THESIS

on

A STUDY OF THE FACTORS INVOLVED IN THE ECONOMIC USE OF WATER AND WATER COST OF DRY MATTER ON SEVERAL IRRIGATED AREAS IN OREGON

Submitted to the

OREGON AGRICULTURAL COLLEGE

In Partial Fulfillment of the Requirements

For the Degree of

Master of Science

in

THE SCHOOL OF AGRICULTURE

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May, 1916

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SYNOPSIS.

1. This report is based on experiments conducted by the State Engineer's Office, the Oregon Agricultural College and the Office of Public Roads and Rural Engineering of the Department of Agriculture working cooperatively. The plans under which the duty of water was worked out are similar to those used by Mr. Don H. Bark in work in Idaho for the Office of Experiment Stations, and were drawn up by Mr. Bark and Mr. Powers. Shortly after the work was started Mr. Bark left the employ of the Office of Experiment Stations to take a position with the Canadian Pacific Railroad, leaving the work in Oregon in charge of Mr. Powers. In connection with the work on the Chewaucan Marsh lands of Central Oregon special plans had to be devised as this was an entirely new field and the usual plan could not be applied. Special attention has been given to soil moisture conditions in connection with this work. Very little duty of water work has been done in Oregon and there is great need for data in this subject.

2. The weather for the season was a little drier and warmer than usual.

3. The soils included in the experiment ranged from clay loam to coarse sand, and a close relation was found be-

tween texture and the amount of irrigation required.

4. Some of the chief crops of each region were worked with and the meadow crops required relatively large amounts of irrigation as compared to grain, while cultivated crops required less than grain.

5. The results were reduced to an acre basis and expressed in terms of the most economical yield per unit water and maximum yield per unit land. The water cost of dry matter was also determined in most cases and in Willamette Valley experiments the results are given in terms of maximum profit per acre and profit per acre inch.

6. Whenever used, manure and fertilizers reduced the amount of warer necessary to produce a crop.

7. In the Baker Valley the maximum yield of potatoes was obtained with the irrigation of 7.79 inches, of barley with 16.30 inches, and of timothy with 30.55 inches.

8. The maximum yield of barley in the Wallowa Valley was secured by the use of one twelve inch irrigation, oats practically the same, but alfalfa showed very little variation with amounts of water running from 18 to 33 inches.

9. Wheat in the Deschutes Basin gave the best returns

when 17.8 inches of water were used, and oats when 8.28 inches were used.

10. The best yield of Marsh Grass on the Chewaucan Marsh was obtained by the use of 11.28 inches of water, and the average amount used was 10 inches. Barley required 33.72 inches to give a yield of 35 bushels, on adjoining coarse-textured upland.

11. In the Goose Lake Valley the maximum yield of oats was secured by the use of 9.2 inches depth; the maximum barley yield with 6.83 inches; and the maximum wheat yield with 16 inches depth. Potatoes gave a maximum yield with 7.5 inches depth for the season.

12. The results on the experiment farm at Hermiston shows 84 inches of water used to secure maximum returns with alfalfa; while 44 inches gave the most economic use of water on the sand soil of that farm.

13. In the Willamette Valley results show the returns from several crops with different amounts of water and th the effect of crop rotations and manure in lowering the amount of water required.

14. A close relation was found between irrigation, the fluctuations in water table, the substrata, and concentration of alkali on different flat areas.

15. Since the results from one seasons work can not be regarded as conclusive because of the changing weather conditions it is desirable that these experiments be carried on several years in order to arrive at average figures. The problem of determining the duty of water for natural meadow lands offers a comparatively new field of investigation, and one of great importance to the further development of hundreds of thousands of acres of these lands.

Introduction.

Agreement. The Agricultural College, The State Engineer's Office, and the Office of Public Roads and Rural Engineering of the Department of Agriculture entered into a triangular, co-operative agreement in the spring of 1915 for the purpose of conducting duty of water investigations in Oregon.

Organization. Plans for the investigation were made by Mr. Don H. Bark, Irrigation Engineer of the Department of Agriculture, and W.L.Powers, Associate Professor of Drainage and Irrigation of the Oregon Agricultural College. Soon after initiating the work Mr. Bark left the employ of the Department to accept a similar position in Canada and the field work and office studies on which this thesis is based were carried out under the personal direction of Mr. Powers. Dr. Samuel Fortier of the Department of Agriculture and Mr. John H. Lewis, State Engineer, contributed in a general supervisory capacity to the investigation.

The writer as an employee of the Office of Public Roads and Rural Engineering, had personal charge of the experiments in the Powder Valley, and also gave his personal attention to the experiments in the Wallowa Valley and at Corvallis. He also assisted Professor Powers in the investigations in the Malheur Valley, made mechanical analyses and humus determinations of the soils used in the experiments, drew the sketches used in this thesis, which were included in the report presented to the Chief of Irrigation Investigations on the work completed this season and assisted in the preparation of this report.

Others who collected data used in this work are: Mr. E.R. Greenslet, another agent of the Office of Public Roads and Rural Engineering, who worked in the vicinity of Paisley; Mr. ~~H.~~ C. G. Stricklin, an employee of the State Engineer's Office, who had charge of the experiments in the Wallowa Valley; and Mr. W. W. Howard, County Agriculturist of Malheur County.

Need of Data. In the early irrigation development of Oregon, little was known of the amount of water needed by soils and crops and so liberal claims were made. The duty or efficiency of water refers to the quantity of water used to irrigate a given area of crop to maturity. The duty is said to be high where a small amount of water is used in proportion to the area served. The practice of primative methods of irrigation has been persisted in throughout much of Eastern Oregon, largely thru lack of transportation, large holdings of land, appropriation of abnormally large amounts of water and a desire to maintain a low cost of production. The demand for definite evidence as to the amount of water needed for certain soils and crops becomes more urgent as large projects develop and higher values and more intensive methods become necessary. Large projects with more expensive water require more efficiency in the use of water. More definite information is needed as streams become fully appropriated and the adjudication of rights becomes necessary. If too little water is provided for settlers crop shortages result, while excessive allowances may injure the soil to the point of unprofitable economy under present economic conditions. As water becomes very valuable in places the net profit per acre foot will become of increasing importance.

The Water Cost of Dry Matter.

Results of Previous Experiments.

According to different writers the Duty of Water may be expressed as "the area of crop which can be matured with a given volume of water", (Meade); "the relation between a given quantity of water and the area which it serves", (Fortier) and "the quantity of water needed to mature crops ", (Widtsoe). Taking this latter definition and expressing the quantity of water as the number of pounds required to produce one pound of dry matter of the crop and we have the most exact and scientific measure of the duty of water known. Widtsoe further states that duty of water may be expressed in depth over the field as acre inches or acre feet, and the number of acres irrigated by a quantity of water, as second feet, or miner's inches.

Many factors influence the amount of water required to produce one pound of dry matter. The climate, the soil, the fertility of the soil, and amount of water used on the crop are some of these factors.

Climate. Climate is one of the factors over which the farmer can have no control, and as shown by many experiments is one of the most important factors affecting the duty of water. Lawes and Gilbert[1] working in the damp, cool climate of England found that it required 247 pounds of water to produce a pound of dry matter of wheat, while Widtsoe[2] in the arid climate of Utah found that 546 pounds were necessary. Other crops followed in the same proportion. Leather[3] working in the dry climate of India secured results that compare quite closely to those of Widtsoe in Utah. The past season in Baker Valley of Eastern Oregon Professor Powers and the writer found that it took 807 pounds of water to produce one pound of wheat, but this was under field conditions and included transpiration as well as evaporation.

Previous Crops. The crops previously grown on the soil in addition to the effect they have on the fertility of the soil, release certain compounds that are toxic to some succeeding crops.

Season. Each season has its effect on the crops and influences the amount of water required to grow them. Thus Widtsoe[2] in Utah found the transpiration ratio varied for wheat from 258 to 2,017 pounds in different seasons, and Leather[3] in India found the variation for the same crop to be from 422 to 1,133 pounds. Other crops showed similar variations. Part of these differences might be accounted for by the varying contitions of fertility of the soil, but a large part is undoubtedly due to the influence of the season on the growth of the crop.

Soil fertility is one of the most important factors affecting Duty of Water, and yet is one which is usually entirely overlooked in duty of water experiments. Mr. C. C. Thom[4], of the Washington State College, grew plants in a sterile soil by adding plant food in solutions of varying strength. It took 1,800 pounds of water to produce a pound of dry matter when the solution contained 1/100 of one percent of the plant foods, but only 236 pounds when the solution contained 1/3 of one percent.

In field experiments the Utah Station[2] found that it required 929 pounds of water to produce a pound of corn when no fertilizer was added to the soil; 703 when manure was added; and 635 when 1/10 of one percent of sodium nitrate was used. These facts are sufficient to show that fertility is one of the factors that should be considered in determining duty of water. Unfortunately nothing along this line could be done in the field work this year except at the Corvallis Station.[5] The results here agree closely to the results of the Utah Station.

Varying Amounts of Water. The following table from Widtsoe[2] showing the evapo-transpiration ratio for certain crops illustrates how varying amounts of water affect the water requirements of crops.

Inches applied.	Wheat.	Corn.	Alfalfa.	Potatoes.
10.	948.	275.	621.	1,255.
15.	1,038.	356.	977.	1,411.
25.	1,317.	474.	1,053.	-----
30.	-----	527.	1,253.	2,242.

In every case larger quantities of water caused more water to be required. However there is a lower limit below which the water cost begins to increase. In the experiment conducted in Eastern Oregon last summer this lower limit was passed in several cases, or the water cost of the crop was higher on some of the minimum plats than on these that received larger amounts of water.

Crops. Crops vary in the amount of water they require. Corn and the Kafir Corns are plants of low water requirements, while alfalfa and allied plants need large quantities of water. The two following tables show the water requirement of a number of the general farm crops according to different workers, in different countries. No attempt has been made to include all the crops that have been experimented on nor to include all the experiments that have been made. Such a review would require a large bulletin and could not be included in the limits of this paper.

Transpiration Ratio.

	England Lawes and Gilbert[1]	Germany Hellriegal[5]	Utah Widtsoe[2]	India Leather[3]	United States Briggs and Schantz[6]
Wheat	247	338	546	850	507
Barley	257	---	---	680	537
Oats	---	376	---	870	614
Corn	---	---	386	450	322
Clover	269	310	---	---	709
Alfalfa	---	---	---	---	1068
Peas	259	273	---	830	800
Rye	---	---	843	---	765
Rape	---	---	---	---	377
Sorghum	---	---	---	---	306
Millet	---	---	---	---	275
BuckWheat	---	---	---	---	578

Evapo-transpiration Ratio.

	Wisconsin King[7]	Utah Widtsoe[2]	Germany Wollny[8]	Oregon Powers[10]		Irrigation Investigations In Oregon 1915[11]
Wheat	---	1,017	---	----	1,085	2,695
Barley	464	801	774	----	789	2,016
Oats	504	871	665	----	1,138	2,845
Corn	270	552	233	548	---	---
Clover	577	---	---	548	---	----
Alfalfa	---	1,096	---	735	---	1,344
Peas	477	1,118	416	[illegible]	---	---
Beets	---	760	---	767	---	---
Kale	---	---	---	940	---	---
Marsh grass	---	-----	---	~~666~~	---	2,208
Carrots	---	710	---	666	---	---
Beans	---	---	---	248	----	---
Potatoes	---	1,375	---	1,050	---	555
Cabbage	---	4,413	---	---	---	---
Onions	---	2,993	---	---	---	[illegible]
Timothy	---	-----	---	---	---	1,410

In this table the figures give the water cost of the whole crop, except in the last column which show the requirement for the marketable portion only. So far as know the requirement for marsh grass is a new figure, this being a virgin field of work. No other figures were found for timothy. or Kale.

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General Plans and Methods.

Scope of Investigations. These experiments were planned on a broad scale in the hope that they might be extended to include the chief irrigated valleys and the chief soils and crops of the irrigated sections of Eastern Oregon. The gross duty has only been considered in a general way. It was planned to carry on the experiments under practical field conditions as far as possible and to do everything possible to insure fair, impartial results. It was realized that the depth, texture, capillarity, water capacity and areas of chief soil types and their fertility and topography would need to be considered, that the evaporation, rainfall, the growing season, the irrigation season and the time and frequency of irrigation would need to be determined and that the proportion of each district devoted to each of the chief crops and their average yields under good, practical methods of farming, as well as transpiration requirements, would need to be measured, that market conditions, cost of production, value of land and crops would need to be taken into account. With the established factors which affect duty of water well in mind, the following plan was drafted.

Plans for Duty of Water Investigation in Oregon.

1. Select as many 12to 18 acre tracts of grain, alfalfa or cultivated crops as each man can handle with the time he has to devote to the work.

2. Each tract selected must lay so that all water applied to it or wasted from it can be measured through weirs, and must be comparable throughout as to stand of crop, toporgraphy, soils, previous preparation, fertility, etc. Only chief soil types and staple crops should be selected.

3. Each tract is to be divided into three approximately equal parts. The farmer or owner is to be allowed to select one of the three and to irrigate it in the customary manner using his usual customs, the duty of water assistant is to be on the ground during each irrigation in order to measure the water applied and wasted, after which the two remaining tracts are to be irrigated by applying about 50% more to one and 50% less to the other during the season than the owner has used on his own tract. Weir tables and directions for measuring water and forms for tabulation of water.measurments will be furnished by D. H. Bark of 438 Yates Building, Boise, Idaho.

4. Both the precipitation received and evaporation

from the free water surface where possible is to be determined for the locality.

5. Wherever possible, especially upon those in which county agents are interested, the tract should be divided into four approximately equal plots instead of three, the fourth plot to receive a good, even application of well rotted manure and to receive the same amount of water as is ordinarily used by the farmer is required. The water applied and wasted is to be measured in the same manner as other plots.

6. County Agents and substation men are especially urged to select one farm on which the effect of crop rotation upon duty of water can be studied, a grain crop, and a row crop and a legume should be included in the rotation; the row crop may be and a check plot should be provided which remains in permanent meadow, all water applied and wasted to be measured.

7. Samples of soil from each of the first four feet should be taken from at least three different representative places, which can be compounded and sealed promtly and then mailed, by franks which will be furnished, to the Department of Agronomy at Corvallis for moisture determination. Wherever possible further samples should be taken both before and within forty-eight hours after each irrigation, and also at harvest time, to learn the

range of usable water in the field. Where these moisture determinations can be followed out samples of the crop should be taken for moisture determination at the time the yield is weighed or measured. The crop samples should be large enough to determine the moisture content and ratio of dry matter in plant parts.

Forms for recording moisture data in the field and for converting and reporting the results will be furnished by Prof. W. L.Powers of the Agronomy Department at Corvallis.

8. In localities where drainage may become a problem, test wells should be installed and systematic records kept of the soil conditions, fluctuations of the water table, and of its relation to the concentration of the alkali.

9. It is planned to make determinations of the water capacity under field conditions for the chief soil types of each valley in which theinvestigation is conducted and to judge the soil types with the aid of a few mechanical analyses so as to correlate the work between districts.

10. The crop for each plot must be cut, stacked and threshed separately. In order to determine the yield per acre, all areas will be carefully surveyed, at the

end of the season. All yields will be weighed wherever possible, but where weighing is impracticable the yields of the grain will be determined by machine measure, care being used that the automatic weigher of the threshing machine is not readjusted during the threshing of the plots. Alfalfa can be measured in the stack where it can not be weighed.

11. A bulletin describing water measurements, an acre foot weir table and forms for tabulating water measurments accompany these instructions, the instructions in the measurement bulletin should be carried out, with the exception of the sizes of the weir boxes. The flume in which the weirs are installed should be made 2½ feet wide, 2 feet deep and 2 feet long for 1-foot weirs; 3½ feet wide, 2 feet deep and 3 feet long for 2-foot weirs; 4½ feet wide, 2½ feet deep and 3 feet long for 3-foot weirs. All depth of water flowing over the crests should be measured in feet or hundredths of a foot by small steel rules that will either be furnished by the Agronomy Department of the O. A. C. or should be purchased by the men. These can be procured from Keuffel and Esser of Troy, N.Y., for 40¢ each.

Special Plans for Duty of Water Investigations with Natural Meadows.

12. On natural meadows, trials of use of water may

need to be made on rather large areas and be made where seepage can be largely avoided and where definite channels afford a means of collecting runoff so it can be measured.

Water variation trials will be difficult and will probably need to be confined to small areas at the side of themarsh where dykes of sheet piling can be provided and to isolate the different plants. The water may need to be controlled by pumping. Plats may need to be one-tenth or one-twentieth acre or possibly where sheet piling is used, only one rod square.

13. Where possible, small plats of field peas, oats, or a mixture of alsike clover and timothy should be seeded on dyked land.

14. Transpiration should be determined for natural meadow plats under field conditions. Determinations of soil moisture and crop moisture being made as described in Section 7.

15. Tank experiments will give more complete control of conditions and serve to check the field work. A few tanks will be furnished where needed. These may be thirty inches in diameter and three feet deep. A stop cock should be provided to control drainage so it can be measured. They should be set in representa-

tive soil in a fenced lot in the marsh, having the same exposure as the surface of the marsh. Each foot of soil should be kept separate and put into the tanks separately in as near its original degree of compactness as possible. Fill tank to within three inches of top. Tanks should be allowed to stand a day or two and each foot of soil carefully sampled for soil moisture determination and weighed before irrigation or growth in the tanks begins. All irrigation and drainage should be weighed or measured. Tanks should be treated as follows:

Tank A. Transplant the native sod--grasses--and irrigate and drain as nearly like ordinary field conditions as possible. Keep the grass in a healthy, vigorous condition.

Tank B. Native Sod. Keep soil in tank saturated and drain if necessary to maintain healthy color in the plants.

Tank C. Native Sod. Keep soil moist but avoid much saturation.

Tank D. Field peas, alsike or timothy. Seed rather heavy, and keep soil fairly moist. Provide a good moisture content when peas come into bloom.

Tank E. Oats, barley or transplanted alfalfa plants. Irrigate to keep soil in a good moist condition.

Tank F. It would be desirable to provide an evaporation tank to measure the evaporation from a free water surface.

16. A limited number of mechanical analyses and water capacity determinations will be needed in connectinon with these tests and these can be made by the College.

Methods. The water measured and wasted was measured in all cases as planned using good trapizodal weirs. Moisture determinations were made in most all cases and permit fairly accurate calculations of the soil water loss during the season. Moisture content of crops was also determined, both marketable and rough portions. These, together with rainfall records from each locality, permit calculations of the approximate water cost under field conditions., Areas of plats were determined by actual survey and yields in nearly all cases were weighed. Field men were of sufficient assistance to owners to reimburse losses in most cases and practicall no remuneration for crop losses has been required.

The water capacity of the surface foot of soil, from each experiment field was determined in duplicate by the cylinder method. Galvanized cylinders, six inches in diameter and twelve inches long, were carefully forced down into the soil their entire length. A core of soil extending through thesurface foot which was thus secured in its natural field structure. This was removed and saturated in a covered coal oil can after which it was drained for about thirty-six hours to constant weight. Duplicate soil moisture samples were then taken from each cylinder and shipped to the Experiment Station laboratory for oven drying. The net weight of the cylinder was then corrected for the total moisture content expressed in percent of the whole. The weight per cubic foot and the acré inches total water capacity per acre foot were then calculated. The hygroscopic moisture capacity of the soils was determined to aid in estimating theusable water capacity later. Data thus obtained appears further on.

Usable Water Capacity. The usable water capacity of a soil is of great value in estimating thenumber of inches depth that can be retained by a soil at one irrigation. The usable capacity is limited by the minimum point on the one hand and the excess point on the other hand. Excepting peat soil, there are few loams that will take up and hold as much as two acre inches in the first acre foot. The fine sandy loams of Eastern Oregon will take up from $1\frac{1}{4}$ to $1\frac{3}{4}$ acre inches per foot of soil when dry and the fine sand about one inch per acre foot. The coarse sand on theUmatilla project has a usable water capacity of $\frac{1}{2}$-inch per acre foot.

According to the researches of Briggs and Shantz, the minimum point or wilting coeficient is one and one one-half times the hygroscopic capacity of a soil. The lento-capillary point or point at which crops begin to secure moisture from soil less readily was found for a loam soil at theUtah Station to be when the percentage of soil moisture was 13. The heavy brown silt loam at Corvallis has a total water capacity of about 42%, yet the usable water capacity ranges between about the 14 and 27% points or is nearly two acre inches for the first foot. Further soil moisture determinations made in the field when crops are checked in their growth for lack of moisture and say 48 hours, after heavy irrigation together with the maximum capacities and hygroscopic capacities already determined, will make it possible to carefully estimate the inches usable capacity of soils studied.

Soil Composition and Weather Data.

Soil Classification. Classiffication of soils employed have been made by noting depth and texture by collecting samples from nearly all experiment fields for mechanical analyses and humus determinations. These determinations have been made of the surface soil, the humus determinations being made by the ignition method and is therefore rather high in most cases. Physical composition of soils used and effect of texture upon h the water used is shown in the following table.

Table No. 1.

Table No. 1.

TABLE SHOWING MECHANICAL COMPOSITION OF SOILS
WORKED WITH
also
QUANTITIES OF WATER GIVING MOST ECONOMICAL AND MAXIMUM YIELDS - 1915

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SOil Location	Total Sands	Fine Gravel	Coarse Sand	Med. Sand	Fine Sand	Very Fine Sand	Silt	Clay	Humus	Sub-soil	QUANTITY OF WATER GIVING Most econ. Yield	Maximum Yield
Clay 19-34S-19E	39.75	2.73	12.56	6.15	31.68	6.62	34.32	26.93	7.95	Same	6.60"	6.60"
Clay Loam 29-34S-19E	40.96	2.99	6.96	4.04	19.28	8.99	36.55	22.41	7.60	Same	11.28"	11.28"
Loam 4-9S-39E	47.00	3.09	5.62	3.92	19.02	13.21	40.57	12.43	7.65	Granitic Fragments	4.49"	7.79
F. S. Loam 34-7S-38E	56.08	3.35	5.04	3.58	27.78	14.62	34.54	9.38	5.89	Granitic Sand	10.09"	16.31"
F. S. Loam 25-2S-44E	56.69	2.35	5.72	3.90	16.46	28.22	38.38	4.93	10.14	Gravel	18.79"	33.68"
F. S. Loam 22-2S-44E	62.72	5.40	11.21	6.36	22.46	16.91	29.53	7.75	7.57	Gravel	8.90"	12.85"
Medium Sand 33-14S-12E	78.09	8.15	11.98	8.60	23.97	24.96	15.73	6.08	3.87	On rock	8.28"	8.28"
Medium Sand 30-14S-12E	81.90	3.90	9.18	17.82	26.54	23.43	12.38	5.72	3.19	On rock	3.30"	17.88"
Coarse Sand 24-33S-18E	86.34	12.80	30.08	15.80	18.10	8,90	9.51	4.15	2.65	Gravelly Sand	33.72"	33.72"
Coarse Sand 3-4N-28E	93.38	4.57	37.49	45.24	5.91		V.F.S) Silt)	6.62		Coarse Sand	28.00"	84.00"

Time of Irrigation. Irrigation, like cultivation and many other field operations, is of greater value if given just at the right time. The time to irrigate may be judged by (1) the kind of crop and its stage of development; (2) the appearance of the crop; (3) weather conditions and (4) the soil moisture content. Experiments at Corvallis show that evaporation from a water surface gives the mean effect of all weather conditions. These experiments also show moisture content of the soil is a most valuable indicator of the best time to irrigate. It was planned to watch the soil moisture content and by making some moisture determinations learn themoisture point for the chief soils and crops where there was the most response to irrigation. This point at which further moisture is removed from the soil with difficulty has been called the lento-capillary point.

Soils are arranged in Table I according to texture. The greater quantity of water used and needed on coarse-texturd soils is very apparent. Gravelly sub-soil also is shown to have a very decided effect on the quantity of water required.

Reconnoissance soil surveys of most of the localities where investigations were conducted have been made by the College for the Reclamation Service and the approximate areas of different soil types in each locality have been determined. In these reports, the preliminary estimates of the amount of water required have been made and the largest amounts of water have always been recommended where soils are of coarser texture. As far as possible, water variation trials were located on the chief soil types of the district in which investigations were made.

Weather Data. The normal rainfall and mean temperature for the summer of 1915 taken from records of Weather Station is given in the accompanying table.

Table No. 2.

Table No. 2.

SUMMARY OF WEATHER CONDITIONS - 1915
showing
Rainfall and Temperature for Growing Season, with Normals, together with
Rainfall for 12 months, beginning Oct. 1, 1914 and ending Oct. 1,1915

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RAINFALL

tation	Year	12 mos. Oct.-Oct.	Apr.	May	June	July	Aug.	Sept.	6 months Apr.-Sept.
er.......	(1915	12.46	1.59	3.18	0.45	1.09	T	0.06	6.37
	(Normal	13.20	0.94	1.73	1.16	0.43	0.39	0.75	5.40
vallis...	(1915	30.60	1.40	2.39	0.54	1.09	0.00	0.39	5.81
	(Normal	42.29	2.81	2.25	1.28	0.26	0.38	1.34	8.32
miston...	(1915	6.85	0.39	1.26	0.48	0.24	T	0.00	2.37
	(Normal			No Normal					
eph......	(1915	-	2.72	3.23	-	3.17	-	0.52	-
	(Normal	18.82	1.56	2.15	1.90	0.92	0.85	1.15	8.53
eview....	(1915	12.33	0.87	2.60	0.39	2.02	0.27	0.07	6.22
	(Normal	16.69	1.14	1.52	1.10	0.26	0.28	0.77	5.07
sley.....	(1915	13.08	1.02	1.72	0.23	1.56	0.06	0.08	4.67
	(Normal			No Normal					
neville..	(1915	7.33	0.10	1.95	0.40	0.35	0.00	0.50	3.30
	(Normal	9.08	0.72	1.01	0.81	0.32	0.26	0.65	3.77

TEMPERATURE

tation	Year	12 mos. Oct.-Oct.	Apr.	May	June	July	Aug.	Sept.	6 months Apr.-Sept.
er.......	(1915	46.9	49.4	49.8	56.2	63.1	71.1	54.6	58.8
	(Normal	46.3	44.5	50.7	58.6	65.0	64.9	57.0	58.1
vallis...	(1915	53.9	54.6	54.7	65.1	68.3	75.4	61.4	62.9
	(Normal	52.9	45.8	54.9	59.6	65.3	65.1	59.5	58.3
miston...	(1915	53.0	56.2	60.2	68.0	73.8	76.9	62.8	66.3
	(Normal	53.6		No Normal					
eph......	(1915	-	44.9	48.0	-	-	-	52.9	-
	(Normal	44.5	41.6	48.6	54.7	62.5	62.0	53.3	53.8
eview....	(1915	44.0	46.4	45.8	54.8	61.9	68.4	54.4	55.3
	(Normal	45.4	44.0	50.7	58.7	66.6	66.5	57.1	58.6
sley.....	(1915	46.4	48.0	48.6	57.1	63.8	70.8	56.0	57.6
	(Normal			No Normal					
neville..	(1915	48.5	49.4	51.8	57.6	63.2	69.2	55.3	57.7
	(Normal	49.0	46.7	52.0	58.2	64.9	63.2	56.6	56.9

EVAPORATION

tation	Apr.	May	June	July	Aug.	Sept.	6 months Apr.-Sept.
vallis	4.44	3.91	4.08	5.50	4.35		17.54
miston	4.44	5.54	9.24	8.80	6.91	4.63	39.56
sley		2.56*	7.68	7.00	3.40*		20.56

* - Record for two weeks

Text lost on original.

The table containing weather data or Table No.2 is arranged to show the normal, annual, temperature and rainfall conditions and the monthly normals for the summer season or growing season. During the past season, the early spring was a little drier than normal while the late spring and early summer was a little damper than normal.

Evaporation from the water surface has been measured at Hermiston, Paisley and Corvallis in tanks about twenty inches in diameter and thiry inches deep. The soil about these tanks has been kept moist. It is believed that evaporation gives a good mean effect of all weather elements on the loss of moisture and indicates the degree of dryness of the weather.

Experiments in the Powder Valley.

The chief irrigated section of the Powder Valley is the Baker district. It is the largest body of improved irrigated land in the State, comprising about 100,000 acres of land. The valley averages about 3300 feet in elevation, and is almost entirely surrounded by mountains.

Climate. The climate of the Baker Valley is arid from an agricultural standpoint, very little rain falling during the growing season. The average rainfall is about

13 inches, but the greater part of this falls in the winter in the form of snow. May and June receive considerable rain. The weather records show that the past season was below normal in respect to rainfall, especially for the winter months. Since the small streams depend on the winter snows for their water this resulted in a shortage of water for irrigation which made itself felt early in the season. The effect of the heavy May and June rains was largely lost because of the lateness of the season. What rain fell during July and August never penetrated the dust in the fields. As regards winds, storms, and frost the season was normal. The temperature during July, August and September was slightly higher than normal. The growing season in the Baker Valley is rather short, but long enough for grains, two crops of alfalfa, and some hardly fruits on the bench lands where the air drainage permits.

Physiography and Geology. The Baker Valley is completly surrounded by mountains, the Powder River systems on north and northeast being comparatively low, while the spurs of the Blue Mountains rise abruptly on the west to a height of 7,000 to 9,000 feet.

The East fork of the Powder River flows longitudially thru the Valley and forms the principle drainage channel. It is joined near the north end of the Valley by the North Fork. Both these streams furnish considerable water for irrigation. From the mountains on the Westmany small strams flow into thePowder River. These streams being fed by melting snow on the precipitous slopes of the mountains are intermittent in nature, there being a high and a low water period. The high water begins in April and May and lasts until July, during which time most of the irrigation must be done. This has led to a sort of flood water type of irrigation. Two small reservoirs, the Killimacue on Rock Creek, and the Pine Creek reservoir, serve to hold part of the flood water for use later in the summer.

According to the Bureau of Soils Report the Baker Valley was at one time a lake. Later the land was elevated and most of the soil that had been laid down in the lake bottom was washed away. Since that time the present soils of the Valley were formed, principally from washings from the hills or by disentegration in place. The Blue Mountains are the oldest of the mountains surrounding the Valley. They are of granitic origin with basaltic intrusions. The hills on the east side are granite capped with basalt. The granite has been the chief source of the soils of theValley. As far as possible experiments were conducted on the chief soil types of the Valley.

These have been mapped by the Bureau of Soils and are shown with the number of acres and the percent of the total number in the following table.

Soils	Acres	Percent
Maricopa sandy loam	30,784	30.3
Yakima loam	29,860	29.4
Maricopa gravelly loam	17,216	17.0
Muck	12,353	12.3
Yakima sandy loam	10,816	10.7
Total	101,120	----

The principle crops on the sandy loam are grain and hay, alfalfa doing well on this land. On the Yakima loam and the Muck land hay is the principle crops, mostly wild grasses and timothy, tho some wheat is grown. Grain and hay are the chief crops on the gravelly loam and Yakima sandy loam. Some fruit is grown in the valley, principally on the Maricopa sandy loam. Potatoes do well on the Yakima loam or any of the lighter soils.

Irrigation. There is no large system of irrigation canals in the valley, but the different farms are supplied with water by individual ditches, or several farms may be supplied by one ditch. The fact that there are so many small streams makes this easily accomplished. During the irrigation season these small ditches are kept running constantly, a great loss of water occuring thru seepage and evaporation. In general the only system of irrigation practiced in the valley is that of flooding from field laterals. The soils of the valley do not wash badly and this is not a bad system at all so far as getting the water over the land cheaply and quickly is concerned, but is apt to be wasteful of water. A considerable body of land directly north and east of Baker is sub-irrigated. A system of furrow irrigation would probably result in considerable economy in the use of water.

Results of Experiments. The soil, weather conditions, crops, water used and yields on the experiment fields are shown in table 3 A. These fields were located on the 3 chief soil types which represent 77% of the total area of the valley.° These three types of soil are loam, sandy loam and gravelly loam. The chief crops produced are, alfalfa, timothy and clover and some potatoes. In this locality, alfalfa yields from three to four tons per acre, timothy and clover from two to three tons per acre and the average yield of wheat would be perhaps forty bushels per acre while barley would yield perhaps sixty bushels per acre on an average. Potatoes yield from one hundred to one hundred fifty bushels per acre on these soils. The soil and weather conditions, water used and crop yields obtained have been calculated to an acre basis and are shown in the following table.

Table 3-A.

°Field operations of the Bureau of Soils, 1903.

Table 3-A

SUMMARY - DUTY OF WATER TRIALS, GIVING SOIL AND WEATHER CONDITIONS AND WATER USED ON CROPS WITH YIELDS - 1915

.oOo.

Column / Crop	I Plat	SOIL CONDITIONS: II Alti-tude	III Soil Type	IV Soil Humus	V Hygr. Moist	VI W.CAPACITY ins.	VII W.CAPACITY %	VIII Vol. wt. Pounds-Cu. ft.	IX Soil Depth in feet	X Plat area (A)	MOISTURE CONDITIONS: XI Rain, Apr.-Sept.	XII Date 1st Irrig.	XIII Irrig. season	XIV Irrig. Tot Depth	XV Soil Wat Used	YIELDS: XVI Yld. acre	XVII Yld. acre inch	XVIII # D.M. Mrkt-able	CROP RATIO: XIX Lbs. Market-able	XX Water Per # Dry Matter Total
														ins.	ins.					
Potatoes Exp. 1 4-9S-39E	1. Max	3500	Loam	7.65	2.60	3.98	33.75	68.05	4' - 6'	2.27	6.37	7/11	--	7.79	-.76	133.3	17.1	5038.9	669	
	2. Ave	"	"	"	"	"	"	"	"	1.70	"	7/14	--	5.62	-1.51	125.0	20.4	4953.75	478	
	3. Min	"	"	"	"	"	"	"	"	1.67	"	7/15	--	4.49	.08	116.6	25.9	4757.51	519	
Barley Exp. 2 34-7S-38E	1. Max	3500	Grv.Lm.	-	-	-	-	67.81	4' - 6'	5.70	6.37	6/9	34 da.	16.30	3.81	54.4	3.34	2323.9	2575	1030.0
	2. Ave	"	"	-	-	-	-	"	"	5.04	"	7/12	"	15.74	7.00	52.3	3.32	2221.7	2961	1184.4
	3. Min	"	"	-	-	-	-	"	"	2.72	"	6/7	"	10.09	-.52	50.4	5.00	2082.9	1729	691.6
																	Tons			
Timothy Exp. 3 31-8S-39E	1. Max	3667	Loam	-	-	-	-	68.05	3' - 4'	3.24	"	5/22	86 da.	35.28	-0.8	3.987	.0113	7049.0	1309	-
	2. Ave	"	-	-	-	-	-	"	"	4.48	"	5/23	84 "	30.56	-0.8	4.138	.0135	7316.0	1116	-
	3. Min	"	-	-	-	-	-	"	"	13.9	"	5/23	88 "	25.42	2.58	2.463	.0097	4154.6	1869.6	-
Timothy Exp. 4 1-8S-39E		3200	Grv.Lm.	-	-	-	-	-	2	76.0	"	5/26	79 "	17.88	-	2.210	.0123	4066.4	1347	-
Alfalfa Exp. 5 35-7S-38E		3300	F.S.Lm	6.28	1.33	4.175	34.5	62.69	2	62.0	"	5/1	128	9.07	2.07	3.238	.0350	5996.8	659.9	-
Alfalfa Exp. 6 37-7S-39E		3200	Loam	-	-	-	-	68.05	3	21	"	5/21	12	17.49	2.20	4.225	.0244	7790.9	756	-
Wheat Exp. 7 26-7S-38E		3300	F.S.Lm.	5.89	2.30	4.945	37.95	67.81	4' - 6'	23	"	6/7	11	16.21	2.55	56 bu.	3.45	2812.3	2019	807.6

Results of Experiments in Powder Valley.

Table 3-A

In this table the water variations trials are grouped so as to afford a comparison of the various factors studied which affect the duty of water. Columns four to ten of the table show the soil properties; such as soil types humus content, hygroscopic moisture capacity, the water capacity in inches and percent, volume weight and soil depth. The following columns show the area of plats, the amount of rain water, irrigation water and soil water used. The yields per acre, Column 17 in the Summary Table, shows maximum production while the yield per acre inch, Column 18, indicates the most economical yield per unit of water applied. Column 19 shows the yield of marketable dry matter per acre, while the following columns show the water cost per pound of marketable dry matter and total dry matter produced. The water cost of dry matter gives a very accurate means of expressing the efficiency of use of all the water consumed. The wt. per cubic foot seems low but no explanation for this can be found.

Three tracts were selected on which it was possible to make variation trials. The water used and the yield was determined on four other farms and sufficient soil moisture determinations were made so that calculations of the soil water used and the water cost could be made. Owing to the fact that irrigation had begun on some of the land when work was started, it was not possible to find most suitable tracts on some of the types. The system of irrigating which is contour flooding over the entire field made it difficult to find tracts which could be subdivided for irrigation with different amounts of water according to the plans outlined.

The experiment with potatoes was conducted on a loam soil classified by the Bureau of Soils as "Yakima Loam". This soil requires a comparatively small amount of irrigation yet the irrigations for this season were probably lower than usual and more water could have been profitably used. The scarcity of water prevented carrying the maximum plats to the point where excessive irrigation would show diminishing returns. The maximum yields --133.3 bushels per acre was secured from the use of 7.6 acre inches of irrigation which is not a large irrigation even for potatoes. The most economical return per unit water or twenty-six bushels per acre inch was secured with a minimum irrigation which was four and one-half inches per acre. The average or intermediate plat gave most economical production of dry matter. The difference in soil water used accounts for the lower water cost secured in the average plat whereas the most economical returns from the irrigation water was secured from the minimum plat.

The barley plats were on a gravelly loam, classified as "Maricopa Gravelly Loam". They were located on rolling land and some water undoubtedly escaped through gopher holes and could not be measured. The water used in these plats ranged from ten to sixteen inches and the yields from fifty bushels to fifty-four bushels per acre. The maximum plat gave the maximum yield while the minimum irrigation gave the most economical yield and the most economical production of dry matter. With the under-drainage that this soil has it would be difficult to irrigate it up to the point where the yield would actually be decreased.

The timothy plats were located on "Maricopa gravelly Loam" but they were situated near a small stream and were more sandy than the typical gravelly loam. There was also a better supply of organic matter present. Only a small stream of water was available for this land which resulted in high evaporation and seepage loss. This latter loss was partly compensated for by the fact that the land is partly tile-drained and it was possible to determine the seepage from the drains. The hay on the minimum plat burned badly but that on the other plats was in excellent condition. The maximum yield of timothy and clover was secured at 30½ acre inches per acre and the yield was four and one-tenth tons per acre of cured hay. The average plat here also gave the most economical return per unit water and the lowest water cost per pound of dry matter.

The use of water on seventy-six acres of timothy also located on the gravelly loam was determined. A large head of water was used in irrigating this land and little water was wasted but the yield was low. It is believed that more water could have been used profitably.

The water applied to a sixty-two acre field of alfalfa grown on the fine sand loam was also measured. There is considerable stone in this soil up the size of a cocoanut or larger with the space between the gravel filled with fine earth. What may be regarded as a minimum amount of water was used this season that water was scarce and this farm has one of the youngest fights on the stream. The yield, however, was good.

The water used on twenty-one acres of alfalfa located on a loam soil on the creek bottom was also measured. The field was well drained by Rock Creek and a plentifull supply of organic matter was present. One irrigaion was given the first crop and no water was given the second and the second cutting was very light. More water would undoubtedly have increased the yield.

The water was measured on a twenty-three acre wheat field on a fine sandy loam area north of Rock Creek and this land was in excellent condition and good care was given the crop so that no water whatever was wasted during the irrigation. The yield was above the average on this type of land for the season and the amount of water applied may be regarded as pretty close to the optimum amount to use in a dry season.

Since these measurements have been made but for one season when the water supply was low, definite conclusions are scarcely warranted. However, they do give some good indications as to the optimum use of water. Measurements were made on several fields in this locality by Mr. C. E. Stricklin, of the State Engineer's Office in the previous year which was a year of more abundant precipitation. The seventy-six acre field during the previous season used 1.21 acre feet per acre; the 62-acre field received 3.14 acre feet and yielded two and one-half tons per acre and the water used on 199 acres of meadow served by one lateral where the soil was maricopa sandy loam was also determined the previous season, 2.23 acre feet per acre being used, the yield was three tons per acre.

Relation of Irrigation to Alkali and Drainage. Perhaps eight or ten percent of Baker Valley is poorly drained and injured more or less by alkali. In the affected area, about fifty percent is black alkali. In order to study the effect of irrigation on these alkali and drainage problems, typical area of alkali land was selected and a row of wells sunk across the tract. This line of wells was located in a bottom having a very gentle slope to the east. The line of wells ran due east from the center of the west side of Section 5, Townshipe 8 South, Range 39 East. Careful notes were kept of the depth or thickness of different soil strata encountered and readings were taken of the water table at regular intervals throughout the summer. A record of the water table fluctuations and a cross-section of the soil are shown in the accompanying print, Plates I and II. These studies were made on the flat a mile and one-half southwest of Haines.

The soil section shows the surface to be a heavy loam which is underlaid at a depth of from two to five feet with a rather porous, gravelly subsoil through which water percolates rapidly. The maximum concentration of alkali was found to occur where the loam was thin and where the water table was within two feet of the surface.

Where the surface layer of loam soil was thicker, it seemed to lessen the amount of evaporation and accumulation of alkali at the surface.

The water table measurments began early in June or following the season of high water supply and at that time the water table was from two to two and one-half feet below the suface. This gradually receded during the season until it was below the reach of a five-foot soil sugar in all the wells by the fourth of September. It appears from these studies that drains could be installed in a friable stratum where they would lower the water table quickly so as to check capillarity and evaporation at the surface and lessen the accumulation of alkali or provide means for flushing it down and out of the land. In its present condition, this land produces but little salt grass pasture. A fair average price for reclaimed land in the vicinity would be close to $100 per acre. Irrigation and drainage would both be required to reclaim this land. Reclamations of these areas may prove profitable where good outlets are close at hand.

Water Table and Alkali Conditions on the Malheur Project.

About twenty thousand acres of bottom land in the Malheur Valley is more or less alkaline. This land has a large supply of plant food but would require both irrigation and drainage for its reclamation. A study of the sub-soil and alkali conditions during the irrigation season of 1915 has been made. Two rows of borings were made across the flat and the river bottom west of Ontario by the writer and Mr. Howard and from notes taken when these borings were made sections of the soil have been sketched. Mr. W.W.Howard, County Agriculturist made observations of the water table at frequent intervals throuhout the season. Profiles showing the fluctuations in the water table and the soil strata can be found in the accompanying sketch, Plates III and IV. The soil study shows that the soil is a heavy loam to heavy clay loam in character but is underlaid with a sandy streak at from four to seven feet below the surface. Water feeds into this sandy streak readily and it is believed this would form a good medium in which drains might be placed. At the beginning of the irrigation season, the water table was down several feet below the surface. As irrigation progressed during t the season, the water table rose until it was within a foot or so of the surface at the lower edge of the plat which is next to higher irrigated bench land. The maximum amount of of alkali was deposited in about three and one-half feet above the water table, indicating the depth at which drains would need to be placed in order to overcome the dposition of this salt. These studies indicate that reclamation by irrigation and drainage is feasible on this area.

Experiments in Wallowa Valley.

General Conditions. Wallowa Valley is situated in the northeastern corner of the state and ranges in elevation from 2800 to 4400 feet. The surface of the land has considerable slope towards the river and down stream. The valley, like the Baker Valley is surrounded by hills and mountains and the general conditions are similar to those of the Baker Valley though perhaps the upper part of the Valley is a little cooler than the Baker Valley. Grain, hay and live stock are the chief agricultural products. Perhaps a larger percentage of the area is devoted to grain than in the Baker Valley, the area devoted to grain being fully fifty percent of the irrigated land. ABout 50,000 acres of irrigated land is being farmed. Irrigation water is secured from numerous streams which head in the mountains and storage is easily secured in Wallowa Lake. The contour method of flooding is usually used in applying the water to crops.

There are two chief types of soil in the valley. The soil in the valley floor has been more affected by water and is somewhat darker in odor. It is a fine sandy loam and has been under cultivation for nearly a generation. The bench lands have been irrigated more recently and the soil in these is a brown, fine sandy loam but is underlaid with a rather fine-grained subsoil whereas the bottom land is usually underlaid with porous gravel at a depth of from two to five feet. Both types of soil are adapted to and are used for the growing of alfalfa grain and hardy root crops. The average value of improved irrigated land would be from sixty to ninety dollars per acre and alfalfa, timothy and clover yields from a ton and a half to four tons per acre; oats and barley from fifty to sixty bushels per acre; wheat perhaps twenty-five bushels per acre while a good average yield of roots would perhaps be twenty tons to the acre. Three water variation trials were conducted in this valley during the past season by Mr. C. E. Stricklin of the State Engineer's Office. Trials were all carried on in one locality in the valley floor and were all located on the dark, fine sandy loam which is the most extensive soil type in the valley. The results of water variation trials in this valley are summarized in the following table.

Table 3-B

Table 3-B

SUMMARY - DUTY OF WATER TRIALS, GIVING SOIL AND WEATHER CONDITIONS AND WATER USED ON CROPS WITH YIELDS - 1

.oOo.

Column / Crop	I Plat	SOIL CONDITIONS: II Altitude	III Soil Type	IV Soil Humus	V Hygr. Moist	VI W. CAPACITY ins.	VII W. CAPACITY %	VIII Vol. wt: Pounds Cu. ft.	IX Soil Depth in feet	X Plat AREA (A)	MOISTURE CONDITIONS: XI Rain, Apr. Sept.	XII Date 1st Irrig	XIII Irrig. Season	XIV Irrig Total Depth	XV Soil Water Used	YIELDS: XVI Yld. acre	XVII Yld. acre inch	XVIII #D.M. Mrkt-able	CROP RATIO: XIX bs. rket-ble	XX Water Per # Dry Matter Total
																bu	bu			
Barley	1. Max.	4100	FS Loam	7.57	2.33	5.40	42.4"	66.255	2-5'	4.47	6.40"	7/12		12.85"	3.08"	63.62	4.9	3267.5	44	617.6
Exp. 1																				
22-2N-44E	2. Ave.	"	"	"	"	"	"	"		5.15	"	7/15		10.45"	2.57"	54.56	5.2	2862.13	34	613.6
	3. Min.	"	"	"	"	"	"	"		6.08	"	7/13		8.90"	3.34"	53.10	5.9	2783.56	13	605.2
Oats	1. Max.	4100	FS Loam	7.57	2.33	5.40	42.4"	66.255"		3.68	6.40	7/8		12.46"	3.97"	65.0	5.2	1851.2	781	1112.4
Exp. 2	2. Ave.	"	"	"	"	"	"	"		2.78	"	7/8		6.50"	3.70"	60.0	9.2	1619.8	316	926.4
22-2N-44E	3. Min.	"	"	"	"	"	"	"		3.56	"	7/10		3.81"	3.60"	55.0	14.4	1566.4	992	796.8
																tons				
Alfalfa	1. Max.	4100	FS Loam	1014	2.20	5.70	46.5	63.88		4.30	6.40	7/19		33.68"	1.20"	3.092	.092	56.90.	639	---
Exp. 3	2. Ave.	--	--	--	--	--	--	--		4.30	"	7/20		22.33"	3.38"	3.052	.136	5617.0	292	- --
25-2N-44E	3. Min.	--	--	--	--	--	--	--		4.30	"	7/21		18.79"	2.75"	3.086	.164	5679.2	112	- --

Table 3-C

				%	%		%									bu				
Oats	1. Max.	2700	Medium sand	3.19	1.09	4.32	31.0	72.96#	3'	2	1.14	6/26		17.88"	0.08"	32.15	1.80	943.68	574	1829
Exp. 1	2. Ave.	"	"	"	"	"	"	"	"	2	1.14	6/20		12.42	1.80	29.7	2.40	867.59	000	1600
30-14S-12E	3. Min.	"	"	"	"	"	"	"	"	2	1.14	7/2		3.30	0.57	27.35	8.20	802.88	410	564
Wheat	1. Max.	2750	M sand	3.87	1.37	3.88	24.76	82.25	2	1	1.14	6/30		11.4	1.81	20.0	1.75	1074.0	019	1207
Exp. 2	2. Ave.	--	--	"	"	"	"	"	"	1	1.14	6/26		8.28	2.42	22.0	2.66	1181.4	2264	905
33-14S-12E	3. Min.	--	--	"	"	"	"	"	"	1	1.14	7/8		9.96	2.23	17.0	1.70	912.90	300	1320

.oOo.

Results of Experiments in Wallowa Valley. Table 3-B

The soil on which these plats were located contains a good supply of humus and the surface soil is a very good loam. The gravelly sub-strata affords rapid drainage and it would be extremely difficult to over-irrigate the plats to the point where the yields would actually be decreased on this type of soil. There would be far greater danger of soil injury by leaching than by alkali over the entire area taken as a whole.

The use of water on the barley ranged from about nine to thirteen inches. Yields increased with irrigation ranging from fifty-three bushels up to 63.6 bushels, per acre, the maximum yield being secured with the maximum amount of irrigation. The minimum irrigation gave the most economical returns per unit water and the most economical returns as judged by the water cost per pound of dry matter. The oats received from four to twelve and one-half inches of water and the estimated yields ranged from 55 to 65 bushels per acre. As in the case of the barley, the most economical production per unit water was with the minimum irrigation while the maximum yieldswas secured with the maximum irrigation, and the water cost was decidedly less with the minimum plat which indicates that this soil has been subjected to consederable leaking. Alfalfa ordinarily receives two irrigations and is cut twice during the season in this valley. Heavy spring rains replaced the first irrigation and but one irrigation was applied except on the maximum plat. The amount of water applied ranged from eighteen to thirty-six inches or a little over per acre and the yield was practically three tons in all cases. This gave a decidedly m more economical yield per unit water and a decidedly lower water cost with the minimum plat or the lowest amount of water used. The lack of differences in yield from applying a great deal more water to the maximum plat indicates that irrigation is of little value late in the season or in quantities above the capacity of the soil to retain it. No doubt these soils are frequently irrigated beyond the retaining capacity for water at additional expense per irrigation and loss of plant food. Better returns can be expected from the same amount of water if applied in moderate applications at more frequent intervals. Mr. Stricklin states that the maximum oats plat may have had a little advantage from having fed stock on the field.

E Experiments in the Deschutes Basin.

Experiments during the past season were conducted in three districts in Central Oregon. The Deschutes Basin region which is under irrigation or liable to be irrigated situated in Crook and Jefferson counties and ranges in elevation from 2500 to 3600 feet above the sea level. The average elevation would be about 3000 feet which is the elevation at Redmond. The rainfall over the area would average about twelve inches and the growing season is sufficient for grain and hardy root crops, potatoes and a little fodder corn, The average-size irrigated farm runs from forty to sixty acres and the more intensive types of live stock farming such as dairying and hog raising must become the leading types of agriculture. A sparce growth of juniper and sage brush originally covered the land and extensive irrigation development began about ten years ago. The toporgaphic features of the country and the irrigation enterprises and proposed projects are thoroughly described in the Deschutes report published by the Reclamation Service under Oregon Co-operative work. Preliminary soil surveys of about two hundred thousand acres in this district have been made by the College in connection with the investigations of the Reclamation Service and soil data maps giving the location and extent of different soil types will be found in the Deschutes report. The soil texture becomes coarser at higher elevations and the chief types are fine sandy loam, fine sand, medium sand and medium to coarse sand, .Medium sand or medium loamy sand is the prevailing type in the Redmond district while in the canyon bottom about Squaw Creek some fine sand is found. The soil is underlaid with porous basalt at a depth of eighteen to thirty-six inches and small areas of rock "out-crops" appear at frequent intervals over the area.

Previous Experiments in Deschutes Basin. Mr. H.B. Farmer of the Department of Agriculture measured the water used on twenty farms in the Redmond district under direction of Doctor Fortier in 1912. Approximately one thousand acres of crops were included in the experiment and the average seasonal use of water was 4.16 feet per acre. On farms where the furrow method was used in distributing water, perhaps a fourth less water was used than where flooding was practiced. Decidedly less water was used on cultivated crops than on the meadow crops included in trials.

The College operated an irrigation demonstration farm one mile north of Redmond in 1912. The total amount of water used on practically each and every plat or field on this farm was also measured. The rainfall for the season was perhaps two inches above normal and the area was about equally divided between meadow crops, grain crops and cultivated crops. Care was observed in applying water just at the time needed and the farm had the advantage of moisture conserving tillage practice while the application of water was governed by the determinaations of the soil moisture supply for different crops. The soil was in a fairly good state of fertility and was kept in very good tilth. These practices and conditions are largely responsible for the relatively low quantity of water used. The water allowed within this p project is 1.8 acre feet for the ninety-day summer season. This would amount to fifty-four acre feet for 31 acres. The amount actually used on the thirty-one acres irrigated on this farm was 32.3 acre feet which is equivalent to 1.04 acre feet per acre for the ninety-day period. During the whole growing season 40.75 acre feet was used or about 1.3 acre feet per acre.

On this farm numerous water variation trials were made and the results expressed in yield per acre as well as yield per acre inch and crop value per acre inch can be found in Bulletin No. 119 of the Oregon Experiment Station. Only a few of the most important results will be mentioned here. Briefly, it was demonstrated that the quantity of water needed is influenced by the kind of crop and time of seeding, method of irrigation and particularly by fertility and cultivation.

As an example of the effect of fertility on economical use of water, one experiment with potatoes is given. One acre of Burbank potatoes was planted on old ground and received two-three-inch irrigations or a total depth of six inches per season. One - half of this plat was treated with potassium sulphate at the rate of 160 punds per acre. The yield unfertilized was 147 bushels per acre or 24.5 bushels per acre inch. The fertilized plat yielded 235 bushels or 39.2 bushels per acre inch. The cost of fertilizer was four dollars per acre and the value of the 88 bushels increase from fertilizer at fifty cents a bushel gives a gross profit of $40 per acre. This experiment shows that the yield per acre inch is more economical with a good state of fertility. The water in all the fertility experiments on this farm was used more effectively or efficiently where fertilizers were applied.

Measurements of water used on three farms determined by John Dubuis, field inspector for the Desert Land Board are given in a report by that Board on the Central Oregon Irrigation Project. The measurements were made in 1914 which was a dry year. Farm No. 1 was located near Alfalfa postoffice where the soil had an average depth of about 18 inches and was sandy loam. The crop was alfalfa and the amount of water used on this farm was 3.19 acre feet per acre for the ninety-day period. Farm No. 2 was located near Redmond. The soil was described as "fine sand" to "fine sandy loam" of comparatively good depth. On this farm 5.7 acre feet per acre was used in the ninety-day season and it is stated that the amount received by the owner was unsatisfactory and Mr. Dubuis attributes this to a lack of a larger head and lack of a rotation system of delivery. Farm No. 3 was located near Cline Falls on medium sandy loam and the water used was 2.44 acre feet per acre. The owner reported that some young alfalfa suffered for lack of moisture on this farm. It is understood that the crops were mainly alfalfa on the latter farm and it must be assumed that the other farm was representative as the kind of crops grown is not stated. The Dubuis Report shows that about fifty-seven percent of the Central Oregon Irrigation Company's project improved lands are devoted to meadows--mainly alfalfa and clover--and about 35% is grain crops while about 13% is cultivated crops. Alfalfa and clover yield three tons per acre. Oats and barley thirty-five to sixty bushels and potatoes one hundred fifty to two hundred bushels per acre.

Experiments in 1915. Two water variation trials were conducted by the Assistant Water Master, Mr. Rodney Soth in co-operation with the College on what is known as the "Lower Bridge" country in Section 30 and Section 33. Township 14 South, Range 12 East in 1915. The elevation of these plats is about 2700 feet and the weather conditions of the season were slightly drier than normal.

Soil on which the wheat was grown was a medium sand while analysis shows the soil on which the barley was grown to be the same type but is some what loamer and contains more humus although this is not clearly shown from the analysis made. The average depth of soil in these plats is about three feet and the substrata is gravel or volcanic ash hardpan. The soil of the wheat field had only been in cultivation for two years. Irrigation was by the furrow or corrugation method in both instances. Furrows were three feet apart and one irrigation was applied. The results of these trials are given in Table 3-C.

Results of Experiments in Deschutes Basin-1915

Table 3-C. The results of the accompanying table were explained by Mr. Soth as follows: The stand and the yield in the case of the oat plants was uniformily good. In the wheat plat, the stand was not so uniform nor so good. A juniper tree in each of the first two plats would tend to lessen the accuracy of the experiment due to the effect of the roots and the shading of the ground under the trees. On the oat plats, it was found that the greatest yield or 32.15 bushels per acre was obtained with the maximum amount of water which was 17.88 inches. However, there was not a great deal of variation in the yields from defferent plats. The most economical yield,

27.25 bushels per acre, was obtained from the use of 3.3 acre inches of irrigation to the acre. This plat also gave decidedly the best water cost of dry matter. In the case of the oats, it would appear that more water can be applied profitably than has heretofore been used unless the water were to be applied at more critical time. In the wheat plat, the sand was not so uniform and the yields are estimated yields as the oats were not harvested separately. The average plot gave the most economical yield per unit water applied and per pound of dry matter produced. Evidently too much water was applied on the maximum plat.

Experiments in the Valley of Chewaucan Marsh.

General Conditions. This area is located in Central Lake County and the nearest railroad points are Bend, 148 miles north or Lakeview, some 45 miles to the south. The elevation of the marsh is 4300 feet while the delta or low bench to the north rises about fifty feet higher. This valley is believed to have been formed by faults. There is a steep scarp on the east side of the marsh and surrounding hills on the other side soon become mountainous in going back from the marsh. The fault seems to connect with Summer Lake Valley. The Chewaucan River which enters the marsh from the northwest near Paisly continues to the Lower Marsh and enters Lake Abert. Gravel and sand brought down by the Chewaucan River have formed a narrow pass extending south from its mouth and a larger and more elevated terrace extends over an area of several thousand acres north of Paisley.

The rainfall is perhaps twelve inches per year and the growing season is sufficient for grain and aflalfa on the terraces where there is air drainage. Even fruit is grown in sheltered spots in the vicinity of Paisley.

No careful soil survey has been made in this valley although such a survey would be of great valure in determining the best amount of water for the different soil areas of the valley. From a little preliminary soil investigation made during the past season, it seems that the bulk of the soil on the marsh below the meander line is peat from six inches to thirty inches in depth and underlaid with a streak of sandy material and then a, silt muck extending to unknown depths. There is a subsoil containing considerable chalky material and this is likely diatomaceous earth. The average depth of the peat soil is perhaps twenty inches. The vegetation on this type of soil is chiefly native grasses, such as sugar grass, blue joint, red top, wire grass and scattering patches of flags and tulles. Toward the south part of this marsh is an extensive body of tulles and the soil in that area appears to be a deep peat. Such a soil is very light in weight and has a very high retaining capacity and an abundant supply of the elements phosphorus or nitrogen. Usually the supply of potash and the reaction of such a soil is uncertain. Above the meander line is a peaty loam which is only extensive along the northwest part of the area of the marsh. This soil has a slight advantage in elevation; less water loving vegetation is present and instead timothy and native clover is growing with the native grasses. Above this intermediate type is a more extensive area of dark loam. This extends east from the town of Paisley for a mile or so and becomes narrower towards the south. Good crops of grain are produced on this land. The terraces near Paisley are medium to coarse sand with gravelly subsoil. Finer grades of sand and sandy loams are said to exist farther north but these have not been carefully defined. This medium sand is rather loamy though it has very rapid drainage and is low in humus. Some alfalfa, grain and fruit are produced on these well drained terraces, where ditches supply enough water in the vicinity of Paisley. The Marsh land is largely under control of large cattle companies who cut the native grasses for hay or use them for winter pasture. The Chewaucan River largely disappears in the marsh but some drainage appears again crossing the lower marsh and flowing into Abert Lake. The flood water is spread out over the marsh by a sysem of wild flooding and a drainage canal later removes the greater part of the excess to permit haying and drying out the land for winter pasture. Measured yields the past season would indicate the average yield of native grasses on the marsh would range from one to two tons per acre of hay per season.

Experiments Undertaken. It was realized that the problem of securing duty of water data on the marsh would be difficult. However, it was planned to get data on the use of water by measuring the amount applied and wasted from the large fields; work by a few tank experiments. Experiments undertaken were located on the peat; and peat loam and medium to coarse sand. Several water capacity tests were made of each type by the cylinder method to determine the average weight per cubic foot and the maximum water capacity under field conditions. This test is also calculated to aid in estimating usable water capacity of the soils in question. The agent in charge of the field work from the Department of Agriculture was E.R.Greenslet who had previously worked under the direction of Mr. Bark in Idaho. The principal data obtained is summarized in Table 3-D.

Table 3-D.

Table 3-D

SUMMARY - DUTY OF WATER TRIALS, GIVING SOIL AND WEATHER CONDITIONS AND WATER USED ON CROPS WITH YIELDS - 1915

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Column I		SOIL CONDITIONS									MOISTURE CONDITIONS					YIELDS			CROP RATIO	
Crop	Plat	II Alti-tude	III Soil Type	IV Soil Humus	V Hygr. Moist	VI W.CAPACITY ins.	VII %	VIII Vol. wt: Pounds Cu. ft.	IX Soil Depth in feet	X Plat area (A)	XI Rain. April Sept.	XII Date 1st Irrig	XIII Irrig. SEASON	XIV Irrig. Total Depth	XV Soil Water Used	XVI Yld. acre	XVII Yld. acre inch	XVIII # D.M. Mrkt-able	XIX Lbs. Market-able	XX Wat. per D. M. Total
																tons				
Marsh	1. Max.	4300	P Loam	7.6%	3.60%	~~3.67~~ 6.5	64.5	~~64.5~~ 52.5	deep	.1	2.02"	6/3	--	27.48"	3.69"	0.89	.030"	1325.55	4407	--
Grass	2. Ave.	"	"	"	"	"	-"-	"	"	.1	2.02"	6/3	--.	11.28"	1.14"	1.03	.091"	1534.06	2256	--
29-34S-19E																				
	3. Min.	"	"	"	"	"	-"-	"	"	.1	2.02"	--	--	0.00	1.29"	0.57	--	848 .96	881	--
Marsh	1. Max.	4300	Loam	--	--	----	--	--	deep	.1	2.02"	6/1	--	18.12"	4.48	0.70	0.038"	1042.58	4377.7	--
Grass	2. Ave.	"	-"	--	--	---	--	--	"	.1	2.02"	6/15	--	6.60"	3.02	0.73	0.110	1087.24	2419.0	--
19-34S-19E	Min.	"	---	--	--	--	--	--	"	.1	2.02"	--	--	0.00	2.30	0.70	--	1042.58	936.5	--
		"														bu				
Barley	1. Max.	4350	C Sand	2.65	2.26	3.60	23.2	81.0	4'on g.	3.71	2.02"	6/14	--	34.80"	6.47	15.1	0.433	1287.79	7597	3798
	2. Ave.	"	"	"	"	"	--	--	"	2.43	2.02"	6/21	--	33.72"	4.37	35.4	1.05	1936.47	4681	2340
33S-18E	3. Min.	"	"	"	"	"	--	--	"	2.40	2.02"	6/20	--	26.28"	3.92	23.3	0.88	1926.39	3780	1890
										sq ft						grs.		gm		
Marsh	1. Max.	4300	Peat	--	--	7.63	147.17	27.42	10'	1.40	2.02"	6/20	--	26.475"	11.47	125	4.64	78.0	1684	--
Grass	2. Ave.	"	"	"	--	"	"	"	"	"	2.02"	6/20	--	13.815"	7.87	71	5.14	46.0	1696	--
Tanks																				
Paisley	3. Min.	"	"	--	--	"	"	"	"	"	2.02"	6/20	--	4.00"	16.09	94	23.5	70.0	1021.8	--
Allen																				
Hermiston																				
Alfalfa	1. Max.	460	C Sand	Trace	--	3.05	18.	88.3	deep	"	3.6	4/6	210	84"	2	5.69	.067	9673	2009	--
	2. Ave.	--	"			-----	--	"	--	"	--	4/6	202	44"	2	4.63	.105	7871	1321	--
	3. Min.	--	"			--	--	"	--	"	--	4/6	190	28"	2	3.50	.125	5950	1139	--

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Results of Experiments in Valley of Chewaucan Marsh.

Table 3-D. The marsh grass plate used in Experiment No. 1, Section 29, 34 South, 19 East were located on on peaty loam. The water applied ranged from nothing on the minimum plat up to 27.48 inches on the maximum plat. The average plat gave the largest yield and best quality of hay and yielded 1.03 tons per acre. This was also the most economical production per unit of w water used. The water cost appears to be lower on the minimum plat. The dykes on these plats were not absolutely tight and the minimum plats had a good moisture content early in the season.

The native grass plats used in Experiment 2, located in Section, 19, 34 South, 19 East were on a loam with a very good humus content. The minimum plat received no irrigation; the average plat received 6.6 inches and the maximum 18.12 inches. The greatest yield per acre was .73 tons and also the most economic return per inch of water was realized on the average plat. The total soil, rains and irrigation water received on this plat was so large that the calculation of water cost was much lower than on the minimum plat. These plats appeared to be fairly free from seepage.

Three tanks eighteen inches in diameter and twenty-six inches deep were filled with peat soil from the march. The tanks were inverted on the sod which was so-called "sugar grass" (Carex aquatilis) and the first foot of soil and sod trimmed out to fit the tanks. The second foot of soil was removed to the tanks in as near its original compactness as possible after which the sod or first foot of soil was transplanted into the tank in one section. The grass was a few inches tall when transplanted; was injured very little by the operation; made a good growth in the tanks and had a healthy color. The maximum tank was kept flooded like the marsh during the time that the marsh grass was in a saturated condition. The maximum plat received 26.81 inches depth of water during the seasoj and the average plat received 13.81 and the minimum tank 4 inches, for the season. The entire growth for the maximum tank was 125 grams while the minimum tank yielded 94 grams and the average tank 71 grams. The minimum tank gave decidedly the most economical yield per unit water and the water cost of dry matter in this tank was but little over half the water cost of dry matter produced on the other tanks.

Regarding these experiments, Mr. Greenslet says, "The investigations this season seem to show that sugar grass has a much higher 'firing' point than tame grasses. The minimum moisture content or firing point for sugar grass appears to be about 35% (soil moisture percentage being expressed in percent dry weight of soil) and there is a proportionally high optimum moisture content which is about 55% for this grass. The studies, however, also show that the marsh under present conditions if kept up to a mosture content of about three times what should be required for the production of marsh grasses, as indicated by the experiments of the season and equal to several times that would be required for tame grasses."

The barley plats were on medium to coarse sand about one-half mile north of Paisley and from 26.28" up to 34.80" of water was used on these plats. The average plat received 33.72 inches and yielded 35.4 bushels per acre or 1.05 bushels per acre inch. This was the most economical yield both in inches depth of water and in acres land considered. The water cost per pound of dry matter was lower in case of the minimum plat. The water cost figures are high. The quantity of water used on all these plats is rather high and the amount applied per irrigation was considerably more than the soil root zone could contain. From determinations made during the season, it is estimated that the usable water capacity of this soil would not be far from one acre inch per irrigation would be about all the irrigation water that could be retained, even if the soil were well dried out at the time of irrigations were tobe applied. To apply these lighter irrigations, it would be necessary to have shorter runs and a larger irrigating stream during the time the water is applied.

Relation of Irrigation to Alkali and Water Table. A row of wells was installed following the section line across the marsh from the terrace at the west side of the marsh nearly to the east edge of the valley. The wells were one-fourth mile apart and extended over a length of about five miles. Careful notes were taken of the soil strata encountered and from these notes t taken by Mr. Greenslet, a cross section of the soil showing the soil formation have been prepared. The water table was read at regular intervals during the season. At the beginning of the season, the water table was within four feet of the surface on the low terrace just east of Paisley. The water table approached near to the surface until there was surface water a little farther out in the marsh than the location of the old government meander line. The water table gradually receded after the flood season and as the season was one of low water supply the water table had receded to the bottom of the drainage canal or to an average depth of about five feet below the soil surface throughout the section by the first of August. These readings are being continued. Sketches of the conditions are shown in Plates V and VI.

The experiments were undertaken for this district rather late in the season and should be regarded as of a rather preliminary nature. Several tests were made with crops which seemed suited to the conditions. Field peas did very well on the loam soil just below the town of Paisley but made a rather sickly growth on the marsh due to the lack of drainage. A plot of alsike clover and timothy was seeded on the edge of the marsh and an excellent stand and vigorous growth was secured. This test is being continued . Oats and barley also made very heavy growths where the water table was within two feet of the surface. Records of evaporation from the water surface were kept in connection with these experiments. Information gathered during the season would be of considerable value in planning further experiments on the marsh lands of Central Oregon. There are perhaps 300,000 acres of such land which at present are devoted mainly to production of native grasses for pasture and hay.

Experiments in Goose Lake Valley.

General Conditions. The Goose Lake Valley in Southern Lake County lies in a basin caused by faults in the earth's crust. In outline the irrigable area approaches a crescent shape with the points extending along the lake to the boundary line between California and Oregon. To the west and north, the country rises gradually and becomes mountainous while to the east, the mountains rise more abruptly. Practically all of the irrigable land is of sedimentary origin while the mountains surrounding the basin are of basaltic material. The elevation is about 4800 feet above sea level;and the annual rainfall is about fifteen inches per year and the growing season is short.

The area is naturally divided into (1) gently sloping benches and (2) a valley floor. The valley floor includes the lands that are wild flooded and in natural grass meadows, together with some adjoining land. In the floor of the valley and in the narrow flood plains of the several strams which drain into the valley from the Northwest, the soils are silt loam, silt clay and clay loam. To the north and west, there is low bench partly in sage brush and partly dry farmed. The main soil type there is sandy loam of good depth. There is a higher bench of more limited area and of somewhat more gritty texture and rugged topography. The surface soil on this higher bench is light sandy loam. The sage on the higher bench is mixed with antelope brush or winterfat.

Flood irrigation has been practiced to extend and maintain the meadow area and the water is secured from streams entering the valley mainly from the north and west. Small strams from the hills and mountains on the east side of the valley are used on the ranches along the east side of the lake. Irrigation has been provided for most of the bench lands above described by the Goose Lake Valley Canal Company through storage in Drews Valley and construction of a canal covering the bench land. The past season was the first one during which water has been used on these bench soils.

Grain, hardy root crops, clover and timothy can be grown on this bench land while alfalfa and field peas will also do well on a large part of the area. Some potatoes and even hardy fruits have been produced in sheltered places close to the lake and where there is good air drainage. The bottom lands are quite frosty but in addition to the native grasses some hardy grain for hay and hardy root crops and perhaps alsike clover could be produced. The area is best suited to the development of the general grain, hay and stock farm and on these bench lands not over fifty percent should be in meadow.. A legume meadow should be rotated with grain and hardy cultivated crops. The native grass yields about $1\frac{1}{4}$ tons per acre and is the main crop that has been irrigated in the past. Timothy and clover or alfalfa should yield from two and one-half to four tons per acre with irrigation, on the bench land. The yields secured from the experiment fields are of interest as indicating the possibilities with irrigation.

Experiments in this section were carried out by Mr. H.C. Koons, Irrigationist for the Goose Lake Valley Irrigation Company in co-operation with the College. Experiments were conducted on the light sandy loam that was scarcely as good as the average bench land soil. The root crops, however,were on a lower piece of soil which was clay loam. The experiments were planned to determine the value of irritation for the first time on the bench land so dry plats were included in the trials. The plats were rather small in order to permit full contol of irrigation, harvesting etc. and other conditions. In addition to these plats, the use of water was roughly determined for thirty acres of grain and one hundred and twenty acres of alfalfa. Corrugation methods were used to distribute the water from the laterals. Results of irrigation experiments will be found in Table 3-E.

Table 3-E.

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Text lost on original.

Column Crop	I Plat	II Altitude	III Soil Type	IV Soil Humus	V Hygr. Moist	VI W.Capacity ins.	VII %	VIII Vol.wt. Pounds Cu.ft.	IX Soil Depth in feet	X Plat area (A)	XI Rain, April Sept.	XII Date 1st Irrig.	XIII Irrig. Season	XIV Irrig. Total Depth	XV Soil Water Used	XVI Yld. acre	XVII Yld. acre inch	XVIII #D.M. Mrktable	XIX Lbs. Marketable	XX Water per # D.M. Total
ats		4700	Light S.L.S	--	--	3.59	23.34	80.0	4'	0.33	4.21"	6/15	---	9.20"	--	bu 46.4	5.0			
		"	"	--	--	"	"	"	4'	0.33	"	6/19	--	7.39"	--	44.0	5.95			
		"	"	--	--	"	"	"	4'	0.33	"	--	--	0.00	--	14.5	--			
arley		4700	L. S. Loam	--	--	"	"	80.0	4'	0.50	4.21	6/23	--	6.83"	--	56.6	8.3			
		"	"	--	--	"	"	"	4'	0.50	"	6/23	--	5.97"	--	42.1	7.03			
		"	"	--	--	"	"	"	4'	0.50	"	--	--	0.00"		17.2	--			
heat		4700	L.S. Loam &	--	--	"	23.38	79.4	4'	0.50	4.21	6/14	--	15.99"	--	34.4	2.15			
		"	Gravel	--	--	"	"	"	4'	0.50	"	7/3	--	9.34	--	25.8	2.76			
		"	"	--	--	"	"	"	4'	0.50	"	7/14	--	5.53	--	20.2	3.65			
		"	"	--	--	"	"	"	4'	0.50	"	--	--	0.00	--	12.3	--			
otatoes		4700	L.S. Loam	--	--	"	23.34	80.0	4'	0.10	4.21"	7/16	--	--	--	--	--			
		"	"	--	--	"	"	"	4'	0.10	"	7/28	--	7.5	--	27.3	36.4			
		"	"	--	--	"	"	"	4'	0.10	"	7/23	--	5.0	--	108.6	21.72			
		"	"	--	--	"	"	"	4'	0.10	"	--	--	0.00		75	--			
eets		4700	Clay L	--	--	"	"	80.0	4'	0.25	4.21	7/3	--	11.41	--	ton 6.5	5.7			
		"	"	--	--	"	"	"	4'	0.10	"	--	--	0.00	--	2.3	--			
utabagas		4700	Clay L	--	--	"	"	"	4'	0.10	"	7/3	--	9.61	--	4.9	--			
		"	"	--	--	"	"	"	4'	0.05	"	--	--	0.00	0-	1.8	--			

Carricher ranch

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Results of Experiments in Goose Lake Valley. Table 3-E.

The plats included in those trials were given careful attention and the stand of grain was uniformly good. The grain yields were almost in direct proportion to the water received. Dry-farmed wheat on the bench lands in this valley yielded from ten to fifteen bushels of grain per acre for the season. Irrigation of wheat and other grains gave greatly increased yields and the maximum irrigation gave the maximum yield. However, little increase in yield was secured where more than 7.4 inches was applied to oats and this was decidedly the most economical yield per unit of water. Altogether, it was the best use of water for the trials. The maximum plat of barley received 66.83 inches of water and yielded 56.6 bushels per acre. The yield per acre inch on this plat was slightly better than on the average plat, and represents the best use for this trial. Wheat gave an increase in yield up to sixteen inches depth per acre and yet the greatest yield per unit water was secured from a five and one-half inch irrigation.

The use of manure and of fertilizers on this place gave decidedly more economical returns per unit of water applied and for the total irrigation applied and though their effect was not measured accurately, it is estimated that the increase from the use of either flowers of sulphur or manure was fully 25% of the total yield.

Results of Experiments on the Umatilla Project.

General Conditions. The Umatilla Project is located in the Columbia Basin extending east from where the Umatilla River empties into the Columbia. The irrigated and irrigable lands in this district range fo from 300 to 700 feet above sea level. The average annual rain for the district is about 8 inches and the growing season for alfalfa is nearly six months. The climate is arid and high winds are frequent. The past season was a little drier than normal. The one depth of irrigation on Umatilla Project the past season was 5.57 acre feet. This is less than used in former years and indicates that the duty is increasing, on this project.

Irrigation projects in operation secure water mainly from Umatilla River. The land included in construction and contemplated projects are generally sandy. General soil surveys of about 250,000 acres have been made in this district by the College and the chief soil types are fine loamy sand, fine sand, medium to coarse **sand**, and coarse sand. These soils come from sediment chiefly of basaltic material, probably deposited when the river waters were backed up over the lower part of this river basin. The material has since been reworked by the wind.

Alfalfa is grown on over half of the irrigated land. The average yield is about 5½ tons per acre. The long season, however, permits the growing of a great variety of truck crops and fruit. Intensive types of live stock farming such as dairying and hog raising are coming to be combined with the fruit on the moderate sized ranches of the district.

The soil on which the experiments in question were run is medium to coarse sand and similar to some 65,000 acres in the district. It is low in humus and in usable water retaining capacity is very low. The average amount of water delivered on the project runs eight or nine acre feet deep per season. Data secured from the water variation trial with alfalfa by R.W.Allen, Superintendent of the Umatilla Experiment Farm as a part of the regular work of that Station is given in Table 3, Section F.

Mr. Allen describes the trial as follows: "To three plats of alfalfa, number 1, 2, 3, water was applied at intervals of one, two and three weeks respectively.

A uniform rate of application of four acre inches per was used for all irrigations. Plat 1 received 24 applications or eighty-four acre inches of water and produced 5.69 tons of hay which amounts to .067 tons per acre inch of water. Plat 2 received 12 applications or 44 acre inches of water and yielded 4.63 tons of hay which amounts to .105 tons per acre inch of water. Plat 3 received 7 applications of water, totaling 28 acre inches and produced $3\frac{1}{2}$ tons of hay which amounts to .125 tons per acre inch of water.

While plat 1 produced the most hay per unit of land, it shows the duty of water to be quite low. Plat 3 gave the highest duty of water but produced an insufficient acre yield. Upon considering the optimum duty of water and yield of forage as indicated by this experiment, Plat 2 is the most desirable as upon it 44 acre inches of water produced .105 tons per acre foot, making a total of 4.63 tons of hay per acre. This experiment gave practically the same result in the previous season.

Mr. Allen secured the evaporation and rainfall data for the season given in tables elsewhere in this report.

<u>Summary of Water Variation Trials in Eastern Oregon-1915</u>. Very few previous measurements of water have been made and still less duty of water data is available for Eastern Oregon. The work was undertaken when the growing season was already at hand and many co-operators who could not arrange trials for the present season have arranged to undertake such work next season. Practically, all County Agents have made such plans. These investigations have been somewhat preliminary in character and would need to be extended through a series of years including wet and dry years through a rotation of crops, the chief soils and the chief crops of the principal valleys being represented in order to determine approximately the best amount of water to use under present conditions or to secure definite data regarding the absolute duty of water. Since the work has been carried on for but one season in most places in Eastern Oregon, it has been felt that the data would be of more value if taken up and discussed by districts. A summary showing the most economical yield per unit of water and the plat giving the maximum yield and the amount of water it received is given in the following table.

Table IV

Table IV.

Summary of All Water Variation Trials in Eastern Oregon.

			QUANTITY OF WATER GIVING			
			Best Returns Per Unit Water		Maximum Yield	
Valley	Crop	Soil	Water Applied	Yield Per Acre	Water Applied	Yield Per Acre
			Inches		Inches.	4.138 T
1. Baker	Timothy	Loam	30.56	4.138 tons	30.56	54.4 bu.
2. Baker	Barley	Grav.loam	10.09	50.4 bu.	16.30	133.3 "
3. Baker	Potatoes	Loam	4.49	116.6 "	7.79	65.0 "
4. Wallowa	Oats	F.S.Loam	3.81	55.0 "	12.46	63.6 "
5. Wallowa	Barley	"	8.90	53.1 "	12.85	3.092 T
6. Wallowa	Alfalfa	"	18.79	3.086 tons	33.68	32.15 bu.
7. Cent. Ore.	Oats	Med.Sand	3.30	27.35 bu.	17.88	22.0 "
8. Cent, Ore.	Wheat	" "	8.28	22.0 "	8.28	35.4 "
9. Chewaucan	Barley	Coarse sand	33.72	35.4 "	33.72	1.033 "
10. Chewaucan	Marsh gr.	Peaty loam	11.28	1.03 tons	11.28	0.73 "
11. Chewaucan	Marsh gr.	Loam	6.60	0.73 "	6.60	125 grams
12. Chewaucan	Marsh gr.	Peat	4.00	94 grams	26.475	5.69 T.
13. Col. Basin	Alfalfa	Coarse sand.	28.00	3.50 tons	84.00	46.4 bu.
14. Goose Lake	Oats	L. S. Loam	7.39	44.0 bu	9.20	56.6 "
15. Goose Lake.	Barley	" " "	6.83	56.6 bu	6.83	34.4 "
16. Goose Lake	Wheat	" " "	5.53	20.2 "	15.99	

This table shows the quantity of water used in securing the most economical returns (1) per unit water and (2) per unit land during the past season. Frequently the same amount of water gave the best returns from both standpoints and in such cases was evidently the best use for the season.

Previous Experiments in Western Oregon.

There has been considerable interest in irrigation in two sections of Western Ore. and previous experiments bearing on duty of water in this region are briefly described below:

Experiments in the Rogue River Valley. This valley is located in the west-central part of Jackson County and its elevation ranges from 1,000 to 2,000 feet above sea level. It is surrounded by rugged mountainous country. The natural drainage passes northward through the valley in Bear Creek which flows into the Rogue River at the north end of the valley. The rainfall in the floor of the valley is about twenty-eight inches per year, yet the summers are dry with a summer rainfall of about two and one-half inches for the three summer months. The growing season is sufficiently long as to permit fruit raising to be practiced on a commercial scale.

A soil survey has been made of this area by the Bureau of Soils and many soil types were found to exist arranging from gravelly loam to adobe.

Numerous small irrigation enterprises are found throughout the area and a gravity canal brings water into the east portion of the valley. Plans are on foot for more extensive irrigation development. Irrigation investigations in Rogue River Valley covering a period of five years are reported in Oregon Station Bulletin No. 113, entitled, "Orchard Irrigation Studies in the Rogue River Valley", by C.I.Lewis, E.J.Kraus, and R.W.Rees, published in 1912.

From these studies, it was found (1) that some of the heavy soils; such as the "stickies" gave best results with good cultivation without water; (2) the soil type possessing a medium to slightly heavy texture are usually benefited by an irrigation of from two to four acre inches depth per acre divided equally between two irrigations, the first early in July and the second the middle or latter part of August; (3) free soils when properly cultivated was found to respond best to about two irrigations totaling about four to six acre inches per acre, one irrigation applied early in July and the other early in August; (4) the best results were obtained on pumice or sandy textured soils by the use of about six to eight acre inches per acre per season distributed to three irrigations, one each in June, July and early in August; (5) irrigation of young pear trees on stucky soil is reported a questionable practice. Since these experiments, two unusally dry seasons and increase in the size of the trees made the need of irrigation in this district more deeply felt.

Previous Experiments in the Willamette Valley. The Willamette Valley is the largest area of tillable land in Western Oregon. There is something like 3,000,000 acres in cultivation at the present time. The average elevation of this valley is about 300 feet above sea level and the average rainfall is 42 inches per year. While the climate is humid, there is a dry summer season with a normal rainfall of but 2.03 inches for the three summer months. The chief soil types of the valley which are silt loam and sandy loam, the silt loam being one of the most extensive types under cultivation in the valley. The chief field crops and their yields are represented in the results of experiment given later on.

Experiments were initiated on the Experiment Station at Corvallis in 1907 in co-operation with the U?S. Department of Agriculture, Office of Irrigation Investigations. These experiments were extended and enlarged by the College and seven year's results are reported in the Oregon Station Bulletin No. 122, entitled,"Irrigation and Soil Moisture Investigations in Western Oregon", by W.L.Powers, published in 1914.

The detailed conditions under which these experiments were conducted as well as experiments of the past season, later reported, are contained in this bulletin. Only a brief summary is here given.

Irrigation caused an increase in the yield of all crops. For the seven-year average the increase was 65%. The amount of water which it was found best to use would vary considerably between wet and dry seasons. The most economical increase in alfalfa from irrigation has been made from the use of four acre inches per acre in wet seasons and about six inches per acre in dry seasons while the maximum yield has been obtained with six inches in a wet season and about twelve inches in a dry season. The most economical return of potatoes has been secured with two inches in a wet season and with three or four inches in a dry season while the maximum yield of potatoes has been secured with three inches in a wet season and six inches in a dry season, This indicates about the amount of water that can be beneficially used on the brown silt loam soil of the valley for cultivated crops and for meadow crops. The wilting point for this soil is about fourteen percent; the optimum moisture content about twenty-three percent and the maximum moisture content for proper cultivation about twenty-seven percent. This gives a comparatively large usable water retaining capacity which for this soil is nearly two acre inches per acre foot of soil.

Experiments at Corvallis in 1915.

The previous experiments indicated that crop rotation and the use of manure to maintain the humus supply, the tilth and available fertility of the soil was important in connection with irrigation. Experiments have threfore been continued to determine the value of rotation against continuous cropping both without water and with various amounts of irrigation applied. Additional experiments have been carried on to determine the value of manure in securing economical use of water. While these experiments were conducted on small plats, this gives a better control of all conditions than can be secured in the field experiments above reported. The results of the past season therefore are included in this report for they are regarded of value in checking up the field experiments and in verifying some of the condtions indicated by the field work. The arrangement of plats and the general plan of this experiment are indicated in the accompanying diagram. Plate VI.

Table 3 F 720

SUMMARY - DUTY OF WATER TRIALS, GIVING SOIL AND WEATHER CONDITIONS AND WATER USED ON CROPS WITH YIELDS 1915

.oOo.

		SOIL CONDITIONS								MOISTURE CONDITIONS							YIELDS		CROP RATIO		
Column	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	
Crop	Plat	Altitude	Soil Type	Soil HUMUS	Hygr. Moist	W. CAPACITY INS.	%	Vol. wt. Pounds Cu. ft.	Soil Depth ' feet	Plat area (A)	Rain, April: Sept.	Date 1st Irrig.	Irrig. Season	Irrig: Total: Depth: inches	Soil Water Used inches	Yld. acre	Yld. acre inch	#D.M. Mrkt able	Lbs. Marketable	Water per # D.M. Total	
Potatoes	1	266	B.Si. loam	5.45	5	5.44	34	80.0	6'	0.10	2.03"	7/28	20	1"	3.90	205.3	205.3	3100	544.0	462	0.
	2	"	"	"	"	"	"	"	"	"	2.03	--	20	00	4.64	201.1	--	2905	518.0	404	--
	3	"	"	"	"	"	"	"	"	"	2.03	7/28	"	2"	4.32	214.5	107.2	2917	672.6	545	2.
	4	"	"	"	"	"	"	"	"	"	2.03	7/28	"	3"	3.01	220.0	73.3	3360	617.0	438	1.
	27	"	"	"	"	"	"	"	"	"	2.03	7/28	"	2"	4.32	232.8	116.4	3417	622.0	379	6.
	28	"	"	"	"	"	"	"	"	"	2.03	--		00	3.86	201.1	--	2644	462.0	286	--
	29	--	--	"	"	"	"	"	"	"	2.03	7/28	"	3"	3.01	252.0	84.0	3568	532.0	335	6.
	30	--	--	"	"	"	"	"	"	"	2.03	7/28	"	4"	1.77	310.3	77.6	4350	405.0	275	11.
Average						"	"	"	"	"	2.03			2.5"						"380"	5
																tons					
Beets	9	--	--	"	"	"	"	"	"	"	2.28	7/28	30	5.5"	2.70	11.375	2.06	2560	917.	715	0
	10	--	--	"	"	"	"	"	"	"	2.28	7/28	"	2.5"	3.70	12.245	4.90	2880	404	502	2
	11	--	--	"	"	"	"	"	"	"	2.28	--	"	0.0	4.90	8.775	--	3939	291	677	-
	12	--	--	"	"	"	"	"	"	"	2.28	7/28	"	1.5"	5.70	11.015	7.33	4960	357	653	2
	19	---	--	"	"	"	"	"	"	"	2.28	7/27	"	2.0"	2.32	14.030	7.01	3175	520	418	6
	20	--	--	"	"	"	"	"	"	"	2.28	--	"	0.0	3.84	7.735	--	3501	700	539	-
	21	--	--	"	"	"	"	"	"	"	2.28	7/28	"	3.0"	3.0	12.110	4.04	2940	638	517	2
	22	--	--	"	"	"	"	"	"	"	2.28	7/28	"	6.0"	2.74	16.380	2.73	3230	771	608	2
Average								"		"				3.4"						"578"	2
Red Clover																					
2d yr	13	--	--	"	"	"	"	"	"	"	3.82	7/24	35	10"	9.97	13.965	1.39	5940	937	--	0
	14	--	--	"	"	"	"	"	"	"	3.82	--	"	0.0	12.41	12.885	--	6110	674	--	-
1 yr	15	--	--	"	"	"	"	"	"	"	3.82	--	"	0.0	11.63	11.595	--	5060	773	--	-
	53	--	--	"	"	"	"	"	"	"	3.82	7/24	"	4.0"	11.49	16.650	4.16	7660	628	--	3
2d yr	54	--	--	"	"	"	"	"	"	"	3.82	7/24	"	4.0"	11.49	15.260	3.81	5860	827	--	2
	16	--	--	"	"	"	"	"	"	"	3.82	--	"	0.0	11.63	11.675	--	5960	794	--	-
1 yr	17	--	--	"	"	"	"	"	"	"	3.82	--	"	0.0	12.41	13.960	--	5580	737	-	
	18	--	--	""	"	"	"	"	"	"	3.82	7/24	"	10.0"	9.97	15.825	1.58	5790	969	--	

Results of experiments at Corvallis in 1915, Table 3-F. This table shows the soil conditions, the amount of rain, irrigation, soil water used by the crops. The potato plats received from nothing up to four acre inches depth of irrigation and the dry plats in both cases yielded 214 bushels and 232 bushels respectively. With three inches of irrigation, 220 and 252 bushels were obtained while with four inches of irrigation, 310 bushels per acre were obtained. The plats receiving two and three inches of irrigation gave very economical returns and the water was well used on these plats while the plat with four inches gave a slightly greater total yield. Potatoes were somewhat immature and this would represent about the maximum amount of water that could be profitably used during the season in question. The water cost per pound total dry matter on these plats ranged from 545 pounds on one two-inch plat to 275 pounds on the four-inch plat. The average water per acre inch is obtained by a long processes of calculation which included estimations of the cost of production, calculation of the cost of irrigation treatment, etc.. This method is expained in detail in Bulletin No. 122. The four-inch plat gave a maximum profit per acre inch in this trial. The net profit per acre inch gives the most absolute basis of comparison of efficient use of water that we have found.

The best plats in this rotation received from nothing up to six acre inches depth per acre of irrigation. While the maximum yield was secured with the maximum irrigation, very good yields were secured with two or three inches depth or irrigation. An irrigation of $1\frac{1}{2}$ inches depth gave the most economical increase per-unit water applied. The water cost per pound of total dry matter produced on the best plats averaged 578 pounds. The lowest use was with a five and one-half irrigation and the most economical water cost was secured with a two-inch irrigation. This two-inch irrigation also gave the greatest net profit per acre inch and altogether had the best record of any individual plat in the trial.

The clover plats while arranged in duplicate were partly first year and partly second crop year clover and to eliminate the effect of age, four dry plats were used during the present season on which to base the value of the effect of increase from irrigation. The maximum yield of green feed per acre was obtained with a four-inch irrigation and was 16.65 tons per acre. This was a yield of 4.16 tons per acre inch and was the most economical increase produced from irrigation. Two irrigations, totaling ten inches depth per acre, gave a lower yield. The lowest water cost was obtained from one four-inch plat and the lowest water cost obtained with irrigation was secured from four inches of irrigation in both cases. The four inch plat also gave the maximum profit per acre inch which was $3.74. It represents the best use of water on this crop for the season.

The above three crops are in rotation but includes barley as a nurse crop for young clover but this barley is matured without irrigation. The eight alfalfa plats which were intended as continuous crops to check the value of rotation in the above experiment was new seeding and no yields were obtained during the past year. The results of this experiment are further summarized in the following table:

Table V.
Showing Avarage of Irrigated Plats

Plat	Irrig	Yield Acre	PER Acre In.	Profit per Acre inch	Profit Per Acre	Ratio
		Potatoes	Bu.			
2&28	00	201.1	--	$ --	$80.55	386
1&27	$1\frac{1}{2}$"	219.0	160.8	$3.72	87.48	420
3&29	$2\frac{1}{2}$"	233.2	11.8	4.51	93.16	440
4&30	$3\frac{1}{2}$"	260.0	16.8	6.89	107.15	256
		Beets	T			
11&20	00	8.25	----	----	.64	608
12&19	1.75"	12.52	2.31	4.23	8.49	535
10&21	$2\frac{3}{4}$"	12.18	1.42	2.19	6.72	509
9&22	$5\frac{3}{4}$"	13.88	9.52	1.15	7.54	661
		Red Clover	T			
1,15,16,&17	00	12.53	----	----	44.12	744
53&54	4"	15.90	1.08	3.06	52.75	727
13&18	10"	14.89	.15.	.44	43.28	837

While the value ofcrop rotation has not been well demonstrated as to its effect upon the amount of water required in this experiment data given in Oregon Station Bulletin No.122 shows clearly the value of an irrigated over an unirrigated rotation crop in giving more efficient and more profitable returns per unit of land and water used.

Effect of Manure on Duty and Efficient Use of Water. A second series of plats on this field where the soil is slightly heavier are included in the experiment to determine the value of rotation and manure in lowering the amount of irrigation needed. Four plats each of barley, alsike clover, white beans and carrots are included in this rotation. There are two dry plats and two irrigated plats of each kind of crop. One dry plat and one irrigated plat received manure while the other one did not. Irrigated and unirrigated bean plats are used as continuous crops to check this rotation. Each of the two irrigated plats for each crop received the same amount of irrigation the past season. The detailed data need not be given here. The results of this experiment are summarized in the following table and show the yield per acre, the yield per acre inch, the water cost of dry matter; and the net profit per acre inch and the total profit per acre:

Table VI
Manure vs. No Manure

Plat	Irrig.	Yield per Acre	Yield per Acre Inch	Profit per Acre inch	Profit on Whole crop	Crop Ratio Pounds
Alsike						
		Tons				
39-Manure	Dry	10.400	---	----	$35.60	566
40-No "	"	6.550	---	----	20.20	998
50-Manure	6.0"	15.460	2.577	$4.565	47.59	459
51-No "	6.0"	13.715	2.286	3.470	41.02	577
Beans						
		Bu.				
35-Manure	Dry	8.6	---	----	10.80	2532
36-No "	"	7.8	---	----	8.40	2832
46-Manure	2½"	11.7	4.68	3.63	17.48	1492
47-No "	"	9.4	3.76	0.89	10.67	1887
Carrots						
		Tons				
37-Manure	Dry	9.010	---	----	2.53	244
38-No "	"	9.460	---	----	3.65	212
48-Manure	3"	17.105	5.701	4.74	17.86	225
49-No "	"	12.428	4.142	1.22	7.33	673

These results clearly indicate the value of manure in decreasing the amount of water needed and increasing its efficiency. The increased fertility and improved tilth where manure is applied makes it possible for the plat to produce a pound of dry matter with a smaller amount of water, the essential solution being more concentrated.

SUMMARY

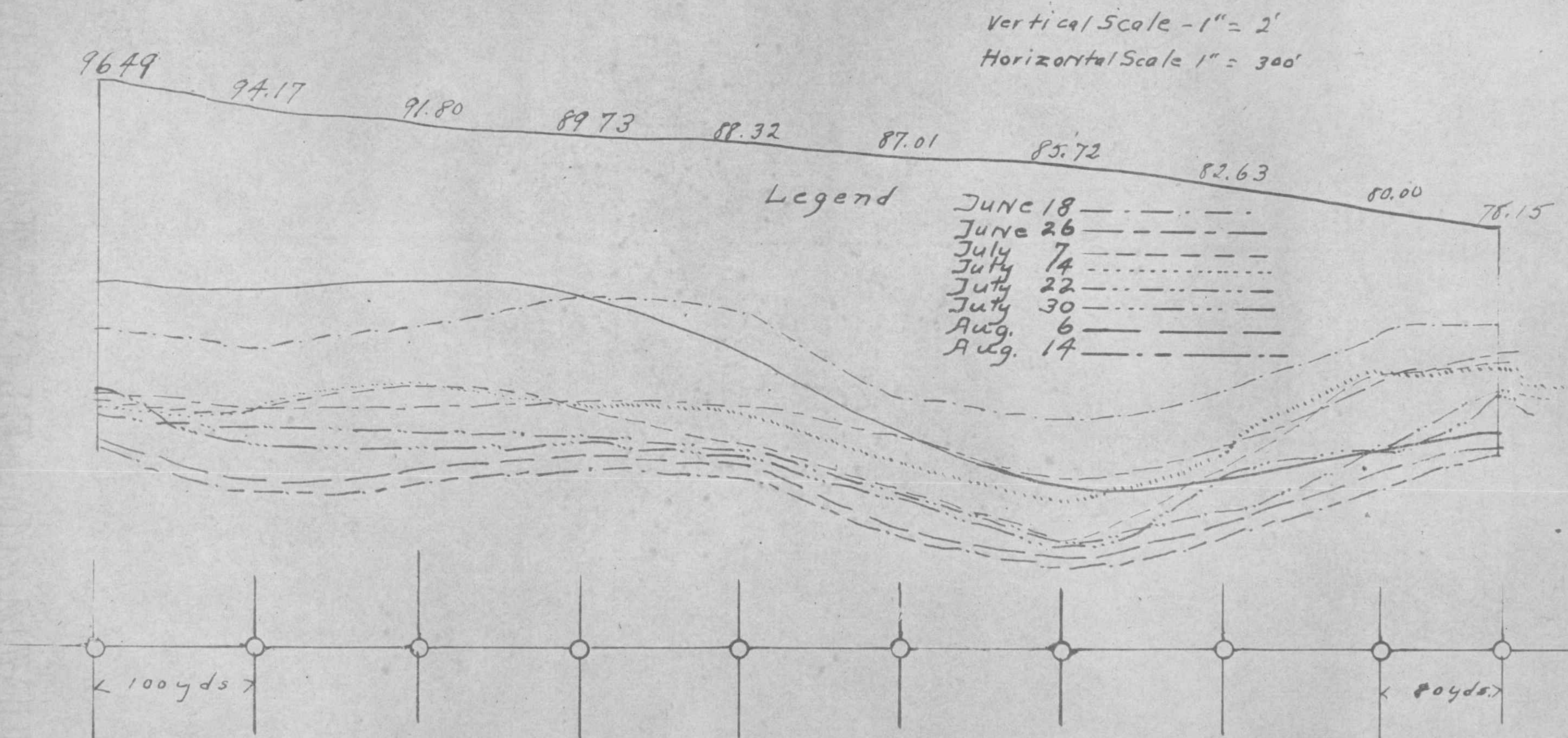
1. Only a brief summary of the results and conclusions will be given.
2. The soils ranged from coarse sand to heavy loam, less water being required on the heavier soils.
3. The crops used were the staple crops of the localities in which work was done, such as natural meadows, timothy, alfalfa, wheat, oats, barley, potatoes, and other root crops. The natural meadows and timothy required the most water, potatoes and cultivated crops the least.
4. On the fine sandy loam of Eastern Oregon about 12-15 inches of water should be sufficient for a crop of grain, about 8 inches for potatoes and other cultivated crops, and about 30 inches for meadows.
5. The greatest accumulations of alkali occurred when the evaporation is the greatest and the redissolving of the salts the least, which is when the water table is from 2 to 3½ feet from the surface.
6. On the lighter types of soil in the Willamette Valley light applications of water have given economical returns when applied to cultivated crops and meadows. The use of irrigation on grain or on the heavier types of soil is of doubtful value.

PROFILE

showing

Water Table - Haines, Ore. 1915.

OREGON COOPERATIVE IRRIGATION INVESTIGATIONS



Corvallis, Oregon.

December 13, 1915.

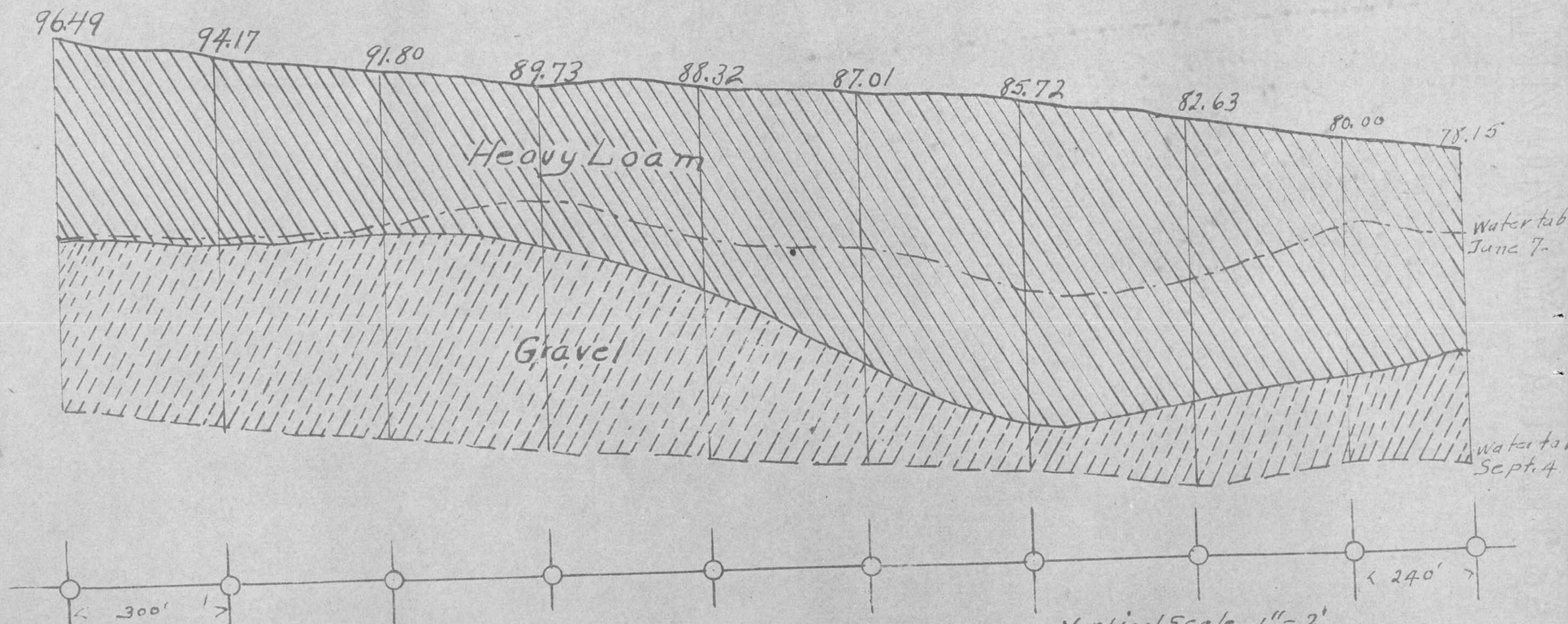
CROSS SECTION

showing

Soil Formation and Water Table

Haines, Oregon.

OREGON COOPERATIVE IRRIGATION INVESTIGATIONS

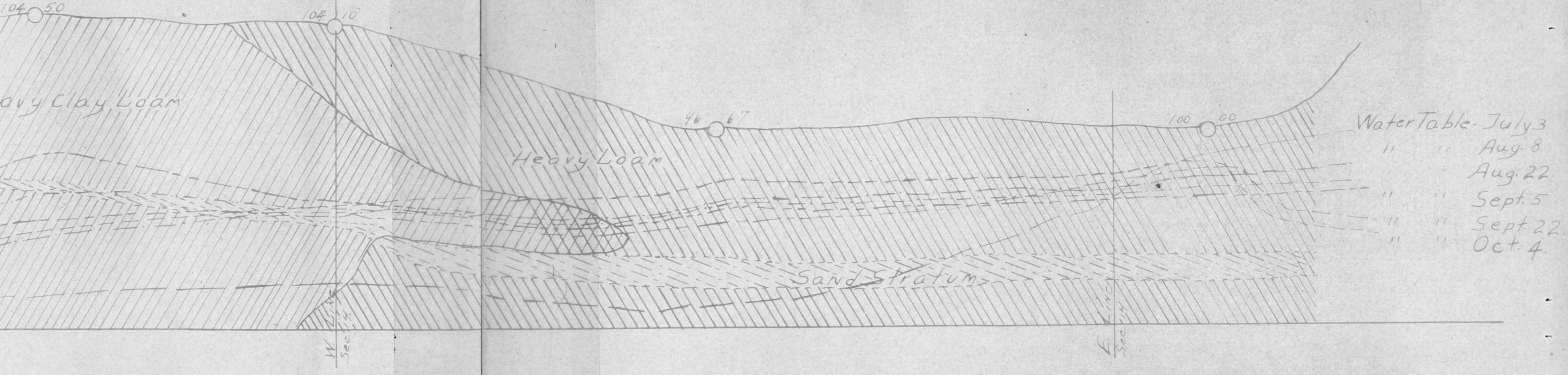


Vertical Scale - 1" = 2'
Horizontal Scale 1" = 300'

Corvallis, Oregon.
December 13, 1915.

Profile Along North Line.
OF
14 AND 15, T 18, R 46 E, W.M.

OREGON COOPERATIVE IRRIGATION INVESTIGATIONS



Vertical Scale - 1" = 4'
Horizontal Scale - 8" = 1 mile

Corvallis, Oregon.

December 13, 1915.

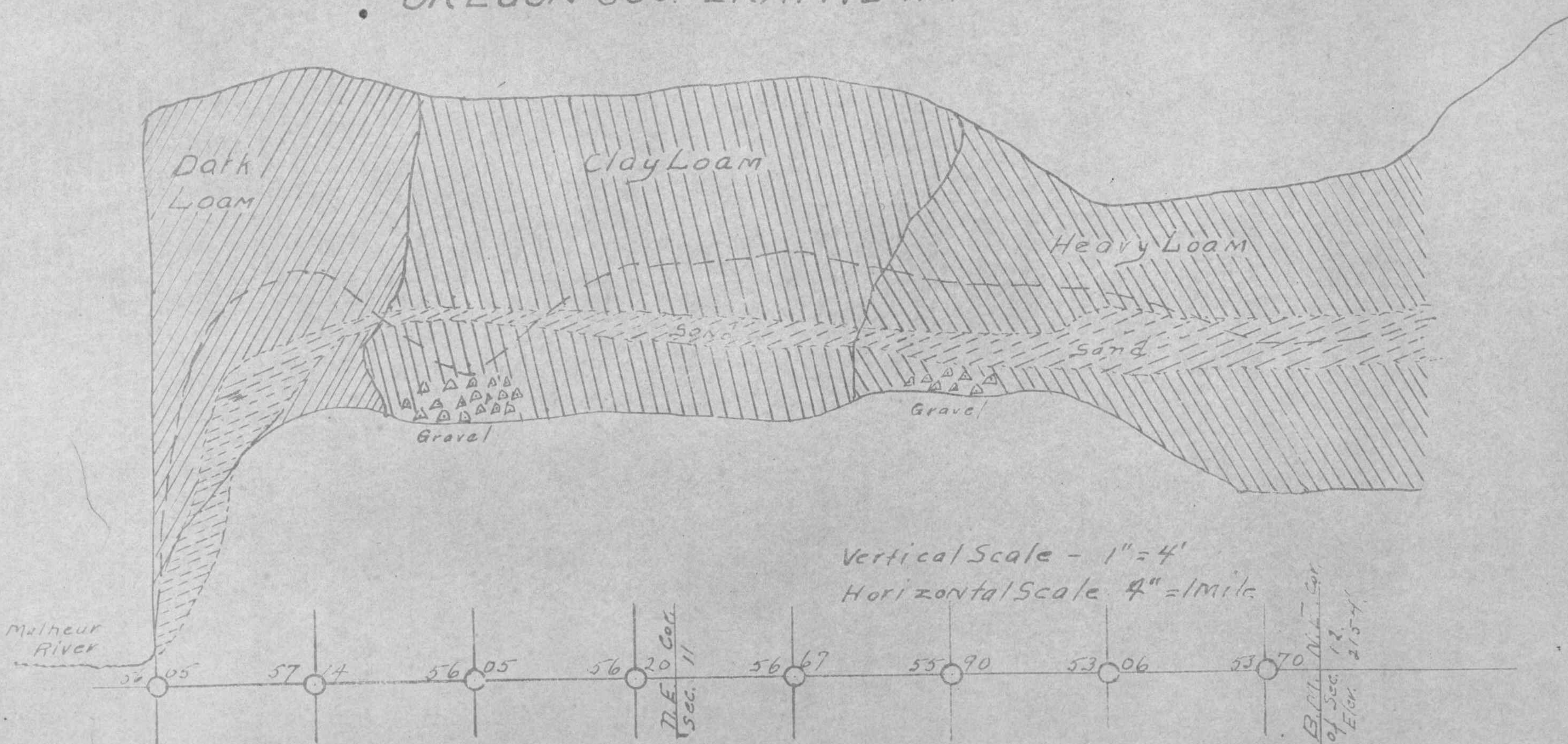
Plate IV

PROFILE

Along North Line of Sections 11 and 12, T 18 S, R 45 E W.M.

Season of 1915

OREGON COOPERATIVE IRRIGATION INVESTIGATIONS



Corvallis, Oregon.
December 17, 191

Plate V

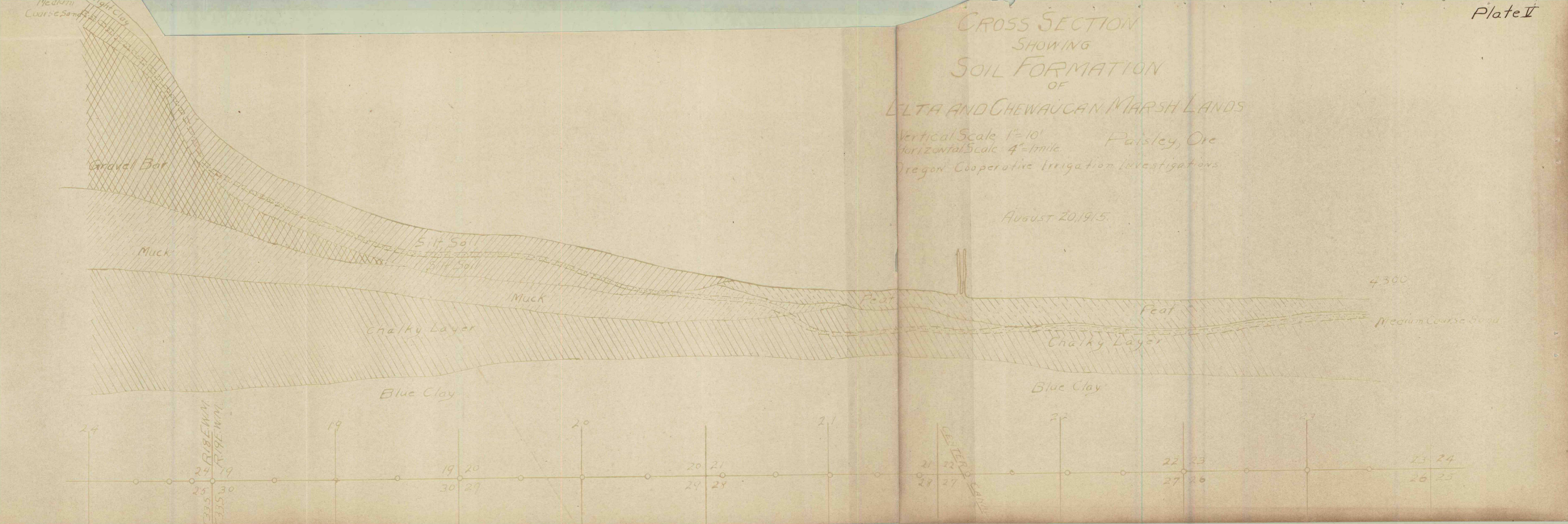
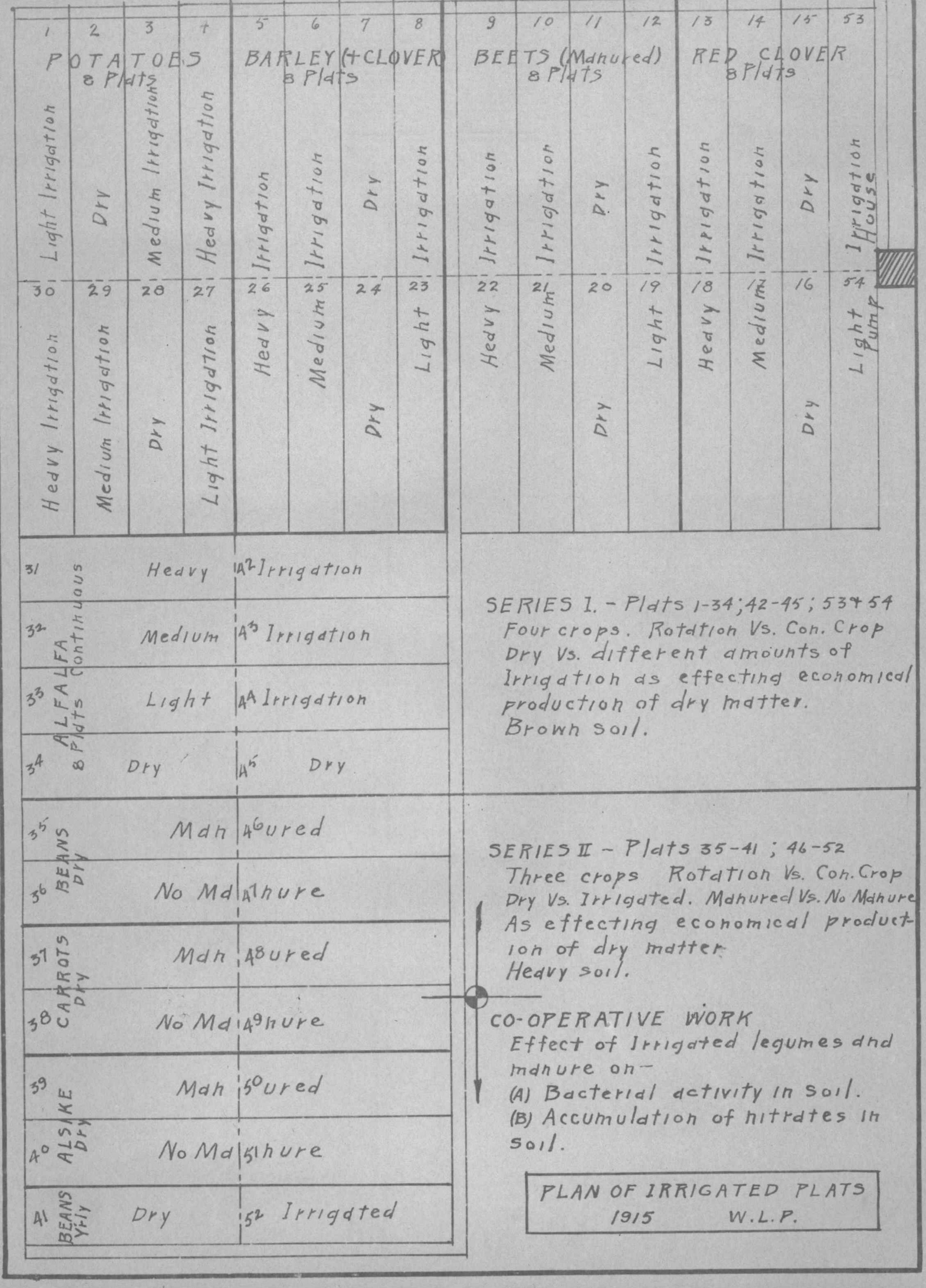
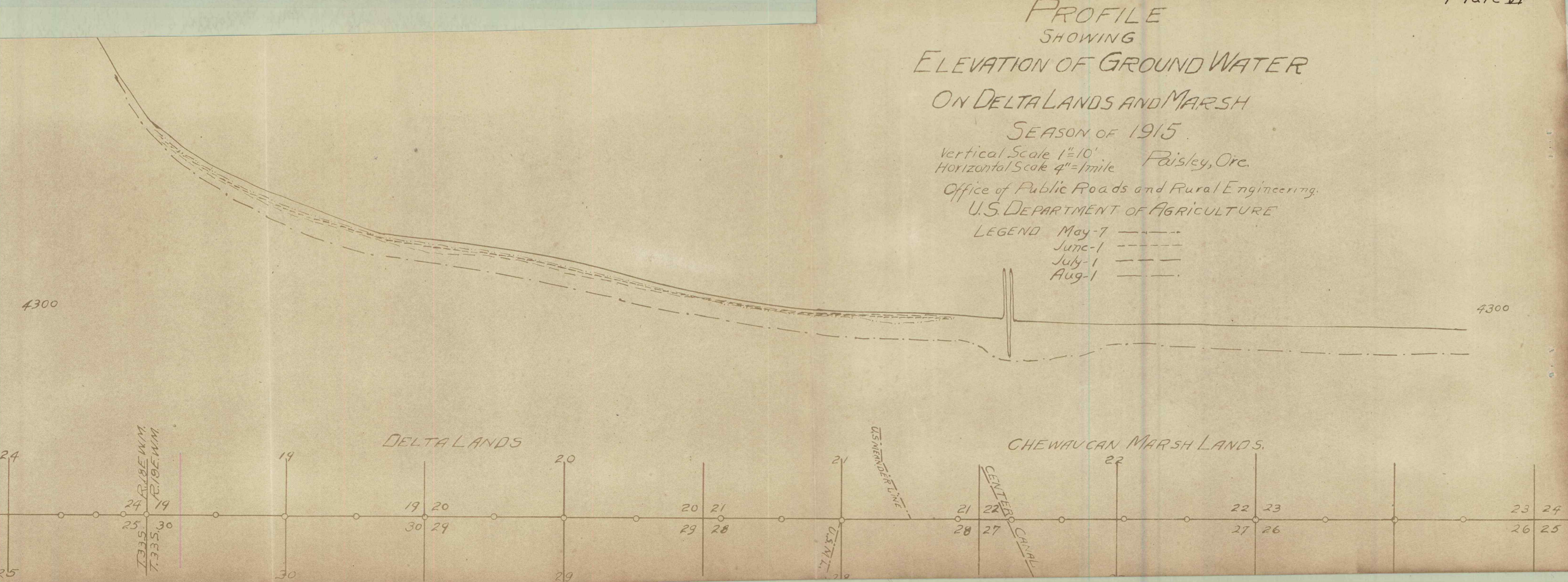

CROSS SECTION
SHOWING
SOIL FORMATION
OF
ELTA AND CHEWAUCAN MARSH LANDS
Vertical Scale 1"=10'
Horizontal Scale 4"=1mile
Paisley, Ore
Oregon Cooperative Irrigation Investigations
AUGUST 20, 1915.
Medium Course Sand
Light Clay
Gravel Bar
Muck
Silt Soil
Silt Soil
Muck
Chalky Layer
Blue Clay
Peat
Peat
4300
Medium Course Sand
Chalky Layer
Blue Clay
R18E.W.M.
R19E.W.M.
Center Line
24
19
20
21
22
23
24 19
25 30
19 20
30 29
20 21
29 28
21 22
28 27
22 23
27 26
23 24
26 25

Plate VII

N+S Plats 158' x 27' - 3' Borders — E+W Plats 118.5' x 36.73'



PLAN OF IRRIGATED PLATS
1915 W.L.P.


PROFILE
SHOWING
ELEVATION OF GROUND WATER
ON DELTA LANDS AND MARSH
SEASON OF 1915.
Vertical Scale 1"=10'
Horizontal Scale 4"=1 mile
Paisley, Ore.
Office of Public Roads and Rural Engineering.
U.S. DEPARTMENT OF AGRICULTURE
LEGEND May-7
June-1
July-1
Aug-1
4300
4300
DELTA LANDS
CHEWAUCAN MARSH LANDS.
R.18E.W.M.
R.19E.W.M.
T.33S.
T.33S.
U.S. MEANDER LINE
U.S.M.L.
CENTER CANAL
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24 19
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