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LOS ALAMOS PROJECT

LOS ALAMOS, NEW MEXICO

Report On

WATER SUPPLY

Black & Veatch
Consulting Engineers
Kansas City, Missouri
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7426

Report on

Water Supply

Los Alamos Project

1. General.

The Los Alamos project has been subjected to frequent and recurring water shortages since its inception. This condition has resulted for the most part from continually increasing project requirements, which substantially exceeded original estimates, and from the failure of available supplies to meet originally anticipated yields.

During the development of the Project additional water supply was provided from time to time by a series of temporary expedients. Each was dictated by an immediate emergency which made it necessary to develop additional sources in the shortest possible time. In each case construction was accomplished with materials most readily available and in accordance with emergency wartime standards. The success of the water supply program is attested by the fact that water was made available from severely limited resources in sufficient quantity to permit the Project to complete its major mission.

The present water supply is not adequate for the continuing requirements of the Project. It is the purpose of this report to present an engineering analysis of the situation and to submit recommendations whereby an adequate and permanent water supply can be provided.

2. Previous Water Supply Investigations.

All reports of investigations of the Los Alamos water supply prior to October 1943 are included in a comprehensive report prepared by the U. S. Engineer office, Albuquerque District, dated 9 October 1943. A subsequent report prepared by W. C. Kruger, Architect and Associates, R. O. Ruble, Engineer, covers the operation of the system to January 1945. The data

contained in these reports have been of much value in connection with this study.

3. Water Consumption.

Water consumption at the main Project site has been metered since March 1944. Water used by the outlying sites is not metered and these uses have accordingly been estimated. Table I is a record of water consumption for the years 1944 and 1945 on the basis of the best available information.

Table I

Water Consumption for 1944 and 1945

Year	Month	Metered at Project	Guaje Meter	Outlying Sites (Estimated)	Total for Month	Average Day
1944	Jan.	6,000,000 Est.		350,000	6,350,000	204,800
	Feb.	6,000,000 Est.		900,000	6,900,000	246,400
	March	7,877,400		2,370,000	10,247,400	330,500
	April	6,975,900		2,800,000	9,775,900	325,900
	May	7,112,900		2,990,000	10,102,900	325,900
	June	7,801,100		3,015,000	10,816,100	360,500
	July	8,108,800		3,115,500	11,224,300	362,000
	Aug.	8,871,100		3,115,500	11,986,600	386,600
	Sept.	8,337,400		3,015,000	11,352,400	378,400
	Oct.	7,794,900		3,115,500	10,901,400	351,700
	Nov.	8,181,400		3,015,000	11,196,400	373,200
	Dec.	8,958,900		3,115,500	12,074,400	389,500
1945	Jan.	10,724,200		3,115,500	13,839,700	446,400
	Feb.	10,857,500		2,814,000	13,671,500	488,300
	Mar.	11,528,500		3,115,500	14,644,000	472,400
	Apr.	12,187,300		3,015,000	15,202,300	506,700
	May	15,398,500		3,115,500	18,514,000	597,200
	June	14,630,600		3,015,000	17,645,600	588,200
	July	15,625,600		3,115,500	18,741,100	604,500
	Aug.	15,049,500*	7,096,200	3,115,500	25,261,200*	814,900*
	Sept.	12,731,800	7,646,700	3,015,000	23,393,500	779,800
	Oct.	11,989,500**	7,969,100	3,115,500	23,074,100	744,300
	Nov.	12,532,600	7,034,500	3,015,000	22,582,100	752,700
	Dec.	10,511,500***	2,906,100****	3,115,500	16,533,100	533,300

Note:- *Water metered at project is believed to include a part of the water previously metered by Guaje meter. Total for month and average day for August 1945 is, therefore, believed to be greater than actual usage.

**Includes 1,000,000 gallons estimated for Oct. 3-4-5.

***Meter not operating 19 December.

****No flow 14 December to 29 December inclusive.

The following Table II is a tabulation of the population by groups for the last nine months of 1945. These figures indicate that water consumption for all purposes, including industrial usage, has varied from 71 gallons per capita per day to 109 gallons per capita per day during this period. During the period September, October and November, for which water consumption records are believed to be reasonably accurate, the per capita consumption was 109 gallons per day, 107 gallons per day and 99 gallons per day respectively. If the estimated industrial usage of 200,000 gallons per day is subtracted from the total consumption, the average for domestic consumption for the three month period becomes 77 gallons per capita per day. This is very conservative when compared with water use in cities having similar climatic conditions and reflects the conservation measures which have necessarily been imposed.

Table II

Population by Groups - 1945

Month	Technical Staff	Post Employees	Army Personnel	Navy Personnel	Children	Soldiers	Contractors' Employees	Total
April	1762	1473	100	55		2929	296	6615
May	1933	1534	115	61		2718	716	7077
June	2079	1629	120	66	883	2803	725	8305
July	2095	1653	127	74	899	2789	480	8117
August	2073	1537	138	89	896	2610	295	7638
Sept.	1938	1495	153	96	901	2354	211	7148
October	1784	1530	154	96	852	2278	273	6967
Nov.	1717	1727	165	82	923	2791	216	7621
Dec.	1680	1768	174	84	881	2706	237	7530

4. Project Water Requirements.

Current planning for future Project requirements is based on a total population of 5000, as follows:

Technical Personnel	1200		
600 families at 3 persons per family		1800	
Single women		300	
Single men		300	
			2400
Service Population			2400
	Total		4800

New permanent housing for immediate development is being planned on the basis of 500 two and three bedroom units. This will require the development of a site not presently included in the housing area.

Water supply for a permanent development must be on a more liberal basis than has been possible during the emergency period. Strictly domestic usage can be expected to increase to approximately 100 gallons per capita per day. In addition allowances must be made for lawn beautification and other irrigation. It is believed that a minimum of 18 inches of irrigation water per annum will be required to supplement the annual rainfall of 18.5 inches in order to maintain lawns, shrubbery and gardens. The estimated average daily demand will therefore be:

Domestic		
5000 persons at 100 g.p.c.d.	500,000	gallons
Industrial and Commercial	250,000	"
Irrigation		
500 acres at 18" per year	670,000	"
Public Uses and Loss	80,000	
Total	1,500,000	"

If the irrigation requirements are furnished during a six month season, this will result in a demand of 2,170,000 gallons per day during six months of the year and a demand of 830,000 gallons per day during the remaining six months of the year.

5. Existing Supply Works.

The existing sources of water supply are described in detail in the reports of other investigations which have previously been referred to. The following summarized description is included for ready reference:

(a) Los Alamos Creek.

This constituted the original water supply to the project. A small rockfill dam collects the drainage from approximately 6.3 square miles and impounds approximately 13 million gallons of water. A collection system below the dam intercepts the small amount of leakage through the structure and this is pumped back to the reservoir. A six and eight inch pipe line having a maximum capacity of 525,000 gallons per day leads from the reservoir to the main project site.

(b) Water Canyon.

This source consists of a small diversion dam and intake structure which intercepts the run-off from a drainage area of approximately 2.5 square miles. A six inch flow line having a maximum capacity of 475,000 gallons per day conducts the water from this source to a point of connection with the supply line from Los Alamos reservoir. A part of the water from this source is taken from the pipe line en route and is pumped to four storage tanks having a total capacity of 160,000 gallons which supply S-Site, No. 2 Fire Station and T-Site.

(c) American Spring.

This is a small but reliable source located on a drainage area adjacent to Water Canyon. The flow of the spring is intercepted and conducted through a 2-inch line to the intake in Water Canyon.

(d) Valle Canyon.

The normal stream flow from this small drainage area is conducted through a 4-inch line to the storage tanks which supply S-Site. This source is not available during the winter months because of freezing.

(e) Pajarito Canyon.

The intake in Pajarito Canyon intercepts the flow from a drainage

area of 2.0 square miles. A new 6-inch flow line conducts the water from the intake to a 30,000 gallon tank which supplies the Anchor Ranch installation. The overflow from the tank is conducted to a junction with the Water Canyon line. Any surplus water at the intake is conducted in a metal flume to a small open reservoir at Anchor Ranch which is used as a reserve fire supply.

(f) Guaje Canyon.

This supply is delivered through approximately 33,800 feet of four, five and six inch pipeline which is constructed over rough and difficult terrain. The drainage area above the point of diversion is approximately 5.6 square miles. The maximum yield from this source is approximately 170 g.p.m. which is the maximum capacity of the pipe line. The pipe line has been winterized but operation during the winter months is unreliable owing to difficulties in keeping the line open. The supply line connects with the Project system near the West gate. Water can be discharged into the system by gravity or into the Los Alamos reservoir by the operation of a booster pump. The maximum capacity of the line is obtained with the operation of the booster pump.

Figure 1, which has been prepared from Plate No. 1 "Report on Water Supply Los Alamos Project" by U. S. District Engineer Office, Albuquerque District, dated 9 October 1943 and drawing titled "Operation Map, Water Supply System", numbered OPR-1, revised 10 January 1946, shows the location and arrangement of existing water facilities.

6. Operation of System.

The 13 million gallon reservoir in Los Alamos Canyon constitutes the major portion of the distribution storage and is so situated as to receive and store any surplus water from the other sources.

The Water Canyon line receives water from the American Spring, Water

Canyon, Valle Canyon and Pajarito Canyon. From this system are served S-Site, Fire Station No. 2, T-Site, Anchor Ranch Site and Two Mile Mesa. The latter installation is served by a 30,000 gallon tank which is supplied from the line and kept filled by means of an altitude valve. Surplus water from the Water Canyon line is used to supply a 300,000 gallon tank located on high ground near the junction with the line leading from Los Alamos Reservoir and the remainder is discharged into Los Alamos Reservoir. With the exception of the water taken off to supply the S-Site storage tanks, the operation of this system is by gravity.

The Guaje Canyon line normally discharges into the distribution system but surplus water from this source can be pumped into the Los Alamos Reservoir.

A 250,000 gallon elevated wooden storage tank provides pressure on the distribution system. This tank is filled from the Guaje line or by gravity from Los Alamos Reservoir. Two 150,000 gallon wooden ground storage tanks provide emergency fire storage, the water being made available by two engine driven fire pumps.

7. Yield of Various Water Sources.

Accurate and continuous measurements of the yield from the various sources during the past three years have not been maintained. However, operating experience with the system makes it possible to determine rather closely the capabilities of the supply.

Table III shows precipitation at Los Alamos for the years 1943, 1944 and 1945 together with the monthly averages for the period of record 1910 to 1944 inclusive.

Table III

Precipitation at Los Alamos

	Average 1920 to 1944, Inc.	1943	1944	1945
January	0.93	-	1.49	0.69
February	0.68	T	0.76	0.25
March	1.01	0.43	1.06	1.23
April	1.19	-	1.36	0.62
May	1.44	-	0.51	-
June	1.47	2.89	1.65	0.13
July	3.23	2.04	3.45	0.91
August	3.36	4.58	1.57	2.93
September	2.16	1.16	2.17	No Record
October	1.58	0.96	3.77	"
November	0.66	0.85	1.06	"
December	0.73	1.55	1.57	"
12 Months	18.44	14.46	20.42	
% of Average	100	78	110	

This tabulation shows that precipitation for the year 1943 was 78% of normal. Precipitation during the winter 1942-1943 was substantially below normal and stream flows during the spring and summer months were deficient. The situation was improved by rains during the late summer and fall.

Precipitation during 1944 was 110% of the average and, therefore, above normal. Hence, stream flows during 1944 were above normal.

During the first 8 months of 1945 precipitation was only 50% of normal. No record was kept for the last 4 months of the year, but precipitation during this period is known to be substantially below normal. The deficiency has continued through January 1946 and, unless it is made up by late snows and early spring rains, stream flows during the coming spring and summer months may be extremely deficient.

From records maintained in the office of the Operations Officer, the operation of the system from the standpoint of supply and storage can be closely approximated for the period June 1945 to December 1945. During the first three weeks in June, Los Alamos Reservoir remained filled and some water

was undoubtedly lost over the spillway. This reflected the end of the r from melting snow. Beginning the last week in June and continuing until middle of September approximately 7.7 million gallons of water were drav from storage. Between the middle of September and the end of October th water in storage increased from 5.3 million gallons to 6.9 million gallc Thereafter water was drawn from storage at a uniform rate until 10 Decer when approximately 4.9 million gallons remained. On this date the Guaje failed and the remaining storage was used in 8 days. Had the Guaje line mained in service, it is estimated that the water in storage would have until early in February.

Table IV shows the calculated net yield of all sources of supply the period June 1945 to December 1945.

Table IV

Yield From All Sources of Water Supply

June - November 1945

Month	Total Consumption	Drawn From Storage	Yield From All Sources
June	17.7 MG	0.5 MG	17.2 MG
July	18.7	1.8	16.9
August	25.3	3.5	21.8
September	23.4	1.5	21.9
October	23.1	0.8 (Add)	23.9
November	22.6	2.1	20.5
Total	130.8 MG	8.6 MG	122.2 MG

An estimate of the water situation by Mr. Armstead on 21 Septemb lists the yield from the various sources as follows:

Guaje	170 g.p.m.
Pajarito	50
Water Canyon	70
American Spring	10
Valle Canyon	30
Los Alamos	40
Total	370 g.p.m.

This is equivalent to 532,800 gallons per day or approximately 16 million gallons per month. Mr. Armstead estimated the total average consumption including outlying sites at 586,500 gallons per day of which 154,500 was being drawn from storage. His report includes the following note:

> "Approximately 150,000 to 200,000 gallons are being used daily from the reservoir. The reservoir is low now and the daily usage to Camp is high. We might receive some relief from winter snows but that will not be and cannot be expected until last of February, 1946, or March, 1946."

Table IV reflects higher consumption figures than those used by Mr. Armstead and, hence, higher yields from the streams.

If it is assumed that the yield from all sources for the period June to November inclusive was 122.2 million gallons, then, the average yield for the six months period would be 667,700 gallons per day. Meter readings on the Guaje Canyon line show that 29,746,500 gallons were delivered from this source for the 4 month period August to November inclusive. This is an average of 243,800 gallons per day.

There is no point in further refinement of figures. The unit flows estimated by Mr. Armstead are probably representative of average conditions and are consistent with previously observed conditions. The conclusion can be drawn that the safe yield of all existing sources under average conditions of rainfall will not exceed 0.67 million gallons per day and that during dry years the yield will fall to less than 0.5 million gallons per day.

8. <u>Runoff From Small Drainage Areas</u>.

Estimates of runoff from small drainage areas are always uncertain owing to the large number of local factors which affect precipitation and yield. In the absence of specific records, or of records in which a direct comparison can be made, estimates of annual yields and, in particular, minimum annual yields can be no more than an approximation tempered by the

judgment of the individual making the analysis.

Mr. D. C. Bondurant, Engineer, Flood Control Section, U. S. Engineer Office, Albuquerque District, has studied conditions affecting runoff from the small drainage areas now being utilized to supply the Los Alamos Project and has made estimates of the annual supply which might reasonably be expected from a five square mile drainage area. The results of these studies are contained in a memorandum dated 13 March 1943 and a report titled "Hydrological Analysis, Los Alamos Project" which are included in "Report on Water Supply, Los Alamos Project" by U. S. Engineer Office, Albuquerque District, dated 9 October 1943. These analyses have been carefully reviewed and the findings and estimates presented therein are considered sound. Accordingly it is estimated that safe annual yields per square mile of drainage area on the water sheds under consideration would be:

Maximum	192 acre feet
Average	75 acre feet
Minimum	20 acre feet

The above referenced memorandum and report by Mr. Bondurant are attached hereto at Appendix A.

9. Development of Existing Sources of Supply.

The total area of all water sheds now being utilized is approximately 18 square miles. Complete development of all sources would, therefore, result in yields of,

Maximum	3456 acre feet
Average	1350 acre feet
Minimum	360 acre feet

To provide an average demand of 1.5 million gallons per day will require an annual supply of 548 million gallons or 1680 acre feet. This exceeds the average annual runoff from the existing sources. In order to furnish the required supply it would be necessary to provide storage capacity to store

water during years of maximum yield for use during years of average and minimum yield or develop a larger drainage area.

Consideration has previously been given to the construction of a dam in Water Canyon. Approximately 70 acre feet of storage can be provided by the construction of a dam a short distance below the present point of diversion. However, such a dam would be 50 feet high and the cost could not be justified for the small amount of storage which would be provided.

Additional storage could be provided by the construction of a second dam at a lower elevation in Los Alamos Canyon, but the cost per unit of volume would be excessive and the amount of storage limited.

The existing collection and diversion works are capable of utilizing substantially all flows from Pajarito Creek and Valle Canyon and these sources are, therefore, completely developed.

10. Development of Guaje Canyon.

A water supply of 1.5 million gallons per day could be developed in Guaje Canyon by the construction of a dam at a location below the point where Rendija Canyon enters Guaje Canyon. A reservoir at this location would have a drainage area of some 25 square miles. A storage capacity of 1200 acre feet would insure an adequate supply during years of minimum yield. However, such a project could not be justified from the standpoint of cost. An inspection of the site indicates that the construction of a dam would involve a number of serious engineering problems and would cost in excess of one million dollars. In addition, it would be necessary to construct approximately 7 miles of pipe line to reach the Project and pump all water against a static head of at least 1400 feet.

An annual supply of 0.5 million gallons per day could be provided by the construction of a dam at a location about 500 feet above the temporary

booster station in Guaje Canyon. A dam at this location would collect the yield from a drainage area of approximately 8.5 square miles and a reservoir having a capacity of 500 acre feet would be required. In order to deliver 0.5 million gallons per day to the Project it would be necessary to replace the existing 4-inch temporary line with a larger pipe line of permanent construction. It would also be necessary to pump all water against a head of approximately 400 feet in order to get over the high point in the pipe line. Since a supply of 0.5 million gallons per day, together with the other existing supplies, would not be sufficient for the Project requirements and since the cost of developing 0.5 million gallons per day in Guaje Canyon would be comparable to the cost of another project which will furnish the required supply, the construction of a reservoir at this location is not justified.

The present diversion dam in Guaje Canyon is at elevation 7868 which is high enough to deliver water to the Project by gravity. The drainage area above the intake is approximately 5.6 square miles and the capacity of the pipe line, with the booster pump in operation, is 170 g.p.m. On an annual basis, this source could be expected to yield something over 400 acre feet under average conditions of which approximately 50% could be delivered to the Project by the pipe line. Under minimum conditions the yield might be as low as 110 acre feet per year.

As has been previously stated, the pipe line from Guaje Canyon is constructed over rough and difficult terrain and even though the line has been winterized, operation during the winter months is unreliable. During the winter 1945-1946 the line was out of service for several weeks and much time and effort were expended in restoring it to service. This resulted in the replacement of faulty pipe sections and the installation of additional air release and blowoff valves. The line is now in a relatively good state of

maintenance.

When operable, the present Guaje Canyon supply constitutes an inexpensive source of supply. Operation of the pipe line should, therefore, be continued during the summer months. Maintenance should be planned with the view to eventually replacing the 4-inch section of the line with 6-inch pipe so that diversions can be made at a higher rate when water is available at the source. The present intake dam should be replaced with a permanent structure consisting of a small overflow dam and intake structure to facilitate operation of the system.

11. Development of Valle Grande.

Consideration has been given to the possibility of developing an additional water supply from the Valle Grande which lies over the divide immediately west of the Project. Measurements of Jemez Creek at this location indicate a minimum flow of approximately 900 g.p.m. or 2.19 c.f.s. However, the utilization of the supply would require the construction of about 9 miles of pipe line and the pumping of all water against a head of at least 1000 feet to get over the divide. The development of this supply would involve problems incident to diversion from another water shed. There are certain existing irrigation rights which would undoubtedly have first priority, and in order to utilize the supply, it might be necessary to pump the total requirements for the year during the winter months when the water was not needed for irrigation. This would require substantial storage and comparable pipe line and pumping capacities which would result in excessive costs. The development of a supply from the Valle Grande is, therefore, not recommended.

12. Well Supplies

Prior to 1922 the Los Alamos School, which formerly occupied the Project site, secured its water supply from a well. However, in that year the well went dry and the school was compelled to build a pipe line to Los Alamos Canyon. The yield from the well was undoubtedly quite small since the water requirements for the school were not large.

The entire area of the Project is generally underlain by "Tuffa" which in itself is a pervious formation. Also the area is drained by the numerous deep Canyons which penetrate the mountain areas. The level of the ground water table is therefore controlled by the elevation of the Rio Grande River and ground water, in quantity, could not be expected above the general elevation of the river.

13. Wells in Rio Grande Valley.

The valley of the Rio Grande River is a continuous gorge running north and south across the state. This gorge, which has been cut through the various structures as they have risen to form the numberous mountain ranges along its course, has been filled by the sands, gravels and clays of later erosions. Deep well borings collected by Dr. E. H. Wells, Geologist, New Mexico School of Mines, indicate that the canyon backfill of sand, gravel and clay may be as much as 4000 feet deep at Albuquerque.

The city wells at Albuquerque which were constructed in 1932 and 1933 penetrate the alluvial fill to depths of from 425 to 716 feet. The well drilled to a depth of 716 feet had a yield in 1935 of approximately 1000 gpm and the lower 200 feet of the well had not been developed. The yield from four wells was reported to be 2500 gpm. The water from the Albuquerque wells has a total hardness of approximately 100 p.p.m. and is entirely satisfactory from a chemical standpoint.

At Espanola a well owned by the local power company is drilled to a depth of 240 feet. Mr. J. L. Mathieson, who drilled the well, states that it delivers 400 gpm. Other wells at Espanola have lower yields and there are records of wells in the river valley which yield only small quantities of water.

A water supply from wells in the Rio Grande valley can be delivered to the Project by the construction of approximately 10 miles of pipe line. Such a supply will have the disadvantage of a relatively high operating cost since the total pumping head will be in the order of 2000 feet. However, a supply from this source will be adequate for all future Project requirements and can be made available in a shorter time and at a lower cost than supplies of the required quantity from other sources.

14. Test Wells.

During February and March 1946 a series of test wells were drilled in Sections 7, 13 and 14 T 19N R 7E. The locations of these wells are shown in Figure 2. At the beginning of the drilling operations, it was believed that the most favorable location for wells would be near the river in Section 7 and Rio Grande Test Wells Nos. 1, 2, 3 and 4 at this location were drilled first. The results indicate that a supply could be developed from the upper gravel at well depths ranging from 50 to 80 feet. Below this stratum and to a total depth of 495 feet the formation consists mostly of clay with occasional layers of fine sand which would be capable of yielding only small quantities of water.

Drilling operations were then moved to Guaje Canyon and Guaje Test Wells Nos. 1, 2, 3, 4 and 5 completed at the locations shown in Figure 2.

The results of the Guaje test wells show that wells capable of

yielding 500 to 1000 gpm each can be developed by construction to depths of approximately 300 feet. The most favorable locations were found at Guaje Test No. 1 and No. 4. Guaje Test No. 1 was constructed by cable tool drilling to a depth of 78 feet in order to penetrate the boulders and a 6 inch casing was set to 76.5 feet. The well was then drilled to a depth of 400 feet by rotary drilling. A 4 inch slotted casing was then installed and the well was pumped by air at a rate of 165 g.p.m. for over eight hours. With this method of pumping, it was not possible to accurately measure the drawdown, but approximate measurements indicate that it was less than 30 feet. A sample of water was collected for chemical analysis.

Attached hereto at Appendix B are the logs of all test wells. An examination of these logs and particularly the log of Guaje Tests Nos. 1 and 4 will show that the formation consists of strata of sand and gravel of varying thicknesses which are separated by lenses of clay. All test wells which were constructed to depths of 300 feet or more were free flowing upon completion. The measured artesian head at the top of Guaje Test No. 1, after it was cased, was 6 pounds. However, this artesian head is not of particular significance and will probably diminish rapidly after permanent wells are constructed and placed in operation. Two inch slotted casings were placed in Guaje Test Wells Nos. 4 and 5 and these with the 4 inch cased Guaje Test No. 1 will be maintained as observation wells.

Guaje Test No. 2 was completed by cable tool drilling to a depth of 50 feet. This well was not completed by rotary drilling because of the excellent showings obtained in Guaje Tests Nos. 1 and 4.

The following Table V shows the results of the chemical analysis

of the water sample which was collected from Guaje Test Well No. 1.

TABLE V

REPORT OF CHEMICAL ANALYSIS OF WATER

GUAJE TEST WELL NO. 1

29 March 1946

Calcium (Ca^{++})	5.4 p.p.m.	Carbonate (CO_3^{--})	8.4 p.p.m.
Magnesium (Mg^{++})	0.7	Bicarbonate (HCO_3^-)	92.0
Sodium (Na^+)	44.0	Sulfate (SO_4^{--})	14.0
Silica (SiO_2)	24.0	Chloride (Cl^-)	5.0
Iron (Total Fe)	0.56	Nitrate (NO_3^-)	0.0
Manganese (Mn)	0.0	Fluoride (F^-)	0.5
Total Hardness	16.0	Total Solids	183.0
Carbonate Hardness	16.0	Color	Sl. milky
Non-Carbonate Hardness	0.0	Turbidity	20.0
Total Alkalinity	89.0	pH	8.3
$NaHCO_3$ Alkalinity	73.0		

This analysis shows the water to be low in total solids and extremely soft, the total hardness being only 16 p.p.m. or slightly less than 1 grain per gallon. All of the hardness is carbonate or temporary hardness. However, the sample indicates the presence of 0.56 p.p.m. of iron. This is a very small amount of iron but is sufficient to render the water undesirable for domestic use and may result in some staining of plumbing fixtures and laundered fabrics. It is possible that the permanent wells may show less iron than is indicated by the sample from the test well, but if the iron content is as much as 0.3 p.p.m., provision should be made for its removal. This can be accomplished by oxidation with chlorine and filtration through pressure filters. In this particular case, aeration of the well water is not recommended because the water is extremely soft and saturation with oxygen might cause it to become corrosive.

15. Recommended Project.

The water supply project as recommended will provide a supply of 1000 g.p.m. and will be capable of expansion to 2000 g.p.m. It will consist of:

(a) Wells. A minimum of three wells to be constructed in the area in the N 1/2 of the NW 1/4 of Section 13 and the NE 1/4 of the NE 1/4 of Section 14 T 19N R 7E. These wells will be constructed by sinking a 20 inch casing to the impervious clay which is encountered at a depth of approximately 80 feet. Below this depth the wells will be constructed to a diameter of 30 inches by rotary drilling to a total depth of approximately 300 feet. A 12 inch inner casing will be installed with screen sections set at the various sand and gravel formations. The space between the inner casing and the outer diameter of the well will be filled with selected gravel. Additional gravel will be added as required during the development of the well to replace any sand which may be removed.

On the basis of the test drilling results, it is believed that gravel wall wells constructed in this manner will be capable of producing up to 1000 g.p.m. without excessive drawdown. However, it is planned to install 500 g.p.m. pumps in order to insure minimum pumping levels and long life for the wells. This will make it possible to supply a total of 1000 g.p.m. on a continuous basis with one well in reserve.

(b) Water Supply Pipe Line. A water supply pipe line approximately 45,000 feet long will be required to deliver the water from the wells to the Project. This pipe will be 14 inch steel pipe O.D. and will be lined and coated with bitumastic enamel. The pipe line will be constructed with flexible couplings and will be provided with vacuum breaker and air relief valves at all summits and blow-off valves at selected low points. The line

will be covered to a depth of three feet for protection against damage and freezing.

(c) Pumping Stations. Four pumping stations will be required to accomplish the total lift from the well field to the Project distribution system. Each station will consist of a receiving tank and two 1000 g.p.m. horizontal centrifugal electric driven pumps. Pumping Station No. 1 will be located near the well field and will have a 150,000 gallon receiving tank which will receive the discharge from the well pumps. The other stations, located at selected points along the pipe line, will be provided with 60,000 gallon receiving tanks. Each booster pump will operate against a head of approximately 450 feet.

The booster pumps will be equipped with high water and low water cut-outs for the protection of the equipment.

(d) Electric Power. Power for the well pumps and pumping stations will be taken from the 44,000 volt transmission line which has been built to the Project from Santa Fe. Power will be supplied from the Project power plant. The total power demand for water pumping will be approximately 615 Kw.

(e) Chlorination. A semi-automatic chlorinator will be installed at Pumping Station No. 1 for the chlorination of all water pumped to the Project.

(f) Filters. Three 500 g.p.m. pressure filters, if required for iron removal, will be installed at Pumping Station No. 1. These filters will filter all well water prior to delivery into the 150,000 gallon storage tank.

(g) Meters. A totalizing meter will be installed on each well discharge line to measure the amount of water pumped from each well.

A rate of flow indicator and totalizing meter will also be installed at Pumping Station No. 1 to measure all water pumped to the Project.

(h) Elevated Storage. A one million gallon standpipe will be constructed immediately adjacent to the existing 250,000 elevated wooden storage tank to provide additional distribution storage. This tank will be 65 feet high and 52 feet in diameter.

Figure 2 shows the location of the well field, pipe line and pumping stations as proposed. Figure 3 is a profile over the route of the pipe line.

16. Construction Cost.

The estimated cost of the new water supply as recommended is:

Wells & Well Houses				
Test drilling	3300 ft.	@	$ 3.00	$ 9,900
Water supply wells	3 ea.	@	17,500.00	52,500
Well houses, pumps & piping	3 ea.	@	10,000.00	30,000
Pipe Line				
14" pipe line & appurtenances	45,000 ft.	@	7.60	342,000
8" " " "	1,400 ft.	@	6.60	9,240
Power Transmission Line				
Transmission lines, substations & controls			L. S.	96,000
Booster Pumping Stations				
Pumping stations & equipment	4 ea.	@	25,000.00	100,000
Iron removal plant & chlorinator			L. S.	30,000
Standpipes				
1 M.G. tank, foundations & piping	1	@	35,000.00	35,000
150,000 gal. tank, foundation & piping	1	@	10,000.00	10,000
60,000 gal. tank, foundation & piping	3	@	7,500.00	22,500
Access Road				
Access road including clearing & grading	3 mi.	@	15,000.00	45,000
			Total	$782,140