Controlling Gully Erosion with Earth Dams in North-Central Texas

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Introduction

Displaced sediment pollutes water bodies, diminishes channel storage for flood control, and destroys aquatic habitat. Loss of topsoil also degrades farmland, reducing its ability to sustain crops and degrade pollutants. Gully erosion is a significant problem in the Eastern Cross Timbers physiographic province where hardwoods have been cleared for agriculture and housing developments, exposing sandy soils to rainfall and erosive runoff. This article describes the use of earth dams for controlling gully erosion in part of the Eastern Cross Timbers of north-central Texas (Figure 1).

Study Area

Low sandy hills and knobs developed on outcropping rocks of the Upper Cretaceous Woodbine Formation characterize the Eastern Cross Timbers physiographic province. The Woodbine Formation contains fine-textured sand and sandstone, with interbedded shale and clay, deposited in transitional (shoreline) sedimentary environments (Peckham et al., 1963). Sandy loam soils developed on the Woodbine Formation are highly susceptible to water erosion (USDA, 1975).

In the early 1900's hardwoods in the study area were cleared for farming. Clearing led to gully erosion, which has washed away pasture and created safety hazards for cows (Figure 2). Vegetation in the study area consists primarily of scattered oaks, grassland, and invasive cedars.

Erosion Control Structures

Over the past eight years, the U.S. Natural Resource Conservation Service (NRCS) and the landowner have designed and built 12 small earth dams to control gully erosion in the study area. The dams were designed to trap runoff near the heads of gullies and thereby prevent the gullies from growing.

Procedures for designing the ponds can be found in USDA (1997). They are too extensive to cover in detail here, but the basic steps follow. First estimate the volume of runoff for the design storm, in this case the 10-year storm (recommended for small ponds). Estimate the runoff volume using the rainfall amount, runoff rating (curve number), and catchment area. Find the maximum amount of rainfall expected in a

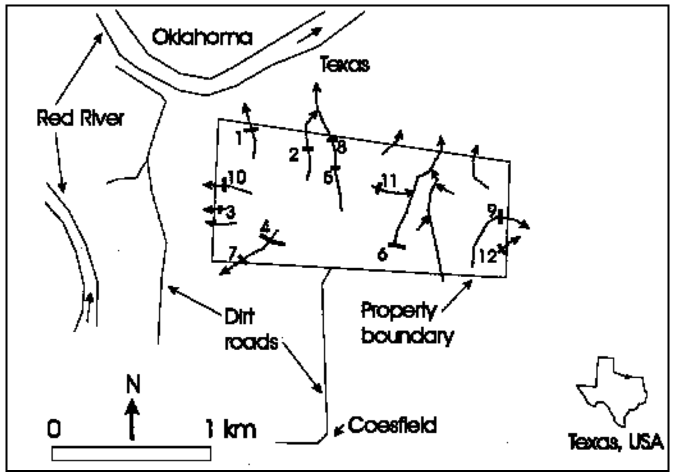

Figure 1. Location of study area, gullies (dashed), and dams. Base map from U.S. Geological Survey, Horseshoe Bend 7.5-Minute Quadrangle.

Figure 2. Gully erosion in study area.

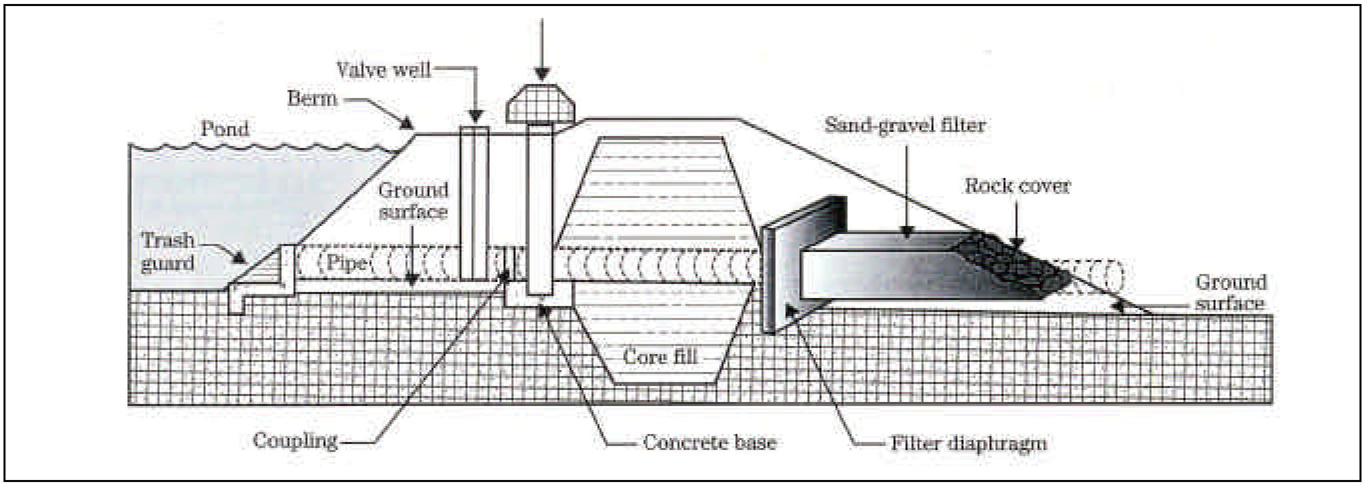

Figure 3. Barrel and riser schematic (USDA, 1997).

24-hour period (in this case 6.3 inches) for the appropriate recurrence interval in USDA (1986, Figure B-5).

Estimate a runoff curve number (ranging from 1 to 100, with higher values producing more runoff) from catchment land cover and soil characteristics. The study area has 50 to 75% cover in pasture/grassland/range, is not heavily grazed, and is in hydrologic soil group C (slow infiltration rate) (USDA, 1975). These characteristics render a runoff curve number of 79 (USDA, 1997).

Use the rainfall amount and runoff curve number to obtain a runoff depth (in this case 3.9 inches) from USDA (1997, Table 5). Multiply the runoff depth by the catchment area to obtain the runoff volume. Use the runoff volume to size the pond and compute peak discharge.

From USDA (1997, Figure 17), estimate the unit peak discharge from the time of concentration (time for runoff to travel from hydraulically most distant point of watershed to outlet), abstraction ratio (fraction of rainfall that does not become runoff), and rainfall distribution type. Multiply the unit peak discharge by the catchment area and runoff depth to obtain the peak discharge. Build the barrel and spillway to accommodate this discharge.

Estimate the time of concentration from USDA (1997, Figure 16) using the flow length (longest flow path in watershed), runoff curve number, and average watershed slope. Compute the abstraction ratio by dividing the initial abstraction (USDA, 1997, Table 6) by the rainfall amount. Find the rainfall distribution type (in this case Type II) on a map of four distribution types covering the U.S. (USDA, 1997, Figure 15).

Table 1 lists design parameters for two typical dams in the study area. Dams 5 and 6 have a barrel (pipe) and riser (pipe) structure, whereas the others have a barrel-only structure. In a barrel and riser structure, a riser placed pond-side, vertically within the dam, connects to a barrel that conveys water through the dam, discharging at the base of the dam on the downstream side (Figure 3). When water reaches the top of the riser, it falls with pressure and is forced through the barrel. A guard keeps sticks from falling into the riser. The riser and barrel can handle more water than a barrel-only structure.

Emergency spillways accommodate excess water during flood conditions. Such conditions are infrequent, but could wash out a dam if water levels rose too high. Typically, these spillways occupy either side of a dam, elevated about two feet above the pond's spill pipe (Figure 4). Texas regulations require that ponds and spillways discharge water to the original channel prior to leaving one's property. The spillways spread water over large areas to minimize erosion.

After completing each structure, the catchment areas were seeded with grass to hold the soil, thereby reducing erosion at the source. Bare areas of the study area are seeded each year, usually in the spring. Grass binds the soil and reduces sediment loading to ponds. Prior studies have shown that vegetation is an effective way to solve gully erosion problems, especially in small drainage areas (SCS, 1989).

Results

The dams have alleviated gully erosion throughout the study area, whereas unimproved gullies have continued to grow. For example, Figure 2 shows an unimproved gully, which has developed over a period of approximately three years. Over that time, approximately 1,500 ft3 of soil was eroded from the area covered in the photo. In contrast, Figure 4 shows a stabilized area where grass is beginning to take root (in foreground and background of photo).

Table 1. Design Parameters for Dams 1 and 6

Parameter	Dam 1	Dam 6
Drainage area (acres)	17.4	48.0
Volume of earth fill in dam (yd3)	8,483	7,749
Elevation of top of dam (ft)	697.0	697.6
Width of top of dam (ft)	12.0	12.0
Riser diameter (in)	—-	42.0
Barrel diameter (in)	8.0	21.0
Riser length (ft)	—-	14.5
Barrel length (ft)	126.0	114.0
Elevation of barrel inlet (ft)	693.0	694.3
Elevation of barrel outlet (ft)	667.0	671.5
Elevation of emergency spillway (ft)	695.0	695.6

Figure 4. Dam 1 (spillway in background).

Downstream, the dams reduce the amount of water flowing over the land surface. During wet periods, water spills through the dams, but vegetated and rock-lined discharge areas absorb hydraulic energy and slow erosion. High evaporation rates, approximately 70 inches per year (USDC, 1992), remove water from the ponds and reduce flow through the dams. Headwall retreat ceases upon inundating the upstream edge of a gully with pond water.

Earthen dams built to control gully erosion could also augment groundwater, by trapping surface water and enabling it to percolate downward. However, there is little potential for enhanced groundwater recharge in the study area because of low infiltration rates, small catchment areas (dams target gully headcuts), and high evaporation rates.

In addition to controlling erosion, the ponds provide a source of water for cattle and support aquatic biota. Cattails, willows, reeds, cedar, oak, and hickory have grown in and around the ponds. The ponds also support turtles, frogs, fish, ducks, and egrets. Younger ponds are turbid, but this problem clears with time as grass takes root in catchment areas. The main drawbacks observed at this stage of the project include increased mosquitoes and pond sedimentation.

Core measurements at several established ponds (from three to eight years old) showed an average of less than 1 ft of sedimentation (over the entire period). Accumulations were largest around the edges of ponds where they are fed by small rills. Potentially, sedimentation will deplete storage in the ponds and require periodic dredging. A 70% storage capacity can be maintained by dredging the ponds approximately every five years. Dredging will take place at the end of summer, when there is little or no water in the ponds. Dredged material will be used to fill eroded terrain, compacted, and seeded.

Periodic maintenance will ensure long-term project viability. Without dredging, the ponds would fill with sediment in approximately 20 years. The average cost of a pond/dam/spillway structure is about $10,000. Annual maintenance averages about $300 per structure, including dredging (when necessary), making repairs, and seeding bare catchment areas.

References

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