FILE MEMORANDUM
ON
REVIEW OF WATER QUALITY CHANGES
IN EDWARDS RESERVOIR--
ESPECIALLY NEAR THE BAD WATER LINE

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by

R. W. Harden

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CONTENTS

TABLES

Contents - continued

ILLUSTRATIONS

FILE MEMORANDUM
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PRINCIPAL CONCLUSIONS AND RECOMMENDATIONS

1. The water quality changes in individual wells have to date mostly been small. No large, lateral shift in the position of the bad water line is apparent from the data available, and none is believed to have occurred in historical times.
2. The present study indicates that there are considerably more wells in which water quality variations occur than have been recognized, or were recognizable, in the past. This is probably due mostly to a longer period of record now being available for some of the wells over periods when larger and more prolonged changes in stage of the reservoir have occurred.
3. Wells located very close to the bad water line tend to show larger and more easily recognizable changes in quality than other wells, but some changes in water quality are noted for wells located some distance both north and south of the bad water line.
4. It does not appear that a more exhaustive study of the bad water

line is warranted at present, but additions to the present network of wells sampled, particularly in Bexar County, appear to be warranted.

5. Because of the potential importance to San Antonio of quality changes along the bad water line in Bexar County and inasmuch as quite a few small changes are apparently occurring, it is recommended that additional wells both along the bad water line and south of the bad water line be included in the semi-annual sampling program of the USGS cooperative study. Table 5 lists all the wells in Bexar and Atascosa Counties that we recommend be in the program. Some of those listed are already a part of the program, and nearly all have been included at one time or another. Each well should be sampled each year in January and August and a preliminary type analysis made. In addition, a search for additional, existing wells in Bexar County located both close to the bad water line and also south of the bad water line should be made, and probably all wells found should be added to the program.

INTRODUCTION

History and General Background

Poor quality water exists in the Edwards Reservoir down dip from those areas containing good quality water. The change between the good and poor quality water is fairly abrupt in all areas where well control is available, and a so-called "bad water line" has been delineated on the maps of the Edwards Reservoir. The location of the bad water line has been drawn by various past workers at approximately the same position, although some minor changes in the position of the line, as drawn, have been made from time to time as additional information became available, and also possibly because of the use of slightly different criteria being used at various times to define the bad water line. So far as is known there has been no large lateral movement of the bad water line in historical times.

Inasmuch as there is apparently no physical barrier to movement between the two qualities of water, and because it is believed that appreciable movement might occur under some conditions, at least locally, a water quality observation well network was established in the late 1950's as a part of the continuing USGS cooperative study of the Edwards Reservoir. The program has consisted of periodic resampling of wells along the bad water line. Prior to about 1959 almost no wells were sampled periodically. Beginning in 1959 and continuing through about 1962, approximately 125 wells along the bad water line were sampled semi-annually. In the few years that followed the program was reduced and fewer wells were sampled. The number of wells sampled was further reduced in 1966 and 1967, when about 35 wells were sampled semi-annually. Current USGS plans call for enlarging the program to about 80 wells when the stage of the reservoir falls below elevation 620 in the Dodd Field recorder well.

In general, the net result of the timing of the changes in the number of wells sampled has been that continuous records are available for a good many wells for mostly the 1959 through 1962 period when there was little change in reservoir stage, and for relatively few wells over those time periods when the stage of the reservoir was changing significantly.

The results of the chemical analyses of water collected from the observation wells are periodically published by the Edwards Underground Water District. To date, these include Bulletins 1, 4, 7, 10, and 13. The interpretations of the USGS of these data are included in the periodic progress reports on the Edwards Reservoir which have been published by the Texas Board of Water Engineers and the successors of that agency.

Purpose and Scope of the Present Review

This memorandum presents the results of a review of the water quality data for the observation wells through 1967. It also includes some observations on the general water quality of the Edwards. The primary purpose of reviewing the water quality observation well data has been to identify where and when changes in water quality have occurred and the nature of the changes. In addition to this memorandum several figures and tables have been prepared in draft form, and they accompany this memorandum. The basic data used for this review as well as quite a few other graphs which were prepared are not included with this memorandum because of their sheer bulk. These data and graphs have been made a part of this firm's files and can, and should, be referred to in any detailed study or review of this memorandum.

This memorandum sets out what was done and presents some of the thoughts, possibilities, and comments which arose during the review. Not all of the items and comments included are considered to be in complete or final form. They have been included, nevertheless, in the hope of making future reviews easier and also of possibly aiding other future studies on the hydrology and water quality of the Edwards.

The principal items that were done as part of the current review include:

1. Study of a draft memorandum and notes prepared by R. A. Scalapino on his review of the water quality observation well data through 1962. This earlier review is filed in Section 3-48 of our San Antonio file, and also includes a map entitled "Chloride Content of Water from Wells" on which the available data for the different observation wells up through 1962 is summarized. This map is included herewith.

2. The results of the chemical analyses of water from observation wells for the period 1962 through 1967 were posted on the work sheets filed in Sections 9-2 through 9-7c of our San Antonio file. The data were obtained from the published reports of the Edwards

Underground Water District, except for data for the 1967 year which was obtained directly from the USGS office in San Antonio.

3. A list of both the current and historical USGS water quality observation wells was prepared and it accompanies this memorandum. The list is identified as Table 1, and shows the well numbers currently used, the number of analyses available for a particular well, and the period of record. For the locations of these wells it is necessary to consult the map referred to above as well as published, general well location maps for the Edwards Reservoir area.

4. Our file work copy of the hydrograph for the Beverly Lodges-Dodd Field recorder was updated, and hydrographs for one well in Guadalupe County and one in Atascosa County were prepared. These data are not included herewith but are a part of Section 10 of the San Antonio file.

5. All of the results of chemical analyses of water samples from the observation wells available to date were studied. The chloride and/or sulfate contents of the water for many of the wells were plotted on 20-year graph paper. These graphs of water quality were then compared with each other as well as with the hydrographs depicting the stage of the reservoir. The graphs prepared are filed in Sections 9-2 through 9-7c of the San Antonio file.

6. Graphs which are herein referred to as "frequency distribution" graphs were made of the sulfate and chloride contents of water from the major springs of the Edwards Reservoir. These are attached hereto and are identified as Figures A and B.
7. Similar "frequency distribution" graphs were made of the chloride and sulfate contents of water from Edwards wells by county and by area. These graphs are also attached and are identified as Figures C, D, E, and F.
8. Graphs were made of the correlation between the sulfate and chloride contents of water from the same well for many of the observation wells. These graphs are attached to the back of the respective work sheets in Sections 9-2 through 9-7c of the file.
9. A few other graphs were also prepared in attempting to analyze certain data. These are identified as Figures G and H and are attached hereto.
10. A list, labeled Table 2, was made giving the items which could be responsible for quality changes.
11. A list, labeled Table 3, was prepared giving the precision reported by the USGS for their chemical determinations.
12. A list, labeled Table 4, was made giving those wells for which quality changes have been previously, or are currently, noted.

WATER QUALITY CHANGES NOTED

Kinney County

It is believed that many of the observation wells in Kinney County show water quality changes. The wells for which changes are currently noted are given in Table 4. Most of the changes are very small and only a few appear to be correlative with the stage of the reservoir, at least as shown by water levels in wells in Bexar County. As there is not much pumping in Kinney County, it is believed that most of the changes probably result from natural movement of water in the formation.

The quality changes for wells Y-14, Y-16, and Y-17 appear to correlate with the general stage of the reservoir, and they do so in what is herein termed a direct manner. That is, they react as one would expect as the stage of the reservoir changes. As the stage rises, the mineralization of the water becomes less and as the stage falls, the mineralization increases.

Possibly worthy of note are the data for Wells V-23 and V-29. For Well V-23 the chloride content of the water correlates inversely with the sulfate content. The reason for this is not known. For Well V-29 there has been a decrease in mineralization of the water to date. This is particularly noticeable in the sulfate content which has progressively dropped from about 550 parts per million in 1964 to slightly over 300 parts per million in 1967. The cause of this decrease is not known.

The data for Kinney County have not presently been studied in as much detail as they could be largely because of the relative remoteness of the area to San Antonio. It appears that to attempt to better understand the changes in water quality in Kinney County, at least the following items should be considered and/or done.

1. Obtain the records on the water-level observation wells in Kinney County and see if the changes in water quality in Kinney County correlate with the local water-level fluctuations.
2. Determine when the recent irrigation developments in southern Kinney County occurred and see if there is a correlation in the timing of these developments and changes in water quality in any of the wells.
3. Compare the water quality changes with the presence and/or absence of flow from Las Moras Springs.
4. Make a more detailed study of the general water quality in the county and obtain and study the complete construction records on the water quality observation wells.

Uvalde County

It is believed that many of the wells in Uvalde County exhibit changes in water quality over the period of record. Those for which changes have been noted are listed in Table 4. For wells H-6-82 and H-4-95, the water quality changes correlate with the stage of the reservoir in a direct way.

For the other wells listed in Table 4, the quality changes either do not appear to correlate with stage or they do so only for a part of the period of record. Quite a few wells show decreases in the sulfate and/or chloride content of the water occurring between about 1959 and 1961 or 1962, and this may represent a freshening caused by the rise in reservoir stage from 1957 through 1961. These same wells, however, tend to show no correlation with stage at other times.

Medina County

The southern limit of good water in Medina County has not been defined, and all of the Edwards wells in Medina County which have been sampled periodically are in the good water area. The wells for which some quality variations have been noted are listed in Table 4. Water from all of the wells has a chloride content between about 10 and 30 parts per million. The quality changes in several of the wells appear to generally correlate in a direct manner with the stage of the reservoir.

Atascosa County

Of the three wells which have been periodically sampled in Atascosa County, changes in water quality are noted for two. For Well 3 the water quality data available for 1958 through 1962 correlates in a direct manner with the stage of the reservoir. After 1962, however, this is not the case. For Well 4, which is located in the bad water area, the data show a progressive freshening of the water from about 600 parts per million chloride to about 350 parts per million chloride over a time when the stage of the reservoir was declining. This type of change is herein termed inverse, that is, as the stage of the reservoir lowers, the mineralization of the water becomes lower, and conversely, as the stage rises the mineralization becomes higher.

Bexar County

More wells have been periodically sampled in Bexar County than in other areas of the Edwards Reservoir, and it is in Bexar County that the location of the bad water line is best defined at present. Also, there is a relatively large number of wells located close to the bad water line, and some of the most easily recognizable water quality variations have occurred in Bexar County.

The wells for which recognizable changes are currently noted are listed in Table 4. The changes have been mostly small except in a few wells which for practical purposes are located on the bad water line. Although not many analyses are available for the 1956-57 period when the reservoir was at a record low stage, it does not appear that there has been any large lateral movement in the position of the bad water line in historical times.

The chloride content for about 20 of the wells has been plotted on 20-year graph paper. In general, there appear to be two kinds of quality changes in the Bexar County wells for which changes are noted. In about half or slightly more than half of the wells, the quality changes appear to vary in a direct manner with the stage of the reservoir as indicated by the

Beverly Lodges-Dodd Field recorder. For some wells the direct variation in quality with stage of the reservoir is quite obvious. For others it is less obvious, and in some it is considered only a possibility. For some of the wells in which a direct variation in quality with stage occurs, or possibly occurs, the water quality becomes worse in the pumping season, which is probably to be expected for a well in which water quality varies directly with stage.

For quite a few of the other wells in which quality changes have been noted the variations appear to correlate in an inverse manner with the stage of the reservoir. That is, as the stage of the reservoir has declined, the mineralization of water from the wells has become lower or conversely, as the stage rose, the mineralization increased. Here again, for some of the wells the inverse correlation is quite obvious, while for others it is less obvious, and in some it is only a possibility. Also, for some of the wells in which the quality changes are inverse with stage, the water quality becomes better in the pumping season, which again is probably to be expected. Not all the inverse wells show this, however; in fact, the opposite appears to be sometimes true.

It should be kept in mind that although quite a few of the quality changes which appear to have occurred have been herein classed as inverse based on the records presently available, it is considered possible that at least some of those presently termed inverse may, in actuality, be direct variations which are merely lagging the changes in stage to an extent that makes them appear to be inverse. The short period for which records are currently available is insufficient to fully appraise this possibility, and a longer period of record is needed to understand many of the changes.

In a further effort to appraise the likelihood of whether or not some of the changes have actually occurred, or whether they are merely fortuitous variations, a map was prepared showing the locations of some of the water quality observation wells showing changes. This map is attached hereto and is labeled Figure H. The bad water line is also shown on the map. For all of the wells for which a direct variation in water quality with stage appears to be occurring, as shown by the available water quality data, a "D" was placed by the location of the well. For all of those wells for which an inverse variation with stage is indicated, an "I" was placed by the location of the well. For a few of the wells in which the available records indicate that a change from direct to inverse may have occurred, both a "D" and "I" were placed by the well location. For those wells in which the water quality appeared to get worse in the pumping season, a "w" was placed by the well. For those wells in which the water quality appeared to get better during the pumping season, a "b" was placed by the well location. Question marks appear by some of the letter designations on the map. They represent an attempt at indicating those wells in which the above correlations are less certain.

From an inspection of the map it appears that direct variations in water quality with stage probably have occurred in all the counties of the Edwards Reservoir. As can be seen on the map, the wells for which inverse variations in water quality with stage are believed to have occurred apparently are mostly grouped in one area in southwestern Bexar County adjacent to the Atascosa County line. For a few of the so called "inverse" wells in southwestern Bexar County there is some hint in the available records that a change within the period of record has occurred, with the change being that the water quality formerly reacted with stage in a direct manner but presently reacts in an inverse manner.

The period over which data are available and the magnitude of the quality changes for many of the wells in the southwestern Bexar County area are such that, on an individual well basis, some of the present correlations have to be considered only tentative. When viewed collectively, however, the data appear to show a reasonably consistent pattern, probably indicative of water movement within the reservoir.

It was noted as early as 1956 that water from some wells close to the bad water line in central Bexar County increased in mineralization at times of low stage. From the information on Figure H, it can be seen that for nearly all of the observation wells in central and eastern Bexar County direct variations in quality with stage are believed to be occurring. These direct variations probably essentially represent small advances of the bad water towards the north at times of declining stage and small retreats to the south at times of rising stage. On the other hand, the inverse variations of quality with stage for the wells in the southwestern Bexar County area are believed to essentially represent the opposite, namely small retreats of the bad water towards the south at times of declining stage and small advances to the north at times of rising stage. Whether or not the advances and retreats in these two areas are directly related is not known, but the information currently available suggests this possibility. It also suggests that some future shifts in the bad water line near San Antonio might be as much, or more, a function of the pumpage at San Antonio as of the general stage of the reservoir.

Guadalupe County

Of the wells which have a moderately long record in Guadalupe County, only Well D-67 appears to have variations in water quality which correlate with the stage of the reservoir. For this well there appears to be an overall correlation of water quality with the stage in a direct way. The two analyses available for Well D-2 indicate a direct correlation of water quality with stage, but as only two analyses are available this correlation may only be apparent.

One analysis for Well D-56 shows substantially lower chloride content than all other analyses. The reason for this is not known, but inasmuch as most of the other analyses for this well are approximately the same, it would appear that the variation may be a function of pumping time or of some other well condition and not of a reservoir condition.

Comal County

Of the wells for which changes are noted in water quality in Table 4 for Comal County, only Well G-84 appears to, at least partially, correlate in a direct way with the stage of the reservoir. Also, for several past years the water quality for this well appears to have become worse during the summer.

For Well G-83 the water quality varies considerably, and it is believed that this is due to the construction of the well. For all the other wells for which changes are noted in Table 4, it is not known whether or not the changes are due more to well conditions or to reservoir conditions. Many of the wells in Comal County do not have casings that extend completely through the formations overlying the Edwards, and it is reported that in some wells poor quality water is encountered in formations above the Edwards.

Hays County

Of the wells for which quality changes are noted in Table 4 for Hays County, only the changes in Well H-25 appear to have a correlation with reservoir stage. The changes in Well H-25 appear to correlate in a direct manner with stage and oftentimes the water quality in the summer is slightly poorer than in the early part of the year. The most likely reasons for the variations in water quality in the other wells listed in Table 4 appear from present data to be related to poor quality water entering the wells from formations shallower than the Edwards or to variations in the length of pumping time prior to sampling.

SOME COMMENTS ON THE GENERAL WATER QUALITY IN THE EDWARDS RESERVOIR

The general chemical character of the water in the fresh water portion of the Edwards Reservoir is quite uniform. In an effort to isolate and identify differences in the water quality in various areas and from various sources, six graphs of the water quality were prepared. The graphs tend to show frequency distribution and are labeled Figures A, B, C, D, E, and F.

Figures A and B represent an effort to categorize the water quality of the various springs of the Edwards and to detect any small differences between the springs. The sources of the data used in preparing Figures A and B are our files and the published records of the U. S. Geological Survey. The graphs show the number of separate determinations of sulfate or chloride content having a certain value. Thus, the height of one of the individual bars for a spring gives the total number of times the water was determined to have that particular sulfate or chloride content. Using Hueco Springs on Figure A as an example, there were sulfate analyses available on 11 separate samples from the springs. One of the analyses showed a sulfate content of 6.8 ppm, one showed 8 ppm, one showed 9 ppm, three showed 11 ppm, three showed 13 ppm, one showed 14 ppm, and one showed 16 ppm.

From Figures A and B, it can be seen that there are differences in the basic water quality coming from the various springs. From Figure A, it can be seen that Las Moras Springs is slightly lower than Hueco Springs in sulfate content, and that Comal and San Marcos are about the same. It can also be seen that San Felipe Springs is about the same to slightly lower than Las Moras Springs in sulfate content. Barton Springs is typically higher in sulfate content than all the other springs, and the sulfate content of Barton Springs apparently fluctuates within rather wide limits compared with the other springs.

From Figure B, it can be seen that San Felipe and Las Moras Springs are about the same in chloride content, that Hueco Springs may be slightly lower than Las Moras or San Felipe Springs, that Hueco is about like Comal, that San Marcos is higher than Comal, that Barton is typically much higher than San Marcos, and that Barton fluctuates rather widely in relation to the other springs.

From Figures A and B, it can be seen that in the San Antonio segment of the Edwards Reservoir, that is, from Las Moras to San Marcos, there is a general increase in the sulfate and chloride content from west to east. This is in agreement with the general direction of movement of water in the reservoir. Also, the differences shown by the graphs between Hueco and Comal Springs tend to support past conclusions regarding the source of

Hueco Springs. The reasons for the rather large variations in chloride and sulfate content for Barton Springs were not explored in this study as the matter was not considered pertinent.

Because there do appear to be recognizable differences between the waters issuing from the major springs of the Edwards, similar plots were made of the chloride and sulfate contents of water from wells tapping the Edwards Reservoir in Kinney through Hays Counties. These are labeled Figures C, D, E, and F. Figures C and D represent the sulfate and chloride contents of well waters in the various counties. The sources of the data plotted are the map showing the results of chemical analyses published as a part of Bulletin 5606 of the Texas Board of Water Engineers and the results of analyses from the USGS water quality observation well program. The difference between these graphs and those for the springs is that the bars represent the number of wells for which a given determination was reported by the laboratory. For example, there are six wells in Comal County (including Guadalupe County) for which sulfate contents of 12 parts per million were reported. The data shown do not represent several analyses on one well, but only one analysis for each well was used in preparing the graphs. The 1966 analyses, or the most recent analyses prior to 1966, were used for the plotted data which are from the USGS water quality observation well program. Consequently, if one used other analyses from the observation well program the appearance of the graphs would be somewhat different, although it is believed not significantly so.

On Figure C it can be seen that the upper limit of the sulfate content is about the same in all the counties. The lower limit of the sulfate content, however, changes slightly from county to county as do the most likely values for the fresh water. From Figure C, the sulfate content of the fresh water appears to generally increase from west to east with the most notable exception being for Comal County where there are a good many wells for which sulfate determinations were one or less ppm. Most of the wells for which the sulfate contents were one or less ppm are located in the general area of the Cibilo-Dry Comal drainage area.

From Figure D, the chloride content of water from Edwards wells, it can be seen that from at least Bexar County through Hays County the upper limit of the chloride content of the water is high and about the same, whereas in Kinney and Uvalde Counties the upper limit of the chloride content is much lower, being the lowest in Kinney County. The most likely values for the chloride content of the fresh water are approximately the same, although some small differences do appear to exist between some counties. Figures A, B, C, and D show a general pattern of increases in the chloride and sulfate content from Kinney County to approximately Bexar County, with little or no changes occurring from about Bexar County to Hays County except for the Cibilo-Dry Comal drainage area already noted.

Figures E and F show the chloride and sulfate content of water samples from wells located in the Edwards outcrop area of the Edwards Reservoir.

The data are graphed by counties and are from the same sources as those plotted on Figures C and D. In the case of Figures E and F, the data are only for those wells located north of the southern boundary of the Edwards outcrop. In quite a few of the counties not many wells located in the outcrop area have been sampled and the few data may not be indicative of conditions. In other counties, for example Comal County, the coverage is relatively good and so the data are probably more indicative of conditions.

The chloride content of the well water shown in Figure F is fairly uniform for all the counties. The sulfate content of the well waters, however, is far less uniform.

ADDITIONAL WORK ITEMS WHICH COULD BE DONE

For any reservoir like the Edwards, new techniques and methods of analysis are always possible. There follows a list of some of the items which were thought of and considered during this review but which were not fully pursued. It is possible they may prove to be helpful in future studies of water quality.

1. Obtain more of the water-level records for each county of the Edwards and compare them with the water quality variations recognized in the same counties.
2. Make a set of graphs similar to those shown in Figures E and F, except instead of using the outcrop area attempt other separations

of the Edwards Reservoir based possibly on the structure contour map and the maps of elevation of water level at various stages. Although data to do this may not be sufficient in all counties to give representative results, it might be representative enough in some areas or in conjunction with other data, such as well yields, to assist in identifying the general areas or zones through which more movement takes place.

3. Using the chloride and sulfate values shown by Figures A and B for the major springs, study the areal distribution of various water qualities in the Edwards in surrounding areas in an effort to appraise the most likely flow areas to the springs in the immediately surrounding areas. In doing this it may be helpful to consider quantitatively the various possibilities of mixing various volumes of given qualities for various combinations of possible sources.

4. Plot on 20-year graph paper the chloride and sulfate values of the water for more of the observation wells.

5. Investigate the precision of the new automatic chloride recorders in use by the U. S. Geological Survey and obtain the approximate cost for their use for a long or short period.

6. Make a thorough search for all the past water-level records in wells in the bad water area, especially in Bexar County, to attempt

to learn more about the differences in elevation and change of water level in the bad water area in relation to the good water area.

7. Obtain and evaluate the available information on the quality of the water of the base flows and the flood flows entering the Edwards Reservoir in the various recharge areas.
8. Review the recent USGS professional paper giving the results of USGS research regarding the use of calcium-magnesium ratios in studies of ground-water movement through limestone and dolomite.
9. Study in more detail all of the well construction records for the wells which appear to exhibit water quality changes.

TABLE 1

USGS WATER QUALITY OBSERVATION WELLS
IN THE EDWARDS RESERVOIR

USGS Well No.	Period of Record	Number of Analyses	Asterisk indicates data has been plotted
	KINNEY COUNTY		
M-5	1948-1961	3	
M-10	1948-1967	16	*
M-12	1948-1964	10	*
M-14	1937-1967	17	*
N-5	1948-1965	12	*
T-2	1948-1962	4	*
U-14	1964-1967	4	
U-15	1958-1965	12	*
V-7 (Las Moras Springs)	1959-1967	14	
V-23	1960-1965	9	*
V-29	1959-1967	17	*
W-17	1962-1963	3	
X-5	1939-1967	17	*
Y-5	1938-1962	7	*
Y-14	1960-1962	6	*
Y-15	1960-1961	3	
Y-16	1961-1965	9	*
Y-17	1960-1965	9	*
	UVALDE COUNTY		
G-6-2	1960-1963	7	*
H-4-34	1960-1963	7	*
H-4-57	1960-1964	7	*

Table 1 - USGS Water Quality Observation Wells in the Edwards Reservoir (continued)

USGS Well No.	Period of Record	Number of Analyses	Asterisk indicates data has been plotted
	UVALDE COUNTY (continued)		
H-4-64	1937-1967	16	*
H-4-95	1957-1963	8	*
H-5-1	1945-1963	6	*
H-5-72	1957-1965	10	*
H-5-163	1959-1967	17	*
H-5-240	1959-1967	12	*
H-5-272	1961-1962	3	
H-5-284	1961-1967	3	
H-6-25	1956-1967	12	*
H-6-74	1957-1965	12	
H-6-82	1957-1965	9	*
H-8-69	1956-1965	9	
I-4-48	1958-1962	6	
I-7-15	1960-1966	12	*
	MEDINA COUNTY		
I-5-46a	1955-1959	2	*
I-5-48	1952-1961	4	
I-5-55	1930-1967	16	*
I-5-74	1959-1967	12	*
J-4-143	1956-1967	12	*
	ATASCOSA COUNTY		
3	1957-1966	13	*
4	1959-1964	6	*
5	1957-1963	12	*

Table I - USGS Water Quality Observation Wells in the Edwards Reservoir (continued)

USGS Well No.	Period of Record	Number of Analyses	Asterisk indicates data has been plotted
	BEXAR COUNTY		
Cy 155	1952-1965	10	*
Cy 175	1934-1962	9	*
Cy 278	1961-1965	6	
Cy 284	1956-1967	15	
Cy 296	1962-1964	2	
F-249	1959-1965	12	
G-7	1958-1967	16	
G-7a	1956-1959	7	
G-8	1942-1961	10	*
G-9a	1956-1961	7	
G-10	1942-1959	8	
G-11	1942-1957	6	
G-12	1952-1957	6	
G-17	1942-1957	6	
G-20	1942-1957	6	
G-33	1956-1965	16	*
G-63	1956-1964	11	
G-64	1959-1962	6	
I-60	1944-1957	3	
I-61	1944-1957	4	
I-125	1955-1963	10	
I-190	1952-1957	4	
I-191	1952-1957	4	
I-195	1959-1962	6	
I-205	1960-1964	10	*
I-206	1960-1966	12	
J-40	1956-1967	22	*
J-50	1958-1967	15	
J-62	1950-1957	4	
J-64	1956-1959	6	
J-66	1950-1963	15	*

Table 1 - USGS Water Quality Observation Wells in the Edwards Reservoir (continued)

USGS Well No.	Period of Record	Number of Analyses	Asterisk indicates data has been plotted
	BEXAR COUNTY (continued)		
J-67	1956-1959	5	
J-75	1956-1963	11	*
J-78	1959-1965	8	
J-79	1956-1958	4	
J-87	1956-1967	23	*
J-90	1956-1967	18	*
J-91	1959-1965	13	
J-92	1961-1962	3	
J-93	1957-1965	14	*
J-94	1961-1962	3	
K-2	1956-1967	19	*
K-20	1950-1959	2(?)	
M-13	1949-1963	11	*
M-39	1951-1963	10	*
M-44	1955-1967	20	*
M-45	1955-1965	16	*
M-46	1959-1962	6	*
M-47	1961-1965	9	*
M-48	1955-1965	17	*
N-4	1946-1963	10	
N-5	1959-1963	8	
N-6	1946-1967	18	
N-7	1959-1965	12	
N-7a	1960-1961	3	
N-28	1961-1963	6	*
N-118	1957-1964	14	*
N-119	1956-1965	17	*
N-120	1959-1963	6	
N-121	1957-1965	13	*

Table 1 - USGS Water Quality Observation Wells in the Edwards Reservoir (continued)

USGS Well No.	Period of Record	Number of Analyses	Asterisk indicates data has been plotted
	GUADALUPE COUNTY		
D-2	1958-1959	2	
D-18	1958-1965	12	
D-30	1959-1961	4	
D-56	1959-1964	9	
D-67	1949-1966	13	*
	COMAL COUNTY		
F-75	1959-1965	11	
G-50 (Comal Springs)	1936-1957	42	*
G-67	1944-1965	12	
G-83	1959-1965	8	
G-84	1959-1967	15	*
G-85	1959-1963	7	
G-86	1959-1965	10	
G-87	1959-1963	5	
G-88	1959-1962	6	
G-89	1959-1963	5	
H-2	1959-1963	6	
H-6	1936-1965	12	
H-7	1936-1963	8	
H-20	1936-1967	17	
H-23	1936-1963	8	
H-43	1959-1963	7	
H-49	1959-1966	13	
H-50	1961-1962	4	
H-51	1959-1965	6	
H-52	1960-1965	10	
	HAYS COUNTY		
E-70	1952-1965	9	*
E-76	1959-1967	15	

TABLE 2

ITEMS WHICH COULD AFFECT THE REPORTED WATER QUALITY OF SAMPLES AND BE RESPONSIBLE FOR CHANGES IN QUALITY

1. The precision with which the laboratory can actually make the determinations. This involves both the general precision of current analysis methods as well as the differences between older methods and the currently used methods.
2. Changes in any of the following items during the period over which analyses are available.
   a. Well depth and construction.
   b. Local pumping cones.
   c. The length and rate of pumping prior to sampling.
   d. Well use.
   e. The stage of the reservoir, ranging from daily to long-term.
   f. Local or regional flow patterns brought about by local or regional cones and/or stage of the reservoir.
3. Leakage from overlying or underlying formations, including changes in the amount of leakage with the relative stage of the Edwards Reservoir and the leaking reservoir(s).
4. Differences in the native water quality of the Edwards with depth, including differences in head within the Edwards Reservoir with depth.

Table 2 - Items Which Could Affect the Reported Water Quality of Samples and Be Responsible for Changes in Quality (continued)

5. Very long-term geologic trends.

6. Differences in recharge water quality with time, location, and amount.

7. Storage in the vicinity of the sampled well in relation to the rate of movement of the stored water.

TABLE 3

PRECISION REPORTED BY USGS FOR VARIOUS CHEMICAL DETERMINATIONS

Constituent	Reported Precision	
Bicarbonate		2-5 %
Sulfate	From 10-100 ppm:	± 2 ppm
	Above 100 ppm:	5 %
Chloride	From 10-100 ppm:	2-5 %
	Above 100 ppm:	2-3 %
Hardness	Old soap method:	10^{+} %
	EDTA method:	5 %
Specific Conductance		5^{+} %

(Data from USGS WSP-1473)

TABLE 4

WELLS NOTED AS HAVING HAD SOME WATER QUALITY CHANGES

	Well No. Under Person or Agency Noting Change		
County	USGS	Scalapino-1963	Harden-1967
Kinney Co.	None noted	M-5	M-5
		T-2	M-10
		V-23	M-14
		Y-5	N-5
		Y-9	T-2
			U-15
			V-23
			V-29
			W-17
			X-5
			Y-5
			Y-9
			Y-14
			Y-17
Uvalde Co.	None noted	H-5-163	G-6-2
		H-6-82	H-4-34
			H-4-57
			H-4-64
			H-4-95
			H-5-1
			H-5-72
			H-5-163
			H-5-240
			H-6-25
			H-6-82
			I-7-15
Medina Co.	None noted	None noted	I-5-46a
			I-5-55
			I-5-74
			J-4-143
Atascosa Co.	None noted	3	3
			4

Table 4 - Wells Noted as Having Had Some Water Quality Changes (continued)

County	USGS	Scalapino-1963	Harden-1967
Bexar Co.	G-8	Cy 175	Cy 155
	J-40	G-8	Cy 175
	J-75	J-66	G-8
	J-90	J-75	G-33
	M-44	J-91 (Buda)	I-205
		M-46	J-40
		M-47	J-66
		M-48	J-75
		N-28	J-87
		N-119	J-90
		N-121	J-93
			K-2
			M-13
			M-39
			M-45
			M-46
			M-47
			M-48
			N-28
			N-118
			N-119
			N-121
Guadalupe Co.	None noted	D-56	D-67
Comal Co.	None noted	G-83	G-83
		H-23	G-84
			G-86
			H-6
			H-23
			H-43
			H-51
Hays Co.	None noted	E-79	E-70
		E-82	E-79
		F-7	E-82
			F-7
			H-25

TABLE 5

LIST OF WELLS IN BEXAR AND ATASCOSA COUNTIES WHICH SHOULD BE SAMPLED SEMI-ANNUALLY IF PRACTICABLE

County and Well No.

BEXAR CO.

Cy 155
Cy 175
Cy 278
Cy 284
Cy 296

F-249

G-7
G-8
G-33
G-63
G-64

I-125
I-195
I-205
I-206

J-40
J-50
J-66
J-67
J-75
J-78
J-79
J-87
J-90
J-92
J-93
J-94
J-99

County and Well No.

BEXAR CO. (continued)

K-2
K-20
K-26

M-13
M-39
M-44
M-45
M-46
M-47
M-48

N-4
N-5
N-6
N-7
N-7a
N-28
N-118
N-119
N-120
N-121

Q-43a

ATASCOSA CO.

3
4
5

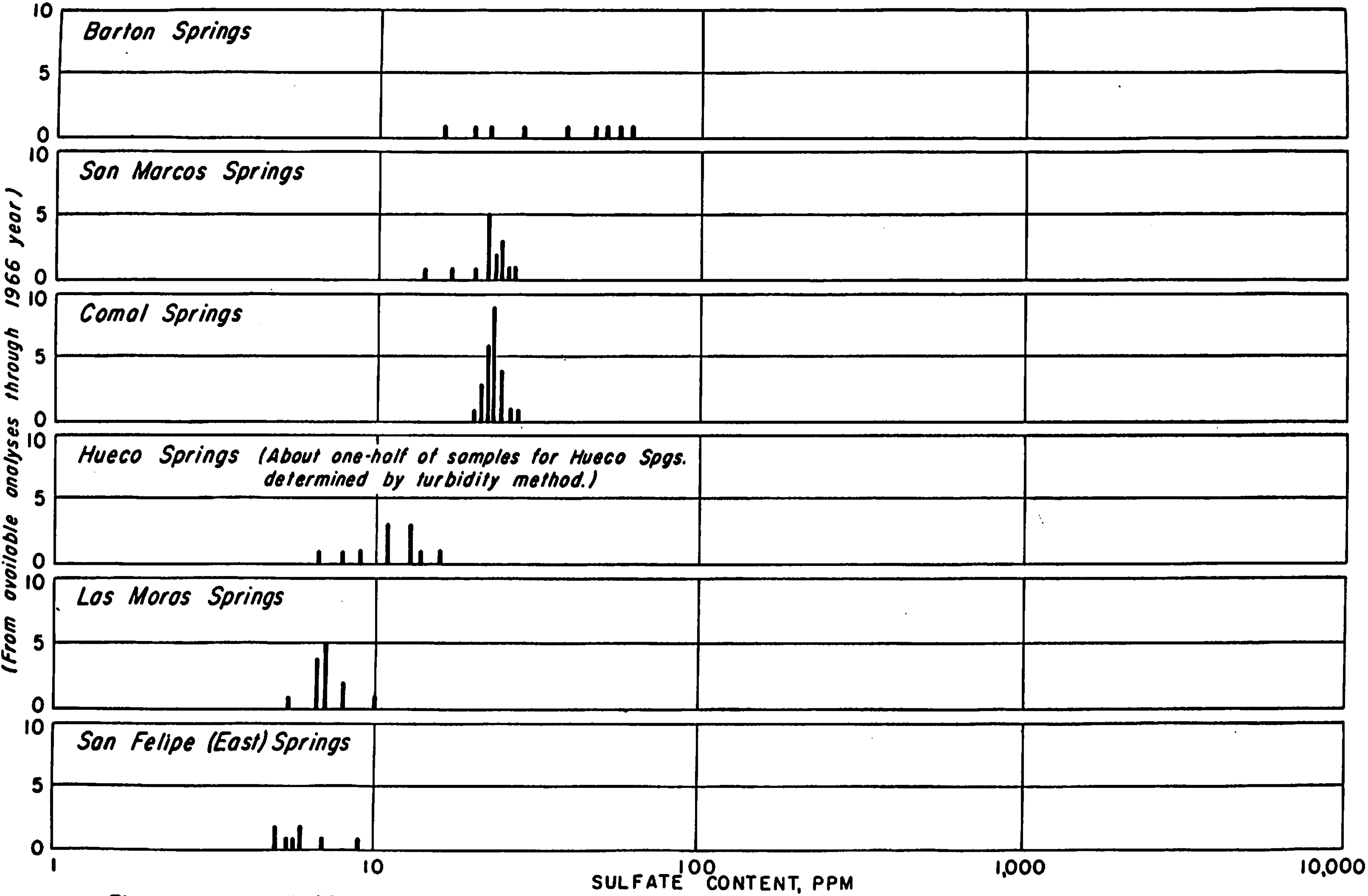
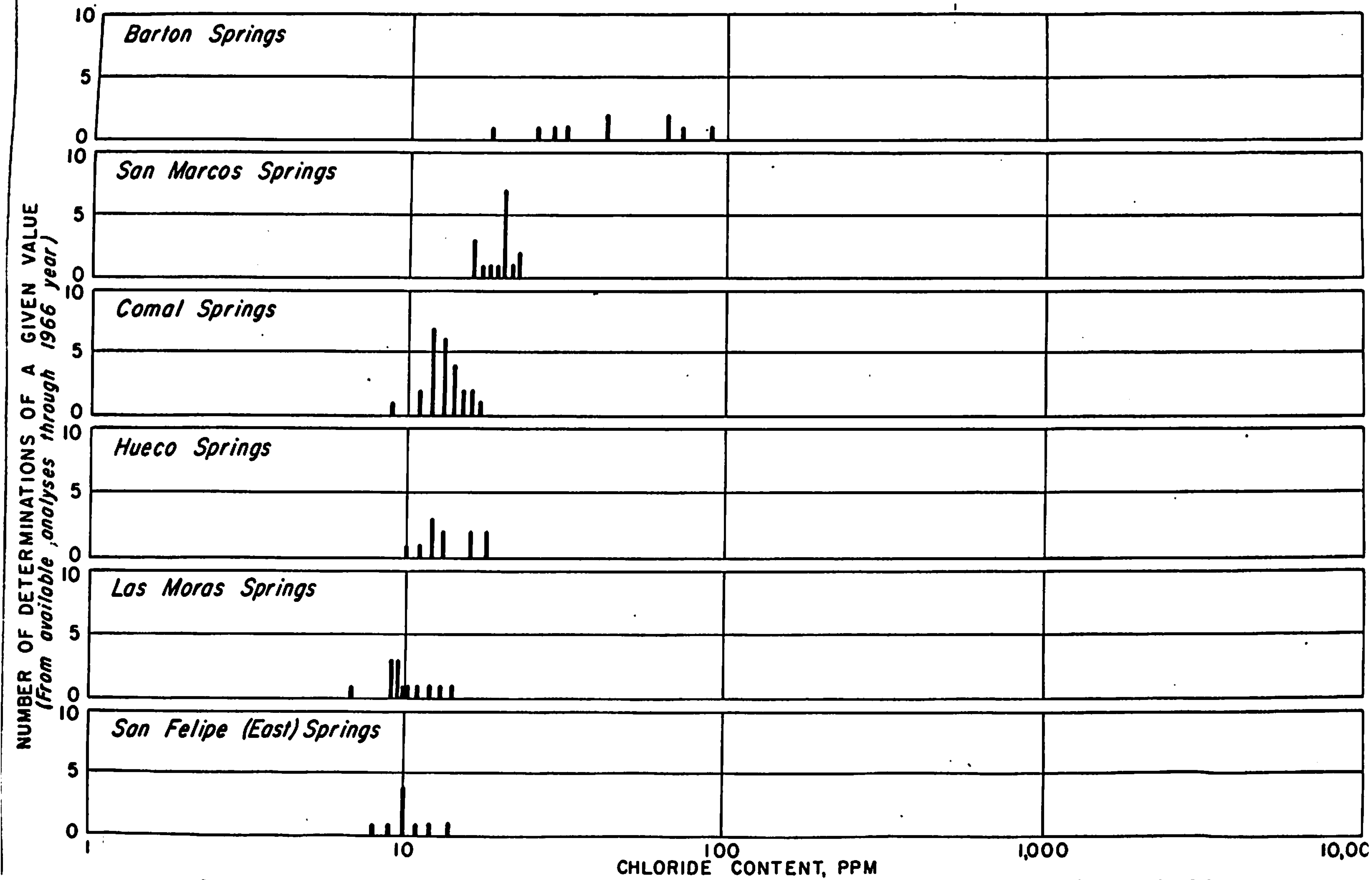


Figure A. SULFATE CONTENT OF EDWARDS WATER FROM MAJOR SPRING DISCHARGE POINTS



NUMBER OF DETERMINATIONS OF A GIVEN VALUE
(From available analyses through 1966 year)
Barton Springs
San Marcos Springs
Comal Springs
Hueco Springs
Las Moras Springs
San Felipe (East) Springs
0
5
10
1
10
100
1,000
10,0C
CHLORIDE CONTENT, PPM

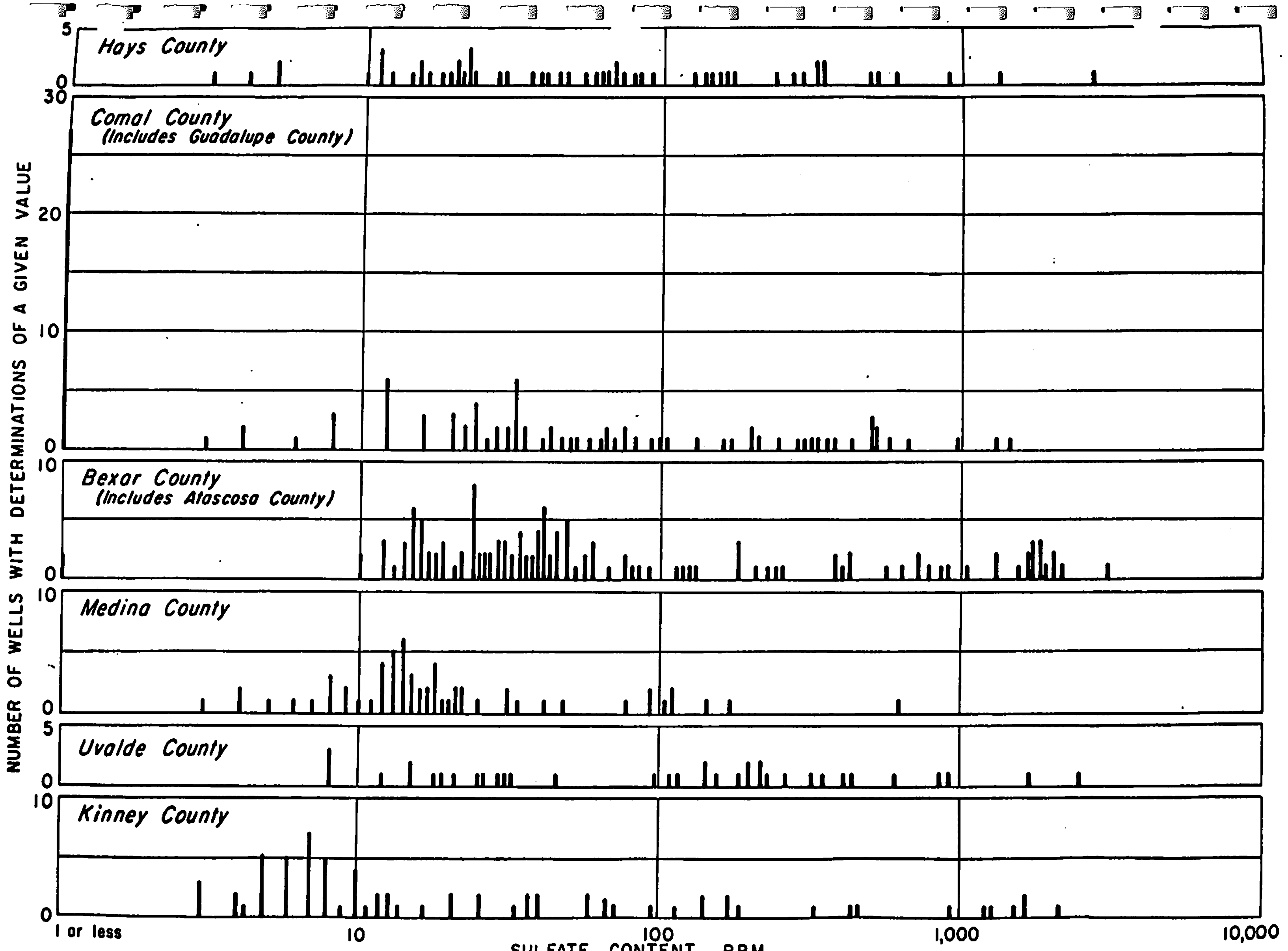


Figure C. SULFATE CONTENT OF WATER FROM EDWARDS WELLS

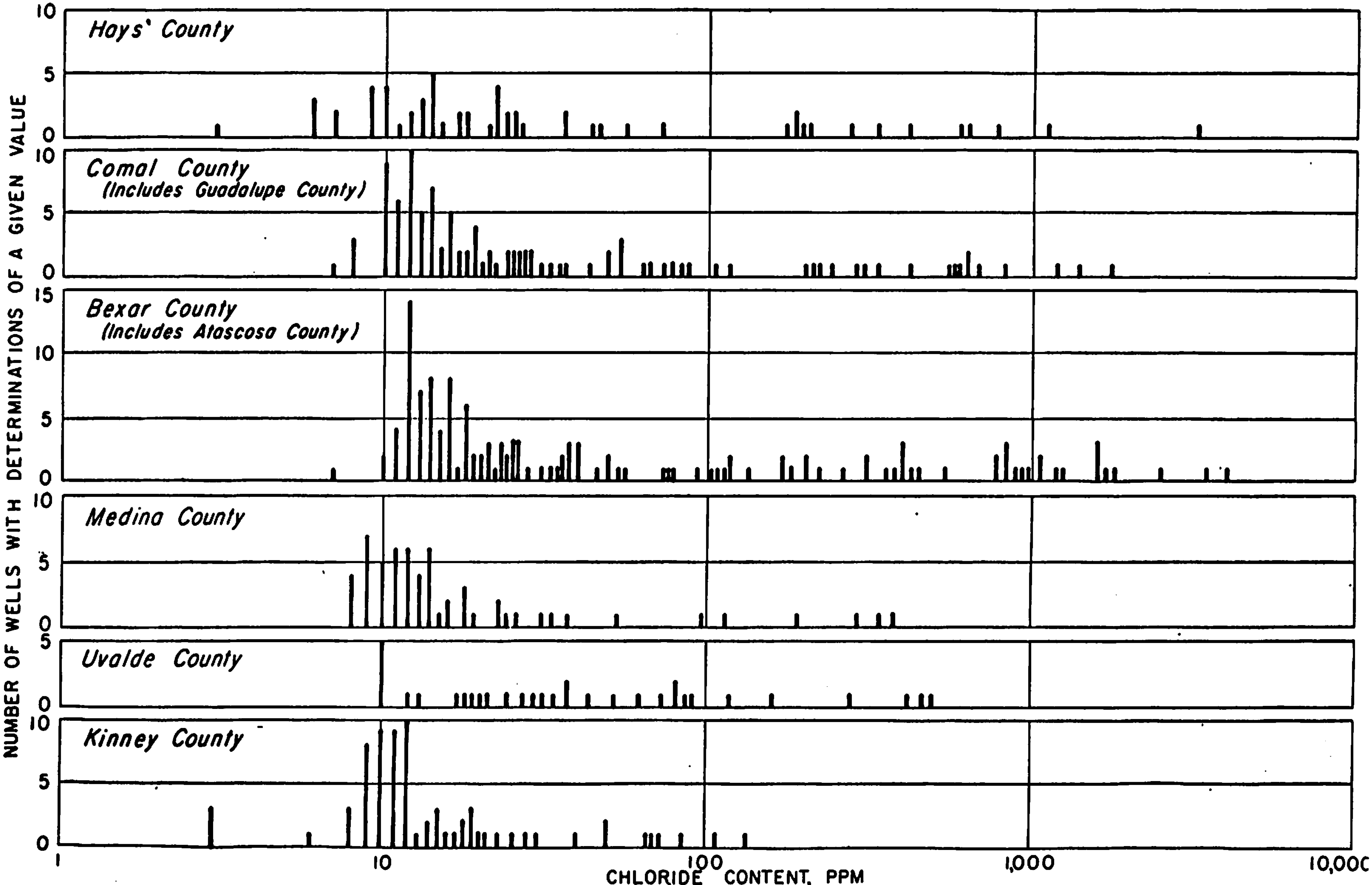
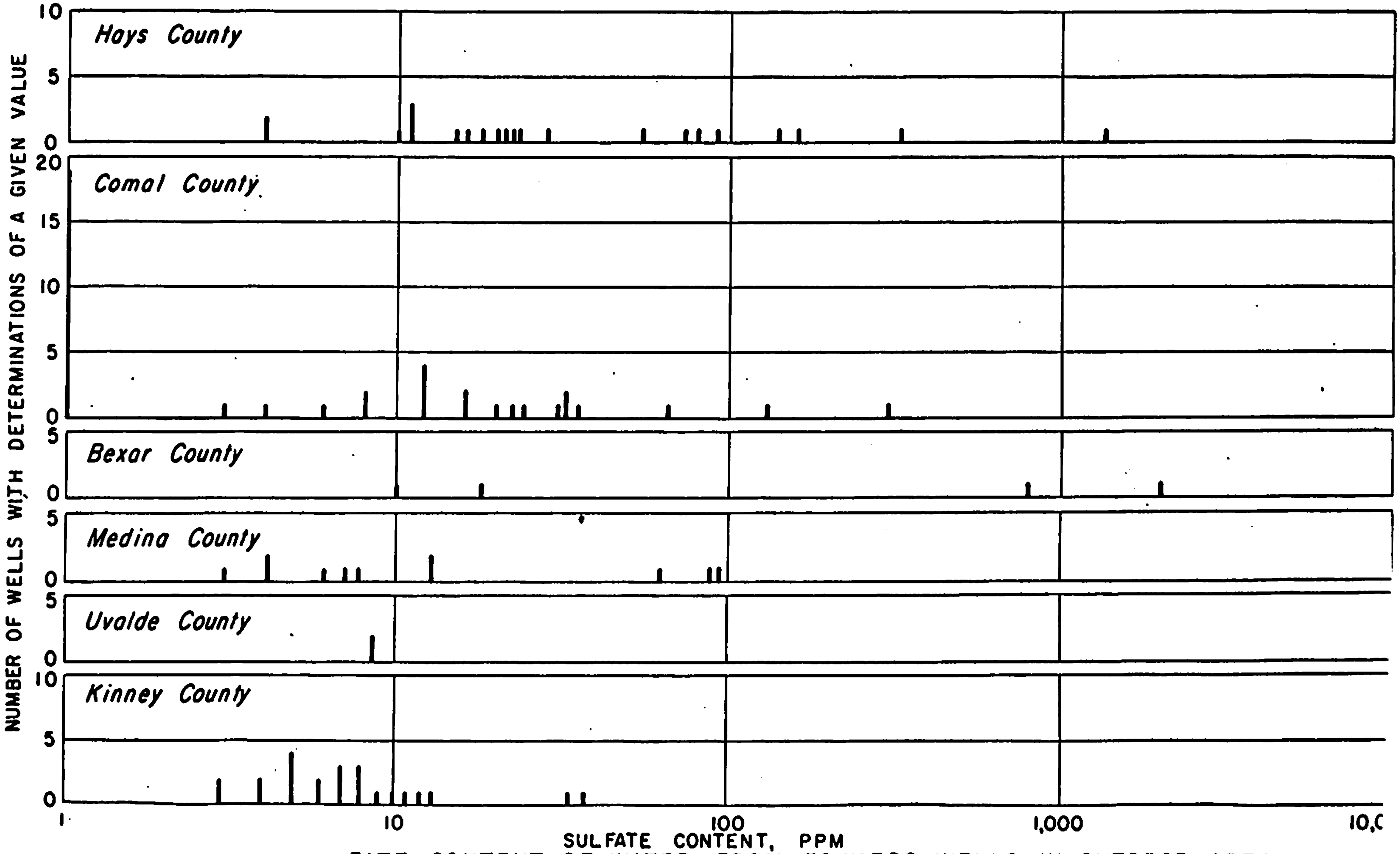


Figure D. CHLORIDE CONTENT OF WATER FROM EDWARDS WELLS



... CONTENT OF WATER FROM EDWARDS WELLS IN OUTCROP AREA

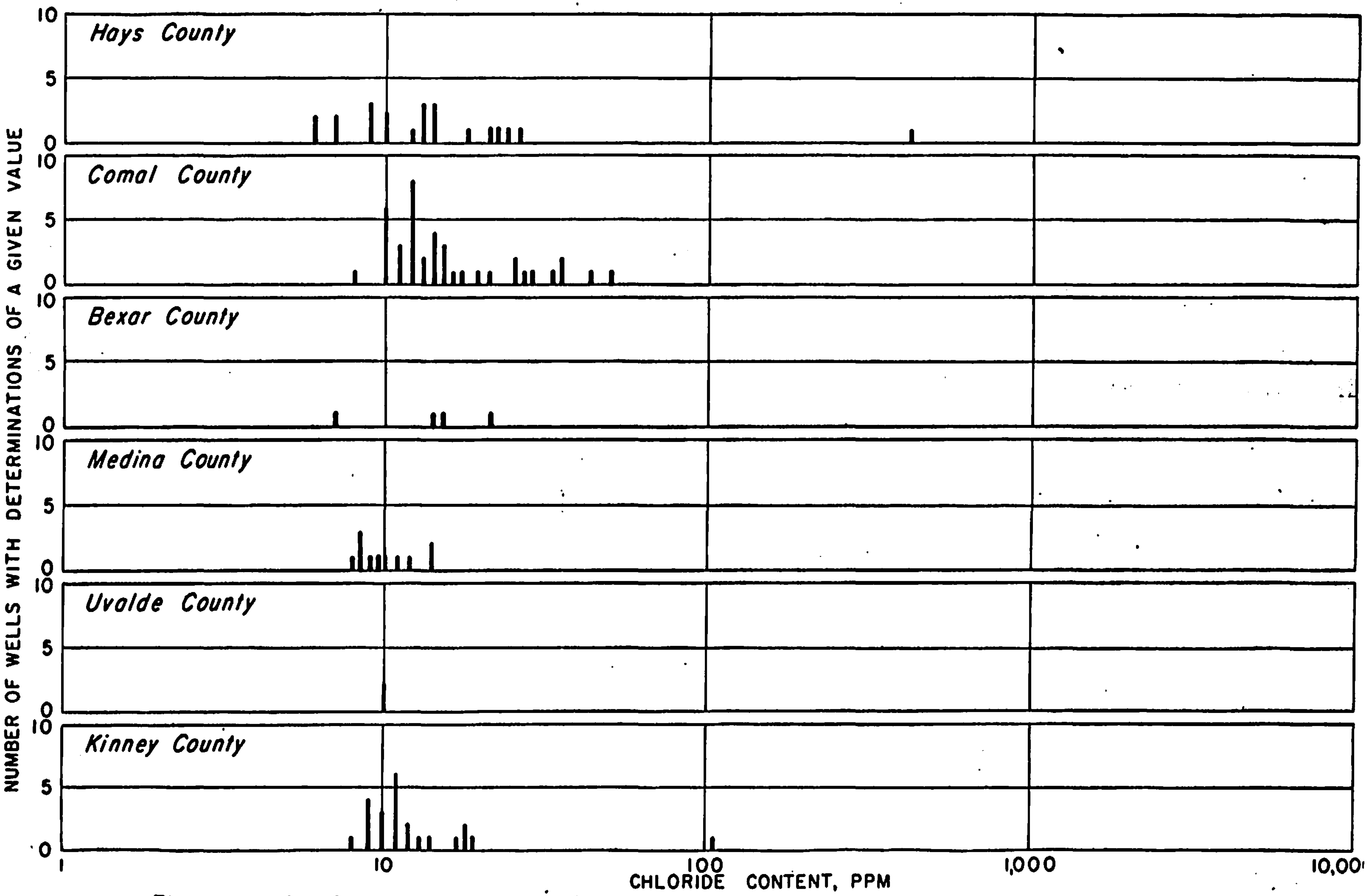
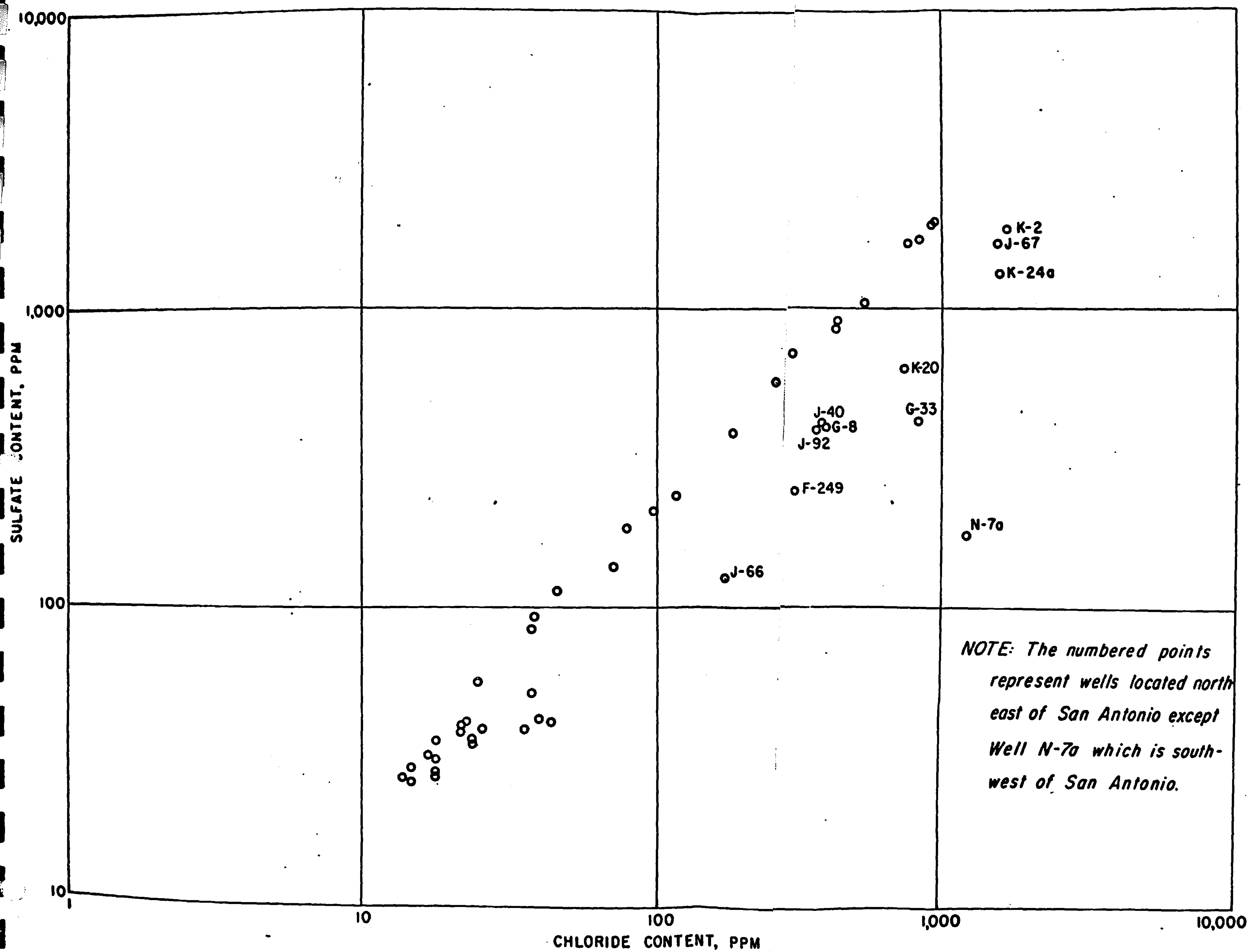


Figure F. CHLORIDE CONTENT OF WATER FROM EDWARDS WELLS IN OUTCROP AREA


10,000
1,000
100
10
SULFATE CONTENT, PPM
1
10
100
1,000
10,000
CHLORIDE CONTENT, PPM
K-2
J-67
K-24a
K-20
G-33
J-40
G-8
J-92
F-249
N-7a
J-66
NOTE: The numbered points represent wells located northeast of San Antonio except Well N-7a which is southwest of San Antonio.

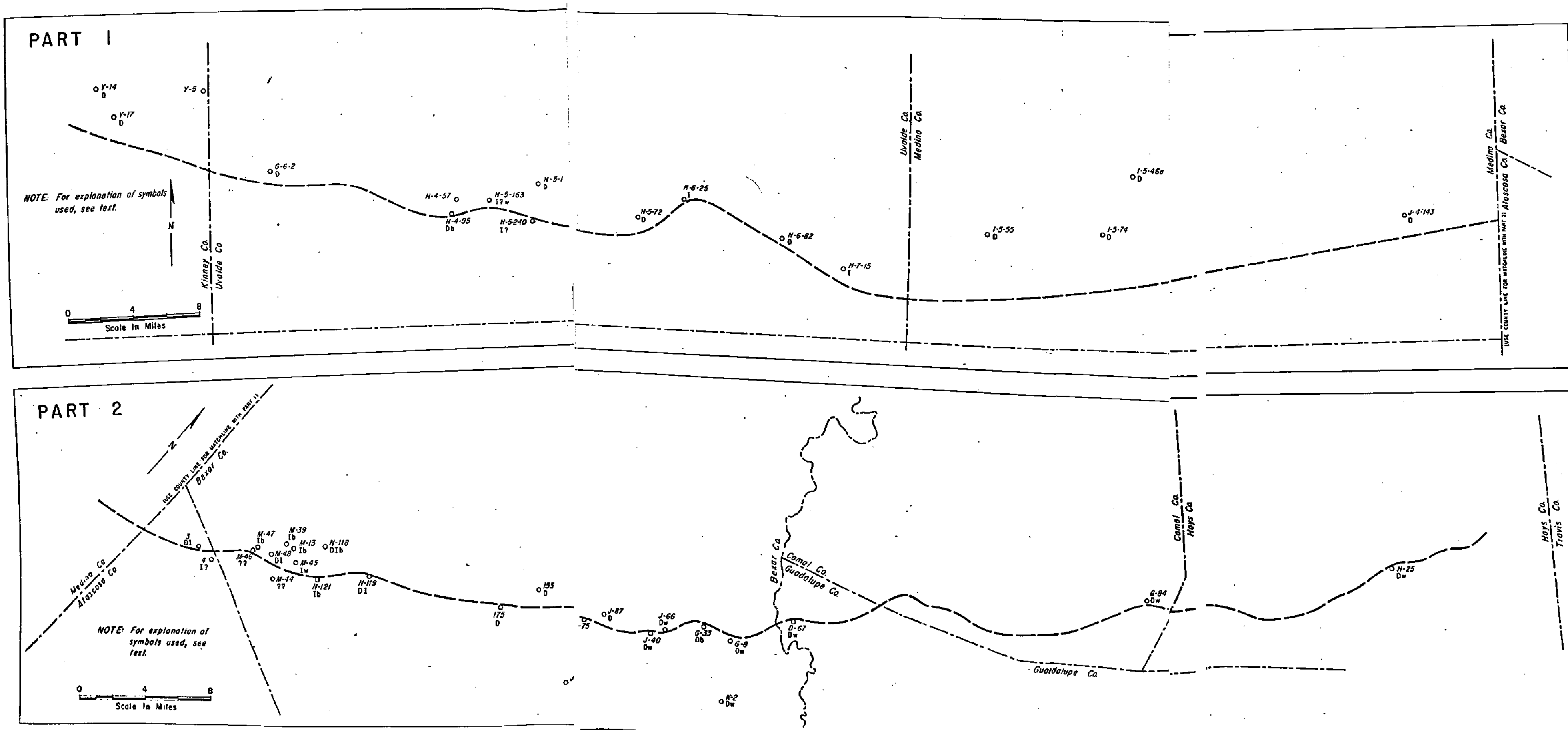


Figure H. LOCATIO F WATER-QUALITY OBSERVATION WELLS EXHIBITING CHANGES WITH STAGE OF RESERVOIR

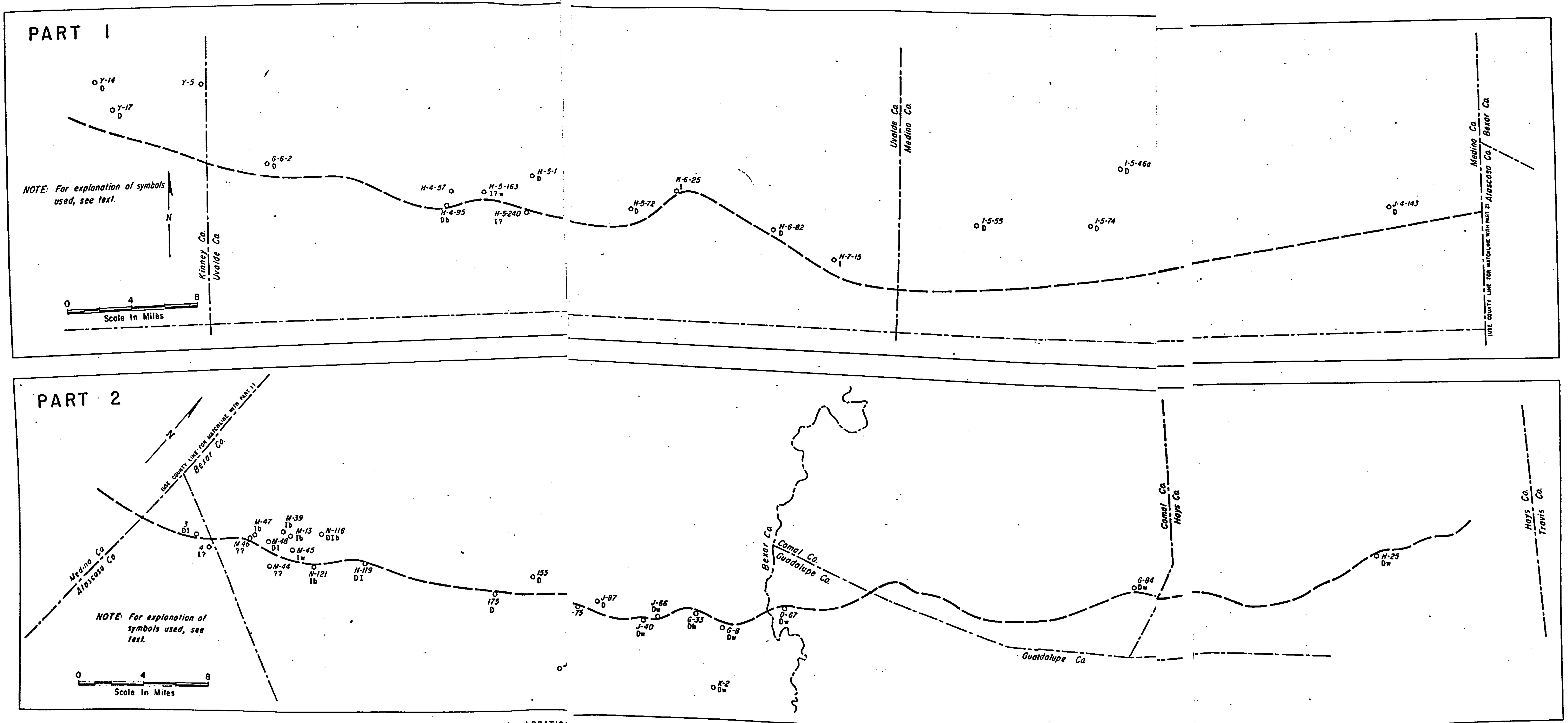


Figure H. LOCATION OF WATER-QUALITY OBSERVATION WELLS EXHIBITING CHANGES WITH STAGE OF RESERVOIR

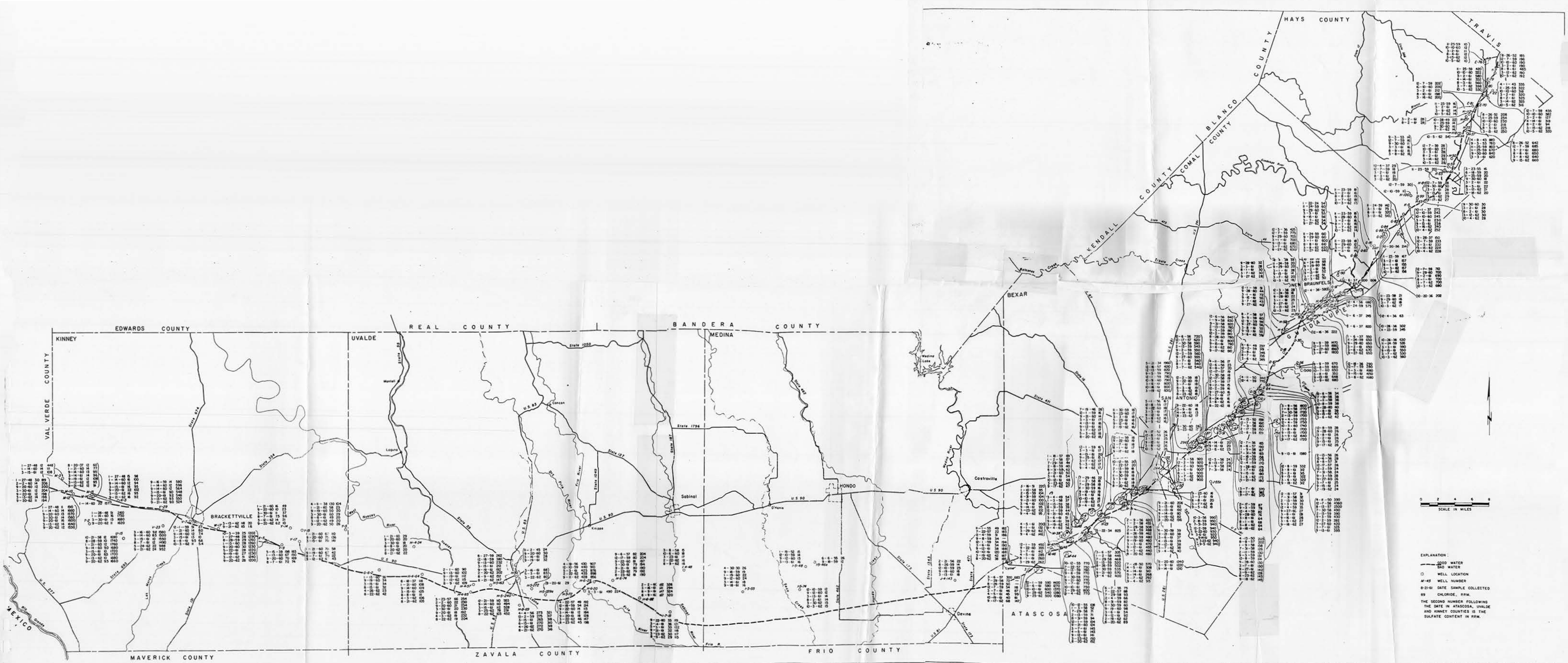


Figure I CHLORIDE CONTENT OF WATER FROM WELLS

Note: Large-format version of the original plate is on the following page.

Figure I CHLORIDE CONTENT OF WATER FROM WELLS