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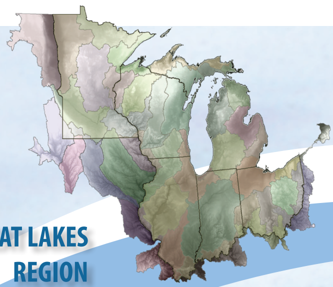

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Approaches to Enhancing Ecosystem Services in Modified Headwater Channel Systems

Jessica L. D'Ambrosio, Jonathan D. Witter, Andy Ward, Dan Mecklenburg
The Ohio State University Department of Food, Agricultural and Biological Engineering; The Ohio NEMO Program; Ohio Department of Natural Resources

Introduction

Headwater systems, because of their small size and high degree of past and present modifications, provide the most opportunity to enhance ecosystem services. This fact sheet presents common approaches to managing, maintaining, and constructing modified headwater channels with a goal to return some degree of ecological function to these systems that might not necessarily represent "restoration" to a pre-disturbance condition. The approaches presented here should be considered for low gradient (<1%), wadeable systems that might have drainage areas of 100 acres to 10 square miles.

Ecosystem Services

Ecosystem services are those benefits provided to humans by natural systems.[1] Lakes provide recreation or drinking water, forests provide fuel and fiber, and crops provide food. Ecosystem services also benefit the entire environment, not necessarily just humans. For example, wetlands filter out pollutants, reduce flood flows, and provide habitat for many species. A headwater stream system, consisting of a main channel with a particular pattern (bends and meanders), dimension (width and depth), profile (bed slope), and an active connected floodplain that floods frequently (Figure 1), provides a suite of ecosystem services that contribute to its ecological function. The diversity of headwater channel systems, from high energy channels supplying coarse gravel downstream to wetland streams to meandering channels with wide floodplains, allows us to manage and construct channels that, over time, require less maintenance while providing adequate drainage, better water quality, and improved ecological function.

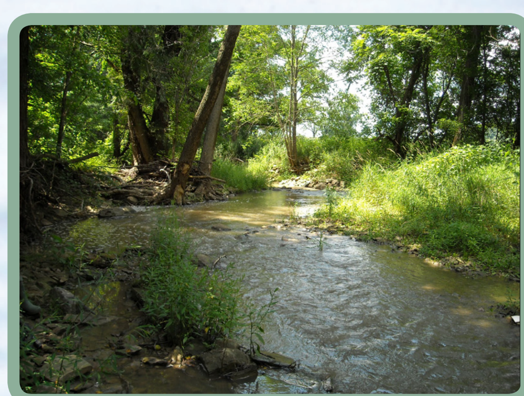

Figure 1. An example of natural headwater stream system with an attached floodplain.

Modified Channels and Their Maintenance

To improve drainage, collect subsurface drainage, and reduce the frequency of flooding headwater channels are modified to a typical trapezoidal geometry (Figure 2) such that 5- to 100-year recurrence interval storm events are contained entirely within the channel. These systems are cleaned out, or maintained, to remove sediments and woody vegetation that may accumulate because these channels are built too wide to effectively transport small flows in low gradient, low energy landscapes that might historically have been wetlands with no naturally defined channel.

Figure 2. A headwater channel that has been straightened and deepened to a trapezoidal geometry.

Rarely is there sufficient space or energy for nature to re-establish all the ecosystem services of a high quality stream system that existed prior to disturbance; however, occasionally one finds robust ditch systems that can provide desirable ecosystem services and ecological function while still providing adequate drainage.[2,3]

Approaches to Channel Enhancement

The goal for any channel project should be to leave, enhance, or establish a channel that is connected to an active floodplain. In a ditch system, the channel is called the inset channel. In a natural system, where the channel is attached to an active floodplain it is called the bankfull channel. If the bankfull channel becomes detached from the floodplain it is called an incised channel (Figure 3).

Figure 3. An incised channel that has detached from its original floodplain.

The main differences in enhancement approaches are associated with: (1) the space provided for the floodplain; (2) how the inset/bankfull channel is established; (3) the dimension, pattern and profile of the inset/bankfull channel; and (4) what measures are taken to stabilize the system.

The approach selected depends on a variety of factors based on site-specific information and project goals including, but not limited to: a real or perceived problem being caused by the system (i.e., meander migration), available funding, meeting state or federal regulations, site-specific conditions, willing landowners, acute toxic problems, reducing flooding or erosion, promoting agriculture, development or industry, or protecting native species and habitats. We briefly discuss the most common approaches as well as their advantages and disadvantages.

DO NOTHING

The *Do Nothing* approach is simply leaving the system in its current state. It is common for channels to go through a period of initial stabilization after construction or a maintenance activity. Allowing these adjustments can help channels achieve needed drainage functions, some level of ecological services, and may even result in a more stable system. This approach is the least expensive and may be the best solution if some ecosystem functions are already present in the system as a result of recovery, or the costs of enhancing the system outweigh the benefits. Generally, if the system is not causing a problem, the *Do Nothing* approach should be considered.

PASSIVE ENHANCEMENT

Passive enhancement means stopping activities that cause degradation or prevent recovery to allow natural processes to return to a channel system.[4] Passive enhancement encompasses a range of options and might include changing land use in the watershed to prevent soil erosion and increase water infiltration; managing livestock to protect riparian vegetation and stream banks; planting native vegetation; keeping toxic chemicals out of the water; managing activities from construction sites, timber harvesting, and road building to prevent sedimentation; and choosing not to build, harvest, or graze in sensitive areas.[4]

The passive enhancement approach may be selected to target a specific ecosystem function or when resources are limited. This approach provides little to no engineering input, can be relatively inexpensive, and can greatly enhance certain impaired ecosystem functions. In highly modified channel systems, passive enhancement might include livestock fencing, purchasing conservation easements, invasive species removal, planting native vegetation, and establishing no-mow zones. Although passive approaches may have positive effects, the approach may not be viable for channels that have been so degraded that recovery can take decades or longer, especially where accelerated erosion of high banks is severe.[1]

TWO-STAGE CHANNEL SYSTEM

The development of silt bars or benches within the channel bottom reflects natural adjustments to maintenance or channel disturbance. The bench acts as a floodplain within the over-wide and over-deep channel to dissipate energy. Benches also help to confine low-flow in the large drainage channel within a well-defined small channel in the center of the large channel, thereby protecting banks of the large channel from erosion. Observations of naturally formed benches (Figure 4) have led to a procedure to construct these features as an approach to enhancing ecosystem function in a channel.[5,6] This approach can be considered a floodplain creation approach and often is referred to as a two-stage channel (Figure 5).

Figure 4. In an existing modified channel system, nature has formed a meandering inset channel and attached floodplain (benches).

The primary goal is to allow existing channels to efficiently transport sediment using natural processes with little maintenance while allowing adjacent activities on the landscape to continue. The overall benefit to the system will be stability requiring little or no maintenance, increased drainage capacity, reduced flow depths during high flows, and reduced sediment lost from the system. A key ecological benefit of this approach is that vegetation is left along the fringe of the existing channel and no work is done to reshape or narrow the current channel. This preserves existing in-stream ecology and greatly reduces construction costs. This approach can improve water quality particularly for nutrient uptake and removal by improving soil-water interactions on the benches, which function more like long, linear wetlands. The best locations for the two-stage channel approach may be where benches already are naturally forming because: (1) there is an available supply of very fine sediment at the bottom of the channel; and (2) a major part of the flow entering the channel is subsurface drainage, which contains very little sediment so this flow picks up sediment once inside the ditch. Shallow ditches draining small drainage areas are the most cost effective and have the highest the water treatment potential. Average construction costs of this approach might range from $5 to $50 per linear foot.

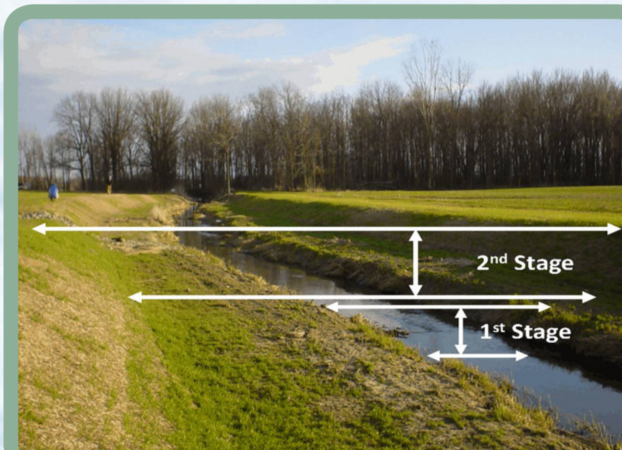

Figure 5. A two-stage channel with a low flow inset channel (1st stage) and a constructed floodplain bench (2nd stage) within the ditch.

SELF-FORMING SYSTEM

The self-forming approach establishes initial conditions for channel system development, having both a desired target stable end state and beneficial ecosystem services as natural processes evolve. The self-forming approach typically involves excavating the bed of a channel to an over-wide width and allowing natural processes to develop bars, benches and an inset channel that is stable and sustainable by natural depositional processes (Figure 6). The self-forming approach is, in effect, creating a valley without a flood-plain, which results in the spreading of channel flows at low-flow rates. Herbaceous vegetation quickly establishes in the bed of the channel, which promotes sediment deposition.

One of the main benefits of this approach is that it allows space for the system to self-organize to a form that optimizes existing watershed and valley conditions. Depending on these conditions, the approach may result in a well-defined channel or may represent more of a wetland-like system. Another benefit is that the benches form from sediment and associated pollutants that would otherwise be transported downstream acting as both a sediment and pollution sink. This sink occurs at an accelerated rate in the early stages of succession and diminishes to natural rates as the benches become higher. Additionally, because the benches are self-formed they have better soil structure and much higher organic matter content than might be found in constructed benches.

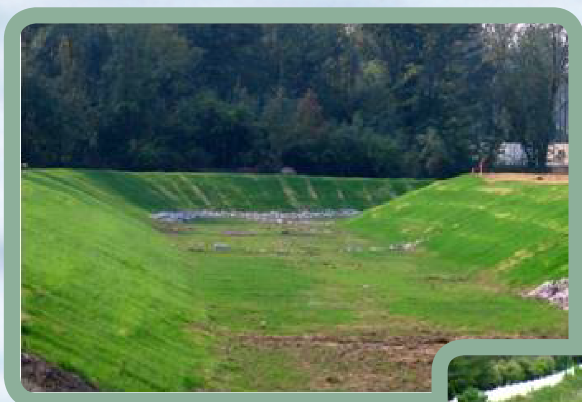

Figure 6. A self-forming channel just after construction (above); the same channel three growing seasons after construction (right).

Locations where the self-forming approach is suitable include low-gradient channels that are not prone to incision; channels transporting low quantities of coarse bed material, where vegetation will be vigorous and unlimited; where in-stream habitat and biota already might not be achieving their attainment status; or where early succession habitat is encouraged. In many cases the cost of this approach will be similar to that of a two-stage ditch.

CONSTRUCTED CHANNEL SYSTEM

The constructed channel approach, involves construction of the channel itself and typically the floodplain. Designs may reconnect channel-forming flows to the floodplain either by raising the bed of the channel to the existing floodplain or by excavating the floodplain down to the channel (Figure 7). This approach may include channel shaping such as meanders, riffles, and pools. Channel structures often are used to improve aquatic habitat functionality, grade control and provide bed and bank stability. These structures include a combination of large rocks and the root masses and trunks from trees. There are numerous methods for determining the criteria for constructed stream design that require a sound understanding of theory and careful consideration of the applicability of the chosen approach to a particular project.[7] The constructed stream approach may be better suited to sites that have stabilized from past disturbances, where past and future land use change is well-known, or where adequate knowledge of sediment transport and fluvial processes are well understood.[1,8,9] The primary benefit of this approach is that can provide an immediate solution to unstable channel erosion problems. The constructed stream approach requires significantly more engineering and materials costs than other channel enhancement approaches with some construction cost estimates ranging from $50 per linear foot in agricultural settings to more than $200 per linear foot in urban areas.[10]

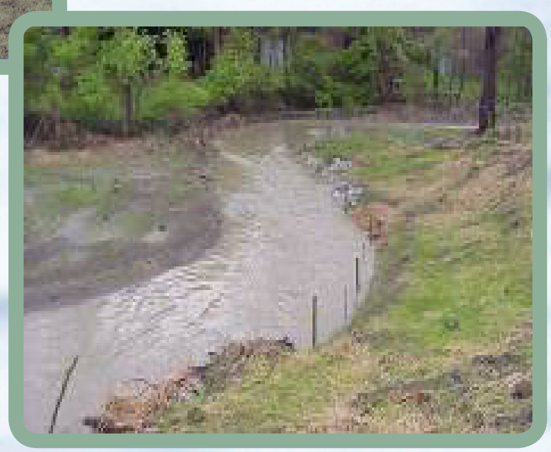

Figure 7. Constructing a channel and floodplain (above); the channel immediately after construction (right).

Conclusions

Various strengths and weaknesses of each approach become evident in different settings and given various site constraints with the best approach being the one that provides the most ecological services given the site conditions; therefore, enhancement of ecosystem function potential should follow a priority or weight of evidence approach[11] to determine the best option for a given site or conditions at that site.

To evaluate the feasibility of a project, it makes sense to compare project objectives and performance goals to determine if the end outcome is adequate even if it should not result as was planned over the long-term.[1] At any location, a "*Do Nothing*" approach always should be considered. When more "active" approaches are selected, the primary objective should be to re-establish contact between the channel and its floodplain to transform unstable channels into stable channels that develop and maintain their dimension, pattern, and profile over time.[12,13] It is important to evaluate multiple approaches at any given site and choose the approach that best fits project goals and site conditions.

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