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The Control, Development and Utilization of the Missouri River and its Tributaries

G. E. Condra
University of Nebraska

H. W. Caldwell
University of Nebraska

O. V.P. Stout
University of Nebraska

F. J. Phillips
University of Nebraska

N. A. Bengtson
University of Nebraska

See next page for additional authors

Authors
G. E. Condra, H. W. Caldwell, O. V.P. Stout, F. J. Phillips, N. A. Bengtson, and George L. Sheldon

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THE CONTROL, DEVELOPMENT AND UTILIZATION OF THE MISSOURI RIVER AND ITS TRIBUTARIES.

REPORT OF A SYMPOSIUM HELD AT THE STATE UNIVERSITY, MAY 20, 1908.

The speakers at this conference were Professors Condra, Caldwell, Stout, Phillips, Bengtson, and Gov. George L. Sheldon, with Dean Charles E. Bessey presiding. The principal object of the meeting was to make known reliable information in regard to the Missouri river, concerning which there is widespread interest and in some instances a tendency to magnify the future possibilities of the river. This paper is an account of the conference. It gives some of the thoughts that were emphasized at the symposium, reciting the facts as they were given by those who have investigated the respective phases of the theme.

The subject, "Geographic Conditions in the Missouri River Basin," was discussed by Prof. G. E. Condra. Professor Bessey said, while introducing the first speaker and subject: "That a river is more than water flowing between visible banks. It includes the slopes over which or through which a sheet of water passes slowly or rapidly to a central stream. This drainage is essential to the open river."

GEOGRAPHIC CONDITIONS IN THE MISSOURI RIVER BASIN.

BY G. E. CONDRA,
Professor of Geography and Economic Geology, University of Nebraska.

MR. CHAIRMAN, LADIES AND GENTLEMEN: I will try to outline some of the factors which control the Missouri river. Dean Bessey, the father of science in Nebraska, has given us a good definition of a river. A great river is not the same in its various parts or courses. It is conditioned by many things, such as structure, topography, subsoil, rainfall, temperature and evaporation. The rate and volume of flow; the quality of water, whether turbid or clear; the source and direction of a stream; its quiet and rapid waters, low and high stages, these and other conditions are not accidents; they are readily accounted for by those who study the environments of rivers.

The drainage basin of the Missouri has an area of about 492,000 square miles, including all of Nebraska and much of Kansas, Iowa, South Dakota, North Dakota, Montana, Wyoming and Colorado. The principal tributaries from south to north are the Kansas, Platte, Niobrara, Cheyenne, Little Missouri, Yellowstone and Milk rivers. The trunk stream, known as the Missouri river proper, is formed in southwestern Montana by the union of the Jefferson, Madison and Gallatin rivers. This is known as the head of the Missouri; however, we should recognize the fact that the head waters of the river lie in all of its tributaries along the east front of the Rocky Mountains and even out on the plains, the sources being in many streams and at many places. The largest affluents join the main river on the right, *i. e.*, coming from the west over long slopes of the Great Plains, which slant down from an elevation of 5,000 to 6,000 feet along the east border of the Rocky Mountain region to an elevation of about 1,210 feet at the mouth of the Niobrara; 950 feet at the mouth of the Platte; 725 feet at the mouth of the Kansas river, and nearly 400 feet at the junction of the Missouri with the Mississippi.

Drainage in the mountain courses comes down from elevations of 10,000 feet and higher at places. Let me give an outline of certain conditions in the basin.

General Structure.—There are many kinds of rocks in the basin, some hard and resistant, others soft and easily eroded. The bed rock in the table lands and plains, consisting of clays, shales, sandstones and limestones, is plainly stratified, the beds lying in a nearly horizontal position. At most places the bed rock here is covered by subsoil. The line between the high plains and the mountains is marked by strata which dip out under the table lands. Going into the mountains one sees rocks and structures entirely unlike those just described. They are the granites and metamorphic rocks. In brief, it may be stated that each principal tributary flows over several geological formations and that the nature of the streams is controlled somewhat by the structure of these formations. Waterfalls, rapids, quiet courses and the size, form and depth of valleys are explained in part by structure.

Topography and Subsoil.—The Missouri river basin contains rugged mountains, cut by deep canyons; high table lands, smooth and eroded; bad land regions, covering several thousand square miles; sand hill areas, occupying more than 20,000 square miles; loess plains, smooth and dissected, fully 50,000 square miles; a large extent of the glacial plains; and wide areas where close-textured, Cretaceous clays lie near the surface. The run-off is not the same on any two of the above named areas. The rainfall of the sand hills nearly all goes to underground drainage and issues as springs which give permanent streams. The clayey subsoils and rough topographies give quick run-off, followed by dry stream beds. This condition is best illustrated in the bad lands of South Dakota, Montana, Wyoming and Nebraska. The loess of southern Nebraska and northern Kansas will catch and hold a heavy rainfall, at least until it becomes thoroughly moistened, after which its run-off is large, causing floods.

Rainfall and Evaporation.—The mean annual rainfall decreases from about 25 inches in Missouri to about 12 inches at places in Montana. It is slightly heavier in the mountains than on the high plains. The snowfall is greatest in the mountains and least in the southern part of the basin. The maximum rainfall on the plains is in the spring and early part of summer. Evaporation is thought to be greatest in the southern part of the basin, especially on the high plains, where the relative humidity is low. Named from west to east, the Missouri drainage occupies, according to some authors, sub-humid, arid, sub-humid and humid belts. The Platte river and the Missouri river proper flow across each of these belts and are very noticeably affected by the climatic conditions in each belt.

Forested Areas.—These are confined to the mountains and usually to those parts of the valleys which lie in the sub-humid and humid belts. The region of low rainfall is, as a rule, one of little or no tree growth. Some of the mountain ranges are covered on their sides with thick forest; others contain either thin stands or bare slopes. The run-off, for several reasons, is most permanent where there is a forest covering. It is in this connection, *i. e.*, in the making of the Platte and the Missouri more regular in flow, that Nebraskans should favor forestation wherever it is feasible. There is strong evidence to show that a large amount of the Missouri river basin was forested before the time of the advent of the Indian and white man into the region.

The Mountain Tributaries.—These head in the snow fields and forested slopes and receive an abundance of water in the springtime. They are small, and rapid, due to steep gradients. In many places the run-off of these streams continues throughout the year. The streams are used for power in the mountains and for irrigation on the plains. Some of these rivers are strong enough to find their way to the Missouri during the summer months; others dwindle under the dry air, exposing their sandy beds, only the underflow continuing down-valley.

Overloaded Rivers.—The Platte is the world's best example of a stream that has a heavier load of silt and sand than it can carry. It breaks down large bowlders in the mountains; rolls them along its channel, loosening the small pieces. The pebbles and fine grains are carried eastward, especially at flood stages. When the river decreases in volume from one cause or another the load is dropped at least for a time, adding to the river's thick bed of sand. These processes make a broad flood plain and cause the river to become wide and shallow, therefore unsuited for navigation. The Missouri is moderately loaded with clay and silt, brought to it mostly by the Yellowstone river and the bad-land streams, making the water turbid.

*Missouri River.**—The head-water streams, known as the Three Forks, are each about 90 or 100 feet wide at their junction in Montana. Here the elevation is 4,061 feet; the valley is narrow and deep and the waters

* In this connection I am indebted to Mr. M. A. Bengtson for most of my data.

are clear and swift, flowing over pebble beds. The valley continues narrow to Cascade, a distance of 158 miles, in which the river falls an average of 4.4 feet per mile. Between Cascade and Great Falls the valley width is from one to five miles; the river falls 1.18 feet per mile; a wide flood plain, meanders and sand bars occur along this course of the river. The altitude at Grand Forks, Montana, is 3,295 feet.

From Great Falls to Fort Benton, a distance of 45 miles, the altitude is reduced to 2,619.16 feet, or an average fall of 15.02 feet per mile. This stretch is by far the most rapid in the river. The stream flows in a canyon the greater part of the distance, has many long stretches of rapids, very little flood plain and few meanders. The rapids cease a few miles above Fort Benton and there the navigable Missouri begins. From Fort Benton to the junction of Hell creek, a distance of 281.8 miles, the valley is narrow, with practically no flood plain; the walls are steep and high. From Hell creek to the mouth of the Yellowstone river the valley has an average width of from two to four miles, a broad flood plain, and well-developed meanders begin at the mouth of Hell creek. The fall of the river from Fort Benton to Fort Buford, at the mouth of the Yellowstone river, is from an altitude of 2,619.16 feet to 1,859.85 feet in a distance of 527.4 miles, or an average of 1.44 feet per mile.

From Fort Buford, North Dakota, to Bismarck, the river falls from an altitude of 1,859.85 feet to 1,634.36 feet in a distance of 307.3 miles, which is an average of 0.73 foot per mile. The valley width varies from one to four miles, generally being about one and one-half to two miles. The channel is obstructed by numerous bars and islands; meanders are well developed, and cut banks are numerous but not of much significance. From Bismarck, North Dakota, to Chamberlain, South Dakota, the altitude is lowered to 1,324 feet in a distance of 382.6 miles, or an average of 0.81 foot per mile. The same characteristics of valley and flood plain predominate below Bismarck as above.. The only unusual feature is the Great Bend above Chamberlain, where the river makes a big loop and, after flowing a channel distance of twenty-five miles, it comes back to within two miles of where it began its loop.

From Chamberlain to Running Water, South Dakota, the altitude falls to 1,207.66 feet in 127.3 miles, an average of 0.81 foot per mile. From Running Water to Yankton the distance is 43.6 miles and the altitude falls to 1,157 feet, an average of 1.16 feet per mile. The valley from Chamberlain to Yankton does not vary much in width, being generally from one to two miles wide, and the channel swings from one side to the other with marked regularity. The meander limit has evidently not been reached and the valley bears a good many indications of youth. The banks are being cut slowly at many points along the way, but not rapidly enough to jeopardize seriously the value of bottom lands. It is also to be noted that the grade of the river from its entrance into North Dakota to Yankton, South Dakota, shows great uniformity. It is then to be expected, as is the case, that the valley characteristics shall also be uniform.

From Yankton, South Dakota, to Sioux City, Iowa, the altitude drops from 1,157 feet to 1,109.93 feet in 86.2 miles, or an average fall of 0.546 foot per mile. Just below Yankton the valley width increases abruptly from about three miles to nearly eighteen miles. The stream throughout this distance is characterized by well-developed meanders, cut-offs, oxbow lakes, and prominent cut banks. The channel in some places has shifted more than a mile since 1891. This shifting has been attended by the destruction of valuable farms, and hardships upon certain towns. For instance, Vermilion, South Dakota, was formerly a river port, whereas now it is three miles inland. Ionia, Nebraska, was a prosperous country village, but now even the townsite has been washed away. Where the town formerly stood the river now flows, and only a solitary house remains. This house is located on the uplands and apparently safe from the ravages of the Missouri.

From Sioux City to Blair, Nebraska, the channel distance is 116 miles; the altitude lowers to 1,011.2 feet, an average fall of 0.85 foot per mile. From Blair to Omaha, a distance of 35.5 miles, the average fall is 1.0+ feet per mile. Between Sioux City and Omaha the flood plain varies in width from four to ten miles and the river does not strike the Iowa bluffs until Council Bluffs is reached. There the valley is much constricted, being less than five miles wide. From Omaha to Nebraska City the altitude lowers from 975.55 feet to 947.66 feet in 51.4 miles, an average fall of 0.54 foot per mile. From Nebraska City to Rulo the elevation changes from 947.66 feet to 864.54 feet in a distance of 70.7 miles, an average fall of 1.1 feet per mile. From Rulo, Nebraska to the mouth of the Missouri the distance is 537.5 miles and the total fall 448.18 feet, an average fall of 0.83 foot per mile.

It should be noted that the Missouri flows on alluvial land throughout much of its middle and lower courses. Only here and there does it strike bed rock at the cut-banks. The fall is far from uniform and the difference between high and low stages is marked, the maximum flow at the junction with the Mississippi being about twenty-eight times that of the minimum. Sandbars and snags are features throughout the river length. In Montana, the Dakotas and along most of the Nebraska border, the river is usually closed by ice during a part of the winter. The flood stages are two, in March or April and June or July.

We have reviewed some of the conditions in the basin. Now, for the purpose of placing before you certain problems which are to be handled by other speakers, let me ask the following questions:

1. Will the storing of flood water for power and irrigation purposes in the tributaries affect the flow of the trunk stream? Will this in any way tend to decrease the floods of the lower Mississippi?

2. What are the relations of the forest to run-off? Should Nebraska promote the forestation of the Rocky Mountains, if so, why? Should our state encourage tree planting on flood plains and on lands bordering the rivers?

3. To what extent has there been navigation on the Missouri? What conditions made it unsure and unprofitable?

4. Is there any possibility of bringing the Missouri under control for use in navigation and especially to prevent its destruction of Nebraska's best farm land?

Dean Bessey introduced the second speaker as follows: "History records with her stylus the achievements of men. She tells how they subdue deserts, thread forests, cross mountain barriers and bring into subjection the rivers by forcing them to carry cargoes and to yield up their power. Professor Caldwell will tell us some of the things that have occurred on the Missouri river."

EARLY NAVIGATION ON THE MISSOURI RIVER.

BY H. W. CALDWELL,
Head Professor of American History, University of Nebraska.

Perhaps the most important problem in modern civilization has to do with transportation.

Two hundred or even one hundred years ago there was relatively little importance in this question since each community lived largely to itself. In these modern days, however, the interchange of commodities has become a necessity. Each community calls to its assistance the activities of every other community. Take the dinner table of any well to do family. It will contain contributions from the eastern and western hemispheres; both north and south will be represented. The table may be made of wood from one land; the linen and the plate on the table may come from Mexico, France, Ireland, and distant Japan; the food will represent the products of home and distant lands; Cuba, Brazil, China, Germany, Hawaii and Italy may each contribute its share. Nebraska indeed produces only a small proportion of its supplies; on the other hand a less proportion of its products are consumed within its boundaries. For the world, therefore, this problem of transportation has become an essential one; for the United States it may be said to be the problem of problems. This means of intercourse, then, cannot be neglected by the citizen or statesman, and this is especially true here in Nebraska. The cost of transportation and the equality of service interest every one, and are the two chief ingredients of the problem.

In a way the cycle seems to be completing itself. At an earlier date the wagon road, together with some natural water routes, formed the chief means of travel and exchange. Then improved and increased water carriage was developed. Both these means were neglected on the advent of the railroad, and for a time it seemed as if neither dirt roads nor water ways were regarded as worth consideration. Today the automobile seems to have revived the good roads spirit, and the congestion of railroad traffic the demand for improved water ways. Doubtless these are to be supplements to the railroads rather than substitutes for them. But the revived interest is shown in water-ways conventions and in good road lectures. It is beginning to be recognized that water routes tend to equalize rates, as well as to control the rate itself. At points of natural congestion, the river or the lake may relieve the strain. At St. Louis, Pittsburg and Chicago river and lake aid in distribution, and lessen the congestion, as well as control the rates for bulky articles. Experience shows that bulky products, as coal down the Ohio, iron ore from Duluth and grain from Chicago may be transported to their destination at a mere fraction of the cost by land carriage. When conditions are at all favorable, therefore, careful study should be given to find out whether water routes may be developed.

The problem for Nebraska and this northwest, therefore, is to secure water competition, to relieve the congestion that comes from the enormous product of bulky articles in this plains region, if it is possible. Of course the only hope lies in the Missouri river and its chief tributaries. A brief study of the river and the commerce that in earlier days floated on its turbulent waters may be worthy of a few moments of our time.

Speaking as the historian it may be noted that the first time the Missouri river was seen by a white man was in 1673, when Marquette and Joliet saw its muddy flood pour into the Mississippi river. Some time between 1699 and 1705 the river was ascended for some hundreds of miles, but the exact date is somewhat uncertain. By 1724 it was fairly well mapped, but its upper course was first explored in 1738 by Verendrye.

Commerce on the Missouri was begun, of course, by the Indians in canoes. French trappers followed and soon began to use the cotton wood tree canoe, as the birch bark canoe was unfitted for service on this snaggy stream. Other early forms of boat used by white men were the perogue, the batteau, the mackinaw and the bull-boat. All of these forms were used by the fur traders especially, but continued to be used in later days for carrying supplies and provisions. The fur trade ended about 1845 and these types of boats practically passed away at that date. With the beginning of the 19th century the keel-boat, the chief means of river navigation for many years, began its career. Manuel Lisa was one of the first to employ it in the up-river trade. Lewis and Clark in 1804 ascended the river by its means, as did Pike in 1806. J. J. Astor in 1810 had a fleet of five of these boats. The means of propulsion was a rope, perhaps 300 yards long, with ten to twenty men on land to draw the boat up-stream; sails, poles and oars were also used as occasion or necessity might determine. Some of these keel boats were nearly a hundred feet in length, and capable of transporting many tons of freight. In 1819 the first steamboat entered the river, and from that time to 1830, occasional trips were made, with a gradually increasing number of boats in use. During the next decade regular lines of steamers, equipped with one engine, were placed in service on the river. However, the years 1850 to 1860 were the golden years of Missouri river commerce. In 1858, the best year of all, about sixty regular packet steamers were employed, and tramp steamers to the number of thirty or forty found service along the river. The value of the commerce was greater, at its best, from St. Louis north on the Missouri, than it was north of St. Louis on the Mississippi. Many of the steamers used at this time were handsome and well equipped. Some of the largest ones measured 240 feet in length, with forty-foot beam, and were capable of carrying 400 people and 500 tons of freight. They were then called "floating palaces." At Leavenworth in one year 306 steamers entered and cleared, while in 1859 at Sioux City some 312 vessels, with goods to the value of $1,250,000, entered in one season.

The decline began with the civil war, as the guerrilla made the service dangerous as well as unprofitable. For a time about the close of the war, the Montana mines caused a revival of river traffic, but it was of short duration, as the railroad trunk lines from the east began to touch the river. St. Joseph was reached in 1859, Omaha in 1867, Sioux City in 1868, and Bismarck in 1873. By the latter date the profits of river traffic were gone, and the vessels that continued in service did so largely as tramps, and because they were in existence. Many were snagged, others broken up, and the remainder transferred to other rivers. The last steamer to leave the upper river is variously reported; some say 1885, others 1890.

The possibility of restoring this traffic is problematical. The rates then were much greater than land rates today, so if it may be developed into a profitable commerce, it must be after new inventions and more scientific methods have been applied. The possibility is sufficiently enticing to call for a careful study; but it would be the height of folly to go it blind, and spend millions until the problem had been investigated by the unbiased scientist in all its phases. The problem of storage, power, and navigation must be considered as a whole and the solution reached only after investigation.

At the close of Professor Caldwell's address, the chairman said: "Flowing water represents power. Every flowing river can do work. It can generate electricity, run trolley cars and light our houses. It can lift a part of itself out upon the fields to water the thirsty plants. Occasionally the drainage area contains more flowing water than the central stream can carry away, and then the water floods the land. These surplus waters scour the soil, they destroy fences, bridges and buildings. They impoverish the soil and the owners of the soil. Professor Stout will tell us of the work done by the great river along the lines just outlined."

THE RELATIONS OF POWER AND IRRIGATION AT THE HEAD-WATERS OF THE MISSOURI TO FLOODS IN THE LOWER COURSES OF THE RIVER.

BY O. V. P. STOUT,

Head Professor of Civil Engineering, University of Nebraska.

Major Chittenden, of the Corps of Engineers of United States army, has said that in no portion of her works has Nature left so much to be done by the engineer to supplement her deficiencies as in the modification of the natural flow of streams. Major Chittenden has been stationed for many years on the Missouri river and is probably the most thorough student of that stream in all its aspects and relations that we know. It is, therefore, fair to assume that the Missouri river inspired the statement which has just been quoted.

So far as a river like the Missouri is concerned, its uses for which it is or can be made available, are agriculture, transportation and power. In addition to the studies and works necessary to develop these uses we have also to interest ourselves in the works that are necessary to insure life and property against the destructive tendencies of the great stream. So far as power and transportation and the prevention of the ravages of the river are concerned there is a single, simple condition which may be kept in view as the ideal which is to be approached as closely as practicable. This ideal is a condition of absolutely uniform flow in the channel at all points, and is an ideal which is, in this case, as far removed from the actual as can well be imagined, for the Missouri river is subject throughout its course to extremes of high and low water. If absolute uniformity in the flow could be obtained all power developments would be able to deliver the constant output which is desired. The craft engaged in transportation would have a single and well known set of conditions to encounter, and the river, in due course of time, would settle itself into a regular and permanent bed, and the shifting and change which is now so prominent a feature would disappear. When, however, we consider the application of the water of the river to agricultural uses we find that absolute uniformity of flow is not consistent with complete utilization, since the demand for water for irrigation is a variable one even throughout the irrigation season, and ceases entirely during a large portion of the year. It is to be remembered also that it withdraws or diverts the water from the channel of the river, and that a large proportion, probably about two-thirds, is permanently withdrawn, given off by evaporation from the surface of the irrigated fields and crops. This is borne away in the upper currents of the air so that there is no assurance or ground for belief that when it does return to the land it will fall on the drainage area from which it was originally withdrawn. The other one-third of the water which has been diverted for irrigation will sink into the ground and in the form of return and seepage waters will sooner or later reappear in the main stream. It is easy to see that this action would interfere with any scheme or plan which aims to bring about a uniform rate of flow in the river.

However, even though irrigation would be a distributing factor in a scheme which contemplated a constant rate of flow in a stream, it is of itself an effective means toward the reduction of the extremes in the flow of streams. The features responsible for this effect being the storage of flood waters, which reduces the highwater stages, and the return of the seepage waters which augments the low water stages.

The discussion of the storage of water in connection with the utilization of streams for irrigation, power, and transportation has appealed chiefly to those who in some degree have been interested in these industries. The storage of water as a measure of protection against floods, however, has seemed to attract popular interest and as is usual in such cases, some mistaken ideas are entertained. The matter has been the subject of investigation in this country at various times for the last fifty or sixty years, and the conclusion generally has been the equivalent of that which Major Chittenden has formulated, "The function of reservoirs will always be primarily the promotion of industrial ends; secondarily only, a possible amelioration of flood conditions in the rivers." An illustration which seems to apply in this connection is that of the large reservoirs on the head waters of the Mississippi river. Experience has shown that these reservoirs are substantially effective in improving the navigation conditions on the upper Mississippi river down as far as St. Paul and that water power developments along the same stretch of river also are indebted to these reservoirs for an increased steadiness of flow. So far as flood conditions, however, are concerned, it is said that the effect of these reservoirs on the stage at St. Paul is inappreciable. This fact should not occasion surprise when it is remembered that although these reservoirs are among the largest in the world and store entirely the water drained from an area which is in itself large, this area is only a little more than ten per cent of the area drained by the river above St. Paul, so that a little less than ninety per cent of the area which was originally available to produce floods at St. Paul still remains effective to that end.

When we come to consider the regulation of the rate of flow in the Missouri river, by means of reservoirs at its head waters, we are confronted by some facts of history and experience which convince us that such an expedient can be only in part effective. Thus in the great flood of 1844 which has never, within the period of record been equalled on the Missouri river at Kansas City nor on the Mississippi river at St. Louis, low water was reported at Sioux City, showing that this flood owed none of its intensity to waters which came down from the mountain drainage areas at the head of the river and that reservoirs in that region could not have served to mitigate the flood.

The United States Reclamation Service, which has been in existence since 1902, has surveyed, estimated and in part constructed reservoirs for irrigation on the Missouri river catchment area, to the extent of an aggregate capacity exceeding four million acre feet. Four million acre feet is the equivalent of about 60,000 cubic feet per second for one month, or of 20,000 cubic feet per second for three months. The first of these amounts withdrawn from the Missouri river is sufficient to reduce materially the height of the June rise and the second is sufficient, if permitted to be applied to that use, to raise materially the height of the low stage in the river. Major Chittenden has estimated that the stage of the upper flood waters might reduce the flood height at Sioux City to an extent of from three to six feet, according to how completely the work of reservoir construction was carried out. A five year record at Sioux City shows the range in height of river there to be about twenty-two feet. Six feet taken off at the flood height, and an equal amount added to the low stage would reduce the extreme range in height from twenty-two feet to ten feet, which reduction would be a long step in the direction of securing the uniformity of flow which is so desirable from the standpoints which have been mentioned.

An idea which seems to be very generally prevalent is that the floods in the Missouri river are, to a large extent, responsible for the destructive high waters which occur on the lower Mississippi river. The most casual study of the records, however, will show that this is not the case. The high floods in the lower Mississippi correspond closely in point of time to those in the Ohio river, and occur several weeks earlier in each year than the flood in the Missouri river. The Missouri river flood is much smaller in volume than the Ohio river flood and is superposed on the Mississippi waters at a time when the Ohio and the upper Mississippi are in moderate flood at most.

The question of storge of the waters in the upper Ohio and its tributaries was discussed extensively about the middle of the last century, and the conclusion seems to have been that such storage if carried out to an extent to make it effective was impractical on account of magnitude and cost. The subject, however, has been lately reviewed by the Chief Hydrographer of the United States Geological Survey, who has had the advantage of a large amount of topographic and hydrographic data in addition to which was available in connection with the investigations of earlier engineers, and the modern view-point also has been modified by the developments in electrical transmission of power, and by the recognized desirability of conserving our coal supply. The conclusion reached in this later investigation, although advanced as a somewhat tentative one, is that the storage of water on the upper Ohio and its tributaries, costing from one hundred and twenty-five million to two hundred million dollars, would be repaid by the returns from power development alone; that the advantages to navigation would be material and pronounced, and that an effective measure of flood protection would be secured. It is not believed that this case can be taken as the basis for assuming that a similar investigation on the Missouri river would lead to a similar conclusion. As previously noted, the largest flood on the Missouri did not originate in a region where reservior sites can be found.

The Missouri River Commission which was in existence from 1884 to 1902 spent about nine and one-half million dollars on works of regulation and protection in the river, about two million dollars of this amount being spent above Sioux City, and the balance between Sioux City and the mouth. The expenditure of this large sum of money accomplished little for the benefit of navigation, since for this purpose the work must be systematic and continuous. The chief benefit which has been derived was in the nature of protection to private property, and even in this respect the demands for protection have been many times greater than could possibly be accommodated with the means at hand. This work, which has consisted largely of bank protection and similar construction, lacks the general utility which attaches to reservoir construction. If a reservoir is constructed and used intelligently it is known absolutely that flood heights will be reduced, low water stages will be raised, navigation conditions will be improved, the value and availability of the stream for power development will be increased, and riparian property will be more secure. There can be no doubt as to the direction of these effects. As to the measure of the effects in any given case there may be a wide range of uncertainty and difference of opinion.

In the introduction of the fourth speaker, the chairman said: "Every river has relation to forests. Where there are forests there are rivers; where there are no forests there are no rivers, the only possible exception being in the sand hill areas. When man wholly destroys the forests, the rivers disappear. In place of the stream is a dry river bed, abandoned as a continuous river course. It may carry as much water in a year as a river, but its flow comes as a sudden down-rush which soon leaves all dry again. In a real river it is not so; the water slowly oozing from the damp, forest covered soil, is constantly renewed. It is a living stream, not a fitful flood. The river margin favors the growth of trees. Soon the stream becomes fringed with a forest belt, which, if not destroyed, broadens out over the drainage area. When this is accomplished, the steady flow of the river is increased. *Give me the time and the means* and I can make the Platte a navigable stream all the year around! We will now ask Professor Phillips to discuss the subject which interests him most."

THE RELATIONS OF FORESTS TO RUN-OFF WATER.

BY F. J. PHILLIPS,
Professor of Forestry, University of Nebraska.

MR. CHAIRMAN, LADIES AND GENTLEMEN: The relation of forests in conserving water supply is an exceedingly important one. There is scarcely an old resident who has seen forests disappear but has also noted a marked increase in floods and the serious damage which results. On the other hand, where a nation has re-established protective forests on steep slopes and secured far-reaching, beneficial results, as France has done, it should be a strong object lesson to every nation where there is need for similar work. The general laws pertaining to the growth of forest trees and those relating to rainfall and stream flow are everywhere the same and what several nations have already learned by cruel experience ought to be an object lesson to the younger nations which are concerned with the same problems.

In our own country no waterway is so important as the Missouri-Mississippi and certainly in no part of this continent does the run-off reach such a maximum or produce such devastating results as it does along this stream course. Muir appropriately describes the situation when he says, "Think of this mighty stream, springing in the first place from the sea, flying on the wind, alighting on the mountains in hail and snow and rain, lingering in many a fountain feeding the trees and grass; then gathering its scattered waters, gliding from its noble lake, and going back home to the sea, singing all the way! On it sweeps through the gates of the mountains, across the vast prairies and plains, through many a wild, gloomy forest, cane-brake, and sunny savanna; from glaciers and snow banks and pine woods to the warm groves of magnolia and palm; geysers dancing at its head, keeping time with the sea waves at its mouth; roaring and gray in rapids, booming in broad, bossy falls, murmuring, gleaming in long, silvery reaches, swaying now hither, now thither, whirling, bending in huge doubling, eddying folds, serene, majestic, ungovernable, overflowing all its metes and bounds, frightening the dwellers upon its banks; building, wasting, uprooting, planting; engulfing old islands and making new ones, taking away fields and towns as if in sport, carrying canoes and ships of commerce in the midst of its spoils and drift, fertilizing the continent as one vast farm." Truly, this magnificent waterway demands our most serious consideration and our engineers and scientists should unite in trying to make it the best controlled stream of its size on earth as well as making the work serve as a model for smaller streams.

Conditions such as prevail at the headwaters of the Missouri show the value of maintaining a dense forest cover. The general elevation of the region is between 8,000 and 9,000 feet. Sudden, heavy rainfall is common during the summer. Snow comes early in winter and piles up to housetop depths before spring. Slopes are steep and were it not for some of the best forests that occur in the Rocky mountains every foot of slope soil would be washed away in less than a decade. It is well that the government controls most of these forests and that adequate provision will be made not only to maintain these forests but to actually improve them. The proximity of this work to the state of Nebraska and the great importance of the river to the state make it imperative that some consideration be given to the specific effect which a forest has in regulating the water supply.

A brief statement of the effect of the forest may be made as follows:

1. It has often been argued that the forest increases the rainfall. Most of the scientific investigators have found that forests do not increase the rainfall and only one or two men contend that the forests do increase rainfall. It is a generally accepted truth that the forests do not increase rainfall.

2. Forest trees do intercept a considerable portion of the rainfall on its way to the ground, thus allowing more time for the water to sink into the slope soils than would be the case if the slopes were bare.

3. The bases of standing trees together with decaying vegetation and other ground litter have a barrier effect which aids in preventing surface run-off on slope land. The greatest importance of this is manifested when comparison is made between a forest from which the litter has been burned and one in which the litter forms a perfect ground cover.

4. Forest litter and a dense humus serve as a great natural reservoir, which is much more retentive of moisture than bare soil would be. This decaying vegetation absorbs water quickly and has an immense capacity for holding it, and hence this factor serves as an effective check against flooding in mountain regions. Often the erosive effect of a torrential rain of more than four inches will be entirely prevented by forest humus.

5. A forest-covered slope has a more porous soil than a bare slope or one covered with grass and hence the soil proper is more capable of water absorption than would be the case if the soil were bare.

6. Forest-covered slopes constantly increase in soil depth and thus in water-holding capacity, while bare slopes rapidly lose soil and soon become incapable of retaining water. It has often been noted that in the United States, slope soil which has been forming for centuries was entirely washed away in the short course of three to five years after the complete removal of the forest. If we retain the forest under the proper management it will serve as a permanent resource which will give an annual yield of wood; destroy the forest and it may take centuries of time to re-establish a satisfactory cover.

7. The forest soil sends much more snow water to the water table than does bare soil, since the snow melts much more slowly in the forest than in the open. This is due largely to the shade furnished by the tree crowns, but is also due to a limited extent to the lessened evaporative force of the wind. The average temperature of the forest soil is 2° to 3° (Centigrade) lower than bare soil, which has an effect equal to about the same number of degrees in latitude for the bare soil. The importance of this temperature effect is shown by the fact that snow-fed streams flow approximately twice as much during the day as at night, hence an average difference of 2° to 3° must have an appreciable influence in the annual run-off.

Briefly, then, the value of forest cover lies in the greatly increased amount of water which is sent to the water table instead of becoming surface run-off, thus effectually regulating flow whenever the forest cover is in sufficient proportion to the size of the watershed. It serves, too, in retaining flow during early spring, when there is least need for the water and making available more water for summer, when there is greatest need for it.

Unfortunately, we have not had a sufficient amount of scientific study in this country on the changes which result in deforesting a water-shed which has been previously densely forested. The government has, however, made scientific comparisons between two adjoining water-sheds which were as closely similar as was possible to select. This comparison brought out many strong facts in favor of retaining the forest cover on slope lands, yet the results were not as striking as they would have been had they been tried on a water-shed which was densely forested and then had the forest removed.

The question has probably been most thoroughly worked out in France where two-thirds of all the torrents of Europe occur. During the French Revolution immense slope areas were entirely denuded of forest growth and at least 800,000 acres of agricultural land was washed away or seriously affected by flooding. The danger was becoming worse each year and fully 1,500 streams were considered dangerous. The first policy for flood prevention was a vast system of reservoirs and dams. Then sodding the slopes was tried and finally recourse had to be made to reforestation. This method was effectually started under national laws in 1882 and alreads 163 of these torrential streams are under full control, while nearly 700 of the remainder are beginning to show the beneficial influence of reforestation. The difficulties of the work can be fully comprehended only when it is understood that it was sometimes necessary for the tree planters to carry soil up the slopes in baskets in order to make a suitable bed for the trees to grow in.

Another phase of protective work is of vital significance to Nebraska. There is a vast area of slope land within our state which is not perfectly suited for agriculture yet and which is well adapted for forest growth. The relative value of keeping these slopes tilled, in sod and in forest is fairly well shown by Professor Shaler, who says: "As soon as the tilled soil is moistened, each raindrop acts to break up the clods, bringing the material into the condition of mud, in which it is readily borne away by the rills, which, if the shower be heavy, quickly form in such numbers as to interlace the surface. In a few moments these little streams, at first obscure, gather into distinct rills, which, with quickly-swinging curves, carve out a model of a new drainage system. In the course of an hour a very rapid downfall on a bare, plowed field, with a declivity of not more than five feet in a hundred or less than the average slope of land, may have an average of one-third of an inch of its surface soil removed to the channels of a stream which drains it."

"A brief comparison of the effects of a heavy rainfall on a newly-tilled surface, bare of vegetation, and on a like area which is protected by the natural covering of living and dead plants will show the peculiar influence of the vegetable shield on the history of soils. On wood and grass lands the rainfall has practically no erosive effect whatever. In the forest the matter of decayed vegetation is in most cases able to take in three or four inches of water, which it yields up so slowly as to distribute the flow over weeks and in such a manner that it removes not a bit of soil." There is, however, a great distinction in sod and forest land, since a well-matted sod land has a large run-off, while the proper forest cover has a minimum run-off. This rapid run-off and lack of erosion on sod land is due to the surface mat of roots characteristic of the grasses, and while grasses may prevent erosion, the sodding of slopes may augment floods.

Still another phase of forestation should be tried extensively on the river-bank and flood-plane areas within our state. France and Russia have made provision for forestry work on the banks of streams which flow through regions quite similar to our own, and it is a well-known fact that there is no soil binder which compares in efficiency with forest growth. This type of land is capable of producing high-class forest growth and may be capable of yielding a considerable supply of timber if great care will be taken in selecting only mature timber. Since the amount of tree growth depends very largely on the amount of soil moisture, it becomes readily apparent that these areas would support some of the best stands of timber that could be found in the state.

In conclusion, then, it may be stated that no phase of water-shed protection demands more serious consideration than does forest growth. If our forests are rightly managed, there is no doubt that they will still serve a very high protective function and may even supply a considerable amount of wood. Destroy our protection forests and the entire gain from harvesting all of the timber on any great water-shed may be entirely offset by the damages of a single flood, while each recurring flood is bound to grow proportionately more serious. The most progressive of European nations maintain the strictest vigilance over their protective forests; and what Germany, France, Austria and Switzerland can do, with good results, certainly can be done in this country, with equally good or even better results. Our protection should not only concern the mountain states but also those which adjoin them on all sides, and since the increased future development of almost the entire Rocky mountain region depends upon water and timber, the question is one vital to our best welfare. We should stand strongly for forest protection and forestation in the mountains and for an extension of forest areas in Nebraska.

The chairman in presenting the next speaker said: "Streams, like children, are apt to form bad habits. They meander and, in doing so, get into trouble, and, what is worse, they make trouble for others. Professer Bengtson, who has studied these bad habits of the Missouri, will tell us about them."

MEANDERS OF THE MISSOURI RIVER AND THEIR EFFECTS.*

BY N. A. BENGTSON,

Instructor in Geography, University of Nebraska.

MR. CHAIRMAN, LADIES AND GENTLEMEN: I will briefly describe the meanders as they occur along the Nebraska border. Dr. Condra gave you a picture of geographic conditions in the basin and Professor Caldwell has reviewed the history of the early utilization of the river. My remarks are to be illustrated with about twenty lantern slides.

The "treacherous Missouri" is an expression common to people in the Missouri valley. The expression was originally applied by the steamboat pilots in the days when river transportation was a prominent industry. It was prompted by the fact that the channel in most of its course is in a bed of fine sand and therefore suffers frequent change of exact location. Recently a new meaning has been given, bearing more upon the relation existing between the river and its flood plain. The

* This paper is a part of Mr. Bengtson's second degree thesis, which was prepared under the direction of Dr. G. E. Condra and presented to the Department of Geography, the University of Nebraska, May 15, 1908.

truth of the expression now may be questioned. Popular writers are wont to picture the Missouri river as a stream whose course is uncertain, and that a town on its banks today may tomorrow be several miles inland. While it is true that it has a shifting channel, and sometimes forms cut-offs, these are merely minor incidents in its work. The "cut-banks" are the results of meanders, whose laws of progress have long ago been stated and discussed at length by Professors Davis, Russell, and others. But inasmuch as the rate at which meanders progress varies with different streams and with different parts of the same stream, attempts to forecast the course of the Missouri have frequently proven disastrous.

The Missouri river is corrading its banks to a greater or less degree along nearly its entire course bordering Nebraska. Commercially speaking, the cutting is generally slow and takes place only during the flood seasons. At periods of low water the banks are protected by the talus formed of surface material, which slides down by wind and water action. This material is generally fine silt, which in water becomes very compact and hence protects the coarser and more sandy layers at the water's edge. The bank of the stream opposite the cut-bank is almost invariably aggrading, forming a sand bar, or shingle bank. We should therefore not forget that the work of the stream is of two kinds, erosion and deposition, both about equal.

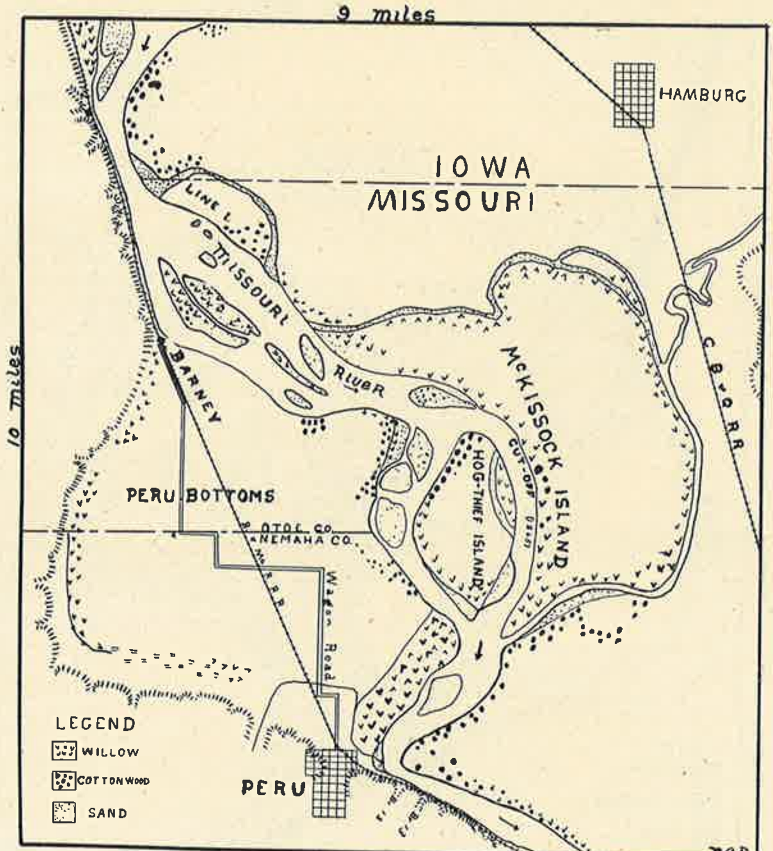
The Missouri river above Yankton, South Dakota, has a comparatively narrow valley, its flood plain being generally less than a mile wide. The course of the stream is characterized by long swings, striking the banks along either side alternately at distances of about four to eight miles. In that part of the course the meander limit has not been reached, and hence the progress of the meanders is affected by the escarpments bordering the flood-plain. Where this is the case the channel of the stream does not shift abruptly, as the records show but little change in the course of thirty years. At the South Dakota-Nebraska line only a slight change has taken place since 1881, the date of the first accurate data available. At but one place above the mouth of the Niobrara river has the channel changed its position in the flood plain more than forty rods within the time stated. At Niobrara the valley widens. From there to Yankton its width is from two to three miles, and with the wider floodplain channel migration becomes more marked. On the Nebraska side of the front of the first meander below Niobrara a strip of floodplain three miles long and averaging one-eighth mile in width has been cut away since 1882. The land has not been flooded within this time and is generally about six to eight feeet above flood waters. This bank, which is opposite Springfield, South Dakota, and just west of Santee Agency, Knox county, Nebraska, is the first important cut-bank along the Missouri river in Nebraska. The cutting there cannot become very rapid in the near future because of the influence of the direction of the bluffs. Where the river leaves the Nebraska escarpment and swings toward Springfield, South Dakota, the direction of the bluffs changes from north 25° east to north 37° east. The bend thus formed serves as a spur which deflects the stream and will prevent in large part very rapid cutting of the floodplain west of Santee Agency. The South Dakota floodplain south of Bon Homme and the first two Nebraska floodplains east of Santee Agency are not as favorably situated. The directions of the bluffs are such that rather violent cutting will continue on the upstream sides of the floodplain and the rapid addition of accretion land on the downstream sides. The first Nebraska floodplain east of Santee Agency has had about 800 acres cut away from its west side since 1882 and rapid cutting is still in progress. On the east side of the floodplain building is going on at nearly the same rate, but the accretion land, has no commercial value for many years after its formation on account of the danger from floods. The accretion land is gradually built up, however, first by deposition of silt from flood waters, later by deposits due to wind action. The willow growths which spring up about the third year after the formation of the accretion land bear a vital relation to wind deposits. The willows grow very dense and hence when the wind blows from sand bars or cultivated fields over the willow thickets its velocity is checked and much of its suspended dust and sand is deposited. Thus in the course of a comparatively short time floodplain deposits may be elevated above the altitude of the flood stage of the river. When that point is reached other trees prosper, such as the elm, cottonwood, and some oaks. This stage of heavy timber may be noted as the third stage in development of accretion lands for industrial uses. The forest stage is generally followed by man's activities. The forests are removed and the land reclaimed for agricultural purposes. The floodplain north of Herrick, Knox county, Nebraska, has also suffered considerable cutting since 1881. But cutting is not now very rapid because the stream strikes the bluff above Herrick almost at right angles and hence is deflected back at an angle almost equally sharp. Cutting under these conditions will proceed in proportion to the normal progress of the meander. That progress, judged by human standards, is necessarily slow and in consequence does not threaten seriously the land values.

Just east of Yankton the valley widens abruptly, from there to Sioux City averaging from ten to seventeen miles. The river between these cities nowhere touches the South Dakota escarpment while it strikes the Nebraska bluffs seven times. The course in this wide floodplain is characterized by more abrupt curves and these generally swing against the comparatively loose materials of the floodplain. At Sioux City the river makes a 90° turn in its course, coming in from the west, and its course below the city is due south. That these conditions, wide floodplain and abrupt change in the direction of the river, have a direct relation to development of meanders cannot be doubted. Above Yankton the meanders are nearly symmetrical. The downstream portion of the loop is about equal and similar to the upper. Below Yankton the upstream part of the meander is generally much longer and makes a smaller angle with the mean stream direction than the lower part. This is clearly shown by every meander between Yankton and Sioux City. Below Yankton the river first strikes the Nebraska bluff near St. Helena. The mean direction of the stream is east 28° south, distance twelve miles. For the first ten miles the river is nearly straight, flows east 8° south, then turns sharply and now flows south 10° west. Thus in the upper part of the meander the angle with the mean stream direction is 20° while in the lower part it is 72°. There are no cut banks of any consequence in the upper stretch, very little change having occurred since 1892, so that for industrial purposes the floodplain may be said to be safe. In the lower course of the meander the position of the channel has shifted from one-fourth to one and one-half miles. In 1892 the river struck the bank one-half mile northwest of St. Helena, now it first touches it nearly a mile southeast. About six hundred acres have been cut away from the South Dakota floodplain and very nearly the same area added to the Nebraska side since 1892. The shifting at St. Helena since 1881 has been almost two miles. The land cut away was relatively high, well-drained, very fertile, and ranked with the best soil in the United States in productiveness. The accretion land is low, sandy, poorly drained, produces at present only rushes and willows, but may eventually become good farm land. For this generation and probably the next the loss is greater than the gain.

The same type of change has occurred below St. Helena at Vermillion Ferry, Ionia, Ponca Landing and near the mouth of Aowa Creek. At Vermillion Ferry the stream has shifted its postion one and one-fourth miles, and at Ionia about one mile since 1882. At Ponca Landing and Aowa Creek the changes have not been quite as marked, but the difference is of degree not of type. The strikingly rapid work has all been on the front of the short, sharp curves of the meanders while on the longer stretches the erosion has at no place exceeded one-eighth as much, and in many places no important changes have occurred. It seems true that the direction of the stream and the wide floodplain cause the meanders to have a long upstream course of gentle curve and a short downstream course at a sharp angle to the mean direction of the stream. In the long sweep of the meander cutting is slow for a greater distance; in the short swing the cutting is intense for a short distance. The total results measured in acreage eroded or areas aggraded are probably nearly equal. The cutting on the front of the sharp curve bears the more vital relation to man because of its relative rapidity and the short span of human life. The direction of the bluff in relation to the floodplain and the angle at which the stream strikes the bluffs are also factors whose importance should be emphasized. These relations are deserving of very careful study, and should immediately be made the basis of extensive research on the part of the state and federal governments.

The control exercised by the direction of the bluffs in relation to the stream course is well illustrated in many places, and especially so at Blackbird Hill, Decatur, Florence, Bellevue, Plattsmouth, Nebraska City and Peru. Space forbids detailed discussion of conditions at each of these places but the last two named stand as typical examples. The direction of the bluffs north of Nebraska City has an influence over the direction of the stream that bears a vital industrial relation. In the lower part of Copeland's Bend the direction of the bluff changes from east 28° south to east 40° south, then its direction changes so that in the north part of Nebraska City the direction is south 20° east. The stream follows the concave face of the bluff and hence at its turn is deflected toward the Iowa floodplain, striking it about one-half mile north of the Burlington railroad bridge. This causes a cut bank against the floodplain and a tendency to build a bar next the Nebraska side. If not checked this would mean a shifting of the channel to the eastward with its attendant sequels. A sandbar would be built under the bridge, the railroad grade to the eastward would be cut away and the bridge would be left a useless structure, spanning only an area of accretion land. To overcome this tendency the Burlington railroad company is compelled to protect the floodplain above the bridge from being cut. Hence extensive riprap work has been resorted to, but the force of the stream is such that this work must be kept up continually at great expense. Constant vigilance is necessary for breaks in the riprap must be attended to promptly. The cause of this condition is not the erratic Missouri, but rather an expression of the influence of bluff direction upon the consequent course of the stream. The work of the Burlington in its efforts to save its bridge also protects a large portion of the floodplain from encroachment by the river.

Conditions north of Peru, Nebraska, furnish an interesting example of the same kind of control of river changes. (See Fig. 3.) When Nebraska was organized as a territory the river had the position indicated as the old bed of the Missouri river. This was made the eastern boundary of the territory. At the flood of 1865 the cutoff was effected, a portion of the floodplain transferred to the Iowa-Missouri side. This portion, known as McKissock Island, had water practically only on three sides. Another area was included between the forks of the river and received the name Hog-Thief Island from the fact that for a time there was a doubt as to which state had legal jurisdiction there. Various literary masterpieces have been called forth by the conditions affecting the historic station of Barney. In 1879 the Burlington and



Missouri River near Peru, Nebr. 1879.

FIG. 3.

Missouri River Railroad had the position indicated by a straight line from Peru, direction north 26° west, until it reached the bluff near Barney. The river was then more than two miles due north of the Otoe-Nemaha county line. It first struck the bank near Minersville and followed the bluff for several miles. The angle from which the stream came in was such that as the meander progressed there must be some deflection from the bank. The bluffs make an angle of 15° with a north and south line. These conditions caused the main channel to be deflected to the south-east as indicated by the cut-bank on Line Island, but there was a small distributary following the bluff until near Barney where it was deflected toward the east. While this condition lasted the high floodplain was not being cut very rapidly because the bluffs, situated as they were, served as a protective barrier. In this position normal deflection would tend to throw the stream just south

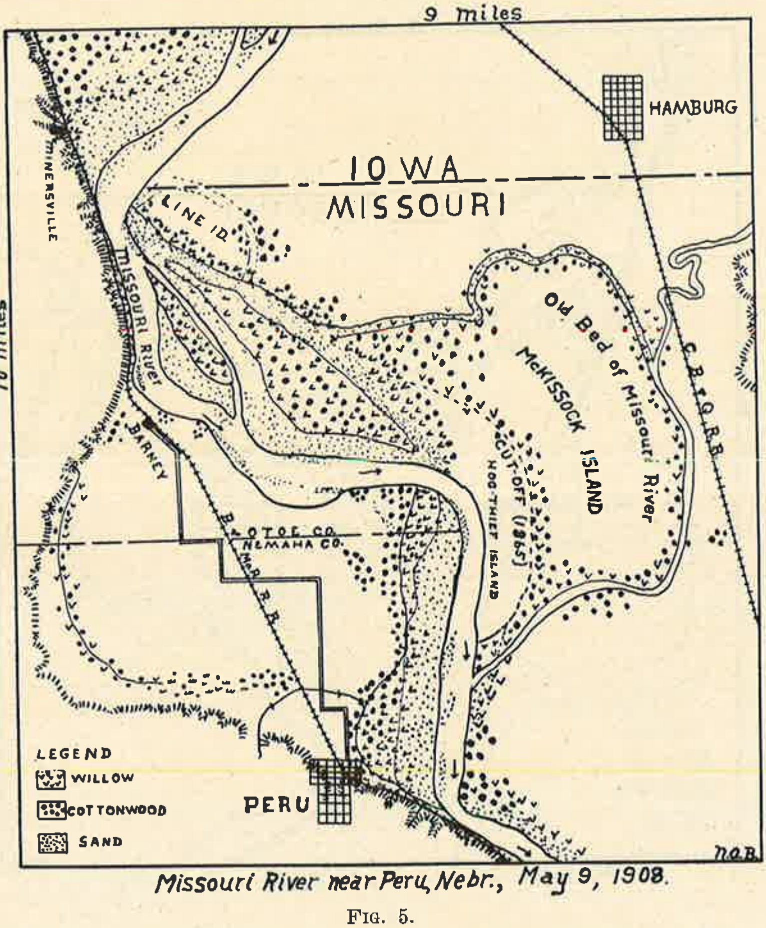


Fig. 5.

of Line Island. The cutting on the floodplain was done by only a portion of the stream. With the downstream progress of the meander it was inevitable that very rapid cutting would ensue.

Before 1890 the branch of the channel between Hog-Thief Island and McKissock Island was abandoned and a fusion of islands had occurred. The geological significance of these movements is of interest. The county superintendent of Nemaha county, Nebraska, to which the island belongs, must pass thru parts of Nebraska, Iowa and Missouri in order to visit the school at the island. The farmers there cannot sell their products in their own state, their industrial relations are with Missouri and Iowa, but they help determine the political affairs of Nebraska. In the election of 1907 the island vote determined the political complexion of two of Nemaha's county officials. In 1890 the course of the upper meander had become more pronounced. The stream cut the bank almost at right angles at Minersville, was deflected and gave rise to a cut bank north of Line Island with sand bars on both sides of the channel below that point. The Barney station had been moved almost three-fourths of a mile farther south. About 500 acres of land had been cut away just north of Barney. To the east where the main force of the current struck fully 800 acres were removed. But at this time landowners near Barney felt but little apprehension for they considered the bar a protection to them and took it as proof that the channel would migrate toward the Missouri side. This bar was being cut slowly on the north side, and it was but a question of time until the meander should progress beyond it and the stream exert its full force on the floodplain unless held in check by artificial means.

Since 1890 the changes have been marked. (See Fig. 5.) The meander has progressed beyond the south spur of the bluffs and since then the cutting has been rapid. In July, 1907, Barney station was moved to a point nearly half a mile southwest of its former location. The railroad had to find a new right of way. Notwithstanding all these marked changes note a conformity to the same general features shown previously. The floodplain was for a long time partially protected by a spur in the bluff, and while the meander was thus checked cutting was not rapid. When the barrier was passed abnormal cutting began. North of Peru the plain has not been flooded since 1882, lacking 3 or 4 feet. Structural conditions of the floodplain favor erosion. At low water the plain is about sixteen to twenty feet above the river surface. The lower twelve feet is loosely cemented sand interstratified in places with thin layers of fine silt or clay. The upper three to six feet are composed of much finer materials, mostly silt mixed with organic matter which becomes very compact and is sometimes known as "gumbo." This is a condition very common in the Missouri river floodplain and causes erosion to be done very largely by undermining which leads to the falling in of strips of land from two to twenty feet wide and sometimes several rods long. The cutting varies with the local conditions at each place and with the stage of the river. Cutting occurs at but relatively few places at low water stages and always slowly, while just the opposite is true of the high water stages. The cutting on the Peru floodplain was unusually great during the summer of 1907 partially at least because the last of the sand bar noted on the map for 1890 was cut away early in July. This bar had served to divide the current, hence only a part of the force of the stream was exerted against the higher terrace. The bar also increased friction and thus reduced the cutting power. The losses due to cutting in 1907 as measured in acres were severe. The owners named suffered as follows: Mr. Wells, 60 acres; Mr. Rawson, 40 acres; Mr. Cook, 12 acres; Mr. Brunsdon, 40 acres; Mr. Adams, 36 acres; Mr. Wheeler, 23 acres; or a total loss from June 1, 1907, to May 8, 1908, of 211 acres. In productiveness this land ranks with the best that can be found anywhere. If it were not menaced by the river it would easily have a market value of $100 per acre. Thus computed the loss in the single season was $21,100. A careful study of the records shows that in this floodplain area fully 2,000 acres of excellent land have been cut away since 1879, the value of which can conservatively be stated at $200,000. This represents the losses at but one place, and Nebraska has many areas which have suffered to a greater or less extent.

In the agitation for a conservation of our natural resources the case of the Missouri river floodplain deserves careful consideration. The Missouri river is known as an erratic stream. This is undeserved. The Missouri responds to its geographical conditions. However, there are stages when a slight control may cause its development to respond to man's needs, whereas the omission of such may result in serious later disasters. The cutting is most severe during high water stages, this

FIG. 6.—"The Last Stand." View looking north showing where Mr. Brunsdon's 240-acre farm was formerly situated. Photo July 15, 1907. Six miles north of Peru, Neb. Mr. Brunsdon in the foreground on the edge of his farm. Land in foreground was washed away within a week after photo was taken.

being especially true of the June rise. Forestation and the construction of an extensive system of reservoirs for storage of its headwaters may make it possible to regulate in some degree the volume of the stream quite completely and thus assist in eliminating the disasters due to the annual floods. This construction work has been begun, having in view chiefly the power and irrigation interests. Let the Missouri floodplain problem also be considered and make its protection as perfect as possible. River navigation also is aided by uniform river volume, but it demands that the channel be kept free from snags. For this purpose the government should furnish patrol boats whose whole duty should be to keep the deep water channel free from dangerous obstructions.

Keeping the channel open would also aid in checking channel migration and thus reduce the cutting tendency of the stream. Each of these factors is of great importance. But more is needed. A careful study should be made of the whole floodplain in its relation to the development of the meanders. The changes are generally not erratic. The changes occur as the result of a cause or series of causes. It is very probable that in many cases it would be economically possible to check the ravages of the stream if proper corrective measures were taken in time. For instance, from a study of conditions north of Peru (see Fig. 3), it would seem that if a retaining wall had been built from the bluff about a half mile south of the Iowa-Missouri line in a southeasterly direction the

FIG. 7.—A view showing the work of the Missouri river in relation to homes. The site of Mr. Brunsdon's former home north of Peru, Nebraska, almost washed in. Photo taken November 30, 1907.

stream could have been kept in its channel just south of Line Island and the extensive losses on the Peru floodplain avoided. The cost of such a wall should not have been prohibitive because the necessary limestone and sandstone are exposed in the bluff and but a very short haul would have been necessary. Two hundred thousand dollars' worth of land has been destroyed. In the face of such figures we can readily see that even if the retaining wall would have cost $20,000 it would have been a profitable investment. These projects are too extensive for individuals to contend with. The government spends its millions in reclaiming arid lands and we laud its generosity in a worthy cause. Is it then asking too much for the government to protect from destruction the lands which are of the best that can be found anywhere?

In conclusion, permit this summary: The protection of the Missouri river floodplain demands a careful and extensive study of all factors involved. The control of the Missouri will be greatly affected by four factors,—systematic forestation; the construction of reservoirs for storage of headwaters, thus equalizing flow and possibly to some extent preventing floods; the constant patrol of its channel, clearing of snags, thus tending to keep its channel open and lessen migration; a careful study of local conditions having in view the proper, timely precautionary measures of control at cut banks, if any such are economically possible. These problems should at once receive the attention of our state and federal governments in response to the plea for conservation of our great natural resources.

The chairman introduced the last speaker, saying: "We have with us to-night one of our University boys, one who has made good. I am pleased to present to you Governor Sheldon who will speak on ways and means."

WAYS AND MEANS.

GOV. GEO. L. SHELDON.

Mr. President, Ladies and Gentlemen: I have enjoyed these discussions. They have been instructive and very unlike political meetings. I have attended several meetings of late where politicians were ready to speak, but less willing to listen.

More attention should be paid to our water problems and to all of the factors which affect the farms and farmers. The water of our rivers seems lazy. It prefers not to work, but rather to wander sluggishly around its meanders, accomplishing little.

There are selfish interests to be considered in this problem of ways and means. However, they do not concern us in the present connection. The control and utilization of our rivers will require the expenditure of funds from the state and federal treasuries. The cost and returns must be considered. If the benefits in dollars and cents will exceed the necessary investment, then it may be best to perfect plans and go ahead. It is not the spirit of our government that one man's property should be torn down to build up that of another.

You investigators are working out a subject of great interest to the people. Apparently too many of our citizens are ready to act without the necessary study of the fundamentally important facts and factors. Our streams and valleys are worthy of study and control. The possibilities of their development are great, but let's make as few mistakes as possible and do the right thing.

Returning from California recently I came along the Platte valley, and I thought as I looked over it that I would not, if it were in my power, exchange that valley for the whole of California, because there is greater possibility of wealth here than in all the state of California. This valley is to be the seat of a very large and prosperous population.

If it is possible economically to check the ravages of the Missouri and to use the stream for any profitable use, we should further consider the matter in all of its aspects as has been done to-night.