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The potable waters of New Mexico : with special reference to the city water supply

John Weinzirl

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The Potable Waters of New Mexico: With Special Reference to the City Water Supply.

BY JOHN WEINZIRL.

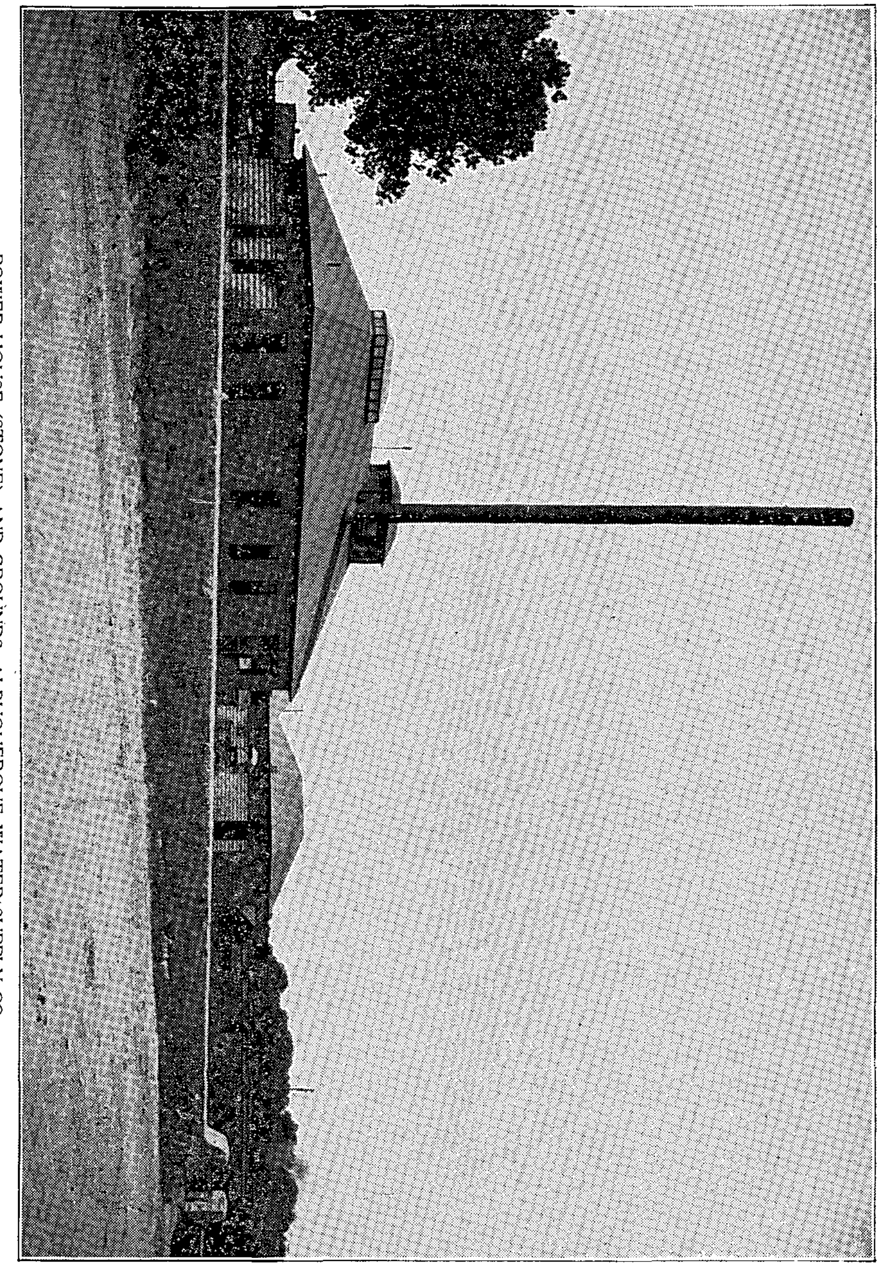
There is perhaps no more imporant problem that city governments have to meet than that of providing an adequate supply of pure and wholesome water. The importance of this problem becomes painfully apparent when the supply is suddenly found to be inadequate during the summer months when irrigation draws heavily upon the supply, or when a large fire breaks out and the water pressure is low with no means of increasing it. The importance of pure water is forced upon our attention, also, when a city is suddenly confronted by a typhoid epidemic due to an infected water supply. The number of lives lost in our larger cities due to this cause is appalling to contemplate. The census of 1890 gives a mortality of 46.3 per 100,000 of population; and for 1900, 33.8. This loss of life and accompanying suffering is unnecessary and can be reduced to a minimum by the application of the sanitary knowledge we now possess. During the past quarter century the number of cases of typhoid in our cities has been reduced by approximately one-half. The census of 1900 shows a reduction in 10 years of 27 per cent. The application of present knowledge should reduce this disease to a rarity.

Another factor that tends to increase our appreciation of a pure water supply is furnished by the general infection of water reservoirs by algæ during the summer months when the water becomes foul and almost undrinkable. Few cities, indeed, have escaped this difficulty. Fortunately, this problem is now practically solved. Then, there are certain minor troubles that are sure to enter and which render life miserable to a degree not generally appreciated. These difficulties are hardness, salt content, and especially alkalinity. By hardness is meant the power to neutralize soap, thus forming an insoluble soap or scum which interferes in washing, not to speak of the waste of soap, which is rendered useless. The constant annoyance and expense is truly serious when considered as extending through years. Again, when the mineral content of a water is heavy and is made up largely of sodium and magnesium sulphates (Glouber's and Epsom salts) which act as cathartics, many persons suffer severely from the use of such waters, and they may be forced to change their residence to a more favored place. Alkali (sodium carbonate) in water may also affect persons unfavorably, especially in cases with delicate digestion. It is usually considered the most objectionable of all the common salts contained in water, but this refers to its use for irrigation rather than for drinking purposes. This salt is the same as the cooking soda found in every kitchen where its use and action is well known. Probably we should consider it harmful to the body only when present in the water in considerable quantity.

Perhaps enough has been said to arouse the reader to a fair appreciation of the importance of the problems surrounding our water supplies. Fortunate, indeed, are those cities whose residents and officials take an active interest in meeting and overcoming these difficulties so far as may be possible. Truly the sanitary and economic intelligence of a community is measured by the success with which they meet these problems.

PLAN OF WORK.

The present investigation was undertaken from a practical point of view. No attempt has been made to trace the minor and unimportant constituents of any of the waters; rather the attempt has been to determine those elements that tend to materially improve or seriously impair the quality of the supply. Incidentally the work was intended to bear upon certain general problems having somewhat of a local character, such as the di-



POWER HOUSE (STONE) AND GROUNDS, ALBUQUERQUE WATER SUPPLY CO.

rection of the flow of the underground waters, and the source of the salts contained in them.

In stating the results of the analyses, the old plan of combining bases and acids as salts which are most probably present has been followed. The principle of ionization of salts in aqueous solutions, makes it quite certain that in drinking waters the substances are present, not as salts mainly, but as ions of Na, Ca, Mg, Cl, SO_4 and CO_3, etc. It is, therefore, not strictly correct to combine all the Cl with Na and call it Na Cl; but each of the atoms acts as an ion more or less independent of the other ions present, and exerts its own individual peculiar effect. From the point of view of the ionic theory we should go a step farther and give the amount of each element present individually, and not as oxides as is generally done; yet the writer has considered it best for the present purpose to return to the older method of stating results, giving them in grains per U. S. gallon, since this method is more familiar and hence more likely to appeal to those for whom the present bulletin is written. To save recalculation and make the results comparable with others, they are usually given as parts per 1,000,000 also.

ALBUQUERQUE CITY WATER.

The first analysis of Albuquerque city water was made by Parsons of Chicago about 1895. The data are as follows:

Sodium Chloride ($NaCl$)	2.10 grains per gal.
Sodium Sulphate (Na_2SO_4)	1.62 grains per gal.
Sodium Carbonate (Na_2CO_3)	—— grains per gal.
Calcium Sulphate ($CaSO_4$)	12.15 grains per gal.
Calcium Carbonate ($CaSO_3$)	3.20 grains per gal.
Magnesium ($MgCO_3$)	1.43 grains per gal.
Aluminum and Iron Oxides ($Al_2O_3 + Fe_2O_3$)	.42 grains per gal.
Silica ($Si\ O_2$)	.33 grains per gal.
Total	21.23 grains per gal.

In this analysis the sulphuric acid is calculated as sulphate of lime or gypsum, while no sodium carbonate is given. This statement must be wrong, since the water reacts alkaline on boiling, which is not the case with any of the substances given in the analysis. The sulphuric acid should have been calculated as sodium sulphate, and the remaining sodium as sodium carbonate. With this correction the analysis appears to be quite satisfactory as a comparison with later analyses shows.

In July, 1903, the writer made an analysis of the water from the deepest well (704 feet) which the Water Supply Company had just sunk. The analysis is as follows:

Sodium Chloride	1.03 grains per U.S. gal.
Sodium Sulphate	5.25 grains per U.S. gal.
Sodium Carbonate	1.71 grains per U.S. gal.
Calcium Carbonate	3.71 grains per U.S. gal.
Magnesium Carbonate	1.70 grains per U.S. gal.
Iron and Aluminum Oxides.	.25 grains per U.S. gal.
Silica	4.92 grains per U.S. gal.
Cryst. Water, etc..........	.18 grains per U.S. gal.
Total solids...........	18.75 grains per U.S. gal.

This water coming from the deeper strata would presumably be freer from salts than that derived from strata nearer the surface. A comparison with the first analysis shows 2.48 grains less of solids. The silica which is a neutral and inactive substance, is much more abundant, the increase being 4.59 grains. Considering the silica (sand) as neglegible, then this water is much superior, although an exact comparison cannot be made because of the method of stating the results in Parson's analysis. His analysis gives a high quantity of sulphates which seems questionable in view of a number of tests on the general supply made by the writer.

We cannot consider the above analysis as applying to water taken from the 704-foot zone, because no water was encountered here; the casing was punctured at 185 feet from the surface, and hence the water is practically from this level only.

It may not be out of place to introduce here, as a matter of record and as bearing upon the subsequent discussion, the log kept by the Water Company while drilling the deep well, since this is interesting from several points of view. This is the deepest boreing up to the present time that we have in the Rio Grande valley. The log follows:

Total Depth	No. Feet of Material	MATERIAL ENCOUNTERED
10	10	Surface material, sand, etc.
35	25	Course gravel with sand; surface water stratum.
40.5	5.5	Blue clay.
71.5	31	Course gravel and sands; this stratum furnishes eight 6-inch wells.
75.5	4	Cemented sand.
80.5	5	Yellow clay.
179	98.5	Cemented sands with streaks of sand stone.
185	6	Coarse sand and gravel; a splendid flow of water was encountered at this depth, the water rising to 18 feet from the surface.
189	4	Yellow clay.
243	54	Cemented sand and clay.
292	49	Tough yellow clay, with traces of sand.
318	26	Cemented sand.
356	38	Yellow clay.
360	4	Soft yellow clay resting on three inches of sand stone.
384	24	Sand and clay.
395	11	Shale and sand.
440	45	Cemented sand.
454	14	Yellow clay and sand stone.
469	15	Cemented sand, with streaks of sand stone.
473	4	Coarse sand and clay.
487	14	Sand and clay.
491	4	Yellow clay.
498	7	Sand and clay.
510	12	Sand, clay and gravel.
512	2	Shale.
542	30	Sand and clay.
572	30	Sand with streaks of sand stone.
614	42	Quicksand and sand stone.
638	24	Hard fine sand.
661	23	Clay, sand and sand stone.
667	6	Hard sand stone.
704	37	Cemented sand.

From the above log it is seen that three distinct water zones were encountered, viz., at 35, 71½ and 185 feet. It is also seen that the original rock strata were not reached in this boring. It may be mentioned that the same sort of material was encountered in the University and Military Post wells to be presently considered.

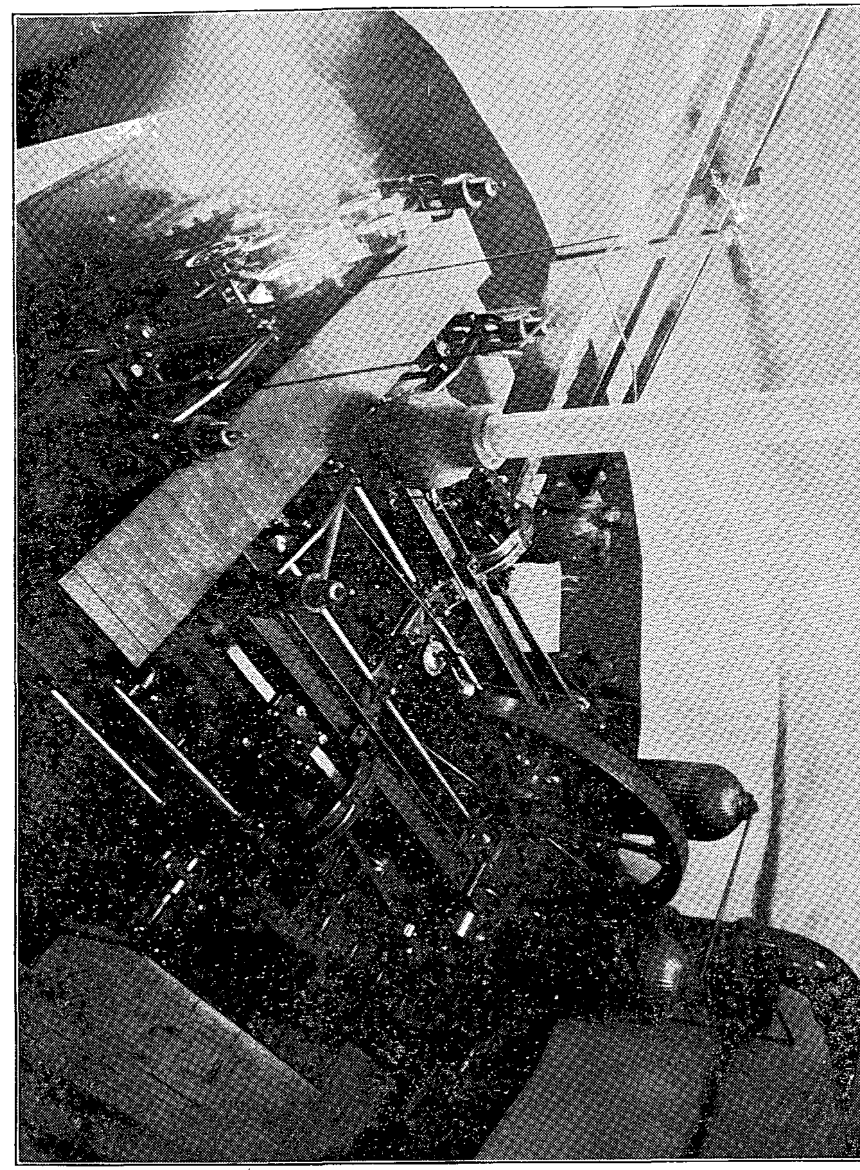
A third analysis of the city water was made in April, 1905. This sample was taken from the water mains and consisted of the mixed supply of all the wells, most of which are sunk to the 70-foot level (none being less), the deepest to 704 feet. The results are as follows:

	Parts per 1,000,000	Grains per U. S. Gal.
Sodium Chloride	25.34	1.48
Sodium Sulphate	78.49	4.58
Sodium Carbonate	5.89	.34
Calcium Carbonate	103.95	6.06
Magnesium Carbonate	24.68	1.44
Iron and Aluminum Oxides	1.20	.07
Silica	67.20	3.92
Total	306.75	17.89
Total residue heated to 150°C. for 1 hr.	304.00	17.72
Free Ammonia	trace	trace
Albuminoid Ammonia	.13	.0076
Hardness (by soap method)		7.19°

This analysis shows almost exactly the same amount of solids as the one of the water from the deep well. The two waters are, however, somewhat different in the proprtion of their salt content, the sodium chloride and calcium carbonate being higher, while all the others are lower.

COMPARISON OF CITY WATER WITH RIO GRANDE WATER.

The wells of the Water Supply Company are situated in the Rio Grande Valley, about 14 feet above the level of the river, which is one mile distant to the west. The foothills (rising 100 to 200 feet) join immediately on the east of the grounds. It, therefore, becomes a matter of considerable interest to know how this water compares with the river water, or in other words to know whether this water comes from the



PUMP PIT ALBUQUERQUE WATER SUPPLY CO.'S PLANT river by seepage, and what changes, if any, it has undergone. Unfortunately the Rio Grande water changes its character decidedly and rapidly—depending upon which of its tributaries is discharging the largest volume, and hence altering the salts it contains. A general average of samples selected during a long period of time would give a better basis for comparison, but this fact was not considered in time for the present purpose. The N. Mex. Exp. Station has results covering a year, but since the samples were taken 200 miles farther down the stream, their data are not valid here. A single analysis made in February, 1905, may be introduced here as affording some indication of conditions.

RIO GRANDE WATER.

	Parts per 1,000,000	Grains per U. S. Gal.
Sodium Chloride	41.18	2.402
Sodium Sulphate	108.23	6.312
Sodium Carbonate	23.51	1.371
Calcium Carbonate	117.16	9.803
Magnesium Carbonate	26.34	1.535
Iron and Aluminum Oxides	.80	.046
Silica	21.20	1.236
Total	291.40	22.705
Suspended matter	708.60	35.613
Total, dissolved and suspended	1000.00	58.318
Hardness		8.34°

Comparing the last analysis of the city water with the above, we notice considerable similarity, the main difference being a general increase in the various constituents, save magnesium carbonate and silica, the total increase in soluble solids being very nearly 5 grains per gallon. The silica is 2.68 grains lower, however. It would seem, therefore, that the city water is drawn to a certain extent, at least, from the Rio Grande seepage water; that its qualities are decidedly improved by the filtration; and that the more objectionable elements, such as sodium chloride, sodium sulphate, and sodium carbonate are reduced from 10.085 to 6.40 grains, or 36.6 per cent.

COMPARISON OF CITY WITH UNIVERSITY WELL WATER.

One mile east of the city water plant the University of New Mexico's well is located. This is situated above the foothills previously referred to, and on the so-called *"mesa"* or plain leading to the mountains, 9 miles distant to the east. This well is 240 feet deep, with a 6-inch casing, and affords an abundant supply of water. The question naturally arises, how does this water compare with that in the valley? A sample was taken December, 1904, after the mill had been running long enough to pump clear water. The analysis gives the following results:

UNIVERSITY WELL WATER.

	Parts per 1,000,000	Grains per U. S. Gal.
Sodium Chloride	16.98	.99
Sodium Sulphate	42.20	2.46
Sodium Carbonate	8.92	.52
Calcium Carbonate	76.50	4.46
Magnesium Carbonate	25.90	1.51
Iron and Aluminum Oxides	1.71	.10
Silica	41.16	2.40
Total	213.37	12.44
Total residue by evaporation	205.00	11.95

If we compare the above with the last analysis of the city water we note a large reduction in the total residue—a reduction of 5.77 grains or 32.5 per cent. The reduction is in the amount of sodium chloride, sodium sulphate, calcium carbonate and silica, while the other constituents remain very nearly the same.

We have here an excellent water, especially as compared with western waters generally. That it is radically different from the Rio Grande water, or even that of the city wells, is shown by a superficial consideration. It would seem that the source of this water is not the Rio Grande, but that it must be sought elsewhere.

PROPOSED MILITARY FORT WELL WATER.

Still another interesting comparison may be made between the waters given above and the well on the proposed Military Post site, which is located 7 miles east of Albuquerque, on the mesa, at a distance of about three miles from the base of the Sandia mountains. The sample of water from this well was taken December 7, 1904, by Mr. Johnson, who drilled it. The water had not yet cleared when sampled, but unavoidable conditions made it the best sample obtainable. The water was filtered, as is the case with all the samples in this record, before being analyzed. The results follow:

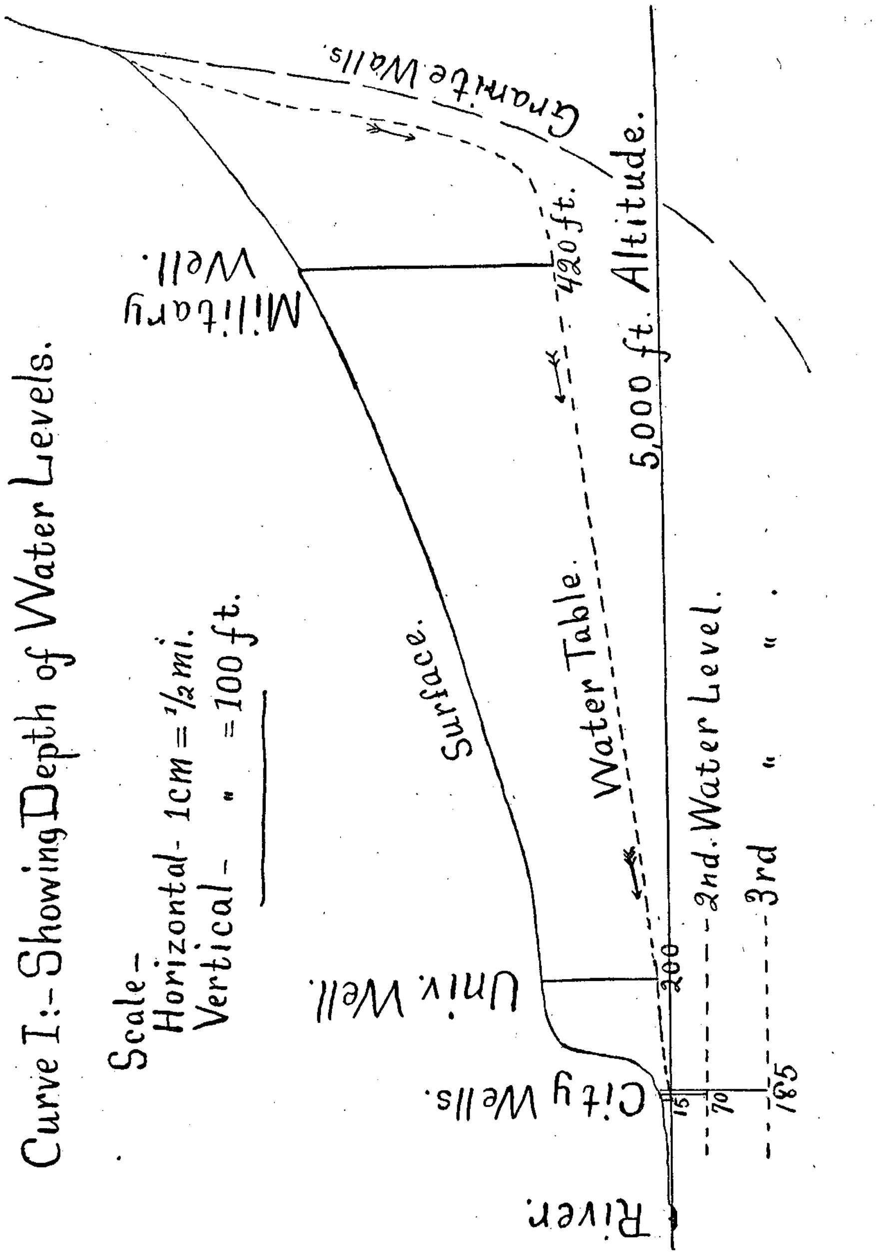
MILITARY WELL WATER.

	Parts per 1,000,000	Grains per U. S. Gal.
Sodium Chloride	2.91	.17
Sodium Sulphate	38.93	2.27
Sodium Carbonate	34.13	1.99
Calcium Carbonate	86.81	5.06
Magnesium Carbonate	4.63	.27
Iron and Aluminum Oxides	2.92	.17
Silica	27.10	1.58
Total	197.43	11.51
Residue by evaporation	197.25	11.50

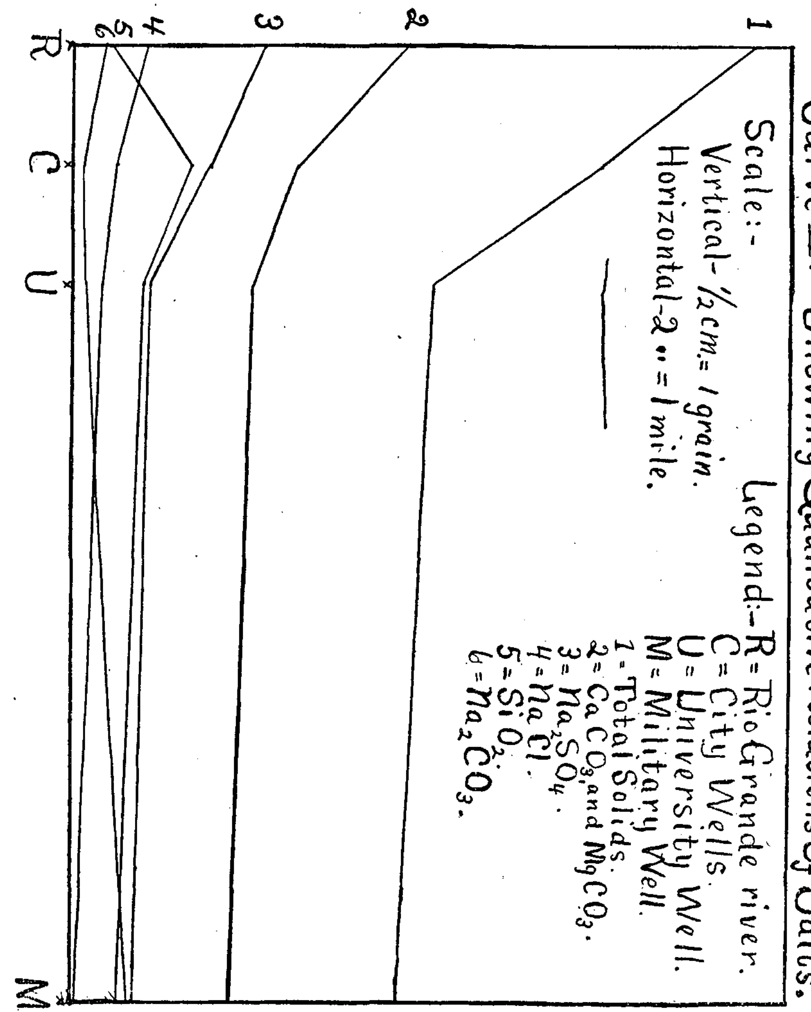
This water is quite similar to that from the University well, the solids being very nearly the same. Nor do the compounds present vary decidedly from it; there is an increase in the sodium and calcium carbonates, which may be due to the presence of the limestone cap on the Sandia mountains. The other constituents are correspondingly lower. It is certainly surprising that these two waters resemble each other so closely, and it is only natural to conclude that they have the same source.

SOURCE OF MESA UNDERGROUND WATER.

What then is the source of the underground waters of the mesa? The most natural explanation is to consider them as derived from the waters which fall on the mountains, run down the canyons, and immediately sink into the mesa gravels at the mouths of these canyons. They sink into these gravels until they reach an impervious stratum of clay, where they accumulate in a vast sheet of underground water. This view may be illustrated by the following curve, with the accompanying sketch of the granites and mesa gravels, the water resting upon the clay stratum.



To support the view just presented we have the analyses of the waters showing a remarkable similarity. This similarity, with the abrupt change on reaching the valley wells and the Rio Grande waters is best illustrated by a another curve (Curve II) which gives the total solids and the respective salts in them.



The above curve plainly indicates the similarity of the two mesa well waters, the striking difference of the river water, and the city well water forming a transition between the two; or, rather the transition is a result of a mixing of the waters from the two sources.

If the views just stated are correct, then certain important conclusion follow:

(1) If the underground waters of the mesa are derived from the waters falling in the mountains, then the supply is not inexhaustible; for if sufficient wells are sunk to drain the present water layer, which, however, is 50 feet or more in depth at the University, then no more water can be taken out than that which enters from the canyons, and this supply is limited, that is, it cannot be increased indefinitely. Actually part of the water suplied will penetrate through the clay and be found in the next clay stratum below. Hence not all of the canyon water can be obtained from the first zone.

(2) The second important conclusion is, that mountain water, or practically its equivalent, can be obtained anywhere upon the mesa by sinking wells to the first water layer or zone. For city purposes such wells are liable to prove more reliable and satisfactory than an attempt to pipe water from some canyon with its limited supply.

MOUNTAIN VS. CITY WELL WATER.

In this connection it is important to consider the question whether mountain water is more desirable than Albuquerque city well water, and whether the supply in each case is equally abundant. To answer the last and easier part of the question first,—it would seem to follow from the preceding considerations that the city well water, coming from the two sources, both the underground mountain and river waters, that this source was practically inexhaustible. On the other hand, wells sunk on the mesa to tap the mountain water zone, if sufficient in number, would probably prove fully adequate for city purposes, although this is not absolutely certain. Therefore, the present source of supply, or wells sunk on the mesa, both meet the first essential of a city water supply, viz., an inexhaustible source of water.

As to the first part of the question there would seem at first thought to be but one answer: that the mountain or underground mesa water is the more desirable, since it contains 32.5 per cent. less of solids; but an examination of Curve II

shows that, while there is an increase in nearly all the solids, this is apparently not the case with the sodium carbonate or alkaline salt. Mountain waters contain this salt in a greater proportion because it is derived, not from the mesa gravels, etc., but from the decomposition of the feldspars and similar silicates containing sodium. The reaction producing the sodium carbonate is one of hydration and carbonization due to water and carbon-dioxide from the air, and is of the following type:

$$Na_2SiO_3 + H_2CO_3 = Na_2CO_3 + SiO_2 + H_2O.$$

This reaction occurs mainly, if not wholly, in the granites containing the feldspars, and is, therefore, most active in the mountains.

The fact that the sodium carbonate decreases gradually is explained by its reaction with the calcium salts that it meets. The reeaction is as follows:

$$Na_2CO_3 + CaSO_4 = Na_2\,SO_4 + CaCO_3,$$

or possibly,

$$Na_2CO_3 + CaCl_2 \text{ (present as ions)} = 2\ Na\,Cl + CaCO_3.$$

Thus the sodium carbonate decreases, while sodium chloride and sodium sulphate increases, which agrees with the observations. Apparently the calcium carbonate is greatly increased, but this is not necessarily so, for if the carbonic acid decreases, which is apt to be the case, then this salt is deposited as the substance cementing the gravels and sands, it may, therefore, be actually decreased, thus decreasing the total solids of the water and at the same time rendering it softer.

The reduction in passing through the gravels, of the amount of sodium carbonate, and possibly of calcium carbonate also, lessens or even nullifies the advantage that mountain water may have over mesa, or even valley waters. (For discussion of principles here outlined, see Chamberlin's and Salisbury's Geeology, Vol. I, 1904.) If, however, we consider all the salts of a water objectionable, then the advantage probably remains with the mountain water, because, in its passage through the soil, certain salts are apt to be more than proportionately increased.

If now we consider the question as a whole, we may say that, if the supply of mountain water is positively known to be fully adequate to meet any demand that is likely to be made upon it, then it may be somewhat the more desirable of the two; but if the quantity is uncertain, then the valley or mesa source becomes in general the more satisfactory.

SANITARY CONSIDERATIONS.

Let us now return to the sanitary consideration of these waters. Plainly they must all be considered in prime sanitary condition coming from deep wells, with no objectionable features surrounding them. The city water supply is pumped into the mains and part of this overflows into a reservoir situated on the mesa about one mile east of the wells. This reservoir holds about 4,000,000 gallons, the supply stored averaging about 3,000,000. This reservoir serves two purposes: firstly, it serves to give a suitable water pressure for fighting fires in the city; and, secondly, it saves running the pumps at night. Desirable as these objects are, they are offset in part, if not wholly, by certain attendant disadvantages, as follows: firstly, the water in the reservoir is not regularly emptied, hence it partakes of the nature of stagnant water; secondly, an open reservoir is subject to infection by typhoid and other bacteria, and at best furnishes a favorable breeding place for algæ (so-called green moss of pools) which, while harmless in themselves, yet decompose and give the water a putrid odor and flavor. This latter difficulty is encountered by all cities having such reservoirs, the trouble becoming so pronounced during the summer months that the water is largely abandoned for drinking purposes. Fortunately this difficulty is practically solved by the "copper treatment" discovered by Dr. Geo. T. Moore and K. F. Kellerman (Bul. No. 64, Bureau Plant Ind. U. S.. Dept of Agr.). This treatment consists in adding to the water stored a small amount of copper sulphate not to exceed one part per million. This exceedingly dilute solution which is harmless to animals, is sufficient to destroy the vegetative cells of the algæ and many other plants, including most species of bacteria. The treatment is, therefore, available also as a weapon against typhoid when infection has taken place. However, it was not intended by the authors that this treatment should take the place of scrupulous care on the part of water companies to keep their supplies pure, but merely as a weapon to be used when occasion absolutely demanded it. In other words, a reservoir should be cleaned at short intervals, say every three months, and at no time should the supply be allowed to become stagnant.

EXPERIMENTS WITH COPPER TREATMENT.

For several seasons the reservoir of the Albuquerque Water Supply Company has been badly infected by algæ, thus causing both the consumers and the company great annoyance. Extensive improvements were made to combat this trouble, but with little success.

After consultation with the City Physician, Dr. J. W. Elder, who has taken an active interest in the city's sanitary welfare, the writer recommended, a trial of the copper treatment ,and the same was applied July 20, 1904. Twenty pounds of copper sulphate were carefully applied to about 4,200,000 gallons of water, thus making a porportion of one part of the salt to 1,750,000 parts of water. This amount is so small that when a litre of the water was evaporated the residue failed to give a test for copper with potassium ferrocyanide.

A bacteriological analysis of a sample of the water taken immediately before applying the treatment gave 208,000 bacteria to the cubic centimetre (about 20 drops). A similar analysis on July 23, two days after the treatment (more accuratey 42 hours) gave 58,000 bacteria per cc., or a reduction of 72 per cent. At the same time all floating algæ had disappeared, those clinging to the walls of the reservoir had turned brown and were rapidly settling to the bottom, dead. The flavor and odor of the water was noticeably improved, but the trouble was not wholly overcome.

By July 29, the conditions had grown worse again and a second treatment was given. This time 25 pounds of copper sulphate were used, giving a proportion of 1 to 1,400,000. The treatment sufficed to kill out the algæ pretty thoroughly with a decided improvement in the water. No more treatments were given for algæ.

Following the heavy rains and floods of October, 1904, Albuquerque had a slight epidemic of typhoid in November. Water taken direct from the reservoir showed gas production when inoculated into glucose bouillon fermentation tubes incubated at 39-40°C. The organisms present resembled B. *coli communis*; it was, therefore, decided that the application of the copper treatment would be a safe precaution to take, which was done. The epidemic died out within a month. That the supply was infected cannot be positively stated, since the analyses were not adequate to prove this point. At this time part of the water supply was still taken from shallow wells (20 feet deep) which gave water not much better than that from the surface. Since then these wells have all been closed and no water comes from less than the 70-foot level.

At the present time (June 5, 1905) there is no typhoid in the city, and the water has no bad flavor or odor. An inspection of the reservoir shows the water free from algæ and perfectly clear, a condition never before seen by the writer during eight years of observation, the algæ having persisted even during the winter months. It is worth whille recording, however, that at present, Chara—a more highly organized genus of plants—has taken possession, the bottom and sides of the reservoir being covered. What the effect of this plant will be upon the water remains to be seen. We do not intend to apply the copper treatment unless this becomes absolutely necessary.

CHEMICAL SANITARY TESTS.

An analysis made by Merck & Co., New York, in May, 1902, gave the following:

Chlorim as Sodium Chloride, 33 parts per 1,000,000.

Free Ammonia, 0.004 parts per 1,000,000.

Albuminoid Ammonia, .014 parts per 1,000,000.

Nitrates and Nitrites, absent.

The conclusion is as follows: "This water at the time of examination is exceptionally pure and free from all contamination. . . . It could be used with perfect safety for drinking and other domestic purposes."

Referring back to the writer's recent analysis, we see that the chlorides are lower than given by Merck, the free amonnia is present as a trace only, while the albuminoid ammonia is 0.13 parts per 1,000,000 or somewhat higher. Still, this falls within Merck's standard of safety which is 0.15 parts. The

water, therefore, easily meets the requirements of a chemical sanitary examination. It is doubtful, however, whether such a favorable report would be obtained during the summer months when the algæ are numerous.

Certainly the bacterial content recorded above (208,000 per cc.) is excessive and undesirable. In comparison, a pure well water such as the water under consideration originally is, would contain perhaps 10 to 100 per cc. This large increase in the number of bacteria in water from the reservoir is due to the fact that the water is allowed to remain in the reservoir and become partially stagnant. This difficulty could be partially remedied by dividing the present reservoir so as to make two, the water being pumped into one while the other is emptying and *vice versa*. This would give frequent renewal of the water stored. Or still better would be a standpipe without any reservoir. This would demand greater pumping capacity, the engines being run continuously, and perhaps also a larger number of wells.

With some improvement in the method of handling the water, and with our new method of fighting algal contamination, it would seem that Albuquerque possesses an abundannt supply of pure and wholesome water, thus meeting the two prime essentials of a city water supply.

MINERAL WATERS NEAR ALBUQUERQUE.

Before passing on the consideration of the water supplies of other cities of the territory, we may, perhaps, better discuss the mineral waters found near Albuquerque, thus completing the waters of Albuquerque and vicinity.

We have as yet no reliable analysis of the water at Whitcomb Springs, though it is known that these springs are heavily charged with mineral, especially calcium carbonate which is quite extensively deposited where they issue from the mountains. Free carbon-dioxide is also present in quantity. These springs are situated in one of the canyons of the Sandia mountains, known as Tijeras Canyon, about 20 miles east of Albuquerque. Although sold in small quantities formerly, it is not now upon the market.

COYOTE SPRINGS.

These Coyote Springs are located in Hell Canyon a few miles south of Tijeras, in the same mountain range, and about 12 miles east of Albuquerque. Waters from three separate sources are bottled and marketed in the city. Analyses from three springs are available.

TOPHAM'S COYOTE WATER.

This mineral water was analyzed in May, 1901, with the following results:

Sodium Chloride	15.87	grains per U.S. gal.
Sodium Sulphate	5.68	grains per U.S. gal.
Sodium Carbonate	0.75	grains per U.S. gal.
Calcium Carbonate	23.51	grains per U.S. gal.
Magnesium Carbonate	6.62	grains per U.S. gal.
Iron and Aluminum Oxides	.43	grains per U.S. gal.
Silica	1.17	grains per U.S. gal.
Total	54.03	grains per U.S. gal.

Residue on evaporation, heated to 180°C—1 hour, 48.99.

There are also traces of potassium and lithium chlorides, and phosphates.

A second analysis of this water was made in March, 1905, with substantially the same results, save that the residue on evaporation at 150°C was 53.55 grains. The residue in the first analysis was undoubtedly heated too high, thus causing a loss in carbon-dioxide. The free carbonic acid gas was determined in the second sample and gave as a result 268.51 grains per U. S. gal., or 2335 cc to the litre. It is not certain that this water was not partly charged in the bottling works.

This water, which is bottled and sold extensively in the city, is not a heavy mineral water and is especially adapted for persons with whom the heavier waters do not agree. It is a very pure water, and when charged gives a highly agreeable drink.

HARSCH'S COYOTE WATER.

There are two springs from which Mr. A. Harsch gets water; the springs are called by him the "Iron" and the "Soda Springs." Practically all his extensive trade is supplied from the soda spring, however. The results from the two springs are as follows:

SODA SPRING.

	Parts per 1,000,000	Grains per U. S. Gal.
Sodium Chloride	625.68	36.48
Sodium Sulphate	169.66	9.89
Sodium Carbonate	82.31	4.80
Calcium Carbonate	533.66	31.11
Magnesium Carbonate	193.49	11.28
Iron and Aluminum Oxides	24.00	1.40
Silica	13.20	.77
Residue on evaporation	1642.00	95.73

Free Carbon-dioxide, 2463.00 or 1250 cc. per litre.

Potassium chloride and a trace of phosphates are also found.

IRON SPRING.

	Parts per 1,000,000	Grains per U. S. Gal.
Sodium Chloride	689.04	40.17
Sodium Sulphate	164.29	9.58
Sodium Carbonate	59.50	3.47
Calcium Carbonate	633.67	36.94
Magnesium Carbonate	205.30	11.97
Iron Oxide	33.58	1.96
Aluminum Oxide	29.62	1.73
Silica	11.20	.65
Residue on evaporation	1826.20	106.47

Free Carbon-dioxide, 1619.20 or 822 cc. per litre.

It is seen that both these waters are quite heavy mineral waters. The carbon-dioxide is abundant, giving a pure clear sparkling water with an agreeable taste. In the case of the "iron water," the iron was separated and determined quantitatively, the result showing an appreciable amount of iron. It is not sufficient to separate as iron oxide and so precipitate on the bottle.

The value of all these waters depends mainly upon the sodium salts they contain. The sodium chloride promotes thirst, hence more water is taken into the body, and the leaching, so to speak, of the system is greater. The sulphate is Glauber's salt and is a cathartic in its action. The carbon-dioxide present makes the drink most agreeable and may be of value in stimulating gastric digestion in certain cases. The importance of calcium and magnesium salts in the body is undoubtedly great, but whether they are readily absorbed from mineral waters and rendered available for the tissues is uncertain.

SANTA FE CITY WATER SUPPLY.

Passing now to the consideration of the water supplies of the other cities of the territory, let us take up the several cities with reference to their location on the larger streams or their tributaries, taking them in order down stream. Beginning with the Rio Grande river, the first city to consider is Santa Fe, which takes it supply from one of the tributaries rising in the mountains near by. The water is piped to the city.

SANTA FE WATER.

	Parts per 1,000,000	Grains per U. S. Gal.
Sodium Chloride	15.84	.92
Sodium Sulphate	24.00	1.40
Sodium Carbonate	7.01	.41
Calcium Carbonate	85.47	4.98
Megnesium Carbonate	33.08	1.93
Iron and Aluminum Oxides	7.14	.42
Silica	15.56	.91
Total	188.10	10.97
Total residue on evaporation	193.00	11.25

Hardness, 7.1°.

From the above we see that Santa Fe has an excellent water supply so far as its mineral content is concerned. All the constituents are low, calcium carbonate or lime stone being the most abundant. This with the magnesium carbonate makes the water somewhat hard for washing and boiler purposes, but it is not excessively hard.

Further data cannot be given because of lack of information. A request for fuller information was sent to the Water Supply Company of Santa Fe, and this request was duly received as instanced by its publication together with the analysis, in the Daily New Mexican. The manager of the company is Frank Owen.

Probably this supply is subject to certain difficulties which are generally characteristic of supplies taken from flowing streams.

1. The supply is likely to run short at times, due to prolonged drouth or excessive irrigation.

2. In times of heavy rains in the mountains, the supply is certain to be muddy. This difficulty can be partially overcome by a sufficient number of reservoirs where the solids are allowed to settle. If the reservoirs have sufficient capacity and are kept full, the supply from the stream may be shut off until the flood period is past. This is the more satisfactory method.

3. Streams are always subject to possible infection from careless residents living near them. Typhoid excreta allowed to pass into the stream present the most serious possibility, though this is not very likely to happen in mountainous districts such as the above is.

4. The reservoirs are certain to be infected by algæ during the summer months.

SOCORRO WATER SUPPLY.

After Santa Fè we should consider Albuquerque's water supply; since that has been done at some length, we may take up Socorro, the next in order. Socorro, like Albuquerque, is situated on the Rio Grande, and about 100 miles south of that city. Its water supply, however, is taken from a small group of springs in the mountains, about 4 miles to the west. The water from the whole group of springs is caught in a small basin from which it is piped to the town. Unfortunately this water is not carried continuously through pipes, but is used at intervals by certain flour mills for power, and at several other places for domestic and irrigating purposes. This gives opportunity for possible contamination of an otherwise ideal water supply. Probably this could not be prevented due to old water rights. The temperature of the water at the springs is about 92°F. The sample analyzed was kindly provided by Dr. C. Edw. Magnusson, then of the School of Mines. It was taken November 21, 1903. The analysis is as follows:

SOCORRO WATER.

	Parts per 1,000,000	Grains per U. S. Gal.
Sodium Chloride	71.36	4.16
Sodium Sulphate	67.07	3.91
Sodium Carbonate	21.78	1.27
Calcium Carbonate	52.14	3.04
Magnesium Carbonate	20.41	1.19
Iron and Aluminum Oxides	1.20	.07
Silica	24.36	1.42
Total residue by evaporation	258.32	15.06

Hardness (soap method), 5.55°.

This water contains about four grains more solids than the Santa Fe water, and nearly three grains less than the Albuquerque city water. The calcium and magnesium salts are low, thus rendering the water quite soft and excellent for laundry purposes. The other salts are somewhat higher, but they are far from being excessive. Certainly such a water supply is a valuable resource to the town.

It may be noted that the reservoir at the springs from which the water is piped, is so small that algal contamination is never likely to become serious. The only question concerning this supply is its adequacy to meet the demands. While it may be sufficient for the present it is difficult to see how the supply could be greatly increased to meet the demands of an increased population.

It may be noted that this is the only municipal or public water supply in the territory not owned by a private corporation.

SILVER CITY WATER SUPPLY.

Silver City is located in the southwestern part of the territory, and takes its water supply from a branch of the Rio Mimbres, a tributary of the Rio Grande. The Silver Valley Water Works, a company supplying the city water, kindly furnished the analysis published below, but the author of this analysis could not be learned, though a special request to the superintendent was made for it.

The analysis, however, is as follows:

Silica	1.109	grains per U. S. gal.
Oxide of Iron and Aluminum	.070	grains per U. S. gal.
Carbonate of Lime	9.830	grains per U. S. gal.
Sulphate of Lime	3.652	grains per U. S. gal.
Carbonate of Magnesia	3.769	grains per U. S. gal.
Sodium and Potassium Sulphates	trace	
Sodium and Potassium Chlorides	.990	grains per U. S. gal.
Loss, etc.	.436	grains per U. S. gal.
Total	19.856	grains per U. S. gal.

The above analysis gives no sodium carbonate or alkali present. Either this water is radically different from the other waters of the territory, or the analyst has made an error in interpreting his results. Since this water is taken from a flowing stream there is no reason to believe that it differs radically from other New Mexico waters and is, therefore, alkaline. That is to say, the sodium and potassium were probably not determined, but if they had been they would have been found sufficient to saturate all the chlorin and sulphuric acid found, leaving a remained which must be considered as sodium carbonate. This fact could easily have been determined by boiling the water and testing it for the presence of alkali. Assuming then the analysis to be correct and that the error has been in interpretation, we observe that about two-thirds of the residue is carbonates of lime and magnesia, thus rendering this water very hard. This would cause much trouble in the laundry, and is undesirable for boiler and other purposes. The other constituents, however, are low in amount thus giving a very satisfactory drinking water.

It is to be regretted that we haven't another analysis of this water. Superintendent A. F. Nichol was requested to supply a sample for analysis, but failed to avail himself of the opportunity offered.

It apears that the Rio Mimbres has been subject to serious floods which have interferred more or less seriously with the water works. It also seems that improvements are contemplated which will overcome this difficulty.

There is no reason to suppose that this water supply is not subject to all of the disadvantages enumerated under the Santa Fe water.

LAS VEGAS WATER SUPPLY.

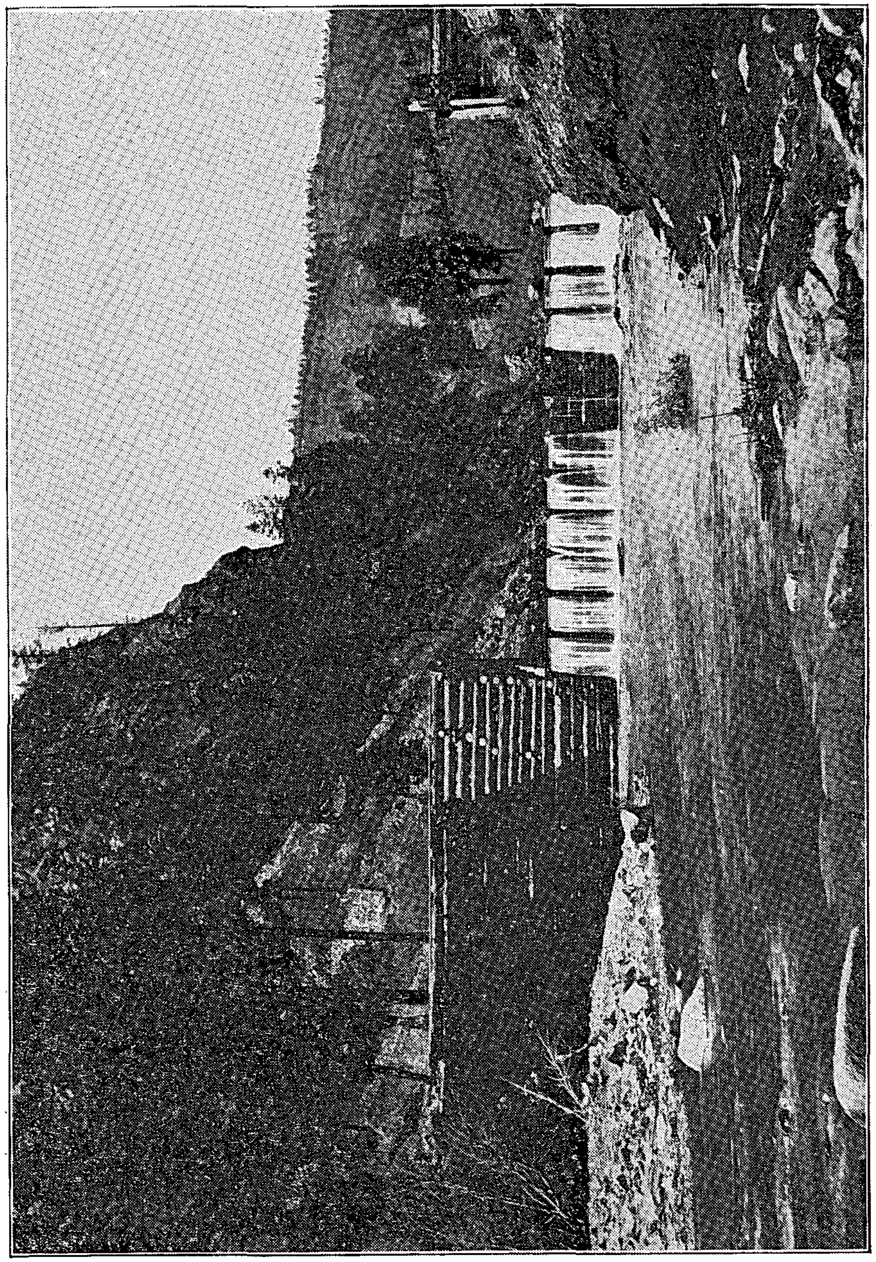
The water supply of Las Vegas is drawn from the Gallinas river, a tributary of the Rio Pecos, and hence belongs to a different drainage basin from the waters so far considered. The supply is taken above the Las Vegas Hot Springs, seven miles distant from the city. It is carried all the way through a 12-inch iron pipe and stored in a reservoir two miles from town. The supply has always been ample and can be largely increased. Heavy rains flood the stream and cause the water to become muddy, but this difficulty is guarded against by shutting off the supply pipes to the reservoir. This reservoir holds sufficient water to supply the city for a week, when the trouble would ordinarily have subsided.

A sample taken from the city mains March 20, 1905, gave the following results when anaylzed.

LAS VEGAS WATER.

	Parts per 1,000,000	Grains per U. S. Gal.
Sodium Chloride	15.84	.92
Sodium Sulphate	6.34	.37
Sodium Carbonate	17.31	1.01
Calcium Carbonate	73.58	4.29
Magnesium Carbonate	13.93	.81
Iron and Aluminum Oxides	.80	.05
Silica	16.04	.94
Total	143.84	8.39
Total residue on evaporation	121.60	7.09
Ammonia, free	none	none
Albuminoid	.1325	.0077
Hardness	102.00	5.95°

The analysis shows this to be an exceptionally pure water, both from a mineral and sanitary point of view. All the salts



RESERVOIR AND CENTER INTAKE, AGUA PURA CO., LAS VEGAS.

are slight in quantity excepting the calcium carbonate, and this is present in a moderate quantity, thus making the water quite soft.

The Las Vegas water supply is provided by the Agua Pura Company, of Las Vegas. Mr. F. H. Pierce is secretary of the company.

OTHER WATER SUPPLIES.

There are several other cities in the territory whose water supplies fall within the scope of this paper. A personal letter was addressed to the mayor or the water company in each case, but no word has been received. Whether the trouble is with the water or the officials the reader must decide for himself.

Raton, located near the northern boundary, is said to take its supply from mountain springs, but that this supply has not been adequate at all times.

Roswell does not have a public supply, but is blessed in having a number of artesian wells. It is understood that the town is taking steps preliminary to providing a public supply which will be more available, especially in case of fire.

Gallup has a public supply, but it has been found inadequate at times. Here a larger supply is planed for the near future.

The writer is not aware of any other towns in New Mexico having a public water supply.

GENERAL CONDITIONS.

If now we consider the public water supplies of New Mexico as a whole, we find that they are most excellent. Few cities are blessed with a purer supply. As to mineral content, Dr. Smart, an American authority, gives 17.5 grains of solids as a safe limit, but that 58.3 grains should condemn a water. Wanklyn, the English authority, gives 33.5 grains as permissible. W. W. Skinner, of the University of Arizona, says that western waters cannot be judged by the old standards, and proposes the following standard for sanitary purposes:

From 0 to 29.15 grains—good.
From 29.15 to 58.30 grains—fair.
From 58.30 to 116.60 grains—acceptable.
Above 116.60 grains—bad.

Judged by this standard the above waters are excellent indeed. Judged by the older standards of safety, then all the waters meet them.

It appears almost increditable that waters from New Mexico, with its relatively unleached soil and its ignious rocks and lime stones, should show such a moderate mineral content. The explanation probably is as follows: All of the waters contain sodium carbonate. This precipitates the lime or calcium carbonate that is taken up from the lime stone regions, producing a water that is relatively soft and having a low amount of salts, especially lime and magnesia.

Another point of general interest which may be inferred from the consideration of the waters of Albuquerque and vicinity, is, that the formation of valley gravels, mesa, etc., is general for river towns in the territory. It follows, therefore, that all or at least most of these towns could take their supplies from wells sunk on the mesa near the town. Such wells would give them substantially mountain water which could be used separately or added to the existing supply if desirable. This valuable resource should not be overlooked.