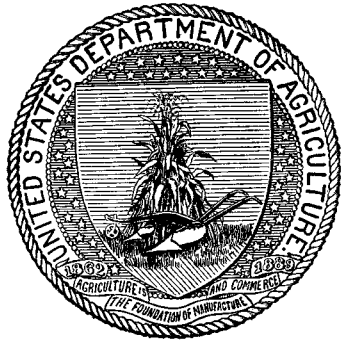
U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF SOILS—MILTON WHITNEY, Chief.

SOIL SURVEY OF THE GARDEN CITY AREA, KANSAS.

BY

JAMES L. BURGESS AND GEORGE N. COFFEY.

[Advance Sheets—Field Operations of the Bureau of Soils, 1904.]



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

[PUBLIC RESOLUTION—No. 9.]

Joint Resolution Amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture."

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, be amended by striking out all after the resolving clause and inserting in lieu thereof the following:

That there shall be printed ten thousand five hundred copies of the report on field operations of the Division of Soils, Department of Agriculture, of which one thousand five hundred copies shall be for the use of the Senate, three thousand copies for the use of the House of Representatives, and six thousand copies for the use of the Department of Agriculture: *Provided,* That in addition to the number of copies above provided for there shall be printed, as soon as the manuscript can be prepared, with the necessary maps and illustrations to accompany it, a report on each area surveyed, in the form of advance sheets, bound in paper covers, of which five hundred copies shall be for the use of each Senator from the State, two thousand copies for the use of each Representative for the Congressional district or districts in which the survey is made, and one thousand copies for the use of the Department of Agriculture.

Approved, March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils.]

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Soil map, Garden City sheet, Kansas.

SOIL SURVEY OF THE GARDEN CITY AREA, KANSAS.

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LOCATION AND BOUNDARIES OF THE AREA.

The Garden City area is situated in the southwestern part of the State of Kansas. The area surveyed lies between the parallels of 37° 49′ 23″ and 38° north latitude and the meridians of 100° 30′ and 101° west longitude. Its southern boundary is the fifth standard parallel, and the fourth guide meridian passes through Garden City.

The area embraces 227 square miles in the southwestern part of Finney County, and 108 square miles of the northwestern part of Gray County, making a total area of 335 square miles. It lies in what is known as the semiarid belt of the Middle West, and includes a large area of the sand-dune region that lies south of the Arkansas River.

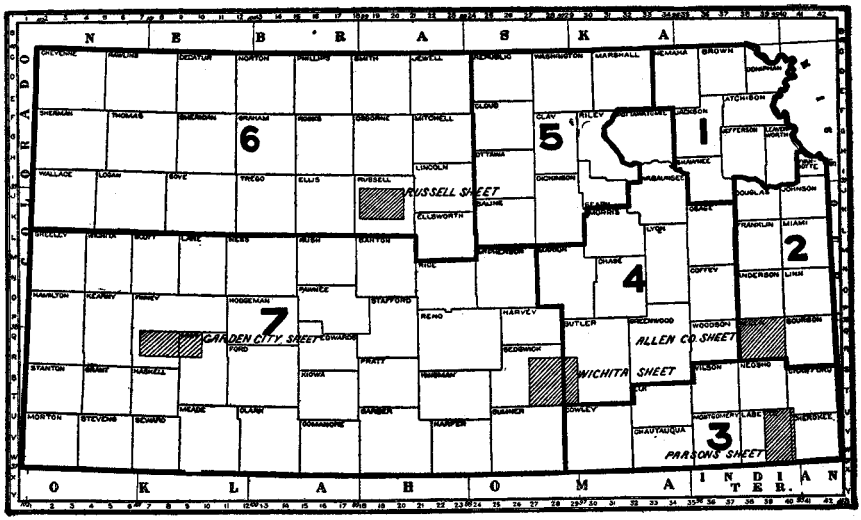

FIG. 1.—Sketch map showing location of the Garden City area, Kansas.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

In 1878 William and James R. Fulton came from Ohio and located claims where Garden City now stands. These were the first white settlers in what is now Finney County, and their dwelling house, to-

gether with the section houses at Sherlock and Pierceville, were the only houses in the county at that time. The Atchison, Topeka and Santa Fe Railway Company had just completed its road and opened the way for immigration. Countless herds of buffalo then roamed over the plains. The old Santa Fe trail, over which travel used to pass from east to west prior to the advent of the railroad, ran through the present town of Garden City. This town was incorporated in 1885.

The main interest in the area at this time was stock raising, and this has continued to be so to the present day. A few good wheat crops were raised in the early days of settlement, but the people became inclined to make their living from the grass of the plains and general farming was neglected. Irrigation was not thought necessary, and what little was done was in the way of an experiment. In 1879 the Garden City Canal was constructed and some land irrigated from it. As intimated above, crops of wheat, corn, barley, oats, and rye were raised in the early days of the settlement of the county, but the climate seemed to favor stock raising and the production of forage crops became all-important.

In 1885 the "boom" came. Allured by the hope of obtaining a homestead in this part of the West, thousands rushed to western Kansas, where a few favored seasons had produced abundant crops. The town site enlarged greatly, and town property sold for what would now be considered fabulous prices. Every quarter section of land for miles around had a house on it. A reaction followed. Failure came, not because the land was poor, but because the people who came did not understand the facts of soil and climate that exist in this part of the West. They attempted to introduce eastern methods into western conditions; they tried to farm the semiarid plains according to ideals brought with them from the humid belt. Consequently, those who were more easily discouraged returned home and left their claims unpatented, thinking the country had nothing to offer them, and it was only a few months until everybody wanted to sell and nobody wanted to buy. Most of those who stayed and fitted their practices to existing conditions have good homes and are prospering. The tide of immigration from the East has not been entirely cut off by the reaction that followed the "boom days," and farm lands are being gradually bought up and homes erected. Irrigation systems have been put in; the sugar-beet and durum-wheat industries are just now emerging from the experimental stage; the stock industry is in a fair state of development, and all lines of agriculture to which the soil and climate are adapted hold out inducements to the farmer who is willing to inform himself as to the best methods of soil culture to be practiced in this part of the West.

CLIMATE.

The Garden City area is wholly within that part of the Great Plains region characterized as subhumid. The climate is variable from humid to arid, but in the mean annual precipitation there is a marked deficiency. This part of the Great Plains is one of droughts; not of perpetual droughts, since there are humid intervals in short periods of groups of years; but the mean annual fall is below what is required for successful agriculture. Among the periodic variations, those of marked deficiency have the longer duration. Yet the humid intervals have enabled the pioneer to achieve a result that encouraged him to believe that the climatic conditions of the country were undergoing a permanent change. The records of the precipitation within this section, extending over a quarter of a century, disclose several of these humid periods, always offset, however, by periods of almost desert dryness, and indicate in the long run climatic stability.

The "boom days" in 1885 were caused by a succession of these humid years. For example, during the five years following 1880 the rainfall at Dodge City, 50 miles east of Garden City, averaged 6.1 inches during May, 3.4 inches during June, and 4.6 inches during July. The next five years are shown by the records to be years of exceeding dryness as compared with those that preceded them, resulting in abandoned farms, abandoned homes, and an almost abandoned town. There are few areas where a careful study of climatic conditions may bring greater results to the prospective purchaser.

Records of a quarter of a century show a uniform decline in precipitation across the Great Plains region westward. At Garden City the annual rainfall is about 19.81 inches, while evaporation is far in excess of this. At Dodge City the evaporation is over 54 inches annually, and while no records seem to have been kept here, it is certain that the evaporation in the Garden City areas is as great as it is at Dodge City.

The wind movement across this area is quite rapid, especially in March, April, July, and October. The records at Dodge City, taken hourly during 1897, show the average rate of wind movement for that year to be a little more than 10 miles an hour. As Dodge City is only 50 miles to the east, it is reasonable to suppose that these figures indicate quite closely the wind movement at Garden City.

While it is true that the rainfall here is quite as great as it is in the Dakotas, in the same longitude, it usually comes in the form of cloudbursts and quickly-passing thundershowers, and most of it runs off before it has time to sink into the soil. This fact emphasizes the importance and necessity of some method of cultivation by which the soil shall be made to store these storm waters and save them for crop production.

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As the amount of precipitation has such an important bearing upon the agriculture of the area, and varies so much from year to year, the records at Garden City from 1897 to 1903, inclusive, are given in the following table:

Actual precipitation at Garden City, Kans., from 1897 to 1903, inclusive.

Month.	Year.						
	1897.	1898.	1899.	1900.	1901.	1902.	1903.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
January	.....	1.55	0.35	0.15	0.20	0.25	0.25
February	2.33	.00	1.18	.88	.55	.87	4.45
March	.19	.50	1.30	1.22	2.20	2.46	.70
April	2.09	.97	1.00	5.20	3.90	.70	5.10
May	.61	6.49	.42	2.05	1.20	6.26	1.49
June	3.19	6.39	4.40	2.79	1.30	2.43	2.83
July	3.49	2.59	6.21	2.18	1.48	.98	.77
August	5.80	2.04	1.00	.80	2.03	.88	3.65
September	.33	4.24	1.93	3.10	4.57	1.00	.35
October	1.78	.43	.75	.52	.60	2.62	.40
November	Tr.	1.55	1.26	Tr.	.00	.20	.40
December	.50	2.00	.78	.40	.31	1.00	.25
Total	20.31	28.75	20.58	19.29	18.34	19.65	20.64

The following table shows the normal monthly and annual temperature and precipitation at three Weather Bureau stations—Lakin, Garden City, and Dodge City. The former is about 20 miles west and the latter 50 miles east of Garden City. The records on which the normals are based cover periods of thirteen, eight, and twenty-nine years, respectively.

Normal monthly and annual temperature and precipitation.

Month.	Garden City.		Lakin.		Dodge City.	
	Temperature.	Precipitation.	Temperature.	Precipitation.	Temperature.	Precipitation.
	°*F.*	*Inches.*	°*F.*	*Inches.*	°*F.*	*Inches.*
January	30.0	0.53	29.8	0.22	26.6	0.44
February	28.9	.99	31.4	.95	31.8	.63
March	41.8	.54	41.5	.63	41.6	.98
April	55.5	1.50	53.3	1.57	53.7	1.58
May	65.3	2.04	63.3	1.80	62.9	3.19
June	73.0	4.35	72.1	2.10	72.6	3.34
July	76.2	3.71	78.0	2.00	77.6	3.11
August	74.8	2.57	76.0	2.07	75.2	2.86
September	69.0	1.47	69.1	1.52	67.6	1.35
October	54.9	.68	57.0	1.01	55.1	1.20
November	40.3	.51	42.2	.20	40.2	.49
December	30.7	.92	32.2	.60	32.6	.63
Year	53.4	19.81	53.8	14.67	53.1	19.80

The temperature in this area, as is general over the Great Plains region in the semiarid belt, rises rather high during the day and falls comparatively low at night. This fact precludes the growth of such plants as flourish in districts where warm, moist nights prevail during the growing season. Killing frosts have been known to occur as late as May 26 and as early as September 7. The average, however, permits a growing season of about five months without serious frosts. The average dates of occurrence are April 27 and October 3.

While the extremes of heat and cold are quite pronounced in this area, the dry air and great rate of evaporation cause these extreme conditions not to be felt seriously by either man or beast. Many times the thermometer may fall as much as 20° or 30° below zero during the winter months, yet the cattle on the prairies that enter on the winter in good shape live through these periods without more shelter than a wind-break and are apparently unharmed.

PHYSIOGRAPHY AND GEOLOGY.

The Garden City area is located in the region known as the Great Plains. The surface features are, in general, those of a broad, gently rolling plain, through which the Arkansas River has carved out a valley from 1 to 3 miles in width and from 40 to 150 feet below the general level of the uplands. This stream flows diagonally across the area from northwest to southeast, and divides it into two almost equal parts. The elevation where the river enters the northwestern part of the area is 2,860 feet above sea level, and this decreases to about 2,675 feet where it leaves the southeast corner, giving a fall for this stream of about 6½ feet to the mile. There are a few points in the area that fall little short of 3,000 feet, but the average elevation is probably about 2,810 feet above tide level.

The valley is about 2½ miles wide at Garden City, and increases west of this place to as much as 3 miles. To the east it narrows rapidly, until, at the Point of Rocks, it is not more than 1 mile wide. From the Point of Rocks to the eastern boundary of the survey it has an average width of about 1½ miles. The river valley is comparatively level. There are a few local depressions and other irregularities of surface, caused by the shifting of the channel. These irregularities give rise to a first and a second bottom along most of its course in the area. Most of the river bottom is on the north side of the river, but there is a considerable stretch of first-bottom land on the south side of the river, just south of Sherlock, and south and west of Pierceville. The width of the first-bottom land varies all along the course of the river, narrowing and widening with the shifting of the channel during flood time. It is seldom, however, more than one-half mile in width.

About 2 miles east of Garden City is a valley known as the "White Woman Valley," running from the river northward through the northern boundary of the area. This old stream channel has a rise of about 8 feet to the mile, with quite gentle bluff lines. It is from one-fourth to one-half mile wide, and is now covered with heavy soil.

Beginning about 5 miles east of Garden City, and extending beyond the eastern boundary of the area, the bluffs on the north side of the river rise rather abruptly from 40 to 150 feet above the valley. These form the roughest and most broken part of the area. North and west of Garden City and on the south side of the river the bluffs are comparatively gentle.

The topography of the upland portion of the area north of the river is of a distinctly different type from that south of this stream. With the exception of a small area of sand dunes east of Garden City, the surface north of the river is level or gently rolling. Most of this level portion lies in the northeastern part of the area, principally in Gray County. There are about 120 square miles of these gently undulating prairies. In the extreme northeast corner the surface is somewhat broken by an eroded area that forms a part of the drainage basin of the Pawnee River. The prairies are dotted by many small depressions, but these have little influence upon the general character of the topography.

The topography of the uplands south of the river may be described in two words—"sand dunes." The height of these dunes varies from less than 5 feet to more than 60 feet, and will probably average as much as 30 feet. These dunes are usually larger and more numerous for the first 2 miles south of the river valley, but directly south of Garden City the country for a distance of 6 miles is a pile of sand hills. While practically all of the uplands south of the river is covered with sand, there are some areas which are comparatively smooth, and could be irrigated without much leveling if water were obtainable.

Early geologists mapped the strata in this area as Cretaceous, but later and more detailed investigation has brought to light facts that seem to justify their correlation with the Tertiary. Nearly the whole of the area north of the river is covered by what Mr. Hay[a] calls the Tertiary marl. He describes it as not unlike the loess of the Missouri Valley. It appears to be practically identical with the loess in Nebraska, Iowa, Missouri, Illinois, and that part of the West generally where the loess is most typically developed.

The marl in this area is composed of a small percentage of sand,

[a] Bul. 57, U. S. Geological Survey.

a large percentage of silt, and some clay, and usually contains a relatively large percentage of lime and gypsum. In places it is sometimes difficult to distinguish between the Plains marl and the Tertiary grit, which lies below or at a lower level, but these places generally mark surface boundary lines between the two formations. The marl is of a uniform buff color, contains chalky nodules of irregular shape, and is everywhere of nearly the same texture.

The Tertiary marl, or loess, as found in this part of the State, rests, as a rule, on eroded surfaces of the Permian, Jura-Trias, Cretaceous, and Tertiary grit formations. It forms the dead level of the high prairie between the greater rivers, thinning off toward their valleys, but following the slopes of their tributary dales.

The Tertiary grit, or "Mortar beds," as it is sometimes called, does not cover a large part of the area as an outcrop, but seems to underlie the whole area at varying depths. It is composed of sand, gravel, and pebbles, all of which are sometimes converted into a solid mass by the large percentage of lime which it usually contains. The extent and composition of the Tertiary grit seems to indicate that it has been the shingle of some old shore line, which has subsequently been buried beneath the Tertiary marl. The composition of the beds, together with their areal distribution, strongly suggests that it has been, in great measure at least, transferred from the mountain sides by the great floods that doubtless occurred during Tertiary time. The sand, gravel, and pebbles included in the grit are composed of feldspar, quartz, and various silicates of magnesia, iron, aluminum, etc., while interspersed through the mass of the rock are found mica, hornblende, and various other minerals found to-day in the Rocky Mountain region, from which it is undoubtedly derived.

The Alluvium or Recent deposits in the Arkansas Valley have a considerable areal extent. They are composed largely of arenaceous materials which have been brought down by the flood waters or liberated from the Tertiary grit by the winds and rains, aided by gravitational forces, and transported to lower levels. The Alluvium has, therefore, a local and a distant origin, and this fact gives it all the more value from an agricultural point of view.

The sand dunes south of the river are of recent origin. Dunes may now be seen that have recently been blown out of the river bed in the direction of the hills, while the main body of the hills, where not well protected by vegetation, gradually shifts with the fierce winds that in the early spring come from the northwest. The material of these dunes has doubtless come in part from the Tertiary grit formation and in part from the great body of sand that is gradually moving down the river.

SOILS.

The soils of this area, by reason of their geological and physiographic features, fall into two divisions, namely, the soils of the uplands and the soils of the valley. Those of the uplands are usually quite uniform, while those of the valley have been irregular in their deposition.

Nine types have been recognized and mapped according as they differed in texture, depth of soil and subsoil, drainage features, topographic position, and agricultural value. The soils of the immediate valley lie in a general parallelism to the present river bed, and show in their topographic features marked indications of recent fluvial action.

Below are given the name and extent of each of these several soil types:

Areas of different soils.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Dunesand	83,200	38.7	Laurel loam	8,704	4.0
Marshall silt loam	77,120	35.9	Finney clay	2,240	1.0
Colorado sand	10,944	5.1	Colorado adobe	1,472	.7
Laurel sandy loam	16,000	7.4	Total	214,720	
Rough stony land	8,768	4.1			
Finney sandy loam	6,272	2.9			

DUNESAND.

The Dunesand in the Garden City area, while almost a pure medium to fine sand, is sufficiently compact to hold itself in position, except in places where the vegetation has been removed. The sand is of a tawny or yellowish color, composed largely of quartz and feldspar, and is from a few feet to 60 feet deep. In the first 2 feet some organic matter is collecting and aiding in the production of weeds and grasses which are holding the sand in place. The greater portion of this type rests on what resembles, and is doubtless identical with, the Tertiary marl found north of the river.

The Dunesand covers nearly all of the area lying south of the river and a small percentage of that lying north of the river. Several well-defined dunes are found east of Garden City in secs. 17, 18, 19, 20, T. 24 S., R. 31 W.

The topographic features of the Dunesand contrast strikingly with those of the other types in this area. The dunes are from a few feet to 60 feet high; their crests are usually close together, separated by steep and narrow depressions that, in some places, assume the shape

of miniature valleys. As a rule excellent water is obtained at from 50 to 60 feet below the surface when wells are sunk in the lower depressions. This water is practically free from alkali and quite pleasant to drink. This type of soil is well drained, but its moisture-holding capacity is becoming more and more pronounced as the growth of vegetation and the processes of weathering advance.

From 1 to 2 miles south of the river is found a depression where both the topography and the presence of waterworn gravel indicate a former river channel. From this old channel the present dunes were doubtless largely derived when the river swung northward and left the old bed to the action of drifting winds.

The chemical and mineral composition of the Dunesand agrees with that of the rocks from which it is derived, namely, the Tertiary grit, and the granites, and the various plutonic and volcanic eruptives of the distant western mountains. The sand is composed of quartz, feldspar, mica, iron oxide, and various other, but minor, constituents. The Dunesand was doubtless formed partly from the breaking down of the Tertiary grit and partly from the weathering of the rocks on the mountain sides at the headwaters of the Arkansas River. The sand from the latter source has undergone a greater and greater degree of comminution on its eastward march down the river and is now a medium and fine sand, the particles of which are more or less rounded.

The most important use to which the Dunesand is put at present is that of pasture land. It warms up easily and early in the spring and makes an excellent pasture in the summer and early autumn. Water sinks deeply and quickly into this sandy soil, the roots of grasses go down readily, and vegetation covers the sandy area soon after the first spring rains.

The Dunesand is now generally covered with vegetation, consisting principally of sage brush, Spanish dagger, and bunch, blue stem, and Redfield grasses, and is not now drifting perceptibly. When the vegetation is removed, however, the dunes are practically uncontrollable. From a very small beginning, where the plow has gone, some have lost whole farms. The sand being rather fine and of uniform size and rounded shape blows easily once the vegetation is removed. It is extremely unwise, therefore, as some have found by practical experience, to remove in any way the vegetation from the Dunesand. The effect of pasturing too many head of cattle on these dunes is the same as that produced by the use of the plow. Too much care can hardly be taken to encourage the growth of grass and trees on this type of soil.

The dunes found north of the river seem to be much older and of

more compact nature; they do not drift, and furnish a somewhat richer pasture than the dunes to the south.

Below are given the mechanical analyses of this type of soil:

Mechanical analyses of Dunesand.

No.	Locality.	Description.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
11116	NE. cor. sec. 13, T. 25 S., R. 33 W.	Fine to medium sand, 0 to 6 inches.	0.6	7.2	18.3	60.1	9.7	0.6	3.4
11115	SW. ¼ sec. 18, T. 25 S., R. 32 W.	Medium to fine sand, 0 to 72 inches.	1.1	8.0	12.2	56.2	16.6	1.0	4.6

COLORADO SAND.

The Colorado sand is a medium to fine sand of a light-brown or yellowish color. It is typically 6 feet deep, though it varies somewhat, becoming deeper or more shallow as it grades out into the surrounding Dunesand and sandy loam.

The Colorado sand is located in various parts of the area; but the greater portion is found south of the river in the Dunesand district. There are only two small areas north of the river, one about 2½ miles west and the other about 6 miles east of Garden City. Both these areas are cut by the railroad.

The surface of the Colorado sand is usually gently rolling and will require some expense in leveling before irrigation can be successfully practiced. Its topographic and textural drainage features are excellent. In mineralogical and chemical composition it is identical with the Dunesand.

The Colorado sand in this area has been derived from practically the same sources as those from which the Dunesand has been derived, namely, in part from the weathering of the Tertiary grit and in part from the weathered material in the upper drainage basin of the Arkansas River. It has since been blown about by the winds and is still in many places changing its surface features.

There is little or no farming done on this type in the present area. Sometimes a small plat is found on which sorghum is grown, but most of it is used as range land. The soil blows easily when disturbed, and, in the absence of irrigation, its cultivation will always be attended by more or less difficulty for this reason. Its texture is quite open, and should it be irrigated freely by the use of the flood waters

its texture, and incidentally its water-holding capacity, would be favorably affected. This type contains no alkali.

The following table gives the results of mechanical analyses of the Colorado sand as it occurs in the Garden City area:

Mechanical analyses of Colorado sand.

No.	Locality.	Description.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
11087	NE. ¼ sec. 15, T. 24 S., R. 33 W.	Brown loose sand, 0 to 72 inches.	0.7	8.7	16.1	43.9	21.6	2.8	6.1
11088	Cen. sec. 9, T. 24 S., R. 33 W.	Brown loamy sand, 0 to 18 inches.	2.4	11.7	19.5	40.4	15.3	3.8	6.9
11089	Subsoil of 11088	Yellow sand, 18 to 36 inches.	.6	7.1	15.2	46.1	20.6	4.2	6.0

MARSHALL SILT LOAM.

The Marshall silt loam is an extremely uniform type. The soil is a dark or chocolate brown silty loam, in which is found from 15 to 20 per cent of very fine sand. The particles of sand are all so fine that the soil retains the soft, smooth feel characteristics of a silty loam. The dark color usually extends to a depth of 16 to 18 inches, but the zone of weathering often reaches to 30 or 40 inches, depending upon the topography. The subsoil is a light-gray or grayish-yellow, very mealy, silty loam many feet in thickness. It was very dry and powdery at the time of the survey, because the rainfall had not been sufficient to wet the ground to any great depth. The less amount of rainfall here as compared with areas farther east, where the precipitation is greater, has caused much less weathering of the soil materials. There has been no leaching of the subsoil, and it therefore contains larger amounts of lime than is found in the type in humid regions.

A phase of this type, differing slightly from the typical upland soil, occurs in the second bottom, north of Garden City, and in the White Woman Valley. In this position it is usually underlain at about 6 feet by clay, and this fact, together with its topographic position, gives it a slightly different agricultural value.

The Marshall silt loam generally occupies the upland prairies, and is the major type found north of the river. It is especially well developed in the northeastern part of the survey, where it forms almost the exclusive soil type, dotted here and there with small areas of the Finney clay, which has been derived from it.

The surface of the Marshall silt loam is generally level, with sufficient relief for good drainage. The soil is highly retentive of moisture when a good mulch is kept on the surface, but because of its fine texture evaporation quickly relieves it of its moisture content when capillarity is unbroken. It is easily put in condition for crops and is an ideal soil for general agricultural purposes; but its elevated position above the water table, the light rainfall, and the present methods of soil management render general agriculture on this soil unprofitable, except in seasons of abnormal precipitation. This should by no means be true, since this is the best soil in the area and doubtless the best in this part of the State.

This soil is derived from the Plains marl, which, as has been stated already, is similar to the loess of Missouri and other central States. It seems probable that this is a wind-blown deposit, as it is uniformly composed of such materials as could easily be transported long distances by the wind. The zone of weathering has not yet reached more than 40 or 50 inches below the surface. Sections seen in old wells, "dugouts," and cellars expose the columnar structure and lime pipes so characteristic of the loess as found elsewhere. Roots extend to great depths, there being no hardpan or impervious stratum to obstruct the downward movement of either roots or water.

The Marshall silt loam is free from harmful amounts of alkali. The second-bottom phase contains a small percentage and there is a possibility of injury here from alkali unless proper methods are employed to prevent it. The soil and subsoil contain a considerable amount of lime, but there are no noticeable injurious effects on crops. This type is used largely as range land. There is a considerable amount of wheat grown in the northeastern part of the survey. Spelt and barley do well in favorable seasons, but the durum wheats will doubtless prove to be the most important cereal for this type of soil. This soil seems to be especially adapted to the growth of wheat, and the aridity of the climate strongly suggests the use of the durum varieties. Indeed, it has been proven conclusively that the durum varieties will give a good average yield during seasons in which the ordinary wheats prove to be an entire failure. The durum or macaroni wheat has recently been introduced by the Bureau of Plant Industry and the results have so far been quite favorable. As much as 25 bushels to the acre has been harvested from this soil, with an average of 10 bushels or less, depending on the season. Should the winter and spring precipitation be conserved by proper methods of cultivation, supplemented by an occasional cultivation of the wheat while small to prevent the formation of a crust and thus minimize evaporation, excellent yields of wheat could be obtained almost every year.

The surface of this soil is level enough to admit the use of all kinds

of farm machinery, and with proper methods of soil management there is no doubt that this would become one of the great wheat soils of the West.

The following table gives mechanical analyses of this soil type:

Mechanical analyses of Marshall silt loam.

No.	Locality.	Description.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
11108	SE. cor. sec. 27, T. 24 S., R. 31 W.	Brown silty loam, 0 to 16 inches.	0.2	0.8	0.7	3.7	20.2	54.2	19.9
11100	NE. ¼ sec. 8, T. 24 S, R. 31 W.	Brown silty loam, 0 to 24 inches.	.0	.3	.3	3.0	19.4	56.3	20.5
11181	Subsoil of 11100	Silty loam, 40 to 72 inches	.0	.1	.1	.6	14.6	63.7	20.4
11109	Subsoil of 11108	Yellow silt, 16 to 72 inches.	.1	1.3	1.1	4.0	15.2	56.6	21.5

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 11100, 2.9 per cent; No. 11108, 0.93 per cent; No. 11109, 8.8 per cent; No. 11181, 7.0 per cent.

FINNEY SANDY LOAM.

This is a medium to fine sandy loam of varying depth, ranging from a few inches to a few feet or more, and is always underlain by a silt loam, sometimes quite heavy and usually of great depth. The greatest development of this type is found on the uplands about 5 miles east of Garden City, and here the subsoil is quite uniform in texture and of very great depth. There is also a considerable area extending about 2½ miles northwest of Garden City. This area is finer than the upland areas and the subsoil is slightly heavier. This second-bottom phase is represented by samples Nos. 11092 and 11093.

The surface of this type is generally rolling, especially in the uplands, where small areas of sand are frequently found dotting the surface. That portion of this type found west of Garden City is comparatively level and may be irrigated with little expense for leveling. All of this soil has good drainage features, both textural and topographic, and by reason of its heavy subsoil it also has excellent moisture-holding capacity. This is evidenced by the observation that even the imperfect mulch formed by the disk drill in seeding this soil to sorghum kept the moisture beneath the surface long after the adjoining unbroken sod had been reduced to a powdery dryness.

The subsoil of the Finney sandy loam is a silt loam of a loesslike

nature, while the soil is a sandy loam, very light in some places. The subsoil seems to have been deposited by wind or water action or both and the sand has since been blown over it. The origin of the sand is similar to the Dunesand, and this type represents areas where only a thin layer of sand was deposited over what is known as the "Plains marl," which occupies the uplands generally on the north side of the river. It has been some time since this deposition of sand took place, and subsequent weathering and plant growth have produced marked effects on the texture. This sandy soil contains a good percentage of clay and silt, and furnishes a habitat for a variety of weeds and grasses. It is free from alkali, except that the subsoil contains considerable lime, but this effects the surface only where this type merges into the Rough stony land.

With the exception of that portion which is found on the second bottom this type is generally used for range purposes, though an occasional field is found seeded to sorghum. On the second bottoms the Finney sandy loam is sometimes planted to alfalfa, which, on this soil, is more remunerative as a seed crop than as a forage crop. On the uplands as much as 2 tons of sorghum may be secured in favorable seasons.

The following table gives the results of mechanical analyses of this type, as found in the Garden City area:

Mechanical analyses of Finney sandy loam.

No.	Locality.	Description.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
11094	NW. cor. sec. 24, T. 24 S., R. 32 W.	Brown sandy loam, 0 to 24 inches.	0.8	10.5	14.9	24.9	16.8	20.0	12.0
11092	NE. ¼ sec. 10, T. 24 S., R. 33 W.	Fine sandy loam, 0 to 30 inches.	.4	3.0	6.5	23.2	26.4	27.8	12.4
11090	NW. ¼ sec. 24, T. 24 S., R. 32 W.	Yellow sandy loam, 0 to 20 inches.	.7	9.0	12.3	21.5	17.3	26.2	13.2
11095	Subsoil of 11094	Yellow silt, 24 to 72 inches.	.2	1.1	1.5	6.4	26.8	49.7	14.1
11093	Subsoil of 11092	Silty loam, 36 to 72 inches.	.2	1.1	.8	4.5	11.3	55.9	26.2

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 11093, 9.7 per cent; No. 11095, 7.8 per cent.

FINNEY CLAY.

The Finney clay is a dark tenacious clay soil, from 2 to 6 feet deep, overlying a heavy silt loam of great depth. When the soil becomes dry large cracks, often 2 inches or more in width, are formed.

It is found almost wholly in the upland prairies north of the river, occupying small local depressions, known as "buffalo wallows." The largest areas are found in the northeastern part of the survey, surrounded on all sides by the Marshall silt loam.

The soil has been deposited in these depressions by the wash from the surrounding slightly higher levels. It has at present little agricultural value in this area, and in a few places the presence of this stiff heavy clay soil presents some difficulty in the cultivation of the surrounding lighter soil. These spots are usually covered with a poor variety of swamp grass.

The following table gives the results of mechanical analyses of a soil and a subsoil of this type:

Mechanical analyses of Finney clay.

No.	Locality.	Description.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
11105	NW. ¼ sec. 21, T. 24 S., R. 31 W.	Brown clay, 0 to 40 inches.	0.3	0.7	0.5	3.8	14.2	41.0	39.5
11106	Subsoil of 11105	Gray silty loam, 40 to 72 inches.	.1	.6	.3	1.3	13.7	59.3	24.7

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 11105, 0.52 per cent; No. 11106, 2.3 per cent.

ROUGH STONY LAND.

Rough stony land is usually a mass of sand, gravel, and pebbles, containing some clay and silt, all heavily charged with lime. It is of a light-gray color, due to the presence of large amounts of calcium. The zone of weathering has reached a depth of from 10 to 30 inches, below which is a compact, and more or less consolidated, conglomerate bed having a small percentage of fine earth. Where weathering is most advanced the material is little else than a mass of sand, gravel, and pebbles, in places containing some fine earth.

This type occupies the more precipitous bluff lines north of the river, and extends from near Garden City to the east boundary of the survey. Small areas are noted elsewhere, but the greatest extent is found along the bluffs, where erosion has cut and carved it into ravines of various sizes and shapes. The surface of the soil is very irregular and rough, so much so that most of it is unfit for agricultural purposes. It is derived from and is a part of the Tertiary grit noted by geologists as occupying the bluff lines in this and other

parts of the Arkansas Valley. On the more level portions sorghum is sometimes grown, but the type as a whole is used as range land, and much of it is not worth even the cost of fencing for this purpose. Only an inferior and scant vegetation exists on it, except in some of the wider draws, where buffalo grass is found.

LAUREL SANDY LOAM.

This type of soil is composed of various grades of sand and gravel, mixed with a variable percentage of silt and clay. In some places the percentage of fine material is great enough to give the soil the characteristics of heavy sandy loam; then again this fine earth may be present in quantities so small as to give the soil approximately the texture of a gravelly sand. The different grades of material are so intermingled as to render impracticable any attempt to differentiate them into separate types of soil. The depth of the soil varies greatly, but it is nearly always underlain by a bed of sand and gravel at from 18 to 36 inches.

There are two phases of the Laurel sandy loam in this area occupying the first and second bottoms, respectively. The second bottom phase lies north of the river and is usually found about midway between the river and the bluff line, but in the eastern part of the survey it is found skirting the bluff line. Much of it occurs west of range 32 W. around and west of Garden City. The surface is usually gently rolling, with an occasional abrupt depression caused by the filling in of some former river channel, and in some places small arroyos finger out from the higher grounds adjoining.

The first-bottom phase lies parallel to and on both sides of the river and adjacent to it, except at a few points where either the Laurel loam or the Colorado sand supersedes it. It includes also the larger islands of the river. Sand ridges, covered with vegetation, frequently appear lying parallel to the course of the stream. Between the narrow ridges, strips of clay and silt are found. In fact, this phase of the type grades quickly from a clay in some places to almost pure sand in another, and, from the various textured materials composing it and thrown together by the shifting currents of the river, it closely resembles meadow.

With the exception of that portion of the type lying immediately under the bluff, the Laurel sandy loam is wholly of fluvial origin, representing a surface that has at different times been occupied by the river bed. The fact is emphasized by the presence of a bed of coarse sand and gravel at varying depths underlying all of the type found in the river bottom. The underlying sand and gravel is practically the same in appearance as that found in the present river channel. Much of the material in the first bottom has evidently been deposited by comparatively recent fluvial action, having been transported long distances from the west by the river during flood seasons. As the

floods subsided the coarser particles were first deposited, while the fine materials, such as silt and clay, remained in suspension in the water left in the sloughs and pools, and were laid down on the coarser material beneath. The river occasionally overflows at various points and adds considerable silt and clay to the soil, the result being that the texture is gradually becoming finer and the soil stratum deeper. That portion of the type found along the bluff line has doubtless been formed from the weathering of the Tertiary grit or mortar beds found just above it. This weathered material has been carried by the sudden and heavy rains down into the lowlands and spread out in a sinuous line, reaching from near the White Woman Valley to the east boundary of the survey.

The Laurel sandy loam is practically free from harmful amounts of alkali, and only a few points are found where indications of alkali were pronounced, yet if irrigation should be practiced the heavier phases of the type might give some trouble. The remedy is discussed in the chapter on alkali. Judging from the sand and gravel contained in this soil, the principal minerals composing it are quartz and feldspar.

The second-bottom phase of this soil is generally so open that moisture either evaporates or passes readily down below the zone of root action before the plant can use it. The soil greatly needs more fine material, and this can be added by a free use of the sediment-laden flood waters. This phase of the type lies in a position quite favorable to irrigation, and the greater part of it lies under the ditch, but unfortunately many of the farmers do not take advantage of the opportunity afforded them for irrigation. Since it occupies such an important position in the agricultural development of the valley, the necessity for the use of the annual flood waters can not be too strongly urged. On the heavier phases fair crops of alfalfa, sorghum, sugar beets, Kafir corn, and macaroni wheat are sometimes harvested. Under favorable conditions of cultivation and moisture from 8 to 12 tons of beets, one-half to 1 ton of alfalfa hay, and 2 tons of sorghum or Kafir corn per acre can be produced, but the average yields are far below these figures. Vegetables seem to do well when sufficient water is applied, and it is not improbable that such crops as potatoes and cantaloupes would pay handsomely even in the light sandy phases if sufficient water can be obtained.

The first-bottom phase is at present used largely as range land and permanent meadow. It doubtless could be made to bring profitable returns if used for general agricultural purposes. The water table is too near the surface for the growth of alfalfa, but almost any shallow-rooted forage crop adapted to the climate would do well. With proper cultivation, there is little doubt that this soil would produce cantaloupes of excellent quality. Where the land is used for

permanent pasture it would be advisable to give the surface a thorough disking and to sow alsike clover or some other pasture plant that will not be injured by the fluctuations of the water table.

The following table gives the results of mechanical analyses of the fine earth of the Laurel sandy loam:

Mechanical analyses of Laurel sandy loam.

No.	Locality.	Description.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
11085	NE. ¼ sec. 18, T. 24 S., R. 33 W.	Sandy loam, 0 to 15 inches.	1.0	8.9	13.6	32.6	19.1	12.7	11.6
11101	SW. ¼ sec. 2, T. 24 S., R. 33 W.	Brown fine sandy loam, 0 to 30 inches.	0.7	3.3	4.7	13.4	37.5	28.0	12.0
11114	SE. ¼ sec. 5, T. 24 S., R. 33 W.	Sandy loam, 0 to 36 inches.	1.2	7.0	10.7	28.6	23.0	14.6	15.0
11107	SW. ¼ of SW. ¼ sec. 4, T. 24 S., R. 33 W.	Brown sandy loam, 0 to 36 inches.	5.8	12.0	11.5	16.6	22.8	14.8	16.5
11086	Subsoil of 11085	Reddish sand, 15 to 36 inches.	12.7	28.5	21.5	17.8	9.6	5.5	4.3
11102	Subsoil of 11101	Coarse sandy loam, 30 to 40 inches.	3.1	10.6	15.7	27.8	14.1	9.9	18.7

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 11101, 5.2 per cent; No. 11102, 6.5 per cent; No. 11114, 0.95 per cent.

COLORADO ADOBE.

The first 3 to 5 inches of the soil of the Colorado adobe is a heavy medium to fine sandy loam of a dark or chocolate-brown color. There is also a small percentage of coarse sand and gravel, the latter having been brought up from the underlying gravel bed by prairie dogs, while the finer grades of sand have been deposited by the wind. In the section from 5 to 18 inches less sand and more silt and clay is present, giving a texture heavier and more nearly a clay loam. This layer has a very pronounced adobe structure, is very hard, and when crushed breaks into cubes. It is rather impervious to water. When heavy rains occur the water stands, until evaporated, in the "buffalo wallows" that dot the surface. This adobe stratum is in turn underlain by a rather heavy fine sandy loam of a lighter color, which becomes gradually lighter in texture with depth, until a bed of old river sand and gravel is reached at from 4 to 8 feet below the surface.

The greatest area of this type lies upon the second bottom in the northwest corner of the survey in secs. 4, 5, and 6, T. 24 S., R. 33 W., and in sec. 1, T. 24 S., R. 34 W. Other and smaller bodies are found at various points in the area, the most important of which lies in the White Woman Valley, east of Garden City, in secs. 7 and 10, T. 24 S., R. 32 W.

The surface of this soil is only slightly rolling, and is nearly level in most cases. The greater portion of it lies 8 or 15 feet above the water table. This, and the additional facts that its surface is slightly rolling, that its subsoil becomes lighter in texture with depth, and that it is underlain at about 50 inches by a bed of sand and gravel, tends to furnish this type with excellent drainage features.

The Colorado adobe owes its origin in great measure to river action, but has since been materially modified by weathering and by the wash of clayey material from the hillsides. There is some wind-blown sand on the surface, sufficient in amount to make a sandy loam that may be from 2 to 3 inches deep in some places. The material for the first 12 or 18 inches has undergone considerable weathering, and there is incorporated with it a considerable quantity of organic matter.

This type contains a small percentage of alkali. No serious trouble has as yet been experienced with it, but its presence indicates that the conditions might become troublesome should irrigation be practiced.

This " gumbo soil " will produce good crops of sorghum, wheat, and even alfalfa, if only enough water can be obtained. It needs deep plowing, proper tilth, an occasional saturation—say, two or three times a year—followed always by a good 3-inch mulch of loose dry soil, which must continually be maintained. With these conditions fulfilled there is no doubt that excellent crops can be obtained each year, whereas at present only moderate yields are secured in favorable seasons.

At present some sorghum, alfalfa, and Kafir corn are produced on this type, and a yield of from one-half to 1½ tons to the acre is secured, but when properly handled, the Colorado adobe will produce excellent alfalfa, beets, sorghum, and other crops that may be grown at this elevation.

The following table gives the results of mechanical analyses of this soil:

Mechanical analyses of Colorado adobe.

No.	Locality.	Description.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
11110	SE. ¼ of NE. ¼ sec. 6, T. 24 S., R. 33 W.	Brown fine sandy loam, 0 to 5 inches.	2.7	5.2	4.1	11.4	27.0	32.8	16.6
11111	Subsoil of 11110	Heavy silty loam, 5 to 60 inches.	.8	1.7	2.1	8.5	15.1	45.4	26.4

LAUREL LOAM.

This type of soil, as found in the Garden City area, presents features varying somewhat according to its location. It is the best soil in the Arkansas Valley, and is especially well developed in that part of the valley lying immediately east and west of Garden City.

As a second-bottom type it is not found on elevations of more than 10 or 15 feet above the present river bed; hence the water table can always be reached by deep-rooted crops, such as alfalfa and clover. The surface is generally level, with just sufficient relief to give good drainage. The soil is a rather heavy dark-brown loam, becoming lighter in color with depth. It varies considerably, both in texture and depth of soil and subsoil. In some places the percentage of sand is rather large, but these areas are not of sufficient extent to have any marked effect on the agricultural value of the type. These variations are due largely to the mode of deposition. The subsoil is much more sandy and gravelly than the soil. Sometimes almost pure sand is found at from 30 to 36 inches, and the type is nearly always underlain by a bed of gravel at from 3 to 6 feet. As it appears in the valley, the soil seems to have a twofold origin. The lower portions show the former presence of the river channel, where the coarse sand and gravel are not unlike that found in the river bed of to-day. The upper portion has been formed by the occasional inundations of the river when it began to abandon its old channel and swing southward and by the washing in of silt and clay from the adjoining uplands.

Another phase of the Laurel loam occupies a portion of the first bottom on both sides of the river, usually occurring in long, narrow strips parallel with the course of the stream. The largest body is found on the north side of the river, extending a few miles east and west of Garden City. The soil varies from a dark-gray heavy sandy loam to a heavy silt loam, with only a small percentage of sand. The average depth of soil is about 12 inches, but its depth varies in places, owing to its irregular deposition by fluvial action and the occasional floodings to which it is subjected. It is underlain by an interstratified fine sand and silt of mottled reddish and gray color. As a result of deposition by the shifting currents of the river the depth of both soil and subsoil varies considerably, but it is always underlain at from 26 to 36 inches by a bed of waterworn gravel. As the subsoil is very porous, the soil is easily and quickly saturated and as easily dried out when the flood season is over. In places, however, the subsoil has sufficiently fine texture to lift the capillary water up from the water table, which is only from 4 to 6 feet below the surface during the dry season. Weathering and decaying plant remains have had a marked influence on the texture of the soil, and its composition is such as to render it an excellent soil for the growth of grasses and

various other forage plants, except alfalfa, for which the water table is thought to be too near the surface. Where the soil is as much as 12 inches deep, good crops of beets, sorghum, and cantaloupes, no doubt, could be produced, although it is used at present principally as pasture and permanent meadow.

As before stated, the type as a whole is the best soil in the Arkansas Valley, the areas occupying the second bottom being the more valuable for agricultural purposes. Without irrigation alfalfa yields from one-half to 1½ tons per acre. By the aid of irrigation, using windmills, as much as 23 tons of sugar beets has been obtained from this soil. While the second-bottom phase is especially adapted to the growth of alfalfa and sugar beets, all other crops grown in the area, such as macaroni wheat, oats, spelt, rye, barley, millet, potatoes, etc., would doubtless give large yields on this soil. The texture is excellent, the moisture-holding capacity is ample, the subsoil is quite favorable to root growth, and the soil is well supplied with humus.

The following table gives the results of mechanical analyses of the soil and subsoil of the Laurel loam:

Mechanical analyses of Laurel loam.

No.	Locality.	Description.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
11096	Sec. 22, T. 24 S., R. 32 W.	Dark-brown loam, 0 to 36 inches.	1.0	3.3	4.5	15.3	19.7	34.1	21.9
11103	SE. ¼ sec. 7, T. 24 S., R. 33 W.	Gray loam, 0 to 12 inches.	.4	2.7	5.5	17.5	23.9	27.4	22.4
11083	NE. ¼ sec. 21, T. 24 S., R. 32 W.	Dark heavy loam, 0 to 33 inches.	1.0	2.8	4.2	9.2	20.8	33.0	28.8
11097	Subsoil of 11096	Sand, 36 to 72 inches	3.6	11.1	14.5	43.8	17.6	4.4	5.0
11104	Subsoil of 11103	Gray sand, 12 to 36 inches.	1.2	7.0	13.6	36.9	25.7	10.6	5.1
11084	Subsoil of 11083	Yellow sand, 33 to 48 inches.	2.6	10.5	18.4	28.1	16.2	13.9	10.3

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 11083, 15.9 per cent; No. 11084, 4.0 per cent.

HARDPAN.

There is no typical hardpan in this area, but in the river valley there are local variations in both the Laurel loam and the Laurel sandy loam that have some of the characteristics of a hardpan. In the sandy loam it offers some resistance to the penetration of roots, but in the loam its chief evil lies in the resistance which it offers to the upward movement of capillary water from the subsoil. The

soil is always found to contain much more moisture and to retain it longer on areas where this subsurface crust has been broken up. It has been formed, no doubt, by the light rains. These usually penetrate the soil from 1 to 18 inches, and carry lime and such other soluble material as may be in the soil down to lower depths, where, coming into contact with various other chemical constituents, certain silicates are formed—usually a soft limestone. This compact stratum is seldom found below 18 inches.

To correct this condition subsoiling is recommended, together with yearly saturation of the soil to greater depths. It is highly important in the bottom lands that capillarity be continuous from the water table, which is about 6 feet below the surface, to the zone of root growth above. With proper methods of cultivation this condition of soil texture is quite practicable on most of the first and second bottom lands, except possibly the more sandy areas. It is found, as would naturally be the case, that when a condition of continuous capillarity is maintained much smaller applications of irrigation water are necessary in the growth of crops.

Sometimes it is impracticable to subsoil as much as 18 inches deep, but there is always enough water in the river during the annual floods to give all the bottom lands and vast areas besides all the water they need for complete saturation. The soil should be plowed as deeply as possible, left in a loose, porous condition, and then flooded till this hard stratum is dissolved and capillary action set up between the soil and subsoil. When this condition is obtained, a mulch of 2 or 3 inches will render this action continuous and prevent the re-forming of the hardpan.

WATER SUPPLY FOR IRRIGATION.

The normal amount of precipitation in the Garden City area is not large enough to insure good yields of the crops grown in more humid regions. Therefore, for general agriculture to be a success, it is necessary either to supplement the rainfall by irrigation or to introduce crops that can be grown in a semiarid region. While humid years sometimes occur when large yields are secured, and the rainfall is generally sufficient to produce moderate crops of sorghum, Kafir corn, and alfalfa on the bottom lands and wheat upon the uplands, still with the present methods of cultivation the yields are uncertain and practically total failures sometimes occur. The soils in general are very productive, and irrigation and proper cultivation only are necessary to insure large and profitable returns. It is claimed by practical farmers in the area that one or two good irrigations yearly will give a good steady growth of alfalfa and permit from three to five cuttings annually.

A comparatively large utilization of the soil waters is being made

by means of windmills—more particularly with reference to the home garden and lawn. There is, to be sure, a limited acreage of alfalfa and beets irrigated by windmills, but the great cost of providing sufficient power of this character to put large fields under water prevents any considerable extension of this system of irrigation. In the production of all general farm crops advantage should certainly be taken of the flood water of the river. The underground water, of course, comes up clear and adds nothing to the soil in the way of improved texture. Moreover, it soaks rapidly into the sandy soils and where used in small amounts tends to cement the soil particles at from 6 to 12 inches below the surface, thus forming what is locally called hardpan. The use of soil water on gardens and lawns is to be highly recommended in view of the fact that these need water much more frequently than they could possibly receive it from the ditches, but there is no doubt that the flood waters are more beneficial and economical when they can be used.

Several irrigation ditches have been constructed. In 1879 the Garden City Ditch was constructed by the farmers and some of the business men of the town who were interested in irrigation as an experiment. It is now owned by the farmers and has been used more or less ever since its construction. In 1881 what is now the "Farmers' Ditch" was built. It has since been purchased by the farmers, and is now the most serviceable canal in this part of the valley. In 1882 the Great Eastern was dug and has had practically the same history as the Farmers' Ditch. It has only recently been bought by a number of men who are interested in farming and is being put in condition. This canal has excellent farming land under it and should become one of the best, if not the best, canal in the valley. The Amazon was constructed in 1887 by a company at considerable cost and was then bonded for $300,000, thus putting it out of practical use, because in order to secure a fair interest on this sum of money the water rights had to be put so high that the ordinary farmer would not use them. It has since been purchased by the farmers and is now doing good work. While this canal is outside of the area surveyed, if used to its full capacity laterals could be extended into the area and thus afford irrigation to land north of Purcellville. It has a capacity of 400 cubic feet and covers an irrigable area of 8,000 acres.

All of these canals do not appear on the accompanying map, but they all run some distance in Finney County and cover very large tracts of fertile prairie soil. They all have comparatively poor dam sites, and some good work remains to be done along this line. The dams are frequently washed out by the floods, thus throwing the canal out of use for that year.

Many farmers are taking advantage of such opportunity as occurs

to flood their fields. However, there are some who are not taking advantage of this means of greatly increasing the yield of their crops. There is enough water in the river and enough ditch capacity in the valley to give every farm from Sherlock to Mansfield from two to three irrigations yearly.

ALKALI IN SOILS.

The area as a whole is free from harmful amounts of alkali. However, the heavier soils of the lowlands contain sufficient salt to become harmful if extensive flooding of the uplands should be practiced. But since economical irrigation does not permit of seepage water, these lowlands should not only remain out of danger from upland irrigation, but what little salt they do contain should be, and can be, eliminated by cultivation. Out of more than a dozen borings and other tests we failed to find in the worst localities a salt content of more than 0.70, and the average quantity was 0.324 per cent. These borings were taken where the indications of alkali were most pronounced and where it is most likely to be found—that is, on the heavy soils of the lowlands along the river and in the depressions on the uplands. The most important alkali district in the area is found in the depression of the White Woman Valley, east of Garden City. On some of the lower levels of this depression there may be seen a white efflorescence of salt during the dry season. Salt grass covers the depression generally, but the percentage of salt is not large enough to interfere seriously with agriculture. Where the soil is thoroughly cultivated the salt grass and other indications of salt disappear. A great deal of this White Woman Valley in this area is used for pasture, and when the salt grass is young it makes a good sweet forage plant. The remainder of the valley is sown to sorghum, macaroni wheat, etc. These both do well and are not injured by the quantity of salt found in the soil there. As stated above, other places in the area have some alkali, but not of sufficient concentration to injure crops in a noticeable degree, except in occasional local spots. The part of the area where the accumulation of alkali is most likely to occur is that part which lies immediately under the low bluff line between Sherlock and the Point of Rocks, on the north side of the river. There is not a serious amount of alkali here yet, but irrigation will have to be carefully and economically practiced in order to keep the salt in the lower and heavier strata of soil where it is at present. There is not very much of this strip, and it can be, and should be, controlled by methods of cultivation which tend to lessen the total amount of evaporation from the surface of the soil. For the management of this strip of heavy soil deep cultivation, flooding with the annual flood waters (not with the underflow water), and subsequent

mulching to about 3 inches to prevent evaporation is recommended. Probably the best crops to be grown on this soil are sorghum and sugar beets, both of which tend to rid land of small amounts of alkali.

There is a small amount of alkali in the immediate river bottom in the Laurel loam. The average content is very low, however, and there does not seem to be any reason to expect serious trouble here.

AGRICULTURAL METHODS.

While many of the farmers in the Garden City area have the latest improved machinery and pursue modern methods of agriculture, there are others whose methods of soil management are not suited to the conditions which obtain in this semiarid region. There has been much improvement in agricultural practices within the last few years, but there is still need of further development. Too many farmers are inclined to plant their crops without the proper preparation of the seed bed, and too few use the best methods of handling the soil after the crops have been planted and become large enough to need cultivation.

The moisture supply is one of the most important factors in determining the yield of crops. In an area where the precipitation is not large enough to supply a sufficiency of moisture for the best development of general farm crops and where it is so irregular in distribution and so often in the form of torrential downpours, great care should be taken to make the best possible use of it. The aim of the farmer should be to get as much as possible of the rain water into the soil and then to keep it there until it can be used by the crops. The agricultural methods practiced by a majority of the farmers fall far short of securing these results, and therefore the yields and the profits are not as large as they should be.

The records of the Weather Bureau show that the greater part of the precipitation falls during the months of May, June, July, and August. One of the general characteristics of the rainfall in the region of the Great Plains is that a large part of it falls as heavy showers, and unless the ground is plowed deeply and put in condition so that the rains can readily penetrate the soil the water runs off and the crops do not receive as much benefit as they might. Greater attention should be given by the farmers to the proper preparation of the soil by deep plowing, in order to prevent as much as possible the loss of moisture by the running off of the water. This is especially necessary upon the heavier types of soil, like the Laurel loam, Marshall silt loam, and Colorado adobe. The Laurel sandy loam is more open and porous and admits water more freely, but the moisture conditions of this type can also be improved by this method of treatment.

The good which will result from getting the rains to enter the soil will be largely lost, however, unless the moisture is kept there by maintaining a good surface mulch. The farmers in the area do not generally recognize the importance of this conservation of moisture, and consequently their methods are not adapted as well to it as they should be. The more progressive farmers of the area are beginning to practice what is popularly known as the Campbell system of soil culture. This system is simply and only a practical application of well-known natural laws and agricultural principles.

The farmers following the Campbell system endeavor to achieve two results, namely, first to get the moisture in the ground, and then to keep it there till the plant is ready to use it. This is done in the semiarid West by deep plowing, and even subsoiling, followed by subsurface packing and shallow cultivation and mulching. First make a good, deep, loose-soil reservoir, then when a good rain or snow comes it will tend to fill up the reservoir. As soon as the surface is dry enough disk it, pack it, and mulch it. All subsequent rains can easily and quickly penetrate the soil when it is moist just below the surface. The Campbell system is highly recommended to the farmers in this area.

Until recently few cultivated crops have been grown. Sorghum, corn, and Kafir corn have been raised for some time, but with the exception of corn these were put in with the drill and little or no cultivation followed. The lister has now been introduced and these crops are now usually put in with this implement. The use of the lister is to be recommended for such crops in this area. What cultivated crops are produced, such as sugar beets, potatoes, and vegetables, are grown with the ordinary methods of cultivation.

Some of the farmers take as many as ten or more crops of sorghum from the same field in succession. These farmers would treat other annuals in the same manner, but this practice is to be discouraged. The best farmers in the valley are beginning to see the detrimental effect of such a system and are changing their methods. There is now being introduced a yearly rotation among the annuals, with a noticeably beneficial effect.

Sorghum is now followed by oats, rye, or barley, and beets by sorghum. It is highly probable that the introduction of cowpeas into the rotation would be quite beneficial in adding humus and nitrogen to the soil.

An important question in this area is what rotations and diversification can be introduced in order that the farmers may be mutually helpful when their crops are to be harvested. This question has been partly solved by the recent introduction of the sugar beet and macaroni wheat industries, but these crops do not fully solve the problem.

One difficulty in the solution of the problem is found in the fact that when one man makes a success growing a certain crop, as alfalfa, for example, every other man, without regard to the natural adaptability of his soil to the crop under consideration, begins to seed his fields to alfalfa when he should seed them to wheat or beets or some crop that would not need all of his attention when the hay crop is being harvested. Consequently, when all have some alfalfa growing, some of the hay crop must be neglected and many times lost for lack of help to harvest it.

Farmers in the river valley largely use windmills for irrigating sugar beets, potatoes, strawberries, and garden vegetables. Windmill irrigation is highly recommended for intensive farming, but it is impracticable when applied to general field crops. More extensive irrigation of field crops by means of the annual flood water in the Arkansas River can not be too strongly urged. One or two good floodings in the spring, followed each time by thorough mulching to conserve the moisture, would insure good crops each year, whereas the yields on these farms are always uncertain and in many seasons complete failures. Happily for this part of the country, the importance of irrigation is becoming more and more recognized each year, and better and more certain crops are the result.

Some farmers sow alfalfa on the hard unbroken ground, putting it in less than 2 inches deep sometimes. This practice should be discouraged since many of the seeds fail to germinate and a poor stand results. A good seed bed should always be prepared and this thoroughly saturated some time before the seed is sown. The following method of seeding alfalfa can hardly fail to produce a good stand. Plow the ground deeply in the fall and let it lie loose and open during the winter in order to catch and conserve the winter precipitation. If at any time during the winter this soil reservoir is saturated, or nearly so, the surface should at once have a 3-inch mulch formed over it and maintained until time to sow the seed in the spring. When the soil is once moistened there will be little danger of the subsequent rains running off the surface, but they will sink into the the soil readily, so soon as the thin mulch has been penetrated, and will add greatly to the existing amount of moisture previously stored in the soil. This mulch should be renewed as often as an examination shows the subsurface soil to be getting dry. By keeping the soil moist all winter it will be in prime condition to receive the seed in the spring; the spring rains will penetrate the soil immediately; the soil will show moisture at 3 or 4 feet instead of from 1 to 1½ below the surface, and a good stand of alfalfa can hardly fail to be obtained. The amount of moisture that would be conserved by this method would sustain the young plants for a long time and keep them in a

thrifty condition. Then, when the annual floods came down, the field should have the benefit of thorough irrigation. Thus sufficient water would be put into the soil to send the plant roots 10 or 15 feet deep and, in the lowlands, this is sufficient to reach the water table.

AGRICULTURAL CONDITIONS.

General agriculture in the Garden City area is practically confined to the river bottoms. North of Garden City some farming is done upon the uplands, and an occasional field of sorghum or Kafir corn may be seen in some other sections, but the uplands generally are devoted entirely to grazing. A few ranch houses are practically the only dwellings in this part of the area. The uplands are too dry to produce general crops, except in seasons of abnormal rainfall. The introduction of crops better suited to the semiarid region should induce an extension of agriculture upon the uplands.

As practically all of the farmers in the area live upon and cultivate the bottom lands the discussion of agricultural conditions must be practically confined to this part of the area. The majority of the farmers are in a fairly prosperous condition. In humid seasons large crops are secured for which good prices are received. In these years nearly all of the farmers have ready cash. When dry years occur those who do not have their farms under irrigation sometimes find that they have not been able to pay expenses. As the supply of water in the river is rather irregular and uncertain even those who irrigate can not always obtain water at the time when most needed by the crop.

The size of the farms in the valley averages about 160 acres. These farms are nearly all under the ditch, but many of them have no water rights, although rights may be easily obtained should the owners desire to do so. Most of these farms are owned by the men who operate them. There are some large ranches operated by salaried managers, but these are not usually in the river bottom.

The labor question is sometimes quite serious. The farmers complain that when their hay is ready to harvest the wheat crop in that part of the State east of them is also ready for harvest and all the farm hands go away to the wheat fields. It is therefore often very difficult to obtain labor at that critical period. The beet industry is not yet sufficiently well developed to justify the importation of Mexican labor. When this industry has become well established, as it is believed it will in a few years, there should be less difficulty in obtaining labor.

The principal products are alfalfa, sorghum, Kafir corn, spelt, wheat, oats, garden vegetables, fruits, and cattle. Of these the forage crops and cattle are of the most importance. Alfalfa is grown very extensively in the valley. Most of the forage is consumed at

home, but some is shipped to distant markets. Within the last three years macaroni wheat and sugar beets have been introduced, and promise a bright future for the farmers of the valley. The indications are that macaroni wheat will give the best returns on the Marshall silt loam. The adaptation of soils to other crops is receiving more and more attention each year. It is now recognized that, with equal attention, the greatest tonnage of beets can be secured from the Laurel loam, and this soil also produces the best alfalfa. The uplands have long been recognized as excellent wheat lands, if only enough water could be obtained. Such fruits as cherries, strawberries, and plums do well, but the apple crop is said to be uncertain. A good growth of tree can be had, but the fruit generally fails to mature. It is believed that cantaloupes could be grown with success.

Good transportation facilities are furnished the people of this area by the Atchison, Topeka and Santa Fe Railway. The people are within a few hours of Kansas City, Topeka, St. Joseph, Pueblo, and Denver. These markets can readily handle, and at fair prices, all the strawberries, plums, cherries, peaches, potatoes, etc., that the people of this area have to sell. It costs no more to ship beets from Garden City to Rockyford than it would were the producers living and raising beets within a mile of the factory. This is a great inducement, offered by the factory people to the farmers of the valley.

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