irrigation. This project is being integrated by the Bureau of Reclamation and the Corps of Engineers of the U. S. Army and complies, in all respects, with the provisions of the Rio Grande Compact. One of the important features of the proposed project is the detention and control of silt on tributary streams, thereby reducing the average rate of silting of Elephant Butte Reservoir from about 17,000 acre-ft to about 5,000 acre-ft annually. The project will not eliminate the silt problem of the basin, of course, since it merely retains the silt load in reservoirs upstream from Elephant Butte Reservoir. It will alleviate a bad situation for many years, however, during which time it is to be hoped more adequate control measures will become available.

LUNA B. LEOPOLD,[34] JUN. AM. SOC. C. E.—The Rio Grande and Colorado River watersheds differ somewhat from many other large basins in that normal erosion in the semiarid areas is more widespread and more obvious than in humid areas. Therefore, there is a tendency to minimize the importance of watershed management as a factor that might influence the rates of sediment production.

The author states (see heading, "Prolonging the Life of Lake Mead: Land Management") that in the semiarid areas natural erosional forces are relatively so important that the best land management can have only minor effects in reducing the sediments carried by streams. It should be emphasized, however, that continued mismanagement could increase the sediment available to streams. In a watershed such as the Rio Puerco, an important sediment-producing tributary to the Rio Grande, gullying has proceeded so far that land management alone could have but negligible effect on the lateral widening of the gully walls and the deepening of the existing arroyos in their upper reaches. In the Rio Grande and Colorado watersheds, however, there are myriad small valleys which are not yet gullied and where land management, as a preventive method, can be effective in keeping sediment out of the main channels. Flash flows tend to clog the main channel with debris that might be moved into the reservoirs by larger floods. The larger the area of watershed dissected by arroyos, the larger will be the percentage of storm rainfalls capable of producing flash flows in the tributary channels.

The history of arroyo cutting of the Rio Puerco will serve to illustrate the rapidity with which dissection of such alluvial valleys proceeds and the effect of recent erosion on the problem of sedimentation of reservoirs. The Rio Puerco comprises 23.6% of the total area above Elephant Butte Dam. The average annual runoff at its mouth[35] amounts to 62,000 acre-ft. Stream-flow records at San Acacia, just below the mouth of the Rio Salado, indicate that the Rio Puerco contributes 6.6% of the runoff and 60% of the suspended load passing that station.[36]

Prior to 1885 the Rio Puerco, an ephemeral stream, was subject to numerous small floods and occasional great ones, the water spreading over a wide and

[34] 1st Lt., Army Air Forces Weather Service, Los Angeles, Calif.

[35] "Rio Puerco Watershed, New Mexico," U. S. D. A. Survey Report, Flood Control, 1941, p. 221 (unpublished).

[36] *Ibid.*, p. 307.

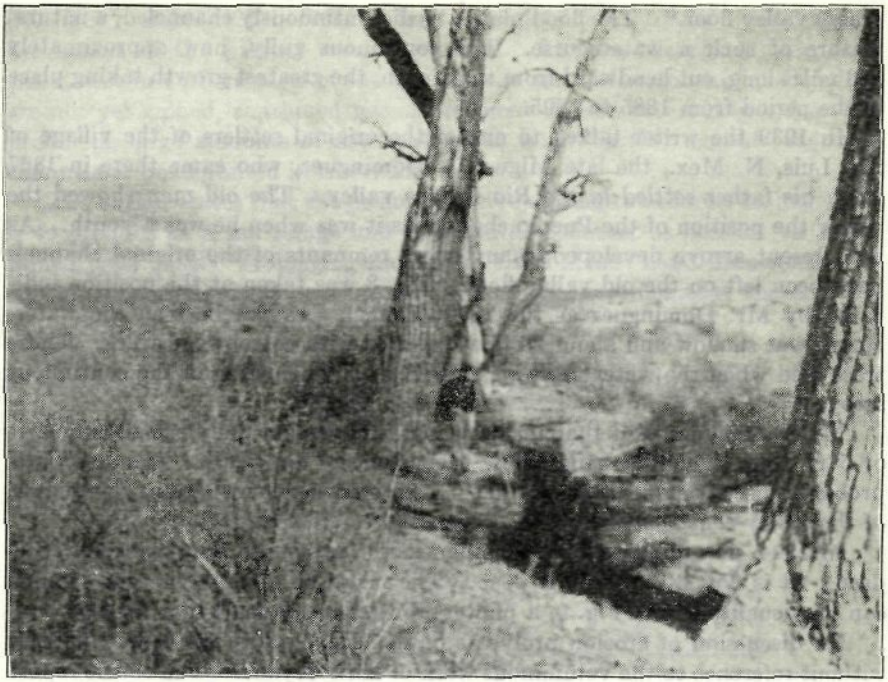

FIG. 8.—OLD STREAM CHANNEL OF THE RIO PUERCO, NEAR SAN LUIS, NEW MEXICO

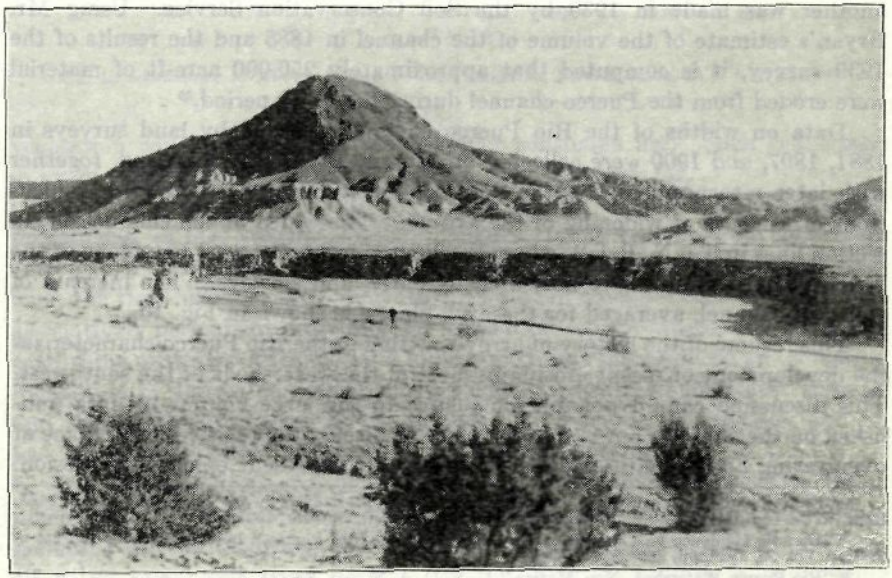

FIG. 9.—ARROYO OF THE RIO PUERCO IN 1940, ABOUT THREE MILES BELOW SAN LUIS, NEW MEXICO

grassy valley floor.[37] The flood plain was discontinuously channeled, a natural feature of such a watercourse. The continuous gully, now approximately 156 miles long, cut headward from the mouth, the greatest growth taking place in the period from 1885 to 1895.

In 1939 the writer talked to one of the original settlers of the village of San Luis, N. Mex., the late Miguel G. Dominguez, who came there in 1867 when his father settled in the Rio Puerco valley. The old man showed the writer the position of the Puerco channel as it was when he was a youth. As the present arroyo developed, many small remnants of the original channels have been left on the old valley floor. Fig. 8 was taken at the position indicated by Mr. Dominguez as the 1870 channel. As can be seen the watercourse was shallow and about 20 ft wide, lined with cottonwood trees. These trees died when the water table was lowered by the cutting of the continuous arroyo.

Mr. Dominguez said that in his youth there was a gully "head-cut" 4 ft or 5 ft deep about one mile below the village of San Luis. The gully was probably discontinuous at that time. Such evidence corroborates the picture of the valley constructed by Kirk Bryan and G. M. Post.[37]

In 1904, according to Mr. Dominguez, the arroyo at San Luis was 12 ft deep. It is now 30 ft to 40 ft deep. The magnitude of the present channel can be visualized from Fig. 9, a photograph taken by the writer in 1940.

No discussion of erosion problems of the Rio Grande would be complete without reference to the voluminous work of Kirk Bryan.[38] The classic report by Messrs. Bryan and Post[37] provides detailed data on southwestern erosion history. These men made a survey of the Rio Puerco channel in 1927 and another was made in 1939 by the Soil Conservation Service. Using Mr. Bryan's estimate of the volume of the channel in 1885 and the results of the 1939 survey, it is computed that approximately 250,000 acre-ft of material were eroded from the Puerco channel during the 54-yr period.[39]

Data on widths of the Rio Puerco channel recorded by land surveys in 1881, 1897, and 1900 were collected by Messrs. Bryan and Post and, together with later measurements by the Soil Conservation Service,[39] provide indications of the rate of widening of the arroyo. The width of the channel on six section lines in T 6 N, R 1 W where the Puerco forms the west boundary of the N. D. Chavez Grant were measured by early land surveys. The increase of width of channel, averaged for these six places, is shown in Fig. 10.

This résumé of the history of arroyo cutting in the Rio Puerco characterizes the development of recent erosion in most of the watersheds of the southwest. This discussion cannot possibly do justice to the large volume of data published on the subject; nor is this the place to discuss the relative importance of overgrazing and climatic change as causes of the present epicycle of erosion.

[37] "Erosion and Control of Silt on the Rio Puerco, New Mexico," by Kirk Bryan and G. M. Post, Rept. to the Chf. Engr., Middle Rio Grande Conservancy Dist., October, 1927.

[38] "Historic Evidence on Changes in the Channel of the Rio Puerco," by Kirk Bryan, *Journal of Geology*, Vol. 36, 1928, pp. 265–282.

[39] "Rio Puerco Watershed, New Mexico," U. S. D. A. Survey Report, Flood Control, 1941, p. 218 (unpublished).

The fact remains that overuse of land has contributed to the timing and to the extent of the present erosion problem. Because there are many subtributaries in various parts of the Rio Grande and Colorado watersheds which are not yet gullied, continued mismanagement of land can still be a factor in producing large amounts of sediment which might further aggrade the main channels or be deposited in reservoirs.

The author states that the prime objective of range and forest management is to produce as much forage and merchantable timber as possible on a sustained yield basis ("Prolonging the Life of Lake Mead: Land Management"). The qualification might well be added that this assumes that the soil and

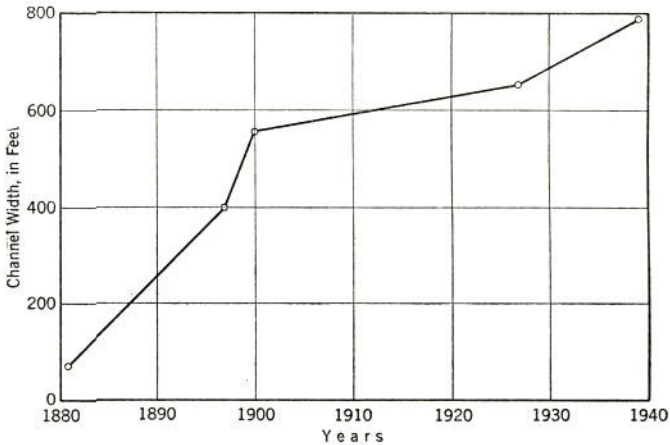

FIG. 10.—INCREASE IN WIDTH OF RIO PUERCO CHANNEL, NEW MEXICO, IN T 6 N, R 1 W

vegetation will be ecologically stable under continued use. Such is the case in most areas where deterioration has not progressed too far.

Planting of forests solely to prevent erosion is seldom a sound financial investment, as Mr. Stevens states. This is certainly true in so far as private enterprise is concerned. From the standpoint of the nation as a whole, however, the time has already come when the value of cover on certain watersheds as relatively permanent protection for areas downstream far exceeds the actual cash value of the land itself. It is to be hoped that there will be an increasing realization of the value of watershed cover as protection for water supplies and as a factor promoting soil stability. These are separate values and no less important than the value of the merchantable produce.

The sedimentation problem brings the engineer face to face with many nonengineering aspects of land use. In many respects watershed control, including all the biological considerations of grazing, forestry, and farming, constitutes an engineering problem in that it is susceptible to engineering