THE LESSON OF CONEMAUGH

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The experiences of civilization teach many lessons that go unheeded until some great disaster comes as an object-lesson to recall to men's minds things known but half-forgotten. The Conemaugh disaster belongs to this category. ***For more than four thousand years civilized men have been constructing reservoirs in which to store water for various purposes***. The conditions to be fulfilled in their construction are well known, for the lesson has been enforced upon mankind from the dawn of civilization to the present time by disasters too many to be enumerated.

Hydraulic engineering is the oldest scientific art. No other can compare with it in this respect, except that of architecture in its application to the building of temples and pyramids; but scientific engineering is even older than scientific architecture. ***Everywhere throughout the world civilization began in arid lands, and hydraulic engineering was the first great problem to be solved; and for this reason it was solved at an early time, and well solved.*** Something has been added through the years, but not much. In our own times these problems have come to be of far greater importance than they were in antiquity and the civilized world has now reached ***the dawn of a day of hydraulic engineering of such magnitude that all the works hitherto accomplished are insignificant compared to those now to be planned and executed.*** Let the significance of this statement be briefly set forth.

One of the purposes for which hydraulic engineering has been prosecuted in late civilization is the utilization of powers otherwise running to waste. For a time a check has been given to this form of development by the introduction of steam, but at present the great transition in modern industries is from the employment of muscular power to the employment of the physical powers of nature, and it is probable that the resort to water-power will rapidly increase in the immediate future. It certainly will if the dream of modern electrical science is realized, so that ***water-power can he economically converted into electric power and transported from place to place.***

If this is done,—and its accomplishment is hardly to be considered Utopian,—all our highland streams will immediately become of value as powers, and ***dams and reservoirs must be constructed in far greater numbers than in the past.*** Modern sanitary science condemns well water for domestic purposes in cities, towns, and villages. Disease is at the bottom of a well; health in the waters of the heavens; and the people must have this pure water. ***The demand for highland waters for such purposes is rapidly increasing. The speedy development of city and town life under the new industrial conditions makes this one of the most important uses to which water can be applied.***

"Wherever the houses of men are clustered reservoirs or systems of reservoirs must be built. Nothing can be more certain than that the storage of water for this purpose will greatly and quickly increase throughout the United States.

Along the course of every river there is a flood-plain of greater or less width. This is the plane established by the sediment washed from the hills and upper country and deposited along the course of the river outside of its low-water channel, but within the area covered by water at the time of greatest floods. These greatest floods are infrequent, and are not coincident with the annual floods, but much higher. The plane of the ordinary flood is much lower than this great flood-plain, which is established by the maximum floods, occurring ten, twenty, or even fifty years apart. Such flood-plains are the most fertile lands, and always tempt the agriculturist. Yet torrents sweep over them from time to time, destroying property in vast amounts, and even life.

In lands already highly cultivated, densely populated, and of great value, protection from floods has come to be an important problem. One, and only one, method of protection is possible: ***the flood waters must be stored and allowed to find their way to the sea during times of low water.*** The preservation of lands in this manner accomplishes another end, as the navigable streams are improved thereby. Great floods destroy low-water channels by blocking them with natural dams. ***By storing the water of such floods, and discharging it during low-water time, these channels are kept open and a more equable volume is preserved.***

There is another use to which flood waters are put. Experience has shown that they contain vast stores of fertilizing elements. All other fertilizers that man can utilize sink into insignificance when compared with those furnished by flood waters. In highly-civilized and densely-populated lands this source of fertilization is already used, and it will be used more and more as the years go by. In the United States we are just beginning to appreciate this. The conditions under which agricultural operations have hitherto been carried on have not directed the attention of our farmers to this subject until of late years. It is far within the facts to state that any region of our country may have its agricultural production doubled by the use of its flowing waters for the fertilization of the lands. The time is rapidly coming when the flood waters of the country will be used for this purpose on a grand scale, and reservoirs will be constructed all over the land, as they are now in process of building in England, Germany, Prance, Italy, and other countries.

About two-fifths of the area of the United States is so arid that agriculture is impossible without artificial irrigation, the rainfall being insufficient for the fertilization of ordinary crops. In this region all agriculture depends upon the use of running streams***. In all of this country, wherever agriculture is prosecuted, dams must be constructed, and the waters spread upon the lands through the agency of canals.*** Again, as the season of growing crops is comparatively short, —in most of the country; it lasts from two to three months only,—***the waters of the non irrigating season will run to waste unless they are stored in reservoirs.***

Already the storing of these waters is begun; the people are constructing reservoirs, and will continue the process ***until all of the streams of the arid region are wholly utilized in this manner, so that no waste water runs to the sea.*** Less than a third of the streams of the arid region run to the sea, even now, as the great majority are "lost rivers." A little further explanation is necessary to understand how these waters are to be utilized.

The arid region is mountainous. Mountain ranges enclose valleys, while plains, mesas, and plateaus carry dead volcanoes on their backs. The precipitation of moisture on these lands is confined to the mountains, where it is excessive. The fertile lands along the plains and mountains are arid. In all the region ***agriculture is possible only by collecting the mountain waters and using them on the plains and valleys***. Wherever a farm, a village, or a city is made, hydraulic works are necessary, and dams must be constructed and reservoirs built. Considering the whole country at large, its hydraulic industries are gigantic. In the region of country where land is more abundant than water, the value inheres in the water, not in the land. Land, like air, is found in greater quantities than can be used; water is the necessary, and value is given to the land by the water-right which it carries; if the water-right is dissevered, the land is valueless. These are not unfavorable conditions for agriculture, however. ***The farmer's industry is more attractive and more profitable in an arid than a humid region***. All of the early civilization of the world began in arid lands, and ***the best agriculture of the world to-day is carried on by means of artificial irrigation. The seemingly-desert plains of the arid region of the West are, in fact, abundantly rich when watered artificially.*** The gentle storms of a humid region fructify the land, but its tempests drown vegetation. In such regions the planting season is now too dry and now too wet, and many a prospectively-rich harvest has been destroyed by a harvest-time storm.

Agriculture in arid lands is not subject to these vicissitudes. The mountains catch the floods, while the Valleys are fertilized by the hand of man, who turns the waters upon them at his will. At the day and hour he pleases he spreads the water upon his garden, his vineyard, or his field in quantities governed by his judgment. When harvest time comes, he reaps his field with a mind free from the fear of storms. ***Ultimately one of the great agricultural regions of this country will be found in the irrigated plains and valleys of the West.*** Sage-brush plains, sand-dune deserts, and alkaline valleys will be covered by gardens, fields, and groves, all perennially fertilized from thousands of mountain lakes.

Enough has been said to show that the storage of water in reservoirs is not one of the trivial incidents of modern industry, but one of its most important factors, and that in this country we have only reached the beginning of its development. ***We may expect, in the course of a few generations, that all the highland streams of America will be controlled and utilized, and that the floods will be bridled and become the trained servants of man, as wild beasts have been domesticated for his use.***

In view of these facts, it is only the thoughtless man, governed by the impulse of the hour, and dragged from the throne of his reason by the emotions which arise at human suffering, who will believe that the vast industries which have been mentioned must be stopped because hydraulic power, when improperly controlled, may become an agent of destruction. Badly-constructed houses may fall and overwhelm families, but no check to the construction of houses will be made thereby. Fires will cause conflagration, yet homes will be warmed. Bridges may give way and trains leap into the abyss, yet bridges will be erected. Cars will leave the track and plunge travelers over embankments, but railroads will be operated. Dams will give way and waters overwhelm the people of the valley below, but dams will still be built.

What lesson, then, is there in the Conemaugh disaster ? Nothing new to scientific engineering, but a very old lesson, that must needs be taught to mankind again and again. From the accounts which have appeared in the scientific journals, it seems that the dam was properly constructed. Earth dams are more common than all others. Most of the dams constructed for four thousand years have been, in all essential particulars, like that at Conemaugh. Where, then, was the trouble? In the construction of the dam there was a total neglect to consider the first and fundamental problem—the duty the dam was required to perform. The works were not properly related to the natural conditions, and so a lake was made at Conemaugh which was for a long time a menace to the people below, and at last swept them to destruction.

When the construction of such a dam is proposed, the first thing to be done is to determine the amount of water to be controlled and the rate at which it will be delivered to the reservoir under maximum conditions of rainfall or snow-melting. The proper method of procedure is to determine, first, the area of the drainage basin supplying the reservoir; second, the declivities of the supplying basin.

The very first thing, then, is a topographic survey. The second need is a hydrographic survey. The precipitation in rain and snow over the basin must be determined as an average from year to year, and also the maximum precipitation at the times of great flood. This must be supplemented by the gauging of streams to determine their average volume and maximum volumes. All of these factors are necessary and preliminary to the construction of a safe and efficient reservoir system by making mountain lakes. ***Before a reservoir dam is constructed, it is of prime importance to determine what will be required of it. With these facts ascertained, the engineer can easily plan works adequate to control the forces involved;*** he can readily determine how much water he can store, and what waste-way will be necessary to discharge the surplus.

The art of dam-construction is quite within the grasp of every intelligent engineer. In the case of solid masonry dams, the waste-way is over the whole surface of the dam, as at the Great Palls of the Potomac, where a dam has been constructed to divert the water into the reservoirs that supply Washington. But masonry dams are few; earth dams, and those related to them, are many, and, with these, special waste-ways must be provided, adequate to meet all possible emergencies. The rules for their construction are well known, and have been known for tens of centuries.

In American engineering, that which has been most neglected is a precise determination of the duty of the dam,—the conditions which it must fulfill or else be destroyed. These can be determined only by a topographic survey, which gives the area of the drainage basin and its grade-curves. To this must be added a hydrographic survey, which may have to extend over some years. It is not necessary that this survey in all its parts should be over each basin where a reservoir is to be constructed. The average and maximum rate of precipitation may be determined for large regions, and the general facts used for the several cases, always allowing a margin for safety. But the topographic survey and the stream-gauging are essential to each individual basin.

There are other factors to be determined that are important to persons engaged in constructing reservoirs for industrial purposes. Two may be mentioned here. The streams feeding the reservoir should be gauged for the purpose of determining the amount of sediment they carry, in order that the life of the reservoirs may be known, or that the proper engineering appliances maybe devised to discharge such sediment; and the rate of evaporation should be ascertained, so as to know how much water is lost thereby.

In the construction of reservoirs in the arid region there are important problems not pertaining to humid regions. To a large extent the sources of the water are in high mountains, where the chief precipitation is snow, which, to some extent, stores itself in snow-banks and glacial fields, to be melted by the summer sun at the time when irrigation is required. The upper portions of these mountains are largely treeless—a condition favorable to the storage of snow. In a forest region the snows are evenly distributed over the entire surface, and are quickly melted when the summer rains and suns come; but in a treeless region the snows are accumulated in great drifts in the lee of rocks and cliffs and under the walls of gorges and canyons. Such great drifts are themselves stupendous reservoirs of water, and artificial works are necessary only to control the flow properly and distribute the water at the places and times needed. Wherever the chief precipitation is snow, forests are a disadvantage if the waters are needed in the valleys below for irrigation, for the forests keep the snow distributed over broad areas of ground and expose it to the winds on their trunks, branches, and leaves, so that altogether the mountain evaporation is enormously increased as compared with the evaporation from snow-drifts and ice-fields. On the other hand, in low mountain and hilly regions of humid lands, forests about the sources of the streams are of advantage in two ways: the water being in excess, increased evaporation is advantageous; and the forests serve to hold back the water and thus equalize the flow through the year and greatly mitigate the floods.

Whether forests increase the amount of rainfall has long been discussed, and lately it has been the subject of careful scientific investigation. The outcome of all this research is that, if forests do, in fact, increase rainfall, it is to such a slight extent that our present means of investigation are not sufficiently refined to prove it.

Such are the facts to be collected as preliminary to the construction of a reservoir system. To neglect the essential facts is to be guilty of criminal neglect. The history of mountain-lake construction, throughout all the countries of engineering enterprise, is full of lessons like that taught at Conemaugh, and the lessons have always been enforced by the destruction of property and life; they have always been emphasized by dire disaster.

Modern industries are handling the forces of nature on a stupendous scale. The coal-fields of the world are now on fire to work for man; chemical forces, as giant explosives, are used as his servants ; the lightnings are harnessed and floods are tamed. Woe to the people who trust these powers to the hands of fools! Then wealth is destroyed, homes are overwhelmed, and loved ones killed.

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