1506-00011

GROUNDWATER EXPLORATION
CONSTRUCTION and TESTING REPORT

HORIZON HILLS BACK-UP WELL

Prepared for
Horizon Hills General Improvement District

TH #1-3 5948
TH #4-5 4426
Conductor 13825
24,199

Test well 12101
Pumping 6033
18,134

42,333

DRAFT

Prepared by
Washoe County Utility Division
January 1986

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Summary and Recommendations

1. Exploratory test holes were drilled up to 400 feet in fractured rhyolite and/or metavolcanics. Extensive fracturing occurs in the interval 280-380 feet below land surface. This interval appeared to have adequate water producing potential.

2. An 8-inch test well with 165 feet of 16-inch conductor casing was installed to 396 feet. A sanitary seal around the conductor casing was installed to a depth of 165 feet. The well has triple mill-slot casing from 270 feet to 390 feet. This well produces from fractures in the bedrock.

3 A step drawdown test determined the well to be inefficient at moderate pumping rates. The inefficiency is due to large friction losses in the fractures that serve as an extended well rather than the well construction itself. A constant discharge test was run at 209 gpm and 186 gpm for 72 hours. Drawdown rates never stabilized and at least two impermeable boundaries or dewatered fractures were encountered.

4 The water quality was generally good except for iron and manganese. During the pumping test manganese levels remained constant at 0.22 ppm while iron levels dropped from 0.94 ppm to 0.42 ppm. Secondary drinking water standards for iron and manganese are 0.60 and 0.1 respectively.

5 This well could be equipped with a 150 gpm pump and used as an alternate supply to the existing well. Pumping should never exceed an average of 80 gpm on a continuous basis. Water treatment is necessary to meet State requirements for iron and manganese.

INTRODUCTION

The Horizon Hills General Improvement District Board of Trustees authorized the Washoe County Utility Division to conduct an investigation in locating a secondary source of water supply for its subdivision. A "back-up" well is necessary to comply with State regulations and County codes for subdivision water supplies. The goal of the investigation was to locate a water source that would meet the water quantity and quality requirements of the subdivision. This report documents the investigation, which included exploratory drilling, test well construction and aquifer testing.

The location of Horizon Hills Subdivision at the base of Peavine Mountain lends itself to groundwater quality and quantity problems. The highly mineralized and hydrothermal altered rock of Peavine Mountain causes mineralized water, specifically dissolved iron and manganese. Because there are no sizeable alluvial aquifers or surface streams in the vicintiy, fractured bedrock is the only reliable source of water supply. However, locating such a well is quite often a risk. Washoe County chose a site for exploratory drilling in an area close to the subdivision in a rhyolite plug that appeared highly fractured and without evidence of hydrothermal alteration.

A contract was awarded to Sargent Irrigation in January 1985 for an exploratory test hole and air lift pumping test to determine water quality and quantity. Because of the highly fractured nature of the geology, and favorable indications for water quality and quantity, an 8-inch test well was constructed and tested. A pumping test was completed in December 1985 and the results, analysis and recommendations are included herein.

Exploratory Drilling

The exploratory drilling contract called for one 500 foot test hole. Five test holes were eventually drilled. The following is a synopsis of each test hole.

Test Hole No.1 was drilled to 200 feet with a reverse rotary air drill rig. Alternating lenses of iron stained rhyolite and clay were encountered. The project geologist (Michael Widmer) terminated the test hole at 200 feet because of unfavorable hydrogeologic condtions.

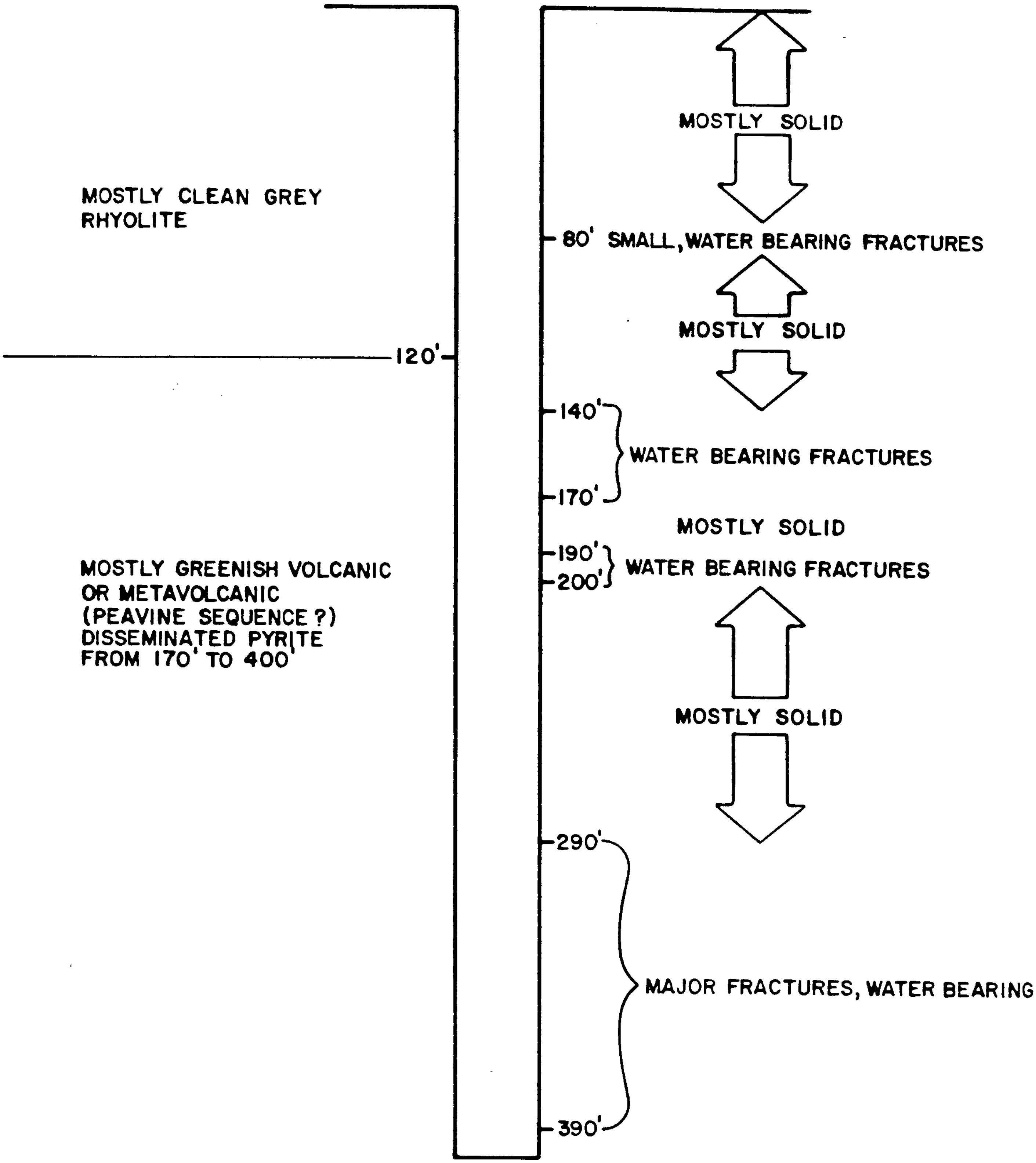
Test Hole No. 2 was drilled approximately 200 feet to the south of Test Hole No. 1 and drilled to a depth of 350 feet before the rollers of the tri-cone drill bit were lost in the hole. This test hole encountered highly fractured rhyolite and metamorphosed volcanics with apparent good water bearing potential.

Test Hole No. 3 was drilled approximately 6 feet to the east of Test Hole No. 2 to a depth of 403 feet. The same geology and water bearing fractures as in test hole No. 2 were encountered. This test hole was drilled air-reverse with a hammer bit and tri-cone bits. Several bits were ruined due to the hardness and fractured state of the geology. The hammer bit became inoperable below 300 feet due to excessive water pressure. A mud rotary rig was set up over the hole and never drilled deeper than 80 feet because of lost circulation problems. This circulation problem was such that the drilling mud flowed into non-water bearing fractures at a greater rate than drilling mud could be provided at the surface. Cement was used to try and plug the fractures, but was unsuccessful.

Test Hole No. 4 was drilled to 80 feet by a mud rotary rig and encountered the same problems of lost circulation. This test hole was located 25-feet from Test Hole No. 3.

Test Hole No. 5 was drilled to 300 feet by the air-reverse rotary rig with an air hammer bit. Excessive water pressures inhibited the hammer bit operation below 300 feet. Sargent decided not to drill below 300 feet with a tri-cone bit.

Based on the information obtained from the exploratory drilling, it was agreed upon to drill and construct a test well to 400 feet with a reverse rotary mud rig. The lost circulation zones would be circumvented by installing a 16 inch conductor casing to 165-feet with a cable tool drill rig. A lithologic log is shown in figure 1. Test holes 2-5 all encountered the same geology. Test holes 1, 2, 4, and 5 were plugged with neat cement.



WASHOE COUNTY DEPARTMENT OF PUBLIC WORKS

UTILITY DIVISION		FIGURE I	SHEET NO 1 OF 1 SHEET(S)
DATE JAN. 1986	BY MCW / JR	LITHOLOGIC LOG EXPLORATION HOLE # 3	
Scale NONE	APPROVED		

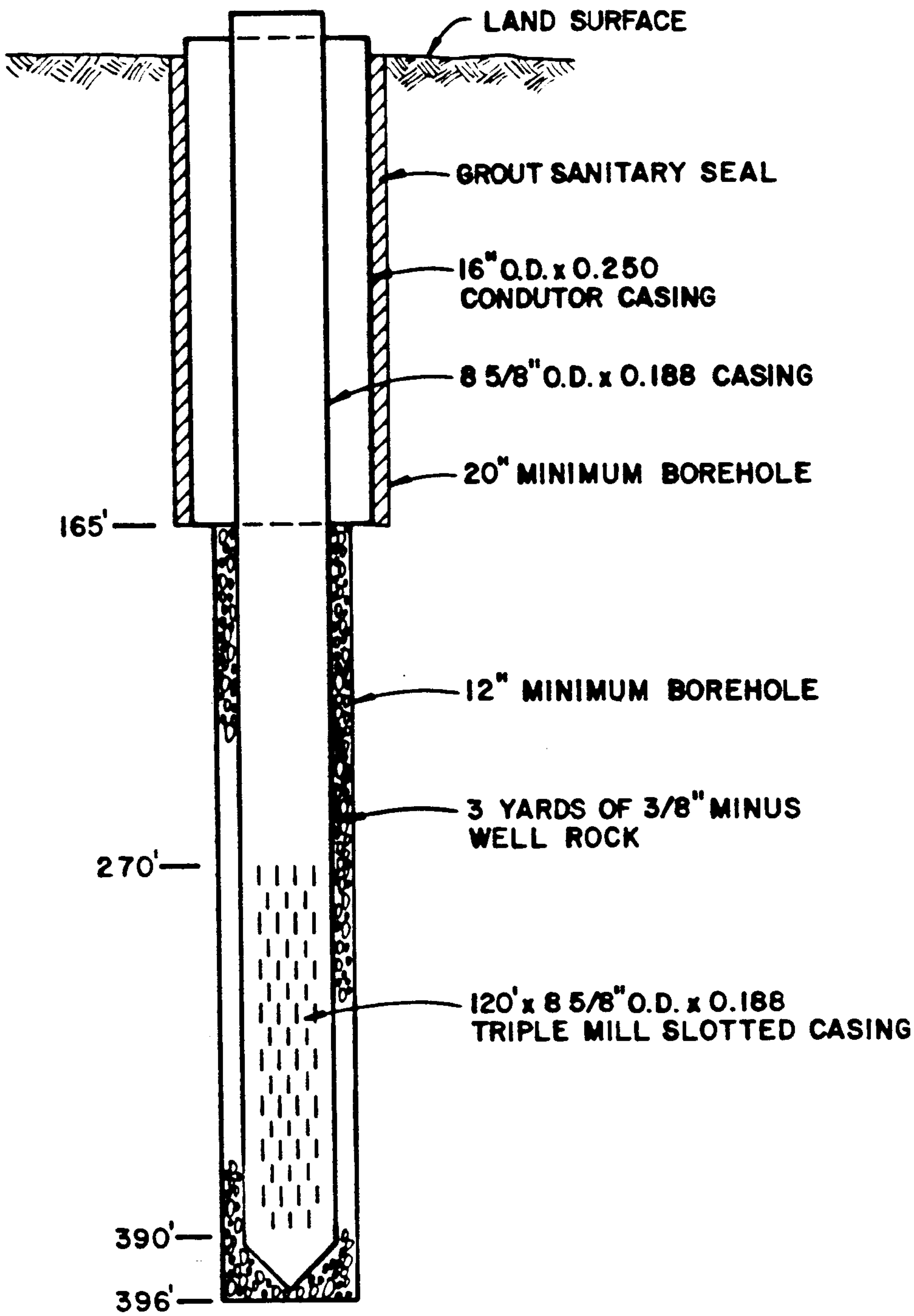
REVISIONS | DATE

Test Well Construction and Development

Construction of a test well began August 8, 1985 in Test Hole No. 3 with the drilling of a 20 inch hole by a cable tool rig. A 16-inch conductor casing was inserted to a depth of 165 feet and completed September 11th. On September 12th, eight yards of grout (neat cement) was used for a sanitary seal to a depth of 165 feet to land surface. This conductor casing work was subcontracted to MacKay Drilling.

On October 23rd, Sargent Irrigation set-up a reverse rotary mud rig and began drilling a 12 inch borehole in Test Hole No. 3. The borehole was completed to a depth of 400 feet on October 31st. Well construction was completed November 1st (see figure 2). Two fifty pound bags of sodium acid-pyrophosphate were added to the well to help breakdown the drilling fluids (bentonite clay mud). Four hours of well development (pumping and air-lifting) occurred on November 1st and 2nd. On November 4th, three yards of pea gravel was installed in the well-borehole annular space to serve as a formation stabilizer. Downhole problems prevented a drawdown tube from being included in the well construction.

Four hours of additional well development occurred on December 15th. A turbine line-shaft pump was installed to a depth of 350 feet. The well was pumped at rates varying from 160 gpm to 240 gpm with periods of surging. This pumping and surging (turning pump off to create a backwash effect) helps to remove sediment from the well and to create a better filter from the gravel pack or formation stabilizer. Drilling fluids are also removed from the well/aquifer. After development the water was clear and had very little sediment.



WASHOE COUNTY DEPARTMENT OF PUBLIC WORKS

REVISIONS	DATE	UTILITY DIVISION		FIGURE 2	SHEET NO 1 OF 1 SHEET(S)
		DATE JAN. 1986	BY MCW / JR	AS BUILT CONSTRUCTION DETAILS	
		Scale NONE	APPROVED		

Pumping Test

Two pumping tests were conducted from December 16th to December 20th. The line-shaft turbine test pumping equipment consisted of 350 feet of 4-inch pump column with twelve stages of 7 inch bowl assembly and engine. The discharge rate was measured by a 4.124-inch I.D. horizontal discharge pipe with a 3.375-inch I.D. orifice plate. A manometer was attached to the discharge pipe and adjustments to flow were made by a gate valve or engine r.p.m. adjustments. Water level measurements were made via a drawdown tube provided to a depth of 333 feet and were made to the nearest 1/100 foot.

Step-Drawdown Test

A step-drawdown test is used to determine well efficiency, well yield, specific capacity and pumping levels at various pumping rates. Various and increasing pumping rates are established for a minimum period of 100 minutes with a minimum of three periods. This test was conducted December 16th for 400 minutes (6 2/3 hours) at pumping rates of 115 gpm, 162 gpm, 209 gpm and 242 gpm. The data is shown in figures 3-5.

Figure 3 shows the drawdown in the well versus time and pumping rate. For each step the pumping rate is noted as well as the specific capacity for each step. Specific capacity describes the well capability to pump water at a pumping rate per foot of drawdown in the well. The drawdown in a well is a function of head losses in the well and head losses in the aquifer formation and the pumping rate - this in turn is used to determine its efficiency. It is standard practice to determine these losses by the equation:

$$S_W = BQ + CQ^2 \qquad (1)$$

where S_W is the drawdown in the well, Q is the pumping rate or discharge, B is the coefficient of well loss and C is the coefficient of formation loss. When the specific drawdown (inverse of specific capacity) is plotted versus

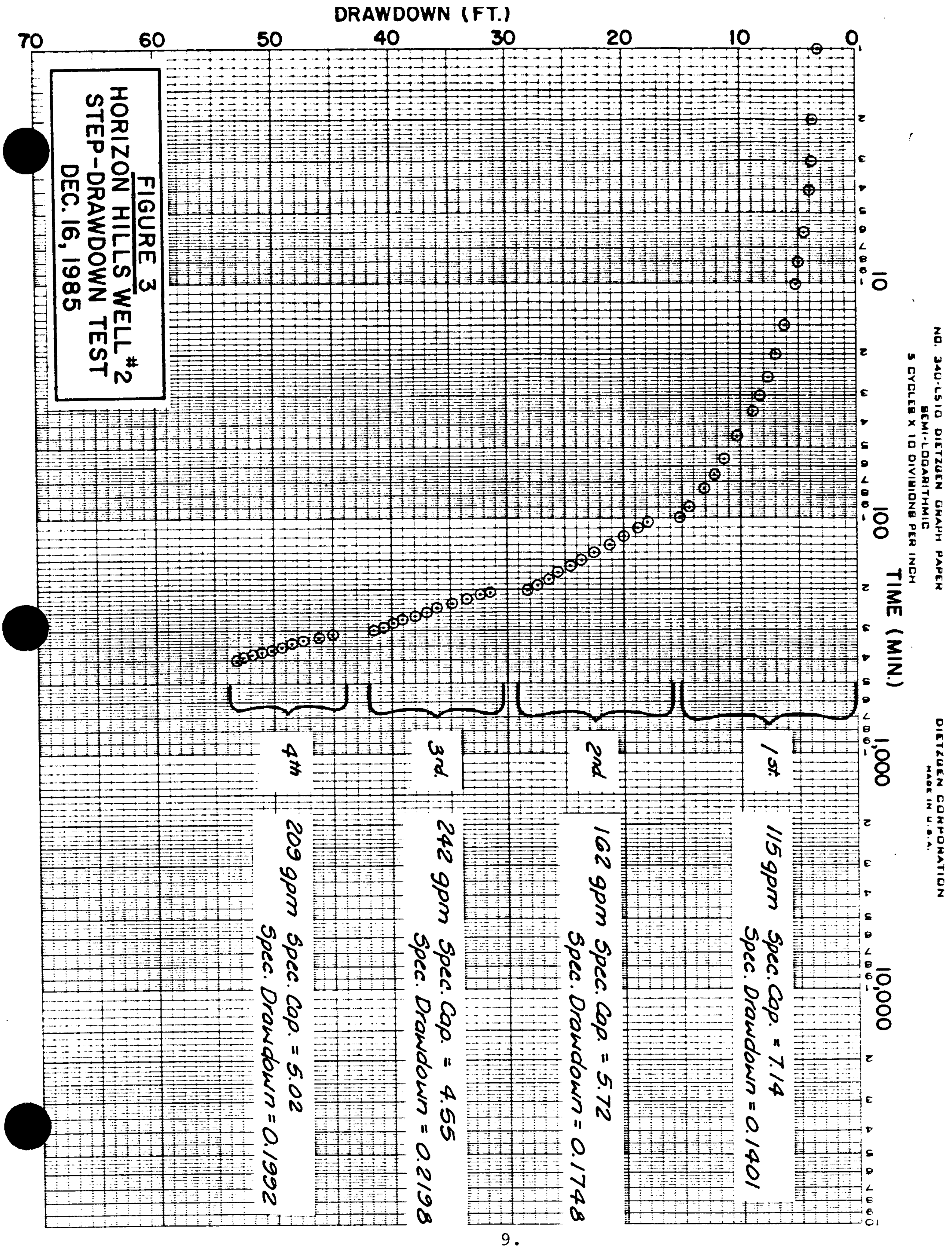


FIGURE 3
HORIZON HILLS WELL #2
STEP-DRAWDOWN TEST
DEC. 16, 1985
DRAWDOWN (FT.)
70
60
50
40
30
20
10
0
TIME (MIN.)
10
100
1,000
10,000
1st
115 gpm Spec. Cap. = 7.14
Spec. Drawdown = 0.1401
2nd
162 gpm Spec. Cap. = 5.72
Spec. Drawdown = 0.1748
3rd
242 gpm Spec. Cap. = 4.55
Spec. Drawdown = 0.2198
4th
209 gpm Spec. Cap. = 5.02
Spec. Drawdown = 0.1992
NO. 340-L510 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH
DIETZGEN CORPORATION
MADE IN U.S.A.

discharge, a straight line can be drawn through these points as depicted in figure 4. The slope of this line is equal to the formation loss coefficient and the line intercept with the graph is equal to the well loss coefficient. Table 1 shows the calculations used to determine these coefficients.

Table 1

Step Drawdown Tests - Specific Capacity

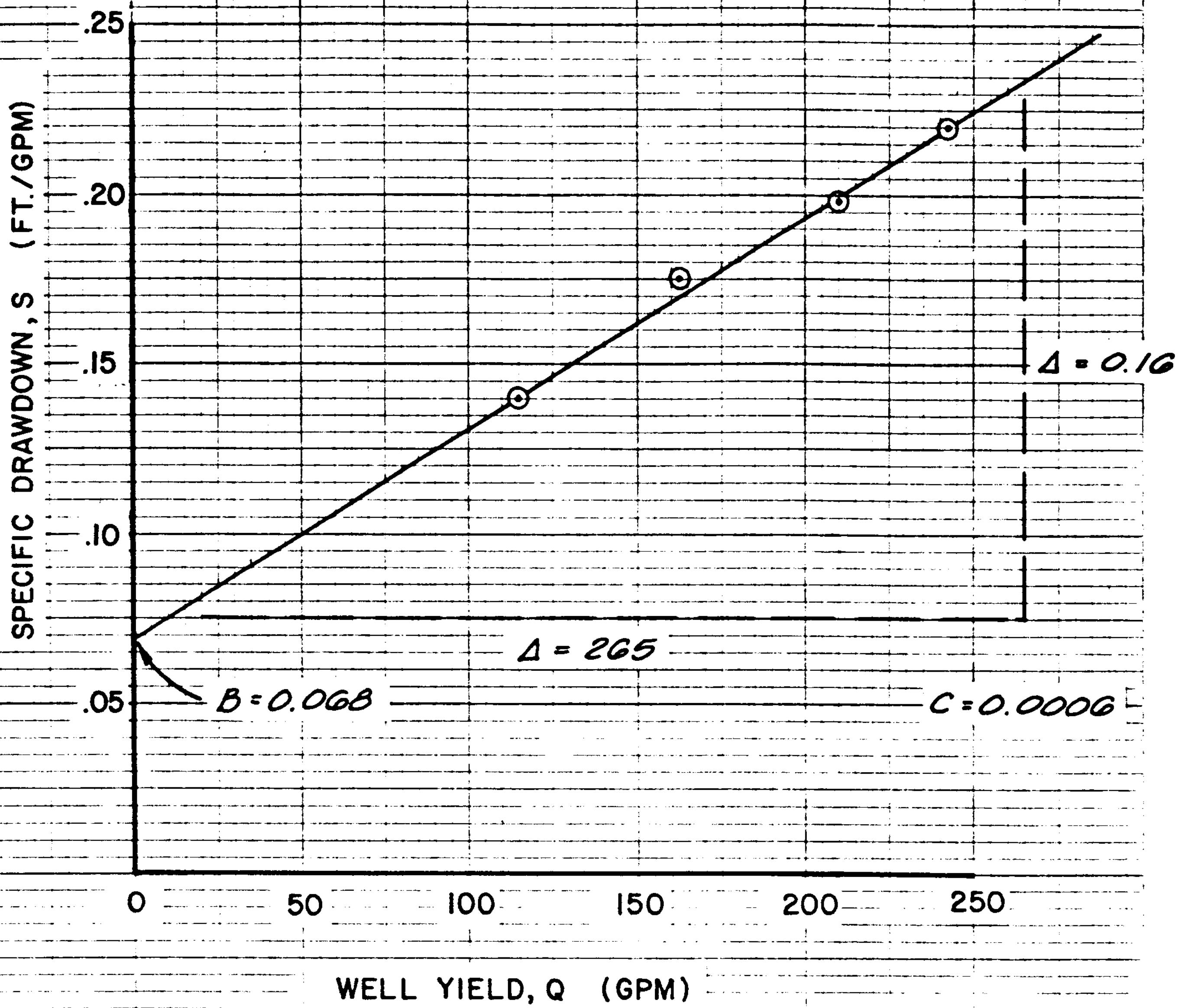
Step	Q Well Yield (gpm)	S_w Drawdown after 100 min. (ft)	Q/S Specific Capacity (gpm/ft)	S/Q Specific Drawdown (ft/gpm)
1	115	15.27	7.14	0.1401
2	162	28.30	5.72	0.1748
3	209	41.65	5.02	0.1992
4	242	53.16	4.55	0.2198

Well efficiency is ultimately described by this graphical method from the equation

$$E = \frac{1}{1 + (C/B)\,Q} \qquad (2)$$

Table 2 shows these calculations and figure 5 graphically displays the results.

FIGURE 4
SPECIFIC DISCHARGE VERSUS WELL YIELD
DATA FROM STEP-DRAWDOWN TEST



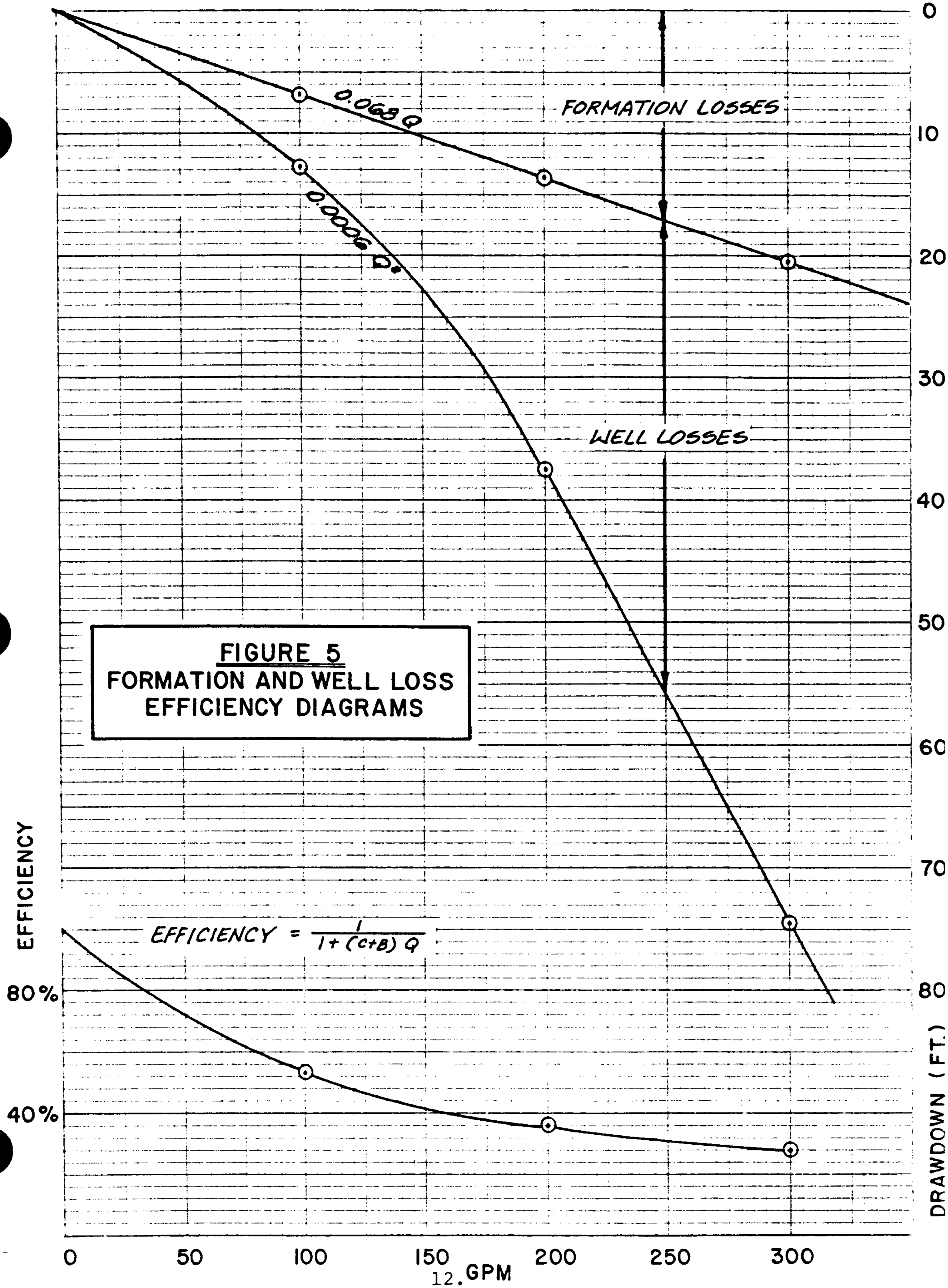


FIGURE 5
FORMATION AND WELL LOSS EFFICIENCY DIAGRAMS

Table 2		
Calculated Drawdown and Well Efficiency		
Q Well Yield (gpm)	S_W Calculated Drawdown (ft)	E Well Efficiency (%)
100	12.8	53
200	37.6	36
300	74.4	27

$$S_W = (0.068)Q + (0.0006)Q^2$$

$$E = \frac{1}{1 + (C/B)\,Q}$$

As can be seen in figure 5, well losses account for most of the drawdown as the discharge rate is increased. Well losses should be a minor portion of the total drawdown. These losses reflect the construction of the well among other things. At the designed pumping rate of the well, efficiencies should be in the range of 70-90%. As can be seen from the graph, an efficiency of only 42% is achieved at a pumping rate of 150 gpm. The physical reason for such low efficiencies and high well losses stems from the well penetrating fractured bedrock. These water bearing fractures actually serve as an extension of the well itself. Such low efficiencies typify fracture flow wells. The efficiency of this well may initially increase due to more development of the fractures through pumping. Well efficiency should be tested on an annual basis in order to insure proper maintenance and longevity of the well.

Constant Discharge Test

A constant discharge test is run in order to determine aquifer parameters and discover any boundary conditions. Aquifer parameters describe how well the aquifer transmits water and its storage capabilities. Transmissibility is used to predict future drawdowns or pumping levels in the well. Obviously, for a well being used for twenty years or longer, this information is invaluable. Boundary conditions such as faults (impermeable boundary) or large bodies of water - rivers, lakes and streams (recharge boundary) have a cause and effect on the aquifer's natural condition and flow pattern. A pumping well's drawdown rate will be effected by these boundary conditions with either an increase or decrease in drawdown over time. An increase in the drawdown rate infers that an impermeable boundary of the aquifer has been reached by the well drawing water from the aquifer. In a fracture flow well, this may mean that certain fractures may be entirely dewatered.

On December 17th, a 72-hour pumping test was initiated. A pumping rate of 209 gpm was chosen, but later reduced to 185 gpm because the pump was not capable of sustaining the higher pumping rate. Figure 6 shows the drawdown in the well versus time.

The early time data (20 minutes) shows a low drawdown rate before an increased, but constant drawdown rate occurs. This probably results from dewatering small upper fractures and storage effects. An increase in drawdown then results from the constant discharge drawing more water from the main production zone of fractures (280 feet - 380 feet). At 3500 minutes (2 1/2 days), an increase in the drawdown rate occurs. This doubling of the drawdown rate reflects an impermeable boundary where no flow occurs. Because of the nature of this fracture flow aquifer, it probably reflects the actual dewatering of a larger fracture.

Recovery Data

The recovery test occurs after the constant Q pumping test is ended and the pump is turned off. Water level measurements are taken at specific time

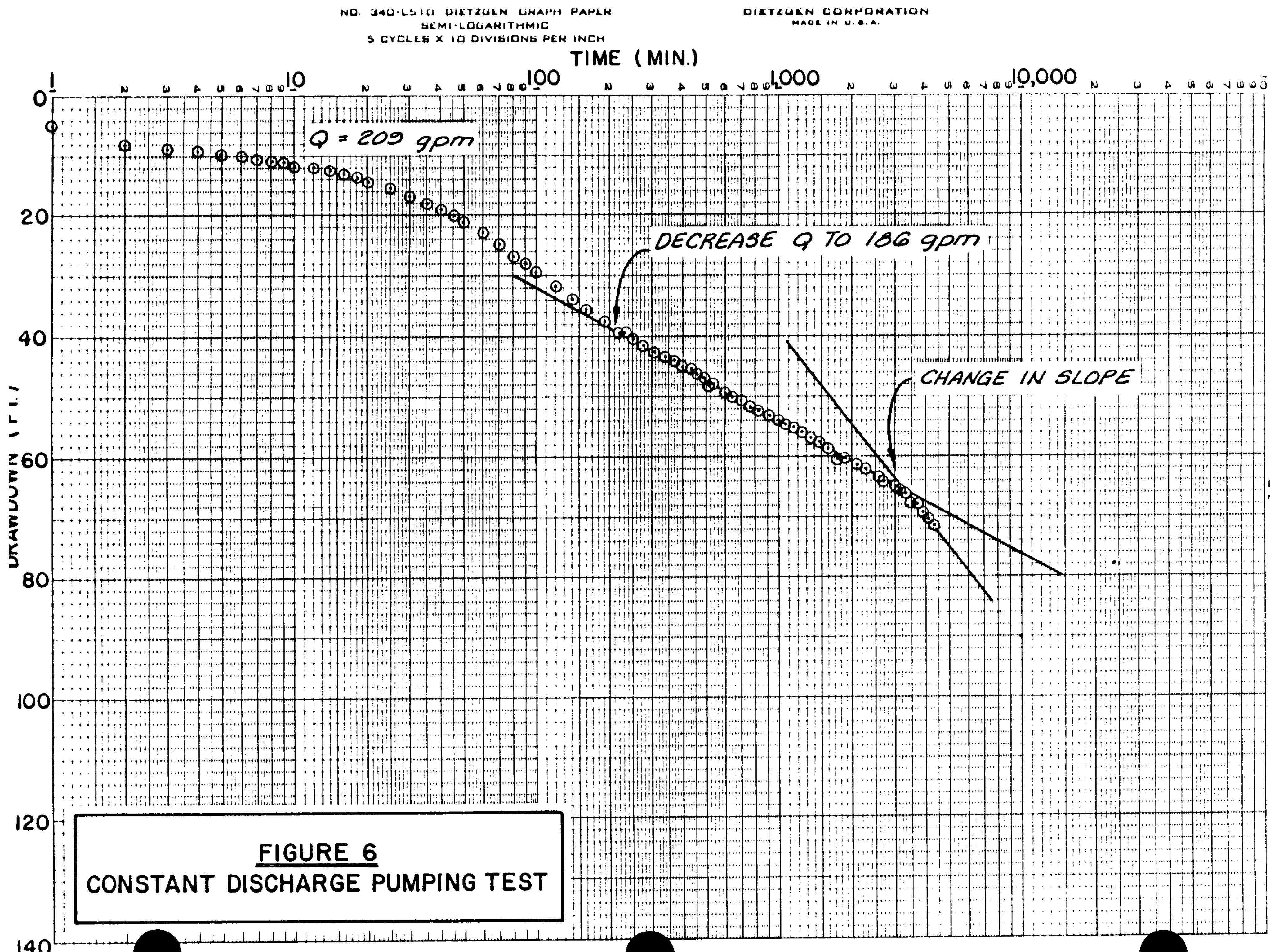


FIGURE 6
CONSTANT DISCHARGE PUMPING TEST