SCIENCE

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STORAGE OF STORM-WATERS ON THE GREAT PLAINS.

SOMEWHAT exaggerated expectations have been aroused by the speculations of certain theorists in regard to the possibilities of water storage on the high, wind-swept, treeless plains lying between the 98th meridian and the Rocky Mountains. These visionaries have virtually promised every farmer a reservoir on his land if he would only make the effort to secure it.

The need of storage, if it can be made a success, is indisputable. Rivers are few, and, as a rule, inadequate to the irrigation of more than the lands of their own valley. Artesian wells are limited to certain sharply defined basins. Other wells are generally too deep for profitable irrigation by pumping, except for small plats of fruit and garden vegetables. If the mesas are to be extensively irrigated it must be by storage of storm-waters. Can it be done? If there is any doubt about it we would better know the truth than to encourage delusive hopes. Let us seek some quantitative numerical expression for the possibilities and limitations of storage.

The great robber of moisture on the plains is evaporation. The activity of the winds is so great and constant that more vapor is raised from exposed water surfaces than in many regions of greater heat. The annual evaporation is seldom, if ever, less than four feet, and may rise to eight feet. We may safely put the average as high as five feet.

The rain fall varies from one to two feet. Its seasonal distribution is favorable, the late spring months and the summer months receiving the greatest amount. So far as the quantity and seasonal distribution of the rainfall are concerned the chances of impounding some of it look encouraging. But it is not so much the aggregate of precipitation as the percentage of it which flows off on the surface, which determines the feasibility of storage. In a treeless region of great evaporation and porous soil and subsoil, the total run-off is always low, and much of that is subterranean. Humphreys and Abbott, in their report on the Mississippi River, estimate the total run-off of the Missouri valley at 15 per cent of the rain fall. This includes the springs which feed the rivers, as well as the superficial run-off. This subterranean factor is unusually large on the plains, because there are large areas on the mesas and among the sand hills, which have no surface streams. All moisture reaching the rivers from these areas percolates beneath the surface, and the superficial run-off is by so much diminished.

Again, if the average for the whole Missouri valley is 15 per cent of the rain fall, it is less than that on the plains, because the whole basin includes wooded areas and steep mountain slopes, from both of which the run-off is more than the average. If we reckon 7.5 per cent as the superficial run-off of the plains, that will certainly be as favorable as the considerations just presented will possibly admit. It is more likely to be too high than too low, for fully half, if not more, of the run-off is subterranean, and the total is less than 15 per cent, while we have allowed half of 15 per cent for surface flow which may be impounded.

The third important consideration is seepage. A reservoir may be made absolutely water-tight, but it is not likely to be. Rather is it absolutely certain that for small storage on the farm, executed without the aid of professional engineering, and under rigid conditions of economy, so that cementing, or puddling with clay, is out of the question on account of the expense, the loss by seepage will always be considerable. The possible variations of such loss are so great that we can do no better than to make a somewhat arbitrary assumption of its amount, say two feet annually. If the site is so badly selected, and the dam so poorly built, that the water will be lowered more than two feet annually by percolation, success is improbable; on the other hand, less than two feet would be too small a margin to allow for seepage under the circumstances. More would be fatal, and less is improbable.

The fourth consideration is the ratio of catchment basin to reservoir surface. This factor is more under human control than the others. At first blush it might be thought to be wholly a matter of choice. And so it is if the reservoir is artificially excavated. It may be dug deep and narrow to prevent evaporation. Its surface may be made only one-millionth of the catchment basin, if that is desirable. But the economy of water storage for irrigation will not admit of more excavation than that required to procure earth for the dam. Aside from the cost of digging it, a deep pit would require a pump to raise the water. Natural depressions must be utilized. But these are always broad and shallow on the uplands. Deep cañons and valleys are excluded because they are below the lands to be irrigated. They may answer for the valley lands below them, but not for the table-lands which we are considering. In the wide shallow basins of the uplands, if the waters have any considerable depth, they will spread abroad, cover much good land, and lose much by evaporation. But they must have considerable average depth throughout the year for two reasons. The maximum depth will occur after storms, the minimum during periods of drought. Unless the average is high it may readily happen that little or no water is available just when the crops need irrigation. Furthermore, the depth should be considerable, or else the reservoir will flood nearly as much land as can be irrigated from it. E. S. Nettleton, chief engineer of the Irrigation survey, U. S. Dept. of Agriculture, estimates that an annual average of nine inches of water over the whole surface of the field will be required for successful irrigation on the plains. One acre of reservoir with an annual average depth of four and one-half feet will therefore irrigate six acres of land. The value of the flooded land will absorb the profits of the operation if the ratio is greater than that, that is, if the depth of water is less.

It is evident that when water is impounded in natural depressions on the table-lands the reservoir will necessarily cover a considerable fraction of its catchment basin. Take the proposition that every farm may have a reservoir, and see how it will figure out. For an average annual depth of four or five feet the water will spread over several acres, certainly not less than five acres. On a farm of 160 acres the catchment basin cannot be more than 32 times as large as the reservoir. Drawing from the lands of one's neighbors cannot be counted upon. Your neighbor below will be as likely to draw from your land as you are to draw from your neighbor above. The chances are even, and, in the general summing up of catchment areas, each can only count upon his own. Indeed he cannot count upon all of his own land, for, if it is all devoted to gathering and storing the water, where is the field to be irrigated? That must lie below the reservoir, as the catchment basin must lie above it. This simple matter of levels imposes another rigid limitation upon successful storage. Tillage of the catchment basin, causing greater absorption of the rainfall — possibly complete absorption of it — is another contingency which may defeat storage.

If the farmer owns a half section, 328 acres, and if we make due allowance for irrigated fields, and for slopes which face away from the reservoir, he may possibly get a ratio as high as 50:1. This is not enough for successful storage. On a section, 640 acres, it might be as high as 100:1, if the slopes were happily disposed. Instead, therefore, of a possible reservoir on every farm, it is clear that only very large farms having a favorable topography can enjoy this luxury. The ratio 100:1 probably represents the maximum of favorable conditions which can ordinarily be realized on the plains. Hence we need not consider the possible results of any higher ratio. Nor need we go below the ratio 50:1, since that is already below the requirements of successful storage.

It appears then that, instead of the ratio of catchment to the storage area being a matter of choice, it is subject to quite narrow limitations.

We set out to seek quantitative results. By using data given above for evaporation, run-off, and seepage, which are believed to be fairly good approximations to the actual values of those factors, we may construct[1] the following table: —

Table showing the annual average depth of water for ratios varying from 50:1 to 100:1, and for rainfall varying from one to two feet, the annual evaporation being five feet, seepage two feet, and the run-off 7.5 per cent.

Ratio of Catchment to Reservoir Surface.	Depth of Water for a Rainfall of				
	12 inches.	15 inches.	18 inches.	21 inches.	24 inches.
50:1	None.	None.	None.	None.	.5 ft.
60:1	"	"	"	.87 ft.	2. ft.
70:1	"	"	.87 ft.	2.19 ft.	3.5 ft.
80:1	"	.5 ft.	2. ft.	3.5 ft.	5. ft.
90:1	"	1.44 ft.	3.12 ft.	4.81 ft.	6.5 ft.
100:1	.5 ft.	2.37 ft.	4.25 ft.	6.13 ft.	8. ft.

This table must not be taken to mean more than was intended. "None" does not mean that a reservoir under the given conditions would not contain water at any time in the whole year. It might be full after a storm, yet the average expectation of finding water there at any date when it is needed for irrigation is correctly expressed by zero.

[1] The formula for computation is $\frac{R \times r \times r'}{100} - (e+s) = D$, in which R = rainfall, $\frac{r}{100}$ = run-off, r' = ratio of basin to reservoir, e = evaporation, s = seepage, and D = annual average depth of water resulting from the given conditions.

The table is intended merely for a quantitative expression of results which will follow if the assumed data are fairly correct. And, if they are somewhat erroneous, whoever knows a more accurate value for any factor can readily insert it, and correct the table. Quantitative expressions, even when based upon assumptions and hypotheses, are more instructive than vague and speculative generalizations. This table, for instance, shows certain limitations of water storage so narrow and rigid that any errors which are likely to be detected in the assumed data will not overcome them.

To specify some of these limitations, take the first column of the table. It means unmistakably that no storage can be made from a rainfall of one foot. The highest ratio, that of 100:1, a ratio which can seldom be realized, gives only six inches as the permanent average depth of water in the reservoir. None of the assumed data can very well be so far astray that its correction will raise the amount to a reliable irrigation head of water. Possibly full at one time, but dry as a powder-horn at other times, such a reservoir would be useless, because it would be unreliable. Certainty — that most valuable feature of farming by irrigation as opposed to an enforced dependence upon the fickle goddess of weather in the rain-belt — would be lost. The farmer must have the water just when he needs it, not just when it happens to come. The figures for average annual depth show the maximum which can be relied upon with certainty at any given date. While it might sometimes be greater, there is no rational assurance of it.

The seasonal distribution of the rainfall is so far favorable to a speedy use of stored waters, without serious loss by evaporation, as to make the case somewhat better than appears in the table. But over against this is the neutralizing consideration that the greater rainfall of spring and summer is more fully absorbed than the lighter precipitation of winter upon frozen ground. Melting snows yield a greater run-off than summer rains. This increases the average period of storage before use, and correspondingly diminishes the chances of success.

These changes are still too slender to be at all reliable if the rainfall is fifteen inches. Indeed, it is not until we come to the column headed "18 inches" that we find any encouragement. One result at the bottom of that column looks hopeful, but that calls for a catchment surface one hundred times as large as the reservoir — a condition which, when coupled with the further limitation of enough good irrigable land under the reservoir, not one farm in a hundred can fulfil.

The promising figures are twice as numerous in the next column, and three times as numerous in the last. But even with two feet of rainfall the chances of failure and success are about even. The ratio must be at least 75:1, or a mean between the lowest and highest in the table.

For areas having a greater rainfall than two feet, where the impounded waters might be useful for other purposes, but would hardly be needed for irrigation, the possibilities of storage may be easily discovered by extending the table.

Water storage upon the high mesas of the treeless belt is, if not wholly a delusion, at least somewhat delusive. More hopeful is the expedient of deep tillage, which is also a sort of storage. Hidden from sun and winds in the loose soil and sub-soil, the moisture will thus be preserved at the very spot where it is needed to sustain vegetation.

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DR. BAILLON'S "Dictionnaire de Botanique," the publication of which was commenced in 1869, is now completed.