

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle "Continuing Measurements of a Swelling Clay in a Ponded Cut"		5. Report Date December 1974	6. Performing Organization Code
7. Author(s) Malcolm L. Steinberg		8. Performing Organization Report No. Research Report 118-8	
9. Performing Organization Name and Address Center for Highway Research The University of Texas at Austin Austin, Texas 78712		10. Work Unit No.	11. Contract or Grant No. Research Study 3-8-68-118
12. Sponsoring Agency Name and Address Texas Highway Department Planning & Research Division P. O. Box 5051 Austin, Texas 78763		13. Type of Report and Period Covered Final January 1970 - August 1973	
14. Sponsoring Agency Code			
15. Supplementary Notes Work done in cooperation with the Federal Highway Administration, Department of Transportation. Research Study Title: "Study of Expansive Clays in Roadway Structural Systems"			
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17. Key Words expansive clay, ponding, potential vertical rise, moisture content, elevation rods, evaporative seal, lime		18. Distribution Statement	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 43	22. Price

CONTINUING MEASUREMENTS OF A
SWELLING CLAY IN A PONDED CUT

by

Malcolm L. Steinberg

Research Report 118-8

Study of Expansive Clays in
Roadway Structural Systems
Research Project 3-8-68-118

conducted for

The Texas Highway Department

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR HIGHWAY RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

December 1974

The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PREFACE

This report is the eighth in a series developed under Research Study 3-8-68-118, "Study of Expansive Clays in Roadway Structural Systems." It provides recent information from studies of a ponded cut in an expansive clay in Bexar County reported in Research Report 118-6. Results from adjacent non-ponded sections are also recorded and appropriate comparisons made. Thanks are due to the sponsors of the overall study, the Texas Highway Department and the Federal Highway Administration.

LIST OF REPORTS

Report No. 118-1, "Theory of Moisture Movement in Expansive Clay" by Robert L. Lytton, presents a theoretical discussion of moisture movement in clay soil.

Report No. 118-2, "Continuum Theory of Moisture Movement and Swell in Expansive Clays" by R. Ray Nachlinger and Robert L. Lytton, presents a theoretical study of the phenomenon of expansive clay.

Report No. 118-3, "Prediction of Moisture Movement in Expansive Clay" by Robert L. Lytton and Ramesh K. Kher, uses the theoretical results of Research Reports 118-1 and 118-2 in developing one and two-dimensional computer programs for solving the concentration-dependent partial differential equation for moisture movement in expansive clay.

Report No. 118-4, "Prediction of Swelling in Expansive Clay" by Robert L. Lytton and W. Gordon Watt, uses the theoretical results presented in Research Report 118-1 and the moisture distribution computer programs of Research Report 118-3 to arrive at a method for predicting vertical swelling in one and two-dimensional soil regions.

Report No. 118-5, "An Examination of Expansive Clay Problems in Texas" by John R. Wise and W. Ronald Hudson, examines the problems of expansive clays related to highway pavements and describes a field test in progress to study the moisture-swell relationships in an expansive clay.

Report No. 118-6, "Measurements of a Swelling Clay in a Poned Cut," by W. Gordon Watt and Malcolm L. Steinberg, reviews the use of ponding as a solution to the problem of swelling clays and presents the procedures used and results obtained to date from a ponding project conducted in 1970 in San Antonio, Texas.

Report No. 118-7, "The Waco Ponding Project," by Robert L. McKinney, Jr., James E. Kelly, and Chester McDowell, presents results of 1957-72 field studies concerned with the effectiveness of ponding and lime stabilization of clay subgrade in minimizing volume change beneath portland cement concrete pavements.

Report No. 118-8, "Continuing Measurements of a Swelling Clay in a Poned Cut," by Malcolm Steinberg, brings up to date the results of studies of a ponded cut in an expansive clay in Bexar County.

ABSTRACT

Initial work on a ponded cut in an expansive clay in Bexar County was reported in Research Report 118-6. Developments since then are reported here and include the setting of additional measuring devices, testing and continuing observations, ponding of additional sites, and recording and evaluation of the data.

KEY WORDS: expansive clay, ponding, potential vertical rise, moisture content, elevation rods, evaporative seal, lime.

SUMMARY

This report continues to explore the effects of ponding, the technique of flooding a clay subgrade with water to cause the soil surface to heave before a pavement is constructed rather than after. Results of observations of the maintenance problems and pavement conditions are noted and an attempt is made to relate the depths of movement and effectiveness of the ponding with the longer range goal of developing a method for reducing costs of roadway life.

IMPLEMENTATION STATEMENT

Ponding is a practical method of causing a soil which may heave to do so before a pavement is placed rather than after. The findings of this study continue to support those reported in Research Report 118-6.

If the potential vertical rise seems likely to exceed one inch and the facility merits it, ponding should be set up on cut and fill sections together with sand drains through the zone of instability to get the moisture well into the expansive clay. An evaporative seal of lime, or perhaps emulsion asphalt with wide shoulders and easily drained ditches, seems worthwhile. Flexible asphaltic base and pavement systems seem possibly to function with the least distress and maintenance costs on these expansive clays.

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I. INTRODUCTION

This report brings studies of a ponded cut in an expansive clay in Bexar County up to date. The initial work was reported in Research Report 118-6. This report reflects developments following the first report: the setting of additional measuring devices, testing and continuing observations, ponding of additional sites, and recording and evaluation of the data. Results of observations of the maintenance problems and pavement conditions are noted. An attempt is made to relate the depths of movement and effectiveness of the ponding with the longer range goal of developing a method for reducing costs of roadway life. Reference to Report 118-6 is recommended; duplication of data is not intended in this report.

II. OTHER RESEARCH

The problem of swelling clay is receiving increased attention. A report by the Mississippi Highway Department in cooperation with the U.S. Department of Transportation Federal Highway Administration and Mississippi State University authored by Teng et al (Ref 6) notes that damage from swelling clays in the United States is estimated to exceed one billion dollars in one year. Their study covers a research project of 4,400 feet on a Mississippi highway contract in an expansive Yazoo clay of which 1,100 feet were ponded, about half in a cut and the remainder in a fill section. Sand drains were drilled to a depth of 20 feet prior to 140 days of ponding. Swells in excess of a foot were recorded in cut sections and the fill sections swelled almost 0.5 foot. Another part of the test section included a heavy asphalt subsurface seal. Results two years after contract completion indicate no surface movement in the ponded sections and little movement in the asphalt seal areas (Ref 6).

The U.S. Army Waterways Experiment Station is also involved in a research project of considerable scope with the same Yazoo clay (Ref 4). Primarily a

test section with elevation rods and pressure and suction plates at varying depths below the surface, the project should provide some interesting practical data in the coming years. It is directed by Dr. L. D. Johnson, who has also been involved in expansive clay problems at Lackland Air Force Base in San Antonio. The application of these results to our highways should be useful.

Other publications relevant to the problem include one by Dr. R. L. Lytton which looks at the recurrence of the natural movement of these clays in definite patterns (Ref 5). An effort is made to relate the maintenance costs with the type of section used and the movements. The report does not provide a simple solution but offers a better grasp of the problems. Another Center for Highway Research study, a survey of earth slope failures and remedial measures, takes a practical look at problems closely related to those of swelling clays and control measures which have been tried (Ref 1). Halliburton's Oklahoma State University investigative series on subgrade moisture variations is also invaluable for expansive clay data (Ref 3).

III. PONDING THE REMAINING AREA OF CUT ON U.S. 90

The preliminary results from the first sections ponded in Bexar County in February 1970 stimulated interest (Fig 1). It was decided to expand the test sites to the area of the remaining ponding south of the survey line and to get two additional groups of elevation rods outside these areas as further control data sources. This new cut section was completed in January 1971, almost a year after the first areas were ponded. Ponding was completed on the sections from Station 263 to 274, Area 4 (Fig 2), in February 1971. Subgrade balancing and lime placement took place in the latter part of April. Next the sections from Station 242 to 250, Area 5, were ponded. The last area, from Station 250 to 263, was ponded in April, with lime placement and select material placement beginning in May and completed on July 1. The first groups ponded did not have select material placement completed until July 5. Of interest was the use of a surfactant with the water in one of the ponds. Use of the surfactant, which was donated by the manufacturer together with the services of his field engineer, who directed its placement, was viewed as a possible way to get the water deeper into the clay formation. No perceptible difference was noted in the quantity percolated nor was any significant change

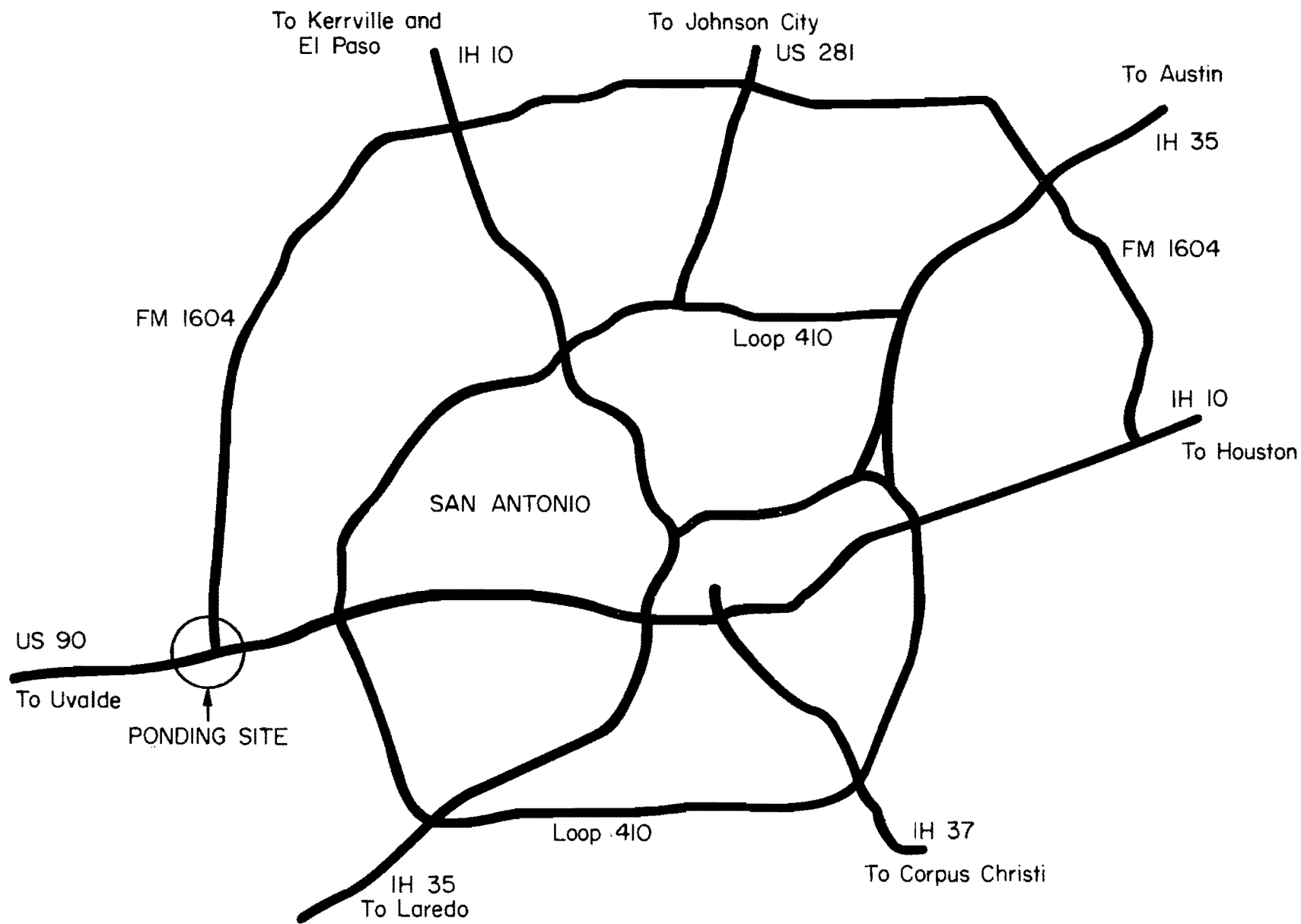


Fig 1. Location of ponding site.

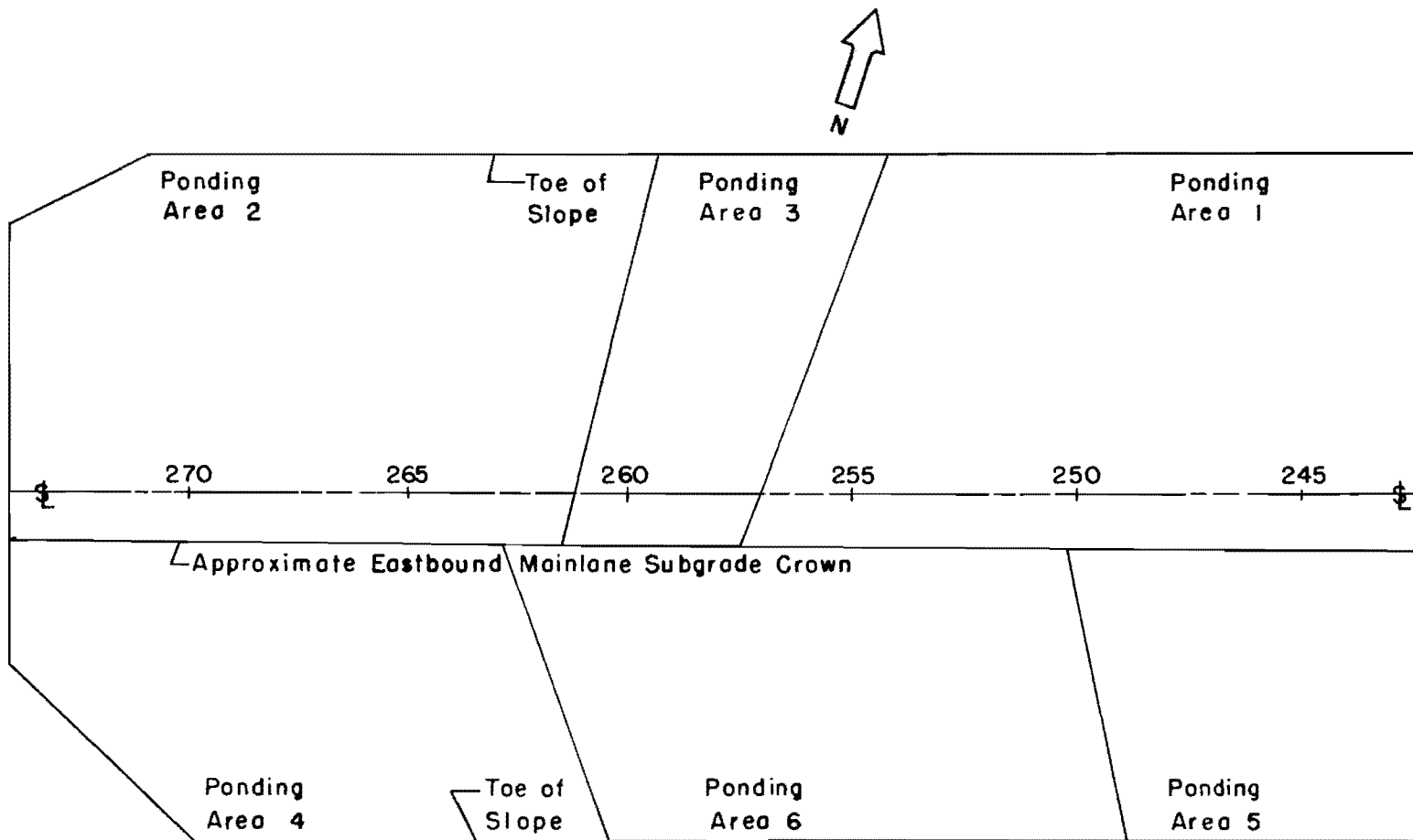


Fig 2. Layout of ponding areas.

observed in elevation or moisture readings. The combination did kill goldfish and its removal was carefully considered since the water remaining in the dikes after the ponding period was usually permitted to drain out through natural waterways. In this case it was fed into the stocktanks and its effect on larger animals was of concern.

IV. SUPPLEMENTAL INSTRUMENTATION AND TESTING

In late 1970, additional elevation rod groups were set at Stations 173 and 226, in the median area, and three groups of the same type were set 120 feet left of the survey line at Stations 245, 250 and 255. The groups out of the ponded area were thought of as control locations, the one at 173 having a high potential heave capability, according to Texas Test Method Tex-124-E. The latter three were in the second section to be ponded and were intended primarily as checks against the values of movements of those set initially at the same stations in the median area (Fig 3). The moisture results recorded were taken from samples secured by the drilling rig and tested at the District Laboratory.

V. RESULTS FROM THE ELEVATION RODS

Following the ponding, all of the first three groups of elevation rods set in the median had considerable heave at the 2-foot depth and have either held the rises or continued to move up over the three-and-a-half-year period of observation (Figs 4, 5, 6, 7, 8, and 9). The magnitude of the rises has ranged from almost 3 inches at Station 255, mostly during the ponding period, to almost 4 inches at Station 245, the bulk of which occurred immediately following ponding. At two of the three sites, in the first readings after ponding, heaves were noted in the rods set at the 4.5-foot depth, although they were of less magnitude than those in the shallower rods. Movement from the deeper rods has been recorded at only one location, Station 245, at 10.5 feet, and that was about two years after the ponding. The three sets of rods grouped at Stations 245 (120 feet left), 250 (112 feet left), and 255

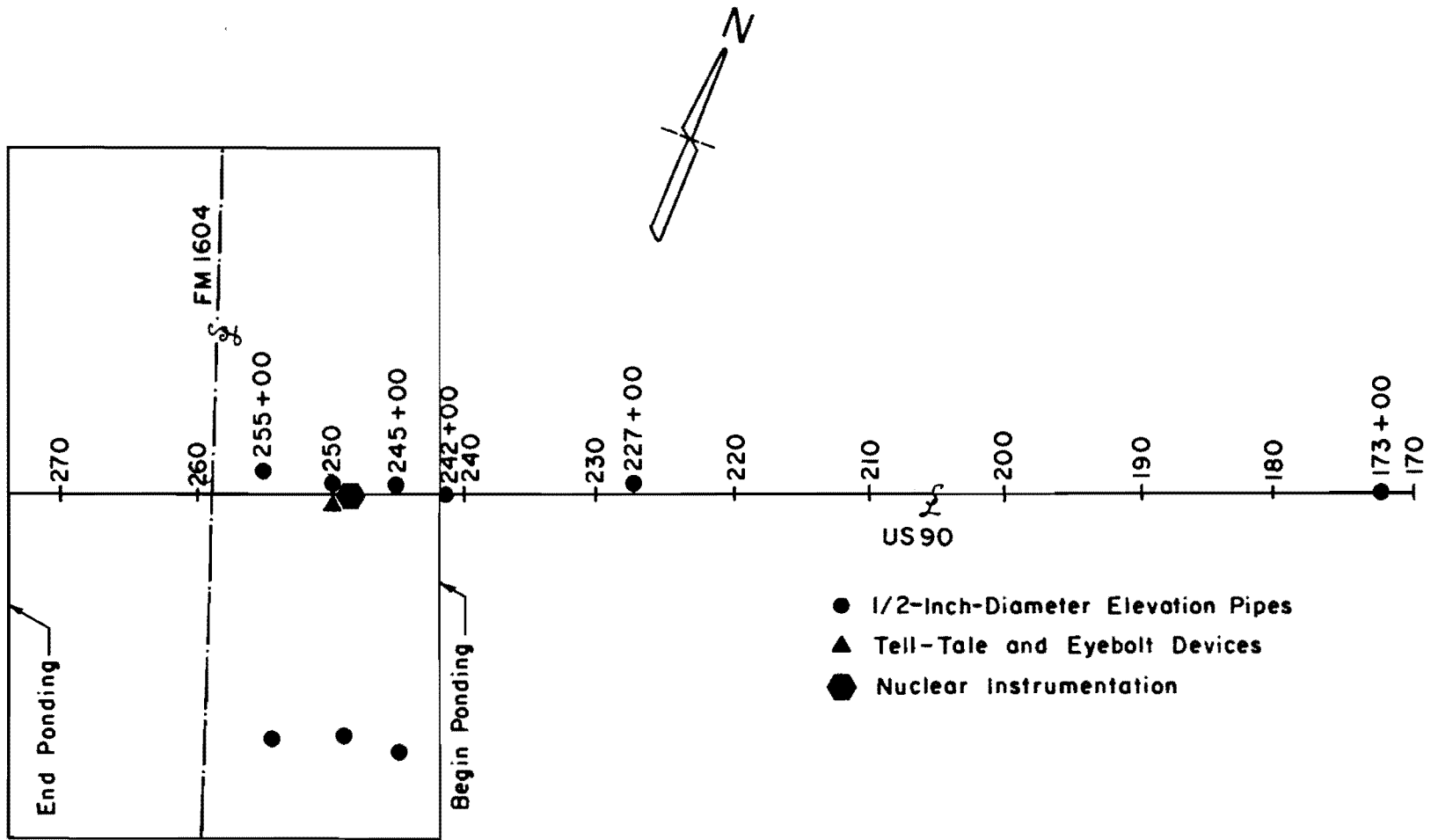


Fig 3. Locations of various test devices.

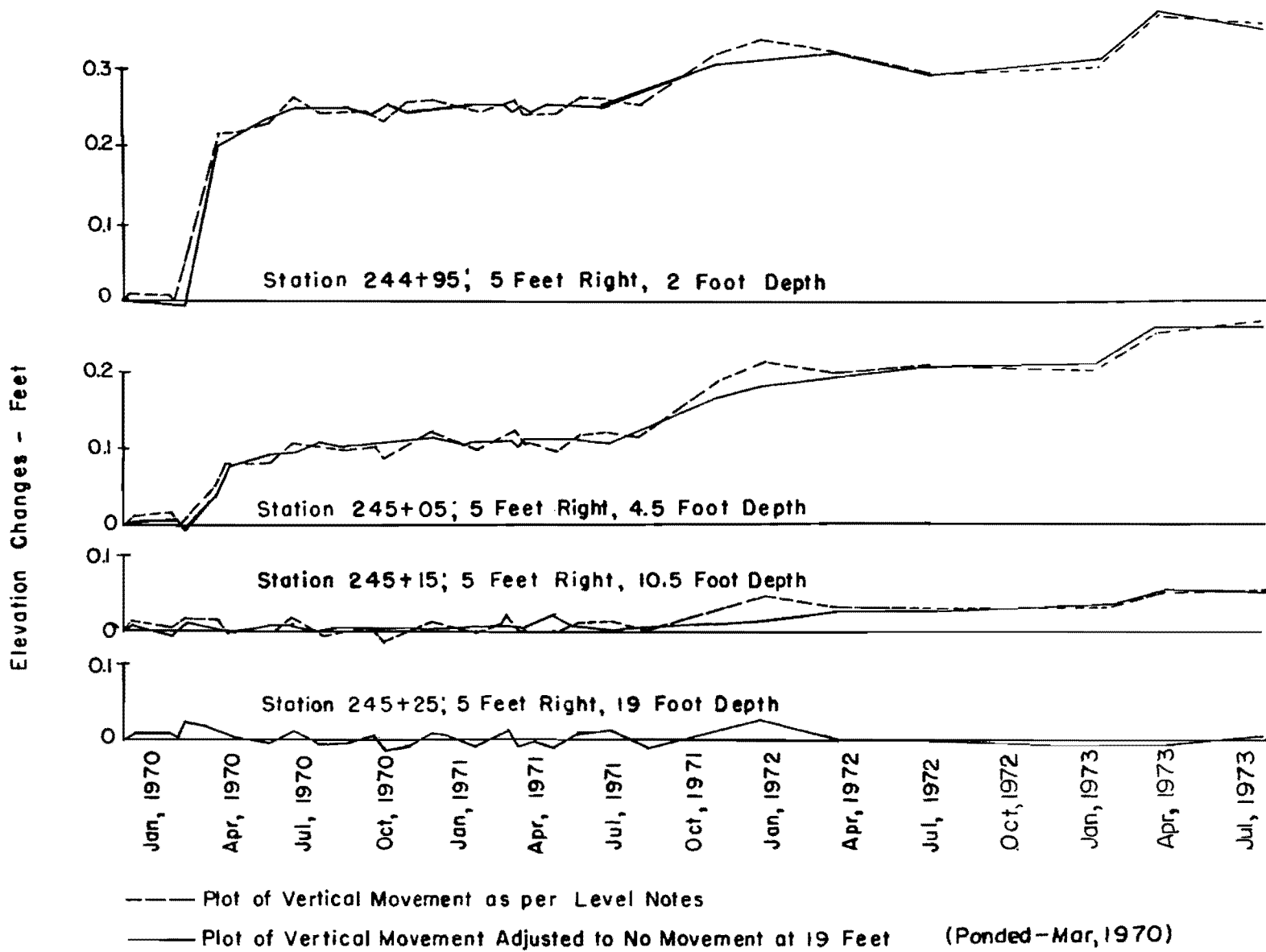


Fig 4. Vertical movement at station 245.

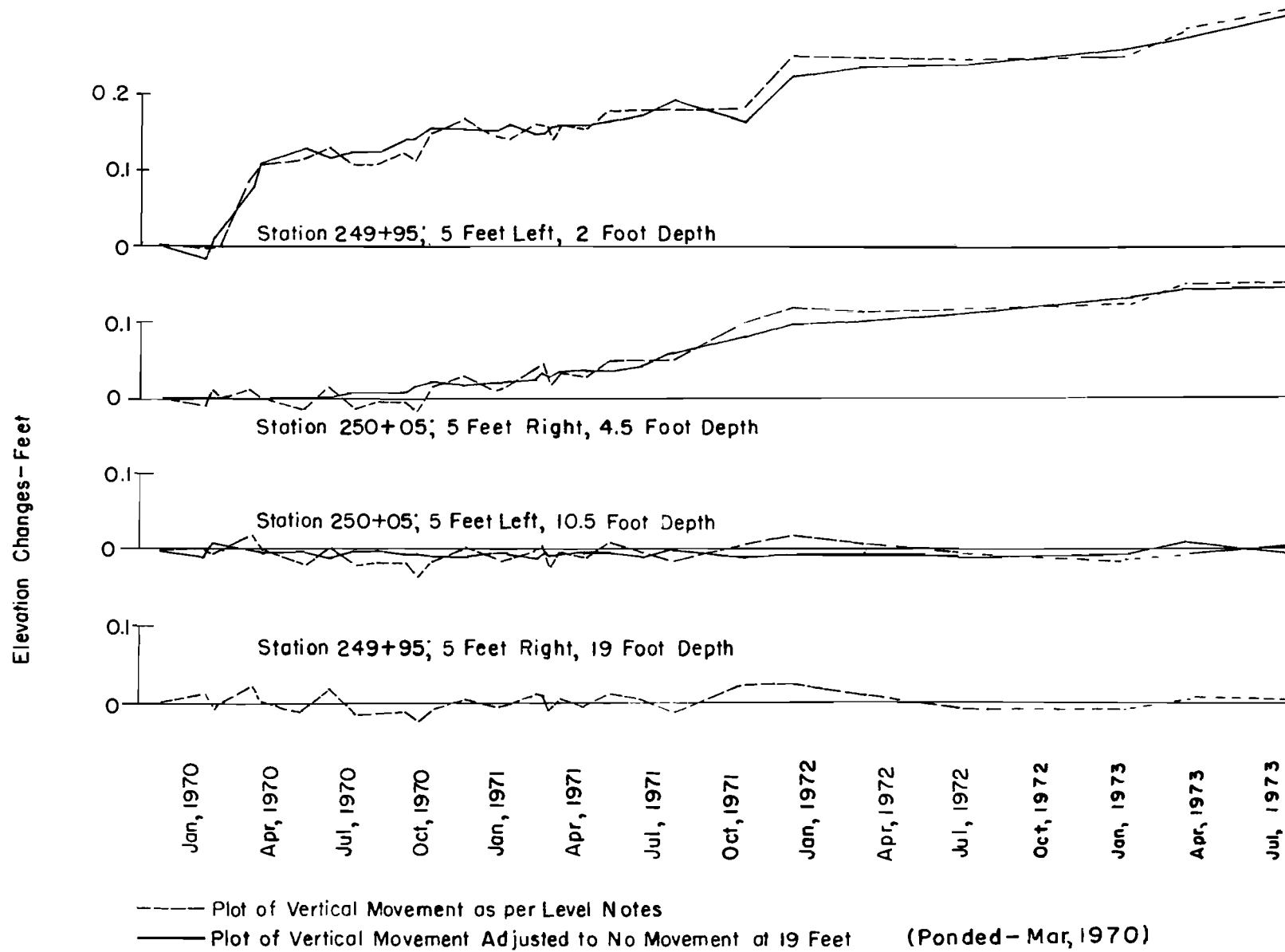


Fig 5. Vertical movement at station 250.

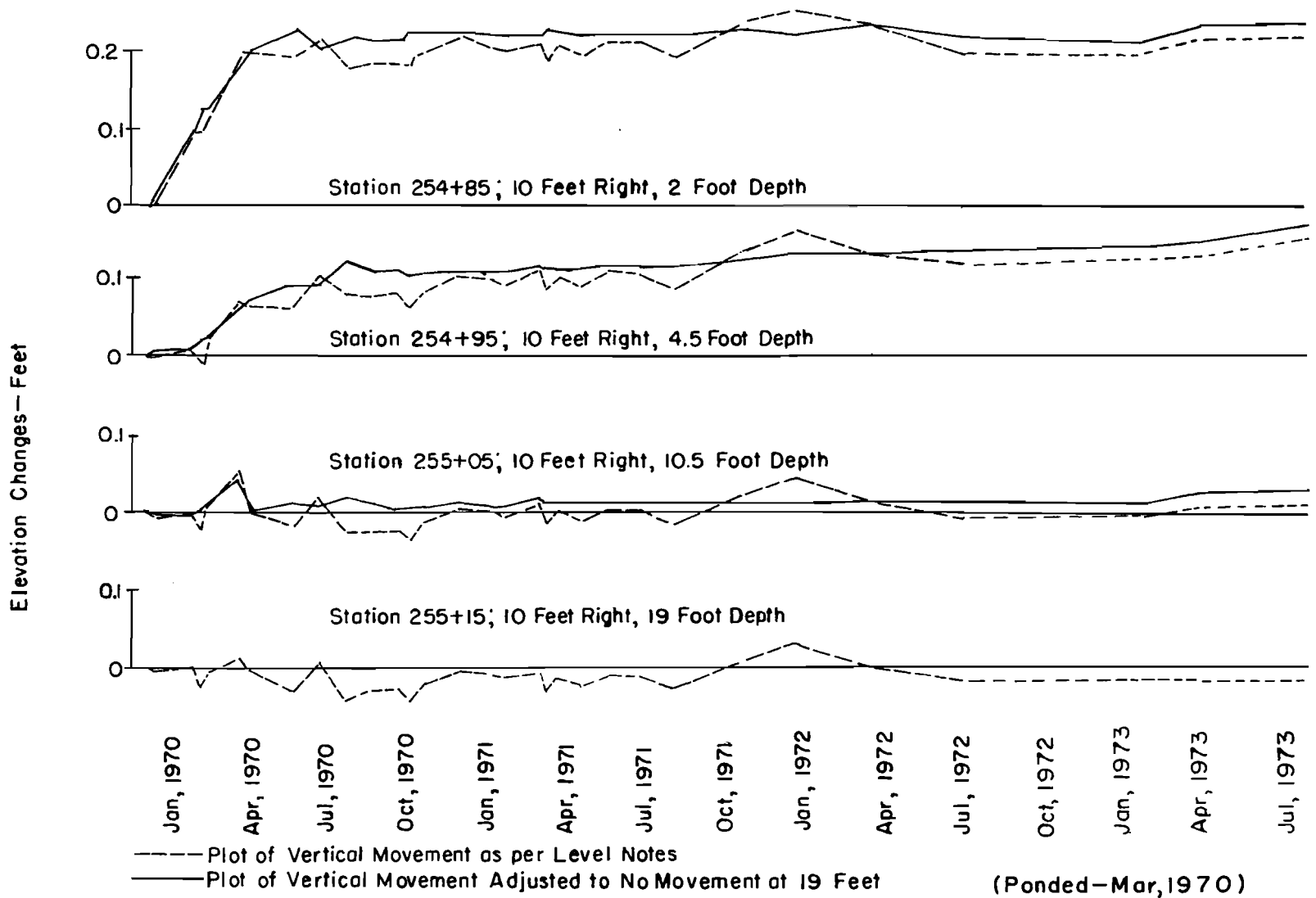


Fig 6. Vertical movement at station 255.

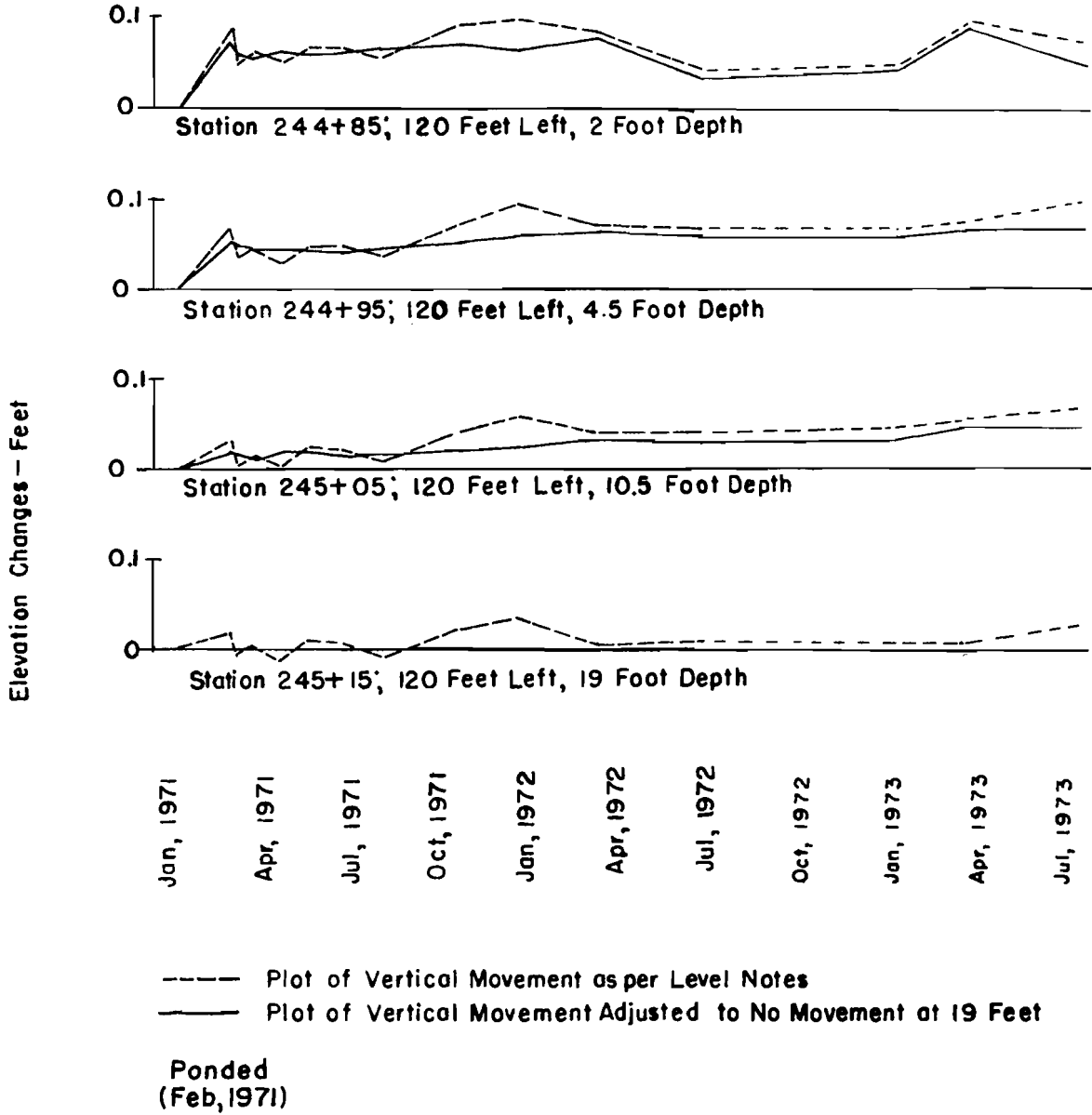


Fig 7. Vertical movement at station 245 (120 feet left).

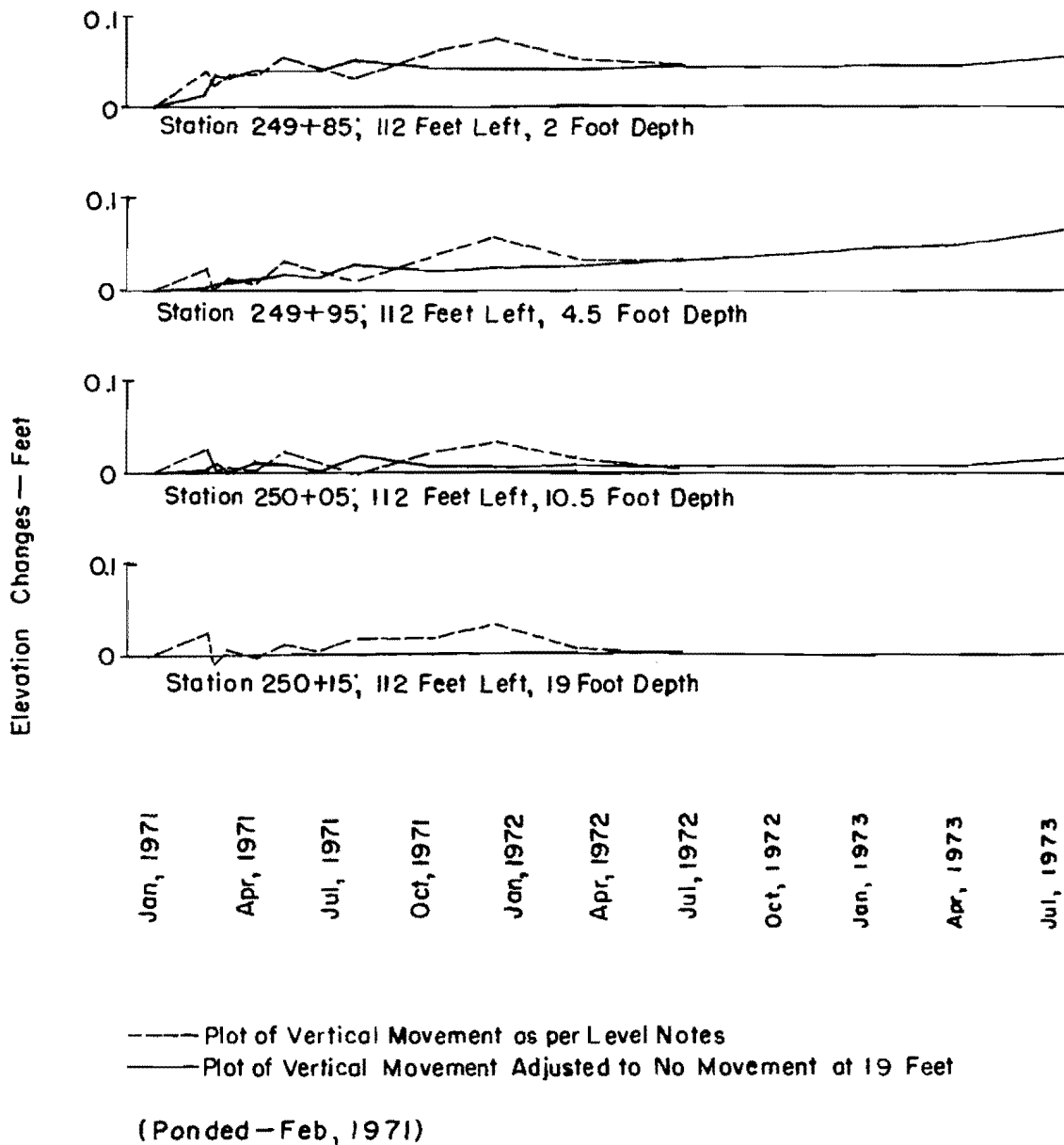


Fig 8. Vertical movement at station 250 (112 feet left).

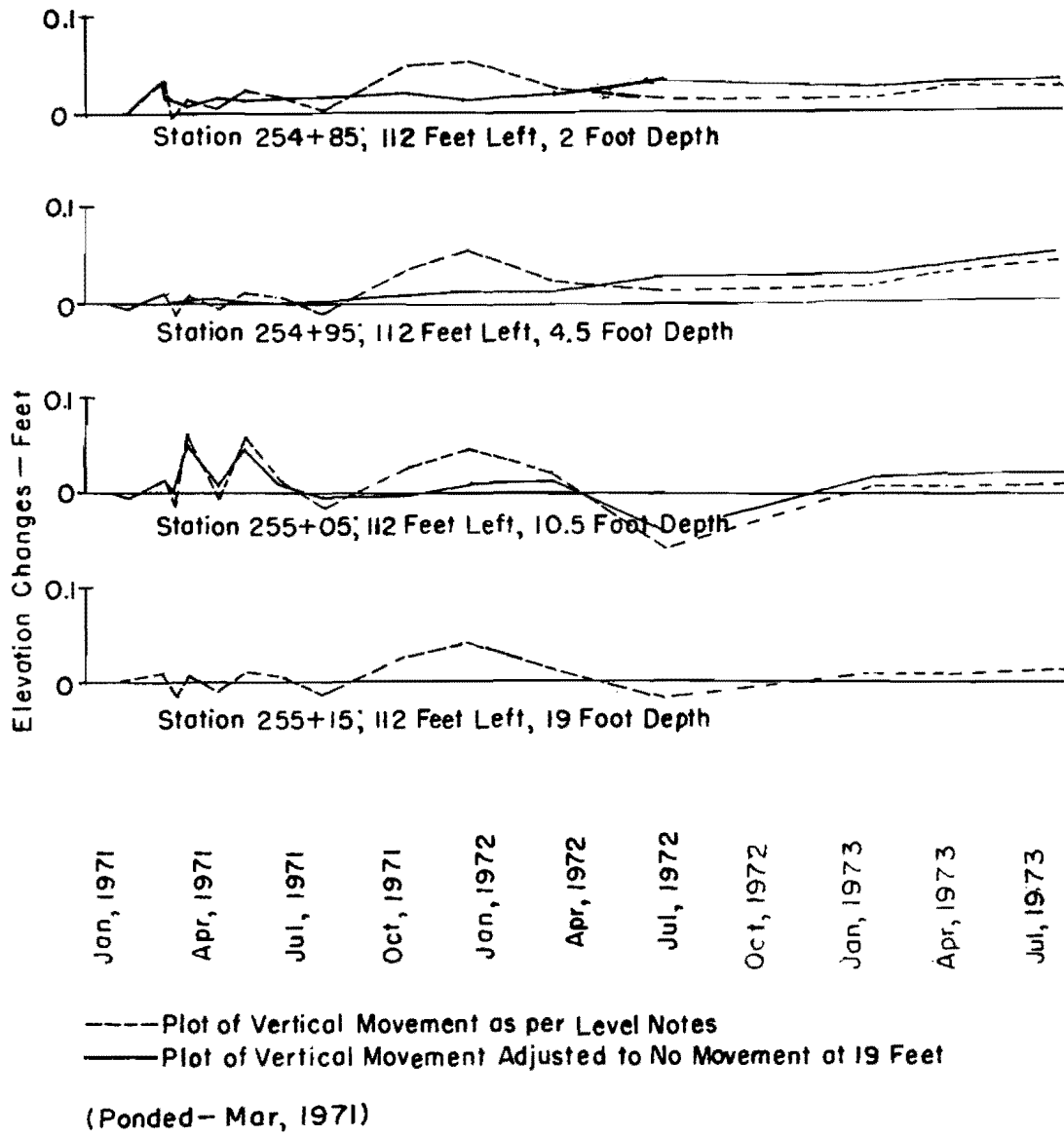


Fig 9. Vertical movement at station 255 (112 feet left).

(112 feet left) show a similar pattern, but to a lesser degree (Figs 7, 8, and 9). The upward movement in the rods set at the 2-foot depth is reflected in the first reading after ponding. At Station 245 (120 feet left) this also showed in the 4.5-foot rod. At the other locations we begin to see upward movement in the rods set at up to 10.5 feet deep except at Station 255 (112 feet left), none as much as in the rods set in the median areas and ponded first, however. The elevation rods set outside the ponding areas reflect a pattern of upward movement. The group set earliest, just outside the ponded area, shows the most movement. Naturally, the greatest predicted vertical heaves were in the sections that were ponded. However, at Station 241 considerable rises were recorded for the rods set at 2 and 4.5 feet (up to 3-1/2 inches), and a pattern of upward elevations is developing from the 10.5-foot depth (Fig 10). At Station 227 a similar pattern of upward movement is observed through the rods set at 10.5 feet (Fig 11). The upward heave is noted in the readings at Station 173, but only from the rods set at 4.5 feet and 10.5 feet (Fig 12). The shallowest rod has demonstrated an erratic path that reflects shrinkage as much as anything else, but the heave from the intermediate depths is pronounced.

In comparing maximum movements for these rods with the theoretical movements calculated by Texas Test Method Tex-124-E we see that the potential has not been reached. It is some satisfaction to realize that we have caused a good amount of swell to develop in the ponded areas, compared to the elevations taken in the median areas (Fig 13). It remains to be seen whether or not the calculated values will be reached, but Lytton in his report (Ref 5) notes an 11-year period for some movements of this type.

An examination of the moisture tests shows a considerable range and change in the tests taken closer to the surface. These variations seem particularly pronounced in the non-ponded areas, where at depths of 10 feet and less the moisture might vary from 6 percent to over 30 percent. This type of variation is also noted at Station 245 (120 feet left) which was ponded. Below 10 feet there was relatively little change in moisture content. Since water from the ponding probably did not penetrate to this depth it might be assumed that this condition more nearly reflects the natural condition of the soil, or the differences in the soils. With this moisture consistency we observe that at Station 227 the range is from 42 percent to 45 percent, and at 173 the range is from 23 percent to 26 percent (Figs 14-22). The earlier

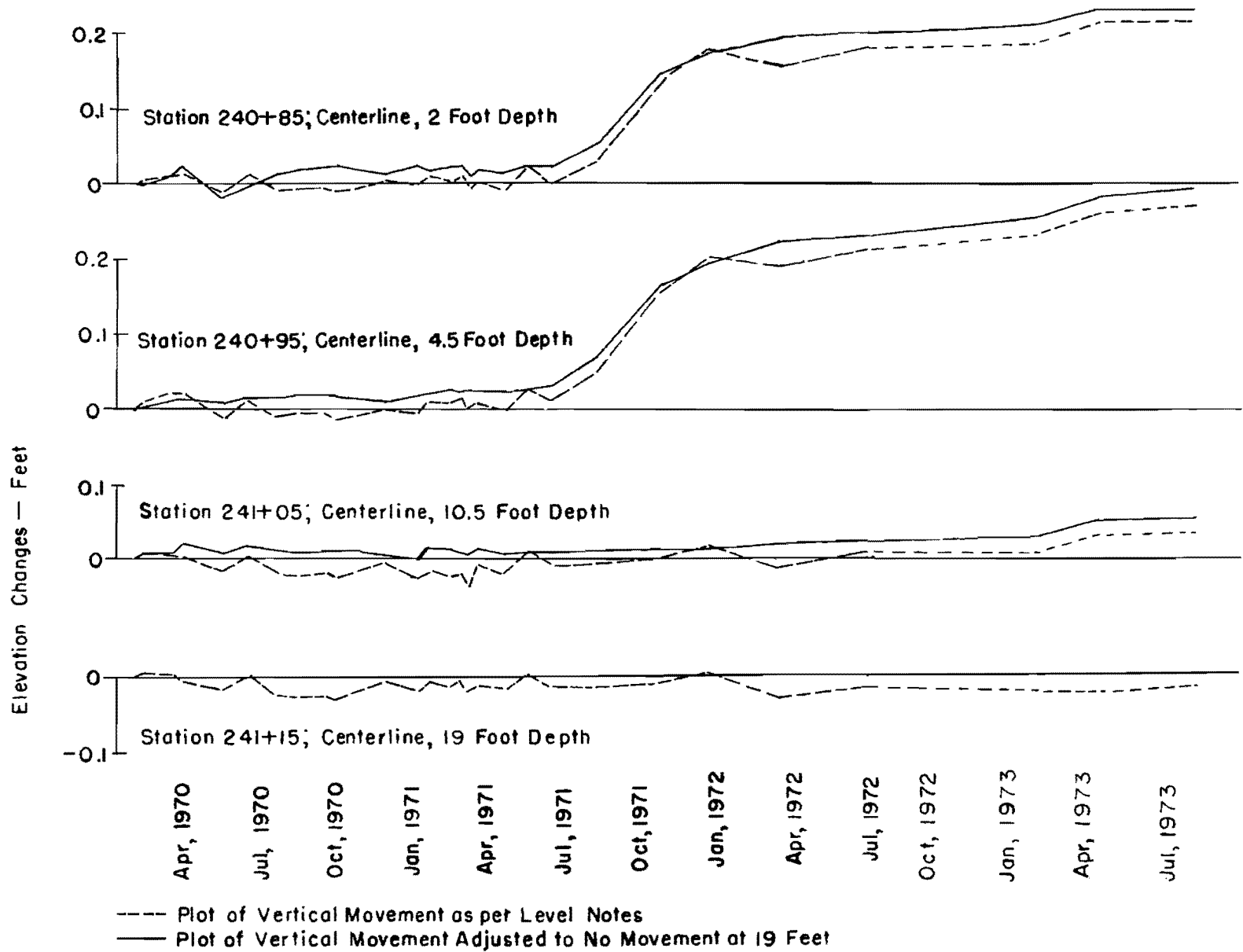
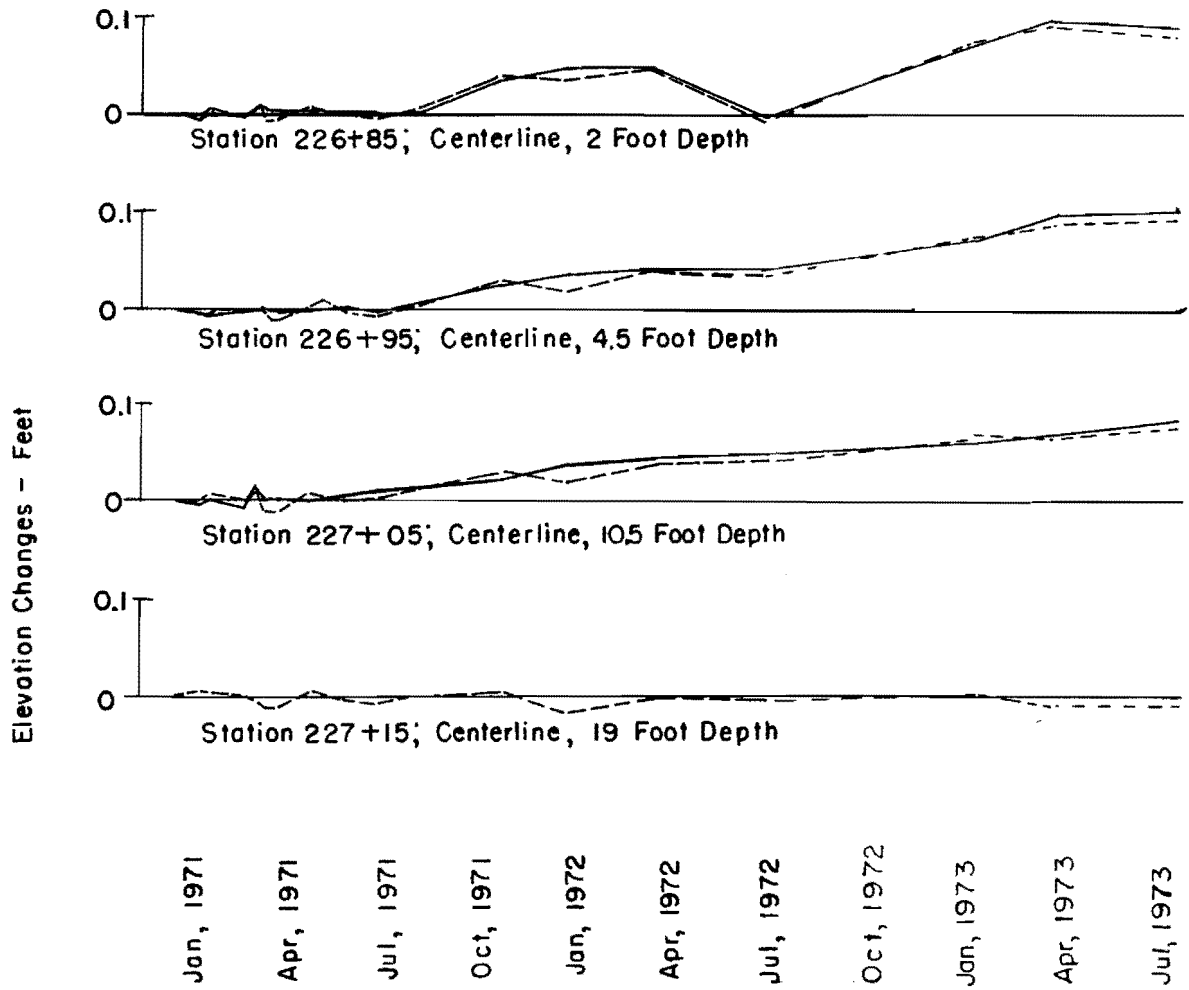


Fig 10. Vertical movement at station 241 (centerline).



--- Plot of Vertical Movement as per Level Notes
 — Plot of Vertical Movement Adjusted to No Movement at 19 Feet

Fig 11. Vertical movement at station 227 (centerline).

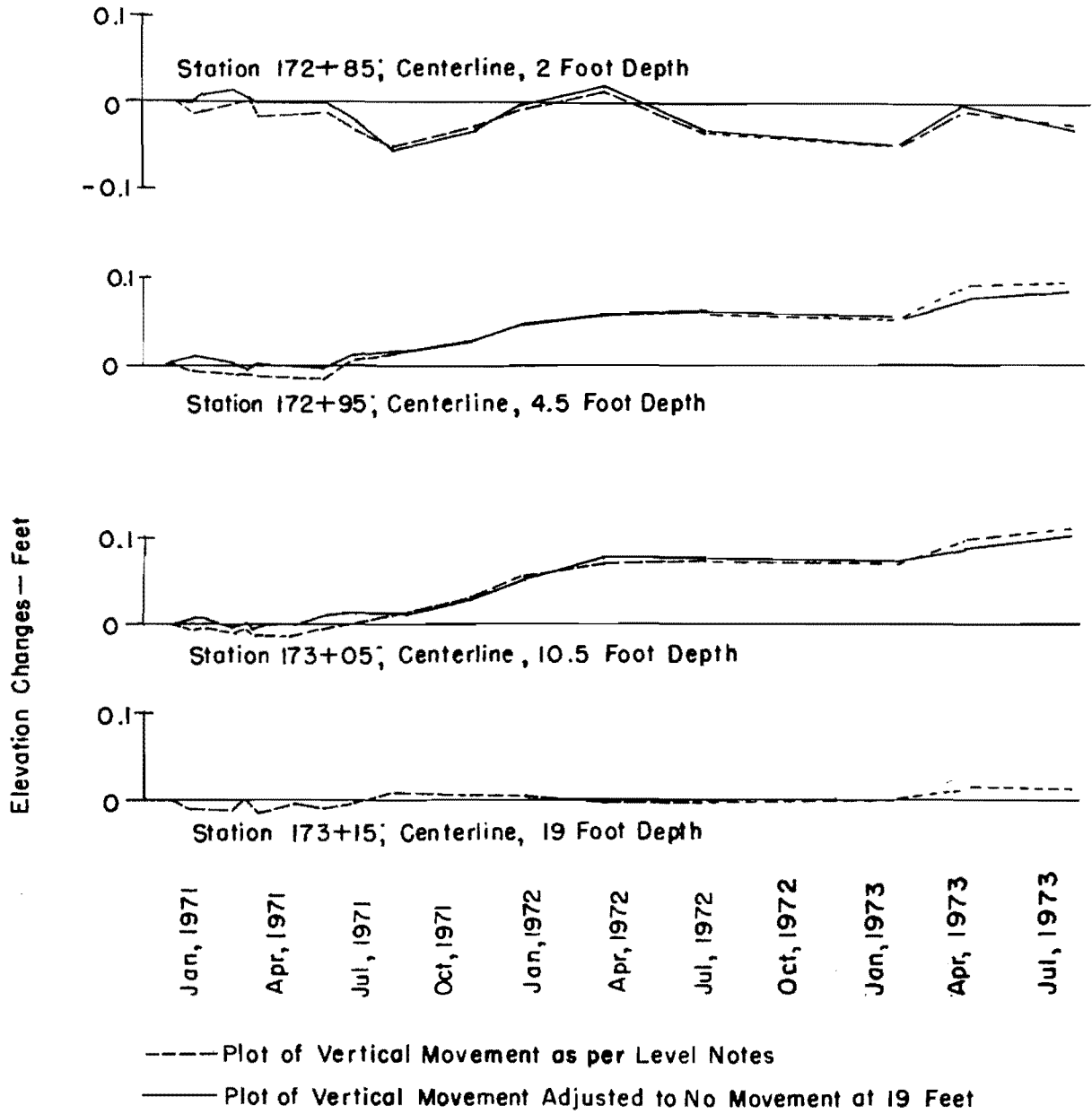


Fig 12. Vertical movement at station 173 (centerline).

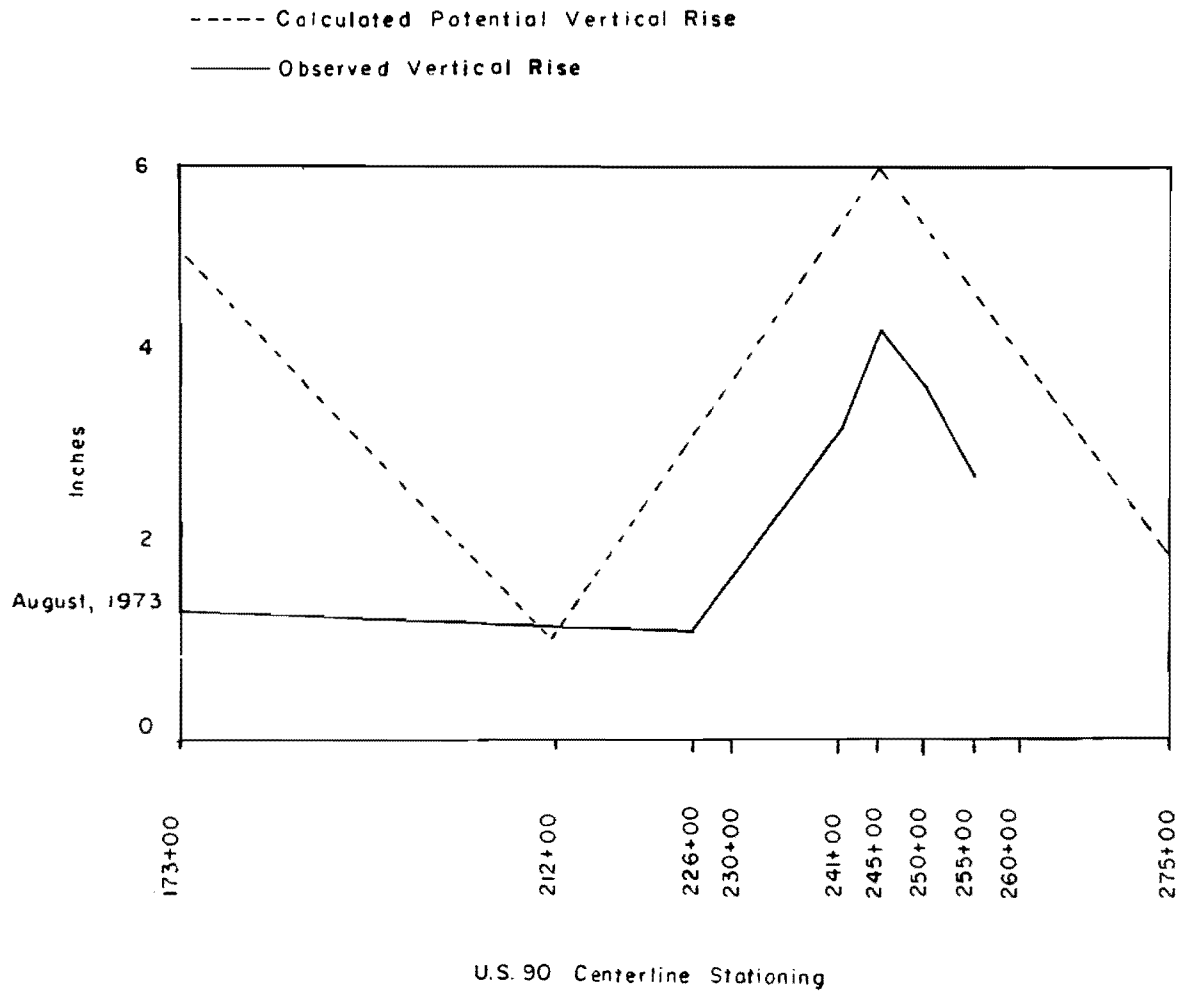


Fig 13. Calculated and observed vertical rise.

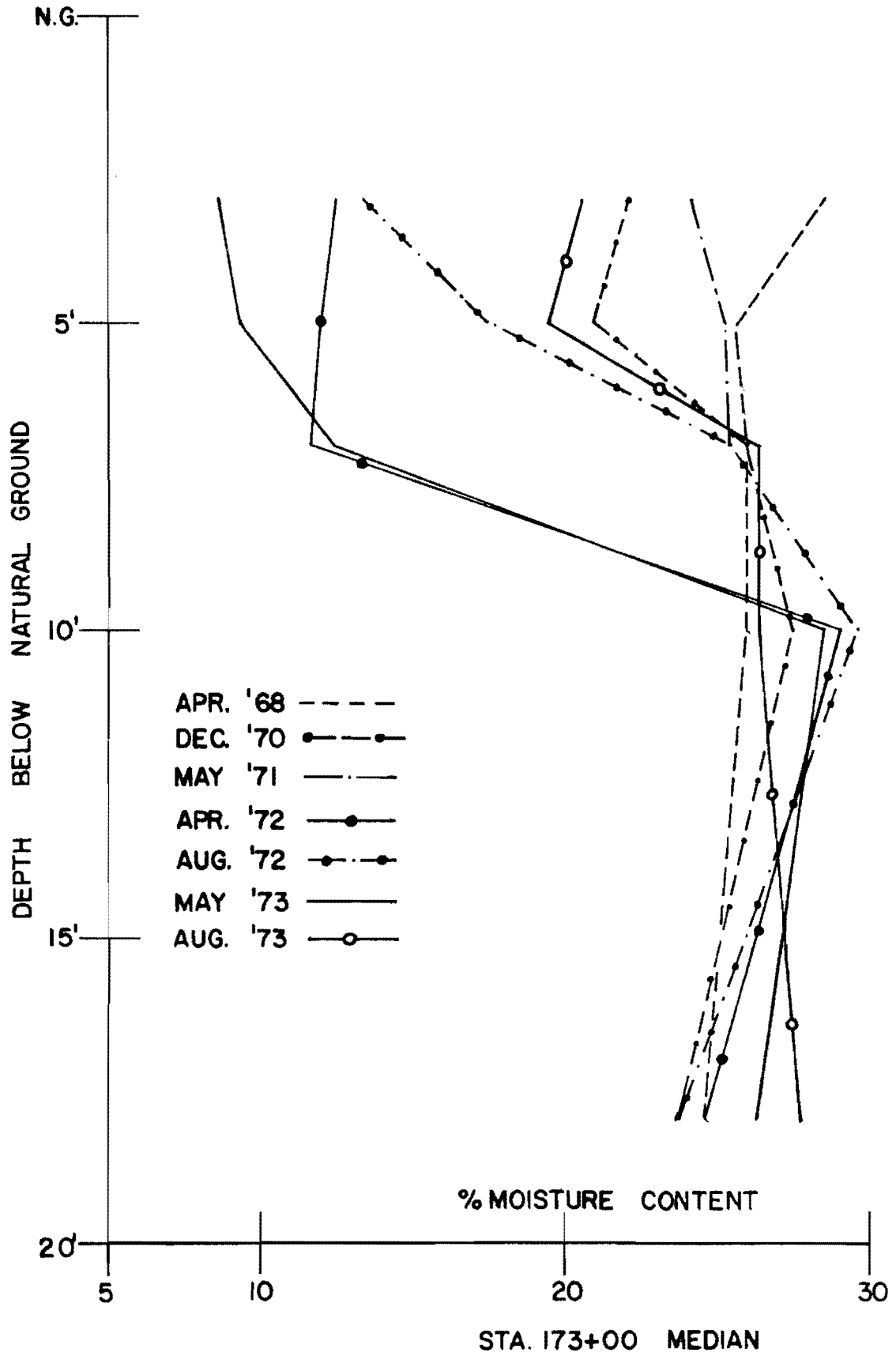


Fig 14. Percent moisture content at station 173.

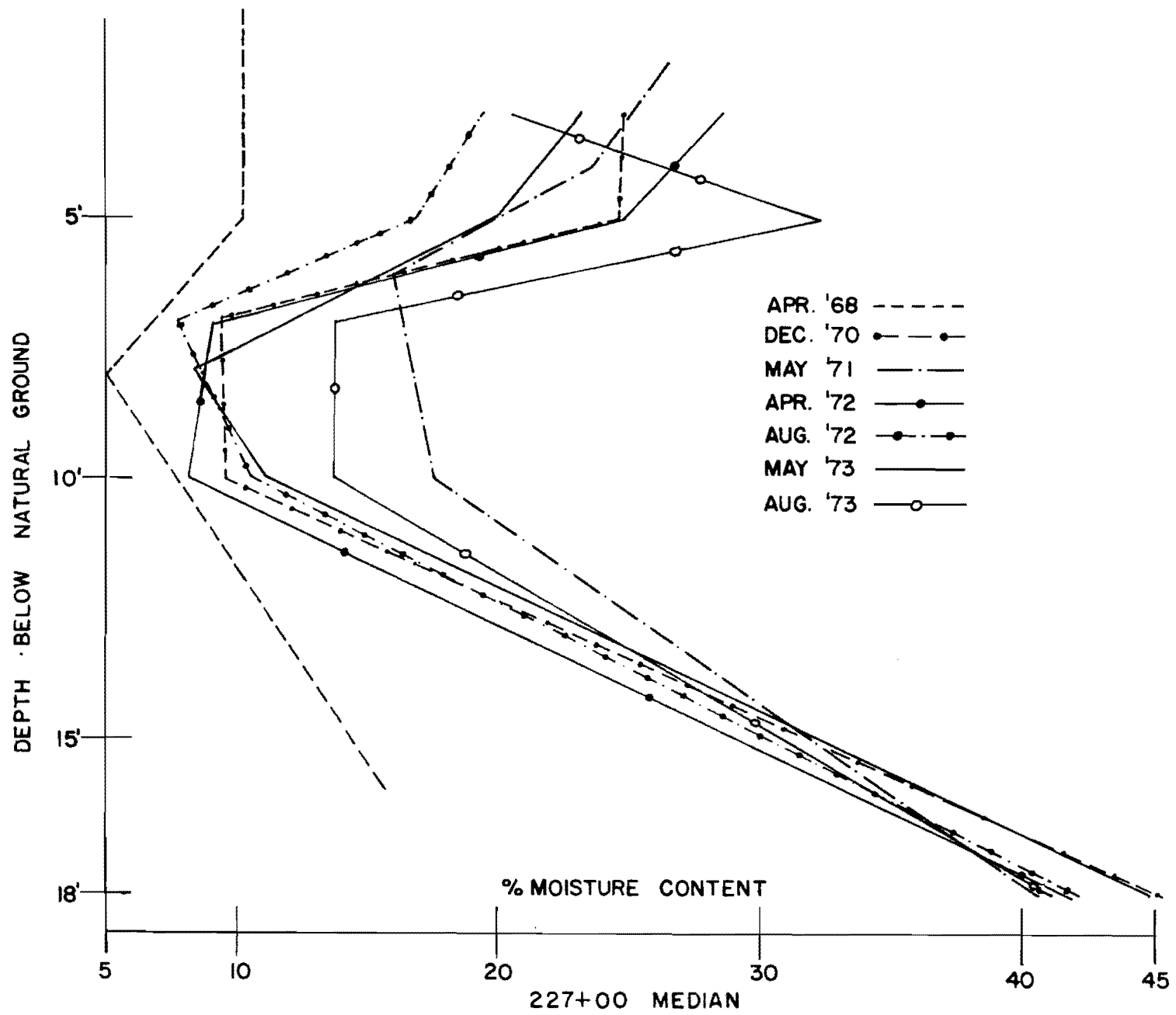


Fig 15. Percent moisture content at station 227.

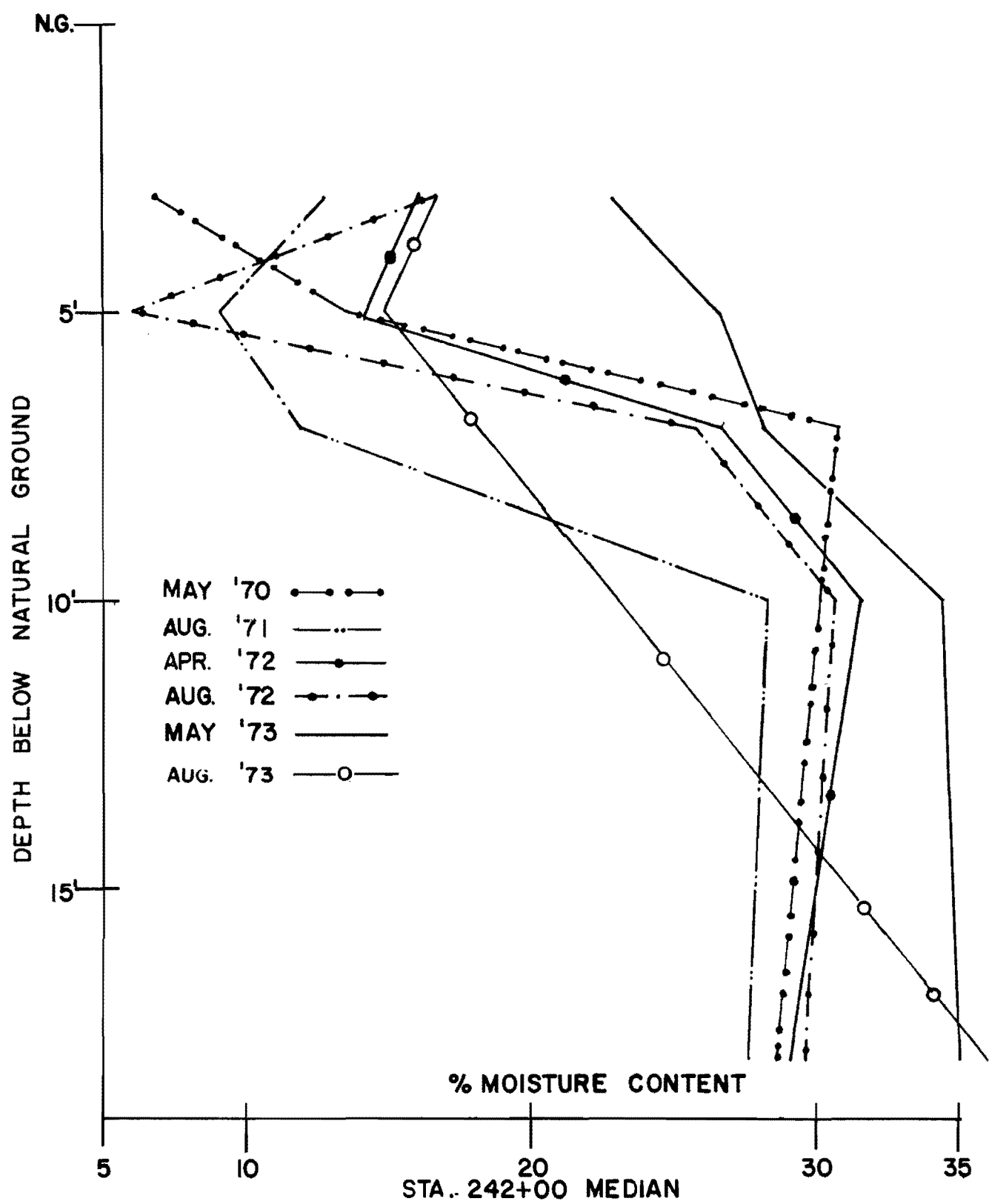


Fig 16. Percent moisture content at station 242.

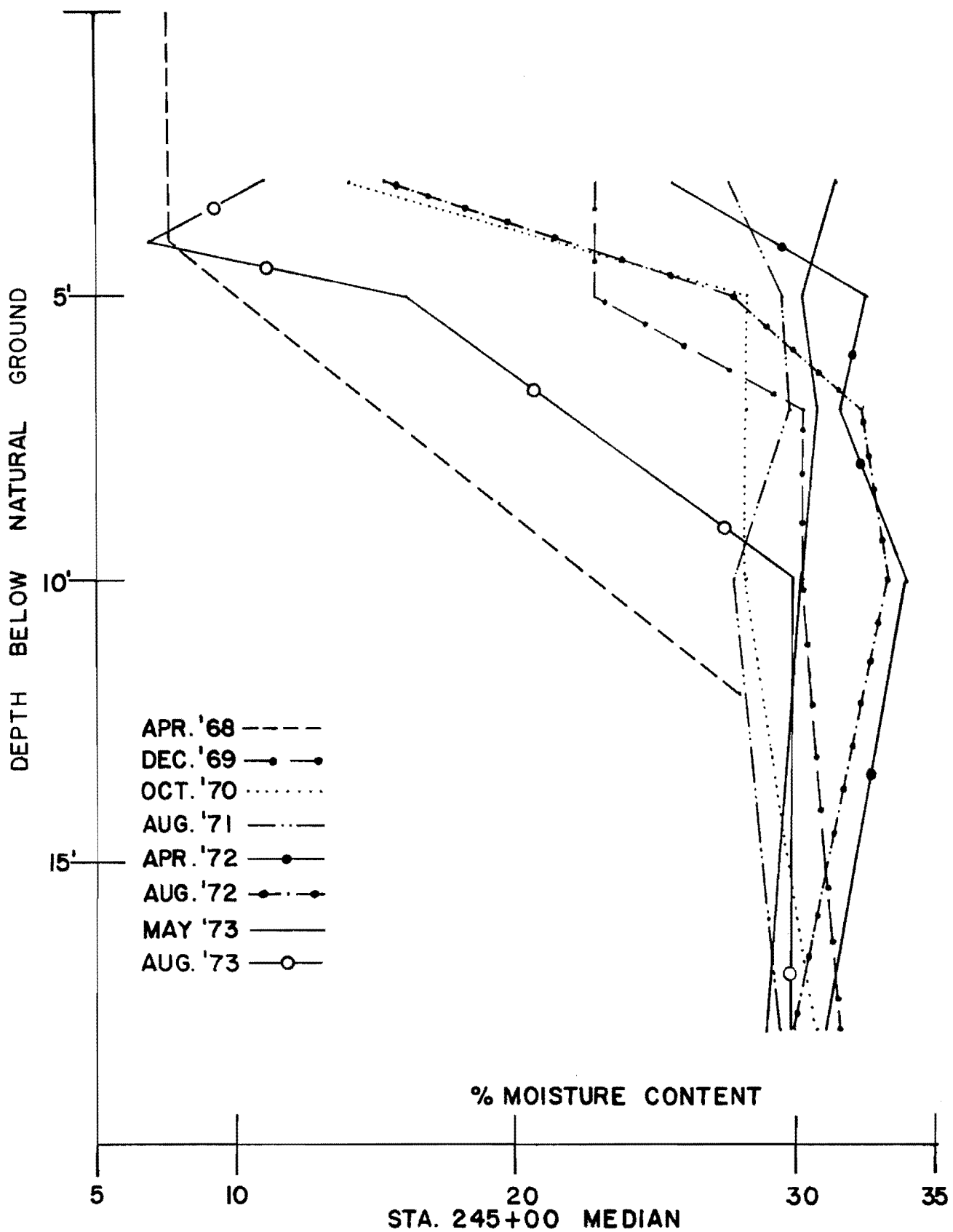


Fig 17. Percent moisture content at station 245.

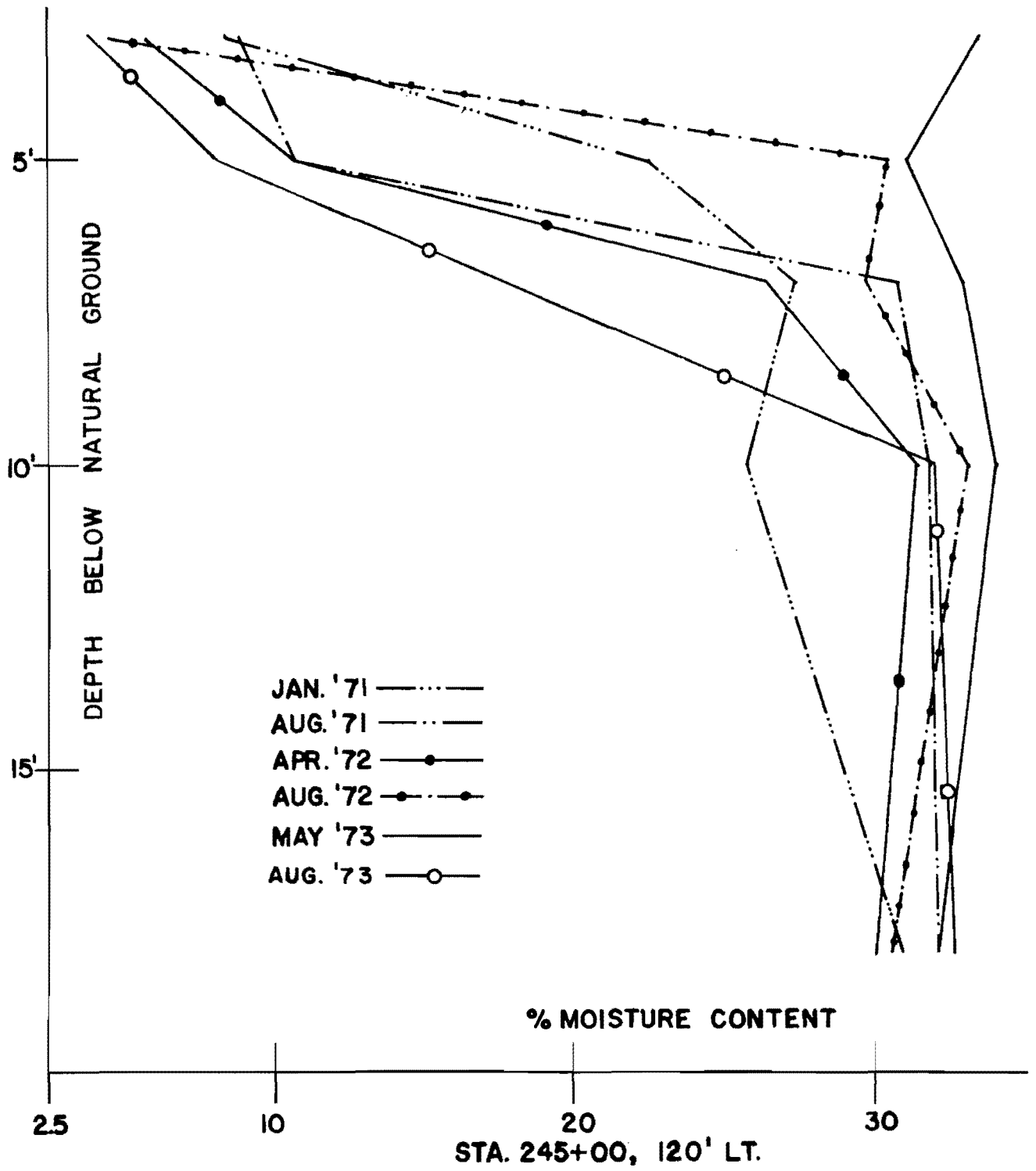


Fig 18. Percent moisture content at station 250 (120 feet left).

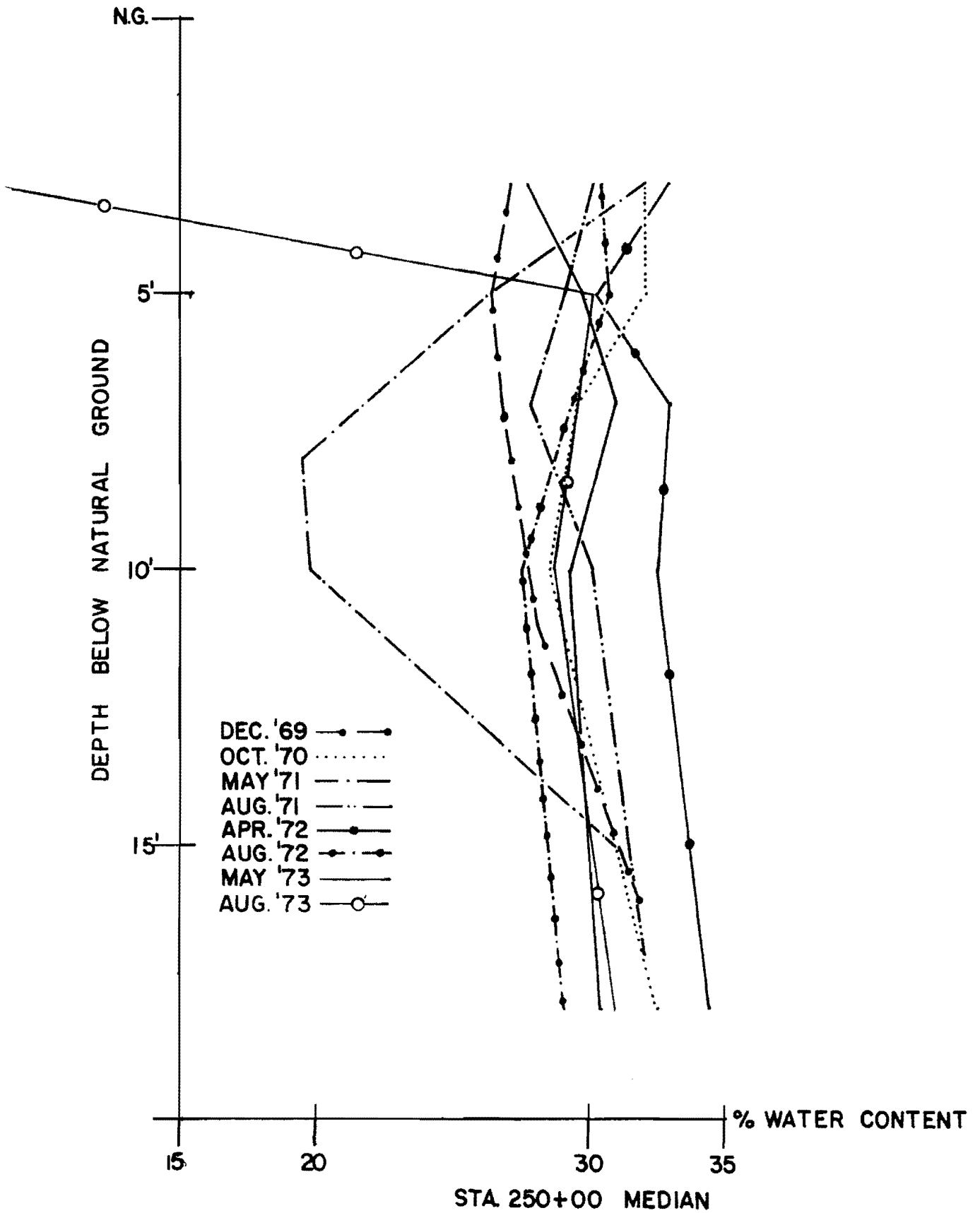


Fig 19. Percent water content at station 250.

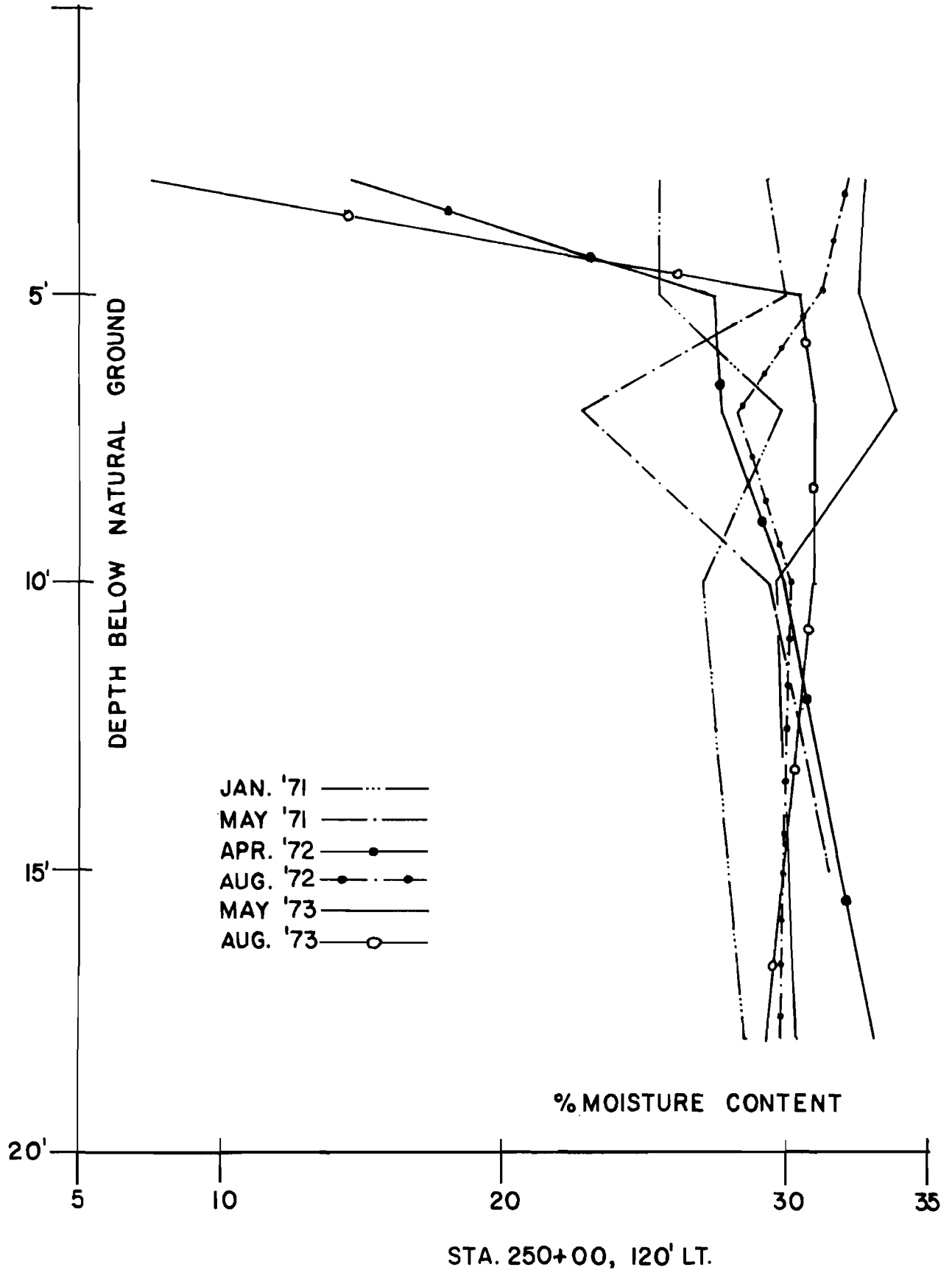


Fig 20. Percent moisture content at station 250 (120 feet left).

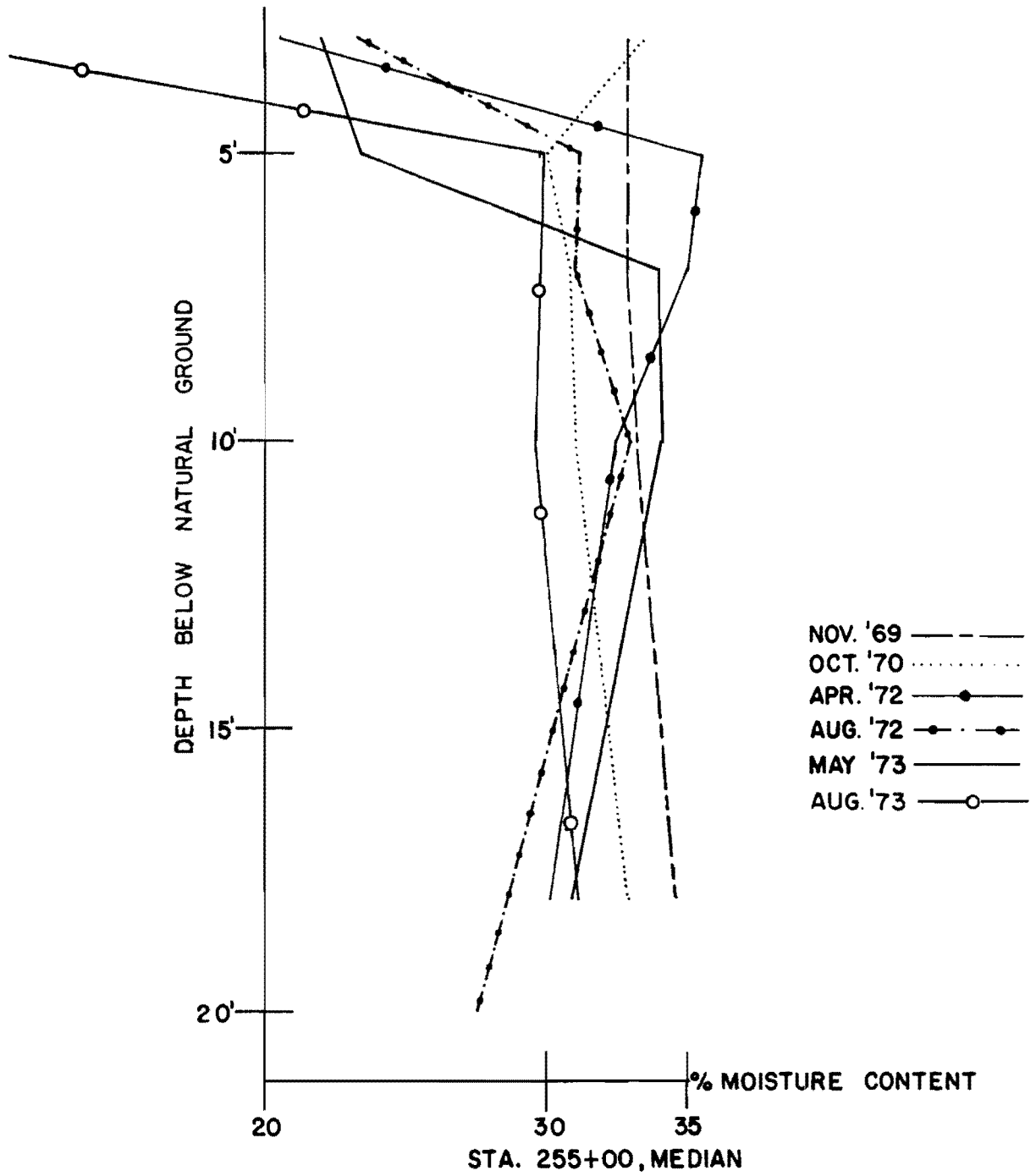


Fig 21. Percent moisture content at station 255.

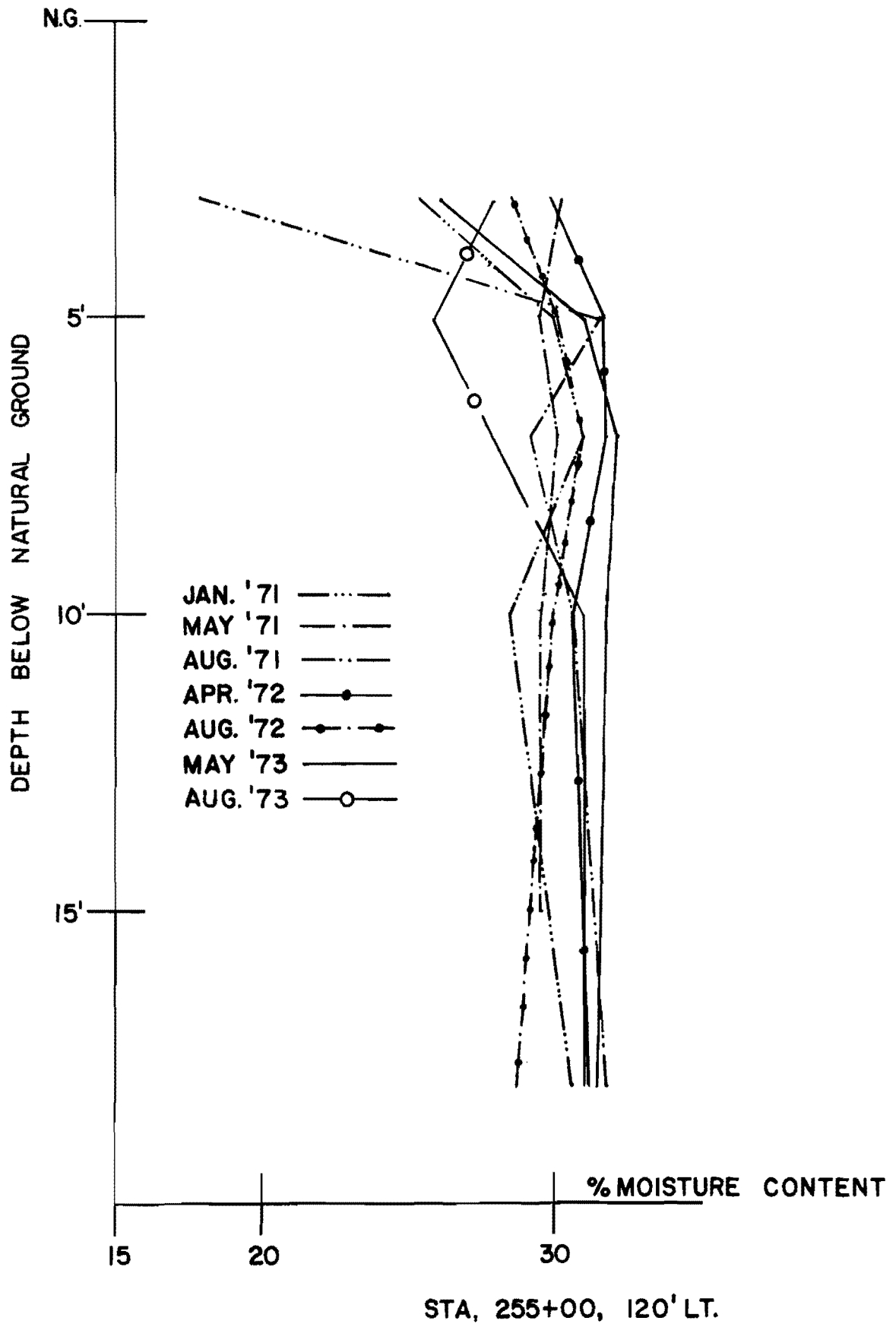


Fig 22. Percent moisture content at station 255 (120 feet left).

report of this ponding, based on the nuclear moisture readings, did show a pronounced rise in the moisture contents following ponding. Unfortunately, the closing of many of the access tubes prevented continued readings at these locations. Getting drilling rigs into recently drained ponded areas is difficult and the continuity in testing is missed.

Studying the vertical movements at the test locations and comparing these movements with the moisture changes did not reveal the close relationship that other testing indicated. An extension of the soil profiles originally plotted along the survey line and an additional profile based primarily on the bridge foundation logs show the variations in the subsoil conditions in an area that may be considered as fairly uniform (Figs 23 and 24).

A comparison of the rainfall records with elevation rod readings does not provide a simple answer either, such as when it rains the soil is going to swell. The fact that these official rainfall records are taken at the airport, which is almost 20 miles from the test site, is one factor that would cloud these attempts at establishing this relationship (Fig 25).

A road condition survey is included for correlating if possible the patching and distress noted in this section of U.S. 90 with the different construction techniques involved (Fig 26). No clearcut conclusions concerning the relationship are made at this time. McDowell's study of the Waco project a decade after construction indicates significantly less maintenance work was required on the ponded areas (Ref 2).

VI. OBSERVATIONS, CONCLUSIONS, AND RECOMMENDATIONS

Expansive clays will move in areas where there are considerable changes in moisture. Usually they will heave. Our elevation rod readings show these movements. In the areas that were ponded the heaves followed the ponding. Where there was no ponding in these clays, there were also rises. The ponding tended to cause some or all of the heave to occur before the pavement was placed.

The movement, according to the elevation rods, comes primarily from the shallower depths, initially from the 2 or 4.5-foot deep rods. Now there are considerable signs to indicate movement from the rods 10.5 feet deep.

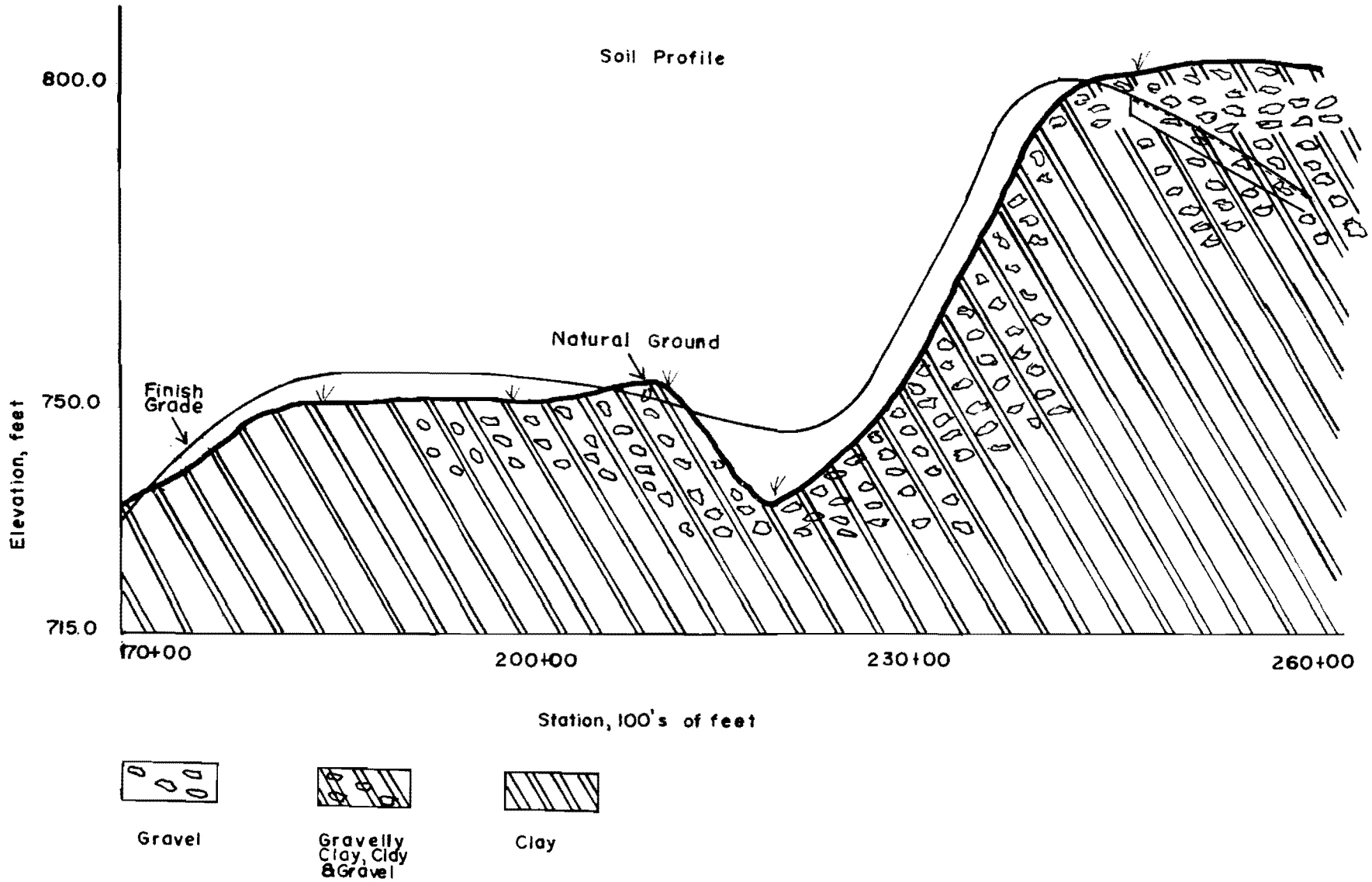


Fig 23. Soil profile along the survey line.

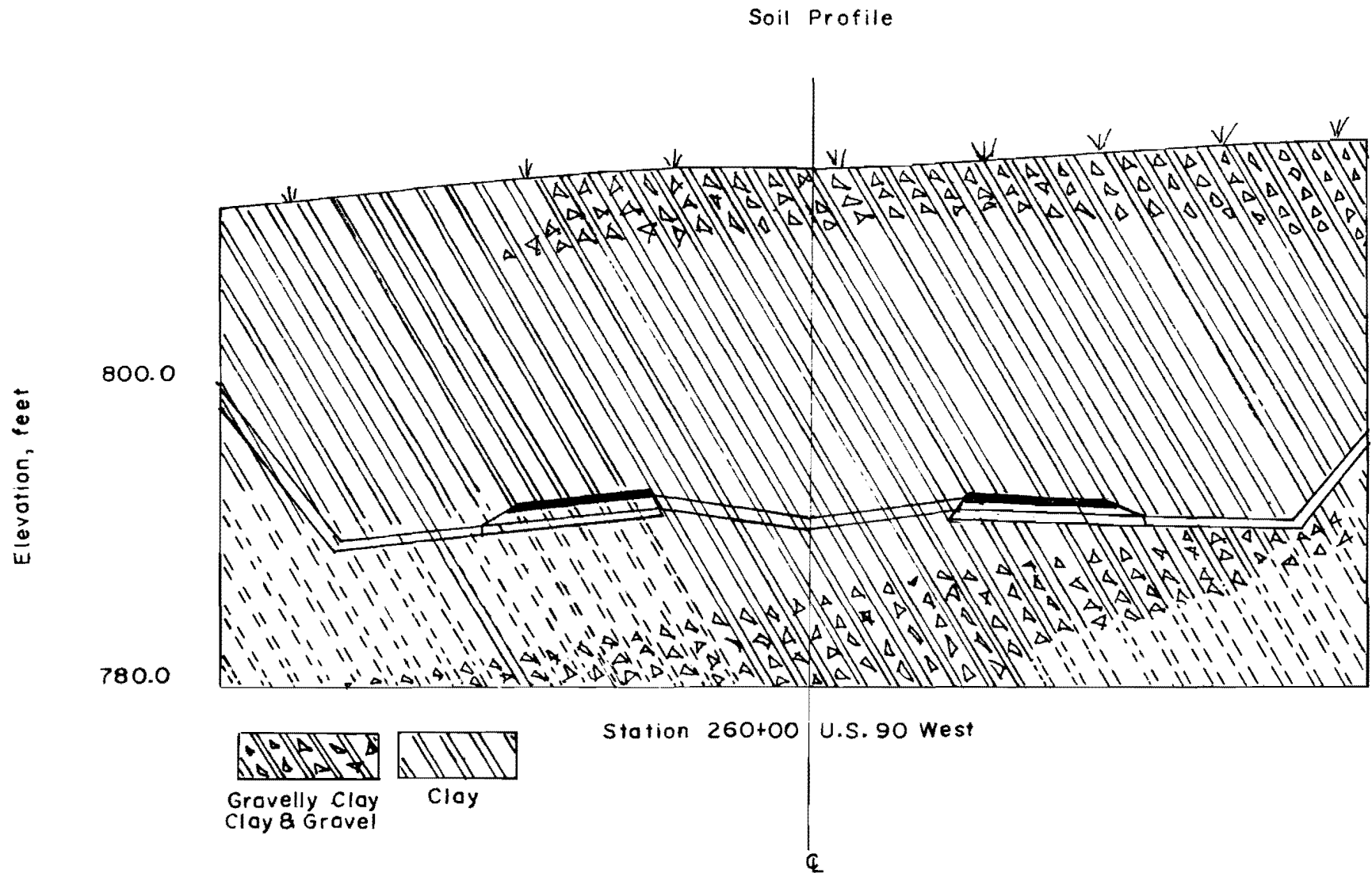


Fig 24. Soil profile based on bridge foundation logs.

Station 240 + 95

Observed Vertical Rise

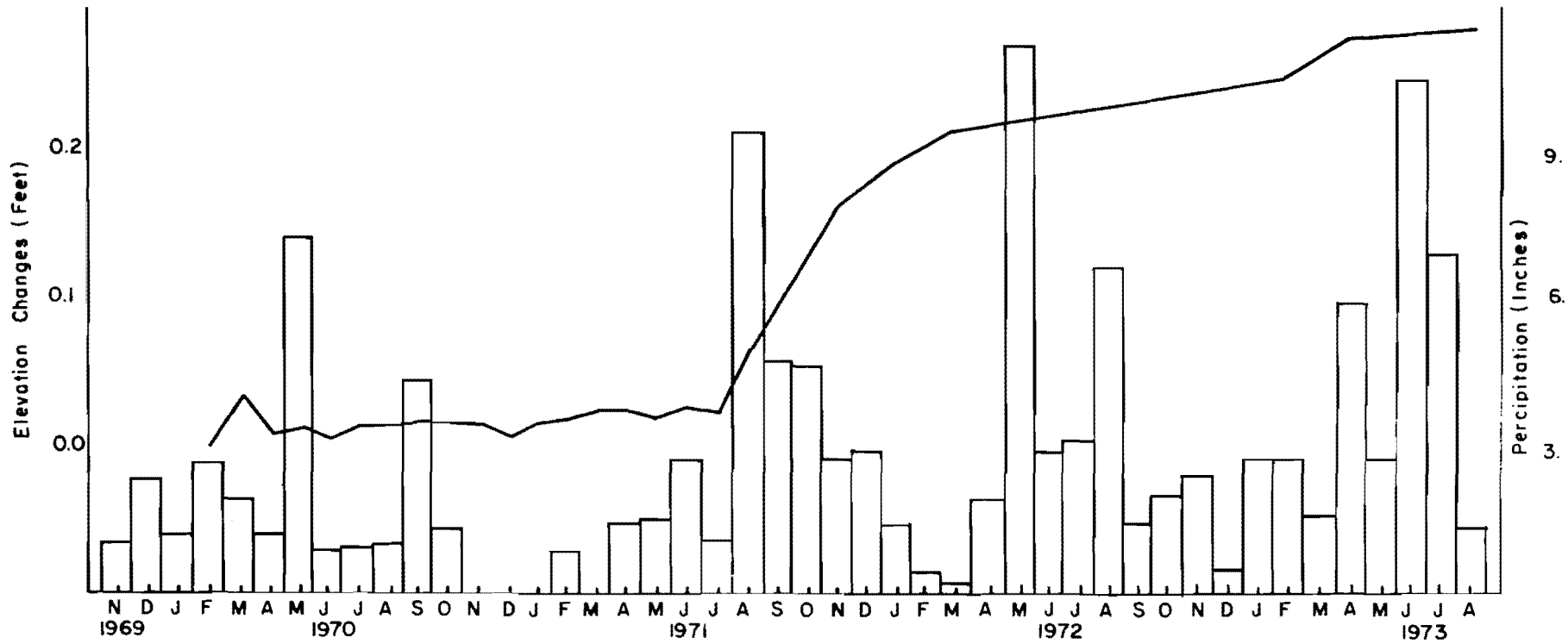
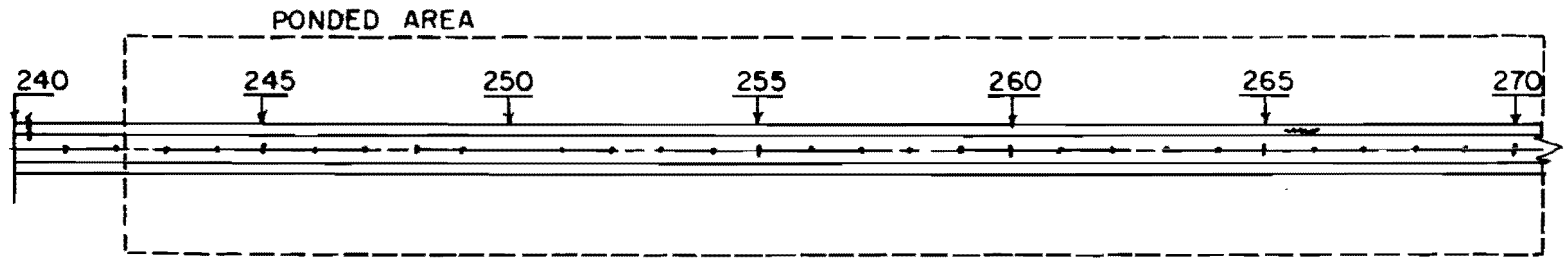
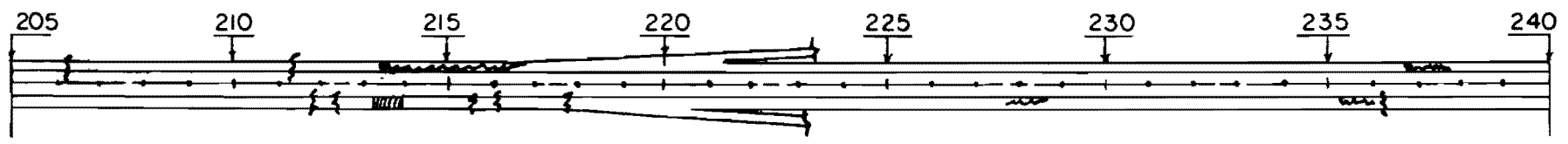


Fig 25. Rainfall records and elevation rod readings at station 241.



~~~~~ - CRACK  
 // // // - LEVEL-UP

RESEARCH PROJECT  
 U.S. HWY. 90 WEST  
 STA, 170~270

Fig 26. Road condition survey.



A study of the recent moisture tests indicates that there is a great deal of variation in the moisture contents at the shallow depths. Beneath the 10-foot level there is little change in moisture according to our most current tests. Earlier testing with the nuclear devices showed that ponding caused the moisture content to increase at depths of up to 3 feet. When drying out does occur there is no general shrinkage. The heaves hold and in most cases start growing again after a moisture increase. Other studies have emphasized the moisture and movement relationship strongly. Why the elevation rods in the later series of ponding areas did not move as much as the first group is less clear. Among the possible reasons are:

- (1) Water from the first pondings percolated into the area causing horizontal movements and stress release rather than later vertical movement.
- (2) The slope which was close to these test locations may have reduced moisture loss through evaporation or the longer period between the excavation and ponding in the earlier areas may have resulted in more shrinkage cracks and more waterways to take the water deeper or farther with more resultant vertical movement.
- (3) As the profiles tend to show, there may be considerable soil differences between these locations.

Some of the later movements in the non-ponded areas might also reflect greater surface drying and cracking with an increase of moisture contents due to rains because these sections had no subgrade lime moisture seal. The liming could reduce subgrade evaporation and the opening of passageways for water that contribute to the clay's swelling.

There is no need to conduct every known experiment; the wide variety of testing and information available can help to build a better road for less total life of project cost. Several things can be recommended. The first is testing to determine what potential vertical rises are to be expected on a project. Second, if the potential vertical rise seems likely to exceed one inch, and the facility merits it, ponding should be set up on cut and fill sections together with sand drains to get the moisture well into the expansive clay. An evaporative seal of lime, or perhaps emulsion asphalt with wide shoulders and easily drained ditches, seems worthwhile. The third possibility is use of flexible asphaltic base and pavement systems, which seem to function with the least distress and maintenance costs on these expansive clays. Since major moisture variation and elevation rod movement occurred in

the top 10 feet it could be conjectured that this represents the zone of instability. Securing passage of the ponded water into this zone, with sand drains, for instance, drilled to this depth, and then sealing the moisture with a lime or asphalt seal might well create a preswelled condition in a new zone of stability. Possibly subsequent movement would be minimal, insignificant, and require less maintenance expenditures.

It is satisfying that what has been done here has been reported. Some outstanding results from other projects have been lost because records were not kept. Whatever is attempted should be noted so that successes and failures alike will be known. The result should be better roads for Texas and the nation.

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#### THE AUTHOR

Malcolm L. Steinberg is Senior Resident Engineer with the District Office of the Texas Highway Department in San Antonio. He is currently in charge of environmental studies and is a public affairs officer. Of primary interest are transportation problems, ranging from planning through the construction stage. He is the author of several papers and is coauthor of the brief "Acequias of San Antonio," which led to their designation as a National Historic Civil Engineering landmark. He has been active in the American Society of Civil Engineers and has filled numerous offices in the Society.