

BULLETIN No. 43.

APRIL, 1897.

REPORT FROM BEEVILLE STATION

(NUMBER 1.)

- I. SOILS.
- II. CLIMATE.
- III. WATER SUPPLY.
- IV. IRRIGATION EQUIPMENT.

POSTOFFICE:

COLLEGE STATION, BRAZOS CO., TEXAS.

Reports from this Station are sent free to farmers of the State on application to
J. H. CONNELL, DIRECTOR, P. O. College Station, Texas.



AUSTIN:
BEN C. JONES & CO., PRINTERS.
1898

[927]

TEXAS AGRICULTURAL EXPERIMENT STATIONS.

OFFICERS.

GOVERNING BOARD.

(BOARD OF DIRECTORS A. & M. COLLEGE.)

HON. F. A. REICHARDT	Houston.
HON. W. R. CAVITT.....	Bryan.
HON. F. P. HOLLAND	Dallas.
HON. GEO. C. PENDLETON	Belton.
HON. CHAS. ROGAN	Brownwood.
HON. JEFF. JOHNSON.....	Austin.

STATION STAFF.

THE PRESIDENT OF THE COLLEGE.

J. H. CONNELL, M. SC.....	Director.
H. H. HARRINGTON, M. SC.....	Chemist.
M. FRANCIS, D. V. M.....	Veterinarian.
R. H. PRICE, B. S.....	Horticulturist.
B. C. PITTUCK, B. S. A.....	Agriculturist.
P. S. TILSON, M. S.....	Associate Chemist.
H. NESS, B. S.....	Assistant Horticulturist.
C. C. TODD, B. S.....	Assistant Chemist.
H. C. KYLE, B. S. A.....	Foreman of Farm.
J. G. HARRISON	Bookkeeper.

SUPERINTENDENT OF BEEVILLE STATION.

S. A. MCHENRY.....	Beeville, Bee Co.
--------------------	-------------------

NOTE.—*The main station is located on the grounds of the Agricultural and Mechanical College in Brazos County. The postoffice address is College Station, Texas.*

THE BEEVILLE EXPERIMENT STATION.

BY J. H. CONNELL AND S. A. MCHENRY.

The cultivation of field or garden crops in extreme South and Southwest Texas has been so uncertain under the prevailing methods of cultivation that only a small acreage has yet been put under the plow. The stock range business is the principal industry, and until a few years since no effort was made to produce the grains for domestic use and stock feeding or the vegetables and fruits required for the stockman's family. In the face of low prices, the cotton acreage has, however, steadily increased in the section referred to, because cheap labor is obtainable, and only a small amount of cultivation was found necessary. By thorough preparation of land, and the careful cultivation of ordinary field crops, many persons have grown large fields of corn and cultivated hay crops. The use of windmills for irrigating the home vegetables and flower gardens has encouraged the planting of trucking crops, and resulted in the shipment of large amounts of fruits and vegetables to more Northern markets during mid and late winter.

The State Legislature has for some years past made provision for the investigation of the agricultural possibilities of that large area of Texas lying near Bee county. A large part of the funds first appropriated has been expended in equipping the station with necessary buildings, fencing, tools, livestock, and miscellaneous equipment. But, from the first week of possession, the Station authorities have steadily pursued lines of agricultural experiment that have been suggested by the more progressive citizens of that section. Land was first broken in March, 1894. All of that now under cultivation was covered with a strong growth of chaparral, mixed with mesquite and prickly pear. The cost of clearing and sod-breaking this land amounted to \$2.50 per acre. The work was performed by Mexicans, working at the rate of 60 cents per day.

I. SOILS.

The Beeville section presents a gently rolling surface, and in some portions no trees or brush are found over miles of territory. Along the water courses the post oak, live oak and elm form the characteristic timber growth. The curly, or running, mesquite grass covers all of the open prairie and scrub timber lands, and to this excellent grass the stockmen of Southwest Texas owe their prosperity. The surface of the soil is a dark brown sandy loam, which lies over a whitish marl, carrying a large per cent of lime. This dark surface soil in some cases shades into a chocolate red, or turns to a sandy white on some of the hill sides. In the valleys, it is almost black, because of the large amount of decayed vegetable matter contained, and in such situations it is usually heavy and obstinate under the plow, and the surface soil is several feet

in depth, while on the slopes and tops of hills it varies from six inches to eighteen inches in depth. This soil has been analyzed by the Chemical Section of the Main Station, and its chemical constituents are given in the table found below.

Analysis of Soils.—Samples of Group No. 1 were taken from surface and subsoil of the land near to, and almost east of, windmill. The land is slightly sloping, and is considered typical of the vegetable-growing soils of Bee county. The first sample, which is marked "a," taken at this place, was from the top six inches of soil (strictly surface soil). The next sample, marked "b," was taken to include the soil lying between the 24 and 30-inch depth (strictly subsoil), and the third sample ("c") consisted of soil taken at a depth of 48 to 54 inches below the surface (deep subsoil). Study of this first group of samples will show that the sand gradually disappears as we examine the portions furthest from the surface (see first line), and that its place is largely taken by lime (see fifth line). The organic matter, consisting of partly decayed vegetation, is quite prominent in the surface soil, and probably affords an abundant supply of nitrogen for the use of field crops, but its availability can not be fully determined by laboratory test. From field trials conducted at Beeville, we conclude that the nitrogen present in this "organic matter" is rendered easily available by the application of a small amount of acid phosphate, which also adds sulphuric acid to the soil. Organic matter, phosphoric acid, potash and lime are the materials most esteemed in soils, and the table shown below gives some interesting data as to the presence of minute quantities only of phosphoric acid contained in samples of Group No. 1, representing the typical soil of that section. Generally speaking, soils are thought to be deficient in phosphoric acid if they contain less than 0.10 per cent, but it will be noted that in the samples taken from this spot, at different depths, the amount does not exceed 0.04 per cent. This soil is in a very fine state of division, and probably gives up its content of phosphoric acid more freely than do average soils of coarser texture when subjected to chemical test. If this view be taken, the lack of phosphoric acid in this sample becomes more marked. Field trials, planned to test the presence of active forms of plant food upon this soil, have shown clearly that such lands are deficient in phosphoric acid, and the indications given by such field trials show that "acid phosphate" is probably the best form in which this deficient plant food may be supplied.

Samples of Group No. 2 were taken from orchard land, and are representative of lands lying on the slope of hills. These samples were taken from the land just southeast of reservoir, on the west side of driveway, and a little east of centre of the peach orchard. The organic matter present in this soil at a depth of two feet indicates the presence of a large supply of nitrogen, and this is still in evidence at a depth of four feet. The lime formation does not come so near the surface at this place as upon the ground where samples of Group 1 were taken, but at a depth of four feet lime abounds. Phosphoric acid and potash are notably lacking in all of the samples of this particular soil, and in that of Group 3.

The samples of Group 3 were taken from a spot located across the draw or valley from the peach orchard, and upon the same side of driveway. This is a type of the field crop soil. Corn and cotton have been grown here for a short time. The organic matter in this land slightly exceeds that found in the other sample examined, indicating an abund-

ant supply of nitrogen for years to come, when only field crops are to be produced. It is important that the full value of organic matter in our Western soils be appreciated. Dr. Hilgard, of the California Experiment Station, claims that one part of humus contained in such soils is worth as much as three parts of this matter when contained in the humid soils of the more Eastern States, because of its concentrated form. Phosphoric acid and potash, according to this analysis, are both present to an insufficient extent, and field trials made upon this particular section of the farm have indicated that acid phosphate, when applied at the rate of 200 or 400 pounds per acre, causes a profitable increase in yield of the corn crop; but the use of potash has failed to encourage the growth of crops on this land. The quantity of sulphuric acid present in all of these soils appears to be below the normal, and it seems probable that the sulphuric acid contained in the acid phosphate, which has been applied to this soil, supplied lacking sulphuric acid, as well as the deficient phosphoric acid.

TABLE I.

ANALYSIS OF BEEVILLE SOILS.

	Group Number 1.*			Group Number 2.*			Group Number 3.*		
	Sample a.	Sample b.	Sample c.	Sample a.	Sample b.	Sample c.	Sample a.	Sample b.	Sample c.
1. Silica and Sand .	87.92	67.9	19.82	89.06	80.2	18.99	89.74	62.88	29.21
2. Organic matter ..	4.36	4.79	1.63	3.70	4.38	2.36	4.87	5.12	3.42
3. Water	1.55	2.55	0.92	2.07	4.25	0.62	2.50	3.30	1.05
4. Oxides of Iron and Alumina.....	4.57	7.08	2.86	3.65	10.13	2.95	0.95	6.33	1.49
5. Lime	0.76	10.21	43.19	0.67	0.72	39.93	0.60	9.04	35.37
6. Magnesium Oxide	0.47	0.63	0.65	0.41	0.31	0.94	0.13	0.51	0.39
7. Sulphuric Acid ..	0.09	0.10	0.19	0.05	0.04	0.24	0.08	0.10	0.10
8. Potash.....	0.32	0.24	0.11	Trace	Trace	0.16	Trace	Trace	Trace
9. Sodium Oxide ...	0.13	0.16	0.25	0.75	0.37	0.21	0.86	0.69	0.62
10. Carbon Dioxide..	0.58	0.67	29.56	.....	.....	32.8	1.14	12.05	28.40
11. Phosphoric Acid.	0.04	0.03	0.04	0.01	0.13	0.04	0.06	0.04	0.01

*In each case Sample "a" is from the first 6 inches of surface soil, Sample "b" is the subsoil taken at a depth of 24-30 inches, Sample "c" is deep subsoil taken at a depth of 48-54 inches.

Analyses made by Profs. Tilson and Todd.

Organic Matter of Soils.—By far the larger portion of the lands of Texas are virgin soils, untouched by plow, and contain a large amount of valuable organic matter in the surface layer that tends to quickly decompose and pass away when once the land is brought under the plow. These conditions are especially true of the prairie lands that form our Gulf coast region. Strong winds combine with the hot summer sun and moist winter season to dry up, decompose and waste the vegetable matter that gives peculiar value to these light soils. Some of the soils of the coast region, while new, like the soil on the Station grounds near Beeville, contain so much of this partly decomposed vegetable matter that they are rendered

Special Notice.

Recently, the notice found below was attached to Bulletin No. 42 and sent to each of our subscribers. Several thousand replies have been received but many yet remain to be heard from. Not wishing to hastily remove names from our lists, we again invite our readers to apply for enrollment for reports upon those subjects in which they are interested. If YOU receive this notice it indicates we are without response to our former circular, and no more reports will be sent to YOU unless YOU instruct us to the contrary.

This plan of revision has been approved by all who understand it, and we expect that a wider distribution of publications will be possible than under the former system:

“The cost of publishing 12,000 or more copies of each bulletin issued by the Texas Station is so great, that economy causes us to *change our mailing system*. Hereafter each bulletin will not be sent to every name on the list, as formerly; but only to those persons directly interested in the line of investigation reported on. In this way we will send horticultural bulletins only to fruit growers and those wishing reports on vegetable culture; farmers will receive the results of investigations with field crops, etc.; stockmen will be sent reports on feeding, diseases, etc., relating to that industry.

Persons whose names are now on our mailing list must give notice at once by postal card as to which, *one or more*, of the following lists they wish their names to be entered in:

- List 1—General Farm Crops.
- “ 2—Fruits and Vegetables.
- “ 3—Stock Husbandry.

Address:

AGRICULTURAL EXPERIMENT STATION,
P. O. College Station, Texas.

N. B.—Please write name, postoffice address and county plainly.

sticky, and, when first broken, very closely resemble the black fertile lands of North Texas in their physical properties. They often require a "black-land plow" with which to turn successfully the land during the first few years of cultivation. After this, they appear to grow more sandy, and the plow scours to such an extent that the black-land steel-shape is dropped and the chilled style of plow comes into use. The soil has changed its composition by losing its organic matter and humus. It is not so dark colored as before, is not so warm natured in early spring, and will part with its moisture more quickly than when it contains from 15 to 18 per cent of humus.

Bee County forms a part of the geological section of Texas known as the "Fayette beds." In some instances, there are hurtful chemicals in these soils which aid in the destruction of organic matter and humus. These are noted by the authors of the Texas Geological Survey in their report upon the soils of the "Fayette beds" of the coast region.

Upon page 48 of that report the following interesting facts are suggested: "Sulphur and gypsum are often of very frequent occurrence (in the Fayette beds), the latter often being found as twin crystals in the shape of arrow heads. The beds also frequently contain carbonate of lime in the shape of nodules, or impregnating the strata. One of the most marked characteristics of the clay, and especially of the chocolate-colored beds, is a white, bleached appearance on the surface, while, a few inches in, they regain their dark color. This, and the presence of sulphur and gypsum, are intimately connected phenomena, and can be easily explained by the combined decomposition of the iron pyrites, carbonate of lime, and the vegetable coloring matter of the dark clays. The iron pyrites decompose with the formation of sulphate of iron and sulphuric acid; the sulphuric acid attacks the carbonate of lime, forming gypsum and carbonic acid; the former is deposited as crystals, and the latter goes off in the air and surface waters. The sulphate of iron attacks the organic matter in the clays, and is again reduced to iron pyrites with the evolution of sulphuretted hydrogen and oxygen. The oxygen forms carbonic acid with the vegetable matter, and rapidly goes off into the air. *This reaction repeats itself until the clays finally become devoid of all vegetable material, and hence of coloring matter, and exposes a white surface.* The sulphur, which originally formed a part of the sulphuretted hydrogen, but which has now lost its hydrogen, is deposited as a yellow or white crust on the surface and in the cracks of the strata."

Protective Measures.—Some practical suggestions, bearing upon how best to retain organic or vegetable matter in our light sandy surface soils will not be out of place. (1) To neutralize the effect of long exposure to hot summer sun, we can use broadcast-sown forage crops, and can occasionally grow crops for green manure that will shade the land for a large part of the heated season, and in this way not only protect the plant food already resident in the soil, but enrich the soil by the addition of other materials. To succeed in this, we can best use, probably, in order named, the velvet bean, the cow or field pea, crimson clover, and sweet sorghum or kaffir corn, sown broadcast. Preference should be given the beans and peas. (2) All of the vegetable matter than can be procured in the form of straw, leaves, and litter should be added to such soils, and, when practicable, green and growing crops should be lightly plowed in. (3) As far as possible, the land should be

kept under some crop, and should not lie fallow or be left exposed to weather without protection by shading leaves and the interlacing roots of some crop. *It is practicable to produce two or three crops annually upon these soils.*

No agricultural plant of our knowledge has the foliage-making powers possessed by the velvet bean (also known as the banana pea). As a shading, nitrogen gathering plant, it is probably better adapted to the Southwest than the cow pea or the soja bean. This Station sent small trial packages of velvet bean seed to nearly all portions of Texas, and many of those cooperating with the Station report that in the face of drouth and late planting this crop succeeded well, and finally made an abundant vine and leaf growth. In many cases, the vines are reported as twelve and fifteen feet in length. Only a few seeds were matured from the 1897 crop, but this failure was due to late planting. The probable value of this crop to the light soils of the State, if used as a fertilizing agent, can be better appreciated if we bear in mind the fact that our cultivated soils tend constantly to lose those materials of which this vine is largely composed—nitrogenous matter.

II. CLIMATE AND RAINFALL.

A valuable table is herewith presented, giving the meteorological data of the Beeville station, embracing the period from January, 1896, to August, 1897, inclusive. The table has been compiled with the help of Mr. A. M. Hildebrandt, from daily observations at Beeville, taken twice a day, 8 a. m. and 8 p. m.

The first two columns indicate the highest and lowest temperature recorded at any day of the month. The third and fourth columns indicate the daily mean, maximum and minimum during the entire month. The fifth column indicates the monthly mean temperature derived from the means of the daily maximum and minimum.

While we must depend for the data of water supply upon the monthly distribution of rainfall, yet they afford us no indication whatever as to whether the nature of the rainfall was such as to be of direct benefit to the crop. The amount of rainfall, however considerable, might have precipitated with such rapidity, or at such short intervals, as to render it impossible for the soil to absorb it, and thus prove of no benefit whatever to the crop, and sometimes even causing damage to it.

It has, therefore, been thought advisable to show, besides the total monthly precipitation, the relative distribution, as well as the greatest amount of precipitation in twenty-four hours. These are shown in columns 6, 7, and 8.

Column 6 shows the total monthly precipitation.

Column 7 shows the relative distribution through the month.

Column 8 shows the greatest amount of precipitation in 24 hours.

The ninth column indicates the number of days clear, fair, and cloudy. The letters, c., f., cl., denote clear, fair, and cloudy, respectively. The tenth column indicates the direction of wind.

The coldest temperature observed was during the unusually severe season of January, 1897; which injured, but did not destroy, the cabbage crop growing at that time on the Station grounds.

TABLE II.

RAINFALL AND TEMPERATURES AT BEEVILLE STATION, JANUARY, 1896, TO AUGUST, 1897.

Months.	Maximum.	Minimum.	D. mean max.	D. mean min.	Monthly mean temperature.	Total precipitation in inches.	No. rainy days.	Greatest precipitation in 24 hrs.	Cloudiness.	Direction of wind.	
1896 January ..	30	.....	48	.....	2.97	4	1.95	.....	.....	.....
February .	82	31	69	47	58	3.30	4	1.87	.....	N.	
March	89	37	73.8	50.5	62.1	1.27	2	0.87	.....	S. and SE	
April	93	34	80.6	58.8	69.7	1.62	4	0.90	c. 16, f. 10, cl. 4.	S.	
May	99	62	94	68	81	1.87	2	1.25	c. 23, f. 7, cl. 1.	S.	
June	102	65	99	72.5	85.7	0.67	1	0.67	.....	S.	Record of t° extends from 6-30th.
July	103.5	50	94	73.2	83.6	5.80	7	3.05	c. 24, f. 5, cl. 2.	S.	Record of t° extends from 1-7th and 12-31st.
August....	99.5	65	96.5	72.5	84.5	1.05	3	0.85	.....	S.	
September	99	54	91.9	69	80.4	5.64	9	2.07	c. 20, f. 8, cl. 2.	S.	
October...	89	52	75.5	61.6	68.5	3.72	6	0.92	c. 14, f. 11, cl. 6.	S. and NE.	
November .	88	30	74.2	54	64.1	0.30	4	0.12	c. 9, f. 19, cl. 3.	N. and NE.	
December .	81	26	68	44.6	56.3	0.92	2	0.60	c. 13, f. 12, cl. 6.	N.	[1-24th.
1897 January ..	76	19	60.3	44.6	52.4	1.27	3	0.77	c. 7, f. 12, cl. 11.	N.	Record of t° extends from 3-11th and 17-27th.
February .	87	35	70.5	52.6	61.5	0	0	0	c. 7, f. 12, cl. 9.	N. and NE.	Record of t° extends from 4th and 13-30th.
March	91	37	80.8	58.4	69.6	1.00	1	1.00	c. 3, f. 14, cl. 14.	N. and S.	
April	93	41	82.6	58.9	.....	0.57	2	0.35	c. 11, f. 17, cl. 2.	S.	
May	93.0	54.5	90.3	68	79.1	2.82	5	1.50	c. 11, f. 20, cl. 0.	S.	
June	100.5	63	89.1	72.6	80.8	5.37	4	3.12	c. 17, f. 10, cl. 3.	S.	
July	104	60.5	98.7	71.1	84.9	0.60	1	0.60	c. 20, f. 11, cl. 0.	S.	
August....	104	69	96	73.3	84.6	0.52	5	0.15	c. 8, f. 17, cl. 6.	S.	

Average Annual Precipitation in Texas from Data Contained in Special Bulletin No. 5,
Texas Section, Climate and Crop Service, U. S. Weather Bureau, Galveston, 1895.

CHART.

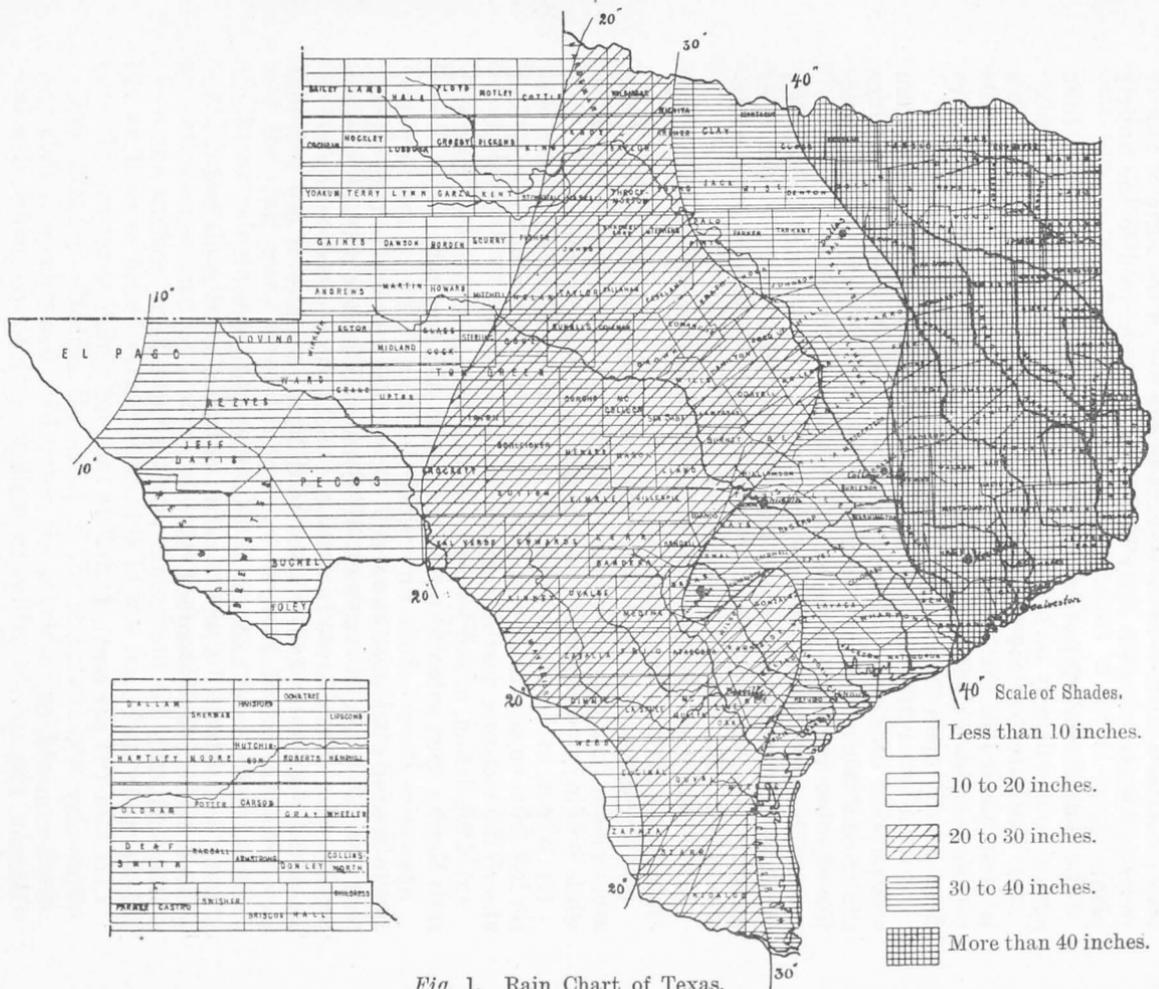


Fig. 1. Rain Chart of Texas.

III. AGRICULTURAL WATER SUPPLY.

Soil Water.—Water is nature's greatest vehicle. Competent engineers have estimated that 150,000 tons of dissolved rock are carried to the sea annually by the Mississippi River. Even in the system of the growing plant, we know that water serves to carry the dissolved food elements into every part of the plant, where the solid matter is used for growth and development, and the water evaporates from the "stoma" of the leaves. After a time, it again returns to the soil in the form of rain or irrigation water, to again carry its burden of plant food to the hungry plant.

The general conditions that control the evaporation of moisture from agricultural soils may be briefly mentioned under the following heads:

(a) The nature of the crop, and its ability to evaporate water. This is most marked in the cases of clovers, cereals, peas and beans, while cotton occupies a position lower upon the list, and, therefore, does not draw heavily upon the supply of moisture in the soil.

(b) The absorptive capacity of a soil depends upon its composition and physical condition, and is a measure of its evaporative limit, since the amount taken in will determine the "fly-off." Hence, the good practice of subsoiling, deep plowing, and thorough cultivation.

(c) The drying-out tendency of a soil increases with its porosity, which depends upon its coarse constituents. Heavy sands loose their moisture most rapidly, because the large circulation of air that continually occurs. (See table next page.)

(d) Atmospheric temperature (heat and cold) largely controls evaporation in a manner familiar to all.

(e) The altitude of land above sea level influences the rarity of the atmosphere, and may encourage evaporation in the higher altitudes, while tending to discourage it as the sea level is approached.

(f) Winds, or drying-air currents, may determine the amount of water lost from an acre in a given time, since they pass through the soil and absorb the moisture near the surface during each day.

(g) Percolation, or soil seepage, causes a loss upon irrigated land and soils having open subsoils during the season of heavy rain.

Absorptive Power.—Soils vary widely in their ability to absorb water, and to hold it when once absorbed. Those that are slow to take up water are usually slow to evaporate it. Some soils have a marked capacity for absorbing the moisture from the air. Schubler reports that air nearly saturated with water and exposed to different samples of dry soil, lost moisture to the extent shown below:

Coarse quartz sand took up no moisture, and graded 0.

Limy sand attracted a small amount of water, and was marked 3.

Good plowing land absorbed, 23.

Clay soils, 28.

Loam soils, 35.

Clay soils (80 per cent), 41.

Pure clay, 49.

Garden mould, 52.

Humus, 120.

The amount of humus and clay in our soils, therefore, exerts a very marked effect upon the ability of the crop to withstand drouth. This capacity of the soil is of much greater importance in all portions of the country than is commonly thought, but is of the highest value in those sections where sea breezes bring moist air nightly to the dry land and thirsting crop. The amount of water contained in such air can be better appreciated by noting the success with which the people living near the coast in the southern portion of Texas often catch their daily supply of water for domestic use from the moist atmosphere of the night upon metal roofs that serve as condensers in that climate. Those soils that are rich in humus, and that possess a fair per cent of clay, may, under some conditions, prove themselves independent of actual rainfall, because of their ability to drain moisture from the atmosphere, and in this way support plant life to a limited extent.

Retentive Power.—After testing the ability of soils to absorb large quantities of water directly, and then measure their capacity for retaining this water, Schubler reported that sand could, under such conditions, absorb 25 per cent of its own weight of water, and in four hours' time the sand evaporated 88 per cent of its water content under the same conditions prevailing, in which a lime sand lost by evaporation 75 per cent of its water. The lime sand was capable of absorbing 29 per cent of its weight of water, while garden mould absorbed 89 per cent, and humus 181 per cent of original weight of water. In all of these cases, the difference in evaporative capacity was equally marked between these soils, showing that humus (decayed vegetable matter) retained its moisture, while clays evaporated a large amount in the same length of time. The table here presented will allow a closer study of the results obtained by Schubler:

Character of soil.	Per cent absorbed.	Per cent evap. in four hours.
Quartz sand	25	88.4
Lime sand	29	75.9
Clay soil (60 per cent)	40	52
Loam	51	45.7
Heavy clay (80 per cent)	61	34.9
Garden mould	89	24.3
Humus	181	25.5

As before stated, the dryness of the air surrounding the soil very largely determines rapidity of evaporation, since the dryer the air, the greater the tendency to rob the soil of its moisture. From the foregoing, we may safely assume that soils rich in vegetable matter (humus) lying near the Gulf coast, accessible to moist breezes, have the evaporative conditions reduced to a minimum. We have not yet been able to thoroughly equip the Beeville Station with complete instruments for the accurate measurement of amount of water evaporated daily from a unit of ground surface, or of water surface, throughout the growing season, but we hope to install such instruments in the near future and determine this matter definitely for that section.

Deep Plowing.—Besides the effect of the composition of soils upon their ability to catch and hold water, the *physical* condition of agricultural soils, when plowed deep, shallow, or cultivated—largely influences their water receiving and retaining powers. Tramped pasture lands,

that are firm and hard upon the surface, turn off, or shed, a very large part of the rain that falls upon them, and dry out quickly; while, on the other hand, deep plowed lands soak up a larger part of the rainfall, and remain moist for a longer time during the season of drouth; not only because they contain a larger amount of water in each acre, but because the sun and air can not reach the lower portions of the water and quickly evaporate it. This has been termed "plow irrigation."

Careful experiments have shown that larger crop yields follow subsoiling throughout the semi-arid districts of the Southwest, and in many cases the increased yield is profitably produced. At Beeville, this method of plowing is being systematically investigated, and complete results will be given in due time; but enough has already been proven to justify us in endorsing the practice of deep plowing on both new and old lands in the extreme southern portion of the State; provided only that the work be done early in the fall season, and so present opportunity to catch and hold all available rains for the use of the coming crop.

Subsoiling has given excellent results in raising cotton at Beeville. The yield from a piece of uniform land was more than doubled for the season of 1897 by subsoiling the land to a depth of 12 inches; both plats of ground were given the same cultivation. The yield upon the subsoiled plot was at the rate of 700 pounds of seed cotton per acre, while the land ordinarily treated yielded only 335 pounds. It may be safely estimated that a single subsoiling treatment costs as much as an original breaking, but since the work need not be repeated annually, *the cost per annum* of such deep plowing amounts to but one-third of the cost of the breaking.

On the well watered soils of Collin county, Texas, we conducted subsoiling experiments in 1894, and in every case the yield of corn and cotton was decidedly increased where subsoiling was practiced. The report of these experiments with cotton states (see Bulletin 34, p. 553), "if we estimate the cost of subsoiling at \$2.50 per acre, the increased yield pays for the work done the first season and gives a profit of \$2.20 per acre."

For the past few years, a system of soil preparation known as the "Campbell system" has been favorably reported on by many investigators in the West. Some special tools are required for giving the treatment known as "subsoil packing," and where grain crops are to be cultivated, special seed drills and cultivators are required. The system provides that after a very deep break-plowing, another treatment is given with a subsoil "packer," which compacts the lower portion of the surface soil, and thus protects the *subsoil* from too free contact with the air. Like all other thorough methods of preparing land, this demands the use of more capital and a larger expenditure of labor than does ordinary extensive culture. This system will be thoroughly tried on the Station grounds at Beeville during the season of 1898, and a report of the results obtained will be published.

UNDERGROUND WATER SUPPLY.

The Beeville country is underlaid at a depth of 50 to 150 feet by a coarse water-bearing sand that supplies an abundant flow of good water in dug or bored wells at all times. This water rises to within thirty

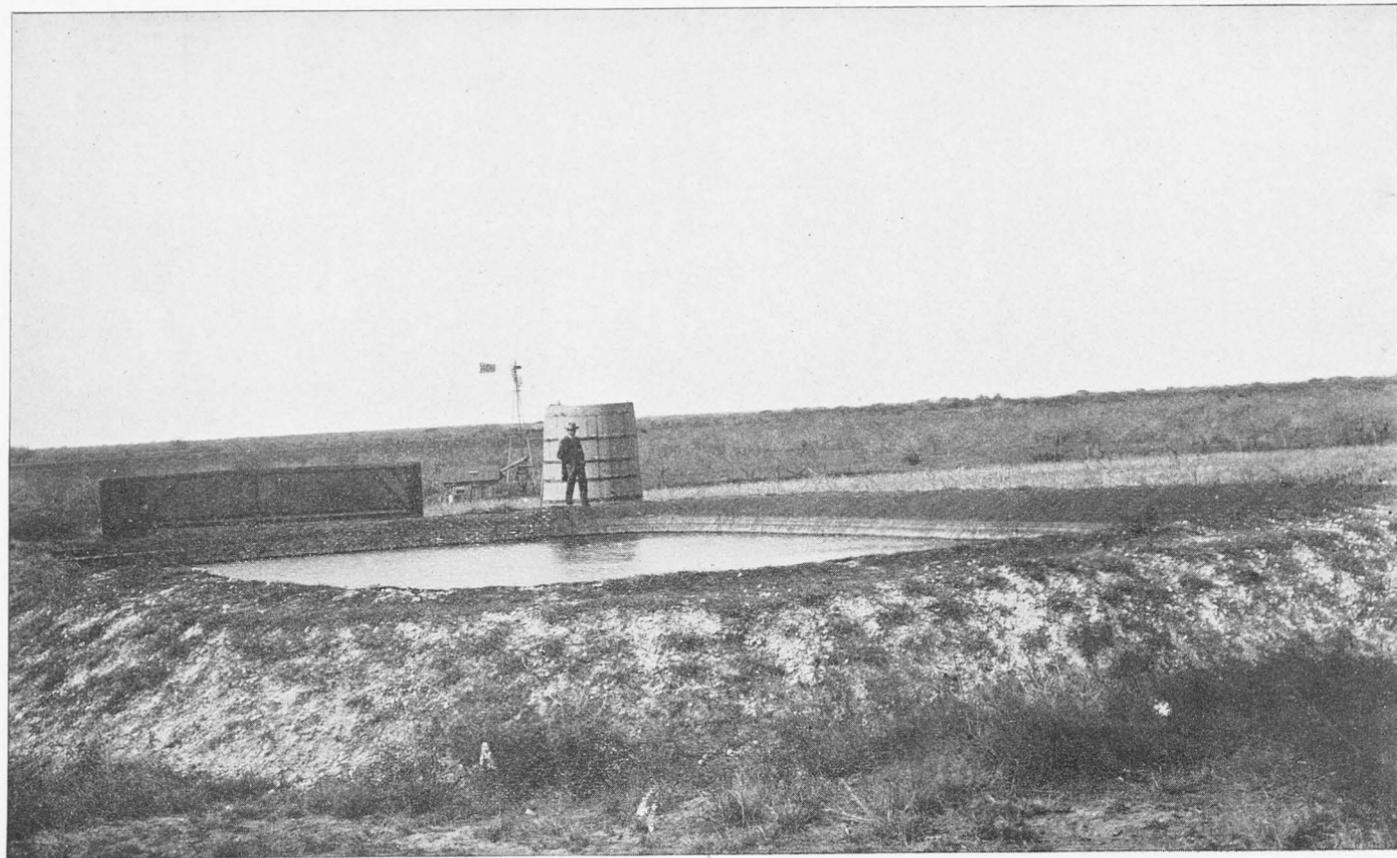


PLATE I.—VIEW OF BEEVILLE IRRIGATION RESERVOIR.

BLANK PAGE IN ORIGINAL

feet of the surface in some cases, and can be economically raised for irrigation purposes and is largely used for domestic consumption. Windmills are in general use, but thus far we have been unable to learn of the successful use of mills for irrigating crops of more than one or two acres in each case. When the nature of the soil near Beeville, the exceptionally mild climate of that section and the proximity of this water supply to the surface are considered, the advantages of far South Texas for the growth of vegetables and fruit may be fairly judged. In most cases, cypress cisterns only are used as reservoirs, and windmills supply these with a limited amount of water. That section of the State has but recently turned its attention to the production of fruits and vegetables, and but little capital has thus far been invested in the development and equipment of truck and fruit farms in Bee county. In some of the adjoining counties, particularly Nueces, the trucking and fruit interests have been fairly developed, although it must be borne in mind that not more than ten or fifteen years have elapsed since the first pioneer work in this line of diversified farming was attempted.

Sheet Water.—The three wells sunk at Beeville in 1894 by the waterworks company of that place have furnished interesting data concerning the amount and duration of the underground water supply in the Beeville section. During two and a half or three years these wells have filled up to the extent of some eight feet, and the flow is not thought to be as strong as when first bored. These wells were dug and bored by a Mr. Karsh. From Mr. Greathouse, who was in charge of the Beeville city water supply, the following data has been obtained: "The three wells are within ten feet of each other, and are 89, 90 and 267 feet deep. In each well a small supply of water was found at a depth of fifty feet. The main supply is reached at a depth of 89 to 91 feet, when coarse water-bearing sand is struck. As much as 100,000 gallons have been pumped from these wells in twenty-four hours. The pump is located in the bottom of a dry cistern at a depth of twenty feet below the surface of the ground. In boring the 267-foot well, no water was found below 90 feet. At about 200 feet below the surface a layer of dry sandstone rock was passed, having a thickness of two feet. No other rocks were found in this well. At a depth of 267 feet blue mud was reached and boring was stopped. Mr. Karsh, from other observations in that section, claimed that this stratum of mud was some 300 feet thick and contained no water-bearing sand. In a well bored at Skidmore, southeast of Beeville, a well was sunk to a depth of 1100 feet, and no water was found below the 90-foot level. This observation, combined with the tendency of the water to rise in the wells bored throughout this section, indicates that this sheet water might prove artesian water in places where wells are bored in strongly depressed surfaces of that section. Artesian wells are now flowing satisfactorily on the ranches lying a short distance to the south of Beeville, one of the most prominent of which is that upon the land of Mrs. Murphy.

The effect of long continued drouths upon the underground water supply has been marked—the decreased flow, resulting from severe drouth, probably reaches its lowest point during the months of September or October, according to observations made on the public wells in Beeville and the irrigation well in use on the Station farm near that place. The flow during April from this last well was



FIELD CROPS.

Fig. 2—Showing Plan of Beeville Station Grounds.

twenty-five gallons per minute, but in September the supply had fallen to thirteen gallons. It is our intention to sink in the near future one or more bored wells within a few feet of the first, to an equal depth, and then connect the new wells with the dug portion of the old, and thus collect the water from the wells at a common point to be raised by a single pump for irrigation use.

The well on the station grounds is dug to a depth of 57 feet, and a 4-inch hole bored from this point to a depth of 74 feet. The water usually stands 8 feet deep in the dug portion of the well, or a distance of 49 feet from the surface of the ground. While using a windmill for driving the pump, the water fell some 20 feet in this well, and when pumping with a gasoline engine we exhausted the water to a point as far down as was reached by the deep well cylinder, but on forty strokes per minute (in April, 1897), this pump, on a 15-inch stroke, was run to lift 1000 gallons of water per hour for twelve hours, and in removing these 12,000 gallons the water in the well was lowered, but not exhausted.

In September, 1897, a careful test was made of the available supply in this well. The pump was placed on a 24-inch stroke and was run at the rate of 44 strokes per minute. At this rate the well supplied 24 gallons per minute delivered at the reservoir (equal to 1440 gallons per hour), but this fast pumping partially exhausted the supply of water in the well, after which a flow of 13 gallons per minute was obtained. This, we concluded, was the normal force of the stream supplying the well after some months of drouth and very low average rainfall throughout the section to the north and west supposed to supply this sheet-water that flows at a depth of 75 to 90 feet below Bee county. During the preceding spring season the supply had been materially stronger.

On the farm of Mr. Ripple, one-half mile from the Station, a well of good water was made on a hill by going 80 feet deep. The water in this well rises within 55 feet of the surface and is of excellent quality and in good supply. Fully 100 such wells are in use at Beeville.

The value and purity of this water supply for irrigation purposes can not be doubted; extensive use has shown no harmful effect upon the land or crops that have been longest irrigated. Geological investigations point to the counties south of the counties of Bexar, Gaudalupe and Gonzales as the catchment-basin for the rainfall supplying this "sheet water."

Artesian Water.—This sheet water is "artesian" in character when we reach the lower lands bordering the San Antonio river, some twenty miles to the north. In Goliad and Refugio counties, three excellent artesian wells are reported upon the ranches of the O'Conner Bros., some five miles south of the San Antonio river; the first of these wells is 960 feet deep, and supplies 100,000 gallons of water daily. The second well is 850 feet deep, and supplies 200,000 gallons of water daily; while the third well is 1000 feet deep, and gives a flow of 500,000 gallons of good water. Two wells near Goliad, only 60 feet deep, supply 14,000 gallons of water per day. From the San Antonio river south, the surface of the country gradually rises until the watershed between the Nueces and San Antonio rivers is reached, near Beeville, causing an elevation at this point that is unfavorable to artesian water supply. A well has been sunk to a depth of 1000 feet in the town, with negative

results. Nearer the coast, at Corpus Christi in Nueces county, a well at a depth of 600 feet gave 80,000 gallons of salt and sulphur water per day, so heavily loaded with solid matter that it was thought unfit for use. Another well sunk at that place to a depth of 1765 feet produces oil and some other foreign matters that give it medicinal properties, but render it unfit for ordinary uses.*

Throughout the entire coast region of Texas artesian water is available, and as we go northward and approach Brazoria county the probabilities in favor of artesian water supply are increased. At Velasco, in Brazoria county, water is obtained at 1100 feet, and if we pass further north, near to the Alvin, Galveston and Houston section, the underground water supply grows more abundant and is more readily obtained. Wells sunk nearer than ten or fifteen miles of the Gulf Coast have often proved salty, or have been found to contain other objectionable minerals.

IV. IRRIGATION.

The profits and pleasures of irrigation farming are many and possess a vivid reality never realized by him who "regards the clouds" and fears to reap or sow. The irrigation farmer has conquered one of the gravest uncertainties of the agricultural situation, for with sunshine assured he may add a portion of soil, a portion of water, and another part consisting of skilled labor, and reap with certainty a bountiful harvest. Even in the eastern parts of the United States, where rainfall is less uncertain than in the West, the progressive farming element now appreciates the necessity for artificial water supply in order that the largest crops possible may be secured for the work expended and capital invested in the agricultural industries of that section.

For many years the lands in only the extreme eastern portion of Texas were thought fit for cultivation or for any purpose other than stock-raising. Gradually the cultivated line has traveled west and southwest. Twenty years ago it passed the Brazos on its march westward and southwestward, and is now steadily invading the "pear country." Large cultivated farms have sprung from out the brush and prickly pear, and now Wichita Falls, Brownwood, Pecos, San Angelo, and Corpus Christi are within the "cultivated zone." As our people increase in numbers and wealth, these outposts are destined soon to be but points on a continuous line of well developed agricultural lands, and our developed West Texas resources will touch hands with those of Oklahoma and New and Old Mexico. New methods must be largely resorted to; old ideas and customs that now invite agricultural failure must first be laid aside, and the spirit of enterprise will complete what sturdy determination has half finished.

No portion of Texas is rainless or a desert. As more reliable knowledge is gained of her surface areas, her native plant growth, her rainfall, and her climate, the expression "arid waste," as applied to Texas, loses its force year after year with her own people and the people of other States. It is necessary to supply only partial irrigation in any portion

**Texas Geol. Survey.*

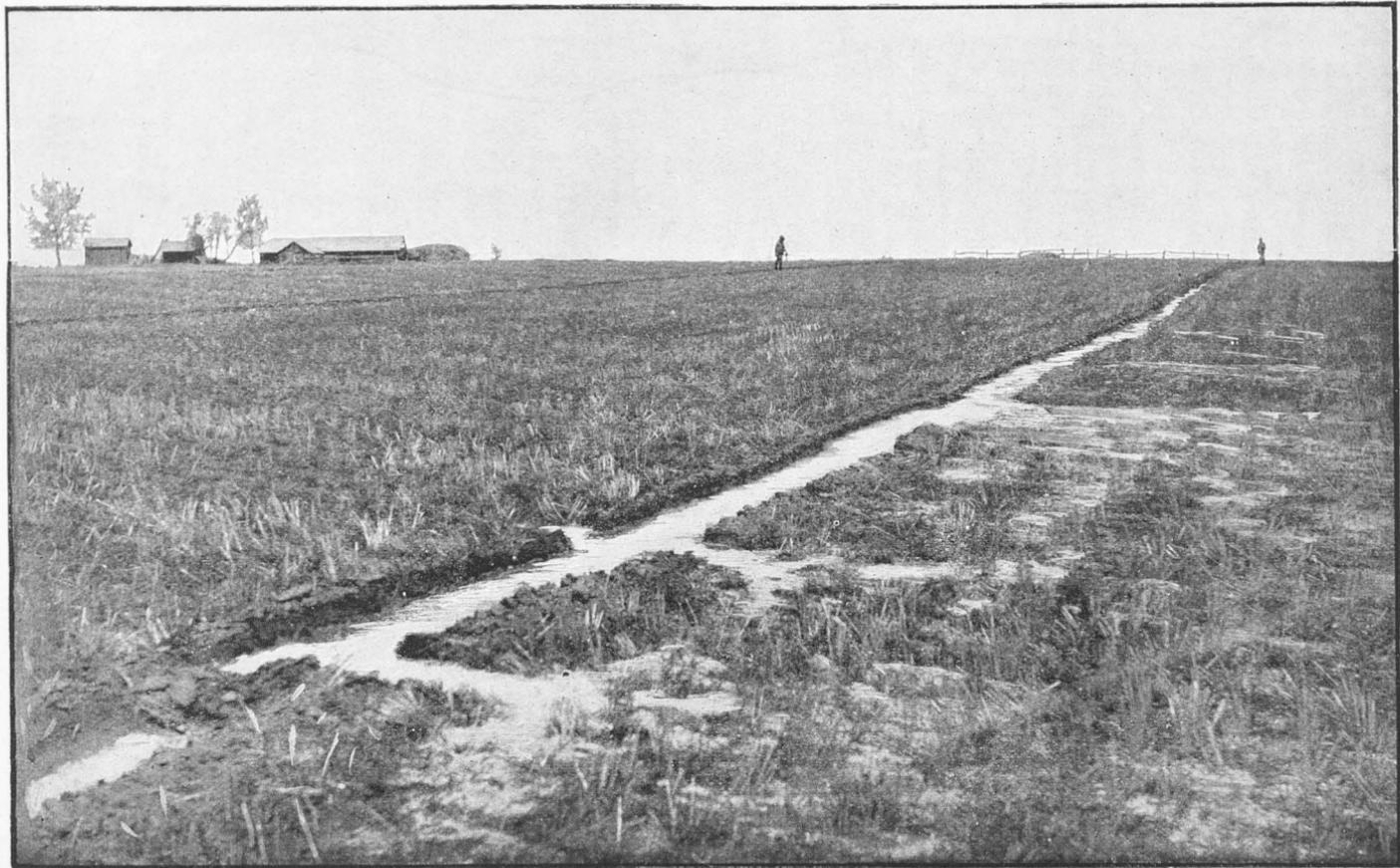


PLATE II.—IRRIGATION BY FLOODING.

BLANK PAGE IN ORIGINAL

of Texas. As we approach the eastern part of the State a larger rainfall develops and the necessity for irrigation diminishes until the Louisiana line and the upper coast region are reached, where a fall of 50 inches of rain per annum is met with.

The rainfall in Southwest Texas approximates 20 to 30 inches per annum, depending on distance from coast, elevation above sea, and proximity to the Rio Grande. Reference to the rainfall chart presented on page 935 will show to what extent the Southwestern parts of Texas are well watered.

"The Duty of Water."—This is an irrigation term that is used to give an idea of the amount of water required to grow a crop successfully upon a given area. The duty of water will vary with the nature of the soil and the crop, method of application, the evaporative conditions, and the manner in which the land is cultivated. Ordinarily, we say that the duty of water is 100 and 200 acres per each "second foot," though it sometimes falls as low as 50 acres, and if water be very scarce or hard to secure it may reach as high as 500 acres per second foot.

A "second foot" of water may be represented by a stream one foot wide and one foot deep, delivering water at the rate of one cubic foot per second, sixty cubic feet per minute, or 3600 cubic feet per hour—equivalent to 86,400 cubic feet in twenty-four hours, or 646,316.928 gallons, an amount sufficient to cover about two acres to a depth of one foot. If such a stream flows for one year, it would carry a sufficient amount of water to cover about 724 acres to a depth of one foot. Water to a depth of one foot extending over an acre is called an "acre foot;" this amounts to 43,560 cubic feet of water, equivalent to 325,851.4512 gallons. The duty of water per acre is commonly said to be "two acre-feet for the growing season," but this varies with many conditions.

The "miner's inch" is another term used as a unit of measurement for irrigation water; this term applies to the quantity of water that will flow through an opening one inch square (in a board two inches thick) under a pressure of six inches in one second of time. A miner's inch during a minute supplies about $11\frac{1}{2}$ gallons of water. In California the legalized miner's inch is 9 gallons per minute; while in Colorado it is 11.7 gallons.

The amount of water applied at any one irrigation rarely amounts to less than two inches, and should the land have become dry and cracked (as sometimes occurs in land having clay subsoils), fully double the ordinary amount must often be used. Lands that are to be irrigated should therefore be kept under cultivation for the purpose of conserving the moisture of such soils when practicable. A marked example of the maximum amount of water used per acre is given by C. W. Irish in the "Year Book" of the United States Department of Agriculture for 1895, who states that where now stands the town of Fresno, California, the dry agricultural soils in the early days took a large amount—a miner's inch per acre applied throughout the year. "This quantity would cover that amount of land 14 feet $5\frac{3}{4}$ inches deep, and then it no more than sufficed for the purpose of crop production in those thirsty soils." It is now estimated that one cubic foot will serve 500 acres of that land under irrigation at the present time, because the ground has been filled with water.

It is estimated that for each pound of dry matter produced in the ordinary plant, at least 300 pounds of water must be evaporated by the leaf. Experiments have shown that cereals require more water than do the clovers. Oats evaporate 376 pounds of water for each pound of dry matter produced, while peas use but 273 pounds. The Colorado Station estimates that for the production of 3000 or 4000 pounds of alfalfa hay per acre, some 12 or 16 "acre inches" of water must have been used. This estimate does not take into account the water evaporated from the surface of the soil, which is an important factor in all irrigation work.

The duty of water varies more widely, however, with the nature of surface and subsoils to which the water is applied than with the crop to be grown. Open, or porous, subsoils cause a wasteful application of water that in some cases can be avoided only by use of hose and sprinkler, entirely abandoning the open ditch and furrow method of application. Such soils are common in sandy portions of Florida and upon the deep sandy soils of the Texas coast line. In such cases, windmills have been found an insufficient means of supplying water for irrigation use.

In case the subsoil is impervious and near the surface, the amount of water required to properly irrigate an acre is reduced to a minimum. Much care must be exercised that the water be used judiciously or the crop will be injured, because such soils bake quickly where exposed to hot sun after being fully saturated. Underground crops, such as the sweet and irish potato, may become entirely rotted under such conditions.

Pumping Outfit.—The well and the pump station at Beeville, consisting of a windmill and gasoline engine, so arranged as to use either wind or explosive gas as power for driving the pump, is situated in a depression, or "draw." The reservoir is located on the rise of the hill and is 560 feet east of the well and pump station. The top of the reservoir is some 15 feet above the ground level of well. Water must be pumped from its level to surface of well (49 to 70 feet) plus the "rise" from well to discharge pipe in reservoir (15 feet). This provides for a total pump lift of 64 to 85 feet. When pump is used regularly and water is lowered in well the lift is probably about 80 feet.

WINDMILL IRRIGATION.

In our first efforts to establish a pumping outfit on the Station grounds, we installed a good 12-foot Ideal steel windmill, with Cook "deep-well" cylinder pump. This mill gave very satisfactory results in strong winds. In moderately strong winds, the pump delivered to the reservoir eight gallons per minute, or at the rate of 480 gallons per hour. In high wind, the amount pumped would equal 600 gallons per hour, and in light winds 250 gallons was the amount delivered.

In many cases the windmill failed to show sufficient strength to run the pump for days at a time, and in such cases the experimental crops would suffer severely from drouths. Some valuable experiments suffered so much from this cause that as soon as funds were available, a 4-horse-power gasoline engine was purchased for the purpose of using it as a substitute for the windmill when the mill failed to supply the

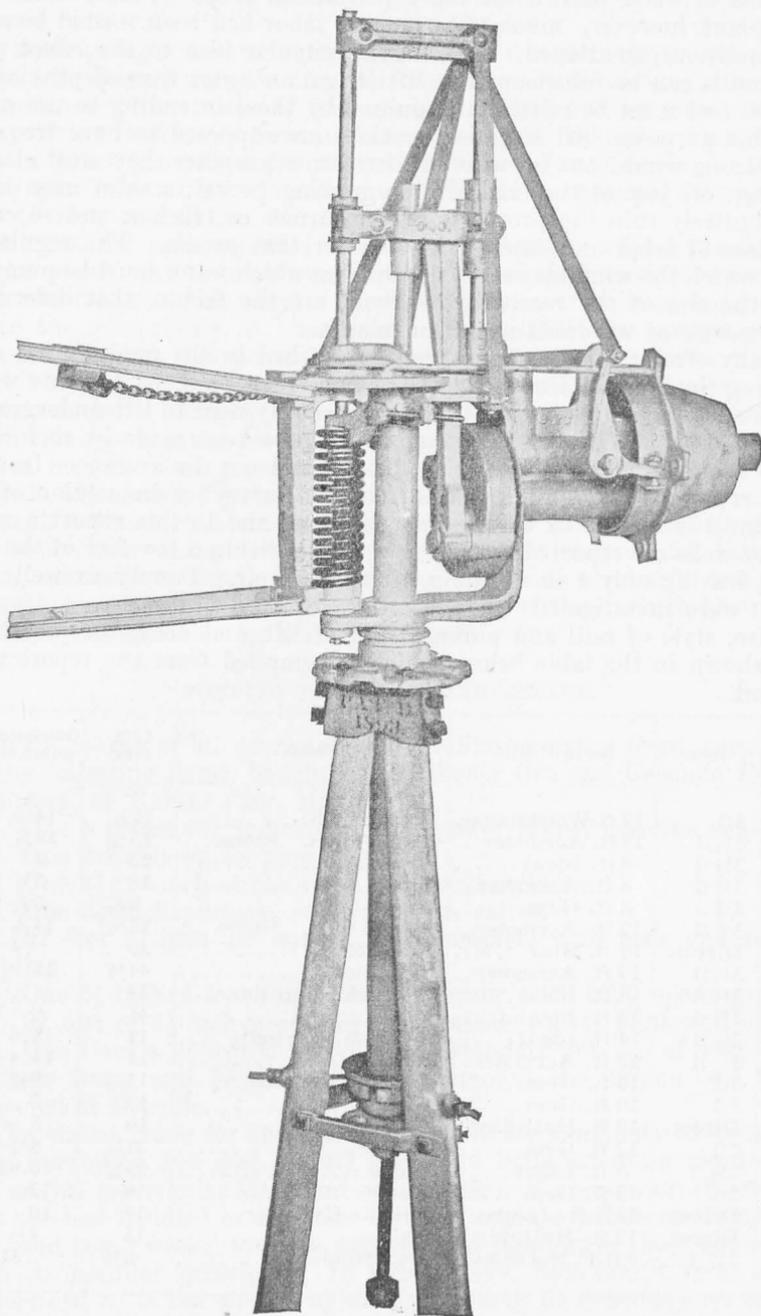


Fig. 3—Photo of Working Parts—"Ideal" Windmill.

amount of water needed for the experimental crops. Before installing this plant, however, much experimental labor had been wasted because of conditions mentioned. An existing popular idea to the effect that windmills can be relied upon to lift irrigation water from depths of 75 to 100 feet must be critically examined by those intending to use mills for this purpose. All semi-arid sections are supposed to have frequent and strong winds, but for windmill irrigation purposes they must also be *regular*, or, just at the critical crop-growing period, a calm may occur and entirely ruin the prospects of the farmer or trucker, and so cause the loss of labor and capital invested for that season. The regularity with which the wind blows, the depth from which water must be pumped, and the size of the receiving reservoir, are the factors that determine the success of windmill irrigation plants.

Many erroneous ideas have been established in the public mind concerning the famous Garden City (Kansas) irrigation district, where windmills of nearly all styles have been successfully used to lift underground water. In many cases, the lifts stated to have been made by such mills have been the maximum for that district and not the average. In a recent report by the United States Geodetic Survey* a description of the windmill irrigation of that section is given, and in this report a number of wells are reported as forcing water to within a few feet of the surface, leaving only a short pump lift to reservoir. Twenty-six wells and mills were investigated.

Size, style of mill and pump, depth of lift, and discharge per stroke are shown in the table below, which is compiled from the report mentioned.

Well No.	Gear.	Style of Mill.	Pump.	Lift, feet.	Discharge per pump stroke.
2	3:1	12 ft. Woodmanse.	9½ x12 inch.	17¾	14½ qts.
3	3½:1	12 ft. Aermoter ..	9½ x12 inch. Stone ...	13¾	14½ qts.
4	2½:1	8 ft. Ideal	Stone	12	2 qts.
5	3½:1	8 ft. Aermoter ..	Stone	13	¾ qts.
6	3:1	8 ft. Gem.	Stone	9 ⁷ / ₈	3 ⁸ / ₁₀ qts.
7	3½:1	12 ft. Aermoter ..	9½ x12 inch. Stone ...	15½	14 ⁸ / ₁₀ qts.
8	Direct.	10 ft. Star	3x5 inch.	30	.4 qts.
9	3½:1	16 ft. Aermoter ..	8x16 inch.	44½	11 qts.
10	2½:1	8 ft. Ideal	2½ inch. diameter ...	33	⅓ qts.
11	2½:1	12 ft. Ideal .....	.....	45	9 qts.
12	2½:1	14 ft. Ideal	9½ inch. Frizelle ...	11	11.6 qts.
13	3½:1	12 ft. Aermoter ..	Stone	11	14.4 qts.
14	3:1	12 ft. Gem.	8x9 inch. Gause.....	15½	9¾ qts.
15	3:1	10 ft. Gem.	Stone	15	7 qts.
16	Direct.	10 ft. Halliday ..	Gause	16	3 qts.
17	2:1	12 ft. Gem.	Gause	21¾	8¾ qts.
18	2½:1	8 ft. Ideal	Stone	14¾	2.92 qts.
19	2:1	12 ft. Gem.	Stone	18	12 qts.
20	Direct.	15½ ft. Jumbo....	6 inch Cylinder	14	10 qts.
21	Direct.	12 ft. Halliday ..	Stone	15	4½ qts.
25	2½:1	8 ft. F. Morse & Co.	2½ x4 inch.	8½	.31 qts.

It must be borne in mind that all of these mills were not of same age, did not have the same elevation above ground, did not use

*The "Windmills for Irrigation."—Murphy. (No. 8.)

the same pumps, nor were the supply and discharge pipes the same. Therefore the results given in the table are not to be used for strict comparisons of one make of mill against another, *but are presented here to enable our readers to form a clearer idea of the amount of water that may be lifted by mills under practical conditions*, such as are known to exist near Garden City. It will be noticed that the greatest lift reported was 45 feet, in well No. 11.

Some of the mills reported made 1 pump stroke to 3 1-3 revolutions of the wheel, while others were directly geared, and made a stroke for each revolution of the wheel. A wide difference of opinion has existed as to the advisability of "back-gearing" windmills for pumping purposes, and upon this point the author reports and concludes in part that "the pumping power of steel back-gearred mills is greater than that of wooden mills working with direct stroke." Another matter touched on in this report is the power of windmills. He states that after investigation he finds "the pumping power of windmills, or the useful work they do when raising water with reciprocating pumps of sizes from 4 to 10 inches diameter is small—not greater than 0.65 of 1 horse power for twelve-foot mills, and much less than that claimed for these by some windmill makers. The pumping power of windmills made for irrigating purposes is much greater than that of those which have been used for raising water for stock purposes."

PUMPING WITH GASOLINE ENGINE.

In the spring of '97 we installed a gasoline pumping plant, consisting of the following items, bought of the Weber Gas and Gasoline Engine Company, of Kansas City, Missouri:

1. One 4 actual ($5\frac{1}{2}$ indicated) horse power Weber gasoline engine.
 2. One variable stroke pump jack.
 3. One $3\frac{1}{2}$ x18-inch stroke Cook deep well cylinder.
 4. One $3\frac{1}{2}$ -inch plunger, complete with valves.
 5. 97 feet $1\frac{1}{2}$ -inch ash sucker rods, complete with male and female coupling.
 6. One $3\frac{1}{2}$ -inchx6-foot Cook's brass strainer, with 2600 openings.
 7. 97 feet of $3\frac{1}{2}$ -inch inside, $3\frac{3}{4}$ -inch outside socket joint well casing.
 8. One Cook's improved power pump standard for top of well.
- These items cost \$384.45, of which amount the engine cost \$225, delivered at Beeville.

The claims made for engines of this style are simplicity of construction, durability, low cost of fuel used, and little attention required to run engine (no regular attendant or engineer). No person on the station grounds had handled or used one of these engines before receiving this one, and some weeks' use was necessary to familiarize those concerned with its peculiar principles. In this respect, however, it is as easily understood as is the steam engine, and it may be depended on to run for hours without the attention of any one, and in this matter gives entire satisfaction.

Cost of Water.—The cost of lifting water by engine for irrigation purposes is a matter of the greatest importance, and we have striven to secure some useful data upon this point by testing the station pumping plant as

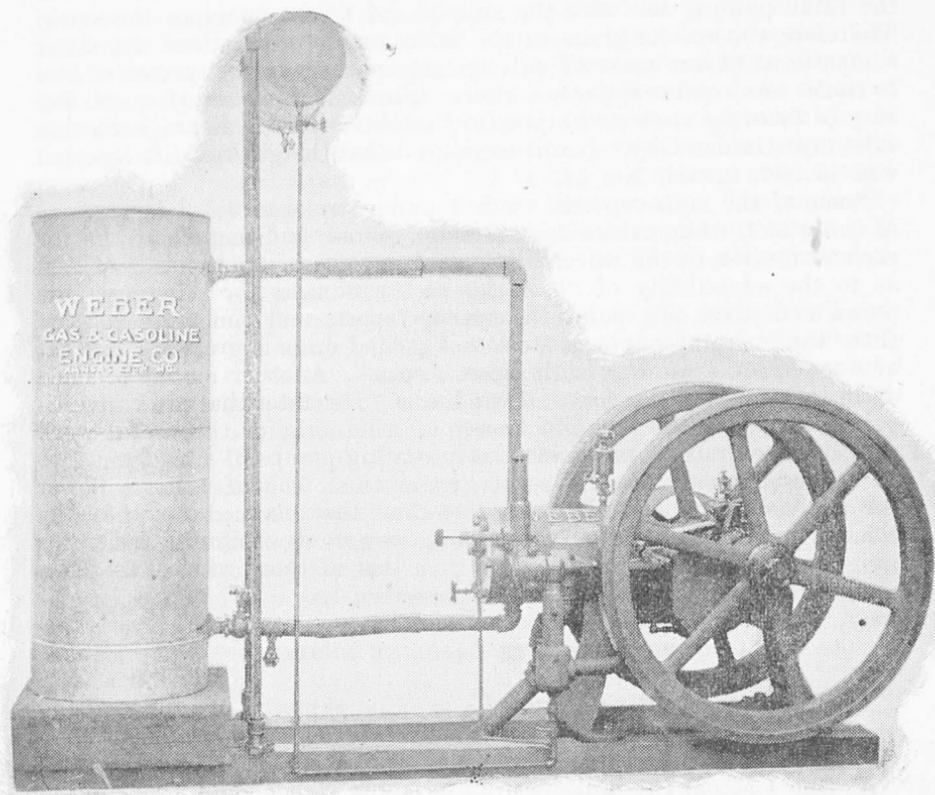


Fig. 4—Gasoline Engine.

to the amount of gasoline consumed in the lifting of 1000 gallons of water a vertical height of 65 or 85 feet and forcing it through 560 feet of $2\frac{1}{2}$ -inch pipe. Gasoline costs 16 cents per gallon at Beeville, and we find that one gallon used as fuel in the 4-horse-power engine* delivers some 1900 gallons of water to the reservoir under conditions given. The cost of water per 1000 gallons with our plant is, then, 8.42 cents. Calculating the cost of single irrigation at this rate, assuming that 2 acre inches are supplied, we see that the 54,309 gallons (2 acre inches) costs \$4.58 per application for each acre, or at the rate of \$2.29 per "acre inch." We confidently hope that this cost will be reduced when another well of water is added to our pump supply. Should land be permitted to become very dry before irrigation is resorted to, the cost per acre for application of water will correspondingly increase.

There are few crops indeed that will not repay the cost of the water applied during seasons of drouth, if water can be secured at approximately the rates that the water now used at Beeville costs. When we consider that all of the water demanded by a crop does not need to be pumped upon South Texas land, but, on the contrary, an annual rain-

*A larger engine than was needed for immediate pump work was purchased because we expect to use this power for other purposes, and wished to increase the water supply for irrigation use by putting down another pump well.

fall of 25 or 30 inches occurs, we are better able to appreciate how little the cost of such water per acre will probably prove, since two, or at least three, irrigations will supply abundant water each season for garden or field crops grown in that section. Only partial irrigation need be resorted to, but without some irrigation for use at a critical moment the economic production of vegetables has proven very hazardous in our limited experience. With cotton and with corn, fair to good crops can be expected without the assistance of artificial water supply, and, as has already been indicated, certain grasses and clovers thrive freely under natural conditions. (See rainfall chart, page 935.)

Effect of Irrigation.—According to the United States Census Reports of 1890, the value of the irrigated farming lands in this country was \$83.28 per acre; while the value of farm lands not under irrigation was but \$20.95 per acre. When our people can more fully appreciate the force of these vital facts the thousands of square miles of Texas territory now available for irrigation, and now but slightly used, will develop into tracts of fruitful farming lands, and will increase in value many fold. In addition to the supply of underground artesian and sheet water there is an abundant supply of rainfall that now runs off unused through our streams that should be stopped in surface tanks and used as impounded rain waters (or "run off"), for the irrigation of thousands of the fertile acres now in Texas. In the course of a few years we will see many of these lands thus developed by their present owners, or the lands will be developed and utilized by others. First in order of development will be those fertile soils lying to the southwest where climatic conditions are thought to be most inviting to new settlers.

THE IRRIGATION RESERVOIR.

In establishing our irrigation reservoir and system of distributing water, we were guided by the following well tried rules:

(1) Select the highest convenient point for the location of the reservoir, so that gravity may distribute the water from it to the cultivated land. If too high a point is selected, the cost of pumping the water to the reservoir is unnecessarily increased, and the length and grade of the head ditches and laterals that carry the water to the fields are rendered extreme.

(2) The soil should be tested to determine how thoroughly it will hold water that may be stored in it. We found it impossible to confine the water in our reservoir when first made for trial purposes, although we puddled the bottom with tramping stock, hauled manure with which to line the bottom and sides, and then used muck for this purpose—all to no effect. However, there is much land in Bee county and adjoining territory upon which reservoirs for storage and accumulative purposes may be built with less expense than that upon which the Beeville Station is situated.

(3) The size of the reservoir should be determined by the capacity of the pump supplying the water, the area to which the water is likely to be applied at any one time, and the frequency of application. In fixing upon the size of the reservoir, it is well to understand that vegetables require more frequent waterings and a larger amount of water

per month than do field crops and orchards. If at first the reservoir proves small it may be easily enlarged.

(4) Generally speaking, the height of the dam on the outside should not be greater than four feet, but the dirt used should be taken from the inside, and in this way deepen the reservoir while raising the sides. If the soil does not require "surfacing" with some other material, the width of the dam should be three or four times its height, but if the reservoir is to be surfaced or paved on the inside with some material—such as asphalt, mastic, or cement concrete—the width may be reduced to twice the height, leaving the inside slope one to two, and the outside slope about equal to the inside slope, and on the ground side as shown in the figure below.

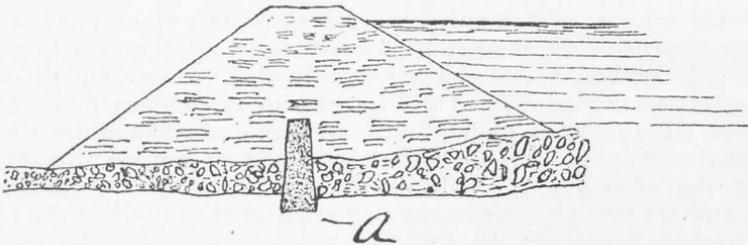


Fig. 5—Vertical Cross-Section of dam, showing partial concrete or masonry core at *a*.

Before work is done upon the dam, properly speaking, "reseating" should be provided for. This is best done by plowing where the foundation of the dam is to be to a depth of 12 or 18 inches; remove the earth, and then build the dam upon this ditch. If there is any danger of seepage or leakage through the earthen sides of the dam, especial care must be given to tramping and puddling the soils. This work should be done from the beginning by keeping the outer edges of the dam constantly higher than the inside, and by watering at night the furrow thus made. The work done next morning upon this wet loose pile of earth compacts it, and works it together much more solidly than if no water had been used.

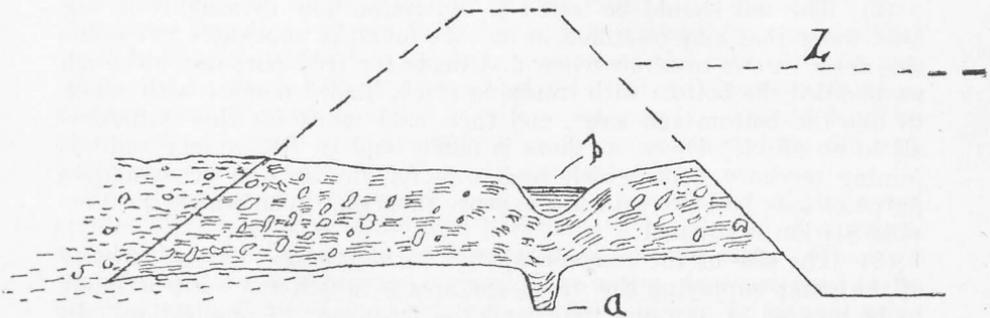


Fig. 6—Cross-Section of dam in course of construction, showing the reseated portion *a*, and the trench with water to form puddle core *b*. The line *L* represents water level.

Surfacing, Facing, and Sodding.—Close soils may be depended upon to hold water without any extra care given to finishing the inside with mastic, concrete, etc. In many cases the outside can be shaped up to a sharp angle with spade while wet, and the earth will become stable; but porous soils require some other protecting material on the inner surface to prevent penetration by storage water. We found this to be the case in our work at Beeville. After examining the cost of several different applications, including asphalt, asphalt and sand mastic, cement concrete, and coal tar and sand mastic, we selected the latter as the cheapest and best suited to our purposes, but not until we had conducted several minor experiments to test the efficiency of these materials.

The sides of the reservoir to be coated or lined with mastic were made as smooth as the coarse and crumbling nature of the limy subsoil would permit before any material was laid on. An even slope of 45 degrees was given these walls, and a coat of mastic applied evenly throughout to a thickness of one-half inch over the insides of walls and on the bottom of the reservoir. This mastic was applied at the rate of 52 pounds per square yard surface; it was composed of 25 per cent coal tar, 73 per cent sand, 2 per cent lime. Before mixing these materials, some of the coal tar was boiled for a short time and then burned off or "flashed" to cause it to set or "pitch" when the material cooled. All of the materials were hot when mixed, and were applied hot to the ground surface, beginning at the bottom and working up. A few days after the application of the mastic had been made and time allowed for it to harden, a coat of flashed coal tar paint was applied to the mastic, which, when dry, gave a glazed, impervious surface resting on an elastic foundation or base that did not sun-crack or open when the soil contracted. The work of mixing and applying the coal tar preparation in this or any other form is most disagreeable work, and we found it necessary to give personal supervision to all details throughout to insure uniformity. Even then some parts of the work required retouching a few days later to fill some of the openings and small holes caused by loose gravel and

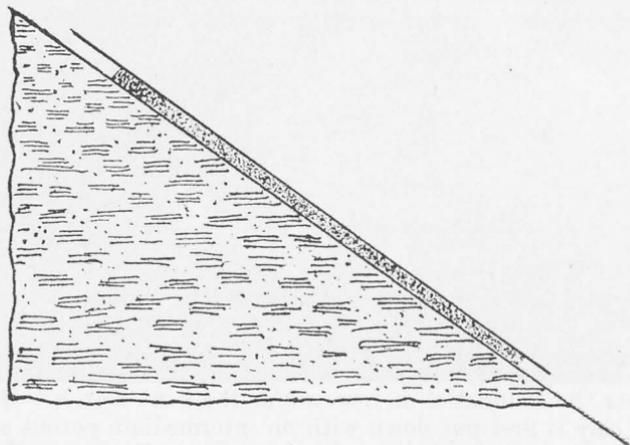


Fig. 7—Showing Cross-Section and Surface of Reservoir Wall with coal tar mastic or asphalt Concrete laid on the sloping water-bearing surface.

small clods located upon the side that penetrated the mastic while soft. In placing the waste pipe in position near the bottom of lower wall, fresh earth was left for some feet above and near the waste pipe. Care was taken at the time to pack this dirt as firmly as possible, but in spite of this the earth settled and caused some cracks to develop in the mastic along the new earthwork. All other parts of the wall were thoroughly seasoned before the mastic was applied, because they had been in place for some weeks before the final work was begun.

The reservoir is eight feet deep, and 28x48 feet at the bottom, while the top is 44x64 feet. The total cost of the materials used was about \$120. The labor of excavating and building amounted to some \$48, making a total cost of this experimental reservoir \$168. In building another such reservoir, we could safely cheapen its cost to the following extent: Material, \$75; labor, \$30 or \$35; total cost, \$105.

Cement and Sand Concretes represent another class of materials used for lining, surfacing or paving reservoirs in many portions of the country. Cement is used both with stones, as a paving, and mixed with sand and gravel to form concrete. The usual form of such work is discussed in Bulletin 46 from Utah, by S. Fortier, which is described as "consisting of a layer of screened gravel, or broken rock well rammed, upon which is laid the requisite thickness of concrete. For a short distance both above and below the flow-line, stone pitch laid in cement mortar on a thin bed of cement concrete should be substituted for the cement concrete; for the reason that the stone if of a good quality is better able to withstand without injury the action of frost and waves."

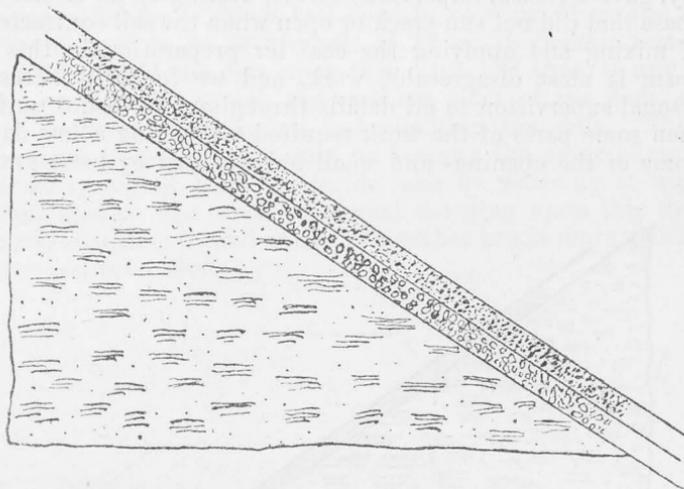


Fig. 8—Showing Cement Concrete laid on gravel or crushed rock foundation. (Reproduced from Bulletin 46, Utah Agricultural Experimental Station.)

"Water slopes lined with cement concrete fail usually in one or two ways; either the foundation is insecure or the bank settles. Quite often a layer of clay is first put down with no intermediate porous stratum of gravel or small stones, and when the water is rapidly drawn down in the reservoir the wet mass of clay is liable to 'slump' and carry with it the concrete lining.



PLATE III.—IRRIGATING BY THE FURROW OR RILL SYSTEM.

BLANK PAGE IN ORIGINAL

“Engineers and superintendents frequently build reservoirs in earth, and line the inner slopes and bottom with cement concrete before the banks have properly settled, and without first thoroughly soaking the interior walls. In a properly made bank there will be no subsidence to speak of; but to pave a reservoir without first allowing the water to remain up to high water mark for days and even weeks is to invite failures.”

Asphalt Mastic.—In the trials made at this Station with asphalt as a binding material to form an impervious coat, we found that it was too easily subject to the sun’s heat to give satisfactory results in this section. It was combined with sand, lime, coal tar, and dryers, but all of the results obtained with such concretes or mixtures proved their unfitness. Coal tar was used to cut down the block or solid asphalt, and similar results were obtained from this material. If stiffened by the addition of a large per cent of lime or sand, the elasticity of the concrete was lost, and on clay lands the cracks would open in the surfacing corresponding to cracks in the clay. If these solid matters were reduced in amount, then the sun’s heat would cause the surfacing to melt and run down the slopes.

In Bulletin 46, from the Utah Station, a cut is presented showing the method of paving or lining reservoirs with asphalt concretes, and this is reproduced on page 952 to show how the tar mastic was applied to the walls of the Beeville reservoir. In the report referred to the formula for asphalt concrete or mastic used successfully in Utah is stated to consist of the following:

“Gravel, 70 per cent by weight.

“Sand, 30 per cent by weight.

“Liquid asphalt, 10 per cent to 15 per cent by weight.

“The sand and gravel are heated to a temperature of over 300 degrees and mixed with the liquid asphalt at a slightly lower temperature. It is put on hot in a manner similar to street paving, and varies from one to four inches in thickness.”

In all cases where asphalt is to be had at very cheap rates, the use of wood block or brick may be resorted to by dipping these in asphalt, and paving the inside of larger reservoirs with such material. A finishing coat of one-half or one inch of the mastic may be given. These materials will permit the use of asphalt under conditions of hot sunshine.

To protect the outside surfaces of the dam from constant washing, Bermuda or Curly Mesquite grass should be set upon the top and sides, and within a few months these plants will present an effectual covering. The level of the bottom of the dam must be above that of the fields to which the water is to be applied, and the flume or outlet should be near the bottom of the reservoir, but some water should at all times be left in the reservoir for the safety of the bottom, for if exposed to the sun it is likely to crack and lose a large part of the first water pumped into it. A cheap flume may be constructed of two-inch plank, shaped to have a 6x8 opening. This is provided with a board and leather valve, as seen in figure below. A round gas pipe of six-inch diameter, with a head-gate valve, gives excellent satisfaction at Beeville, and is more durable and costly than a flume made of lumber.

Distributing Ditches.—A plan of the Beeville reservoir and ditches that carry the water to the fields where it is to be used is presented on

page 940. The grades are steep, and some trouble is experienced in their tendency to wash out, but this has been checked by "pitching" the bottom and sides of the "V" shaped ditch on the steep grades. The laterals for spreading the water in the fields should not be further apart than one hundred yards for any garden work, although the distance may be somewhat greater for field work. In case the land is slow to absorb the water, a shorter distance is necessary, and will save time and give a more regular distribution of the water. If distance between the laterals on any slope is too great, the upper ends of the furrows are saturated before the lower ends receive their quota of water, since all of the water of the furrow must pass by the points first wet. This results in puddling and damaging the upper ends of the furrow.

APPLYING WATER.

We should use the largest possible flow or head in applying water consistent with the safety of soil and crop. Washing must not be permitted, however, nor must the amount of waterflow be allowed to get beyond the control of the attendant. The amount any one man can handle will vary with the absorptive capacity of the soil and the care with which the land has been laid out and levelled for irrigation. One man can distribute two acres of water on well prepared land during a day, while four or five men may be needed to control the same amount should the ground be left irregular, causing pools to form and washes to occur. Grading the land must be attended to before the crop is set and immediately after the laterals have been located. The laterals should be carefully put in, and, generally speaking, a fall or grade of one inch to one hundred linear feet will insure a free flow, but will not cause washing. The grade of the furrow can be largely controlled by the direction in which the rows or rills are run away from the laterals.

The Furrow System.—If land along the line of the furrows has been left with irregular surface, mounds and depressions occurring here and there, the grade for the furrows should be steeper than if the land had been properly levelled.

As soon as the laterals have been located, the ground to be irrigated, should be graded or levelled; various tools are used for this purpose. For small areas, a common dump or road scraper drawn by one or two mules will answer the purpose; on larger fields specially constructed machines are to be recommended. Land graders may be purchased of the large hardware and implement firms in this State. Grading is essential, and must be properly done in any case where water is to be used economically, and applied at the least cost of labor.

If the laterals are properly located and the furrows ready to receive the water, the flume is opened and the lateral is dammed near the head of the land to be irrigated, and the overflow water passes into the furrow. Sometimes permanent dams are provided with gates built in the laterals, but portable canvass and sheet iron dams are generally used.

The judgment of the irrigator must determine how much water is to be permitted to flow into each furrow (or control the "head"), but the quantity must not be so great as to produce washing, nor must it pass through so quickly as to merely wet a narrow strip throughout the length of each furrow. If allowed to wash the small particles of soil from one part of the furrow to another, the lower portion of the furrow

is deadened by the silty deposit. If, on the other hand, the water is allowed to stand in the furrow sufficiently long to fully saturate the land, much harm results, because the soil "runs together." This is especially true of sandy soils poor in vegetable matter. Soils vary widely in their ability to pass water laterally through them by absorption. In some cases every three or four feet must be provided with a furrow in order to successfully irrigate the entire surface. Such soils lack "tensile power." On other soils only every other or every third furrow may be used, and the same results accomplished. These are usually sandy soils containing a high per cent of vegetable matter and underlaid by a close impervious subsoil. Subsoil irrigation can be successfully practiced on no other soils than these last described, because we can not afford to lay laterals every three or four feet throughout the ground to be irrigated.

At Beeville we find it necessary to irrigate every furrow, or every other furrow, when we wish to water the growing crop, while on the main Station grounds, in Brazos county, we find it sufficient to water every other or every third furrow at each irrigation. This difference is due, in all probability, to a difference in the character of the subsoils in the two cases cited. On the Beeville farm the subsoil is a porous limestone formation; while at the main Station, in Brazos county, the subsoil is a very close, impervious subsoil; clay lying only six or eight inches under the surface.

In the year book published by the United States Department of Agriculture for 1895 some valuable cuts are shown to illustrate the several methods of applying irrigation water, some of which are reproduced here with the explanatory statements relating to each method shown.

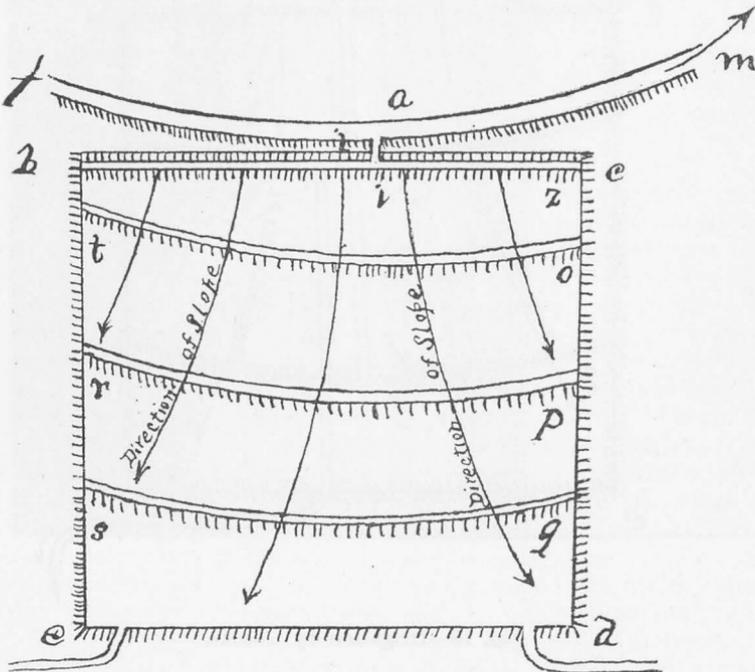


Fig. 9—Irrigation by Furrows.

"Irrigating Hillside.—Fig. 9 shows the method of spreading the water over a hillside field, in which, as in fig. 10, $f m$ is the main ditch and the slope of the hill as shown by the arrows; $t o$, $r p$, and $s q$ are small ditches or plow furrows cut on a level line around the face of the hill. The water is let into the field by the short ditch at i , and is then spread over the space $b c t o$ by means of a marginal ditch $y z$, from which it is made to flow in small streams and in a regular manner over the space between it and the lower ditch $t o$. This is done by men wearing rubber boots and furnished with shovels as in the first method. The surplus water runs down to the ditch $t o$, and is caught by it and held until it is full and the water runs over, which it will do all along $t o$, as it is level from end to end. It is now the work of the irrigationist to cause it to spill evenly across the space $t o r p$, covering every part of it as in the case of flooding first described."

"Irrigation by Ditches.—Fig. 10 shows a modification of the basin plan, as applied to ground with considerable slope and consisting of hillside land wherein $f m$ is the main ditch on the highest side of the field, of which $b c d e$ mark the boundaries. Its surface slopes in the direction of the arrows; $o o$ and $q q$ are 'check levees,' or slight embankments, built on level lines around the curved surfaces of the field. A supply ditch, $i j$, leads the water into the 'checks' or basins $b c$, $o o$, and $q q$, etc., and $t w l$ is a waste ditch for discharging the surplus water from the checks when no longer needed. The 'check levees,' $o o$, $q q$, are usually constructed so as to be about 6 to 12 inches high, and sometimes higher."

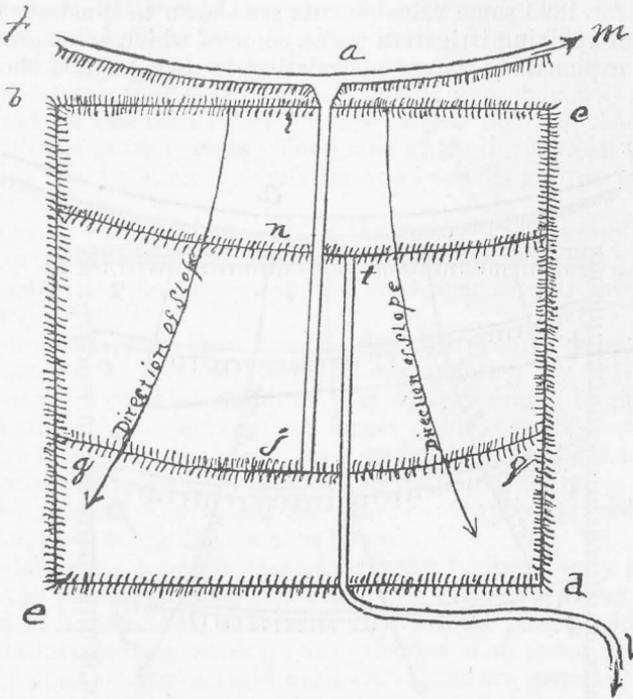


Fig. 10—Irrigation by Checks.



PLATE IV.—FLOODING A FIELD BY BASINS.

BLANK PAGE IN ORIGINAL

"Irrigation by Basins or Checks.—The basin plan is used on flat surfaces, where there is not enough slope to cause the water to flow readily in a thin sheet over the land, as in flooding or along furrows."

"It is largely used in the irrigation of the cereals and of orchards, and can be applied to surfaces where the slope is not over 2 feet fall in 100 and should be used where a large quantity of water must be held upon the land until it soaks into it."

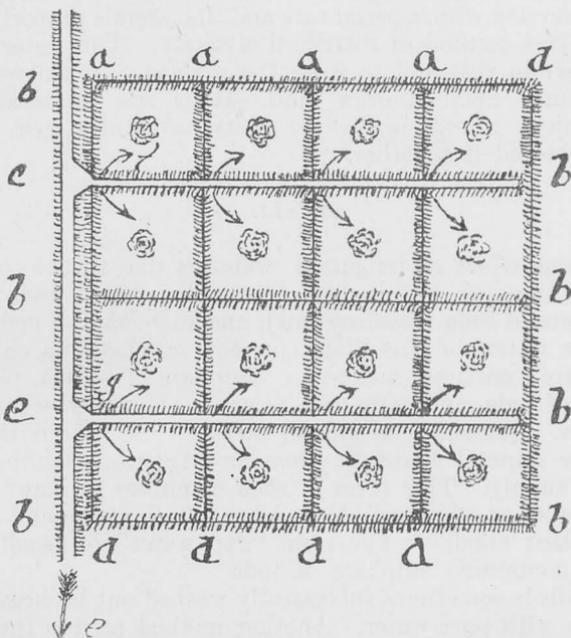


Fig. 11—Irrigation by Basins.

"Fig. 11 shows the application of this method to the irrigation of an orchard; *d e* is the main ditch located on the highest side of the orchard, the slope of which is from left to right of the figure; *b b*, *b b*, *a a*, *a a*, etc., are solid embankments about a foot high, in this case, made by backfurfrowing three furrows together with a plow, and then shaping them up smooth and true with a shovel; *c b* and *c b* are such ridges with a ditch made in the top of them, along which the water flows from notches *c c* in the main ditch, and is let into the square basins formed by the system of embankments through notches at the points marked by the curved arrows. The water is made to flow through these notches by means of a shovelful or two of earth thrown into the ditch in the form of a dam. The irregular shaped dots in the center of the basins represent the orchard trees."

"This method is used when large quantities of water are to be put upon lands, sometimes to the depth of four or five feet, as in upper Egypt, where the clear water of the Nile, on its first rise, is used to dissolve out of the surface soil the salts which accumulate between the cropping seasons. The surcharged waters are turned out of the basins

into the river, and then the basins are filled with the muddy waters of the high flood, the slimy deposit from which furnishes fertility to the crops. Each of the basins so used incloses thousands of acres of level lands of small areas with short rows. Irrigation by the return furrow system is often practiced, as shown in figure below."

Broadcast crops are usually irrigated by the flooding system and require less labor in the application of water, but use a maximum amount of water at each application, because all of the surface must be saturated. The land must be leveled with especial care and the laterals properly located in order to use this method of distribution safely. The water constantly tends to gather in rills and to wash the surface into gulleys; this tendency is greater upon uneven land. It is also noticeably greater when the crop is young, before the roots have interlaced throughout the soil and bound it together.

ALKALI.

The injurious effect of irrigation water is due to the presence of such alkaline bases as soda, potash, ammonia, etc. These usually appear as sulphate of soda (glaubers salt), and carbonate of soda (salsoda), though in the waters of this State common salt (sodium chloride) and alum waters are sometimes met with. Sulphate of potash, phosphate of soda, nitrate of soda, and carbonate of ammonia rarely occur in underground waters. Quantity considered, carbonate of soda is the most injurious of the mineral elements, from an irrigation standpoint, found in our water supply. This form of soda combines in many cases with vegetable mould or "humus" forming a black compound when dry, known as "black alkali." The term "gyp water" is usually given to those waters containing sulphate of soda.

Alkali in soils is sometimes successfully washed out by heavy rainfalls, or by flooding with pure water. Another method used is the growth of such crops as show a fondness for the alkaline plant-food elements of the soil. In this connection it must be borne in mind that soils troubled by alkali are only suffering from an excess of certain kinds of food that will not permit the utilization of other necessary food elements present in the soil. Sorghum, sugar beets and salt brush are crops that have been successfully grown upon land that tend to alkalinity, and the surplus alkali has often been safely removed in their use. Thorough cultivation or increased evaporation often causes a white deposit near the surface, which leaves the subsoil free from the harmful effects of alkali, and this gives relief to the growing crop, should the supply of alkali in the subsoil be limited and not too near the surface. Gypsum is used at the rate of 400 or 500 pounds per acre as a remedy for black alkali, and common lime is recommended for white alkali. A dry atmosphere resulting in scant vegetation is favorable to the formation of alkali, and upon many such soils irrigation water and a growth of a few crops washes out or carries off the poison in the soil, thus proving an effectual remedy.

(The Station is indebted to Mr. F. H. Newell of the Bureau of Geological Survey, Department of Interior, Washington, D. C., for use of plates I, II, III, and IV, appearing in this Bulletin.)