Western Regional Office - www.ncenet.com/LTPP
1885 S. Arlington Ave., Suite 111 - Reno, Nevada 89509 - Tel 775/329-4955 - Fax 775/329-5098

Long-Term Pavement Performance

November 21, 2001
File: 800.12.7.1

Mr. Jon Watson, P.E.
Montana DOT
PO Box 201001
2701 Prospect Ave.
Helena, MT 59620-1001

RE: SPS-1 Final Report

Dear Mr. Watson:

Enclosed please find a copy of the final SPS-1 Construction Report describing the work performed near Great Falls.

Should you have any questions or comments, please do not hesitate to contact me.

Sincerely,
NICHOLS CONSULTING ENGINEERS, Chtd.

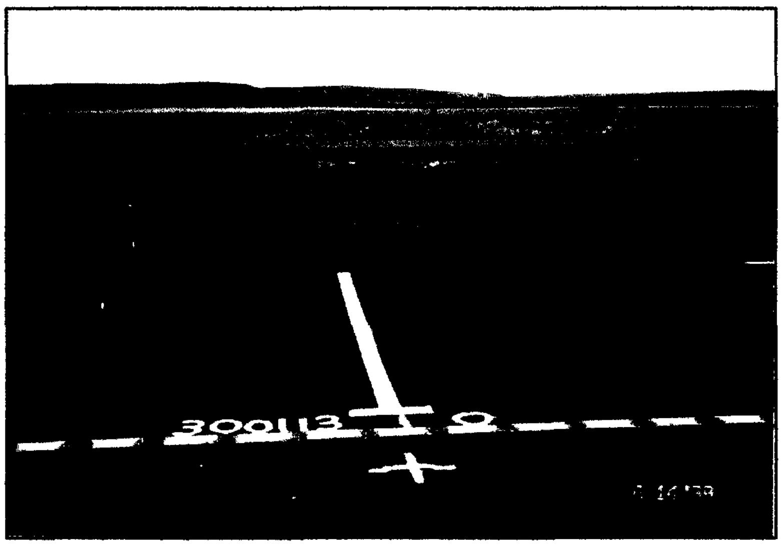
Sirous Alavi, Ph.D., P.E.
LTPP WRSC Project Manager

SA/rkp
Enclosure

cc: Monte Symons
Jack Springer
Gonzalo Rada
James Blossom

FEDERAL HIGHWAY ADMINISTRATION
Long Term Pavement Performance (LTPP)
Specific Pavement Studies

MONTANA SPS-1 CONSTRUCTION REPORT



Final

Prepared for:

Montana Department of Transportation

November 2001

TABLE OF CONTENTS

Page

List of Figures

Page

List of Tables

Page

MONTANA SPS-1
CONSTRUCTION REPORT

ABSTRACT

The structural performance of asphalt concrete (flexible) pavements is affected by many factors such as layer thickness, type of materials, surface and subsurface drainage, and traffic. Under the Strategic Highway Research Program (SHRP), Specific Pavement Studies (SPS) experimental studies are carried out as part of the Long Term Pavement Performance (LTPP) Program across the nation. The SPS-1 experiment, "Strategic Study of Structural Factors for Flexible Pavements," is a study designed to evaluate the effect of pavement layer thickness, base layer type, and drainage on the performance of asphalt concrete pavements. Twelve asphalt concrete sections were constructed on the northbound lanes of I-15, about 24km (15mi) south of Great Falls, Montana. Construction began on April 21, 1998 and the paving operations were completed on October 29, 1998. This report summarizes the details of Montana SPS-1 construction, and includes the pavement layer details, materials, and construction sequence problems during construction and some minor deviations that were observed during construction.

I. INTRODUCTION

The SHRP SPS-1 experiment was designed to more precisely determine the relative impact of structural factors that influence the performance of flexible pavements. The factors addressed in this study include drainage, base type and thickness, and asphalt surface thickness. The study objectives also include determination of the influence of environmental region and soil types on these factors. This report covers the construction of the SPS-1 project on the northbound lanes of I-15 near Great Falls, Montana. Section II of this report gives the project location, description, and attributes. Section III describes the materials and construction procedures used for each type of layer and then continues to detail the construction sequences and operations on a test section by test section basis. The construction of test sections is summarized in section IV and finally the key observations are documented in section V.

SPS-1 EXPERIMENT DESIGN

Figure 1 presents the SPS-1 experimental design. The shaded cells were constructed in Montana.

SPS-1 OBJECTIVES

The primary objectives of the SPS-1 experiment are:

- Evaluation of existing design methods
- Development of improved design equations for new and reconstructed pavements
- Determination of the specific design features on pavement performance
- Development of a comprehensive database for use by state and provincial engineers and other researchers

PAVEMENT STRUCTURE COMBINATIONS				FACTORS FOR MOISTURE, TEMPERATURE, SUBGRADE TYPE, AND LOCATION															
				WET								DRY							
				FREEZE				NO FREEZE				FREEZE				NO FREEZE			
				FINE		COARSE		FINE		COARSE		FINE		COARSE		FINE		COARSE	
DRAIN	BASE TYPE	TOTAL BASE THICK	SURFACE THICK	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
No	AGG	8"	4"		K1		M1		O1		Q1		S1		U1		W1		Y1
			7"	J1		L1		N1		P1		R1		T1		V1		X1	
		12"	4"	J2		L2		N2		P2		R2		T2		V2		X2	
			7"		K2		M2		O2		Q2		S2		U2		W2		Y2
	ATB	8"	4"	J3		L3		N3		P3		R3		T3		V3		X3	
			7"		K3		M3		O3		Q3		S3		U3		W3		Y3
		12"	4"		K4		M4		O4		Q4		S4		U4		W4		Y4
			7"	J4		L4		N4		P4		R4		T4		V4		X4	
	ATB / 4"AGG	8"	4"	J5		L5		N5		P5		R5		T5		V5		X5	
			7"		K5		M5		O5		Q5		S5		U5		W5		Y5
		12"	4"		K6		M6		O6		Q6		S6		U6		W6		Y6
			7"	J6		L6		N6		P6		R6		T6		V6		X6	
YES	PATB / AGG	8"	4"	J7		L7		N7		P7		R7		T7		V7		X7	
			7"		K7		M7		O7		Q7		S7		U7		W7		Y7
		12"	4"		K8		M8		O8		Q8		S8		U8		W8		Y8
			7"	J8		L8		N8		P8		R8		T8		V8		X8	
		16"	4"		K9		M9		O9		Q9		S9		U9		W9		Y9
			7"	J9		L9		N9		P9		R9		T9		V9		X9	
	ATB / PATB	8"	4"		K10		M10		O10		Q10		S10		U10		W10		Y10
			7"	J10		L10		N10		P10		R10		T10		V10		X10	
		12"	4"	J11		L11		N11		P11		R11		T11		V11		X11	
			7"		K11		M11		O11		Q11		S11		U11		W11		Y11
		16"	4"	J12		L12		N12		P12		R12		T12		V12		X12	
			7"		K12		M12		O12		Q12		S12		U12		W12		Y12

AGG = Dense-graded untreated aggregate base
ATB = Dense-graded asphalt treated base
PATB = 4" thick open-graded permeable asphalt-treated drainage layer, underneath ATB or over AGG base
4" AGG = 4" thick dense-graded untreated aggregate base layer underneath ATB
[ ] Shaded cells were built in Montana

Figure 1. Experiment design for Montana SPS-1.

II. SPS-1 PROJECT DESCRIPTION

This section of the report describes in detail the geographical location, section layout, climatic zone, subgrade and structural attributes, and construction of individual sections.

LOCATION AND LAYOUT

This SPS-1 project is located on the northbound outer lane of Interstate 15 between the Km posts 426 and 429 (mileposts 266.5 and 268.1), about 24km (15mi) south of Great Falls in Cascade County, Montana. Figure 2 presents the geographic location of the project. The project is comprised of 12 asphalt concrete sections of varying widths and thicknesses having different base course materials. The layout, stationing, order, and structural attributes of individual sections are presented in figures 3 and 4 and table 1. The average as-built in-place layer thicknesses are shown in table 2.

CLIMATE

The project is located in the LTPP dry-freeze climatic zone. The average maximum and minimum temperatures during the summer and winter seasons are enumerated below:

	Summer	Winter
Average Maximum Temperature	27°C (80.4° F)	1.9°C (35.5° F)
Average Minimum Temperature	11°C (51.8° F)	-9.0°C (15.7° F)

The average annual precipitation is 381mm (15.0 in).

TRAFFIC

According to the information provided by the Montana Department of Transportation (DOT), the estimated 18-kip equivalent single axle loads (ESALs) in the study lane is 174,000 per year. For a design period of 20 years, the total design 18-kip ESALs is estimated to be 3,480,000.

GEOMETRICS

The SPS-1 test sections were built on a straight, flat stretch of northbound I-15. The maximum grade is -0.145% at the north end of the project.

EMBANKMENT CONDITIONS

The test sections were constructed on fill over a coarse grained granular (less than 50 percent passing the #200 sieve) subgrade.

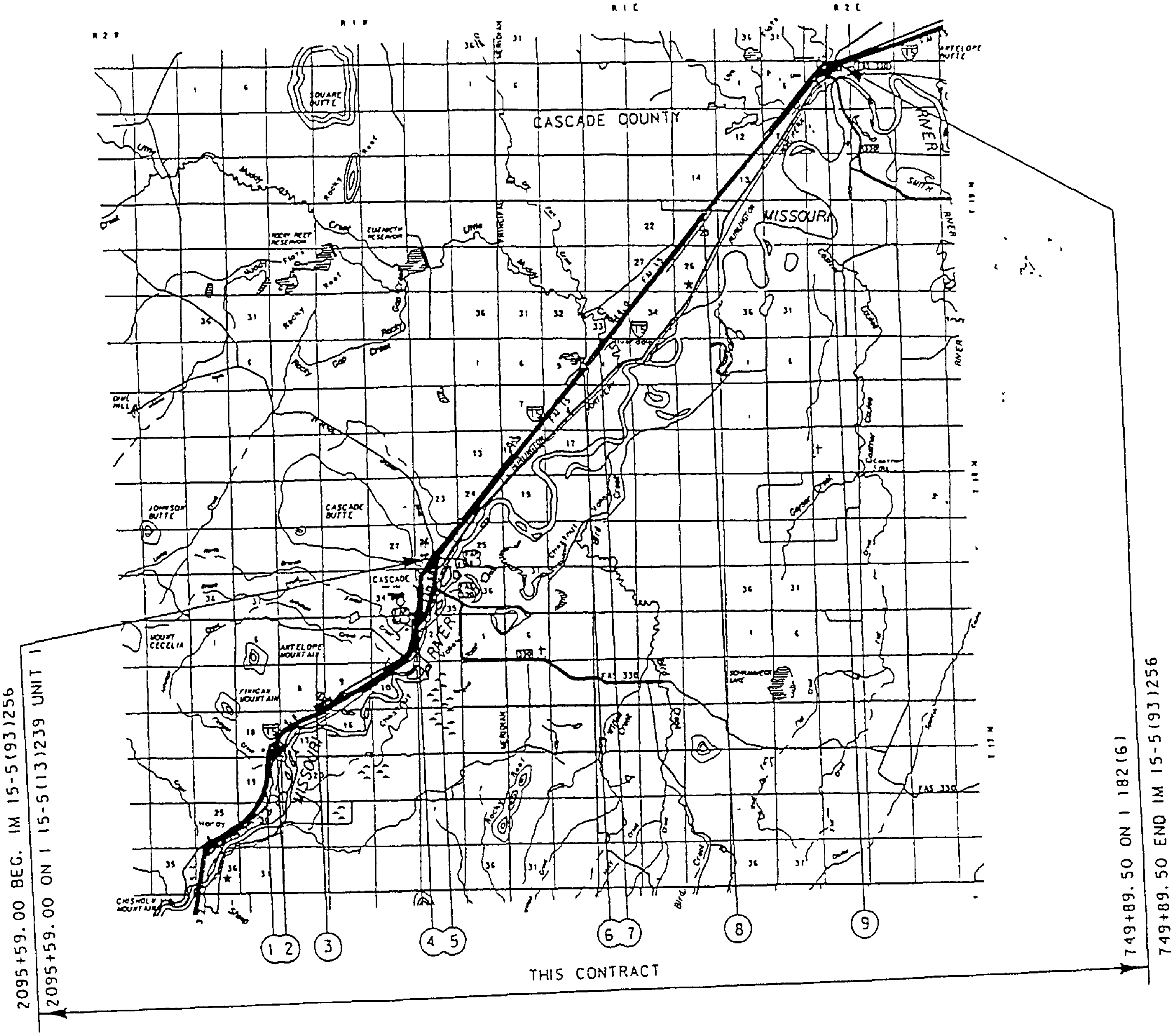


Figure 2 Geographic location of test sections, Montana SPS-1

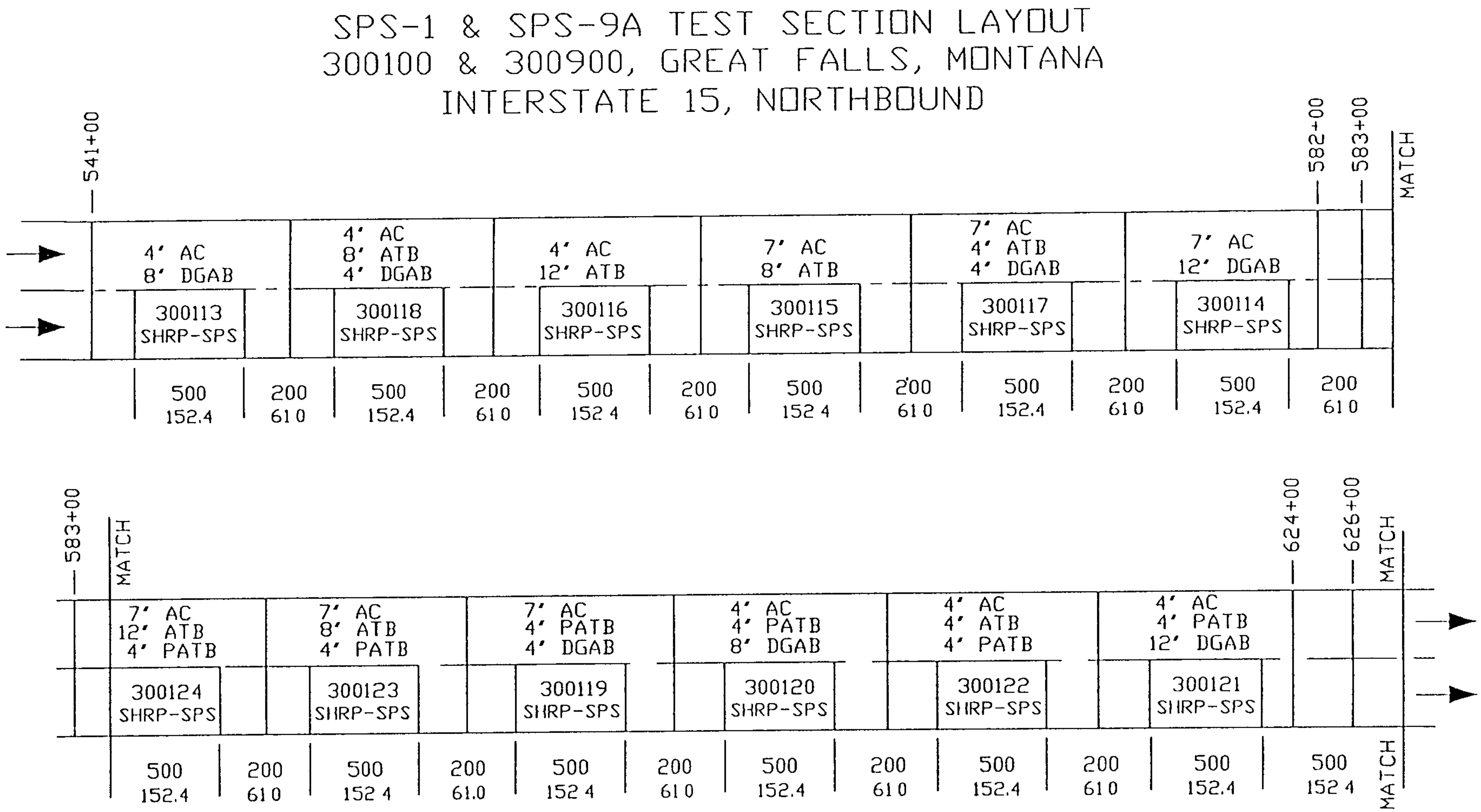
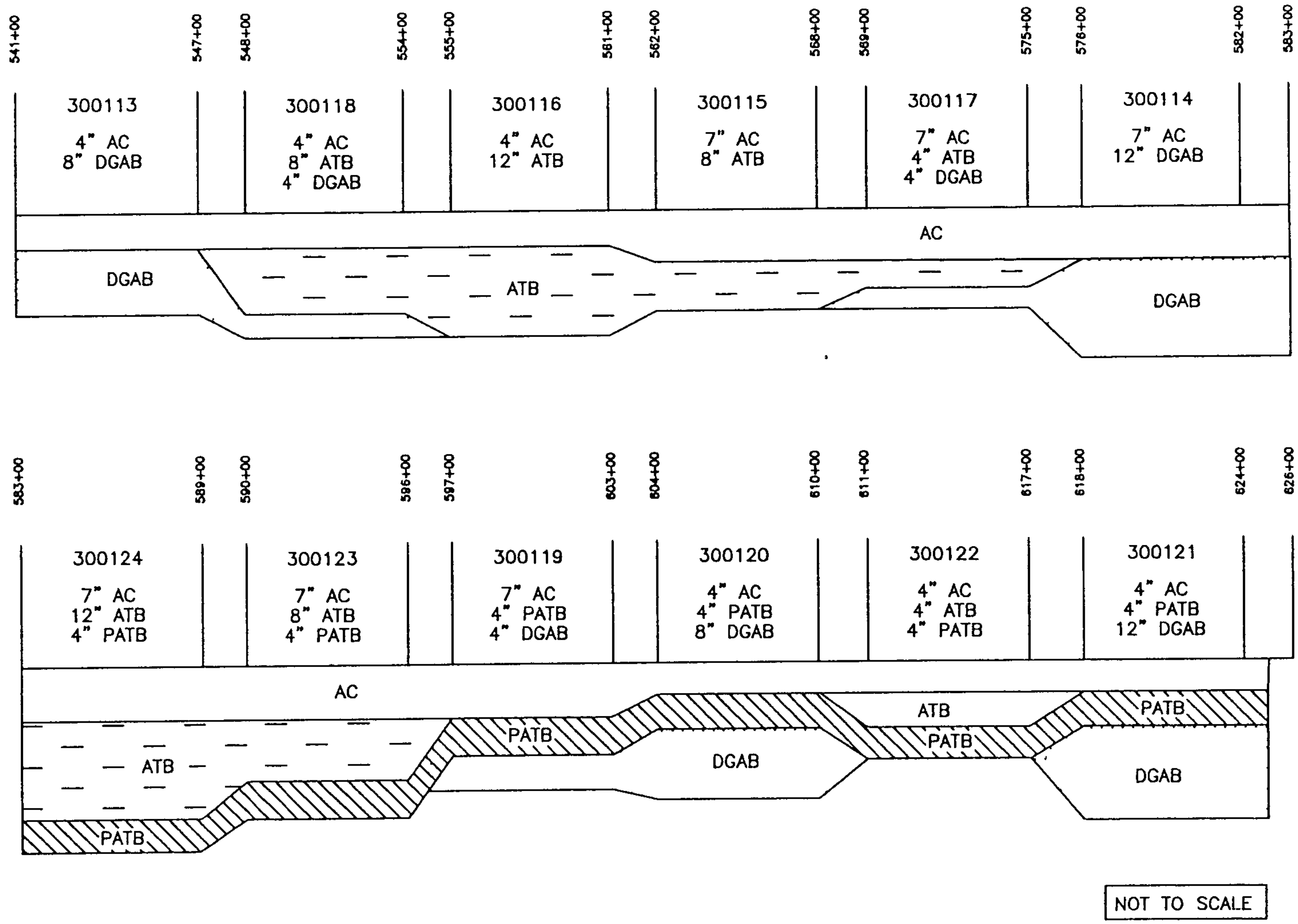


Figure 3. Layout of test sections, Montana SPS-1.



AC – Asphalt Concrete
PATB – Permeable Asphalt Treated Base
ATB – Asphalt Treated Base
DGAB – Dense Graded Aggregate Base

Figure 4. Structural attributes of test sections, Montana SPS-1.

Table 1. Test section location table showing SPS-1 construction and project stations.

Site	Location	Construction Stationing	Test Section Stationing	Test Section	Notes
Transition		540+00 to 541+00		100'	
30013	Begin	541+00	0-50	4" AC 8" DGAB	
	Begin Monitoring	541+50	0+00		
	End Monitoring	546+50	5+00		
	End	547+00	5+50		
Transition		547+00 to 548+00		100'	
300118	Begin	548+00	0-50	4" AC 8" ATB 4" DGAB	
	Begin Monitoring	548+50	0+00		
	End Monitoring	553+50	5+00		
	End	554+00	5+50		
Transition		554+00 to 555+00		100'	
300116	Begin	555+00	0-50	4" AC 12" ATB	
	Begin Monitoring	555+50	0+00		
	End Monitoring	560+50	5+00		
	End	561+00	5+50		
Transition		561+00 to 562+00		100'	
300115	Begin	562+00	0-50	7" AC 8" ATB	
	Begin Monitoring	562+50	0+00		
	End Monitoring	567+50	5+00		
	End	568+00	5+50		
Transition		568+00 to 569+00		100'	
300117	Begin	569+00	0-50	7" AC 4" ATB 4" DGAB	
	Begin Monitoring	569+50	0+00		
	End Monitoring	574+50	5+00		
	End	575+00	5+50		
Transition		575+00 to 576+00		100'	
300114	Begin	576+00	0-50	7" AC 12" DGAB	
	Begin Monitoring	576+50	0+00		
	End Monitoring	581+50	5+00		
	End	582+00	5+50		
Transition		582+00 to 583+00		100'	
300124	Begin	583+00	0+50	7" AC 12" ATB 4" PATB	
	Begin Monitoring	583+50	0+00		
	End Monitoring	588+50	5+00		
	End	589+00	5+50		
Transition		589+00 to 590+00		100'	
300123	Begin	590+00	0-50	7" AC 8" ATB 4" PATB	
	Begin Monitoring	590+50	0+00		
	End Monitoring	595+50	5+00		
	End	596+00	5+50		
Transition		596+00 to 597+00		100'	
300119	Begin	597+00	0-50	7" AC 4" PATB 4" DGAB	
	Begin Monitoring	597+50	0+00		
	End Monitoring	602+50	5+00		
	End	603+00	5+50		

Table 1. Test section location table showing SPS-1 construction and project stations. (cont'd)

Site	Location	Construction Stationing	Test Section Stationing	Test Section	Notes
Transition		603+00 to 604+00		100'	
300120	Begin	604+00	0-50	4" AC 4" PATB 8" DGAB	
	Begin Monitoring	604+50	0+00		
	End Monitoring	609+50	5+00		
	End	610+00	5+50		
Transition		610+00 to 611+00		100'	
300122	Begin	611+00	0-50	4" AC 4" ATB 4" PATB	
	Begin Monitoring	611+50	0+00		
	End Monitoring	616+50	5+00		
	End	617+00	5+50		
Transition		617+00 to 618+00		100'	
300121	Begin	618+00	0-50	4" AC 4" PATB 12" DGAB	
	Begin Monitoring	618+50	0+00		
	End Monitoring	623+50	5+00		
	End	624+00	5+50		

Table 2. Average in-place layer thicknesses (inches) for SPS-1 sections, Montana.

Section Number	DGAB	PATB	ATB	AC
300113	8.4	--	--	4.3
300014	12.4	--	--	7.2
300115	--	--	9.1	7.4
300116	--	--	12.6	4.4
300117	4.7	--	4.3	7.2
300118	4.2	--	8.8	4.6
300119	4.3	4.7	--	7.2
300120	8.1	4.6	--	4.3
300121	12.5	4.3	--	4.4
300122	--	4.3	4.0	4.6
300123	--	3.9	8.4	7.5
300124	--	4.2	13.5	7.2

PROJECT PERSONNEL

This project was constructed under the supervision of the Montana DOT and Empire Sand and Gravel was the Prime Contractor. All LTPP required material sampling was carried out by Montana DOT personnel. The Western Region LTPP contractor, Nichols Consulting Engineers (NCE), had observers on site for the duration of the construction to aid in sampling and data collection efforts, help complete data forms, and record deviations from the experimental plan. The following personnel were involved in the project at various phases of construction:

Montana DOT

Tim Sauer	Tom Roberts
Doug Wilmont	Mike Ostertag
Part Ernst	Stan Kuntz
Jim Blossom	Matt King
Brian Stremcha	

Empire Sand and Gravel

Bob Marshall	Robert Oberlander
Tom Salverson	Tony Tams

WRCOC (NCE)

Pete Pradere	Jason Puccinelli
Douglas Frith	Scott Gibson

III. CONSTRUCTION

The SPS-1 project in Montana was constructed between April 1998 and November 1998. The construction plans required milling off the existing asphalt concrete layer, a complete removal of the base course and existing embankment and replacing the existing embankment with a select borrow material. This was carried out as explained in the Existing Embankment and Subgrade Preparation section of this report. The following discussion will detail the construction for this project, including the deviations from the construction plans.

EQUIPMENT

The following equipment was used in the processing and construction work of subgrade and aggregate base layers on the SPS-1 test sections on I-15 in Montana.

- CAT 637D Scraper
- CAT CS-563C Steel Drum Roller
- Ingorsoll and Pro Pac Series 150 Steel Drum Rollers
- Dynapac Sheepsfoot Roller
- CAT 140G Blade
- CAT 14H Blade
- CAT CP 563 C Sheepsfoot Roller
- Belly Dump Trucks
- Water Truck
- Hand held Portable Compactor

EXISTING EMBANKMENT AND SUBGRADE PREPARATION

The existing embankment consisted of well graded granular material (A-1-A) that was mostly sandy with some 75mm (3 in) minus cobbles having less than 50% passing the #10 sieve and less than 15% passing #200 sieve with good drainage properties. The construction plans called for the complete removal of the existing embankment and replacing it with select borrow material that matched the natural subgrade. However, the depth of the existing embankment was greater than estimated. A complete removal of the embankment was discussed, but due to project delays, administrative and financial implications, and a shortage of special borrow material, a decision was made to excavate to the contracted depth only. This resulted in an additional layer of A-1-A material, varying in thickness between 0m (0 in) to 0.4m (16 in) over the entire test site. This additional pavement layer was not designated as a separate layer in the pavement structure, even though additional sampling of this (A-1-A) material was performed. Special borrow material, similar to the existing subgrade, was placed on each of the 12 sections to bring them up to plan grade.

After removal up to the contracted depth, the remaining existing embankment was worked with graders and scrapers to achieve proper distribution of the material and to attain the required profile. Water trucks and steel rollers were employed to attain the target compaction.

Bulk Sampling

Bulk sampling of existing embankment material and subgrade was performed by excavating test pits. The bulk sampling locations were also used for compaction testing of underlying layers using nuclear density gauges. The sampling and density testing locations are indicated in figures 5 and 6. A summary of subgrade and existing embankment material bulk sample section locations, stations, sample number, and material descriptions are given in tables 3 and 4, respectively. Photographs 1, 2, 3 and 4 in appendix B show the work carried out on existing embankment/prepared subgrade.

Inspection

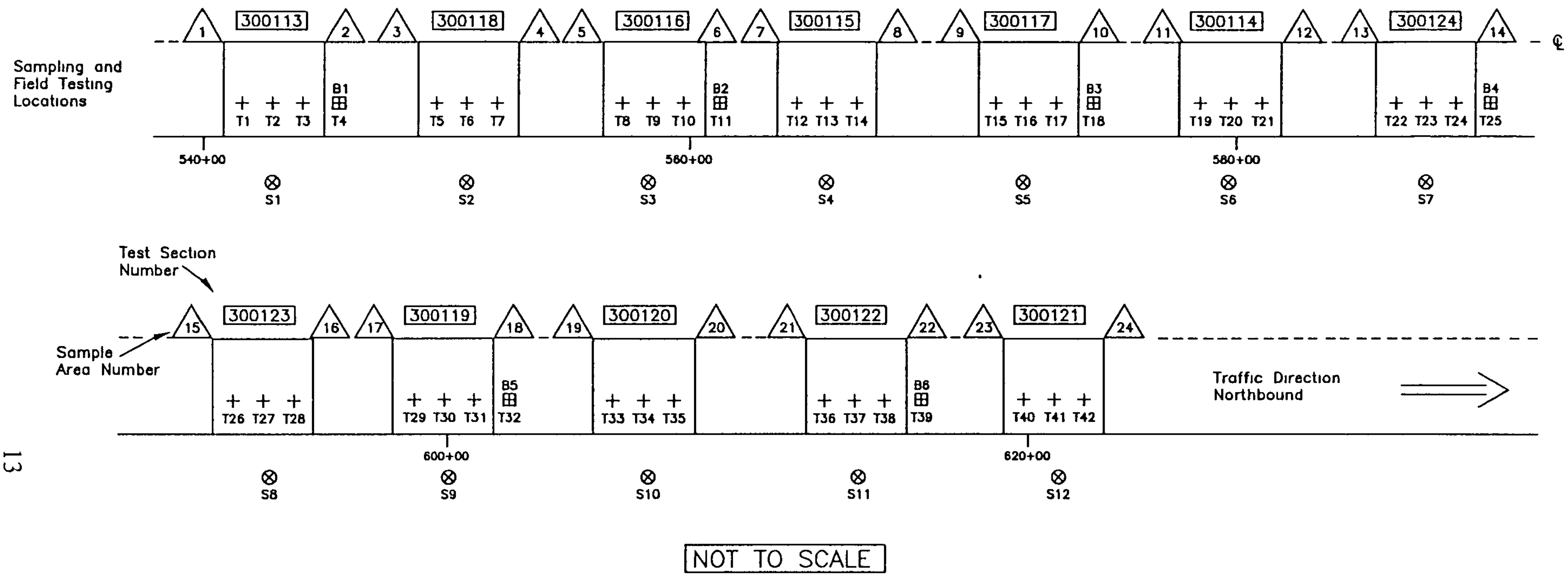
During the inspection process, notes were made to document abnormalities and deviations capable of affecting the individual test sections' performance. Both the northbound lanes were monitored. Of these two lanes, the test sections are located in the outer travel lane carrying most of the truck traffic and the inner lane is the passing lane. The abnormalities observed were soft spots caused by the presence of excess moisture due to rains on June 12, 1998 and/or clay in the subgrade and existing embankment layer. The soft spots observed in sections 300116, 300117, 300121, and 300122 of the test lane were documented. Section 300116 had a soft spot beginning at station 5+40 all the way to the end of section with a width of about 5.19m (17 ft). This soft spot was excavated to a depth of 0.91m (3.0 ft), class 2 geofabric was laid, and excess existing embankment material was backfilled and compacted to Montana DOT specifications.

The soft material in the rest of the soft spots in test sections 300117, 300121, and 300122 was completely removed and replaced by excess adjacent embankment material or by special borrow material and compacted to the specs. The locations, extent, and depths of soft spots in individual test sections are listed in table 5. The passing lane had some soft spots; these too were treated in similar fashion. The locations, extent, and depths of soft spots and remedial measures undertaken for mitigation in the passing lane are listed in table 6.

Natural subgrade materials were excavated from the shoulder to complete the embankment. This material was placed on top of the remaining layer of A-1-A pit run material that was not removed. This material was only used for the outside lane and shoulder. A fine grained waste material was hauled in from the pit to construct the inside or passing lane beginning approximately 0.61m (2 ft) from the centerline on the inside lane. Photographs 5, 6, 7 and 8 in appendix B show the effects of rain on prepared subgrade/existing embankment and also the remedial measures that were under taken.

Field Density and Field Moisture Testing

Field density and field moisture tests were performed on the existing embankment and prepared subgrade layers. The density tests were carried out using nuclear gauge (ID#3440 20996) at locations indicated in figures 5 and 6 in accordance with the procedures in AASHTO T239-97. As stated earlier, additional tests were performed on the retained existing embankment material. The results of the density tests are tabulated in tables 7 and 8. As can be seen in tables 7 and 8,



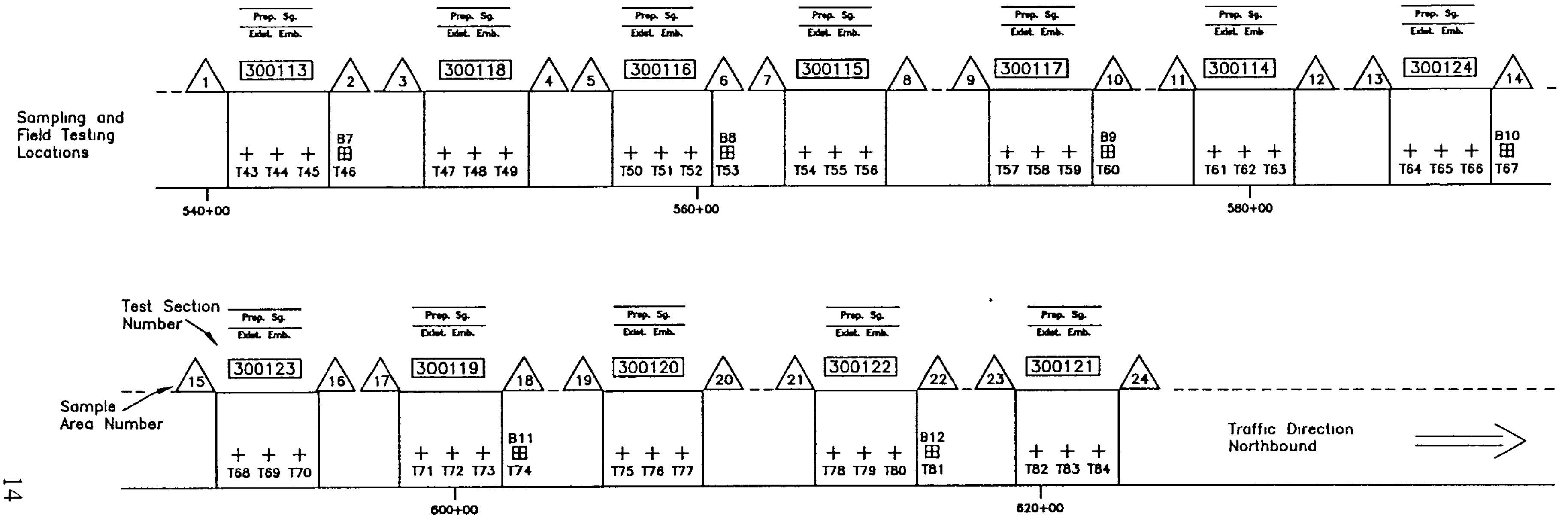
□ 2' x 2' bulk sampling location (B1–B6) to 12" below top of Existing Embankment

⊗ Shoulder probe (S1–S12)

\+ Location of nuclear moisture–density tests (T1–T42)

△ Sample areas

Figure 5. Overview of material sampling and testing on Existing Embankment, SPS-1 Montana.



NOT TO SCALE

□ 2' x 2' bulk sampling location (B7–B12) to 12" below top of Prepared Subgrade

\+ Location of nuclear moisture–density tests (T43–T84)

Prep Sg – Prepared Subgrade

Exist Emb – Existing Embankment

△ Sample areas

Figure 6. Overview of material sampling and testing on Prepared Subgrade, SPS-1 Montana.

Table 3. Existing embankment bulk samples and soil types by section.

Section	Bulk Sample No	Depth of Material	Material Description
300113	BG01 BS01	0" to 6" 6" to 15.5"	3" minus gravel 3" minus clayey gravel
300116	BG02 BS02	0" to 5 5" 5.5" to 15"	3" minus gravel Sandy loam
300117	BG03 BS03	0" to 5" 5" to 16"	3" minus gravel Sandy loam
300124	BG04 BS04	0" to 6" 6" to 20"	3" minus gravel Sandy loam
300119	BG05 BS05	0" to 6 5" 6 5" to 16"	3" minus gravel Sandy loam
300122	BG06 BS06	0" to 6" 6" to 16"	3" minus gravel 3" minus gravel

Table 4. Subgrade (SG) bulk samples and soil types by section.

Section	Bulk Sample No.	Depth to Subgrade from Top Finished Embankment	Material Description
300113	BS07	19"	Sandy loam
300116	BS08	19"	Sandy loam
300117	BS09	16.5"	Sandy loam
300124	BS10	15.5"	Sandy loam
300119	BS11	16.5"	Sandy loam
300122	BS12	20"	Sandy loam

Table 5. Test lane problems for existing embankment/subgrade.

Section	Location	Problem	Solution
300116	5+40 to end 5 ft right to 29 ft right 3 ft deep	Soft spot due to clay and excess moisture in material	Dug out, fabric laid from 5 ft right to 17 ft right, and refilled with excess existing embankment
	5+00 to 5+25 6 ft right to 24 ft left 3 ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment
300117	2+30 to 2+70 18 ft right to 6 ft left 1.5 ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment
300122	2+56 to 3+00 9 ft right to 21 ft right 1.5 ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment
300121	0+50 to 2+50 6 ft right to 20 ft left 3 ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment
	2+35 to 5+25 Centerline to 27 ft right 2 5 ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled using pit run material

Table 6. Non-test lane problems for existing embankment/subgrade.

Section	Location	Problem	Solution
300116	4+30 to 5+00 Centerline 24ft left 3ft deep	Soft spot due to clay and excess moisture in material	Dug out, fabric laid from 5 ft right to 17 ft right, and refilled with excess existing embankment
300117	0+50 to 2+00 4ft left to 25ft left 2.5ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment
	Beginning to 0-25 Centerline to 12ft left 2ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment
	0-25 to 0+50 12ft left to 25ft left 2ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment
300114	2+00 to 3+25 6ft left to 25ft left 3ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment
	3+50 to 4+50 22ft right to 38ft right 3ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment
	2+10 to 2+40 9ft left to 20ft left 3ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment
	3+00 to 3+50 6ft left to 20ft left 3ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment
300122	0-25 to 0+25 18ft left to 30ft left 3 ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment
	0+50 to 1+50 18ft left to 30ft left 4.5ft deep	Soft spot due to clay and excess moisture in material	Dug out and refilled with excess existing embankment

Table 6. Non-test lane problems for existing embankment/subgrade. (cont'd)

Section	Location	Problem	Solution
300121	Beginning to 0+15 20ft left to 32ft right 2ft deep	Soft spot due to clay and excess moisture in material	Dugout and refilled with excess existing embankment
	0+50 to 5+50 Centerline to 30ft left 3 5ft deep	Soft spot due to clay and excess moisture in material	Dugout and refilled with pit run material
	2+50 to 5+50 23ft right to 40ft right 1ft deep	Soft spot due to clay and excess moisture in material	Blade reworked this and refilled with original material
	Beginning to 2+50 21ft right to 30ft right 1.5ft deep	Soft spot due to clay and excess moisture in material	Blade reworked this and refilled with original material

Table 7. In-situ density and moisture test results on existing embankment.

Test No	Test Section Station	Section	Project Station	Offset	Rod Depth (in)	Depth to Top of Pavement (in)	Avg. In-Situ Bulk Density (pcf)	Avg In-Situ Moisture Content (%)
T1	1+00	300113	542+50	6' rt of CL	8	31	139.3	4 8
T2	2+50	300113	544+00	6' rt of CL	8	31	137.6	5.2
T3	4+00	300113	545+50	6' rt of CL	8	31	141.3	5 9
T4	5+25	300113	546+75	6' rt of CL	8	31	138.2	7.1
T5	1+00	300118	549.50	6' rt of CL	8	31	133.2	4 9
T6	2+50	300118	551.00	6' rt of CL	8	31	123.2	7 4
T7	4+00	300118	552 50	6' rt of CL	8	31	128.3	6 1
T8	1+00	300116	556+50	6' rt of CL	8	31	123.8	6 2
T9	2+50	300116	558+00	6' rt of CL	8	31	133 7	5.4
T10	4+00	300116	559+50	6' rt of CL	8	31	131 3	5.5
T11	5+25	300116	560+75	6' rt of CL	8	31	132 8	5 4
T12	1+08	300115	563+50	6' rt of CL	8	31	128 0	5 2
T13	2+50	300115	565+00	6' rt of CL	8	31	131.2	5.8
T14	4+00	300115	566+50	6' rt of CL	8	31	128.7	5 7
T15	1+00	300117	570+50	6' rt of CL	8	31	121 9	6.2
T16	2+50	300117	572+00	6' rt of CL	8	31	131.3	4 8
T17	4+00	300117	573+50	6' rt of CL	8	31	125.8	5 8
T18	5+25	300117	574+75	6' rt of CL	8	31	131 0	5 6
T19	1+00	300114	577+50	6' rt of CL	8	31	130 9	5 5
T20	2+50	300114	579+00	6' rt of CL	8	31	127.1	5.1
T21	4+00	300114	580+50	6' rt of CL	8	31	125.5	6 2
T22	1+00	300124	584+50	6' rt of CL	8	31	134 9	5.5
T23	2+50	300124	586+00	6' rt of CL	8	31	120 4	5 1
T24	4+00	300124	587+50	6' rt of CL	8	31	118.3	4 7
T25	5+25	300124	588+75	6' rt of CL	8	31	118 2	5 1
T26	1+00	300123	591+50	6' rt of CL	8	31	120 6	4.4
T27	2+50	300123	593+00	6' rt of CL	8	31	118.2	5.2
T28	4+00	300123	594+50	6' rt of CL	8	31	126 6	3 9
T29	1+00	300119	598+50	6' rt of CL	8	31	126 5	4.6
T30	2+50	300119	600+00	6' rt of CL	8	31	135 0	4 3
T31	4+00	300119	601+50	6' rt of CL	8	31	136 4	5.1
T32	5+25	300119	602+75	6' rt of CL	8	31	129 9	5 3
T33	1+00	300120	605+50	6' rt of CL	8	31	131 9	7 1
T34	2+50	300120	607+00	6' rt of CL	8	31	136 7	4 6

Table 7. In-situ density and moisture test results on existing embankment. (cont'd)

Test No.	Test Section Station	Section	Project Station	Offset	Rod Depth (in)	Depth to Top of Pavement (in)	Avg. In-Situ Bulk Density (pcf)	Avg In-Situ Moisture Content (%)
T35	4+00	300120	608+50	6' rt of CL	8	31	129.6	4 5
T36	1+00	300122	612+50	6' rt of CL	8	31	133 4	5 4
T37	2+50	300122	614+00	6' rt of CL	8	31	134.3	5 9
T38	4+00	300122	615+50	6' rt of CL	8	31	132 7	6.8
T39	5+25	300122	616+25	6' rt of CL	8	31	133 5	6 0
T40	1+00	300121	619+50	6' rt of CL	8	31	129.4	6.8
T41	2+50	300121	621+00	6' rt of CL	8	31	129 8	7 2
T42	4+00	300121	622+50	6' rt of CL	8	31	132 2	5 0

Table 8. In-situ density and moisture test results on prepared subgrade.

Test No.	Test Section Station	Section	Project Station	Offset	Rod Depth (in)	Depth to Top of Pavement (in)	Avg. In-Situ Bulk Density (pcf)	Avg In-Situ Moisture Content (%)
T43	1+00	300113	542+50	6' rt of CL	8	12	109 8	12.2
					4	12	109.6	12 9
T44	2+50	300113	544+00	6' rt of CL	8	12	108 2	16.0
					4	12	108 1	16.1
T45	4+00	300113	545+50	6' rt of CL	8	12	106 2	19.3
					4	12	104 7	19 2
T46	5+25	300113	546+75	6' rt of CL	8	12	106.5	18.6
					4	12	107 4	18 1
T47	1+00	300118	549+50	6' rt of CL	8	16	110.2	14.9
					4	16	110 7	14.8
T48	2+50	300118	551+00	6' rt of CL	8	16	112.5	13.5
					4	16	110.9	13 4
T49	4+00	300118	552+50	6' rt of CL	8	16	112 9	13 1
					4	16	111 3	13.5
T50	1+00	300116	556+50	6' rt of CL	8	16	107 6	15 6
					4	16	108 5	15.7
T51	2+50	300116	558+00	6' rt of CL	8	16	110 2	14.9
					4	16	110.1	14.5
T52	4+00	300116	559+50	6' rt of CL	8	16	114 4	15 2
					4	16	108 1	15 4
T53	5+25	300116	560+75	6' rt of CL	8	16	114 0	13 9
					4	16	113.4	13 9
T54	1+00	300115	563+50	6' rt of CL	8	15	113.3	12 3
					4	15	113.1	12 6
T55	2+50	300115	565+00	6' rt of CL	8	15	103 4	16 6
					4	15	99 0	17 4
T56	4+00	300115	566+50	6' rt of CL	8	15	103 9	17 5
					4	15	101.9	17 5
T57	1+00	300117	570+50	6' rt of CL	8	15	108 6	9 6
					4	15	102.2	9 8
T58	2+50	300117	572+00	6' rt of CL	8	15	113 5	8.0
					4	15	109 2	8 5
T59	4+00	300117	573+50	6' rt of CL	8	15	110 7	10 1
					4	15	108 5	10 3
T60	5+25	300117	574+75	6' rt of CL	8	15	109 3	8.8
					4	15	103 6	9 4

Table 8. In-situ density and moisture test results on prepared subgrade. (cont'd)

Test No	Test Section Station	Section	Project Station	Offset	Rod Depth (in)	Depth to Top of Pavement (in)	Avg. In-Situ Bulk Density (pcf)	Avg In-Situ Moisture Content (%)
T61	1+00	300114	577+50	6' rt of CL	8	19	111.1	16.6
					4	19	106 2	16.8
T62	2+50	300114	579+00	6' rt of CL	8	19	109.3	13.6
					4	19	104.1	14.6
T63	4+00	300114	580+50	6' rt of CL	8	19	110.3	12.3
					4	19	105.7	12.6
T64	1+00	300124	584+50	6' rt of CL	8	23	126.6	9.8
					4	23	120.0	10.5
T65	2+50	300124	586+00	6' rt of CL	8	23	107.4	15.2
					4	23	106 1	15.1
T66	4+00	300124	587+50	6' rt of CL	8	23	113.1	11.1
					4	23	113.4	11 5
T67	5+25	300124	588+75	6' rt of CL	8	23	113 9	12.3
					4	23	115 8	12.1
T68	1+00	300123	591+50	6' rt of CL	8	19	112.2	14 3
					4	19	110.3	14.3
T69	2+50	300123	593+00	6' rt of CL	8	19	115.1	12 9
					4	19	114.6	13.1
T70	4+00	300123	594+50	6' rt of CL	8	19	113.1	12.3
					4	19	110.7	12.1
T71	1+00	300119	598+50	6' rt of CL	8	15	111.8	9 6
					4	15	112 6	9 3
T72	2+50	300119	600+00	6' rt of CL	8	15	112.0	11 0
					4	15	112 3	11.0
T73	4+00	300119	601+50	6' rt of CL	8	15	113.1	12.4
					4	15	110.9	12.8
T74	5+25	300119	602+75	6' rt of CL	8	15	112.2	8 0
					4	15	109.0	8 1
T75	1+00	300120	605+50	6' rt of CL	8	16	105.8	9 7
					4	16	105 0	10 0
T76	2+50	300120	607+00	6' rt of CL	8	16	104 4	13.3
					4	16	101.7	13.5
T77	4+00	300120	608+50	6' rt of CL	8	16	107 5	12.9
					4	16	106 9	12 4

Table 8. In-situ density and moisture test results on prepared subgrade. (cont'd)

Test No	Test Section Station	Section	Project Station	Offset	Rod Depth (in)	Depth to Top of Pavement (in)	Avg. In-Situ Bulk Density (pcf)	Avg In-Situ Moisture Content (%)
T78	1+00	300122	612+50	6' rt of CL	8	12	97.7	13 4
					4	12	98.7	13 0
T79	2+50	300122	614+00	6' rt of CL	8	12	99.8	13 8
					4	12	98 2	13.7
T80	4+00	300122	615+50	6' rt of CL	8	12	103 3	13 2
					4	12	97.8	13.3
T81	5+25	300122	616+75	6' rt of CL	8	12	105.3	7 8
					4	12	101.0	8 0
T82	1+00	300121	619+50	6' rt of CL	8	20	101 5	13 8
					4	20	98 5	14 5
T83	2+50	300121	621+00	6' rt of CL	8	20	99 8	14.6
					4	20	97.6	14 6
T84	4+00	300121	622+50	6' rt of CL	8	20	103.0	14.2
					4	20	100.1	14 0

the bulk densities are significantly higher for the existing embankment. The existing embankment averages approximately 2082 kg/m3 (130 pcf) and the prepared subgrade averages approximately 1762 kg/m3 (110 pcf). Because the embankment was supposed to be composed of the same material as the existing natural subgrade, these density results reflect that the densities were taken on the AIA material discussed above.

Shoulder Auger Probes

Shoulder auger drilling to a depth of 6.1m (20 ft) was performed on June 17, 1998, to determine the existence of bedrock or any stiff underlying layer within 6.1m (20 ft) of pavement surface. Table 9 lists the section locations and soil types for shoulder probes performed on existing embankment. No rock or other stiff layer was encountered.

FWD Testing

Falling Weight Deflectometer (FWD) testing of the subgrade was performed on June 29, 1998, by the Western Regional Coordination Office Contractor (WRCOC) in accordance with the procedures and guidelines outlined in SPS Directive S-4, "Deflection Testıng of Subgrade and Base Layers for SPS-1, SPS-2, and SPS-8 Experiments." A sampling of the results of the FWD testing are presented in appendix B. The deflections shown are non-normalized sensor 1 deflections that are intended to provide an indication of the uniformity of the section. The complete deflection data records are available in the LTPP database.

The purpose of the deflection testing was to identify any significant variation in the subgrade support. Even on uniform materials, deflection testing on subgrade produces more highly variable results than testing on finished pavement. This is because seating conditions are less uniform and loads are distributed over a much smaller area. As can be seen from the charts the deflection basin is very narrow, meaning that the large sensor 1 deflections are not transmitted much beyond sensor 2, only one foot (.3 m) away.

The results of the testing show that the deflections range from approximately 20 mils (.5 mm) to 120 mils (3.05 mm) over the entire site. Within each section the variation is typically on the range of 40 mils (1 mm) to 80 mils (2mm). Sections 300122 and 300123 show the most uniformity of the 12 sections. They reflect the overall variation of the site, however, with 300122 being uniformly at the lower end of the range and 30123 being uniformly at the higher end of the range.

Prepared Subgrade Surface Elevations

Baseline elevation surveys on the surface of prepared subgrade were carried at locations indicated in figure 7. These locations were typical for the rest of the layers. The purpose of the elevation surveys was to obtain a profile of prepared subgrade surface and to determine the thickness of subsequent layers. The profiles are shown in appendix A.

Table 9. Auger probes performed on shoulder of existing embankment/prepared subgrade.

Test No.	Test Section Station	Section	Project Station	Offset	Type of Equipment Used	Depth of Layer	Material Description
S1	2+50	300113	544+00	6' rt of outside lane edge	CL6-62-98	0 to 2 ft	Sand silt
						2 to 3 ft	Large gravel cobbles
						3 to 6 ft	Silty sand (trace of clay)
						6 to 12 ft	Fine sandy silt
						12 to 19 ft	Silty fine sand
						19 ft ↓	Wet silt
S2	2+50	300118	551+00	6' rt of outside lane edge	CL6-63-98	0 to 1.5 ft	Silty sand
						1.5 to 2 ft	Gravel
						2 to 3 ft	Very fine sandy clay
						3 to 4 ft	Light gray silty clay
						4 to 11 ft	Fine sand (brown)
						11 to 14 ft	Silt (tan)
						14 to 17 ft	Gray silty sand
						17 ft ↓	Fine sand
S3	2+50	300116	558+00	6' rt of outside lane edge	CL6-64-98	0 to 1.5 ft	Sandy silt
						1.5 to 2 ft	Gravel cobbles
						2 to 3 ft	Sandy silt (dark brown)
						3 to 7 ft	Silty sand (light brown)
						7 to 8 ft	Silty moist clay (tan)
						8 to 17 ft	Damp silt (tan)
						17 ft ↓	Wet silty sand
S4	2+50	300115	565+00	6' rt of outside lane edge	CL6-65-98	0 to 1.5 ft	Silt
						1.5 to 2 ft	Gravel
						2 to 4 ft	Dark silty sand
						4 to 6 ft	Sand silt (tan)
						6 to 10 ft	Dark brown silty clay
						10 to 16 ft	Tan silt
						16 ft ↓	Moist gray silty clay
S5	2+50	300117	572+00	6' rt of outside lane edge	CL6-66-98	0 to 1 ft	Silty sand
						1 to 2 ft	Gravel
						2 to 4 ft	Fine sand (dark brown)
						4 to 16 ft	Sandy silt (tan)
						16 ft ↓	Fine moist sand (gray)

Table 9. Auger probes performed on shoulder of existing embankment. (cont'd)

Test No.	Test Section Station	Section	Project Station	Offset	Type of Equipment Used	Depth of Layer	Material Description
S6	2+50	300114	579+00	6' rt of outside lane edge	CL6-67-98	0 to 3 ft	Silty clay
						3 ft ↓	Fine sand (brown)
S7	2+50	300124	586+00	6' rt of outside lane edge	SIMCO 4"	0 to 1 ft	Fine, moist, brown sand
						1 ft to 2 ft	Brown sandy gravel
						2 ft ↓	Brown sand (some coarse sand)
S8	2+50	300123	593+00	6' rt of outside lane edge	SIMCO 4"	0 to 6 ft	Fine, brown, moist sand with a trace of silt
						6 to 9 ft	Gray silt with occasional pea gravel
						9 ft ↓	Light brown, fine, moist sand
S9	2+50	300119	600+00	6' rt of outside lane edge	SIMCO 4"	0 to 1 ft	Fine, brown, moist sand
						1 to 2 ft	Brown, sandy gravel
						2 to 6 ft	Fine, brown, moist sand
						6 to 9 ft	Dry, brown silt with occasional pea gravel
						9 to 13 ft	Fine, light brown, moist sand
						13 ft ↓	Gray, very moist silt
S10	2+50	300120	607+00	6' rt of outside lane edge	SIMCO 4"	0 to 1 ft	Brown, sandy gravel
						1 to 7 ft	Fine, light brown, sandy silt
						7 to 14 ft	Fine, light brown sand with a trace of silt
						14 ft ↓	"No description reported"
S11	2+50	300122	614+00	6' rt of outside lane edge	SIMCO 4"	0 to 1 ft	Brown, sandy gravel
						1 to 4 ft	Fine, moist, sandy silt
						4 to 7 ft	Gray, moist silt
						7 ft ↓	Fine brown sand
S12	2+50	300121	621+00	6' rt of outside lane edge	SIMCO 4"	0 to 2.5 ft	Brown, sandy gravel with cobbles
						2.5 to 9 ft	Gray silt
						9 ft to ↓	Light brown, fine sand

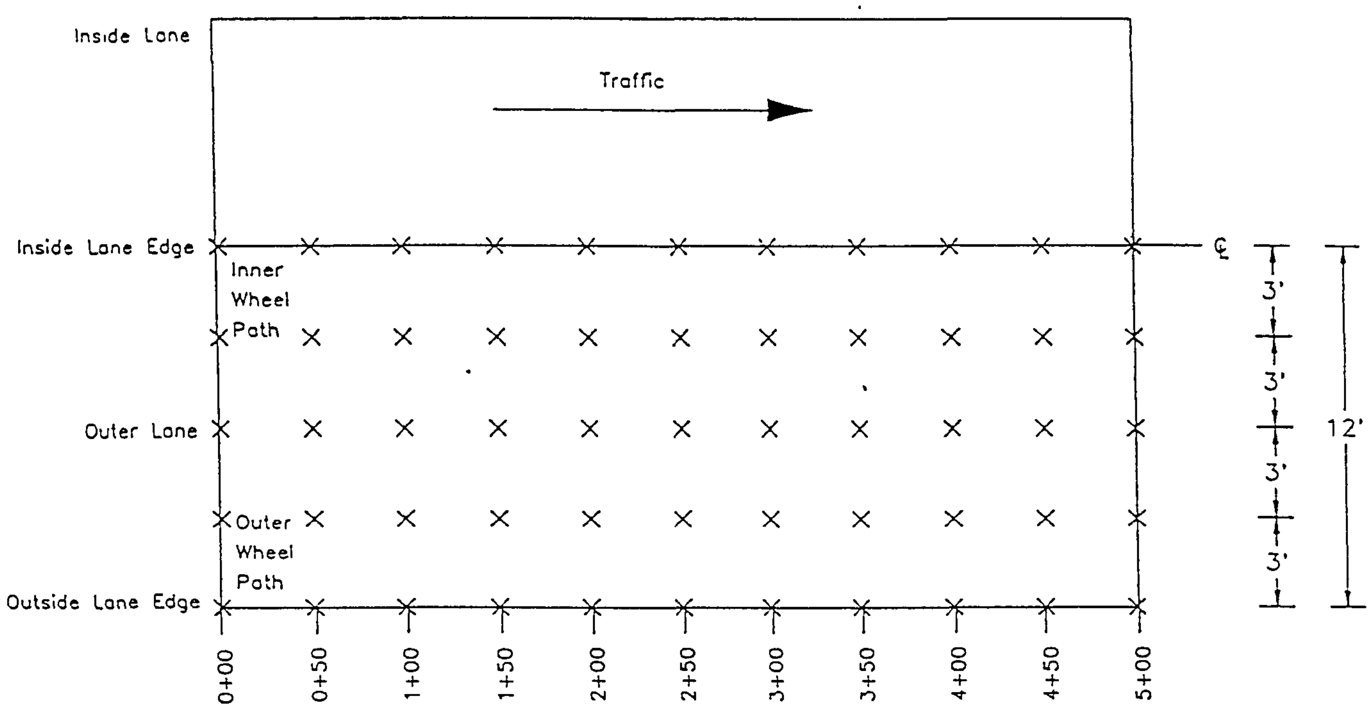


Figure 7 Test section elevation measurement location for Montana SPS-1

Weather Conditions

During the subgrade and existing embankment preparation, the weather conditions were quite unpredictable. Rains caused several interruptions to the construction operations. Heavy rains on June 17 brought the construction work to complete halt, rains on June 19 left water puddles in the tire marks of construction equipment resulting in several soft spots. Some of these soft spots had excess water, the excess water was removed using pumps. Photographs 5 and 6 in appendix B show the excess water and de-watering after the rains on June 12, 1998. The remedial measures undertaken to mitigate the soft spots have been explained earlier. These excavations are shown in photos 7 and 8 in appendix B.

DENSE GRADED AGGREGATE BASE (DGAB)

Placement of the dense graded aggregate base (DGAB) began on July 10, 1998, and was completed on July 29, 1998. Seven test sections (0113, 0114, 0117, 0118, 0119, 0120, 0121) with varying DGAB layer thickness were constructed. DGAB material was brought in by belly dump trucks. It was then windrowed and worked by the graders and scrapers to achieve the required grade and profile. Water trucks, steel wheel rollers and pneumatic rollers were employed to achieve target compaction and moisture. The nominal layer thickness for sections varied between 101mm (4 in) to 305mm (12 in) as indicated in figure 3. Photographs 9 and 10 in appendix B show the preparation of DGAB layer. The average actual in place thicknesses of DGAB layers was determined from elevation surveys are provided in table 10. Appendix A contains plots of the layer thicknesses by station.

The base was not placed in discrete lifts and then watered and compacted, but was built up and worked continuously. A belly dump truck would deliver material to the grade and this material would then be knocked down by a motor grader, watered, and rolled in a continuous process across the grade that often included several sections. The process would stop when the desired grade and compaction level was achieved.

Inspection

The finished DGAB layer was visually inspected. Some problem areas were identified and remedial measures were carried out. The problem locations and respective remedial measures for both the test and non-test lanes are listed in tables 11 and 12.

Bulk Sampling

Bulk sampling of DGAB material was performed by excavating a test pit in the finished layer that would provide the required quantity of material. After the bulk sampling, the trenches were backfilled with similar material and compacted to the target density. Bulk sample numbers, locations, sections, and stationing information is tabulated in table 13.

Table 10. DGAB layer thicknesses.

Section	Avg.	Specified	Min.	Max	Std. Dev.
300113	8.4	8"	6 7	9 6	74
300118	4.2	4"	2.9	6.2	.88
300117	4.7	4"	3 6	6.8	.70
300114	12.4	12"	11.0	13.6	.62
300119	4.3	4"	2 9	5.6	69
300120	8.1	8"	6 7	9.6	.66
300121	12.6	12"	11.3	13.8	.59

Table 11. Test lane problems for dense graded aggregate base (DGAB).

Section	Location	Problem	Solution
300113	1+75 to 4+50 3 ft. right to 16 ft. right 8 inches deep	Soft spot due to clay and excess moisture in subgrade	Blade reworked this soft spot; in the process, subgrade and DGAB was mixed
300118	1+75 to 2+50 2 ft. right to 8 ft. right 6 to 8 inches deep	Soft spot due to clay and excess moisture in subgrade	Blade reworked this soft spot; in the process, subgrade and DGAB was mixed
	0+75 to 1+00 centerline to 6 ft. right 8 inches deep	Soft spot due to clay and excess moisture in subgrade	Blade reworked this soft spot; in the process, subgrade and DGAB was mixed

Table 12. Non-test lane problems for dense graded aggregate base (DGAB).

Section	Location	Problem	Solution
300116	3+50 to 4+00 centerline 4 ft. left 6 inches deep	Soft spot due to clay and excess moisture in subgrade	Blade reworked this and re-filled with original material

Table 13. DGAB bulk samples and soil types by section.

Section	Bulk Sample No.	Test Section Station	Thickness of Material
300113	BG03	5+25	8 inches
300117	BG04	5+25	4 inches
300121	BG05	5+25	13 inches

Field Density and Field Moisture Tests

Field density and field moisture content tests were performed on the finished DGAB layer in accordance with AASHTO T 238-97 and T239-97, respectively, at the locations indicated in figure 8. The test results are tabulated in table 14. Density results show that the density and moisture levels are very consistent throughout the site no matter what the thickness of the final layer.

Finished DGAB Surface Elevations

Elevation surveys on the surface of prepared DGAB surface were carried at locations indicated in figure 7. The purpose of the elevation surveys is to obtain a profile of prepared DGAB surface and to determine the thickness of DGAB layers. Profiles of the test sections are presented in appendix A. Although these profiles reflect some variation in thickness, they are generally uniform and consistent.

FWD Testing

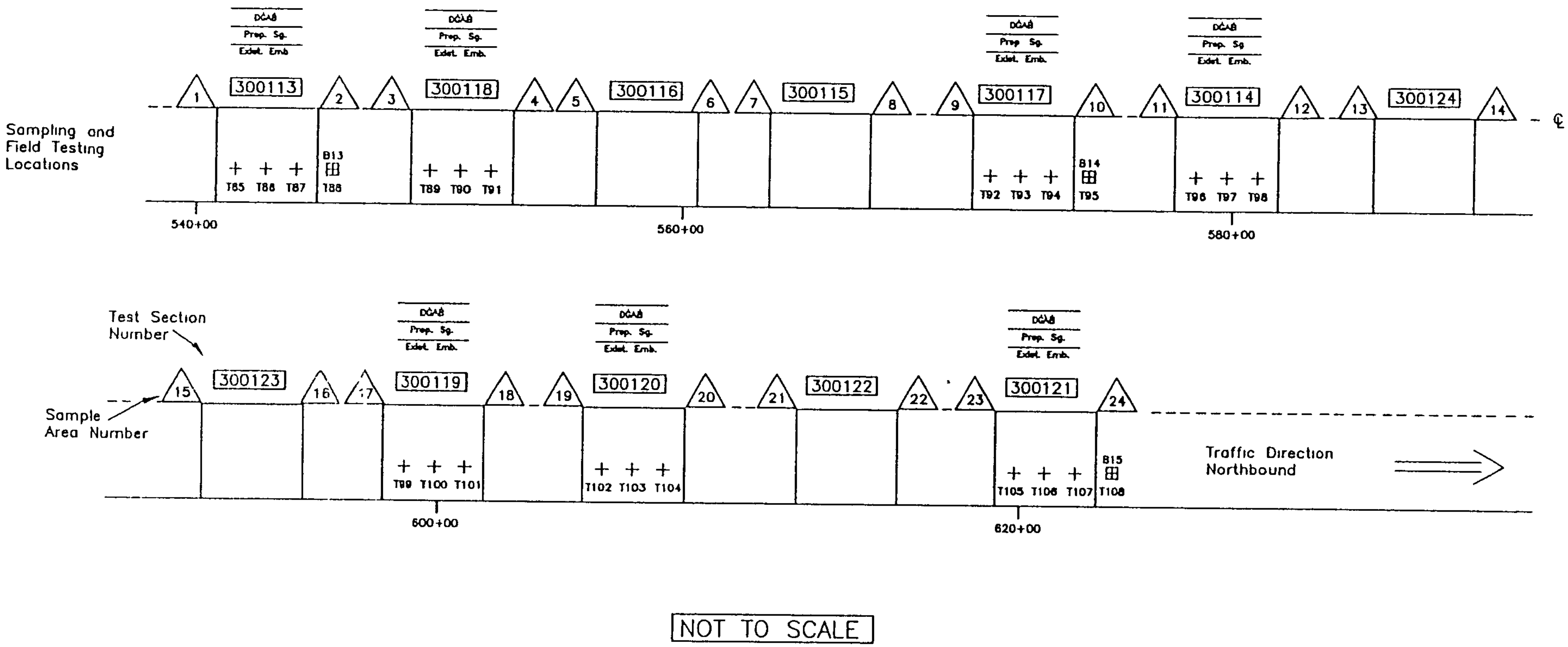
FWD testing of the DGAB was performed on October 21, 1998, by the WRCOC in accordance with the procedures and guidelines outlined in SPS Directive S-4, "Deflection Testing of Subgrade and Base Layers for SPS-1, SPS-2, and SPS-8 Experiments." A sampling of the results of the FWD testing are presented in appendix B. The deflections shown are non-normalized sensor 1 deflections that are intended to provide an indication of the uniformity of the section. The complete deflection data records are available in the LTPP database. The deflection testing shows a significant reduction in deflection level and variation over the testing done on the subgrade.

Edge Drain System

The edge drain system was constructed before the placement of Permeable Asphalt Treated Base (PATB) for those six sections that had PATB as one of the pavement layers. Excavation for the edge drain system began on September 30, 1999. The contractor created a device (1 ft x 3 ft steel plate) that was bolted on to a grader blade. This grader blade plate was then aligned over the proposed location of longitudinal drain and slowly driven. In two to three passes, 0.4m (18 in) deep trench was formed. Loose material in the trench was manually removed by workers and the bottom was tamped with hand held gasoline powered compactors.

Excavation for the longitudinal drains and laying of geotextile started on October 1, 1998. The drainage construction was performed in the following sequence:

- Excavation of trench to required depth
- Removal of all loose material and tamping of bottom of the trench
- Laying of class 2 woven geotextile
- Placement of bedding layer of filter material containing select graded crushed gravel material



□ 2' x 2' bulk sampling location (B13–B15) to 12" below top of Dense Graded Aggregate Base

\+ Location of nuclear moisture-density tests (T85–T108)

Prep Sg – Prepared Subgrade

Exist. Emb. – Existing Embankment

DGAB – Dense Graded Aggrgate Base

△ Sample areas

Figure 8 Overview of material sampling and testing on Dense Graded Aggregate Base, Montana SPS-1

Table 14. In-situ density and moisture test results on DGAB.

Test No.	Test Section Station	Section	Project Station	Offset	Rod Depth (in)	Depth to Top of Layer (in.)	Avg. In-Situ Density (pcf)	Avg. In-Situ Moisture Content (%)
T85	1+00	300113	542+50	6’ rt of CL	6	4	139.0	5.5
T86	2+50	300113	544+00	6’ rt of CL	6	4	135.3	5.5
T87	4+00	300113	545+50	6’ rt of CL	6	4	139.2	5.7
T88	5+25	300113	546+75	6’ rt of CL	6	4	139.3	5.3
T89	1+00	300118	549+50	6’ rt of CL	2	12	139.0	5.1
T90	2+50	300118	551+00	6’ rt of CL	2	12	138.9	5.7
T91	4+00	300118	552+50	6’ rt of CL	2	12	139.3	5.3
T92	1+00	300117	570+50	6’ rt of CL	2	11	138.9	5.9
T93	2+50	300117	572+00	6’ rt of CL	2	11	133.9	5.3
T94	4+00	300117	573+50	6’ rt of CL	2	11	139.7	5.7
T95	5+25	300117	574+75	6’ rt of CL	2	11	139.3	5.9
T96	1|00	300114	577+50	6’ rt of CL	8	7	139.2	5.5
T97	2+50	300114	579+00	6’ rt of CL	8	7	133.9	5.3
T98	4+00	300114	580+50	6’ rt of CL	8	7	139.6	5.1
T99	1+00	300119	598+50	6’ rt of CL	2	7	138.7	5.7
T100	2+50	300119	600+00	6’ rt of CL	2	7	139.9	5.5
T101	4+00	300119	601+50	6’ rt of CL	2	7	138.7	5.4
T102	1+00	300120	605+50	6’ rt of CL	6	8	139.0	5.7
T103	2+50	300120	607+00	6’ rt of CL	6	8	139.0	5.6
T104	4+00	300120	608+50	6’ rt of CL	6	8	139.2	5.6
T105	1+00	300121	619+50	6’ rt of CL	8	4	138.2	6.4
T106	2+50	300121	621+00	6’ rt of CL	8	4	137.5	5.9
T107	4+00	300121	622+50	6’ rt of CL	8	4	139.0	5.7
T108	5+25	300121	623+75	6’ rt of CL	8	4	140.2	5.2

- Placement of drainage pipe at specified slope
- Placement of select graded filter material around the pipe
- Backfilling of the trenches with the materials similar to the original layer structure

Because of the flatness of the terrain, it was necessary to slope the drainage pipes rather than the trenches. It was also decided to provide a crown in the middle of the pipe midway between the outlets so that the runoff drains in both directions. Proper drainage profiles were ensured by frequently checking the invert levels of the pipe. Photographs 11, 12, 13, 14, 15 and 16 in appendix B show the edge drain construction.

The prime coat placed on the subgrade was badly damaged by the loader filling in the drain trench. After the installation was complete, the subgrade surface was watered and rolled. No additional prime coat was used prior to the placement of the permeable asphalt treated base (PATB) or the dense graded aggregate base (DGAB).

PERMEABLE ASPHALT TREATED BASE (PATB)

Construction of the permeable asphalt treated base (PATB) began on October 19, 1998, and was completed on October 24, 1998. PATB was placed on six sections (300119, 300120, 300121, 300122, 300123, and 300124). On three of the six sections, the PATB was placed on the subgrade, and on the other three sections, the PATB was placed directly on the DGAB. The nominal thicknesses of PATB sections are indicated in figure 4 and the actual thicknesses are summarized in table 15.

Table 15. Permeable asphalt treated base (PATB) layer thicknesses.

Section	Average Thickness (in)	Specified Thickness (in)	Minimum Thickness (in)	Maximum Thickness (in)	Standard Deviation (in)
300124	4.2	4	3 9	4.5	0.35
300123	3.9	4	3 6	4.3	0 36
300119	4.7	4	4 5	4.9	0 23
300120	4.6	4	4.4	4 8	0 30
300122	4.3	4	3.9	4.7	0 34
300121	4.3	4	4.0	4.7	0.28

PATB Construction

A CAT AP1055B Rubber Track Paver, end dump trucks, and a 23,000 lb. CAT Double Drum Vibratory Roller with 2.1m (7 ft) drums were used in the PATB construction. Five truckloads of PATB material was delivered at section 300124 at 8:30 a.m. on October 19, 1998. One truckload of material was laid on the right shoulder on fabric for visual inspection between stations 0+50 and 0+10, varying in width from 3.7m (12 ft.) to 3.05m (10 ft.) Out of spec gradations and faulty control systems on the paver necessitated the return of five truckloads of PATB material to the plant. Since the material was placed on the shoulder and not on the test lane, it was not removed. After these problems were remedied, the PATB laydown began. There were no problems with mix for the rest of the day. The mix temperature at the plant was 138°C (280°F) and the mix had a good cooling rate. To establish the compaction temperature for the mix, an attempt was made to roll the PATB material on the shoulder at 66°C (150°F), which resulted in the movement of the mat. The material was sensitive to rolling and had to cool to 43°C-46°C (120° F - 115°F) before the commencement of rolling. The PATB mix temperature at the plant was reduced to 121°C-127°C (250°F - 260°F) after approximately three hours of paving in view of the ambient temperature, cooling rate, and compaction temperature. This did not adversely affect the laydown or compaction operations.

The PATB layer was placed in two passes in the test lane. The first was from the outside shoulder towards the centerline about 3.7m (12 ft) wide. The second was from the centerline to the edge of the first pass. The passing lane was placed last in one 4.88m (16 ft) wide pass. PATB material was placed continuously in all six sections in each pass. Waiting time between trucks was five minutes and the waiting time between laydown and compaction varied between 2.0 hours to 2.5 hours during the early part of the day and to about 0.5 hours during the latter part of the day. Photographs 17 and 18 in appendix B show the construction of PATB layer.

Bulk Sampling of PATB

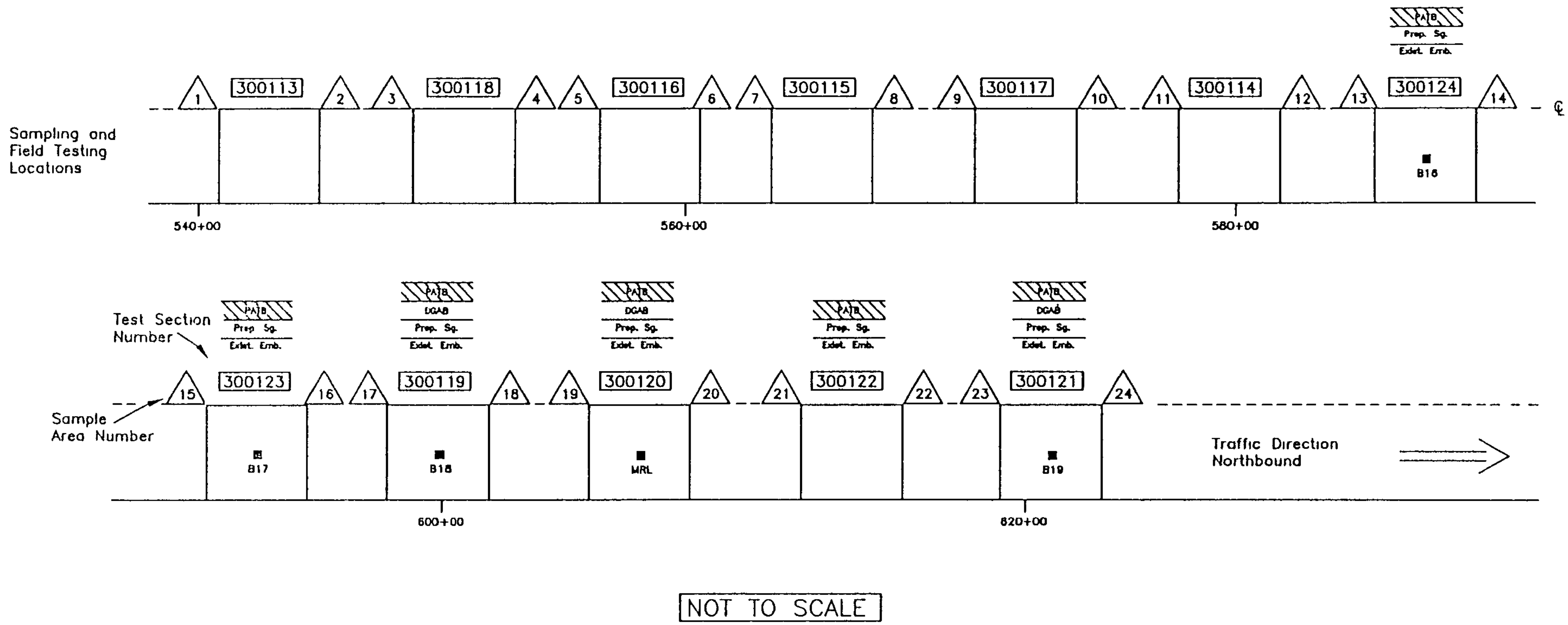
Four bulk samples of PATB materials were collected from the locations indicated in figure 9. No coring of the PATB layer was performed. The samples were taken from behind the paver as the material was being placed in the sections shown.

PATB Surface Elevations

Elevation surveys on the surface of prepared PATB were carried out at the locations indicated in figure 7. The purpose of the elevation surveys is to obtain a profile of prepared PATB surface and to determine the thickness of PATB layers. The actual average section thicknesses are presented in table 2. The PATB thickness by section are presented in appendix A. The profiles in appendix A show that the PATB thickness is very consistent throughout the site.

ASPHALT TREATED BASE (ATB)

Asphalt treated base (ATB) was used in seven of the 12 sections (300118, 300116, 300115, 300117, 300124, 300123). The ATB construction work began on October 21, 1998, and was completed on October 25, 1998. The design thicknesses of these layers were 101mm (4 in), 203mm (8 in), and 305mm (12 in) as shown in figure 4. The ATB material was hauled in by belly dump trucks and the mix was windrowed ahead of the paver. Two Dynapac Double Drum 50 series vibratory rollers were utilized for compaction. Paving grade control was achieved by a 6.1m (20 ft) ski on one side of the paver and by the electronic sensors on the other side. The first few loads of mix placed on the shoulder and the test lanes appeared to be rich (containing excess asphalt cement). Visual inspection of the mix revealed excess binder and fines. The contractor made some adjustments to the mix in terms of reducing both binder and baghouse fines. After the adjustments, there were no more problems with the mix for the rest of the construction.



■ Bulk sample of PATB (B16–B19)

Exist Emb – Existing Embankment

Prep Sg – Prepared Subgrade

DGAB – Dense Graded Aggregate Base

PATB – Permeable Asphalt Treated Base

MRL Bulk mixture sample

△ Sample areas

Figure 9 Overview of material sampling and testing on Permeable Asphalt Treated Base, Montana SPS-1

The ATB laydown was done in 50mm (2 in) lifts. Thus, ATB sections 305mm (12 in) thick were constructed in six 50mm (2 in) lifts. Temperature checks behind the paver were in the 138°C-143°C (280°F - 290°F) range. The design and as built thickness of the ATB layers are presented in table 16. As can be see from table 16, the average the average as built thickness was 106mm (4.2 in), 220mm (8.8 in), and 330mm (13.1 in) for the 100mm, 200mm, and 300mm (4, 8, and 12 in) sections respectively. Photographs 19 and 20 in appendix B show the ATB construction.

ATB Mix Design

The asphalt mix design for the ATB prepared by Montana DOT is shown in appendix C. The mix used an 5/100 penetration grade asphalt binder. Recommended mix properties were 6% AC with 1.4 % hydrated lime at and 75 blow Marshall compaction. This resulted in a theoretical compacted Marshall specimen with a Rice Specific Gravity of 2.445, a unit weight of 2354 kg/m3 (147.0 pcf), 3.7% air voids, Marshall stability of 15.6 kN (3515 lbs.), and Marshall flow of 15.

Bulk and Core Sampling of ATB

Bulk samples of asphalt cement, aggregate, and uncompacted ATB mixture were obtained for testing. Cores of ATB were also collected for resilient modulus and tensile strength tests after the completion of the project. All bulk sampling was performed at locations shown in figure 10.

Core samples of the ATB layer were taken along with samples of the Asphalt Concrete Surface in the sections where ATB was placed. Table 17 shows core locations for all the asphalt concrete and bound base (ATB). Cores C7-C26, C31-C40, and C51-C54 include an ATB layer as part of the core.

Field Density Testing

Field density tests were performed on the ATB layer at locations indicated in figure 10. The in-situ densities of ATB layers are presented in table 18. The in-situ density results range from 2242 kg (140.0 pcf) and 2388 kg (149.1 pcf). The densities consistently tested to be approximately 2323 kg/m3 (145 pcf).

Elevation Surveys of ATB Surface

Elevation surveys of the ATB surface were carried out at locations indicated in figure 7, to determine the ATB surface profile and thickness. The actual average section thicknesses are presented in appendix A. The ATB layer thickness by section is shown in appendix A. As can be seen from the elevation surveys and the core data in table 16, the layer thicknesses are very consistent with the greatest variation occurring, as would be expected, in the 305mm (12 in) sections.

Table 16. Asphalt treated base (ATB) layer thicknesses.

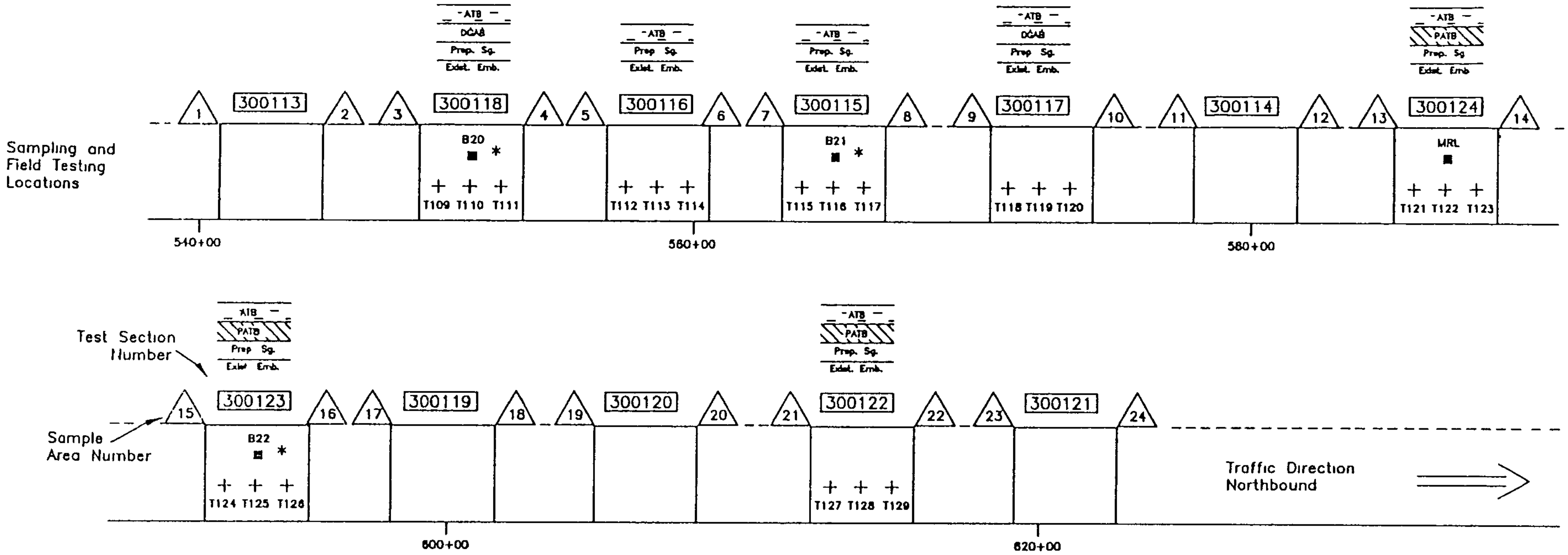
Section	Average Thickness (in)	Specified Thickness (in)	Minimum Thickness (in)	Maximum Thickness (in)	Standard Deviation (in)
300118	8.8	8	8.3	9 3	0.21
300116	12.6	12	12.2	13.7	0.24
300115	9 1	8	8.8	9.7	0 25
300117	4.3	4	3 9	4.7	0 19
300124	13.5	12	13.0	14 9	0.26
300123	8.4	8	8.0	8.7	0.28
300122	4.0	4	3.7	4 3	0 20

Table 17. Asphalt concrete and bound base core locations.

Sample Location Designation	Test Section Station	Project Station	Offset, Feet		Test Section	Sample Area
			Center Line, Rt	Outside Lane Edge, Lt		
C1	0-25	541+25	4 5	7.5	300113	1
C2	0-25	541+25	6.0	6 0	300113	1
C3	0-25	541+25	7.5	4.5	300113	1
C4	0-25	541+25	9.0	3.0	300113	1
C5	5+25	546+75	6.0	6 0	300113	2
C6	5+25	546+75	9.0	3 0	300113	2
C7	0-25	548+25	4 5	7 5	300118	3
C8	0-25	548+25	6.0	6.0	300118	3
C9	0-25	548+25	7.5	4.5	300118	3
C10	0-25	548+25	9.0	3.0	300118	3
C11	5+25	553+75	6.0	6.0	300118	4
C12	5+25	553+75	9.0	3.0	300118	4
C13	0-25	555+25	6 0	6 0	300116	5
C14	0-25	555+25	9.0	3.0	300116	5
C15	5+25	560+75	6.0	6.0	300116	6
C16	5+25	560+75	9.0	3 0	300116	6
C17	0-25	562+25	6.0	6 0	300115	7
C18	0-25	562+25	9.0	3.0	300115	7
C19	5+25	567+75	6.0	6.0	300115	8
C20	5+25	567+75	9.0	3 0	300115	8
C21	0-25	569+25	4.5	7 5	300117	9
C22	0-25	569+25	6.0	6.0	300117	9
C23	0-25	569+25	7.5	4.5	300117	9
C24	0-25	569+25	9.0	3.0	300117	9
C25	5+25	574+75	6 0	6.0	300117	10
C26	5+25	574+75	9.0	3.0	300117	10
C27	0-25	576+25	6.0	6.0	300114	11
C28	0-25	576+25	9.0	3.0	300114	11
C29	5+25	581+75	6.0	6.0	300114	12

Table 17. Asphalt concrete and bound base core locations. (cont'd)

Sample Location Designation	Test Section Station	Project Station	Offset, Feet		Test Section	Sample Area
			Center Line, Rt	Outside Lane Edge, Lt		
C30	5+25	581+75	9.0	3.0	300114	12
C31	0-25	583+25	4.5	7.5	300124	13
C32	0-25	583+25	6.0	6 0	300124	13
C33	0-25	583+25	7.5	4.5	300124	13
C34	0-25	583+25	9.0	3.0	300124	13
C35	5+25	588+75	6.0	6.0	300124	14
C36	5+25	588+75	9.0	3.0	300124	14
C37	0-25	590+25	6.0	6.0	300123	15
C38	0-25	590+25	9.0	3.0	300123	15
C39	5+25	595+75	6.0	6.0	300123	16
C40	5+25	595+75	9.0	3.0	300123	16
C41	0-25	597+25	4.5	7.5	300119	17
C42	0-25	597+25	6 0	6 0	300119	17
C43	0-25	597+25	7.5	4.5	300119	17
C44	0-25	597+25	9.0	3.0	300119	17
C45	5+25	602+75	6.0	6.0	300119	18
C46	5+25	602+75	9.0	3.0	300119	18
C47	0-25	604+25	6.0	6.0	300120	19
C48	0-25	604+25	9.0	3.0	300120	19
C49	5+25	609+75	6.0	6.0	300120	20
C50	5+25	609+75	9 0	3 0	300120	20
C51	0-25	611+25	6.0	6.0	300122	21
C52	0-25	611+25	9.0	3.0	300122	21
C53	5+25	616+75	6.0	6.0	300122	22
C54	5+25	616+75	9.0	3 0	300122	22
C55	0-25	618+25	4.5	7.5	300121	23
C56	0-25	618+25	6.0	6.0	300121	23
C57	0-25	618+25	7.5	4.5	300121	23
C58	0-25	618+25	9.0	3.0	300121	23
C59	5+25	623+75	6.0	6.0	300121	24
C60	5+25	623+75	9.0	3.0	300121	24



\+ Location of nuclear moisture–density tests (T109–T129)

■ Bulk sample of ATB (B20–B22)

Prep. Sg – Prepared Subgrade

Exist. Emb. – Existing Embankment

DGAB – Dense Graded Aggrgate Base

ATB – Asphalt Treated Base

PATB – Permeable Asphalt Treated Base

△ Sample areas

* Asphalt cement from plant (B26–B28)

MRL Bulk mixture sample

NOT TO SCALE

Figure 10 Overview of material sampling and testing on Asphalt Treated Base, Montana SPS-1.

Table 18. In-situ density test results on ATB.

Test No.	Test Section Station	Section	Project Station	Offset	Depth to Top of Layer (in)	Avg. In-Situ Density (pcf)
T109	1+00	300118	549+50	6' rt of CL	4	144.7
T110	2+50	300118	551+00	6' rt of CL	4	149.1
T111	4+00	300118	552+50	6' rt of CL	4	146.7
T112	1+00	300116	556+50	6' rt of CL	4	146 2
T113	2+50	300116	558+00	6' rt of CL	4	143 4
T114	4+00	30011	559+50	6' rt of CL	4	143.0
T115	1+00	300115	563+50	6' rt of CL	7	143.9
T116	2+50	300115	565+00	6' rt of CL	7	144.2
T117	4+00	300115	566+50	6' rt of CL	7	145 5
T118	1+00	300117	570+50	6' rt of CL	7	142.7
T119	2+50	300117	572+00	6' rt of CL	7	141 9
T120	4+00	300117	573+50	6' rt of CL	7	140 5
T121	1+00	300124	584+50	6' rt of CL	7	147.1
T122	2+50	300124	586+00	6' rt of CL	7	149.0
T123	4+00	300124	587+50	6' rt of CL	7	146 6
T124	1+00	300123	591+50	6' rt of CL	7	146 2
T125	2+50	300123	593+00	6' rt of CL	7	146.4
T126	4+00	300123	594+50	6' rt of CL	7	145.3
T127	1+00	300122	612+50	6' rt of CL	4	143.5
T128	2+50	300122	614+00	6' rt of CL	4	141.9
T129	4+00	300122	615+50	6' rt of CL	4	140.0

FWD Testing of ATB Surface

FWD testing of the finished ATB surface was not performed.

Section By Section ATB Construction

LTPP Section 300118

The 203mm (8 in) layer of ATB on this section was constructed in four 50mm (2 in) lifts directly on top of DGAB material. The first two lifts were placed on October 20, 1998. After the adjustments in ATB mix enumerated earlier, the construction work continued without a hitch. The third and fourth 50mm (2 in) lifts were placed on October 23 and 25, 1998, respectively. Visible segregation was not observed in this section.

LTPP Section 300116

The 305mm (12 in) ATB layer in this section was constructed in six 50mm (2 in) lifts directly on top of the subgrade layer. Placement of the first two lifts occurred on October 20, 1998. The third lift was placed on October 23, 1998. The fourth and fifth lifts were placed on October 24, 1998. The final lift was placed on October 25, 1998. The mix on the final lift of this section appears to contain some segregation. At one point, there were concerns that the contractor may run out of ATB material before the test sections could be completed. A decision to complete the travel lane and outside shoulder before starting the passing lane was made. As it turned out the contractor did not run out of ATB material.

LTPP Section 300115

The 203mm (8 in) of ATB on this section was constructed in four lifts directly on top of subgrade material. Placement of the first two lifts was accomplished on October 20, 1998. The third lift was placed on October 23 and the final lift on October 24. There was no visible segregation.

LTPP Section 300117

The 102mm (4 in) layer of ATB on this section was constructed directly on top of the DGAB. Both lifts were placed on October 25, 1998. There was no visible segregation.

LTPP Section 300124

The 305mm (12 in) ATB layer in this section was constructed in six 50mm (2 in) lifts directly on top of the PATB layer. Placement of the first two lifts occurred on October 21, 1998. The third lift was placed on October 23, 1998. The fourth and fifth lifts were placed on October 24, 1998. The final lift was placed on October 25, 1998. There was no visible segregation.

LTPP Section 300123

The 203mm (8 in) of ATB on this section was constructed in four lifts directly on top of the PATB material. Placement of the first two lifts was accomplished on October 21, 1998. The third lift was built on October 23 and the final lift on October 24.

LTPP Section 300122

The 102mm (4 in) layer of ATB on this section was constructed directly on top of the PATB. The first 50mm (2 in) lift was placed on October 21, 1998, and the last lift was placed on October 22, 1998. Generally no major deviations were observed during ATB construction.

ASPHALT CONCRETE (AC)

All twelve LTPP SPS-1 sections were paved with asphalt concrete. Asphalt concrete construction work began on October 21, 1998 and was completed on October 28, 1998. The construction work was accomplished by utilizing a Blaw Knox PF 220 paver and two DynaPac Double Drum 50 series steel drum rollers. Asphalt concrete material was delivered to the paver in end dump trucks. The design thickness of the AC layers was either 100mm or 178mm (4 in or 7 in), depending on the individual section.

As per the SPS-1 experimental design, two sections were placed on DGAB, three on PATB, and seven on ATB. The AC construction was completed in an efficient manner without any major problems. The nominal, average, minimum, and maximum thickness of the AC layers based on post construction cores on all 12 sections are listed in table 19. The AC layer thickness for each section is presented in appendix A.

Table 19. Asphalt concrete layer thicknesses*.

Section	Average Thickness (in)	Specified Thickness (in)	Minimum Thickness (in)	Maximum Thickness (in)	Standard Deviation (in)
300113	4.3	4	4.1	4 4	0.30
300118	4.6	4	4 5	4 8	0 21
300116	4.5	4	4.3	4.7	0.12
300115	7.5	7	7.0	7 8	0 19
300117	7.2	7	6.6	7.9	0.10
300114	7.2	7	6 9	7.6	0 16
300124	7.2	7	6 7	7 8	0 11
300123	7.5	7	7.3	8 0	0.18
300119	7 2	7	6.4	7.7	0 17
300120	4.3	4	4.1	4.6	0.16
300122	4.6	4	4 0	5.0	0.15
300121	4.4	4	3 2	4.9	0.22

*Thickness based on post-construction cores.

AC Mix Design

The asphalt mix design prepared by Montana DOT is shown in appendix D. The mix used a PG Grade 70-28 asphalt binder. Recommended mix properties were 5.6% AC with 1.4 % hydrated lime at and 75 blow Marshall compaction. This resulted in a theoretical compacted Marshall specimen with a Rice Specific Gravity of 2.450, a unit weight of 2372 kg/m3 (148.1 pcf), 3.0% air voids, Marshall stability of 9.3 kN (2100 lbs.), and Marshall flow of 11.

AC Pavement Construction

The AC pavement layer was constructed between October 26 and October 28, 1998. The construction initially built up the bottom most lifts of sections 300115, 300117, 300114, 300124, 300123, and 300119. These were completed on October 26, 1998. Placement of the final two lifts began on October 27, 1998. The test lane was placed in the first pass. The inner lane and inner shoulder were covered in the next pass. The last and final lift was placed on October 28, 1998. The average placement temperature was in the 150°C-155°C (302°F-311°F) range.

As can be seen from table 19, the average thickness for the 180mm (7 in) sections was 185mm (7.3 in) overall and for the 100mm (4 in) sections it was 114mm (4.5 in) overall. The variation in thickness in the AC layers is fairly high for a layer placed by a paving machine. This is primarily because the final lifts of the AC acted as a sort of leveling course, correcting the minor discrepancies in grade and cross slope that existed at the surface of the ATB, PATB, or DGAB on which it was placed.

Rolling Pattern

The rolling pattern was established by compacting AC material placed on the outside shoulder. The pattern for each lift was:

Breakdown: 20.2 tonne (22.3 ton) double drum roller in vibrating mode, single coverage

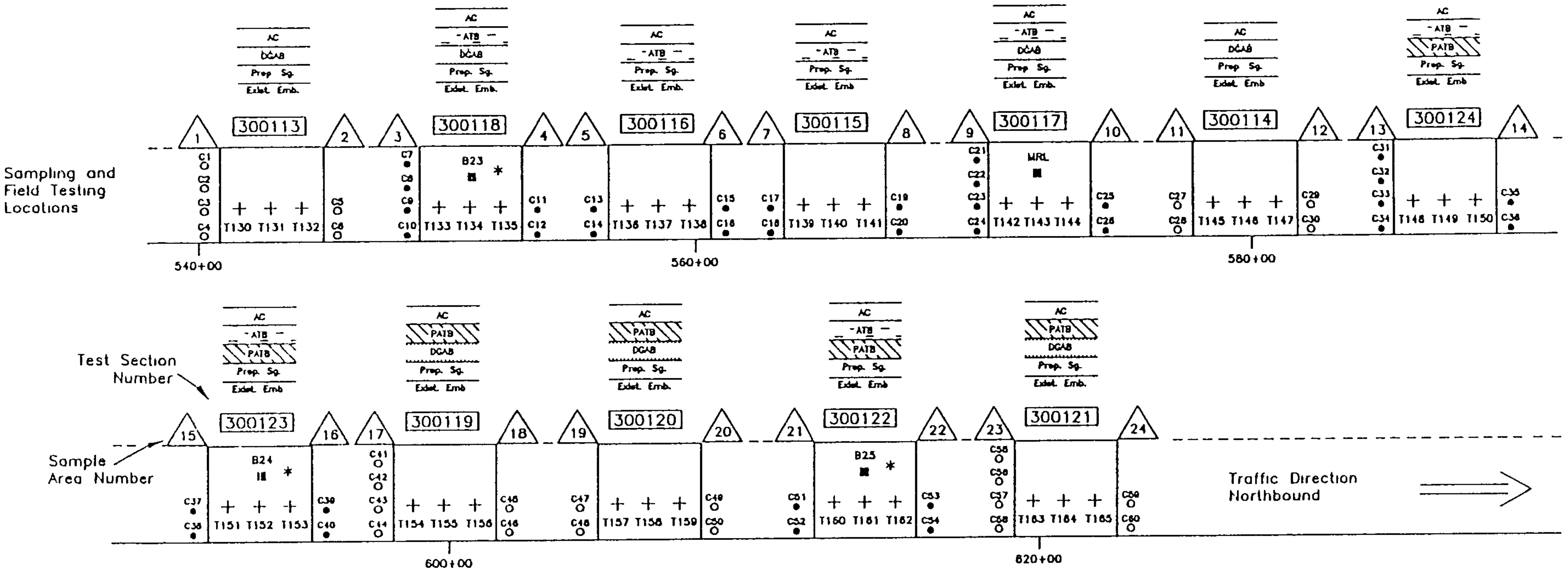
Intermediate: 20.2 tonne (22.3 ton) double drum roller in static mode, double coverage

Finish: 20.2 tonne (22.3 ton) steel wheel tandem roller, single coverage

This rolling pattern was used for all the lifts.

Bulk and Core Sampling of Asphalt Concrete

Bulk samples of asphalt cement used in the asphalt concrete were collected, as were cold feed samples of coarse and fine aggregates at the plant. Bulk samples of loose mix and 102mm (4 in) diameter cores of finished AC surface were collected at sampling locations indicated in figure 11. Table 17 shows core locations for the asphalt concrete surface. Cores C7-C26, C31-C40, and C51-C54 include an ATB layer as part of the core.



- o 4" OD Core of AC Surface (C1–C6, C27–C30, C41–C50, C55–C60)
- • 4" OD Core of AC Surface and Asphalt Treated Base layers (C7–C26, C31–C40, C51–C54)
- + Location of nuclear moisture–density tests (T130–T165)
- ■ Bulk sample of AC Surface (B23–B25)

Prep Sg – Prepared Subgrade

Exist Emb – Existing Embankment

DGAB – Dense Graded Aggrgate Base

ATB – Asphalt Treated Base

PATB – Permeable Asphalt Treated Base

AC – Asphalt Concrete Surface

MRL Bulk mixture sample

△ Sample areas

* Asphalt cement samples from plant (B29–B31)

NOT TO SCALE

Figure 11 Overview of material sampling and testing on asphalt bound layers, Montana SPS-1.

Field Density Testing

Field density tests on asphalt concrete layers were performed to determine field compaction at locations indicated in figure 11. The test locations and density test results are presented in table 20. The field density tests range from 2252 kg/m3 (140.6pcf) to 2343 kg/m3 (146.3 pcf) with an average of approximately 2290 kg/m3 (143 pcf).

FWD Testing of AC Surface

FWD testing on the finished AC surface was carried out on November 11, 1998, in accordance with the procedures given in the LTPP FWD Operator's Manual. Appendix A has normalized deflection profiles from November 1998 and June 1999 for each section. This data appears to show a clear seasonal effect. This data along with subsequent FWD testing is collected and stored in the LTPP database.

AUTOMATED WEATHER STATION/SEASONAL MONITORING INSTALLATIONS

An automated weather station (AWS) was installed May 19, 1998, at the north end of the SPS-1 site. This station will collect continuous temperature, precipitation, wind, and solar radiation data. In addition to the weather station, an LTPP seasonal site was funded by Montana DOT in the summer of 2000 and installed adjacent to section 300114. This site collects data on ground-water, pavement temperature, frost penetration, and in-situ moisture contents. Pavement monitoring data (FWD, longitudinal profile, and distress) is also collected at the seasonal site with a higher frequency than for typical LTPP test sections.

Table 20. In-situ density test results on AC.

Test No.	Test Section Station	Section	Project Station	Offset	Avg. In-Situ Density (pcf)
T130	1+00	300113	542+50	6' rt of CL	145.6
T131	2+50	300113	544+00	6' rt of CL	145.9
T132	4+00	300113	545+50	6' rt of CL	141.6
T133	1+00	300118	549+50	6' rt of CL	143 2
T134	2+50	300118	551+00	6' rt of CL	145.2
T135	4+00	300118	552+50	6' rt of CL	146 0
T136	1+00	300116	556+50	6' rt of CL	144 6
T137	2+50	300116	558+00	6' rt of CL	144.4
T138	4+00	300116	559+50	6' rt of CL	144 2
T139	1+00	300115	563+50	6' rt of CL	141.9
T140	2+50	300115	565+00	6' rt of CL	141.9
T141	4+00	300115	566+50	6' rt of CL	145.9
T142	1+00	300117	570+50	6' rt of CL	144 2
T143	2+50	300117	572+00	6' rt of CL	146.3
T144	4+00	300117	573+50	6' rt of CL	142.9
T145	1+00	300114	577+50	6' rt of CL	141.5
T146	2+50	300114	579+00	6' rt of CL	144.0
T147	4+00	300114	580+50	6' rt of CL	143.9
T148	1+00	300124	584+50	6' rt of CL	145 7
T149	2+50	300124	586+00	6' rt of CL	145.0
T150	4+00	300124	587+50	6' rt of CL	145.7
T151	1+00	300123	591+50	6' rt of CL	143.5
T152	2+50	300123	593+00	6' rt of CL	143.2
T153	4+00	300123	594+50	6' rt of CL	143.1
T154	1+00	300119	598+50	6' rt of CL	143.4
T155	2+50	300119	600+00	6' rt of CL	146.1
T156	4+00	300119	601+50	6' rt of CL	144.2
T157	1+00	300120	605+50	6' rt of CL	143 0
T158	2+50	300120	607+00	6' rt of CL	140.6
T159	4+00	300120	608+50	6' rt of CL	143.8
T160	1+00	300122	612+50	6' rt of CL	146.2
T161	2+50	300122	614+00	6' rt of CL	145 1
T162	4+00	300122	615+50	6' rt of CL	142 3
T163	1+00	300121	619+50	6' rt of CL	143 5
T164	2+50	300121	6621+00	6' rt of CL	144.8
T165	4+00	300121	622+50	6' rt of CL	140 6

IV. SUMMARY

Construction of the LTPP SPS-1, "Strategic Study of Structural Factors for Flexible Pavements," experimental study project was carried out on the northbound travel lane of I-15, about 10 miles south of Great Falls, Cascade County, Montana. The construction work began on April 7, 1998, and was completed on October 29, 1998.

The existing embankment was not completely removed as planned because the depth of existing embankment exceeded the estimated quantities. Complete removal of this layer was considered but was not carried out due to time and budgetary constraints. A layer of approximately 0mm to 0.4m (0 in to 16 in) in thickness of this material remains in the pavement structure more than 0.30m (1 ft) below the final subgrade finish grade. Additional samples were taken of this 76mm (3 in) minus pit run material. Density tests were performed on this layer as enumerated in table 7 earlier in the report.

Inclement weather conditions caused significant interference with the subgrade and embankment preparation. The problems caused by weather and partial removal of existing embankment are discussed at length in Section V, Key Observations.

Placement of DGAB was begun on July 10, 1998, and completed on July 29, 1998. Seven of the 12 test sections have DGAB layer.

PATB was placed in six of the 12 sections between October 19 and October 25, 1998. There were some concerns regarding the gradations of the first five truckloads of PATB. A truckload of PATB was first placed on the shoulder to visually check the gradations. Four of the five trucks were returned to the plant. The material placed on the shoulder was not removed. After the gradation was adjusted to the specifications, PATB construction was resumed.

ATB construction began on October 21, 1998, and was completed on October 25, 1998. Initially, there were some concerns with the ATB mixture pertaining to richness and tenderness. The contractor addressed these problems by reducing the binder content and baghouse fines.

Asphalt concrete construction began on October 26, 1998, and was completed on October 29, 1998. There were no significant problems with AC construction.

Overall, there were very few problems encountered in the construction. The test sections built should provide valuable information to the SPS-1 experiment.

V. KEY OBSERVATIONS

Key observations within each layer will be discussed in this section.

SUBGRADE AND EXISTING EMBANKMENT

During the excavation of the existing embankment, the contractor found that there was more of the 75mm (3 in) minus pit run (A-1-A) material than anticipated. The A-1-A material is characterized by well graded granular material, mostly sandy with some cobbles having less than 50% passing the #10 sieve and less than 15% passing #200 sieve with good drainage properties. The plans stated that 0.30m (1.0 ft.) to 0.45m (1.5 ft) of this material would be excavated and replaced with a "special borrow" material which consisted of natural subgrade characterized by well graded silty sands (an A-2 material). However, the depth of the A-1-A material was greater than expected. After excavation to plan grade, there would still remain a layer of 0mm (0 in) to 403mm (16 in) of A-1-A material. Complete removal of the A-1-A material was discussed, but this would have resulted in a shutdown, change orders, and additional expenses. A final decision was made to excavate only to the contracted depth and leave the 0mm (0 in) to 403mm (16 in) of A-1-A material as is and to place the "special borrow" material on top of it. However, there was a shortage of "special borrow" material and the contractor had to use some clean sandy material from a borrow pit in the inside passing lane. There are additional test samples on the remainder of the 101mm (4 in) to 305mm (12 in) of A-1-A material.

During the placement of subgrade, rain interrupted construction several times and caused the subgrade to become saturated. Some waterlogging developed in a few sections, but the contractor was careful to remedy all saturated areas and mitigated waterlogging prior to placing the next layer of fill. All compaction tests after pumping mitigation were within the specifications. One particular section, section 300116, required the use of class-2 geofabric to stabilize the subgrade.

DENSE GRADED AGGREGATE BASE (DGAB)

Generally, the DAGB construction went well without any major problems. There were, however, some minor localized problems on section 300113 and section 300118. Section 300113 had a soft spot beginning at station 1+75 to 4+50, 0.91m (3 ft) right of centerline extending to 4.88m (16 ft) right of centerline about 8 in deep due to some clay and excess moisture in subgrade. Section 300118 had soft spots beginning at station 0+75 to 1+00, from centerline extending up to 1.83m (6 ft) to the right of centerline about 203mm (8 in) deep and again beginning from station 1+75 to station 2+50, 0.61m (2 ft) right of the centerline extending up to 2.44m (8 ft) right of the centerline about 152mm (6 in) to 203mm (8 in) deep due to some clay and excess moisture in the subgrade. These soft spots were worked on by a blade to mitigate the soft spots. This resulted in mixing of subgrade with DGAB in these areas.

PERMEABLE ASPHALT TREATED BASE (PATB)

At first, there were problems with the electronic control system of the paver and the PATB mix appeared to have out-of-specification gradations. These problems were remedied by the contractor and laydown operations began. The PATB compaction temperature was established at about 45°C (115°F) by field trials. The PATB layer was placed in two lifts of approximately equal thickness in all six sections. Deviations in construction procedures were not observed.

ASPHALT TREATED BASE (ATB)

The initial few loads of ATB mix placed on the shoulder appeared to be tender. Visual inspection of the material indicated excess binder and fines. These were adjusted at the plant to produce correct ATB mix. ATB layers were placed in 51mm (2 in) thick lifts. Generally, the ATB construction was completed without any problems. Compaction was achieved without any significant difficulties and the layers were constructed to the required line and grade. Details on the ATB work can be found in the body of this document.

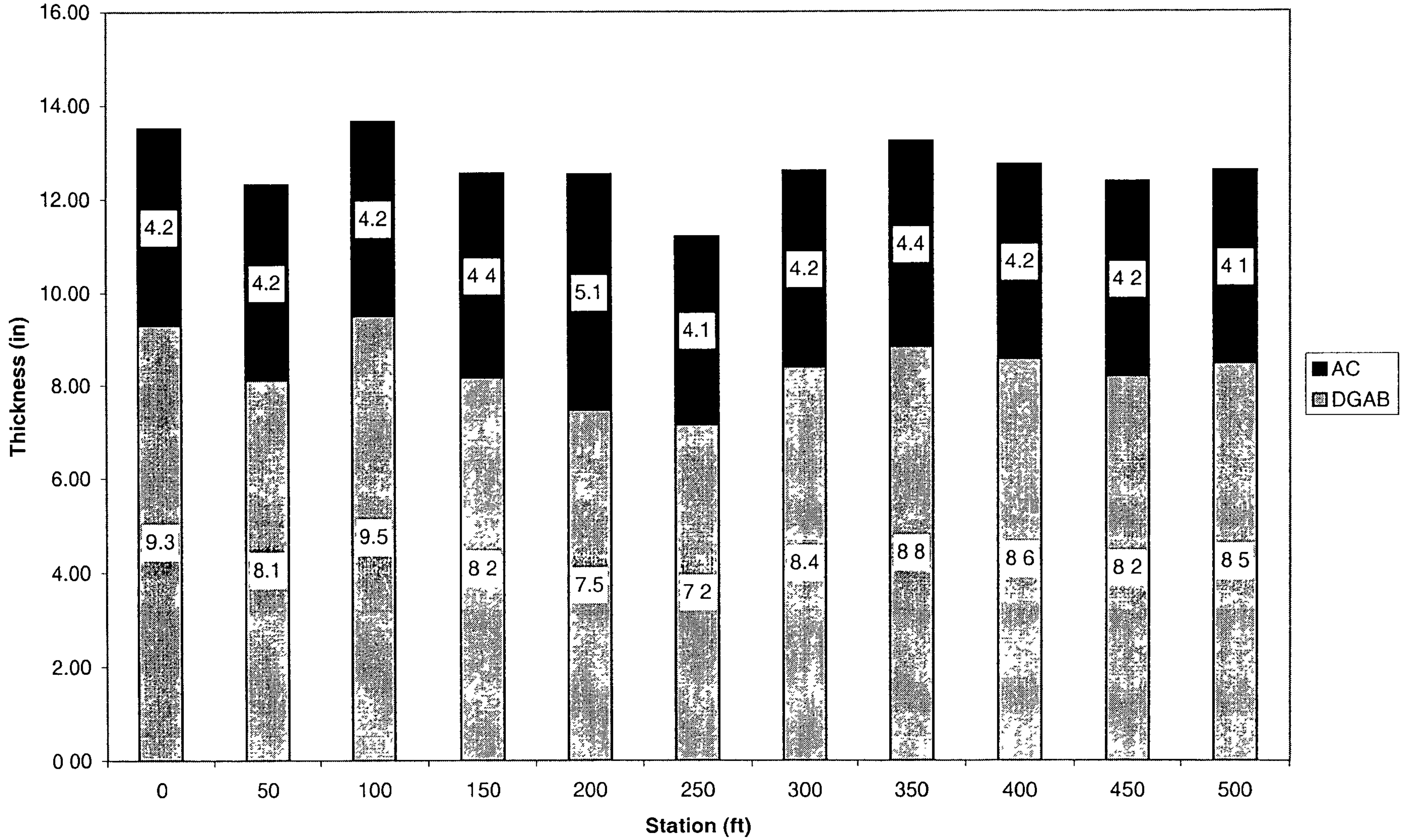
ASPHALT CONCRETE (AC)

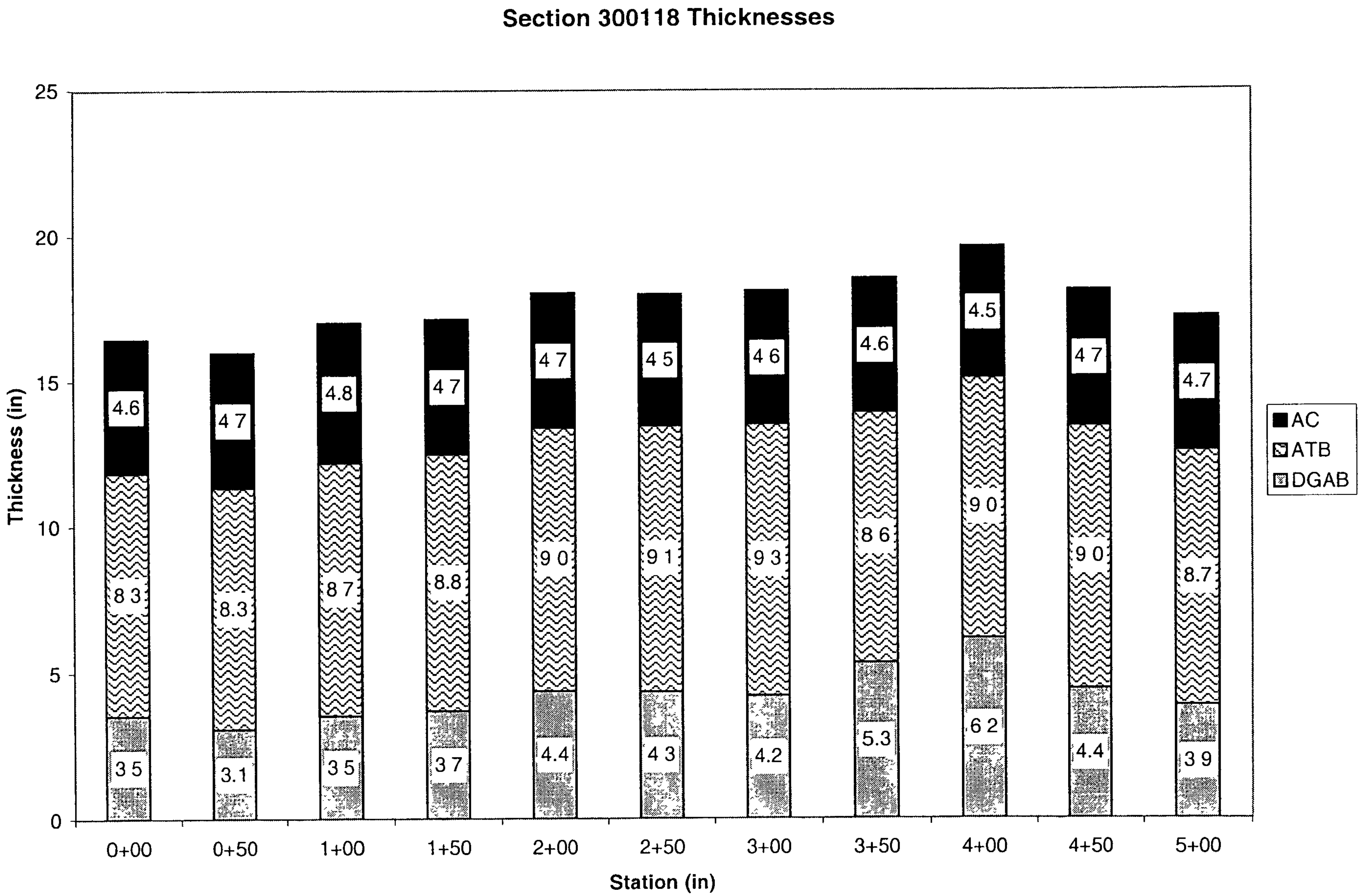
The asphalt concrete construction was carried out in an efficient and professional manner without any major problems. The nominal thickness of asphalt concrete layers was 102mm (4 in) and 178mm (7 in), depending upon the test section. The asphalt concrete layers were placed in 64mm (2.0 in) thick lifts and were compacted.

APPENDIX A

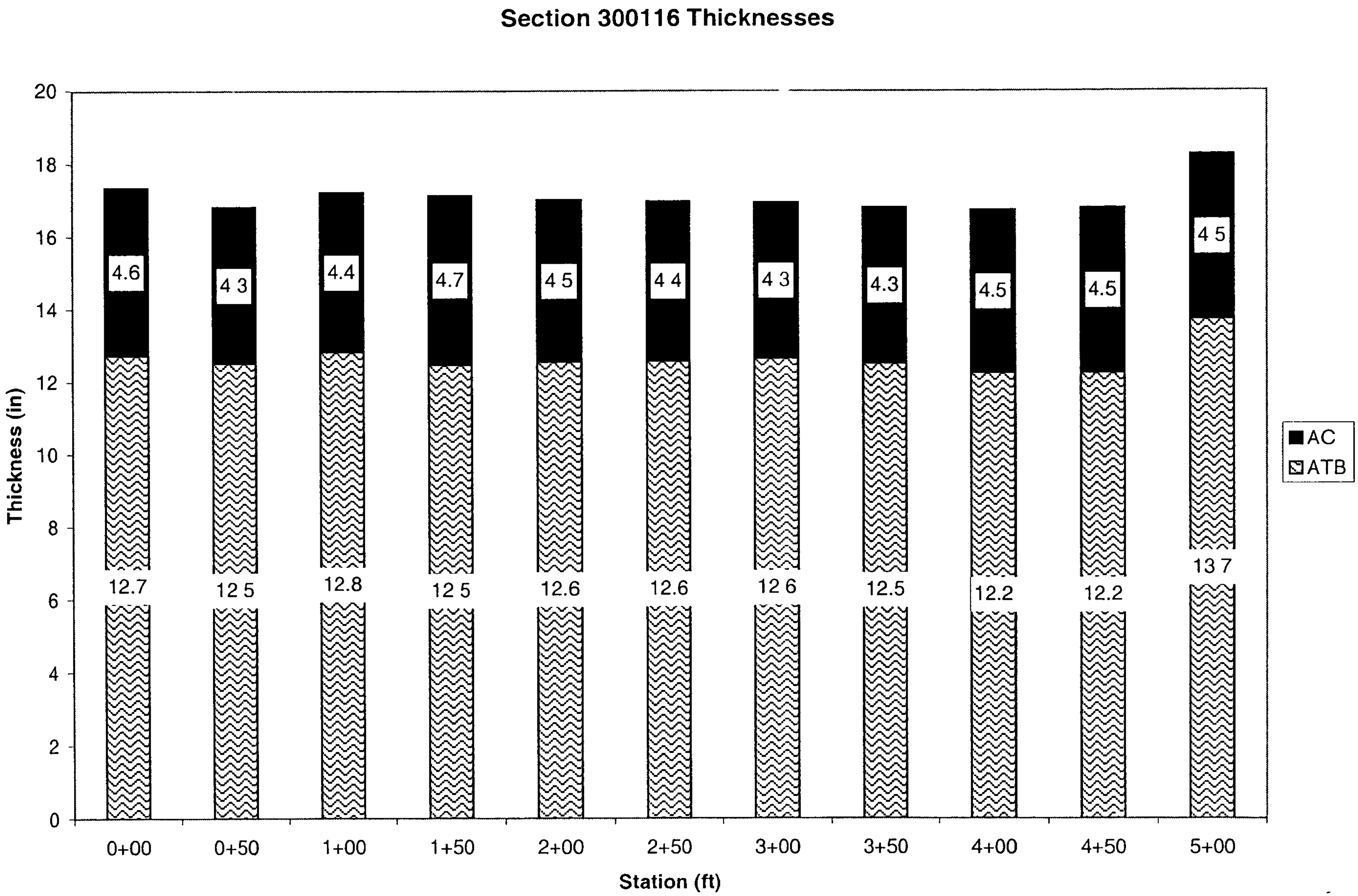
Layer Thicknesses

Section 300113 Thicknesses

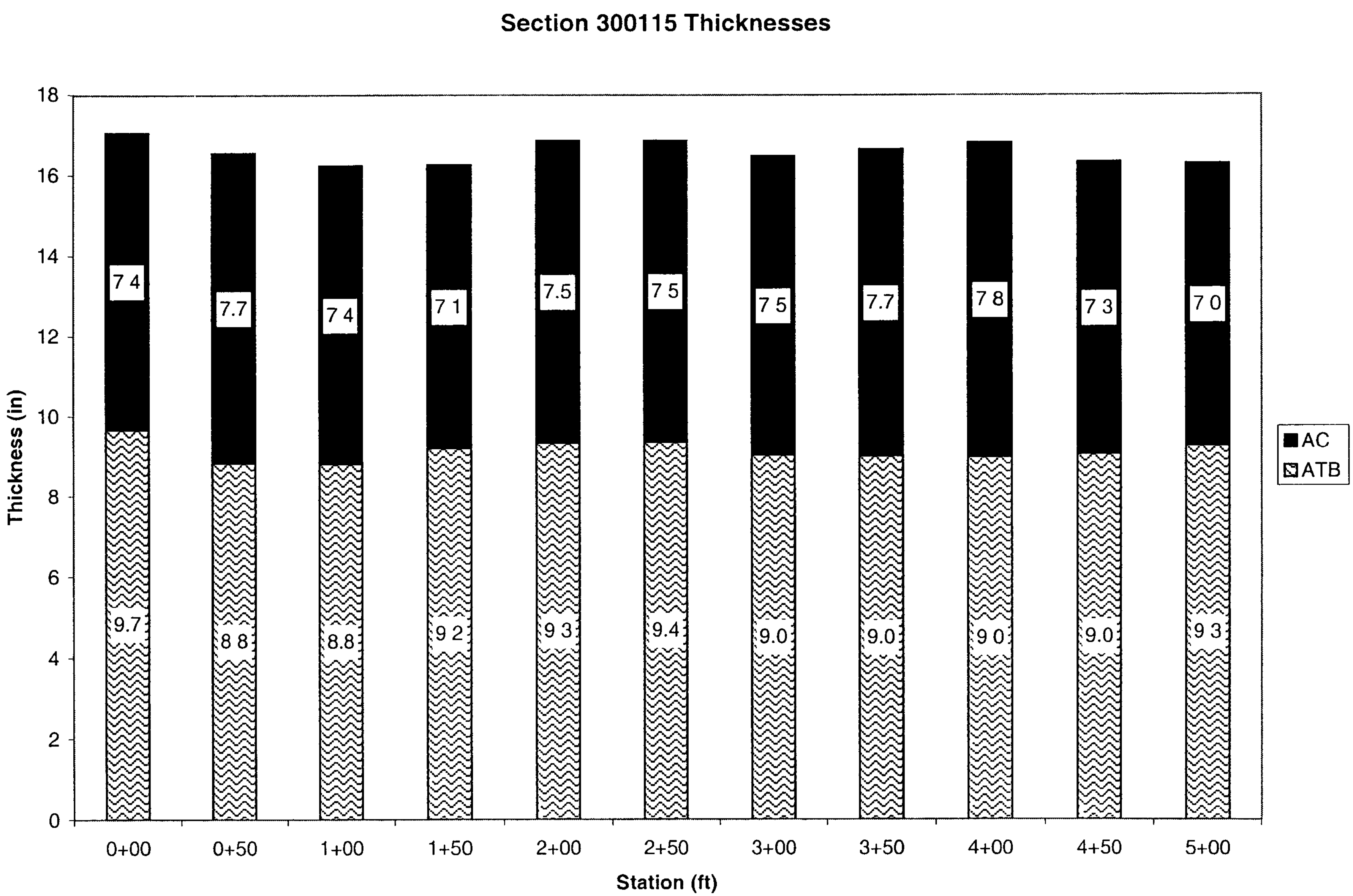




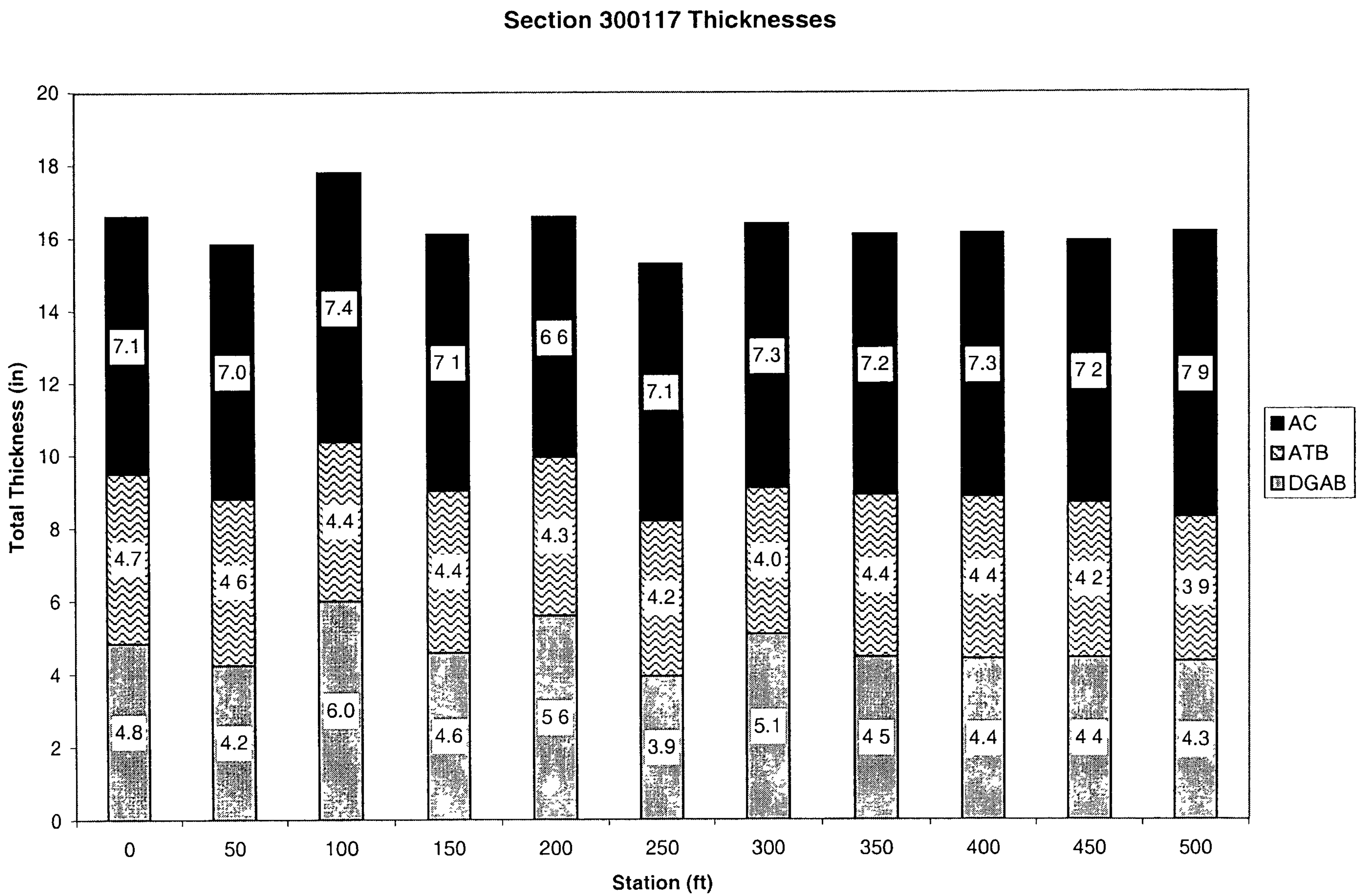
Section 300118 Thicknesses
Thickness (in)
25
20
15
10
5
0
4.6
4 7
4.8
4 7
4 7
4 5
4 6
4.6
4.5
4 7
4.7
8 3
8.3
8 7
8.8
9 0
9 1
9 3
8 6
9 0
9 0
8.7
3 5
3.1
3 5
3 7
4.4
4 3
4.2
5.3
6 2
4.4
3 9
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station (in)
AC
ATB
DGAB



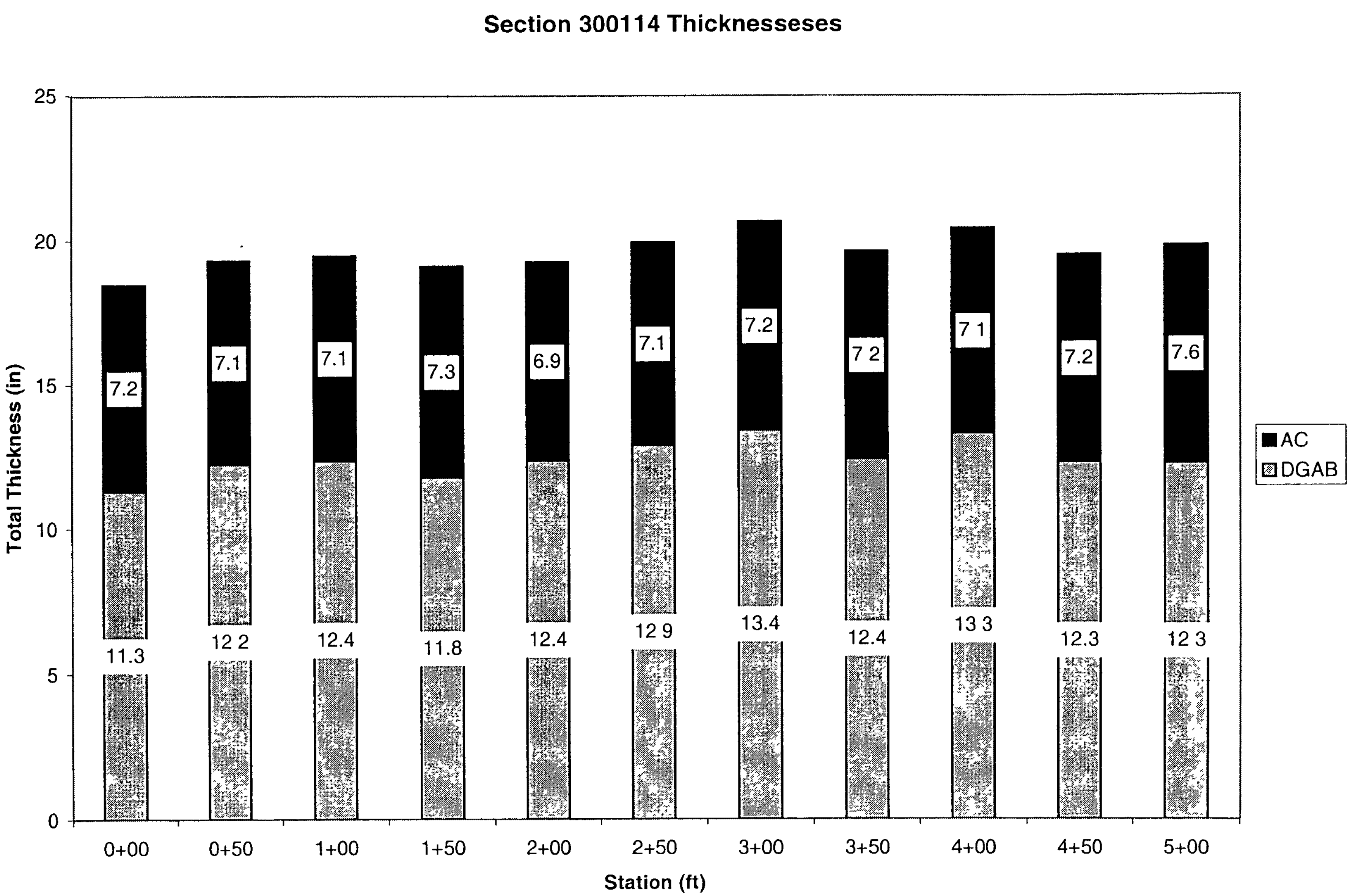
Section 300116 Thicknesses
Thickness (in)
20
18
16
14
12
10
8
6
4
2
0
4.6
4 3
4.4
4.7
4 5
4 4
4 3
4.3
4.5
4.5
4 5
12.7
12 5
12.8
12 5
12.6
12.6
12 6
12.5
12.2
12.2
13 7
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station (ft)
AC
ATB



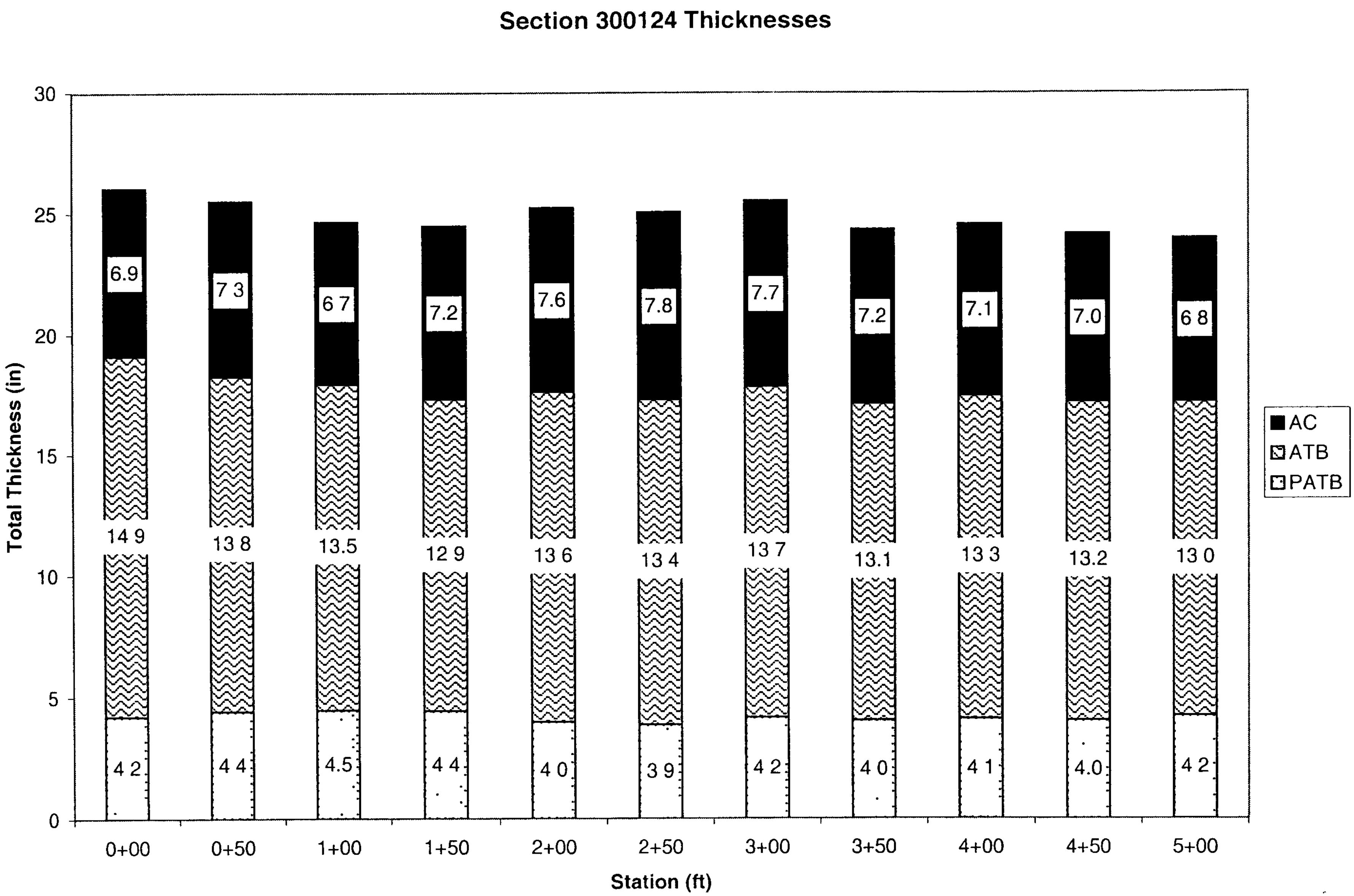
Section 300115 Thicknesses
Thickness (in)
Station (ft)
0
2
4
6
8
10
12
14
16
18
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
AC
ATB
7 4
7.7
7 4
7 1
7.5
7 5
7 5
7.7
7 8
7 3
7 0
9.7
8 8
8.8
9 2
9 3
9.4
9.0
9.0
9 0
9.0
9 3



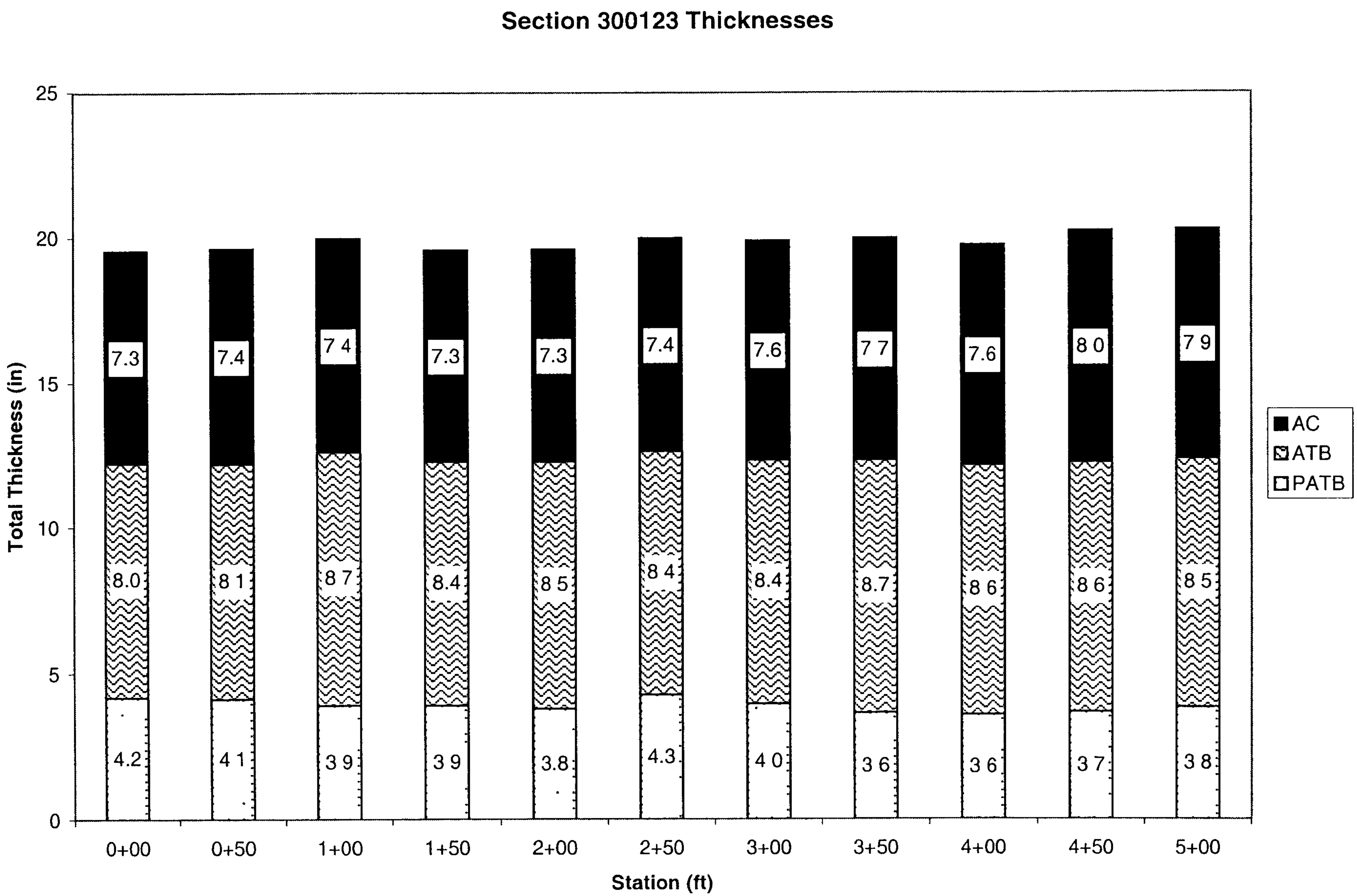
Section 300117 Thicknesses
Total Thickness (in)
20
18
16
14
12
10
8
6
4
2
0
7.1
7.0
7.4
7 1
6 6
7.1
7.3
7.2
7.3
7 2
7 9
4.7
4 6
4.4
4.4
4.3
4.2
4.0
4.4
4 4
4 2
3 9
4.8
4.2
6.0
4.6
5 6
3.9
5.1
4 5
4.4
4 4
4.3
0
50
100
150
200
250
300
350
400
450
500
Station (ft)
AC
ATB
DGAB

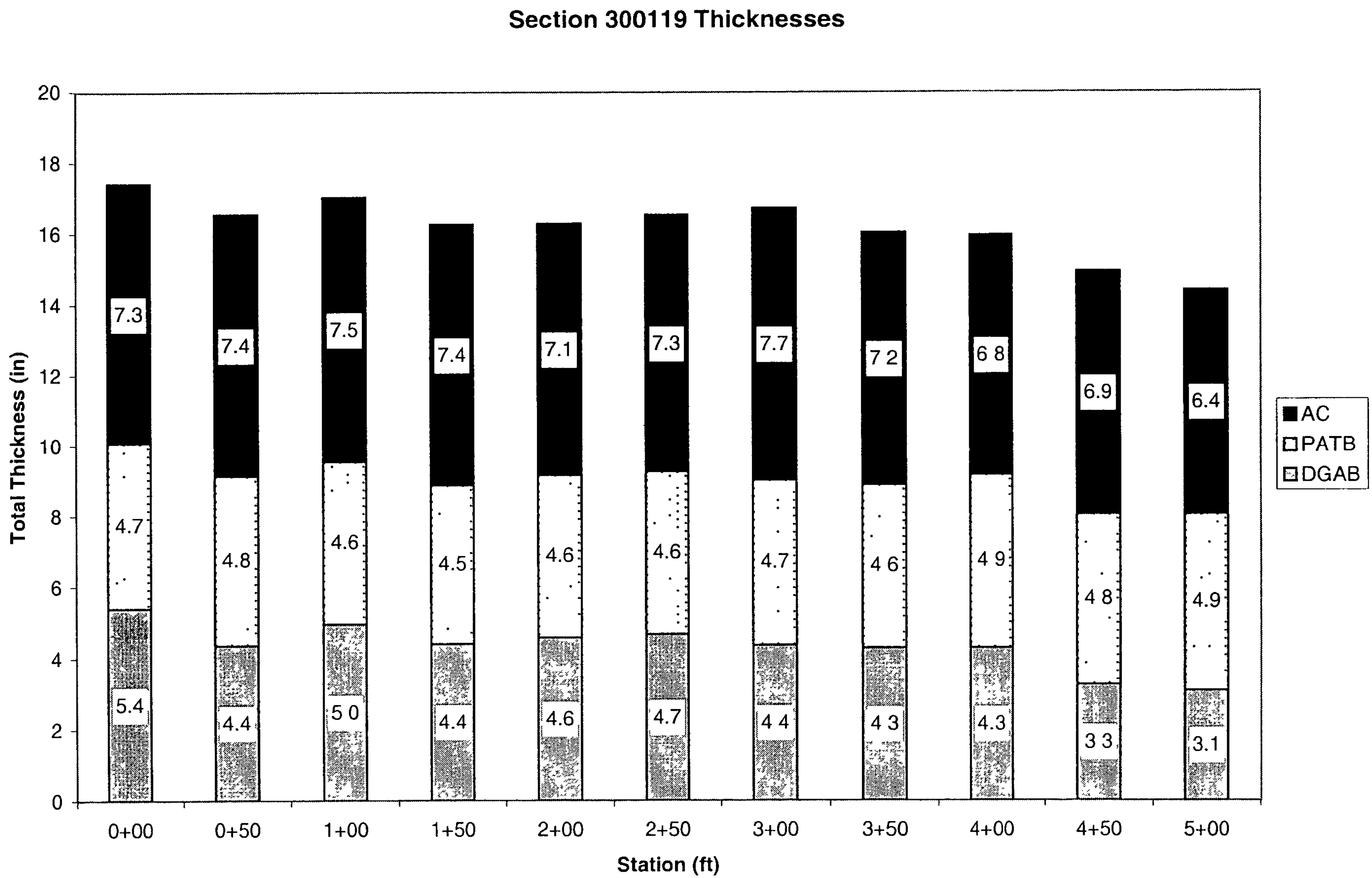


Section 300114 Thicknesseses
Total Thickness (in)
25
20
15
10
5
0
7.2
7.1
7.1
7.3
6.9
7.1
7.2
7 2
7 1
7.2
7.6
11.3
12 2
12.4
11.8
12.4
12 9
13.4
12.4
13 3
12.3
12 3
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station (ft)
AC
DGAB



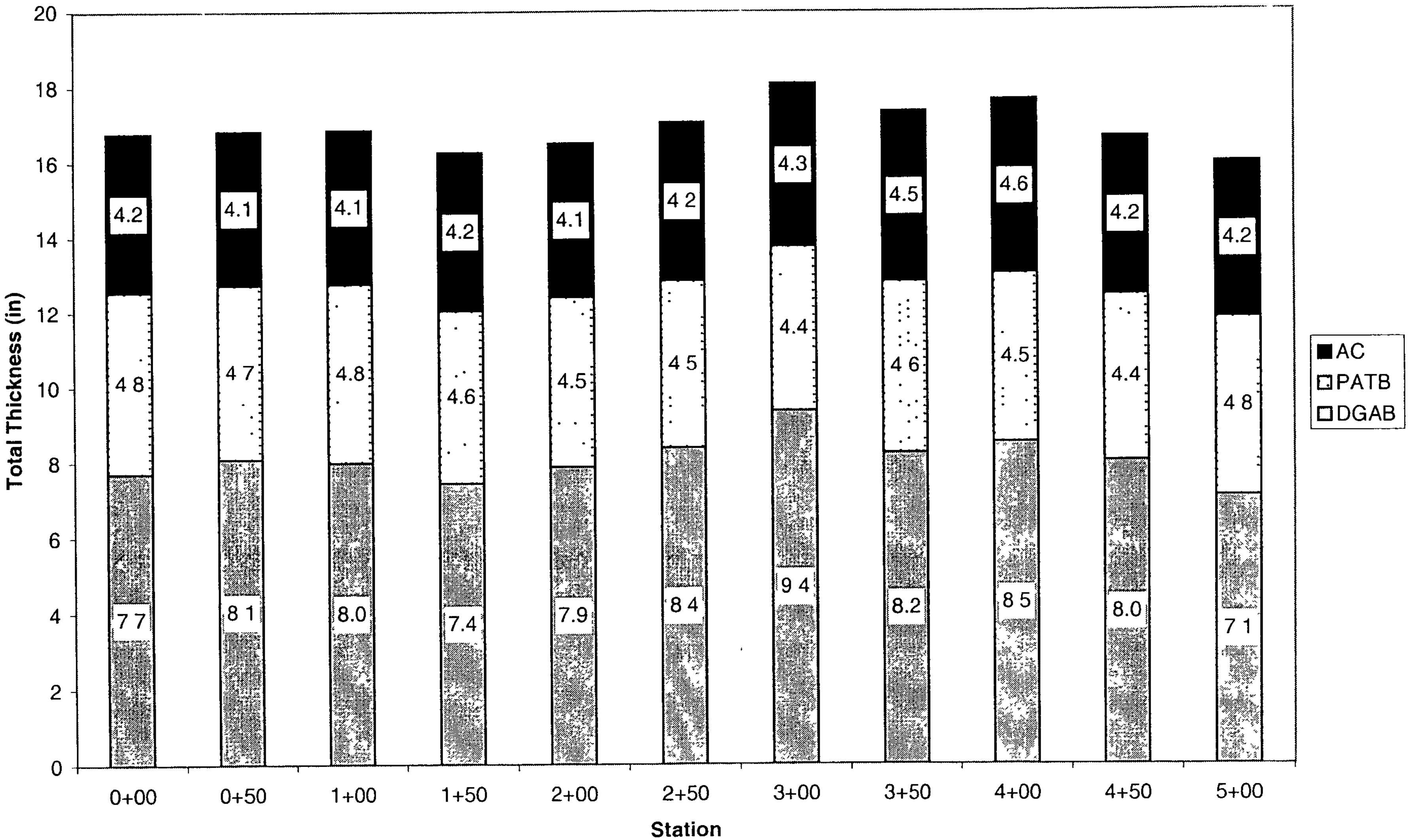
Section 300124 Thicknesses
Total Thickness (in)
Station (ft)
0
5
10
15
20
25
30
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
AC
ATB
PATB
6.9
7 3
6 7
7.2
7.6
7.8
7.7
7.2
7.1
7.0
6 8
14 9
13 8
13.5
12 9
13 6
13 4
13 7
13.1
13 3
13.2
13 0
4 2
4 4
4.5
4 4
4 0
3 9
4 2
4 0
4 1
4.0
4 2

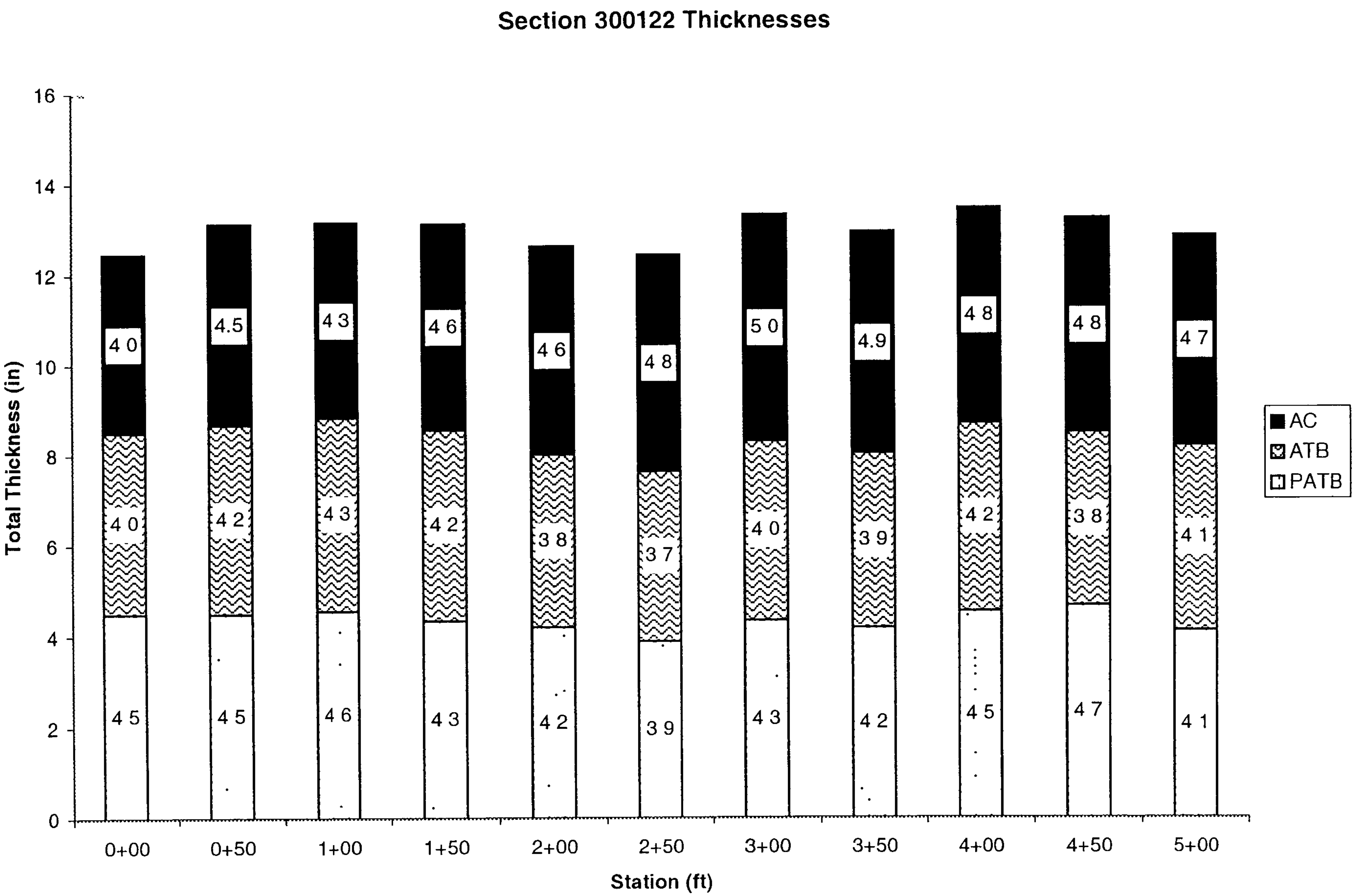

Section 300123 Thicknesses
Total Thickness (in)
Station (ft)
0
5
10
15
20
25
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
AC
ATB
PATB
7.3
7.4
7 4
7.3
7.3
7.4
7.6
7 7
7.6
8 0
7 9
8.0
8 1
8 7
8.4
8 5
8 4
8.4
8.7
8 6
8 6
8 5
4.2
4 1
3 9
3 9
3.8
4.3
4 0
3 6
3 6
3 7
3 8



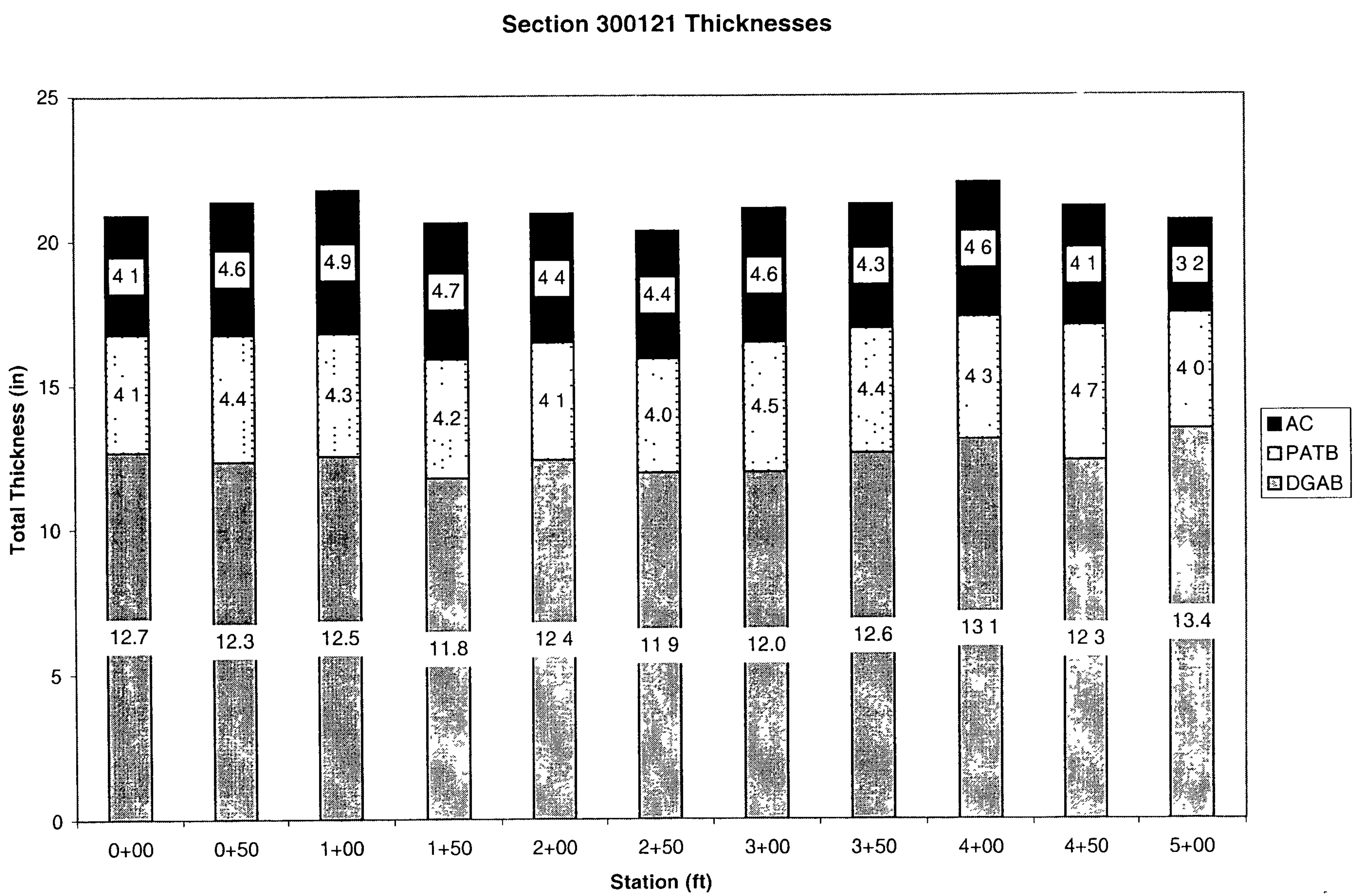
Section 300119 Thicknesses
Total Thickness (in)
20
18
16
14
12
10
8
6
4
2
0
7.3
7.4
7.5
7.4
7.1
7.3
7.7
7 2
6 8
6.9
6.4
4.7
4.8
4.6
4.5
4.6
4.6
4.7
4 6
4 9
4 8
4.9
5.4
4.4
5 0
4.4
4.6
4.7
4 4
4 3
4.3
3 3
3.1
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station (ft)
AC
PATB
DGAB

Section 300120 Thicknesses





Section 300122 Thicknesses
Total Thickness (in)
16
14
12
10
8
6
4
2
0
4 0
4.5
4 3
4 6
4 6
4 8
5 0
4.9
4 8
4 8
4 7
4 0
4 2
4 3
4 2
3 8
3 7
4 0
3 9
4 2
3 8
4 1
4 5
4 5
4 6
4 3
4 2
3 9
4 3
4 2
4 5
4 7
4 1
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station (ft)
AC
ATB
PATB

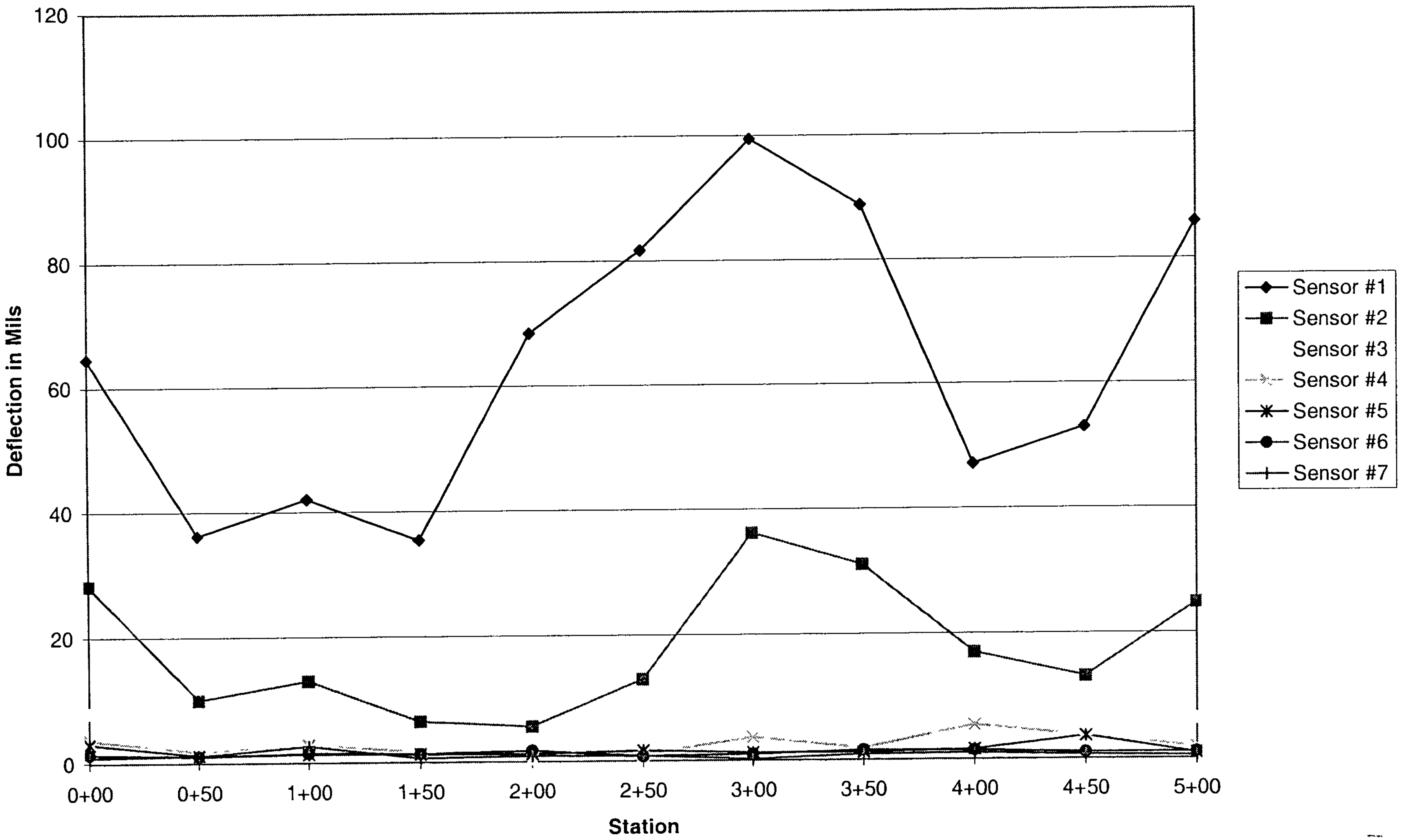

Section 300121 Thicknesses
Total Thickness (in)
25
20
15
10
5
0
AC
PATB
DGAB
4 1
4.6
4.9
4.7
4 4
4.4
4.6
4.3
4 6
4 1
3 2
4 1
4.4
4.3
4.2
4 1
4.0
4.5
4.4
4 3
4 7
4 0
12.7
12.3
12.5
11.8
12 4
11 9
12.0
12.6
13 1
12 3
13.4
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station (ft)

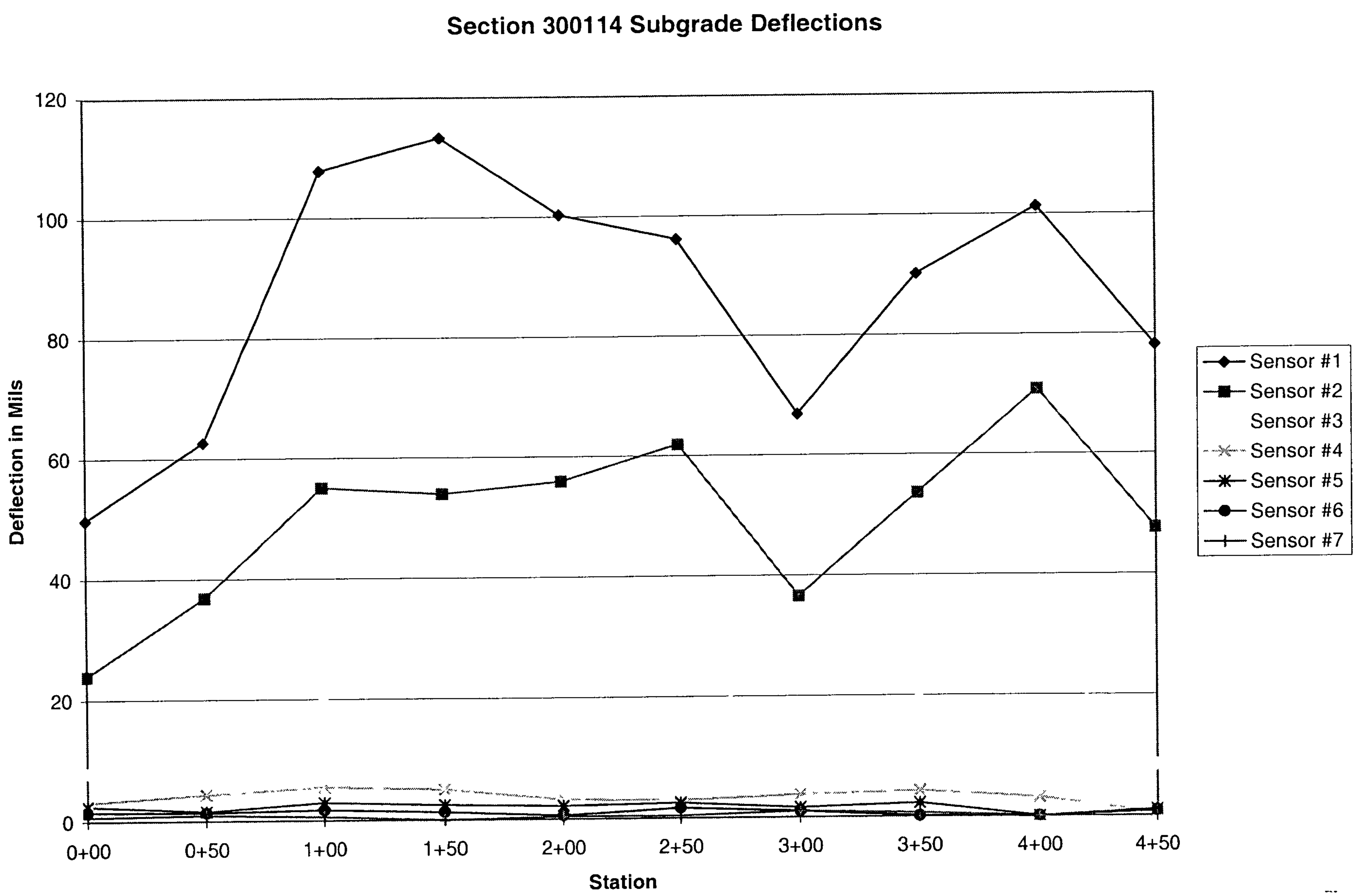
APPENDIX B

FWD Deflection Profiles

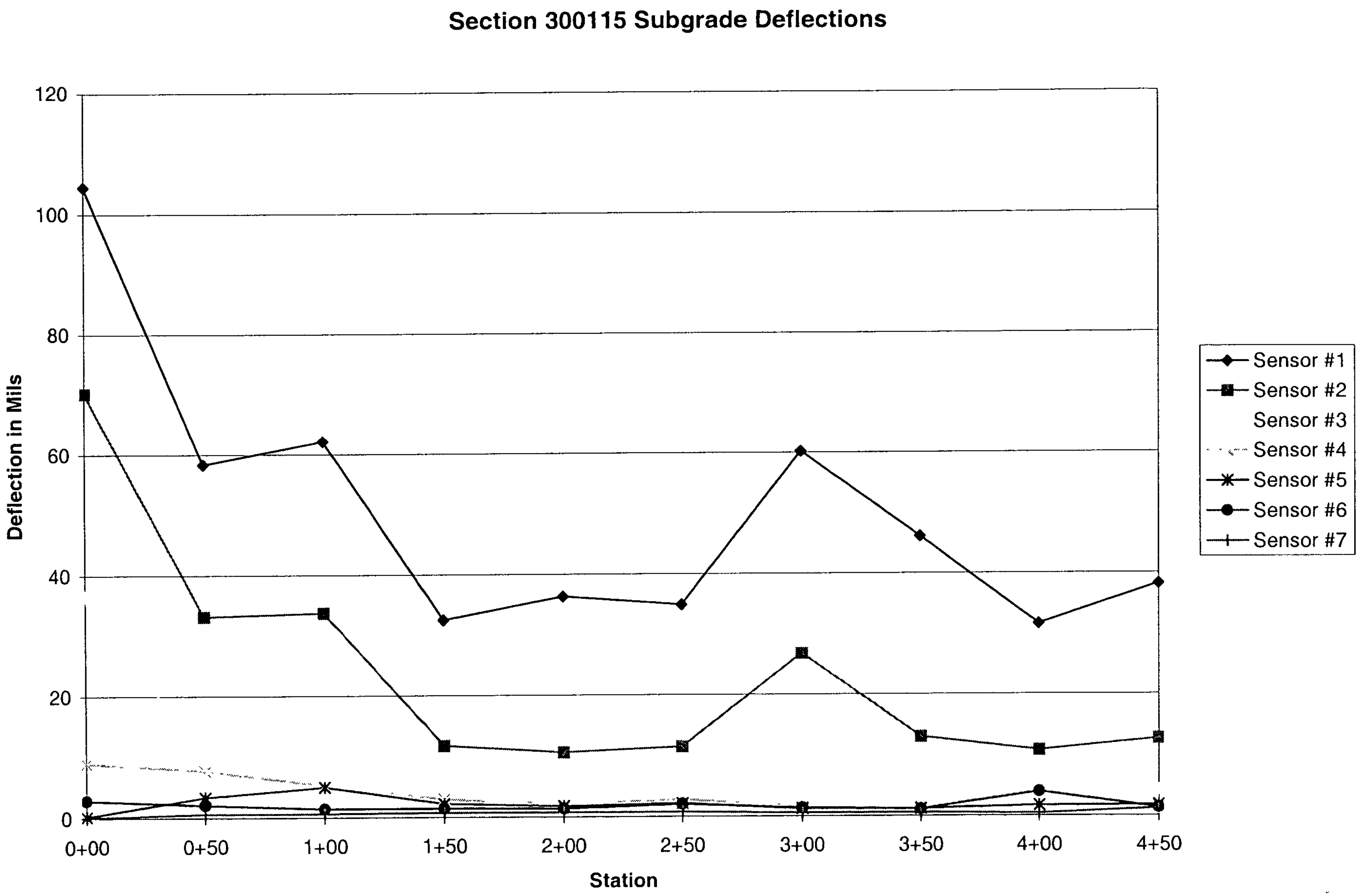
Subgrade Deflection Profiles

Section 300113 Subgrade Deflections

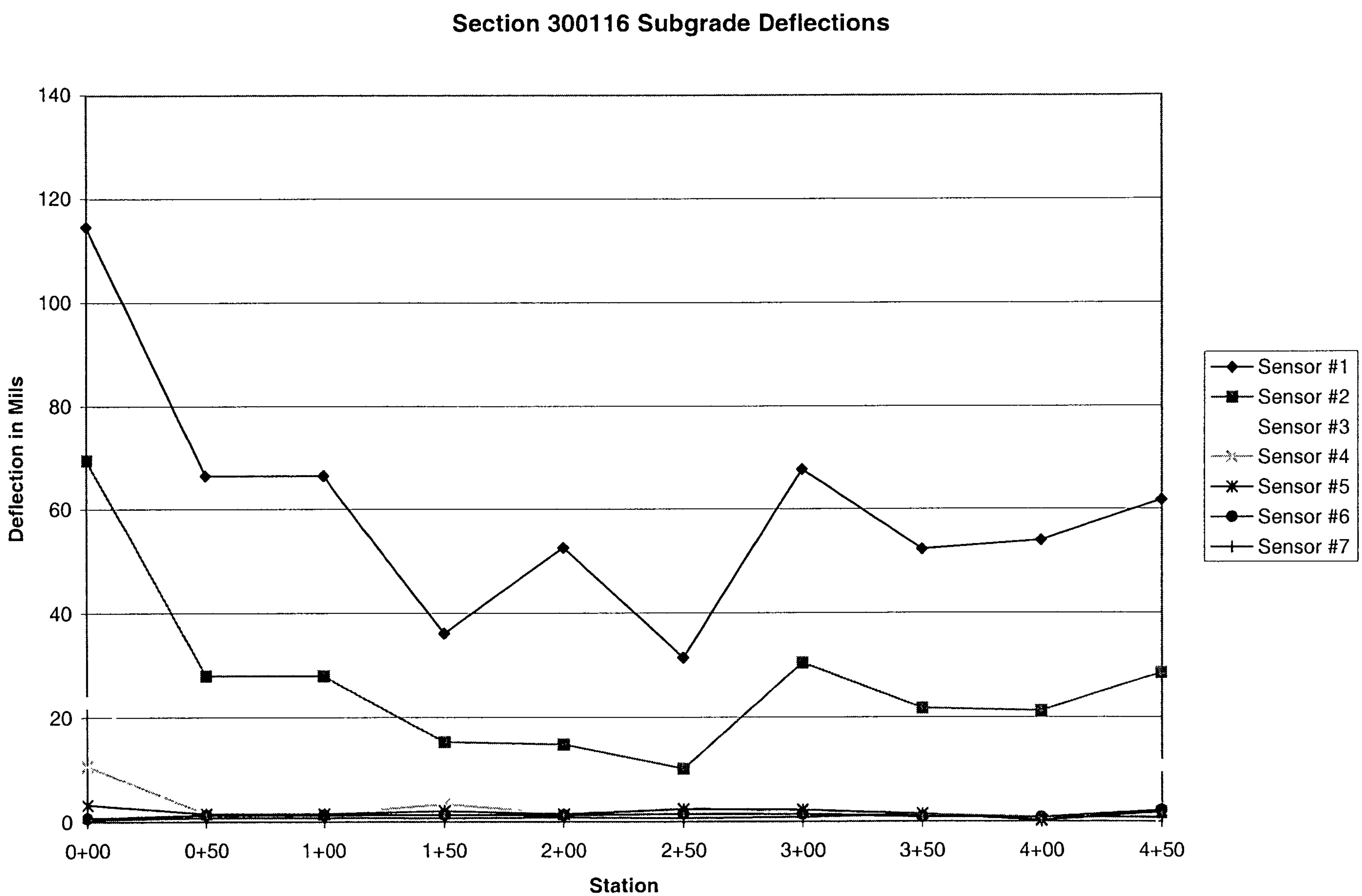




Section 300114 Subgrade Deflections
Deflection in Mils
120
100
80
60
40
20
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7

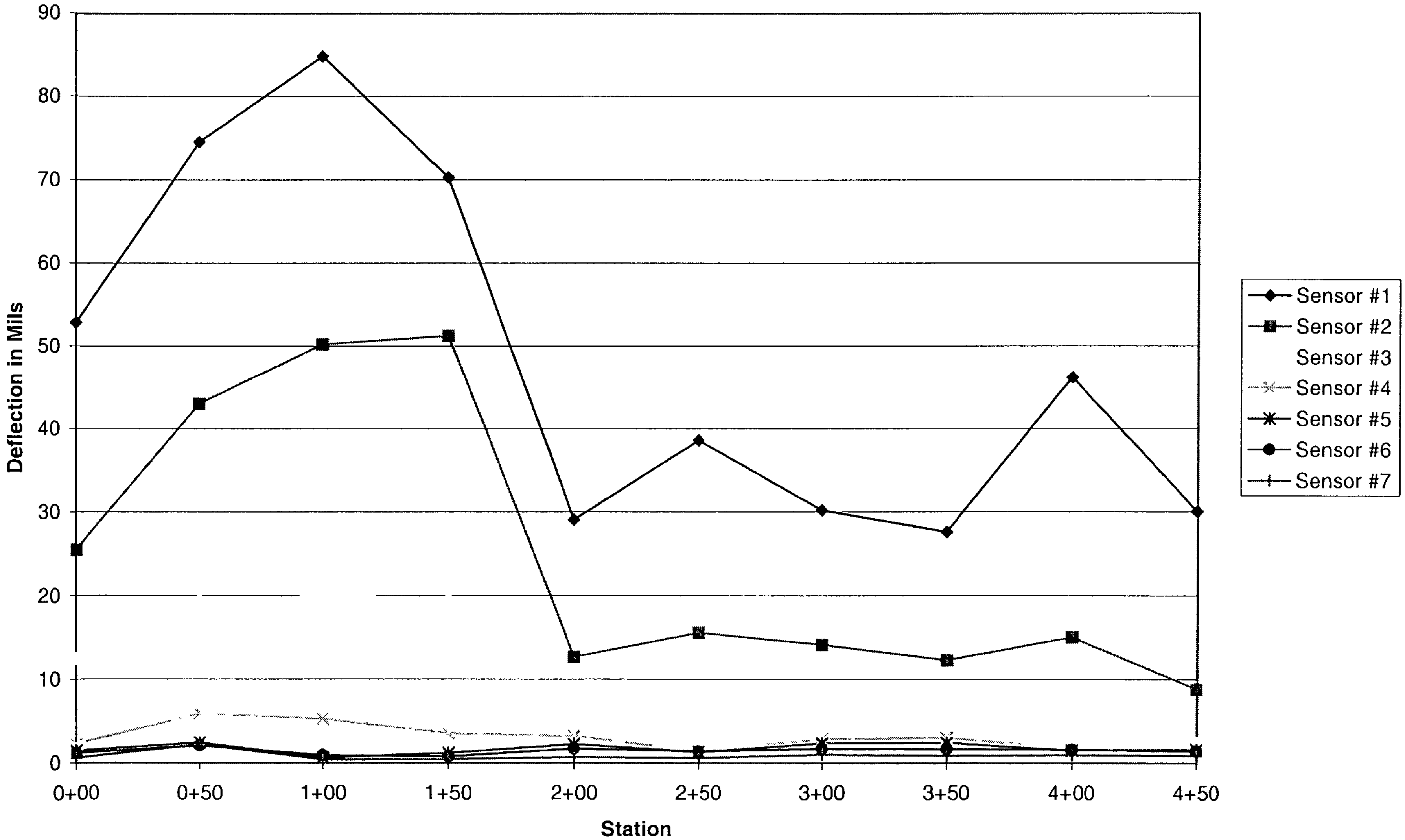


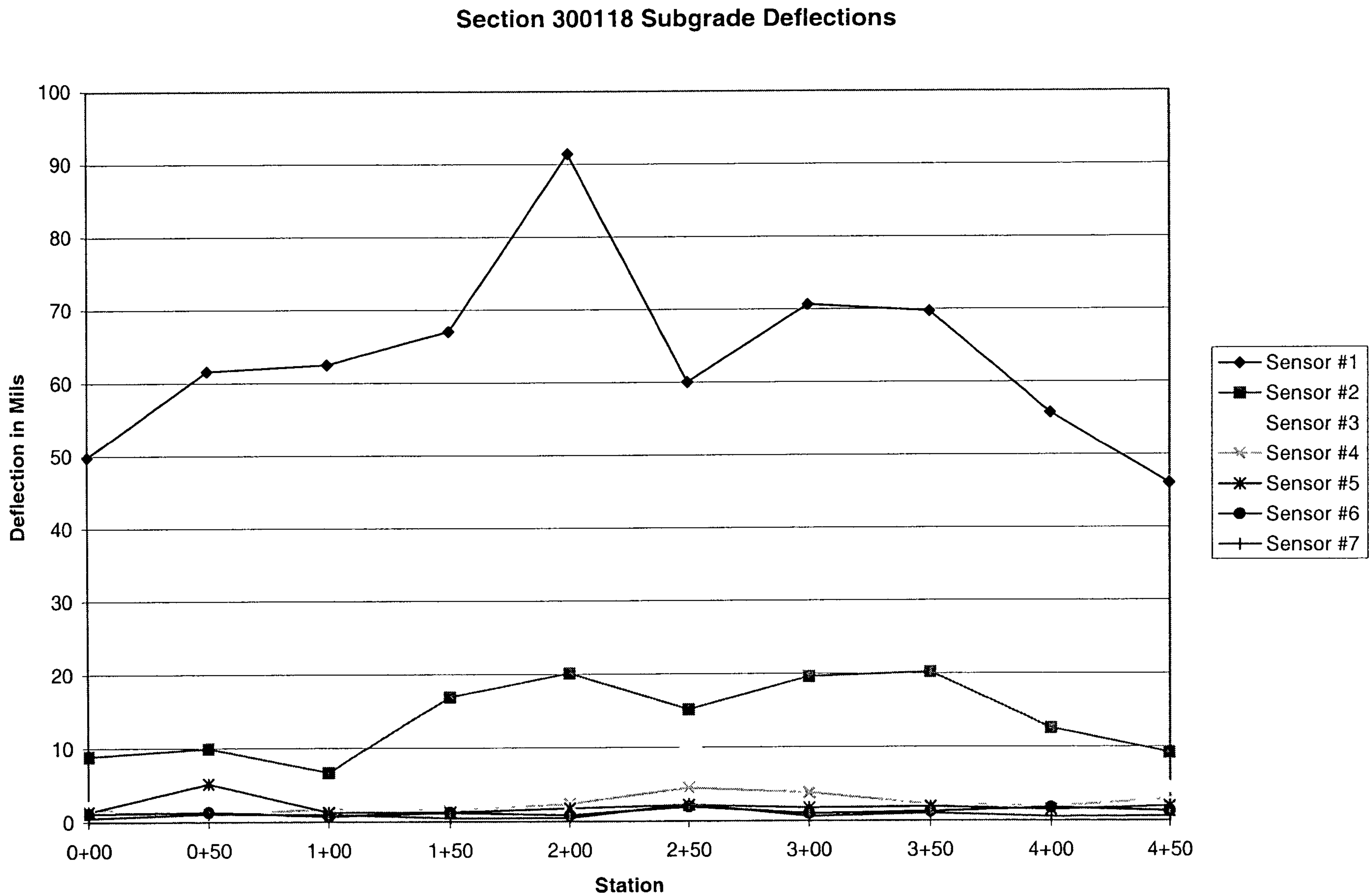
Section 300115 Subgrade Deflections
Deflection in Mils
120
100
80
60
40
20
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7



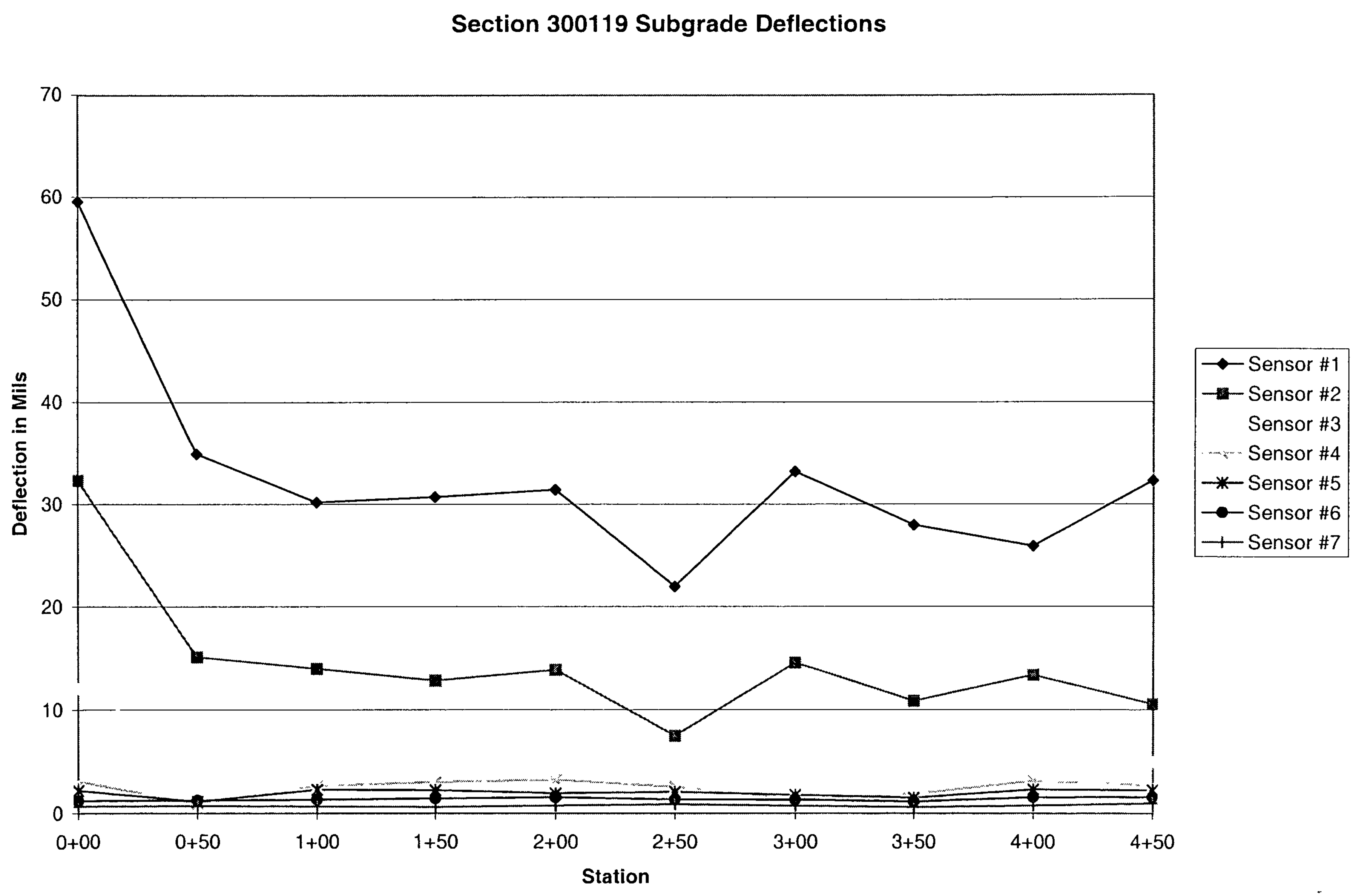
Section 300116 Subgrade Deflections
Deflection in Mils
140
120
100
80
60
40
20
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7

Section 300117 Subgrade Deflections

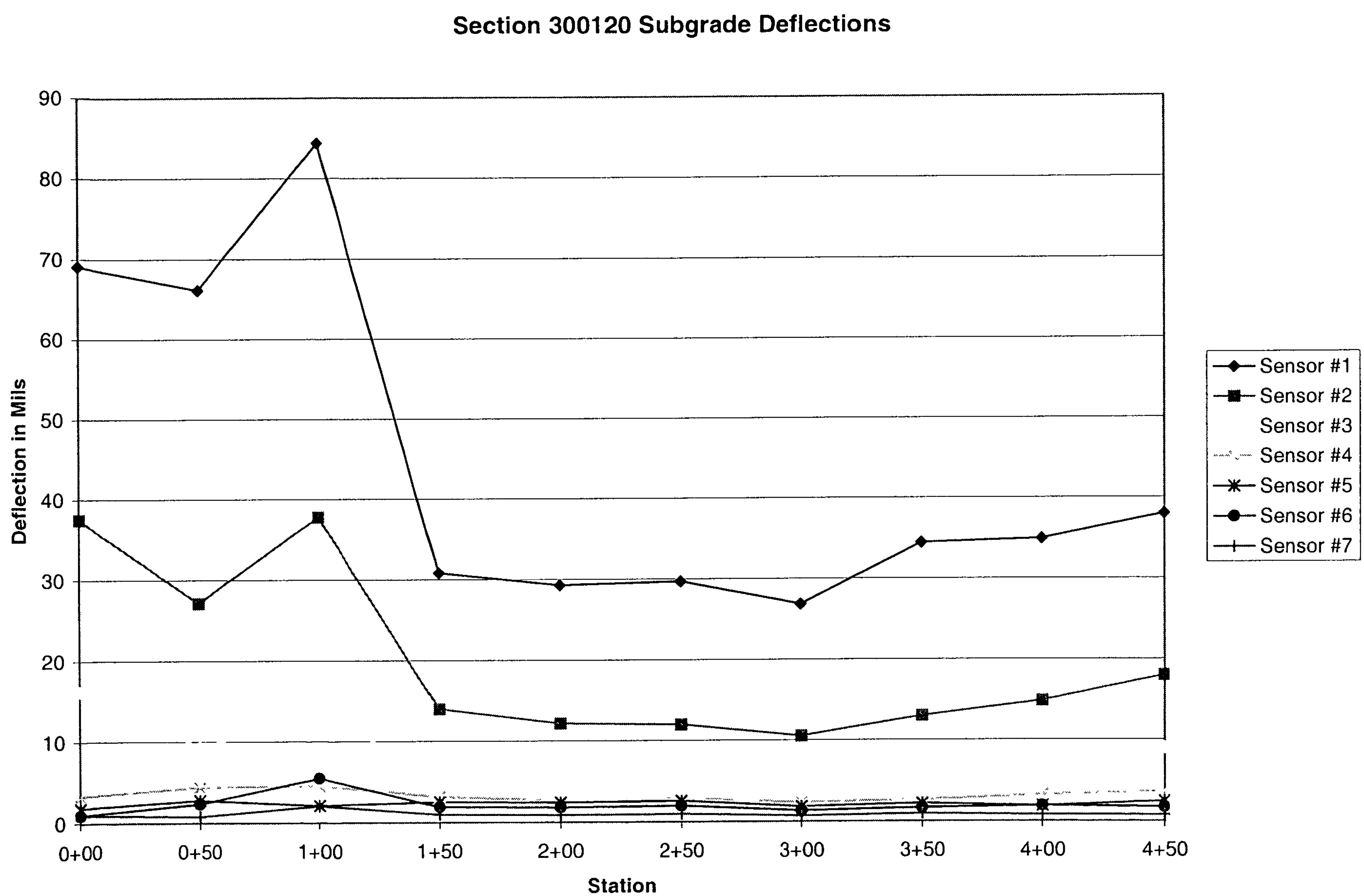




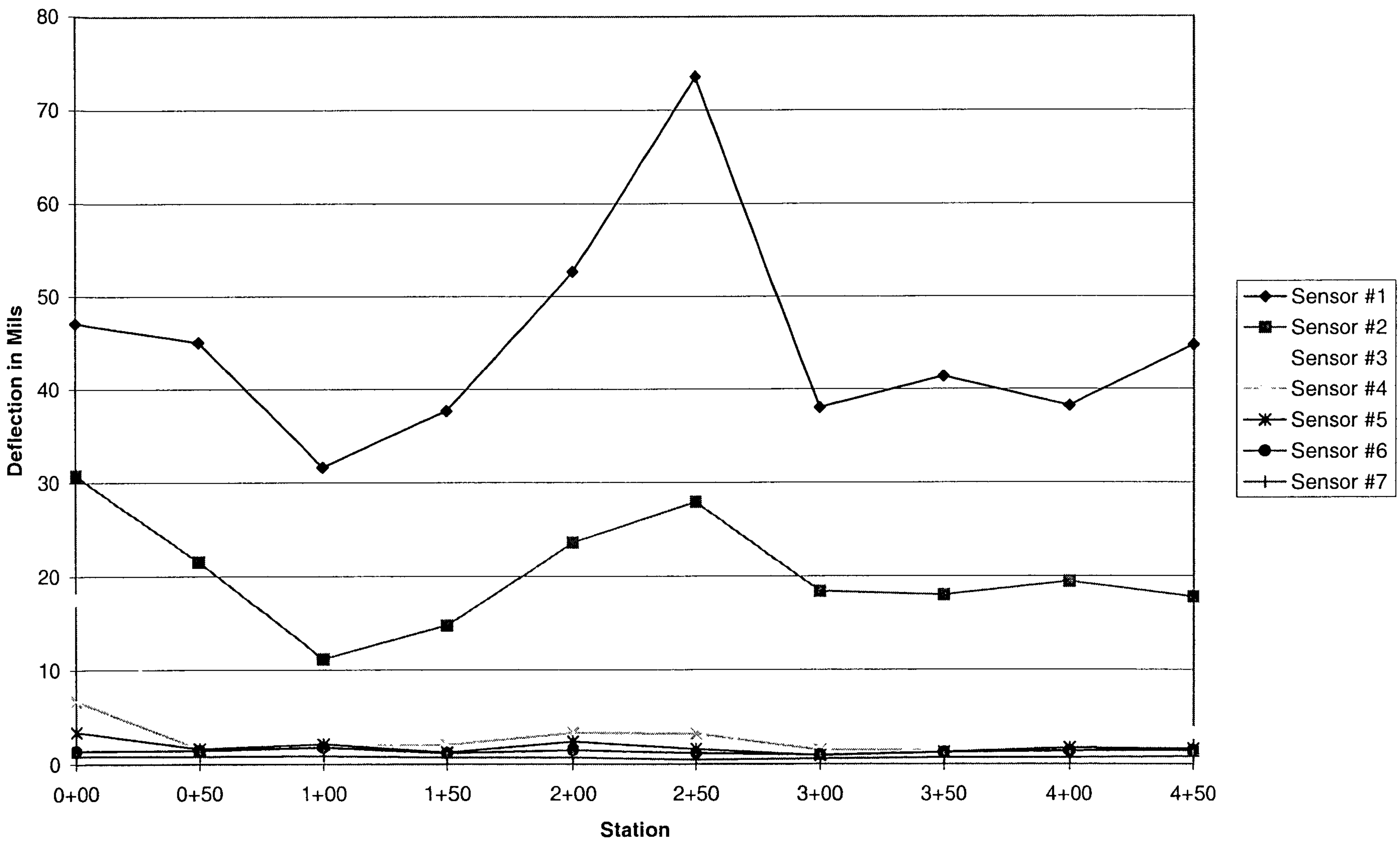
Section 300118 Subgrade Deflections
Deflection in Mils
100
90
80
70
60
50
40
30
20
10
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7



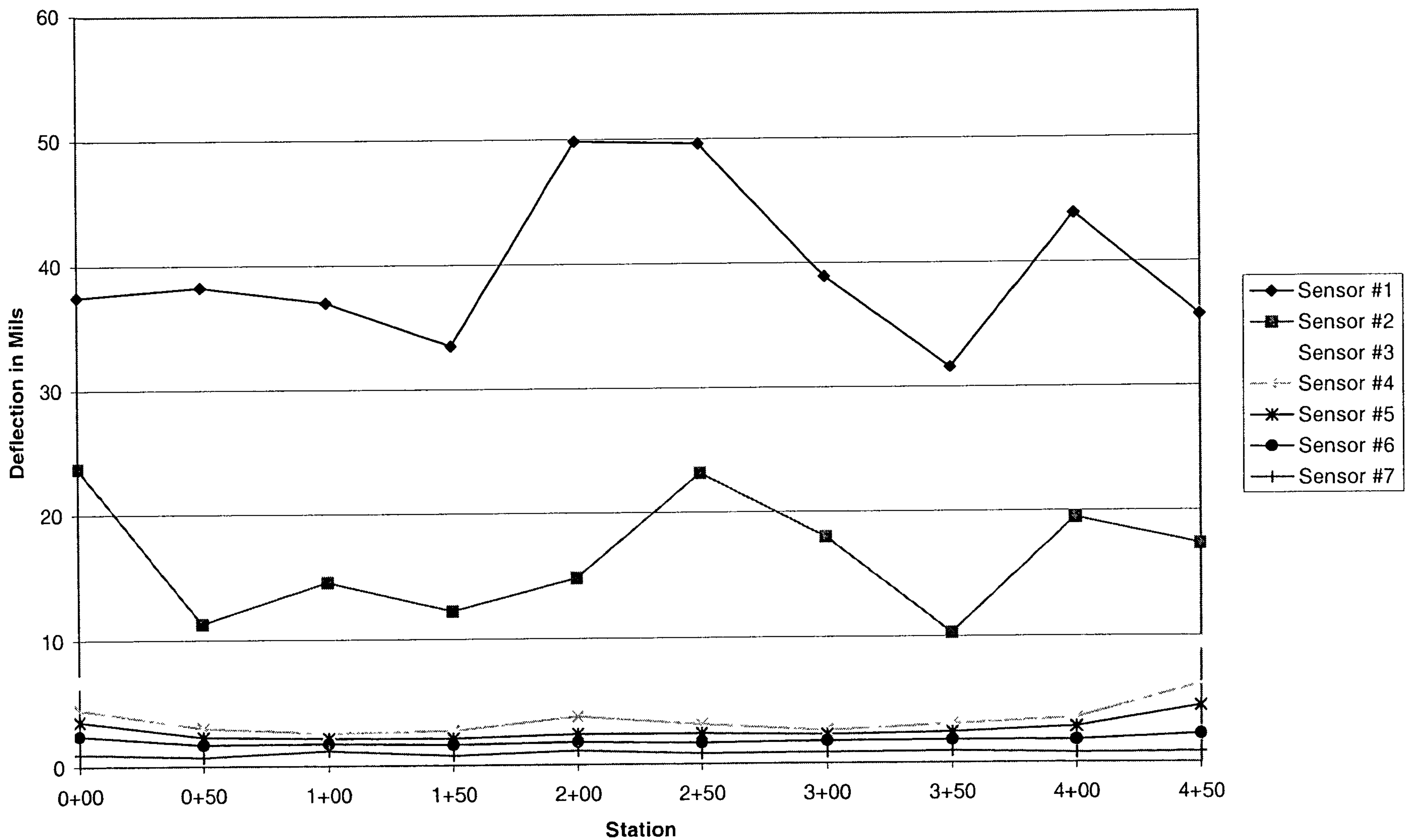
Section 300119 Subgrade Deflections
Deflection in Mils
70
60
50
40
30
20
10
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7

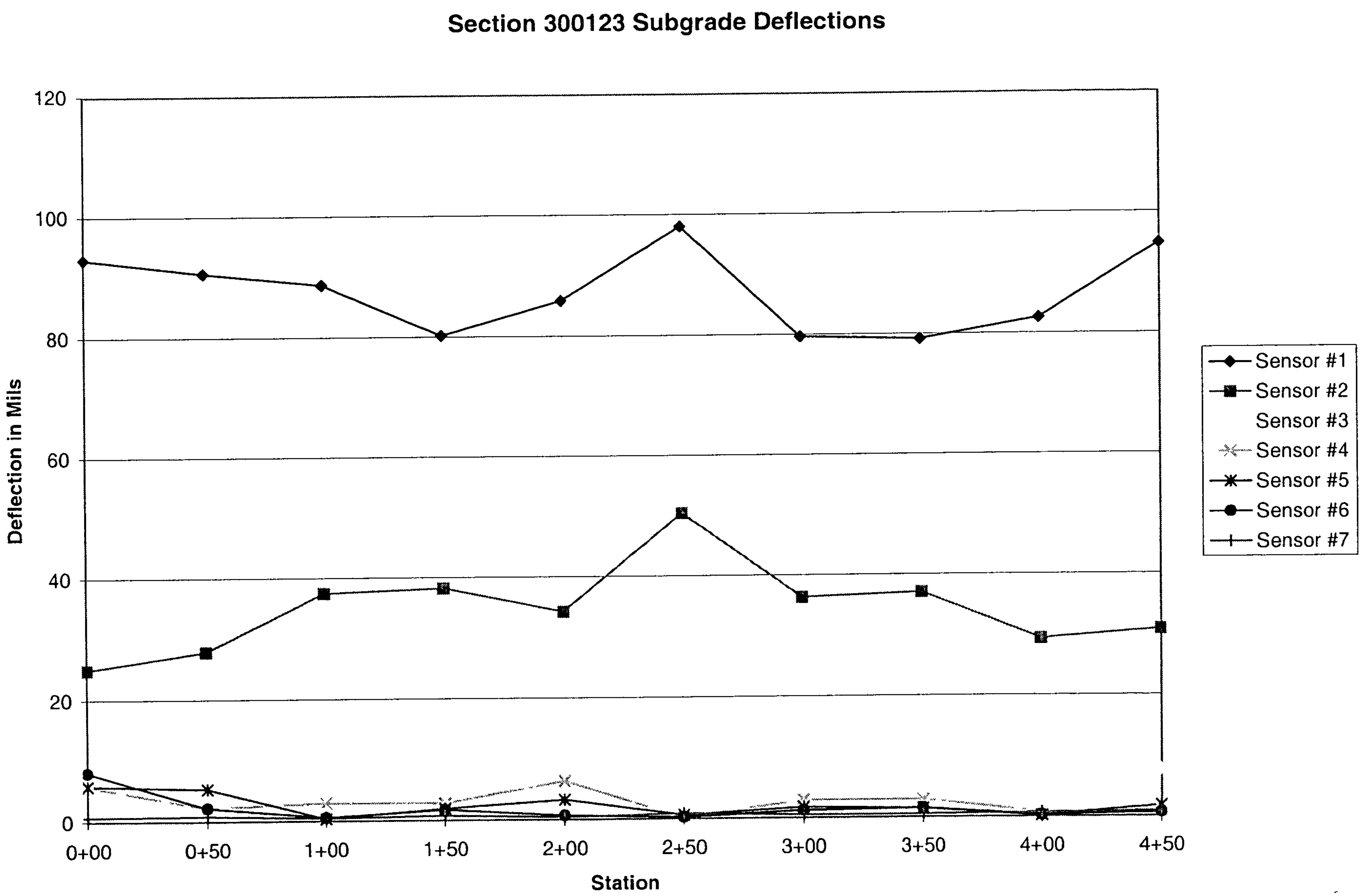

Section 300120 Subgrade Deflections
Deflection in Mils
90
80
70
60
50
40
30
20
10
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7

Section 300121 Subgrade Deflections

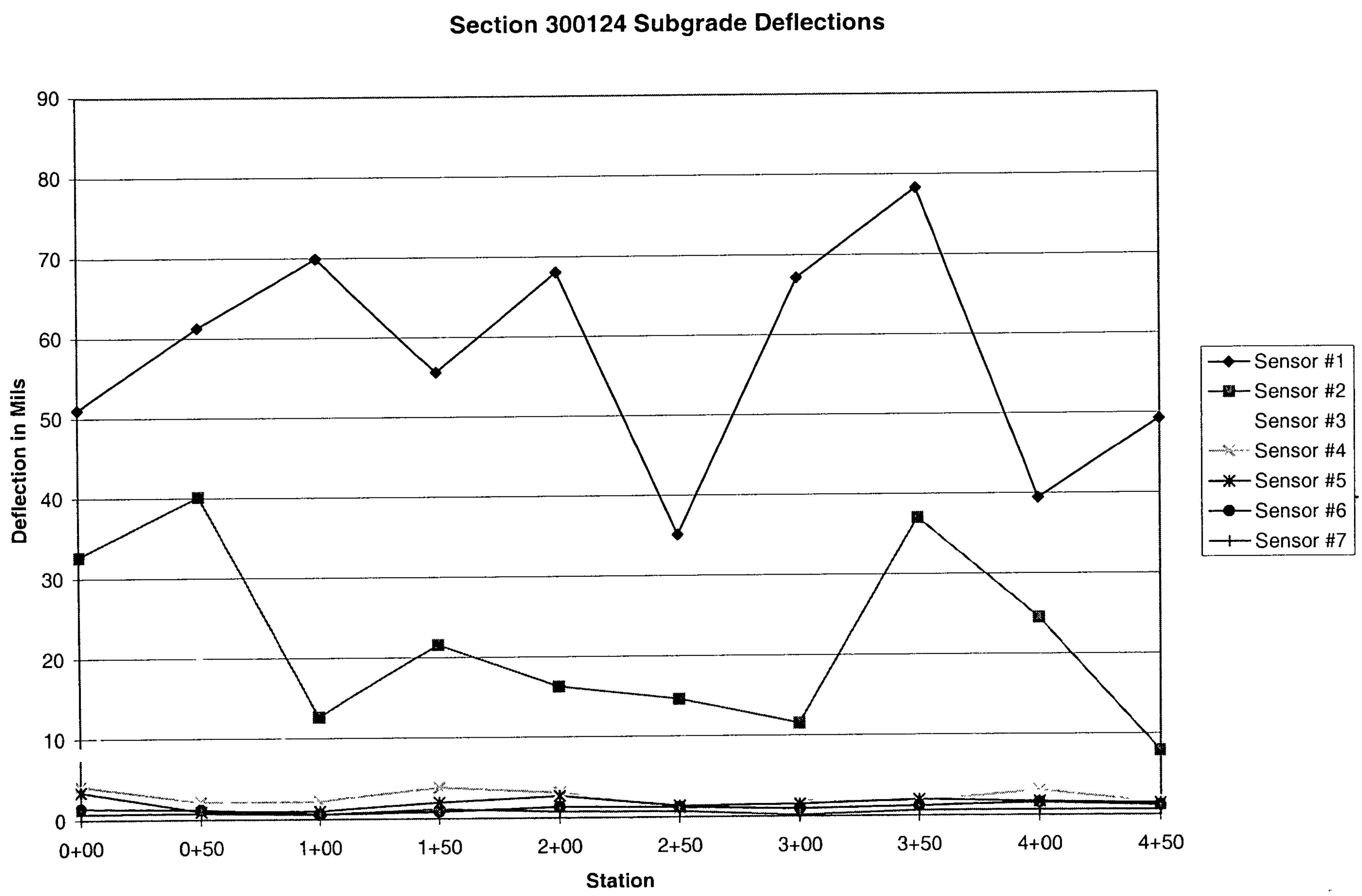


Section 300122 Subgrade Deflections



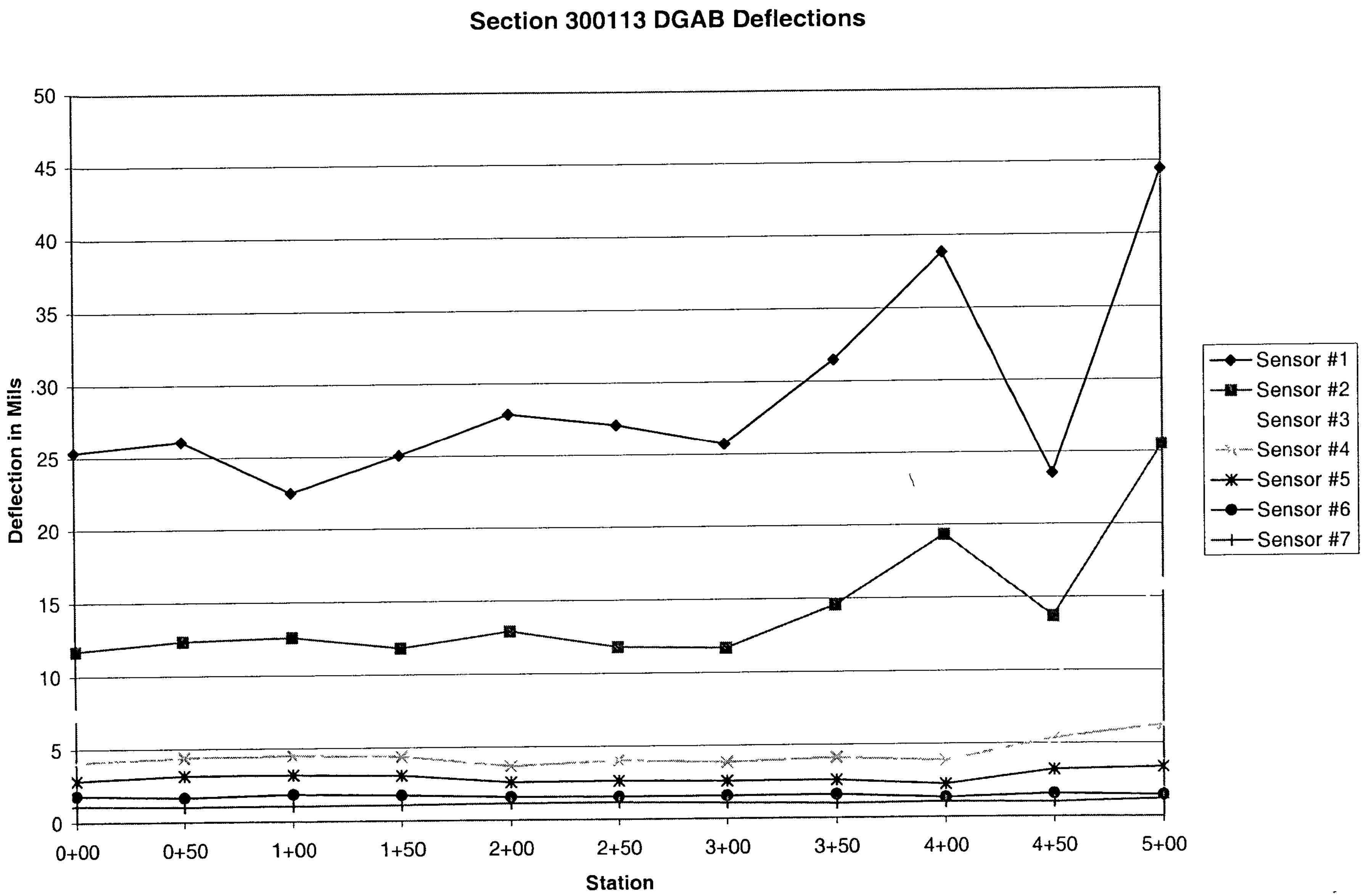


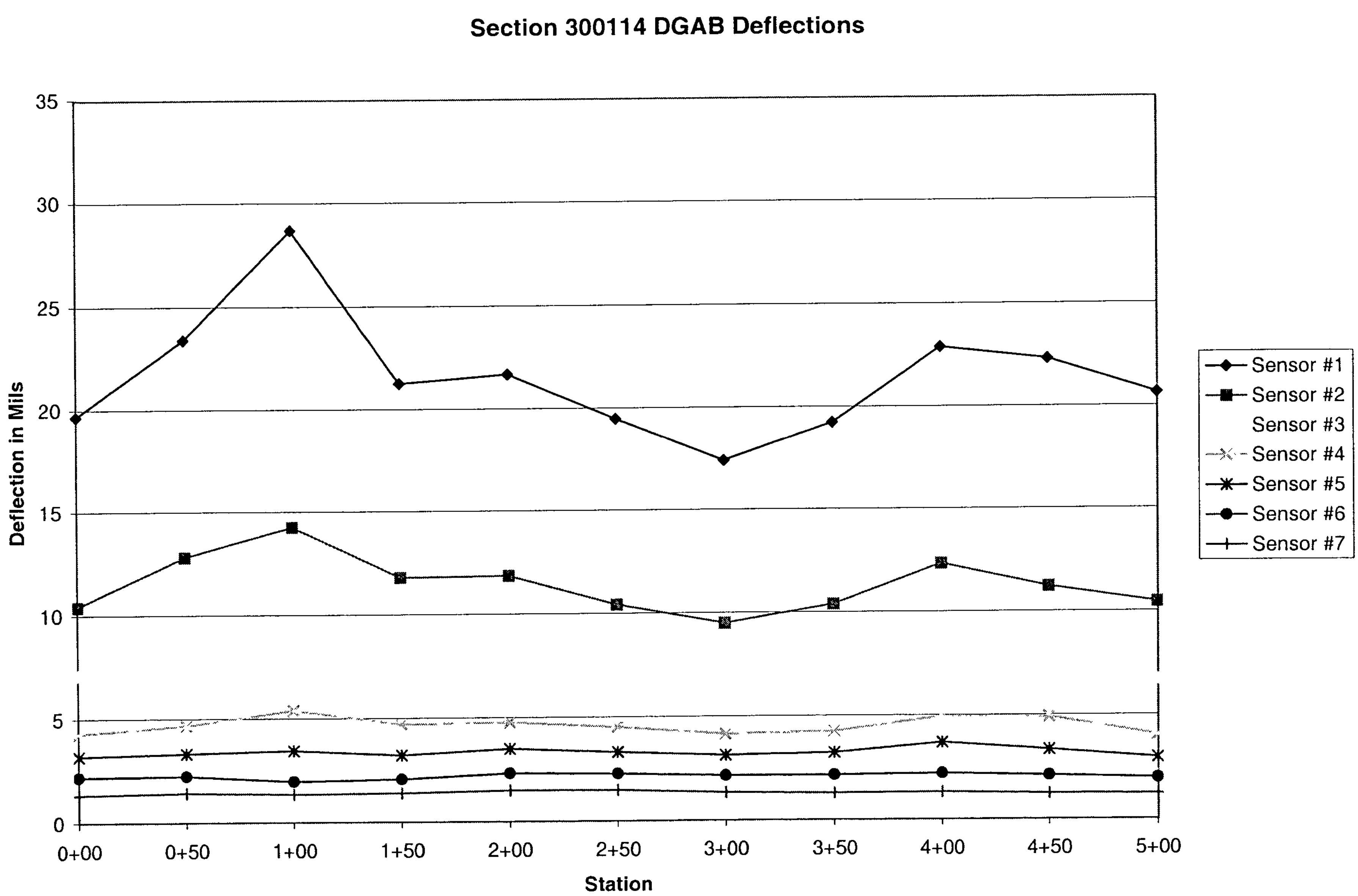
Section 300123 Subgrade Deflections
Deflection in Mils
120
100
80
60
40
20
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7



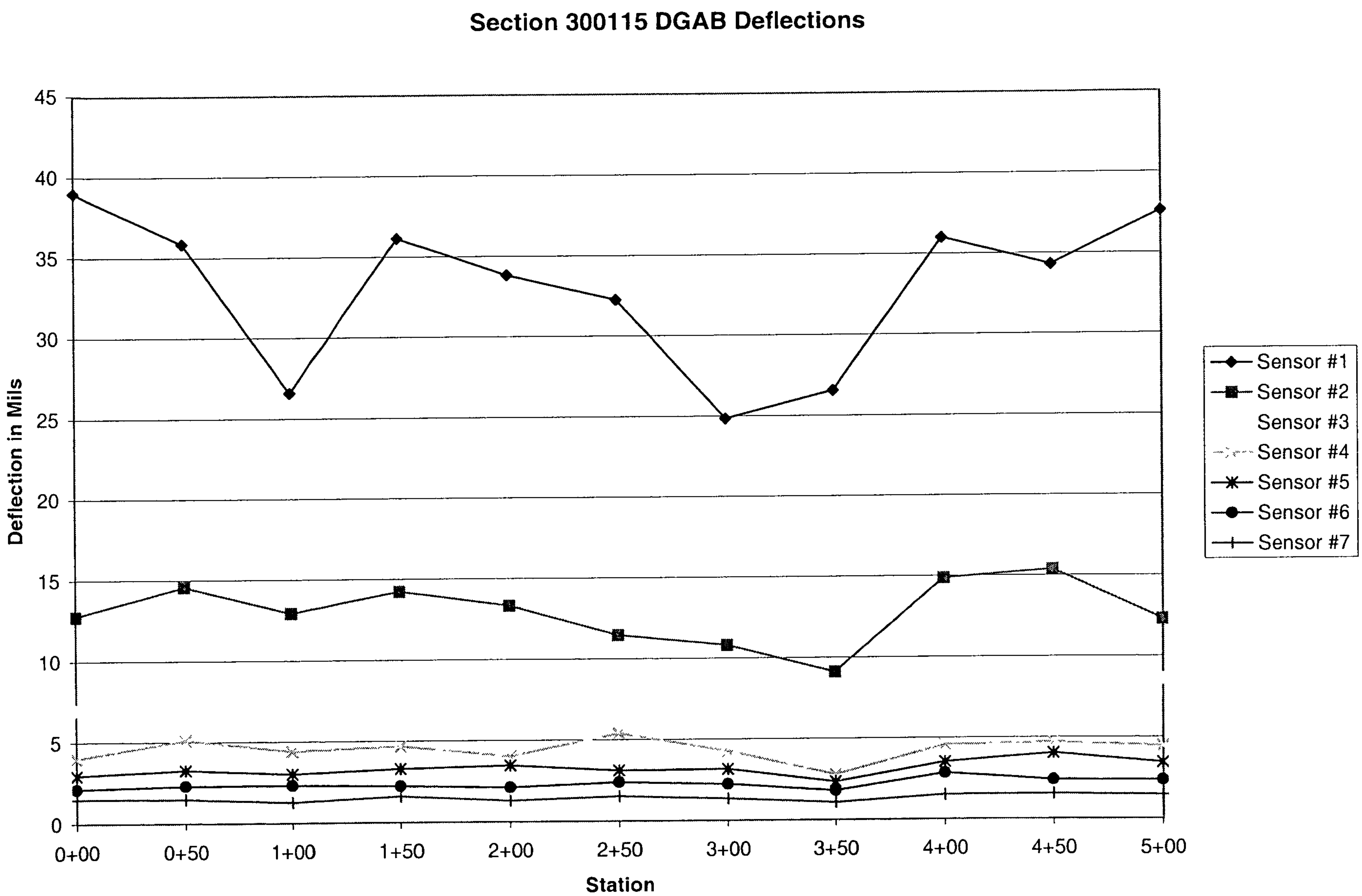
Section 300124 Subgrade Deflections
Deflection in Mils
90
80
70
60
50
40
30
20
10
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7

DGAB Deflection Profiles

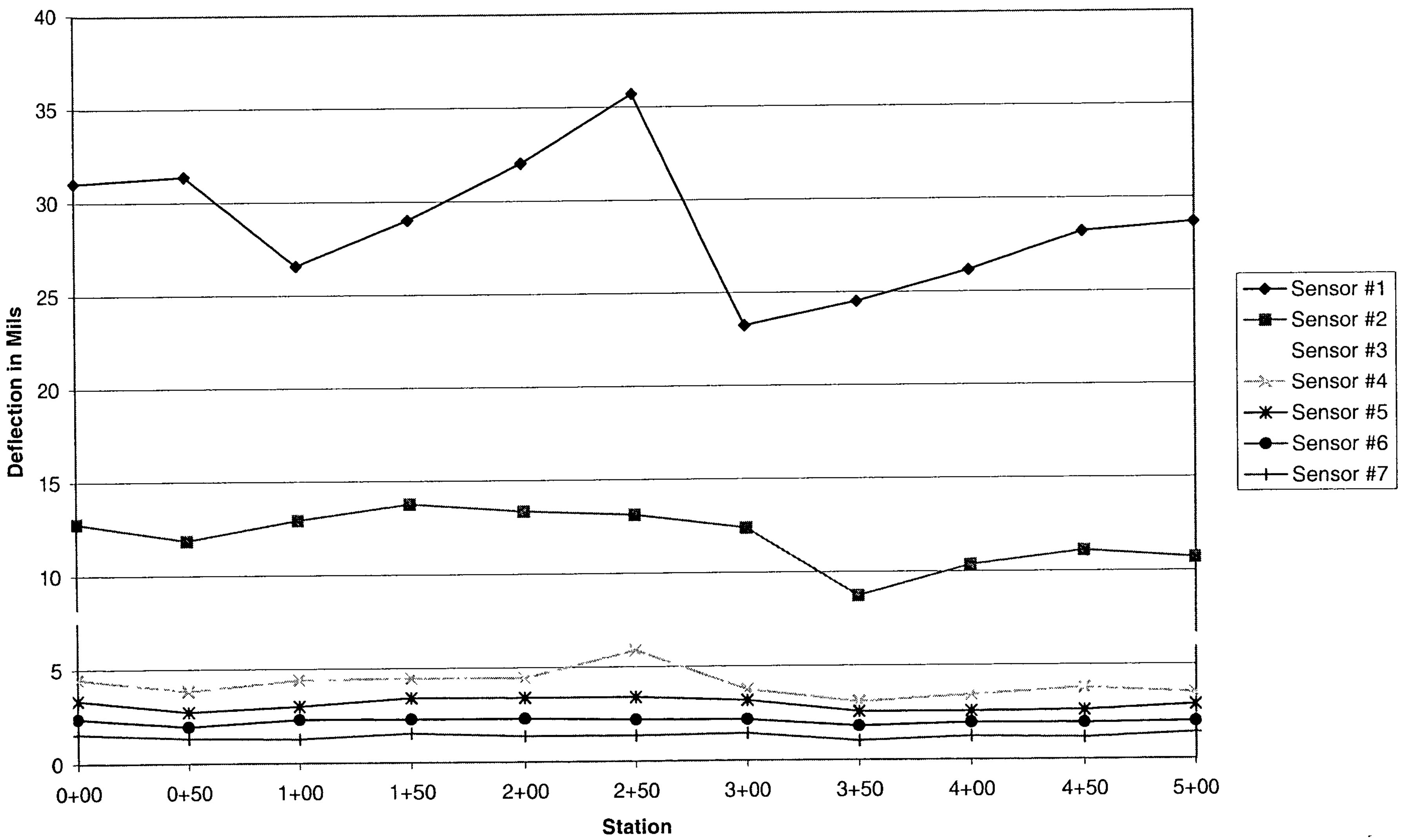

Section 300113 DGAB Deflections
Deflection in Mils
50
45
40
35
30
25
20
15
10
5
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7

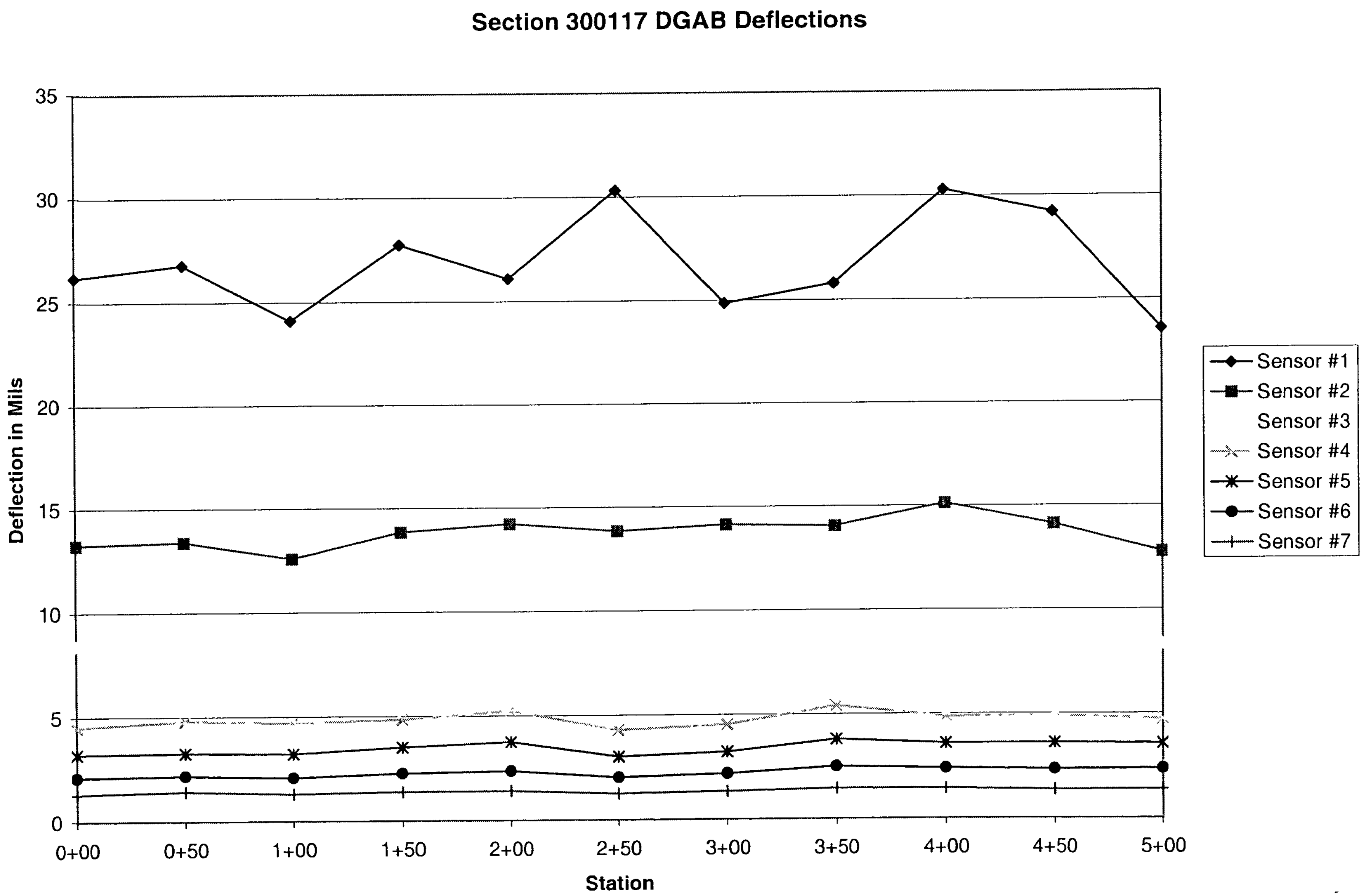


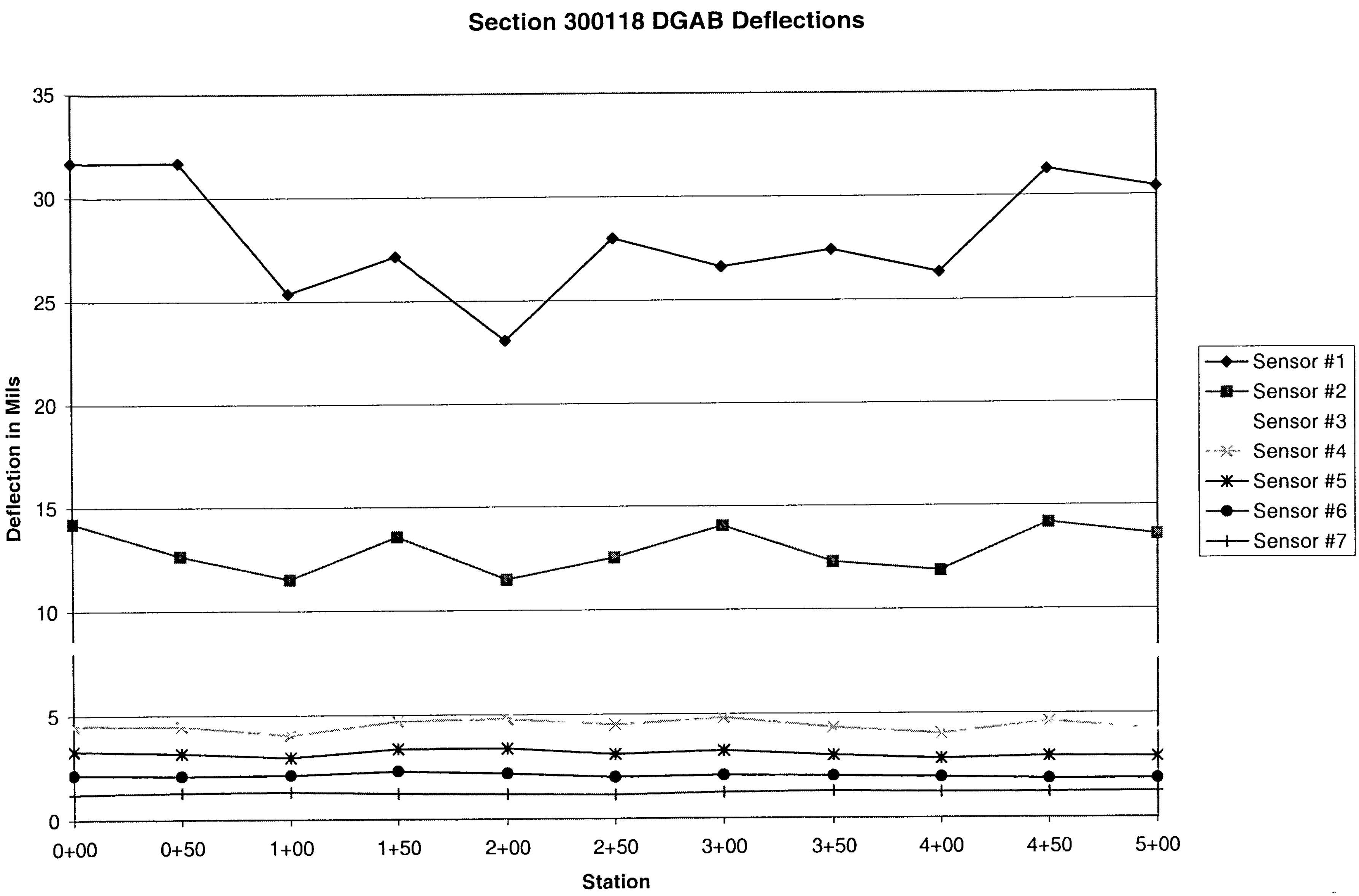
Section 300114 DGAB Deflections
35
30
25
20
15
10
5
0
Deflection in Mils
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7


Section 300115 DGAB Deflections
Deflection in Mils
45
40
35
30
25
20
15
10
5
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7

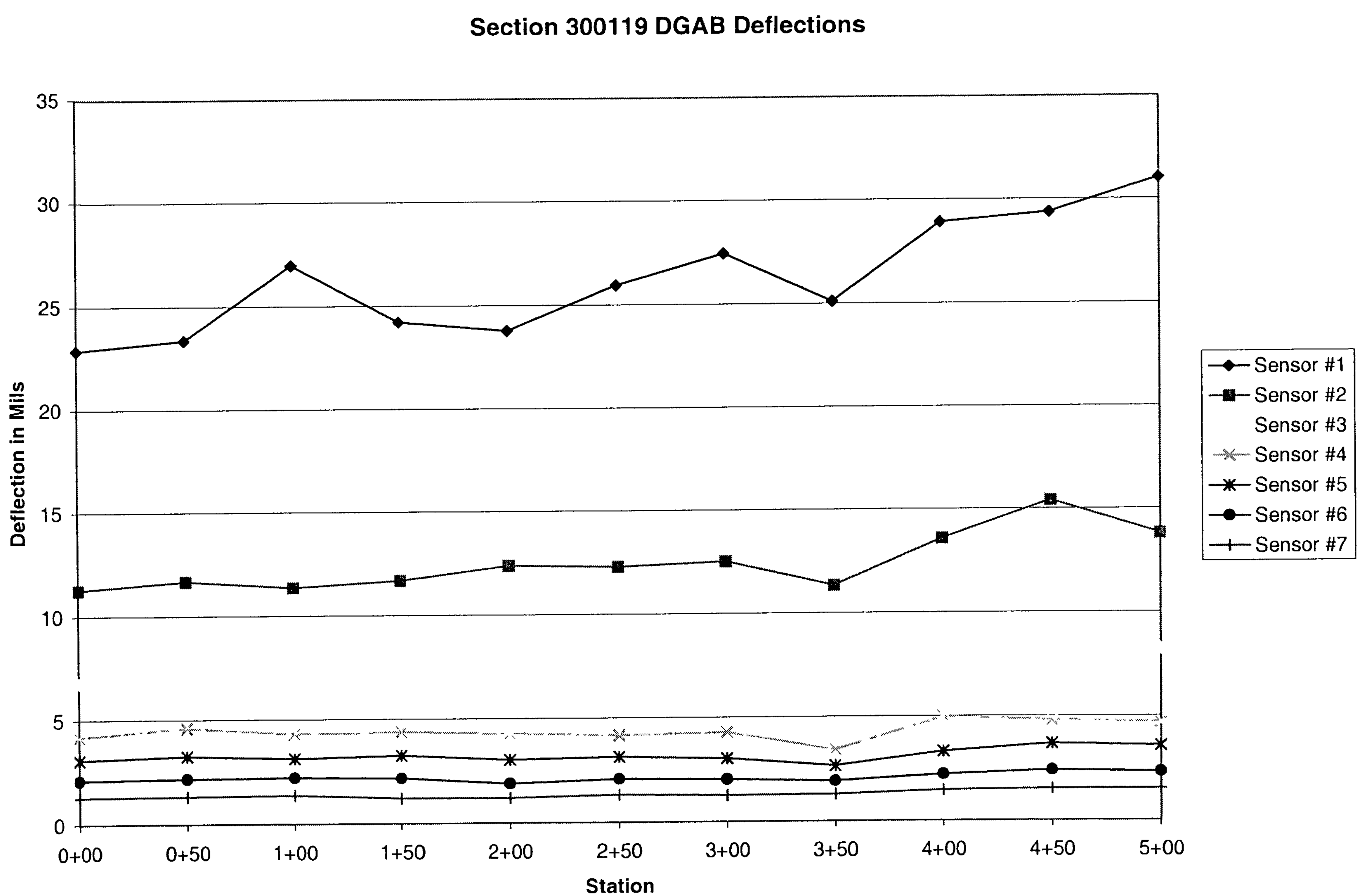
Section 300116 DGAB Deflections



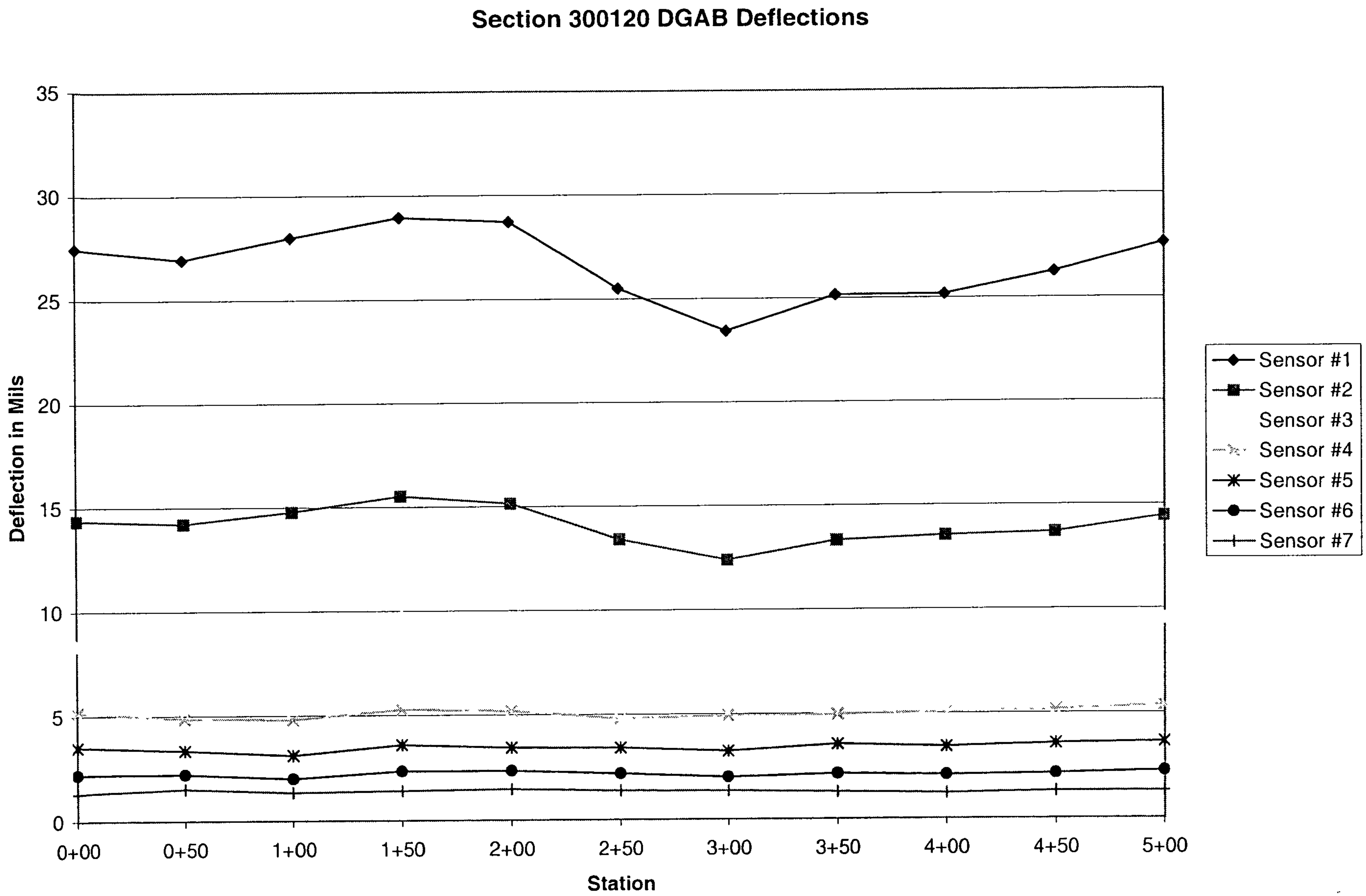

Section 300117 DGAB Deflections
35
30
25
20
15
10
5
0
Deflection in Mils
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7



Section 300118 DGAB Deflections
Deflection in Mils
35
30
25
20
15
10
5
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7

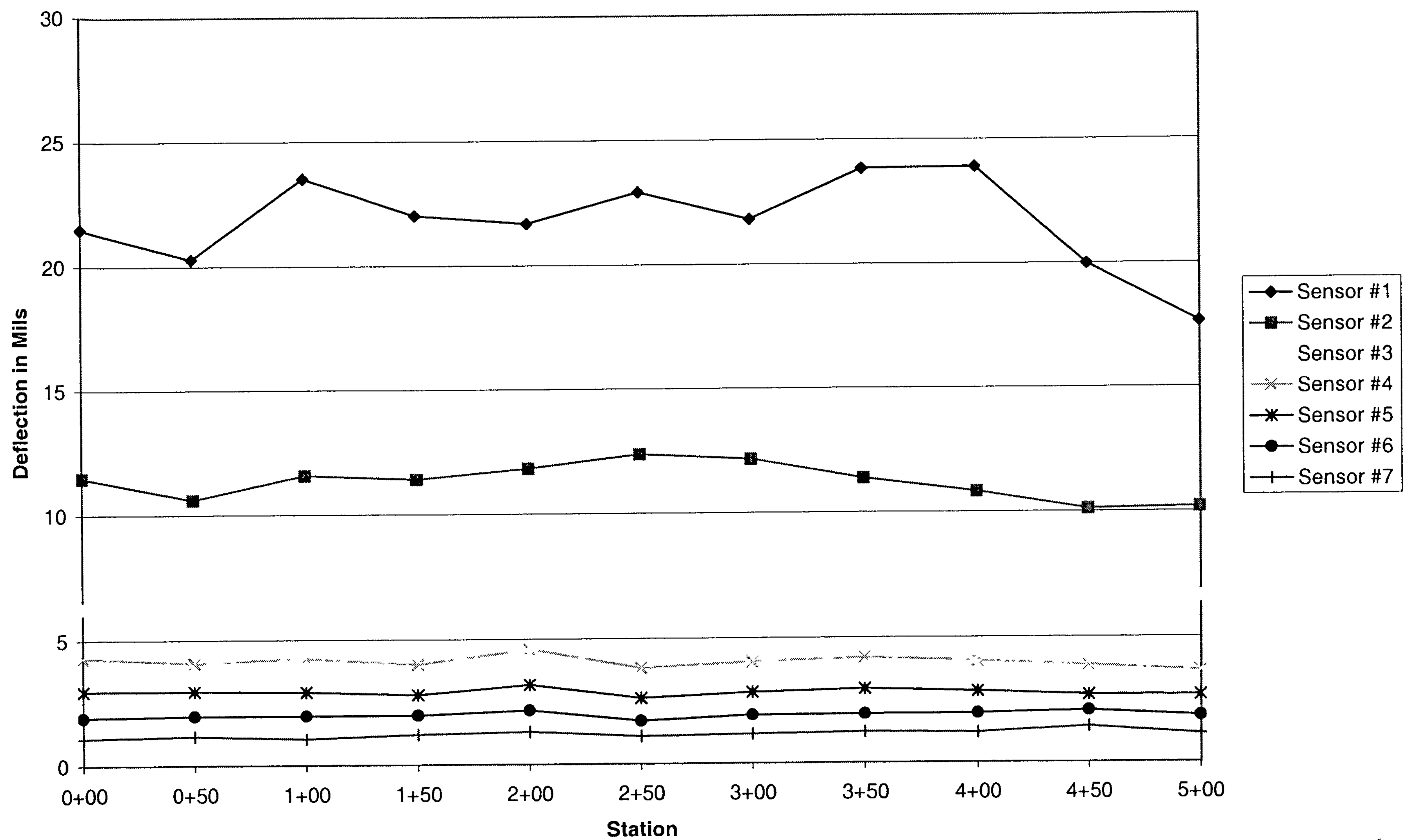


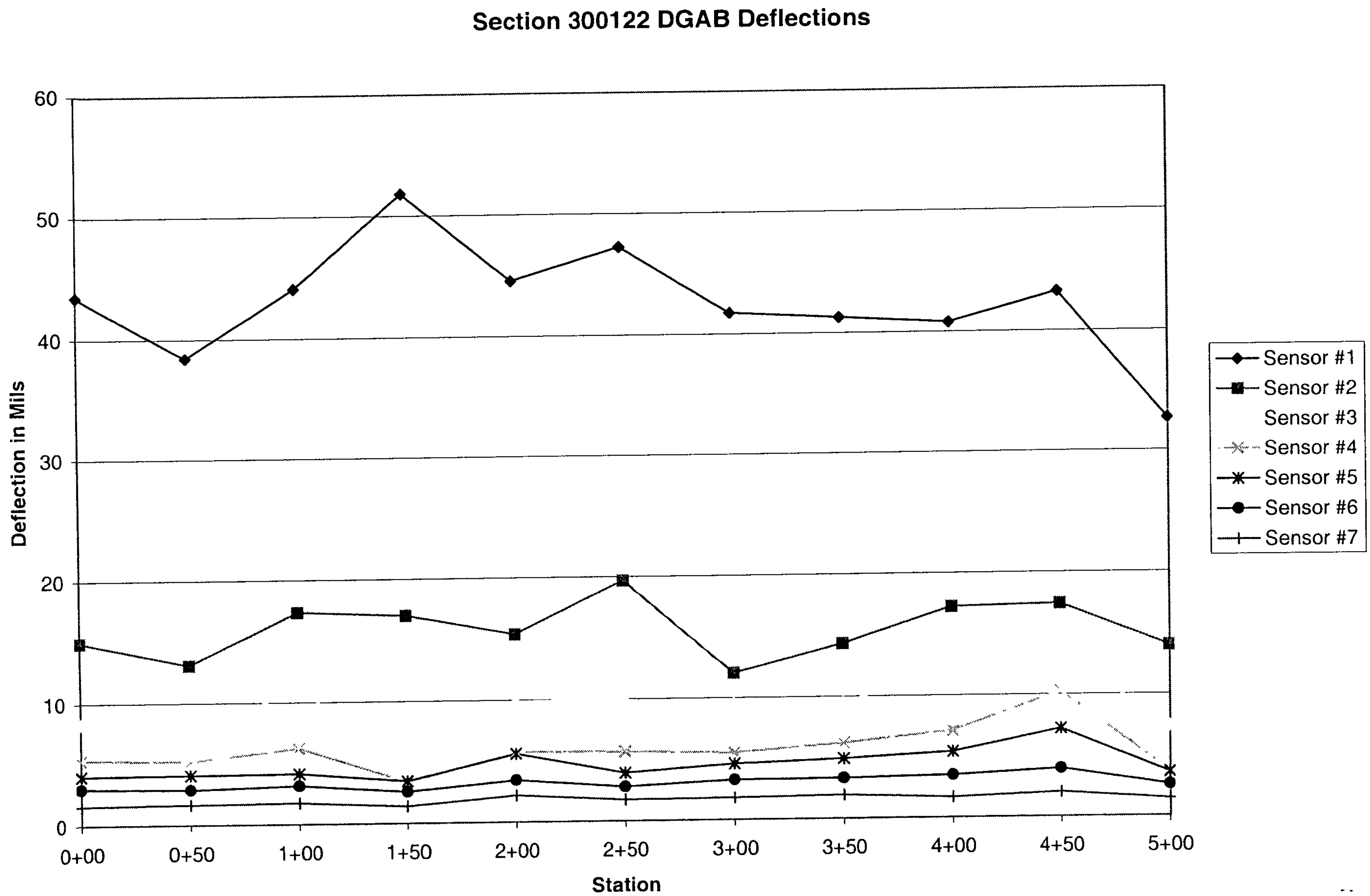
Section 300119 DGAB Deflections
35
30
25
20
15
10
5
0
Deflection in Mils
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7



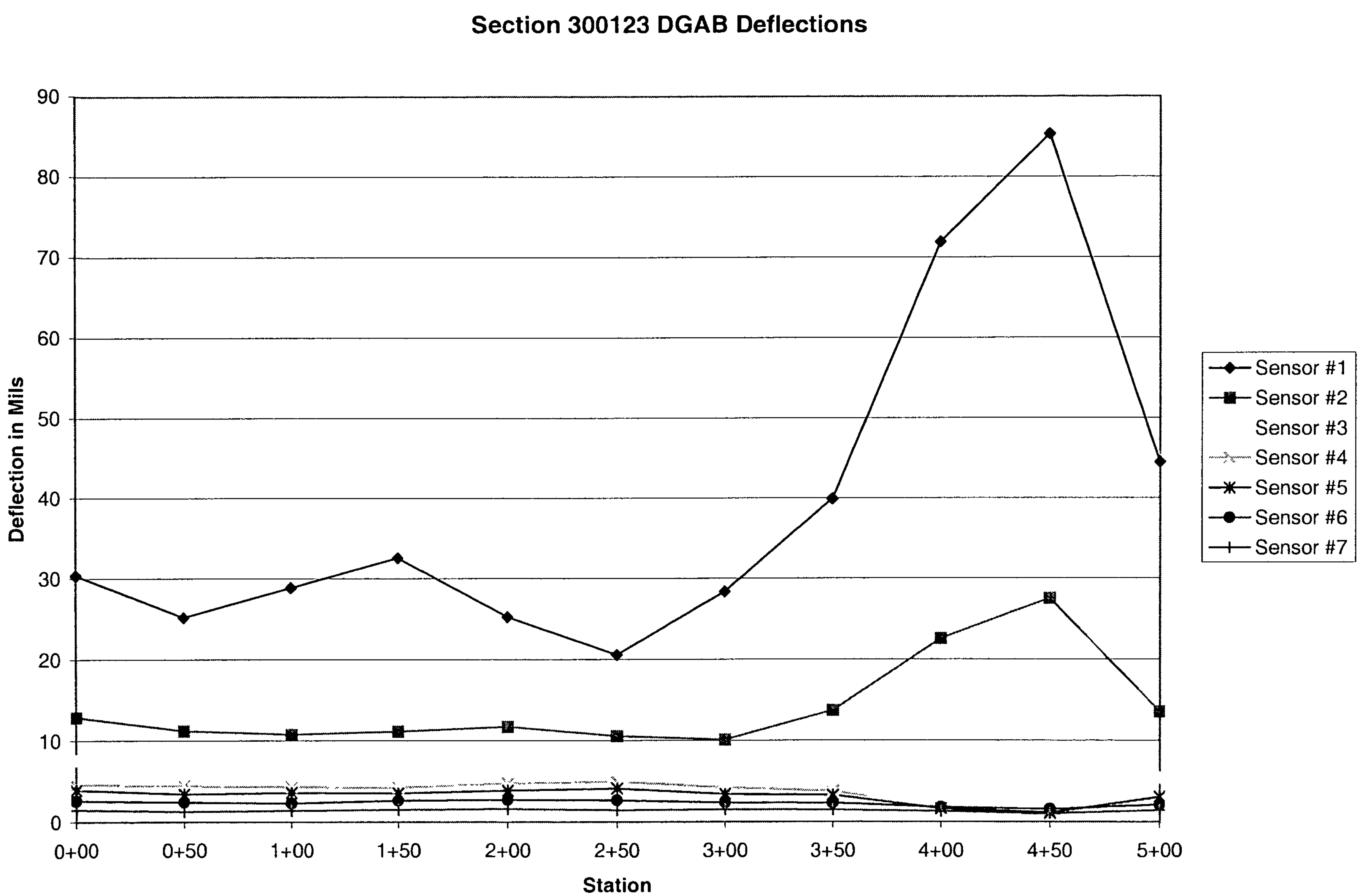
Section 300120 DGAB Deflections
35
30
25
20
15
10
5
0
Deflection in Mils
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7

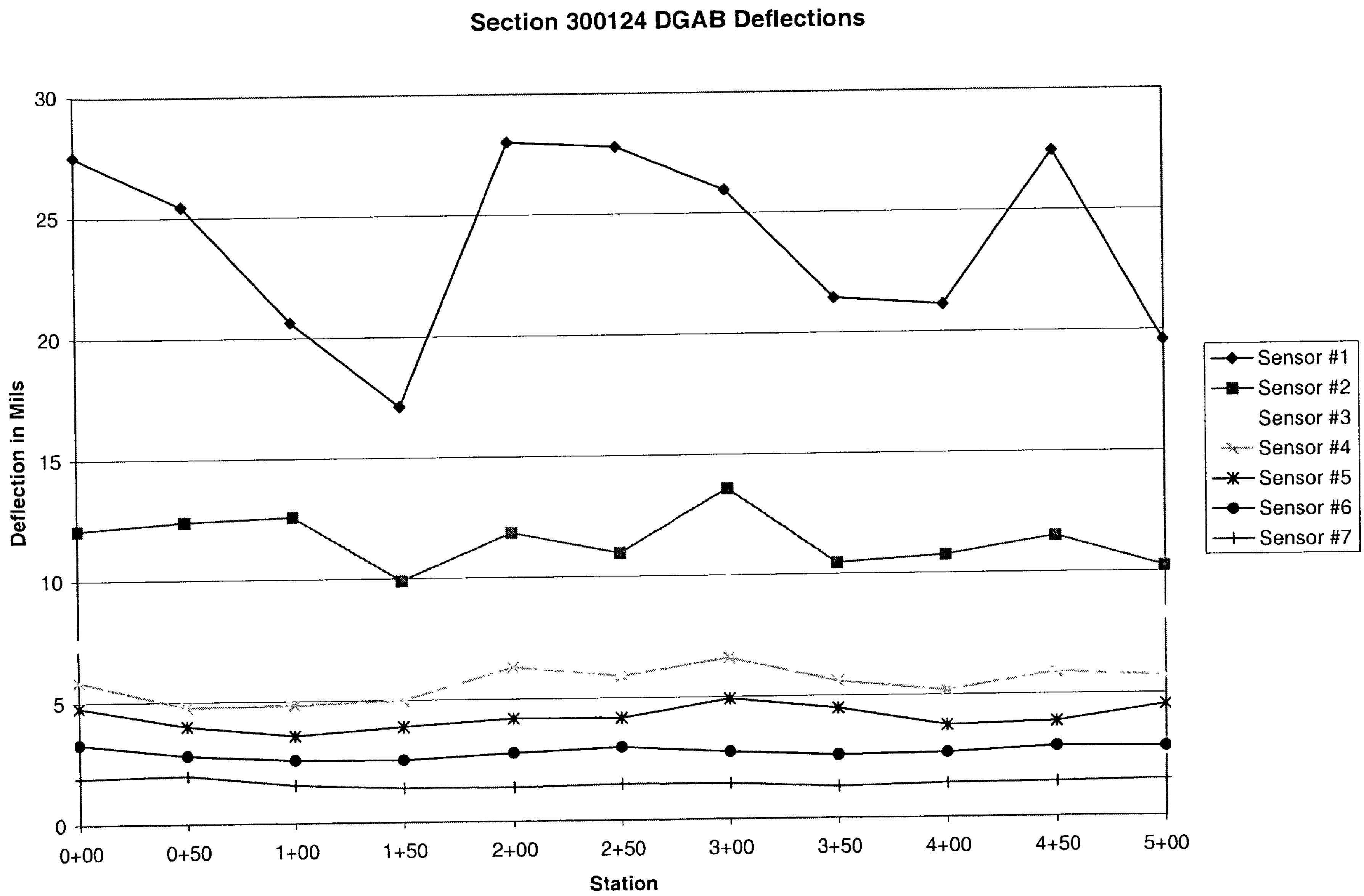
Section 300121 DGAB Deflections



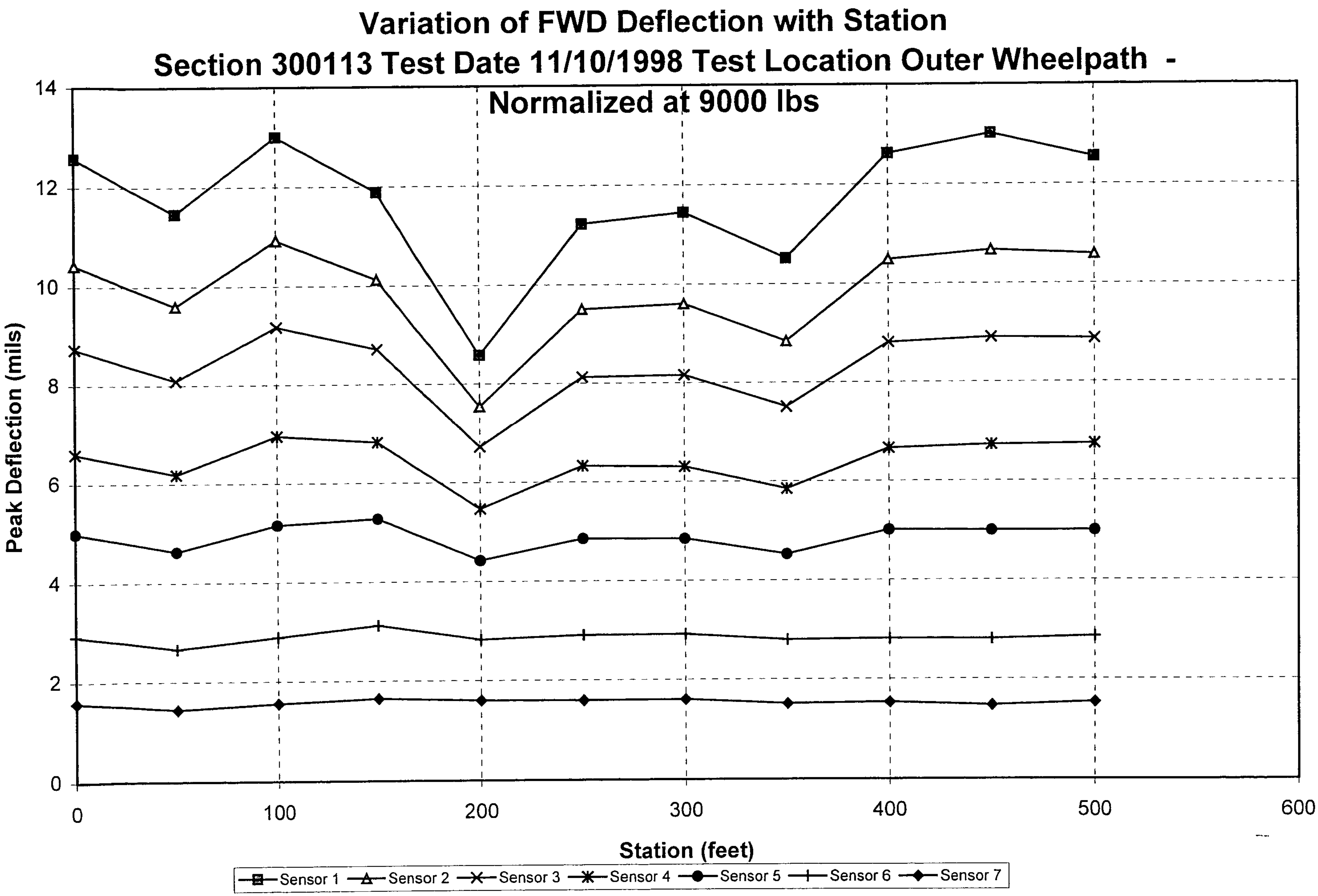


Section 300122 DGAB Deflections
Deflection in Mils
60
50
40
30
20
10
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7

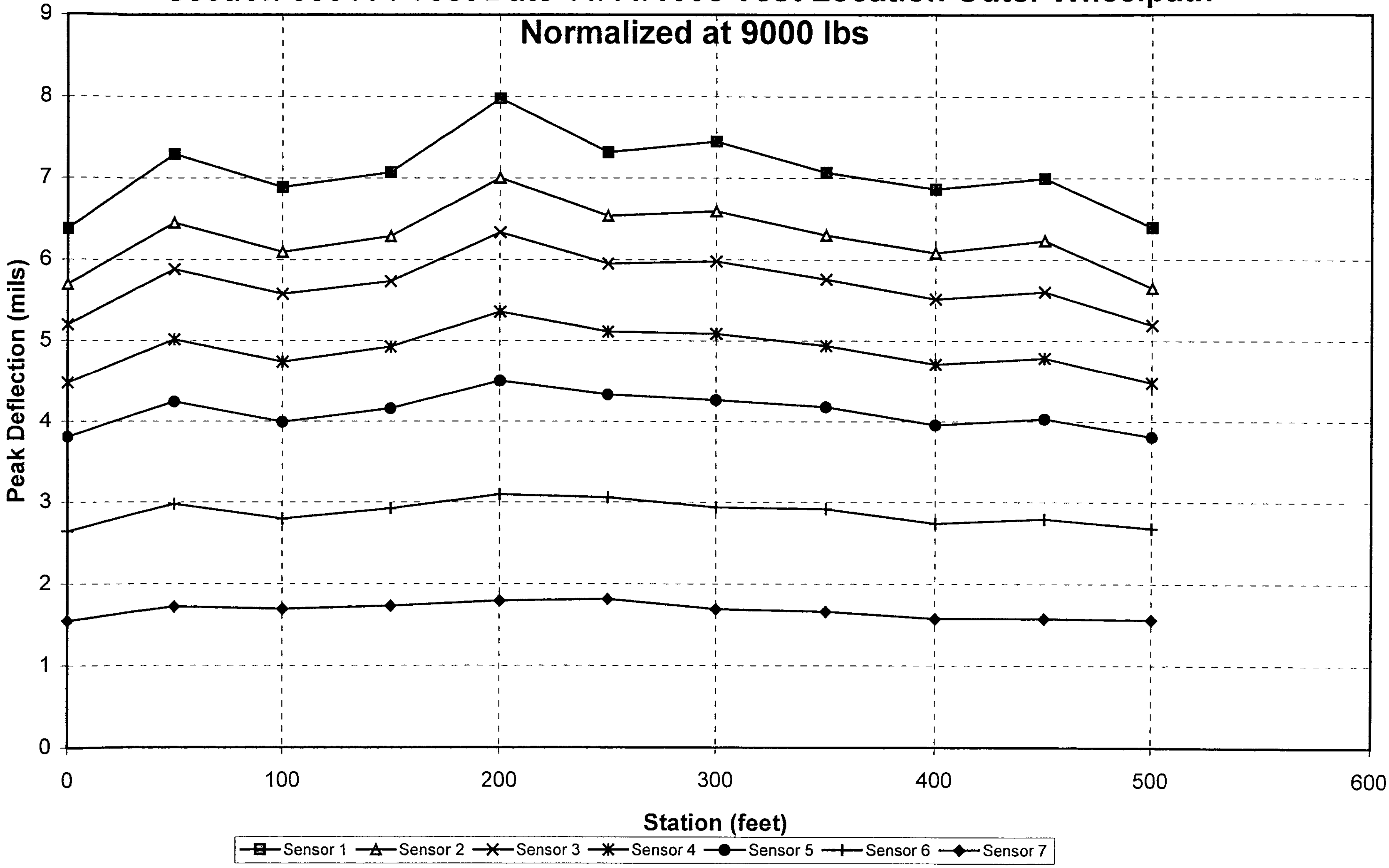

Section 300123 DGAB Deflections
Deflection in Mils
90
80
70
60
50
40
30
20
10
0
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7

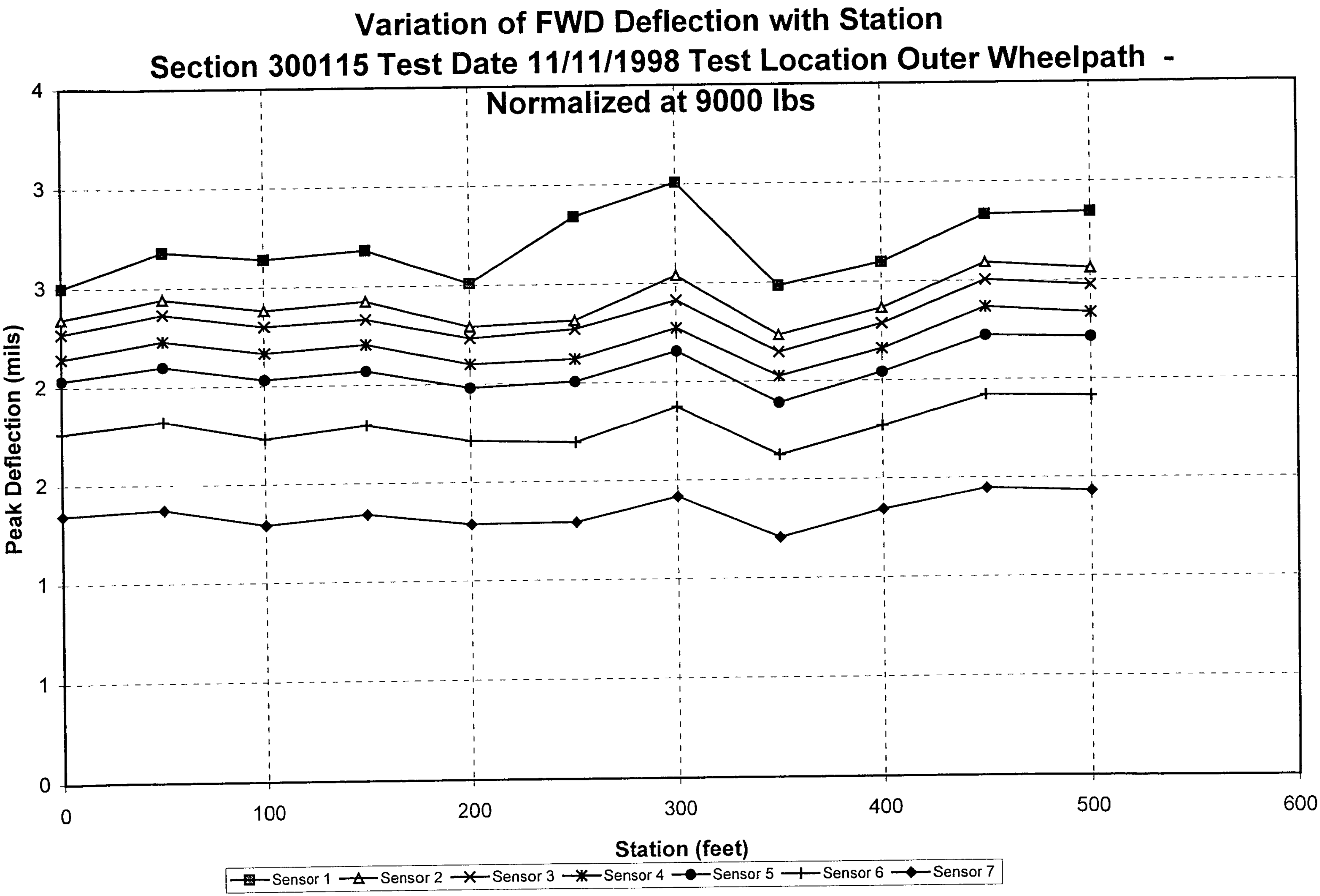

Section 300124 DGAB Deflections
30
25
20
15
10
5
0
Deflection in Mils
0+00
0+50
1+00
1+50
2+00
2+50
3+00
3+50
4+00
4+50
5+00
Station
Sensor #1
Sensor #2
Sensor #3
Sensor #4
Sensor #5
Sensor #6
Sensor #7

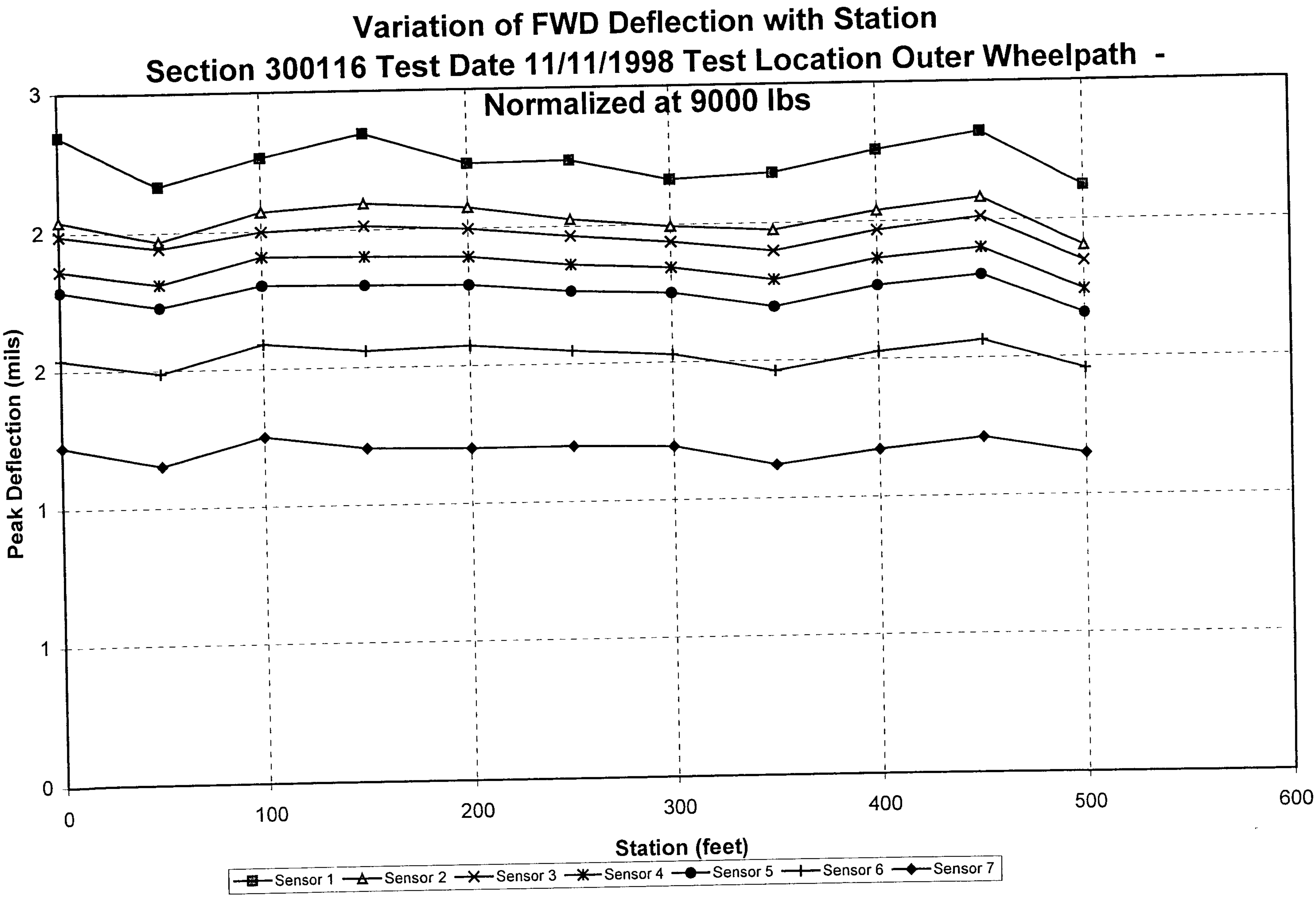
AC Surface Deflection Profiles
1998 & 1999

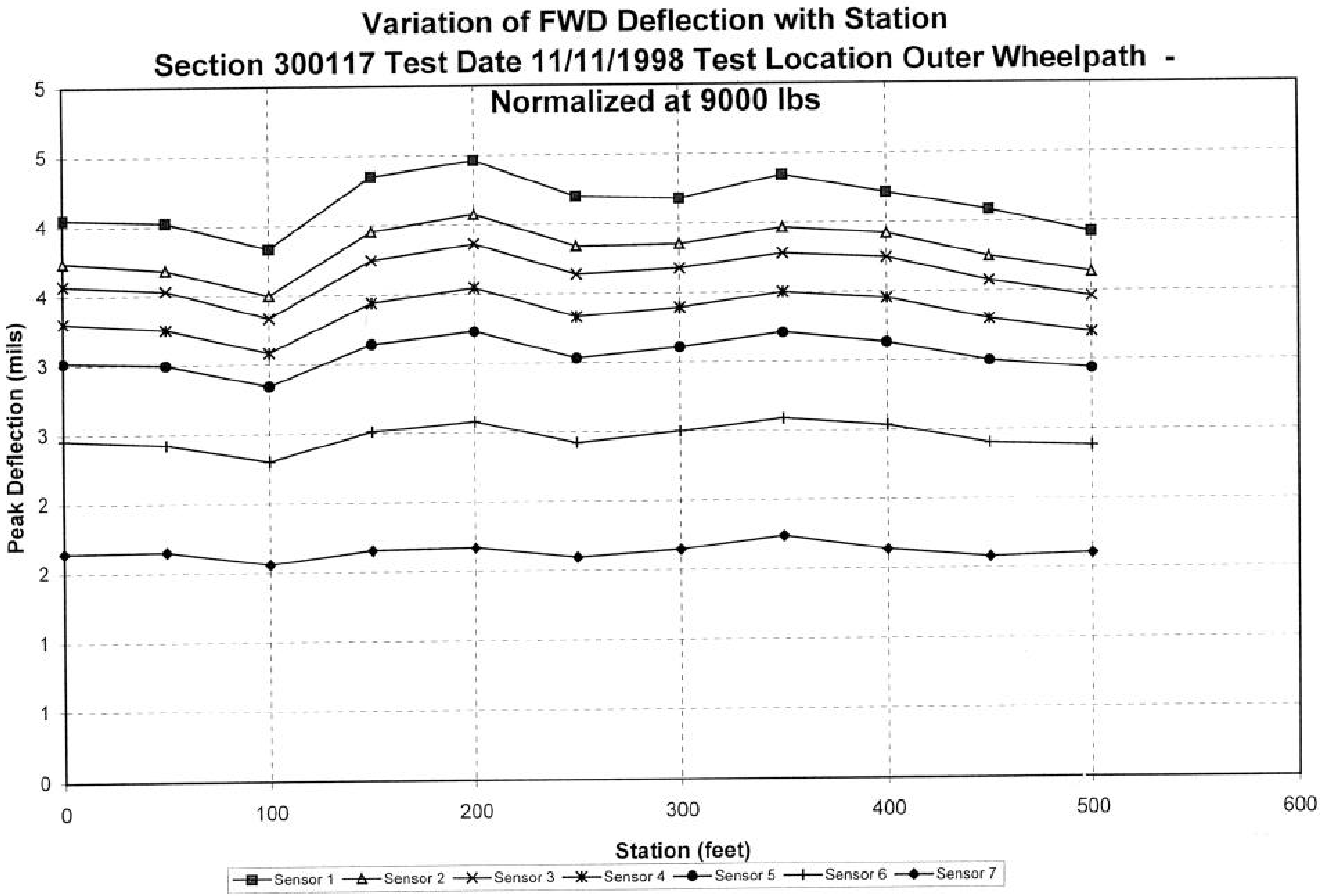

Variation of FWD Deflection with Station
Section 300113 Test Date 11/10/1998 Test Location Outer Wheelpath - Normalized at 9000 lbs
Peak Deflection (mils)
Station (feet)
0
2
4
6
8
10
12
14
0
100
200
300
400
500
600
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7

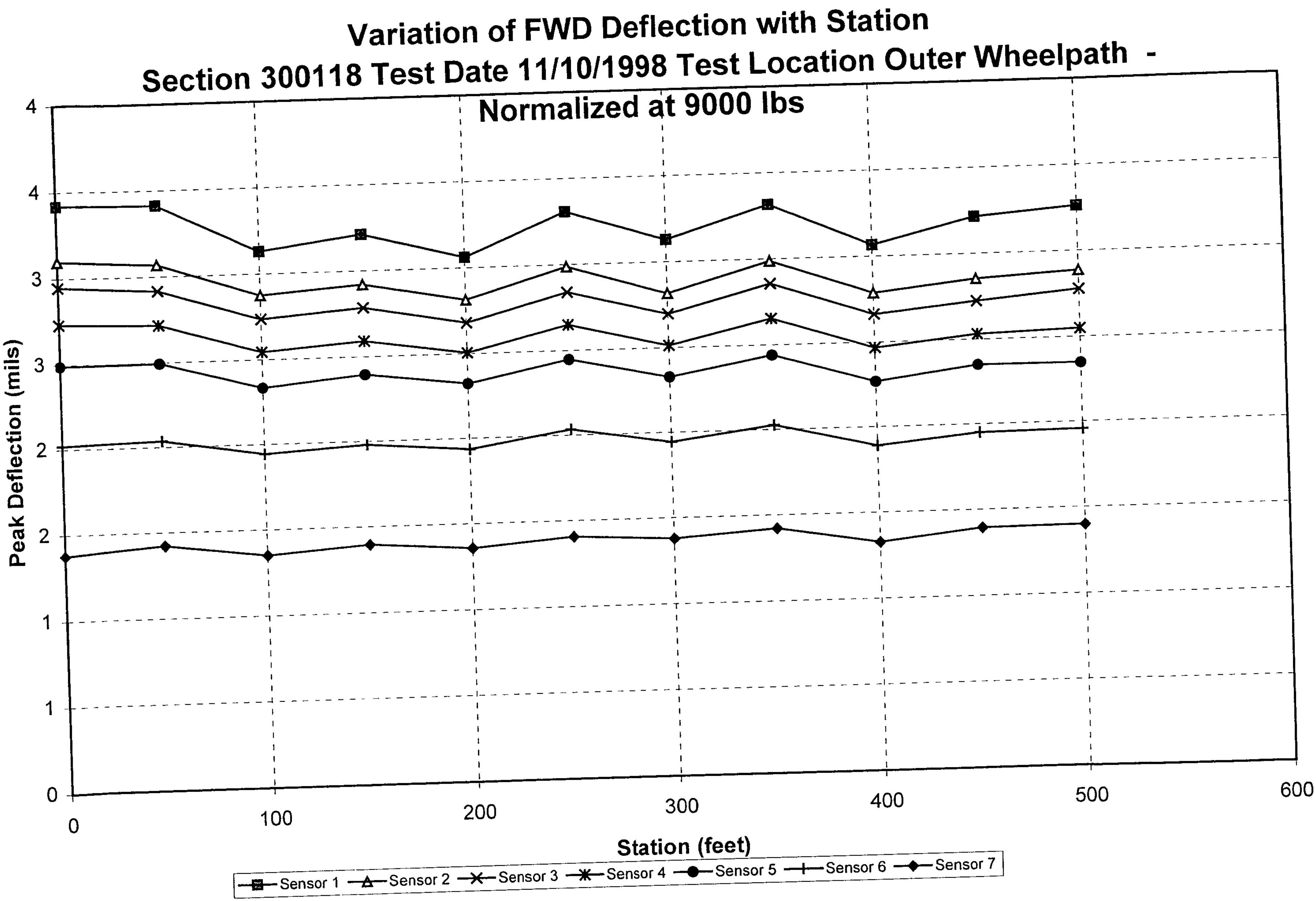
Variation of FWD Deflection with Station
Section 300114 Test Date 11/11/1998 Test Location Outer Wheelpath - Normalized at 9000 lbs

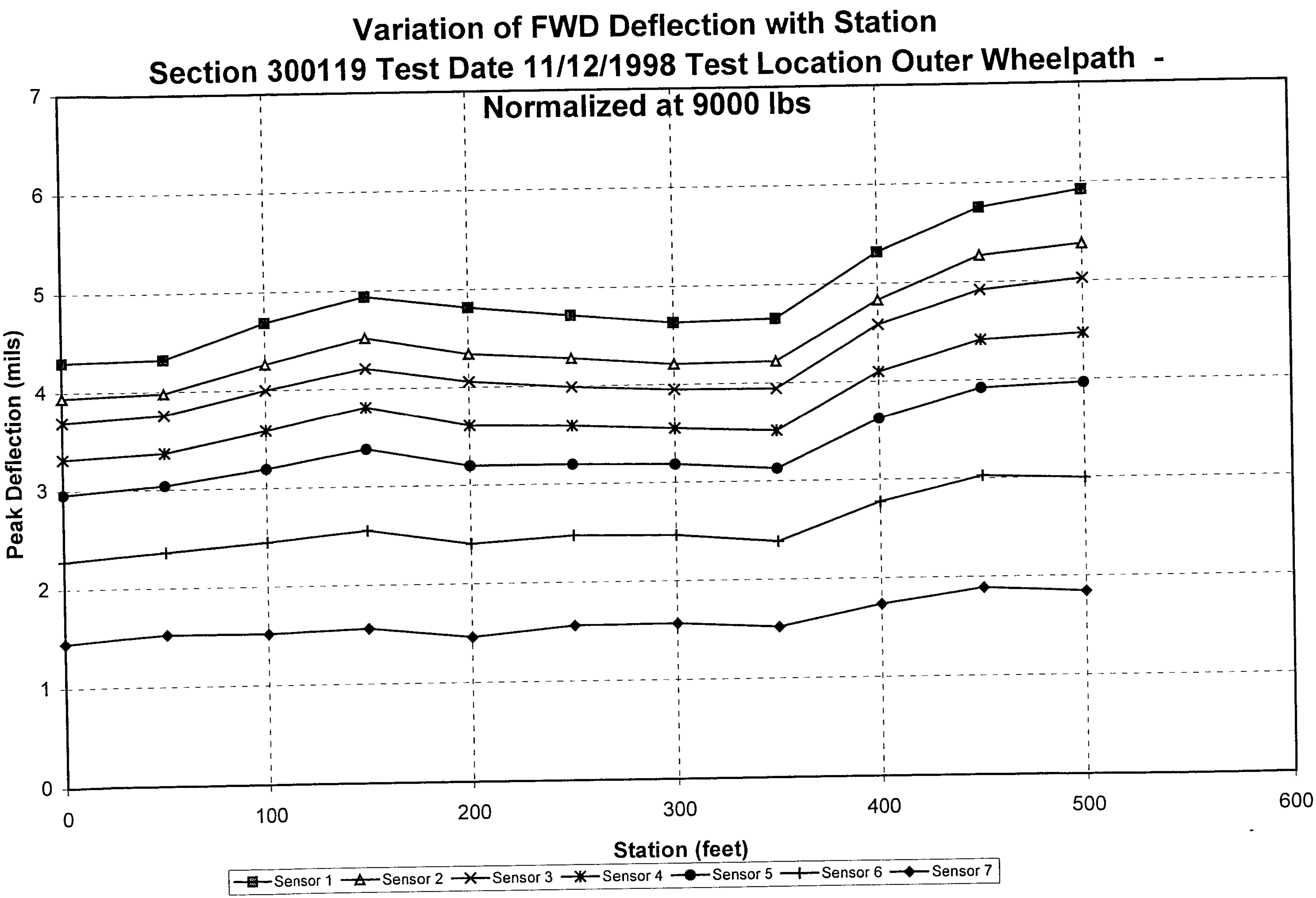


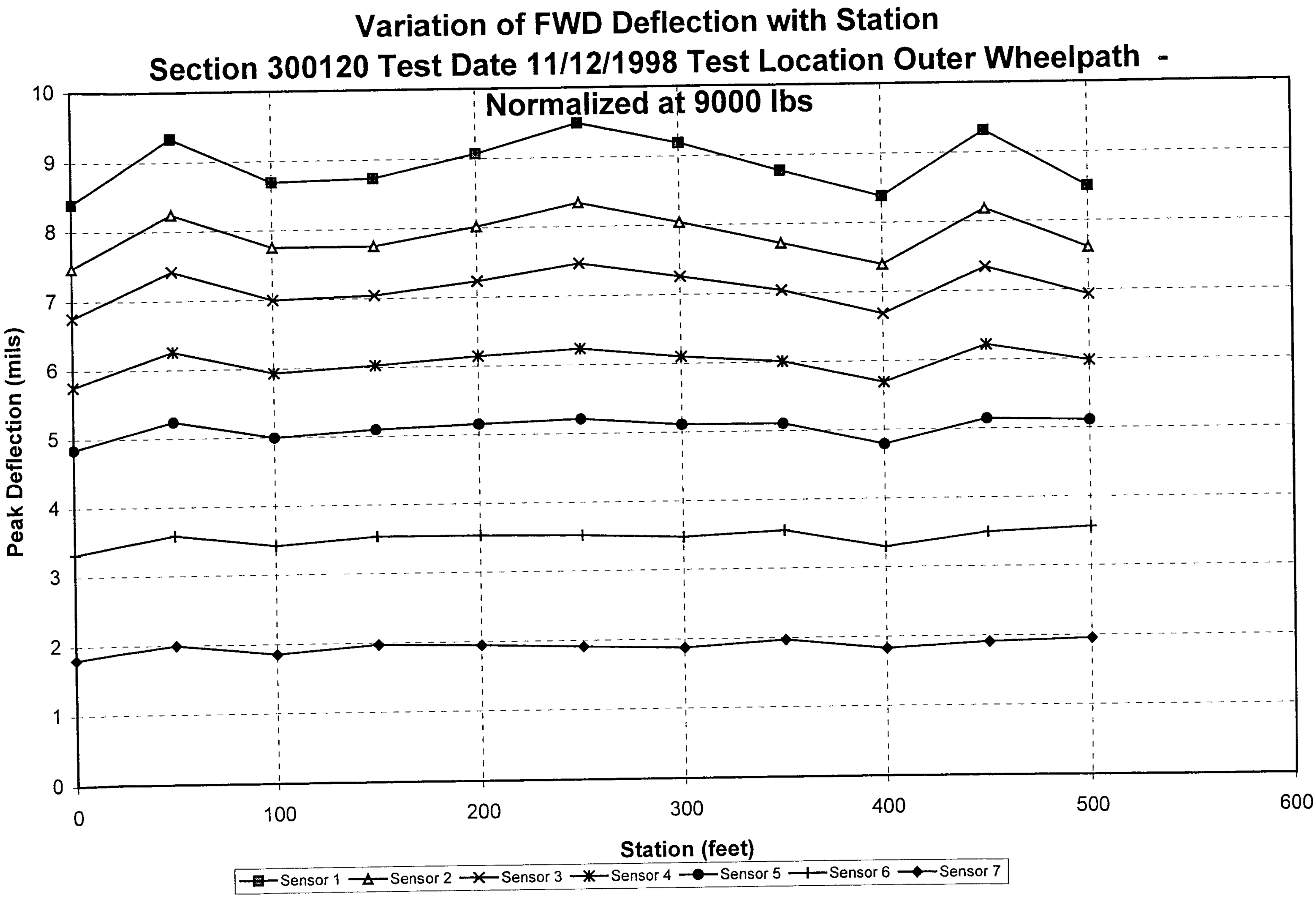

Variation of FWD Deflection with Station
Section 300115 Test Date 11/11/1998 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
4
3
3
2
2
1
1
0
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7

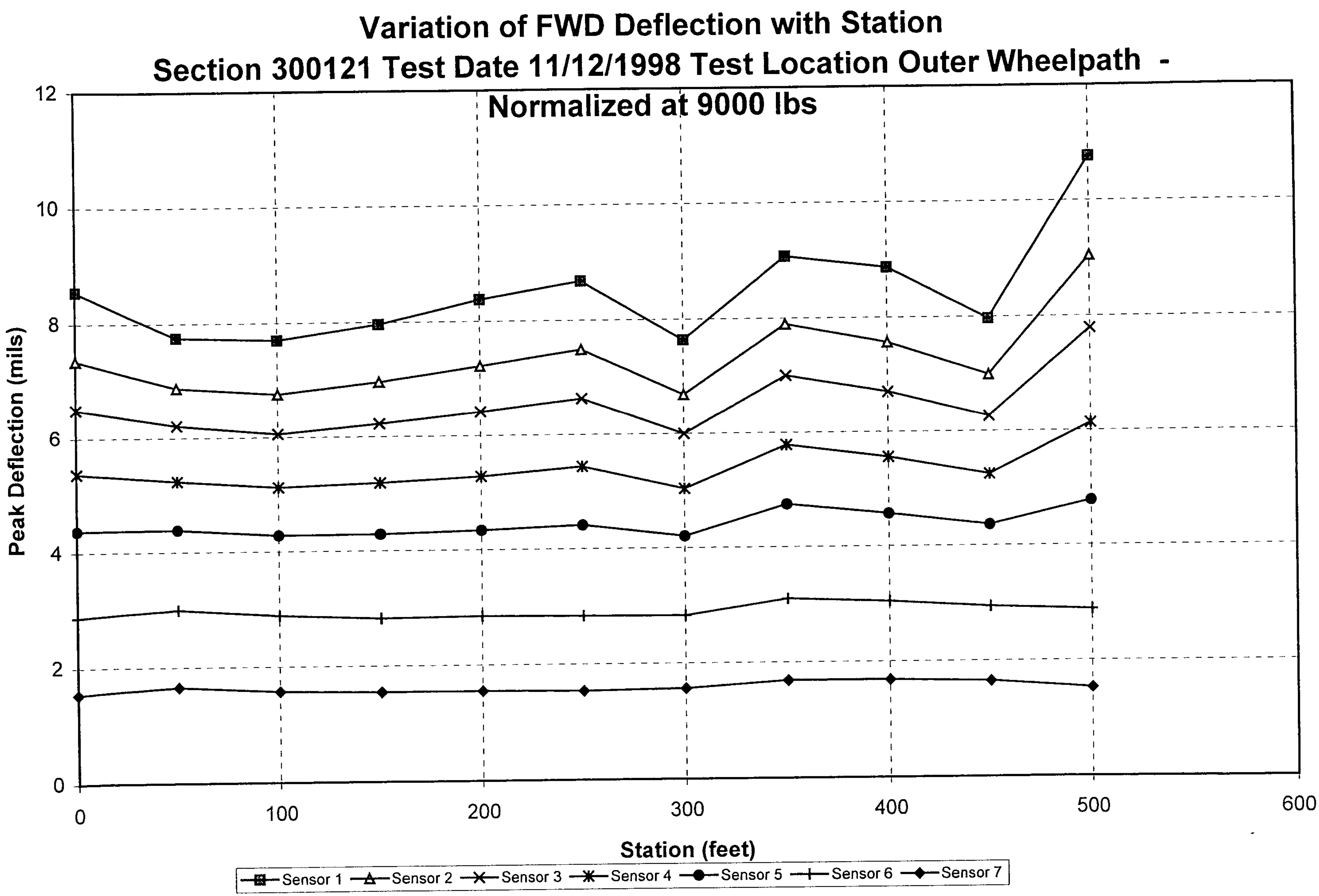

Variation of FWD Deflection with Station
Section 300116 Test Date 11/11/1998 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
3
2
2
1
1
0
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7


Variation of FWD Deflection with Station
Section 300117 Test Date 11/11/1998 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
5
5
4
4
3
3
2
2
1
1
0
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7

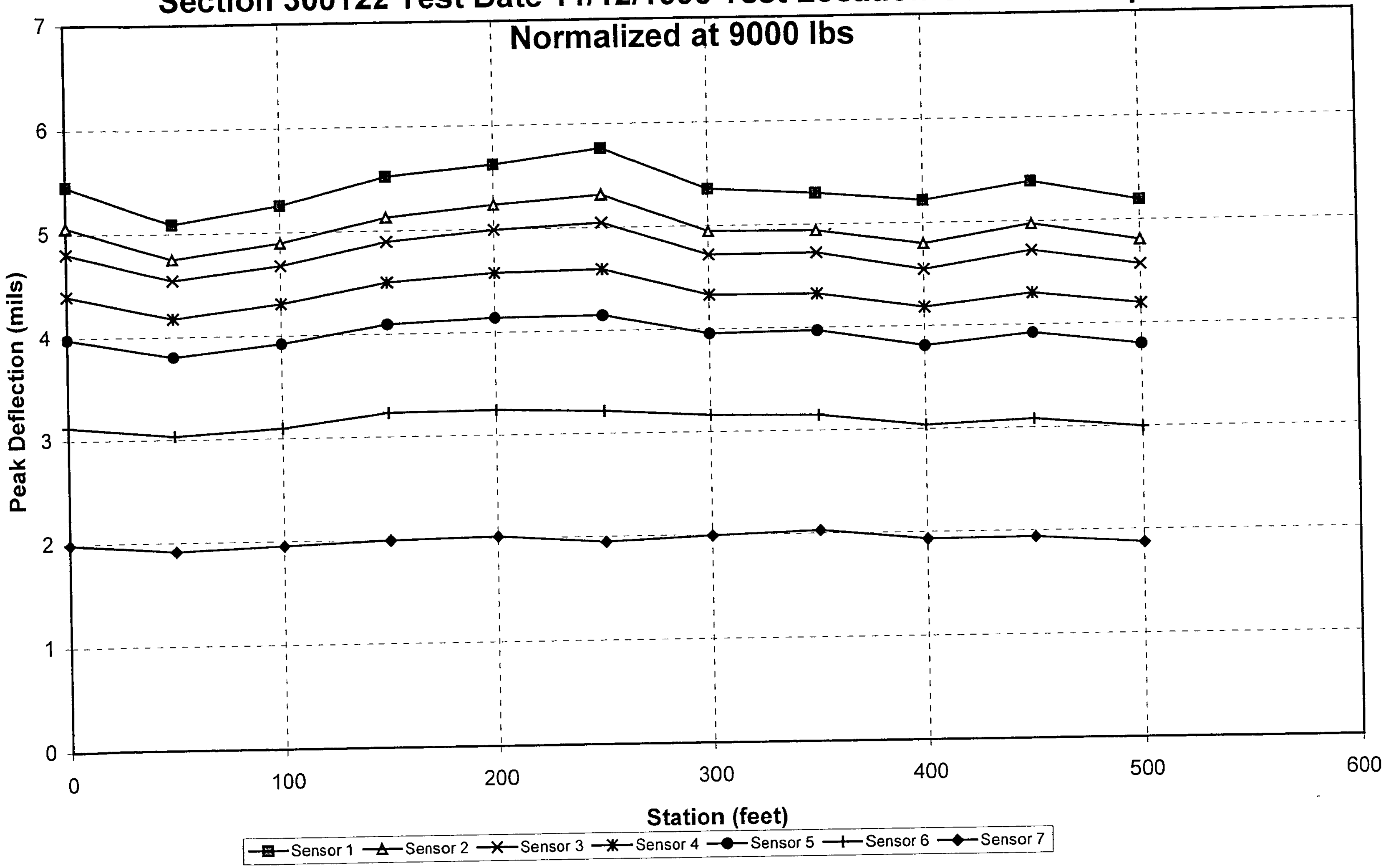

Variation of FWD Deflection with Station
Section 300118 Test Date 11/10/1998 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
4
4
3
3
2
2
1
1
0
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7


Variation of FWD Deflection with Station
Section 300119 Test Date 11/12/1998 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
0
1
2
3
4
5
6
7
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7

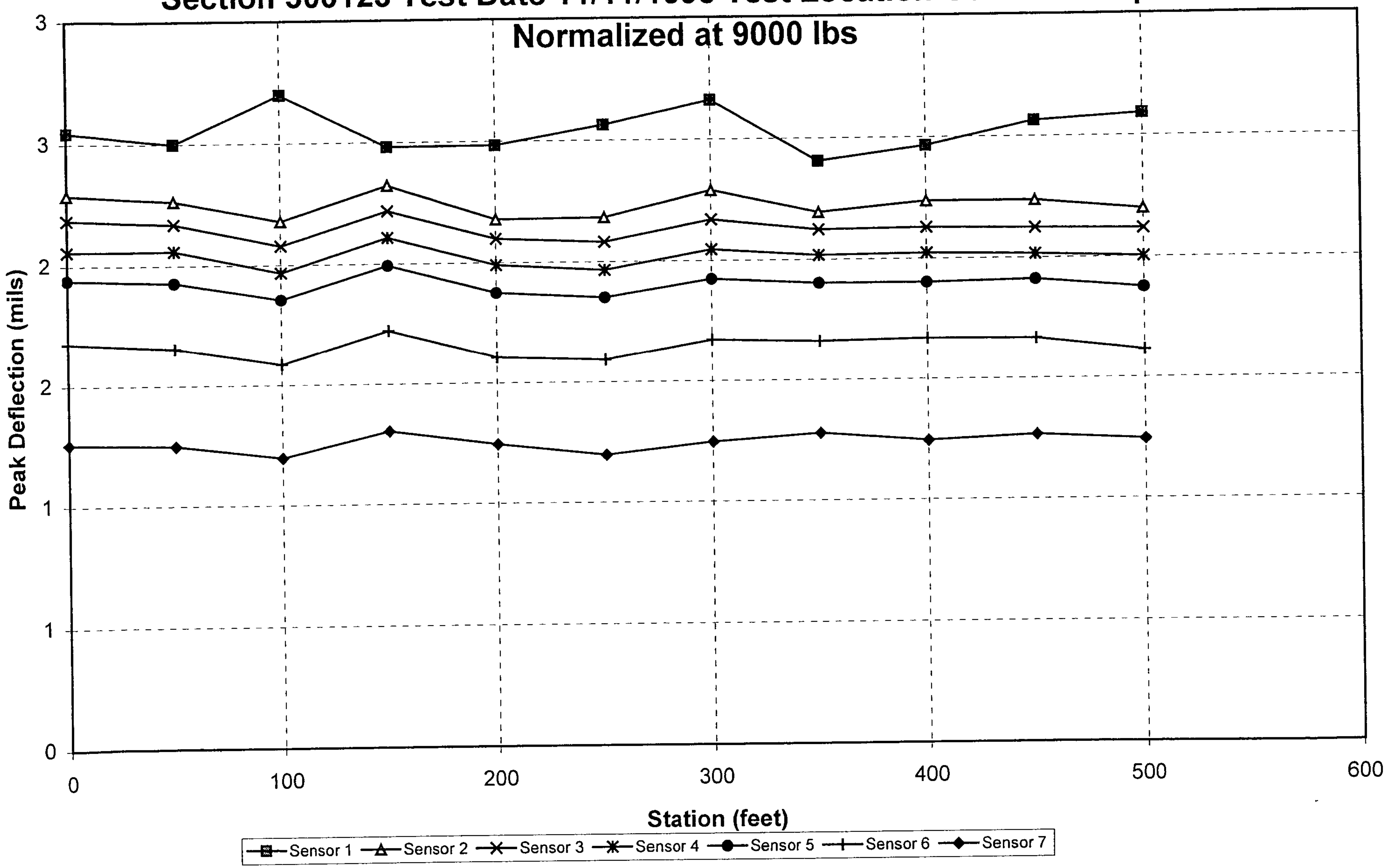

Variation of FWD Deflection with Station
Section 300120 Test Date 11/12/1998 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7

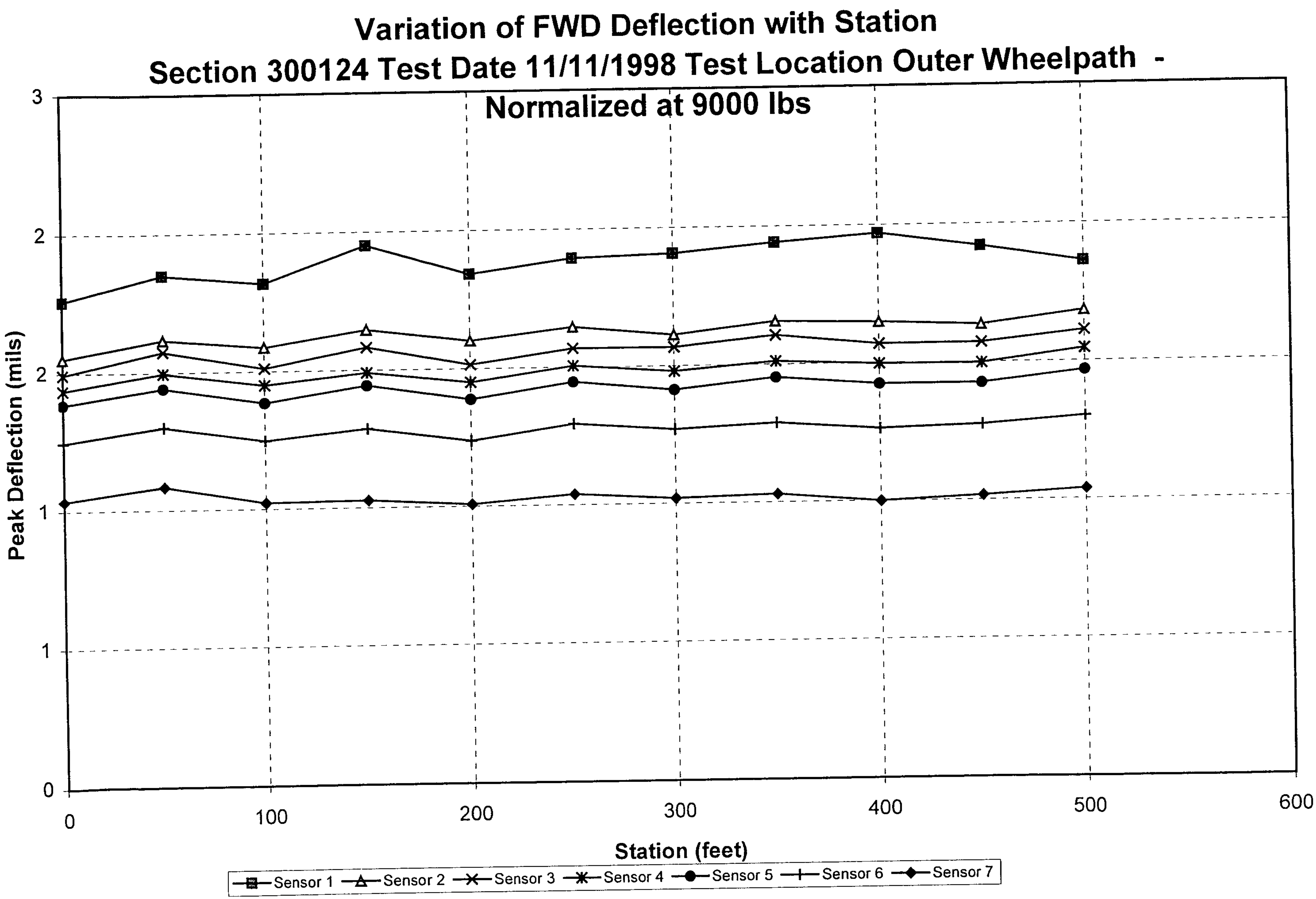

Variation of FWD Deflection with Station
Section 300121 Test Date 11/12/1998 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
0
2
4
6
8
10
12
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7

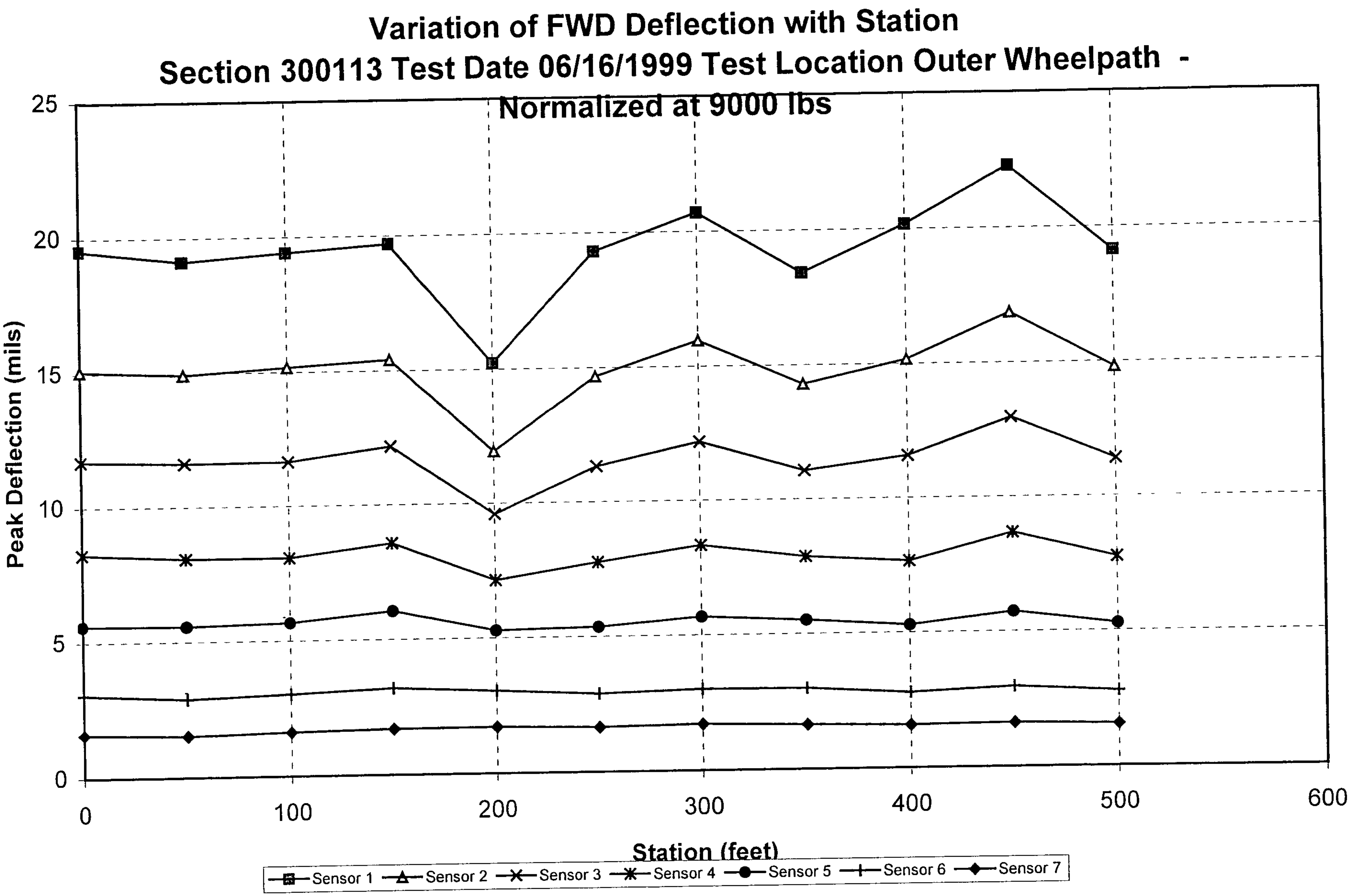
Variation of FWD Deflection with Station
Section 300122 Test Date 11/12/1998 Test Location Outer Wheelpath - Normalized at 9000 lbs



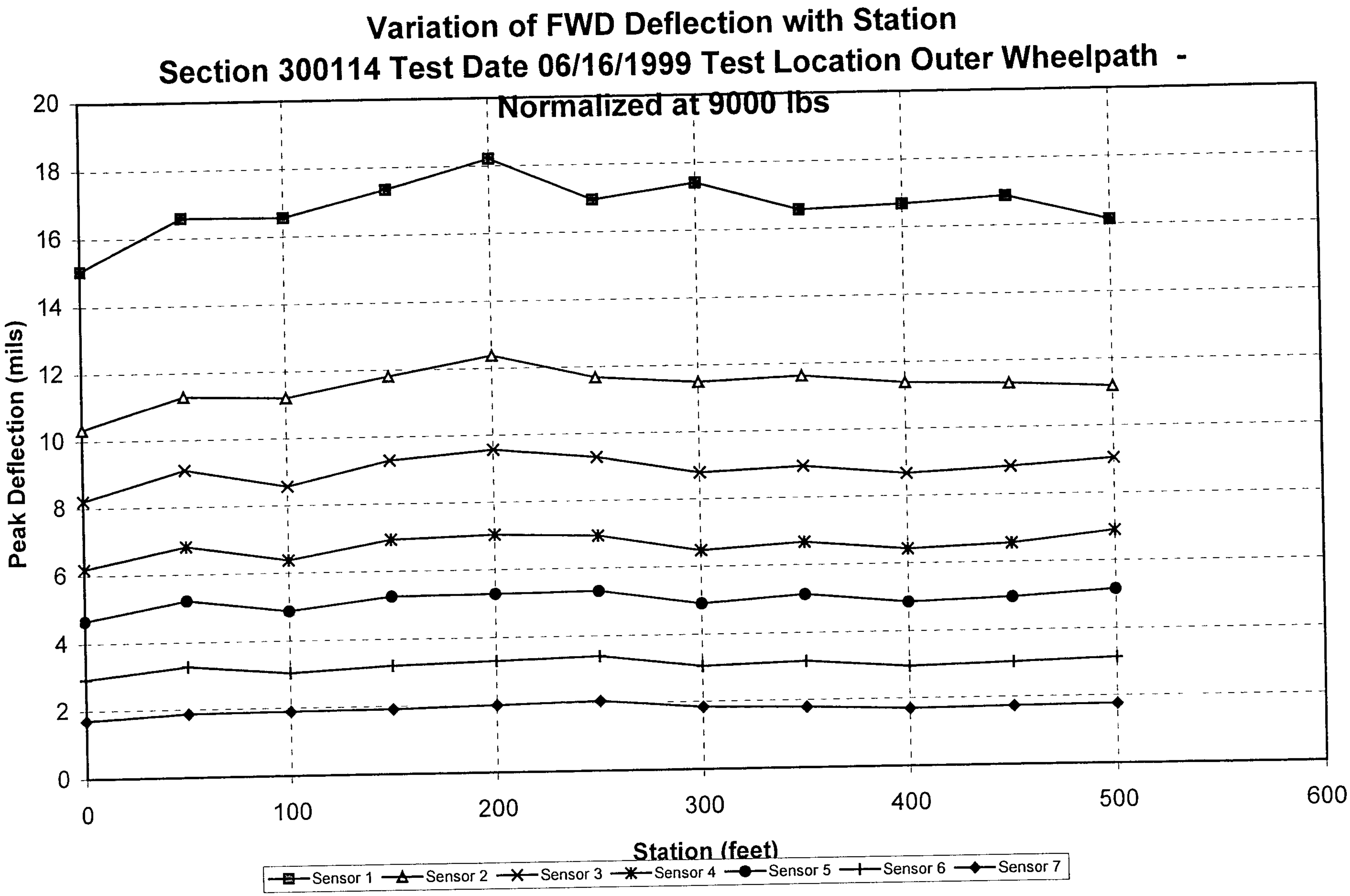
Variation of FWD Deflection with Station
Section 300123 Test Date 11/11/1998 Test Location Outer Wheelpath - Normalized at 9000 lbs



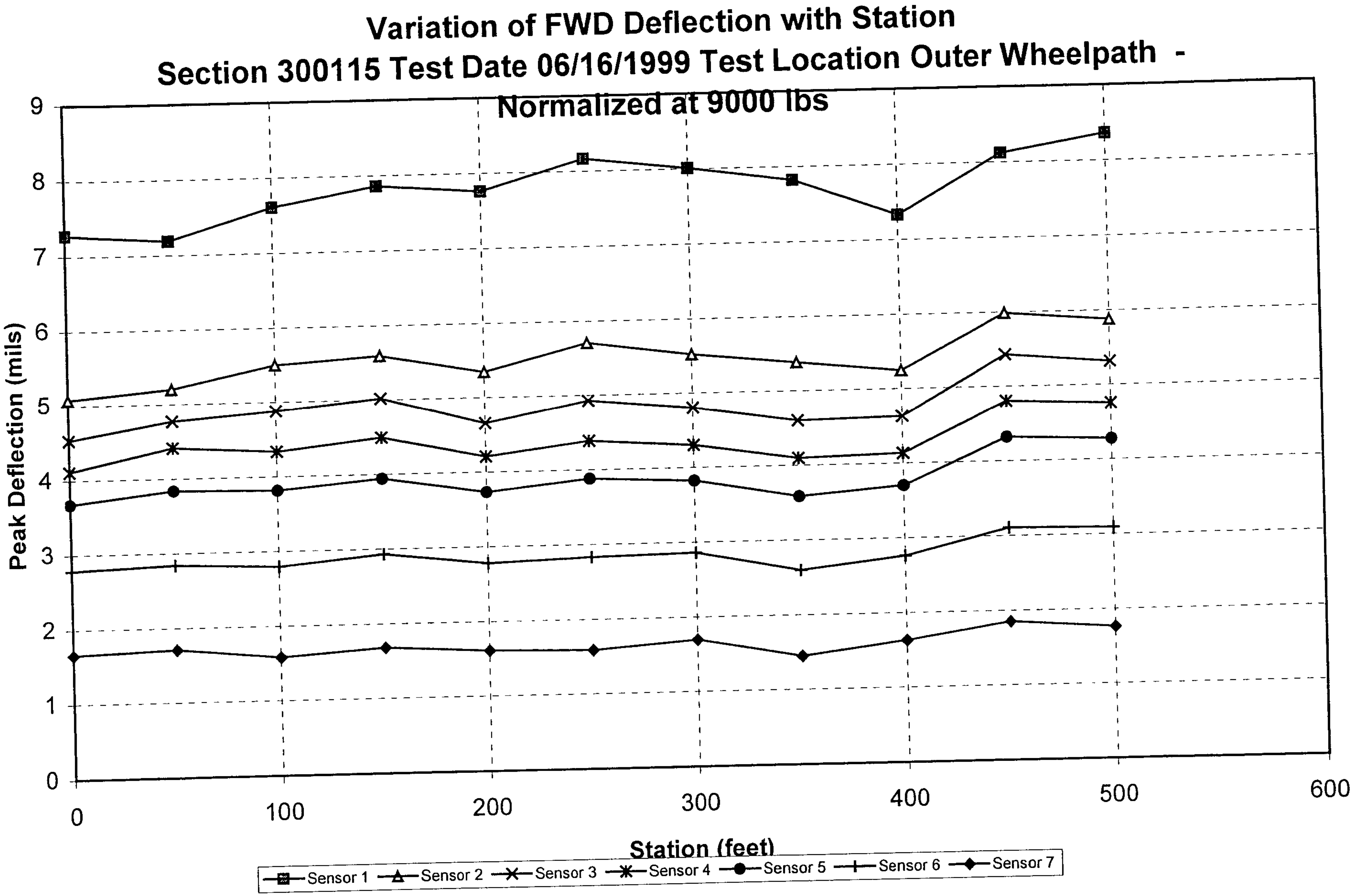

Variation of FWD Deflection with Station
Section 300124 Test Date 11/11/1998 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
3
2
2
1
1
0
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7



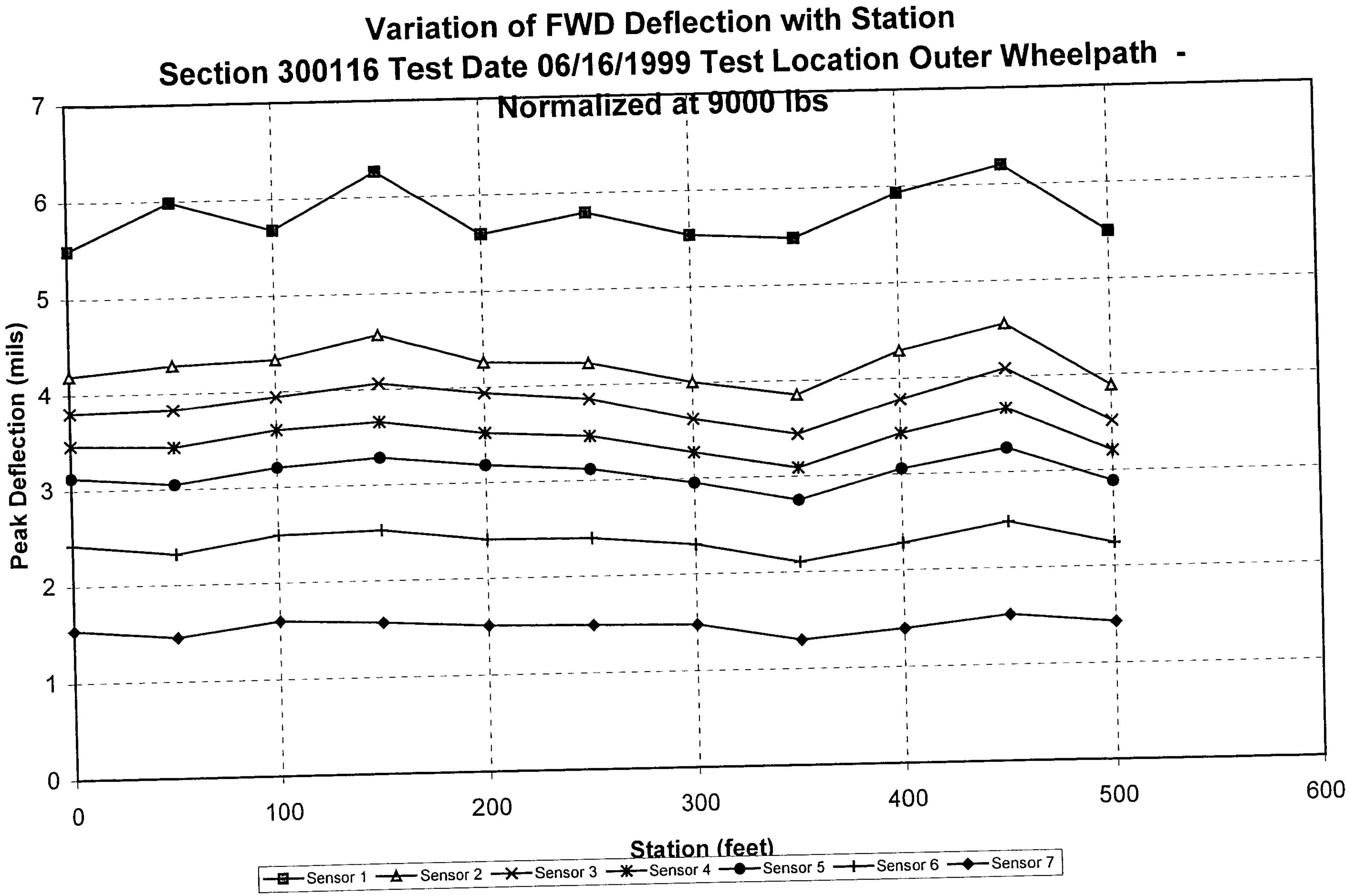
AC Surface Deflection Profiles - June 1999



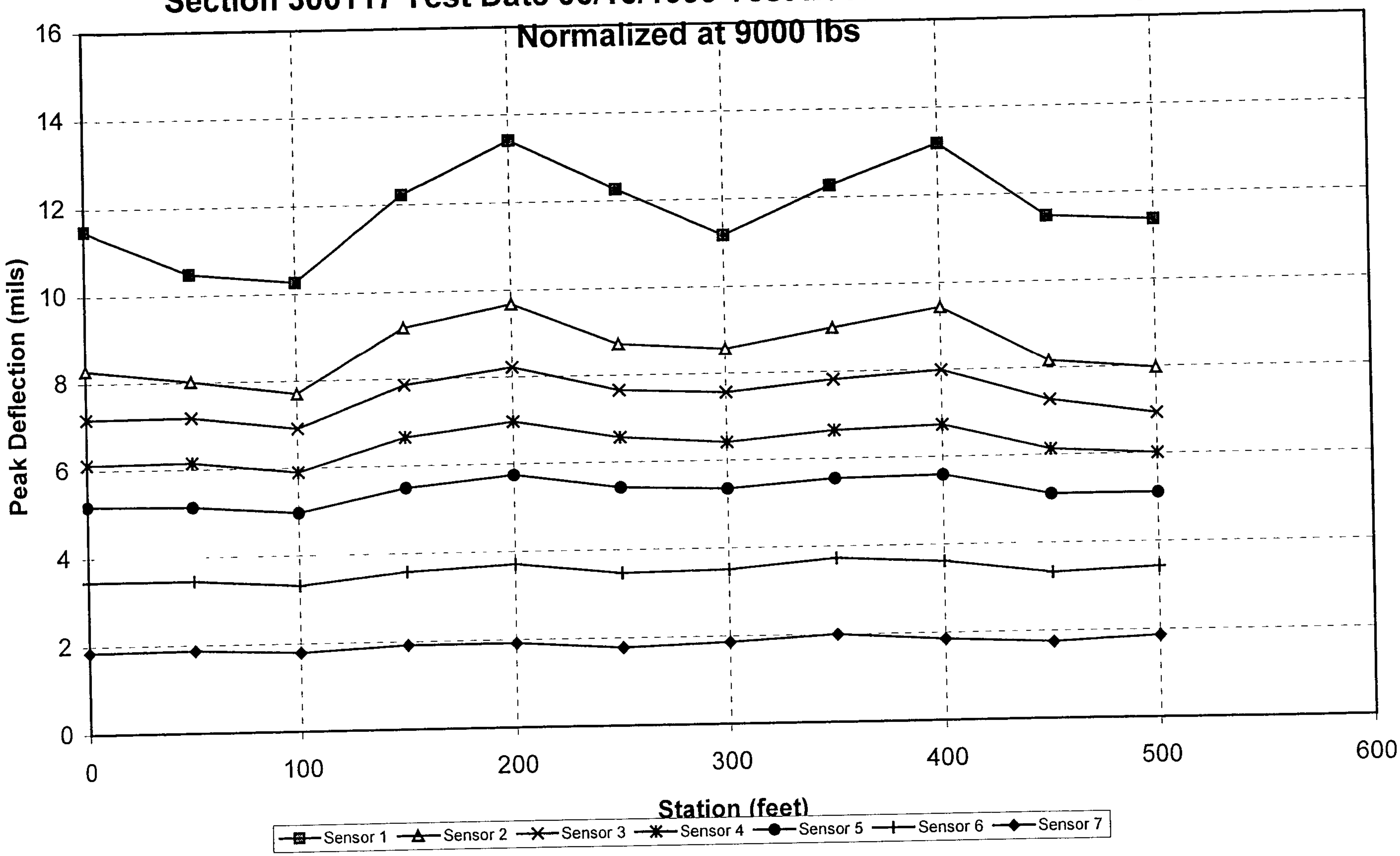
Variation of FWD Deflection with Station
Section 300114 Test Date 06/16/1999 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
20
18
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7

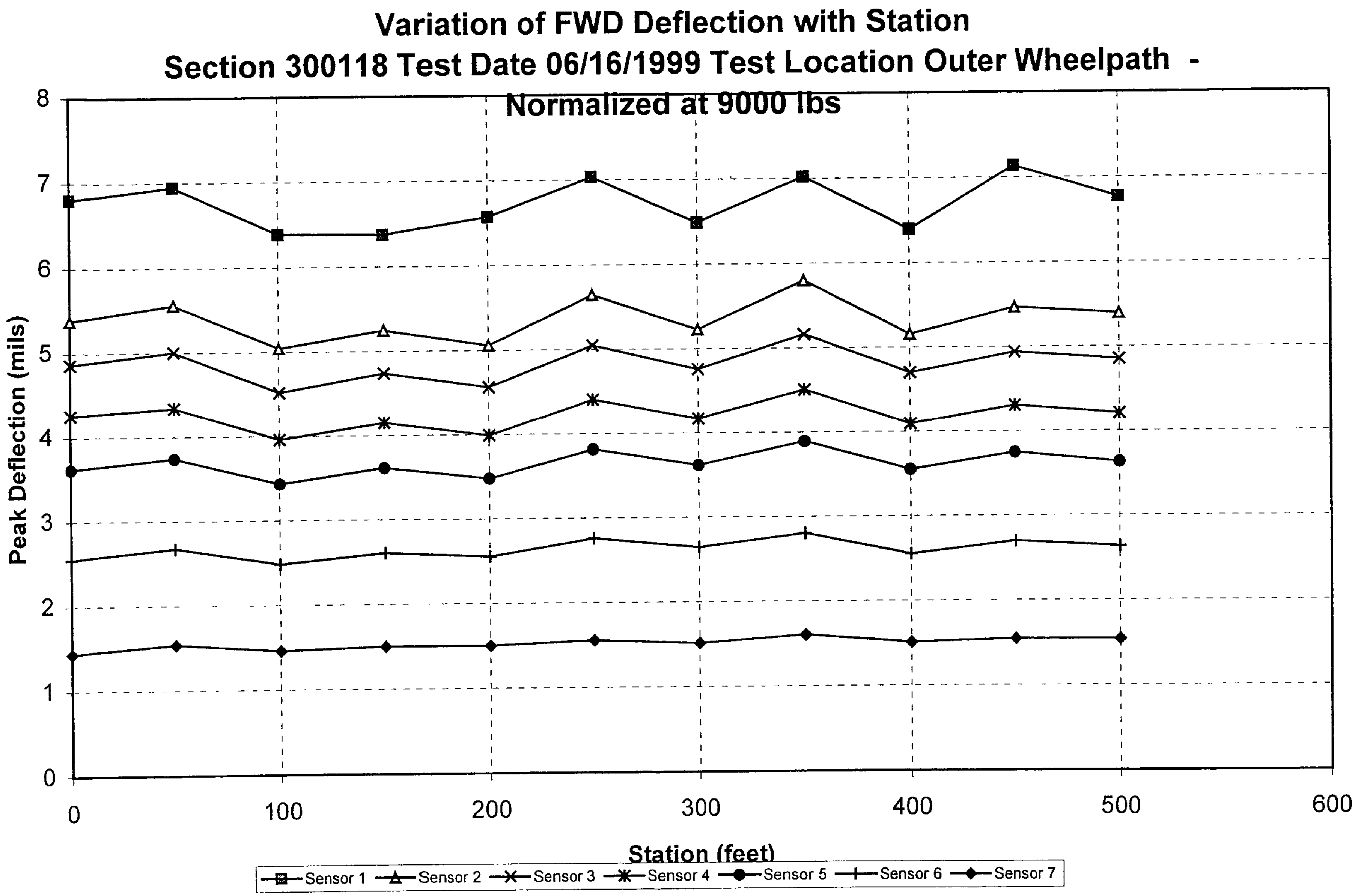


Variation of FWD Deflection with Station
Section 300115 Test Date 06/16/1999 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
0
1
2
3
4
5
6
7
8
9
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7

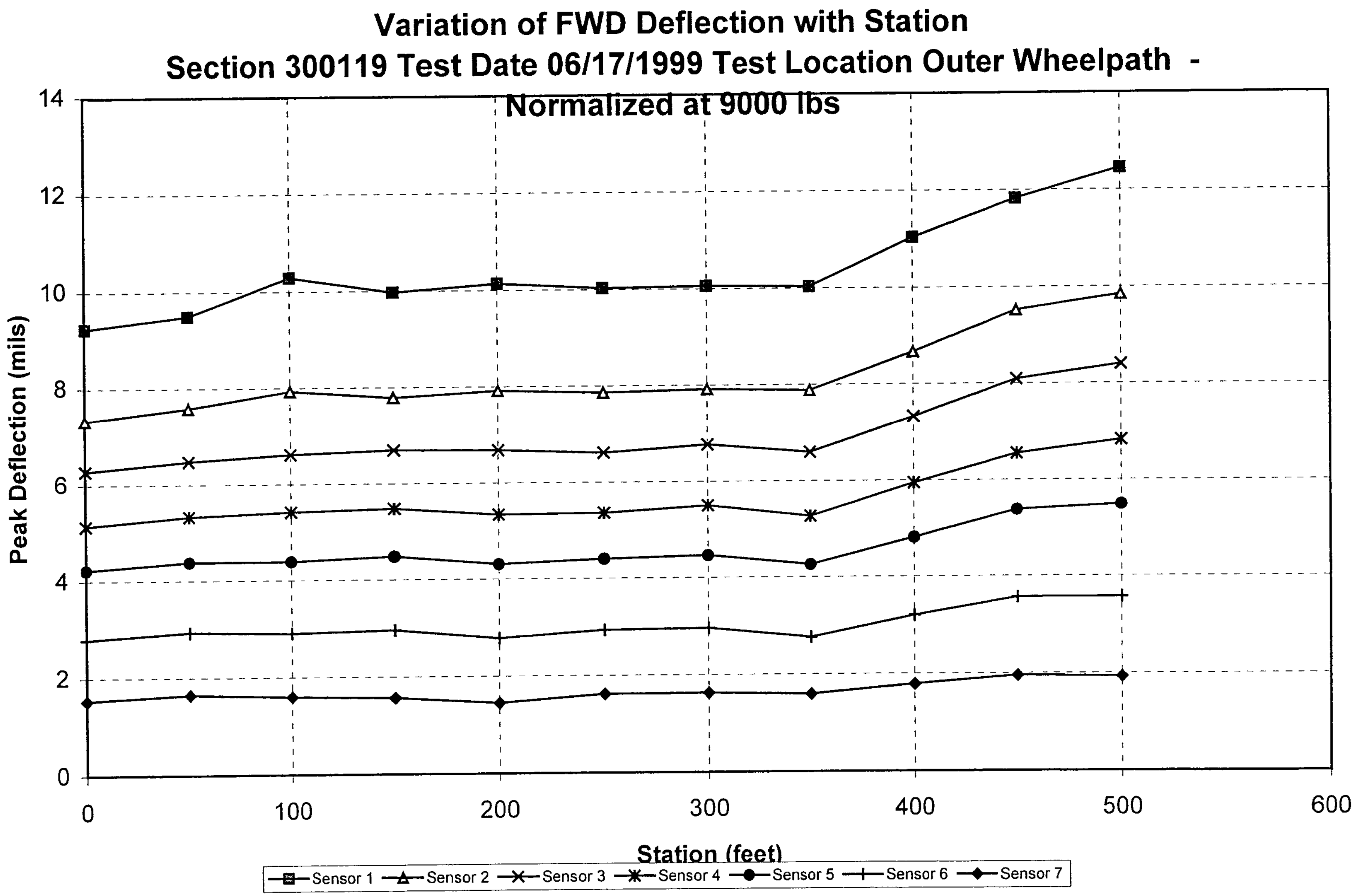

Variation of FWD Deflection with Station
Section 300116 Test Date 06/16/1999 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
0
1
2
3
4
5
6
7
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7

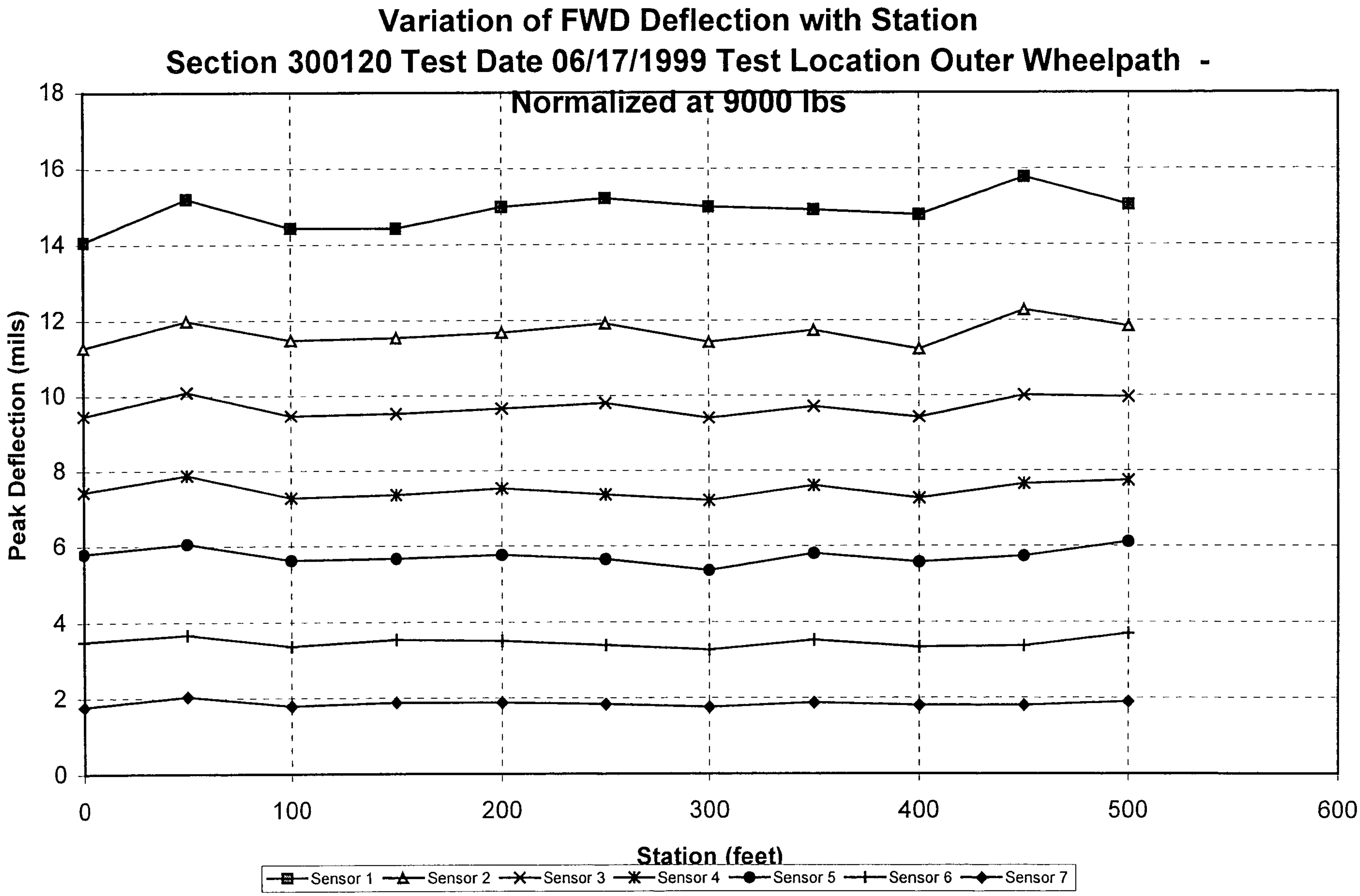
Variation of FWD Deflection with Station
Section 300117 Test Date 06/16/1999 Test Location Outer Wheelpath - Normalized at 9000 lbs



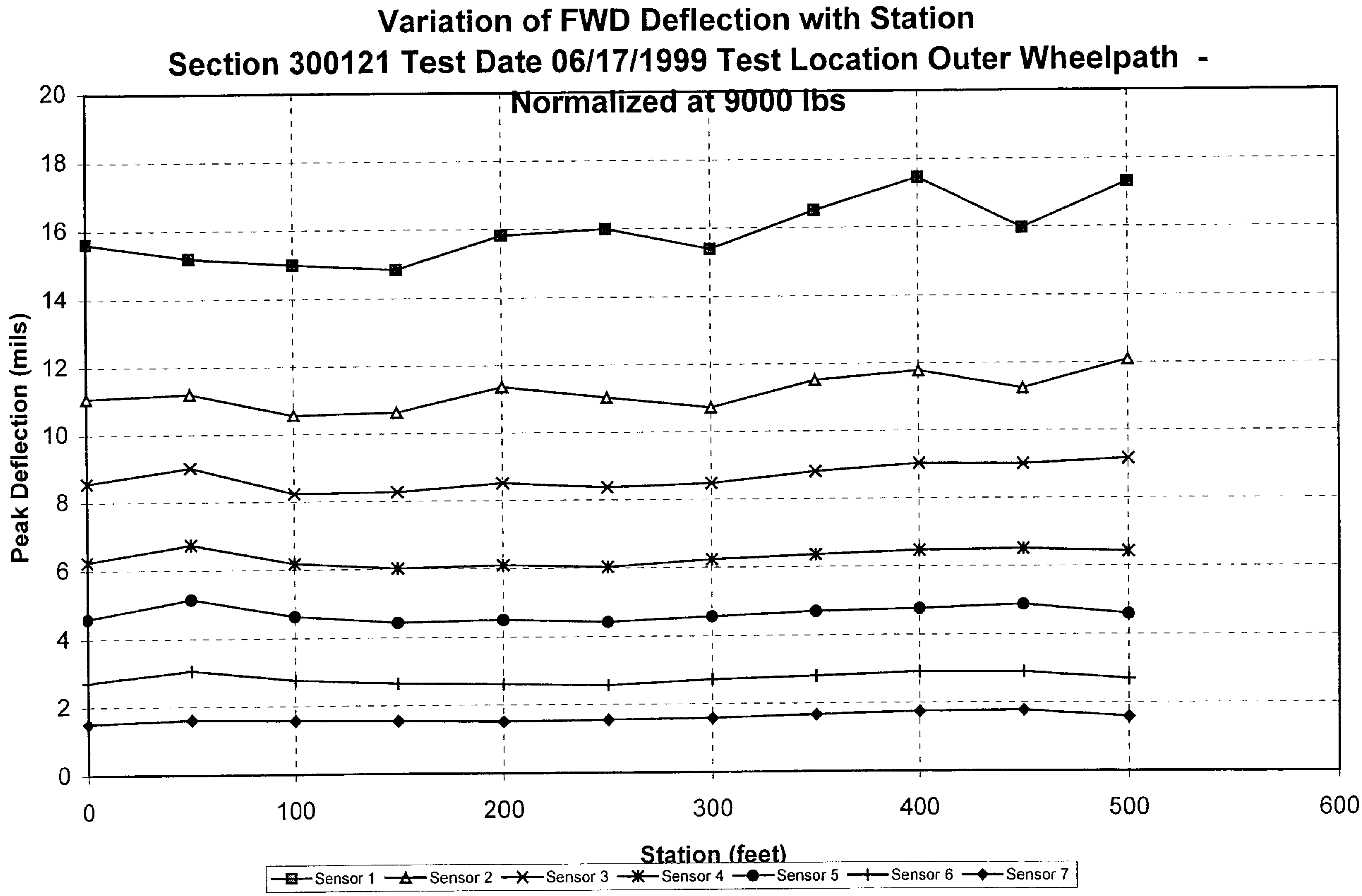


Variation of FWD Deflection with Station
Section 300118 Test Date 06/16/1999 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
Station (feet)
0
1
2
3
4
5
6
7
8
0
100
200
300
400
500
600
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7

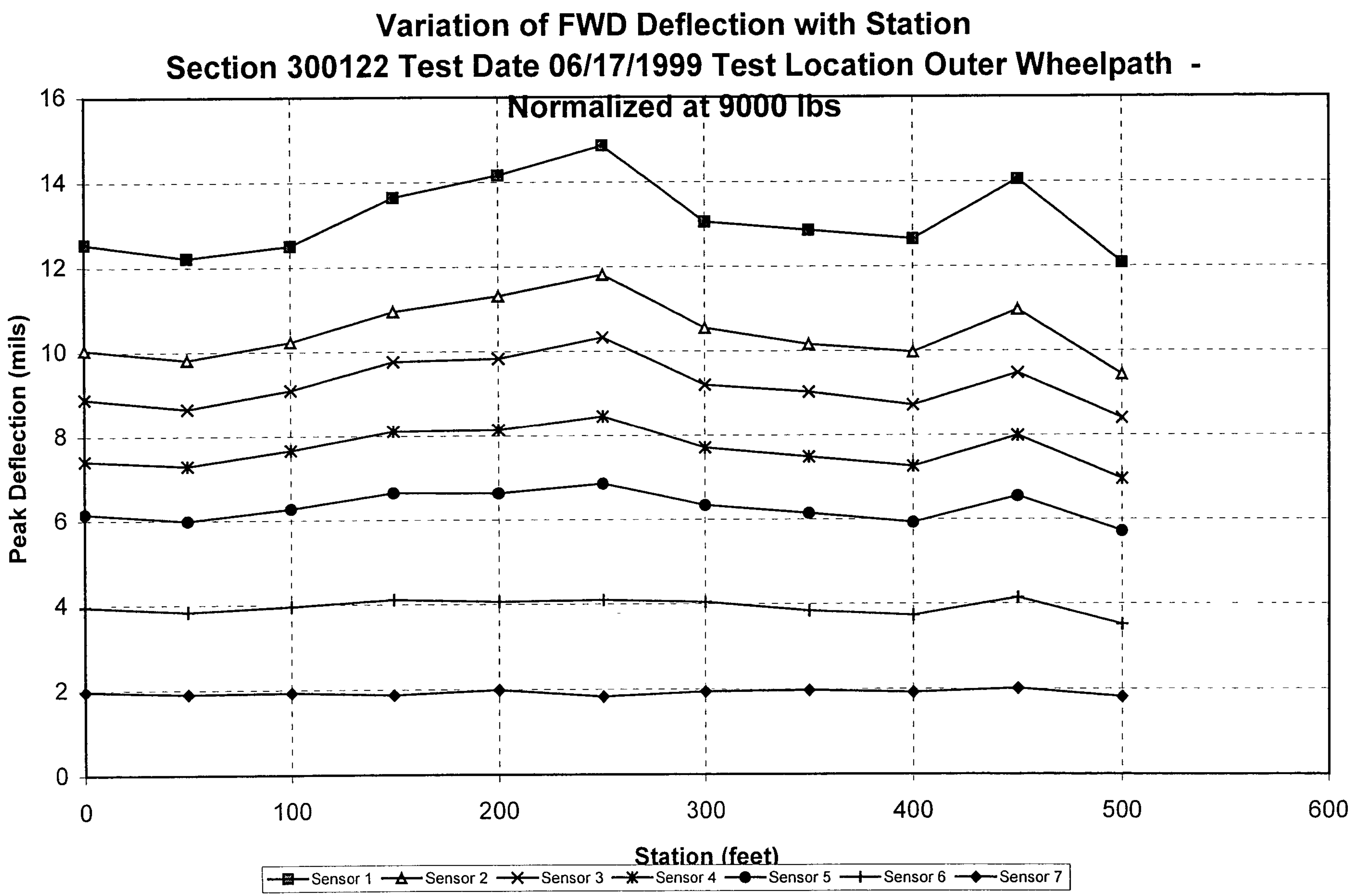

Variation of FWD Deflection with Station
Section 300119 Test Date 06/17/1999 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
0
2
4
6
8
10
12
14
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7



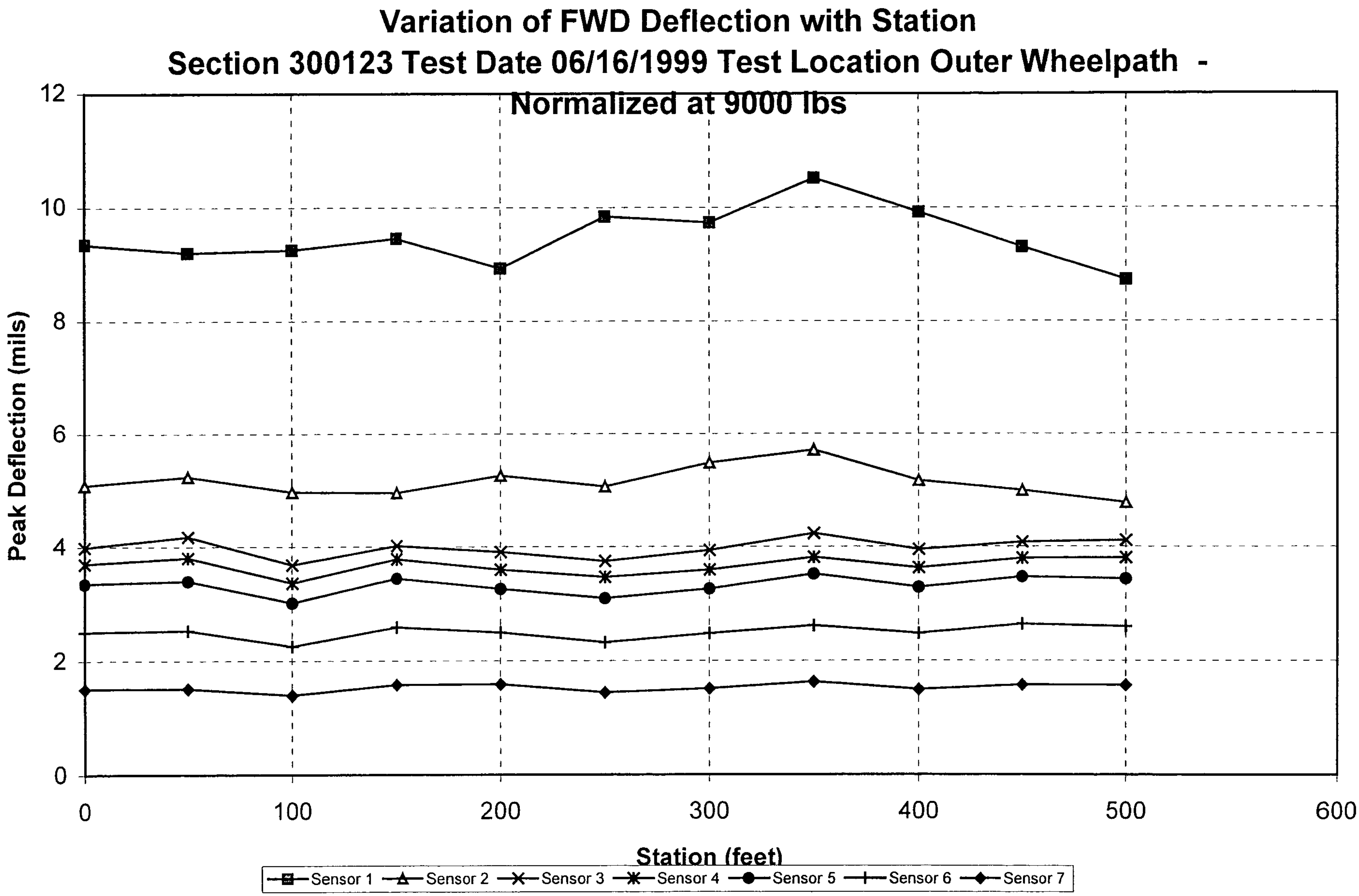
Variation of FWD Deflection with Station
Section 300120 Test Date 06/17/1999 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
0
2
4
6
8
10
12
14
16
18
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7

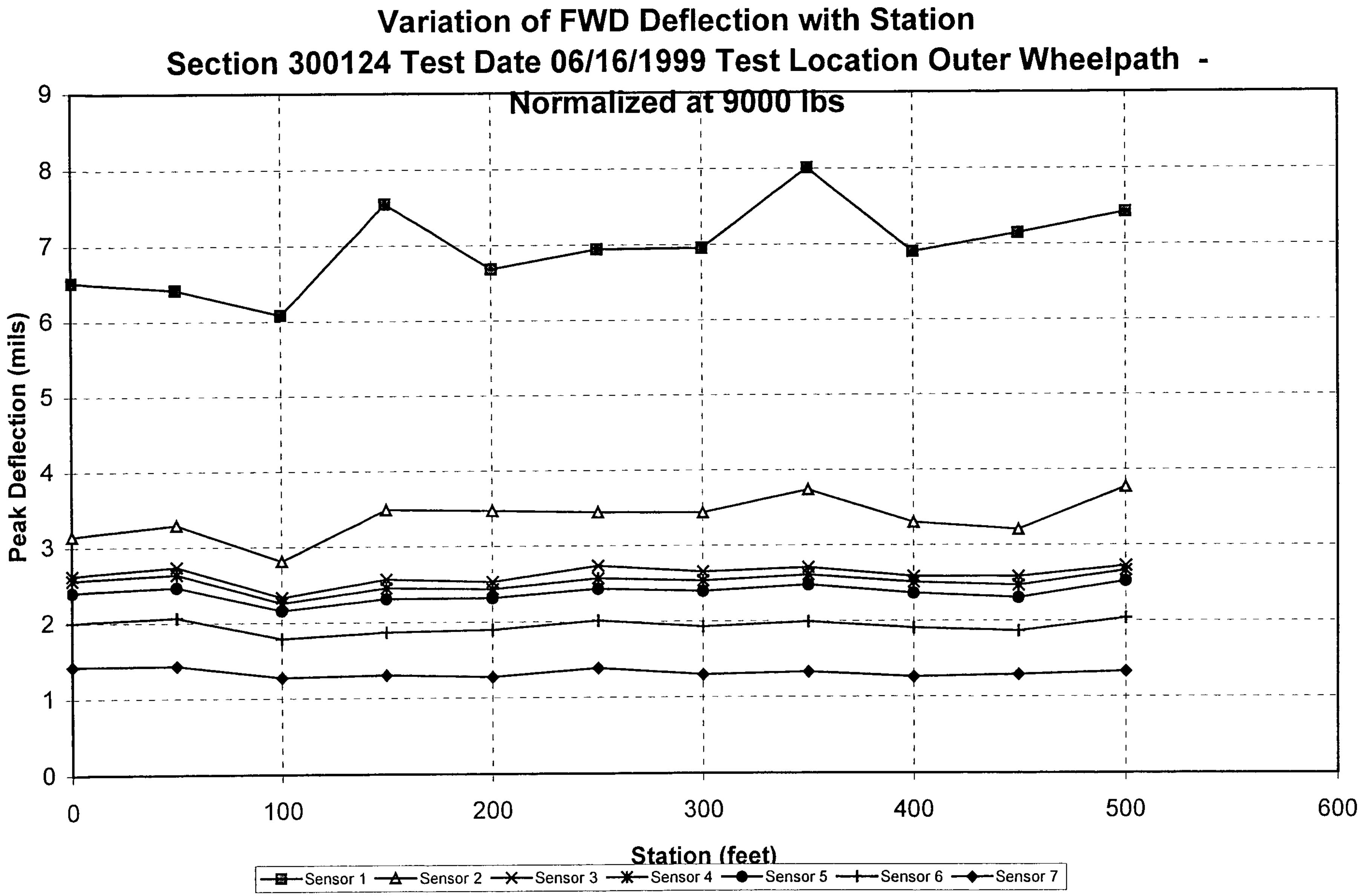


Variation of FWD Deflection with Station
Section 300121 Test Date 06/17/1999 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
20
18
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7



Variation of FWD Deflection with Station
Section 300122 Test Date 06/17/1999 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
0
2
4
6
8
10
12
14
16
0
100
200
300
400
500
600
Station (feet)
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7


Variation of FWD Deflection with Station
Section 300123 Test Date 06/16/1999 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
0
2
4
6
8
10
12
Station (feet)
0
100
200
300
400
500
600
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7



Variation of FWD Deflection with Station
Section 300124 Test Date 06/16/1999 Test Location Outer Wheelpath -
Normalized at 9000 lbs
Peak Deflection (mils)
0
1
2
3
4
5
6
7
8
9
Station (feet)
0
100
200
300
400
500
600
Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Sensor 7

APPENDIX C

SPS-1 Construction Photographs

APPENDIX C - MONTANA SPS-1 CONSTRUCTION PHOTOGRAPHS

Appendix C consists of the following construction photographs:

Photograph 1. Excavation and removal of existing embankment.

Photograph 2. Bulk sampling of existing embankment.

Photograph 3. Placing and preparation of embankment.

Photograph 4. Bulk sampling of prepared subgrade.

Photograph 5. Water puddles left on the prepared subgrade.

Photograph 6. Dewatering of prepared subgrade after rainstorm.

Photograph 7. Excavation of removal of soft spot in prepared subgrade.

Photograph 8. Stabilization of soft spot in section 300116 with Class 2 geofabric.

Photograph 9. Placement of DGAB in progress.

Photograph 10. Preparation of DGAB in progress.

Photograph 11. Excavation for longitudinal drain under PATB section.

Photograph 12. Preparation of drainage trench.

Photograph 13. Laying of Class 2 geofabric.

Photograph 14. Placement of graded filter material in the trench.

Photograph 15. Placement of perforated PVC pipe to required grade.

Photograph 16. The drain backfilled with select graded filter material.

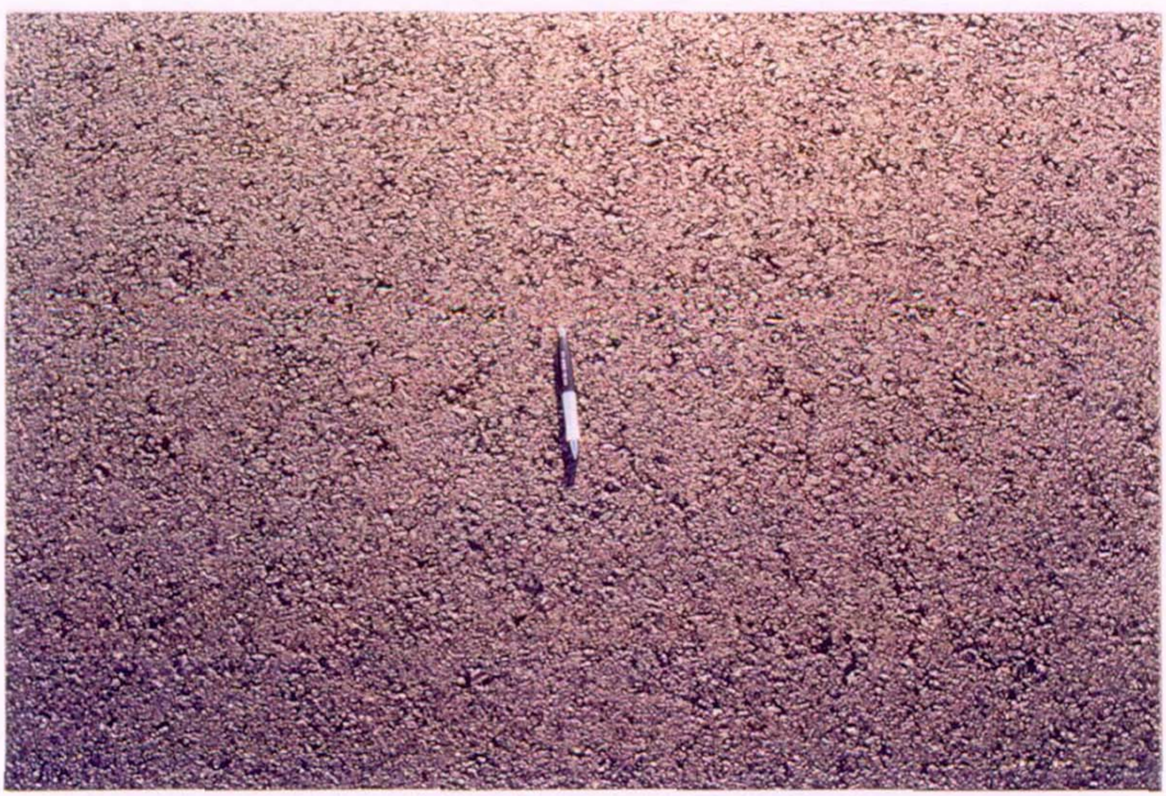
Photograph 17. PATB construction in progress.

Photograph 18. PATB construction in progress.

Photograph 19. ATB construction in progress.

Photograph 20. ATB construction in progress.

Photograph 21. AC layer construction.



Photograph 22. Finished AC pavement.

Photo 23. Automated Weather Station (AWS).

APPENDIX D

Asphalt Treated Base Mix Design

MASTER FILE COPY

Montana Department of Transportation
Helena, MT 59620-1001

Memorandum

To: Eugene W. Stettler, P.E.
District Administrator-Great Falls

From: R. Scott Barnes, P.E.
Physical Testing Supervisor

Date: June 16, 1998

Project: IM 15-5(93)256

Termini: Hardy Creek - Ulm (NB)

Bit. Surf. Type: Plant Mix Base (1st Mix Design)

Lab No.: 749482

Attached please find the results of tests performed on aggregate submitted from the Bogden - Henen source, Pit Lab Nos. 744809-16.

The material was graded to the stockpile average before testing.

The temperature used during mixing was 295°F. To conform to the AASHTO asphalt temperature viscosity requirement of 170± 20 centistokes (cSt.) during mixing, the contractor must discharge hot bituminous mixture within the temperature range of 290°F to 300°F. Field production within this temperature range should reasonably reproduce design values. Compaction of the Marshall specimens was performed at temperatures such that the asphalt viscosity was 280±30 centistokes. Use of these temperatures is necessary to produce Marshall specimens that are comparable to those produced in the Helena Laboratory. Using the asphalt proposed for this project, the temperature range is 270°F to 279°F.

The following Rice Gravities should be used at the start of production only to determine the percent voids of the field Marshall test specimens. These values are as follows:

% Asphalt	Max. Density
5.0	2.479
5.5	2.462
6.0	2.445
6.5	2.428
7.0	2.411

Field Rice Gravities testing should be started and continued throughout Bituminous Plant Mix production to determine any change in the voids.

1. Based on this data, we recommend that production commence at 6.0% 85/100 Asphalt Cement from the MRC refinery.

2. 1.4% hydrated lime is required as a chemical additive to improve the Marshall Stabilities. The attached data indicates this mixture is susceptible to moisture induced damage. Uniform dispersal of the hydrated lime throughout the entire mixture is essential to avoid structural damage by moisture intrusion.

3. No monitors are required.

If you have any questions regarding these results or recommendations, please contact us.

RSB:PE:G:MT:59.cg

Attachments

2603
MT-306/14

Lab. Form No. 606
(Rev. 12/15/97)

STATE OF MONTANA
DEPARTMENT OF HIGHWAYS
Materials Bureau

1994 ADT 3400
2014 ADT 6100
ESALS 479

PLANT MIX SURFACING, GRADE

Lab. No. 749482 Sample No. 1 Project No. IM 15-5(93)256
Termini HARDY CREEK - ULM(NB)
Date Sampled 2-19-98 Date Received 4-03-98
Sampled by B. STREMCHA Title MLT I Address GT. FALLS, MT.
Submitted by J. BLOSSOM Title DMS Address GT. FALLS, MT.
Area Source Represented by Lab. No. 744809-16 Sample taken at
Owner BOGDEN & HENEN Address CASCADE, MT.

TEST RESULTS ON AGGREGATE

Sieve	% Passing As Tested
1-½"	100
1"	99
¾"	88
½"	71
⅜"	63
4M	45
10M	32
40M	18
200M	4.7

LL NP
PL NP
PI NP
SE 26
Wear 19

Fracture 1 face 90
2 face 84
Dust
Asphalt Ratio 0.78

Volume Swell
NO 14.2% SOFT
HL 11.6% SOFT
– 13.8% SOFT
— %

Absorption CS 1.335 Fine 2.692 Blend 1.945

Bulk Dry Sp. Gr. of Agg. Fine 2.551 CS 2.646

NOTE: VMA of this Mix Design 15.0 VFA 75.3%

6" MARSHALL TESTS 6

%	Type	% Asphalt	Rice Gravity	Unit Weight Lbs./Ft.³	% Voids	Lb. Stability	Flow	Appearance
1.4	HYD. LIME	4.0	2.513	143.5	8.5	3696	12	DRY
(	)	5.0	2.479	145.5	5.9	3644	12	NORMAL
(	)	6.0	2.445	147.0	3.7	3515	15	NORMAL
1.4	HYD. LIME	6.0	2.445	147.0	3.7	3515	15	INTERPOLATED

MODIFIED LOTTMAN

Mineral Filler %	Mineral Filler Type	Percent Asphalt	Breaks (PSI) Dry	Breaks (PSI) Wet	Retained Strength	Adhesion
---	None				%	75 %
1.4	Hyd. Lime				%	90 %
					%	%

Copies	Distribution
	Admin. Maintenance Div.
2	District Admin./Eng. Great Falls
1	District Const. Eng. Great Falls
1	Project Manager Great Falls
1	Dist. Mat. Supr. Great Falls
	Area Lab
1	Chief Const. Bureau
1	Chief Materials Bureau
2	Bit. Mix Design Sect.
1	FHWA
1	Materials Bureau File
1	Empire Sand + Gravel

Recommended: 6.0 % 85/100 A/C 1.4 % HYDRATED LIME

Refinery MRC

REMARKS:

75 Blow Compaction

Date 6/18/98 Name B Bruce CEFF
Checked

Discussed with Bob Passow + Tim Sauer.

Montana Department of Transportation

Q:\MT-STD\FORM123.ENG
MBA FORM NO. 123
3255-1300
(Rev. 2-96)

MAST. R FILE COPY

Materials Bureau
2701 Prospect Ave.
Helena, MT 59620-1001

Sampling Procedure MT201,207
Testing Methods
____ Deg MT227 ____ Wear T-96
____ PS T-11,T-27,T-89,T-90 M145,MT305,MT217
____ R Value T 190
____ IC T 165,MT213,MT309
____ Marshall MT 311
____ Mod. Lottman T283

District Lab. No. 3132
Lab.No. 749482 Sample 1 Hole ____ Project IM 15-5(93)256 [2273]
Termini Hardy Creek - Ulm (NB)
Date Sampled 2-19-98 Date Received APR 03 1998 Kind of Deposit ____
Sampled By B. Stremcha Title MLT I Address Gt. Falls, Mt.
Submitted By James O. Blossom Title DMS Date ____
Quantity ____ Area by Stationing ____
Area is in N 1/2 Sec. 34 T- 19 N R- 1 E
Lab.No 744809-16 County Cascade
Owner Bogden & Henen Address Cascade, MT
Sta. and/or Tons Production Sample Stockpile Depth ____
Examined for Plant Mix Base for Mix Design

Wt.of Sample Taken ____ lbs. 100 00 %
Wt.Retained 4-Mesh ____ lbs. ____ %
Wt Passing 4-Mesh ____ lbs. ____ %
Before Wash ____ After ____ LBW ____

LL (25 Max) PL ____ PI (4 Max)
Wear 19 % Fld.Agg.Chart No. ____
Fracture (+75)* % Sp.Gr. (F) ____ (C) ____
Max. Dens. ____ Soil Class ____
Opt. Moist. ____ Wt./Ft³ ____
Dust Ratio ____ Sand Equiv. ____
Degradation ____

Wt.Ret		Wt.Pass	Pct.	Spec.
	4"			
	3"			
	2½"			
	2"			100
	1½"			95-100
	1¼"			
	1"			
	¾"			70-89
	½"			
	⅜"			50-70
	4M			0-50
	No. *10*			
	40M			9-30
	80M			
	200M			0-10

Volume Swell

Age	Treat	%Swell	Spec.	Specimen Condition

Adhesion

% Adhesion	Bitumen	Adhesive Agent

Checked And Approved — Date: APR 07 1998 — Name: D.K.

REMARKS: Fracture(+75 Two Faced +3/8") Please Design Using 85-100 from MRC.

3 Extra bags

____ Dist Eng. ____
____ Dist Matl's Supr ____
____ Area Lab
____ Mgr Fld Proj ____
____ Maint Div
____ Constr Bur
____ Pre-Constr Bur
____ County File
____ Surfacing Design ____ Helena
____ Lab File

Dist. Distribution
1 Materials Bureau
1 Dist. Lab. File
1 EPM, D. Wilmot
____ Sample

There is no evidence of disintegration in the +4M portion after soaking for 24 hr. in water.

CB30QA MONTANA DEPARTMENT OF TRANSPORTATION 1-94

CONTRACTOR'S PROPOSED JOB MIX AGGREGATE GRADATION

PROJECT NO IM 15-5 (93) 256 DESIGNATION Hardy Creek-Ulm (northbound)

CONTRACTOR Empire Sand & Gravel Inc. PREPARED BY Todd Talkington

PLANT MIX GRADE Bituminous Base DATE DESIGN NEEDED as soon as possible

PIT NAME Hanen/Bogden Pit PIT LAB NO'S. 744809-16

PIT DESCRIPTION NE¼ sec 34 SE¼ sec 27 SECTION SW¼ 26 TOWNSHIP 19 North RANGE 1 East

TYPE OF BLEND 85-100 SOURCE MT Refinery

ASPHALT GRADE ____ SOURCE ____

ASPHALT MODIFIER TYPE ____

MDL SPEC ____	YES ___ NO ___
MEETS MDL ____	YES ___ NO ___

CONTRACTOR - Enter the type, stockpile production gradation averages, and proposed blend ratio for each aggregate. Complete the combined gradation, the single proposed job mix target value, the specified target range, and tolerances for each specified sieve size.

STOCKPILE BLENDING DATA										SPECIFICATIONS		
AGGR TYPE	1" Base								COMB GRAD	JOB MIX TARGET	TOTAL +/-	SPECIFIED TARGET RANGE LO - HI
% USED	100%											
Sieve Sizes	Total % Pass	% of Total	Total % Pass	% of Total	Total % Pass	% of Total	Total % Pass	% of Total				
1 1/2"									100	100		95 100
1"	99.1	99.1							99.1			-
3/4"	88.1	88.1							88.1			70-89
5/8"	-	-										-
1/2"	71.2	71.2							71.2			-
3/8"	62.7	62.7							62.7			50-70
4 M	44.7	44.7							44.7			35 ~~[illegible]~~ 50
10 M	31.7	31.7							31.7			-
40 M	18.2	18.2							18.2			9-30
200 M	4.7	4.7							4.7			0-10

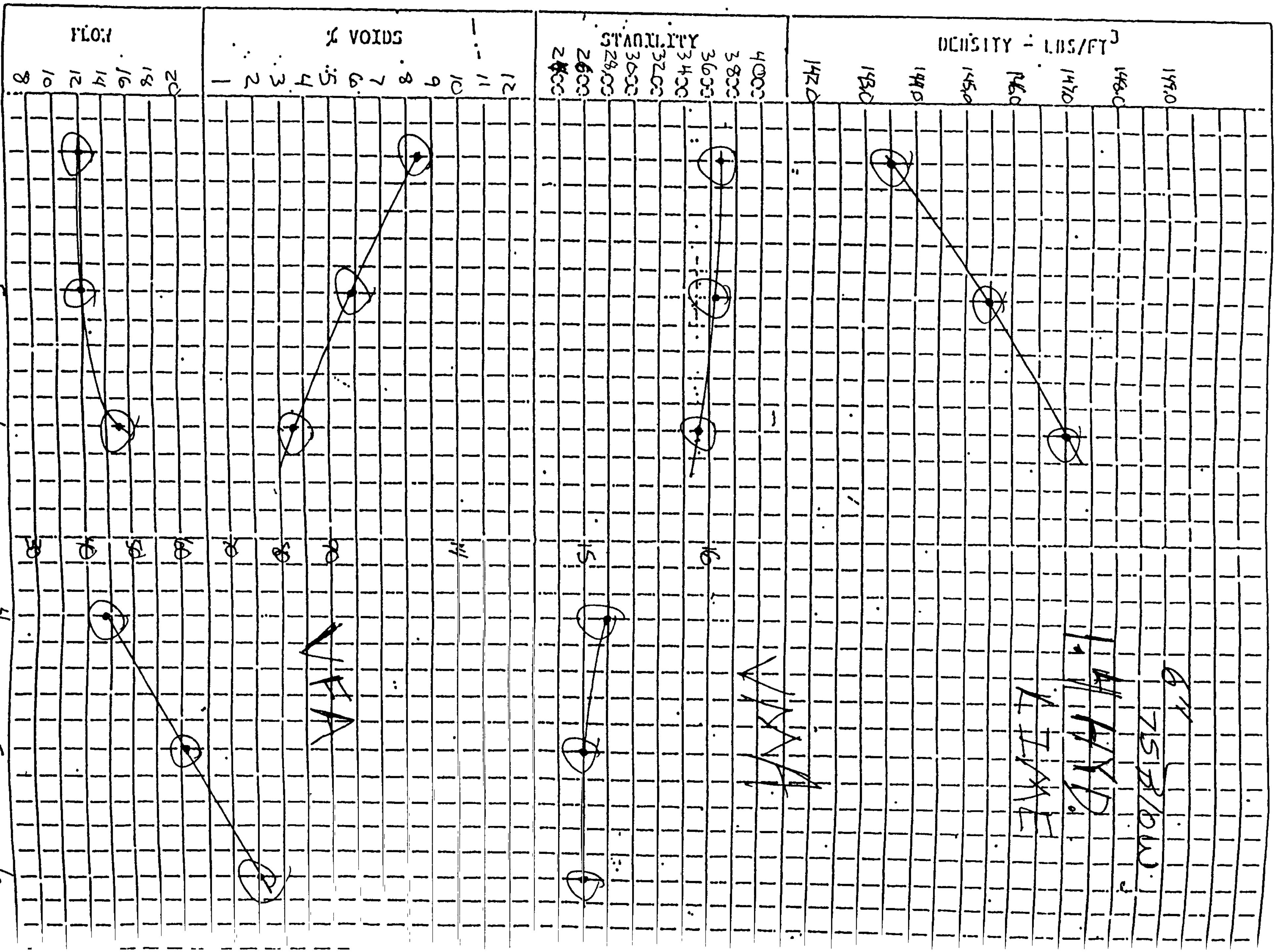
CONTRACTOR SIGNATURE: Todd Talkington Date: 2-5-98

Samples submitted for mix design J. Blossom Date 2-17-98

Project Manager or Lab Supervisor

Lab. Form No. 5-D

MARSHALL METHOD GRAPH



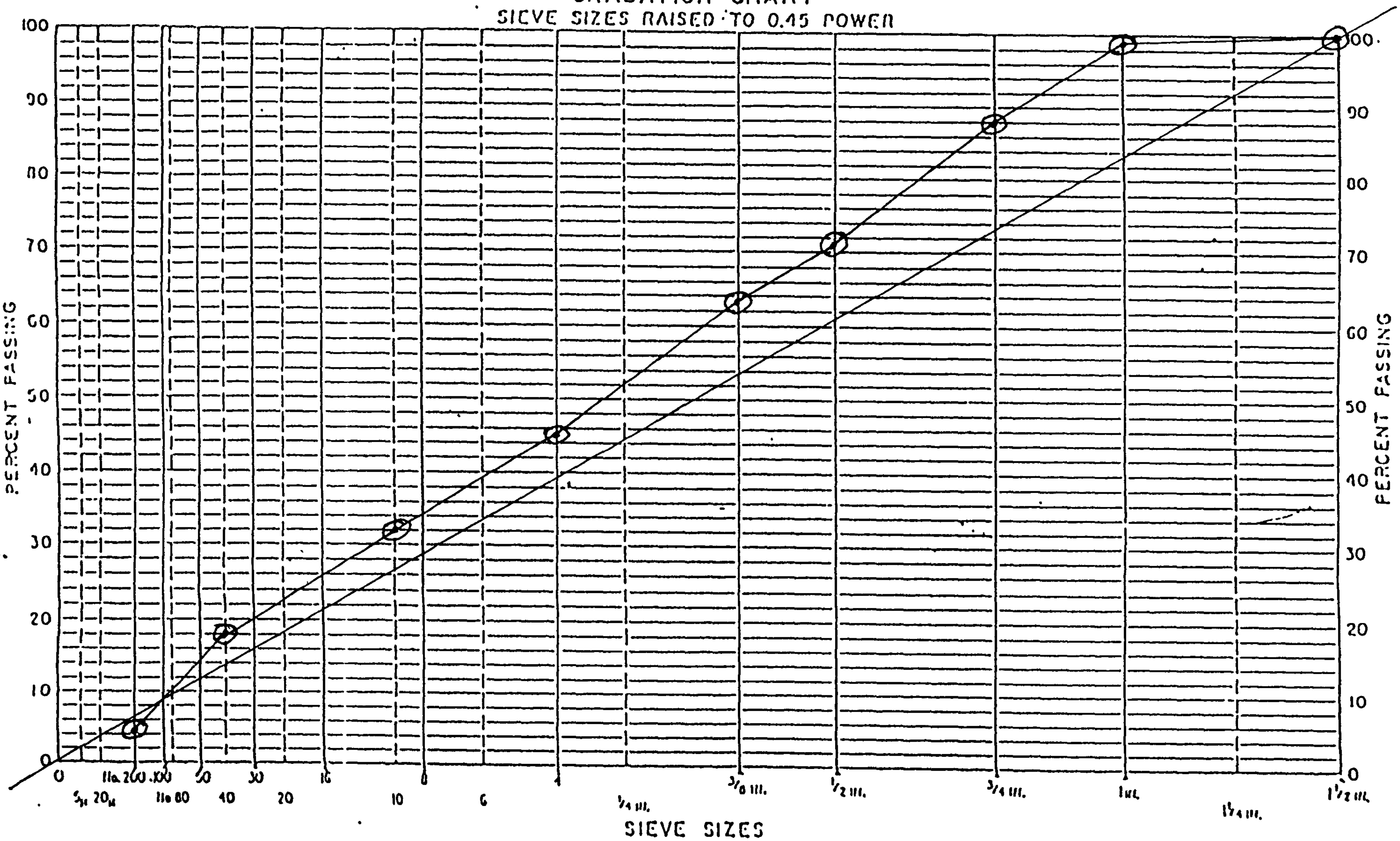
PROJECT NO. IM 15-5(93)256 LAB. NO. 749482

Form PR-1115

U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

GRADATION CHART

SIEVE SIZES RAISED TO 0.45 POWER



▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradation: HARDY CREEK - WIM (NB)
IM 15-5 (93) 256
749487

Sheet No.
Date

USCOMM-DC

APPENDIX E

Asphalt Concrete Surface Mix Design

MASTER FILE COPY

Montana Department of Transportation
Helena, MT 59620-1001

Memorandum

To: Eugene W. Stettler, P.E.
District Administrator-Great Falls

From: R. Scott Barnes, P.E.
Physical Testing Supervisor

Date: May 7, 1998

Project: IM 15-5(93)256

Termini: Hardy Creek - Ulm (NB)

Bit. Surf. Type: 3/4" PMS Grade D (1st Mix Design)

Lab No.: 749481

Attached please find the results of tests performed on aggregate submitted from the Bogden & Henen source, Pit Lab Nos. 744809-16.

The material was graded to the job mix target before testing. The gradation shown "As Tested" results by combining 5% of the chip stockpile, 41% of the crushed fine stockpile, and 54% of the coarse stockpile.

The temperature used during mixing was 305°F to conform to the manufacturer's recommendations. Field production within the range of 290°F to 315°F should provide similar bituminous mixture.

Laboratory Marshall compaction was performed at 285°F. The supplier recommends roadway compaction be performed between 225°F and 300°F. A temperature viscosity chart and manufacturer's recommended mixing and compaction temperatures are attached.

The following Rice Gravities should be used at the start of production only to determine the percent voids of the field Marshall test specimens. These values are as follows:

% Asphalt	Max. Density
5.0	2.474
5.5	2.454
6.0	2.434
6.5	2.414
7.0	2.394

Field Rice Gravities testing should be started and continued throughout Bituminous Plant Mix production to determine any change in the voids.

1. Based on this data, we recommend that production commence at 5.6% PG 70-28 Asphalt Cement from the MRC refinery.

2. 1.4% hydrated lime is required as a chemical additive to improve the Modified Lottman and the Marshall Stabilities. The attached data indicates this mixture is susceptible to moisture induced damage. Uniform dispersal of the hydrated lime throughout the entire mixture is essential to avoid structural damage by moisture intrusion.

3. No monitors are required.

If you have any questions regarding these results or recommendations, please contact us.

RSB:PE:G:MT:10.cg

Attachments

2639
MT-306/14

Lab. Form No. 606
(Rev. 12/15/97)

STATE OF MONTANA
DEPARTMENT OF HIGHWAYS
Materials Bureau

1994 ADT 3400
2014 ADT 6100
ESALS 479

PLANT MIX SURFACING, GRADE ___

Lab. No. 749481 Sample No. 1 Project No. IM 15-5(93)256
Termini Hardy Ck.-Ulm(NB)
Date Sampled 2-19-98 Date Received APR 03 1998
Sampled by B.Stremcha Title MLT I Address Gt. falls Mt.
Submitted by L. Blossom Title DMS Address
Area Source Represented by Lab. No. 744809-16 Sample taken at
Owner Bogden & Henen Address Cascade,Mt

TEST RESULTS ON AGGREGATE

	% Passing As Tested
1-½"	
1"	
¾"	100
½"	83
⅜"	68
4M	44
10M	28
40M	14
200M	5.0

LL NP
PL NP
PI NP
SE 74
Wear 16

Fracture 1 face 96
2 face 91

Dust Asphalt Ratio 0.89

Volume Swell
NO 24 % hard
HL 16 % hard
CF 26 % hard
___ % ___

Absorption CS 1.227 Fine 1.319 Blend 1.267

Bulk Dry Sp. Gr. of Agg. Fine 2.622 CS 2.652

NOTE: VMA of this Mix Design 15.1 VFA 80.1%

MARSHALL TESTS

%	Type	% Asphalt	Rice Gravity	Unit Weight Lbs./Ft.^{3}	% Voids	Lb. Stability	Flow	Appearance
	NONE	5.0	2.474	144.8	6.2	2031	9	NORMal
		5.5	2.454	146.8	4.1	2008	10	Slightly Rich
		6.0	2.434	147.3	3.0	1960	10	Slightly Rich
		6.5	2.414	148.2	1.6	1895	10	Rich
		7.0	2.394	147.3	1.4	1898	12	Very Rich
1.4	hydlime	5.0	2.474	146.9	4.9	2406	11	NORMal
		5.5	2.454	148.1	3.3	2119	10	Slightly Rich
		6.0	2.434	148.5	2.2	2096	11	Slightly Rich
		6.5	2.414	149.1	1.0	2002	11	Rich
		7.0	2.394	148.3	0.8	1872	12	Very Rich
1.4	hydlime	5.6	2.450	148.1	3.0	2100	11	interpolated

MODIFIED LOTTMAN

Mineral Filler %	Mineral Filler Type	Percent Asphalt	Breaks (PSI) Dry	Breaks (PSI) Wet	Retained Strength	Adhesion	
---	None	6.0	65.3	46.0	70.4%	80 %	PMAC
1.4	Hyd. Lime	5.7	83.4	51.3	61.5 %	95+ %	
—	NONE	6.0	93.1	44.3	47.6%	75 %	CONV
1.4	hyd lime	5.7	101.9	68.5	67.2	90	

___ Admin. Maintenance Div.
2 District Admin./Eng. Great Falls
1 District Const. Eng. Great Falls
1 Project Manager Great Falls
1 Dist. Mat. Supr. Great Falls
___ Area Lab ___
1 Chief Const. Bureau
1 Chief Materials Bureau
2 Bit. Mix Design Sect.
1 FHWA
1 Materials Bureau File
1 Empire Sand & Gravel

Recommended: 5.6 PG 70-28 A/C 1.4 hydrated lime

Refinery MRC

REMARKS: 75 Blow Compaction

Discussed with Bob Passow BJB

Date 5/7/98 Name B Bruce CETII
Checked

CONTRACTOR'S PROPOSED JOB MIX AGGREGATE GRADATION

PROJECT NO IM 15-5(93)256 DESIGNATION Hardy Creek - Ulm (northbound)

CONTRACTOR Empire Sand & Gravel Inc. PREPARED BY Todd Talkington

PLANT MIX GRADE GR "D" DATE DESIGN NEEDED as soon as possible

PIT NAME Hansen/Bogden Pit PIT LAB NO'S. 744809-16

PIT DESCRIPTION NE¼ sec.34, SE¼ sec.27 SECTION SW¼ 26 TOWNSHIP 19 north RANGE 1 east

TYPE OF BLEND PG 70-28 SOURCE MT Refinery

ASPHALT GRADE SOURCE

ASPHALT MODIFIER TYPE Poly Mod.

MDL SPEC	YES	NO
MEETS MDL	YES	NO

CONTRACTOR - Enter the type, stockpile production gradation averages, and proposed blend ratio for each aggregate. Complete the combined gradation, the single proposed job mix target value, the specified target range, and tolerances for each specified sieve size.

STOCKPILE BLENDING DATA										SPECIFICATIONS		
AGGR TYPE	3/4" Rock		3/8" Crushed Fines		3/8" Chips				COMB GRAD	JOB MIX TARGET	TOTAL +/-	SPECIFIED TARGET RANGE LO ~ HI
% USED	54 %		41 %		5 %							
Sieve Sizes	Total % Pass	% of Total	Total % Pass	% of Total	Total % Pass	% of Total	Total % Pass	% of Total				
1 1/2"												-
1"												-
3/4"	100	54.0	100	41.0	100	5.0			100			-
5/8"	—	—	—	—	—	—						-
1/2"	71.6	38.7	100	41.0	100	5.0			84.7	83	7	76 - 90
3/8"	40.0	21.6	100	41.0	100	5.0			67.6	68	7	61 - 75
4 M	4.5	2.4	98.0	40.2	31.7	1.6			44.2	44	7	37 - 51
10 M	1.7	0.9	65.2	26.7	5.9	0.3			27.9	28	6	22 - 34
40 M	1.4	0.8	30.7	12.6	3.0	0.2			13.6	14	4	10 - 18
200 M	1.1	0.6	10.6	4.3	2.2	0.1			5.0	5	1.5	3.5 - 6.5

CONTRACTOR SIGNATURE: Todd Talkington Date: 2/3/98

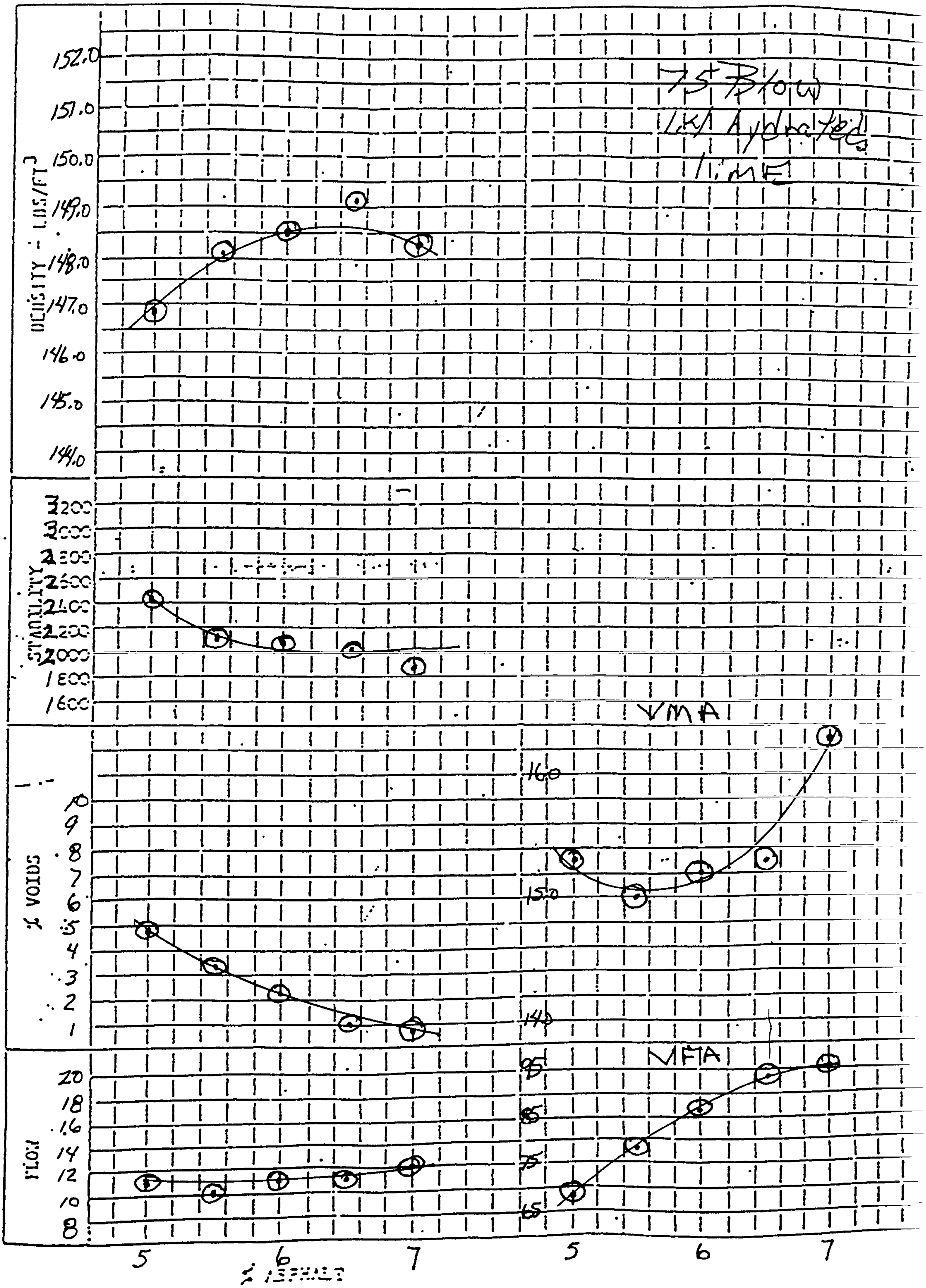
Samples submitted for mix design: James Q Blossom Date 2-17-98

Project Manager or Lab Supervisor

PROJECT NO. IM 15-5(93)256 LAB. NO. 749481

Lab. Form No. 5-D

MARSHALL METHOD GRAPH

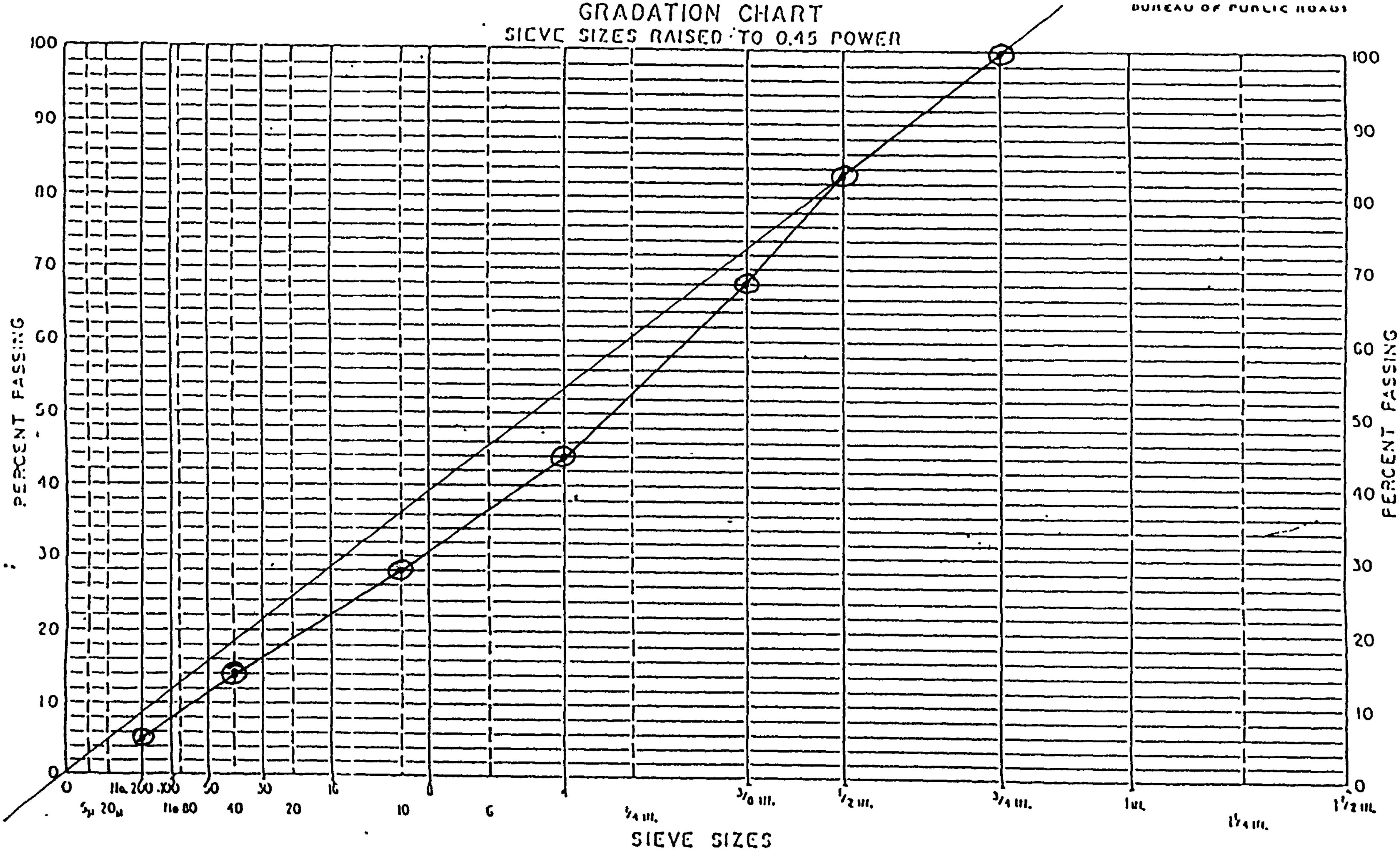


FORM PR-1115

U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

GRADATION CHART

SIEVE SIZES RAISED TO 0.45 POWER



▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES

Identification of gradations: Hardy Creek- U/M
IM 15-5(93)256
749481

Sheet No.

Date

USCOMM-DC 42833-P11

When Polymer Modified Asphalt is in a contract, the MDT requires that this completed form and all of the attachments must be provided.

Project ____________ . - - - , - - - - - - -

Termini ______________________________

Prime Contractor ______________________________

Send a five gallon sample of the proposed Polymer Modified Asphalt Cement (PMAC), accompanied by the following information, to the Materials Bureau for approval at least 30 days prior to use.

Company providing Polymer Modified Asphalt Cement: Montana Refining Company

Identity of Base Asphalt: Montana Refining Company

Identify of Polymer Modifier: EVA

(1) Attached Materials Safety Data Sheets

(2) Attached temperature-viscosity chart and/or table for viscosity from 275 degrees F. to 340 degrees F. or to the maximum mixing temperature of the asphalt.

(3) Mix Design Information

a. Marshall Mixing temperature range no special range F ____________ °F

b. Marshall Compaction temperature range no special range ____________ °F

c. How to do reblending of the polymer asphalt and other special requirements when performing laboratory procedures such as mix designs with this Modified Asphalt.

(4) Field Temperatures Requirements

a. Plant Mix Discharge Temperatures

Maximum 315 degrees F.

Minimum 290 degrees F.

b. Roadway Compaction Temperatures

Maximum 300 degrees F.

Minimum 225 degrees F.

(5) What adjustments in placement or compaction techniques are needed.

(6) Describe any special laboratory or field handling procedures which should be followed.

Individual providing information: Alan L. Hobbs

Address: Montana Refining Company 1900 10th Street N. E., Great Falls, MT 59404-1955

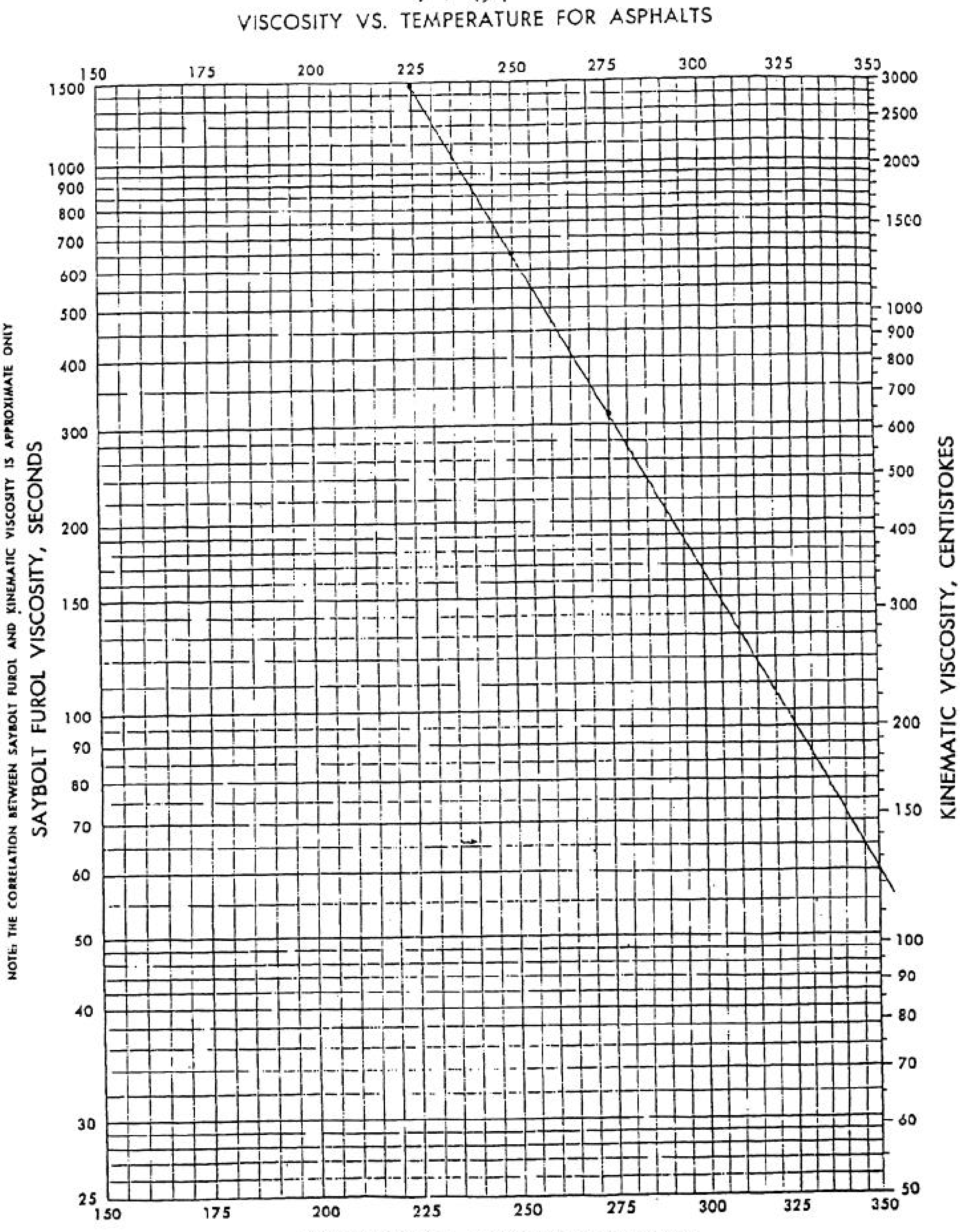
Phone No. 406-761-4100

Signature: [signature] Date: 9-14-1996 (prime contractor)

Return the completed form to MDT's Project Manager for this contract.

BJB:Q:MT:176.eg

PMA



Prepared By
THE ASPHALT INSTITUTE
COLLEGE PARK, MARYLAND
Form No. TV-1