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Channel Aggradation by Beaver Dams on a Small Agricultural Stream in Eastern Nebraska

M. C. McCullough[1], J. L. Harper[2], D.E. Eisenhauer[3], M. G. Dosskey[4]

ABSTRACT

We assessed the effect of beaver dams on channel gradation of an incised stream in an agricultural area of eastern Nebraska. A topographic survey was conducted of a reach of Little Muddy Creek where beaver are known to have been building dams for twelve years. Results indicate that over this time period the thalweg elevation has aggraded an average of 0.65 m by trapping 1730 t of sediment in the pools behind dams. Beaver may provide a feasible solution to channel degradation problems in this region.

KEYWORDS. Beaver dams, channel aggradation, sediment, agricultural watershed.

INTRODUCTION

In eastern Nebraska, most land, which at one time was tallgrass prairie, has been converted to agricultural land use. This conversion has impacted stream channels both directly and indirectly. One major impact of row-crop agriculture is the increase in overland runoff and peak flows in channels. Between 1904 and 1915 many stream channels in southeastern Nebraska were dredged and straightened (Wahl and Weiss 1988), resulting in shorter and steeper channels. These changes have resulted in severe channel incision and stream bank instability in eastern Nebraska and throughout the deep loess regions of the central United States (Lohnes 1997). This trend towards continued channel degradation continues to this day (Zellars and Hotchkiss 1997), creating environmental and economic concerns.

Beaver affect geomorphology of streams in ways that may counteract channel degrading processes. Beaver dams reduce stream velocities, causing the rate of sediment deposition to increase behind the dam (Naiman et al. 1986) and giving the channel gradient a stair-step profile (Naiman et al. 1988). In a forested ecosystem, Naiman et al. (1986) studied beaver dams in 4th order and smaller streams and found that small individual dams could hold 2000 – 6500 m^3 of sediment with an average of 10.6 beaver dams/km of stream. They calculated that approximately 10,000 m^3 sediment/km of channel were retained by beaver dams in two forest watersheds in Quebec, Canada.

Beaver dams may help stabilize and aggrade incised stream channels in agricultural watersheds in eastern Nebraska. However, the influence of beaver dams on channel morphology and stability in developed agricultural areas is not known. The objective of this study was to determine if beaver dams can aggrade incised streams in agricultural regions.

METHODS

The study was done on Little Muddy Creek, Otoe County, in southeast Nebraska. The study stream reach is second-order, perennial and has 430 hectares of upland watershed. Land use in the watershed is mainly agricultural, with approximately 75% of the land in cropland and 25% in

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pasture or Conservation Reserve Program (CRP). The predominant soils in the uplands are eroded, fine-textured loess and glacial till soils with slopes from 2 – 7 % (USDA, 1982). In the drainages, soils are clay and silt loams and silty clays.

Little Muddy Creek is a tributary in the upper watershed to the Little Nemaha River, which drains into the Missouri River. Land clearing until the 1930's increased surface runoff, soil erosion from the uplands and sedimentation in the streams, which lead to increased flooding. To reduce flooding the Little Nemaha River and its tributaries were dredged, straightened and cleared of vegetation starting in the early 1900's. This disturbance is regarded as the main cause of present channel instabilities throughout the basin (Rus 2003). In the upper reaches of the basin, Muddy Creek was straightened between 1947 and 1953. Knickpoints from channel straightening migrated upstream and most effects on streambeds had already occurred (Rus 2003). In our study area, knickpoints are still evident, working up the 1st order portions of the streams (D.E. Eisenhauer, personal communication, 2003). A recent USGS study (Rus 2003) indicated that in the Little Nemaha River Basin, streambed degradation since settlement averaged 1.9 meters for 21 bridge locations throughout the basin.

The study stream reach was 1130 meters long and was divided into upstream, affected and downstream reaches. The affected reach, from 136 to 922 m in channel distance had beaver dams since 1991 and during our survey there were 6 active dams. The upstream reach, from 0 - 136 m, had not had any beaver dams during this same period. There were not beaver dams on the downstream reach from 922 to 1121 m until the fall of 2002 when three new dams were constructed (D.E. Eisenhauer, personal communication, 2003). Since the stream survey was completed in the spring of 2003, the sedimentation effects of the new dams in the downstream reach were considered to be of negligible significance. At the boundary between the affected reach and downstream reach was a driveway culvert crossing. By dividing the stream reach into upstream, affected, and downstream segments, a comparison could be made regarding relative sediment accumulation in areas with beaver activity versus no beaver activity.

The stream reach was surveyed over a period from February to April 2003. Beaver dam locations and the stream centerline were surveyed using a mapping grade GPS unit. Stream cross-sections were measured using a surveying total station. Ten cross-sections were surveyed in the affected reach at locations above and below each active dam. A total of five cross-sections were surveyed in the free-flowing reaches upstream and downstream of the affected reach to determine channel characteristics prior to beaver recolonization. All cross-sections were measured perpendicular to stream flow direction. Cross-section survey points included stream terrace, channel profile, thalweg, and water surface.

Three point bars were selected to sample sediment deposits. Soil cores were taken at three spots at each point bar and were analyzed for bulk density and particle size distribution.

A projected streambed was developed to determine the expected cross-section had the beaver dams not been built. To determine the projected streambed, a projected thalweg elevation was calculated. A linear regression was performed on thalweg points (Fig. 1) that occurred in the free-flowing reaches (upstream and downstream). Leopold (1994) also used a linear approximation of thalweg elevation versus distance downstream. The equation of the line was used to estimate the elevation of a projected thalweg at each cross-section in the affected reach of the stream. It was assumed that the projected thalweg would have occurred at the same location across the stream as the surveyed thalweg.

The surveyed streambed was plotted on the same graph as the projected streambed and the cross-sectional area of sediment accumulation was calculated by using the trapezoidal rule. To determine volume of sediment accumulated, the distance between two successive cross sections was multiplied by the average of their cross-sectional area. The total mass of sediment collected was determined by multiplying the calculated volume by the dry bulk density.

The effect of the culvert at a downstream distance of 910 m was taken into account when calculating the sediment accumulation attributed to beaver dams. Sediment accumulation was estimated for the 736 m upstream portion of the 785 m long affected reach.

Hydraulic grade was calculated using surveyed water surface elevations at each surveyed cross section and immediately upstream and downstream of each dam.

RESULTS

The stream profile (Figure 1) shows a significant amount of sediment accumulation. The projected thalweg was calculated using a regression line between surveyed thalweg points in the upstream free-flowing reach and the downstream reach. The stream terrace slope was calculated using a regression line for surveyed terrace points through the entire study reach. In this case, the stream terrace slope is 0.0046. The projected thalweg slope was 0.0054, which is very close to the slope of the stream terrace. This is to be expected because the thalweg and stream terrace should be nearly parallel, with the thalweg having a slightly greater slope to account for the gradual deepening of the channel with distance downstream.

Channel aggradation in the affected reach was calculated as the difference between the surveyed and projected thalweg elevations. The average channel aggradation in the affected reach was 0.65 m. The shaded area on Figure 1 represents an approximation of channel aggradation.

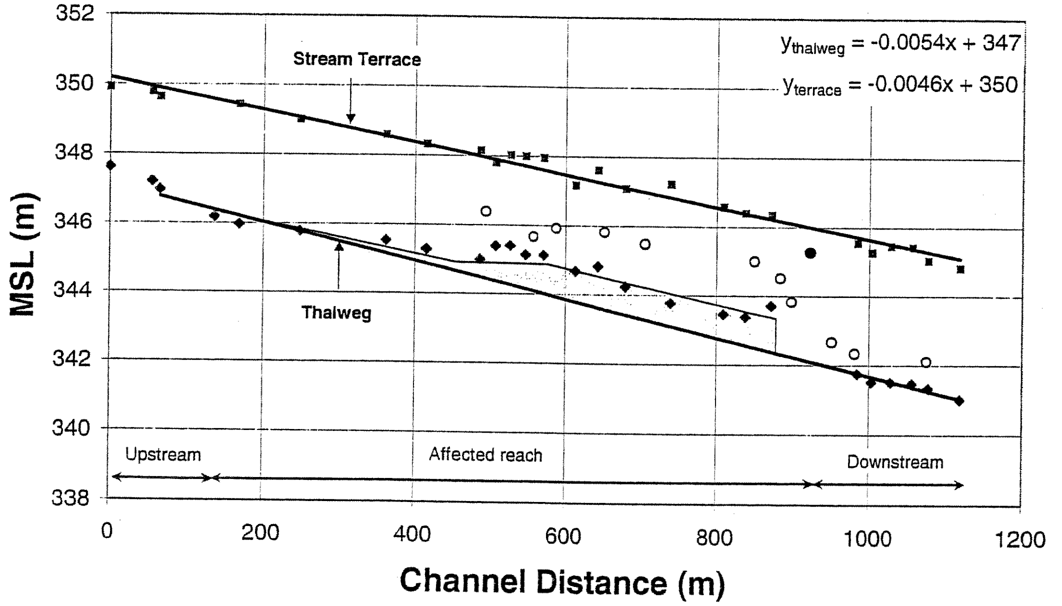

Figure 1. Stream profile of Little Muddy Creek near Burr, Nebraska. Squares are elevations of the stream terrace, diamonds are elevations of the thalweg, and open circles are elevations of tops of the dams. The closed circle at 910 m is a road centerline. The shaded area is an approximation of the sediment collected in the affected reach due to beaver dams.

Figure 2 shows a sample cross section. Once the projected streambed and sediment accumulation was determined for each cross section, the cross-sectional area was determined using the trapezoidal rule. The cumulative volume of sediment collected was determined by averaging two successive cross-sectional areas, then multiplying by the distance between the two cross sections. The sum of all these volumes in the affected reach was 1450 m^3 in 736 m of stream or 1970 m^3/km.

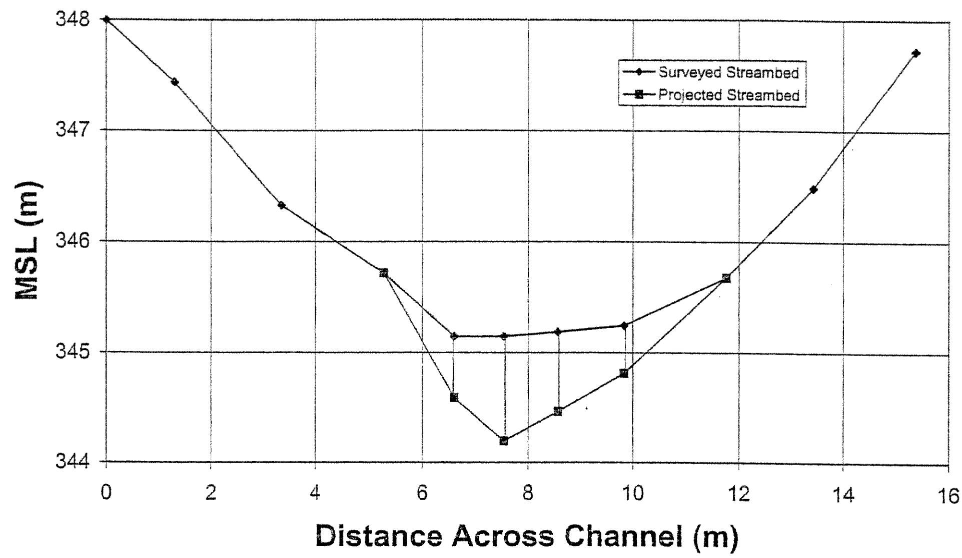

Figure 2. Sample cross section. This cross section, occurring at 550 m downstream, is a typical cross sectional profile. The top line represents the surveyed streambed, the bottom line represents the projected streambed. The trapezoids marked were used to calculate the cross-sectional area of accumulated sediment.

The dry bulk density of the accumulated sediment was determined for nine sediment samples, then averaged to determine an average bulk density. The average bulk density of all samples was 1.2 g/cm^3. The total mass collected was calculated to be 1730 t.

The hydraulic grade for the affected reach was 0.0039. This is a smaller slope than the projected thalweg (0.0056) and stream terrace (0.0046). Average water surface drop for all active dams in the affected reach was 0.45 m, creating a stair-step effect on the hydraulic grade line.

DISCUSSION

In this study, we found that beaver dams do affect sedimentation and aggrade stream bottoms in channels in agricultural streams. These results are consistent with similar studies in forest watersheds in Quebec, Canada (Naiman 1986). We found an average accumulation of sediment by beaver dams to be 1970 m^3/km, where Naiman (1986) found an average of 10,000 m^3/km. Naiman (1986) estimated an average of 10.6 dams/km stream, where we found 9 dams/km stream. Naiman's (1986) study was done in a relatively undisturbed boreal forest stream, while our study was done in an incised stream in a relatively disturbed agricultural watershed.

During the period of the topographic survey there were 6 active dams in the affected reach, however, abandoned dams were apparent. The abandoned dams also could have played a role in accumulation of sediment in the channel over the twelve years since beaver recolonized the area, no just the active dams.

The downstream reach of the stream had three new dams (less than 6-months old), the sedimentation effects of which were assumed to be of negligible impact to channel slope. Cross-sections surveyed in the downstream reach were done far enough away from new dams so as to avoid areas of recent sedimentation in order to more accurately represent the thalweg elevation of the "pre-beaver" steambed.

Beaver dams may be a viable solution to incision problems in this region and could be much less expensive than conventional engineering techniques. On this incised stream in Otoe County, beaver dams have caused channel aggradation. Where beaver have been active for the past 12 years, the stream channel bed has risen about 0.64 m and about 1730 t of sediment have been trapped in the beaver ponds (see Figure 1). By contrast, in a comparably sized watershed (405 hectares) in nearby Saline County, the cost of stabilizing 0.8 km of Sand Creek, a deeply incised stream with unstable banks, with traditional human-engineered drop structures has been estimated to cost $110,000 (Cermak et al. 2002).

Based on the stream length of 1130 m and an average of 1.0-1.2 beaver colonies per km of stream length (Chapman and Feldhamer 1982), this stream has about 1.2-1.4 beaver colonies, which is approximately 5-12 beavers. Beaver populations may have reached carrying capacity in this watershed and may go through a period of decline as stands of riparian forest are diminished. In some areas surrounding larger dams, riparian canopy was completely open.

Camp Creek, a similar stream nearby to Little Muddy Creek, was evaluated for beaver dam density and changes to hydraulic grade line. For Little Muddy Creek we found an average of 9 dams/km of stream, while Camp Creek averaged 7 dams/km. The ratio of average slope of the floodplain to hydraulic grade line was 1.2 for Little Muddy Creek and was 1.9 for Camp Creek. The problem of channel incision is regional in scale, as is the recolonization of beaver to smaller streams in agricultural watersheds.

It is expected that beaver would have inhabited the study reach to biological capacity prior to European settlement. Then, disturbance to riparian habitat and trapping pressures resulted in diminished populations and areas of local extinction by the 1930's. The native vegetation prior to settlement would have been tall grass prairie uplands with predominantly cottonwoods and willows in the riparian areas. The current riparian condition in which today's beaver are recolonizing is quite different from conditions prior to European settlement. Water flux tends less toward infiltration and more towards surface runoff, resulting in a flashy stream with more dramatic pulses of flow within shorter periods of time during the year. Observations of this study watershed indicate that beaver dams were damaged in smaller, 2-year return period storms. Dams were regularly damaged by storm flows, but beaver rebuilt them during the summer and fall to maintain their presence along this reach.

CONCLUSION

Surveying and sediment sampling were used to determine whether beaver dams cause channel aggradation. Results from this experiment showed that beaver dams did cause an increase in sediment, causing channel aggradation in an incisied stream in an agricultural watershed. In a 736 m affected reach of Little Muddy Creek, approximately 1730 t of sediment were collected behind beaver dams in the twelve years since beaver recolonized the stream. Within this reach there was an average of 0.65 m of channel aggradation due to sedimentation trapping by beaver dams. Beaver dams create a stair-step effect on the hydraulic gradient line, reducing flow velocities, causing sediment deposition behind dams.

Further research is needed to determine whether beaver dams are an ecologically and economically feasible solution to channel degradation. Most research regarding beaver habitat and populations have been done in forested or mountainous areas. The carrying capacity and ecological impacts of beaver in predominantly row-crop agricultural areas could be quite different from those found in forested and mountainous regions.

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REFERENCES

1. Cermak, J., Hawley, D. and L. Stahr. 2002. Sand Creek bank stabilization project. Project report for BSEN 480: Senior design project, Biological Systems Engineering Department, University of Nebraska-Lincoln, Lincoln, Nebraska.

2. Chapman, J.A. and G.A. Feldhamer. 1982. Wild mammals of North America: Biology, Management and Economics. John Hopkins University Press. Baltimore, Maryland.

3. Leopold, L.B. 1994. A View of the River. Harvard University Press, Cambridge, Massachusetts.

4. Lohnes, R.A. 1997. Stream channel degradation and stabilization: the Iowa experience: Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision, May 1997, Oxford, Mississippi.

5. Naiman, R.J. and G. Pinay. 1994. Beaver influences on the long-term biogeochemical characteristics of boreal forest drainage networks. Ecology 75:905-921.

6. Naiman, R.J., Melillo J.M. and J.E. Hobbie. 1986. Ecosystem alteration of boreal forest streams by beaver (Castor Canadensis). Ecology 67:2365-2369.

7. National Research Council. 2002. Riparian Areas: Functions and Strategies for Management. National Academy Press, Washington, D.C..

8. Rus, D.L., Dietsch, B.J. and A. Simon. 2003. Streambed Adjustment and Channel Widening in Eastern Nebraska. Water-Resources Investigations Report 03-4003. U.S. Geological Survey. Lincoln, NE.

9. United States Army Corps of Engineers. 1996. Southeast Nebraska Streambank Erosion and Streambed Degradation Control Design Manual. Hydraulic Engineering Branch, Engineering Division, Omaha District.

10. Wahl, K.L. and L.S. Weiss. 1995. Channel degradation in southeastern Nebraska rivers. In: Ward, T.J., editor. Watershed Management: Planning for the 21st Century.American Society of Civil Engineers, New York, New York.

11. Zellars, J.A. and R.H. Hotchkiss. 1997. Channel stability adjacent to highly irrigated land: Eagle Run Creek, Omaha, Nebraska: Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision, May 1997, Oxford, Mississippi.

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