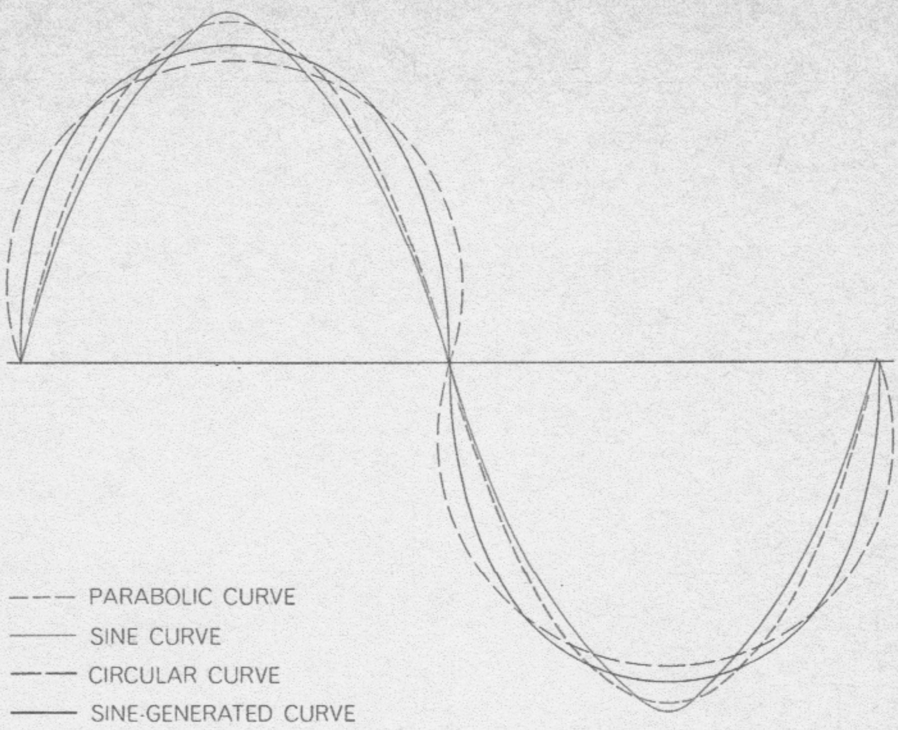
in the ability of water to erode, transport and deposit the material of the river's medium. Especially on a curve, the velocity gradient against the channel bank sets up local eddies that concentrate the expenditure of energy and localize erosion. An idealized flow pattern in a typical meander is shown in the top illustration on page 68. The left side of the illustration indicates the velocity vectors at various points for five cross sections along the curve. As the cross sections indicate, the depth of the channel changes systematically along the curve, the shallowest section being at the point of inflection and the deepest section at the axis of bend. At the same time the cross-sectional shape itself changes; it is symmetrical across the channel just downstream from the point of inflection and most asymmetrical at the axis of bend, the deeper section being always nearer the concave bank. The velocity vectors show a normal decrease in velocity with depth except at the axis of bend and near the concave bank, where the highest velocity at any point in the meander occurs somewhat below the surface of the water.

The right side of the same illustration shows the streamlines of flow at the surface of the meander. The maximum-velocity streamline is in the middle of the channel just downstream from the point of inflection; it crosses toward the concave bank at the axis of bend and continues to hug the concave bank past the next point of inflection. Riverboatmen navigating upstream on a large river face the problem that the deepest water, which they usually prefer, tends to coincide with the streamline of highest velocity. Their solution is to follow the thalweg (the deepest part of the river, from the German for "valley way") where it crosses over the center line of the channel as the channel changes its direction of curvature but to cut as close to the convex bank as possible in order to avoid the highest velocity near the concave bank. This practice led to the use of the term "crossover" as a synonym for the point of inflection.

The lack of identity between the maximum-velocity streamline and the center line of the channel arises from the centrifugal force exerted on the water as it flows around the curve. The centrifugal force is larger on the faster-moving water near the surface than on the slower-moving water near the bed. Thus in a meander the surface water is deflected toward the concave bank, requiring the bed water to move toward the convex bank. A circulatory system is set up in the cross-sectional plane, with surface water plunging toward the bed near the concave bank and bed water rising toward the surface near the convex bank. This circulation, together with the general downstream motion, gives each discrete element of water a roughly helical path that reverses its direction of rotation with each successive meander. As a result of this helical motion of water, material eroded from the concave bank tends to be swept toward the convex bank, where it is deposited, forming what is called a point bar.

Erosion of the concave banks and deposition on the convex banks tends to make meander curves move laterally across the river valley. Because of the randomness of the entire process, the channel as a whole does not move steadily in any one direction, but the combined lateral migration of the meanders over a period of many years results in the river channel's occupying every possible position between the valley walls. The deposition on the point bars, combined with the successive occupation by the river of all possible positions, results in the formation of the familiar broad, flat floor of river valleys—the "floodplain" of the river. The construction of a floodplain by the lateral movement of a single meander can be observed even in the course of a few years; this is demonstrated in the bottom illustration on page 68, which is made up of four successive cross sections surveyed between 1953 and 1964 on Watts Branch, a small tributary of the Potomac River near Washington.

The overall geometry of a meandering river is an important factor in determining the rate at which its banks will be eroded. In general the banks are eroded at a rate that is proportional to the degree with which the river channel is bent. Any curve other than a sine-generated curve would tend to concentrate bank erosion locally or, by increasing the total angular bending, would add to the total erosion. Thus the sine-generated curve assumed by most meandering rivers tends to minimize total erosion.



VARIATION IN CURVATURE of a sine-generated curve is less than for any other regular geometric curve. This means that when the changes in direction are tabulated for small distances along several hypothetical meanders, the sums of the squares of the changes in direction will be less for a sine-generated curve than for any other curve. The changes in direction were measured in degrees over 10 equally spaced intervals for each of the four curves depicted here. When the squares of these changes were summed, the following values were obtained: parabolic curve, 5,210; sine curve, 5,200; circular curve, 4,840; sine-generated curve, 3,940. The four curves are equal in length, wavelength and sinuosity.

Riffles and Pools

In the light of the preceding discussion it is possible to examine some of the hydraulic properties of meanders in greater detail. If a river channel is re-