SOIL SURVEY OF THE KLAMATH RECLAMATION PROJECT, OREGON.

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DESCRIPTION OF THE AREA.

The following report covers the soil survey of the territory embraced in the Klamath reclamation project of the United States Reclamation Service, together with certain areas of tillable land which lie adjacent to the project but above the irrigation ditches.

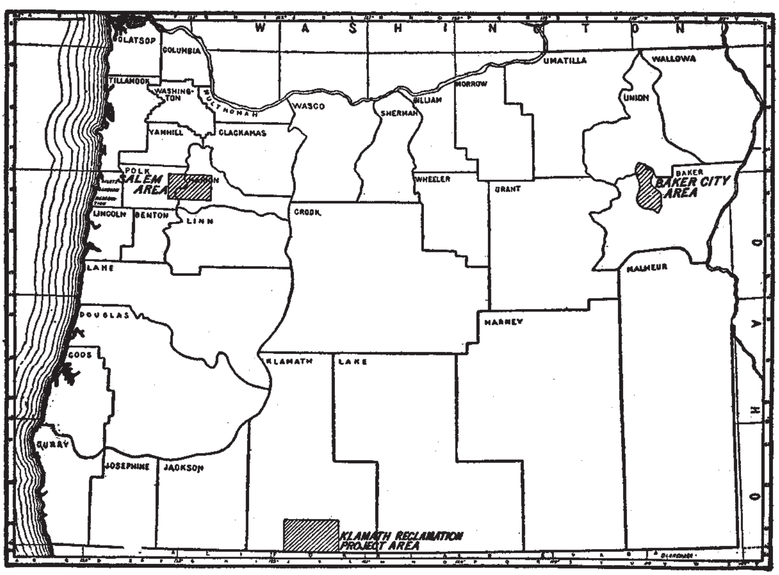

FIG. 38.—Sketch map showing location of the Klamath Reclamation Project area, Oregon.

This area lies between the meridians of 121° and 122° west longitude, and parallel 42° north latitude—the boundary line between California and Oregon—crosses the area near its southern part.

The Klamath country is a basin having an altitude of over 4,100 feet, surrounded on all sides by mountains of greater elevation.

On the west and southwest is the Cascade Range, two prominent peaks of which, Mount Pitt to the west and Mount Shasta to the southwest, their summits capped with perpetual snow, rise to elevations of 9,760 and 14,440 feet, respectively. Between these peaks there stretches a wide range of mountainous region with many summits reaching an elevation of almost 10,000 feet. These ranges are heavily timbered and covered with snow during the winter season. On the north and east are other mountains of less elevation, eastern outliers of the Cascade Range, with timbered crests and slopes interspersed with occasional outcrops of rock, while to the south and southeast are the famous lava beds of northern California, from which rise numerous barren hills and mountains.

Extending through the area and dividing it into several distinct valleys are other mountains and hills of less elevation. These are also timbered to a considerable extent, forests of pine occupying the higher portions, while on the slopes are scattering junipers, with sage, wild plum, and other shrubs. In many places on the steeper slopes fragments of rock have crumbled from the outcrops above and stretch in broad, barren, dark-colored strips for long distances down the slopes.

These hills and mountains, which occur as elongated ridges, have a general northwest and southeast trend and divide the area into five rather distinct valleys, in some of which minor hills occur.

The most important of the valleys into which the area is divided is the Klamath or "Main Valley," as it is called, stretching from Klamath Falls in a southeasterly direction to Tule Lake, a distance of about 25 miles. Klamath Valley has an average width of about 4 miles, contains approximately 64,000 acres, and includes the principal older irrigated sections of the area. Extending west from near the central part of Klamath Valley and really a part of it is a higher valley known as "Spring Lake Valley," embracing about 9,000 acres of tillable land.

Southwest of Klamath Valley and separated from it by a high barren ridge and by Spring Lake Valley is the basin of Lower Klamath Lake, in which the marsh or tule lands occur. This basin has an area of about 130 square miles or 85,000 acres.

Extending east from the southern end of Klamath Valley there is, along the northern shore of Tule Lake and including a small valley known as "Sand Hollow," a strip of agricultural land of about 10,000 acres in extent. South of this strip it is planned to reclaim an area of about equal extent from the bed of Tule Lake.

East of the northern part of Klamath Valley, but separated from it by rather high hills, is a small triangular basin known as "Poe Valley," containing approximately 9,000 acres. At Olene, near the northwest corner of this valley, Lost River passes through a low gap from Poe Valley to Klamath Valley.

Stretching northeast and then southeast along Lost River is a narrow valley the upper and broader part of which is known as "Langell Valley." This valley is about 16 miles long, is from 2 to 3½ miles wide, and contains about 25,000 acres.

Northeast from Poe Valley and extending north from the narrow valley of Lost River is another small farming area known as "Yonna Valley." It is about 9 miles long, averages from 1 to 2 miles in width, and contains about 9,000 acres.

In the entire area surveyed there is a land area of 159,360 acres. Some portions of this are not suitable for farming purposes and other parts can not be brought under irrigation. It is estimated, however, that the total area of tillable land, including that which is to be reclaimed, will be between 150,000 and 180,000 acres.

The Klamath country, so called from the Indian word meaning "the assembled" or "the tribes," is a region abounding in numerous and beautiful lakes.

Lower Klamath Lake lies in the western and southwestern portion of the Klamath Basin and is surrounded by high hills and mountains. These mountains end abruptly at the swamp or lake shore, except in the northeastern part, where the basin opens into Klamath Valley. From Klamath Falls, situated on the narrow stretch of land lying between the upper and lower Klamath Lakes, to Laird, at the extreme southern end the length of the valley, is about 25 miles and the average width about 5 miles, except for 8 miles between Klamath Falls and Miller Island, where the width is about 1½ miles.

This area (approximately 85,000 acres) is known as "Lower Klamath Lake," but there exists in it about 55,000 acres of swamp land which is not covered with water during dry seasons or times of low water in the lake. This land is covered with tall tules, with an admixture of cattails, flags, mint, sawgrass, and yellow pond lilies. At times of low water much of this land is used for pasturage for cattle and horses and for the production of tule hay.

The open water, consisting approximately of 30,000 acres, is divided into several lakes approximately as follows: Lower Klamath Lake (proper), 26,000 acres; Miller Lake, 3,400 acres; White Lake, 800 acres; and Ewauna Lake, 320 acres. Lake Ewauna, the deepest, and lying nearest Klamath Falls, has a depth of about 15 feet, being a widening of the Klamath River. Miller Lake lies in the middle western part and is separated from the tule or swamp land by a high sandy reef 3½ miles in length. This lake is very shallow and alkaline. White Lake is quite similar to Miller Lake, being isolated from the main body of water by tule swamps and low ridges of tufaceous material which almost inclose it. Its waters are similar to those of Lower Klamath Lake and are quite shallow, but connect naturally with Lower Klamath Lake through the tule swamps. An artificial connection, called "Adams Cut," has been made, connecting it with Klamath Lake and the Merrill country, which has until recently derived its irrigation from this source. The open water of Lower Klamath Lake lies in the center of this area, occupying the lowest portion. It approaches the hills at only one place at its southern end, where it is much deeper than elsewhere. The water in this lake is quite shallow, but a deep deposit of floating sludge and black muck lies below it. This sludge is often piled in spots by the movements of wind and water, obstructing navigation. The principal source of water for this group of lakes is Upper Klamath Lake, through Link River. The outlet is Klamath River, which flows through the upper part of the basin, then turns west through a narrow pass in the mountains near Keno. At the entrance to this pass a basaltic obstruction has prevented the lowering of the river bed, and resulted in this chain of lakes and wide area of marshy land. A wide channel several miles in length passes southward from the river, supplying the lower lakes and swamps. During seasons of heavy rainfall or during the long dry summers, the Klamath River flows southward through these straits, but at certain seasons when the river begins to fall this channel carries considerable water northward from the lower lakes into the Klamath River, thus presenting the anomaly of a river flowing in one direction during a portion of the year and in the opposite direction at other times.

East from Lower Klamath Lake and separated from it by a mountain barrier 1,000 feet high and less than 2 miles in width is another large body of water covering about 150 square miles and known as "Tule Lake." Only a few small areas along the margin of this lake are at present covered by tules.

In addition to these larger lakes there are within the area proper Nuss Lake, Alkali Lake, Dry Lake, and numerous other small but unnamed lakes, while in the vicinity of the area, but outside of it, are Upper Klamath Lake, Clear Lake, Swan Lake, Round Lake, Long Lake, and many others.

The Klamath area has a peculiar and interesting natural drainage system. The drainage of the western part of the area has already been described. The remainder and larger portion of the area, including Klamath, Poe, Langell, and Yonna valleys, is drained by Lost River and its tributaries. This stream, which has its source in Clear Lake, flows northwest, west, and then southeast, a total distance of over 60 miles, emptying into Tule Lake, the waters of which extend to within 6 miles of the source of the river. In Langell Valley this stream flows for several miles under ground, coming to the surface in the vicinity of Bonanza as large springs. It has several tributaries, the most important of which are Miller Creek, which enters Langell Valley from the east, Buck Creek, which drains Yonna Valley, and Lost River Slough, which crosses the northern part of Klamath Valley. This last-named stream extends from near Klamath River to Lost River, apparently occupying the former course of a large stream. In addition to these streams there are many smaller ones, which carry the waters of the rainy seasons into Lost River or into the lakes.

In this area there are also many small, basinlike depressions, with no outlet, which collect the run-off of the rainy season, forming small, shallow lakes which dry up during the summer. These are most numerous in Spring Lake Valley, but occur throughout the area.

The first permanent settler, Wendoless Nuss, came to the Klamath country in 1866 and others soon followed. The object of these earlier settlers was stock raising rather than farming. In 1867 Linkville, the name of which was later changed to Klamath Falls, was founded, and in 1872 a post-office established, the mail being carried from Ashland and delivered once a week. In 1875 a stage line making semiweekly trips was established between Ashland and Linkville. In 1882 Klamath County was formed, the population at that time being only about 700, and settlement continued to be very slow for some time.

In 1884 and 1885 irrigation in a small way was begun, and the value of the country for agriculture began to be recognized. Since that time settlement has been much more rapid. The greatest stimulus to settlement, however, has come during the last three years through the selection of this area as one of the irrigation projects of the United States Reclamation Service, and through the extension of the northeastern branch of the Southern Pacific Railroad to Klamath Falls.

Klamath Falls, situated at the upper end of Lake Ewauna, is the largest town of the area, having a population of between 2,000 and 2,500 people. It is situated on Link River, which may be made to furnish an abundance of power for manufacturing purposes. It is the county seat of Klamath County.

Merrill, situated about 22 miles southeast of Klamath Falls, on Lost River, is near the center of the best developed farming section of the area and has a population of about 300. Bonanza, situated on Lost River 25 miles east of Klamath Falls, has a population somewhat less than that of Merrill. Merrill and Bonanza are both reached by a high-power transmission line, the power being generated by Link

River. This supplies light and power needed for manufacturing purposes, flour mills in both towns being run by electricity. Keno, situated in the extreme western part of the area, and Dairy, situated 7 miles northwest of Bonanza, are small towns at which considerable business is transacted.

The lack of transportation facilities has in the past greatly retarded the development of the Klamath country. Horses, cattle, and sheep which could be driven to the railroad and shipped to market were the only source of revenue. Until recently stock was driven to Montague or other points on the main line of the railroad, distances of from 75 to more than 100 miles. At the present time, however, a branch of the Southern Pacific system is being extended from Weed, Cal., to Klamath Falls. This line is being rapidly constructed and will no doubt in the near future reach Klamath Falls.

Supplies for Bonanza, Poe, Yonna, and Langell valleys are now hauled principally from Klamath Falls, while those for Merrill and the southern part of the area are hauled from different points on the new line of railroad around the south end of Lower Klamath Lake, Mount Hebron and other points on this line being now used for shipping points for stock from the entire area.

The principal markets for stock as well as the principal points from which supplies are received are Portland and San Francisco, each distant about 350 miles from Klamath Falls.

The stream channels and lakes of the western part of the area are plied by steamers, which carry passengers and freight, and by rafts of logs, aiding very materially in the commerce of the region. Klamath Falls, Teeters Landing, Keno, and Laird are points reached by these streams.

CLIMATE.

The climate of the Klamath area is semiarid in character, the average annual rainfall being about 14 inches. This falls principally during the winter and spring months, the heaviest precipitation occurring in the months of March and April. During the summer season little rainfall occurs, although light showers are not uncommon. During the fall, winter, and early spring snowfall is of frequent occurrence, the snow sometimes remaining on the ground for a considerable time.

Owing to the high elevation and the influence of the higher mountains to the west of it the Klamath area has a low average temperature, but not one of great extremes. During the winter season the temperature rarely falls below zero, and during the hottest weather rarely exceeds a temperature of 95° F. The nights are uniformly cool. The following table compiled from reports of the Weather Bureau shows the mean temperature at Klamath Falls for a period of several years and the average monthly temperature for this period:

Mean monthly temperature for Klamath Falls.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1884	29	26	37	42	54	56	61	65	49	44	42	29
1885	34	37	47	53	56	58	72	71	56	51	39	35
1886	31	43	38	47	56	61	64	65	57	47	38	41
1887	39	28	46	47	55	57	66	64	58	50	38	31
1888	20	38	38	51	55	56	64	......	64	50	38	36
1889	28	36	44	51	54	66	69	65	58	49	......	......
1894	......	......	42	46	57	57	72	73	......	......	......	......
1895	......	......	......	......	54	64	67	67	57	56	44	......
1897	......	......	......	......	......	......	......	......	......	......	......	31
1898	26	36	37	......	......	62	72	71	60	46	35	29
1899	33	33	39	46	49	62	70	61	66	......	......	......
1900	39	......	......	......	54	60	......	......	......	45	41	34
1901	25	31	38	44	55	57	68	70	55	52	41	33
1902	30	38	39	45	53	61	63	68	64	47	38	33
1903	32	27	37	46	......	63	65	......	......	......	......	34
1904	27	31	35	47	58	59	......	......	......	50	45	33
1905	36	36	43	48	47	......	......	......	......	......	......	......
1906	28	32	35	48	55	59	75	69	51	......	......	......
1907	......	42	35	48	54	58	68	52	56	58	39	35
1908	33	35	38	49	......	55	......	65	......	......	......	......
Average for period	31	34	39	47	54	59	67	69	58	49	39	33

From this table it will be noted that December, January, and February are the three coldest months, but that the mean temperature for this period is not low, while July and August, which are the hottest months, show a comparatively low summer temperature.

The growing season does not begin until late in the spring and is often cut short by early frosts in the fall. No record is obtainable of the dates on which killing frosts have occurred, but that their occurrence is a serious menace to the successful growing of fruits and vegetables easily injured is a fact recognized by all who are familiar with the conditions. When the growing season has once begun, however, the clear air, warm sunshine, and fertile soil produce almost phenomenal results in a comparatively short time.

AGRICULTURE.

Agriculture in the Klamath Basin is comparatively undeveloped. Some ranches have been under cultivation for twenty years or more, but most of them have been cleared much more recently, and each year there is an extension of the farming area. At the present rapid rate of settlement, within a very few years all available farming land, including not only that which can be irrigated but also the dry farming area, will be brought under cultivation.

The present state of agriculture has been reached by very gradual stages. As has already been noted, the early settlers were engaged almost exclusively in stock raising and the nearest approach to farming was the cutting of wild hay for winter feed. During the summer stock was grazed among the mountains and lava beds and in winter brought into the lower and better protected valleys, where they fed on the grass of the marshes. During some entire winters they would find an abundance of feed, but during others heavy and continued snowfall would make the feeding of hay necessary. At such times an insufficient supply of hay often resulted in heavy loss from starvation.

In time the settlers began to sow rye and cut it for hay, and at the present time, outside of the irrigated section, rye constitutes the principal hay supply. The ease with which rye could be grown in time led to the growing of other grain crops and the production of grain by very simple and inexpensive dry farming methods, which have continued in use to the present time. The sagebrush is cleared off and the loose soil plowed to a depth of a few inches, after which the grain is drilled or sown broadcast and harrowed in. Summer fallowing has not yet come into use in this area, the soil being rich and productive and the rainfall usually sufficient to produce a fair crop.

In some cases the soil is prepared for the second crop of grain by a thorough harrowing, which leaves the surface in fair condition and has the advantage of leaving the stubble of the preceding crop on the ground, thus preventing to a considerable extent the drifting of the sandy soils.

Grain crops are also grown in the irrigated sections of the area and not only give much larger yields but are also much more certain than are the nonirrigated crops. On the better soils under favorable conditions irrigated wheat and barley each give a yield of from 30 to 40 bushels per acre and oats from 60 to 75 bushels per acre, the grain being of excellent quality. When dry-farmed the yields under favorable conditions of soil and weather are about half of those stated.

When irrigation was begun in a small way the water was used principally on pasture land, but in time alfalfa was introduced and at present is the principal irrigated crop of the area. It yields two good crops a year, with occasionally a smaller third crop, but is usually pastured after the second cutting. The average yield of alfalfa for the entire irrigated section the past year was almost 3 tons per acre for the two cuttings, while many fields yielded 4 tons with two cuttings and a few as high as 5 tons. Alfalfa is also grown without irrigation in certain restricted areas. Part of this is grown where no ground water can be reached within several feet of the surface, the crop being entirely dependent upon the moisture conserved in the soil from rainfall. Some is also grown without irrigation where ground water is reached at depths varying from 3 to 6 feet. In the first case only a thin stand can be maintained and the growth is not large, one small cutting usually being obtained. Where ground water is nearer the surface the yield under favorable conditions is fairly satisfactory, but owing to the tendency of the ground water to fluctuate and in this way injure the roots such alfalfa usually dies out within a few years.

In this area the opinion seems to be prevalent that alfalfa needs no fertilization, but even on fertile and almost virgin soil, such as that found in the Klamath Basin, when irrigated it responds readily to a liberal use of well-rotted manure.

By giving more attention to the preparation of the seed bed so that a good stand may be secured, by using greater care in leveling the fields so that some spots will not die from lack of water while others are drowned from an oversupply of it, and by using all available manure on the alfalfa fields, the yields may be very materially increased.

In the irrigated sections alfalfa constitutes the principal feed for work animals during the entire season. It is also used to some extent for dairy cows, but the principal part of it is used for feeding stock which is brought into the valley from the ranges in the fall. The price of alfalfa in the stack during 1908 ranged from $7 to $8 a ton.

Timothy, usually mixed with alfalfa, is grown to a very limited extent and gives a yield of 1½ to 2½ tons per acre. This hay is of excellent quality.

The growing of potatoes has received considerable attention, and both soil and climate seem well suited to this crop, except for occasional erratic frosts. Potatoes are grown principally on the slopes above the floor of the valley, such slopes being freer from frosts than the lower lying areas. They are grown largely without irrigation, the areas devoted to them being principally above the irrigation ditches. The soil receives a shallow plowing in the spring, the potatoes are planted, and often receive little cultivation, but a yield of from 50 to 100 bushels to the acre is not uncommon. When irrigated much larger yields are obtained.

In the small valley of Link River and on some of the sheltered slopes in and near Kalamath Falls gardening is receiving some attention. Garden truck of excellent quality is grown, but on account of the shortness of the growing season the crops are somewhat uncertain, since only those not easily injured by frosts can be depended upon.

The price of land in the area varies greatly, depending upon the kind of soil, location, and improvements. The price of the better grades of land unimproved and usually covered with a heavy growth of sagebrush ranges from $20 to $50 an acre, while improved land of the same character is held at $50 to $75 an acre and in some cases at $100 an acre. This does not include the cost of water which will be furnished by the Reclamation Service, this charge depending upon the cost of constructing the irrigation system. It is not yet known what the cost will be, but when determined it will be paid by the owners of the land in ten annual payments, after which the system will become the property of the landowners and the cost of water will be the amount necessary to pay the maintenance and operating expenses of the system.

In 1900 the average size of the farms in Klamath County was nearly 500 acres. One of the conditions, however, under which the Reclamation Service has agreed to furnish water for irrigation is that no holding receiving water shall contain more than 160 acres. Where farms contain more than this amount the excess must be sold or turned over to the Government for sale.

With the completion of the railroad to Klamath Falls this area will be in direct communication with San Francisco and Portland, and it will no longer be necessary to limit the products of the country to live stock and those crops which can be consumed at home. The railroad will not only make these and other markets accessible, but will make it practicable to exploit the timber resources of the region. This development will mean an increased demand for farm products which the people of the Klamath Basin will be in a position to supply.

Of the staples which this area seems best suited to produce dairy products are among the most important. With its cool summers and not severe winters, its fair yields of excellent alfalfa, and its abundant water supply it should be an excellent dairy country.

At present a small creamery is in operation at Bonanza, receiving barely enough cream to pay for running, and another was operated for a while at Merrill, but closed for lack of patronage. This want of interest seems to be due largely to insufficient knowledge of the requirements of the business and to scarcity of good dairy cows.

At the present price of butter fat a high-grade dairy cow, properly fed and cared for, should yield a gross income of from $60 to $100 a year. On the better grade of alfalfa land in the Klamath area 20 cows can be kept throughout the year on from 40 to 60 acres, and including the returns from calves and separated milk fed to hogs should yield a net income of not less than $1,000 a year. It is doubtful, however, if at present general farming or dairying should be attempted on a farm of much less than 80 acres.

The raising of hogs on alfalfa may be made a very profitable business, but so far has received little attention in this area. If young hogs are placed on alfalfa as soon as it is well started in the spring they will make an excellent growth throughout the summer and fall, and after being fed for a few weeks on crushed barley, wheat, or field peas are ready for market.

On account of the wide area of open range adjacent to the Klamath project the raising of large numbers of horses, cattle, and sheep and the supplying of winter feed for them will always be an important business. The country and climate seem especially suited to the development of good horses.

Several crops which might become profitable are receiving little or no attention. Timothy is grown successfully in only limited areas of the West, yet timothy hay of good quality commands a high price on the market. With the opening of transportation facilities it would seem that timothy or timothy mixed with alfalfa or clover could be made a profitable crop for shipment.

The growing of Canadian field peas seems to have received little attention in this area, although both soil and climate are well suited to their production. This crop may be cut for hay or when the peas have begun to ripen may be used as pasture for hogs or sheep. When so used they make one of the best fattening crops.

The saving of alfalfa seed, where alfalfa will mature seed in paying quantities, is a profitable business, yet one which seems to have been entirely overlooked in this area. During the months of July and August, wherever conditions have been favorable for the ripening of alfalfa seed, as along the ditch banks or in fields which have a poor stand and have received only a little water, the alfalfa plants are found to be loaded with seed of the finest quality. If it is desired to produce seed a field having a very thin stand should be selected and in this area the first crop should be used. If necessary the crop may be irrigated early in the season, but after the blossoms begin to form no more water should be applied and the soil should be allowed to become fairly dry. When the seed pods have begun to turn brown the alfalfa should be cut.

The cost of thrashing and cleaning alfalfa seed is usually $1 a bushel and the yield of a good crop should be from 2 to 5 bushels per acre. Alfalfa seed is selling now (1908) at prices ranging from $8 to $11 a bushel wholesale.

Among the crops best suited to the Peat are barley, oats, timothy, redtop, alsike clover, and red clover. Cabbage, turnips, lettuce, celery, and onions should give good yields. Potatoes should also yield well, although the danger from frost may be somewhat greater than on the uplands.

The chief value of the Peat will be the production of root, forage, grain, and hay crops for the feeding of cattle, sheep, hogs, and horses. Dairying and the production of animals for the block will always be a leading industry, to which the conditions are eminently adapted.

From the character of the soils in the Klamath area and their similarity, both in origin and texture, to the soils of other regions in which fruit growing has become an important industry, the conclusion has been reached that this area is also well suited for fruit growing. If the soil alone were to be considered this probably would be true, but unfortunately the climate of the Klamath area, with its killing frosts late in the spring and early in the fall, is such that fruit growing on a commercial basis will always be a rather uncertain business. Proof of this is to be found in the weather records of the area and in the yields obtained in the few small orchards old enough to bear, the results seeming to show that only about two good crops in five years may be expected, with very small or no crops in the intervening years. It is believed, however, that by selecting the best sheltered portions of the basin, by introducing hardy varieties, such apples as the Spitzenburg, Banana, Jonathan, and Bellflower, for instance, and by protecting the orchards with closely planted wind-breaks, much more fruit may be grown than at present, and no ranch should be without a small, well-protected orchard, even though the crop is uncertain. It is even possible that by the use of all available means for protection, orchards on a large scale, through the yielding of large crops of good fruit at intervals, might be made profitable, but such experiments should not be undertaken by new settlers, who, more than anyone else, need crops which can be depended upon.

Cherries, plums, blackberries, raspberries, gooseberries, and currants grow well and give large yields, while in the mountains northwest of the area there are hundreds of acres of wild huckleberries, from which large quantities are gathered each year. Wild plums are also common in this region.

In different parts of the area experiments have been carried on in a small way with sugar beets, and a large tonnage of beets having a high sugar content produced. The soils of a considerable proportion of the area, especially in the vicinity of Merrill and along the north shore of Tule Lake, are well suited in character and in slope of land for this crop. The successful growing of sugar beets, however, requires an intensive type of farming for which the people of this area do not yet seem to be prepared.

Better farming methods are needed throughout the area. Although good crops are now produced, better preparation of the soil and more careful seeding will more than repay for the extra labor.

Already weed pests are getting such a foothold that they can be eradicated only with great difficulty. One of the worst of these pests is the "death" or "poverty" weed (*Iva axillaris*), common throughout the alkali and poorly drained sections. This plant alone the past year caused losses in grain and alfalfa fields amounting to many thousands of dollars. Foxtail (*Alopecurus*) is another weed which grows in wet, poorly drained areas and is especially troublesome in alfalfa fields.

The Russian thistle, one of the worst weed pests with which the western farmer has to deal, has already made its appearance in a few places in the area, and unless vigorous means are taken to eradicate it, will undoubtedly cause great loss to the farmer in the near future.

SOILS.

The soils of the Klamath area are derived principally from three sources: First, from the "chalk" which underlies a large part of the basin; second, from the disintegration of the basaltic rocks of which the adjacent hills are composed; and, third, from the decay of organic matter.

Extending under the basin is a light-colored material locally referred to as "chalk," "chalk rock," or "hardpan." When dry it varies in color from almost white to a light yellow or buff, but when wet and mixed with a small quantity of other mineral matter or decayed organic matter it becomes much darker, often being dark gray or almost black in color. In places it is clearly stratified, the different thin layers being shown by differences in color, but in other places it has a massive structure. When dry it is so light that it floats on water, and the soil formed from it is very fine and light in weight, resembling flour more than soil. It varies considerably in composition, the field examinations showing variation in color, weight, and texture. Tests with hydrochloric acid in places gave a rapid effervescence, thus indicating the presence of considerable quantities of carbonate of lime, while in many other places the application of acid produced no effervescence. A complete analysis of a sample taken from the ditch bank southeast of Klamath Falls shows it to contain a high percentage of silicate and a very low percentage of potash and phosphoric acid. Examination of this material from different parts of the area by means of the electrolytic bridge showed considerable variation in the soluble salt content, but as a whole it carries a much higher percentage of such salt than is carried by the sands or sandy loams. An examination of this "chalk" under the microscope shows it to contain minute shells, the remains of diatoms which probably lived in fresh lake waters. The diatoms are of many different varieties. Samples from different parts of the basin vary in the proportion of diatomaceous material from only a few scattering fragments in some samples to masses made up almost entirely of diatoms in others.

This material, which will be referred to in this report as "chalk," because so known locally, was deposited in earlier times in a lake which covered the entire basin and was probably formed through the damming of the Klamath River by a recent lava flow.[a] While it varies considerably in composition as a whole, the "chalk" is made up largely of volcanic ash which was carried by winds and waters and deposited in this shallow lake together with the diatomaceous earth, and is composed largely of siliceous or glassy material, resulting in this case in an unproductive soil.

Throughout the larger part of the area this "chalk" occurs as subsoil, the upper portion of it being mixed with the overlying or weathered soil, which varies greatly in thickness. In a few places, however, the chalk has no surface covering and is washed down into the lower portion of the valleys, where it is mixed with the soils or forms the surface material. The following table shows the relative amount of diatomaceous material in this formation:

Microscopical examination for diatomaceous material.

Number of sample.	Location.	Relative amount.
19285	SW. ¼ sec. 17, T. 48 N., R. 2 E	Medium.
19293	One-fourth mile S. cen. sec. 28, T. 48 N., R. 2 E	Do.
19294	Subsoil of 19293	Do.
19295	....do	Large.
19296	....do	Do.
19297	Three-eighths mile E. cen. sec. 29, T. 48 N., R. 3 E	Medium.
19298	Subsoil of 19297	Do.
19299	....do	Small.
19307	One-half mile SW. cen. sec. 23, T. 40 S., R. 8 E	Do.
19308	Subsoil of 19307	Medium.
19309	....do	Do.
19312	SW. cor. sec. 16, T. 47 N., R. 3 E	Large.
19317	SW. ¼ sec. 24, T. 39 S., R. 8 E	Medium.
19319	One-fourth mile SW. cen. sec. 4, T. 41 S., R. 9 E	Large.

The hills and mountains surrounding and extending through the Klamath area are volcanic in origin and, excepting the "chalk" found at their base and in places extending under the volcanic rocks, are formed of basalt of different kinds. Much of this basalt is very hard and its transformation into soil would seem a very difficult matter, but under the agencies of weathering it breaks down rather rapidly, forming the soils not only on the slopes of the hills, but also over much of the basin.

[a] Diller, Geology and Petrography of Crater Lake National Park, page 7.

The soils upon the south and southwest slopes which receive the most sunshine and the greater part of the rainfall are light and sandy, while on the north and northeast slopes, where the changes of temperature are less frequent and less marked and where the soil during the winter season often remains moist for long periods, the tendency is toward heavier soils. This difference in texture is caused in other ways, as by the action of seepage water or water from springs upon the soil, thus breaking the coarse particles down into finer ones, often by this means forming an adobe from a sandy soil. Hot springs are especially efficient in rock decomposition, thus hastening the formation of heavy soils. This is quite noticeable in the vicinity of Klamath Falls and on the west side of Langell Valley, where north-slope seepage water and hot springs have in places combined to form areas of adobe.

The overflow lands along streams, especially if kept moist for a considerable period, also become heavier through the action of the water on the soil grains. The heavy soils along Lost River and those in the bottoms of the numerous shallow basins in the area have been formed in part by this means.

These basalt soils, except in very limited areas, are not found resting upon the rocks from which they were formed, but as they are loosened by frost and heat are gradually carried down the slopes by gravity and by the rain and wind.

Soils which remain in place, covering the rocks from which they have been formed, are known as residual soils, those which have gradually moved down the slopes as colluvial, those which have been suspended in streams and redeposited as alluvial, and those which have been carried by the wind as eolian. Representatives of all four of these divisions are to be found among the soils of basaltic origin in this area.

In addition to the soils composed largely of "chalk" and those of basaltic origin, there is a third class of soils quite different from either. In certain parts of the area conditions have been and are still very favorable for the rapid growth of tules, marsh grass, and like plants, and these have grown so luxuriantly that at present the soil contains a very high percentage of organic matter from their decay. Locally these areas are known as marsh soils. They are confined principally to the basin occupied by Lower Klamath Lake, while the soils of the other two classes are mingled almost indiscriminately throughout the remainder of the area.

The soils of the area are with but few exceptions light and friable, easily cultivated, and not difficult to handle when irrigated, and their value for the particular crops suited to this section depends very largely upon the depth of soil, freedom from alkali, and thorough drainage.

On account of similarity in origin and arrangement the principal upland soils of this area have been correlated with the soils of the Yakima series, while the remaining soils, consisting of the marsh soils and those which have been modified by the addition of organic matter and by being reworked and deposited on flood plains and in basins, have been placed in a new series to be known as the Klamath soils.

The following table gives the name and extent of each of the soil types found in the Klamath reclamation project area:

Areas of different soils.

Soil.	Acres.	Per cent.	Soil.	Acres.	Per cent.
Yakima sandy loam	70,464	44.2	Yakima loam	6,912	4.3
Yakima sand	25,600	16.1	Klamath fine sandy loam	2,048	1.3
Yakima fine sandy loam	17,280	10.8	Yakima clay adobe	384	.3
Yakima clay loam	15,680	9.8	Peat	384	.3
Klamath loam	11,776	7.4	Total	159,360	
Klamath clay adobe	8,832	5.5			

Yakima Series.

The members of the Yakima series are probably residual soils derived mainly from basaltic rocks in place, or they may be in part sedimentary from the same material reworked and deposited in ancient lakes. The series occurs in the intermountain region, and has been mapped already in Oregon, Idaho, Montana, and Washington. In many places volcanic ash forms an important constituent of these soils. In the present area the diatomaceous earth has contributed to their formation.

YAKIMA SANDY LOAM.

The Yakima sandy loam is typically a light-brown, yellowish-brown or reddish-brown sandy loam, the color becoming much darker when the soil is moist. In certain limited areas the color is gray and in others, where the content of organic matter is large, it is very dark brown or black.

The lower portion of the soil and the subsoil is light brown or yellowish brown or gray in color, while the lower subsoil is a light-yellow or buff color when moist, often almost white when dry.

In texture this soil is a medium to fine sandy loam in which the sand grains are neither waterworn nor very sharp, but are roughly angular, giving the soil a harsh, rough feel when rubbed in the hands. The surface soil is usually light, the surface 3 or 4 inches in many parts of the area being a sand, but the surface soil grades into a slightly heavier sandy loam which extends to a depth of from 15 inches to 3 feet or more, the average depth for the entire area probably being about 30 inches. The lower subsoil or "chalk" carries a rather high percentage of silt and clay, being in texture a clay loam or sometimes a silt loam.

Limited areas of this soil with sand-covered surface occur in the vicinity of Manning Ridge, in portions of Sand Hollow, and in many other parts of the area. There are other sections of the area in which the sandy loam has a surface covering of silty material resembling pumice which extends to a depth of 2 or 3 inches. The best example of this is to be found southeast of Miller Hill. In other parts of the area the sandy loam becomes quite heavy, approaching a heavy fine sandy loam or light loam in texture. These heavier places often occur where some small intermittent stream enters the valley, carrying silt and clay, also making the soil heavier by their admixture. Examples of such areas caused by small streams are to be found east of the Carr Ranch, on the south side of Poe Valley, and in many other parts of the area. This heavier soil also occurs in places on the hill slopes away from the influence of intermittent streams, an example of which is seen in sec. 2, T. 39 S., R. 9 E., 2½ miles southeast of Klamath Falls. In limited areas the Yakima sandy loam contains considerable coarse sand, an example of this variation being noted along the east side of Tule Lake north of Bloody Point. It also shows considerable variation in the vertical section, the surface material often being quite fine but underlain by soil of coarse texture, while the reverse is sometimes true. It is in the depth of soil and character of the subsoil, however, that the greatest variations occur. On the upper portions of some of the slopes and at the point of the hills it often contains numerous rock fragments sufficiently large to interfere with cultivation, the soil being shallow and resting on the basalt from which it has been formed. In these higher places small areas of comparatively good soil often occur interspersed with rock-covered areas which can not be cultivated. A considerable area of soil of this character occurs on the east side of Langell Valley. On the lower slopes of some of the hills the light sandy loam has been found extending to a depth of 4½ feet, although it is not usually so deep. In the lower portions of the valleys the sandy loam is in places not over 15 inches in depth, these shallower areas usually occurring in or near the low, poorly drained areas, although in most places it has a greater depth. In parts of the area the subsoil contains thin layers of soft sandstone slightly cemented with carbonate of lime, while in other places at a depth of about 3 feet a conglomerate 4 or 5 inches thick and composed of waterworn gravel and small pebbles rather firmly cemented is encountered. This conglomerate occurs in Spring Lake Valley south of Miller Hill, on the point of the hill northwest of White Lake City, and in other parts of the area.

As a whole the Yakima sandy loam may be said to be the best soil of the area, occupying as it does the gentle hill slopes and the better drained portions of the valleys, the deeper and better drained portions being the more desirable. The surface is usually smooth and easily prepared for irrigation. The soil is comparatively free from alkali. In its virgin state the sandy loam is usually covered with a dense growth of black sage, some of this being 3 inches in diameter at the base and having a height of from 3 to 8 feet. Where the soil is shallow the sage is small and scattering. On the higher slopes are juniper, wild currant, gooseberry, plum, and in some places pine.

This soil is well suited for the raising of alfalfa, grain, potatoes, and fruits.

The average results of the mechanical analyses of fine-earth samples of the soil and subsoil of this type are shown in the following table:

Mechanical analyses of Yakima sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18677, 18940, 19180, 19324, 19327.	Soil	1.1	8.9	9.5	37.7	14.7	17.5	10.7
18678, 18941, 19181, 19325, 19328.	Subsoil	1.4	8.7	8.6	35.5	14.1	19.6	12.1

The following sample contained more than one-half of 1 per cent of calcium carbonate ($CaCO_3$) No. 19181, 3.31 per cent.

YAKIMA SAND.

The Yakima sand is typically a yellowish or reddish-brown medium to fine smooth sand, the subsoil being of about the same texture as the surface soil, but usually lighter in color. In portions of the area, however, the sand is underlain at a depth of about 3 feet by yellowish sticky sandy loam, the upper portion of which is sometimes slightly cemented, forming a thin, soft sandstone or hardpan which breaks down rather easily. In other small and unimportant areas it also contains a rather large proportion of coarse, rough sand.

The surface of the Yakima sand is comparatively smooth, although somewhat more uneven than that of the sandy loam, and when uncultivated is almost uniformly covered by a dense growth of little rabbit brush, the yellowish-green foliage of which is easily recognized. In some portions of the area, however, where the sand is underlain by heavier soil, sagebrush is found growing on the sand. Normally it is free from alkali, but in areas of heavier subsoil and where drainage is deficient, alkali is formed in injurious quantities.

The Yakima sand, like the sandy loam, has been formed principally from the breaking down of the basaltic rocks of the hills, but the sand has been sorted out by the wind and in some cases by water and has been left in its present position.

The largest areas of this soil occur along Lost River, between the East Branch of the main canal and Stuckel Bridge and in Sand Hollow, but smaller bodies, many of them too small to be shown in the map, are found throughout the area.

The large body of sand along Lost River was probably carried to its present position by the flood waters of that stream when the volume of water was greater than at present, while the large body in Sand Hollow and the smaller bodies in other parts of the area are probably to a considerable extent wind deposits. In a few limited sections this soil is found drifted into small dunes, but drifting has been impeded to a considerable extent by the vegetation which it supports. When broken it drifts rather badly, but when a stand has been obtained it produces good crops of grain and alfalfa, being especially adapted to the growing of the last-named crop. On account of the permanent sod formed by alfalfa this soil should be used for that crop as much as possible. It also gives good yields of potatoes.

The average results of mechanical analyses of the soil and subsoil of this type are shown in the following table:

Mechanical analyses of Yakima sand.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18675,18934,19178.	Soil.........	2.7	13.8	12.2	49.0	10.2	6.9	5.0
18676,18935,19179.	Subsoil.....	3.3	13.8	11.2	45.3	10.4	8.9	7.4

YAKIMA CLAY LOAM.

The Yakima clay loam is an ashy-gray or almost white silty clay loam. When dry it has a fluffy and flourlike texture. When wet it is quite sticky and in places shows an adobe structure. It is to a considerable extent a residual soil, having been formed from the "chalk" beds, the upper portion of which has been gradually changed into a soil through weathering, the decay of plants, and cultivation, and mixed with sand from adjacent areas. The surface soil from a few inches to about 15 inches usually grades into the "chalk" from which it has been formed. In many places, however, silt and clay from exposed "chalk" beds on the hillsides have been washed down into the valleys and deposited along the small stream courses. In other places the "chalk" from surrounding areas has been washed into the numerous basinlike depressions which occur in some parts of the survey, forming small areas of silty adobe. These are especially noticeable in Spring Lake Valley. In many parts of the area, and especially in Poe Valley, there are low, broad areas separated from the adjacent higher level areas by a sort of bench 2 or 3 feet in height, the clay loam occupying the lower areas and sandy loam the higher.

Over the greater proportion of the area this clay loam has a surface covering of from a few inches to as much as 15 inches of sand, sandy loam or fine sandy loam, this being most noticeable near the adjacent areas of sandy soil. In some places this surface covering is in the form of mounds, giving the areas a very uneven surface. A good example of this is seen along the gravel road southeast of Klamath Falls.

Where the clay loam is covered to a depth of from 12 to 15 inches by sandy soil, is well drained, and free from alkali, it is fairly productive, but where the "chalk" forms a considerable portion of the surface soil it is a poor and unproductive type. Where it can be irrigated it may be greatly benefited by a liberal use of manure and by plowing under green crops. When once seeded to alfalfa it produces fairly good crops, but, as a whole, it is less productive than the sand or sandy loam, and usually carries injurious amounts of alkali. It occupies the lower portions of the valleys and is often poorly drained.

This soil is distributed throughout the larger part of the area, and in its natural state supports a growth of large rabbit brush, greasewood, salt grass, and other alkali-resistant plants.

The average results of mechanical analyses of the soil and subsoil of this type are shown in the following table:

Mechanical analyses of Yakima clay loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18679, 18681, 19080.	Soil.........	0.3	3.6	2.5	7.2	8.1	54.0	24.3
18680, 18682, 19081.	Subsoil......	1.4	5.8	4.4	11.5	9.1	43.8	24.3

The following sample contained more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 19081, 2.86 per cent.

A determination of the organic matter gave the following percentage: No. 18679, 5.75 per cent.

YAKIMA FINE SANDY LOAM.

The Yakima fine sandy loam is a smooth fine sandy loam varying in color from ashy gray to brown or yellowish brown, and is made up almost entirely of fine sand, very fine sand, silt, and clay derived from the breaking down of the basalts of the hills. In method of formation, depth of soil, character of subsoil, and crop value it has rather wide variations, which can best be described as separate phases of the same soil.

On the west slope of Klamath Valley, 1½ miles west of Stukel Bridge and extending a considerable distance to the south, is an important body of the Yakima fine sandy loam. It is light brown or yellowish brown in color and extends to a depth of 5 or 6 feet, there being little difference in color or texture between the soil and subsoil. Other smaller bodies of this soil occur on the hill slopes in different parts of the area, but on account of their small size and indefinite boundaries they have been included with the Yakima sandy loam.

Extending west from Adams Cut, southwest of Merrill, is another rather large body of this soil, the lower lying portions of which contain considerable alkali, this being especially true in the part adjacent to White Lake. As this soil extends farther up on the hill slopes it usually becomes shallower and is underlain either by "chalk" or by basalt at depths varying from a few inches to 2 or 3 feet. The hills directly west of Merrill consist of numerous small bodies of this shallow fine sandy loam, underlain by "chalk" or by a soft, porous volcanic rock, interspersed with nonarable, rock-covered areas.

These soils are colluvial and residual in origin, the larger part of them being above the lines of possible irrigation ditches, and are used for dry farming, grain and potatoes being the principal crops.

In their natural condition these soils support a dense growth of sagebrush and in the vicinity of White Lake a growth of greasewood.

Near the center of the Klamath Valley is another phase of the Yakima fine sandy loam, one of the largest bodies of which extends north from Lost River Slough. Another occupies the valley floor 1 mile west of Stukel Bridge. This soil is in most places separated from the soils of the adjacent hill slopes by a rather clearly defined bench or terrace, and is characterized by an almost perfectly flat topography. Where this soil occurs adjacent to Lost River it is usually darker in color and heavier in texture than the typical soil, this condition resulting from more recent deposits along the river. Under these conditions there is no sharp line of demarcation between this soil and the more recently deposited Klamath fine sandy loam.

The material of which this soil is made up differs but slightly from that of the fine sandy loam of the hill slopes, except in having been spread out over a plain. This deposition probably occurred at one stage of the lake which formerly filled the Klamath Basin.

The surface soil is a very light, friable, smooth, fine sandy loam, which extends to a depth of from 15 to 30 inches, where it is underlain by a sandy loam slightly heavier in texture. This reaches to a depth of 6 feet or more, or is in turn underlain by the "chalk." The upper portion of this subsoil is often cemented into a soft, easily disintegrated hardpan, 2 or 3 inches in thickness, which frequently contains considerable quantities of black alkali. The subsoil below the hardpan also contains alkali.

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On account of the high capillary power of this soil and the presence of alkali in the subsoil, the danger from a surface accumulation of alkali in injurious amounts when the soil is irrigated is very great. In its natural condition this phase of the Yakima fine sandy loam supports a scattering growth of large rabbit brush, salt grass, and in some places greasewood. A strip of this soil free from alkali and hardpan extends for a considerable distance along the north edge of Tule Lake. The value of the Yakima fine sandy loam as a whole depends upon the depth of soil, freedom from alkali, and possibility of irrigation and drainage. Where these conditions are favorable it is one of the best soils of the area, well suited to the growing of alfalfa, grain, potatoes, and such fruits and garden truck as may be grown in the area.

The average results of mechanical analyses of the soil and subsoil of this type are shown in the following table:

Mechanical analyses of Yakima fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18938, 19717	Soil	0.4	5.7	6.4	33.1	20.4	24.8	9.1
18939, 19718	Subsoil	.7	4.2	4.4	28.1	24.6	26.3	11.6

YAKIMA LOAM.

The Yakima loam consists of a reddish-brown loam containing much fine sand in the surface 3 or 4 inches, below which it becomes heavier in texture. When dry it is friable and has the appearance of being a fine sandy loam, but when wet it is quite sticky. Upon drying after being wet and compacted it breaks with a shaly fracture. At a depth of about 16 inches the surface soil grades into a yellowish sticky loam, also containing much fine sand. This subsoil may extend to a depth of 6 feet or more or may be underlain by basalt fragments or by chalk at a depth of 3 or 4 feet. In places many small sharp rock fragments are scattered over the surface and through the soil. It has also in places been transformed by the action of moisture into a dark-brown or almost black adobe, these adobe areas being too small to be indicated on the soil map.

In many places where this soil approaches the marshes or the lower portions of the valleys it becomes dark in color, heavier in texture, and often contains some alkali, thus resembling, and in places merging into, the loam of the Klamath series. Bodies of this loam occur along the rather steep hill slopes west of the Klamath River in Langell Valley and in other parts of the area. The greater part of this type is well drained, comparatively free from alkali, retains moisture well, and is suited to orchards, grain, and alfalfa. In its natural condition it supports a scattering growth of sagebrush, wild currant, juniper, and in places large rabbit brush.

The results of the mechanical analyses of fine-earth samples of the soil and subsoil of this type are shown in the following table:

Mechanical analyses of Yakima loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
19713	Soil	1.1	4.9	5.6	15.1	14.2	46.2	12.4
19714	Subsoil	.7	3.2	2.9	9.1	22.6	50.9	10.1

YAKIMA CLAY ADOBE.

The Yakima clay adobe is a dark-brown or almost black soil, residual in origin and resting on the parent basaltic rock from which it was derived, or in some cases upon the "chalk" of the valley floor. It varies in depth from 2 to 4 feet or more and often contains irregular fragments and blocks of basalt, which in places are sufficiently numerous to interfere with cultivation. When dry this soil breaks into the small irregular cubelike pieces characteristic of adobe soils. As found in this area the soil is not very uniform, many portions of it being a loam in texture and in some places the adobe structure is also wanting. Although small areas occur in a number of places, only two of these are of sufficient extent to be shown in the map, one at Klamath Falls and the other on the east side of Langell Valley.

The Yakima clay adobe is rather difficult to cultivate, especially if not in the proper moisture condition, but if well drained it is a durable, productive soil suited to the crops of the area.

The results of mechanical analyses of the soil and subsoil of this type are shown in the following table:

Mechanical analyses of Yakima clay adobe.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18679	Soil	0.1	1.1	0.4	1.3	2.6	60.1	34.7
18680	Subsoil	.5	2.4	2.8	8.6	7.4	54.7	23.3

KLAMATH SERIES.

The soils of the Klamath series are alluvial and lacustrine in origin, occurring as stream flood plains, frequently or occasionally overflowed, and as the beds and margin of shallow lakes.

The soils consist of basaltic material, volcanic ash, and diatomaceous earth of the Yakima series reworked, deposited, and modified by the action of the water and by the addition of organic matter, which in many places forms a very high percentage of the soil.

In color these soils vary from dark gray when dry to black when wet. The subsoil is lighter in color and usually lighter in texture than the surface soil. Much of the soil of this series carries an appreciable quantity of alkali, especially that along the lake margins. Where free from excess of alkali and well drained these soils should prove very productive.

KLAMATH FINE SANDY LOAM.

The Klamath fine sandy loam is a gray, dark gray, and, in places, almost black fine sandy loam. It is smooth and uniform in texture, friable, and easily cultivated. At a depth of about 15 inches the surface soil grades into a gray light fine sandy loam which extends to a depth of 6 feet or more. Near the contact between the soil and subsoil the texture is usually heaviest and in some places at about this depth a thin, slightly cemented layer is encountered.

The Klamath fine sandy loam is usually comparatively free from alkali, although in places it carries small quantities.

This soil occurs in small bodies along Lost River and its tributaries and has been deposited largely by flood waters from those streams. Where this soil occurs adjacent to the Yakima fine sandy loam of the lower valley phase there is no sharp boundary line between them.

In its natural state the Klamath fine sandy loam supports a dense growth of sagebrush and large rabbit brush. Where cleared and prepared for irrigation it is well suited to alfalfa, grain, or garden truck.

The results of mechanical analyses of the soil and subsoil of this type are shown in the following table:

Mechanical analyses of Klamath fine sandy loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
18936	Soil	0.0	1.4	1.0	31.7	11.1	38.0	17.6
18937	Subsoil	.0	1.0	2.1	41.3	12.7	27.1	15.2

KLAMATH LOAM.

The Klamath loam consists of an ashy-gray, dark-gray or almost black loam to a depth of from 1 to 3 feet, underlain by a gray loam or in some cases by a gray, sticky fine sandy loam, which may extend to a depth of 6 feet or more, or may be underlain by the "chalk." The surface of this soil often appears gray from the tufaceous material which it contains, but in many of the lower lying areas it is quite black. In most places it carries alkali, but only in the small basinlike depressions and in the areas along the margins of the marshes is the quantity sufficient to be injurious.

When wet this soil is in places mucky and sticky, but when in the optimum moisture conditions it is friable and easily cultivated.

The principal areas of Klamath loam occur in the lower parts of Yonna, Langell, and Poe valleys, and along the margin of the marsh lands of Lower Klamath Lake. There are also a few small areas of this soil in Klamath Valley east of Lost River and along Lost River Slough. As in the case of the fine sandy loam, there are in places no sharp lines of demarcation between the black loam of the Klamath series and the brown residual and colluvial loam of the Yakima series.

The native growth of this soil consists principally of sagebrush, usually rather stunted, large rabbit brush, salt grass, and other alkali-resistant plants.

It is dry farmed to grain and potatoes to a limited extent. Alfalfa does not produce so well as on the sandier soils, although grain crops are often much heavier. Where well drained and irrigated it will be found well adapted to redtop, timothy, red clover, and other crops suited to the climate.

The average results of mechanical analyses of the soil and subsoil of this type are shown in the following table:

Mechanical analyses of Klamath loam.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
19317, 19322, 19715.	Soil.........	0.4	6.7	5.8	17.6	7.8	43.9	17.2
19318, 19323, 19716.	Subsoil.....	.5	5.7	7.2	25.3	15.3	28.1	17.6

The following samples contained more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 19317, 6.56 per cent; No. 19318, 0.66 per cent.

A determination of the organic matter gave the following percentages: No. 19317, 26.20 per cent; No. 19318, 0.56 per cent.

KLAMATH CLAY ADOBE.

The surface soil of the Klamath clay adobe is ashy gray in color when dry and black when moist. It extends to a depth of about 30 inches, below which it grades into a yellowish silty clay loam, loam, or sometimes into a sandy loam, the subsoil always being lighter in color and texture than the surface soil. The dark-colored surface soil is a true adobe, cracking badly, wide cracks often extending to the subsoil, and when broken it separates into little cubes.

The principal bodies of the Klamath clay adobe lie along Lost River in Langell and Poe valleys, where the soil has been formed from material brought into the valleys by the river. The color is due in a large part to the high organic matter content. Other small bodies are found in the beds of small shallow lakes near the marsh. These were in most cases too small to be shown on the map.

This soil along Lost River is used exclusively for pasture and mowing land, the native flags, bluestem, foxtail, and other grasses being cut for hay or grazed. In these small lake-bed areas this soil is usually strongly impregnated with alkali, and in portions of the Poe Valley it also contains alkali in small quantities, but in the remainder of the area it is comparatively free from injurious salts.

In order to farm this soil, both protection from overflow and provision for drainage would be necessary, but even then, on account of its refractory nature and the difficulty of handling it under irrigation, it would be poorly suited for farming. It is best suited to the raising of timothy and redtop, which do fairly well when a sod has once been established.

The results of mechanical analyses of the soil and subsoil of this type are shown in the following table:

Mechanical analyses of Klamath clay adobe.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
19313	Soil	0.0	1.9	1.3	5.5	3.7	20.0	66.7
19314	Subsoil	.1	1.1	1.8	8.8	3.9	31.5	51.9
19315	Lower subsoil	.4	3.0	3.9	19.4	12.0	30.6	29.7

The following samples contained more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): No. 19313, 2.90 per cent; No. 19314, 1.14 per cent.

A determination of the organic matter gave the following percentages: No. 19313, 2.57 per cent; No. 19314, 1.03 per cent.

PEAT.

The soil of the Klamath Lake basin is Peat and has been formed from the decomposition of tules in the swamps and shallow lake water. Its origin is rather recent, for the black tule peat and muck containing plant fiber and pieces of plants and roots extends in the heaviest deposit to a depth of 8 or 10 feet only. In similar soils elsewhere in California such deposits often occur to a depth of 40 feet. Water-bearing sands occur at shallow depths and heavy tufaceous and diatomaceous deposits devoid of fiber are found under all parts of the swamp and lake between the depths of 5 and 13 feet. These evidences of recent tule deposits tend to show that at one time there occurred a much greater flow of water into bodies of water much deeper than is now found and too deep for the growth of tules.

By a decrease in regional rainfall and a wearing away of the barrier in the Klamath River at Keno the lake has become much shallower, enabling the growth of tules to cover more than three-fifths of the former lake surface. Overlapping of growing tules into the open water has caused pieces to break away, forming floating islands. These islands, lodging in shallow waters, form nuclei for further encroachments on the lake. This mass of tule roots and stems, making a dense mat on the surface and rotting away below, formed the present top soils of the swamp or marsh lands.

When the lake was deeper than at present, large quantities of volcanic tufa, ash, and pumice were washed into the lake from the surrounding mountains, which contain large deposits of these materials. Small siliceous plants called diatoms grew in such abundance that their siliceous casts formed very considerable deposits, markedly affecting the lake bottom deposits. As the lake subsided the tufaceous deposits became less pronounced, but the diatomaceous depositions continued until at present they form a large proportion of the tule, muck, and sludge of the upper soil of the swamps and lakes. This mixture of fine, light, volcanic and diatomaceous material gives these subsoils a plastic, slimy, and in places a somewhat rubbery consistency. The proportion of this material decreases rapidly as the soil surface is approached, where it becomes a minor part of the peat or muck. There exists in all cases sufficient quantities to turn the soils a light ashen-gray color when dry, but on subsequent wetting they revert to a dark-brown or black color.

In weight the tule soils are very light, all of them floating when dry and the tule mat always floating when becoming detached.

The tule soils are very porous, readily permitting the percolation of irrigation or rain water. The large admixture of fine tufaceous and diatomaceous material greatly increases the capillary power of the Peat, and more especially in the lower depth. Usually the first part of the tule mat is somewhat lacking in this respect. Where this tule mat has subsided and decomposed into a black fine-grained muck, as in the narrow strip along both sides of Klamath River, capillary power is greatly increased.

In structure and depth the Peat shows some variation, but a general uniformity. The tule mat consists of tangled roots and stems, with an addition of tufaceous and diatomaceous earth to a depth varying from 12 to 20 inches. Directly under this mat occurs a mass of muck and broken tules, usually very loose and watery. At depths varying from 5 to 9 feet this muck gives way to a bluish-gray tufaceous material which contains no roots or fiber, although heavily charged with organic matter. This material is usually loamy in texture, but varies in different parts of the swamp and lake, being much heavier, more compact, and drier in the southern part. In the northern part this subsoil is often replaced by coarse basaltic sand or sandy loam at depths varying from 3 to 7 feet. This condition usually occurs in the region of Klamath River.

In many other parts of the marsh lands boring to a depth of 15 feet showed similar conditions, with the tule muck varying from 5 to 9 feet in depth. In all cases there existed a sheet of water between the muck and the heavier material of the subsoil, which rose to within 2 feet or less of the surface when liberated.

While the main body of the Peat soil is described above, there are certain variations too small or too insignificant to map, such as black mucky loam, black loam, clay loam, and sludgy material. The black mucky loam is a light-textured soil consisting of well-rotted and finely decomposed tules showing no fiber. It is usually 6 feet in depth and occurs along the Klamath River and the outer edges of the adjacent swamps. It is usually slightly elevated above the surrounding region and is covered with wild grasses, such as bluestem, foxtail, juncus, salt grass, and bunch grass, which afford hay and pasturage. From its excellent capillary powers considerable alkali is accumulated on the soil surface in a white crust. On account of its low elevation but little of these salts is washed away, as is the case in the adjacent land.

About the edge of the swamps heavy black loam and clay loam occur in narrow strips. On the heavier of these soils no tules grow.

In the open waters of Lower Klamath Lake there is found a heterogeneous, sludgy mass of diatomaceous and tufaceous material, to which have been added disintegrated and rotted vegetable matter and fragments of diatoms and infusoria which teem in these waters. This material is dark colored when wet, but becomes gray when dry. It is extremely light in weight, but absorbs many times its weight in water. When drained it loses water very slowly and at all times will retain large quantities. In the bottom of the lake wholly submerged are found growing large quantities of seaweed and duckweed (*Lemna* sp.), which serve partially to hold this slimy sludge together. This ooze is so light and loose that wind disturbances moving the water pile it in masses in various parts of the lake. Where it extends to the surface of the water, tules often take root, forming a tule mat which in turn becomes Peat. In this manner the lake ooze is giving way to Peat. In depth this ooze or sludge may vary from 6 to 15 feet, where it is underlain by a solid bottom of gray or blue-gray diatomaceous and tufaceous loam or fine sandy loam filled with fragments of shells, mussels, and snails. This hard bottom underlying the water is much deeper than that underneath the Peat. Considerable quantities of black alkali occur uniformly throughout this ooze and would, unless drained out, interfere with crops when the land is reclaimed. It is classed as inferior soil material, but would, perhaps, when thoroughly drained, wear down into a muck soil which would be capable of supporting certain crops like redtop and others suited to the region.

The following results of chemical analyses are given by Heileman.[a]

The average of ten analyses showed calcium (CaO), 5.75 per cent; potash (K_2O), 0.25 per cent; phosphoric acid (P_2O_5), 0.22 per cent; total nitrogen (N), 1.10 per cent; loss on ignition (organic matter), 43.90 per cent.

The table below gives the results of a number of chemical analyses of material taken from Peat areas. These analyses were made in the Bureau laboratory.

Mineral constituents extracted by hydrochloric acid (Sp. g. 1.115), according to the method of the Association of Official Agricultural Chemists.

Sample and locality from which taken.	Constituents.				
	Phosphoric acid (P_2O_5).	Potash (K_2O).	Lime (CaO).	Aluminum oxide (Al_2O_3).	Ferric oxide (Fe_2O_3).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
19183. SE. ¼ sec. 34, T. 39 S., R. 9 E.; conglomerate, 33 to 37 inches	0.20	....	1.43	6.21	4.95
19185. Klamath Falls. Yellow chalklike material along ditch	.03	0.12	.54	....	....
19285. SW. ¼, SW. ¼ sec. 17, T. 48 N., R. 2 E.; Peat, 0 to 12 inches	5.06	.40	4.90	....	....
19293. One-fourth mile S. cen. sec. 28, T. 48 N., R. 2 E.; Peat, 0 to 12 inches	.31	.11	1.73	....	....
19294. Under No. 19293; Peat, 12 to 60 inches	.14	.25	3.30	....	....
19295. Under No. 19294; Peat, 60 to 108 inches	.04	.06	.92	....	....
19296. Under No. 19295; Peat, 108 to 138 inches	.27	.19	.28	....	....
19297. Three-eighths mile E. cen. sec. 29, T. 48 N., R. 3 E.; Peat, 0 to 12 inches	.31	.12	.09	....	....
19298. Under No. 19297; Peat, 12 to 90 inches	.22	.18	9.29	....	....
19299. Under No. 19298; Peat, 90 to 150 inches	.11	.03	1.44	....	....
19307. One-half mile SW. cen. sec. 23, T. 40 S., R. 8 E.; Peat, 0 to 20 inches	.11	.43	1.62	....	....
19308. Under No. 19307; Peat, 20 to 60 inches	.11	.56	12.90	....	....
19309. Under No. 19308; Peat, 60 to 96 inches	.02	.27	3.37	....	....

To subdue the Peat areas for farming it will first be necessary to burn off the standing tules, drain the soil to a proper depth, and then plow the tule mat some time in advance of planting. Plowing should be done in the fall with light, sharp steel plows. The tule sod is usually turned over to a depth of 4 to 6 inches, allowed to settle, and then disked and later harrowed down with a drag harrow. The soil should then be ready for a spring crop of grain or potatoes. For preparing the land for grass or cultivated vegetables a crop or more

[a] Klamath, The California-Oregon Irrigation District created by the United States Government.

of grain should be grown in order to render the soil uniformly fine and smooth. At least one season and perhaps two or three will be necessary to reduce the Peat to a state of perfect tilth.

The following table gives the average results of mechanical analyses of samples of Peat taken at four different depths:

Mechanical analyses of Peat.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
19285, 19293, 19297, 19307, 19319.	Soil	5.2	32.0	9.0	8.9	1.1	27.5	16.5
19294, 19298, 19308.	Subsoil	3.3	23.4	6.8	7.5	1.1	35.0	23.0
19295, 19299, 19309.	Lower subsoil.	Tr.	2.5	3.6	35.1	10.1	29.2	20.0
19296	Third subsoil.	.2	2.6	4.4	7.9	1.2	50.4	33.9

A determination of the organic matter gave the following percentages: No. 19285, 44.80 per cent; No. 19293, 44.50 per cent; No. 19294, 31.40 per cent; No. 19295, 1.31 per cent; No. 19296, 1.55 per cent; No. 19297, 42.20 per cent; No. 19298, 35.70 per cent; No. 19299, 1.84 per cent; No. 19307, 79.85 per cent; No. 19308, 19.60 per cent; No. 19309, 1.59 per cent; No. 19319, 44.32 per cent.

Soil of Tule Lake Bed.

On the north side of Tule Lake the bed of the lake slopes to the south very gently, the fall being only 5 or 6 feet to the mile. When people first came into the Klamath Basin the lake occupied a much smaller area than at present, the old emigrant trail having passed along the north edge of the lake, where at present the water is from 10 to 15 feet deep. Even within the memory of present settlers the lake shore has advanced a considerable distance, in several places posts which once formed fences being now seen sticking out of the water half a mile from shore. This rise of the water, however, is not a constant one, being greater when wet seasons occur and less during seasons of lighter rainfall. For this reason it is believed that the rise of the water during recent years is due to a series of seasons of slightly increased rainfall, rather than to the stoppage of an underground outlet.

It is the purpose of the United States Reclamation Service to reclaim between 12,000 and 15,000 acres of this lake bed by lowering the water the necessary 15 feet or more. This is to be done by making a reservoir of Clear Lake, thus cutting off the water supply of Lost River and by turning the seepage water which enters Lost River from the Upper Project through a ditch into Klamath River. With a large part of the water supply cut off it is thought that evaporation alone will in a few years restore the lake to the old level.

In order to study the soils of the area which will be reclaimed in this way several borings were made in various parts of the lake bed under water 3 to 15 feet deep. In nearly all places where examinations were made the soil was found to be a smooth-textured light fine sand quite similar to, but lighter than, the narrow strip of fine sandy loam which extends along the lake shore between Adams Point and Bevins Point. In the shallow water near the shore this soil contains rather small quantities of organic matter, but in the deeper parts the soil is darker in color and contains more organic matter, probably due to the decay of tules which formerly grew along the lake margin but were killed by the rise of its waters. Along the lake shore north of Bloody Point and also south of the mouth of Lost River the soil is much coarser than along the north side of the lake, this coarser soil probably extending out into the lake for a considerable distance. It was very difficult to determine the depth of the soil in the lake bed, but from the borings made under water and along the edge of the lake it is believed to vary in depth from 2 to 4 feet and to be underlain, like the soils of the remainder of the valley, by the diatomaceous earth.

From the surface indications of alkali along the lake shore near the mouth of Lost River it might be concluded that the reclaimed lands would contain injurious quantities of salts. Careful examination of these soils shows, however, that the amount of alkali which they contain is small, being confined to the surface inch or two, below which there is only a trace. A lowering of the ground water by drainage and a thorough surface flooding should remove this surface alkali. An examination of all samples taken from the lake bed showed them to be free from alkali, and with the exception of two small spots no alkali was found in the soils or subsoils in the entire area east of Adams Point. If these soils when reclaimed are kept properly drained little is to be feared from the accumulation of alkali. They will be found well adapted to the growing of alfalfa, grain, potatoes, and all other crops suited to the sandy soils of the area.

The average results of the mechanical analyses of the Tule Lake bed soils are shown in the following table:

Mechanical analyses of soils from Tule Lake bed.

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
19169, 19170, 19171, 19173, 19174, 19175, 19176, 19177.	Soil.......	0.6	4.7	4.8	47.0	25.4	12.6	4
19172...............	Subsoil....	.3	3.0	9.9	57.0	15.0	11.4	3.5

The following sample contained more than one-half of 1 per cent of calcium carbonate ($CaCO_3$): Nos. 19172, 1.92 per cent.

A determination of the organic matter gave the following percentages: No. 19169, 0.64 per cent; No. 19170, 0.70 per cent; No. 19171, 0.78 per cent; No. 19173, 1.32 per cent; No. 19174, 1.40 per cent; No. 19175, 0.94 per cent; No. 19176, 0.70 per cent; No. 19177, 1.84 per cent.

IRRIGATION.

Irrigation, in a small way, has been practiced in the Klamath Basin for over twenty years, an irrigation ditch having been constructed by the Klamath Falls Irrigation Company in 1884, and another, known locally as the Adams ditch, by the Little Klamath Ditch Company, in 1885. Each of these systems has been enlarged from time to time. In addition to the land irrigated from these ditches there were a few small areas along Lost River irrigated from springs and by water raised from the river with water wheels. The total area irrigated, however, was probably not more than 25,000 acres.

Soon after the organization of the United States Reclamation Service engineers were sent to inspect the Klamath country with a view to organizing a reclamation project, a favorable report was received, a water users' association formed, sufficient lands signed up in the Lower Project, and in May, 1905, the project was formally accepted by the Secretary of the Interior. Bids for construction work were opened in December, 1905, and active work began early the next year, the Government purchasing the systems then in operation.

The area to be irrigated is to be divided into the Upper Project and the Lower Project, the latter consisting of Klamath Valley, a part of Poe Valley, the marsh lands, and the lands adjacent to Tule Lake, which are to be irrigated with water diverted from Upper Klamath Lake. The Upper Project consists of Langell and Yonna valleys and a part of Poe Valley to be irrigated with water stored in Clear Lake.

Sufficient land was not taken up in the Upper Project to permit its being accepted until 1908, when work on the storage reservoir was begun.

When both projects are completed there will be, including 50,000 acres of marsh lands, between 150,000 and 180,000 acres under irrigation.

The principal irrigated crop of the area is alfalfa. Water is applied to the fields early in the growing season and again a short time before each cutting, making three irrigations in all. Three methods of irrigation are used, the border method, the check system, and flooding from small laterals, the last two being the most extensively practiced, and so far as observed with about equal success. The tendency, however, seems to be toward overirrigation, especially where the check system is used, the water often being held on the checks for a much longer period than is necessary to bring the soil into a proper moisture condition.

On account of the readiness with which the sandy soils of this area take up the irrigation water, where the slope is not too great, the border method of irrigation is recommended. By this method the field to be irrigated is laid off into long, narrow strips separated by low, broad borders, these being 6 to 8 feet wide and not over 8 or 10 inches high. These strips extend entirely across the field with the slope of the land, there being no cross borders or checks. The soil between the borders should be made smooth and level from side to side, but should have a uniform slope from the upper to the lower end of the check. Water is admitted at the upper end of the checks and just enough used to reach the lower end, or if larger amounts are used the excess is carried off at the lower end by means of a drainage ditch. By regulating the head of water admitted the desired degree of moisture may be secured without overirrigation. This method also has the advantage of low borders easily crossed by machinery and has been used successfully where the fall is as much as 10 feet to the mile.

Grain is grown under irrigation as well as dry farmed. The fields are usually watered from small laterals when the grain has become of sufficient height to shade the ground well. In most cases one application of water is sufficient. In the areas of sand an irrigation before seeding to prevent the shifting of the sand has been used to some extent, but on account of the rapidity with which the surface of the sand dries out this practice has not been found very efficient.

IRRIGATION OF PEAT AREAS.

When the irrigation of the tule lands has progressed to a point where the growing of crops is possible irrigation will be necessary. In other marsh areas a system of subirrigation has been used successfully, and such a system has been suggested for this area. A subirrigation system requires a comparatively level surface such as the unreclaimed marshes present at present. That the marsh lands when drained and allowed to settle will have such a surface seems somewhat doubtful. This conclusion is based on the fact that the surface topography of the Klamath Basin wherever not covered by marsh is comparatively uneven, and that the water flowing into the marshes carries very little silt the deposition of which would tend to level the surface upon which the marsh rests. The level marsh as it exists now has developed through the extension of the edge of the tule mat over the water, thus covering many irregularities filled with water and ooze, which upon drying will again become uneven. That such a condition exists is indicated by the tendency of the Peat to sink at the edge when one walks on it near open water and by the readiness with which large areas may be made to shake like a jelly, thus indicating the unstable nature of the material between the surface mat and firm subsoil. There are also in many places through the marshes small bodies of open water and channels of considerable extent. For these reasons it is believed that when the marsh is allowed to settle the topography will be much too uneven for successful subirrigation. Another objection to the adoption of any system of subirrigation in this area is to be found in the danger from the surface accumulation of alkali.

Throughout the Klamath Basin alkali in varying quantities occurs in the soils and is especially troublesome wherever the "chalk" subsoil is covered by a shallow surface soil only or where conditions have been favorable for the accumulation of alkali at the surface. At almost all points along the edge of the marshes occurs a strip of soil so highly charged with alkali that it is unfit for crop use. This accumulation has resulted from circumstances favorable to the evaporation of alkali-charged water, and while representing conditions much more serious than those that would result from a system of subirrigation seems to indicate the danger of such a system.

In the Klamath Basin a considerable part of all the soluble salts consists of bicarbonates, which in the presence of large quantities of decomposing organic matter such as will be found in the marsh lands, would be readily converted to the more injurious carbonates or black alkali. Tests made along the edge of the marshes show that this change has, in those places, already taken place.

It is believed, then, that when the marsh lands have been reclaimed a system of irrigation which will provide for the application of the water at the surface accompanied by thorough drainage of the subsoil will in every way prove the safest and most satisfactory.

DRAINAGE.

One of the most serious problems of the Klamath area is lack of proper drainage. The surface soil of the area is so light and sandy and takes up the water so readily that the tendency to overirrigate is very great. The subsoil, however, as has already been noted, is in nearly all cases composed of a silty chalklike material which is more or less impervious. At or near the surface of this subsoil there are in many places thin layers of soft sandstone or hardpan and in others a well-cemented conglomerate. In most places this subsoil upon the application of water becomes soft and permits the penetration of plant roots and the slow passage of water. When irrigation water is applied in large quantities it sinks rapidly until it reaches the subsoil, where its progress is impeded. One result of this condition is to waterlog the lower part of the soil, the zone of saturation approaching the surface as more water is applied. An examination of the soil near an irrigated field during the irrigation season will almost invariably show the soil just above the subsoil to be saturated. In a saturated soil the air necessary for the best plant development is driven out and growth partly suspended. If this condition exists long the plant roots become diseased and die.

A second serious effect of overirrigation results from the water which has been checked by the heavier subsoil seeking an escape along the surface of the heavier layer. By this means it passes into the lower areas, filling the soil to the surface, and often forming shallow lakes and swamp areas. The extent of areas ruined in this way increases from year to year in most areas where excessive quantities of water are used in irrigation.

Although irrigation has been carried on in this area only a comparatively short time, considerable bodies of land have been seriously injured from lack of drainage, and there is scarcely an irrigated field in which more or less damage has not been done by excess of water.

The remedy is to be found in the construction of drainage ditches which will carry off the excess of water and in using the amount of irrigation water necessary for the best plant growth, but not an oversupply of it.

Drainage ditches are as necessary to a complete irrigation system as are the irrigation ditches.

ALKALI.

Alkali is found in all the soils of the Klamath area, the smallest quantities occurring in the well-drained sands and sandy loams of the hill slopes, where the quantity in most places is so small that it is not injurious.

In the "chalk" beds it occurs in much larger proportions, but varies greatly in different places, there being little more than a trace in some places and sufficient amounts to be quite injurious to plant growth in others. The waters of the hot springs of the area also carry a considerable amount of alkali.

The heaviest accumulations of alkali in the surface soil and subsoil occur in the lower portions of the numerous shallow basins, where it has been carried from the surrounding areas by the rains of the winter season and then left in the soil after the water has evaporated. Alkali occurs along the shores of some of the lakes and marshes, where the evaporation of water and the deposition of the alkali which it contains is continually going on. Other areas are encountered where the subsoil has been filled by excess of irrigation water. It is from the formation and extension of these latter areas that the greatest injury may be expected.

Although the sandy soils of the hill slopes in most places contain only a very small quantity of alkali, water that has percolated long distances through them and along the surface of the heavier subsoils becomes more or less strongly impregnated with these soluble salts. There are, however, places on the slopes where relatively large quantities of alkali occur, the white crystals of which are sometimes brought to the surface by the plow or in digging post holes. The ground water always contains an appreciable, although usually small, amount of alkali derived from these sources. If this ground water is not permitted to accumulate in basins, but is carried off by proper drainage, little or no harm is done, but if it is allowed to accumulate, when it has risen to within a certain distance of the surface the water is carried to the surface by capillarity and escapes into the air, but the alkali is left behind as a surface deposit. Continued evaporation and deposition results in a surface accumulation which no field crop can withstand. In this way considerable areas in the irrigated sections of the Klamath area have already been injured by alkali, and with the extension of irrigation these areas will not only become larger but others will be formed, unless provision is made for thorough drainage.

Where it is not possible to secure sufficient drainage, the surface accumulation of alkali can be greatly retarded by using as little water as possible on the surrounding, loose-textured, higher lying areas, and by keeping a crop on the soil during the growing season. When the soil is not covered by a crop the surface should be cultivated, thus breaking the capillary tubes in the soil, the most favorable conditions for the rise of alkali being a high water table and a bare, hard-packed soil.

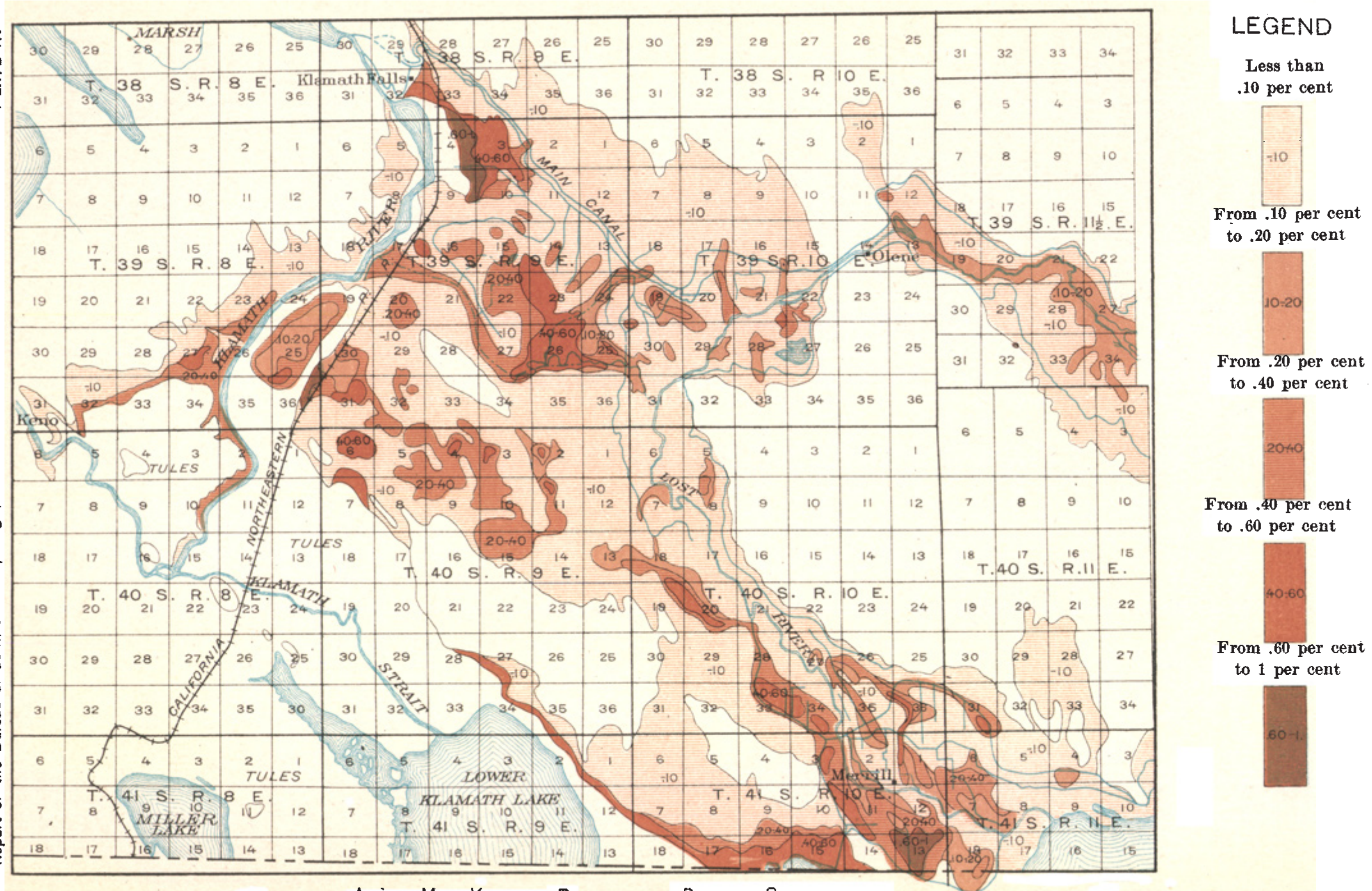
In poorly drained areas where an accumulation of alkali has already taken place, the total quantity in the soil to a depth of 6 feet is often small and is frequently concentrated at the surface. Such areas can often be reclaimed by providing good drainage, thoroughly cultivating the soil, flooding it, cultivating again, and sowing at once to a rapidly growing crop, barley or oats being best. If only a partial stand is secured, as soon as the crop is harvested the ground should again be plowed and flooded and as soon as possible thereafter cultivated. By repeating this process for two or three years much land can be sufficiently freed from alkali to enable a good stand of alfalfa to be secured. Where the accumulation of alkali is heavy thorough drainage of the soil and continuous flooding for a considerable time may be necessary.

The essential steps in reclaiming any alkali soil are thorough drainage, surface flooding, cultivation, and growing crops. Reclamation at best, however, is a slow and expensive process, the necessity of which should, to as great an extent as possible, be avoided.

In the principal alkali sections of the Klamath area carbonates, bicarbonates, chlorides, and sulphates all are present in varying amounts. In some limited areas, however, and especially where white gypsum crystals of alkali are found in the subsoil no carbonates occur, but in all the principal alkali areas where there has been an accumulation through the collection of drainage or the rise of ground water, black alkali was found in amounts varying from only a trace to a high concentration.

In a vertical soil section the heaviest concentration of alkali is usually found at a depth of about 3 feet, unless it has been brought

PLATE II.



Report of the Bureau of Soils, U. S. Dept. Agr., 1908.

ALKALI MAP, KLAMATH RECLAMATION PROJECT SHEET.

nearer the surface by the ground water or washed down by irrigation. At this depth it is much less injurious than when occurring at or near the surface. In the area places can be found in which a concentration of alkali in the surface foot of soil amounting to 0.2 of 1 per cent is seriously injuring the crops while in other places a concentration five times as great in the fourth or fifth foot seems to be in no way affecting them.

On the map accompanying this report (Pl. II) alkali areas of different concentrations are indicated by different colors. The outlining of these areas is based on numerous tests made to the depth of 6 feet, the average alkali content of the 6-foot section being indicated on the map. Thus it will be seen that the alkali map will not always agree with the surface appearance of the soil.

On account of the relatively large proportion of black alkali which occurs in nearly all parts of this area, a concentration of 0.2 to 0.4 of 1 per cent will be found to be injurious, in many places preventing the growing of a crop; these unproductive places usually occur, however, as small spots surrounded by more productive soil. Where more than 0.4 of 1 per cent occurs, especially if conditions are favorable for its concentration at the surface, crops can not be grown with any degree of success.

Even in those areas containing less than 0.2 of 1 per cent there are sections in which the alkali by its accumulation at the surface is proving somewhat harmful, and other sections in which there is danger of injury from such accumulation, although there are no indications of damage at present.

The following table gives the results of chemical analyses of a number of samples of alkali soils:

Chemical analyses of alkali soils.

Constituents.	18679. Center W. side sec. 33, T. 38 S., R. 9 E.; silt loam, 0 to 36 inches.	19312. SW. corner sec. 16, T. 47 N., R. 3 E.; tufa formation.	19313. One-fourth mile E. cen. sec. 24, T. 40 S., R. 13 E.; clay loam, 0 to 30 inches.	19314. Under No. 19313; clay loam, 30 to 52 inches.	19315. Under No. 19314; silty clay loam, 52 to 72 inches.	19316. One-third mile E. cen. sec. 10, T. 40 S., R. 8 E.; alkali crust, 0 to 1 inch.
Ions:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Calcium (Ca)	2.04	0.04	0.00	0.00	0.72	0.08
Magnesium (Mg)	.58	.53	.42	1.14	1.13	.07
Sodium (Na)	25.36	35.56	29.05	27.35	25.51	39.98
Potassium (K)	5.83	1.04	.93	.85	.83	.52
Sulphuric acid (SO_4)	49.43	19.68	.00	20.54	8.76	.00
Chlorine (Cl)	6.12	18.29	7.80	4.55	3.59	.00
Bicarbonic acid (HCO_3)	10.64	6.46	42.62	45.57	59.46	12.99
Carbonic acid (CO_3)	.00	18.40	.00	.00	.00	46.36

Chemical analyses of alkali soils—Continued.

Constituents.	18679. Center W. side sec. 33, T. 38 S., R. 9 E.; silt loam, 0 to 36 inches.	19312. SW. corner sec. 16, T. 47 N., R. 3 E.; tufa formation.	19313. One-fourth mile E. cen. sec. 24, T. 40 S., R. 13 E.; clay loam, 0 to 30 inches.	19314. Under No. 19313; clay loam, 30 to 52 inches.	19315. Under No. 19314; silty clay loam, 52 to 72 inches.	19316. One-third mile E. cen. sec. 10, T. 40 S., R. 8 E.; alkali crust, 0 to 1 inch.
Conventional combinations:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Calcium sulphate ($CaSO_4$)	7.00	0.12	0.00	0.00	2.45	0.00
Potassium bicarbonate ($KHCO_3$)	.00	.00	.00	.00	.00	1.33
Sodium bicarbonate ($NaHCO_3$)	14.72	8.58	58.72	62.77	81.93	15.95
Sodium carbonate (Na_2CO_3)	.00	32.53	.00	.00	.00	81.96
Magnesium sulphate ($MgSO_4$)	2.77	2.64	2.07	5.65	5.63	.00
Potassium sulphate (K_2SO_4)	11.66	2.33	2.07	1.90	1.84	.00
Potassium chloride (KCl)	.00	.00	.00	.00	.00	.00
Sodium chloride (NaCl)	10.06	20.18	12.87	7.50	5.91	.00
Sodium sulphate (Na_2SO_4)	53.79	23.62	24.27	22.18	2.24	.00
Calcium bicarbonate ($Ca(HCO_3)_2$)	.00	.00	.00	.00	.00	.31
Magnesium bicarbonate ($Mg(HCO_3)_2$)	.00	.00	.00	.00	.00	.45
Per cent soluble	1.37	8.19	0.63	0.31	0.39	18.70

Constituents.	19317. SW. ¼ sec. 24, T. 39 S., R. 8 E.; mucky loam, 0 to 36 inches.	19318. Under No. 19317; sandy loam, 36 to 72 inches.	19319. One-fourth mile SW. cen. sec. 4, T. 41 S., R. 9 E.; peat, 0 to 72 inches.	19182. SW. ¼ sec. 18, T. 40 S., R. 10 E.; white soluble material, 20 to 40 inches.	19184. SE. corner sec. 36, T. 39 S., R. 8 E.; alkali crust from sink near Tule Lake, 0 to 3 inches.
Ions:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Calcium (Ca)	2.04	1.13	2.03	15.82	0.04
Magnesium (Mg)	.00	.00	3.11	4.57	.01
Sodium (Na)	25.28	25.86	19.94	6.29	37.15
Potassium (K)	.69	1.30	3.51	1.88	.51
Sulphuric acid (SO_4)	2.86	8.08	19.05	67.44	6.53
Chlorine (Cl)	.00	.00	4.86	1.60	4.11
Bicarbonic acid (HCO_3)	67.76	63.63	47.50	2.40	20.06
Carbonic acid (CO_3)	1.37	.00	.00	.00	31.59
Conventional combinations:					
Calcium sulphate ($CaSO_4$)	4.05	3.84	6.90	53.80	.13
Potassium bicarbonate ($KHCO_3$)	1.76	.00	.00	.00	.00
Sodium bicarbonate ($NaHCO_3$)	88.26	87.68	65.44	3.31	27.51
Sodium carbonate (Na_2CO_3)	2.45	.00	.00	.00	55.85
Magnesium sulphate ($MgSO_4$)	.00	.00	15.40	22.65	.04
Potassium sulphate (K_2SO_4)	.00	2.87	3.42	4.17	1.15
Potassium chloride (KCl)	.00	.00	3.77	.00	.00
Sodium chloride (NaCl)	.00	.00	5.07	2.63	6.77
Sodium sulphate (Na_2SO_4)	.00	5.61	.00	13.44	8.55
Calcium bicarbonate ($Ca(HCO_3)_2$)	3.48	.00	.00	.00	.00
Magnesium bicarbonate ($Mg(HCO_3)_2$)	.00	.00	.00	.00	.00
Per cent soluble	0.42	0.25	0.74	3.50	76.37

In cultivated fields the occurrence of alkali in injurious quantities, if near the surface, is indicated by spots of bare soil or by the stunted vegetation, by white surface accumulations, and, if black alkali is present, by black deposits on the soil, especially in the vicinity of poorly drained areas.

The best method of detecting an alkali soil is by an inspection of the wild vegetation which it supports. Some plants thrive only in a soil containing alkali, others grow equally well in an alkali soil or in one free from it, while still others avoid a soil containing alkali even in small amounts. A knowledge of these plants will often enable one to detect the presence of alkali even where there are no surface indications.

In the Klamath area the best indicator of alkali is the true greasewood (*Sarcobatus vermicularis*), a small shrub 2 to 4 feet high, resembling somewhat a small cedar and easily recognized by its luxuriant dark-green foliage, the leaves having the appearance of short, green, fleshy stems. The presence of this plant is a sure indication of alkali, and the larger, more vigorous plants are found where the concentration of alkali is heavier.

The best indicator of an alkali-free soil on uncultivated land is the black sage (*Artemesia tridentata*) known by its gray color, pungent sage odor, and by a peculiarity of its leaves, some of which have three lobes at the tip. Sage will not grow in an alkali soil, but since it is a shallow-rooted plant it may sometimes thrive in a soil the subsoil of which contains alkali. An example of this is to be found in the vicinity of White Lake City, where scattering plants of greasewood, which roots deeply, are found among a heavy growth of sage. As a rule, however, thrifty sage may be relied on as an indicator of alkali-free soil.

Large rabbit brush (*Chrysothamus nauseosus*), sometimes called yellow sage, is often mistaken for black sage, which it resembles somewhat in size and shape of plant, but it lacks the sage odor and instead of the three-lobed leaves it has a very narrow, sharp-pointed leaf. In the late summer the bright yellow flowers of this plant are very conspicuous in many parts of the area. The large rabbit brush seems to grow equally well in alkali and nonalkali soil, and its value as an indicator is to be found in the fact that on many areas of light sandy soil well suited for sage large rabbit brush has full possession. The soil in such areas usually contains alkali.

Death weed, or poverty weed (*Iva axillaris*), is also an alkali weed, thriving best where there is an appreciable amount, but also able to grow where alkali occurs in very small quantities.

Salt grass (*Distichlis spicata*), a short, harsh grass, growing in a close mat like Bermuda grass and having long, tough roots, grows only on alkali soil, but being able to thrive where there is very much or very little alkali, its chief value consists in aiding one to look for other indicators.

Salt brush, or salt weed (*Atriplex expansa*), and several smaller varieties are found throughout the area. This is a vigorous growing, broad spreading plant, with mealy silver-colored leaves. It thrives best on soils containing small but not excessive amounts of alkali.

Wild heliotrope (*Heliotropum curassavicum*), a low-growing, fleshy plant, with smooth, oval, succulent leaves, and spikes of dense white flowers growing on one side of the curved stem, is found on many of the areas of highest alkali concentration.

The waters in Klamath and Lost rivers and also in some of the springs of the area are remarkably free from alkali. The waters of Lower Klamath Lake and White Lake contain from 40 to 60 parts of soluble salts per 100,000, of which a considerable portion is carbonates and bicarbonates, while the waters of Miller Lake and also of some of the hot springs of the area contain a much higher percentage.

The following table gives the composition of the soluble salts in these waters:

Chemical analyses of water.

[Parts per 100,000.]

Constituents.	56. Lower Klamath Lake. T. 41 S., R. 9 E.	59. Lower Klamath Lake. ⅜ mi. W. cen. sec. 35, T. 48 N., R. 2 E.	62. Lower Klamath Lake. ¼ mi. E. cen. sec. 17, T. 47 N., R. 3 E.	65. White Lake. NE. corner sec. 21, T. 48 N., R. 3 E.	79. Miller Lake. NE. ¼ sec. 15, T. 41 S., R. 8 E.	82. Willow Creek. NE. ¼ sec. 17, T. 47 N., R. 2 E.	86. Warm Spring. ½ mi. S. cen. sec. 17, T. 40 S., R. 9 E.
Ions:							
Calcium (Ca)	1.89	3.14	2.09	2.02	1.40	2.38	2.72
Magnesium (Mg)	1.36	1.63	1.99	1.63	2.69	1.06	2.06
Sodium (Na)	5.58	8.45	7.06	5.48	160.66	.57	6.19
Potassium (K)	3.06	4.87	3.18	2.21	25.06	1.23	2.53
Sulphuric acid (SO_4)	1.44	1.30	1.59	1.54	24.55	1.72	.00
Chlorine (Cl)	2.52	4.55	2.79	2.69	58.30	1.15	1.31
Bicarbonic acid (HCO_3)	22.52	34.11	29.52	23.26	225.40	11.89	33.00
Carbonic acid (CO_3)	1.62	1.95	1.79	1.15	61.77	.00	1.69
Conventional combinations:							
Calcium sulphate ($CaSO_4$)	1.98	1.84	2.29	2.24	4.70	2.46	0.00
Calcium chloride ($CaCl_2$)	3.69	7.15	3.87	3.75	.00	1.81	2.06
Magnesium chloride ($MgCl_2$)	.27	.00	40	.38	.00	.00	.00
Magnesium bicarbonate ($Mg(HCO_3)_2$)	7.57	9.75	11.34	9.23	.00	6.48	12.48
Potassium bicarbonate ($KHCO_3$)	7.83	12.46	8.15	5.58	.00	3.11	6.47
Sodium bicarbonate ($NaHCO_3$)	15.76	25.34	20.77	16.83	310.52	2.13	18.01
Sodium carbonate (Na_2CO_3)	2.88	3.46	3.18	2.02	109.20	.00	3.00
Magnesium sulphate ($MgSO_4$)	.00	.00	.00	.00	13.27	.00	.00
Potassium sulphate (K_2SO_4)	.00	.00	.00	.00	19.32	.00	.00
Potassium chloride (KCl)	.00	.00	.00	.00	30.64	.00	.00
Sodium chloride (NaCl)	.00	.00	.00	.00	71.34	.00	.00
Calcium bicarbonate ($Ca(HCO_3)_2$)	.00	.00	.00	.00	.00	4.01	7.98
Total solids	40.00	60.00	50.00	40.00	560.00	20.00	50.00

SUMMARY.

The Klamath area has an elevation of over 4,000 feet, consists of several valleys separated by hills and mountains (the eastern outliers of the Cascade Range), and abounds in lakes and marshes.

On account of its isolation settlement has been very slow, but has been recently stimulated by the extension of the railroad, by its selection as a reclamation project, and by a thorough advertising of the country.

The climate is semiarid and temperature equable, yet on account of frosts the growing season is short.

Agriculture is comparatively undeveloped, but through the extension of irrigation, the introduction of alfalfa, and successful grain growing, general farming in the valleys is rapidly taking the place of exclusive stock raising. The country seems well suited for this and especially for the development of an important dairy business, but there is much opportunity for improvement by the adoption of more intensive methods of farming and by the introduction of new crops, of which Canadian field peas, sugar beets, timothy, and alfalfa for seed are among the most important.

The soils consist of marsh soils and upland soils. The upland soils, being composed largely of disintegrated basalt, volcanic ash, and diatomaceous earth, are friable, easily cultivated, and in general productive. The marsh soils contain a high percentage of organic matter, and although they have been used to only a small extent, it is believed that when reclaimed they will also prove rich and productive.

Of the upland soils the more productive are the deeper, well drained, and alkali-free sands, sandy loams, and fine sandy loams, all of which are especially well suited for the production of alfalfa.

The water supply is abundant and the tendency is toward over-irrigation with serious results following from lack of drainage and the surface accumulation of alkali.

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