thirty minutes, suggests to the field engineer that the road shoulders along the edges of the pavement should be reinforced with slag, gravel, cinders or broken stone, thoroughly bound with fine soil or sand and water proofed with tar or oil

Soils which slake down in from 30 to 50 minutes should be kept under constant supervision for proper maintenance which may take the form of the addition of a few stone chips or gravel from time to time

Table I presents the data from which the standardizing factors for the test were determined.

A STUDY OF THE MOISTURE CONTENT OF OHIO SOILS

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Because of the well-known fact that saturated soils lose most if not all of their bearing value it was early decided to carry on a series of observations upon the water content of different soils at different depths and throughout the year in order to determine if possible how the soils received the water held in them and what maximum and minimum amounts of water different soils would hold in the field Further, it was considered a necessary observation to make at all locations where levels were being taken upon pavements to determine the vertical displacement taking place during the year

Therefore at all displacement stations, and quite a number of other places, a number of soil moisture stations were established As the observation trips, over the rather extended circuit of displacement stations, could not well be taken much oftener than once a month, it was decided to run two or more observation points upon the campus near the laboratory so that weekly moisture readings could be made and a rough check kept upon the changes in soil moisture content

The general field stations were all numbered, but the two local points were lettered Two sets of readings were taken at each of the two home points A point on the high ground near the laboratory and a second point on the low land near the Olentangy River were selected for the check stations At each of these points a concrete slab, 3 inches thick and 30 inches square, was placed upon a well drained and cleaned surface Then each week borings were made and soil samples taken from beneath the slabs and also from the open ground within five or ten feet of the slabs

The soil samples were taken in tight, seamless tin cans, taken to the laboratory, weighed, dried, reweighed and the moisture contained

in the soil determined in percentage of the dried weight of the soil The samples were taken from the surface and at 6, 12, 18 and 24 inches in depth

The station on the high ground was lettered "A" for soils taken from beneath the slab and "O A" for soils taken from the open ground alongside the slab Similarly the samples taken on the low ground near the river were lettered "B" and "O B"

Observations were begun at the local stations on December 10, 1924, and have been maintained to date, except for an occasional period missed and one long period from May 15 to August 5, 1926, when there were no laboratory assistants to carry on the work

The field stations were established along the State highways at points where the displacement measurements were being taken and at other points wherever soil variations might yield valuable information The first full field observations were begun in January, 1925, although a few readings were taken in December, 1924

The surface moistures change quickly from wet to dry with rather wide ranges, from 2 0 per cent up to 124 per cent These changes are easily accounted for as they are due to rain, snow, thawing weather and drying weather With this phase of the question we are little interested This phase affects only the shoulders of the highway and the engineer can easily take precautions to prevent it doing damage to the pavement or from seriously affecting traffic

However, with the moisture in the subsoil, from 6 inches in depth down to two or more feet in depth, the matter of how the moisture gets there and of its control is a much more difficult problem to solve Knowledge about it is limited When the control of the moisture in the first two feet of subsoil beneath the pavement is assured, the art of efficient and economic highway construction will be greatly advanced

In platting up the moisture content of the soils for stations "A" and "B," it was found that the moisture in the sub-soils at 6, 12, 18 and 24 inches in depth grouped rather closely together and maintained a more or less even curve, increasing in amount in the late fall and keeping fairly constant during the winter and spring, then decreasing for awhile and again keeping constant during the late summer and early fall While the moisture content of the various sub-soil depths remained nearly alike and changed in amounts rather slowly, the surface soil changed in moisture content rapidly and jumped from very high to far below the moisture contained in the sub-soil samples

Different soils or different locations showed very marked differences in water content on the same day This might be due to the com-

position of the soil, to unknown different drainage conditions in the sub-soil, to a difference in the capillarity of soils, or in some cases to variations in distribution of the rainfall or snow

TABLE I

SUMMARY OF MOISTURE CONTENTS OF SOILS AT STATIONS "A" AND "B"

(Maximum)

		Beneath slab					Open ground				
Year	Sta	Surf	6″	12″	18″	24″	Surf	6″	12″	18″	24″
1925	A	49 4 2/2	33 6 7/3	30 2 7/3	29 9 7/3	34 2 7/3	56 2 2/2	29 8 2/2	29 6 7/3	29 1 7/3	31 2 7/3
1925	B	35 6 7/3	36 5 7/3	40 5 7/3	39 7 7/3	34 3 7/3	56 8 1/12	32 4 7/3	30 3 7/3	35 8 7/3	35 1 7/3
1926	A	47 1 1/30	29 8 1/30	21 8 1/23	21 3 4/17	31 1 8/38	50 7 3/6	31 4 2/6	25 1 3/20	29 5 4/10	27 2 3/20
1926	B	53 8 1/23	29 7 8/28	47 7 1/30	28 3 12/19/25	26 6 12/19/25	47 4 1/23	31 4 2/20	28 4 1/30	25 2 2/27	30 2 1/30

(Minimum)

		Beneath slab					Open ground				
Year	Sta	Surf	6″	12″	18″	24″	Surf	6″	12″	18″	24″
1925	A	8 4 9/4	8 5 8/22	8 8 9/25	10 2 9/4	——	6 4 9/25	5 6 9/4	6 1 9/4	6 2 9/4	8 7 10/10
1925	B	7 4 9/15	11 3 9/15	14 3 9/15	15 9 8/22	11 8 10/3	3 9 9/4	6 3 9/4	8 6 9/4	11 4 9/25	9 9 9/4
1926	A	15 2 5/17	14 4 8/14	13 3 8/14	13 9 8/14	17 6 8/7	10 3 5/17	14 4 5/17	14 8 5/17	14 5 5/17	15 4 5/17
1926	B	16 9 8/7	19 5 8/14	20 6 8/14	19 6 8/14	11 2(?) 8/21	13 8 5/17	16 7 5/17	19 5 5/17	19 0 5/17	18 7 5/17

A DISCUSSION OF THE DATA FROM "A" AND "B" SOIL STATIONS

Table I shows for the local stations on the University Campus the results of the observations for 1925 and 1926 The maximum and minimum moistures obtained, with the dates upon which the observations weer made, are given The extremes noted were in the surface soil and upon the open ground stations They were for station "O B ",—driest 3 9 per cent and wettest 56 8 per cent of the dry weight of the soil For station "O A ," the driest moisture content was 5 6 per cent at 6 inches in depth and the wettest 56 2 per cent on the surface

The average moisture contents are given in Table II for the wet and dry seasons of 1925 and 1926 From this table it may be noted that the ratio of the dry to wet season moisture content is as follows

1925 *Moisture Content Ratios*	*Ratios for* 1926
Sta A —Dry season 64 6% of wet season	Dry season 84 5% of wet season
Sta B —Dry season 61 8% of wet season	Dry season 86 8% of wet season
Sta O A —Dry season 59 7% of wet season	Dry season 78 3% of wet season
Sta O B —Dry season 61 7% of wet season	Dry season 75 7% of wet season
Average 61 9	Average 81 3

TABLE II

AVERAGES OF MOISTURE CONTENT IN THE SOILS OF STATIONS "A" AND "B" FOR THE WET AND DRY SEASONS

Depth	Beneath slab					Open ground				
	Surface	6"	12"	18"	24"	Surface	6"	12"	18"	24"
"A"—Average for 1925 wet season, 32 weeks	22 9	19 0	17 7	18 0	20 6	22 3	19 2	16 3	16 9	20 4
"A"—Average for 1925 dry season, 13 weeks	12 7	10 2	10 6	12 3	17 2	15 8	11 2	9 4	9 4	11 5
"A"—Average for 1926 wet season, 44 weeks	25 1	20 5	16 3	16 6	21 1	29 0	24 3	25 3	22 9	22 0
"A"—Average for 1926 dry season, 3 weeks	18 7	14 7	13 8	15 3	21 2	11 1	15 3	15 6	14 8	16 9
"B"—Average for 1925 wet season, — weeks	26 8	24 9	26 1	25 5	24 6	23 3	22 3	23 0	23 6	21 1
"B"—Average for 1925 dry season, 12 weeks	12 8	15 2	16 8	17 5	16 7	14 4	13 2	13 8	14 0	14 5
"B"—Average for 1926 wet season, 46 weeks	29 9	24 2	25 3	22 9	22 0	29 5	24 0	22 2	22 2	20 9
"B"—Average for 1926 dry season, 2 weeks	23 4	20 8	21 5	20 6	20 4	13 8	16 7	19 5	19 0	18 7

The soils carried on an average 31 2 per cent more moisture in 1926 than in 1925 The rainfall in 1925 was 24 22 inches up to November 1st; it was 36 95 inches for the same period in 1926

Note that the two "B" stations carry more water, both in the wet and dry reason, than do the "A" stations, and that slab stations carry more than the open stations, with only one exception As the opportunity for surface drainage was equally good in both cases, it is probable that the higher moisture content of the "B" soils over the "A" soils is due to the composition of the soil This station lies much nearer the water table which may account for the increased moisture content The soil analysis for these two soils is given in Table III

TABLE III

SOIL ANALYSIS OF "A" AND "B" SOILS

Soil	Coarse mater	Sand	Silt	Clay	Moisture volume			Atterberg limits		
					Capillar	Equiv	Change	L L L	L P L	Pl No
"A"	5 9	28 5	29 8	41 7	25 5	18 2	12 9	23 9	15 7	8 2
"B"	0 0	12 0	38 6	49 4	31 9	21 6	19 7	36 8	20 3	16 5

The "B" soil shows greater clay content, greater capillary action, higher moisture equivalent and greater plastic limit, all indicating a soil having a greater capacity for water and a greater avidity in satisfying the demand

A graph of the moisture content of the soil at the "O B " station is given in Figure 1 This is representative of what is shown by graphs of the other stations, Figures 2, 3 and 4 The curves representing the moisture in the four sub-soil depths keep fairly close together, while the surface moisture curve jumps rather wildly back and forth There are some fluctuations of the sub-soil curves and one quite marked occurring on July 3, 1925 The data showing some of these fluctuations are presented in Table IV, in order to show the apparent irrelevancy of some of the usually supposed factors active in the change of soil moisture, namely, rainfall, evaporation, temperature, etc

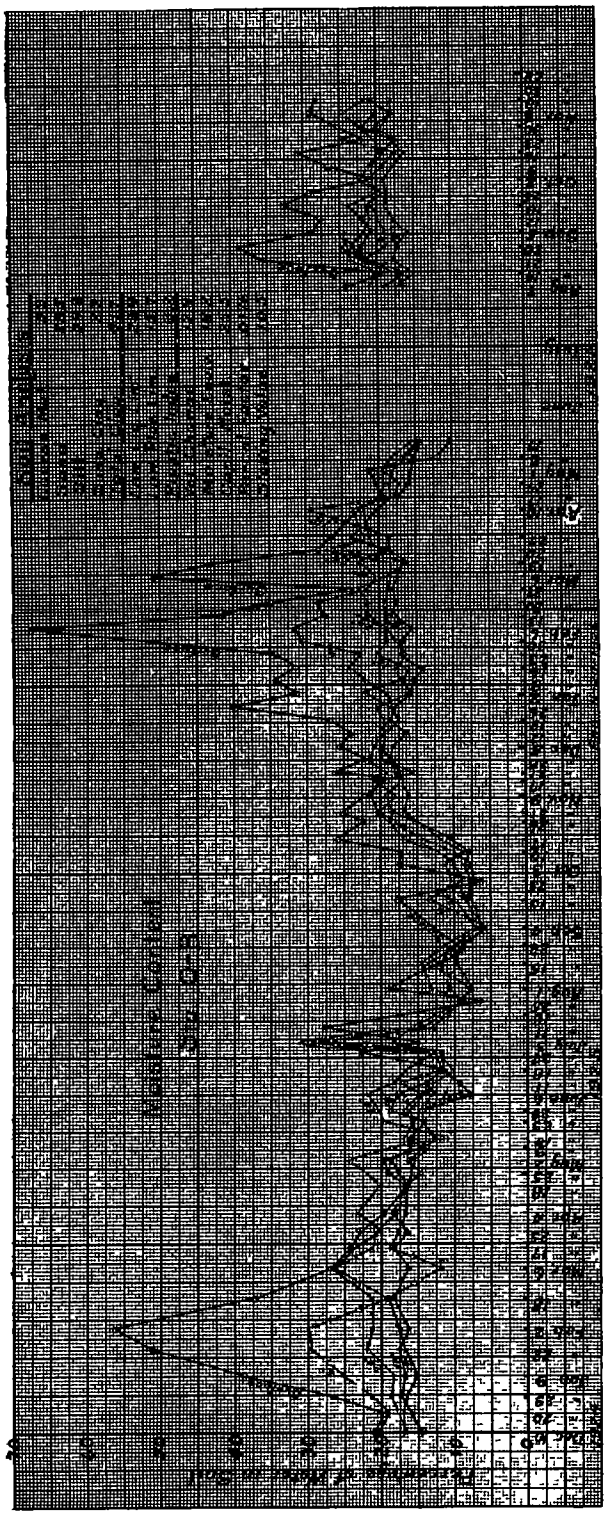

Figure 1

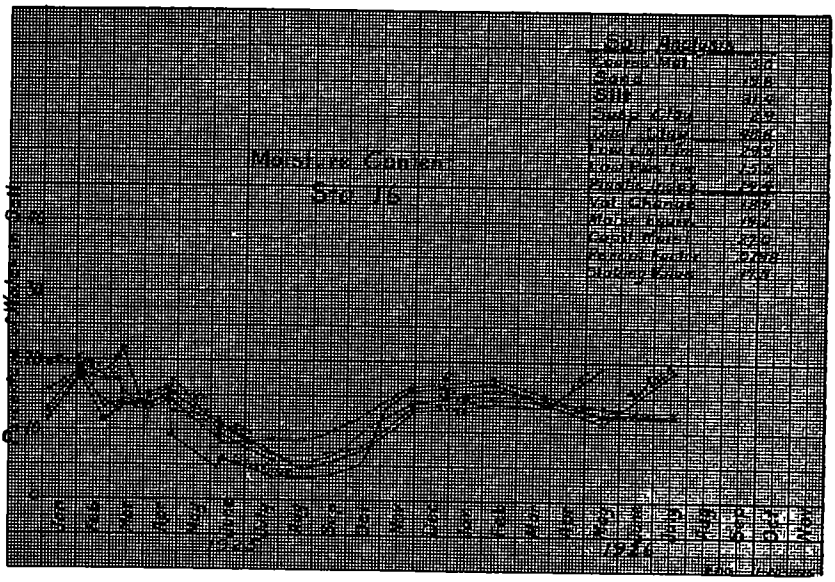

Figure 2

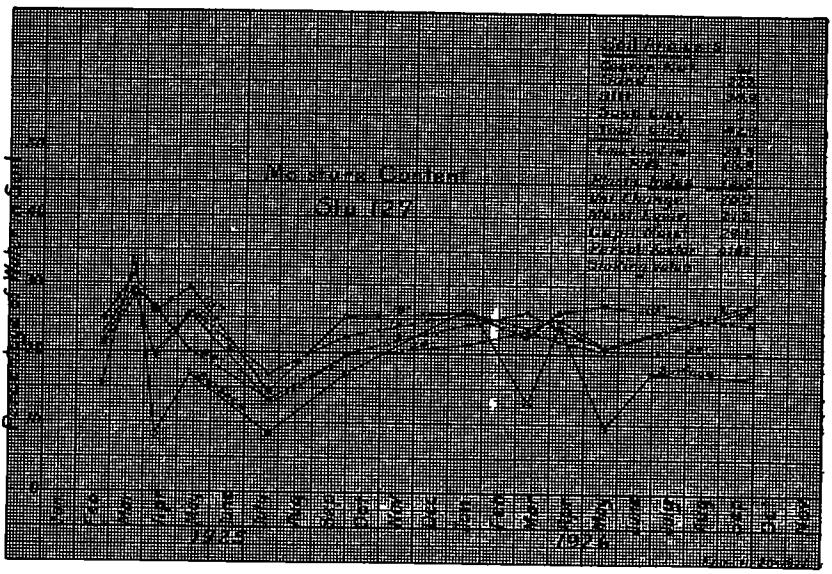

Figure 3

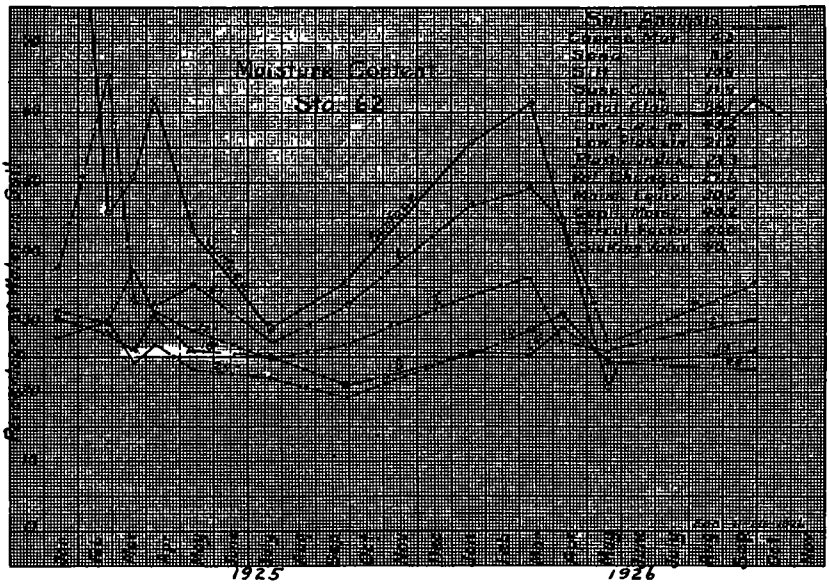

Figure 4

MOISTURE FLUCTUATIONS IN THE SUB-SOILS AT STATIONS "A" AND "B"

A comparison of the average sub-soil moistures for the observation period preceding and for the period at which the fluctuation occurred follows

TABLE IV
MOISTURE CONTENTS

Date	*"A" + Water*	*"O A" + W*	*'B' + W*	*O B' + W*	*Diff 'O A - O B'*	*Diff 'A-B'*	*10-day Rainfall*	*Evap*	*Mean Temp F*
1925									
May 2	18 0	19 6	25 2	25 5	−5 9	−7 2	1 67"		43°-70°
April 25	20 3	18 6	25 9	21 1	−2 5	−5 6			
Fluctuation	−2 3	+1 0	−0 7	+4 4					
July 3	32 0	27 1	37 8	33 4	−6 3	−5 8	1 54"	237" per day	65°-78°
June 27	18 4	12 4	23 3	16 8	−4 4	−4 9			
Fluctuation	13 6	14 7	14 5	16 6					
Sept 15	9 5	9 9	14 6	14 8	−4 9	−5 1	1 74"	119"	68°-81°
Sept 4	9 9	5 6	15 2	9 1	−3 5	−5 3			
Fluctuation	−0 4	+4 3	−0 6	+5 7					
Aug 21	19 1	21 2	20 6	25 3	−4 1	−1 5	4 35"	089"	70°-78°
Aug 14	15 3	17 1	19 8	20 0	−2 9	−4 5			
Fluctuation	+3 8	+4 1	+0 8	+5 3					

The May 2 fluctuation averaged 1 5 per cent decrease beneath the slabs and 2 7 per cent increase in the open ground There are no figures upon evaporation but it was undoubtedly much less than in midsummer The rainfall for the ten-day period ending on May 2 was 1 67 inches, the mean temperature ranged from 43° to 70° F

The fluctuation on July 3 was the most pronounced of any The moisture content of all the four stations rose an average of 14 8 per cent from June 27 to July 3 Rainfall 1 54 inches, evaporation 0 237 inches per day, mean temperature 65° to 78° F. More evaporation, less rain, greater mean temperature and yet an increased moisture content of nearly 5½ times that which occurred in May

The fluctuation on September 15, 1925, averaged 5 0 per cent increase for the open ground and 0 5 per cent decrease beneath the slabs,—for a rainfall of 1 74 inches, an evaporation of 0 119 inch per day, and a mean temperature ranging from 68° to 81° F

The fluctuation of August 21, 1926, averaged an increase for all four stations of 3 5 per cent, for a rainfall of 4 35 inches, rain falling on every day but one in the ten-day period, evaporation of 0 089 inch per day, and a mean temperature ranging from 70° to 78° F

There seems to be neither rhyme nor reason to these short-time fluctuations With weather and rainfall conditions fairly uniform, the soil moisture increase varies from 2 7 per cent to 14 8 per cent, while in the one case with 2 6 times as much rainfall, rather widely distributed, the fluctuation amounts to a bare 3 5 per cent

While rainfall, evaporation and temperature do affect the rising and falling soil moisture through the year they do not seem to be the most marked factors in sudden fluctuations

Table IV also illustrates the effect that soil characteristics have upon the water content of a soil The "B" station soil although apparently as well drained upon the surface as the "A" station soil, yet averages for the eight dates given above, 4 7 per cent more moisture than the "A" soils, or about 27 5 per cent greater amount in "B" than in "A"

Table V gives the average moisture content for some 45 general stations along the State highways Five of these stations were beneath the road pavement, five were taken in the field some forty to sixty feet from the pavement and other thirty-five were from the shoulder of the road, usually about half way between the pavement and the ditch

The average moisture content in these three cases was as follows:

		Surface	6″	12″	18″	24″
5 field	stations averaged	67 1%	29 0%	25.4%	20 6%	20 2%
5 slab	" "	43.1	23 1	22 1	22.6	22 6
34 shoulder	" "	32 7	18 5	17 7	17 7	17 8

As was to be expected the moisture in the upper parts of the field stations was the greatest, the next greatest beneath the slabs and the least amount from the shoulder stations Apparently the reduced temperature and lessened evaporation keeps the moisture content beneath the slab greater from top to bottom than in either of the other two positions

The quantity of clay in the soil seems to have no effect whatever upon the average water content

SUMMARY OF CONCLUSIONS

1 The surface of the soils tested change their moisture quickly from 2 per cent to 124 per cent of their dry weight due to rain, snow, thawing and drying weather

2 That sub-soils below 6 inches in depth change comparatively slowly in water content and over very much narrower margins The general averages range from 13 or 14 per cent to 22 or 23 per cent water content, except in open fields or beneath concrete slabs where it may run to 26 or 28 per cent.

3 That for the dry portion of the summer or fall the water content of the sub-soil may run from 60 to 65 per cent of the water content during the winter and spring.

4 That due to some undetermined factor, possibly exposure, subdrainage, soil composition or a combination of all, certain soils show nearly double the moisture content at all times than do other soils

5 That wet and dry years may make 30 to 50 per cent difference in the amount of water which any given soil may hold

6 That fluctuations occur in the water content of sub-grade soils which it is impossible, from the present data, to trace directly to rainfall, evaporation, or other surface weather conditions

7 When the bearing value of the various types of soil has been determined, these data of moisture content throughout the year under different conditions may become of great value

TABLE V

SOIL DATA FOR FORTY-FIVE STATIONS ALONG THE STATE HIGHWAYS

Soil No	Pl No	L L L	Vol Ch	Soil			Per cent moisture				
				Sand	Silt	Clay	Max Surf	6″	12″	18″	24″
60	3 6	17 6	15 4	13 5	22 7	63 8	33 6	16 3	17 1	16 6	15 6
15x	5 2	23 8	10 5	16 1	29 2	54 7					
21x	5 8	21 2	9 3	21 0	50 5	28 4	31 2	13 6	13 9	14 0	13 8
81	6 8	23 7	13 3	25 0	41 2	33 8	21 7	16 9	18 3	20 4	19 4
32	7 2	21 9	12 4	5 1	23 9	71 0	40 7	24 2	23 4	21 9	22 4†
76	7 2	23 5	16 5	26 6	33 4	40 0	25 0	18 6	19 8	19 2	17 4
58	8 2	27 9	10 6	8 8	37 0	54 2	28 3	18 1	15 9	16 9	19 2
83	9 9	27 0	17 0	25 8	23 4	50 8	22 1	17 4	16 9	15 6	15 1
78	10 1	24 8	14 9	20 6	24 6	54 8	31 4	18 9	19 1	17 8	18 8
60x	10 4	27 4	14 8	19 8	36 6	43 6	31 1	14 8	17 1	16 4	16 7
74	10 4	28 6	15 3	29 4	31 3	39 3	43 7	26 3	23 4	19 9	16 6
25	10 5	28 8	12 5	26 6	15 7	57 7	40 0	17 4	16 5	18 1	21 9
17x	10 6	30 2	19 3	0 3	51 0	48 7	35 6	19 4	20 5	21 0	20 9
69	10 9	29 6	19 1	12 5	20 7	66 8	20 7	16 4	18 2	16 0	16 8
168	11 1	28 4	18 5	28 2	23 5	48 3	44 2	19 9	18 6	17 9	18 8*
22	11 3	31 1	6 5	24 3	30 2	45 5	35 2	15 5	14 6	16 1	16 0
128	11 6	26 4	13 9	17 1	34 6	48 3	29 0	13 2	12 9	14 7	14 5
123	11 6	30 0	18 5	11 3	21 4	67 3	28 4	22 6	22 9	23 6	23 1
59	11 7	27 9	15 7	17 2	39 1	43 2	36 4	15 5	15 0	14 4	16 3
68	11 8	30 4	23 2	14 3	25 1	60 6	29 6	19 0	16 3	17 3	17 6
34	12 6	30 0	13 8	6 5	33 6	59 9	56 9	32 1	30 0	28 9	30 6†
75	12 6	29 0	17 5	25 0	24 3	50 7	20 1	14 1	14 7	14 2	14 0
54	12 6	32 5	21 3	12 2	19 1	68 7	43 1	16 6	15 6	12 0	
71	12 7	29 7	15 8	15 1	26 4	58 5	19 9	14 5	14 1	14 0	15 0
127	13 0	29 3	20 9	22 2	34 9	42 9	33 5	22 5	23 4	25 1	21 8
17y	13 2	33 0	11 9	5 4	43 2	51 4	38 5	16 2	17 8	17 2	16 7
16	14 4	29 9	18 9	19 8	31 4	48 8	21 8	14 2	13 3	13 3	13 9
57	14 8	29 8	21 3	12 2	19 1	68 7	34 8	16 9	16 7	18 0	17 0
61	14 8	32 8	20 8	13 6	22 7	63 7	69 9	27 3	23 8	24 0	21 7†
72	15 5	32 2	21 2	16 9	26 2	56 9	76 0	23 2	21 5	21 6	20 6
77	15 5	36 0	26 7	5 1	9 1	85 9	28 0	18 2	18 5	17 6	17 7
120	16 2	34 9	24 6	7 7	22 9	69 4	45 8	22 0	21 8	21 1	20 8*
15	17 1	33 8	17 7	17 1	30 6	52 3	36 0	26 1	21 5	21 6	20 2
21	17 1	35 2	20 2	3 4	37 6	59 0	32 6	19 0	17 7	17 0	16 4
85	17 8	34 5	21 7	26 1	21 4	52 4	31 6	21 2	17 9	16 2	15 3
119	18 3	36 3	22 8	9 6	29 5	60 9	42 7	22 1	20 0	20 5	22 2*
24	18 5	38 7	11 1	11 7	18 6	69 7	29 3	26 2	35 6	23 2	23 0
31	20 0	38 5	26 1	10 2	16 5	73 3	36 8	22 2	19 5	16 9	16 5
103	20 2	39 6	17 3	9 3	27 1	63 6	37 9	27 3	25 0	26 8	25 0*
63	21 8	39 6	28 1	15 6	24 9	59 5	43 6	22 8	19 5	21 1	21 4†
33	23 2	42 0	24 0	0 3	29 0	70 6	41 1	23 5	22 7	23 0	25 5
62	23 3	45 2	27 6	3 0	10 9	86 1	124 2	38 7	30 4	26 9	25 1†
104	23 6	45 3	17 7	11 3	29 9	58 8	44 8	24 0	25 3	26 6	26 2*
29	25 1	43 4	25 7	2 0	16 0	82 0	41 6	22 7	20 7	21 0	22 7
21y	28 9	49 7	24 0	11 8	11 1	77 1	23 9	14 5	13 7	13 6	12 8

†Stations located in the field off of right-of-way
*Stations located beneath the pavement