake and layered perpendicular to the branches along the contour of the slope. After the twine is secured over the branches, the stakes are driven into the ground to further compress the branches to the slope face. Finally, soil is placed to lightly cover the branch mattress.

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. Kickers work best when there are live trees on the bank in which the logs can be anchored. Kickers are typically used on streams where the channel width is less than 100 ft. The kicker log should be anchored such that it is able to rise with the water. The first kicker shall be installed upstream of the eroded area at a 30-40 degree angle. The current should be deflected to the center of the channel. Install additional kickers as necessary to deflect the current to the center of the channel for the entire eroded reach of the channel. Steel aircraft cable 3/8” in diameter and larger shall be used to anchor the kicker logs. The size of the kicker log should be compatible with the channel width and stream flow at the site.

References:

1. Natural Resource Conservation Service, National Engineering Handbook, Part 654, Technical Supplement 14I – Streambank Soil Bioengineering, August 2007
2. Ohio Stream Management Guide

6.3.2 Rock Rip Rap

Description:

Armoring of channel banks by placing angular rock of various sizes that lock together

Purpose:

Create a hardened surface over an easily eroded surface to stabilize a slope or prevent erosion

Where Applicable:

Along channel banks where excessive flow velocities or flow related stresses are eroding channel banks
In areas where gradual channel migration is not permissible
Critical areas where bank failure poses a public safety risk

Advantages:

Rip rap remains stable over a wide range of flow velocities and flow conditions
Materials are generally widely available across Ohio
Relatively ease of installation and low maintenance

Limitations:

Costs can become prohibitive for large projects
Site must be accessible to large excavation equipment for rock placement
May pass erosion problems downstream

Design and Construction Considerations:

Design – Placing rock along channel banks is a common method used to control erosion. Rock size, density, and gradation requirements should be considered in the design and clearly defined in the engineering plans. When installing stream bank erosion protection, the velocities during everyday flows as well as the velocities during large storm events should be considered in the design process.

Toe protection is the placement of rock to protect the toe of a bank from scour, and does not extend the full height of the slope. Toe protection is commonly used from the flow line of the channel upward to the normal flow depth. Placing rock in this zone protects soil that is commonly saturated, has reduced vegetation and erodes easily.

Toe protection should be considered when a lower portion of the bank is constantly being eroded. As this erosion continues, shear stresses in the bank above the erosion increase, and eventually results in a failure of the entire bank. Reinforcing the toe of the slope prevents erosion at the base, and preserves the entire slope.

Full bank armoring is used where excessive flow velocities erode the entire bank. These areas can occur in both straight sections and around bends or curves. When armoring an entire bank, flow velocities must be calculated to determine the desired size and gradation of rock. In addition, the use of smaller rock, or bedding, is often required to prevent internal erosion or address material limitations within the bank. NRCS Technical Release 25 provides a stability evaluation and design process that can be used to select the required rock size in chapter 6.

Bank slopes of 2:1 or flatter are preferred when using rip rap to armor banks. Rock placed on steeper slopes tends to roll into the channel, especially during high flows. For exceptional flow velocities, the rock surface can be grouted to increase erosion resistance.

Bedding or filter fabric is typically placed beneath rip rap. Bedding is smaller stone placed on the sub-grade. Bedding and fabric act as a barrier to prevent moving water in the channel from eroding the soil beneath the rock.

Proper rock size and gradation are required for successful implementation and minimizing project costs. 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 6.3.1 provides the minimum size ranges for given stream flow velocities.

Table 6.3.2 (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)

As an alternative to this table, NRCS Engineering Field Handbook Chapter 16, Appendix A has several reference tables and graphs that can be used to determine acceptable rock size and gradation given anticipated flow velocities.

In the design of new channels predicting where excessive erosion will occur, or altering the design to avoid areas of such erosion can be determined using Technical Release 25 from the Natural Resources Conservation Service (TR-25). Chapter 6 in TR-25 reviews design methods and review processes to consider bank stability and flow characteristics.

Use of dormant cuttings (willow or other rapidly-rooting species) may be installed between the rock in riprap revetments. 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 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.

Any rock placed above the high water mark should be covered with topsoil or excavated material from the channel after it has drained. The soil should be seeded immediately with a fast-growing native seed mixture.

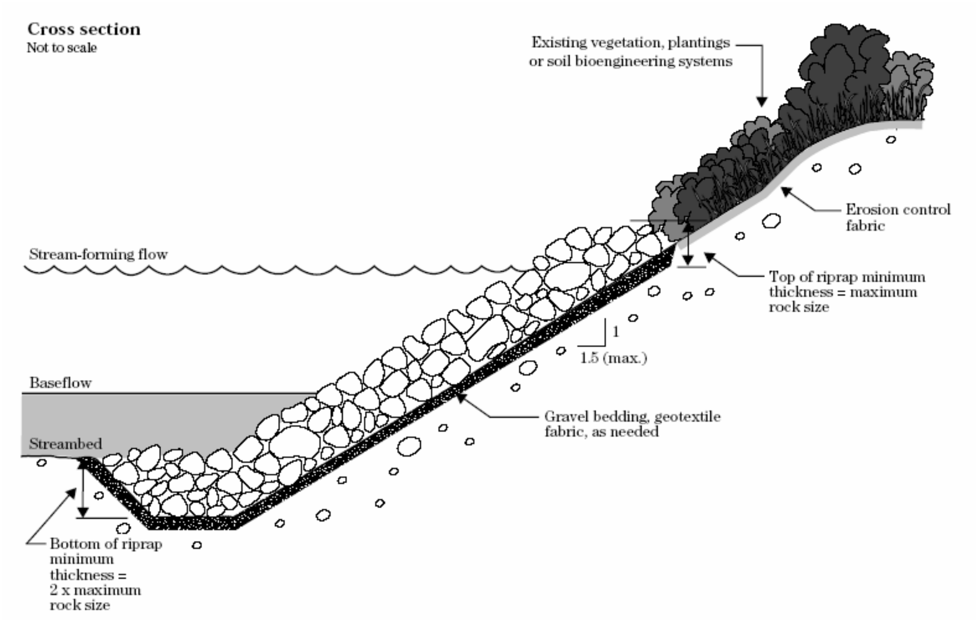

Figure 1 Typical Rock Rip Rap Installation. Source: NRCS Engineering Field Handbook Chapter 16

Quality of Materials – Rock used must be of sufficient hardness and should be free of cracks and other deficiencies to resist weathering. Moreover, porous rock will absorb water, and is more susceptible to breakdown from freeze - thaw cycles.

Rock must be angular with defined edges. This allows the rock to lock together in a massive unit. Rounded rock, such as field stone, will not lock together and tends to roll and shift during strong flows or extended runoff events.

Ohio Natural Resources Conservation Service maintains a list of approved quarries. Rock from these quarries has been tested and meets the specifications for hardness and weathering resistance.

Site Preparation – Banks should be prepared to the lines and grades described in engineering plans. Areas needing fill should be filled with well compacted earth or similar rock fill. Debris, roots, and other unacceptable materials should be removed from the sub-grade prior to placement of rock.

Construction – Riprap should be placed to the full design depth in one operation to form a reasonably homogeneous layer with larger rocks uniformly distributed among and in full contact with smaller rocks and spalls. The layer of riprap should be 1.5 times the thickness of the largest stone and should be placed to leave smooth tight surface with minimal voids. Some hand placing of rock may be required to achieve the desired surface. The bottom row of stone should be entrenched into the stream bed to prevent undercutting.

References:

1. Engineering Field Handbook Chapter 16, Streambank and Shoreline Protection; Natural Resources Conservation Service
2. Technical Release 25, Design of Open Channels; Natural Resources Conservation Service
3. National Engineering Handbook, Section 19, Construction Inspection; Natural Resources Conservation Service
4. Ohio Stream Management Guide # 16 Riprap Revetments

6.3.3 Gabion Baskets

Description:

Welded wire or wire mesh baskets fastened together, and filled with properly graded rock
Wire baskets are typically galvanized or vinyl coated
Baskets are typically 3' wide by 3' high with a minimum stone size of 4"

Purpose:

Create an erosion resistant surface or armored bank where banks have failed due to erosion or other bank stability problems

Where Applicable:

In areas where bank failures have occurred, and the area must be reclaimed
Where a very high degree of reliability is needed or where public safety concerns are high
When the streambank slope cannot be cut back due to physical constraints

Advantages:

Forms an erosion resistant wall that is somewhat flexible
Can be applied to very steep slopes (1 horizontal to 3 vertical)

Limitations:

Requires hand labor for basket facing
Limited contractor experience
Projects may be quite costly on high banks
Not applicable where stream bottom is eroding and may undercut gabion

Design and Construction Considerations:

Rock gabions are rectangular containers made of heavy galvanized wire mesh or welded wire. The wire used is often vinyl coated. Empty gabion baskets are placed in position, fastened together, and filled with appropriate sized stone, then folded and fastened shut. This allows the use of smaller sized rock, where flow velocities would require much larger rock. The gabion baskets allow the smaller individual rock to act as one massive unit. To prevent stone from washing through the mesh of the wire baskets the minimum stone diameter should be 4 inches. By lacing adjacent gabions together they form a somewhat flexible wall. The gabions should be tilted slightly back into the bank.

Vegetation can be incorporated into the gabion baskets by placing live branches between the wire mesh baskets. These branches will then root into the gabion baskets and soil behind the baskets. Proper selection of branch cutting and species is a must for successful establishment.

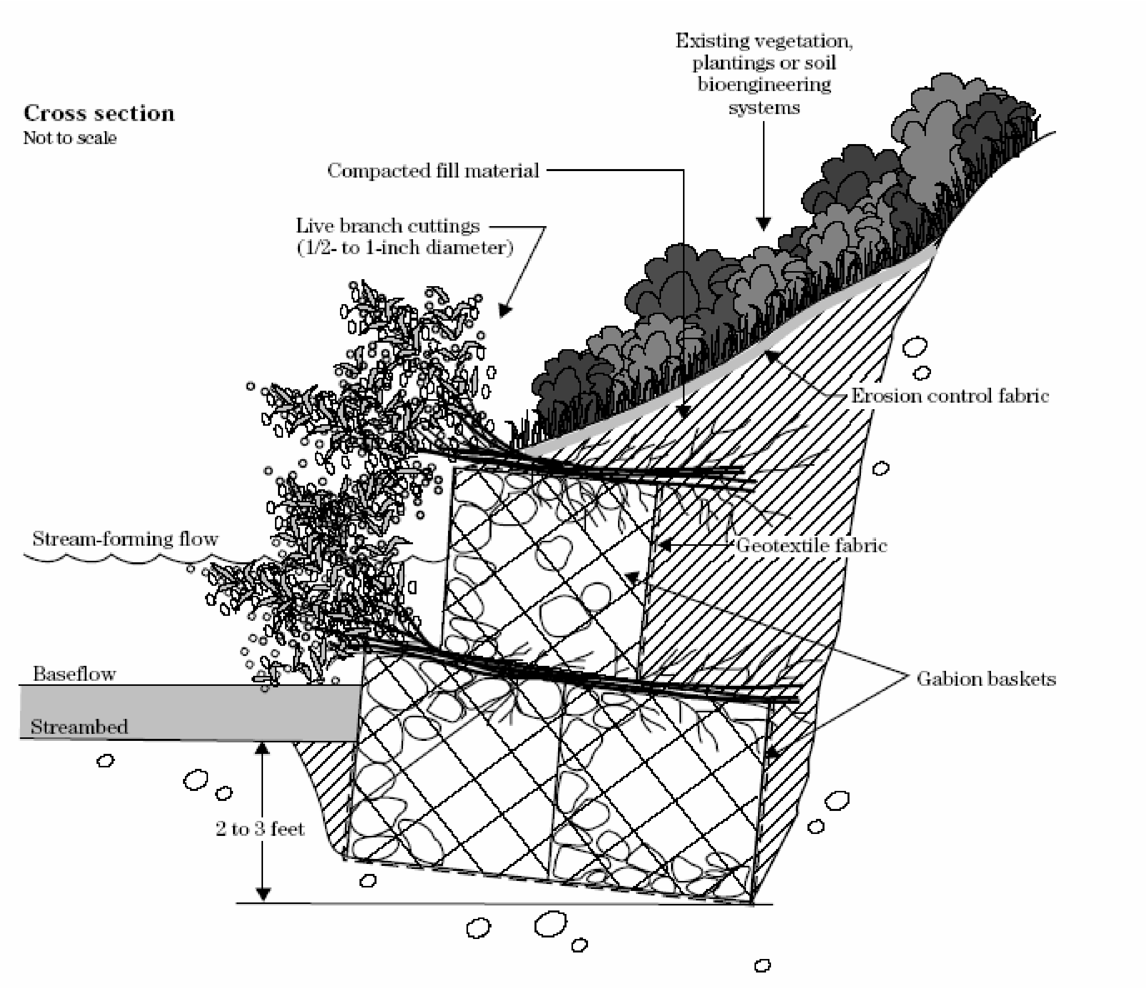

Figure 2 Typical Gabion Basket Installation; Source Engineering Field Handbook Chapter 16

Rock gabions are effective when the bank slope is steep (1.5:1 or steeper) and the existing bank requires structural support, and in areas space is limited and a more vertical structure is required.

Gabion baskets are not designed to resist large lateral earth loads. Where gabions are constructed to a height of 5 feet or more, the effects of overturning and sliding must be analyzed.

Gabion baskets can also be placed as a continuous mattress for slope protection on slopes that are 2:1 or flatter. Steeper slopes should be analyzed for slope stability as part of the gabion design. Mattress thickness of 9 inches is often suitable for flow velocities of up to 9 feet per second. Thicker mattresses should be used for higher velocities; 18 inch thick mattresses are usually suitable for velocities up to 14 feet per second.

Installation – Complete installation recommendations and requirements can be found in the Engineering Field Handbook Chapter 16, Streambank and Shoreline Protection published by the Natural Resources Conservation Service and NRCS Construction Specification 64, Wire Mesh Gabions and Mattresses.

Gabion installations will require foundation preparation and removal of any loose or undesirable foundation materials. The bottom layer of gabions shall be entrenched into the stream bed at least one or two feet deep. The bottom layer of baskets should be level along the project length and pinned into the stream bed with steel rods that are 3 or 4 feet long. Baskets must set securely and be placed on a uniform foundation.

The joints of the wire baskets shall be staggered during construction to make the structure stronger and more stable. Each row should be stair-stepped back from the previous row. All adjacent baskets shall be laced together. Tie wires or stiffners are installed from the exposed face across the baskets after filling each lift (12”) of the basket to prevent bulging. Tie backs must be installed at the upstream and downstream ends of the project.

Filter fabric is typically required across the rear of the gabion baskets to prevent backfill from eroding into the gabion baskets. A highly permeable fabric should be used. Furthermore, proper backfill (e.g. #57 gravel) behind the baskets must be determined during project design.

Vertical joints in gabion baskets must be staggered to increase durability. Joints should be offset by ½ the cell width, typically 18 inches.

References:

1. Engineering Field Handbook Chapter 16, Streambank and Shoreline Protection; Natural Resources Conservation Service
2. Ohio Stream Management Guide # 15 Gabion Revetments

6.3.4 Retaining Walls

Description:

Vertical or near vertical structural walls constructed of timber, concrete, steel, aluminum, or other such material

Purpose:

To eliminate bank erosion, and reduce or eliminate lateral channel migration

Where Applicable:

In areas where bank failures have occurred, and the area must be reclaimed

Where a very high degree of reliability is needed or where public safety concerns are high

Advantages:

Can be made of several different materials

High degree of reliability and long design life

Limitations:

Relatively expensive compared to other bank stabilization or armoring practices

Retaining walls must be designed and engineered on a site by site basis

Design and Construction Considerations:

Design of retaining walls should be evaluated and designed by a professional engineer. Primary consideration in design needs to be given to prevent scour and erosion at the foundation of the footer, and to prevent erosion around the structure from overtopping.

Due to the expense typically incurred for retaining walls, they are not typically used in rural drainage projects. Retaining walls are typically used where area or public safety is of such concern to justify the expense.

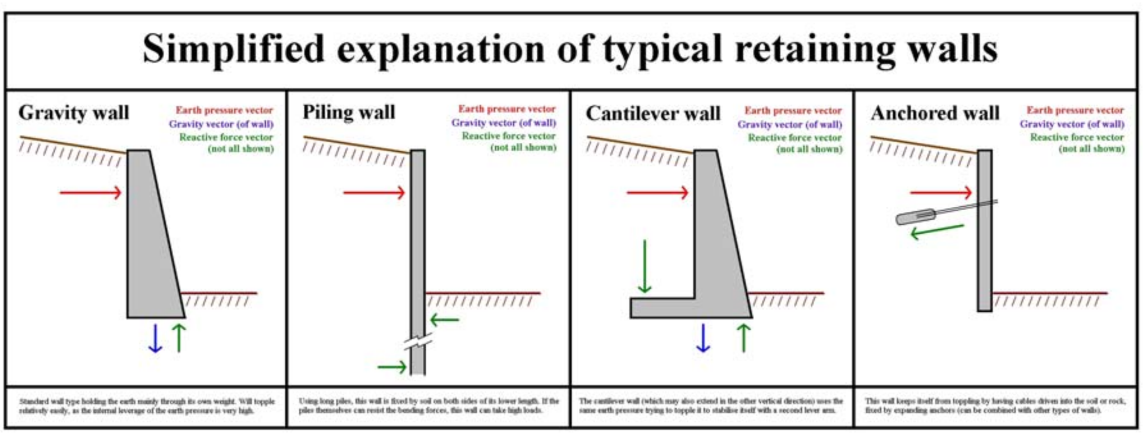

Figure 3 Source Wikipedia; Wikimedia Commons

Basic design approaches for retaining walls are summarized in Figure 3, and a brief discussion of each is contained below.

Gravity Wall – Design is based on the weight of the structure necessary to resist lateral pressures and earth loads. Shorter gravity walls historically have been made from stone, but can also be made of concrete. Newer technologies and materials have allowed the construction of much higher retaining walls, and include materials such as concrete, stone, geo-synthetics, and gabion baskets.

Piling Wall – Often used in areas with soft soils and where minimal construction space is available. Piling walls are typically built of steel, aluminum, wood, or other suitable materials. Proper drainage is very important to maintain the anticipated lateral earth pressures, and prevent failure. Taller piling walls may require a tie-back anchor for stability and economic design.

Cantilevered Wall – These walls act like a beam and are typically built from reinforced concrete. Foundation materials on these structures are vital to prevent sliding, or rotation of the entire wall over time.

Anchored Wall – These walls use various cables or other anchoring techniques to create a stable wall. This approach has dramatically increased in recent years with the advent of geo-synthetic materials.

Regardless of the design approach, a professional engineer should evaluate the proposed construction site and design of retaining walls.

References:

1. Engineering Field Handbook Chapter 16, Streambank and Shoreline Protection; Natural Resources Conservation Service
2. Wikipedia – Retaining Walls Search

6.3.5 Geosynthetics (1 - NRCS, August 2007)

Description:

A geosyntethic material is defined as a planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as part of a manmade project, structure, or system (American Society for Testing and Materials International (ASTM) D4439). Geosynthetics used in stream restoration and stabilization include geotextiles, geogrids, geonets, geocells, and rolled erosion control products.

Purpose:

Geosynthetic materials may be used for various functions and applications in channel work and stabilization projects.

Where Applicable:

- separation and/or filtration beneath erosion protection materials
- reinforcement of steep streambank slopes
- mechanically stabilized earth walls
- earth retaining structures
- erosion protection

Advantages:

Can be used in areas where traditional materials are unstable
Can be used in sites with limited access

Limitations:

Expense of materials and equipment/labor necessary for installation may be higher than other alternatives

Design and Construction Considerations:

Geotextile filter

Nonwoven needle-punched geotextiles are typically less costly than woven geotextiles. Nonwoven geotextiles have typically been used by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) beneath erosion protection materials to serve either filtration or separation functions. The U.S. Army Corps of Engineers (USACE) has traditionally used woven geotextiles for these functions. A heat-bonded or resin-bonded nonwoven geotextile should not be used for geotextiles serving as a filter. The permeability of heat-bonded and resin-bonded geotextiles is too low to allow adequate seepage and dissipation of hydrostatic pressure. A woven geotextile is recommended when water will frequently flow through the geotextile and the retained soil particles have the potential to move within the soil structure towards the geotextile. In this condition, a nonwoven geotextile has a greater potential for clogging since it will allow very few particles to filter through the geotextile. If soil particles have the potential to move within the soil structure, a woven geotextile will often allow fine sand and silt particles to pass through the geotextile until a natural graded filter is developed within the soil structure behind the geotextile. To retain fine sand and silt soil particles, a granular filter of ASTM C33 sand overlain by a properly sized geotextile is often used. Recommended geotextile properties for geotextiles providing filtration are provided in the Guide for the Use of Geotextile (USDA Soil Conservation Service (SCS) 1991). Recommended geotextile properties for geotextiles providing drainage, separation, and filtration beneath erosion protection are provided in Geotextile Specification for Highway Applications (American Association of State Highway Transportation Officials (AASHTO) 2000). It is important to note that some soil bioengineering techniques do not function well under geotextiles, and placing holes through the geotextile may provide a seepage path that would weaken the structure. This may require a trade-off analysis to balance the advantages of incorporating soil bioengineering techniques against the advantages of an intact filter geotextile. Finally, it should be noted that some streambanks may have sufficient gravel or clay content (PI>15), precluding the need for either bedding or geotextiles.

Reinforced slopes

The reinforced slope obtains its internal stability from the tensile strength of the geosynthetic reinforcement layers. The reinforced slope design may be completed with guidance provided by USACE (1995b), U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA) 2001c), or Designing with Geosynthetics (Koerner 1998). The computer program ReSlope may also aid in the design. Once the internal stability of the slope is satisfied, the external stability must be evaluated, including an analysis of sliding, overturning, bearing capacity, and settlement. The global stability of reinforced slopes must be analyzed with the appropriate slope stability analysis method. Slope stability analyses are typically performed with computer software such as SLOPE/W, PCSTABLE, or UTEXAS software.

Erosion protection

Selection and installation of an erosion control blanket or a turf reinforcement mat is a function of the hydraulic characteristics of the site, streambank slopes, and expected lift of the product. Erosion control blankets are used for temporary erosion protection until adequate vegetation can be established. Turf reinforcement mats are considered permanent erosion protection and are designed to reinforce the soil surface and root system of the vegetation.

References:

(1) Natural Resource Conservation Service, National Engineering Handbook, Part 654, Technical Supplement 14D – Geosynthetics in Stream Restoration, August 2007.

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6.4 Subsurface Drains

6.4 Subsurface Drains

Subsurface drains are an integral part of the drainage infrastructure in Ohio. Many of the subsurface tile in Ohio was installed 75 years ago or more. As a result, many of these systems are failing and need of repair or complete replacement. The following sections consider the design and replacement of such systems.

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6.4.1 Subsurface Drain Design & Installation

Description:

A conduit, such as corrugated plastic tubing, clay tile, concrete tile, or pipe installed beneath the ground surface to collect and/or convey drainage water in headwater areas.

Purpose:

Drain excess water from the plant root zone of the soil profile.

Where Applicable:

Where fine soil texture; massive soil structure; low soil permeability; topography; soil compaction; restrictive geologic layer; and excess precipitation affect agricultural production or residential and commercial property.

Advantages:

Enhances agricultural production

Reduces surface runoff and soil erosion

Protects structures and foundations from water damage

Constraints:

May negatively affect water levels of adjacent landowners

May be relatively expensive to install

Outlets that are on another land owner may be difficult to maintain

Design & Construction Considerations:

One or more of the following shall determine the required capacity:

1. Application of a locally tried and proven drainage coefficient to the acreage drained, including added capacity required to dispose of surface water entering through inlets.

2. Yield of ground water based on the expected deep percolation of irrigation water from the overlying fields, including the leaching requirement.

3. Comparison of the site with other similar sites where subsurface drain yields have been measured.

4. Measurement of the rate of subsurface flow at the site during a period of adverse weather and ground water conditions.

5. Application of Darcy's law to lateral or artesian subsurface flow.

6. Estimates of lateral or artesian subsurface flow.

The required capacity of the drain can be determined from charts and tables in Chapter 14 of the Engineering Field Manual for Conservation Practices.

http://www.oh.nrcs.usda.gov/technical/engineering/references/tech_refs.html
Where the land to be drained has adequate surface drainage, either natural or artificial, the following coefficients are recommended.

	Inches to be Removed in 24 Hours	
Soil	Field Crops	Truck Crops
Mineral	3/8 to 1/2	1/2 to 3/4
Organic	1/2 to 3/4	3/4 to 1-1/2

Where it is necessary to admit surface water to the subsurface drain system through surface inlets:

	Inches to be Removed in 24 Hours			
Soil	Field Crops		Truck Crops	
	Blind/Inlets	Open Inlets	Blind/Inlets	Open Inlets
Mineral	1/2 to 3/4	1/2 to 1	3/4 to 1	1 to 1-1/2
Organic	3/4 to 1	3/4 to 1-1/2	1 to 2	2 to 4

Where high value truck crops might be damaged by water standing on them from 2 to 4 hours during hot weather, a higher coefficient than those given above and/or closer drain spacing shall be necessary to hold crop damage to a minimum.

Size

The size of subsurface drains shall be computed by applying Manning's formula. The size shall be based on the required capacity and computed by using one of the following assumptions:

1. The hydraulic gradeline is parallel to the bottom grade of the subsurface drain with the conduit flowing full at design flow.

2. The conduit flowing partly full where a steep grade or other conditions require excess capacity.

3. Conduit flowing under pressure with hydraulic gradeline set by site conditions on a grade that differs from that of the subsurface drain. This procedure shall be used only if surface water inlets or nearness of the conduit to outlets with fixed water elevations permit satisfactory estimates of hydraulic pressure and flows under design conditions.

The outlet pipe is part of the hydraulic system, and its grade and roughness characteristic ("n" value) must be considered in determining the required size of the outlet pipe.

All subsurface drains shall have a nominal diameter that equals or exceeds 3 inches.

Depth, Spacing, and Location

The depth, spacing, and location of the subsurface drain shall be based on site conditions, including soils, topography, ground water conditions, crops, land use, outlets, and saline or sodic conditions. The recommendations in the Ohio Drainage Guide will be used unless special field studies are made to determine spacing requirements.

The minimum depth of cover over subsurface drains in mineral soils shall be 2 feet. This minimum depth shall apply to normal field levels and may exclude sections of line near the outlet sections laid through minor depressions where the conduit is not subject to damage by frost action or equipment travel.

The minimum depth of cover in organic soils shall be 2.5 feet for normal field levels, as defined above, after initial subsidence. Structural measures shall be installed if it is feasible to control the water table level in organic soils within the optimum range of depths.

The maximum depth of cover for standard duty corrugated plastic tubing shall be 10 feet for trench widths of 2 feet or less (measured at tubing and to 1 foot above top of tubing). Heavy-duty tubing shall be specified for depths greater than 10 feet, trench widths more than 2 feet, or in rocky soils.

For computation of maximum allowable loads on subsurface drains, use the trench and bedding conditions specified and the crushing strength of the kind and class of drain. The design load on the conduit shall be based on a combination of equipment loads and trench loads. Equipment loads are based on the maximum expected wheel loads for the equipment to be used, the minimum height of cover over the conduit, and the trench width. Equipment loads on the conduit may be neglected when depth of cover exceeds 6 feet. Trench loads are based on the type of backfill over the conduit, the width of the trench, and the unit weight of the backfill material. A safety factor of not less than 1.5 shall be used in computing the maximum allowable depth of cover for a particular type of conduit.

Minimum Velocity and Grade

In areas where sedimentation is not a hazard, the minimum grades shall be based on site conditions and a velocity of not less than 0.5 feet per second (ft/s). If a hazard exits, a velocity of not less than 1.4 ft/s shall be used to establish the minimum grades if site conditions permit. Otherwise, provisions shall be made for preventing sedimentation by use of filters or by collecting and periodically removing sediment from installed traps, or by periodically cleaning the lines with high-pressure jetting systems or cleaning solutions.

Maximum Velocity without Protection

Excessive flow velocity in the drain may induce piping of soil material into the drain line.

Maximum velocities by soil texture

Soil Texture	Velocity (ft/s)
Sand and Sandy Loam	3.5
Silt and Silt Loam	5.0
Silt Clay Loam	6.0
Clay and Clay Loam	7.0
Course Sand and Gravel	9.0

Maximum Grade and Protection

On sites where topographic conditions require that drain lines be placed on steep grades and design velocities will be greater than indicated under "Maximum velocity without protection," special measures shall be used to protect the conduit or surrounding soil. These measures shall be specified for each job according to the particular conditions of the job site.

The protective measure shall include one or more of the following:

1. Enclose continuous perforated pipe or tubing with fabric-type filter material or properly graded sand and gravel.
2. Use non-perforated continuous tubing, a watertight pipe, or seal joints.
3. Place the conduit in a sand and gravel envelope or blinding with the least erodible soil available.
4. Select rigid butt end pipe or tile with straight, smooth sections and square ends to obtain tight fitting joints.
5. Wrap open joints of the pipe or tile with tar impregnated paper, burlap, or special fabric-type filter material.
6. Install open-air risers for air release or entry.

Iron Ochre Control

If drains are to be installed in sites where iron ochre and manganese dioxide problems are likely to occur, provisions should be made to provide access for cleaning the lines. Each drain line should outlet directly into an open ditch and/or should have entry ports as needed to provide access for cleaning equipment. Drain cleaning provisions should be installed in such a way that the drains can be cleaned in an upstream or rising grade direction. If possible, drains in ochre-prone areas should be installed during the dry season when the water table is low and the iron and manganese dioxide is in its insoluble form.

Where possible, in areas where the potential for such problems is high, protection against their development can be provided by designing an outlet facility to ensure permanent submergence of the drain line.

Protection against Root Clogging

Problems may occur where it is necessary to place drains in close proximity to perennial vegetation. Roots of water-loving trees, such as willow, cottonwood, elm, and soft maple, or some shrubs and grasses growing near subsurface drains may enter and obstruct the flow.

Where possible, use non-perforated tubing or closed joints through the root zone area. Where this is not possible, water-loving trees should be removed from a distance of at least 100 feet on each side of the drain. A distance of 50 feet should be maintained from other species of trees except for fruit trees. Orchards can often be drained by drain lines located close to the fruit trees.

Where crops and grasses may cause trouble on drain lines, facilities may be installed to provide a means for submerging the line to terminate the root growth as desired or to maintain a water table above the drainlines to prevent growth into the system.

Materials

Subsurface drains include conduits of plastic, clay, concrete, bituminized fiber, metal, or other materials of acceptable quality.

The conduit shall meet strength and durability requirements for the site. All conduits shall meet or exceed the minimum requirements of the appropriate specifications published by the American Society for Testing and Materials (ASTM), American Association of State Highway and Transportation Officials (AASHTO), and the American Water Works Association (AWWA).

Foundation

If soft or yielding foundations are encountered, the lines shall be stabilized and protected from settlement by adding gravel or other suitable materials to the trench, by placing the conduit on a treated plank that will not readily decompose or on other rigid supports, or by using long sections or perforated or watertight pipe having adequate strength to ensure satisfactory subsurface drain performance. The use of a flat treated plank is not recommended for corrugated plastic tubing.

Filters and Filter Material

Filters will be used around conduits, as needed, to prevent movement of the surrounding soil material into the conduit. The need for a filter will be determined by the characteristics of the surrounding soil material, site conditions, and the velocity of flow in the conduit. A suitable filter should be specified if:

1. Local experience indicated a need.
2. Soil materials surrounding the conduit are dispersed clays, silts with a plasticity index less than 7, or fine sands with a plasticity index less than 7.
3. Deep soil cracking is expected, or
4. The method of installation may result in voids between the conduit and backfill material.

If a sand-gravel filter is specified, the filter gradation shall be designed in accordance with National Engineering Handbook (NEH) Part 633, Chapter 26, Gradation Design of Sand and Gravel Filters.

Specified filter material must completely encase the conduit so that all openings are covered with at least 3 inches of filter material except that the top of the conduit and side filter material may be covered by a sheet of plastic or similar impervious material to reduce the quantity of filter material required. In all cases the resulting flow pattern through filter material shall be a minimum of 3 inches.

Artificial fabric or mat-type filter materials may be used, provided that the effective opening size, strength, durability, and permeability are adequate to prevent soil movement into the drain throughout the expected life of the system.

Envelopes and Envelope Material

Envelopes shall be used around subsurface drains if they are needed for proper bedding of the conduit or to improve the characteristics of flow of ground water into the conduit.

Materials used for envelopes do not need to meet the gradation requirements of filters, but they must not contain materials that will cause an accumulation of sediment in the conduit or that will render the envelope unsuitable for bedding of the conduit.

Envelope materials shall consist of sand-gravel, organic, or similar material. Sand-gravel envelope materials shall all pass a 1.5-inch sieve; not more than 30 percent shall pass a No. 50 sieve; and not more than 5 percent shall pass the No. 200 sieve. ASTM-C-33 fine aggregate for concrete has been satisfactorily used and is readily available.

Where organic or other compressible materials are used, they shall be used only around a rigid wall conduit and above the centerline of flexible tubing. All organic or other compressible material shall be of a type that will not readily decompose.

Placement and Bedding

The conduit should not be placed on exposed rock or stones more than 1.5 inches in diameter for 6 inch or larger tile and stones no more than ¾ inch diameter for tile less than 6 inches. Where such conditions are present the trench must be over-excavated, a minimum of 6 inches and refilled to grade with a suitable bedding material.

The conduit must be placed on a firm foundation to ensure proper alignment. Prevent runoff and surface water from entering the trench.

If installation will be below a water table or where unstable soils are present, special equipment, installation procedures, or bedding materials may be needed. These special requirements may also be necessary to prevent soil movement into the drain or plugging of the envelope if installation will be made in such materials as quicksand or a silt slurry.

For trench installations of corrugated plastic tubing 8 inches or less in diameter, one of the following bedding methods will be specified:

1. A shaped groove or 90° V-notch in the bottom of the trench for tubing support and alignment.
2. A sand-gravel envelope, at least 3 inches thick, to provide support.

3. Compacted soil bedding material beside and to 3 inches above the tubing.

For trench installations of corrugated plastic tubing larger than 8 inches, the same bedding requirements will be met except that a semi-circular or trapezoidal groove shaped to fit the conduit will be used rather than a V-shaped groove.

For rigid conduits installed in a trench, the same requirements will be met except that a groove or notch is not required.

All trench installations should be made when the soil profile is in its driest possible condition in order to minimize problems of trench stability, conduit alignment, and soil movement into the drain.

For trench installations where a sand-gravel or compacted bedding is not specified, the conduit should be blinded with selected material containing no hard objects larger than 1.5 inches in diameter. Blinding should be carried to a minimum of 3 inches above the conduit.

Where the conduit will be bedded with fine-grained friable soil or a sand and gravel mixture, the minimum trench width will be at least 0.5 ft. greater than the outside diameter of the conduit. When the conduit is installed in conditions where cloddy material will likely be used for bedding, the trench width will be at least 1.0 ft. greater than the outside diameter of the conduit. In all cases the conduit will be laid in the center of the trench.

All installations shall meet the minimum requirements of the appropriate ASTM specification.

6.4.2 Auxiliary Structures and Protection

Structures installed in drain lines must not unduly impede the flow of water in the system. Their capacity must be no less than that of the line or lines feeding into or through them. The use of internal couplers for corrugated plastic tubing will be allowed.

If the drain system is to carry surface water flow, the capacity of the surface water inlet shall not be greater than the maximum design flow in the drain line or lines. Covers or trash racks should be used to ensure that no foreign materials are allowed in the drain lines. The capacity of a relief well system will be based on the flow from the aquifer, the well spacing, and other site conditions and will be adequate to lower the artesian waterhead to the desired level. The size of relief wells is generally based on the available materials rather than on hydraulic considerations. Such wells will not be less than 4 inches in diameter.

Junction boxes, manholes, catch basins, and sand traps must be accessible for maintenance. A clear opening of not less than 2 feet will be provided in either circular or rectangular structures.

The drain system must be protected against velocities exceeding those provided under **“Maximum velocity without protection”** and against turbulence created near outlets, surface inlets, or similar structures. Continuous or closed-joint pipe must be used in drain lines adjoining the structure where excessive velocities will occur.

Junction boxes shall be installed where three or more lines join or if two lines join at different elevations. In some locations it may be desirable to bury junction boxes. A solid cover should be used, and the junction box should have a minimum of 1.5 feet of soil cover.

If not connected to a structure, the upper end of each subsurface drain line will be capped with a tight-fitting external cap of the same material as the conduit or other durable materials.

6.4.3 Outlet Pipes

The outlet must be protected against erosion and undermining of the conduit, entry of tree roots, damaging periods of submergence, and entry of rodents or other animals into the subsurface drain.

A continuous section of rigid pipe without open joints or perforations will be used at the outlet end of the line and must discharge above the normal elevation of low flow in the outlet ditch. Standard corrugated plastic tubing is not suitable for the outlet section. Minimize the visual impact of projecting outlets.

The outlet pipe and its installation will conform to the following requirements:

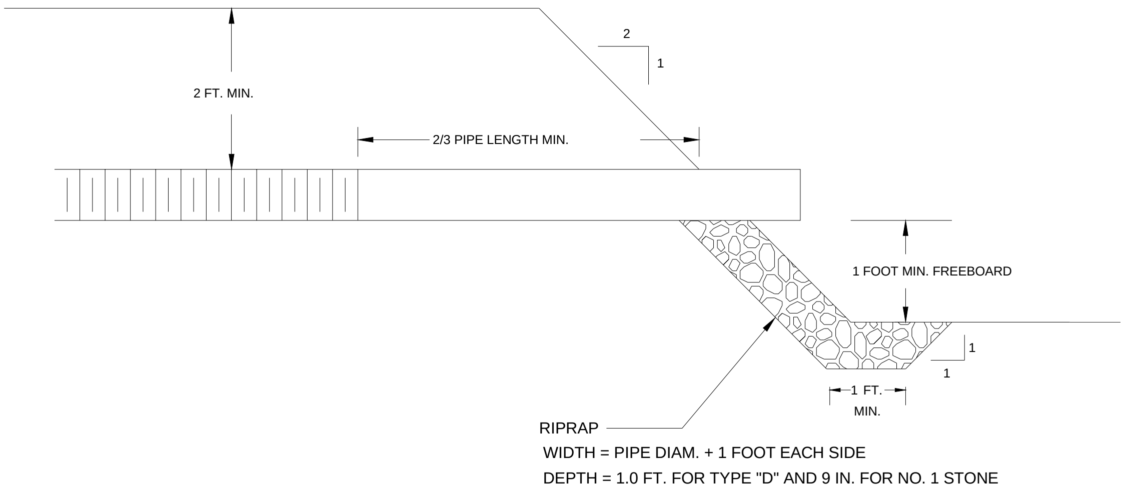
1. Two-thirds of the pipe will be buried in the ditch bank, and the cantilever section must extend to the toe of the ditch side slope or the side slope protected from erosion. The minimum length of the pipe will normally be 8 feet. Under certain conditions shorter sections are appropriate; e.g., steep sided main and laterals (1 (horizontal) : 1 (vertical) or less) with a narrow bottom width of 3 feet, commonly referred to as “minimum ditches,” for outletting individual subsurface drain laterals.

   For conduits 10 inches in diameter and greater, longer outlet sections shall be considered, such as:

   * 10 inches and 12 inches in diameter, use 12 feet.
   * 15 inches and 18 inches in diameter, use 16 feet.
   * Use 20 feet outlet pipe for all diameters larger than 18 inches.

2. If ice or floating debris may damage the outlet pipe, the outlet shall be recessed to the extent that the cantilevered part of the pipe will be protected from the current in the ditch.
3. Headwalls used for subsurface drain outlets must be adequate in strength and design to avoid washouts and other failures.

Watertight conduits strong enough to withstand the expected loads will be used if subsurface drains cross under irrigation canals, ditches, or other structures. Conduits under roadways must be designed to withstand the expected loads. Shallow subsurface drains through depressed or low areas and near outlets must be protected from damage caused by farm machinery and other equipment and from freezing and thawing.



OUTLET PIPE DETAILS

6.5 Removal of Debris

6.5 Removal of Debris in Channels

Low gradient channels and the subsequent low channel velocities allow for the accumulation of tree snags, brush and other debris. This accumulation reduces the cross-section of the channel available for water flow, which causes an increase in water surface elevation and possible overbank flooding for storm frequencies that would otherwise stay within bank. Debris and log jams in the channel may cause problems of accumulations against bridges or culverts. This may in turn compromise the structural stability of the bridge.

Average flow velocities during storm events are similar for channels with or without obstructions, however; obstructions will create localized areas of increased and decreased flow velocities in the area of the obstruction. These localized changes in velocity may increase the chance for bank and bottom erosion and or sedimentation and debris accumulation.

The obstructions may store water in the channel cross-section and in turn impair the drainage from subsurface outlet pipes.

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6.5.1 Log Jam and Crop Residue Removal

Description:

Removal of material (trees, crop residue, or white goods) from the channel cross section and securing or disposing of them so they do not reenter the channel.

Purpose:

Remove material from the cross section of the channel that may cause erosion, debris accumulation, structural problems, and or impair drainage.

Where Applicable:

Where the obstruction is or will have the potential to obstruct 75% of the channel bottom width or is causing problem with a bridge or culvert.

Advantages:

Allows channel capacity to be maintained with little impact to the channel.

Design & Construction Considerations:

Log Jams

Single logs in large channels may provide beneficial habitat for aquatic species.

During channel inspections, log jams shall be classified using the following four classifications. Figure 1 illustrates the typical classifications

- Type A – Single tree or log or part of tree that obstructs channel flow
- Type B – Three or more trees or logs grouped together in the channel at one location. May consist of scattered logs or trees within a 150-foot section.
- Type C – Medium sized logjam and debris that obstructs part or all of channel.
- Type D – Large logjam maybe one large jam or several log jams with in a 300-foot section that obstructs all of channel flow.

The following items shall also be included in the inspection of each log jam.

Is all debris associated with logjam woody and of natural composure?

Or is there trash, appliances, furniture in it as well?

Approximate length of a Type D logjam?

Is the logjam in front of a bridge or culvert?

Figure 2 gives an illustration of some typical plans used in log jam removal projects.

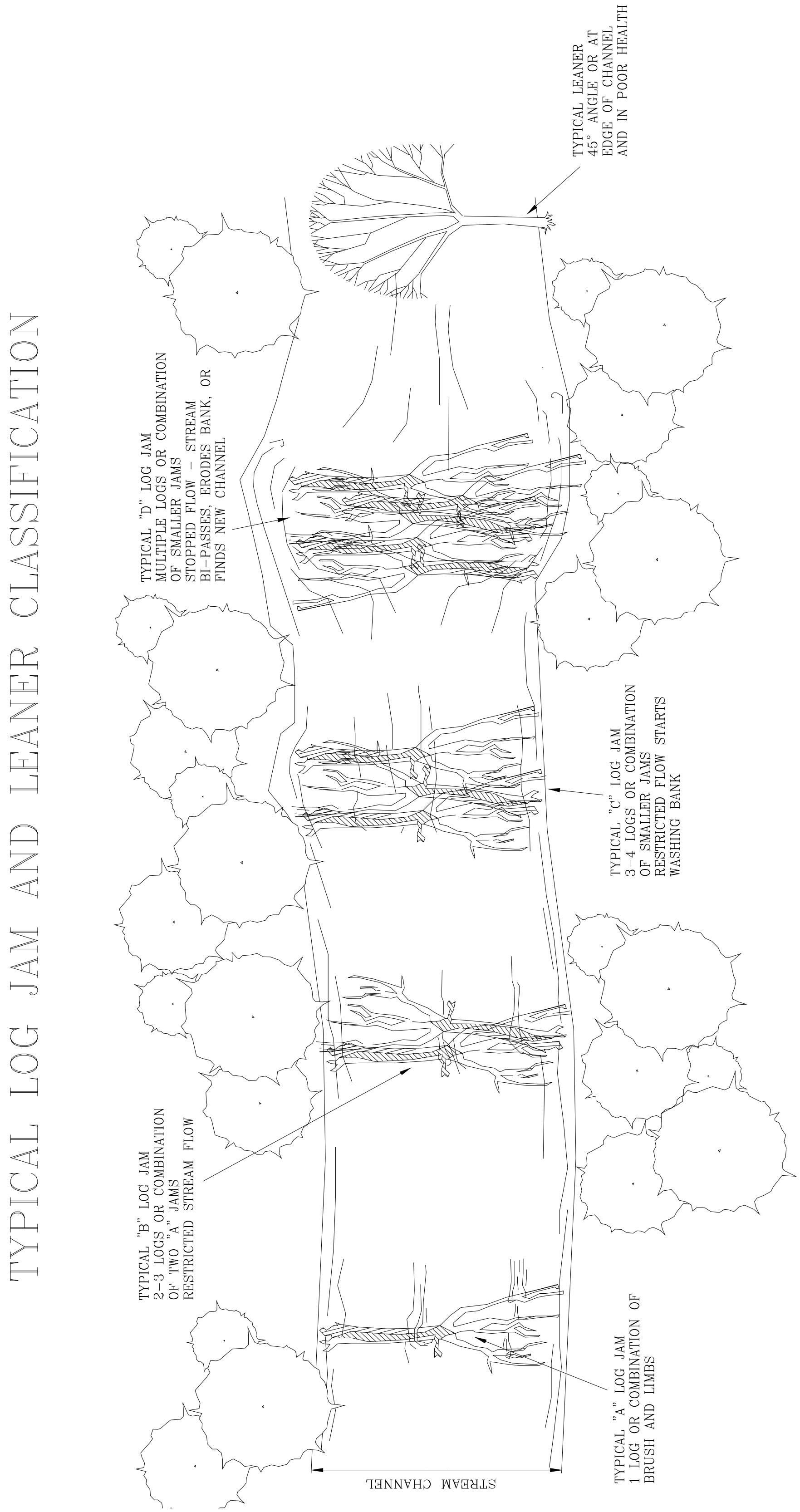
TYPICAL LOG JAM AND LEANER CLASSIFICATION
TYPICAL LEANER
45° ANGLE OR AT
EDGE OF CHANNEL
AND IN POOR HEALTH
TYPICAL "D" LOG JAM
MULTIPLE LOGS OR COMBINATION
OF SMALLER JAMS
STOPPED FLOW – STREAM
BI-PASSES, ERODES BANK, OR
FINDS NEW CHANNEL
TYPICAL "C" LOG JAM
3–4 LOGS OR COMBINATION
OF SMALLER JAMS
RESTRICTED FLOW STARTS
WASHING BANK
TYPICAL "B" LOG JAM
2–3 LOGS OR COMBINATION
OF TWO "A" JAMS
RESTRICTED STREAM FLOW
TYPICAL "A" LOG JAM
1 LOG OR COMBINATION OF
BRUSH AND LIMBS
STREAM CHANNEL

Figure 1

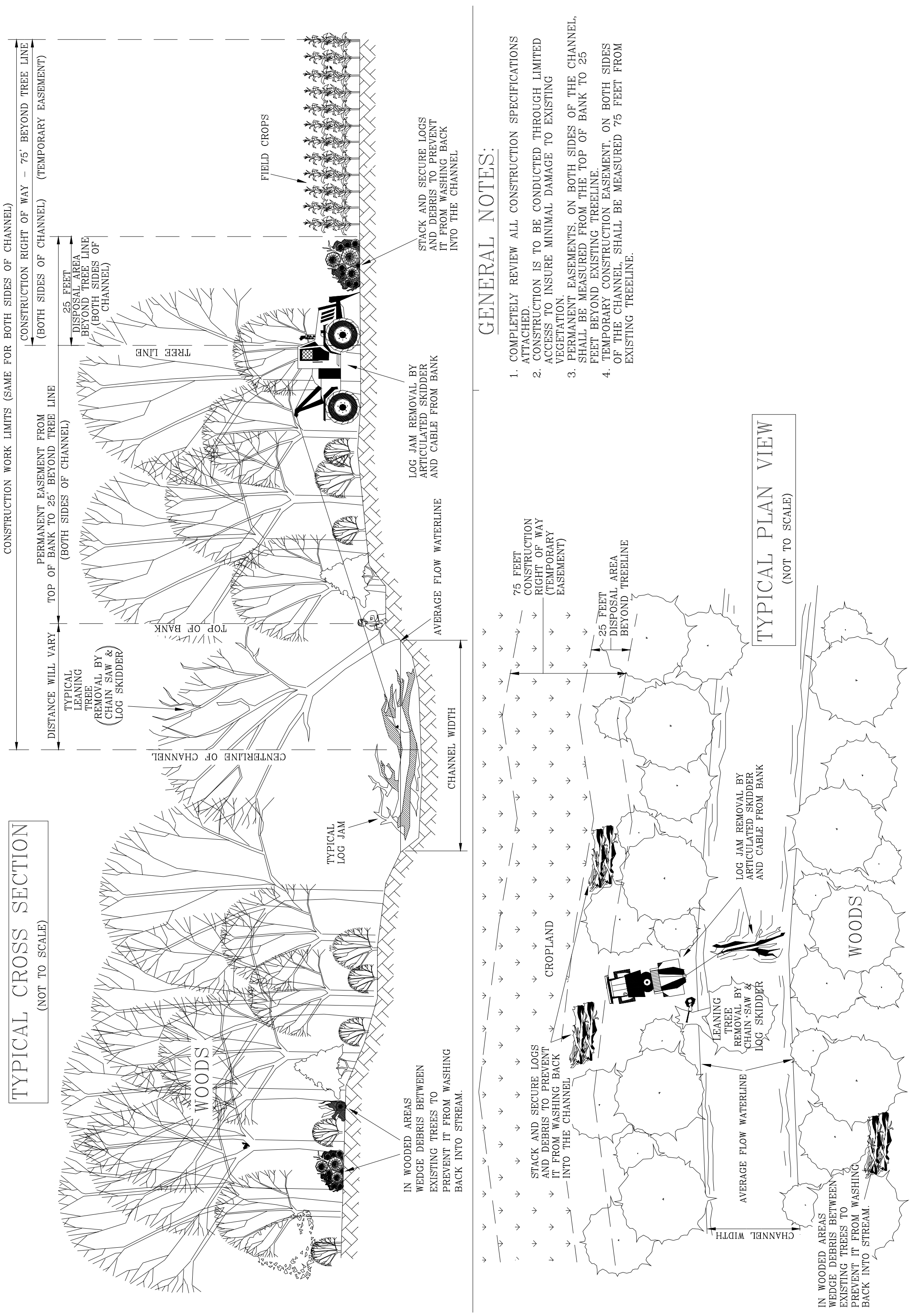
TYPICAL CROSS SECTION
(NOT TO SCALE)
CONSTRUCTION WORK LIMITS (SAME FOR BOTH SIDES OF CHANNEL)
CONSTRUCTION RIGHT OF WAY - 75' BEYOND TREE LINE (BOTH SIDES OF CHANNEL) (TEMPORARY EASEMENT)
PERMANENT EASEMENT FROM TOP OF BANK TO 25' BEYOND TREE LINE (BOTH SIDES OF CHANNEL)
25 FEET DISPOSAL AREA BEYOND TREE LINE (BOTH SIDES OF CHANNEL)
DISTANCE WILL VARY
TYPICAL LEANING TREE (REMOVAL BY CHAIN SAW & LOG SKIDDER)
TREE LINE
TOP OF BANK
CENTERLINE OF CHANNEL
FIELD CROPS
WOODS
TYPICAL LOG JAM
CHANNEL WIDTH
AVERAGE FLOW WATERLINE
LOG JAM REMOVAL BY ARTICULATED SKIDDER AND CABLE FROM BANK
STACK AND SECURE LOGS AND DEBRIS TO PREVENT IT FROM WASHING BACK INTO THE CHANNEL
IN WOODED AREAS WEDGE DEBRIS BETWEEN EXISTING TREES TO PREVENT IT FROM WASHING BACK INTO STREAM.
GENERAL NOTES:
1. COMPLETELY REVIEW ALL CONSTRUCTION SPECIFICATIONS ATTACHED.
2. CONSTRUCTION IS TO BE CONDUCTED THROUGH LIMITED ACCESS TO INSURE MINIMAL DAMAGE TO EXISTING VEGETATION.
3. PERMANENT EASEMENTS, ON BOTH SIDES OF THE CHANNEL, SHALL BE MEASURED FROM THE TOP OF BANK TO 25 FEET BEYOND EXISTING TREELINE.
4. TEMPORARY CONSTRUCTION EASEMENT, ON BOTH SIDES OF THE CHANNEL, SHALL BE MEASURED 75 FEET FROM EXISTING TREELINE.
TYPICAL PLAN VIEW
(NOT TO SCALE)
75 FEET CONSTRUCTION RIGHT OF WAY (TEMPORARY EASEMENT)
25 FEET DISPOSAL AREA BEYOND TREELINE
CROPLAND
WOODS
LOG JAM REMOVAL BY ARTICULATED SKIDDER AND CABLE FROM BANK
LEANING TREE REMOVAL BY CHAIN SAW & LOG SKIDDER
STACK AND SECURE LOGS AND DEBRIS TO PREVENT IT FROM WASHING BACK INTO THE CHANNEL
AVERAGE FLOW WATERLINE
CHANNEL WIDTH
IN WOODED AREAS WEDGE DEBRIS BETWEEN EXISTING TREES TO PREVENT IT FROM WASHING BACK INTO STREAM.

Figure 2

Crop Residue

Conservation tillage and no-till systems can lead to crop residue reaching the channel and forming an obstruction in the channel. Once this material forms an obstruction, only removal by mechanical means will clear the obstruction. This material will need to be removed to a point that it will not reenter the channel.

6.5.2 Snag & Clear

Purpose:

To remove channel obstructions and debris from the channel cross section to regain lost capacity.

Removal of dead trees and trees leaning over the channel to eliminate potential debris and log jams in the future.

Where Applicable:

In channels where required flow capacity is hindered by obstructions

Where numerous dead and leaning trees are adjacent to the channel

Advantages:

Increase in channel capacity with reduced impact to the channel compared to other construction and excavation options

Often results in minimal project costs

Can be completed while leaving the riparian corridor intact

Limitations:

Access may be limited depending on existing vegetation and corridor conditions

Site requirements may require excessive hand labor to complete

Continual supervision at construction site may be required for inexperienced work crews

May increase future maintenance demands when compared to other design approaches

Design and Construction Considerations:

If clearing and snagging is likely to result in channel erosion, impairment to the landscape resource quality, or impairment to habitat for fish and wildlife, either the clearing and snagging should not be done or practices to minimize such damage should be applied concurrently with the clearing and snagging.

The capacity of the channel, both before and after improvement, should be determined by use of the Manning formula, using applicable values of the roughness factor “n” for both conditions. The value of “n” used to determine channel capacity after improvement should reflect the degree of maintenance expected in future years.

The area to be cleared and snagged may include the perimeter of the channel, the flow area of the floodway, or both. Trees or other objects adjacent to the channel that may fall into the channel should also be included.

Clearing and snagging should not impair channel stability. The effect of removing obstructions on downstream reaches should also be considered.

The effects on water quality and quantity should be considered in all clearing and snagging projects. Items to consider are:

Quality

1. Effects of discharge on the flood plain and channel relative to erosion and sediment production, both during construction and after establishment.
2. Effects sediment load, sediment-attached substances, organic loadings.
3. Relationships between stream quality and aquifer quality where ground water recharge occurs.
4. Temporary and long-term effects on visual quality of water and landscape.
5. Effects on on-site and downstream water temperatures.

Quantity

1. Possible downstream flooding
2. Effects of changed drawdown on bank stability.
3. Effect of changed flow conditions on ground water recharge.

References:

Natural Resources Conservation Service, Conservation Practice Standard 326; Clearing and Snagging

6.5.3 Low-head Dam Removal

Purpose:

Removing a low head dam can be considered for removal for a number of reasons. They may include items such as public safety. This could include the safety of boaters, swimmers, and those playing on the dam. The dam may also be removed due to the condition of the dam. The dam may be in a condition in which a failure could result in loss of life, injury and/or property damage.

The dam may be considered for removal based upon improving or harming the environment. Removing the low head dam may increase the recovery of species to the area, but it may also allow unwanted sediments to harm species and/or change the habitat in an area above the dam.

A dam may also be considered for removal based upon the past, present and future use to the dam. Does the low head dam serve a purpose for society?

Where Applicable:

Where the issues considered point to the direction of removal.

Advantages:

May removes a safety hazard.

May provide and environmental benefit.

Removes the need for funds to maintain and repair the low head dam.

Limitations:

May cause harm to the environment based up the sediment deposited behind the dam. Removal may disrupt the habitat above and below the dam. Removal of the dam may cause an impact on the social and economic benefit of society.

Considerations:

There are number of issues that need to be considered before removing a low-head dam. These issues and links for required permits to remove a low-head dam can be found at:

http://www.dnr.state.oh.us/water/Home/dsafety/lowhead_dams/default/tabid/3357/Default.aspx

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6.6 Grade Stabilization

6.6 Grade Stabilization Structures

Grade stabilization structures pass runoff from one elevation to a lower elevation without causing undo erosion or damage to other structures nearby. The Natural Resources Conservation Service (formerly Soil Conservation Service) within the United States Department of Agriculture has developed an extensive set of grade stabilization structures with complete design references. Most of these design references are available online or at the local Soil and Water Conservation District.

Many site-specific factors must be considered when selecting the particular type and design of a grade stabilization structure. Different structures lend themselves to different site settings. Consideration must be given to the overfall height, design capacity, topography and soils of the site.

The Engineering Field Handbook written by NRCS gives an in depth discussion on these design considerations, design concepts and general applicability of these structures. This handbook can be found online at:

http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17545.wba

One of the primary design inputs for any grade stabilization structure is the design capacity. In order to determine the required design capacity, first a design storm must be selected. The Ohio design standard for grade stabilization structures identifies the design storms to be used depending on the type of structure, watershed size, overfall, etc. This design standard can be found at:

http://efotg.nrcs.usda.gov/references/public/OH/Oh410_Standard_
Grade_Stabilization_Structure.pdf

These guidelines are used for structures installed through Farm Bill programs, and for settings typically seen in drainage projects in rural areas. However, there may be projects that require a higher degree of protection than required in agricultural fields or other rural settings. State highways, industrial parks, subdivisions, etc. should be given special consideration, and may have higher design requirements listed in local zoning or required by other public agencies. Developing designs and engineering plans with other local officials is a must.

Grade stabilization structures can be open weirs, chute spillways, closed conduits, etc. Moreover, structures can be built from rock, concrete, steel aluminum, wood, concrete blocks, etc. Selection of the structure must consider specific site conditions, available materials, availability of labor, and the overall economics for the project.

The following sections describe grade stabilization structures commonly used in drainage projects.

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6.6.1 Sod Chutes

Description:

A steep, sodded section constructed to convey a design flow at a safe velocity

Purpose:

To conduct surface runoff to the bottom of a constructed ditch flow line without excessive erosion or damage

To control overfall or abrupt changes in the slope of a constructed waterway or watercourse

To conduct the flow of a constructed channel through an overfall into a natural channel

Where Applicable:

For relatively small watershed outlets into a channel without excessive overfall

Advantages:

Low material and construction costs

Maintenance can be conducted easily with other vegetation management in the area

Limitations:

Limited to relatively low overfalls, small design capacities, and suitable soils

Design & Construction Considerations:

Siting – The sod chute is best fit for small watersheds and sites where dense sod can be established and maintained. When the outlet channel is narrow, or conditions at the lower end of the chute are unfavorable to maintaining vegetation, a toe wall should be used. Conditions such as excessive moisture, poor or rocky soils, and excessive siltation from other channels are considered to be poor conditions.

The toe wall raises the lower end of the chute, keeping it above the unfavorable conditions below. The tow wall can be constructed of timber, gabion baskets, concrete, aluminum, or other acceptable materials. Refer to the spillway type structures for toe wall design alternatives.

Materials – Vegetation required for the chute may be established by transplanting sod or, if runoff can be diverted around the site, may be established by seeding and erosion control matting or other acceptable mulching methods. Vegetation species must be tolerant of the anticipated soils conditions, intermittent inundation, and the anticipated flow velocities for the chute.

Design – Design nomenclature for the sod chute are shown in the following illustration from NRCS Engineering Field Handbook Chapter 6. Sod chute design is very similar to the design of grassed waterways. However, sod chutes have sod established before water flows across them allowing for higher permissible velocities than typically used in grassed waterways.

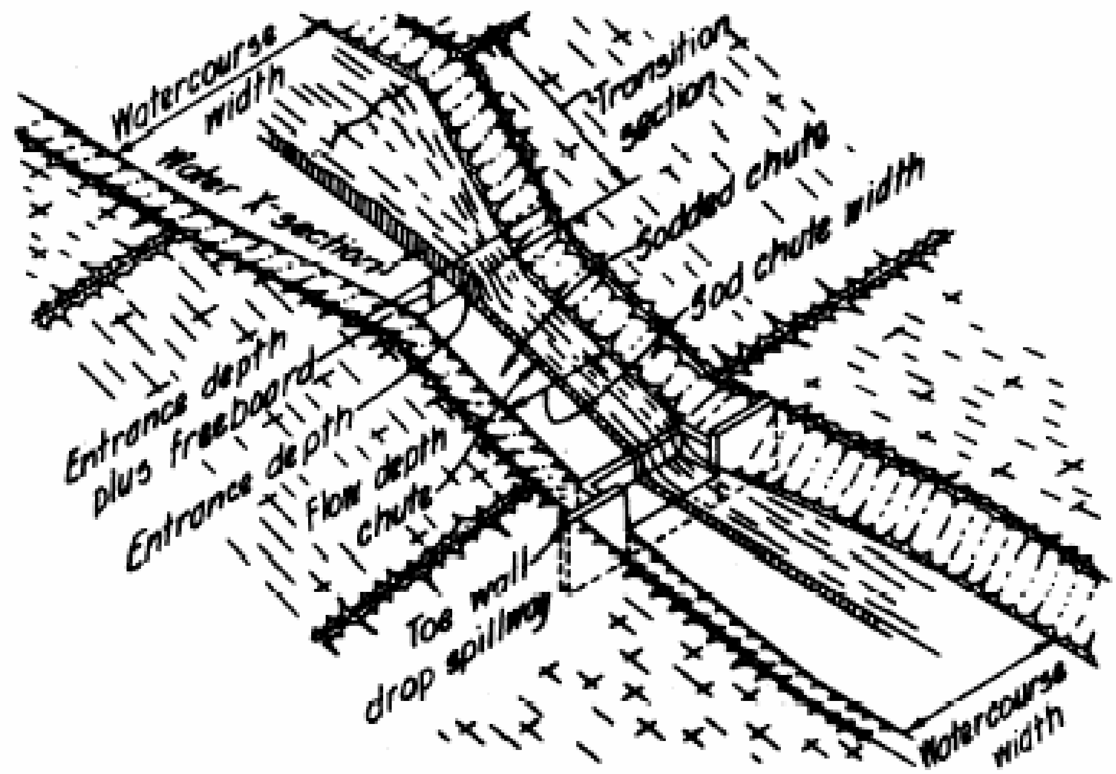

Figure 3 Design Nomenclature. Source: NRCS Engineering Field Handbook

Chute slopes should be 6:1 or flatter, with flatter slopes being better. The chute bottom should be flat from side to side to distribute flow across the entire chute width. Chute widths should be less than the watercourse entering the chute. To accommodate flows entering the chute, a transition section must be constructed to gradually reduce flow width to the planned chute width.

Adequate flow depth is also required at the chute entrance to assure the design entrance capacity. Dikes may be required at the entrance to provide the depth required.

A design chart developed by NRCS is contained on the following page. This chart gives the required entrance depth for many different chute flow depths and bottom widths.

Construction – proper construction techniques will improve the success of the sod chute and greatly reduce repair costs and the chance of failure. The following points should be considered for every potential sod chute site.

1.) Do not build the chute on fill material. Only construct sod chutes on original soil.
2.) Carefully grade the site to get a uniform flat bottom from side to side, leaving it in a condition similar to a seedbed.
3.) If the site is to be sodded:
    a. Cut the sod thin
    b. Lay sod in strips across the chute
    c. Start at the chute bottom and progress upgrade
    d. Stagger sod joints
    e. Lay sod 2 feet up on chute side slopes
    f. Fill in all open joints with loose soil
    g. Tamp or roll all laid sod
    h. Pin sod down with staples or by other acceptable means
4.) Protect from livestock or other traffic during establishment or other critical seasons
5.) Mowing is required for proper maintenance of the sod chute.

References:

Engineering Field Handbook; Chapter 6, Grade Stabilization Structures Natural Resources Conservation Service, United States Department of Agriculture

Ohio NRCS Design Standard 410; Grade Stabilization Structures

SOD CHUTE — DIMENSION TABLE
TRAPEZOIDAL CROSS SECTION

CHUTE SLOPE	2% SLOPE RATIO 50:1					4% SLOPE RATIO 25:1					6% SLOPE RATIO 16¼:1				
PERMISSIBLE VELOCITY, FT./SEC.	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8
CONDITION OF SOD	FAIR SOD	GOOD SOD		EXCELLENT SOD		FAIR SOD	GOOD SOD		EXCELLENT SOD		FAIR SOD	GOOD SOD		EXCELLENT SOD	
ENTRANCE DEPTH FT.	0.8	1.1	1.5	1.9	2.4	0.8	1.1	1.5	1.9	2.3	0.7	1.0	1.4	1.8	2.2
CHUTE DEPTH FT.	0.6	0.8	1.0	1.2	1.4	0.5	0.7	0.9	1.1	1.3	0.4	0.6	0.8	1.0	1.2
REQUIRED CAPACITY Q= C.F.S.	BOTTOM WIDTH OF CHUTE, FEET														
10															
15											10				
20						10					14				
25						12					18				
30						15					22	10			
35						18					27	12			
40	10					21					31	15			
45	12					25	10				36	17			
50	14					28	12				40	20	10		
60	18					34	16				48	25	12		
70	21	10				40	20	10			57	29	15		
80	25	11				46	23	11				34	18	10	
90	29	13				53	27	13				39	21	11	
100	33	15				59	31	15				44	25	13	
120	40	19	10				38	20	10			54	31	17	10
140	48	24	11				45	25	12				37	21	11
160	55	28	14				52	29	16				43	26	14
180		33	16				60	34	19	10			49	30	17
200		37	19					39	22	11			56	34	20
220		41	22	10				43	25	14				38	23
240		45	25	12				48	29	16				42	26
260		50	27	14				52	32	18				47	29
280		54	30	16				56	35	20				51	32
300		58	33	18	10			61	38	23				55	35

CHUTE SLOPE	8% SLOPE RATIO 12:1					10% SLOPE RATIO 10:1					14% SLOPE RATIO 7:1				
PERMISSIBLE VELOCITY, FT./SEC.	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8
CONDITION OF SOD	FAIR SOD	GOOD SOD		EXCELLENT SOD		FAIR SOD	GOOD SOD		EXCELLENT SOD		FAIR SOD	GOOD SOD		EXCELLENT SOD	
ENTRANCE DEPTH FT.	0.5	0.7	1.0	1.3	1.6	0.5	0.7	0.9	1.2	1.5	0.4	0.5	0.8	1.0	1.2
CHUTE DEPTH FT.	0.3	0.4	0.5	0.7	0.9	0.2	0.3	0.4	0.6	0.7	0.2	0.3	0.3	0.4	0.5
REQUIRED CAPACITY Q= C.F.S.															
10	10					12					15	10			
15	14					18	10				24	12			
20	19	10				24	12				32	18	10		
25	24	12				30	15				40	20	13		
30	30	15				36	19	10			49	25	16	10	
35	35	18	10			42	22	12				29	19	11	
40	40	22	12			48	26	14				34	22	13	
45	45	25	14			54	30	17	10			38	25	15	
50	50	28	16				33	19	11			42	27	17	10
60	60	34	19	10			40	24	14	10		47	33	21	13
70		40	23	13			47	28	17	11			39	25	16
80		46	27	16			53	33	20	13			45	29	19
90		53	31	18	10			37	24	15				33	22
100		59	35	21	13			42	27	18				37	25
120			43	26	17			51	33	22				45	31
140			50	32	21				39	26					37
160			59	37	25				46	30					42
180				42	28				52	34					48
200				48	32					38					
220					36					43					
240					40					48					
260					43					52					
280					47										
300															

EXAMPLE

Given: Q = 90 c.f.s. Estimated runoff from watershed.

Height to control: 2.5 feet.

Try 8% slope of chute or 12:1, Chute length = 2.5 X 12 = 30 ft. (length is O.K. for site)

Good sod available and good soil:

Select velocity: 6 feet per second.

SOLUTION

In the left hand column under "REQUIRED CAPACITY" c.f.s. find "90" c.f.s. Follow this to right and under column "8%" slope and "6" ft. per second velocity find "31" feet bottom width. In same column on line "CHUTE DEPTH" find "0.5" foot. In same column on line "ENTRANCE DEPTH" find "1.0" foot.

CONSTRUCTION DIMENSIONS

Slope: 8% or 12:1 slope.

Bottom width: 31 feet.

Total depth: 1.0' (entrance depth) + 0.4' (freeboard) = 1.4 feet.

Chute depth: 0.5 feet. (Normal excavation and shaping will provide required depth plus additional depth for freeboard.)

NOTE: Minimum bottom width 10 feet.

BASIS OF DESIGN

$$V = \frac{1.486}{n} R^{2/3} S^{1/2} \quad n = .040$$

4:1 SIDE SLOPES

Figure 4 Sod Chute Design Chart. Source NRCS Engineering Field Handbook

6.6.2 Rock Chutes

Description:

A steep, rock lined channel, constructed to convey a design flow at a safe velocity from one elevation to a lower elevation

Purpose:

To stabilize grade and control erosion at the lower end of a grassed waterway or other constructed watercourse

Where Applicable:

Applies over a wide range of design flows and overfalls

Advantages:

Construction equipment and materials required are readily available, and commonly completed across Ohio

Adaptable to a wide range of site conditions

Limitations:

Proper gradation of rock and quality riprap is a must

Proper construction may require additional equipment time or hand placement of some riprap

Design & Construction Considerations:

NRCS's Engineering Field Handbook Exhibit OH6-1 reviews detailed design parameters for rock chutes, and several design solutions for various sizes of rock chutes. This design information can be found on pages 29 through 40 of Ohio's EFH supplements. This document can be found online at:

ftp://ftp-fc.sc.egov.usda.gov/OH/pub/Admin/NEH/Adobe/Combined_EFH_Supplements.pdf

Preliminary Information – To begin the design of a rock chute the first information that is required is the design flow capacity, and specific site information. Design will require a topographic survey of the site and analysis of the watershed draining to the site.

Materials – Rock used for construction must be of a specific gradation. This gradation is designed to withstand the anticipated velocities within the rock chute and still choke off large voids within the rock layer. Moreover the rock must be properly proportioned so individual pieces will lock together and act as a single massive structure. Care must be taken when observing both the quality and gradation of rock in order to construct a durable rock chute.

Bedding is also required beneath the placed rip rap. Crushed limestone aggregate meeting AASHTO #57 gradation is typically used as bedding. Some sites may require two layers of bedding when sub-grade materials are excessively erodable. Bedding prevents failure due to erosion beneath the structure. The bedding reduces flow velocities at the soil surface, and provides a suitable surface on which rock can be placed.

Design – The basic design inputs for rock chutes are ***Design Capacity (cfs)***, ***Chute Slope***, ***Side Slope***, and ***Bottom Width***. Figure 3 shows different chute components. Once determined, these variables can be used to select a suitable design for the site requirements.

The design capacity will be determined by the watershed and design storm selected for the project. The design storm should be a minimum of the peak discharge from a 5 year, 24 hour duration storm. Depending on the project location, site variables, and other local requirements, the design storm may need to be greater. Determination of the design storm should be done in coordination with other local agencies.

Larger design capacities generally require flatter chute slopes, side slopes, and wider bottom widths in order to control flow velocities through the structure. Higher velocities through the chute result in higher shear stresses, and higher potential for failure.

Ideally, design velocities through the structure should be reduced as much as possible to minimize the potential for failure. As flow velocities increase, construction materials and construction techniques become critical for a successful structure.

The chute slope will determine the required length of the rock chute. Flatter chute slopes result in longer rock chutes with lower design velocities. However, flatter chute slopes also take up more space and require additional rock and bedding to construct, resulting in additional expense.

The bottom width and side slopes of the chute affect the design similarly to the chute slope. Wider bottoms and flatter side slopes result in slightly lower velocities, but higher construction costs.

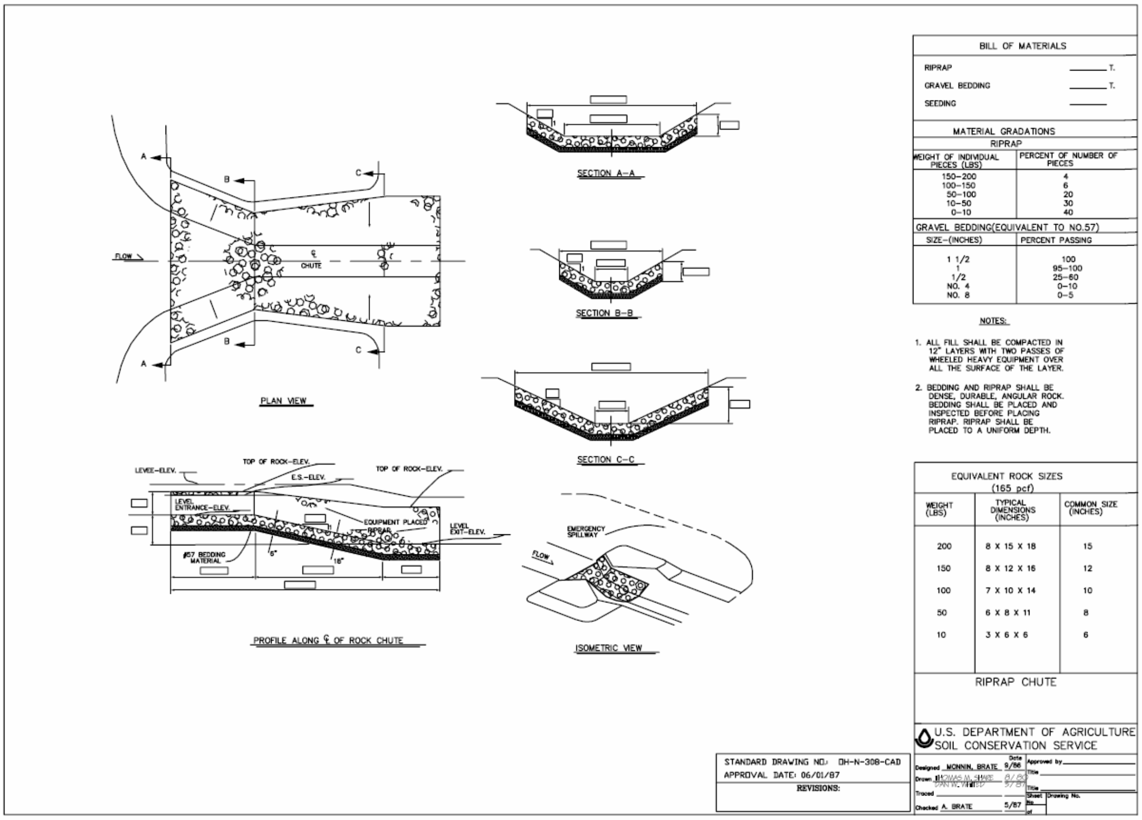

Figure 5 Rock Chute Illustration. Source Ohio NRCS Standard Drawing OH-N-308

Variables given in Exhibit OH6-1 for different rock chutes are V, d_e, and d_c. V is the anticipated flow velocity through the chute section in feet per second. The variable d_e is the required depth of flow at the chute entrance, while d_c is the flow depth through the chute. The d_e and d_c variables given in the tables have a freeboard of one foot built in. The actual depth of flow through the structure can be determined by subtracting one foot from the table values.

Construction – All trees, brush, stumps, and other undesirable materials must be removed from the proposed site of the construction. Biodegradable or unstable materials can result in erosion beneath the structure, and increase likelihood of structural failure of the rock chute.

Preparation of the sub-grade must be cut or filled to the design elevations. If fill is required, it must be cohesive earthen material and thoroughly compacted in place, or bedding material may be used.

When preparing the sub-grade, additional chute width must be allowed to make up for width that will be lost while placing bedding and rock rip rap.

Bedding is typically placed in a layer 6 inches deep, and compaction typically is not needed. Rip rap must be placed to full 18 inch depth in one operation. Rock should be placed to achieve a uniform compact surface. This allows the rock to lock together. Some rock may need to be hand placed to achieve a dense uniform surface.

Upon completion of construction, the rock surface should be 'aged' by working gravel or soil into the surface of the rock chute. Finally the chute should be seeded as quickly as possible once all construction is complete.

References:

Engineering Field Handbook; Chapter 6, Grade Stabilization Structures Natural Resources Conservation Service, United States Department of Agriculture

Ohio NRCS Design Standard 410; Grade Stabilization Structures

ROCK CHUTE DESIGN CHARTS

The rock chute design charts in this exhibit are designed for use with Standard, Drawing OH-N-308 for the design of small rock riprap lined chutes.

Design Criteria:

Rock chutes can be designed as full flow open structures or island type structures. Minimum capacity shall be determined from the tables in Ohio Engineering Standard, Grade Stabilization Structure – 410.

The design charts in this exhibit include one (1) foot of freeboard in the entrance and chute depth. This will provide adequate safety for full flow open structures that may experience flows greater than design.

Island type structures require an emergency spillway. The crest of the emergency spillway shall be set at an elevation equal to the chute entrance plus the entrance design flow depth. Entrance design flow depth equals the chart value d_e minus the freeboard (1-foot).

The structure must be designed to fit the site. Other important factors to consider in selecting the shape and elevations are: waterway depth and width at entrance, low bank elevation, topography, projection into the field, and economics.

Chute slopes shall be 4:1, 5:1, 6:1, or 8:1.

Chute side slopes shall be 2:1, 3:1, or 4:1.

The entrance apron shall have a minimum length of 10 feet and be flared out to twice the design bottom width at the upstream edge.

The exit apron shall be a minimum length of 2 times the structure overfall (F).

The rock riprap shall be placed at a minimum depth of 18 inches.

Rock riprap must have a well-graded size distribution. The design charts are based on a d_{50} of the riprap equal to 80 pounds. Riprap with rocks of uniform size or with a skip graded mixture shall be avoided.

Table 1 provides the gradation required.

RIPRAP GRADATION	
Weights of Individual Pieces	% Number of Pieces
150 – 200 lbs.	4
100 – 150 lbs.	6
50 – 100 lbs.	20
10 – 50 lbs.	30
0 – 10 lbs.	40

Table 1

The bedding material shall be placed at a minimum depth of 6 inches.

Bedding gradation shall be small enough to prevent erosion of the underlying soil and it must be large enough to prevent movement through the riprap. In some cases it may be necessary to use a two layer bedding with the smaller sized bedding placed on the foundation material and the larger sized bedding directly below the riprap.

Bedding shall meet the gradation requirements of Table 2.

GRAVEL BEDDING (equivalent to ODDT No. 57)	
Size – Inches	% Passing
1 ½	100
1	95 – 100
½	25 – 60
No. 4	0 – 10
No. 8	0 - 5

Table 2

Structures with a chute design capacity exceeding 100 CFS must be designed on an individual basis. Consult the area engineer for assistance.

Chart Definitions:

Q = Design flow capacity of structure in cubic feet per second (CFS).
V = Velocity in chute in feet per second (FPS).
De = Depth of flow plus 1 foot freeboard at the entrance in feet.
Dc = Depth of flow plus 1 feet freeboard in the chute in feet.

Any combination of chute slopes, side slopes, and bottom widths for which values of V, d_e, and d_c are given in the charts may be used. The entrance and exit aprons must be proportioned to fit the individual site.

Example: Peak discharge = 50 CFS

Acceptable Solutions:	Chute Slope	Side Slope	Bottom Width
	4:1	4:1	6
	5:1	3:1	5,6,8
	5:1	4:1	3,4,5,6,8
	6:1	2:1	8
	6:1	3:1	4,5,6,8
	6:1	4:1	3,4,5,6,8
	8:1	2:1	3,4,5,6,8
	8:1	3:1	3,4,5,6,8
	8:1	4:1	3,4,5,6,8

Construction Note:

The success of a rock riprap chute can be greatly increased if several construction techniques are followed. First the proper gradation of good durable rock riprap must be used.

Second, the riprap must be placed in such a manner to obtain a solid, compact layer. This may require some hand placing and tamping with the construction equipment.

Third, the rock layer needs to reach an "aged condition" as soon as possible. This can be obtained by spreading gravel or soil over the riprap surface to fill the voids. Seeding the entire riprap surface with grass will also help.

ROCK CHUTE DESIGN CHART
Chute Slope = 4:1 (25.0%)
n = 0.04

Q		Side Slope = 2:1						Side Slope 3:1						Side Slope 4:1					
		Bottom Width – Ft.						Bottom Width – Ft.						Bottom Width – Ft.					
		3	4	5	6	8	10	3	4	5	6	8	10	3	4	5	6	8	10
10	V	7.7	7.5	-	-	-	-	7.6	7.4	-	-	-	-	7.3	7.0	-	-	-	-
	d_e	1.6	1.5	-	-	-	-	1.6	1.5	-	-	-	-	1.5	1.5	-	-	-	-
	d_c	1.4	1.3	-	-	-	-	1.3	1.3	-	-	-	-	1.3	1.3	-	-	-	-
15	V	9.0	8.6	8.0	-	-	-	8.6	8.2	7.6	-	-	-	8.8	7.9	7.5	-	-	-
	d_e	1.8	1.7	1.6	-	-	-	1.7	1.6	1.6	-	-	-	1.7	1.6	1.6	-	-	-
	d_c	1.4	1.4	1.3	-	-	-	1.4	1.4	1.3	-	-	-	1.4	1.4	1.3	-	-	-
20	V	10.0	9.3	8.9	-	-	-	9.1	9.1	8.6	-	-	-	8.7	8.6	8.3	-	-	-
	d_e	1.9	1.8	1.7	-	-	-	1.8	1.8	1.7	-	-	-	1.8	1.7	1.7	-	-	-
	d_c	1.5	1.4	1.4	-	-	-	1.5	1.4	1.4	-	-	-	1.5	1.4	1.4	-	-	-
25	V	-	10.0	9.4	9.2	-	-	10.0	9.6	9.2	8.9	-	-	9.2	9.0	8.7	8.7	-	-
	d_e	-	1.9	1.8	1.8	-	-	1.9	1.9	1.8	1.7	-	-	1.9	1.8	1.7	1.7	-	-
	d_c	-	1.5	1.5	1.4	-	-	1.5	1.5	1.4	1.4	-	-	1.5	1.5	1.4	1.4	-	-
30	V	-	-	10.0	9.4	-	-	-	10.1	9.7	9.6	-	-	10.0	9.5	9.3	9.3	-	-
	d_e	-	-	1.9	1.8	-	-	-	1.9	1.9	1.8	-	-	2.0	1.9	1.8	1.8	-	-
	d_c	-	-	1.5	1.5	-	-	-	1.5	1.5	1.4	-	-	1.6	1.5	1.5	1.4	-	-

V = Velocity, d_e = Entrance Depth, d_c = Critical Depth

ROCK CHUTE DESIGN CHART
Chute Slope = 4:1 (25.0%)
n = 0.04

Q		Side Slope = 2:1						Side Slope 3:1						Side Slope 4:1					
		Bottom Width – Ft.						Bottom Width – Ft.						Bottom Width – Ft.					
		3	4	5	6	8	10	3	4	5	6	8	10	3	4	5	6	8	10
35	V							-	-	10.3	10.0	-	-	10.3	10.3	9.8	9.7	-	-
	d_e							-	-	1.9	1.9	-	-	2.0	2.0	1.9	1.8	-	-
	d_c							-	-	1.9	1.9	-	-	1.6	1.6	1.5	1.5	-	-
40	V							-	-	10.4	10.4	-	-	10.7	10.4	10.1	10.0	-	-
	d_e							-	-	-	1.9	-	-	2.1	2.0	2.0	1.9	-	-
	d_c							-	-	-	1.5	-	-	1.7	1.6	1.6	1.5	-	-
45	V														-	10.6	10.5	-	-
	d_e														-	2.0	2.0	-	-
	d_c														-	1.6	1.5	-	-
50	V														-	-	10.6	-	-
	d_e														-	-	2.0	-	-
	d_c														-	-	1.6	-	-
60	V														-	-	-	10.9	-
	d_e														-	-	-	2.0	-
	d_c														-	-	-	1.5	-

V = Velocity, d_e = Entrance Depth, d_c = Critical Depth

ROCK CHUTE DESIGN CHART
Chute Slope = 5:1 (20.0%)
n = 0.04

Q		Side Slope = 2:1						Side Slope 3:1						Side Slope 4:1					
		Bottom Width – Ft.						Bottom Width – Ft.						Bottom Width – Ft.					
		3	4	5	6	8	10	3	4	5	6	8	10	3	4	5	6	8	10
10	V	7.5	7.2	-	-	-	-	7.2	6.8	-	-	-	-	6.7	6.4	-	-	-	-
	d_e	1.6	1.5	-	-	-	-	1.6	1.5	-	-	-	-	1.5	1.5	-	-	-	-
	d_c	1.4	1.3	-	-	-	-	1.4	1.3	-	-	-	-	1.3	1.3	-	-	-	-
15	V	8.3	7.8	7.3	-	-	-	7.8	7.4	7.1	-	-	-	7.4	7.2	6.7	-	-	-
	d_e	1.8	1.7	1.6	-	-	-	1.7	1.6	1.6	-	-	-	1.7	1.6	1.6	-	-	-
	d_c	1.5	1.4	1.4	-	-	-	1.5	1.4	1.4	-	-	-	1.4	1.4	1.4	-	-	-
20	V	9.1	8.6	8.2	-	-	-	8.7	8.3	8.1	-	-	-	8.0	7.9	7.6	-	-	-
	d_e	1.9	1.8	1.7	-	-	-	1.8	1.8	1.7	-	-	-	1.8	1.7	1.7	-	-	-
	d_c	1.5	1.5	1.4	-	-	-	1.5	1.5	1.4	-	-	-	1.5	1.4	1.4	-	-	-
25	V	9.7	9.3	8.7	8.5	-	-	8.9	8.9	8.3	8.2	-	-	8.4	8.3	8.0	7.9	-	-
	d_e	2.0	1.9	1.8	1.7	-	-	1.9	1.9	1.8	1.7	-	-	1.9	1.8	1.7	1.7	-	-
	d_c	1.6	1.5	1.5	1.4	-	-	1.6	1.5	1.5	1.4	-	-	1.6	1.5	1.5	1.4	-	-
30	V	10.3	10.0	9.3	9.2	-	-	9.5	9.4	9.2	8.8	-	-	9.0	8.8	8.6	8.5	-	-
	d_e	2.1	2.0	1.9	1.8	-	-	2.0	1.9	1.9	1.8	-	-	2.0	1.9	1.8	1.8	-	-
	d_c	1.7	1.6	1.5	1.5	-	-	1.6	1.6	1.5	1.5	-	-	1.6	1.6	1.5	1.5	-	-

V = Velocity, d_e = Entrance Depth, d_c = Critical Depth

ROCK CHUTE DESIGN CHART
Chute Slope = 5:1 (20.0%)
n = 0.04

Q		Side Slope = 2:1						Side Slope 3:1						Side Slope 4:1					
		Bottom Width – Ft.						Bottom Width – Ft.						Bottom Width – Ft.					
		3	4	5	6	8	10	3	4	5	6	8	10	3	4	5	6	8	10
35	V	-	10.4	9.8	9.6	-	-	10.4	9.8	9.6	9.3	-	-	9.4	9.3	9.1	9.0	-	-
	d_e	-	2.1	2.0	1.9	-	-	2.2	2.0	1.9	1.9	-	-	2.1	2.0	1.9	1.8	-	-
	d_c	-	1.6	1.6	1.5	-	-	1.7	1.6	1.6	1.5	-	-	1.7	1.6	1.5	1.5	-	-
40	V	-	-	10.3	10.0	-	-	-	9.9	9.7	9.7	-	-	9.9	9.7	9.4	9.4	-	-
	d_e	-	-	2.1	2.0	-	-	-	2.1	2.0	1.9	-	-	2.1	2.0	2.0	1.9	-	-
	d_c	-	-	1.6	1.6	-	-	-	1.7	1.6	1.5	-	-	1.7	1.6	1.6	1.5	-	-
45	V	-	-	-	10.4	9.8	-	-	10.3	10.0	10.0	-	-	10.2	10.1	9.7	9.5	-	-
	d_e	-	-	-	2.1	1.9	-	-	2.2	2.1	2.0	-	-	2.2	2.1	2.0	2.0	-	-
	d_c	-	-	-	1.6	1.5	-	-	1.7	1.7	1.6	-	-	1.7	1.7	1.6	1.6	-	-
50	V							-	-	10.4	10.3	9.8	-	10.5	10.3	9.9	9.7	9.5	-
	d_e							-	-	2.2	2.1	1.9	-	2.3	2.2	2.1	2.0	1.9	-
	d_c							-	-	1.7	1.6	1.5	-	1.8	1.7	1.7	1.6	1.5	-
60	V							-	-	-	-	10.4	-	-	10.8	10.6	10.4	10.0	-
	d_e							-	-	-	-	2.0	-	-	2.3	2.2	2.1	2.0	-
	d_c							-	-	-	-	1.6	-	-	1.8	1.7	1.7	1.6	-

V = Velocity, d_e = Entrance Depth, d_c = Critical Depth

ROCK CHUTE DESIGN CHART
Chute Slope = -6:1 (16.7%)
n = 0.0-4

Q		Side Slope = 2:1						Side Slope 3:1						Side Slope 4:1					
		Bottom Width – Ft.						Bottom Width – Ft.						Bottom Width – Ft.					
		3	4	5	6	8	10	3	4	5	6	8	10	3	4	5	6	8	10
10	V	7.0	6.7	-	-	-	-	6.6	6.5	-	-	-	-	6.5	6.2	-	-	-	-
	d_e	1.6	1.5	-	-	-	-	1.6	1.5	-	-	-	-	1.5	1.5	-	-	-	-
	d_c	1.4	1.3	-	-	-	-	1.4	1.3	-	-	-	-	1.4	1.3	-	-	-	-
15	V	7.7	7.4	7.1	-	-	-	7.4	7.2	6.9	-	-	-	7.2	6.9	6.7	-	-	-
	d_e	1.8	1.7	1.6	-	-	-	1.7	1.6	1.6	-	-	-	1.7	1.6	1.6	-	-	-
	d_c	1.5	1.4	1.4	-	-	-	1.5	1.4	1.4	-	-	-	1.4	1.4	1.4	-	-	-
20	V	8.7	8.0	7.5	7.4	-	-	8.0	7.9	7.6	7.2	-	-	7.6	7.4	7.3	-	-	-
	d_e	1.8	1.8	1.7	1.6	-	-	1.8	1.8	1.7	1.6	-	-	1.7	1.7	1.7	-	-	-
	d_c	1.6	1.5	1.5	1.4	-	-	1.5	1.5	1.4	1.4	-	-	1.5	1.5	1.4	-	-	-
25	V	9.5	8.9	8.3	8.1	-	-	8.7	8.4	8.1	7.7	-	-	8.1	7.9	7.7	7.5	-	-
	d_e	2.0	1.9	1.8	1.7	-	-	1.9	1.9	1.8	1.7	-	-	1.9	1.8	1.7	1.7	-	-
	d_c	1.6	1.6	1.5	1.5	-	-	1.6	1.5	1.5	1.4	-	-	1.6	1.5	1.5	1.4	-	-
30	V	9.7	9.4	8.8	8.6	-	-	8.8	8.8	8.6	8.4	-	-	8.6	8.4	8.1	8.1	-	-
	d_e	2.1	2.0	1.9	1.8	-	-	2.0	1.9	1.9	1.8	-	-	2.0	1.9	1.8	1.8	-	-
	d_c	1.7	1.6	1.6	1.5	-	-	1.7	1.6	1.5	1.5	-	-	1.6	1.6	1.5	1.5	-	-

V = Velocity, d_e = Entrance Depth, d_c = Critical Depth

ROCK CHUTE DESIGN CHART
Chute Slope = 6:1 (16.7%)
n = 0.04

Q		Side Slope = 2:1						Side Slope 3:1						Side Slope 4:1					
		Bottom Width – Ft.						Bottom Width – Ft.						Bottom Width – Ft.					
		3	4	5	6	8	10	3	4	5	6	8	10	3	4	5	6	8	10
35	V	-	9.8	9.2	9.0	-	-	9.2	9.0	8.9	8.7	-	-	9.0	8.7	8.4	8.3	-	-
	d_e	-	2.1	2.0	1.9	-	-	2.1	2.0	1.9	1.9	-	-	2.1	2.0	1.9	1.8	-	-
	d_c	-	1.7	1.6	1.6	-	-	1.7	1.7	1.6	1.5	-	-	1.7	1.6	1.6	1.5	-	-
40	V	-	-	9.8	9.4	-	-	9.8	9.4	9.4	9.1	-	-	9.3	9.1	8.8	8.7	-	-
	d_e	-	-	2.1	2.0	-	-	2.2	2.1	2.0	1.9	-	-	2.1	2.0	2.0	1.9	-	-
	d_c	-	-	1.7	1.6	-	-	1.8	1.7	1.6	1.6	-	-	1.7	1.7	1.6	1.6	-	-
45	V	-	-	-	9.8	9.4	-	10.2	9.8	9.6	9.4	9.1	-	9.6	9.5	9.1	8.9	8.6	-
	d_e	-	-	-	2.1	1.9	-	2.3	2.2	2.1	2.0	1.9	-	2.2	2.1	2.0	2.0	1.9	-
	d_c	-	-	-	1.6	1.5	-	1.8	1.7	1.7	1.6	1.5	-	1.8	1.7	1.7	1.6	1.5	-
50	V	-	-	-	-	9.6	-	-	10.3	9.9	9.7	9.2	-	9.9	9.7	9.5	9.3	8.9	-
	d_e	-	-	-	-	2.0	-	-	2.2	2.2	2.1	1.9	-	2.3	2.2	2.1	2.0	1.9	-
	d_c	-	-	-	-	1.6	-	-	1.8	1.7	1.7	1.6	-	1.8	1.7	1.7	1.6	1.6	-
60	V							-	-	-	10.2	9.8	-	10.3	10.2	9.8	9.7	9.4	-
	d_e							-	-	-	2.2	2.0	-	2.4	2.3	2.2	2.1	2.0	-
	d_c							-	-	-	1.7	1.6	-	1.9	1.8	1.8	1.7	1.6	-

V = Velocity, d_e = Entrance Depth, d_c = Critical Depth

ROCK CHUTE DESIGN CHART
Chute Slope = 6:1 (16.7%)
n = 0.04

Q		Side Slope = 2:1						Side Slope 3:1						Side Slope 4:1					
		Bottom Width – Ft.						Bottom Width – Ft.						Bottom Width – Ft.					
		3	4	5	6	8	10	3	4	5	6	8	10	3	4	5	6	8	10
70	V							-	-	-	-	10.3	-	10.8	10.8	10.5	10.4	10.0	-
	d_e							-	-	-	-	2.1	-	2.5	2.4	2.3	2.2	2.1	-
	d_c							-	-	-	-	1.7	-	2.0	1.9	1.8	1.8	1.7	-
80	V							-	-	-	-	-	10.3	11.1	11.0	10.7	10.5	10.2	-
	d_e							-	-	-	-	-	2.1	2.6	2.5	2.4	2.3	2.2	-
	d_c							-	-	-	-	-	1.7	2.0	1.9	1.9	1.8	1.7	-
90	V													11.6	11.4	10.9	10.7	10.7	10.4
	d_e													2.7	2.6	2.5	2.4	2.3	2.2
	d_c													2.1	2.0	1.9	1.9	1.8	1.7
100	V													11.9	11.8	11.4	-	-	-
	d_e													2.7	2.6	2.6	-	-	-
	d_c													2.1	2.0	2.0	-	-	-
110	V													12.1	12.1	11.7	-	-	-
	d_e													2.8	2.7	2.6	-	-	-
	d_c													2.2	2.1	2.0	-	-	-

V = Velocity, d_e = Entrance Depth, d_c = Critical Depth

ROCK CHUTE DESIGN CHART
Chute Slope = 8:1 (12.5%)
n = 0.04

Q		Side Slope = 2:1						Side Slope 3:1						Side Slope 4:1					
		Bottom Width – Ft.						Bottom Width – Ft.						Bottom Width – Ft.					
		3	4	5	6	8	10	3	4	5	6	8	10	3	4	5	6	8	10
10	V	6.2	6.1	-	-	-	-	6.0	5.9	-	-	-	-	5.8	5.5	-	-	-	-
	d_e	1.6	1.5	-	-	-	-	1.6	1.5	-	-	-	-	1.5	1.5	-	-	-	-
	d_c	1.4	1.4	-	-	-	-	1.4	1.3	-	-	-	-	1.4	1.3	-	-	-	-
15	V	7.1	6.8	6.5	-	-	-	6.7	6.6	6.2	-	-	-	6.4	6.3	6.1	-	-	-
	d_e	1.8	1.7	1.6	-	-	-	1.7	1.6	1.6	-	-	-	1.7	1.6	1.6	-	-	-
	d_c	1.5	1.5	1.4	-	-	-	1.5	1.4	1.4	-	-	-	1.5	1.4	1.4	-	-	-
20	V	7.9	7.5	7.0	6.8	-	-	7.4	7.1	7.0	6.6	-	-	7.0	6.7	6.5	6.4	-	-
	d_e	1.9	1.8	1.7	1.7	-	-	1.8	1.8	1.7	1.6	-	-	1.8	1.7	1.7	1.6	-	-
	d_c	1.6	1.5	1.5	1.4	-	-	1.6	1.5	1.5	1.4	-	-	1.6	1.5	1.5	1.4	-	-
25	V	8.1	8.0	7.9	7.3	-	-	7.9	7.5	7.3	7.0	-	-	7.4	7.3	7.0	6.9	-	-
	d_e	2.0	1.9	1.8	1.7	-	-	1.9	1.9	1.8	1.7	-	-	1.9	1.8	1.7	1.7	-	-
	d_c	1.7	1.6	1.5	1.5	-	-	1.6	1.6	1.5	1.5	-	-	1.6	1.6	1.5	1.5	-	-
30	V	8.7	8.4	8.1	7.8	-	-	7.9	7.9	7.5	7.5	-	-	7.7	7.6	7.4	7.1	-	-
	d_e	2.1	2.0	1.9	1.8	-	-	2.0	1.9	1.9	1.8	-	-	2.0	1.9	1.8	1.8	-	-
	d_c	1.8	1.7	1.6	1.5	-	-	1.7	1.6	1.6	1.5	-	-	1.7	1.6	1.6	1.5	-	-

V = Velocity, d_e = Entrance Depth, d_c = Critical Depth

ROCK CHUTE DESIGN CHART
Chute Slope = 8:1 (12.5%)
n = 0.04

Q		Side Slope = 2:1						Side Slope 3:1						Side Slope 4:1					
		Bottom Width – Ft.						Bottom Width – Ft.						Bottom Width – Ft.					
		3	4	5	6	8	10	3	4	5	6	8	10	3	4	5	6	8	10
35	V	9.2	8.8	8.5	8.3	-	-	8.4	8.2	8.2	8.0	-	-	8.1	8.0	7.7	7.6	-	-
	d_e	2.2	2.1	2.0	1.9	-	-	2.1	2.0	1.9	1.9	-	-	2.1	2.0	1.9	1.8	-	-
	d_c	1.8	1.7	1.7	1.6	-	-	1.8	1.7	1.6	1.6	-	-	1.7	1.7	1.6	1.6	-	-
40	V	9.4	9.2	8.9	8.6	8.2	-	8.9	8.5	8.4	8.2	7.9	-	8.4	8.2	8.1	7.7	7.5	-
	d_e	2.3	2.2	2.1	2.0	2.0	-	2.2	2.1	2.0	1.9	1.9	-	2.1	2.0	2.0	1.9	1.9	-
	d_c	1.9	1.8	1.7	1.6	1.5	-	1.8	1.8	1.7	1.6	1.5	-	1.8	1.7	1.7	1.6	1.5	-
45	V	9.8	9.6	9.2	9.0	8.5	-	9.2	8.9	8.5	8.5	8.1	-	8.6	8.6	8.4	8.1	7.8	-
	d_e	2.4	2.3	2.2	2.1	1.9	-	2.3	2.2	2.1	2.0	1.9	-	2.2	2.1	2.0	2.0	1.9	-
	d_c	1.9	1.8	1.8	1.7	1.6	-	1.9	1.8	1.7	1.7	1.6	-	1.8	1.8	1.7	1.7	1.6	-
50	V	10.0	9.7	9.5	8.9	8.7	-	9.4	9.3	9.0	8.8	8.3	-	8.9	8.7	8.6	8.4	8.0	-
	d_e	2.5	2.3	2.2	2.1	2.0	-	2.3	2.2	2.2	2.1	1.9	-	2.3	2.2	2.1	2.0	1.9	-
	d_c	2.0	1.9	1.8	1.8	1.6	-	1.9	1.8	1.8	1.7	1.6	-	1.9	1.8	1.7	1.7	1.6	-
55	V	10.6	10.4	10.1	9.7	9.3	-	9.9	9.6	9.5	9.4	8.8	-	9.3	9.2	9.1	8.9	8.5	-
	d_e	2.6	2.5	2.4	2.3	2.1	-	2.5	2.4	2.3	2.2	2.0	-	2.4	2.3	2.2	2.1	2.0	-
	d_c	2.1	2.0	1.9	1.8	1.7	-	2.0	1.9	1.8	1.8	1.7	-	2.0	1.9	1.8	1.8	1.7	-

V = Velocity, d_e = Entrance Depth, d_c = Critical Depth

ROCK CHUTE DESIGN CHART
Chute Slope = 8:1 (12.5%)
n = 0.04

Q		Side Slope = 2:1						Side Slope 3:1						Side Slope 4:1					
		Bottom Width – Ft.						Bottom Width – Ft.						Bottom Width – Ft.					
		3	4	5	6	8	10	3	4	5	6	8	10	3	4	5	6	8	10
70	V	10.9	10.8	-	-	-	-	10.2	10.1	9.8	9.7	9.3	8.9	9.7	9.6	9.5	9.2	8.9	-
	d_e	2.8	2.6	-	-	-	-	2.6	2.5	2.4	2.3	2.1	2.0	2.5	2.4	2.3	2.2	2.1	-
	d_c	2.2	2.1	-	-	-	-	2.1	2.0	1.9	1.8	1.7	1.7	2.0	2.0	1.9	1.8	1.7	-
80	V	11.4	-	-	-	-	-	10.5	10.5	10.1	10.1	9.8	9.3	10.1	9.9	9.7	9.6	9.4	9.1
	d_e	2.9	-	-	-	-	-	2.7	2.6	2.5	2.4	2.1	2.1	2.6	2.5	2.4	2.3	2.1	2.1
	d_c	2.3	-	-	-	-	-	2.2	2.1	2.0	1.9	1.8	1.7	2.1	2.0	1.9	1.9	1.8	1.7
90	V							10.9	10.8	10.7	10.6	10.0	9.6	10.3	10.3	10.1	10.0	9.7	9.4
	d_e							2.8	2.7	2.6	2.5	2.3	2.2	2.7	2.6	2.5	2.4	2.3	2.2
	d_c							2.2	2.1	2.0	2.0	1.9	1.8	2.2	2.1	2.0	1.9	1.8	1.7
100	V							11.3	11.2	11.0	10.8	10.4	9.9	10.7	10.5	10.4	10.3	10.0	9.8
	d_e							2.9	2.8	2.7	2.6	2.4	2.3	2.8	2.6	2.5	2.4	2.3	2.2
	d_c							2.3	2.2	2.1	2.0	1.9	1.8	2.2	2.1	2.1	2.0	1.9	1.8

V = Velocity, d_e = Entrance Depth, d_c = Critical Depth

6.6.3 Block Chutes

Description:

A steep channel lined with precast concrete block, constructed to convey a design flow at a safe velocity from one elevation to a lower elevation

Purpose:

To maintain a constructed grade change, and minimize or eliminate erosion to the structure and surrounding area

Where Applicable:

Applies over a wide range of design flows and overfalls

Advantages:

Block chutes can withstand higher flow velocities than rock chute structures

Higher design capacities, and reduced structure foot print when compared to rock chutes

Limitations:

Block chutes require hand placement of all block on the chute

Limited construction experience may cause excessive time required for construction

Design & Construction Considerations:

Selection – Block chutes are have been used less than rock chutes in many applications due to cost and additional labor requirements. However, in areas where space is limited, or design the design capacity is over 90 to 100 cfs, block chutes are often an economical alternative to rock chutes.

In order to maintain acceptable flow velocities within a rock chute, chute slopes must be decreased as design flows increase. This results in a longer structure, and requires more rock. Block chutes can withstand higher velocities, and can be designed with a chute slope of approximately 3:1, resulting in a smaller structure compared to rock chutes.

When considering a block chute, the use of quality seconds from the concrete block manufacturer is acceptable to reduce project costs. Hand labor will be required to set the blocks on the slope.

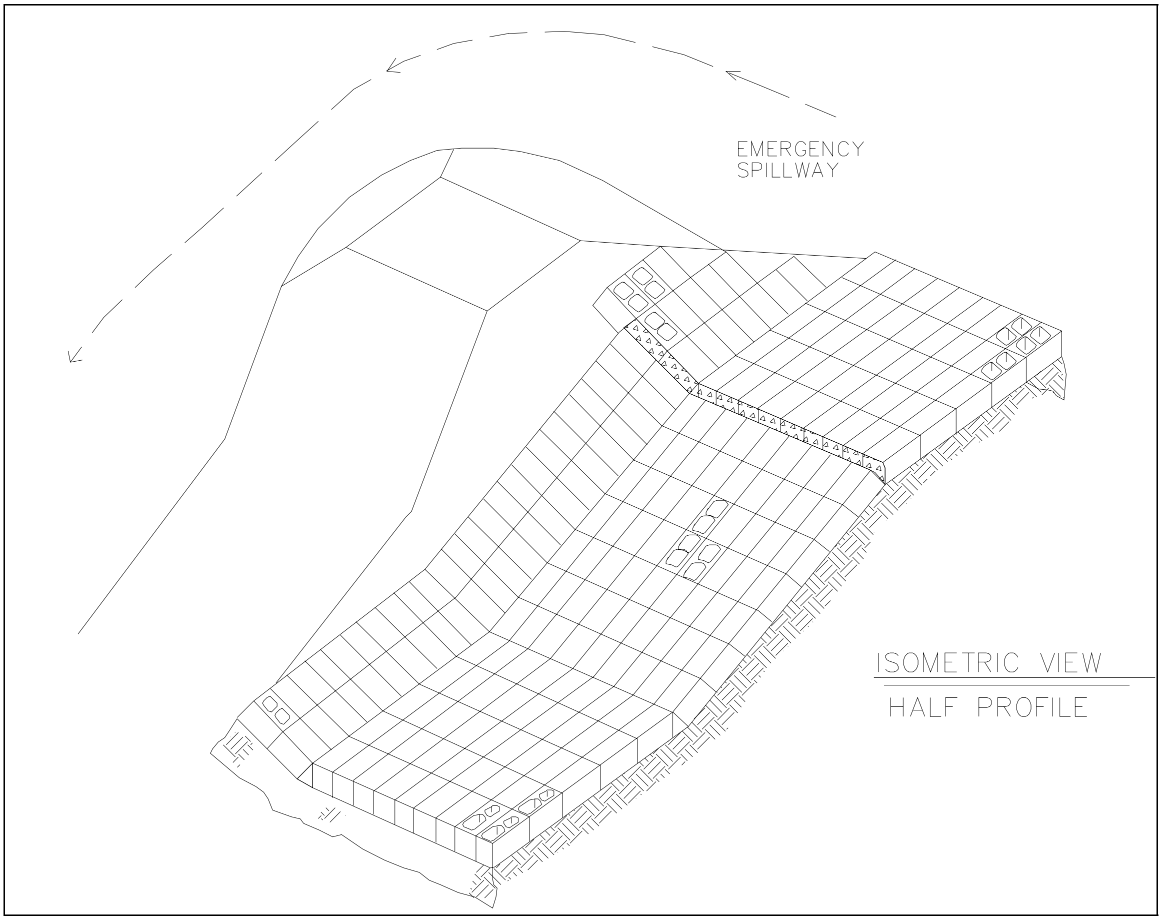

Figure 6 Block Chute Isometric. Source Ohio NRCS CADD Resources

Design - NRCS's Engineering Field Handbook Exhibit OH6-5 reviews detailed design parameters for block chutes. This design information can be found on pages 67 through 69 of Ohio's EFH supplements. This document can be found online at:

ftp://ftp-fc.sc.egov.usda.gov/OH/pub/Admin/NEH/Adobe/Combined_EFH_Supplements.pdf

The design information has also been attached to this document. This design document can be used with NRCS Ohio Standard Drawing No. N-307.

Once the design capacity has been determined, the NRCS design reference can be used to develop a full design, and engineering plans.

Construction – Construction requirements and guidelines are set forth in the NRCS design reference attached. Careful block placement and immediate aging of the structure will improve structure integrity and longevity.

Aging of the structure is accomplished by spreading spoil over the surface of the block chute, filling the voids within the concrete block. After spreading spoil, the surface should be seeded to encourage establishment of grasses or other desired species. Broadcasting generous amounts of seed with a hand seeder or similar method is recommended. Reseeding may be necessary in order to establish a quality stand.

In order to protect against flows greater than the design capacity, the structure must be protected with levees as shown in Figure 4 below. The levees prevent erosion at the block structure by forcing higher flows around. If erosion or damage does occur, the repairs will be less costly than rebuilding the structure itself.

References:

Engineering Field Handbook; Chapter 6, Grade Stabilization Structures Natural Resources Conservation Service, United States Department of Agriculture

Ohio NRCS Design Standard 410; Grade Stabilization Structures

CONCRETE BLOCK CHUTE

Description

The concrete block chute is a structure with its flow area lined with pre-cast concrete building blocks. The earth sub-grade is shaped to the lines and grade of the structure, covered with 3 to 6 inches of sand or gravel, and filter fabric is placed over the sand or gravel before placing the concrete blocks. The openings in the blocks are filled with loose, friable soil and seeded to grass.

Functional Use

The concrete block chute may be used to control over-falls or abrupt changes in grade of a natural or constructed waterway; prevent erosion at the ends of waterways; lower water over drainage ditch-banks, and conduct water from an adjacent flat area to the bottom of a ditch.

Design

Concrete block chutes shall be designed in accordance with NRCS Ohio Engineering Standard – Grade Stabilization Structure (410). Structures can be either full flow or island type and shall have the minimum design capacity shown in this standard.

The capacity of the structure Q in cfs, is determined by the equation:

$Q = CLH_p^{1.832}$
C = coefficient = 1.455 (according to a model study by Evans, Illinois, SCS, 1987)
L = Weir length or bottom width of chute (feet).
H_p = Maximum water depth above the chute entrance apron (feet).

The model study by Evans (1986) concluded that tailwater depth equal to the maximum water surface above the chute entrance must be provided to ensure that the hydraulic jump occurs on the structure. The level outlet apron may be submerged to provide needed tailwater depth.

Ohio Standard Drawing No. N 307 has been developed for use with this structure. Table 1 of this exhibit, CAPACITY OF BLOCK CHUTES, shall be used to size the structure. The enclosed computation sheet, Table 2, can also be used to compute several of the quantities.

Chute widths will normally be less than the upstream waterway width. The last 50 feet of the waterway may be used for a transition section to change the bottom width and/or side slopes of the waterway to match the chute inlet dimensions. Dikes may be required to ensure that the design flow is directed to the structure. The height of the dike and/or sides of the inlet section of the chute should provide 1.0 feet of freeboard above the depth of flow in the waterway.

Construction

Particular attention must be paid to the proper installation of the structure. Care must be taken to use the right materials and follow the placement steps as explained in the enclosed construction specification.
The filter fabric specified must have an effective opening size of 0.25 mm (250 microns) or smaller. Several methods are presently in use by manufacturers for measuring the effective opening size and it is important that the designer identify the type of procedure used by the manufacturer. The most common methods for expressing the equivalent opening size are listed below:

1. Sizes listed in units of microns or millimeters.
2. Equivalent Opening Size (EOS) expressed in U.S. Standard Sieve Numbers.
3. Apparent Opening Size (AOS) expressed in U.S. Standard Sieve Numbers.

4. 0_{95} expressed in microns or millimeters.

The effective opening size of 0.25 mm equals U.S. Standard Sieve Number 60. Since the sieve numbers represent the number of openings per inch of length, the sieve numbers increase as the effective opening sizes get smaller.

CAPACITY OF BLOCK CHUTES – CFS

Hp (Feet)				Bottom Width (Feet)*
1.0	**1.5**	**3.0**	**2.5**	
4	8	13	20	2.6 (4)
8	15	27	40	5.2 (8)
12	23	40	60	7.8 (12)
15	31	54	81	10.3 (16)
19	39	67	101	12.9 (20)
23	47	81	121	15.5 (24)
27	54	94	141	18.1 (28)
31	62	107	161	20.7 (32)
35	70	121	181	23.3 (36)
39	77	134	201	25.9 (40)

*Number in parentheses is the chute bottom width in number of blocks.

TABLE 1

BLOCK CHUTE QUANTITIES COMPUTATION SHEET

Concrete Blocks

f (ft)	x (ft)	z (ft)	Chute Length # Blocks	x Chute Width # Blocks 1/	= # Blocks In Floor	+ # Blocks In Both Sides	= Total # Blocks
3	8.9	9.2	17	x	=	+ 126	=
4	12.8	13.2	20	x	=	+ 150	=
5	15.2	15.8	22	x	=	+ 166	=
6	19.0	19.7	25	x	=	+ 182	=

(Choose One Row)

1/ # Blocks in Chute Width based on Table 1.

Filter Fabric

Total # Blocks	x 0.9	= A	Bottom Width (ft.)	+ 4	=	x 4	= B	Total Filter Fabric (sq. ft.) A + B
	x 0.9	=		+ 4	=	x 4	=	

Plastic Material

Bottom Width (ft)	+ 4	=	x 3	= Plastic Material (sq. ft.)
	+ 4	=	x 3	=

Table 2

6.6.4 Timber Spillways

Description:

Straight or box inlet drop spillway constructed of treated lumber to lower runoff from field or higher elevations to culvert or channel flow lines.

Purpose:

To eliminate erosion at substantial grade changes.

To maintain stable grades upstream of structure to reduce gully erosion

Where Applicable:

Where substantial overfall must be maintained with very limited space

Advantages:

Reduced footprint required compared to chute type structures

Constructed of materials that are readily available and economical

Relatively inexpensive labor requirements compared to other structures

Limitations:

Longevity of the structure is less when compared to concrete structures

Allowable overfall reduced compared to concrete wall structures

Design & Construction Considerations:

Selection – Timber drop spillways are an economical structure with a range of flow capacities, and adaptable to a range of overfall. These structures are constructed of pressure treated lumber, and can be constructed with a modest amount of construction experience.

Timber structures are not as resilient as concrete structures, and their design life is less than that of more expensive reinforced concrete structures. However, timber structures can be built with most of the labor supplied by the landowner if the project situation allows it.

NRCS has developed a complete design reference for both box inlet and straight drop structures. The design reference is attached at the end of this document, and can also be found on pages 70 through 75 of Ohio's EFH supplements. This document can also be found online at:

ftp://ftp-fc.sc.egov.usda.gov/OH/pub/Admin/NEH/Adobe/Combined_EFH_Supplements.pdf

Exhibit OH 6-6 are to be used with Ohio NRCS's Standard Drawing OH-N-309 and OH-N-310. These drawings are available online at:

http://www.oh.nrcs.usda.gov/technical/engineering/cadd2_dwg_s_to_z.html

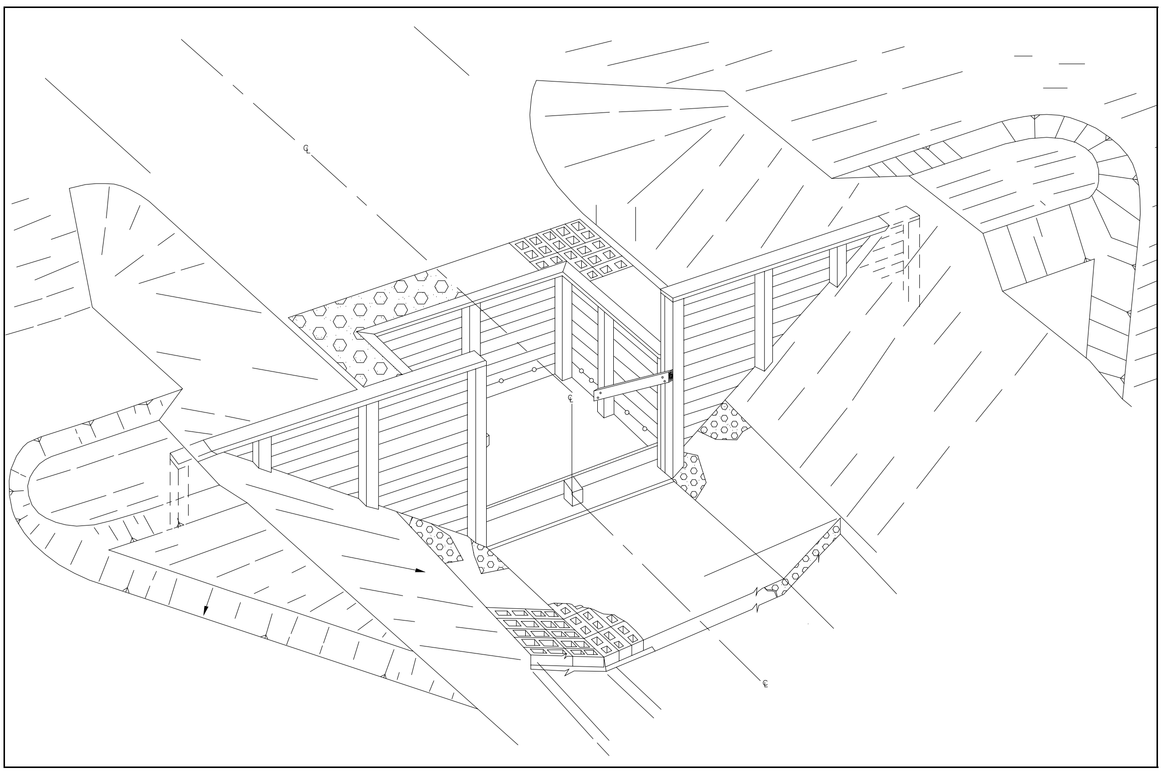

Figure 7. Timber Drop Box Illustration, Source: NRCS OH-N-309

Design – After determining the required design capacity the design reference can be used to develop a full plan and engineering plans.

Care must be taken to reinforce areas immediately above and below the structure. Flow velocities and energy dissipation are highly erosive immediately around the structure, and rock or other material is typically used to armor these areas.

Timber structures can also be used as a headwall or stable outlet for a subsurface drain. If a tile will be brought through the structure, care must be taken to maintain the integrity of the structure, and discourage erosion or pipe around the tile outlet.

Construction – Pressure treatments to preserve lumber has changed over the last several years. Contractors must make sure the fasteners that are being used are compatible with lumber and preservatives that will be used.

References:

Engineering Field Handbook; Chapter 6, Grade Stabilization Structures Natural Resources Conservation Service, United States Department of Agriculture

Ohio NRCS Design Standard 410; Grade Stabilization Structures

TIMBER SPILLWAYS

Design Charts

The timber spillway design charts in this exhibit are to be used with Standard Drawings OH-N-309 and OH-N-310. Both straight wall and dropbox structures are included.

DEFINITIONS:

Q	=	Design capacity of structure in cubic feet per second (cfs).
b	=	Dimension of box perpendicular to the headwall in feet (ft.) for dropbox structures.
w	=	Width of box in feet (ft.) for dropbox structures.
l	=	Weir length in feet (ft.); notch width for straight drop structures; sum of 2b+w for dropbox structures.
h	=	Design head for the structure; also the notch height in feet (ft.).
f	=	Overfall; distance from the weir to the box floor in feet (ft.).
BW	=	Bottom width of approach channel in feet (ft.).
X	=	Distance from the side of the box to the toe of the dike (ft.).

DESIGN CRITERIA

Straight Drop Spillways – Standard Drawing OH-N-309

Q	=	Range from 22 cfs to 62 cfs.
f	=	Overfall from 3.0 ft. to 4.0 ft.
L	=	Weir length is 8 ft.
h	=	Heads range from 1.0 ft. to 2.0 ft.

Selection of the head and overfall shall be based on the site topography, dimensions of the drainway entering the structure, economics and design criteria.

STRAIGHT DROP SILLWAY CAPACITY

Weir Length	Capacity cfs		
(L)	h=1.0	h=1.5	h=2.0
8	22	40	62

Dropbox Spillways – Standard Drawing OH-N-310

Q	=	Range from 41 cfs to 158 cfs.
f	=	Overfall from 3.0 ft. to 4.0 ft.
L	=	Weir length is either 15 ft. or 23 ft. with box dimensions of 3'6" x 8'0" or 7'6" x 8'0" respectively.
h	=	Heads range from 1.0 ft. to 2.0 ft.
BW	=	The approach channel bottom width shall be a minimum of 24 feet.

Selection of box dimensions, head and overfall shall be based on the site topography, dimensions of the drainway entering the structure, economics, and design criteria.

DROPBOX SPILLWAY CAPACITY

Box Depth (b)	Box Width (w)	Weir Length (L)	Minimum "X"	Capacity cfs h=1.0	h=1.5	h=2.0
3'6"	8'0"	15	2	41	78	122
7'6"	8'0"	23	4	53	100	158

Emergency Spillways

For island type structures an emergency spillway shall be constructed on one or both sides of the structure. The crest elevation of the emergency spillway shall be set 0.2 feet below the top of the headwall to ensure that emergency flow will develop when the structure spillway reaches design capacity.

The top of dike shall be set at a minimum of 1 foot above the flow depth in the emergency spillway or top of headwall, whichever is higher.

QUANTITIES

STRAIGHT DROP SPILLWAY STANDARD DRAWING OH-N-309

Overfall F = 3’

H (ft.)	Boards 2” x 6” T & G (lin. ft.)	Posts 6” x 6”				Boards 2” x 8” (8’ length)
		4’	6’	8’	10’	
1.0	512	1	4	8	---	3
1.5	536	1	---	8	4	3
2.0	560	1	---	8	4	3

Overfall F = 3.5’

H (ft.)	2” x 6” T & G (lin. ft.)	Posts 6” x 6”				2” x 8” (8’ length)
		4’	6’	8’	10’	
1.0	552	1	---	8	4	3
1.5	576	1	---	8	4	3
2.0	600	1	---	8	4	3

Overfall F = 4.0’

H (ft.)	2” x 6” T & G (lin. ft.)	Posts 6” x 6”				2” x 8” (8’ length)
		4’	6’	8’	10’	
1.0	592	1	---	8	4	3
1.5	616	1	---	8	4	3
2.0	640	1	---	8	4	3

Quantities Cont'd.

Drain Fill	Behind Structure – 2.4 cubic yards
Weir Protection	
Riprap Option Riprap – 1 cubic yard	
or	
Concrete Block Option	Blocks – 27 each Drain Fill – 0.3 cubic yard
Structure Floor	
Concrete Option	Concrete – 1.1 cubic yards Drain Fill – 1 cubic yard
or	
Concrete Block Option	Blocks – 72 each Drain Fill – 1 cubic yard
or	
Riprap Option Drain Fill – 4 cubic yards	
Outlet Channel	
Riprap Option Drain Fill – 12 cubic yards	
or	
Concrete Block Option	Blocks – 112 each Drain Fill – 1.2 cubic yards

QUANTITIES

DROPBOX SPILLWAY STANDARD DRAWING OH-N-310

Overfall F = 3'

B	W	H (ft)	2" x 6" T & G (lin. ft.)	Posts 6" x 6" 4'	6'	8'	10'	Boards 2" x 8" 8'	10'	12'	Boards 2" x 6" 6'	8'	10'
3'6"	8'0"	1.0	516	1	4	7	---	2	2	2	3	---	1
		1.5	540	1	---	7	4	1	1	2	3	---	1
		2.0	564	1	---	7	4	1	1	2	3	---	1
7'6"	8'0"	1.0	596	1	4	9	---	2	1	2	3	---	1
		1.5	620	1	---	9	4	2	1	2	3	---	1
		2.0	644	1	---	9	4	2	1	2	3	---	1

Overfall F = 3.5'

B	W	H (ft)	2" x 6" T & G (lin. ft.)	Posts 6" x 6" 4'	6'	8'	10'	Boards 2" x 8" 8'	10'	12'	Boards 2" x 6" 6'	8'	10'
3'6"	8'0"	1.0	558	1	---	7	4	1	1	2	---	3	1
		1.5	582	1	---	7	4	1	1	2	---	3	1
		2.0	606	1	---	7	4	1	1	2	---	3	1
7'6"	8'0"	1.0	646	1	---	9	4	2	1	2	---	3	1
		1.5	670	1	---	9	4	2	1	2	---	3	1
		2.0	694	1	---	9	4	2	1	2	---	3	1

Overfall F = 4.0'

B	W	H (ft)	2" x 6" T & G (lin. ft.)	Posts 6" x 6" 4'	6'	8'	10'	Boards 2" x 8" 8'	10'	12'	Boards 2" x 6" 6'	8'	10'
		1.0	600	1	---	7	4	1	1	2	---	3	1
3'6"	8'0"	1.5	624	1	---	7	4	1	1	2	---	3	1
		2.0	648	1	---	7	4	1	1	2	---	3	1
		1.0	696	1	---	9	4	2	1	2	---	3	1
7'6"	8'0"	1.5	720	1	---	9	4	2	1	2	---	3	1
		2.0	744	1	---	9	4	2	1	2	---	3	1

		3'6" x 8'0" Box	7'6" x 8'0" Box
Drain Fill – behind structure		2 cubic yards	2.5 cubic yards
Weir Protection			
Riprap Option	Riprap	1.3 cubic yards	2.1 cubic yards
or			
Concrete Block Option			
	Blocks	46 each	64 each
	Drain Fill	0.5 cubic yard	0.7 cubic yard
Structure Floor			
Concrete Option			
	Concrete	0.6 cubic yard	1.1 cubic yards
	Drain Fill	0.5 cubic yard	1 cubic yard
or			
Concrete Block Option			
	Blocks	36 each	72 each
	Drain Fill	0.5 cubic yard	1 cubic yard
or			
Riprap Option			
	Riprap	1.8 cubic yards	3.9 cubic yards
Plastic Sheeting		85 feet^2	125 feet^2

Outlet Channel

Riprap Option		12 cubic yards
or		
Concrete Block Option		
Blocks		112 cubic yards
Drain Fill		1.2 cubic yards
Lag Screws	½" x 5"	8 each
Nails	6" ring	25 pounds

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6.6.5 Reinforced Concrete Spillways

Description:

Box inlet drop spillway constructed of reinforced concrete.

Purpose:

Stabilization structure often used along drainage ditches or natural channels

Where Applicable:

Where overfall of 3 to 5 feet needs to be maintained, and high flow capacities are required

Advantages:

Very durable structure

Adaptable to many design flow capacities and a range of overfall

Relatively high capacity

Limitations:

Relatively expensive compared to other structures

Site must be accessible to heavy equipment and concrete trucks

Design & Construction Considerations:

Selection – Reinforced concrete drop box spillways have been used for several years in projects across Ohio. These structures have proven to be a very durable structure, with a design life well in excess of 25 years.

These structures are well suited for use on projects where large design flow capacities are required. The open structure is generally not susceptible to be plugged with crop residue or other debris. These structures are commonly used as headwalls along open ditches or other maintained drainage ways. Concrete structures can also be used as a stable outlet for subsurface drains.

Concrete structures are somewhat more expensive relative to other grade stabilization structures. Moreover, the site must be accessible to heavy equipment and concrete trucks.

NRCS has developed a complete design reference for both box inlet and straight drop structures. The design reference is attached at the end of this document, and can also be found on pages 41 through 55 of Ohio's EFH supplements. This document can also be found online at:

ftp://ftp-fc.sc.egov.usda.gov/OH/pub/Admin/NEH/Adobe/Combined_EFH_Supplements.pdf

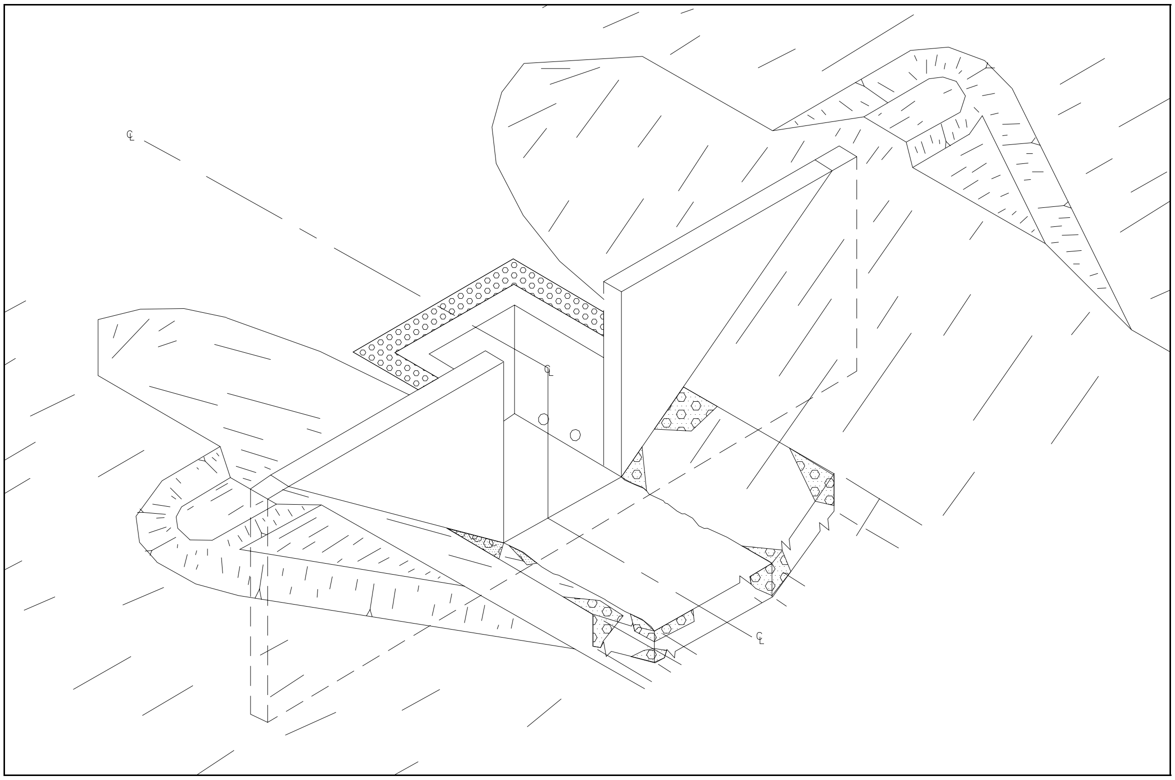


Figure 8. Reinforced Concrete Box Drop Illustration; Source Ohio NRCS OH-300

Exhibit OH 6-6 are to be used with Ohio NRCS's Standard Drawing OH-N-300 through OH-N-305. These drawings are available online at:

http://www.oh.nrcs.usda.gov/technical/engineering/cadd2_dwg_d_to_p.html

Design – these structures can be adapted to a wider range of applications than those listed in the design reference attached, however, structural analysis will have to be completed on the proposed design.

Construction – Proper drainage and armoring are required around the structure to prevent erosion around the structure. This includes armoring the surfaces around the structure with rip rap, as well as providing drainage with granular fill around the structure and weep holes in the lower portion of the box.

Failure to install these measure result in excessive erosion along the box, and eventually undermining of the entire structure.

References:

Engineering Field Handbook; Chapter 6, Grade Stabilization Structures Natural Resources Conservation Service, United States Department of Agriculture

Ohio NRCS Design Standard 410; Grade Stabilization Structures

REINFORCED CONCRETE DROP BOX SPILLWAY

Design Charts

The R/C drop box spillway design charts in this exhibit are to be used with Standard Drawings OH-N-300 through OH-N-305.

DEFINITIONS:

Q	=	Design capacity of structure in cubic feet per second (cfs).
b	=	dimension of box perpendicular to the toewall in feet (ft.).
w	=	width of notch in feet (ft.).
l	=	weir length; sum of 2b + w in feet (ft.).
h	=	design head for the structure; also the height of toewall above the weir in feet (ft.).
f	=	overfall; distance from the weir to the box floor in feet (ft.).
BW	=	bottom width of entrance channel.
x	=	distance from the side of the box to the toe of the dike(ft.)

DESIGN CRITERIA

Q	=	range from 45 cfs to 400 cfs minimum capacity shall be Q5 for D.A. less than 320 ac. Q10 for D.A. greater than 320 ac.
f	=	overfall from 3.0 ft. to 5.0 ft. weir lengths from 8 to 26 feet with box dimensions of 2x4 to 8x10.
h	=	heads range from 1.5 to 3 feet. The entrance channel bottom width shall be a minimum of 2L-hz where L = weir length; h= head; z = sideslopes.

Selection of box dimensions, head and overfall shall be based on the site topography, economics, and design criteria.

EXAMPLE

Drainage area = 20 acres.
Design depth of waterway 1.5 feet.
Weir elevation 104.0.
Outlet elevation 101.0.
Overfall 3.0 feet.

DESIGN WORKSHEET
REINFORCED CONCRETE
DROP BOX SPILLWAY
ISLAND TYPE STRUCTURES

Owner: D. Brown — Field No. 6

Designer: R. Sams — Date: 10 May 1984

Checker: G. Smith — Date: 10 May 1984

Structure drainage area: 250 — Weir elevation: 104.0

Design depth of waterway: 1.5 — Outlet elevation: 101.0

Overfall: 3.0

Structures with Less than 320 ac. Drainage Area

Q5 35 from OH-ENG-140
Q25 120 from OH-ENG-140

Structures with more than 320 ac. Draiange Area

Q10 --- from OH-ENG-140
Q25 --- from OH-ENG-140

Sizing Structure

Select structure dimensions to fit capacity, outlet channel, overfall, and available head.
EFM notice OH6-2 Sheets ______

Capacity required: Q5 35 Q10
design: 45

Dimensions
box width (w) = 4
depth (b) = 2
overfall (f) = 3.0
weir length (L) = 8
head (h) = 1.5
min. (x) = 1.0

Inlet Channel Dimensions

1. Width shall be BW = 2L-hz L = weir length, h = head, z = sideslopes
   BW = 10

2. Slope shall be flat upstream far enough to encompass the entrance to the emergency spillway.

Emergency Spillway EFM Chapt. 11 or 1 = 2.75 $LH^{3/2}$

Q25 120 minus Qbox 45 = Qemergency 75

Crest elevation = 0.5' less than top of toewall 105.0

width = 28 ft., sideslope = 5:1, flow depth = 1.0 ft.

free board = 1.0, top of fill elevation = 107.0

Completing Standard Drawings

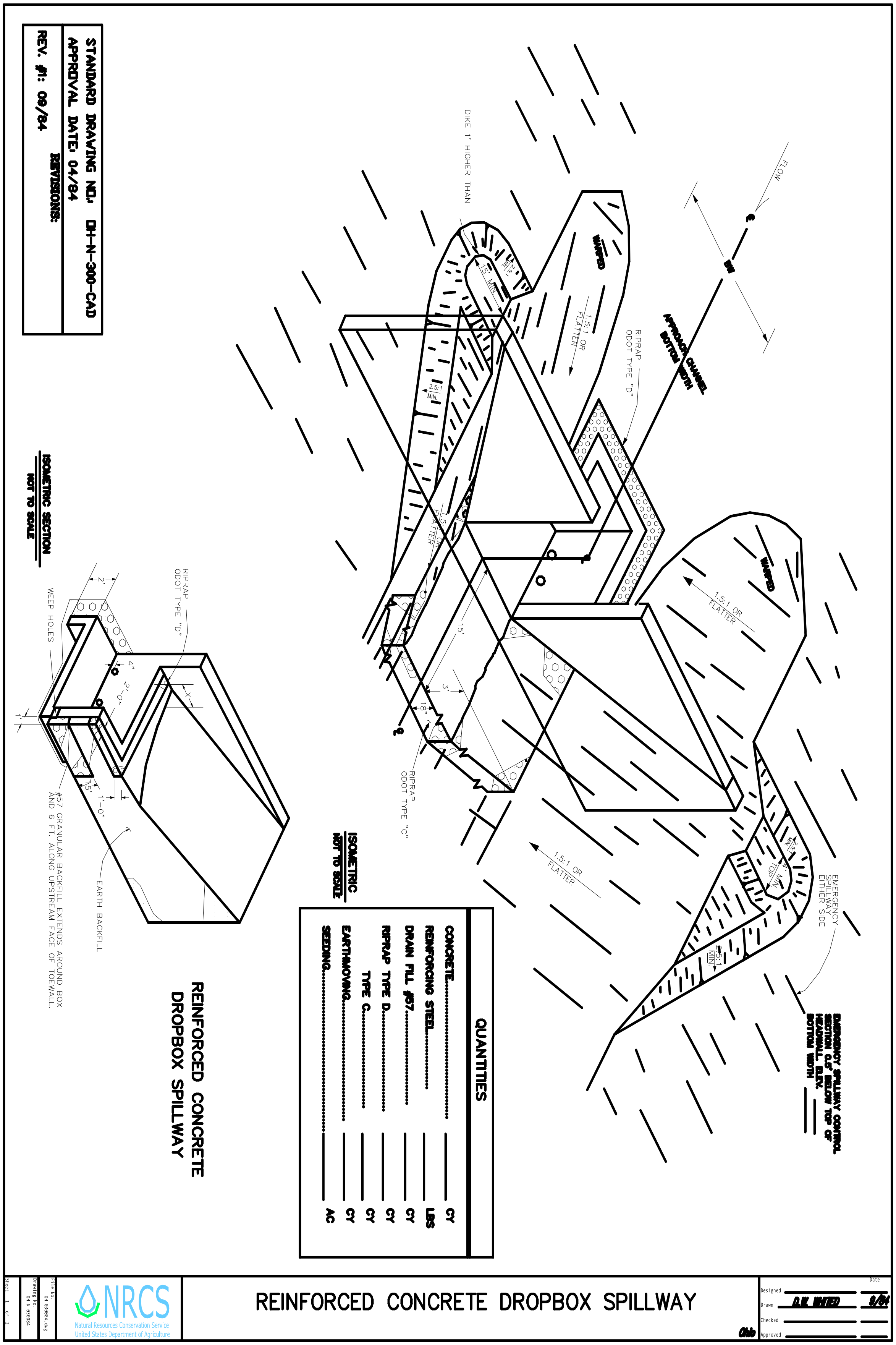
A. Select the appropriate standard drawing for the correct overfall 3.0, 3.5, 4.0, 4.5, 5.0.

B. Fill in the appropriate dimensions from the design sheet.

C. Fill in the steel schedule from the appropriate sheets.

Mark 2, 3, and 5-8 bars are on sheets __________ to ______
Mark 1 and 3 bars are on sheet _________

D. Select steel totals and concrete totals from sheets __________ thru ________



STANDARD DRAWING NO. OH-N-300-CAD
APPROVAL DATE: 04/84
REVISIONS:
REV. #1: 09/84
ISOMETRIC SECTION
NOT TO SCALE
ISOMETRIC
NOT TO SCALE
REINFORCED CONCRETE DROPBOX SPILLWAY
FLOW
APPROACH CHANNEL BOTTOM WIDTH
RIPRAP ODOT TYPE "D"
RIPRAP ODOT TYPE "C"
1.5:1 OR FLATTER
2.5:1 MIN.
WARPED
DIKE 1' HIGHER THAN
EMERGENCY SPILLWAY EITHER SIDE
EMERGENCY SPILLWAY CONTROL SECTION 0.5' BELOW TOP OF HEADWALL ELEV.
BOTTOM WIDTH
WEEP HOLES
EARTH BACKFILL
#57 GRANULAR BACKFILL EXTENDS AROUND BOX AND 6 FT. ALONG UPSTREAM FACE OF TOEWALL.
QUANTITIES
CONCRETE CY
REINFORCING STEEL LBS
DRAIN FILL #57 CY
RIPRAP TYPE D CY
TYPE C CY
EARTHMOVING CY
SEEDING AC
REINFORCED CONCRETE DROPBOX SPILLWAY
NRCS
Natural Resources Conservation Service
United States Department of Agriculture
Designed
Drawn D.K. WHITED 9/84
Checked
Approved
Date
Ohio

Reinforced Concrete
Drop Box Spillway

Overfall Height f = 3.0, 3.5, 4.0, 4.5, 5.0
Notch Depth h = 1.5, 2.0, 2.5, 3.0

Box Depth (b)	Box Width (w)	Weir Length (l)	Minimum "X" 1/	Capacity cfs h=1.5	h=2.0	h=2.5	h=3.0
2	4	8	1.0	45	70	100	130
2	6	10	1.0	55	85	120	160
4	4	12	2.0	65	100	140	190
4	6	14	2.0	75	115	170	210
4	8	16	1.5	85	135	190	260
4	10	18	2.0	95	150	210	285
6	4	16	2.5	85	135	190	245
6	6	18	3.0	95	150	210	280
6	8	20	3.0	105	165	235	310
6	10	22	2.5	115	180	255	345
8	10	26	4.0	130	205	295	400

1/ "X" is the distance from the side of the box to the toe of the dike.

Capacity from Agriculture Handbook 301

$$Q = \frac{(C_1)(C_2)(C\sqrt{2g})(h^{3/2})(L)}{1.1+.01f}$$

C = constant = .4275
g = gravity 32.2 ft/sec^2
L = weir length
C_1 = modifier due to head h/w Agriculture Handbook, page 8.
C_2 = modifier due to box inlet shape b/w Agriculture Handbook, page 8.
f = overfall
h = head

Simplified

$$Q = \frac{C_1 C_2\, 3.43\, h^{3/2} L}{1.1+.01f}$$

for b-2, w=4, h=3, f=4.0

h/w = 3/4 = .75 find C_1 = 1
b/w = 2/4 = 0.5 find C_2 = 1.04

$$Q = \frac{(1)(1.04)(3.43)(3)^{3/2}(8)}{1.14} = 130.1 \text{ use } 130$$

REINFORCED CONCRETE DROP BOX SPILLLWAY
STEEL SCHEDULE

Overfall f = 3.0
All bars are #4 = ½ dia.

b=2 w=4

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	10	11-6	2-0
3	3	10	2-0	3-0
4	1	-	-	-
5	3	6	1-6	2-0
6	3	6	2-0	3-2
7	3	6	3-2	3-0
8	1	4	14-6	-

b=2 w=6

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	10	11-6	2-0
3	3	10	2-0	4-0
4	1	-	-	-
5	3	9	1-6	2-0
6	3	9	2-0	3-2
7	3	6	3-2	4-0
8	1	4	15-6	-

b=4 w=4

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	10	11-6	3-0
3	3	10	3-0	3-0
4	1	-	-	-
5	3	6	1-6	3-0
6	3	6	3-0	3-8
7	3	12	3-2	3-0
8	1	4	14-6	-

b=4 w=6

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	10	11-6	3-0
3	3	10	3-0	4-0
4	1	-	-	-
5	3	9	1-6	3-0
6	3	9	3-0	3-2
7	3	12	3-2	4-0
8	1	4	15-6	-

b=4 w=8

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	10	11-6	3-0
3	3	10	3-0	5-0
4	1	-	-	-
5	3	12	1-6	3-0
6	3	12	3-0	3-2
7	3	12	3-2	5-0
8	1	4	16-6	-

b=4 w=10

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	10	11-6	3-0
3	3	10	3-0	6-0
4	1	-	-	-
5	3	15	1-6	3-0
6	3	15	3-0	3-2
7	3	12	3-2	6-0
8	1	4	17-6	-

b=6 w=4

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	10	11-6	4-0
3	3	10	4-0	3-0
4	1	-	-	-
5	3	6	1-6	4-0
6	3	6	4-0	3-2
7	3	18	3-2	3-0
8	1	4	14-6	-

b=6 w=6

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	10	11-6	4-0
3	3	10	4-0	4-0
4	1	-	-	-
5	3	9	1-6	4-0
6	3	9	4-0	3-2
7	3	18	3-2	5-0
8	1	4	16-6	-

b=6 w=8

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	10	11-6	4-0
3	3	10	4-0	5-0
4	1	-	-	-
5	3	12	1-6	4-0
6	3	12	4-0	3-2
7	3	18	3-2	5-0
8	1	4	16-6	-

b=6 w=10

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	10	11-6	4-0
3	3	10	4-0	6-0
4	1	-	-	-
5	3	15	1-6	4-0
6	3	15	4-0	3-2
7	3	18	3-2	6-0
8	1	4	17-6	-

b=8 w=10

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	10	11-6	5-0
3	3	10	5-0	6-0
4	1	-	-	-
5	3	15	1-6	5-0
6	3	15	5-0	3-2
7	3	24	3-2	6-0
8	1	4	17-6	-

Overfall f = 3.5
All bars are #4 = ½ dia.

b=2 w=4

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	12	11-6	2-0
3	3	12	2-0	3-0
4	1	-	-	-
5	3	6	1-6	2-0
6	3	6	2-0	3-8
7	3	6	3-8	3-0
8	1	4	14-6	-

b=2 w=6

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	12	11-6	2-0
3	3	12	2-0	4-0
4	1	-	-	-
5	3	9	1-6	2-0
6	3	9	2-0	3-8
7	3	6	3-8	4-0
8	1	4	15-6	-

b=4 w=4

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	12	11-6	3-0
3	3	12	3-0	3-0
4	1	-	-	-
5	3	6	1-6	3-0
6	3	6	3-0	3-8
7	3	12	3-8	3-0
8	1	4	14-6	-

b=4 w=6

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	12	11-6	3-0
3	3	12	3-0	4-0
4	1	-	-	-
5	3	9	1-6	3-0
6	3	9	3-0	3-8
7	3	12	3-8	4-0
8	1	4	15-6	-

b=4 w=8

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	12	11-6	3-0
3	3	12	3-0	5-0
4	1	-	-	-
5	3	12	1-6	3-0
6	3	12	3-0	3-8
7	3	12	3-8	5-0
8	1	4	16-6	-

b=4 w=10

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	12	11-6	3-0
3	3	12	3-0	6-0
4	1	-	-	-
5	3	15	1-6	3-0
6	3	15	3-0	3-8
7	3	12	3-8	6-0
8	1	4	17-6	--

b=6 w=4

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	12	11-6	4-0
3	3	12	4-0	3-0
4	1	-	-	-
5	3	6	1-6	4-0
6	3	6	4-0	3-8
7	3	18	3-8	3-0
8	1	4	14-6	-

b=6 w=6

Mark	Type	Quan.	A	B
1	1	-	11-6	-
2	3	12	11-6	4-0
3	3	12	4-0	4-0
4	1	-	-	-
5	3	9	1-6	4-0
6	3	9	4-0	3-8
7	3	18	3-8	4-0
8	1	4	15-6	-

b=6 w=8

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	12	11-6	4-0
3	3	12	4-0	5-0
4	1	-	-	-
5	3	12	1-6	4-0
6	3	12	4-0	3-8
7	3	18	3-8	5-0
8	1	4	16-6	-

b=6 w=10

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	12	11-6	4-0
3	3	12	4-0	6-0
4	1	-	-	-
5	3	15	1-6	4-0
6	3	15	4-0	3-8
7	3	18	3-8	6-0
8	1	4	17-6	-

b=8 w=10

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	12	11-6	5-0
3	3	12	5-0	6-0
4	1	-	-	-
5	3	15	1-6	5-0
6	3	15	5-0	3-8
7	3	24	3-8	6-0
8	1	4	17-6	-

Overfall f = 4.0
All bars are #4 = ½ dia.

b=2 w=4

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	14	11-6	2-0
3	3	14	2-0	3-0
4	1	-	-	-
5	3	6	1-6	2-0
6	3	6	2-0	4-2
7	3	6	4-2	3-0
8	1	4	14-6	-

b=2 w=6

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	14	11-6	2-0
3	3	14	2-0	4-0
4	1	-	-	-
5	3	9	1-6	2-0
6	3	9	2-0	4-2
7	3	6	4-2	4-0
8	1	4	15-6	-

b=4 w=4

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	14	11-6	3-0
3	3	14	3-0	3-0
4	1	-	-	-
5	3	6	1-6	3-0
6	3	6	3-0	4-2
7	3	12	4-2	3-0
8	1	4	14-6	-

b=4 w=6

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	14	11-6	3-0
3	3	14	3-0	4-0
4	1	-	-	-
5	3	9	1-6	3-0
6	3	9	3-0	4-2
7	3	18	4-2	4-0
8	1	4	15-6	-

b=4 w=8

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	14	11-6	3-0
3	3	14	3-0	5-0
4	1	-	-	-
5	3	12	1-6	3-0
6	3	12	3-0	4-2
7	3	12	4-2	5-0
8	1	4	15-6	-

b=4 w=10

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	14	11-6	3-0
3	3	14	3-0	6-0
4	1	-	-	-
5	3	15	1-6	3-0
6	3	15	3-0	4-2
7	3	12	4-2	6-0
8	1	4	17-6	--

b=6 w=4

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	14	11-6	4-0
3	3	14	4-0	3-0
4	1	-	-	-
5	3	6	1-6	4-0
6	3	6	4-0	4-2
7	3	18	4-2	3-0
8	1	4	14-6	-

b=6 w=6

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	14	11-6	4-0
3	3	14	4-0	4-0
4	1	-	-	-
5	3	9	1-6	4-0
6	3	9	4-0	4-2
7	3	18	4-2	4-0
8	1	4	15-6	-

b=6 w=8

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	14	11-6	4-0
3	3	14	4-0	5-0
4	1	-	-	-
5	3	12	1-6	4-0
6	3	12	4-0	4-2
7	3	18	4-2	5-0
8	1	4	16-6	-

b=6 w=10

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	14	11-6	4-0
3	3	14	4-0	6-0
4	1	-	-	-
5	3	15	1-6	4-0
6	3	15	4-0	4-2
7	3	18	4-2	6-0
8	1	4	17-6	-

b=8 w=10

MARK	TYPE	QUAN.	A	B
1	1	-	-	-
2	3	14	11-6	5-0
3	3	14	5-0	6-0
4	1	-	-	-
5	3	15	1-6	5-0
6	3	15	5-0	4-2
7	3	24	4-2	6-0
8	1	4	17-6	-

Overfall f = 4.5
All bars are #4 = ½ dia.

b=2 w=4

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	16	11-6	2-0
3	3	16	2-0	3-0
4	1	-	-	-
5	3	6	1-6	2-0
6	3	6	2-0	4-8
7	3	6	4-8	3-0
8	1	4	14-6	-

b=2 w=6

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	16	11-6	2-0
3	3	16	2-0	4-0
4	1	-	-	-
5	3	9	1-6	2-0
6	3	9	2-0	4-8
7	3	6	4-8	4-0
8	1	4	15-6	-

b=4 w=4

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	16	11-6	3-0
3	3	16	3-0	3-0
4	1	-	-	-
5	3	6	1-6	3-0
6	3	6	3-0	4-8
7	3	12	4-8	3-0
8	1	4	14-6	-

b=4 w=6

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	16	11-6	3-0
3	3	16	3-0	4-0
4	1	-	-	-
5	3	9	1-6	3-0
6	3	9	3-0	4-8
7	3	12	4-8	4-0
8	1	4	15-6	-

b=4 w=8

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	16	11-6	3-0
3	3	16	3-0	5-0
4	1	-	-	-
5	3	12	1-6	3-0
6	3	12	3-0	4-8
7	3	12	4-8	5-0
8	1	4	15-6	-

b=4 w=10

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	16	11-6	3-0
3	3	16	3-0	6-0
4	1	-	-	-
5	3	15	1-6	3-0
6	3	15	3-0	4-8
7	3	12	4-8	6-8
8	1	4	17-6	-

b=6 w=4

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	16	11-6	4-0
3	3	16	4-0	3-0
4	1	-	-	-
5	3	6	1-6	4-0
6	3	6	4-0	4-8
7	3	18	4-8	3-0
8	1	4	17-6	-

b=6 w=6

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	16	11-6	4-0
3	3	16	4-0	4-0
4	1	-	-	-
5	3	9	1-6	4-0
6	3	9	4-0	4-8
7	3	6	4-8	4-0
8	1	4	15-6	-

b=6 w=8

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	16	11-6	4-0
3	3	16	4-0	5-0
4	1	-	-	-
5	3	12	1-6	4-0
6	3	12	4-0	4-8
7	3	18	4-8	5-0
8	1	4	16-6	-

b=6 w=10

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	16	11-6	4-0
3	3	16	4-0	6-0
4	1	-	-	-
5	3	15	1-6	4-0
6	3	15	4-0	4-8
7	3	18	4-8	6-0
8	1	4	17-6	-

b=8 w=10

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	16	11-6	5-0
3	3	16	5-0	6-0
4	1	-	-	-
5	3	15	1-6	5-0
6	3	15	5-0	4-8
7	3	24	4-8	6-0
8	1	4	17-6	-

Overfall f = 5.0
All bars are #4 = ½ dia.

b=2 w=4

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	18	11-6	2-0
3	3	18	2-0	3-0
4	1	-	-	-
5	3	6	1-6	2-0
6	3	6	2-0	5-2
7	3	6	5-2	3-0
8	1	4	14-6	-

b=2 w=6

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	18	11-6	2-0
3	3	18	2-0	4-0
4	1	-	-	-
5	3	9	1-6	2-0
6	3	9	2-0	5-2
7	3	6	5-2	4-0
8	1	4	15-6	-

b=4 w=4

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	18	11-6	3-0
3	3	18	3-0	3-0
4	1	-	-	-
5	3	6	1-6	3-0
6	3	6	3-0	5-2
7	3	12	5-2	3-0
8	1	4	14-6	-

b=4 w=6

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	18	11-6	3-0
3	3	18	3-0	4-0
4	1	-	-	-
5	3	9	1-6	3-0
6	3	9	3-0	5-2
7	3	12	5-2	4-0
8	1	4	15-6	-

b=4 w=8

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	18	11-6	3-0
3	3	18	3-0	5-0
4	1	-	-	-
5	3	12	1-6	3-0
6	3	12	3-0	5-2
7	3	12	5-2	5-0
8	1	4	15-6	-

b=4 w=10

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	18	11-6	3-0
3	3	18	3-0	6-0
4	1	-	-	-
5	3	15	1-6	3-0
6	3	15	3-0	5-2
7	3	12	5-2	6-0
8	1	4	17-6	-

b=6 w=4

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	18	11-6	4-0
3	3	18	4-0	3-0
4	1	-	-	-
5	3	6	1-6	4-0
6	3	6	4-0	5-2
7	3	18	5-2	3-0
8	1	4	14-6	-

b=6 w=6

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	18	11-6	4-0
3	3	18	4-0	4-0
4	1	-	-	-
5	3	9	1-6	4-0
6	3	9	4-0	5-2
7	3	18	5-2	4-0
8	1	4	15-6	-

b=6 w=8

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	18	11-6	4-0
3	3	18	4-0	5-0
4	1	-	-	-
5	3	12	1-6	4-0
6	3	12	4-0	5-2
7	3	18	5-2	5-0
8	1	4	16-6	-

b=6 w=10

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	18	11-6	4-0
3	3	18	4-0	6-0
4	1	-	-	-
5	3	15	1-6	4-0
6	3	15	4-0	5-2
7	3	18	5-2	6-0
8	1	4	17-6	-

b=8 w=10

Mark	Type	Quan.	A	B
1	1	-	-	-
2	3	18	11-6	5-0
3	3	18	5-0	6-0
4	1	-	-	-
5	3	15	1-6	5-0
6	3	15	5-0	5-2
7	3	24	5-2	6-0
8	1	4	17-6	-

MARK	TYPE	QUAN.	A	B	MARK	TYPE	QUAN.	A	B
OVERFALL f=3.0 **h=1.5**					**OVERFALL f=3.5** **h=1.5**				
1	1	4	11-6		1	1	4	11-6	
4	1	36	6-0		4	1	36	6-6	
		h=2.0					h=2.0		
1	1	6	11=6		1	1	6	11-6	
4	1	36	6-6		4	1	36	7-0	
		h=2.5					h=2.5		
1	1	8	11-6		1	1	8	11-6	
4	3	36	7-0		4	1	36	7-6	
		h=3.0					h=3.0		
1	1	10	11-6		1	1	8	11-6	
4	1	36	7-6		4	1	36	8-0	
OVERFALL f=4.0 **h=1.5**					**OVERFALL f = 4.5** **h=1.5**				
1	1	4	11-6		1	1	4	11-6	
4	1	36	7-0		4	1	36	7-6	
		h=2.0					h=2.0		
1	1	6	11-6		1	1	6	11-6	
4	1	36	7-6		4	1	36	8-0	
		h=2.5					h=2.5		
1	1	6	11-6		1	1	6	11-6	
4	1	36	8-0		4	1	36	8-6	
		h=3.0					h=3.0		
1	1	8	11-6		1	1	8	11-6	
4	1	36	8-6		4	1	36	9-0	
OVERFALL f=5.0 **h=1.5**									
1	1	6	11-6						
4	1	36	8-0						
		h=2.0							
1	1	6	11-6						
4	1	36	8-6						
		h=2.5							
1	1	8	11-6						
4	1	36	9-0						
		h=3.0							
1	1	10	11-6						
4	1	36	9-6						

REINFORCED CONCRETE
DROPBOX SPILLWAY
Steel and Concrete Quantities

Overfall f – 3.0

b	w	h = 1.5			h = 2.0			h = 2.5			h = 3.0		
		Steel		Concrete	Steel		Concrete	Steel		Concrete	Steel		Concrete
		ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.
2	4	614-0	410	5.1	655.0	440	5.4	696.0	460	5.7	717-0	480	6.0
2	6	640-0	430	5.5	681.0	450	5.8	722.0	480	6.1	763-0	510	6.4
4	4	663-0	440	5.6	704.0	470	5.9	745.0	500	6.2	786-0	530	6.5
4	6	721-0	480	6.1	762.0	500	6.4	803.0	540	6.7	844-0	560	7.0
4	8	779-0	520	6.6	820.0	550	6.9	861.0	580	7.2	902-0	600	7.5
4	10	837-0	550	7.1	878.0	590	7.4	919.0	610	7.7	960-0	640	8.0
6	4	732-0	490	6.2	773.0	520	6.5	814.0	540	6.8	855-0	570	7.1
6	6	802-0	540	6.8	843.0	560	7.1	884.0	590	7.4	925-0	620	7.7
6	8	872-0	580	7.3	903.0	610	7.6	954.0	640	7.9	995-0	660	8.3
6	10	942-0	630	7.9	983.0	660	8.2	1024.0	680	8.5	1065-0	710	8.8
8	10	1047-0	700	8.8	1088.0	730	9.1	1129.0	750	9.4	1170-0	780	9.7

Overfall f = 3.5

b	w	h = 1.5			h = 2.0			h = 2.5			h = 3.0		
		Steel		Concrete	Steel		Concrete	Steel		Concrete	Steel		Concrete
		ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.
2	4	655-0	440	5.5	696-0	460	5.8	737-0	490	6.1	755-0	530	6.4
2	6	704-6	470	5.9	745-6	500	6.2	786-6	530	6.5	804-6	560	6.8
4	4	731-0	490	6.1	772-0	515	6.4	813-0	540	6.7	831-0	580	7.0
4	6	792-6	530	6.6	833-6	560	6.9	874-6	580	7.2	892-6	630	7.5
4	8	854-0	570	7.1	895-0	600	7.4	936-0	630	7.7	954-0	670	8.0
4	10	915-6	610	7.6	956-6	640	7.9	997-6	670	8.2	1015-6	710	8.5
6	4	807-0	540	6.7	848-0	570	7.0	889-0	590	7.3	907-0	640	7.6
6	6	880-6	590	7.3	921-6	620	7.6	962-6	640	7.9	980-6	690	8.2
6	8	954-0	640	7.9	995-0	660	8.2	1036-0	690	8.5	1054-0	740	8.8
6	10	1027-6	690	8.5	1068-6	710	8.8	1109-6	740	9.1	1127-6	790	9.4
8	10	1139-0	760	9.4	1180-0	790	9.7	1221-0	820	10.0	1239-6	830	10.3

Overfall f = 4.0

b	w	h = 1.5			h = 2.0			h = 2.5			h = 3.0		
		Steel		Concrete	Steel		Concrete	Steel		Concrete	Steel		Concrete
		ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.
2	4	716-0	480	5.9	757-0	510	6.2	775-0	520	6.5	816-0	570	6.8
2	6	769-0	510	6.3	810-0	540	6.6	828-0	550	6.9	869-0	610	7.2
4	4	799-0	530	6.6	840-0	560	6.9	858-0	570	7.2	899-0	630	7.5
4	6	864-0	580	7.1	905-0	600	7.4	923-0	620	7.7	964-0	670	8.0
4	8	929-0	620	7.6	970-0	650	7.9	988-0	660	8.2	1029-0	720	8.5
4	10	994-0	660	8.2	1035-0	690	8.4	1053-0	700	8.8	1094-0	760	9.1
6	4	882-0	590	7.2	923-0	620	7.5	941-0	630	7.8	982-0	690	8.1
6	6	959-0	640	7.9	1000-0	670	8.2	1018-0	680	8.5	1059-0	740	8.8
6	8	1036-0	690	8.5	1077-0	720	8.8	1095-0	730	9.1	1136-0	790	9.4
6	10	1113-0	740	9.1	1154-0	770	9.4	1172-0	780	9.7	1213-0	850	10.0
8	10	1232-0	820	10.1	1273-0	850	10.4	1291-0	860	10.7	1332-0	890	11.0

Overfall f = 4.5

b	w	h = 1.5			h = 2.0			h = 2.5			h = 3.0		
		Steel		Concrete	Steel		Concrete	Steel		Concrete	Steel		Concrete
		ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.
2	4	777-0	520	6.3	818-0	550	6.6	836-0	560	6.9	877-0	590	7.2
2	6	833-6	560	6.8	874-0	580	7.0	892-6	600	7.4	933-6	620	7.7
4	4	867-0	580	7.0	908-0	610	7.3	926-0	620	7.6	967-0	650	7.9
4	6	935-6	620	7.6	976-6	650	7.9	994-6	660	8.2	1035-6	700	8.5
4	8	1003-0	670	8.1	1044-0	700	8.4	1062-0	710	8.7	1103-0	740	9.0
4	10	1072-6	720	8.7	113-6	740	9.0	1131-6	760	9.3	1172-6	780	9.6
6	4	957-0	640	7.6	998-0	670	8.0	1016-0	680	8.2	1057-0	710	8.6
6	6	1031-6	690	8.4	1072-6	720	8.7	1090-6	730	9.0	1131-6	760	9.3
6	8	1118-0	750	9.0	1159-0	770	9.3	1177-0	790	9.6	1218-0	810	9.9
6	10	1198-6	800	9.7	1239-6	830	10.0	1257-6	840	10.3	1298-6	870	10.6
8	10	1324-6	880	10.7	1365-6	910	11.0	1383-6	920	11.3	1424-6	950	11.6

Overfall f = 5.0

b	w	h = 1.5			h = 2.0			h = 2.5			h = 3.0		
		Steel	Concrete		Steel	Concrete		Steel	Concrete		Steel	Concrete	
		ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.	ft.-in.	lbs.	c.y.
2	4	861-0	580	6.7	879-0	590	7.0	920-0	610	7.3	961-0	640	7.6
2	6	921-0	620	7.2	939-0	630	7.5	980-0	650	7.8	1021-0	680	8.1
4	4	958-0	640	7.5	976-0	650	7.8	1017-0	680	8.1	1058-0	710	8.4
4	6	1030-0	670	8.1	1048-0	700	8.4	1089-0	730	8.7	1130-0	750	9.0
4	8	1101-0	740	8.6	1119-0	750	8.9	1160-0	770	9.2	1201-0	800	9.5
4	10	1174-0	780	9.3	1192-0	800	9.6	1233-0	820	9.9	1274-0	850	10.2
6	4	1055-0	700	8.3	1073-0	720	8.6	1114-0	740	8.9	1155-0	770	9.2
6	6	1133-0	760	8.9	1151-0	770	9.2	1192-0	800	9.5	1233-0	820	9.8
6	8	1223-0	820	9.6	1241-0	830	9.9	1282-0	860	10.2	1323-0	880	10.5
6	10	1307-0	870	10.3	1325-0	890	10.6	1366-0	910	10.9	1407-0	940	11.2
8	10	1440-0	960	11.3	1458-0	970	11.6	1499-0	1000	11.9	1540-0	1030	12.2

DESIGN WORKSHEET
REINFORCED CONCRETE
DROP BOX SPILLWAY
ISLAND TYPE STRUCTURES

Owner ____ Field No. __________________________

Designer ____ Date: ______________________

Checker ____ Date: ______________________

Structure drainage area: ______________________________ Weir elevation: _____________________

Design depth of waterway: ___________________________ Outlet elevation: ____________________

Overfall: ___________________________

Structures with Less than 320 ac. Drainage Area

Q5 _________ from OH-ENG-140
Q25 ________ from OH-ENG-140

Structures with more than 320 ac. Draiange Area

Q10 ________ from OH-ENG-140
Q25 ________ from OH-ENG-140

Sizing Structure

Select structure dimensions to fit capacity, outlet channel, overfall, and available head.
EFM notice ___________ Sheets ____________

Capacity required: _____________________ ______________________
design ____________________ ______________________

Dimensions:

box width (w) = _________
depth (b) = _________
overfall (f) = _________
weir length (L) = ______
head (h) = _________
min. (x) = _________

Inlet Channel Dimensions

1. Width shall be BW = 2L-hz L = weir length, h = head, z = sideslopes
BW = __________

2. Slope shall be flat upstream far enough to encompass the entrance to the emergency spillway.

Emergency Spillway EFM Chapt. 11 or 1 = 2.75 $LH^{3/2}$

Q25 __________ minus Qbox __________ = Qemergency _________

Crest elevation = 0.5’ less than top of toewall _________________

width = ___________ ft., sideslope = ____________, flow depth = _____________ ft.

free board = ________________, top of fill elevation = _____________

6.6.6 Pipe Structures

Description:

Closed conduits such as pipes or culverts designed for pressurized flow

Purpose:

Provide a stable structure to move water from higher field elevation to lower elevations

Where Applicable:

Locations where water must be lowered from field elevations to lower channel elevations

Advantages:

High overfall can be addressed economically

Very small footprint required for structure

Limitations:

Must be able to store water temporarily for proper operation of the structure

Capacity relative to other grade stabilization structures is low

Higher possibility of becoming plugged with residue or debris

Design & Construction Considerations:

Structure Types – Any closed conduit structure designed to develop head pressure over a pipe and transfer flows under pressure can be considered a pipe structure, including pipe drop structures, hooded inlet structures and culverts.

Design processes for these structures rely on a hydraulic evaluation of the proposed structure and site-specific survey information. The Engineering Field Handbook published by NRCS gives detailed design and evaluation procedures for these structures in Chapter 3 Hydraulics, and Chapter 6 Grade Stabilization Structures.

Design software for these structures is also available from the NRCS at:

http://www.il.nrcs.usda.gov/technical/engineer/enggsoft.html

A full understanding of the design process and site requirements is needed to fully review structure designs. The following is a brief discussion of three pipe structure types.

Pipe Drop Structures – As shown in Figure 7 below, pipe drop structures are commonly used as the principal spillway for ponds, lakes, and reservoirs. These structures are commonly built where a relatively large drop in elevation is needed. For proper operation, water storage must be possible at the project sites. Water storage over the riser inlet is used to develop the pressure required to force water through the structure.

Pipe Drop Structures

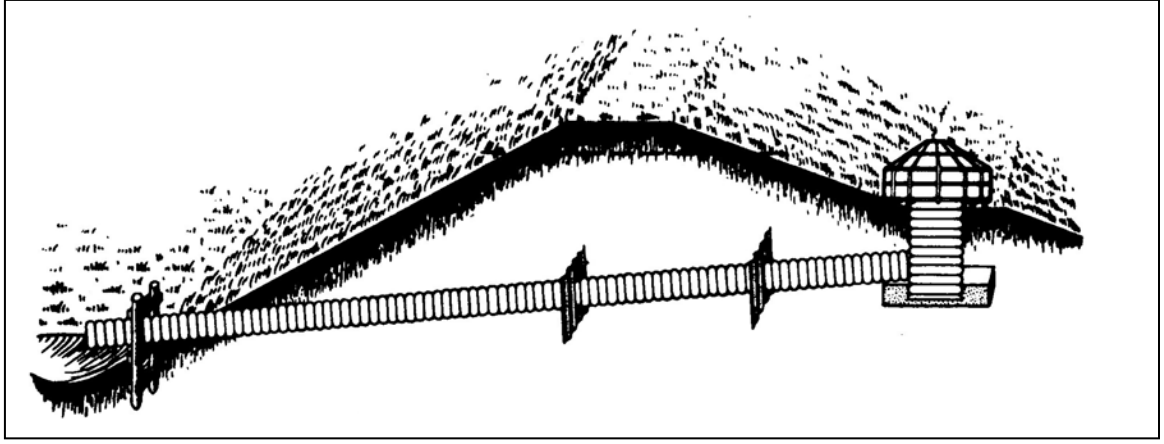


Figure 7. Illustration Pipe Drop Structure; Source NRCS Engineering Field Handbook, Chapter 6

Pipe drop structures must be built out of pressure rated materials, and sized properly to insure the design life and stability of the structure. These structures are susceptible to damage due to debris and the actions of ice on the structure.

Hooded Inlet Structures – Hooded inlet structures are essentially culverts with a unique inlet design. A hooded inlet structure with anti-vortex plate is shown in Figure 8.

The inlet of the pipe is cut at a 45^{O} angle and installed with the longer portion of the pipe at the top. This installation forms a 'hood' over the inlet, and drastically reduces hydraulic losses at the inlet.

This configuration greatly reduces the stage required over the pipe to establish full flow. Depending on the material used, water stacked to a depth of 1.4 to 1.8 times the pipe diameter will result in full flow of the pipe.

Figure 8. Illustration Hooded Inlet Structure; Source NRCS Engineering Field Handbook, Chapter 6

Hooded inlets structures are commonly used as the outlet for small ponds and detention basins. The use of these structures is discouraged in areas that are frequently mowed. Mowing operations can easily damage the hood over the inlet, and greatly reduce the design capacity of the pipe.

These structures can be plugged with debris or damaged by ice or frost action.

Culverts –Commonly used under roads and lanes to pass runoff from one side to another, culverts require temporary storage of water to develop the head pressure required to create full pipe flow. Design and evaluation of these structures must be done by qualified individuals, especially with respect to public roads.

References:

Engineering Field Handbook; Chapter 6, Grade Stabilization Structures Natural Resources Conservation Service, United States Department of Agriculture

Ohio NRCS Design Standard 410; Grade Stabilization Structures

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6.6.7 Side Inlet Structures

Description:

Closed conduits such as pipes or culverts designed to carry surface water beneath a berm, from agricultural fields to an outlet channel

Purpose:

Provide a stable structure to move water from higher field elevation to lower elevations

Where Applicable:

Relatively flat agricultural areas where surface water can be stored in the field temporarily before draining to an open channel

Advantages:

Can be used in flat agricultural areas to reduce required pipe sizes

Very small footprint required for structure

Limitations:

Land use must tolerate temporary flooding after runoff events

Not designed to carry peak runoff rates after significant storm events

Design & Construction Considerations:

Side inlet structures are fully described in the NRCS design standard 410, Grade Stabilization Structures. These structures are used in flat agricultural areas, where temporary flooding can be tolerated. The primary reason for the development of these structures is to significantly reduce the pipe size required for a given watershed size.

These structures can be constructed of corrugated metal pipe, steel pipe, plastic tubing, etc. They also may be designed for non-pressure or pressurized flow.

Side inlet structures should only be considered in agricultural watersheds with an average watershed slope of 2% or less. Steep watersheds will deliver water to the structure site, and may not have the storage capacity required for proper operation.

References:

Engineering Field Handbook; Chapter 6, Grade Stabilization Structures Natural Resources Conservation Service, United States Department of Agriculture

Ohio NRCS Design Standard 410; Grade Stabilization Structures

6.7 Open Channel Designs

6.7 Design Options and Considerations Open Channels

Once the design requirements for an open channel have been determined, selection of a channel type can be made. The following sections review different design and construction approaches to open channels.

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6.7.1 Trapezoidal Drainage Channel

Description:

A constructed trapezoidal channel typically excavated in flat landscapes to facilitate drainage.

Purpose:

To serve as an outlet for surface runoff and subsurface drains where natural drainage is inadequate for the proposed land use

Where Applicable:

At the upper end of small watersheds where the required depth for subsurface drain outlets must be maintained
Where soils and existing grades will not support natural stream function

Advantages:

Low material and construction costs
Minimal area required for construction and implementation

Limitations:

Will not support ecological services for water quality

Design & Construction Considerations:

Trapezoidal channels have been used for decades as an economical and efficient way to dispose of excess water. These channels have historically been built to address drainage needs where natural drainage proved insufficient for the proposed land use.

When considering the construction and installation of a trapezoidal channel, careful consideration must be given to the existing channel, and minimizing water pollution, and damage to fish and wildlife habitat. Section 2.2 of this manual reviews a process recommended by ODNR and Ohio EPA to evaluate existing channel to arrive at design options that will minimize water quality impacts in the channel.

In design of the channel, the designer must consider site geology, required channel capacity, required cross section and channel grade, channel stability, appurtenant structures required, disposal of spoil, vegetation establishment, and erosion control during and after construction. A brief review of these design points is given below. A complete discussion of these design points is given in NRCS Design Standard 582, Open Channel.

Geological Investigation – Geological investigations are required to properly identify materials anticipated during construction, and to evaluate allowable flow velocities and stability. Guidance for conducting geological investigations in Ohio is given in NRCS's National Engineering Manual, Subpart 531A.

Capacity – The required capacity for open channels will be determined by the project goals and problems that are to be addressed. Minimum design capacities may be determined by local or regional drainage curves or by the anticipated peak discharge from a design storm. Once the required capacity has been determined, water surface profiles must be determined using the guidelines described in TR 25. Manning's n values use to predict capacity should reflect the anticipated vegetation and other retardant factors within the channel.

Cross Section – Required cross section must be determined using the required capacity and channel grade. A minimum depth may be required to provide outlets for subsurface drains. Cross section dimensions should also consider bank stability concerns and construction equipment that may be used.

Channel Stability – Stable channels do not aggrade or degrade along the flowline, have stable banks that do not erode to the extent that the channel cross section is changed significantly, and do not for excessive sediment bars. Stability must be evaluated under two conditions. The 'As-Built' condition and the 'Aged' condition must be evaluated to check both maximum flow velocities and anticipated flow depth and overall channel capacity.

Appurtenant Structures – Channel design must include all structures required to ensure proper function of the channel and allow surface and subsurface flows into the channel with out significant erosion. Effects the proposed work will have on existing culverts, bridges, pipelines and other structures must also be evaluated.

Disposal of Spoil – Disposal of spoil should be done in such a manner as to prevent damage to adjacent land uses, prevents erosion at the site, and does trap existing drainage patterns with no outlet, and directs surface water to protected outlets.

Vegetation Establishment – Vegetation should be established as soon as practical on all disturbed areas. Seeding should be completed daily within the channel cross section, and upon final grading on berm areas. Vegetation requirements should be clearly stated in project plans and specifications.

Erosion Control – Excavation and construction practices should minimize erosion potential at the site. This may include regular seeding intervals, conducting work within reaches to limit the disturbed area, and reduce construction windows within individual reaches, and mechanical measures to control erosion.

References:

Field Office Technical Guide, Standard 582, Open Channel; Natural Resources Conservation Service

Technical Release 25, Design of Open Channels; Natural Resources Conservation Service

4.7.2 One-Sided Construction

Definition:

A one-sided channel is typically a constructed channel with a trapezoidal cross section. Construction is limited to one-side slope and bottom of the channel. The other bank is not disturbed unless a bank erosion or tile outlets need to be addressed.

Conditions where practice applies:

Where land drainage is needed for surface drainage or adequate depth for subsurface outlets.

Where the existing side slopes of the channel are stable.

Where capacity can be obtained with only bottom and one side-slope excavation.

Discussion:

This form of construction accomplishes the objective of providing adequate capacity, depth for subsurface outlets, reduced construction cost, and some ecological benefit.

The channel is constructed by using an excavator to reach to the opposite side slope toe and pulling the bottom and side slope towards the excavator. Care should be taken to extend the opposite side slope to the proper channel elevation. If the slope is not extended then the resultant side slope may become unstable resulting in erosion and loss of vegetation on the undisturbed bank. See typical one-sided figure.

Design and Construction Considerations:

Channel construction or modification is to be in accordance with an approved plan developed for the site. Technical Release No. 25, Design of Open Channels, shall be used in the surveys, planning and site investigations for channel work. Those portions of TR 25 relating to design criteria shall be followed, using the procedure best adapted to site conditions. All Ohio drainage and water laws shall be adhered to in the planning and construction of this practice.

In selecting the location and design of channels, careful consideration is to be given to minimizing water pollution, damage to fish and wildlife habitat, protection of forest resources and the quality of the landscape. Considering requirements for construction and operation and maintenance, selected woody plants must be preserved. Selection is to consider the overall landscape character, prominent views and the fish and wildlife habitat requirements.

Capacity

The capacity for open channels shall be determined by procedures applicable to the purposes to be served and in accord with related engineering standards, guidelines, and handbooks. The water surface profile or hydraulic grade line for design flow shall be determined in accord with guidelines for hydraulic design in TR 25. The “n” value for aged channels shall be based on the expected vegetation, along with other retardant factors, considering the level of maintenance prescribed in the operation and maintenance plan developed with the owners or sponsors. The required capacity maybe established by consideration of volume-duration removal rates, peak flow, or a combination of the two as determined by the topography, purpose of the channel, desired level of protection, and economic feasibility.

Cross Section

The required channel cross section and grade are determined by the plan objectives, the design capacity, the materials in which the channel is to be constructed, the vegetative establishment program and the requirements for operations and maintenance. A minimum depth may be required to provide adequate outlets for subsurface drains, tributary ditches, or streams. Urban and other high value developments through which the channel is to be constructed must be considered in design of the channel section.

Channel Stability

Characteristics of a stable channel are:

- The channel neither aggrades nor degrades beyond tolerable limits.
- The channel banks do not erode to the extent that the channel cross section is changed appreciably.
- Excessive sediment bars do not develop.
- Gullies do not form or enlarge due to the entry of uncontrolled surface flow to the channel.

All channel construction and modification (including clearing and snagging shall be in accord with a design which can be expected to result in a stable channel and can be maintained at reasonable cost. Vegetation, riprap, revetments, linings, structures or other measures are to be used where necessary to ensure stability.

The method applicable to site conditions in TR-25 shall be used in determining the stability of proposed channel improvements. Bankfull flow is the flow in the channel that creates a water surface at or near the normal ground elevation, or the tops of dikes or continuous spoil banks that confine the flow for a significant length of a channel reach.

Channels must be stable under conditions existing immediately after construction (as-built condition) and under conditions existing during effective design life (aged condition).

Channel stability shall be determined for discharges under the following conditions:

1. **As-Built Condition** – Bankfull flow, design discharge, or 10-year-frequency flow, whichever is smallest, but not less than 50 percent of design discharge. The allowable as-built velocity (regardless of type of stability analysis) in the newly constructed channel may be increased by a maximum of 20 percent if:

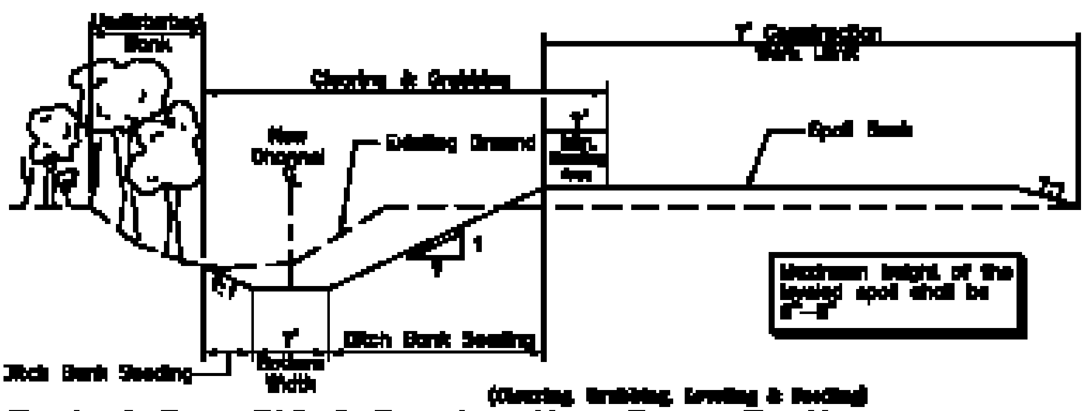
a) The soil and site in which the channel is to be constructed are suitable for rapid establishment and support of erosion-controlling vegetation,

b) Species of erosion-controlling vegetation adapted to the area and proven methods of establishment are known, and

c) The channel design includes detailed plans for establishing vegetation on the channel side slopes.

d) Provisions are made with the owner, operator or contractor to seed the channel sideslopes during construction. Also channel excavation and seeding operations will be limited to that time of year when seedings are within the growing season for the type of vegetation specified.

2. **Aged Condition** – Bankfull flow or design discharge, whichever is larger, except that it is not necessary to check stability for discharge greater than the 100-year frequency. Stability checks that are flow related are not required if the velocity is 2 ft/s or less. In cases where the seed and/or mulch are washed away by high channel flows, provisions will be made for immediate reseeding and/or mulching. Seed channel banks with tall fescue within 24 hours after the banks are excavated. Fertility and pH must be adequate to support vegetation.



Typical One-Sided Construction Cross Section

Not to Scale

Further Information:

References:

1 -Field OfficeTechnical Guide, Standard 582, Open Channel; Natural Resources Conservation Service

Technical Release 25, Design of Open Channels; Natural Resources Conservation Service

6.7.3 Two-Stage Channel

Description:

Channels constructed with flat benches such that lower flows are confined to a smaller, internal channel; constructed by excavating the ground adjacent to the existing channel down to the elevation of a self-forming floodplain; cutting the banks back to form a flat bench. The bench can be constructed on both sides of the channel or entirely on one side.

Purpose:

To confine base and low flows to a channel form that restores sediment-moving discharge and mimics natural stream function and ecology.

Where applicable:

Low gradient channels not undergoing incision (down cutting)

Channels with a high rate of deposition

Advantages:

Increased bank stability

Reduced maintenance due to sediment moving discharge of lower stage

Increases drainage capacity, lowering the water surface elevation of floods

Provides detention by creating valley storage

Allows beneficial characteristics of the channel bed and low banks to be preserved (e.g. course substrate, pool and riffle bed form, low bank vegetation, meander pattern)

Limitations:

Higher initial construction cost

Greater opportunity cost due to channel width

May not be deep enough to reach sub-surface drain outlets

Larger volume of excavated parent soil to dispose of

Design & Construction Considerations:

A two-stage channel generally exhibits both improved drainage function and ecological services, relative to traditional single-stage ditches, but at a significant increase in construction and opportunity cost.

Drainage Function - The wide bottom of a traditional single-stage, trapezoidal channel causes low flows to run shallow and slow, effectively reducing the channel's ability to transport sediment. Deposition of this sediment results in a need for frequent "dipping out" to maintain the design capacity. Placing these low flows into a lower stage, which is narrower and deeper, develops sediment-conveying (i.e. self-cleaning) discharge. (See *Hydraulic Characteristics of Compound Cross Section in Agricultural Drainage Ditches*, section #-# for further discussion.)

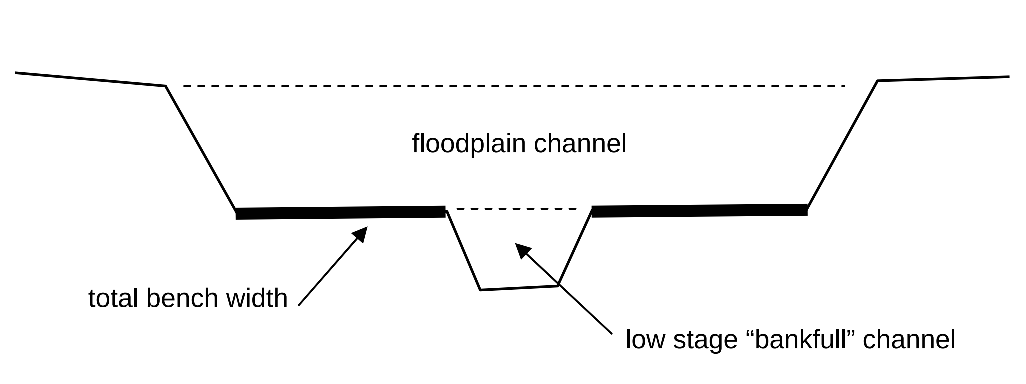
Aquatic Ecology - A two-stage channel has the potential to create and maintain better habitat than a single-stage, trapezoidal channel. The narrow, deep nested channel provides sufficient water depth for aquatic species during periods of low flow. Grass on the benches can provide quality cover and shade over the nested channel. Substrate in the nested channel is sorted, with fine sediment conveyed or deposited on the benches and course material forming the bed.

Cost - Earthwork and associated costs of two-stage channel can be greater than that of a traditional single-stage channel. Consideration of the earthwork is not limited to the expense of excavation but also the disposal of spoil. Removed material is usually inorganic parent material, rather than topsoil, and may be difficult to utilize or disperse. Constructing the bench completely on one side of the channel may facilitate construction.

The opportunity cost of a two-stage channel is the loss of potentially farmable land. A two-stage channel often results in a greater top width that a traditional single-stage channel of equal capacity. Every 10 feet of additional top width consumes over an acre per mile. These opportunity costs, if they include farmable land, may need to be compensated for.

Riparian Vegetation - Grass on the benches can provide quality cover and shade if watersheds are not larger than a few square miles. However, if benches and side slopes soils composed of parent material, often of very low hydraulic conductivity, low organic matter and high bulk density, vegetation may suffer.

Channel Stability - The reduction in the erosive potential of larger flows, as they are shallower and spread out across the bench, increases the stability of the channel. Stability of the banks may be improved where the toe of the bank meets the higher bench rather than the channel bottom. Here the bank height is effectively reduced and the shear stress (erosive force) on the toe of the bank is less. Also, the upper banks and bench material will be dry, not in constant contact with low flow. The low flow channel is generally centered between the higher side slopes to the benefit of both banks.



Two Stage Channel Cross-Section

Design – The low stage channel should be sized such that it carries the bank-full flow. Bankfull flow is generally determined through the use of a regional curve or reference reach study and usually corresponds to a less than 2-year return interval. The lower channel will typically have 1:1 side slopes and a course material bed. Bench elevation corresponds to a lower stage that carries bankfull flow. Total bench width should generally be 2 to 4 times the lower stage channel width. The depth and side slopes of the floodplain channel should be designed for stability and desired return interval discharge. Because of the uniform shape, Manning’s Equation can be used to calculate discharge. For additional design details see “*Sizing the three wide options, two-stage channels, constructed streams and over-wide channels”*.

References:

National Engineering Handbook; Part 654, Stream Restoration Design, Natural Resources Conservation Service, Unites States Department of Agriculture.

6.7.4 Over-Wide Channel

Description:

A two-step technique that starts with the construction of a simple cross section of adequate width to allow the second step, the self-formation of more complex inset stream. The second step is driven by stream power and the interaction of vegetation and sediment.

Purpose: To serve as an outlet for surface runoff and subsurface drains where natural drainage is inadequate for the proposed land use

Where applicable:

Entrenched channels where the channel incision is unlikely,

Where both drainage is needed and ecological services are to be maximized

Advantages:

Increased bank stability

Increases drainage capacity

Provides detention by providing valley storage

Limitations:

Higher initial construction cost

Larger volume of excavated parent soil to dispose of

Greater area of disturbance during construction

***Discussion*:**

<u>Final Form:</u> The essential difference between this practice and others is that this practice is in part self-forming. As such the specific final form is not imposed but at best predicted. Two distinct outcomes are possible. There will either be a defined inset channel with a bed free of vegetation or vegetation will become established across the entire bottom width. The threshold between the two types is the point of “channel inception” and is primarily a function of the amount of flow and channel slope but also vegetation and sediment load. As the watershed size and flow diminish upstream of this point no defined inset channel is predicted. The existing condition is perhaps the best indicator of which final form will develop (see design section).

<u>Sediment Sink:</u> With or without a defined channel an over-wide channel will function as a sediment sink.

Upstream of the point of inception with no inset channel it will in essence be a linear flow through wetland, an excellent sediment trap and will aggrade. The higher trapping efficiency is offset to some extent by the channels greater width, it has a bigger area to fill up. An over-wide channel upstream from the point of inception may or may not require more maintenance than a more hydraulically efficient channel.

Downstream of the point of inception the inset channel causes the same narrow-deep flow competent at maintaining the channel depth. However the principle mechanism of self-forming is the deposition of floodplain benches. This channel construction approach in effect creates a temporary void, a measurable volume that will eventually be filled up with sediment that would otherwise be transported downstream. Sediment deposition rates are a function of the floodplain height so deposition will slow but continue at rates similar to two-stage ditches, constructed or natural streams as the benches fully form.

Composition of self-formed soil benches are rich and active. Their development is a complex physical and biological process; driven by annual layers of vegetation and deposition. This may be critical for pollutant assimilation and riparian quality and an important distinction of this practice.

Ecologically the over-wide channels are endemic. They are a product of the existing watershed and local valley conditions resulting in the most appropriate fit.

Design criteria: (1-NRCS Standard 582)

Design Criteria:

Channel construction or modification is to be in accordance with an approved plan developed for the site. Technical Release No. 25, Design of Open Channels, shall be used in the surveys, planning and site investigations for channel work. Those portions of TR 25 relating to design criteria shall be followed, using the procedure best adapted to site conditions. All Ohio drainage and water laws shall be adhered to in the planning and construction of this practice.

In selecting the location and design of channels, careful consideration is to be given to minimizing water pollution, damage to fish and wildlife habitat, protection of forest resources and the quality of the landscape. Considering requirements for construction and operation and maintenance, selected woody plants must be preserved. Selection is to consider the overall landscape character, prominent views and the fish and wildlife habitat requirements.

Capacity

The capacity for open channels shall be determined by procedures applicable to the purposes to be served and in accord with related engineering standards, guidelines, and handbooks. The water surface profile or hydraulic grade line for design flow shall be determined in accord with guidelines for hydraulic design in TR 25. The “n” value for aged channels shall be based on the expected vegetation, along with other retardant factors, considering the level of maintenance prescribed in the operation and maintenance plan developed with the owners or sponsors. The required capacity maybe established by consideration of volume-duration removal rates, peak flow, or a combination of the two as determined by the topography, purpose of the channel, desired level of protection, and economic feasibility. The width of the channel bottom shall then be increased 3 times what is required for the channel capacity.

Cross Section

The required channel cross section and grade are determined by the plan objectives, the design capacity, the materials in which the channel is to be constructed, the vegetative establishment program and the requirements for operations and maintenance. A minimum depth may be required to provide adequate outlets for subsurface drains, tributary ditches, or streams. The channel will need to be constructed to avoid low areas that will lead to standing water during periods of low flow. This involves maintaining tight tolerances on the grade as well maintaining a constant elevation of the channel bottom from side to side.

Channel Stability

All channel construction and modification (including clearing and snagging) shall be in accord with a design which can be expected to result in a stable channel and can be maintained at reasonable cost. Vegetation, riprap, revetments, linings, structures or other measures are to be used where necessary to ensure stability.

The method applicable to site conditions in TR-25 shall be used in determining the stability of proposed channel improvements. Bankfull flow is the flow in the channel that creates a water surface at or near the normal ground elevation, or the tops of dikes or continuous spoil banks that confine the flow for a significant length of a channel reach. Channels must be stable under conditions existing immediately after construction (as-built condition) and under conditions existing during effective design life (aged condition).

Channel stability shall be determined for discharged under these conditions as follows:

1. **As-Built Condition** – Bankfull flow, design discharge, or 10-year-frequency flow, whichever is smallest, but not less than 50 percent of design discharge. The allowable as-built velocity (regardless of type of stability analysis) in the newly constructed channel may be increased by a maximum of 20 percent if:
a) The soil and site in which the channel is to be constructed are suitable for rapid establishment and support of erosion-controlling vegetation,
b) Species of erosion-controlling vegetation adapted to the area and proven methods of establishment are known, and
c) The channel design includes detailed plans for establishing erosion resistant vegetation on the channel side slopes.
d) Provisions are made with the owner, operator or contractor to seed the channel side slopes during construction. Also channel excavation and seeding operations will be limited to that time of year when seedings are within the growing season for the type of vegetation specified.

2. **Aged Condition** – Bankfull flow or design discharge, whichever is larger, except that it is not necessary to check stability for discharge greater than the 100-year frequency. Stability checks that are flow related are not required if the velocity is 2 ft/s or less.
In cases where the seed and/or mulch are washed away by high channel flows, provisions will be made for immediate reseeding and/or mulching.

Seed channel banks with tall fescue within 24 hours after the banks are excavated. Fertility and pH must be adequate to support vegetation.

References:

Depositional Response of a Headwater Stream to Channelization, East Central Illinois, USA Landwehr and Rhoads, River Research and Applications 2003

Statistical Relationships of Drainage Ditch Features to Watershed Characteristics, Probable Discharges and Maintenance Practices, Mecklenburg, Weeks Ward and Brown, ASAE Annual Meeting 2001

Water quality benefits of grassed fluvial features in drainage ditches.Ward, A., Moore, M.T., Bouchard, V., Powell, K., Mecklenburg, D., Cooper, C.,M., Smith, S.Jr., 2004. *Advances in Hydro-Science and Engineering,* 4: 1-14.

6.7.5 Constructed Stream

Definition:

A constructed floodplain and channel. Constructed streams includes a broad range of work that involve constructing channel bed and banks. Starting at one end of the spectrum a constructed streams is a traditional drainage ditch. The channel bed and banks are constructed with little resemblance to a self-formed stream. The range is construction of increasing degree of features based on self-forming channels with the intention of greater stream integrity, ecological services as well as sound engineering and drainage. Constructed features may include size and proportions of an inset channel, floodplain, bars or benches, meander pattern, bed-form, bed material, habitat features and various channel training structures.

Conditions where practice applies:

Where channel incision is probable

High bedload streams

Where there is some urgency in establishing habitat or aesthetics

Where the cost can be justified

Discussion:

All of the options presented employ to varying degrees on “natural channel design”. Each is a channel design based to some extent on aspects of self-forming channels. A wide range of outcomes are encompassed. Perhaps at one end of the spectrum would be a pipe sized based on flows predicted by the size of self-formed channels. Culverts sized and offset based on self-formed channel capacity and floodplain elevations is another. At the other end of the spectrum are dynamically stable streams channels and functioning riparian areas. A common intermediate example of natural channel design might be constructed channels and riparian areas based on self-formed dimensions but incorporate rigid grade control bed features -or channel training with ridged bank features. An often stated goal of natural channel design is the establishment of biological integrity. Another, perhaps more appropriate goal is channel form that will perform ecological services.

Design Criteria:

Width Over bank width. ADD Refer to *Sizing the three wide options, Two-Stage Ditch, Constructed Streams and Over-wide channels*.

Reference Reach approach

Dimension pattern and profile

See *Rainwater and Land Development*

Bed Material

Further Information:

ACOE Hydraulic Design of Stream Restoration

NRCS Stream Corridor Restoration