PROJECT REVIEW REPORT

EVALUATION
OF THE
URETEK DEEP INJECTION (UDI) PROCESS
FOR
IMPROVING PERFORMANCE OF
US 65
CARROLL COUNTY, MISSOURI

Prepared by

Randall W. Brown, PhD, PE
Rick Gatewood
Amy B. Hyde
URETEK USA, Inc.

THIS REPORT IS A COLLABORATIVE EFFORT OF
THE MISSOURI DEPARTMENT OF TRANSPORTATION (MODOT)
AND URETEK USA, INC.

PUBLIC RELEASE VERSION (18 SEPTEMBER 2011)

To: Michael R. Vinton (Vice President – Sales)

Subject: Project Review Report for US 65, Carroll County, Missouri
(Emergency Stabilization of Roadway, May 2011)

Date: Sunday, September 18, 2011

INTRODUCTION

Per your request, the URETEK Engineering Group assembled and reviewed the documentation for this project. In an effort to make the large volume and variety of data palatable and useful to the reader, this report employs a format of a concise summary backed by detailed attachments.

REPORT ORGANIZATION

- **Appendix A – Project Summary Report**
  (by Rick Gatewood, Regional Representative, URETEK USA, 14 June 11)

- **Appendix B – Project Photos with Commentary**

- **Appendix C – DCP Report (pre-treatment)**

- **Appendix D – FWD Analysis**
  (by John P. Donahue, PE, Construction and Materials Liaison Engineer, MODOT, 23 June 11)

DISCUSSION

- **Appendix A provides the 14 June 11 memorandum Rick Gatewood prepared describing the origin and execution of this project.**

- **Appendix B presents the photographs taken during project execution along with Mr. Gatewood's commentary.**

- **Appendix C presents the results of the Dynamic Cone Penetrometer (DCP) tests. These tests were accomplished prior to treatment to assess the injection pattern, injection depths, and polymer to be used.**

  (Note: URETEK USA employs the DPM 30-20 Model DCP manufactured by Pagani Geotechnical Equipment of Piacenza, Italy.)

  Five pre-treatment DCP tests were done throughout the repair area for site assessment.

- **Appendix D offers the Falling Weight Deflectometer (FWD) analysis performed by John P. Donahue, PE, Construction and Materials Liaison Engineer, MODOT. For the convenience of the reader, the summary charts prepared by Mr. Donahue were extracted and placed in this appendix. Public release of the complete package of EXCEL spreadsheets is at the discretion of the Mr. Donahue and MODOT.**

PROJECT SUMMARY

- **Project Location/Designation**
  - **US 65 @ Route WW, Carroll County MO**
  - **URETEK USA Job Number: 11MO09004**

- **MODOT Contacts**
  - **John P. Donahue, PE**
    Construction and Materials Liaison Engineer (MODOT)
    1617 Missouri Boulevard
    Jefferson City, MO 65109
    573-526-4334 Phone
    573-690-3828 Cell
    John.Donahue@modot.mo.gov

  - **James Gillespie**
    Resident Engineer
    James.Gillespie@modot.mo.gov

- **URETEK USA Contacts**

    - **Michael R. Vinton, Vice President – Sales, 281-841-6555**
    - **Rick Gatewood, Regional Representative – Sales, 660-351-2119**
    - **Randall W. Brown, PhD, PE, Vice President – Engineering, 281-415-4760**

- **Project Description**

  During construction, the soils underlying an asphalt roadway were stabilized using the URETEK Deep Injection (UDI) process. Due to the client's stated requirement that the road be open for traffic in time for the Memorial Day weekend, a real-time assess-design-treat-evaluate procedure was employed to expedite stabilization.

  MODOT conducted FWD testing throughout the project to evaluate the effectiveness of the UDI process. Mr. John Donahue (MODOT) performed a detailed analysis of all FWD data collected. His analysis was generously shared with URETEK USA and constitutes a significant portion of this Project Review Report.

- **Project Execution**

    - **Wednesday, 18 May 11 – Initial Site Visit by Rick Gatewood**

    - **Thursday, 19 May 11 – Proposal Submitted to MODOT**

    - **Friday, 20 May 11**
        - **Proposal accepted by MODOT**
        - **URETEK USA crew mobilizes from Michigan**

    - **Monday, 23 May 11**
        - **Crew arrives in Missouri**
        - **Crew performs site visit and loads polymer on the production truck**

    - **Tuesday, 24 May 11**
        - **Crew lays out work area**
        - **Crew performs DCP tests**
        - **MODOT performs FWD testing**
        - **Conference Call (Gatewood, Vinton, and Brown) regarding**
            - **FWD test results**
            - **Need for a 24-hour cure time before FWD testing**
            - **DCP results**

    - **Wednesday, 25 May 11**
        - **MODOT FWD testing verifies the 24-hour cure time policy**

- **MODOT stops field work due to tornado activity**

- **Thursday, 26 May 11**
  - **Injections resume**

- **Friday, 27 May 11**
  - **Injections completed at 0700 CDT**

- **Project Notes**

  - **Gatewood observed 2" rutting of the asphalt base material under the load of a coring rig during his initial site visit**

  - **Gatewood learned MODOT officials observed finger-width cracks under the load of an empty 18-wheeler**

  - **The base course material was 10"-12" of reclaimed asphalt with crushed stone. Thus, on-site personnel surmised the problem was likely in the subbase.**

  - **MODOT's area of concern for subbase stabilization was 541' long x 24' wide**
    - **Available data regarding the composition/characteristics of the subbase soil = minimal**
    - **Subbase is suspected to be a natural material resulting from a hillside cut**

  - **Injection Summary**

    - **Polymer = URETEK 486 STAR Blue Dot (4-pcf free rise)**

    - **"Worst" Areas (as defined by DCP and FWD testing)**
      - **Injection Depth = - 3'**
      - **Injection Pattern = 3' x 3'**

    - **"Relatively Better" Areas**
      - **Injection Depth = - 4'**
      - **Injection Pattern = 4' x 4'**

    - **Total Area Treated = 12,984 square feet**

- **Project Results**

  - **Post-injection FWD results indicate the treatment was effective in stabilizing the area**

- **From Mr. Donahue's analysis:**
  - **Average increase in subgrade modulus after UDI = 60%**

    Brown's Comment: This finding means UDI produces an increase in soil stiffness which results in the pavement system being better able to support loads

  - **Average decrease in maximum deflection after UDI = 35.1%**

    Brown's Comment: This finding means UDI produces an increase in soil stiffness that reduces deflections which results in longer pavement life

CONCLUSIONS

- **Based on feedback from MODOT, UDI was the critical component in stabilizing the roadway in a timely manner so the roadway could be opened to traffic.**
- **Mr. Donahue's extensive FWD analysis provides valuable objective data to support the espoused claims regarding UDI.**

Please advise if I can assist further.

Randall W. Brown, PhD, PE
Vice President for Engineering

- **Appendix A – Project Summary Report (Gatewood)**
- **Appendix B – Project Photos with Commentary**
- **Appendix C – DCP Report (pre-treatment)**
- **Appendix D – FWD Analysis (Donahue)**

APPENDIX A
PROJECT SUMMARY REPORT
(by Rick Gatewood, Regional Representative, URETEK USA, 14 June 2011)

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The URETEK Method™
Deep Injection™
Stitch-In-Time™

Rick Gatewood
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June 14, 2011

Dr. Randall Brown
URETEK Engineering Group
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Re: US 65 at Rte. WW in Carroll County, Missouri
Summary Report

Randy,

This is a great opportunity for us to demostrate our URETEK Deep Injection (UDI) process to Missouri DOT and other DOTs across the United States. I want to give you all the details from start to finish so that you can use this project as an example of what URETEK and the UDI process can do.

On Wednesday, May 18, 2011, I was giving a formal UDI power point presentation to Scott Stone, John Donahue and Thomas Anna with MoDOT in Jefferson City, MO. Halfway through the presentation, John stopped me and said “Rick, I just got off the phone with a Resident Engineer in District 2 that has a subbase problem that we do not know how to fix…this may be the answer that we are looking for”. I followed John to the job site, 2 1/2 hours away.

When John and I arrived at the job site, MoDOT had just finished coring the asphalt base material. The coring rig slowly moved away from the core and caused a 2” rut in the base material. Earlier that day, MoDOT had observed an empty 18-wheeler passing over the area that caused cracks wide enough to stick your fingers into.

US 65 is a 2-lane asphalt highway with gravel shoulders. This area of Missouri is mostly farm land with rolling hills and small streams. MoDOT wanted to lower the top of this particular hill by 5 feet for better visiblity of the traveling public. MoDOT had completely closed this area of highway and detoured the traffic.

The area of concern for subbase stabilization was 541 LF x 24’ wide. MoDOT will have better details for the base material; however, I believe it was 10” – 12” of reclaimed asphalt with crushed stone. The wearing course will be 3 ½” of asphalt, laid after URETEK stabilizes the subbase.

On Thursday, May 19, 2011, I sent John a proposal based off conversations I had with you, Mike Vinton, Keith Castilla, & Guillermo Valdes.

On Friday, May 20th, MoDOT approved the proposal and URETEK Operations got a crew headed to Missouri. This was an emergency project for MoDOT because they wanted to open the road before the Memorial Day weekend – the following weekend.

Monday – May 23, 2011
The crew loaded material and looked at the job site with MoDOT.
The crew had already worked 50 to 60 hours in Michigan and then drove 25 to 30 hours over the weekend to get to Chillicothe, MO. They needed to rest and get ready to start work the next morning.

Tuesday – May 24, 2011
The crew laid out the work with pavement markings at every 25 feet – starting at the North station (279+00) and working South. This matched MoDOT's Station Marks and helped keep track of what was done in each 25' x 24' wide section. MoDOT used Falling Weight Deflection (FWD) tests to determine the pre & post densities of the base material and sub-base material. URETEK used Dynamic Cone Penetrometer (DCP) tests to determine the density of the sub-base.

The first DCP was done at Station 279+25; whereas, we had single digit blow counts from 100 cm to 219 cm. We injected 4 pound Blue Dot material at 4' below the base surface on a 4' x 4' grid pattern. In the second section (Station 279+25 to 279+50) we did injections at 3' below the base surface and at the same 4' x 4' hole pattern.

MoDOT performed FWD tests right after we finished injecting and found the numbers to be worse than before we started. It was determined (via phone call with you and Mike Vinton during the repairs) that we needed to wait 24 hours before re-testing the area to allow the polymer to fully cure.

Wednesday – May 25, 2011.
MoDOT re-tested the first sections with their FWD tests. The FWD deflections decreased and showed stabilization of the subbase, as needed. The weather turned for the worst and a tornado was spotted 10 miles from the work site – MoDOT stopped work for the day.

Thursday – May 26, 2011
MoDOT only wanted 1 level of injection to speed up the repairs and to possibly open the road before Memorial Day weekend. They had the crew inject at the -3' elevation in the worst areas and at the -4' elevation in the areas that were not so bad. They also had the crew use a 3' x 3' injection

pattern in the worst areas and a 4' x 4' injection pattern in the areas that weren't so bad.

The crew worked from 7:00 AM on Thursday until 7:00 AM on Friday to finish the work.

Friday – May 27, 2011
MoDOT elected not to add the wearing course until the Tuesday after Memorial Day. Elected may not be the correct word…the Contractor refused to mobilize his crews over the weekend and I told them it would be best to wait 24 hours before adding the additional weight.

James Gillespie – MoDOT's Resident Engineer called me "the man of the hour" when I entered his office on Friday morning. He thanked me so much for what URETEK had done, that it was almost embarrassing. James had really pressured us to get the job done ASAP. He offered to bring his men out to help; although that was shot down from the powers above. James also had a light tower delivered so we could work at night.

Tuesday – May 31, 2011
The Contractor – Norris Asphalt Paving, added a tack spray to the base material and then rolled a fabric down before laying the wearing course.

June 14, 2011
I called James Gillespie to see how the new asphalt pavement was holding up after being in service for about 2 weeks. James said that he has walked the area twice and has not seen any distress in the pavement. He also said MoDOT did some additional FWD testing and found all numbers to be below 20 mils, except in the 2 worst areas. The 2 worst areas started with 110 & 105 mils and are now at 26 & 22 mils, respectively. Anything below 20 mils is good for asphalt paving.

SUMMARY

Please review the attached copy of the DCP tests.

John Donahue with MoDOT would like a copy of our records to make a report on this project. He will provide us with pre & post FWD tests results.

Contact me if you have any questions or need any additional information.

Rick Gatewood
(660) 351-2119
rick.gatewood@uretekusa.com

APPENDIX B
PROJECT PHOTOS WITH COMMENTARY

MoDOT – US65 in Carroll County, Image P5180 235

Water Truck used for coring – caused ruts in base material.

MoDOT – US65 in Carroll County, Image P5180 236

2” rut caused by water truck.

MoDOT – US65 in Carroll County, Image P5180 237

Core of asphalt base material – 10 to 12” thick.

MoDOT – US65 in Carroll County, Image P5180 241

Condition of base & reason for concerns.

MoDOT – US65 in Carroll County, Image P5240 250

MoDOT's falling weight deflectometer trailer.

MoDOT – US65 in Carroll County, Image P5240 251

MoDOT's falling weight deflectometer trailer.

MoDOT – US65 in Carroll County, Image P5250 252

Hole spacing: 4’ centers, each way (near), 3’ centers (far)
Photo shows Station Marks, DCP locations, and FWD locations (large white dots).

MoDOT – US65 in Carroll County, Image P5250 256

North bound shoulder before gravel was added. Shows depth of base material.

MoDOT – US65 in Carroll County, Image P5250 257

Bubbles in shoulder during UDI

MoDOT – US65 in Carroll County, Image P5250 262

Tubes being installed in a typical 25 LF x 24’ wide section

MoDOT – US65 in Carroll County, Image P5250 281

Tubes being installed at night.

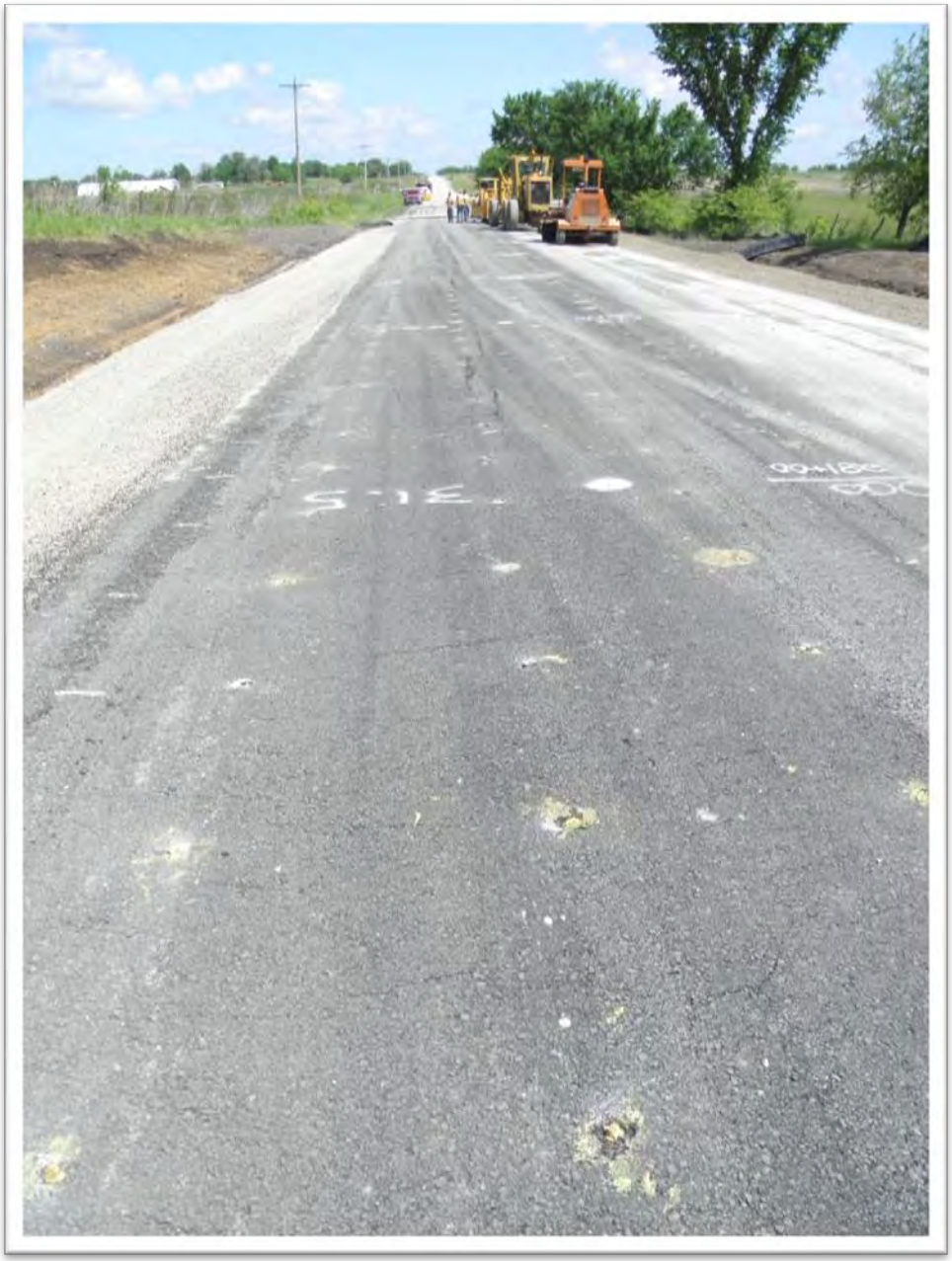
MoDOT – US65 in Carroll County, Image P5250 276

Tubes being installed at night.

MoDOT – US65 in Carroll County, Image P5310 288

Site after UDI.

MoDOT – US65 in Carroll County, Image P5310 289



Site after UDI and contractor adding gravel to shoulder.

APPENDIX C
DCP REPORT
(PRE-TREATMENT)

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Dynamic Cone Penetrometer Log Sheet

Location Information

County	Carroll	Pavement Material	None / Future Asphalt
State	MO	Pavement Thickness	
Roadway	US 65 at Rte WW	Base Material	Asphalt
Penetrometer Operators		Base Thickness	10"
Start Time		SubBase material	
Finish Time		SubBase Thickness	
Penetrometer test #	P1	Date	Data Recorder Ben Clay
Other Information	Station 25 (279+25)		

in depth	ft depth	cm depth	Pre Blows		Post Blows	in depth	ft depth	cm depth	Pre Blows		Post Blows
3.94	0.33	10	asphalt			200.79	16.73	510			
7.87	0.66	20	asphalt			204.72	17.06	520			
11.81	0.98	30	asphalt			208.66	17.38	530			
15.75	1.31	40	60			212.60	17.71	540			
19.69	1.64	50	90			216.54	18.04	550			
23.62	1.97	60	50			220.47	18.37	560			
27.56	2.30	70	28			224.41	18.70	570			
31.50	2.62	80	13			228.35	19.02	580			
35.43	2.95	90	2			232.28	19.35	590			
39.37	3.28	100	0			236.22	19.68	600			
43.31	3.61	110	0			240.16	20.01	610			
47.24	3.94	120	0			244.09	20.34	620			
51.18	4.26	130	1			248.03	20.66	630			
55.12	4.59	140	2			251.97	20.99	640			
59.06	4.92	150	4			255.91	21.32	650			
62.99	5.25	160	5			259.84	21.65	660			
66.93	5.58	170	4			263.78	21.98	670			
70.87	5.90	180	5			267.72	22.30	680			
74.80	6.23	190	4			271.65	22.63	690			
78.74	6.56	200	6			275.59	22.96	700			
82.68	6.89	210	6			279.53	23.29	710			
86.61	7.22	220	10			283.46	23.62	720			
90.55	7.54	230	10			287.40	23.94	730			
94.49	7.87	240	9			291.34	24.27	740			
98.43	8.20	250	10			295.28	24.60	750			
102.36	8.53	260	12			299.21	24.93	760			
106.30	8.86	270	10			303.15	25.26	770			
110.24	9.18	280	10			307.09	25.58	780			
114.17	9.51	290	12			311.02	25.91	790			
118.11	9.84	300	12			314.96	26.24	800			
122.05	10.17	310	16			318.90	26.57	810			
125.98	10.50	320	13			322.83	26.90	820			
129.92	10.82	330	15			326.77	27.22	830			
133.86	11.15	340	16			330.71	27.55	840			
137.80	11.48	350	14			334.65	27.88	850			
141.73	11.81	360	17			338.58	28.21	860			
145.67	12.14	370	19			342.52	28.54	870			
149.61	12.46	380	25			346.46	28.86	880			
153.54	12.79	390	22			350.39	29.19	890			
157.48	13.12	400	19			354.33	29.52	900			
161.42	13.45	410	20			358.27	29.85	910			
165.35	13.78	420	22			362.20	30.18	920			
169.29	14.10	430	25			366.14	30.50	930			
173.23	14.43	440	24			370.08	30.83	940			
177.17	14.76	450	23			374.02	31.16	950			
181.10	15.09	460	22			377.95	31.49	960			
185.04	15.42	470	27			381.89	31.82	970			
188.98	15.74	480	24			385.83	32.14	980			
192.91	16.07	490				389.76	32.47	990			
196.85	16.40	500				393.70	32.80	1000			

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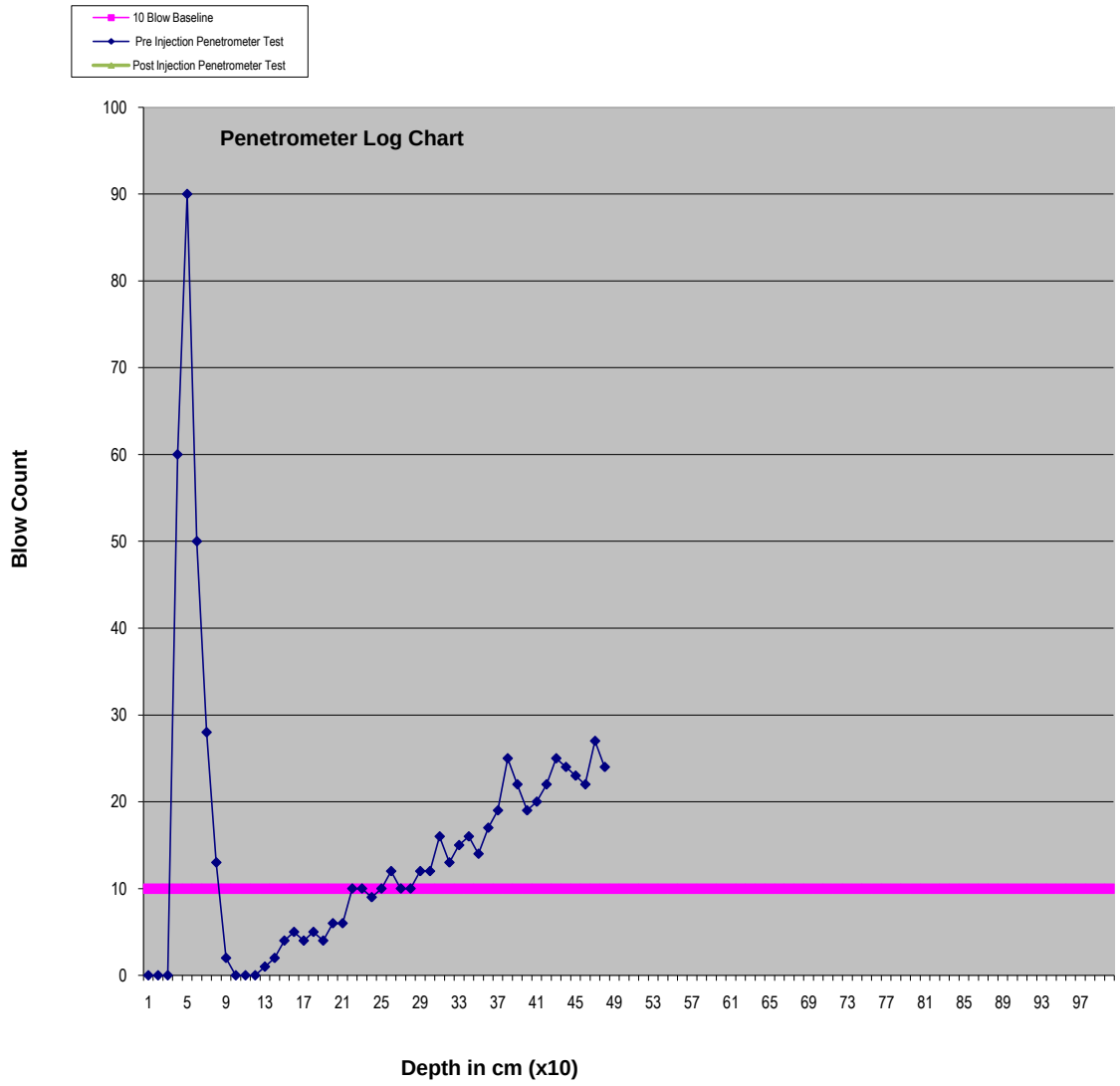
Dynamic Cone Penetrometer Log Sheet

Location Information

County	Carroll	Pavement Material	None / Future Asphalt
State	MO	Pavement Thickness	
Roadway	US 65 at Rte WW	Base Material	Asphalt
Penetrometer Operators		Base Thickness	10"
Start Time		SubBase material	
Finish Time		SubBase Thickness	
Penetrometer test #	Station 25 (279+25)	Date	Data Recorder Ben Clay
Other Information			



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Penetrometer Operators		Base Thickness	10"
Start Time	7:00 PM	SubBase material	
Finish Time		SubBase Thickness	
Penetrometer test #	P2	Date #######	Data Recorder Rick
Other Information	Station 150 (280+50)		

in depth	ft depth	cm depth	Pre Blows		Post Blows	in depth	ft depth	cm depth	Pre Blows		Post Blows
3.94	0.33	10	base			200.79	16.73	510			
7.87	0.66	20	base			204.72	17.06	520			
11.81	0.98	30	base			208.66	17.38	530			
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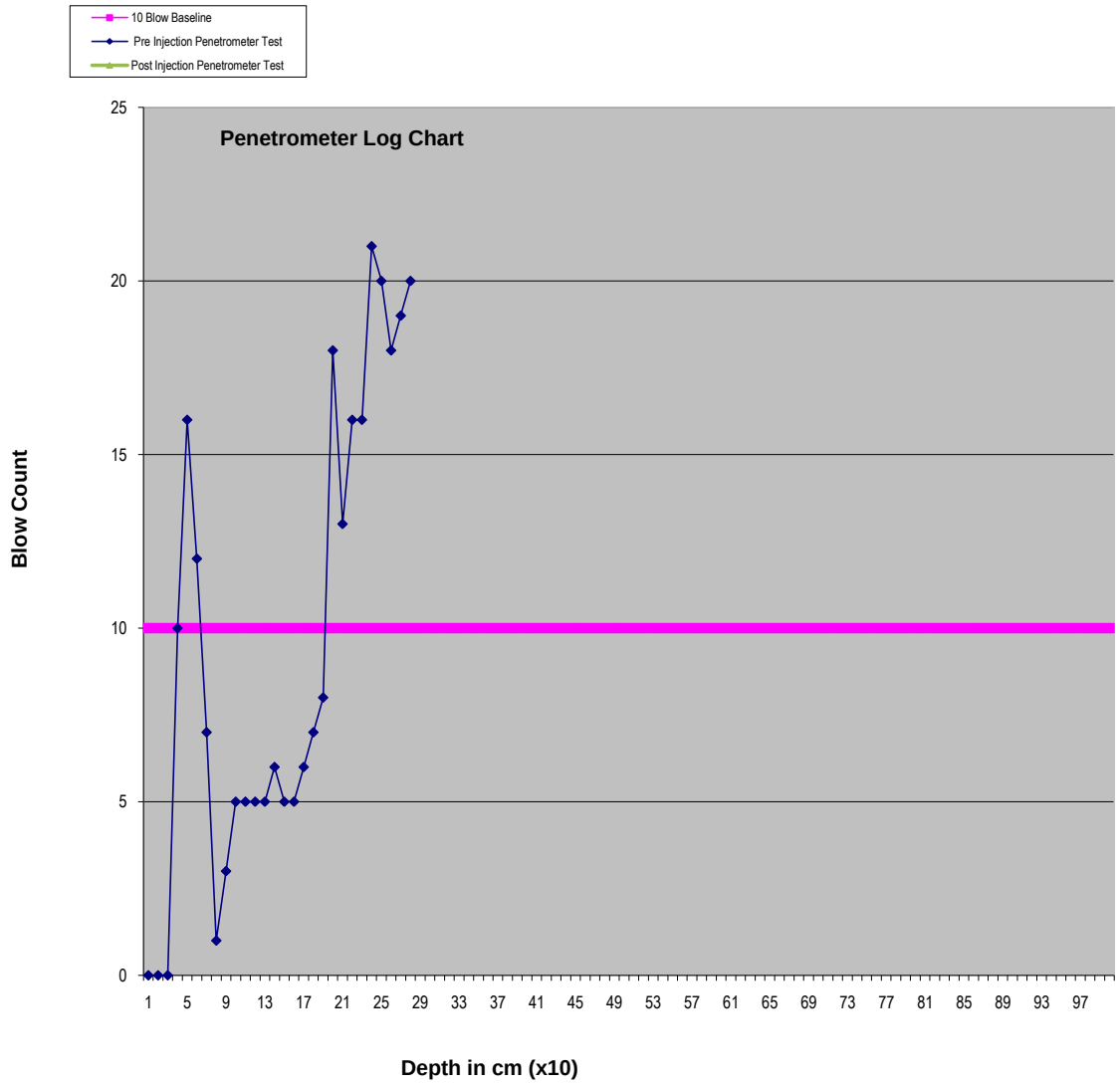
Start Time	0.791666667			SubBase material	
Finish Time				SubBase Thickness	
Penetrometer test #	Station 150 (280+50)	Date	40687	Data Recorder	Rick
Other Information					



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Dynamic Cone Penetrometer Log Sheet

Location Information

County	Carroll	Pavement Material	None / Future Asphalt
State	MO	Pavement Thickness	
Roadway	US 65 at Rte WW	Base Material	Asphalt
Penetrometer Operators		Base Thickness	10"
Start Time	7:30 PM	SubBase material	
Finish Time		SubBase Thickness	
Penetrometer test #	P3	Date #######	Data Recorder Rick
Other Information	Station 250 (281+25)		

in depth	ft depth	cm depth	Pre Blows		Post Blows	in depth	ft depth	cm depth	Pre Blows		Post Blows
3.94	0.33	10	base			200.79	16.73	510			
7.87	0.66	20	base			204.72	17.06	520			
11.81	0.98	30	base			208.66	17.38	530			
15.75	1.31	40	58			212.60	17.71	540			
19.69	1.64	50	40			216.54	18.04	550			
23.62	1.97	60	7			220.47	18.37	560			
27.56	2.30	70	2			224.41	18.70	570			
31.50	2.62	80	3			228.35	19.02	580			
35.43	2.95	90	6			232.28	19.35	590			
39.37	3.28	100	5			236.22	19.68	600			
43.31	3.61	110	5			240.16	20.01	610			
47.24	3.94	120	6			244.09	20.34	620			
51.18	4.26	130	5			248.03	20.66	630			
55.12	4.59	140	7			251.97	20.99	640			
59.06	4.92	150	6			255.91	21.32	650			
62.99	5.25	160	7			259.84	21.65	660			
66.93	5.58	170	10			263.78	21.98	670			
70.87	5.90	180	15			267.72	22.30	680			
74.80	6.23	190	12			271.65	22.63	690			
78.74	6.56	200	11			275.59	22.96	700			
82.68	6.89	210	11			279.53	23.29	710			
86.61	7.22	220	9			283.46	23.62	720			
90.55	7.54	230	8			287.40	23.94	730			
94.49	7.87	240	7			291.34	24.27	740			
98.43	8.20	250	6			295.28	24.60	750			
102.36	8.53	260	7			299.21	24.93	760			
106.30	8.86	270	8			303.15	25.26	770			
110.24	9.18	280	10			307.09	25.58	780			
114.17	9.51	290	8			311.02	25.91	790			
118.11	9.84	300	14			314.96	26.24	800			
122.05	10.17	310	15			318.90	26.57	810			
125.98	10.50	320	24			322.83	26.90	820			
129.92	10.82	330	16			326.77	27.22	830			
133.86	11.15	340	15			330.71	27.55	840			
137.80	11.48	350	15			334.65	27.88	850			
141.73	11.81	360	15			338.58	28.21	860			
145.67	12.14	370				342.52	28.54	870			
149.61	12.46	380				346.46	28.86	880			
153.54	12.79	390				350.39	29.19	890			
157.48	13.12	400				354.33	29.52	900			
161.42	13.45	410				358.27	29.85	910			
165.35	13.78	420				362.20	30.18	920			
169.29	14.10	430				366.14	30.50	930			
173.23	14.43	440				370.08	30.83	940			
177.17	14.76	450				374.02	31.16	950			
181.10	15.09	460				377.95	31.49	960			
185.04	15.42	470				381.89	31.82	970			
188.98	15.74	480				385.83	32.14	980			
192.91	16.07	490				389.76	32.47	990			
196.85	16.40	500				393.70	32.80	1000			

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URETEK Engineering Department
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Tomball Tx, 77375

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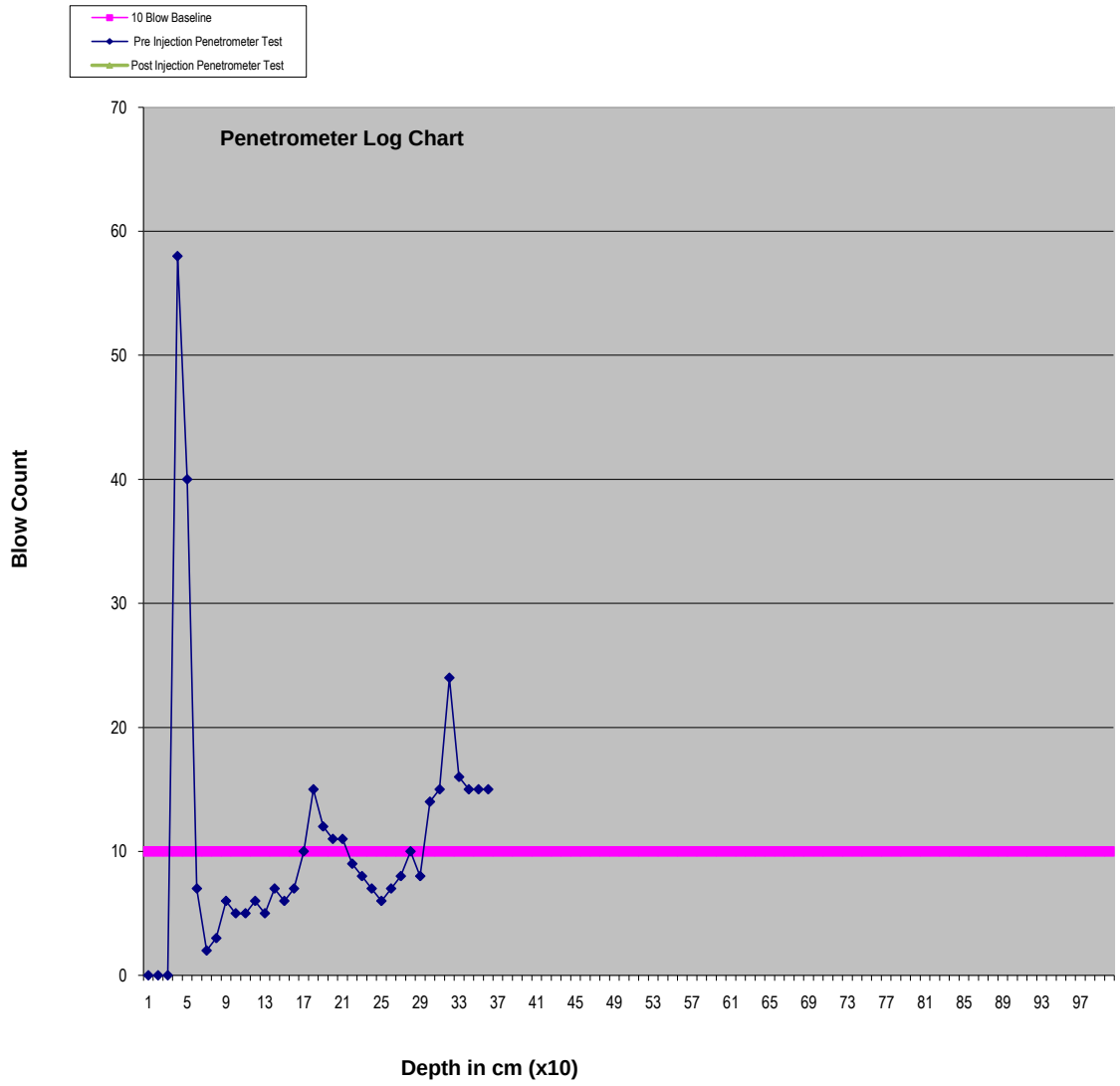
Dynamic Cone Penetrometer Log Sheet

Location Information

County	Carroll			Pavement Material	None / Future Asphalt
State	MO			Pavement Thickness	
Roadway	US 65 at Rte WW			Base Material	Asphalt
Penetrometer Operators				Base Thickness	10"
Start Time	0.8125			SubBase material	
Finish Time				SubBase Thickness	
Penetrometer test #	Station 250 (281+25)	Date	40687	Data Recorder	Rick
Other Information					



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Dynamic Cone Penetrometer Log Sheet

Location Information

County	Carroll	Pavement Material	None / Future Asphalt
State	MO	Pavement Thickness	
Roadway	US 65 at Rte WW	Base Material	Asphalt
Penetrometer Operators		Base Thickness	10"
Start Time	4:30 PM	SubBase material	
Finish Time		SubBase Thickness	
Penetrometer test #	P4	Date #######	Data Recorder Rick
Other Information	Station 325 (282+25)		

in depth	ft depth	cm depth	Pre Blows		Post Blows	in depth	ft depth	cm depth	Pre Blows		Post Blows
3.94	0.33	10	base			200.79	16.73	510			
7.87	0.66	20	base			204.72	17.06	520			
11.81	0.98	30	base			208.66	17.38	530			
15.75	1.31	40	9			212.60	17.71	540			
19.69	1.64	50	26			216.54	18.04	550			
23.62	1.97	60	10			220.47	18.37	560			
27.56	2.30	70	2			224.41	18.70	570			
31.50	2.62	80	4			228.35	19.02	580			
35.43	2.95	90	4			232.28	19.35	590			
39.37	3.28	100	5			236.22	19.68	600			
43.31	3.61	110	5			240.16	20.01	610			
47.24	3.94	120	5			244.09	20.34	620			
51.18	4.26	130	4			248.03	20.66	630			
55.12	4.59	140	5			251.97	20.99	640			
59.06	4.92	150	5			255.91	21.32	650			
62.99	5.25	160	8			259.84	21.65	660			
66.93	5.58	170	11			263.78	21.98	670			
70.87	5.90	180	14			267.72	22.30	680			
74.80	6.23	190	14			271.65	22.63	690			
78.74	6.56	200	15			275.59	22.96	700			
82.68	6.89	210	13			279.53	23.29	710			
86.61	7.22	220	10			283.46	23.62	720			
90.55	7.54	230	11			287.40	23.94	730			
94.49	7.87	240	12			291.34	24.27	740			
98.43	8.20	250	11			295.28	24.60	750			
102.36	8.53	260	11			299.21	24.93	760			
106.30	8.86	270	7			303.15	25.26	770			
110.24	9.18	280	6			307.09	25.58	780			
114.17	9.51	290	6			311.02	25.91	790			
118.11	9.84	300	11			314.96	26.24	800			
122.05	10.17	310	14			318.90	26.57	810			
125.98	10.50	320	17			322.83	26.90	820			
129.92	10.82	330	14			326.77	27.22	830			
133.86	11.15	340	16			330.71	27.55	840			
137.80	11.48	350				334.65	27.88	850			
141.73	11.81	360				338.58	28.21	860			
145.67	12.14	370				342.52	28.54	870			
149.61	12.46	380				346.46	28.86	880			
153.54	12.79	390				350.39	29.19	890			
157.48	13.12	400				354.33	29.52	900			
161.42	13.45	410				358.27	29.85	910			
165.35	13.78	420				362.20	30.18	920			
169.29	14.10	430				366.14	30.50	930			
173.23	14.43	440				370.08	30.83	940			
177.17	14.76	450				374.02	31.16	950			
181.10	15.09	460				377.95	31.49	960			
185.04	15.42	470				381.89	31.82	970			
188.98	15.74	480				385.83	32.14	980			
192.91	16.07	490				389.76	32.47	990			
196.85	16.40	500				393.70	32.80	1000			

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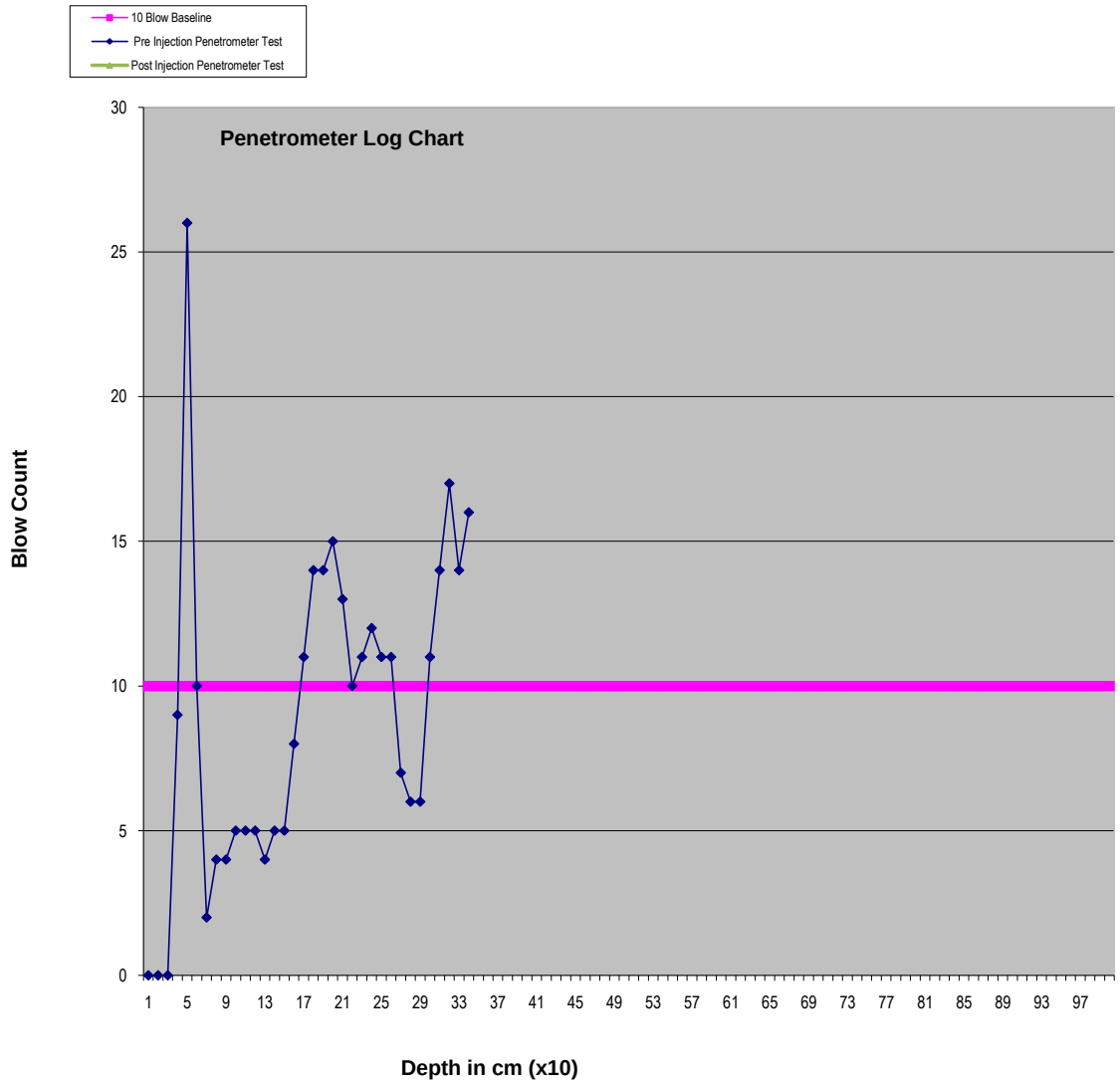
Dynamic Cone Penetrometer Log Sheet

Location Information

County	Carroll			Pavement Material	None / Future Asphalt
State	MO			Pavement Thickness	
Roadway	US 65 at Rte WW			Base Material	Asphalt
Penetrometer Operators				Base Thickness	10"
Start Time	0.6875			SubBase material	
Finish Time				SubBase Thickness	
Penetrometer test #	Station 325 (282+25)	Date	40689	Data Recorder	Rick
Other Information					



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Dynamic Cone Penetrometer Log Sheet

Location Information

County	Carroll	Pavement Material	None / Future Asphalt
State	MO	Pavement Thickness	
Roadway	US 65 at Rte WW	Base Material	Asphalt
Penetrometer Operators		Base Thickness	10"
Start Time		SubBase material	
Finish Time		SubBase Thickness	
Penetrometer test #	P5	Date #######	Data Recorder Rick
Other Information	Station 425 (283+25)		

in depth	ft depth	cm depth	Pre Blows		Post Blows	in depth	ft depth	cm depth	Pre Blows		Post Blows
3.94	0.33	10	base			200.79	16.73	510			
7.87	0.66	20	base			204.72	17.06	520			
11.81	0.98	30	base			208.66	17.38	530			
15.75	1.31	40	8			212.60	17.71	540			
19.69	1.64	50	27			216.54	18.04	550			
23.62	1.97	60	8			220.47	18.37	560			
27.56	2.30	70	5			224.41	18.70	570			
31.50	2.62	80	10			228.35	19.02	580			
35.43	2.95	90	7			232.28	19.35	590			
39.37	3.28	100	6			236.22	19.68	600			
43.31	3.61	110	6			240.16	20.01	610			
47.24	3.94	120	5			244.09	20.34	620			
51.18	4.26	130	7			248.03	20.66	630			
55.12	4.59	140	8			251.97	20.99	640			
59.06	4.92	150	10			255.91	21.32	650			
62.99	5.25	160	10			259.84	21.65	660			
66.93	5.58	170	9			263.78	21.98	670			
70.87	5.90	180	11			267.72	22.30	680			
74.80	6.23	190	12			271.65	22.63	690			
78.74	6.56	200	15			275.59	22.96	700			
82.68	6.89	210	14			279.53	23.29	710			
86.61	7.22	220	12			283.46	23.62	720			
90.55	7.54	230	11			287.40	23.94	730			
94.49	7.87	240	11			291.34	24.27	740			
98.43	8.20	250	10			295.28	24.60	750			
102.36	8.53	260	9			299.21	24.93	760			
106.30	8.86	270	7			303.15	25.26	770			
110.24	9.18	280	6			307.09	25.58	780			
114.17	9.51	290	6			311.02	25.91	790			
118.11	9.84	300	12			314.96	26.24	800			
122.05	10.17	310	14			318.90	26.57	810			
125.98	10.50	320	15			322.83	26.90	820			
129.92	10.82	330	16			326.77	27.22	830			
133.86	11.15	340	14			330.71	27.55	840			
137.80	11.48	350				334.65	27.88	850			
141.73	11.81	360				338.58	28.21	860			
145.67	12.14	370				342.52	28.54	870			
149.61	12.46	380				346.46	28.86	880			
153.54	12.79	390				350.39	29.19	890			
157.48	13.12	400				354.33	29.52	900			
161.42	13.45	410				358.27	29.85	910			
165.35	13.78	420				362.20	30.18	920			
169.29	14.10	430				366.14	30.50	930			
173.23	14.43	440				370.08	30.83	940			
177.17	14.76	450				374.02	31.16	950			
181.10	15.09	460				377.95	31.49	960			
185.04	15.42	470				381.89	31.82	970			
188.98	15.74	480				385.83	32.14	980			
192.91	16.07	490				389.76	32.47	990			
196.85	16.40	500				393.70	32.80	1000			

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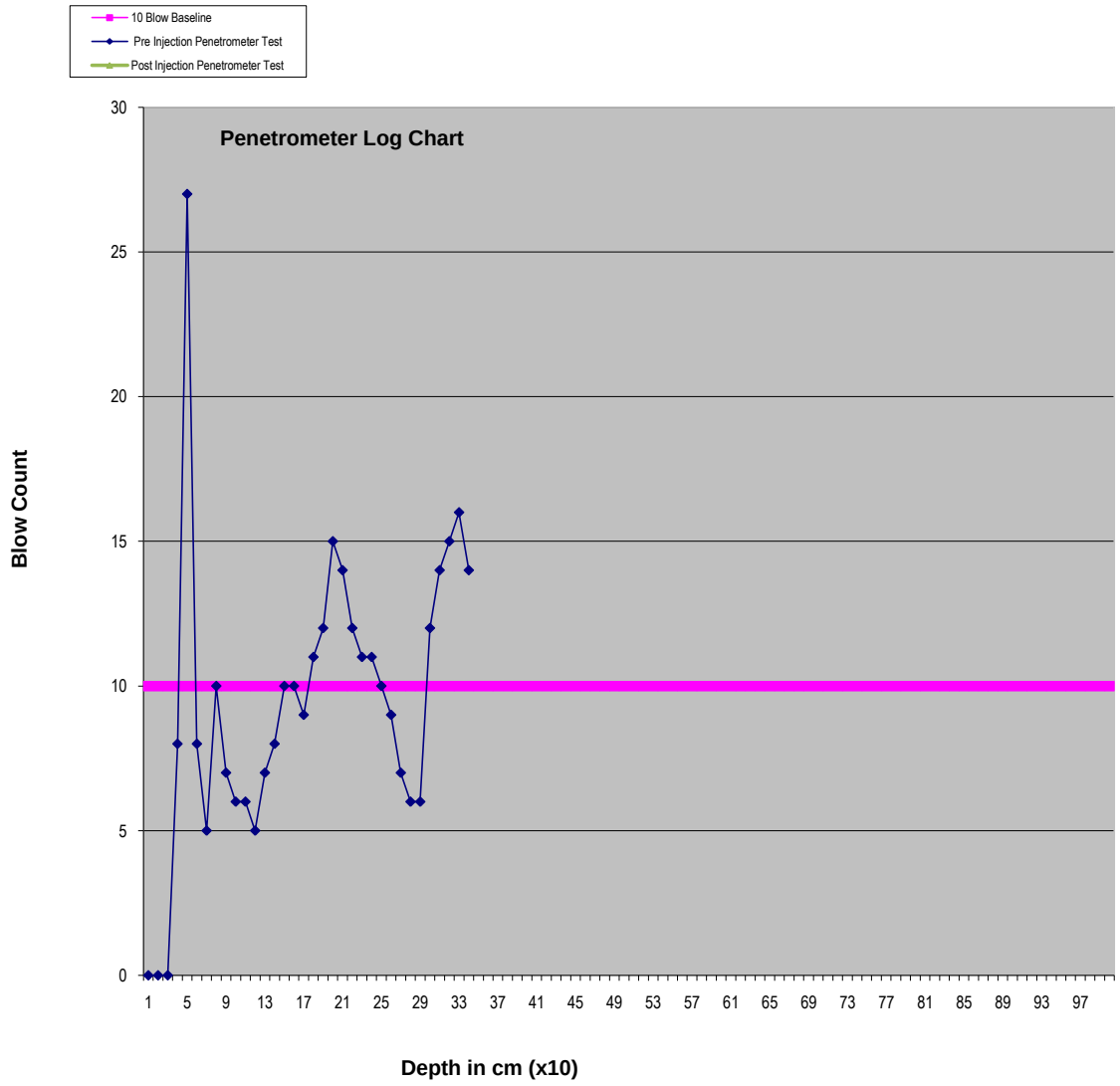
Dynamic Cone Penetrometer Log Sheet

Location Information

County	Carroll			Pavement Material	None / Future Asphalt
State	MO			Pavement Thickness	
Roadway	US 65 at Rte WW			Base Material	Asphalt
Penetrometer Operators				Base Thickness	10"
Start Time				SubBase material	
Finish Time				SubBase Thickness	
Penetrometer test #	Station 425 (283+25)	Date	40689	Data Recorder	Rick
Other Information					



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APPENDIX D
FWD ANALYSIS
(by John P. Donahue, PE, Construction and Materials Liaison Engineer, MODOT, 23 June 11)

Amy Hyde

Importance: High

From: John.Donahue@modot.mo.gov [mailto:John.Donahue@modot.mo.gov]
Sent: Thursday, June 23, 2011 11:31 AM
To: Rick Gatewood; Robert.Hughson@modot.mo.gov
Cc: Randy Brown; Steve Reed; James.Gillespie@modot.mo.gov; Dennis.Brucks@modot.mo.gov
Subject: Re: US 65 in Carroll County - FWD results

Attached is the FWD analysis that I finally had time to finish.

Several notes...

The maximum deflection is normalized for a 9000 lb load. This is necessary because the dynamic load from the plate drop is rarely ever exactly 9000; typical deviations make it vary up or down up a few hundred pounds. The polyurethane deep injection process made a significant reduction in maximum deflections. The geogrid installation and placement of the remaining 3.75"
HMA also improved things. See the 'Averages' worksheet for details. There were occasional anomalies where the max deflections actually increased slightly after the geogrid and overlay, but the deflections were already at acceptably low levels. A typically healthy full depth asphalt pavement should have max deflections under 20 (mils); only four test locations had final deflections greater than 20 (mils) and even these were still in the low to mid-20's.

AREA represents the area of a slice taken through any deflection basin between the center of the test load and 3 feet. The basin is normalized by dividing it by the maximum deflection at the load center, thus making it a dimensionless measure. A typical range for a structurally sound full depth asphalt pavement is 23 to 27. The average AREA for the US 65 section actually started at 23.6, dropped slightly after deep injection to 23.2 and dropped even further to 21.6 after construction was completed. This doesn't necessarily mean there is a structural problem. The AREA parameter must be taken in context with subgrade modulus, which is discussed below.
The temperature of the HMA lift on the geogrid might have still been somewhat elevated when the testing was performed and would explain the higher max deflections with respect to the radial deflections resulting in a lower AREA.

The subgrade modulus was estimated at 24' and 36 " from the load center using a Boussinnesq point load equation modified for a circular load on a one-layer system. The idea is to use the deflection of a sensor that is just outside the zone of pressure influence in the asphalt layer. In other words, we want a deflection that is entirely the result of compression in the subgrade and not combined with measurable compression in the asphalt layer. This is typically somewhere just beyond 24" for thicker asphalt pavements. The average results between the two radii do not vary much, which is an indication that the deflection locations are just far enough out. There is roughly a 60% increase in modulus after the deep injection.
There is also modest improvement after the geogrid and 3.75" final HMA, which indicates that the calculation is not purely affected by the subgrade modulus, since there really is no further improvement occurring in the subgrade at this point; instead, additional structure on top is producing some influence. Overall, the average subgrade modulus is now around 15 (ksi), which is considered stable for supporting a pavement structure.

(See attached file: J2P0777_FWD Analysis.xlsx)

John P. Donahue, P.E.

Construction and Materials Liaison Engineer Missouri DOT
1617 Missouri Blvd.
Jefferson City, MO 65109
Tel: (573) 526-4334
Mobile: (573) 690-3828

From: Rick Gatewood <Rick.Gatewood@uretekusa.com>
To: "John.Donahue@modot.mo.gov" <John.Donahue@modot.mo.gov>
Cc: Randy Brown <DrRWBrown@uretekusa.com>, Steve Reed <sreed@uretekusa.com>
Date: 06/20/2011 09:22 AM
Subject: US 65 in Carroll County - FWD results

John,

Whenever possible, please forward the FWD results to me, Dr. Brown and Steve Reed.

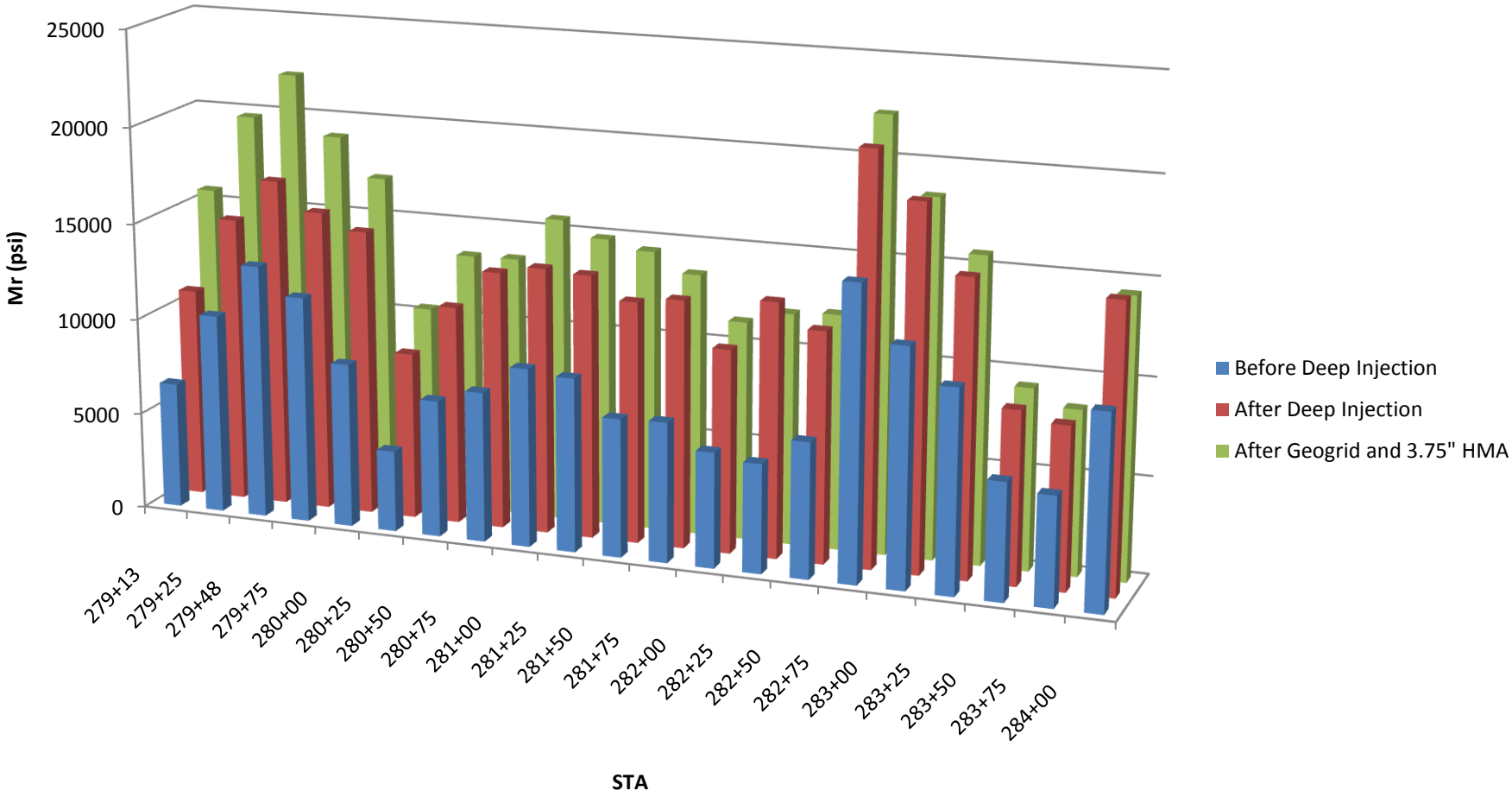
Thank you,
Rick Gatewood
URETEK USA MIDWEST
660-351-2119

US 65 in Carroll County

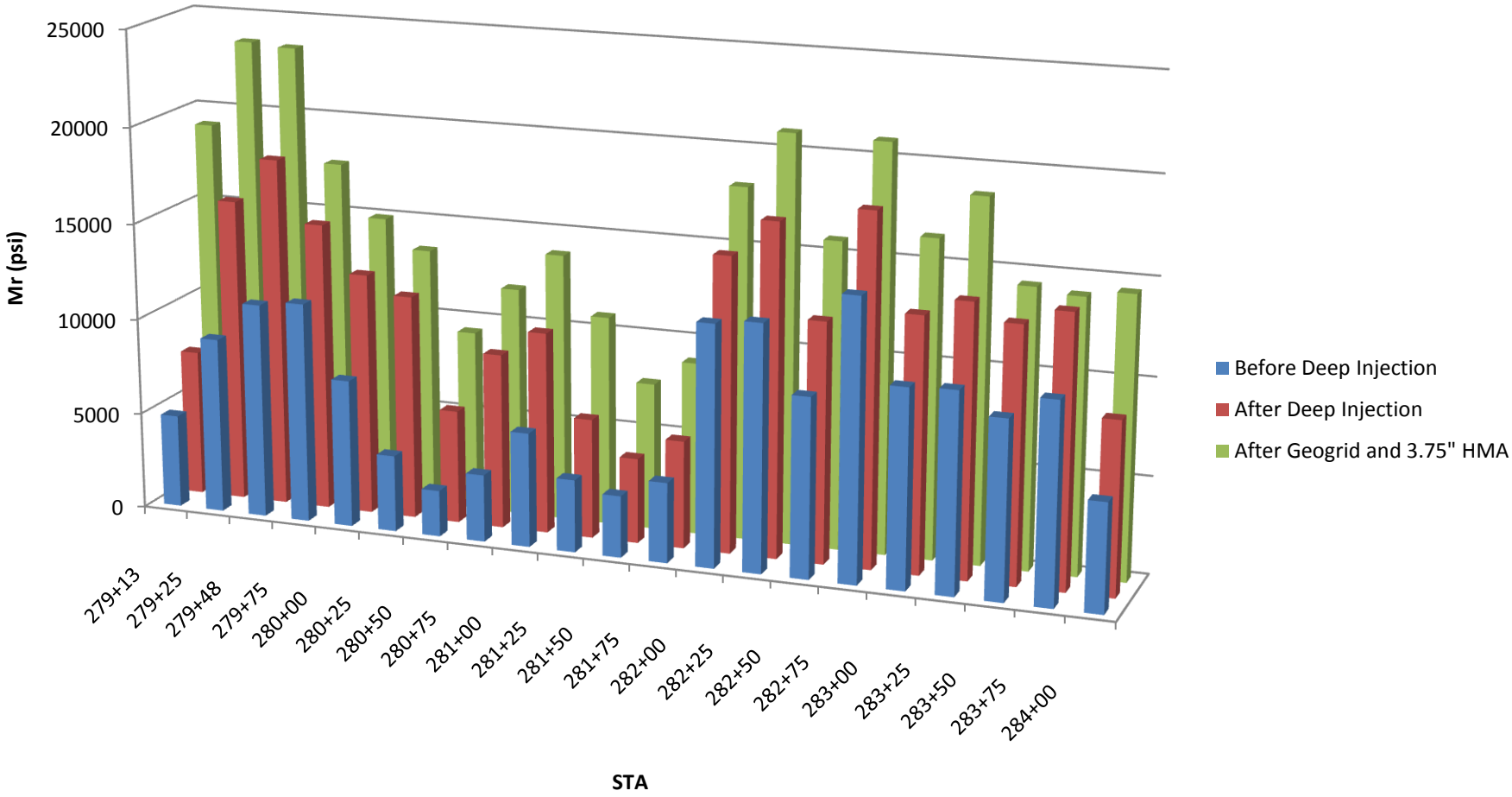
AVERAGES

Max Deflection (mils)	
Before Deep Injection	**33.5**
After Deep Injection	**19.7**
After Geogrid and 3.75" HMA	**15.3**
AREA	
Before Deep Injection	**23.6**
After Deep Injection	**23.2**
After Geogrid and 3.75" HMA	**21.6**
Subgrade Modulus (psi) @ 24" Radius	
Before Deep Injection	**8218**
After Deep Injection	**12601**
After Geogrid and 3.75" HMA	**15263**
Subgrade Modulus (psi) @ 36" Radius	
Before Deep Injection	**8518**
After Deep Injection	**12781**
After Geogrid and 3.75" HMA	**14117**
% Max Deflection Decrease	
After Deep Injection	**35.1**
After Geogrid and 3.75" HMA	**36.9**
% Subgrade Mod @ 24" Increase	
After Deep Injection	**62.3**
After Geogrid and 3.75" HMA	**103.6**
% Subgrade Mod @ 36" Increase	
After Deep Injection	**58.1**
After Geogrid and 3.75" HMA	**76.2**

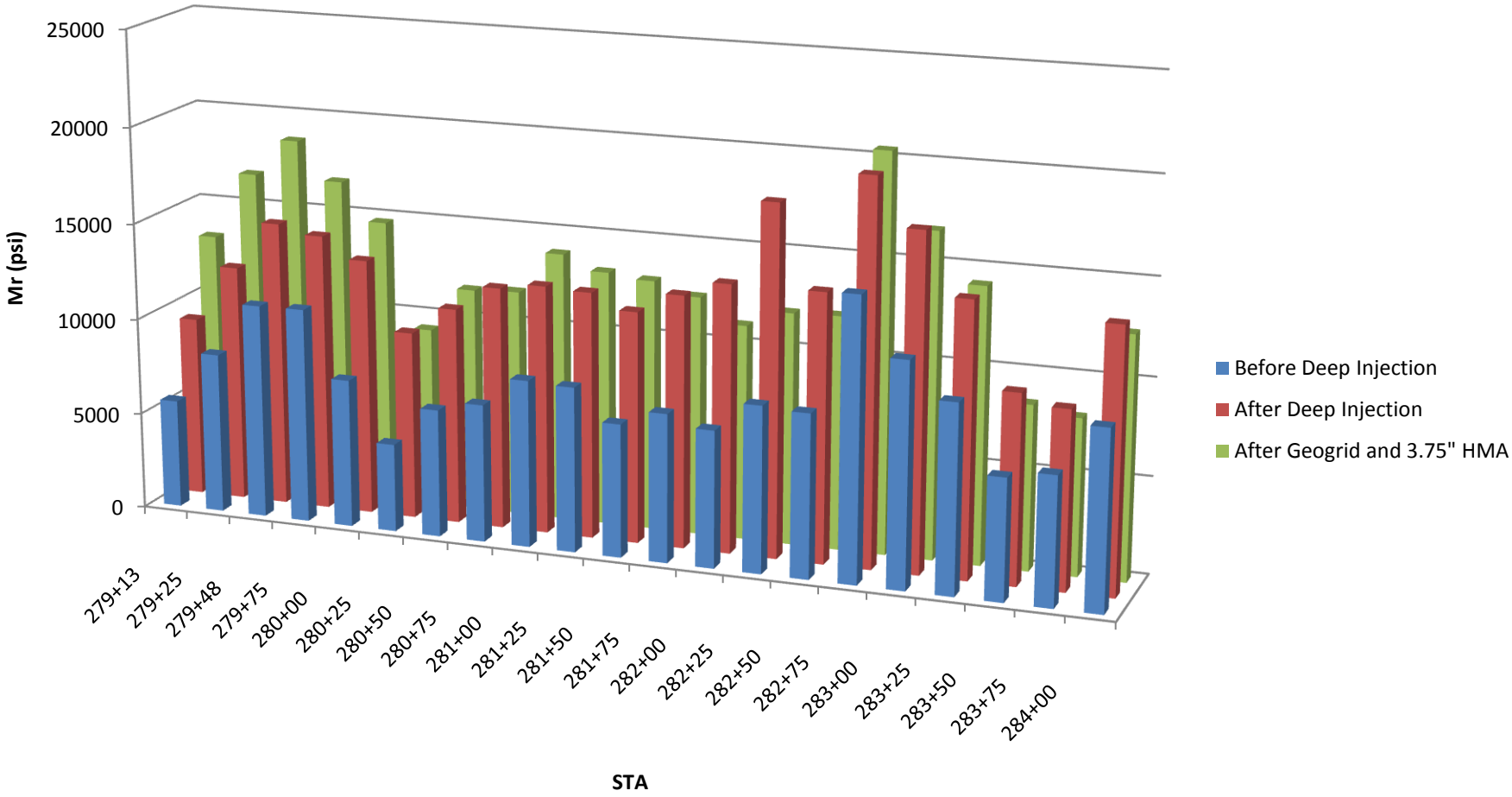
Subgrade Modulus @ 24" Radius for NB US 65



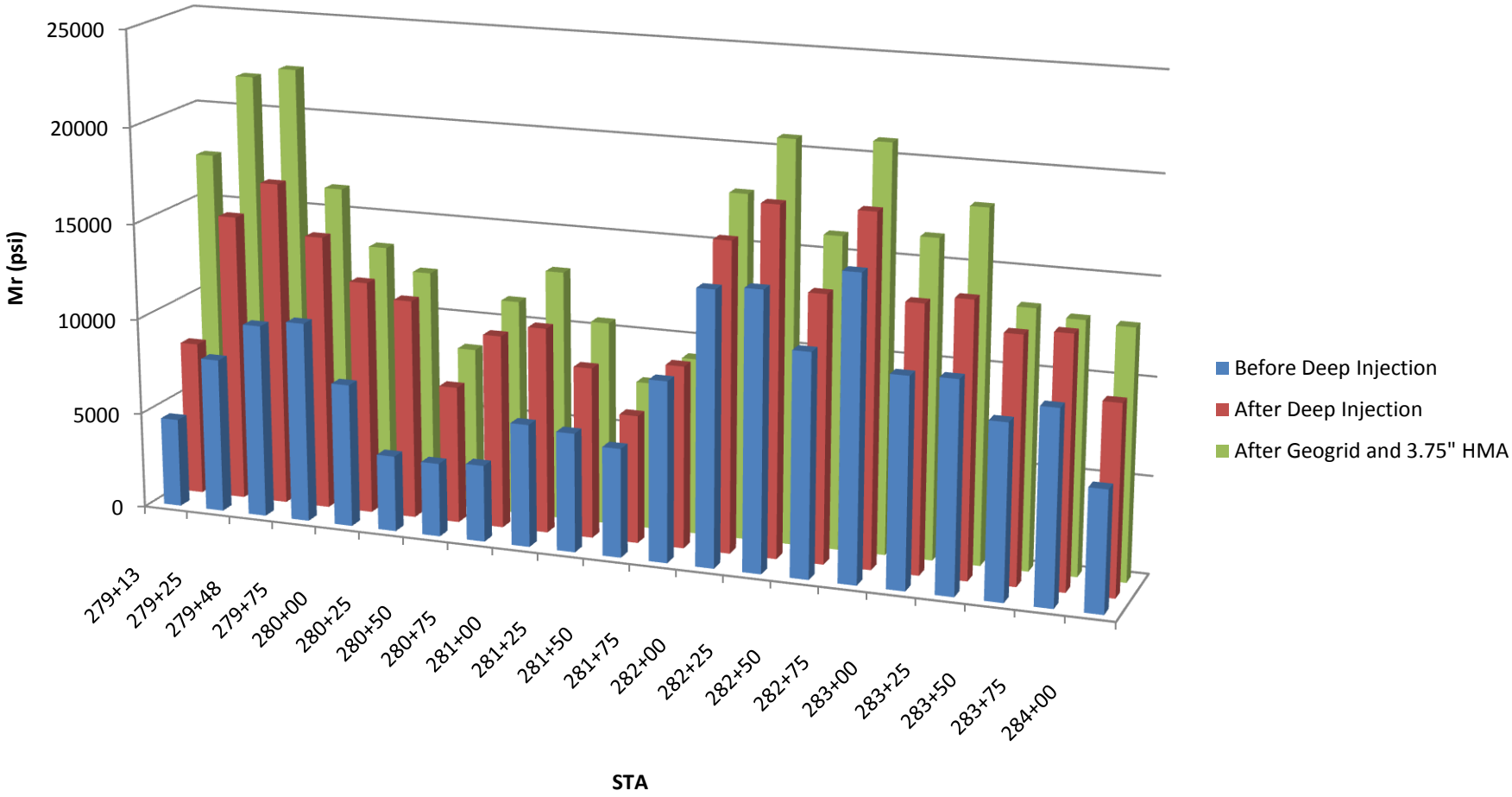
Subgrade Modulus @ 24" Radius for SB US 65



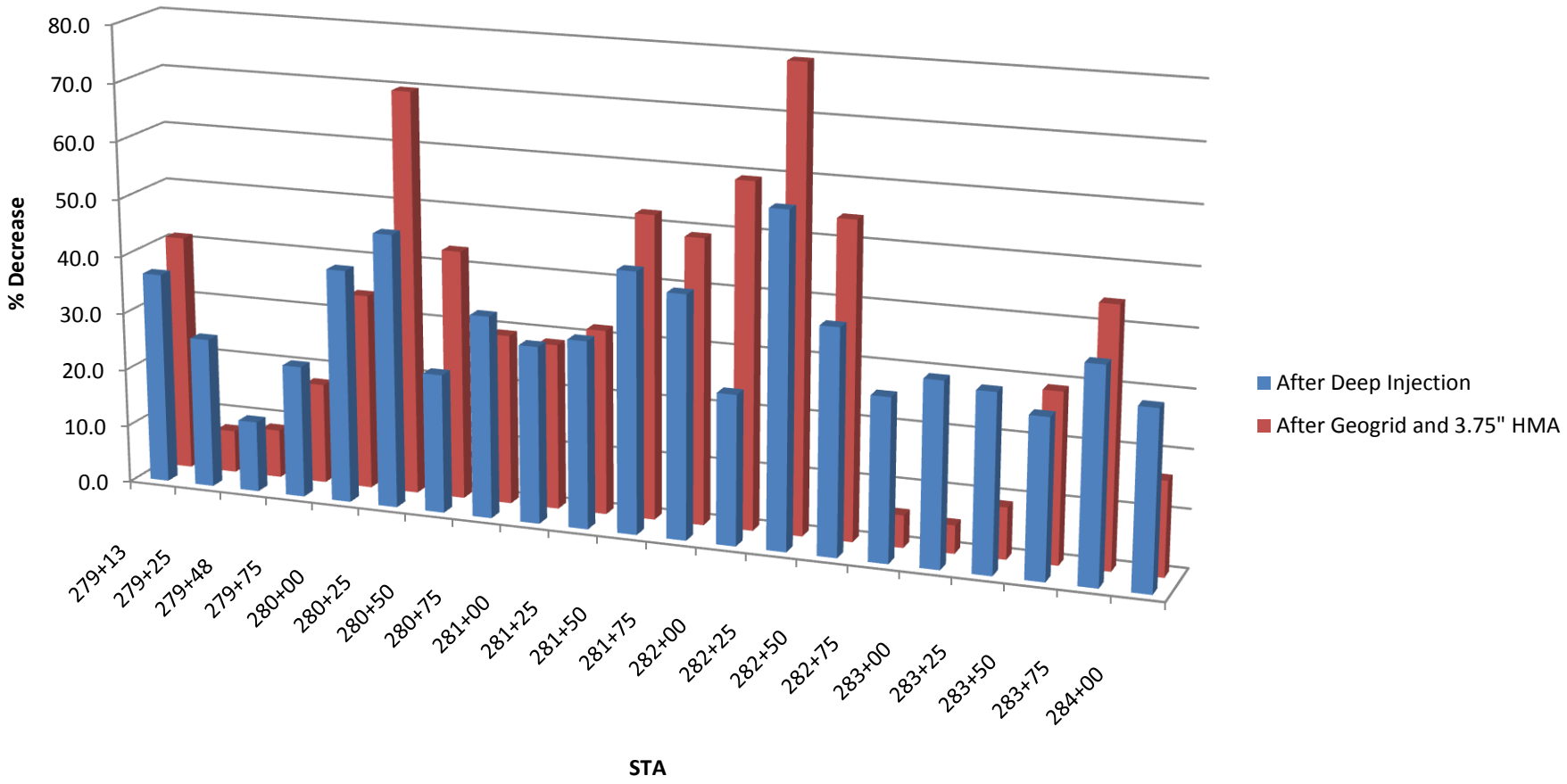
Subgrade Modulus @ 36" Radius for NB US 65



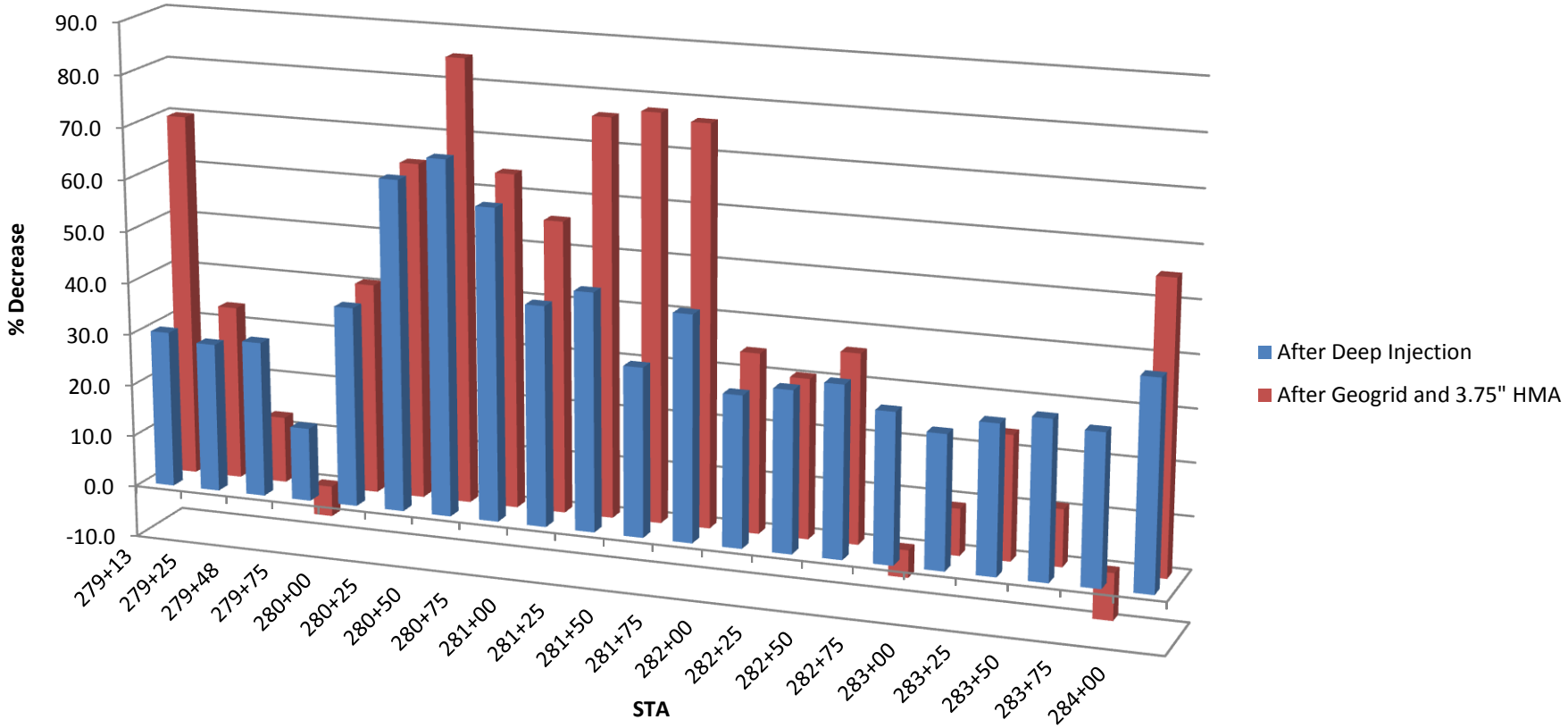
Subgrade Modulus @ 36" Radius for SB US 65



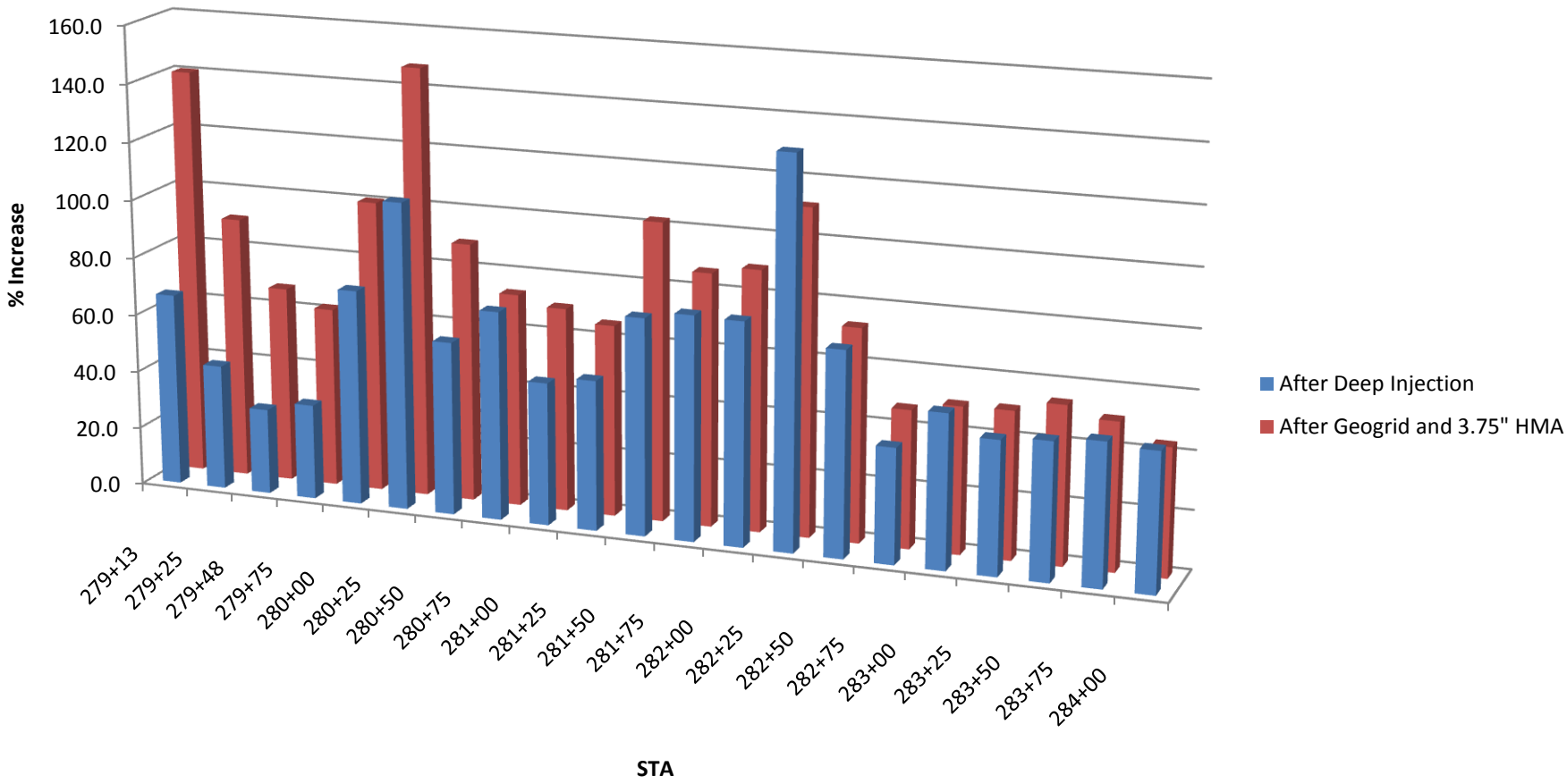
Percent Maximum Deflection Decrease for NB US 65



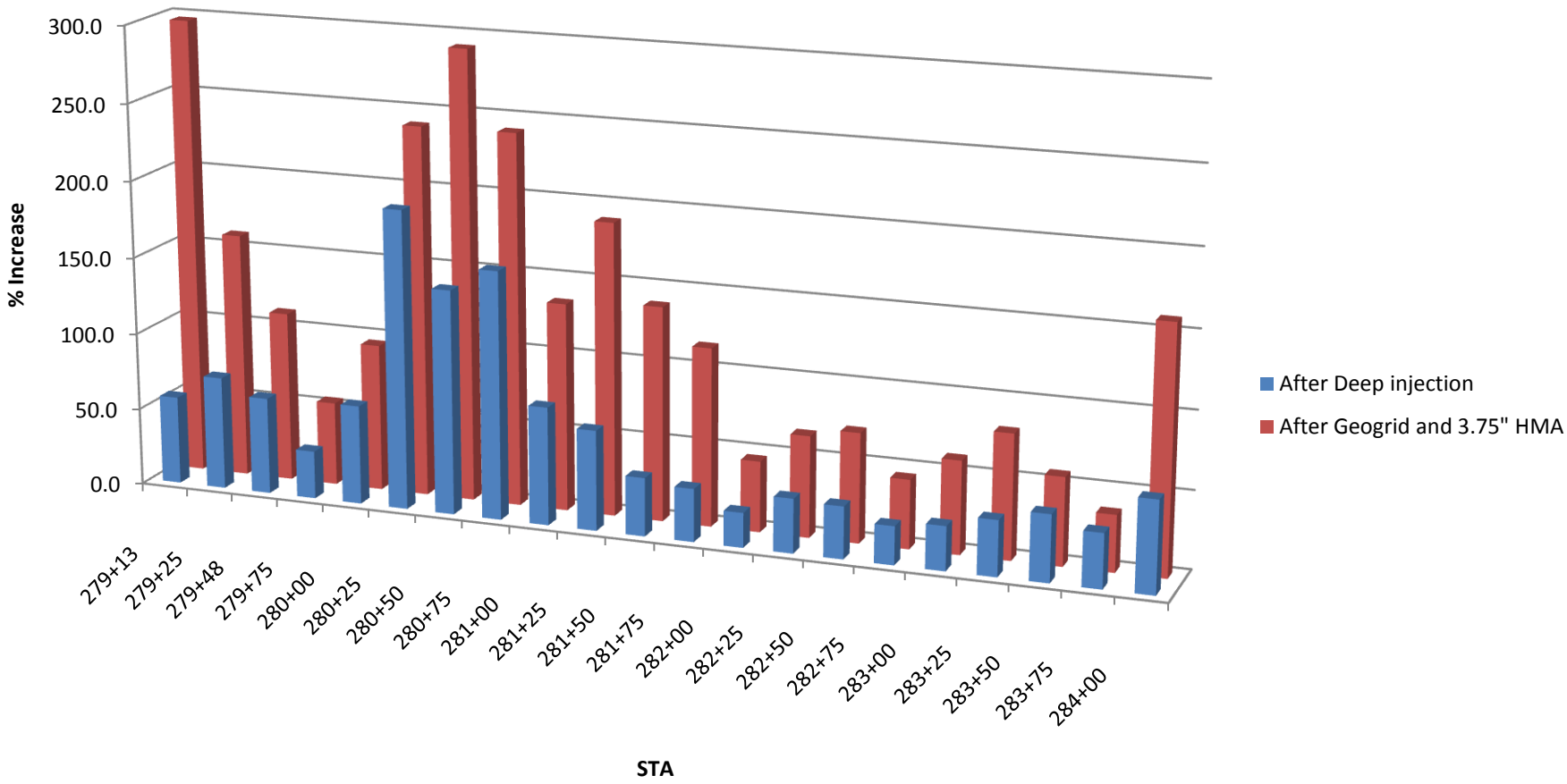
Percent Maximum Deflection Decrease for SB US 65



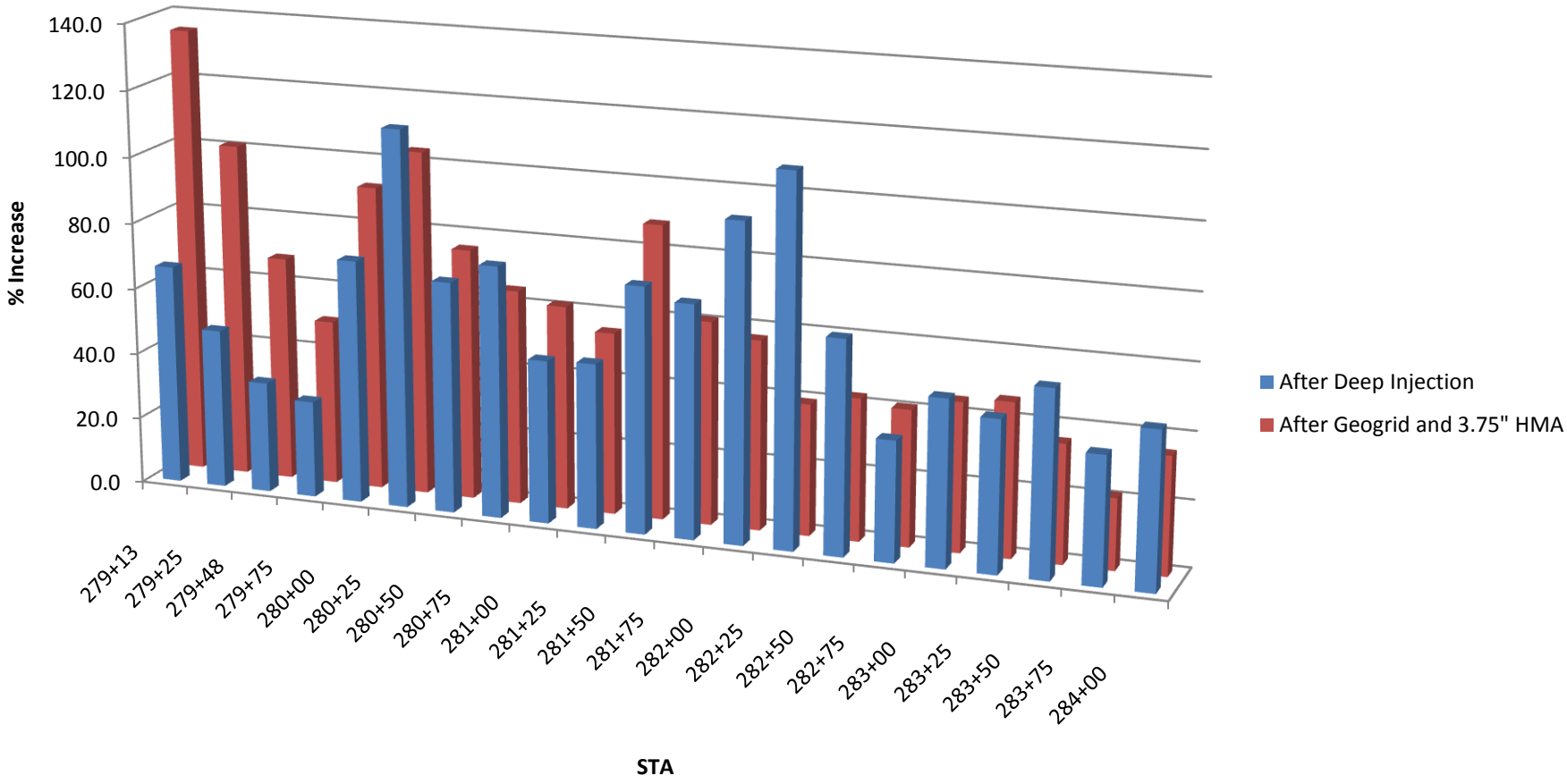
Percent Increase in Subgrade Modulus @ 24" Radius for NB US 65



Percent Increase in Subgrade Modulus @ 24" Radius for SB US 65



Percent Increase in Subgrade Modulus @ 36" Radius for NB US 65



Percent Increase in Subgrade Modulus @ 36" Radius for SB US 65