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SOIL SURVEY IN WEBER COUNTY, UTAH.

BY

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INTRODUCTION.

The area considered under the above title, situated in the northern section of Utah and mostly in Weber County, is bounded on the east by the Wasatch Mountains and on the west by Great Salt Lake. In extent it is approximately 18 miles east and west by the same distance north and south, and includes 310 square miles, or 198,400 acres, of land, of which 25,000 acres are in Boxelder County and 22,000 acres in Davis County.

This district comprises three prominent features: First, an area of sloping land adjacent to the base of the mountains and usually formed directly from them; second, a larger and more level area farther removed from the mountains which has been formed by material brought from the interior of the ranges by the action of the Weber and Ogden rivers; and, third, a very level area, the upper portion of which is a deposit of the present Great Salt Lake, which within the memory of the present inhabitants has emerged from that body of water.

The first feature is characterized by a rapid slope from the mountains, by an uneven surface, with hillocks and escarpments, the latter marking the shore lines of the ancient vacillating Lake Bonneville, and by a stony or gravelly surface. The land usually lies above the present irrigation systems and is consequently but little farmed, except where used for the production of wheat without irrigation.

The second feature is a comparatively level stretch of country, usually sandy and quite free from gravel, having a gentle slope toward the lake. It is a low, flat delta which, as shown by the character of the soil and the many abandoned river channels in different parts, has been formed by material brought down by the Ogden and Weber rivers within comparatively recent times. It is to this part that agriculture is at present mostly confined.

About Ogden, North Ogden, Plain City, Hooper, and the intermediate country the rural population is quite dense, and the farms, usually small, are devoted to an intensive system of agriculture. On the better lands peaches, pears, prunes, and plums are successfully grown. Sugar beets furnish the raw material for one large beet-sugar factory, and tomatoes are grown in sufficient quantities to supply eight canneries. Other truck crops are also grown.

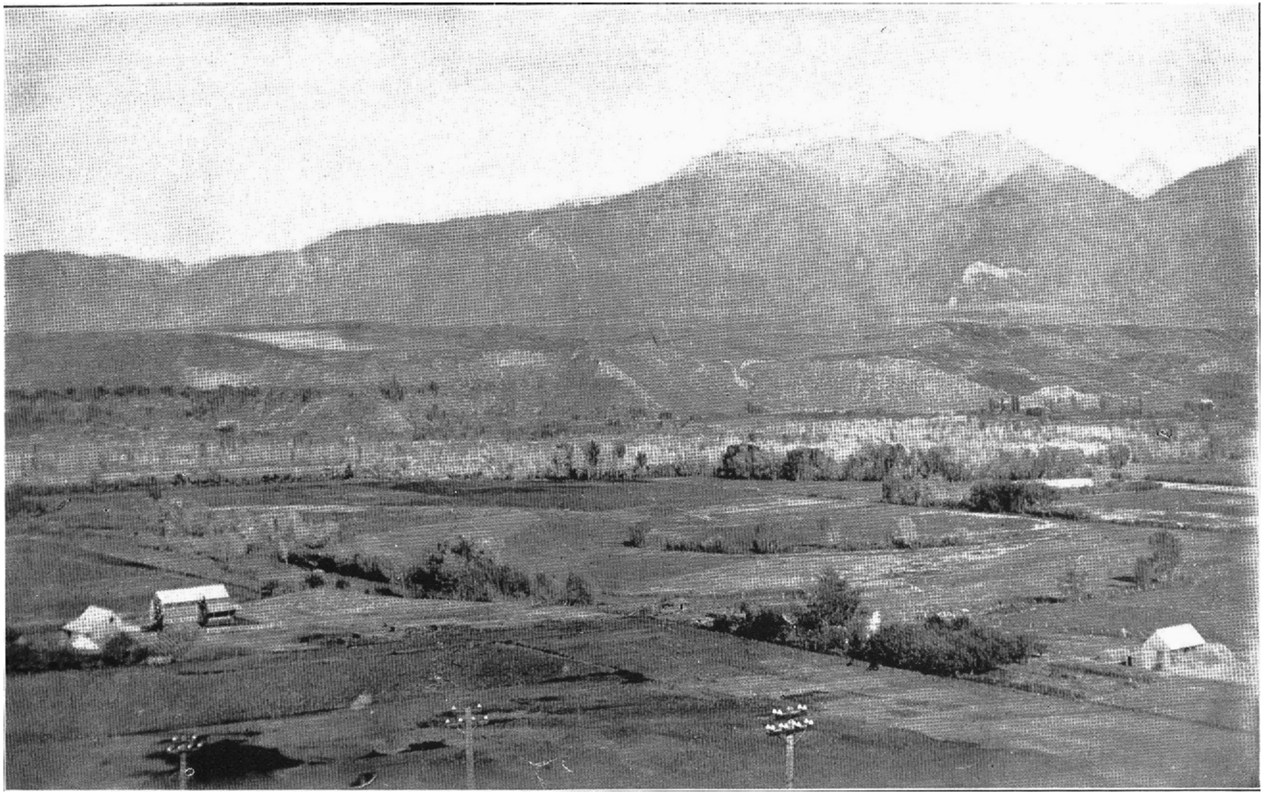
The third feature embraces about 60,000 acres, and is characterized by extremely smooth, level surfaces and intensely salty conditions and consequent lack of vegetation. Within the memory of the older inhabitants it has all been submerged by the waters of Great Salt Lake, which accounts for its salty and barren condition.

The entire area of this survey lies within the Bonneville Basin, which is a subdivision of the Great Interior Basin, and all of the land here considered has been submerged by that ancient lake except the lower portion, where in part the surface has been made since the recession of the waters. In 1899 a survey similar to this one was made in Salt Lake County, Utah, a full report of which is contained in Report No. 64 of the United States Department of Agriculture, entitled "Field Operations of the Division of Soils, 1899." The reader is referred to that report for a brief description of the Great Interior Basin and its subdivisions, a knowledge of which is quite essential to a clear understanding of some of the conditions which will be discussed in subsequent pages of this report.[1]

The Wasatch range of mountains, which borders the district on the east, extends northward to the Bear River Canyon and southward for some distance beyond Utah Lake, the total length of the range being approximately 200 miles. The mountains face the west with a bold front, rising abruptly to a height of from 5,000 to 6,000 feet above the valley, or about 10,000 feet above sea level. One remarkable feature of this range is its backbone of Archæn rock, which crops out at various places, namely, just north of Ogden, just east of Ogden, beginning north of Uinta and extending south for about 25 miles, and just south of Salt Lake City. This Archæn rock was the backbone and modeler of the Wasatch range, and stood during the rock-making period of the Paleozoic and Mesozoic times. It is considered a western spur of the protaxis of the Rocky Mountain system. Above and around this rock are represented nearly all the rocks of the Cambrian, Silurian, Devonian, and Cretaceous eras, including the Upper Cretaceous. The rocks from north of Ogden to and beyond Salt Lake City are very much flexed, not only into folds having an east and west flexure, but also into others having east and west axes superimposed on each other. From Ogden the strata bend eastward to Weber; then westward to the Great Gap, where all of the abovementioned rocks are found. Here the flexure was so great that it became disastrous to the strata, which are broken through. From the Gap southward there is a folding, the direction of its axis at the Gap being nearly due east and west, from which the outcrop extends westward and again southwestward.

North of the Uinta Mountains is the great Wasatch Eocene Basin, and south of this range is the Uinta Eocene Basin. Between the necks of these basins, east of the Gap, is quite a large area of igneous rock (trachyte), accompanying or succeeding the enormous warping and flexing which here took place. The Wasatch Eocene

[1] For a full report on Lake Bonneville, see monograph by G. K. Gilbert, U. S. Geological Survey, 1890.



View across the Weber Valley near Uinta.

This narrow valley has been cut through the old delta within comparatively recent times.

Basin and the Uinta Eocene Basin were formerly the Wasatch and Uinta lakes of the Eocene epoch; and the Great Salt Lake is a remnant of the Cretaceous sea which during that era (maximum submergence during the Upper Cretaceous) probably extended from the Gulf of Mexico to the Arctic region. This area is of great interest to the geologist as revealing a great majority of the steps of mountain making in the continent from the very beginning of geologic history to the present time. It is from this great diversity of rocks that the soils of the Ogden district have been formed through the action of weathering and transportation.

Topographically the area varies in elevation from the present level of the lake, which is slightly less than 4,170 feet above sea level, to the Bonneville shore line, which is 1,000 feet higher. Near the mountains the land slopes quite rapidly and is in many places quite uneven. Farther back it becomes quite level and slopes gently toward the lake, becoming very level near the shores of that body of water.

A very large delta occurs at the mouth of the Weber Canyon as a result of material brought down during the Bonneville period by the Weber River. It extends as far west as the railroad tracks, with a mean height of fully 300 feet above the present river channel, the river having cut down to this depth since the Bonneville period, and thus formed a narrow valley from half a mile to a mile in width, having abrupt bluffs on either side. A similar delta, though not as large, was formed by the Ogden River.

CLIMATE.

The climate is characterized by low annual precipitation, moderate temperature, moderate wind movement, low relative humidity, and abundant sunshine. According to the thirty years' record at Ogden, kept by the United States Weather Bureau, the mean annual rainfall is 14.1 inches. Of this amount, only 1.9 inches fall during the months from June to September, inclusive, and as this is the period during which crops make most of their growth, irrigation water is very essential to the practice of agriculture. The climatological data are shown in the following table:

Monthly and annual precipitation at Ogden, Utah, 1896 to 1900, and the mean for thirty years.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896	1.62	0.30	2.87	1.25	3.57	0.10	0.20	0.28	0.58	0.70	1.93	0.95	13.95
1897	1.80	2.85	2.37	1.70	.30	.98	Tr.	......	.55	1.93	1.51	2.25	16.24
1898	1.47	.19	1.82	.37	5.23	.81	.00	.30	.30	1.47	1.12	.60	13.68
1899	1.25	1.98	2.65	.53	.89	.98	Tr.	.45	......	2.45	.85	1.50	13.53
1900	.20	1.08	.10	1.93	1.10	.31	.15	.28	1.32	2.01	3.87	.18	12.53
Mean for 30 years	1.7	1.5	1.8	1.5	1.5	.6	.2	.4	.7	1.3	1.1	1.8	14.1

On the sandy uplands above the irrigation canals some wheat is grown by dry farming, but the yields are moderate, and in years of low rainfall are sometimes a failure. No other crops are profitably grown except by irrigation.

The annual precipitation in the mountains is greater than in the valleys, and it is estimated that it includes 6 feet of snow, which lingers on the mountains the greater part of the summer. This is important in relation to irrigation, because it makes the water supply plentiful throughout the season.

The annual evaporation from a free water surface in this section of the State is estimated at 8 feet. Data from the Inland Salt Company at Saltair show the evaporation from their ponds to be about 37 inches from June to September, inclusive. It should be borne in mind, however, that this is from a saturated salt solution, and that the presence of much salt lowers the vapor tension, and consequently the rate of evaporation. The evaporation from a fresh-water surface would no doubt have been much greater.

During the present year Great Salt Lake has fallen from 2 feet 7 inches above the zero mark on June 15 to 6 inches below said mark on October 15, the fall being 37 inches in four months, or exactly the same as the evaporation from the above salt ponds for the same length of time but in a different year. This fall in the water of the lake is believed to be entirely due to evaporation, but it does not represent the entire amount of evaporation. Small streams of water from the rivers and from springs, which occur around the periphery of the lake, are at all times sending water into the lake, and there is also a small amount of rainfall during this period. The record further shows that the fall of the lake from August 15 to October 15 was 24 inches, this being the time when the streams flowing into the lake become very low and the fall represents more nearly the true evaporation from the lake surface. The conditions for the two months preceding August 15 are favorable to a greater evaporation than they are for the following months, and it is safe to say that the total evaporation from the lake surface from June 15 to October 15 exceeds four feet by several inches. It must be borne in mind that the lake water contains 22 or 23 per cent of salt, which considerably lessens the vapor tension, and therefore makes the evaporation from its surface less than would be the case from a surface of nearly pure water.

HISTORY OF IRRIGATION.

The first irrigation in the State of Utah was at Salt Lake City in the year 1847. In fact, this undertaking of the Mormons in that year marks the beginning of modern irrigation in the United States. Traces of irrigation antedating that of the Mormons at Salt Lake City have been found in New Mexico and Arizona (in the systems, long since abandoned, of an extinct race of aborigines) and in southern California, where irrigation was practiced by the Mission priests. From the region of the present Salt Lake County the Mormons soon spread to various sections of the State, and as early as 1850 irrigation works were constructed along the streams in what is now Weber County. At Ogden the Lynne Irrigation Canal was constructed in 1850 by the cooperative labor of the settlers, and in a similar way the Pioneer Canal near Uinta was built in 1851; while in the following year the Uinta Central Canal was built. Following these, the Plain City Canal was built for a distance of 10 miles, the work being done by the use of shovels and wheelbarrows. The Hooper Canal, which furnishes water for the settlement of that name, was not built until 1867. Since first built it has been enlarged and its head gates placed farther up on the river, so that it now has a capacity of 150 second-feet of water at its intake and a capital stock of $80,000.

Two important canals of quite recent construction are those of the Pioneer Power Company and the Davis and Weber Counties Irrigation Company. The last named has a capital stock of $250,000, which includes the controlling stock in a large reservoir some distance above the Devils Gate on the Weber River. This canal has a capacity of 125 second-feet of water, and being the highest of the canals taken from the Weber River, its water supply is plentiful and always of the best quality. The land also which it is intended to irrigate is higher than most of the irrigated lands, and is quite free from alkali.

The canal system of the Pioneer Power Company is elaborate, and includes 35 miles of mains and laterals. The main branch is 30 feet wide on the bottom and carries a depth of 5 feet of water. The system is said to have cost the company about $100,000. It irrigates a large tract of level land lying west and southwest of Plain City. As yet not enough land is being farmed under either of the two last-named canals to utilize all the water they are capable of bringing to the lands. There are numerous other canals, the names and locations of which will be found on the maps accompanying this report. With the exception of the dates of construction and the size, the history of these canals would be largely a repetition of the above. Complete data as to the acres of land irrigated have not been obtained, but it is roughly estimated at from 35,000 to 40,000 acres, or about 20 per cent of the area which has been mapped.

That there is a large loss of irrigation water by seepage and evaporation during transit through canals and laterals from the streams to the land where it is to be applied there can be no doubt. There is a large percentage of irrigated land that is too wet during a considerable part of the year for the best results to be attained. This undue wetness comes principally from leaky canals and from over-irrigated lands. There is great need of unusual care to prevent this loss, especially in a district where land and water are both so valuable as in Weber County. It is not only a loss of irrigation water, but also a damage to many acres of land. In the vicinity of Plain City and about Hooper many acres of land which were once profitably farmed are now lying idle because of their wet condition and consequent small accumulation of alkali at the surface, just sufficient to interfere with the growth of crops. There are thousands of acres of this wet land that by a small expenditure for underdrainage could be made as valuable as the best lands in the district. The small amount of alkali which has accumulated at the surface would, upon the lowering of the water table and application of irrigation water, soon be disseminated in the lower depths of soil where it would do no harm to crops.

The canals are owned for the most part by the owners of the land under irrigation, and the only paid officer is the "water master," whose duty it is to attend to the equitable distribution of the water to the shareholders. At stated intervals along the main canals laterals are taken out to supply the farms along its course. Each lateral has a head gate, the opening or closing of which is controlled by the water master, and the size of the opening is varied according to the number of shares supplied by the lateral and the total water supply for the canal. If the water supply is plentiful, the gates usually remain with a certain-sized opening throughout the season, and the water is permitted to flow continuously. Each shareholder is entitled to use all of the water flowing in the lateral for a stated number of hours and at stated intervals, according to a schedule agreed upon at the beginning of the season.

SOILS.

The soils have been classified under eight types, in the order of the magnitude of their respective areas, as follows:

Classification of soils by areas.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Fresno fine sandy loam	86,400	43	Meadow	7,760	4
Salt Lake sandy loam	49,900	25	Bingham stony loam	5,700	3
Fresno sand	21,800	11	Jordan sand	1,900	1
Jordan loam	15,400	8	Total	198,400	100
Salt Lake loam	9,600	5			

FRESNO FINE SANDY LOAM.

This sandy loam comprises 86,400 acres, or 43 per cent of the entire survey, and is agriculturally the most important of the soil types in this area. Leaving out of consideration the land beyond the old shore line, none of which can for some time be used for any agricultural purpose, the Fresno fine sandy loam constitutes nearly two-thirds of the remaining portion. This soil is divided into two phases, the smaller and least important constituting the sloping land which lies nearest the mountains, and the larger and more important constituting the level area extending out to the old shore line of Great Salt Lake. The sloping land near the mountains usually contains small to medium gravel within 3 or less feet of the surface, and when not within this distance it is usually present at some greater depth. This portion is naturally well drained and free of injurious amounts of alkali, a fact which is well brought out by a study of the alkali and underground water maps. A considerable part of this sloping land lies above the present irrigation canals, and where thus situated it is frequently used for wheat production under dry farming. Where irrigation water is available the more gravelly parts of this land are considered the highest type of peach land, and, indeed, the greater part of this gravelly soil is admirably well adapted to the production of peaches and other stone fruits. As a rule, it is not well adapted to apples and pears, although there are small areas where the gravel is absent or far below the surface where these fruits will do well.

The larger and more level phase of this soil type is usually free from gravel, and where well drained and free from alkali it forms an excellent soil for alfalfa, grain, sugar beets, tomatoes, small fruits, general truck crops, and also for apples and pears.

The following table of mechanical analyses shows the texture of the soil for the first, third, and fifth feet in depth in various places:

Mechanical analyses of Fresno fine sandy loam.

No.	Locality.	Description.	Salts as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
	Fresno fine sandy loam, 0 to 12 inches in depth.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5046	One-fourth mile S. of C. sec. 9, T. 7 N., R. 2 W.	Dry virgin soil	0.13	1.59	.00	Tr.	4.84	32.68	33.10	22.98	4.16
5049	One-fourth mile E. of N. C. sec. 21, T. 6 N., R. 3 W.	do	.33	2.46	.00	.00	2.42	49.15	18.54	21.53	4.69
5068	One-fourth mile W. of C. sec. 27, T. 5 N., R. 1 W.	Low gravelly land, 6 per cent of gravel.	.35	3.22	1.76	1.54	2.36	28.06	34.77	22.33	5.71
5043	One-fourth mile E. of C. sec. 5, T. 6 N., R. 3 W.	Dry virgin soil	.57	2.24	Tr.	.47	.81	16.33	45.44	27.63	6.29
5069	One-fourth mile E. of N. C. sec. 21, T. 5 N., R. 1 W.	Dry farmed land	.17	2.80	.00	Tr.	1.70	22.68	43.90	22.36	6.62
5073	C. of NE. ¼ sec. 17, T. 6 N., R. 1 W.	Dry level land, 24 per cent of gravel.	.44	4.80	1.89	3.41	2.23	11.35	28.40	40.84	7.30
5053	C. of SW. ¼ sec. 24, T. 5 N., R. 3 W.	Low, salty land	1.49	4.20	.00	1.12	3.40	26.84	31.56	23.59	8.68
5036	N. C. sec. 36, T. 6 N., R. 2 W.	Wet, salty land	1.13	2.71	Tr.	4.29	12.43	30.68	17.08	22.40	9.37
	Mean		.58	3.00	.46	1.35	3.77	27.22	31.60	25.46	6.63
	Subsoils.										
5047	Sandy loam, 24 to 36 inches.	Under No. 5046	.62	4.92	.62	1.62	3.60	24.56	25.98	25.46	11.66
5048	Sand, 48 to 60 inches	do	.42	1.44	.00	2.09	20.34	55.06	13.09	2.68	3.76
5050	Sandy loam, 24 to 36 inches.	Under No. 5049	.66	3.24	.00	Tr.	2.37	58.98	16.94	11.12	7.67
5051	Sand, 48 to 60 inches	do	.40	2.47	.00	Tr.	5.82	79.38	9.97	.18	1.72
5054	Sandy loam, 24 to 36 inches.	Under No. 5053	1.17	1.93	Tr.	3.22	5.80	30.18	36.60	12.91	9.03

These analyses show that the soil is made up principally of the two finer grades of sand and silt, the sand giving to the soil its character. In clay content it is unusually low for a sandy loam, having in the surface foot from 4 16 to 9.37 per cent, with a mean of only 6.5 per cent. In the second and third foot in depth the soil usually becomes slightly heavier, a fact which is brought out in the analyses of the third-foot samples, which contain an average of 8.93 per cent of clay. Below this the soil again becomes more porous, containing less clay and more fine sand. The two samples here given are somewhat too sandy for the average conditions at 5 feet, but represent that part in which sand forms the subsoil.

A profile of this type of soil shows that the first-named phase of it is a sandy loam to a depth of 6 feet or more, with medium-sized, usually rounded-gravel occurring on an average from 18 inches below the surface downward. In many places the gravel comes directly to the surface, while in other places it is 3 feet or more below the surface.

The second phase, that is the level and larger portion of this type, shows two conditions of substratum. About half of it consists of 4 feet of fine sandy loam, underlaid by sand to an undetermined depth, while the remainder is fine sandy loam for 6 feet or more in depth.

A knowledge of the character of the underlying stratum is of the utmost importance in relation to soil drainage. Conditions are here found which are very favorable to underdrainage. The gravelly portion of this type of soil has abundance of slope and is always well drained. If the lower portion had an equal slope it would also be well drained. However, it is a large tract of level land which has very few avenues, in the form of streams or deep cuts, by which the ground water can escape. As a result, practically all of the water which reaches this land, in excess of that which is evaporated from the surface of the ground and that which is transpired by the vegetation, is added to the gravitational ground water, thus raising the level of the ground-water table. The excess of water added by irrigating for a long series of years has raised the water table until it is now dangerously near the surface in many places, as shown by the underground-water map. The elevation of the water table too near the surface is also accompanied by an accumulation of alkali at the surface; and the combined effect of these two agents has rendered many acres of otherwise valuable land unfit for the production of any kind of agricultural crops.

The lower portions of this type of soil in their virgin state are very salty in the lower depths. This is accounted for by the fact that the land has been submerged by the waters of the lake within comparatively recent time. Upon subsidence, the salty water of the lake would naturally leave the soil heavily charged with salts. A discussion of the alkali and the ground-water problem will be taken up in subsequent pages.

SALT LAKE SANDY LOAM.

This type of soil, while representing nearly 50,000 acres of land or one-fourth of the whole district, is of practically no value for agricultural purposes, because of its location and extreme saltiness. It is all recent lake bottom, and as late as 1885 was practically all submerged by the salty water of Great Salt Lake. All previously constructed maps of the district show this portion as a part of the lake. The present survey moved the shore line westward to its true position in October, 1900, thus adding to the district about 60,000 acres of land which has previously always been mapped as water. In 1868 the water was 14 feet above the water level of 1900, and at that time submerged considerable land that was shown as such on the older maps.

This type of soil is a sandy loam for 18 inches in depth, below which is usually fine sand. In places it is underlaid at from 1 to 2 feet by beds of mirabilite, that is, sodium sulphate containing water of crystallization which is thrown out of solution in the lake when the water reaches a critical temperature, and often heaped upon the shores in considerable abundance, where it is afterwards covered over by sand or soil.

The ground-water map shows that, under the greater portion of this type, water stands at 3 feet or less from the surface. Near the old shore line it is sometimes 4 feet below the surface. The unaided eye is unable to detect any slope in the land; and, indeed, it is nearly level, having a surface as smooth as a house floor. There is a slight fall, usually of only a few inches to the mile, toward the lake.

As shown on the alkali map, this land is all very salty, containing from 3 to 10 per cent of salt in the upper 6 feet. It is estimated that there are not less than 50,000,000,000 pounds of salt in the first 6 feet of soil over this portion of the district, or sufficient at the rate of 20 tons to the car, each car 30 feet in length, to make a continuous train 7,100 miles long, or twice the distance from New York to San Francisco.

If the lake continues to recede, two or three generations hence may see this land comparatively free from salt, and some of it used for agricultural purposes.

FRESNO SAND.

Fresno sand is third in point of extent and second in agricultural value. It embraces 21,800 acres, or 11 per cent of the entire area, and like the Fresno fine sandy loam it occurs in two phases—an elevated portion with considerable slope, frequently containing gravel and always well drained, and a low, level portion always free from gravel and sometimes troubled with alkali and wetness. The lower portion extends from Hooper in a northeasterly direction to the Weber River as a narrow strip, with a number of isolated areas to the east as a chain running in the same direction. This portion has been largely under irrigation for many years by the Hooper and Wilson canals, and in places has been greatly damaged by the accumulation of alkali and seepage from overirrigation and from leakage from the canals. The larger sloping area was not irrigated until the construction of the Davis and Weber counties canal a few years ago. It is all well drained and free from injurious amounts of salts. At present about 5,000 acres are under irrigation, and of that portion above the canal considerable is used for wheat under dry farming.

The following table of mechanical analyses shows the texture of this type of soil:

Mechanical analyses of Fresno sand.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
	Fresno sand, 0 to 12 inches in depth.		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5059	NW. C. sec. 35, T. 5 N., R. 2 W.	Virgin sandy soil.	0.31	1.43	0.00	0.96	5.32	53.15	31.71	3.78	2.87
5056	SW¼ sec. 13, T. 5 N., R. 3 W.	Sandy truck soil.	.29	2.06	Tr.	4.14	12.03	55.20	18.51	3.91	3.28
5066	N. C. sec. 36, T. 5 N., R. 2 W.	Virgin sandy soil.	.12	1.55	1.50	23.08	22.27	23.44	15.23	7.39	4.69
5065	One-fourth mile east of C. sec. 14, T. 5 N., R. 2 W.	Gravelly sandy soil.	.10	2.39	5.40	13.50	9.77	13.54	15.78	32.76	6.53
			.20	1.86	1.72	10.42	12.35	36.33	20.31	11.96	4.34
	Subsoils.										
5060	Sandy loam, 24 to 36 inches.	Under 5059	.34	1.45	0.00	1.42	2.83	35.21	40.11	13.47	5.11
5061	Sandy loam, 48 to 60 inches.	do	.22	4.03	.71	5.22	5.52	21.60	12.29	41.52	10.34
5057	Sand, 24 to 36 inches.	Under 5056	.37	3.04	Tr.	3.49	10.41	58.89	16.54	2.66	4.72
5058	Sandy loam, 48 to 60 inches.	do	.52	3.68	.47	3.65	6.38	41.30	15.04	19.40	10.48
5067	Sandy loam, 24 to 36 inches.	Under 5066	.18	1.63	Tr.	1.96	10.74	9.45	23.58	33.80	8.21

The analyses show that while this type of soil contains about the same amount of clay as the Fresno fine sandy loam, it is lower in very fine sand and silt and much higher in coarse and medium sand. It is this loose, incoherent texture, together with its position and natural drainage, that makes it especially well adapted to fruit and truck crops. A profile of this type of soil shows it to be a sand, continuing in about the same texture for an undetermined depth, with gravel occurring in the higher portion both east and west of Riverdale, sometimes coming directly to the surface and at other times being at a considerable distance beneath. The gravel is from small to medium in size and does not interfere with cultivation.

In the vicinity of Hooper this type of soil is used for sugar beets, tomatoes, peaches, plums, prunes, and pears. When the ground water is kept 4 feet or more below the surface all of these crops do well, but with water nearer than 4 feet fruit trees generally are a failure and alkali not infrequently appears near the surface. About Hooper there are small areas where black alkali has accumulated in sufficient amounts to be harmful, although the total salt content is not high. The higher portion is well drained, free of salts, and, while it is at present used only for tomatoes, sugar beets, and alfalfa, a large part of it is also admirably adapted to general fruit culture.

JORDAN LOAM.

This type of soil ranks fourth in point of extent and third in agricultural value. It embraces 15,400 acres, or about 8 per cent of the entire area, and takes its name Jordan from its similarity to the loam described under that name in Salt Lake County in 1899.

The table following shows the mechanical analyses of Jordan loam:

Mechanical analyses of Jordan loam.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5062	One-fourth mile E. of N. C. sec. 16, T. 5 N., R. 2 W.	Virgin soil	2.75	6.82	4.00	4.46	2.18	8.10	16.64	41.91	13.63
5074	NE. C. sec. 8, T. 6 N., R. 1 W.	Sloping land	.98	4.75	Tr.	.54	.94	2.00	15.22	56.27	18.45
	Subsoils.										
5063	Loam 24 to 36 inches	Under 5062	.74	6.98	8.44	10.88	4.86	7.96	20.72	29.58	10.76
5064	Loam 48 to 60 inches	......do	.49	3.52	1.28	2.46	1.29	2.52	27.14	45.52	14.62
5075	Clay loam 24 to 36 inches.	Under 5074	1.17	5.69	Tr.	1.50	.65	2.06	9.29	46.57	32.81
5076	Clay loam 48 to 60 inches.	......do	.97	6.06	Tr.	.93	.72	3.72	10.84	48.67	27.95

The above table shows the results of mechanical analyses for the first, third, and fifth foot in depth for this type of soil. The average conditions show a loam soil continuing to 6 feet or more in depth, but in places it is underlaid by sand below 2 feet in depth, while in other places it is underlaid at the same depth by a substratum of clay several feet in thickness. This type of soil occurs in more or less isolated bodies scattered throughout the district, and usually occupies the lower levels or slight depressions.

The largest and most important body of this type occurs in the vicinity of North Ogden, where a considerable part of it is under irrigation. In this vicinity the land is used for grain, alfalfa, and for pears and apples. It is well adapted to all of these crops when well drained, but where the water gets within 4 feet of the surface it will not do well in apples or pears, although grain will do well so long as alkali does not occur near the surface. This type of soil is not suited to the stone fruits.

The areas scattered over the remainder of the district are poorly drained and generally contain considerable alkali. They are frequently used for pasture, but are seldom cultivated. All of this type of soil lies so that it can be irrigated, and when reclaimed will make excellent land for grain and alfalfa.

SALT LAKE LOAM.

This is an unimportant type of soil which occurs principally in the northwest corner of the Ogden district. It is recent lake bottom, very salty, and absolutely bare of vegetation. It differs from the Salt Lake sandy loam described above only in point of texture, being largely silt with a somewhat larger percentage of clay. It is the finer material brought down by the combined action of the Weber River, which formerly emptied into the lake in this vicinity, as shown by several abandoned river channels, and the Bear River, which empties into the lake some distance beyond the northwest corner of this district.

MEADOW.

Meadow embraces 7,700 acres, or about 4 per cent of the Ogden district, and occurs along the present river courses or in their vicinity. It is usually wet land, a considerable part of which is subject to occasional overflow from both the Ogden and Weber rivers. It occurs in two phases, a gravelly portion along the present rivers, either bare or covered by a growth of small maples, willows, and other water-loving trees, and a larger and more important area lying as a low, level body of black soil northwest of Ogden. In its virgin state this latter phase is usually covered with grass, although in some places it is covered with maple and willows. The soil is black or dark colored, due to the large amounts of organic matter which it contains. It varies from a light sandy loam to a heavy loam, and is usually underlaid at 3 feet or more in depth by coarse river wash gravel.

The following table gives the texture of the more sandy part of this soil, as determined for the first and third foot in depth by mechanical analyses:

Mechanical analyses of meadow.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5071	One-fourth mile E. of C., sec. 20, T. 6 N., 1 W.	Black river bottom, 0 to 12 inches.	0.48	5.64	Tr.	3.42	4.28	20.89	28.07	32.19	5.70
5072	Sandy loam, 24 to 36 inches.	Under 5071	.50	6.11	0.91	2.83	3.24	14.70	26.83	39.08	6.50

This soil is free from injurious amounts of alkali, but is usually more or less wet. At the time of the survey there was none of it in which the water table was more than 6 feet below the surface, and along the railroad tracts northwest of Ogden there was a considerable area where the water came within 3 feet or less than 3 feet of the surface. This land needs drainage, and when properly drained its lighter parts make good land for truck, celery, and small fruits, its heavier parts being admirably adapted to cereals and forage crops.

BINGHAM STONY LAND.

Bingham stony land includes about 5,700 acres, or 3 per cent of the district, and occurs as rough land adjacent to the base of the mountains. It lies above all irrigation canals and is too stony to be cultivated. It takes its name from similar land previously described in Salt Lake County, Utah. It consists of a mass of broken rock and bowlders interlaid with fine material, the rock usually coming directly to the surface or projecting some distance above it. This grades down either to bed rock or broken rock in the lower depths. It is adapted to some extent to mountain pasturage.

JORDAN SAND.

Jordan sand previously described in Salt Lake County, Utah, includes about 1,900 acres, or 1 per cent of the area surveyed, and occurs usually as a loose, incoherent sand, frequently blown into dunes and either bare of vegetation or covered by rabbit bush. On account of its position, it is not cultivated. Where water is available it could be leveled and used for very early truck crops, but would probably need the application of manure to supply the soil with humus and make it more retentive of moisture.

The following mechanical analysis shows the texture of the sand, which is made up largely of medium, fine, and very fine grades of sand, there being very little silt and but a small percentage of clay:

Mechanical analysis of Jordan sand.

No.	Locality.	Description.	Salt as determined in mechanical analysis.	Loss on ignition.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5070	NE. sec. 31, T. 6 N., R. 1 W.	Dunes, 0 to 12 inches.	.11	.80	Tr.	3.84	12.76	60.02	18.09	1.33	3.61

HARDPAN.

In certain areas, shown on the soil map by hatchings, a hardpan occurs as a thin stratum, usually from 18 inches to 3 feet below the ground surface. This hardpan, usually from 2 to 4 inches thick, but sometimes more, occurs chiefly in the vicinity of Plain City, and particularly on alkali lands. It marks no change in the texture of the soil, for it occurs more frequently in the sandy loam, and the soil particles of the hard stratum are the same in both size and proportion as they are in the loose soil above and below it. This hard stratum is formed by an accumulation of lime carbonate, at this particular zone in the soil, sufficient in quantity to cement the soil grains together, just as lime is used to cement the grains of sand in the formation of mortar and plaster.

Under ordinary conditions, it is quite pervious to water and to the roots of plants, but when dry it is quite hard and difficult to dig. When moistened with water and soaked for a while it softens considerably, but does not disintegrate to any appreciable extent. It effervesces freely with hydrochloric acid and falls apart into a sandy loam.

As would be expected, the subsoil immediately below the hardpan is quite moist throughout the season, while above it the soil is quite dry during the summer months. The soil above the hardpan is usually free from excessive quantities of alkali, while below the hardpan the salt content is very much greater.

This type of hardpan has been previously encountered and described, but data adequate to explain its mode of occurrence at from 18 inches to 3 feet below the ground surface have been previously wanting. In view of data collected during the present season on the vertical distribution of alkali within the soil, as brought out under the head of "Alkali," together with certain experiments, carried on in the laboratory under the direction of Dr. Cameron, showing the effect of one salt upon the solubility of another when the two are brought together in water, as published in another part of this report, the following possible explanation of its occurrence is given.

The presence of soluble sulphates or chlorides will render the calcium carbonate more soluble than in pure water; but the major part of the calcium carbonate under soil conditions will go into solution as the hydrogen carbonate, more familiarly known as the bicarbonate. This salt (the calcium hydrogen carbonate) is more soluble than the normal carbonate, not only in pure water but in aqueous solutions of salts, such as the chlorides and sulphates. It is thus evident that calcium carbonate, which is but very slightly soluble by itself, can nevertheless be dissolved and transported by soil waters containing carbon dioxide (thus forming the more soluble hydrogen carbonate), especially when soluble chlorides or sulphates are present. But since the calcium salt enters the soil solutions almost entirely as the hydrogen carbonate, even when considerable amounts of chlorides or sulphates are in the solution as well, it is evident that the soil atmosphere and the proportion of carbon dioxide it contains must be considered. Calcium hydrogen carbonate is not a very stable salt, and under conditions of stable equilibrium the amount which can be dissolved or will remain in solution is dependent upon the proportion of carbon dioxide in the atmosphere in contact with the solution.[1] The atmosphere of the soil, as has been shown by various investigators, is usually comparatively rich in carbon dioxide; always richer, certainly, than the atmosphere above the soil.

When water comes upon the surface of the soil from rain, flooding, or artificial irrigation, it passes down through the larger soil spaces rather quickly, more or less completely filling the soil spaces and dissolving not only the more readily soluble salts with which it comes in contact, but to a large extent the gases of the soil atmosphere as well. This solution in its passage downward through the soil and afterwards can and will dissolve calcium carbonate if it come into contact with this substance, this salt going into solution as the hydrogen carbonate until the solution becomes saturated with respect to it, under the conditions which exist in the solution.[2] When evaporation and desiccation recommence at the surface the soil solution, which had passed downward rapidly through the larger soil spaces, now begins to rise again, but slowly, and through the finer capillary spaces and contact films on the surfaces of the soil grains. As this process continues the larger interstitial spaces in the soil, which had become filled with the solution, are again emptied of it, leaving room for the re-creation of a soil atmosphere. Into these spaces will evaporate some water vapor and some of the dissolved gases from the soil solution, notably the carbon dioxide. As this last substance escapes from the solution to the atmosphere the equilibrium between the dissolved carbon dioxide or carbonic acid and the calcium hydrogen carbonate will be disturbed. This latter unstable salt will partially break down to liberate carbon dioxide and restore the equilibrium. At the same time will be formed some of the less soluble normal calcium carbonate, which will in consequence precipitate from the solution, coating the less soluble soil grains, more or less filling up the soil spaces, and modifying the texture and structure of the soil at that point.

The deposition of calcium carbonate at any point, having once commenced, probably facilitates further deposition at that same point for two reasons. While calcium hydrogen carbonate is, as stated above, to be regarded as an unstable compound in solutions in contact with an atmosphere containing less than a certain definite proportion of carbon dioxide characteristic for any given concentration of this salt, nevertheless, as Treadwell and Reuter have shown, an unstable con-

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[1] In this connection, see paper by Dr. Cameron, elsewhere in this report.

[2] The maximum amount of calcium carbonate which can possibly be dissolved by water under the most favorable conditions is probably, as Dr. Cameron has pointed out elsewhere, very large, and has never been determined even approximately. Witness in this connection the large amounts of this substance found in waters from some subterranean springs, etc.

dition of equilibrium can be realized with this particular bicarbonate and a solution may be obtained containing an abnormal amount of this salt. In a somewhat special sense the solution may be regarded as supersaturated with respect to this salt. Dr. Cameron has shown that in all probability it is the bicarbonate of calcium and never the normal carbonate with which one has to deal in natural waters and ground solutions. By long standing, shaking, etc., or by coming in contact with solid calcium carbonate this unstable equilibrium is displaced, carbon dioxide is given off, and normal calcium carbonate precipitated. Thus, if supersaturated solutions of calcium hydrogen carbonate in the soil come in contact with a deposit of calcium carbonate, it may be expected that some of the dissolved salt will be promptly decomposed, with a further precipitation of the normal carbonate.

Again, as stated above, the deposition of calcium carbonate on the soil grains tends to modify the texture or structure of the soil; and it is in just such places of contact between soils of different texture that the escape of carbon dioxide from the soil solutions to soil atmosphere is probably most effective and, in consequence, the deposition of the normal calcium carbonate greatest.

It has been suggested by Mr. Means that the diurnal change in barometric pressure may play a considerable part in the deposition of lime carbonate hardpan in the soils of arid regions. According to this view an increase of barometric pressure will be accompanied by a forcing of the atmosphere above the soil down into the soil and a consequent dilution of the carbon dioxide in the soil atmosphere. Successive increases and decreases of the barometric pressure may be regarded as in effect actually pumping out the carbon dioxide in the upper portion of the soil. In the dry soils of arid regions this aeration process may be regarded as probably effective to depths of from 3 to 6 feet, and the consequent dilution of the carbon dioxide in the soil atmosphere accounts for the formation of the calcium carbonate hardpan at that general depth.

In many cases it is probable that the presence of other more soluble salts has had an important part in the formation of calcium carbonate hardpan. It has been shown by Cameron and Seidell[1] that the solubility of calcium carbonate in sodium sulphate solutions steadily increases with concentration of the latter salt, but that in sodium chloride solutions it rises to a maximum in a solution containing about 10 to 12 grams sodium chloride per liter, and as the concentration with respect to sodium chloride increases beyond this point the solubility of the calcium carbonate decreases.

Should the ground solution in its slow rise through the capillary spaces in the soil reach a concentration with respect to soluble chlo-

[1] See paper by Cameron, elsewhere in this report.

rides beyond that at which the maximum amount of calcium carbonate dissolves, this latter salt would commence to separate from the solution. The presence of much soluble sulphates in the solution would tend to retard this precipitation of solid calcium carbonate, although on the other hand the presence of calcium sulphate or gypsum would much hasten it.

It is a matter of common observation that the calcium carbonate hardpans containing gypsum or more soluble salts, and therefore presumably deposited in large measure from solutions containing much soluble material, are apt to be less compact and dense and more pervious to water and plant roots than lime carbonate hardpans, which are presumably deposited mainly by the loss of carbon dioxide from an aqueous solution of the bicarbonate of lime.

As the lime carbonate hardpan is formed it retards or cuts off the rise of the waters below it to supply the place of that which has evaporated from the surface of the soil. Thus the rise of alkali from the soil below is checked by the hardpan. The addition of water to the surface soil may carry the surface alkali quickly down and into or below the hardpan softened by the water. On the other hand, this softening of the hardpan may allow the escape of the salts in the soil beneath, by capillary action, before the hardpan has had time to dry out, harden, or become compact again, so the effect of added water becomes a most important matter in connection with hardpan and is dependent upon the special conditions that obtain in any given case, such as the texture of the soil, the compactness of the hardpan, the amount of water used, the amount of soluble salts in the lower soil layers, etc.

By some, the wet condition of the soil and the rise of alkali on irrigated land are attributed to the presence of this hardpan, but so far it has not been found sufficiently dense to be impervious to water, and can, therefore, have had very little if anything to do with the rise of the alkali and ground water. When kept wet it becomes soft, and is hardly noticeable, except for the whitish color of the soil in that particular stratum, due to the abundance of lime. When dry it is very hard and difficult to dig, and is a serious obstacle in excavating ditches and post holes.

WATER SUPPLY.

The irrigation water supply for Weber County is exceptionally good, notwithstanding the fact that there is often a shortage in the water supply toward the close of the irrigation season. The chief source of the supply is from the Weber and Ogden rivers, with smaller amounts from North Ogden Canyon and from springs which occur along the base of the Wasatch Mountains. The district is also well supplied with flowing artesian wells, some of which are large enough to irrigate considerable land. The water from the many wells, if properly utilized, would in the aggregate irrigate hundreds of acres, but as yet it is very little used for this purpose.

The following table, giving the estimated monthly discharge of the Weber and Ogden rivers above where the irrigation canals are taken out, is taken from F. H. Newell's report, Progress of Stream Measurements, published by the United States Geological Survey, 1889, and is based on measurements for the year 1898:

Estimated monthly discharge of Ogden and Weber rivers at Ogden and Uinta, respectively.

Month.	Mean discharge in second-feet.		Total in acre-feet.		Total for Weber and Ogden.	Precipitation in inches, 1898.
	Ogden.	Weber.	Ogden.	Weber.		
1898.						
January	65	271	3,997	16,663	20,660	1.47
February	79	320	4,387	17,772	22,159	.19
March	90	392	5,534	24,103	29,637	1.82
April	267	1,329	15,888	79,081	94,969	.37
May	297	1,606	18,262	98,750	117,012	5.23
June	102	752	6,069	44,747	50,816	.81
July	35	291	2,152	17,892	20,044	.00
August	33	92	2,029	5,657	7,686	.30
September	31	171	1,845	10,175	12,020	.30
October	32	302	1,968	18,569	20,537	1.47
November	32	439	1,904	26,122	28,026	1.12
December	32	416	1,968	25,579	27,547	.60
The year	91	532	66,003	385,110	451,113	13.68

Drainage area, 360 square miles, Ogden River.
Drainage area, 1,600 square miles, Weber River.

This table of discharge is for a year when the rainfall at Ogden was below the normal, and we will assume, therefore, that the figures here given are not greater than the normal discharge should be. It will be noticed from this table that about half of the annual discharge occurs during the two months of April and May, and this in spite of the fact that the mean monthly precipitation during this time is no greater than it is for the five preceding months. The precipitation for the preceding months, November to March, inclusive, especially in the mountains, is chiefly in the form of snow, and therefore does not find its way into the streams until it melts. It is during April and May that most of this snow melts, and hence the large discharge of the streams during that period. In Weber County there is little demand for irrigation water at other times than during the five months from May to September, inclusive.

It has been previously stated that the area of the district under irrigation probably does not exceed 40,000 acres. It will be of value, therefore, to compare this area with the water supply according to the table, and see what are the possibilities of increasing the area of irrigated land. On the basis of 2½ acre-feet of water for each acre of land, which is usually considered a liberal allowance, 6 inches of water would be required for each of the five months from May to September, inclusive. On this basis we find that the combined water supply of the two rivers during May is sufficient to irrigate 234,000 acres, for June 102,000 acres, while in July it is sufficient for only 40,000 or just about present irrigated area. In August the supply is very low, and is only sufficient for 15,000 acres, or less than half of the present area. In September the water supply shows a slight rise, but is still inadequate for the present irrigated area. It is seen, therefore, that during the irrigation season there are two months when the water supply far exceeds the demand, one month when it is just sufficient, and two months when there is a shortage. Taking the five months, the total water supply is adequate to irrigate 83,000 acres, or twice the present area, and could the water supply for the whole year be saved it would be sufficient to irrigate 180,000 acres. This assumes no loss by evaporation and seepage during the transit of the water from the streams through canals and laterals to the land, a condition which is far from realized in practice. Loss from this source is not absolute nor permanent, since seepage usually plays the most important rôle, and waters escaping as seepage ultimately find their way, in part, back to the river beds and are again taken out by lower irrigation systems.

These figures bring out an important fact which has long been recognized by the more enterprising men of the community, that is, the necessity for some means of impounding the water that goes to waste just prior to and during the early part of the irrigation season, in order to tide over periods when the natural flow of the river is low, and in order also to increase the acreage under irrigation.

A large reservoir has already been constructed some distance up on the Weber River and a movement is in progress to construct another on the Ogden River. The water from both the Weber and Ogden rivers is of excellent quality for irrigation purposes, that is, it contains so small an amount of salts that it can be used with no fear of injuring the soils by stocking them with alkali, which sometimes occurs in the case of irrigation waters heavily charged with salts.

The following chemical analyses, made under the direction of Dr. Cameron, show the salts in samples of water taken from the Ogden River at Ogden and from the Weber River at the mouth of the Weber Canyon. These samples were taken in October, 1900, when the flow was quite low, but when it had increased slightly, due to recent rains. The samples no doubt show more salts than would be found in the early part of the irrigation season when the water supply is more abundant.

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Amount and kind of salts in river water.

Source of water.	Salts per 100,000 parts of water.	Percentage composition.							
		Ca.	Mg.	Na.	K.	SO_4.	Cl.	CO_3.	HCO_3.
Ogden River at Ogden	44.4	12.16	4.50	8.56	3.15	4.28	17.58	2.03	47.74
Weber River at mouth of canyon	45.5	13.40	4.62	6.16	3.08	6.81	10.11	3.96	51.86

Theoretical combination of acids and bases.

Source of water.	Percentage of combined salts.							
	$CaSO_4$.	$Ca(HCO_3)_2$.	$Mg(HCO_3)_2$.	$MgCl_2$.	KCl.	NaCl.	Na_2CO_3.	$NaHCO_3$.
Ogden River	5.86	42.80	....	17.56	5.86	2.93	3.60	21.39
Weber River	9.45	43.51	13.19	9.89	5.72	....	7.03	11.21

Water taken from the Plain City Canal near its terminus in September was found to contain 56 parts of salts in 100,000 parts of water, of which 36 parts were bicarbonates. Early in October similar determinations were made of the water in the Hooper Canal and in the Davis and Weber Counties Canal. The former contained 51 parts of salts, of which 40 parts were bicarbonates, and the latter 52 parts, of which 34 parts were bicarbonates. None of these determinations show any appreciable amount of carbonates.[1] Late in October the water at the mouth of Weber Canyon was found to contain 47 parts of salts, of which 34 parts were bicarbonates. In contradistinction to the other determinations, this one contained 3.7 parts of carbonates. These determinations show that on an average 70 per cent of the salts in the irrigation water occurs as bicarbonates. The analyses given above show that the salts in the water from the Ogden River contained 64.19 per cent of bicarbonates, while the salts in the water from the Weber River contained 67.91 per cent of bicarbonates. Lime is the most abundant of the bases, and upon combining the salts it gives about one-half of the total in the form of lime salts. Lime salts in irrigation waters when present as sulphates and carbonates are not harmful, but, on the contrary, lime in small amounts is stimulating to plant growth.

APPLICATION OF WATER.

The water supply is of good quality and abundant if the distribution could be controlled. There is great need for storage reservoirs in order to extend the present area of cultivated lands. This fact is realized by the people and is being acted upon by them. The canal systems are plentiful, but in order to increase the irrigated areas they

[1] This is due probably to the high degree of dilution of the salts and to the fact that these salts are mainly lime bicarbonate, which is shown in Cameron's paper (p. 431) to be very stable.

need enlargement and extension rather than the addition of new canals. Every additional canal offers a new avenue for the loss of water, and it is advisable to reduce the long canals to a minimum number. The main canals of the district aggregate, approximately, 130 miles in length, while the laterals probably aggregate considerably more than this. With this great length in canals and laterals, running for the most part over deep, sandy loam or sandy soils, the loss by leakage must be very great. No measurements were made to determine what this loss is, but it is probably fully half of the water that is taken into the head gates of all the canals. In other words, only half of the water taken into the canals reaches the fields to which it is to be applied. A realization of the enormous loss of valuable irrigation water from this source alone should insure far greater care in the location and construction of the main irrigation canals. This is an engineering problem, and where the soils are of such a character as to make it impossible to construct canals that will not lose large amounts of water by leakage the value of both water and land will often justify the expenditure of money for the construction of water-tight pipe lines or cement ditches to carry the water to the land without loss.

Another source of loss of irrigation water, especially in irrigating sandy lands, is from overirrigating or applying more water than the soil is capable of holding, a large part of it thus going into the drainage and doing no good to the irrigated crops. This loss by seepage from lands, as well as from canals, is not only a loss outright, but oftentimes damages either the land irrigated or other land lying at lower levels.

In the case of leaky canals, it is suggested that their sides and bottoms be puddled when in a wet condition by dragging with a plank, by driving sheep or goats through them, or by introducing waters charged with sediments which, upon settling, will fill the pores of the soil in the bottom of the canals.

In the case of irrigating sandy soils or sandy loams underlaid by gravel, it is advisable to run the water for short distances, quickly covering the surface in the case of the flooding method, and then turning the water to adjacent areas so soon as it has wet the soil to the requisite depth, which usually need not exceed 4 feet.

A study of the underground water map brings out the important fact that under the greater part of the irrigated lands the water table is within less than 6 feet of the surface. On account of this state of affairs too much stress can not be placed upon the necessity for great care in preventing a further rise of this ground water by further leakage from canals or from the overirrigation of lands. The advisability of State legislation to compel the ditch owners to guard against undue seepage and to prevent property owners from using excessive amounts of water in irrigation is sufficiently obvious to need no comment.

Property owners whose lands are thus damaged should be enabled to recover damages in the courts.

As a rule, the canals are the joint property of the owners of the irrigated land, each man having shares in proportion to the amount of land owned. Anyone not holding shares can rent water rights from those who own more shares than they have personal need of. The water is generally apportioned among the landowners in proportion to the stock they control. The exact amount of water used per acre in this district has not been determined, but the average for the State of Utah is estimated at about 1 second-foot for each 100 acres. There is generally an abundance of water in the canal, but when there is any deficiency all suffer alike in a reduced supply.

UNDERGROUND WATER.

The underground-water map shows the depth to standing water at the time the survey was made. Notwithstanding the fact that it was made during the driest part of one of the driest years on record, when both rainfall and the irrigation supply were very short, it shows that under a large portion of the district, ground water stands very close to the surface and that as the acreage of irrigated land increases greater care will need to be exercised to prevent a further rise of this ground-water table. Under about one-half of that portion of the district within the old shore line, the ground water was found at from only 3 to 6 feet below the surface, and in certain areas northwest of Ogden and near North Ogden, especially on the meadows and Jordan loam soil, it was found to be within less than 3 feet of the surface. None of the last-named areas are farmed, but are used chiefly as meadow land. While the shallow-rooted cereals, such as wheat, oats, barley, and the grasses, may do well with the ground water at only 3 feet from the surface, the deeper-rooted alfalfa and the fruits in general will not do at all well with the ground water so near the surface. If alkali is present it is almost certain to accumulate at the surface to such an extent as to prevent the growth of crops.

For alfalfa and the fruits the ground water should not be allowed nearer than within 4 feet of the surface, while for trees, especially the stone fruits, it should be even farther below the surface if good results are to be expected. There is great need of underdrainage for this class of lands. Money thus expended will bring sure and lasting returns, provided drainage is installed in a thorough and economical manner. This subject will be discussed in subsequent pages.

There is a large body of land between the Weber River and Little Mountain, under which the water table occurs at from 6 to 10 feet below the surface; but this land is as yet mostly in its virgin state, and if a large part of it should be brought under cultivation the water table would undoubtedly rise. The land is quite level and the lower depths of the soil are quite heavily charged with alkali. It is therefore incumbent upon the owners of this tract of land to guard against too great a rise in the ground water, in case a considerable part of this land is placed under irrigation, the probability of which is indicated by the present canal systems.

The large level area of recent lake-bottom soil usually has standing water at from 2 to 3 feet below the surface, becoming even less than this as the shore is approached.

ALKALI IN SOILS.

The following table gives the composition of the alkali in the crusts from a number of localities, as determined under the direction of Dr. Cameron of the laboratory of the Division of Soils:

Chemical composition of crusts from Weber County (percentage of bases and acids).

No.		Ca.	Mg.	Na.	K.	SO_4.	Cl.	CO_3.	HCO_3.
		P. ct.	*P. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per cent.*
5027	Crust 5 miles west of Ogden	Tr.	Tr.	36.94	1.75	0.69	34.15	13.99	12.48
5028	Crust 2 miles north of Hooper		Tr.	35.73	2.30	8.73	15.99	21.65	15.60
5029	Crust 2 miles east of Hooper	Tr.	Tr.	35.80	3.30	10.05	46.89	2.44	1.52
5030	Crust 2 miles SW. of Plain City	Tr.	0.44	33.56	2.11	8.33	34.34	2.44	18.78
5031	Crust 5 miles SW. of Ogden	Tr.	Tr.	36.34	1.37	13.98	39.19	3.79	5.33
5032	Black alkali crust SW. of Hooper	Tr.	Tr.	36.78	.98	12.52	39.70	4.51	5.51
5033	Crust on lake bottom SW. of Hooper	0.36	1.01	34.96	2.37	6.09	54.87		.34
5034	Crust from escarpment SW. of Hooper	2.29	.95	31.63	2.55	17.32	44.72		.54
5035	Dark crust east of Hooper	Tr.	Tr.	34.58	3.99	11.69	35.15	7.63	6.96
	Mean	.30	.27	35.15	2.30	9.93	38.33	6.27	7.45

The theoretical percentage combination of the above analyses is given in the following table:

Theoretical percentage combination.

No.		Per cent soluble.	$CaSO_4$.	$MgSO_4$.	Na_2SO_4.	NaCl.	KCl.	Na_2CO_3.	$NaHCO_3$.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*Per cent.*
5027	Crust 5 miles west of Ogden	25.55			1.02	53.72	3.34	24.74	17.18
5028	Crust 2 miles north of Hooper	26.40			12.90	22.95	4.38	38.28	21.49
5029	Crust 2 miles east of Hooper	34.21			14.90	72.41	6.29	4.31	2.09
5030	Crust 2 miles SW. of Plain City	1.80		1.44	10.76	53.72	4.00	4.33	25.75
5031	Crust 5 miles SW. of Ogden	8.18			20.67	62.62	2.61	6.77	7.33
5032	Black alkali crust SW. of Hooper	23.75			18.54	64.04	1.86	7.97	7.59
5033	Crust on lake bottom SW. of Hooper	42.58	1.21	5.00	1.83	86.98	4.51		.47
5034	Crust from escarpment SW. of Hooper	26.94	7.76	4.71	11.91	69.92	4.96		.74
5035	Dark crust east of Hooper	5.92			17.30	52.04	7.60	13.50	9.56
	Mean		1.00	1.24	12.20	59.83	4.39	11.10	10.24

It will be seen that sodium (Na) forms the chief part of the base elements, while chlorine (Cl) is chief among the acids. Since the region where these crusts occur is near Great Salt Lake, which is known to contain large amounts of sodium chloride, it is not surprising to find these results. It is noticeable also that carbonic acid ions (CO_3) and hydrogen carbonate ions (HCO_3) form quite a percentage of the acids in seven out of the nine samples, and that in these seven samples both lime and magnesia are present only as a trace. In the remaining two samples both lime and magnesia are present in appreciable amounts, but the carbonate is absent, while bicarbonate occurs in very small amounts.

The following table shows the amount of salt in various depths of the soil and the percentage combination of the bases and acids theoretically combined. As here combined, it is found that on an average slightly more than 64 per cent of the salts occur as chlorides, of which common salt is the usual form. About 14.5 per cent occur as the sulphates, 11 per cent as carbonates, and the remainder as bicarbonates. Of these four classes of salts, the carbonates are by far the most destructive and, owing to their caustic properties, attack the tissues of plants and disintegrate them.

While alkali crusts collected from a number of widely separated points over a district have been taken as representing the composition of the alkali of the district, it had occurred to the writer that, owing to the absorptive power of the soil and the variation in the amounts of the different salts that go into solution when present in excess, there would probably be a variation in the character of the alkali from the surface downward. For this reason representative samples of alkali soils from various parts of the district were analyzed, under the direction of Dr. Cameron, the samples being usually in sets of three, representing the first, third, and fifth foot in depth.

The following table shows the results of these analyses:

Chemical composition of alkali in the soil at different depths.

No.	Depth.	Locality.	Per cent soluble.	Ca.	Mg.	Na.	K.	SO_4.	Cl.	CO_3.	HCO_3.
	Ft.		*Per ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
5036	1	N. C. sec. 36, T. 6 N., R. 2 W	0.96	0.21	0.41	28.01	5.39	5.39	18.87	4.36	37.36
5037	3	do	.59	10.51	.68	18.65	2.71	4.74	16.62	7.12	38.97
5038	5	do	1.48	3.37	.81	26.96	3.37	6.06	28.44	3.23	27.76
5039	1	N. C. sec. 23, T. 7 N., R. 2 W	3.30	2.67	Tr.	31.62	5.45	1.21	55.42	......	3.63
5040	1	S. E. C. sec. 16, T. 7 N., R. 2 W	.82	5.84	.24	24.82	6.33	2.43	42.82	.73	16.79
5041	3	do	.99	5.46	......	26.26	4.44	1.41	39.19	......	23.24
5042	5	do	1.08	2.96	Tr.	29.08	7.04	1.67	47.59	Tr.	11.66
5044	3	¼ E. of C., sec. 5, T. 6 N., R. 3 W	1.06	7.37	1.32	24.02	3.21	3.21	37.99	5.67	17.21
5045	5	do	1.43	.98	Tr.	34.08	2.93	2.66	43.71	4.19	11.45
5053	1	C. of S. W. ¼, sec. 24, T. 5 N., R. 3 W	1.30	11.85	Tr.	20.31	2.46	2.15	28.77	7.38	27.08
5054	3	do	.90	8.03	.45	24.34	1.34	2.45	19.65	12.27	31.47
5055	5	do	1.27	2.20	.47	30.82	4.09	2.04	30.97	11.80	17.61
5062	1	¼ W. of N. E. C., sec. 16, T. 5 N., R. 2 W	2.14	3.65	.65	25.42	4.02	5.79	24.30	7.01	29.16
		Mean	......	5.01	.39	26.49	4.06	3.17	33.41	4.90	22.57

In the following table is given the theoretical percentage combination of the above analyses:

Theoretical percentage combination.

No.	Depth.	$Ca(HCO_3)_2$.	$CaSO_4$.	$MgSO_4$.	Na_2SO_4.	$CaCl_2$.	$MgCl_2$.	NaCl.	KCl.	Na_2CO_3.	$NaHCO_3$.	$Mg(HCO_3)_2$.
	Ft.		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
5036	1	....	0.62	2.07	4.97	....	....	23.24	10.16	7.68	51.46	....
5037	3	34.24	6.78	....	....	....	....	23.73	5.08	12.54	13.90	3.73
5038	5	....	8.49	....	....	2.56	3.10	35.59	6.33	5.66	38.27	....
5039	1	....	1.70	....	....	6.06	....	76.92	10.35	....	4.97	....
5040	1	19.71	3.40	....	....	....	....	61.32	11.92	1.46	....	2.19
5041	3	....	2.02	....	....	13.33	....	44.84	7.88	....	31.93	....
5042	5	....	2.78	....	....	5.00	....	62.97	13.33	....	15.92	....
5044	3	....	4.53	....	....	16.61	5.09	34.15	6.04	10.00	23.58	....
5045	5	....	3.63	....	....	....	....	67.74	5.59	7.40	15.64	....
5053	1	....	2.92	....	....	30.76	....	11.39	4.62	13.08	37.23	....
5054	3	28.79	3.35	....	....	....	....	30.59	11.92	21.65	10.49	2.68
5055	5	....	2.83	....	....	3.77	1.89	38.85	7.70	20.75	24.21	....
5062	1	....	8.13	....	....	3.55	2.52	25.70	7.66	12.34	40.10	....
		6.36	3.94	.16	.37	6.28	.97	41.31	8.35	8.66	23.67	.66

In comparing this table with the table of the crusts, it is seen, in regard to the bases, that lime is always present in the soil alkali in appreciable amounts, whereas in the crusts it is usually absent. Another fact in regard to lime is that it is usually most abundant in the third foot, the mean of the first, third, and fifth foot samples being 4.84, 8.34, and 2.38 per cent, respectively. The mean of the thirteen determinations gives 5.01 per cent, or about seventeen times as much as occurs in the mean of nine crusts. Comparing the lime salts of the crusts and soils as combined on the lower part of each table, we have 1 per cent of it in the former to 16.6 in the latter.

Potash also forms a slightly larger percentage of the soil alkali than of the crusts, while soda, as might be expected, is most abundant in the crusts.

Upon comparing the acids of the crusts and soils quite marked differences occur. While chlorine (Cl) predominates in both the soil and crusts, yet it is more abundant in the latter. In regard to the sulphions (SO_4), there is more than three times the percentage in the crusts than occurs in the soil, while for bicarbonates (HCO_3) the reverse relation is true in about the same proportion. The carbonic acid ions (CO_3) are slightly more abundant in the crusts than in the soils, but do not show any marked tendency to accumulate in the crusts or upper layers of soil, although the view that they do is held by some.

The relation between the carbonates and the bicarbonates shows a ratio of about 1 to 1 in the crusts, while in the soil it is about 1 to 5. This seems to be largely a function of the concentration of the solution, the ratio between the carbonates and bicarbonates increasing with the decreasing concentration of the solution. It seems, therefore, that where crusts are forming at the surface of the soil through the combined agencies of capillarity and evaporation the chlorides and sulphates of soda form in greater proportions than they previously existed in the soil, while calcium remains almost entirely in the soil. The carbonates also show a slight tendency to accumulate in the crusts, while the bicarbonates show a reverse tendency.

The amount of alkali present in the soils and irrigation waters was determined by the electrical method. The chlorides, carbonates, and the bicarbonates were determined by a volumetric method recently devised for rapid field work. In the soil the percentage of alkali was determined in the first, third, and fifth foot in depth and the mean of these three determinations taken as the salt content of the upper five feet of soil. The alkali map represents what may be considered the average conditions of the various areas at the time the survey was made. If the upper foot was free from alkali and the third and fifth foot showed large amounts, the soil was classed according to the average of the three determinations. With such an arrangement or distribution of the salts, which frequently occurs in virgin soils, a crop might be started in excellent shape, or perhaps brought safely to maturity, but with a few irrigations the salts would rise to the surface unless excellent underdrainage was present or was provided for, and the land would become unfit for cultivation.

The alkali map brings out the fact that the uplands are usually free from injurious amounts of alkali; the intermediate lands are often mildly charged with it; while the lower and more level areas near the lake nearly always contain very large amounts. The lake is undoubtedly responsible for the salty condition of the last-named lands, for its waters have covered much of this land within comparatively recent years.

There is a general agreement between the soil and alkali maps, and to some extent between the alkali and ground-water maps. As a rule, the heavier soils carry most alkali, while the sandy soils are least troubled with it. Areas on the ground-water map, with water 10 or more feet in depth, are always free from injurious amounts of alkali. Wherever the water table is within 3 feet or less of the surface for a portion of the season, and alkali salts are present, these will always be found concentrated immediately at or near the ground surface. With the water table 4 feet or more below the surface the surface foot will usually be comparatively free from alkali and the maximum amount of alkali will occur usually about 1 foot above the water table, providing it be not more than 10 feet below the surface.

The above table of chemical analyses of crusts, collected from various parts of the district, shows only two crusts in which sodium carbonate (black alkali) exceeds 20 per cent of the salts present, and an average of them all gives 11.1 per cent of the salts as sodium carbonate. The table giving the composition of the salts in the soils, on page 230, shows two of the samples which contain slightly more than 20 per cent of the total salts in the form of black alkali, while the mean of thirteen determinations shows only 8.66 per cent of it to exist as such.

The mean of a large number of field determinations show that 15 per cent of the alkali in the surface foot of soil is present as carbonates.

The limit of endurance by plants for black alkali is placed at 0.1 per cent, while for white alkali it is placed at 0.5 per cent. We see, therefore, that where we have an excess of black alkali we will generally have also an excess of total salts; and to convert the black alkali to the white by the application of gypsum would be a waste of time and money, for there would still remain an excess of alkali which must be removed before the land could be profitably farmed.

A number of factors enter into the question of the limit of endurance of plants for alkali. It has been brought out that the different crops withstand different amounts, and that with the same amount of alkali plants suffer less in heavy soils than in sandy ones. The more sandy a soil the lower its water-holding capacity, and with a given percentage of salts in the soil the less the percentage of soil moisture and the more concentrated it must be with reference to the salts. It is the concentration of the soil moisture from which the plant has to draw its supply of mineral food that determines the limit of endurance for the plant, rather than the percentage of salts in the soil. The kind of salt, also, has an effect, sodium chloride, percentage comparison, being more harmful than sodium sulphate. Of the relative harmfulness of the different salts for plants, comparatively little is known. This is a subject that demands fuller investigation by the vegetable physiologist.

BLACK ALKALI.

The corrosive sodium carbonate, while forming a considerable part of the alkali salts of the district, seldom exceeds 0.1 per cent without the presence also of an excess of total salts. There are a few areas, however, notably about the towns of Plain City and Hooper, where the black alkali is the chief menace to agricultural progress. In such localities the black alkali, varying in amounts from 0.05 to 0.1 per cent of the soil and over, is shown on the alkali map by two sets of diagonal lines. Where present in amounts varying from 0.05 to 0.1 per cent it is equally as harmful as 0.2 to 0.4 per cent of total salt, and will result in spotted fields. In amounts which exceed 0.1 per cent it is considered fatal to plants. By the application of gypsum it is largely converted to the less harmful white alkali if the soil is well aerated and drained. Where this form of alkali is the source of trouble and where gypsum can be obtained at a cost not too great, it will be advisable to apply gypsum to the surface of the soil in a finely divided state and to incorporate it with the soil by cultivation and irrigation.

For the conversion of 0.1 per cent of black alkali into white alkali about 3½ tons of gypsum for each acre-foot will be required. If there is no rise in the salts, however, it seems probable that only a correction for the first foot in depth would be necessary, since it is at the surface of the ground that the damage from this form of alkali is nearly always observed.

There seems to be little tendency for the black alkali to accumulate at the surface of the soil in a ratio greater than other forms of alkali, and it occurs at all depths the same as any of the salts.

MAPS.

The maps, three in number, which accompany this report are on the scale of 1 inch to a mile, and show the prevailing conditions at the time of the survey, September to October, 1900, for all areas not smaller than 10 acres in extent. Since areas smaller than 10 acres would represent less than one sixty-fourth of a square inch on the map, there is little justification for doing the work in greater detail. The best base maps of the district were obtained from the county officials. These maps gave the section lines, the roads, railroads, rivers, mountains, and the principal towns, and were used as base maps for the soil work. In some instances the location of these features on the map were not correct, and in such cases, notably the river, which changes its course from time to time, changes were made. This is also true in regard to the location of the base of the mountains and of the railroads. The greatest change made on the maps in this respect was the moving of the lake shore line westward, a distance varying from 2 to 11 miles, in order to conform with the present lake shore line.

The location and course of the principal canals were accurately mapped as the regular field work progressed, also the escarpments, hills, and the base of the mountains.

The soil map shows the exact location and extent of the various types of soil which are described in these pages. It has been the endeavor of the author to make the description of these soil types both valuable and practical to the farmer by bringing out what crops are best adapted to the soils and what dangers to guard against in irrigation in order to prevent damage and undue loss of water.

The alkali map shows the distribution of the alkali, and should be of especial value in reference to the virgin soils as showing which are sufficiently free from alkali to produce crops as well as those that will have to be reclaimed before crops can be grown. It shows, in different colors, the mean percentage of salt in the upper 5 feet of soil, the intervals represented by the different colors being 0.0 to 0.2, 0.2 to

0.4, 0.4 to 0.6, 0.6 to 1, 1 to 3, and 3 per cent, calculated on the dry weight of the soil.

Leaving out of consideration the lake bottom land, all of which contains more than 3 per cent of alkali and none of which may be considered fit for any agricultural purpose for some time to come, there remains about 137,000 acres of land, the greater part of which is so situated that it could be irrigated and which, when reclaimed and irrigated, is destined to become valuable agricultural land. Of this portion, about 83,000 acres contain less than 0.2 per cent of alkali and may be considered perfectly safe for farm crops so far as trouble from alkali is concerned. The areas containing from 0.2 to 0.4 per cent of alkali aggregate 16,000 acres, and, while some portions of these areas are cultivated with a moderate degree of success, it is usual to find the field containing spots where the crops fail even under the most favorable conditions. As the lower limit of this range in salt content is approached, the conditions may be quite favorable, especially if the greater part of the salts are below the second foot in depth, but as the upper limit is approached partial to complete failure in the crops is usual. This, however, does not depend upon the salts alone, for, with good drainage, upon applying irrigation water the salts move downward and the conditions rapidly improve, while with poor drainage the salts come to the surface and often destroy the entire crop.

All areas containing from 0.4 to 0.6 per cent of alkali, aggregating 7,000 acres, are unfit for any of our agricultural or horticultural crops. There is one exception to this, namely, in the case of a virgin soil having the salts mostly below the second foot in depth. In such cases, if good natural drainage is present or artificial drainage is provided, the process of reclamation may begin by putting in shallow-rooted crops, such as wheat, oats, or barley, and by liberal applications of water the salts will move further downward so that in succeeding years deep-rooted crops can be grown.

The process of reclamation requires frequent and liberal application of water in order to wash out the excess of alkali, and since barley is more resistant of both alkali and water than wheat or oats, it is recommended as the best crop to use in this connection.

The areas containing from 0.6 to 1 per cent of alkali aggregate 13,000 acres; those with 1 to 3 per cent, 11,500 acres; and those with more than 3 per cent, about 2,500 acres. All of these areas are too salty for any kind of farming, but when sufficiently moist they maintain a native growth of salt grass which makes fair pasture, and on the drier parts there is usually a considerable growth of greasewood (*Sarcobatus virmiculatus*) and other salt-loving plants on which sheep feed during the winter months. The income from this source, however, is very small.

The aggregate of the above areas, containing from 0.2 to more than 3 per cent of alkali, amounts to 50,000 acres. Besides this, there is nearly 60,000 acres of lake bottom soils, all of which contain more than 3 per cent of alkali, the average probably being near 10 per cent. This makes a total of 110,000 acres of alkali land, or somewhat more than one-half of the entire district.

Besides the map showing the total alkali, there was also constructed a black-alkali map. It was found, however, that there were only a few localities in which the corrosive black alkali was in excess that there was not also an excess of total salts. As a consequence of this, the black alkali, when present in amounts from .05 to 0.1 per cent and above 0.1 per cent, is shown on the alkali map by two sets of diagonal lines only on the areas having less than 0.4 per cent of total salts. Such areas are noticeable in the vicinity of Hooper and Plain City.

The ground-water map shows the depth to standing water at intervals of 0 to 3, 3 to 6, 6 to 10, and more than 10 feet below the surface. The map is believed to be of especial value as indicating areas that are in need of immediate drainage, as well as areas where great care should be exercised in the application of irrigation water in order to prevent a further rise in the water table. As previously stated, this map shows the condition in the driest part of one of the driest years on record, and therefore shows the ground water slightly lower than it usually is.

All areas with water within 3 feet or less of the surface are in immediate need of drainage if the productive power of the land is to be increased.

Not all of the lands with the water table within 3 to 6 feet of the surface are in need of drainage at present, but a considerable percentage of such do need drainage, and this is especially true if the water table rises to within 4 feet of the surface during the irrigation season.

Lands with water at 6 feet or more below the surface are in no need of drainage so long as this condition can be maintained. With the water table 6 to 10 feet below the surface under level virgin land, there is danger of a marked rise in the table when such lands are irrigated, and it will often be advisable to provide for this contingency by underdrainage, even before the practice of irrigation begins.

RECLAMATION AND UTILIZATION OF WASTE LANDS.

The foregoing pages and the accompanying maps show the types of soils and their condition with reference to alkali and ground water; also the nature, quality, and supply of irrigation water for the whole district. Let us next consider the practical problem, how best to utilize these resources.

It is of course recognized that the justification for investing capital in the improvement of lands depends not alone upon their character and available water supply, but also upon their location with reference to civilization, markets, and transportation facilities. In other words, it resolves itself into a business proposition, in which the expense is justified only so far as it will ultimately bring profitable returns from the investment.

The Ogden district is perhaps the most important one in the State. Ogden, with a population of about 20,000, is an important business center. It is the largest city in the district and the second largest in the State, as well as being the most important railroad center between Denver and San Francisco. It is the terminus of three great western railway systems, namely, the Union Pacific, the Southern Pacific, and the Rio Grande Western. From it also the Ogden Short Line extends southward to the southern boundary of the State and northward into Idaho, Montana, Oregon, and finally to the Pacific Ocean. These facilities, together with the intensive form of agriculture and horticulture, the many canning factories, and the beet-sugar factory, make the justification for the investment of capital in the reclamation of lands perhaps greater than in any other section of Utah. Probably nowhere in the State will so large a percentage of the better lands be so well adapted to the production of fruit and truck crops as here. Lands in orchards of peaches and pears, with trees coming into bearing, have a valuation as great as $1,000 per acre, and during the present season many such orchards have netted an income of 10 per cent on such valuation. Good truck lands in the immediate vicinity of Ogden have a valuation as great as $500 per acre, and some of them command an annual rental of $50 per acre for that purpose.

There is an abundance of land farther from the city which, on account of its condition, has little more than a nominal value. If drained and freed of its injurious amounts of alkali it would be equally as productive as the land near the city having a valuation of $500 an acre. Deducting a liberal percentage on the above valuation, because of the less desirable location of the land, the value when reclaimed should still be such as to make its reclamation a very inviting proposition for capital.

The estimated cost of reclamation by means of underdrainage is about $20 an acre. Allowing $10 for the water right, the whole cost, exclusive of the first cost of the land, would be about $30 an acre. On this basis it is a proposition not for the poor man but for capital, or for the man who owns such lands free of encumbrance and has an outside means of livelihood. For those who are willing to wait a few years for their returns such improvements will be found paying investments. The cost of bringing these lands to a high state of cultivation, including interest on the money expended, will not equal half of the above valuation on the best truck and orchard lands. Areas in excellent condition, which are especially well adapted to the growing of tomatoes, have a valuation far greater than their first cost plus water right, the cost of all improvements, and interest on the same. Nor are such values fictitious; for a yield of 10 tons per acre, which brings from $8 to $10 per ton at the factories, is common. This gives a gross income of from $80 to $100 per acre, of which one-half should cover the total expense of production and marketing, leaving from $40 to $50 per acre as a net profit, or 10 per cent income on a valuation of from $400 to $500 per acre for the land.

This type of agriculture not only gives employment to much labor on the farms, but also affords occupation for many hands in the factories, as brought out by the following from The Industrial Utah:

There are at present 1,000 hands employed in the canning factories in Weber County. Many of the employees are boys and girls in their teens, and will make enough during the canning season to pay for their books and clothing for the school year. The wages paid by the factories are very satisfactory, much of the labor being paid by the piece, or so much for a given amount of tomatoes or fruit handled by each person. Some young ladies earn as much as $2 per day, while numerous ones receive from 75 cents to $1.50. In addition to the enormous sum paid out in wages, the factories are of untold value for the lessons of thrift and industry they teach.

The output of canned tomatoes from the factories in Weber County during 1900 was approximately 200,000 crates of 24 quart cans each. These were disposed of at from $1.50 to $1.75 per crate, making the total income from this source slightly more than $300,000. Besides this, there were small amounts of peaches, pears, and small fruits canned. This industry is still in its infancy, and by the production of other truck crops suitable for canning—such as peas, beans, rhubarb, asparagus, etc.—the canneries might be much enlarged and their season of operation lengthened with great profit to both the operators and the producers.

It is obviously unnecessary to go into a lengthy and detailed discussion of the commercial advantages offered here. Enough has been said to set forth the advantages offered for the investment of capital in the reclamation and utilization of what are practically waste lands. Such investments, while void of the manifold returns occasionally realized by investors in mining stocks, are also free of the great elements of chance which the latter possess. Having secured a water right for the land and reached a decision as to its crop adaptation, the process of reclamation and improvement can proceed along intelligent lines. Crop adaptation will include the profitable disposal of the products. It would be folly to grow large areas of such a perishable product as strawberries when there would be no suitable market in which to dispose of them.

When lands are strongly impregnated with alkali and possess poor natural drainage, tile drainage should be supplied at the outset, in order to provide for the escape of the salts and to prevent their rise to the ground surface. Lands which are by nature wet will obviously need drainage. Tile drainage requires good outlets, which should be provided at the beginning by the community as a drainage district, each individual landowner contributing to the cost of the same according to the benefits derived as decided upon by a board of disinterested arbitrators.

This means of drainage, of which but little is known in the irrigation districts, has been resorted to throughout the humid regions of the United States and has everywhere proved preeminently successful. While in the experimental stage in California, this system is being recommended for the reclamation of alkali lands by the California experiment station. It is also being tried in Utah, as shown by the following extract from Industrial Utah:

> One of the most striking illustrations of the benefit of drainage is shown on the farm connected with the State Insane Asylum. A tract of about 20 acres that had formerly been excellent farming and pasture land had in recent years, through seepage from a canal above, become a veritable swamp, too wet to even admit of pasturage of cows during the irrigation season. Last fall there was put in 1,500 feet of 3-inch drain tile, consisting of one main line and two laterals. The effect on the land is most remarkable, the soil turning up and pulverizing admirably through plowing this spring. The plot in question forms an object lesson that should be fruitful of results throughout Utah County.

The alkali and ground-water maps which accompany this report should be very useful in deciding what lands are in need of drainage and what are their conditions as regards the presence of alkali. In many instances much labor and money have been spent in the preparation and seeding of land to alfalfa and other crops when the soil was too salty to permit the seeds to germinate. In this respect the alkali map should be of special economic value in showing what lands are incapable of producing crops until the salt content has been reduced.

The areas showing more than 0.4 per cent of alkali are unsafe to seed to alfalfa. Even on the areas showing from 0.2 to 0.4 per cent of alkali there is a risk, especially if the salts show a tendency to accumulate at the surface. With the salts mostly below the second foot success in a moderate degree may be attained. The plants, when once well established, will withstand much more alkali than when in their infancy.

The alkali map shows the mean percentage of the alkali in the upper 5 feet of soil, but shows nothing as to its vertical distribution. Upon this point good judgment is required by the farmer. In general, when crusts are present upon the ground surface the maximum amount of salts occurs in the first foot, and when crusts are absent the maximum amount will not occur nearer to the surface than 3 feet and more often at a greater depth. Greasewood, shad scale, and sage bushes indicate an increase of salts with an increase in depth. Greasewood also indicates high alkali content, while sage indicates a comparatively low content. Salt grass indicates the maximum salt content near the surface.

In reclaiming alkali lands good judgment on the part of the farmer will be required to decide when the process has gone far enough to make it safe to plant crops. There is a great need of men who have the training, facilities, and experience to decide upon just such points. A few men possessing the requisite knowledge locating in the principal irrigation centers could be of inestimable value, and their services should be sought and paid for in a manner commensurate with their value. Trained engineers are employed at high salaries by railroads, mines, and various other corporations, and men possessing the requisite training and experience to give advice and render expert services in regard to agricultural and irrigation problems should be in equally as great demand. If such services could be obtained, large sums of money could often be saved by the farmers and the farmers in turn could well afford to pay for them.

In the case of land at present farmed, good cultivation is essential. This is especially true for all fruit and hoed crops and doubly so when there is any tendency for the alkali to rise and accumulate at the ground surface. Frequent cultivation keeps the ground covered with a loose soil mulch, which reduces capillarity and the consequent loss of water from the surface as well as its resulting tendency to accumulate the salts there. Very salty lands that are not to be reclaimed can often be utilized by seeding to some species of salt-resisting plants, as the Australian saltbush, which has been tried in California and has been found to withstand large amounts of salt and yet be able to furnish considerable low-grade forage for stock.

DRAINAGE.

As previously stated, there are about 50,000 acres of alkali land in the district, which contain 0.2 per cent or more of alkali, exclusive of the lake-bottom soils, which are all very salty. This land is valued, according to its character and location, at from $5 to $40 per acre, or an average valuation of about $20, but taken as a whole it does not bring an income of 5 per cent on such a valuation. If reclaimed and a good water right secured, its value should not be less than an average of $100 per acre, or a total of $5,000,000, as compared with the present valuation of $1,000,000. Considerable of this land has a water right and is located under present canal systems. While there is not enough water for all of it under the present management, it is possible by storage to supply the needed water.

In a few areas of limited extent black alkali is the source of trouble, and while such areas can be reclaimed by the application of gypsum, it is not improbable that this process would cost more than to remove the salts by drainage. For the greater part of the area drainage is the only resource for reclamation. Owing to the sandy and pervious character of the soils of the district, tile drains will be very effective when at a considerable distance apart, and the cost of the tiles at Ogden should not exceed $5 per acre. The excavating, laying, and covering of the tiles should not exceed $10 per acre, while $5 per acre should easily secure the outlets, which will usually be in the form of large open ditches or canals, constructed at the expense of the community. This makes the total cost $20 per acre, as previously estimated.

In the Mississippi Valley and in the East generally the usual depth at which to place tiles is about 3 feet, and the results thus obtained are usually quite satisfactory. The soil conditions in the East are quite different from those in the West. In the East the soils are usually closely underlaid by subsoils which are of such a nature that water moves through them slowly and the roots of plants penetrate them very little. In the West the soils are of uniform texture, the crops grown are usually deep rooted, and the climate is such that the roots keep well below the surface in order to escape the effect of drought.

Tile drains lower the water table only to their own level, and, as previously stated, where the water table is within 3 feet of the surface there will usually occur a concentration of the salts at the surface. In view of these facts, tiles should be placed at least 4 feet in depth for the irrigation districts in order to insure good drainage, and for orchards 5 feet will undoubtedly be better. In the absence of alkali, 3 feet in depth will be sufficient for the cereals, but this is not sufficiently deep for alfalfa, which is the chief forage crop of all our arid regions. Deeply laid drains are more efficient than shallow ones. The water continues to flow in them for a longer period of time, and their lateral influence extends further. The deeper the drains are laid, the greater can be the distance between them. This lessens the amount of tile and reduces the length of trenches to be excavated, which will fully counterbalance the extra expense of deeper excavation.

The size of tiles to use will depend upon the area which each line is required to drain, the maximum depth of water to be removed in a given time, and the fall which the line has. A 4-inch tile, when laid with a grade of 1 to 1,000 and required to remove one-half inch of water in twenty-four hours, will drain about 7½ acres. This should be sufficient for reclamation purposes; and in the case of ordinary wet areas, caused by seepage or overirrigation, a 4-inch tile should drain about 15 acres. To double the grade or fall in a line of pipe increases the rate of discharge about 30 per cent. While the cross sections of pipes vary according to the square of their respective diameters, the increase in discharge by increasing the size exceeds this by a large percentage on account of the comparative reduction in friction on the pipes; for example, if a 4-inch pipe will drain 15 acres, a 6-inch one will drain 46 acres, while an 8-inch one will drain about 104 acres.

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For more detailed information on drainage, the reader is referred to Farmers' Bulletin No. 40 of the United States Department of Agriculture, entitled Farm Drainage, which treats on drainage for the humid climate, but which will for the most part be practical for the irrigation districts also.

For good drainage good outlets are imperative. The size and depth of drains should be adequate to remove the water to a sufficient depth and within a comparatively short time. The grades along the lines of drain should be uniform and free from low places in which water and consequently sediment may settle. Laterals connecting with mains should do so at an angle considerably less than 90 degrees, the angle opening upstream.

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