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POLLUTION CONTROL

REPORT OF DRILLING AND STEP DRAWDOWN
TESTING OF THE SEEPAGE CLEANUP
SYSTEM IN THE VICINITY OF
WELLS TWQ-124 AND 450-A

for

United Nuclear Corporation
Mining and Milling
Gallup, New Mexico

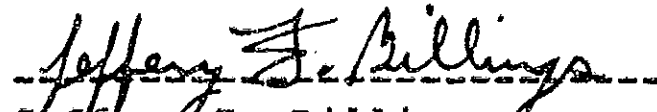
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Billings & Associates, Inc.
Kimberling City, Missouri

and

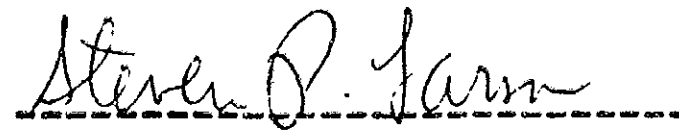
S. S. Papadopolus & Associates, Inc.
Rockville, Maryland

December, 1983



Jeffery F. Billings
Associate/Hydrologist
Billings & Associates, Inc.

Approved by



Steven P. Larson
Vice President
S. S. Papadopolus
& Associates, Inc.



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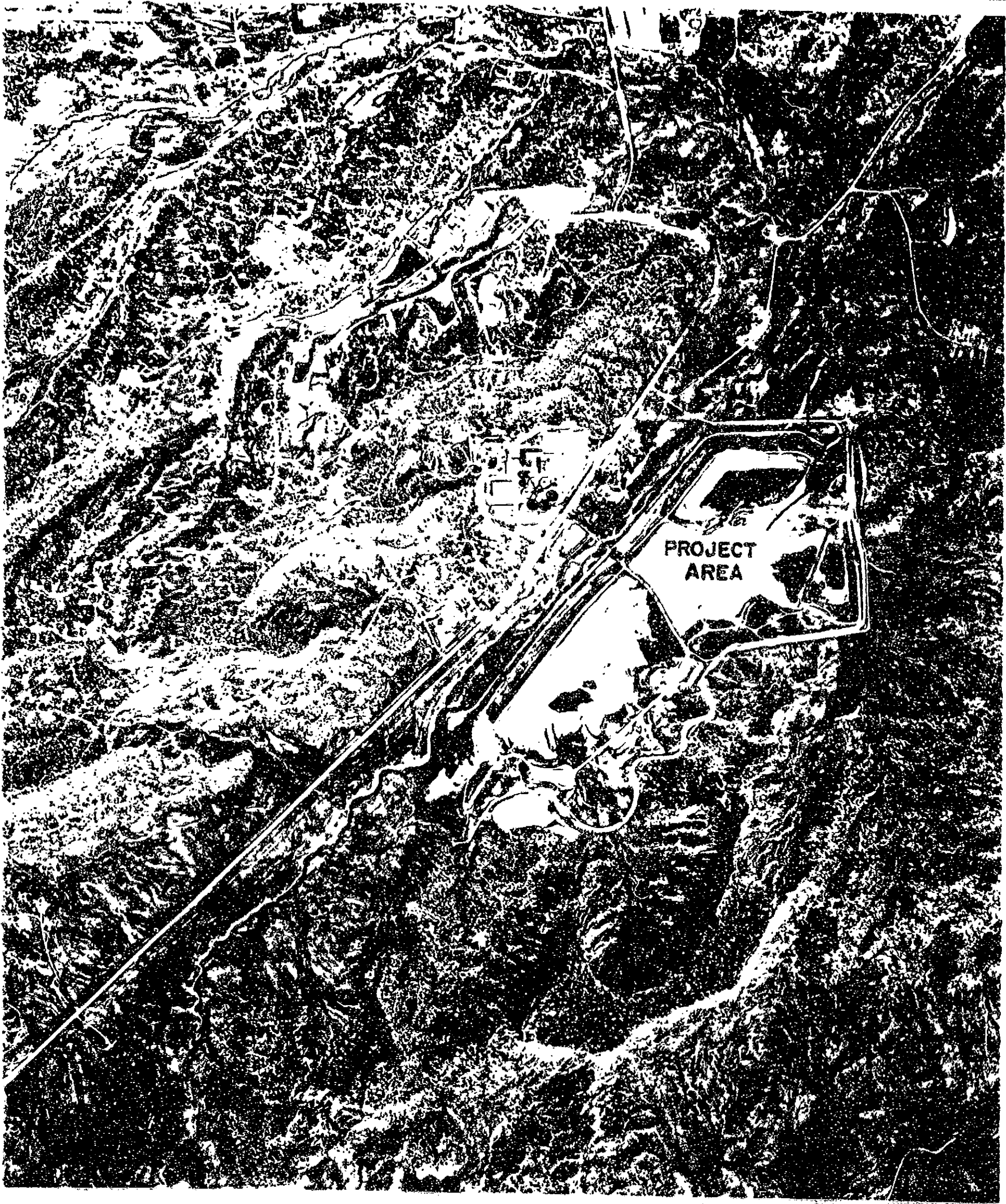
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1.0 PURPOSE

This report presents results of drilling, construction, development and step drawdown testing of wells emplaced for the Seepage Cleanup System in the vicinity of Wells TWQ-124 and 450-A at the United Nuclear Corporation (UNC), Church Rock Tailings Site. An aerial view of the UNC site is presented on Plate 1 (page 2) and a plan view of the well locations and project area is presented on Plate 2 (page 3). This system was constructed for the purpose of cleaning up seepage by groundwater extraction in the vicinity of two wells (TWQ-124 and 450-A), which have been identified by the New Mexico Environmental Improvement Division (NMEID) as containing thorium concentrations in excess of the Radiation Protection Regulations. Operation of this system will provide a localized cleanup system for seepage which has occurred off property to the northeast of the UNC tailings disposal facility (i.e. that seepage in the vicinity of Wells TWQ-124 and 450-A). In addition, this system will provide useful data for future seepage cleanup programs in other portions of the site.



SITE AREA

UNITED NUCLEAR CORP.
CHURCH ROCK, N.M.

BILLINGS & ASSOCIATES, INC.
KIMBERLING CITY, MO.

PLATE 1

SCALE 1" = 1500'

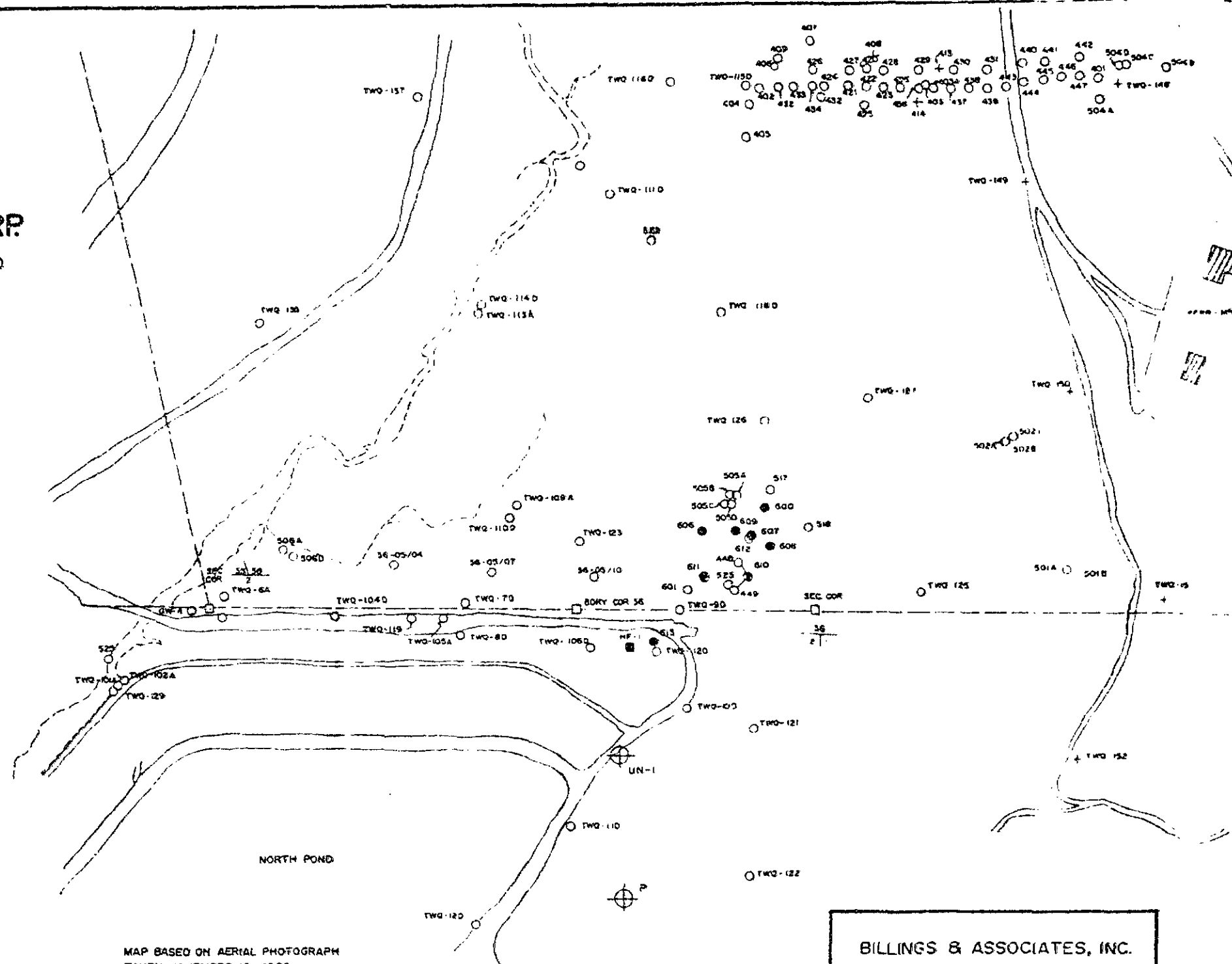
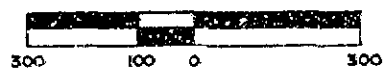
APPROVED BY *[Signature]*

DRAWN BY *[Signature]*

UNITED NUCLEAR CORP.
 CHURCH ROCK, NEW MEXICO
 PROJECT AREA
 NOVEMBER, 1983



NOMINAL SCALE 1" = 300'



- LEGEND**
- EXTRACTION WELLS
 - MONITORING WELLS
 - ══ SELECTED ROADS
 - - - - SELECTED DRAINAGES
 - + PLUGGED HOLES
 - HYDROFRAC WELLS
 - ⊕ SURVEY CONTROL POINTS

MAP BASED ON AERIAL PHOTOGRAPH
 TAKEN NOVEMBER 18, 1980.

BILLINGS & ASSOCIATES, INC.
 KIMBERLING CITY, MO
 APPROVED BY *J.F.H.* DRAWN BY *D.E.T.*

PLATE 2

2.0 INTRODUCTION

The locations of the seepage cleanup wells were based on geohydrologic and water quality information of the project area obtained on site through previously conducted investigations. The EID staff concurred with the well locations prior to drilling. Minor adjustments of some of the well locations were made in the field to accommodate leveling of the drill rig while minimizing pad and mud pit excavations. While a detailed discussion of the previously conducted investigations is beyond the scope of this report, a brief summary is warranted.

The piezometric gradient of Zone 3 and Zone 1 in this area slopes to the east-northeast. Thus, seepage from the North Pond would be expected to move at first in a northerly direction, then in a northeasterly to easterly direction. Water quality information indicates that thorium concentrations are in excess of the NMEID Radiation Protection Regulations in the off-property Wells TWQ-124 and 450-A. Noting that thorium concentrations were not in excess of the regulation to the north and east of Wells 450-A and TWQ-124, a cleanup system was designed that will collect seepage from Wells 450-A and TWQ-124 and down gradient where it is known thorium is not in excess of the NMEID regulations. The spacing of the wells is based on the aquifer parameters previously determined in the area (BAI; September, 1982) for an anticipated pumping time of approximately four months. It was anticipated that by pumping these wells for four months, a sink in the piezometric surface will be established,

thus creating a capture zone for the thorium contaminated water. It should be noted that Wells TWQ-124, 450-A and Gallup 3 are now identified as Wells 610, 611 and 613 respectively. All three of these wells were redrilled with a larger diameter casing placed in the borehole in order to accomodate a submersible pump. In addition, Well 450-B no longer exists as it was originally constructed as a dual completion well with 450-A. The loss of the services of Well 450-B (a Zone 3 well) is insignificant as there are numerous other Zone 3 wells in the area of investigation.

3.0 METHODS

Investigations were conducted prior to drilling in order to determine the most applicable techniques for the drilling, construction, development and step drawdown testing of the cleanup system wells. These investigations are; "Investigation of Well Construction and Completion Techniques for Wells Completed in the Gallup Formation" (BAI; June, 1983) and, "Specifications for Drilling, Construction and Development of the Thorium Seepage Collection Wells" (BAI; June, 1983). These investigations along with previous drilling and testing experience at the UNC site provides the basis for the following general procedures for the installation and step drawdown testing of the seepage cleanup wells. Where necessary, minor field modifications were made to the preliminary well construction specifications (BAI; June, 1983).

3.1 Well Drilling and Construction

The wells were drilled under BAI supervision by a licensed contractor with a rotary drill rig using Revert as the drilling fluid. Rotary drilling was used because of its speed, ease of use in the field and its success in previous drilling at the UNC site. Revert was used as the drilling fluid because it decomposes in two to three days, thereby reducing borehole damage that could result from drilling fluid.

Continual efforts during drilling were made to investigate

the feasibility of using open borehole and pre-casing development techniques by determining the amount of sluffing that would occur if the well was left open. It was determined as will be presented later in this report, that open borehole and pre-casing development techniques is not a feasible alternative for completion of water wells in this area.

An approximate depth of the target formations, Zone 3 and Zone 1 of the Gallup Formation, and the total depths of the wells were identified in the field prior to drilling, from lithologic and geophysical logs of nearby wells. In addition, a lithologic log was obtained during drilling from each of the new wells. Finally, in order to more precisely identify the target formation and total depth of the well, a geophysical log of each new well was taken immediately after the drilling of that well was completed.

The wells were drilled from 3 to 20 feet below the target formation. This procedure was used to facilitate placement of the pump at a depth below the target formation thus creating the maximum drawdown possible. Further details on this method of well construction are presented in the construction specification report (BAI; June, 1983). A shroud was placed around the pump forcing water by the pump motor, in order to keep the pump from overheating.

Drilling speed, circulation, lithologic logs and geophysical logs were observed in order to identify any structural features encountered during drilling. If structural features such as fractures were encountered during drilling, pre-casing

development would have been performed on the well. No noticeable indications of structural features were encountered. Therefore, no development prior to setting casing was performed.

As will be described later in this report, sluffing of the open borehole occurred throughout drilling and construction and any further development would have increased the probability of losing the hole before casing could be emplaced. The drilling fluid was left in the hole while lowering the casing in order to minimize sluffing.

After the target formation and total depth had been identified, the casing and screen were installed in the well according to field determined specifications. A blank section of six (6) inch diameter PVC casing, with a cap on the bottom, was placed at a depth from the bottom of the target formation to the total depth of the well to facilitate maximum drawdown of the well. PVC screen (6 inch diameter) was placed on top of this blank section in the target formation. This construction method allows the well to fully penetrate the aquifer (i.e. target formation). The screen aperture size (0.05 inches) was chosen to retain 95-100 percent of the formation stabilizer and still maintain an appropriate collapse strength.

A formation stabilizer is needed primarily to stabilize the hole from sluffing and to prevent sand from the aquifer entering into the well. Reasons for using this stabilizer are presented in detail in the specifications report (BAI; June, 1983) and will also become evident in a subsequent section of this report that describes in detail specifically how each well was constructed.

A centering guide (centralizer) was placed at the top of the screen in order to insure that the screen was placed in the center of the borehole. Six (6) inch diameter PVC blank casing was placed on top of the screen to a point above the ground surface. The final height above the ground surface of this blank casing was measured to verify that the screen had been placed within the target formation.

The drilling fluid was removed from the inside of the well and the annulus after setting the screen and casing. This was accomplished by lowering the drill stem into the well, sealing the top of the well and pumping clear water through the drill stem into the well. The clear water forces the drilling fluid in the well to move out through the screen and up through the annulus. Circulation was stopped and final well construction began when the return water flowing out of the annulus was clear.

The final step in well construction consisted of first placing a bentonite pellet seal in the annulus, starting at the total depth of the well to the bottom of the target formation. A bentonite seal is used to prevent interformational flow. Depth measurements with a weighted steel tape were made to verify that the top height of the seal was obtained. The formation stabilizer was placed in the annulus to the top of the target formation after the top height of the seal in the annulus had been verified. Verification of the top height was made with a weighted steel tape. A bentonite seal was then placed on top of the stabilizer in the annulus using the same technique as that used for the bottom bentonite seal. A bentonite/cement grout was

then placed in the annulus by the use of a grout pipe and surface pump. A grout pipe and surface pump were used to ensure that a dilution of the grout to water ratio did not occur as the grout was placed in the annulus. Construction of the well was terminated and development of the well began after the cement/grout hardened.

Formation stabilizer material specifications were checked prior to use by collecting ten (10) random samples of the material as received on site. These samples were analyzed and certified by Dennis Engineering (Socorro, New Mexico). The samples were analyzed for grain size and uniformity coefficient by mechanical sieve analysis. Lime content was determined by measuring the amount of lime dissolved in concentrated sulfuric acid. The results of this analysis are presented in Table 1. As presented in Table 1, when compared to specifications contained in Appendix D of the specifications report (BAI; June, 1983), the specifications were met. This testing verifies that a highly uniform, clean, rounded to well rounded non-calcareous formation stabilizer was used in the construction of these wells.

3.2 Well Development and Stabilization

Several techniques were used in the development of the collection wells. The wells were first air lifted for 1.5 to 4.0 hours with an air compressor and eductor pipe (Johnson Division, UOP, Inc., 1975), and then bailed/surged for approximately one-half hour. The well was then air jetted over the entire

Table 1

Formation Stabilizer Analysis Results

Sample #	<u>Cummulative Percent Retained</u>					Uniformity Coefficient	Lime (% of 200 gm.)	Remarks
	Sieve 4	Sieve 6	Sieve 8	Sieve 10	Pan			
1	0	0.4	65.9	97.7	100	1.16	0.2	Rounded to Well Rounded
2	0	0	84.2	97.2	100	1.14	0.2	Same
3	0	0	73.8	97.4	100	1.11	0.0	Same
4	0	0	78.6	97.0	100	1.14	0.1	Same
5	0	0.4	79.6	99.6	100	1.05	0	Same
6	0	0	71.4	92.0	100	1.24	0.1	Same
7	0	0.3	79.7	99.4	100	1.13	0	Same
8	0	0.2	79.9	98.6	100	1.13	0	Same
9	0	0.2	64.8	99.0	100	1.17	0.2	Same
10	0	0.2	67.0	99.0	100	1.17	0.1	Same

screen with a bull plug as described in the specification report (BAI; June, 1983). A field modification was made to the bull plug in order to increase the nozzle jet velocity. This modification consisted of decreasing the number of nozzle ports on the bull plug to four. After air jetting, the well was again bailed/surged for approximately 20 minutes.

The well was allowed to stabilize 11 days after development. Periodic water level measurements were taken during this time. A static water level was measured and recorded when the well had stabilized.

The testing equipment was installed after this stabilization. This equipment consists of a downhole pressure transducer, a submersible pump and a discharge line. A surface flowmeter was installed in the discharge line to measure discharge which is regulated by a control valve. Further details on the testing procedure are presented in the testing section of this report (page 28).

4.0 DRILLING, CONSTRUCTION, DEVELOPMENT
AND STABILIZATION RESULTS

Drilling began with Well 612 on July 27, 1983 and proceeded chronologically in the following order: 610, 608, 609, 611, 606, 613 and 607. The drilling was completed on August 12, 1983. Wells 611, 606, 612 and 607 were completed in Zone 1 of the Upper Gallup Formation. Wells 608, 609, 610 and 613 were completed in Zone 3 of the Upper Gallup Formation.

4.1 Well 612 (Zone 1)

Well 612 was drilled to a total depth of 189 feet (BGS). Continual sluffing of the hole, especially in the short time interval between drill stem connections, was noted throughout the drilling of this well even with the use of drilling mud which aids in the control of sluffing in open boreholes. The use of open borehole development and completion techniques was not possible due to the increased probability of losing the hole because of sluffing. It was thus determined that screen and a formation stabilizer should be placed in the borehole as rapidly as possible to prevent loss of casing and redrilling of the borehole. Such sluffing is a strong indication that open boreholes would not function as continuous production wells.

Lithologic logs were taken during drilling and geophysical logs were taken immediately after drilling to identify the total depth and target formation (Zone 1). Lithologic logs were taken

at ten-foot intervals for all wells and are presented in Appendix A. The geophysical logs taken were Gamma, Neutron-Neutron, Spontaneous Potential, Resistance and Caliper. The geophysical logs are presented in Appendix B.

The casing, screen, stabilizer, bentonite seals and grout specifications were determined after review of the lithologic and geophysical logs. The casing and screen were then placed in the borehole per field determined specifications. The drilling fluid was removed from the borehole after the casing was set by flushing the well with approximately 1200 gallons of clear water. The stabilizer, bentonite seals and grout were then placed in the well per field specifications. The drilling and well construction details for all wells are presented in Appendix C of this report.

The development procedure began by first air lifting the well. Difficulty in lowering the air pipe was noted when air lifting was attempted for this well. The well was jetted and a small amount of gravel was lifted from the well. Bailing was attempted in order to remove this gravel. The source of the gravel was determined to be the formation stabilizer that apparently had entered through a cracked screen or separated connection in the screen or casing. It was determined this well could not be used as a pumping well. Well 607 was subsequently drilled ten (10) feet away and will be used as a pumping well in place of Well 612. The static water levels of Well 612 is 6866.71 feet (MSL) and Well 607 is 6865.90 feet (MSL). A proper seal of Zone 1 in the construction of Well 612 is indicated by

the similarity of these water levels. Therefore, Well 612 will be used as a Zone 1 observation well.

4.2 Well 610 (Zone 3)

Well 610 (Well 124 reamed) was drilled to a total depth of 109 feet (BGS) to serve as a Zone 3 pumping well. The borehole was left open overnight to determine if sluffing would occur. The borehole was redrilled the next morning because several feet of sluffing did occur during the night, thus providing evidence that open borehole completion techniques are not practical.

Twelve hundred (1200) gallons of clear water were circulated through the well, screen and up through the annulus after setting the casing. The formation stabilizer, bentonite seals and cement were then placed in the annulus per field determined specifications as presented in Appendix C of this report.

Development began by air lifting the well for four hours. The well was then bailed/surged for 25 minutes. Sand-free water was noted from the bailing/surging and the well was then air jetted using a bull plug, over the entire length of the screen. The well was then rebailed to determine if any sand had entered the screen due to air jetting. No sand was noted and the development procedure was then terminated.

The well was allowed to stabilize for 11 days to a final static water level elevation of 6923.52 feet (MSL) after well development.

4.3 Well 608 (Zone 3)

Well 608 was drilled to a total depth of 113 feet (BGS). The screen and casing were placed according to field determined specifications based on the lithologic and geophysical logs. However, during the period of time when the casing was set and the clear water was circulated the hole sluffed four feet. A three-foot bottom bentonite seal was then emplaced in the annulus.

The drilling fluid was removed by flushing approximately 1200 gallons of clear water through the casing after the casing had been set. The remainder of the well was then constructed per field specifications as detailed in Appendix C of this report.

The well was air lifted for 3.5 hours and was then bailed/surged for 30 minutes. The screen was surged with the use of the bailer and no sand was noted during this portion of the development. The screen was air jetted with the use of a bull plug. The well was bailed again to determine if sand had entered the screen into the well. No sand was noted and development of this well was terminated.

The well was allowed to stabilize for 11 days with a final static water level of 6922.45 feet (MSL).

4.4 Well 609 (Zone 3)

Well 609 (Zone 3) was drilled to a depth of 112 feet (BGS). Again, the borehole was left open overnight filled with drilling fluid in order to determine if sluffing could be controlled.

However, the hole sluffed several feet during the night even though the drilling mud was left in the hole. The open borehole was reamed again to its total depth of 112 feet (BGS) to remove the sluffed material. All attempts failed to produce a well in which open borehole completion techniques might be used.

The casing and screen were set according to field determined specifications (Appendix C) as determined from the lithologic and geophysical logs. The drilling fluid was removed after the casing had been set by circulating approximately 1200 gallons of clear water through the casing and screen and up through the annulus. The borehole sluffed two feet during the circulation of clear water which resulted in the placement of a three-foot bottom bentonite seal. The well was constructed according to field determined specifications, detailed in Appendix C of this report.

The development was begun by air lifting the well for 2.5 hours. Bailing/surging over the entire screen was carried out for 30 minutes. No sand was bailed from the well during this development procedure. The well was then air jetted through a bull plug over the screen. The well was then bailed again with no sand being produced. Development of the well was then terminated.

The well was allowed to stabilize for 11 days with a final static water elevation of 6923.04 feet (MSL).

4.5 Well 611 (Zone 1)

Well 611 (Zone 1), formerly Well 450-A, was drilled to a total depth of 177 feet (BGS). Continual sluffing was encountered during the drilling of this well. It was necessary to circulate drilling fluid for more than 15 minutes before each drill stem connection could be made. The cuttings of the lithologic log consisted entirely of the pre-existing gravel pack of 450-A.

Casing was set at a total depth of 177 feet (BGS). Drilling fluid was removed by circulating 1200 gallons of clear water through the casing, screen and up through the annulus after the casing was set. The well sluffed another two feet during the circulation of clear water which resulted in the placement of a 10-foot thick bottom bentonite seal. The well was then completed per field determined specifications (Appendix C).

Development of the well proceeded first by air lifting for four hours. The well was next bailed/surged for 30 minutes over the screen. Sand was not obtained from the well during this portion of the development. The well was air jetted over the screen with a bull plug. The well was bailed again with no sand being produced from the well.

The well was allowed to stabilize for 11 days with a final static water elevation of 6874.90 feet (MSL).

4.6 Well 606 (Zone 1)

Well 606 (Zone 1) was drilled to a total depth of 187 feet (BGS). Casing was placed in the hole per field determined specifications (Appendix C). The drilling fluid was removed by circulating 1200 gallons of clear water through the casing, screen and up through the annulus after the casing was set. The hole sluffed ten (10) feet during the circulation of clear water. This amount of sluffing did not affect the field specifications, because a 20-foot blank section of casing exists at the bottom of the well. A 20-foot blank section of casing was placed in the well because the targeted total depth as determined from nearby geophysical logs was 12 feet deeper than the design total depth at the well location. Therefore, the well was drilled 12 feet deeper than needed. This extra depth does not present any difficulties to the project, as a bottom seal was placed in the annulus to prevent interformational flow. The well was then constructed per field determined specifications (Appendix C).

The well was air lifted for 1.5 hours after well construction and was then bailed/surged for 45 minutes. A small amount (approximately three (3) cubic inches) of very fine sand was removed from the bottom of the well during bailing. This sand was the same texture, size and color as the Zone 1 sand obtained from the cuttings. The well was air jetted with a bull plug over the screen after the sand had been bailed from the well (15 minutes). The well was then rebailed with no sand produced from the well. Development of the well was then terminated.

The well was allowed to stabilize for 11 days with a static water elevation of 6873.72 feet (MSL).

4.7 Well 613 (Zone 3)

Well 613 (Zone 3), formerly Gallup-3, was redrilled to a total depth of 93 feet (BGS). Continual sluffing and what appeared to be swelling of shale layers was encountered during the drilling of this well. It was necessary to ream the borehole three times to place the geophysical logging tool and casing at the bottom. The screen and casing were placed in the borehole per field determined specifications. The drilling fluid was removed by circulating 1200 gallons of clear water immediately after the casing was set. A bottom bentonite seal was not placed in this well because the rapidity of shale swelling indicated the borehole might squeeze before the bottom seal could be emplaced. However, Zone 2, a shale and coal layer exists below Zone 3 thereby acting as a natural seal in the prevention of interformational flow between Zone 1 and Zone 3. The stabilizer was placed in the annulus from the bottom of the hole with its volume and height measured to insure all field specifications were met. Had the pellets been placed in the hole and had they not passed the swelling clays, the hole could have been lost and another well would have been necessary. The stabilizer, top seal and grout were installed according to field specifications (Appendix C).

The well was air lifted for three hours. Sand was not

produced from bailing and surging for 20 minutes, over the screen interval. The well was air jetted over the screen followed by bailing.

The well was allowed to stabilize for 11 days with a final static water elevation of 6928.60 feet (MSL).

4.8 Well 607 (Zone 1)

Well 607 (Zone 1) was drilled to a total depth of 172 feet (BGS). This well was drilled to replace Well 612 which had experienced construction problems. Sluffing during the drilling was encountered and continual reaming was necessary to remove the sluffed material. From the time total depth was reached to the time the geophysical tool was at the bottom of the borehole (30 minutes), the well sluffed three feet. Because of this, a bottom bentonite seal was not used. A shale layer (Mancos) exists below Zone 1 at this location as determined by lithologic and geophysical logs and therefore adverse effects from interformational flow are insignificant. Drilling fluid was removed after the screen and casing had been placed by circulating through the screen 1200 gallons of clear water. The well was constructed according to field specifications as detailed in Appendix C of this report.

The well was air lifted for two hours after construction, followed by bailing and surging for 40 minutes over the screen. Bailing produced some very fine sand with the same characteristics as Zone 1 sand. The well was then air jetted

with a bull plug over the screen and was again bailed with a small amount of very fine sand being removed.

The well was allowed to stabilize for 11 days with a final static water elevation of 6865.90 feet (MSL).

5.0 AQUIFER DESCRIPTIONS

This section presents the stratigraphic, geologic and piezometric information for the aquifers at each well location. The stratigraphic and geologic information was obtained from the lithologic and geophysical logs of each well. The piezometric surface was determined from the static water level measurement taken after well development.

Evaluation of these data provide elevations of the top and bottom of the aquifers, geologic characteristics of the aquifers (grain size and type) and type of aquifer (confined or unconfined).

It should be noted, for hydrologic purposes, Zone 3 is screened in the sandstone which contributes significantly to the flow of water and not in the coal/shale layer at the upper portion of Zone 3.

5.1 Well 612 (Zone 1)

Zone 1 occurs between 124 and 167 feet (BGS) based on the geophysical log (Appendix B). This corresponds to a thickness of 43 feet with a top elevation of 6842.82 and a bottom elevation of 6799.82 feet (MSL).

Zone 1 is identified by a light gray, very fine to fine-grained sandstone which is bound on the top and bottom by a shale layer.

The static water level was 6866.71 feet (MSL). Thus, the aquifer is confined at this location.

5.2 Well 610 (Zone 3)

Zone 3 occurs between 61 and 102 feet (BGS) based on the geophysical log (Appendix B). This corresponds to a thickness of 41 feet with a top elevation of 6907.75 and a bottom elevation of 6866.75 feet (MSL). Sandstone in Zone 3 is identified between the elevations of 6904.25 and 6866.75 feet (MSL).

The sandstone of Zone 3 is characterized by a light gray, very fine to fine-grained rock. A medium to coarse sandstone layer occurs at 80 feet (BGS). Some silt and shale is inter-mixed with this sandstone layer. The sandstone is bound on top by a coal layer and on bottom by a shale and coal layer.

The static water level was 6923.52 feet (MSL). Thus, the aquifer is confined at this location.

5.3 Well 608 (Zone 3)

Zone 3 is located between 66 and 106 feet (BGS) based on the geophysical log (Appendix B). This corresponds to a thickness of 40 feet with a top elevation of 6903.47 and a bottom elevation of 6863.47 feet (MSL). The sandstone of Zone 3 is identified between 6898.97 and 6863.47 feet (MSL) for a total thickness of 35.5 feet. The sandstone is characterized by a light gray, fine to coarse-grained rock which is bound on top and bottom by a coal seam.

The static water level was 6922.45 feet (MSL). Thus, the aquifer is confined at this location.

5.4 Well 609 (Zone 3)

Zone 3 is located between 60 and 105.5 feet (BGS) based on the geophysical log (Appendix B). This corresponds to a thickness of 45.5 feet with a top elevation of 6903.51 and a bottom elevation of 6858.01 feet (MSL). The sandstone in Zone 3 occurs between the elevations of 6899.51 and 6858.01 feet (MSL). These elevations correspond to a thickness of 41.5 feet. The sandstone is characterized as predominantly light gray and fine-grained with a medium to coarse-grained layer occurring at approximately 80 feet (BGS).

The static water level was 6923.04 feet (MSL). Thus, the aquifer is confined at this location.

5.5 Well 611 (Zone 1)

Zone 1 is identified between 120 and 161.5 feet (BGS) based on the geophysical log (Appendix B). This corresponds to a thickness of 41.5 feet with a top elevation of 6842.53 and a bottom elevation of 6801.03 feet (MSL). A lithologic log could not be completed as the cuttings that were returned consisted of the pre-existing sand pack from the reaming of Well 450-A. However, lithologic and geophysical logs from nearby wells provided a good estimate of the target depth. The target formation was determined from the geophysical log taken from this well immediately after drilling.

The static water elevation was 6874.90 feet (MSL). Thus, the aquifer is confined at this location.

5.6 Well 606 (Zone 1)

Zone 1 is located between 122.5 and 164.5 feet (BGS) based on the geophysical log (Appendix B). This corresponds to a thickness of 42 feet with a top elevation of 6838.01 and a bottom elevation of 6796.01 feet (MSL). The aquifer is bound on top by a shale and coal break and on bottom by a shale zone. The aquifer is characterized by a light gray, very fine-grained sandstone.

The static water level was 6873.72 feet (MSL). Thus, the aquifer is confined at this location.

5.7 Well 613 (Zone 3)

Zone 3 is located between 40 and 91 feet (BGS) based on the geophysical log (Appendix B). This corresponds to a thickness of 51 feet with a top elevation of 6918.38 and a bottom elevation of 6867.38 feet (MSL). The sandstone of Zone 3 occurs between 6912.38 and 6867.38 feet (MSL). The sandstone is characterized by a light gray, fine to coarse-grained rock. The sandstone is bound by a coal seam on top and bottom.

The static water level was 6928.60 feet (MSL). Thus, the aquifer is confined at this location.

5.8 Well 607 (Zone 1)

Zone 1 is located between 122.5 and 167.5 feet (BGS) based on the geophysical log (Appendix B),. This corresponds to a thickness of 45 feet with a top elevation of 6843.27 and a bottom elevation of 6798.27 feet (MSL).

Zone 1 is identified by a light gray, very fine to fine-grained sandstone. The sandstone is bound on top and bottom by a shale layer.

The static water level was 6865.90 feet (MSL). Thus, the aquifer is confined at this location.

6.0 STEP DRAWDOWN TESTING

The objectives of the step drawdown tests of the Seepage Cleanup System were to define; 1) general performance and efficiency characteristics of the wells, 2) local aquifer characteristics and 3) an estimated maximum pumping rate that could be sustained during the recovery operation, as discussed in more detail in the specifications of the testing equipment report (BAI; June, 1983). This section is presented with descriptions and examples of the analysis techniques used in conducting the evaluations required to achieve these objectives. The reader is referred to the Results section of the report (page 67) when comparing test values described and exemplified by a particular analysis technique.

The step drawdown testing began on August 31, 1983 and was completed on September 6, 1983. One test was performed on each well except Well 610. The test on Well 610 was performed in two segments due to power-supply difficulties encountered during the test. Selection of pumps for step drawdown testing was determined from the development work completed previously on the wells. The discharge was measured with a totalizing flowmeter and was checked periodically with a calibrated container. The water level in the pumping well was measured with a pressure transducer. During some of the tests, where existing wells were located convenient to the locality of the test, water levels in nearby wells were measured with pressure transducers or steel tapes. If a response (i.e. change in water level) is observed in

these nearby wells, it can be evaluated in terms of aquifer characteristics including the storage coefficient. The storage coefficient of an aquifer can best be obtained using the response of the water level in an observation well.

A step drawdown test is performed by pumping a well at several sustained discharge rates for known periods of times with each discrete discharge rate and time being referred to as a step. The discharge is held constant during each step and the water level is monitored. After a period of time (usually an hour to an hour and a half) the discharge is increased and held constant and the water level is again monitored. The discharge is increased over several steps, hence the name step drawdown test, until the required performance characteristics of the well have been determined.

6.1 Analysis Procedures

The analysis procedures are divided into two sections: Analysis of pumping data followed by analysis of recovery data. Field measurements and data necessary for analysis of the pumping data are presented in Appendix D. Measurements and data necessary for analysis of the recovery data are presented in Appendix E. Water level measurements from nearby observation wells obtained during some of the tests are presented in Appendix F.

6.1.1 Pumping Data

Analysis 1: Transmissivity (Jacob Method)

The first analytical technique is the calculation of the transmissivity by a semi-log straight line fit of the drawdown data (Cooper and Jacob, 1946). In this technique, drawdown is plotted on an arithmetic scale with time plotted on a log scale. A straight line is placed through the data and the transmissivity is computed by noting the change in drawdown per log cycle and using the amount of discharge that caused that drawdown. The data collected during the first step were usually analyzed using this procedure. However, in some cases, fluctuations in the discharge during the first step caused water level fluctuations such that the data could not be reliably analyzed by this procedure. Data from the second step were used in these cases since the larger discharge rate was easier to maintain. The transmissivity is calculated for this analysis based on the change in conditions associated with the second step. The graphs used for this technique are presented in Figures 1 through 8. The data from the step test performed on Well 606 (Figure 1) are presented as an example.

The change in pressure per log cycle during the first step is 2.41 (psi) or 5.53 (feet). The discharge causing this change in pressure is 0.82 (gpm). Thus, the transmissivity is: $T = (264 \times 0.82) / 5.53 = 39$ (gal/day/ft).

WELL 606 - STEP TEST

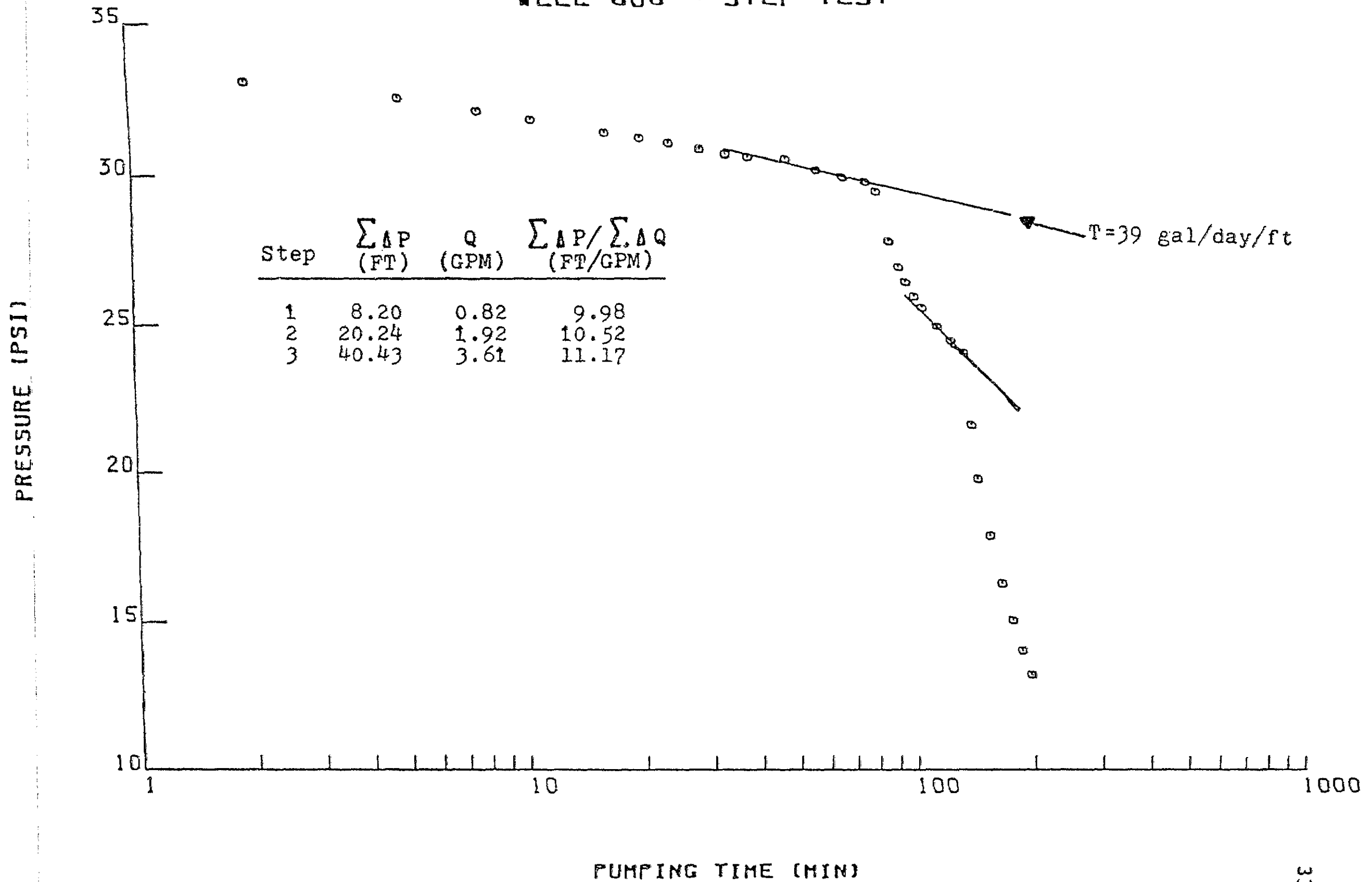


Figure 1 - Well 606: Pressure vs. Pumping Time

WELL 607 - STEP TEST

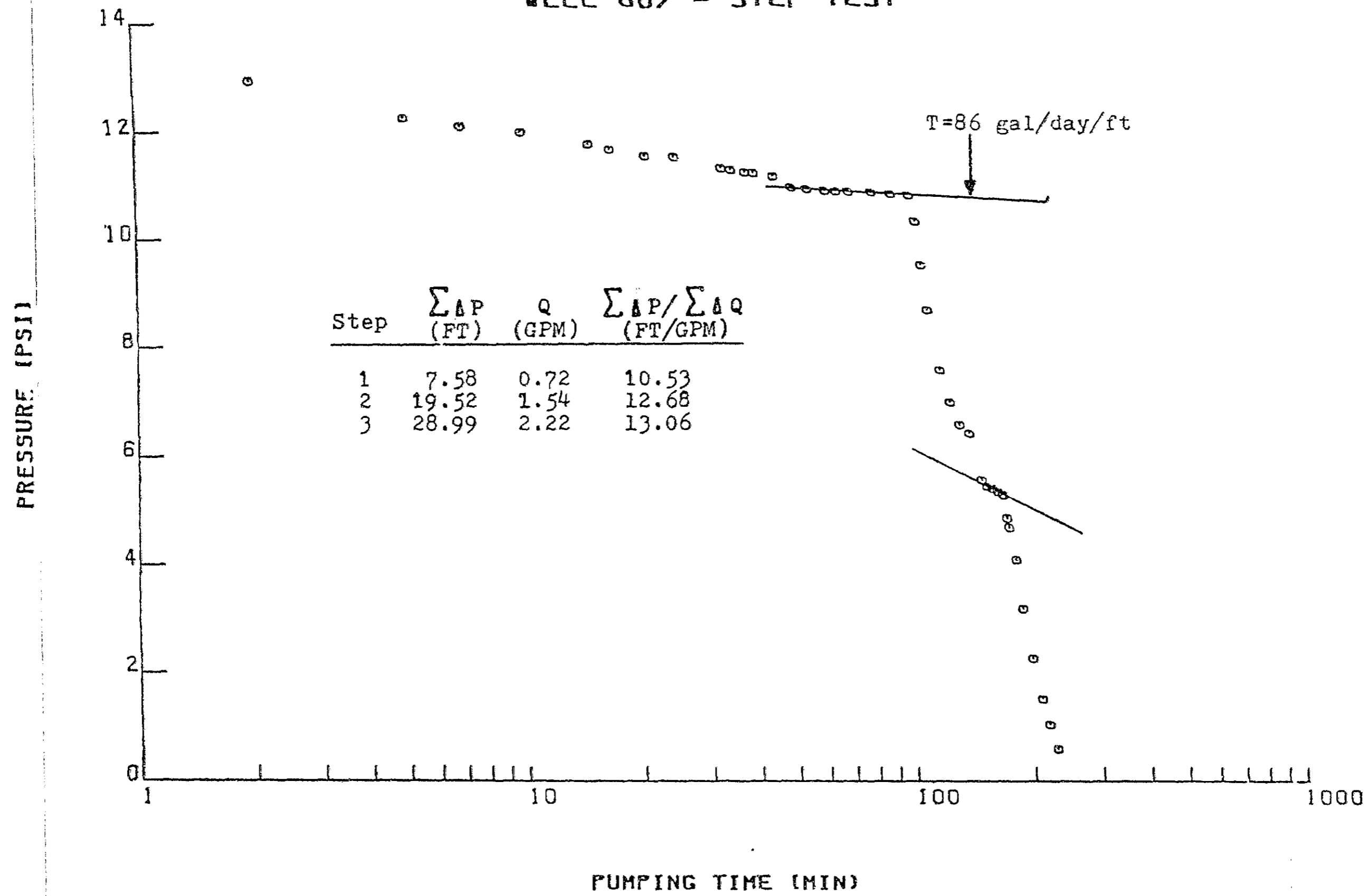


Figure 2.- Well 607: Pressure vs. Pumping Time

WELL 609 - STEP TEST

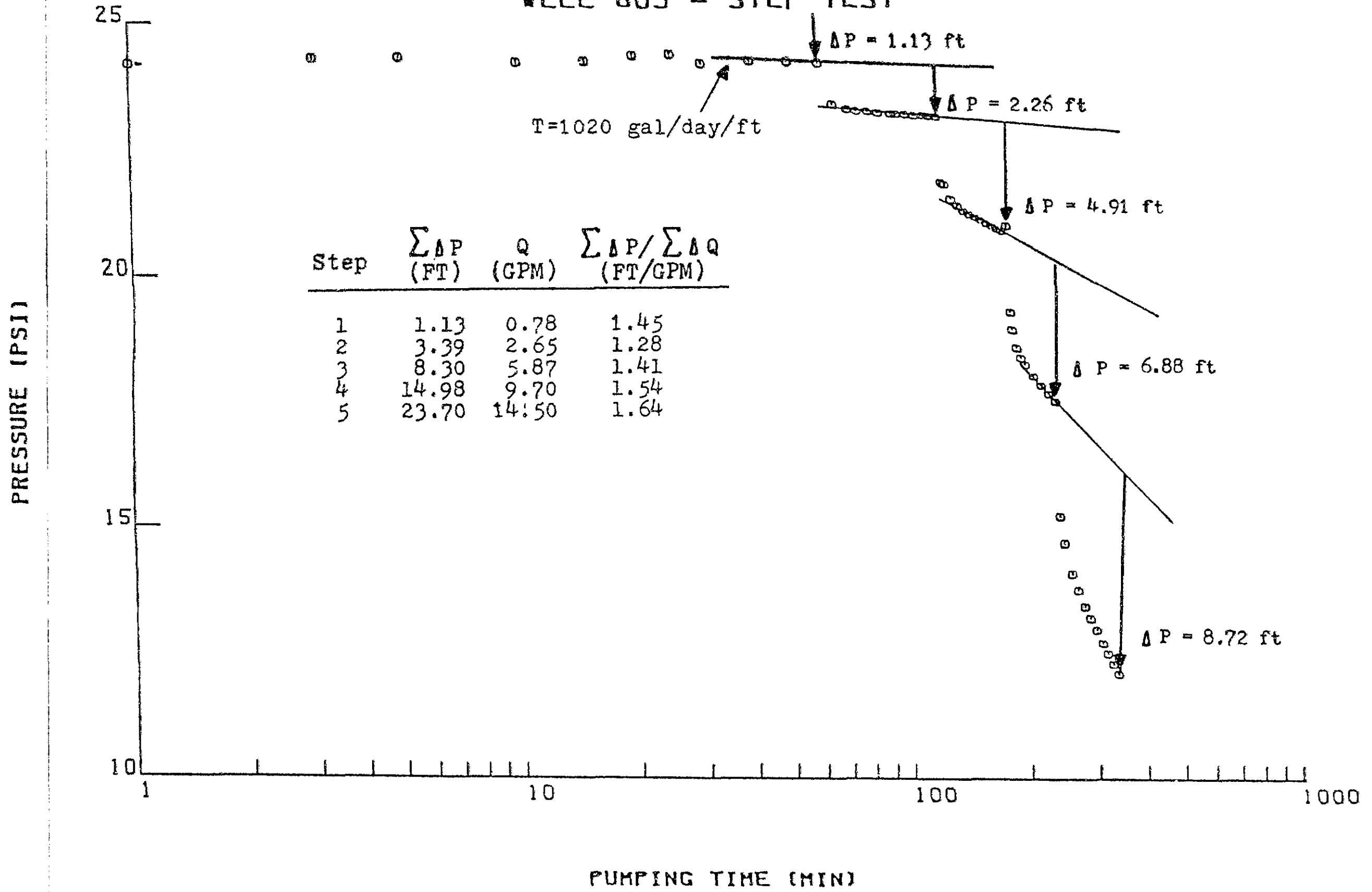


Figure 3 - Well 609: Pressure vs. Pumping Time

WELL 610 - STEP TEST #1

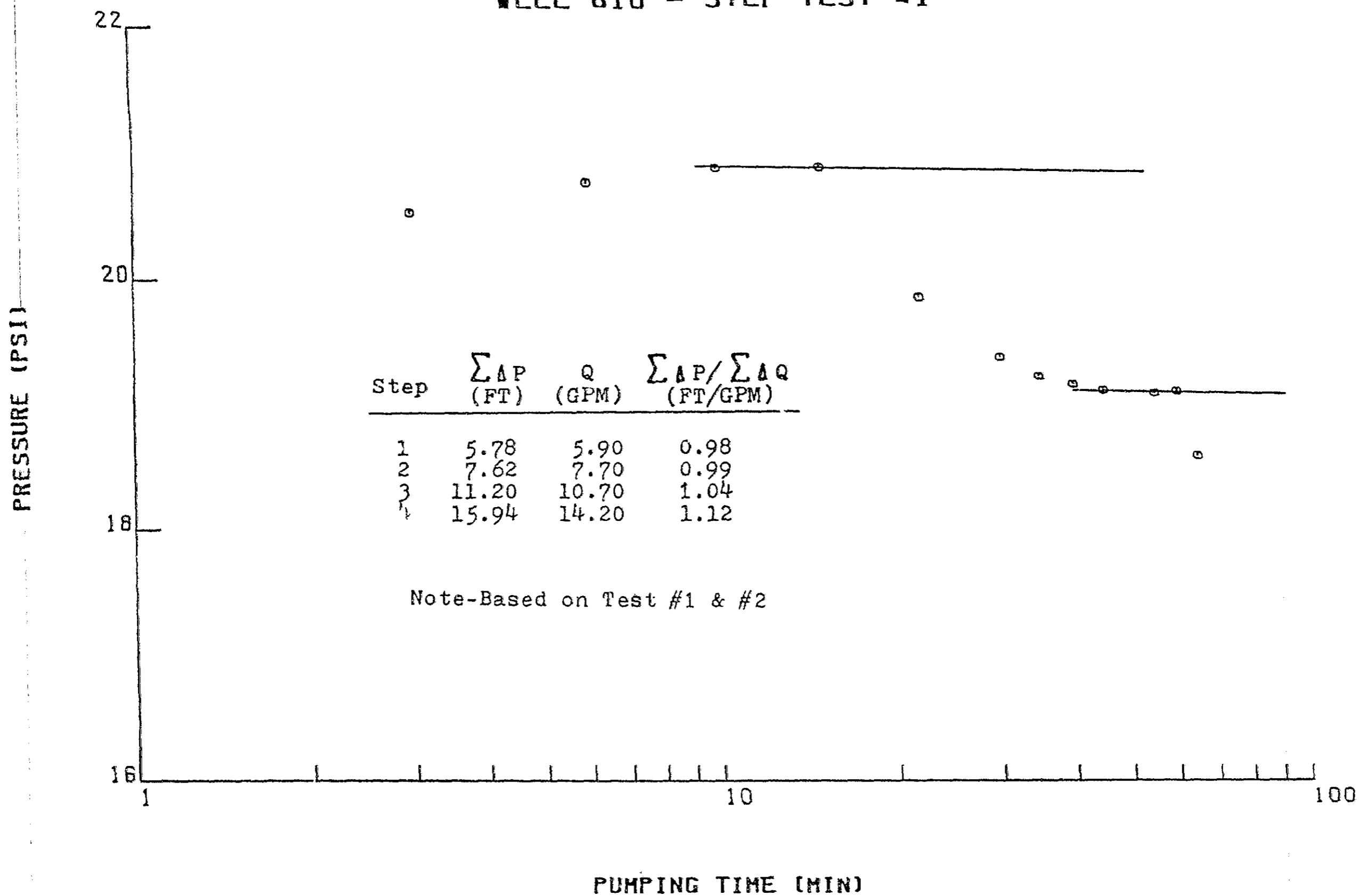


Figure 4 - Well 610: Pressure vs. Pumping Time

WELL 610 - STEP TEST #2

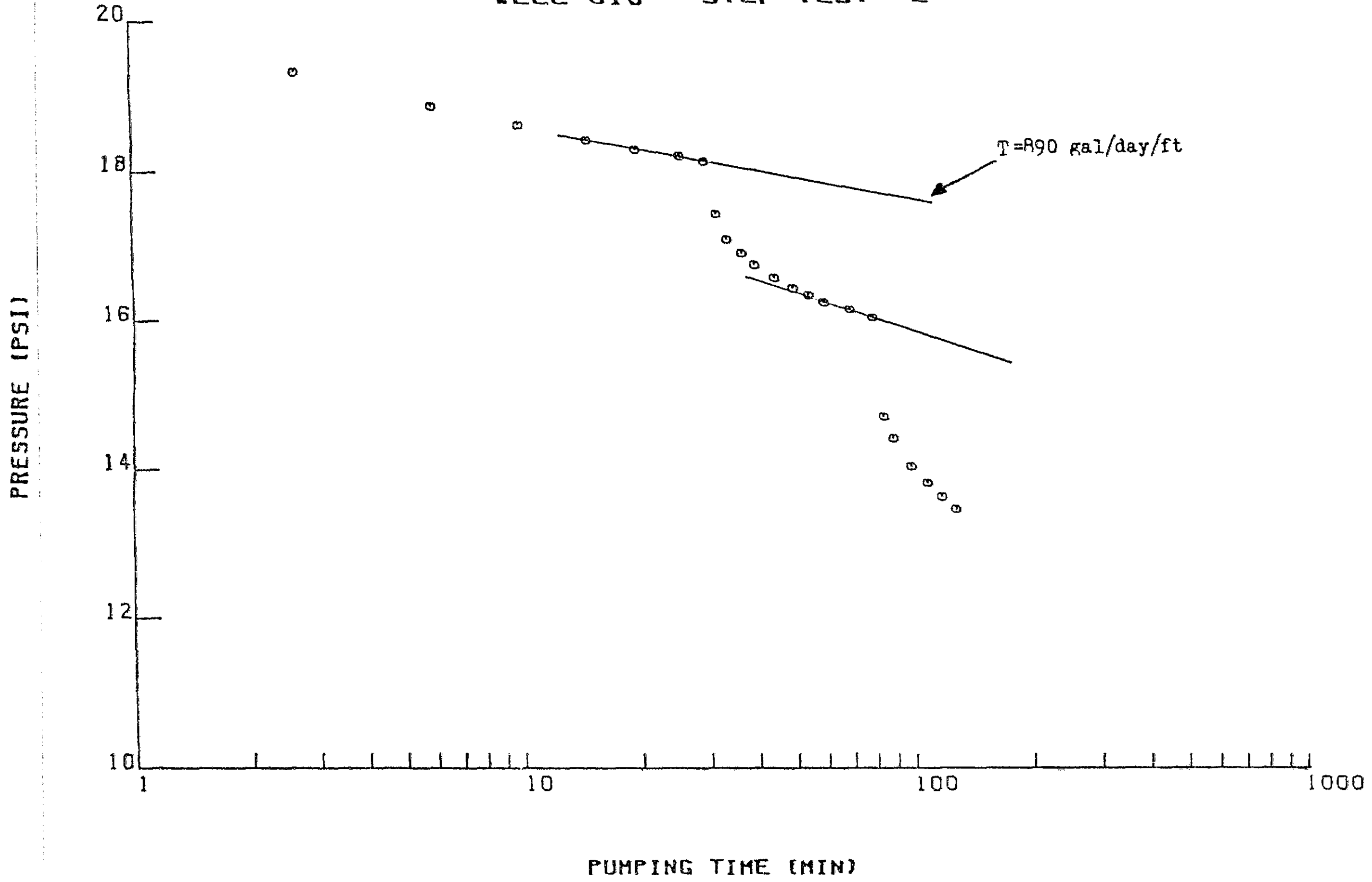


Figure 5 - Well 610: Pressure vs. Pumping Time

WELL 613 - STEP TEST

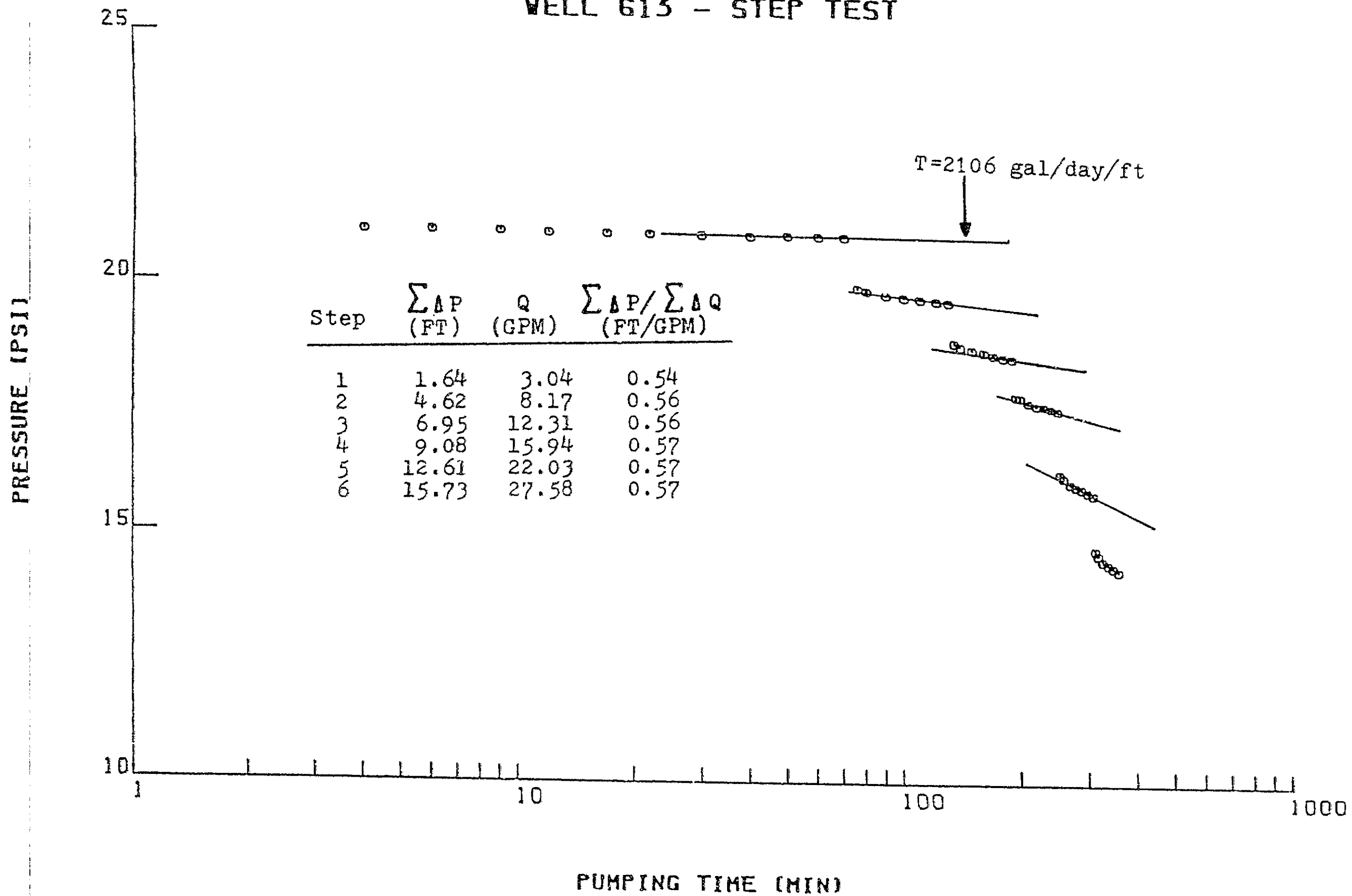


Figure 6 - Well 613; Pressure vs. Pumping Time

WELL 608 - STEP TEST

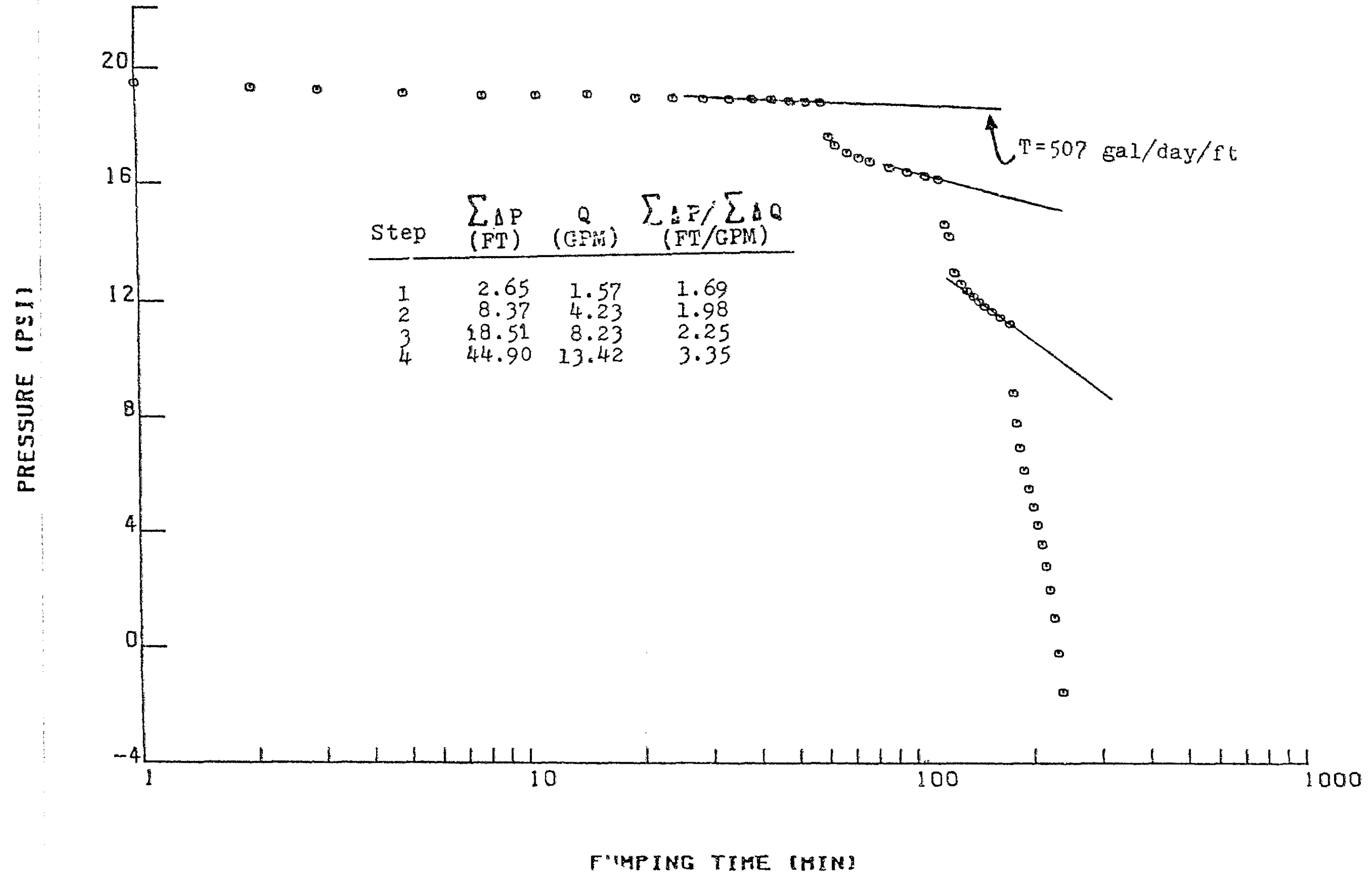


Figure 7 - Well 608: Pressure vs. Pumping Time

WELL 611 - STEP TEST

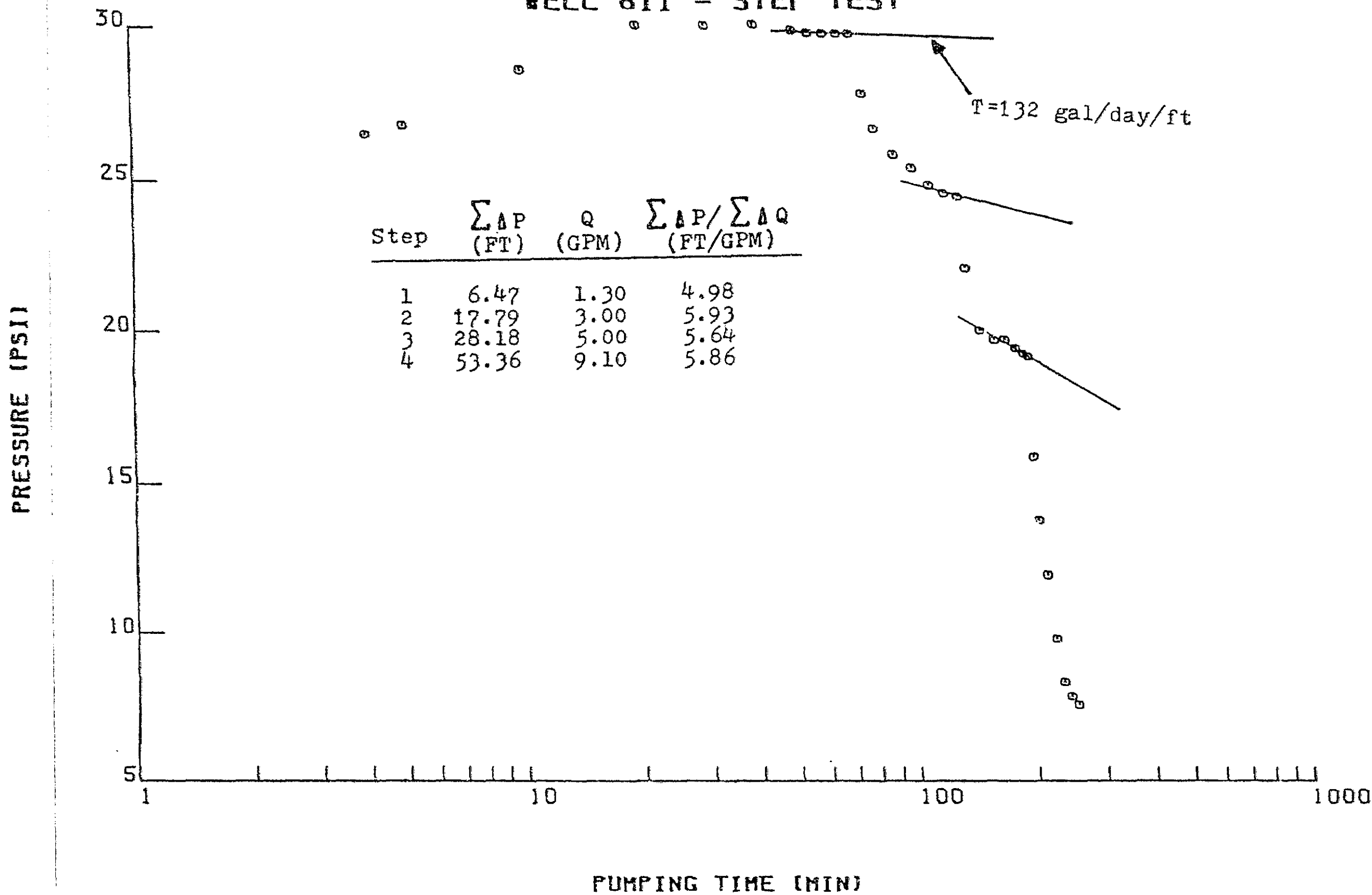


Figure 8 - Well 611: Pressure vs. Pumping Time

Analysis 2: Transmissivity (Cooper-Jacob Method)

The concept of the Jacob method (Cooper-Jacob, 1946) can be formulated to consider the water level changes observed during the entire step drawdown test. In this analysis technique, referred to as the Cooper-Jacob method (Cooper-Jacob, 1946), the time is adjusted in order to account for the variability of the discharge. The technique makes the adjustment by calculating the time required to obtain the observed drawdown if the well had been pumped at a constant discharge equal to the discharge rate occurring at the real time, t . The specific drawdown (drawdown divided by the discharge rate at time, t) is then plotted against the adjusted time on semi-logarithmic paper. A correction to the measured discharge rate to account for borehole storage effects was also included for these tests. A straight line is placed through all the data or through the data from each step and the transmissivity is computed based on the slope of the line or lines. The graphs used in this analysis are presented in Figures 9 through 16. The data from the step drawdown test on Well 608 (Figure 9) are presented as an example.

Placing a straight line through the data of step 1 yields a change per log cycle of the specific drawdown of 0.18 (psi/gpm) or 0.42 (ft/gpm). Thus, the transmissivity is: $T = 264/0.42 = 629$ (gal/day/ft). This process is repeated for the remaining steps with the following transmissivities computed; step 2- $T=468$, step 3- $T=266$ and step 4- $T=62$ (gal/day/ft).

This example is presented to illustrate certain well

WELL 608 - STEP TEST

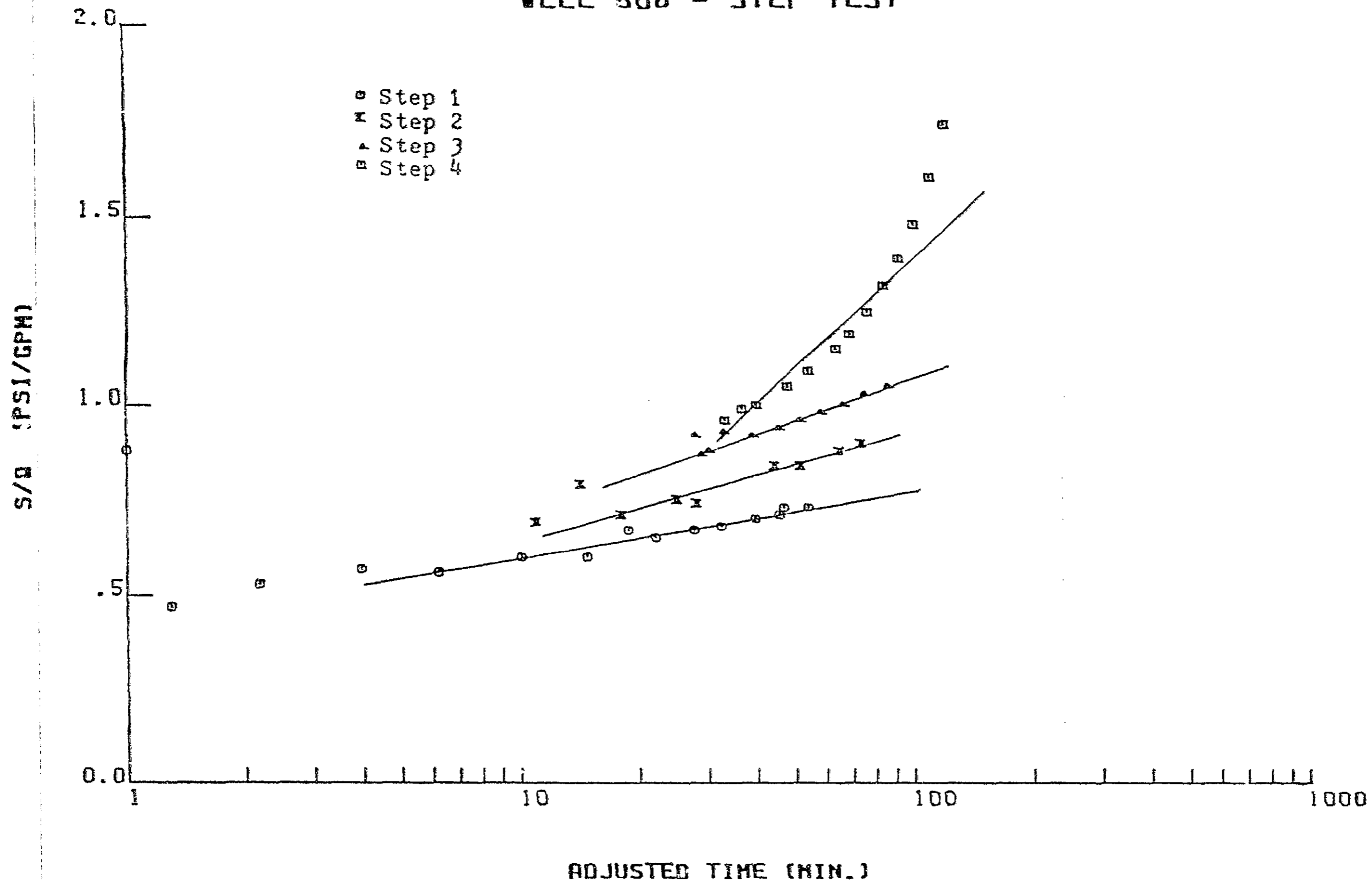


Figure 9 - Well 608: S/Q vs. Adjusted Time

WELL 607 - STEP TEST

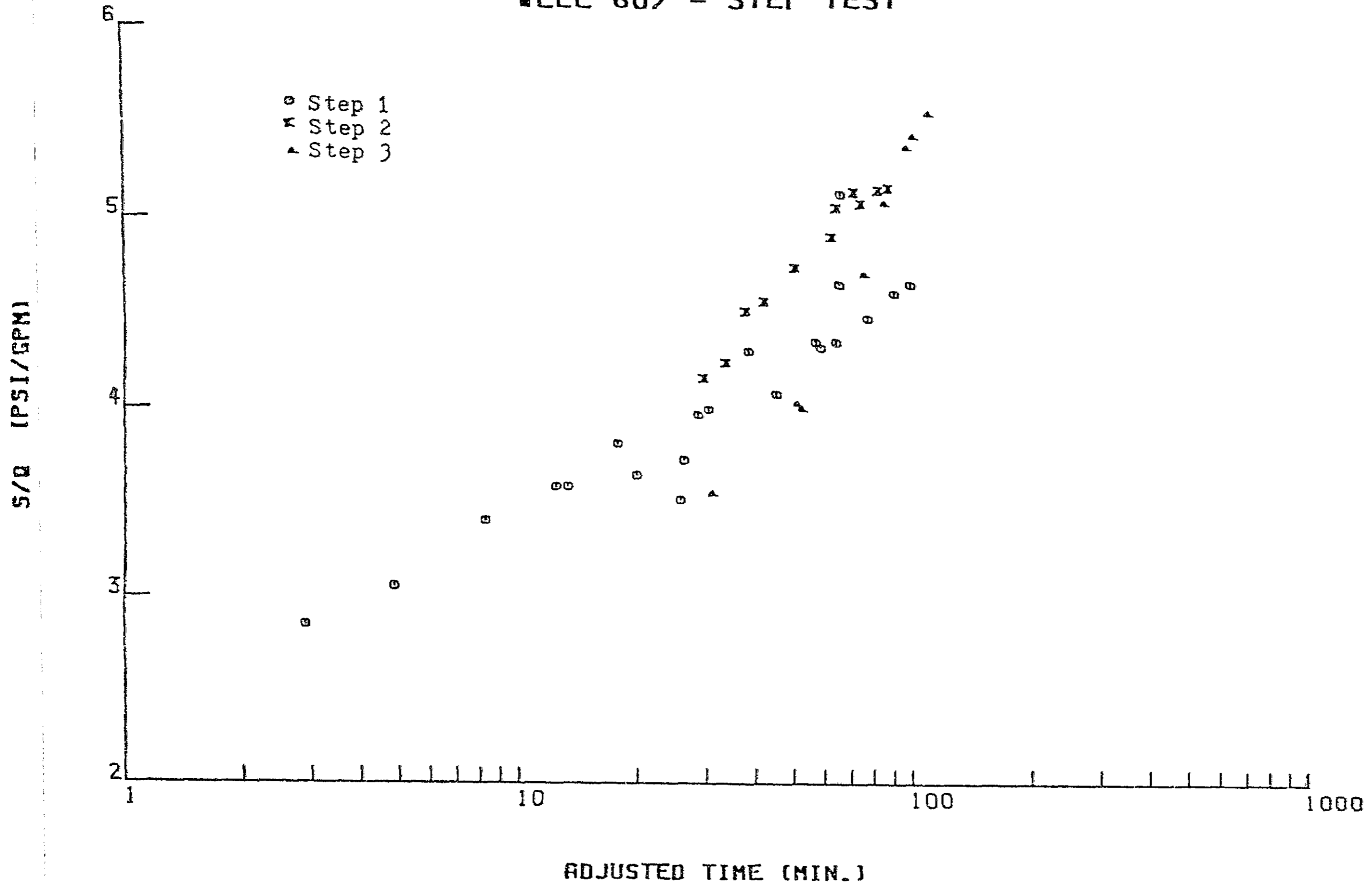


Figure 10 - Well 607: S/Q vs. Adjusted Time

WELL 609 - STEP TEST

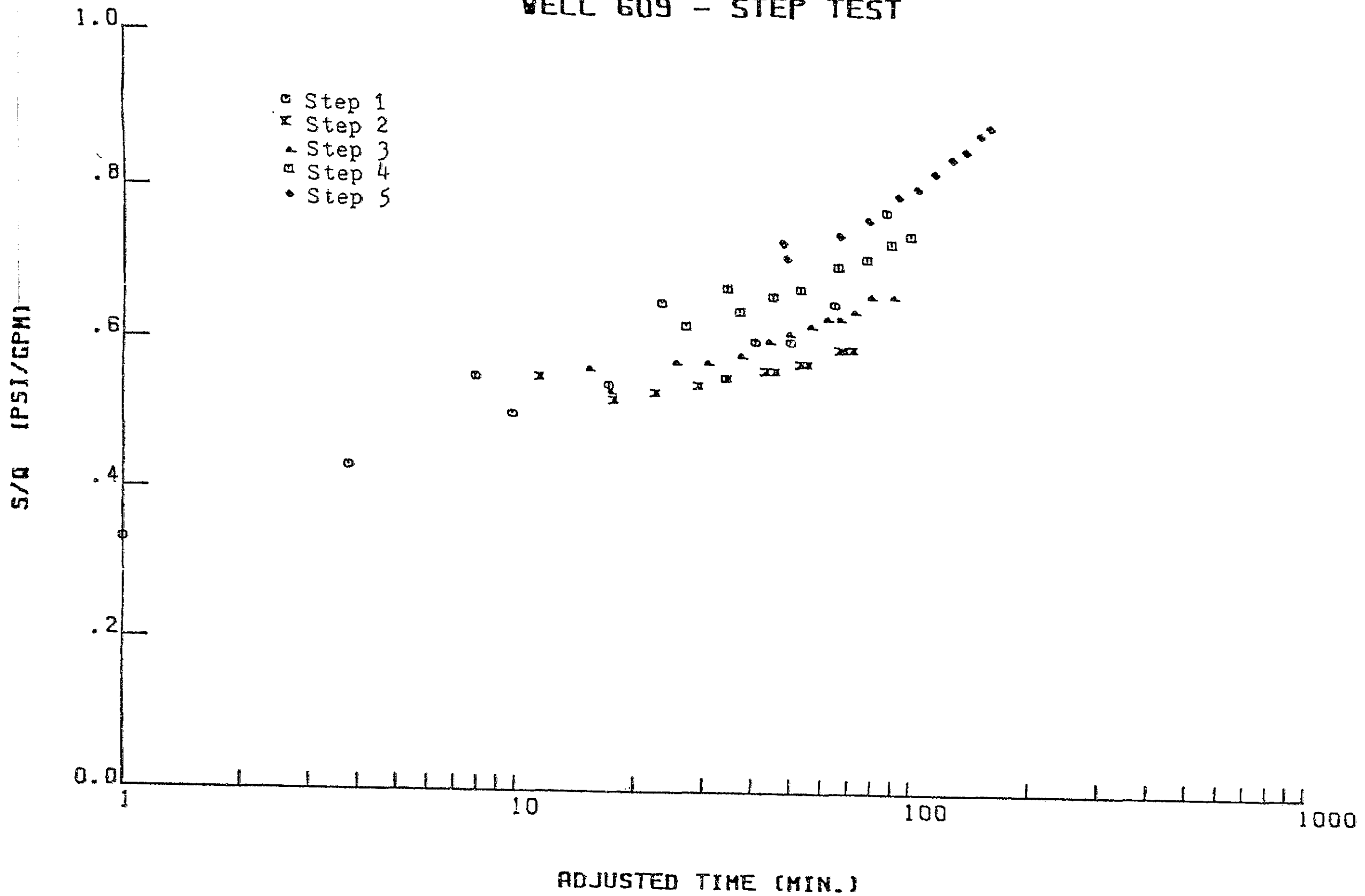


Figure 11 - Well 609: S/Q vs. Adjusted Time

WELL 610 - STEP TEST #1

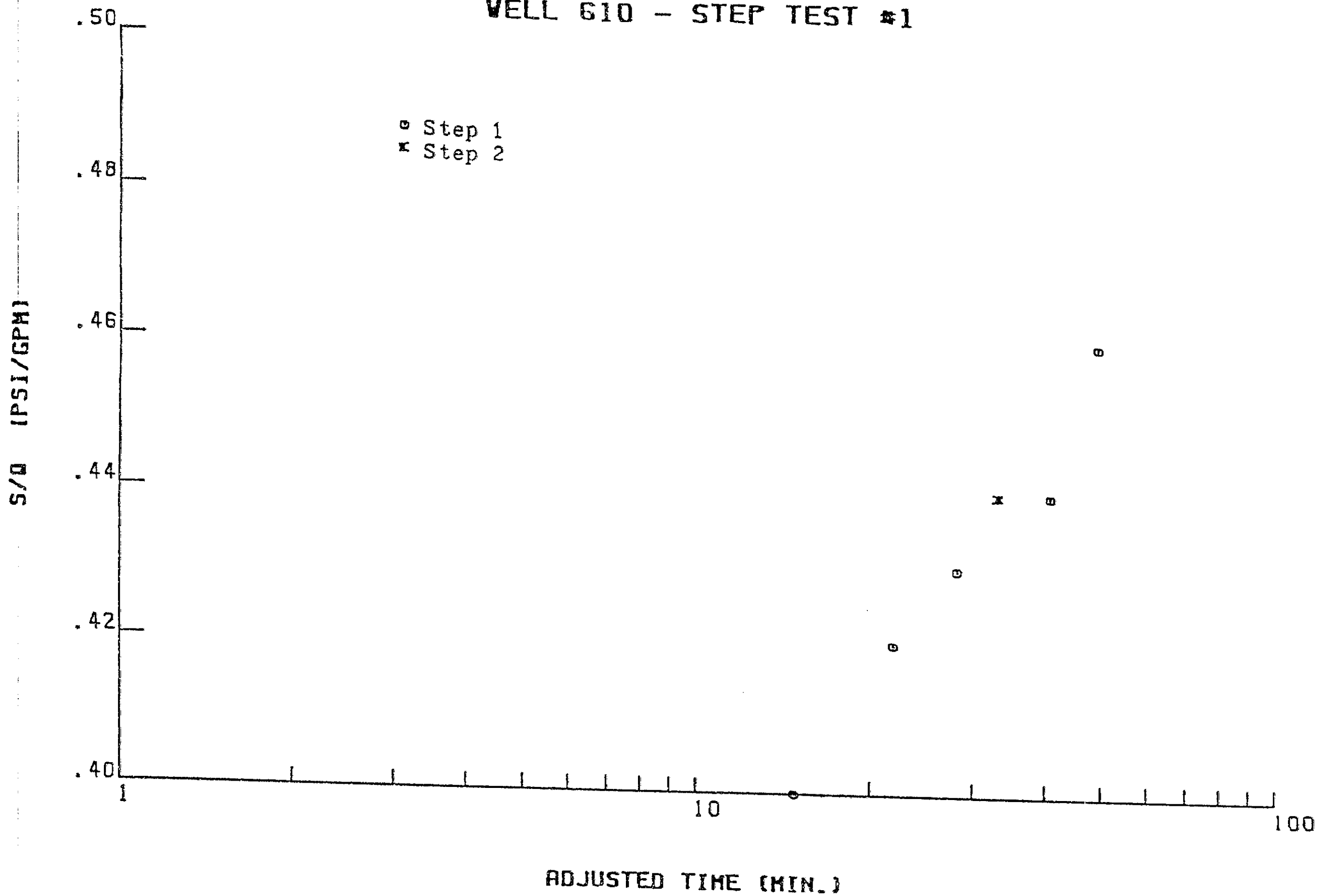


Figure 13 - Well 610: S/Q vs. Adjusted Time

WELL 610 - STEP TEST #2

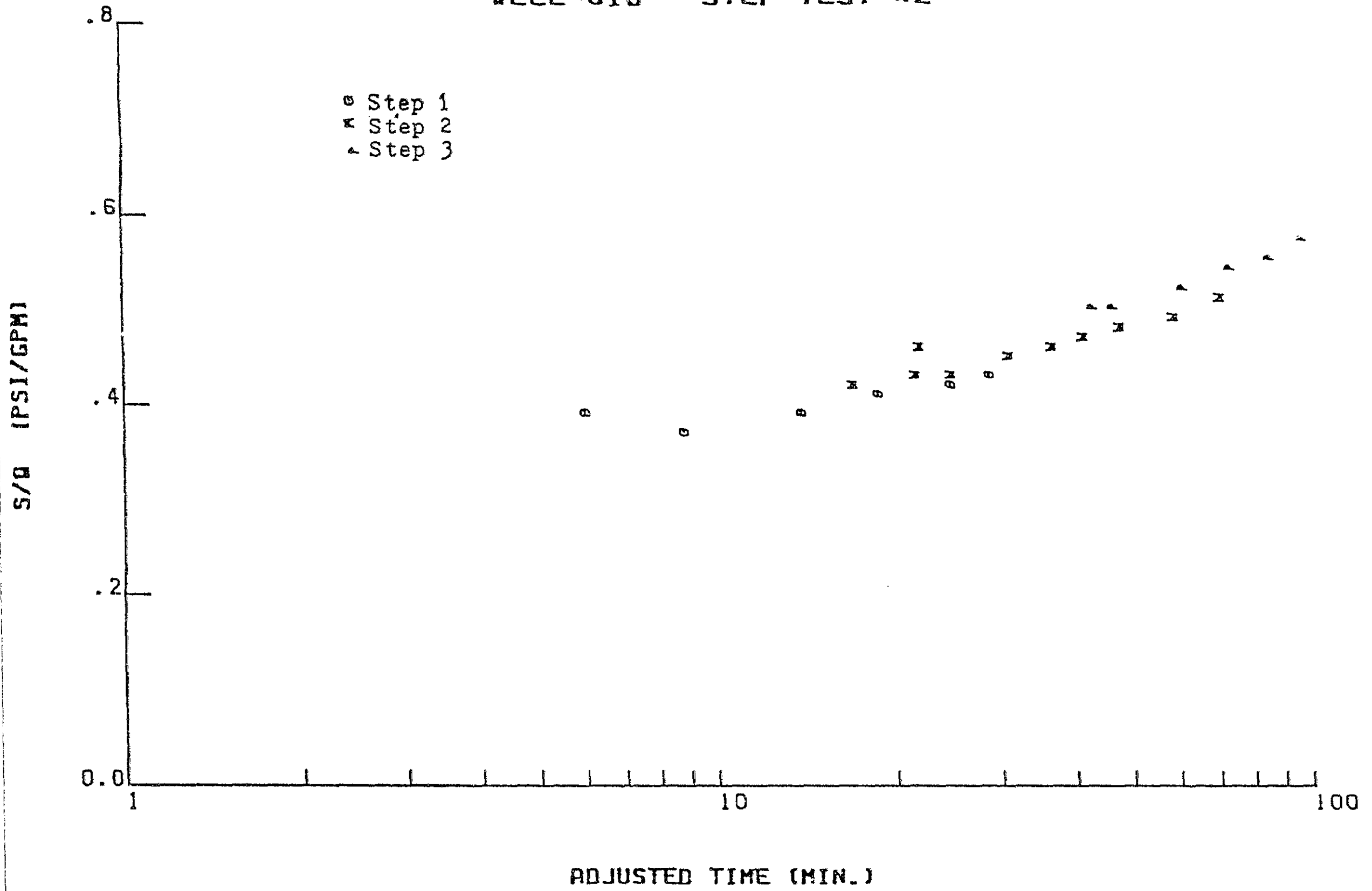


Figure 14 - Well 610: S/Q vs. Adjusted Time

WELL 611 - STEP TEST

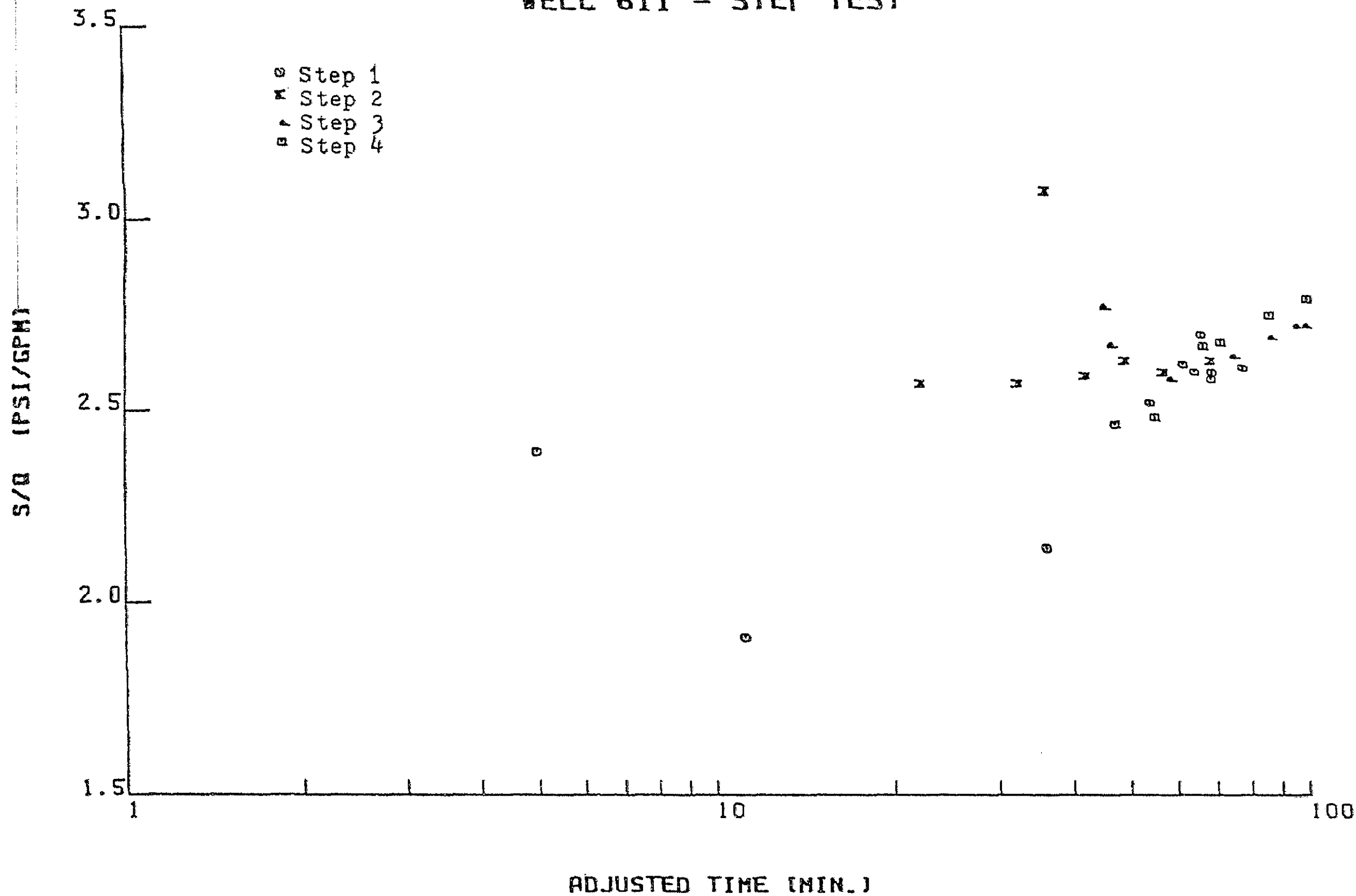


Figure 15 - Well 611: S/Q vs. Adjusted Time

WELL 613 - STEP TEST

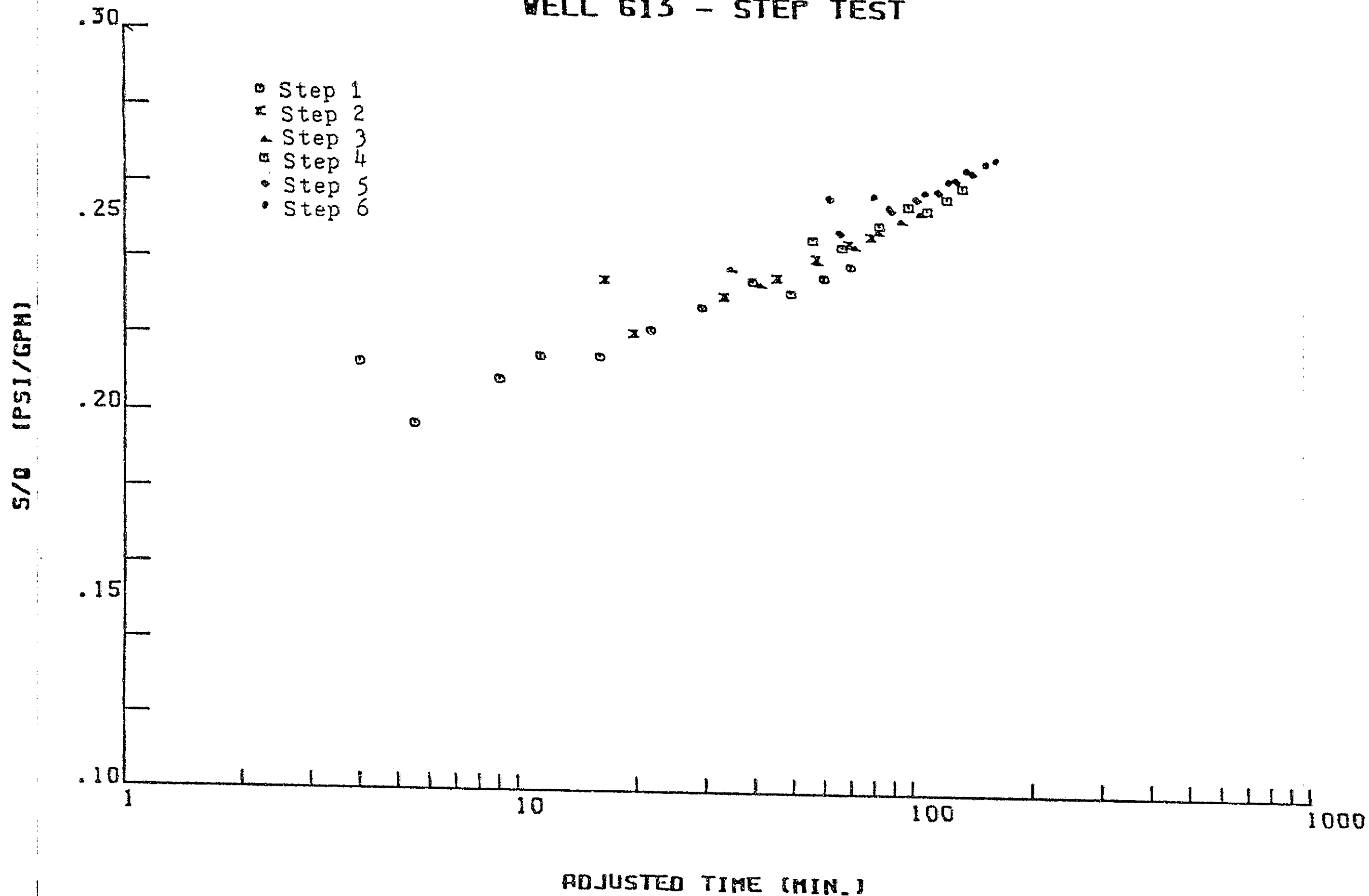


Figure 16 - Well 613: S/Q vs. Adjusted Time

behavior observed during many of the tests. The decrease in the estimates of transmissivity during the first three steps is probably related to a decrease in the formation transmissivity in the vicinity of the well. A larger portion of the formation influences the well drawdown and the net effect of this larger tested area is reflected in the transmissivity estimates as the test proceeds. The response during the fourth step is related to the fact that the water level in the well had declined into the screened interval. Conditions assumed for the analysis procedure are violated when this occurs and the data are not useful for estimating the hydraulic properties. The increased rate of drawdown is caused by a combination of factors such as not having a uniform pressure gradient throughout the screened interval. However, a good measure of the maximum well yield is obtained when this condition occurs.

Analysis 3: Well Performance (Jacob Method)

The analysis method proposed by Jacob (1947) is presented to evaluate well performance and to obtain an indication of the well efficiency. Application of this method is outlined by Hantush (1964). The water level is plotted against the log of pumping time for this analysis as shown in Figures 1 through 8 (pages 31 through 38). The increase in drawdown caused by the increase in discharge is computed by extending the drawdown trend at the end of each step. A common time interval from the origin of each step is selected and the incremental drawdown at the selected

time interval is obtained from the graph. The total drawdown for each discharge rate is computed by summing the increments and is divided by the discharge rate for each step. This ratio is plotted versus the discharge rate to obtain values of well loss and formation loss coefficients. The well loss coefficient (C) on an arithmetic plot is the slope of a straight line drawn through the data. The formation loss coefficient (B) is the intercept of the straight line. These coefficients in turn may be used as a general indicator of the efficiency of the well. The smaller the value of C in relation to B the smaller the effects of well loss.

The graphs used in this analysis are presented on Figures 1 through 8 (pages 31 through 38) (water level versus pumping time) and on Figures 17 through 23. The analysis of the step drawdown test performed on Well 609 (Figure 3) will be discussed as an example. The drawdown (change in pressure from static conditions) for step 1 at a time of 60 minutes is 0.49 (psi) or 1.13 (ft). The discharge for step 1 is 0.78 (gpm) and the ratio of drawdown to discharge is 1.45 (ft/gpm). The incremental drawdown at 60 minutes for step 2 is 2.26 feet giving a total drawdown of 3.39 feet. The discharge for step 2 is 2.65 (gpm) and the ratio of the total drawdown to this discharge is 1.28 (ft/gpm). This process is repeated for the remaining steps of the test. The ratio of drawdown to discharge for each step is plotted versus the discharge on an arithmetic graph (Figure 17). A straight line is placed through the data and the intercept (formation loss coefficient) is determined to be 1.31 (ft/gpm).

WELL 609

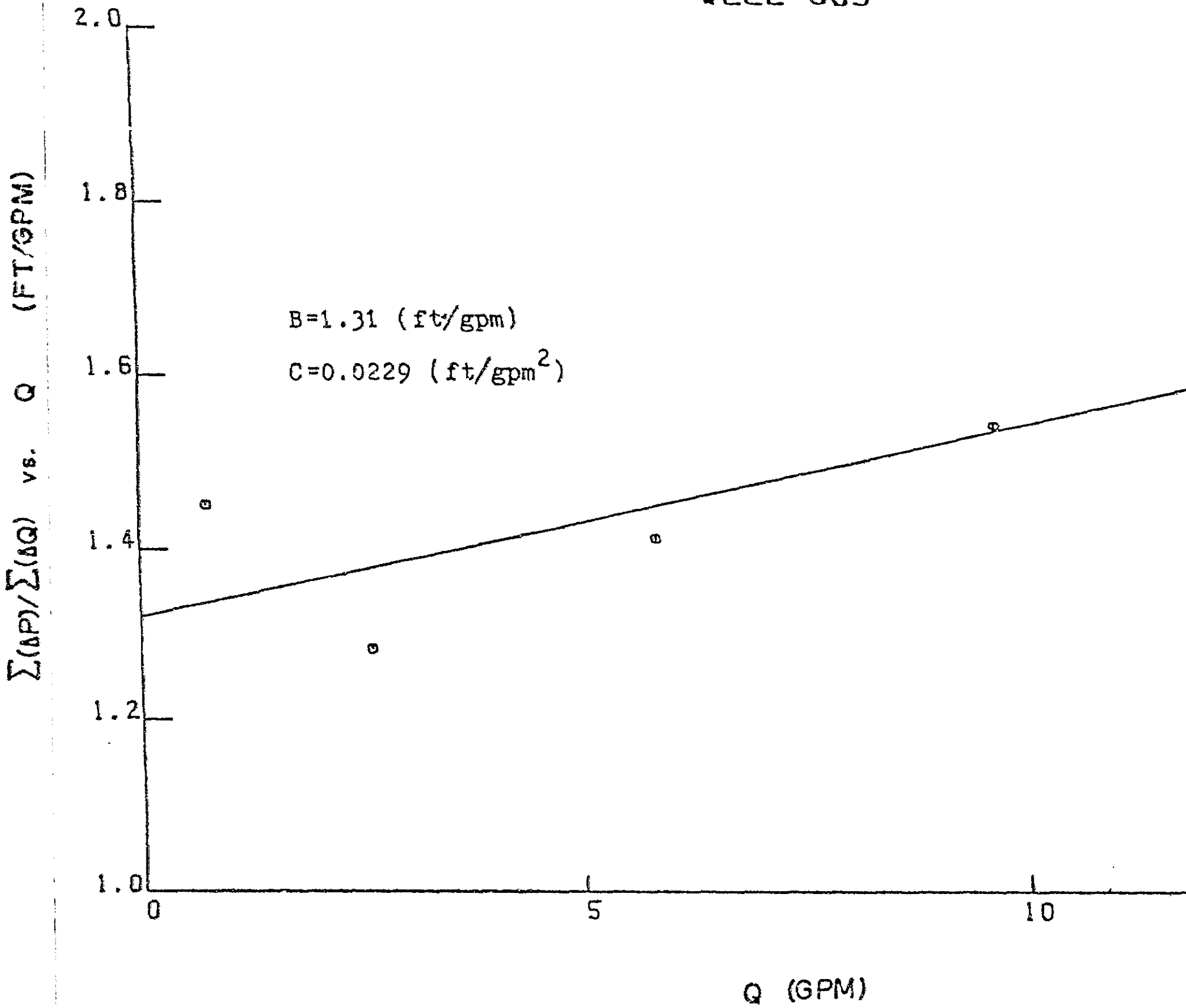


Figure 17 - Well 609: $\Sigma(\Delta P) / \Sigma(\Delta Q)$ vs. Q

WELL 608

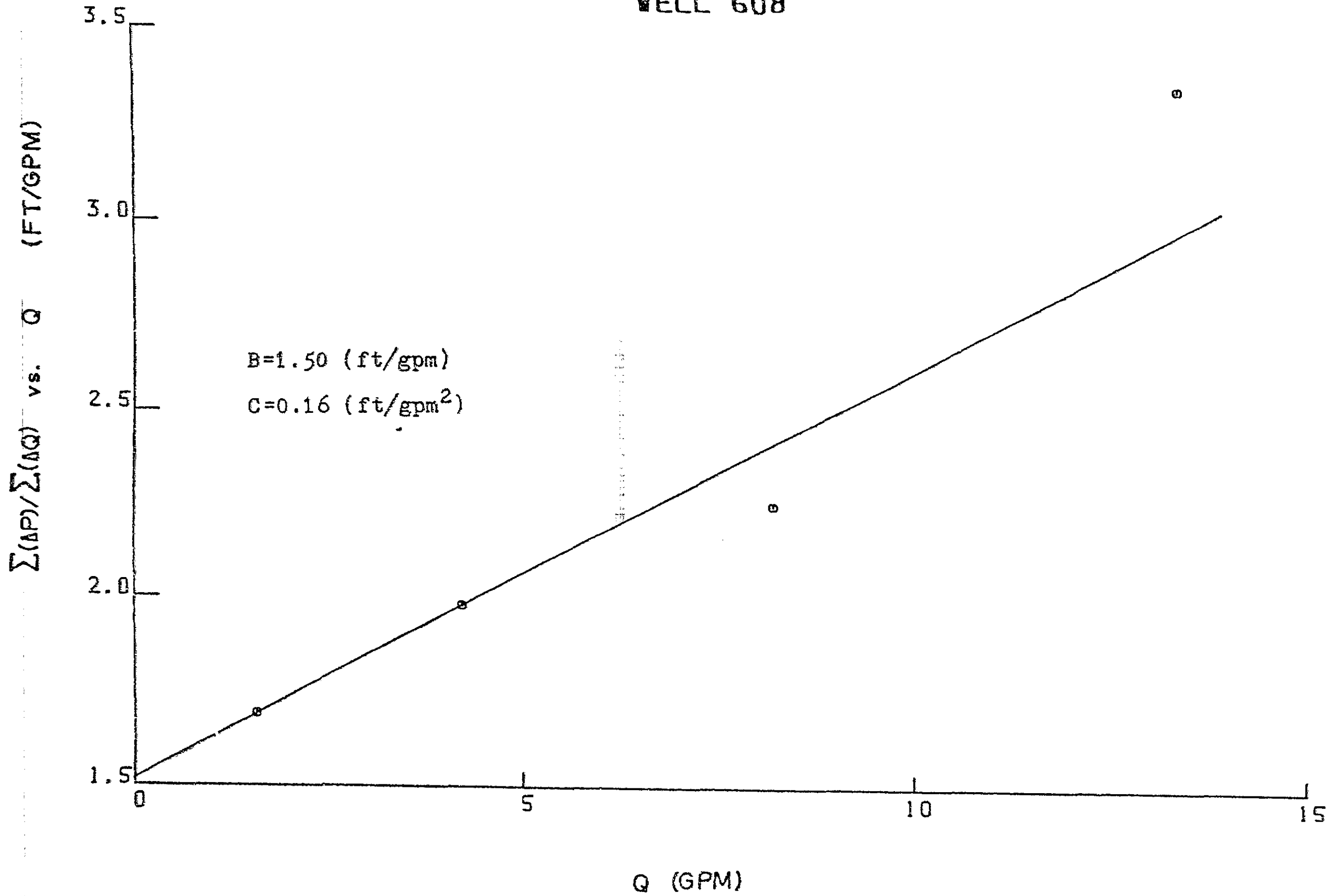


Figure 18 - Well 608: $\Sigma(\Delta P) / \Sigma(\Delta Q)$ vs. Q

WELL 610 (STEP'S #1 & #2)

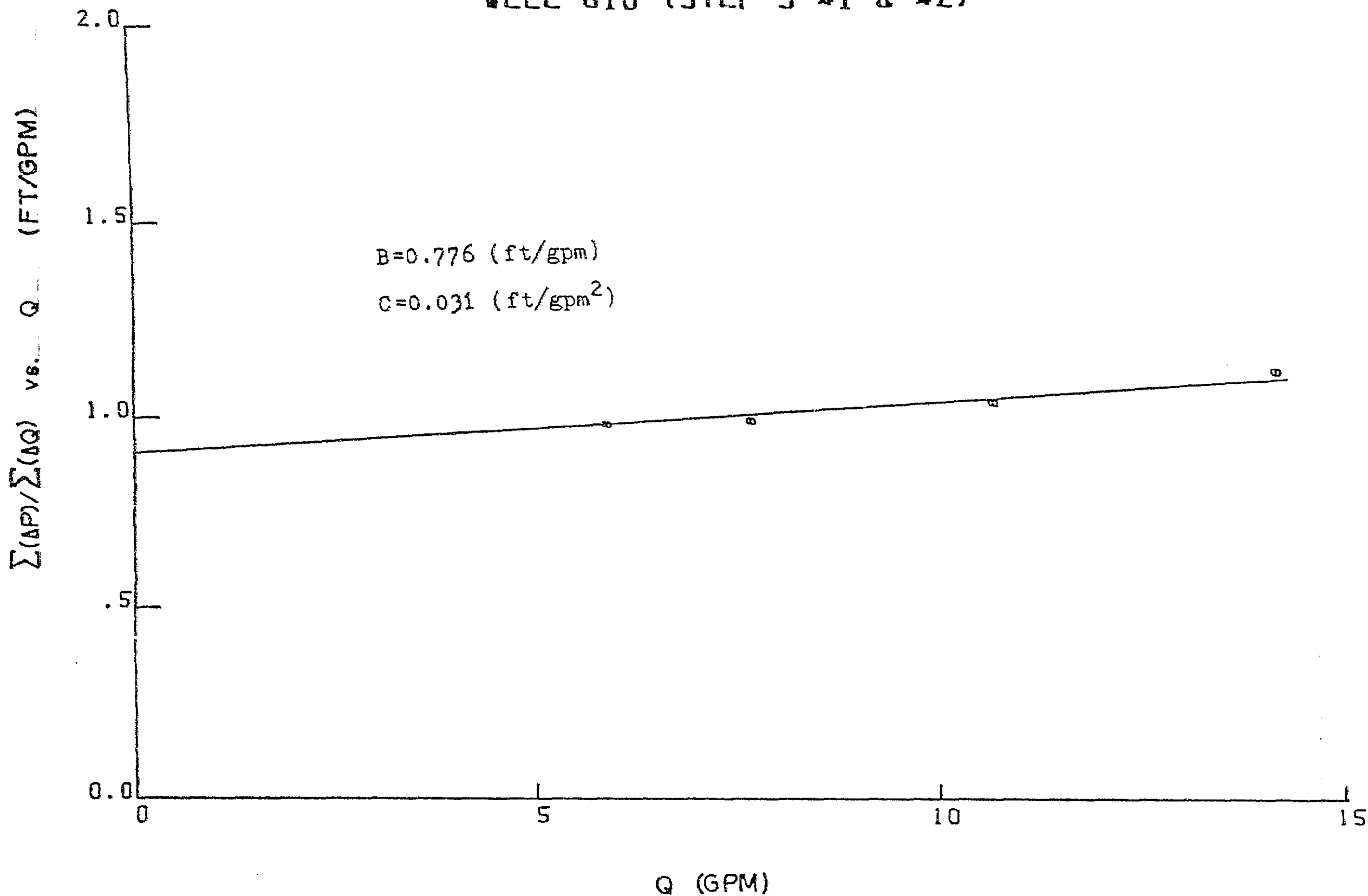


Figure 19 - Well 610: $\Sigma(\Delta P)/\Sigma(\Delta Q)$ vs. Q

WELL 613

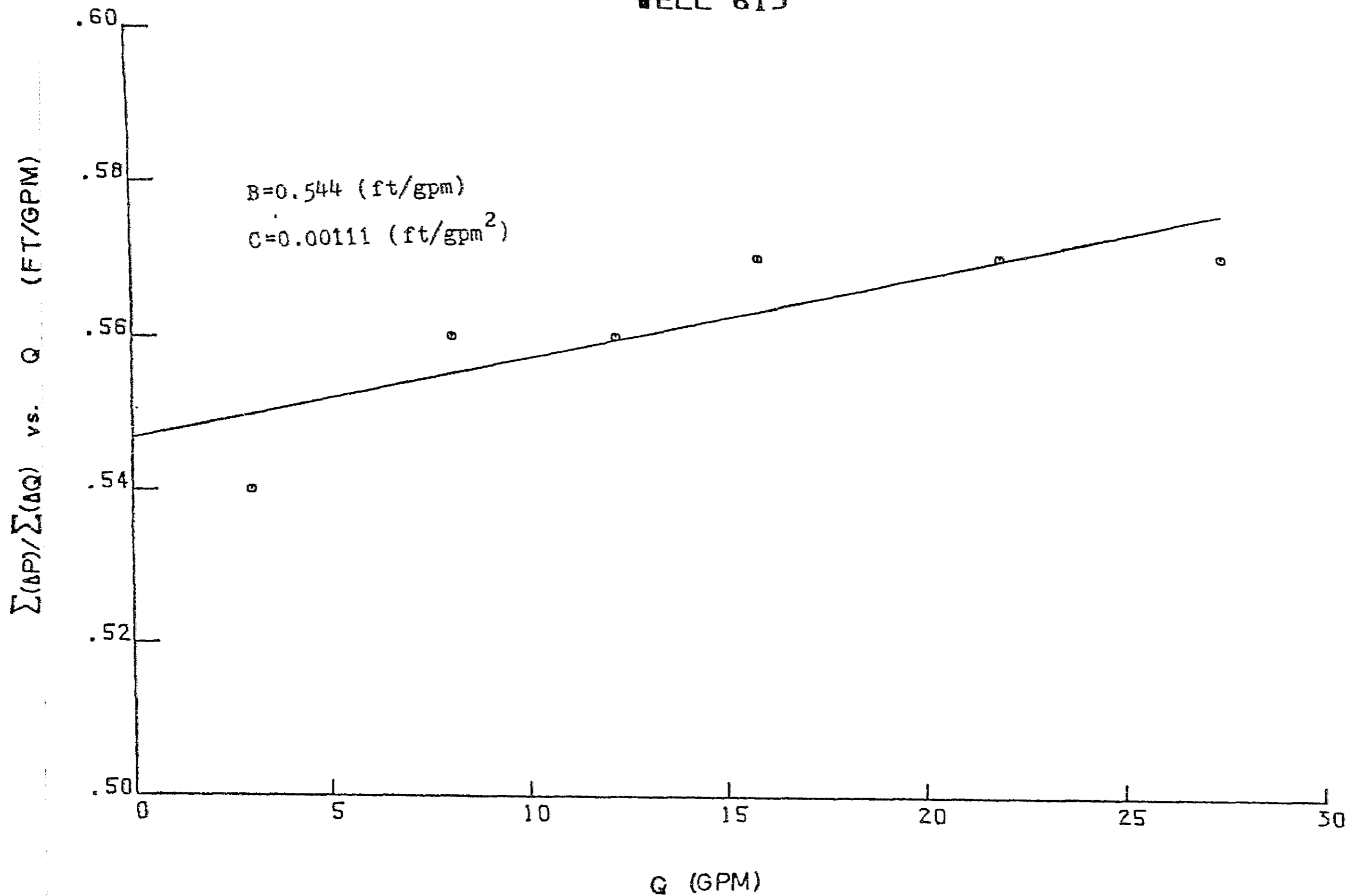


Figure 20 - Well 613: $\frac{\sum(\Delta P)}{\sum(\Delta Q)}$ vs. Q

WELL 606

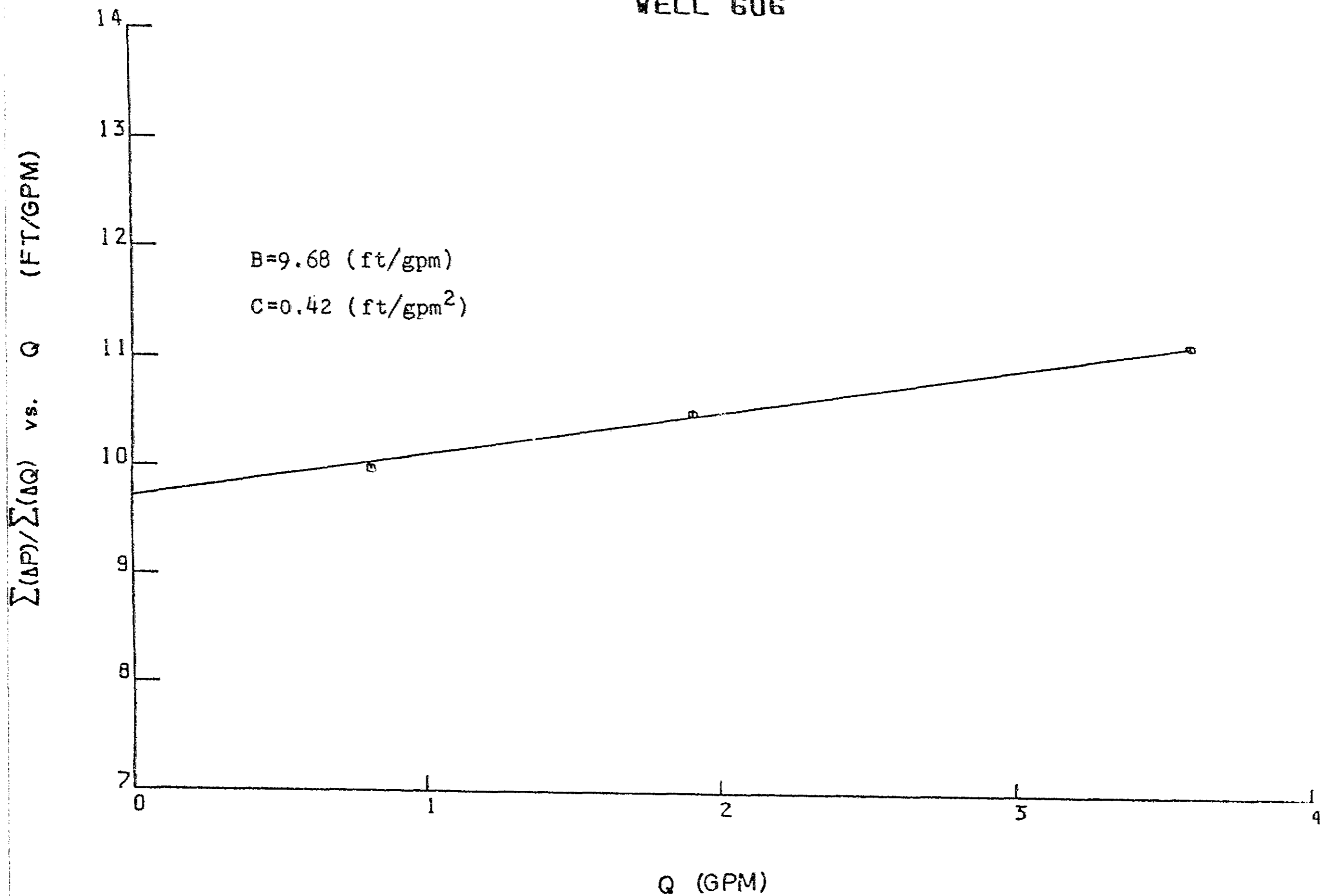


Figure 21 - Well 606: $\Sigma(\Delta P)/\Sigma(\Delta Q)$ vs. Q

WELL 611

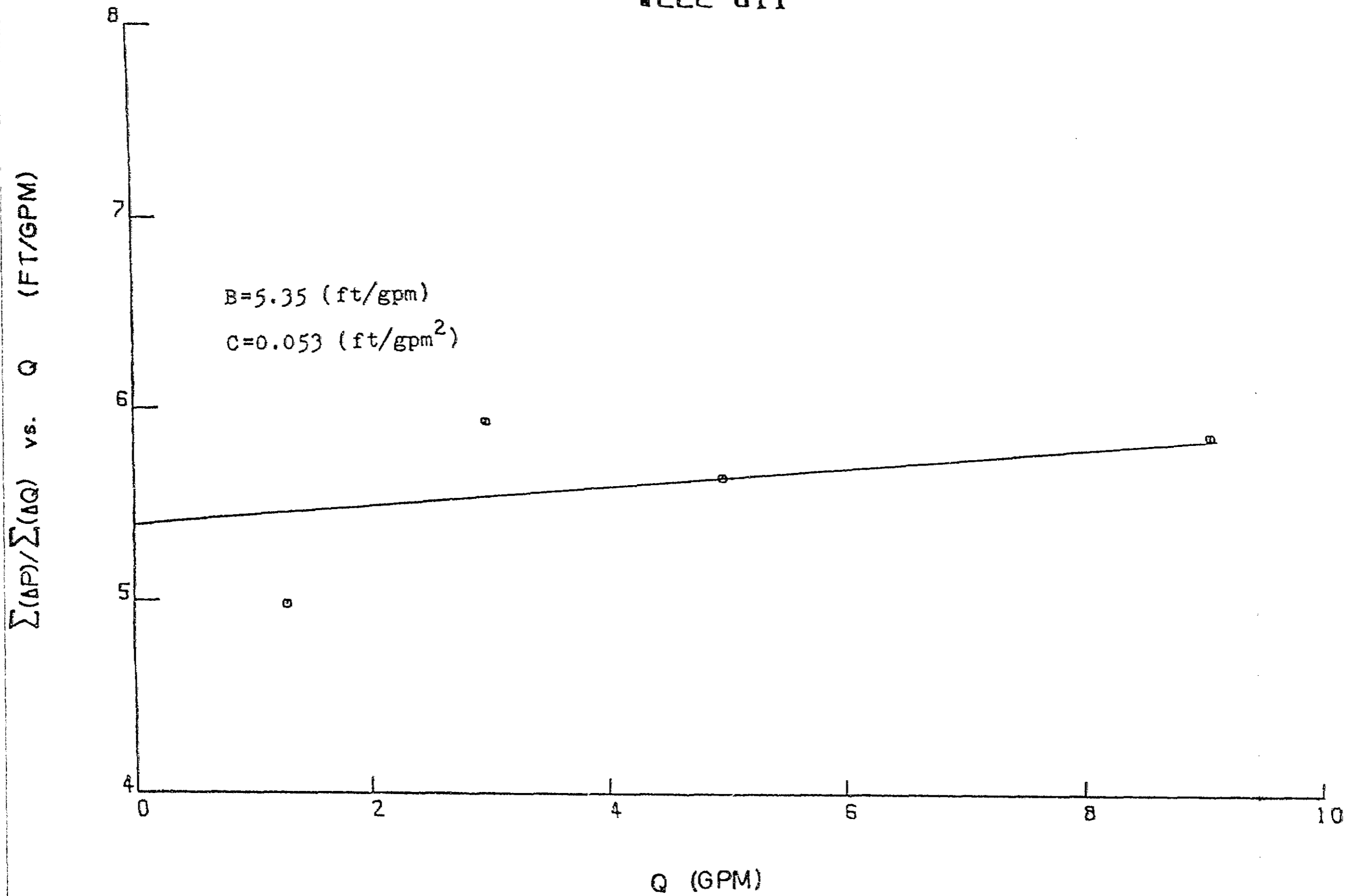


Figure 22 - Well 611: $\Sigma(\Delta P)/\Sigma(\Delta Q)$ vs. Q

WELL 607

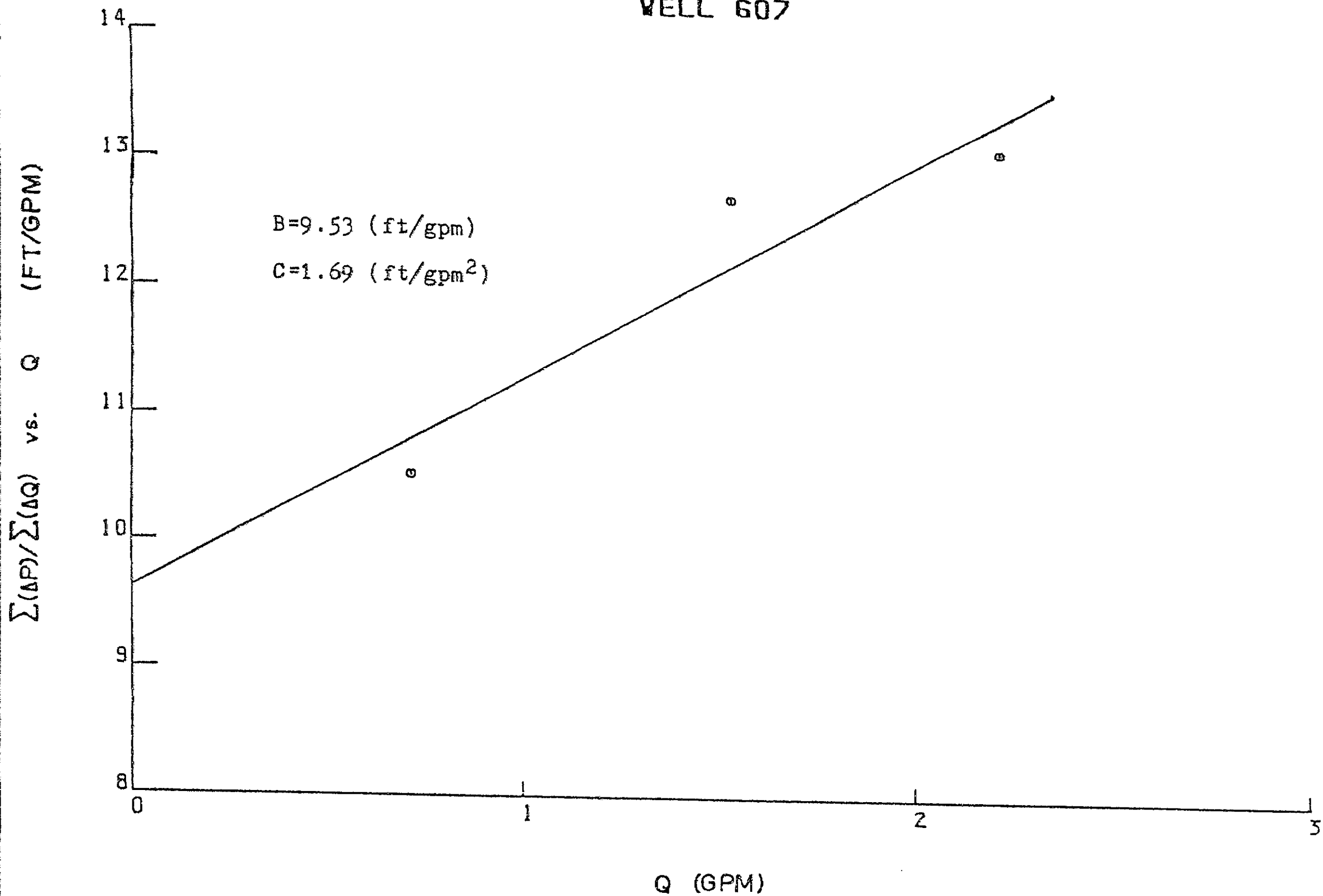


Figure 23 - Well 607: $\Sigma(\Delta P)/\Sigma(\Delta Q)$ vs. Q

The slope of the line (well loss coefficient) is determined to be 0.0222 (ft/gpm²). The value of the formation loss coefficient (1.31) is considerably larger than the well loss coefficient value (0.0222) for this example. This indicates an efficient well.

Analysis 4: Efficiency (Helweg, et al.)

The efficiency of the well may be estimated based on the well loss and formation loss coefficients (Helweg, Scott and Scalmanini, 1983). However, use of this technique to obtain the efficiency may be misleading since a part of the well loss term may actually be formation loss and since most of the larger discharge rates produce drawdowns into the screened interval of the well. In other words, when the water level in the well is lowered into the screened interval of the well, the physical conditions on which the analysis is based, are no longer present.

The results of the efficiency calculations for the discharge rates that do not produce drawdowns into the screened interval are presented in this report for comparison between wells and as indications of the efficiency of the well. The data obtained from the step drawdown test performed on Well 611 is presented as an example. A value of efficiency can be calculated by the ratio; formation loss coefficient multiplied by discharge rate, divided by observed drawdown (Helweg, et al., 1983). Thus, the efficiency of the well at the end of step 1 is 108% ((5.35 ft/gpm x 1.30 gpm) x 100/6.5 ft). The information necessary to perform

the calculation are presented in Figures 8 (page 38) and 22 (page 55). The calculation is repeated for the remaining steps with the following results being obtained: Step 2-90% and step 3-95%.

Analysis 5: Efficiency Indications (Walton)

Indications of the efficiency of the well may also be made by comparing the specific capacity (SC), of the well as the discharge is incremented. The specific capacity is defined as the ratio of pumping rate to drawdown (Walton, 1970). A decrease in the specific capacity at larger discharge rates can be attributed to wellbore effects. The specific capacity is computed for the step drawdown tests by observing the drawdown and discharge at the end of each step. The data needed for these computations are presented in Figures 1 - 8 (page 31 through page 38). The data from the step drawdown test performed on Well 613 is used as an example. Using Figure 6, a drawdown of 0.71 (psi) or 1.64 (ft) is observed at the end of step 1. The discharge causing this drawdown is 3.04 (gal/min). Thus, the specific capacity (SC) at the end of step 1 is 1.85 (gal/min/ft). Repeating this calculation for the remaining steps yields: Step 2-SC=1.77, step 3-SC=1.77, step 4-SC=1.76, step 5-SC=1.75 and step 6-SC=1.75 (gal/min/ft). The change in specific capacity over the six steps is small. This indicates an efficient well (Walton, 1970).

Analysis 6: Recommended Discharge

Extrapolation of the drawdown trends from each step (Figures 1 - 8, pages 31 through 38) to a time period of several weeks allows for the determination of the range of pumping rates that could be used for a particular well. The time drawdown trend caused by its discharge that projects to a pumping level near the top of the pump is the initial pumping rate to be used for that well in the Seepage Cleanup System. However, it should be noted that this discharge rate is preliminary and is subject to change depending upon the behavior of the system once it has begun. Adjustments will be made in the field as required.

Analysis 7: Transmissivity/Storage Coefficient (Theis and Cooper-Jacob Method)

As indicated previously, drawdowns were detected in several observation wells during some of the tests (Appendix F). Specifically, when Well 607 was tested, drawdowns were measured in Well 612, located approximately 11.5 feet southwest of Well 607. Recall that Well 612 is completed in Zone 1 but could not be used as a pumping well because of the construction problems encountered (see page 13). Analysis of the drawdown data from Well 612 was made using the standard Theis type curve method (Theis, 1935). The calculated transmissivity ranged from 60 to 80 gpd/ft and the storage coefficient ranged from 0.014 to 0.015. This analysis yields an estimate of the storage coefficient since the radial distance of the observation point is known.

Drawdowns were also measured in Well 505-B (located approximately 100 feet from Well 609) when Well 609 was pumped. The data are more difficult to analyze since measureable drawdowns did not occur until the later steps of the test. However, an analysis of increased drawdowns during the later steps indicated a transmissivity of about 1800 gpd/ft and a storage coefficient of about 0.004.

Drawdowns were also measured in several wells when Well 608 was pumped. Wells 609 and 610 (about 100 feet from Well 608) had more than 0.2 feet of drawdown and a slight effect (approximately .02 feet) was noted in Well 505-B (located approximately 180 feet from Well 608). The drawdowns in Wells 609 and 610 are noteworthy because virtually the same drawdown pattern was measured in both wells even though they are in different radial directions from the pumping well. This indicates that any structural features such as major fractures either do not exist within the area of influence or that any such features that do exist do not have a significant influence on the hydraulic behavior of the formation between these wells.

The data indicates that the water level of Well 607 may have also been affected during the test on Well 608. Recall that Well 608 is completed in Zone 3 whereas, Well 607 is completed in Zone 1. This observed response in Well 607 may be a preliminary indication of hydraulic communication. However, the response is so small that it is uncertain whether or not there is any hydraulic communication. More extensive pumping in the area of the Seepage Cleanup System during its operation will help

determine if there is indeed such hydraulic communication.

The estimated storage coefficients (S), using the drawdown data as computed by the parameter r^2S , (Cooper-Jacob, 1946) vary over a wide range. However, the most reasonable values of r^2S (i.e. values associated with transmissivities calculated from recovery data) range from about 10^{-4} ft² to 10^{-2} ft². Thus if the well casing radius (0.25 feet) is used for the value of r , the range in storage coefficient would be from 2×10^{-3} to 0.2. If borehole radius (approximately 0.5 feet) is used for the value of r , the estimated values of S would range from 4×10^{-4} to 0.4.

6.1.2 Recovery Data

Analysis of the recovery data was made using the Sternberg (1967) method and using an extension of the Cooper-Jacob (1946) method to account for wellbore storage effects.

Analysis 8: Transmissivity (Sternberg)

The Sternberg method, as outlined by Kruseman and De Ridder (1979), provides that a corrected total pumping time and corrected discharge rate be calculated and the recovery data then be analyzed by the standard Theis (1935) recovery method. The recovery data and computations related to this analysis are tabulated in Appendix E. An example of such an analysis is shown in Figure 24 for Well 611.

WELL 611

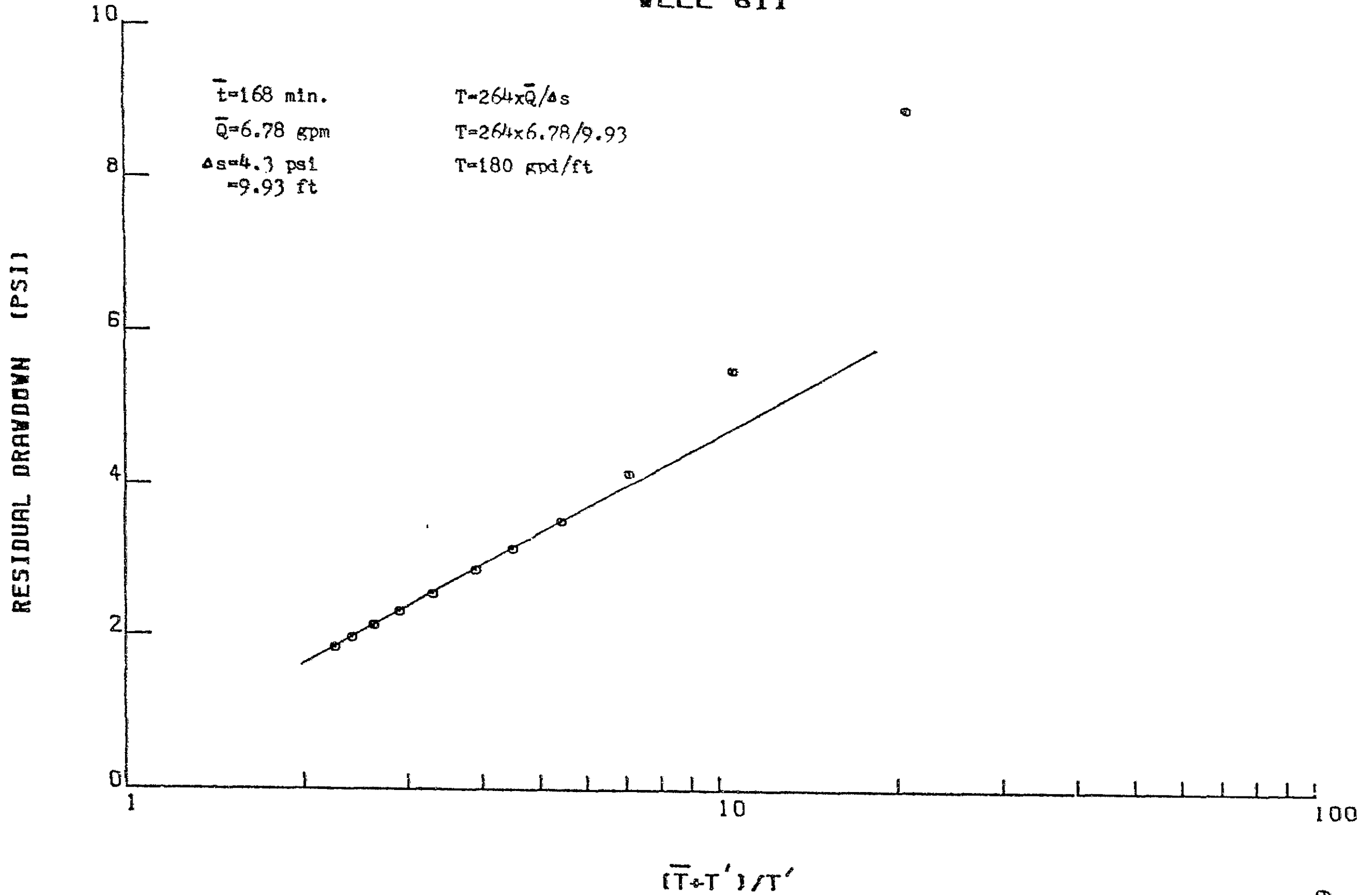


Figure 24 - Well 611: Residual Drawdown vs. $(\bar{t} + t') / t'$

The Sternberg method allows recovery response resulting from a variable pumping rate to be approximated by a response due to a uniform discharge rate over an adjusted time period. Specific error terms or differences between the "true" response due to the variable discharge rate and the approximated response due to a "corrected" uniform rate are minimized by this approximation. The corrected, uniform discharge rate and the corrected pumping time are then used to analyze the recovery data by the Theis recovery method, which assumes a constant, uniform discharge rate. This procedure was modified for these tests to account for wellbore storage effects by extending the pumping time to include the wellbore volume that had been displaced. The increment of the pumping time to account for wellbore effects, corrected total pumping time, and corrected discharge rate used in the Sternberg analyses are given in Table 2 for each well. The adjustment to the pumping time to account for wellbore effects causes some of the adjusted recovery times and values of t/t' for the Theis recovery method to be negative (see Appendix E). These negative values were not considered in the analysis. As noted in this analysis, the adjustment for wellbore effects does not significantly affect the latter recovery data as the aquifer is contributing most of the discharge to the well during this time.

Analysis 9: Transmissivity
(Cooper-Jacob Method: Modified)

An analysis of the same data (Well 611) using an extension of the Cooper-Jacob (1946) method is shown in Figure 25. The

Table 2

Corrections for Sternberg Method

Well #	Pumping Time Increment (minutes)	Corrected Pumping Time (minutes)	Corrected Discharge Rate (gpm)
606	17.2	146.4	2.69
607	15.1	178.8	2.04
611	7.5	168.3	6.78
608	4.8	157.2	10.5
609	2.5	209.3	12.4
610	1.2	56.7	5.56
613	0.74	249.7	21.5

WELL 611

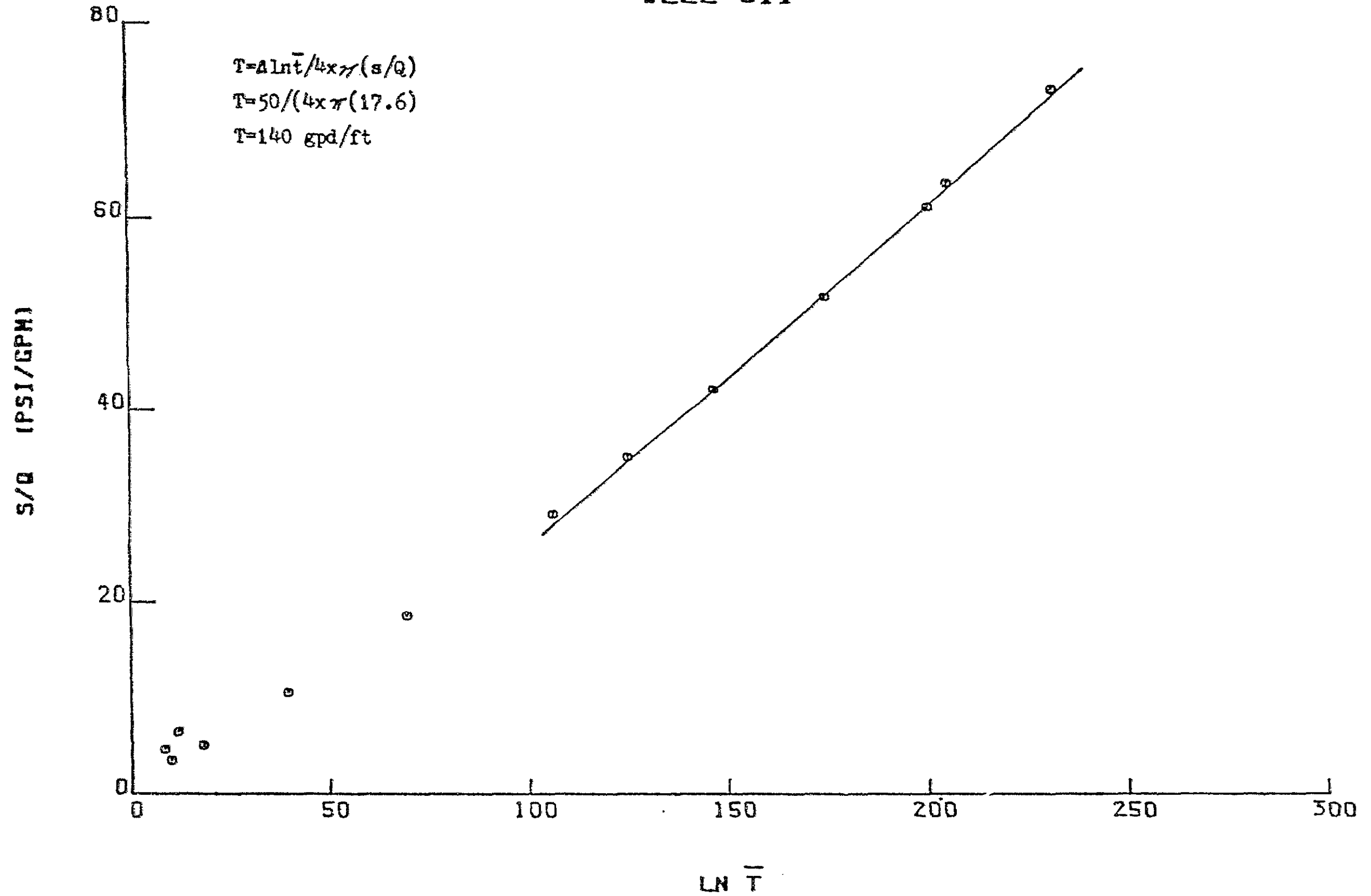


Figure 25 - Well 611: Specific Drawdown vs. $\ln(\bar{t})$

data and computations used in this analysis are tabulated in Appendix E. Since the aquifer continues to discharge water to the well during the recovery period, residual drawdown during this period of decreasing discharge was analyzed using the same procedure as that used for analysis of drawdown during the period of increased discharge (see Analysis 2, page 39). The fourth column in the recovery data tables in Appendix E gives the aquifer discharge or wellbore effect during the recovery period. Note that these discharge rates become very small during the latter part of the recovery period. Thus, the specific drawdown (see column 7 of Appendix E) and the natural logarithm of the adjusted pumping time become rather large. Since the total range of adjusted pumping times would span many logarithmic cycles, an arithmetic plot of specific drawdown versus the natural logarithm of the adjusted pumping time is used to graphically analyze the data as exemplified on Figure 25 (page 65).

7.0 RESULTS

The recommended discharge rates of wells pumped in the Seepage Cleanup System ranges from 1.5 to 7.0 gallons per minute for the Zone 1 wells and 10.0 to 45.0 gallons per minute for the Zone 3 wells (see Table 3).

Formation loss coefficients (B) for the Zone 1 wells range from 53.5 to 9.68 (ft/gpm). Well loss coefficients (C) for the Zone 1 wells range from 0.053 to 1.69 (ft/gpm²). Formation loss coefficients for the Zone 3 wells range from 0.54 to 1.50 (ft/gpm). Well loss coefficients for the Zone 3 wells range from 0.0011 to 0.16 (ft/gpm²). Formation and well loss coefficients for each well are presented in Table 3.

Efficiencies for the Zone 1 wells range from 86 to 108 percent. Efficiencies for the Zone 3 wells range from 74 to 101 percent. These values are presented in Table 3.

Specific capacities for the Zone 1 wells range from 0.08 to 0.20 (gpm/ft). Specific capacities for the Zone 3 wells range from 0.51 to 1.85 (gpm/ft). Specific capacity ranges for each well are presented in Table 3.

Recommended pump sizes for each well are presented in Table 3.

Transmissivity for the Zone 1 wells varies from 31 to 210 (gal/day/ft). Transmissivity for the Zone 3 wells varies from 270 to 3800 (gal/day/ft). Values of transmissivity are presented in Table 4. The storage coefficient for Well 612, a Zone 1 observation well, ranges from 0.014 to 0.015. The storage

Table 3

Well Performance Characteristics Determined by Step Drawdown Tests

Well No.	Zone	Recommended Discharge, If Pumped (gal/min)	B (ft/gpm)	C (ft/gpm ²)	Efficiency (Percent)	Specific Capacity Range (gpm/ft)	Pump Size (HP)
Analysis		6	3	3	4	5	
606	1	2.5	9.68	0.42	86-97	.095-.10	3/4
607	1	1.5	9.53	1.69	91	.08-.095	3/4
608	3	10.0	1.50	0.16	76-89	.51-.59	3/4
609	3	15.0	1.31	0.023	90-102	.69-.78	1 1/2
610	3	19.0	0.78	0.031	74-78	.96-1.02	1 1/2
611	1	7.0	5.35	0.053	90-108	.17-.20	3/4
613	3	45.0	0.54	0.0011	95-101	1.76-1.85	5

Table 4
Summary of Aquifer Characteristics

Well No.	Zone No.	Analysis No.	Transmissivity (gal/day/ft)
606	1	1	39
		2	31-86
		8	50
		9	89
607	1	1	86
		2	36-100
		8	70
		9	88
608	3	1	507
		2	270-630
		8	430
		9	500
609	3	1	1020
		2	320-890
		8	850
		9	1000
610	3	1	890
		2	640-1200
		8	800
		9	800
611	1	1	132
		2	120-210
		8	140
		9	180
612	1	7	60-80
613	3	1	2106
		2	2400-3800
		8	1700
		9	1900
505B	3	7	1800

coefficient for Well 505-B, a Zone 3 observation well, was determined to be 0.004.

8.0 CONCLUSIONS

Continual sluffing of the boreholes was encountered throughout the drilling and construction of the Seepage Cleanup System. It was determined that open boreholes and pre-casing development could not be used because of this sluffing.

The transmissivities obtained from the step drawdown tests on Zone 3 indicate a range from 270 to 3800 (gal/day/ft) (see Table 4). However, tests on Well 600 (Zone 3) indicate a transmissivity of 35 (gal/day/ft) within its area of influence. Because of the high variability (i.e., two orders of magnitude) of transmissivity in the general area of the Seepage Cleanup System wells, a permanent collection system design should be based on a long-term pumping stress. In addition, this high variability may require that sophisticated analysis techniques (e.g. numerical models) be conducted to adequately evaluate system performance and determine modifications to the collection system, if necessary. Data obtained from a long-term pumping stress will determine the types of analysis techniques to be used.

No large decreases in specific capacity were noted during any of the tests (see Table 3). Thus, specific capacity results indicate these wells are suitably efficient.

The formation loss coefficients are considerably larger than the well loss coefficients (see Table 3). Thus, the coefficients indicate a lack of efficiency problems in the wells.

The efficiency calculations (see Table 3) indicate efficiencies in the range of 74 to 108 percent.

APPENDIX A
LITHOLOGIC LOGS

SAMPLE TYP	SIMBOL	DEPTH	DESCRIPTION	COMMENTS
		10	Silt, Some Sandstone	
		20	Light Brown, Fine - Medium, Sandstone	
		30	Light Brown, Fine - Medium, Sandstone	
		40	Light Brown, Fine - Medium, Sandstone	
			Some Shale	
		50	Light Brown to Gray, Fine, Sandstone	
		60	Light Brown to Dark Brown, Sandstone	Oily
		70	Shale, Coal, Iron Pyrite	
		80	Light Gray, Medium - Coarse, Sandstone	
		90	Light Gray, Fine, Sandstone, Some Fine, Brown, Sandstone, Small Chips - mineralize	
		100	Light Gray, Fine, Sandstone, Shaley, Some Medium, Sandstone	
		112		TOTAL DEPTH
CLIENT <u> UNC </u>			BY <u>Jeffery Billings</u>	
LOCATION <u> Churchrock </u>			SHEET <u> 1 </u> of <u> 1 </u>	
PROJECT No. <u> 832-6-1 </u>			BORING No. <u> 609 </u>	

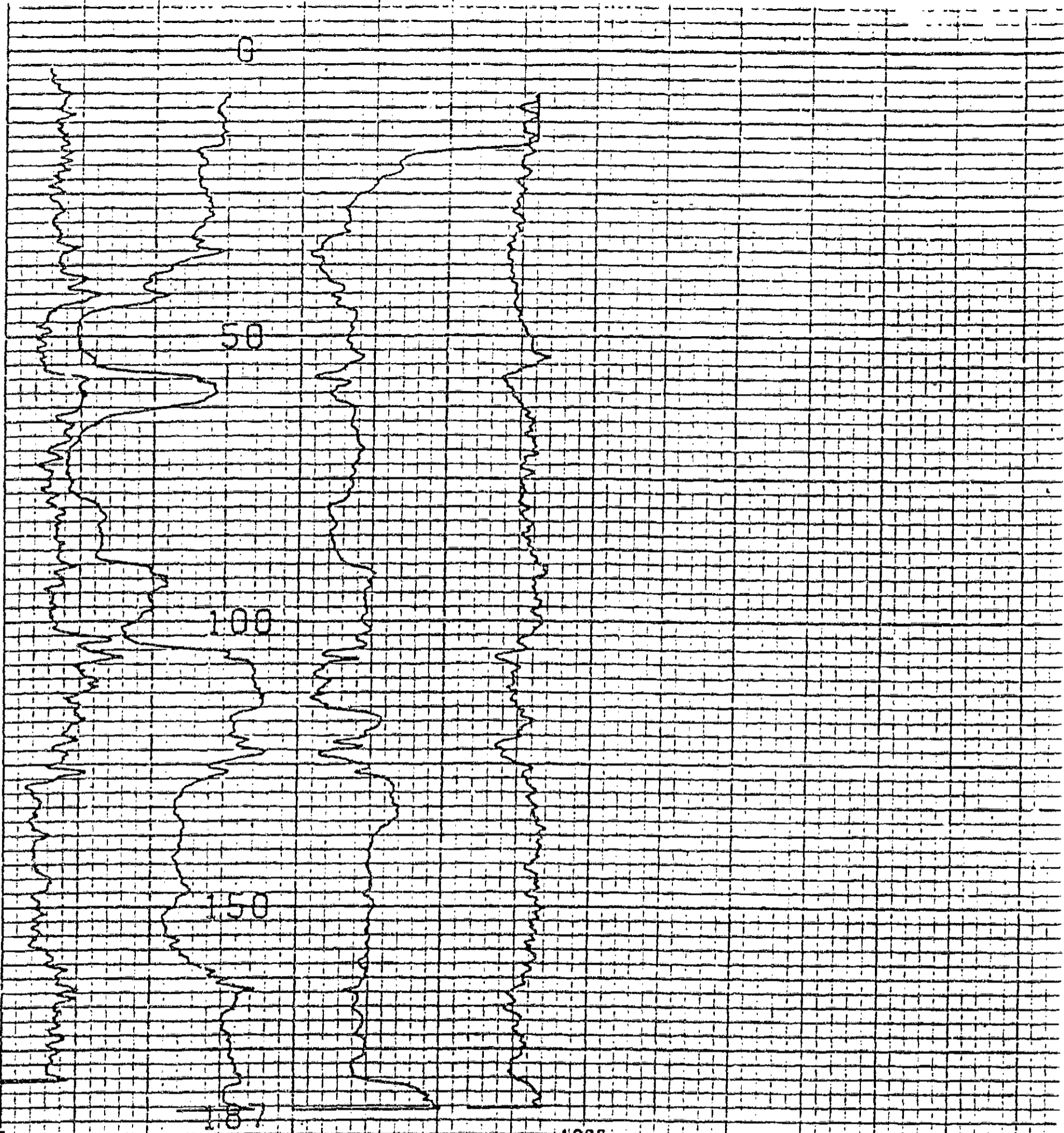
FIELD LOG

SAMPLE TYP	SIMBOL	DEPTH	DESCRIPTION	COMMENTS
		10	Brown Topsoil	Moderate drilling rate
		20	Light Brown, Sandstone, Very Fine	" " "
		30	" " " " "	" " "
		40	Light Brown, Sandstone, Very Fine, Some Shale	" " "
		50	Brown to Dark Brown, Sandstone, Very Fine	" " "
		60	Dark Brown, Very Fine - Fine, Sandstone, Oily	" " "
		70	Coal and Shale	Slow drilling rate
		80	Shale and Light Gray, Very Fine - Fine, Sandstone	Moderate drilling rate
		90	Light Gray, Very Fine - Fine, Sandstone	" " "
		100	Light Gray, Very Fine - Fine, Sandstone and Some Shale	" " "
		110	Dark Gray, Shale	Slow/Moderate drilling rate
		120	Dark Gray, Very Fine, Sandstone	" " " "
		130	Black, Shale	" " " "
		140	Light Gray, Very Fine - Fine, Sandstone	Moderate drilling rate
		150	Light Gray, Fine, Sandstone	" " "
		160	Light Gray, Very Fine - Fine, Sandstone	" " "
		170	Light Gray, Very Fine - Fine, Sandstone	" " "
		180	Light Gray, Very Fine - Fine, Sandstone and Shale	" " "
		185	Shale	TOTAL DEPTH
CLIENT <u>UNC</u>				BY <u>Jeffery Billings</u>
LOCATION <u>Churchrock</u>				SHEET <u>1</u> of <u>1</u>
PROJECT No. <u>832-6-1</u>				BORING No. <u>612</u>

FIELD LOG

APPENDIX B
GEOPHYSICAL LOGS

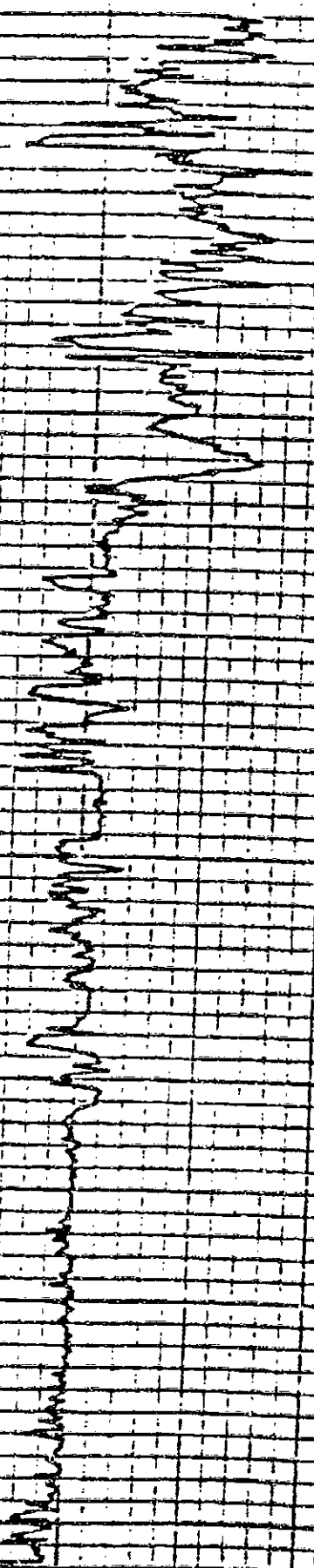
473



1.4		.9	
S-P. MV		N-N KCPS	
26		65	
RESISTANCE OHMS			

606
 J.N.C.
 CHURCH ROCK MILL

175



0

50

100

150

100

CALIPER IN

187

605

U. N. C.

CHURCH ROCK MILL

137

0

50

100

150

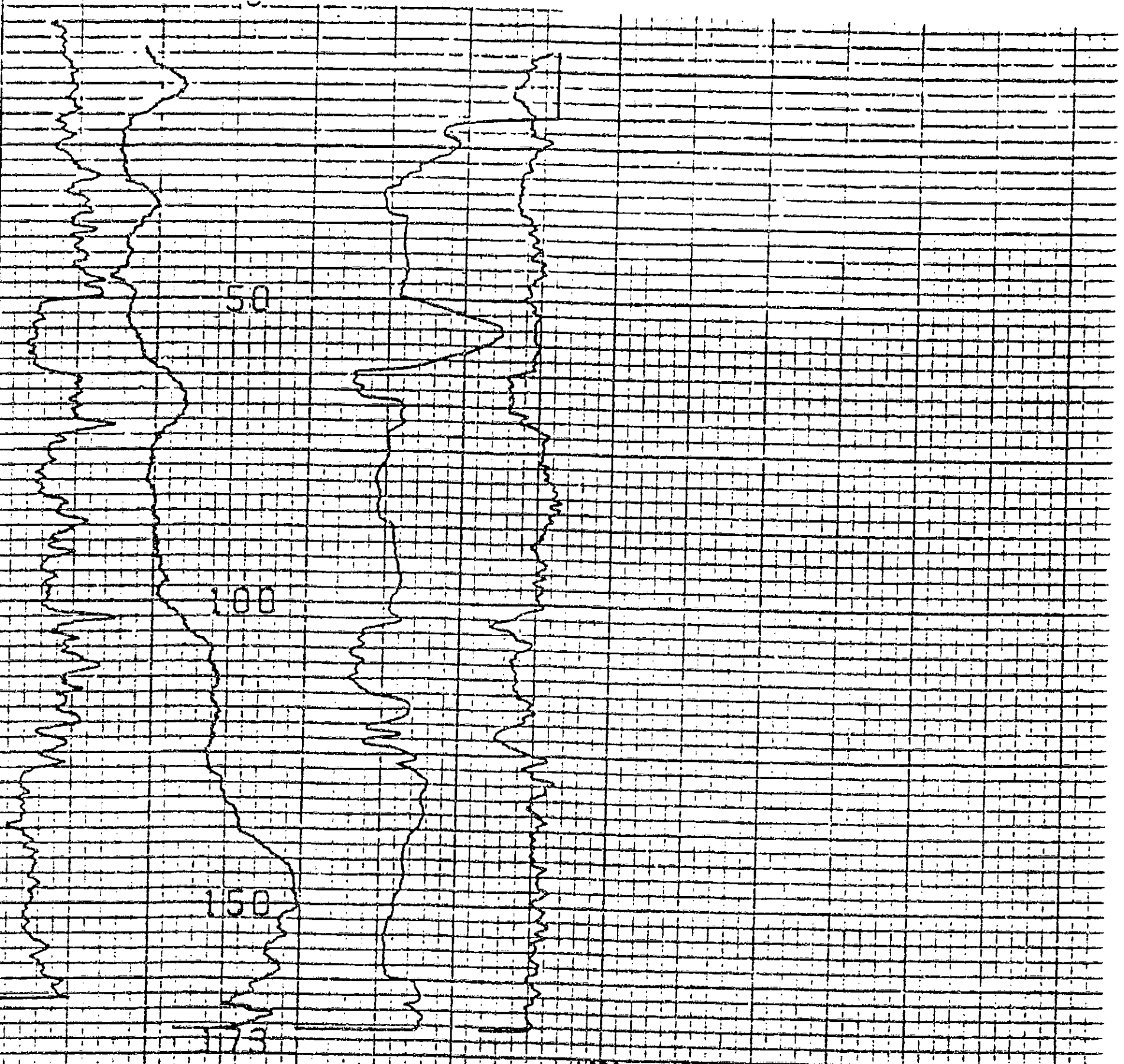
175

CALIPER IN

607

J.N.C.

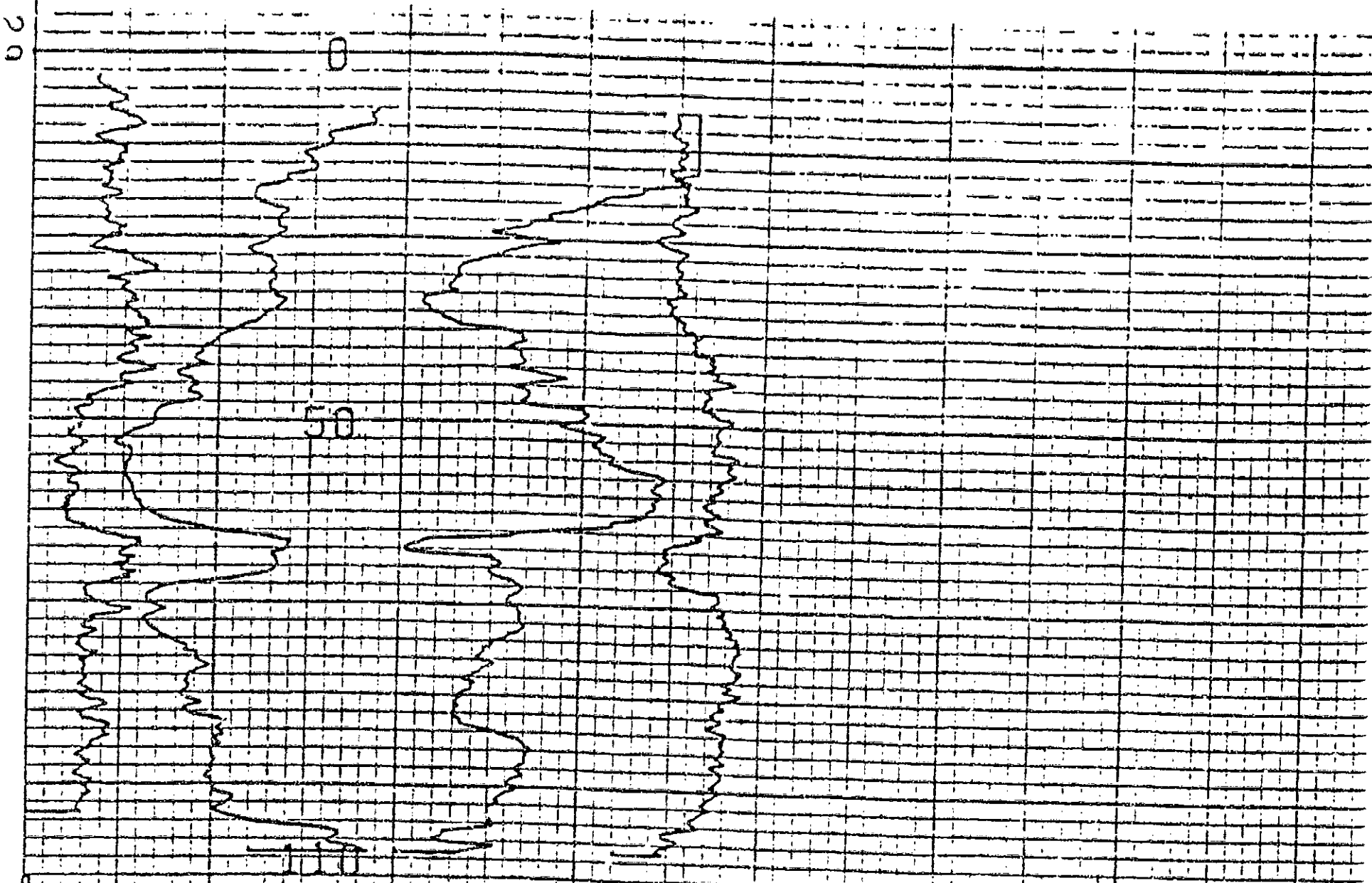
CHURCH REICK MILL



GAMMA CPS		1000	
25	55	2	
SIP. RV		N-N KCPS	
15		75	
RESISTANCE OHMS			

IMPU-LOG VAL2 PLOT 08-12-88
 5017
 J. N. I. C.
 CHURCH ROCK MILL
 HOLE DIAMETER 11.0
 PROBE 13056A 210
 SENSOR 01 CAL STD CPS = 152
 SENSOR 02 CAL RUNI CPS = 201
 SENSOR 03 CAL BIAS = 0
 DATA V0070A TRACK 5 7885

20



1000

GAMMA CPS

27

55

S.P. 18V

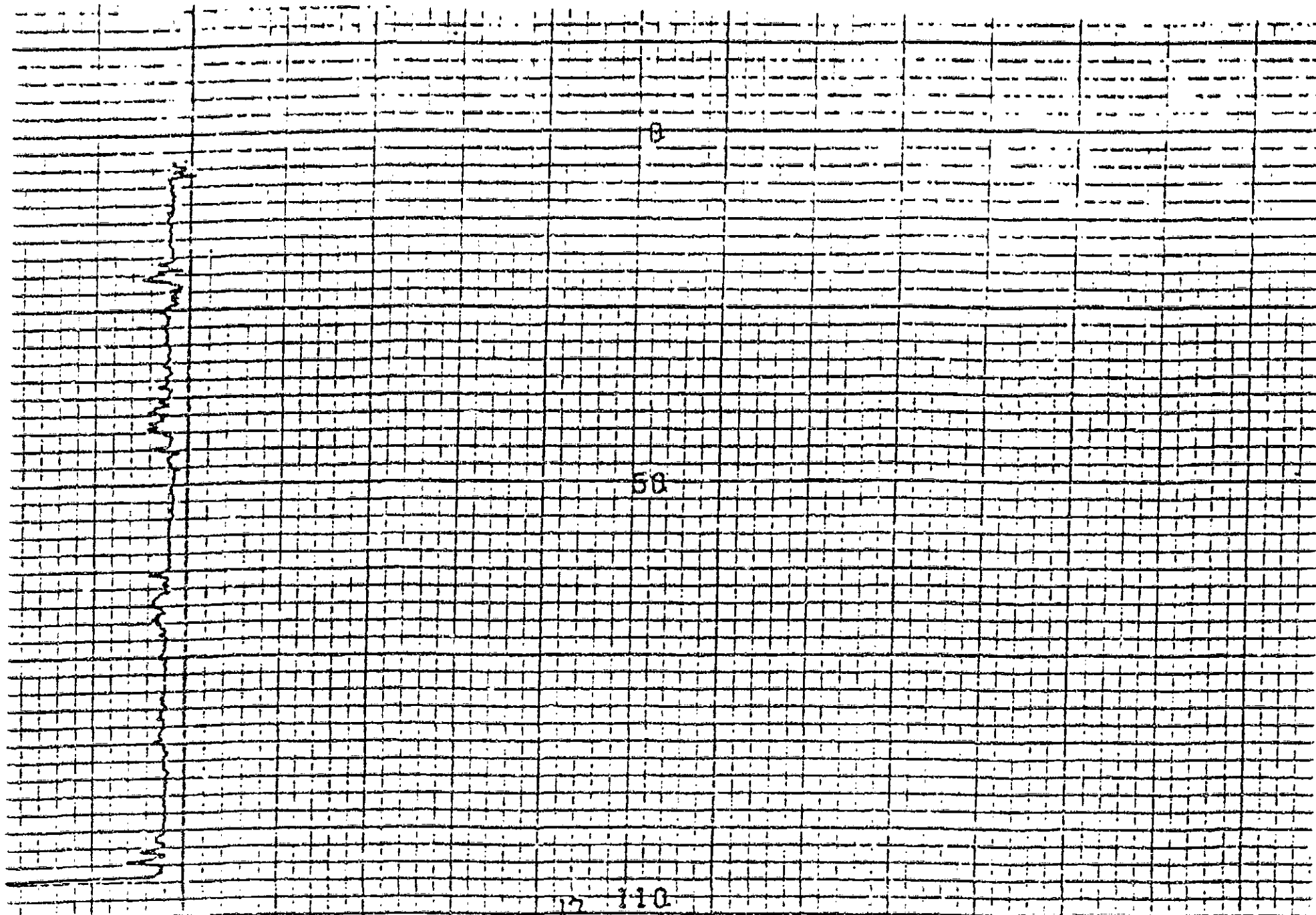
REA KCP'S

25

67

RESISTANCE OHMS

608
 U.N.C.
 CHURCH ROCK M.I.L.

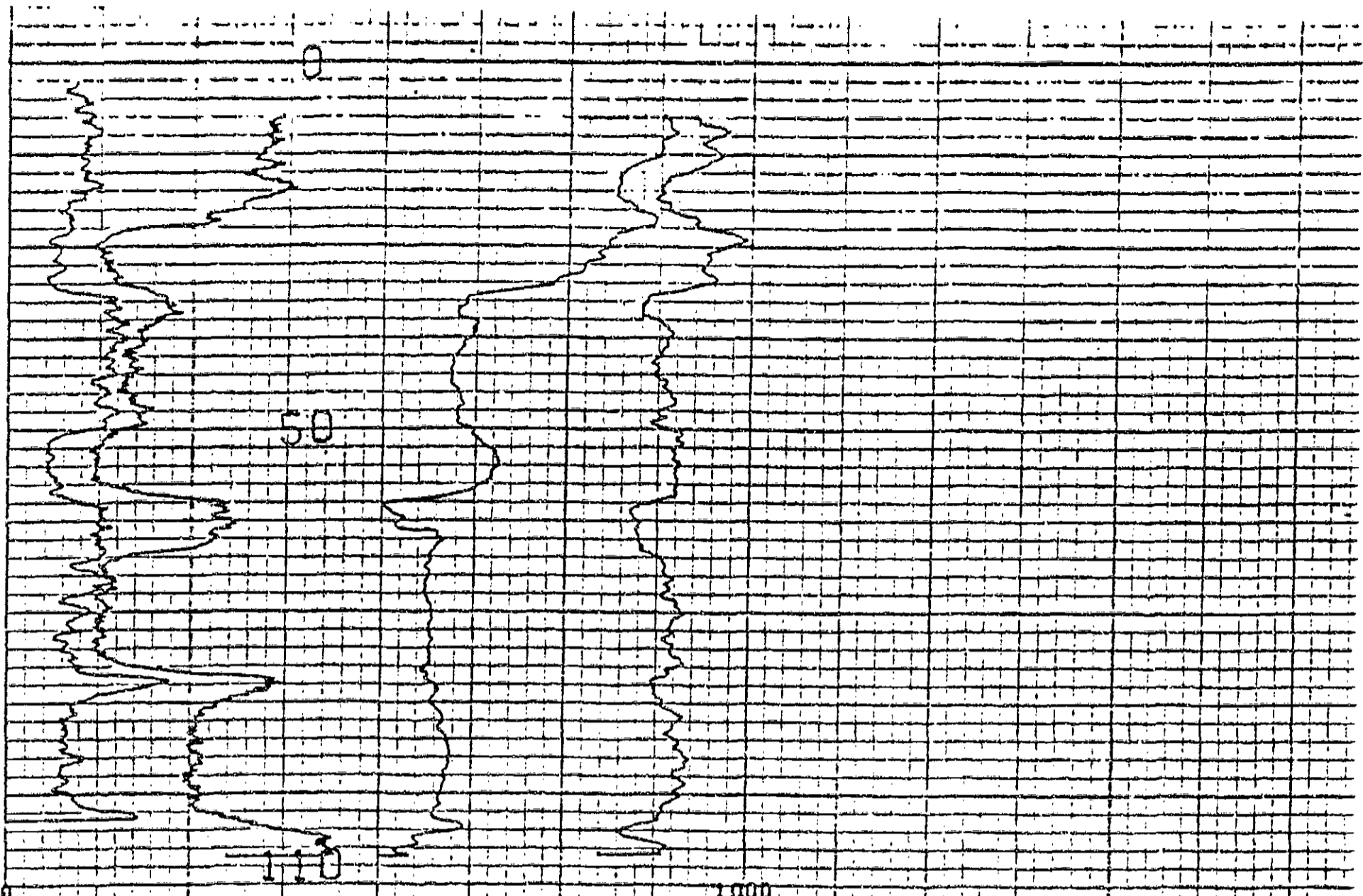


CALIPER. J.N.

50.8

J.N.C.

CHURCH ROCK MILL



1000

48	GAMMA CPS	58	61	69
S-P HV		129	N-N KEPS	
RESISTANCE OHMS				

609
 J.N.C.
 CHURCH ROCK MILL

0

50

100

150

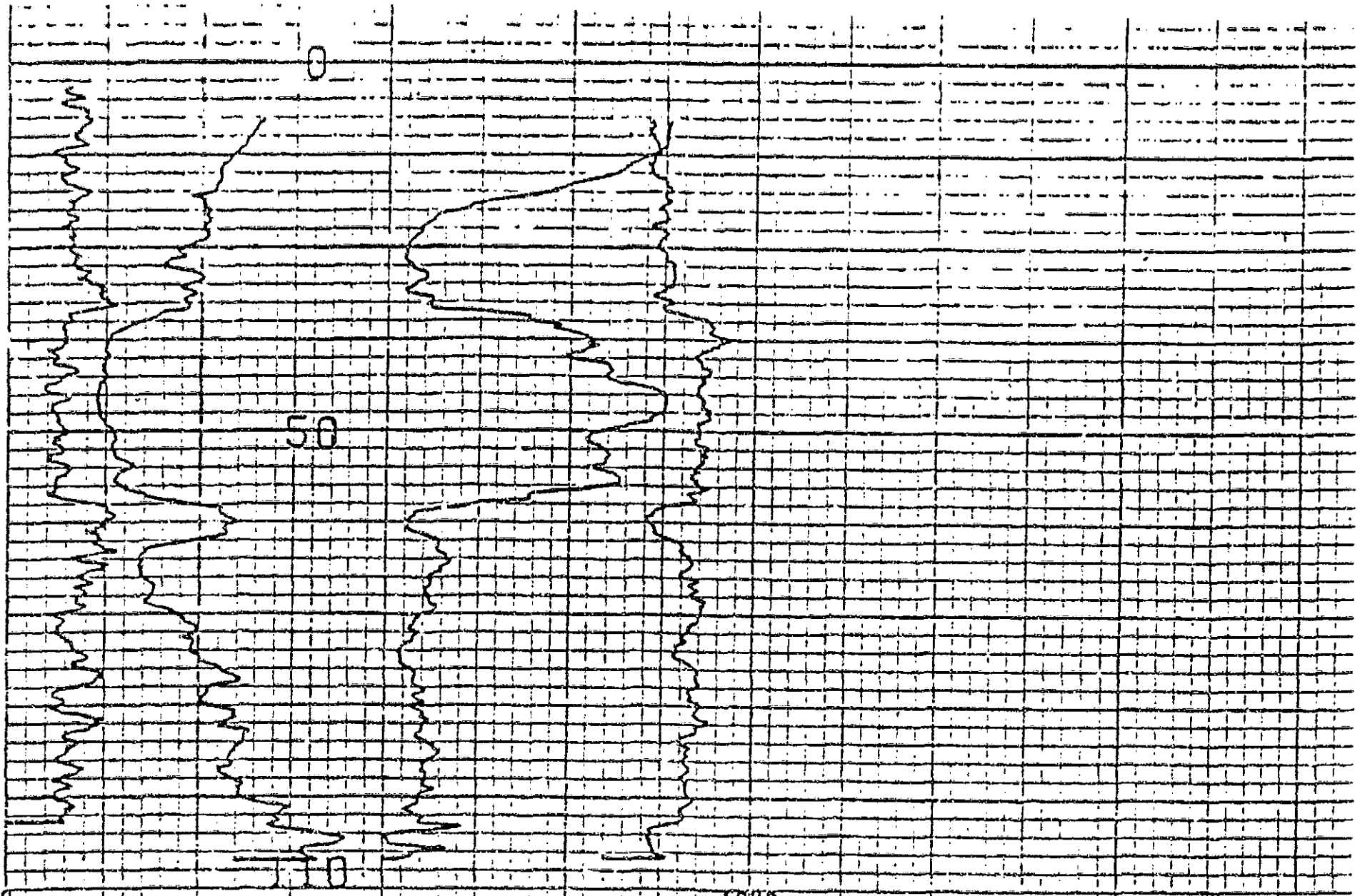
CALIPER IN

609

U.N.C.

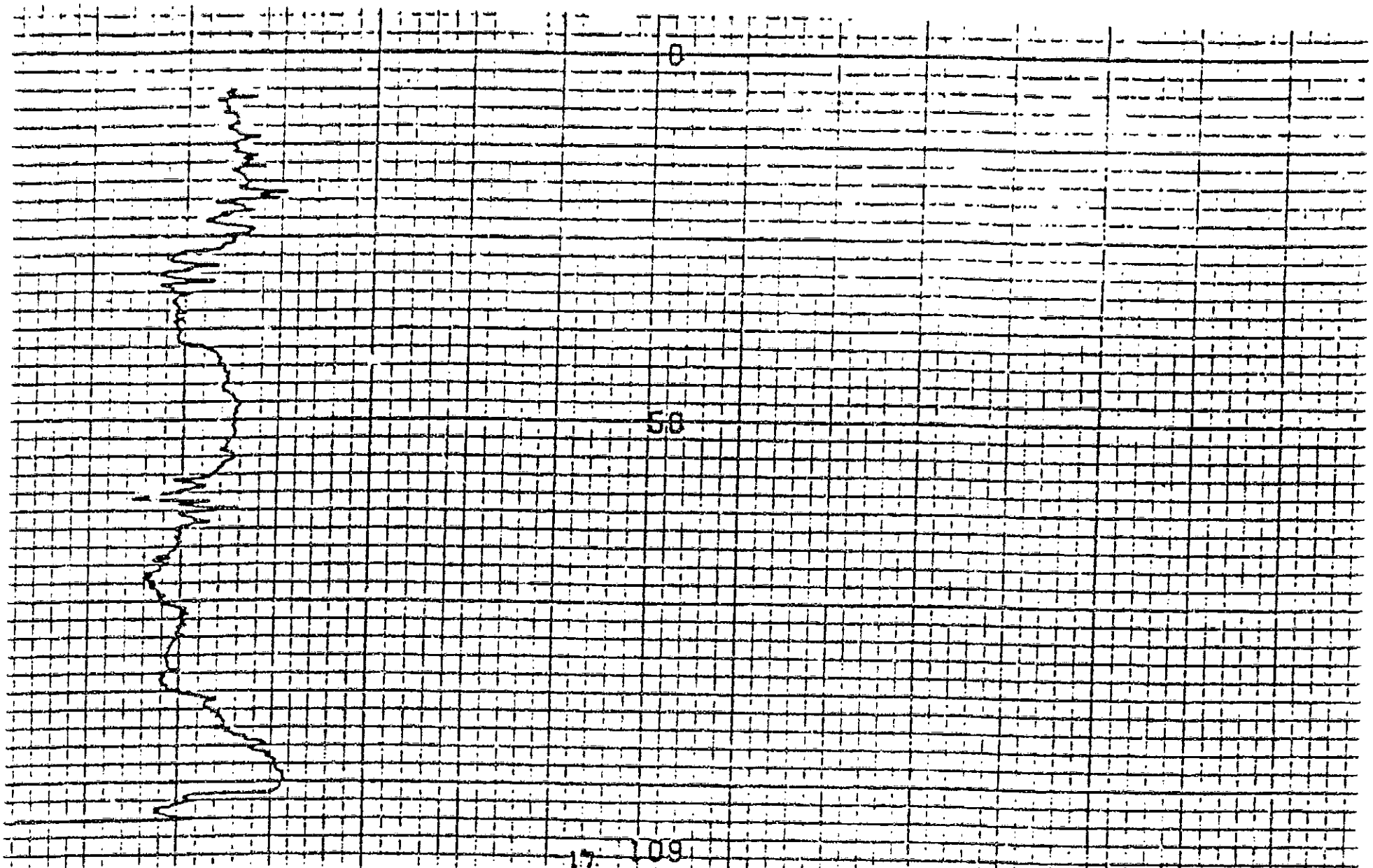
CHURCH ROCK MILL

163



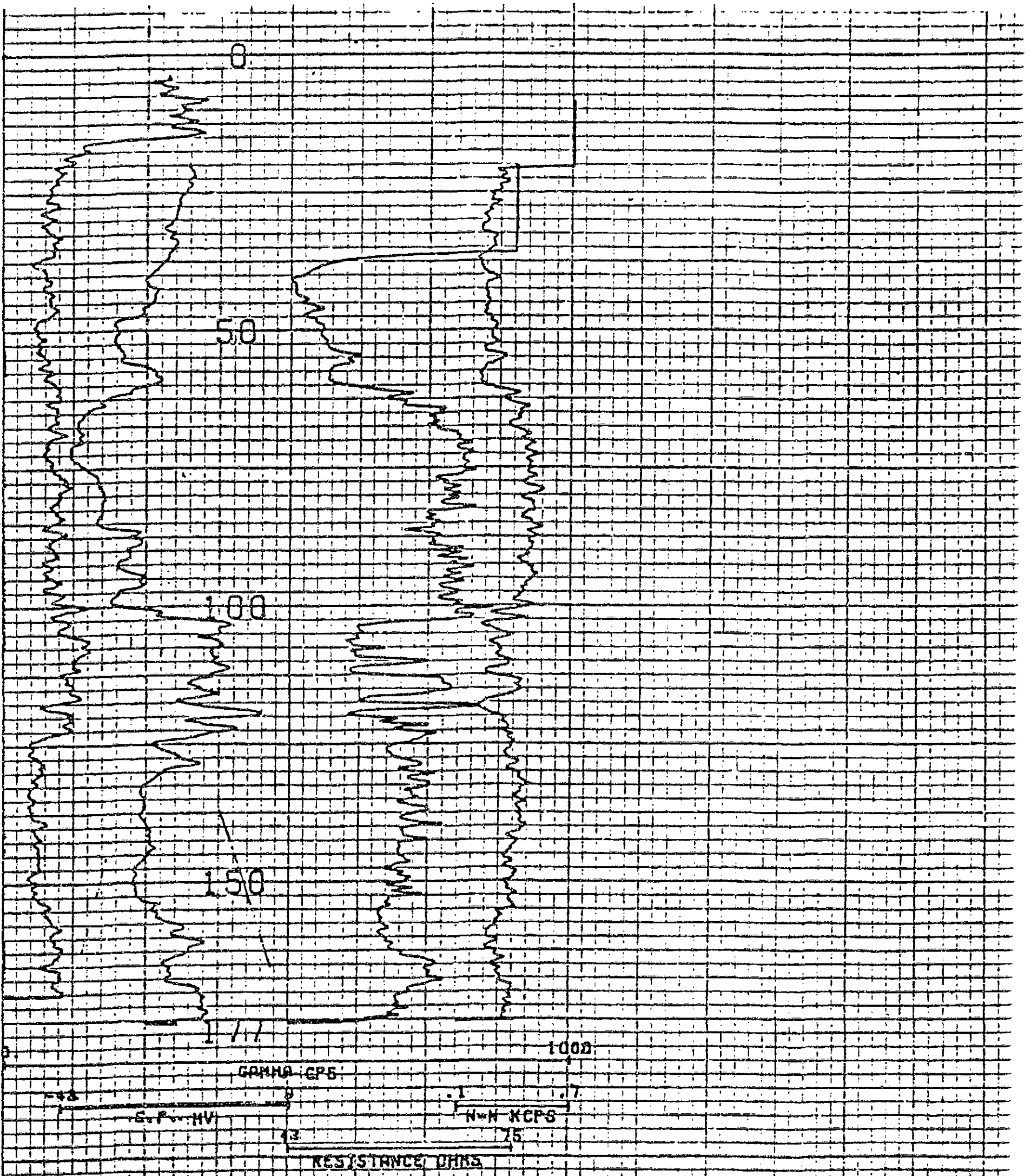
1000
 GAMMA CPS
 15 43 0 8
 S.P. HV 42 N-N KCPS 86
 RESISTANCE OHMS

610
 U.N.C.
 CHURCH ROCK MILL
 HOLE DIAMETER 1.11.0
 22500 2 28000



CALIPER IN

STO
LUN. C.
HURCH ROCK MILL



611
 U.N.C.
 CHURCH ROCK MILL

53

0

50

100

50

20

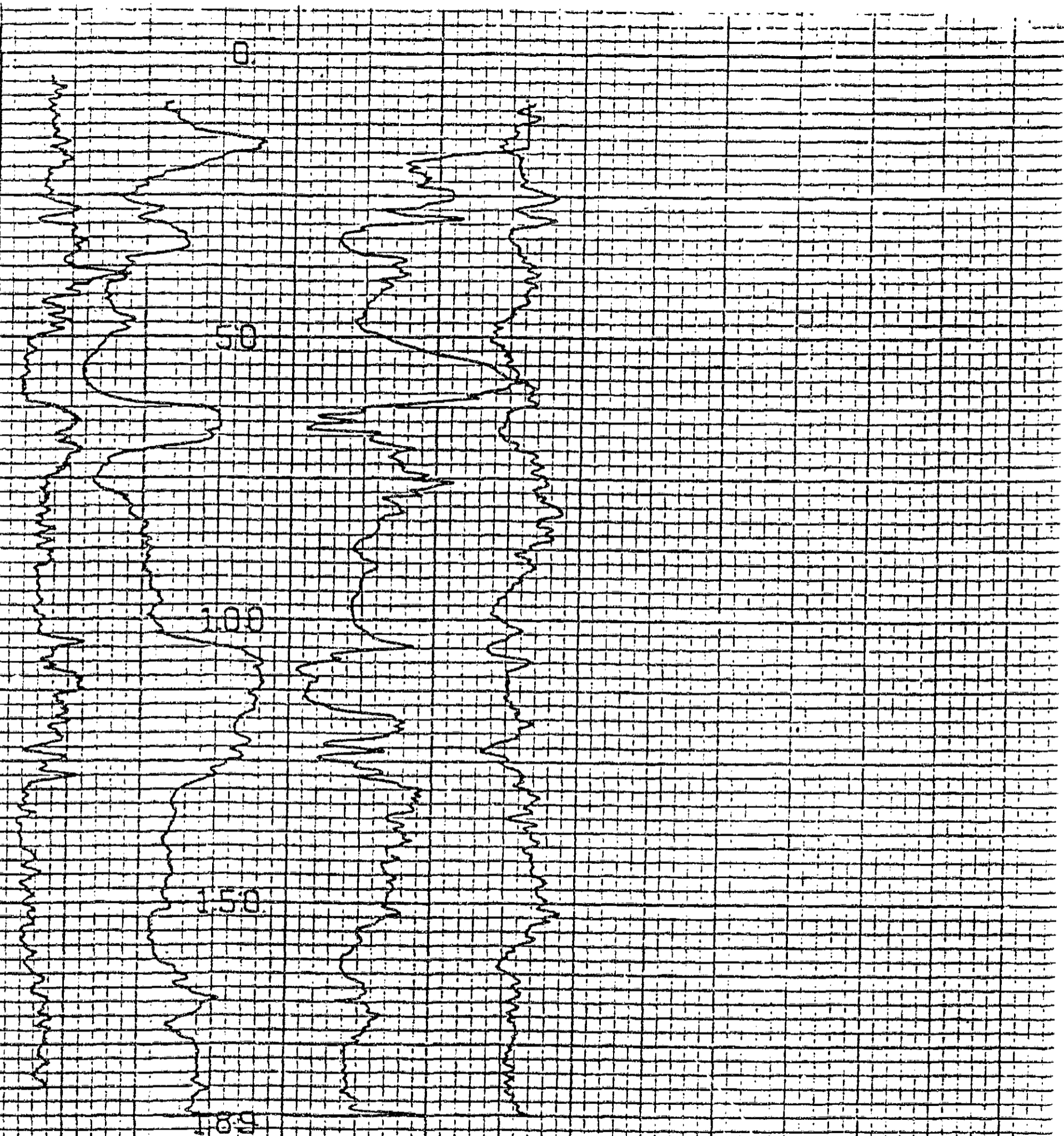
CALIPER IN

50

J. N. P.

CHURCH ROCK, MISS.

200



GAMMA GRS

1000

0-100

0-100

RESISTANCE OHMS

CDREV-LEG-4-6-69 - PLUT. 98-02-83

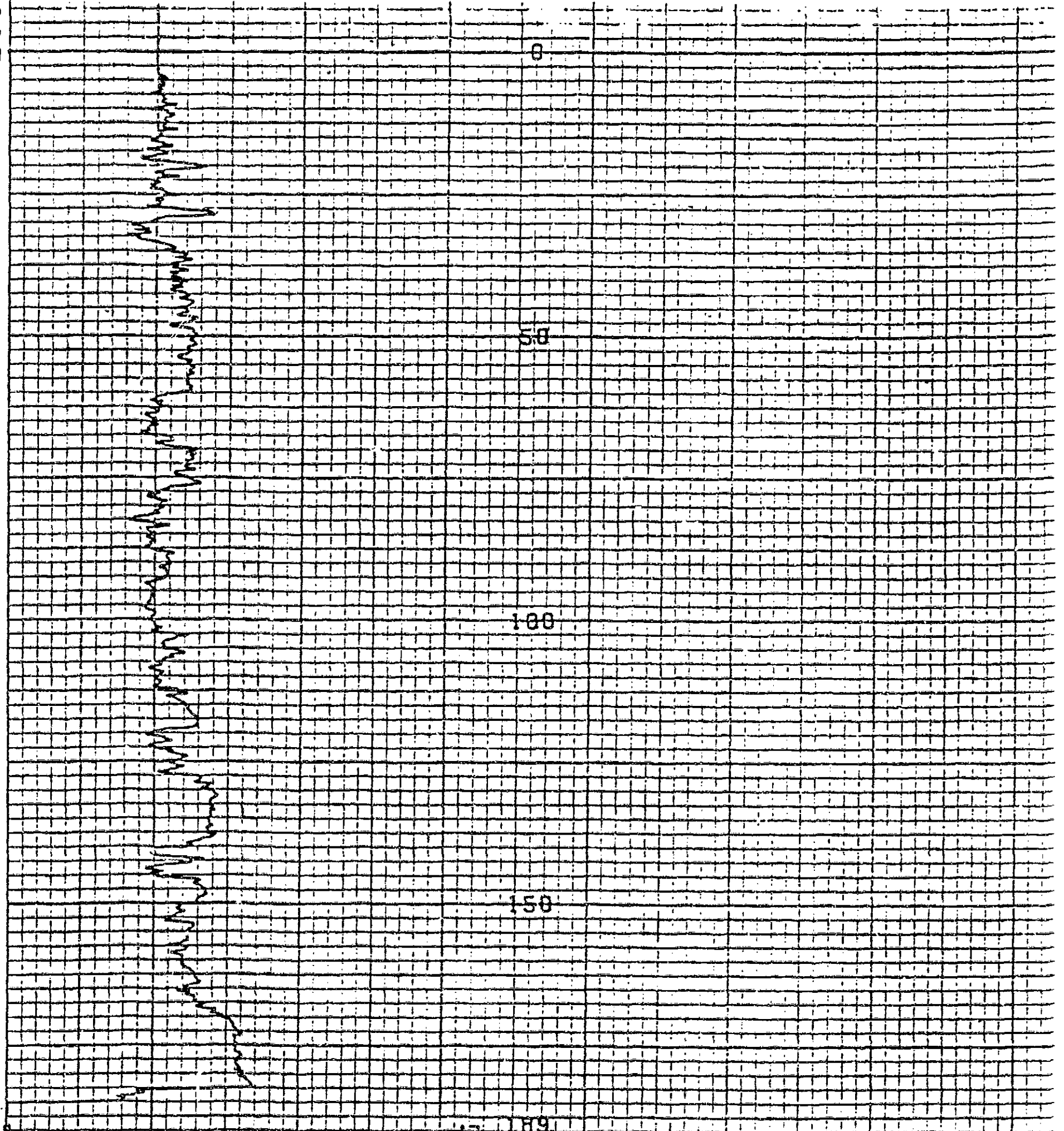
BT2

J.N.C.

CHURCH ROCK MILL

004074

207



CALIPER IN
 17 189

512
 U.N.C.
 CHURCH ROCK MILL

123

8

58

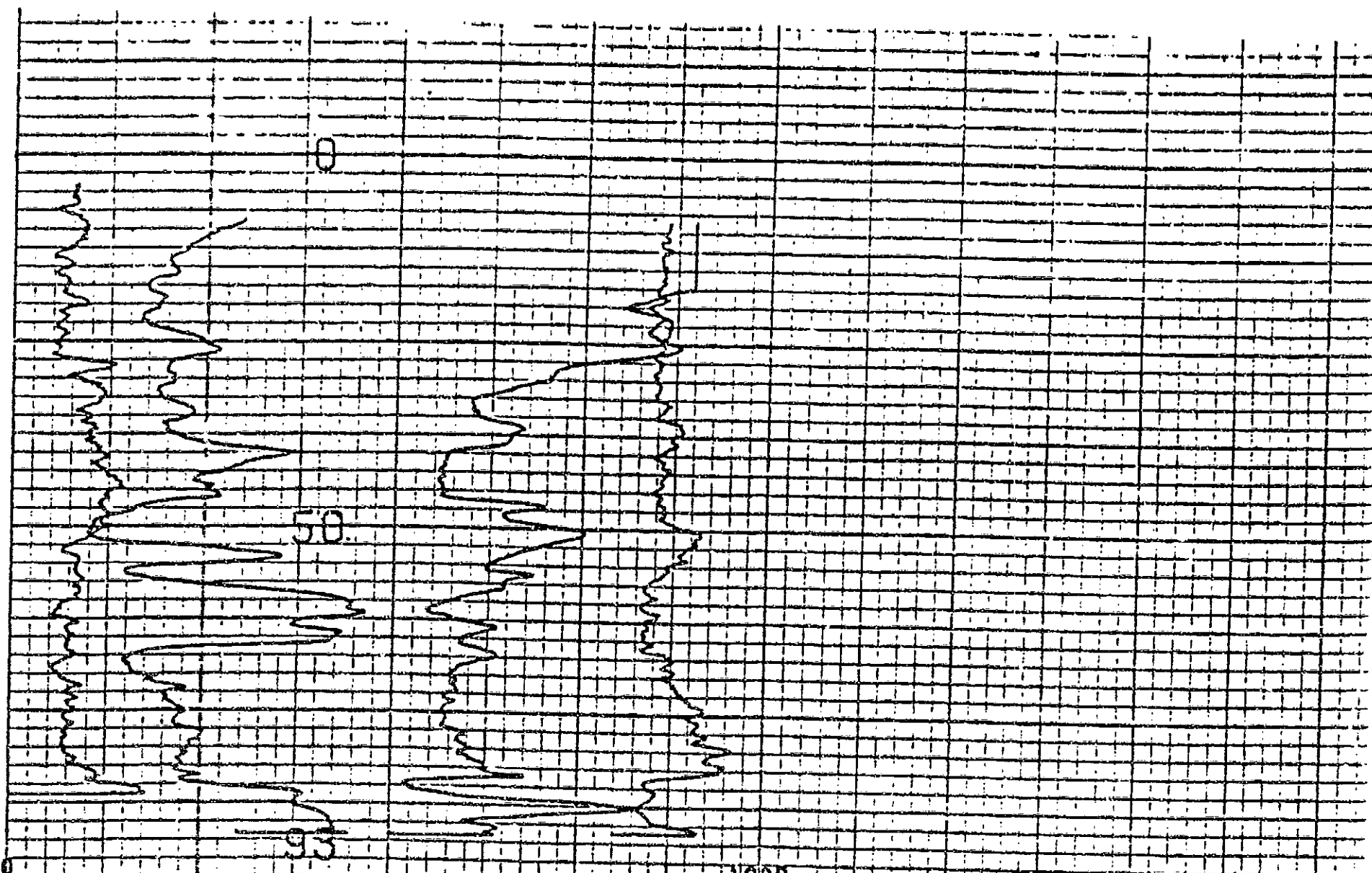
17 93

CALIPER IN

613

J. N. C.

CHURCH ROCK MILL



125 46 7
 S. P. MV N-N KCPS
 21 27
 RESISTANCE OHMS

613
 U.N.C.
 CHURCH ROCK MILL

APPENDIX C
DRILLING AND WELL CONSTRUCTION DETAILS

BILLINGS AND ASSOCIATES

KIMBERLING CITY, MISSOURI

BORING No. 606

DEPTH DRILLED 187

SCREENED FORMATION(S) Zone 1

CLIENT UNC

LOCATION Churchrock

PROJECT No. 832-6-1

SURVEY DATA (coord.) Lat=75764.6904; Dep=60849.6387

TOP OF PIPE ELEV. 6961.75 GROUND ELEV. 6960.51

STATIC W.L. 6873.72

taken 830828

DEVELOPMENT Circulation

of clear water, Air

Lift, Bail/Surge,

Air Jet, Bail

DRILLING

DRILLER La Madera RIG TYPE Failing 1250

START 8-9-83 END 8-10-83

BIT SCHEDULE 0 - 178' = 11.25" Down hole

DRILLING FLUIDS Revert

WATER ENCOUNTERED AT N/A

CONSTRUCTION

CASING SCHEDULE 187 - 167' = 6" Blank PVC(C),

167 - 124' = 6" 50 Slot PVC(S), 124 - (+)2' = 6"

Blank PVC(C)

BACKFILL SCHEDULE 187 - 177' = Sluffed cuttings(SC),

177 - 167' = Bentonite(B), 167 - 122' = Stabilizer(P),

122 - 106' = Bentonite(B), 106 - 0' = Grout(G)

GEOPHYSICAL LOGS N - N, Gamma, Resistance,

Caliper, Spontaneous Potential, Deviation

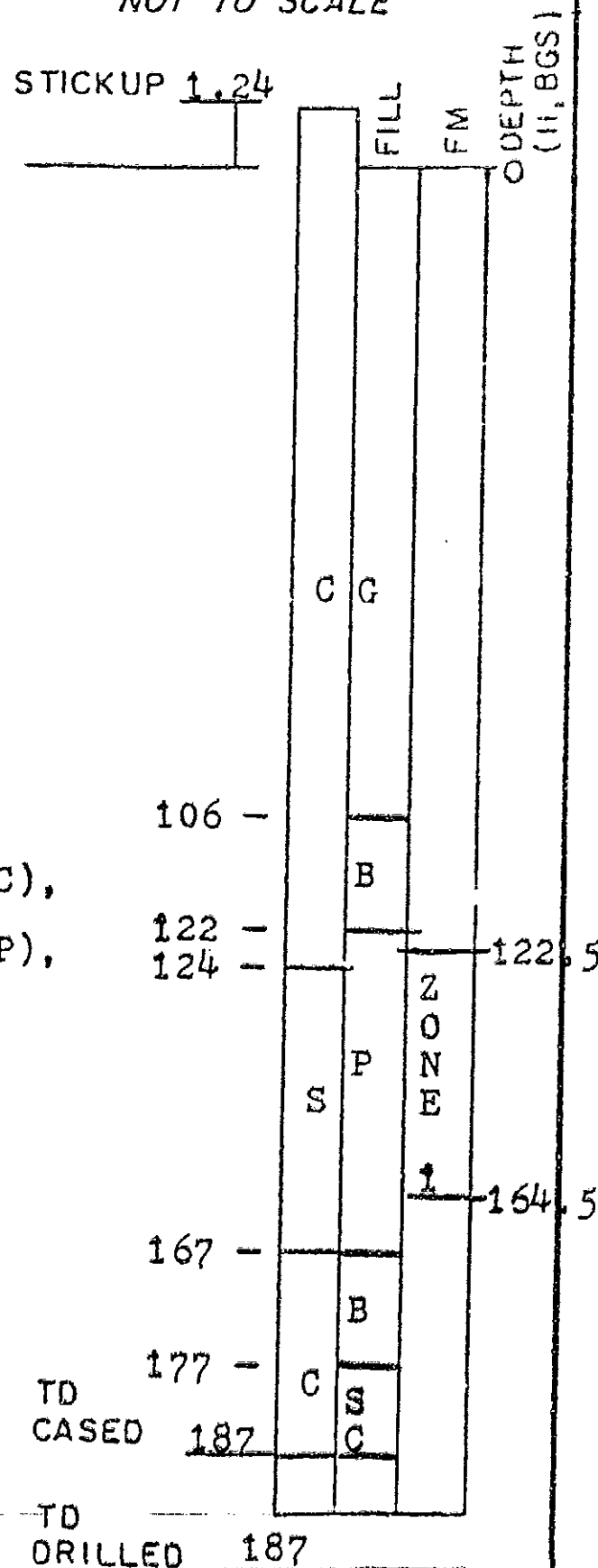
COMMENTS Hole sluffed from the time casing was

placed until outside hole depth was measured.

Centralizer placed at top of screen.

NOT TO SCALE

STICKUP 1.24



BILLINGS AND ASSOCIATES

KIMBERLING CITY, MISSOURI

BORING No. 607

DEPTH DRILLED 172

SCREENED
FORMATION(S) Zone 1

CLIENT UNC

LOCATION Churchrock

PROJECT No. 832-6-1

SURVEY DATA (coord.) Lat=75751.33; Dep=60985.36

TOP OF PIPE ELEV. 6968.24 GROUND ELEV. 6966.27

DRILLING

DRILLER La Madera RIG TYPE Failing 1250

START 8-12-83 END 8-12-83

BIT SCHEDULE 0 - 173' = 11.25" Down hole

DRILLING FLUIDS Revert

WATER ENCOUNTERED AT N/A

CONSTRUCTION

CASING SCHEDULE 169 - 165' = 6" Blank PVC (C),
165 - 123' = 6" 50 Slot PVC Screen (S),
123 - (+)2' = 6" Blank PVC (C)

BACKFILL SCHEDULE 169 - 122 = Stabilizer (P),
122 - 98' = Bentonite (B), 98 - 0' = Grout (G)

GEOPHYSICAL LOGS N-N, Gamma, Spontaneous
Potential, Resistance, Caliper, Deviation

COMMENTS Hole sluffed app. 3 ft. No bottom
Bentonite was used. Sluffing problems during
drilling. Centralizer placed at the top of
the screen.

STATIC W.L. 6865.90

taken 830828

DEVELOPMENT Circulation

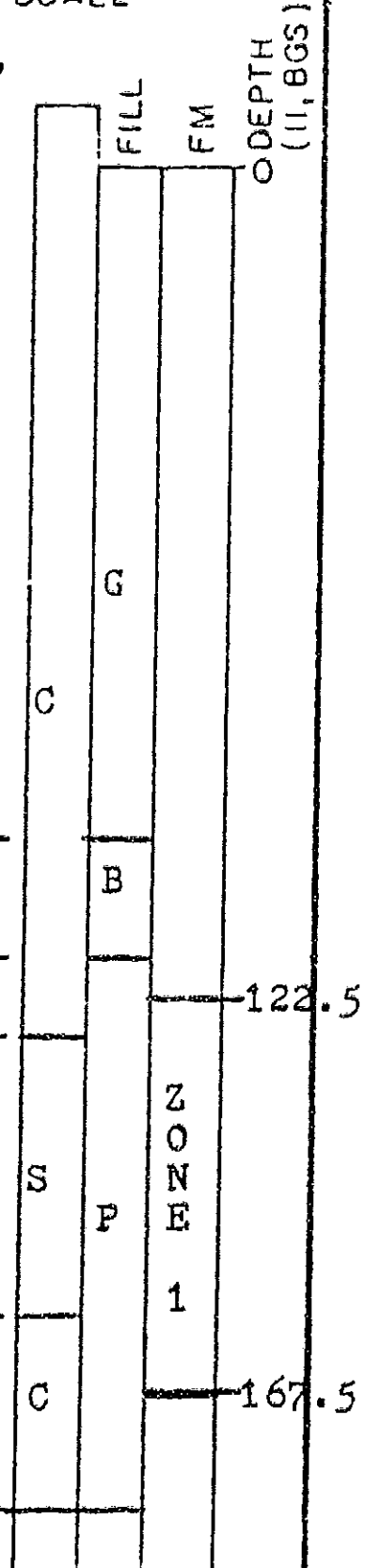
of clear water, Air

Lift, Bail/Surge,

Air Jet, Bail

NOT TO SCALE

STICKUP 1.97



TD
CASED 169

TD
DRILLED 172

BILLINGS AND ASSOCIATES

KIMBERLING CITY, MISSOURI

BORING No. 608

DEPTH DRILLED 113

SCREENED
FORMATION(S) Zone 3

CLIENT UNC

LOCATION Churchrock

PROJECT No. 832-6-1

SURVEY DATA (coord.) Lat=75721.32; Dep=61036.40

TOP OF PIPE ELEV. 6972.24 GROUND ELEV. 6969.97

DRILLING

DRILLER La Madera RIG TYPE Failing 1250

START 8-4-83 END 8-5-83

BIT SCHEDULE 0 - 109' = 11.25" Down hole

DRILLING FLUIDS Revert

WATER ENCOUNTERED AT N/A

CONSTRUCTION

CASING SCHEDULE 113 - 107' = 6" Blank PVC(C),
107 - 72' = 6" 50 Slot PVC Screen(S), 72 - (+)2' =
6" Blank PVC(C)

BACKFILL SCHEDULE 109 - 106' = Bentonite(B),
106 - 70' = Stabilizer(P), 70 - 52' = Bentonite(B),
52 - 0' = Grout(G)

GEOPHYSICAL LOGS N-N, Gamma, Resistance,
Spontaneous Potential, Caliper, Deviation

COMMENTS Hole sluffed a few feet after casing
was set. Only 3 foot thick bottom bentonite seal.
Sluffing problems during drilling. Centralizer
placed at top of screen.

STATIC W.L. 6922.45

taken 830828

DEVELOPMENT Circulation

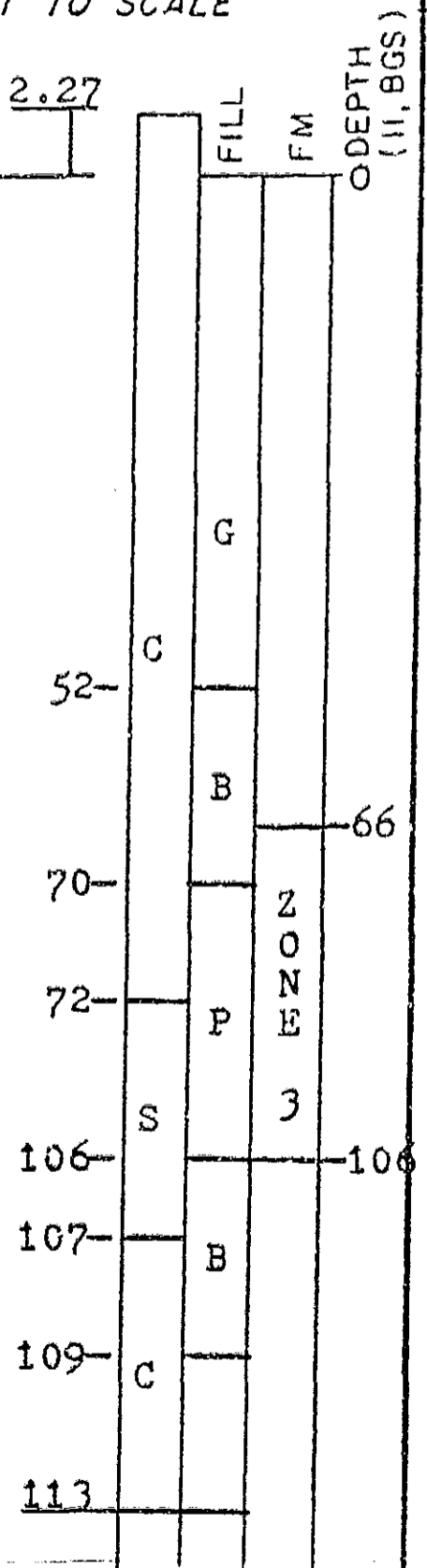
of clear water, Air

Lift, Bail/Surge,

Air Jet, Bail

NOT TO SCALE

STICKUP 2.27



TD
CASED 113

TD
DRILLED 113

BILLINGS AND ASSOCIATES

KIMBERLING CITY, MISSOURI

BORING No. 609

DEPTH DRILLED 112

SCREENED

FORMATION(S) Zone 3

CLIENT UNC

STATIC W.L. 6923.04

LOCATION Churchrock

taken 830828

PROJECT No. 832-6-1

DEVELOPMENT Circulation

SURVEY DATA (coord) Lat=75762.1607; Dep=60945.3480

of clear water, Air

TOP OF PIPE ELEV. 6965.74 GROUND ELEV. 6963.51

Lift, Bail/Surge,

DRILLING

Air Jet, Bail

DRILLER La Madera RIG TYPE Failing 1250

START 8-5-83 END _____

NOT TO SCALE

BIT SCHEDULE 0 - 112 = 11.25" Down hole

STICKUP 2.23

DRILLING FLUIDS Revert

WATER ENCOUNTERED AT N/A

CONSTRUCTION

CASING SCHEDULE 112 - 106' = 6" Blank PVC(C),

106 - 67' = 6" 50 Slot PVC(S), 67 - (+)2' = 6"

Blank PVC(C)

BACKFILL SCHEDULE 112 - 110' = Sluffed cuttings(SC),

110 - 107' = Bentonite(B), 107 - 65' = Stabilizer(P),

65 - 51' = Bentonite(B), 51 - 0' = Grout(G)

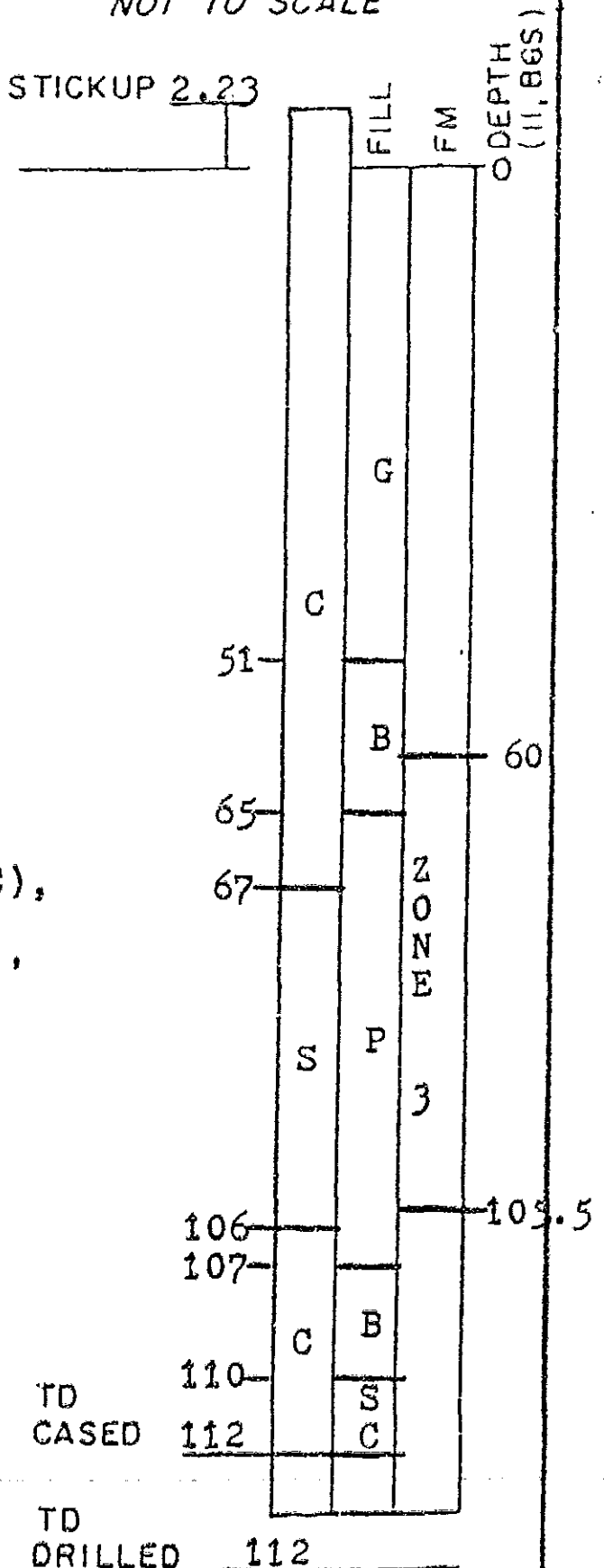
GEOPHYSICAL LOGS N-N, Gamma, Resistance,

Spontaneous Potential, Caliper, Deviation

COMMENTS Hole sluffed app. 2 ft. after casing

was set. Sluffing problems during drilling.

Centralizer placed at top of screen.



BILLINGS AND ASSOCIATES

KIMBERLING CITY, MISSOURI

BORING No. 610

DEPTH DRILLED 109

SCREENED
FORMATION(S) Zone 3

CLIENT UNC

LOCATION Churchrock

PROJECT No. 832-6-1

SURVEY DATA (coord.) Lat=75633.88; Dep=60977.06

TOP OF PIPE ELEV. 6970.12 GROUND ELEV. 6968.25

DRILLING

DRILLER La Madera RIG TYPE Failing 1250

START 8-3-83 END 8-4-83

BIT SCHEDULE 0 - 109' = 11.25" Down hole

DRILLING FLUIDS Revert

WATER ENCOUNTERED AT N/A

CONSTRUCTION

CASING SCHEDULE 109 - 101' = 6" Blank PVC(C),
101 - 65' = 6" 50 Slot PVC Screen(S), 65 - (+)2'
= 6" Blank PVC(C)

BACKFILL SCHEDULE 109 - 98' = Bentonite(B),
98 - 61' = Formation Stabilizer(P), 61 - 49' =
Bentonite(B), 49 - 0' = Grout(G)

GEOPHYSICAL LOGS N-N, Gamma, Resistance,
Spontaneous Potential, Caliper, Deviation

COMMENTS Sluffing problems during drilling.
Centralizer placed at top of screen.

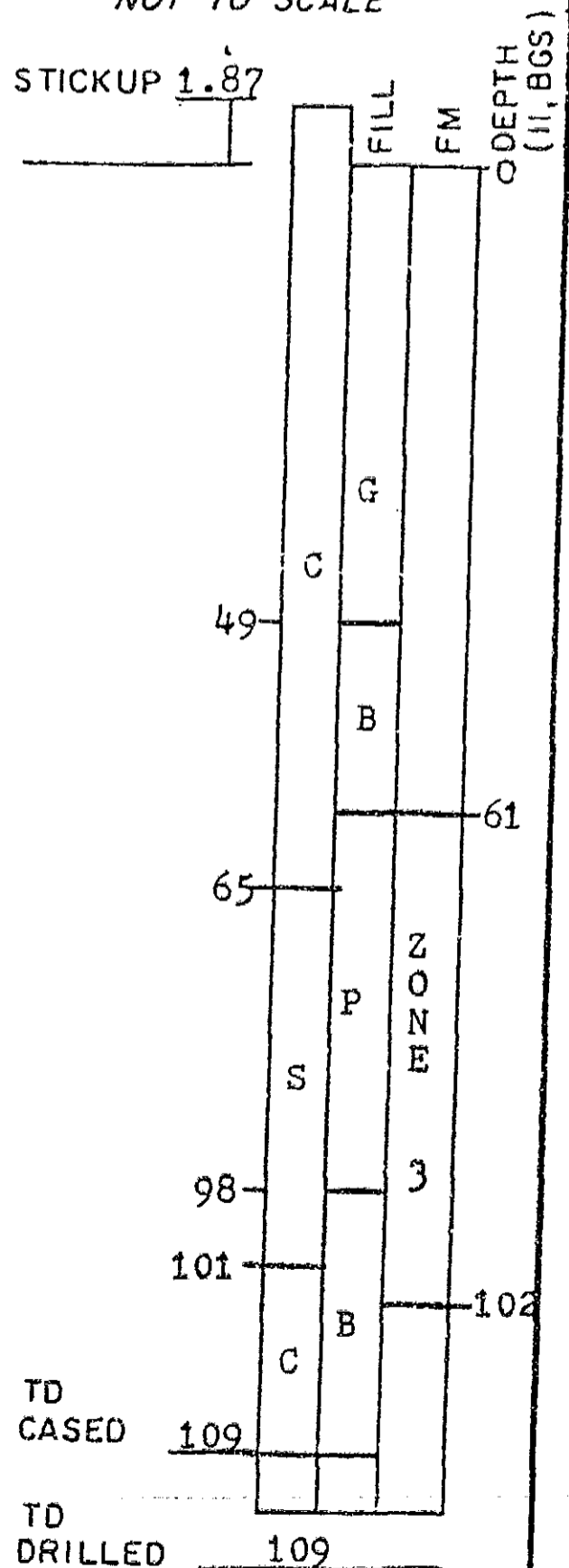
STATIC W.L. 6923.52

taken 830828

DEVELOPMENT Circulation
of clear water, Air
Lift, Bail/Surge,
Air Jet, Bail

NOT TO SCALE

STICKUP 1.87



TD
CASED 109

TD
DRILLED 109

BILLINGS AND ASSOCIATES

KIMBERLING CITY, MISSOURI

BORING No. 611

DEPTH DRILLED 177

SCREENED
FORMATION(S) Zone 1

CLIENT UNC

LOCATION Churchrock

PROJECT No. 832-6-1

SURVEY DATA (coord.) Lat=75634.4890; Dep=60854.7980

TOP OF PIPE ELEV. 6965.15 GROUND ELEV. 6962.03

DRILLING

DRILLER La Madera RIG TYPE Failing 1250

START 8-8-83 END 8-9-83

BIT SCHEDULE 0 - 177' = 13.25" Down hole

DRILLING FLUIDS Revert

WATER ENCOUNTERED AT N/A

CONSTRUCTION

CASING SCHEDULE 177 - 164' = 6" Blank (C),
164 - 120' = 6" 50 Slot PVC(S), 120 - (+) = 6"
Blank PVC(C)

BACKFILL SCHEDULE 177 - 175' = Cuttings(SC),
175 - 165' = Bentonite(B), 165 - 119' = Stabilizer
(P), 119 - 107' = Bentonite(B), 107 - 0' = Grout(G)

GEOPHYSICAL LOGS N-N, Gamma, Resistance,
Spontaneous Potential, Caliper, Deviation

COMMENTS Sluffing problems during drilling.
Centralizer placed at top of screen.

STATIC W.L. 6874.90

taken 830828

DEVELOPMENT Circulation

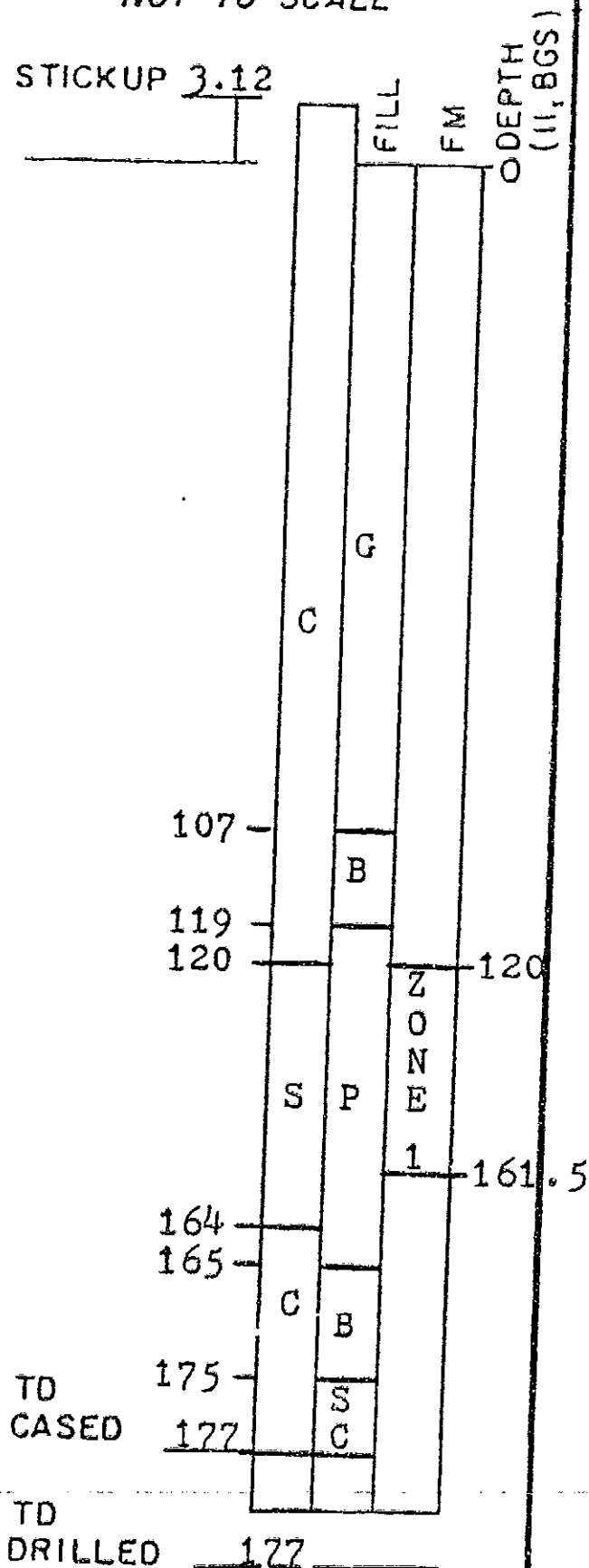
of clear water, Air

Lift, Bail/Surge,

Air Jet, Bail

NOT TO SCALE

STICKUP 3.12



BILLINGS AND ASSOCIATES

KIMBERLING CITY, MISSOURI

BORING No. 612
 DEPTH DRILLED 189
 SCREENED
 FORMATION(S) Zone 1

CLIENT UNC
 LOCATION Churchrock
 PROJECT No. 832-6-1
 SURVEY DATA (coord.) Lat=75744.28; Dep=60976.23
 TOP OF PIPE ELEV. 6967.44 GROUND ELEV. 6966.82

STATIC W.L. 6866.71
taken 830828
 DEVELOPMENT Circulation
of clear water, Air
Lift, Bail/Surge,
Air Jet, Bail

DRILLING

DRILLER La Madera RIG TYPE Failing 1250
 START 7-28-83 END 8-2-83
 BIT SCHEDULE 0 - 185' = 5" Retip
0 - 190' = 11.25" Down hole
 DRILLING FLUIDS Revert

NOT TO SCALE
 STICKUP 0.62

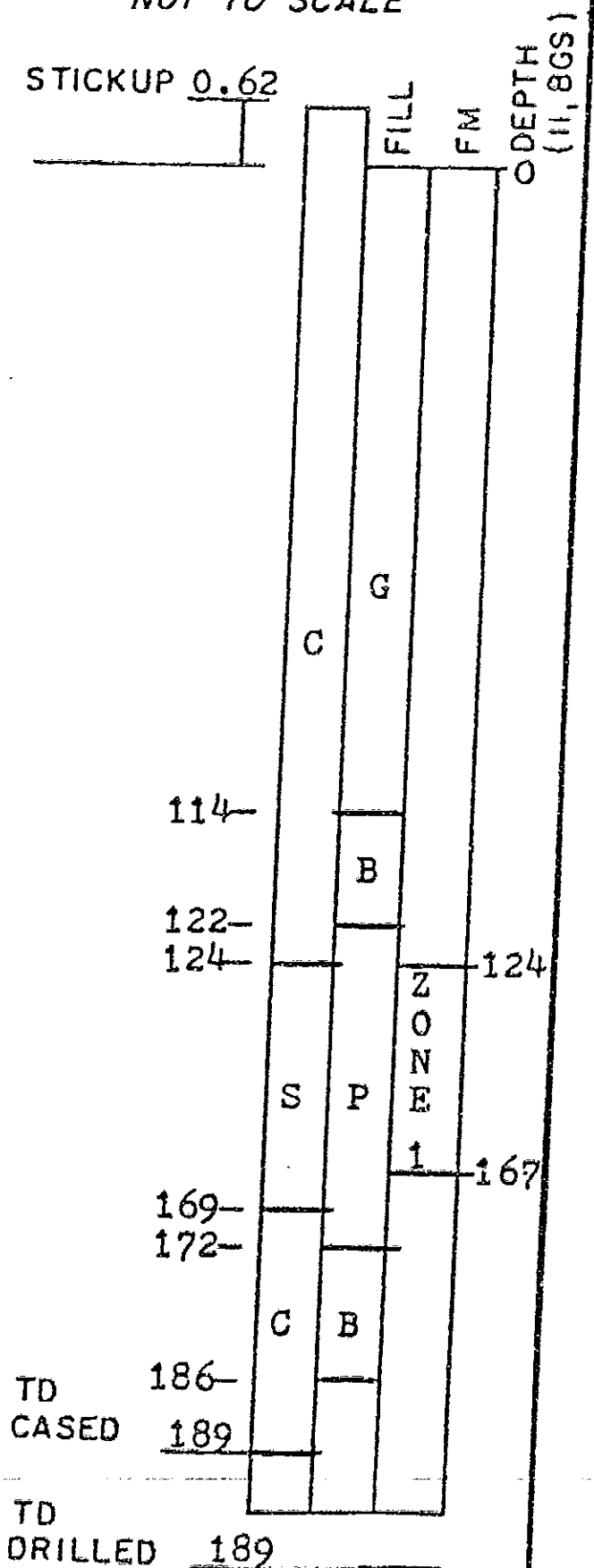
WATER ENCOUNTERED AT N/A

CONSTRUCTION

CASING SCHEDULE 189 - 169' = 6" Blank PVC(C),
169 - 124' = 6" 50 Slot Screen(S), 124 - (+)2' =
6" Blank PVC(C)
 BACKFILL SCHEDULE 186 - 172' = Bentonite(B),
172 - 122' = Stabilizer(P), 122 - 114' = Bentonite
(B), 114 - 0' = Grout(G)

GEOPHYSICAL LOGS N-N, Gamma, Resistance,
Spontaneous Potential, Caliper, Deviation

COMMENTS Sluffing problems during drilling.
Cracked or separated screen, Stabilizer entered
well. Well to be used as an observation well.
Centralizer placed at top of screen.



TD 186
 CASED 189
 TD 189
 DRILLED 189

BILLINGS AND ASSOCIATES

KIMBERLING CITY, MISSOURI

BORING No. 613
 DEPTH DRILLED 93
 SCREENED
 FORMATION(S) Zone 3

CLIENT UNC
 LOCATION Churchrock
 PROJECT No. 832-6-1
 SURVEY DATA (coord.) Same as Gallup 3
 TOP OF PIPE ELEV. _____ GROUND ELEV. _____

STATIC W.L. 6928.60
taken 830828
 DEVELOPMENT Circulation
of clear water, Air
Lift, Bail/Surge,
Air Jet, Bail

DRILLING

DRILLER La Madera RIG TYPE Failing 1250
 START 8-11-83 END 8-11-83
 BIT SCHEDULE 0 - 93' = 11.25" Down hole

NOT TO SCALE

DRILLING FLUIDS Revert

WATER ENCOUNTERED AT N/A

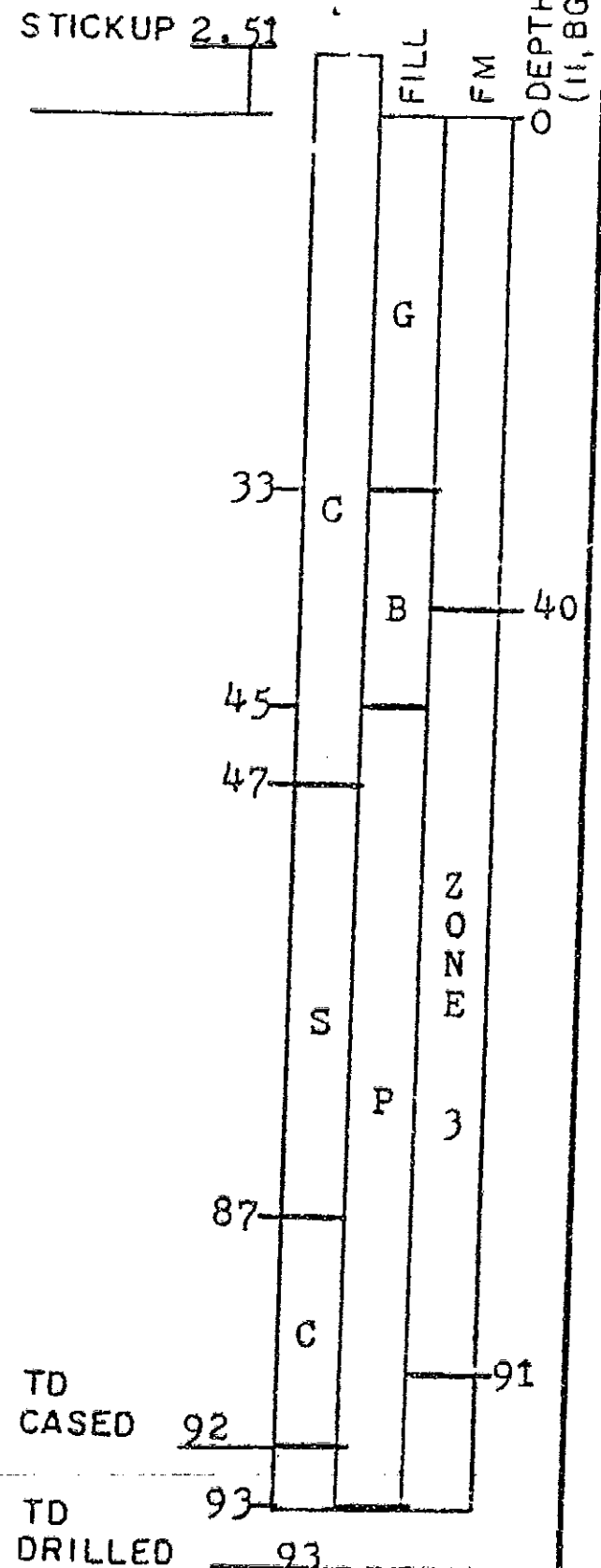
CONSTRUCTION

CASING SCHEDULE 92 - 87' = 6" Blank PVC(C),
87 - 47' = 6" 50 Slot PVC Screen(S),
47 - (+)2' = 6" Blank PVC(C)

BACKFILL SCHEDULE 93 - 45' = Stabilizer(P),
45 - 33' = Bentonite(B), 33 - 0' = Grout(G)

GEOPHYSICAL LOGS N-N, Gamma, Resistance,
Spontaneous Potential, Caliper, Deviation

COMMENTS Difficulty in logging and taping.
Swelling at app. 62 ft. No bottom bentonite
placed because of potential trouble with
swelling. Stabilizer was placed and passed
swelling point. Centralizer at top of screen.



APPENDIX D
PUMPING DATA

Well 606

Index	Time (min)	Pressure (psi)	Drawdown (psi)	Formation Discharge (gpm)	Adjusted Time (min)	S/Q (psi/gpm)	Remarks
1	2	33.05	0.58	0.90	2.0	0.64	Static=33.63 (psi)
2	5	32.49	1.14	0.87	5.1	1.32	
3	8	32.04	1.59	0.90	7.8	1.77	
4	11	31.76	1.87	0.80	12.7	2.34	
5	17	31.34	2.29	0.80	18.2	2.86	
6	21	31.16	2.47	0.77	23.4	3.19	
7	25	30.97	2.66	0.80	25.5	3.32	
8	30	30.77	2.86	0.82	29.4	3.49	
9	35	30.60	3.03	0.84	33.1	3.61	
10	40	30.50	3.13	0.82	40.4	3.82	
11	50	30.43	3.20	0.74	59.8	4.32	
12	60	30.08	3.55	0.88	50.0	4.03	
13	70	29.87	3.76	0.89	60.9	4.22	
14	80	29.71	3.92	0.89	72.0	4.40	Increase Q
15	85	29.38	4.25	1.10	45.9	3.86	
16	91	27.77	5.86	2.03	20.2	2.88	
17	96	26.92	6.71	2.06	27.9	3.26	
18	100	26.41	7.22	1.98	37.0	3.66	
19	105	25.93	7.70	1.98	43.0	3.89	
20	110	25.53	8.10	1.96	50.3	4.13	
21	120	24.90	8.73	1.96	61.9	4.45	
22	130	24.43	9.20	1.94	74.7	4.74	
23	140	24.01	9.62	1.93	86.4	4.98	Increase Q
24	145	21.56	12.07	3.72	22.6	3.24	
25	150	19.76	13.87	3.70	32.8	3.75	
26	160	17.84	15.79	3.64	49.4	4.34	
27	170	16.27	17.36	3.69	60.9	4.70	
28	180	15.05	18.58	3.60	77.0	5.16	
29	190	14.02	19.61	3.52	92.6	5.57	
30	200	13.18	20.45	3.48	105.6	5.88	Stop Pumping

Well 607

Index	Time (min)	Pressure (psi)	Drawdown (psi)	Formation Discharge (gpm)	Adjusted Time (min)	S/Q (psi/gpm)	Remarks	
2	5	12.28	1.93	0.68	2.9	2.84	Static=14.21 (psi)	
3	7	12.13	2.08	0.68	4.9	3.05		
4	10	12.02	2.19	0.64	8.4	3.40		
5	15	11.79	2.42	0.68	12.7	3.58		
6	17	11.69	2.52	0.70	13.6	3.58		
7	21	11.55	2.66	0.70	18.2	3.81		
8	25	11.53	2.68	0.74	20.4	3.64		
9	33	11.32	2.89	0.73	29.2	3.96		
10	35	11.29	2.92	0.73	31.1	3.99		
11	38	11.24	2.97	0.69	39.3	4.29		
12	40	11.23	2.98	0.80	26.9	3.72		
13	45	11.17	3.04	0.60	67.9	5.11		
14	50	10.97	3.24	0.92	26.4	3.51		
15	55	10.94	3.27	0.80	46.2	4.07		
16	61	10.91	3.30	0.76	58.4	4.34		
17	65	10.90	3.31	0.77	60.0	4.31		
18	70	10.89	3.32	0.76	65.6	4.34		
19	80	10.88	3.33	0.75	78.8	4.46		
20	90	10.85	3.36	0.73	92.3	4.59		
21	100	10.82	3.39	0.73	101.1	4.64		Increase Q
22	103	10.34	3.87	0.83	66.9	4.64		
23	106	9.55	4.66	1.10	34.3	4.23		
24	110	8.72	5.49	1.32	30.2	4.15		
25	118	7.60	6.61	1.47	38.6	4.50		
26	125	7.01	7.20	1.58	43.0	4.55		
27	132	6.59	7.62	1.61	51.6	4.73		
28	140	6.43	7.78	1.59	64.1	4.89		
29	150	5.58	8.63	1.71	66.1	5.04		
30	155	5.46	8.75	1.71	73.2	5.12		

Well 607 (continued)

Index	Time (min)	Pressure (psi)	Drawdown (psi)	Formation Discharge (gpm)	Adjusted Time (min)	S/Q (psi/gpm)	Remarks
31	160	5.42	8.79	1.74	76.2	5.06	
32	165	5.36	8.85	1.73	84.4	5.13	
33	170	5.31	8.90	1.73	89.4	5.14	Increase Q
34	174	4.88	9.33	2.64	31.8	3.54	
35	176	4.70	9.51	2.36	52.2	4.02	
36	183	4.09	10.12	2.54	53.7	3.99	
37	190	3.18	11.03	2.35	77.6	4.69	
38	200	2.24	11.97	2.37	87.7	5.06	
39	211	1.50	12.71	2.38	99.9	5.35	
40	220	1.03	13.18	2.44	103.9	5.41	
41	230	0.59	13.62	2.46	113.5	5.53	Stop Pumping

Well 608

Index	Time (min)	Pressure (psi)	Drawdown (psi)	Formation Discharge (gpm)	Adjusted Time (min)	S/Q (psi/gpm)	Remarks
1	1	19.46	0.42	0.48	1.0	0.88	Static=19.88 (psi)
2	2	19.31	0.57	1.21	1.3	0.47	
3	3	19.20	0.68	1.28	2.2	0.53	
4	5	19.08	0.80	1.40	4.0	0.57	
5	8	18.98	0.90	1.60	6.3	0.56	
6	11	18.98	0.90	1.50	10.2	0.60	
7	15	19.02	0.86	1.43	15.0	0.60	
8	20	18.90	0.98	1.47	19.1	0.67	
9	25	18.87	1.01	1.54	22.4	0.65	
10	30	18.85	1.03	1.53	28.1	0.67	
11	35	18.84	1.04	1.53	33.0	0.68	
12	40	18.83	1.05	1.49	40.2	0.70	
13	45	18.82	1.06	1.45	47.6	0.73	
14	50	18.77	1.11	1.51	47.5	0.73	
15	55	18.74	1.14	1.60	46.3	0.71	
16	60	18.73	1.15	1.57	54.9	0.73	Increase Q
17	63	17.53	2.35	2.97	14.4	0.79	
18	65	17.23	2.65	3.86	11.1	0.69	
19	70	16.97	2.91	4.09	18.3	0.71	
20	75	16.81	3.07	4.09	25.4	0.75	
21	80	16.67	3.21	4.34	28.5	0.74	
22	90	16.47	3.41	4.07	44.9	0.84	
23	100	16.33	3.55	4.22	52.4	0.84	
24	111	16.19	3.69	4.19	65.5	0.88	
25	120	16.08	3.80	4.21	74.4	0.90	Increase Q
26	123	14.60	5.28	5.67	33.6	0.93	
27	126	14.20	5.68	6.51	29.4	0.87	
28	130	12.97	6.91	7.48	28.4	0.92	
29	135	12.59	7.29	8.32	30.7	0.88	
30	140	12.35	7.53	8.22	39.8	0.92	

Well 608 (continued)

Index	Time (min)	Pressure (psi)	Drawdown (psi)	Formation Discharge (gpm)	Adjusted Time (min)	S/Q (psi/gpm)	Remarks
31	145	12.15	7.73	8.24	46.5	0.94	
32	150	11.97	7.91	8.28	52.6	0.96	
33	155	11.81	8.07	8.25	59.5	0.98	
34	162	11.62	8.26	8.25	67.8	1.00	
35	170	11.41	8.47	8.26	76.8	1.03	
36	180	11.18	8.70	8.25	88.3	1.05	Increase Q
37	183	8.80	11.08	11.19	37.3	0.99	
38	186	7.78	12.10	12.61	33.8	0.96	
39	190	6.92	12.96	12.92	40.7	1.00	
40	195	6.13	13.75	13.06	48.8	1.05	
41	200	5.47	14.41	13.22	55.2	1.09	
42	205	4.84	15.04	13.03	64.9	1.15	
43	210	4.20	15.68	13.13	70.1	1.19	
44	215	3.53	16.35	13.07	77.6	1.25	
45	220	2.80	17.08	12.98	85.4	1.32	
46	225	1.98	17.90	12.86	93.5	1.39	
47	230	1.00	18.88	12.73	102.0	1.48	
48	235	-0.22	20.10	12.53	112.3	1.60	
49	240	-1.58	21.46	12.33	122.7	1.74	Stop Pumping

Well 609

Index	Time (min)	Pressure (psi)	Drawdown (psi)	Formation Discharge (gpm)	Adjusted Time (min)	S/Q (psi/gpm)	Remarks
1	1	24.21	0.54	1.63	1.0	0.33	Static=24.75 (psi)
2	3	24.32	0.43	1.01	3.8	0.43	
3	5	24.33	0.42	0.76	8.0	0.55	
4	10	24.25	0.50	0.99	9.9	0.50	
5	15	24.28	0.47	0.88	17.4	0.54	
6	20	24.38	0.37	0.62	41.1	0.60	
7	25	24.40	0.35	0.45	88.4	0.77	
8	30	24.24	0.51	0.79	23.7	0.65	
9	40	24.29	0.46	0.83	34.6	0.55	
10	50	24.28	0.47	0.79	50.5	0.60	
11	60	24.26	0.49	0.75	65.3	0.65	Increase Q
12	65	23.46	1.29	2.35	11.6	0.55	
13	71	23.37	1.38	2.64	17.9	0.52	
14	75	23.34	1.41	2.65	22.9	0.53	
15	80	23.32	1.43	2.63	29.5	0.54	
16	85	23.29	1.46	2.64	34.9	0.55	
17	92	23.27	1.48	2.62	43.6	0.56	
18	95	23.27	1.48	2.63	46.2	0.56	
19	100	23.26	1.49	2.59	53.6	0.57	
20	105	23.24	1.51	2.65	55.8	0.57	
21	111	23.24	1.51	2.57	67.5	0.59	
22	115	23.23	1.52	2.59	69.1	0.59	
23	120	23.22	1.53	2.61	72.8	0.59	Increase Q
24	123	21.90	2.85	5.12	15.6	0.56	
25	125	21.87	2.88	5.46	17.7	0.53	
26	130	21.58	3.17	5.59	26.0	0.57	
27	135	21.43	3.32	5.81	31.3	0.57	
28	140	21.34	3.41	5.85	38.0	0.58	
29	145	21.26	3.49	5.83	44.8	0.60	
30	150	21.20	3.55	5.87	50.4	0.61	

Well 609 (continued)

Index	Time (min)	Pressure (psi)	Drawdown (psi)	Formation Discharge (gpm)	Adjusted Time (min)	S/Q (psi/gpm)	Remarks
31	155	21.14	3.61	5.85	57.0	0.62	
32	160	21.08	3.67	5.85	62.8	0.63	
33	165	21.03	3.72	5.87	67.7	0.63	
34	170	20.97	3.78	5.87	73.7	0.64	
35	175	20.93	3.82	5.82	81.1	0.66	
36	180	21.03	3.72	5.68	92.5	0.66	Increase Q
37	183	19.36	5.39	8.01	34.7	0.67	
38	185	19.01	5.74	9.24	27.3	0.62	
39	190	18.64	6.11	9.50	37.4	0.64	
40	195	18.44	6.31	9.60	45.4	0.66	
41	200	18.30	6.45	9.60	53.3	0.67	
42	210	18.06	6.69	9.62	66.8	0.70	
43	220	17.87	6.88	9.63	79.1	0.71	
44	230	17.70	7.05	9.64	90.9	0.73	
45	240	17.7	7.20	9.67	101.8	0.74	Increase Q
46	245	15.24	9.51	13.06	48.5	0.73	
47	250	14.69	10.06	14.16	49.6	0.71	
48	261	14.08	10.67	14.37	67.7	0.74	
49	270	13.75	11.00	14.44	80.0	0.76	
50	281	13.41	11.34	14.39	95.3	0.79	
51	290	13.17	11.58	14.41	106.0	0.80	
52	300	12.93	11.82	14.44	117.3	0.82	
53	311	12.67	12.08	14.45	129.9	0.84	
54	320	12.47	12.28	14.42	140.8	0.85	
55	330	12.26	12.49	14.38	153.1	0.87	
56	340	12.05	12.70	14.43	162.2	0.88	Stop Pumping

Well 610 (#1)

Index	Time (min)	Pressure (psi)	Drawdown (psi)	Formation Discharge (gpm)	Adjusted Time (min)	S/Q (psi/gpm)	Remarks
1	30	19.36	2.22	3.32	30.0	0.67	Static=21.58 (psi)
2	35	19.20	2.38	5.95	14.8	0.40	
3	40	19.13	2.45	5.90	21.9	0.42	
4	45	19.08	2.50	5.85	28.3	0.43	
5	55	19.06	2.52	5.66	41.1	0.44	
6	60	19.07	2.51	5.51	49.4	0.46	Increase Q
7	65	18.56	3.02	6.90	33.3	0.44	Stop Pumping

Well 610 (#2)

Index	Time (min)	Pressure (psi)	Drawdown (psi)	Formation Discharge (gpm)	Adjusted Time (min)	S/Q (psi/gpm)	Remarks
1	6	18.85	2.55	6.50	6.0	0.39	Static=21.40 (psi)
2	10	18.60	2.80	7.54	8.8	0.37	
3	15	18.40	3.00	7.60	13.9	0.39	
4	20	18.27	3.13	7.66	18.7	0.41	
5	26	18.18	3.22	7.67	24.8	0.42	
6	30	18.11	3.29	7.67	28.8	0.43	Increase Q
7	32	17.42	3.98	8.75	22.0	0.46	
8	34	17.09	4.31	10.37	17.0	0.42	
9	37	16.91	4.49	10.53	22.6	0.43	
10	40	16.75	4.65	10.71	24.8	0.43	
11	45	16.58	4.82	10.74	31.0	0.45	
12	50	16.44	4.96	10.74	36.8	0.46	
13	55	16.34	5.06	10.84	41.5	0.47	
14	60	16.25	5.15	10.75	47.9	0.48	
15	70	16.15	5.25	10.67	59.1	0.49	
16	80	16.04	5.36	10.57	70.5	0.51	Increase Q
17	85	14.70	6.70	13.32	43.1	0.50	
18	90	14.41	6.99	14.01	46.6	0.50	
19	100	14.03	7.37	14.08	61.0	0.52	
20	110	13.80	7.60	14.11	73.2	0.54	
21	120	13.61	7.79	14.08	85.2	0.55	
22	130	13.44	7.96	14.05	96.8	0.57	Stop Pumping

Well 611

Index	Time (min)	Pressure (psi)	Drawdown (psi)	Formation Discharge (gpm)	Adjusted Time (min)	S/Q (psi/gpm)	Remarks
1	5	26.78	5.74	2.40	5.0	2.39	Static=32.52 (psi)
2	10	28.58	3.94	2.07	11.2	1.91	
3	20	29.98	2.54	1.19	36.3	2.14	
4	30	29.96	2.56	1.01	54.6	2.52	
5	40	30.07	2.45	0.94	69.3	2.60	
6	50	29.81	2.71	1.00	66.4	2.70	
7	55	29.74	2.78	1.06	62.2	2.62	
8	60	29.71	2.81	1.08	64.9	2.60	
9	65	29.70	2.82	1.09	69.2	2.58	
10	70	29.70	2.82	1.08	78.0	2.61	Increase Q
11	75	27.80	4.72	1.53	36.1	3.07	
12	80	26.64	5.88	2.29	22.3	2.57	
13	90	25.78	6.74	2.62	32.5	2.57	
14	100	25.34	7.18	2.77	42.3	2.59	
15	110	24.78	7.74	2.95	49.5	2.63	
16	120	24.52	8.00	3.07	57.4	2.60	
17	130	24.41	8.11	3.09	69.0	2.63	Increase Q
18	135	22.07	10.45	3.78	45.6	2.77	
19	147	20.00	12.52	4.69	47.0	2.67	
20	160	19.68	12.84	4.97	59.3	2.58	
21	170	19.69	12.83	4.85	75.8	2.64	
22	181	19.40	13.12	4.87	87.7	2.69	
23	190	19.22	13.30	4.90	96.5	2.72	
24	195	19.13	13.39	4.93	100.3	2.72	Increase Q
25	205	13.73	18.79	7.63	47.6	2.46	
26	215	11.90	20.62	8.30	55.6	2.48	
27	225	9.77	22.75	8.52	67.0	2.67	
28	235	8.33	24.19	9.03	71.7	2.68	
29	245	7.84	24.68	8.99	86.4	2.75	
30	255	7.56	24.96	8.94	100.1	2.79	Stop Pumping

Well 613

Index	Time (min)	Pressure (psi)	Drawdown (psi)	Formation Discharge (gpm)	Adjusted Time (min)	S/Q (psi/gpm)	Remarks
1	4	21.04	0.60	2.81	4.0	0.213	Static=21.64 (psi)
2	6	21.04	0.60	3.05	5.5	0.197	
3	9	21.03	0.61	2.92	9.0	0.209	
4	12	20.99	0.65	3.03	11.4	0.215	
5	17	20.98	0.66	3.07	16.2	0.215	
6	22	20.97	0.67	3.01	21.9	0.222	
7	30	20.95	0.69	3.03	29.6	0.228	
8	40	20.93	0.71	3.02	39.8	0.235	
9	50	20.94	0.70	3.02	49.8	0.232	
10	60	20.93	0.71	3.01	60.3	0.236	
11	70	20.92	0.72	3.01	70.2	0.239	Increase Q
12	76	19.89	1.75	7.45	16.7	0.235	
13	80	19.83	1.81	8.18	19.8	0.221	
14	90	19.75	1.89	8.19	33.7	0.231	
15	100	19.71	1.93	8.18	45.8	0.236	
16	110	19.67	1.97	8.17	57.4	0.241	
17	121	19.64	2.00	8.17	69.3	0.245	
18	130	19.62	2.02	8.17	79.1	0.247	Increase Q
19	135	18.81	2.83	11.87	35.0	0.238	
20	140	18.75	2.89	12.33	41.7	0.234	
21	150	18.69	2.95	12.27	58.0	0.240	
22	161	18.64	3.00	12.30	72.0	0.244	
23	170	18.59	3.05	12.29	83.1	0.248	
24	180	18.55	3.09	12.29	94.7	0.251	
25	190	18.53	3.11	12.30	105.6	0.253	
26	195	17.77	3.87	15.76	56.3	0.246	
27	200	17.76	3.88	15.87	66.8	0.244	
28	210	17.66	3.98	15.94	83.1	0.250	
29	220	17.60	4.04	15.85	98.4	0.255	
30	230	17.59	4.05	15.94	109.6	0.254	

Well 613 (continued)

Index	Time (min)	Pressure (psi)	Drawdown (psi)	Formation Discharge (gpm)	Adjusted Time (min)	S/Q (psi/gpm)	Remarks
31	240	17.55	4.09	15.90	122.5	0.257	
32	250	17.50	4.14	15.90	134.1	0.260	Increase Q
33	255	16.24	5.40	20.99	62.3	0.257	
34	260	16.16	5.48	22.11	66.1	0.248	
35	271	16.05	5.59	22.02	89.0	0.254	
36	280	15.99	5.65	22.00	103.2	0.257	
37	290	15.94	5.70	22.04	116.7	0.259	
38	300	15.87	5.77	22.04	129.6	0.262	
39	310	15.82	5.82	22.04	142.1	0.264	Increase Q
40	315	14.70	6.94	26.95	79.9	0.258	
41	320	14.61	7.03	27.59	87.4	0.255	
42	330	14.49	7.15	27.58	107.7	0.259	
43	340	14.42	7.22	27.5	123.4	0.262	
44	350	14.36	7.28	27.5	138.2	0.265	
45	362	14.28	7.36	27.53	153.7	0.267	
46	370	14.25	7.39	27.55	163.2	0.268	Stop Pumping

7

APPENDIX E
RECOVERY DATA

Well 606

Actual Recovery Time, min	Pressure Reading, psi	Residual Drawdown, psi	Discharge due to Wellbore Effect, gpm	Adjusted Recovery Time, min	Sternberg Method, Modified t/t'	Specific Drawdown, psi/gpm	Log of Adjusted Pumping Time
3	14.72	18.91	1.49	-14.17	-9.33	12.67	8.57
5	15.65	17.98	1.35	-12.17	-11.02	13.30	8.79
7	16.55	17.08	1.31	-10.17	-13.39	13.05	8.59
10	17.85	15.78	1.26	-7.17	-19.40	12.52	8.38
15	20.21	13.42	1.37	-2.17	-66.31	9.78	7.32
20	22.69	10.94	1.44	2.83	52.80	7.58	6.80
25	24.62	9.01	1.12	7.83	19.70	8.03	8.09
30	26.11	7.52	0.87	12.83	12.41	8.68	9.57
40	28.13	5.50	0.59	22.83	7.41	9.36	11.77
50	29.37	4.26	0.36	32.83	5.46	11.81	16.07
62	30.29	3.34	0.22	44.83	4.27	14.98	21.65
75	30.92	2.71	0.14	57.83	3.53	19.23	28.96
90	31.39	2.24	0.09	72.83	3.01	24.58	38.10
100	31.62	2.01	0.07	82.83	2.77	30.05	47.20
110	31.81	1.82	0.06	92.83	2.58	32.94	52.59
131	32.10	1.53	0.04	113.83	2.29	38.10	62.13
150	32.29	1.34	0.03	132.83	2.10	46.08	76.06

Well 607

Actual Recovery Time, min	Pressure Reading, psi	Residual Drawdown, psi	Discharge due to Wellbore Effect, gpm	Adjusted Recovery Time, min	Sternberg Method, Modified t/t'	Specific Drawdown, psi/gpm	Log _e of Adjusted Pumping Time
2	1.36	12.85	1.12	-13.05	-12.70	11.48	9.62
3	1.74	12.47	1.11	-12.05	-13.84	11.28	9.28
4	2.11	12.10	1.08	-11.05	-15.19	11.25	9.19
7	3.15	11.06	1.01	-8.05	-21.22	10.97	9.01
10	4.00	10.21	0.82	-5.05	-34.42	12.39	10.19
15	4.67	9.54	0.39	-0.05	-3754.93	24.48	18.02
21	5.44	8.77	0.37	5.95	31.04	23.50	16.55
25	6.81	7.40	1.00	9.95	18.97	7.43	6.70
30	8.13	6.08	0.77	14.95	12.96	7.92	8.41
40	9.90	4.31	0.51	24.95	8.17	8.37	10.87
55	11.30	2.91	0.27	39.95	5.48	10.72	16.31
60	11.59	2.62	0.17	44.95	4.98	15.53	24.17
70	12.01	2.20	0.12	54.95	4.25	18.01	29.24
80	12.31	1.90	0.09	64.95	3.75	21.78	36.56
90	12.53	1.68	0.06	74.95	3.39	26.26	45.12
105	12.76	1.45	0.04	89.95	2.99	32.52	56.84
120	12.92	1.29	0.03	104.95	2.70	41.59	72.93
137	13.06	1.15	0.02	121.95	2.47	48.02	84.65
150	13.15	1.06	0.02	134.95	2.32	52.65	93.46
165	13.22	0.99	0.01	149.95	2.19	72.95	127.47
190	13.33	0.88	0.01	174.95	2.02	68.78	120.56

Well 608

Actual Recovery Time, min	Pressure Reading, psi	Residual Drawdown, psi	Discharge due to Wellbore Effect, gpm	Adjusted Recovery Time, min	Sternberg Method, Modified t/t'	Specific Drawdown, psi/gpm	Log _e of Adjusted Pumping Time
1	2.42	17.46	11.63	-3.84	-39.87	1.50	5.10
3	8.25	11.63	8.48	-1.84	-84.19	1.37	6.67
6	13.16	6.72	4.76	1.16	137.02	1.41	10.37
10	15.72	4.16	1.86	5.16	31.48	2.24	21.66
15	16.73	3.15	0.59	10.16	16.47	5.36	55.61
25	17.50	2.38	0.22	20.16	8.80	10.63	110.87
31	17.74	2.14	0.12	26.16	7.01	18.40	189.05
35	17.87	2.01	0.09	30.16	6.21	21.27	217.15
40	18.00	1.88	0.08	35.16	5.47	24.86	251.14
54	18.30	1.58	0.06	49.16	4.20	25.36	254.69
70	18.48	1.40	0.03	65.16	3.41	42.79	410.55
81	18.60	1.28	0.03	76.16	3.06	40.35	384.76
93	18.70	1.18	0.02	88.16	2.78	48.69	458.38
102	18.76	1.12	0.02	97.16	2.62	57.77	537.12
115	18.84	1.04	0.02	110.16	2.43	58.12	534.47
137	18.96	0.92	0.02	132.16	2.19	58.00	530.97

Well 609

Actual Recovery Time, min	Pressure Reading, psi	Residual Drawdown, psi	Discharge due to Wellbore Effect, gpm	Adjusted Recovery Time, min	Sternberg Method, Modified t/t'	Specific Drawdown, psi/gpm	Log _e of Adjusted Pumping Time
1	14.94	9.81	8.40	-1.45	-143.10	1.17	8.75
3	19.08	5.67	6.02	0.55	383.50	0.94	10.87
5	20.85	3.90	2.57	2.55	83.18	1.52	22.74
7	21.65	3.10	1.16	4.55	47.04	2.67	45.00
10	22.25	2.50	0.58	7.55	28.74	4.30	78.48
15	22.78	1.97	0.31	12.55	17.68	6.39	125.69
20	22.99	1.76	0.12	17.55	12.93	14.41	279.75
25	23.21	1.54	0.13	22.55	10.28	12.04	242.01
30	23.34	1.41	0.08	27.55	8.60	18.65	375.87
35	23.44	1.31	0.06	32.55	7.43	22.52	453.33
40	23.52	1.23	0.05	37.55	6.58	26.44	529.90
45	23.59	1.16	0.04	42.55	5.92	28.49	569.94
55	23.70	1.05	0.03	52.55	4.98	32.82	651.42
65	23.78	0.97	0.02	62.55	4.35	41.70	815.45
75	23.84	0.91	0.02	72.55	3.89	52.16	1000.12
87	23.91	0.84	0.02	84.55	3.48	49.52	940.94
95	23.95	0.80	0.01	92.55	3.26	55.02	1039.45
105	24.00	0.75	0.01	102.55	3.04	51.58	975.85
115	24.03	0.72	0.01	112.55	2.86	82.53	1532.22
126	24.07	0.68	0.01	123.55	2.69	64.31	1190.40
140	24.11	0.64	0.01	137.55	2.52	77.03	1410.51
152	24.15	0.60	0.01	149.55	2.40	61.90	1142.85
165	24.17	0.58	0.00	162.55	2.29	129.64	2335.08
195	24.22	0.53	0.00	192.55	2.09	109.36	1911.02

Well 610

Actual Recovery Time, min	Pressure Reading, psi	Residual Drawdown, psi	Discharge due to Wellbore Effect, gpm	Adjusted Recovery Time, min	Sternberg Method, Modified t/t'	Specific Drawdown, psi/gpm	Log _e of Adjusted Pumping Time
2.25	20.22	1.36	2.15	1.05	54.80	0.63	9.83
3.25	20.42	1.16	0.58	2.05	28.60	1.99	33.72
4.25	20.55	1.03	0.38	3.05	19.56	2.72	46.30
7.25	20.77	0.81	0.21	6.05	10.36	3.80	64.39
10.25	20.90	0.68	0.13	9.05	7.26	5.40	92.00
14.25	21.03	0.55	0.09	13.05	5.34	5.82	103.23
18.25	21.07	0.51	0.03	17.05	4.32	17.54	290.14
22.25	21.13	0.45	0.04	21.05	3.69	10.32	172.19
37.25	21.24	0.34	0.02	36.05	2.57	15.94	252.35
50.25	21.33	0.25	0.02	49.05	2.16	12.42	217.20
72.25	21.38	0.20	0.01	71.05	1.80	30.26	500.89
84.25	21.40	0.18	0.00	83.05	1.68	37.14	604.75

Well 611

Actual Recovery Time, min	Pressure Reading, psi	Residual Drawdown, psi	Discharge due to Wellbore Effect, gpm	Adjusted Recovery Time, min	Sternberg Method, Modified t/t'	Specific Drawdown, psi/gpm	Log of Adjusted Pumping Time
4	13.29	19.23	4.17	-3.52	-46.74	4.62	8.39
8	16.69	15.83	2.47	0.48	355.20	6.40	12.01
16	23.64	8.88	2.53	8.48	20.86	3.51	10.04
25	27.02	5.50	1.09	17.48	10.63	5.04	18.23
35	28.38	4.14	0.40	27.48	7.12	10.47	39.77
45	29.03	3.49	0.19	37.48	5.49	18.46	69.73
55	29.40	3.12	0.11	47.48	4.54	29.00	106.40
65	29.68	2.84	0.08	57.48	3.93	34.88	125.33
80	29.99	2.53	0.06	72.48	3.32	42.10	146.92
95	30.22	2.30	0.04	87.48	2.92	51.58	175.10
110	30.40	2.12	0.03	102.48	2.64	60.75	201.02
125	30.56	1.96	0.03	117.48	2.43	63.19	205.85
140	30.69	1.83	0.03	132.48	2.27	72.61	232.51

Well 613

Actual Recovery Time, min	Pressure Reading, psi	Residual Drawdown, psi	Discharge due to Wellbore Effect, gpm	Adjusted Recovery Time, min	Sternberg Method, Modified t/t'	Specific Drawdown, psi/gpm	Log of Adjusted Pumping Time
1	17.90	3.74	10.61	0.26	945.62	0.35	13.25
2	18.85	2.79	2.76	1.26	198.50	1.01	46.71
3	19.21	2.43	1.05	2.26	111.28	2.32	111.71
5	19.57	2.07	0.52	4.26	59.56	3.95	192.96
7	19.77	1.87	0.29	6.26	40.86	6.43	313.30
10	19.96	1.68	0.18	9.26	27.95	9.12	439.94
15	20.16	1.48	0.12	14.26	18.51	12.72	602.78
20	20.29	1.35	0.08	19.26	13.96	17.86	829.57
25	20.38	1.26	0.05	24.26	11.29	24.07	1092.71
30	20.46	1.18	0.05	29.26	9.53	25.36	1135.84
35	20.52	1.12	0.03	34.26	8.29	32.10	1412.04
46	20.62	1.02	0.03	45.26	6.52	38.58	1634.74
60	20.73	0.91	0.02	59.26	5.21	39.83	1649.93
75	20.81	0.83	0.02	74.26	4.36	53.51	2150.38
90	20.87	0.77	0.01	89.26	3.80	66.20	2580.59
110	20.95	0.69	0.01	109.26	3.29	59.32	2285.73
130	21.02	0.62	0.01	129.26	2.93	60.92	2350.51
155	21.08	0.56	0.01	154.26	2.62	80.24	3052.37
200	21.22	0.42	0.01	199.26	2.25	46.42	1976.04

APPENDIX F
OBSERVATION WELL DATA USED
FOR ANALYSIS

Well 612 (Observation)
Well 607 (Pumping)

$r = 11.5$ ft.

Time (minutes)	Depth to Water (ft.)	Remarks
0	100.99	Static, Start Pump
7	100.99	
25	101.03	
37.5	101.05	
56	101.17	
65	101.23	
78	101.31	
88	101.37	
99.5	101.43	
109	101.49	
120	101.55	
130	101.61	
140	101.70	
150	101.80	
163	101.94	
178	102.10	
197	102.31	
210	102.45	
220	102.58	
230		Stop Pumping
231	102.72	
245	102.91	
255	103.00	
268	103.13	
285	103.15	
295	103.13	
310	103.08	
333	102.93	
360	102.73	
395	102.48	
420	102.34	

Well 505-B (Observation)
Well 609 (Pumping)

r = 102 ft.

Time (minutes)	Depth to Water (ft.)	Remarks
-5	40.43	Static
87	40.43	
135	40.42	
198	40.44	
212	40.45	
232	40.46	
255	40.50	
283	40.56	
295	40.59	
307	40.61	
327	40.66	
337	40.67	
340		Stop Pumping
345	40.70	
355	40.72	
365	40.75	
384	40.80	
407	40.84	
435	40.86	
467	40.88	
488	40.87	
507	40.86	
534	40.86	

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