COLORADO EXPERIMENT STATION

COLORADO AGRICULTURAL COLLEGE

Report on

DRAINAGE BY PUMPING ON TWO COLORADO FARMS in 1930

By
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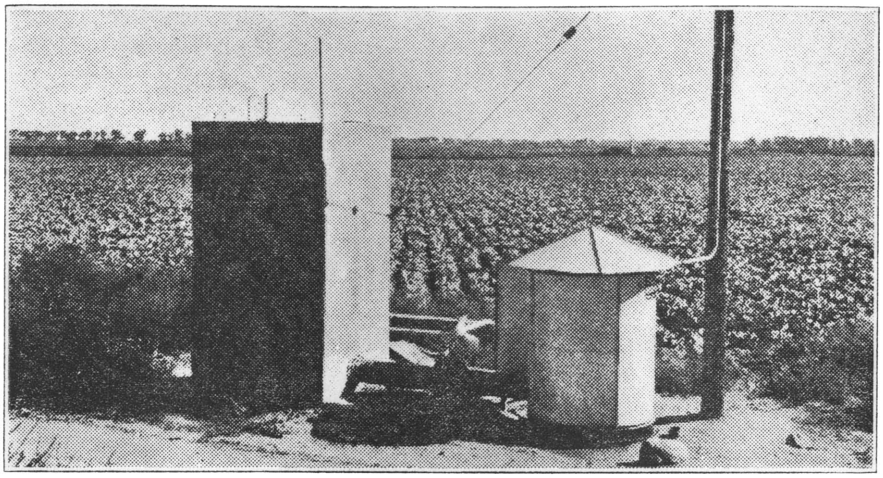
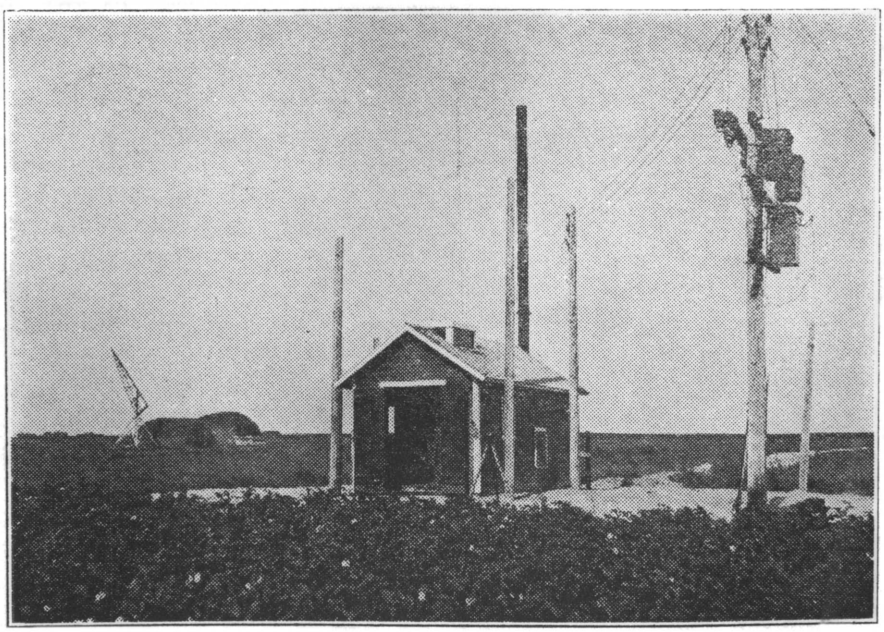


W. R. Clark drainage plant—Cabbage in background is on drained land.



Harry W. Farr drainage plant—The potatoes in foreground are in the previously wet area.

DRAINAGE BY PUMPING ON TWO COLORADO FARMS

By

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The drainage of land by means of pumping ground water from wells, although a relatively new application of the idea, has been attended by great success in widely separated places. The first attempt on an extensive scale was in the Salt River Valley of Arizona in 1918. The favorable results in the first year's operation led to the adoption of the plan in the San Joaquin Valley of California, where nearly 200 drainage wells are now being operated. The number in the Salt River Valley has grown to over 100 plants. There were six drainage plants being operated in the Pioneer Irrigation District of Idaho in 1929, and 36 in the Hudspeth District of Western Texas in 1928. All of these projects have been attended with marked success.

The effect on the ground water level by pumping from wells for irrigation is generally known. Because of the fact that the water table has been lowered 20 to 50 feet in many instances, and in a few cases as much as 100 feet, it logically followed that drainage problems would be solved in the same manner. If this drainage water can be used also for irrigation, there is every reason to believe that pumping will prove an economical success in areas to which it is adapted.

The feasibility of pumping for drainage lies entirely in the character of the soils thru which the well casing must penetrate. Success is assured if the well passes thru continuous gravel strata or gravel and clay, where the clay occurs in non-continuous masses. Should the materials all be dense, then water can not enter the well at a rate rapid enough to make its removal efficient or adequate. The requirements for a drainage well are essentially the same as for any irrigation well. It should have a good yield with a minimum drawdown and loose sands and gravels are necessary. However, a condition that might defeat a drainage project and yet provide a good irrigation well, is one in which a continuous sheet of impervious material, such as clay, overlies good gravel. Such a sheet would allow the soil above it to remain saturated or unaffected by the removal of the water below. The free water near the surface must have easy communication with the water that enters the well.

While a well is being pumped, the water level inside the casing is lowered and water enters thru the perforations by reason of the difference in elevation between the inside and outside levels. The surface of the depressed water table approximates that of an inverted cone with a very large base and whose apex is in the well. The distance from the well at which this depression is measurable is dependent upon the character of the soil, the drawdown, discharge, and time of pumping. This depression takes place quickly after the pump is started, and the water movement is practically vertical during that time. As the point of equilibrium is reached, i.e. the inflow balancing the outflow, the movement toward the well tends to become horizontal. The final result is that the general ground water movement is hastened on the upstream side of the well, and retarded in diminished quantity on the downstream side.

Because of the large circle of influence, a drainage well will be more effective than drainage by means of tile. The tile drain can not function until the water reaches above it and its draw-down is limited by the depth of its submergence and the character of the soil. Its effect, laterally, is then limited to a few hundred feet in easily drained soil, while the effect from a good well may extend a quarter mile or more. The plan is more elastic on a large-scale project than gravity drains because it is a simple matter to increase the capacity of the pumps in a given area lacking complete drainage, or increase the number of pumps. There is no valuable land taken up by unsightly excavations, no division of farms, and the water becomes immediately available for use in irrigation.

In the irrigated sections of northern Colorado, seeped areas are becoming more common and in many cases are not found in depressions. Many such spots have good surface drainage but the soil being so dense, water moves thru it at a very slow rate. The water-holding capacity of some of these dense soils has been exceeded, due to irrigation, causing seep spots to appear. Many wet places are underlaid at comparatively shallow depths by shale or sandstone, and wells would be ineffectual under such conditions. The problem of drainage is to remove enough water from the soils to establish a water table at a depth which will permit healthy plant growth and prevent an accumulation of alkali salts in the surface layer. This problem occurred on the two adjacent farms of Mr. W. R. Clark and Mr. Harry Farr, northeast of Eaton.

The general ground water level on these two farms was probably lower during the 1930 irrigation season than in 1929, but from a record obtained several times a year on other wells in this immediate area, it is thought that the difference would not exceed one foot. River water was short in the early part of 1930 irrigation season and more plentiful in 1929, and for this reason some difference might be expected. In addition to this, during the early part of the season more pumping was being done than at any time in the past. Wells in the heavy pumping section were lowered several feet beyond the 1929 low point, but no such area is near the farms under study. The nearest well, a new one, put into operation the latter part of June, is about a mile north of the Clark well. The nearest wells otherwise are two miles distant.

THE CLARK FARM

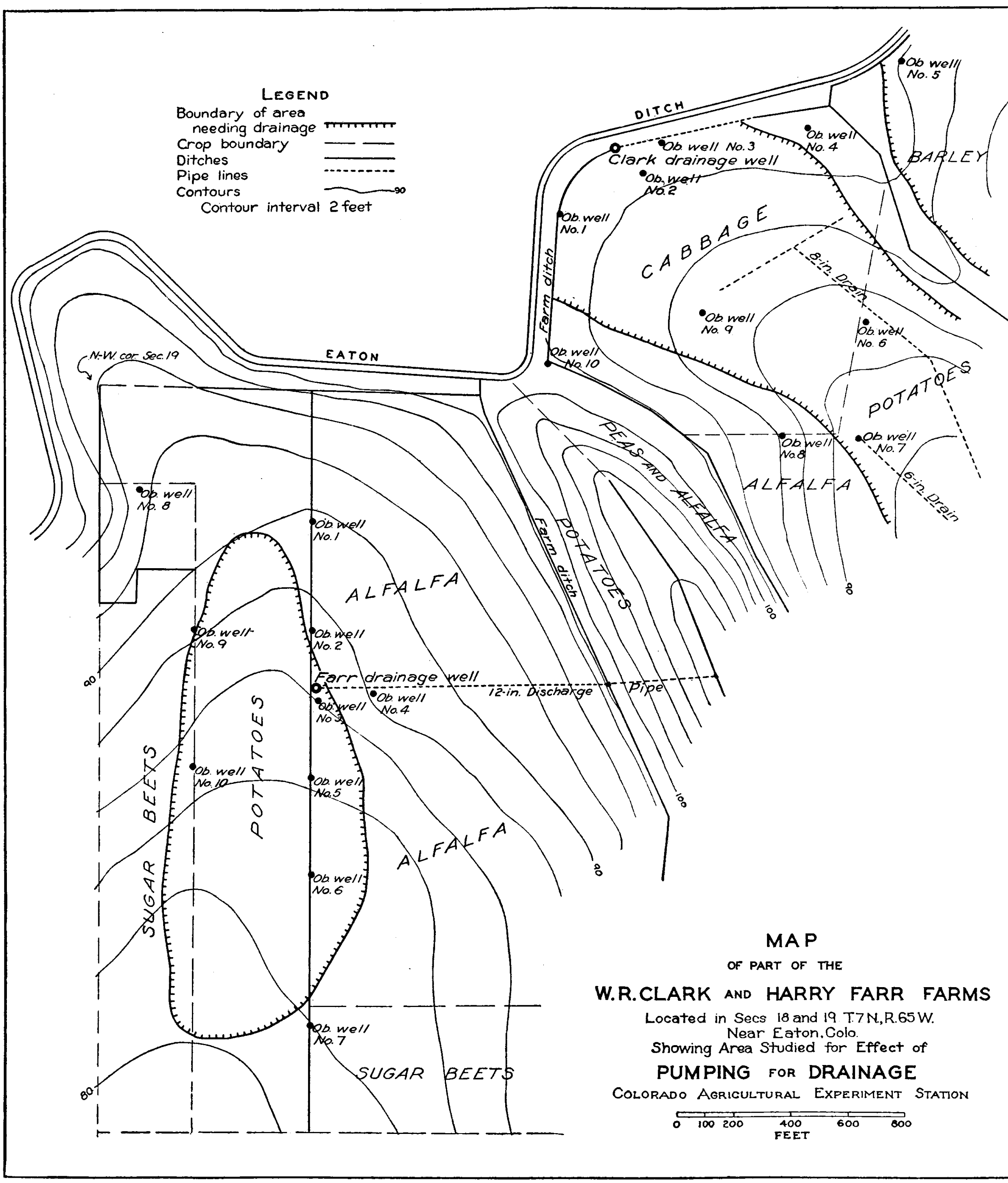
Referring to the map it will be noted that an attempt was made to drain this land by means of tiling. The west 6-inch line is short and extends only to observation well No. 7. The east line is 8 inches and has an east and west lateral at the end. These lines were laid in 1920 and 1928 respectively, and for the most part are in the fine sand which lies from 5 to 7 feet below the surface. That much of this fine sand enters the tile is evidenced by the several depressions over the line and accumulations at the outlet. Measurements of the total flow from this drainage system were made at several times in September, 1929, and thruout the 1930 season at a point about 1,000 feet below observation well No. 7. The rates of flow are shown in the table below. During periods when the crop was being irrigated, the flow increased, but the owner claims that the flow in 1930 was noticeably less than in 1929. It is assumed that this reduction in flow was due to the pumping in 1930.

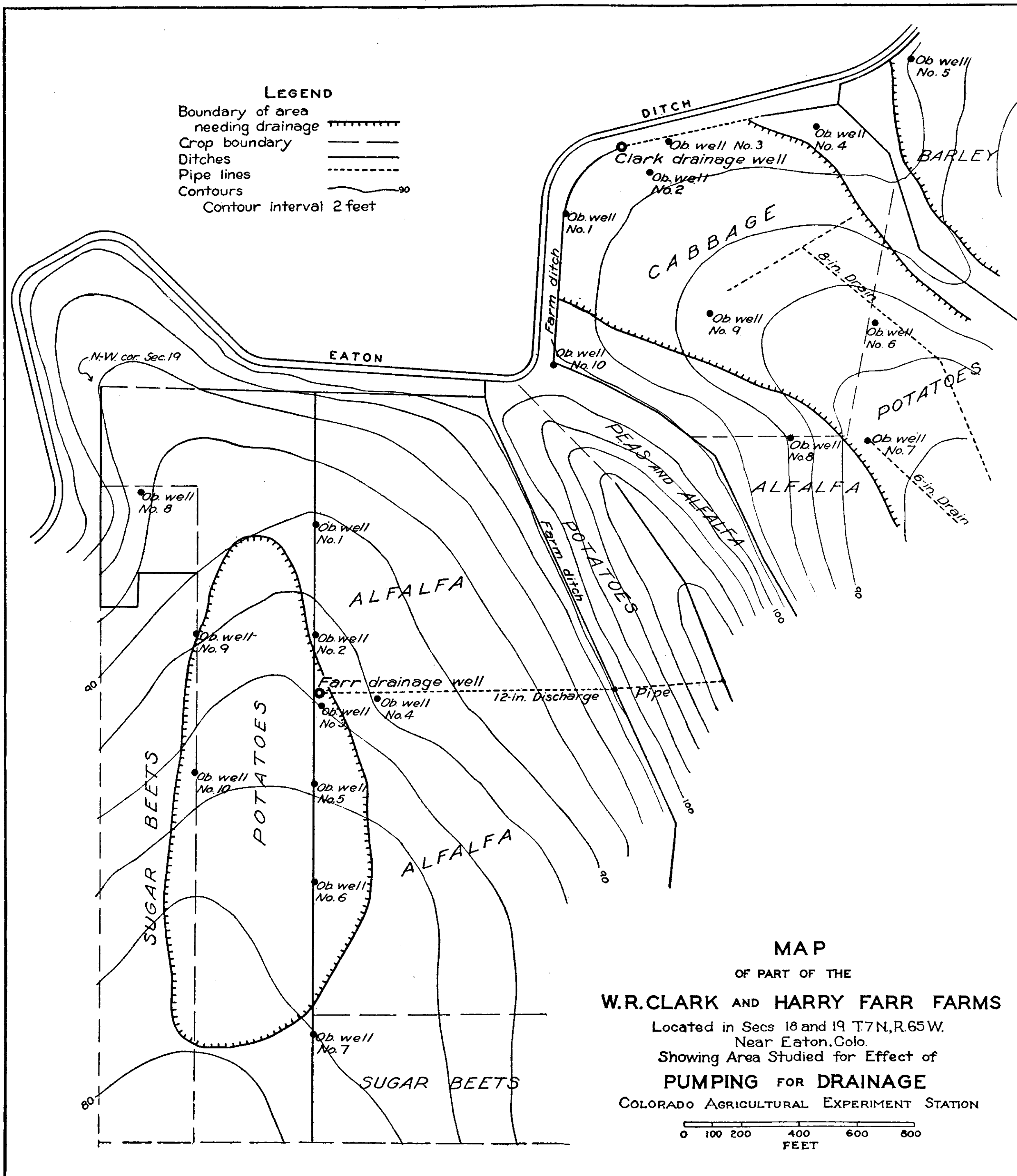
Outflow from Clark Drain

Date			g.p.m.	Date			g.p.m.
1929	Sept.	1	15	1930	May	25	5
		2	14			30	6
		3	15		June	2	6
		13	17			10	5
1930	April	12	6			15	5
		19	4			22	4
		22	4			23	4
		29	5		July	5	4
		30	5			7	2
	May	1	5			13	4
		3	4			26	6
		7	6		Aug.	4	6
		12	5		Sept.	16	5
		15	5			22	5
		19	6			30	5
		22	6		Oct.	15	6
						23	5

In the late summer of 1928 and also 1929, the lower part of the area under study became so water-logged that light farm machinery could not be hauled over it, causing the loss of a potato crop on 15 acres in 1928, and 10 acres of millet in 1929. At times of rains, the water level rose to the ground surface and stood free in the furrows. The land below observation well No. 5 also became very wet at these times, and in 1928 the corn crop on 6 acres was lost.

Because of the experience in 1928 and its probable recurrence, the Experiment Station was asked for an opinion as to the possibility of removing the excess water by pumping. Since no borings beyond six feet had ever been made, it was decided to drill two test holes in order to obtain information on the underground strata. These wells were completed in June, 1929,


LEGEND
Boundary of area needing drainage
Crop boundary
Ditches
Pipe lines
Contours
Contour interval 2 feet
EATON
DITCH
Farm ditch
Clark drainage well
Farr drainage well
12-in. Discharge Pipe
8-in. Drain
6-in. Drain
N-W. cor. Sec. 19
Ob. well No. 1
Ob. well No. 2
Ob. well No. 3
Ob. well No. 4
Ob. well No. 5
Ob. well No. 6
Ob. well No. 7
Ob. well No. 8
Ob. well No. 9
Ob. well No. 10
CABBAGE
BARLEY
POTATOES
PEAS AND ALFALFA
ALFALFA
SUGAR BEETS
MAP
OF PART OF THE
W. R. CLARK AND HARRY FARR FARMS
Located in Secs 18 and 19 T. 7 N., R. 65 W.
Near Eaton, Colo.
Showing Area Studied for Effect of
PUMPING FOR DRAINAGE
COLORADO AGRICULTURAL EXPERIMENT STATION
0 100 200 400 600 800
FEET



MAP
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one being observation well No. 5, and the other at the site selected for the permanent well. The first one, 86 feet deep, showed practically all fine sand and layers of clay, while the other penetrated much fine gravel in its depth of 60 feet. It appeared that a well could be obtained here and because of the dissimilarity of the two wells, the clay formation, not far below the surface, was discontinuous and would allow the water above the clay to be acted upon by pumping. A 48-inch casing with 1/8-inch by 1¼-inch perforations, was sunk to a depth of 35 feet where it was reduced to 40 inches and carried to a total depth of 60 feet. During the digging operations, 4½ cubic-yards of 1/4-inch to 1-inch gravel were fed in around the top of the casing. This gravel went down a considerable distance and formed a partial envelope around the casing. Treatment with gravel increases the effective diameter of the well and prevents fine sand from packing against the perforations. Temporary pumping equipment was installed and operated a short time in the early part of September and data were obtained on the performance of the well for use in purchasing permanent equipment that would fit the conditions.

A few observation wells were hurriedly put down in August, 1929, with a hand auger at the sites of present observation wells Nos. 2, 3, 4 and 6. A short record was obtained in September, as shown in Fig. 1. In March of 1930, ten observation wells were put down with a hand auger to depths between 8 and 12 feet, and a record started of the depth to the water table. The location of these wells is shown on the accompanying map.

The log of the 48-inch well, given below, shows a layer of clay at 15 to 20 feet. While pumping, water could be observed coming thru the perforations in the casing at this level, indicating that the water above was shut off locally from that below, and is probably the reason why observation wells Nos. 2 and 3 were not lowered to a greater extent.

Log of W. R. Clark Well

Feet	Material
0- 6	Soil
6- 9	Sand
9-15	Clay and gravel
15-20	Clay
20-30	Clay and gravel
30-35	Cobblestones and clay
35-40	Fine sand
40-45	Fairly clean coarse gravel
45-47	Clay
47-66	Fairly clean gravel
66	Clay

Log of W. R. Clark East Test Well
Observation Well No. 5

Feet	Material
0- 9	Soil
9-18	Fine gravel and sand
18-86	Sandy loam, layers of clay some of which are quite hard

The permanent pump, a two-stage 16-inch Bean turbine, was installed and ready for operation April 22, 1930. It was operated daytimes only during April and May, but from July 1 to September 13, the end of the season, pumping was almost continuous. The normal depth to the water level in the well would have been between 6 and 10 feet during the season, but while pumping this was lowered to 43 to 48 feet from the surface. The average discharge was about 1,100 gallons per minute.

During the season, depths to the water table at the various observation wells were taken by a laborer assigned by Mr. Clark, except 15 sets of readings which were taken by the writer. About a month's record is missing, due to the tape breaking and the loss of the float. These depths reduced to an arbitrary datum assumed for the study, are plotted in Fig. 1. They show conclusively the effect of pumping, even at the most remote observation well, a distance of 1,330 feet. The peak in June is caused by the arrival of the heavy irrigation season and the irrigation of the crop on the area involved. Up to June 1 pumping was limited to about 12 hours a day, except between April 27 and May 10, when the average was about 17 hours. The depression in the water table caused by this is clearly seen. As the pumping slackened and irrigation increased, the water table rose, but about the 1st of June pumping became continuous and the water table fell. From June 21 to 27 there was no pumping, and there was a sharp rise in the water table, followed by a gradual recession, due to the continuous pumping in July. During August and part of September, an interesting part of the record is missing. August was marked by exceptionally heavy rains, the town of Eaton reporting 4.08 inches. Such a wet spell would cause a rise in the ground waters. By the 16th of September with the pump closed down for three days and operated intermittently for the preceding five days, the water rose to a height equal to that of the beginning of the season, possibly a little higher, but still short by about 3½ feet of where it probably would have been had there been no pumping. September 13th marked the end of the pumping season.

This project may be considered a success from the standpoint that 35 acres of land have been reclaimed and put in full production. A continuation of the previous condition would, no doubt, have resulted in a heavy concentration of salts in the top soil and a destruction of the tilth on at least half the

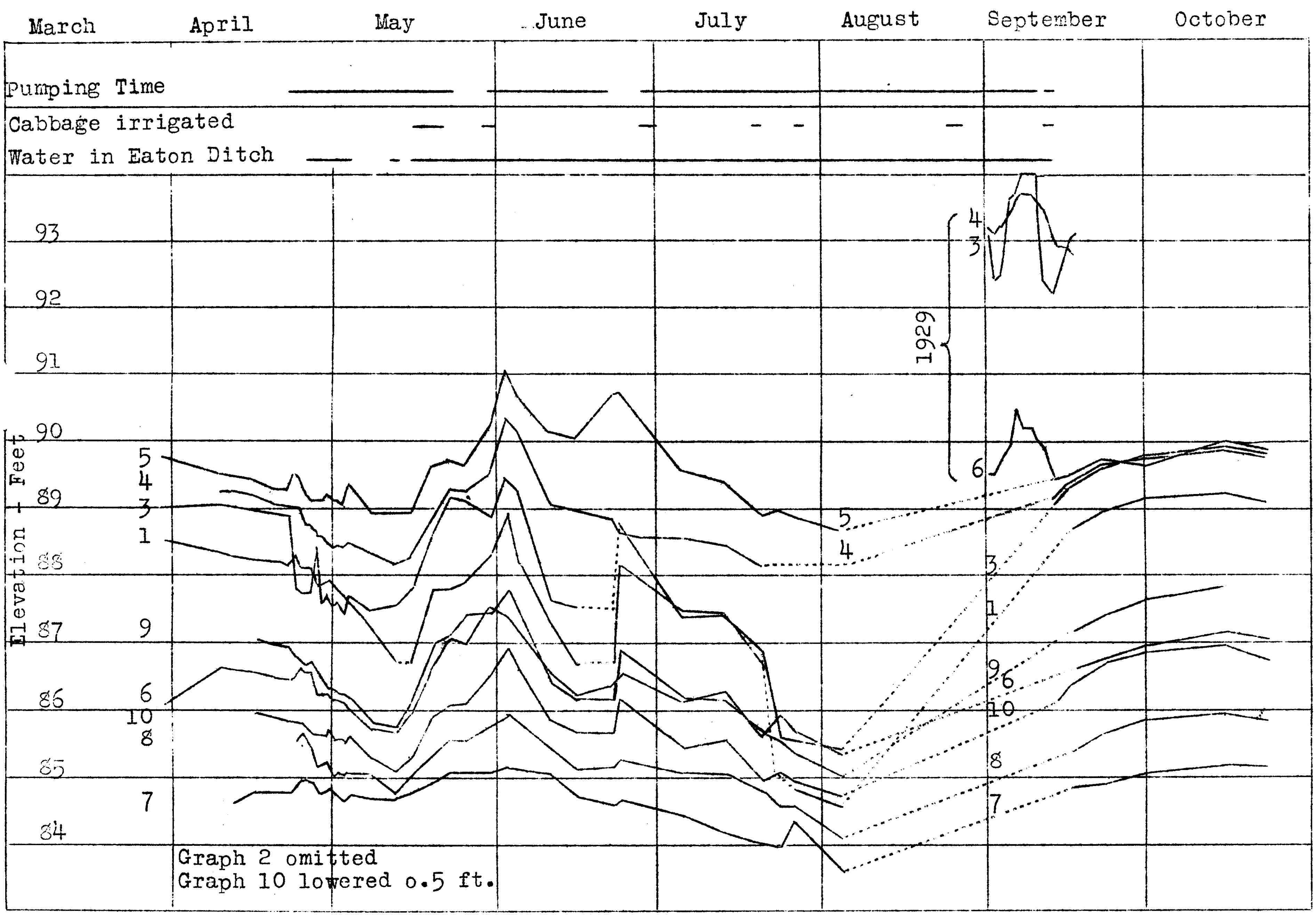

Fig. 1 - Water levels, Clark Farm, 1930

area. The balance would probably produce unprofitable yields and might have become saturated in the same way in time, since the condition was rapidly growing worse.

The water pumped this year was of great value from an irrigation standpoint since, in the early part of the year, there was a shortage which existed until the rains came in August. Reservoir water sold at the highest price in many years. Under such a condition of the reclamation of the land and the use of the pumped water, there can be no doubt as to the financial success of this enterprise. However, there may be years when water is plentiful and crop prices low, when this project might show an economic loss.

Costs

The total cost of the pumping plant was $2,480, not including the concrete header box and pipe line. The well cost complete $1,135, the pump and base installed $1,245, house $48, electrical equipment $52. The header box and 450 feet of 15-inch concrete pipe cost $568. During the season the plant was operated 107.5 days, and 43,840 kilowatts of power were used costing $1,016.80, or $0.0232 per kilowatt hour. A total of 490.5 acre-feet of water were pumped, divided as follows: April, 22.9; May, 68.6; June, 103.9; July, 146.0; August, 107.8; September, 41.3. The power cost per acre-foot was $2.07, and $0.0424 per acre-foot-foot. The capital cost per second-foot was $1,010.

THE FARR FARM

A few years subsequent to the seepage condition developing on the Clark farm, a similar one developed on the Farr place adjoining and separated by a ridge, as shown on the map. During the time when the Clark drainage well was under discussion, the writer was informed that Mr. Farr entertained the same plan for the reclamation of about 18 acres of low land that had become so wet in 1928 that alfalfa had been killed out and water showed on the surface in places. The seeped area had been continuously growing and threatened to involve a still larger area, and drainage by means of tile would have been expensive because of the great distance to an outlet. A conference with Mr. Farr as to the feasibility of the project resulted in his decision to put down test holes to determine whether or not a drainage well could be obtained and also its most advantageous location.

The test holes indicated the best location for the well to be at the northeast edge of the wet area. In the late summer of 1929, drilling operations were begun on a 24-inch well, but the drillers failed to get this well down and a second attempt also r resulted in failure. Another well driller was employed who sunk a 48-inch casing to a depth of 54 feet and completed the well the 1st of May. This well was started by sinking a 5-foot blank casing 25 feet long. The 48-inch casing perforated with 1/8" by 1 1/4" slots, was placed inside of this and the space between was kept full of gravel of the same character as was used on the Clark well. The space on the outside of the 5-foot casing was also kept full of gravel which settled down as material was removed from the 48-inch casing with an orange-peel bucket. In all, 5 cubic-yards of gravel were used in forming a partial envelope around the casing. The log of the well is given below.

Log of Harry Farr Well

Feet	Material	Feet	Material
0- 12	Soil	38½-39	Clay
12- 15	Fine sand	39- 49	Dirty coarse gravel
15- 24	Fairly clean sand and gravel	49- 50	Clay and cemented gravel
24- 27	Fine sand	50- 53	Fine sand
27- 38	Gravel	53- 54	Gravel
38- 38½	Cemented gravel	54	Hard sandy clay

A temporary pump was placed in the well May 3, 1930, and after several days' pumping a test was made to determine the well characteristics. From these data the permanent pump (a 12-inch 2-stage Worthington turbine), was ordered, which was installed July 3d. A steel discharge pipe line 12 inches in diameter and 1,000 feet long was laid to reach a ditch at a higher elevation, and was connected with an old line to the top of the ridge. The discharge at these two points was 710 and 785 gallons per minute respectively. More than one-half of the water pumped was delivered to the lower ditch and used on another farm nearby.

Ten observation wells were put down, as shown on the map, and twice weekly measurements to the water table were made by Mr. Romans, the tenant. These readings reduced to the same arbitrary datum as was used on the Clark farm, are plotted in Fig. 2. The April readings, as at Clark's show a gradual lowering of the water table, due to the draining out of the surplus water of the preceding irrigation season. When water was turned into the Eaton Ditch in April a slight rise occurred, followed by a depression in May which was, no doubt, caused by the small amount of pumping while the well was being tested. After the general irrigation season started, the ground water rose steadily until June 5. The cause of the gradual lowering during the remainder of June is difficult to understand unless the May rise, largely caused by the irrigation of the alfalfa land on the east side, was higher than a stage of equilibrium and the water was draining out.

On the evening of July 3, the pump was put into operation.

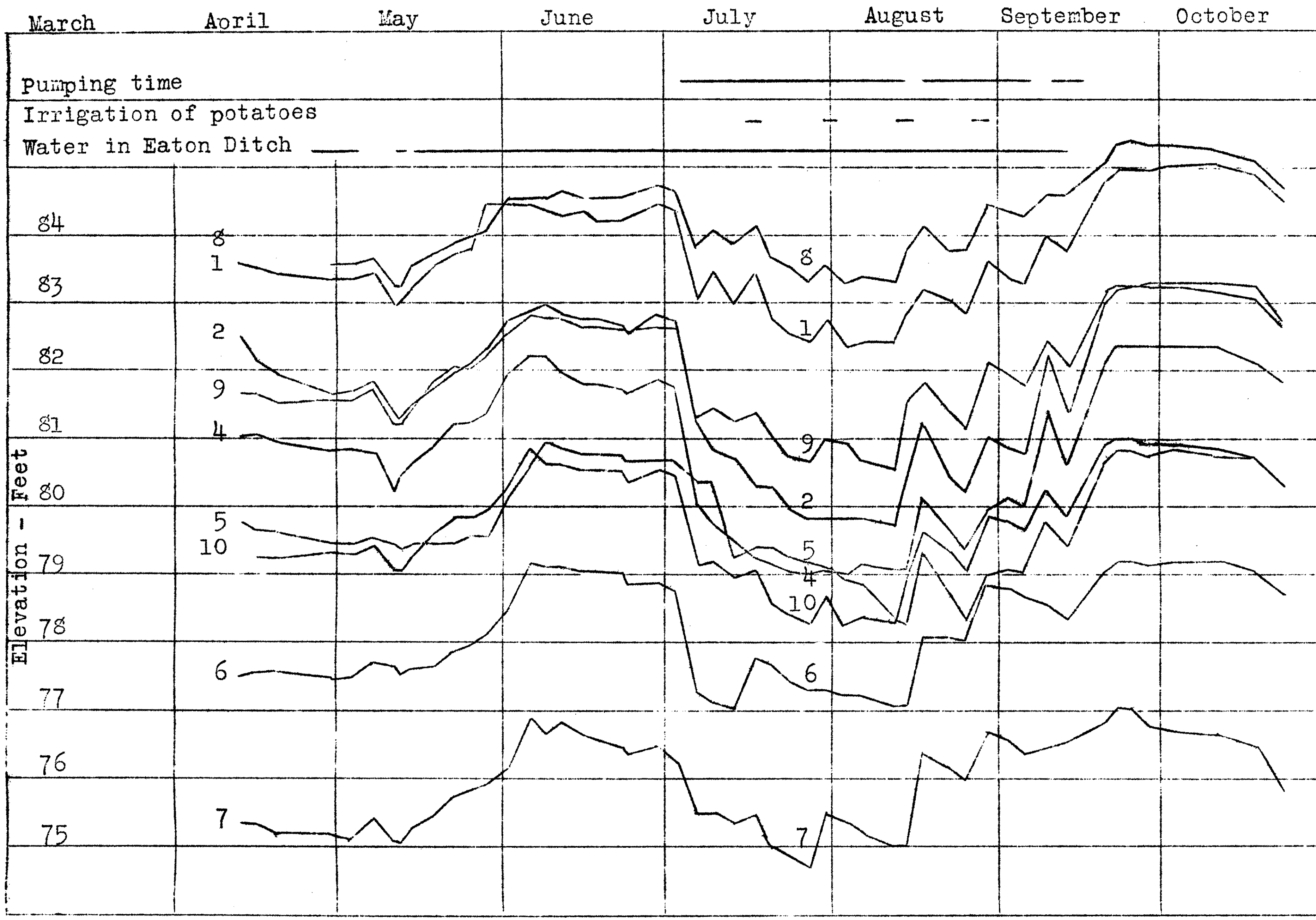

Fig. 2 - Water levels, Farr farm, 1930.

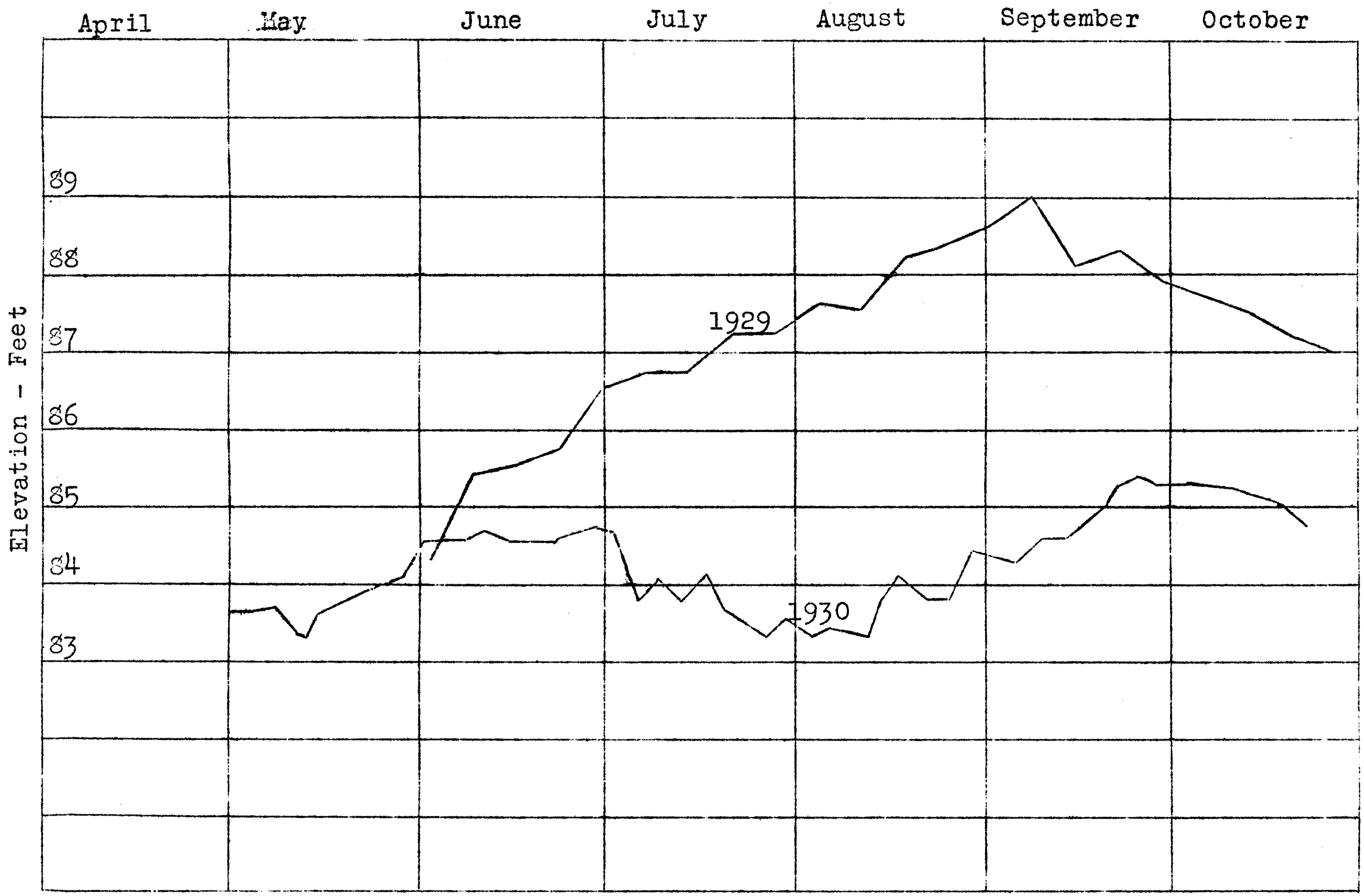

Fig. 3 - Water levels at Farr observation well No. 8 for 1929 and 1930.

The effect was immediately apparent, and with the exception of a few instances due to the irrigation of the crop, there was a continuous lowering of the water table until August 14 when the pump was shut down for three days during which time the potatoes were irrigated. There was a decline then until the third irrigation of potatoes which caused the peak, as shown near the end of the month. During the four day shut-down period in September, another small rise in the water table was noted. From September 11 to the end of the season September 16, altho pumping was not continuous, it caused the water table to recede again. When operations ceased for the season, the water table rose to an elevation slightly higher than the high point in June, but due to the water being turned out of the Eaton Ditch September 13, and the arrival of the end of the irrigation season generally, no further rise in the water table took place after the end of the month.

During 1929, Mr. Romans kept a record of the water level at the location of observation well No. 8, and a good idea was obtained as to the normal fluctuation of the water table. This record has been plotted in Fig. 3, with the 1930 record of the same well.

The evidence is quite conclusive that the pumping kept the water table down over a large area, and at the critical time it was about 4 feet below the surface in the lowest spot. A study of Fig. 3 would indicate that the ground waters in 1930 would not have been so high as in 1929. However, the abnormal rainfall in August would have, without doubt, caused an increased rise in the water table. It is quite probable that the pumping for only 2½ months lowered the water table about 4 feet over the entire area affected, and that this effect was evidenced a quarter mile from the pump.

Here again the water pumped was extremely valuable for irrigation purposes. About the time the pump was started, reservoir water was selling for about $9.00 per acre-foot. The pump reclaimed an area of about 18 acres of practically useless land which threatened to grow larger each year. The owner is much pleased with the result and considers it a sound economical investment.

Costs

The cost of the pumping plant complete, but without the pipe line, was $2,460, divided as follows: Well, $1,000; pump installed, $1,019; electrical equipment and wiring, $41.00; house, poles, cleaning up, etc., $400. The new pipe line installed cost about $1,500, and the balance of the line is worth about $350. The pump was operated 67.1 days during the season, 24,649 kilowatts of power being used costing $632.98, or $0.0257 per kilowatt hour. A total of 216 acre-feet of water were pumped, divided as follows: May, 5.8, July, 93.1; August, 92.1; September, 30.7. The power cost per acre-foot was $2.93, and

$0.0551 per acre-foot-foot. The capital cost per second-foot was about $1,410.

SUMMARY

The conditions for obtaining a well to be pumped for draining the water-logged areas on these two farms proved to be good, as indicated by the results. Drainage was effectively accomplished in both cases. On the Clark farm, the area benefitted is larger than is shown on the map, extending south and east. No great effect was expected on observation well No. 5, and it was planned that if the area around this well did not respond to the pumping a tile drain would be laid along the upper side of the field, using the drainage well as an outlet. This now seems entirely unnecessary. The pumping appears to have kept the water table down from $3\frac{1}{2}$ to $4\frac{1}{2}$ feet lower at the critical time in the affected area than during the preceding season. In each case, the most distant observation well was one-quarter mile from the drainage well and clearly showed the effect of the pumping. It appears from the results that pumping on these two farms need not be started until sometime in June to accomplish the desired results, and it is probable that the residual effect of the pumping will result in a lower water table the following spring.

These two drainage installations are equipped with the most modern and highly efficient type of pump, and the wells are of the largest diameter used for irrigation purposes. The capital cost is, therefore, high in each case, and probably the maximum. Other designs may be made to fit a different condition at less cost. In the case of the Clark farm, if the capital cost is assessed to the area reclaimed, the cost would be about $70 per acre, and for the Farr farm about $130 per acre. Compared with the usual tile drainage, this figure is high, but on the Clark farm $2,000 had been spent on tile drains that were ineffective. The cost on tile drains on the Farr farm would have equalled perhaps exceeded the cost of the well and pump because of the great distance to an outlet. On a large project the capital cost per acre would be much reduced. Either of these pumps should be able to drain 200 acres of land when operated continuously over the season, and by distributing the cost over such an area it would amount to but $12.00 an acre.

The cost of operation of a drainage pump would be very much greater than that of a tile drain, the latter being practically nil. The pumped water must be used for irrigation in order to make the system an economical one.

Pumping, where feasible, is the more effective means of providing drainage because of the higher rate of removal of water and its widespread effect.

If the free ground water is considered to occupy 15 percent of the soil volume on these two farms, then enough water was removed by the Clark pump to lower the water table 6.5 feet under an area of 50 acres. The Farr pump would have lowered the water table 2.9 feet under a similar area. Since water is constantly moving towards these depressions, the average lowering will be less and tends to become balanced.

PUBLISHED LITERATURE RELATING TO DRAINAGE BY PUMPING

Drainage by Means of Pumping in the Salt River Valley, Ariz. By J. C. Marr. Bul. 1456, U. S. D. A., 1926.

Reports of the Salt River Valley Water Users' Association, Phoenix, Arizona.

Pumping for Drainage in the San Joaquin Valley, Calif., By W.W. Weir, Bul. 382, Univ. of California Agr. Expt. Station, 1925.

Effect of Pumping from Deep Wells on the Ground-water Table, by W. W. Weir. Journal of Agricultural Research, Vol. 34, No. 7, 1927. (Reprinted, Univ. of California.)

A Study of Drainage by Pumping from Wells. By W.W.Weir. Agricultural Engineering, Vol. 11, No. 3, 1930.

Drainage of Water-logged Lands by Means of Sub-surface Pumping of Ground Water. By Raymond A. Hill, Hydraulic Engineering, Vol. 4, No. 7, 1928.

Drainage of Land Overlying Artesian Basins. By Willard Gardner, O. W. Israelsen, and W. W. McLaughlin. Soil Science, Vol. XXVI, No. 1, 1928.

A Study of the Cost, Effectiveness and Method of Pumping for Drainage and Supplemented Irrigation. By Hobart Beresford et al., University of Idaho, Agr. Expt. Station, 1930. (Mimeographed report).