done with some definite co-ordination so that a logical, systematic and connected improvement will result.

No two rivers are just alike in slope, discharge, character of bed and banks, nature and size of drainage basin, or kind and amount of sediment carried, but in general it is observed that they are alike in some particulars; that they all have a more or less winding course with a constantly varying hydraulic radius, and consist of a succession of pools where depths are greater than the average, separated by bars where depths are less than the average. The fact is now no longer overlooked that these bars are like submerged weirs and have a decided effect on the elevation of the water surface. The danger of the early methods of improving the Rhone by deepening shoals separately, and cutting through bars independently of their relationship to the remainder of the river, has been repeatedly dwelt on by engineers. Unless contracted artificially, this invariably facilitates the outflow of the water of the pool above the site of the work, with a consequent lowering of the surface, and often causes an ultimate decrease instead of an increase of depths. On the Rhone at La Mulatiere the level of the low water surface was reduced to 4.66 ft. in 17 years by a deepening of the channels on the shoals below.

It seems plain that each separate work in a river should bear a similar relationship to the others as do the links of a chain. This need not prevent the gradual application of the methods selected, but would require that each work should form a part of a definite, comprehensive scheme.

The use of contraction works seems more particularly adapted to the portions of rivers where ample discharge, considerable width, small slope and gentle flow are met with. The Rhine below Strassburg, the Elbe from its entrance into Germany, the Niemen through Prussia, the Rhone below Lyons, are foreign examples of rivers that have been improved by these means. In this country the Mississippi above the mouth of the Missouri is an excellent example of this class of work, and instances of its successful application are found in the Columbia, Missouri and Tennessee Rivers, and on the French Broad and Hiawassee, tributaries of the Tennessee.

The amount of depth attainable by this method is ordinarily very limited. If the contraction is overdone, in rivers with movable beds an excess of scour may result, accompanied by a lowering of the water surface and perhaps a flattening of the slope in the lower reaches; or, if the beds are formed of resisting material, an excess of velocity may be occasioned.

It is an elementary principle that movable river beds must ordinarily be protected wherever contraction works are used, for otherwise the effect is sure to be largely local and the material scoured out by the currents is likely to be deposited elsewhere, frequently on other bars where depths were ample before. The protection of the banks in such cases is usually far from simple, but the bottom protection is often much more difficult and costly. Sometimes this arises from the lack of suitable materials, sometimes from the width of river, sometimes from the character of the material of the bed and banks, but oftenest from the soft and shifting nature of the bottom. For these reasons the regulation of the Ohio by spurs and training works has been abandoned. Until sills for the protection of the river bed were adopted on the Rhone in 1882 the full benefit of the many years of regulation was not obtained.

It is doubtful whether more than a very few feet can be secured by this means in the average case without overdoing the amount of contraction. It has been stated by Prof. H. Engels, a well-known writer on this subject, that:

(1) Only rivers or long reaches of rivers in which natural erosion is fully developed are adapted to regulation. The navigability of unfinished rivers yet in a state of erosion can be improved with permanent results only by canalization.

(2) The most that can be accomplished by regulation is the desired adjustment of the slope of the low water line, and this only on reaches of uniform regimen and uniform characteristics.

(3) The feasible adjustment of the slope to be accomplished when the conditions are most favorable can only be established and brought about by constructive measures after the formation of that part of the channel which rises above low water is completed; after the conditions of the bed have adapted themselves to the change of energy caused by the formation of the mean and high water bed; in other words, after the erosion caused by this formation has come to rest.

(4) To secure the establishment and permanent preservation of the adjustment of slope, the irregularities of the bed in the longitudinal and transverse profiles are to be adjusted after reinforcing the low water shore, and the bed is to be strengthened where attacked by the water on account of the ground plan of the channel. Restriction of width alone will not bring about that degree of navigability which may be attained.

He also states that the depth attainable is expressed in the formula $d = \left(\dfrac{Q}{wk\sqrt{i}}\right)^{\frac{2}{3}}$ in which d is the depth; Q, the measured discharge; w, normal low water width; i, the adjusted slope, and k a constant corresponding to the constant of Chezy's formula. (Trans. Am. Soc. C. E., Vol, xxix, p. 220.)

If these views seem rather extreme as far as they bear on "unfinished" streams, the assumption that the gain is measured by the practicable amount of adjustment of the low water slope is open to much less question.

Dredging as an exclusive method of original improvement is seldom practised on interior rivers of the United States, except where the banks are comparatively low and unstable, the flow very gentle, and the discharge large. Navigable depths of 9 ft. in the Mississippi River below the mouth of the Ohio are now being supplemented by bank protection, the design being ultimately to protect the banks from caving by the use of brush mats and a rip-rap stone, and thus finally limit the bankfull channels to a predetermined width in order to accelerate the carrying velocity and insure regularity of regimen. This will also aid in maintaining depths and, perhaps, finally render much of the dredging unnecessary. Ten suction dredges of great capacity are employed in this work. It has been estimated from the surveys of 1908 that there were 749 miles of caving bank along the length of 790 miles of river between Cairo and the Red River, almost equivalent to one entire bank, and observations in 1892 indicated that 100,000 cu. yds. per mile fell into the river annually between Cairo and Donaldsville, La. It seems plain that until the banks can be protected nothing permanent or satisfactory can be expected. A recent plan for increasing this 9-ft. depth to 14 ft. proposes regulation of the low water slope by the addition of transverse sills combined with a contraction of the banks. Above the mouth of the Ohio and up to the mouth of the Missouri 8-ft depths at low water are maintained by dredging supplemented by the use of permeable dikes to restrict the river width at the bankfull stage to 2,500 ft. These permeable dikes encourage the deposit of silt and the growth of new banks.

Open river regulation is usually the first method studied for new projects. If the depths required for boats are not too great, if the river is wide and dams for canalization expensive, if the banks are low, requiring too many low-lift