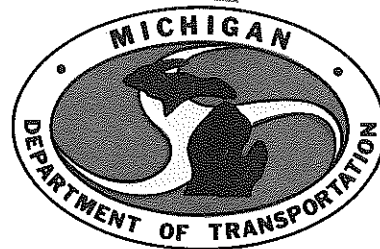


FROST HEAVE INVESTIGATION OF I 275



**TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION**

FROST HEAVE INVESTIGATION OF I 275

E. C. Novak, Jr.

Research Laboratory Section
Testing and Research Division
Research Project 79 TI-622
Research Report No. R-1194

Michigan Transportation Commission
Hannes Meyers, Jr., Chairman; Carl V. Pellonpaa,
Vice-Chairman; Weston E. Vivian, Rodger D. Young,
Lawrence C. Patrick, Jr., William C. Marshall
John P. Woodford, Director
Lansing, April 1982

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Introduction

The I 275 freeway begins at I 75 in the south and extends north to I 696—a distance of approximately 39 miles. The pavement, which is 9-in. thick continuously reinforced concrete (CRC), was opened to traffic in segments beginning in 1975 with the final segment opened in 1977. The general location and alignment of the freeway are shown in Figure 1. For simplicity, each project has been assigned a code number that will be used throughout this report whenever reference is made to a specific project. Code numbers ranging from 1 through 13 have been assigned consecutively from south to north.

Pavement surveys, conducted in 1977, indicated some longitudinal cracking and punch-out failures on three of the projects. The cause of this early distress was immediately investigated and resulted in three reports (1, 2, 3). In brief, these reports indicate that differential frost action in the base was the most probable cause of the longitudinal cracking, and that volume change, or expansion of the subbase on freezing, was responsible for development of abnormally high stresses in the CRC during the thaw cycle, at which time the consolidating subbase changes from a fluid to an elastic pavement support condition.

The base materials for projects 1 through 6 are largely frost susceptible, pumping susceptible, and in addition, have a high capillary potential (3). Therefore, retrofit underdrains cannot improve base drainage because the pore size distribution of the base is too small to allow gravity drainage to occur. On the other hand, drainage of the subbase layer can be improved by retrofit underdrains; but, because of low subbase permeability and a small hydraulic gradient; the improvement may be so small as to be insignificant. The only way these base and subbase drainage deficiencies can be corrected is by their complete removal and replacement, a procedure which is totally impractical. Therefore, two methods of attenuating their detrimental characteristics were recommended in Ref. (2) and (3). The first was to cut off the supply of water that can enter the base at the longitudinal pavement/shoulder joint. It was recommended this be accomplished by retrofitting 'special drains' that deprive the base of the surface infiltrating water it needs for differential frost heave. These drains were also intended to reduce the time for subbase consolidation which, in turn, reduces the time the CRC is subject to excessive stresses. This method was only intended to attenuate development of new longitudinal cracks, and to prolong the life of the pavement once it loses the structural integrity provided by the reinforcing steel. Existing longitudinal cracks provide the base with access to surface water which can cause differential frost heave.

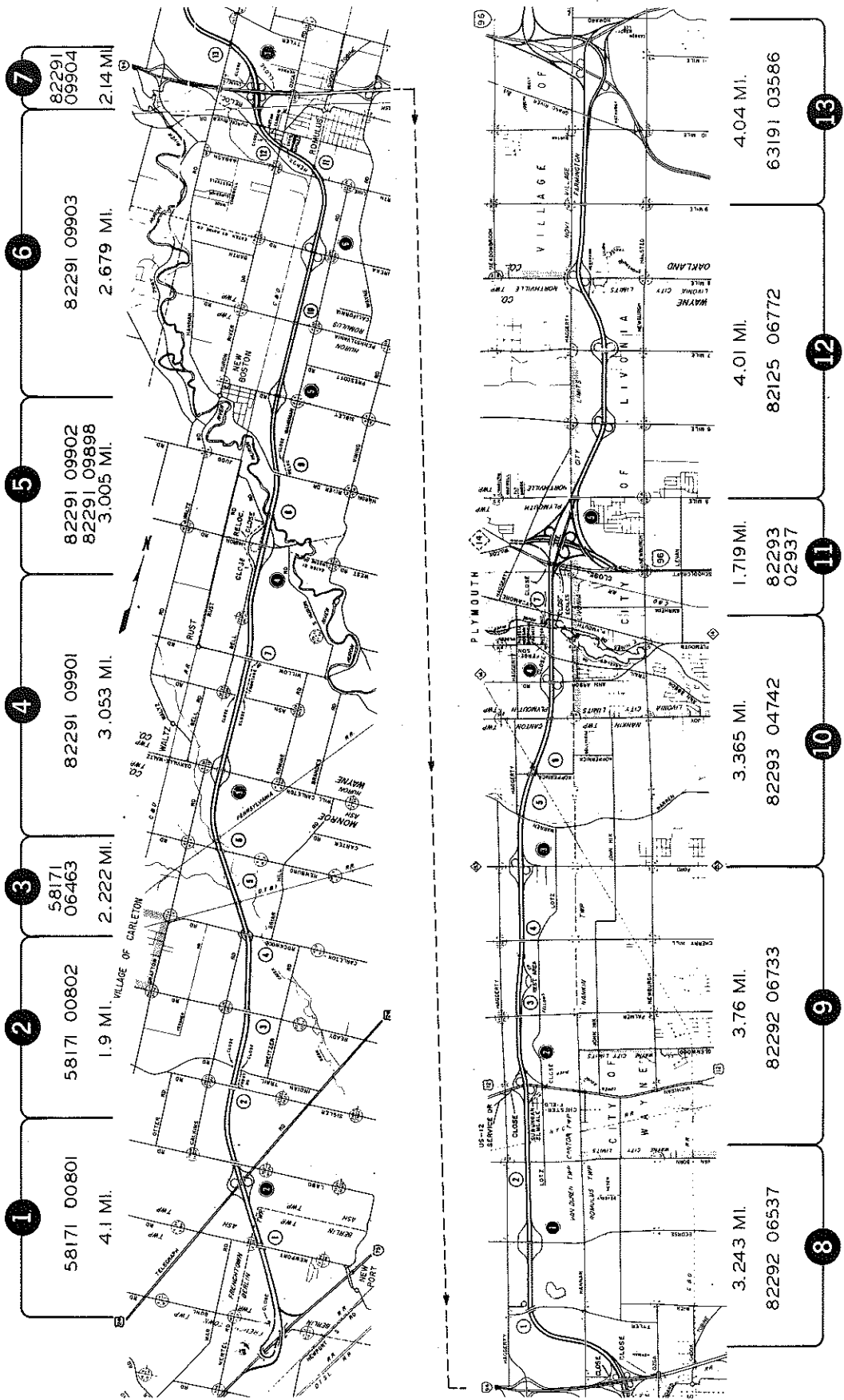


Figure 1. General location and alignment of I 275 and I 96/I 275 freeway. Mileage, contract numbers, and code numbers are also shown.

Therefore, elongation of longitudinal cracks will continue unless they are effectively sealed. Because some longitudinal cracks were observed to be subject to pumping action—differential movement under heavy axle traffic loads—surface sealing of these cracks appears to be futile. Therefore, a second recommendation was made to determine if underslab voids occur at longitudinal cracks, due to the observed pumping action, and to explore the possibility of filling these voids and the longitudinal cracks with special rubberized asphalt. Specially designed undersealing equipment and experimental field work needed to test both the feasibility of such a technique and establish routine procedures are required.

Anticipating that specially designed retrofit drains would be installed and the longitudinal cracks sealed, it was recommended that elevation measurements be taken at scheduled intervals and at selected locations to determine slab movement due to frost action and to determine if the drains perform as expected. Pavement condition surveys conducted by the Research Services Unit of the Laboratory are intended to provide data regarding the effect that drains and surface sealing efforts have on pavement life.

This report presents the results of elevation measurements taken over two freezing seasons, before and after installation of standard retrofit edge drains. During both these freezing seasons, no longitudinal cracks were sealed.

Pavement Elevation Measurements

Pavement sections 3, 4, 5, and 8 were selected for elevation measurements during the 1979-80 and 1980-81 freezing seasons to determine the amount of frost heave experienced in the pavement structure. Of these, sections 4, 5, and 8 had been retrofitted with standard underdrains prior to the 1980-81 freezing season. Elevation measurements were made at 1,500-ft intervals for the southbound lanes of pavement sections 3, 4, and 5 and for the northbound lanes of section 8. The location of each measurement is shown in Figure 2.

The initial profile of the pavement was established each fall prior to the start of the freezing season. Permanent benchmarks were established for each site monitored. Measurements were made at two or three-week intervals, which appeared to provide a reasonable picture of the overall pavement movement. However, more frequent measurements would be necessary to detect short term differential frost heave conditions.

The Freezing Index for the 1979-80 and 1980-81 freezing seasons, shown in Figures 3 and 4, are 621 and 799, respectively. These values, when

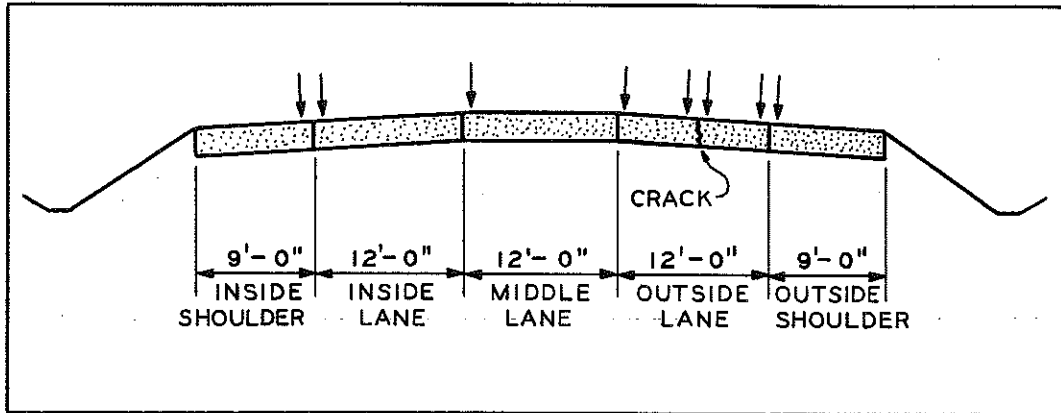


Figure 2. Locations on the pavement surface where elevations were measured.

compared with the average Freezing Index of 550 for the area and a corresponding design value of 850, indicate that both seasons were colder than normal and that the 1980-81 season was significantly colder than 1979-80.

As indicated in Ref. (3), maximum frost heaves are to be expected under severe cold weather conditions, during which considerable quantities of salt are used for ice control. The 1980-81 freezing season, with its extended severe cold and heavy snowfalls, could be an example of this condition.

Results of the pavement elevation surveys made during the 1979-80 and 1980-81 freezing seasons are given in the Appendix. These results indicate that:

1) With each passing season the raised pavement surface, in general, did not return to its previous level, indicating that the pavement base and subbase become less dense as a result of frost action.

2) In most cases the accumulated frost heave was greater in the 1980-81 season, which was after the retrofit underdrains were installed. However, the increase is believed to be related to the more severe weather in 1980-81.

3) Most, if not all, of the frost heave comes from the granular base and subbase materials rather than from the subgrade. This is indicated by the fact that maximum heave takes place near the beginning of the freezing season before the frost has penetrated into the subgrade.

The frost heave data shown in the Appendix are summarized in Figures 5 through 9.

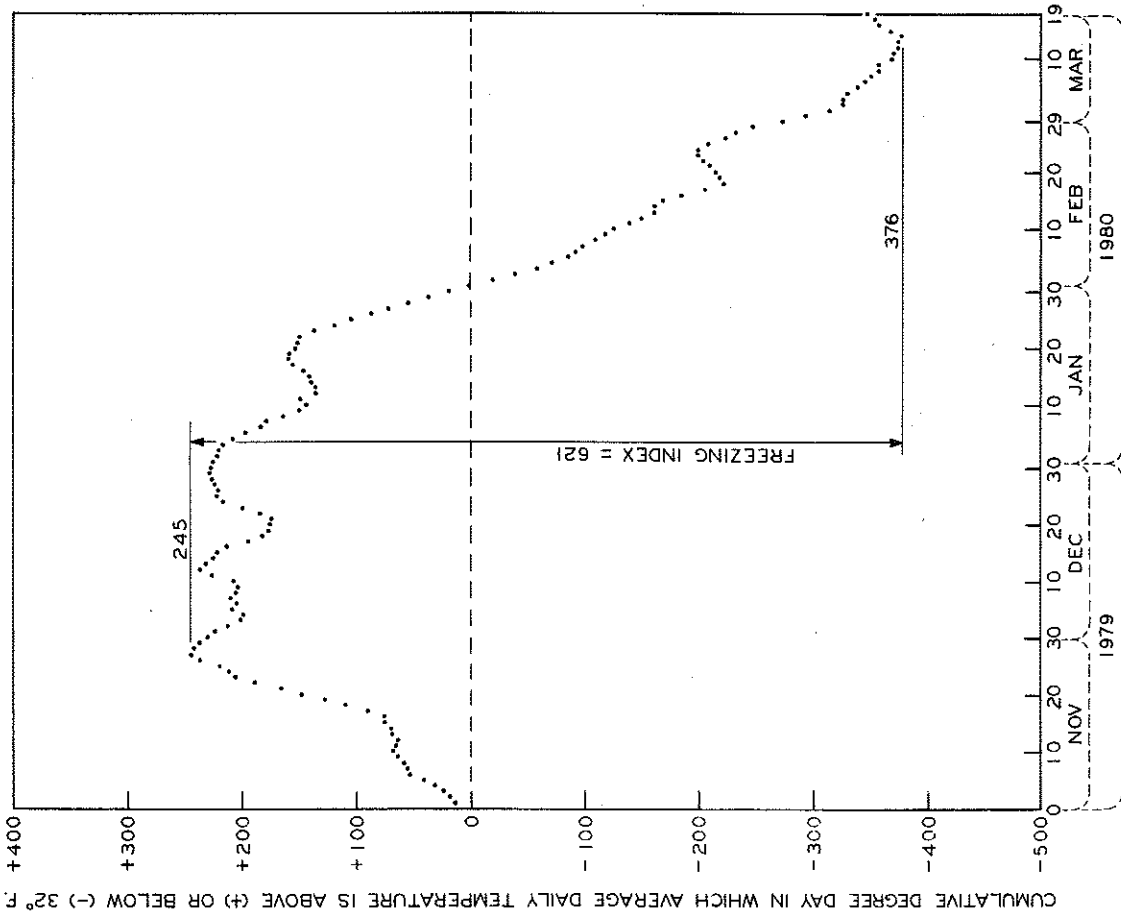


Figure 3. Freezing Index for the 1979-80 freezing season.

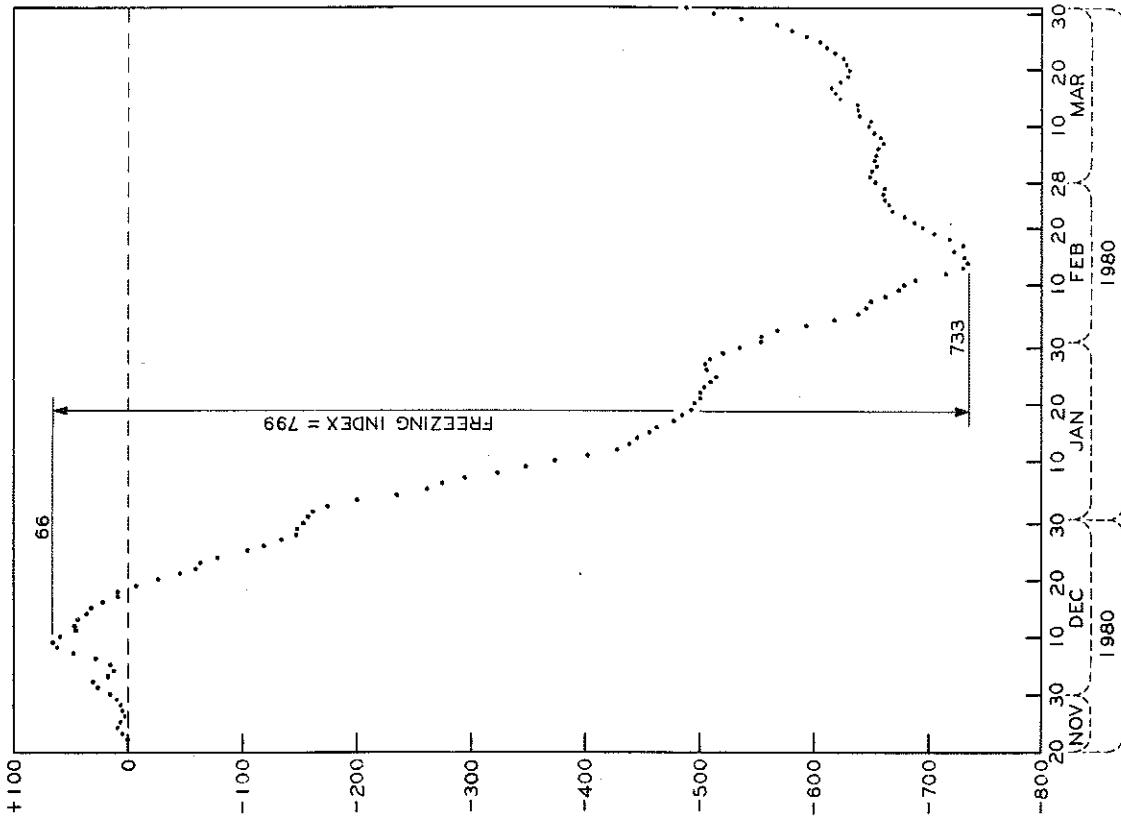


Figure 4. Freezing Index for the 1980-81 freezing season.

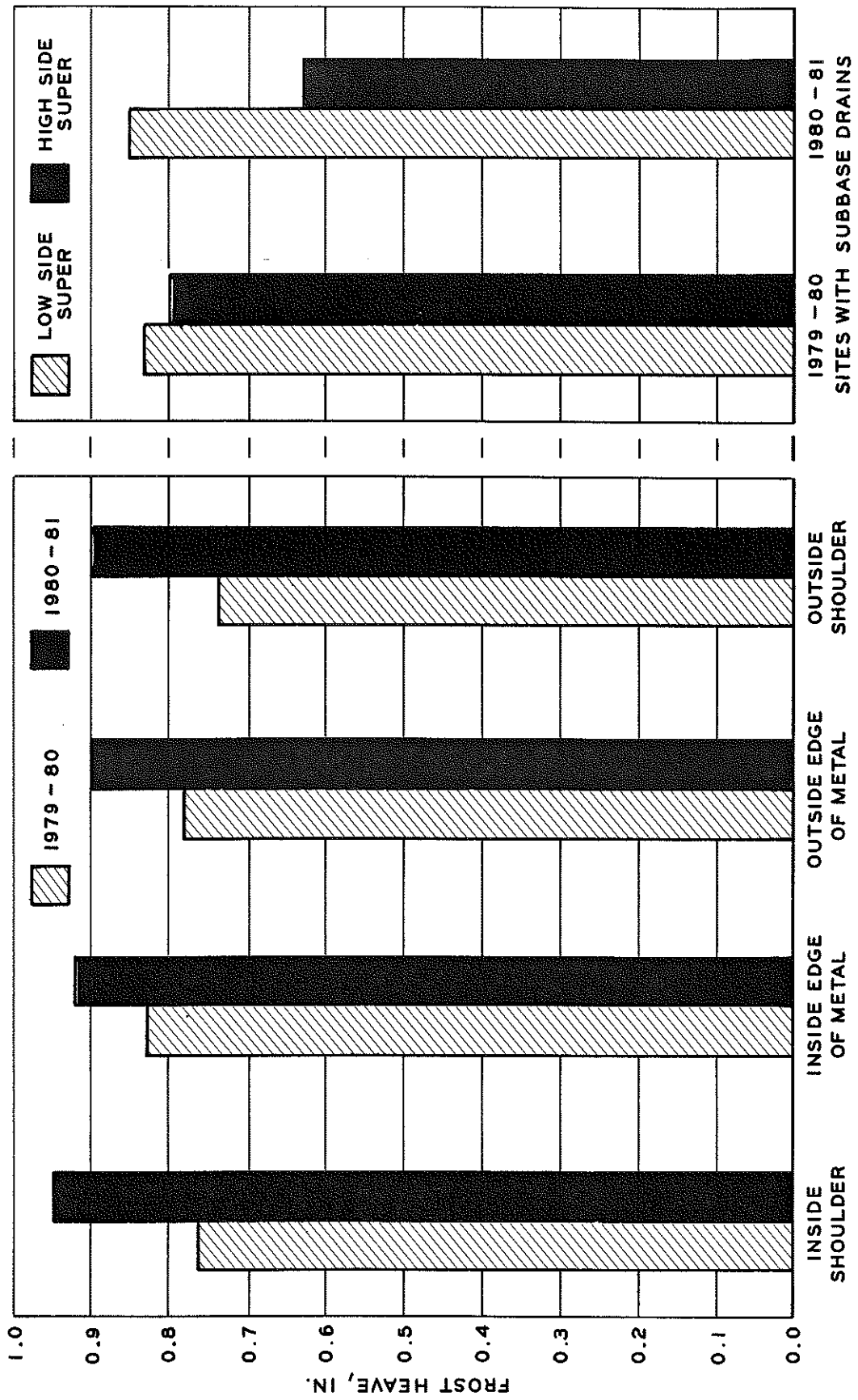


Figure 5. The average of the maximum frost heave measured at each site.

Figure 6. The average of the maximum frost heave measured on the low side of superelevated pavement, compared to the high side, for sites having retrofit underdrains.

Figure 5 shows that the average of the maximum frost heave measured at both drained and undrained sites was greater for the 1980-81 season than it was for the previous season. These results show that the retrofit underdrains have had little, if any, influence on minimizing the frost heave potential of the pavement. However, as has previously been reported, the type of drain installed on I 275 does not reduce frost heave, rather it reduces the period of time that the pavement is in a weakened condition following spring thaws. The drains accomplish this by reducing the length of the drainage path which, in turn, increases the rate of consolidation of the subbase and, therefore, the base layers.

Figure 6 compares the average maximum frost heave for the low side of the superelevated sections with that of the high side for sites having retrofit underdrains. These data show surprisingly little difference in heave between the 1979-80 and the 1980-81 freezing seasons. The indication is that for superelevated sections of pavement, retrofit underdrains reduce frost heave where the supply of surface water is insignificant but have little or no effect where the surface supply of water is abundant. It is also interesting to note that there is only 26 percent less frost heave on the high side of the superelevated sections compared to the low side. This indicates that while sealing joints and retrofitting special underdrains might, hopefully, prevent differential frost heave, it should not be expected to greatly reduce total frost heave.

Figure 7 compares the average of the maximum frost heave measured at sites with and without underdrains and before and after retrofitting underdrains. The results show that sites with underdrains heave about 1/2 in. less than those without underdrains. This figure also shows that the percent increase in frost heave from 1979-80 to 1980-81 freezing seasons was, 15 percent for drained sites compared to 30 percent for undrained sites. The indication is that retrofit underdrains are attenuating maximum frost heave. Of what value this may be in terms of increased pavement life requires long-term monitoring of longitudinal crack development of projects having retrofit underdrains compared to those without underdrains.

Figure 8 compares the average autumn pavement elevation for the 1979, 1980, and 1981 seasons. These data show that where less frost heave occurs there is less residual heave as a result of frost action. These data also show that recompactive effort and residual heave are inversely proportional. That is, in the traffic lane where compactive effort is greatest, permanent heave is smallest. These data also indicate the pavement sections studied are experiencing a reduction in the rate of accumulation of residual heave.

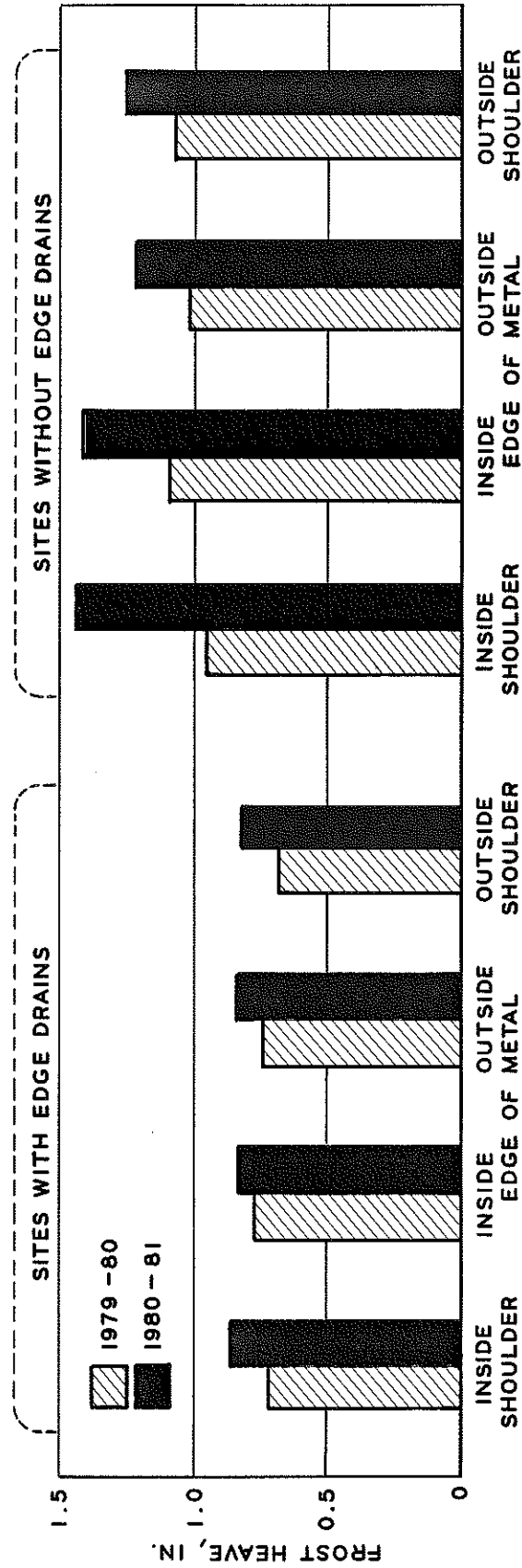


Figure 7. The average of the maximum frost heave measured at sites where retrofit underdrains were installed and sites where they were not installed.

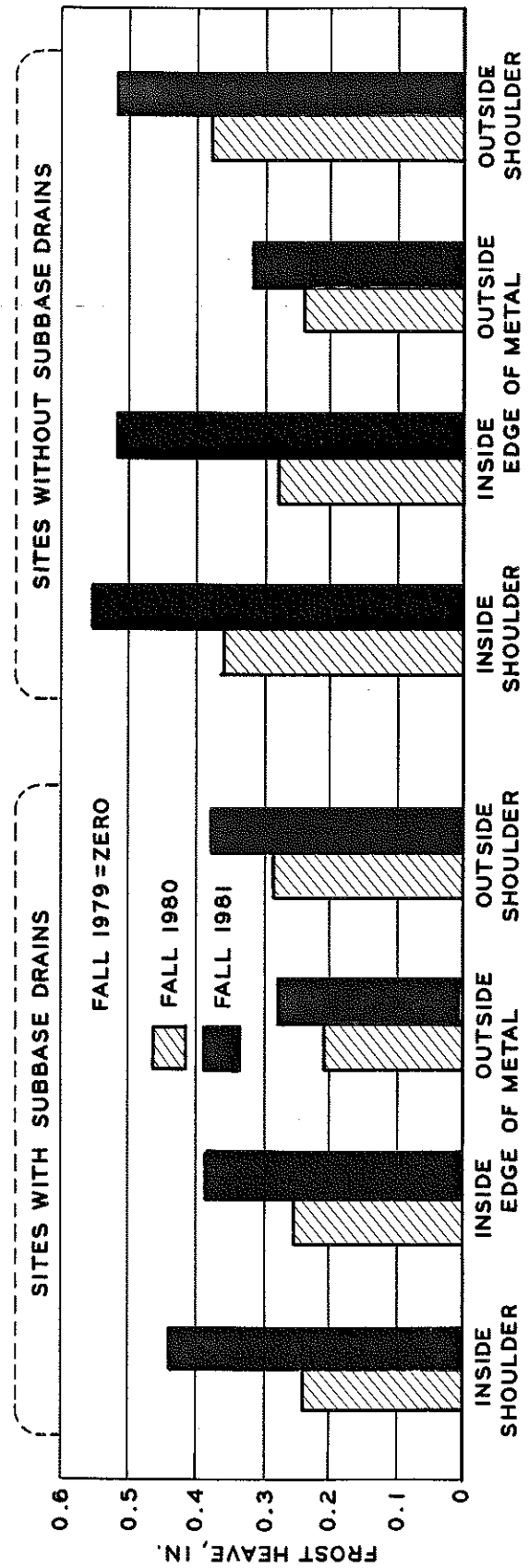


Figure 8. Average pavement elevation at the indicated locations, using 1979-80 elevations as data.

Figure 9 compares the maximum frost heave of undrained sites compared to drained sites (1980-81 data). These data show that considerably more frost heave occurs in section 3 where there are no retrofit underdrains compared to sections 4, 5, and 8 where drains were installed. Figure 7 shows this same relationship also existed before underdrains were installed. And, as Ref. (3) points out, section 3 has the poorest drained foundation of the sections compared. Ref. (3) also indicated that section 3 may not be subject to differential frost heave and this may explain why it has not longitudinally cracked. However, the large frost heave movements to which the pavement is subjected should, due to seasonal overstressing, shorten the life of the pavement. Plowed-in trenchless underdrains, of the type recommended by T. A. Coleman, may be beneficial in attenuating long-term deterioration of section 3.

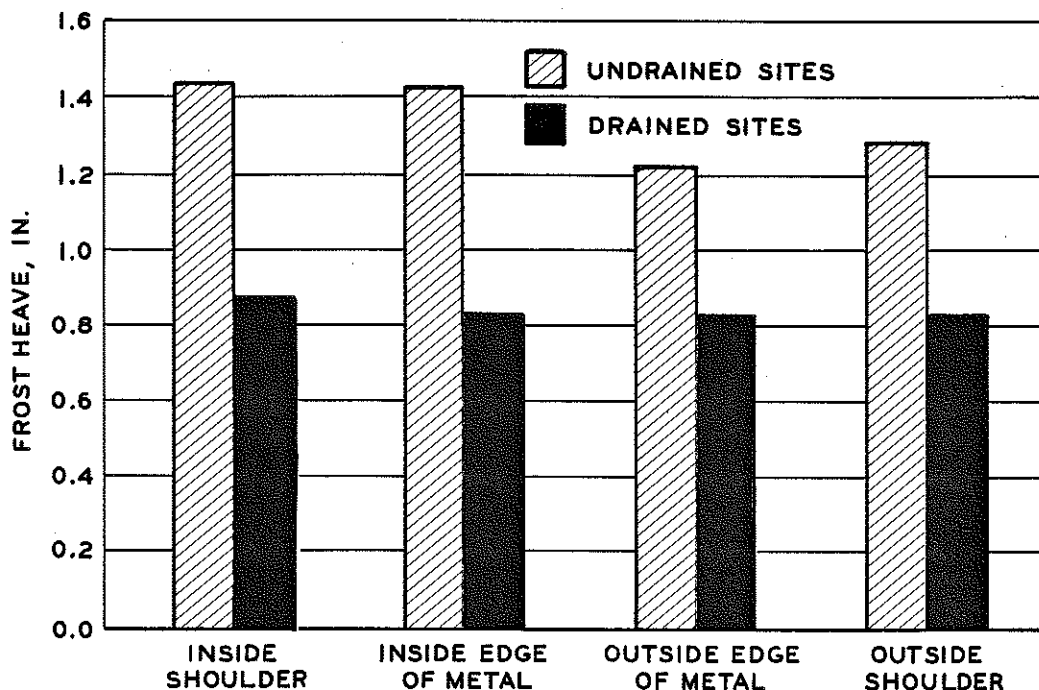


Figure 9. Average maximum frost heave of drained sites compared to undrained sites, 1980-81 data.

Recommendations

On the basis of the information presented in Ref. (1), (2), and (3), and on the results of frost heave measurement surveys presented in this report, the following recommendations are offered.

1) Plowed-in trenchless underdrains should be installed in section 3 to minimize, as much as possible, overstressing of the pavement during thaw periods. The cost of those drains may be small compared to the possible long-term benefits. However, positive economical justification is not yet determinable. Frost heave measurements should be made on sections 6, 7, 9, 10, 11, 12, and 13 in order to determine the magnitude of heave they are subject to. If frost heave exceeds 1 in., such as occurs in section 3, these sections should also benefit from retrofit plowed-in underdrains.

2) All sources of surface infiltrating water have the potential for differential frost heave. Therefore, it is important that all joints and, in particular longitudinal cracks, be sealed. Because longitudinal cracks experience differential movement, surface sealant methods appear futile. Therefore, full-depth crack sealing techniques should be investigated at the earliest possible opportunity.

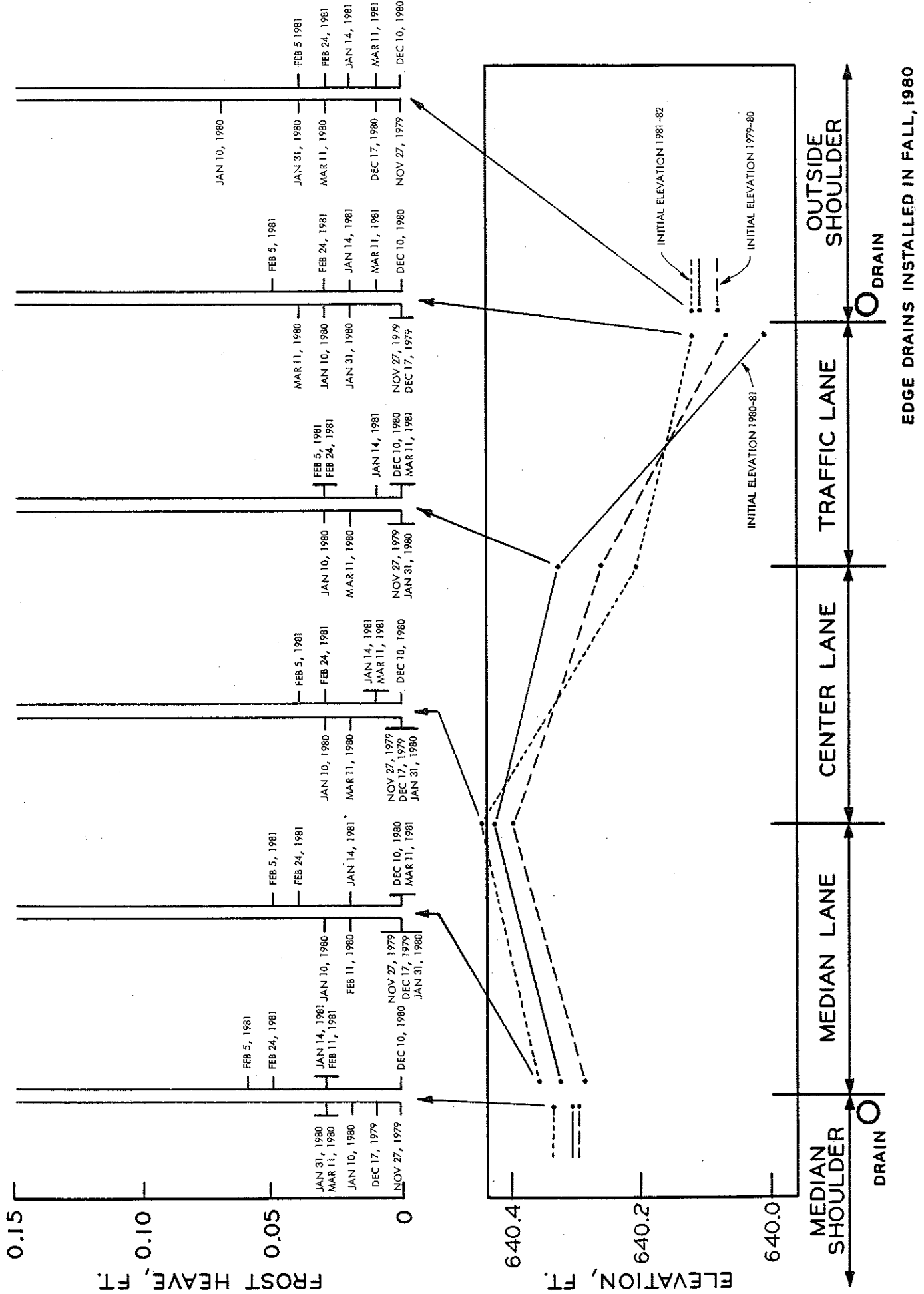
3) Dense graded aggregates should not be used for pavement base layers. The reason for this recommendation is that they are, to varying degrees, frost susceptible, susceptible to pumping, and susceptible to differential frost heave, all of which accelerate pavement deterioration. In addition, these characteristics cannot be corrected by retro-actions.

4) Sand or Class II materials should not be used for the subbase layer over clayey or other relatively impervious subgrades unless the layer can be made thick enough, the drainage path short enough, and the sand be permeable enough to allow one-half of the gravity drainable water to drain in 10 days or less. In addition, when gravity drainage is completed the subbase must be less than 90 percent saturated so that volume change (frost heave) does not occur on freezing. Subbase drainability control should be conducted prior to or during construction when corrective action, if needed, is least expensive. Retro-action is the most expensive means of improving internal drainage because the pavement may already be damaged before retro-action is taken and retro-action has only a minimal opportunity to improve subdrainage.

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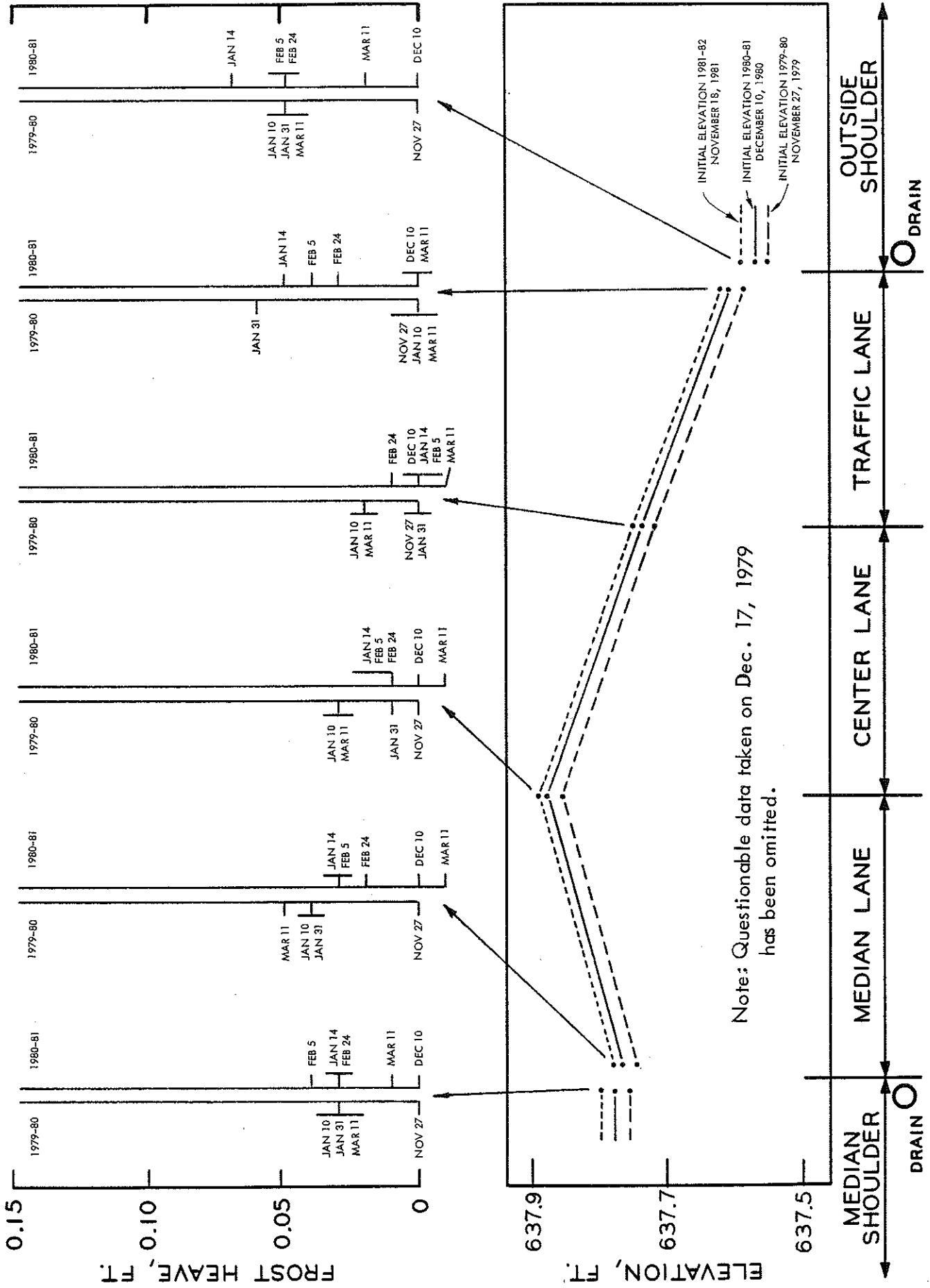
1. Investigation of the Foundation Condition of I 275, Research Project 73 F-129, Departmental correspondence from E. C. Novak, Jr. to G. R. Cudney, February 15, 1979.
2. "Investigation of Pavement Problems on I 275," Michigan Department of Transportation, Research Report No. R-1126, October 1979.
3. "Base and Subbase Properties Affecting Longitudinal Cracking of I275," Michigan Department of Transportation, Research Report No. R-1152, April 1981.

APPENDIX



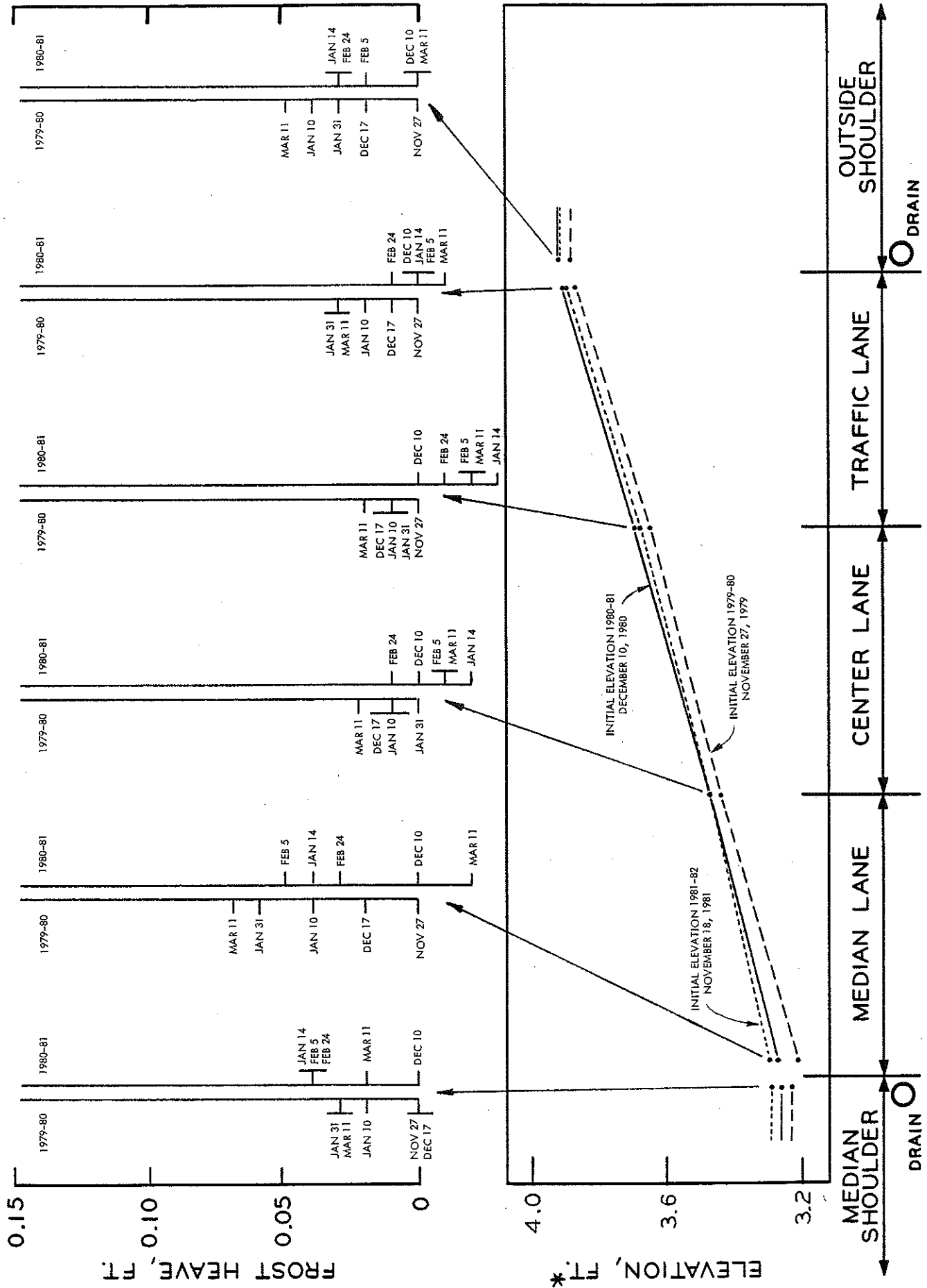
EDGE DRAINS INSTALLED IN FALL, 1980

Pavement heave at Site No. 10, Sta. 848+00, southbound I 275.



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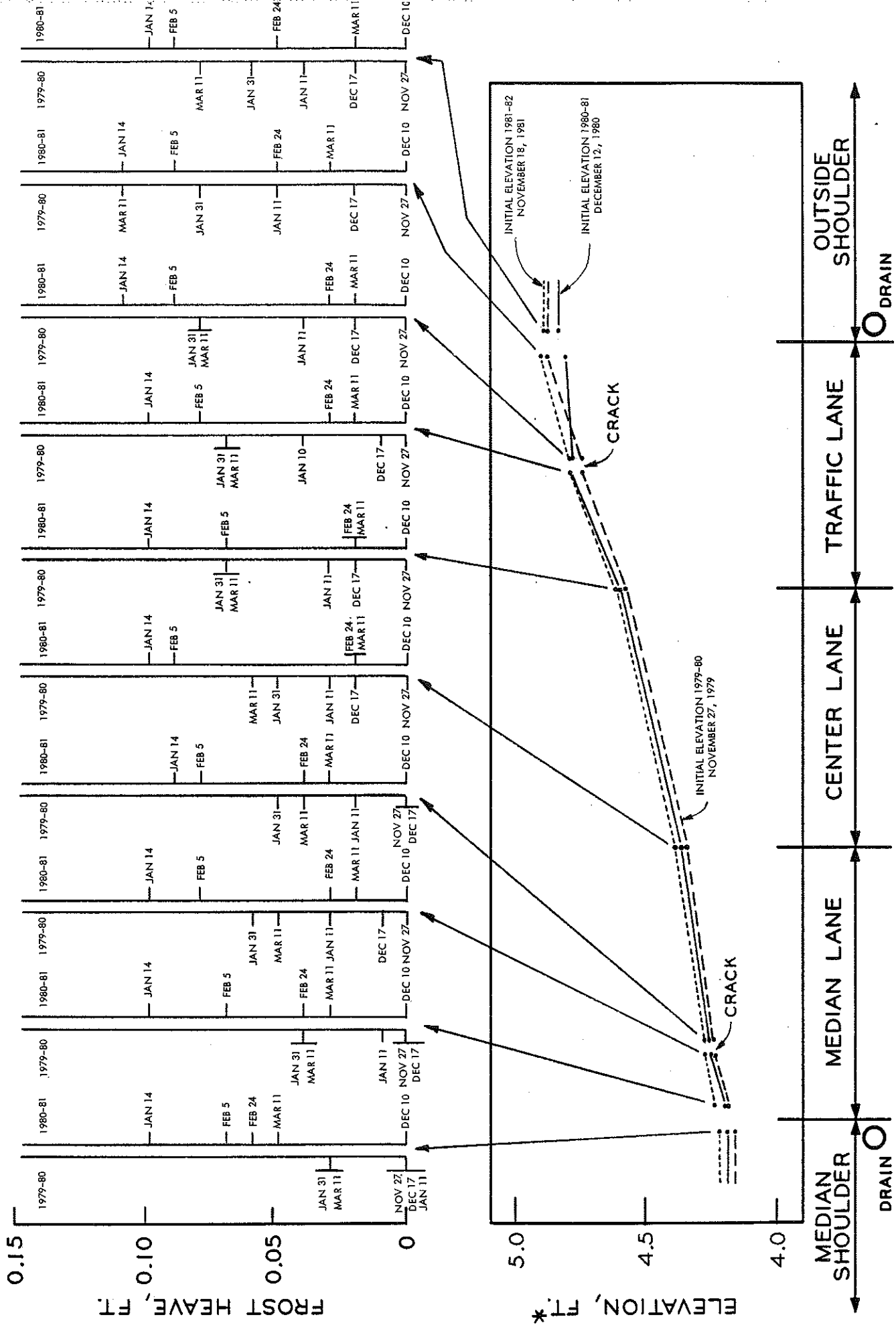
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*RELATIVE TO ASSUMED BENCHMARK ELEVATION

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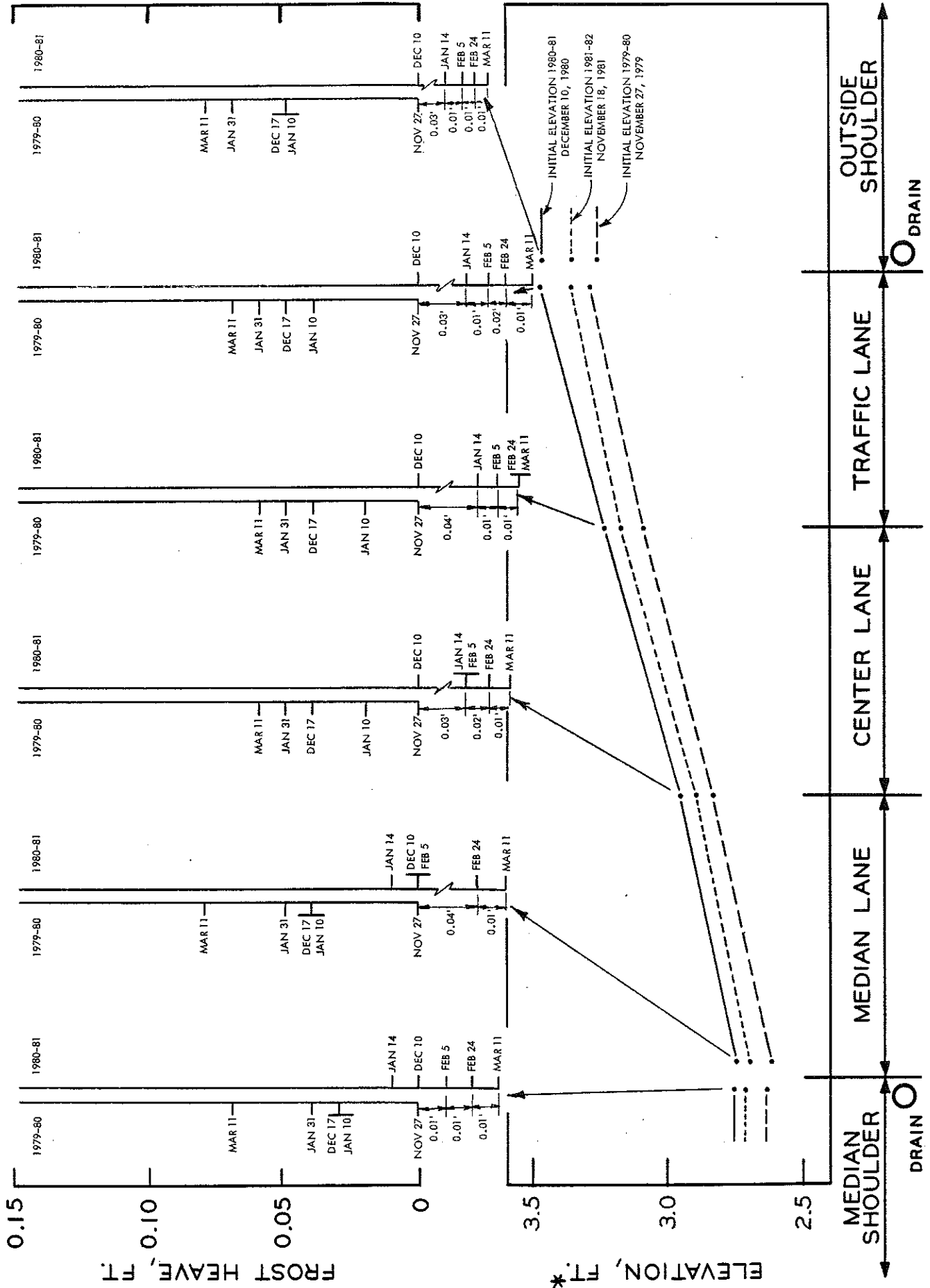
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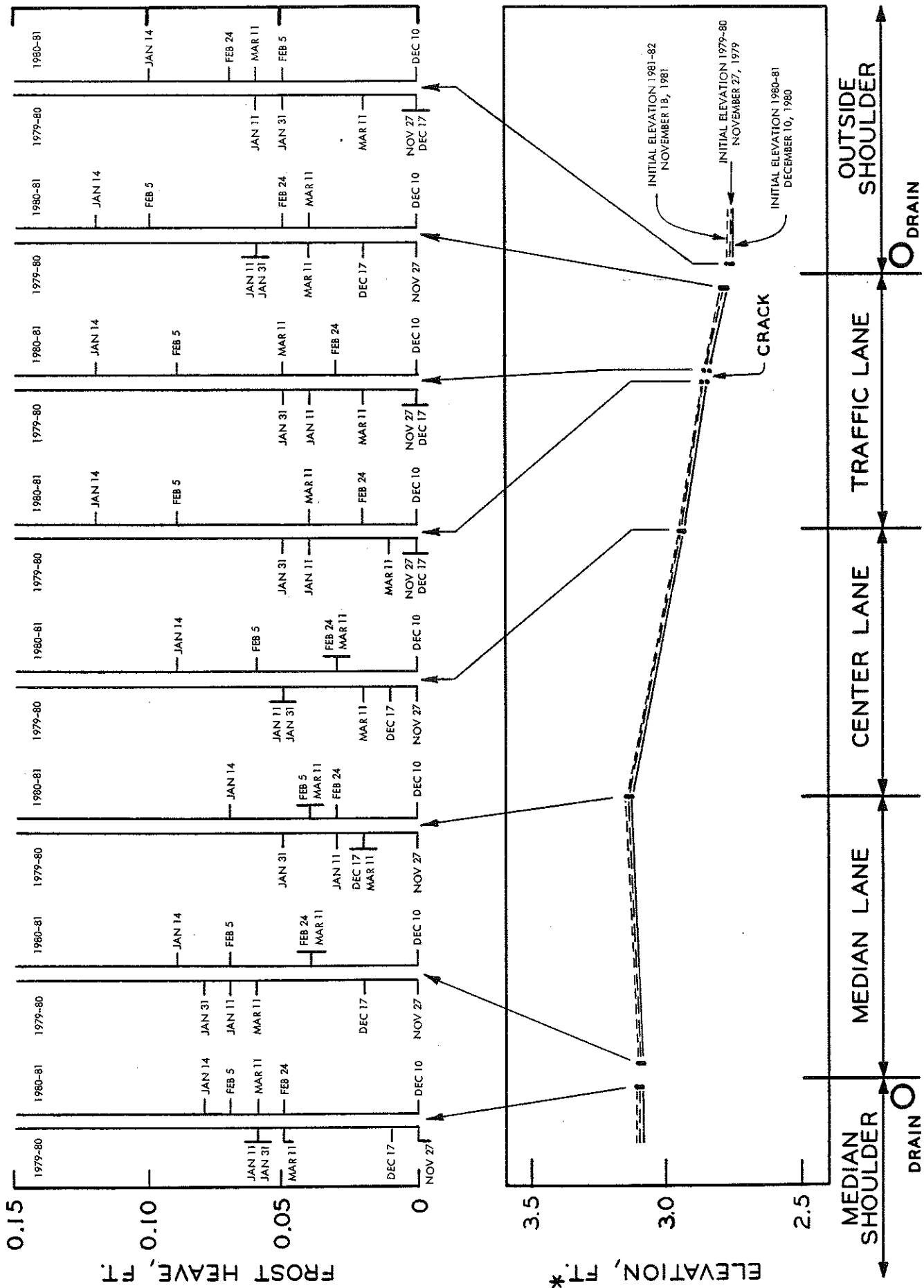
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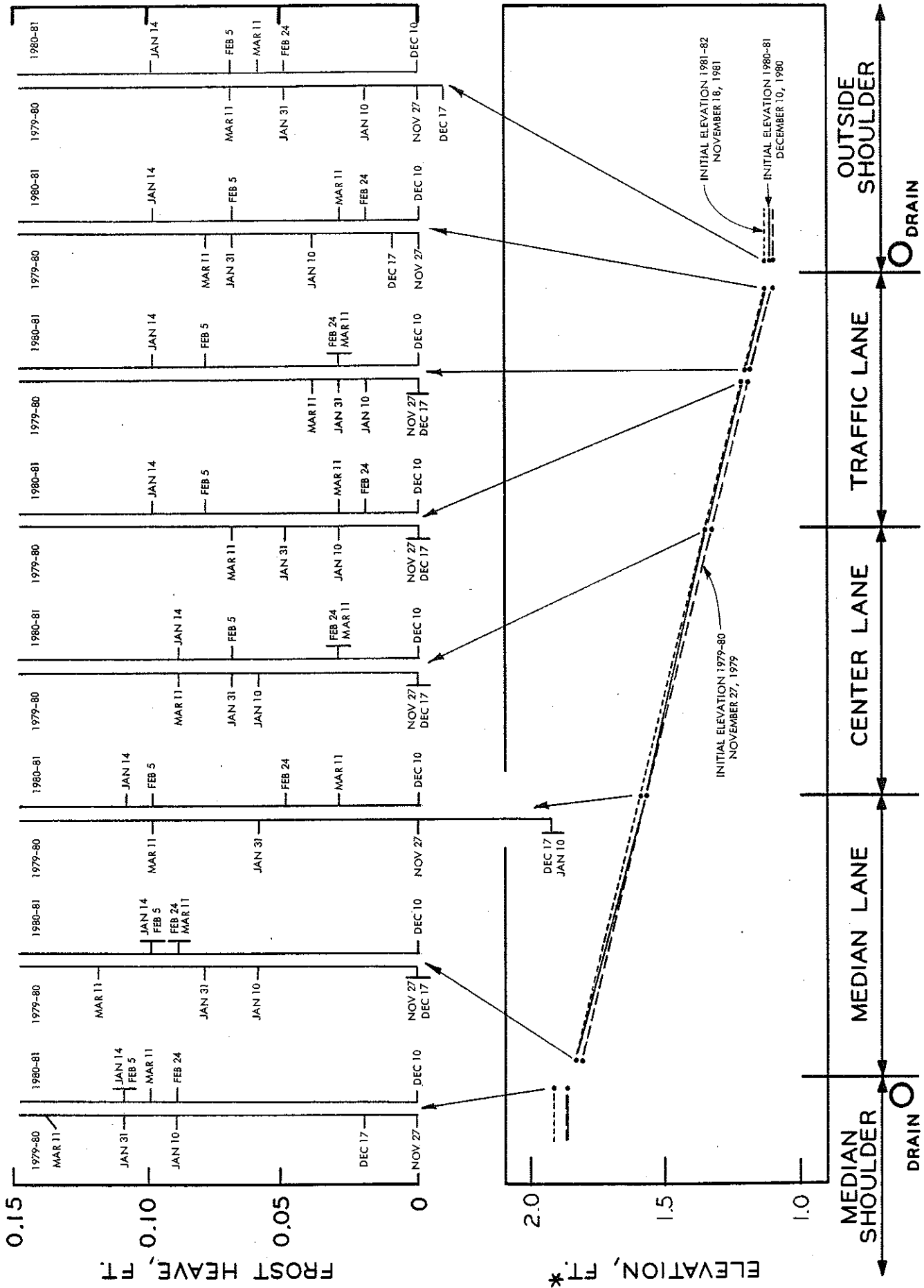
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*RELATIVE TO ASSUMED BENCHMARK ELEVATION

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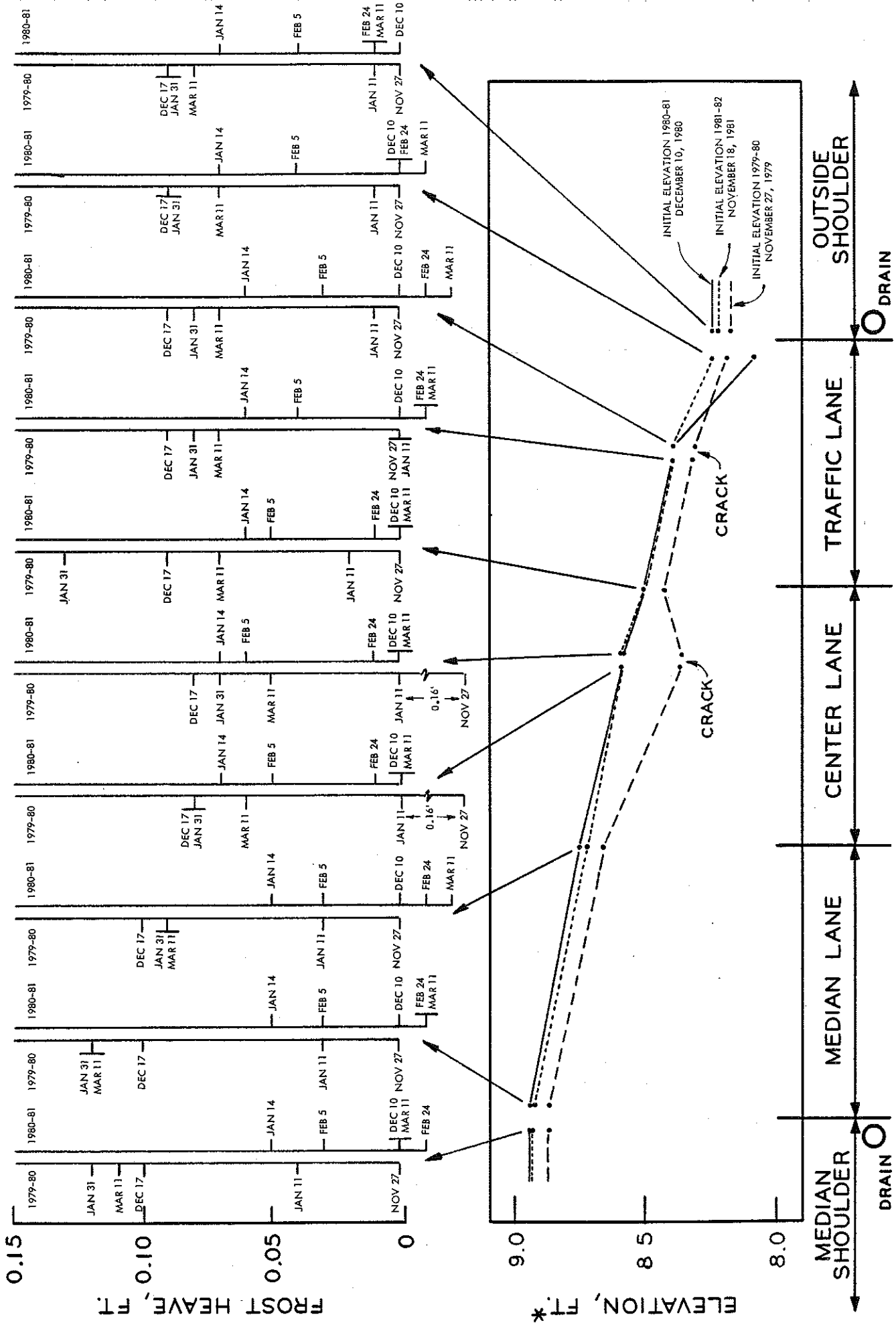
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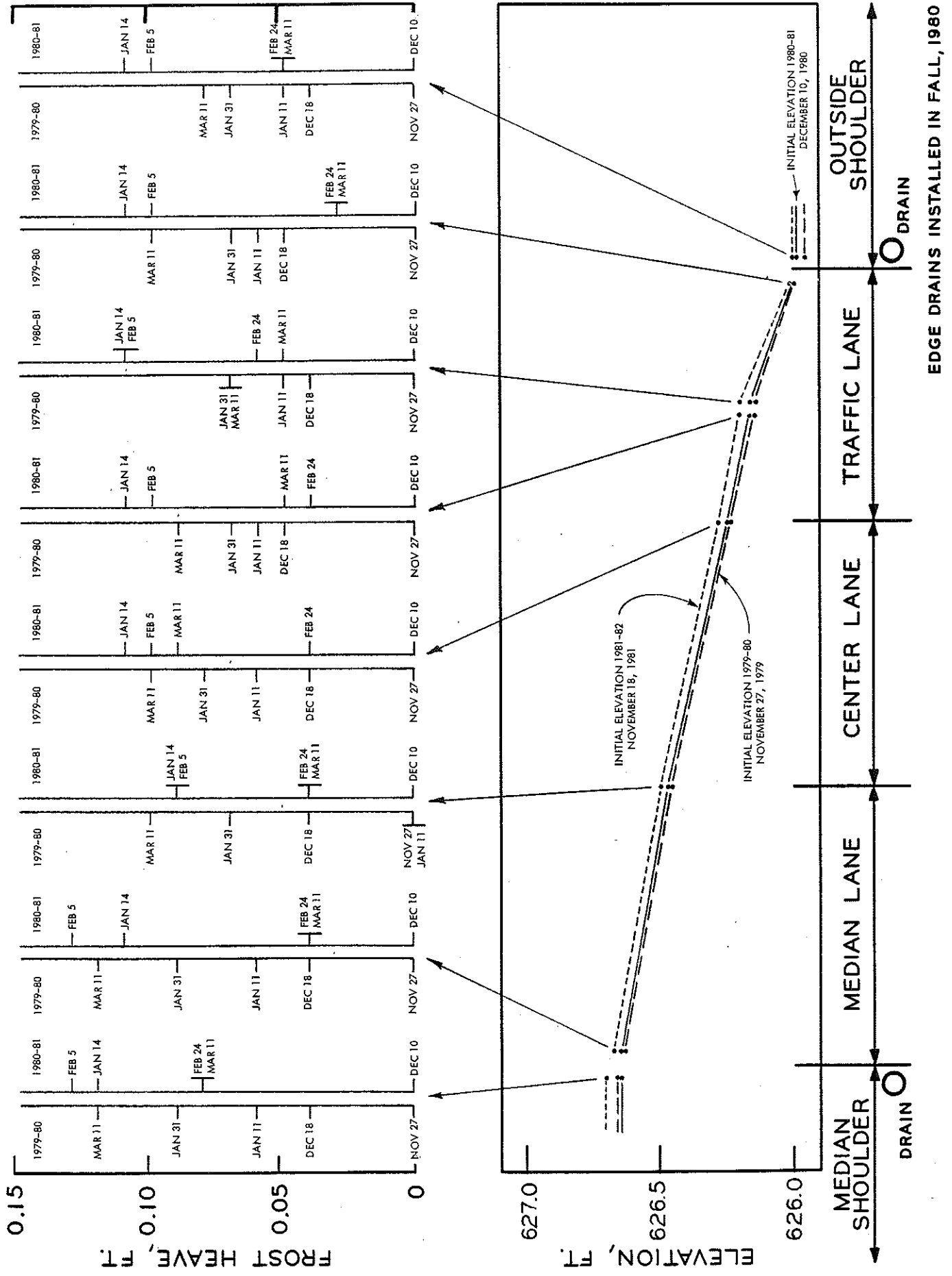
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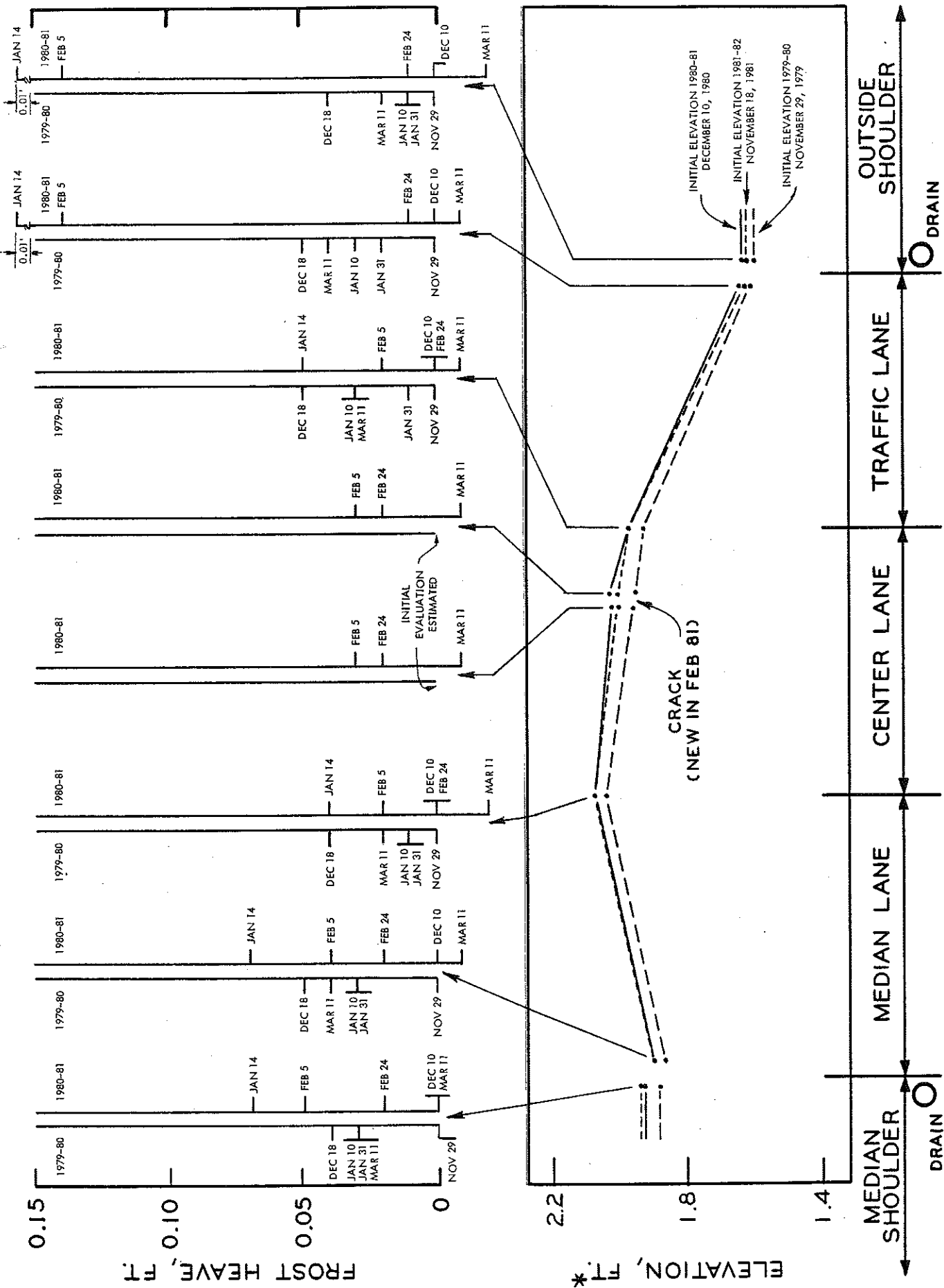
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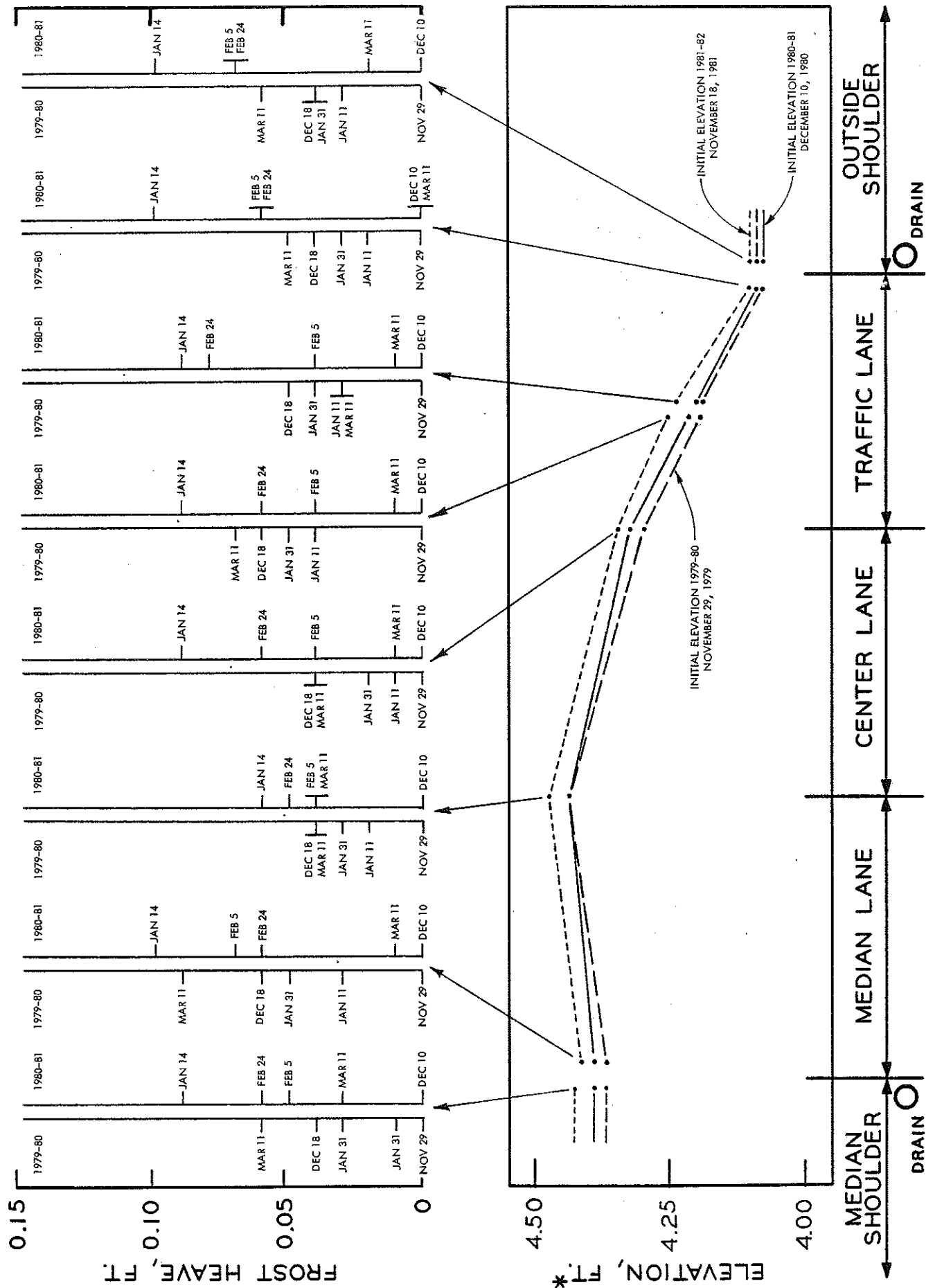
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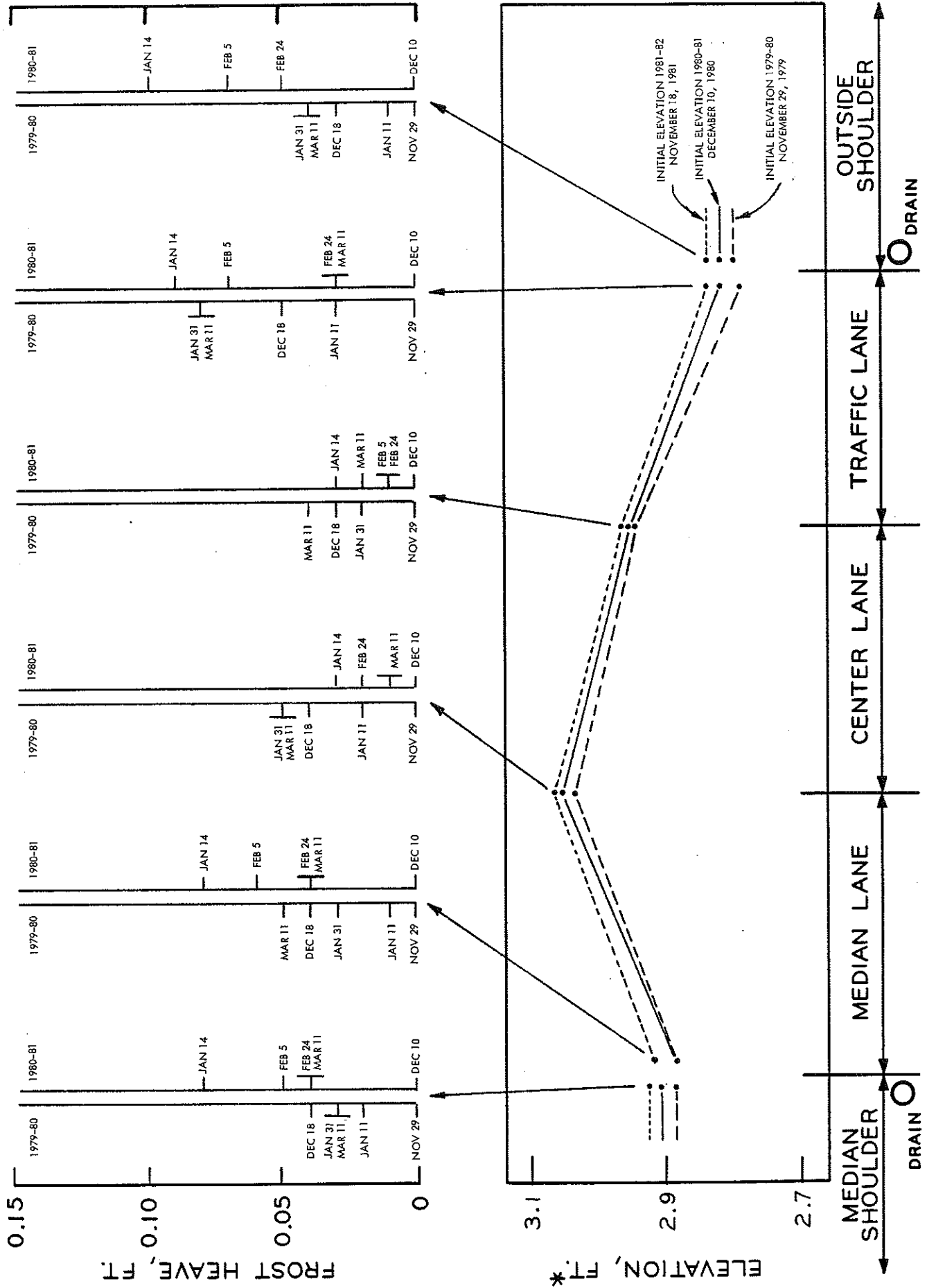
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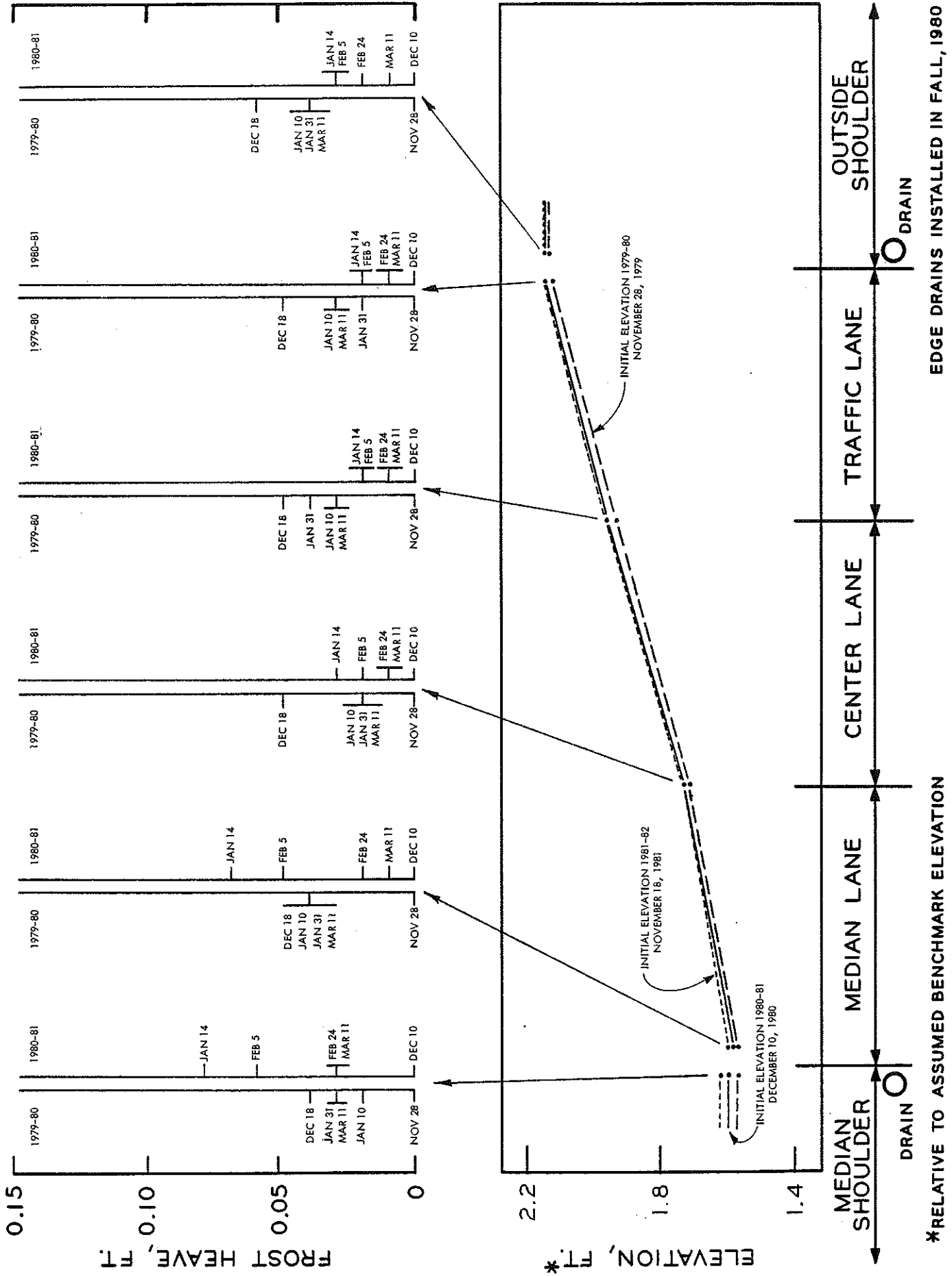
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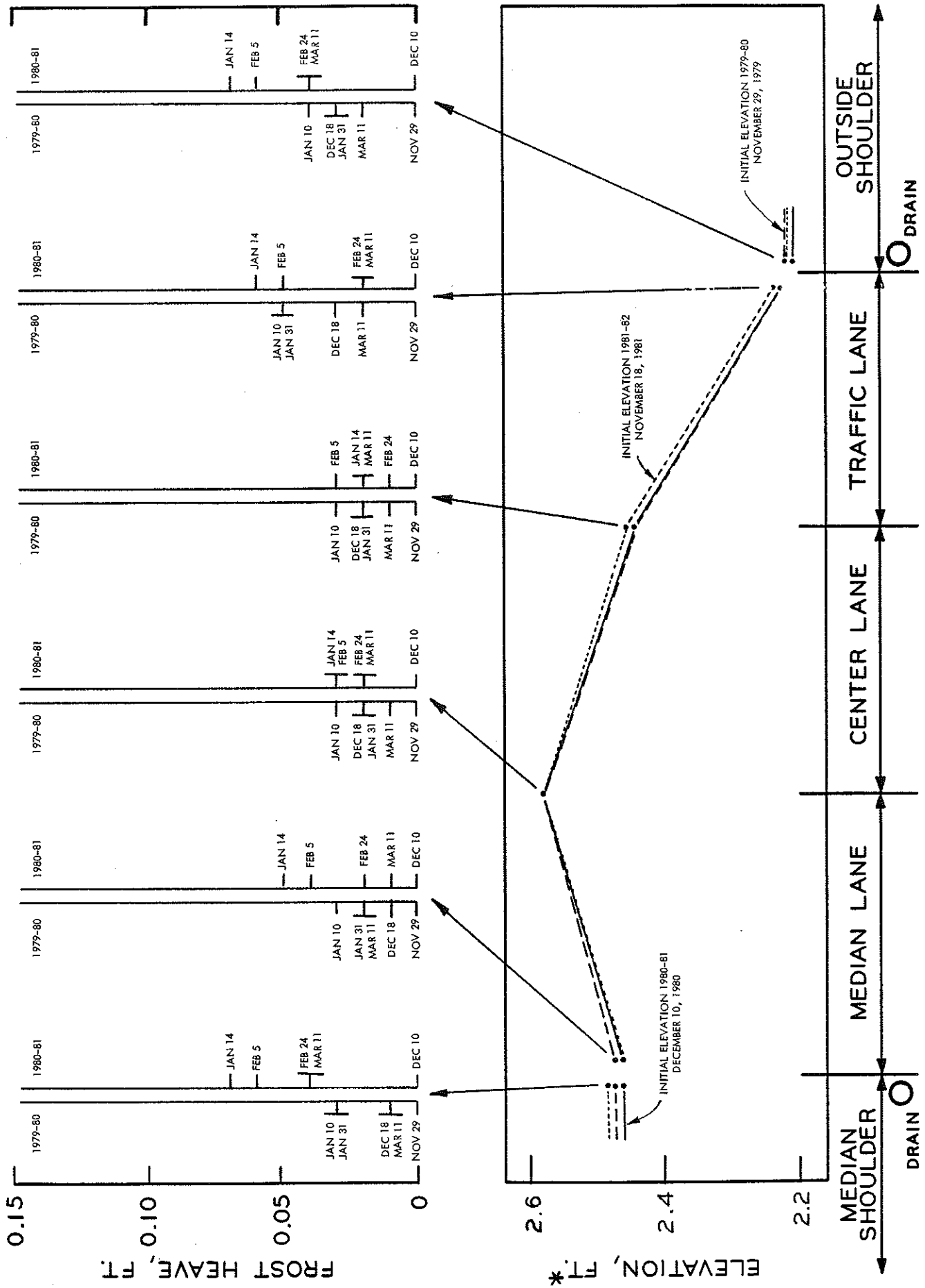
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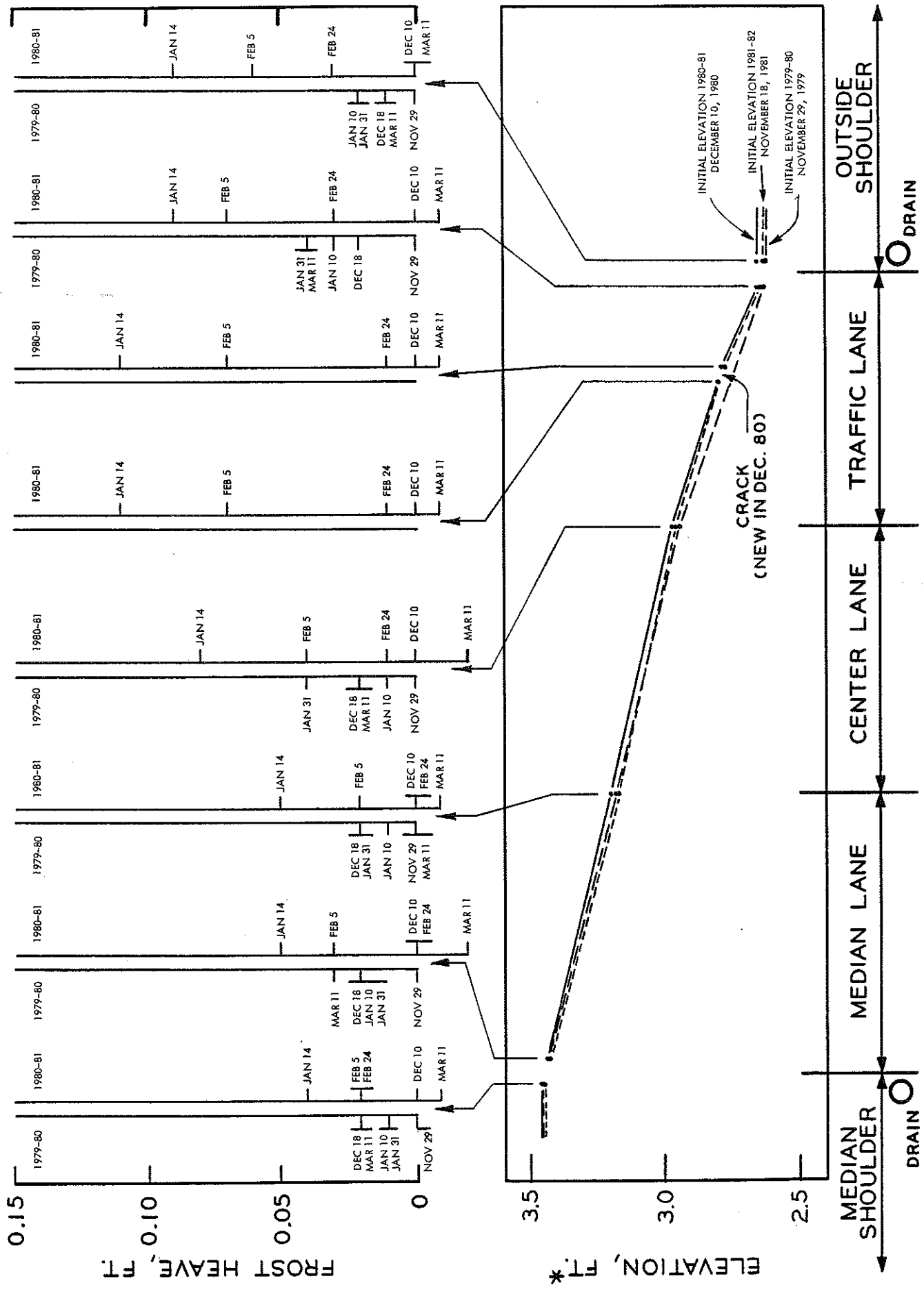
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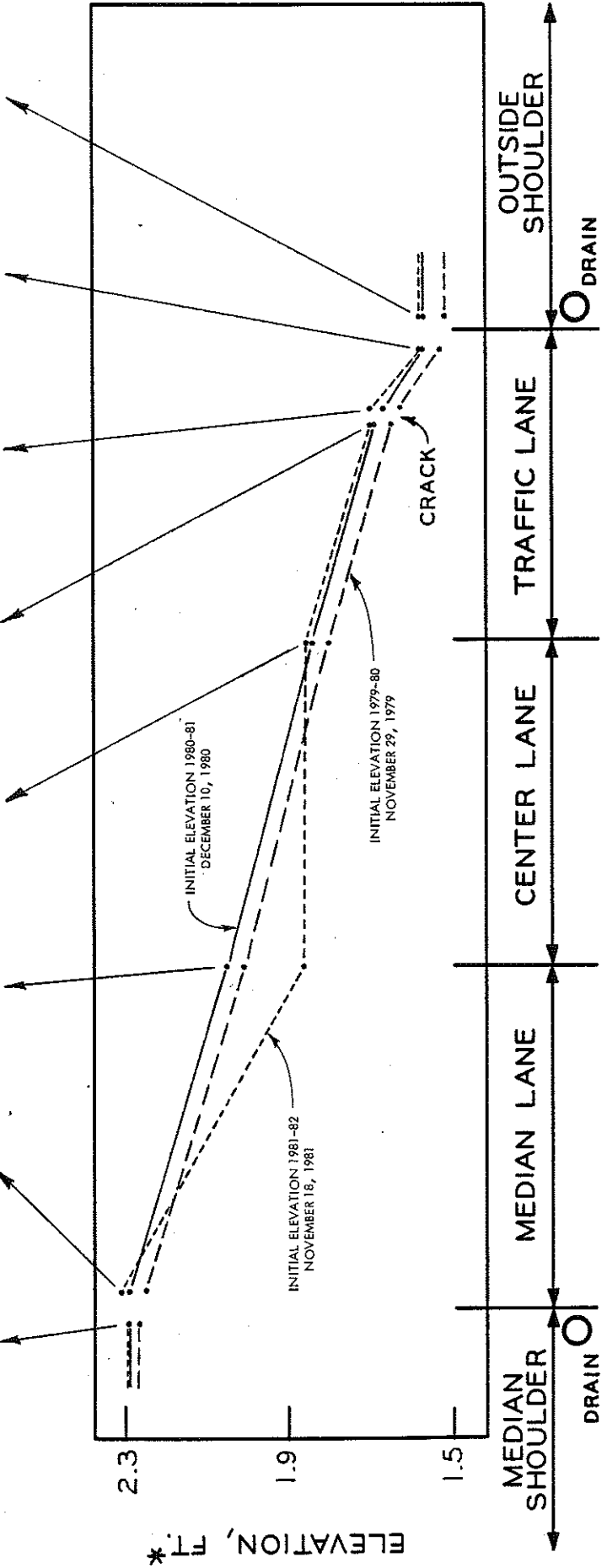
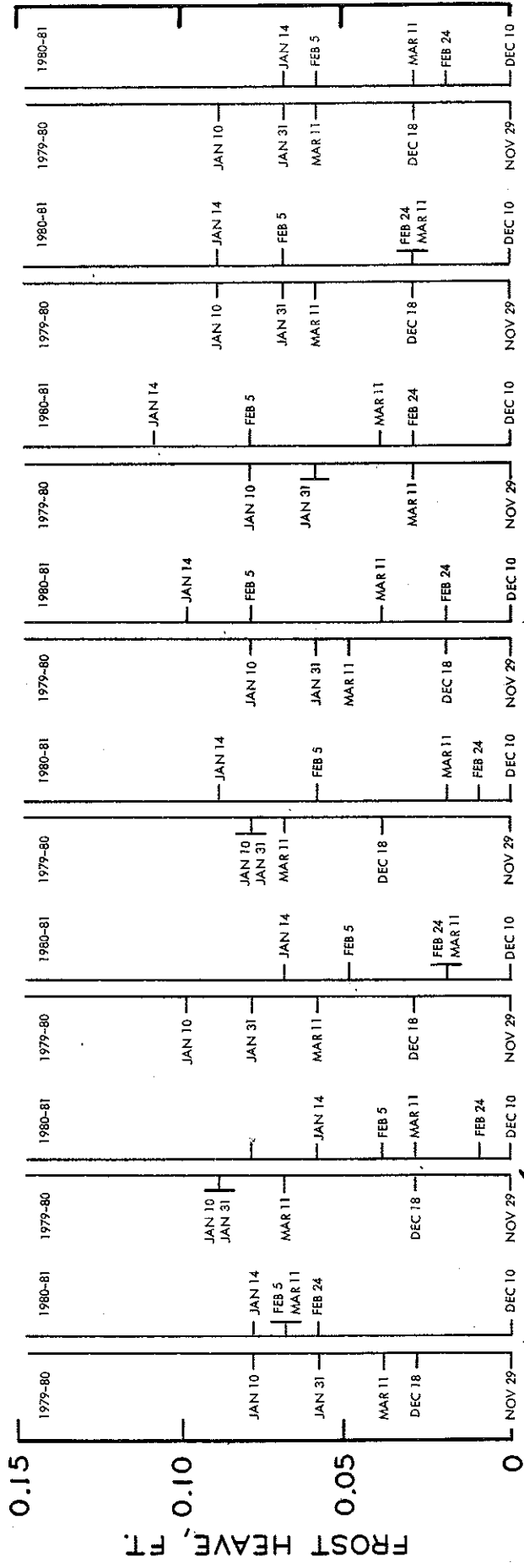
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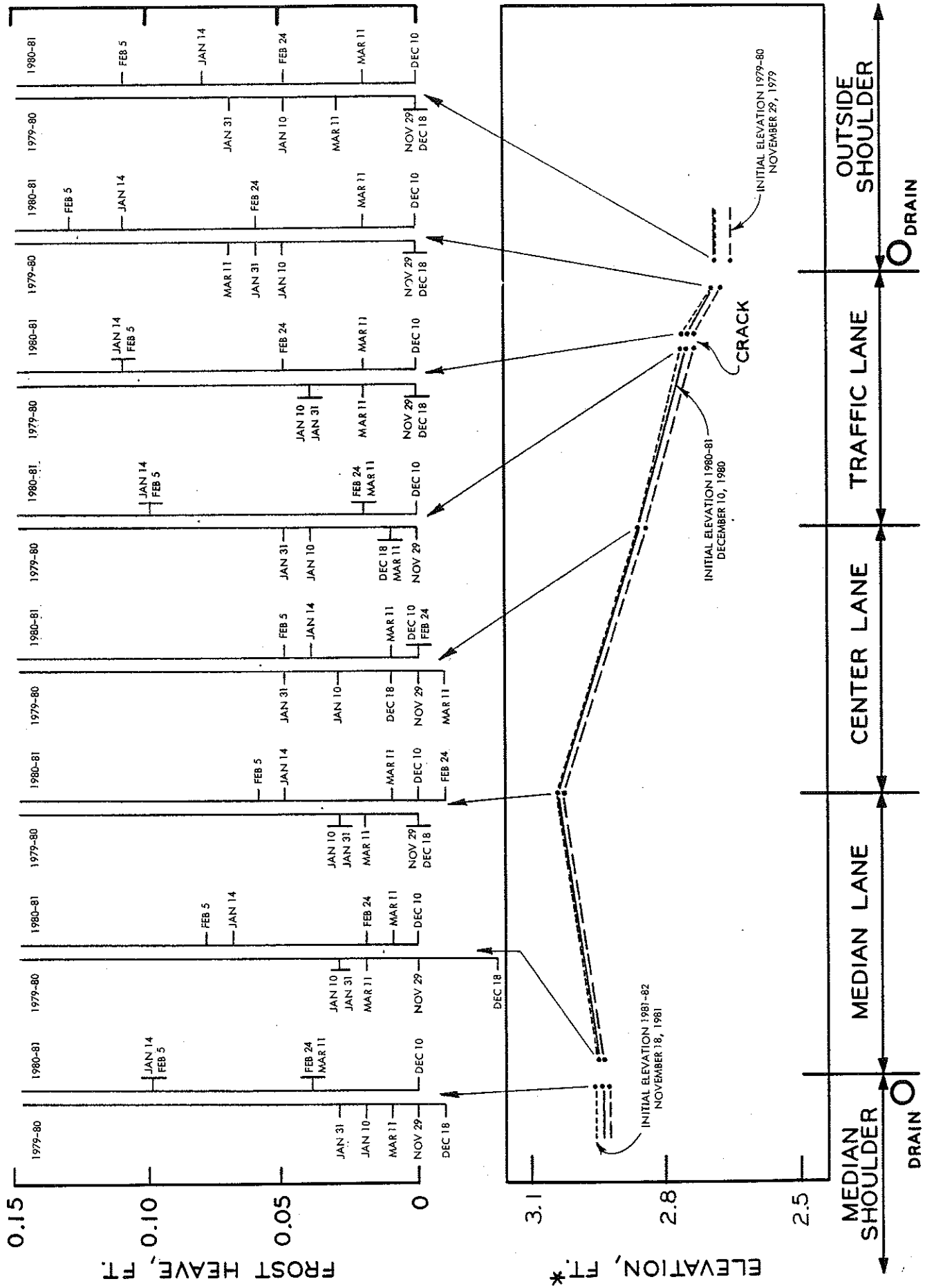
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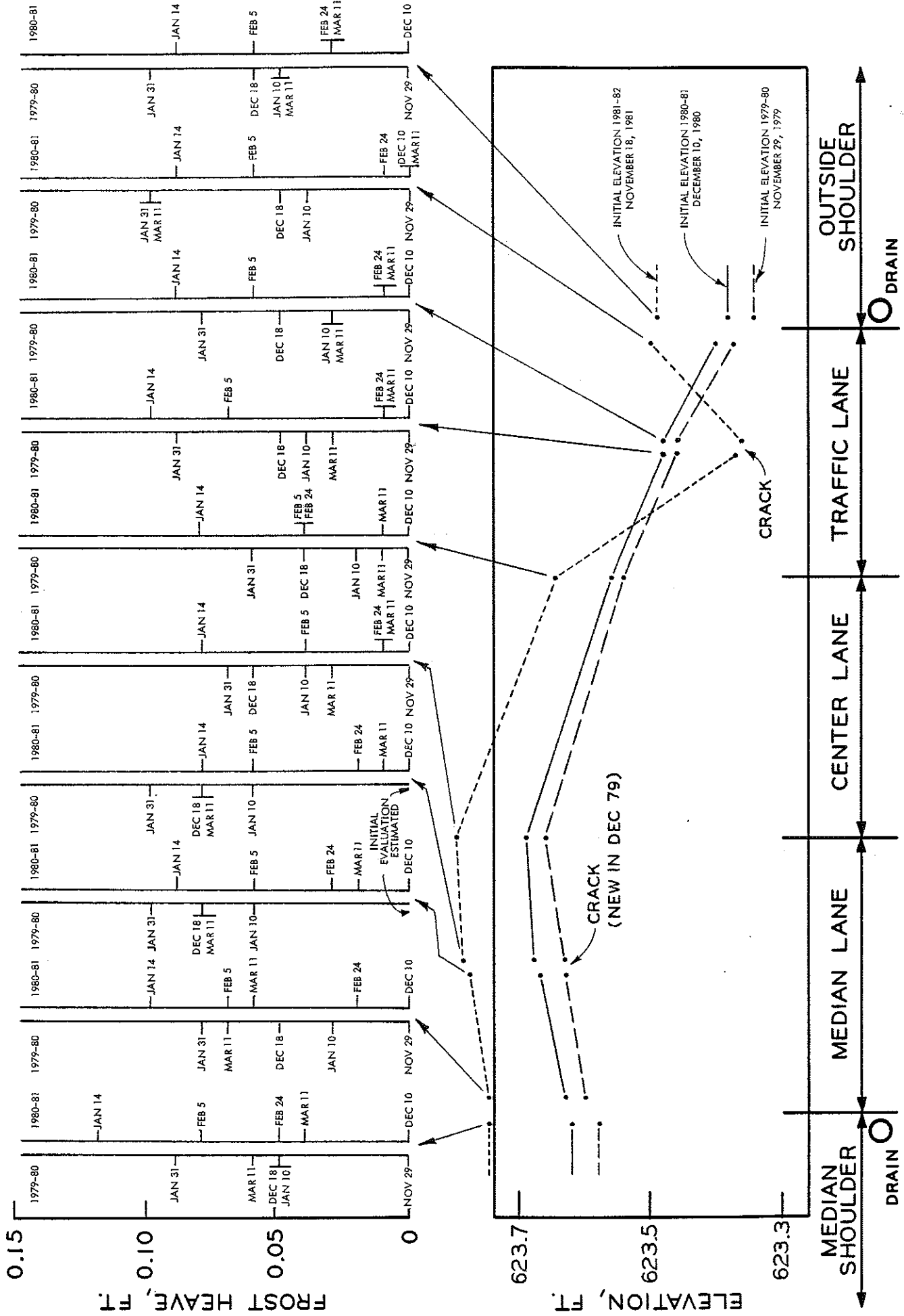
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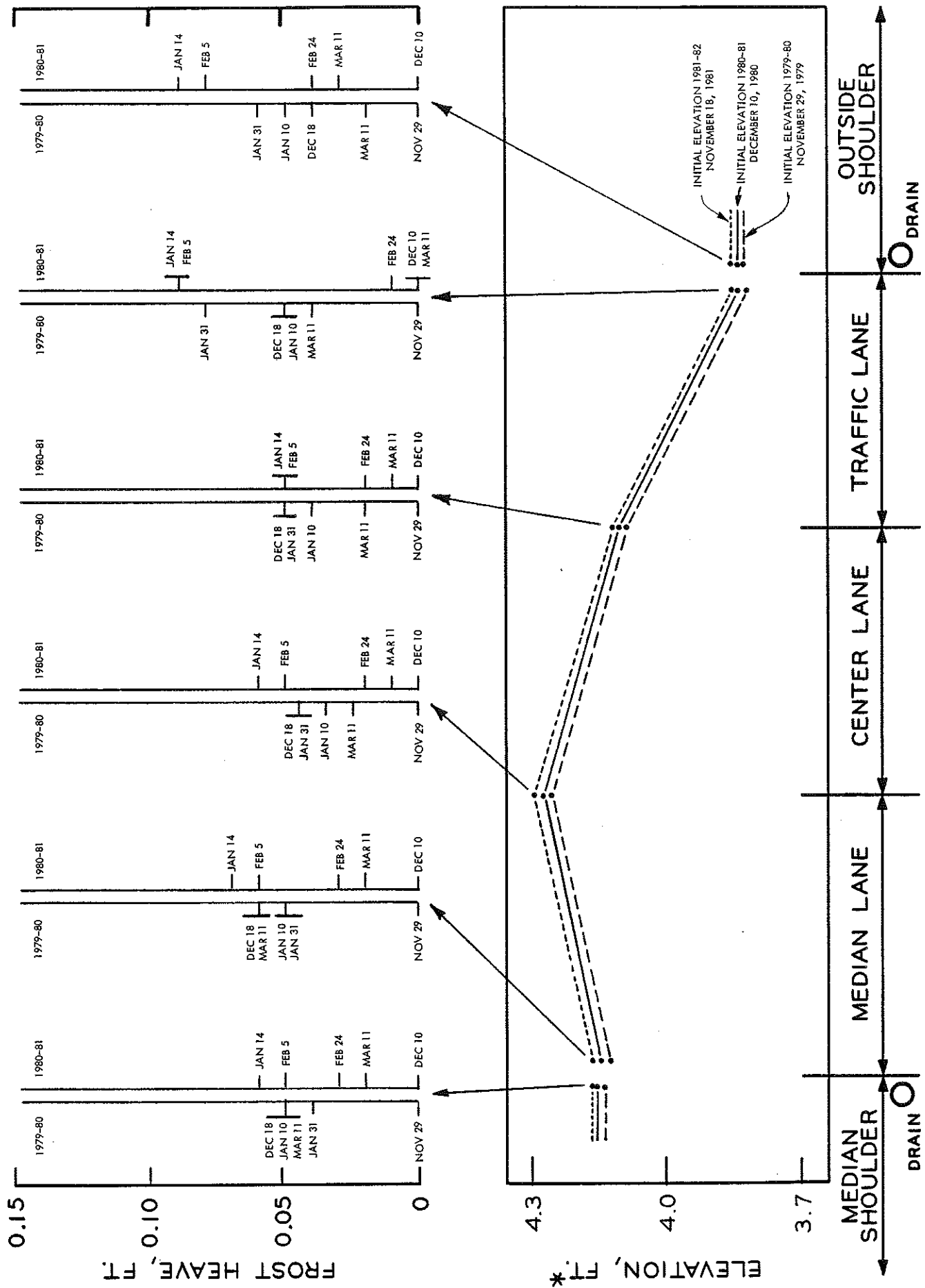
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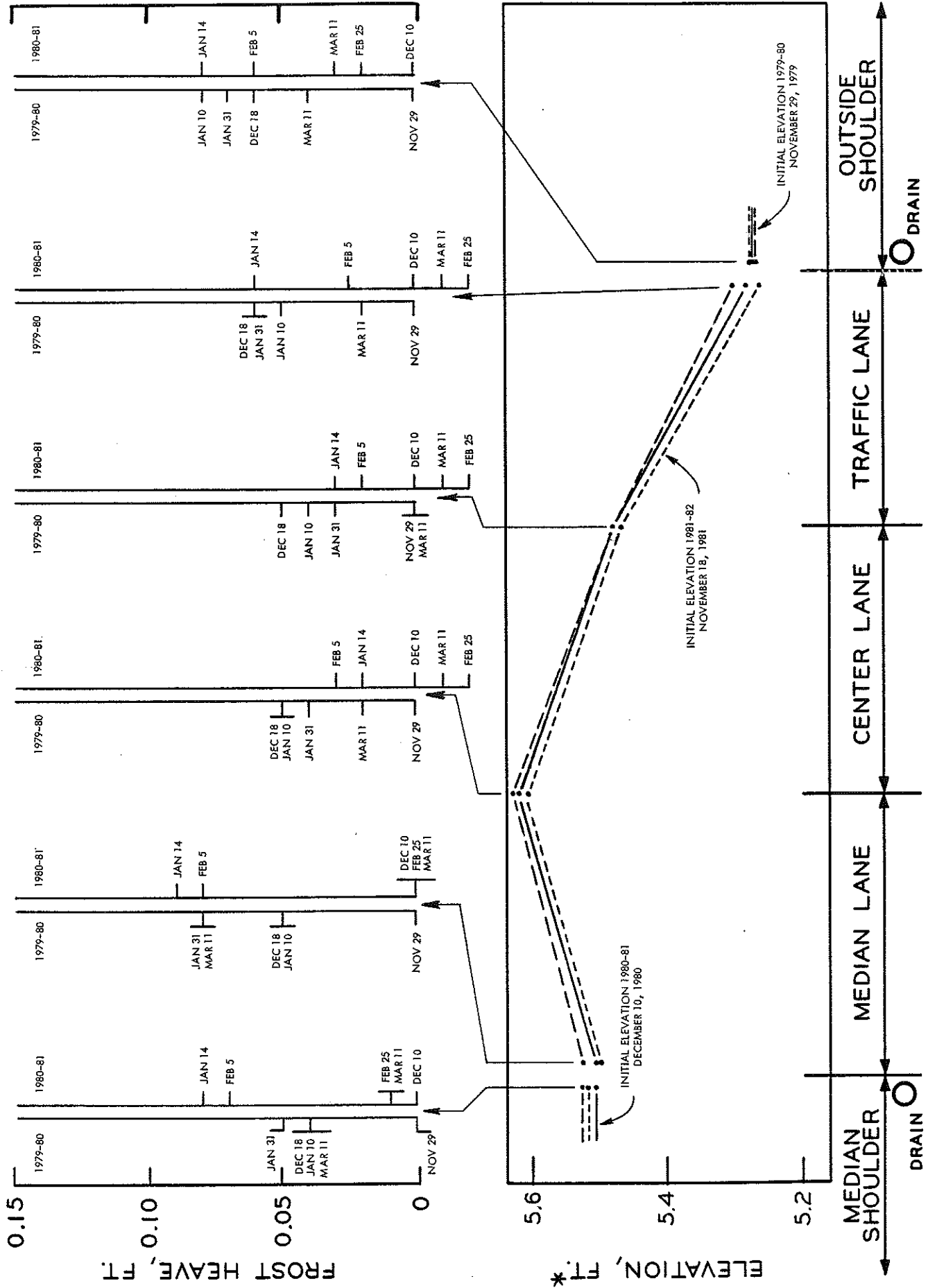
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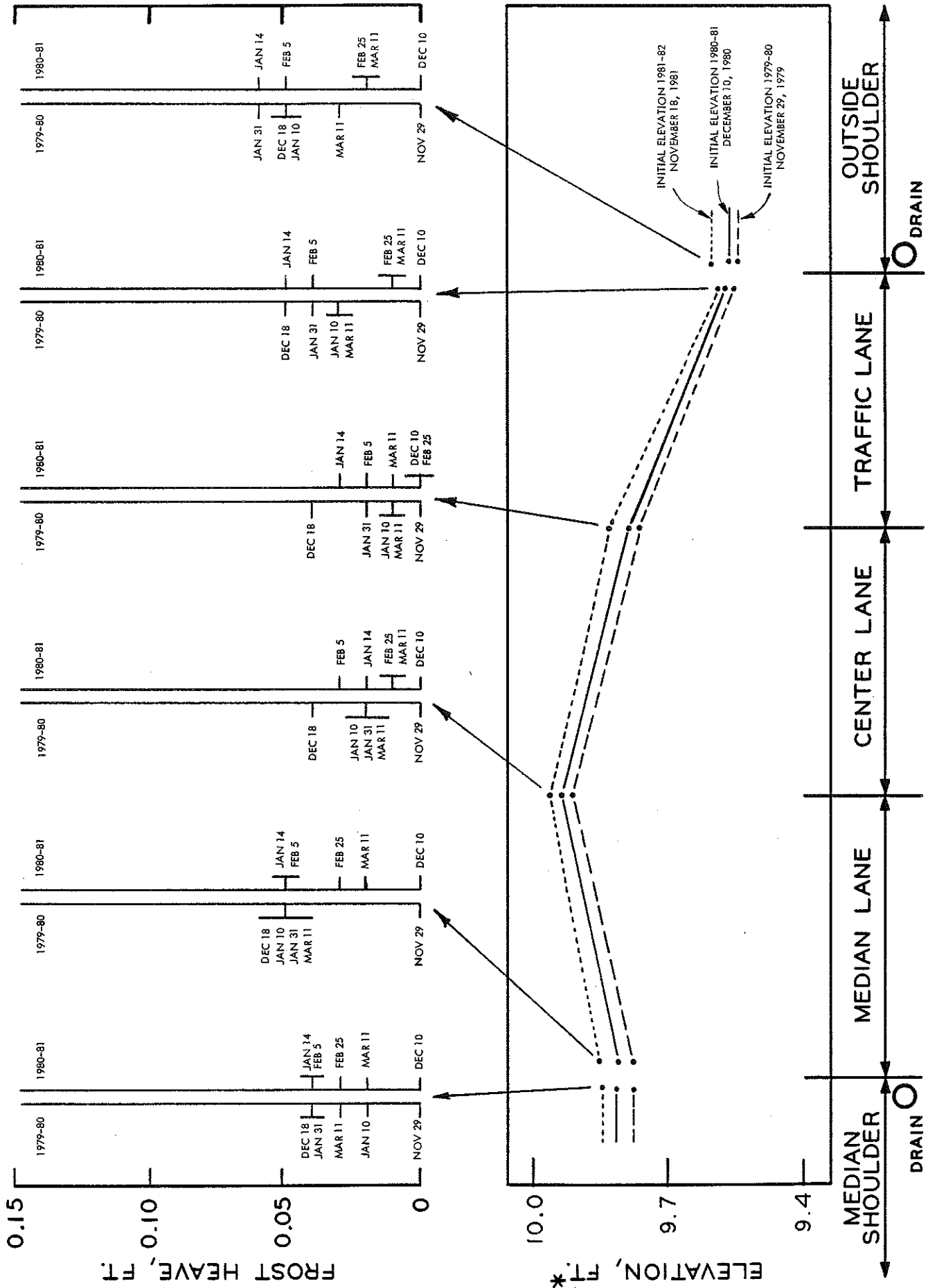
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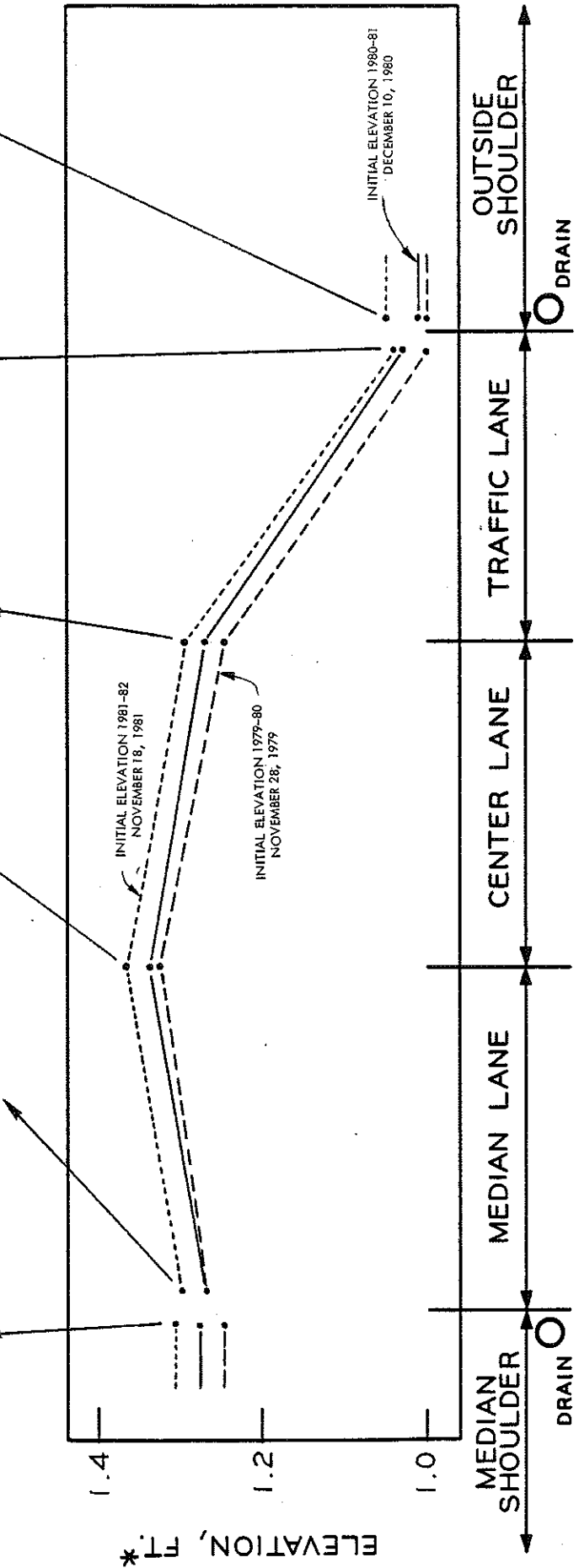
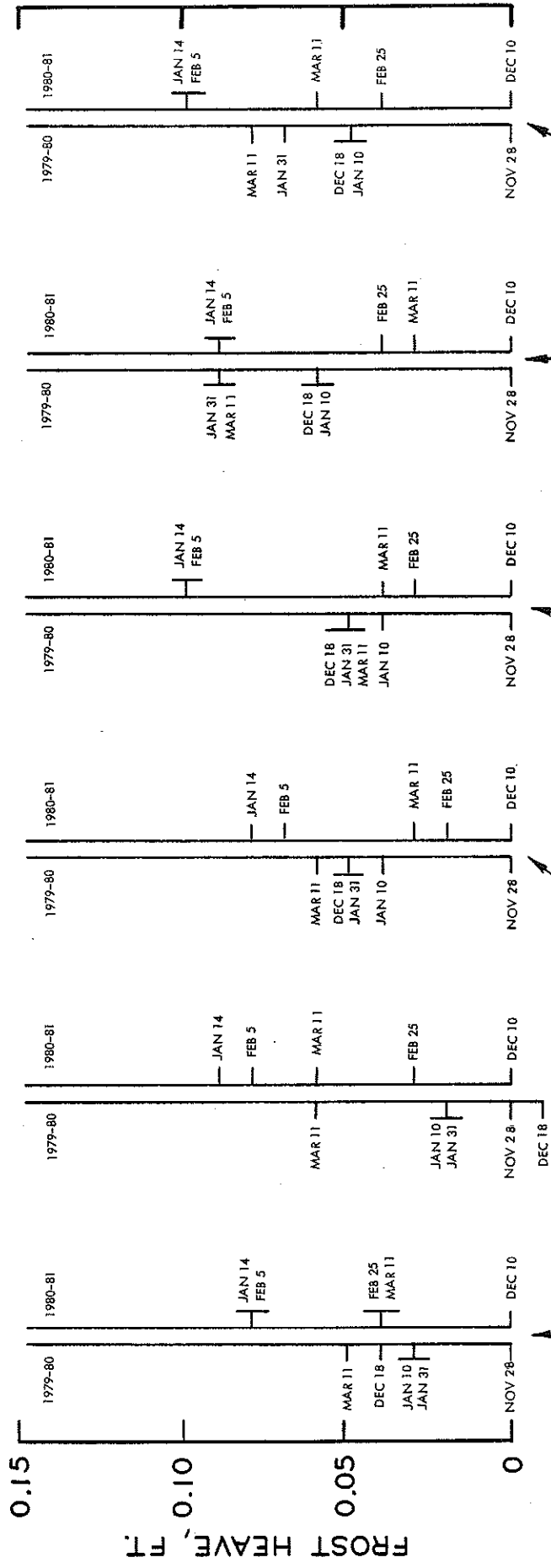
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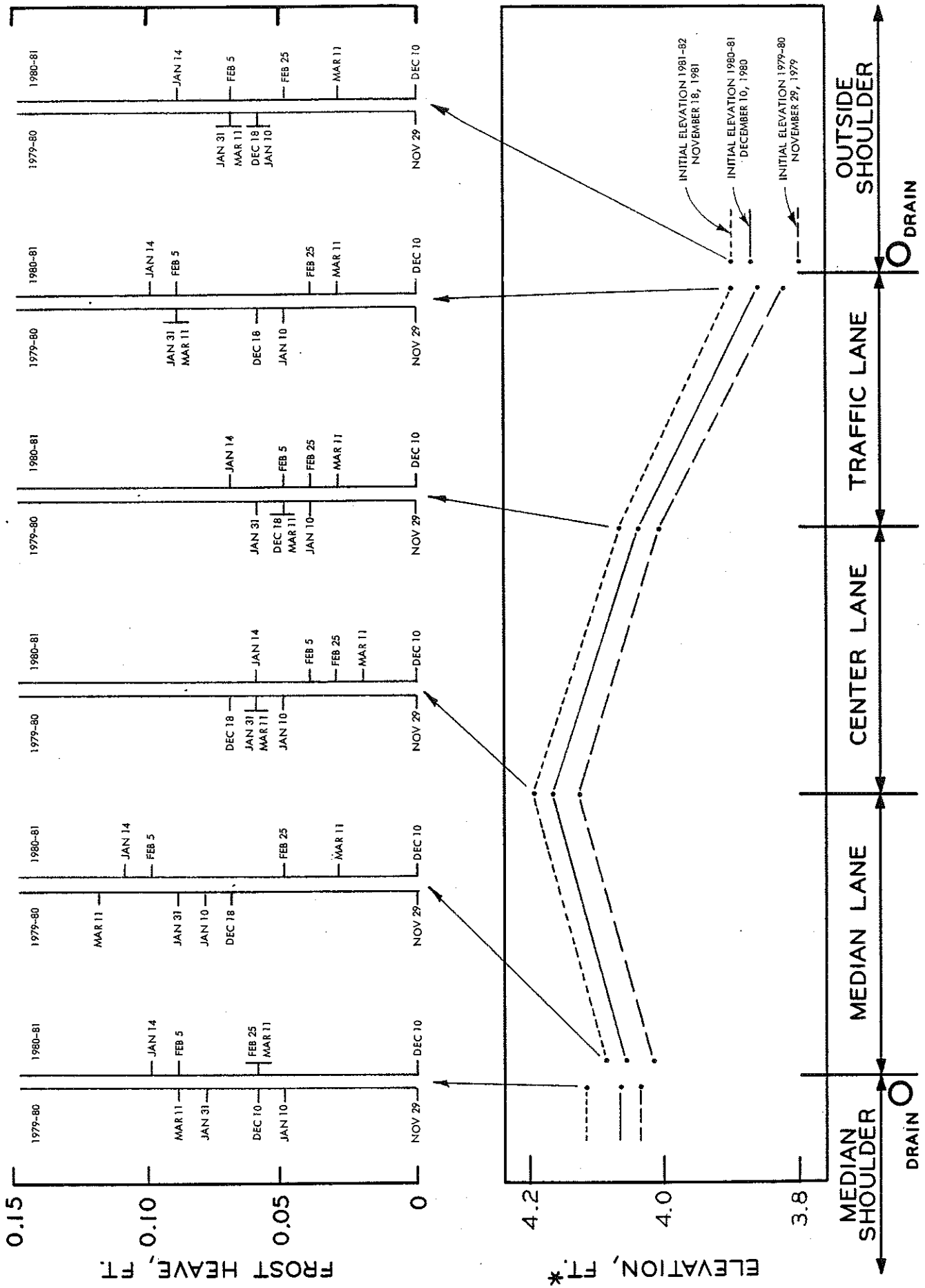
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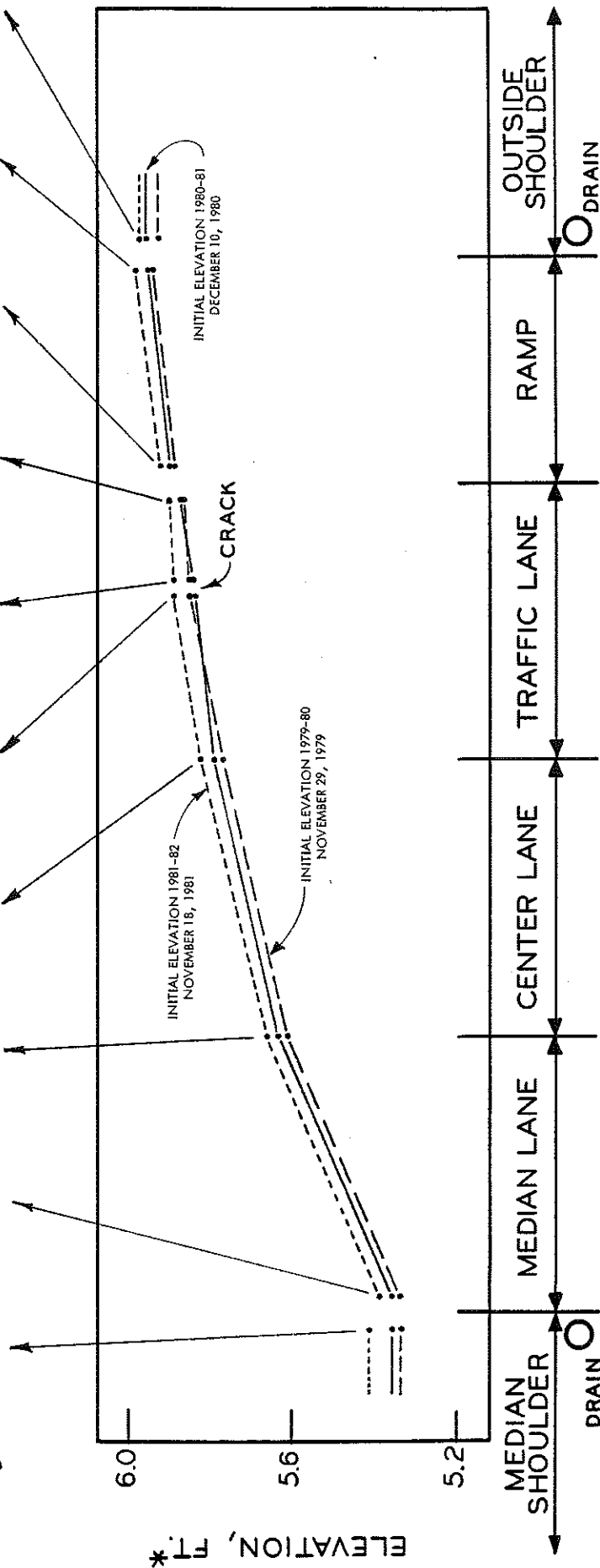
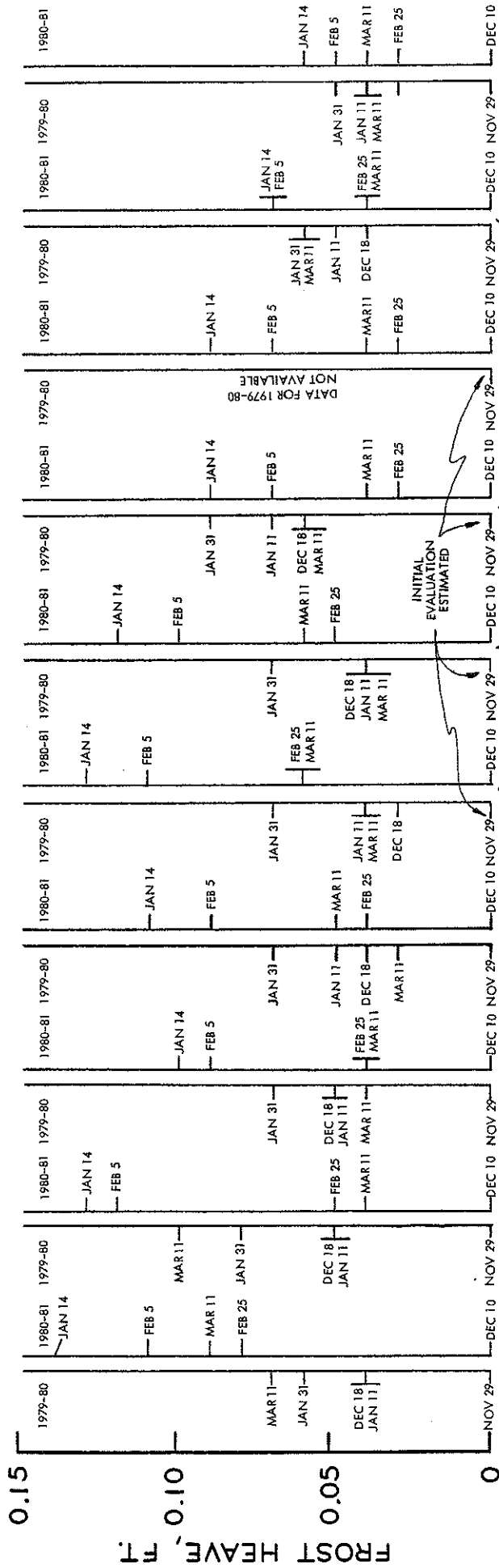
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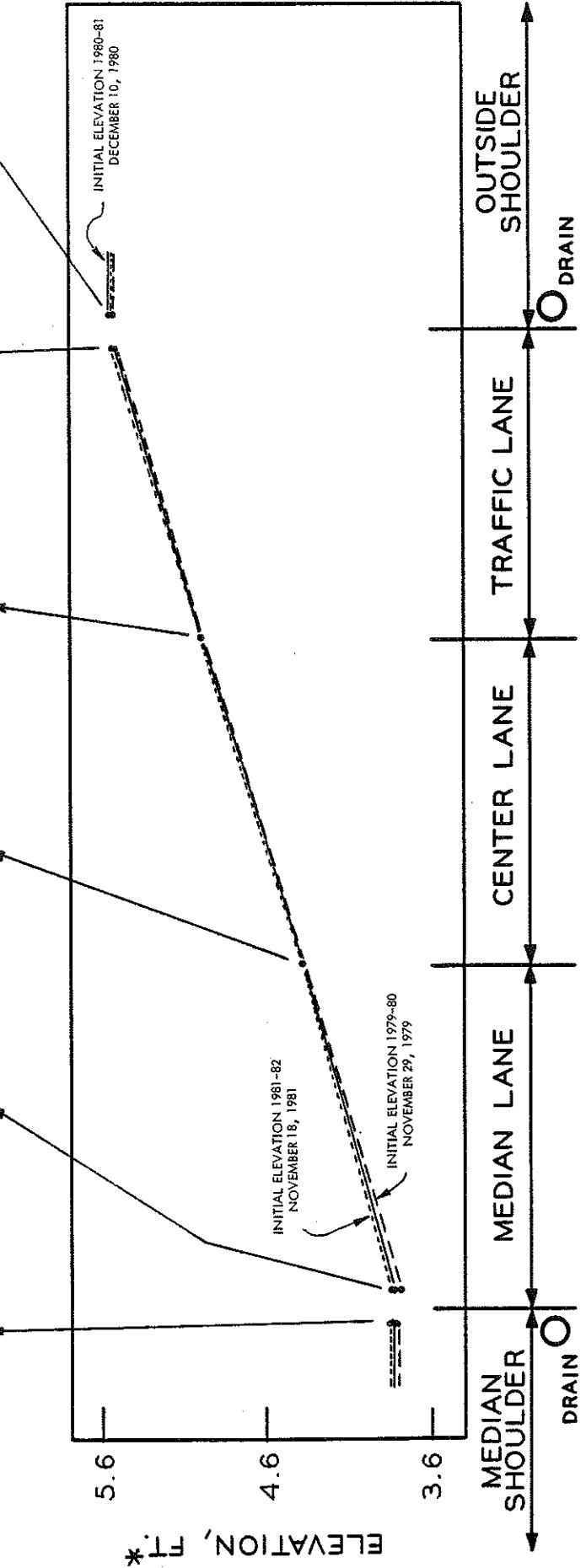
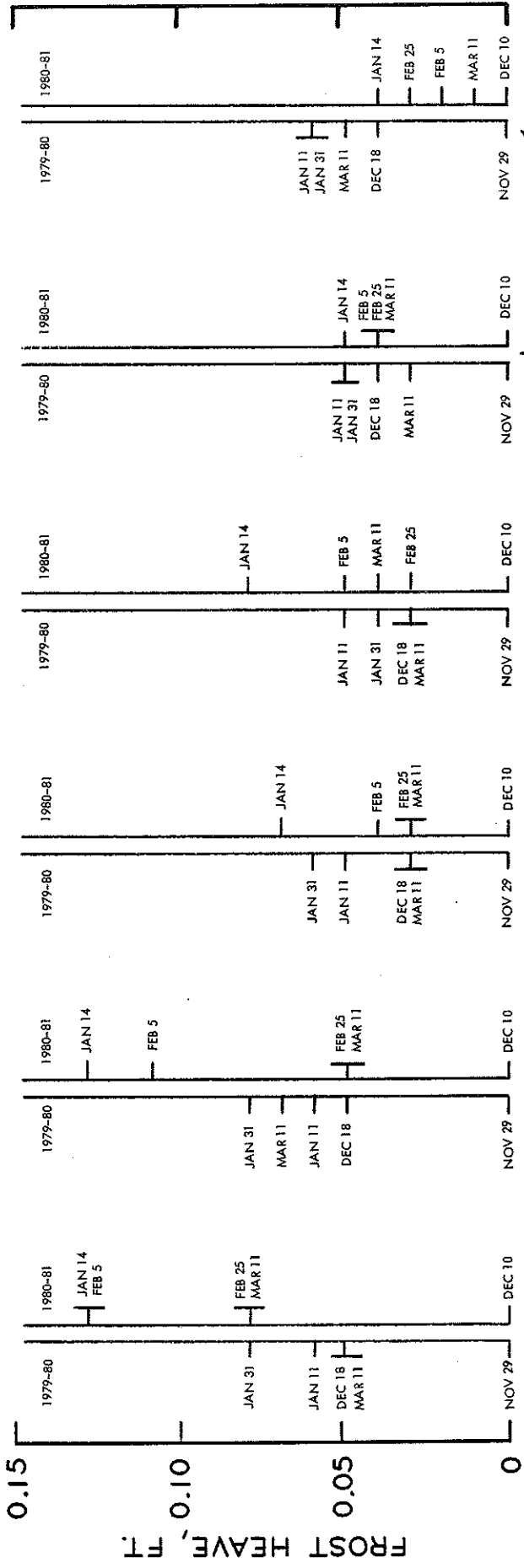
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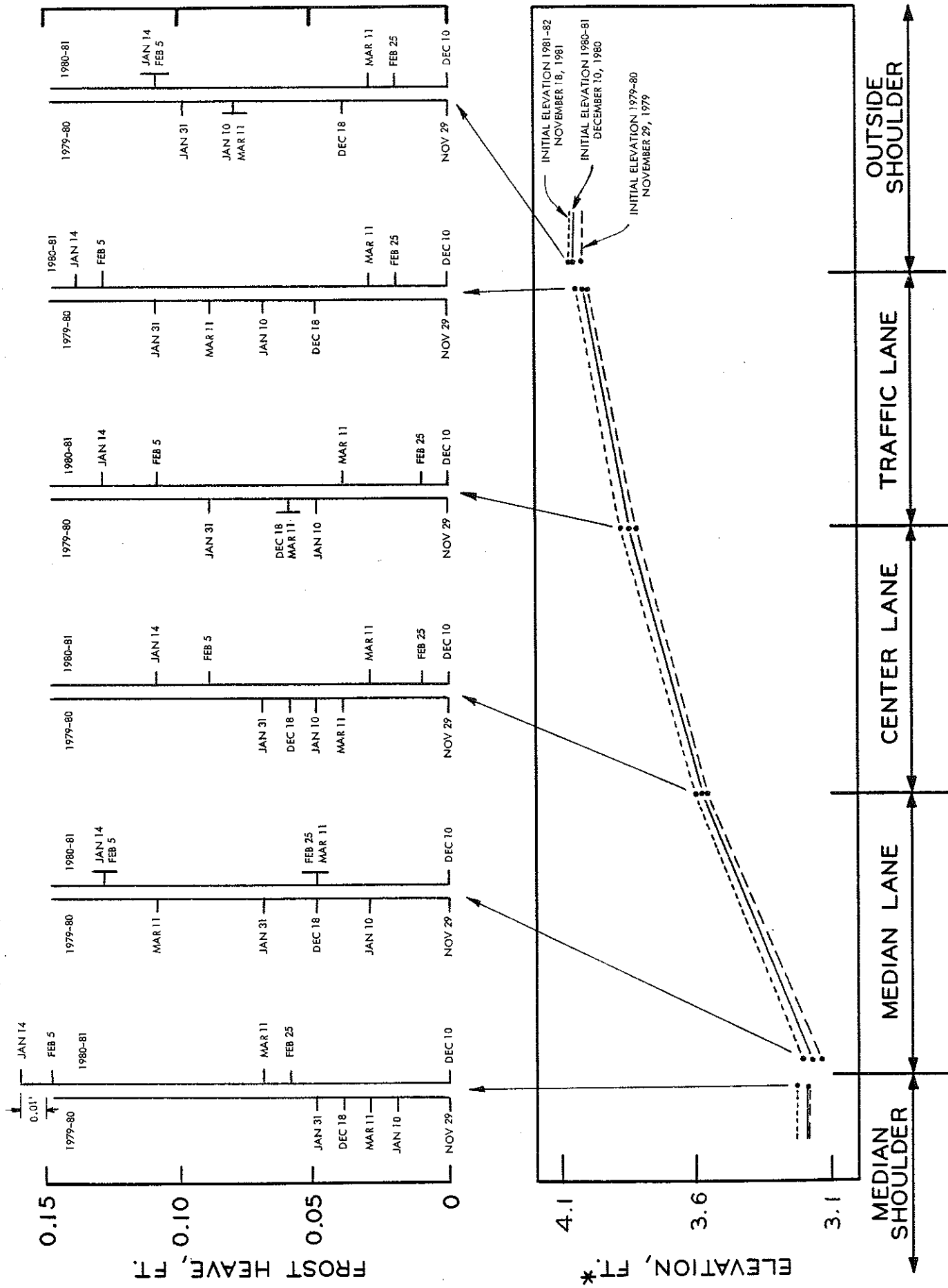
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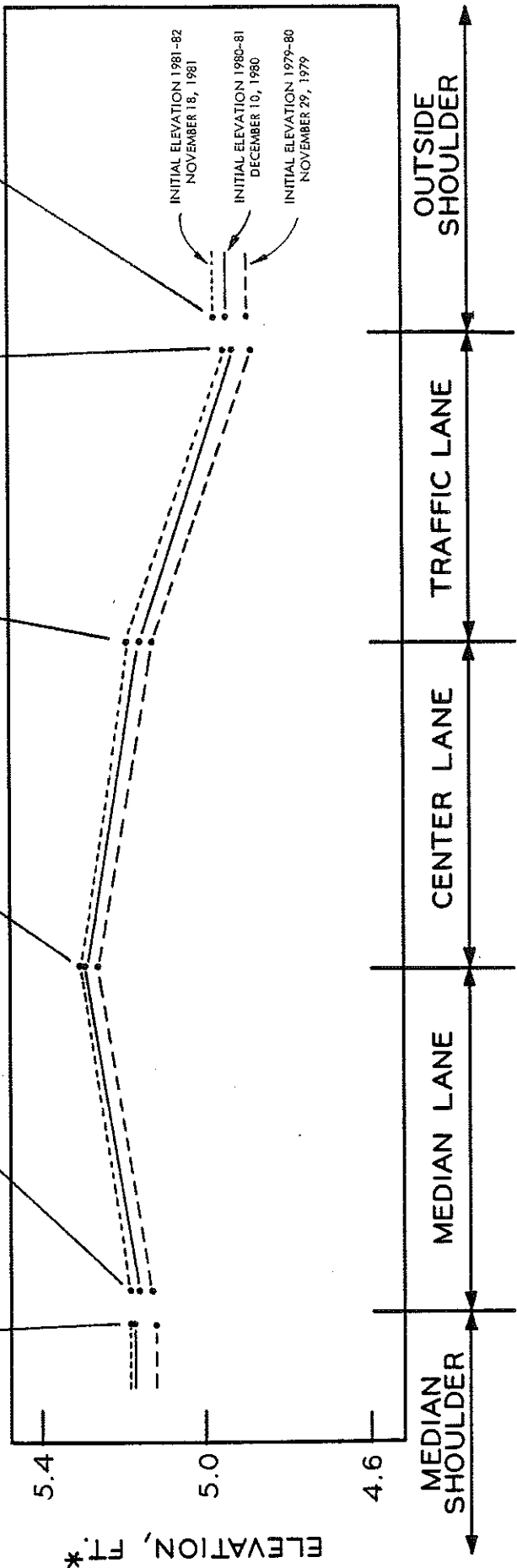
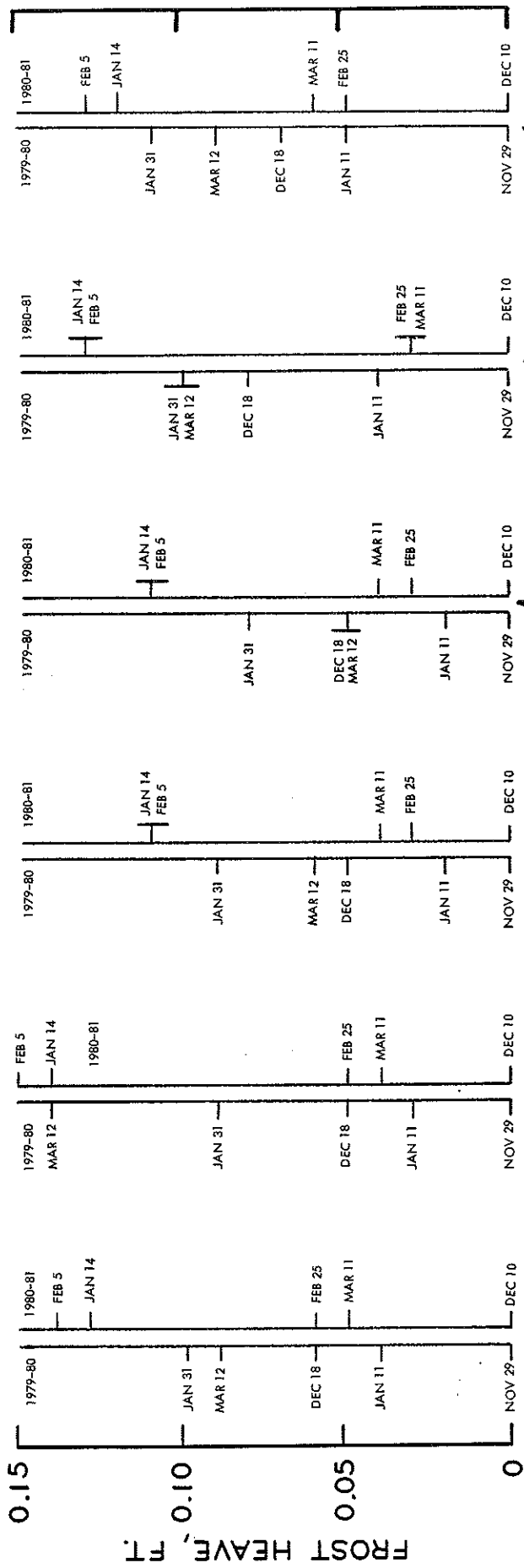
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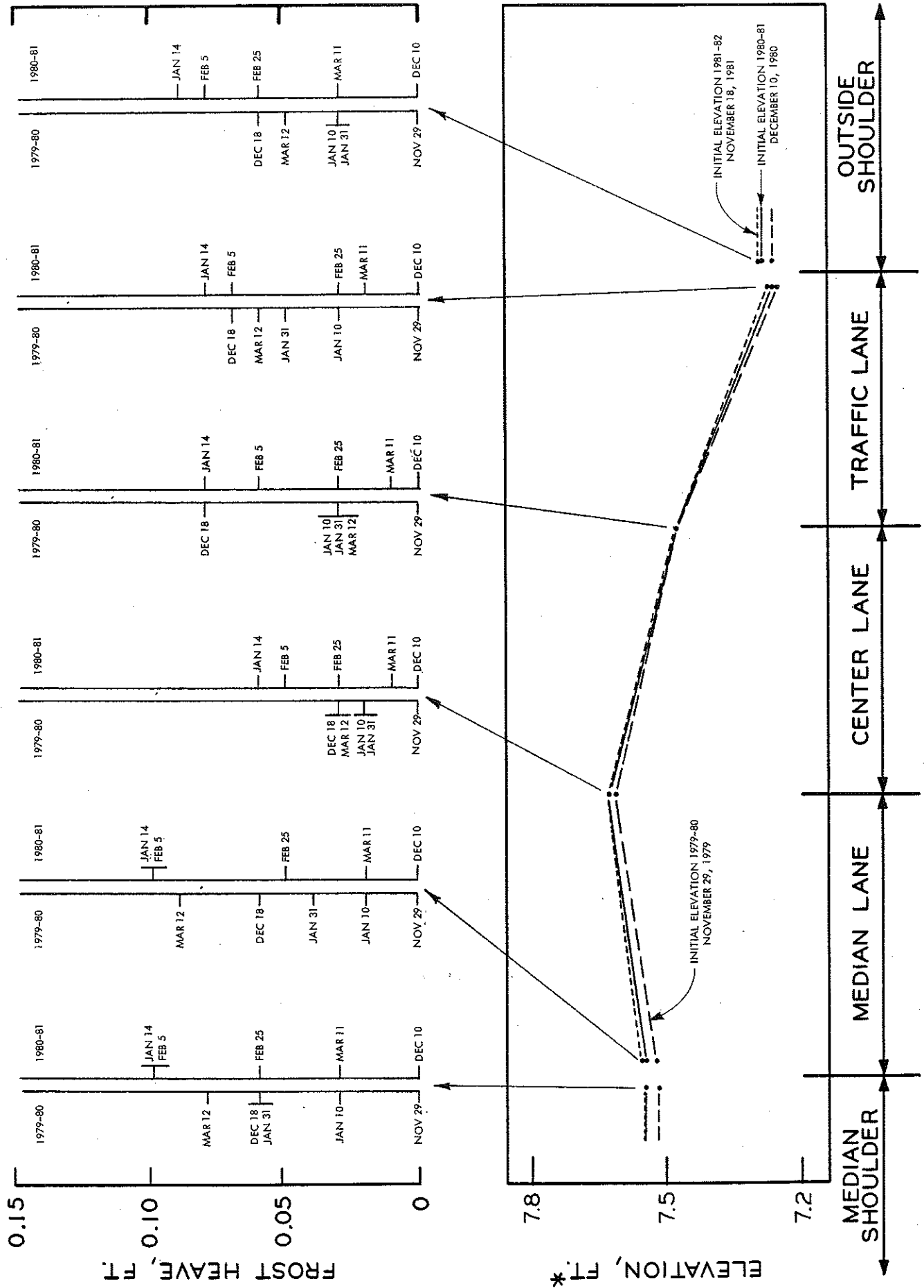
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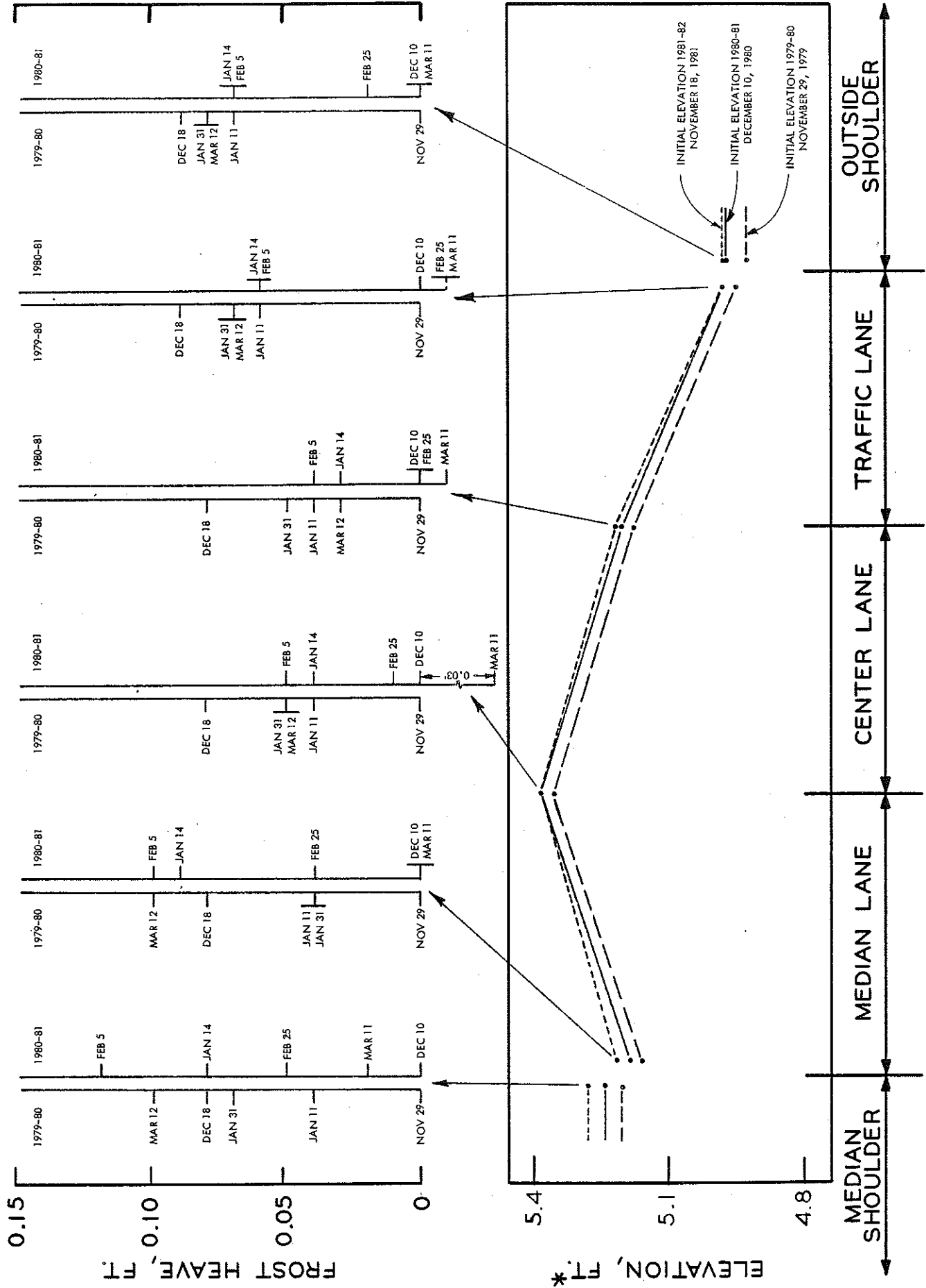
*RELATIVE TO ASSUMED BENCHMARK ELEVATION

Pavement heave at Site No. 32, Sta. 501+00, southbound I 275.



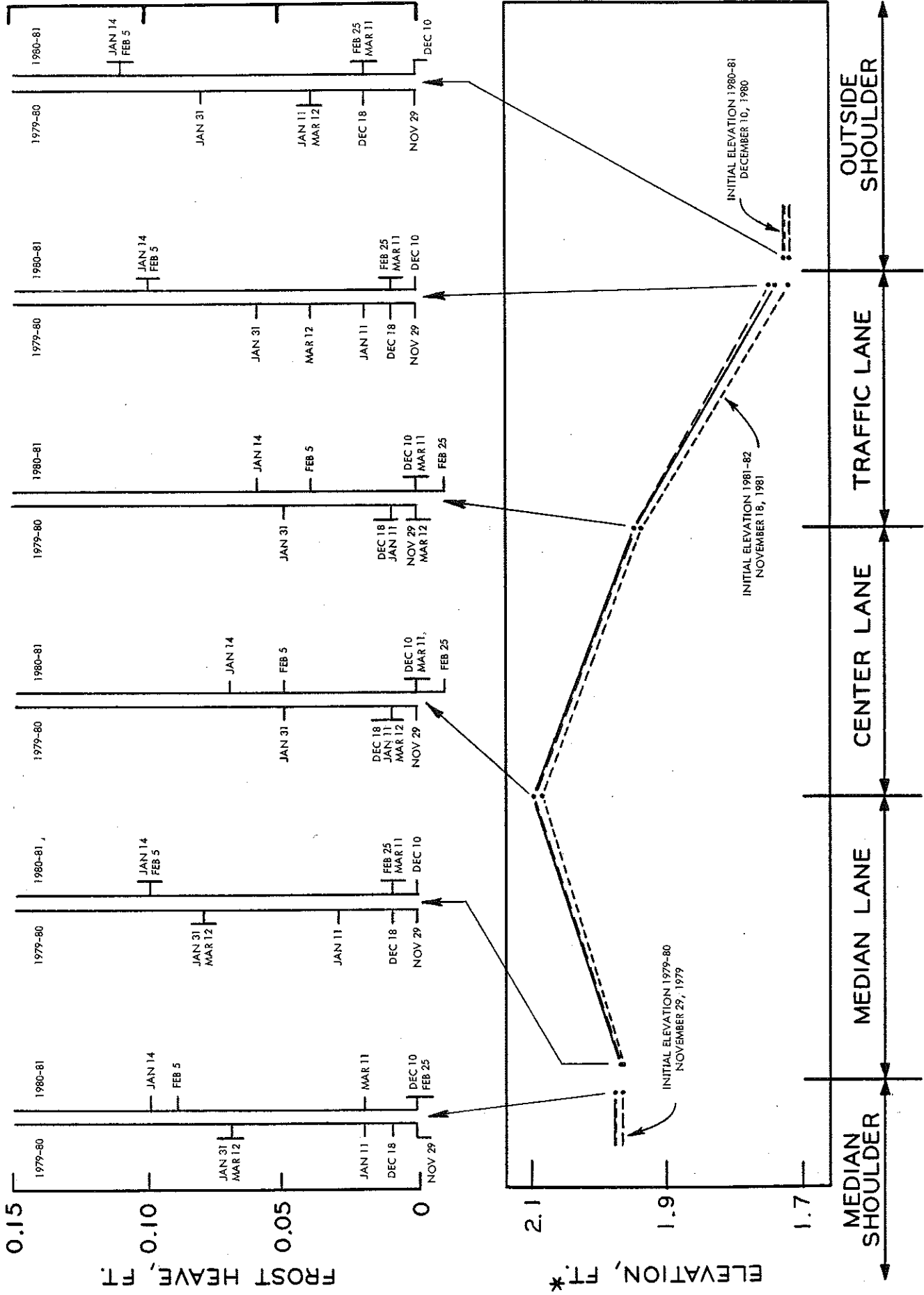
*RELATIVE TO ASSUMED BENCHMARK ELEVATION

Pavement heave at Site No. 33, Sta. 486+00, southbound I 275.



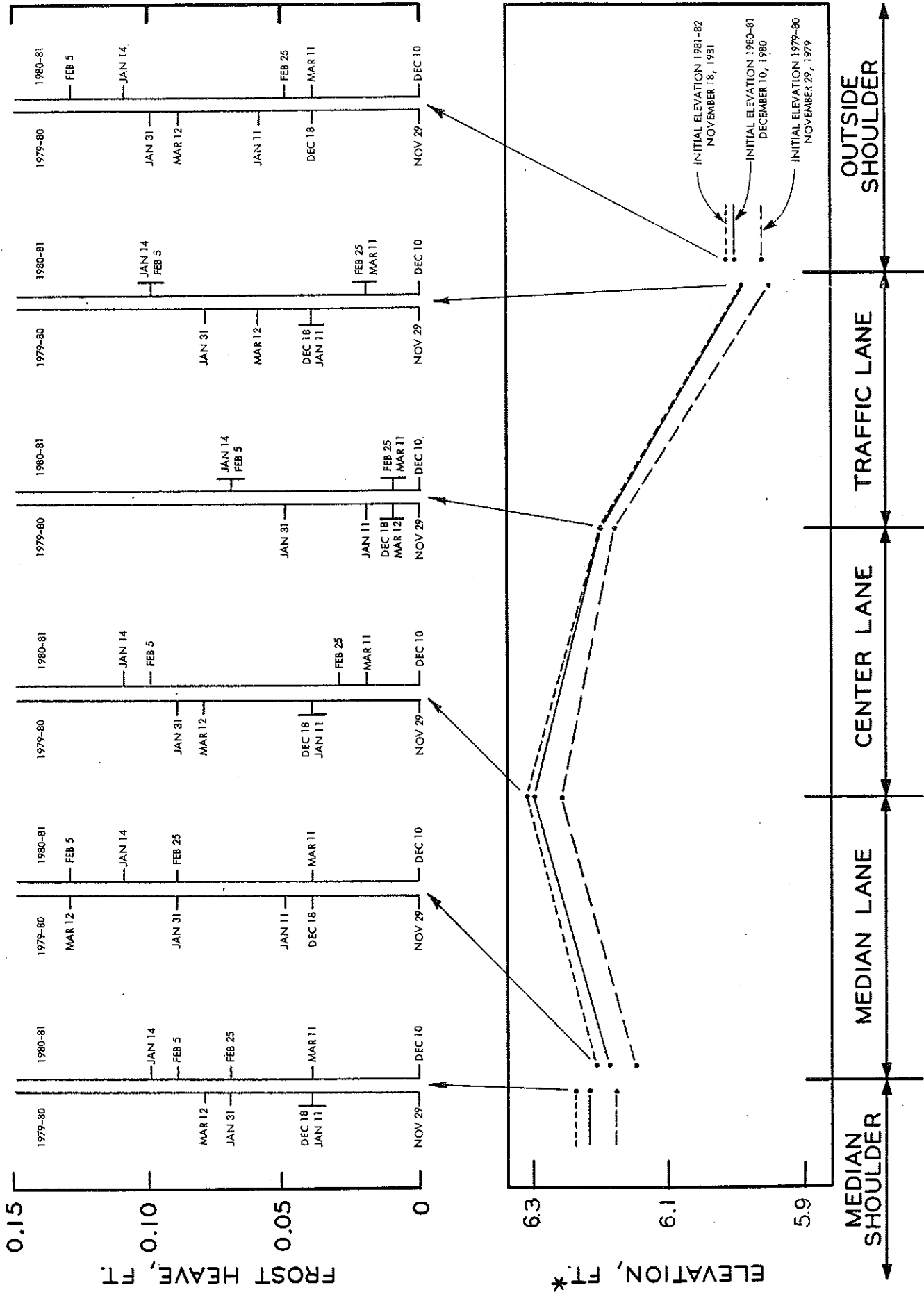
*RELATIVE TO ASSUMED BENCHMARK ELEVATION

Pavement heave at Site No. 34, Sta. 467+00, southbound I 275.



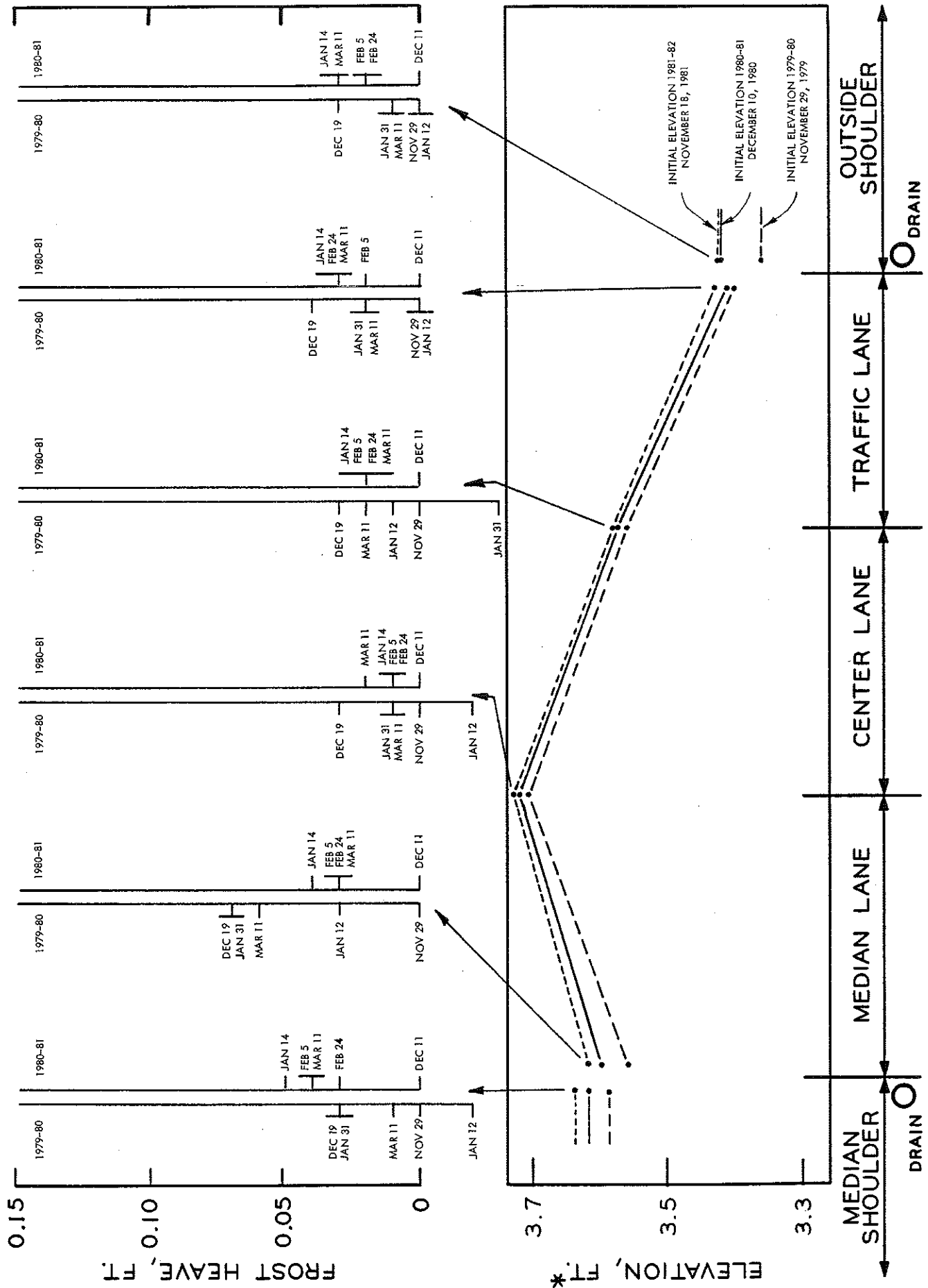
*RELATIVE TO ASSUMED BENCHMARK ELEVATION

Pavement heave at Site No. 35, Sta. 452+00, southbound I 275.



*RELATIVE TO ASSUMED BENCHMARK ELEVATION

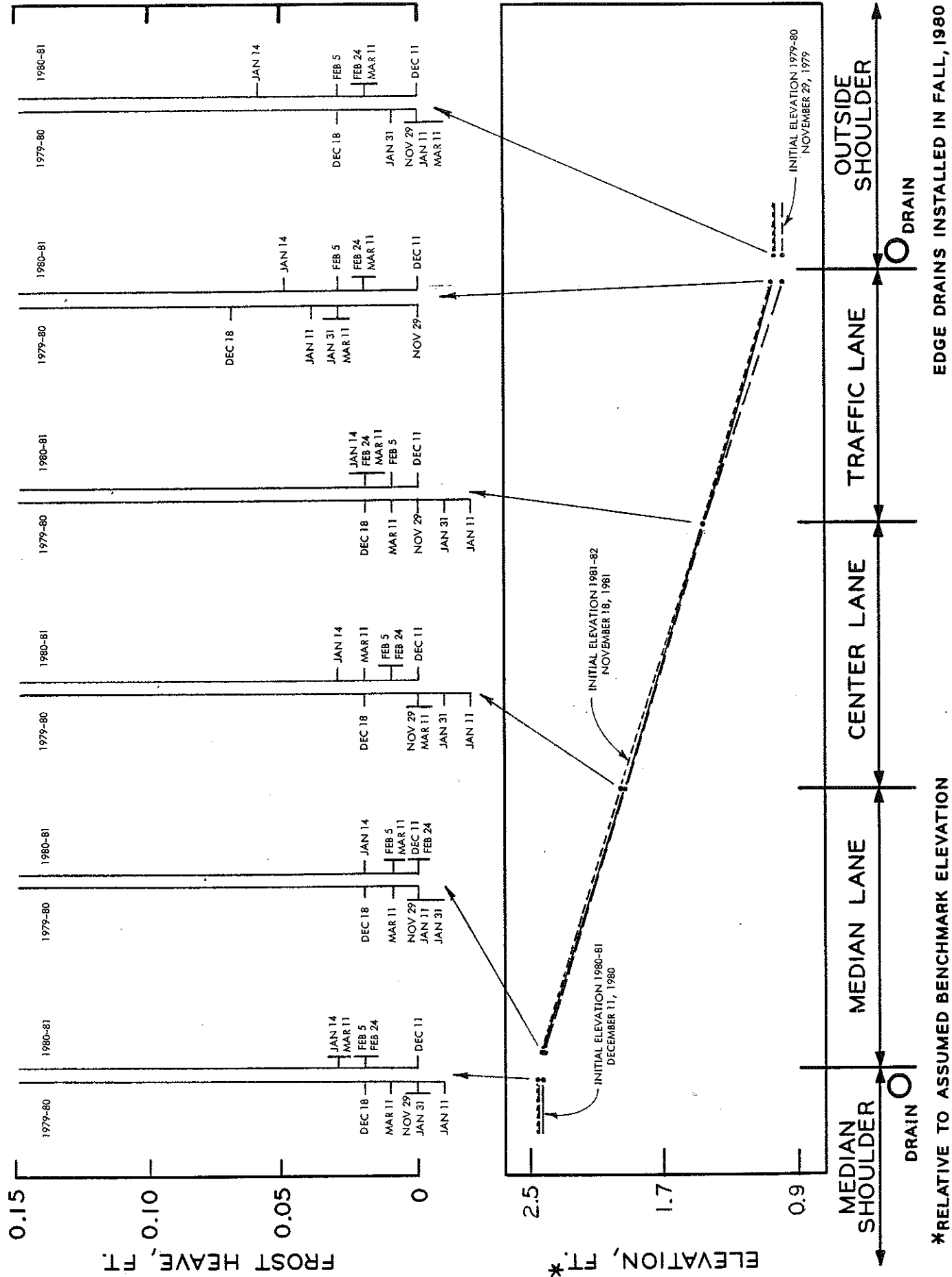
Pavement heave at Site No. 36, Sta. 439+00, southbound I 275.



*RELATIVE TO ASSUMED BENCHMARK ELEVATION

EDGE DRAINS INSTALLED IN FALL, 1980

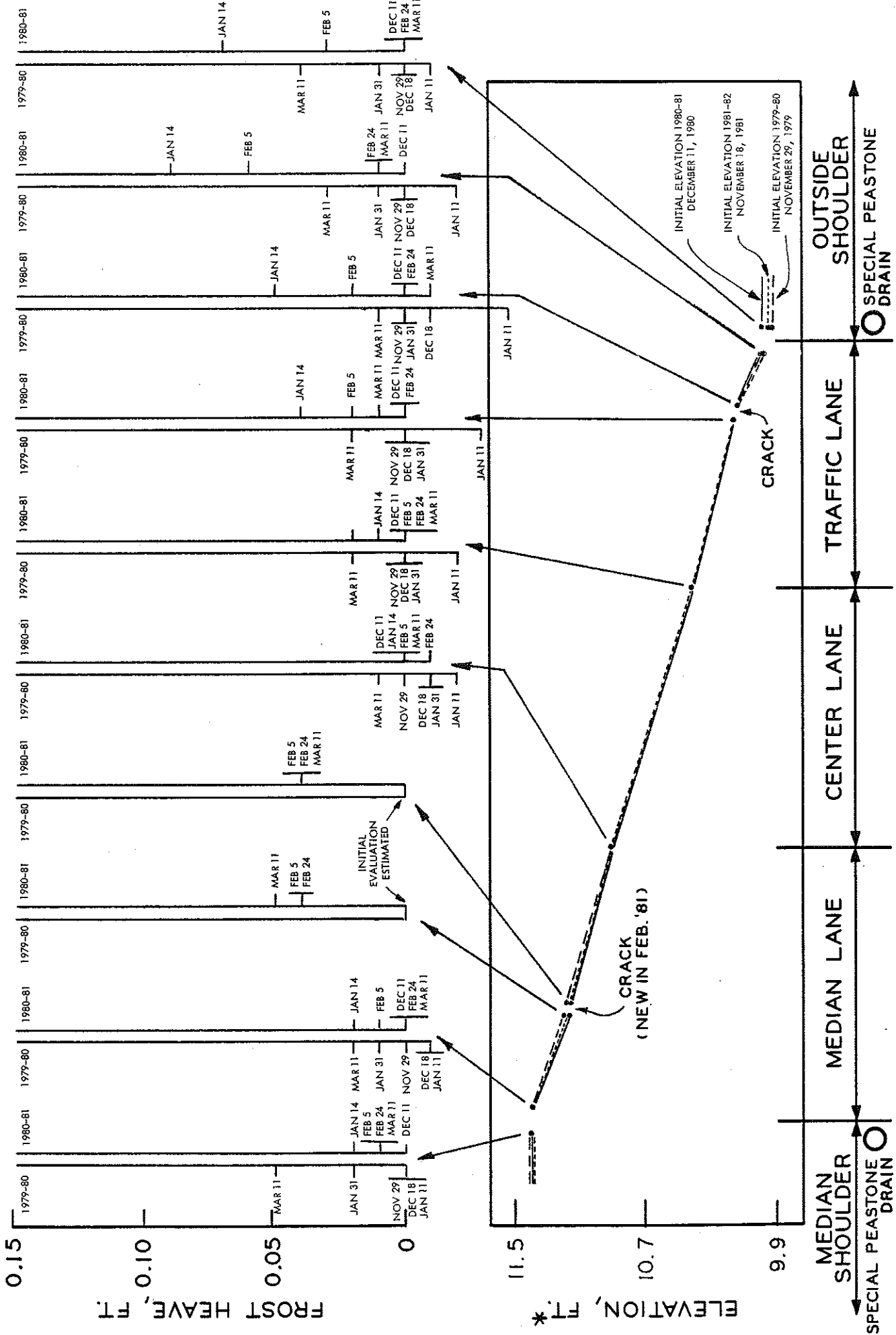
Pavement heave at Sta. 1116+00, northbound I 275.



*RELATIVE TO ASSUMED BENCHMARK ELEVATION

EDGE DRAINS INSTALLED IN FALL, 1980

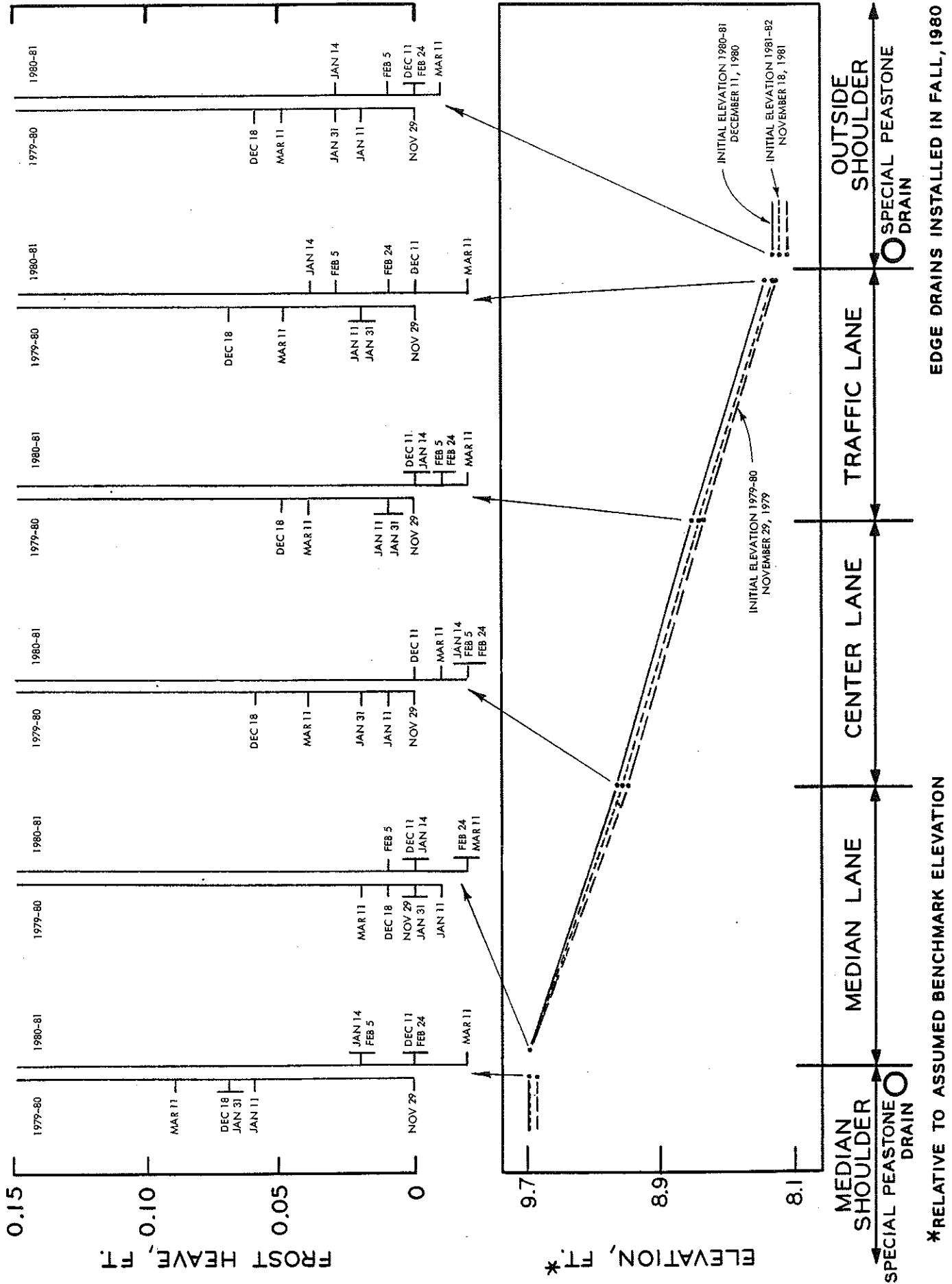
Pavement heave at Sta. 1131+00, northbound I 275.

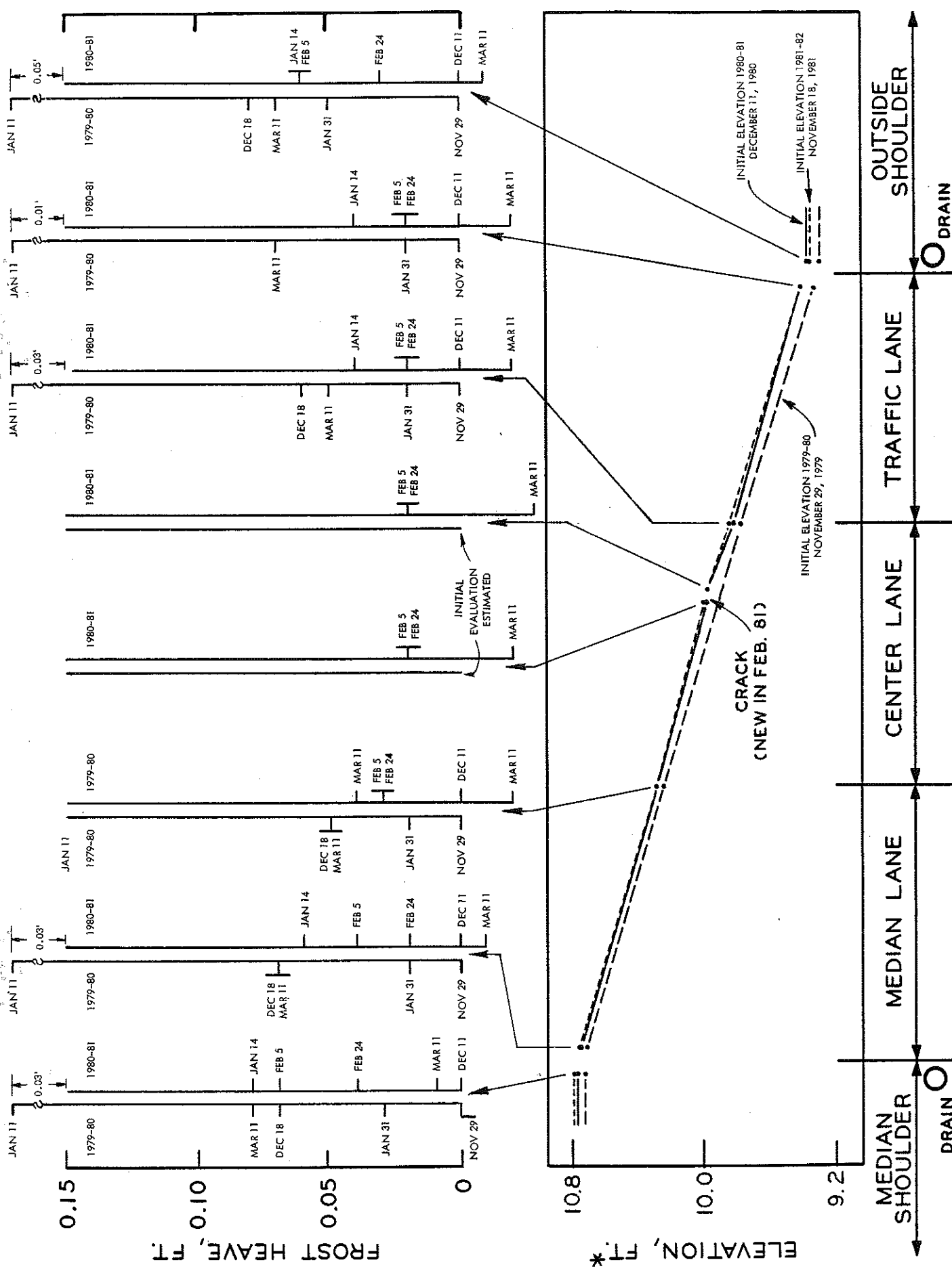


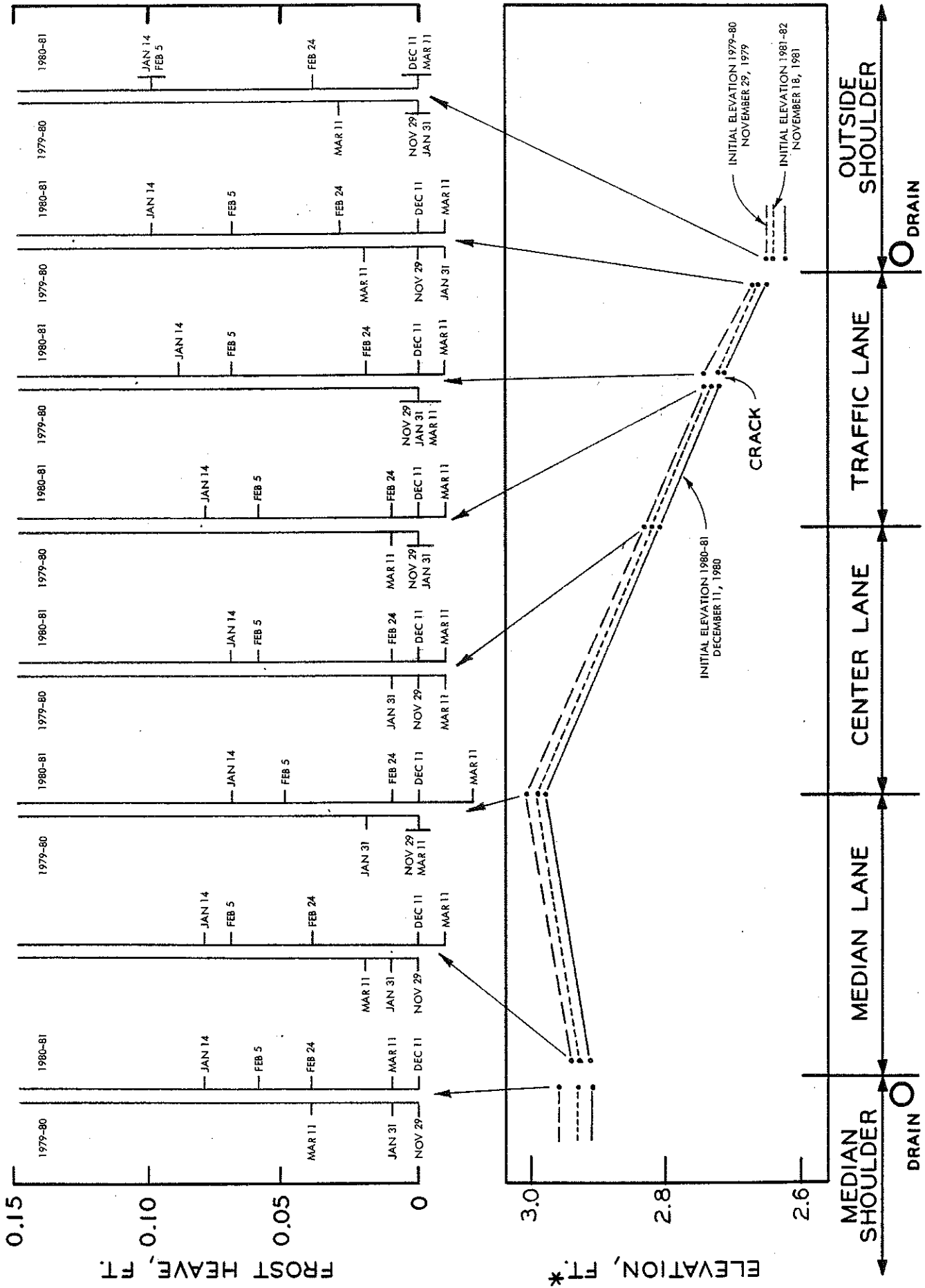
*RELATIVE TO ASSUMED BENCHMARK ELEVATION

EDGE DRAINS INSTALLED IN FALL, 1980

Pavement heave at Sta. 1146+00, northbound I 275.



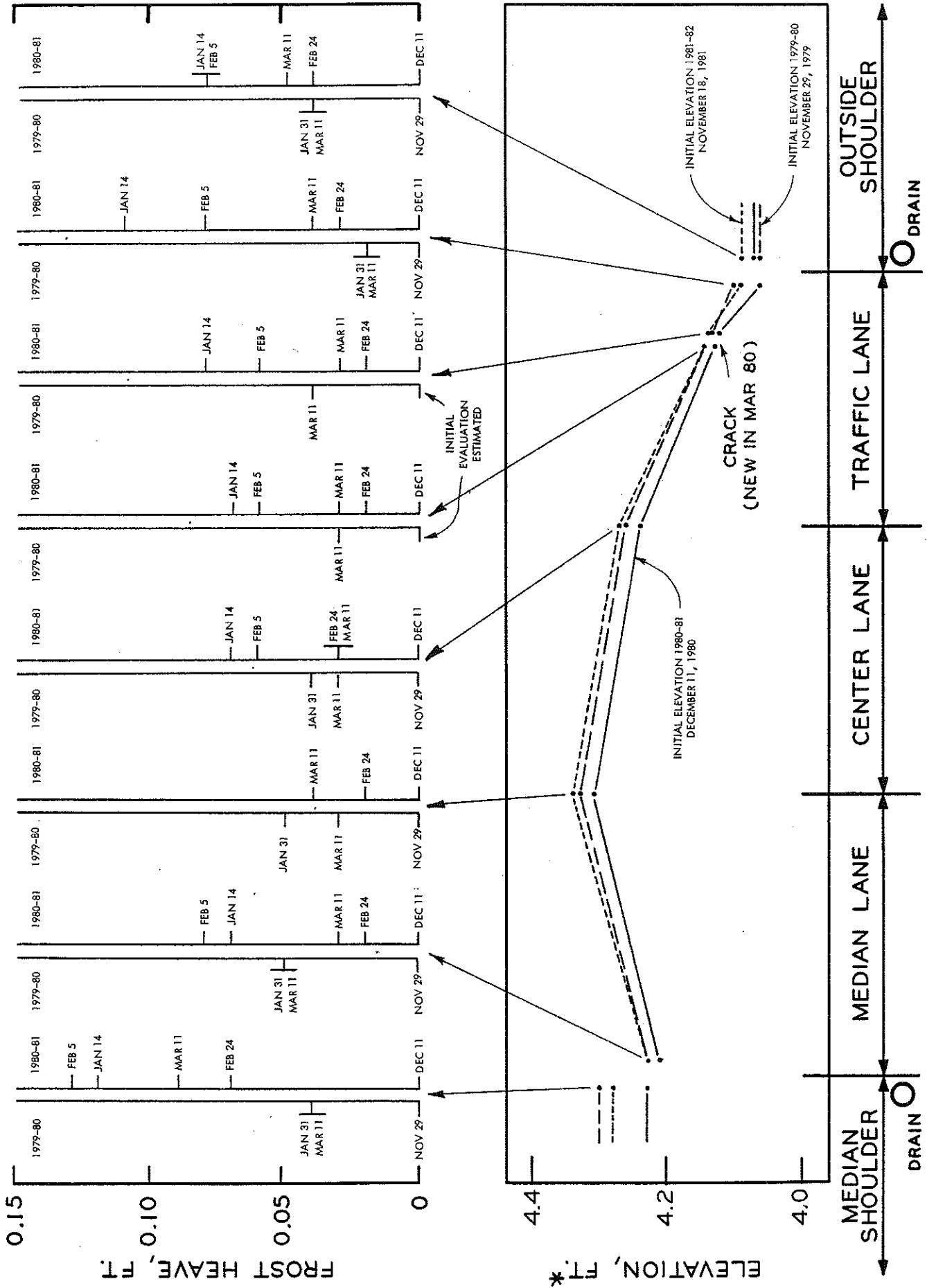




*RELATIVE TO ASSUMED BENCHMARK ELEVATION

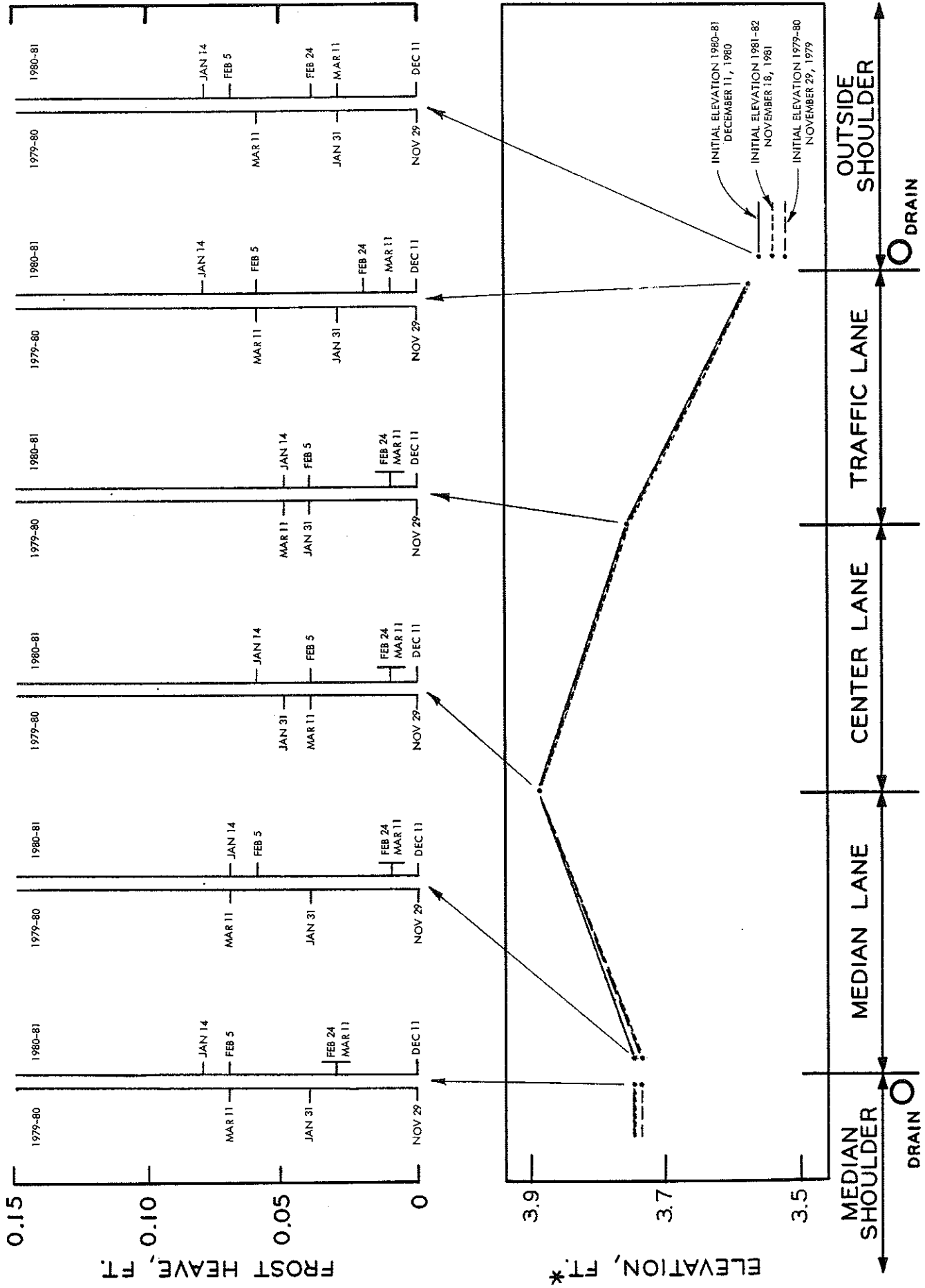
EDGE DRAINS INSTALLED IN FALL, 1980

Pavement heave at Sta. 1201+00, northbound I 275.

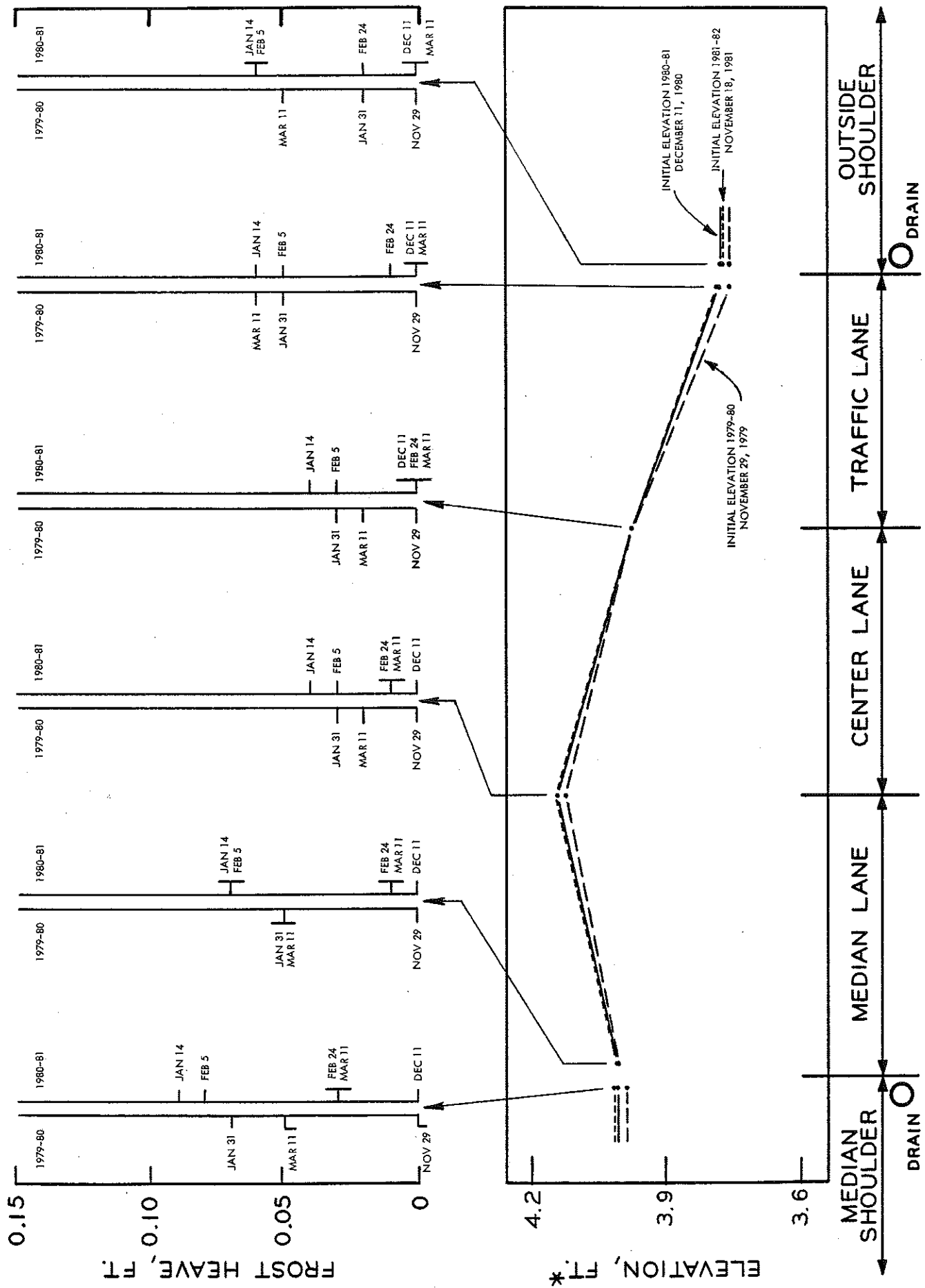


*RELATIVE TO ASSUMED BENCHMARK ELEVATION

Pavement heave at Sta. 1218+00, northbound I 275.



*RELATIVE TO ASSUMED BENCHMARK ELEVATION
 EDGE DRAINS INSTALLED IN FALL, 1980
 Pavement heave at Sta. 1243+00, northbound I 275.



*RELATIVE TO ASSUMED BENCHMARK ELEVATION

EDGE DRAINS INSTALLED IN FALL, 1980

Pavement heave at Sta. 1263+00, northbound I 275.