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16. ABSTRACT

The work described in this report was completed several years ago. We felt it was desirable, at this time, to summarize the construction control efforts and the data to complete our file on the project.

On about June 1, 1964, construction work began on an 11.9 mile segment of former State Route 74 between Route 680 and 1/2 mile south of Route at Cordelia.

The work consisted of grading, paving, and the construction of five bridges to act as grade separations on this realignment to full freeway standards. Inherent with this work were special design problems with roadway fills and structure approach embankments constructed over mud deposits of varying thickness, and with the utilization of the existing route as a frontage road.

Preconstruction design features included surcharges, mud blasting, controlled rates of loading and waiting periods.

Piezometers, settlement platforms, inclinometers and heave stake lines were installed in the special treatment areas to monitor fill settlement, pore pressure, and lateral movement during construction.

Locations of the special treatment areas and the accompanying construction control devices are indicated on the attached plans.

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State of California
Department of Public Works
Division of Highways
Materials and Research Department

May 23, 1969

10-Sol-21-C
19202-762400 (Old #2-Q)

Mr. Neal Andersen
District Engineer
Division of Highways
Stockton, California

Dear Sir:

Submitted for your consideration is:

REPORT

on

CONSTRUCTION CONTROL

on

ROAD 10-SOL-21-C

at

ROUTE 680 TO 0.5 MILE SOUTH OF ROUTE 80

Study made by ..... Foundation Section
Under general direction of..... Travis Smith
Work supervised by ..... W. G. Weber
Report prepared by ..... E. C. Wrye
R. J. Freeman

Very truly yours,

JOHN L. BEATON,
Materials and Research Engineer

By Travis Smith
Travis Smith
Assistant Materials and
Research Engineer - Foundation

Attach.
cc:GA Hill:AC Estep
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INTRODUCTION

The work described in this report was completed several years ago. We felt it was desirable, at this time, to summarize the construction control efforts and the data to complete our file on the project.

On about June 1, 1964, construction work began on an 11.9 mile segment of former State Route 74 between Route 680 and 1/2 mile south of Route 80 at Cordelia.

The work consisted of grading, paving, and the construction of five bridges to act as grade separations on this realignment to full freeway standards. Inherent with this work were special design problems with roadway fills and structure approach embankments constructed over mud deposits of varying thickness, and with the utilization of the existing route as a frontage road.

Preconstruction design features included surcharges, mud blasting, controlled rates of loading and waiting periods.

Piezometers, settlement platforms, inclinometers and heave stake lines were installed in the special treatment areas to monitor fill settlement, pore pressure, and lateral movement during construction.

Locations of the special treatment areas and the accompanying construction control devices are indicated on the attached plans.

PROJECT SUMMARY

The settlements have occurred slowly and are expected to continue for a long period of time. No settlements have occurred to date at a rate higher than was originally anticipated.

The road appears to be stable. The differential settlement caused by the incomplete removal of the mud in several areas has resulted in a variable thickness of pavement in order to form an even surface.

Future maintenance was expected in the area between Stations 395 and 405. Mud displacement in this area was deemed uneconomical. As a result, the fill was built as a floating fill and has a slow and steady rate of settlement.

Several change orders were found to be necessary during construction. These involved changes in grade height, methods of fill placement, additional struts, and mud stripping.

A few minor failures (with cracks) occurred during construction due to differential settlements. No movement of any consequence was measured on the railroad fills.

SITE DESCRIPTION

The fill was constructed on a tidal mud flat. At seven locations the roadway completely extended out over the edge of Suisun Bay and, within the seven locations, soft saturated materials occurred to 20 feet in depth. These areas were also subjected to inundation by sea water at high tide and flooding by duck club operators in the area.

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Station 196 - 204+50

This area was designed for mud displacement by end dumping from south to north. However, the area under the main line to the centerline of the east frontage road from Station 195 to 202 was stripped, by change order, to a depth of twelve feet. (Photo #1). As the stripping operation advanced, the area was progressively backfilled with a rocky material to the original ground elevation. This rocky material then served as a working table for the dragline. A controlled rate of loading of one foot per week was used on the main line and the east frontage road. The total height of fill of the main line varied from from 10 feet to 18 feet including a 5-foot overload. The east frontage road fill ranges from 5 feet to 10 feet and did not have an overload.

A noticeable mud wave occurred at Station 197 during construction. When the loading operations ceased, (Photo #3) the mud wave movement began to slow down. The grade line on the east frontage road was increased by five feet over original planned grade causing an even larger movement of the mud wave. Also the main line fill slumped about half a foot. Ten borings made in the area when this fill was up to subgrade indicated 6-1/2 feet to 12 feet of soft material remaining in this area. Borings in the east frontage road showed 7 feet to 12-1/2 feet of mud.

An additional strut 25 feet wide and 5 feet high was built on the mud flat for a distance of 1200 feet along the east frontage road, (Photo #3). The placement of this fill caused a mud wave. At Station 197, the mud rose to an approximate height of seven feet and extended out approximately 150 feet into the marsh area (Photo #4). Instrumentation in this area consisted of six settlement platforms, five piezometers, seven inclinometers, and two heave lines. The placement of this strut eliminated the usefulness of all of the inclinometers in this fill area and the piezometers were carried away in the mud wave, (Photo #5).

Small cracks appeared one day after strut-loading began. About one-half day later, the fill visibly moved with the result that the east frontage road settled one foot and a crack one-half foot wide appeared, (Photo #6).

Station 309 - 319

The fill was constructed over a marshy area, which has a 5-foot fibrous root mat, by placing a 3-foot working table and then loading at a controlled rate of one foot of fill per week. The main line has a fill height of 10 feet while the east frontage road has a height of 5 feet. Two waiting periods of not less than thirty days each were prescribed during construction due to the apparent instability of the fill.

Installed for monitoring this section were six settlement platforms, six piezometers, three inclinometers, and two heave lines.

Station 319 - 327

The area was designed to be constructed with a controlled rate of loading of one foot per week after a 3-foot working table was placed.

As the working table was being placed, the area to the east of the ultimate centerline became very soft with mud and water seeping through the fill. Construction proceeded by placing a 15-foot fill between the existing highway and the ultimate centerline and then stripping the area from

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A controlled rate of loading of one foot per week was applied after the fill was up to a level of 6 feet. The main fill had a total fill height of 15 feet including an overload of 5 feet and the east frontage road fill has a height of 5 feet with no overload.

Design grade was increased from Station 395 to 405 on the east frontage road due to the area being inundated by water and the low level of the fill. When the additional material was placed, cracks and settlement appeared at Station 401 on the east frontage road (Photo #8). Borings in this area indicate a small finger of an old water channel cut through this section of fill and that 19 feet of soft mud underlies this section of the east frontage road.

Installed in this section were one settlement platform and five piezometers.

Station 405 - 420

A combination of stripping and displacement was used at this marshy location. The area was stripped to a depth of about 10 feet to a brown layer of peat and was immediately backfilled with material to form a working table for the draglines. As the fill was being placed, a mud wave occurred and the draglines kept removing the mud in order to keep it moving.

A strut 5 feet high and 40 feet wide was built between the fill and the existing highway from Station 405 to 414. Another strut 5 feet high and 40 feet wide was placed on the right side of the fill in the swamp area from Station 406 to 420.

Instrumentation consisted of one piezometer in this area.

Several test holes were drilled through the fill when it was up to subgrade. The findings indicate that small pockets of mud exist, mainly around Station 405 to 407. This is due to an existing road leading to a game club. This road was used as a strut in the beginning of the fill and was not stripped. Therefore, complete displacement could not be achieved in this locality.

SETTLEMENT

At Station 118 to 121 generally less than one foot of settlement has occurred and plots indicate a leveling off of the settlements. In the vicinity of Station 200, on the main line, settlements range from 0.1 to 0.7 feet. Future settlements in this area are expected to be very slight as borings made through the fill indicate only a thin layer of mud remains under this area. Future settlements are expected to continue on the east frontage road at a slow rate due to the fact that the area was only stripped to the centerline of the road.

Settlement on the main line (Station 309 to 314) is still occuring at a slow but stready rate and will continue for some time in the future. From Station 314 to 328, on the main line, around 0.2 feet of settlement has occurred to date and plots show a steady straight line of no settlement for the last five months.

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The pore pressures from Station 309 to 328 are all under one-half a ton per square foot with indications that 25 percent consolidation had occurred to March 1965 on the east frontage road, and around 35 percent consolidation had occurred on the main line. In the Ibis Overcrossing on the east frontage road around 43 percent consolidation of the soft underlying material had occurred up to March of 1965. The pore pressures in this area (Ibis Overcrossing) were fairly steady at about 0.5 ton per square foot all during the construction and waiting period.

From Station 394 to 407 on the main line, the pore pressures reached a maximum of 0.9 ton per square foot and tapered off to a little over one-half a ton per square foot. Consolidations to March 1965 were around 25 percent at Stations 394 to 398 and from 43 percent at Station 401 to 13 percent at Station 407 on the main line. The east frontage road at Station 400 indicated a completed consolidation.

Plots of the excess hydrostatic pressure readings are found in the Appendix.

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SOIL CONDITIONS

The tidal sediments found in this area consisted of wet, soft to very soft silty clay containing highly fibrous organic matter. This organic matter extended to a depth of 5 feet where the foundation soil changed into a soft silty clay and, in some cases, extended for another 15-20 feet into a stiff blue clay.

INSTRUMENT INSTALLATIONS

After placement of a working table, 35 settlement platforms were installed at various locations on the main line and on the east frontage roads. Twenty-three of the settlement installations were riser type and twelve were the closed water level type. Due to inundation of the surrounding areas in the winter months, riser type settlement platforms were used on most of the lower fills. Closed water level type settlement platforms were used in the structure approach fills.

Thirty piezometers were installed in the fills using the uncased, closed systems with one-foot-long porous stones. Various depths were used ranging from 5 to 20 feet, depending upon soil conditions. Ten open type piezometers were place at the toes of fills which were in swamp areas and were placed at depths ranging from 10 to 20 feet below original ground.

In the marsh areas and in the vicinity of Station 200 (which is near a railroad embankment) there was a question of stability. To indicate either disturbance of the railroad embankments or failure of the highway fills, 16 inclinometers were placed at varying intervals near the toes of the fills.

Heave lines were placed in a manner to indicate both horizontal and vertical movement of the railroad embankments. Hubs were placed on the highway fills at various other locations for the purpose of determining settlements.

Location of the settlement platforms, piezometers, inclinometers and heave lines can be found on location maps in the appendix of this report.

A total of 31 auger borings were made by the Materials and Research Department during construction, using District equipment and personnel. The purpose of the test holes was to determine displacement of the soft underlying material after the fills were up to subgrade level.

CONSTRUCTION

Several locations were instrumented and monitored. Details of each site are discussed in the following pages.

Station 118 - 121

A 3-foot working table was placed by end dumping fill material. A 1-foot per week controlled rate of loading prevailed up to the last five feet of fill which was the overload material. The last five feet of fill were placed at the rate of 2-1/2 feet per week. Completed fill height was 12 feet including the 5-foot overload. A waiting period of one year allowed for consolidation. Strutting on the extremities of the fill facilitated proper drainage. Installed in this section were three settlement platforms, six piezometers and three heave lines.

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the ultimate centerline out past the limits of the east frontage road, (Photo #7). This work was done by Change Order. The area near Station 319 was stripped to a depth of eight feet by means of a drag-line. The depth of stripping gradually became less as firmer material was encountered until, at Station 327, stripping ceased. As stripping progressed, the area behind was immediately backfilled and grade was brought up to match that of the fill to the west of ultimate centerline.

Five settlement platforms, five piezometers, four inclinometers and two heave lines were installed in this area.

Fill to a height of fifteen feet above original ground, including a 5-foot overload, was placed on the main line and a fill of 5 feet with no overload was placed on the east frontage road.

Station 341 - 343

Fill was to be placed at a controlled rate of one foot in seven days after a 3-foot working table was established. The fill was constructed in this manner except for the last three feet of overload which was placed in one lift. Borings were made in this area when the fill was to sub-grade. The findings indicated that little or no soft material was in evidence under the fill. Fill height in this area is 10 feet with a 5-foot overload.

Instrumentation in this area consisted of two settlement platforms, five piezometers, two inclinometers and one heave line.

Ibis Overcrossing

The Ibis Overcrossing east frontage road, Station 367 - 377, was to be constructed with the fill to be placed at a rate not to exceed one foot in seven days.

The contractor was disturbed due to the softness of the ground in this area, and was concerned with the possibility of losing his equipment. Therefore, he placed a two to three-foot working table on his first pass over this area. No adverse effects resulted from this initial rapid loading. A fill 5 feet high with no overload was placed on this frontage road.

Instrumentation in this area consisted of seven settlement platforms, four piezometers, and one heave line.

Station 390 - 405

This area was designed for mud displacement but no movement could be obtained due to a heavy mat of fibrous roots and peat. A test section was set up at Station 402 to 405 on the proposed ultimate centerline to see if blasting with dynamite could condition the mud for movement. A 6-foot fill existed up to the centerline at this point along the test site.

Holes were placed at 25-foot intervals and at a depth of 10 feet. Approximately 20 pounds of blasting powder were placed in each test hole. The blast left craters with a depth of 5 feet and 10 feet in diameter. The craters indicated a 4-foot dry fibrous mat of roots and peat. The fibrous mat was too heavily entwined and deep to allow the mud to surface and it was decided that the mat could carry the load. For that reason no immediate loading was applied to the fill next to the test site.

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On the east frontage road, from Station 310 to 324, the settlement is almost complete and the remainder of the settlements will occur at a very slow rate.

At Station 343 to 345 a settlement of 0.2 feet has occurred and any future settlement will be very minor.

Instruments in the area of the Ibis Overcrossing on the east frontage road have indicated a settlement of nearly 0.2 feet and show that a small amount of settlement will continue to occur in the future.

A settlement of one foot has occurred at Station 395 to 401. The settlement plots for this area show a curve which indicates that the settlement is still continuing at a steady rate. These plots indicate that from 60% to 90% consolidation had occurred as of June 1966.

The North Bridge Approach in the Benicia Arsenal has a settlement of 0.3 feet. No settlement has occurred in the last 6 months. Estimated settlement for this fill was 0.5 feet.

Plots of the settlement platform readings are found in the appendix of this report.

INCLINOMETERS AND HEAVE STAKES

Unfortunately, the areas in which inclinometers were installed became inundated with water in the winter months and the reading of these installations became very difficult. The limited readings taken, however, indicated that very little or no movement had occurred. The only movement of any magnitude was in the area along the east frontage road (between Station 195 to 201) when a mud wave occurred in February of 1965 after a 25-foot wide by 5-foot high strut was built. The readings on a heave stake line (No. 2) indicated a maximum horizontal movement of 19 feet to the right and a maximum vertical movement of 5.5 feet at Station 197 and 198.

Heave lines were placed to monitor the stability of railroad fills which were adjacent to the construction fills at Station 117 to 121 and at Station 195 to 201. No appreciable horizontal or vertical movement occurred at either of the two railroad embankments. The appendix contains plots of the inclinometers and heave stake readings.

EXCESS HYDROSTATIC PRESSURE

At Station 118, in June of 1964, pore pressures of 0.4 tons per square foot were recorded on the centerline after the working table was in place. Pore pressures gradually increased with the loading to a maximum pressure of a little over 0.6 tons per square foot. (In the early part of July a 5-foot overload was placed.) This pressure remained steady up to November 1964 when pressures started falling off. The last reading of 0.1 ton per square foot indicated consolidation is virtually complete. The pressure at the toe maintained one-half the pressure of the centerline all through this period.

No piezometers were placed in the center of the fills in the Station 200 area due to stripping operations. Later borings indicated insufficient underlying soft material to necessitate instrumentation. Unfortunately, the installations at the toe of the fill were flooded and insufficient readings were taken to ascertain hydrostatic pressure.

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APPENDIX

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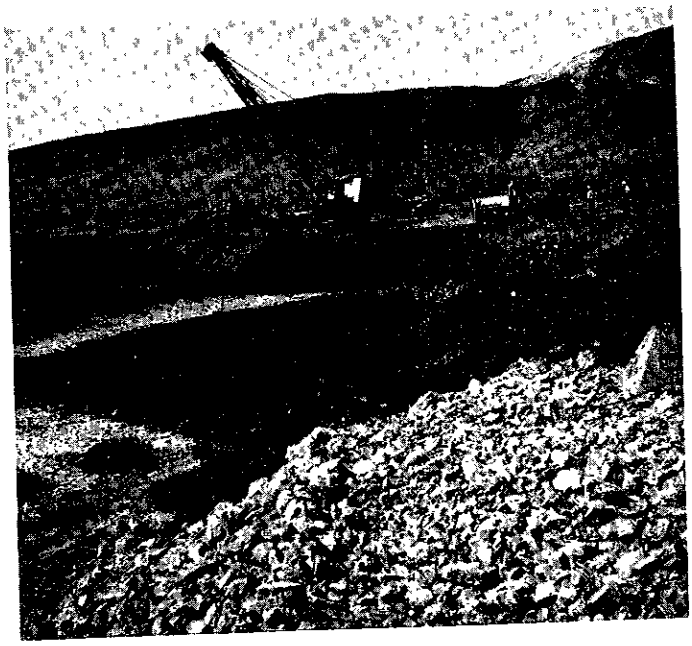
Photo No. A-1



Station 196 7-3-64
Mud Stripping

Photo No. A-2

Station 197 7-21-64
Mud Wave At Toe of Fill

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Photo A-3

Station 194± to 202± 2-11-65
25-foot Strut Constructed Along East Frontage Road

Photo A-4

Station 197 2-15-65
Mud Wave After 25-foot Strut Placed on East Frontage Road

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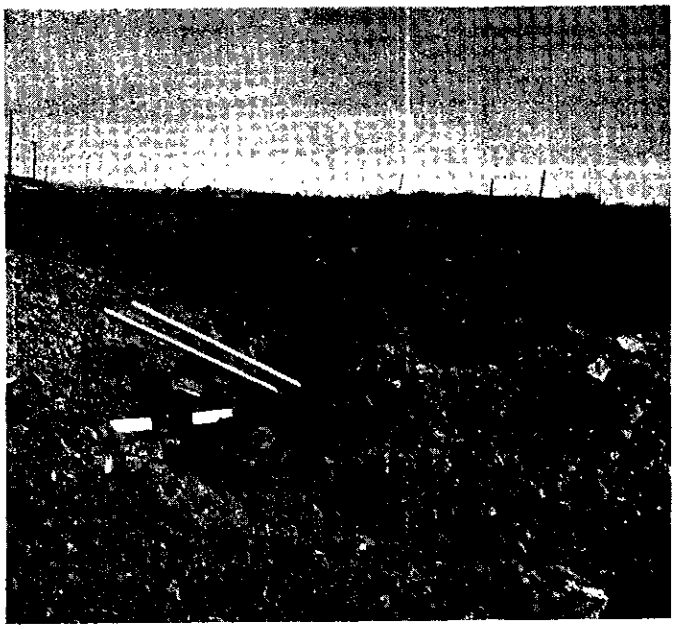
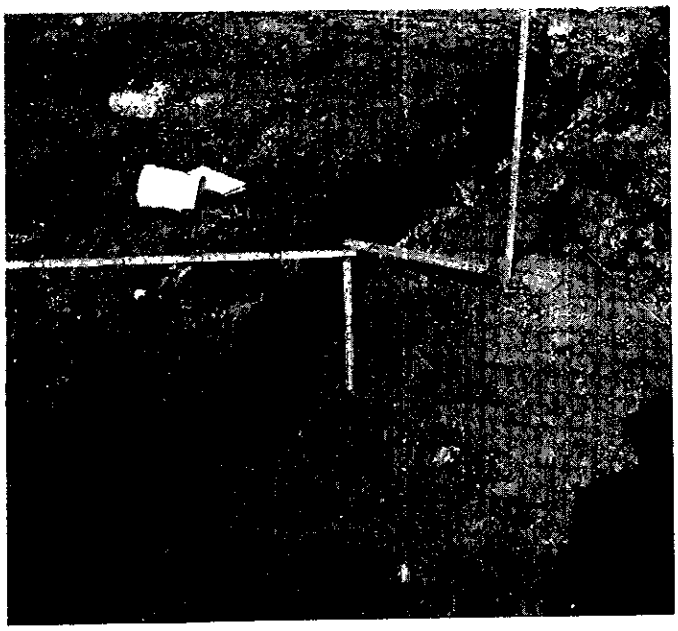
Photo A-5



Station 197 2-15-65

Photo A-6



Station 194+50 2-15-65
East Frontage Road

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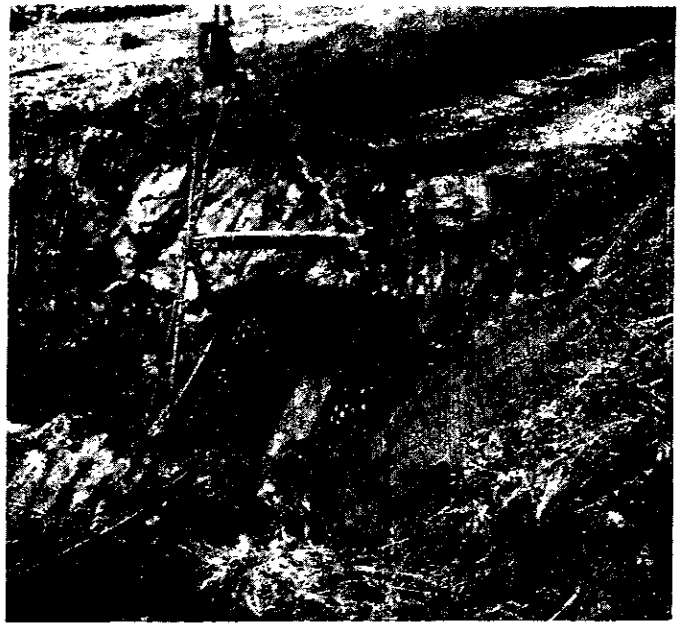
Photo A-7



Station 322 9-18-64

Photo A-8

Station 401 12-3-64

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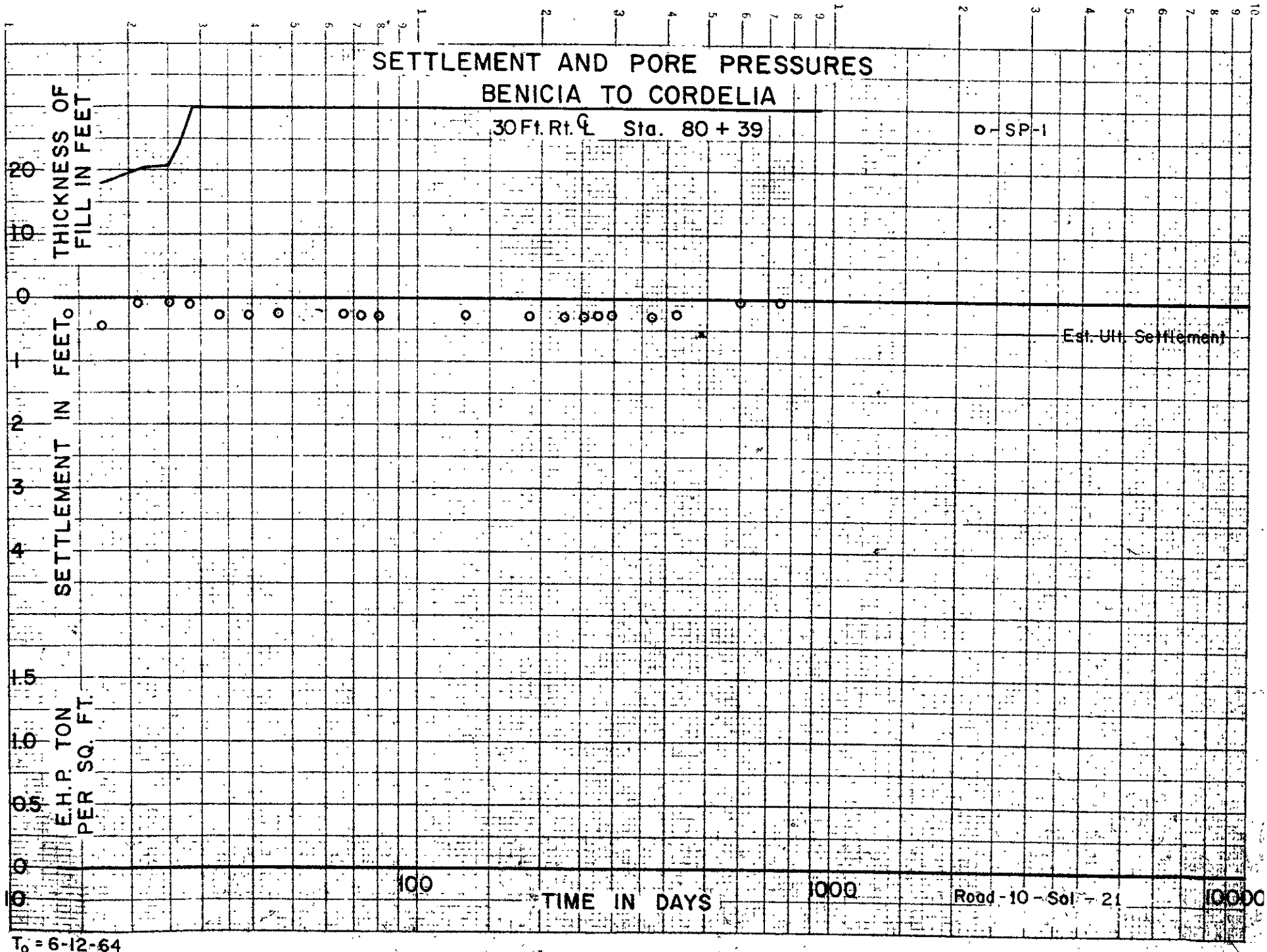

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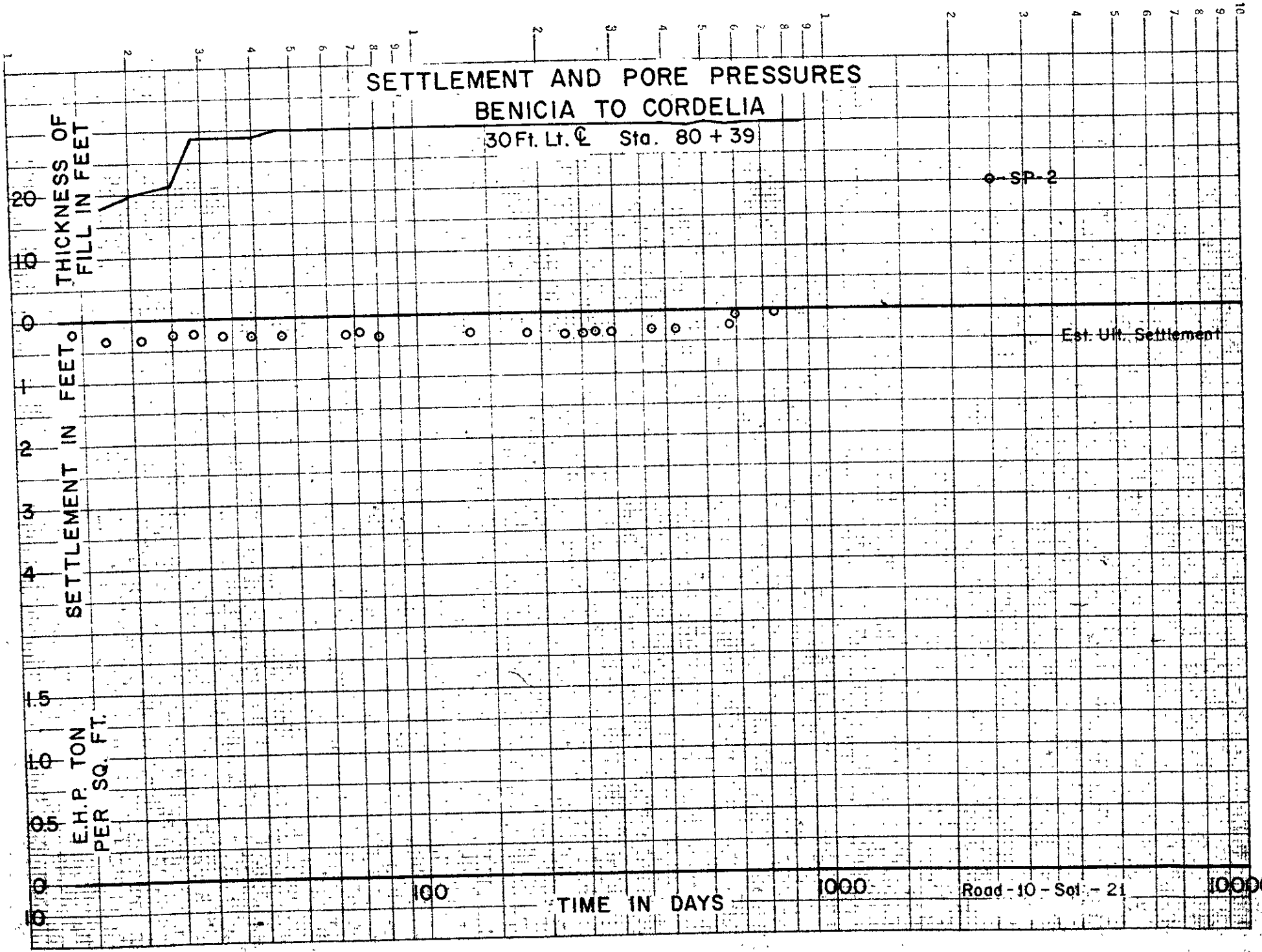

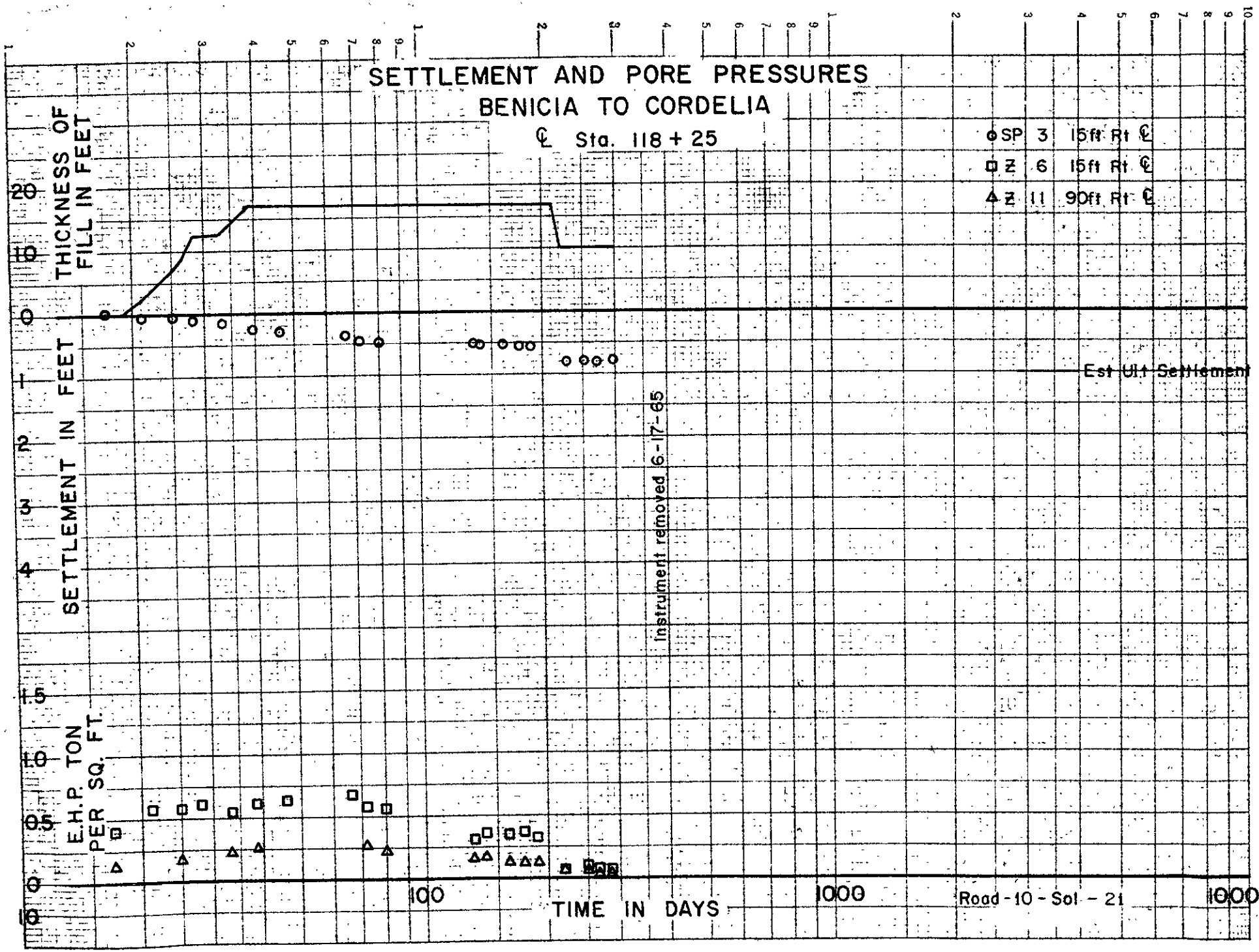

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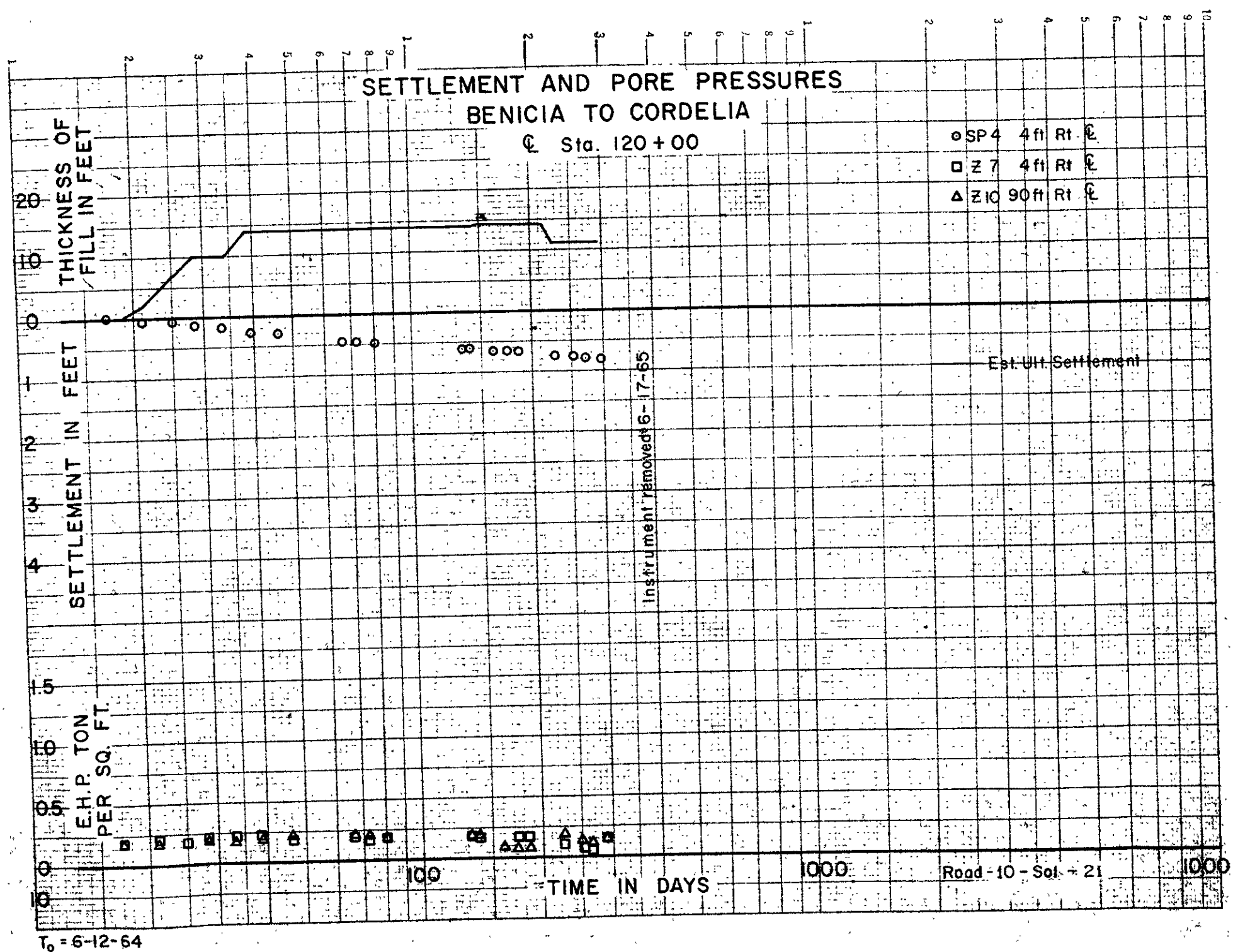

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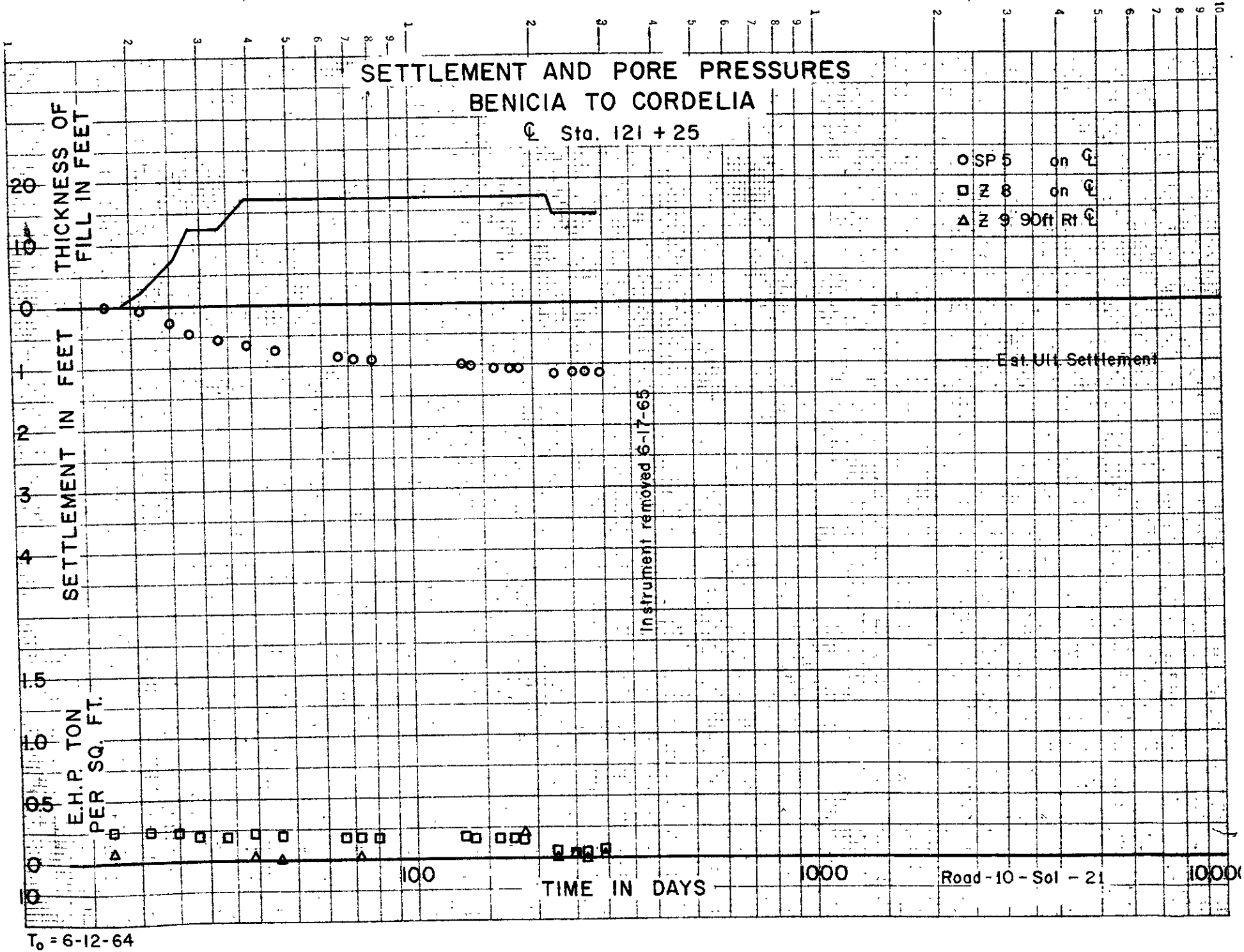

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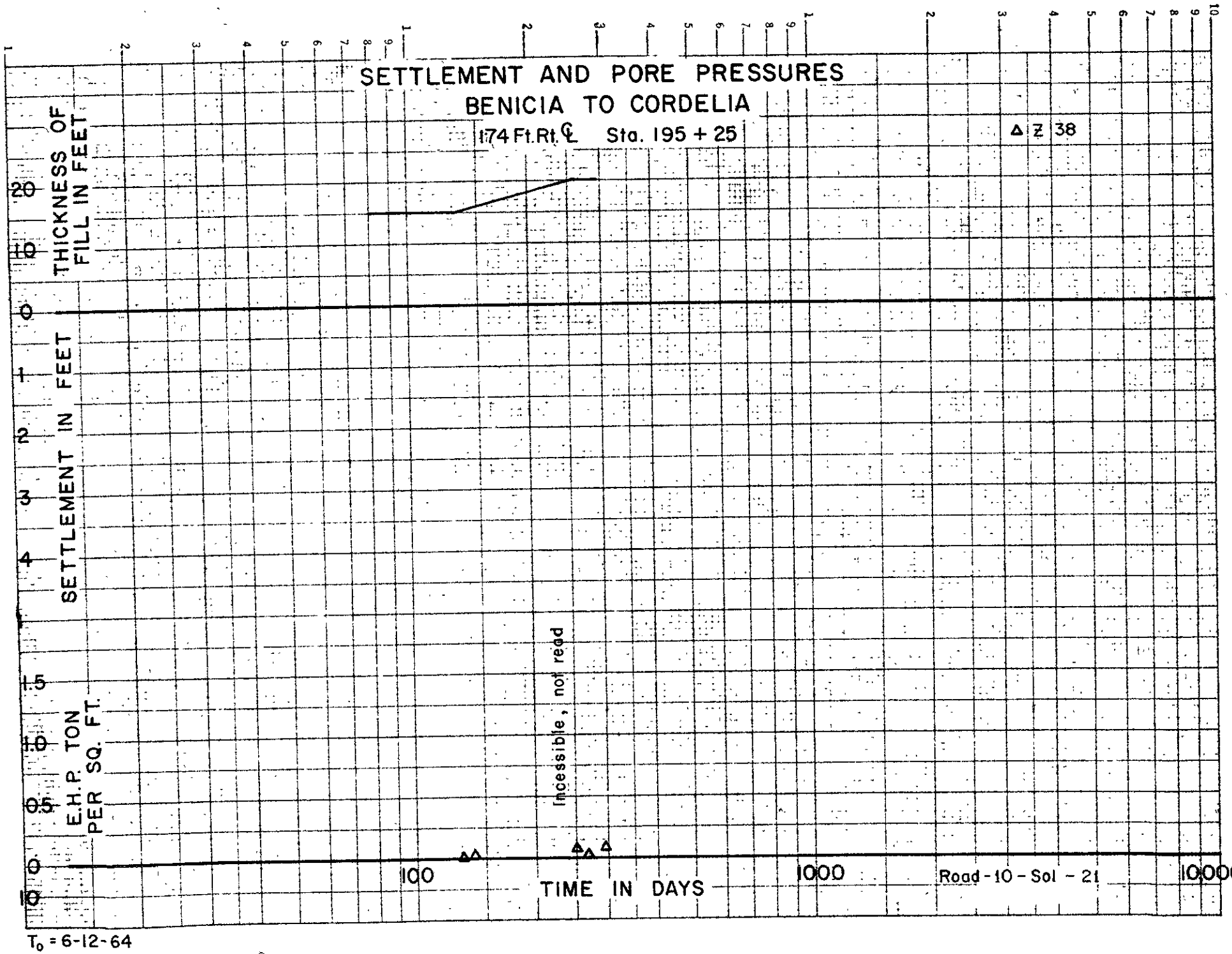

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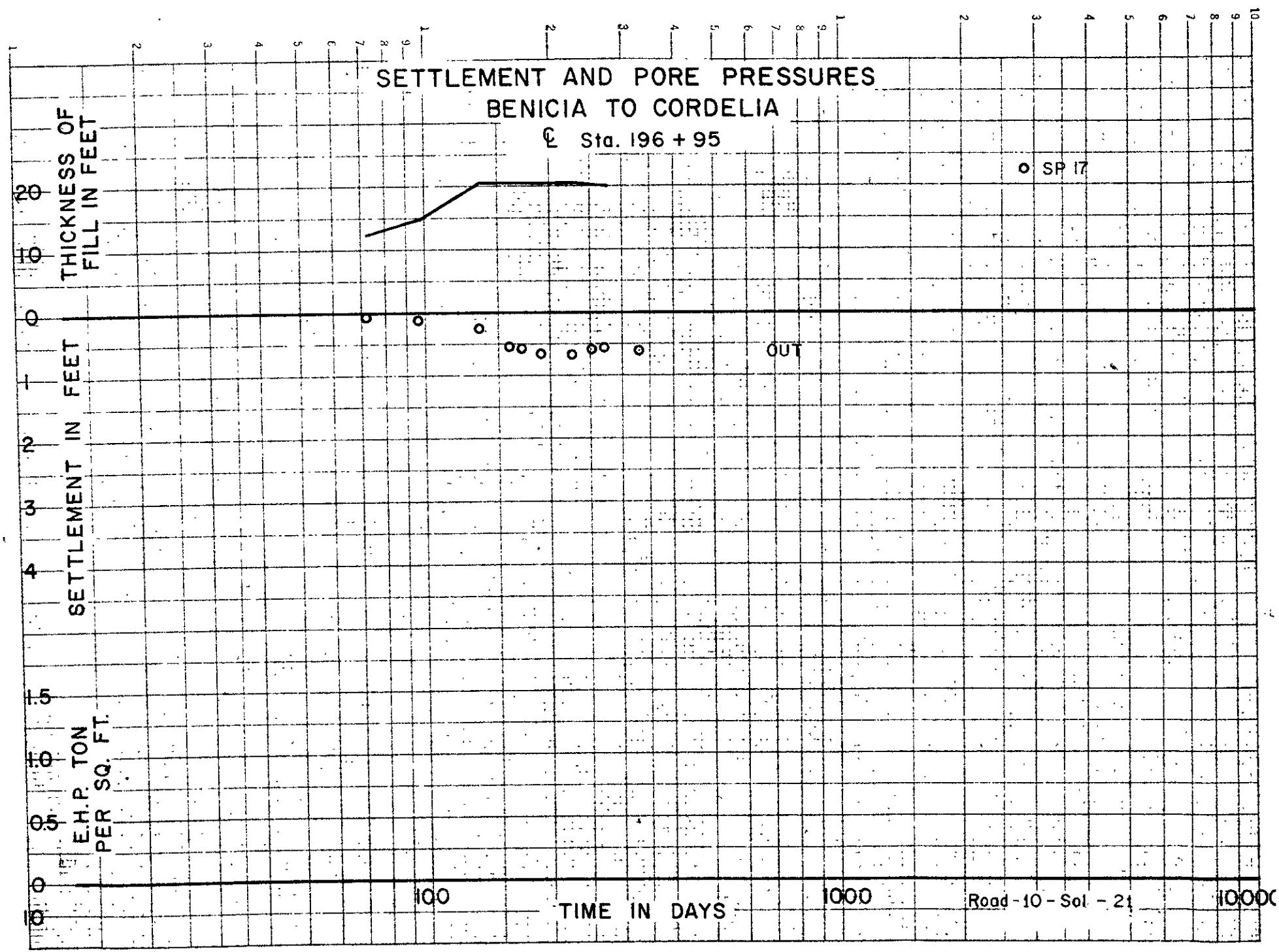

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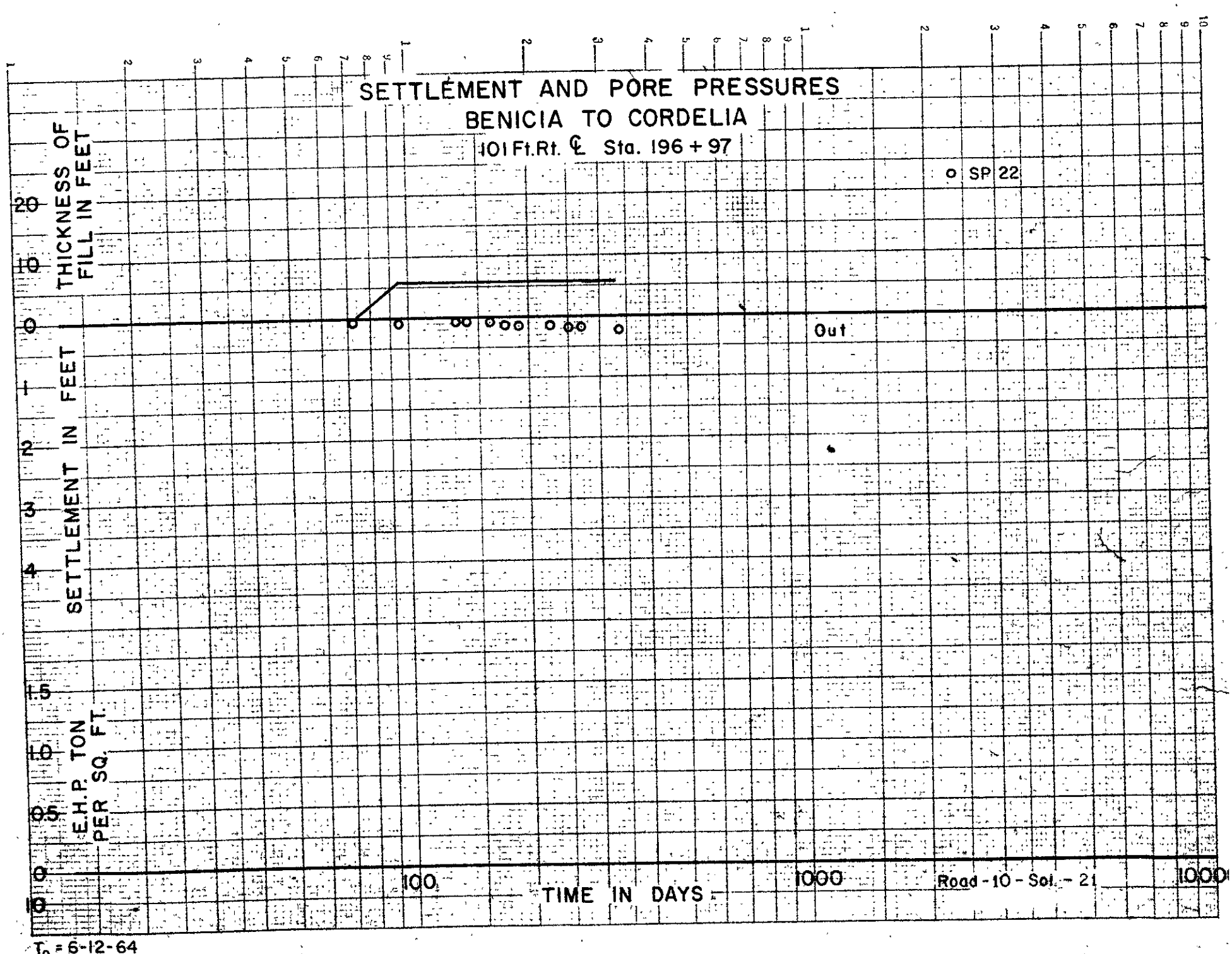

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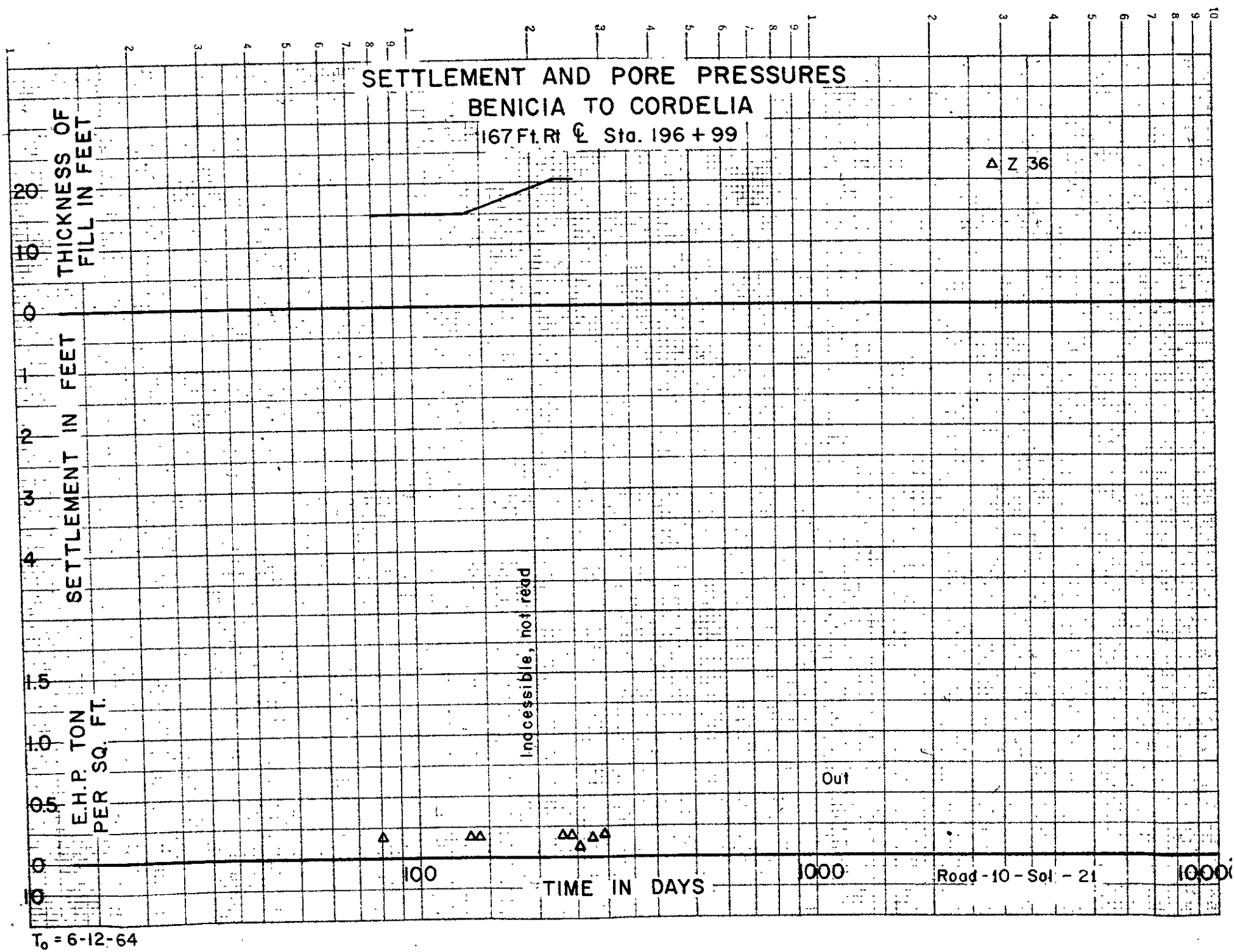

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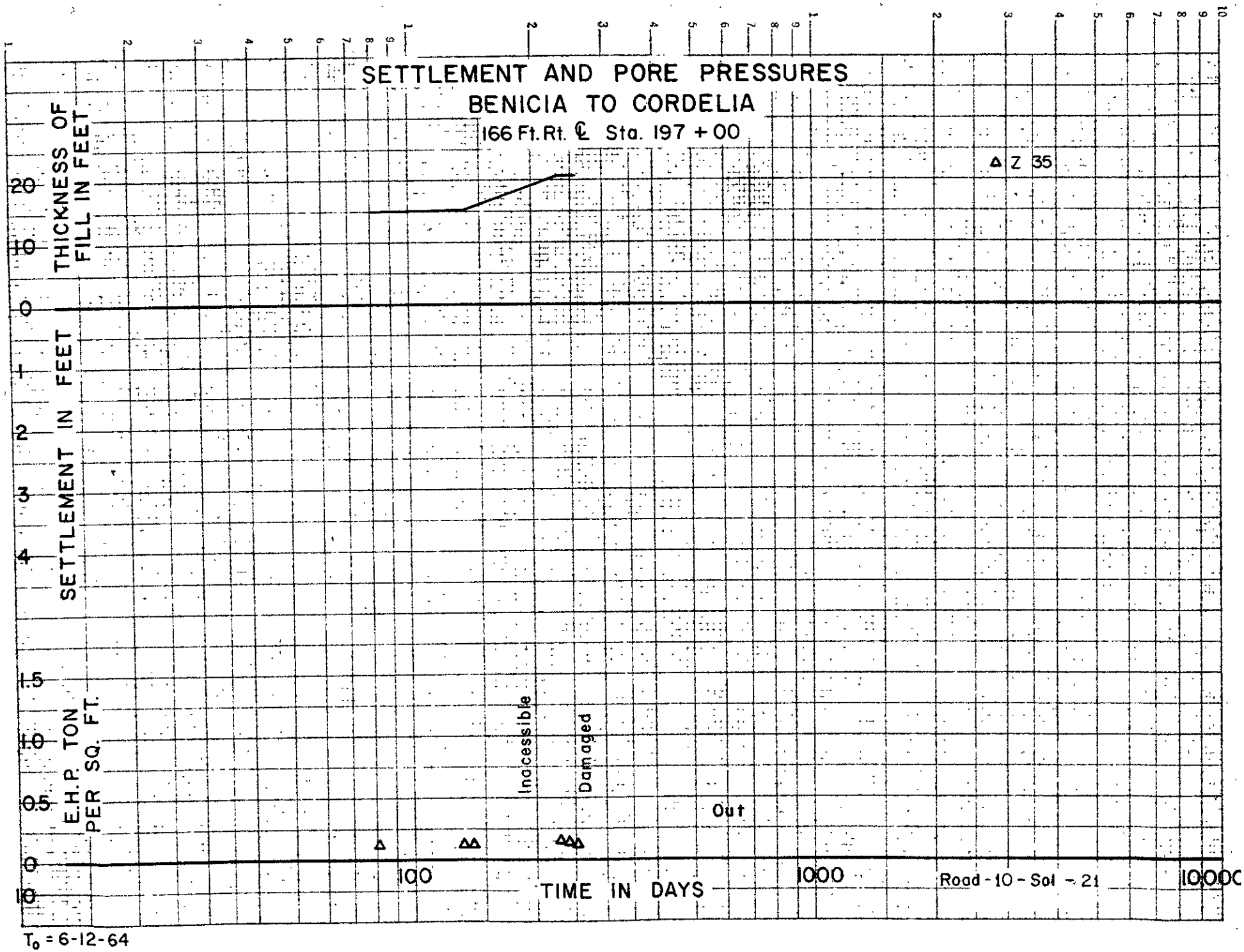

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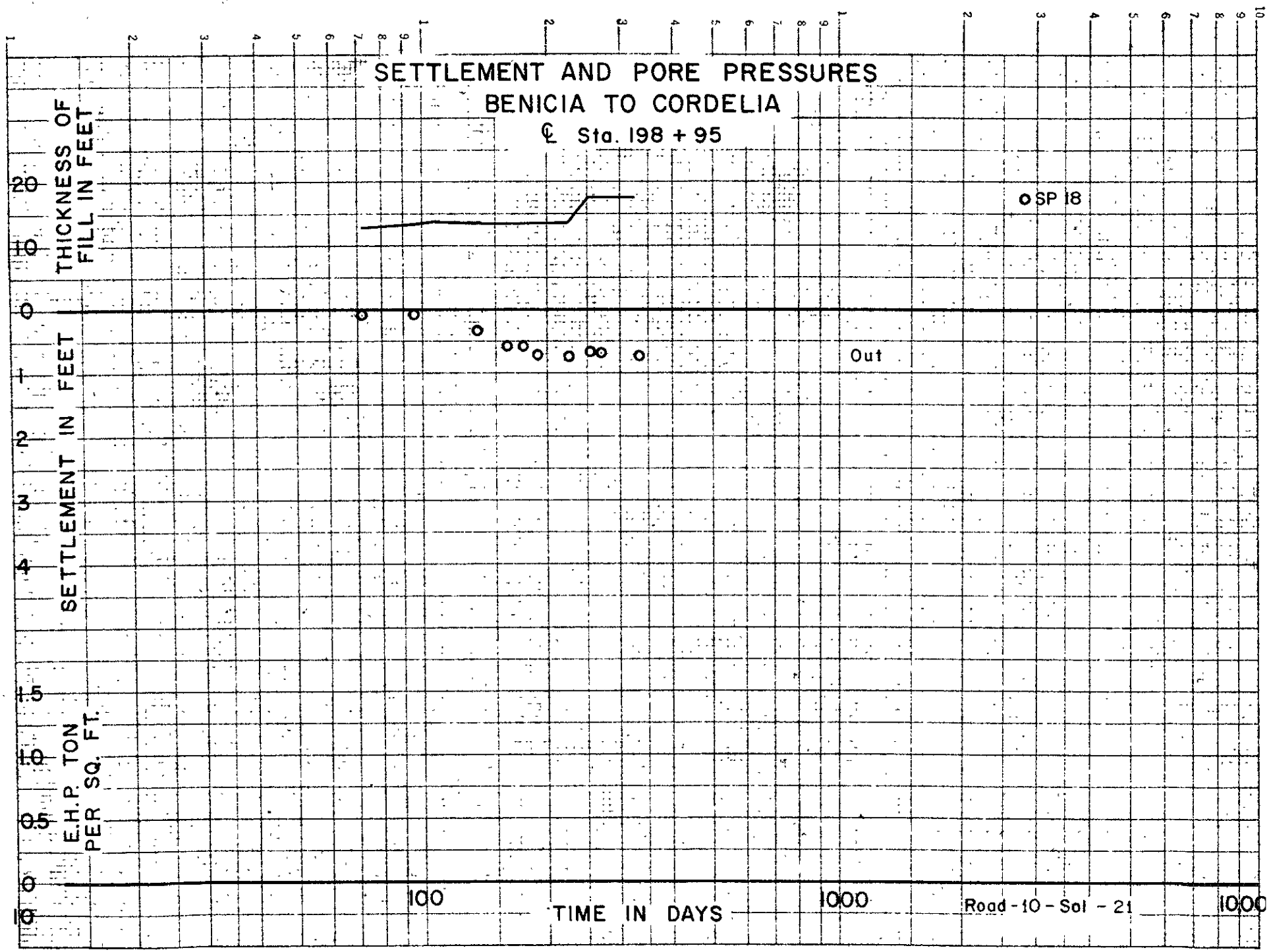

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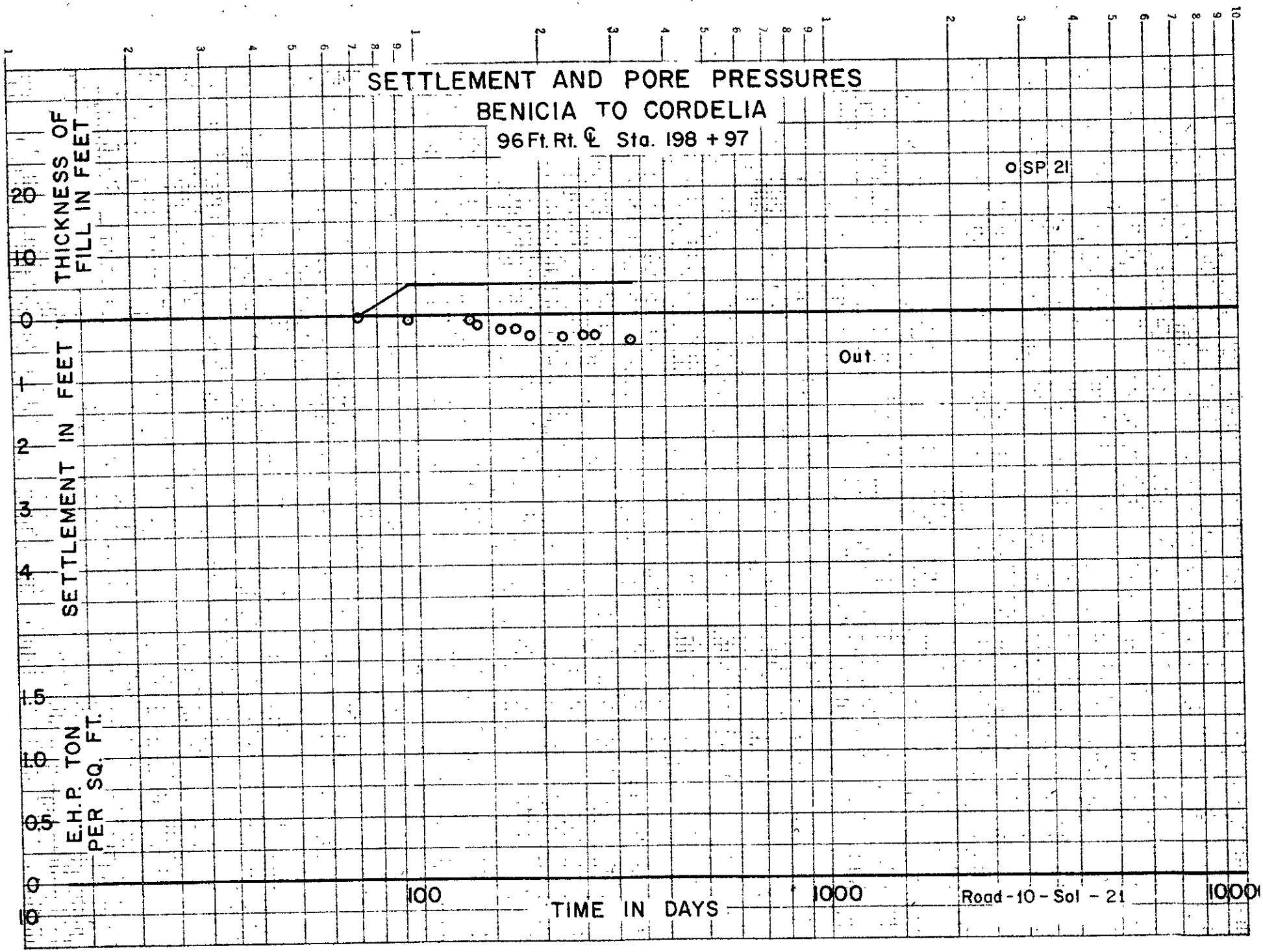

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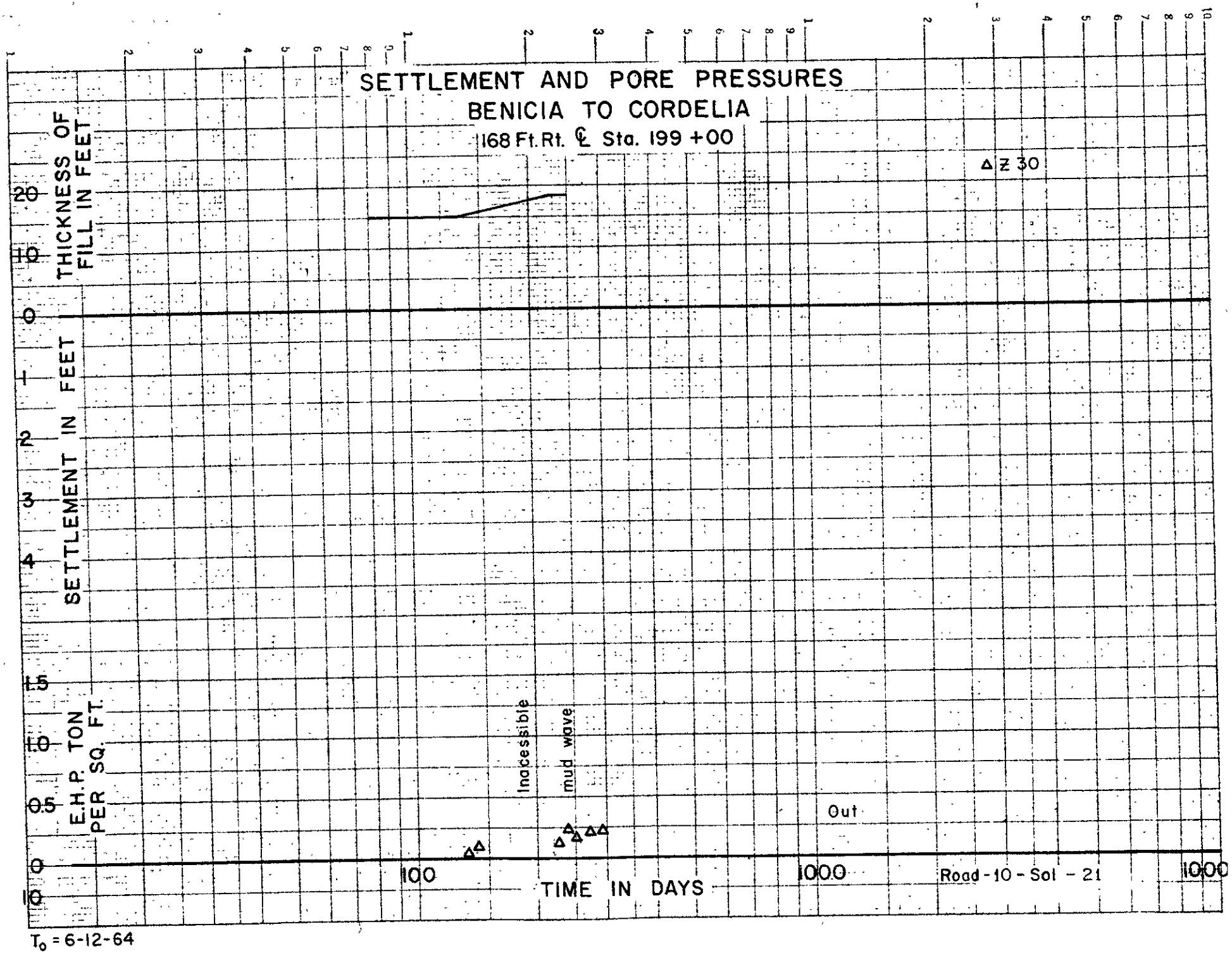

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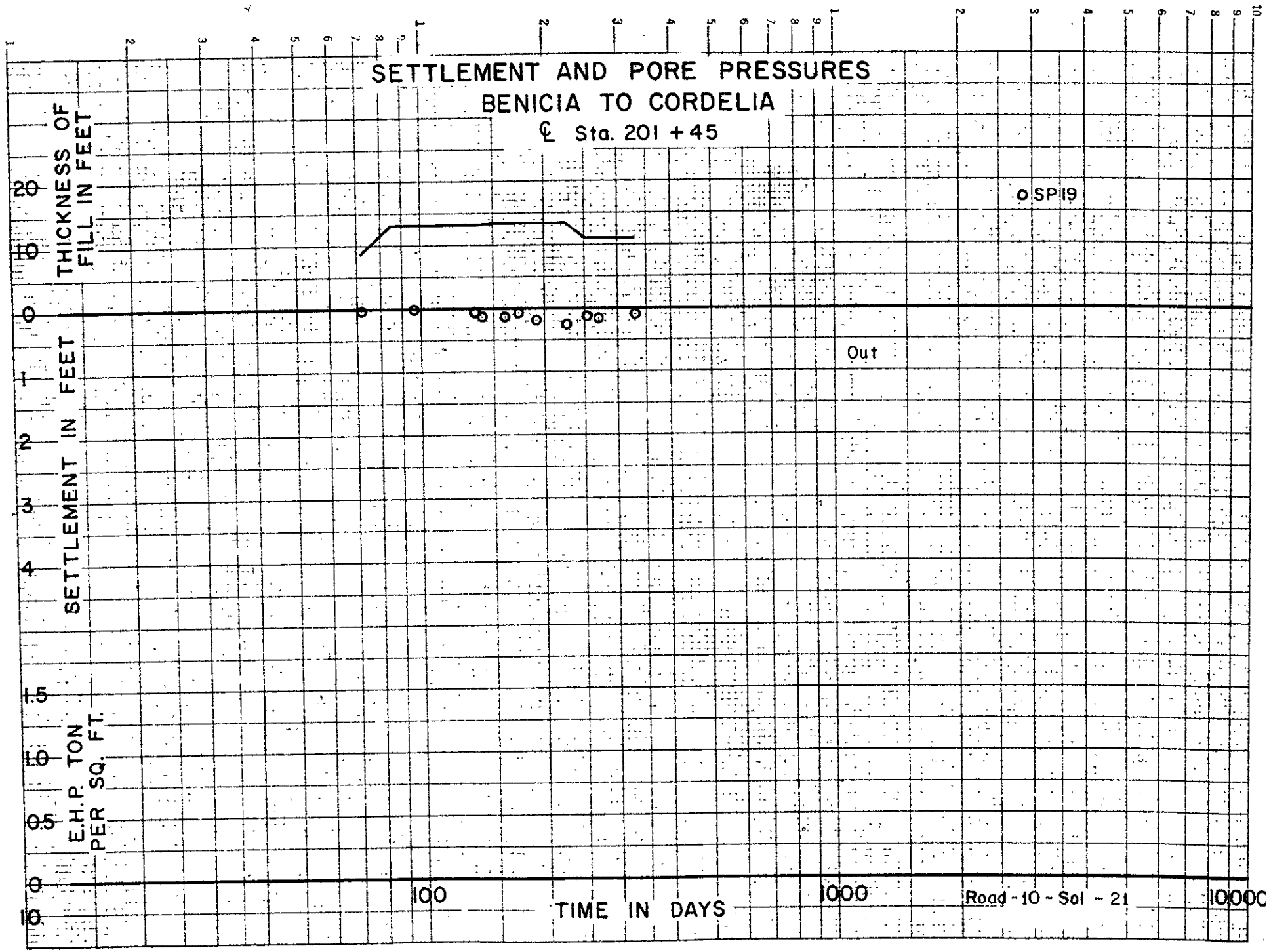

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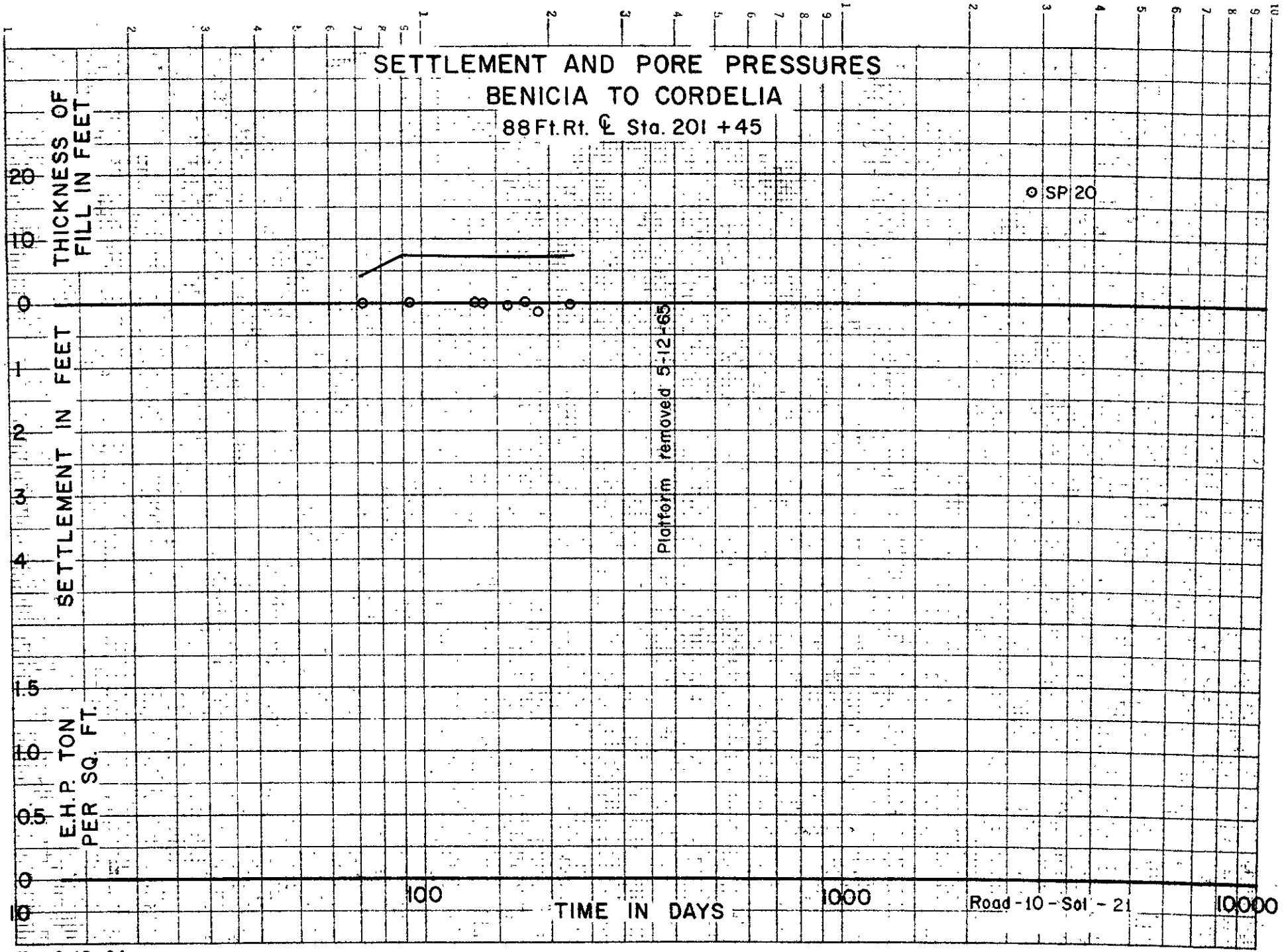

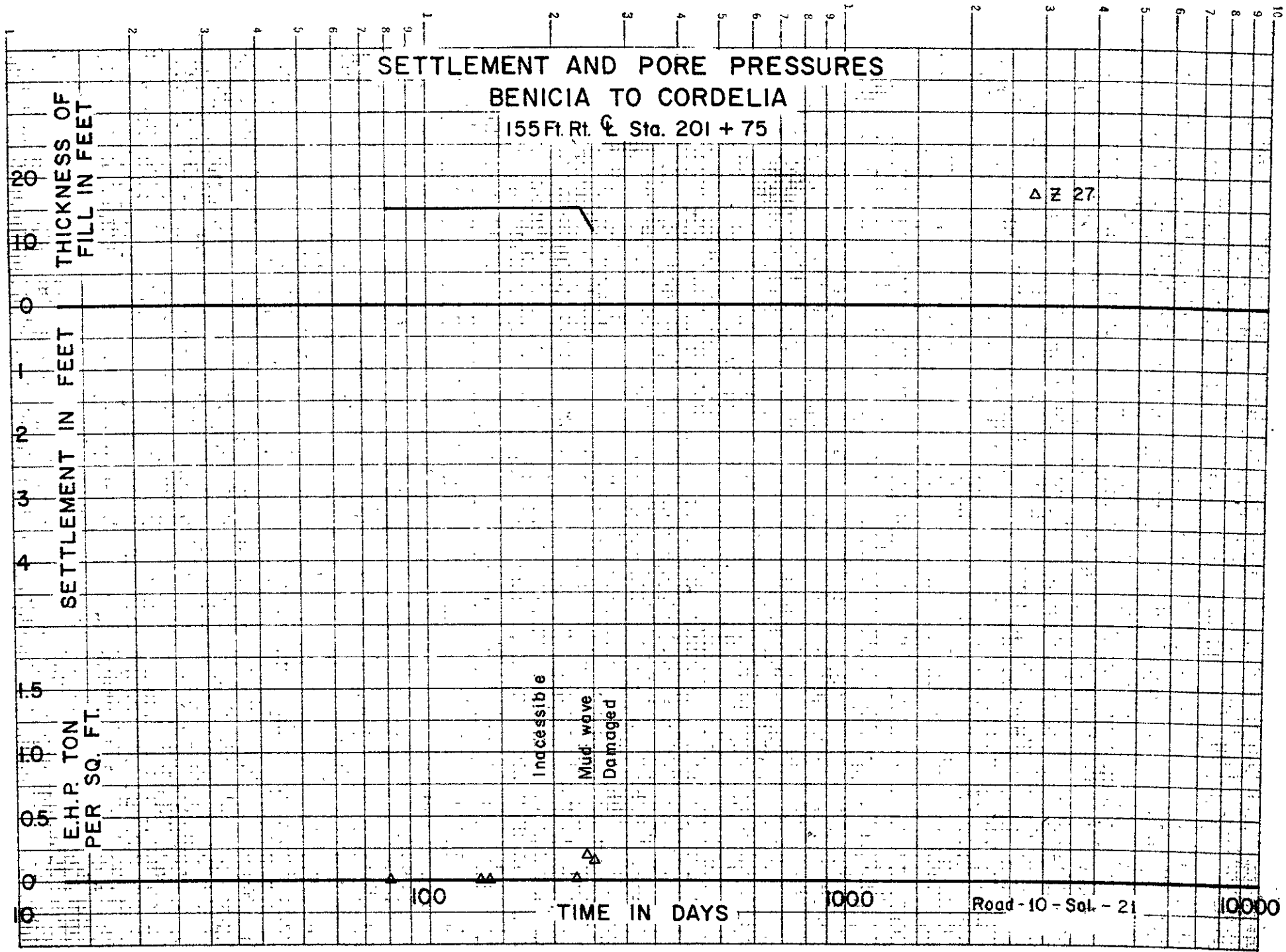

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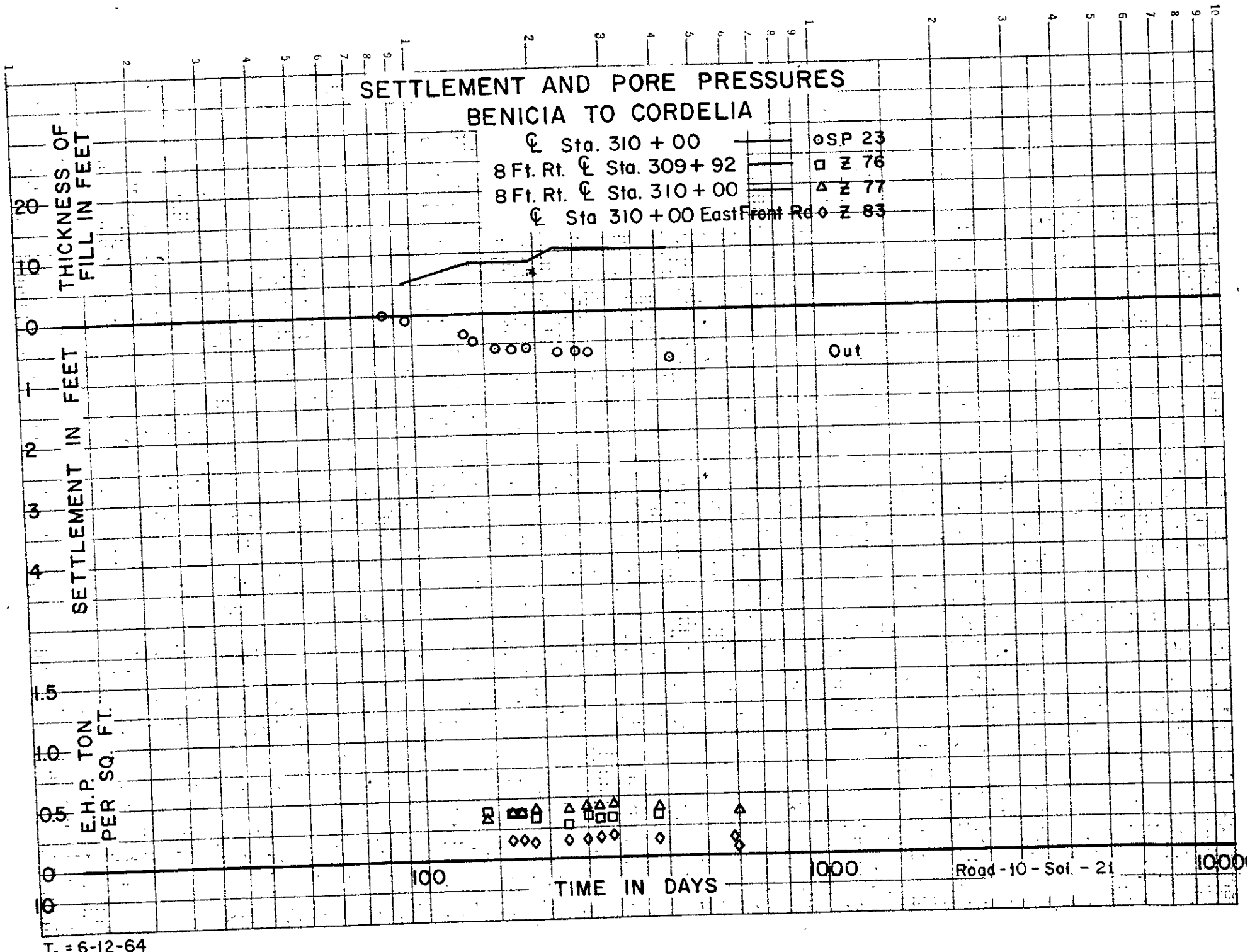

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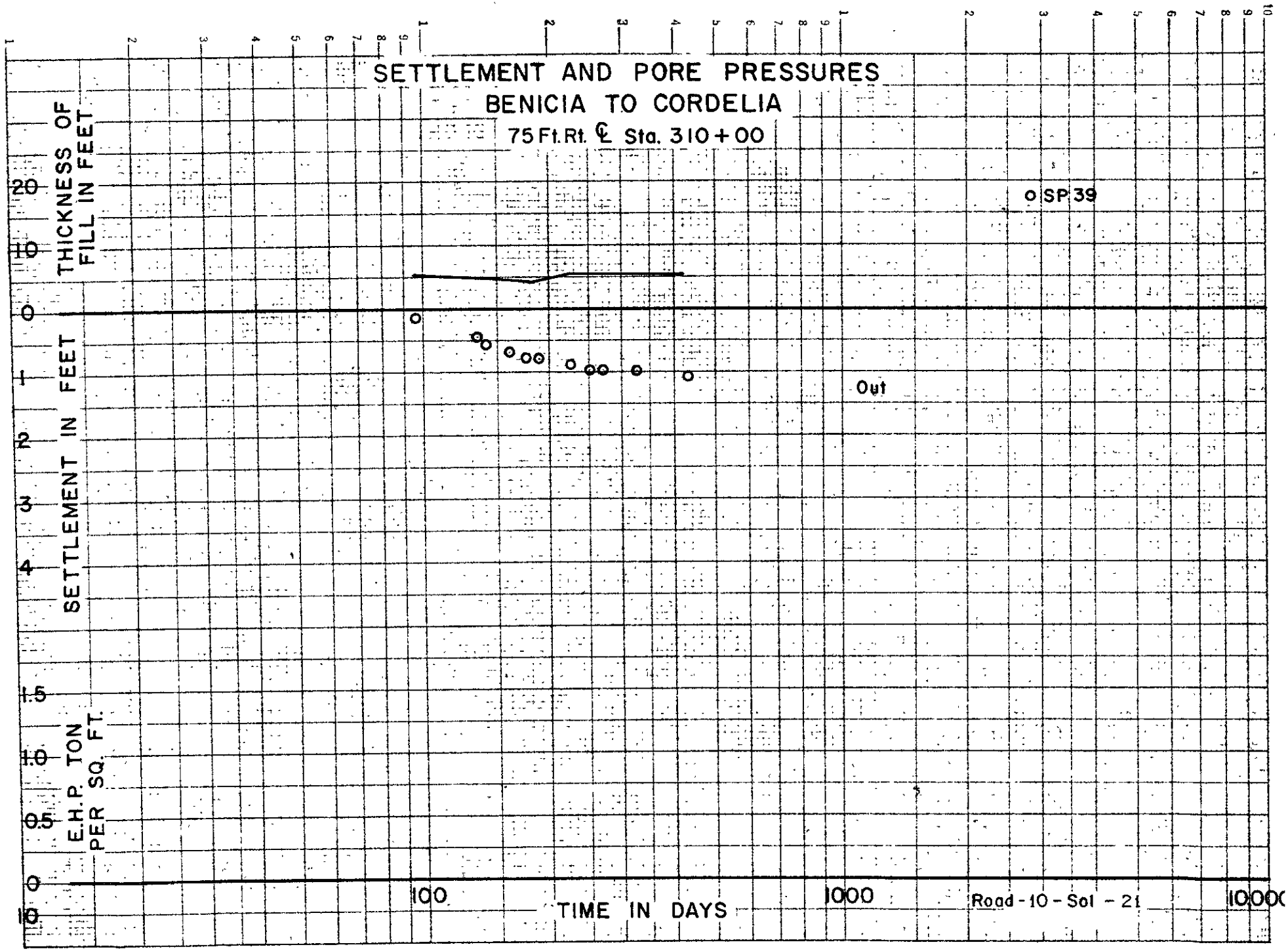

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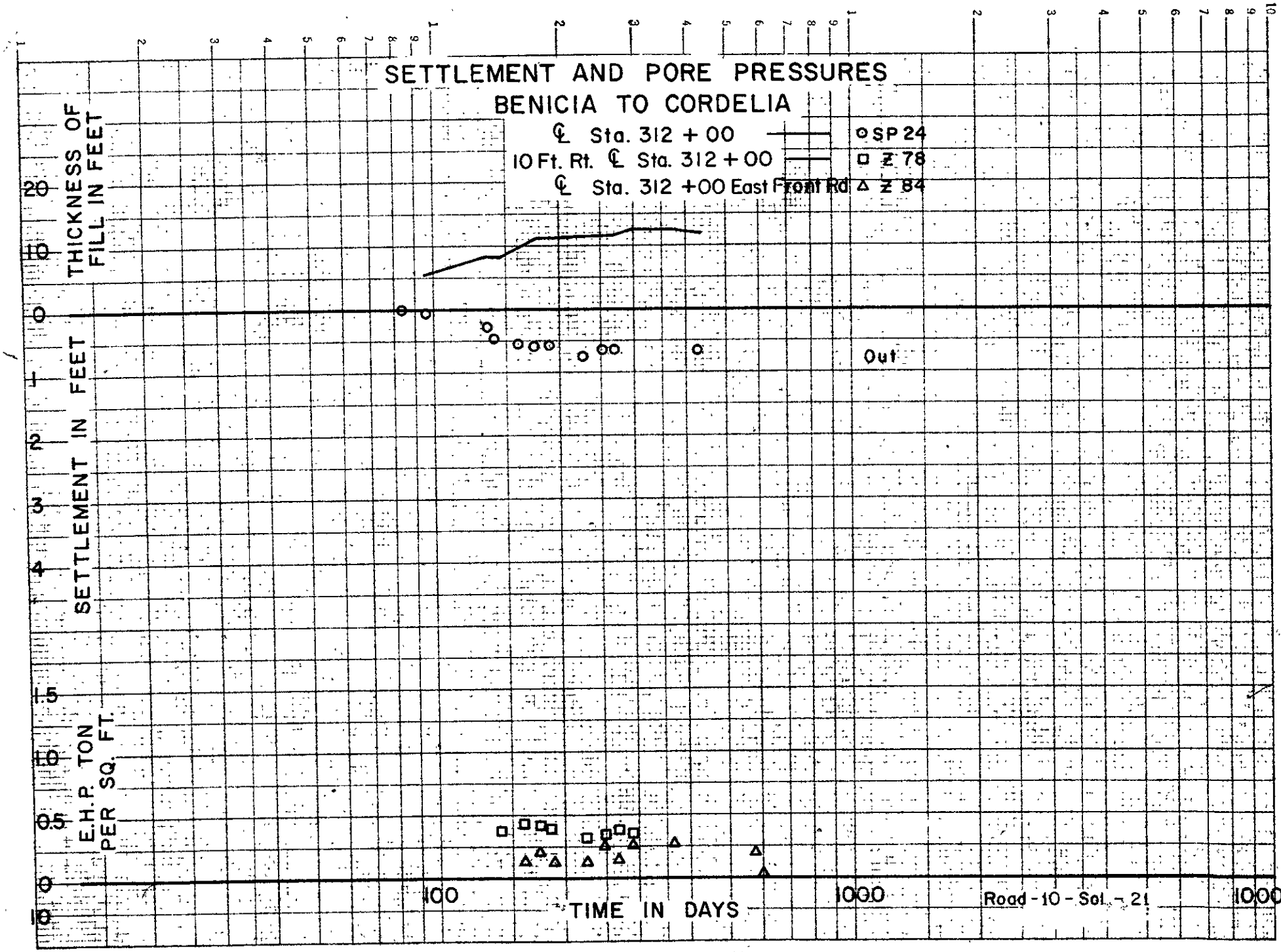

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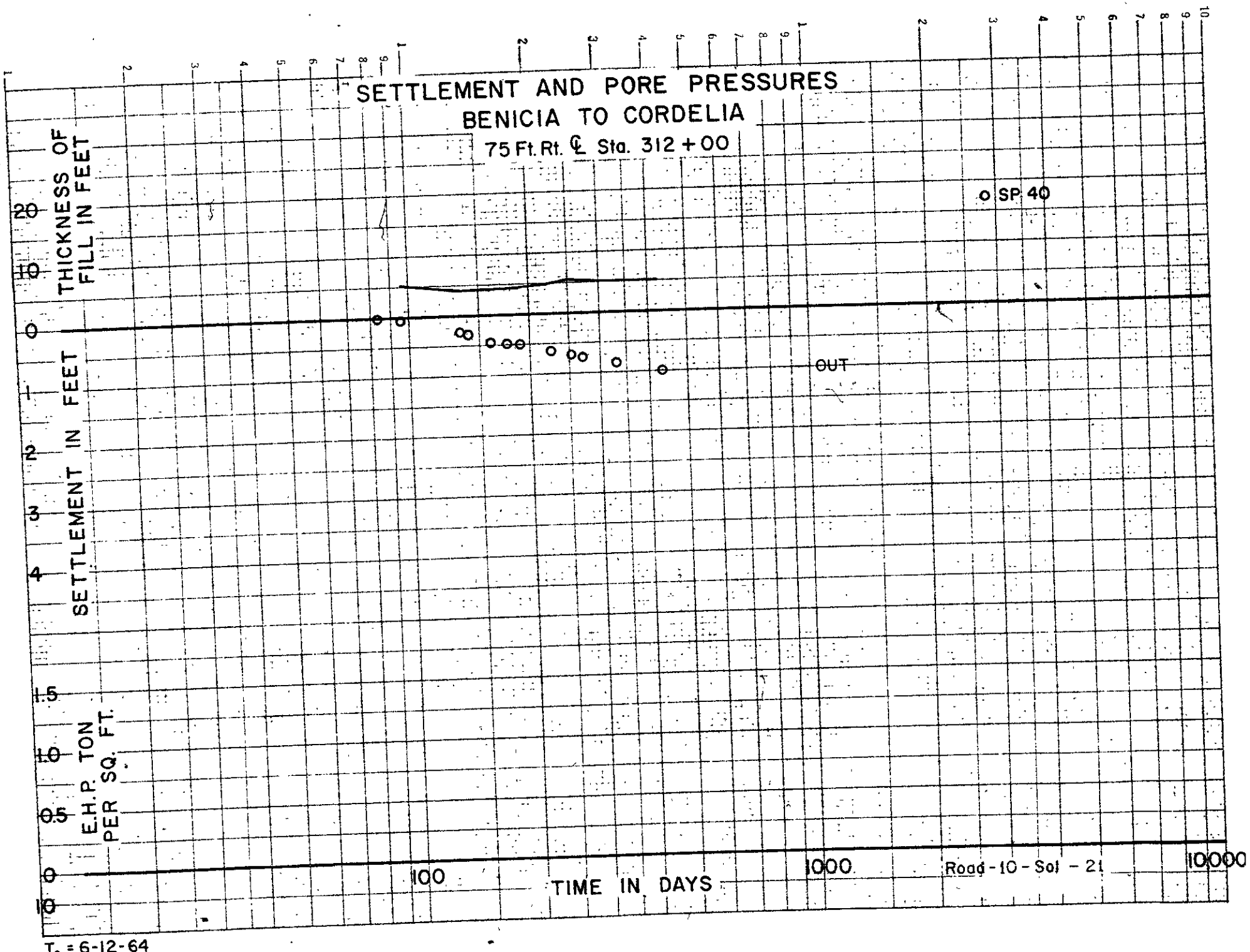

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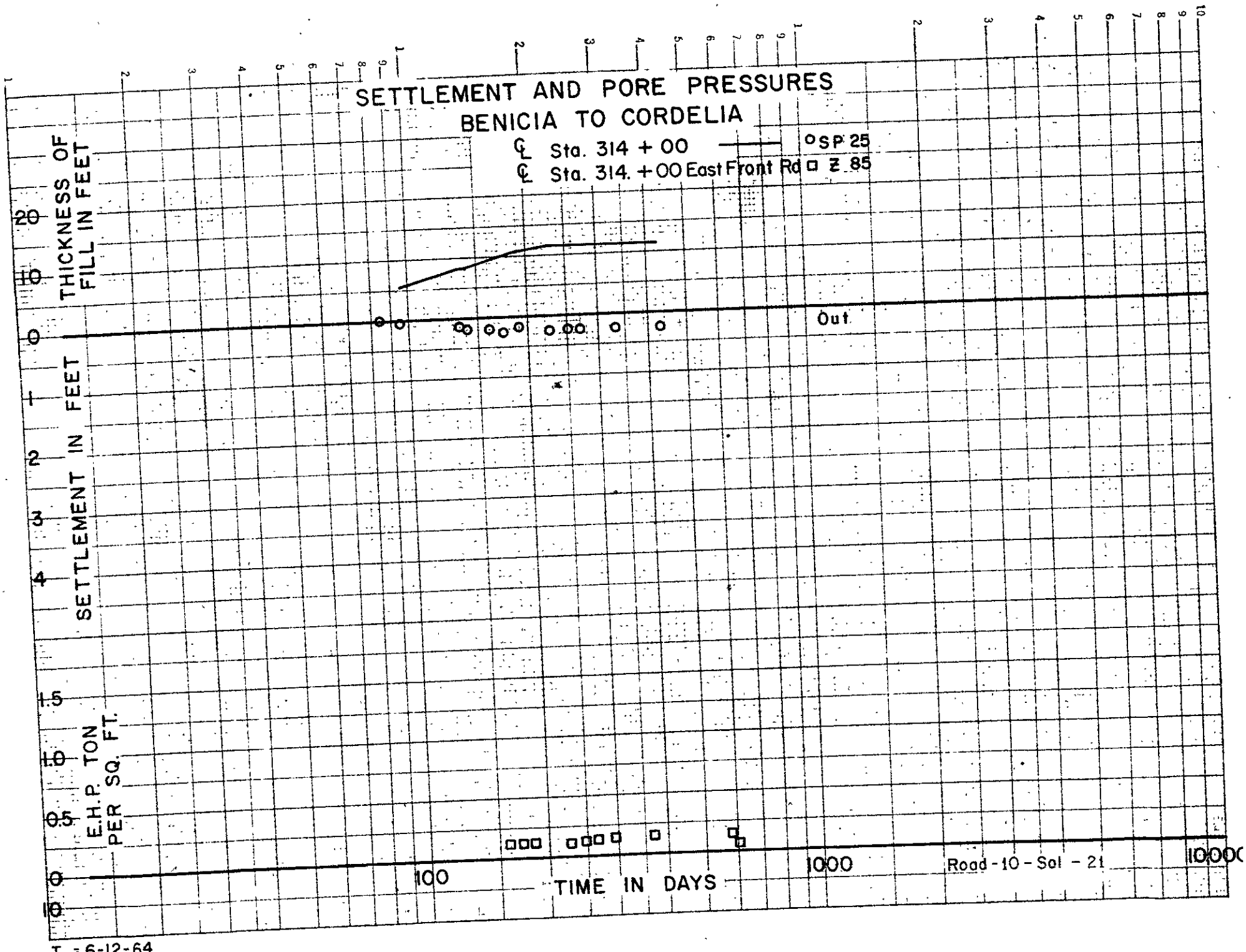

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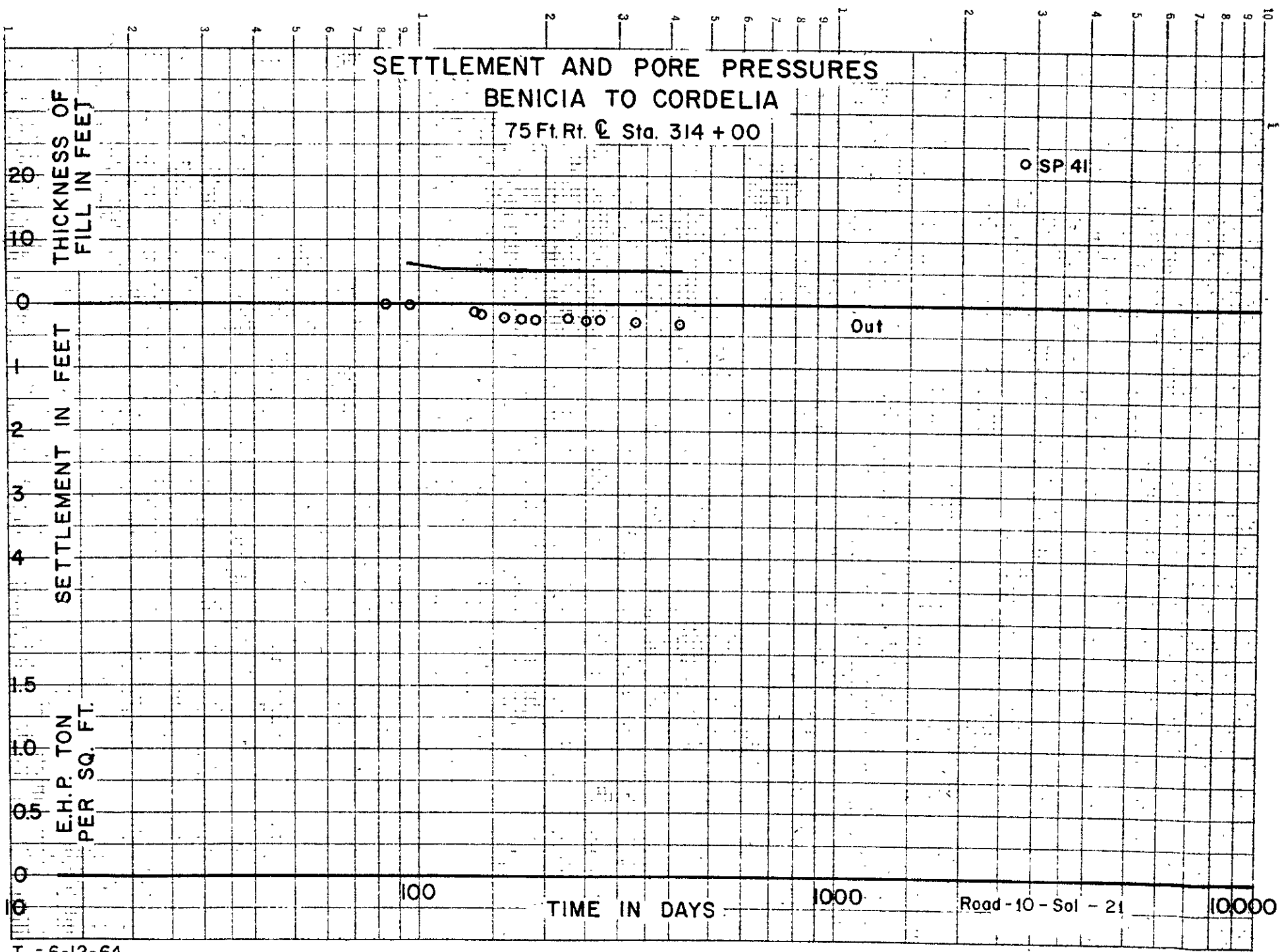

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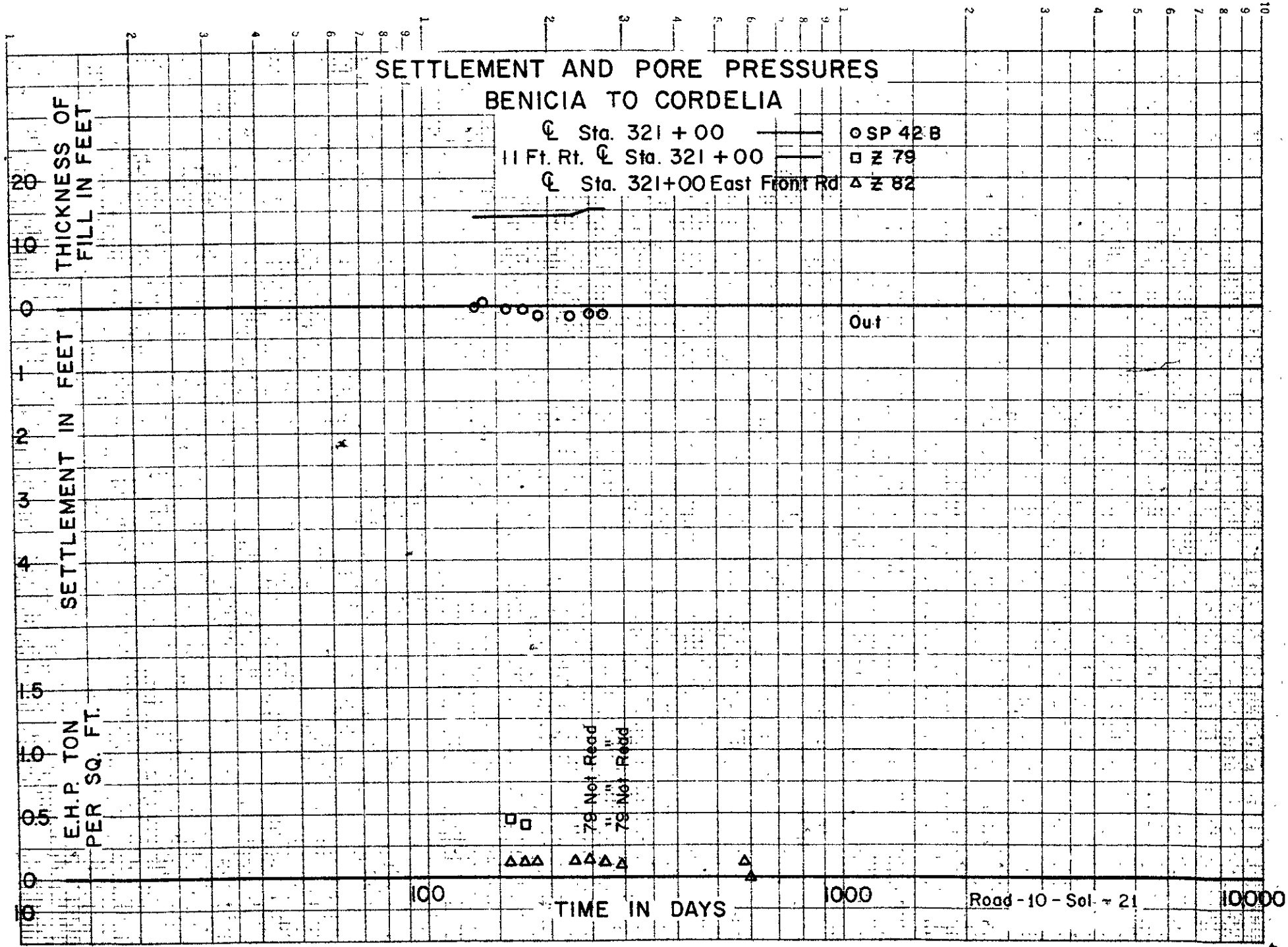

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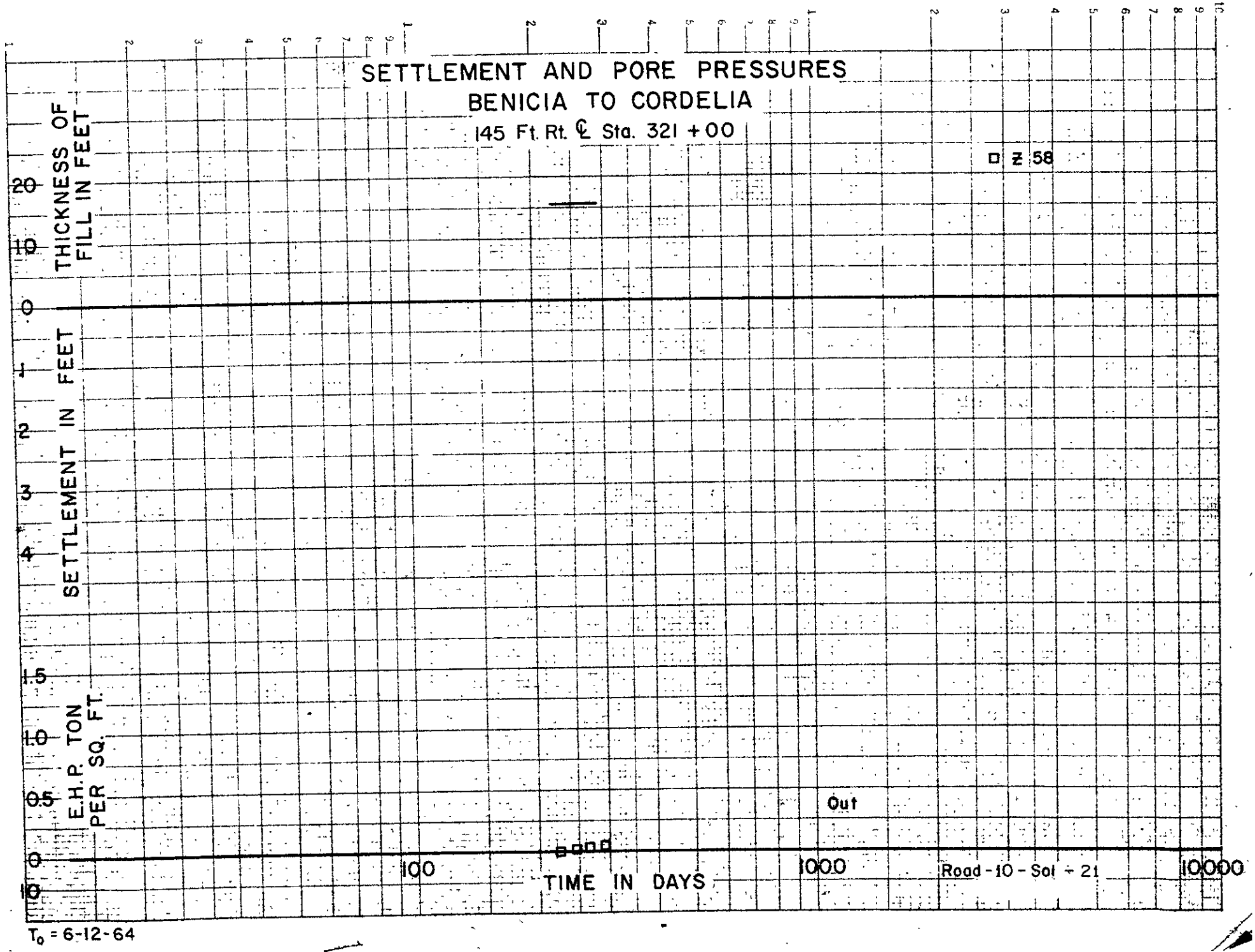

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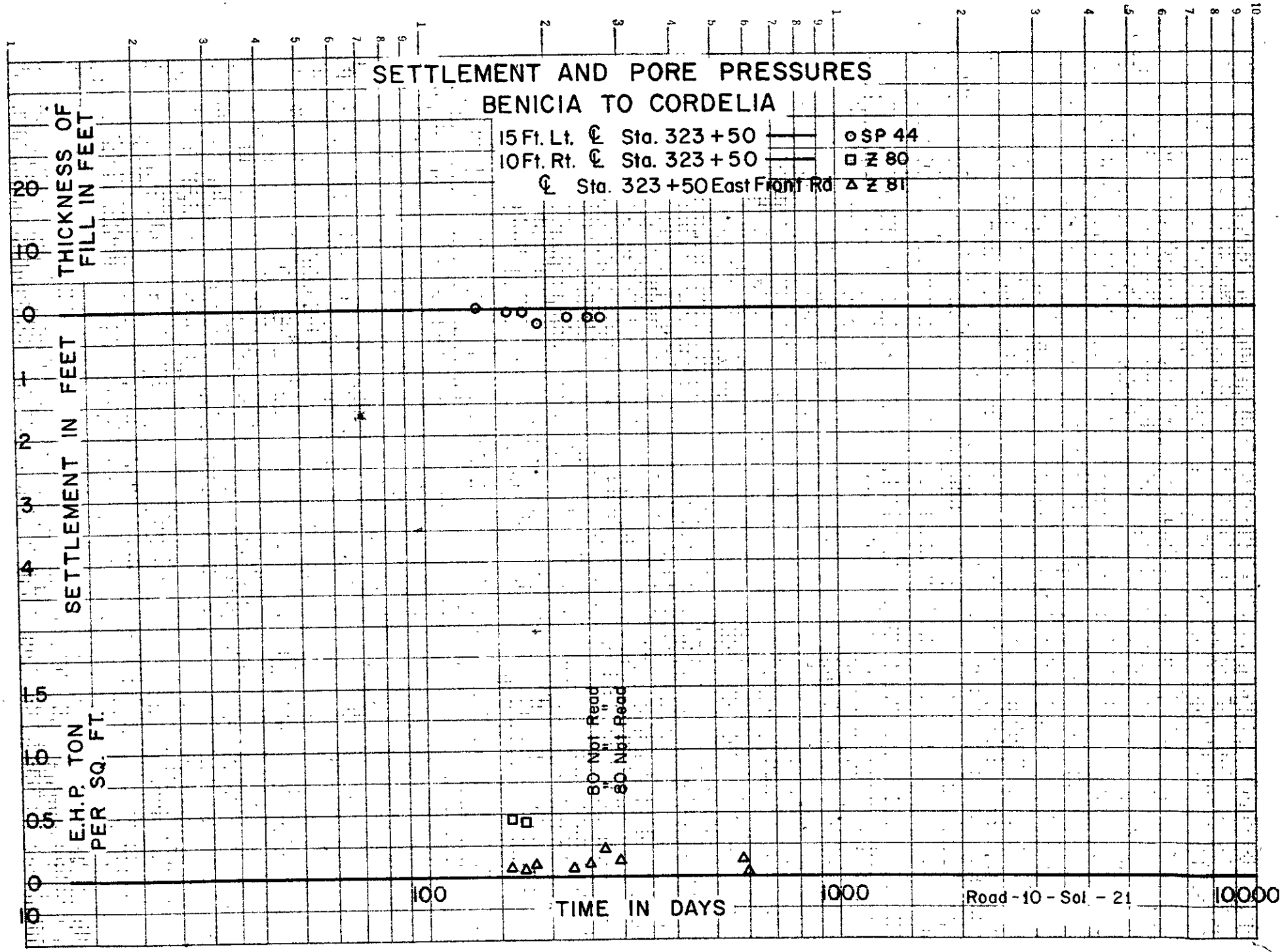

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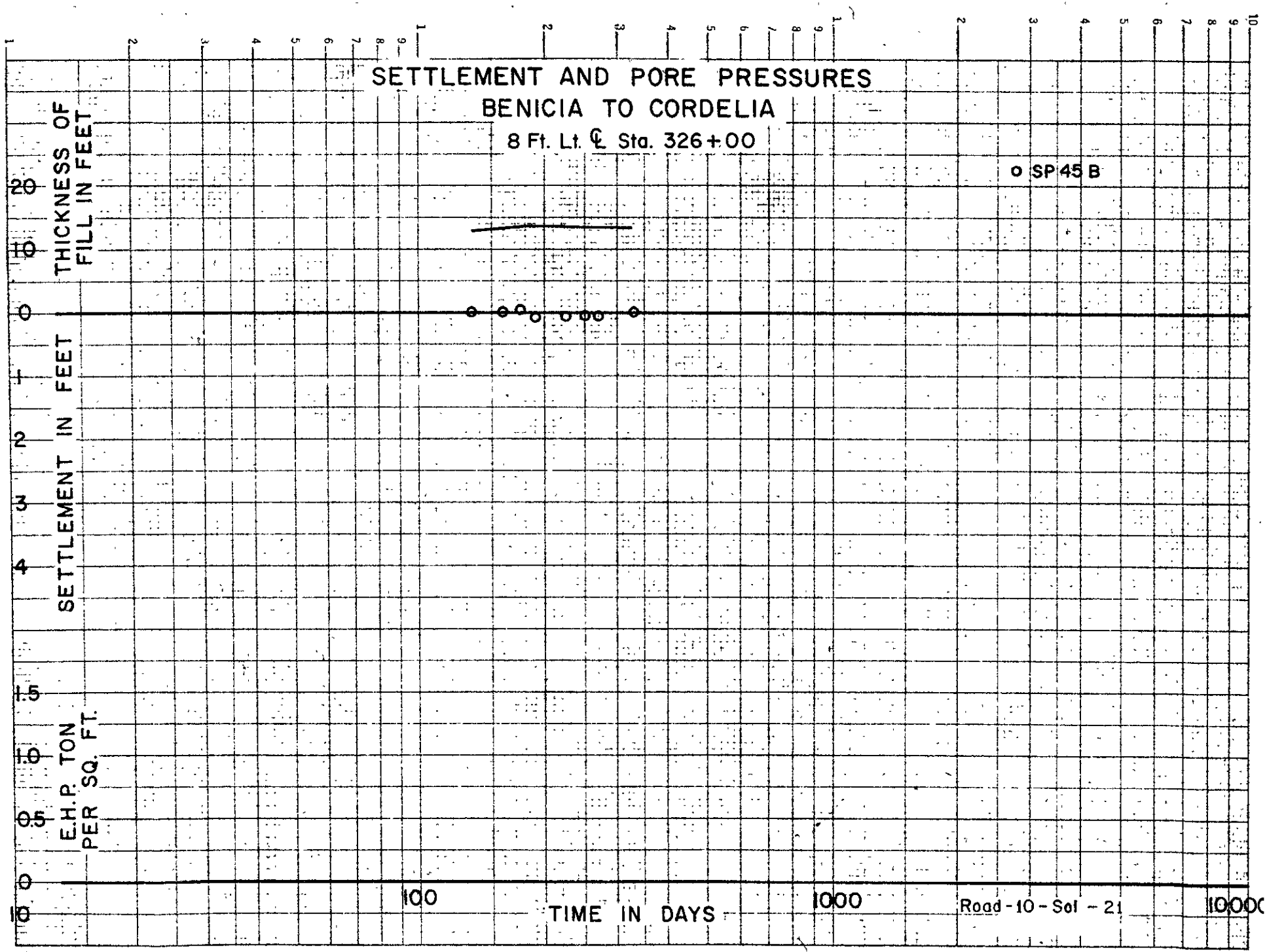

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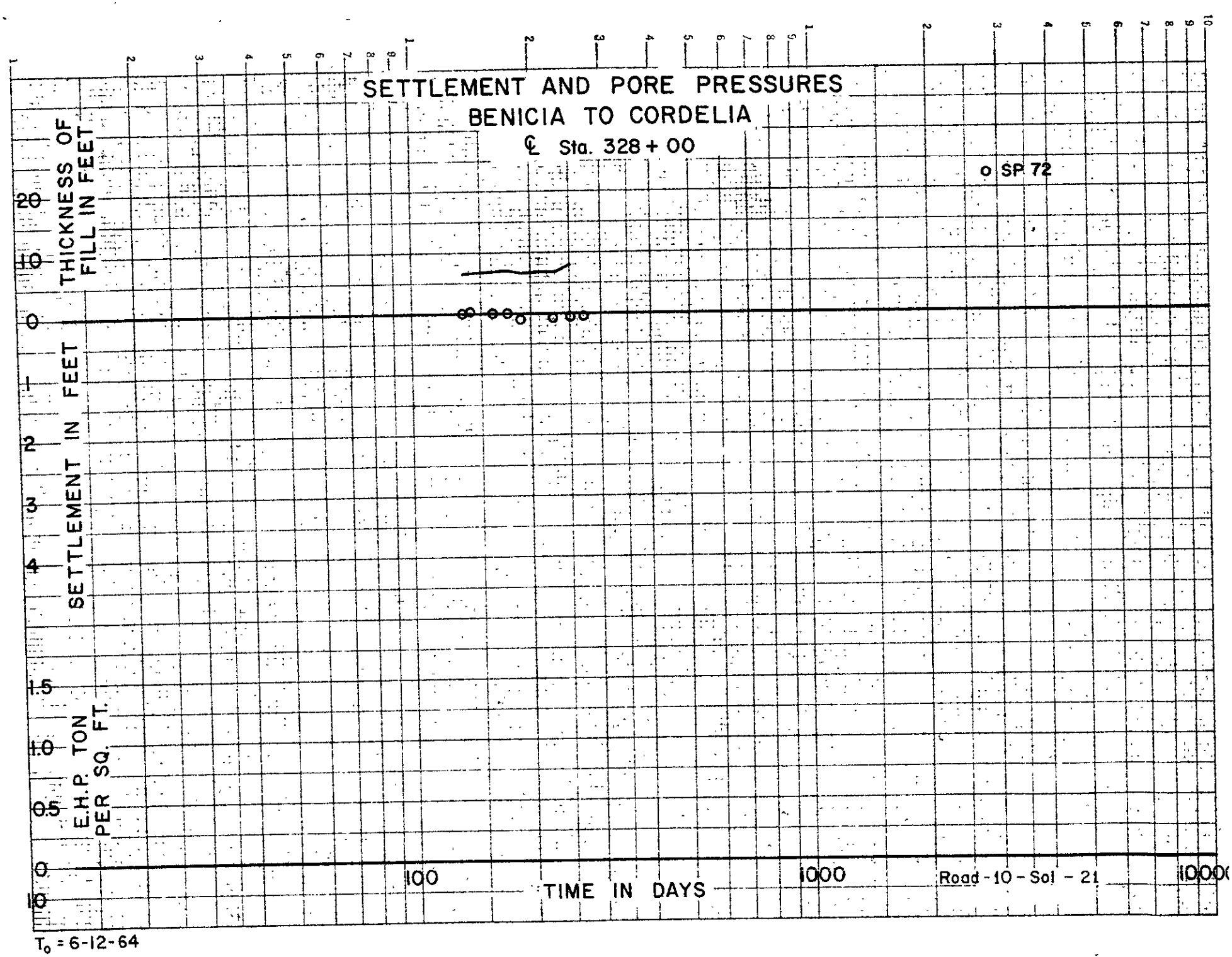

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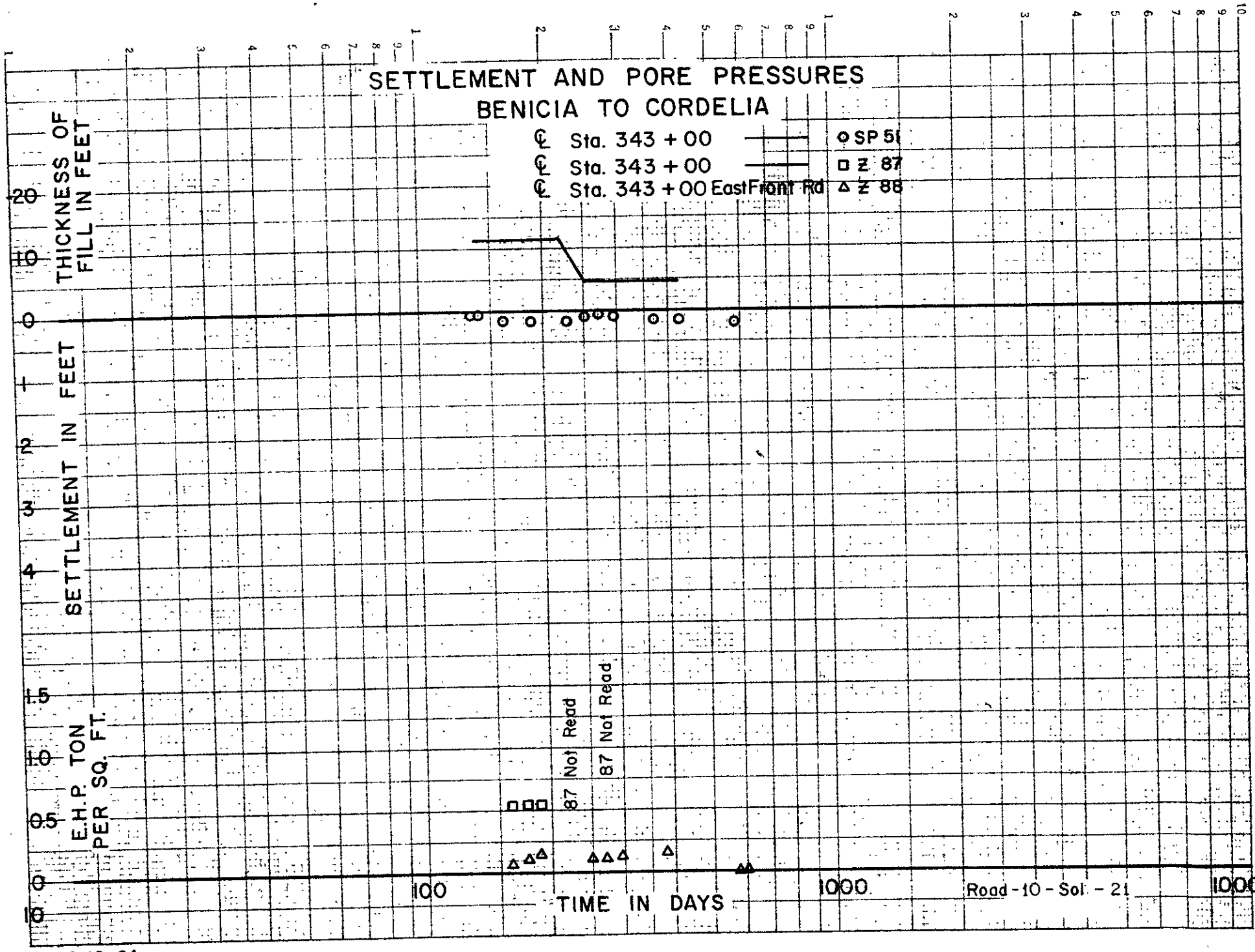

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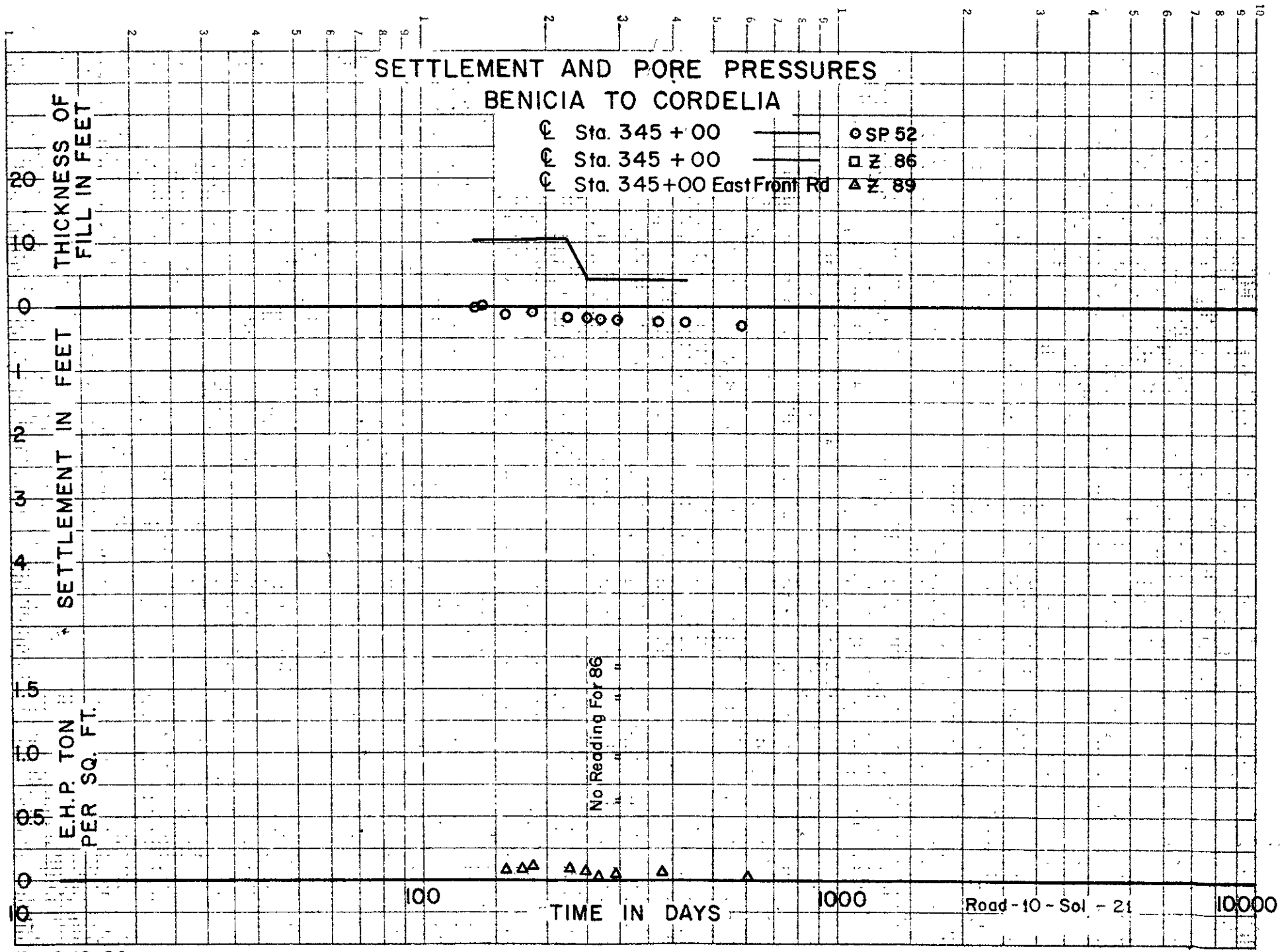

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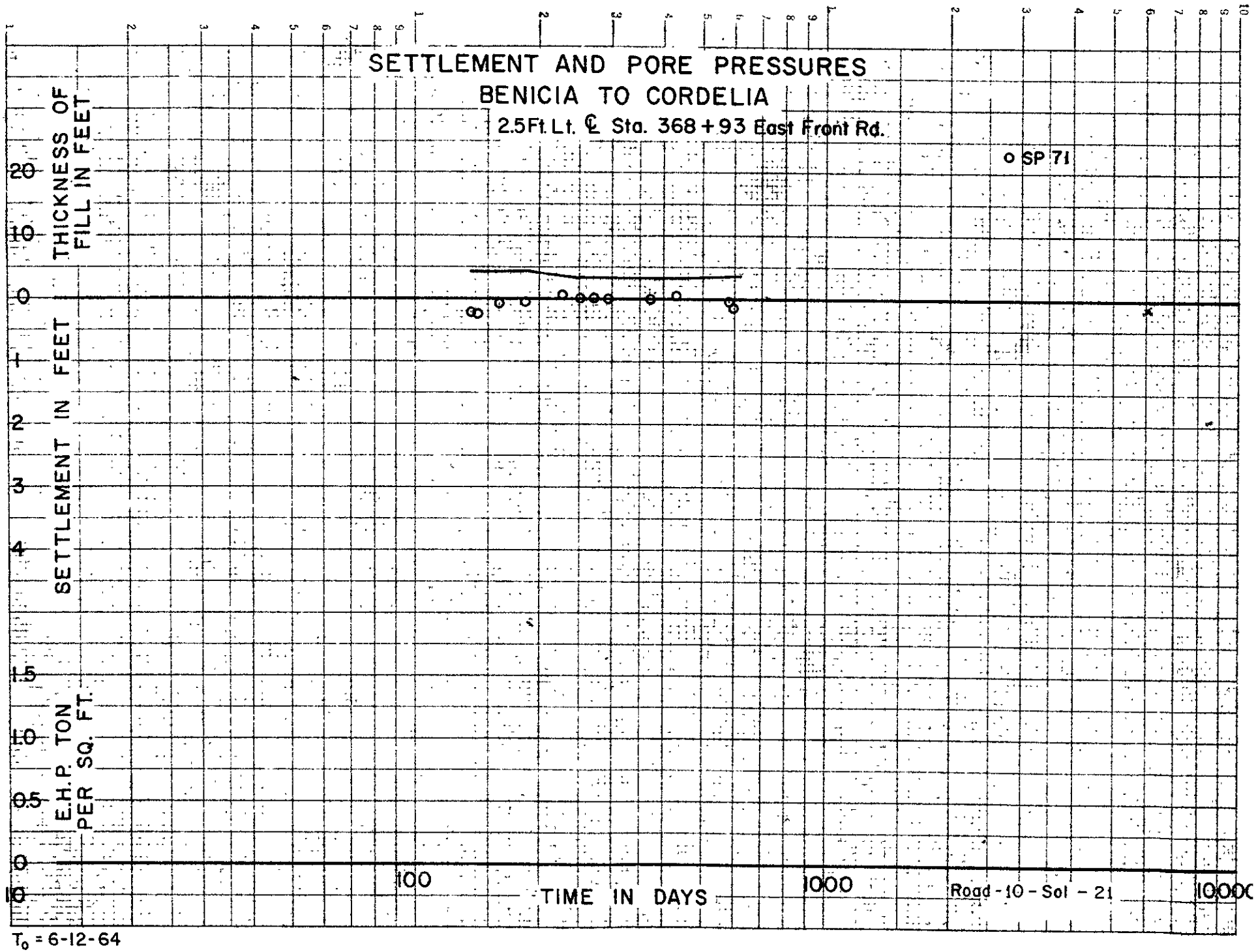

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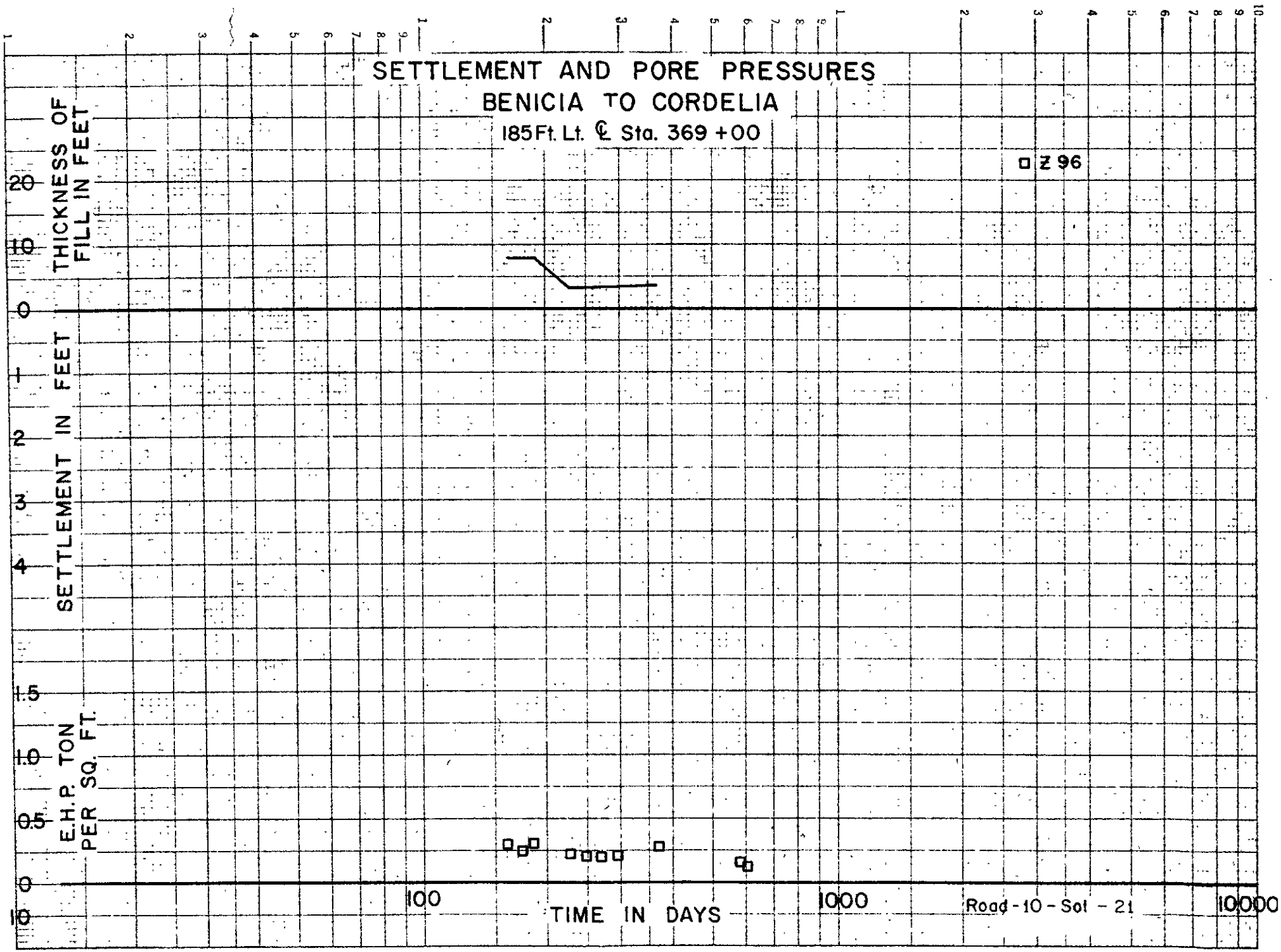

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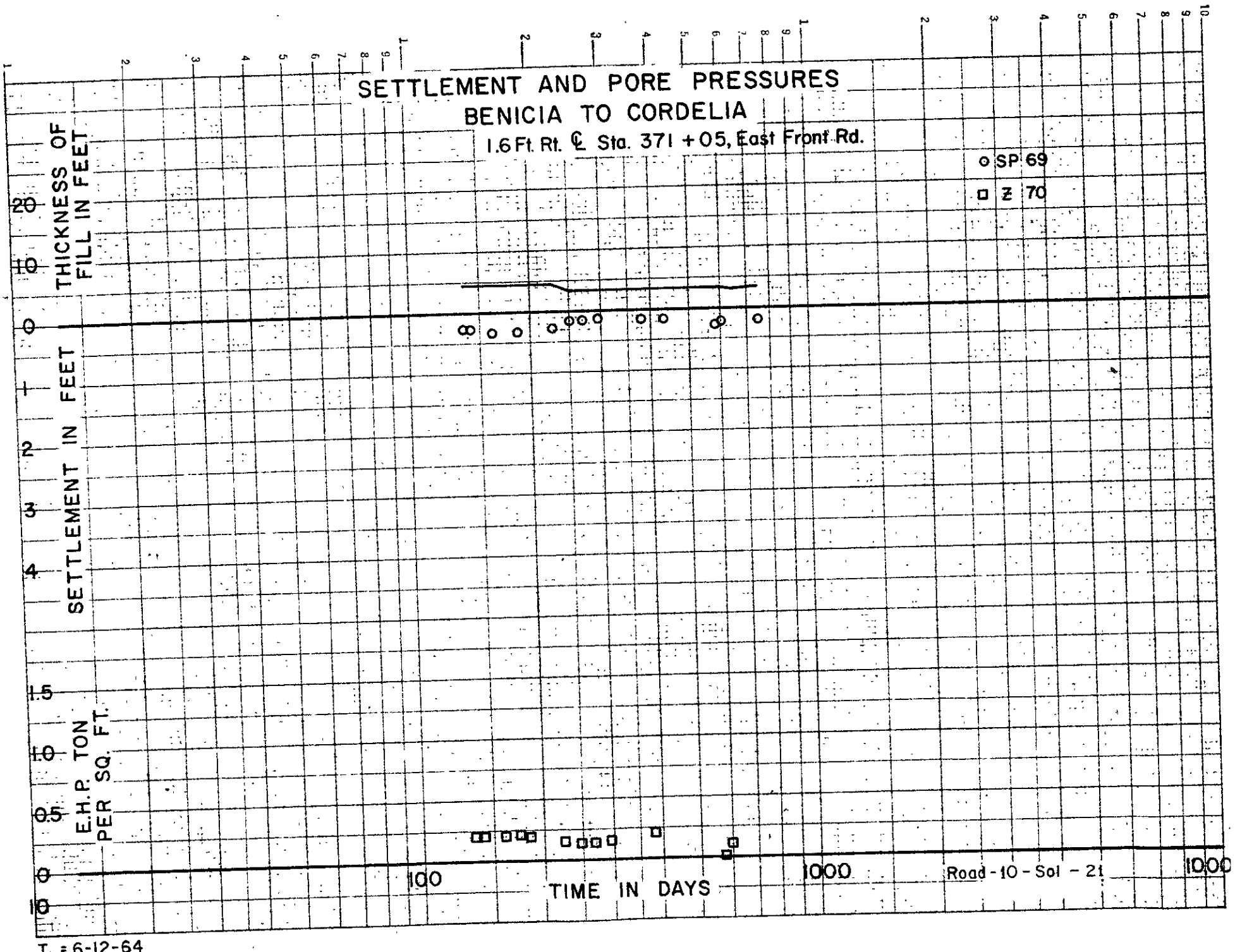

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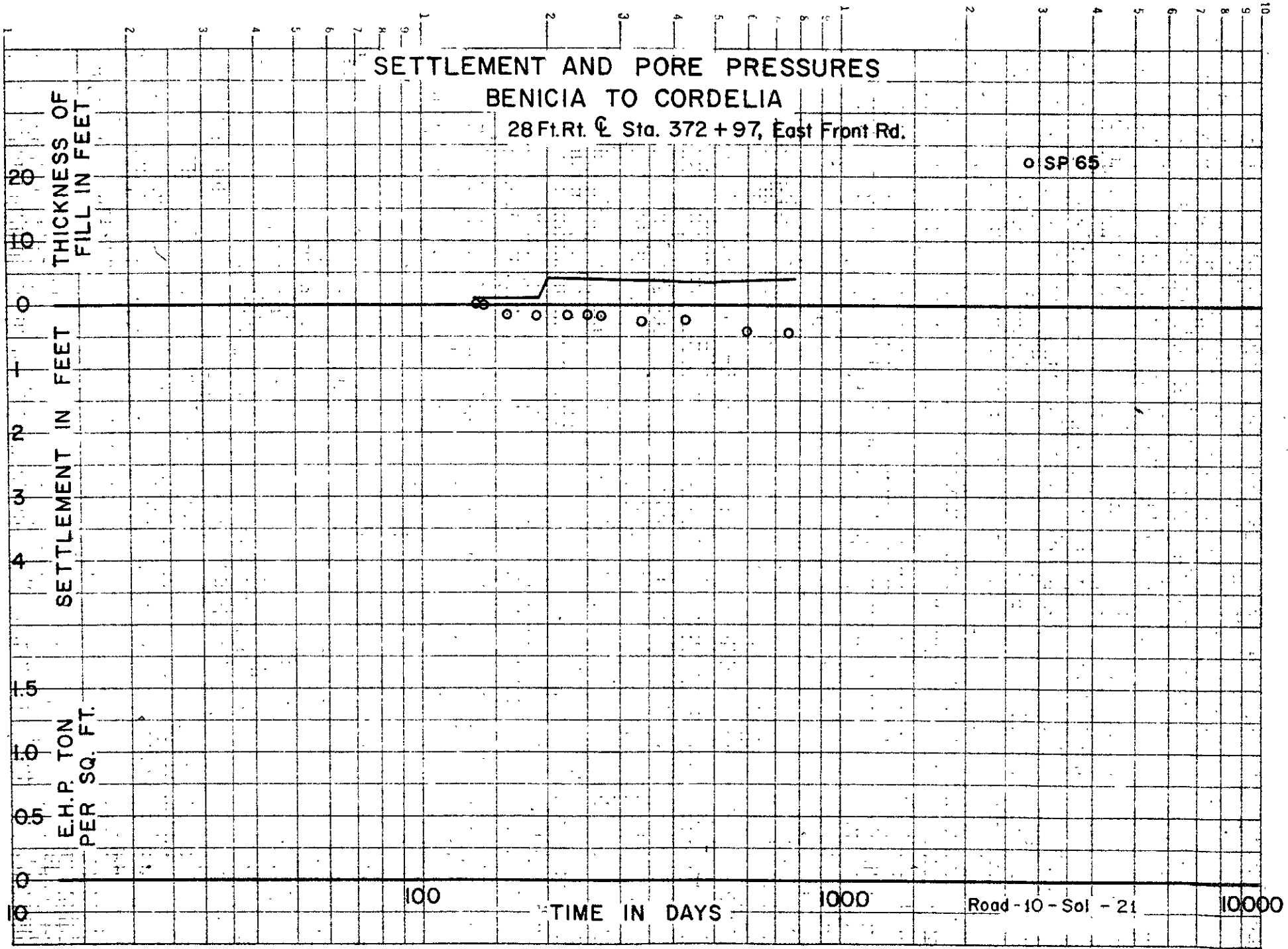

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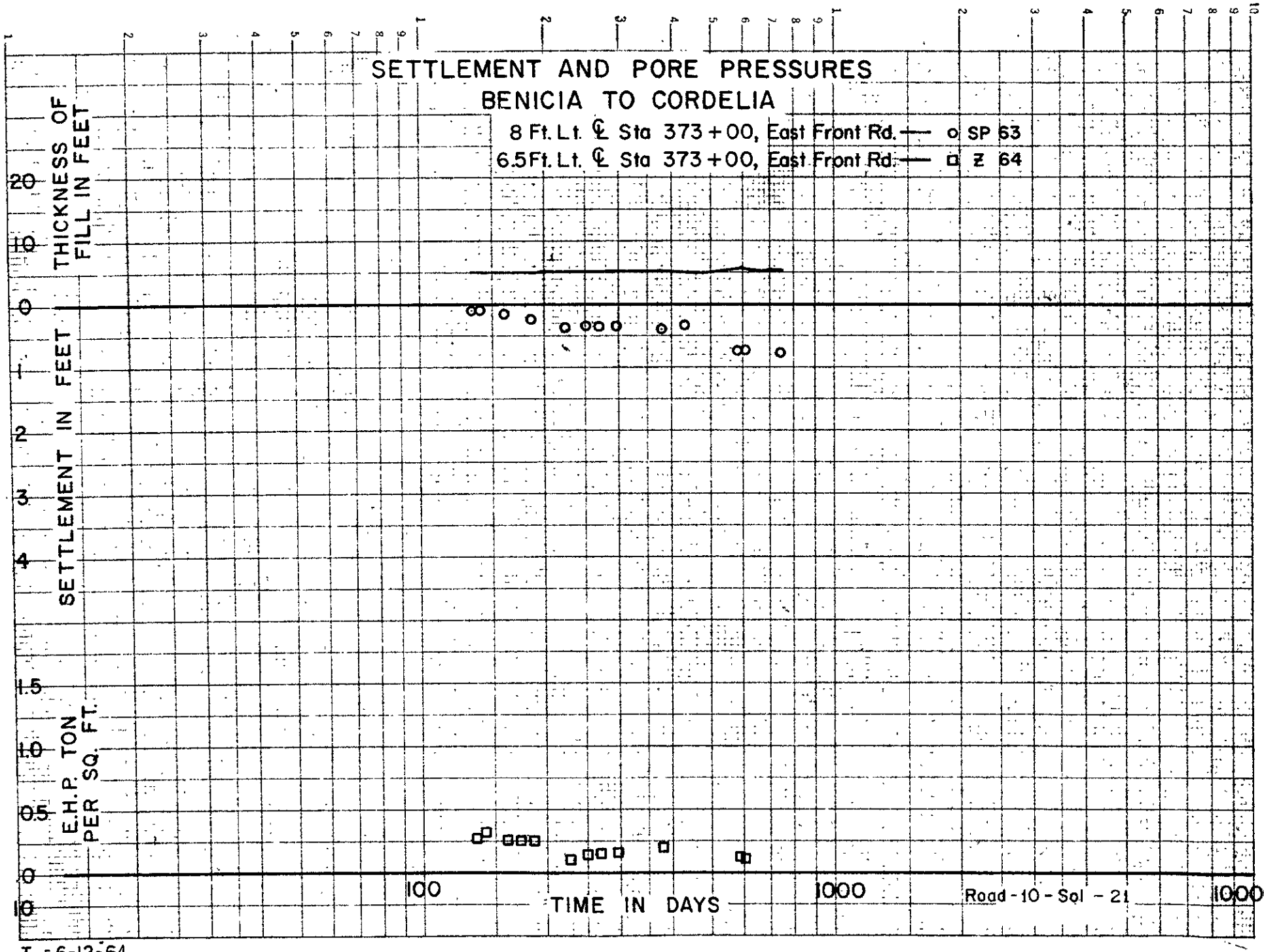

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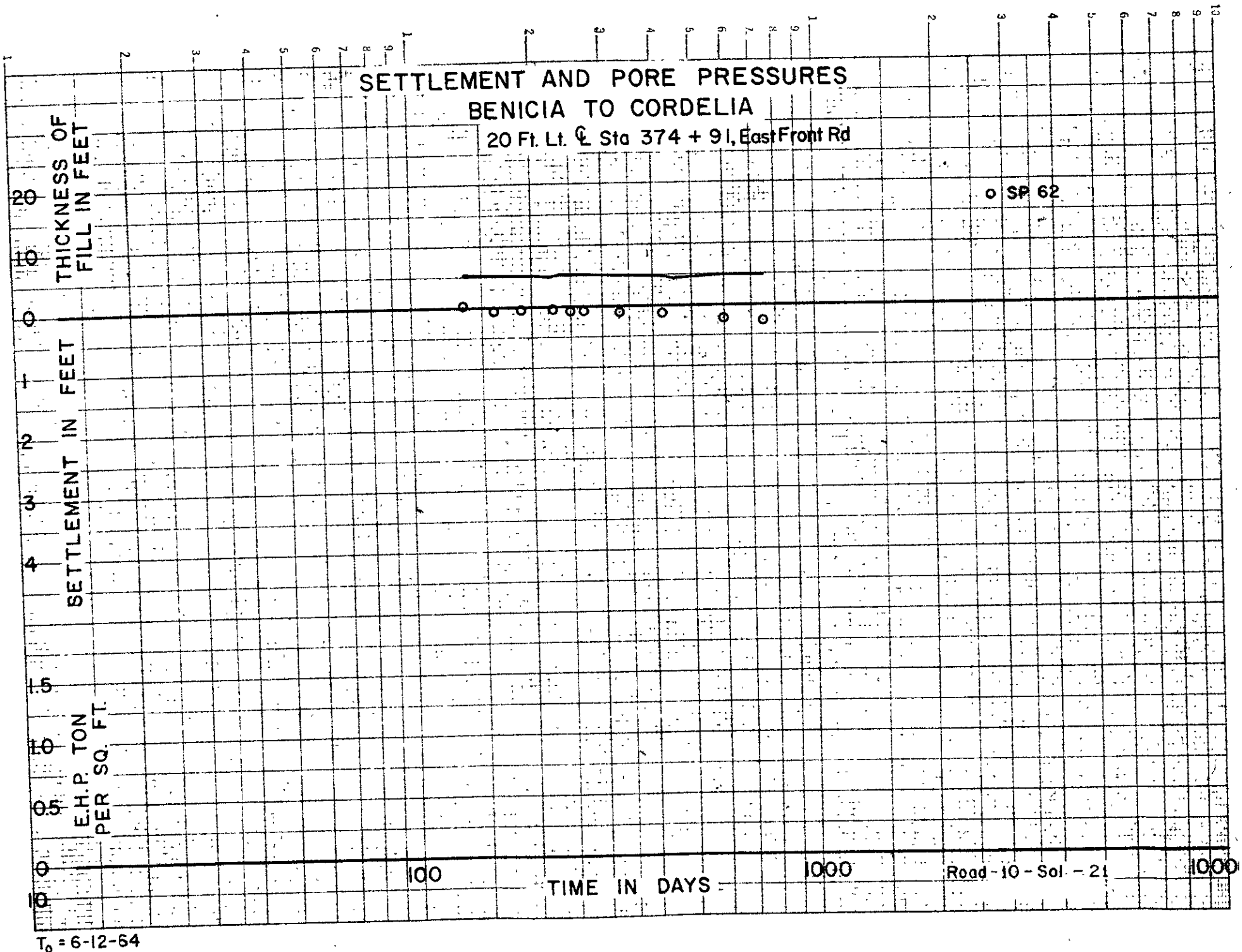

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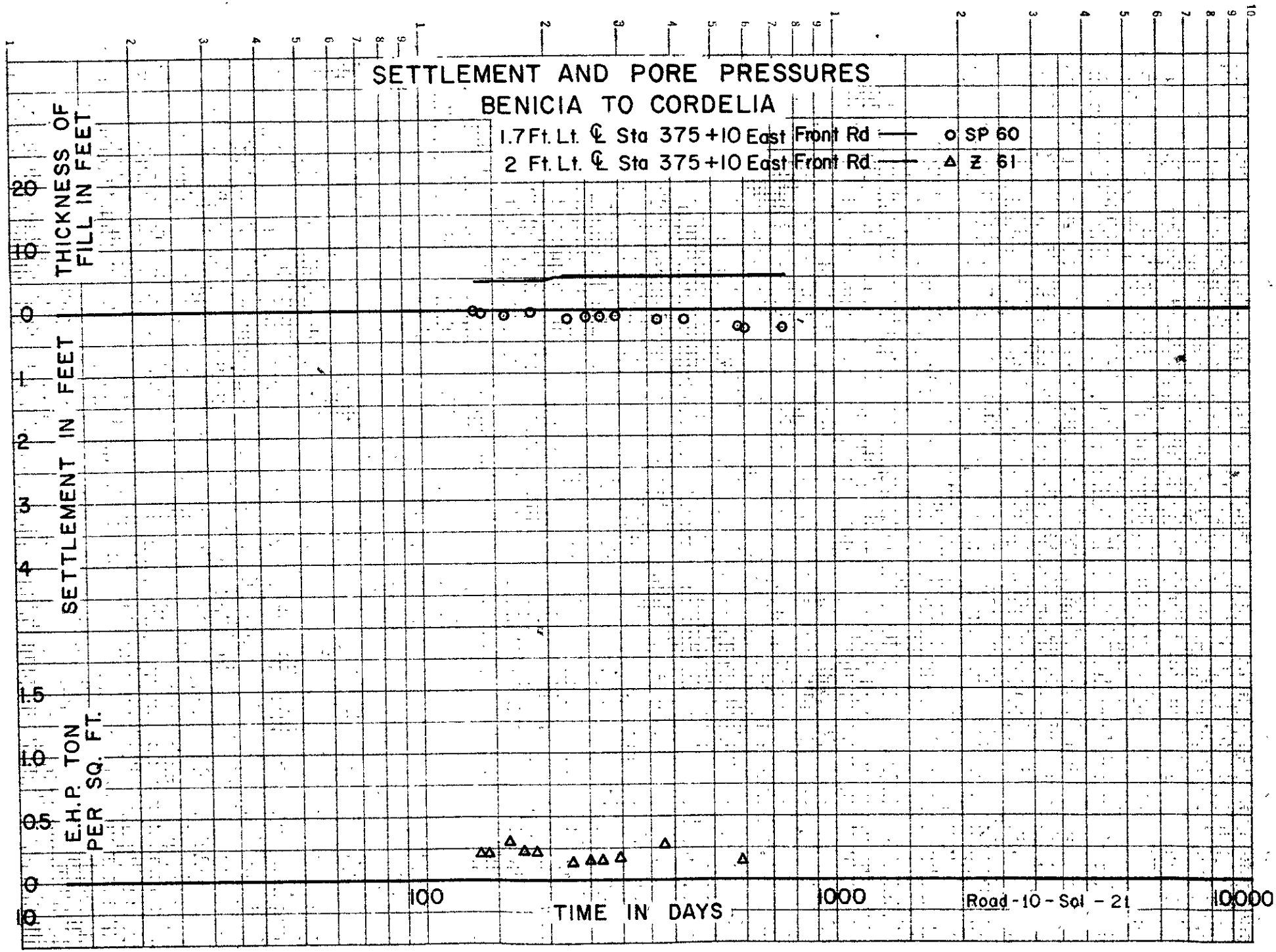

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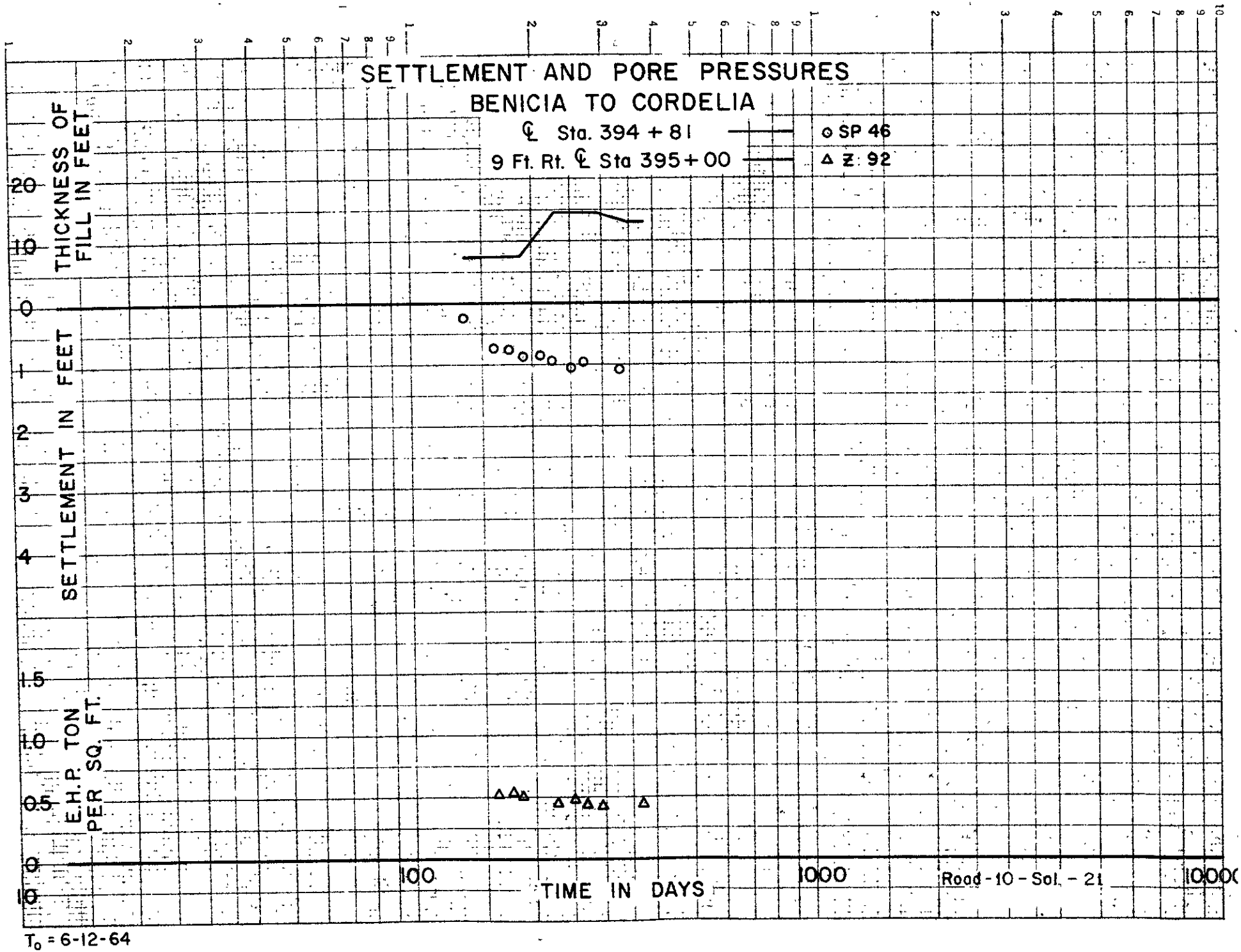

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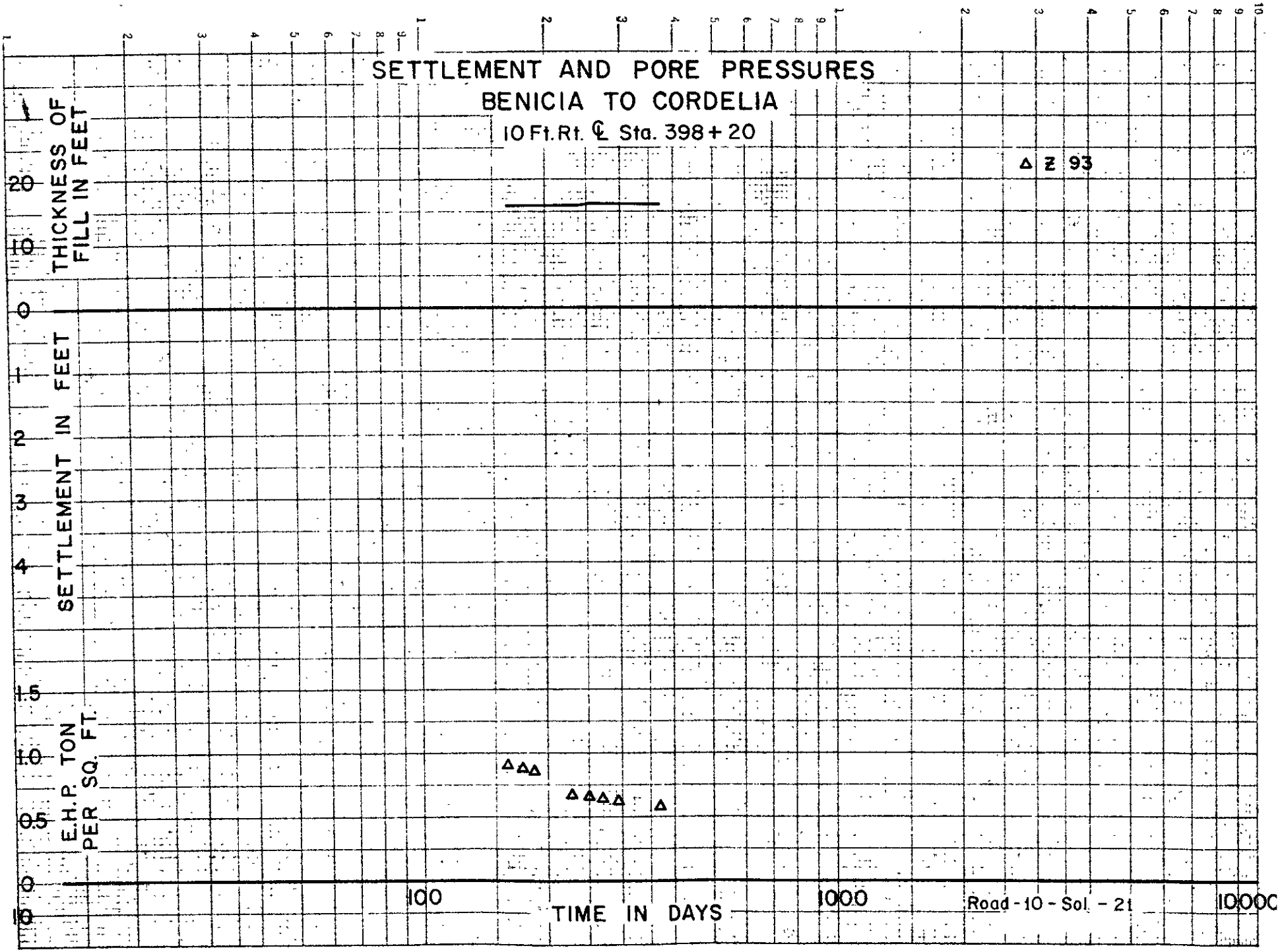

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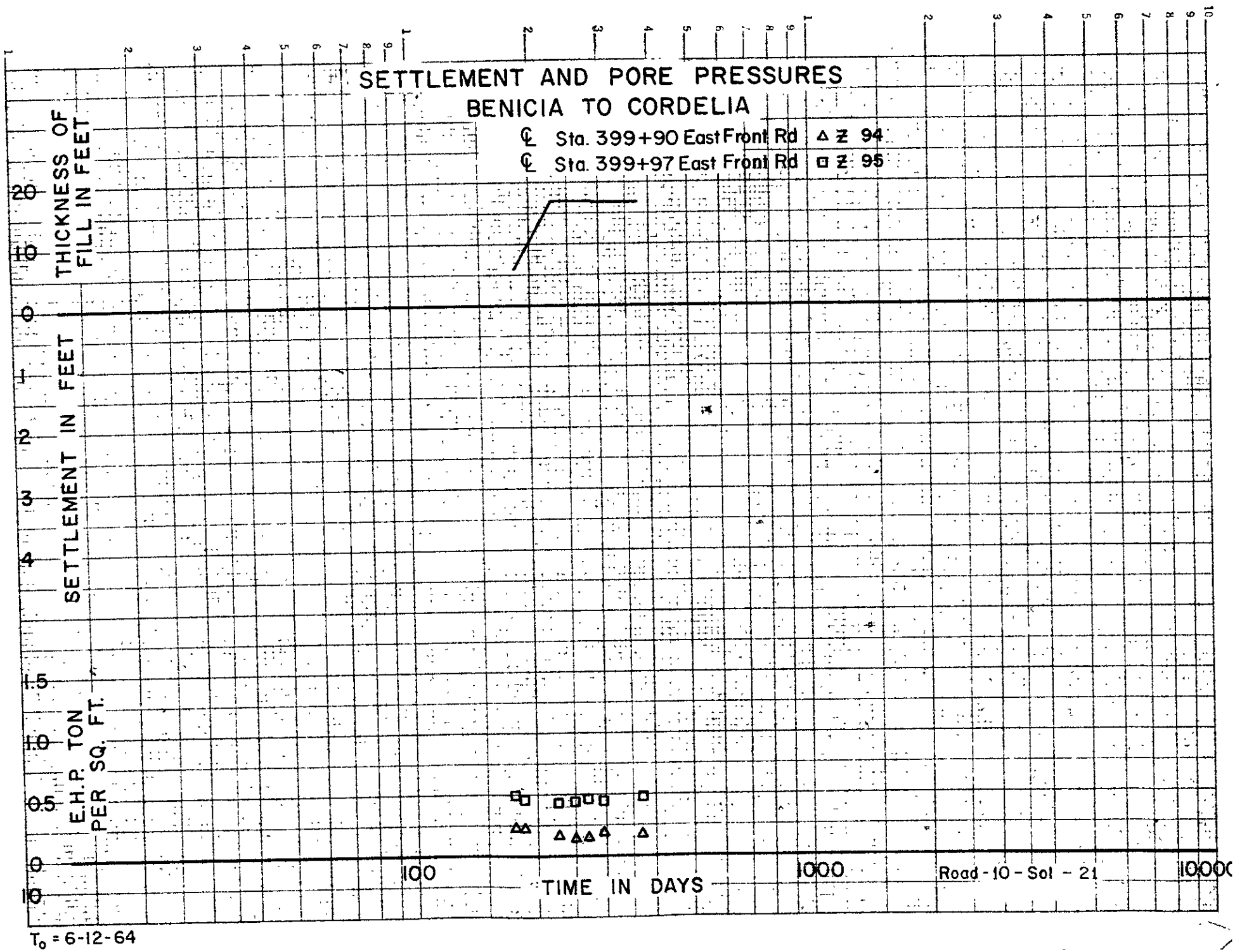

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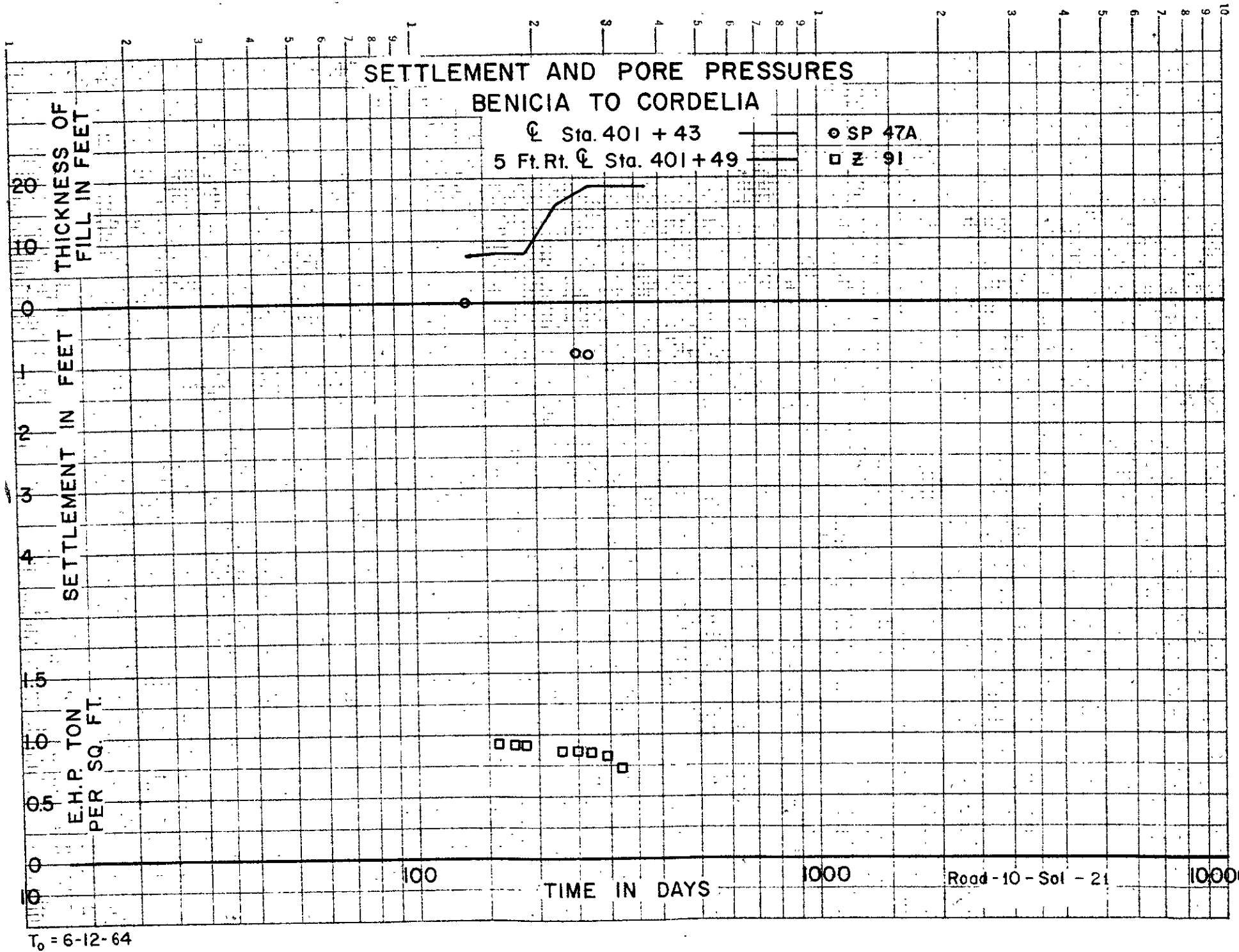

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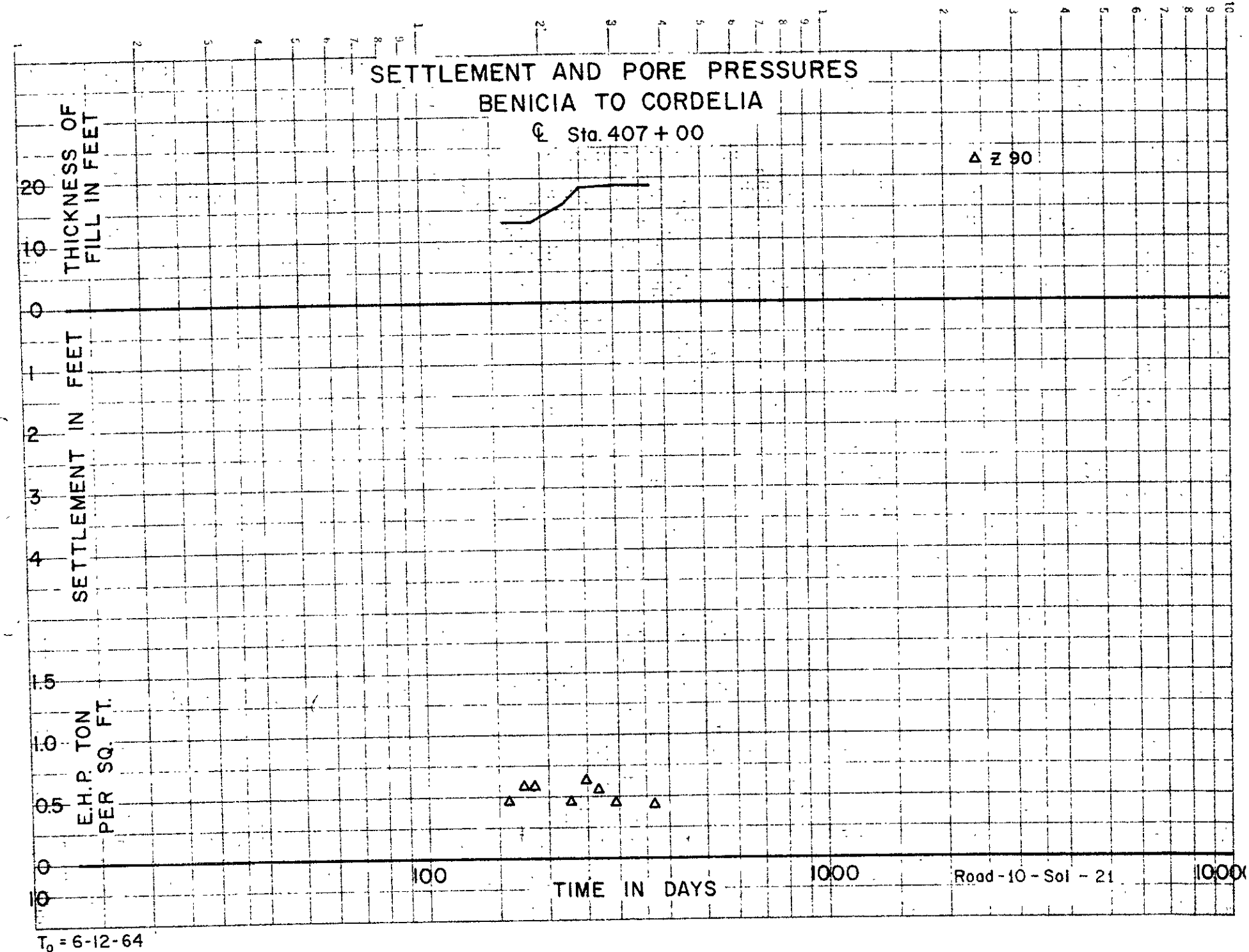

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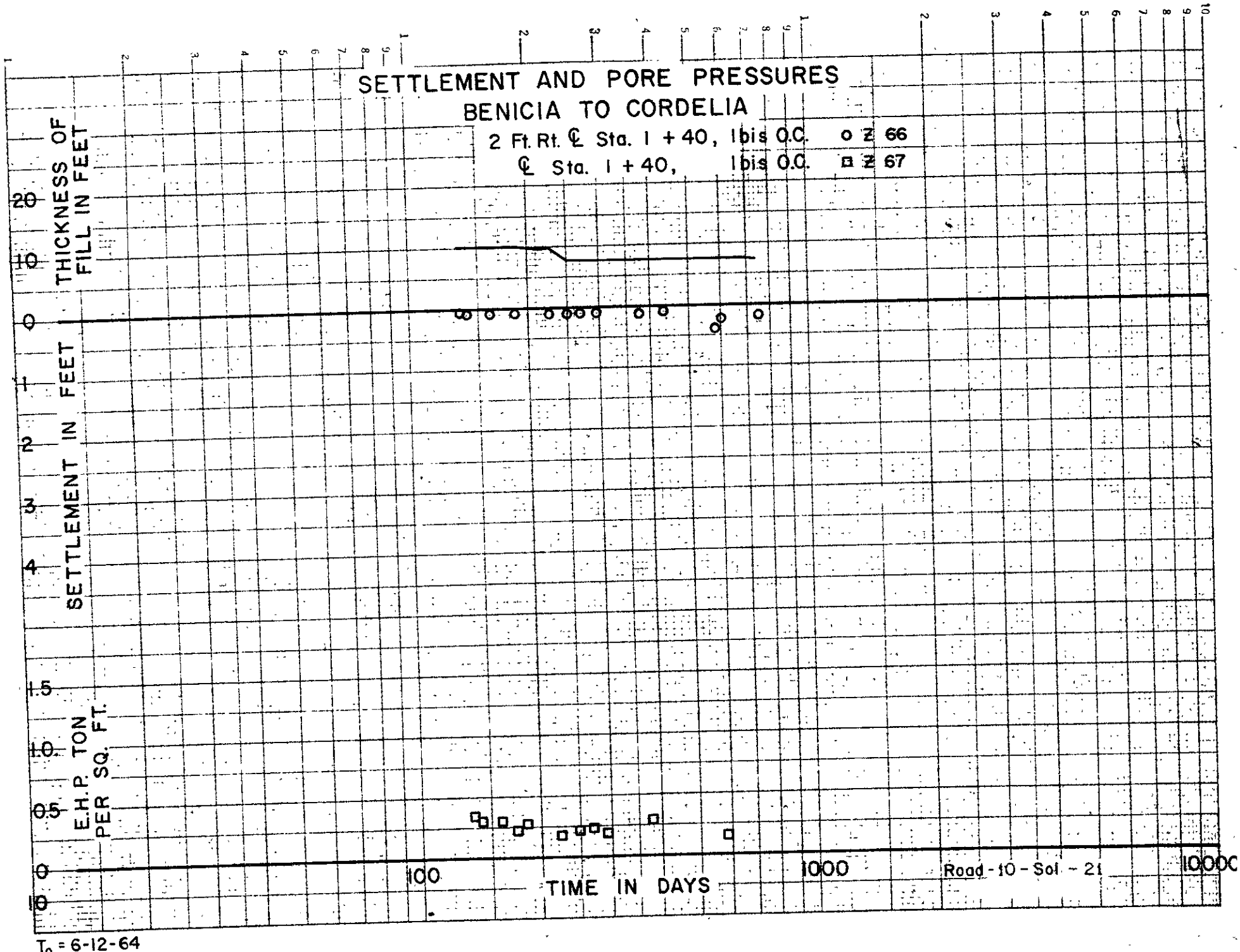

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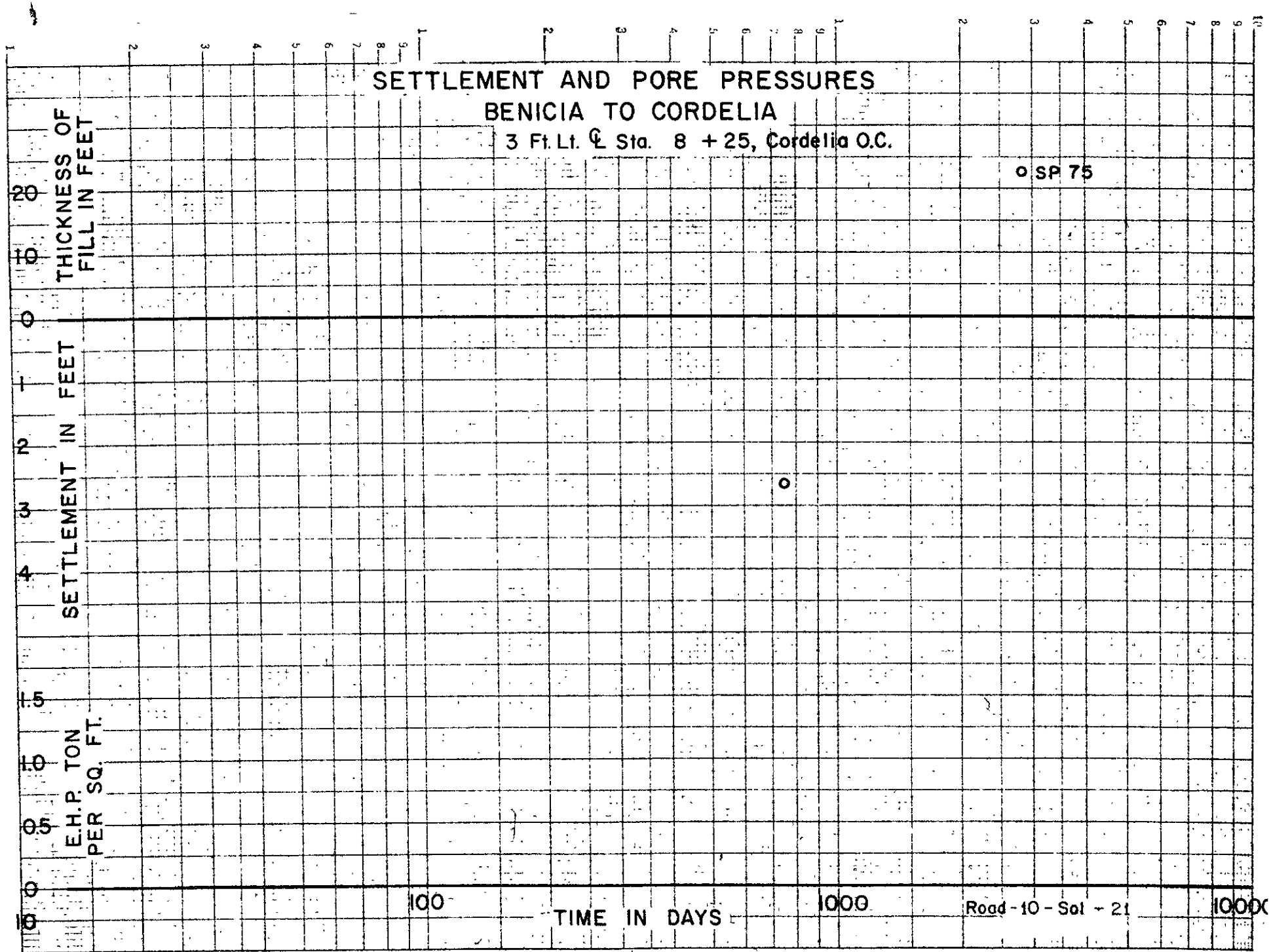

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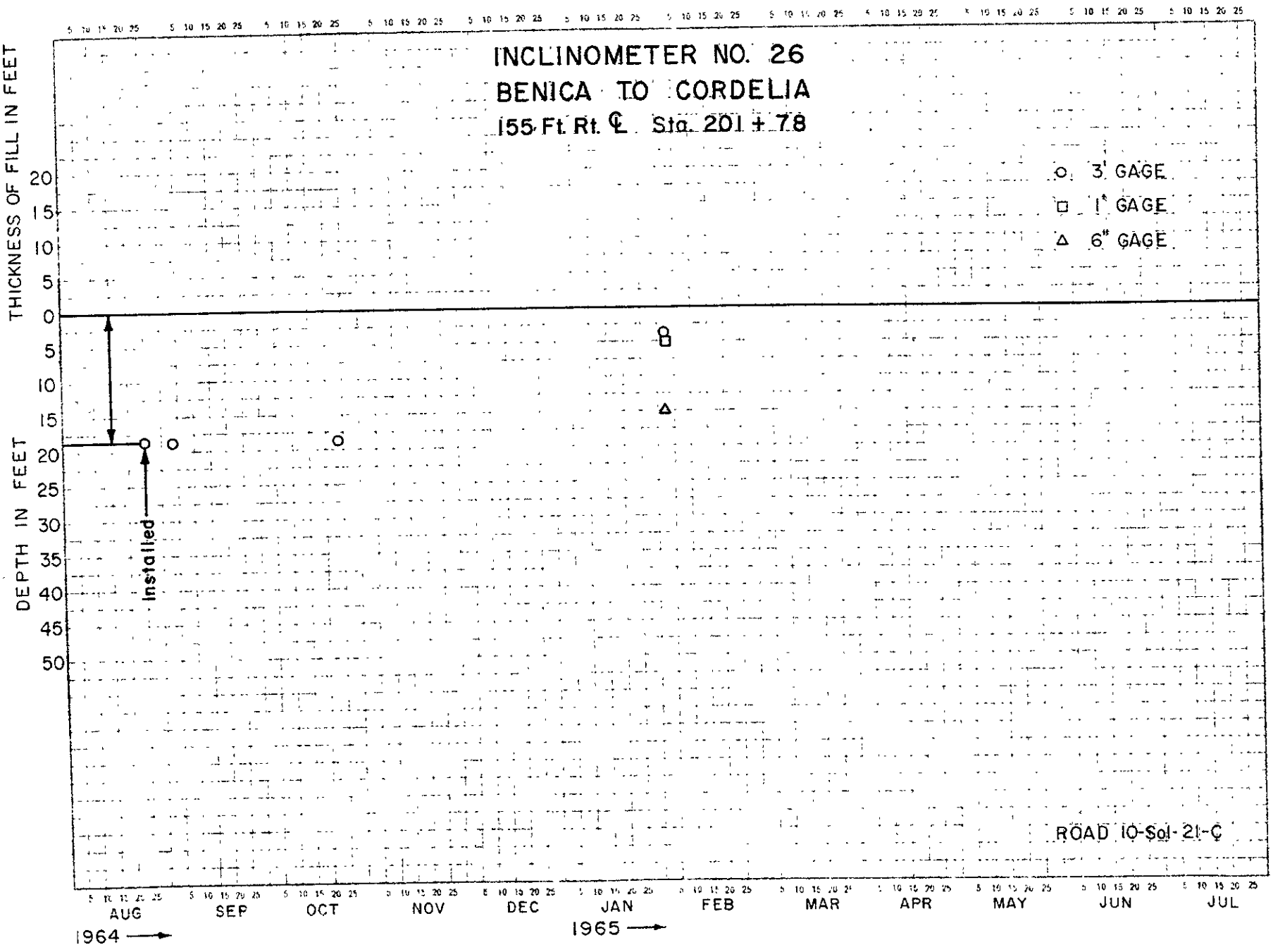

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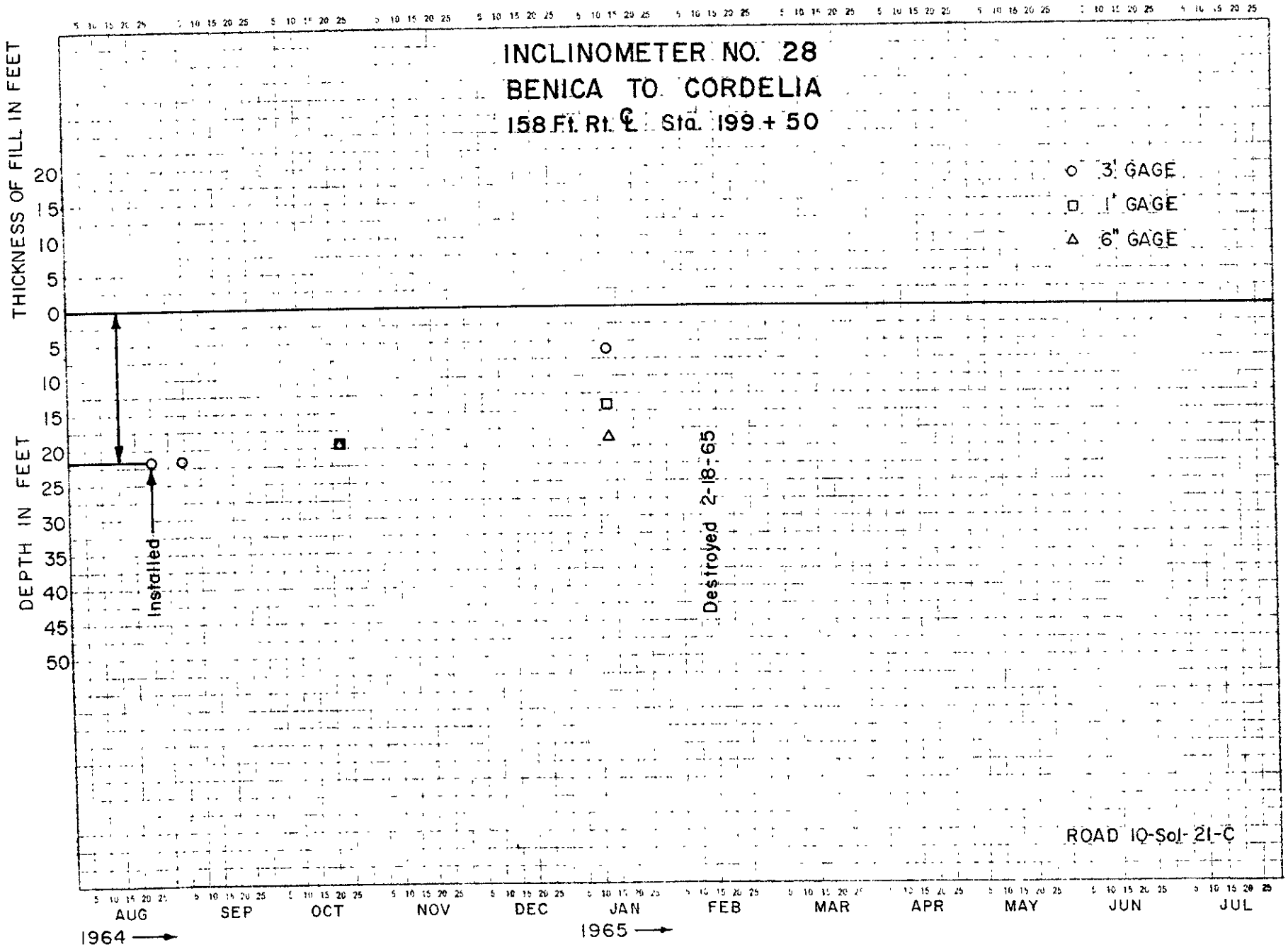

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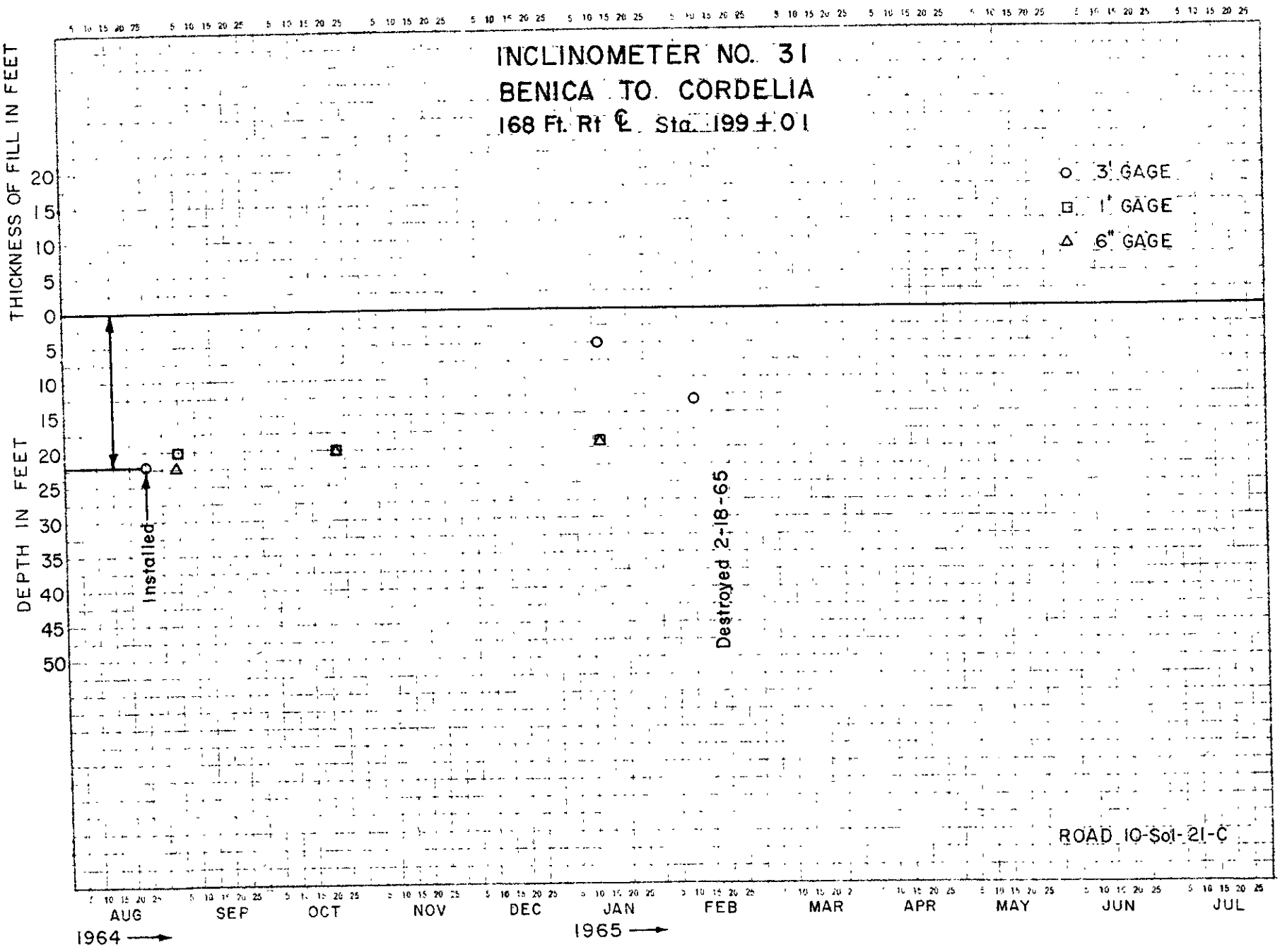

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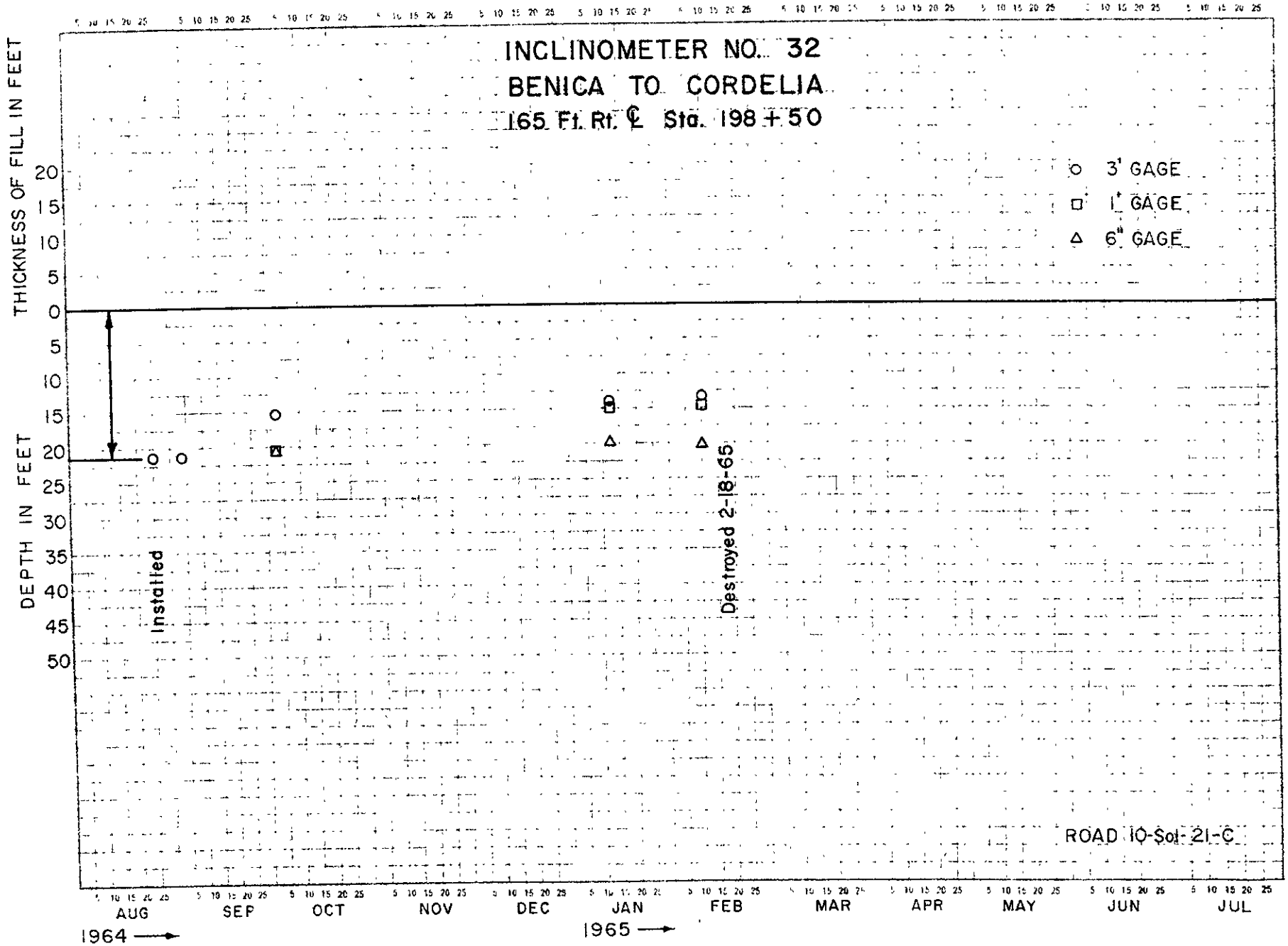

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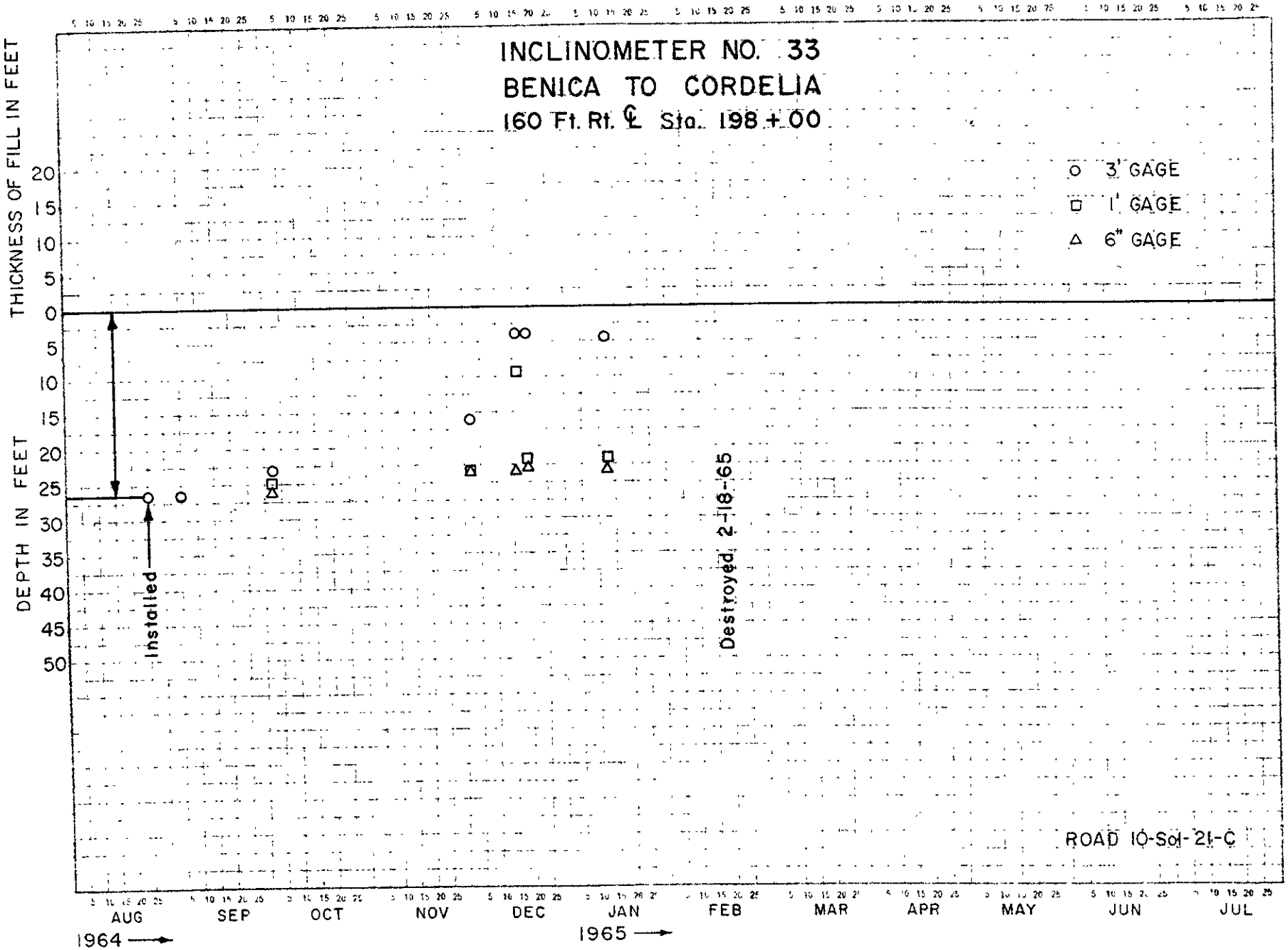

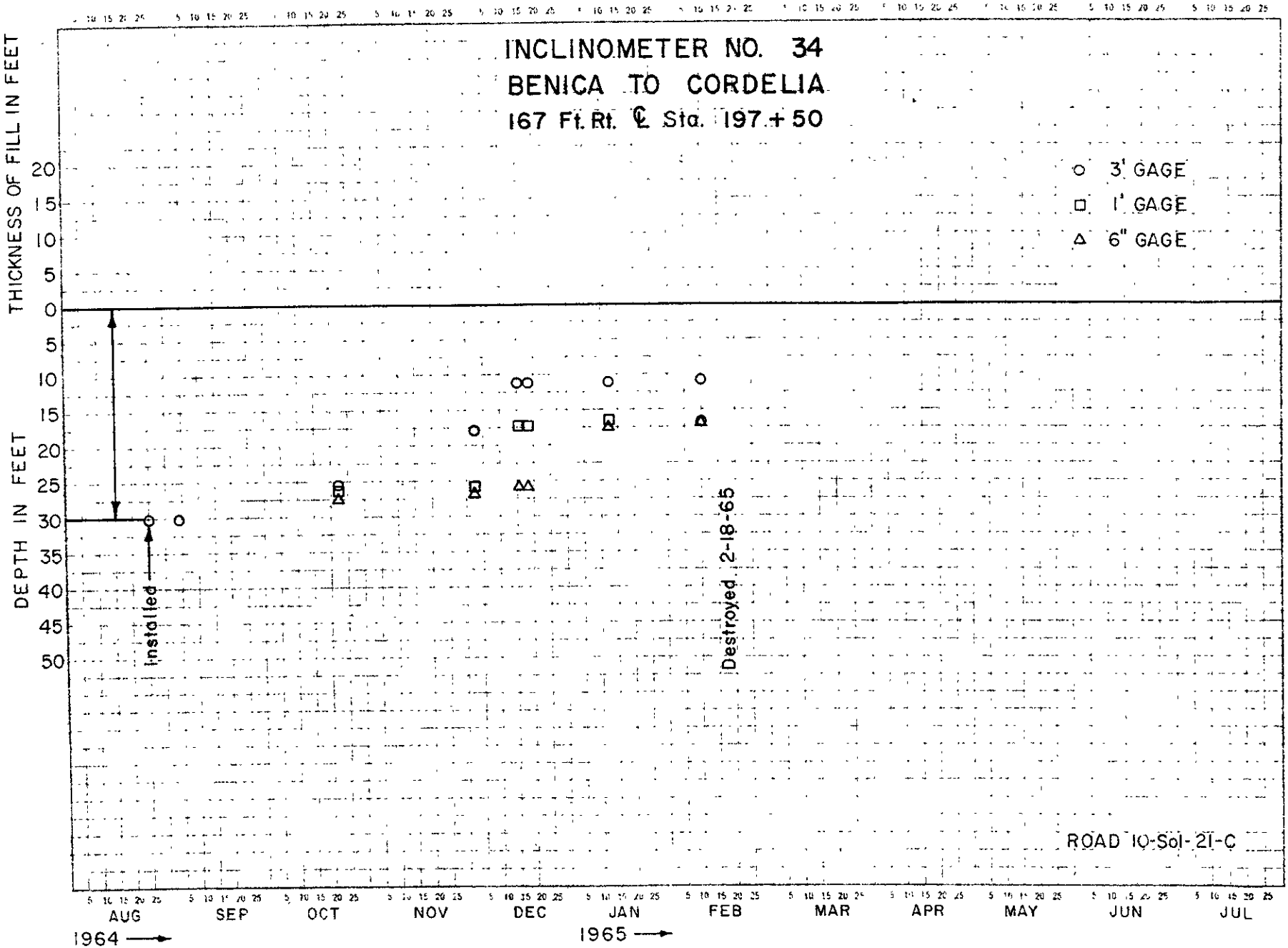

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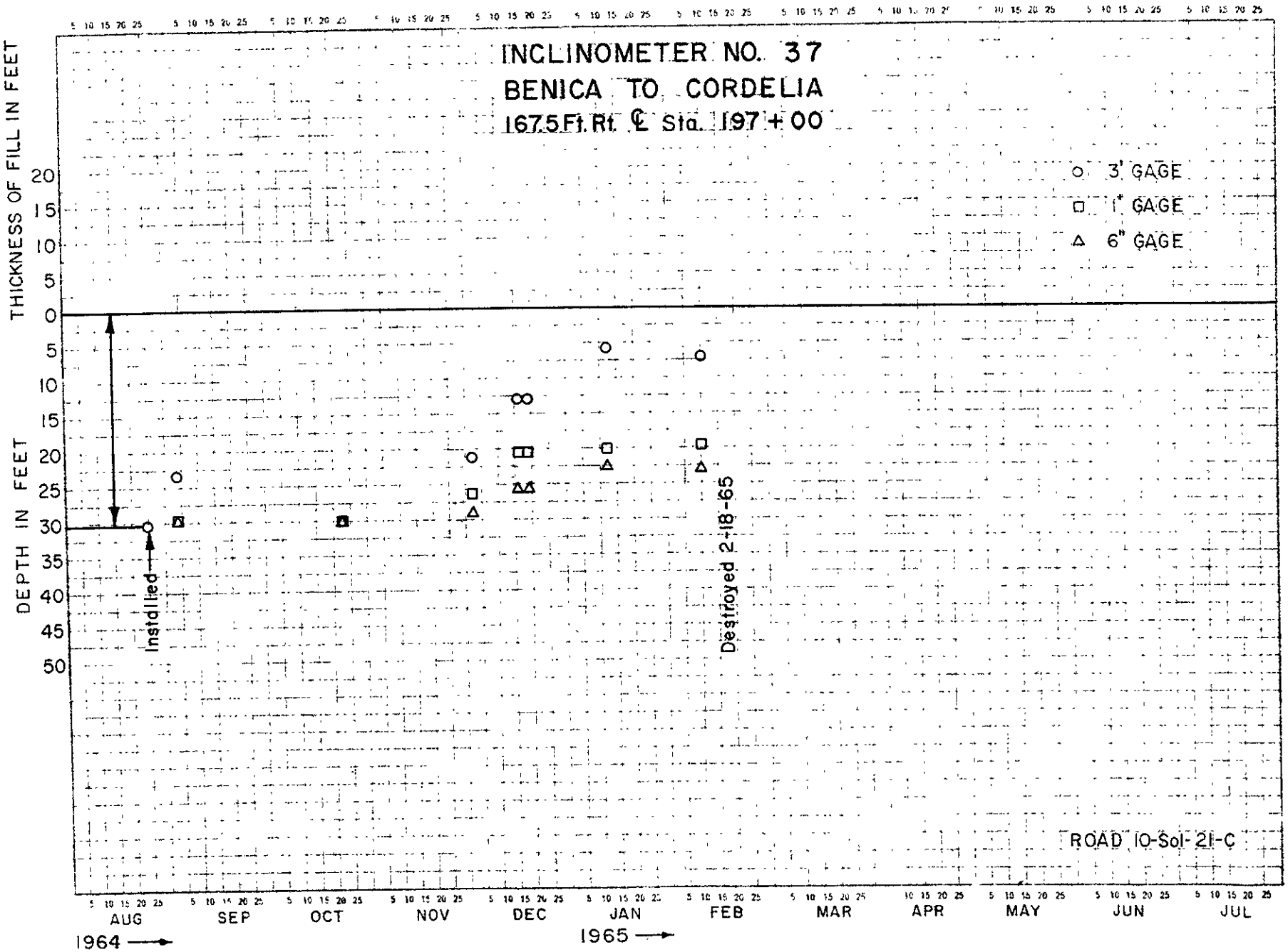

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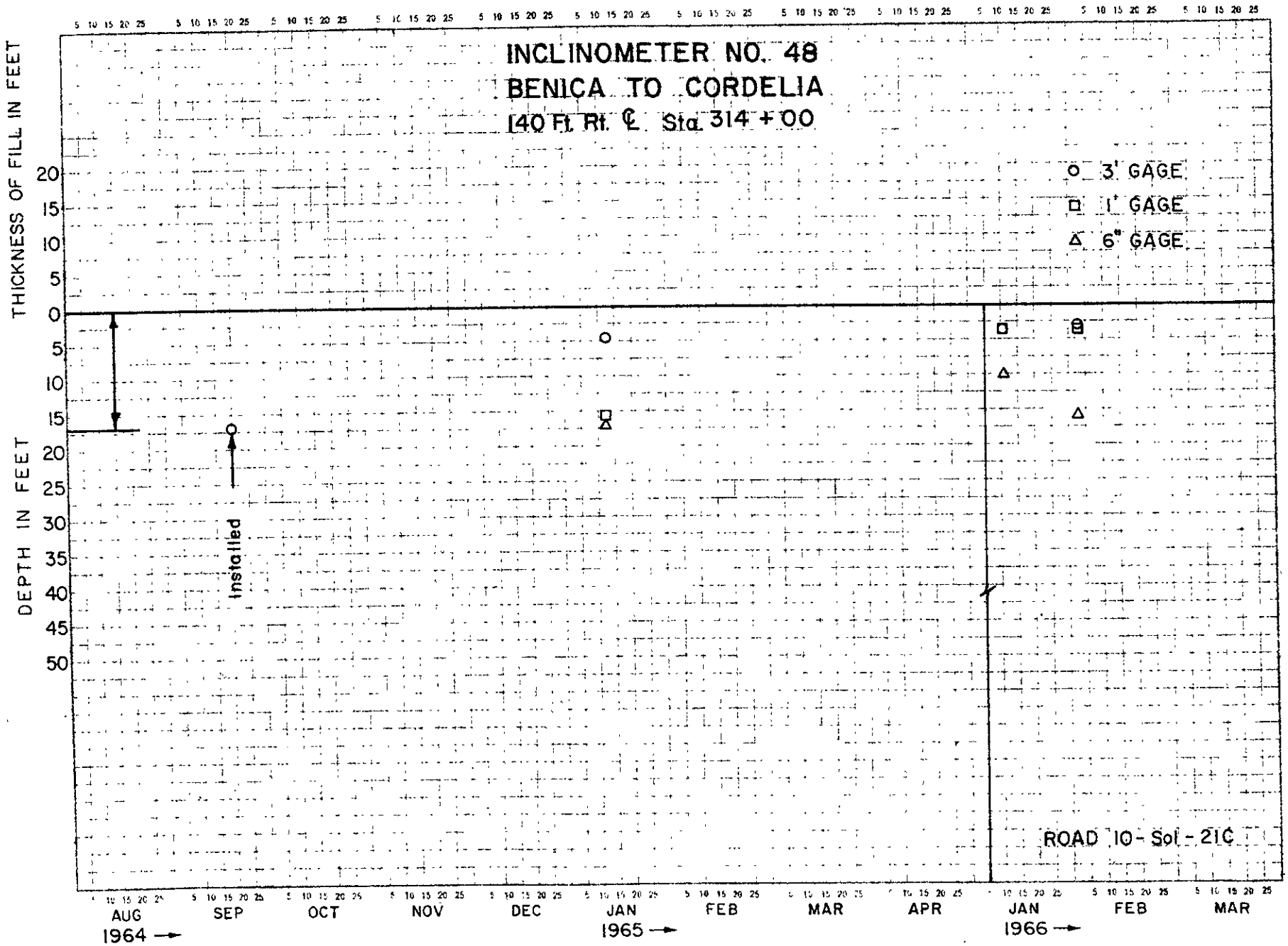

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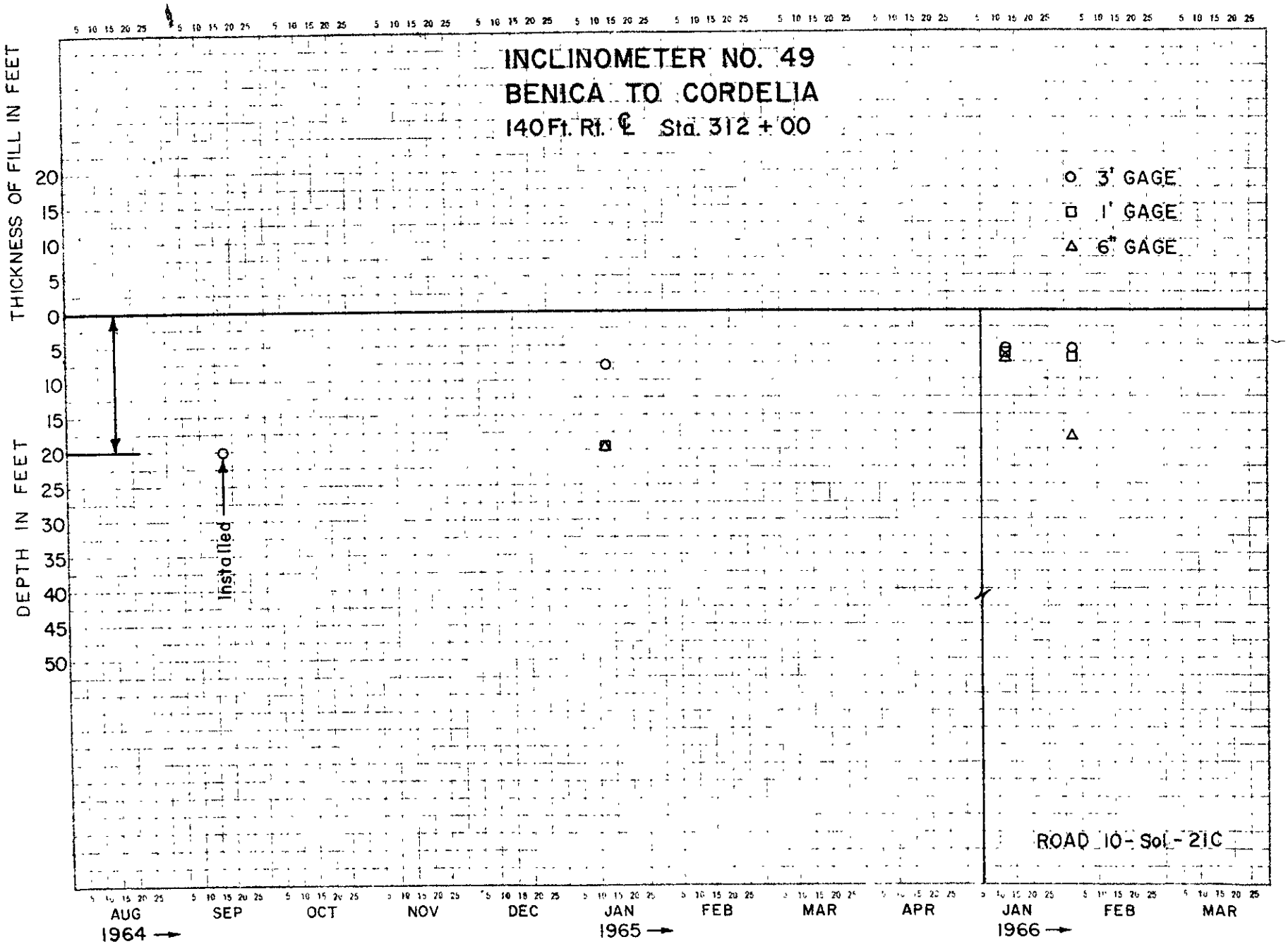

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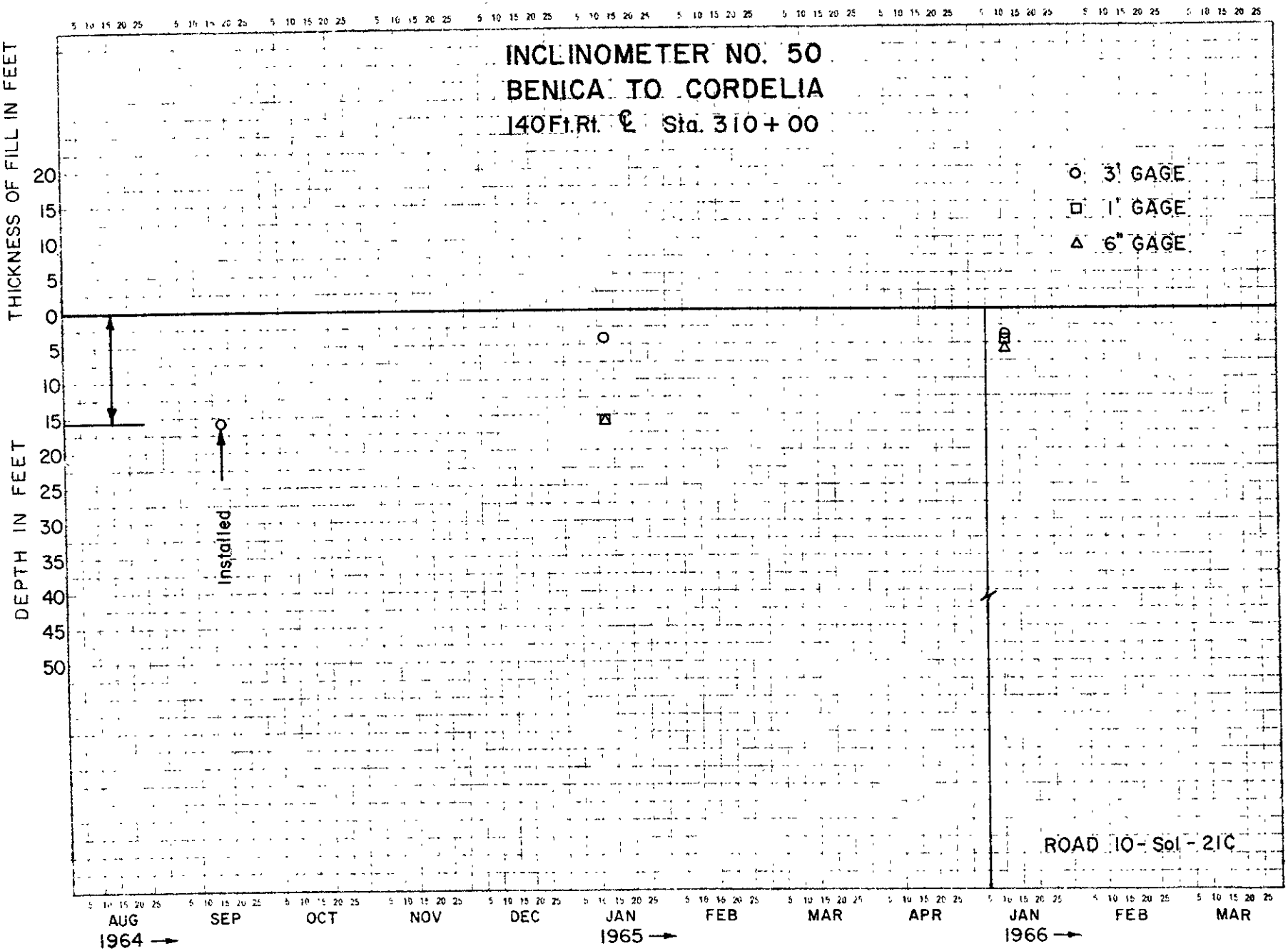

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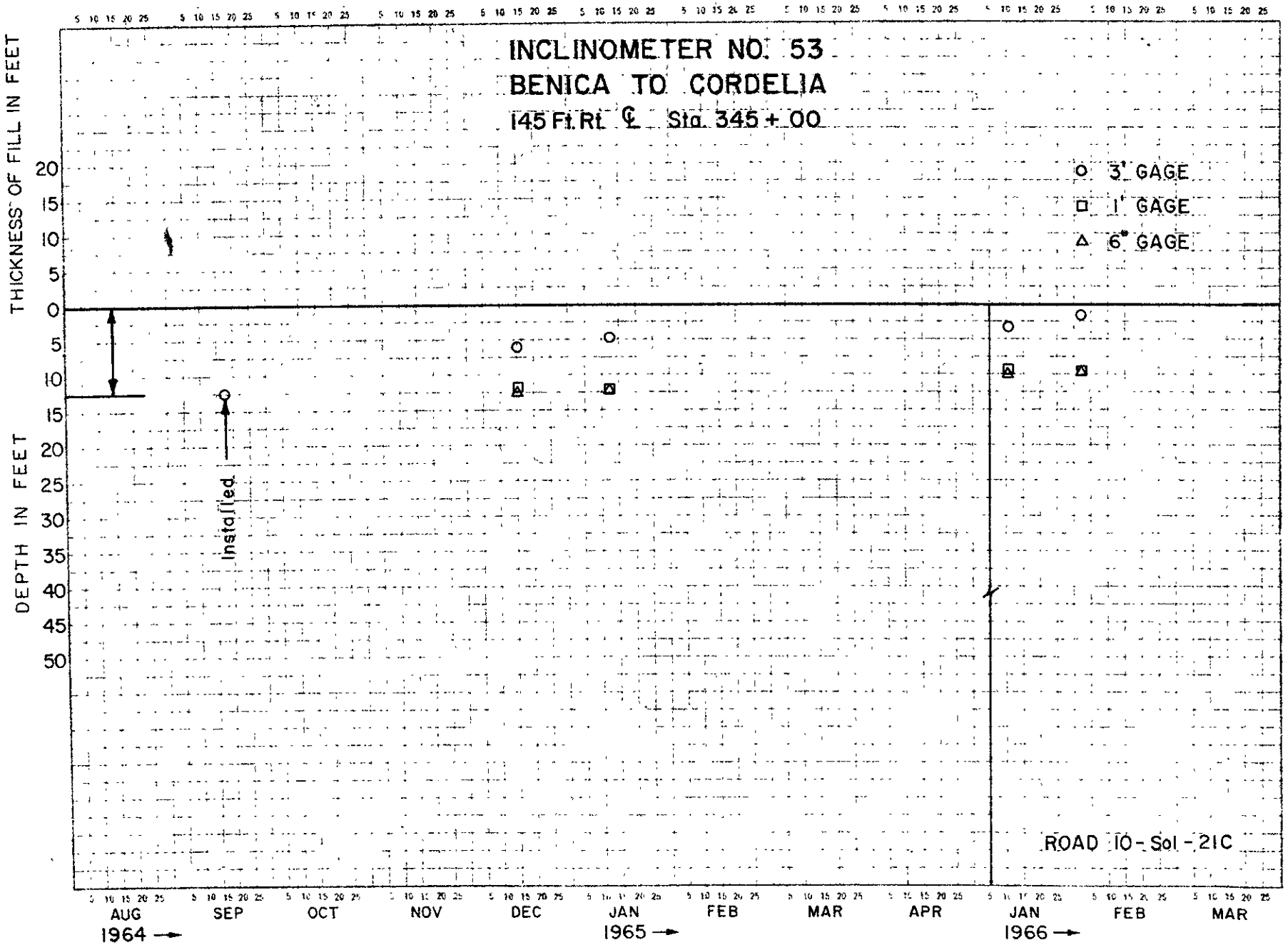

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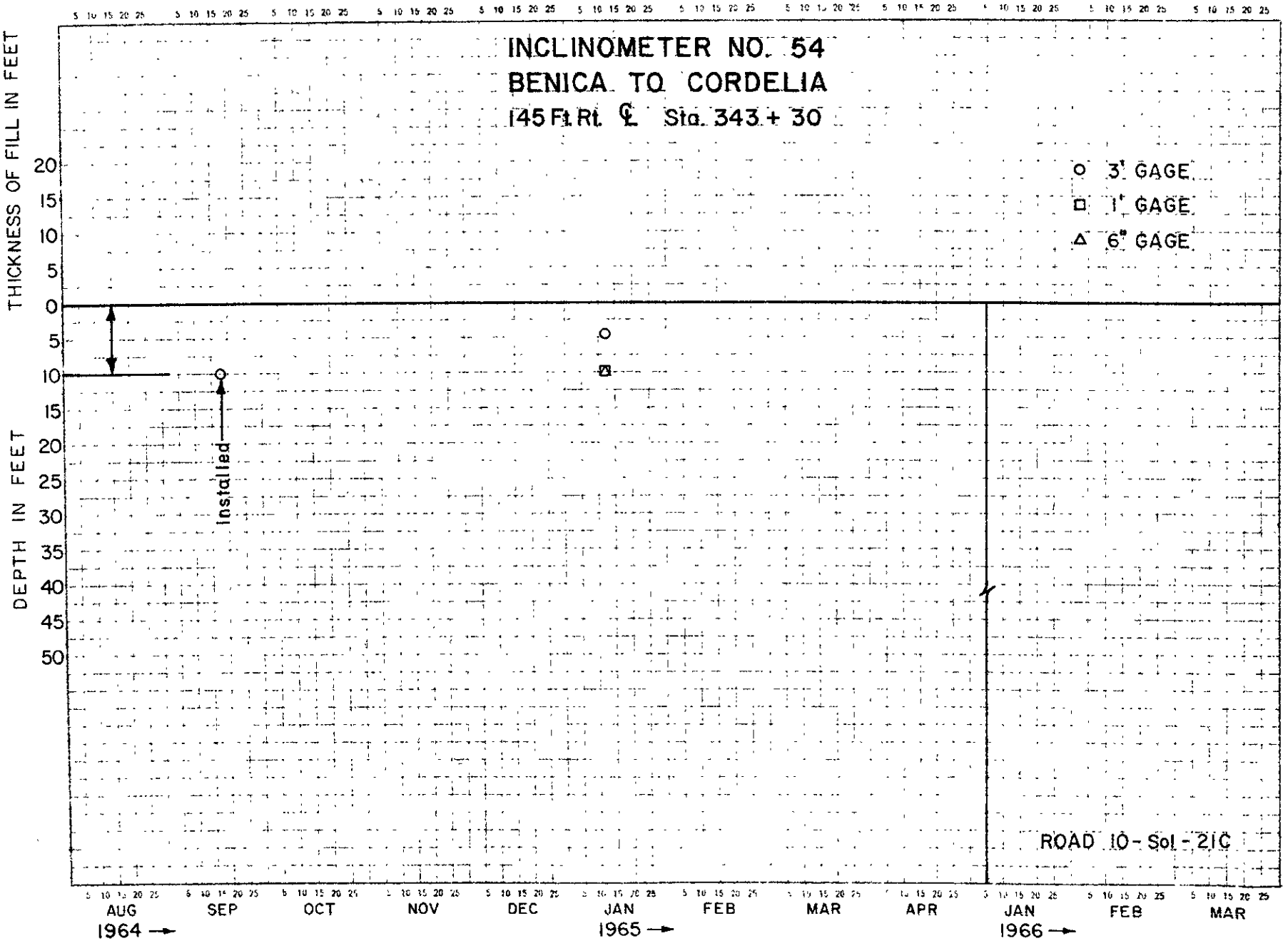

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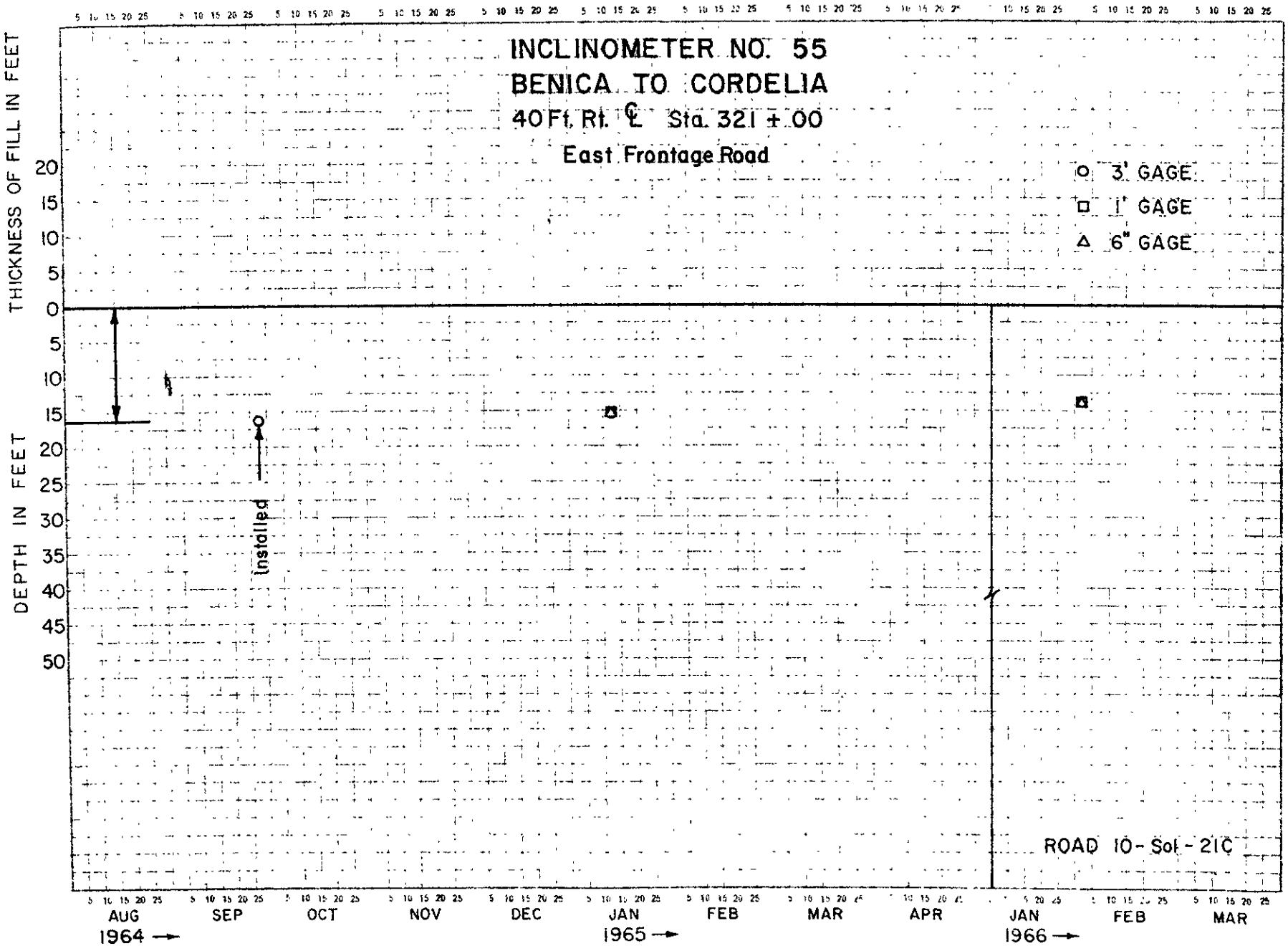

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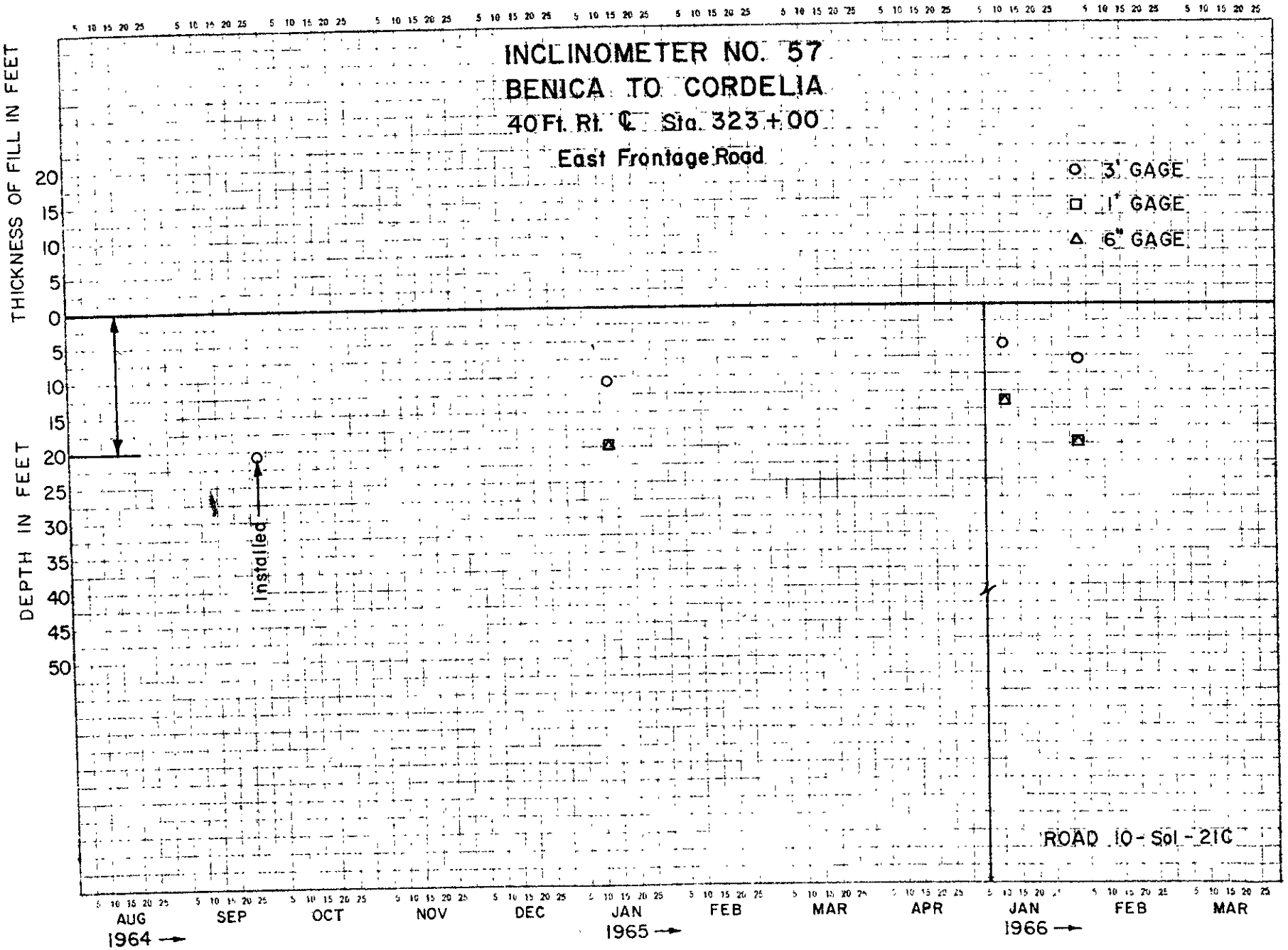

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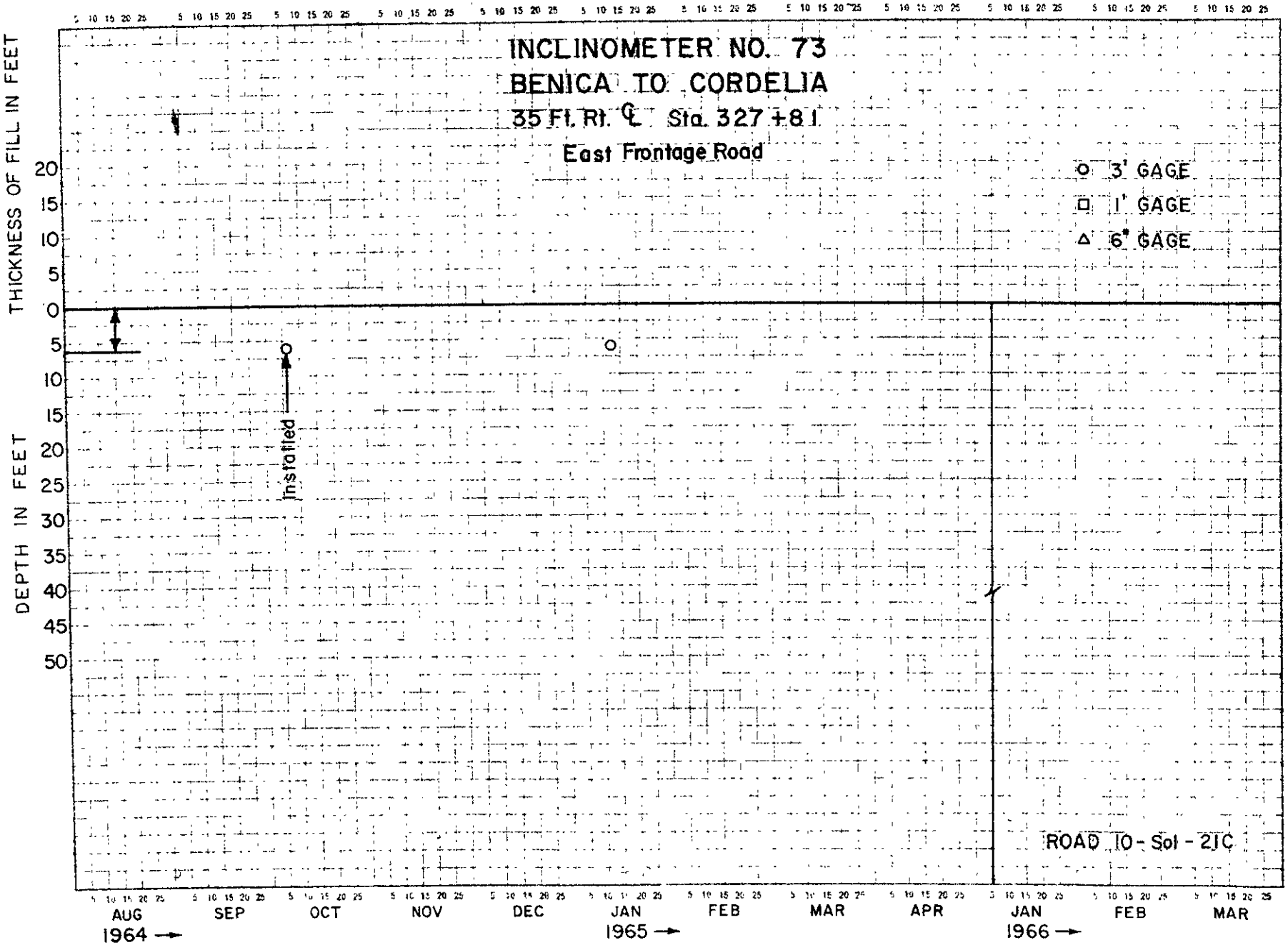

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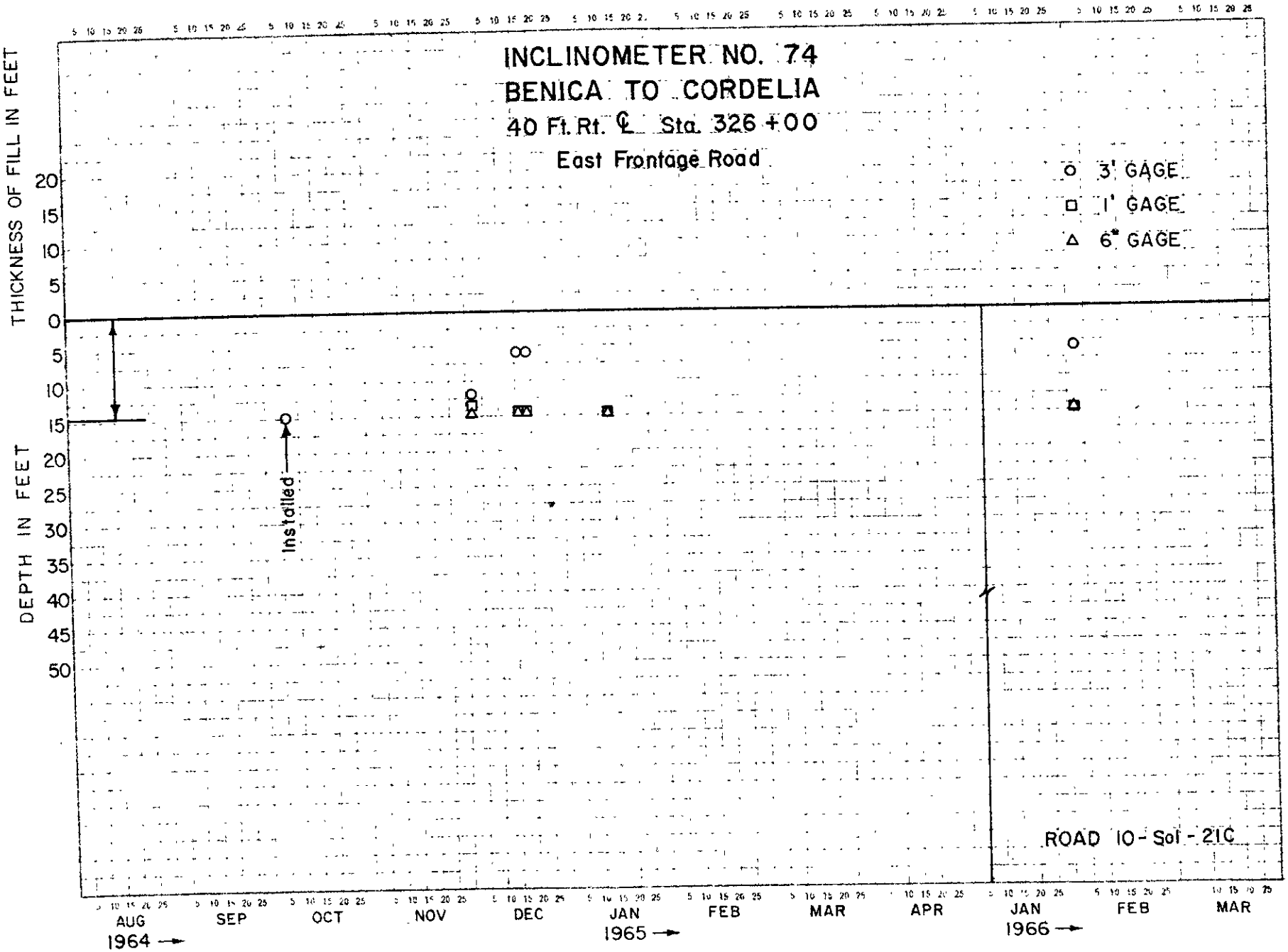

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 1

ROAD 10-Sol-21

Station 117 | Station 117+50 | Station 118 | Station 118+50

Thickness of Fill at Ult. ℄ - feet

Elevation Heave Stakes - feet

Horizontal Movement - feet

no reading
covered with water

Jun Jul Aug Sep Oct Nov Dec Jan Feb
1964 1965

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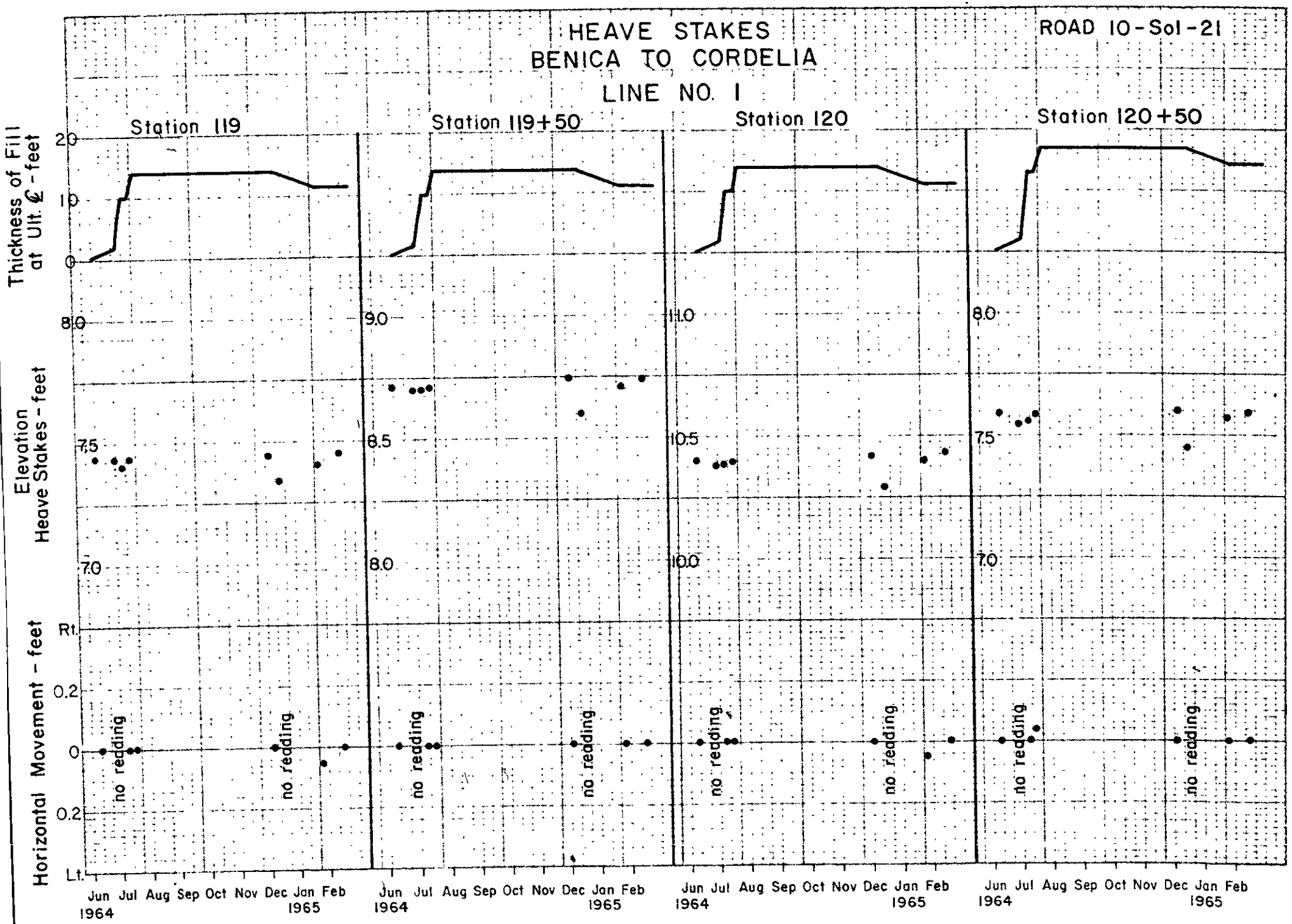
HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 1

ROAD 10-Sol-21



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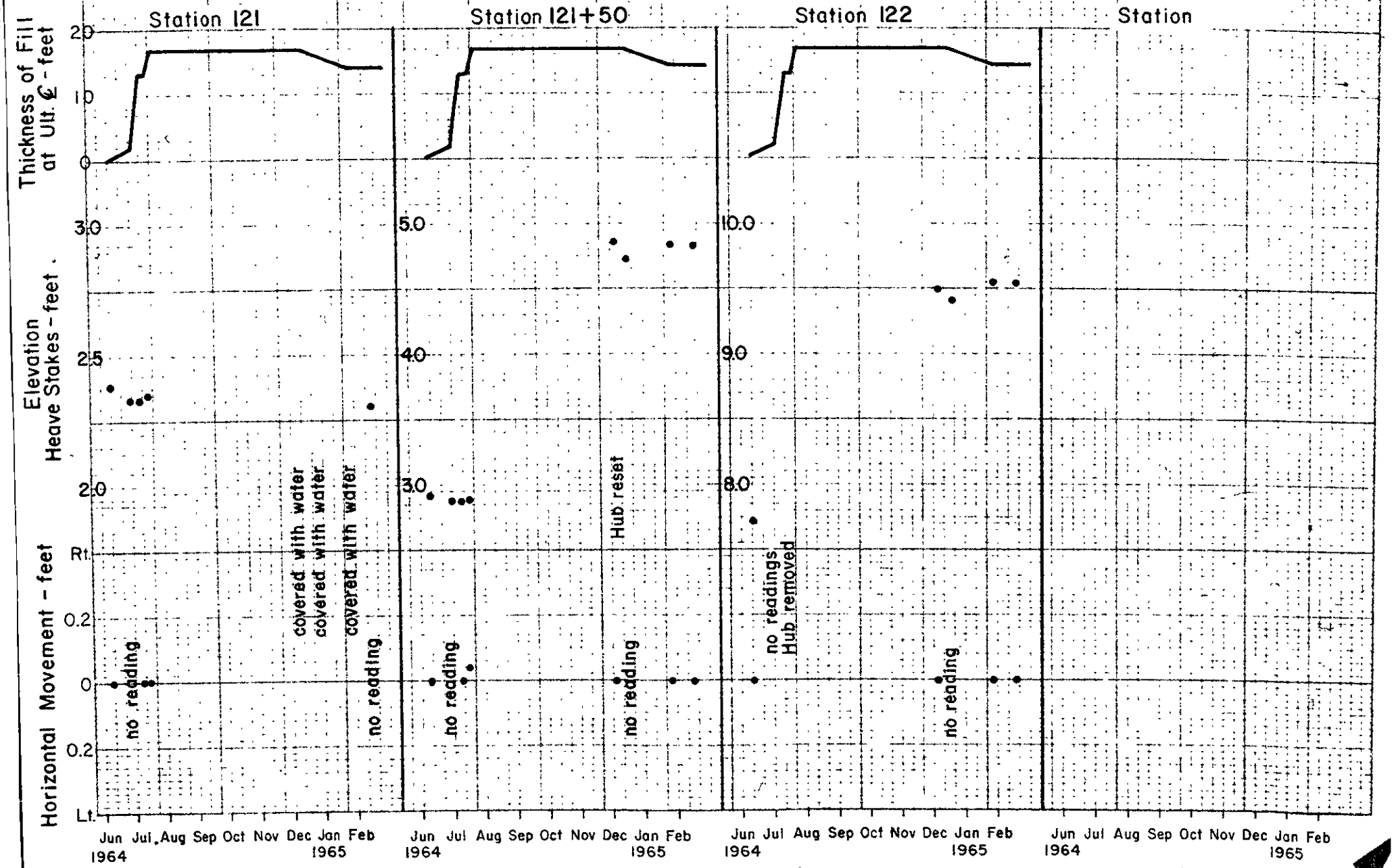
HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 1

ROAD 10-Sol-21



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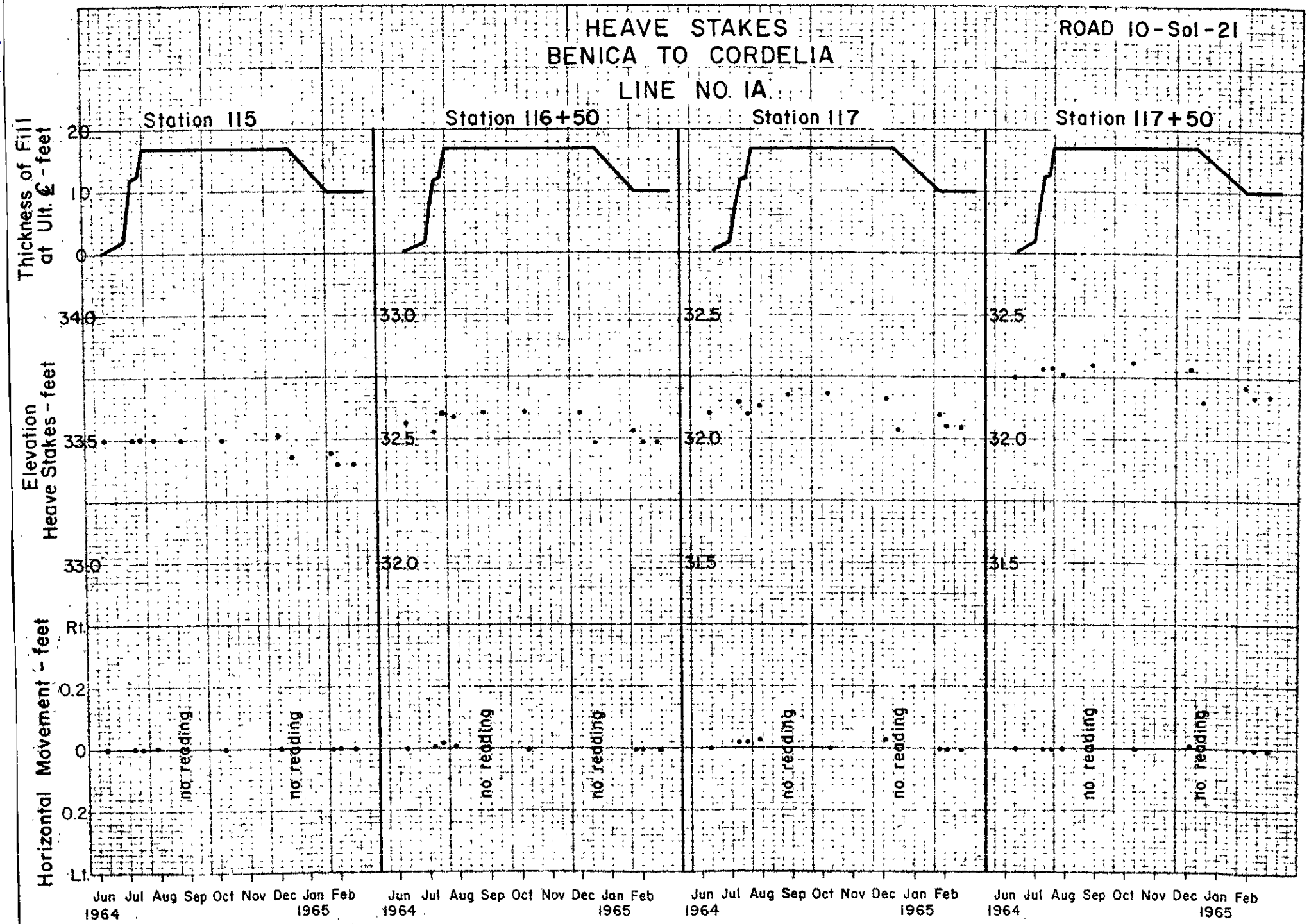

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 1A

ROAD 10-Sol-21

Station 118 | Station 118+50 | Station 119 | Station 119+50

Thickness of Fill at Ult. ℄ - feet

20
10
0

Elevation Heave Stakes - feet

Station 118	Station 118+50	Station 119	Station 119+50
32.5	32.5	32.5	32.0
32.0	32.0	32.0	31.5
31.5	31.5	31.5	31.0

Horizontal Movement - feet

Rt.
0.2
0
0.2
Lt.

no reading

Jun Jul Aug Sep Oct Nov Dec Jan Feb
1964 1965

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 1A

ROAD 10-Sol-21

Station 120 | Station 120+50 | Station 121 | Station 121+59

Thickness of Fill at Ult. ℄ - feet

20
10
0

Elevation Heave Stakes - feet

Station 120	Station 120+50	Station 121	Station 121+59
31.5	31.0	31.0	30.5
31.0	30.5	30.5	30.0
30.5	30.3	30.0	29.5

Horizontal Movement - feet

Rt.
0.2
0
0.2
Lt.

no reading

Jun Jul Aug Sep Oct Nov Dec Jan Feb
1964 1965

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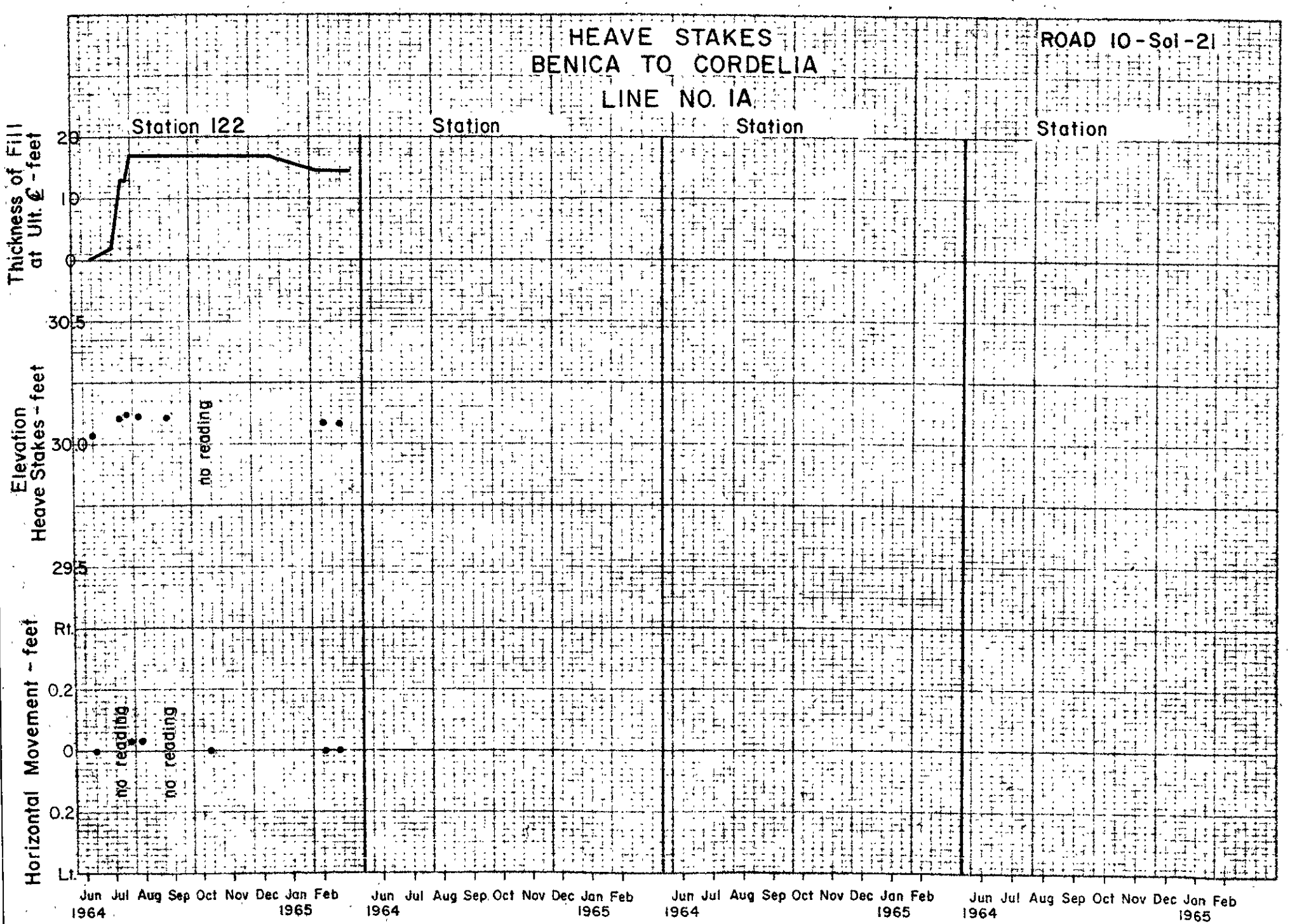
HEAVE STAKES
BENICA TO CORDELIA
LINE NO. IA

ROAD 10-Sol-21



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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 18

ROAD 10-Sol-21

Station 116 | Station 117 | Station 118 | Station 119

Thickness of Fill at Ult. ℄ - feet

Elevation Heave Stakes - feet

Horizontal Movement - feet

Rt. 0.2 0 0.2 Lt.

no reading

no reading

no reading

Hub destroyed

no readings

no reading

Jun Jul Aug Sep Oct Nov Dec Jan Feb
1964 1965

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 1B

ROAD 10-Sol-21

Station 120 | Station 121 | Station 122 | Station 123

Thickness of Fill at Ult. ℄ - feet

Elevation Heave Stakes - feet

Horizontal Movement - feet

no reading

Jun Jul Aug Sep Oct Nov Dec Jan Feb
1964 1965

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 2

ROAD 10-Sol-21

Station 193 | Station 194 | Station 195 | Station 196

Thickness of Fill at Ult. ℄ - feet

Elevation Heave Stakes - feet

Horizontal Movement - feet

Rt. / Lt.

covered with water

no reading

2.0

0.50

0.52

0.48

7.3

4.36

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 2

ROAD 10-Sol-21

Station 197 | Station 198 | Station 199 | Station 200

Thickness of Fill at Ult. ℄ - feet

Elevation Heave Stakes - feet

Horizontal Movement - feet

Rt / Lt

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Station 197: 6.65; 1.64; 1.83; no reading; no reading; no reading; 1.91; no reading; 16.6

Station 198: 5.79; 1.48; no reading; 1.75; no reading; no reading; 1.85; no reading; 18.3

Station 199: 0.62; no reading; no reading; 0.72; no reading; 4.8

Station 200: 2.38; no reading; no reading; no reading; no reading; 1.0

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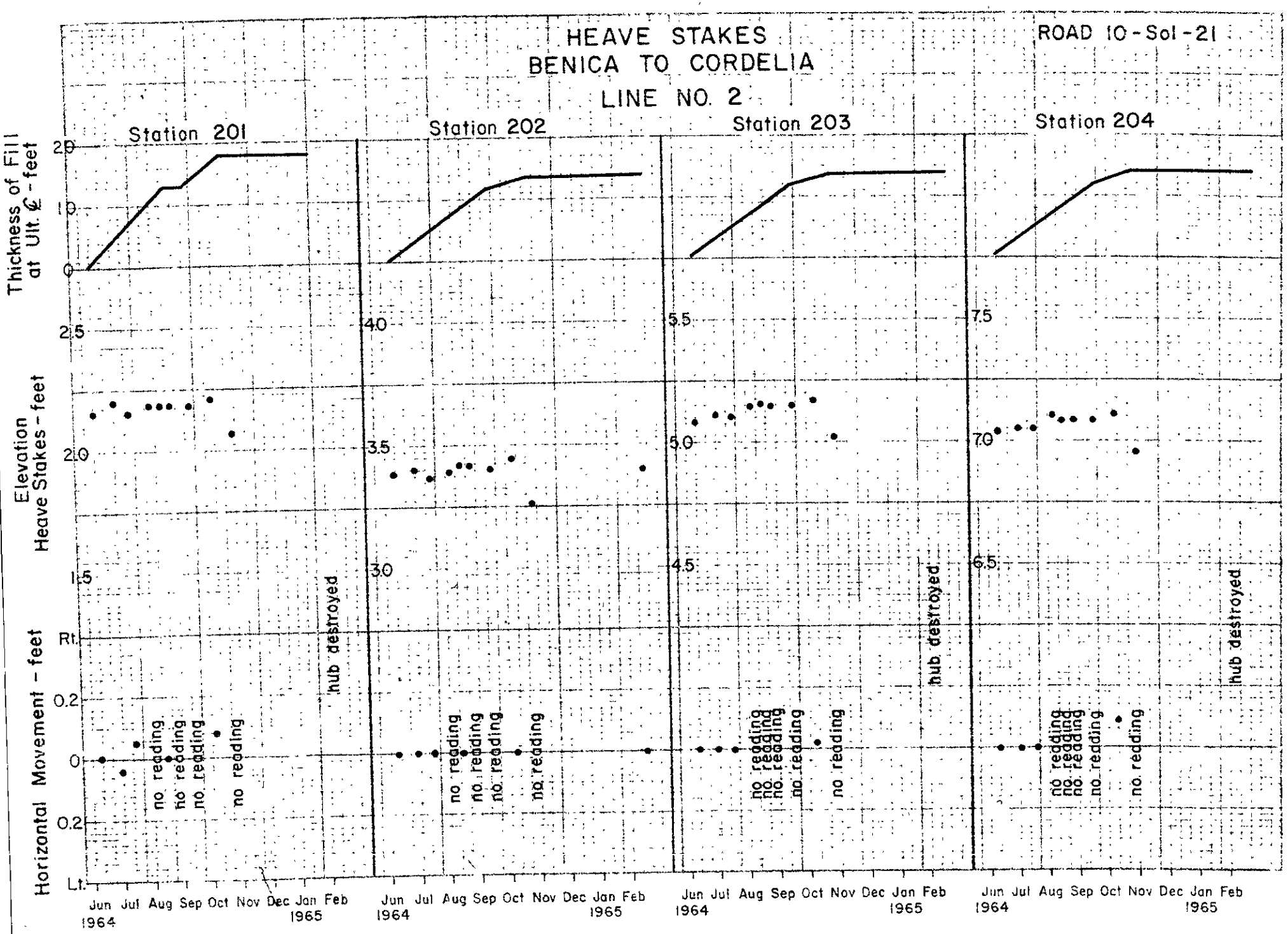

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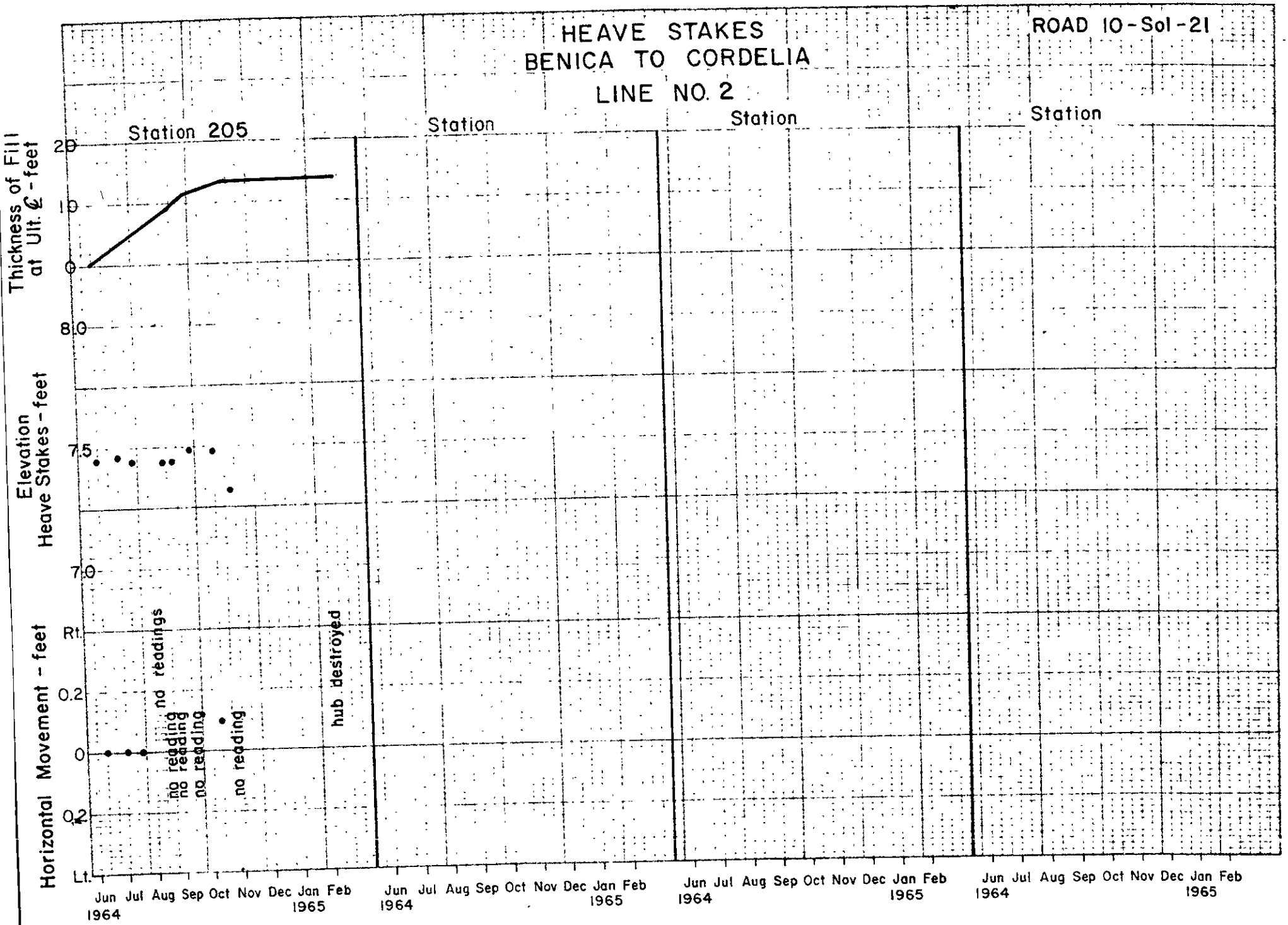

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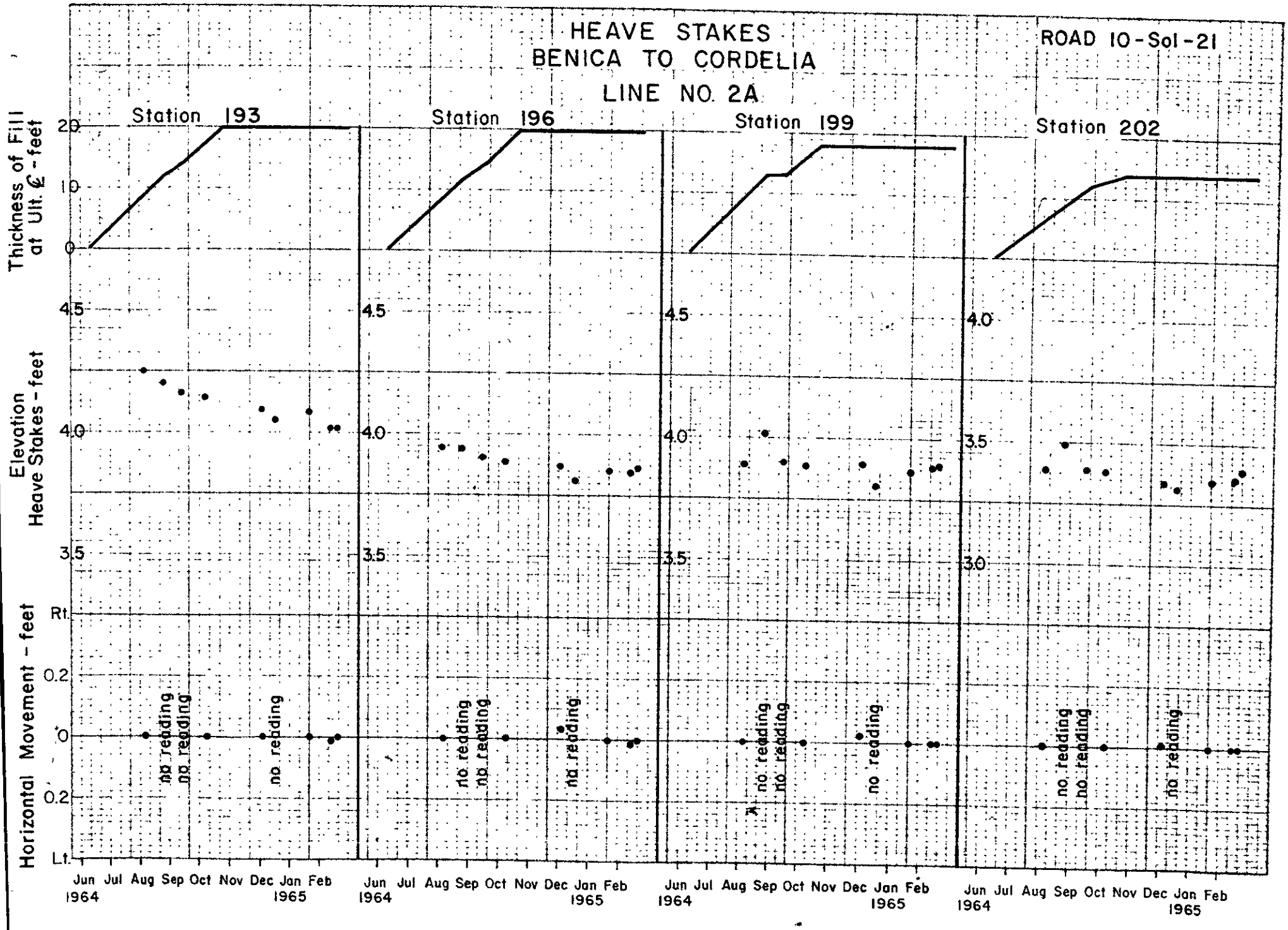

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 2A

ROAD 10-Sol-21

Station 205 | Station | Station | Station

Thickness of Fill at Ult. ℄ - feet

Elevation Heave Stakes - feet

Horizontal Movement - feet

20
10
0
3.0
2.5
2.0
Rt.
0.2
0
0.2
Lt.

no reading
no reading
covered with water

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 3

ROAD 10-Sol-21

Station 309 | Station 310 | Station 311 | Station 312

Thickness of Fill at Ult. ℄ - feet

Elevation Heave Stakes - feet

Horizontal Movement - feet

Station 309: 20, 10, 0, 9.5, 9.0, 8.5, Rt. 0.2, 0, 0.2, Lt.

Station 310: 11.0, 10.5, 10.0

Station 311: 13.5, 13.0, 12.5

Station 312: 13.5, 13.0, 12.5

no reading
no reading
hub destroyed

no reading
no reading
hub destroyed

no reading
no reading
no reading
no reading

no reading
no reading
no reading
no reading

Jun Jul Aug Sep Oct Nov Dec Jan Feb
1964 1965

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 3

ROAD 10-Sol-21

Station 313 | Station | Station | Station

Thickness of Fill at Ult. ℄ - feet

Elevation Heave Stakes - feet

Horizontal Movement - feet

20
10
0
14.0
13.5
13.0
Rt.
0.2
0
0.2
Lt.

no reading
no reading
no reading
no reading

Jun Jul Aug Sep Oct Nov Dec Jan Feb
1964 1965

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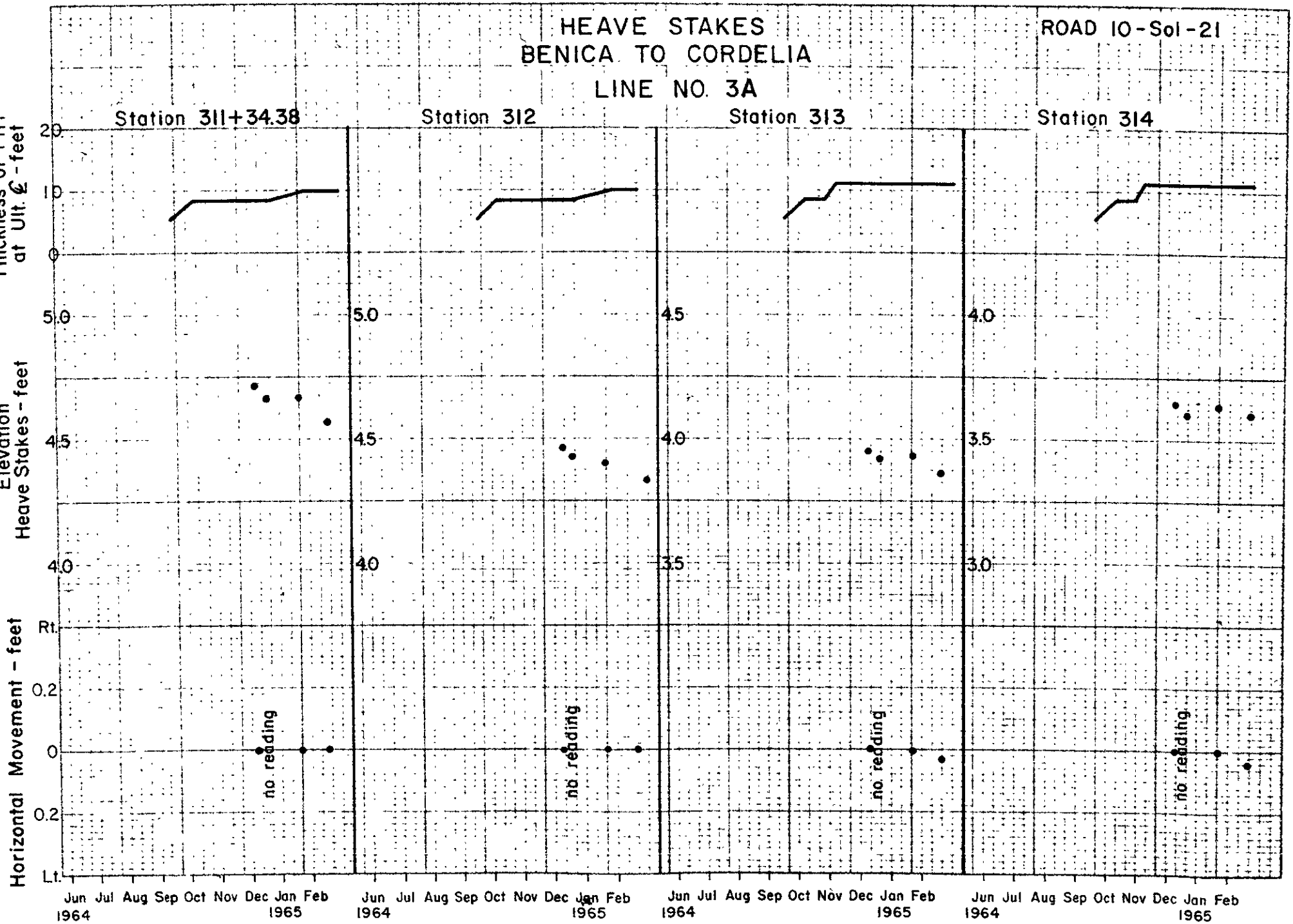

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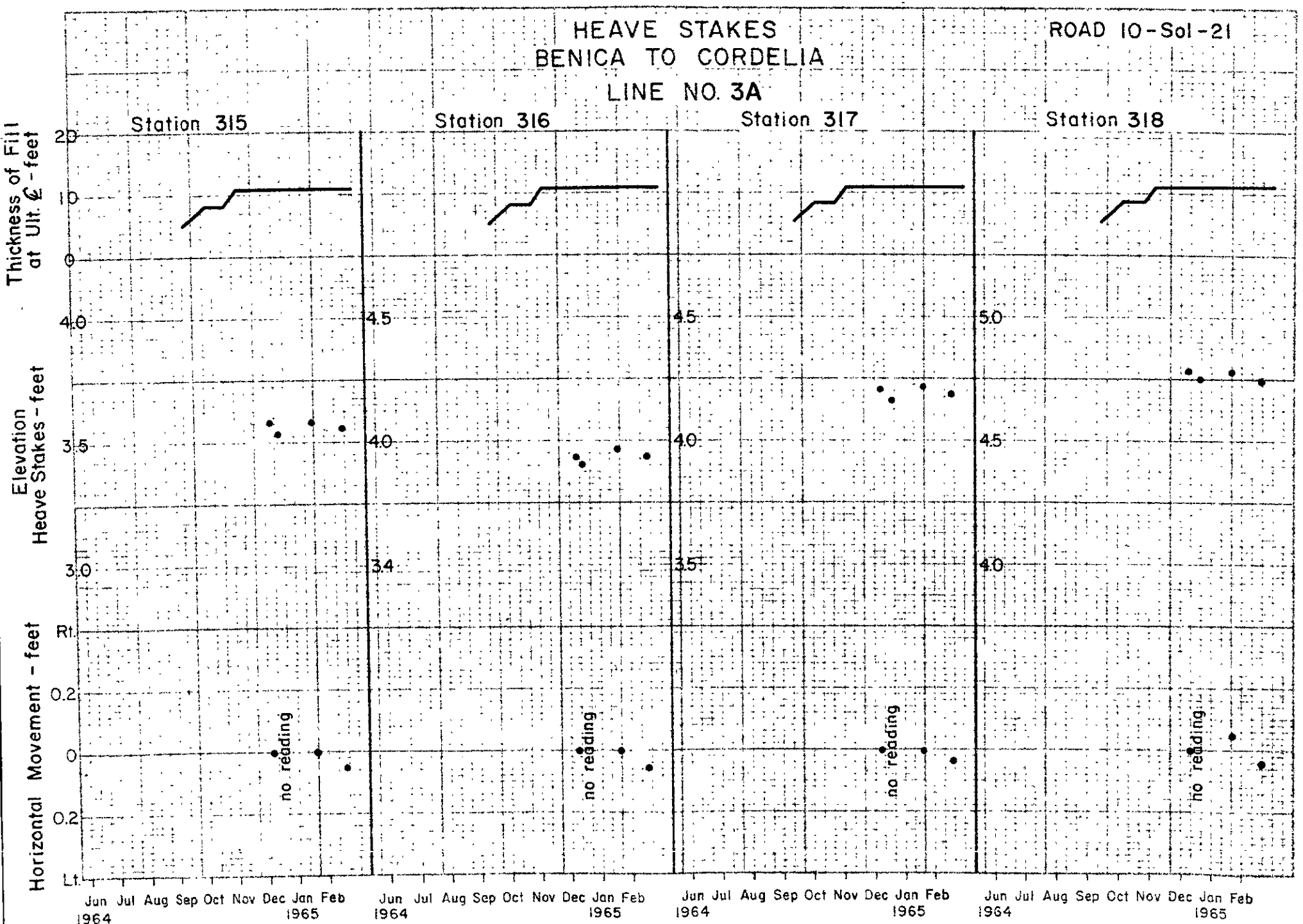

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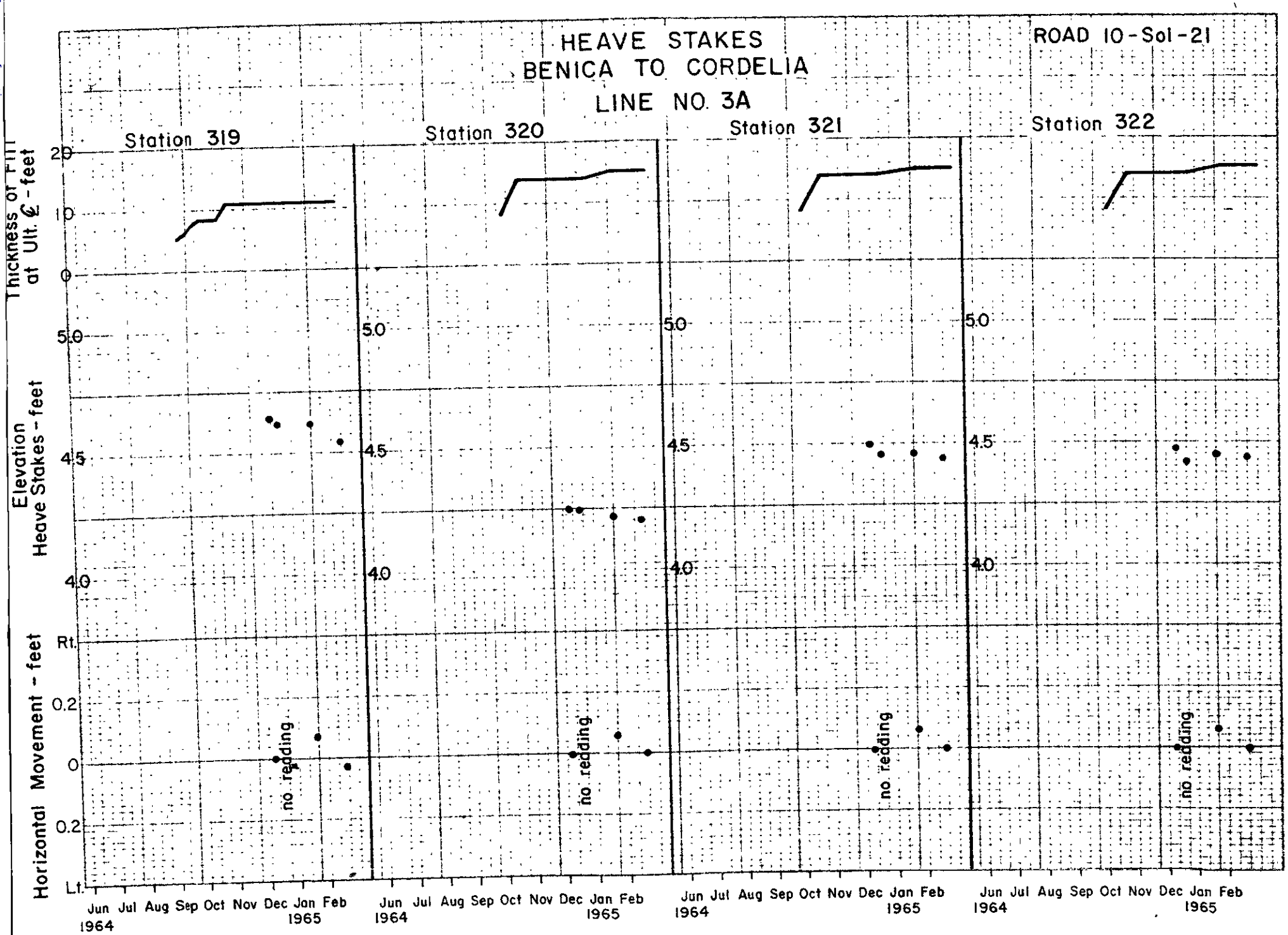

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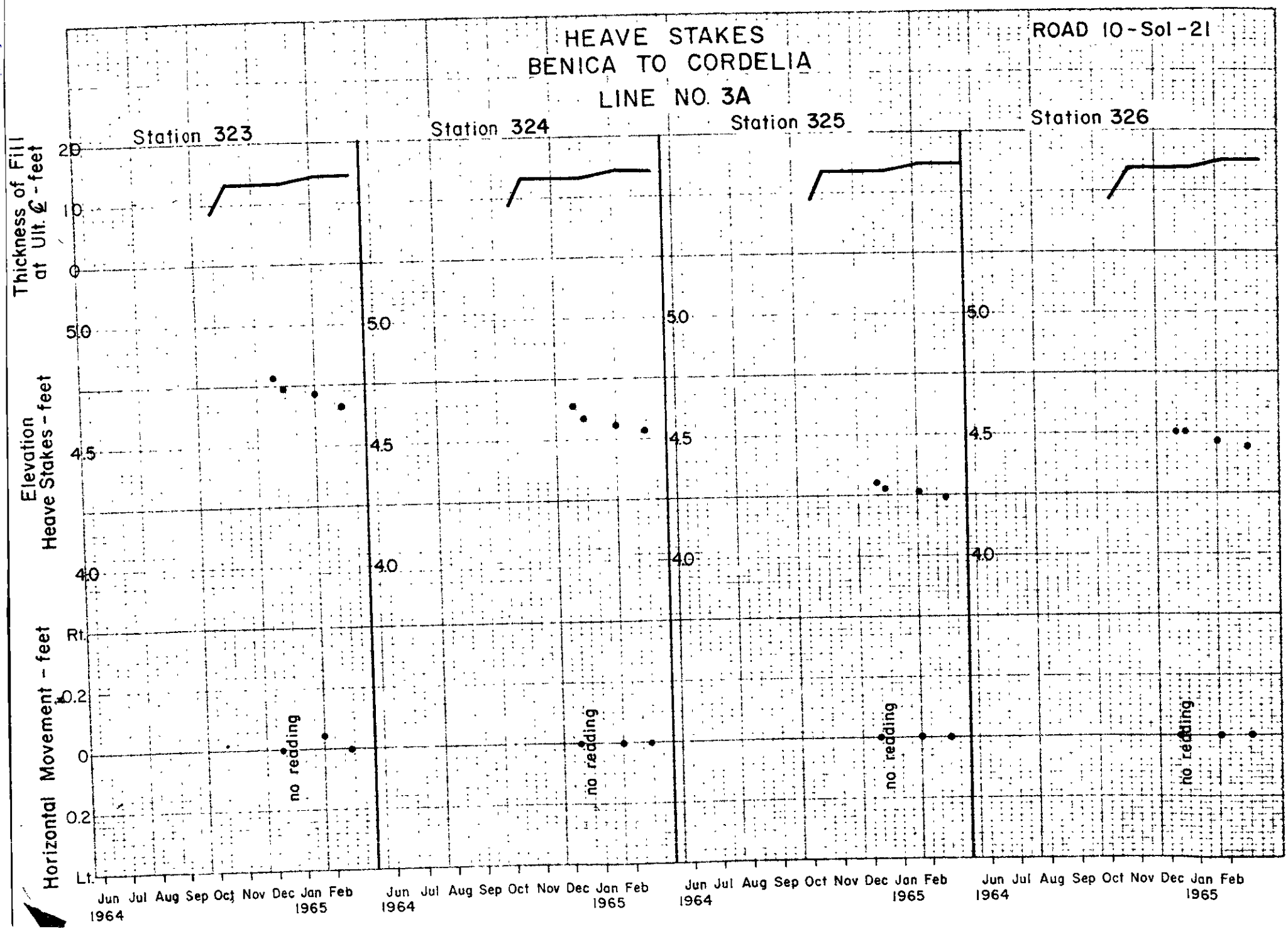

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 3A

ROAD 10-Sol-21

Station 327 | Station | Station | Station

Thickness of Fill at Ult. ℄ - feet

Elevation Heave Stakes - feet

Horizontal Movement - feet

20
10
0
5.0
4.5
4.0
Rt.
0.2
0
0.2
Lt.

no reading

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1964 1965

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 3B

ROAD 10-Sol-21

Station 319 | Station 320 | Station 321 | Station 322

Thickness of Fill at Ult. ℄ - feet

Elevation Heave Stakes - feet

Horizontal Movement - feet

no reading

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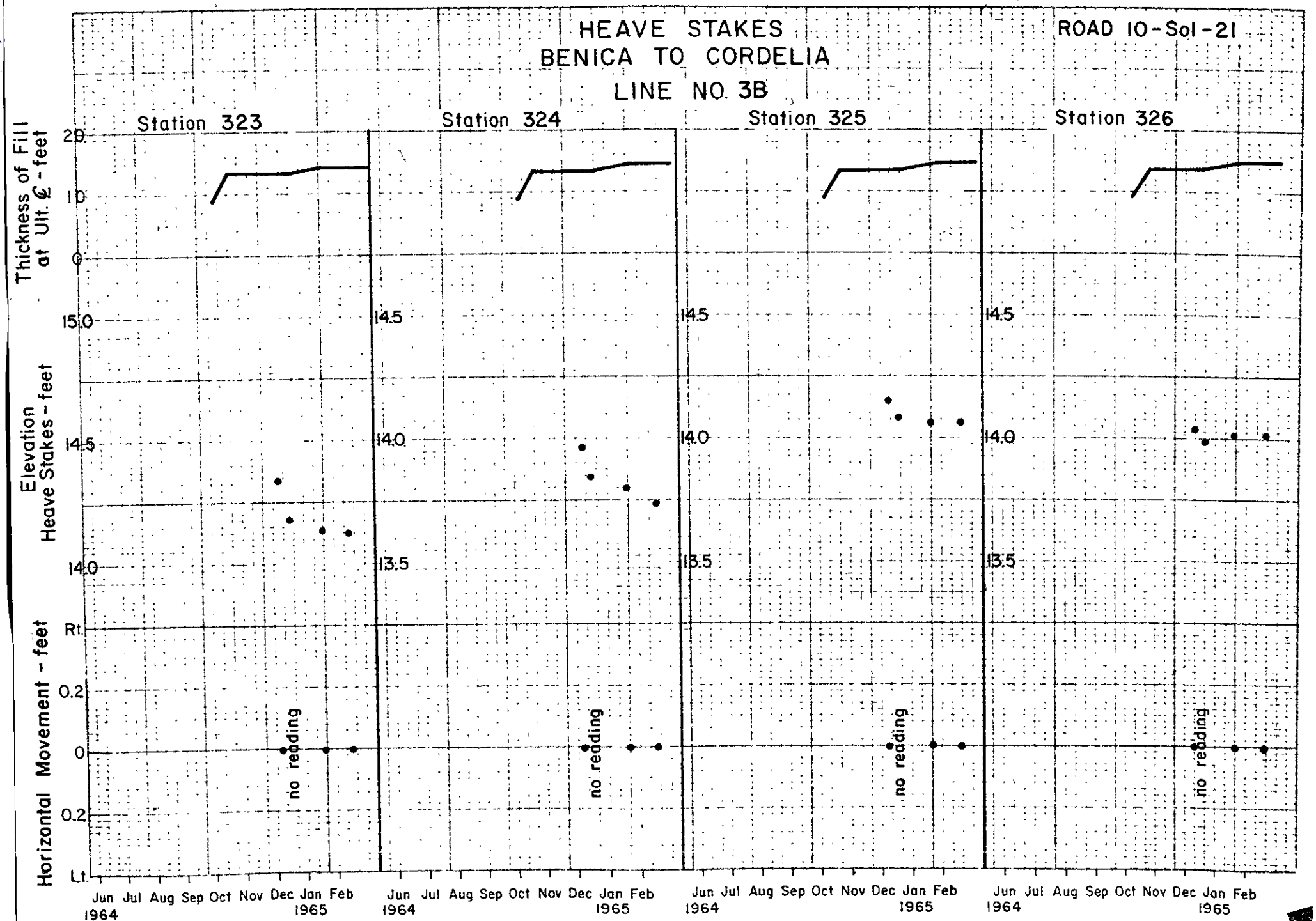
HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 3B

ROAD 10-Sol-21



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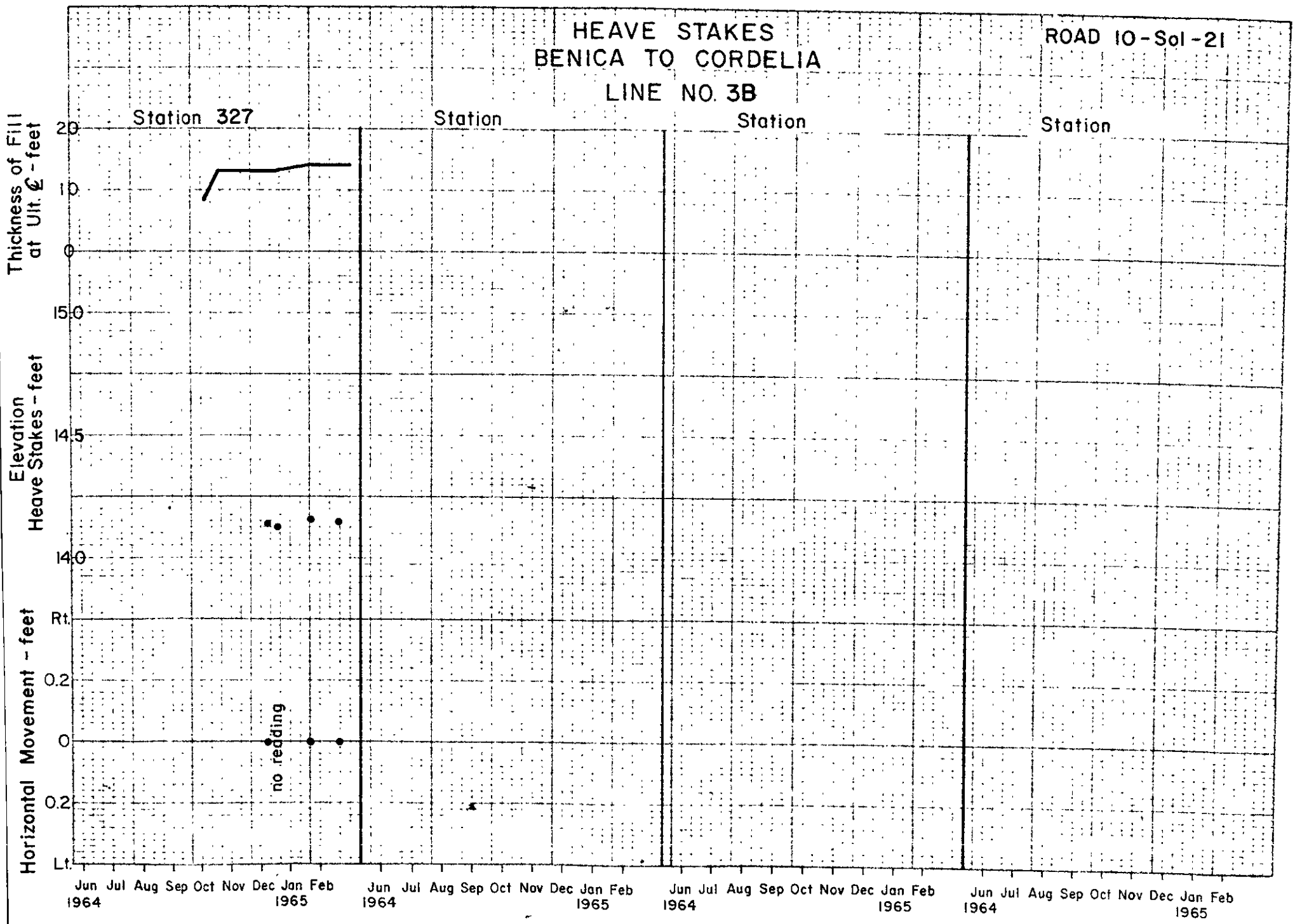

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 3C

ROAD 10-Sol-21

Station 341 | Station 342 | Station 343 | Station 344

Thickness of Fill at Ult. ℄ - feet

20
10
0

Elevation Heave Stakes - feet

17.0 | 18.0 | 19.0 | 20.0
16.5 | 17.5 | 18.5 | 19.5
16.0 | 17.0 | 18.0 | 19.0

Horizontal Movement - feet

Rt.
0.2
0
0.2
Lt.

no reading

Jun Jul Aug Sep Oct Nov Dec Jan Feb
1964 1965

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HEAVE STAKES
BENICA TO CORDELIA
LINE NO. 3C

ROAD 10-Sol-21

Station 345 | Station 346 | Station | Station

Thickness of Fill at Ult. ℄ - feet

20
10
0

Elevation Heave Stakes - feet

20.0
19.5
19.0

Horizontal Movement - feet

Rt.
0.2
0
0.2
Lt.

no reading

no reading

Jun Jul Aug Sep Oct Nov Dec Jan Feb
1964 1965