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Fluvial Processes In Dryland Rivers

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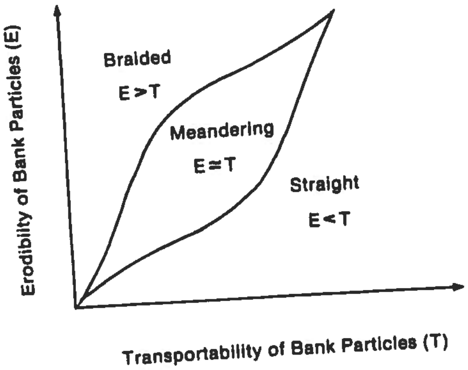

Fig. 5.18. Relationships among transportability of bank particles, erodibility of bank particles, and channel patterns. (After Brotherton 1979, p. 221)

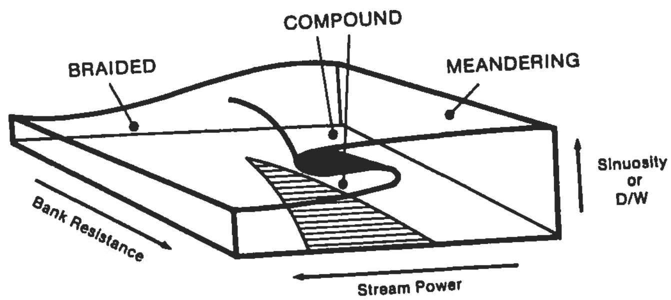

Fig. 5.19. Catastrophe theory representation of the relationships among stream power, bank resistance, and channel patterns. Compound channels lie in the fold or bifurcation set, two possible states of the channel exist depending on the magnitude of the discharge. (After Graf 1987a)

5.4.2 Channel Change and Recovery

The processes by which channel change from one type to another occurs are floods, changes in sediment inflows, and vegetation changes. Floods are almost always the forcing factors which convert meandering channels to braided configurations. In the western United States, floods were responsible for dramatic changes in channel patterns from meandering to braided on several streams of varying size (Table 5.6). The experience of the Gila River in eastern Arizona and western New Mexico was typical (Burkham 1972). Prior to the late 1890s the channel was narrow (a few tens of meters in some reaches) and meandering, but in 1905 a series of massive floods swept all traces of the meandering channel away and produced a braided channel more than a kilometer wide in some reaches. Dense phreatophyte growth and sedimentation narrowed the channel, expecially after 1940, and in the early 1980s the stream had a compound appearance,

Table 5.6. Representative changes in channel width along rivers in the western United States

River	Change	Time
Canadian River, Oklahoma	0.8 - 3.2 km	Flood in 1906
Rio Salado, New Mexico	15 - 168 m	1882 - 1918
Red River, Texas-Oklahoma	No change	1874 - 1937
Red River, Texas-Oklahoma	1.2 - .0.8 km	1937 - 1953
Cimarron River, Kansas	15 - 366 m	1874 - 1942
Cimarron River, Kansas	366 - 168 m	1942 - 1954
Platte River, Nebraska	1,161 - 111 m	1860 - 1979
S. Platte River, Colorado	790 - 60 m	1897 - 1959
N. Platte River, Wyoming	1,200 - 60 m	1890 - 1977
Gila River, Arizona	45 - 90 m	1875 - 1903
	90 - 610 m	1903 - 1917
	610 - 61 m	1917 - 1964
Salt River, Arizona	No Change	1868 - 1980
Fremont River, Utah	30 - 400 m	Flood of 1896

Notes: Sources include Hefley (1935), Bryan (1927), Schumm and Lichty (1963), Eschner et al. (1983), Hunt et al. (1953), Burkham (1972), Nadler and Schumm (1981), Graf (1983a).

apparently returning to its meandering geometry of almost a century before. Schumm and Lichty (1963) noted a similar series of events for the Cimarron River in southwestern Kansas.

In the cases listed in Table 5.6, change in channel pattern occurred without significant deepening of the channel. Occasionally pattern changes accompany incision and removal of large quantities of valley alluvium. The Fremont River near the Henry Mountains, Utah, experienced entrenchment of up to 7 m during a flood event in 1896 (Hunt et al. 1953; Graf 1983a). At the same time a braided channel 1.5 km wide replaced the original meandering 30 m wide channel (Fig. 5.20). Remnants of the meandering channel are now isolated on the surface of the terrace that once was the valley floor. Similar pattern changes and excavations occurred on the Paria River of southern Utah and northern Arizona (Hereford 1986).

The adjustment from braided channels back to meandering ones is much slower than the meandering to braided change (Fig. 5.21). Braided channels fill slowly with accumulated sediment. First a transitional form appears, the compound channel, and finally the meandering single channel dominates the system. Some observers refer to this process as "recovery," implying that the meandering form is indicative of some elusive state of environmental good health. Either the braided, compound, or meandering form might be a temporarily stable form, but in dryland rivers the change from one form to another is expectable and one condition may not be more likely than the others. Many fluvial sedimentary deposits reflect numerous changes in pattern over long time periods (Karl 1976).

The precepts of catastrophe theory are especially well suited to describing channel changes. If a single point on the surface of the catastrophe shown in Fig.

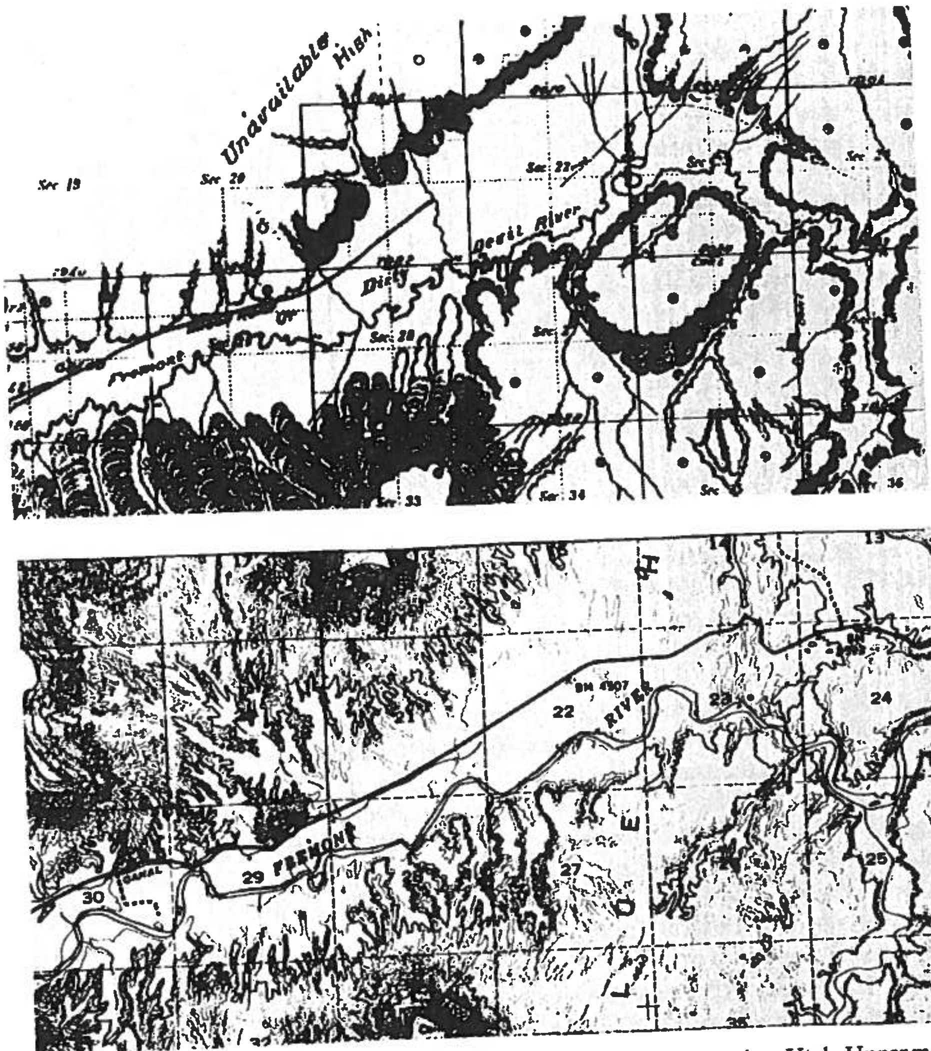

Fig. 5.20. Channel changes along the Fremont River, Henry Mountains region, Utah. Upper map from U. S. General Land Office Survey by A. D. Ferron of Township 28 South, Range 9 East of the Salt Lake Meridian, surveyed January 1883. Lower map from U. S. Geological Survey topographic map, Factory Butte, Utah, from aerial photography made in 1953. The river changed from a meandering to a braided pattern as a result of a flood in 1896 (Graf 1983a). Note especially the changes near the boundary of survey sections 22 and 23

5.19 represents the condition of a river reach at a particular time, system change is represented by moving the point about on the catastrophe surface. The path by which the point moves, determined by various combinations of stream power and bank resistance, can result in abrupt changes if the path crosses the fold area. Movement of the point might also depict relatively gradual change if the point moves in a path that avoids the fold. Observations on the Gila and Cimarron rivers suggest that the dramatic increases in stream power (and destruction of resistant

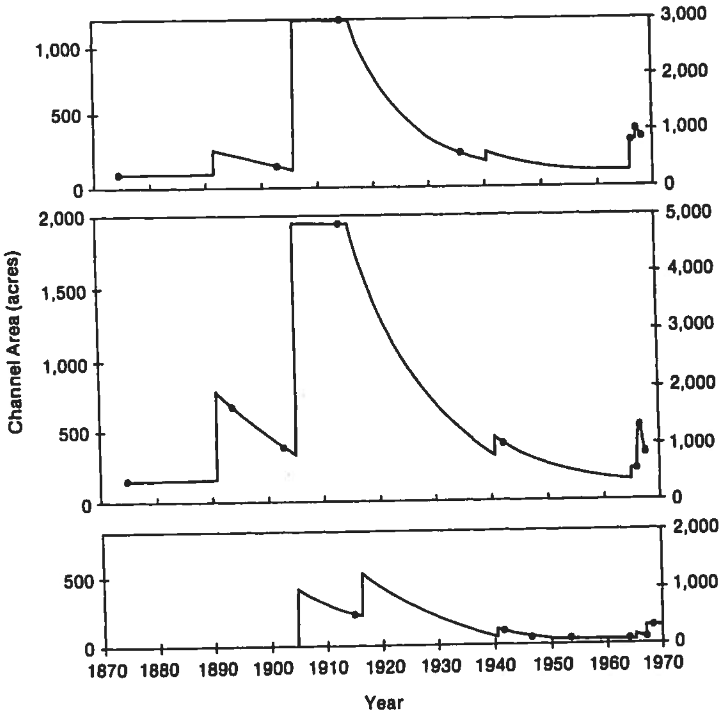

Fig. 5.21. Width changes along the channel of the Gila River, southeastern Arizona, showing the rapid expansion that occurred during floods followed by the much slower narrowing process which has been periodically interupted by renewed expansion. (After Burkham 1972)

channel-side vegetation) that accompany floods cause the point representing system conditions to move across the fold from right to left in Fig. 5.19. The results are abrupt reductions in sinuosity and depth/width ratios that characterize the change from meandering to braided. Later, reductions in stream power during flows much less than those of the large flood and increasing bank resistance from reestablished vegetation return the point to its original position by movement around the back of the fold in Fig. 5.19.

Quantitative description of the catastrophe surface and the conditions of the channels it represents is not yet common, but the general principle suggests that human management of the process is possible. Such management already occurs as an unintended byproduct of irrigation withdrawals which reduce flows and available stream power. Eschner et al. (1983) document consistent reductions in channel width of the Platte River in Nebraska between 1860 and 1979. The most dramatic change occurred near Cozad, Nebraska, where the channel width declined from 1,161 m (1,870 ft) to 110 m (177 ft) with gradual adjustment from braided to meandering geometry (Fig. 5.22). The channel changes have been produced by depletion of flows by irrigation efforts in upstream reaches where the changes have been greatest (Fig. 5.23; Karlinger et al. 1983).

When braided streams make the transition to compound and ultimately to meandering configurations, the narrowing process is accomplished by expansion

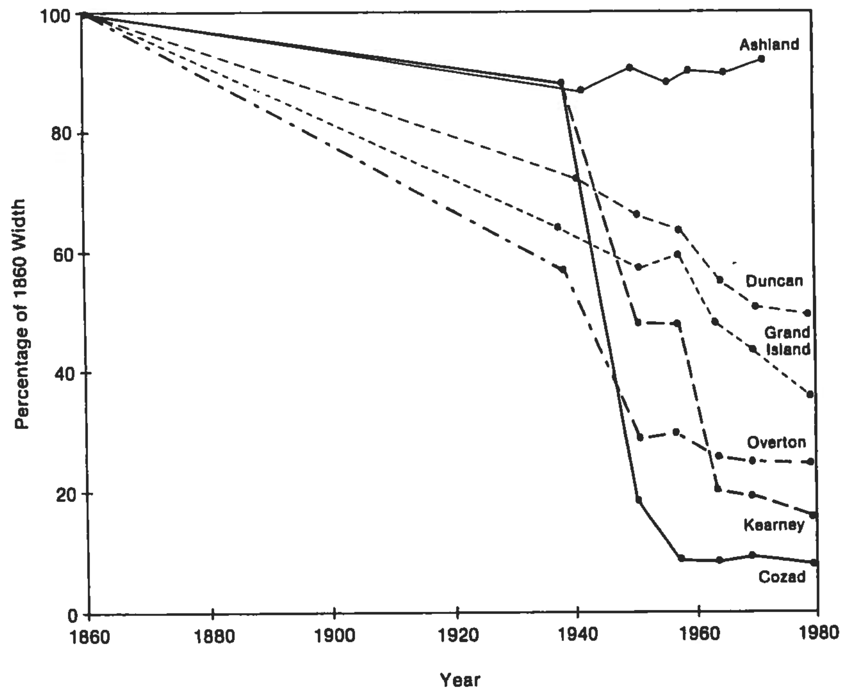

Fig. 5.22. Reductions in channel width of the Platte River, Nebraska, 1860–1979, based on maps and aerial photographs. Ashland is the site farthest downstream from irrigation diversions which deplete streamflows. (After Eschner et al. 1983, p. 30)

of bars and islands, stabilization of macro bedforms, and the attachment of bars and islands to banks by infilling of channels that once separated them. Karlinger et al. (1983) showed that in the Platte River, Nebraska, the stabilization of macro bedforms was critical to the narrowing process in a large braided channel. When sufficiently large flood flows were available to move large amounts of sediment through the system, macro bedforms in the channel appeared as waves of material several orders of magnitude larger than ripples and dunes. Crowley (1981b) showed that the macroforms are not the equivalent of dunes, but represent features with ramplike slopes facing upstream and fall faces oriented downstream. The macroforms migrate downstream under flood conditions at rates of up to 24 m (77 ft) per year (Crowley 1981a). Reductions in flood flows result in the stabilization of the macroforms and their conversion to islands that ultimately become attached to banks, resulting in channel narrowing. Nadler and Schumm (1981) showed that in the South Platte River, Colorado, the infilling of secondary channels led to rapid reductions in total channel width.

5.4.3 Horizontal Instability

Instability in channels resulting from changes in discharge, sediment load, and riparian vegetation may be manifest in horizontal migration of the channel form.