No. ______

CANADA
DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
TOPICAL REPORT NO. 49

AN AQUIFER TEST, ST. LAZARE, VAUDREUIL MAP-AREA, QUEBEC

BY
J. J. TREMBLAY

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An Aquifer Test in a Buried Valley Near St. Lazare Vaudreuil Map-area, Quebec

Purpose

This study was undertaken to determine quantitative information on a flowing artesian aquifer, occurring in a buried valley, which was outlined by the Geophysical section of the Geological Survey. Such work was to give information on the recharge, transmissibility, storage coefficient, boundary effects and leakage, and direction of flow.

Locality

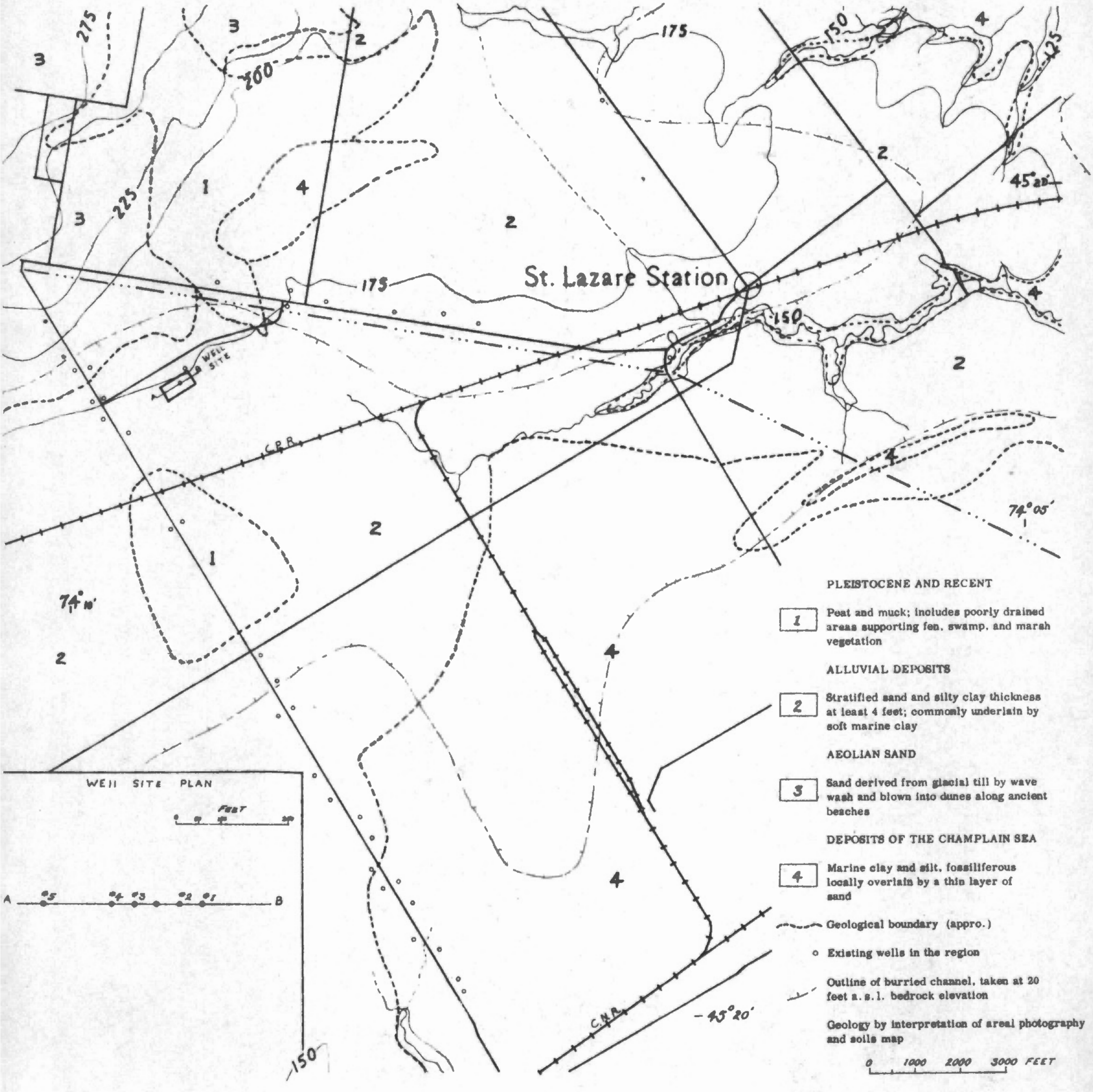
The well site chosen was in the county of Soulanges, at latitude 22 degrees 37 minutes north and longitude 74 degrees 09 minutes 18 seconds west, which is approximately 3 miles west of St. Lazare Station and 8 1/2 miles northwest from the village of Cedars.

Geology

Along with this report is a geological map outlining the surficial geology. The area is a part of the St. Lawrence Lowlands. The well site is situated in a regional depression of the bedrock extending easterly across the east half of the Vaudreuil map sheet; depths to bedrock of a hundred feet below sea level are common in this depression.

At the site of the test well the succession is as follows:

Elev. a.s.l. in feet	Material
171	Alluvial sand
165	Leda clay


St. Lazare Station
C.P.R.
C.N.R.
WELL SITE
275
200
225
175
150
125
45°25'
74°05'
74°10'
45°20'
1
2
3
4
WELL SITE PLAN
FEET
A
B
1
2
3
4
5
PLEISTOCENE AND RECENT
1 Peat and muck; includes poorly drained areas supporting fen, swamp, and marsh vegetation
ALLUVIAL DEPOSITS
2 Stratified sand and silty clay thickness at least 4 feet; commonly underlain by soft marine clay
AEOLIAN SAND
3 Sand derived from glacial till by wave wash and blown into dunes along ancient beaches
DEPOSITS OF THE CHAMPLAIN SEA
4 Marine clay and silt, fossiliferous locally overlain by a thin layer of sand
Geological boundary (appro.)
Existing wells in the region
Outline of burried channel, taken at 20 feet a. s. l. bedrock elevation
Geology by interpretation of areal photography and soils map
0 1000 2000 3000 FEET

Elev. a.s.l. in feet	Material
130	Yoldia clay
95	Varved clay
87	Till
82	Glacial gravels and sands
63	Sandy till
13	Bedrock

North of the site, there is an extensive area covered with sand derived from glacial till. The exact thickness of these sands is unknown, but there are known sections over 40 feet thick. These sands cover many square miles and are thought to be the region of recharge for the glacial gravels and sands beneath the till layer in the depression of the bedrock.

The geology of the site can be correlated to the geology southwest of the area (Cornwall area, Geol. Surv. Canada Preliminary Report 60-28). The lower till although sandy has a high percentage of silt and clay, and can be related to the Malone till indicating a westerly movement of the ice up the St. Lawrence. This till is very calcareous, and no pebbles of igneous origin were seen in it. The overlying glacial gravel contains pebbles that are well rounded, indicating that they have been water worn, and their deposition is probably related to streams in front of the retreating ice margin. These gravels of the retreat phase are covered by a shallow till that contains calcareous and also some igneous pebbles. This till sheet would be related to the Fort Covington advance that came from the north. The varved clays would be related to a glacial lake that existed at the close of the Fort Covington advance in the Cornwall area. The Yoldia clay is common in the lowlands and indicates a brackish water environment of the Champlain sea. The Leda clay is the deep sea phase of the Champlain sea. The sand overlying the clay is possibly of alluvial origin marking the close of the marine stage and the emergence of the land..

WELL DRILLING

Specifications called for a 10 inch well with a 15 foot screen installed between 90 and 175 feet. The exact location of the screen to be determined after grain size analysis of the aquifer. Five, 2 inch observation wells were called for, numbers 2 and 3 to be 50 feet, numbers 1 and 4 100 feet and number 5 250 feet from the well. The observation wells would also have screens and would preferably be in the top portion of the aquifer. On completion of the well a 72 hour pumping test was planned with a pumping rate between 200 and 600 gallons per minute. This high pumping rate was to determine any possible boundary or recharge region to the aquifer and also to allow sufficient drawdown to reduce the experimental errors in measurement.

Completion problem

The observation wells were drilled to different depths. The

10 inch well was drilled to a depth of 167 feet; after analysis of the sandy material, a 15 foot section of screen was installed between the depths of a 105 and 120 feet. The following table gives the data on these wells.

	Well No. 1	Well No. 2	Well No. 3	Well No. 4	Well No. 5	Main Well
Depth	100 ft.	100 ft.	108 ft.	100 ft.	114 ft.	120 ft.
Diameter	2 in.	2 in.	2 in.	2 in.	2 in.	10 in.
Elev. of w. 1	181.56 ft.	181.48 ft.	181.61 ft.	181.77 ft.	182.20 ft.	181.01 ft.
Ground elev.	171.15 ft.	171.13 ft.	171.41 ft.	171.52 ft.	171.46 ft.	172.17 ft.
Length of screen	4 ft.	4 ft.	4 ft.	4 ft.	1.5 ft.	15 ft.

Through sieve analysis it was found that approximately 18 feet of glacial gravels underlying the Fort Covington till, represented the best aquifer and would yield more water than the underlying till which although quite sandy, contained 50 per cent by weight clay silt particles; as shown in figure 1.

On the basis of the sieve analyses the screen was to be installed between the depths of 95 to 110 feet from the surface. The size of the openings of the screen was chosen to permit natural development of the well (see grain size analysis figures 2 to 8). Screen size slots allow from 60 to 80 per cent of the material of the formation to go through the screen; sometimes, when the formation is of uniform size a lesser amount is allowed to go through the screen slots.

The screen was installed at the recommended depth, but upon mild development, the well burst through the confining layer. The result was that more water was coming up outside the 10 inch well casing than there was coming into it; further development only aggravated the situation. In order to prevent this, a large diameter pipe was installed over the 10 inch pipe. The larger pipe was 12 inches in diameter and was fitted at the bottom end with a section of 16 inch diameter pipe, that was tapered at one end giving it a bell shape.

While driving the outside casing the inside casing also went down some 7 feet, then only 8 feet of screen remained exposed to receive water; with such a short section exposed it was impossible to receive the desired amount of water, furthermore it was feared that development would overstrain the confining layer and produce a leak at that layer again.

With the idea of adding material under the confining layer and thus dissipate the pressures due to well development, it was decided to lower the screen to a depth of 120 feet. When this was accomplished, there was a section of 16 feet of sand and gravel below the confining till and above the top of the screen. Development then began, and after intense development the confining layer burst again.

This time the well furnished enough water to allow a test. Much of the development on the well had been done by surging and pumping with a compressor; for that reason, the well field was left for 3 days in order to establish its equilibrium.

October 30, 1961 the pumping test was started at 4.05 p.m.; the pumping rate was 100 u.s.g. per minute. The drawdown was measured in the observation wells at every minute for 17 minutes after pumping began, then every 3 or 4 minutes up to the 100 minute mark, then every 20 minutes to the 200 minute mark; and then every hour for the remainder of the test; the wet tape method was used in measuring the water level. The flow was determined with Parshall flume on which a continuous daily water recorder had been installed.

The drawdown on the pumping well was excessive from the very beginning, but the drawdown on the observation wells was within what was to be expected with such a low pumping rate. The maximum drawdown in the closest observation well was 3 feet, while the drawdown in the main well was over 60 feet, which is an indication of a very large well loss in the main well.

After 70 hours of pumping recovery measurements were obtained in the same manner and within the same time interval as the drawdown measurements were. The main well overflowed 6 feet above the ground 9 minutes after pumping stopped, the others had recovered 24 hours after the pumping had stopped.

Pumping test results

The reason why the main well had a large well loss is partly due to the fact that the confining layer had burst and in part due to the place where the screen was set: indeed by lowering the screen, most of the screen was set in the underlying Malone till. Nevertheless a reasonably accurate assessment of the constants of the acquifer was obtained from the analyses of the drawdowns in the observation wells. Values for the transmissibility and the storage was obtained for each well and are tabulated on the following page. Boundary conditions did exist and are apparent on the recovery curve of the observation wells. Analysis of the distance from the boundary to the main well indicate that they are probably existing wells that were allowed to overflow or existing wells that are being pumped. The pumping rate was not high enough to indicate that there was vertical leakage from the clays to the aquifer, but a suspected leakeage is very probable due to the high sulphurous content of the water which is a quality attributed generally to waters coming from clays.

Table showing transmissibility and storage obtained by the test Theis nonequilibrium formula, drawdown versus distance

Well No. 1, 2 and 5			Well No. 3 and 4	
Transmissibility	Storage	Time	Transmissibility	Storage
3.18×10^{4}	$.192 \times 10^{-4}$	10 min.	$.76 \times 10^{4}$	1.04×10^{-3}
3.08 x "	.675 x "	1 hour	.79 x "	$.236 \times 10^{-3}$
2.73 x "	10^{-3}	10 hours	9.55 x "	3.15×10^{-2}
1.98 x "	1.54 x "	20 hours	.955 x "	5.1 x "
2.98 x "	.665 x "	30 hours	1.4 x "	.915 x "
2.07 x "	3.7 x "	40 hours	1 x "	.55
2.07 x "	5.6 x "	50 hours	1.25 x "	.185
2.07 x "	6.3 x "	60 hours	1.16 x "	$.266 \times 10^{-1}$
2.33 x "	1.7 x "	70 hours	.973 x "	7.1×10^{-2}

Drawdown versus time

Theis method			Jacobs method	
Transmissibility	**Storage**	**Well No.**	**Transmissibility**	**Storage**
2.45 x 10^{4}	.775 x 10^{-3}	1	2.06 x 10^{4}	.360 x 10^{-3}
2.58 x "	1.52 x "	2	2.06 x "	1.02 x "
2.58 x "	2.3 x "	3	2.20 x "	1.32 x "
3.82 x "	.52 x "	4	3.02 x "	1.88 x "
2.73 x "	.377 x "	5	3.20 x "	.19 x "

Recovery

Well No.	Transmissibility
1	1.26 x 10^{4}
2	1.29 x "
3	1.52 x "
4	1.69 x "
5	1.69 x "

Thiem equilibrium formula

Transmissibility	Well No.
2.32 x 10^{4}	3 & 4
7.6 x "	1 & 2
7.3 x "	4 & 5

*The units of the factor transmissibility are: imp. gal./day/ft. The storage coefficient has no units.

If we assume that the well screen had been placed at the recommended elevation, that the confining layer had not have burst, that the aquifer was of infinite areal extent and constant thickness, that the discharge well had an infinitesimal diameter and completely penetrated the thickness of the aquifer, and that the water taken from storage in the aquifer was discharged instantaneously with the decline in head, then the drawdown in the main well, providing no excessive well loss had occurred, would follow Theis nonequilibrium formula.

$$s = \frac{114.6\ Q\ W(u)}{T}$$

Where $W(u) = -0.577216 - \text{In}\ u + u - \frac{u^2}{2x2!} + \frac{u^3}{3x3!} - \frac{u^4}{4x4!} \cdots\cdots \frac{(-1)^{n}\ u^{n}}{nxn!}$

and $u = \frac{1.56\ r^2\ S}{T\ t}$

s = drawdown at any point in the aquifer

Q = discharge of pumped well   83.5 gal. per min.

T = coefficient of transmissibility of the aquifer 2.07×10^{4} Imp. gal./day/foot

t = time since pumping started in days

r = distance from discharging well

S = coefficient of storage of aquifer $.19 \times 10^{-3}$

From the above equation, with the given rate of pumping of 83.5 gal./min., the transmissibility 2.07×10^{4} Imp. gal./day/foot, and with the storage coefficient $.19 \times 10^{-3}$, if equilibrium is not reached, the drawdown 0.5 feet away from pumped well will be,

$$u = \frac{1.56\ r^2\ s}{T\ t} = \frac{1.56 \times (0.5)^2 \times .19 \times 10^{-3}}{2.07 \times 10^{4}\ \ t} = \frac{3.57 \times 10^{-9}}{t}$$

$$s = \frac{114.6\ Q\ W(u)}{T} = .461\ W(u)$$

When

$t = 1$ day $\quad u = 3.57 \times 10^{-9} \quad W(u) = 18.86 \quad s = 8.68$

$t = 10$ days $\quad u = 3.57 \times 10^{-10} \quad W(u) = 21.16 \quad s = 9.69$

$t = 30$ days $\quad u = 1.19 \times 10^{-10} \quad W(u) = 22.26 \quad s = 10.30$

$t = 100$ days $\quad u = 3.57 \times 10^{-11} \quad W(u) = 23.47 \quad s = 10.80$

and the drawdown a 1000 feet away would be

$$U = \frac{1.56\, r^2 S}{T\ \ t} = \frac{1.56 \times 10^6 \times .19 \times 10^{-3}}{2.07\ 10^4 t} = \frac{1.43 \times 10^{-2}}{t}$$

$$h. - h = \frac{114.6 \times Q\ Wu}{T} = \frac{114.6 \times 83.5 \times Wu}{2.07 \times 10^4} = .461\ Wu$$

When

$t = 1$ day $\quad u = 1.43 \times 10^{-2} \quad Wu = 3.70 \quad s = 1.70$

$t = 10$ days $\quad u = 6.9 \times 10^{-4} \quad Wu = 6.70 \quad s = 3.08$

$t = 30$ days $\quad u = 4.77 \times 10^{-4} \quad Wu = 7.06 \quad s = 3.26$

$t = 100$ days $\quad u = 1.43 \times 10^{-4} \quad Wu = 8.29 \quad s = 3.82$

If one doubles the rate of pumping theoretically the drawdown should also double.

Conclusions

The pumping test did not completely fulfill its objective. No information was obtained on the direction of flow nor on recharge, but the storage coefficient and the transmissibility was obtained: that information is of high importance in outlining the future groundwater potential of the aquifer.

The confining layer of till above the glacial gravel is very shallow and due to the high water pressure on its surface, burst repeatedly, thus causing a terrific well loss. The clays above the till layer cannot be considered as a confining layer once it is disturbed by drilling.

Recommendations

It was found that the observation wells that were driven 2 inch well points, were much more effective wells than the main well. Three of the 5 were flowing at the rate of 30 gallons a minute at the surface of the ground. Assuming that the pumping rate on such wells were 50 gallons a minute, these wells could be spaced 250 feet apart without interfering too much with each other. This means that a dozen of these wells, providing the same conditions are present would yield a million gallons of water a day.

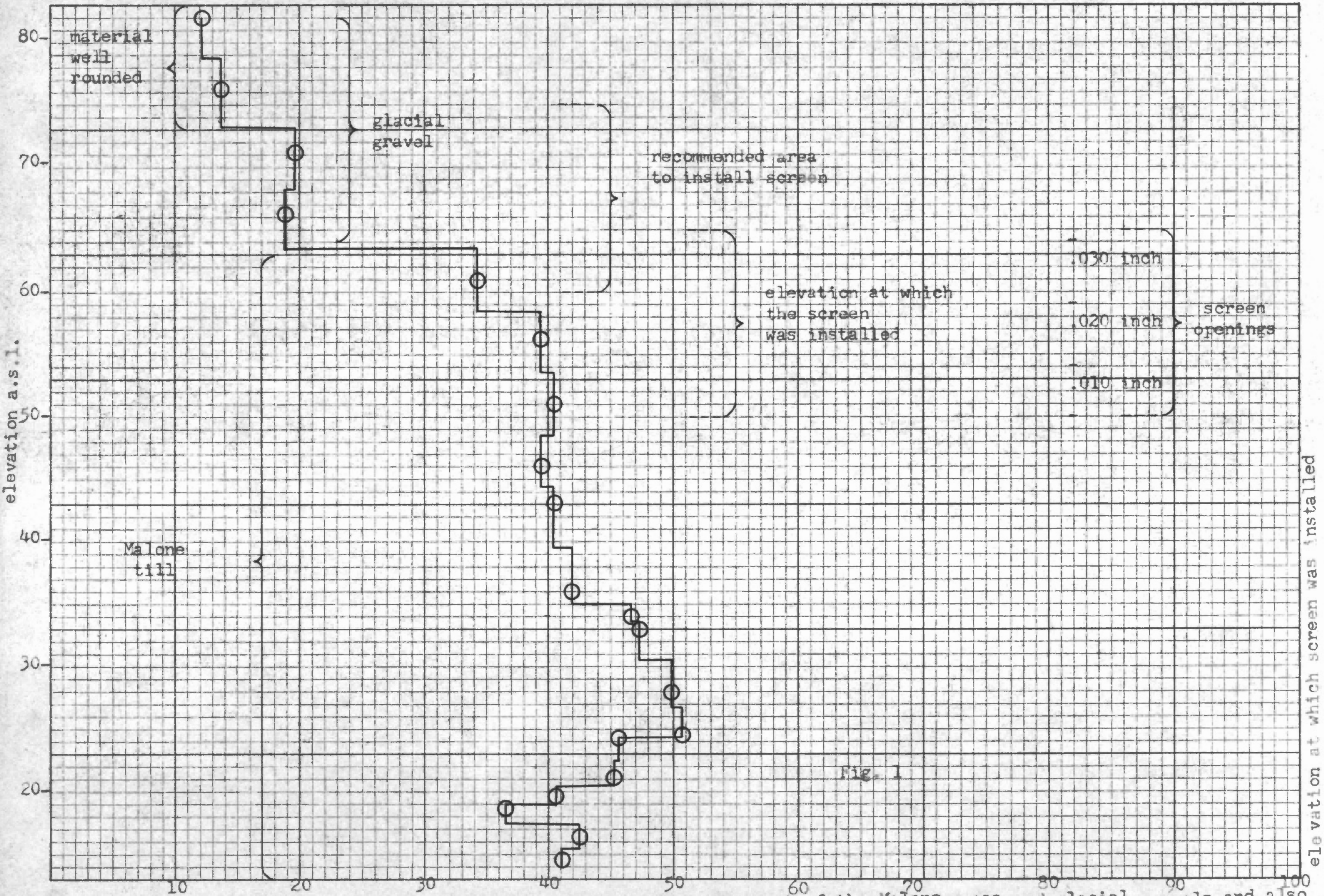
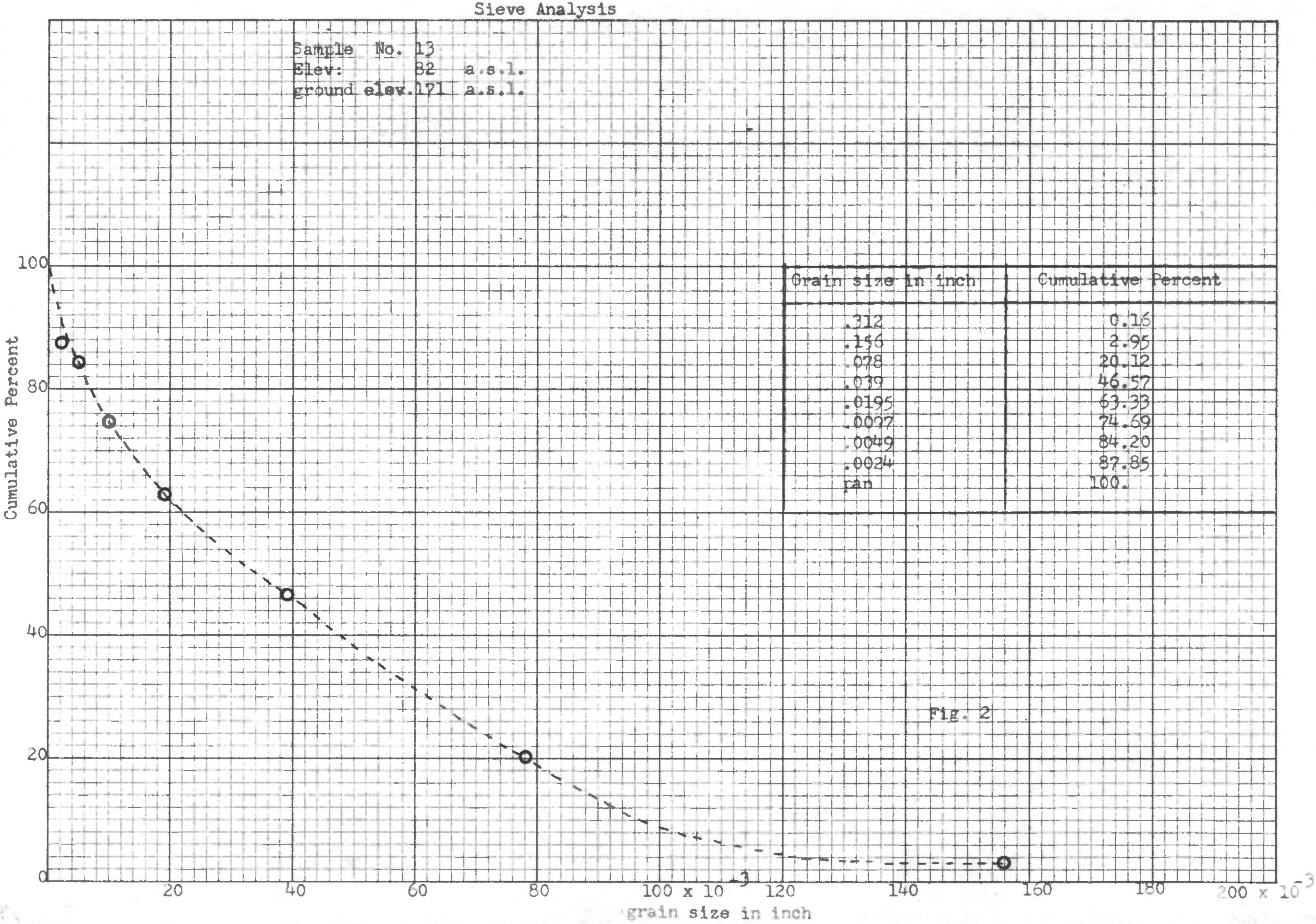


Fig. 1

graph showing silt & clay content in percent by weight of part of the Malone till and glacial gravels and also elevation at which screen was installed

Sieve Analysis

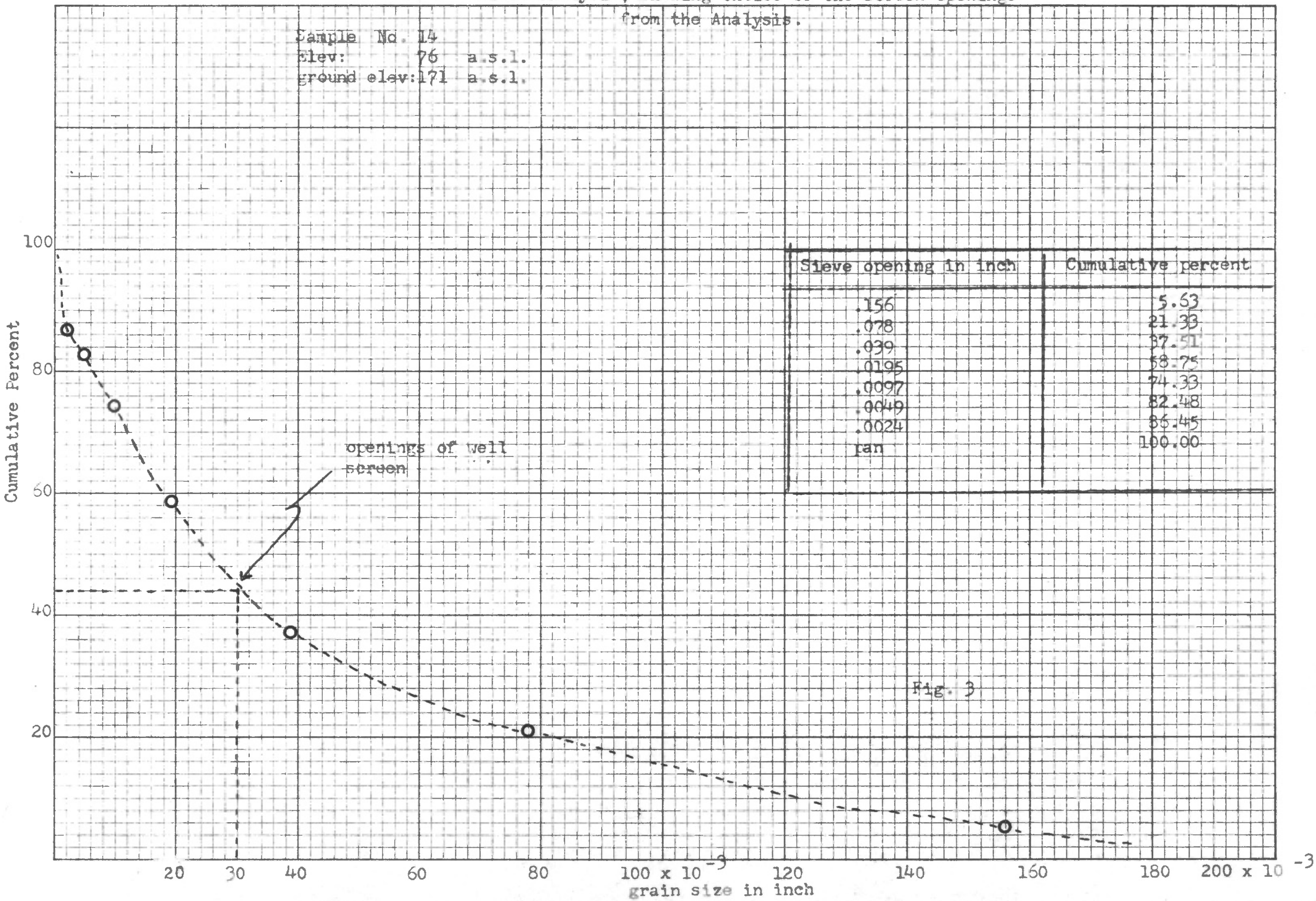
Sample No. 13
Elev: 82 a.s.l.
ground elev. 171 a.s.l.



Grain size in inch	Cumulative Percent
.312	0.16
.156	2.95
.078	20.12
.039	46.57
.0195	63.33
.0097	74.69
.0049	84.20
.0024	87.85
pan	100.

Fig. 2

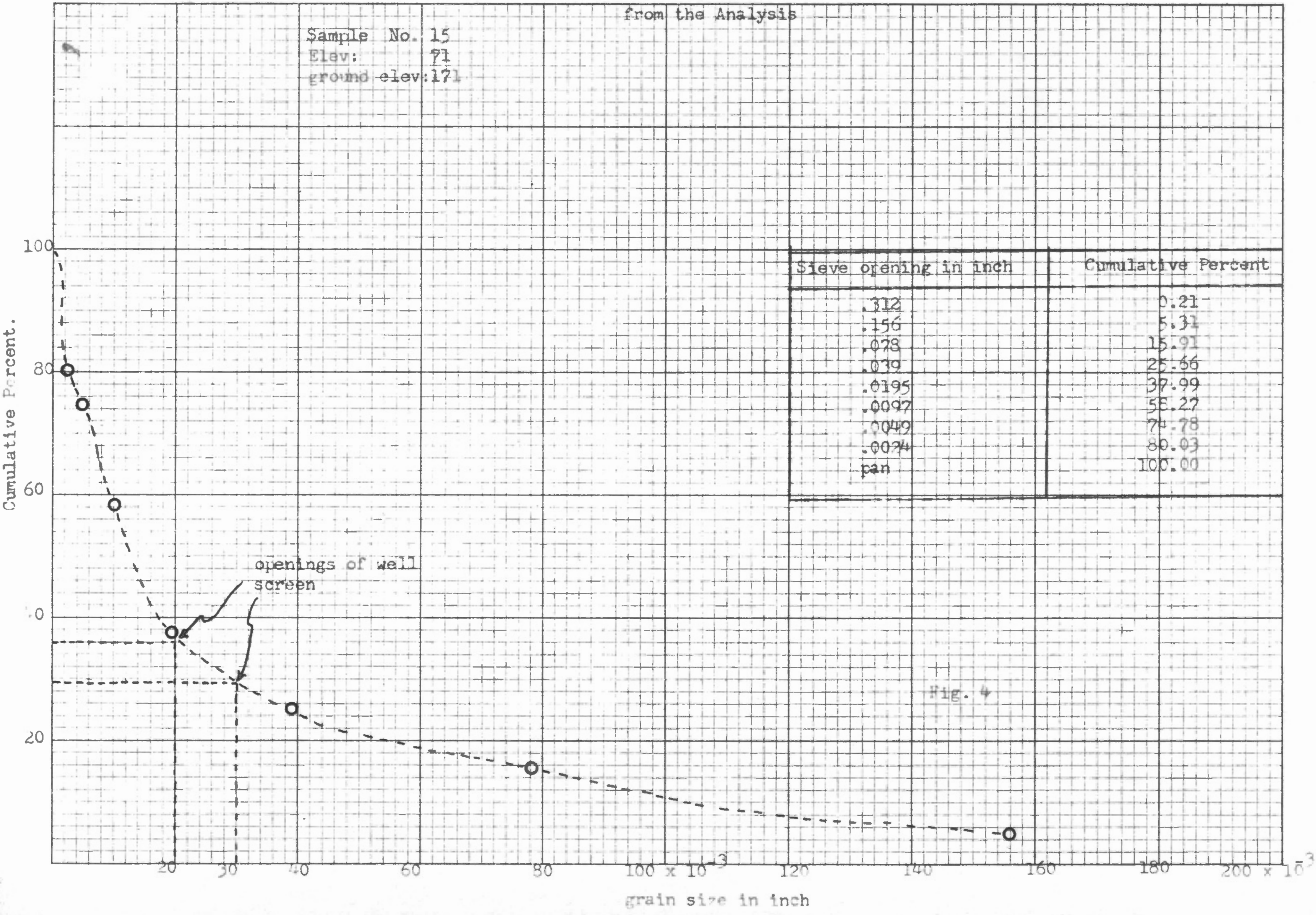
Sieve analysis, showing choice of the screen openings from the Analysis.



Sieve opening in inch	Cumulative percent
.156	5.63
.078	21.33
.039	37.51
.0195	58.75
.0097	74.33
.0049	82.48
.0024	86.45
pan	100.00

Fig. 3

Sieve analysis, showing choice of the screen openings
from the Analysis

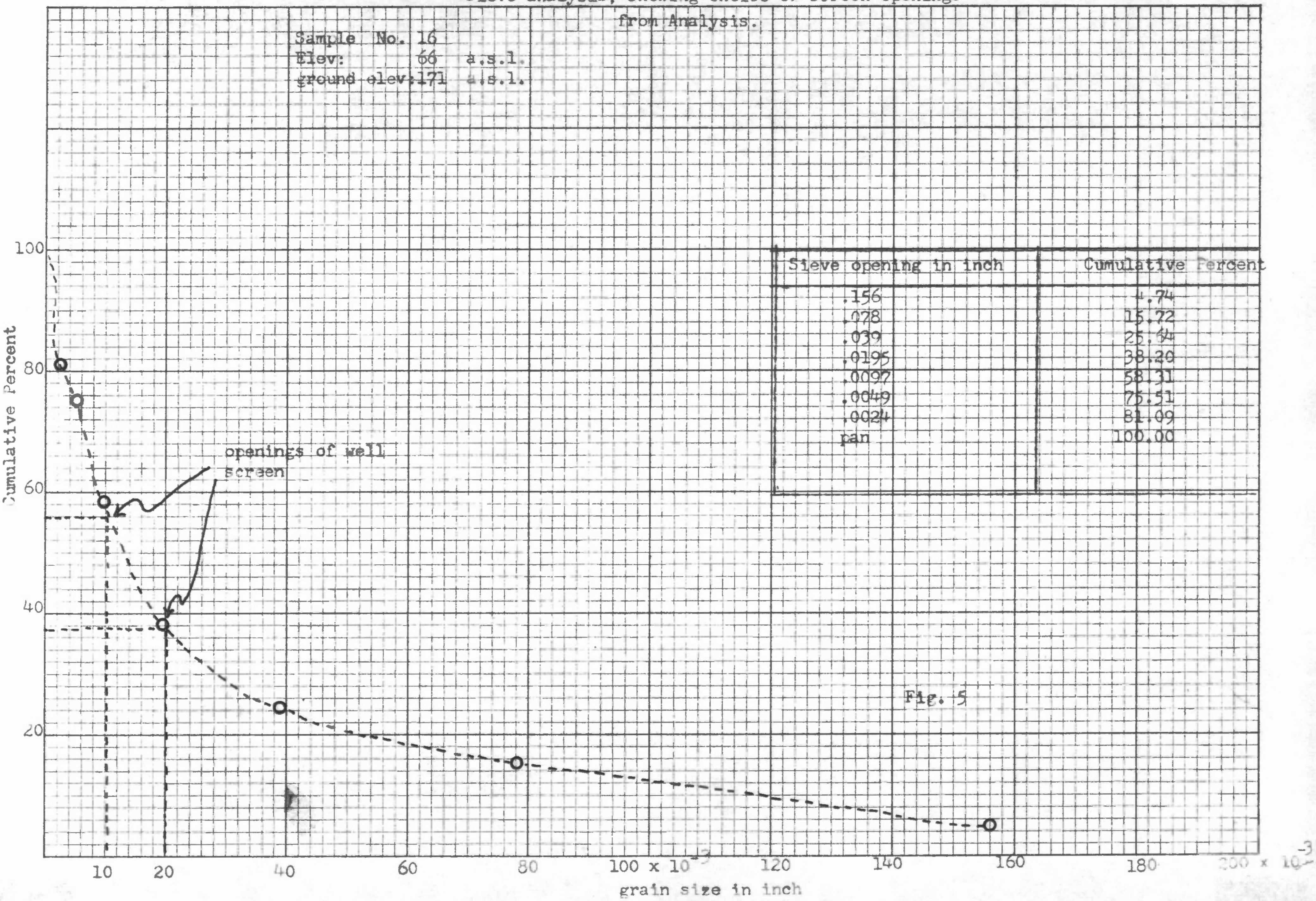


Sample No. 15
Elev: 71
ground elev: 171

Sieve opening in inch	Cumulative Percent
.312	0.21
.156	5.31
.078	15.91
.039	25.66
.0195	37.99
.0097	56.27
.0049	74.78
.0024	80.03
pan	100.00

Fig. 4

Sieve analysis, showing choice of screen openings from Analysis.

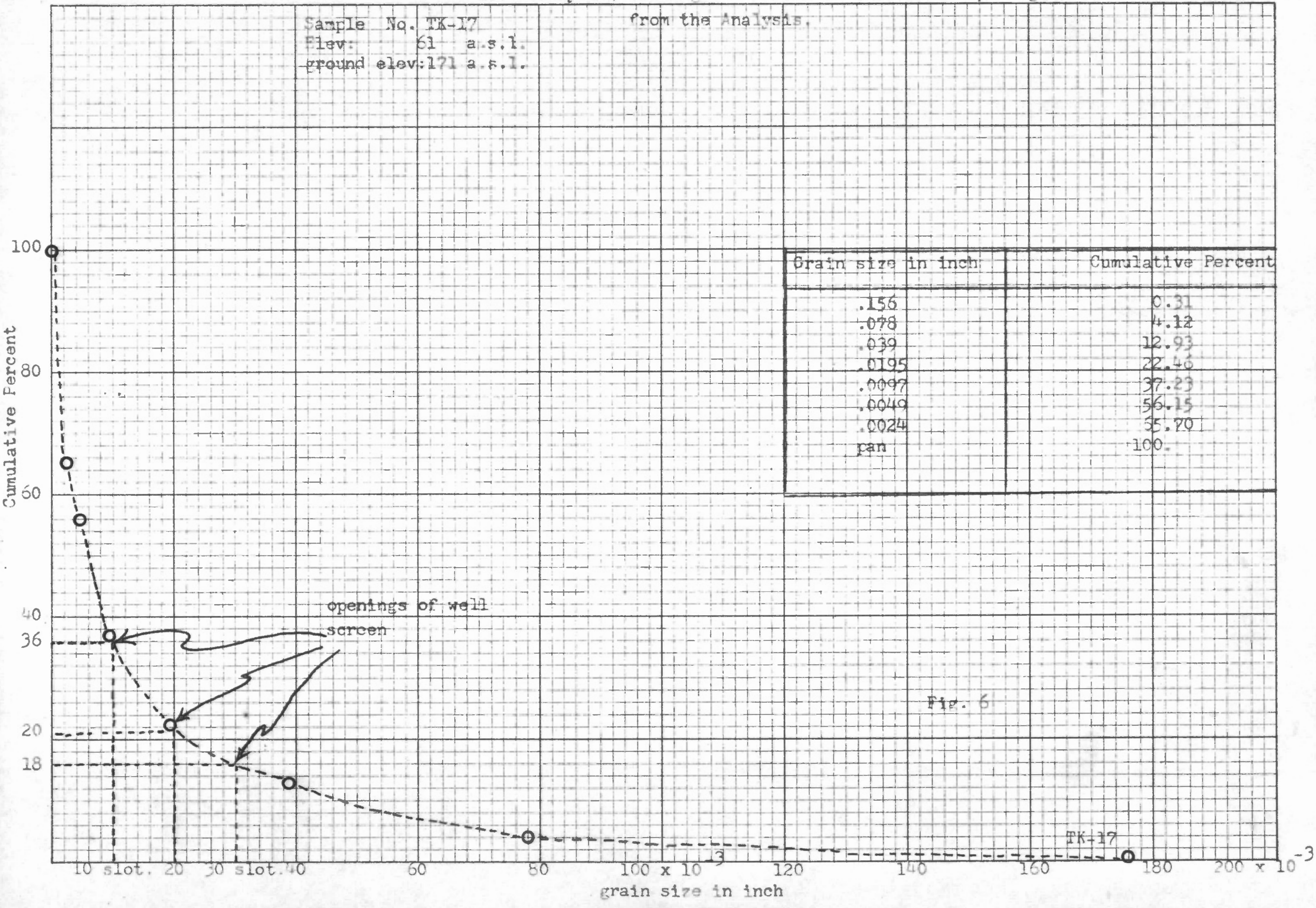


Sample No. 16
Elev: 66 a.s.l.
ground elev: 171 a.s.l.

Sieve opening in inch	Cumulative Percent
.156	4.74
.078	15.72
.039	25.64
.0195	38.20
.0097	58.31
.0049	75.51
.0024	81.09
pan	100.00

Fig. 5

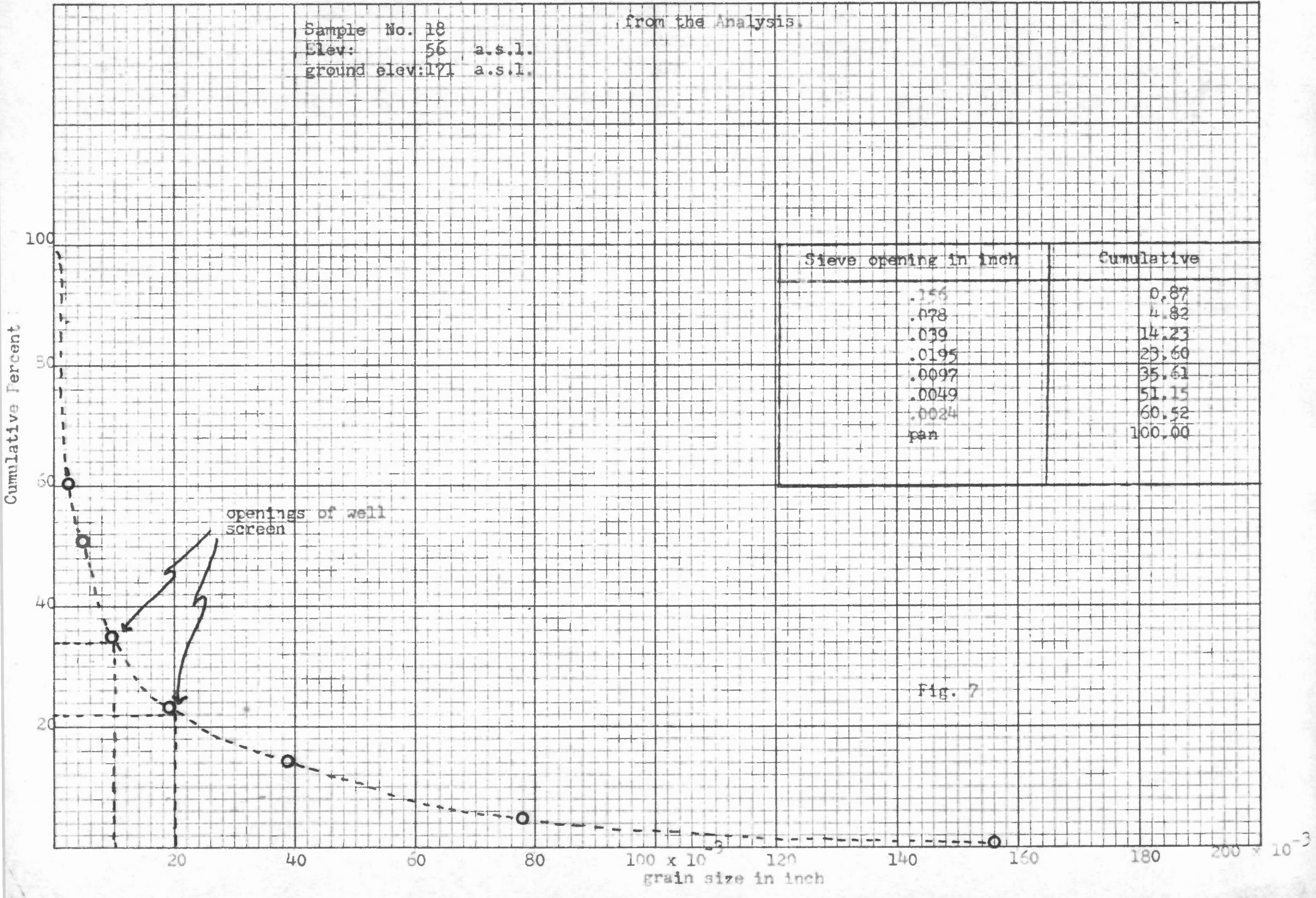
Sieve analysis, showing the choice of the screen openings from the Analysis.



Grain size in inch	Cumulative Percent
.156	0.31
.078	4.12
.039	12.93
.0195	22.46
.0097	37.23
.0049	56.15
.0024	55.70
pan	100.

Fig. 6

Sieve analysis, showing the choice of the screen openings from the Analysis.

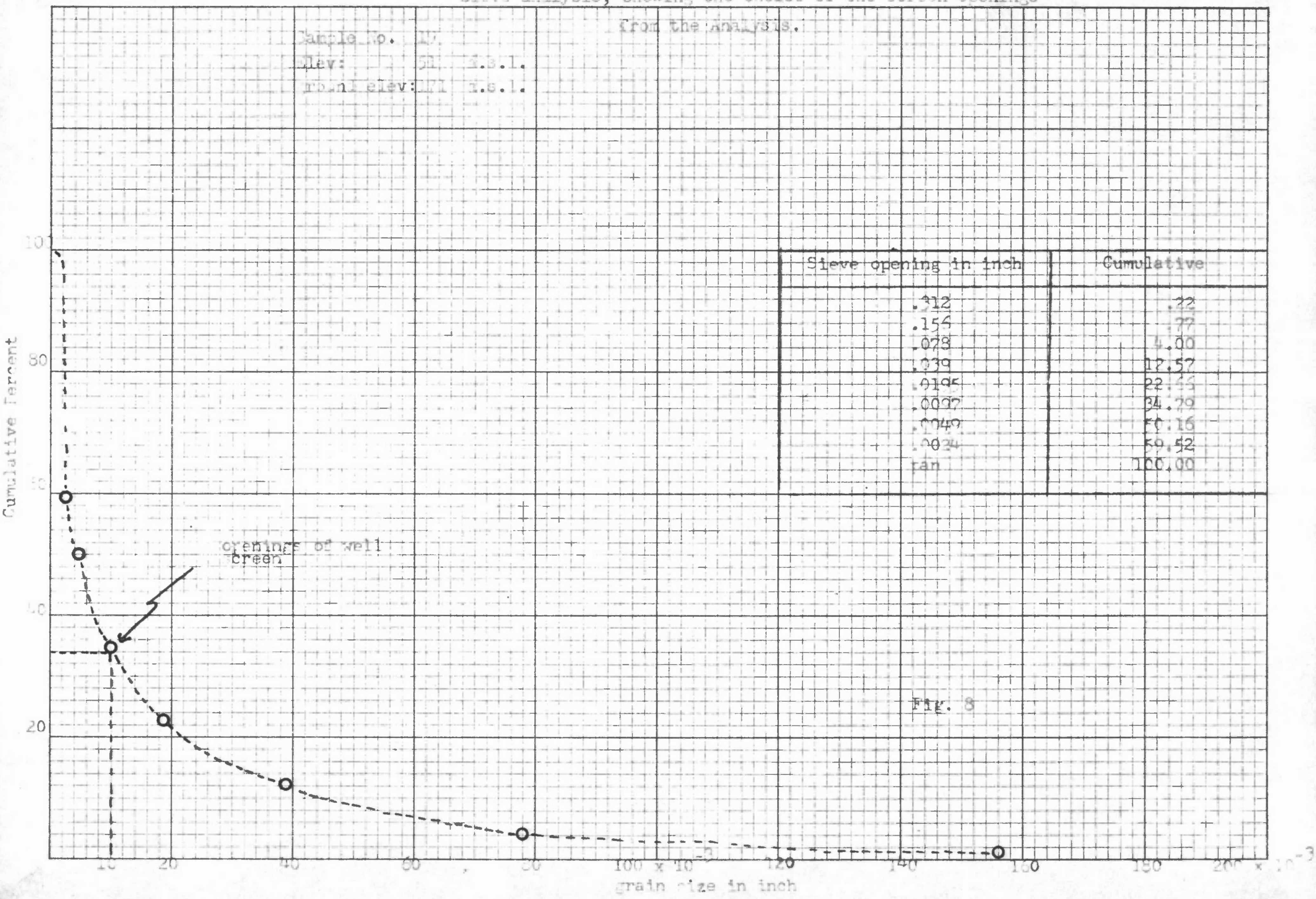


Sample No. 18
Elev: 56 a.s.l.
ground elev: 171 a.s.l.

Sieve opening in inch	Cumulative
.156	0.87
.078	4.82
.039	14.23
.0195	23.60
.0097	35.61
.0049	51.15
.0024	60.52
pan	100.00

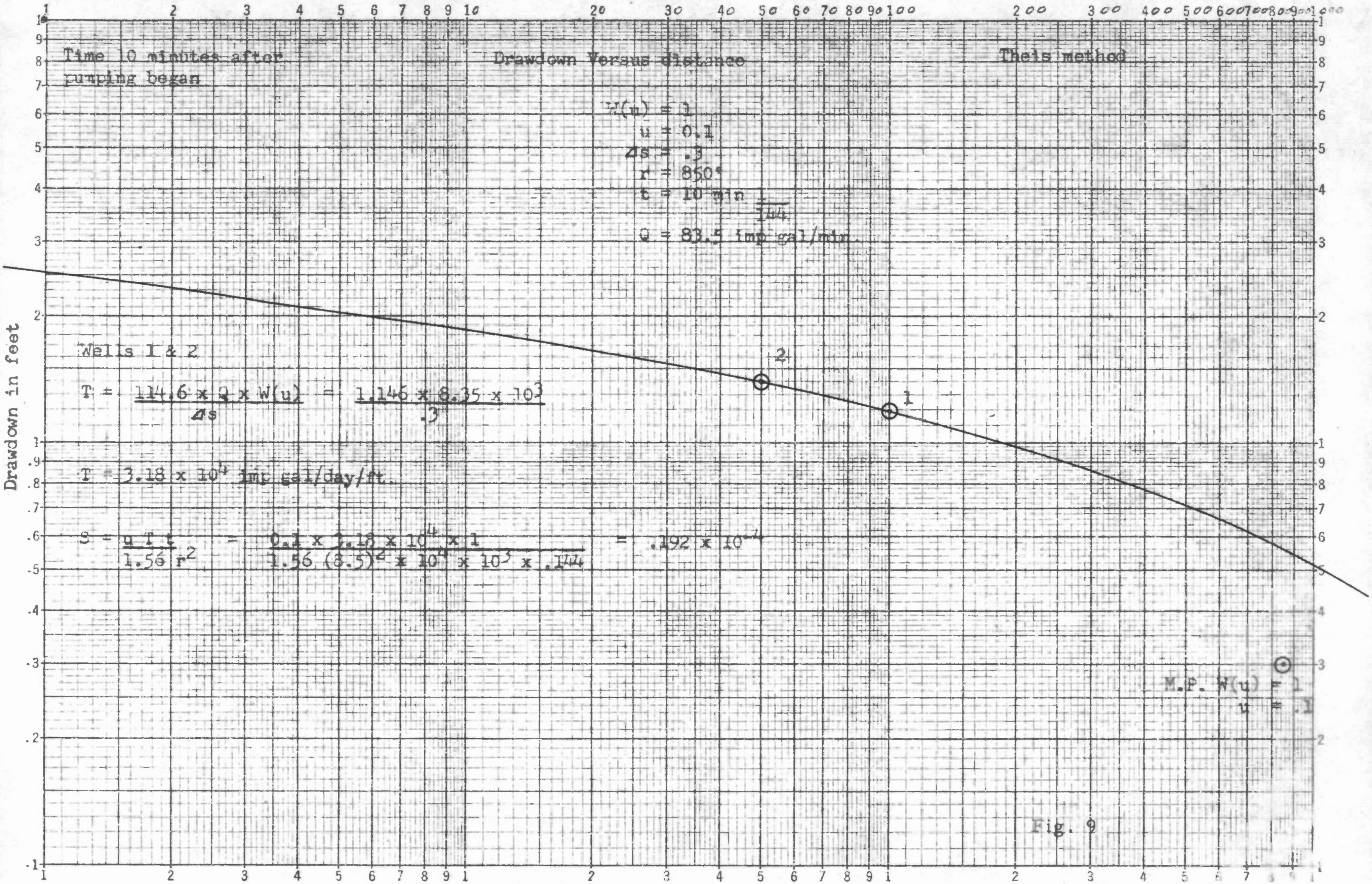
Fig. 7

Sieve analysis, showing the choice of the screen openings from the analysis.



Sieve opening in inch	Cumulative
.312	.22
.156	.77
.078	4.00
.039	12.57
.0195	22.46
.0097	34.79
.0049	50.16
.0024	59.52
pan	100.00

Fig. 8



$W(u) = 1$

$u = 0.1$

$\Delta s = .3$

$r = 850'$

$t = 10\ \text{min}\ \frac{1}{144}$

$Q = 83.5$ imp gal/min.

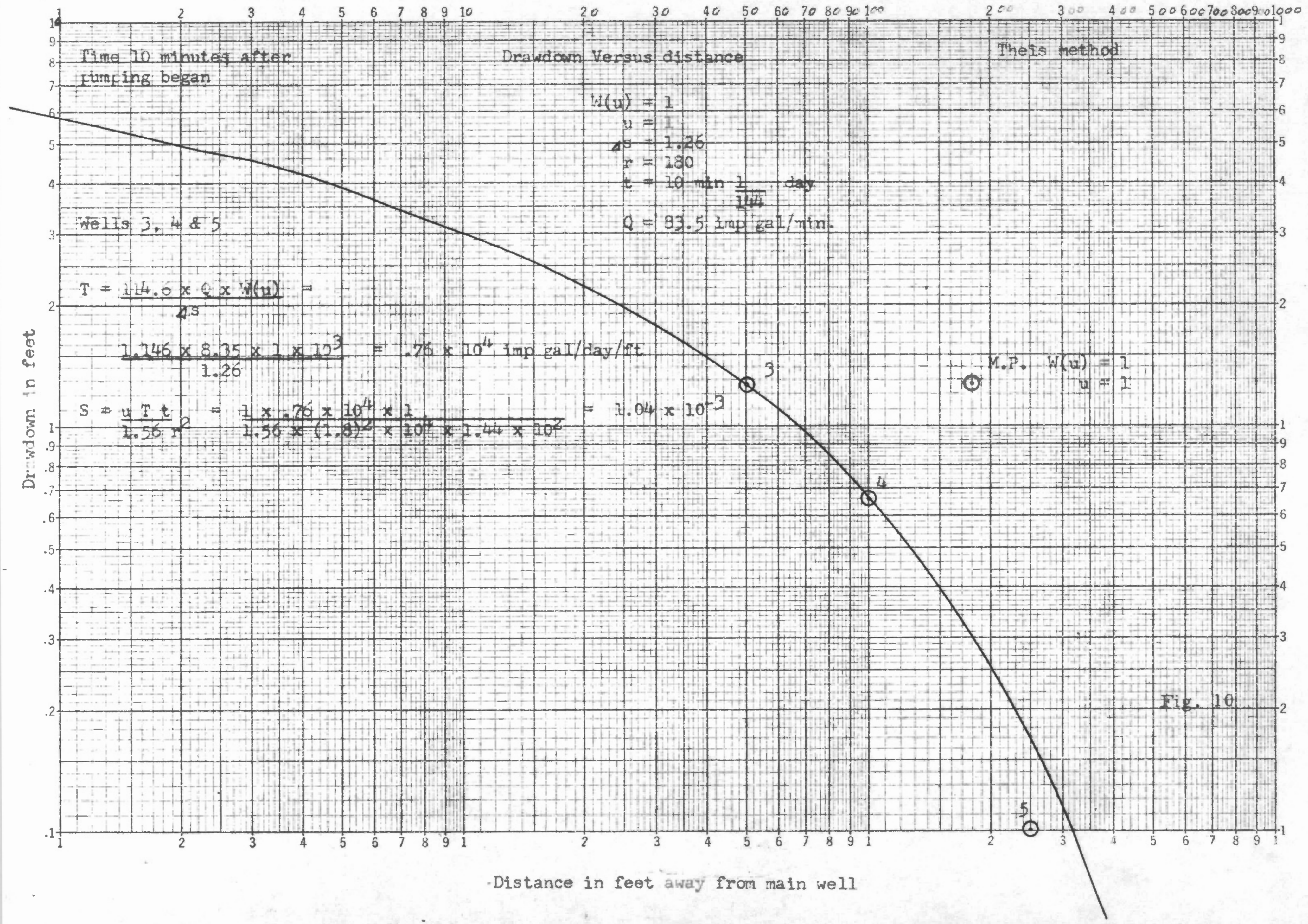
Wells I & 2

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s} = \frac{1.146 \times 8.35 \times 10^3}{.3}$$

$T = 3.18 \times 10^4$ imp gal/day/ft.

$$S = \frac{u\,T\,t}{1.56\,r^2} = \frac{0.1 \times 3.18 \times 10^4 \times 1}{1.56\,(8.5)^2 \times 10^4 \times 10^3 \times .144} = .192 \times 10^{-4}$$

Fig. 9



Drawdown Versus distance

Theis method

Time 10 minutes after
pumping began

Wells 3, 4 & 5

$W(u) = 1$
$u = 1$
$\Delta s = 1.26$
$r = 180$
$t = 10 \text{ min } \frac{1}{144} \text{ day}$

$Q = 83.5$ imp gal/min.

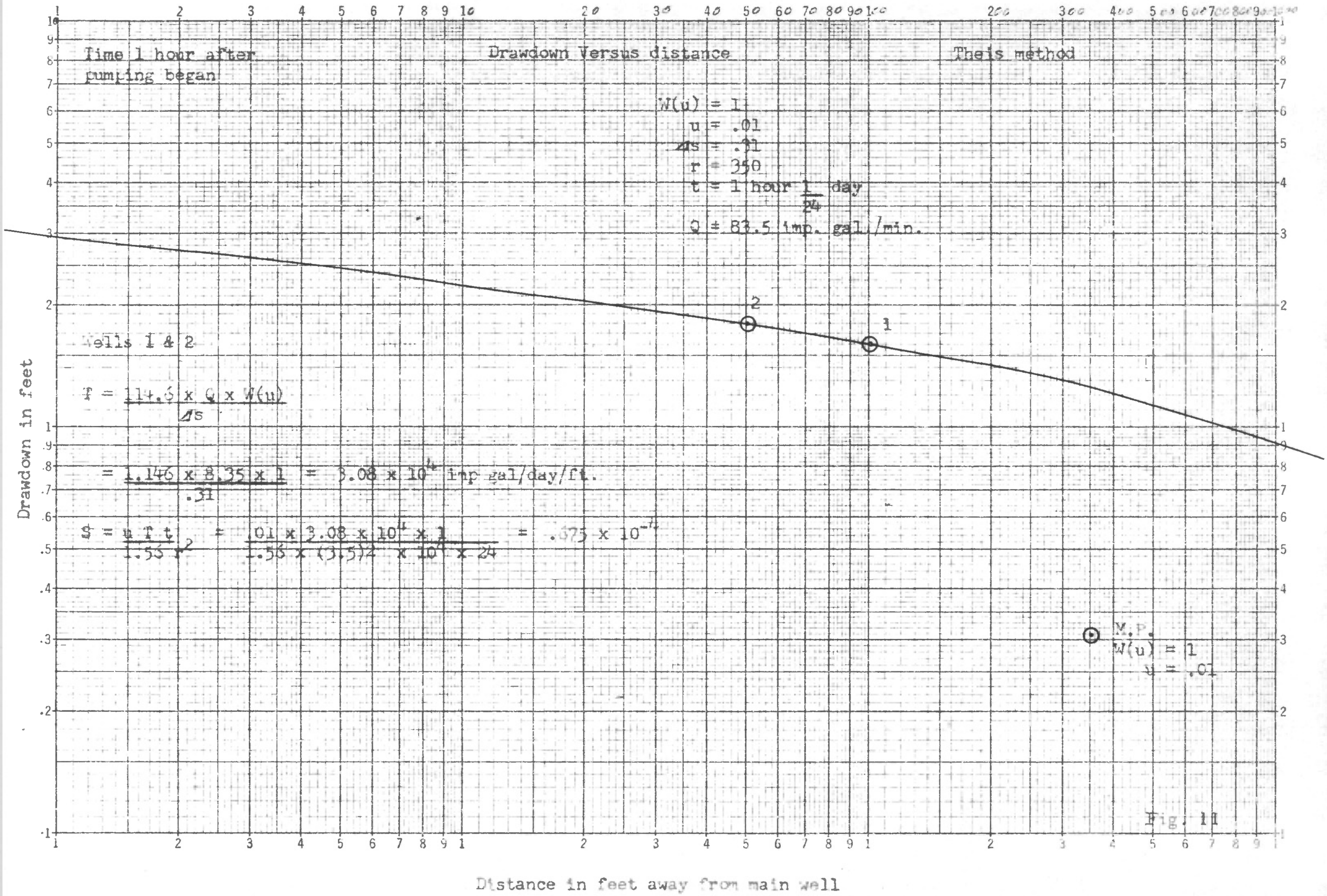
$$T = \frac{114.6 \times Q \times W(u)}{\Delta s} =$$

$$\frac{1.146 \times 8.35 \times 1 \times 10^3}{1.26} = .76 \times 10^4 \text{ imp gal/day/ft}$$

$$S = \frac{u\ T\ t}{1.56\ r^2} = \frac{1 \times .76 \times 10^4 \times 1}{1.56 \times (1.8)^2 \times 10^4 \times 1.44 \times 10^2} = 1.04 \times 10^{-3}$$

M.P. $W(u) = 1$
$u = 1$

Fig. 10



W(u) = 1
u = .01
⊿s = .31
r = 350
t = 1 hour $\frac{1}{24}$ day
Q = 83.5 imp. gal./min.

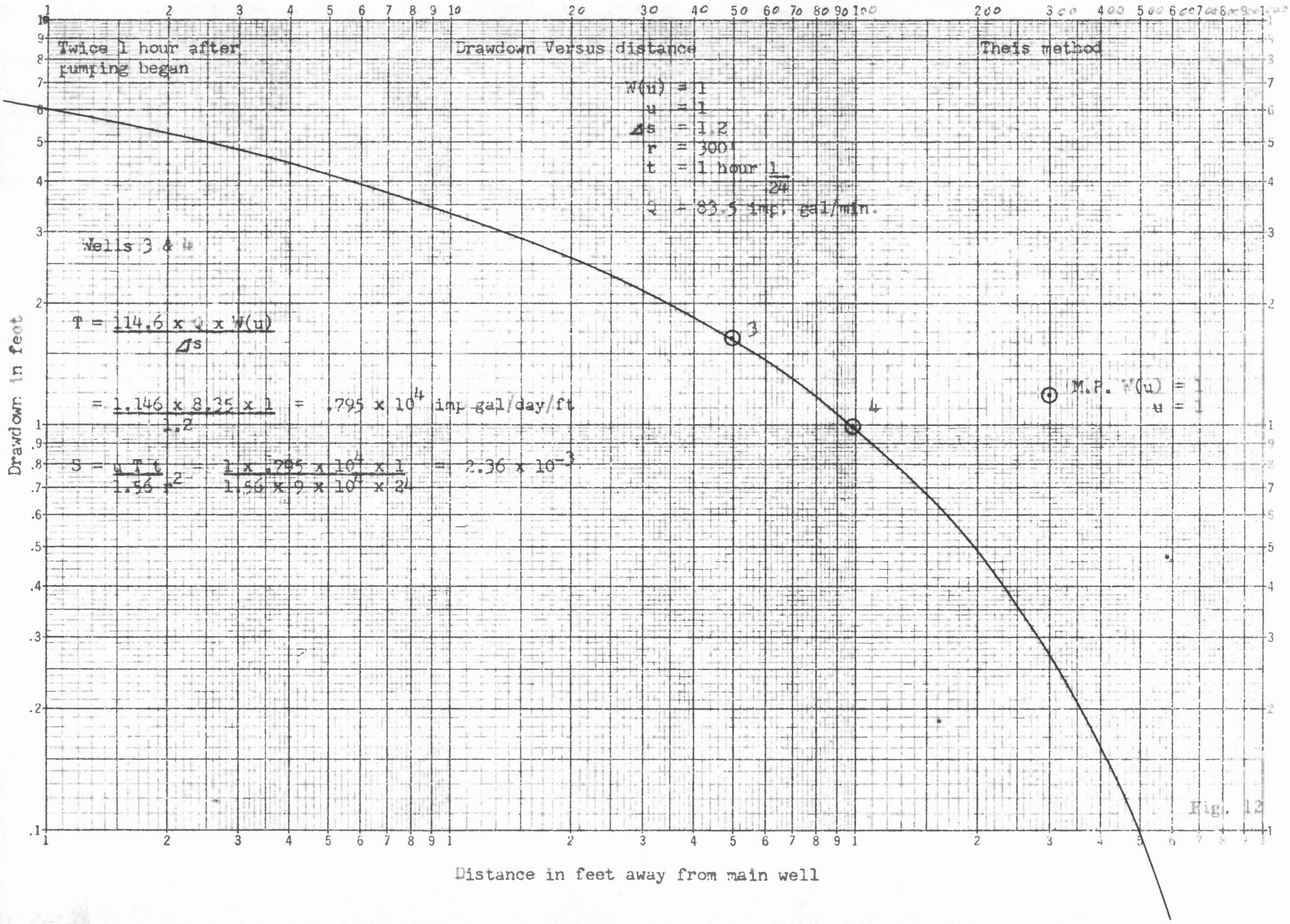
Wells 1 & 2

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s}$$

$$= \frac{1.146 \times 8.35 \times 1}{.31} = 3.08 \times 10^4 \text{ imp gal/day/ft.}$$

$$S = \frac{u\,T\,t}{1.56\,r^2} = \frac{.01 \times 3.08 \times 10^4 \times 1}{1.56 \times (3.5)2 \times 10^4 \times 24} = .675 \times 10^{-4}$$

Fig. 11



Twice 1 hour after pumping began

Drawdown Versus distance

Theis method

$W(u) = 1$
$u = 1$
$\Delta s = 1.2$
$r = 300'$
$t = 1 \text{ hour } \frac{1}{24}$
$Q = 83.5$ imp. gal/min.

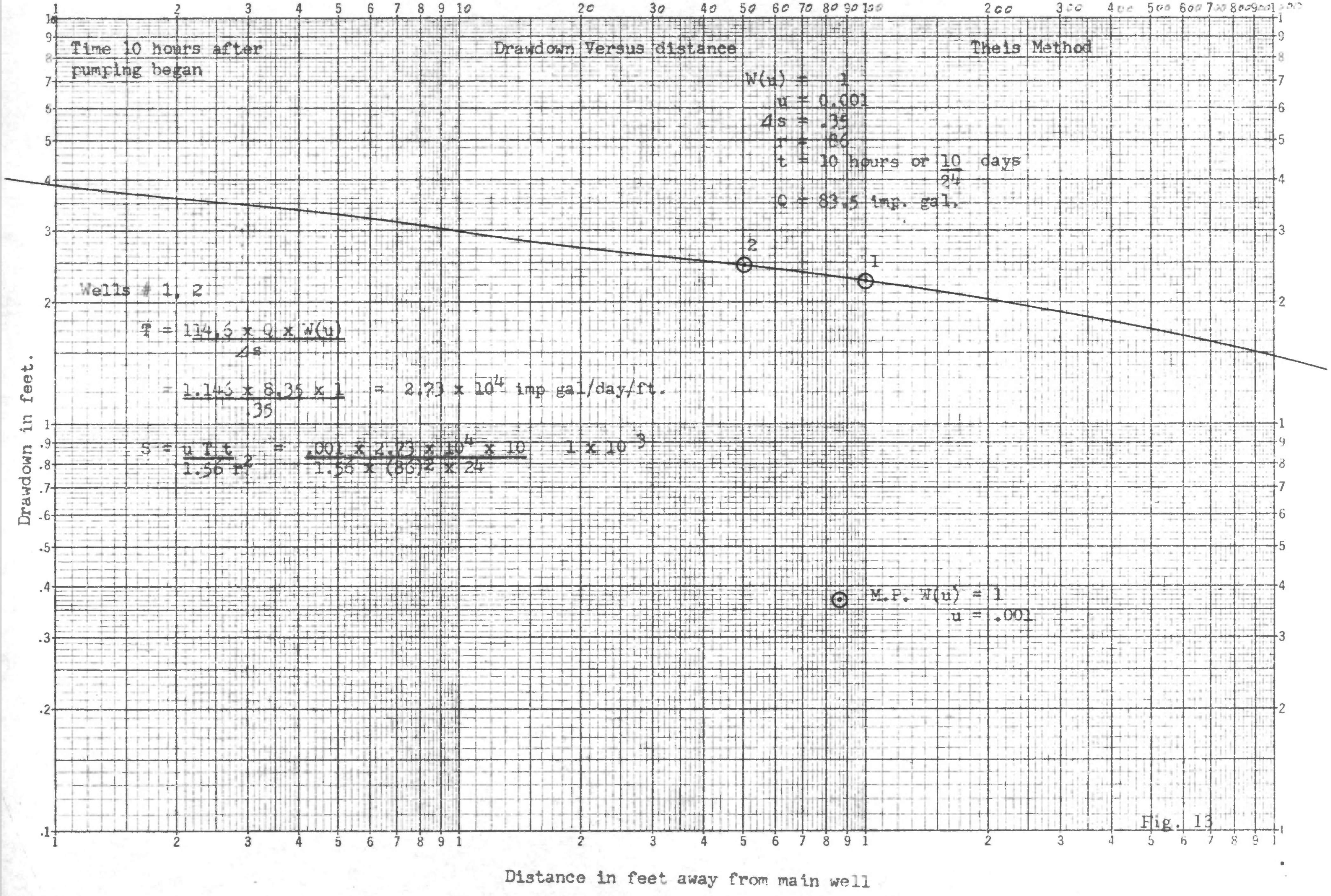
Wells 3 & 4

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s}$$

$$= \frac{1.146 \times 8.35 \times 1}{1.2} = .795 \times 10^4 \text{ imp gal/day/ft}$$

$$S = \frac{u\,T\,t}{1.56\,r^2} = \frac{1 \times .795 \times 10^4 \times 1}{1.56 \times 9 \times 10^4 \times 24} = 2.36 \times 10^{-3}$$

Fig. 12



$W(u) = 1$
$u = 0.001$
$\Delta s = .35$
$r = 86$
$t = 10$ hours or $\frac{10}{24}$ days

$Q = 83.5$ imp. gal.

Wells # 1, 2

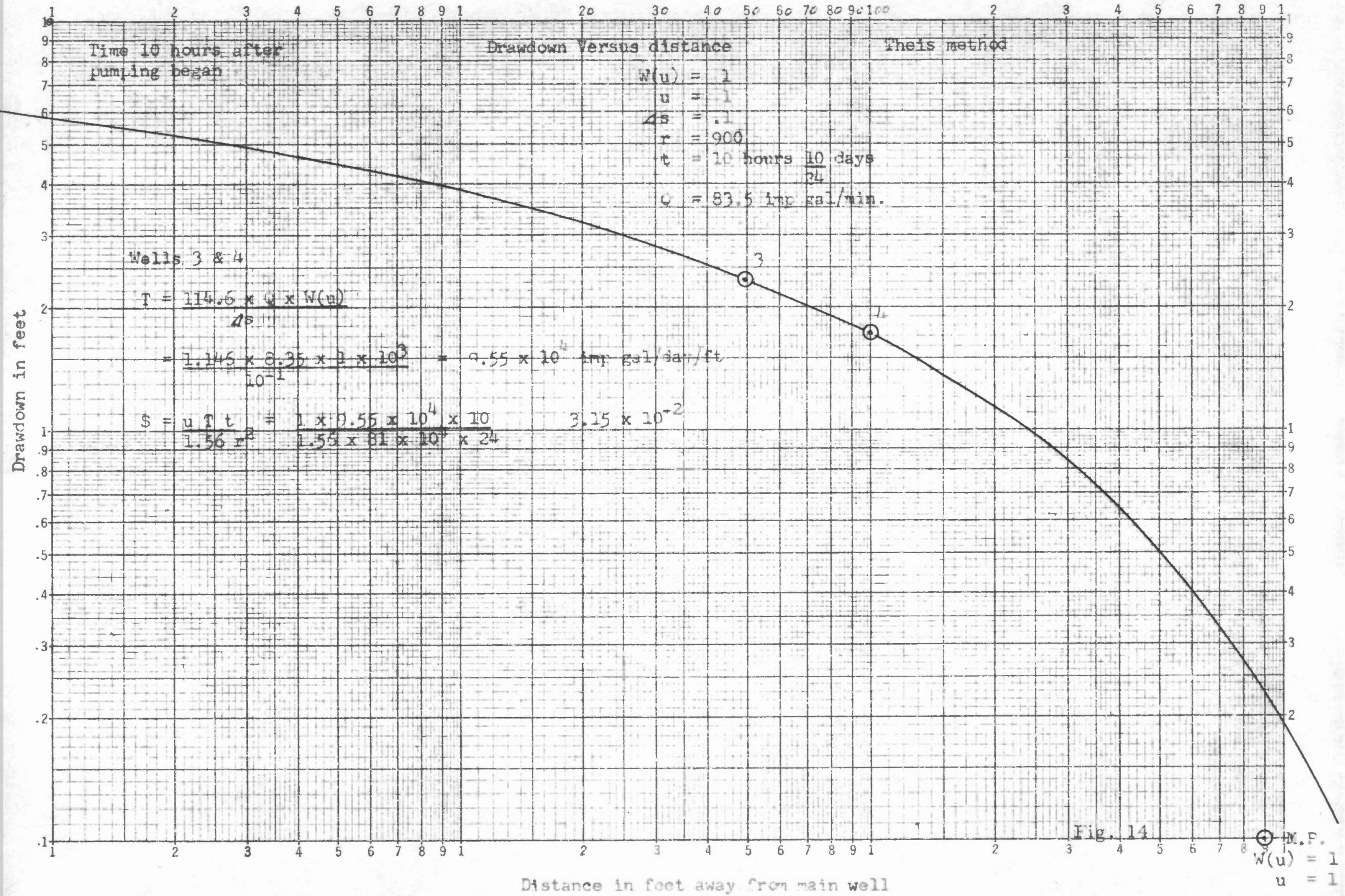
$$T = \frac{114.6 \times Q \times W(u)}{\Delta s}$$

$$= \frac{1.146 \times 8.35 \times 1}{.35} = 2.73 \times 10^{4} \text{ imp gal/day/ft.}$$

$$S = \frac{u\,T\,t}{1.56\,r^{2}} = \frac{.001 \times 2.73 \times 10^{4} \times 10}{1.56 \times (86)^{2} \times 24} \quad 1 \times 10^{3}$$

M.P. $W(u) = 1$
$u = .001$

Fig. 13



Time 10 hours after pumping began

Drawdown Versus distance

Theis method

$W(u) = 1$
$u = 1$
$\Delta s = .1$
$r = 900$
$t = 10$ hours $\frac{10}{24}$ days
$Q = 83.5$ imp gal/min.

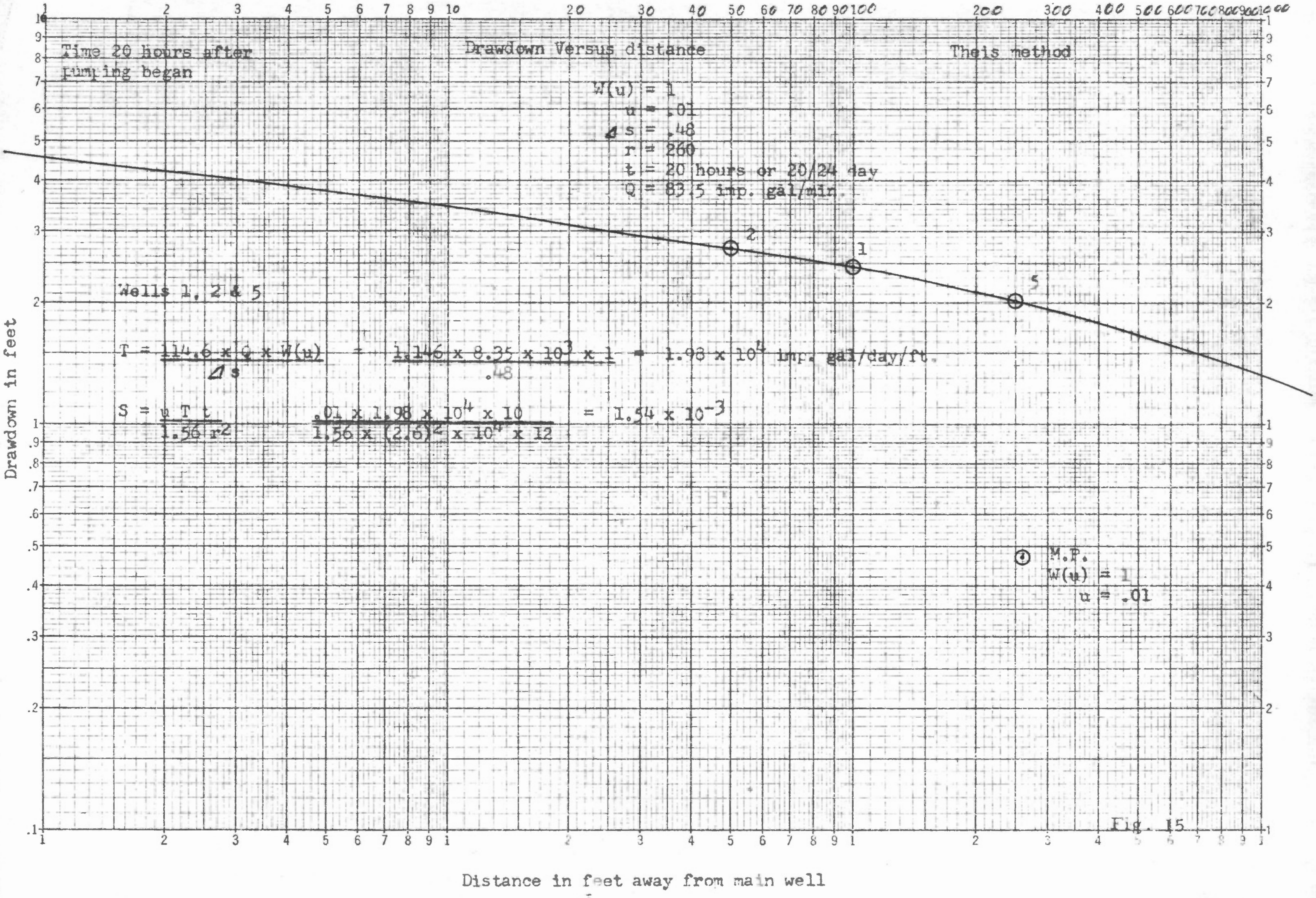
Wells 3 & 4

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s}$$

$$= \frac{1.146 \times 8.35 \times 1 \times 10^3}{10^{-1}} = 9.55 \times 10^4 \text{ imp gal/day/ft}$$

$$S = \frac{u\ T\ t}{1.56\ r^2} = \frac{1 \times 9.55 \times 10^4 \times 10}{1.55 \times 81 \times 10^4 \times 24} \qquad 3.15 \times 10^{-2}$$

Fig. 14



$W(u) = 1$
$u = .01$
$\Delta s = .48$
$r = 260$
$t = 20$ hours or 20/24 day
$Q = 83.5$ imp. gal/min.

Wells 1, 2 & 5

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s} = \frac{1.146 \times 8.35 \times 10^3 \times 1}{.48} = 1.98 \times 10^4 \text{ imp. gal/day/ft.}$$

$$S = \frac{u\ T\ t}{1.56\ r^2} \quad \frac{.01 \times 1.98 \times 10^4 \times 10}{1.56 \times (2.6)^2 \times 10^4 \times 12} = 1.54 \times 10^{-3}$$

M.P.
$W(u) = 1$
$u = .01$

Fig. 15

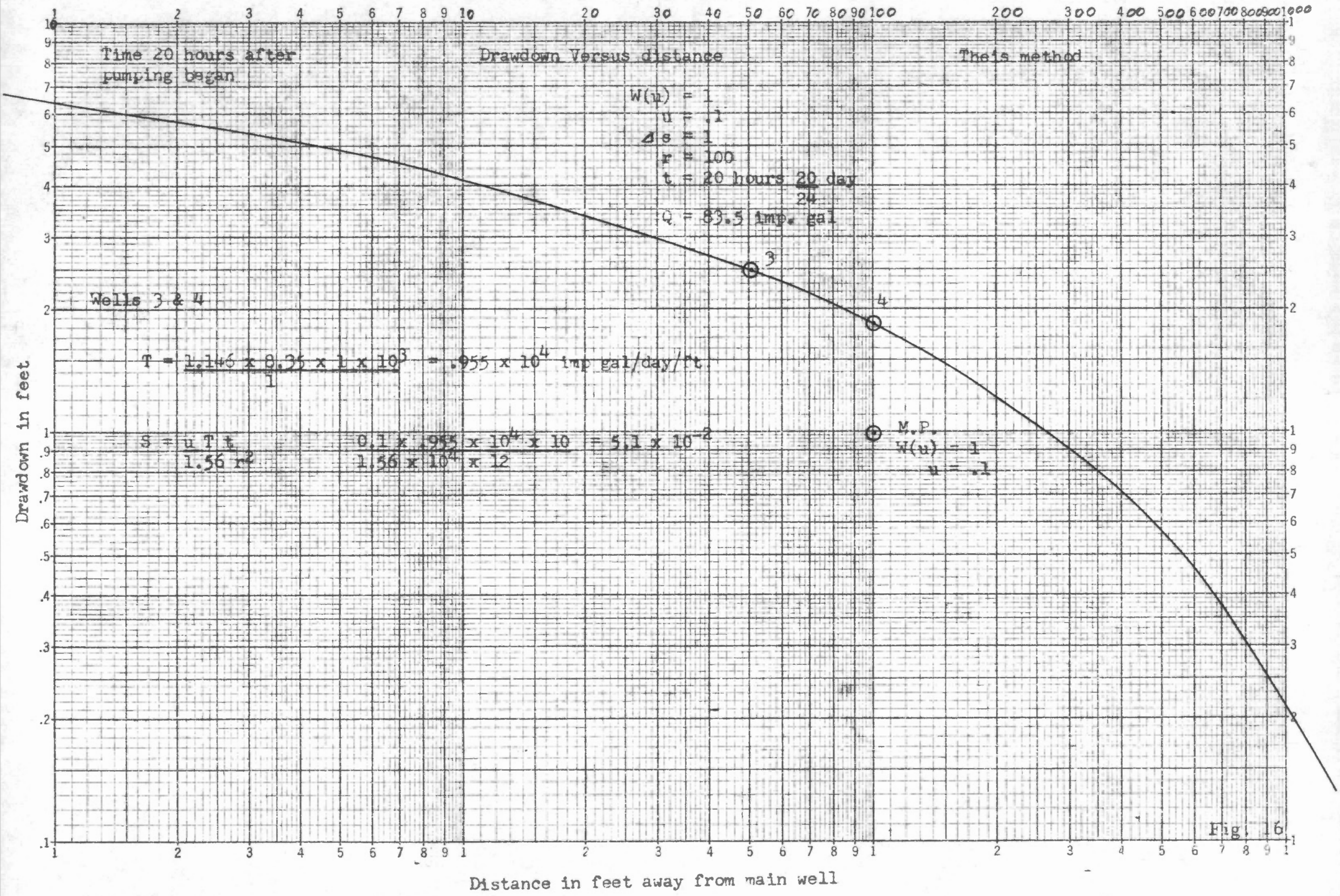


Fig. 16

Drawdown Versus distance

Theis method

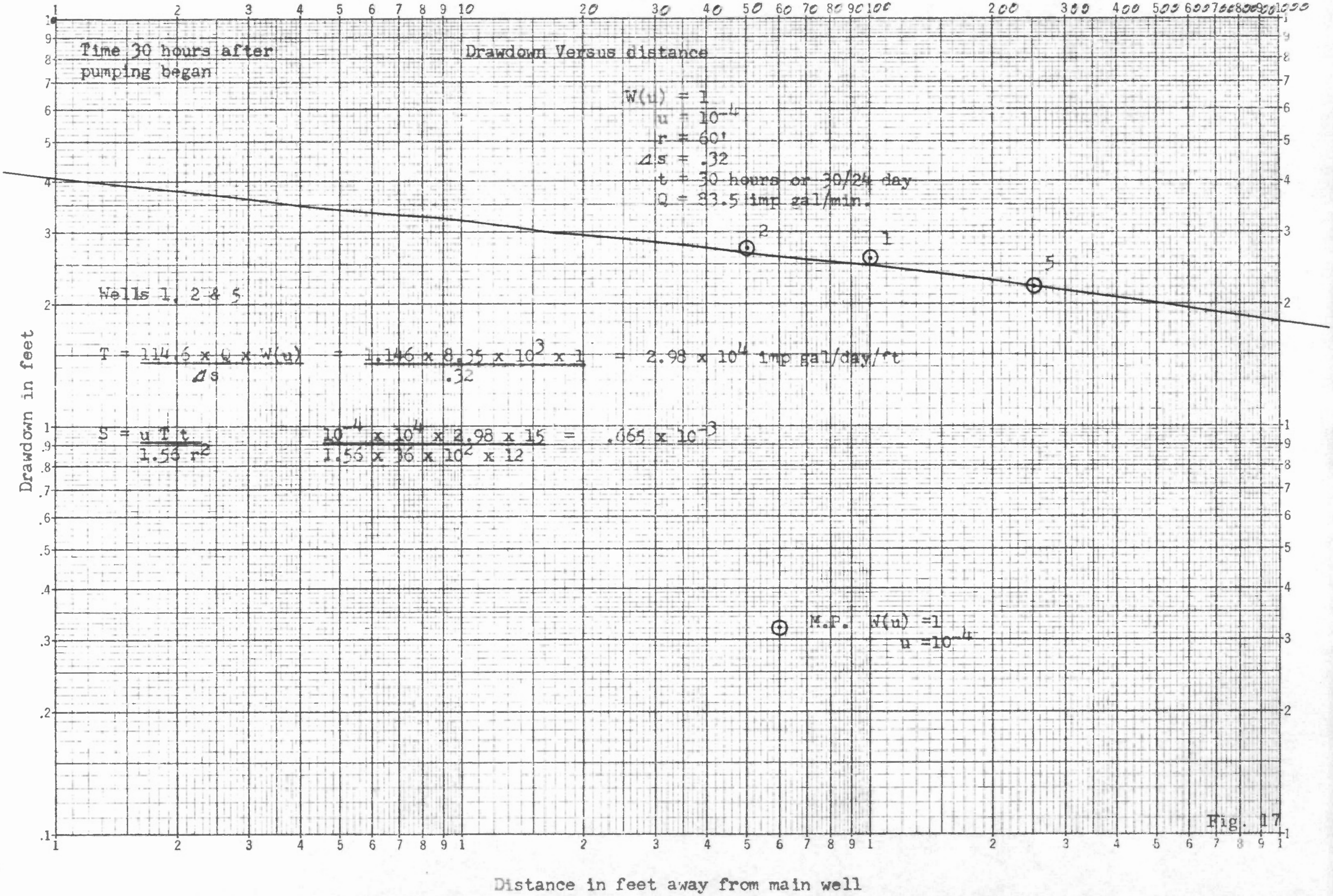
Time 20 hours after
pumping began

$W(u) = 1$
$u = .1$
$\Delta s = 1$
$r = 100$
$t = 20 \text{ hours } \frac{20}{24} \text{ day}$
$Q = 83.5 \text{ imp. gal}$

Wells 3 & 4

$$T = \frac{1.146 \times 8.35 \times 1 \times 10^3}{1} = .955 \times 10^4 \text{ imp gal/day/ft}$$

$$S = \frac{u\,T\,t}{1.56\,r^2} \qquad \frac{0.1 \times .955 \times 10^4 \times 10}{1.56 \times 10^4 \times 12} = 5.1 \times 10^{-2}$$

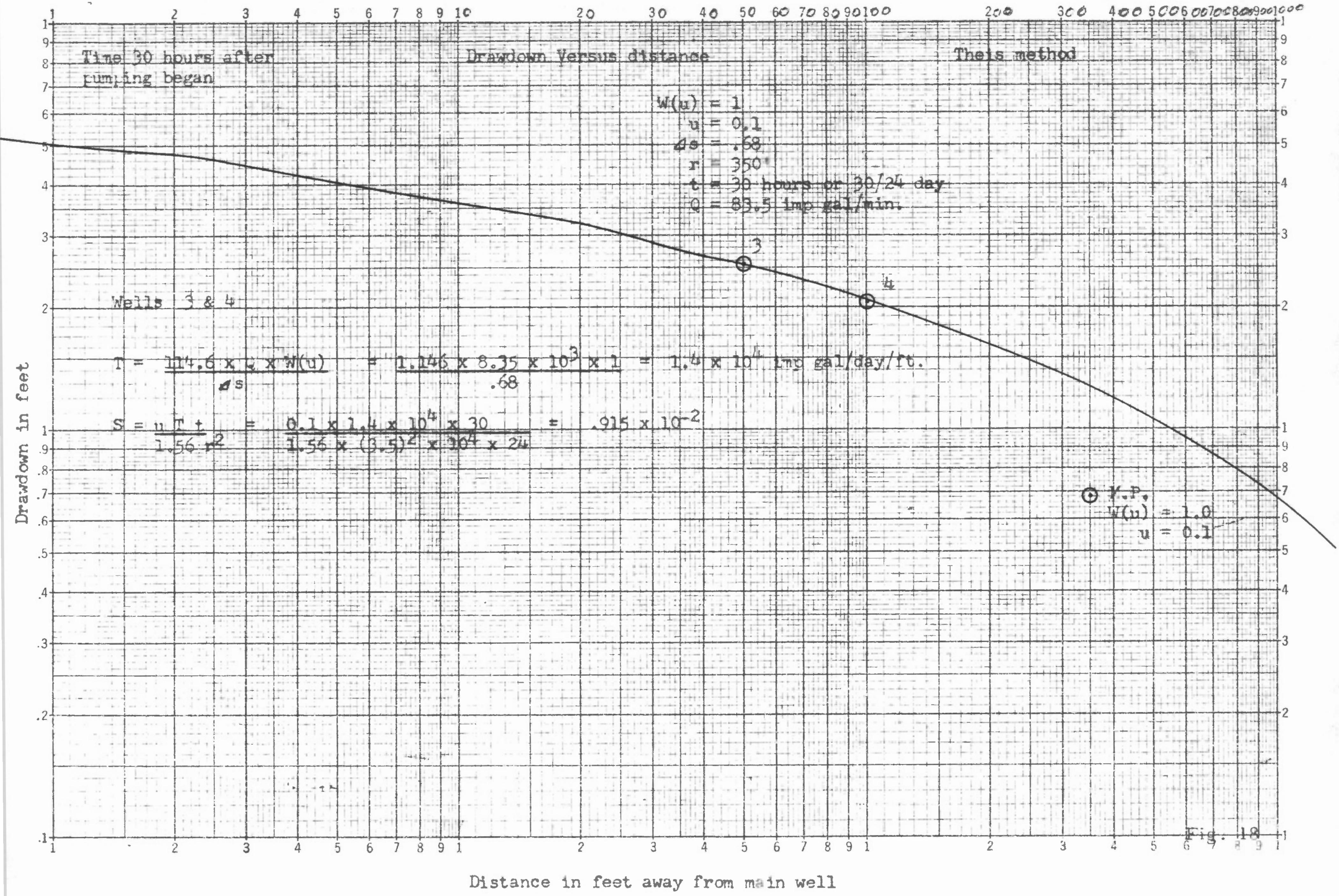


W(u) = 1
u = 10^{-4}
r = 60'
Δs = .32
t = 30 hours or 30/24 day
Q = 83.5 imp gal/min.

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s} = \frac{1.146 \times 8.35 \times 10^3 \times 1}{.32} = 2.98 \times 10^4 \text{ imp gal/day/ft}$$

$$S = \frac{u\ T\ t}{1.56\ r^2} \qquad \frac{10^{-4} \times 10^4 \times 2.98 \times 15}{1.56 \times 36 \times 10^2 \times 12} = .065 \times 10^{-3}$$

Fig. 17



Drawdown Versus distance

Theis method

Time 30 hours after pumping began

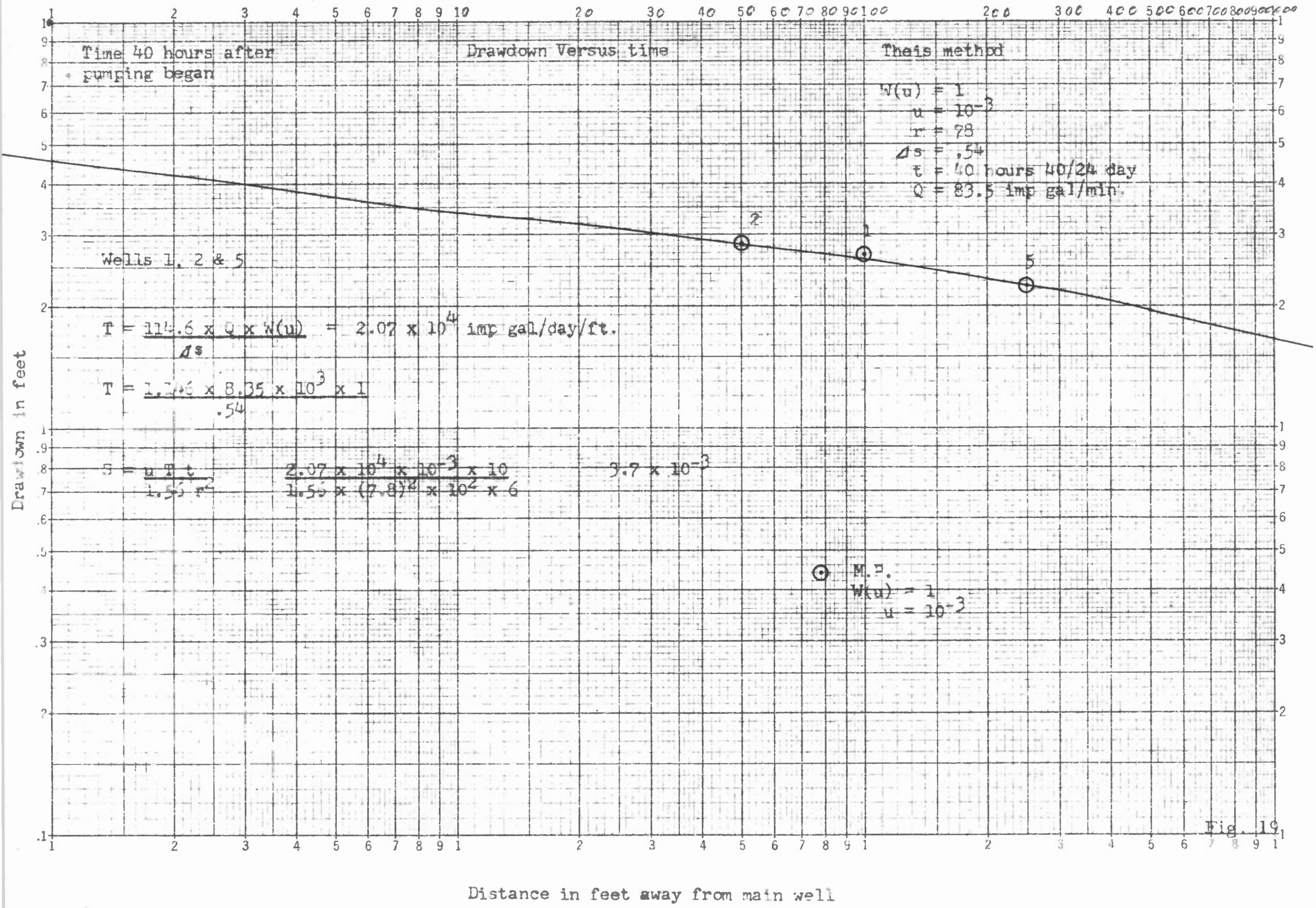
$W(u) = 1$
$u = 0.1$
$\Delta s = .68$
$r = 350'$
$t = 30$ hours or $30/24$ day
$Q = 83.5$ imp gal/min.

Wells 3 & 4

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s} = \frac{1.146 \times 8.35 \times 10^3 \times 1}{.68} = 1.4 \times 10^4 \text{ imp gal/day/ft.}$$

$$S = \frac{u\,T\,t}{1.56\,r^2} = \frac{0.1 \times 1.4 \times 10^4 \times 30}{1.56 \times (3.5)^2 \times 10^4 \times 24} = .915 \times 10^{-2}$$

Fig. 18



$W(u) = 1$
$u = 10^{-3}$
$r = 78$
$\Delta s = .54$
$t = 40$ hours 40/24 day
$Q = 83.5$ imp gal/min

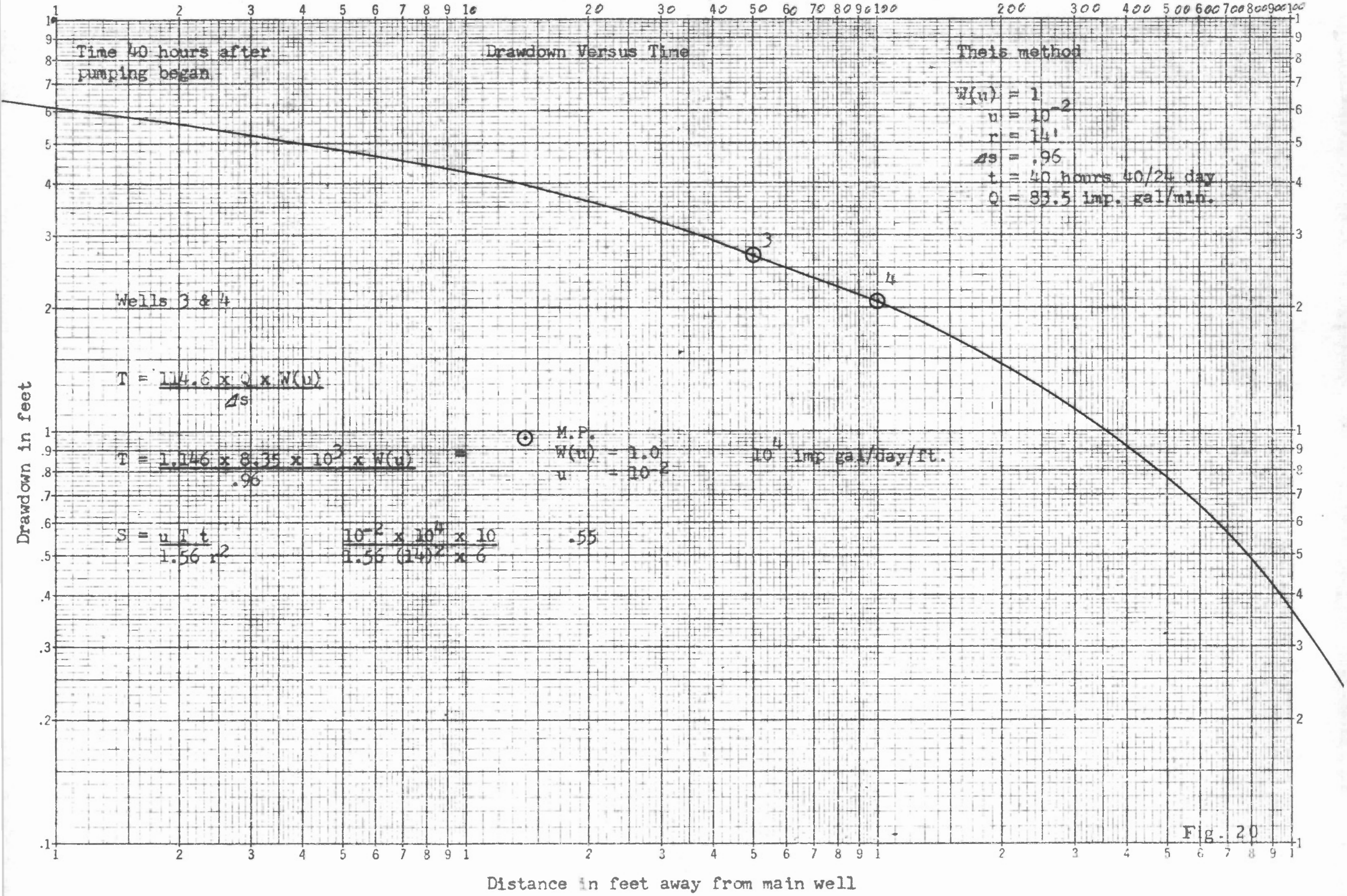
M.P.
$W(u) = 1$
$u = 10^{-3}$

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s} = 2.07 \times 10^{4} \text{ imp gal/day/ft.}$$

$$T = \frac{1.346 \times 8.35 \times 10^{3} \times 1}{.54}$$

$$S = \frac{u\,T\,t}{1.56\,r^2} \qquad \frac{2.07 \times 10^{4} \times 10^{-3} \times 10}{1.56 \times (7.8)^2 \times 10^2 \times 6} \qquad 9.7 \times 10^{-3}$$

Fig. 19



Time 40 hours after
pumping began

Theis method

$W(u) = 1$
$u = 10^{-2}$
$r = 14'$
$\Delta s = .96$
$t = 40$ hours 40/24 day
$Q = 83.5$ imp. gal/min.

Wells 3 & 4

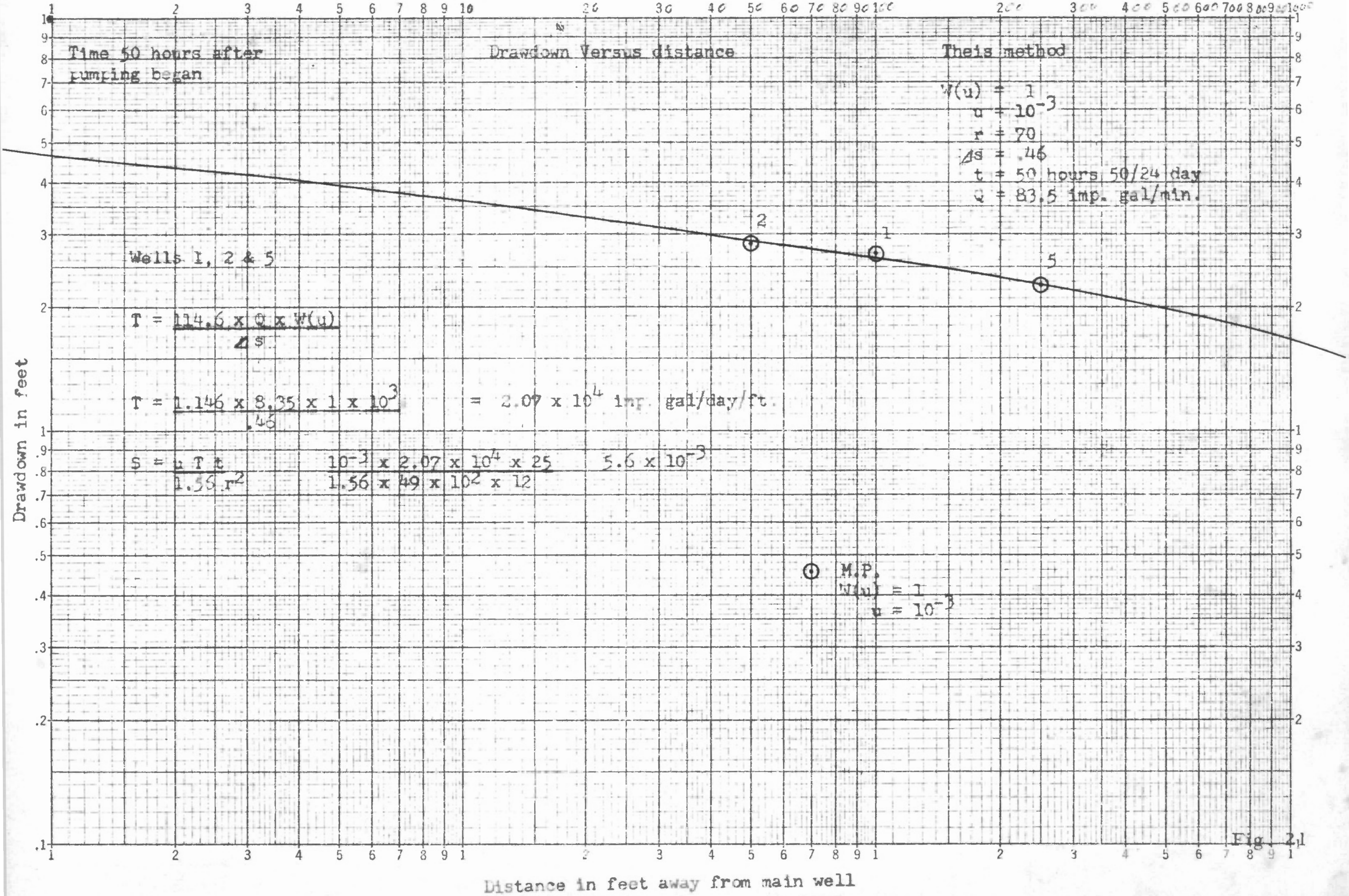
$$T = \frac{114.6 \times Q \times W(u)}{\Delta s}$$

$$T = \frac{1.146 \times 8.35 \times 10^3 \times W(u)}{.96} = 10^4 \text{ imp gal/day/ft.}$$

$W(u) = 1.0$
$u = 10^{-2}$

$$S = \frac{u\,T\,t}{1.56\,r^2} \quad \frac{10^{-2} \times 10^4 \times 10}{1.56\,(14)^2 \times 6} \quad .55$$

Fig. 20



Time 50 hours after pumping began

Drawdown Versus distance

Theis method

$W(u) = 1$
$u = 10^{-3}$
$r = 70$
$\Delta s = .46$
$t = 50$ hours 50/24 day
$Q = 83.5$ imp. gal/min.

Wells 1, 2 & 5

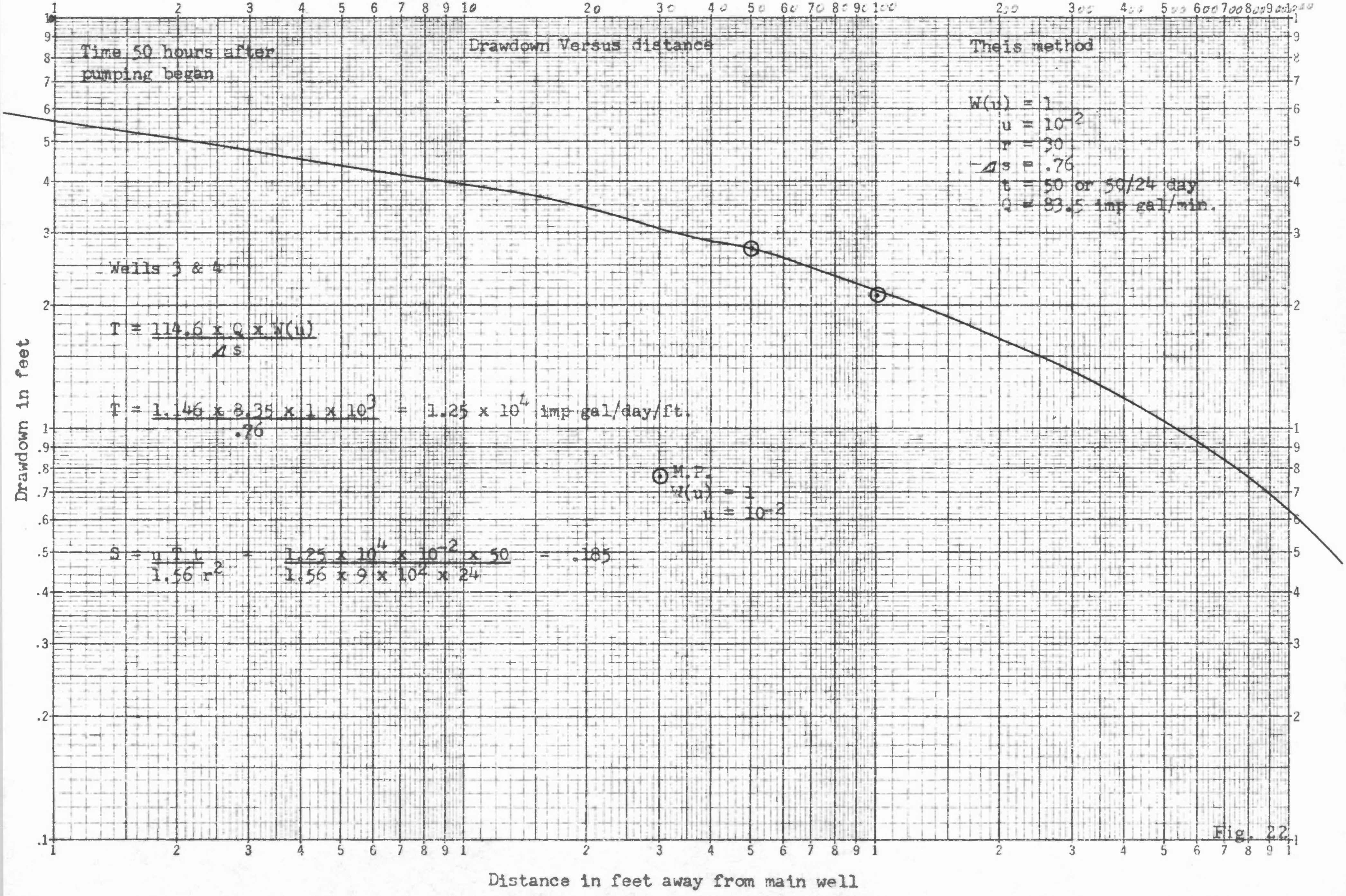
$$T = \frac{114.6 \times Q \times W(u)}{\Delta s}$$

$$T = \frac{1.146 \times 8.35 \times 1 \times 10^{3}}{.46} \quad = 2.07 \times 10^{4} \text{ imp. gal/day/ft.}$$

$$S = \frac{u\,T\,t}{1.56\,r^{2}} \qquad \frac{10^{-3} \times 2.07 \times 10^{4} \times 25}{1.56 \times 49 \times 10^{2} \times 12} \qquad 5.6 \times 10^{-3}$$

M.P.
$W(u) = 1$
$u = 10^{-3}$

Fig. 21



$W(u) = 1$
$u = 10^{-2}$
$r = 30$
$\Delta s = .76$
$t = 50$ or $50/24$ day
$Q = 83.5$ imp gal/min.

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s}$$

$$T = \frac{1.146 \times 8.35 \times 1 \times 10^3}{.76} = 1.25 \times 10^4 \text{ imp gal/day/ft.}$$

$$S = \frac{u\,T\,t}{1.56\,r^2} = \frac{1.25 \times 10^4 \times 10^{-2} \times 50}{1.56 \times 9 \times 10^2 \times 24} = .185$$

Fig. 22

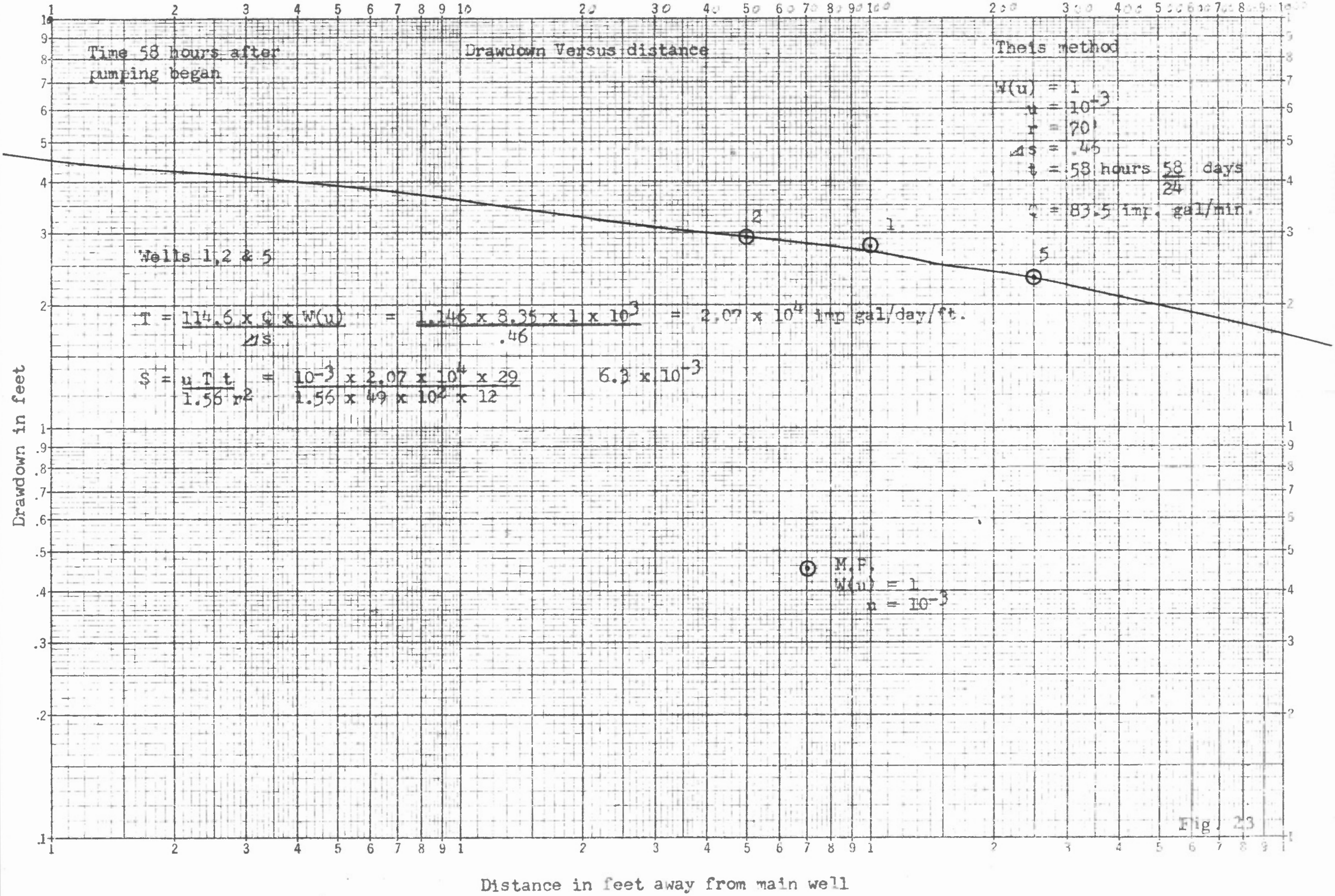

Time 58 hours after pumping began
Drawdown Versus distance
Theis method
W(u) = 1
u = 10-3
r = 70'
Δs = .46
t = 58 hours 58/24 days
Q = 83.5 imp. gal/min.
Wells 1,2 & 5
T = 114.6 x Q x W(u) / Δs = 1.146 x 8.35 x 1 x 10^3 / .46 = 2.07 x 10^4 imp gal/day/ft.
S = u T t / 1.56 r^2 = 10^-3 x 2.07 x 10^4 x 29 / 1.56 x 49 x 10^2 x 12   6.3 x 10^-3
2
1
5
M.F.
W(u) = 1
u = 10^-3
Drawdown in feet
Distance in feet away from main well
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
.1
.2
.3
.4
.5
.6
.7
.8
.9

Fig. 23

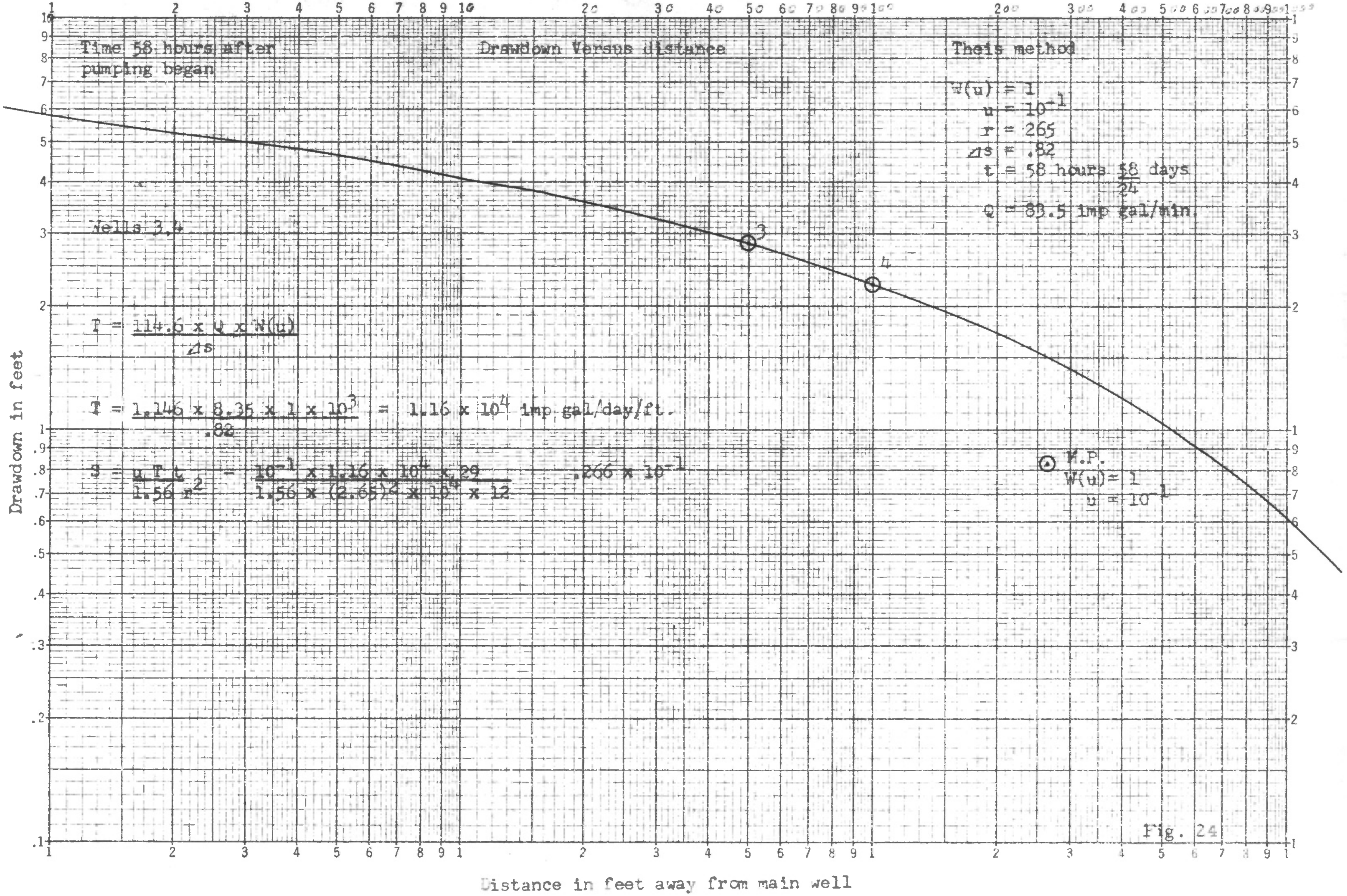


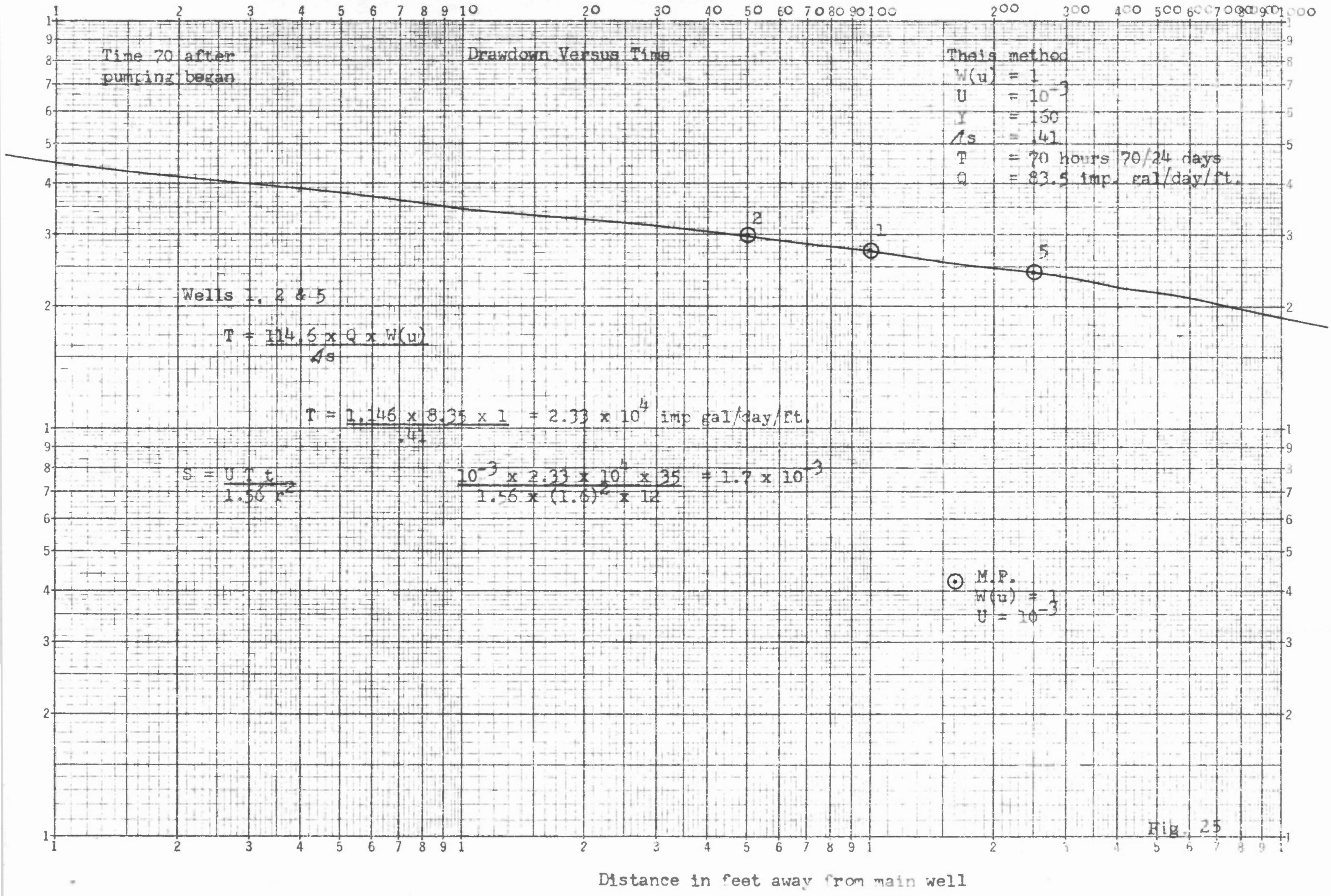
Fig. 24

$W(u) = 1$
$u = 10^{-1}$
$r = 265$
$\Delta s = .82$
$t = 58$ hours $\frac{58}{24}$ days
$Q = 83.5$ imp gal/min.

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s}$$

$$T = \frac{1.146 \times 8.35 \times 1 \times 10^{3}}{.82} = 1.16 \times 10^{4} \text{ imp gal/day/ft.}$$

$$S = \frac{u\,T\,t}{1.56\,r^{2}} = \frac{10^{-1} \times 1.16 \times 10^{4} \times 2.29}{1.56 \times (2.65)^{2} \times 10^{4} \times 12} \quad .266 \times 10^{-1}$$



Theis method

W(u) = 1

U = 10^{-3}

Y = 150

Δs = .41

T = 70 hours 70/24 days

Q = 83.5 imp. gal/day/ft.

M.P.

W(u) = 1

U = 10^{-3}

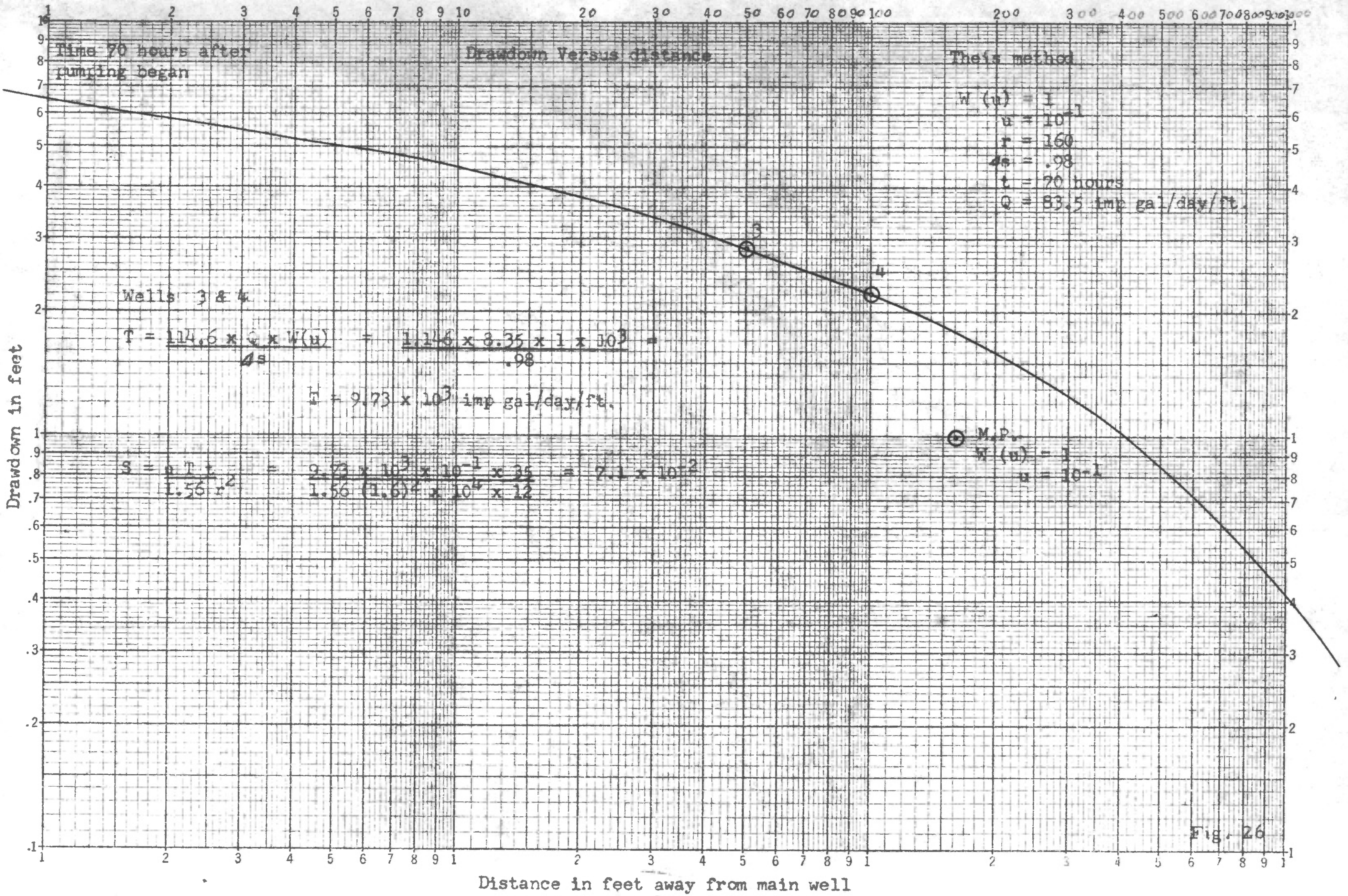
Wells 1, 2 & 5

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s}$$

$$T = \frac{1.146 \times 8.35 \times 1}{.41} = 2.33 \times 10^{4} \text{ imp gal/day/ft.}$$

$$S = \frac{U\,T\,t}{1.56\,r^{2}} \qquad \frac{10^{-3} \times 2.33 \times 10^{4} \times 35}{1.56 \times (1.6)^{2} \times 12} = 1.7 \times 10^{-3}$$

Fig. 25



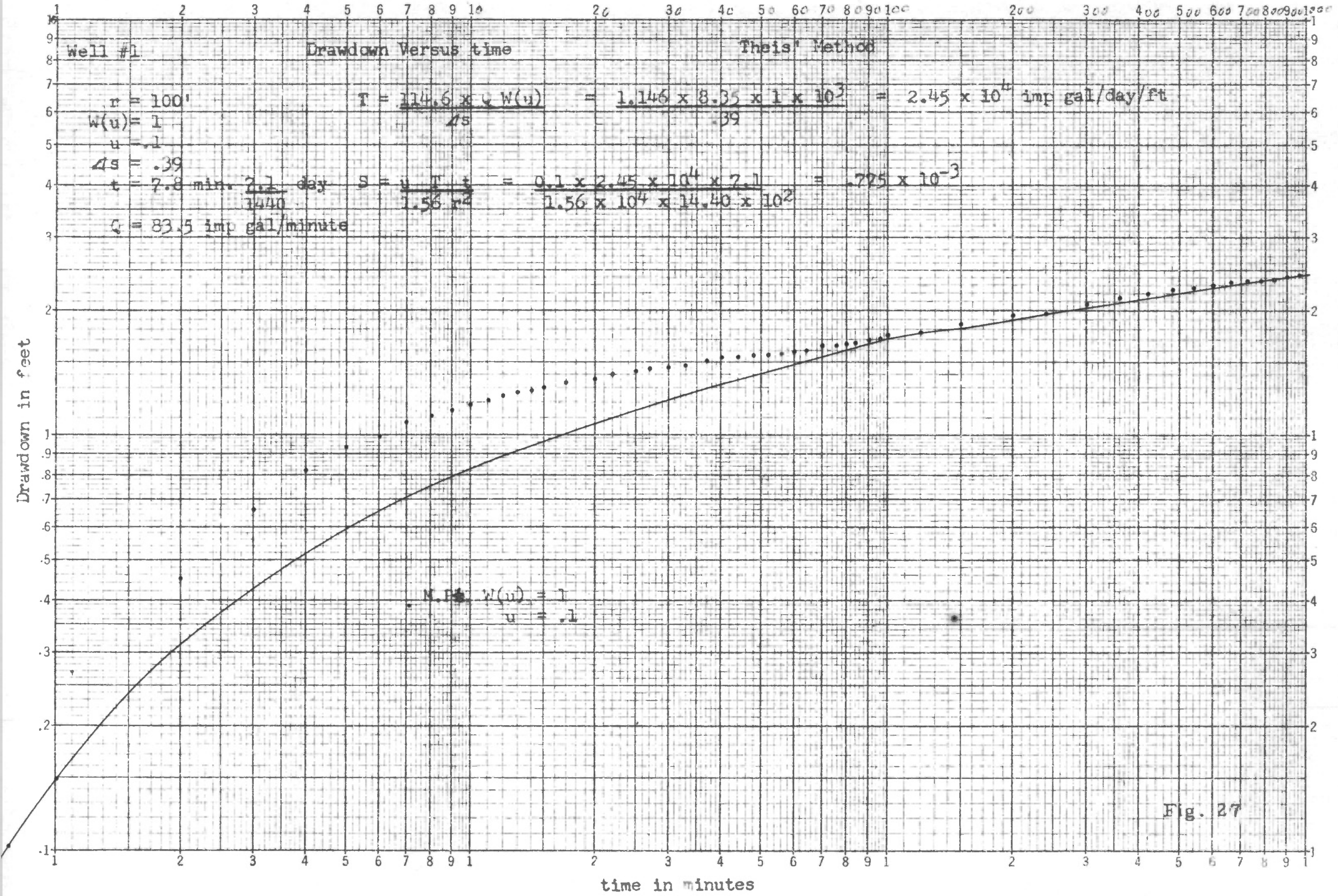
Wells 3 & 4

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s} = \frac{1.146 \times 3.35 \times 1 \times 10^3}{.98} =$$

$$T = 9.73 \times 10^3 \text{ imp gal/day/ft.}$$

$$S = \frac{u\,T\,t}{1.56\,r^2} = \frac{9.73 \times 10^3 \times 10^{-1} \times 35}{1.56\,(1.6)^2 \times 10^4 \times 12} = 7.1 \times 10^{-2}$$

Fig. 26



Well #1

Drawdown Versus time

Theis' Method

r = 100'

W(u) = 1

u = .1

$\Delta s = .39$

$t = 7.8 \text{ min. } \frac{2.1}{1440} \text{ day}$

Q = 83.5 imp gal/minute

$$T = \frac{114.6 \times Q\, W(u)}{\Delta s} = \frac{1.146 \times 8.35 \times 1 \times 10^3}{.39} = 2.45 \times 10^4 \text{ imp gal/day/ft}$$

$$S = \frac{u\ T\ t}{1.56\ r^2} = \frac{0.1 \times 2.45 \times 10^4 \times 2.1}{1.56 \times 10^4 \times 14.40 \times 10^2} = .775 \times 10^{-3}$$

Fig. 27

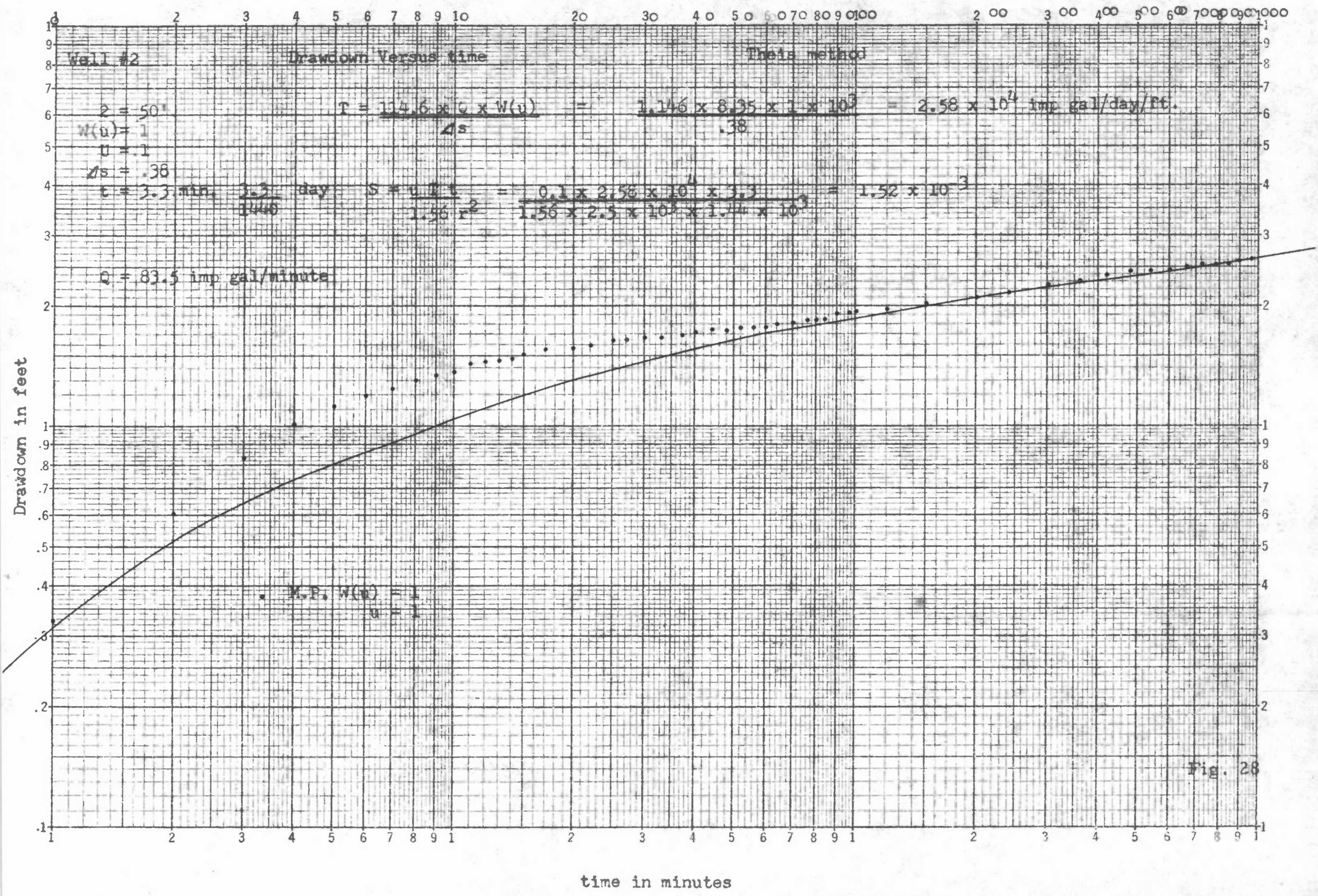
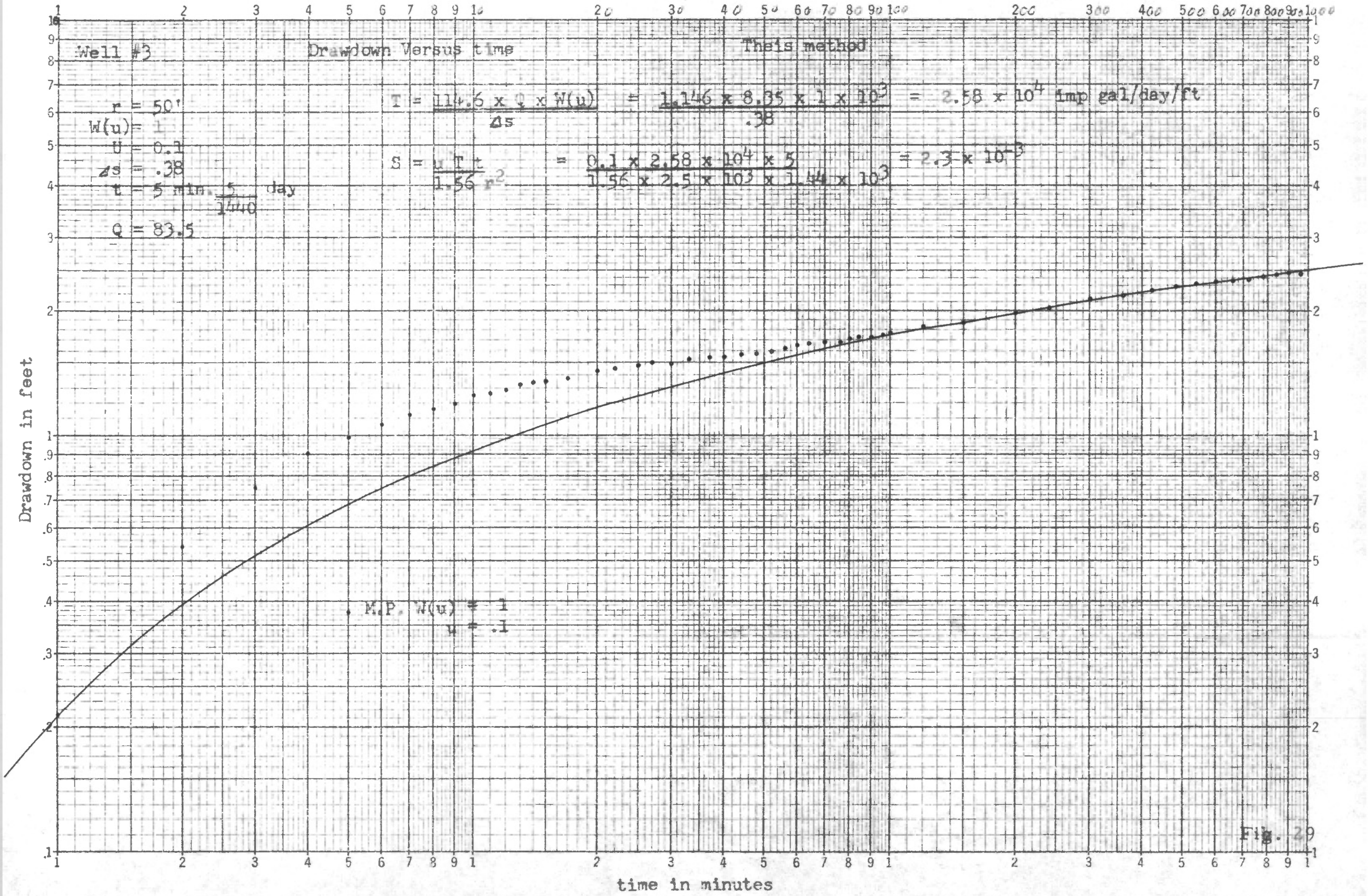
Well #2
Drawdown Versus time
Theis method
2 = 50'
W(u) = 1
U = .1
Δs = .38
t = 3.3 min. $\frac{3.3}{1440}$ day
$T = \frac{114.6 \times Q \times W(u)}{\Delta s} = \frac{1.146 \times 8.35 \times 1 \times 10^3}{.38} = 2.58 \times 10^4$ imp gal/day/ft.
$S = \frac{u\,T\,t}{1.56\,r^2} = \frac{0.1 \times 2.58 \times 10^4 \times 3.3}{1.56 \times 2.5 \times 10^3 \times 1.44 \times 10^3} = 1.52 \times 10^{-3}$
Q = 83.5 imp gal/minute
M.P. W(u) = 1
u = 1
Drawdown in feet
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
2
3
4
5
6
7
8
9
time in minutes
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000

Fig. 28



Well #3

Drawdown Versus time

Theis method

r = 50'
W(u) = 1
U = 0.1
Δs = .38
t = 5 min. $\frac{5}{1440}$ day
Q = 83.5

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s} = \frac{1.146 \times 8.35 \times 1 \times 10^3}{.38} = 2.58 \times 10^4 \text{ imp gal/day/ft}$$

$$S = \frac{u\,T\,t}{1.56\,r^2} = \frac{0.1 \times 2.58 \times 10^4 \times 5}{1.56 \times 2.5 \times 10^3 \times 1.44 \times 10^3} = 2.3 \times 10^{-3}$$

Fig. 29

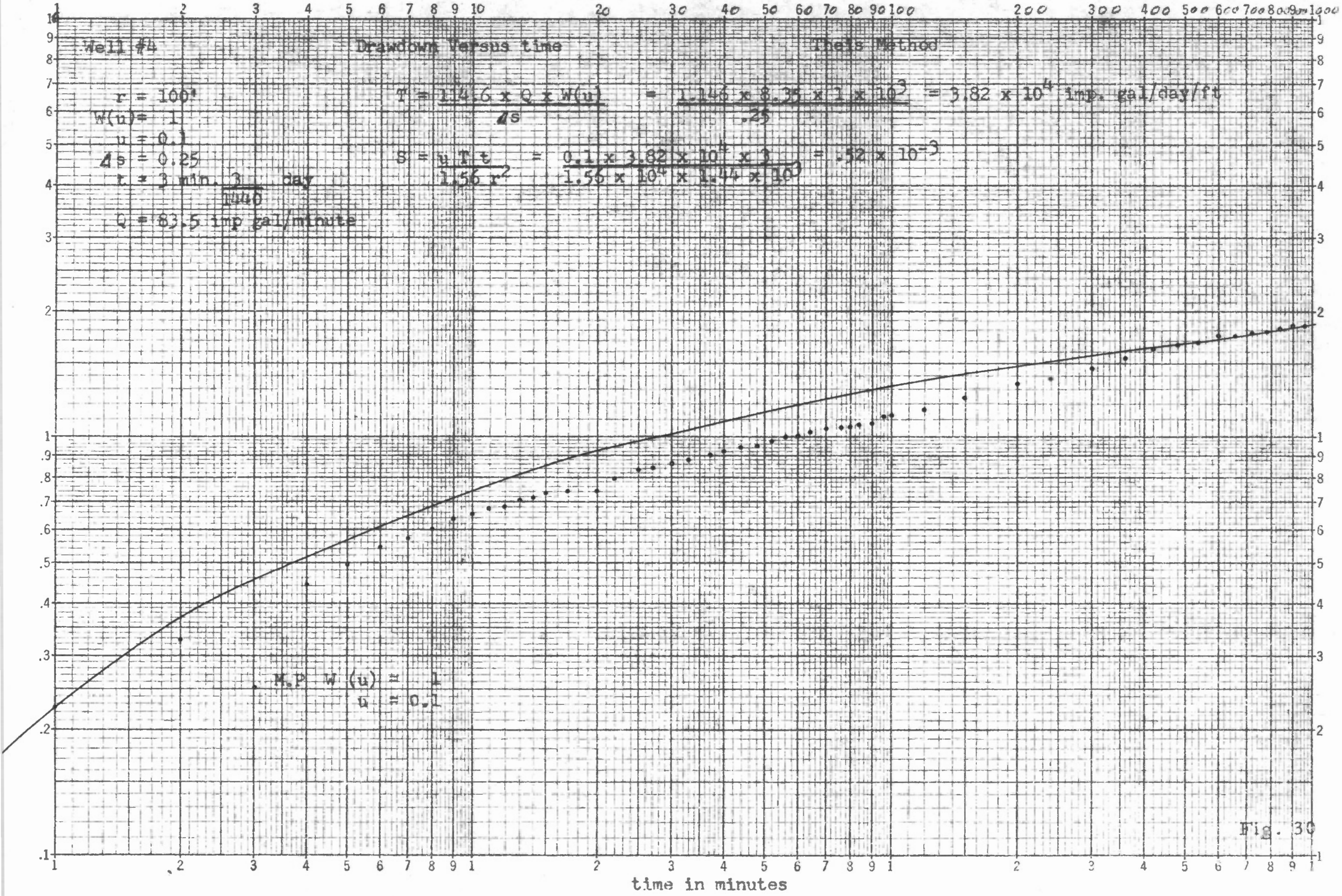


Fig. 30

Well #4

Drawdown Versus time

Theis Method

r = 100'

W(u) = 1

u = 0.1

Δs = 0.25

t = 3 min. $\frac{3}{1440}$ day

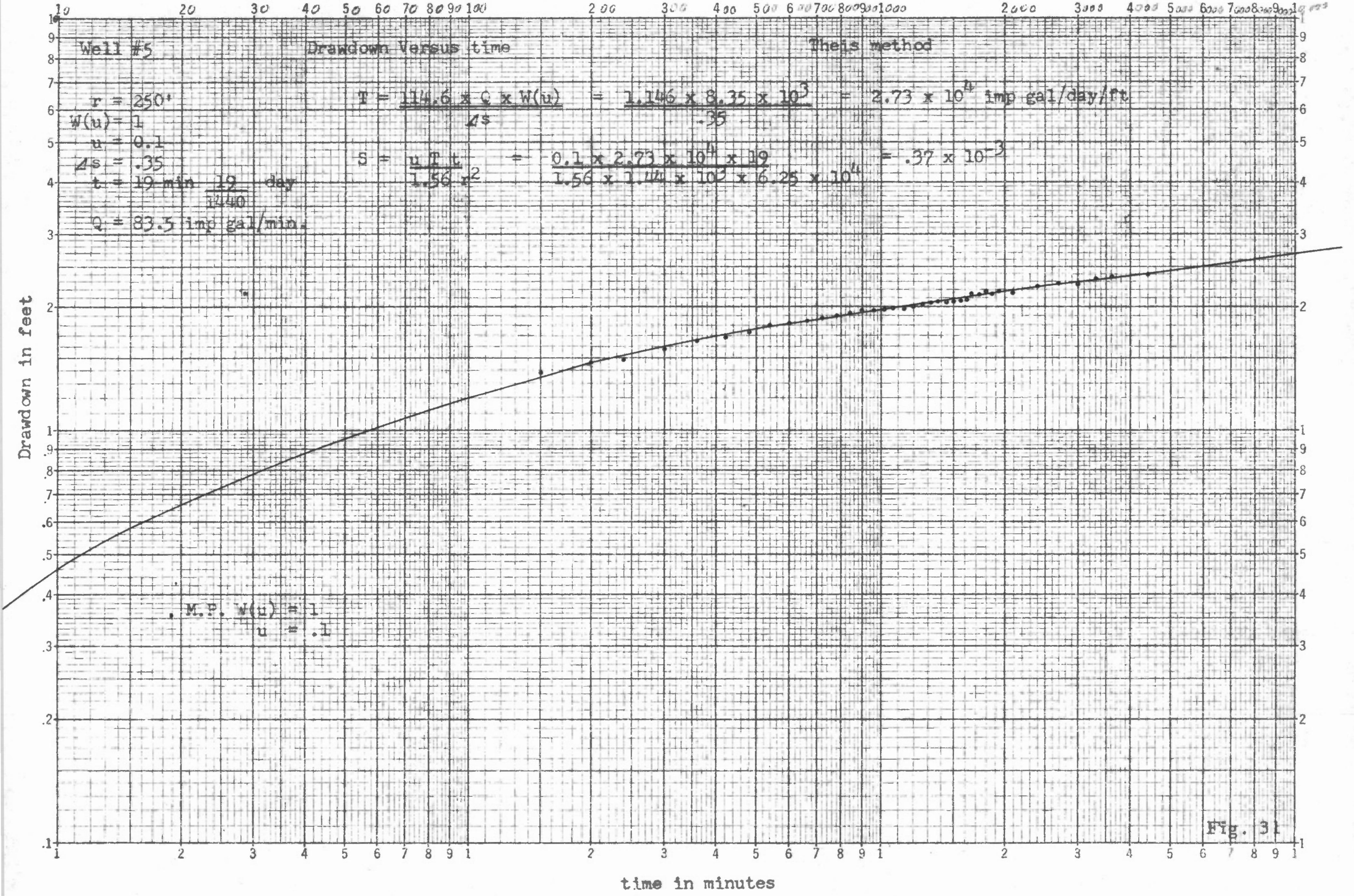
Q = 83.5 imp gal/minute

$$T = \frac{114.6 \times Q \times W(u)}{\Delta s} = \frac{1.146 \times 8.35 \times 1 \times 10^3}{.25} = 3.82 \times 10^4 \text{ imp. gal/day/ft}$$

$$S = \frac{u\,T\,t}{1.56\,r^2} = \frac{0.1 \times 3.82 \times 10^4 \times 3}{1.56 \times 10^4 \times 1.44 \times 10^3} = .52 \times 10^{-3}$$

M.P W (u) = 1

u = 0.1



Well #5

Drawdown Versus time

Theis method

r = 250'

W(u) = 1

u = 0.1

$\Delta s = .35$

$t = 19 \text{ min } \frac{19}{1440} \text{ day}$

Q = 83.5 imp gal/min.

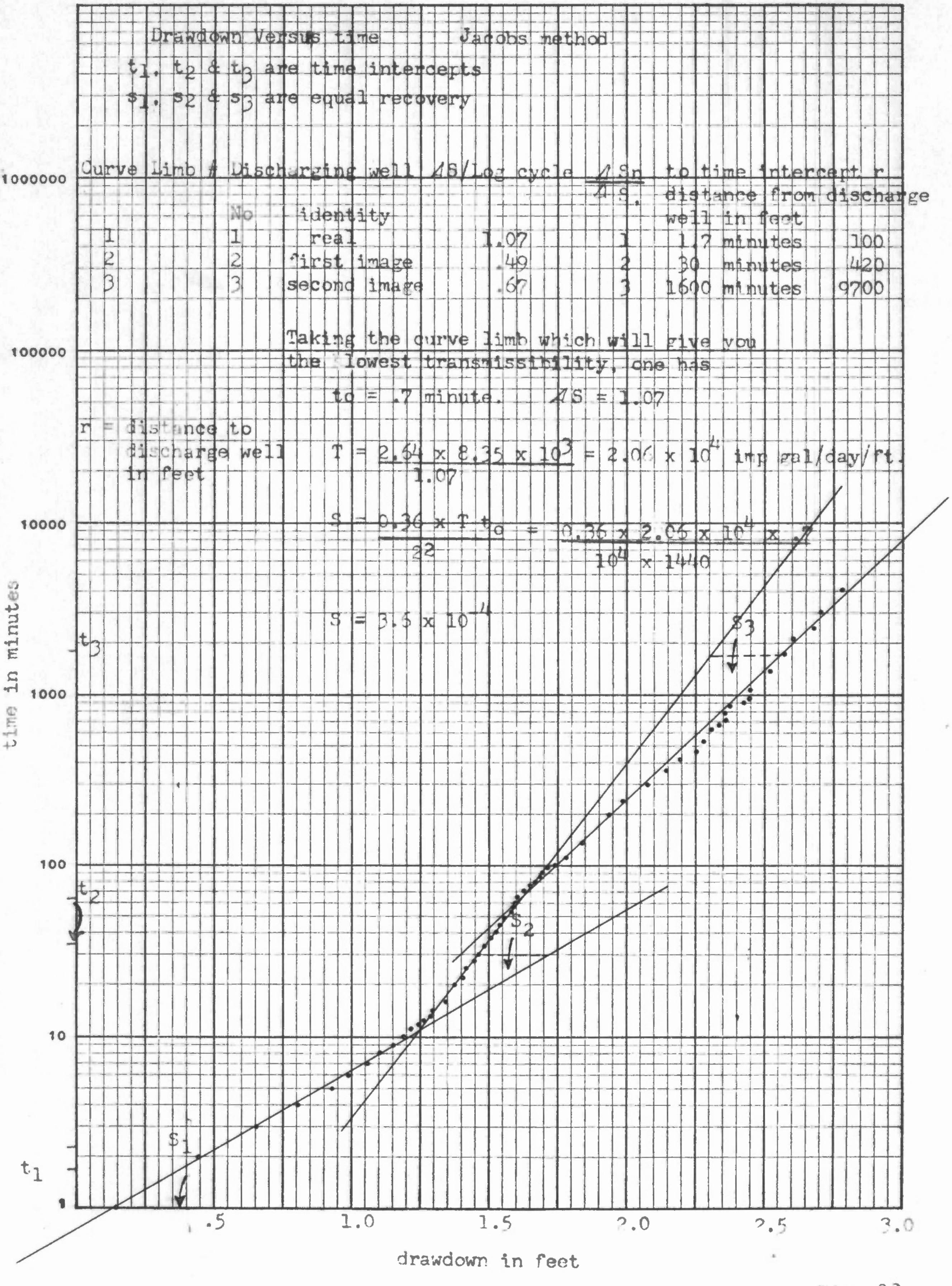
$$T = \frac{114.6 \times Q \times W(u)}{\Delta s} = \frac{1.146 \times 8.35 \times 10^3}{.35} = 2.73 \times 10^4 \text{ imp gal/day/ft}$$

$$S = \frac{u\,T\,t}{1.56\,r^2} = \frac{0.1 \times 2.73 \times 10^4 \times 19}{1.56 \times 1.44 \times 10^3 \times 6.25 \times 10^4} = .37 \times 10^{-3}$$

M.P. W(u) = 1
u = .1

Fig. 31

MODEL St-LaZare Pump Test Well #1. **DATE**



Drawdown Versus time Jacobs method

t_1, t_2 & t_3 are time intercepts

s_1, s_2 & s_3 are equal recovery

Curve Limb #	Discharging well No	identity	ΔS/Log cycle	$\frac{\Delta S_n}{\Delta S_1}$	to time intercept	r distance from discharge well in feet
1	1	real	1.07	1	1.7 minutes	100
2	2	first image	.49	2	30 minutes	420
3	3	second image	.67	3	1600 minutes	9700

Taking the curve limb which will give you the lowest transmissibility, one has

to = .7 minute. $\Delta S = 1.07$

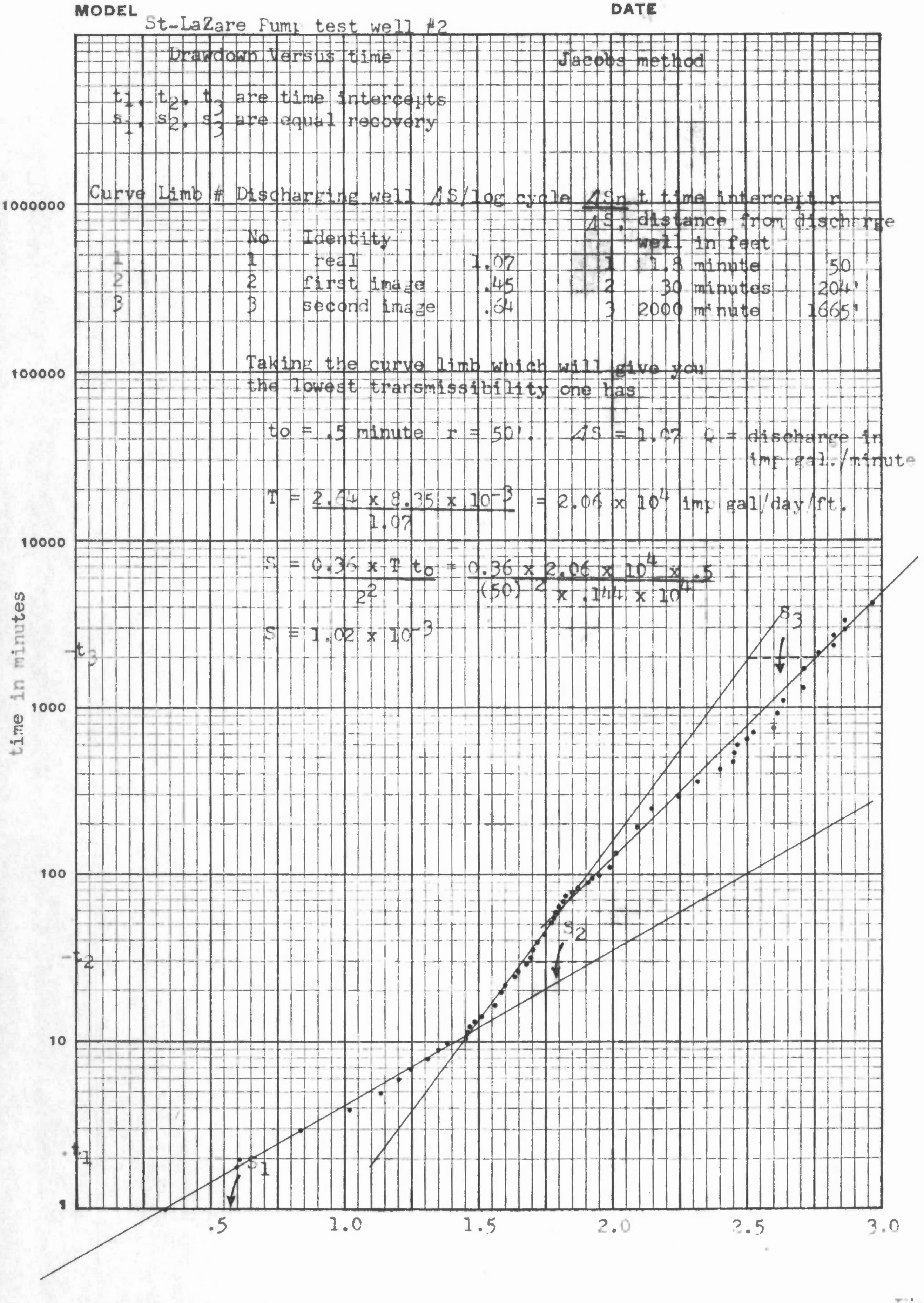
r = distance to discharge well in feet

$$T = \frac{2.64 \times 8.35 \times 10^3}{1.07} = 2.06 \times 10^4 \text{ imp gal/day/ft.}$$

$$S = \frac{0.36 \times T\, t_o}{2^2} = \frac{0.36 \times 2.06 \times 10^4 \times .7}{10^4 \times 1440}$$

$$S = 3.5 \times 10^{-4}$$

Fig. 32



St-LaZare Pump test well #2

Drawdown Versus time

Jacobs method

t_1, t_2, t_3 are time intercepts
s_1, s_2, s_3 are equal recovery

Curve Limb #	Discharging well No	Identity	ΔS/log cycle	$\frac{\Delta S_n}{\Delta S_1}$	t time intercept	r distance from discharge well in feet
1	1	real	1.07	1	1.8 minute	50
2	2	first image	.45	2	30 minutes	204'
3	3	second image	.64	3	2000 minute	1665'

Taking the curve limb which will give you the lowest transmissibility one has

$t_o = .5$ minute $r = 50'$. $\Delta S = 1.07$ Q = discharge in imp gal./minute

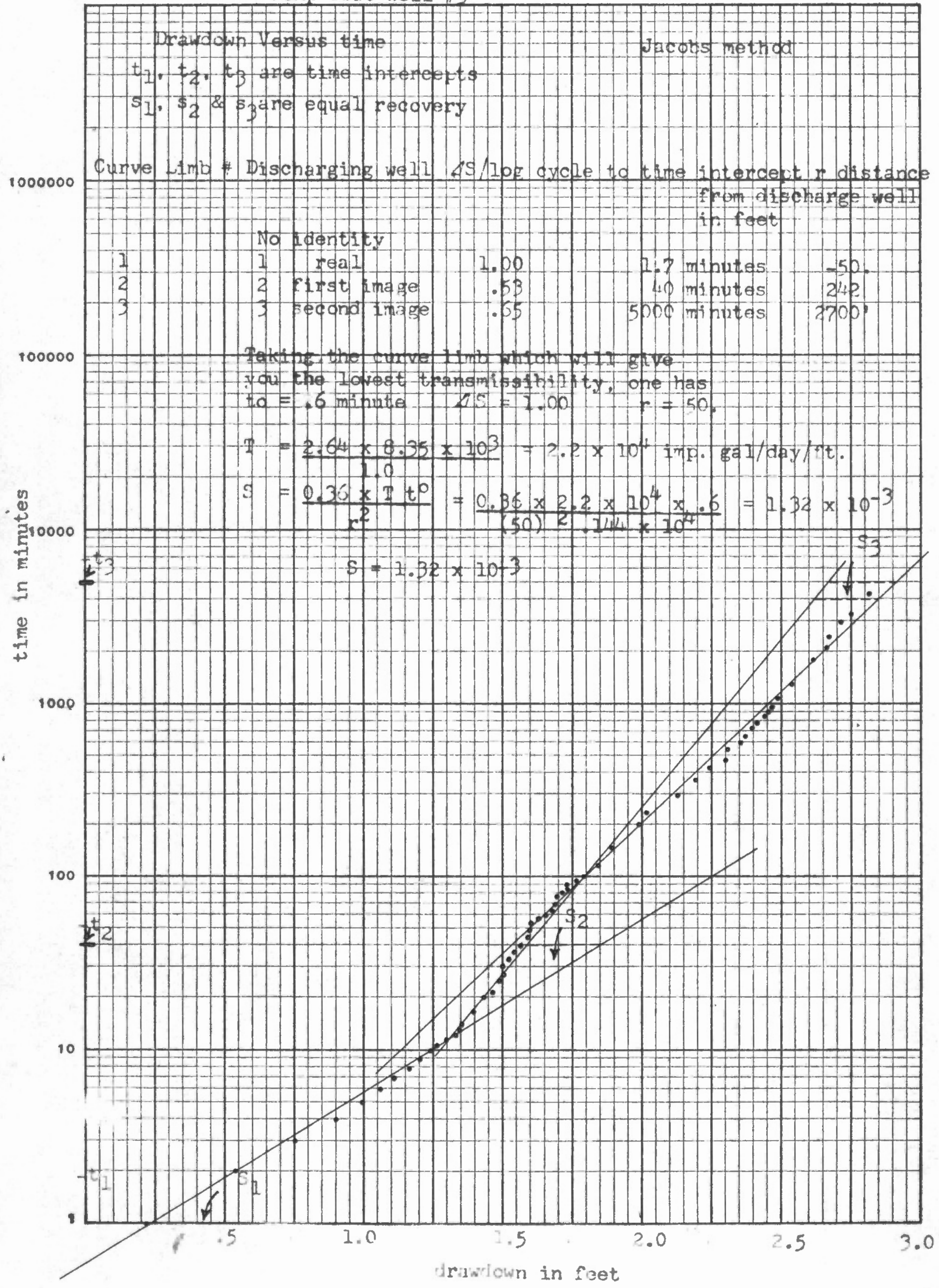
$$T = \frac{2.64 \times 8.35 \times 10^{-3}}{1.07} = 2.06 \times 10^4 \text{ imp gal/day/ft.}$$

$$S = \frac{0.36 \times T\, t_o}{2^2} = \frac{0.36 \times 2.06 \times 10^4 \times .5}{(50)^2 \times .144 \times 10^4}$$

$$S = 1.02 \times 10^{-3}$$

Fig. 33

MODEL St-Lazare Pump Test well #3 **DATE**



Drawdown Versus time

Jacobs method

t_1, t_2, t_3 are time intercepts

s_1, s_2 & s_3 are equal recovery

Curve Limb #	Discharging well No	identity	ΔS/log cycle	to time intercept	r distance from discharge well in feet
1	1	real	1.00	1.7 minutes	50.
2	2	first image	.53	40 minutes	242
3	3	second image	.65	5000 minutes	2700'

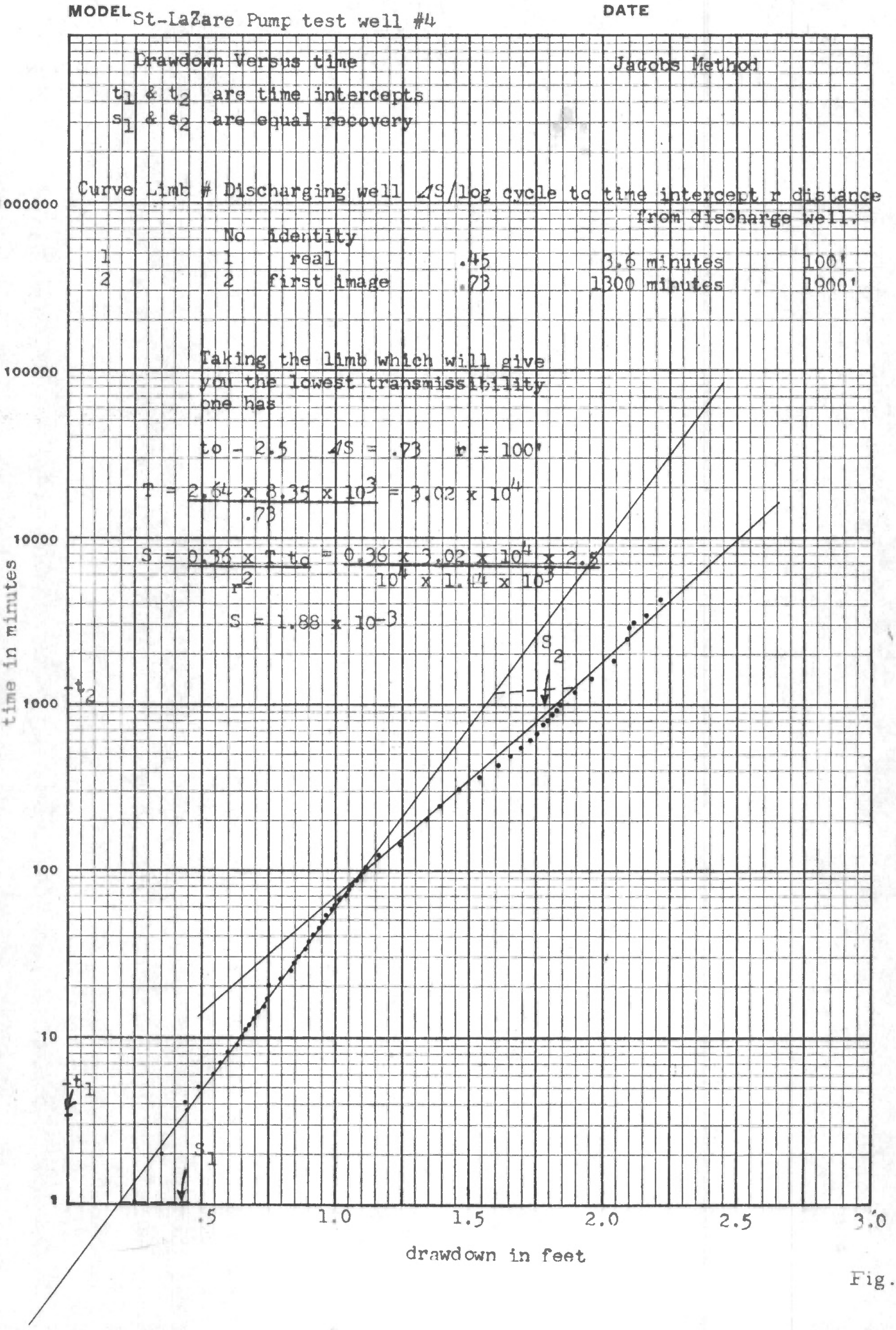
Taking the curve limb which will give you the lowest transmissibility, one has to = .6 minute ΔS = 1.00 r = 50.

$$T = \frac{2.64 \times 8.35 \times 10^3}{1.0} = 2.2 \times 10^4 \text{ imp. gal/day/ft.}$$

$$S = \frac{0.36 \times T\, t^o}{r^2} = \frac{0.36 \times 2.2 \times 10^4 \times .6}{(50)^2 \ .144 \times 10^4} = 1.32 \times 10^{-3}$$

$$S = 1.32 \times 10^{-3}$$

Fig. 34



MODEL St-LaZare Pump test well #4

DATE

Drawdown Versus time

Jacobs Method

t_1 & t_2 are time intercepts
s_1 & s_2 are equal recovery

Curve	Limb # Discharging well No	Identity	ΔS/log cycle	to time intercept	r distance from discharge well.
1	1	real	.45	3.6 minutes	100'
2	2	first image	.73	1300 minutes	1900'

Taking the limb which will give
you the lowest transmissibility
one has

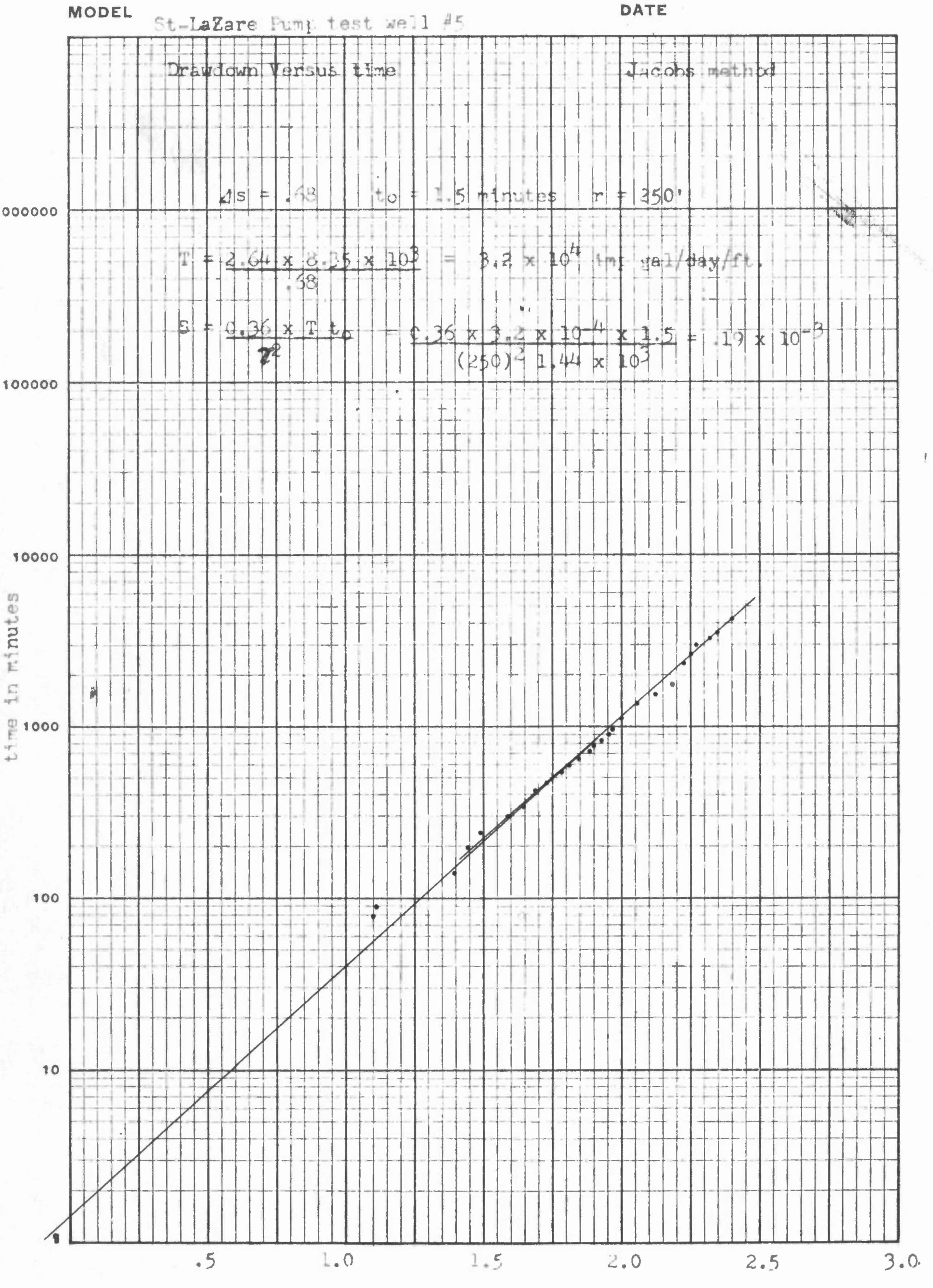
t_o - 2.5 ΔS = .73 r = 100'

$$T = \frac{2.64 \times 8.35 \times 10^3}{.73} = 3.02 \times 10^4$$

$$S = \frac{0.36 \times T\, t_o}{r^2} = \frac{0.36 \times 3.02 \times 10^4 \times 2.5}{10^4 \times 1.44 \times 10^3}$$

$$S = 1.88 \times 10^{-3}$$

Fig. 35



St-LaZare Pump test well #5

Drawdown Versus time

Jacobs method

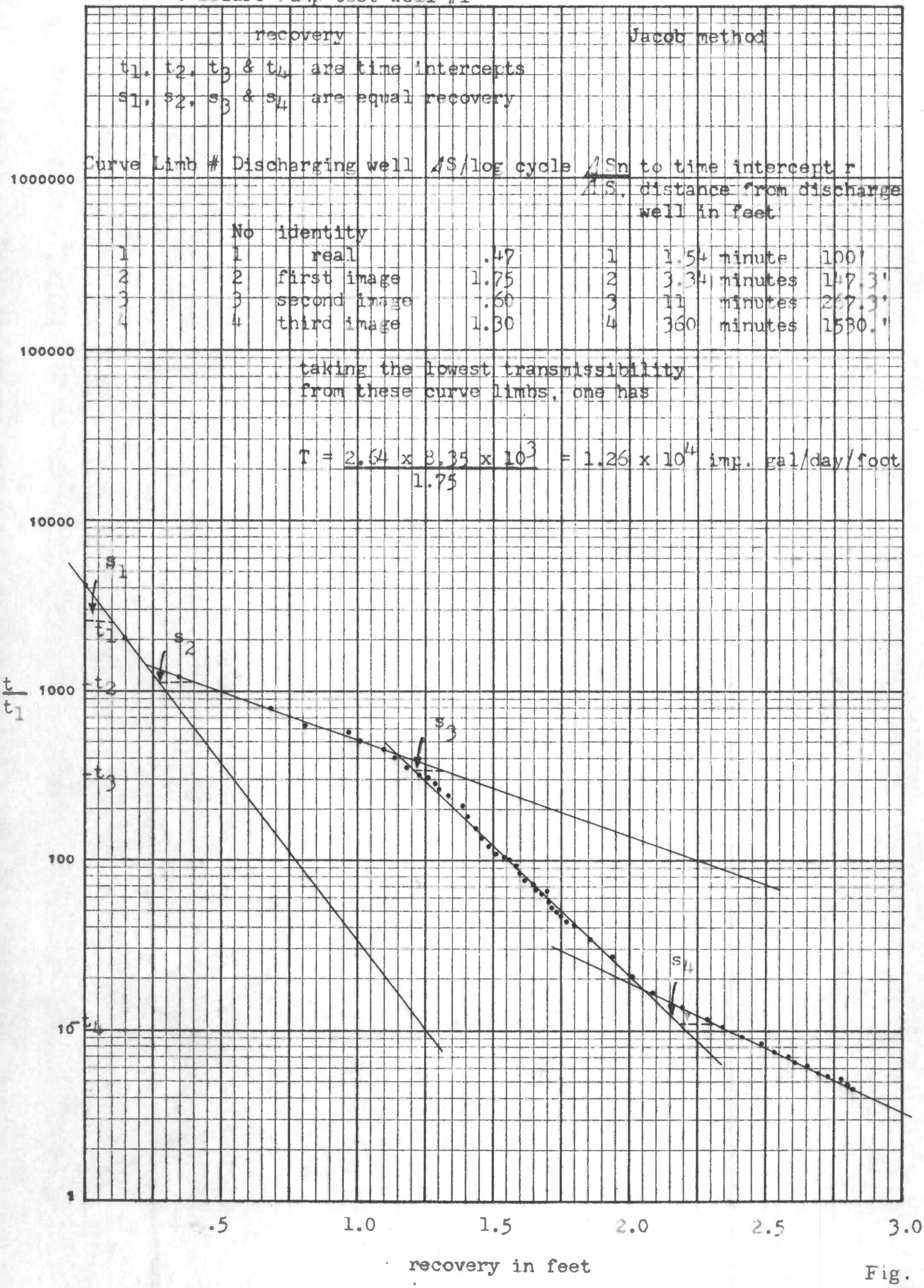
$\Delta s = .68$ $t_o = 1.5$ minutes $r = 250'$

$$T = \frac{2.64 \times 8.25 \times 10^3}{.68} = 3.2 \times 10^4 \text{ imp gal/day/ft.}$$

$$S = \frac{0.36 \times T\, t_o}{r^2} = \frac{0.36 \times 3.2 \times 10^{-4} \times 1.5}{(250)^2\ 1.44 \times 10^3} = .19 \times 10^{-3}$$

Fig. 36

MODEL St-Lazare Pump test well #1 **DATE**



recovery

Jacob method

t_1, t_2, t_3 & t_4 are time intercepts

s_1, s_2, s_3 & s_4 are equal recovery

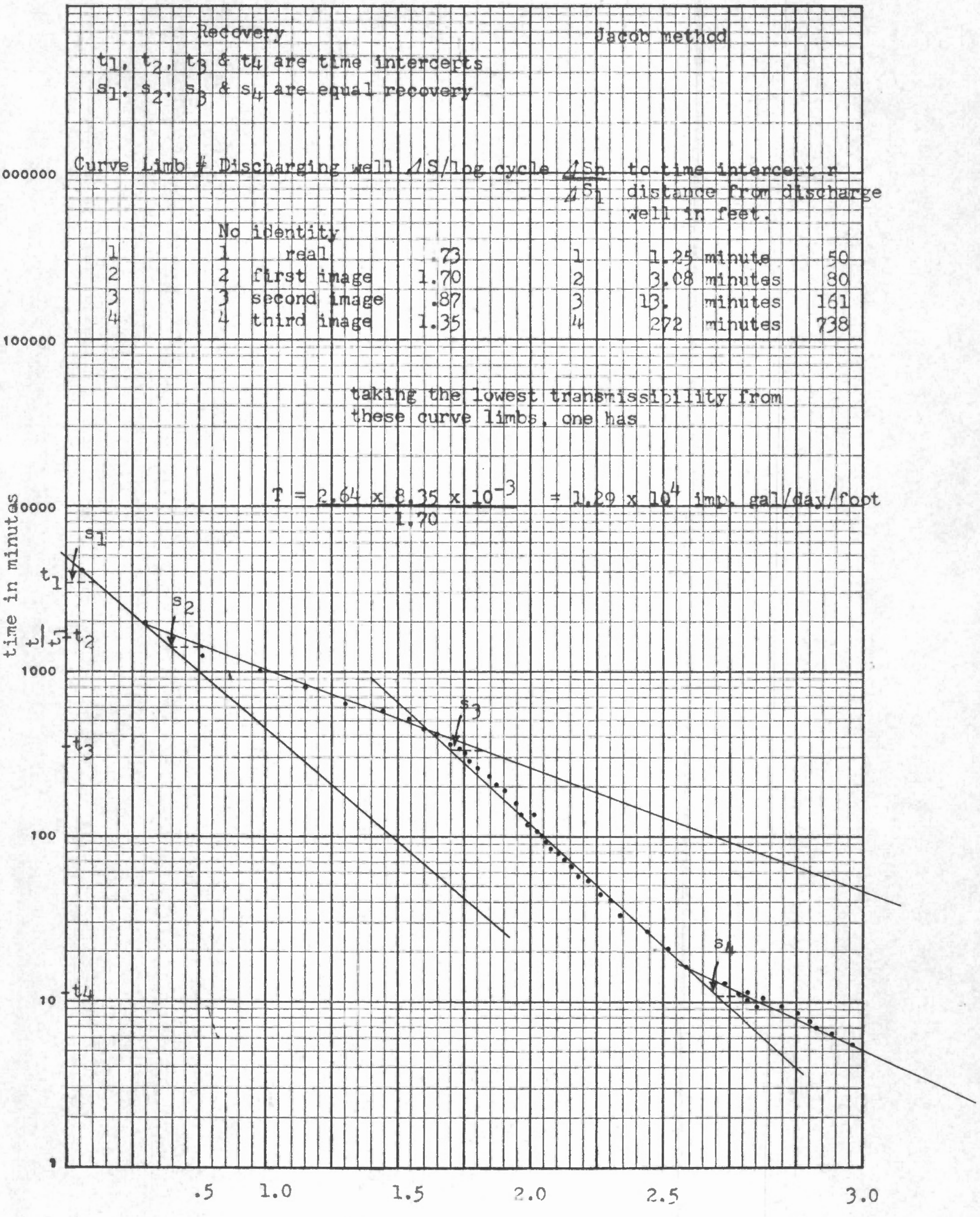
Curve Limb #	Discharging well No	Discharging well identity	ΔS/log cycle	$\frac{\Delta S_n}{\Delta S}$	to time intercept		r distance from discharge well in feet
1	1	real	.47	1	1.54	minute	100'
2	2	first image	1.75	2	3.34	minutes	147.3'
3	3	second image	.60	3	11	minutes	267.3'
4	4	third image	1.30	4	360	minutes	1530.'

taking the lowest transmissibility from these curve limbs, one has

$$T = \frac{2.64 \times 8.35 \times 10^3}{1.75} = 1.26 \times 10^4 \text{ imp. gal/day/foot}$$

Fig. 37

MODEL St-Lazare Pump test well #2 **DATE**



Recovery

Jacob method

t_1, t_2, t_3 & t_4 are time intercepts

s_1, s_2, s_3 & s_4 are equal recovery

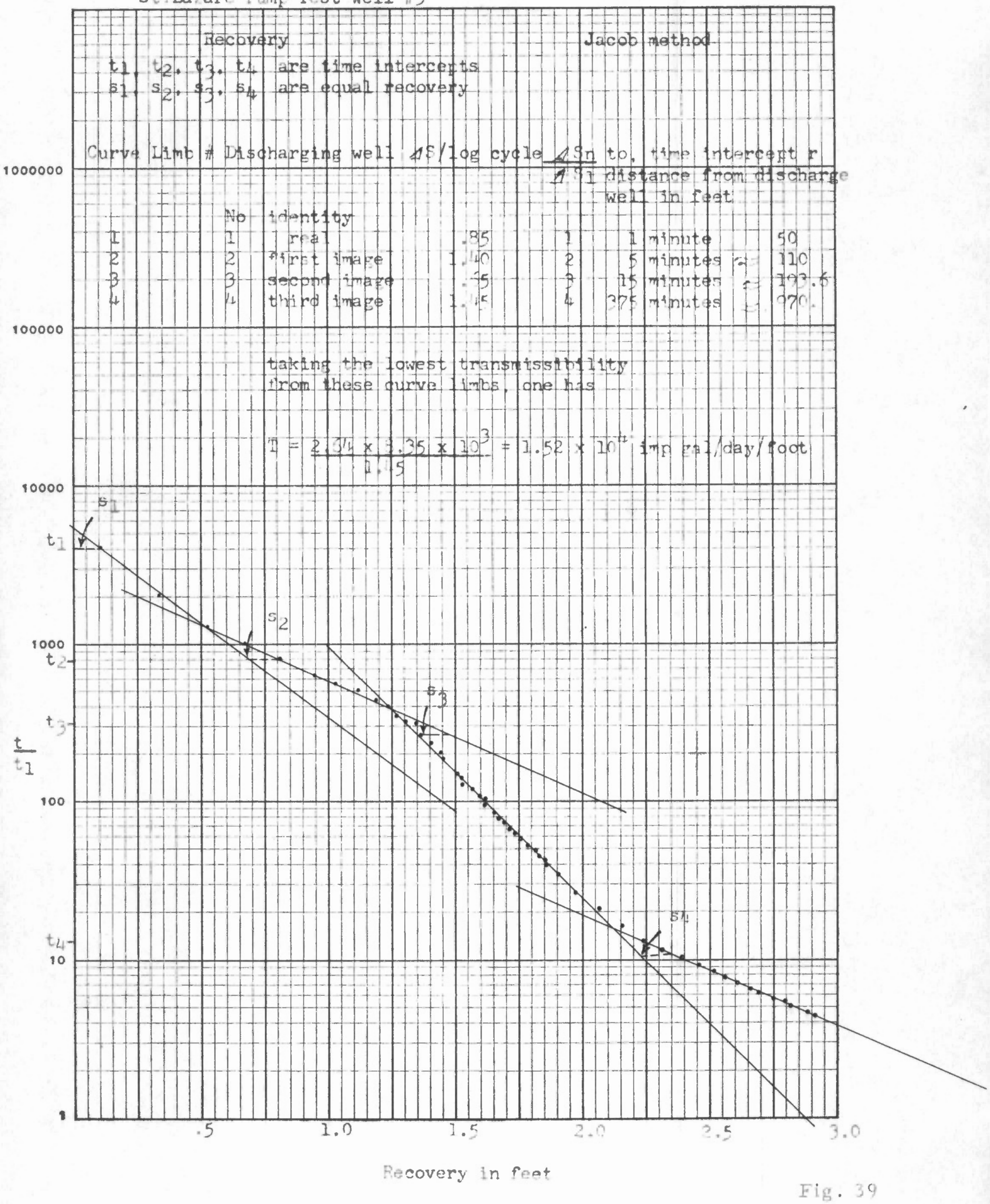
Curve Limb #	Discharging well No	identity	ΔS/log cycle	$\frac{\Delta S_n}{\Delta S_1}$ to time intercept		r distance from discharge well in feet.
1	1	real	.73	1	1.25 minute	50
2	2	first image	1.70	2	3.08 minutes	80
3	3	second image	.87	3	13. minutes	161
4	4	third image	1.35	4	272 minutes	738

taking the lowest transmissibility from these curve limbs, one has

$$T = \frac{2.64 \times 8.35 \times 10^{-3}}{1.70} = 1.29 \times 10^{4} \text{ imp. gal/day/foot}$$

Fig. 38

MODEL St.Lazare Pump Test well #3 **DATE**



Recovery Jacob method

t_1, t_2, t_3, t_4 are time intercepts
s_1, s_2, s_3, s_4 are equal recovery

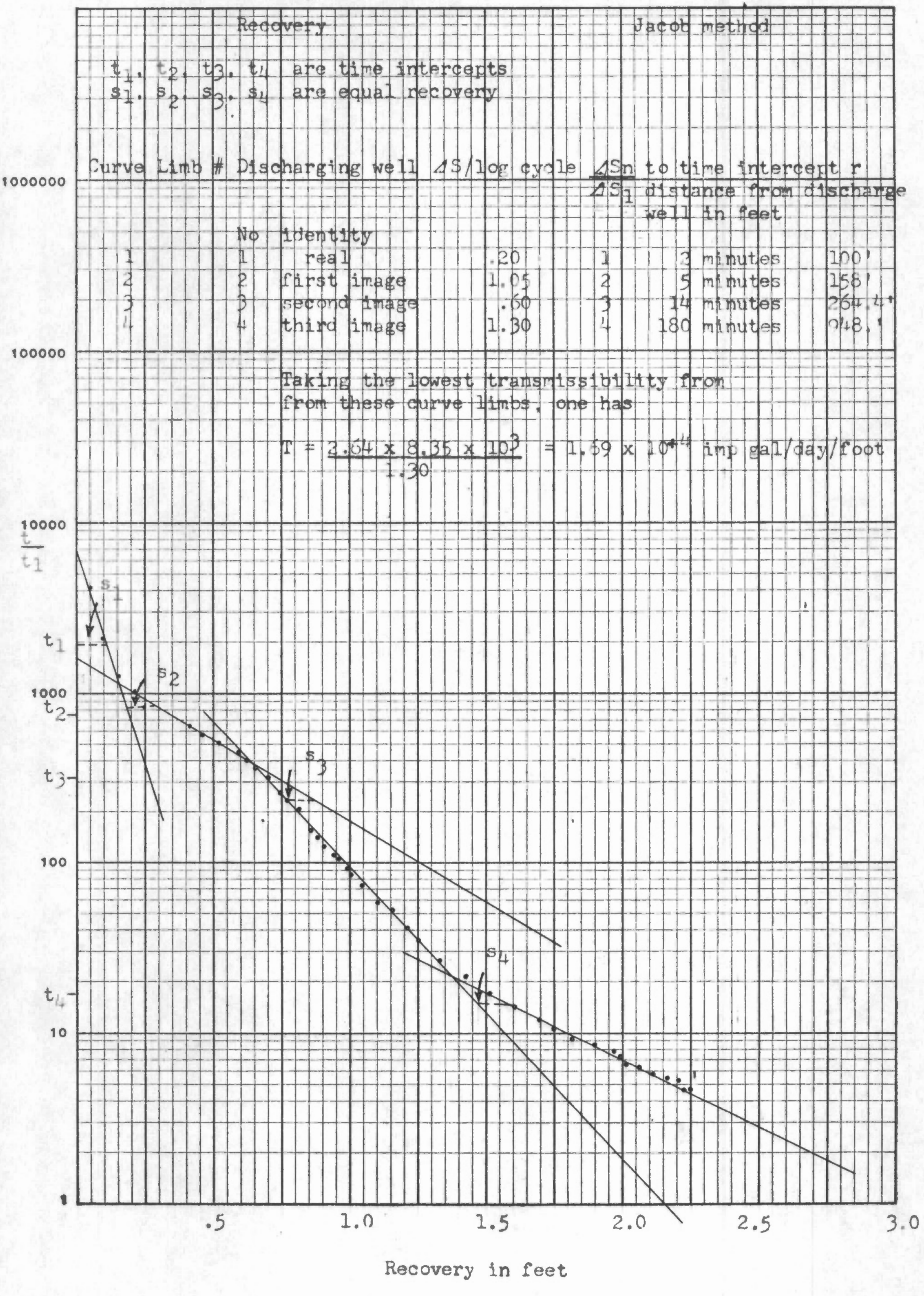
Curve Limb #	Discharging well No	identity	ΔS/log cycle	$\frac{\Delta S_n}{\Delta S_1}$	to, time intercept	r distance from discharge well in feet
1	1	real	.85	1	1 minute	50
2	2	first image	1.40	2	5 minutes ≈	110
3	3	second image	.35	3	15 minutes ≈	193.6
4	4	third image	1.45	4	375 minutes ≈	970.

taking the lowest transmissibility from these curve limbs, one has

$$T = \frac{2.64 \times 8.35 \times 10^3}{1.45} = 1.52 \times 10^4 \text{ imp gal/day/foot}$$

Fig. 39

MODEL St-Lazare Pump test well #4 **DATE**



t_1, t_2, t_3, t_4 are time intercepts
s_1, s_2, s_3, s_4 are equal recovery

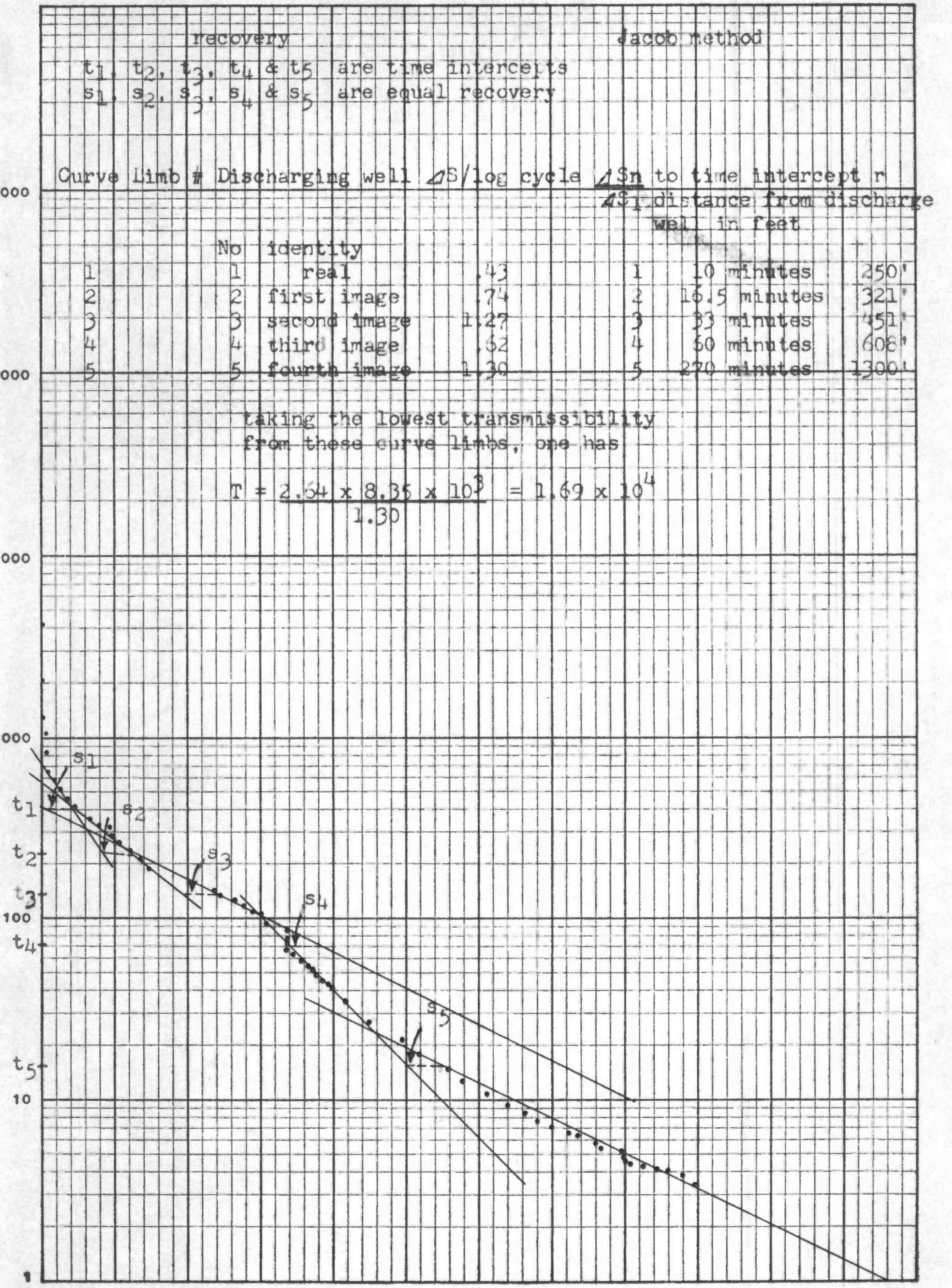
Curve Limb #	Discharging well No	Discharging well identity	ΔS/log cycle	$\frac{\Delta S_n}{\Delta S_1}$	to time intercept	r distance from discharge well in feet
1	1	real	.20	1	3 minutes	100'
2	2	first image	1.05	2	5 minutes	158'
3	3	second image	.60	3	14 minutes	264.4'
4	4	third image	1.30	4	180 minutes	948.'

Taking the lowest transmissibility from
from these curve limbs, one has

$$T = \frac{2.64 \times 8.35 \times 10^3}{1.30} = 1.69 \times 10^{4} \text{ imp gal/day/foot}$$

Fig. 40

MODEL St-LaZare Pump Test well #5 **DATE**



recovery

Jacob method

t_1, t_2, t_3, t_4 & t_5 are time intercepts
s_1, s_2, s_3, s_4 & s_5 are equal recovery

Curve Limb #	Discharging well No	identity	ΔS/log cycle	$\frac{\Delta S_n}{\Delta S_1}$	to time intercept	r distance from discharge well in feet
1	1	real	.43	1	10 minutes	250'
2	2	first image	.74	2	16.5 minutes	321'
3	3	second image	1.27	3	33 minutes	451'
4	4	third image	.62	4	60 minutes	608'
5	5	fourth image	1.30	5	270 minutes	1300'

taking the lowest transmissibility
from these curve limbs, one has

$$T = \frac{2.64 \times 8.35 \times 10^3}{1.30} = 1.69 \times 10^4$$

Fig. 41