SOIL SURVEY OF THE GREELEY AREA, COLORADO.

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LOCATION AND BOUNDARIES OF THE AREA.

The Greeley area occupies that part of the Great Plains lying immediately east of the Rocky Mountains in the north-central part of Colorado. Almost all of the area lies to the west of the eighth guide meridian west. The area is irregular in outline, the greatest width north and south being 27 miles and the greatest length east and west about 35 miles. It is bounded on the south by a line running east and west 2 miles north of the first correction line north and on the west by the foothills of the Rocky Mountains. The survey embraces all of the territory originally forming the Greeley

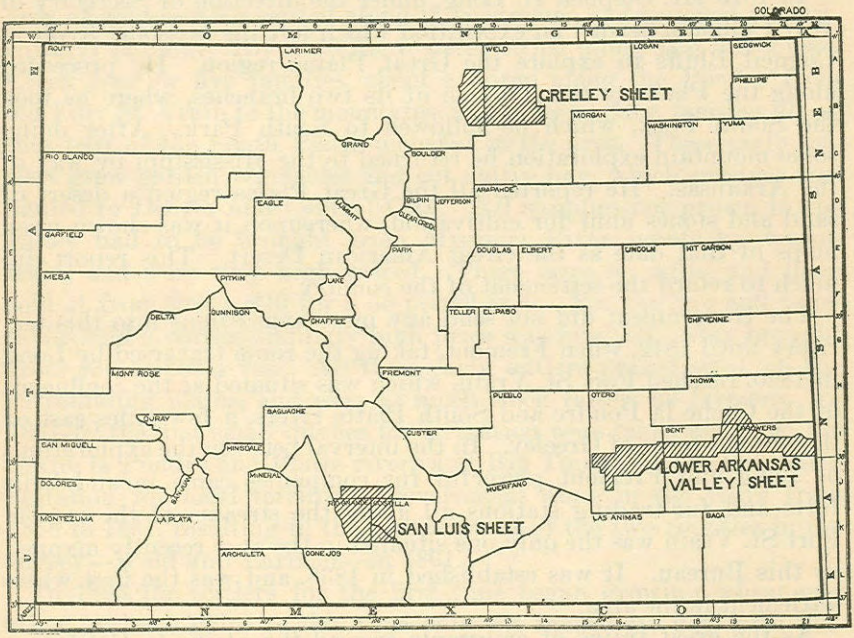

FIG. 40.—Sketch map showing location of the Greeley area, Colorado.

Colony tract and includes parts of Weld and Larimer counties.

The total area covered by the survey is 439,744 acres, or approximately 687 square miles. Most of this territory is under irrigation. Greeley, Fort Collins, and Loveland are the principal towns in the area.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

For many years after the eastern and western coasts were fairly well known and forts and trading posts dotted the great inland waterways of our country, the Great Plains and Rocky Mountain region were as a sealed book. This great semiarid plains region to the west of the Missouri River had no navigable waterways, and no one had the temerity to brave the dangers of an overland expedition. With the return of the Lewis and Clark expedition came Chief Big White of the Mandan Indians. After listening to his stories Ezekiel Williams organized a party of 20 men, who proceeded from St. Louis to Old Fort Mandan, expecting to cross on a trapping trip from this point overland to the Pacific coast. After a great many misfortunes three of this party reached the Rockies along the South Platte in the year 1808. One reached the Arkansas and floated down in a canoe, finally reaching American settlements; the other two crossed the Rockies to southern California. So far as history records, these were the first white men to visit this region.

In 1819 Mr. Stephen H. Long, under the direction of Secretary of War Calhoun, headed an expedition which left the Missouri River at Council Bluffs to explore the Great Plains region. He proceeded along the Platte to the junction of its two branches, where he took the South Fork, which he followed to South Park. After doing some mountain exploration he returned to the Mississippi by way of the Arkansas. He reported all the Great Plains region a desert of sand and stones unfit for cultivation, whereupon it was shown upon maps of that date as the Great American Desert. This report did much to retard the settlement of the country.

The Government did not send any more expeditions into this territory until 1842, when Fremont, taking the route traversed by Long in 1820, reached Fort St. Vrain, which was situated at the confluence of the Cache la Poudre and South Platte rivers, a few miles east of the present town of Greeley. In the interval between the explorations of Long and Fremont powerful fur companies came in and built forts and fur-trading stations all along the streams of the region. Fort St. Vrain was the only one situated in the area recently mapped by this Bureau. It was established in 1838, and was the first white settlement in the area.

As the great trains of emigrants crossed the plains to California in 1849 and later, a few of the gold seekers were diverted to prospect the eastern front of the Rockies by rumors of gold found there. These all remained near defensive establishments and accomplished but little.

In 1856 Mariano Modena, a Mexican, built a small fort on Big Thompson Creek, 4 miles above the present town of Loveland. Here

he had a trading post and raised a few garden vegetables, which were the first artificial products of the area. Later, when the stage line was established between Denver and Old Fort Laramie, his fort was one of the stations. Hay for the horses was cut from natural grasses along Big Thompson Creek, and grain was grown in a limited way for the same purpose.

In the late fifties a few small gold finds were made along tributaries of the Platte. Rumors of these discoveries and the publication of the diary of one of the explorers in 1858, under the title of Pike's Peak Guide and Journal, caused a great caravan of gold seekers and other adventurers to cross the plains in 1859 and the early sixties. Many of these failed to find gold. Many were farmers from the States. Prices for all provisions and feed were enormously high. The valleys of the Poudre and Platte rivers and Big Thompson Creek were low, moist, and produced much natural hay without irrigation. The presence of Government troops at many forts in the plains region had minimized danger from Indian raids, so that those who preferred the sure returns of farming and stock raising to the hazards of gold seeking settled along these streams and engaged in agricultural pursuits. By 1860 there were settled along Big Thompson Creek four or five families, about a dozen along the Poudre from old Fort St. Vrain to the mountains, and three or four families along that part of the South Platte included in the area. These early settlers grew garden vegetables and cut native hay, which produce was hauled to Denver and Central City. All supplies not grown in the valley had to be brought from Missouri River points by wagon train, and were very high priced. There were no mills, and flour sold at from $20 to $40 for a 50-pound sack. For the hay and vegetables sold a correspondingly high price was received. Hay brought from $30 to $90 a ton. All these early settlers grazed stock on the surrounding plains, and were as much stock raisers as farmers. In 1861–62 the first small ditches for irrigation were taken out from the Cache la Poudre and Platte rivers and Big Thompson Creek. Much agitation for local territorial government came in the years from 1858 to 1861, resulting in the organization of the two counties in the survey—Weld and Larimer—in 1861.

In 1865 the settlers for the first time began growing wheat and other grains. Prior to this time only the immediate flat, level bottoms along the streams had been irrigated, but in this year a small cooperative ditch on Big Thompson Creek watered several hundred acres of the high lands.

As late as 1868 frequent Indian scares greatly agitated the settlers and retarded further extension of farms, but no massacres ever took place. In 1861 troops were sent to La Port, the first town on the Cache la Poudre, to protect settlers along that stream. Two years

later they were sent to the present site of Fort Collins, where they were stationed for some years.

In the early years of farming many trials were undergone by the settlers. In addition to Indian scares the grasshopper plague threatened to drive them out. All the farms were in the small valleys, which were subject to floods. During 1864 one of the most general Indian scares occurred, nearly all the settlers leaving their farms for the protection of neighboring settlements. Floods destroyed their fences and other permanent improvements, and the few crops on high places were completely destroyed by the grasshoppers.

The first wheat was hauled to Golden to mill. Later a mill was built at Boulder, and in 1866 mills were built south of the present site of Loveland, on Big Thompson Creek, at what was then Thompson. These mills gave a great impetus to wheat growing, as the surrounding region furnished a ready market for all mill products.

From 1865 to 1870 many small individual and cooperative ditches were taken out along the streams to irrigate, principally, the bottom lands. About 1865 potato growing began in a commercial way. These early crops were marketed principally at Fort Laramie, Denver, Black Hawk, and Central City.

In the later sixties many eyes were turned to the great semiarid West. The success of the Mormons in Utah and the early Mexican irrigators along small streams in the Southwest had suggested the advantages of irrigation farming. The presence of mining camps in the mountains afforded a ready market and tempted many to come to these new regions.

The greatest impetus agriculture had in this region, however, came not so much from a desire for gain as from a desire to fulfill the socialistic and economic ideals of cooperation enthusiasts. In 1869 Mr. N. C. Meeker, who had had experience in cooperation experiments, and who had written quite a little for the metropolitan newspapers, came to the notice of Mr. Horace Greeley, then editor of the New York Tribune. Mr. Meeker was engaged to make a tour through Kansas and Colorado to Utah, at which point he was to investigate particularly the cooperative features of the Mormon settlements. Heavy snows on the Union Pacific Railroad prevented him from reaching Utah, but he returned to New York imbued with the thought that the large, practically unsettled regions of the semiarid West presented peculiar features that would make possible the fulfillment of his ideals of cooperative settlements. Horace Greeley heartily sanctioned the scheme. A call was issued in the Tribune for members to join a projected colony whose location was not yet decided. All classes of sober, temperate citizens were called upon to respond. The result was the formation in New York of the Greeley Colony organization. A location committee sent to Colorado, Utah, and

Wyoming to select a site decided upon the present site of Greeley, along the Cache la Poudre, and in the spring of 1870 the first colonists arrived. Because of the cooperative features, the interest taken in the colony by Mr. Greeley, and the consequent wide publicity given the undertaking in his paper, the colony became widely advertised. Next to the work of the Mormons it proposed the most extensive irrigation works in the United States. Attention was attracted in every part of the United States, which led to the quite rapid settlement and development of the lands adjoining those of the colony.

The Union Pacific Railroad having been completed in 1868, a branch line, the Denver Pacific, was projected and almost immediately built from Denver to Cheyenne, bringing railroad transportation directly to this area. Old canals were enlarged and new ones, planned to cover practically all the territory now farmed, were soon afterwards constructed.

Like so many other cooperative and colonistic schemes, Greeley Colony as such soon disbanded, and all lands and other holdings passed into private hands. The canals formed an exception, being still administered cooperatively.

Before the disbandment of the colony, however, a number of other settlements or colonies patterned after Greeley were established along the Cache la Poudre and the Platte. Chief among these was what is now the town of Fort Collins. In 1872 this was a small insignificant settlement. Several of the early colonists at Greeley conceived the idea of making of it a colony similar to Greeley. It was called Agricultural Colony, but, as in the case of the Greeley Colony, the organization soon disbanded.

In 1882, when a railroad had connected Greeley and Fort Collins, the intermediate town of New Windsor was founded. The Larimer and Weld canal having been extended to take in lands along the Denver Pacific, the town of Eaton, 8 miles north of Greeley, was started. In 1875 the present town of Loveland was established, and in that year a mill and a grain elevator were put into operation. Other mills quickly followed at Greeley, Fort Collins, Eaton, and New Windsor.

Up to about 1890 wheat, oats, barley, potatoes, and garden vegetables were the principal cultivated crops grown throughout the entire area. Native hay was cut extensively along the bottom lands. During these years of poor rotation the productivity of the lands, despite great quantities of manure that were added, became greatly reduced. Some resorted to stock raising, principally for the benefits accruing to the land from the use of manure. In the later eighties a few began the growing of alfalfa. Its use as a beneficial crop in the rotation was little understood. Because of imagined difficulties of getting rid of the crop its introduction met with great resistance, but a few successes soon demonstrated that it could be easily handled as a rotation

crop and quickly led to its universal use, until at present it is one of the most important crops grown. It has not only paid in the hay produced, but has resulted in the restoration of the productiveness of the soils to such a degree that as large yields of wheat and potatoes are now produced as in the early seventies from the virgin soils. The introduction of alfalfa marks the greatest epoch in agriculture the valley has yet seen.

Experience having demonstrated that sugar beets were suited to the region, a factory was built at Loveland in 1900. To secure this the citizens gave a bonus of $10,000 and 1,500 acres of land. The introduction of sugar-beet growing resulted in the utilization of much of the lands that had become slightly alkaline, and their culture has proved very remunerative. Quickly following the factory at Loveland others were built at Fort Collins, Greeley, New Windsor, and Eaton. These factories have meant much to the country, and have introduced a new crop into the rotation. Their installment marks another epoch in the history of the agriculture of the region.

As the country has developed and greater shipping facilities have become necessary, some small villages have been built up at the various switches and sidings. Lucerne, Ault, and Timnath are chief among these. Lucerne is about halfway between Greeley and Eaton; Ault 4 miles northwest of Eaton, and Timnath about midway between New Windsor and Fort Collins.

In 1902 a branch line railroad was extended from Fort Collins along Boxelder Creek to afford an outlet for the beets grown in that valley. Since that time the small village of Wellington has sprung up at its terminus.

The old towns of Bellevue and Laporte, along the upper Cache la Poudre, have never grown beyond country post-offices.

For a great many years Evans, in the southern part of the area on the Denver Pacific Railroad, rivaled Greeley, but in recent years it has had little growth, and remains practically the same in population as twenty years ago, a mere village of three or four dozen families.

CLIMATE.

The climate of the Greeley area is semiarid. The moisture-laden winds coming in from the west lose most of their humidity in passing over the mountains lying to the west, and this is the cause of the light precipitation in the area.

The source of most of the rainfall of the area is in the east winds. As they reach the mountains and rise to pass over them their moisture is condensed and precipitated, the greater amount falling nearer the mountains. This fact is brought out by a comparison of the amount of rainfall at Greeley and at Fort Collins, the annual pre-

cipitation at the latter place being about 3 inches more than at the former.

According to the records of the Weather Bureau taken at Fort Collins and Greeley, the normal precipitation is 14.68 and 11.92 inches, respectively. At Fort Collins the period of heaviest rainfall occurs during the months from April to September, inclusive, the normal for the six months being 1.81 inches. During April and May the heaviest precipitation of the season occurs, the normal for April being 2.13 and for May 2.90 inches.

At Greeley the rainy season occurs during the months from April to July, inclusive, the monthly average in this case being 1.77 inches. The rainfall during the summer months is insufficient to mature the crops, so that irrigation is practiced generally throughout the growing season.

Severe hailstorms are a very destructive feature of the climate of this locality. They are generally accompanied by high winds. During the season of 1904 the authors observed a severe storm of this character. It occurred early in July and covered a strip of territory about 1 mile wide, crossing the area in a northeasterly and southwesterly direction, touching the town of Greeley. The crops over which this storm passed were all severely damaged. The grain crops were completely destroyed, but the potatoes and beets partially recovered from the effects of the storm and fair yields were secured. These storms are a great drawback to the agriculture of the area, for hardly a season passes without a storm of this character. They are likely to occur at any time during the growing season, and at any place. They are not as a rule general, but usually cover a strip of territory varying from 1 to 4 miles in width.

The prevailing winds are generally from the northwest, and during the fall months they frequently become quite severe, often developing into dust storms, which usually last two or three days.

December, January, and February are the coldest months of the year, the normal temperature being 29.3° F., 26° F., and 26.2° F., respectively, at Fort Collins, and 27.5° F., 25.1° F., and 26.8° F. at Greeley. The warmest period of the year occurs during June, July, and August, the average normal temperature for the period being 67° F. at Fort Collins and 69.4°F. at Greeley. The average normal yearly temperature for the two stations is 47.4° F.

The growing season lasts about five months. The average date of the last killing frost in the spring is May 6 at Fort Collins and April 30 at Greeley. The average dates of the first killing frost in fall at the points named are September 23 and September 25, respectively.

The following table gives the normal monthly and annual tempera-

ture and precipitation as compiled from Weather Bureau records taken at Fort Collins and Greeley:

Normal monthly and annual temperature and precipitation.

Month.	Fort Collins.		Greeley.		Month.	Fort Collins.		Greeley.	
	Temperature.	Precipitation.	Temperature.	Precipitation.		Temperature.	Precipitation.	Temperature.	Precipitation.
	° F.	Inches.	° F.	Inches.		° F.	Inches.	° F.	Inches.
January	26.0	0.57	25.1	0.26	August	67.8	1.18	70.1	0.98
February	26.2	.57	26.8	.44	September	59.6	1.21	61.0	.88
March	35.7	.94	36.2	.63	October	48.2	.95	49.4	.76
April	45.8	2.13	47.7	1.83	November	35.2	.41	36.0	.57
May	55.3	2.90	57.3	2.19	December	29.3	.37	27.5	.32
June	64.4	1.59	67.1	1.36	Year	46.9	14.68	47.9	11.92
July	69.0	1.86	71.1	1.70					

In general, however, the climate of this section of Colorado is very agreeable and healthful throughout the year. One of the characteristic features is the prevalence of sunshine. A few cloudy days occur, but usually not over three days in succession during the growing season. The summers are mild and pleasant, extremely hot days being of rare occurrence. The winters, though the temperature often falls several degrees below zero, are not severe. The dryness of the atmosphere, together with the prevalence of sunshine, prevents the extremely low temperatures from being felt as they would be in more humid sections. During both the summer and winter months the climate is invigorating, and especially helpful to those suffering from pulmonary complaints.

PHYSIOGRAPHY AND GEOLOGY.

With reference to its physiographic features the Greeley area falls naturally into two distinct divisions—the river valleys proper and the uplands. The surface features of the uplands in general consist of rolling and undulating prairies, with occasional low hills and ridges. The slope of these hills and ridges is, as a rule, not so excessive but that with proper management they can for the most part be profitably cultivated. The general slope of the area is to the southeast, the elevation ranging from 5,000 feet in the eastern portion of the area to about 5,500 or 6,000 feet above sea level near the western boundary. The hills which mark the western boundary rise abruptly out of the plains, and attain an elevation of from 8,000 to 9,000 feet above sea level.

Since the formation of the plains in this part of Colorado, erosion has been rapidly at work in the degradation and removal of the original material, resulting in the formation of well-rounded hills

and low ridges, bluffs, and terrace lines, small valleys, and occasional deep arroyos. The soils of the area are generally quite deep, but occasional rock outcrops are seen along the bluffs and terrace lines.

North of the Larimer County Canal the surface is extremely rolling and undulating. This territory is above the irrigable districts, and is for the most part covered with the native grasses of the plains. South of this canal and extending to the bottom lands of the Cache la Poudre River the surface assumes a more level appearance, still maintaining, however, its undulating character, and interrupted by occasional small hills and ridges.

The many small streams, which are usually of intermittent character, and which traverse this portion of the area in a southerly direction, have formed small valleys 30 to 50 feet lower than the surrounding country and from one-sixteenth to one-fourth of a mile in width. As the streams approach the river their valleys usually become wider and shallower, sloping gently to the hills on each side. In the eastern part of the area, bordering the valleys of Owl and Lone Tree creeks, the surface is comparatively level, with occasional low hills and ridges. The valley floors of these streams slope gradually toward the stream beds, and are cut by numerous old stream channels, sloughs, and swampy areas. East of the valley of Owl Creek the surface again assumes a rolling and undulating appearance.

The boundary between the uplands and the Cache la Poudre Valley proper is marked north of the river in places by steep bluff lines, while in other places a more gradual slope prevails with low, minor ridges or terrace lines, each terrace representing the boundary of a former flood plain. South of the Cache la Poudre River the surface features are very similar to those north of this stream. In general, this part of the area represents a broad ridge between the Cache la Poudre and Big Thompson Creek. The surface of this broad ridge consists of rolling, and in some instances extremely undulating uplands with a general fall to the southeast. The terrace line marking the boundary between this part of the uplands and the river bottoms is very irregular. In some instances it is marked by steep bluffs, but in others the slope is gradual and cut by numerous small washes or gullies. In most cases the rise is quite abrupt, the elevation varying from 25 to 50 feet above the level of the river. The greater proportion of the drainage waters of this territory runs into the Cache la Poudre River, only a small amount reaching Big Thompson Creek.

The surface of the uplands is dotted by numerous natural and artificial lakes and local depressions or drainage basins. In the northwestern part of the area some of these lakes are connected in chains or groups, forming excellent storage reservoirs, for which they are mainly used. A number of these lakes and drainage basins are of an

intermittent character, containing water only during the rainy season. As the western boundary of the area is approached, and especially along the base of the foothills, the surface becomes extremely undulating, presenting hills, ridges, and valleys prominently developed. The ridges have been given the local appellation of "hogbacks." The most prominent ridge occurs near the western edge of the area, north of the Cache la Poudre River. Between this ridge and the mountains is a comparatively level valley which has been formed by a small mountain stream. This ridge generally slopes gently to the east, while its western edge inclines at a very high angle, and in some cases is nearly vertical.

The sedimentary hills and ridges occurring along the base of the mountains south of the river have been cut through, generally at right angles to the trend of the strata, by numerous small streams that flow down from the mountains. These have formed small, shallow valleys, and in some instances rather deep arroyos. The streams are intermittent, being dry the greater part of the year. Where Big Thompson Creek and the Cache la Poudre River emerge into the plains great notches have been cut in the eastern front of the mountains.

The principal valley of the area occurs along the Cache la Poudre River. It varies from one-half to more than 1 mile in width, and is from 75 to 100 feet lower than the adjacent uplands. Along parts of the valley the sides are rather steep and sometimes precipitous bluffs, while in other places they are formed by more gentle slopes. The character of the surface of the valley formed by Big Thompson Creek is similar to that just described. The valley of the South Platte River, in the southeastern part of the area, is much wider than either of those just mentioned, and is bounded, as a rule, by more prominent bluffs.

The surface of these valleys is comparatively level, with a gradual fall from the margins toward the stream beds. The bottoms are subject to annual overflow, and are cut by old stream channels, sloughs, and swampy areas. A few low hillocks and ridges, seldom exceeding an elevation of 3 or 4 feet, occur in different parts of the bottom lands.

All of the lines of drainage of the area lead to the South Platte River. The principal stream is the Cache la Poudre River, which traverses the area in a southeasterly direction and empties into the South Platte about 5 miles east of Greeley. It receives the greater proportion of the drainage waters of the area from the numerous minor streams which flow into it both from the north and the south. These streams flow through small valleys and are fed mainly by seepage from the soils. As already stated, the channels of many of the small streams are dry the greater part of the year, containing water only after con-

tinued wet periods. During the wet season there is generally a very strong flow of water, and the surface drained by these streams often suffers greatly from the effects of erosion.

Big Thompson Creek receives the drainage waters of the southwestern corner of the area. It traverses the area for only a comparatively short distance, and receives only a small portion of the drainage waters. The South Platte River, which crosses the southeastern portion of the sheet, enters the area about 1 mile east of Evans, flows in a northeasterly direction to its confluence with the Cache la Poudre, and thence southeast, passing out of the area about 1 mile north of the southeast corner of the area. It receives all of the drainage waters of the area.

The geological formations of the area are comparatively simple and easily understood. With the exception of a small strip of territory bordering the western edge of the area, the underlying rock formations consist chiefly of alternating beds of sandstone, limestone, and shale, classified by Hayden as rocks of the Cretaceous and post-Cretaceous periods. These were laid down one after the other in the bottom of a vast ocean that once covered this region. These beds vary considerably in thickness, and lie in nearly horizontal strata, inclining slightly to the east at about the same slope as the plains.

Underlying the Cretaceous rocks are found those of the Jura-Triassic, which consist chiefly of a series of arenaceous beds, called by Hayden the red arenaceous deposits or Triassic. The deposits are exposed along the western edge of the sheet, and form one of the most conspicuous features of the geology of the area. They contain both salt and gypsum, the latter mineral often in great quantities, and are sometimes referred to as saliferous or gypsum-bearing beds. Mixed with these beds are several layers of bluish siliceous limestone, which in the northern part of the area are generally quite thick, but gradually thin out to the southward or are covered over by débris. These limestone strata are most prominent in the formation of the Colorado gravelly loam, although some of the rocks of the older formation to the westward have contributed to a certain extent to the origin of this soil.

The rocks of the Cretaceous period are classed under three groups. The Dakota group, which is the lowest of the series, occurs as a long, narrow strip, exposed in the western part of the area. It rests directly upon the Jurassic beds, and partakes of about the same stratigraphical features, but owing to the hardness of the strata forms more persistent "hogback" ridges than any other formation. This group consists of clean, gritty, even-grained sandstones, varying from a siliceous conglomerate to a hard quartzite. Beds of argillaceous shales, often containing carbonized vegetable matter, alternate

with the layers of sandstone. The color of the rocks of this group varies from a light gray or white to a rusty yellow, and occasionally to a red in the softer parts.

The Fort Benton group rests upon the upper members of the Dakota. This group consists of arenaceous clays with three layers of argillaceous sandstone, passing into highly laminated black or gray shales. The whole group is quite homogeneous in character, and often attains a thickness of from 200 to 600 feet.

The Niobrara group lies above the Fort Benton group. The lower members are a series of limestone and calcareous shales, while the upper part is composed mainly of dark-gray shales, often arenaceous, and containing many layers of sandstone with some concretions.

Overlying this group and marking the close of the Cretaceous period is the Fox Hills group. It is composed of dark, soft shales, which are followed by a whitish sandstone. This is in turn covered by a succession of gray to yellowish-brown shales, alternating with a series of similarly colored sandstones. This group occupies a comparatively wide strip of territory east of Fort Collins, and is particularly prominent in the origin of the soils of the uplands northeast of Loveland.

Covering a little more than the eastern half of the sheet and lying above the Cretaceous formations is the post-Cretaceous. It is described by Hayden as the transitional layer between the marine beds of the Cretaceous and the fresh-water deposits of the Tertiary. It is composed mainly of ordinary indurated sandstones, together with beds of carbonaceous shale and coal. This formation, designated by geologists as the Laramie group, is regarded as the coal-bearing series proper of the Rocky Mountains. In the northeastern part of the area a few small coal mines have been opened, but the coal produced is not considered valuable for general purposes. It is used largely by the pumping plants, and the quality is considered good enough for this purpose. The coal produced is sold for about $2.50 a ton at the mines. The mines are owned by individuals and are not as yet extensively developed.

The soils of the bottoms belong to the recent Alluvium of the Quaternary. The areas are not extensive, being seldom over 1 mile in width along Big Thompson Creek and the Cache la Poudre and South Platte rivers.

SOILS.

The soils of the Greeley area divide themselves naturally, according to the two main physiographic features, into upland types and river bottom types.

The upland soils are for the most part of residual origin, having been formed by the disintegration of the rocks upon which they rest.

Only one type of the upland soils is strictly of colluvial origin—that bordering the foot slopes of the Rocky Mountains. The upland soils, as a rule, show no general stratification. The mineral constituents of these types are very similar in character to those of the parent rock, and in some instances, especially in the fine sandy loam type, the soil extends to bed rock without marked variation in texture or structure.

The river-bottom types are true alluvial soils. The mineral particles and rock fragments composing these types are, as a rule, more varied in character than those of the colluvial and residual soils of the uplands, and the soils in general show partial stratification.

In the area represented on the map accompanying this report not only are colluvial, residual, and alluvial soils represented, but a number of varieties of each, classified according to their textural differences, physiographic positions, and relative crop values.

The soils of the area, as a rule, are very productive, and with the exception of the lighter and coarser areas, possess marked moisture-retaining properties, which greatly increase their agricultural value.

The following table shows the area of each of the types recognized and the proportion each forms of the total area surveyed:

Areas of different soils.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Colorado fine sandy loam	196,480	44.8	Fort Collins loam	14,144	3.2
Colorado loam	78,784	17.9	Billings clay loam	12,800	2.9
Billings loam	41,984	9.6	Colorado adobe	5,632	1.2
Laurel sandy loam	33,792	7.7	Billings silt loam	4,032	.9
Colorado gravelly loam	33,408	7.6	Total	439,744	
Colorado sand	18,688	4.2			

LAUREL SANDY LOAM.

The Laurel sandy loam is an alluvial soil ranging in depth from 2 to 5 feet. The texture of this type is subject to considerable variation, depending largely upon the position occupied. It consists of two phases—a sandy phase and a loam phase—the latter not occurring in areas large enough to warrant classification as a separate type.

The lighter phase, which forms the greater area of this soil, varies from a coarse sandy loam to a fine micaceous sandy loam, each variation existing in such small areas and so interbedded that it was impossible to outline them separately. The soil generally becomes more sandy with depth, passing gradually into coarse sand and water-worn gravel. In some instances, however, it grades into a stratum of heavy, black, tenacious clay loam, a few inches in thickness, which is underlain by sand and gravel.

The heavier phase consists of a loam to a depth of about 3 feet. It occurs only in small areas or local patches occupying depressions which represent old sloughs and former stream channels. The line of demarcation between the soil and subsoil is often very sharp, the transition from loam to coarse sand and gravel taking place within 2 or 3 inches.

Organic matter is present in large quantities in the soil and imparts to it its characteristic dark-brown or black color.

Small sand and gravel patches occur scattered over this type in the form of low ridges or hummocks. Near these ridges and bordering the streams gravel is found in varying amounts, scattered over the surface and through the soil. The subsoil consists of coarse sand, which grades into coarser sand and waterworn gravel at lower depths. The color, as in the soil, varies from light to dark gray, depending upon the amount of organic matter present.

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

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.*
12080	Cen. W. side sec. 34, T. 8 N., R. 69 W.	Black fine sandy loam, 0 to 36 inches.	1.5	5.1	3.5	29.3	26.7	27.5	6.2
12079	½ mile NW. of SE. cor. sec. 24, T. 5 N., R. 69 W.	Black fine sandy loam, 0 to 36 inches.	.6	5.7	7.4	28.7	22.8	26.3	8.3

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 12079, 1.87 per cent; No. 12080, 1.2 per cent.

The main bodies of this soil occupy the valley floor proper of Thompson Creek and Cache la Poudre and the South Platte rivers. It occurs as a narrow strip, averaging about three-fourths of a mile in width along these streams throughout their entire course across the area. One small fingerlike patch occurs along Lone Tree Creek, extending up that stream for a distance of 2 miles from the main body bordering the Cache la Poudre River.

The topographic features of the areas covered by this type of soil are not very marked. The surface is comparatively level, with a gradual slope toward the streams. It is cut by numerous sloughs, old river channels, and small swamp areas. The sand and gravel ridges or hummocks already mentioned occur over the surface, but these rarely exceed an elevation of 3 or 4 feet. The boundaries of this type

are often marked by abrupt rises, especially where bordering the foot of the mesa lands.

Owing to its low-lying position and to seepage from the irrigated uplands the drainage of this type, except in the higher areas, is comparatively poor. During wet seasons much of it is subject to overflow from the streams which it borders. The water table is near the surface the greater part of the year, and at the time the survey was made the depth to ground water rarely exceeded 6 feet.

The Laurel sandy loam is of alluvial origin, having been deposited in comparatively recent time by the Cache la Poudre and South Platte rivers and Big Thompson Creek. The heavier phase of the type was deposited in those places where the streams were at one time sluggish or had their flow checked by obstructions, and has been modified by the washings of finer materials from the higher levels into the depressions.

Only small areas of this soil are affected by alkali. In most cases the percentage of alkali is small, the worst affected areas rarely containing more than 0.40 per cent for the 6-foot profile. The greater part of these salts generally occurs in the first and second feet. Surface accumulations are found over the area in which the first foot contains the largest percentages, but the quantity found in these places is seldom sufficient to injure vegetation.

The Laurel sandy loam is rich in plant food, and where unaffected by alkali is well adapted to small fruits, grains, truck crops, and native hay. It is particularly well suited to the growing of cabbages, onions, and sugar beets, and is generally considered one of the best beet soils in the area, producing good yields, with a high percentage of sugar. Tomatoes and potatoes do well upon this soil where it is fairly well drained. Potatoes are not, however, grown extensively, on account of their tendency to rot during wet periods. Oats and wheat are not sown to any great extent, because they produce too rank a growth and the grain often becomes lodged. On the higher levels and in well-drained areas generally alfalfa thrives, but its production on the lower or poorly drained areas is not to be recommended unless a thorough drainage system is first established. The type is not well adapted to the larger tree fruits, but plums and cherries can be successfully grown. It is well adapted to such small fruits as strawberries and raspberries, and a considerable part of the type is devoted to their production. Good yields are generally obtained, and the fruit is of excellent quality.

The yields of the various crops grown on the Laurel sandy loam vary considerably with the character of the seasons and the methods of cultivation. Under ordinary conditions, where a stand is secured and the grain does not lodge, oats average 60 bushels to the acre, though crops have been harvested that yielded as much as 110

bushels per acre. Barley averages about 50 bushels, while wheat lodges as a rule, so that only fair yields are obtained. Onions yield 300 sacks of about 110 pounds each; cabbage, 15 to 20 tons; potatoes, 200 bushels in favorable seasons, and sugar beets from 15 to 20 tons per acre. Alfalfa yields about 5 tons, three or four cuttings being obtained in a season. The average yield of hay, consisting of the native grasses, chief among which are wire grass, salt grass, and blue stem, is about 1 ton per acre.

BILLINGS CLAY LOAM.

The Billings clay loam is the heaviest type of soil found in the present survey. It consists of a uniformly heavy loam or clay loam, varying in depth from 2 to 5 feet. The clay content increases with depth, and at from 8 to 15 inches the soil becomes very compact and tenacious. The color ranges from dark gray to black, the latter predominating.

The subsoil of this type, unlike the soil, is subject to considerable variation in texture, ranging from a heavy sandy loam to coarse sand and fine gravel. Along the streams and extending back on each side for some distance the subsoil is composed mainly of sand and gravel. Higher areas farther away from the streams, and bordering the outer margins of the type, are generally underlain by a stratum of heavy sandy loam, which gradually increases in depth with the distance from the stream, and in general, as the outer margin of the type is approached, extends to a depth of 6 feet or more.

The color of the subsoil varies from gray to black, depending largely upon the texture, the loamy phase being the darker. Considerable organic matter is present in both the soil and subsoil.

The following table gives the mechanical analyses of typical samples of this soil:

Mechanical analyses of Billings clay 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.*
12072	SW. cor. sec. 2, T. 7 N., R. 65 W.	Brown loam, 0 to 36 inches.	0.2	2.0	2.3	16.4	16.5	36.3	26.1
12074	4 miles E. of Lucerne	Brown clay loam, 0 to 48 inches.	.3	1.4	1.4	10.2	12.9	46.1	27.6
12073	Subsoil of 12072	Light loam, 36 to 72 inches.	.4	2.0	2.7	19.0	20.6	31.4	23.6

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 12072, 3.3 per cent; No. 12073, 6.1 per cent; No. 12074, 1.9 per cent.

The Billings clay loam occupies only a small portion of the area surveyed. The largest area mapped borders Lone Tree and Owl creeks. The remainder of the type occurs in small areas along the intermittent streams.

In general the surface of this soil is comparatively level, with gentle slopes toward the bordering streams. The surface is cut to some extent by sloughs, former stream channels, and small swampy areas. Near the streams small gravel ridges are found, varying in height from 2 to 4 feet.

The natural drainage conditions of the greater portion of this type are very good. The underlying sand and gravel afford an excellent medium for carrying off the surplus water, and the areas are generally high enough above the streams to give adequate fall for surface drainage. It is only during periods of excessive rainfall that this soil is overflowed. However, a few small swampy and poorly drained areas occur near the beds of streams. The water table is found at a depth varying from 2 to over 10 feet.

The origin of the Billings clay loam is distinctly alluvial, the component materials derived from various sources having been deposited by the streams within recent times. The soil of the largest area, occurring in the northeastern part of the sheet, is composed largely of decomposed shale, as shown by the presence of a large quantity of shale fragments on the surface in the northern part of this area. The material composing the other areas has been derived mainly from washings from the surrounding higher levels, but contains a greater or less proportion of sediment brought down from the north. The sand and gravel composing the subsoil have undoubtedly been transported to their present position from gravelly areas far north of the area surveyed.

This soil is practically free from injurious amounts of alkali. A few of the lower areas show some accumulations, especially where the water table is near the surface, but the amount rarely exceeds 0.40 per cent for the entire 6 feet. The percentage for the first 3 feet is sometimes much higher than this, in some instances reaching 1 per cent. Slight surface accumulations occur over some of the wet and poorly drained areas, but the amount is generally insufficient to injure the vegetation in these places, usually consisting of the native grasses.

Gypsum also occurs to some extent throughout this soil, especially where it is alkaline. The higher areas of the type are well suited to the production of alfalfa, wheat, oats, potatoes, and sugar beets; while the lower areas are adapted to native hay, and are largely used for this crop, especially along the streams. The soil is very difficult to cultivate and requires much labor to put it in proper condition for sowing the crops, but if good tilth is secured before planting satisfactory yields are generally obtained.

During favorable seasons alfalfa yields from 2 to 4 tons per acre from three cuttings, wheat from 15 to 25 bushels, oats about 60 bushels, and potatoes from 100 to 200 sacks per acre. Sugar beets are not grown to any extent on this type. The soil is undoubtedly well suited to this crop, and the yields compare favorably with those secured on the Laurel sandy loam. The average yield of native hay is about 1 ton per acre, varying from three-fourths ton to 1½ and sometimes 2 tons.

COLORADO FINE SANDY LOAM.

The Colorado fine sandy loam consists of a fine sandy loam with a depth of 3 feet, underlain by a heavy fine sandy loam or loam to a depth of 6 feet or more. The depth of the surface soil varies considerably, ranging from 2 to 4 feet, and in some instances extending to a depth of 6 feet. In some localities, where this soil has been washed by rain and irrigating waters, the material composing it is mainly a medium sandy loam. In other places the finer material has been washed into depressions, the resulting soil approximating a heavy fine sandy loam or loam extending to a depth of over 6 feet, and mixed with varying amounts of organic matter.

In general, as the depth of the soil increases the silt and clay content becomes greater. At varying depths a zone of heavy sandy loam or loam is almost invariably encountered. It varies in thickness from 1 to 3 feet, and is in turn underlain by material very similar in texture to that of the surface soil. The color of the greater part of this soil ranges from light to dark brown. In the low areas the color, as a rule, is much darker, varying from a dark gray to almost black, depending upon the amount of organic matter present. Some gravel is occasionally found scattered over this type, but it does not occur in sufficient quantities to be of any importance.

The following table gives the mechanical analyses of samples of this type:

Mechanical analyses of Colorado fine 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.*
12061	6 miles N. of New Windsor.	Brown fine sandy loam, 0 to 18 inches.	0.6	2.2	1.5	21.7	39.1	25.2	9.6
12062	¼ mile S. of NE. cor. sec. 10, T. 7 N., R. 69 W.	Fine sandy loam, 0 to 36 inches.	.8	3.5	2.4	17.4	30.7	32.0	13.0

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 12061, 0.68 per cent; No. 12062, 5.3 per cent.

The Colorado fine sandy loam, which is the most extensive type mapped, covering more than one-third of the total area surveyed, occupies most of the upland portion of the Cache la Poudre and South Platte valleys. The most extensive body occurs northwest of Greeley, extending north from that town to the northern limits of the survey, and west to an irregular line about 4 miles east of Fort Collins. The southern boundary of this large area is marked by the bottom lands of the Cache la Poudre River. Another and much smaller area occurs east of the valleys formed by Owl and Lone Tree creeks, and extends south to the river soils of the Cache la Poudre and South Platte rivers. Its eastern and northern boundaries extend beyond the limits of the survey. Only comparatively small areas of this type occur south of the Cache la Poudre and South Platte rivers. The largest body found in this part of the area extends west from the town of Greeley as a narrow strip about one-half mile in width, bordering the northern edge of the mesa lands. Another small body occurs in the vicinity of Kersey. A few areas of very limited extent occur as isolated patches over the eastern half of the sheet.

The surface of the Colorado fine sandy loam presents the most prominent physiographic features of any of the soils surveyed. In general, it varies from rough, hilly, and rolling uplands to slightly undulating plains, sloping gently toward the streams. Most of the rough hilly areas occur north of the Larimer County Canal. South of this canal the surface assumes a more level character, which it maintains until it reaches the river bottom soils. The line of demarcation between this soil and others is often marked by abrupt rises, varying from 2 to 4 feet in height, and in some cases by precipitous bluffs 15 to 25 feet high. Numerous small and generally intermittent streams flow across the areas occupied by this type and have cut out narrow V-shaped valleys. These valleys are as a rule continuous in crossing the area, but in some instances they have been dammed and made into small reservoirs, or are shut off by lakes into which the streams empty. The valleys vary in width from one-sixteenth to over one-fourth of a mile and in depth from 10 to 50 feet. As the main stream is approached they generally become more shallow and are marked by more gentle slopes. The surface is dotted by swampy areas and many natural and artificial lakes varying in size from 25 to over 1,000 acres. Many of these lakes are being used as reservoirs for the storage of water for irrigation. During the greater portion of the year many of the lakes are dry, and the bottoms generally contain a much heavier type of soil.

The loose texture of the Colorado fine sandy loam, together with its rough, hilly, or slightly undulating surface, affords excellent natural drainage. In some instances, and especially on the lighter phases of the more elevated areas, the natural drainage is excessive, and the

lands have to be irrigated very frequently in order to produce good crops. The soil is generally of sufficiently coarse texture to permit the rapid percolation of water, so that a large percentage is absorbed by it. During heavy rains, and especially after the land has been thoroughly irrigated, the surplus water readily finds its way into the numerous small streams which flow across the type and empty into the river. It very frequently happens, however, that during periods of this kind the soil washes to some extent, forming shallow gullies on the slopes of the uplands. In a number of instances it was observed that during a single heavy rainstorm the stream beds had been filled to a depth of over 1 foot with eroded material from the higher levels. To prevent this excessive erosion is an important problem with the farmers.

The type in general is but little affected by seepage waters, but in the draws and local depressions adjacent to the canals and heavily irrigated lands the drainage conditions are poor, often necessitating the construction of artificial drains to reclaim such areas.

The Colorado fine sandy loam is of residual origin, the material being derived from the disintegration of the underlying sandstone, shaly sandstone, and shales. The heavier phase of the type owes its origin to the disintegration of the finer grained rocks.

Except in the draws and local depressions affected by seepage, alkali does not occur in sufficient quantities to injure crops. Over some of the more level areas of the higher lands slight surface accumulations occur, but the amount is generally so small as to be of little consequence. In the low seepage areas alkali is found in the soil in varying amounts, ranging from 0.20 to 0.60 per cent, the greatest amount generally occurring in the upper part of the soil. A number of the lakes are slightly alkaline, and a slight surface accumulation of alkali often covers the soil immediately surrounding them. Gypsum crystals are also found in this soil, but only in small quantities.

The Colorado fine sandy loam is especially well adapted to the production of wheat, oats, barley, alfalfa, and potatoes. For the production of potatoes it is considered the best in the area, and a large proportion of the best lands of this type is devoted to that crop. The average yield per acre of potatoes is about 175 sacks of 2 bushels each, although much higher yields are very often obtained. During favorable seasons the average yields per acre of the other crops are about as follows: Wheat, 30 bushels; oats, 50 bushels; barley, 25 bushels, and alfalfa, about $3\frac{1}{2}$ tons from the three crops usually obtained in a season. Sugar beets are grown extensively on the areas that are only slightly undulating or sloping, and on these areas produce an average of about 12 tons per acre.

The uncultivated areas of the type are generally covered with the native grasses, which are used for pasturage.

COLORADO ADOBE.

The Colorado adobe is a typical adobe soil. The mechanical analyses show it to be composed largely of silty material, and under field conditions it appears to be a heavy soil. In the local depressions the soil is very heavy, the silt and clay content being much greater than in the surrounding areas. Under cultivation the surface soil of the upland phase has, in general, the appearance of a loam, and on some of the lighter areas it resembles a heavy sandy loam, still possessing, however, its adobe structure.

The Colorado adobe is characterized by its stickiness when wet, and, considering its heavy texture, by its perviousness to water. The soil takes water readily when subjected to heavy applications, and on drying breaks up into roughly cubical blocks, varying in size from a fraction of an inch to an inch in diameter.

The soil is generally over 6 feet deep, and is underlain by shales or shaly sandstone. Northeast of Eaton the underlying strata contain beds of coal. The type varies in color from dark gray to black in the local depressions, and from light to dark brown on the uplands. Considerable organic matter is present in the soil, especially in the lower areas.

The following mechanical analyses show the texture of the typical samples of this soil:

Mechanical analyses of Colorado adobe.

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.*
12075	W. side sec. 20, T. 6 N., R. 68 W.	Fine sandy loam, 0 to 14 inches.	0.1	0.6	0.7	18.9	30.9	36.0	12.6
12078	NW. cor. sec. 29, T. 6 N., R. 68 W.	Silty clay, 0 to 36 inches..	.0	.2	.2	5.8	10.0	56.8	26.9
12076	Subsoil of 12075.....	Brown clay loam, 14 to 28 inches.	.1	.2	.3	9.8	20.9	39.6	29.1

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 12076, 0.92 per cent; No. 12078, 1.9 per cent.

This soil occupies only a small proportion of the area surveyed. It occurs as local patches, scattered throughout the area, and is found most typically developed on the slopes of some of the gently rolling hills and in some of the level upland areas. It is also found in the

local, basinlike depressions of the uplands, and as small, fingerlike patches along the courses of arroyos and minor stream channels.

The type possesses no marked physiographic features. The surface varies considerably, however, from a level plain to gently rolling uplands with basinlike depressions. Along the small streams, on the slopes of the hills, its surface is often cut by many small shallow gullies. In some instances the streams have cut down several feet through the soil, forming deep and narrow channels with perpendicular walls.

With the exception of a few of the local drainage basins, the natural drainage of this soil is good. In some of the lower areas, especially in the basins, the drainage conditions are poor. These places are subject to seepage from the heavily irrigated higher lands, and during a portion of the year may be covered with water.

When properly cultivated, this soil possesses marked water-holding power, so that crops do not suffer greatly during droughts for lack of moisture.

The Colorado adobe is a residual soil, formed by the disintegration and decay of the shale or shaly sandstone upon which it rests. The soil occurring in the lake bottoms or local depressions has been modified by the washing of the finer material from the higher areas of this type and the adjoining soils; the deposition of this sediment over the bottoms of these depressions having probably taken place from intermittent lakes or stagnant water.

The cultivable areas of the Colorado adobe are practically free from injurious quantities of alkali. In the low-lying areas affected by seepage and in some of the local basinlike depressions alkali is sometimes found in quantities varying from 0.20 to 0.60 per cent. In these areas the alkali is generally evenly distributed throughout the first 6 feet of soil. Occasionally the first foot is practically free from alkali, the quantity gradually increasing with depth. The shales from which this soil is derived contain a high percentage of mineral salts, which probably accounts for the increased amounts found in the lower portions of the soil.

Only a small proportion of this soil is at present under cultivation. The greater part is too rolling and hilly to be profitably irrigated, and is used for pasturage. As a type it is well adapted to the production of hay, grains, and such other crops as require a moderately strong soil. On some of the lighter areas potatoes are grown, but it is not considered a good soil for this crop. Under proper management it produces good yields of wheat and oats. Excellent yields of alfalfa are annually secured, and the areas in cultivation are mainly devoted to the production of this crop.

COLORADO SAND.

The Colorado sand consists of a coarse to fine sand varying in color from light gray to yellow or reddish brown. This last color is due largely to the presence of fragments of feldspar, which, together with small angular quartz grains, form the chief mineral constituent of the soil. A moderate amount of organic matter also occurs in this soil.

The Colorado sand is generally over 6 feet deep, but is occasionally underlain at a depth of from 3 to 6 feet by a light sandy loam. The type is fairly uniform throughout its occurrence in the area, the irrigated lands being somewhat heavier than the unirrigated.

The soil is easily cultivated, and breaks down readily on being turned up by the plow, forming an excellent surface mulch. The type in general contains a very small percentage of silt and clay, but on some of the loamy phases subject to heavy applications of water it shows a tendency to puddle slightly, and if allowed to dry out rapidly forms small clods.

The following table shows the results of mechanical analyses of typical samples of this soil:

Mechanical analyses of Colorado sand.

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.*
12059	½ mile N. of SE. cor. sec. 22, T. 5 N., R. 66 W.	Gray loose sand, 0 to 24 inches.	0.7	5.5	10.3	45.9	29.3	3.8	4.4
12057	¼ mile N. of SE. cor. sec. 14, T. 5 N., R. 66 W.	Brown fine sand, 0 to 24 inches.	.9	5.4	8.6	44.4	27.3	8.5	4.5
12060	Subsoil of 12059	Brown fine sandy loam, 24 to 72 inches.	.3	2.1	3.0	29.1	32.0	20.7	12.6
12058	Subsoil of 12057	Gray fine sandy loam, 24 to 72 inches.	1.8	6.7	6.2	25.4	19.9	20.3	19.7

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 12058, 26.0 per cent; No. 12060, 2.8 per cent.

The Colorado sand covers only a small proportion of the area. The largest area occurs in the uplands on the south side of the Cache la Poudre River, southwest of Greeley, and there are isolated patches immediately west of this area. Only two comparatively small areas are found north of the river. These occur in the northeast corner of the sheet, bordering the valley of Owl Creek.

The surface of this soil is hilly or rolling. It generally caps the domelike elevations of the plains, sometimes dipping well down into

the depressions and grading rapidly into the Colorado fine sandy loam. A few small streams have cut small, narrow valleys through the areas of this type. This is particularly noticeable along Sheep Draw.

The physiographic position, together with the loose, porous nature of the soil, affords excellent natural drainage. As in the lighter areas of the Colorado fine sandy loam, the drainage is often excessive, and the land has to be irrigated frequently to produce good crops. It absorbs moisture rapidly, so that very little is lost flowing off the surface. Owing to the heavier subsoil this soil is superior to most sandy soils of the West for retaining moisture, and crops do not, as a rule, suffer greatly during droughts.

This soil has probably originated from two sources. The greater part of the material represents the more resistant particles deposited by ancient débris-bearing streams issuing from the foot slopes of the Rocky Mountains during the formative period of the Great Plains. Since the deposition erosion has progressed rapidly, cutting and washing away this material, until only the present soil remains, capping the higher places. It is also probable that this soil has in part been formed from the weathering in place of the underlying sandstone rocks.

No injurious quantities of alkali occur in this soil. Along Sheep Draw there are slight surface accumulations, but they are of no importance.

Only a small proportion of this land is under cultivation, it being for the most part above the irrigation canals. Considering, however, the loose, porous nature of the soil, it retains moisture well, and generally produces better crops than most soils of similar character in the West. When well supplied with moisture it is well adapted to crops that require a light soil.

The native vegetation of the unirrigated areas consists chiefly of sage, soapweed, Spanish bayonet, and a few of the grasses indigenous to the Great Plains. The irrigated areas are devoted to the production of stone fruits, principally plums, to alfalfa, and on loamy areas to potatoes and wheat. Good yields are generally secured, but it is occasionally necessary to apply organic and mineral fertilizers to secure good returns from crops requiring a stronger soil.

COLORADO LOAM.

The Colorado loam consists of a loam or silty loam with a depth of 6 feet or more, generally very uniform in texture, often extending without variation to bed rock. The prevailing color of the type is yellow, but the color varies from a bluish gray to a light brown. In the lower areas the type contains a relatively higher percentage of silt,

and is generally of a darker color, owing to the greater proportion of organic matter.

The soil, to a depth of from 6 to 12 inches, often possesses marked adobe properties, which at times make it very difficult to distinguish it from the true adobe soils. It becomes quite sticky when wet, and if allowed to dry out quickly, breaks up into the roughly cubical blocks characteristic of adobe soil. It also washes very easily when subjected to stream erosion, often forming arroyos several feet in depth, with perpendicular walls.

There is some variation in this type, and in some places the soil is underlain at a depth varying from 3 to 6 feet by very light sandy loam or sand. In the northwestern portion of the area large gravelly bodies occur. The gravel is found scattered over the surface and through the soil, and consists chiefly of angular fragments of sandstone and shale, varying from a fraction of an inch to 5 or 6 inches in diameter. The proportion of gravel is greatest upon the higher ridges of the type.

The following table shows the mechanical analyses of typical samples of this soil:

Mechanical analyses of Colorado 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.*
12063	¼ mile N. of SE. cor. sec. 32, T. 6 N., R. 6 W.	Light loam, 0 to 36 inches.	0.0	0.2	0.2	5.4	41.2	41.3	11.7
12067	Cen. S. side sec. 12, T. 5 N., R. 69 W.	Loam, 0 to 36 inches	.2	.6	.7	12.9	25.4	36.9	23.0
12068	SW. cor. sec. 22, T. 8 N., R. 69 W.	Loam, 0 to 36 inches	1.1	1.3	1.7	11.2	17.5	39.9	27.2
12064	Subsoil of 12063	Fine sandy loam, 36 to 72 inches.	.0	.1	.2	6.6	49.4	31.8	11.7

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 12063, 6.8 per cent; No. 12064, 7.6 per cent; No. 12067, 7.1 per cent; No. 12068, 6.5 per cent.

In extent the Colorado loam ranks second in the area surveyed. It occurs in large areas of irregular outline, occupying the upland portions of the area in the southwestern and northwestern parts of the sheet. The largest body of this type occurs in the southwestern part of the area, extending about 8 miles north of Loveland and east for a distance of about 12 miles. The northeastern boundary of this area is marked by the bottom lands of the Cache la Poudre River. A

small body of the type occurs southwest of Loveland, occupying a portion of the uplands on the opposite side of Thompson Creek.

The second largest body of this soil is found in the northwestern part of the area, extending west from Wellington to the foot slopes of the mountains, and south to a line running roughly parallel to the Cache la Poudre River, about 2 miles north of Fort Collins. Two smaller bodies occur north and east of Wellington.

This type occupies rolling and hilly uplands, with occasional small areas presenting comparatively level surfaces. For the most part the hills are well rounded, rising generally 30 to 80 feet above the adjacent depressions, and sloping gradually toward the river, but occasionally they are broken by outcrops of the underlying sandstone and shales. This is particularly the case in the northwestern part of the sheet, where the western edge of the type is marked by steep precipitous bluffs 30 to 50 feet high.

Near the foothills the surface is dissected by many small streams, which have formed small, narrow valleys, or, in some places where erosion has been greatest, deep arroyos with perpendicular sides. The area is dotted by many natural and artificial lakes and local depressions. A few of the lakes are intermittent, containing water only after prolonged wet periods. The soil of these lake bottoms and local depressions is of much heavier character than the typical Colorado loam, and when occurring in areas large enough has been classed as a distinct type.

With the exception of a relatively small area lying along the natural draws and drainage depressions, the Colorado loam possesses excellent drainage conditions. The greater part of the type is well situated for irrigation, and when once thoroughly wet it possesses marked moisture-retaining properties as well as high capillary power.

The Colorado loam is a residual soil, formed by the disintegration of sedimentary rocks. North of the Cache la Poudre River these rocks consist chiefly of sandstone, which is very fine grained, sometimes presenting the appearance of indurated mud and shales, which weather into a soil having a relatively high silt content. South of this stream the sandstone is of a somewhat coarser grain, and the resulting soil is generally lighter than that occurring north of the river.

Like most of the soils of the area, this type does not, as a rule, contain sufficient alkali in the first 6 feet to impair its agricultural value. Considerable alkali occurs, however, in the lower part of the subsoil, as evidenced by the appearance of crystallized salts on the surface in the draws and local depressions affected by seepage from the heavily irrigated uplands. The amount found in these local areas varies considerably, depending largely upon the position of the water table. It is seldom, however, that the amount occurring in the soil exceeds

0.60 per cent for the first 6 feet. The Colorado loam, as a rule, is very productive, and when well supplied with moisture and properly managed is well suited to a number of different crops. It is in general considered one of the most valuable soils of the Greeley area, and all of it except the unirrigable portions is under cultivation. These latter areas, the largest of which occupies a small part of the uplands about 4 miles northeast of Loveland, north of Loveland and Greeley Canal, are for the most part covered with the native grasses of the plains, and are devoted to grazing.

The irrigable areas are particularly well adapted to orchard and small fruits, alfalfa, wheat, oats, barley, potatoes, corn, and sugar beets. While potatoes do well, it is not considered so valuable a soil for this crop as the Colorado fine sandy loam. Of the fruits, apples and cherries are chiefly grown, although the soil is considered well suited to plums and peaches. Strawberries and raspberries are also grown, and are of excellent quality. The production of fruits is developing into a profitable industry.

When properly supplied with moisture and rightly managed, the yields of other crops are as follows: Wheat, 25 to 30 bushels per acre; oats, 50 to 60 bushels; barley, 30 bushels; corn, 30 to 40 bushels; alfalfa, 3 to 4 tons from three cuttings; sugar beets, 15 tons; and potatoes, about 175 bushels. Most of the corn produced in the area is grown in the vicinity of Loveland. The soil in this locality seems to be particularly well suited to this crop, and considerable land is devoted to its production.

COLORADO GRAVELLY LOAM.

The Colorado gravelly loam consists of a gray to almost black heavy fine sandy loam or loam of a rather fine, silty texture to a depth of 6 feet or more, containing varying amounts of red and white sandstone, granite, and shale fragments. The quantity is greatest near the mountains and diminishes gradually toward the east. The gravel and stone range in size from small fragments to pieces 5 or 6 inches in diameter. In the local depressions and drainage areas it is a heavy silt or clay loam, generally of a much darker color than the higher areas. The soil washes very easily, and in cuts the subsoil is frequently of a very heavy, compact nature, often possessing some of the characteristic properties of an adobe soil. In the southwestern portion of the area, and a few miles northwest of Laporte, a phase occurs where the soil is a red sandy loam extending as a rule with but little variation to bed rock.

The following table shows the result of mechanical analysis of a sample of this soil:

Mechanical analysis of Colorado gravelly 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.*
12082	SE. cor. sec. 4, T. 7 N., R. 69 W.	Gravelly loam, 0 to 24 inches.	1.7	3.2	2.2	15.6	16.4	51.0	10.0

The Colorado gravelly loam occupies only a small proportion of the area surveyed. It embraces a small strip of territory from one-half mile to about 4 miles wide, bordering the entire western edge of the sheet. It includes all of the foot slopes of the Rocky Mountains occurring within the area, and is almost all above the irrigation systems.

The topographic features of this soil consist of hills and ridges cut at right angles by many small intermittent streams that flow down from the mountains into the plains. The surface rises gradually from the eastern to the western boundary of the type. Here the surface is very irregular, consisting of the high hills and ridges characteristic of the foot slopes of the Rocky Mountains.

The Colorado gravelly loam has excellent natural drainage. The surface is so rolling and hilly that only a very small part of the rainfall is absorbed by the soil, while the many small stream channels furnish excellent outlets for the drainage waters. A little alkali occurs in the soil along some of these streams and draws, but in general the soil is free from injurious quantities of salt.

The Colorado gravelly loam is distinctly a colluvial soil formed from weathered rock débris brought down from the mountain immediately west of the area by mountain torrents, and during the process of disintegration and decay this material has been further modified by stream action.

The irrigable portion of this type is well adapted to fruits, particularly apples, and to wheat, oats, barley, alfalfa, and sugar beets. When well supplied with moisture the yields compare favorably with those obtained on the Colorado fine sandy loam. It frequently happens, however, that owing to the difficulty with which some of these lands are irrigated, the crops are not sufficiently supplied with moisture, and in cases of this kind the yields fall considerably below the average.

The unirrigable districts are for the most part covered with a scanty growth of weeds and a few of the native grasses. During wet seasons the grasses grow rapidly and the lands are devoted to grazing.

BILLINGS LOAM.

The Billings loam, like the Laurel sandy loam, varies widely in texture. In general, it consists of a loam, usually from 2 to 5 feet deep, and underlain by a gritty or gravelly loam, or in some instances by sand or sandy loam. The texture, however, ranges from a heavy sandy loam to a heavy clay loam, which gradually becomes heavier with depth until the subsoil is reached. Each of these variations occurs in such limited areas and is so intermingled with the others as to make a separate classification impossible.

The color of the soil varies from a reddish brown to a dark gray, and in some instances, owing to an increased amount of organic matter in the soil, is almost black. The subsoil is generally of a much lighter color. A small amount of fine gravel is occasionally found scattered over the surface and through the soil, but the proportion is not high enough to affect the cultivation of the crops.

This soil occurs as small, narrow strips, the maximum width rarely exceeding one-half mile, bordering the streams that flow across the Colorado fine sandy loam. The type is found only north of the river in that part of the Colorado fine sandy loam which lies northwest of Greeley. Nearer the streams the surface is generally level, though sometimes cut by old channels or small swampy areas. Farther back the land usually rises quite abruptly, forming the sloping walls of the small valleys. The outer part of the strip is fairly well drained, but near the streams the drainage is naturally poor. In the bends of the canals and in areas most affected by seepage, water is at or near the surface throughout the season. Most of this seepage, however, is carried off by the streams which the type borders, while the underlying stratum of sand and gravel also furnishes outlet for the surplus water. The cultivable areas rarely require irrigation, the crops being supplied with moisture from seepage.

The Billings loam owes its origin mainly to the material washed down from the surrounding uplands, the heavier phases of this type having been formed from the accumulation of the finer and more loamy material in the depressions and low-lying areas. In addition to local wash a small proportion of the material composing the soil has undoubtedly been transported to its present position from some distance to the north by the streams which it borders. The sandy and gravelly subsoil has been derived largely from the same source.

In the seepage areas of this type alkali occurs in varying amounts, but rarely exceeds 0.60 per cent for the 6-foot profile. The greatest

amount is generally found in the upper portion of the soil, the subsoil being practically free from injurious amounts. Slight surface accumulations occur, but the amount is small and seldom sufficient to injure plants. The worst areas are found, as a rule, in the bends of the canals. Seepage in these places is generally great, and the alkali occurs in relatively large amounts on the surface and through the soil. The first and second feet are generally the most highly impregnated. This, however, depends largely on the position of the underground water.

This type in general is a somewhat stronger soil than the Colorado fine sandy loam. The cultivable areas are adapted to about the same kind of crops as the Colorado fine sandy loam, with the possible exception of potatoes, and all crops can be grown without irrigation. The soil is generally too wet for potatoes, and the tubers often rot, while the plants are very susceptible to blight. The soil is especially well adapted to sugar beets, and the yields and percentages of sugar content compare favorably with those secured on the soils of the river bottoms. During favorable seasons the average yields of crops secured on this soil are about the same as those obtained from the Colorado fine sandy loam. The wet, swampy areas are covered for the most part by some of the swamp and salt grasses, which are used either for pasture or hay.

FORT COLLINS LOAM.

The Fort Collins loam consists of a reddish to very dark brown light loam from 4 inches to 1 foot in depth, underlain by a layer of heavy loam from 1 to 4 feet in thickness. Beneath this layer of loam the subsoil grades again into a light loam, similar in character to the soil, and extending to a depth of 6 feet or more. The soil becomes very sticky when wet, and bakes badly, often breaking into rough cubical blocks like adobe soils upon exposure after puddling.

In the areas occurring in the extreme eastern portion of the sheet, north of the South Platte River, there is a phase varying somewhat from the typical soil. Here the soil consists of a heavy loam, generally extending to a depth of 6 feet or more without any noticeable change in texture.

The table following shows the results of mechanical analyses of typical samples of this soil.

Mechanical analyses of Fort Collins 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.*
12069	2 miles SE. of Lucerne.	Loam, 0 to 36 inches	1.0	2.4	2.0	13.9	28.9	32.9	19.0
12071	¼ mile E. of SW. cor. sec. 27, T. 18 N., R. 69 W.	Sandy loam to loam, 0 to 36 inches.	.8	3.4	5.2	20.8	17.0	30.1	22.7

The following samples contain more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 12069, 5.2 per cent; No. 12071, 1.2 per cent.

The Fort Collins loam covers a relatively small area. It occurs most typically developed in two areas near Fort Collins, the larger extending southeast from that town to the Fossil Creek Reservoir and the smaller lying east of Fort Collins across the river. A few other areas occur as isolated patches in the northwestern part of the survey. Four comparatively large areas are found in the southeastern part of the sheet. The largest of these occurs in the great bend of the South Platte River, while the second in size extends southeast from the town of Eaton to the river bottoms.

The surface of this soil is practically level, though some areas are slightly rolling or undulating. The surface is unmarked by rock outcrops, bluffs, or prominent terrace lines, but is sometimes pitted by erosion and occasionally cut by small, intermittent stream channels. There are a number of natural and artificial lakes and a few basinlike depressions. The latter often contain a much heavier type of soil, and during a portion of the year the bottoms are covered with water.

The Fort Collins loam is for the most part a residual soil, formed by the weathering in place of clayey sandstones and sandy shales. It is quite probable, however, that a small proportion of the material composing this soil has been derived from the ancient débris of the mountain slopes that formerly covered this territory. The material thus deposited was probably much lighter than at present and devoid of large gravel, and has since weathered into the loam.

Most of this soil is well drained. In the eastern part of the area, however, the drainage conditions are rather poor, often necessitating the use of artificial drains to produce good crops. The type here is quite badly affected by seepage from the canal, and the water table is sometimes found within 2 to 4 feet of the surface. Owing to its heavy texture, the soil absorbs moisture rather slowly, so that a large

percentage of the rainfall is lost by surface drainage. When once thoroughly irrigated it retains moisture well and is able to withstand drought better than most of the soils of the area.

Only limited areas of the Fort Collins loam affected by seepage contain sufficient quantities of alkali to injure crops. In some of the sloughs and local depressions from 0.20 to 0.60 per cent of alkali is found. In section 4, T. 5 N., R. 64 W., occurs the worst affected area, the soil containing over 1 per cent for the first 6 feet, with about 2 per cent occurring in the third foot. Below this the alkali diminishes in amount, the sixth foot containing about 0.80 per cent. Many surface accumulations are found in the area occupied by this soil, but the amount is generally so small as to be entirely negligible.

The Fort Collins loam is, when properly managed, not difficult to cultivate, and is well adapted to the growing of all crops suited to the climate. It is a moderately strong soil, and is considered one of the most fertile and valuable soils of the area. The principal crops grown, and those to which the type is best adapted, are the fruits, chiefly apples, wheat, oats, barley, potatoes, alfalfa, and sugar beets. In the vicinity of Fort Collins this is considered the best apple soil of the area, and there are many small tracts devoted to this crop. The fruit produced is of excellent quality and the yields are generally very large. Alfalfa is grown on this soil for hay alone, none of it being pastured. It yields from 3 to 4 tons from the three cuttings usually secured in a season. The soil is in general too heavy for potatoes, except on a sandy phase east of Lucerne, which produces some of the finest potatoes in the area, yielding from 150 to over 300 bushels per acre. Sugar beets average about 15 tons per acre, while the average yields of the grains compare favorably with those secured on the Colorado loam.

BILLINGS SILT LOAM.

The Billings silt loam is a grayish to dark-brown, silty, easily cultivated loam from 18 inches to 3 feet deep, underlain by a sandy loam, or loam which is in turn underlain by gravel. When wet the soil has quite a sticky feel and tends to compact in the roads. Upon drying it cracks, somewhat in the nature of adobe soils. In some places small gravel strew the surface, brought up from the gravel strata below by prairie dogs.

This soil is found principally along Boxelder Creek near the town of Wellington. Only small areas were found. It has a smooth, apparently level surface, and requires little or no smoothing to prepare it for irrigation.

Very little irrigation has taken place as yet in the section where this soil is found; hence it is yet well drained and free from alkali salts. Extensive irrigation upon the highlands might result in its

becoming water-logged, as the other low-lying soils have been thus affected, but drainage could be installed with little difficulty with Boxelder Creek as an outlet.

The soil is of alluvial origin, having been deposited from the waters of Boxelder Creek during past overflow or rainy seasons when this creek covered much of the bottom lands.

This silt loam soil is especially adapted to the growing of sugar beets. Grains and alfalfa also do well, but the best paying crop grown is the sugar beet. The average yields of these crops are as follows: Wheat, 30 to 40 bushels per acre; sugar beets, 15 tons; and alfalfa, about 4 tons in a season of three cuttings.

The following mechanical analysis shows the texture of this soil:

Mechanical analysis of Billings silt 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.*
12081	SE. cor. sec. 28, T. 9 N., R. 69 W.	Clay loam, 0 to 26 inches.	0.0	0.1	0.4	5.6	7.5	53.0	33.3

The above sample contained 6.4 per cent of calcium carbonate ($CaCO_3$).

UNDERGROUND AND SEEPAGE WATERS.

At the beginning of irrigation in the area mapped the general level of the water table was very different from the level to-day, having materially risen since water was applied in a general way. As early as 1896 Professor Carpenter found that 30 per cent of the water diverted and applied in irrigation again found the river bed as seepage. The value of this water at prices then obtaining was $300,000 to $500,000 Owing to increased irrigation and the greatly enhanced value of irrigation water, both the quantity and value of this seepage must now be greatly increased.

Many of the low lands in the smaller valleys and along the rivers have become virtually swamped by the excess of seepage. Deep drainage of these lands should not only so reclaim them that profitable crops may again be grown, but would develop a large quantity of water to be used in irrigation.

Many pumping plants have been installed in these low lands to supply water for irrigation and have been almost universally successful. Several deep wells have been bored in the valley to develop

artesian water. Wells that flow a small amount of water have been obtained, but the supply from this source is practically negligible.

WATER SUPPLY FOR IRRIGATION.

Practically all the cultivated land of the Greeley area is irrigated. This irrigation is mainly by gravity ditches drawing water from Cache la Poudre and South Platte rivers, Big Thompson Creek, and a number of other small creeks that flow across the area. Quite a number of wells have been sunk in the water-bearing gravels along the rivers and creeks, which in the aggregate furnish water for a considerable acreage. The main source of supply, however, is that from Cache la Poudre River and Big Thompson Creek. Many reservoirs and lakes have been constructed to impound flood waters for use in late summer, these forming a valuable regulation of the regular run-off. Practically the whole supply of flood and normal run-off waters is thus utilized. The area of irrigable land is far in excess of the supply of water, so that these reservoirs instead of adding to the total acreage of irrigated lands, simply assure a more permanent and adequate supply for the lands already covered by ditches.

All the water used is of good quality, coming principally from the high mountains on the west. The well and drainage water is also of good quality, no harm following its use.

The subject of water supply and irrigation in this region is discussed at length in No. 9 of the Water-Supply and Irrigation Papers of the United States Geological Survey by David Boyd. This paper covers nearly every phase of the subject, and gives a much more detailed discussion than is possible in the limited scope of this report.

Probably the greatest development possible in this area lies in the sinking of wells and the installation of pumping plants. Practically all of the low lands of the area have a very high water table, making irrigation by pumping very economical. The price of water rights under the older ditches has advanced until the interest on the original investment and the water rental often exceed the cost of installation and maintenance of pumping plants.

ALKALI IN SOILS.

Alkali is quite generally found in the small swales and valleys of the area, in the nonoverflow part of the river bottoms, and often along canals and reservoirs. The areas are usually but a few acres in extent, although in the aggregate the extent is considerable. Trouble from alkali in all cases is here preceded and accompanied by trouble from excessive ground water. Examinations show that many areas that appear to be badly alkaline in fact do not have harmful accumulations, but damage to crops is almost wholly due to water-logging.

With the rainfall that the area receives it may be safely said that if seepage water were disposed of the alkali areas would disappear.

Directly, the alkali comes from the evaporation of seepage water from the surface of the soil. The salts are taken up by the water as it percolates through the soil, and may come from an accumulation already in the soils or from chemical reactions due to the weathering of the soils. Irrigation water, or water in the streams where they emerge from the mountains, is practically pure, the amount of salts contained being negligible.

Several samples of the alkali salts, as found efflorescing on the surface, and samples of the alkali soils, were analyzed in the laboratory of the Bureau. Mr. Headden, of the Colorado Agricultural Experiment Station, in Bulletins Nos. 46, 58, 65, and 72, has discussed the subject of alkali in the soil. David Boyd, in the History of the Union Colony, has also discussed the subject.

The following table gives the results of analyses made by this Bureau:

Chemical analyses of alkali crusts.

Constituent.	715a 1 mile W. of Lucerne, alkali crust 0 to ½ inch.	716a 4 miles E., 1 mile N. of Lucerne, alkali crust 0 to ½ inch.	717a 2 miles S. of Trinvalt, alkali crust 0 to ½ inch.
Ions:	*Per cent.*	*Per cent.*	*Per cent.*
Calcium (Ca)	3.61	3.89	2.47
Magnesium (Mg)	7.98	10.57	8.54
Sodium (Na)	15.36	10.75	15.28
Potassium (K)	1.66	.65	1.71
Sulphuric acid (SO_4)	65.06	72.75	65.75
Chlorine (Cl)	6.48	1.30	6.17
Conventional combinations:			
Calcium sulphate ($CaSO_4$)	12.05	13.16	8.54
Magnesium sulphate ($MgSO_4$)	39.31	52.55	42.50
Potassium chloride (KCl)	3.01	1.20	3.42
Sodium sulphate (Na_2SO_4)	36.90	31.88	38.14
Sodium chloride (NaCl)	8.43	1.11	7.40
Per cent soluble	6.64	10.79	10.54

These analyses bear out the findings of the earlier investigators, viz, that the salts are mainly sodium and magnesium sulphates. Gypsum is also present in quantities, but this salt is difficultly soluble, as well as harmless, and it should not be considered as a part of the alkali.

It has been stated that the accumulations of alkali are due to evaporation of seepage waters from the surface in poorly drained or seepage areas. Wherever there is alkali, water is found close to the surface. This water has only small amounts of salts, so that the part of the

soil below the water table has no harmful accumulation. Therefore the alkali is strictly a surface accumulation. In some instances rainfall or irrigation has washed a part of the alkali down into the second or third foot of soil, but there are no deep-seated accumulations. The surface condition always represents the maximum of the evil.

RECLAMATION OF ALKALI LANDS.

Already many acres of lands that a few years ago were considered too alkaline to grow crops have been reclaimed and now are highly productive.

Headden, in the beginning of Bulletin 72, already cited, says: "I am convinced that the only question of alkali that we have resolves itself into one of drainage, and beyond this there is no alkali question for us." Because of the semiarid nature of the region this is probably a true interpretation of the problem. If the soils now alkaline be drained, deeply plowed, and carefully cultivated, such accumulations of alkali as now exist will no doubt disappear in the course of time. There can be no question, however, that the smoothing and heavy flooding of the lands affected, after drainage, would accomplish the desired purpose much sooner. Whether or not this flooding is a desirable thing will depend on the availability of water for the purpose and the degree of alkalinity of the area to be treated. If the lands are not so bad as to preclude the growth of sugar beets the feasibility of flooding to reclaim is doubtful. The greater part of the swamp and alkali lands if drained, plowed deep, and cultivated carefully, would produce immediately a paying crop of beets. If, however, beets will not grow, sorghum or barley should be sown and flooded.

On the whole, the alkali problem, as compared with that of strictly arid regions, is not a difficult one, and the aggregate of lands so affected is much less than in most irrigated regions of the arid West.

AGRICULTURAL METHODS.

On most of the farms in this district a rotation of crops has been devised that tends to preserve the fertility of the soil and obviate the necessity of artificial fertilization. Before the advent of the sugar factories potatoes, grain, and alfalfa were the crops principally grown upon the high lands in the eastern part of the area and on the best-drained bottom lands, while on the lower bottoms many vegetables were produced. The wetter parts of the bottoms were given chiefly to the growing of native grasses for hay and pasture. In the western part of the area the prevailing soils are heavier and have never been considered good for potatoes. Many apple and plum orchards have been successful. Prior to the introduction of the sugar beet the

field crops were almost wholly grain and alfalfa. Sugar beets have not yet a well-defined place in the rotation, but are grown or not grown in a rather hit and miss way.

Any intelligent crop rotation for this region must take cognizance of the kind or type of soil, the topography or surface grade, and the state of drainage. These things have of necessity been somewhat recognized in actual farm practice, but are not so well recognized as controlling factors in the crop rotation as they should be.

There are several more or less distinct crop rotations practiced by the best farmers on the various soils and in the various districts of the area. On the slightly rolling sandy loam uplands near Greeley and Eaton, grain one year, alfalfa sown with it and harvested for two years after, then potatoes two years, and back to grain and alfalfa again, is the rotation most in vogue. A few farmers are supplanting the last year of potatoes by a beet crop, or growing beets for the two years. The advisability of growing beets on these lands instead of potatoes is a much mooted question. Beets are more difficult to irrigate and require a greater amount of water for their maturity. For these reasons it is most difficult to grow beets on lands that have a steep slope, so that different fields having the same soil type may differ greatly in their suitability for these two crops. In general, the lands having steep slopes are more suitable for potatoes than for beets, and if the slopes become too pronounced neither is profitable. The lands of steep slopes are generally given over exclusively to grain and alfalfa, and these crops are doubtless more valuable for such lands than those just mentioned or any others requiring intertillage. In the western part of the area there is a great deal of the sandy-loam soil, but potatoes have never been grown extensively west of New Windsor, so that when sugar beets were introduced all the lands sufficiently level to permit proper irrigation were devoted more readily to this crop than to potatoes. The rotation for these lands is wheat one year, with alfalfa sown with the wheat and harvested for two years thereafter; then sugar beets for two years, and back again to grain and alfalfa. The many apple, plum, and cherry orchards and the berry lands of course have no rotation.

On the bottom lands along the larger streams and small creeks the following rotations are practiced: Grain one year, alfalfa two years, and potatoes two years for the best-drained parts; grain one year, alfalfa two years, and sugar beets two years for the poorly drained; and native grasses for the swamped areas. As stated, garden and truck crops are quite extensively grown in parts of the river bottoms, but no rotation is practiced, applications of barnyard manure being relied upon to keep up the productiveness of the soils.

In any rotation of crops the joint object is to get the greatest returns from the land and at the same time prevent deterioration of the soil. Nitrogen is the element of plant food most often deficient in the soil, and also the most expensive to purchase in fertilizers. Alfalfa is a leguminous or nitrogen-gathering plant, hence its presence in each rotation noted above. Since the introduction of alfalfa in the eighties, practically all the soils have, by consistently using this crop in rotation, been brought to as high a state of productiveness as they were in the early seventies when farming began. Alfalfa as a money crop does not give the returns that sugar beets or potatoes do, so that as cultivation becomes more intense the aim of the farmers should be to reduce to a minimum the leguminous crop, and increase, so far as the soil will stand it, the money crops. Moreover, alfalfa has such a heavy root system that it is quite difficult to break up the fields for other crops. If some other legume equally as valuable as alfalfa, but less difficult to handle, could take its place, this would be a great advance. In the southern part of the State, in the San Luis Valley, field peas are grown very successfully, and are very valuable as a fattening feed for lambs or hogs. If these field peas were introduced here to supersede the alfalfa on the beet and potato lands, these crops could no doubt be alternated with peas, and the income from a given acreage greatly increased. Wheat may be grown under so many different conditions of nonirrigation that its price is usually so low as hardly to furnish a profit on these high-priced lands, and it must eventually be dropped from the rotation, except on the lands too rough to grow potatoes or beets.

As indicated, potatoes are quite generally planted in the rotation to follow alfalfa. The land is spring plowed from 6 to 10 inches deep and thoroughly harrowed. Planting is done with a horse planter, one row at a time, with an interval between the rows of about 3½ feet, and the hills from 11 to 23 inches apart. The time of planting is from the middle of May to the middle of June, so that the forming of the tubers will take place after the hottest of the weather. After planting a ridge is thrown up over the row of planted seed with a cultivator, and the whole field harrowed to kill early weeds. The rainfall is usually sufficient in the early season, and irrigation is rarely practiced before a healthy growth of vines is made and a good root system established. After the potatoes come up they are cultivated twice, the last cultivation leaving the row ridged to a height of 6 or 8 inches. The crop is then "laid by," except for the irrigation that is so necessary for the production of the large tubers for which the region is so justly famed. A furrower is run through the field in each space between the rows, and about August the first irrigation is begun. The object in irrigation is to maintain a uniform

moisture condition that at no time must approach swamping, as too high a moisture content is injurious to the tubers. It is to prevent too copious wettings that the deep furrows are made. The amount of irrigation necessary or the number of applications of water is dependent upon the kind and slope of the soil. Steeply sloping fields require more frequent irrigations than the more level ones, and the very leachy soils dry out more quickly than the heavier ones. From two to four irrigations in the month of August and early part of September are necessary to mature the crop. A few potatoes for the early market are dug during the latter part of September, but the main crop is dug principally during October.

Digging potatoes has been reduced to a science and is largely done by horse machinery. A digger drawn by four horses and requiring only one man as driver digs and leaves exposed the potatoes of one row at a time. In an ordinary day's work this machine will cover 5 acres. A sorter and sacker is next drawn through the field, the potatoes being picked up and placed in a sort of hopper, from which they are sorted, the small ones being run into a separate sack. To pick up, sort, and sack the potatoes, and then sew the sacks for a digger requires the services of ten to twelve men, according to the yield per acre.

At all the railway stations there are immense warehouses and cellars where potatoes are stored, and nearly all farmers have one or more large cellars on the farm that also give storage room. Many potatoes are shipped as soon as dug. Those which are put in storage are disposed of as the market demands or the needs of the owner require.

While upon the best-managed ranches sugar beets have found a place in the rotation, and the injurious effects of continuous cropping to this exhaustive crop are well understood, a few have planted beets upon the same land for four or more years, and some are advocating such practices as being in no wise detrimental to the soil. On such soils it is important that other crops be grown in rotation if the productiveness is to be long maintained. The necessity for rotation has so often been demonstrated that it seems unnecessary to enter into a discussion of the matter here, other than to sound a note of warning to the oversanguine, who, because sugar beets are profitable, are rapidly impoverishing their soil for the larger immediate return that comes from growing only this crop.

Sugar beets are sown with a large beet drill resembling a wheat drill, in rows 18 inches apart. Deep spring plowing and thorough cultivation prepare the seed bed. Sowing takes place from May 10 to about June 10. It requires 18 to 20 pounds of seed to the acre. The seed is drilled quite thick in the row, and after reaching such a

size as to insure continued thrift the beets are thinned to one in a place 9 to 12 inches apart.

During their growth the beets are hoed twice, cultivated twice, and irrigated sufficiently to keep the soil in a favorable moisture condition. Irrigation is by the furrow method, furrows being made in the alternate spaces between rows. Harvesting begins from the 15th to the 25th of October, and is usually finished by December 1. All the hand work is, as a rule, done by contract, Russian families taking the contracts at from $20 to $22 an acre. The team work is done by the farmers themselves. During the season of 1904 beets were bought at a flat price of $5 a ton delivered at the factories or at one of the many beet dumps along the railroads of the valley. Switches with these receiving stations occur at intervals of about 2 miles along all the railroads.

Alfalfa is usually sown with spring wheat. It is rarely pastured, being cut almost exclusively for hay. Occasionally a crop is allowed to mature for seed. Three cuttings per season are obtained, which yield from 3 to 5 tons per acre. The hay is used for feeding stock upon the farm, and, along with grain shipped from the corn-growing regions, for fattening sheep taken from the surrounding ranges. The rainfall is insufficient to injure the stacks, so the crop is stacked and left in the field until such a time as it is needed.

Irrigation for alfalfa is by flooding from small ditches run along the highest parts of the fields, from which the water is caused to spread out by putting in small dams just below the part of the field it is desired to flood. In this way very rolling fields are successfully flooded and produce good crops.

Oats and wheat are the two grains principally grown. They are both sown in the spring. If following potatoes or beets the ground is often not plowed, but simply broken up by a disk harrow and the seed sown. These grain crops are flooded in the same way as the alfalfa fields. After irrigation ceases the small furrows are plowed in so that harvesting machinery may cross them.

Self-binders are used in harvesting, the bundles being placed together in small cocks in the field. Much thrashing takes place in the field soon after cutting, but all the grain can not be handled immediately, and many fields are stacked and thrashed later as the machines make their rounds. Often it is the first of November before the entire crop has been thrashed.

The orchards of the area are plum, apple, and cherry. Seldom are the trees cultivated after coming into bearing, but they receive irrigation from small furrows and are usually sown to alfalfa. While the trees are yet young garden crops, corn, potatoes, or sugar beets are grown in the spaces between the rows. Irrigation and cultivation of these crops furnish sufficient moisture and tillage for the trees.

Doubtless better success would be had with the bearing orchards if cultivation continued, as much moisture is lost from evaporation from the uncultivated surface, and in times of scarcity of water the trees often suffer from lack of moisture.

During the last few years raspberries have become quite an important crop in the vicinity of Loveland. These are planted in rows 6 to 8 feet apart each way, and cultivated and irrigated as are the other hoed crops of the area. The winters are too severe for the vines if left uncovered, so each fall, in the latter part of October or the first of November, the vines are bent down along the row and covered to the depth of a foot or more with earth. This protects them from freezing, and in the spring, upon being uncovered, they show no ill effects from their winter's burial.

AGRICULTURAL CONDITIONS.

Generally speaking, the farming class of this area is very prosperous. Land values, owing to the introduction of the beet crop, have practically doubled in the last five years, and the crops now grown pay a good interest on this new valuation, besides giving a fair remuneration for the labor expended in their production.

The experience of recent years has demonstrated that much of the sandy loam in the western part of the area is well adapted to the growth of potatoes, so that as the growing of this crop is extended and sugar beets more and more take the place of the grain crop on the heavier soils, land values may be expected to advance still further.

Many farmers own the farms they cultivate, but large acreages are owned by capitalists who rent the land to the farmers in 80 to 320 acre tracts. A part of the crop is given as rental to the owner.

The largest estate in the valley is composed of the lands obtained by B. H. Eaton in the early history of irrigation in the valley. At present the size of the farms given to general farming ranges from 80 to 320 acres, the average size being 160 acres. The acreage in individual holdings, however, will of necessity soon be reduced for all lands suited to the growth of sugar beets or potatoes. A 40-acre farm of such lands will produce sufficient revenue for the maintenance of an ordinary family, and as development advances this will likely be the standard size of the farm. Those lands which, because of topographic features, are, at the present stage of development, only suited to the growing of grain and alfalfa, can easily be handled in 160-acre tracts, and as these crops do not require so much labor or bring in such large returns as the potato or beet crops, the farms should be larger.

Practically all the hand labor necessary in the care and harvesting of the potato and beet crops is done by contract. In the beet industry

many Russian families have found employment. As already stated, they usually contract to do the hand work for $20 to $22 an acre. Every member of the family over 7 years old is counted as a field hand, and contracts are taken on a basis of 7 acres per person. This class of labor is very satisfactory, and requires little overseeing on the part of the farmers. A more equitable system would be one based on tonnage for at least the tapping, as under the present system there is no incentive to the laborers to increase the tonnage. Under the present system it costs from $40 to $45 an acre to grow and market a crop of beets. As the beets bring $5 a ton at the factory or receiving stations along the railroads, all receipts over 9 tons per acre are profit. If only the lands suited to beets be planted and an intelligent system of rotation be followed, an average of 15 tons per acre should be obtained, thus yielding a profit of $30 an acre.

Farm laborers hired to do the team work are usually from the older farming sections of the middle West. They are a good class of laborers, and expect to become landowners or renters themselves. To get skilled irrigators is quite a problem. Whenever Mexicans can be obtained their services are satisfactory and much sought after.

The principal hand work necessary for the potato crop is in picking up and sacking the tubers. This is usually done by contract, the price ranging from 5 to 8 cents a sack. Nomadic whites are usually employed, and are not so satisfactory as the laborers procured by contract to do the beet work. As the potato picking lasts but a short time, however, and a great number of men are then needed, it is difficult to see how this condition can be bettered.

Farmhouses are of all kinds and sizes, but not infrequently are substantial structures of brick. The older settlers, who own their farms, have excellent houses and outbuildings.

Country school buildings are principally of brick, the few old frame structures being rapidly replaced by modern ones of brick.

All of the products of the valley are of good quality. "Greeley potatoes" have a reputation throughout the United States, and are justly celebrated. Large, uniform in size, and of excellent quality, they find a ready market wherever potatoes are needed.

Sugar beets grow extremely well, and have a fair average percentage of sugar. Alfalfa fields are as good as in any place the writer has seen in the United States, and produce hay of an excellent quality. Such fruits and vegetables as are grown are of good quality and flavor. Wheat and oats are of fair average quality. Occasionally rust attacks the wheat, as was the case in 1904. This greatly reduces the yield and lowers the grade. In only two years since the settlement of the country has this rust been general.

The area is traversed by a branch of the Union Pacific running from Denver to Cheyenne; the Colorado and Southern from Denver to Fort Collins and Wellington; and a branch of the Colorado and Southern, which connects Greeley and Fort Collins. These lines furnish ready railroad communication to all parts of the valley.

Greeley, Fort Collins, and Loveland are the principal towns of the valley, and furnish quite a home market for fruits and vegetables. At Greeley, which is a town of 5,000 or 6,000 inhabitants and the county seat of Weld County, is situated the State Normal School. Fort Collins, the county seat of Larimer County, is about the same size, and is the site of the State Agricultural College.

As stated in the history of agricultural development, Greeley, Fort Collins, New Windsor, Eaton, and Loveland all have beet-sugar factories, as well as flour mills, which consume a great deal of the wheat of the area. Much of the wheat, fruit, vegetable, and potato crops is shipped to outside markets, the mining towns of the State taking large quantities and paying good prices for all these products.

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