AN EXPERIMENTAL STUDY OF
THE GROUND WATER SITUATION
IN THE LANSING AREA

Thesis for the Degree of B. S.
MICHIGAN STATE COLLEGE

H. F. Schwabe

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An Experimental Study

of the

Ground Water Situation in the Lansing Area

A Thesis Submitted to

The Faculty of

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of

AGRICULTURE AND APPLIED SCIENCE

by

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Candidate for the Degree of

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Introduction

The importance of water to life is well known, and the popular belief that underground waters are inexhaustible is now reveled as a pure myth. The ever-increasing demand on our water resources by the growth and advancement of the Industrial Age has rudely awakened many communities to the importance of water for continued economic growth. Thus, the cry to protect and preserve water for the present generation and those to come. It's not the oceans, lakes, or rivers that are causing the concern but the under-ground waters which are the only source of supply for some communities and the only economical unpolluted source for a good many more. The Lansing area, which was selected as the field problem for this report, has increased its water consumption tremendously in the past few years and has experienced a considerable decline in ground-water level. With a very apparent upward trend in population growth as well as industry a continued rise in well-water demand seems assured. Therefore a study of the hydrology of this area is timely and important.

Acknowledgements

The writer is especially indebted to Mr. J. G. Ferris of the United States Geological Survey for data furnished and assistance on field tests; Mr. M. Richmond, Supt. of Water and Sewage Dept., City of East Lansing, for cooperation offered in the set-up of pumping tests and the use of operating records; Mr. Joseph Slater, Plant Engineer of Michigan State College for data offered; and to my wife, for the tedious typing task.

Nation-Wide Ground Water Situation

Water, our principal mineral resource, is as necessary to the support of life as air and sunlight. Although, to a limited degree we can alter its distribution, the quantity and quality of the natural resource is controlled principally by the geology and hydrology of an area. We cut and wasted our timber until finally it became so desperately scarce that it was necessary to institute a program of conservation (a program of preservation and proper utilization of resources). Now also, we hear the cry go up in many sections of the United States, water!

The cry was a part of our last presidential campaign. In the Southwest, the states of Arizona and California have been fueding for years over water rights. Some sections in these states were forced to ration water. Vigilantes checked meters for water hogging. The California legislature was asked to put up $1,000,000 for ideas on how to get sweet water from the sea cheap. California's Central Valley was hard hit with dairy herds cut down or lost entirely as well as other crops lost because of lack of water.

Experts are reckoning the time when the last newcomer will cross the Rockies heading West, because there will not be enough water for all. Some Los Angeles engineers have already set the deadline at 1968. This shortage does not apply entirely to surface waters, but to a large extent to the rapidly deminishing supply of underground water. Old wells have been drilled deeper and deeper, some have gone dry, many near the ocean have become contaminated by infiltration of sea water as the ground-water level has been lowered far below sea level. Many farms are deserted because wells no longer can supply sufficient water.

Irrigation is the life blood of dry Arizona's economy, with two thirds of its water supply derived from underground sources. This underground supply is swiftly being drained away. S. F. Turner, U.S. engineer at Tucson said: "The situation can no longer be solved by drilling new wells." In several areas water levels have dropped 55 feet in six years.

Some land has already returned to desert and much more faces the same fate. But the premium price of agricultural crops makes farmers dig more wells for irrigation.

In the Texas Panhandle nature stores an estimated 50,000 acre-feet of water a year whereas farmers withdraw 750,000 acre-feet. In one locality a barrel of water costs more than a barrel of oil, due to the under-ground water shortages.

The Middle West and the East are also depleting their underground water supplies. Louisville, Kentucky reports a 40-foot drop in ten years; Indianapolis water table down 50 feet; Baltimore reduced pumping because of salt contamination; and, Brooklyn's water table has dropped 35 feet below sea level.

Lansing Area Situation

This report will be concerned with the City of Lansing and East Lansing and the closely surrounding area. Greater reference will be made to the East Lansing area.

East Lansing's water consumption has increased steadily over the past years with a particularly sharp uptrend thru the early 1940's. The city has drilled two new wells in North Side City Park which at present are being prepared for the installation of pumps and a new treatment plant is now under construction. The mean annual consumption approximates 1,000,000 gallons per day and the summer consumption averages 1,500,000 gallons per day.

Michigan State College also a large consumer of well water, has tremendously increased pumpage because of its rapid growth.

The trend of average annual pumpage by Michigan State College is summarized by the following table:

Year	Mean annual pumpage in gallons per day
1942	632,000
1943	[illegible],000
1944	623,000
1945	712,000
1946	1,023,000
1947	1,250,000

Note that in the 5-year period ending in 1947 the water consumption of the college was doubled. There is no indication that this trend will diminish, but rather it will hold steady or may possibly increase.

The City of Lansing has also rapidly increased its average daily withdrawal of well water. The upward trend of average annual pumpage can readily be seen by the following summarized table:

Year	Mean annual pumpage in million gallons per day
1910	2.9
1920	4.7
1930	8.5
1940	9.8
1943	12.7
1945	13.5
1946	13.3
1947	13.8
1948 (to Nov.)	15.6

Lansing Township and Industries with private wells (forge plants, automotive plants, railroads, air-conditioning units etc.) average approximately 2,000,000 gallons per day. Landell Metropolitan will start steady pumping operations soon to add to the water demand from this area. The sum total of the averages in this area is 20,000,000 gallons per day of with-drawal from the local ground water resources. This larger volume shows no indication of a decrease but rather more than likely an increase because of population growth and larger industrial demand.

The static head in East Lansing has dropped 23 feet in the past nine years, and in Lansing from data taken on four observation wells, the static head has declined considerably, as the following table shows:

Static head drop over period of;

	1930-40	1940-44	1944-45	1945-46
Lansing Well # 4	26'	6'	12'	2.5'
Lansing Well # 6	10'	37'		20.0'
Lansing Well # 7	13'	46'		28.65'
Lansing Well # 8	10'	6'		6.0'

(data from United States Geological Survey)

The general effect of this increased pumping has lowered the piezometric surface in all areas observed. The number and location of wells in Lansing and vicinity can be found from Figure 1.

Area Interference

When a well is pumped the water table or piezometric surface in the vicinity of the discharging well is drawn down in the shape of an inverted cone with its apex at the pumped well. As pumping continues the cone of influence deepens and enlarges its base area or circle of influence, until the total recharge within the circle of influence is equal to the discharge of the pumping well or until the cone of influence intercepts a surface source such as a lake or stream. When draw-down cones or circles of influence overlap interference between wells occurs and a decline in yield or an increase of drawdown in each well will result. The amount of interference depends on the permeability, thickness, and storage capacity of the aquifer; the rates of discharge by the several pumping wells; the distance between wells; and the regional conditions of recharge and discharge.

An automatic water-stage recorder was installed at the North Side City Park on # 2 well in East Lansing. The fluctuations of the piezometric surface were recorded for a six months period. The individual and the combined pumpage to the city mains from East Lansing's East and West well stations were plotted for the six months period. Figure 2. This is not an exact figure of the total withdrawal from the wells, because the wells are not metered but only the amount of water treated at the plants and going into the city system is metered. Figures 3a and 3b show typical daily charts from the treatment plant flow meters. The wash water, and regenerating water at both plants, which use the zeolite process, is wasted. This effects the graph's magnitude but slightly, and the overall picture will not change because both plants waste an almost equal amount. The East Wells are 2300 feet from the North Side City Park, the point of observation, the West Wells are 8300 feet, and the College Wells about 8700 feet.

Over the period of observation there are several indications of interference between the East and West wells and the point of observation. If either well shows interference with the observation point it can be concluded that they mutually interfere. In May on the 9 th and 20 th, the East well shows an increase followed by a decrease in pumping, and the water level shows a draw-down and recovery respectively. The Michigan State College rapid increase in pumping the 22 nd, 27 th, and 28 th indicates interferance by a corresponding draw down of the water level graph when East Lansing's total pumpage would indicate a recovery curve should occur. The month of June generally shows a combined trend of all three users, East and West wells of East Lansing and the College wells. The only good indication of West well interference is on the 17 th of June. West station increased pumpage to over 1,000,000 gallons per day, East remained constant and the College decreased pumping which started a recovery curve on the water-level chart, but the increased pumping by the West wells flattened out the recovery curve. On the 29 th of June, West and College reduced pumping, but East increased pumpage. The combined magnitude of the pumpage reduction by West station and College was considerably greater than the incr-ase at the East station and consequently a general rise of water level occurred. However the proximity of the East station to the observation well results in greater interference effect for a given pumpage change and thus the increased pumping by the East station flattened the recovery trend of the water-level graph.

Fron the 1 st to the 6 th of July the East plant pumped at a small and constant rate except for one day, the 4 th. The West plant made a small overall increase in rate over that period except for a sharp drop on the 4 th. The College dropped in rate sharply and a general recovery curve of the water level followed. The sharp decrease of both the College and the West plant on the 4 th erased the effect of the East plan's large increase. The rest of the month of July the water-level curve follows the pumping to the West well almost in detail, effected considerably by the large abrupt changes in College pumping.

In August all stations pumped the 1 st and 2 nd at an increasing rate. On the 3 rd, East and College decreased considerably but West increased and effected the recovery curve in that it slowed it up a great deal. On the 5 th College and West boosted their rate, East did not and the water level declined again, the curve steepening when East raised its rate. Another strong proof of College interference is the increase in rate of East Lansing pumpage from the 15 th to

22 nd and the resulting draw down of the observation well. Then the College went from .8 of a million gallons per day on the 22 nd to 1.25 million gallons per day on the 23 rd and increased up to 1.5 million gallons per day which abruptly steepened the draw down of water level. The College dropped back on the 28 th and more on the 29 th, East Lansing held and draw down of the piezometric surface leveled off on the 28 th and started up on the 29 th.

In September all stations increased on the 2 nd starting a receding water level. East wells stayed constant thru the 6 th, the College dropped steadily the 3, 4, and 5 th and the West well dropped by .6 million gallons per day which started the recovery curve. College and East were constant from the 9 th to the 15 th. On the 10 th West increased pumpage which leveled off the recovery curve and reduced pumpage on the 11 th which increased recovery again. The general trend in October seems to be a combined effect of all three pumping stations. A few peaks or depressions can be spotted, such as the low on the 12 th effected by the East plant's increased pumpage and on the 20 th the college increased and East Lansing decreased but the water level still declined. However just trends were shown and nothing too conclusive could generally be depicted for October.

The evidences just cited for mutual interference, between East Lansing's East Plant and West Plant and Michigan State College and the point of observation, proven from several observation over a 6 months period, means that they all pump from the same aquifer. A closer study and more minute comparisons of these graphs will show more indications of this interference than those pointed out in this report.

The United States Geological Survey has previously proven mutual interference between Michigan State College and Clever Farms, and Clever Farms and the City of Lansing. Therefore it can logically be concluded that the three major users of well water or in fact all users of well water in this local area, Lansing, Lansing Township, Industrial, Air Conditioning, Landell Metropolitan, Michigan State College, and East Lansing all are inter-related and operate from the same aquifer.

Further proof of this inter-relation can easily be observed from three graphs prepared (Figure 4a,b,c,) for pumping test data. It was desired to stabilize pumping conditions and the piezometric surface as much as possible prior to the test, so that changes resulting due to the test could more readily be detected. With the cooperation of the City of East Lansing the stage was set. The West Plant (where test was to be run) was shut down, Wedensday, November 24 th at 4 P.M. At 7 P. M. the East Plant ran a constant rate of 550 gallons per minute, (to supply the cities needs) until 5 A.M. on the 27 th. So East Lansing was at a constant and steady rate. The College dropped from 1.5 million gallons per day on the 24 th to .83 million gallons per day on the 25 th (Thanksgiving Vacation) and it stayed at this low rate thru out the week end picking up at 8 A.M. November 30 (school started). Our water level recorder showed a steady climb of recovery broken only on the afternoon of the 26 th when the College for a two hour period jumped from 800 to 1150 gallons per minute and East Lansing West well # 2 went on from 0 - 700 gallons per minute for the duration of the test until 6:30 P.M. Recovery still continued and even when East Lansing picked up, after the test was run, November 27, and 28 th recovery still was in effect from the College's pumpage reduction. School started and a decline started, but then a deeper low in the curve is shown from approximately noon on the 29 th to early morning on the 2 nd of December. The general decline was indicative of the College, but this sudden increase with three distinct pockets was unexplained. By canvass of the principal well users it was learned that Lansing's Riverside plant located along the Red Cedar River between East Kalamazoo and the Pere Marguette Railroad, started pumping at the high rate of 3420 gallons per minute from 5:15 to 8:55 P.M. on November 29 th, from 5:00 to 7:15 P.M. on the 30th and from 7:15 to 11:25 P.M. on December 1 st, pumping a total of 759,000 gallons, 713,000 gallons and 824,000 gallons respectively. In this short period, East Lansing pumpage was steady with no major volume changes. This direct interference of Lansing with East Lansing would possibly explain many other trends in the graphs of the six months period.

Pumping Test

The physical properties of the ground water reservoir can be determined by a pumping test. The transmission and storage capacities of a formation are important factors in determining the yield of a well. The coefficient of transmissibility is the rate of flow in gallons per day thru a vertical strip one foot wide extending the height of the saturated portion of the aquifer, under a hydraulic gradient of one foot per foot, at a water temperature of 60°F. The coefficient of storage is defined as the amount of water in cubic feet released from storage in a vertical column of the aquifer with a one square foot base when the head is lowered one foot.

By plotting time versus the amount of draw down and observing the rate of pumping and distance of the pumping well to the observation well, these coefficients can be determined.

By a study of the departure from normal of the slope of the draw down curve interference of other well may be determined. Impermeable barriers in the formation may also be determined in this manner. If there is surface recharge, or a geologic barrier in the area the slope studies will reveal these features.

A sampling of the field data collected during the pumping test is shown by the following tabulation. Final results of the water-level measurements and other field observations form the basis for the construction of Figures 5 and 6.

Date 11-26-48 East Lansing West Plant, **Well # 1**

Well # 2 Pumping, Q = 700 g/m

Hour	Tape Reading at Measuring Point	Tape Reading at Water level	Depth to water	s	r^2/t
2:24PM	100.00'	32.22	67.78		
2:25	# 2 Pump started				
2:31	100.00'	32.13	67.82	.04	2.4×10^8
...	...	...	...	...	...
2:46	100.00'	31.89	68.11	.33	6.85×10^8
...	...	...	...	...	...
3:15	100.00'	31.21	68.79	1.01	2.88×10^7
...	...	...	...	...	...
4:00	100.00'	30.25	69.75	1.97	1.52×10^7
...	...	...	...	...	...
5:12	100.00'	29.26	70.74	2.96	8.62×10^6

r = 1000' approximately

The Theis Graphical Method permits an analysis of the field data based on the rate of decline of water level on a single observation well.

Theis equation:[1]

(1)

$$s = \frac{114.6Q}{T} \int_{\frac{1.87r^2S}{Tt}}^{\infty} \frac{e^{-u}}{u}\,du$$

Where: s = drawdown in feet.

Q = discharge of pumped well, in gallons per minute

r = distance of observation well from pumped well, in feet

T = coefficient of transmissibility in gallons per day per foot under unit hydraulic gradient.

S = coefficient of storage, as a ratio or decimal fraction

t = time of pumping in days

The exponential integral of the above equation is replaced by the term W(u) which is read "well-function of u" and the equation is rewritten as follows:

(2)

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

(3)

$$u = \frac{1.87r^2S}{Tt}$$

We have Q and s from our data and by plotting values of the drawdown s against values of r^2/t on logarithmic paper to the same scale as the type curve, W(u) against u, a curve similar to the "type curve" is developed. The graph of observed data is superimposed on the "type curve", with axes parallel, and a position is found where graph most nearly matches the "type curve". An

[1] Theis, C.V., The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans. 1935, pp. 519 - 524.

arbitrary point is chosen (Figure 5 when x on plotted graph falls on type curve at arrow). W(u) and u are then found on the "type curve" and T can be found from equation 2 and from equation 3 using the T just found S can be determined.

from "**type curve**"

$u = 0.1$

$W(u) = 1.82$

from test data

$r^2/t = 4.1 \times 10^4$

$s = 4.1$

(2)

$$T = \frac{114.6 \times 700 \times 1.82}{4.1} = 35{,}600 \text{ gallons per day per foot}$$

(3)

$$S = \frac{0.1 \times 35{,}600}{1.87 \times 4.9 \times 10^6} = 3.89 \times 10^{-4}$$

Another form of equation (2) has been developed by Theis[1] which determines the coefficient of transmissibility as follows:

(4)

$$T = \frac{264q \times \log_{10}(t_2/t_1)}{s_2 - s_1}$$

Where: t_2 = time of second observation

t_1 = time of first observation

s_2 = drawdown in feet of second observation

s_1 = drawdown in feet of first observation

The data is plotted on a semi-logarithmic coordinates with t plotted on log scale and s plotted on rectangle scale (Figure 6)

(4)

$$T = \frac{264 \times 700 \times \log_{10} \frac{1000}{100}}{(6.2 - 2.1)} = 45{,}000 \text{ gallons per day per foot}$$

1 Theis, C.V. op. cit., pp. 522

More weight is given to the "type curve" method in this test because the duration of the test was too short and not enough observation points were established for a complete analysis by the semi-log method.

A previous test ran on a College well had a "T" value $\frac{1}{4}$ of that of West well # 1. This indicates a decided change in the formation between the two sites. A change in the permeability or thickness of the sandstone is indicated. Further tests from different wells and observation points would locate this geologic barrier where transmissibility has a high coeficient on one side and low on the other.

Pumping tests tell the capacity of the well and also the value of economical well spacing. This last has long been ignored and greatly abused--economical well spacing. Two or more wells whose cones of depression overlap are impaired in their yield. In this case the combined yield of the wells will be less if pumped simultaneously than the sum of individual yields if pumped separately.[1]

Recharge

The water we use today has been circulating since the world began. Water rides the eternal merry-go-round called the hydrologic cycle; from moisture in the clouds it falls to the earth as precipitation. Some goes directly to streams then to lakes and evaporates to be tranformed back to moisture in the clouds. Some percolates into the soil to feed plant life and is given back to the atmosphere

1 --
Legette, R.M. The Mutual Interference of Artesian Wells on Long Island, New York.

by transperation. Some percolates farther thru the top soil and sub-soil to permeable deposits of unconsolidated material or to porous rocks. Sometimes it continues downward and flows laterally to be discharged as base flow of surface streams, as springs, as recharge to other aquifers, or to be salvaged by wells for the use of man. Thus recharge to the sandstone aquifers may take place by (1) seepage from surface streams, (2) infiltration of rain water or precipitation, and (3) from under ground lateral flow.

Need of Further Investigation

Available records indicate there has been a steady decline in static water levels in this area since 1910. Steady increase in pumpage by practically all users especially the four large consumers; Lansing Township; City of Lansing, Michigan State College and East Lansing, have accompained their growth. With the increase in population there follows an increase in water demand more industries and again more water. The recent growth of air-conditioning requires large quantities of water to supply the coolent and it then is wasted. It takes 65,000 gallons to produce a ton of steel; 7 - 10 gallons to make one gallon of gasoline; 15 gallons to provide for one gallon of beer.

What we must do is conserve our allowance of water as long as we can. Water can be made to WALK instead of RUN, and sometimes it can stand still. When the hydrologic cycle is speeded up the LAND SUFFERS. Conservation Department reports the "ground-water table hits lowest point in 14 years." Only by means of mathematical analysis and by a study of long term records of water levels and precipitation can the decline be distinguished as that caused by overdevelopment and precipitation deficiencies.

The water-level trends in this area have been given and also that area consumers are drawing from the same aquifer. As pumping increases in areas of mutual interference, the piezometric surface declines to maintain the same pumping rate or discharge. More power is needed when this is done to raise the water thru the increased lift. As the water level drops, the effective transmissibility of the aquifer is reduced and this decreases the yield, which results in more added power and you have a vicious cycle started,- the consumers dilemma and well diggers and motor manufacturers delight.

Also increased draw down may cause cementation of the water-bearing strata in the de-watered areas which further reduces the future yield per foot of draw-down.

A local planning commission of those concerned should be established to thoroughly investigate and study the problem before it becomes a serious condition. The State Geology Division has been concerned with the seriousness of ground-water conditions because Senate Bill No. 195 was presented and prepared by them to establish controls and regulations for the drilling of wells, Sec. 31 to 64. A local commission for future long range planning and mutual cooperation would be a step in the right direction.

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Readers Digest, "What Are We Going To Do For Water" pg. 25
August 1948

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Geological Survey

Figure 1.
Location of wells, Lansing
and vicinity.

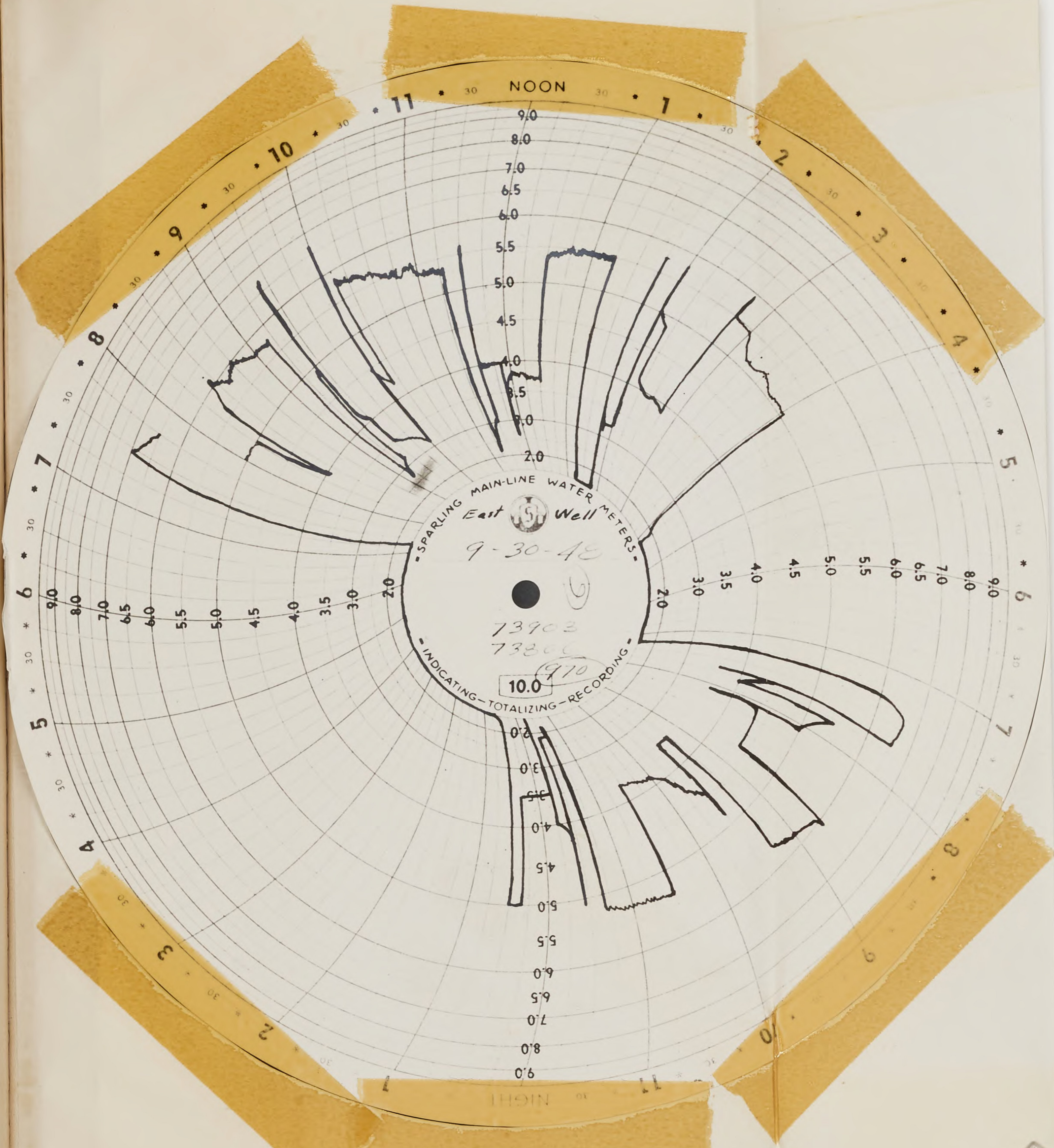


Figure 3a
A daily flow meter chart of East plant.

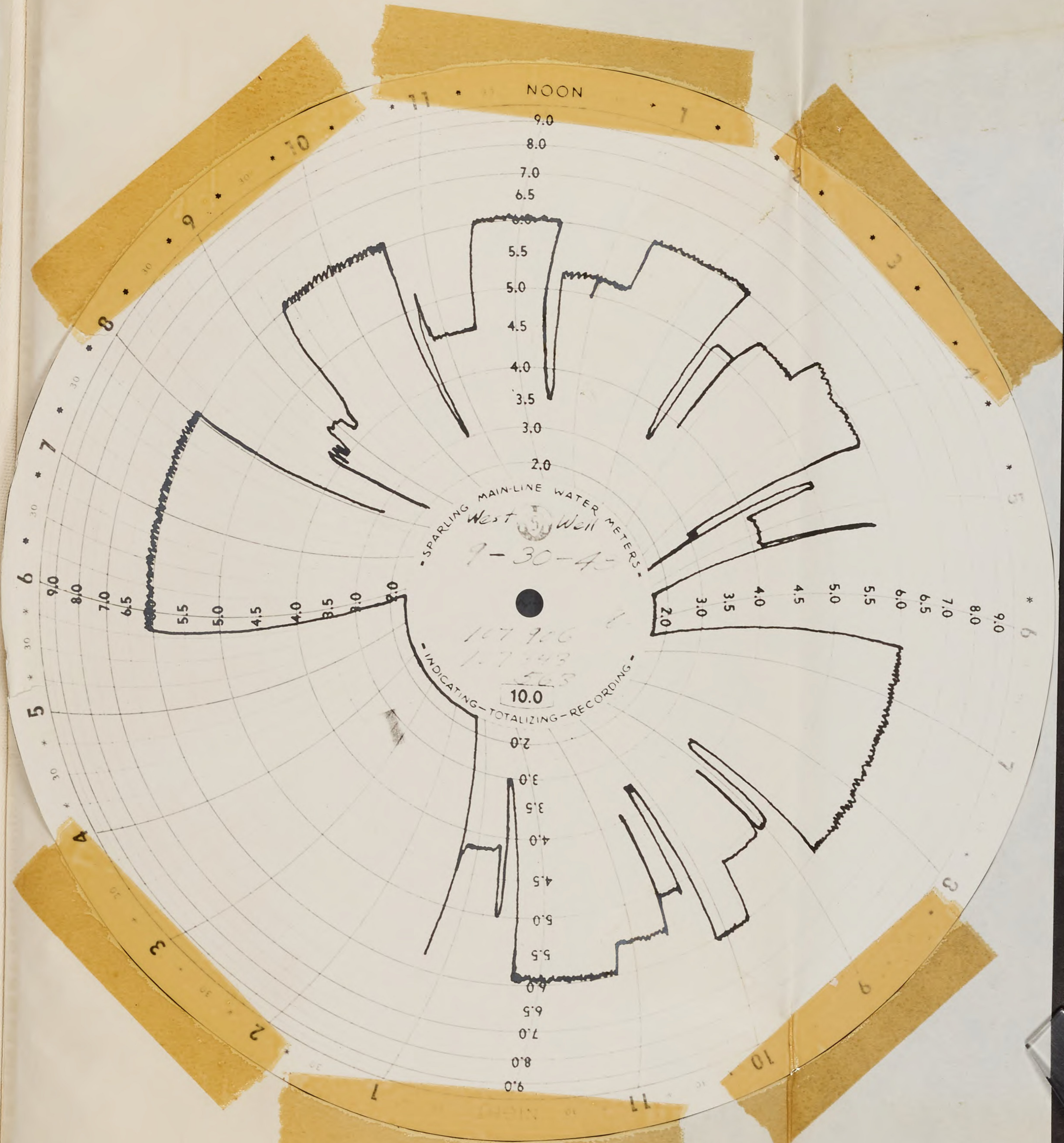
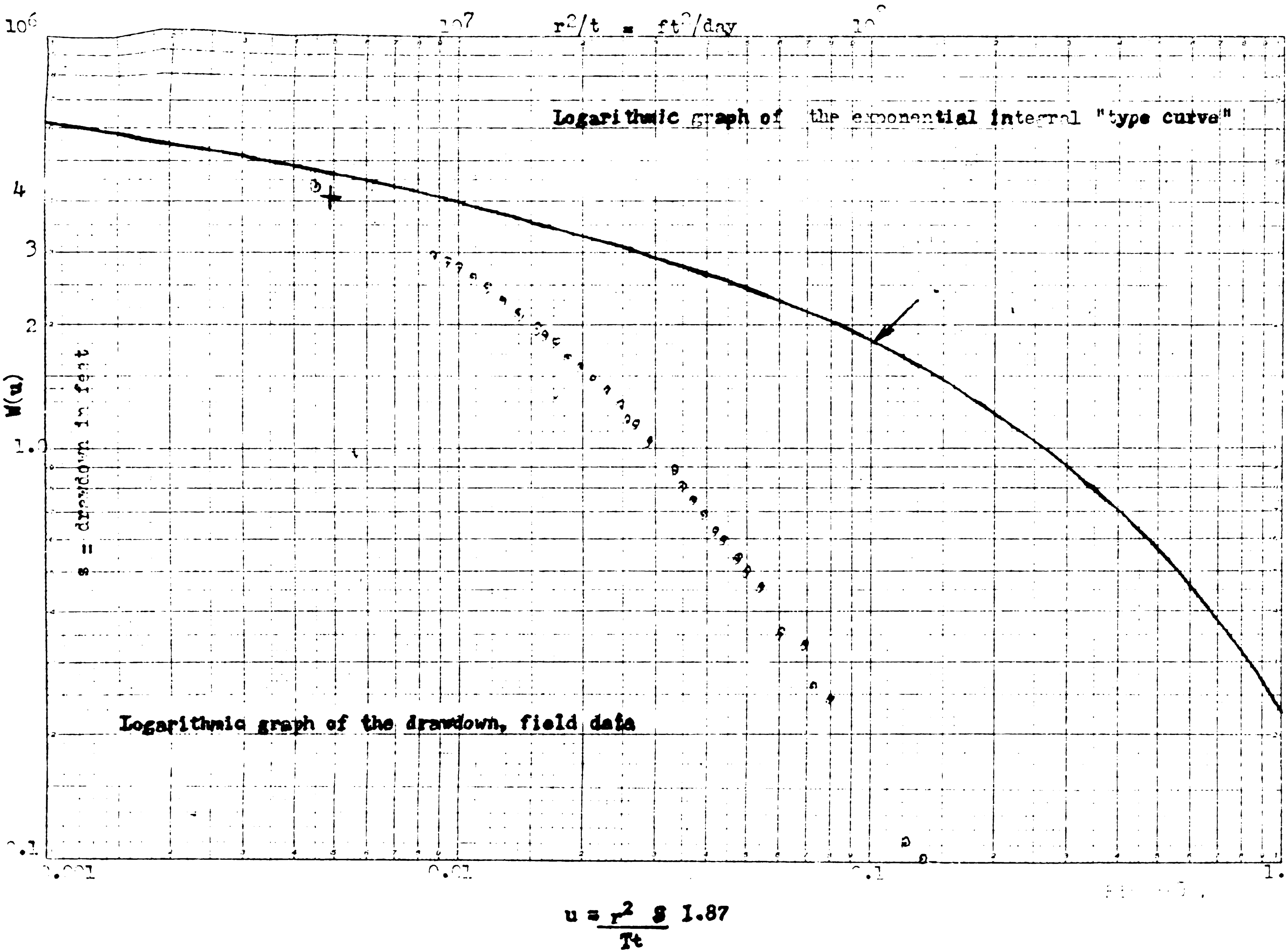
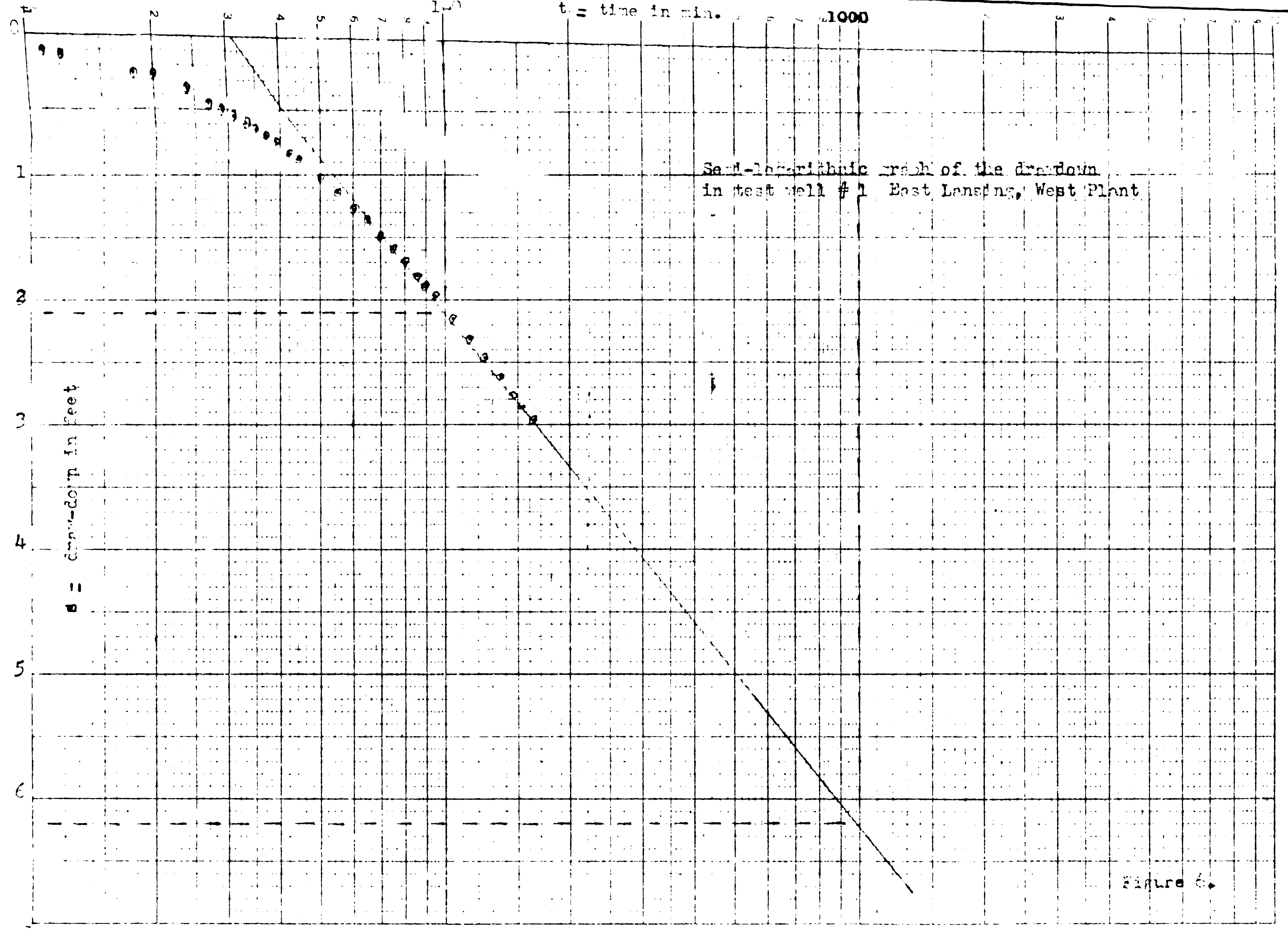


Figure 3b
A daily flow meter chart
of West plant.

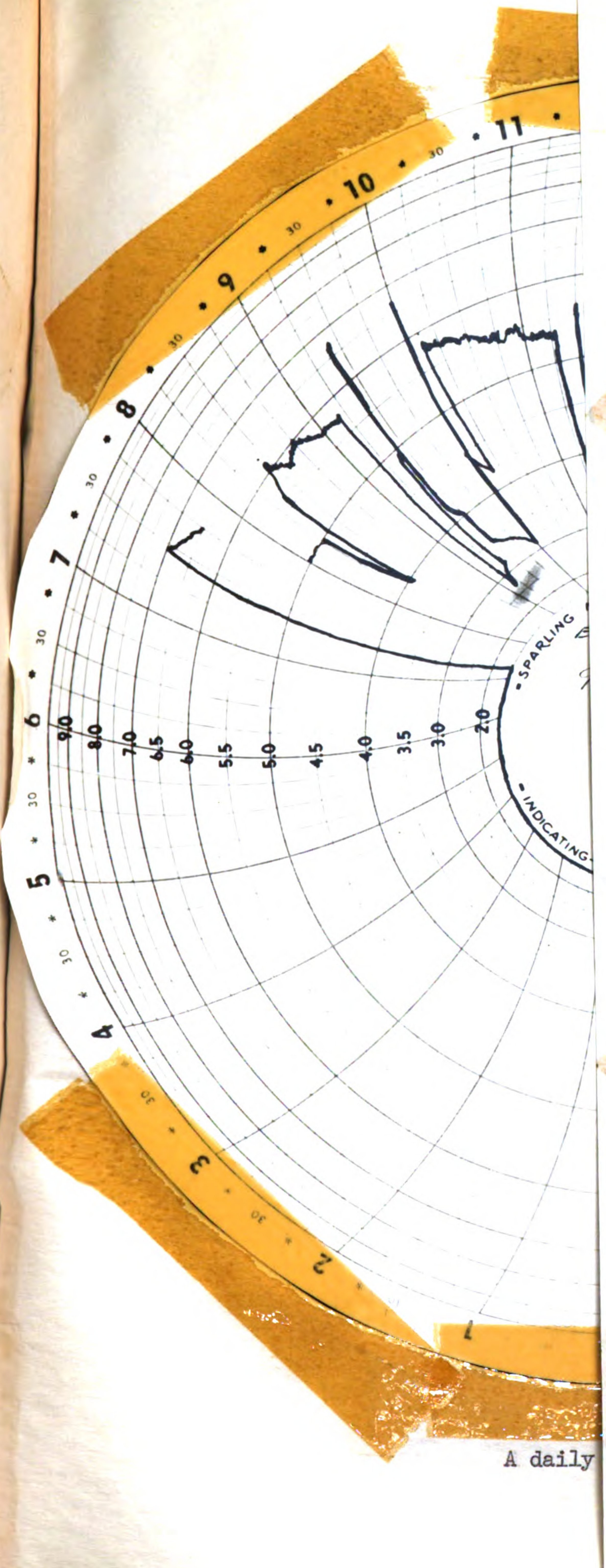


10^6
10^7
$r^2/t = ft^2/day$
10^8
Logarithmic graph of the exponential integral "type curve"
4
3
2
1.0
0.1
W(u)
s = drawdown in feet
W(u)
Logarithmic graph of the drawdown, field data
0.001
0.01
0.1
1.0
$u = \frac{r^2 S}{Tt} 1.87$



t = time in min.
1000
s = draw-down in feet
Semi-logarithmic graph of the drawdown
in test well # 1 East Lansing, West Plant

Figure 6.


11
30
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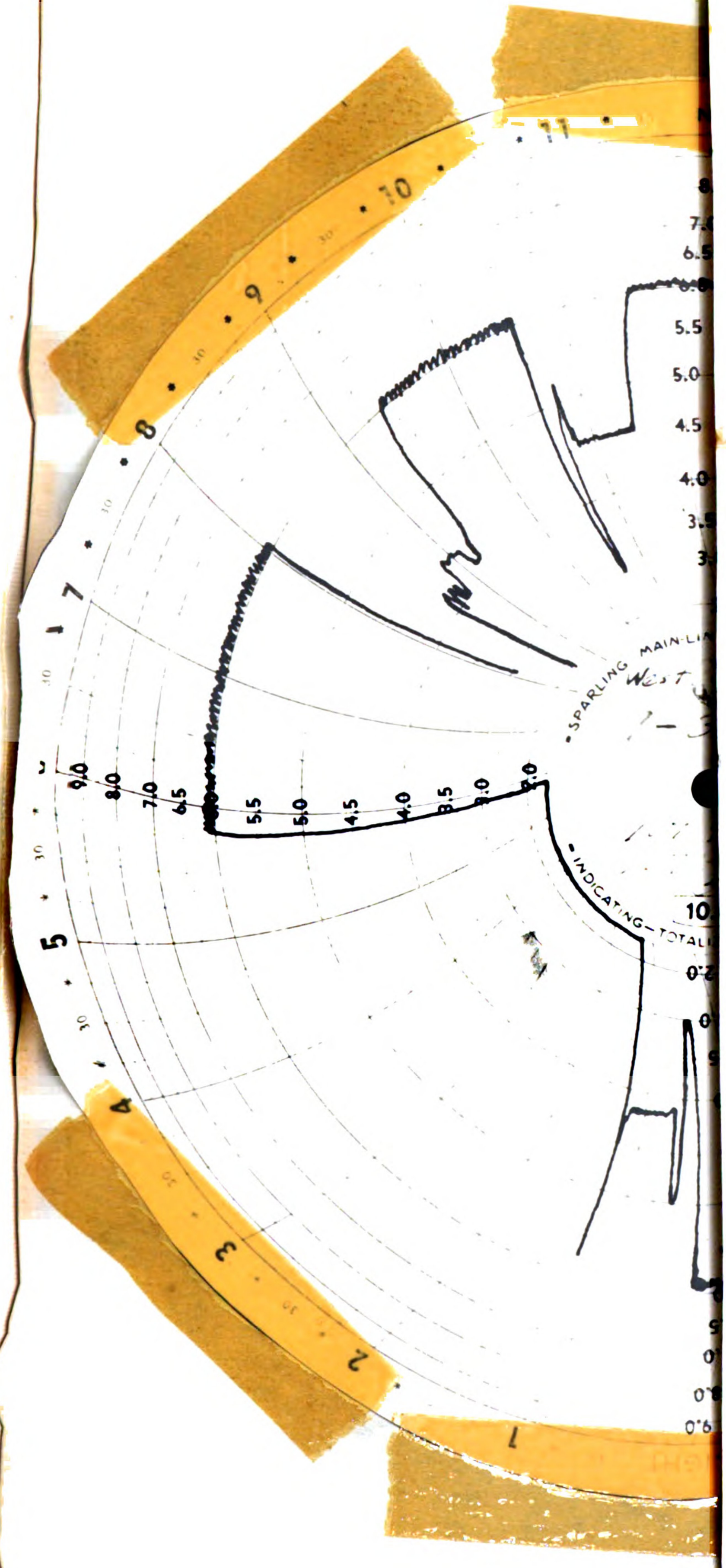
4.5
4.0
3.5
3.0
2.0
SPARLING
INDICATING

A daily


SPARLING
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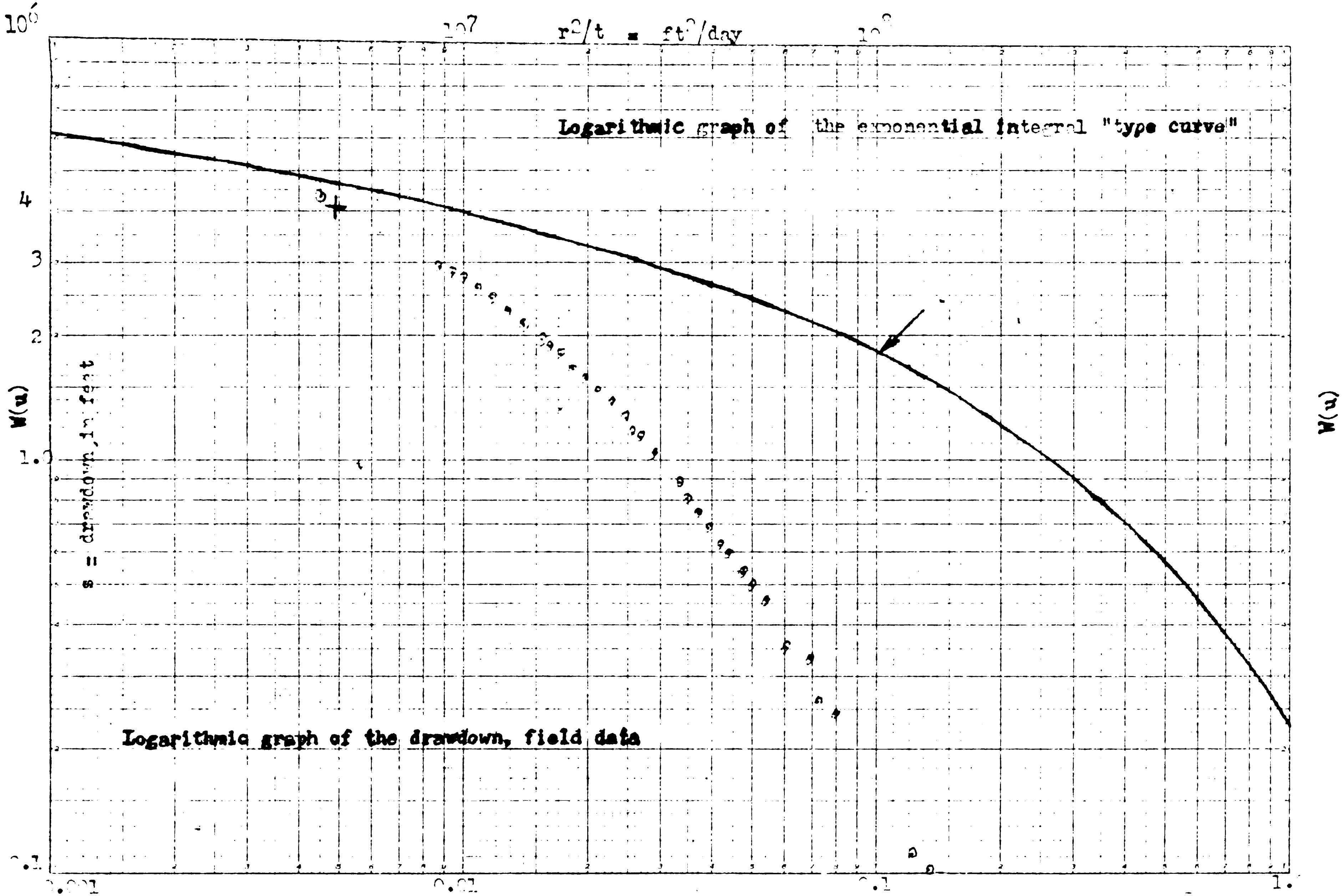
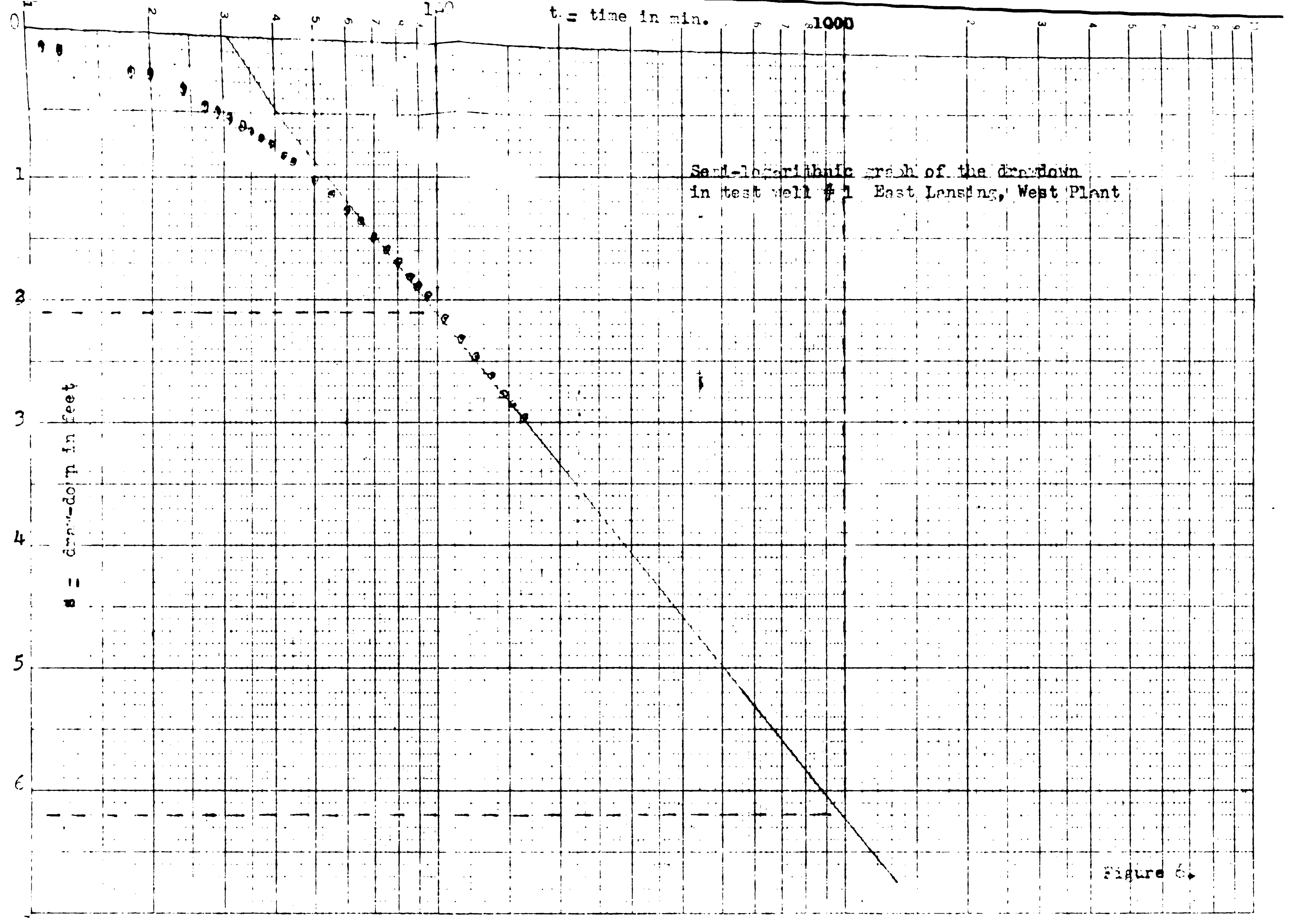
11



$u = \frac{r^2 S}{Tt} 1.87$



t = time in min.
s = draw-down in feet
Semi-logarithmic graph of the drawdown in test well # 1 East Lansing, West Plant

Figure 6.

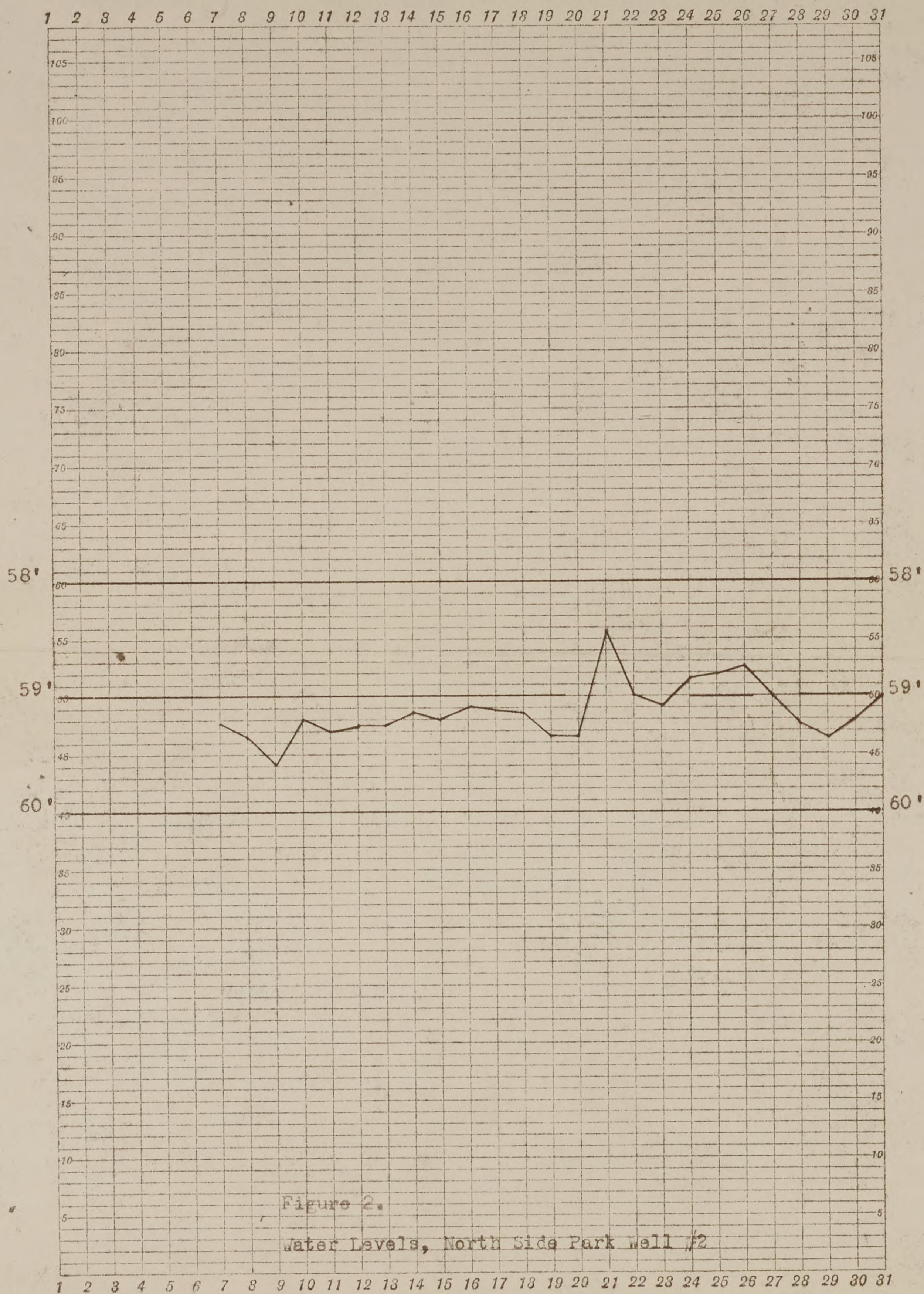


Figure 2.

Water Levels, North Side Park Well #2

Month of May 1948

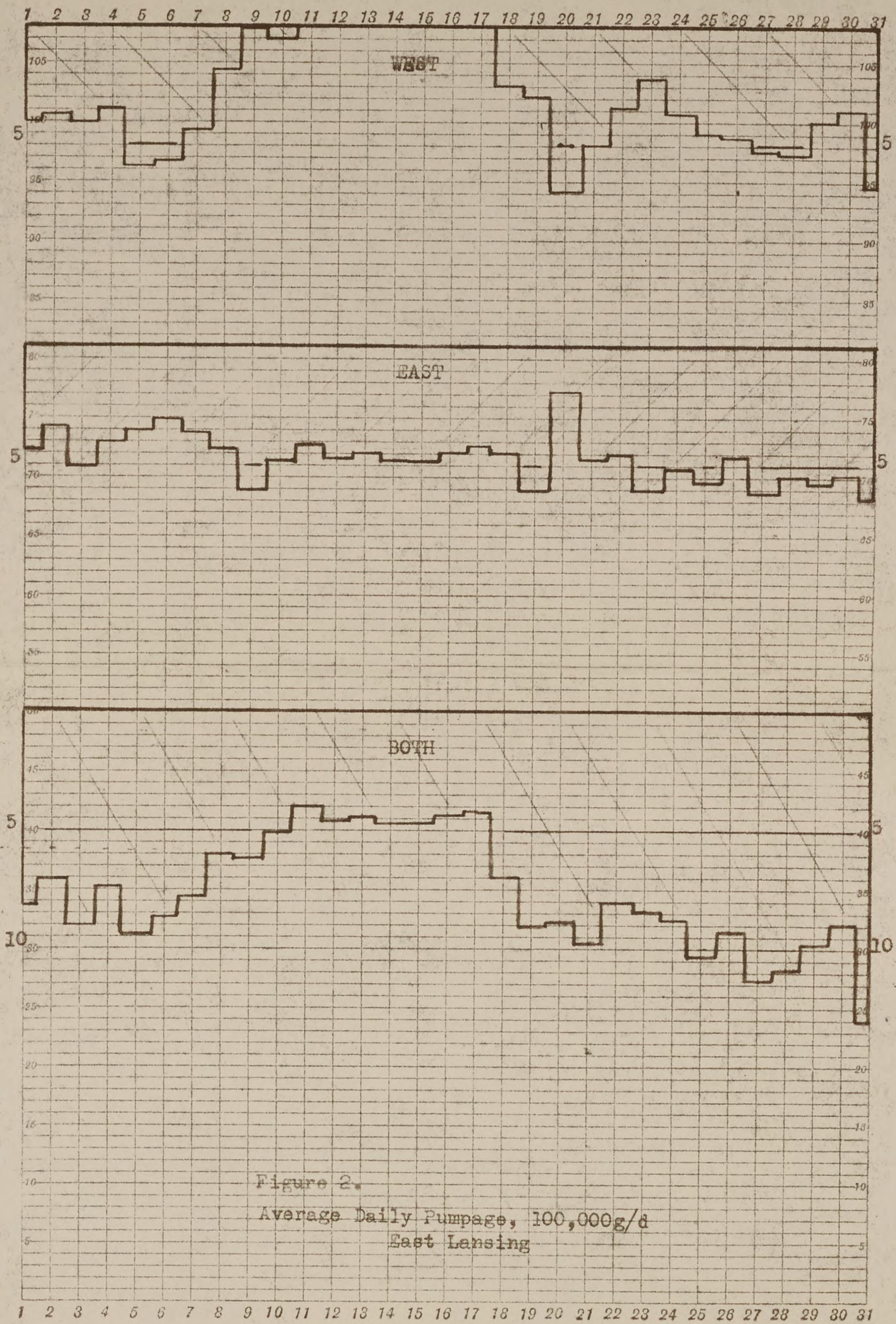


Figure 2.
Average Daily Pumpage, 100,000g/d
East Lansing

Month of May 1948

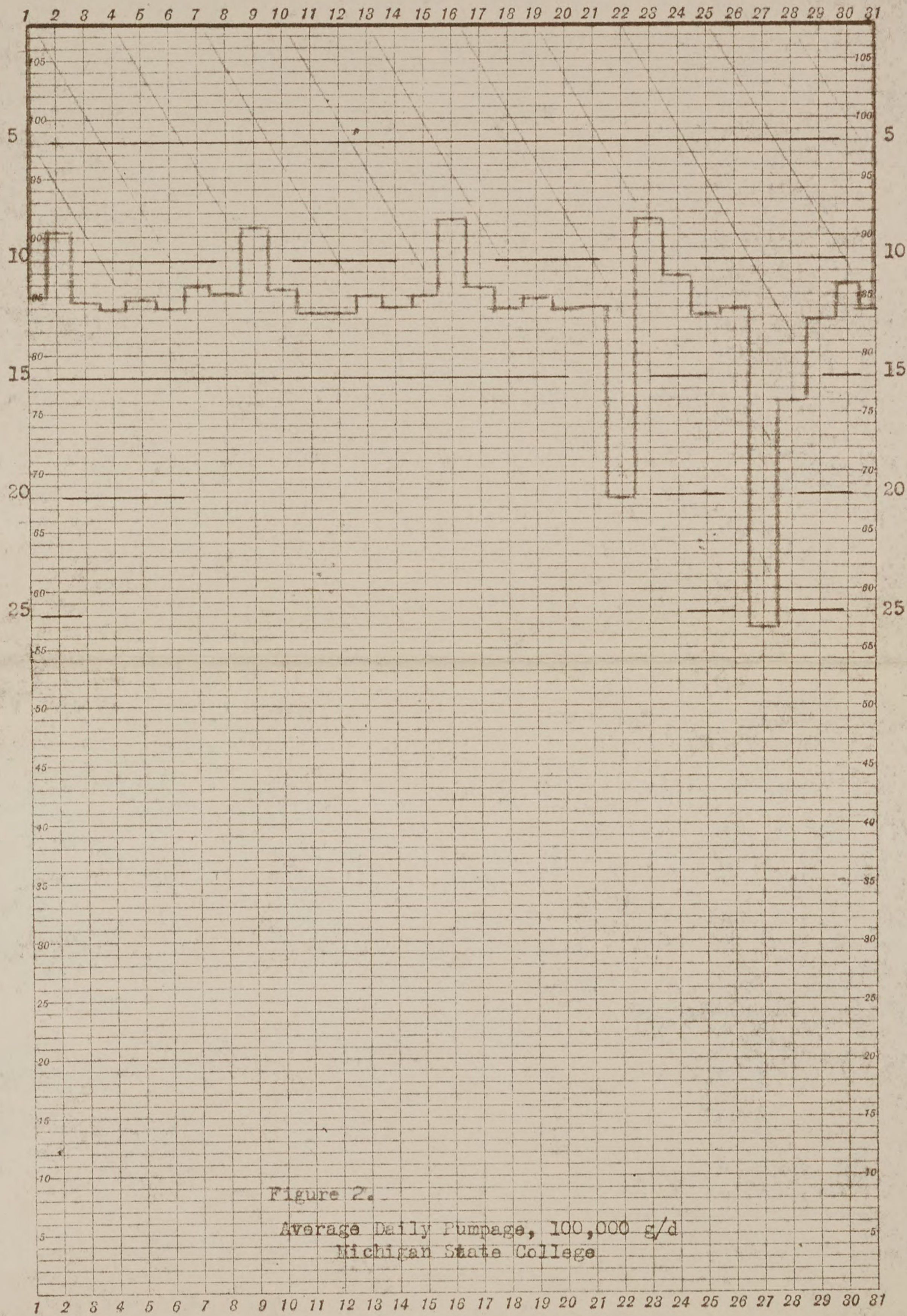


Figure 2.

Average Daily Pumpage, 100,000 g/d
Michigan State College

Month of May 1948

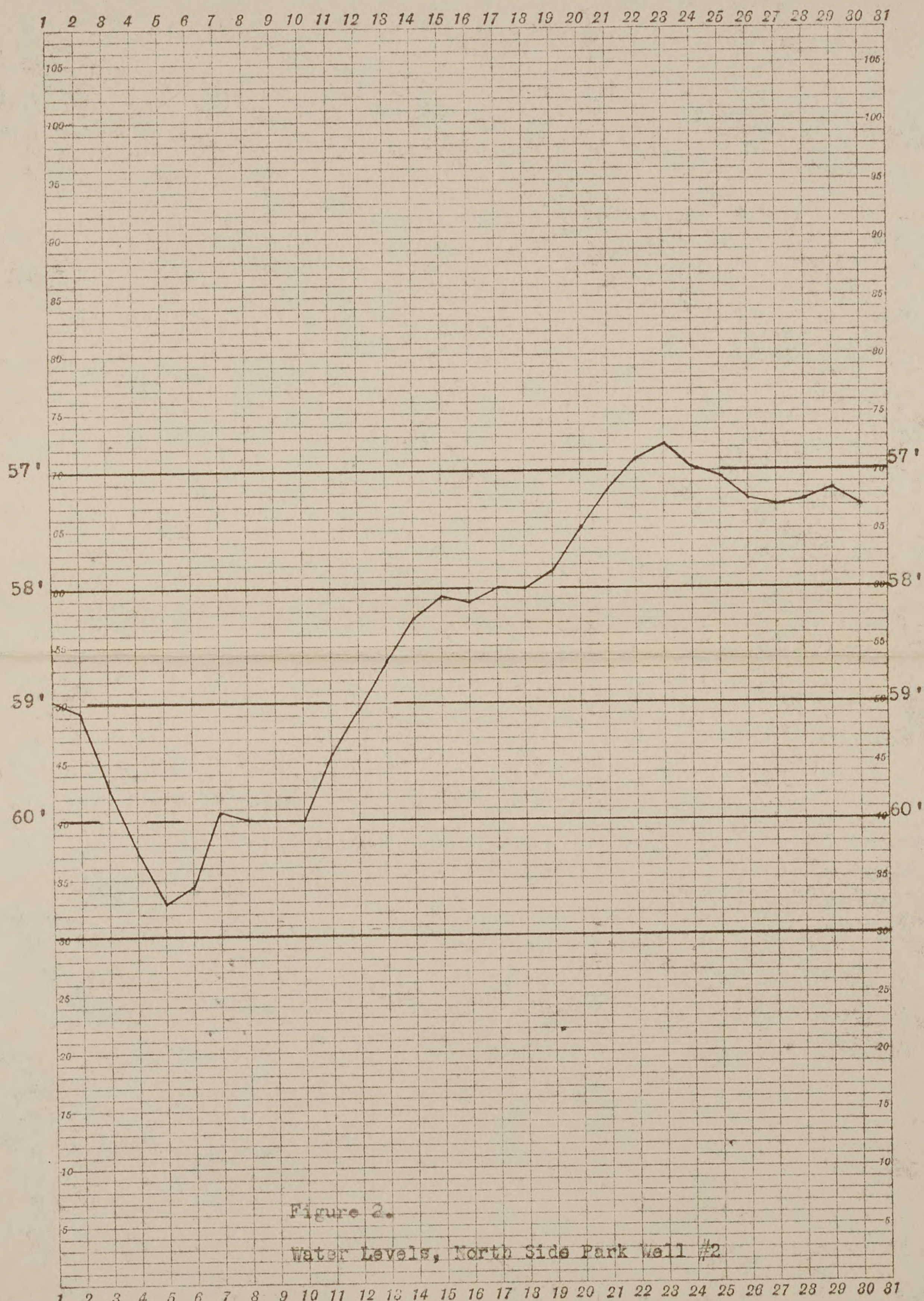


Figure 2.

Water Levels, North Side Park Well #2

Month of June 1948

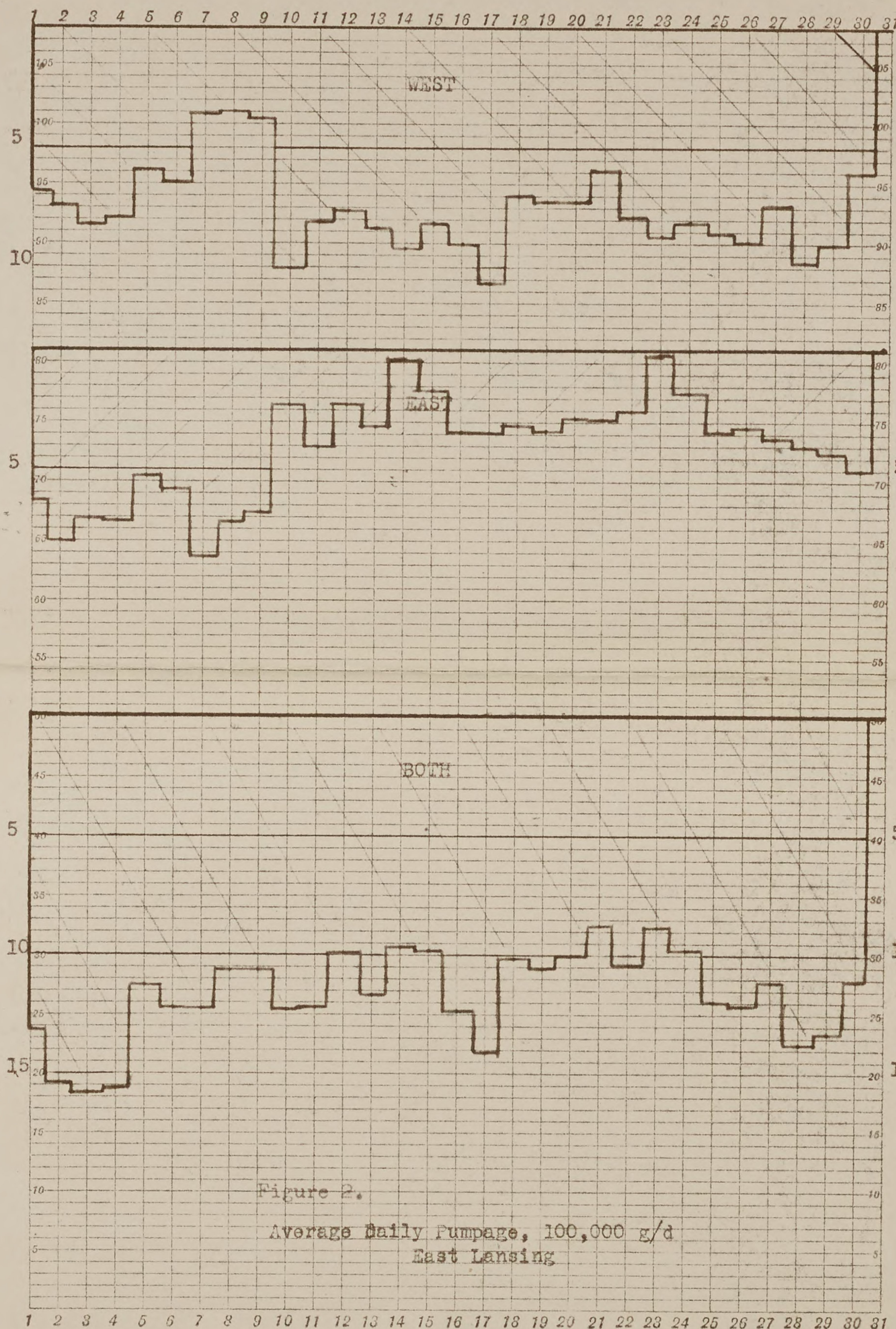


Figure 2.

Average Daily Pumpage, 100,000 g/d
East Lansing

Month of June 1948

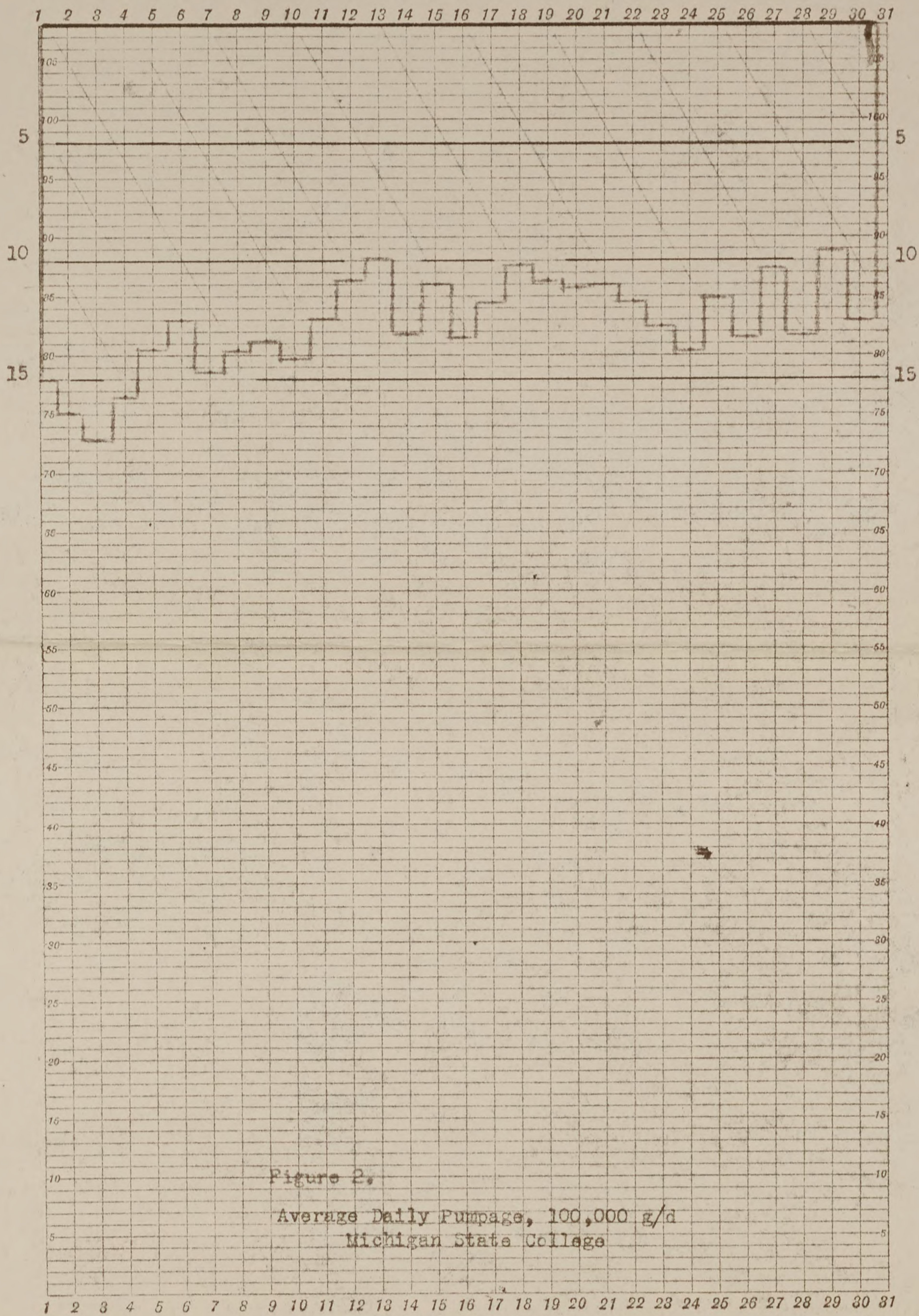


Figure 2.

Average Daily Pumpage, 100,000 g/d
Michigan State College

Month of June 1948.

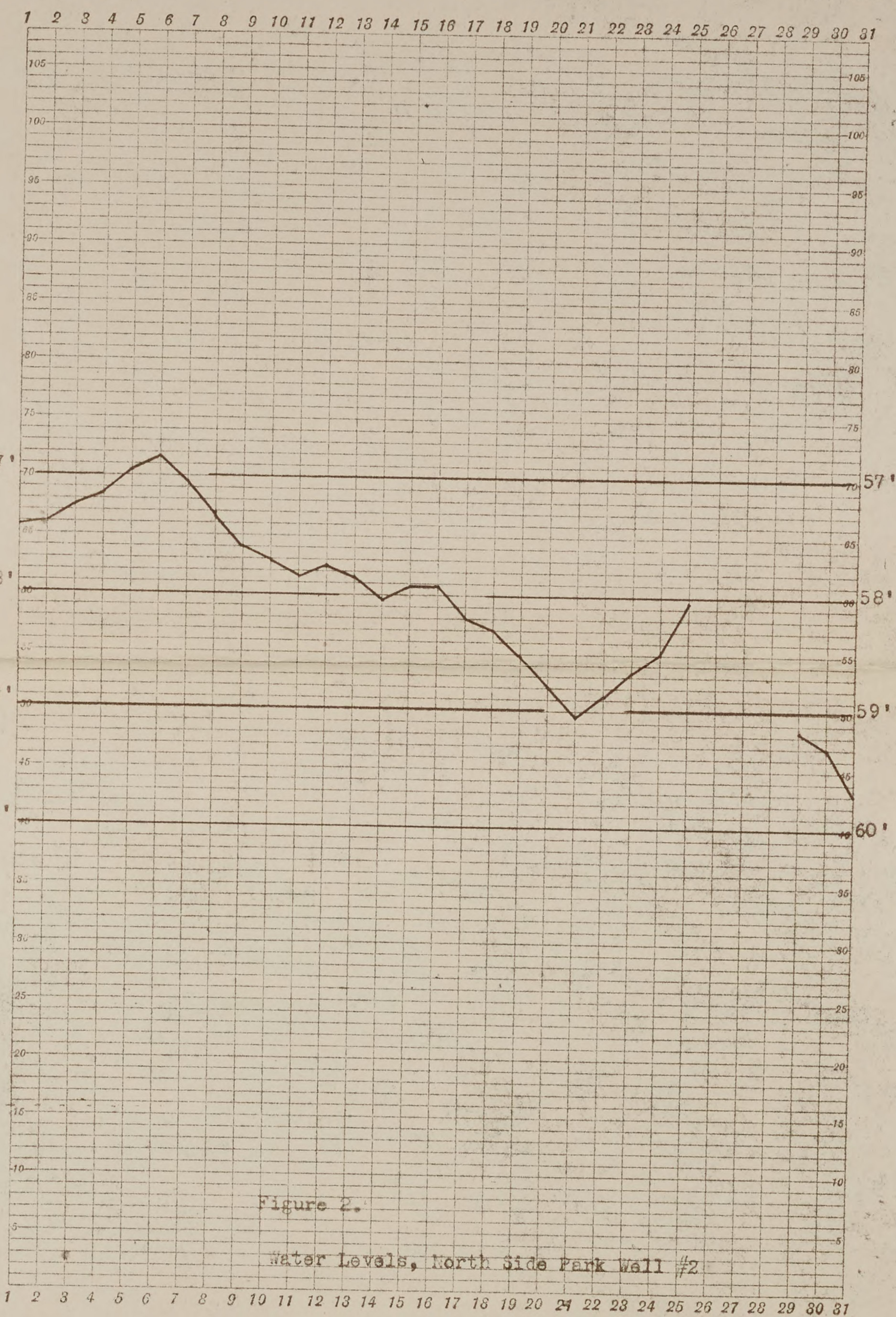


Figure 2.

Water Levels, North Side Park Well #2

Month of July 1948

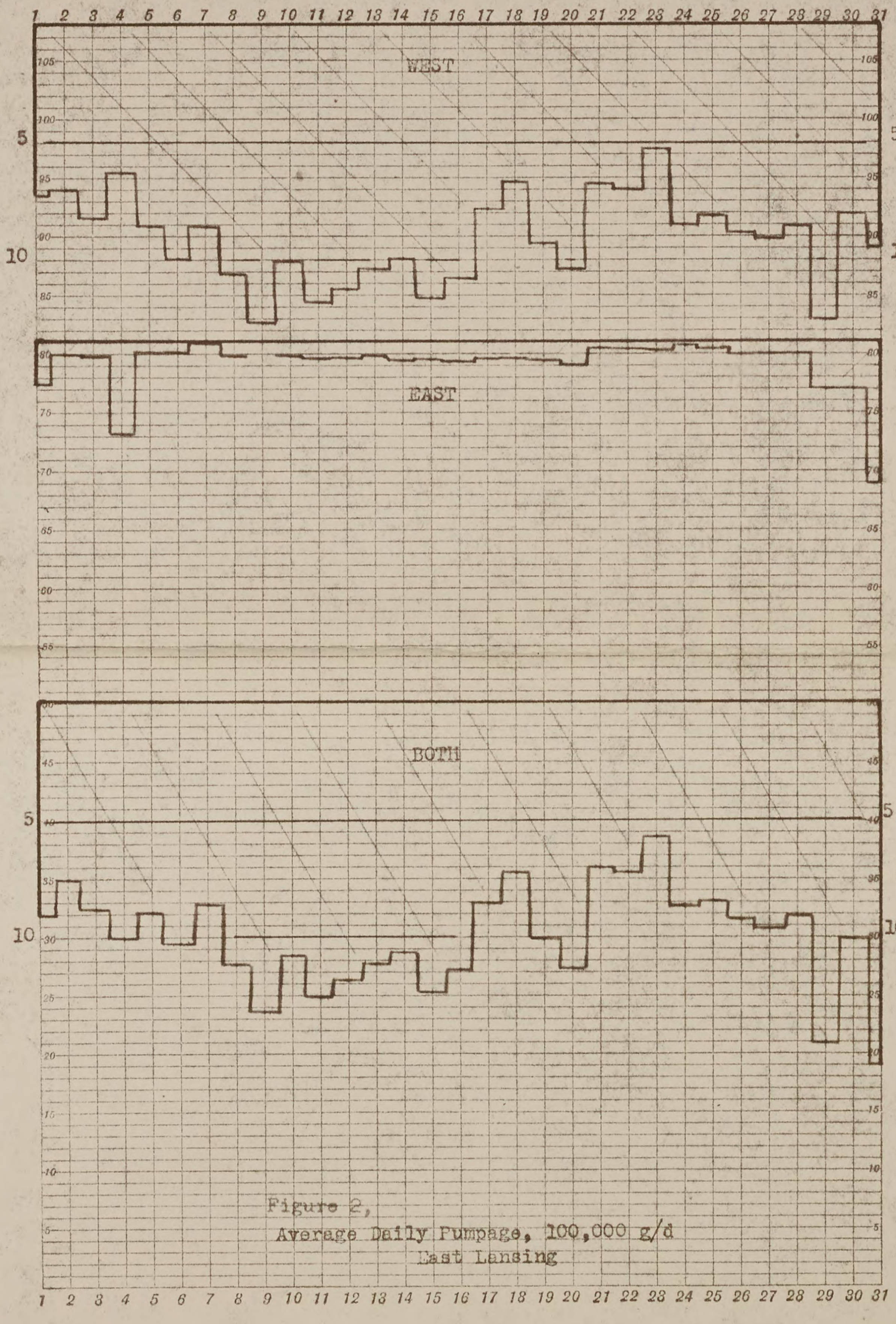


Figure 2,
Average Daily Pumpage, 100,000 g/d
East Lansing

Month of July 1948

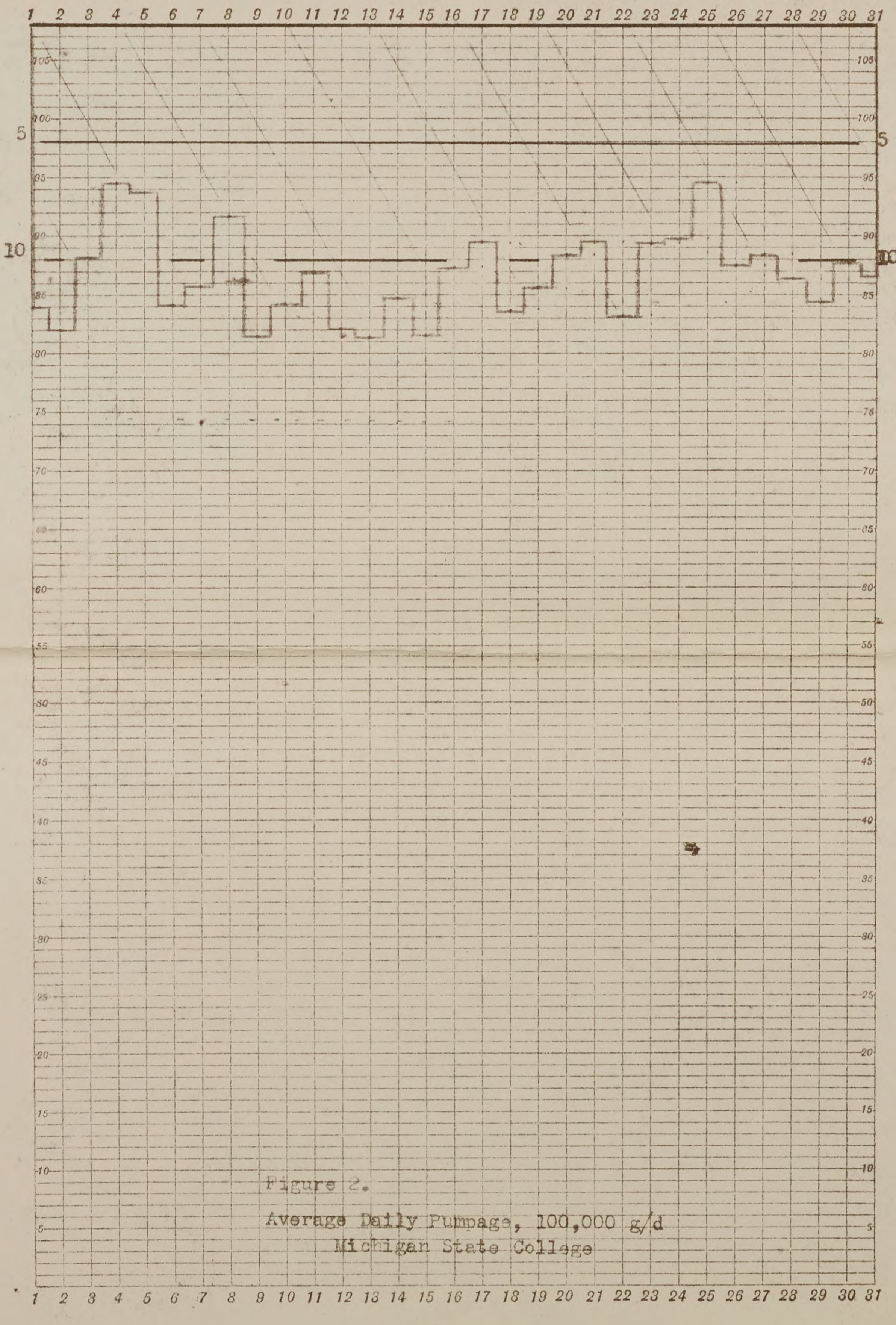


Figure 2.

Average Daily Pumpage, 100,000 g/d
Michigan State College

Month of July 1948

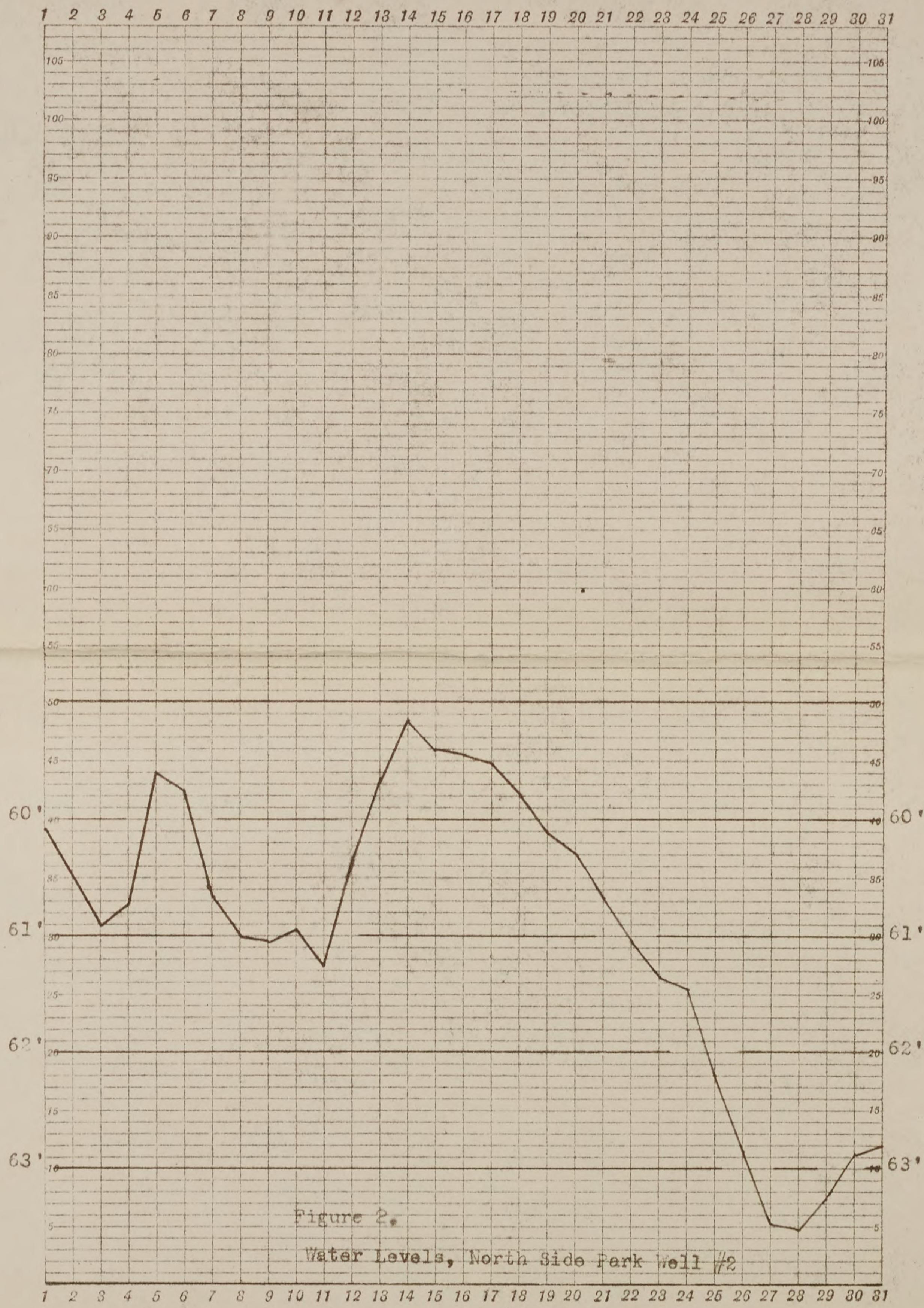


Figure 2.

Water Levels, North Side Park Well #2

Month of August 1948

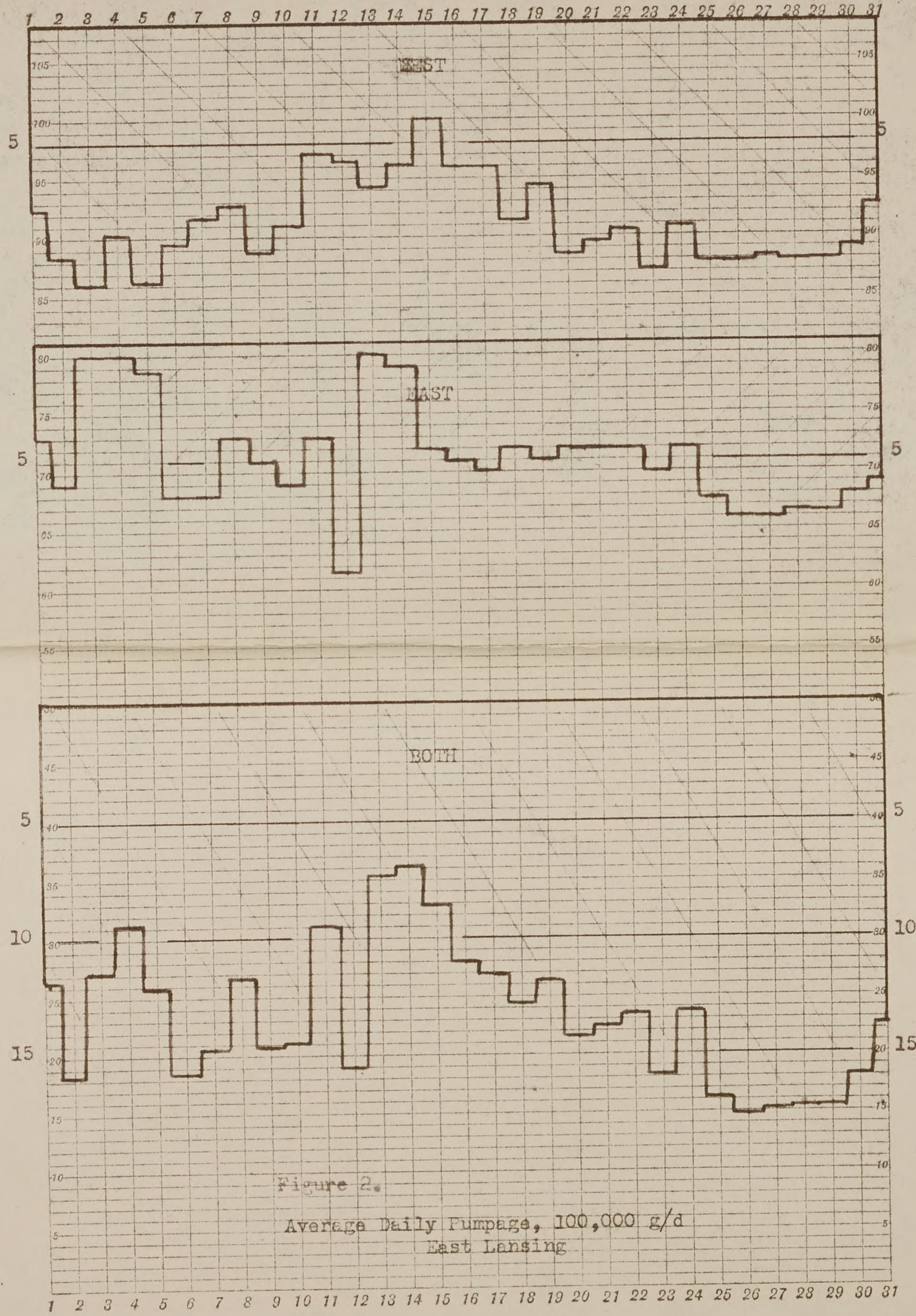


Figure 2.

Average Daily Pumpage, 100,000 g/d
East Lansing

Month of August 1948

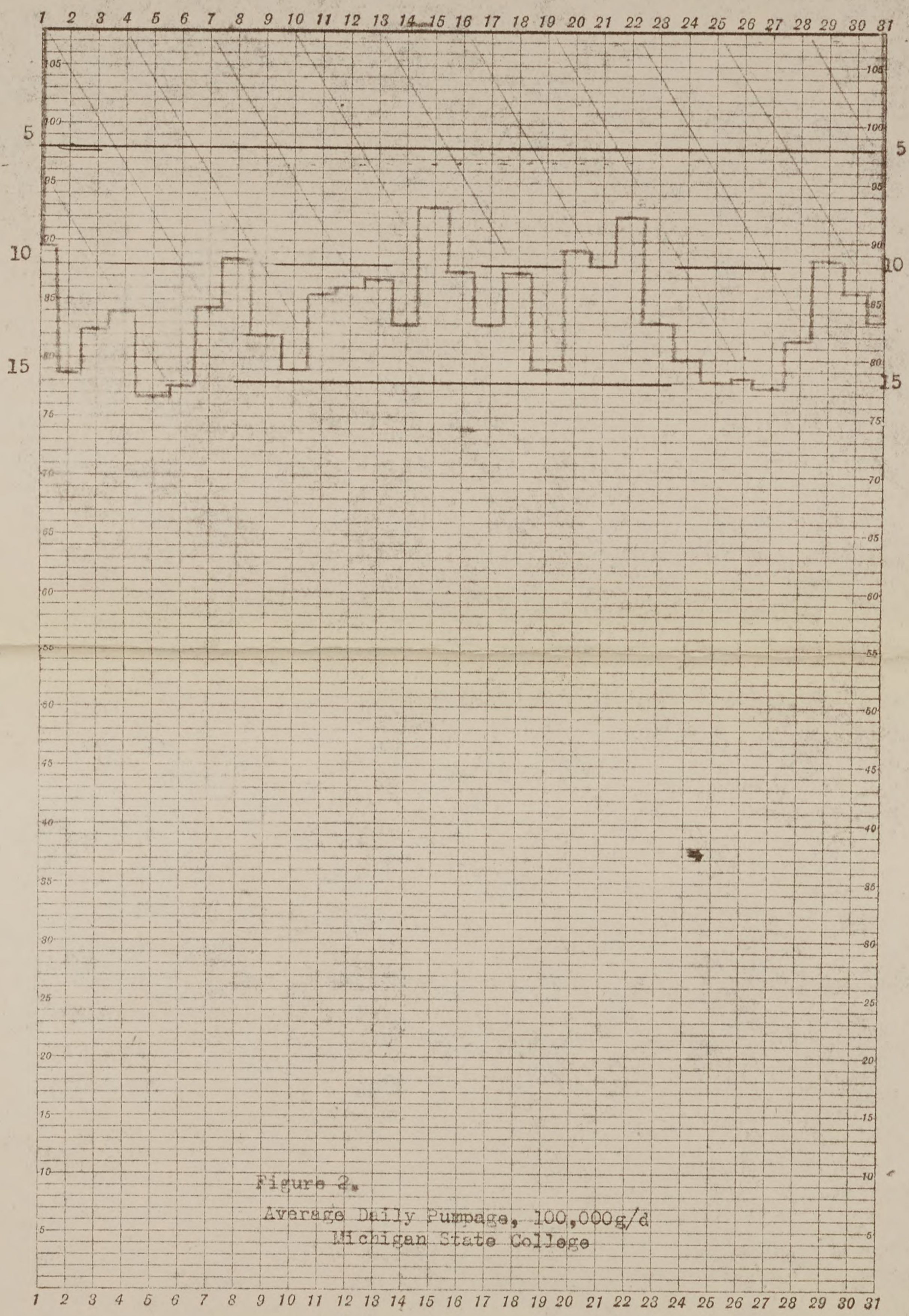


Figure 2.

Average Daily Pumpage, 100,000g/d
Michigan State College

Month of August 1948

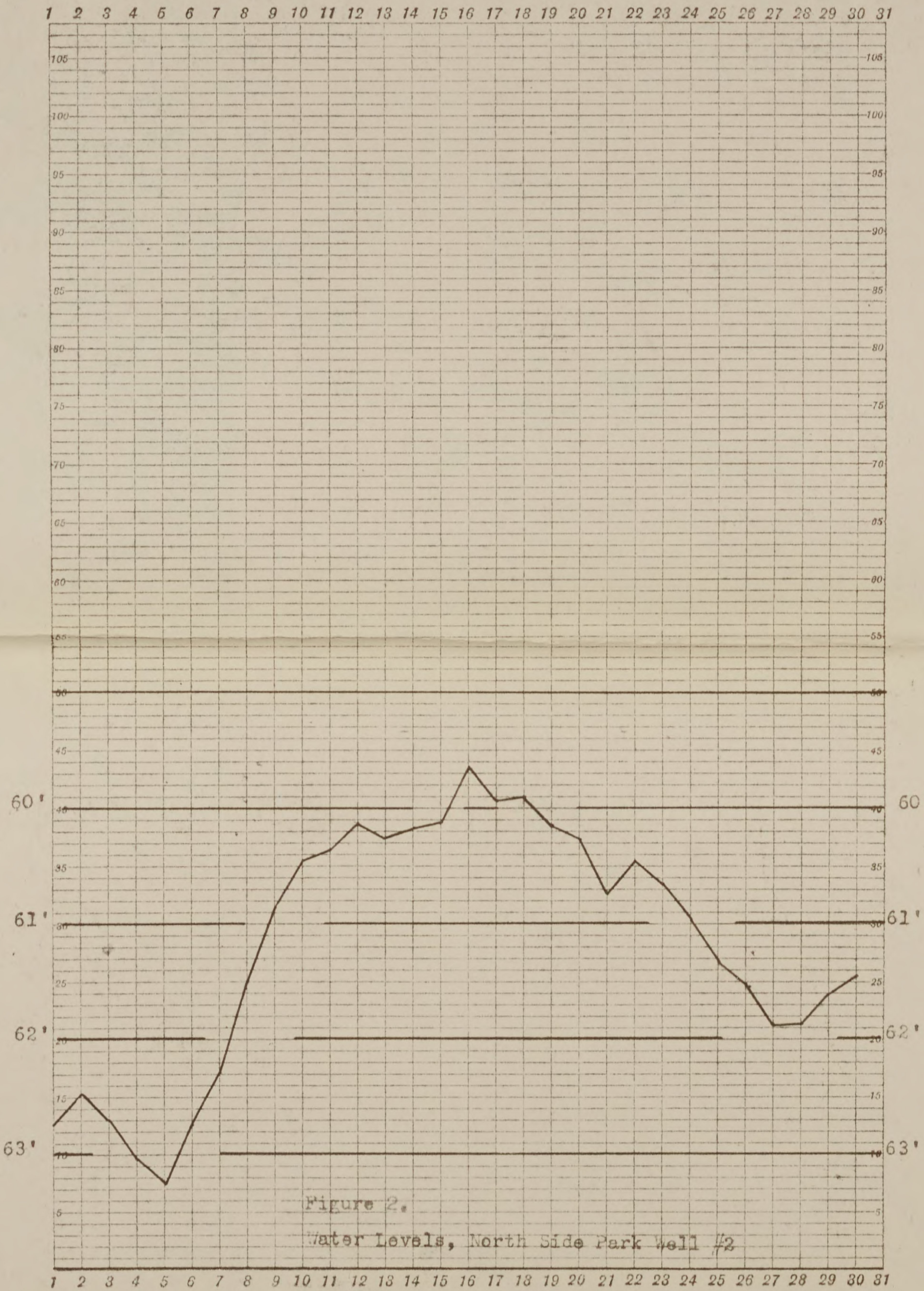


Figure 2.

Water Levels, North Side Park Well #2

Month of September 19 48.

Figure 2.

Average Daily Pumpage, 100,000 g/d
East Lansing

Month of September 1948

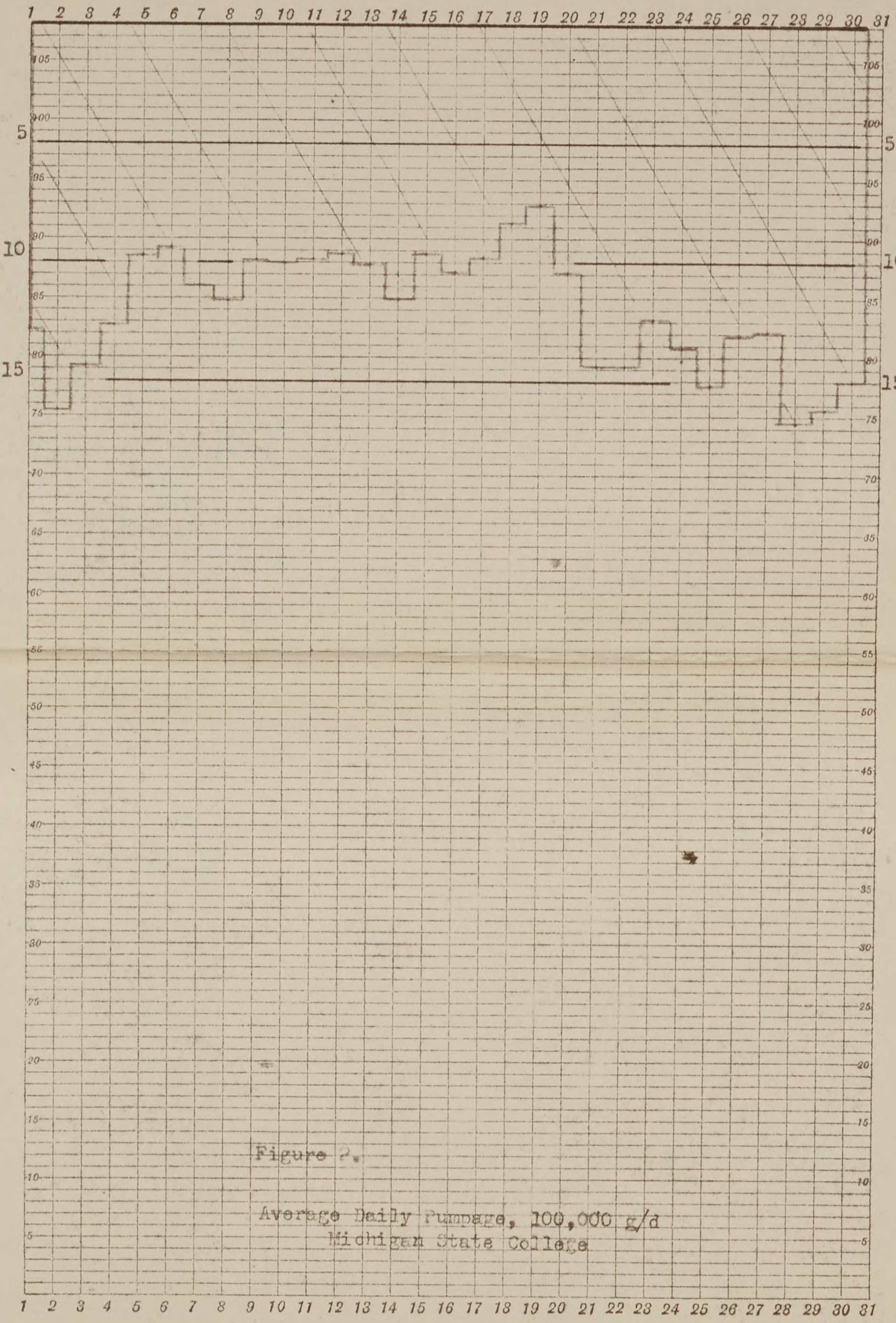


Figure 2.

Average Daily Pumpage, 100,000 g/d
Michigan State College

Month of September 1948

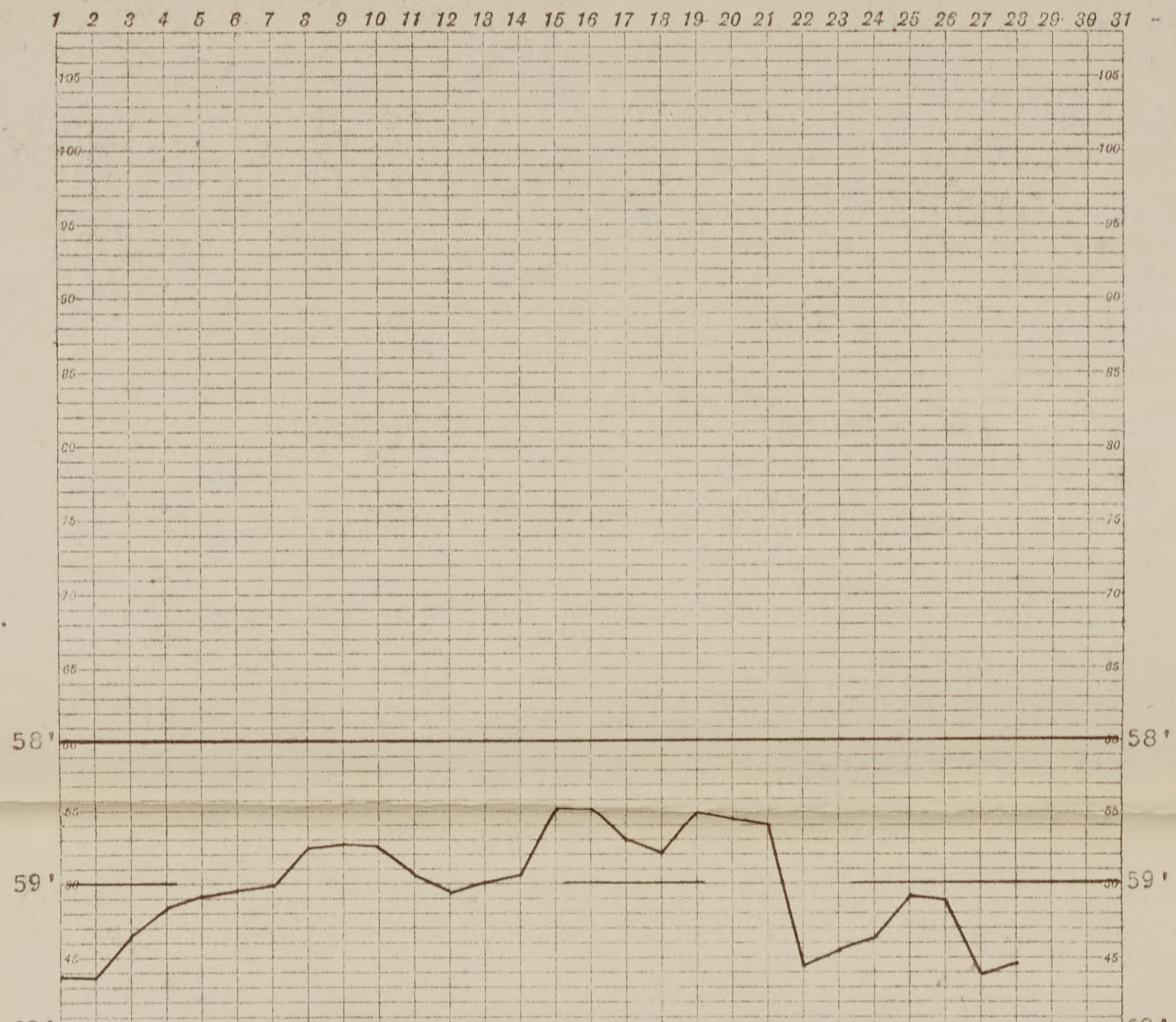


Figure 2.

Water Levels, North Side Park Well #2

Month of October 19 48

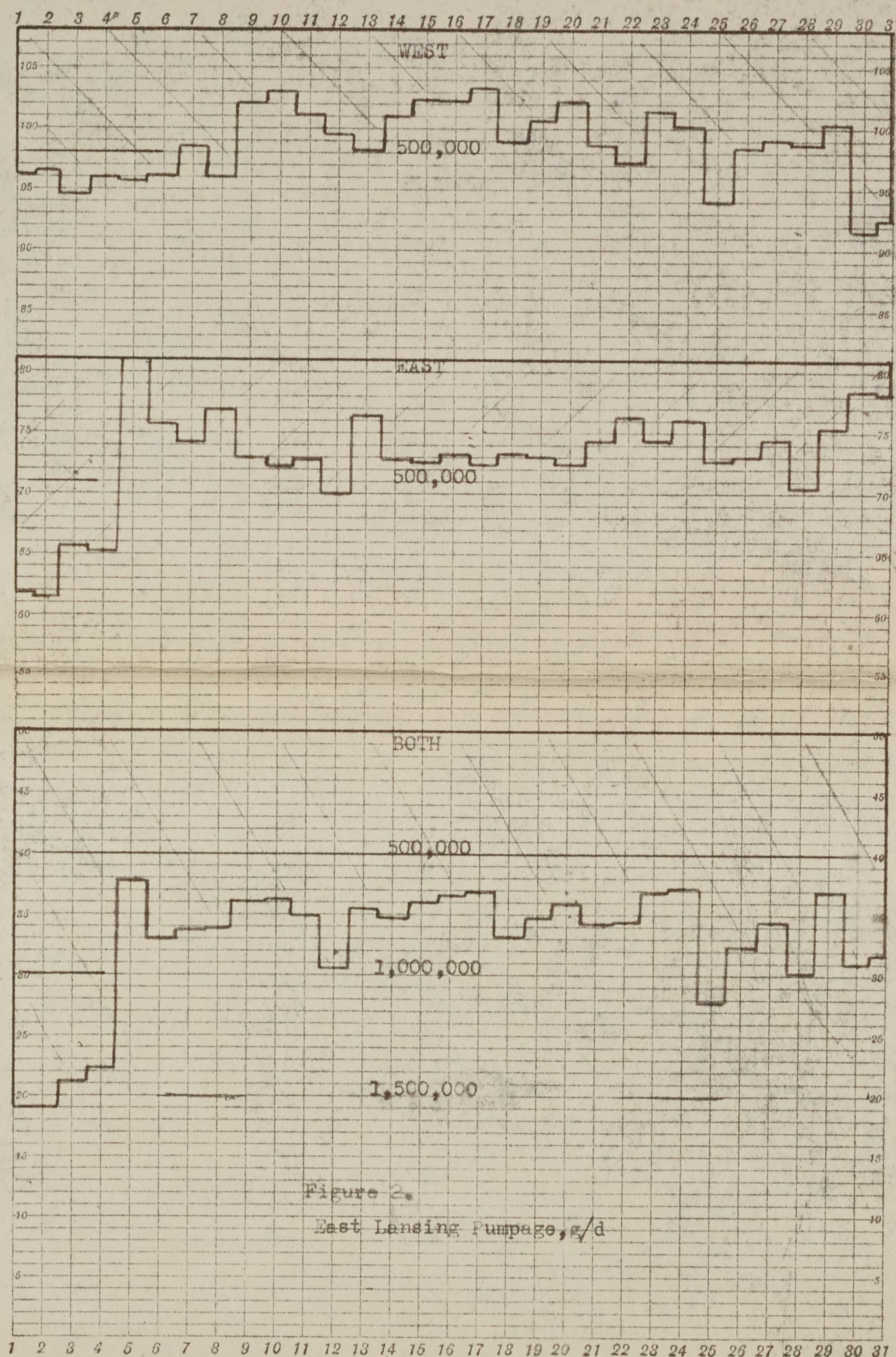


Figure 2.
East Lansing Pumpage, g/d

Month of October 1948

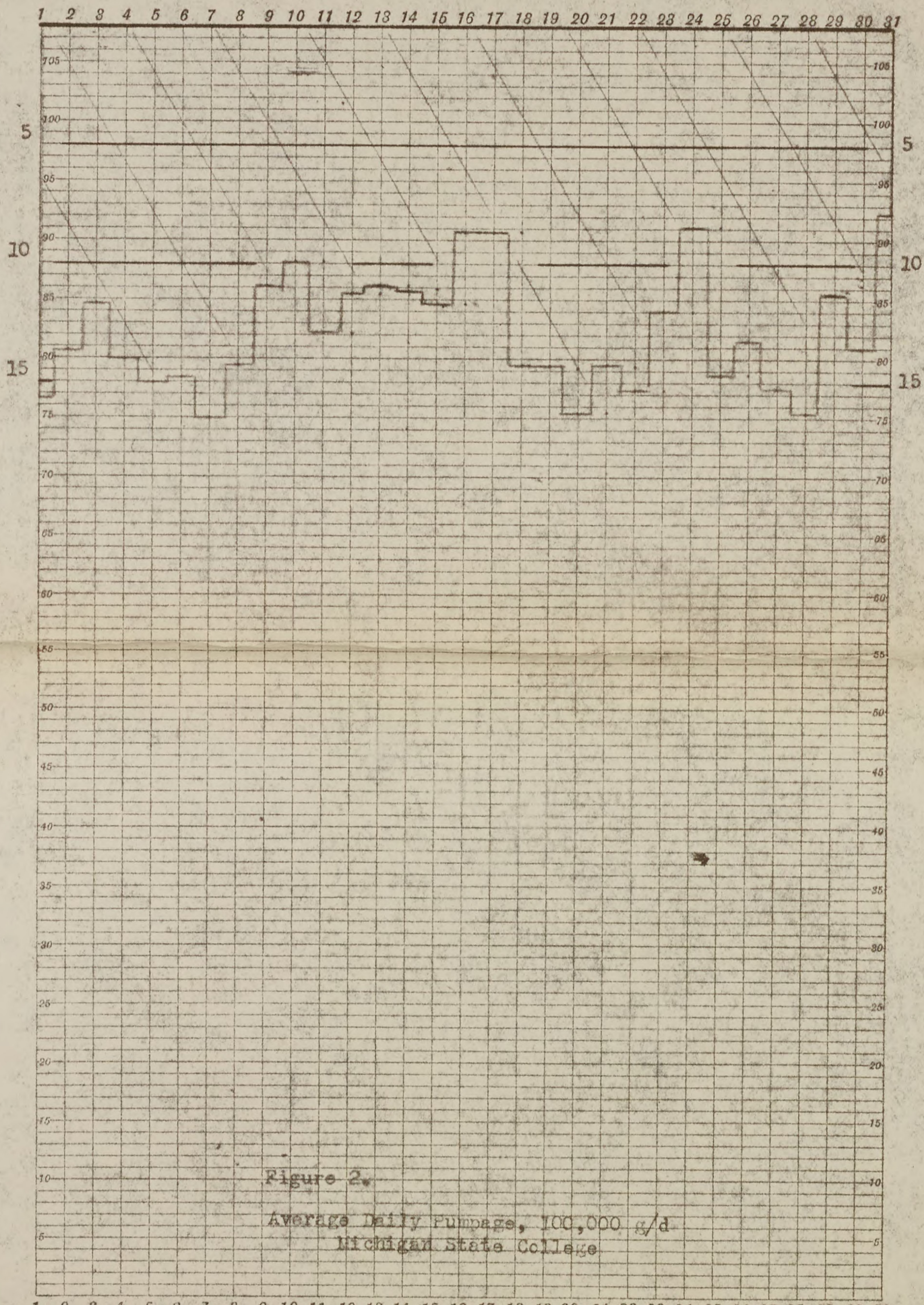


Figure 2.

Average Daily Pumpage, 100,000 g/d
Michigan State College

Month of October 1948

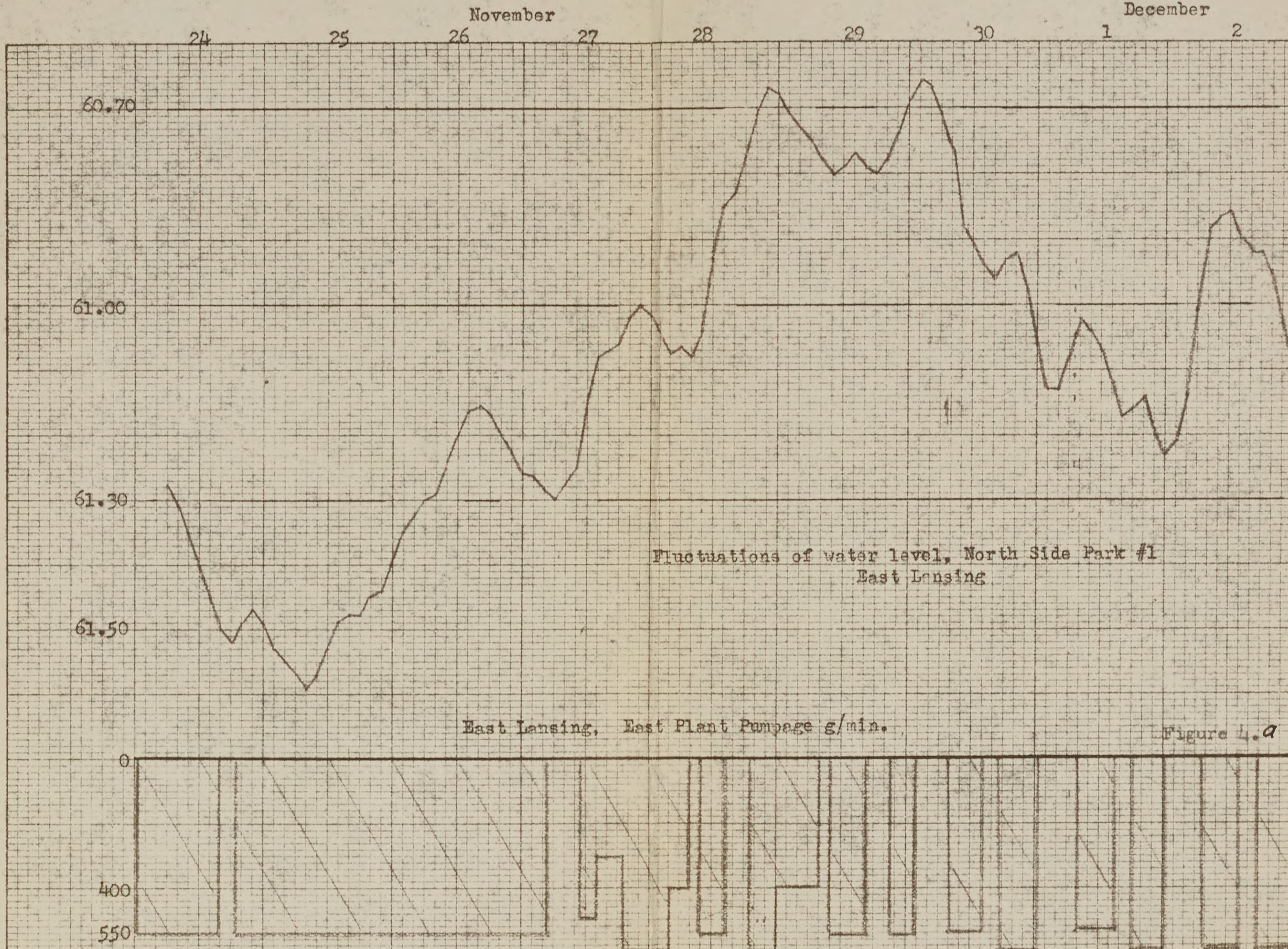

November
December
24
25
26
27
28
29
30
1
2
60.70
61.00
61.30
61.50
Fluctuations of water level, North Side Park #1
East Lansing
East Lansing, East Plant Pumpage g/min.
0
400
550

Figure 4.a

KEUFFEL & ESSER CO., N. Y. NO. 359-21
12 × 20 to the inch.
MADE IN U. S. A.

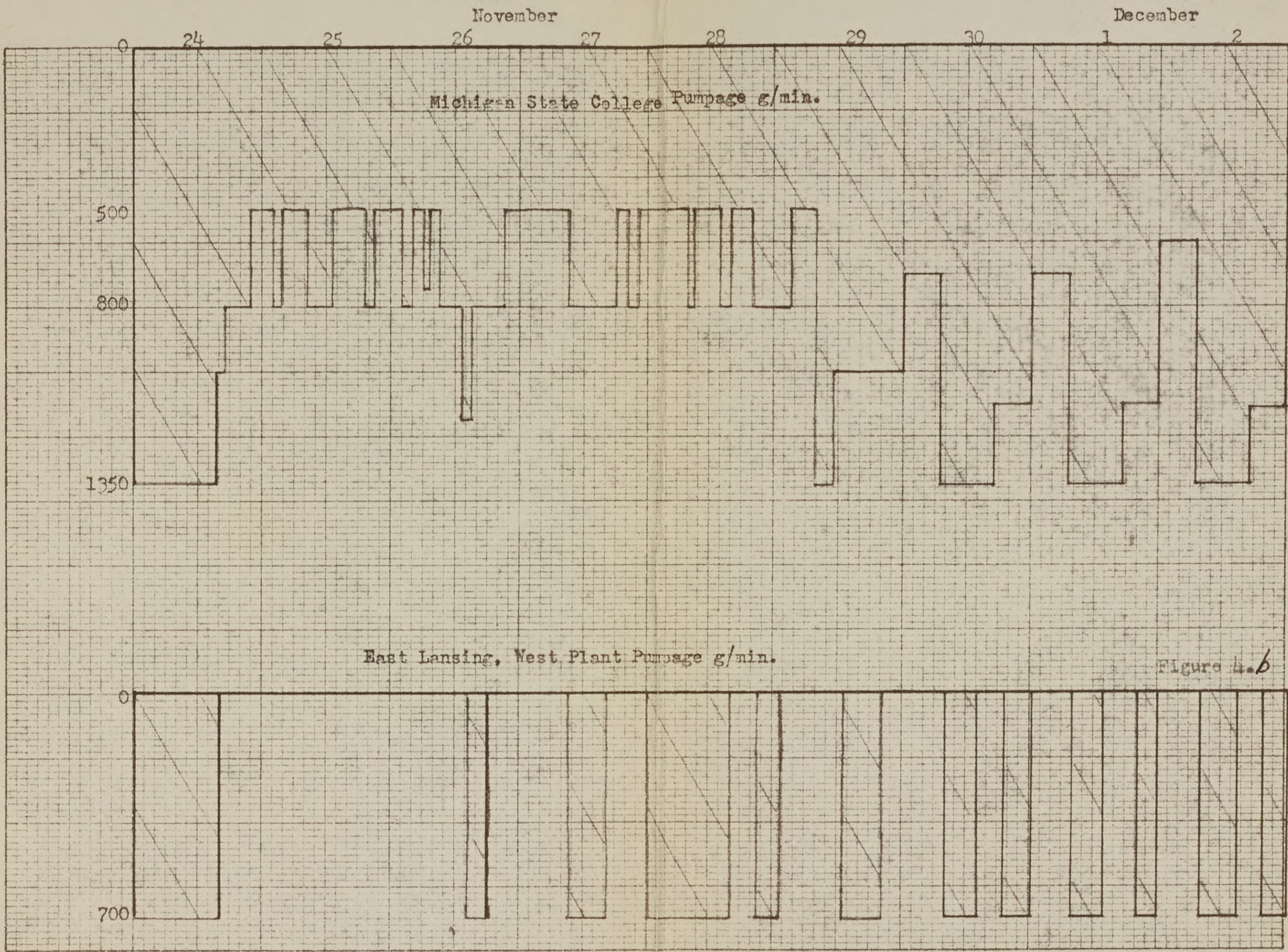


Figure 4.b

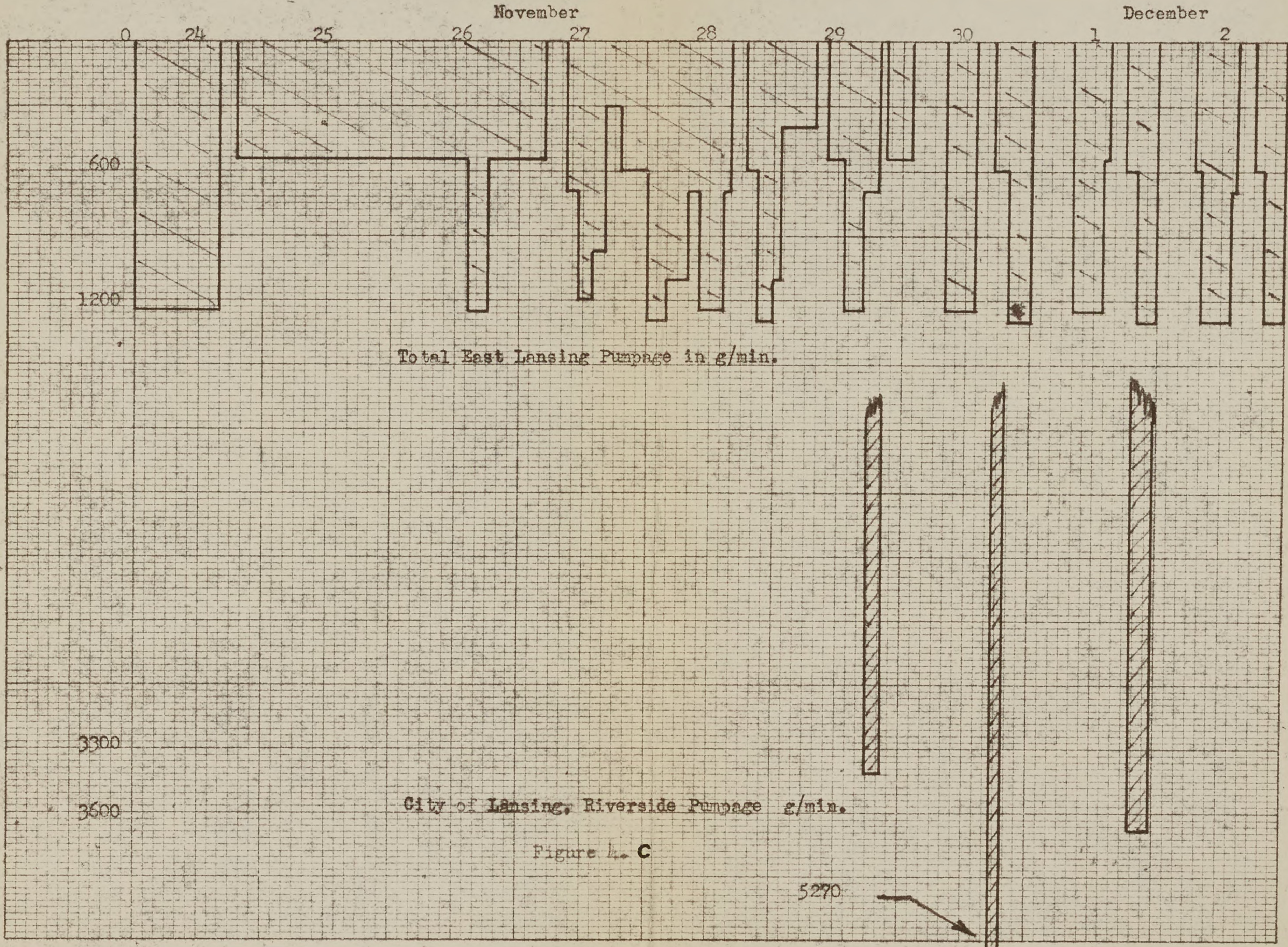

November
December
0
24
25
26
27
28
29
30
1
2
600
1200
Total East Lansing Pumpage in g/min.
3300
3600
City of Lansing, Riverside Pumpage g/min.
5270

Figure 4. C

Pocket has: 1 Suppl

LEMENTARY
ATERIAL