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Drainage Districts of Southeastern Nebraska

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DRAINAGE DISTRICTS OF SOUTHEASTERN NEBRASKA[1]

BY CALVIN TURNER MOORE

INTRODUCTION

Throughout certain parts of the United States the importance of drainage is receiving increased recognition each year. The scope of investigations and operations covers many localities that are affected with "springy" lands, swamps, shallow lakes, overflowed lands, and tide lands.

Drainage work is wide and varied, ranging in extent of operation from the laying of small tile drains on private properties to the construction of large and costly open-cut ditches designed to drain broad areas.

The fundamental reason for constructing and maintaining drainage systems is either to increase the productive value of farm land already under cultivation, or to bring into productivity uncultivated tracts. The rapid growth of population in the United States, the increased value of farm land, and the consequent demand for farm products make small and large drainage projects feasible. A few years ago lower land values and lower market prices for farm products would have prohibited the construction of the larger systems of drainage.

GOVERNMENT DRAINAGE WORK

The question of drainage in various parts of the United States has become of such importance that the Department of Agriculture now maintains a staff of drainage engineers. During the fiscal year of 1909-10, twenty-seven men were employed on this staff and made investigations and surveys in twenty different states and territories. The work of these engineers is classified and described as follows:

(1) Improvement of farm lands now under cultivation.
(2) Drainage of swamp lands.
(3) Reclamation of lands subject to frequent overflow from streams.
(4) Drainage of irrigated lands.

[1] Editorial Note: This paper was presented as a thesis to the Faculty of the Graduate College in the University of Nebraska in partial fulfillment of requirements for the degree Master of Arts, Department of Geology.

(5) Collection of data.
(6) Preliminary and reconnaissance work.
(7) Dissemination of information.

The following, taken from R. D. Marsden's Report on Drainage Investigations 1909-10, gives the special work on which the field engineers were detailed. "The entire time of one engineer is given to the work of tile drainage in various parts of the humid region where special information and advice upon that subject are needed, and five are stationed in the Western States to study the problems which arise in attempts to drain irrigated lands and to assist the owners who desire to reclaim tracts which have become injured by seepage or by alkali. Other field engineers are employed in examining and reporting upon the status of drainage in various localities, such examinations being made upon special requests, which are filed from time to time with the office. They are also charged with the study of advising engineers, farmers, and others regarding the best practice in drainage, or collecting practical and technical data pertaining to methods of reclaiming land, of giving assistance to land owners in the organization of drainage districts, and of suggesting preliminary plans for reclaiming areas of farm lands on those subject to periodical overflow, all of which may be made useful for agriculture. The office engineers reply to inquiries received by mail concerning perplexing drainage problems. They also examine plans which are transmitted by mail or in person, and in many instances suggest improvements or modifications which are of great value. They review, check, and edit the reports prepared by the field engineers upon the various projects which they have worked out, and disseminate as far as practicable the information obtained by the entire staff of engineers."

Drainage Work in Nebraska

The drainage engineers from the Government staff have been of considerable assistance on several preliminary investigations and surveys for various projects in eastern Nebraska. Some of the localities examined are in Burt, Washington, Saunders, Nemaha, Johnson, Richardson, Otoe, and Sarpy counties.

The principal areas of Nebraska requiring drainage ditches lie along the Missouri River in the northeastern part of the State, along the lower Platte and its tributaries, and along the Greater and Little Nemaha Rivers and some of their tributaries.

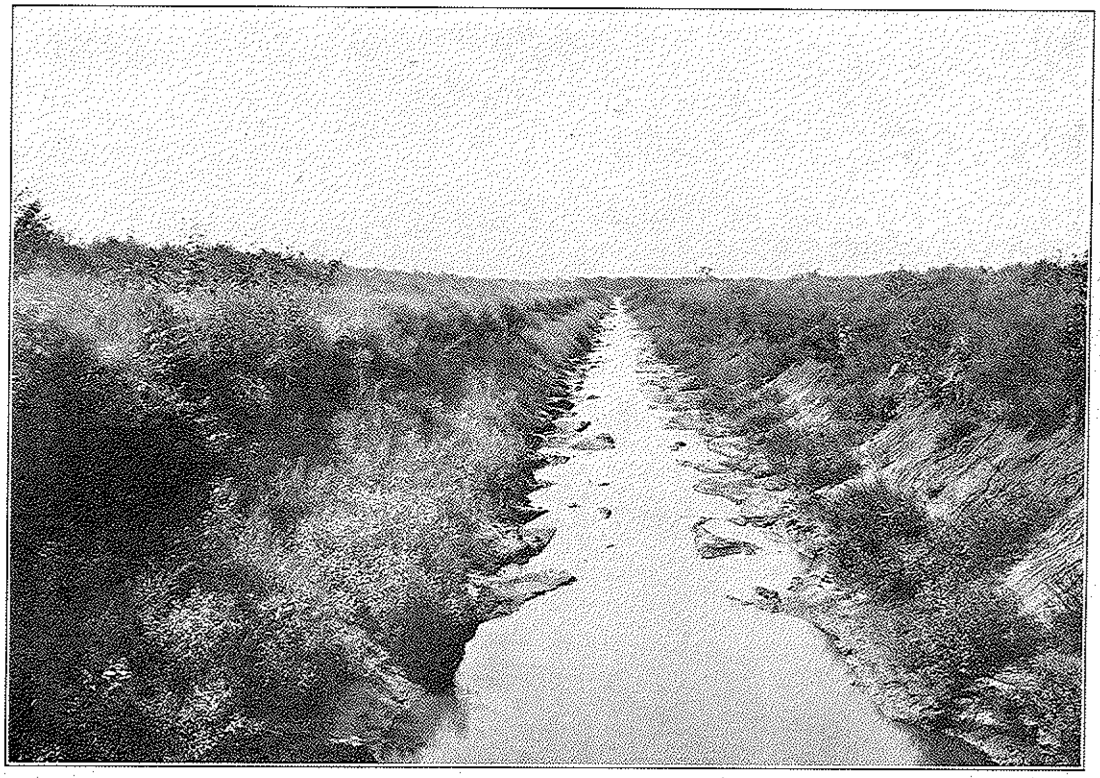

Fig. 1.—Drainage canal near Bracken, Nemaha Drainage District No. 1. Photographed by E. H. Barbour.

Drainage Laws of Nebraska

The drainage laws of Nebraska are very liberal when compared with those of some other states. The State Board of Irrigation, Highways and Drainage has "*original jurisdiction* over all matters pertaining to water rights for irrigation, power or other useful purposes, highways and drainage." (From 1913 Irrigation Laws of Nebraska.) The irrigation laws were expanded to include all drainage projects within the State by the Legislature which convened in 1912, and this clause went into effect July 17, 1913.

Each District Board of Supervisors is responsible to the State Board for the drainage work in its district. The following section from Article II of the Irrigation Laws of Nebraska explains the filing of plans and specifications with approval by the State Board.

"Sec. 41. *Drainage district plans.*—All plans for proposed drainage districts shall be approved by the State Board before any contract is let or work begun. The State Board through its representatives shall have authority to order any change they may see fit in said plans and require the drainage district to conform thereto, and shall at all times during the construction have the right to inspect said work and make recommendations pertaining to the same. Upon request of any interested party or parties of a proposed drainage district, the State Board may prepare for them plans and specifications for any proposed drainage work at actual cost of doing the same." (Drainage Laws, 1913, page 100.)

Copies of the Irrigation, Highway, and Drainage Laws of Nebraska may be had on application to the State Engineer's office at the State Capitol Building.

The following quotation is a part of the State Engineer's recommendation relative to the passage of a law compelling drainage districts to file their plans with the State Board of Irrigation, Highways, and Drainage:

"During the past few years there have been a number of drainage districts formed throughout the State. In many cases these have been formed for the purpose of straightening out and shortening the channels of small streams. Several instances have come to the attention of this office where several districts have been formed for the straightening out of the channel of the same stream. Different engineers were employed to work out the plan and locate the drainage ditches of each different district. The district higher up on the stream would often

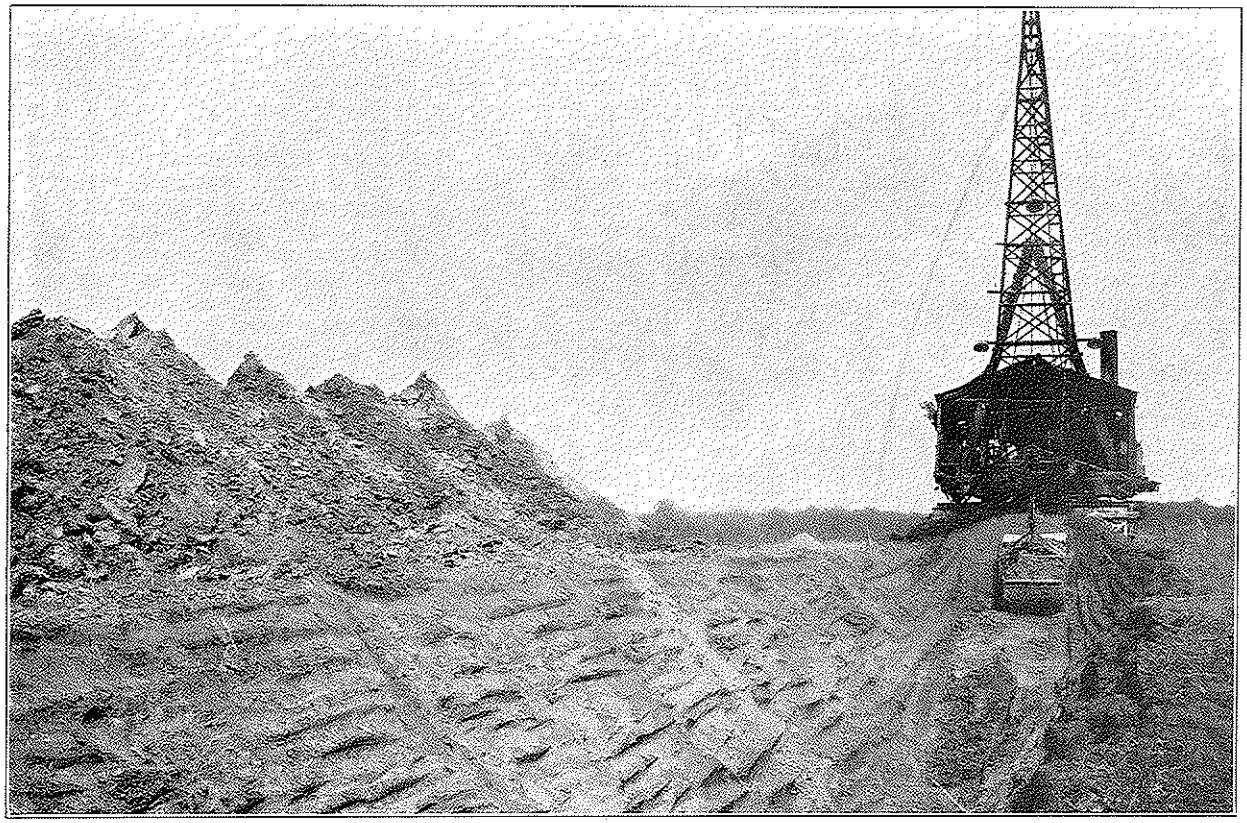

Fig. 2.—Drag-line dredge of Callahan Brothers, Munn and Reise, Margrave's Ranch, southeast of Preston, Richardson County, District No. 1. Photographed by E. F. Schramm.

build a canal of larger cross section than the one lower down the stream, which should have been designed to carry more water than the upper one. This shows clearly that one or the other of these canals was not built to the best advantage and economically.

"Different questions like this arise which are greatly influenced by the local people, who desire special favors and privileges and the best results for drainage as a whole are not accomplished. *It is recommended that a law be passed compelling all drainage districts to file an application, setting forth all the facts pertaining to their proposed drainage project and that the same be acted upon by the State Board, the same as an application for irrigation or power purposes and that the drainage district be required to file detailed plans of their proposed project and that the same be approved by the State Board, subject to any change which they may see fit to make before the construction work can begin.* In this way the drainage work of the entire State will be put under the supervision of the State Board, and the State Engineer may go upon the ground and make such surveys and examinations as he may deem necessary, so as to enable him to recommend to the Board and the Drainage Districts the best plan for carrying out the proposed project, which opinion will be unbiased by any local conditions or favors that might exist otherwise. Thus a uniform plan for the straightening of the channels of different streams can be successfully worked out throughout their entire length.

"Surveys might be made by the State Engineer's office of different streams and all low and seep lands, showing the best and most feasible ways of draining and straightening and shortening the channels of creeks, so that proposed districts could be formed more easily and to a better advantage than they are under the system which is in use at this time."

Drainage Work in Southeastern Nebraska

The remainder of this paper deals with the drainage projects on the Greater and Little Nemaha Rivers in southeastern Nebraska.

Geography

The area of southeastern Nebraska, with which this report deals, is located geographically within the following boundaries: The Missouri River on the east, the Nebraska-Kansas State line on the south, the range line between R. 5 E. and R. 6 E. on the west, and the township

line between T. 10 N. and T. 11 N. on the north. These boundaries include the entire watersheds of the two Nemaha Rivers. The actual watersheds of these two rivers may be described as follows: Practically the entire area of Richardson, Nemaha, Otoe, and Johnson counties, the east third of Pawnee, the northeast corner of Gage, the southeast corner of Lancaster, and a strip averaging two miles wide along the south line of Cass County.

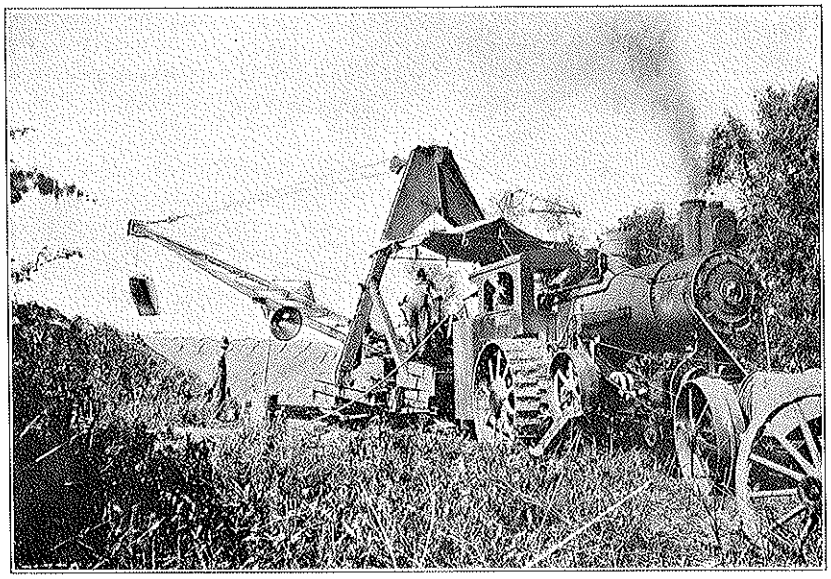

Fig. 3.—The "little dredge" at work on the lateral ½ mile north of Bracken. Photographed by E. H. Barbour.

The number of square miles of watershed by counties is given approximately as:

Lancaster	110 sq. mi.
Gage	100 sq. mi.
Cass	60 sq. mi.
Johnson	385 sq. mi.
Pawnee	150 sq. mi.
Otoe	560 sq. mi.
Nemaha	350 sq. mi.
Richardson	525 sq. mi.
Total	2,240 sq. mi.

To this total must be added 288 square miles of watershed lying south of the Nebraska-Kansas line, all of which flows into the Greater Nemaha.

The salient geographical features and the watersheds of the two Nemahas are shown on the map of Divides of Southeastern Nebraska.

Drainage Districts

Great Nemaha River: On this river four drainage districts have been incorporated, and a fifth is in process of organization.

1. Richardson County Drainage District No. 1 begins at the Missouri River and extends westward to the junction of the North and South Forks of the Nemaha River near Salem, Nebraska, thence along the South Fork to the west line of Sec. 5, T. 1 N., R. 14 E., and along the North Fork to the west line of Sec. 23, T. 2 N., R. 14 E.

2. Richardson County Drainage District No. 2 begins at the up-stream end of the North Fork in Richardson County District No. 1, and extends westward to the Pawnee-Richardson County line.

3. Richardson County Drainage District No. 4 begins at the up-stream end of Richardson County No. 1 on the South Fork and extends to the Pawnee-Richardson County line. This district was being organized according to last reports.

4. Pawnee County Drainage District No. 1 begins at the Pawnee-Richardson County line and extends to the Pawnee-Jefferson County line.

5. Johnson County Drainage District No. 1 begins at the Pawnee-Johnson County line and extends up-stream to a point 1.5 miles northwest of Sterling, Nebraska, ending in Sec. 21, T. 6 N., R. 9 E.

Little Nemaha River: Two districts are incorporated in the valley of this river.

1. Nemaha County Drainage District[1] No. 2 begins at the Missouri River and extends up-stream to the Nemaha-Otoe County line.

2. Otoe County Drainage District No. 1 begins at the Nemaha-Otoe County line. There will be three ditches in this district, one along the North Fork, one along Hopper Creek, and one on the South Fork to the Johnson County line.

The region within the watersheds of the two Nemahas is entirely agricultural and grazing, though there are some successful brick plants

[1] Nemaha County District No. 1 is on Camp Creek. This creek has a catchment basin of approximately 55 square miles. The ditch is small and partly reclaims the Peru Swamp.

and a few stone quarries. There are a few thin coal seams in this field, but no coal mines are being operated at the present time.

A number of the towns have a population of 1,000 to 2,000, and two or three of them have 5,000 inhabitants.

Railway facilities are fairly good over the entire area, the Chicago, Burlington and Quincy, and the Missouri Pacific Railroads having the greatest mileage.

Topography

The topography represented within this region is that of mature age, the range of relief being from sea level elevation 850 feet at the

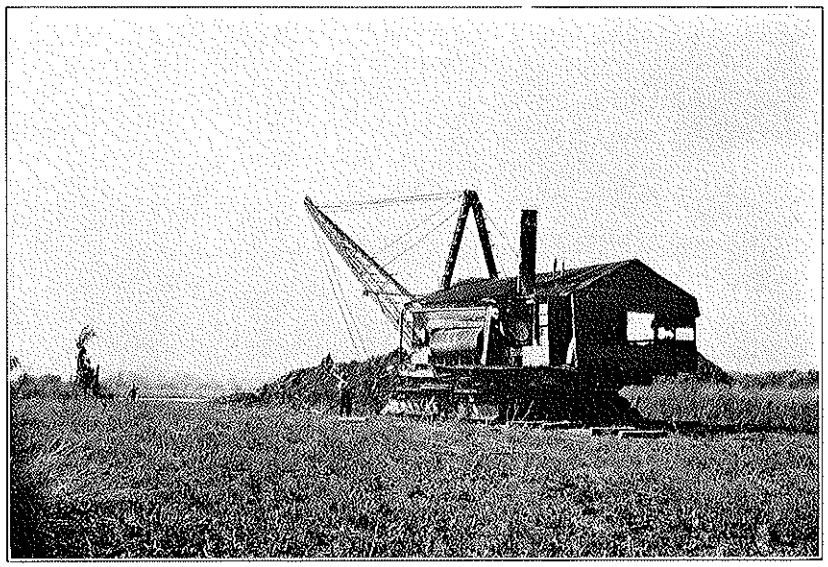

Fig. 4.—Callahan Brothers, Munn and Reise dredger on Margrave's Ranch southeast of Preston, Richardson County, District No. 1. Photographed by E. H. Barbour.

Missouri River to sea level elevation 1,500 feet in Lancaster County. The valleys of the smaller streams are well incised into the land surface, having narrow, well-defined divides, with comparatively broad, even slopes to the stream beds.

The larger streams, as a general rule, have broad, flat bottoms which end laterally in steep slopes rising abruptly to the uplands. The

limestone strata outcropping near the tops of these side-slopes weather much more slowly than the underlying shales and form the sharp bluffs characteristic of these valleys.

Hydrography

The drainage systems of this area are typically those of a mature topography in a region of moderate relief and rainfall. The streams divide and subdivide until the small intermittent feeders form a complete network over the entire area. The perennial streams, especially the larger ones, have developed a continuous and tortuous series of meanders. This is facilitated by the readiness with which the surface formations of the region erode. In many places meander development has progressed to such an extent that the natural stream bed has a course two or three times the length of the ditches that have been constructed. In Richardson County several oxbow lakes have been formed. These furnish positive evidence as to the past behavior of the Great Nemaha.

Great Nemaha River: The Great Nemaha heads in the southern part of Lancaster County and drains an area of approximately 1,200 square miles within Nebraska. It also carries the run-off of 290 square miles of northeastern Kansas, which makes a watershed of 1,490 square miles. The waters south of the State line are carried by the South Fork and other streams lying to the east, and they affect only Richardson County Drainage District No. 1. Approximately four-fifths of the watershed lies along the lower half of the stream.

Considering the North Fork as the main channel, the Great Nemaha has a general course of S. 60° E. The divide between the North Fork and the Little Nemaha River follows close to the trunk stream of the North Fork along the upper portion of the valley. The lower valley has two large tributaries flowing from the north; namely, Muddy Creek and Long Branch. On the south side of the river numerous large tributaries, such as Four Mile, Rattle Snake, Rock, Honey, and Walnut creeks, empty into the main channel throughout its entire length. These streams carry nearly all the water coming from across the State line. Two-thirds of the watershed lies on the south side of the trunk stream.

The approximate number of square miles of watershed draining into the heads of the North Fork drainage districts are:

Johnson County District No. 1	150 sq. mi.
Pawnee County District No. 1	375 sq. mi.
Richardson County District No. 2	475 sq. mi.
Richardson County District No. 1	600 sq. mi.

LITTLE NEMAHA RIVER: The Little Nemaha River, which heads in Lancaster County, drains an area of approximately 1,000 square miles. Its general course is nearly S. 45° E. The watershed lies mostly in the upper half of the valley, three-fourths of its area being above the Nemaha-Otoe County line, a condition opposite that of the Great Nemaha. If Hopper Creek is considered the main channel, the drainage of the Little Nemaha is very nearly symmetrical to the trunk stream, the drainage areas of the North Fork, Hopper Creek, and the South Fork being nearly equal.

Nemaha County Drainage District No. 2, at its head on the Otoe County line, receives the flow from a catchment basin of 750 square miles.

At present Otoe County Drainage District No. 1, which was recently organized, is making surveys to continue the ditch from Nemaha County District No. 1, up North Fork, Hopper Creek, and South Fork.

GEOLOGY

The oldest known exposures are Carboniferous and are represented by limestones and shales of Pennsylvanian age. These limestones and shales are found along the steep bluffs which lie between the river valleys proper and the uplands. The next oldest known exposures are represented by limestones and shales of the Permian series. In parts of the western portion of this drainage area, the Carboniferous rocks are overlain unconformably by loosely cemented ferruginous sandstones of the Dakota series of the Cretaceous period. The Pleistocene epoch is represented by glacial drift which caps the older Carboniferous and Cretaceous formations, and forms most of the hilltops within this area. In some places this drift is in turn capped by Loess. The Loess was probably the deposit of an out-wash plain derived from some later stage of glaciation, possibly the Iowan stage. The drift underlying the Loess is of the Kansan stage. In many places in this drift the pink Sioux quartzite erratics of various sizes are conspicuous.

The last epoch represented is the recent. Under this head would come the classification of the soils of the area. The following is taken from the "Soil Survey of Nemaha County, Nebraska," and is representative of the soils of the region under discussion.

"The soils in this part of the State may be grouped into three district divisions. The upland soils are derived from glacial and loessial

material, the alluvial terraces from fluvial silts, and the first bottoms from recent stream deposits. The upland group embraces the Knox, Marshall, and Carrington series; the alluvial terraces are classed as Waukesha series and the first bottoms comprise the Wabash and Sarpy series and Riverwash. Most of the soils of the uplands and terraces are silty, and the same is true of most of the first bottoms, except on the Missouri River, where the silty clay loams and very fine sand loams are important. With the exception of the Knox series, and recently deposited soils along the Missouri River, the soils are dark in color and rather high in organic matter."

Fertility, Crops, and Land Values

In general the soils of both the hill and valley lands of southeastern Nebraska are fertile. The hill lands usually rise steeply from the river valleys to an average elevation of 40 to 60 feet. These uplands are, for the most part, covered with a dark loam from a few inches to several feet in depth. This loam overlies a glacial deposit of variable thickness. Under the glacial deposit are interbedded strata of limestones and shales, the outcrops of which form the bluffs along the river valleys. This upland or hill country produces good crops, and is particularly adapted to grazing purposes.

The bottom land along the rivers and the lower valleys of the larger tributaries has a surface of black loam underlain by clay. There is also a deposit of silt on the surface of the land subject to overflow. These overflowed lands are the most fertile of the region on account of the rich sediment deposited by frequent floods. This fertility has been fairly well tested by the production of crops in districts where ditches are completed. For the past two years the land overflowed before the ditches were excavated has produced the best crops in that portion of the State now being considered.

The principal crops of southeastern Nebraska are wheat, corn, hay, and other farm products of secondary importance.

The average value of crops on the hill land is from $18.00 to $22.00 per acre, and during exceptional seasons run as high as $25.00 per acre.

The crops on the overflowed land, for several years before draining, were absolute failures, having been destroyed or in some instances carried away by the flood waters. One landowner makes the positive assertion that for a number of years the revenue from a large portion of the overflowed bottoms "did not even pay the taxes." Several thousand acres of the flooded lands, within the two Nemaha River systems,

were entirely abandoned for agricultural purposes. Since ditching, however, this same land has produced crops ranking among the best of the entire region. One farm in particular averaged about $28.00 per acre in 1913.

Upland farms are valued at $90.00 to $150.00 per acre, owing to their location and the improvements upon them. The value of the bottom lands is difficult to determine. Before the ditches were assured, and their success determined, some of the farm land lying on the lowest of the overflowed area could not be sold at any price. Farms which were in better locations as regards overflow, are recorded as selling for prices ranging from $35.00 to $75.00 an acre. In the districts which have been successfully ditched, the price of 100 per cent benefited land has, on a very conservative estimate, doubled in value. A few instances are recorded where the increased value has been as much as 150 per cent.

Natural Channels

To account for the frequent overflows following the heavier rains, it is necessary to describe the more prominent conditions that formerly existed on the trunk streams and larger tributaries.

Let us consider the conditions which existed along the Great Nemaha, as these are representative of the remainder of the area. In the vicinity of Sterling, Johnson County, the river valley proper has a grade of 6.8 feet a mile. This grade decreases toward the mouth of the river until in the eastern portion of Richardson County near Rulo, the grade of the valley is between 2.0 and 2.5 feet a mile. Some of the tributaries, especially those of the upper river valley, have grades of as much as 20.0 feet per mile toward their sources. These streams maintain comparatively steep grades until they emerge from the bluffs along the main river valley and flow out on the bottom lands. This higher gradient gives the tributaries, at flood stage especially, much greater velocities as compared with that of the trunk stream. Most of these tributaries lie in comparatively narrow valleys which have relatively steep side-slopes and are rather deeply incised into the hill lands. This topography furnishes ideal conditions for the collection of heavy loads of sediments by rainwaters.

As the soils of southeastern Nebraska erode very readily, these side streams carry out large amounts of sediment on the main channel bottoms and into the trunk stream itself. The topography of the uplands shows plainly the rapid erosion features of this region.

During floods these rapidly flowing side-streams soon charge the trunk stream with a heavy load of sediment. As the main channel gradient is considerably less than its tributaries, conditions are favorable for the deposition of a part of this load along the banks the instant the stream overflows.

The load carried by flood waters is the direct cause of the natural levees which lie adjacent to the banks of the rivers. In places these levees rise to a foot or more in height. They are present along both the Nemaha rivers and greatly increase the damage done by floods. Their origin is easily explained by the fact that the instant the laden flood waters leave the channel and flow over the banks, the velocity is checked and therefore a part of the load is deposited, adjacent to the banks, forming the levees. These levees are not readily apparent, for on the land-side the slopes are very flat and may extend quite a number of rods across the flood plain. Therefore, since the grade slopes from the channel for some distance, as soon as the flood water overflows a levee, it spreads rapidly over the surface. These levees also impede the return of water to the channel as the overflow recedes, thus holding the water on the bottoms for a longer period of time and this in turn increases the speepage toward the higher lands.

This seepage brings about a condition which greatly damages the land immediately adjacent to the overflowed area. The land itself is not under water except at extraordinary flood stage. However, when the flood waters stand on the adjacent areas for three or four days, they seep back into the soil of this land, softening the ground to such an extent that teams mire deeply and it is impossible for three to ten days after the retreat of the water, to work on this land. Landowners say that the length of time this seep water remains in the soil is almost inconceivable, and the delay in cultivating and harvesting crops often causes serious loss.

The trunk streams of this area are flanked by broad flat valleys that terminate in the bluffs which rise to the uplands on either side. In time of flood these valleys, on account of their low lateral gradients, are conducive to a wide spread of water. The entire loss of crops for several years discouraged farmers from cultivating the overflowed bottoms and these portions of the valleys had grown up to wild grass, weeds, and brush. Along the immediate banks was a growth of small timber, brush, and rank weeds such as wild sunflower (Helianthus) and horse-weed (Ambrosia). At high water stage, on account of the many sharp meanders characteristic to this region the stream currents

did a large amount of under-cutting, causing the trees and brush along the banks to slide and fall into the stream beds. The weight of the root-matted sod and the roots which still clung to the bank frequently held such trees in position and some of them even continued to grow in the bed of the stream. At each successive flood, logs, brush, and weeds lodged on these trees, this drift in turn gathered an accumulation of sand and silt, which aided in preserving the vegetable debris it covered. In the course of a few years many such barriers obstructed the free passage of water through the channel and greatly increased the overflow.

Such obstructions in the stream beds greatly impede and sometimes even entirely destroy the scouring process by which streams keep their channels cleared of accumulations of sand and silt. They not only retard the scour, but by checking the velocity, cause the water to deposit a portion of its load. The effect of this stream filling process is almost continuous along the trunk streams of both the Great and Little Nemaha rivers.

The numerous and tortuous meanders of the Nemaha rivers were another factor of importance in producing overflows. The great length of these meanders considerably reduced the actual grade of the stream. The effect of this reduced grade is a reduced velocity and consequently a reduced volume of water passing a given point in a given time. An example of this is brought to notice in Pawnee County Drainage District No. 1, where the velocity of the water in the old channel at bank-full stage was between 3.5 and 4.0 feet per second, while that of the new channel under the same conditions is a little more than 7.0 feet per second. Considering the cross-section areas the same in the two channels, the new channel will deliver about twice the volume of water per unit time as the old channel. Delay in passage of water down stream is the prime cause of overflows and the chief causes of this delay are, as has been stated, obstructions in the stream beds and meanders of the channel. There are numerous minor causes for the delay in delivery and the increased spread of flood water over the bottom land, but they are not of sufficient importance to demand detailed consideration.

Rainfall and Run-off

The run-off from an area in proportion to the amount of rainfall is dependent upon the condition of the soil at the time of precipitation.

A rainfall precipitated after a period of drouth is largely absorbed by the soil and its run-off is less than that of the same amount of rainfall on the same area when the soil is saturated.

The character of the precipitation greatly affects the rate of run-off. A rainfall of short duration causes greater height of flood waters than does an equal precipitation covering a longer period.

The rainfall of southeastern Nebraska averages 23 to 24 inches per annum, precipitated chiefly during the growing months. This makes the overflows much more disastrous to crops along the bottoms than they would be if the heavier rains came in the winter or if the rainfall were more evenly distributed throughout the year.

As there are very few meter ratings of these streams at times of flood there is little data to present in actual figures. The best record obtainable is from Mr. F. F. Shafer's report from the Government Drainage Engineer's Office on Nemaha County District No. 1, from which is quoted this abbreviated account. "On Nov. 15, 1909, the Great Nemaha was gaged near Tecumseh, Nebr., while running bank-full, and showed a velocity of 4 feet per second or 2.7 miles per hour. This was after a precipitation of 5.40 inches in 40 hours. However, the ground was very dry and absorbed a large amount of the rain-water. This gauging showed a run-off of 1.5 inches in 24 hours. On Nov. 27 and 28, 1909, a rainfall of 1.20 inches in 24 hours caused an overflow in the region of Elk Creek. When computing the cross section area necessary for the new ditch a run-off of 1.00 inch in 24 hours was used above Yankee Creek and 0.75 inches per 24 hours below Yankee Creek." From 1.5 to 2.0 inches per 24 hours was used on the tributaries.

Plans of Improvement

The general plans of improvement for the various districts under consideration are practically the same except for minor details. These plans may be grouped under the following heads:

(1) Clearing banks and right-of-way.
(2) Clearing old channels if used.
(3) Construction of ditches and laterals.
(4) Construction of dikes.

Clearing Banks and Right-of-Way, and Clearing Old Channel:—These subjects may be treated together, since the conditions to be obtained are practically the same. The object of clearing the banks and right-of-way, and the banks and bed of the old channel

when used in the proposed system, is to prevent the bed of the drainage ditch from becoming obstructed by trees and stumps which would be carried into the stream by under-cutting and slides. This type of stream has been described under the head of "Conditions of Natural Channels."

The specifications for clearing vary somewhat in the different districts, as regards width of clearing and other details, but on the whole are nearly uniform.

DITCHES AND LATERALS:—The main channels throughout the districts vary only in such details as cross-section area, side slopes, and size of sub-channels. The entire length of the main channels was excavated either by floating dipper dredges or by drag-line dredges. The price per cubic yard for main channel work was from 7¼ to 8½ cents.

The larger laterals were worked with dredges on their lower portions, and by teams on the upper portions and the small laterals. The contractor usually bids on the drainage work for an entire district, or for a section of a district, and does the dredge work himself while he sublets the team work. Prices for team work are higher than for dredge work.

LEVEES:—There are but few levees needed in these districts. The largest one built is that on the north side of the Great Nemaha beginning at the Chicago, Burlington and Quincy Railroad embankment near the Missouri River. This levee is 227 stations long (nearly 4 miles) and has an average height of 6 feet. There are several smaller levees ranging from a few hundred feet to one-half mile in length.

The plans of improvement will be considered more in detail under the district headings.

DESCRIPTION OF THE FIELD SURVEY

The field survey for a drainage district embraces the preliminary survey and the location survey.

By the preliminary survey necessary data is secured for determining the location of the ditch, the grade to be used, and the cross-section area necessary to carry the storm water. This work includes meandering the trunk streams and their tributaries, running cross levels, meandering the bottom lands to determine the benefited areas, measuring the cross-section of the streams, and the meter rating of the streams at flood periods to determine velocity and run-off.

The location survey is the actual staking out of the ditches. The State law requires location surveys to be measured accurately by chain. The location line must be tied to land survey monuments. Profile levels are run over the located line.

As an approximate estimate of the length of time necessary for a field survey and its cost, the following is copied from Mr. F. F. Shafer's report on Johnson County Drainage District No. 1. It should be noted that two location lines were staked on this piece of work.

"The total length of lines run is over 190 miles, classified as follows:

Cross levels	43.4 mi.
Base levels	12.9 mi.
Check levels	11.4 mi.
Profile levels	35.6 mi.
Meander of stream	41.0 mi.
Meander of bluffs	5.8 mi.
Meander levels	4.4 mi.
Location lines	35.6 mi.
Total	190.1 mi.

"A party of seven men was employed for a period of 35 working days, 3½ of which were lost on account of bad weather. The party consisted of:—one transitman, one levelman, two rodmen, two axemen and one teamster.

"The total cost of the field work was $992.85, of which $241.88 was paid from a local fund raised for that purpose.....The cost per mile of line run was $5.50. Cost per located mile of ditch line, $27.90. Cost per square mile of flooded land, $49.60."

Richardson County Drainage District No. 1

Richardson County Drainage District No. 1 was the first district to organize on either of the Nemaha Rivers, and was established in 1904. Mr. C. G. Elliott, of Washington, D. C., Engineer in charge of Drainage Work of the Department of Agriculture, was called to make a preliminary survey and estimate on the work. He made his report and recommendations about November 1, 1904. Plans and surveys were made immediately in order that excavation might be begun. Considerable delay was caused, however, by various lawsuits relative to damages and benefits, and further delay was occasioned by the fact that several thousand acres of benefited land lay within the Iowa and the Sac and Fox Indian Reservations. The Iowa tribal lands extend east from No Heart Creek and along the south bank of the Nemaha River, and the Sac and Fox land is south of the river between No

Heart Creek on the east and Honey Creek on the west. The law requires all benefited lands to be taxed, and necessitated a special act of Congress to make these Indian lands taxable for benefits received from the drainage ditch and to secure the right-of-way across Indian lands. This ditch tax was drawn from the Indian allotment money held in trust by the United States Government.

The district extends from the mouth of the Nemaha, where it empties into the Missouri River in Sec. 27, T. 1 N., R. 19 E., up stream to near Salem, thence along the North Fork to the West line of Sec. 23, T. 1 N., R. 14 E., and along the South Fork to the west line of Sec. 5, T. 1 N., R. 14 E.

The old river channel has a more tortuous course through this district than through any of the districts lying up-stream from it. The valley grade is flatter, being about 2 feet per mile at the lower end of the district. The scour is less and the tendency to meander is greater than in the districts lying farther up-stream. Meandering occurs to such an extent that at one particular place in the southwest corner of T. 1 N., R. 18 E., the old channel covers a course of approximately 6 miles in gaining 1 mile down the valley. The number of oxbow lakes on the lower Great Nemaha is evidence of its past behavior. Horseshoe and Relf are among the larger lakes. Numerous smaller lakes are almost entirely silted up and might be called marshes. Water may stand in these the greater part of the year, or there may be none in very dry seasons. These marshes have broad slopes and when drained may be farmed with the surrounding land.

The character of the lower river has changed greatly within the last few decades. Mr. R. E. Grinstead, formerly of Salem, says that there were once numerous rocky fords within the district. The river has silted up its bed, however, until in recent years these fords so filled that teams cannot cross the streams and cattle often mire when going into the channel for water. A number of years ago there were several water-power mills within the district, but the milldams became so silted up that the wheels had to be raised at the expense of the power. None of these mills were in operation when the district was organized.

At certain points drift had collected in the old channel until it formed mats, some of which were several hundred feet in length. At low water stage the water seeped through these but during high water such obstructions destroyed from 30 to 50 per cent of the effective capacity of the stream.

The rate of flow in the old channel at bank-full stage was such that it required five or six days for a float to traverse the distance from Dawson to the Missouri River. A straight line between these two points is approximately 28 miles in length, but the old river channel between these points follows a course which is three or four times that length. The ditch channel makes the distance 31.4 miles from the west end of the district on the South Fork to the Missouri River. For fourteen miles the ditch follows the old river channel. On the North Fork there are nine miles of ditch, of which 5.1 miles are the cleared river channel. Since the ditch was completed a float will traverse the distance from Dawson to the Missouri River at bank-full stage in six or seven hours. A comparison of this rate of delivery of water downstream with that given for the old channel shows that flood conditions are greatly improved, if not entirely overcome.

The main ditch cross-section has a base of 30 to 35 feet at grade, with side slopes of 1 vertical to 1 horizontal. The grade is that of the valley, ranging from 3.5 feet per mile at the upper end of the district to 2.0 or less per mile near the Missouri River. The specifications called for a subchannel 5 feet wide and 3 feet deep in the middle of the channel. This subchannel was a new scheme, at least new in this region. It is designed to confine the water at low stage to a narrow channel so as to prevent the growth of willows, other trees, and weeds, within the main ditch.

The land subject to overflow in the district was approximately 29,300 acres, or a little less than 46 square miles. A large amount of this land received 100 per cent benefit.

The approximate area of the catchment basin above the upper end of the district on the North Fork is given by counties as follows:

Lancaster	54 sq. mi.
Gage	100 sq. mi.
Johnson	265 sq. mi.
Pawnee	151 sq. mi.
Otoe	5 sq. mi.
Richardson	200 sq. mi.
Total	775 sq. mi.

The approximate area of the catchment basin above this district, on the South Fork, is:

Richardson	95 sq. mi.
Pawnee	50 sq. mi.
Drainage across Kansas line	125 sq. mi.
Total	270 sq. mi.

This makes a total of 1045 square miles of water-shed above the up-stream ends of the district.

Conditions in the district were such that land on the first bottoms was becoming almost worthless. During protracted rains the river was sometimes out of its banks for a month, the widest expanse of water at flood stage being about 2 miles.

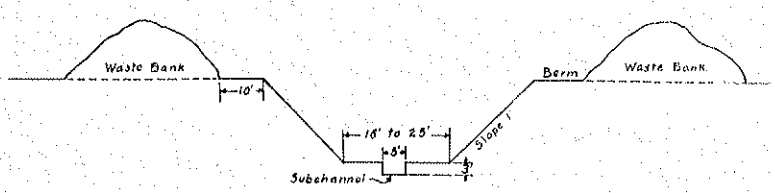

Fig. 5.—Cross-section of main ditch, Drainage District No. 1, Richardson County.

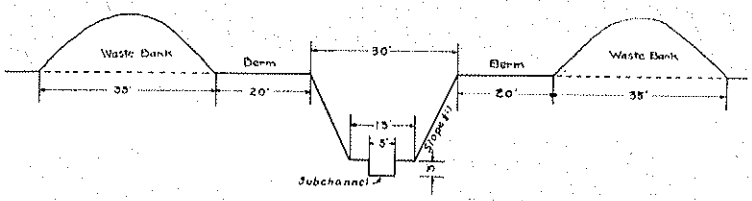

Fig. 6.—Cross-section of main ditch, Drainage District No. 2, Richardson County.

The drainage district survey estimated the benefited lands at 29,283 acres. The engineer evaluated the benefits to all properties as follows:

Property	Acres	Value	Assessment	Per cent
Farms, etc.	26,910.63	942,864.79	224,679.92	79.21
Iowa Indians	378.67	14,490.00	3,218.32	1.20
Sac and Fox Indians	1,996.65	75,088.78	19,887.41	6.31
C., B. & Q. R. R.		66,100.00	16,014.00	5.56
Mo. P. R. R.		14,494.11	3,510.00	1.22
Public Highway		77,340.00	18,600.00	6.50
Total	29,285.95	1,190,387.66	285,909.65	100.00

The following is the engineer's estimate on the project:

Working Section	1- 17 inclusive	360,884 cu. yd. at 11c	$ 39,697.24
Main Channel Section	18- 33 inclusive	474,342 cu. yd. at 10c	47,434.20
Main Channel Section	34- 46 inclusive	426,252 cu. yd. at 10c	42,625.20
Main Channel Section	47- 57 inclusive	232,601 cu. yd. at 11c	25,586.11
North Fork	63- 87 inclusive	220,904 cu. yd. at 10c	22,090.40
Muddy	104-110 inclusive	45,202 cu. yd. at 11c	4,672.22
Hally Creek Lateral	95- 99 inclusive	40,055 cu. yd. at 11c	4,401.05
Tiehen Lateral	100-103 inclusive	6,771 cu. yd. at 11c	744.81
Hard Lateral	88- 94 inclusive	21,230 cu. yd. at 10c	2,123.00
Falls City Lateral	130-139 inclusive	123,820 cu. yd. at 10c	12,387.00
Towle Spur	153 inclusive	3,302 cu. yd. at 11c	363.22
Miles Towle Spur	150-152 inclusive	20,310 cu. yd. at 12c	2,438.42
Muddy Creek	111-113 inclusive	9,071 cu. yd. at 12c	1,088.42
Vetter Lake Spur	114-122 inclusive	55,055 cu. yd. at 10c	5,505.50
More Spur	123-124 inclusive	5,107 cu. yd. at 10c	510.70
Randolph Spur	125-127 inclusive	12,462 cu. yd. at 10c	1,246.20
Bowker Spur	128-129 inclusive	38,796 cu. yd. at 10c	3,979.60
Roys Creek	60- 61 inclusive	7,222 cu. yd. at 10c	722.20
Iowa Creek	62 inclusive	4,713 cu. yd. at 10c	471.30
Dyke	58- 59 inclusive	72,378 cu. yd. at 10c	7,237.80
Highway bridges			22,740.00
Right-of-way, etc.			20,000.00
Printing incidentals, engineering, etc.			7,500.00
Protecting works of spillway			700.00
Flood Gates			700.00
Total estimate of cost			$277,264.57

In addition to this it was necessary to clear the old stream channel where it was used, the estimated cost being as follows:

Muddy Creek	1.7 miles at $200.00 per mi.	$ 340.00
North Fork	5.2 miles at 300.00 per mi.	1,560.00
South Fork	14.0 miles at 500.00 per mi.	7,000.00
Total		$8,900.00

This clearing of old channel makes the entire estimated cost of the project amount to $286,164.57

Since the ditch was completed the damage from overflows has been practically eliminated, except in a few instances when some of the land near Rulo was flooded. The landowners here had petitioned the supervisors to be allowed to rush the work, and had put in a smaller dredge than was used farther up-stream. The result was a smaller cross-section ditch, which could not take care of the water delivered

by the larger ditch above until its channel was eroded to the approximate cross-section area of the larger ditch. At the present time this smaller ditch has enlarged enough to take care of the water.

Mr. R. E. Grinstead, who until recently owned considerable land near Salem, in speaking of the success of the ditch says: "The ditch is taking care of the flood water as is shown by the increase of crops on the first bottom. There has been no overflow within the last three years."

The success of the project is best shown by the increase in land prices and by the crops raised on land formerly subject to overflow. Before the construction of the ditch was assured, Mr. Grinstead sold one farm which lay southeast of Salem for $65.00 per acre. This same land cannot be bought for $150.00 per acre. Another farm of 240 acres sold for $25.00 per acre, and the same land cannot be bought for $100.00 per acre. Mr. Keim of Falls City bought 80 acres for $50.00 per acre just after the ditch was completed, and has refused $6000.00 for the place. A certain farm south of Salem which was considered the poorest and wettest farm on the river bottom before ditching raised 50 bushels of wheat to the acre in 1914. Another farm but little better located raised 75 bushels of corn per acre.

Richardson County Drainage District No. 2

Richardson County Drainage District No. 2 embraces the bottom land, subject to damage from flood water, which lies along the North Fork of the Greater Nemaha River between the east line of Section 22, T. 2 N., R. 14 E., (the up-stream boundary of Richardson County Drainage District No. 1) and the Pawnee-Richardson County line, where the ditch continues as Pawnee County District No. 1. The ditch crosses the county line about one-fourth mile south of the northwest corner of Sec. 18, T. 2 N., R. 13 E. The boundaries of the district are shown on the map.

The old river channel through the district has the characteristic stream bed and meanders of this region. At one place, in Sec. 17, T. 2 N., R. 14 E., a piece of old stream channel has been cut off, leaving a feature similar to an oxbow lake. Long Branch, which enters the trunk stream just south of the town of Humboldt, is the only tributary stream of any importance within the district. This side stream is approximately 15 miles in length and drains an area of possibly 60 or 65 square miles. The grade of old stream channel is

probably not more than 2 to 2.5 ft. per mile, while the grade of the valley is between 4 and 5 feet per mile, the flat grade of the old channel, compared with the valley grade, being due to the tortuous meanders. In some places the stream traverses 2 or 3 miles in passing 1 mile down the valley.

The main ditch channel through this district is slightly over 11 miles in length, and the Long Branch lateral is approximately three-fourths of a mile long. In cutting the main ditch the old stream channel was disregarded, and even in the few places where the two channels coincided the ditch was cut to grade without reference to the old channel. The cross-section of the main ditch, as shown in figure 6 is as follows:

The base at grade is 13 feet, with a width of 30 feet at the surface of the ground. There is a subchannel 5 feet wide and 3 feet deep excavated in the center of the base, in accordance with the construction generally used in this part of the country. The specifications call for a clean 20-foot berm between the edge of the cut and the toe of the waste bank. The waste bank, according to the specifications, should occupy a base of 35 feet, but this detail was not rigidly adhered to.

The overflow land of the district consists of 5,800 acres, or practically 9 square miles, which lies about equally on either side of the river. The area will average a little less than a mile in width; the widest expanse, 1.5 miles, lies just west of Humboldt and the narrowest, three-eighths of a mile, lies about 1½ miles southeast of Humboldt.

The catchment basin of the North Fork above the Pawnee-Richardson County line, the upper end of the district, is approximately 575 square miles, lying in the following counties:

Lancaster	54 sq. mi.
Gage	100 sq. mi.
Johnson	265 sq. mi.
Pawnee	151 sq. mi.
Otoe	5 sq. mi.
Total	575 sq. mi.

The conditions in this district before ditching were quite similar to those in other districts on the river, which have been discussed at some length on foregoing pages.

The drainage district survey determined that 5,800 acres within the district were overflowed by the rise of the river to usual flood stage.

The drainage engineer on this work estimated the benefits to all land and properties involved, as $286,000.00, apportioned approximately as follows:

Farm land	80 per cent	$288,000.00
Highways	11 per cent	31,460.00
C., B. & Q. Railroads	9 per cent	25,740.00
Total	100 per cent	$285,200.00

The Board of Supervisors decided to make the first assessment large enough to complete the project and avoid the trouble of making a second assessment. The 100 per cent benefit land was estimated at $20.70 per acre; the actual average cost, however, was $17.00.

The cost of the entire project is divided as follows:

Organization, administration and working expenses, court costs and attorney fees	$ 7,664.51
Bridges and dams	5,195.01
Damages for cut-off lands	5,883.90
Right-of-way	13,425.43
Construction	74,261.91
Total	$106,430.76

The difference between the estimated and actual cost of the project, which is something over three dollars per acre for 100 per cent benefit land, is represented by money on deposit. As late as May, 1914 this money was on deposit and will probably be used in the upkeep of the ditch, or it may be prorated and returned to the land owners on a majority vote of the district.

This district has not had a flood during the five years, which have elapsed since the completion of this ditch and up-to-date. However, the seasons have been somewhat drier than usual in this region. The district up to this time has had no expense for repairs or upkeep.

The grade of the ditch, which is practically the same as that of the valley, or between 4 and 5 feet per mile, is sufficient to take care of landslides or creeps along the banks, as well as to scour its channel. At present the ditch is nearly twice as wide and considerably deeper than when it was first completed. The ditch was excavated by a drag-line dredger.

The landowners of the district are well pleased with the success of the ditch. Mr. C. M. Linn, of Humboldt, says that formerly it was merely a case of good luck to be able to harvest a crop off the bottom land that was subject to flood. There had been a series of wet seasons for several years before the ditch was completed, and during these

years there were no crops at all on the overflowed land. The seasons of 1912 and 1913 were rather dry, and the best crops in the district were those raised on lands lying between the ditch and the old stream channel.

There have been some small overflows on the bottom land of the districts above since the ditch was completed, but no overflow within this district, except on the very lowest piece of land, which was covered to a depth of 3 or 4 inches for a few hours, causing no damage. The owner said that it did not do a "dollar's worth of damage." Under the old conditions during floods this same land would have been covered by several feet of water, or "deep enough to swim a horse."

There was a two-inch rain just four days before the writer visited Humboldt in April, 1914, but there were no flood conditions, the water in the channel being nearly down to its normal flow.

The following examples of increases in land prices were given by Mr. Linn:

The Stalder farm, which lies two miles west of Humboldt, was on the market for years. As this land was overflowed each year no one would offer to purchase the place. After the ditch was assured, but before it had been well tested, this place sold for $100 per acre plus the ditch tax, a total of $120.70 per acre. Mr. Linn questions if at present one could buy it for $150 per acre.

The owner of the Richard Tosland farm, just west of Humboldt, which has already been mentioned as the first land in the district to overflow, has refused $135 per acre. Before the ditch was assured a buyer for this land could not be found.

Mr. Nims' farm, one mile south of Humboldt, is a 540-acre tract, of which 220 acres is first bottom and the remainder second bench and hill land. A few years before the ditch was assured Mr. Nims placed this farm on the market. It was extensively advertised at $65.00 per acre and the closest offer was $60.00. While the farm is not on the market at present Mr. Nims says it would take $150.00 per acre to buy it.

Both Mr. Linn and Mr. Nims assert that it is very conservative to say that first bottom land has doubled in value within this district since the success of the ditch has been assured.

In a letter received at this office May 8, 1915, Mr. Linn says: "We are refunding $1.50 per acre on 100 per cent land and will have about $3000.00 left for the upkeep of the ditch, which expense up-to-date has been practically nothing, as the ditch is widening and deepening all the time."

Pawnee County Drainage District No. 1

Pawnee County Drainage District No. 1 includes the bottom land, subject to overflow, along the North Fork of the Greater Nemaha River which lies within Pawnee County. This district joins Richardson County Drainage District No. 2 at the Pawnee-Richardson county line, and Johnson County Drainage District No. 1 at the Johnson-Pawnee County line.

The stream bed of the old river channel is similar to that of the other districts of the area under discussion. Clear and Lynn Creeks are the only side streams of enough importance to demand laterals. These streams flow from the west and enter the trunk stream a short distance northeast of the town of Table Rock.

The grade of the river valley through the district is about 5.28 feet to the mile. The grade of the old river channel is between 2 and 3 feet per mile.

The main ditch channel is practically 10 miles in length, and the laterals on Clear and Lynn Creeks are each about 1 mile in length. The ditch was excavated through most of the district without regard to the old river channel. In a few places the old channel was used for short distances, as may be seen by referring to the district map. When used, however, it was deepened and cleared. The main ditch was designed with a 12-foot base at grade, with side slopes of 1 horizontal to 2 vertical. A subchannel 5 feet wide and 3 feet deep was excavated in the bottom of the main channel. This subchannel carries the flow at low-water stage. The grade line of the main ditch and old stream, the ditch grade is at or below the bottom of the river channel. This allows the flow to follow the ditch at low-water stage. The specifications for the main ditch require a clean berm of 25 feet between the top of the slope and the toe of the waste bank.

The above design was adopted to save expense in construction. With a fall of 1 foot in 1,000 feet the velocity is enough to safely and rapidly remove all earth material which sloughs in from the sides. Most of the caving of banks occurs when the stream is above low-water stage, as the banks are then softened. The increased volume and velocity at such times give increased scour and carrying capacity, which soon removes such obstructions.

The land of this district formerly damaged by floods was estimated at 5,731 acres, or a little less than 9 square miles. The boundary of this area, as shown on the map, is very irregular.

The catchment basin of the North Fork above the Pawnee-Johnson County line covers approximately 425 square miles. The engineer for the district estimated the watershed above the county line as 440 square miles. As measured from the Map Showing Divides in Southeastern Nebraska the watershed by counties is as follows:

Lancaster	54 sq. mi.
Gage	100 sq. mi.
Johnson	265 sq. mi.
Otoe	5 sq. mi.
Total	424 sq. mi.

This area during a maximum flood would contribute about 3,000 cubic feet per second of flood water, and during extraordinary flood stage, which fortunately seldom occurs, the discharge might reach or even exceed 4,000 cubic feet per second.

The evaluation of benefits showed 4,731 acres of farm land and other properties, which had received more or less damage from flood water. The Engineer estimated the entire benefits to all property as $331,555.03 which he apportioned as shown below:

Land	79.5 per cent	$263,721.53
Town lots in Table Rock	2.1 per cent	6,995.00
Pawnee County Highways	13.1 per cent	43,475.00
Table Rock Streets	0.5 per cent	1,500.00
C., B. & Q. Railway	4.8 per cent	15,863.50
Total	100.00 per cent	$331,555.03

The work in this district affords an opportunity to compare the Engineer's estimate of cost units with the actual cost units at which the work was let.

Excavation Main Channel	612,340 sq. yd.	9½c	$ 58,172.30	8¼c
Excavation Clear Creek lateral	47,390 cu. yd.	10 c	4,739.00	10 c
Excavation Lynn Creek lateral	30,645 cu. yd.	10 c	3,064.50	10 c
Cleaning old channel	7,500 squares	40 c	3,000.00	40 c
Right-of-way per acre	223.45 acres	$60.00	13,407.00	Mostly $60.00 Some-land higher
Consequential damages			2,000.00	
Organization, administration, etc.			10,000.00	
Highway bridges			13,600.00	
Total			$107,982.80	

The channel of the ditch has a grade of 5.28 feet to the mile. The velocity in this channel when running bank-full is over 7 feet per

second, twice the measured velocity of the old river channel. The capacity of the river at maximum flood stage was about 1,500 cubic feet per second. This leaves a volume of approximately 1,500 cubic feet per second to overflow the banks and spread out over the flood plain. The ditch will carry off four times the amount of water in unit time as the old channel would carry. The new channel does not interfere with the carrying capacity of the old channel as very nearly the same volume of water passes through the old channel as prior to digging the ditch. The ditch channel, however, is widening and deepening its effective cross-section by scour and the sloughing of the sides. The steeper grade, and the absence of meanders, tend to keep the channel swept clean.

The success of this project is fairly certain, as the ditch has been in operation for some time. However, since its completion, there has been no extraordinary flood stage so one could not possibly say as to the results in such a case, though it is obvious that a flood would not be as destructive as before the completion of the ditch.

The beneficial effect of the work is best shown by land prices and the increased crops harvested. Mr. W. A. Fellers, who owns considerable first bottom land near Table Rock, states that he considers the money spent in ditching an exceedingly good investment. His entire assessment was $2,700.00. One 60-acre tract (all 100 per cent benefit land) owned by Mr. Fellers, lies a short distance southeast of Table Rock. He was never sure of harvesting a crop from this land. One season an overflow, following a heavy rainfall farther up the valley, carried away the entire crop of wheat in the shock. Before ditching such overflows would cover the ground for several days and greatly damage the crop. Since ditching, however, if the water rises to the land at all, it begins to recede within two to four hours and does the crops little or no damage.

Mr. E. D. Howe, whose farm lies approximately 6 miles north of Table Rock, gives some interesting data on overflowed lands and land prices. Part of his farm is on the North Fork bottom, a considerable portion of it being 100 per cent benefit land. Mr. Howe has had no overflow water on his land since the new channel was completed. In the spring of 1912 melting snow caused a flood across the Johnson County line above his place, but the new channel carried it away without the low ground being overflowed.

There is one farm, mostly 100 per cent benefit land which had no buyer when listed at $30.00 per acre. After the ditch was assured the

owner raised his price to $75.00 per acre and later to $90.00 per acre.

The following is taken from a letter received at this office on May 10, 1915 from Mr. Howe:

"In June, 1914 heavy rains in Johnson County caused the Nemaha to overflow, destroying wheat and damaging corn. When the flood reached the drainage ditch in Pawnee County, the ditch took care of the water so no damage was done in this district."

Johnson County Drainage District No. 1

Johnson County Drainage District No. 1, which lies along the North Fork of the Greater Nemaha River, begins on the down-stream end, at the Pawnee-Johnson County line, in Sec. 3, T. 4 N., R. 12 E., and continues upstream to a point within Sec. 21, T. 6 N., R. 9 E., one and one-half miles northwest of Sterling.

The old river channel through this district has meandered considerably. The grade of the old channel is 2.0 feet to 2.5 feet in the lower part of the district. In the upper part, the meanders are less pronounced and the grade is 3.5 feet to 5 feet per mile. Very little of the catchment basin along the district lies on the east side of the trunk stream, as the divide between the two Nemahas follows close to the North Fork from Tecumseh to Sterling. On the opposite side of the trunk stream numerous tributaries flow into the North Fork through out the district. Six of these tributaries, Hooker Creek, Deer Creek, Battie's Branch, Yankee Creek, Badger Creek, and Elk Creek, are of enough importance to demand laterals.

The main ditch channel through the district is divided into four sections. Section No. 1 extends from the head of the district to the junction of the Yankee Creek lateral. Section No. 2 extends from the down-stream end of Section No. 1 to the northwest corner of Sec. 11, T. 5 N., R. 11 E. Section No. 3 consists of the cut-off ditch within Sec. 11, T. 5 N., R. 11 E. Section 4 consists of the remaining ditch work down stream to the county line. In Sections Nos. 1, 2 and 3, practically none of the old river channel was used, while in Section No. 4 approximately one-half the distance covered by the ditch follows the old channels.

There are two levees in this district. The longer one, which is one mile west of Sterling, is one-half mile in length; and the other, just up stream from the point where the Chicago, Burlington and Quincy Railway crosses the ditch about one mile northwest of Tecumseh, is only 550 feet in length.

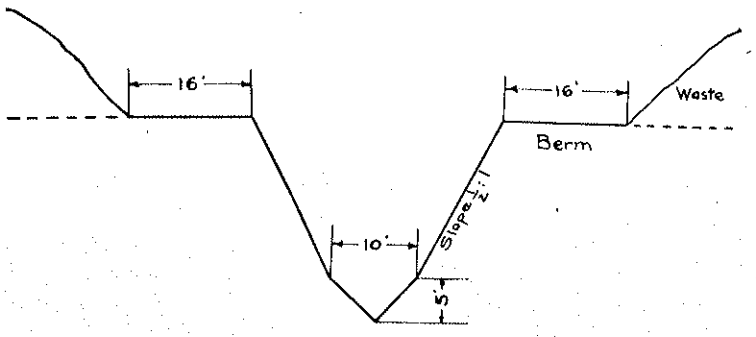

Fig. 7.—Cross-section of main ditch, Drainage District No. 1, upper end, Johnson County.

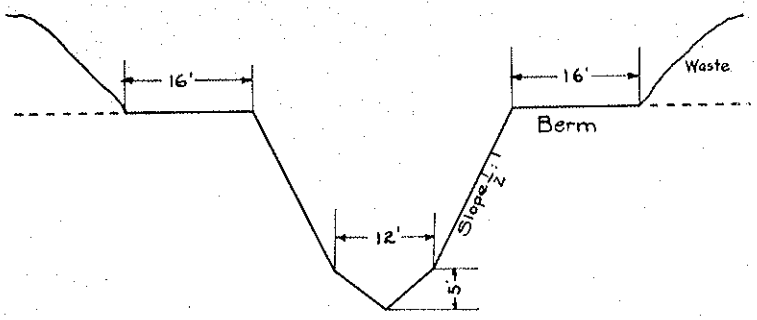

Fig. 8.—Cross-sections 2, 3, and 4, of main ditch, Drainage District No. 1, lower end, Johnson County.

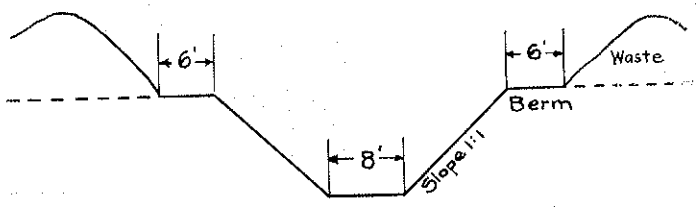

Fig. 9.—Cross-section of a lateral.

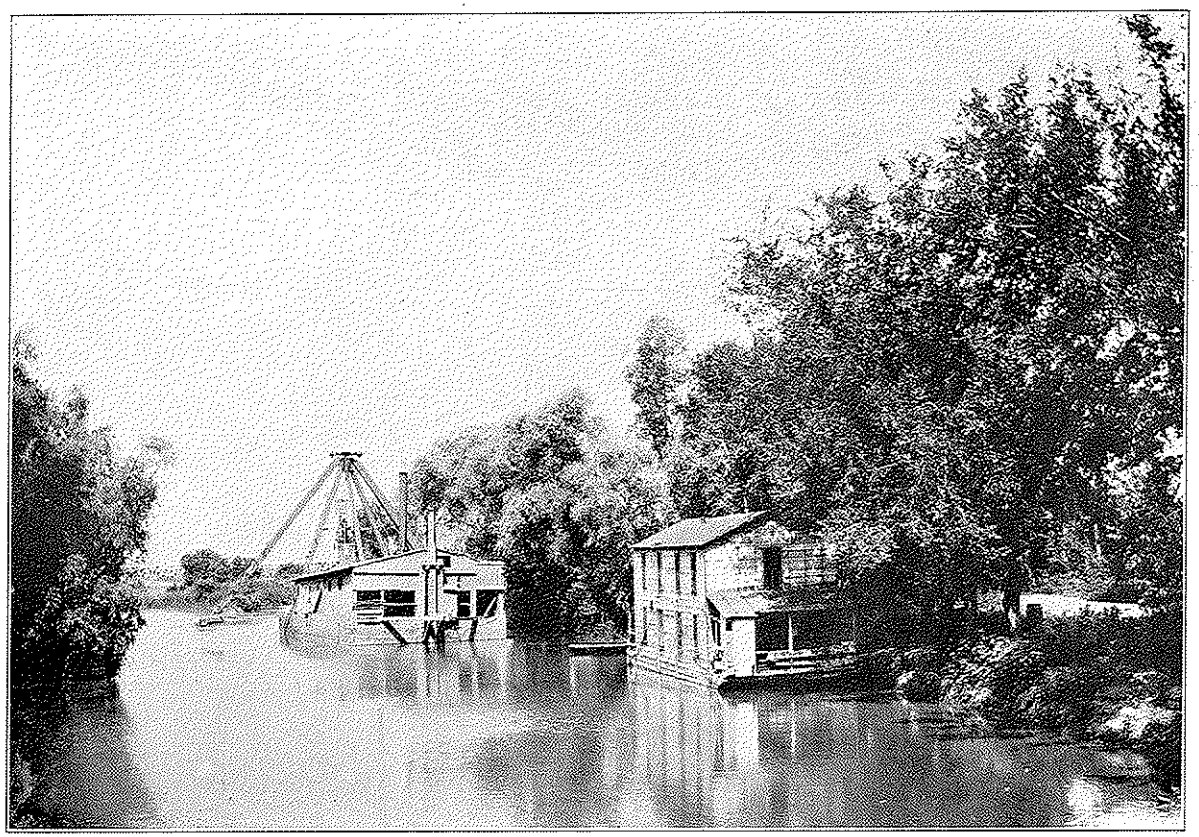

Fig. 10.—Dredge-boat and boat house at mouth of the Little Nemaha River. Photographed by E. F. Schramm.

The main ditch along the North Fork Valley has approximately 19.5 miles of new channel and 4 miles of old channel which has been cleared and deepened. The laterals are given in tabular form below:

Hooker Creek lateral	1.30 mi.
Deer Creek lateral	.55 mi.
Yankee Creek lateral	3.40 mi.
Battie's Branch lateral	.40 mi.
Badger Creek lateral	.55 mi.
Elk Creek lateral	1.00 mi.
Total length of laterals	7.20 mi.

The base of the main ditch channel at grade is 10 feet in Section No. 1, and 12 feet in Sections 2, 3 and 4. The laterals all have 8-foot bases at grade. The specifications call for a 9-foot crown on the two levees, with a slope of 4 to 1 on the stream side and 2 to 1 on the land side. These various cross-sections are shown in Figs. 7, 8 and 9.

The catchment basin above the head of the district covers approximately 155 square miles. As measured from the May showing the Divides of Southeastern Nebraska the watershed by counties is as follows:

Lancaster	54 sq. mi.
Gage	75 sq. mi.
Johnson	5 sq. mi.
Otoe	20 sq. mi.
Total	154 sq. mi.

The watershed above the Pawnee-Johnson County line embraces 424 square miles. This leaves 270 square miles of watershed draining into the ditch within the district.

The Engineer's estimate of the yardage is given in detail below:

MAIN DITCH

Sec. No. 1, 10 ft. base est. yardage	501,509 cu. yds.
Sec. No. 2, 12 ft. base est. yardage	301,934 cu. yds.
Sec. No. 3, 12 ft. base est. yardage	27,682 cu. yds.
Sec. No. 4, 12 ft. base est. yardage	200,363 cu. yds.
Total	1,031,488 cu. yds.

LATERALS

Laterals 8 ft. base slope 1 to 1 6 ft. berm.

Hooker Creek est. yardage	42 516 cu. yds.
Deer Creek est. yardage	31,814 cu. yds.
Battie's Branch est. yardage	28,000 cu. yds.
Yankee Creek est. yardage	118,411 cu. yds.
Badger Creek est. yardage	18,595 cu. yds.
Elk Creek est. yardage	40,912 cu. yds.
Levee 9 ft. top slope 1½ to 1 yardage	13,800 cu. yds.
Total	20,048 cu. yds.
Grand total yardage	132,536 cu. yds.

Two assessments had been made by the supervisors up to the time the writer visited the district. The first was $180,000.00 and the second $60,000.00. At that time the ditch was still in the process of construction and had not been tested out. However, there is absolutely no doubt as to its success, since the ditches further down stream have proven successful under conditions more adverse than those in this district.

Nemaha County Drainage District No. 2

The Nemaha County Drainage District No. 2 was organized several years ago for the purpose of reclaiming and benefiting the overflowed land, and the land damaged by seepage, which lies along the bottoms of the Little Nemaha River Valley within Nemaha County. The district begins on the up-stream and where the river crosses the Nemaha-Otoe County line and continues to the point where the Little Nemaha empties into the Missouri River.

The land benefited by and subject to assessment for the ditches excavacted in this drainage district may be roughly described as an area 22.5 miles in length and a little less than 1.5 miles in width. The land in this district is divided into very nearly equal areas by the Little Nemaha River. The benefited area is approximately 31.4 square miles.

The entire watershed of this stream is about 1,050 square miles. The portion of the catchment basin draining through the main channel of the river, at the point where it crosses the Nemaha-Otoe County line, is given by counties as follows:

Lancaster	56 sq. mi.
Cass	59 sq. mi.
Johnson	120 sq. mi.
Otoe	525 sq. mi.
Total	760 sq. mi.

The remaining 280 square miles drains into the main channel down stream from the Nemaha-Otoe County line, and is given by counties as follows:

Otoe	31 sq. mi.
Nemaha	242 sq. mi.
Richardson	7 sq. mi.
Total	280 sq. mi.

For location of the above drainage see the map of Divides in Southeastern Nebraska.

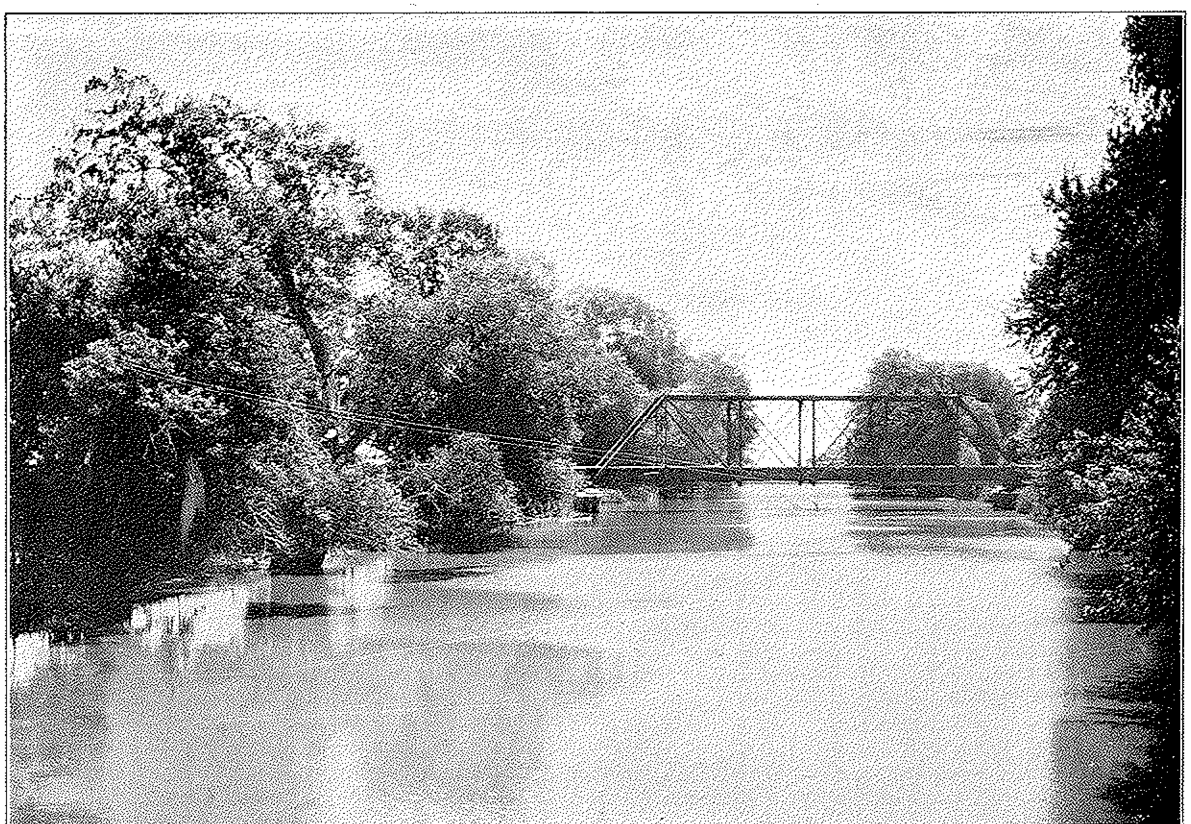

Fig. 11.—The Little Nemaha River, about 75 yards above its juncture with the Missouri River, spanned by the Burlington bridge. Photographed by E. F. Schramm.

Throughout the drainage district under discussion the general course of the river shows a peculiar persistency of direction. The stream itself, however, is very crooked, and in places meanders 2 and even 3 miles in passing through a single section. The average grade of the valley is a little less than 4 feet per mile, (actually averaging 0.75 foot in 1,000 feet) so that these meanders, especially in the lower part of the district, reduce the grade on much of the old main channel to slightly over 1.0 feet per mile. A grade as flat as this even in a straight, clean channel would cause very little or no scour. Taking into consideration the many obstructions of the old channel of the river, such as drift-dams, fallen trees, and meanders, it is, therefore, evident that there was no scour. Mr. A. M. Munn, the evaluating engineer for the district, says in his report that in places these barriers of accumulated debris had decreased the effective flow along the main channel by 30 to 35 per cent. This statement may be taken as quite conservative. It is readily seen that this stream, with its tortuous meanders, barriers, flat grade, and low velocity, was in the process of filling its bed, which decreased its effective cross-section area. With the above conditions in mind, it is evident that the flood waters would become more and more destructive. At the time of evaluation of the benefits, over 20,000 acres in Nemaha County sustained more or less damage from actual overflows or from seepage. For eight years before the ditch was completed the growing seasons were wet, and the attending overflows destroyed or greatly damaged the crops each year. Mr. Sylvester Reed, of Auburn, says that on some of the 100 per cent benefit lands the "income did not pay the taxes." The lowest of the overflowed lands were entirely abandoned for agricultural purposes.

The evaluating engineer rated a very large proportion of the 20,085 acres benefited by this drainage system as 100 per cent land. His rating on the 100 per cent benefit land was $40.00 per acre, and the first assessment was $13.71 per acre. This fund was found to be insufficient for the proposed work, so a second assessment of 15 per cent of the first was levied, making a total of $15.7665 per acre for 100 per cent lands. The following statement gives a summary of the two assessments, delinquent taxes, and the reduction of the first assessment due to errors:

First assessment	$213,124.41
Errors in evaluation	2,711.29
	$210,413.12
Delinquent taxes	3,862.23
Second assessment	30,718.46
Total	$244,993.81

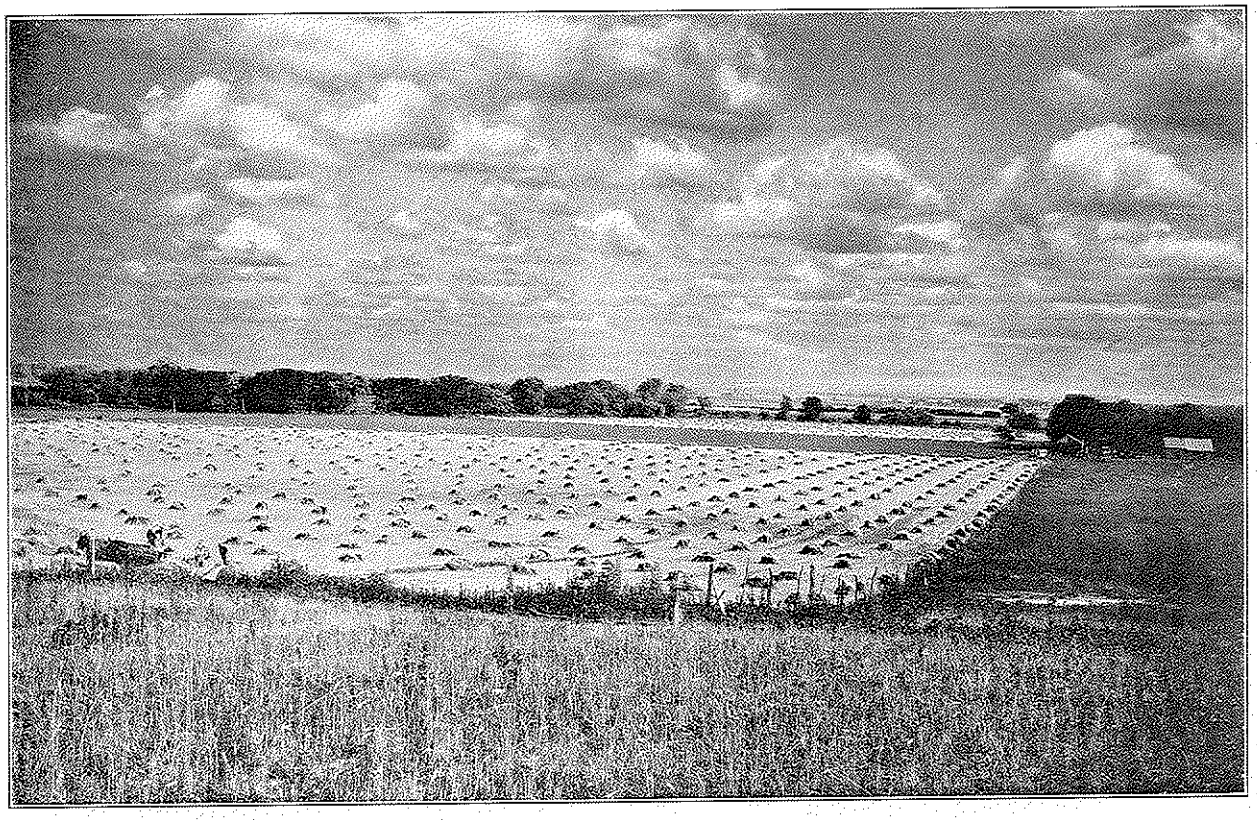

Fig. 12.—Bottom land, about 1½ miles southeast of Nemaha. Typical of Nemaha River bottoms. Photographed by E. F. Schramm.

This represents the total paid by the landowners of the district. Instead of issuing bonds of a high rate of interest for a term of years, the assessments were levied as a flat tax. The Board of Supervisors decided that the landowners could borrow money at a lower rate of interest than that which would have to be paid on a bond issue, and also that the landowners could pay the principal several years before the bonds could mature. The first assessment of $210,000.00 was collected within one year.

Below is a summary of the entire assessment list:

Landowners	$244,993.81
Nemaha County highways	26,339.10
C., B. & Q. Ry. Co.	2,226.26
Mo. P. Ry. Co.	16,023.07
Total	$289,582 24

The County Highway Commissioners made a contract with the district to construct and maintain all bridges made necessary by the ditches within the district. This was to substitute for the first assessment, and the county was to be excused from paying any further assessments.

The Missouri Pacific Railway Company presented a bill for $18,000.00 for river improvements already completed, to offset their first assessment, and contracted to be excused from further assessments.

The usual preliminary and location lines were run to obtain the data necessary for the engineer's calculations as to the size of the ditches required. The specifications for the main channel state that the ditch must have a minimum depth of 14 feet. At the Nemaha-Otoe County line the width at grade was to be 16 feet, increasing gradually to 25 feet near the Missouri River. The main channel throughout its entire length has a subchannel 3 feet wide by 5 feet in the center of the ditch. The side slopes were to be 1 foot horizontal to 1 foot vertical, and a clean 10-foot berm was to be left between the top of the bank and the toe of the waste bank. The grade of the main channel averaged 0.75 foot in 1,000 feet.

The engineer's estimate of the cost of the entire system of drainage was as follows:

Main channel, 1,641,220 cu. yd. at 9c	$147,709.80
Laterals, 613,215 cu. yd. at 11½c	70,519.70
Right-of-way damages, etc.	20,364.10
County highway bridges	26,800.00
Railway bridges	7,245.00
Mill site damages	1,869.00
Total	$274,507.60

The contract for the entire district was let in November, 1909, to the Hummer Construction Company of Marion, Ohio. The work on the main channel began in March, 1910, and was finished in December, 1911. Some of the smaller laterals were sublet and one of these subcontractors did not finish until late in 1913.

The main channel, as let to the head contractor, consisted of 94,911 feet of new main channel (approximately 17.98 miles) and 24,659 feet of old river channel to be cleared (approximately 4.67 miles). This makes the present main channel 22.65 miles in length.

The final estimate made after the work was completed is as follows:

Main Channel:	
Excavation, 1,568,587 cu. yd. at 7¾c	$121,565.40
Clearing old channel, 25,600 squares at 10c	2,560.00
Excess clearing on right-of-way	54.50
Total cost of main channel	$124,179.90
Total cost of laterals	58,231.28
Total	$182,411.18

The expenses of the original organization was $974.06 and that of administration up to April, 1914, was $17,904.43.

The district after paying all expenses, salaries and damages to date, have aproximately $5,000.00 left from the entire assessments made.

In general, the landowners of the district are well pleased with the success of the ditch work. They say there has been no damage done by flood since the ditch has been in operation.

Mr. M. T. Connor, of Auburn, who owns many acres of land on the river bottoms, says that most of the land has doubled in value since the success of the ditch was assured. Land to the south of Auburn that could formerly be bought for $50.00 per acre, is now held at $75.00 to $100.00 per acre. The land prices before the district was organized ranged from $35.00 to $50.00 per acre.

Field Work

In the spring of 1914 the writer made an extended trip through the drainage districts of the area discussed in this report. This field work was classified as:

(1) Examination of district records.

(2) Inspection of ditches, levees, and land subject to overflow.

(3) Interviews with landowners relative to conditions, crops, and land values before and after the various districts were ditched.

ACKNOWLEDGMENT

The writer is much indebted to Messrs. A. R. Keim, C. F. Buckholz, and Judge John Gagnon, of Falls City; Mr. R. E. Grimstead, a Drainage Commissioner, of Salem; Messrs. C. M. Linn and Joy Nims of Humboldt; Messrs. W. A. Fellers and E. D. Howe of Table Rock; Mr. R. C. Gore, engineer, of Tecumseh, and Messrs. Sylvester Reed and M. C. Connors of Auburn, for their courtesy in supplying maps and data; and to Dr. Erwin H. Barbour, State Geologist, and to Prof. E. F. Schramm, of the University of Nebraska, Lincoln, for their advice and assistance.

The writer has quoted freely from the reports of Messrs. Elliott and Frazer, Drainage Engineers for the Department of Agriculture, and Mr. D. D. Price, State Engineer of Nebraska. Professor Schramm furnished the photographs for the cuts used in this paper. The district maps were re-drawn by the writer from the originals which were prepared by Mr. A. M. Munn of Kansas City, Missouri, and Mr. R. C. Gore of Tecumseh, Nebraska. The Map Showing Divides of Southeastern Nebraska was compiled by the writer from the United States Geological Survey topographic maps and from various county maps.

The University of Nebraska,
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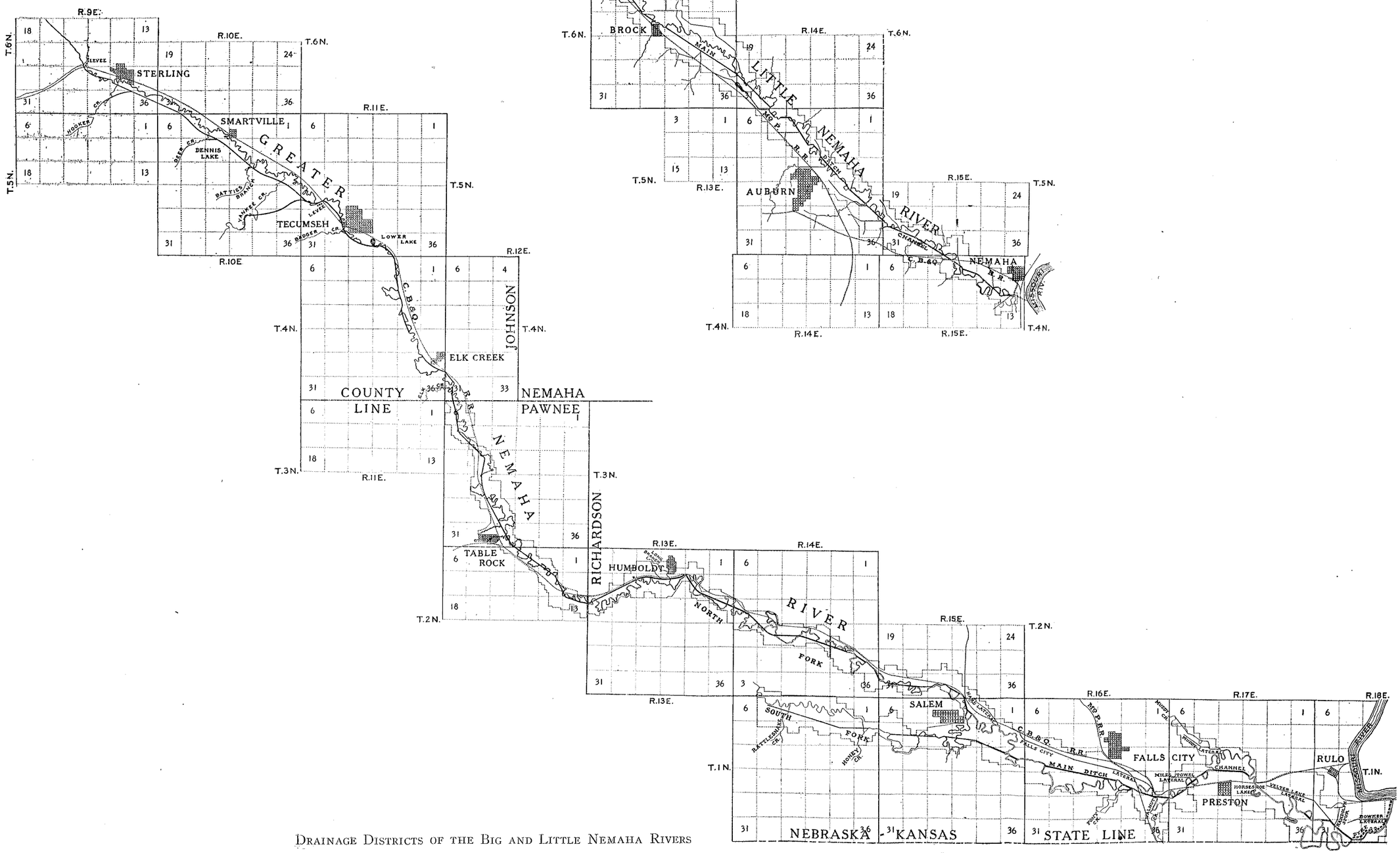

Drainage Districts of the Big and Little Nemaha Rivers