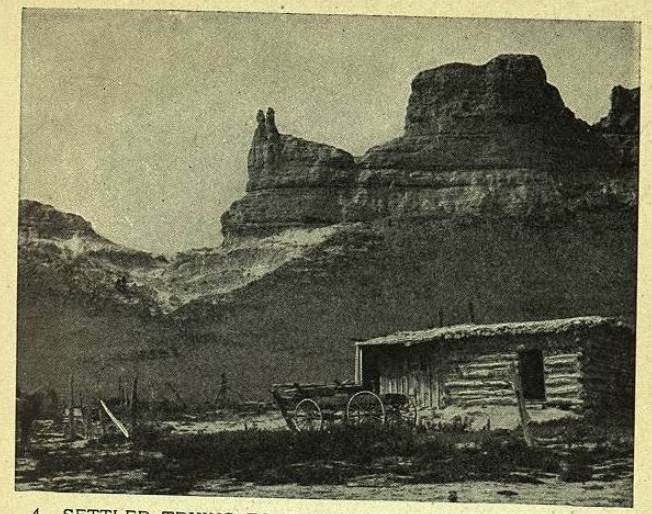
serious, and it is often impossible to find any feasible relief from drought. In many localities, however, wells having a depth of from 100 to 300 feet, as shown on Pl. LVIII, *B*, obtain an ample supply, and in other places artesian conditions have been found to exist, water flowing over the surface in a quantity sufficient not only for stock, but even for the irrigation of small farms, as shown on Pl. LVIII, *A*.

The principal developed artesian area is in the James River Valley of South Dakota. Here are a considerable number of wells ranging in depth from 1200 to 1500 feet, some of them, as shown on Pl. XL, discharging volumes of water of one cubic foot per second, or even more, as described under the head of Artesian Wells, p. 246. These receive water from what is known as the Dakota sandstone, a thick rock, sometimes merging into shale, but usually consisting of coarse, permeable sandstone. It outcrops around the Black Hills and along the front of the Rocky Mountains, and extends easterly under the plains at depths of from 1000 to 2000 feet or more, as shown in Figs. 79 and 80 (p. 250), approaching the surface in the eastern part of Kansas, Nebraska, and the Dakotas. It outcrops along the Arkansas Valley and appears on the surface near Coolidge in western Kansas. Wherever penetrated, it yields an abundant supply of good water, although at a few places it is reported that the water is con-



A. SETTLER TRYING TO CULTIVATE WITHOUT IRRIGATION.

B. WATER FOR IRRIGATION PROVIDED BY WINDMILL.

taminated by salt, probably from some other horizon.

The position and depth of the Dakota sandstone have been mapped around its edges, but in the centre of the plains region the depth beneath the surface to the sandstone is unknown. It is highly desirable to drill one or two deep wells, determining the depth, character, and thickness of the Dakota sandstone, and ascertaining whether it or other sandstones contain water under sufficient pressure to rise to the general level of the country. It is possible that, by the complete development of artesian wells, the opportunities for making homes can be greatly increased.

Wherever wells have been dug or drilled in this area it is the custom to erect windmills, as shown on Pl. LIX, *B*. A great number of these have been built, as the wind is blowing almost continually, with a force sufficient to operate ordinary pumps. Many thousands of them are to be seen, of all forms and sizes, from the clumsy, old-fashioned Dutch mill shown on Pl. LXI and the odd but effective homemade devices shown on Pl. XLII to the light, rapid-running steel mill of latest improved pattern shown on Pl. XLIII. An indefinite extension and multiplication of these is possible, as the power of the wind is practically limitless, and it can usually be depended upon, although sometimes failing at critical times. While each pump will furnish water for only one or two

acres, by increasing the number of pumps, farms of considerable size have been successfully tilled, as described on pages 265 to 270.

NORTH DAKOTA AND SOUTH DAKOTA.

The Dakotas extend from the fertile Red River Valley westerly across the Missouri River, the climate gradually becoming more and more arid until the Black Hills are reached. The country east of the Missouri River, consisting of extensive prairies and rolling uplands, is usually considered capable of raising a crop each season, although failure or diminished yield may occur at least one year in five. Irrigation is not largely practised, but it would be highly beneficial. The principal crop produced is wheat, the extremely deep, rich soil and level surface making possible the great so-called "bonanza" farms, where the apparently boundless ocean of waving grain extends in all directions to the horizon. On these great farms, where all the work is done by machinery, the cost of producing the crop is extremely small, and it is not considered possible or desirable to attempt irrigation; but on the small tracts, where diversified agriculture is practised and the long summer droughts bear heavily upon the plants, it has been found profitable to artificially apply water, particularly in the James River Valley, where there are a large number of artesian wells furnishing water to farms, as shown on Pl. LVIII, *A*.

West of the Missouri River the surface of the country has been deeply eroded, the soft horizontal beds being carved into the fantastic forms of the Bad Lands. Some grazing is found among these, and a little irrigation is practised at ranches along the streams, especially near their head waters, where they issue from the Black Hills. Here a considerable number of ditches have been taken out, and agriculture has been successful because of the excellent markets afforded at the near-by mines.

NEBRASKA.

In this state irrigation is confined almost exclusively to lands along the North Platte River, extending from the Wyoming line easterly to the point where the south branch enters, forming the main Platte River. Farther east the climate becomes relatively humid, and, although a few irrigation systems have been constructed, the use of water has not been general, owing to the fact that in ordinary seasons crops are raised by dry farming.

The Platte and its principal tributaries are characterized by broad, sandy channels, whence has arisen the name. The view, Pl. LX, *A*, shows the North Platte at low water, with streams meandering across the sandy bottom in an interlacing network. At high water the stream spreads out, sometimes to great width, giving the appearance of an enormous volume of water, as shown by

Pl. LX, *B*. It is extremely shallow, however, and there is some foundation for the popular claim that the Platte is a mile wide and too shallow for navigation by a catfish.

There is almost always water in the North Platte and in the Platte, although it is occasionally reported that during droughts the channel is dry on the surface, the water coming from the west gradually disappearing in the broad stretch of sand and gravel, and percolating onward beneath the surface. The South Platte is usually dry during the summer for a hundred miles or more in Colorado, and on down to the junction of the channel with that of the North Platte; hence irrigation development along this stream has been limited to the use of flood waters during the early part of the year. South of the Platte, in the valleys of the Republican and other streams, and also in the northern part of the state, small areas are cultivated successfully by irrigation, and this method of agriculture is slowly extending as farmers become more skilful and appreciate the advantage of security from occasional crop failures.

A large part of the western end of Nebraska is covered with hills of shifting sand, and although the soil is extremely light and easily moved by the strong winds, yet, where moistened in the hollows between the hills, excellent crops have been produced. It is highly probable that the shifting of these hills can be prevented by planting shrubs or

A. LOOKING DOWN NORTH PLATTE RIVER FROM THE NEBRASKA-WYOMING LINE.

B. HEAD GATES OF FARMERS AND MERCHANTS IRRIGATION COMPANY ON PLATTE RIVER, NEAR COZAD, NEBRASKA.

trees, and it has been proposed to cover this vast region more or less completely with forests, making the waste land valuable for the production of timber and rendering possible the utilization of the more level portions for farms.

KANSAS.

In this state the principal irrigated areas are along the Arkansas River, where the conditions are somewhat similar to those along the Platte. The broad, shallow channel is dry for a part of the year, but water is seeping beneath the surface of the valley lands as well as under the stream bed. The ditches, some of them built at large cost, can receive water only in times of flood; but by means of windmills small areas are irrigated, not only in the valleys, but even to a small extent on the adjacent upland plains. Artesian wells have been successfully constructed at a number of localities, notably at Meade in the southern part of the state, one of the small wells being shown on Pl. XXXVIII, *B*.

North of the Arkansas River and between it and the Republican in Nebraska are a number of creeks and rivers flowing eastward and receiving a supply of water during the dry season from perennial streams resulting from seepage, or, in other words, from the underflow reaching the surface. The volume of these is swelled in the early part of the year by local rains, but, taking the year as a whole, the dis-

charge is wonderfully uniform, because of the slow, gradual movement of the water from underground into the channels. Irrigation from these streams has been introduced, but, as noted on preceding pages, owing to the occasional success of crops without irrigation, progress has been slow and halting.

OKLAHOMA AND TEXAS.

In the recently settled territory of Oklahoma little has been accomplished, as the water supply in the western, arid end is limited and the pioneers, coming from humid regions, have as a rule not been familiar with the benefits of irrigation and have tried to get along without artificially applying water. This part of the territory, adjacent to Texas, is given up mainly to grazing, but a few ditches have been constructed for bringing water to alfalfa lands at the cattle ranches.

Throughout the great extent of high plains included within what is known as the Panhandle of Texas, irrigation is almost unknown. It is distinctly a cattle country, and water is regarded as of value principally for the use of cattle. Wells have been sunk on these high plains, and shallow tanks or ponds constructed at intervals of a few miles, to furnish convenient watering places, as shown on Pl. VII. The ranches are of enormous extent, the land having been sold or disposed of by the state of Texas in great tracts to cattlemen. There is a slow but gradual tendency to subdivide

these great tracts and to increase what is known as stock farming — that is, the carrying on of farming in connection with the ownership of small herds, thus multiplying the number of resident owners. Progress in this direction is extremely slow, and it will probably be many years before this vast tract of country will be subdivided so as to support a population at all commensurate with its possibilities.

On the extreme west, Texas extends far into the arid region, and on the border along the Rio Grande irrigation has been practised by the Mexicans living on both sides of the international boundary. From the earliest historical times the small communities have diverted water from the stream, tilled gardens, and raised fruit sufficient for their own needs. This condition of affairs has continued until the present time, some of the ancient ditches having been enlarged, and in a few instances, as at El Paso, large canals built to reclaim land and provide opportunities for new settlers. The flow of the Rio Grande is, however, extremely erratic, and, owing doubtless to diversions in Colorado and New Mexico, the channel of the river is frequently dry for months at a time.

In the western central part of the state, as at San Antonio and other towns settled by the Mexicans, irrigation has always been practised by them, and their example has been followed by their English-speaking neighbors, so that this method of

agriculture may be said to be widely, but not largely, in vogue. In the extreme east the cultivation of rice in the low Gulf counties has recently attained great importance through the flooding of low lands, to which water is brought largely by pumping.

DUTCH WINDMILL AT LAWRENCE, KANSAS.