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Bulletin No. 144 - Water Table Variations: Causes and Effects

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Utah Agricultural College

EXPERIMENT STATION

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Water Table Variations
Causes and Effects

BY

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WATER TABLE VARIATIONS.

BY A. B. BALLANTYNE.

INTRODUCTION.

As stated in Bulletin No. 143 the matter contained there and in the following pages grew out of seepage conditions on the Southern Utah Experiment Farm, which necessitated the removal of a five acre vineyard in 1908 and of a seven acre orchard in 1910. The general soil conditions were there briefly indicated and the extent and physical conditions of the root systems discussed. In this bulletin is shown the effect of rainfall and irrigation water on the soil in relation especially to its free water content at various seasons and how this varies. A brief discussion of the fluctuations shown and of their effect on the soil and vegetation is also included; this, with the conditions of the farm especially in mind.

A history of the seepage conditions on the farm if carefully written would be similar, with slight modifications, to that of many other sections in the intermountain region, with this one factor well in mind—that the soil under discussion is decidedly sandy, especially below the first foot.[1] Such a soil would necessarily permit the very free movement of water within it, if it were not hindered by the presence of too great a quantity of alkaline salts.

For this reason, more or less alkaline soils of different physical texture such as the clays, loams and silts, might not, under excessive irrigation, reveal as great fluctuations of the water table as the ones shown. The seepage conditions might be manifest by only a boggy condition of the soil, and the presence of quantities of free water might be detected only by the well being kept open for some time.

On more porous soils, as the gravels, if the drainage were good less marked fluctuations would occur; but if this drainage were not free, then the fluctuations might be even more marked than those illustrated here.

The Wells: As suggested previously, these borings down to water were made in the fall of 1910, the main purpose being to

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1 For a discussion of the Physical and Chemical characteristics of this soil see Utah Station Bulletin No. 121.

determine the nature of the movement of the free water—or the water table level—within the soil. It was of course known that water applied on the surface would induce a change in the level of the free water in the soil, but it was desirable to know just how much and why it varied.

It may be well to state that in 1910 the line of demarkation between the seeped and normal portions of the farm was practically coincident with the drive which separated the upper and lower halves of the farm.

Six wells were originally bored, and as nearly as possible each was located so as to represent the different areas on the farm and the different stages in the process of becoming seeped.

Well No. 6 was bored in the old vineyard and was intended to represent the highest and best drained land on the farm. Well No. 1 was also on the upper part of the farm but in a small slightly swale-like depression and the surface soil had always shown considerable alkali. The surface soil here is clay loam, which with the alkali has made the rate of growth of the trees in the vicinity less than that of those in the rest of the orchard. It was expected that if seepage effect should appear in the upper half of the farm that this would be one of the first places, and this proved to be true, as the entire southcentral portion of the Elberta peach orchard later sickened and died.

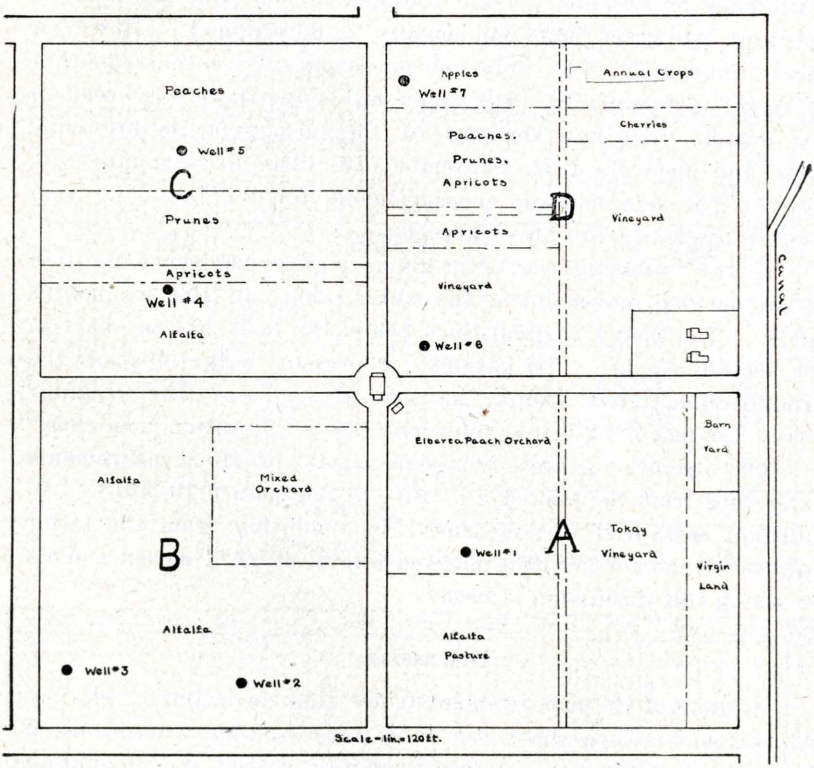
Wells Nos. 2 and 3 were in an old lucern patch on the southwest portion of the farm. The lucern all through this patch was short and stunted and at no time through the season made more than half a normal crop.[1] To the north of well No. 3 half way between that and No. 4 was a small area in which the alfalfa had died out. Well No. 4 was on the edge of the alfalfa field in an area that had originally been planted to orchard and vineyard, but which had been removed on account of seepage.[2] The alfalfa around well No. 4 grew quite well for a few years but later had mostly died out and all of the orchard in the region

1. On this area the third crop of lucern in 1911 was cut and left on the ground and that and the fourth crop were plowed under and the whole patch was seeded to fall oats. The lucern came up with the oats the next spring, and after the grain ripened the lucern grew up and was again plowed under, the land seeded to oats and the process repeated; hence the irrigations after the oats were removed.

2 This area was seeded to oats and alfalfa in the spring of 1911 and a fair stand of alfalfa resulted which remained through 1914.

between wells Nos. 4 and 5 had been destroyed, well No. 5 representing the central portion of this area.

Well No. 7 was bored later than the remainder of the wells. as it was observed that a few trees in the apple orchard were showing the effect of seepage, so this well was put down to ascertain the depth to water in this section. At the time the well was bored the water stood 8 feet 6 inches from the surface. A year before this it was 10 feet from the surface only a very short distance to the northeast of this location.



Method of Measurement: To insure uniformity of measurement, a wooden plate was placed at the edge of the hole even with the surface. A light, 12-foot wooden rule, graduated to tenths of inches, was used in measuring the depth of the water from the surface. This was inserted in the hole and lowered until the tip rested on the mud, the distance noted and if the tip was wet, the amount of it was subtracted from the first reading and the result recorded. If the well was filled in as was usually the case, it was cleaned with the auger and an hour or so later the depth was measured. The measurements were taken to tenths of inches. At first semi-weekly measurements were planned, but later it was found that rainstorms and irrigations usually altered the level of the water table so the measurements were, if possible, taken before and after irrigations.

From October, 1910, to January, 1911, the measurements were made by Joseph T. Atkin who had no soil auger so that the depth of the water could not usually be determined. However, after January 12, 1911, only one measurement was missed—that of Well No. 4—July 12, 1913, and for this one there is a break in the graph; otherwise the rest of the measurements are complete and accurate from September 16, 1910, to September 16, 1913. The semi-monthly measurements for the following year used in the tables are also complete.

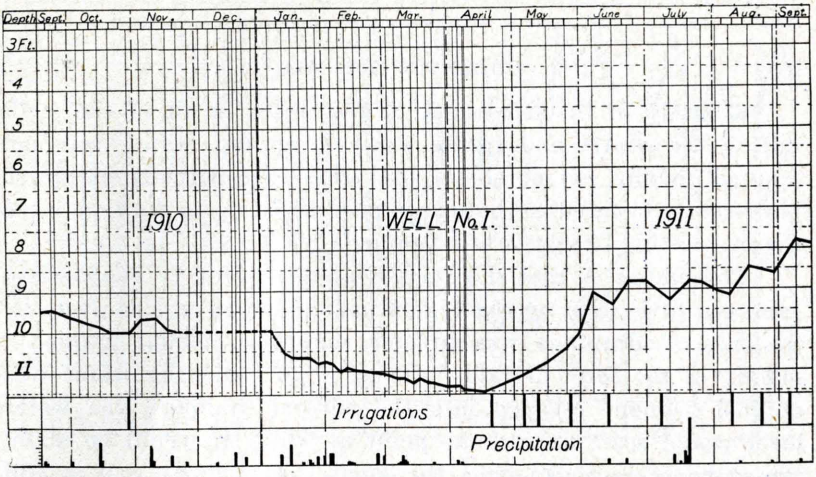
In the following charts, is given a graphical representation of the vertical movement of the water table in the respective wells. The heavy vertical lines below the body of the chart in the section marked "Irrigations" represent irrigations of the ground immediately around the respective wells. The irregular heavy vertical lines below represent the precipitation in inches.

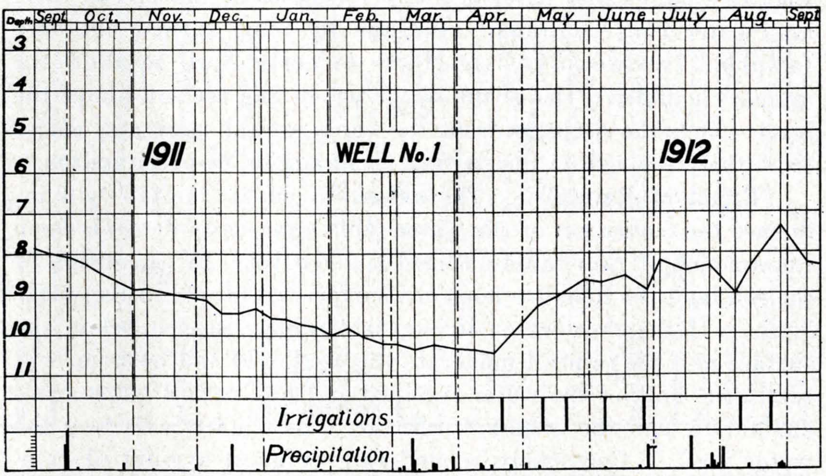
The charts or graphs represent a total of 915 measurements extending from September 16, 1910, to September 16, 1913. In addition each well was measured semi-monthly from the latter date to September 16, 1914, making a total of 1,111 measurements on which this discussion is based.

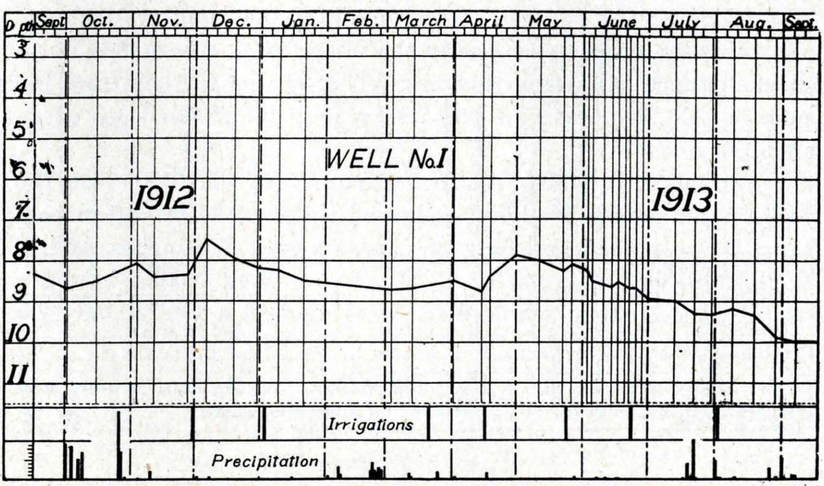
Discussion.

In general the measurements show that an intimate relationship exists between the water table level and the conditions of drainage, precipitation, surface evaporation, and the amount of water applied at, and the frequency of irrigations.

Drainage: On the higher bench lands with deep gravelly subsoils, the other causes will operate slightly—if at all—when the country drainage is unimpeded. On low bottom lands, however, these agencies will have greater effect, the rate of evaporation and amount of rainfall governing to an appreciable extent the level of the water table.







Plates 1, 2 and 3.

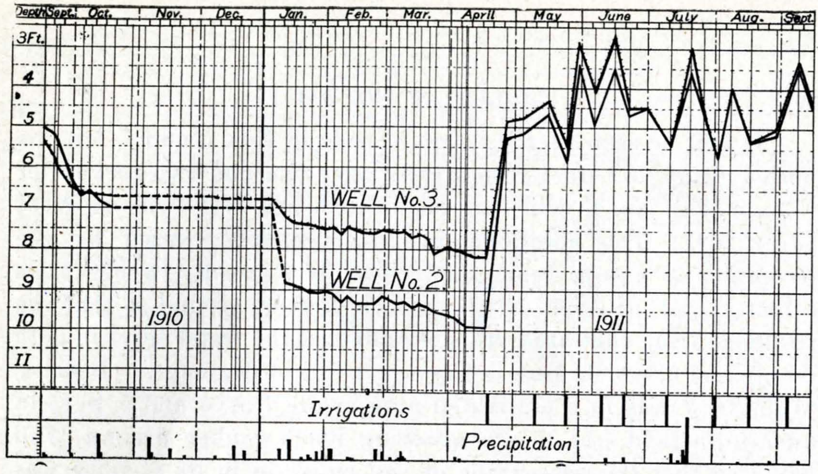
A study of the movement of the water in all of the wells during the winter and spring when irrigating water was not applied to any extent shows that the level without exception persistently lowered as the season progressed up to the time when the first spring irrigation was applied.

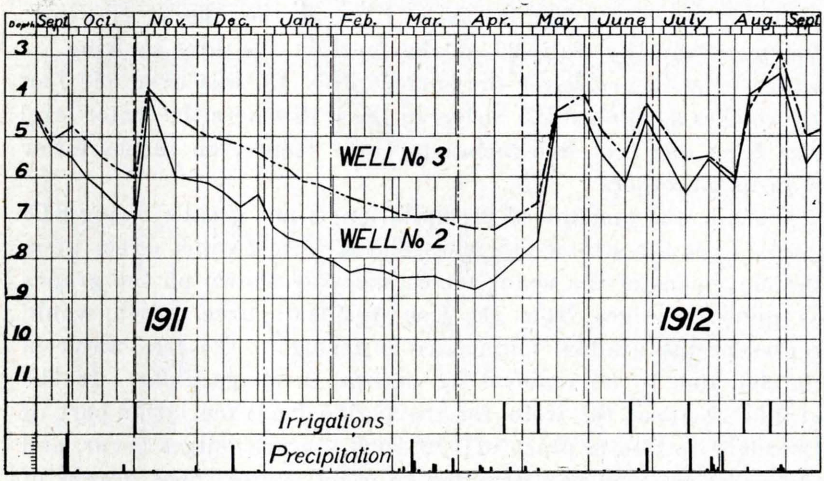
This indicates that the amount of water lost by evaporation (and the little used by the vegetation) and that carried away by the natural drainage was greater than the amount applied—mainly in the form of rain. Thus, if no irrigating water was applied or none escaped into the natural drainage, the water level would soon sink to the point at which it would be maintained by the seepage from the canal. It may be well to add that the main canal extends along the eastern side of the farm and water runs continually through it, being turned out only for about two weeks in late March or early April to allow the annual cleaning. Hence the water which fills the soil above the level which the seepage from the canal would maintain, comes from that received on the surface by irrigation or precipitation.

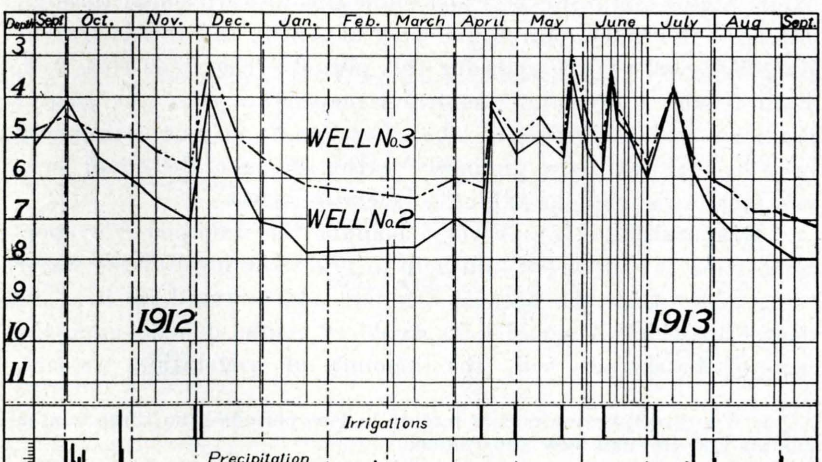
Effect of Rainfall: The extent to which rainfall will influence the movement of the water table apparently depends upon the amount of rain falling within a given time, the condition of the soil, and the distance from the surface of the soil to the water level. If the free water is a considerable distance below the surface and the rainfall moderate the section of soil between will retain the bulk of the water received and will permit but a small amount to join the country drainage, thus slightly affecting the water level. Conversely, a moderate or great amount of rainfall will readily saturate a much thinner section of soil, and the greater quantities of water escaping into the country drainage will cause an appreciable rise in the water level, where it is but a short distance below the surface. That is, the farther from the surface the free water is the less will it be affected by given amounts of rainfall.

For instance Wells Nos. 4 and 5 for July of 1912. On the 15th of this month Well No. 4 showed water at 4 feet, 10 inches; rains between then and July 26 caused a rise of 5 inches, and in Well No. 5 caused a rise of 10.3 inches. Well No. 7 showed a rise of an even foot, while Well No. 1 showed a rise of only 2.5 inches.[1]

1 Wells Nos 2, 3 and 6 also showed rises, but the land around was irrigated in the interval so these are not quoted.







Plates 4, 5 and 6.

It will be seen that the water levels in Nos. 5 and 7 for this period (July 15) were respectively over one and two feet lower than in Well No. 4, while the rise in each was over twice as great (July 26). This additional rise was probably caused by the irrigation of a soja bean crop which was about twenty rods directly east of Well No. 7 and on higher ground so that the drainage from that area probably affected the water level in both Nos. 7 and 5, which were in the direct line of drainage. Besides, Well No. 7 was in a cultivated area, while Nos. 4 and 5 were in an alfalfa field, the alfalfa growing much ranker around Well No. 4 so that the percentage of soil moisture in its vicinity was probably much less than in that of either of the others. However, the mean rise by July 26 of the level in the three showing the water level to be nearer the surface July 15, was over one foot two inches as against 2.5 inches in the wall where the water level was from one foot five inches to three feet seven inches lower than in the others.

While the amount of precipitation is not great[1]—being 8.03 inches—yet the winter stormy spells have a distinct effect upon the movement of the water table especially shown on the graphs as upward bulges from the line or ideal curve which would represent the gradual unimpeded lowering of the free water in the soil due to its removal by natural drainage alone. In the graphs of all of the wells for the period from the latter part of February to late in Marh of1912, such upward bulges occur, and these can not well be attributed to other causes. The graphs of Wells Nos. 4 and 5 for 1911 also show this upward bulge through January, February, March and part of April; and this is true of practically all of the wells for this period. The wells Nos. 2, 3, 4 and 5, where the water was nearer the surface, show the greater tendency in this respect. The same condition would probably have been shown more distinctly in the spring of 1913 had sickness not prevented the taking of measurements.

Evaporation: In a reverse manner the unimpeded evaporation from the surface would help to lower the level of the water table faster than the natural drainage alone would do it. The degree to which it would help would of course depend upon the state of the surface soil, the amount of vegetation present,

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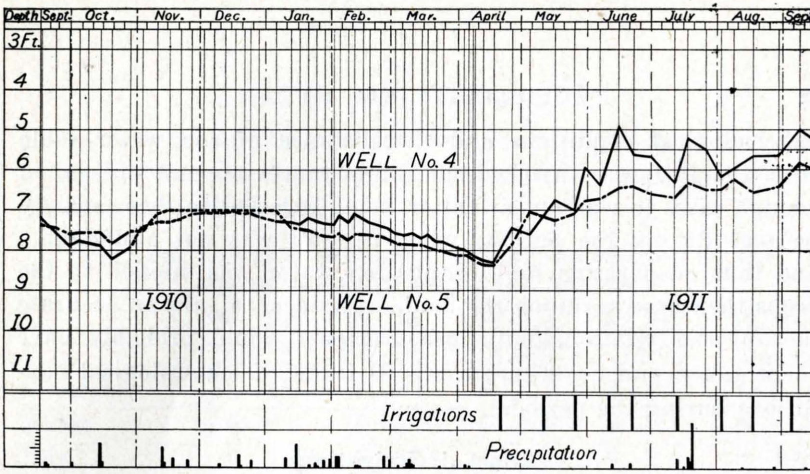
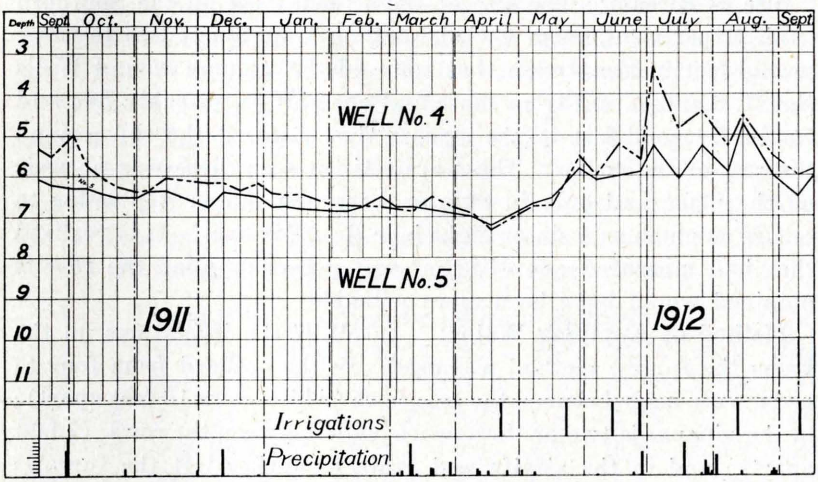
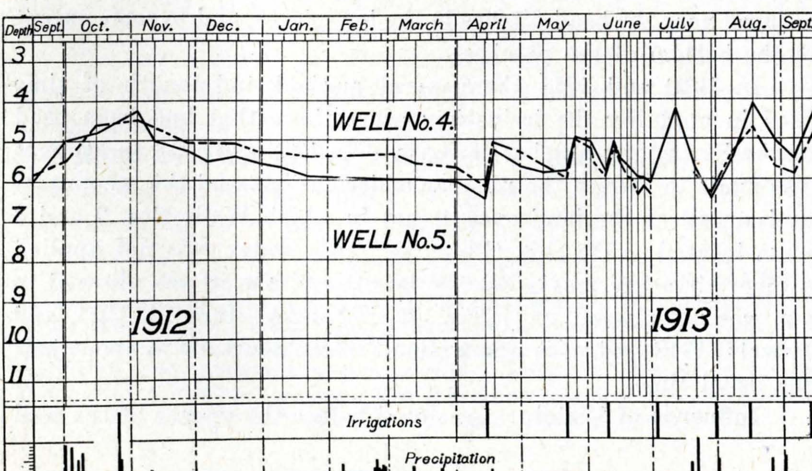
1 The precipitation occurs mainly in two periods—the three winter months and through July and August.







Plates 7, 8 and 9.

meteriological conditions and the distance of the water table from the surface. Marked specific instances are not present in enough cases to warrant attention being directed to them, mainly because during the periods when rainfall was not abundant—and thus evaporation high—irrigation water was applied to the crops then growing upon the land. Besides, to gain an accurate idea of this relation, daily measurements would probably have to be taken and an accurate record made of meterological conditions during the period.

Effect of Irrigations.

Size of Stream: The size of the stream used on the Southern Utah Experiment Farm varied, ranging from about two to three second-feet in the stream that watered the ground around Wells Nos. 1, 6 and 7, and from three and one-half to probably five and one-half second-feet in the stream that watered the soil around the rest of the wells. These are estimates as there was no weir on the place and only in two or three places was it possible to secure as much as a six or eight inch drop for one. It is realized that had measured quantities of water been applied the results obtained would have been more valuable.

Method of Applying Water: In all of the irrigations on the Farm the furrow method was used. In the orchard from four to seven were made between the tree rows (which were 16 feet apart); in the vineyards two or three were made between the rows (7 feet apart); and in the alfalfa and grain a marker left the furrows twenty to twenty-six inches apart. Some flooding nearly always occured near the head ditches in the low places, and to some extent at the bottom of the patches.

In 1910 and 1911 the general method and length of time used in applying the irrigations were those that had been used on the Farm for a number of years. In 1912 and 1913 an attempt was made to reduce the number of irrigations and the amount of each on all of the land except that in which Wells Nos. 2 and 3 were located. On this (Plat "B") the water was not applied oftener than necessary, but the length of time it was allowed to run was not altered, except in two instances—June 21, 1911, and July 17, 1912—when it was watered in six hours, or in about half the usual time.

Influence of Water: As noted before the graphs of the well measurements show that as soon as the fall irrigations ceased, the water level began to lower and continued to do so until the time of the first spring irrigation.[1]

TABLE No. I—MEAN SEASONAL VARIATION SHOWN BY 254 MEASUREMENTS FROM ALL WELLS.

	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
	1910-11	1911-12	1912-13	1913-14	Mean
November	8 3.6	7 0.1	6 5.1	8 3.7	7 6.1
March	9 2.5	8 0.4	7 3.4	8 10.7	8 4.2
July	6 7.0	6 3.5	6 9.5	7 2.6	6 8.6

This is brought out very clearly by a study of Table No. 1 which shows the mean monthly depth of the water table for four years to have been at 7 feet 6.1 inches for the month of November, or at the end of the summer and fall irrigation season. From then until March it sank to a mean depth of 8 feet 4.2 inches, revealing a mean lowering of 10.1 inches. This does not represent, however, the lowest points reached by the water table as Table No. II illustrates. This represents the measurements taken just before the spring irrigation, when the level was lowest.

TABLE No. II—LOWEST LEVELS RECORDED.

			No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	Mean
Date		Year	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
Apr.	17	1911	11 6.0	9 11.	8 2.2	8 3.5	8 4.	11 3.7		9 7.1
Apr.	17	1912	10 5.6	8 6.3	7 4.	7 4.	7 2.7	10 6.	9 7.0	8 8.5
Apr.	14	1913	8 9.0	7 6.0	6 3.	6 2.3	6 6.	9 1.7	8 4.0	7 6.3
Mar.	2	1914	11 0.7	10 5.0	8 2.7	6 7.5	8 7.5	10 4.5	8 11.	9 2.1

The mean lowest level reached in the spring through four years is thus 8 feet, 10 inches, or nearly six inches below the lowest mean monthly level.

Effect of First Spring Irrigation: Immediately after the first spring irrigation—usually given after the middle of April —a rise in the water table is nearly always noted, as will be seen

1 This was usually given between April 15 and April 25, and while it may seem early, yet it is about a month later than is common in the neighborhood. We should also remember in connection with this, the bright, warm winter enjoyed by this locality and that four inches of rain is all of the moisture the soil received after the fall irrigation, in late October or November, to supply the loss by evaporation and the amount used by the plant before active growth begins in early March.

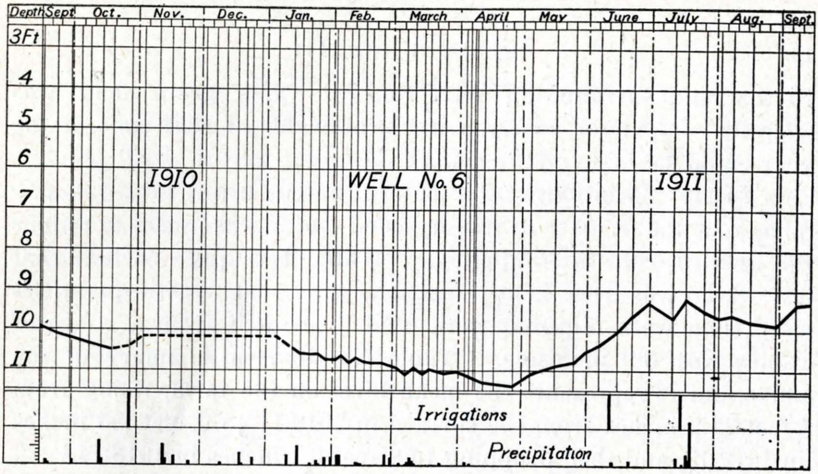
by consulting all of the graphs. The amount of the rise is not constant for the wells in any season nor does any one well show an approximately uniform annual variation from the effects of the first irrigation. As shown by Table No. I the rise continues with variations so that by July the mean rise has been 1 foot 5.6 inches.

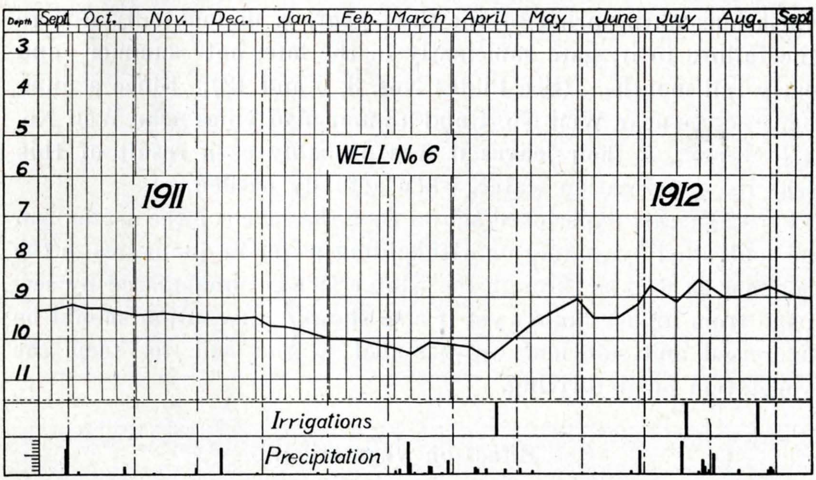
In some instances the sudden variation is extreme, notably in Wells Nos. 2 and 3 for the three years they are mapped. (See Plates 3, 4, and 5). The greatest single variation occurs in Well No. 2 in 1911. (See Plate No. 4). Between the seventeenth and the twenty-sixth of April of that year the water level rose from 9 feet 11 inches to 5 feet 3.5 inches, a total rise of 4 feet 7.5 inches from a single irrigation—a rise that undoubtedly proved a serious injury to the fall sown grain crop whose roots had been constantly growing downward during the winter as the water level receded.

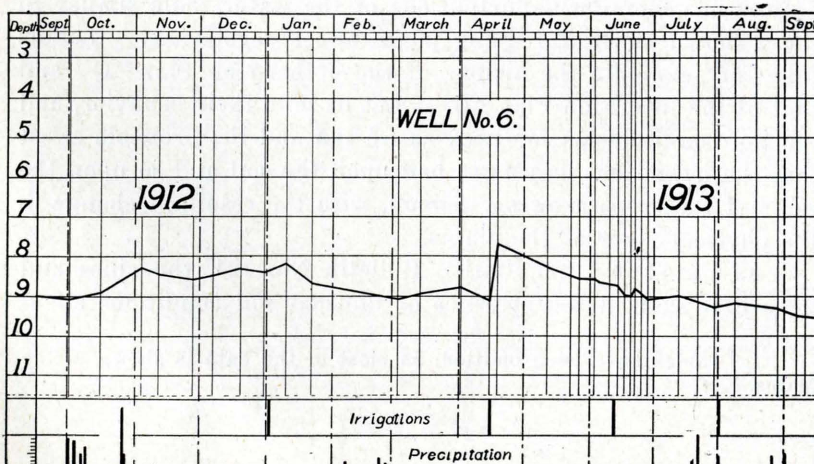
From this extreme condition we go nearly to the opposite in a few instances where the level was but slightly, or not at all, affected. (See Plate No. 4, June 11; Plate No. 5, July 17; also Plate No. 12, June and August). This indicates that the irrigations preceding were either about right or scant in quantity. At any rate the amount of water that passed into the country drainage was very small.

In a few instances the water table shows a slight rise, before the first spring irrigation on the ground immediately around the well. (See Plate No. 5, April; Plate No. 6, March; Plate No. 10, April, May and June; Plate No. 13, April). In these instances it will be seen that the variations occur always after the first irrigation on the farm, and are probably caused by the seepage from the lands either above or below. It may be well to state here that excessive quantities of water applied on land near either 1, 2 or 3 will affect the level in the others; likewise Nos. 1 or 6; Nos. 6 and 4, and Nos. 7, 5 and 4.

Influence of Irrigations on Remote Areas: One other peculiarity we find in the graphs of Wells Nos. 4, 5, 6 and 7 for November, 1911. (See Plates Nos. 8, 11 and 13). Well No. 7 shows a rise of over a foot six inches, and lesser rises are shown by those farther removed—Nos. 4, 5 and 6 respectively. This was probably caused by a neighbor irrigating his grain field that lay next to the farm on the north and northeast, and thus adjacent







Plates 10, 11 and 12.

to the land surrounding Well No. 7. This grain field was literally soaked for nearly a week, as water at that time of the year could be had for the asking.

Yearly Variations: As before stated, after 1911 the frequency of the irrigations was lessened and it was aimed to reduce the quantity of water applied. While it is quite certain that less water was used each irrigation, yet, that vast quantities more than were required were used in evident from a study of Tables Nos. 3-9 inclusive. Table No. 10 is a summary of the above and it represents the mean level on the farm, rising from 7 feet 11.2 inches from the surface in 1910-11 to 6 feet 9.5 inches in 1912-13, and then dropping to 8 feet 0.7 inches in 1913-14.[1]

This sudden lowering in the fall of 1913 and continuing with variations until spring of the next year, is undoubtedly due to the failure to irrigate sufficiently in the late, hot summer and early fall months. (See Plates Nos. 3, 6 and 12). Since a number of trees near Well No. 1 and a number of vines near Well No. 6 lost most of their leaves it was probably as a result of this scarcity of irrigation water, when actually needed.

While this experience shows that the level of the water can be controlled by adding or withholding water in quantities in the summer as well as through the winter (when unhampered by seepage from higher lands) yet it also shows that caution should be exercised and sufficient water added to the soil to keep the vegetation on it thriving.

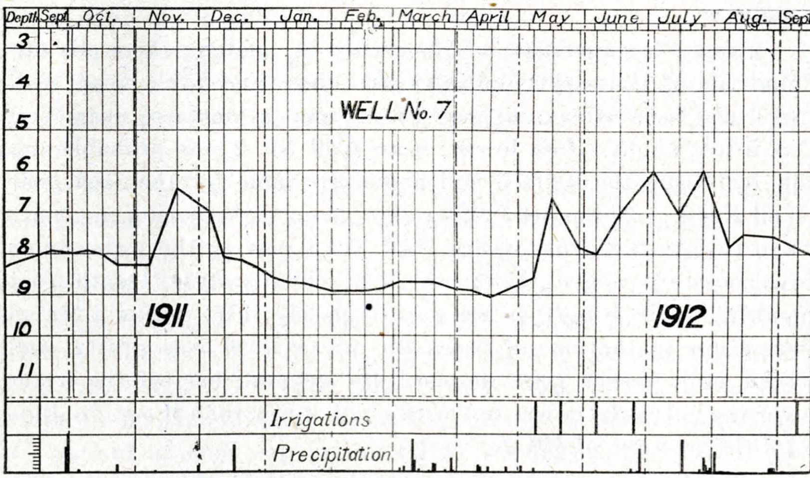
Effect on Vegetation.

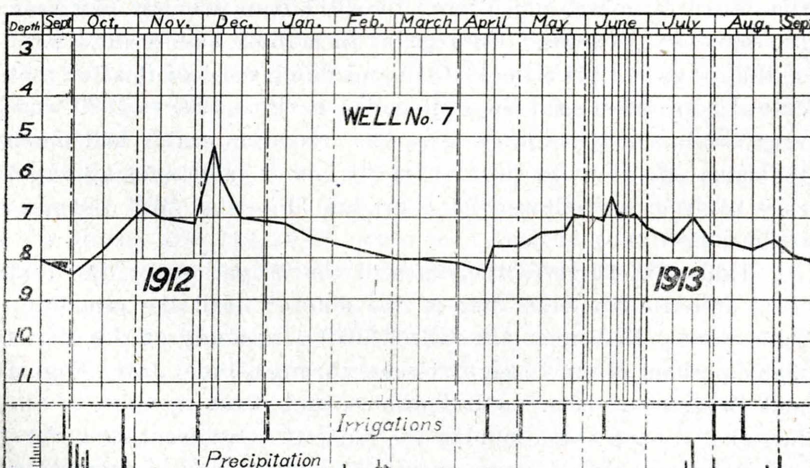
How in general will fluctuations of the water table similar to those shown in the foregoing pages affect vegetation? Let us take for example the history of the orchard on Plat "C" and that of the lucern on Plat "B". Let us note their behavior, and the soil conditions as far back as we can and the probable effect that the irrigations may have had upon the soil and so upon the roots of the crops growing thereon, with the resultant change in the physical vigor of the plants.

As stated in Utah Station Bulletin No. 124, the vines and trees first showed the presence of unusual soil conditions about

1. Tables have been omitted, as most of the data is shown in the Plates.

1905. In Bulletin No. 121 of this station, page 246, it says that during June of that year a soil survey was made of the Southern Utah Experiment Farm and that samples were taken of every other depth of 10 feet. The field notes by J. C. Thomas shows, that on the eastern portion of the Plat "C" orchard the soil from the seventh to the ninth foot was "very moist," and that the tenth foot was "very wet." Also that the soil of the south central part of the orchard was "very wet" at the seventh foot,





Plates 13 and 14.

and below this was so soft and muddy that the hole would be partly filled up after withdrawing the auger. This was near the place where five years later Well No. 4 was bored. The same notes give the condition of the soil where later Well No. 5 was bored as similar to the above except it was a foot lower down.

Of the condition of the soil near where Well No. 2 was later bored they say "Sixth foot soft and sticky"; "seventh foot and below soft and muddy." Where Well No. 3 was bored they say, "sixth and seventh wet; eighth, ninth and tenth feet wet and muddy."

From the experience of the writer in cleaning the wells out hundreds of times this indicates that the water table near Well No. 4 was between six and seven feet from the surface; near Well No. 5 was about a foot lower; near Well No. 2 was probably not six feet from the surface and about the same for the area near Well No. 3. The notes further show that in the boring not more than twenty feet from where Well No. 1 now is, the water table was possibly above the tenth foot, for it says, "tenth foot muddy." These borings were made nearly three weeks after an irrigation so that in all cases the water level was pretty well down, and, if such were the case, the general level of the water over the entire farm was not very much lower than it was in June of 1910, or June of 1911.

As was stated in the beginning the method of irrigating over the entire farm was not altered for 1911 from what it had been for the years previous. The regular farm hand having done most of the irrigating previous to 1910 and doing most of it after that date it is probable that the soil conditions from 1905 to 1910 were very similar to those later, i. e., the irrigation water had much the same effect on the position of the water table causing rapid rises of it to be followed by a gradual lowering until the next irrigation.

Table No. 11 gives the dates of the irrigations on the Plat "C" orchard from the time it was planted until the remaining trees were pulled up in the fall of 1910. A study of this shows many periods of six to eight weeks, through June, July, August and September, between irrigations; and these in spite of the fact that during these months the hottest, driest weather occurs, and, consequently, the rate of soil evaporation and leaf transpiration is greatest. During such periods the soil moisture would probably be exhausted in that portion near the surface and this would result in the development of a deeper rooted system of feeders. This would be true up to the season of 1905 when more water was applied to the soil and probably the water table was raised to some extent. In 1906, 1907, 1908 and 1909, these periods without irrigation water were lengthened, especially in the latter part of the summer; while in the forepart of the season, especially in 1908, the irrigations were frequent.

While it is true that the rainfall was considerable in some of the months this usually falls in the summer in very short heavy showers, and during such the run-off is very great, especially since the soil was cultivated but once after each irrigation, and an almost impervious crust was formed by the first passing shower.

Whether these conditions favored the development of deep root systems or not the matter presented in the bulletin preceding this shows that the trees in the central portion of the Plat "C" orchard sent their roots deep into the soil and that many of these, for some reason, died; so that when the soil around the surface feeders became very dry, the trees became dependent upon the roots which reached deeper, and if these were limited in number or were near free alkaline water they would be unable to supply the amount of good sap demanded by the leaves, and the latter must of necessity wholly or in part wither up and drop off, and eventually the tree would die.

An interesting condition of the orchard in question, in support of the above, was noted during the summer of 1910. In mapping Plat "C" it was considered desirable to note the condition of each tree in the dying orchard. This showed that out of 945 trees originally planted, 371 had been removed prior to the growing season of 1910, while 165 had died during the summer and 166 were dieing, and but 25.7% were in a healthy condition. The above represents the status of the orchard, August 22 to 25.

During the month following several good showers fell, the total precipitation for the month being 1.4 inches. This moistened the soil from four to six inches down and caused many of the trees to start a new growth, sometimes from the ends of the twigs and sometimes from the larger branches near the base. By October 10 the change in the appearance and condition of the trees seemed to warrant another investigation, and accordingly the entire orchard was gone over. Each tree was examined and its relative change was noted with the following results.

Of the 243 trees classed as healthy, August 22-25, 65 were losing their old leaves in quantities (about a month too soon), 12 had fully lost them and had started a new growth, while 4 had only partly lost them (three of them were in bloom), but had also started a new growth. This left but 162 trees of the original number of trees classed as healthy, while 5 that were formerly classed as sick had recovered, thus bringing the total to 167 healthy trees.

Of those previously classed as sick, 64 had lost nearly all of their old leaves, and had started a new growth. Of this number 9 were now dead, but it should be remembered that the former was surrounded on three sides by dead peach trees and that the latter was in an area that had long since gone bad, the ground being covered with a dark alkaline incrustation. That is, the apricots just north had been dead for two or more years, and even one of the Winter Bartlett Pear trees, 32 feet west of the one dug up, had died at least a year before.

This was also borne out by the condition of the surface soil of the area surrounding the Jonathan apple that was dug up and also in the case of the grape vine.

Suggested Remedies.

Since the presence of more or less alkaline water near the surface of soil and—periodically at least—within the space normally occupied by the feeding roots of average plants, is injurious or fatal to them, to produce crops it becomes necessary to do one of three things, i. e., to grow shallow rooted crops or those not affected by the prevailing conditions; or the area must be drained to such depths that the desired crop requires for the development of its root system; or if the situation is realized soon enough measures can be adopted to prevent the filling of the great subterranean reservoir of aerated soil.

On soils where the free water is near the surface and drainage is not feasible, if there is not too great a quantity of alkaline salts present, shallow rooted crops such as corn, onions, sugar beets, beans, etc., may be grown by guarding against too liberal applications of water.

On soils already seeped and where no other remedy will apply a complete system of open, box or tile drains should be put in if the increased value of the land will warrant it.

On areas of land situated like the Southern Utah Experiment Farm, where during the winter the free water sinks to six or eight feet below the surface and where the rise is due to the surface applications alone, an extended system of drains would be absurd; in fact, it is questionable whether they would help at all unless placed very deeply in the soil. The problem here seems to be one to be solved by applying water quickly and frequently and by increasing the organic content of the soil, thus reducing the amount of water that will be required, as well as the frequency of its appearance.

The prevention of these seepage conditions then resolves itself into the old one of an economical use of the available water, so long advocated by the Utah Station. On the land under discussion the longest run for the water was slightly over three hundred feet, or less than twenty rods. It was found that a great saving in time was effected by cutting this run in two and the ground was sufficiently moistened for all purposes. The same general practice can be followed on all porous soils concentrating the stream as much as possible without much washing the land. On clays and loams the runs can be longer and if difficulty is experienced in soaking the ground sufficiently, it may be advisable to spread the stream out more, or to barely cover it and immediately turn the water off and within a few hours to repeat the process.

Finally there will always exist the necessity for the irrigator to know just how far down his water has penetrated, and to ascertain this a soil auger would probably be the best tool available. It should be used frequently and persistently until the irrigator knows just how long a time is required to moisten the soil properly.

SUMMARY.

In the soils under discussion the level of the free water varied.

1. It lowered through the action of the natural drainage, the surface evaporation and the growing vegetation.

2. The normal precipitation caused it to rise—the amount depending upon the distance of the free water from the surface

and the quantity of rain falling; small amounts showing no appreciable influence under the method used in taking the measurements.

3. Long continued irrigations caused the level to rise.

a. This rise was greatest where the free water was nearest the surface.

b. The amount of rise apparently depended upon the length of time the stream was allowed to run on the land. (This is based on the two applications made in half the usual time).

4. The fluctuation of the water level caused by heavy applications of water followed by long dry periods was disastrous to crops.

a. It caused the death of large numbers of trees and vines; the first of the former which died were those where the water was confined to two or four narrow furrows (two for the first few years, then four) made close to the trees. The ones that were alive to the last were on those parts flooded by the regular irrigations.

b. It lessened the lucern fields production to less than one-fifth of its former normal yield.

c. Crops of oats grown after the lucern at no time produced more than half crops.

5. The application of less water more rapidly applied is indicated as the logical remedy for this seeped condition. On other soils and under different conditions drainage might be advisable or necessary. At any rate the effect of irrigation on land with a given stream for a definite period of time should be known by all users of irrigating water. This action of the water can be determined only by using on each tract of land a soil auger or some similar implement,—the borings to be made before, during, after, and a day after the irrigations.

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