Applying knowledge to improve water quality
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Economics of Implementing Two-stage Channels

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Introduction

Two-stage channels (Figure 1A) are an alternative design for open channel systems, which typically are constructed and maintained as a trapezoidal shape (Figure 1B). The two-stage channel design is a more sustainable approach to surface drainage management that provides channel stability, additional drainage capacity, and water quality and habitat benefits. This fact sheet describes typical costs involved in constructing a two-stage ditch, based on nine case study examples from the upper Midwest region of the United States.

Figure 1. A.(top): construction of a two-stage channel. B. (bottom): traditional maintenance of a trapezoidal channel.

Channel stability, capacity, habitat and water quality must be factored into the overall return on investment when considering a two-stage channel. Return on Investment (ROI) considers the long-term benefits associated with the conversion of a trapezoidal channel to a two-stage channel. Benefits include a more self-sustaining stable channel that provides more capacity during high flows and varying levels of nitrogen and phosphorus management to protect downstream water quality. Additionally, some two-stage channels provide excellent habitat for birds and fish. Environmental value typically has been overlooked when considering the ROI for agricultural drainage ditches; nevertheless, environmental value has become increasingly more important. Environmental Value is defined by the quantity and quality of downstream water for commerce (i.e., shrimp harvesting) and recreation (i.e., swimming, fishing and wildlife). The two-stage channel may also be considered an important Best Management Practice (BMP) for resolving impaired waters that require a Total Maximum Daily Load (TMDL) allocation.

Traditional Channel Maintenance Costs

Traditional maintenance activities on a trapezoidal channel include mowing, woody vegetation and debris removal, "dipping out" or excavation of sediment that has accumulated on the channel bed, reconstruction of channel banks to reestablish the trapezoidal form, or some combination of these activities. Mowing (Figure 2) is the least expensive maintenance activity and costs less than $0.10 per linear foot. Removal costs of woody vegetation and debris largely depend on the size and number of trees present. The cost for removing deposited sediments (Figure 3) and reconstructing ditch banks depends on the size and depth of the channel, the degree of sediment accumulation or the nature of the sediment size and supply, elevation of subsurface drainage outlets, and the frequency of the activity. Excess sediment from field erosion requires conservation practices; bank and bed erosion may suggest channel enlargement due to changes in runoff. An informal survey of county engineers, drainage engineers, and contractors suggests that traditional clean out and reconstruction of the channel banks varies from $2-$18 per linear foot, depending on the type of equipment required to reach the bottom of the ditch, seeding costs and infrastructure replacement. Seed, riprap, drain-pipe replacement and geotextile or erosion blankets can add hundreds of dollars to the clean-out project depending on regulatory requirements and the degree of ditch dysfunction.

Figure 2. Mowing an agricultural drainage channel. (source: http://www.ferri-america.com/boom-mowers)

Figure 3. Removal of sediments on the channel bed during a traditional clean-out.

Two-stage Channel Construction Costs

Construction of a two-stage channel involves the excavation of a small floodplain bench within the confines of the existing channel (see Figure 1A). No excavation or manipulation of the channel below the floodplain bench is performed. The type of work and the costs of performing the work needed to construct a two-stage channel system are described in the sections that follow. Costs vary due to site-specific conditions, differences in rates charged by local contractors and suppliers, permit requirements. Nine two-stage channel projects from Indiana, Michigan, Ohio, and Minnesota were evaluated to determine the costs of implementing a two-stage channel design in an agricultural setting. Costs associated with two-stage channel construction can be grouped into the following categories: 1) earthwork, 2) subsurface drainage outlet protection, 3) erosion control, 4) surveying, engineering, and inspection, and 5) repair and maintenance costs.

Earthwork - includes equipment mobilization, site preparation, excavation, hauling, and disposal of soil removed during construction (Figure 4). Contractors may charge a fee ($500-$1,000) to mobilize and transport equipment to and from a project site. Site preparation may involve clearing and grubbing of the channel banks and top of banks to remove trees that may hinder earthwork ($100-$200 unit cost). Site preparation can be costly if dense stands of large trees are removed or infrastructure (i.e., gas or water lines) is present. Soil excavation to construct the benches is typically undertaken with a back-hoe or track-hoe excavator. Costs depend on the volume of material removed, generally expressed in cubic yards of soil excavated. Small volumes of soil can be disposed of near the channel boundary and may be used to construct a berm to prevent field erosion. Larger material volumes may require loading into a dump truck, hauling, and spreading or disposing of soil in an adjacent field or offsite. A bulldozer may be required to level and grade the transported material. Landowners may be able to take advantage of excavated soil to level out low spots in fields. The quality of the excavated material should be evaluated to determine whether spreading the material on a field may impact soil quality and productivity. Poor soils may need to be stockpiled for a period of time if topsoil in the field is removed. The excavated material from the channel is distributed and top soils are then replaced ($150-$200 unit price). Earthwork costs are typically between $2 and $6 per cubic yard in a rural, agricultural setting that requires little site preparation. Deep channels and channels that drain large watersheds typically require more earthwork volume moved and, therefore, incur greater costs. Transport and disposal of excavated soil can substantially add to earthwork costs.

Figure 4. Excavation and grading on a two-stage channel project.

Figure 5. A rock apron at the outlet of a subsurface tile in a two-stage channel project.

Subsurface drainage outlet protection – is the repair or construction of subsurface (tile) drainage outlets onto the two-stage benches or inset channel. The purpose of this is to move drainage water to the channel without causing failures to the subsurface or surface drainage systems. It includes installation of straight and sloped outlet pipes and drop structures. Costs associated with these practices depend on the number and size of structures that need to be constructed. Basic outlet protection such as rock aprons (Figure 5) and animal guards (Figure 6) are usually inexpensive ($50-$800 per outlet). Anti-seep collars (Figure 7) can cost between $400 and $800 per unit. Large drop structures (Figure 8) may be fairly expensive, costing $1,000-$3,000 per structure to install.

Erosion control – includes practices that reduce erosion during and after construction and are vital to ensuring stability of the two-stage channel. These practices may include site seeding (Figure 9), or installation of rip rap, rock chutes, and geotextile fabrics or natural erosion control materials (e.g., straw, coir fabric, jute netting). Seeding can involve allowing the existing seed bank to regenerate or planting with native perennial mixes for wildlife and conservation benefits. Every project should include an initial application of fast-growing, non-invasive annuals (i.e., *Lolium multiflorum* - annual ryegrass) to quickly estab-lisg ground cover after construction.

Seed costs typically are low and do not exceed $600 per acre depending on the seed mixture. A variety of seeding methods have been used in existing two-stage channel projects. Costs for seeding depend on the method used and

Figure 6. Animal guards on the end of a subsurface tile help prevent damage and clogging. (source: http://www.ipm.iastate.edu/)

Figure 7. Anti-seep collars installed on a subsurface drainage project. (source: http://swcd.mo.gov drainage.html)

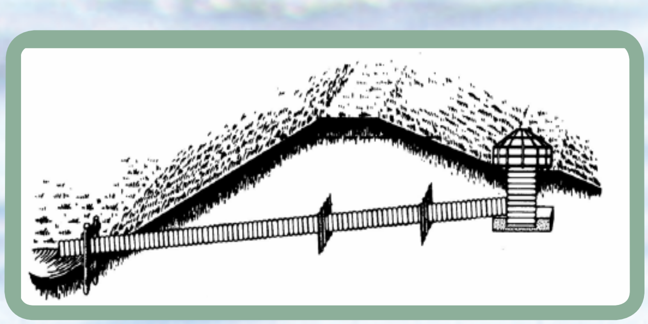

Figure 8. A schematic drawing of a large pipe drop structure. (source: NRCS Engineering Handbook, Chapter 6)

Figure 9. Site seeding using the broadcast seeding method.

range from $0 (natural regeneration) to $200 (broadcast seeding or drilling) to $2,000 (hydroseeding) per acre. Rip rap (Figure 10) may be used in areas where the risk of erosion is higher (e.g., channel bend) or seeding is not acceptable (e.g., bridge crossing).

Rock chutes (Figure 11) are used to transport concentrated surface flow from the field to the channel and cost $600-$1000 per structure. Geotextile fabrics (Figure 12) at $3-$5/square yard) or natural erosion control materials ($3-$5/square yard) are installed on sites where bare soil is unable to resist the forces of flowing water and are a temporary solution until vegetation can be established on the benches or channel banks.

Surveying, engineering, and inspection – costs vary depending on the partners involved in a project and may vary by state and even by county within a state. Channel surveying is typically done by a county surveyor, drainage engineer, or professional surveying group (Figure 13). Engineering design work is typically undertaken by the county engineer, drainage engineer, local Soil and Water Conservation District, Natural Resources Conservation Service office, or a professional engineering company. Costs are typically low for two-stage engineering design (<$5000), but this will depend on local requirements.

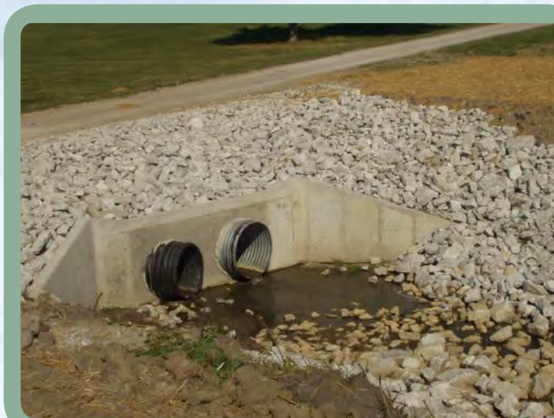

Figure 10. Rip rap can help stabilize stream banks, especially in transition areas. (source: http://seeversfarmdrainage.com)

Figure 11. Rock chutes concentrate runoff from fields and direct it into the ditch. (source: http://www.omafra.gov.on.ca/english/engineer/)

Figure 12. Geotextile fabric can be used to stabilize benches and banks until vegetation can establish.

Figure 13. An engineering survey of an existing trapezoidal channel prior to two-stage construction.

Repair and maintenance costs – involve any necessary repairs that may be needed to stabilize a site following the initial construction phase. Typical costs may involve reseeding areas where vegetation did not establish or fixing erosion problems caused by flooding before the site was fully stabilized. To date, none of the nine two-stage channel projects documented in this fact sheet, the oldest being 10 years old, have required any sediment clean out or dipping and each has remained stable over time.

Typical Two-stage Channel Costs and Distribution

The two-stage channels implemented to date cover a wide range of site conditions in Indiana, Michigan, Minnesota, and Ohio. Of the nine projects that we have obtained detailed cost information the least expensive two-stage channel project was $5 per linear foot and the most expensive was $50 per linear foot. Half the projects documents were approximately $20 per linear foot.

The cost breakdown by category is shown in Figure 14. Earthwork constitutes the majority of costs incurred in a two-stage construction project, followed by seeding type and method, and engineering design.

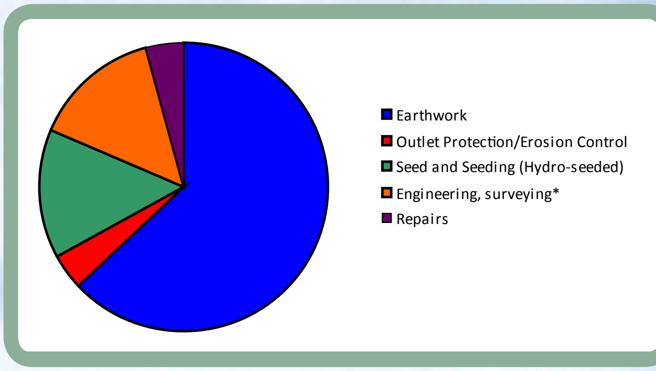

Figure 14. An example of the breakdown of two-stage project costs as percentage of total that is an output from The Ohiio State University's Cost Estimator Tool. (source: http://agdrainage.osu.edu)

The need to assign cost/value to ecosystem services must be considered in any channel enhancement project, given the demands of the Clean Water Act and the influence of these projects on downstream water resources such as lakes, rivers, and oceans. Adverse consequences associated with poor management of headwater channels have included hypoxia in the Gulf of Mexico, toxic *Microcystis* algae outbreaks in lakes, and degradation of the Great Lakes ecosystems. A channel enhancement project may include any of the factors described above and there are a number of additional site-specific factors that may need to be considered including existing conditions at the site, intensity of land management, and the designated beneficial use of the water resource. The Ohio State University has developed a simple, freely available cost estimator tool to help determine these factors and project costs associated with them. This tool can be found at http://agdrainage.osu.edu.

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