GEOHYDROLOGY OF THE MAGDALENA AREA
SOCORRO COUNTY, NEW MEXICO

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SANTA FE

CONTENTS

INTRODUCTION

During July 13-20, 1972, a geologic and hydrologic field reconnaissance was made in the vicinity of Magdalena (figure 1). The purpose of this investigation was to determine favorable locations for additional ground-water exploration.

At present the Magdalena municipal water system is overworked. Only two wells (Park well and Benjamin well) are producing, and the combined maximum daily production of these wells is approximately 135,000 gallons. This water supply is distributed to about 1,200 inhabitants, three motels, three cafes and four gas stations. The pumps have been set as low as possible, and the Benjamin well has been placed on a cyclical 80 gpm production schedule. The pumping water level in the Benjamin well is reported to be at the pump bowls, but the pumping water level in the Park well, which is now producing at 40 gpm, is reported to be above the pump bowls.

Until 1969, the principal industries in Magdalena were mining and lumbering. Recently due to the closing of the mines and sawmills, the primary source of income has been tourism. However, the village is anticipating that a period of economic growth will result from a U.S. Government telescope project on the Plains of San Augustin.

GEOGRAPHY

The village of Magdalena, in Socorro County, central New Mexico, is located about 65 miles south of Albuquerque and 28 miles west of Socorro. It is situated at the base of the northwest end of the Magdalena Mountains and the average ground elevation at the village is 6600 feet above sea level. Granite Mountain and the Bear Mountains are located to the north, and Silver Hill and the Plains of San Augustin are located to the west. Successively located to the east are a narrow north-south intermontane basin, Polvadera Mountain and Socorro Peak, and the Rio Grande Valley. The average gradient of the ground surface decreases very gently eastward from the Plains of San Augustin to the west slope of the Magdalena Mountains and decreases very sharply southeastward from the Magdalena Mountains to the Rio Grande.

Magdalena is situated about two miles south of the confluence of three drainage basins: Hop Canyon which drains approximately 13 square miles on the northwest side of the Magdalena Mountains, Arroyo Gato and tributaries which drain approximately 50-60 square miles west and southwest of Magdalena, and Upper La Jencia Creek and tributaries which drain well over 100 square miles northwest of Magdalena. La Jencia Creek is a tributary of the Rio Salado, which is a tributary of the Rio Grande.

The climate of the area is semiarid with annual precipitation ranging from 14 inches in the lowlands to about 30 inches in the Magdalena Mountains. There are no perennial streams and the vegetation is primarily that of the upper Sonoran life zone.

GEOLOGY

Magdalena is situated at the northwest end of the Magdalena mining district, which includes Granite Mountain and the northern part of the Magdalena Mountains (figure 1). The Magdalena Mountains and Granite Mountain are of the basin and range type and were formed during the Laramide orogeny (a mountain-building process that occurred about 70 million years ago). They consist of westward-tilted and faulted Carboniferous sedimentary rocks that lie on a basement of Precambrian rocks and are covered with predominantly Tertiary volcanic rocks. The reader is referred to Loughlin and Koschmann (1942) for a more complete presentation of the geology of this structurally complex district.

Approximately 50 million years after the Laramide orogeny, the Rio Grande rift was formed. Chapin (1971) has presented evidence for bifurcation of the Rio Grande rift along a weakly-developed, southwest trending limb that extends through the San Augustin Plains and through the Datil-Mogollon volcanic field. This lineament is marked by a series of en echelon northeast-trending fault zones and grabens, the largest of which forms the San Augustin Plains. The inferred locations of some of the major faults in the vicinity of Magdalena that are associated with the Laramide orogeny and rifting are shown in figure 2 (Chapin, 1972, oral communication).

Geologically, the village of Magdalena lies on a Quaternary alluvial fan at the mouth of Hop Canyon (figure 2). Contemporaneous alluvial material blankets most of the mountain slopes, valleys, basins and plains in the area of investigation, and the depth of the alluvium varies with the irregularity of the bedrock topography. Except for occasional exposures of igneous intrusives and volcanic deposits and scant lithologic information available from well logs, the control on subsurface geology in the area is rather nebulous.

East of the north-south graben shown in figure 2, the bedrock is predominantly extrusive and intrusive igneous, and the overlying alluvial material is relatively thin (Chapin, 1972, oral communication). Available well logs show the alluvium to vary from 20-200 feet in thickness, and bedrock types encountered were andesite, monzonite, altered intrusives, or reworked material derived from volcanics. In the graben itself, a thicker section of alluvium (exact thickness unknown) is underlain successively by the Dry Lake Fanglomerate and andesite, both in the Santa Fe Group of Tertiary age. The Dry Lake Fanglomerate is an indurated, porous, poorly sorted alluvial fan deposit that is interfingered with andesite and may be up to 1,000 feet thick (Chapin, 1972, oral communication).

GEOHYDROLOGY

Most of the ground-water supply in the vicinity of Magdalena originates from precipitation that falls on the Magdalena, the Gallinas, and Bear Mountains. The general direction of ground-water movement is eastward to the Rio Grande, but complex structural geology and hydrogeologic boundaries make local interpretations of the movement difficult. The principal aquifers in the area of investigation are the fracture zones in the igneous rocks and the relatively thin layer of overlying alluvial deposits.

VILLAGE OF MAGDALENA WATER SYSTEM

The original Magdalena water system was built in 1936 as a WPA project. Extensions and repairs have been made since then, and the system is reported to be in good working order (New Mexico State Planning Office, 1970). Presently, the water is stored in a 100,000 gallon steel tank south of town. Another tank located north of the railroad tracks also holds 100,000 gallons, but is not in use.

Initially, the village obtained its water supply from intermittent springs in Hop Canyon via 5½ miles of an 8-inch wooden pipeline. Several shallow, dug wells adjacent to the Benjamin well (2.4.28.114) and a 114-foot dug well in Hop Canyon (3.4.2.142) replaced the wooden line (see Appendix 2 for explanation of well-numbering system). These wells produced only from alluvium and have since gone dry. Subsequently two other village wells producing from alluvium in Hop Canyon have gone dry, the most recent being the Pino well (2.4.27.221). Most of the individual stock and domestic wells near Magdalena produce from the alluvium and have relatively low yields (less than 10 gpm).

The Forest Service well (2.4.32.221) and the two producing city wells, the Benjamin well (2.4.28.114) and the Park well (2.4.27.241), are all producing from fractured andesite. The optimum yield from these wells is higher than that of wells producing only from alluvium. The Forest Service well and the Park well are located in a rift fault zone, but the source of the fracturing at the Benjamin well has not been established (figure 2). Records of these wells are in table 1.

The Benjamin well has been pumped quite consistently since its completion. The peak pumping rate has been 130 gpm and more recently it was reduced to 80 gpm. Because the pumping water level is reported to be down at the pump bowls, the well has been placed on a cyclical pumping schedule. Pump test (1964) analyses appear to indicate that the Benjamin well has been pumped excessively, resulting in a partially dewatered aquifer, and reduced transmissivity and yield (see Appendix I for explanation). Theoretically, in order to have maintained the pumping water level above the top of the aquifer for the past eight years, the constant pumping rate should not have exceeded 15 gpm.

The Park well has been used during the summers at a constant pumping rate of 60 gpm and was recently reduced to 40 gpm. Pump test (1964) analyses of this well appears to indicate that a 60-gpm pumping rate has been excessive, and that a constant pumping rate no greater than 35 gpm would have been better (Appendix 1).

Available sources of information indicate that practically all the former village wells that produced from alluvium were pumped in excess of 30 gpm. Although there is no available pump test data on these wells, it appears that pumping rates of this order of magnitude were excessive, and along with interference from recent wells, have partially dewatered the alluvium at the mouth of Hop Canyon and near the Benjamin well.

AREAS FAVORABLE FOR GROUND-WATER EXPLORATION

Limited subsurface control and complex structural geology make the selection of suitable sites for ground-water exploration difficult. Knowledge of subsurface structure, particularly faulting, is important for locating zones of higher transmissivity in the igneous rocks and for locating thick sections of permeable sediments. Both the surface and subsurface igneous rocks at Magdalena are predominantly nonporous and impervious, and their ability to transmit water is the result of fracturing due to both faulting and cooling. East of the north-south graben in figure 2, the best ground-water production is from fractured igneous rocks, and the producing wells (Forest Service, Benjamin, and Park wells) are 200-400 feet deep. Lithologic and structural information at depths greater than 400 feet is scant.

The most probable locations for fractured igneous rocks would be along the inferred locations of the faults associated with the Laramide orogeny and the Rio Grande rift and the intersections of these faults (figure 2). However, completing a test hole along a fault is no guarantee of encountering permeable zones. A geothermal log taken in a 1,000-foot New Mexico Bureau of Mines test hole (2.4.7.431), located in a post-Laramide fault zone, showed the entire penetrated interval to be impervious (Chapin, 1972, oral communication). On the other hand, random exploration can be just as fruitless. An abandoned 385-foot test hole (2.4.21.433), located 1,600 feet northeast of the Benjamin well, penetrated over 365 feet of andesite and encountered virtually no fracturing.

In the north-south graben, located west of Magdalena, the yields of stock wells are reported to be low. Most of the wells are deeper than 350 feet and the average-depth-to-water is over 300 feet (table 1). Because no lithologic logs are available and because no wells have come close to fully penetrating the inferred 1,000 feet of Dry Lake Fanglomerate (Chapin, 1972, oral communication), it is impossible to substantiate the thickness of sediments in the graben and to predict any of the aquifer parameters or characteristics.

Overall, it appears that the completion of exploratory wells, either in the graben or in fractured igneous rock, comparable in depth to existing wells will produce yields of the same order of magnitude as existing wells. It may be possible to attain higher yields with deeper wells. A test hole deep enough to penetrate the entire Dry Lake Franglomerate and a portion of the underlying andesite (1,000-1,500 feet) would certainly be justified in an exploration program in the graben. In order to explore zones below the alluvium and upper fracture zones east of the graben and closer to Magdalena, it seems justifiable to complete a test well along an inferred fault to a depth of 600 or more feet.

Suggested locations and depths of an initial test well are listed below and shown in figure 2. (Letter designations do not indicate priority.):

Letter Designation	Location	Suggested Depth
A	2.4.33.311	650
B	2.4.32.434	750
C	2.5.35.231	1,000-1,500
D	2.4.23.411	700
E	2.4.24.131	700
F	2.4.24.124	700

Location "C" is in the graben and all other locations are on the inferred rift fault. Location "E" may be of interest since it is at the approximate intersection of two faults. These locations have been selected and spaced to minimize interference on or by the existing village wells and Forest Service well. The depths listed are merely suggestions, and the effect greater penetration will have on yield can only be determined from a pump test. It is imperative to perform a pump test with recovery measurements upon completion of the initial test hole so that the aquifer parameters and optimum yield may be computed. From this information, it can be decided if additional exploratory drilling at other locations would be required.

CONCLUSIONS

Because of limited subsurface control, complex structural geology, numerous low yielding wells in the area, and several unsuccessful test hole attempts, it is not possible to predict the success of a test well completed at any of the aforementioned locations. Likewise, the evidence is insufficient to make relative comparisons of the locations. However, it is the opinion of the writer that reasonable evidence exists to support a decision to do exploration drilling at one or more of these locations. Since it is not feasible to make relative comparisons of the success of the locations, it is suggested, in the interest of economy, that the locations closest to town and existing water lines be considered initially (Locations A and B).

Since most of the wells in the area of investigation are less than 400 feet deep, and are basically low in yield, it is the opinion of the writer that the initial test hole be drilled deeper (as previously specified) to determine if a higher yield can be attained. Drilling samples should be collected and analyzed and a pump test performed upon completion. From this, it should be possible to determine the optimum yield of the well and if additional well(s) will be needed, their locations and required depths.

It is strongly urged that the pumping rate of the Benjamin well be reduced to 20 gpm or less as soon as possible. Upon the eventual completion of the new water supply, it is suggested that the Benjamin well be shut in for recovery, and used only as a 15-20 gpm standby source, and the pumping rate of the Park well be kept below 35 gpm.

If the village of Magdalena should decide that the recommended exploration program is too risky, two other alternatives may be considered.

(1) A 200-foot core hole one mile north of town (2.4.16.424), penetrating a mineralized fault zone, is reported by the owner to be capable of yielding 50 gpm. The hole is partially open and it would have to be redrilled, pump tested, and the water quality analyzed to determine its usability.

(2) It may be possible to obtain additional water from the Waldo Tunnel and other mines in the area. Such water supplies may only be intermittent and would have to be analyzed carefully for chemical quality.

APPENDIX 1

PUMP TEST ANALYSES

Pump tests were performed on the Park and Benjamin wells during May 25-27, 1964, by Jewell F. Adkinson Drilling Company and the respective static water levels were reported to be 26.5 feet and 157 feet.

The Benjamin well was pumped at an average rate of 140 gpm for 20 hours prior to recovery. The semilogarithmic plot of the residual drawdown is shown on figure 3. Using Jacob's recovery equation one computes the aquifer transmissivity as follows:

$$T = \frac{2.3\,Q}{4\pi\,\Delta s} \log\frac{t}{t'} \qquad (1)$$

where T = transmissivity in square feet/day

Q = pumping rate during the period preceding recovery in cubic feet/day

Δs = change in drawdown over one log cycle in feet

t = time since pumping started

t' = time since pumping stopped

Substituting the following values in the above equation we obtain:

$Q = 26{,}900$ ft^3/day

$\Delta s = 40$ feet

$\log t/t' = 1$

$$T = \frac{(2.3)(26{,}900)}{4\pi(40)} = \underline{123}\ \text{ft}^2/\text{day}$$

This transmissivity value is at best an approximation, since the hydraulics of well flow in fractured media are complicated by the following factors (Snow, 1972):

(1) Partial penetration of media which are anisotropic, inhomogeneous and pressure dependent.

(2) Variable permeability and storativity with depth.

(3) Variable flow during drawdown

(4) Drawdown versus time is known only at the beginning and end of pumping period.

(5) No observation wells.

With these limitations in mind, we may attempt to use the above transmissivity value to compute the theoretical pumping water-level of the well during July 1972. The Benjamin well has been producing since June 1964 at an approximate, constant, average pumping rate of 120 gpm. The actual, present pumping water level of the well is about 160 feet below (drawdown) the original static water level.

The theoretical pumping water level may be approximated from the following equation:

(2)

$$s_n = s_1 + \frac{Q}{4\pi T} \ln \frac{t_n}{t_1}$$

where Q = pumping rate in ft^3/day

T = transmissivity in ft^2/day

t_1 = 1 (day)

t_n = time since pumping started in days

s_1 = drawdown after 1 day

s_n = drawdown after n days

During the May 1964 pump test the drawdown, after 20 hours of pumping at 140 gpm, was 53 feet. This drawdown is graphically extrapolated to 54 feet at 24 hours. The 24-hour drawdown at 120 gpm is computed by direct proportion.

$$\frac{s_{120}}{120} = \frac{54}{140} \quad \therefore s_{120} = \underline{46 ft}$$

We may compute the drawdown after 8 years of pumping at 120 gpm as follows:

$$s_n = 46 ft + \frac{23,100 ft^3/day}{4\pi(123 ft^2/day)} \ln 2920 = \underline{165 feet}$$

Thus the theoretical drawdown compares very closely with actual drawdown of 160 feet. Both of these levels are considerably below the top of the aquifer which is 22 feet below the original static water level. Maintaining a pumping water level below the top of an aquifer often results in reduced transmissivity and yield. In order to have maintained the pumping water level above the top of the aquifer, it would have been necessary to have used an average, constant pumping rate no greater than 15 gallons per minute.

Similar to the previous calculations, one computes an aquifer transmissivity of 163 square feet per day for the Park well (figure 4). Since May 1964, the Park well has been pumped at approximately 60 gpm from May through September of each year. We may approximate the theoretical pumping water level thru July 1972, from the following equation:

$$(3)\quad S = \frac{2.3Q}{4\pi T} \log\left[\frac{1\cdot2\cdot3\cdots\cdots n}{(1-p)(2-p)(3-p)\cdots(n-p)}\right] + s_1 + \frac{Q}{4\pi T}\ln\frac{t_x}{t_1}$$

where s = drawdown resulting from previous pumping and present pumping in feet.

T = transmissivity in ft^2/day

Q = pumping rate in ft^3/day

p = pumping fraction of cycle

n = number of cycles

s_1 = one-day drawdown at pumping rate Q

t_x = number of days since last pumping period started

t_1 = 1 day

Substituting the following values in the above equation, we obtain:

Q = 11520 ft^3/day (60 gpm)

n = 8 cycles (May 1964 - April 1972)

p = 5/12 (pumping May-Sept. during each cycle)

s_1 = 44 feet (60 gpm) from pump test data

t_x = 90 days

T = 163 ft^2/day

$$S=\frac{(2.3)(11520)}{4\pi(163)}\left[\log\left(\frac{(1)(2)(3)(4)(5)(6)(7)(8)}{(1-5/12)(2-5/12)(3-5/12)\cdots(8-5/12)}\right)\right]+44+\frac{11520}{4\pi(163)}\ln 90$$

s = 7.3 ft + 44 ft + 25.3 = 77 ft.

The theoretical pumping water-level is 77 feet below the original (1964) static water level, and also 15 feet below the top of the aquifer. A maximum constant pumping rate of 35 gpm might have maintained the theoretical, pumping water-level above the top of the aquifer. The present pumping water level is not known but is believed to be well below the top of the aquifer, and probably below the theoretical pumping water level. This difference may be attributed to the limitations of the method of analysis and/or reduced transmissivity and yield.

Appendix 2

Well-numbering system

Wells and springs in this report are identified by a number based on their location. The first segment indicates the township north (N) or south (S) of the New Mexico baseline, the second segment indicates the range east (E) or west (W) of the New Mexico principal meridian, the third segment indicates the section within a township, and the fourth segment indicates the location within the section. The three digits in the fourth section indicate, respectively, the quarter section (about 160 acres), the quadrant (about 40 acres) of the quarter section, and the quadrant (about 10 acres) of the 40-acre tract in which the well is located. Figure 5 shows the system of numbering quarter sections and quadrants, which is done in reading order, as well as the numbering of sections in a township. The letter designation following the fourth segment indicates the well was the second, third, or fourth (a, b, c) well located in that particular tract. The well in figure 5 is in the NE¼NE¼NE¼ sec. 24, T. 22 S., R. 4 E. When a well cannot be located to the 10-acre tract, the remaining digit or digits are zeros.

REFERENCES

Chapin, C. E., 1971, the Rio Grande Rift, Part 1: Modifications and additions, in New Mexico Geol. Soc. Guidebook, 22nd Field Conf., Oct., 1971, p. 191-201.

Loughlin, G. F., and Koschmann, A. H., 1942, Geology and ore deposits of the Magdalena mining district, New Mexico: U.S. Geol. Survey Prof. Paper 200, 168 p.

New Mexico State Planning Office, 1970, Water and sewer plans, Socorro County, New Mexico: N. Mex. St. Planning Office, 82 p.

Snow, D. T., 1972, Hydrology of fractured rocks: New Mex. Technical Service Program, 180 p.

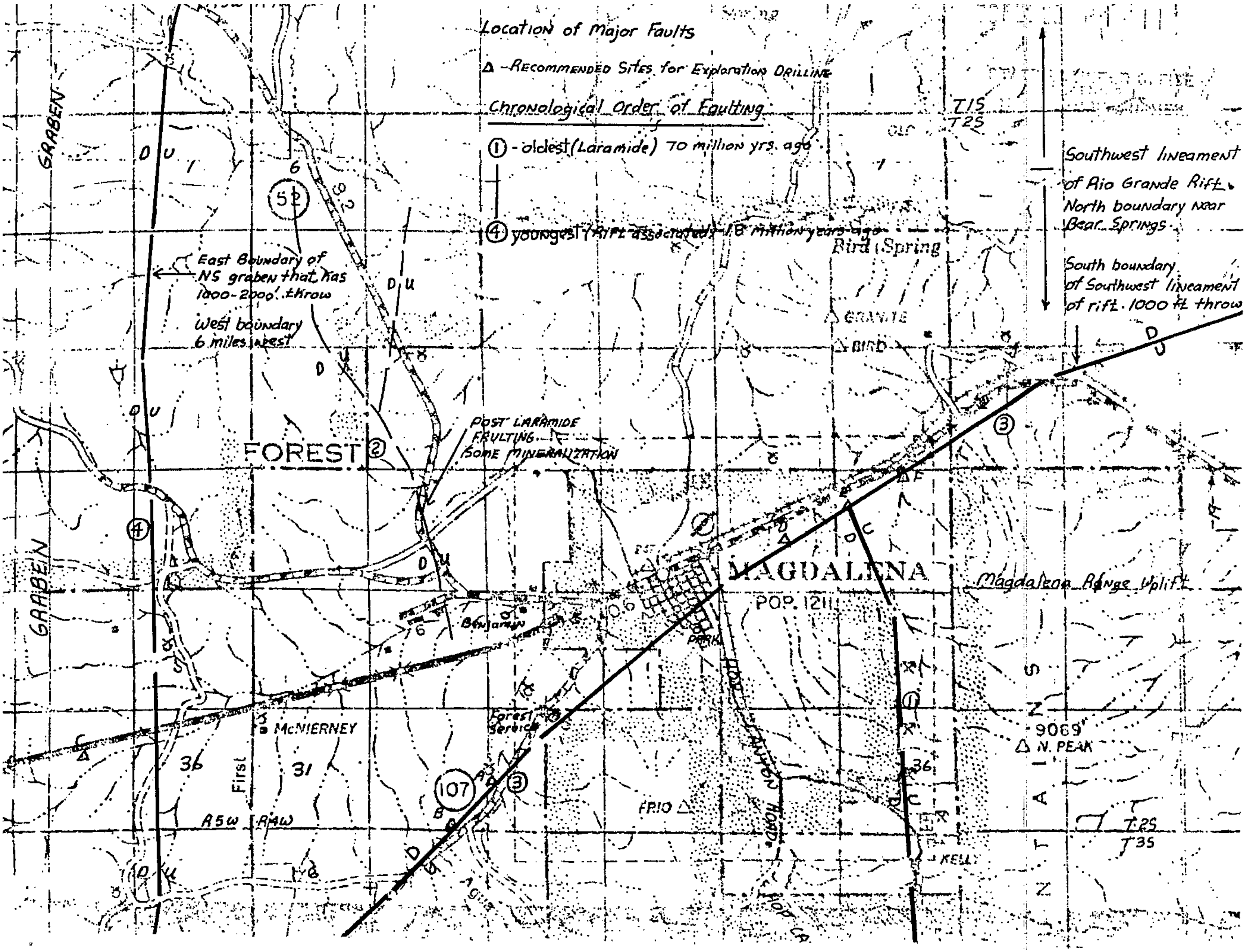
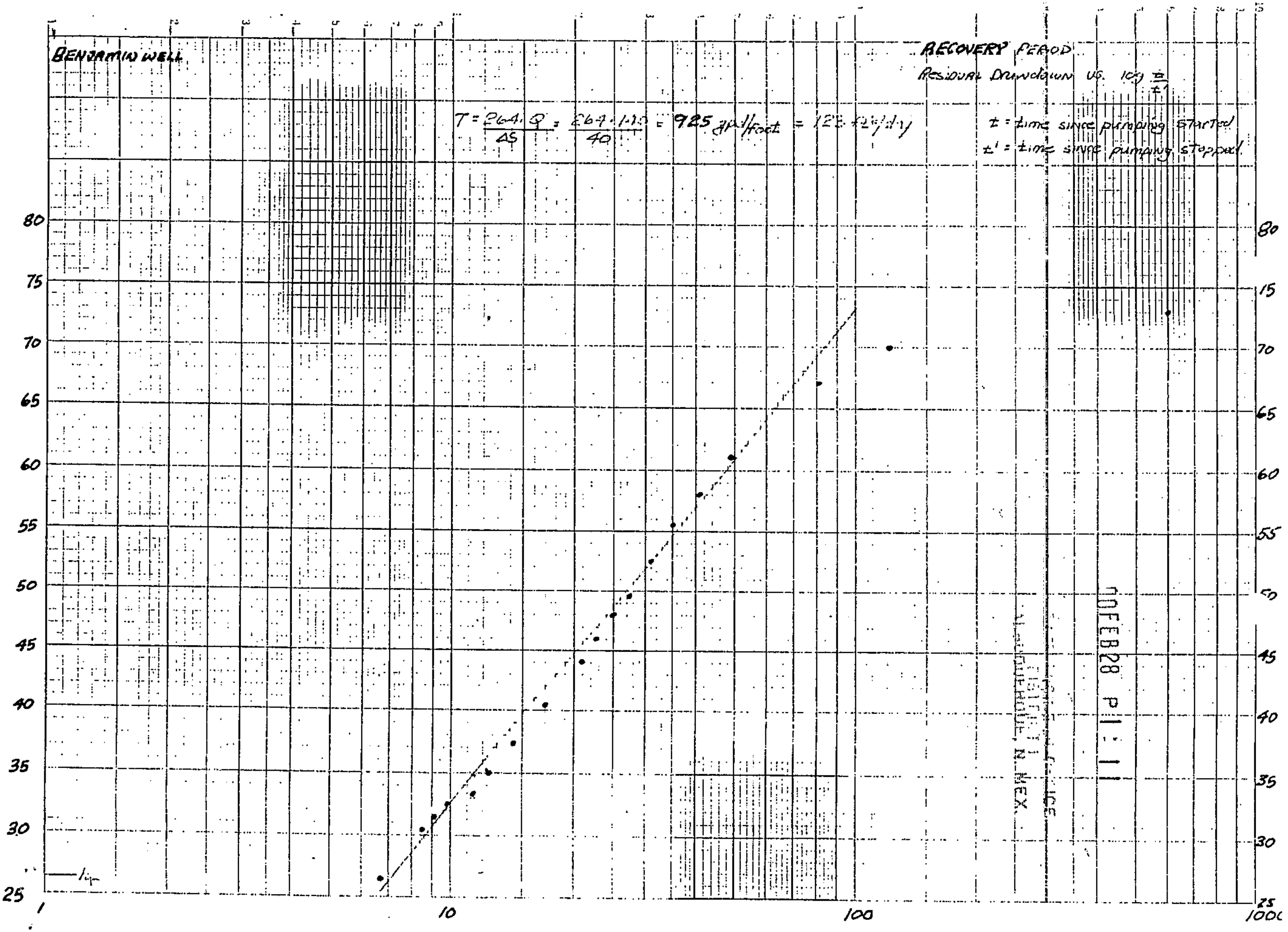

Location of Major Faults
Δ -Recommended Sites for Exploration Drilling
Chronological Order of Faulting
① - oldest (Laramide) 70 million yrs. ago
④ youngest (rift associated) 18 million years ago
T1S
T2S
Southwest lineament of Rio Grande Rift. North boundary near Bear Springs
South boundary of Southwest lineament of rift. 1000 ft throw
Bird Spring
GRANITE
BIRD
GRABEN
GRABEN
East Boundary of NS graben that has 1000-2000' throw
West boundary 6 miles west
52
D U
FOREST ②
POST LARAMIDE FAULTING. Some MINERALIZATION
④
D U
Benjamin
MAGDALENA
POP. 1211
PARK
Magdalena Range Uplift
③
D U
③
①
107
Forest Service
McNIERNEY
36
31
First
R5W R4W
FRIO Δ
9069'
Δ N. PEAK
T2S
T3S
KELL
S N T A I N S
D U

FIGURE 3

MAGDALENA 2



RECOVERY PERIOD

Residual Drawdown vs. log $\frac{t}{t'}$

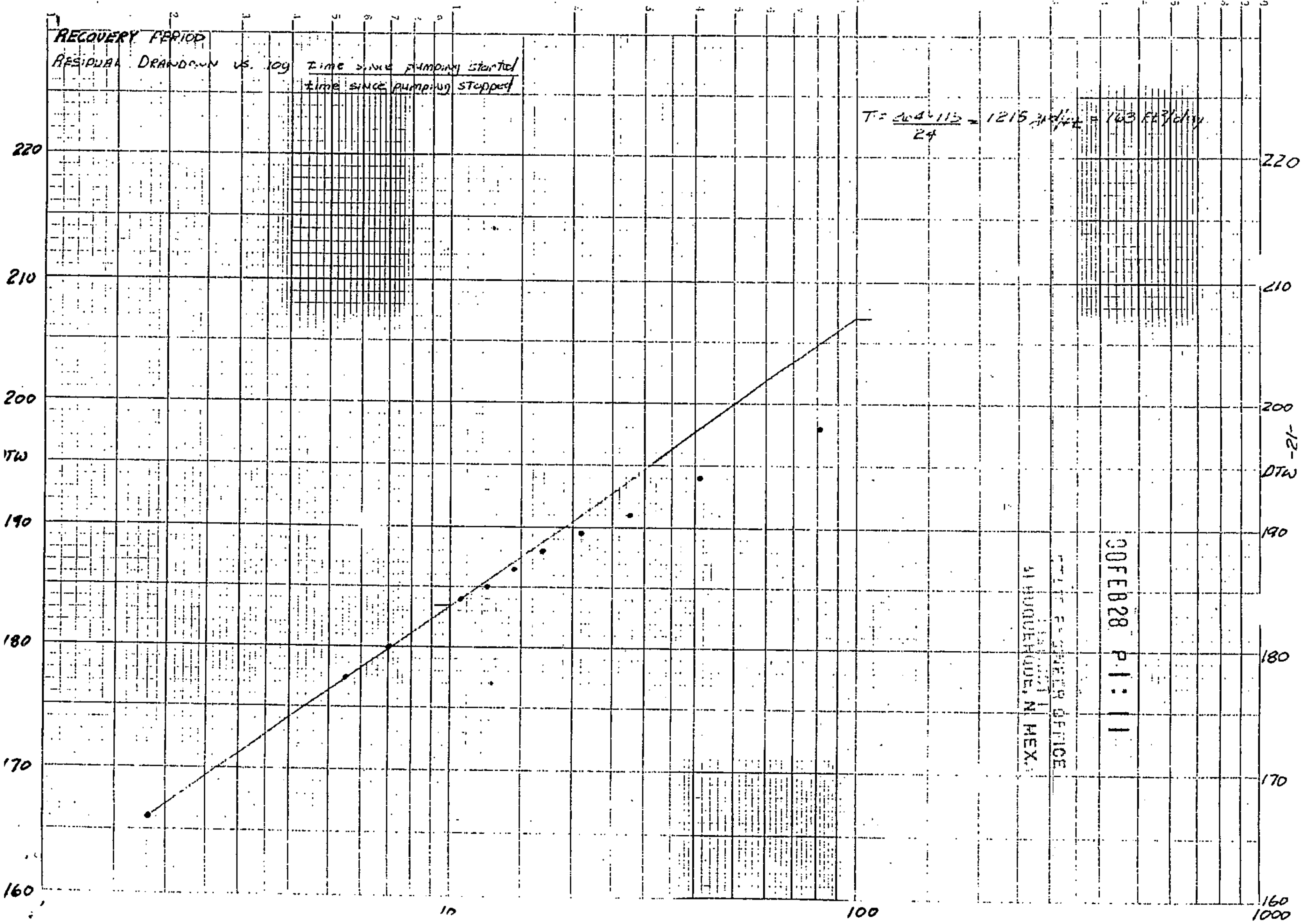
$T = \frac{264 \cdot Q}{\Delta S} = \frac{264 \cdot 140}{40} = 925$ gpd/foot = 123 ft²/day

t = time since pumping started

t' = time since pumping stopped

Figure 4

PARK WELL - MAGDALENA 1



$T = \frac{264 \cdot 115}{24} = 1215$ gpd/ft = 163 ft²/day

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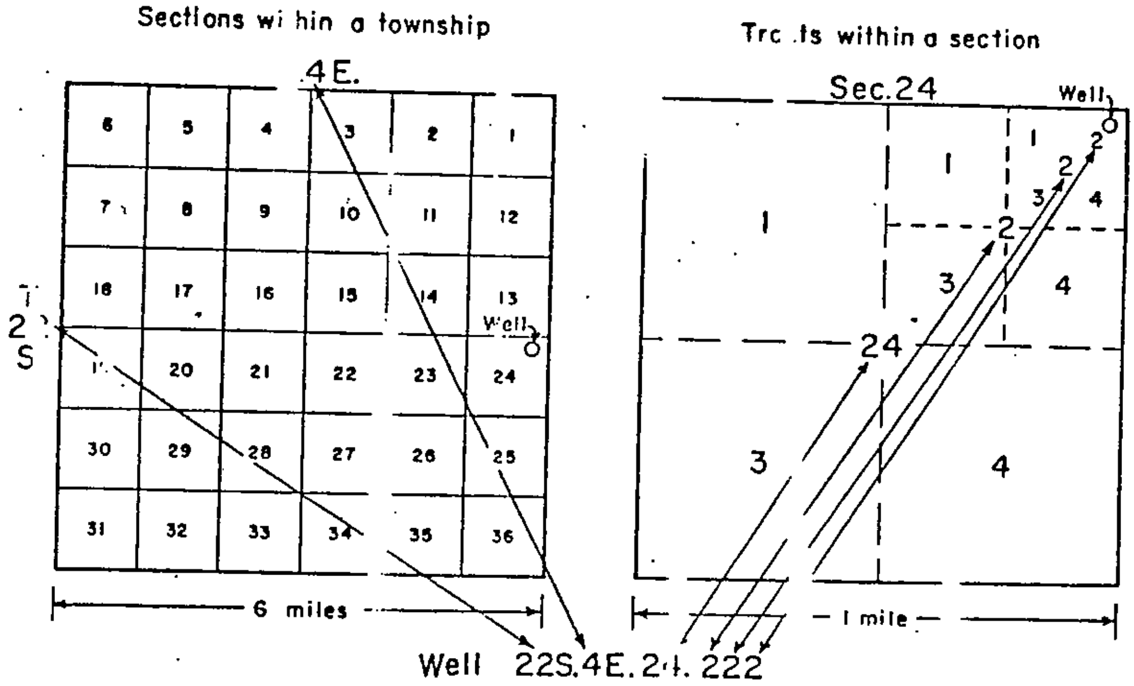

Figure 5.--System of numbering wells and springs in New Mexico.

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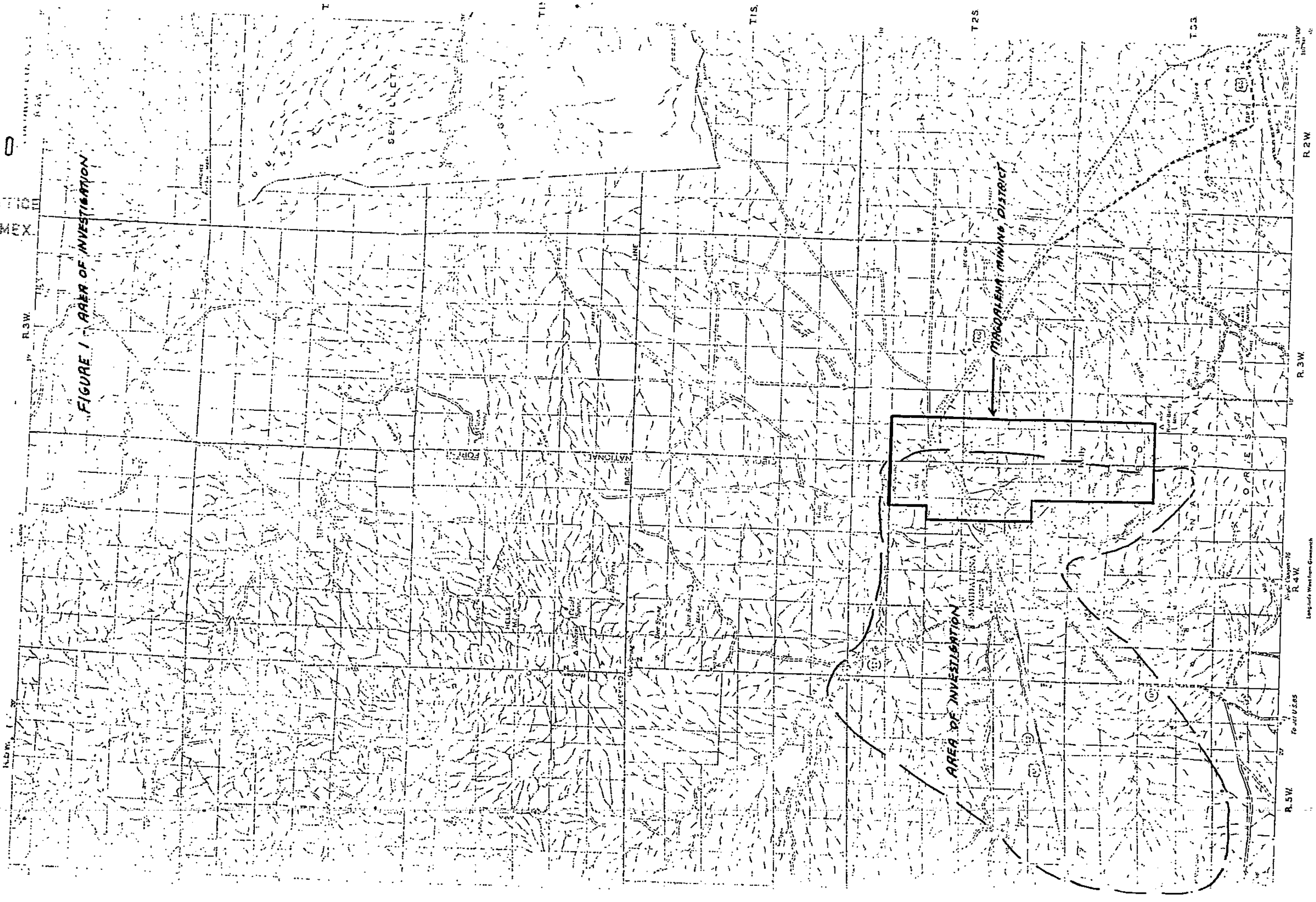

FIGURE 1 - AREA OF INVESTIGATION