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THE BASIS FOR AN INVESTIGATION OF POSSIBLE GROUND WATER CONTAMINATION FROM INDUSTRIAL OPERATIONS AT RMA ORIGINATED AS A FORMAL LETTER REQUEST FROM THE GREAT WESTERN SUGAR COMPANY TO RMA. THIS REPORT IS A COMPOSITE OF THE BASIC FIELD WORK THAT WAS ACCOMPLISHED BY THE USGS AND THE CORPS OF ENGINEERS IN CONNECTION WITH THIS PROBLEM. INCORPORATED ARE CHEMICAL ANALYSES OF WATER AND FIELD WORK AND ANALYSIS OF ELECTRICAL RESISTIVITY DATA.

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ROCKY MOUNTAIN ARSENAL

DENVER, COLORADO

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REPORT
ON
GROUND WATER CONTAMINATION

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
OMAHA DISTRICT
OMAHA, NEBRASKA
SEPTEMBER 1955

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ROCKY MOUNTAIN ARSENAL
DENVER, COLORADO

REPORT ON GROUND WATER CONTAMINATION

INTRODUCTION

The basis for an investigation of possible ground water contamination from industrial operations at the Rocky Mountain Arsenal originated as a formal letter request from the Great Western Sugar Company to Brig. Gen. C. S. Shadle, Rocky Mountain Arsenal, dated 4 June 1954. A copy of that letter is attached in the Appendix as Exhibit A. A subsequent letter from the Great Western Sugar Company addressed to Mr. E. C. Thompson, Chief, Engineering and Service Division, Rocky Mountain Arsenal, dated 18 June 1954, related information pertinent to the problem. A copy of this letter is attached in the Appendix as Exhibit B.

On 5 October 1954 the Commanding Officer of the Rocky Mountain Arsenal requested the Corps of Engineers, Omaha District, to investigate the potentially serious condition. Since the basic study involved various phases of ground water, the U. S. Geological Survey was requested to render services in obtaining information and data pertinent to the problem. Funds were provided by the Department of the Army, Rocky Mountain Arsenal, and the active investigation was started in November 1954 and coordinated by the office of the District Geologist, Omaha District, Corps of Engineers.

This report is a composite of the basic field work that was accomplished by the U. S. Geological Survey and the Corps of Engineers in connection with the problem of ground water contamination from industrial operations at the Rocky Mountain Arsenal. Incorporated are chemical analyses of water prepared by the Soil Conservation Service during the period when the damage to plant growth was noted by the farmers. A complete evaluation of the chemical quality of the ground water is covered in the section "Quality of Water" prepared by the U.S. Geological Survey. The field work and analysis of electrical resistivity data were accomplished by the Corps of Engineers and are covered in the text under "Electrical Resistivity Investigation."

QUALITY OF WATER INVESTIGATION

Scope and Purpose

In the summer of 1954, farmers in the South Platte River valley northwest of Rocky Mountain Arsenal, in common with others in the region, suffered from a scarcity of irrigation water. Normally, most of the irrigation water is obtained by diversions of surface flow in the South Platte River. In recent years and particularly in 1954, many farms have had to obtain part of their water supply from wells in the alluvium which overlies the bedrock of this area. Reports of damage to crops from the use of these well waters were made by several farmers in the area near the Arsenal during the summer of 1954, and a summary of "Reports of Damage" is attached as Exhibit C in the Appendix. Samples were collected at locations shown on Plate 1. Chemical Analyses of these waters were made by the U. S. Soil Conservation Service Laboratory at Fort Collins, Colorado. A tabulation of the chemical analyses is shown in Table 1. These analyses showed that certain wells in the area yielded water containing high concentrations of chloride.

The Quality of Water Branch, U. S. Geological Survey was requested to undertake the chemical analysis of certain waste effluents at the Arsenal, ground waters occurring on the Arsenal property, and water encountered in privately-owned wells in the vicinity, as a part of this study. This study was intended to determine whether the quality of liquid waste disposed of on the Arsenal property had points of resemblance to the quality of water in affected wells.

Sampling Program

Samples were collected by the Quality of Water Branch and by the Corps of Engineers at locations shown on Plate 1. Results of the analyses are shown on Tables 2 and 3. In all, 22 samples were collected in November and analyzed by the U. S. Geological Survey Laboratory. These included four samples of waste, two from First Creek which is reported to carry only treated sanitary sewage, and two of industrial plant waste. One of these represents outflow from an acid neutralization system and the other the ponded material resulting from all waste outflows. The tabulations include five chemical analyses performed by the Corps of Engineers Laboratory on samples collected in October.

Samples were obtained from eight abandoned wells on the Arsenal property, in the general vicinity of the waste disposal pond in Sec. 26, T2S, R67W. These wells represent sources of water supply for local domestic and irrigation purposes before the property was acquired by the United States Government, and were sampled by means of a Foerst-type sampler lowered into the open holes by hand on a cable, or by means of a small bailer. The extent to which these sources can be depended upon to yield reliable samples is uncertain in some instances as a few wells were nearly dry and others had badly rusted casings, but several of the former irrigation wells were apparently in fairly good condition and should have been in good communication with the body of ground water in the alluvium. Samples were obtained by bailing from four test holes drilled for the purposes of the investigation in the northwest part of the Arsenal property. Through cooperation of local residents, samples were obtained from five farm wells. Some of these were reported to have been affected by high chloride concentrations, and others were outside the area thus affected, or represented water from deep aquifers.

Samples were analyzed by the Geological Survey Quality of Water Laboratory in Denver, Colorado. Most of the samples received regular complete mineral analyses, and a number of special determinations were made on the waste samples and the high chloride ground waters. Among these determinations were phosphate, boron, arsenic, and ether-soluble organic acids of the type 2,4 dichloro phenoxyacetic acid (2,4-D). It was believed the anions could be expected to travel more rapidly underground than cations, owing to base exchange and adsorption effects upon the latter. Consequently, the analysis for anions was made in greater detail than for cations. No attempt was made to determine heavy minerals.

Results of Analyses--Liquid Wastes

The outflow from the caustic pond (#108, water sample RMA-1) at the time of sampling was essentially a strong sodium chloride solution strongly alkaline (pH 9.7), with smaller amounts of less desirable substances. This waste stream is mixed with other effluents and the mixture is impounded in several small earth reservoirs in Sec. 26, T2S, R67W. The results of analysis of a grab sample from the waste pond which contained water on 8 November show that the mixture has a similar sodium concentration to that of the sampled inflow. Other inflows to the pond, however, appear to increase the chloride and to decrease the arsenic, fluoride, and pH. Reportedly the unsampled inflows contribute considerable dissolved aluminum. Some of this precipitates as gelatinous Al $(OH)_3$ on the bottom of the pond. It is unlikely that the aluminum will be transported far in ground water unless the pH is maintained at a level above 9 or under 5. Amounts which could be found in waters of the vicinity are not likely to be harmful for irrigation use, and this constituent was therefore not determined.

Because of the large amount present, sodium and chloride are the most undesirable constituents in the waste, or at least are the ones most likely to be carried in damaging amounts into ground water adjacent to the disposal area. Fluoride is present in excessive quantity also, and can be expected to occur in damaging quantity in those waters strongly affected by the waste. Disposal of fluoride in the ponds has not been going on long enough to affect any large area outside. The arsenic present is potentially dangerous also. This substance probably is present as an anion but whether it would be carried long distances in ground water is somewhat questionable. The organic material present in the waste was not positively identified. However, it was suspected from the descriptions of damage to irrigated crops that the water might contain active herbicides. The commercial compounds used for this purpose include 2,4-D (2,4, dichloro phenoxyacetic acid), the chemically similar 2, 4, 5-T, arsenates, borates, and various other substances. The organic matter present which might have herbicidal action was determined by extracting with ether from an acidified portion of the sample and is reported in terms of an equivalent amount of 2,4-D. A considerable amount of such material occurs in the waste.

However, it seems unlikely these large organic molecules will be s...le enough to travel long distances in ground water. The amount of bo... in the waste was small.

Composition of the waste at other times is unknown and may be subject to wide variation. Various amounts of highly undesirable products may have been placed in the disposal ponds in the past. The pond which was sampled has a coarse sandy bottom through which rapid infiltration could be expected.

The two analyses for surface flow of First Creek indicate appreciable variations for this small stream. The amount of arsenic observed in one of these analyses suggests that some minor amounts of pollution may occur in the water reaching the stream.

Amounts of boron, a possible source of damage to crop plants, were very small in all of these samples.

Abandoned Wells on Arsenal Reservation

Analyses were made for all the wells that could be sampled that are located in Secs. 22-28 and 33-35, T2S, R67W and in Secs. 19-20, T2S, R66W. Some of these, including Nos. 4A and 54A, were evidently once used for irrigation and should represent fairly good sources of water from the alluvium. The former domestic and stock wells are less dependable. Several of these may be cased through the alluvium and obtain water from underlying bedrock not affected by contamination. The possible deep wells include Nos. 5A and A91, both of which, however, are somewhat away from the area where contamination would be expected, and well A which obtains at least some water from the alluvium.

The most noteworthy feature of the analyses of these wells is the very high sodium and chloride content of waters from wells in and adjacent to Sec. 26 where the waste disposal pond is located. The concentrations are substantially higher than those observed in the waste at the time of sampling. These facts suggest either that the waste has been more saline in the past, or that a source other than those sampled has contributed. That waste of higher salinity may have been released in the disposal area is certainly not unlikely.

The wells showing highest concentrations were for the most part a mile or less from the final waste disposal pond, in an arc of about 90° centered to the northwest. Evidence for the disposal area being the source of these high salinities must be considered very strong, even if circumstantial. Wells such as the two in Sec. 23 formerly used for irrigation now contain water that would be highly lethal to vegetation because of salinity. Well 4A was reported used to irrigate some land leased from the Arsenal for a time after its establishment. Deterioration of the quality of the water finally forced its abandonment some years ago.

Further evidence of the connection of waste disposal to ground water pollution in the Arsenal reservation is given by the high fluoride content of the more saline water. The two best sample sources, wells 4A and 54A, gave fluoride concentrations of 2.6 and 6.1 ppm respectively. Normal fluoride concentrations in ground waters in alluvium of this area are probably less than 0.5 ppm. Water from well 54A contained .05 ppm of arsenic. The boundary of the area affected by pollution in the Arsenal reservation cannot be definitely fixed on the basis of available data, but probably the area exceeds five square miles. The configuration of the bedrock surface may tend to channel some of the movement of saline ground water so that the area affected is not likely to have regular boundaries. The more saline water also probably tends to move toward areas down the hydraulic gradient without much lateral diffusion so that a fairly sharp boundary between saline and fresh water may exist.

Wells A91 and 5A yield water with a high sodium percentage and high pH that resembles closely the water from the Wolpert well (#104) outside the reservation. The latter well obtains water from the Denver formation. It seems possible therefore that these two wells also reach that formation and obtain water there. If this is true, they do not give any indication of water quality in the alluvium in their vicinity. Only one of these, A91, is in an area of potential pollution. Well A may also obtain at least a part of its water from bedrock. The higher chloride, however, suggests the casing is not tight at the upper water bearing level.

Test Holes

In connection with the studies by the Corps of Engineers, test holes were drilled in the area northwest of the waste disposal ponds. Water samples were obtained from three holes in Sec. 27 and one in Sec. 26. The analyses of these samples help to delineate the areas affected by salinity. DP #31 is about 1-1/2 miles west and slightly south of the disposal pond in Sec. 26. It shows only a slightly higher chloride than would be considered normal in this area. The other three holes all encountered salty water, the saltiest being in the two that were less than a mile from the pond, and either west or northwest of it.

Wells Outside the Arsenal Reservation

Only a few of the wells sampled by the SCS earlier in the year were resampled in this study. The well (#106) of Frank Palumbo is considered to represent water unaffected by any activities on the reservation. It is located in the northeast corner of Sec. 32, T2S, R67W and is therefore upgradient from the waste disposal area. This water has only 70 ppm chloride but has much calcium and sulfate. The two wells at the Powers farm (SW¼ Sec. 15, T2S, R67W) represent domestic water (house well #103) and irrigation water (#105) about 1/8 mile west of the house. The irrigation well #105 was sampled in June by SCS and showed 560 ppm chloride at that time. In the present study, it was found to contain 1010 ppm chloride. This increase raises the concentration to a level which could well be severely damaging to crops. The stock well at the Powers house had only slightly less chloride in November. It does not appear necessary for anything else to be present in this water to produce vegetation damage. No arsenic or 2,4-D type material was fo und in the Powers wells, and only a small amount of boron, probably not enough to damage most plants.

The well (#104) of D. E. Wolpert (NE¼ Sec. 22, T2S, R67W) is immediately opposite the area of pollution but is not affected as it obtains water from a deep aquifer and shallow water is cased out. The Powers wells are about a mile and a half west of the Wolpert well. Other wells in this area where high chlorides are reported were not sampled. However, a sample was obtained from a well owned by Jesse Masumaga (#100)(SW¼ Sec. 10, T2S, R67W) located about a mile west of the home of James Fry, Jr., and more than three miles northwest of the disposal pond. This is outside the area where the more highly mineralized waters were found, but this well may have been affected as it yields water containing more than 100 ppm of chloride.

The area outside the reservation which appears to show definite effects of high salinity in ground water was not defined in this study. However, supplies over a considerable area appeared to be affected on the basis of analyses made earlier by SCS. It is entirely possible that the area affected may increase in size and that the effects may become more severe in the future.

At the Omaha laboratories of the Corps of Engineers, a chloroform extract containing 40 ppm of unidentified organic material was obtained from water taken from the ditch leading into the contaminated lake at Rocky Mountain Arsenal. Water from Powers house well yielded an extract containing 5 ppm of organic material.

Surface Water Irrigation Supply

A spot sample was obtained from a lateral branching from the Burlington Ditch (#101) which supplies irrigation water for this area. The sample was obtained in Sec. 15, T2S, R67W. The ditch diverts from the South Platte River, carrying at the time of sampling largely sewage effluent. The water contained 117 ppm of chloride which is more than in the ground water in the Palumbo well and had a foul black appearance and a putrid odor. It is unknown how much variation in mineral content this source may have or if the single sample provides any valid basis for conclusions. If the chloride concentration observed persists, this would be a source for chloride of this concentration or greater in shallow ground waters in the irrigated area. During future years, it may be expected that water conservation practices in Denver may reduce the amount of dilution available for the sewage effluent and that the quality of the surface supply could deteriorate. Additional use of the river for industrial waste disposal could also have this effect.

ELECTRICAL RESISTIVITY INVESTIGATION

Purpose

Chemical analyses of ground water have established the presence of a body of saline ground water beneath the area of the Rocky Mountain Arsenal and adjacent farmland northwest of the Arsenal. It is believed that the contamination was caused by infiltration of industrial waste from disposal ponding areas. The purpose of the electrical resistivity survey was to determine the limits of underground contamination of the ground water and delineate the flow pattern.

Geology and Ground Water

The overburden material in the vicinity of the Rocky Mountain Arsenal consists primarily of silts, clays, and sands with minor amounts of gravel. This material was derived from the underlying Denver formation which is composed of varying strata of sands and shales. Since the overburden and bedrock are similar in physical makeup, it was assumed for the purpose of the electrical resistivity survey that both horizons should be treated as a homogeneous mass. It was also determined from core borings that the mantle material was moderately pervious and the moisture content increased uniformly with depth. With these factors established, it was apparent that any change in resistivity recorded for a specified depth would reflect the relative concentration of the ionized salt in the fluid.

The annual average precipitation as recorded by the U.S. Weather Bureau is about 14 inches. Although the surface topography is moderately uniform, the surface runoff is probably low due to the high permeability of much of the surficial material.

A study of the ground water conditions in the Arsenal area and also in the area reporting contamination indicated that the ground water contours slope in a general northwest direction as shown on Plate No. 1.

Records indicate that the ground water level has been lowered from 4 to 12 feet since 1941. This is due primarily to the lack of precipitation in recent years and the accelerated use of water from wells for irrigation. This practice has probably caused an increase in movement of ground water from the Arsenal area, and if saline concentrates infiltrated into the ground water at the Arsenal, it is reasonable to assume they were carried in the same general northwest direction.

Application of Electrical Resistivity to Problem

The passage of electric current through earth material is a matter of electrolytic conduction which depends upon the amount of water contained and the number of free ions of dissolved salts present in the soil. The ionized salts serve as conductors of electricity through the solutions. The electrical resistivity or reciprocal of conductivity is almost directly proportional to the number of free ions of dissolved salts present per unit volume of soil.

Resistivity measurements are made by determining the potential drop of an electric current flowing through the ground. In field practice, two potential electrodes are placed equidistant between and in line with the current electrodes. By increasing the interval between the electrodes, the current penetrates to a greater depth, the depth being equal to the electrode spacing.

Resistivity values are computed from the formula $P = 191 \frac{AV}{I}$. A is the distance between electrodes in feet, V is the voltage in millivolts and I is the current in milliamperes. The resistivity values computed from this formula are expressed in ohm-centimeters.

General Resistivity

Resistivity readings were obtained at 339 stations, with electrode spacings or depth penetration of 25, 50, 75, and 100 feet for each station. Interpretations of these resistivity values are shown on four iso-resistivity contour maps, one for each electrode interval, which represents the electrical resistivity characteristic of the material for the corresponding depth.

It was noted that the areas of high and low resistivity values have a definite directional trend and pattern on all four iso-resistivity maps. This condition occurs when the material below the 25-foot depth over the entire area has a uniform resistivity value. Had a marked difference in resistivity trends become apparent on the 50, 75, and 100-foot interval maps, then the change would have been due to a material or resistivity change below the 25-foot depth. Since the resistivity values were relatively unchanged below the top 25-foot zone, it was assumed that the changes in the resistivity values were primarily due to the interception and quality of the ground water, rather than physical and electrochemical changes in material.

The electrical resistivity survey revealed two areas which have pronounced low resistivity values. The general trend of these "low" areas is in a northwest direction. The limits of the "low" area near the northern boundary line have not been delineated as thoroughly as the "low" area northwest of the Contaminated Waste Reservoir A. It may be noted that the "low" areas follow a trend toward the area being contaminated, namely the Powers property, as shown on the iso-resistivity maps, Plates Nos. 2, 3, 4, and 5.

The chemical analyses of water samples obtained by the U. S. Geological Survey, the Soil Conservation Service, and the Corps of Engineers were correlated with the electrical resistivity pattern. There is a definite similarity between the chemical analyses indicating high chemical concentrations and areas of low resistivity values; likewise, lower concentrations of ionized salts are found in areas of higher resistivity values.

Conductivity Tests

In conjunction with the resistivity survey, additional conductivity tests were made in all accessible wells within the Arsenal area. Conductivity measurements of the water were made at three levels in the wells, the top, middle, and near the bottom. No apparent stratification of saline concentrates was observed in the wells. Conductance values were approximately the same at each level for each well tested.

The low readings obtained from the conductivity tests indicate that most of the well water tested in the eastern and southern area of the Arsenal contained only a limited amount of saline concentrates. In the area to the northwest of the Arsenal, the conductance values of well waters were high. These areas of high conductance values coincide with the pattern developed from the low resistivity values, which are associated with high saline concentrations in the ground water.

CONCLUSIONS

Electrical Resistivity

There appears to be a general correlation between the low resistivity values with the high saline concentrations and high conductance values.

If the source of contamination is from the infiltration of disposal wastes into the ground water, it is reasonable to assume that the "low" areas may be the limits of the contamination.

Chemical

The evidence gathered in this study points strongly toward pollution of ground water in the alluvium of the South Platte valley in and adjacent to the Rocky Mountain Arsenal. This pollution is apparently closely related to waste disposal practices on the Arsenal property. The pollutant is essentially sodium chloride. This now occurs in objectionable amounts both inside and outside the Arsenal reservation, but extreme concentrations still are largely limited to the area within the reservation boundary. The other important potential pollutants found in the waste water include fluoride, arsenic, and organic acid radicals which may have toxic effects upon vegetation.

The reported damage to crops from ground waters in the area northwest of the Arsenal during 1954 probably was the result of high sodium and chloride concentrations in the water supplied, aggravated by the use of water in such small amounts that salt left by evaporation and transpiration accumulated in the soil. Normal irrigation practice usually results in the application of an excess of water which leaches residual salts from the soil into the ground water. Although materials which may be toxic to vegetation appear to be present in the waste, no quantities large enough to be significant were found outside the Arsenal grounds in this study.

FUTURE INVESTIGATIONS

The presence of a body of saline ground water is a potential contaminant for a considerable area in the South Platte valley northwest of the Arsenal where water from the same aquifer is used for irrigation and other purposes. In order to determine the areas of existing and potential pollution and to study more carefully the manner in which saline water may move into and through the area, the U. S. Geological Survey will conduct the following investigations of quality of water and ground water conditions.

1. Prepare a well inventory and comprehensive sampling program to establish boundaries of area outside the Arsenal which is now affected and select area for study which may be presently or potentially influenced. The well inventory will include determination of water levels and pertinent physical data relating to wells sampled.

2. Study quality of South Platte River by establishing detailed sampling at a point just below the area potentially affected, supplemented by less frequently collected samples from the river above the area and from the canals supplying surface water for irrigation.

3. On basis of comprehensive ground water sampling, establish a network of wells for periodic sampling. Study well performance with respect to quality of output by recording conductance device attached at beginning of pumping periods.

4. Determine by special sampling techniques the extent to which stratification of saline water in the aquifer may occur both in the Arsenal reservation and outside it, if wells can be found which may be sampled.

5. Establish network of wells for water level observations and run levels to determine elevations of measuring points in wells. On the basis of water level measurements, prepare ground water contour map or maps.

6. Determine if possible the configuration of the shale surface upon which the ground water body in question rests.

7. Prepare report to Rocky Mountain Arsenal interpreting the results of the study after the completion of about one year of intensive study. The program will be continued after 1 July 1956, but on a considerably reduced scale.

3. Matsumoto farm: $E\frac{1}{2}$ $SE\frac{1}{4}$ Sec. 16, T2S R67W.
   Well #120, water samples Nos. 17 and 46; well #121, water samples Nos. 18 and 47.
   Soil Type: Fort Collins clay loam. From Soil Survey of Brighton Area. Series 1932.
   Crop effect: No effect on carrots, beets or onions in 1954. Salt concentration went down as season progressed. All surface irrigation slopes of 0.5%.

4. Yamamoto farm: SW corner Sec. 22 T2S R67W.
   Well #128, water sample No. 41.
   Soil type: Sandy loam surface. Sandy loam to loam subsoil, sand starting 18" to 24".

   Crop effect: Has killed all crops except asparagus. The asparagus crop survives but that is about all. This well has been bad for 7 years.

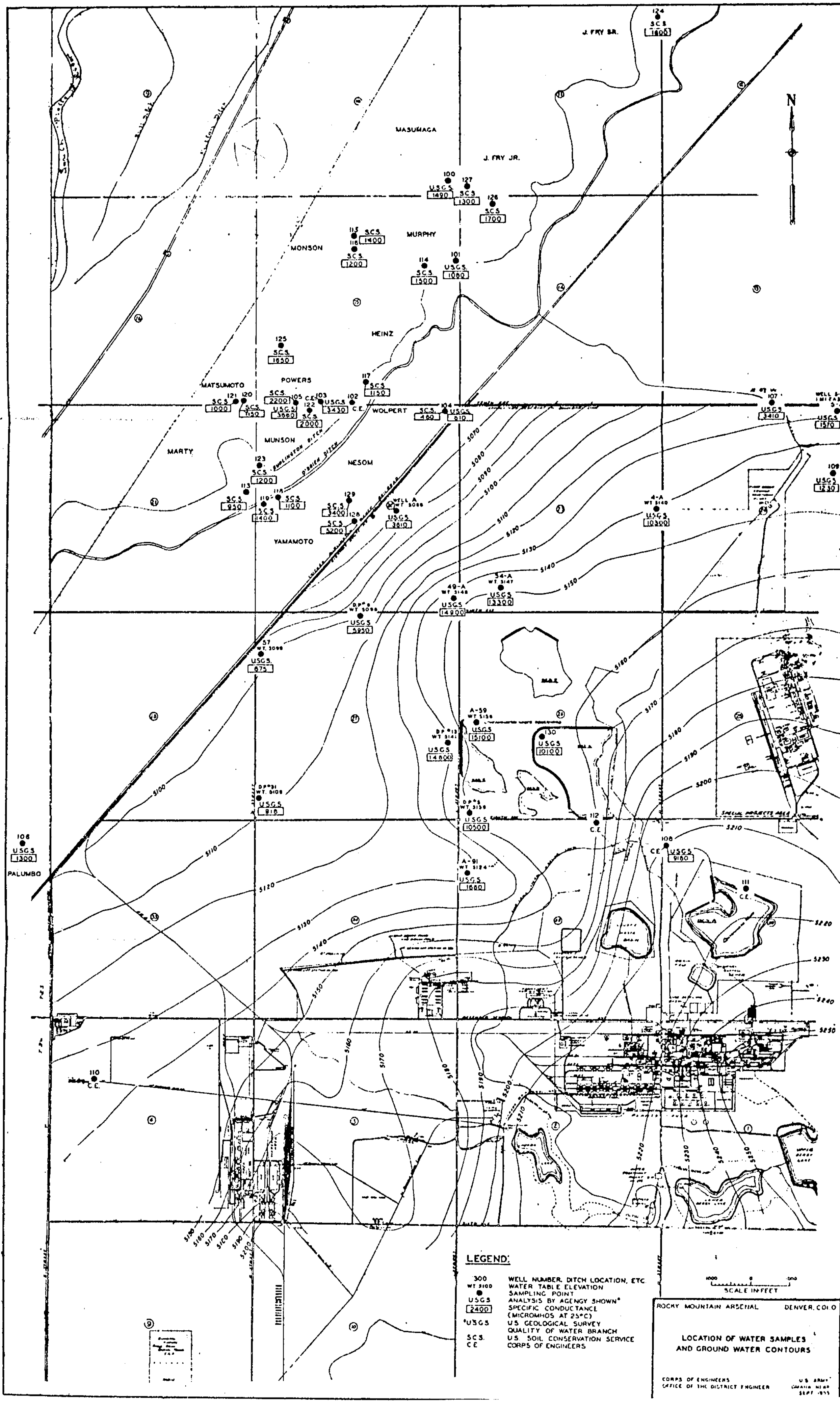
1954 has been an exceptionally dry hot year in Colorado. There was no spring moisture for crops and they had to be irrigated up. The water table in most wells has gone down for the last two years. Many new wells have been dug in this area in the last 5 years.

Sample No. 30 is from a domestic well (#104) about 500 ft. deep. All other wells are 40 to 55 ft. deep.

NOTE: Information furnished by Mr. Davies, West Adams Soil Conservation District, Brighton, Colorado.

EXHIBIT C

APPENDIX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SPECIAL PROJECTS AREA
LEGEND:
300 WELL NUMBER, DITCH LOCATION, ETC.
WT 3100 WATER TABLE ELEVATION
SAMPLING POINT
USGS ANALYSIS BY AGENCY SHOWN*
2400 SPECIFIC CONDUCTANCE (MICROMHOS AT 25°C)
*USGS U.S. GEOLOGICAL SURVEY QUALITY OF WATER BRANCH
S.C.S. U.S. SOIL CONSERVATION SERVICE
C.E. CORPS OF ENGINEERS
SCALE IN FEET
ROCKY MOUNTAIN ARSENAL DENVER, COLO
LOCATION OF WATER SAMPLES AND GROUND WATER CONTOURS
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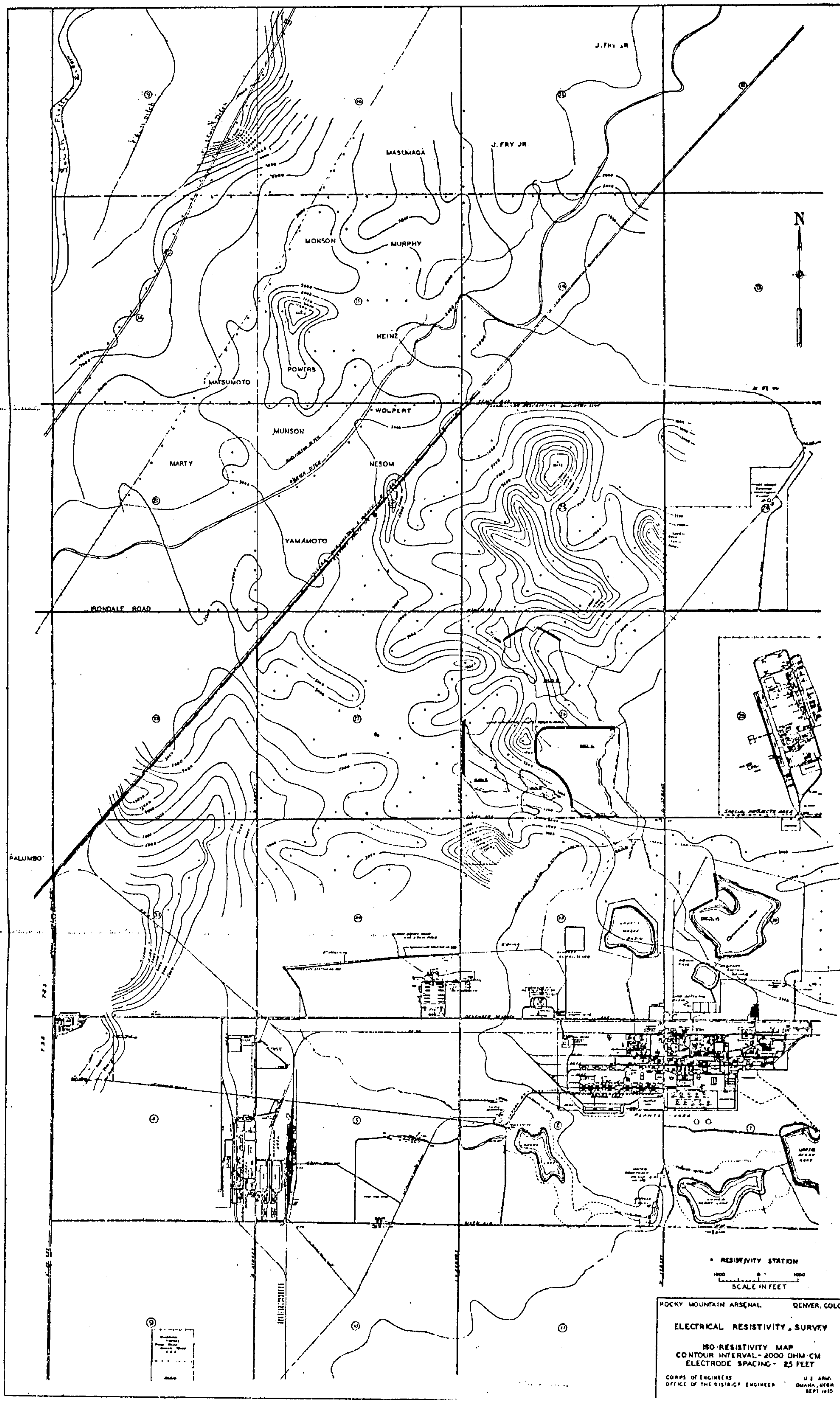
OFFICE OF THE DISTRICT ENGINEER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ELECTRICAL RESISTIVITY SURVEY
ISO-RESISTIVITY MAP
CONTOUR INTERVAL - 2000 OHM·CM
ELECTRODE SPACING - 25 FEET
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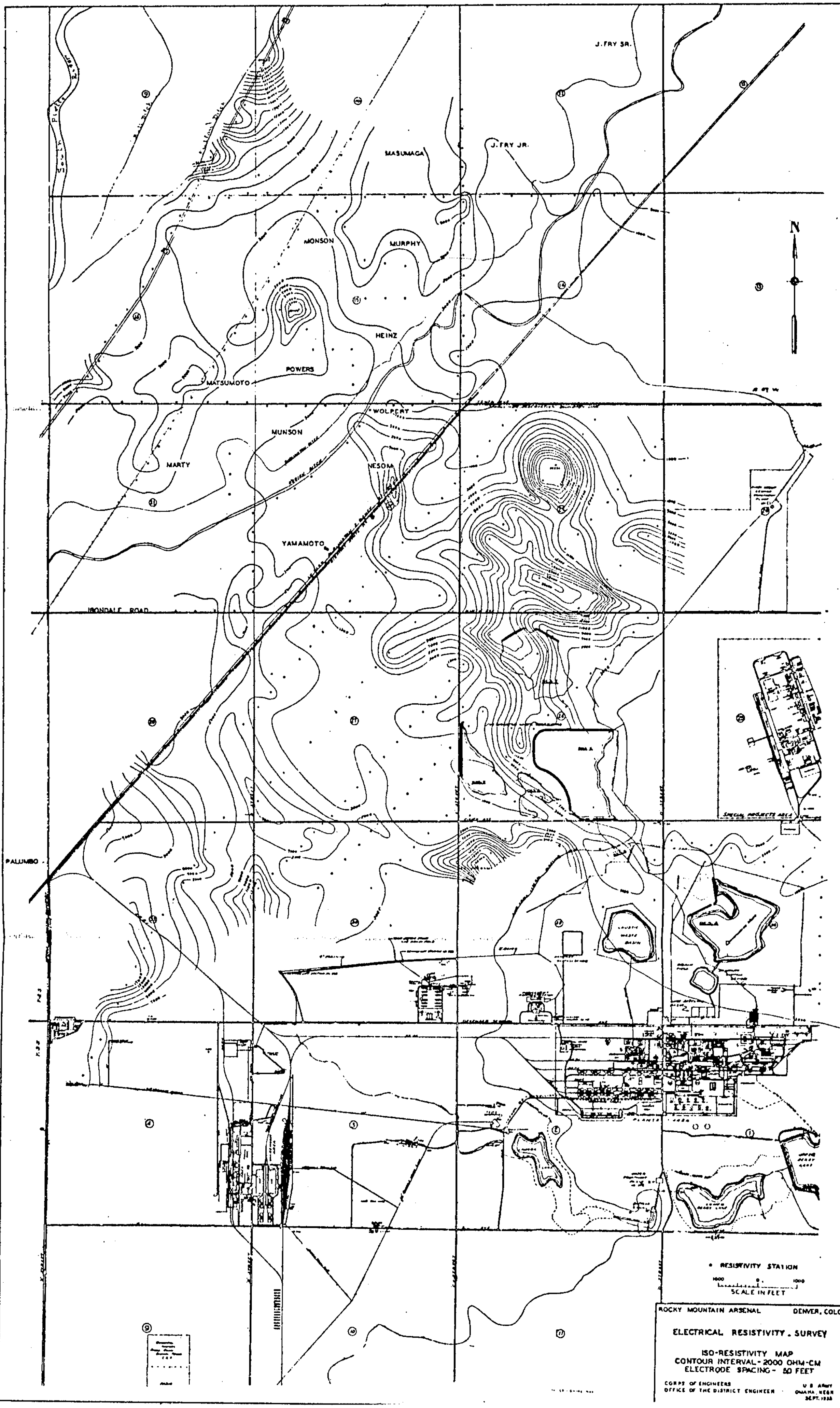
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ELECTRICAL RESISTIVITY . SURVEY
ISO-RESISTIVITY MAP
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ELECTRODE SPACING - 50 FEET
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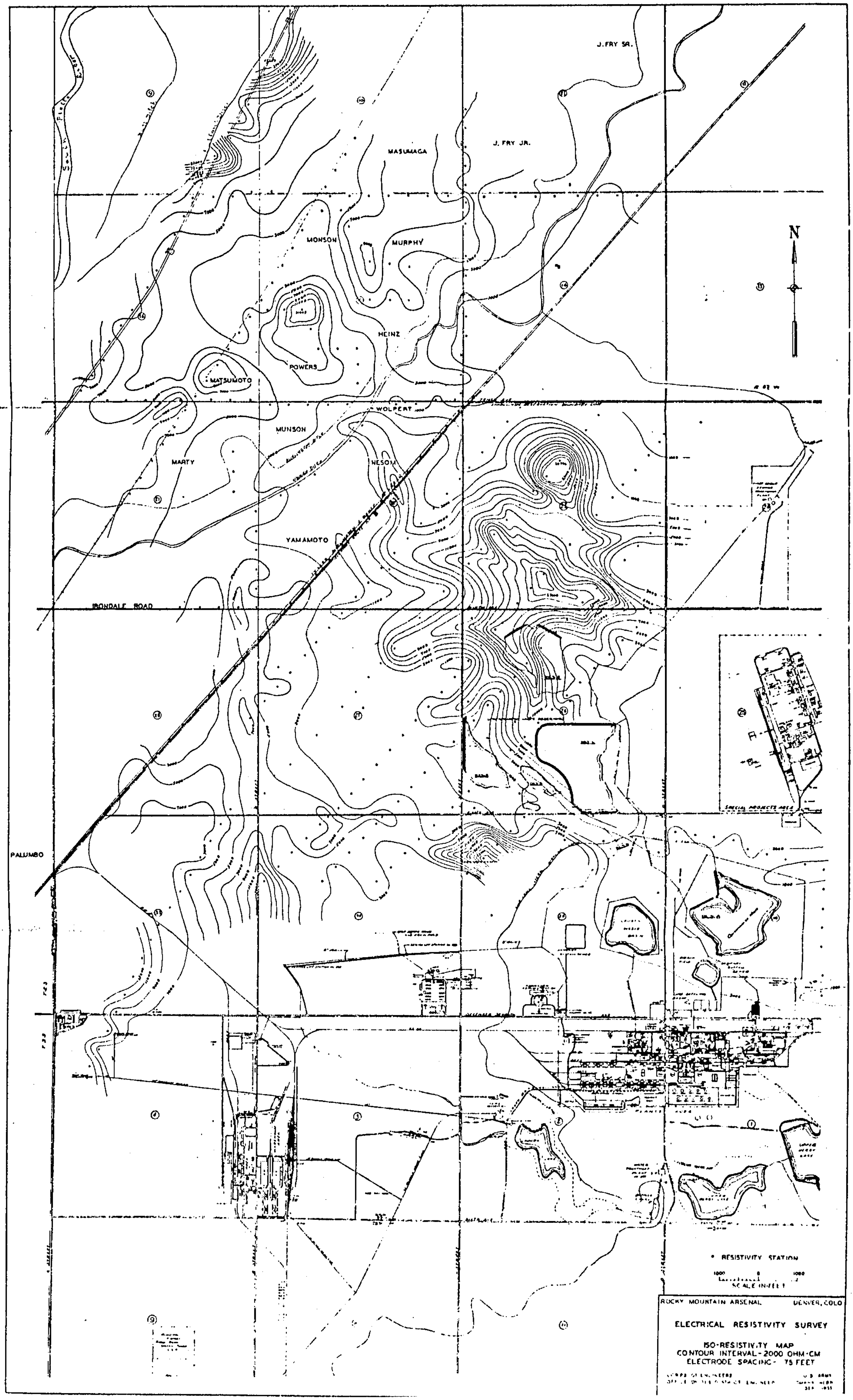
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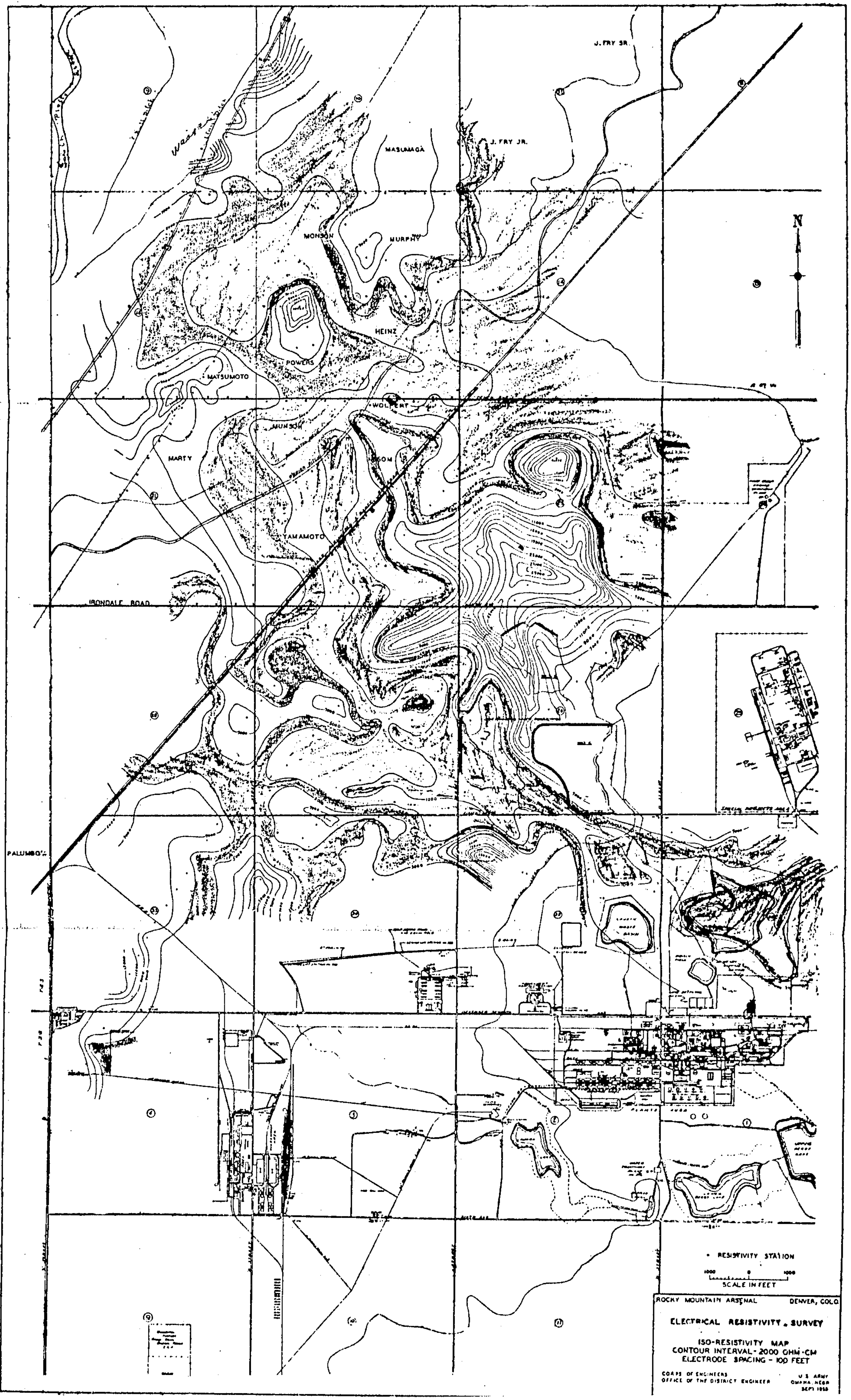
CONTOUR INTERVAL - 2000 OHM-CM
ELECTRODE SPACING - 75 FEET
U.S. ARMY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ELECTRICAL RESISTIVITY SURVEY
ISO-RESISTIVITY MAP
CONTOUR INTERVAL - 2000 OHM-CM
ELECTRODE SPACING - 100 FEET
CORPS OF ENGINEERS
OFFICE OF THE DISTRICT ENGINEER
U.S. ARMY
OMAHA, NEBR.

TABLE 1
ROCKY MOUNTAIN ARSENAL
CONTAMINATION STUDY
WATER ANALYSIS - OUTSIDE OF ARSENAL BOUNDARY
(ANALYSIS BY SOIL CONSERVATION SERVICE)

*Analysis on 11Jun54
**Analysis on 25Jun54
***Analysis on 2Aug54

	#113 Marty Well	#114 Murphy Well	#115 Monson Well	#116 Monson Well	#117 Heinz Well	#118 Nesom Well	#118 Nesom Well	#119 Nesom Well	#119 Nesom Well	#120 Matsumoto Well
Water Sample No.	20*	26*	24*	25*	23*	21*	48***	22*	49***	17*
Total Solids	648	932	1036	920	876		968	1050	1012	792
Sodium	81	123	115	91	56	59	32	64	63	42
Calcium	104	138	104	144	140	144	136	136	172	139
Magnesium	29	46	49	44	51	41	73	66	56	65
Carbonate	0	14	14	0	0	0	0	0	0	0
Bicarbonate	263	371	361	356	400	283	273	250	273	307
Chloride	158	104	165	120	120	248	292	352	336	200
Sulphate	67	509	273	267	239	72	71	32	103	111
Conductance	950	1500	1400	1200	1150	1100	1220	1400	1300	1150
Irrigation Water Class: Good										
Suitable	X									
Permissible		X	X	X	X		X		Permissible to Doubtful	X
Doubtful						X				
Unsuitable								X		

	#120 Matsumoto Well	#121 Matsumoto Well	#121 Matsumoto Well	#122 Munson Well	#123 Munson Well	#124 Fry, Sr. Well	#125 Powers Well	#105 Powers Well	#126 Fry, Jr. Well	#127 Fry, Jr. Well	#128
Water Sample No.	46***	18*	47***	15*	16*	11*	13*	14*	10*	12*	41
Total Solids	820	1452	772	1364	836	1314	1436	1704	1386	996	550
Sodium	36	164	3	215	75	176	150	106	206	159	216
Calcium	124	206	120	344	138	172	106	248	104	128	75
Magnesium	82	58	87	90	41	53	63	76	61	44	29
Carbonate	0	0	0	0	0	14	19	19	0	0	
Bicarbonate	351	345	327	341	233	376	312	323	458	449	4[illegible]
Chloride	228	412	196	764	248	128	406	560	148	106	468
Sulphate	110	340	115	352	72	498	232	207	430	314	43
Conductance	1150	1000	1050	2000	1200	1600	1650	2200	1700	1300	520
Irrigation Water Class: Good											
Suitable											
Permissible	X		X		Doubtful to Permissible	X			X	X	
Doubtful											
Unsuitable		X		X			X	X			X

All values are ppm except conductance.

TABLE 2
ROCKY MOUNTAIN ARSENAL
CONTAMINATION STUDY
WATER ANALYSIS - OUTSIDE OF ARSENAL BOUNDARY

* Analysis by CE Lab-Sampled Oct 1954 ** Analysis by GS Lab-Sampled Nov 1954		#100 Masumaga, SE Sec 10 T2S R67W W.S. RMA-9**	#101 Burlington Ditch Sec 15 T2S R67W W.S. RMA-4**	#102 Burlington Ditch*	#103 Powers House Well SW 15 T2S R67W W.S. RMA-10**	#103 Powers House Well*	#104 Wolpert Well NE Sec 22 T2S R67W W.S. RMA-6**	#105 Powers Irr. Well at House Sec 15 T2S R67W W.S. RMA-7**	#106 Palumbo Well NE Sec 22 T2S R67W W.S. RMA-8**	#107 1st Creek North Boundary of Arsenal W.S. RMA-5**
Total Solids				810		1290				
pH		7.3	7.2	7.4	7.4	7.3	8.8	7.3	7.7	7.8
Sodium	Na	161	120	153	219	138	123	235	79	
Potassium	K	3.4	10	13	6.4	5	2.4	7.4	6.6	
Calcium	Ca	136	67	61	392	170	5.4	416	187	
Magnesium	Mg	35	19	30	92	50	3.5	102	22	
Manganese	Mn			0.4		0				
Aluminum	Al			0.1		0.01				
Iron	Fe			0.5		0.03				
Arsenic	As				0.0					
Boron	B				0.29			0.52		
Silica	SiO_2			16		19				
Hydrogen Rad.	H			0		0				
Hydroxide Rad.	OH			0		0				
Carbonate	CO_3	0	0	0	0	0	10	0	0	0
Bicarbonate	HCO_3	426	298	468	283	272	194	273	250	146
Chloride	Cl	106	117	155	760	401	30	1010	70	850
Fluoride	F	1.6	1.0	1.3	1.2	1.4	2.8	0.8	0.5	0.7
Sulfate	SO_4	296	107	98	472	145	77	304	383	
Nitrate	NO_3	14	0.3	0	16	5.8	0.3	18	25	45
Phosphate	PO_4			16		0				
Chloroform Ext.				-		5				
Conductance		1490	1080		3430		610	3880	1300	3410
Copper	Cu			-		0.032				
Nickel	Ni			-		0.014				
Alkalinity (As $CaCO_3$): Phenolphthalein				0		0				
Total				384		223				
Hardness as $CaCO_3$		484	245	197	1360	630	28		557	

W.S. - Water Sample
All values are ppm except pH and conductance.

TABLE 3
ROCKY MOUNTAIN ARSENAL
CONTAMINATION STUDY
WATER ANALYSIS - WITHIN ARSENAL BOUNDARY

* Analysis by CE Lab-Sampled Oct 1954 ** Analysis by GS Lab-Sampled Nov 1954 *** Analysis by CE Lab-Sampled 1952		#108 Ditch from Res. A at Culvert on D Street W.S. RMA-1**	#108 Ditch from Res. A at Culvert on D Street*	#109 1st Creek at E Street, W.S. RMA-3**	#110 Industrial Water Supply***	#111 G. B. Plant Discharge*	#112 Inflow to Res. C at 8th Avenue*	Well A-91**	Well A-59**	Well A**	Well 4-A**	Well 5-A**	Well 49-A**	Well 54-A**	Well 57**	Test Hole DP#5**	Test Hole DP#8**	Test Hole DP#13**	Test Hole DP#31**	#130 Disposal Pond SE Sec 26 T2S R67W W.S. RMA-2**
Total Solids		6120	6610	807	735	1590	9600				6630	1020	9380	8290	520					6470
pH		9.7	9.6	8.2	8.5	11.6	2.4	7.8	7.8	7.6	7.2	8.8	7.1	7.3	7.0	7.7	7.4	7.2	7.7	6.6
Sodium	Na	2220	2335	130	58	468	2050	320	3250	610	998	327	2770	2570	58	1770	316	2090	68	2270
Potassium	K	7.8	15	8.4	3.9	8	18	5.4	14	6.4	12	3.6	11	11	4.7	12	16	13	7.4	8.5
Calcium	Ca	13	12	97	138	68	12	42	71	208	691	9.6	383	279	79	406	648	884	96	18
Magnesium	Mg	4.9	1.2	29	19.6	17	1.2	4.9	65	11	398	4.9	136	107	18	117	175	228	18	6.1
Manganese	Mn		0			0	0.3													
Aluminum	Al		18			0.24	560													
Iron	Fe		0.03			0.23	0.08													
Arsenic	As	3.4		0.60					0.06		0	0	0.05	0.05	0					0.30
Boron	B	0.16		0.32							0.64	0.05	0.15	0.35	0.01					0.20
Silica	SiO2	4	0	7.2		38	0				20	3.8	18	19	16					1.5
Hydrogen Rad.	H		0			0	34													
Hydroxide Rad.	OH		0.7			68	0													
Carbonate	CO_3	468	236	0	0	361	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Bicarbonate	HCO_3	594	1083	223	232	16	0	245	213	94	211	148	170	153	112	184	145	266	212	348
Chloride	Cl	2050	2190	105	61.1	153	4000	98	4850	485	3270	43	4840	4210	195	3220	1820	4830	104	3020
Fluoride	F	90	95	1.2	0.5	2.2	40	0.3	2.6	0.7	2.6	0.2	2.2	6.1	0.6	1.6	1	1.6	0.6	48
Sulfate	SO_4	369	358	304	273	275	355	477	425	1100	653	539	657	680	34	606	251	683	110	368
Nitrate	NO_3	1.8	0.0	3	6.8	0	0	0.7	3.5	4.2	8.8	1.8	4.8	14	1.3	15	15	7.5	5.7	1.8
Phosphate	PO_4	2.4	2	0.8		0	1				0.4	0.1	0.3	0.1	0					0.6
Chloroform Ext.						0	40													
Conductance		9160		1230				1660	15100	3610	10300	1570	14900	13300	875	10500	5950	14600	918	10100
Copper	Cu					0	0													
Nickel	Ni					0	0													
Alkalinity (As $CaCO_3$): Phenolphthalein			323			532	0													
Total			1287			814	0													
Hardness as $CaCO_3$		52	101	361	426	241	2113	125	444	564	3360	44	1510	1140	271	1490	2340	3140	314	70

W.S. - Water Sample

THE GREAT WESTERN SUGAR COMPANY

General Offices GW Sugar Building

Denver, Colorado

June 4, 1954

Brig. General Charles S. Shadle
Julius Hyman & Company, Inc.
Rocky Mountain Arsenal
Denver, Colorado

Dear General Shadle:

I think that you may be interested in having someone on your staff check the crops on the Jesse Powers' farm across from the Rolla beet dump near Henderson, Colorado, as they are apparently being affected in rather a peculiar way and possibly through some absorption of chemicals in underground water. Mr. Powers' farm is two miles directly northwest of the sump on the Rocky Mountain arsenal property, and is located on the southwest quarter of section 15-2S-R57.

At the instance of Mr. J. G. English, manager of our Brighton factory, I visited Mr. Powers' farm yesterday and was very much impressed by the appearance of the 50 acres of beets he has growing being affected by some chemical. The appearance was somewhat similar to the reaction of 2,4-D on dicotyledonous plants, but more the effect that I have seen from excess quantities of sodium chloride or similar material. Mr. Powers stated that the beets as late as Sunday looked exceedingly good, with an excellent stand and prospect for a crop. Now they are crinkled, yellow in appearance, and apparently passing out.

Mr. Powers has four irrigation wells on his farm, one of which is 525 feet deep from which he secured water to sprinkle irrigate his crop, and within a short time it has deteriorated to the point that it looks as if it is a failure. The same thing happened with a portion of an alfalfa field that was watered from the well, but half of the alfalfa was watered from the irrigation ditch from water from the South Platte River, and has a good, vigorous appearance in contrast to that watered from the irrigation well. We have taken samples from the four wells as well as soil samples and plant samples, and will have them analyzed at our research laboratory.

I think it well that you might check up on this situation inasmuch as Mr. Powers' farm is in an area that grows considerable vegetable crops for the Denver market. There are lots of cabbage, celery, onions, and other crops that may, if watered from these wells, be affected and might become injurious to human beings.

EXHIBIT A

I would be pleased to go with anyone that you might direct, or you can look up Mr. Powers personally and investigate this situation if you are interested. Rest assured that our attitude is one of helpfulness, and we would like to assist in finding out what the difficulty is and where it originates.

Very truly yours,

/s/ P. B. Smith
General Agriculturist

P. B. Smith
mh

EXHIBIT A

THE GREAT WESTERN SUGAR COMPANY

General Offices GW Sugar Building

Denver 17, Colorado

P. O. Box 5308
Terminal Annex

June 18, 1954

Mr. E. C. Thompson
Engineering Office
Rocky Mountain Arsenal
Denver 2, Colorado

Dear Mr. Thompson:

I appreciate very much the opportunity to visit with you this afternoon over the phone concerning the difficulties with the water in the area immediately west of the Arsenal properties.

I am arranging with Mr. J. G. English, manager of our Brighton factory, to have daily samples taken in duplicate and delivered to you about the middle of next week. We will plan to analyze the samples in our research laboratory at 21st and Blake streets and compare the results. If your chemists want to discuss the analyses or the procedures, they can get in touch with Mr. Robert Brown, Superintendent of our research laboratory, whose phone number is Keystone 4-2182.

We have analyzed some eleven different waters in the vicinity of Jesse Powers farm. They vary considerably in solid content, and at least the well close to Mr. Powers' house is several times the amount of chloride according to the AOAC methods.

I related also to you that we had treated some healthy beets with five gallons of the water from this same well, and they have turned yellow and have a similar appearance to those on this farm. Also, we are running a synthetic solution containing the proportions of chlorides, of magnesium, calcium and sodium found in the waters on clean, healthy beets at our experimental station at Longmont, Colorado. This for your information.

Very truly yours,

/s/ P. B. Smith
General Agriculturist

P. B. Smith
mh

EXHIBIT B

REPORTS OF DAMAGE

1. Jesse Powers farm SW¼ Sec. 15, T2S R67W.

Well #125, water sample No. 13, and well #105, water sample No. 14.

Soil Type - Fort Collins clay loam and weld clay loam. - From Soil Survey of the Brighton Area, Series 1932 - Slope 0.3% to 1%.

Crop effect: Sugar Beets. Seedlings turned yellow 5 to 10 days after sprinkle irrigated with water from well #105. 20 acres of beets abandoned. 20 acres of beets kept and irrigated with ditch water; these beets recovered satisfactorily. Five acres irrigated with well water the last of July. Foliage turned yellow with a crepe paper feel and appearance. Beets not killed but damaged.

Irrigated Pasture:
Flood irrigated with well water from well #125 in May. About 25% of grass and legume killed and had the appearance of burning from lack of water. A portion of the pasture irrigated with ditch water with no effect to crop. At the lower end of the field where ditch water had run over where the well water had been, the crop was normal. At the end of two weeks the grass irrigated with well water was 4 inches high, where surface irrigated it was 18 inches high.

Alfalfa: Where sprinklers had overlapped into alfalfa field from Well #105 the alfalfa was 6" shorter at time of first cutting than rest of field. Whole alfalfa field had been irrigated previously with ditch water.

1954 was first year that well water has effected crops adversely. Well #105 has been in constant use since 1932. Well #125 since 1948.

2. Nesom farm: That portion of N½ Sec. 22 T2S R67W between U. S. Highway #6 and O'Brien Ditch.

Well #129, water sample No. 14; well #118, water samples Nos. 21 and 48; well #119, water samples Nos. 22 and 49.

Soil Type - Weld loam and weld fine sandy loam. Sandy loam surface with loam subsoil and sand below 30" to 36".

Crop effect: Corn-Retarded to practically no yield in 1951 from water from well #129. Corn seedlings killed in spring of 1952. Well #129 filled in 1952 and Wells #118 and #119 dug. No effect on corn from water of wells #118 and #119.

Barley: Also killed from well #129 in 1951 and 1952. Top of leaves turned light green to brown in 1954. Tips and base of leaf normal color. Barley sprinkle irrigated in 1954 so may have been due to sun scald rather than salts. Barley yield not materially effected. No corn sprinkled in 1954. Water limited to well water, no ditch water available.

EXHIBIT C