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THE

Artesian Wells of Colorado,

AND THEIR RELATION TO IRRIGATION.

Fort Collins, Colorado.

JULY, 1891.

The Agricultural Experiment Station.

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The Artesian Wells of Colorado.

AND THEIR RELATION TO IRRIGATION.

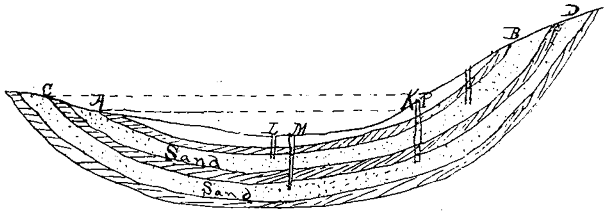
By L. G. CARPENTER.

This bulletin has arisen from the investigation of artesian and other phreatic waters of the plains which was ordered by Congress in April, 1890, and put in the charge of the Department of Agriculture, with Richard J. Hinton, special agent in charge, Robert Hay chief geologist and E. S. Nettleton chief engineer. The writer had to do with the collection of information in Colorado and New Mexico, and from the data then collected, most of that which pertains to the region east of the mountains is derived, with the permission of the Department. That in regard to the San Luis Valley, which was beyond the limit set for that investigation, is largely derived from personal investigation, mostly made since the close of the investigation referred to. The reports of the Congressional investigation are contained in Executive Document No. 222 of the Fifty-first Congress, first session. In this report some seventy pages are given to the wells of Colorado, especially those of the Denver basin, and as they are described in detail, it will not be attempted to describe them here. It may be added that the above investigation, with increased scope, is being continued under the same gentlemen, and promises information of much value in regard to the water resources and possibilities of the Western plains.

By an artesian well is ordinarily meant a flowing well. The name was associated with the province of Artois, in France, from which a knowledge of them spread throughout Europe. They were, however, known and sunk in other countries centuries before, and sometimes of extreme depth.

The cause of the water rising to the surface and flowing, is an illustration of the familiar tendency of water to seek its own level. If the source of the water is higher than the surface of the ground where it is set free, the water rises with a force depending on the height of the source above that point, other things being equal. Whether a well flows or not will then depend on whether the mouth of the well is below or above the source. In many regions, where the ground gradually rises, there is an area outside of which the wells do not flow, because the surface is too high. Examples may be found where the water rises almost to the surface, and where the lowering of the surface a single foot, as by digging a trench, would render it a flowing well. There is evidently no essential difference between the two cases, but according to the ordinary usage one is artesian while the other is not. In both wells the water rises above the stratum where encountered. This characteristic was taken as the basis of the meaning of the word as used by the U. S. Artesian Wells Investigation of 1890. To make a distinction between the two classes, which is practically important, it has been proposed to distinguish them as positive artesian, or simply artesian, and negative artesion—the former indicating those which flow.

The conditions for the existence of an artesian well basin are, that there should be some source of water supply higher than the location of the well, and that there should be a porous stratum which is confined by impervious strata both above and below. These strata must be continuous. In general, the water should have no means of escape lower than the point where the well is, but when the distance to an outlet is considerable, the friction in the intervening distance may be more than sufficient to make up for the difference in level. The pervious stratum may consist of any material which will allow water to pass through it, but most commonly it consists of sand or sandstone. The more open and porous this stratum is, the more abundant will be the flow with any given pressure. No rocks are perfectly impervious, but thickness will compensate to a great extent for a slight porosity. The confining stratum generally consists of clay or shale.



The region where artesian wells are found is generally spoken of as an artesian basin, largely because the typical form of such a region is a genuine basin, with the rim higher than the center. A section of the Denver basin is of this form. The figure may represent an exaggerated section of such a basin, with the porous strata outcropping at B, D, C and A. Anywhere lower than the line AK flowing wells might be expected if the strata are continuous, but as we reach K, or some point nearer B, it will be found that water comes only to the surface, and still higher it may fail to reach the surface. It is also evident that while at P flowing water will not be obtained from the upper stratum, by going deeper it may be secured, because the outcrop of the stratum which furnishes it is higher.

The figure also shows why the pressure is generally greater as the depth is greater. This fact has given rise to a popular belief that if one only goes deep enough flowing water will surely be obtained. Unless the proper conditions are present this is not true, and it is useless to expend money in that hope.

The supply of water which comes from a well or series of wells is never unlimited, though it may be very large, as in the wells of Dakota, or in some of those in the San Luis Valley. Its limit is set by the amount which is supplied to or absorbed by the water-bearing stratum, from water which falls on or flows over the edges of the strata. Where the strata reach the surface at a small angle, the area exposed to absorption or to rainfall is much greater, and the case is more favorable than where the angle is great. The capacity of the wells is limited by the amount these edges can absorb, or to the supply which may fall upon them. The edges may be covered by surface soil, or may be less pervious, in which case the conditions are less favorable for a large supply. If the number of wells is increased largely in any basin, there generally arise indications of a limitation of the supply in the effect of one well upon another, or on the general flow. When such a point is reached, it is time that some consideration be given to the conditions, for the value of such a supply cannot be overestimated. Its value becomes greater with the increase of population. When many wells are put down in a small area, the decrease which is generally noticeable may not indicate that the general supply is overdrawn, but that the local supply is; that is, that the water flows from the wells faster than the supplying strata furnish it.

Very little attention has been given to artesian wells in Colorado as a source of supply for irrigation. In the basins yet developed the conditions are perhaps nót favorable for this use. But, it is to be remembered that with a growing population and greater need, but with a limit to the water supply, the value of water constantly increases. That the sinking of wells for this purpose is practicable is witnessed by the experience of many countries besides our own. In some portions of China it has been practiced from early ages. India derives no small portion of her supply from wells. The French have sunk many wells in the Algerian Sahara, and around these spots the desert gives way to garden spots. Some 60,000 acres are irrigated from them in California. Whether the sinking of wells for this purpose is economically practicable or not, will evidently depend upon the cost of sinking and upon the amount of water to be obtained, and the cost will depend upon the depth as well as upon the character of the strata which it is necessary to pass through.

As to how much one might venture, opinions would naturally differ, but the value of water in this State is indicated by the price of the water rights. In the older settled districts, the water right for eighty acres rarely brings less than $1,200, even in some of the ditches which do not have water in times of scarcity. Such a right generally means 1.44 cubic feet of water per second. This is considerably reduced, except in periods of high water, so that the amount actually received, as a rule, is but a small fraction of the nominal amount. Assuming the flow to be the full amount, the prices for the rights would be about $780 per second foot; but based on the actual amount of water received, they would probably be four times that. As an indication of the value of water in a community older than the average in Colorado, there are one or two instances in the Greeley community, where farming has now been carried on for twenty years. One landowner, Governor Eaton, drained a few years since a piece of land which had become soggy and wet. The drainage, which formed a constant stream, was wasted for some time in one of the canals near by. After a year or two, some of the farmers below this point, and who already had rights in the Cache la Poudre Canal No. 2, one of the best in the valley, deemed this water of sufficient value to them to purchase it for $5,000. This present summer the amount of this drainage water did not exceed 1¾ cubic feet per second, and as the purchase was made three years ago when there was still less, the rate was something like $3,000 per second foot. The owners think it was one of the best investments they ever made.

If water has reached such value in a community not more than twenty years old, and that, too, where tropical fruits or the large returns of a more torrid climate cannot be expected, it may well suggest that before many years it may pay to expend sums for the development of supplies which would not now be thought of, and it impresses the economic importance of conserving such supplies as we have, and of utilizing them to the fullest extent.

One advantage in the artesian wells is in their continuous flow, as in the case of the drainage water above mentioned. In most streams of the State the water is high for a short time only during the season, and during July and August it becomes scanty, so that late crops often suffer in consequence. The surplus water of June runs to waste. Where the flow is uniform throughout the season, a duty of some three or four times that used as the basis of water rights in Colorado may be expected.

The flow from many of the wells is small, so small that the owners think it is of no use in irrigation, and therefore allow the water to run to waste. We have not yet learned how to utilize the small but constant flows as the natives of some of the Eastern countries, like Armenia, where Mr. Nahikian, a native of that country, and a former student of the Agricultural College, says a small stream as large as a pencil is highly prized. The stream alone could effect no irrigation of consequence, but by running into a small reservoir it can be stored, and then a large head used for a short time. The greater effectiveness of a large head is well known in Colorado. In a similar way the water from many of the wells, which now runs uselessly away, could be made to perform a service which would be considerable in the aggregate. Some are already being utilized in this way to a greater or less extent, but generally without storing.

The cost of sinking generally increases more rapidly than the depth, so that except in exceptional cases, such as extremely easy boring, as in the San Luis Valley, or great supplies of water, as in Dakota, it will not pay to attempt deep wells for irrigation purposes. The temperature increases with the depth, which is an advantage if the water is to be immediately applied; but the water is also more mineralized, which is a disadvantage or not, according to the character of the solids present.

Throughout the artesian basins of the State it is the rule, rather than the exception, to meet with wells whose flow is decreasing. This may be due either to the increase in the number of wells, so as to overdraw the local supply, or to defects in the individual well. When the latter, it is generally due to a partial filling of the well with particles, which may have been brought in with the water, or may have fallen from the walls above. In either case, the flow is partially stopped, and may generally be recovered by cleaning.

The prevailing troubles of this kind arise mostly from the common practice of casing the well imperfectly, or sometimes not at all. Usually in the San Luis Valley, and in large numbers of the Denver wells, the casing extends only through the loose surface soil to the first clay stratum. And cases are not unknown where this consists simply of stovepipe, or a tube of boards made on the spot. Such construction has generally been dictated by motives of economy, but it hardly needs to be said that it is a false economy, which may risk the whole supply.

But more serious than the danger to the individual well in such a practice is the damage done to the whole basin. A consideration of the general character of the conditions will show the reason. The lower stratum has generally the greater pressure. There may be strata which are dry and do not furnish water. If a hole be bored through the intervening clay layers, there is a chance for much of the force of the water to be lost, and such loss affects not only the individual well, but the whole surrounding basin.

The different strata rarely furnish water at the same pressure, and sometimes there may be strata without any. The effect of opening an uncased hole through the confining layers, is simply to give the water an opportunity to escape into the dry layers, or into those of lower pressure, which it will as certainly do as it will flow to the surface. The effect is to not only lessen the flow at the surface in this individual well, but it may lessen the pressure in all surrounding wells.

Equally important is it that the casing be carefully packed where it passes through the impervious stratum, both above and below, if it extends through the lower confining bed. Some of the failures in securing flowing water are due to the lack of such packing.

The importance of preserving such supplies of this character as we have cannot be too strongly dwelt upon. The need for this water, whether for irrigation or for domestic use, will not grow less. Its loss for the latter would render some regions almost uninhabitable. And any practice which tends to lessen the efficiency of the whole basin cannot but be strongly condemned.

In some cases the upper confining stratum has been pierced and the well abandoned; perhaps the casing drawn up. This allows the water to waste uselessly into the upper strata or in the surface soil, to the detriment of the whole basin. Where once done, it is next to impossible to henceforth find the hole and stop it, even if it should become desirable.

The public importance of preserving such supplies and the ultimate effect of such practice, is such that it ought by law be required that every well that is sunk should be completely cased, and that no well should be abandoned or the casing withdrawn without plugging the hole at the impervious strata.

There should also be some means of limiting the sinking of wells whenever the further boring affects the flow from those already sunk.

As it is of importance to know of any change in the pressure, as showing such a limit, it is advisable for all those having wells to test them occasionally when circumstances are such as to render it possible. When arranged with hose connections, as many are, it is easy to do so with the moderate pressures which prevail in this State. Attaching the hose so that there is no leak, the end may be raised until the water ceases to flow. If it be lowered, the flow will begin again at the same height, or close to it. This measurement, or the mean of the two, referred to some fixed object, can be used as a means of comparison with other measurements, and if occasionally repeated, will show any change in the pressure, and may indicate the cause of any decrease. For example, a partial filling of the bore, while lessening the flow, will not affect the static pressure, as thus determined. Pressure, as thus determined, may be reduced to pounds per square inch by dividing by $2\frac{1}{4}$.

THE ARTESIAN WELLS OF COLORADO.

The discovery of artesian water in Colorado was an accident. There had been those, however, who believed in its existence, and who make attempts to find it. Probably the earliest was made by General W. J. Palmer, who, while manager of construction of the Union Pacific Railway, made an attempt at Kit Carson in 1871. The Government sunk wells at Akron, Fort Lyon and Cheyenne Wells in 1881-2, but without success, other than a small flow at Fort Lyon. Before this the Pioneer Oil Company, while sinking a well on the bottoms at Pueblo, struck water January 1, 1880. This well, now known as the Clark Mineral Spring Well, is still used, and has led to other trials in the same vicinity, all with small flow.

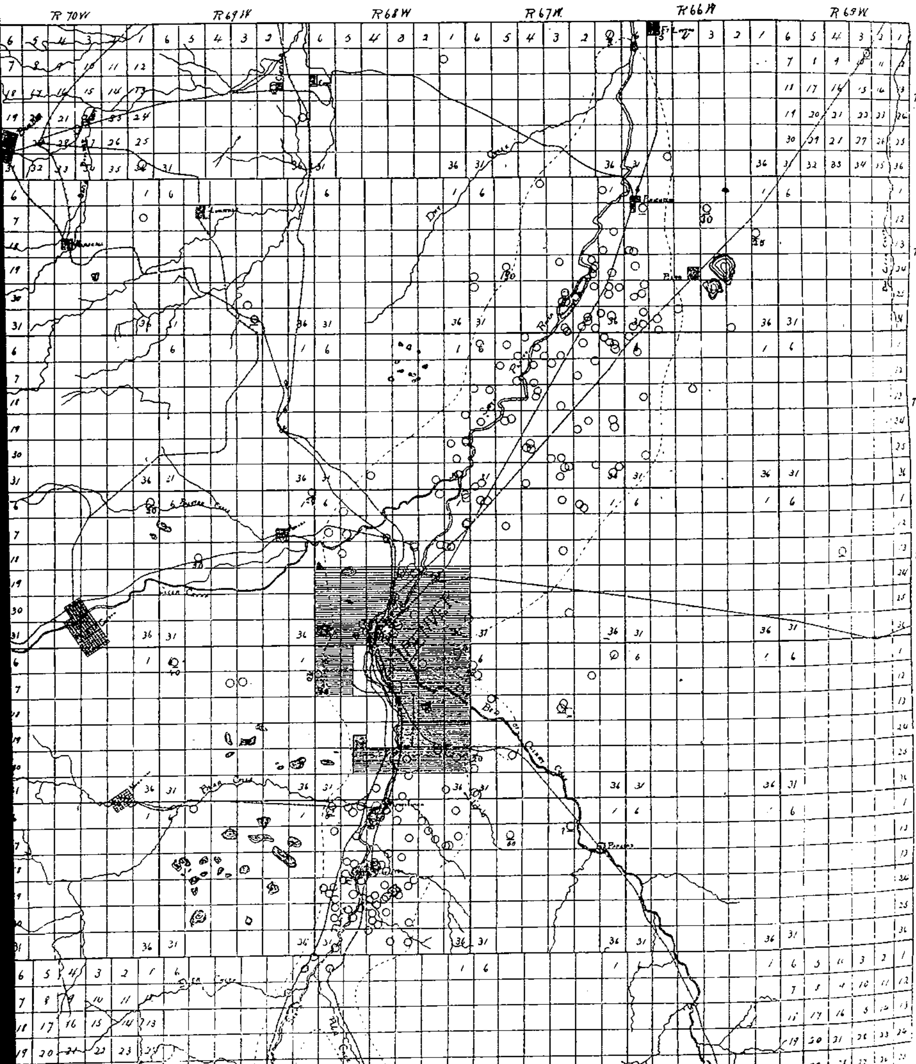
General attention was attracted to this source of water supply by the discovery of water in North Denver in 1883 while prospecting for coal. The water was so much purer than that in use that it immediately led to the sinking of many others for a domestic and manufacturing supply. This led other communities to bore for water, and some very deep wells, as at Greeley and Loveland, have been sunk in the search. The latter town has still outstanding some $8,000 of bonds which was used in the trial. Other attempts have been made at Colorado Springs, Longmont, Walsenburg, Rouse Junction, Stout, and on the plains at Calhan, Otis, Thatchers, etc. The supply has in no case been large, and in most places the attempt was unsuccessful.

Water has been found east of the range at Denver, Pueblo, Greeley, Stout, Florence, and in the Arkansas Valley near the Kansas line. The only important basins

DENVER, COLORADO

ARTESIAN BASIN.

JULY, 1890.



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as yet developed are those of Denver and the San Luis Valley, the latter of which is the most important, and one of the most important in the country, whether judged by its extent, the ease and cheapness of sinking, or the amount of water found.

THE DENVER BASIN.

It was in this basin that the first development to any extent of artesian water in the State was made. Reports upon this basin have been made by the Colorado Scientific Society in 1884, and in the U. S. Artesian Wells Investigation previously referred to. As the writer has there described the wells in detail, it will be here referred to only to illustrate some of the characteristics of basins which are plainly shown by experience therein.

The basin is shown by the map, which is reduced from one given by the writer in the Government report. The location of the wells is shown by the small circles. Where the water did not reach the surface the circle is underlined, and the figures attached indicate the distance the water came from the surface. The limits of the flowing wells are indicated by the dotted line, on each side of the Platte.

The basin is instructive, because it shows the effect of putting down many wells in a small area.

The early wells were nearly all put down for domestic purposes, and were small in size. The water was excellent for boilers, and the increased demand led to the putting down of larger wells and to the use of pumps for factories, hotels and other large users. The result has been that nearly all have ceased to flow. In the Charles well, which was the first to reach the 600-foot stratum, the pressure was quite constant, and about 70 pounds per square inch. When the Daniels & Fisher well was sunk to the same depth not far away, the pressure was immediately reduced to about one-fourth as much. The sinking of the McClelland well still further reduced it. The well is now pumped.

This is only one of many instances.

In the country the wells are not so close together, and the decrease is generally due to other causes. In case of partially filling up, cleaning recovers much of the flow. Thus in the well of the Barclay block, the following measurements were made by Charles M. Dwelle, who had charge of it during the process of cleaning, in 1884:

May 14, 10½ gallons per minute (before cleaning).
May 15, 4 a. m., 17 gallons per minute (after cleaning was begun).
" " 6 a. m., 22 " " "
" " 9 a. m., 32 " " "

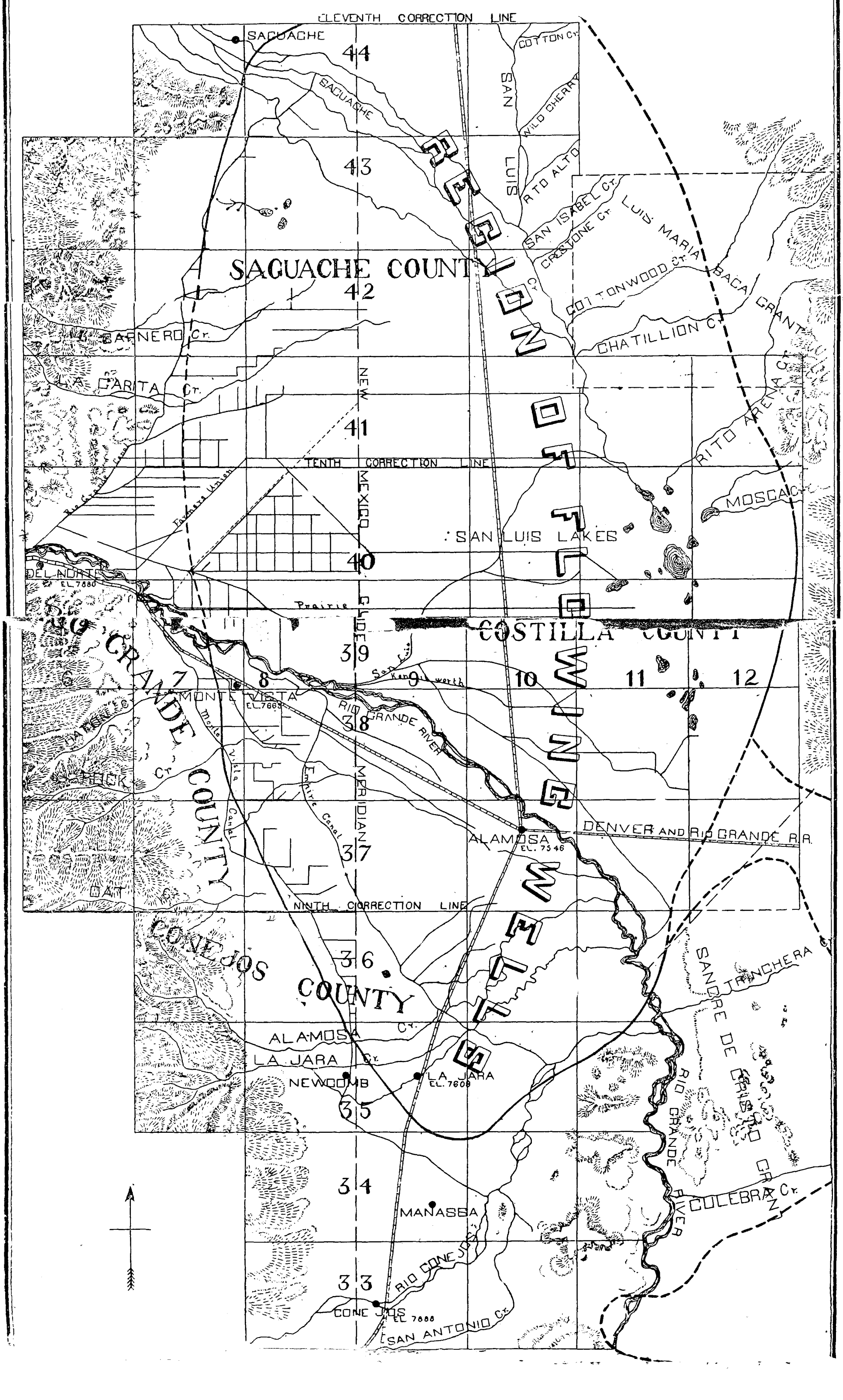
The gathering area of this basin is limited, and with the large number of wells it is not surprising that variation is noticed with the seasons. On the Barclay well, as measured by Mr. Dwelle, the flow from the deeper stratum was as follows:

Aug. 4, 1884,	36	gallons	per	minute.
Jan. 24, 1885,	51	"	"	"
Mar. 9, "	40	"	"	"
Nov. 8, "	35½	"	"	"
Jan. 27, 1886,	12	"	"	"
Feb. 6, "	14	"	"	"
Feb. 9, "	27	"	"	"
April 8, "	12	"	"	"
May 14, "	10½	"	"	"

A part of this variation is due to other wells in the vicinity, but aside from this a fluctuation is noticeable. The variation with the seasons has been plain enough to be remarked in other wells as well.

The flow of the wells frequently increases for a time after being sunk, which is due to the fact that a small reservoir or cavity is nearly always formed. These are usually small, but sometimes the amount of sand brought up is as much as two or three cubic yards.

MAP OF SAN LUIS PARK, COLORADO.



The wells of the Denver basin have been put down almost exclusively for domestic water. There has been comparatively little thought given to their use for irrigation, nevertheless many of the wells are irrigating areas of from one to ten acres. Nearly all those in the country are used to irrigate gardens. Some are used for the raising of fish. The cost of the well, taken with the small amount of water obtained as a rule, prevents many being sunk for irrigation.

THE SAN LUIS BASIN.

The San Luis basin is the most remarkable of any yet developed in the State. Though here the water was found by accident by S. P. Hoine as recently as the Fall of 1887, while sinking a sand point for an ordinary drive well, the ease and cheapness of sinking have been such that there are now probably as many as 2,000. They are so numerous that the residents give no more than a passing glance to one, aud as they are frequently sunk in less than half a day with the simplest of outfits, it is not remarkable that it is impossible to secure any kind of complete list even for a limited locality. Wells are often sunk for $25, and they range from this price upward, according to circumstances. In consequence, it is cheaper to bore artesian wells than it is to attempt to dig wells of the ordinary kind, without the added inducement of the purer water. Hence within the limits of the flowing area nearly every occupied quarter section has a well, and sometimes more. The town of Monte Vista has 88; La Jara at least 17; Alamosa over 25; D. E. Newcomb, 17; S. E. Newcomb, 8, and wells in corresponding numbers are found over all the valley.

To the eye the valley is level as a floor, though it has a slight slope, so uniform that the prevailing practice in ditch construction is to follow the lines of the Government surveys, sometimes for long distances, as in the case of the Prairie Ditch, which runs on a section line for twenty-six miles. Though at a mean elevation of over 7,500 feet, agriculture is a success, and attention has been attracted to its large crops of the cereals and potatoes. The second premium crop of the *American Agriculturist* of 1890, over 800 bushels of potatoes to the acre, was raised near Del Norte.

The valley is surrounded on all sides by the highest mountains of the State, so that the rainfall in the valley is scanty and irrigation is more than ordinarily necessary. The streams, which come principally from the West, soon sink, with few exceptions, and in consequence have built their beds higher than the surrounding plain with the sediment and *debris* which has been left as the waters have sunk. This is true of the Rio Grande as well, as is evident by the canals shown on the map, which run nearly at right angles to the river.

The uniform appearance of the valley, as well as the conditions which have made it an artesian basin, is due to the fact that in former geological times it was an immense lake, formed by the damming of the Rio Grande by the large mass of basalt in the lower end of the valley, and which is probably also the cause of the abrupt bending of the Conejos and other rivers to the north. In consequence of the lake formation, the characteristics are fairly uniform over the whole area, though there is much variability, as is to be expected, in the thickness and number of the strata. Near the ancient bed of the Rio Grande there is especially great variation; elsewhere there is great uniformity over considerable distances. The water is found everywhere, so far as learned, above the rock, which, in the western part of the basin, is comparatively near the surface, but at Alamosa is not found in the well which is 1,000 feet deep. The wells are sunk so easily and rapidly that few records are kept of the strata passed through, but the following, taken by J. M. Chritton, in Township 39 N., Range 9 E, is typical of the whole district:

Strata.	Thickness, feet.	Depth, feet.	Flow
Dark, sandy loam	7	7	
Coarse sand and gravel	13	20	
Fine light-yellow sand	22	42	
Yellow impervious clay	18	60	
Blue clay or soft slate	98	158	
Black sand	1	159	Small flow.
Blue clay	4	163	
Fine black sand	3	166	Fine flow.
Blue clay	45	211	
Fine black sand	12	223	Flow.
Blue clay	53	276	
Black sand; flow so strong that with our pump we could not go deeper.			

The accompanying map shows the extent of the basin, the supposed limits being indicated by the heavy line. These limits were fixed as the probable ones from the data in my possession. In some places they are quite exact. They were drawn before having seen the map given by F. M. Endlich in Hayden's Geological Report for 1875, where the limits of the ancient lake, there called Coronados Lake, are given. The artesian basin agrees so closely with the boundaries of the ancient lake, that it may be taken as its map. In the southeastern portion, a region not visited by myself, Endlich's map shows an extension of the lake to the south and east around the mass of basalt, striking the present course of the Rio Grande again in Township 33. As the accompanying map was completed before seeing the above mentioned map, it was impossible to show more than a portion of this extension of the ancient lake bed, which is indicated by the dotted lines. As the limits of the ancient lake and the artesian basin are practically identical for the upper portion of the valley, and as the same conditions which make the upper portion an artesian basin hold true for the lower, it is probable that artesian water will be found in this extension as well, though I have yet to learn of any borings in this portion.

At Monte Vista the flow which is used is from 107 to 111 feet; at La Jara the first flow is found at about sixty feet, the second at ninety, and the third at 130, the amount found at the same depth being, to some extent, different for different wells, but the temperature being the same.

The shallower wells are, as is to be expected, colder than the deep ones. The temperature of nearly a hundred in different parts of the valley was taken. They varied from 46.2°, from eighty-five feet, a few miles north of La Jara, to 74.7°, from 932 feet, at Alamosa. The shallowest well observed, forty-five feet, had a temperature of 51.8°, but this was in the southeastern part of the basin, near the bend of the Conejos, near which are the Les Ojos Calientes, or warm springs, of Judge McIntire, with temperatures from 74° downwards.

The measurements, as a whole, indicate an increase of one degree Fahrenheit for thirty-four feet increase in depth, which is somewhat more than the average as found by measurements over a large portion of the earth's surface.

The wells with the lower temperatures would seem to be too cold for the best results in irrigation, but where the water is stored in reservoirs and exposed to the sun for a time its temperature would be increased. The warm water from the deep wells could be very beneficially applied, and might render possible, to a limited extent, the growth of crops which could not ordinarily be raised in the valley, or could assist in forcing early crops.

The pressure at none of the wells is great. At Monte Vista and vicinity it was from twelve to fourteen feet when first sunk for depths of from 100 to 135 feet; at La Jara, thirty feet, according to the measurements of Mr.

Carrico; twelve feet in the shallow wells south of Alamosa, and in the deepest wells at Alamosa, fifty-six feet.

The amount of water to be obtained depends upon the character of the strata as well as upon the pressure. If water passes through a stratum with difficulty, there may be wells of high pressure but small flow, and as there is a limit to the rapidity with which water can pass even through sand, the flow is not necessarily in proportion to the size of the pipe. The flow frequently increases for a time after the well is sunk, due to the formation of a pocket or small reservoir at the bottom, which, by increasing the area of the supplying surface, renders a greater flow possible with the same pressure. In general, the deeper wells have the greater flow, because of the greater pressure.

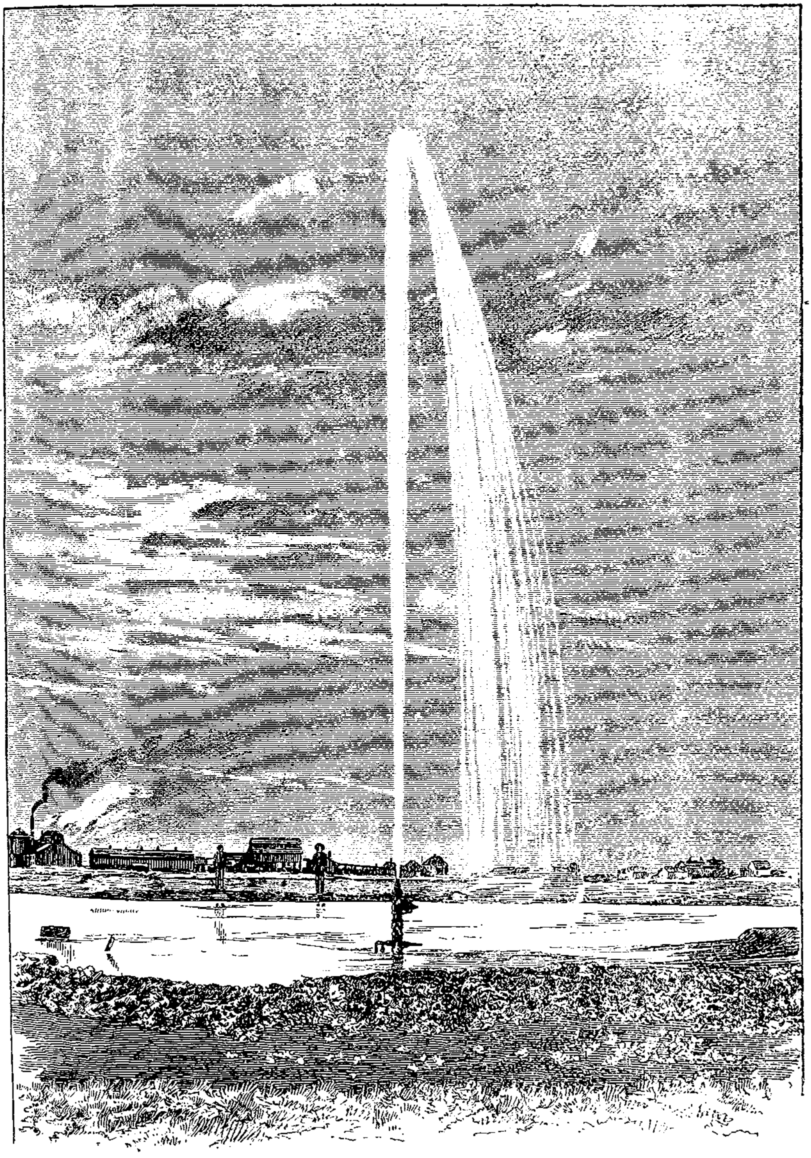
The small wells, which are generally of two-inch bore, flow from five to twenty-five gallons per minute, the latter being considered a good flow, and the cost for the same wells is from $25 to $75. The two deepest and largest wells in the valley are at Alamosa. One, the town well, which flows into a small reservior perhaps forty feet square, was measured by passing the water over a rectangular weir. The weir was placed in an opening in the bank and left for some time, until the water seemed to be neither rising nor falling in the reservoir, when the measurement was taken. The weir was 24 5-16 inches long and the depth flowing over, measured several feet from the weir, was 3 1-12 inches. Allowing a small correction for velocity of approach, this corresponds to a flow of 400 gallons per minute, or nearly one cubic foot per second.

Not far from the town well is that of Conrad Bucher, which was sunk in the summer of 1889, for oil. This was the first deep well sunk in the valley, and has the largest flow. It is nearly 1,000 feet deep, but secures the heavy flow from 932. It has a double casing, the outer one extending to between 500 and 600 feet. The water is run into a reservoir, and is devoted to the raising of carp. With the time at my disposal, it was not possible to arrange it so as to make a satisfactory measurement. When the six-inch inner pipe is reduced to three inches, it throws the stream nineteen feet into the air, and when reduced to one inch it is projected over forty feet. The accompanying view represents this well reduced to one inch. The two flows, from 932 and from 500 feet, together amount to probably 600 gallons per minute. The town well cost $1,865, the latter $2,700, a large part of the expense being for the casing.

The flow of a three-inch well of A. T. Clark, a few miles west of La Jara, which was 166 feet deep and was sunk in one-half day by six men, was ninety-five gallons per minute. The water rose seven inches above the casing.

In Township 42 north, Range 8 east, is the three-inch well belonging to Celso Espinosa, 265 feet deep, which throws a solid stream the full size of the casing 33¾ inches high. This seems to have decreased some, as Mr. Dawson informs me that he had measured it when it threw a stream forty-one inches high. The flow was between two and three hundred gallons per minute. Several others in the same neighborhood, which is near where the Carnero sinks, are reported as having flows corresponding to this.

Most of the wells have been sunk for domestic use only, and irrigation has not been specially considered in connection with them. Where the flows are large they are used to some extent, and sometimes small reservoirs have been built for storage. The three-inch well of Espinosa, already mentioned, is said to irrigate some 100 acres of hay land. J. M. Chritton writes that he was irrigating sixteen acres in 1889 from one well. L. W. Smith, a few



THE CONRAD BUCHER WELL, AT ALAMOSA, COLO.

miles west of Alamosa, irrigated forty acres of crops, consisting of oats, wheat, barley, rye and potatoes, from two three-inch wells in 1889, and stated that he intended to farm 100 acres during the present season by using a reservoir of one and one-half acres. Several wells in the vicinity of Espinosa's furnish water for irrigation.

The supply of water from the river is not yet fully used, so there is not so much inducement to consider means of using water in the quantities furnished by most of the wells, but with the closer settlement of the valley there is no doubt they will be of considerable importance in the aggregate.

The water furnished by the Bucher deep well at Alamosa exceeds one cubic foot per second, and the cost was $2,700, so that if water should reach the value it has in the older farming communities, such a well might be considered a good investment.

Whether the water is intended for irrigation or for domestic use, the supply is so important that it is a matter of great concern to know whether the limit of the supply is being reached, and whether it is affected by increasing the number of wells or not. There is a limit to the number of wells which may be sunk in any basin, which, if exceeded, will cause a decrease in all the existing wells, and may cause some to stop flowing. Because a well ceases to flow is not necessarily an indication that this limit has been reached, for the stoppage may come from other causes. The best practical test is the observation of the pressure, which depends principally on the height of the water level above the point where the test is made. If this level remains the same, the pressure is unchanged. But if this level falls, as in case so many perforations are made that the water flows out faster than it enters, the pressure falls until equality between the flow into the strata and out through the wells is again attained. A diminution of the pressure is therefore to be looked upon with some anxiety.

It becomes a question, then, of considerable importance to know whether there are indications of any lessening of the pressure. The large number of wells at Monte Vista, eighty-eight, in not over a square mile, caused particular attention to be given to that locality. Most of the inhabitants questioned had noticed no decrease, but there seems to be clear evidence there has been. When the wells were first sunk, according to Mayor Mead and others, the head was about fourteen feet. In 1889 it was still sufficient to run water into the sprinkling carts, or it was still over seven feet. Some who were supplied by pipes from this well had to lower the outlet, in order to have running water. In the fall of 1890 the head was not sufficient to force the water four feet above the ground. The well of Capt. C. S. Aldrich, editor of the *Graphic*, when first sunk had a head of fourteen feet, but when measured by myself, in 1890, it was barely five feet. I measured the well of Olando Bonner in January, 1889, and again in September, 1890, and in the meantime it had lost over one-half its force.

This should be a cause of grave concern to this community, for it indicates that if the wells are greatly increased in number in that local area, or, if some should begin pumping, their experience would follow that of the Denver and the Greeley basins, and the water would cease to flow.

The fact that such a decrease has been noticed in one place in the valley suggests the importance to the other places of keeping close watch for similar symptoms. How the pressure may be measured has already been explained.

The source of the supply for the wells is to be found at no great distance, in the streams from the mountains which pour their waters into the sands of the western part of the valley, and to a lesser extent from the streams of the eastern side. These have gradually raised a delta of sand where they enter the plain, higher than the basin proper and consisting of the coarser debris which has been brought down. Farther out in the valley, the beds of clay begin. All of the smaller streams are entirely lost in these beds of debris, as the map shows. Of those which do not disappear, it would be interesting to know whether there is any marked diminution of their volume in passing over this absorbing area. Except in high water, the streams do not extend as far as the map indicates. The watershed of the smaller streams from the west, which entirely disappear, is some 460 square miles, of the Saguache and San Luis creeks about 1,300. The amount brought into the valley by means of these streams is unknown, but the ratio it bears to the area of the watershed will be approximately the same as in the case of the Rio Grande. Through the courtesy of the State Engineer, we have been furnished with the discharge of the latter river for 1890, and by taking the area of the watershed from Hayden's maps with a planimeter, we find that the discharge of the Rio Grande, as measured at Del Norte, corresponds to a depth of twelve inches very nearly over the whole watershed. Assuming the same depth as the amount flowing off from the smaller streams, their total flow would average about 330 cubic feet per second. An unknown amount comes from the San Luis and Saguache creeks and from the mountains of the east. If we assume that this may be as much more, as seems a reasonable estimate, the total amount available would be some 600 cubic feet per second.

Taking all these sources into consideration, it seems safe to conclude that while the supply will most likely exceed 600 feet per second, it is not apt to reach 1,500.

The average flow of the present wells in the valley may be taken as twenty-five gallons per minute, whence their combined flow is in the neighborhood of 110 cubic feet per second.

It is probable, therefore, that the number of wells may be increased until the flow is six times as great, but not likely that it may become fifteen times as great.

Assuming the smaller amount as the amount of water eventually available, if it were all used in irrigation, it might irrigate, at seventy acres to the second foot, some 42,000 acres; and, if used with storage, three or four times as much.

ARTESIAN WELLS ON THE PLAINS.

A word may be said in answer to the numerous inquiries which come as to the probability of finding artesian water on the plains of Colorado. We all know that it would be of great importance if it could be found even in comparatively limited quantities. Attempts have been made at several places, widely scattered, to considerable depths. At Fort Lyon a flow of three gallons per hour was met at 430 feet, but no other to the depth of 700 feet, where the boring was stopped. At Akron, no flowing water was found. Water from a depth of 1,155 feet came within fifty-five feet of the surface. At Otis, not far east of Akron, a boring was made to the depth of 2,400 feet, but no water of any kind is reported. At Kit Carson no water was found within 1,500 feet. A well was sunk at Sheridan Lake, no water; also at Calhan, with the same result. At Cheyenne Wells two have been sunk, but without finding flowing water, though one is pumped for a railroad supply. There may be local areas, similar to the one at Coolidge, in the Arkansas valley on the Kansas line, where flowing water may be obtained, but geological evidence, as well as that obtained from these wells, show that it is improbable that artesian water will be found in any extensive area within a practicable depth.

Besides the wells already referred to, several have been struck on the western side of the range, as at Montrose and on the line of the D. & R. G. Southern. All through the mountains it is probable that small areas, with greater or less amounts of water, will be found, but the area and economic importance is not apt to be great.