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ABSTRACT

The papers in this book were presented at the National Conference on Hydraulic Engineering, August, 1988, Colorado Springs, Colorado. The objective of this conference was to provide a forum for discussion and exchange of information on issues related to hydraulic engineering. Discussion areas included sediment transport, open channel and stable channel design, alluvial fan hazards, overland flow and watershed modeling, scour and erosion, hydraulic structures, computational hydraulics, river mechanics, bays and estuaries, and numerical modeling. Papers were also presented that focused on the 50th Anniversary of the Hydraulics Division, ASCE. Papers from a special session on the changing role of the Bureau of Reclamation are also included.

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Effectiveness of Spur Dike Notching

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Introduction

During the last century, river-training structures--dikes and revetments--have been used to stabilize over 3,500 miles (5,600 km) of major waterways in the United States. Dikes are typically placed at an angle to the channel and force the flow toward an opposite bank protected with revetment that roughly parallels the channel. Dikes have been constructed of stone, timber pilings, and metal jacks; revetments have been made of wood mattresses, timber pilings, stone riprap, and articulated concrete. Quarry-run stone is presently the most common material for both dikes and revetments.

Comprehensive channel-training projects have been associated with morphologic changes along the Missouri and Mississippi Rivers. For example, the water surface area of the Iowa portion of the lower Missouri River decreased 34 percent between 1947 and 1976. Changes in lower Mississippi River low-stage water surface area between miles 320.0 and 929.0 during the period of dike and revetment construction (1964-76) were minor. However, the area of bars and islands decreased by 36 percent while the area of isolated dike-field pools increased from 0.21 to 5.37 square miles (54 to 1,390 ha) (Nunnally and Beverly 1986). These changes represent losses in the quantity and diversity of aquatic habitat. However, the dike and revetment structures themselves, and the relatively shallow areas of lowered velocity immediately adjacent to dikes, provide very valuable habitat to the riverine ecosystem (Sandheinrich and Atchison 1986). For example, velocities in the main channel of the study reach of the Missouri River tend to be higher than that preferred by most species of sport fish. However, velocities in the dike fields are only 25 to 35 percent as great (Pennington et al. 1988, Atchison et al. 1986).

In designing and maintaining river-training works, engineers can ameliorate environmental effects using several different techniques (Shields 1984). The most widely employed technique has been to construct notches in spur dikes (or to allow notches to remain in damaged dikes) to prevent sediment accretion below the dike and to develop diverse depth, velocity, and bed material within the dike field conducive to a diverse aquatic community. Despite the fact that over 1,500 notches have been constructed along the Missouri River and several dozen along the Mississippi River, the physical and biological effects are not well documented (Burch et al. 1984). The purpose of this paper is to describe the physical effects of notching several spur dikes along the middle Missouri River.

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Study Area

The dikes studied are in a reach of the Missouri River centered near Omaha, NE, between river miles 517 and 677.5. Flow is controlled by six main stem dams located upstream of the study reach. The channel throughout the study reach is flanked by stone dikes and revetments. Most spur dikes extend less than 100 ft (30 m) into the channel from the present bank line. The hydrology of the river in this reach and the operation of the associated projects are described by Slizeski, Andersen, and Dorough (1982).

The active portion of the channel is very uniform relative to unstabilized rivers, with a near-constant width of 650 ft (200 m) and sinuosity of about 1.2 above Omaha and 1.4 below. Discharges generally range between 25,000 and 35,000 cfs (700 to 990 cu m/sec) during the April through November navigation season, and are held between 6,000 and 20,000 cfs (170 to 570 cu m/sec) during the period December through March. Velocities in the main channel are rather high, ranging from 5 to 7 fps (1.5 to 2.1 m/sec) during navigation-season discharges. Velocities between spur dikes are lower, and small bars of fine-grained sediments sometimes develop there.

Notches were constructed in 20 spur dikes in the study reach during 1982 and 1983. All notches were about 20 ft (6 m) wide at the construction reference plane (CRP) elevation and had invert elevations of about 5 ft (2 m) below the CRP. The CRP is a sloping plane corresponding to water surface elevations for discharge that is equaled or exceeded 75 percent of the time during the navigation season. Stone excavated from each notch was piled approximately 50 ft (15 m) downstream to create a low reef, as shown in Figure 1. Results presented below are from 12 of the 20 dikes: five located below the Platte River confluence (the downstream reach) and seven located upstream of Omaha (the upstream reach).

Data Reduction and Analysis

Detailed, sequential hydrographic surveys were made of areas immediately adjacent to the notched dikes at roughly semiannual intervals beginning just before construction and continuing for 2 to 3 years. The areas surveyed extended from at least 100 ft (30 m) upstream of each dike to 200 ft (60 m) downstream of each dike, and 300 ft (90 m) channelward from the intersection of the dike and the bank line (Figure 2). A boat-mounted Raytheon fathometer was used to sound depths along closely spaced ranges. Data from 12 of the dikes were found to be of sufficient quality for further analysis after initial reduction and screening (Pennington et al. 1988).

Survey data were used as input to a kriging computer routine that interpolated elevations at each node of a grid for each survey. Whenever there were too few points for accurate interpolation, the program generated missing value codes. Surveys with insufficient spatial coverage were removed from the data base. Gridded data were used to create two- and three-dimensional contour plots and to compute the mean and standard deviation of the bed elevation referenced to the CRP.

Figure 1. Aerial View of Notched Dike at Extreme Low Stage Showing Reef just Downstream of Notch. Reef is Normally Submerged. (Photo Courtesy of K. A. Myers, US Army Engineer District, Omaha)

Mean depth and standard deviation of depth were computed for three equal subareas as shown in Figure 2. Areas enclosed by contours at elevations equal to 0, -2, and -4 ft (0, -0.6, -1.2 m) below CRP were measured from the two-dimensional contour plots using a digitizer. Additional details regarding data reduction and analysis are given by Pennington et al. (1988) and Myers (1986).

Results

Riverbed topography near the dikes responded to notching, especially in the downstream reach. The area of dike-field aquatic habitat increased after notching at most of the study dikes. Effects on area at the CRP elevation were minimal, but area enclosed by the -4 ft (-1.2 m) CRP contour substantially increased. Notching changed habitat area little in the upstream reach, but much more in the downstream reach (Table 1).

Depths adjacent to dikes also responded favorably to notching. Mean bed elevations adjacent to the 12 dikes decreased an average of 2.0 ft (0.61 m) after notching (Table 2). Greatest changes in mean bed elevation occurred immediately downstream of notches (subareas B) and in the downstream reach. Bed elevation change in the two subareas downstream of the notch (B and C) was nearly four times greater in the downstream reach than in the upstream reach. Comparison of contour

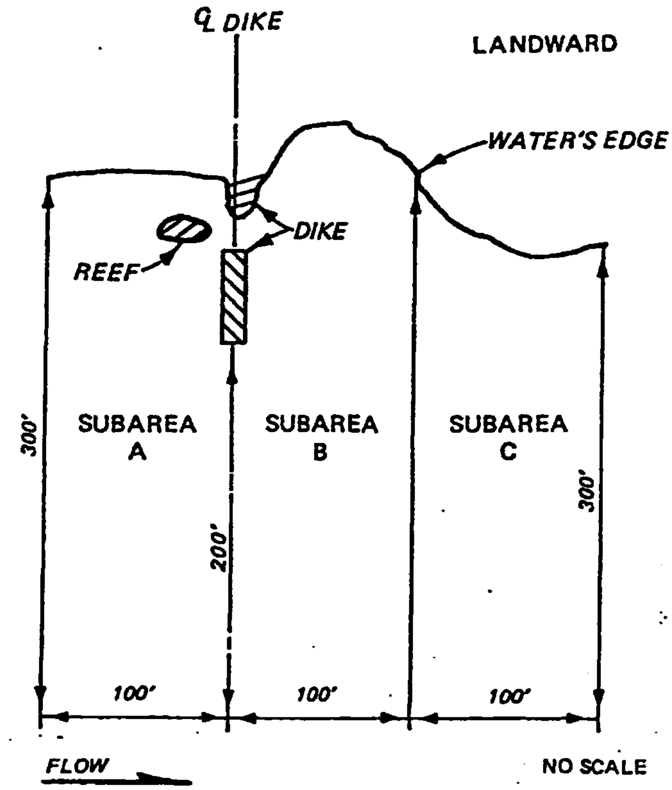

Figure 2. Sketch of Survey Area and Subareas

TABLE 1.--Change in Bed Area Below Indicated Elevation After Notching, in Percent (Acres*)

Location (No. of Dikes)	-4 CRP	-2 CRP	0 CRP
Both reaches (12)	11.2 (1.4)	7.0 (1.0)	3.5 (0.6)
Upstream reach (7)	1.2 (0.1)	-0.7 (-0.1)	-1.3 (-0.1)
Downstream reach (5)	32.1 (1.3)	21.4 (1.1)	12.0 (0.7)

*1 acre = 0.4047 ha.

TABLE 2.--Mean Bed Elevation Change After Notching in Feet (Meters)

Location (No. of Dikes)	Entire Area	Subareas A	Subareas B	Subareas C
Both reaches (12)	2.0 (0.6)	1.2 (0.3)	3.1 (1.0)	1.7 (0.5)
Upstream reach (7)	1.1 (0.3)	1.1 (0.3)	1.9 (0.6)	0.3 (0.1)
Downstream reach (5)	3.2 (1.0)	1.5 (0.5)	4.7 (1.4)	3.5 (1.1)

plots and standard deviations of depth revealed that bed topography near the dikes became more diverse after notching. The changes described above are based on the difference between the prenotching survey and the most recent survey. Surveys from the intervening period showed some variation, as shown in Figure 3.

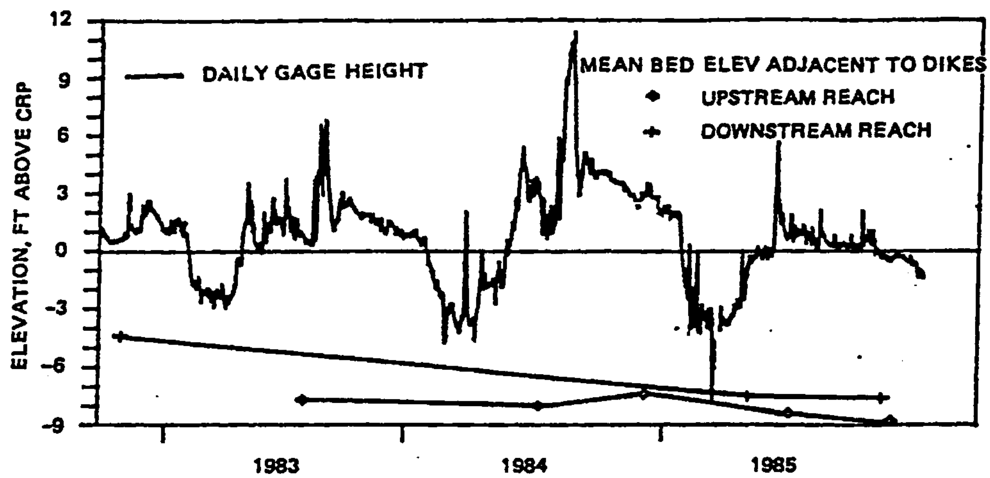

Figure 3. Stage Hydrograph for Missouri River at Blair, NE, and Mean Bed Elevations Adjacent to Notched Dikes. The Fall 1982 Elevation for the Downstream Reach and the Spring 1983 Elevation for the Upstream Reach Represent Prenotching Conditions

Correlation analysis was used to detect association between response variables (changes in area and elevation) and independent geometric variables such as bend radius and channel width. Dimensionless ratios of the variables were used in the analysis. Results were largely inconclusive. The only evident factor governing differential response to notching was the difference in stage hydrographs that was experienced in the upstream and downstream reaches. The downstream reach is influenced by uncontrolled flow from the Platte River and experiences stages that are generally higher relative to CRP and more variable than the upstream reach. Greater depths of flow through the notches would tend to cause more scouring.

Conclusions

Small but important increases in low-velocity channel border habitat can be achieved by an aggressive program of spur dike notching. Habitat response to a specific notch is difficult to predict but is related to the depth of flow through the notch.

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ENVIRONMENTAL GUIDELINES FOR DIKE FIELDS

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ABSTRACT

Dikes have been used to stabilize and train long sections of the Missouri, Mississippi, and other major meandering rivers. Design criteria for dike fields have usually been limited to flood control and navigation objectives. However, recently completed biological field studies have made possible formulation of general dike design criteria based on ecological considerations. As long as dike fields remain aquatic they provide extremely valuable habitat for fish and macroinvertebrates. The crux of the environmental design problem, therefore, is to design dike fields which do not fill with sediment yet still meet river training objectives.

Methods for controlling dike field sediment accretion include varying basic design parameters such as dike length and crest elevation, constructing gaps or notches in dikes, and using dikes which are not attached to the bank. Additional techniques which may be employed to manage existing dike fields include selective repair of failures, dredging deposited sediments, using dredged material to modify habitat, and placing additional rock or other structures underwater to develop aquatic habitat.

Dike notching is presently the most widely employed environmental feature. Although there is some controversy regarding notch effectiveness, the preponderance of presently available biological data favors notching. Most existing notches have been designed based on intuition, but a compilation of experience allows formulation of a more rational approach. A standard notch design should not be used; instead, a range of notch sizes and configurations should be constructed to provide spatial and temporal habitat diversity. Primary design parameters for notches include location (both within a dike field and along the crest of a given dike), shape, width, and depth.

Introduction

Dikes are longitudinal structures placed in waterways to develop and stabilize channels in desirable alignments. Series of dikes are often used to constrict low flows, thus scouring deeper channels and reducing dredging requirements. Dikes have been used widely on major alluvial rivers throughout the United States. Early training works were mainly single or multiple rows of piling clusters connected by stringers, but almost all structures built in the last 20-30 years have

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