the average rainfall at various stations for a forty-year period ending 1913, and also the rainfall for the exceptionally dry years of 1880 and 1883, which for some purposes it might be desired to use. Manchester, N. H., and Providence, R.I., are only about eighty miles apart in a straight line.

From the above, it will be seen that even for a long term period the average amount of rainfall at the points named varies greatly, the extreme variation being 8.93 inches or about twenty-three per cent., while for the dry year of 1880, the extreme variation is 13.99 inches, or over fifty per cent. From this it will be seen that anyone attempting to design a water power or a water supply system for a water shed at all remote from a long established rain gauge must unavoidably make his estimates upon data which have a large element of uncertainty in the makeup.

Marked Change in Years

It has been stated by some writers that a rainfall record of from thirty-five to forty years makes that record fairly reliable as a basis of estimates for the expected average yield of a watershed. While this may be true in an ordinary period, an examination of the rainfall records of the last forty years of the Sudbury river watershed, and others which have commonly been used in this vicinity, shows that a marked change in the amount of rainfall has occurred during the last fifteen years of that period and that while the average for the forty-four years since the Sudbury river records were begun is 44.66 inches, the average for the period 1904 to 1918 (fifteen years) is only 40.97 inches.

The Stony Brook rainfall record of the Cambridge Water Works in Waltham, Mass., shows a similar change. While the average rainfall for the entire period of twenty-nine years the gauge has been established—1890 to 1918—is 41.53 inches, the average for the period 1904 to 1918 (fifteen years) is 38.75 inches. These last are remarkably low average rates for so long a period and there seems to be but one period of that length of time with so low a rainfall record in this vicinity. This is in the Cambridge record of Prof. A. Winthrop from 1760 to 1775 where the average rainfall is shown as 37.38 inches.

Still further the record of the yield or run-off for both these areas shows a corresponding persistent decrease. While the average run-off from the Sudbury river area for the forty-four years is 20.54 inches, the average run-off for the last fifteen years is 15.85 inches. On the Stony Brook area, the average run-off for the twenty-nine years is 17.81 inches, and the average run-off for the last fifteen years is only 15.70 inches.

Proportion of Run-Off Also Decreased

If these records are analyzed by percentages, the interesting fact is shown that in the dry periods, the proportion or percentage of run-off to rainfall is less than that in the wet periods. Thus for the wet period in the Sudbury river area 1875 to 1903, the run-off was 49.3 per cent. of the rainfall, while for the dry period, 1904 to 1918, it was only 38.7 per cent., while for the exceptionally dry year, 1883, it was 34.1 per cent., and for the year 1911, it was 28.1 per cent. Similarly on the Stony Brook area, for the wet period, 1890 to 1903, the run-off was 42.9 per cent. of the rainfall, and for the dry period, 1904 to 1918, it was 40.5 per cent., and for the year 1910, it was only 27.1 per cent. of the rainfall. In other words, a diminished rainfall gives not only a diminished run-off, but a diminished proportion of run-off. From these facts, it is evident that it may not be safe to draw conclusions even from a forty-year record, without a careful study of the records of other places and other periods, that proper allowance may be made for abnormal results which may have been obtained.

There is another rather curious fact shown in the records for the year 1909 which may be noted. While the rainfall for this year is about six inches more than for either the years 1908 or 1910, the run-off for 1909 is about 1.50 inches less than for the year 1908. The Stony Brook record shows the same peculiar result,—a lessened run-off in a year of increased rainfall. The explanation of this anomaly may be that the underground storage had become so depleted by the continued drought of a number of years that the increased rainfall for the one year failed to restore the deficiency in this storage and so caused a lessened run-off for that year.

A very important and interesting question may be raised just here. Will the diminished rainfall as noted during the last fifteen years be permanent or will the rate "come back" to its old level? While no definite or authoritative answer can be given to this query, two things should be remembered in this connection. No permanent marked changes ever take place in the processes of nature without adequate cause. No such adequate cause is apparent by which the rainfall of this section could be permanently diminished, and again, in the past marked changes have occurred in meteorological conditions, cold winters, hot summers, wet and dry seasons—some continuing for considerable lengths of time, but inevitably the balance has been restored and the general mean of conditions re-established. Even if the period of low rainfall given in Prof. Winthrop's somewhat fragmentary records be taken as reliable as showing the entire rainfall for that period, the records of other observers for following years show the amount of rainfall to be well up to or above the average.

How Much Water in the Reservoir?

A very practical and convenient way of using the daily rainfall records is by plotting them in the form of a mass diagram. Probably one of the most common inquiries a superintendent of water works has to answer is one relating to the condition of the reservoir as regards the supply in storage. Much misconception frequently exists in the "average citizen's" mind as to the amount of rain which has fallen to a given date and consequently as to the amount of water which has been received into the storage basins.

It is rather a curious fact that taking a long term of years, the average rainfall for each month differs but little, the rainfall of the so-called "dry months" being on the average but little less than that of the wet months. The greatly increased evaporation during the hot months, together with the demands of growing vegetation, etc., makes the rainfall seem much less than it really is and results in a greatly decreased run-off during those months. As the evaporation from ponds, brooks, reservoirs, etc., amounts to over thirty-nine inches during an average year, it will be seen that the presence of large water surfaces in a water shed may have an important bearing on the amount of run-off to be expected from it.

The distribution of the rainfall during the year has an important bearing on the amount of the yield or run-off. If the rainfall is largely during the season when the ground is frozen, a much larger run-off may be expected than if it occurred during the hot months, when the ground is dry and the evaporation rapid.

From the above, it will be seen that rainfall records can be made to serve a variety of practicable purposes, and that long time records obtained on or near the ground are most reliable and satisfactory.

The cost of an ordinary rain gauge (not automatic or self recording) is small and its care and maintenance requires only the attention which can be given to it by some intelligent employee on the ground, or by some resident for a nominal sum.

Gauges are Useful

If it is desired to obtain automatic records of the rainfall, a more complicated and expensive type of gauge can be installed, and data obtained very useful in the study of many questions not covered by the mere quantity of rainfall, especially such as relate to the time at which the rainfall occurred and its intensity or rate per hour at any given time. These data are very interesting and sometimes are exceedingly valuable as factors relating to the required strength and height of dams, length of spillways, size of culverts, damages caused by floods, overflows, washouts, raising or lowering of the water in storge reservoirs, and a great variety of other questions of a similar nature.

If a water shed is large and the works established upon it are important and involve a large investment of capital, the establishment of an automatic gauge is strongly recommended.