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16. Abstract

This report documents the results of field testing of seventeen types of retroreflective raised pavement markers (RRPMs) installed in August 1992 at four interstate locations around San Antonio, Texas. Reflectivity measurements were taken periodically at each site using a portable reflectometer. These data were supplemented with laboratory reflectivity measurements from RRPMs taken from each site and sent to the TxDOT testing laboratory in Austin, Texas.

Study results indicate that most of the RRPMs experienced significant losses in reflectivity over very short periods of time. Under the range of traffic conditions examined, many RRPMs dropped below approximate minimum reflectivity thresholds after six months in the field. Initial losses in reflectivity were due primarily to dirt accumulation on the reflective lenses. Over time, abrasions and weathering caused reflectivity losses to become permanent.

Three RRPM types that had thin glass layers epoxied over the reflective lenses were still providing significant levels of reflectivity after 54 weeks in the field at all of the test locations. For the other RRPMs, differences in reflectivity loss rates appeared to depend mostly upon the total traffic volumes passing next to the RRPMs at each test site, and less so upon the amount of truck traffic or lane-changing activity.

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RETROREFLECTIVE RAISED PAVEMENT MARKER FIELD TESTING: RESULTS OF THE FIRST YEAR EVALUATION

By

Gerald L. Ullman

Research Report 1946-2
Research Study Number 7-1946

Sponsored by

Texas Department of Transportation

January 1994

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, TX 77843-3135

IMPLEMENTATION STATEMENT

The contents of the report should be useful to the Department in assessing the reflectivity performance of the many different types of retroreflective raised pavement markers being sold, particularly with respect to the effect of differing levels of traffic demand upon reflectivity retention. These data also provide the Department useful information upon which to evaluate current purchasing specifications for RRPMs. As a result of this research, the Department may wish to encourage the use of glass-covered RRPMs on high-volume facilities. This would reduce the frequency of RRPM replacement on such facilities and promote adequate nighttime and wet-weather roadway delineation over longer periods of time.

DISCLAIMER

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The engineer in charge of the project was Mr. Gerald L. Ullman (Texas P.E. registration #66876).

ACKNOWLEDGMENT

The study was designed and is being managed by Mr. Lewis Rhodes, P.E. of TxDOT. The guidance provided by Mr. Rhodes and by Messrs. John Bassett and Arthur Barrow, P.E., of the TxDOT Testing and Materials Division are gratefully acknowledged. Also, this study was made possible by the participation of product suppliers of six different retroreflective pavement marker manufacturers, namely Apex, Batterson, Empco, Ray-O-Lite, Stimsonite, and Swareflex. Finally, the Maintenance section of the San Antonio District Office of TxDOT installed the RRPMs at the four test locations and have provided traffic control support during each of the return visits for reflectivity measurements. Their assistance with this study is gratefully acknowledged.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

This report summarizes the data collected during the first year of the field test of 17 types of RRPMs at four freeway locations around San Antonio, Texas. Reflectivity data were collected at each test site using a portable reflectometer and corroborated with laboratory measurements from samples taken to the TxDOT testing laboratory in Austin, Texas. The results of the first year of the test show that many of the RRPMs fail to provide adequate levels of reflectivity after as little as six months exposure on high-volume facilities. The major exceptions were those RRPMs with thin layers of glass epoxied over the reflective lens. For these markers, reflectivity levels measured above minimum (approximate) threshold SI values at all sites after 54 weeks exposure.

Overall, RRPM service lives tended to be the shortest at site 1, approximately equal at sites 2 and 3, and the longest at site 4. These results seem consistent with the relative daily traffic volumes experienced at each site (highest at site 1, approximately equal at sites 2 and 3, and lowest at site 4).

During the first few weeks in the field, losses in RRPM reflectivity are due in large part to dirt accumulation on the lens. This is a somewhat temporary condition, however, as tire abrasion and weathering eventually scar the lens and make the loss of reflectivity permanent. It appeared that the glass covering of some of the RRPMs reduced the rate at which the permanent reflectivity loss occurred. Even after 54 weeks in the field, reflectivity levels of these RRPMs proved quite high after the dirt and road grime were washed away.

1. INTRODUCTION

Retroreflective raised pavement markers (RRPMs) are used extensively throughout Texas for delineating lanes in both rural and urban areas. Over the past several years, the Texas Department of Transportation (TxDOT) has sponsored a number of studies to assess how quickly RRPMs lose their reflectivity, and to identify what factors influence the rate of reflectivity loss (1-3). The results of this research indicate that sunlight, dirt accumulation, and tire abrasions on the reflective lens of the RRPM all contribute to the loss of reflectivity. Unfortunately, the interaction between these effects makes it extremely difficult to quantify their impacts upon reflectivity. Also, differences in RRPM designs may influence the rate of dirt accumulation and abrasion. Furthermore, manufacturers continually modify their products and introduce new RRPM designs into the marketplace. Finally, different roadway types and geographical areas produce different types of dirt and grit which themselves differ in terms of their abrasive properties.

In response to the need for better data regarding the loss rate of RRPM reflectivity in Texas, TxDOT initiated a two-year field test in August 1992 of seventeen different RRPMs. RRPMs were installed at four different interstate locations near San Antonio, Texas. The purpose of the test was to collect objective measurements of RRPM reflectivity over time, and to assess how losses in RRPM reflectivity may be related to the roadway volumes, amount of truck traffic, and lane-changing frequency at each site. This report presents the results of the data collected during the first year of that test.

DESCRIPTION OF RRPMS UNDER EVALUATION

In June 1992, TxDOT contacted a large number of RRPM manufacturers to solicit participation in the field test. Each manufacturer was allowed to submit up to six different types of markers for testing. A total of 6 manufacturers responded, furnishing 17 different markers. A summary of the general characteristics of each marker (manufacturer, model number, marker dimensions, type of reflective surface, and specific intensity) is provided in Table 1-1.

Table 1-1. RRPM Characteristics

Manufacturer	Model	Dimensions	Reflective Surface	SI
Apex	921	3.8" x 4" x 0.7"	acrylic cube-corner	3.5
Apex*	918	4" x 4" x 0.7"	acrylic cube-corner	4.2
Apex	928	4" x 4" x 0.7"	acrylic cube-corner	2.9
Apex	807	4" x 4" x 0.9"	acrylic cube-corner	2.4
Apex	817	4" x 4.8" x 0.9"	acrylic cube-corner	1.0
Batterson	Reflective Button	4" diameter x 0.8"	microprism high-intensity sheeting	5.2
Empco	901	4" diameter x 0.8"	acrylic cube-corner	1.8
Ray-O-Lite	8704 (S)[a]	4" x 4" x 0.7"	acrylic cube-corner	5.3
Ray-O-Lite	8704 (R)[b]	4" x 4" x 0.7"	acrylic cube-corner	5.3
Ray-O-Lite*	9704	4" x 4" x 0.7"	acrylic cube-corner	6.4
Ray-O-Lite	2002	2.4" x 4.8" x 0.5"	acrylic cube-corner	6.3
Ray-O-Lite	2003	2" x 5.8" x 0.4"	acrylic cube-corner	6.9
Stimsonite*	88	4" x 4" x 0.7"	acrylic cube-corner	7.4
Stimsonite*	911	4" x 4" x 0.7"	glass layer over acrylic cube-corner	9.2
Stimsonite*	948	2.3" x 4.7" x 0.5"	glass layer over acrylic cube-corner	8.0
Stimsonite	953	2.8" x 4.5" x 0.6"	glass layer over acrylic cube-corner	8.7
Swareflex	---	4" x 4" x 0.7"	⅛" glass beads	5.5

* RRPM prequalified by TxDOT
SI = Specific Intensity

[a] (S) = square-shouldered marker
[b] (R) = round-shouldered marker

The majority of the markers are a 4-inch (10.2 cm) square design made of molded plastic, with either a single clear reflective face or opposing clear/red faces. The exceptions to this design include the following:

- Apex models 807 and 817 (constructed of ceramic),
- Batterson and Empco round plastic reflective buttons,
- Ray-O-Lite models 2002 and 2003 (rectangular low-profile prototype designs), and
- Stimsonite models 948 and 953 (also rectangular low-profile designs).

All but two of the markers rely on prismatic cube-corner lenses for reflectivity. Reflectivity of the Batterson marker is achieved by a strip of microprism high-intensity sheeting glued to a portion of the button milled perpendicular to its top. The Swareflex marker uses three rows of small, ⅛ inch (3.2 mm) glass beads embedded in the face of the marker for reflectivity. The Stimsonite models 911, 948, and 953 have a thin layer of glass attached over the acrylic prismatic lens to improve the durability of the reflective face. TxDOT has prequalified several of these markers for use on Texas highways. These are noted by an asterisk (*) in Table 1-1.

The final column in Table 1-1 summarizes the initial laboratory reflectivity test results on each type of RRPM. These values represent the average specific intensity (SI) of five of each type of RRPM, drawn randomly from those submitted by the manufacturers for installation at the test sites. Measurements were conducted using an entrance angle of 4° and observation angle of 0.2°. The specific intensity value indicates the amount of light reflected back from an object per unit of light shining on the object. The average specific intensities range from a low of 1.0 for the Apex model 817, to a high of 9.2 for the Stimsonite model 911. TxDOT requires RRPMs to exceed an SI value of 3.0 when new in order to qualify for use in Texas.

The manufacturers participating in the field tests provided a minimum of 180 markers per model to be evaluated, yielding a total of slightly more than 3,000 markers for the entire study. These were divided into four lots of 45 of each type of RRPM, and were each installed at four interstate locations (four-lane and six-lane facilities) near San Antonio, Texas. The sequence of markers was randomized at each site, and were installed at 20 ft (6.1 m) spacings over at total distance of approximately 2.9 miles (4.7 km). On four-lane facilities, the RRPMs were installed between the inside and outside travel lanes. On six-lane facilities, the RRPMs were installed only on the lane line separating the inside and middle travel lanes. This was done to minimize the impact of lane-changing activity occurring upon RRPM performance. The markers were installed using bitumen adhesive as per standard TxDOT procedures.

DESCRIPTION OF THE STUDY SITES

An initial interim report (4) prepared for this study documented the traffic characteristics of the four sites used for this field test. Figure 1-1 identifies the relative locations of the sites, whereas Table 1-2 summarizes the basic roadway and traffic characteristics of each site measured in July 1992. The sites were initially chosen to encompass a wide range of AADTs in the test conditions. However, it was decided that additional traffic characteristics, such as the number of heavy trucks and the frequency of lane-changing across the RRPMs, would also likely influence RRPM reflectivity and so were also measured during the studies.

Table 1-2. General Characteristics of the Study Sites

Site	Location	Lanes Per Direction	Traffic Volumes	Percent Trucks[a]
1	Northbound I-410	3	36,700 - 58,900 vpd[b]	3 - 6
2	Northbound US-281	3	21,200 - 21,400 vpd[b]	3 - 8
3	Westbound I-10	2	18,600 vpd[c]	6 - 10
4	Westbound I-10	2	3,300 vpd[c]	10 - 15

[a] peak and off-peak percentages, respectively
[b] volumes measured on the southern and northern ends of the test sections, respectively
[c] volume measured in the middle of the test section

As shown in Table 1-2, 24-hour traffic counts taken at each site demonstrate a wide range in traffic volumes. Site 1, located in the northbound direction of I-410 on the west side of San Antonio, carries the greatest amount of traffic daily (between 36,700 and 58,900 vehicles per day [vpd]). The second-most heavily traveled test site was located in the northbound direction of US-281 immediately adjacent to the San Antonio airport. Here, 24-hour traffic volumes are between 21,200 and 21,400 vpd. Site 3, located in the westbound direction of I-10 near Leon Springs, serves approximately 18,600 vpd. Site 4, located in the westbound direction of I-10 near Kerrville, was the lowest volume site (serving approximately 6,500 vpd). Because they were

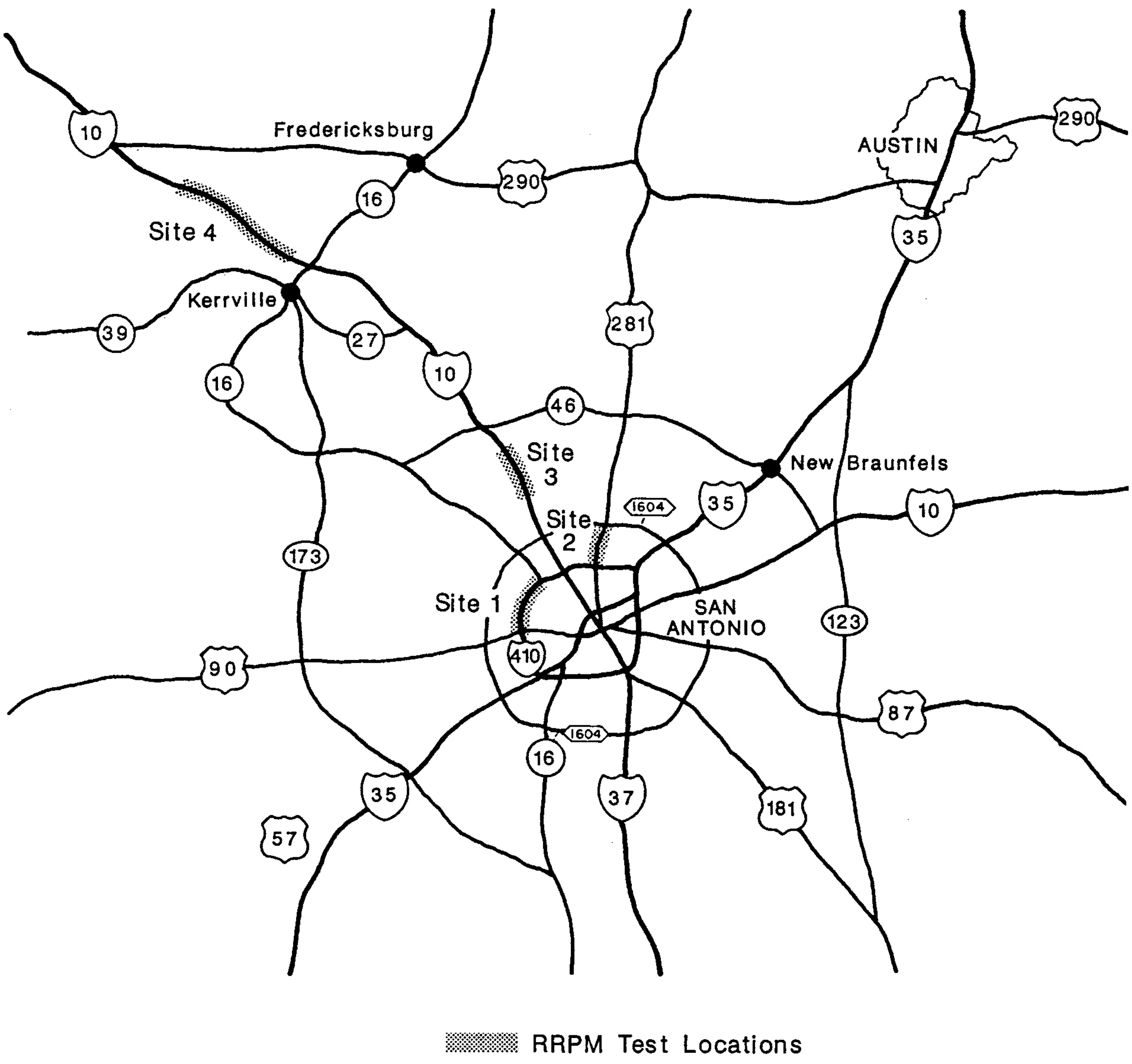


Figure 1-1. Study Site Locations.

located in more urban surroundings, Sites 1 and 2 carried a lower percentage of heavy trucks than did Sites 3 and 4.

RRPMs at Sites 1 and 2 were installed only between the inside and middle travel lanes. Consequently, they were subjected to traffic demands somewhat less than the total 24-hour counts across all travel lanes as documented in Table 1-2. Lane distribution data also collected during the studies were, therefore, used to estimate the amount of traffic actually passing next to the RRPMs at each site. These estimates were also used to compute normalized truck traffic demands and lane-changing rates across the four sites. Table 1-3 summarizes these rates. From this table, one can see that RRPMs at Site 1 were subjected to the greatest amount of daily traffic and frequency of lane changes across the RRPMs. However, it became apparent that although Site 2 served slightly more traffic in total, the volume actually passing next to the RRPMs was less than at Site 3 (for both total traffic and truck traffic rates). In fact, the truck traffic volume passing next to the RRPMs at site 3 was even higher than at site 1. Meanwhile, Site 4 experienced the lowest total traffic volume, truck traffic volume, and lane-changing rate.

Table 1-3. Daily Traffic Characteristics Adjacent to Test RRPMS at Each Site

Site	Traffic Characteristic		
	Total Vehicles Per Day	Trucks Per Day	Lane Changes Per Mile Per Day (Km Per Day)
1[a]	25,100 - 40,300	880 - 1,420	760 - 1,210 (460-735)
2[a]	13,800-14,000	940 - 950	620 - 630 (375-380)
3	18,600	1,650	520 (315)
4	3,300	500	240 (145)

[a] Rates represent the data collected at the southern and northern ends of the study sites, respectively on lanes immediately adjacent to the test RRPMs

The traffic studies were repeated in July 1993 at each study site to determine whether significant changes in traffic conditions occurred during the year. The results of the July 1993 studies, shown in the Appendix A, indicate no significant change in any of the traffic characteristics measured at each site relative to those shown in Tables 1-2 and 1-3.

DATA COLLECTION SCHEDULE OF RRPM REFLECTIVITY

Several times throughout the year, reflectivity of each type of RRPM on the roadway at each site was sampled using portable retroreflectometer equipment. Following the field measurements, one of each type of RRPM was then removed and taken to the laboratory. Laboratory reflectivity measurements were taken of each of these markers in a dry, unwashed state and then repeated after washing the road grime from the reflective face of the RRPM.

Table 1-4 summarizes the planned and actual data collection schedule for the first year of the field test. Measurements were scheduled close together early in the test, when the majority of RRPM reflectivity loss was anticipated to occur. Intervals between measurements were then lengthened as the test progressed. In general, the actual data collection schedule coincided very closely with the planned schedule for the first 12 weeks of the study. The schedule then had to be modified slightly because of weather problems which occurred.

Incomplete data were available for the 12-week and 23-week evaluations. No RRPMs were removed and tested in the laboratory from the 12-week evaluation. Conversely, problems with the portable reflectometer resulted in no field data being collected for the 23-week evaluation (only laboratory data were obtained).

Table 1-4. Planned and Actual Data Collection Schedule

Time after installation of RRPMs	
Planned	Actual
at installation	at installation
2 weeks	2 weeks
4 weeks	4 weeks
6 weeks	6 weeks
8 weeks	9 weeks
12 weeks	12 weeks
20 weeks	23 weeks
28 weeks	32 weeks
36 weeks	48 weeks
52 weeks	54 weeks
78 weeks	---
104 weeks	---

2. RRPM REFLECTIVITY TEST RESULTS

Reflectivity measurements from three to ten samples of each type of RRPM were obtained during each return visit to the test site, yielding a database consisting of nearly 4,000 observations by the end of the 54-week evaluation. Added to this database were another 1,500 reflectivity readings taken from samples sent to the TxDOT laboratory. This chapter presents a summary of these data, covering three specific topics:

- the performance of the portable reflectometer,
- the performance of each type of RRPM over time, and
- the relation between the loss in reflectivity of each RRPM and the traffic characteristics to which it was subjected.

PERFORMANCE OF THE PORTABLE REFLECTOMETER

Advanced Retro Technology, Inc. manufactured and supplied a prototype portable reflectometer (model 1200C) for use during this field test. This unit is self-contained with an internal rechargeable battery, light source, and light detector. A calibrated light source illuminates a small area under a sampling window. This window is placed over an RRPM, and the light detector measures the amount of light reflected back from the RRPM from the calibrated light source. To calibrate the reflectometer, the user first illuminates the pavement on which the RRPMs are attached and sets the detector reading to zero. This factors out the ambient reflectivity of the pavement. Next, a calibration marker that has been measured in the laboratory is placed under the measuring window and illuminated. The user adjusts the reflectometer reading to coincide with the specific intensity (SI) value obtained for that marker in the laboratory.

The measuring methodology employed by the portable reflectometer is different than that called for in the standard American Society for Testing and Materials (ASTM) procedures or the TxDOT procedures for determining RRPM reflectance (3). However, we found that the SI values taken with the reflectometer compared quite favorably with laboratory-measured SI values for the same marker, using Pearson's Correlation Coefficients computed between the portable reflectometer and the laboratory-measured SI values as the basis of comparison. Overall, the reflectometer achieved an overall correlation coefficient of 0.93 with SI values obtained in the laboratory. Furthermore, the reflectometer maintained this high degree of correlation over the entire first year. Figure 2-1 illustrates the reflectometer-laboratory correlation coefficients for each of the field evaluations. Except for a slight dip at the two-week evaluation, correlation between the reflectometer and the laboratory SI values consistently exceeded 0.9.

We suspect that the lower correlation obtained from the two-week evaluation may have resulted from the learning process that data collection personnel went through to learn to calibrate and operate the reflectometer properly. Several individuals took turns making the reflectivity measurements during that early test, and it is possible that slight differences in how each person operated the reflectometer resulted in data which were less precise than in subsequent evaluations (when fewer people collected the data).

The portable reflector correlated fairly well for most types of RRPMs included in this field test. Table 2-1 summarizes the coefficients computed between the reflectometer and laboratory readings by type of RRPM. These coefficients range from a low of 0.70 for the Apex Model 817 RRPM to a high of 0.98 for the Ray-O-Lite Model 2003. Suppliers of the Apex Model 817 noted that the reflective lens of the markers submitted for testing had been manufactured at the wrong angle (a problem they corrected on subsequent RRPMs of that type). This incorrect lens angle may explain the low correlation value achieved, as reflectometer readings of all of the other types of RRPMs achieved correlation coefficients of 0.83 or better.

REFLECTIVITY PERFORMANCE BY TYPE OF RRPM

Appendix B at the end of this report provides the average SI values obtained for each RRPM type by site and by date of study (in weeks after installation). The standard deviations for those averages are also provided to illustrate the variability in the SI readings for each marker. As a summary, Figures 2-2 through 2-5 present the average new and 54-week SI values for each RRPM taken with the portable reflectometer at sites 1 through 4, respectively. For many of the markers, reflectivity levels after 54 weeks were minimal or even non-existent. This was particularly true at site 1, where the RRPMs were subjected to high traffic volumes and frequent lane-changing. Average SI values were slightly higher at sites 2 and 3 for a few RRPMs, but still showed a significant decrease from their SI values when new. As a rule, RRPMs had the highest levels of reflectivity remaining after 54 weeks at site 4 (the lowest volume site). However, even these SI values measured quite low in comparison to the new RRPM SI values.

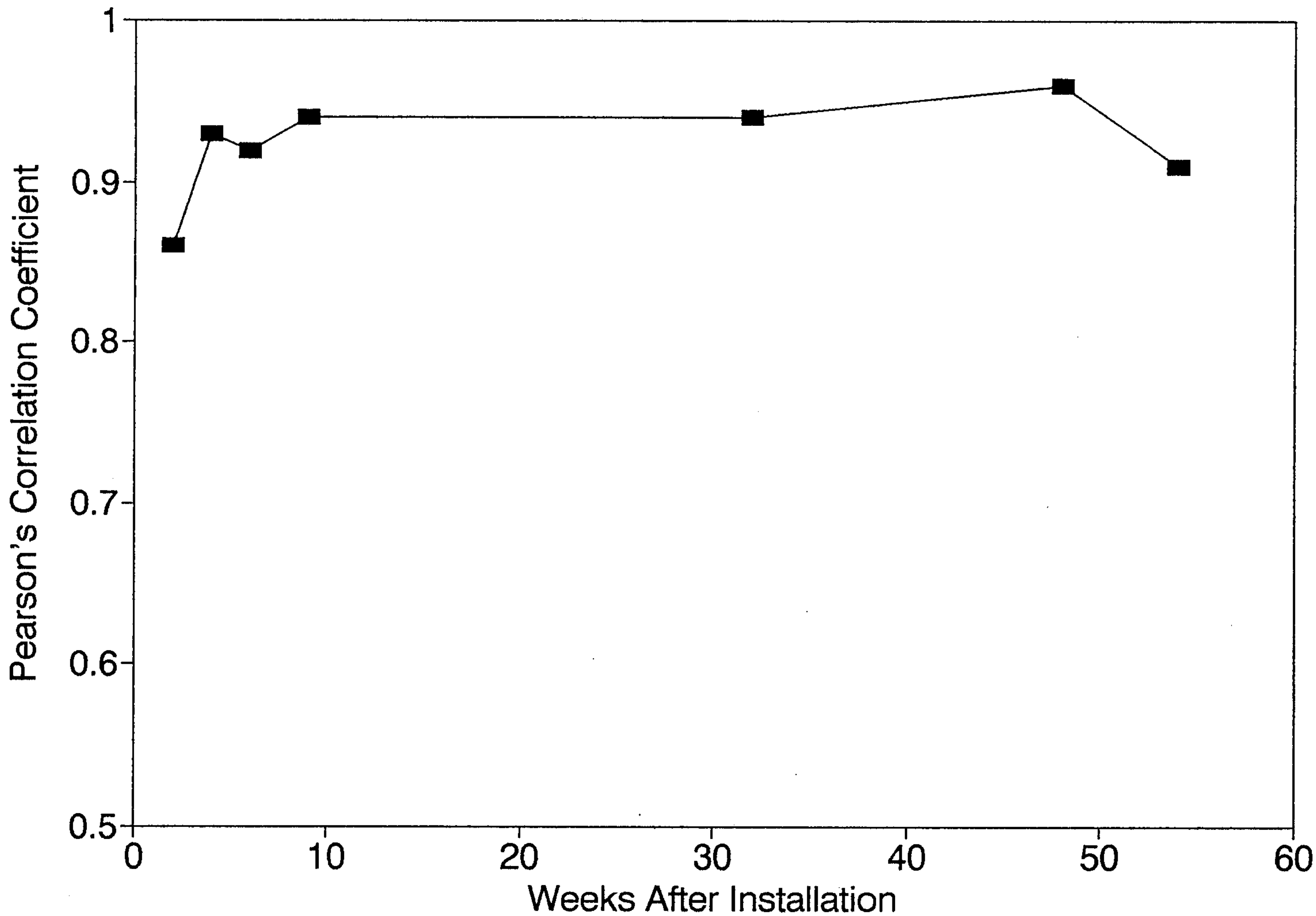


Figure 2-1. Correlation Between Reflectometer and Laboratory SI Values over Time.

Table 2-1. Reflectometer Versus Laboratory SI Values by RRPM Type

RPM Type	Pearson's Correlation Coefficient
Apex 921	0.88
Apex 918	0.94
Apex 928	0.92
Apex 807	0.90
Apex 817	0.70
Batterson	0.97
Empco 901	0.92
Ray-O-Lite 8704 (S)	0.97
Ray-O-Lite 8704 (R)	0.96
Ray-O-Lite 9704	0.95
Ray-O-Lite 2002	0.89
Ray-O-Lite 2003	0.98
Stimsonite 88	0.96
Stimsonite 911	0.94
Stimsonite 948	0.83
Stimsonite 953	0.83
Swareflex	0.93

These 54-week SI values do not completely describe how quickly the various RRPMs lost reflectivity after installation at the test sites. Another important measure of RRPM performance is the length of time they are place before their reflectivity values drop below certain "threshold" levels. For this report, we evaluated RRPM service lives for two threshold values. The first threshold was an SI value of 3.0, the minimum reflectivity level TxDOT requires of new RRPMs. The second threshold level was set at an SI value of 0.5, assumed to be near the minimum useable level of RRPM reflectivity on a high-speed freeway facility. It is based on visibility data from the

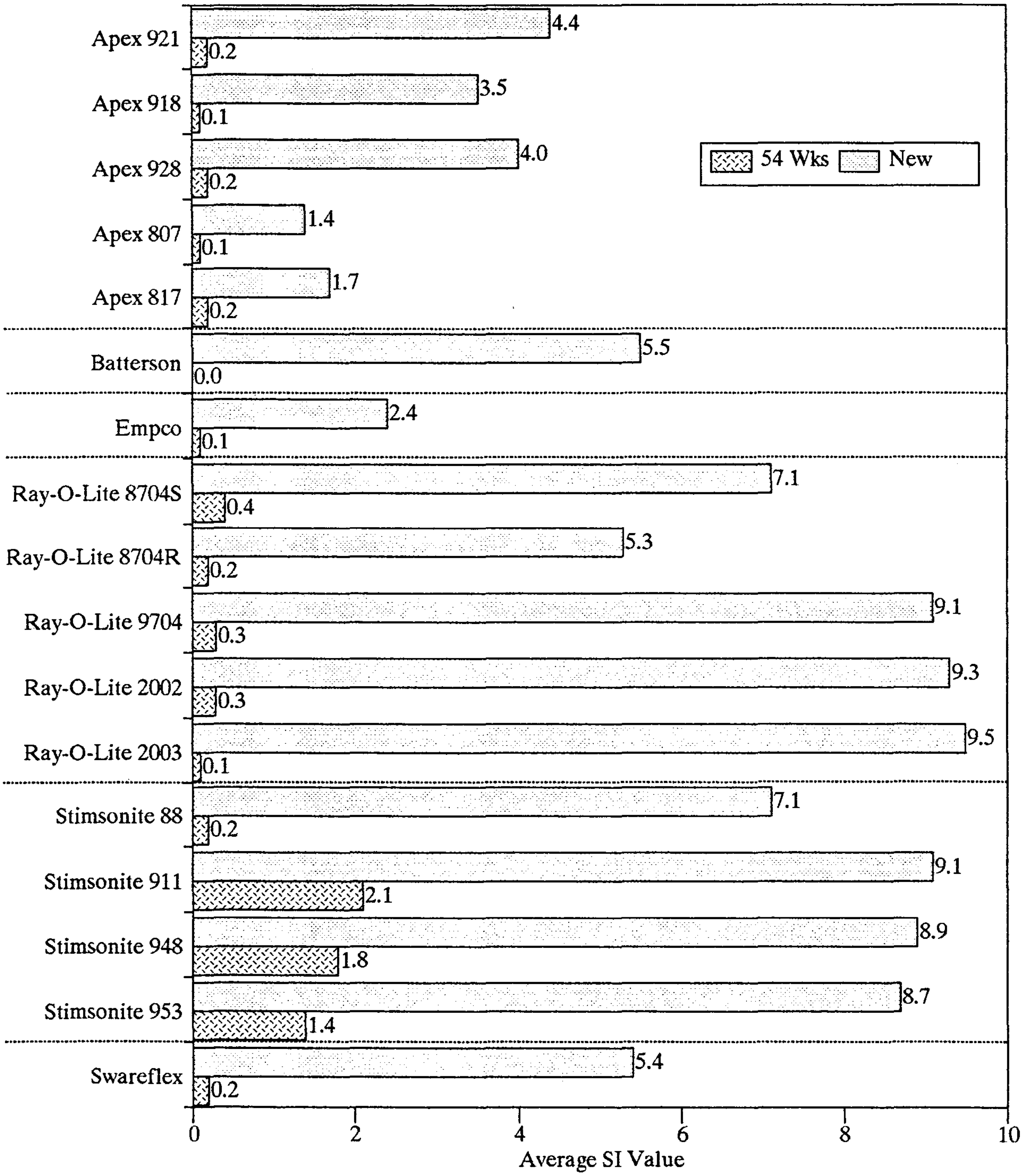


Figure 2-2. New and 54-Week SI Values at Site 1.

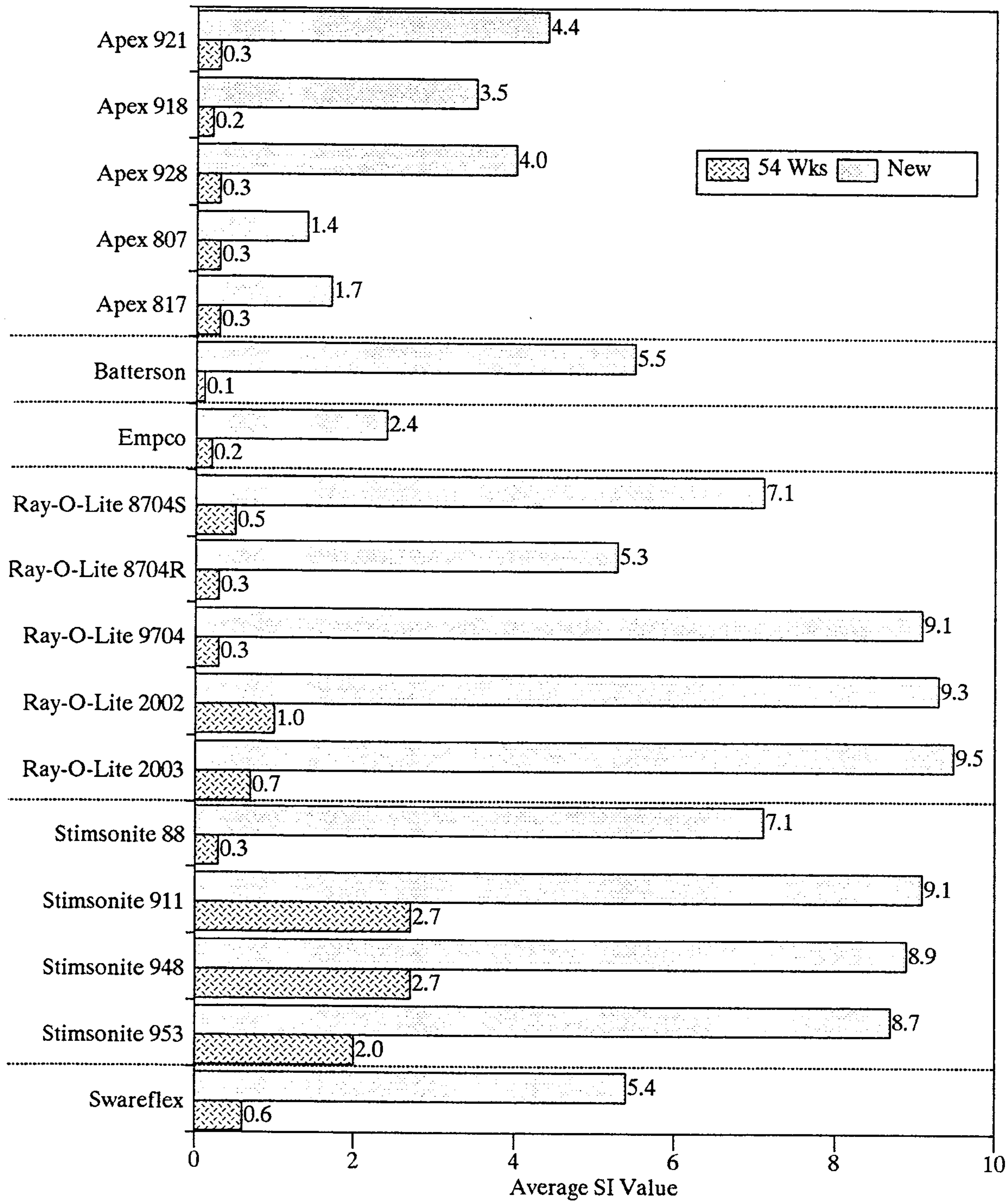


Figure 2-3. New and 54-Week SI Values at Site 2.

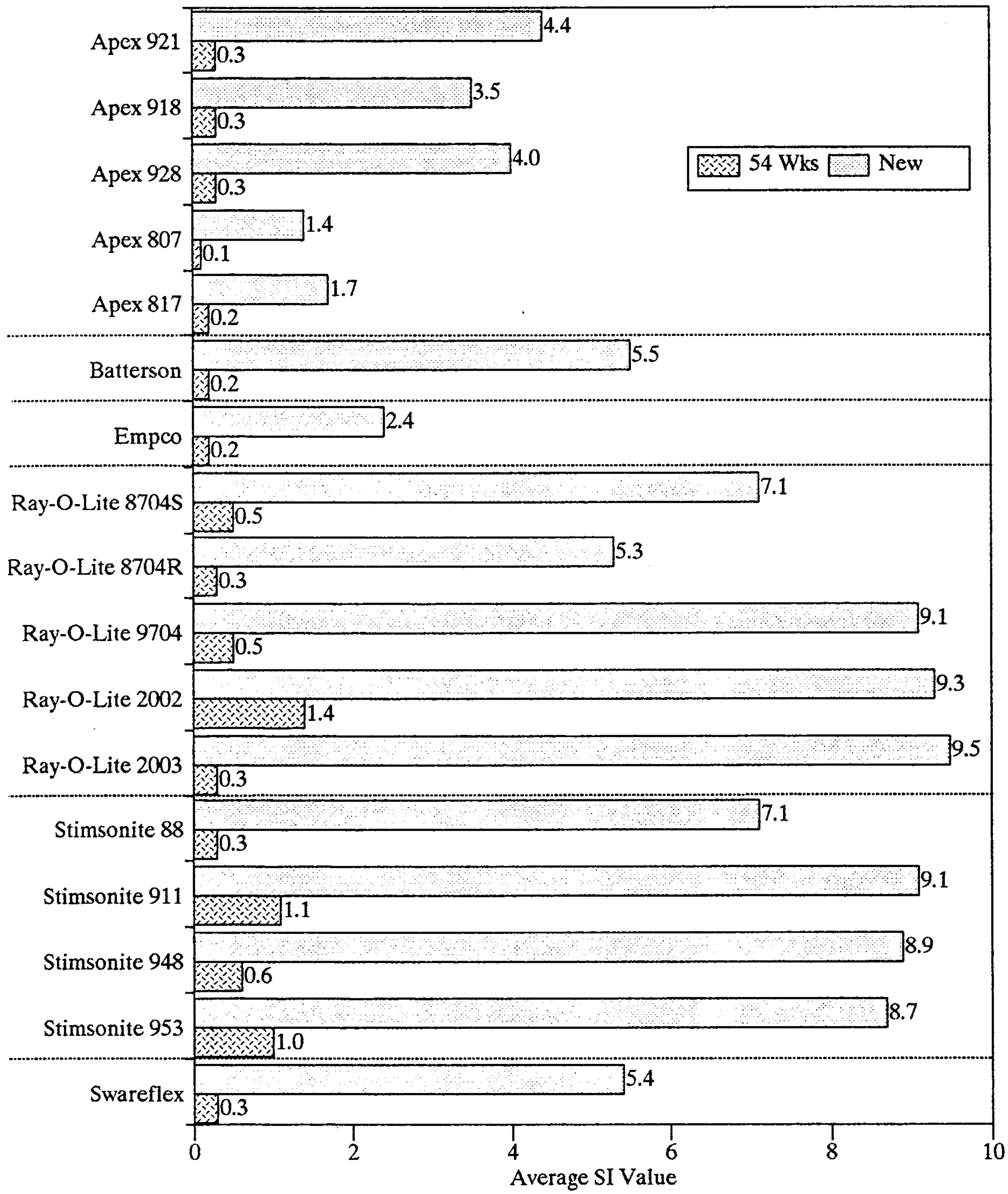


Figure 2-4. New and 54-Week SI Values at Site 3.

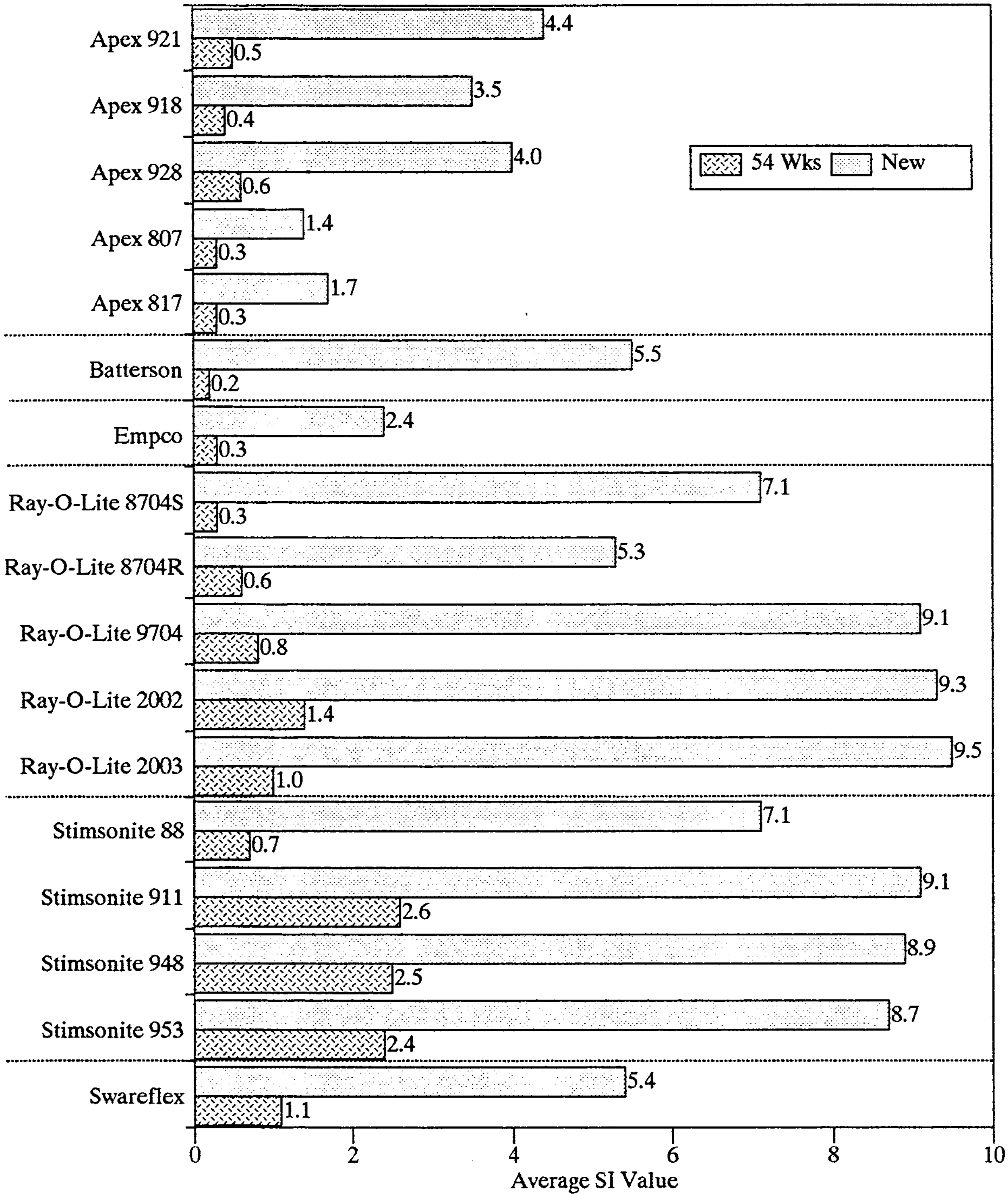


Figure 2-5. New and 54-Week SI Values at Site 4.

previous TTI study (3). In that report, an SI value of 0.5 (as estimated by TxDOT procedures) was said to provide enough reflected light to be detected by older drivers at a distance of 500 to 600 ft under non-lighted roadway conditions with no oncoming headlight glare. We caution the reader that this value may be less than what is actually needed to provide good guidance information to motorists under nighttime driving conditions. Also, the amount of RRPM reflectivity needed by motorists under more adverse driving conditions (i.e., rain, significant oncoming traffic and headlight glare, etc.) is not known at this time.

Table 2-2 summarizes the amount of time (in weeks) that each type of RRPM was in the field before its average SI value dropped below 3.0. Likewise, Table 2-3 summarizes the time until the reflectivity of each type of RRPM dropped below 0.5 SI. These data points represent a straight-line interpolation between data points obtained with the portable reflectometer and in the TxDOT laboratory on each evaluation date. We averaged the thresholds obtained from reflectometer data and the laboratory data to reduce any biases that may have existed due to the type of measurement method utilized.

The data presented in Table 2-2 indicate that most of the RRPMs maintained reflectivity above the minimum "new" value (3.0 SI) for no more than four weeks' time at any of the sites. The few RRPMs that performed at more than the minimum "new" SI value for 5 weeks or longer included the Stimsonite models 911, 948, and 953 (at sites 1, 2, and 4); the Ray-O-Lite models 9704, 2002, and 2003 (at sites 2 and 4); and the Stimsonite model 88 and Swareflex RRPMs (at site 4).

As a general rule, the RRPMs maintained reflectivity for a longer period at site 4 than at the other sites, indicative of the lower traffic volumes present at that location. In contrast, RRPMs at site 3 experienced a much quicker degradation of reflectivity in comparison to the other sites. As indicated in the previous report (4), this site had just undergone an asphalt overlay immediately prior to the RRPM installation. The oil and tar residue still present in the fresh asphalt may have transferred from vehicle tires onto the reflective lens, reducing reflectivity an extra amount.

**Table 2-2. RRPM New Service Life:
Weeks Until SI < 3.0**

RPM Type	Site 1	Site 2	Site 3	Site 4
Apex 921	1	1	1	3
Apex 918	1	1	1	1
Apex 928	1	1	1	1
Apex 807	0[a]	0[a]	0[a]	0[a]
Apex 817	0[a]	0[a]	0[a]	0[a]
Batterson	1	1	1	2
Empco	0[a]	0[a]	0[a]	0[a]
Ray-O-Lite 8704 (S)	2	2	---	1
Ray-O-Lite 8704 (R)	1	---	1	2
Ray-O-Lite 9704	2	5	1	12
Ray-O-Lite 2002	4	18	2	18
Ray-O-Lite 2003	4	18	2	26
Stimsonite 88	2	3	2	9
Stimsonite 911	30	53	48	53
Stimsonite 948	21	27	2	53
Stimsonite 953	24	41	3	38
Swareflex	2	2	1	7

[a] initial SI < 3.0
-- data missing

Table 2-3 presents the average amount of time the RRPMs were in the field before reflectivity values dropped below 0.5 SI. Generally speaking, those RRPMs providing a lower reflectivity value initially dropped to this nominal reflectivity level quicker than those with higher initial SI values. Also, one sees a general trend of slightly longer durations as one proceeds from site 1 to site 4. At site 1, the reflectivity of three of the RRPMs (Apex 807, Batterson, and Empco) dropped to this level after only 3 weeks in the field; a fourth RRPM (Apex 817) reached this level after 8 weeks. Eight of the RRPMs (Apex 921, 918, and 928; Ray-O-Lite 8704 [S], 8704 [R], 9704, and 2003; and Stimsonite 88) lasted 14 to 25 weeks before dropping to this nominal SI level. The Ray-O-Lite 2002 and the Swareflex RRPMs lasted 44 to 54 weeks before dropping to this 0.5 SI value. Finally, the reflectivity of the Stimsonite 911, 948, and 953 RRPMs still exceeded 0.5 SI at the time of the 54-week evaluation at all of the sites.

Table 2-3. RRPM Effective Service Lives: Weeks Until SI < 0.5

RRPM Type	Site 1	Site 2	Site 3[a]	Site 4
Apex 921	15	20	19	26
Apex 918	14	9	19	26
Apex 928	14	22	19	> 28
Apex 807	3	5	2	10
Apex 817	8	3	2	10
Batterson	3	4	4	13
Empco	3	12	15	22
Ray-O-Lite 8704 (S)	20	24	---	22
Ray-O-Lite 8704 (R)	21	---	25	28
Ray-O-Lite 9704	21	25	48	> 32
Ray-O-Lite 2002	44	> 54	> 54	> 54
Ray-O-Lite 2003	25	> 54	> 48	> 54
Stimsonite 88	22	24	27	> 23
Stimsonite 911	> 54	> 54	> 54	> 54
Stimsonite 948	> 54	> 54	> 54	> 54
Stimsonite 953	> 54	> 54	> 54	> 54
Swareflex	54	> 54	49	> 54

--- data missing

It is interesting to note the similarity of the data between sites 2 and 3, despite the much faster initial reflectivity degradation noted for site 3 in Table 2-2. This seems to confirm the hypothesis that the initial reflectivity degradations at site 3 were due to oil and tar residue from the new pavement transferring from vehicle tires onto the RRPMs. After the pavement had cured and the normal vehicle tire-RRPM interaction had scuffed the accumulated residue off of the reflective lenses, the reflectivity of the RRPMs returned to levels similar to those at site 2. The similarity between performance at sites 2 and 3 can be demonstrated if the service lives of each RRPM are ranked by site (with a 1 assigned to the site where the service life was shortest, a 2 assigned to the site where the service life was next shortest, and so on) and then averaged over each site. The results, provided in Table 2-4, show that RRPMs consistently had the shortest service lives at site 1, and longest at site 4. However, the average rankings of sites 2 and 3 are almost identical (2.6 for site 2, 2.3 for site 3). In terms of the traffic characteristics at these four test sites, these rankings correlate most directly with the total daily traffic volumes traveling adjacent to the RRPMs. Shown again in the last column of Table 2-4, we see that the daily volumes are greatest at site 1 and smallest at site 4. Meanwhile, daily traffic volumes (immediately adjacent to the RRPMs) at sites 2 and 3 are very close, being slightly greater at site 3 than at site 2. Referring back to Table 1-3, the other two traffic measures evaluated in this field test (daily truck traffic and daily lane-changing across the RRPMs) do not compare quite this favorably to the average service life rankings by site.

Table 2-4. Average RRPM Service Life Rankings by Site

Site	Average Service Life Ranking[a]	Average Daily Traffic Adjacent to RRPMs
1	1.3	25,100-40,300
2	2.6	13,800-14,000
3	2.3	18,600
4	3.6	3,300

[a] 1 = site where service life is shortest, 2= site where service life is second shortest, etc.

EFFECT OF DIRT ACCUMULATION UPON RRPM REFLECTIVITY

Markers removed from each site and taken to the TxDOT laboratory underwent two reflectivity measurements. The first was performed on each marker as removed from the site (i.e., its reflectivity level as it existed in the field). These values were those against which the portable reflectometer readings were compared. Next, the RRPMs were washed to remove the dirt, oil, and tar residue from each reflective lens. The markers were then tested again. By comparing the SI values of each RRPM unwashed and again washed, we can determine what proportion of reflectivity loss over time results from the actual physical degradation of the reflective surface of each RRPM and what proportion results from dirt and grime accumulation. Whereas the physical degradation of the reflective surface is permanent, dirt and grime accumulation can be washed away to some degree by heavy rains or perhaps during street sweeping operations.

Appendix C presents the percent loss in SI value recorded for each RRPM by site and by date of field evaluation. Since only one of each type of RRPM was typically removed from each site for testing, a considerable amount of variability in the data exists when viewed as shown in the appendix. Averaged over all RRPMs and all study sites, however, one can estimate a general trend, as depicted in Figure 2-6. Here, one sees that a substantial amount of the losses in reflectivity early on result from dirt accumulation on the reflective face of the RRPMs. After about 20 to 26 weeks exposure, however, the amount of reflectivity loss due to dirt accumulating decreases to less than 20 percent. Referring back to Tables 2-2 and 2-3, this is about the time that the reflectivity of many of the RRPMs drop below the 0.5 SI threshold value described previously.

We found no significant differences in these trends when evaluated on a site-by-site basis. The problem at site 3 regarding the oil and tar residue from the new asphalt pavement transferring from vehicle tires onto the RRPMs did not last longer than the first few weeks of the study. However, we did detect substantial differences in dirt accumulation between the RRPMs with a glass-covering over the reflective lens (as well as the glass-beaded RRPM manufactured by Swareflex) and the RRPMs without glass (only the normal acrylic of the lens was exposed to traffic). Figure 2-7 shows these differences. In general, the data illustrate how the greater durability of the glass covering appears to protect the reflectivity of the RRPMs for a longer period of time. For the non-glass (acrylic lens) RRPMs, the losses in reflectivity after about 20 weeks almost all result from permanent degradation of the RRPM itself. In comparison, the amount of SI loss of the glass-covered RRPMs measures much higher initially and decreases

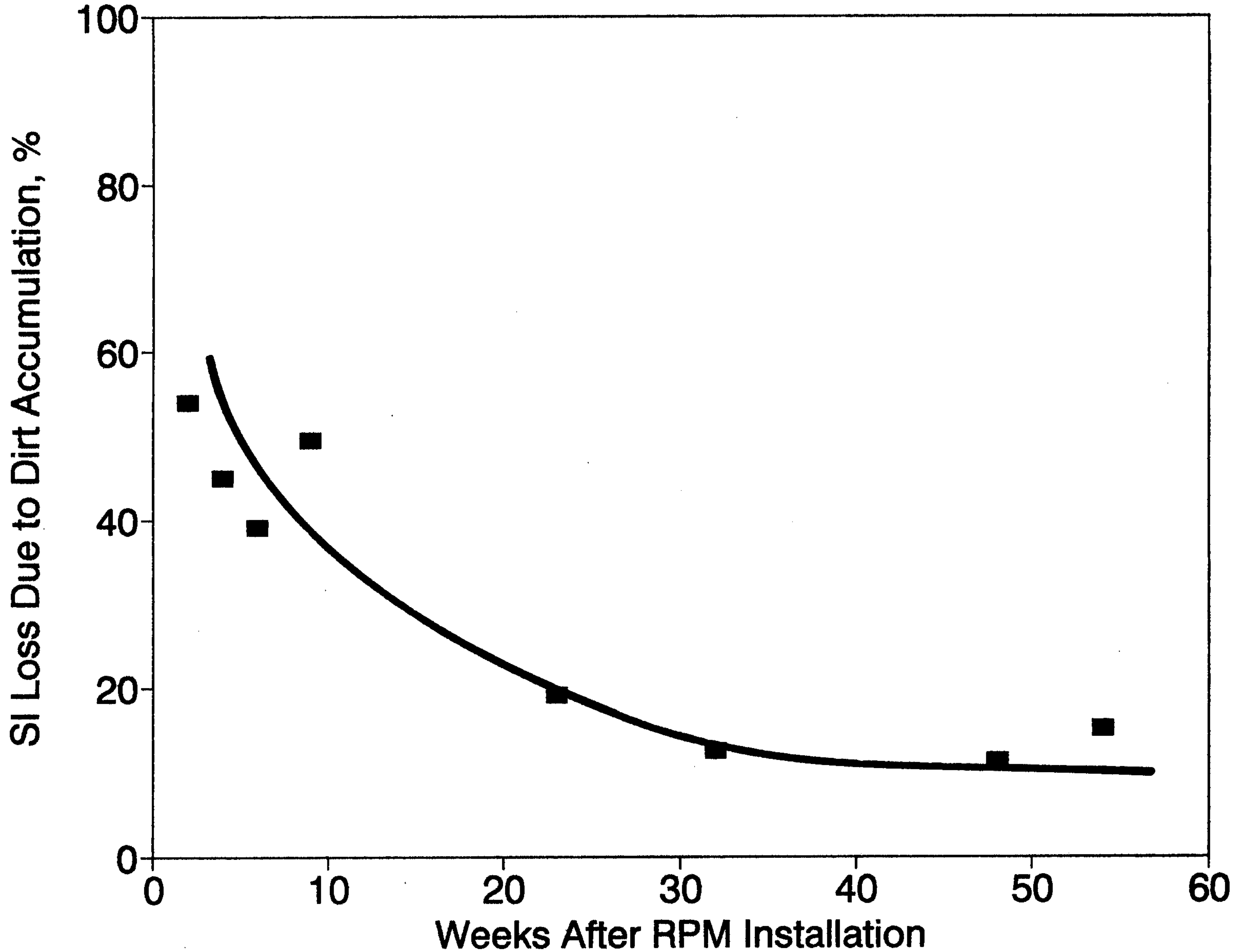


Figure 2-6. Effect of Dirt Accumulation on SI Values over Time.

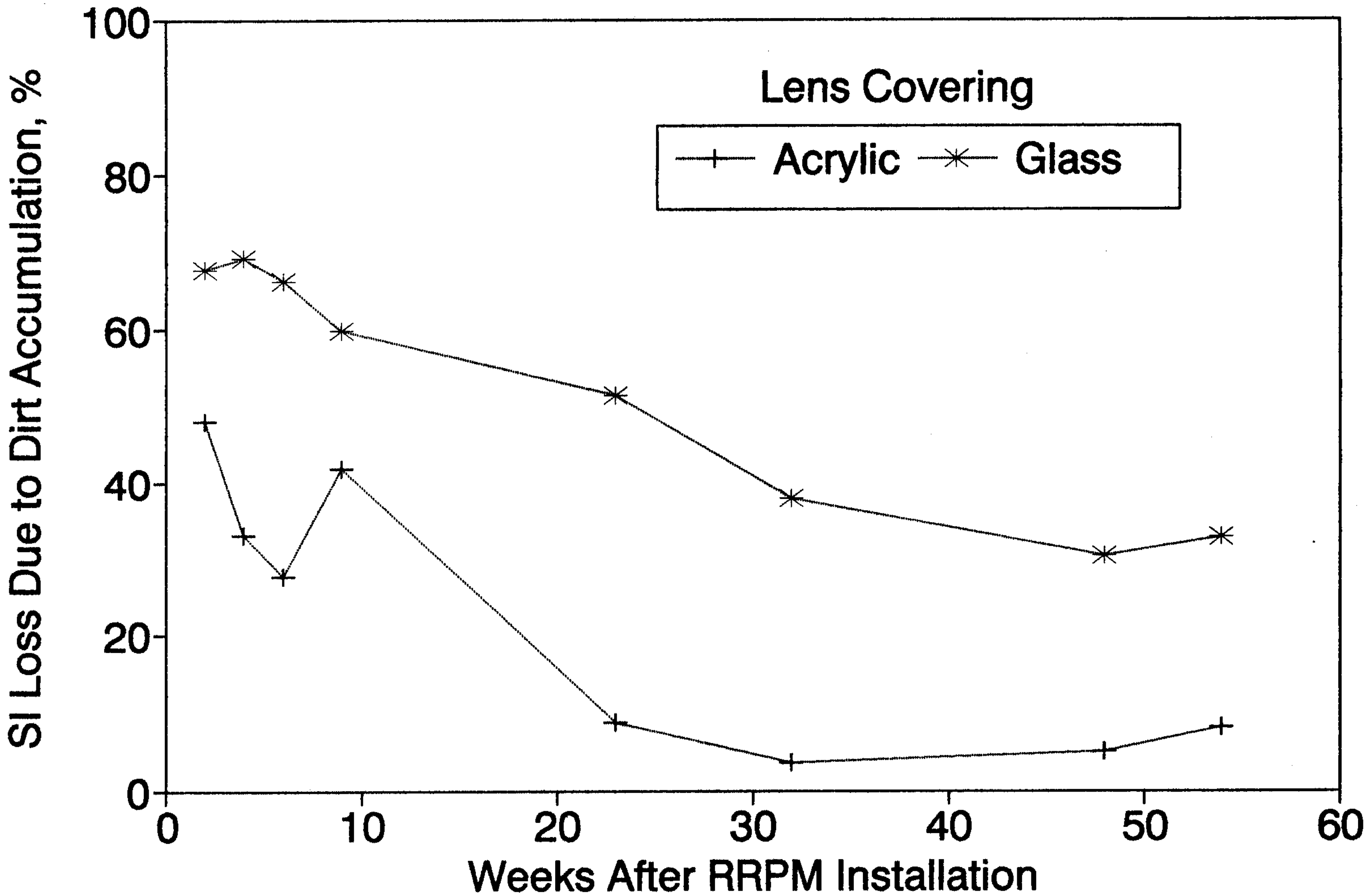


Figure 2-7. Effect of Dirt Accumulation by Type of Lens Covering.

gradually over time. Coupled with the much higher SI values recorded for these RRPMs over time, this figure further demonstrates that the glass covering makes the reflectivity of the markers more durable. Although dirt accumulation still reduces reflectivity somewhat, the glass does appear to protect the integrity of the reflective lens very well over the duration which these data represent.

MARKER RETENTION AND STRUCTURAL DURABILITY

In general, marker loss was not a signficant problem during the first year of field testing. The primary exception to this general trend occurred at site 4, which saw many of the Swareflex RRPMs break loose from the bitumen adhesive pad. Based on the data collected at the 54-week evaluation, approximately 44 percent (4 of 9) Swareflex marker RRPMs had been lost. The bottom of the Swareflex RRPM is a waffle design rather than a smooth base. This waffle design may cut through the bitumen adhesive over time and explain the higher loss rate. We expect that there are other factors involved as well, however, since we did not find similar losses for this RRPM at the other sites.

With respect to the structural integrity of the RRPMs themselves, most again performed quite well over the first year of testing. Almost all types of RRPMs had one or more markers which experienced cracking along some part of the marker base. However, the reflective lenses themselves seemed to remain intact and continue to perform. We did notice that the Apex model 807 RRPM did tend to lose the reflective lens if it became cracked. At sites 2 through 4, one marker out of the ten examined during the 54-week evaluation was missing a reflective lens. At site 1, four of the ten Apex model 807 RRPMs evaluated did not have a reflective lens after 54 weeks in the field. Averaged over the four sites, this represents an 18 percent loss rate (7 of 40 reflective lenses) after one year.

3. SUMMARY AND FUTURE WORK

SUMMARY

This report summarizes the data collected during the first year of the field test of 17 types of RRPMs at four freeway locations around San Antonio, Texas. Reflectivity data were collected at each test site using a portable reflectometer and corroborated with laboratory measurements from samples taken to the TxDOT testing laboratory in Austin, Texas. The results of the first year of the test show that many of the RRPMs fail to provide adequate levels of reflectivity after as little as six months exposure on high-volume facilities. The major exceptions were those RRPMs with thin layers of glass epoxied over the reflective lens. For these markers, reflectivity levels measured above minimum (approximate) threshold SI values at all sites after 54 weeks exposure.

Overall, RRPM service lives tended to be the shortest at site 1, approximately equal at sites 2 and 3, and the longest at site 4. These results seem consistent with the relative daily traffic volumes experienced at each site (highest at site 1, approximately equal at sites 2 and 3, and lowest at site 4).

During the first few weeks in the field, losses in RRPM reflectivity are due in large part to dirt accumulation on the lens. This is a somewhat temporary condition, however, as tire abrasion and weathering eventually scar the lens and make the loss of reflectivity permanent. It appeared that the glass covering of some of the RRPMs reduced the rate at which the permanent reflectivity loss occurred. Even after 54 weeks in the field, reflectivity levels of these RRPMs proved quite high once the dirt and road grime were washed away.

FUTURE WORK

Although the service lives of the majority of RRPMs have been reached at all test sites, a few are still providing reflectivity. Consequently, two additional measurements are scheduled for 1994 to complete the two-year test. These data will be combined with the data already collected and reported herein. Once that is completed, regression analyses will be performed to develop estimates of the service life of each type of RRPM as a function of traffic characteristics. These will be presented in the final report to be prepared at the end of this field test.

4. REFERENCES

1. Tielking, J.T., and J. S. Joel. *On the Retention of Reflective Raised Pavement Markers.* Research Report No. FHWA/TX-87/477-1F. Texas Transportation Institute: College Station, Texas. 1988.

2. McNees, R.W., and J. S. Noel. *Executive Summary, Significant Results and Assorted Tests and Procedures for Reflective Raised Pavement Markers.* Research Report No. FHWA/TX-86/13+322-4F. Texas Transportation Institute: College Station, Texas. 1986.

3. Pezoldt, V.J., R. J. Koppa, R. A. Zimmer, A. T. Perry, and H. W. Milsap. *Raised Pavement Marker Reflectivity.* Research Report No. TX-90/1151-1F. Texas Transportation Institute: College Station, Texas. 1990.

4. Ullman, G. L. *Retroreflective Raised Pavement Marker Field Testing: Initial Interim Report.* Research Report No. TX-92/1946-1. Texas Transportation Institute: College Station, Texas. 1992.

APPENDIX - A SUMMARY OF THE JUNE 1993 TRAFFIC STUDY

Tables A-1 through A-3 present basic traffic data collected at the four test sites in June 1993. Also shown are the data collected at the same sites in July 1992. In Table A-1, total traffic volumes remained essentially unchanged between studies at sites 1 through 3. A rather substantial increase in volumes was noted at site 4 (approximately 1,300 vpd, or about 44 percent). The reason for this increase is not known for certain. However, the data were collected the week (Tuesday through Thursday) prior to the fourth of July weekend. The long three-day weekend may have encouraged slightly more vacationers and tourists to travel that week than would have normally occurred during the summer months.

Table A-1. Comparison of Total Daily Traffic Volumes

Site	Location	Total Vehicles Per Day	
		July 1992	June 1993
1	Northbound I-410	36,700-58,900	33,000-61,700
2	Northbound US-281	21,200-21,400	24,200[a]
3	Westbound I-10	18,600	18,200
4	Westbound I-10	3,300	4,600

[a] Data collection problems occurred at one end of the test site

In general, truck volumes at each of the test sites in June 1993 measured slightly greater than in July 1992, as shown in Table A-2. However, different data collection personnel conducted the vehicle classification studies. Whereas the July 1992 data collection personnel only classified tractor-trailers with four or more axles as trucks, personnel conducting the June 1993 study included tractors without trailers as trucks as well.

Finally, Table A-3 presents a comparison of lane-changing activity at each site for the July 1992 and June 1993 studies. Overall, lane-changing rates were fairly comparable at sites 1 and 3, but less so at sites 2 and 4. It is not known exactly why these rates are so different, although again the difference could result from a slightly different traffic mix at those sites due to the

Table A-2. Comparison of Truck Percentages

Site	Location	Percent of Trucks	
		July 1992	June 1993
1	Northbound I-410	3-6	6-7
2	Northbound US-281	3-8	8-10
3	Westbound I-10	6-10	8
4	Westbound I-10	10-15	20

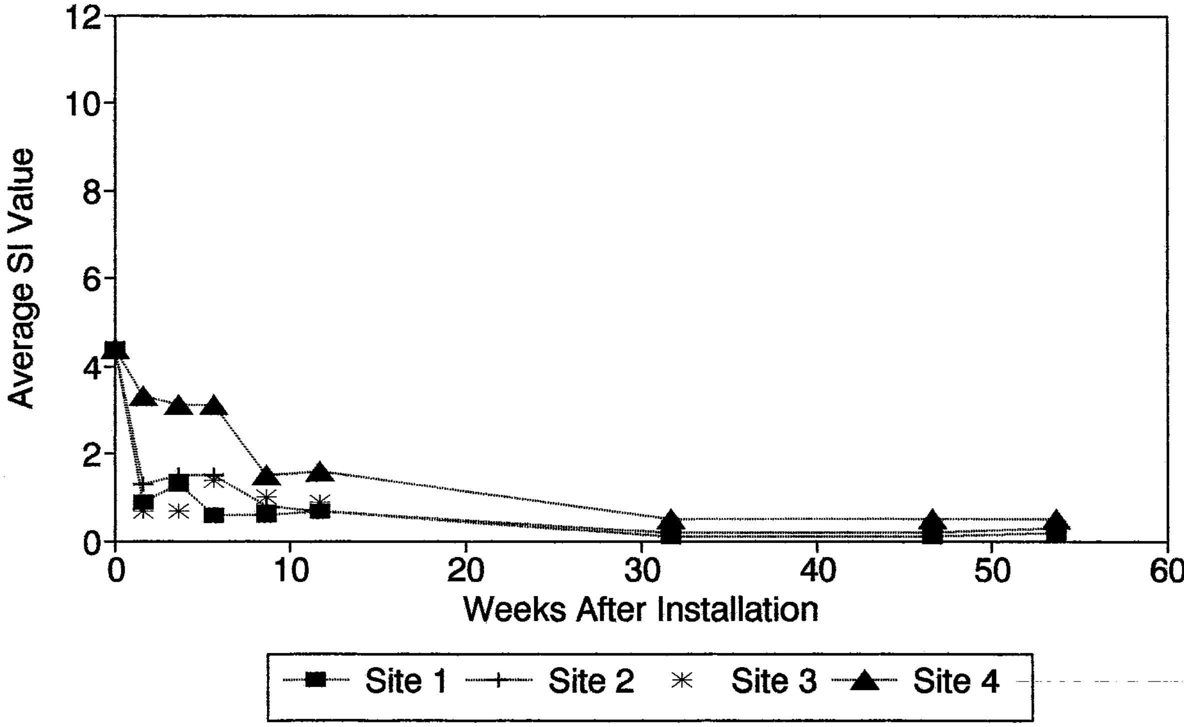
closeness of the fourth of July holiday. One should also note that the rates are based on somewhat smaller sample sizes than the total traffic volumes or truck percentages. At site 4, for example, at total of 14 lane-changes were counted over an approximate 1-mile viewing distance (looking from the top of one hill to the top of the next). Consequently, these rather large differences in lane-changing rates may not prove significant from a practical standpoint.

Table A-3. Comparison of Lane-Changing Activity

Site	Location	Lane Changes Per 1000 Vehicles Per Mile	
		July 1992	June 1993
1	Northbound I-410	24.4	25.7
2	Northbound US-281	44.9	28.2
3	Westbound I-10	27.7	17.3
4	Westbound I-10	71.9	24.5

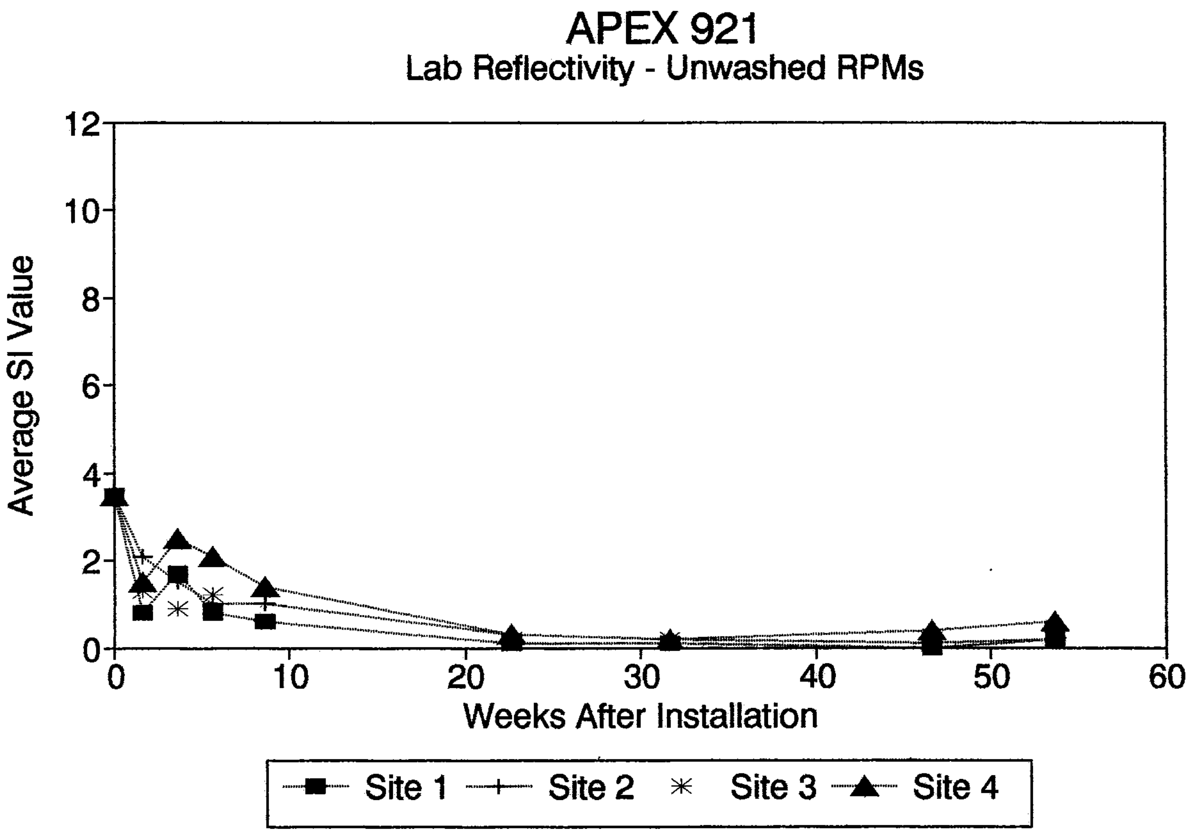
APPENDIX B - REFLECTOMETER AND LABORATORY SI DATA

APEX 921
Field-Measured Reflectivity



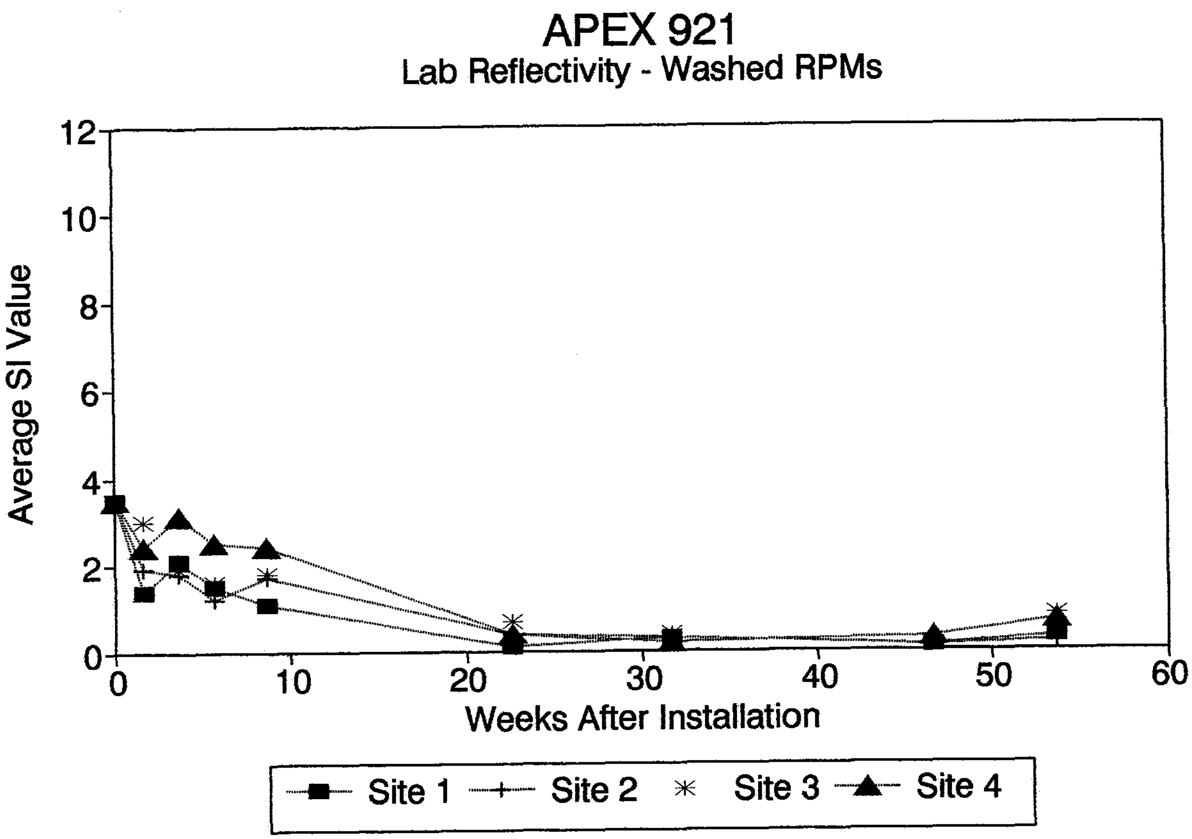
Average Reflectometer SI Values
(Standard Deviation of SI Values)

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	4.4 (1.9)	4.4 (1.9)	4.4 (1.9)	4.4 (1.9)
2	0.9 (0.8)	1.3 (0.2)	0.7 (0.4)	3.3 (1.6)
4	1.3 (0.2)	1.5 (1.2)	0.7 (0.1)	3.1 (1.0)
6	0.6 (0.2)	1.5 (0.8)	1.4 (0.9)	3.1 (0.5)
9	0.6 (0.1)	0.8 (0.6)	1.0 (1.0)	1.5 (0.3)
12	0.7 (0.2)	0.7 (0.3)	0.9 (0.6)	1.6 (0.8)
32	0.1 (0.2)	0.2 (0.1)	0.3 (0.1)	0.5 (0.3)
48	0.1 (0.0)	0.2 (0.0)	0.3 (0.1)	0.5 (0.2)
54	0.2 (0.0)	0.3 (0.1)	0.3 (0.2)	0.5 (0.3)



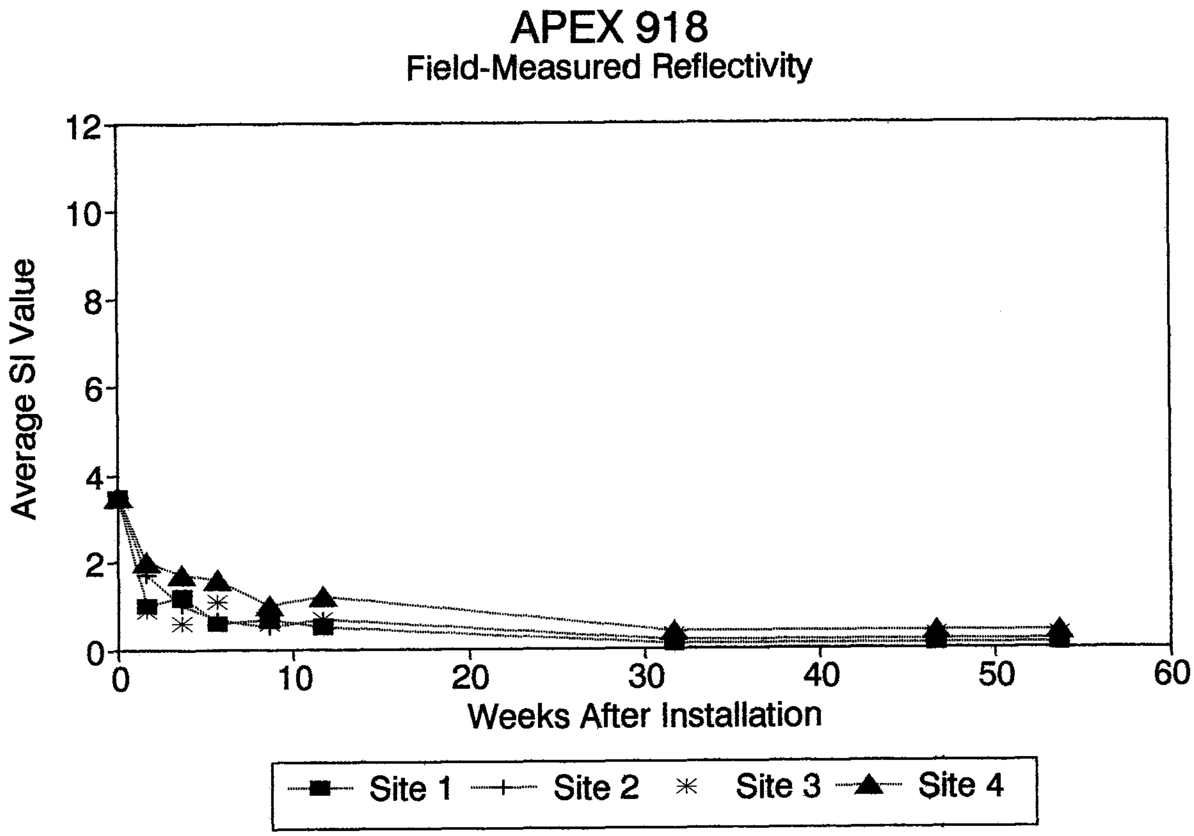
Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	3.5	3.5	3.5	3.5
2	0.8	2.1	1.3	1.5
4	1.7	1.5	0.9	2.5
6	0.8	1.0	1.2	2.1
9	0.6	1.0	0.6	1.4
23	0.1	0.3	0.2	0.3
32	0.1	0.2	0.2	0.2
48	0.0	0.1	0.2	0.4
54	0.2	0.2	0.3	0.6



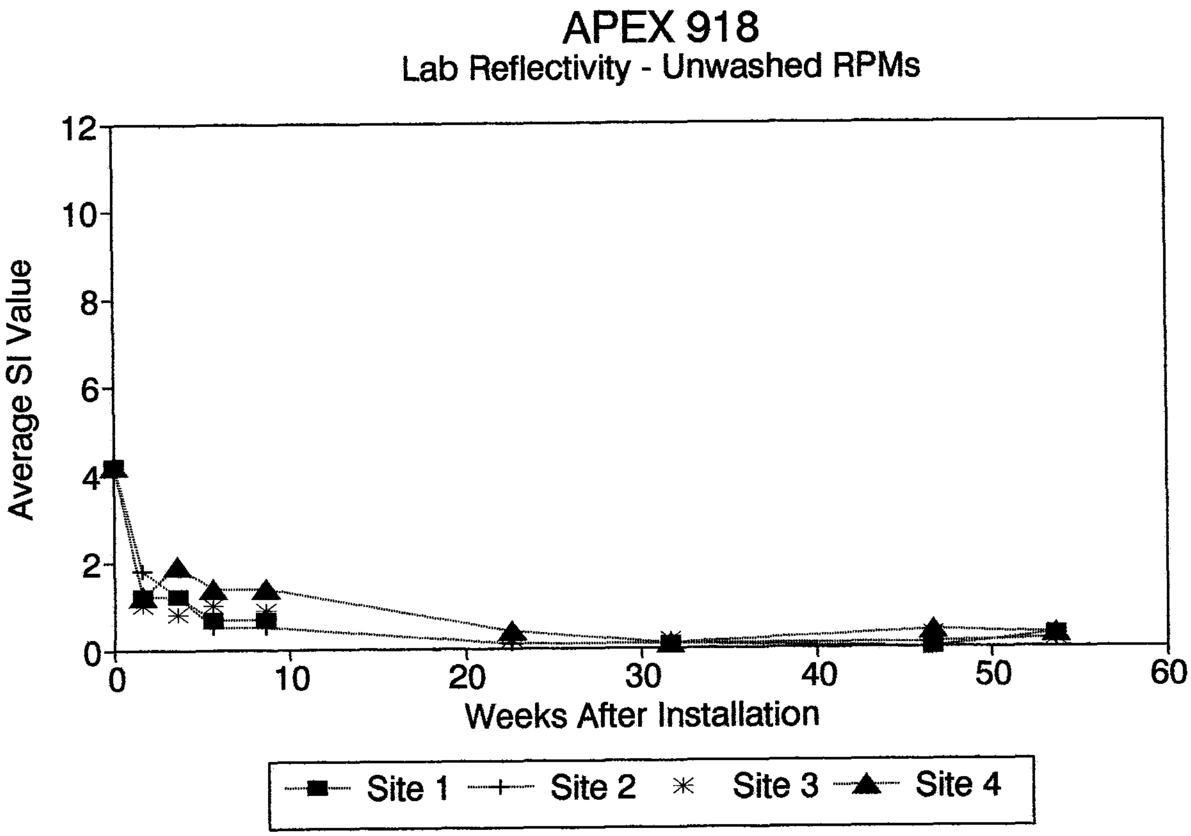
Laboratory SI Values
Washed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	3.5	3.5	3.5	3.5
2	1.4	1.9	3.0	2.4
4	2.1	1.8	1.9	3.1
6	1.5	1.2	1.6	2.5
9	1.1	1.7	1.8	2.4
23	0.1	0.4	0.7	0.4
32	0.3	0.3	0.4	0.2
48	0.1	0.1	0.1	0.3
54	0.3	0.2	0.8	0.7



Average Reflectometer SI Values
(Standard Deviation of SI Values)

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	3.5 (1.1)	3.5 (1.1)	3.5 (1.1)	3.5 (1.1)
2	1.0 (0.5)	1.7 (0.5)	0.9 (0.3)	2.0 (0.7)
4	1.2 (0.2)	1.0 (0.2)	0.6 (0.2)	1.7 (0.6)
6	0.6 (0.2)	0.7 (0.2)	1.1 (0.3)	1.6 (0.2)
9	0.7 (0.1)	0.5 (0.3)	0.6 (0.0)	1.0 (0.3)
12	0.5 (0.0)	0.7 (0.1)	0.7 (0.3)	1.2 (0.4)
32	0.1 (0.0)	0.2 (0.1)	0.3 (0.1)	0.4 (0.2)
48	0.1 (0.0)	0.2 (0.1)	0.3 (0.1)	0.4 (0.1)
54	0.1 (0.1)	0.2 (0.1)	0.3 (0.1)	0.4 (0.1)

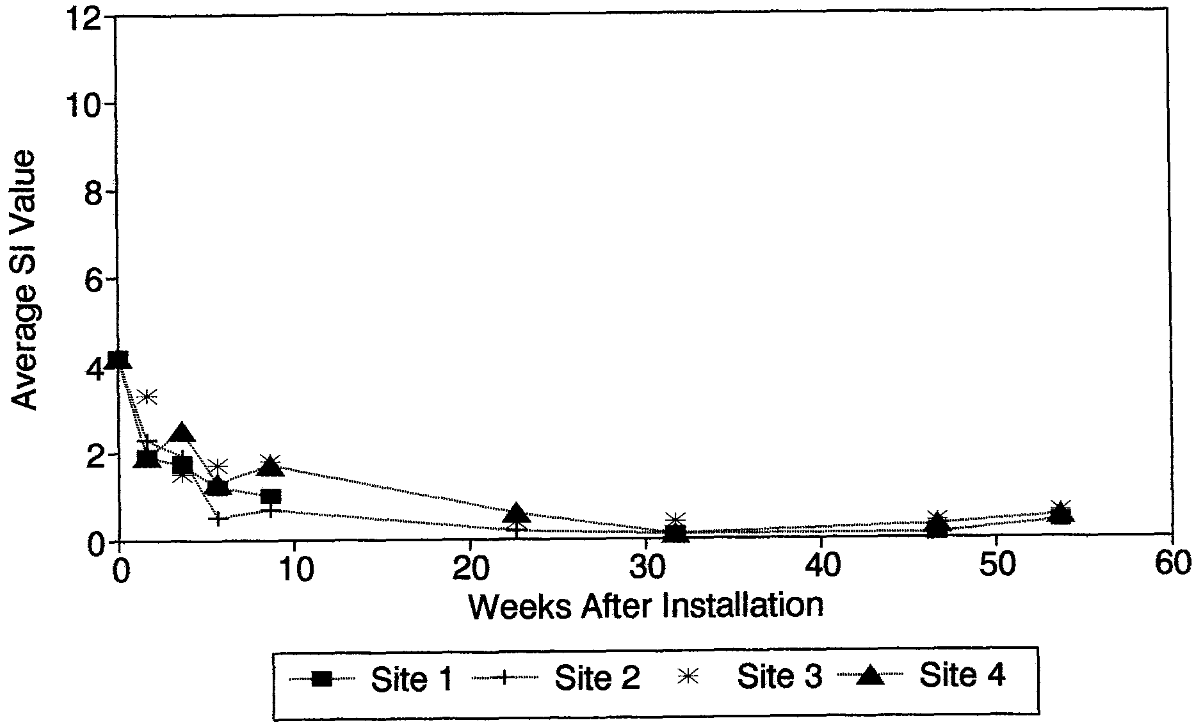


Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	4.2	4.2	4.2	4.2
2	1.2	1.8	1.0	1.2
4	1.2	1.2	0.8	1.9
6	0.7	0.5	1.0	1.4
9	0.7	0.5	0.9	1.4
23	N.A	0.1	0.2	0.4
32	0.1	0.1	0.2	0.1
48	0.0	0.1	0.3	0.4
54	0.3	0.2	0.2	0.3

N.A. Data not available

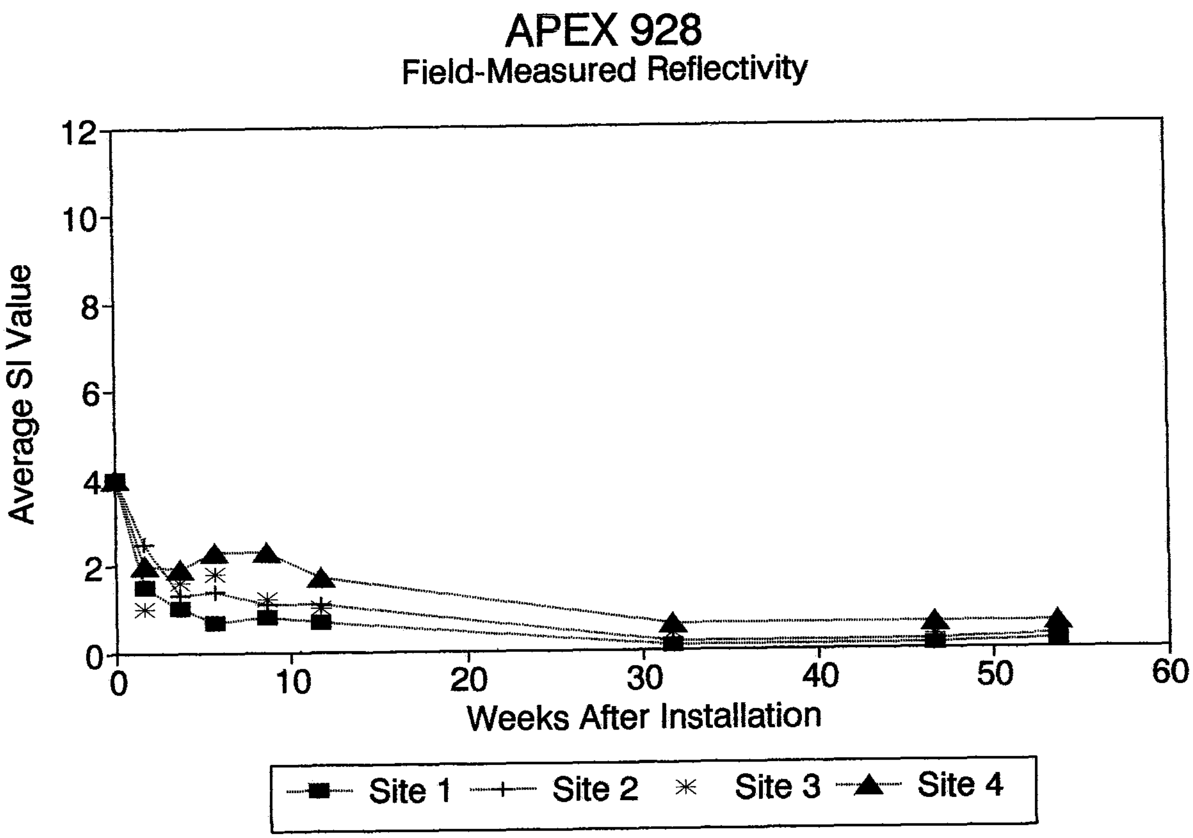
APEX 918
Lab Reflectivity - Washed RPMs



Laboratory SI Values
Washed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	4.2	4.2	4.2	4.2
2	1.9	2.3	3.3	1.9
4	1.7	1.9	1.5	2.5
6	1.2	0.5	1.7	1.3
9	1.0	0.7	1.8	1.7
23	N.A	0.2	0.4	0.6
32	0.1	0.1	0.4	0.1
48	0.1	0.1	0.4	0.3
54	0.4	0.4	0.6	0.5

N.A. Data not available

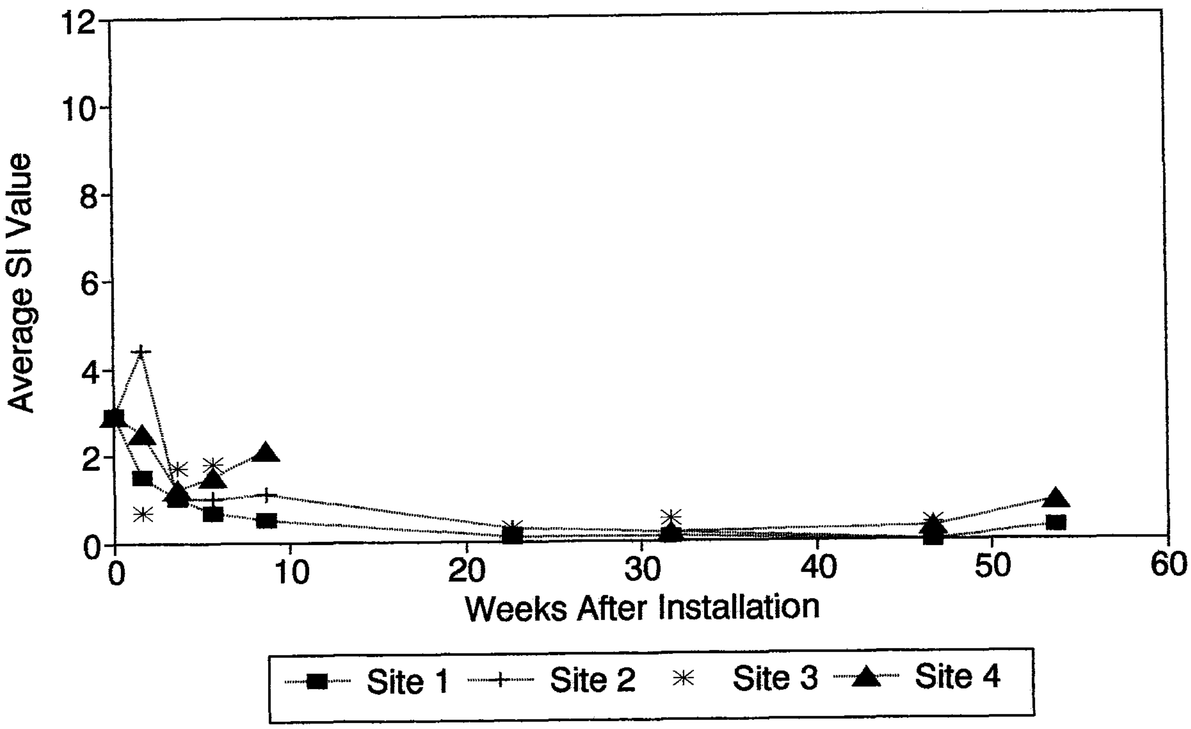


Average Reflectometer SI Values
(Standard Deviation of SI Values)

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	4.0 (1.1)	4.0 (1.1)	4.0 (1.1)	4.0 (1.1)
2	1.5 (0.1)	2.5 (0.3)	1.0 (0.4)	2.0 (0.5)
4	1.0 (0.1)	1.3 (0.4)	1.6 (0.6)	1.9 (0.9)
6	0.7 (0.2)	1.4 (0.3)	1.8 (0.8)	2.3 (0.8)
9	0.8 (0.2)	1.1 (0.2)	1.2 (0.2)	2.3 (0.7)
12	0.7 (0.1)	1.1 (0.2)	1.0 (0.3)	1.7 (0.6)
32	0.1 (0.1)	0.2 (0.1)	0.4 (0.2)	0.6 (0.3)
48	0.1 (0.0)	0.2 (0.0)	0.3 (0.1)	0.6 (0.1)
54	0.2 (0.1)	0.3 (0.1)	0.3 (0.1)	0.6 (0.1)

APEX 928

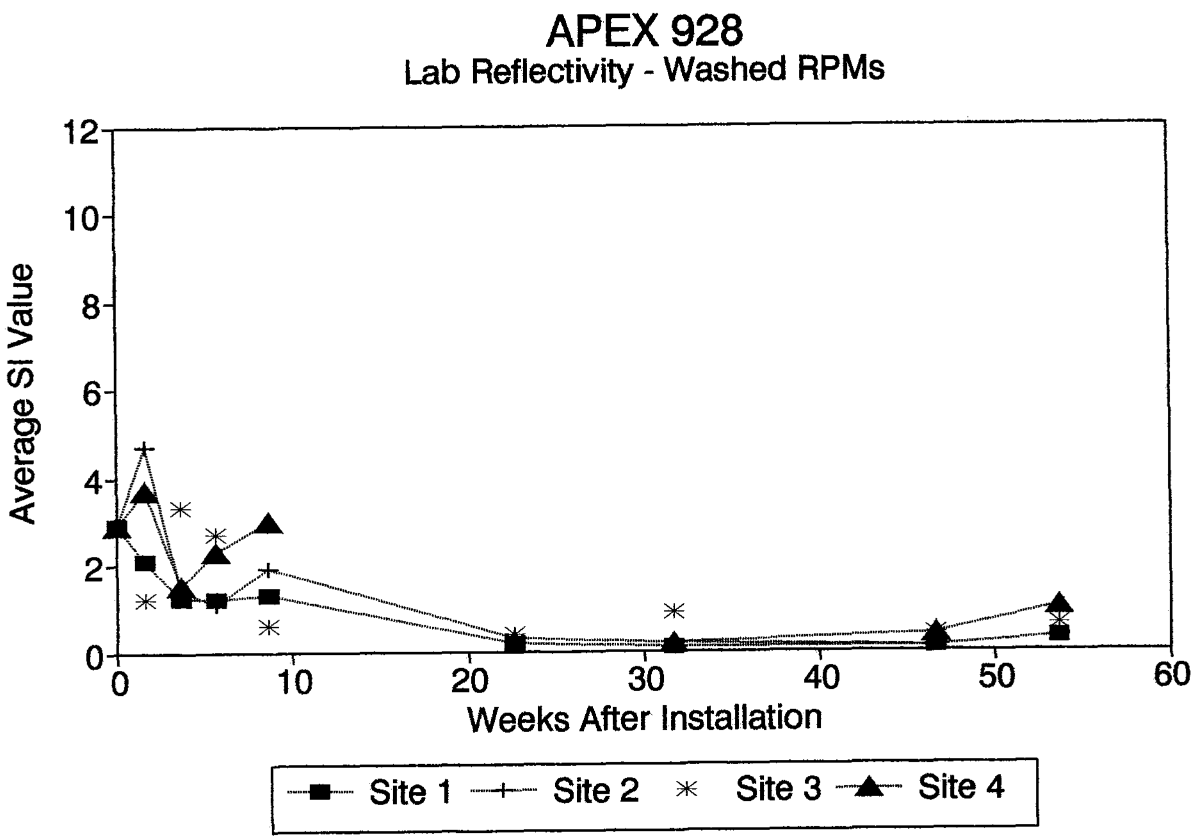
Lab Reflectivity - Unwashed RPMs



Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	2.9	2.9	2.9	2.9
2	1.5	4.4	0.7	2.5
4	1.0	1.0	1.7	1.2
6	0.7	1.0	1.8	1.5
9	0.5	1.1	0.5	2.1
23	0.1	0.3	0.3	N.A
32	0.1	0.2	0.5	0.2
48	0.0	0.0	0.4	0.3
54	0.3	0.3	0.3	0.9

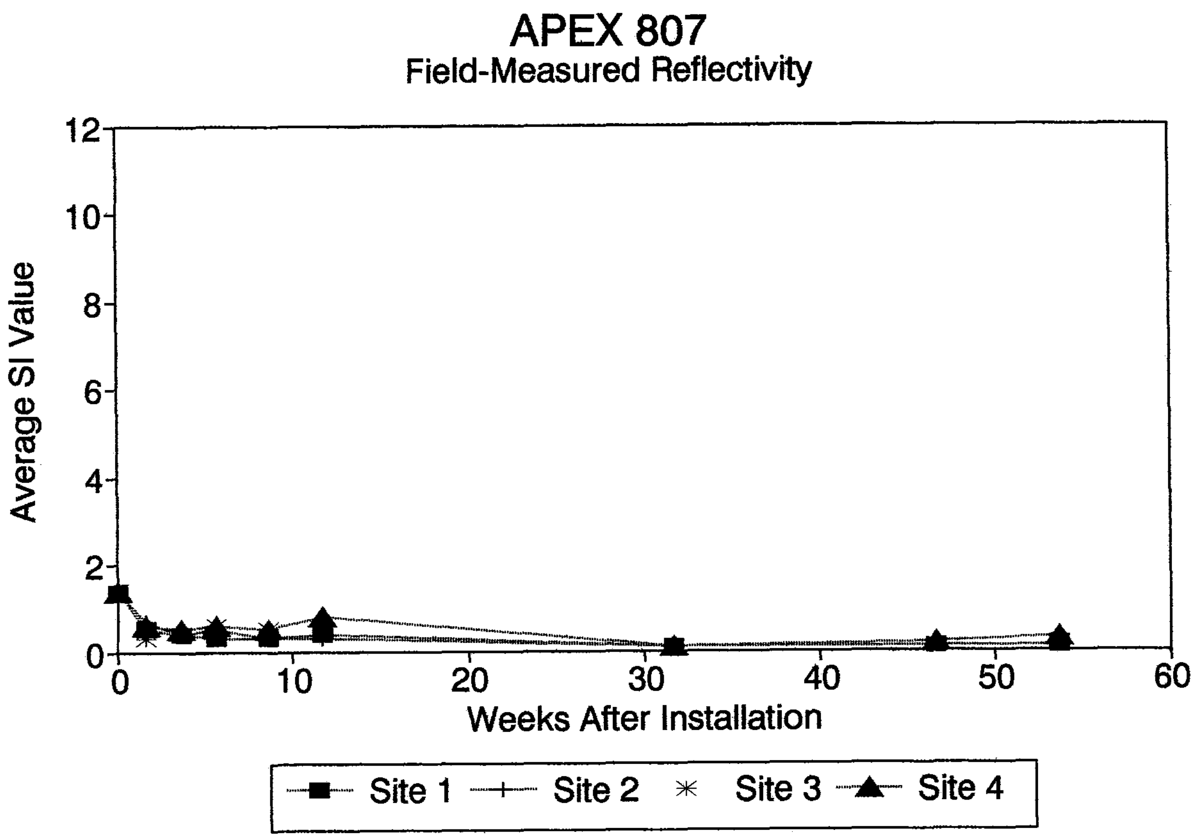
N.A. Data not available



Laboratory SI Values
Washed Markers

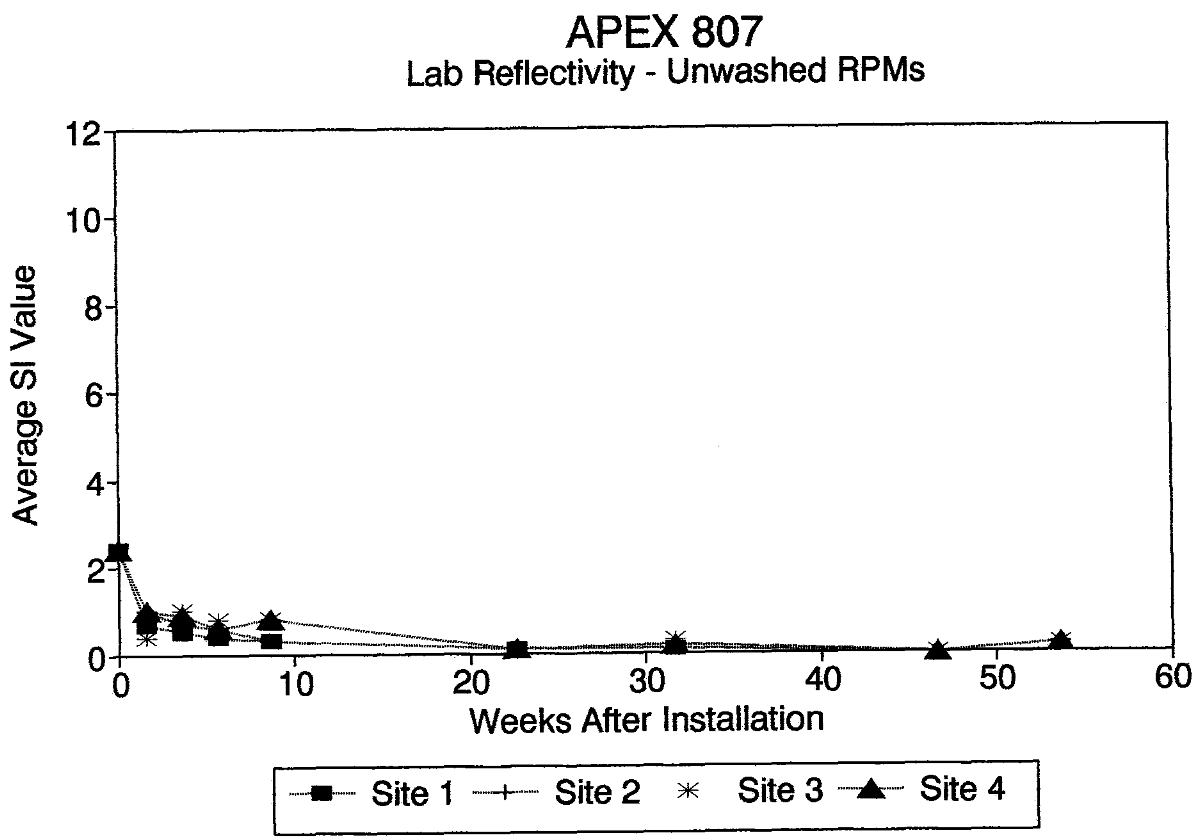
Date	Site 1	Site 2	Site 3	Site 4
8/3/92	2.9	2.9	2.9	2.9
8/16/92	2.1	4.7	1.2	3.7
8/30/92	1.2	1.4	3.3	1.5
9/13/92	1.2	1.1	2.7	2.3
10/6/93	1.3	1.9	0.6	3.0
1/10/93	0.2	0.3	0.4	N.A
3/21/93	0.1	0.2	0.9	0.2
6/27/93	0.1	0.1	0.4	0.4
8/15/93	0.3	0.3	0.6	1.0

N.A. Data not available



Average Reflectometer SI Values
(Standard Deviation of SI Values)

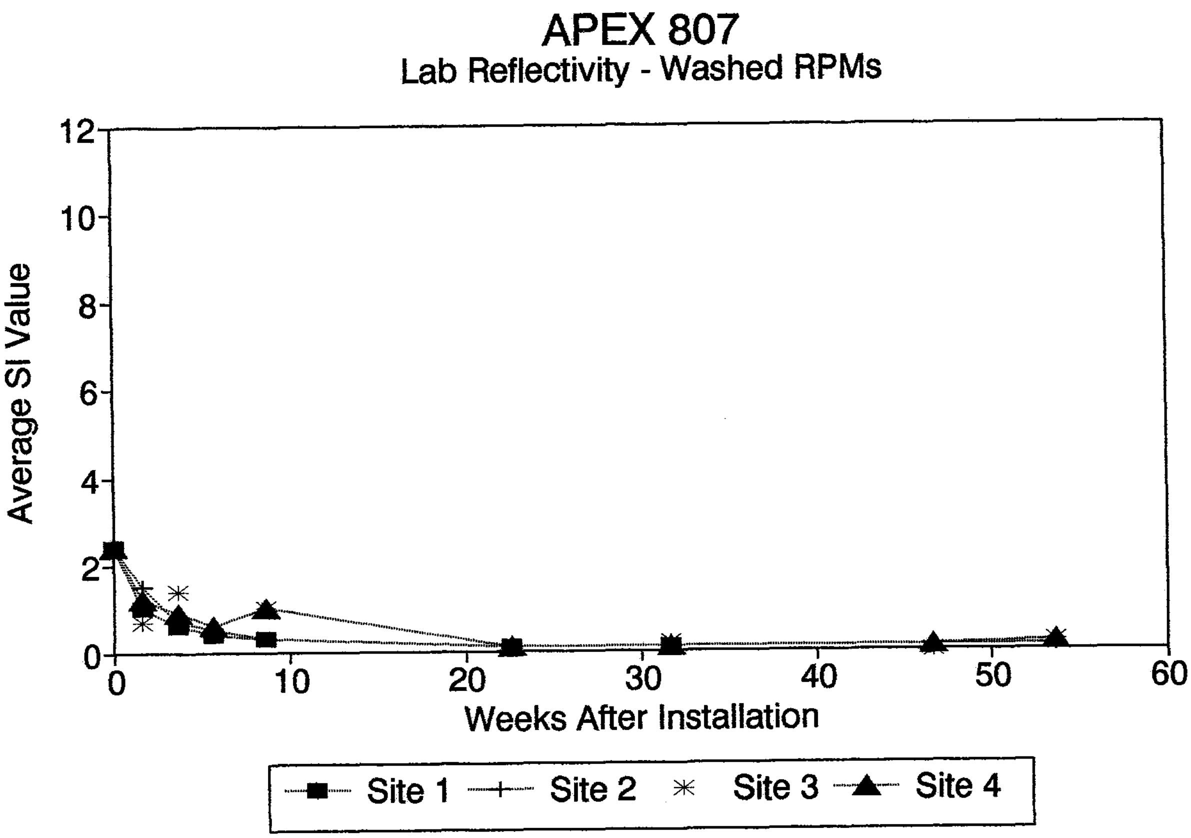
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	1.4 (0.8)	1.4 (0.8)	1.4 (0.8)	1.4 (0.8)
2	0.5 (0.1)	0.7 (0.4)	0.3 (0.3)	0.6 (0.4)
4	0.4 (0.2)	0.4 (0.3)	0.4 (0.3)	0.5 (0.2)
6	0.3 (0.1)	0.5 (0.2)	0.6 (0.2)	0.6 (0.2)
9	0.3 (0.1)	0.3 (0.2)	0.5 (0.1)	0.5 (0.2)
12	0.4 (0.1)	0.3 (0.1)	0.5 (0.3)	0.8 (0.3)
32	0.1 (0.1)	0.1 (0.0)	0.1 (0.1)	0.1 (0.1)
48	0.1 (0.0)	0.2 (0.0)	0.1 (0.1)	0.2 (0.2)
54	0.1 (0.1)	0.3 (0.2)	0.1 (0.1)	0.3 (0.2)



Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	2.4	2.4	2.4	2.4
2	0.7	1.0	0.4	1.0
4	0.5	0.7	1.0	0.9
6	0.4	0.6	0.8	0.6
9	0.3	0.3	0.8	0.8
23	0.1	0.1	0.1	0.1
32	0.1	0.1	0.3	0.2
48	N.A	0.0	0.0	0.0
54	N.A	0.2	0.2	0.2

N.A. Data not available

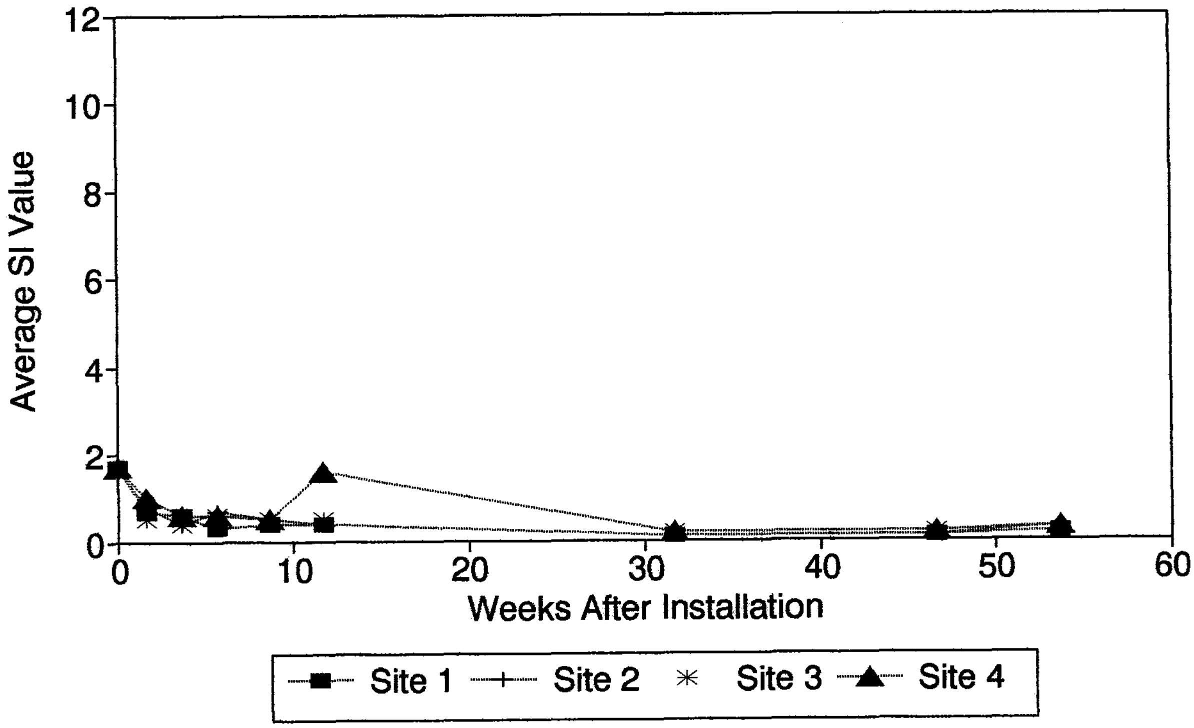


Laboratory SI Values
Washed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	2.4	2.4	2.4	2.4
2	1.0	1.5	0.7	1.2
4	0.6	0.7	1.4	0.9
6	0.4	0.5	0.4	0.6
9	0.3	0.3	1.0	1.0
23	0.1	0.1	0.1	0.1
32	0.1	0.1	0.2	0.1
48	N.A	0.1	0.0	0.1
54	N.A	0.1	0.2	0.2

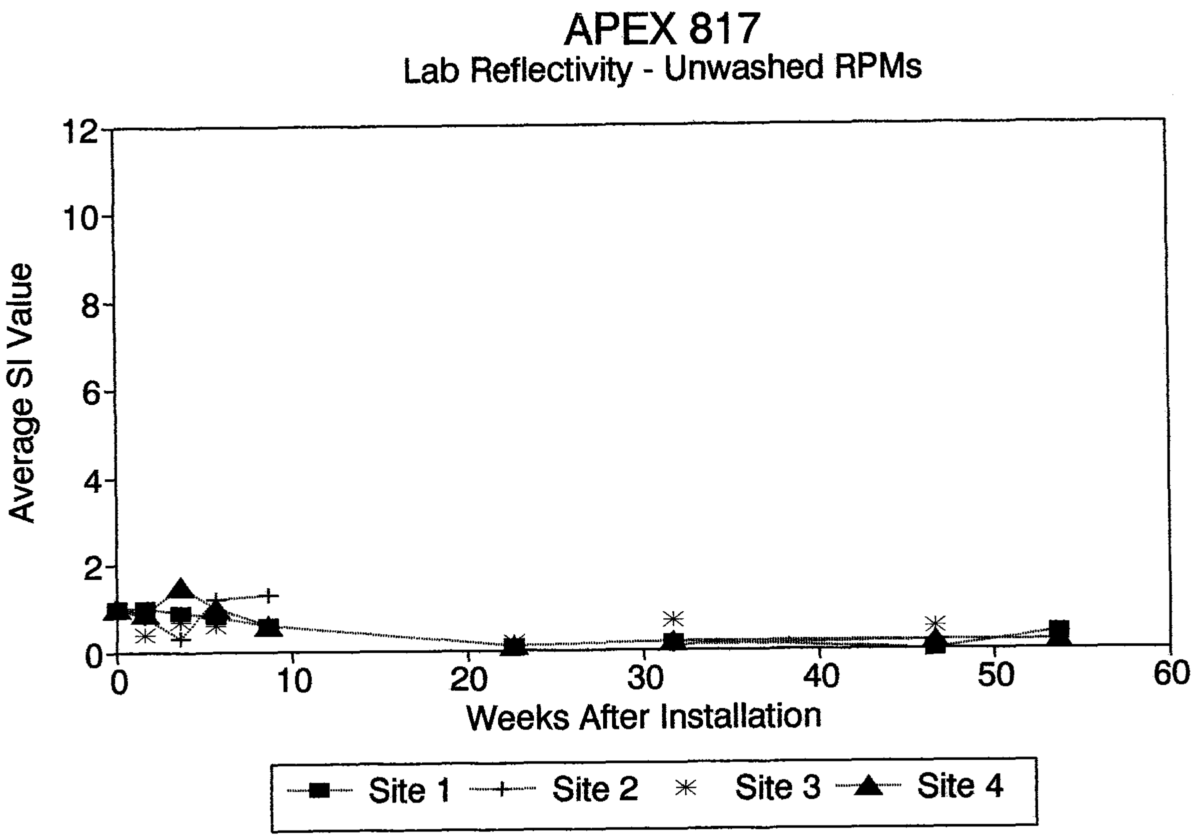
N.A. Data not available

APEX 817
Field-Measured Reflectivity



Average Reflectometer SI Values
(Standard Deviation of SI Values)

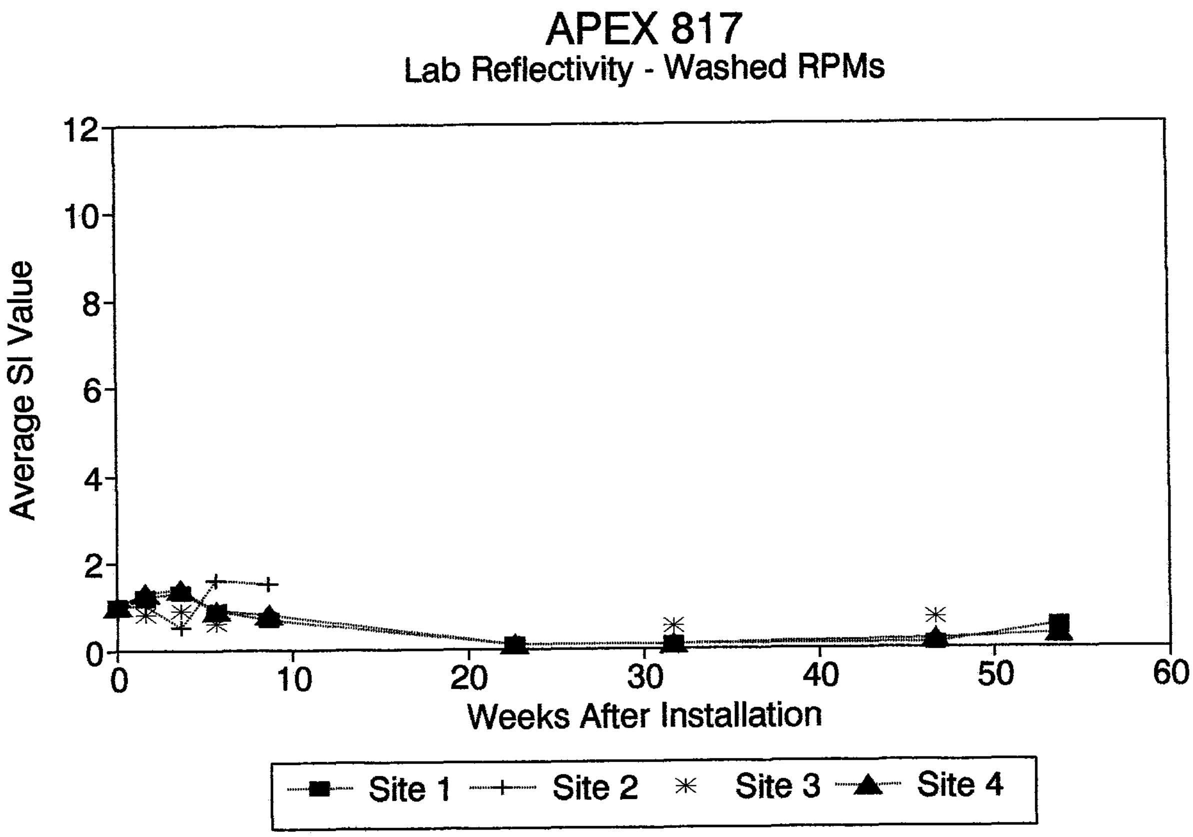
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	1.7 (0.9)	1.7 (0.9)	1.7 (0.9)	1.7 (0.9)
2	0.7 (0.2)	0.8 (0.7)	0.5 (0.3)	1.0 (0.6)
4	0.6 (0.2)	0.4 (0.4)	0.4 (0.3)	0.6 (0.2)
6	0.3 (0.2)	0.7 (0.2)	0.6 (0.2)	0.6 (0.1)
9	0.4 (0.2)	0.5 (0.2)	0.5 (0.1)	0.5 (0.1)
12	0.4 (0.2)	0.4 (0.2)	0.5 (0.3)	1.6 (3.2)
32	0.1 (0.1)	0.1 (0.1)	0.2 (0.1)	0.2 (0.1)
48	0.1 (0.0)	0.1 (0.1)	0.2 (0.1)	0.2 (0.1)
54	0.2 (0.1)	0.3 (0.2)	0.2 (0.1)	0.3 (0.1)



Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	1.0	1.0	1.0	1.0
2	1.0	0.8	0.4	0.9
4	0.9	0.3	0.7	1.5
6	0.8	1.2	0.6	1.0
9	0.6	1.3	0.0	0.6
23	0.1	N.A	0.2	0.1
32	0.2	0.1	0.7	0.2
48	0.0	0.2	0.5	0.2
54	0.4	0.2	0.4	0.2

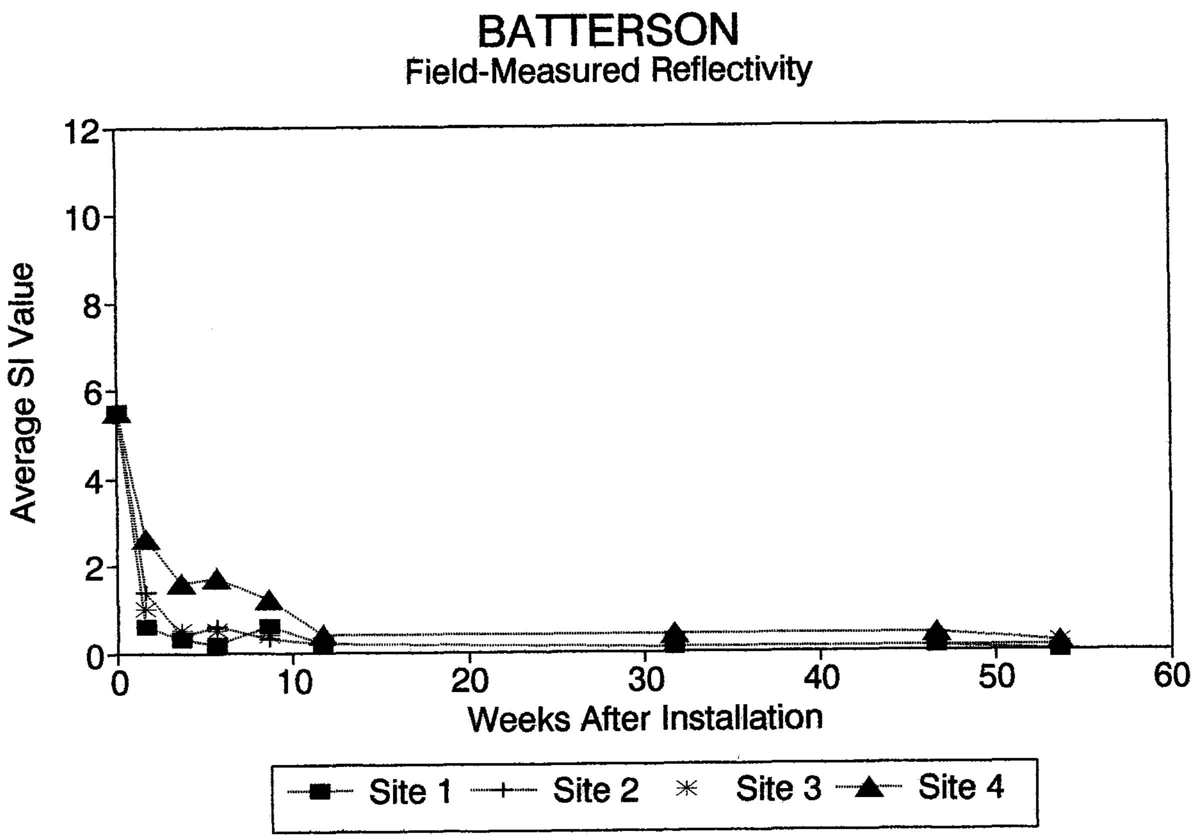
N.A. Data not available



Laboratory SI Values
Washed Markers

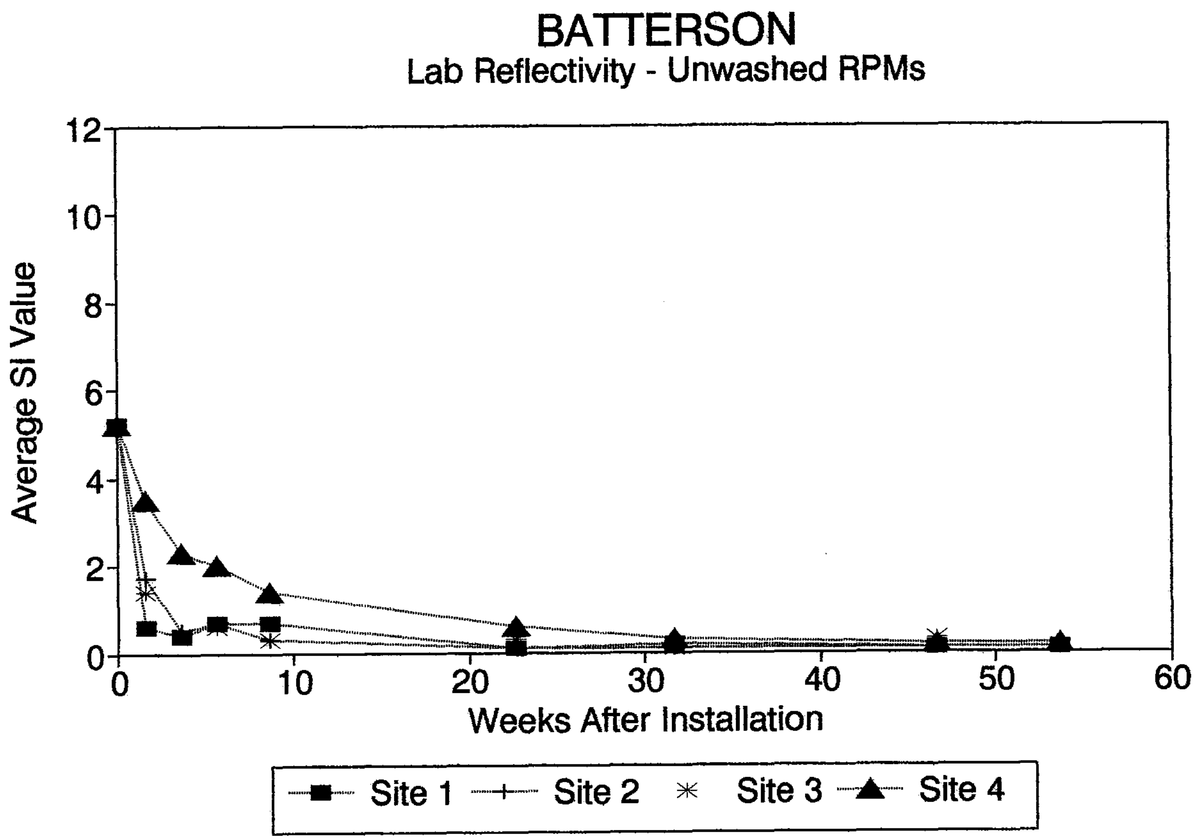
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	1.0	1.0	1.0	1.0
2	1.2	1.0	0.8	1.3
4	1.3	0.5	0.9	1.4
6	0.9	1.6	0.6	0.9
9	0.7	1.5	N.A	0.8
23	0.1	N.A	0.1	0.1
32	0.1	0.1	0.5	0.1
48	0.1	0.2	0.7	0.2
54	0.5	0.3	0.4	0.3

N.A. Data not available



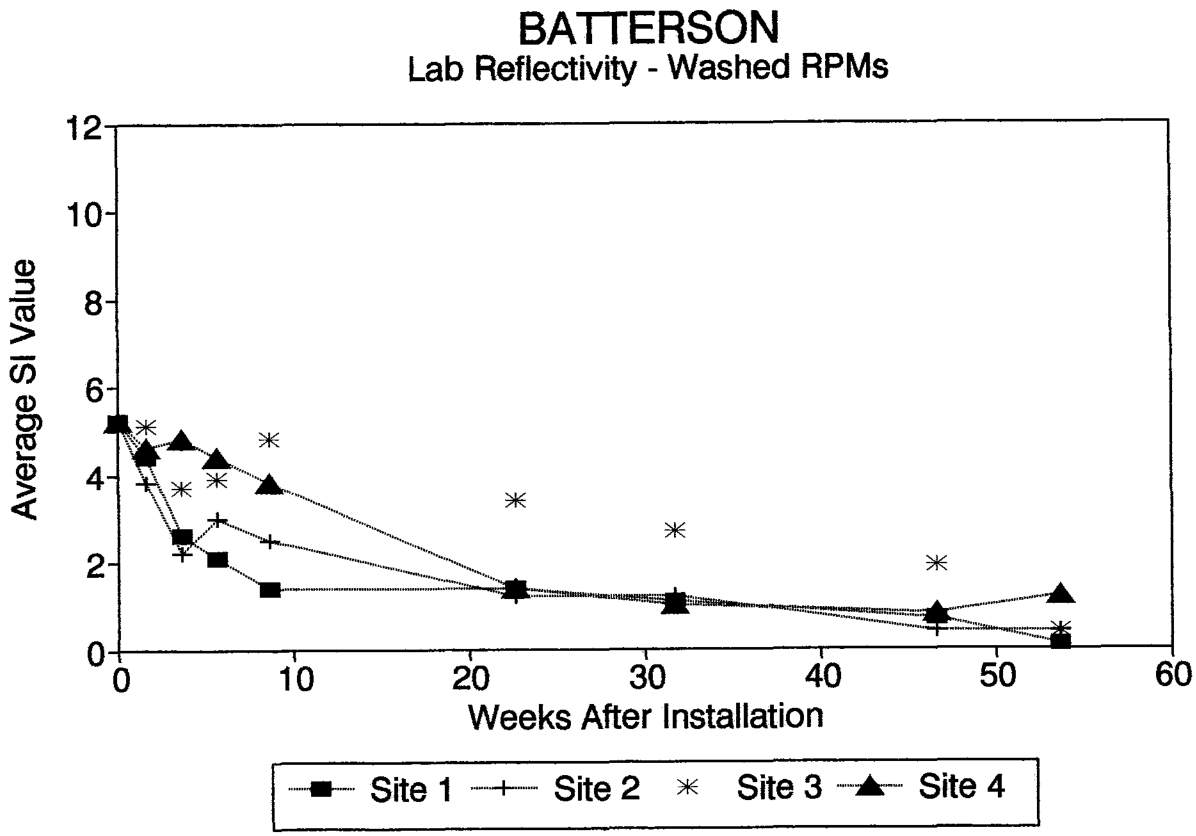
Average Reflectometer SI Values
(Standard Deviation of SI Values)

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	5.5 (1.0)	5.5 (1.0)	5.5 (1.0)	5.5 (1.0)
2	0.6 (0.2)	1.4 (0.1)	1.5 (0.3)	2.6 (0.8)
4	0.3 (0.1)	0.4 (0.1)	0.5 (0.2)	1.6 (0.2)
6	0.2 (0.2)	0.6 (0.0)	0.5 (0.2)	1.7 (0.3)
9	0.6 0.3)	0.3 (0.1)	0.4 (0.2)	1.2 (0.2)
12	0.2 (0.1)	0.2 (0.1)	0.2 (0.1)	0.4 (0.1)
32	0.1 (0.1)	0.1 (0.0)	0.2 (0.1)	0.4 (0.2)
48	0.1 (0.0)	0.1 (0.1)	0.2 (0.1)	0.4 (0.1)
54	0.0 (0.0)	0.1 (0.2)	0.2 (0.1)	0.2 (0.2)



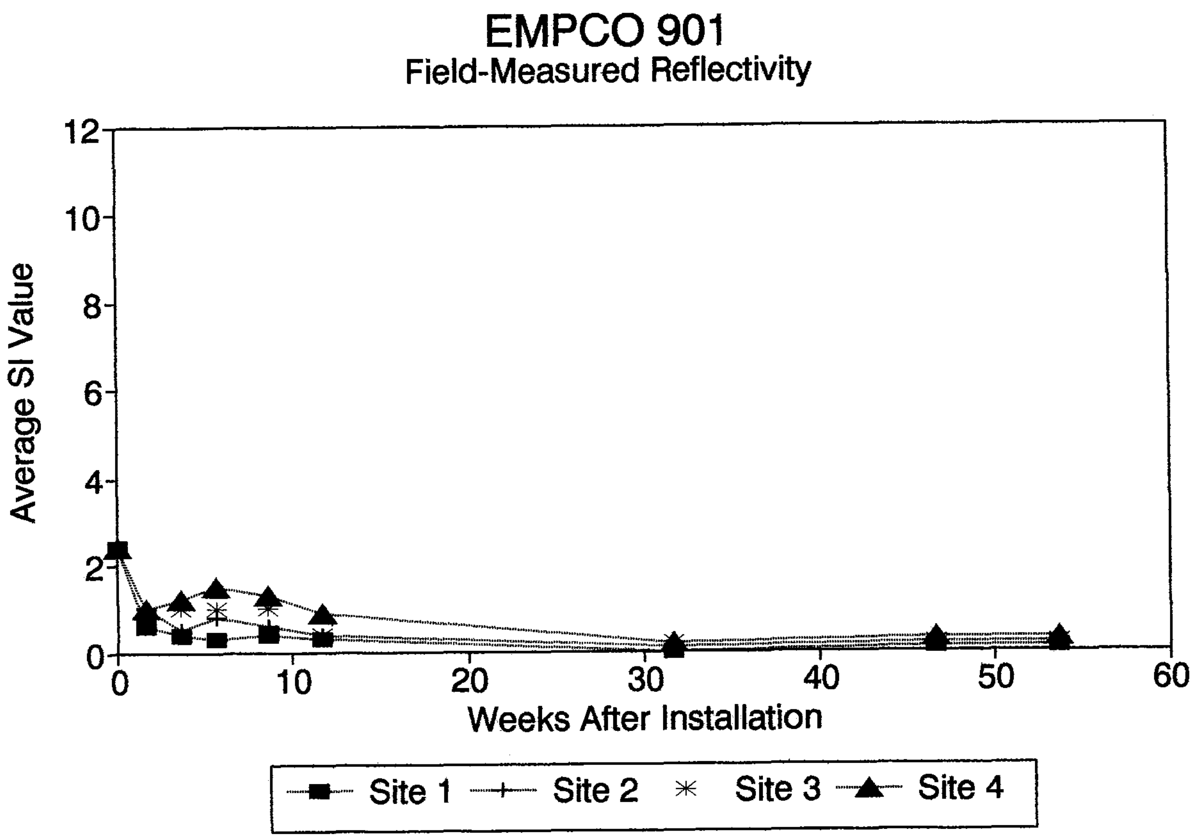
Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	5.2	5.2	5.2	5.2
2	0.6	1.7	1.4	3.5
4	0.4	0.5	0.4	2.3
6	0.7	0.7	0.6	2.0
9	0.7	0.3	0.3	1.4
23	0.1	0.1	0.3	0.6
32	0.2	0.1	0.1	0.3
48	0.1	0.1	0.3	0.2
54	0.1	0.1	0.1	0.2



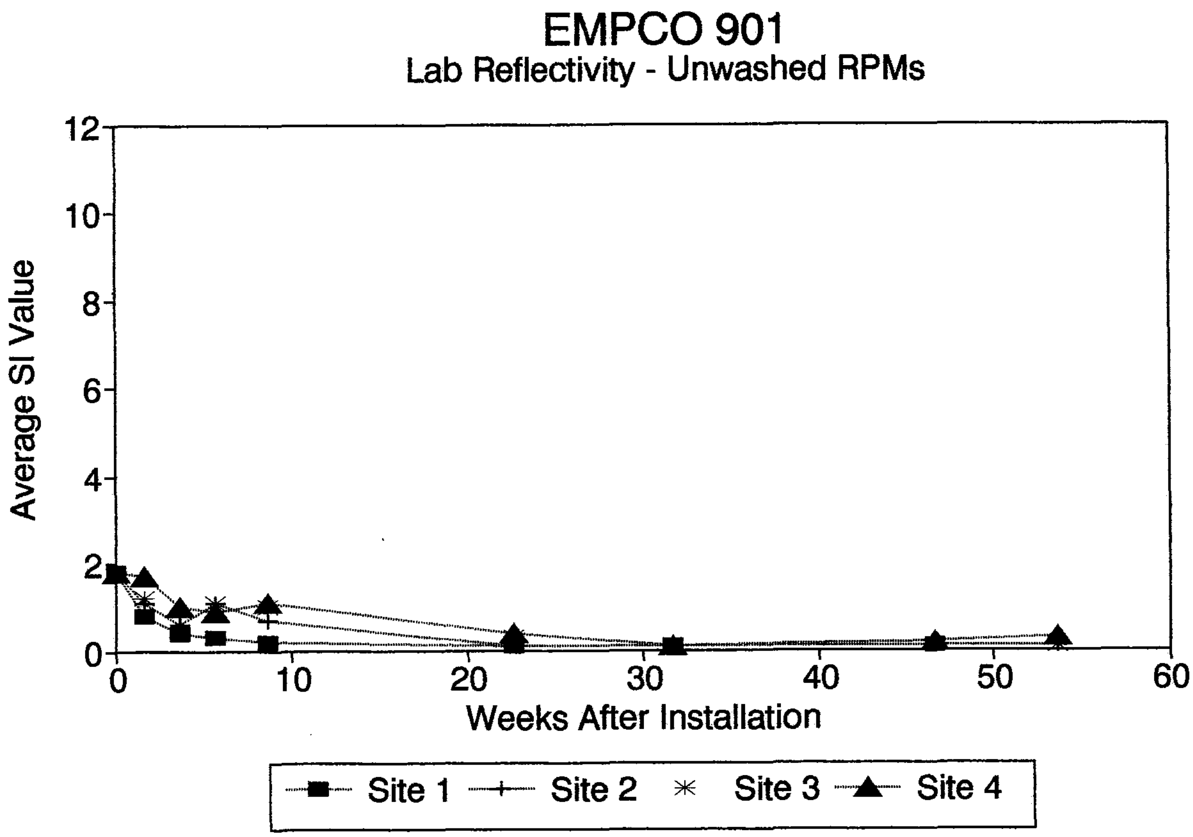
Laboratory SI Values
Washed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	5.2	5.2	5.2	5.2
2	4.4	3.8	5.1	4.6
4	2.6	2.2	3.7	4.8
6	2.1	3.0	3.9	4.4
9	1.4	2.5	4.8	3.8
23	1.4	1.2	3.4	1.4
32	1.1	1.2	2.7	1.0
48	0.7	0.4	1.9	0.8
54	0.1	0.4	0.4	1.2



Average Reflectometer SI Values
(Standard Deviation of SI Values)

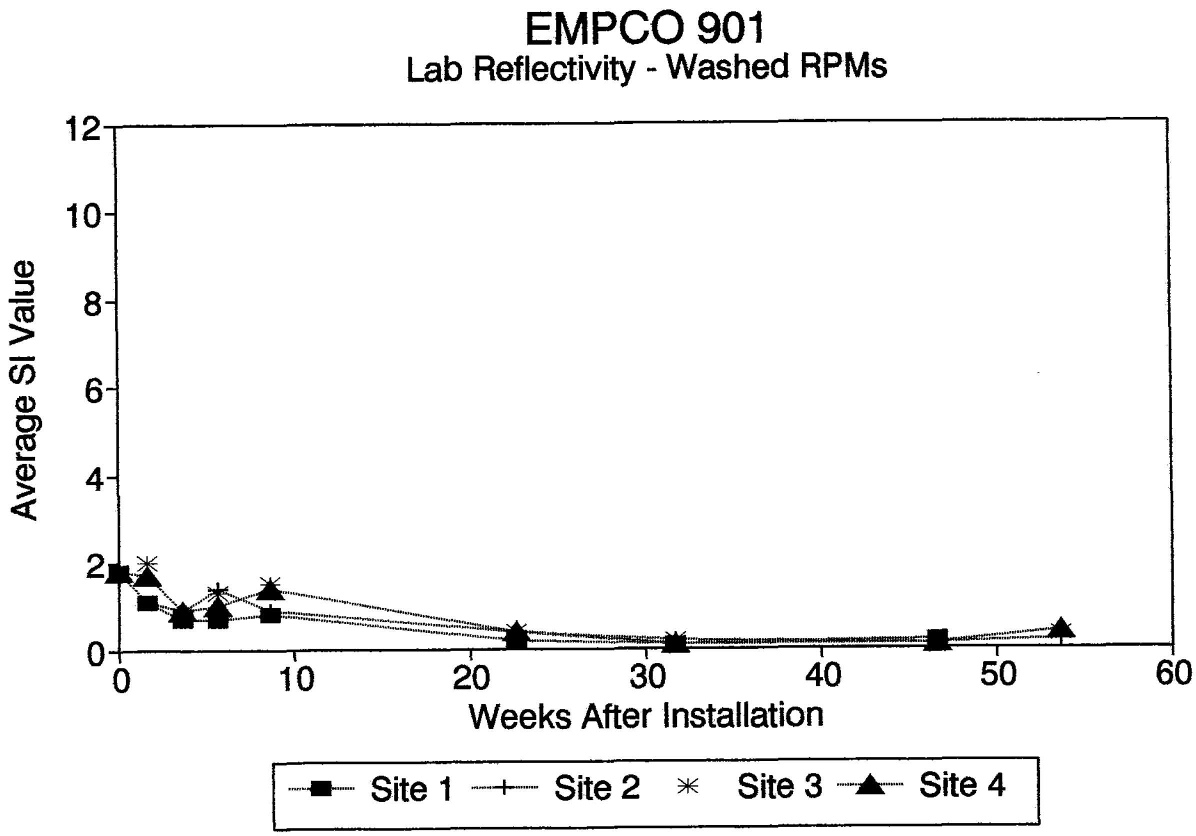
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	2.4 (1.0)	2.4 (1.0)	2.4 (1.0)	2.4 (1.0)
2	0.6 (0.1)	1.0 (0.1)	0.8 (0.4)	1.0 (0.3)
4	0.4 (0.1)	0.5 (0.2)	0.9 (0.0)	1.2 (0.8)
6	0.3 (0.1)	0.8 (0.1)	1.0 (0.2)	1.5 (0.5)
9	0.4 (0.1)	0.6 (0.2)	1.0 (0.1)	1.3 (0.1)
12	0.3 (0.2)	0.4 (0.0)	0.4 (0.2)	0.9 (0.2)
32	0.0 (0.0)	0.1 (0.1)	0.2 (0.1)	0.2 (0.2)
48	0.1 (0.0)	0.2 (0.1)	0.2 (0.1)	0.3 (0.1)
54	0.1 (0.1)	0.2 (0.1)	0.2 (0.1)	0.3 (0.1)



Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	1.8	1.8	1.8	1.8
2	0.8	1.1	1.2	1.7
4	0.4	0.6	N.A	1.0
6	0.3	1.1	1.1	0.9
9	0.2	0.7	1.0	1.1
23	0.1	0.1	0.3	0.4
32	0.1	0.1	0.1	0.1
48	0.1	0.1	0.1	0.2
54	N.A	0.1	0.1	0.3

N.A. Data not available

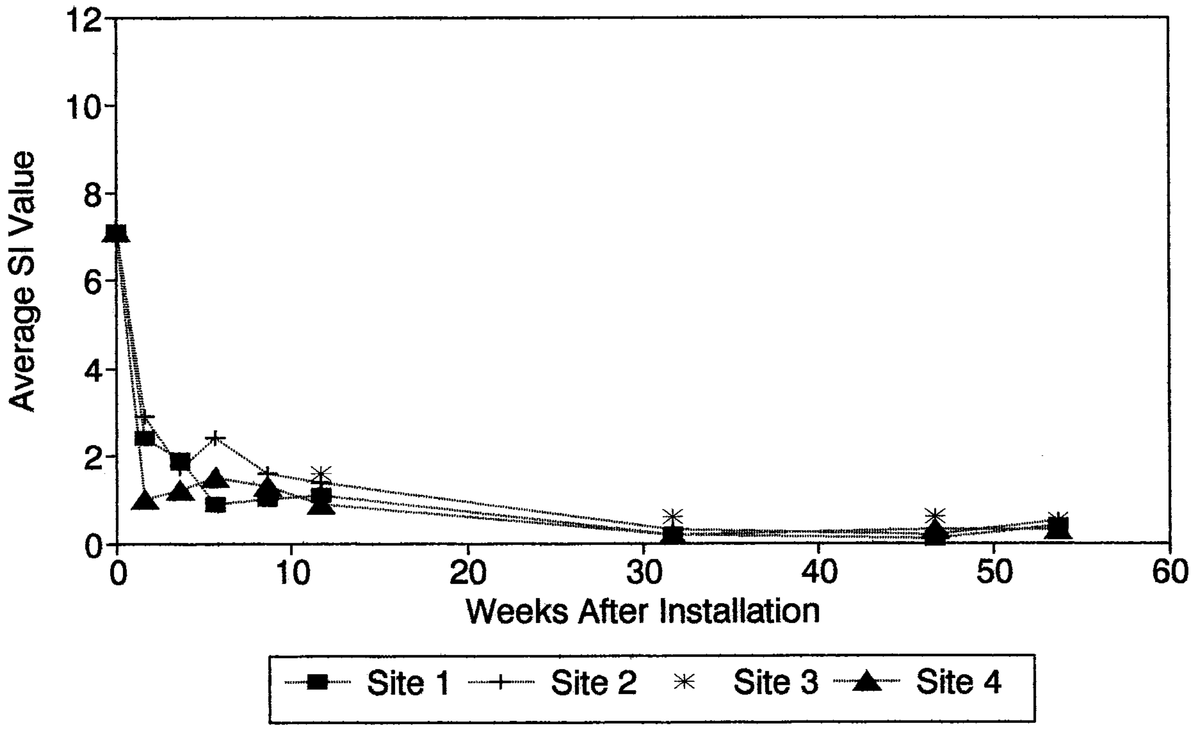


Laboratory SI Values
Washed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	1.8	1.8	1.8	1.8
2	1.1	1.1	2.0	1.7
4	0.7	0.9	N.A	0.9
6	0.7	1.4	1.3	1.0
9	0.8	0.9	1.5	1.4
23	0.2	0.4	0.4	0.4
32	0.1	0.2	0.2	0.1
48	0.2	0.1	0.2	0.1
54	N.A	0.2	0.3	0.4

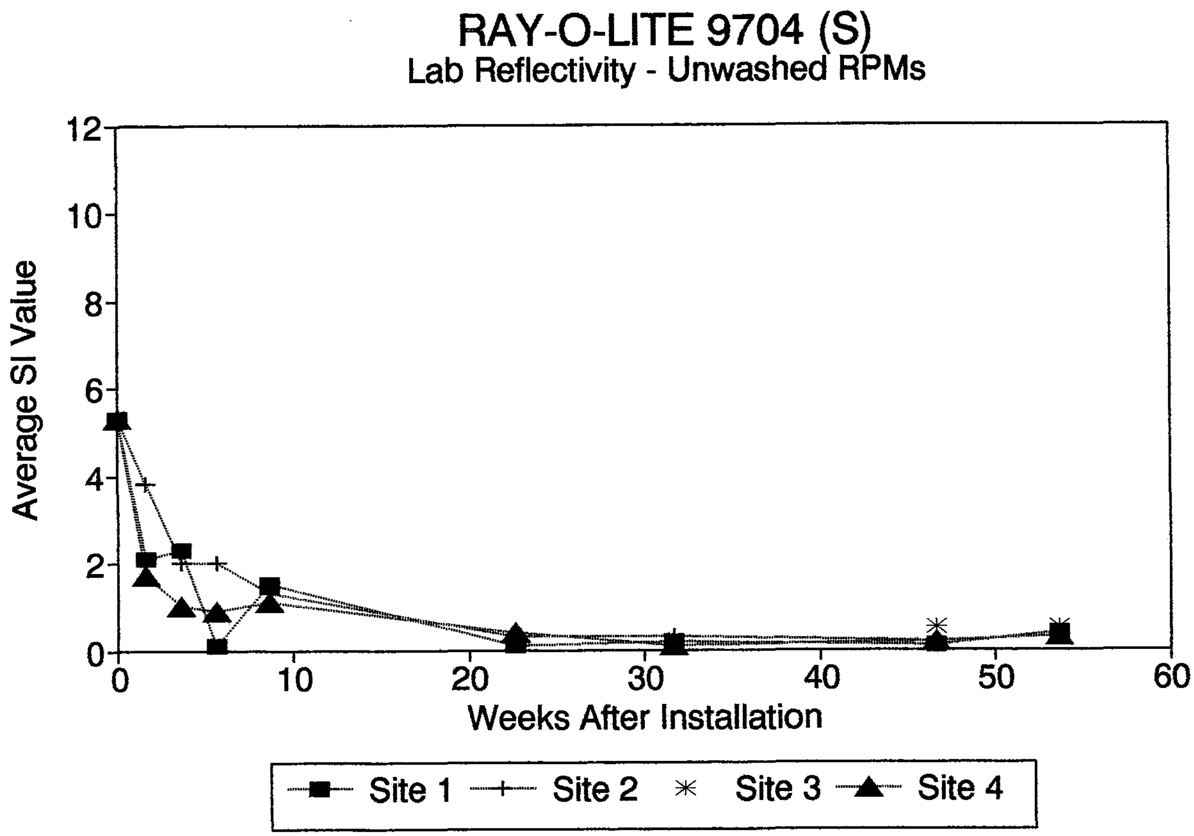
N.A. Data not available

RAY-O-LITE 8704 (S)
Field-Measured Reflectivity



Average Reflectometer SI Values
(Standard Deviation of SI Values)

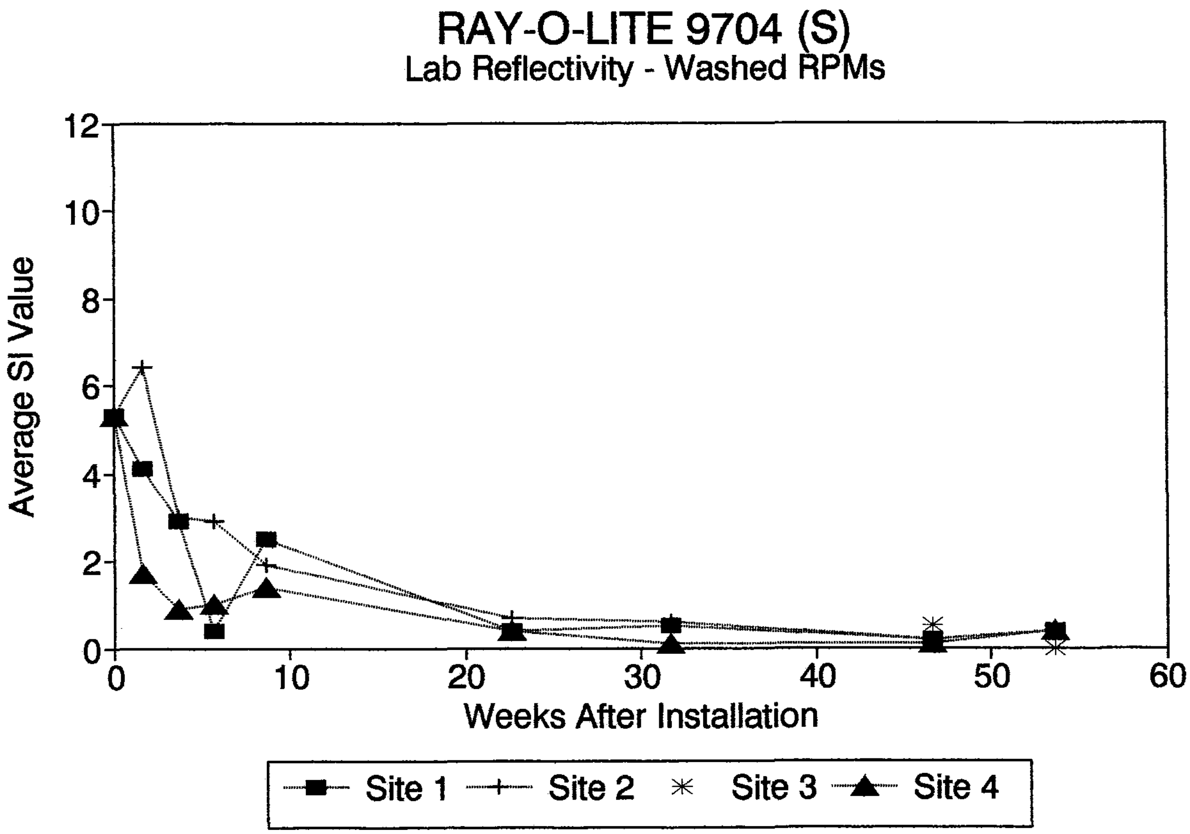
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	7.1 (1.5)	7.1 (1.5)	7.1 (1.5)	7.1 (1.5)
2	2.4 (0.4)	2.9 (0.8)	N.A	1.0 (0.3)
4	1.9 (0.2)	1.7 (0.3)	N.A	1.2 (0.8)
6	0.9 (0.6)	2.4 (0.7)	N.A	1.5 (0.5)
9	1.0 (0.1)	1.6 (0.4)	N.A	1.3 (0.1)
12	1.1 (0.2)	1.4 (0.4)	1.6 (0.4)	0.9 (0.2)
32	0.2 (0.1)	0.3 (0.1)	0.6 (0.2)	0.2 (0.2)
48	0.1 (0.0)	0.2 (0.1)	0.6 (0.1)	0.3 (0.1)
54	0.4 (0.1)	0.5 (0.1)	0.5 (0.1)	0.3 (0.1)



Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	5.3	5.3	5.3	5.3
2	2.1	3.8	NA	1.7
4	2.3	2.0	NA	1.0
6	0.1	2.0	NA	0.9
9	1.5	1.3	NA	1.1
23	0.1	0.3	NA	0.4
32	0.2	0.3	NA	0.1
48	0.1	0.2	0.5	0.2
54	0.4	0.3	0.5	0.3

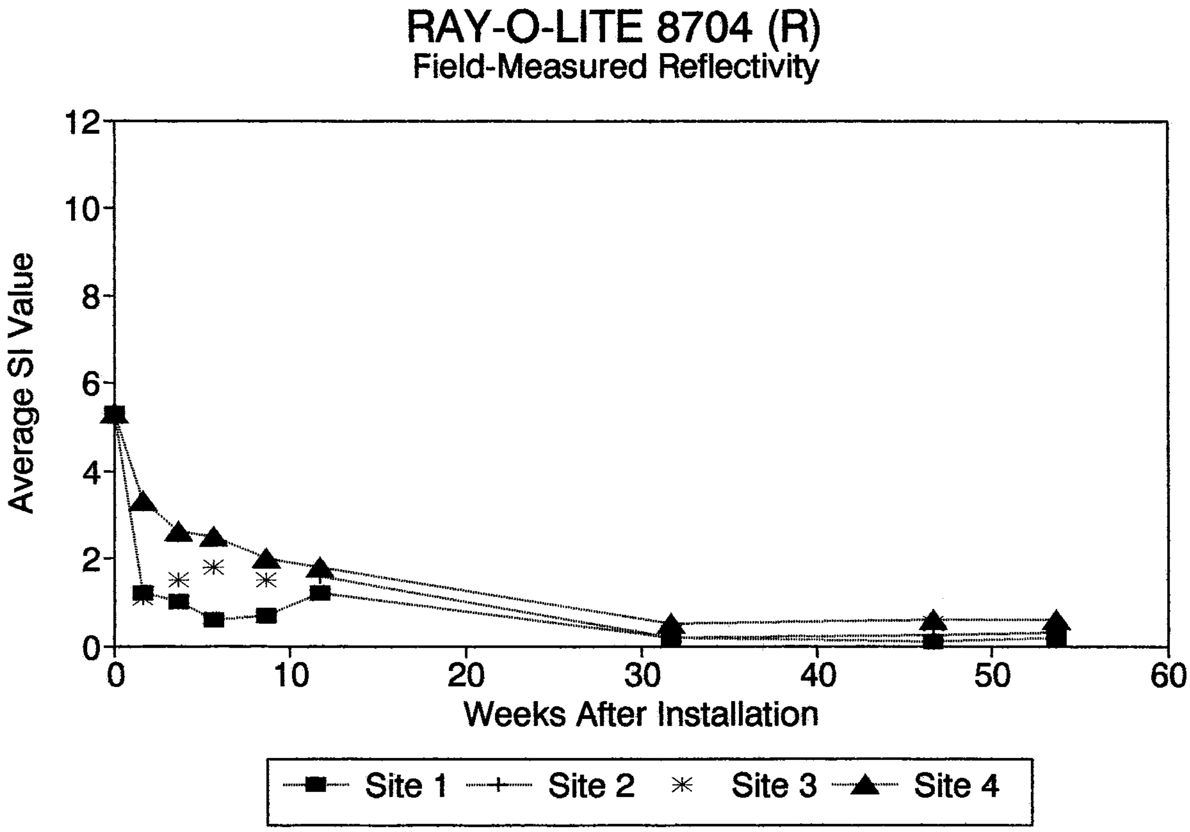
N.A. Data not available



Laboratory SI Values
Washed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	5.3	5.3	5.3	5.3
2	4.1	6.4	N.A	1.7
4	2.9	3.0	N.A	0.9
6	0.4	2.9	N.A	1.0
9	2.5	1.9	N.A	1.4
23	0.4	0.7	N.A	0.4
32	0.5	0.6	N.A	0.1
48	0.2	0.2	0.5	0.1
54	0.4	0.4	0.0	0.4

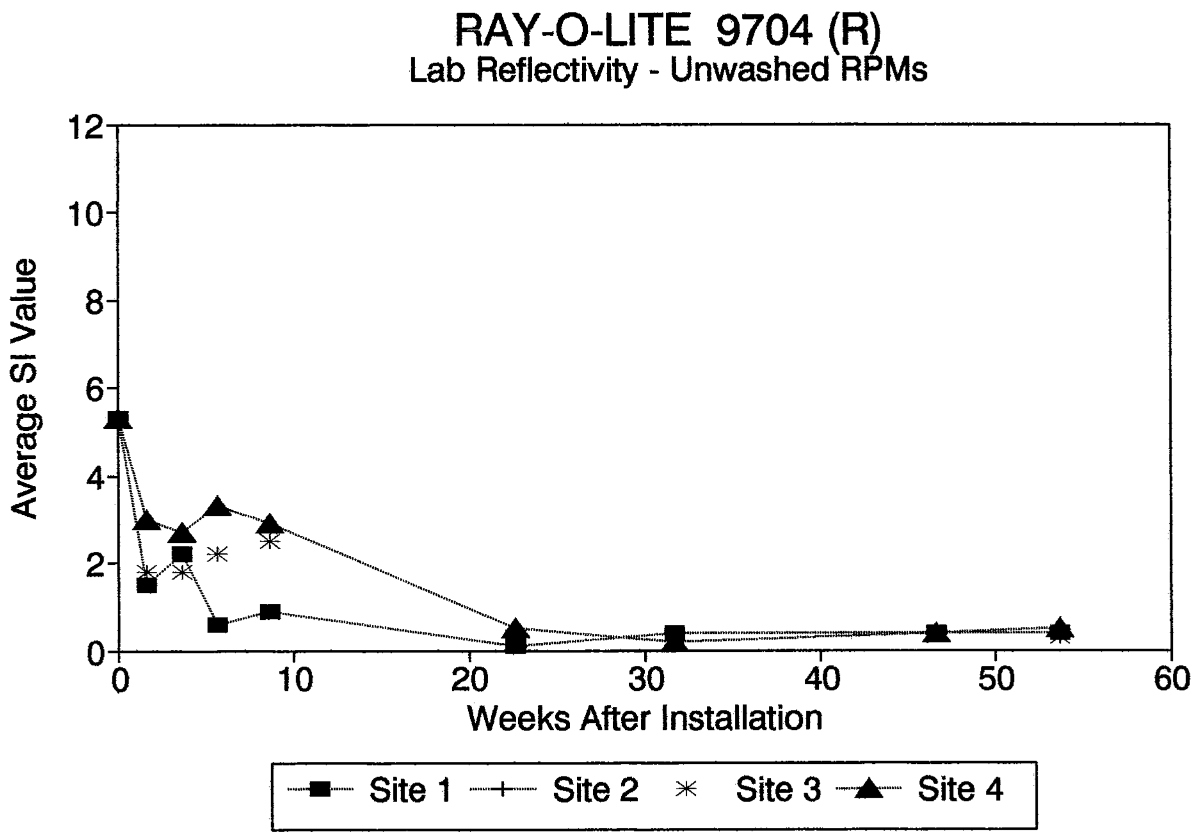
N.A. Data not available



Average Reflectometer SI Values
(Standard Deviation of SI Values)

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	5.3 (1.3)	5.3 (1.3)	5.3 (1.3)	5.3 (1.3)
2	1.2 (0.1)	NA	1.1 (0.4)	3.3 (0.3)
4	1.0 (0.2)	NA	1.5 (0.1)	2.6 (0.5)
6	0.6 (0.3)	NA	1.8 (0.2)	2.5 (0.4)
9	0.7 (0.0)	NA	1.5 (0.3)	2.0 (0.2)
12	1.2 (1.2)	1.6 (---)	1.2 (0.1)	1.8 (0.3)
32	0.2 (0.4)	0.2 (---)	0.3 (0.1)	0.5 (0.3)
48	0.1 (0.1)	0.2 (---)	0.5 (0.3)	0.6 (0.2)
54	0.2 (0.1)	0.3 (---)	0.3 (0.1)	0.6 (0.1)

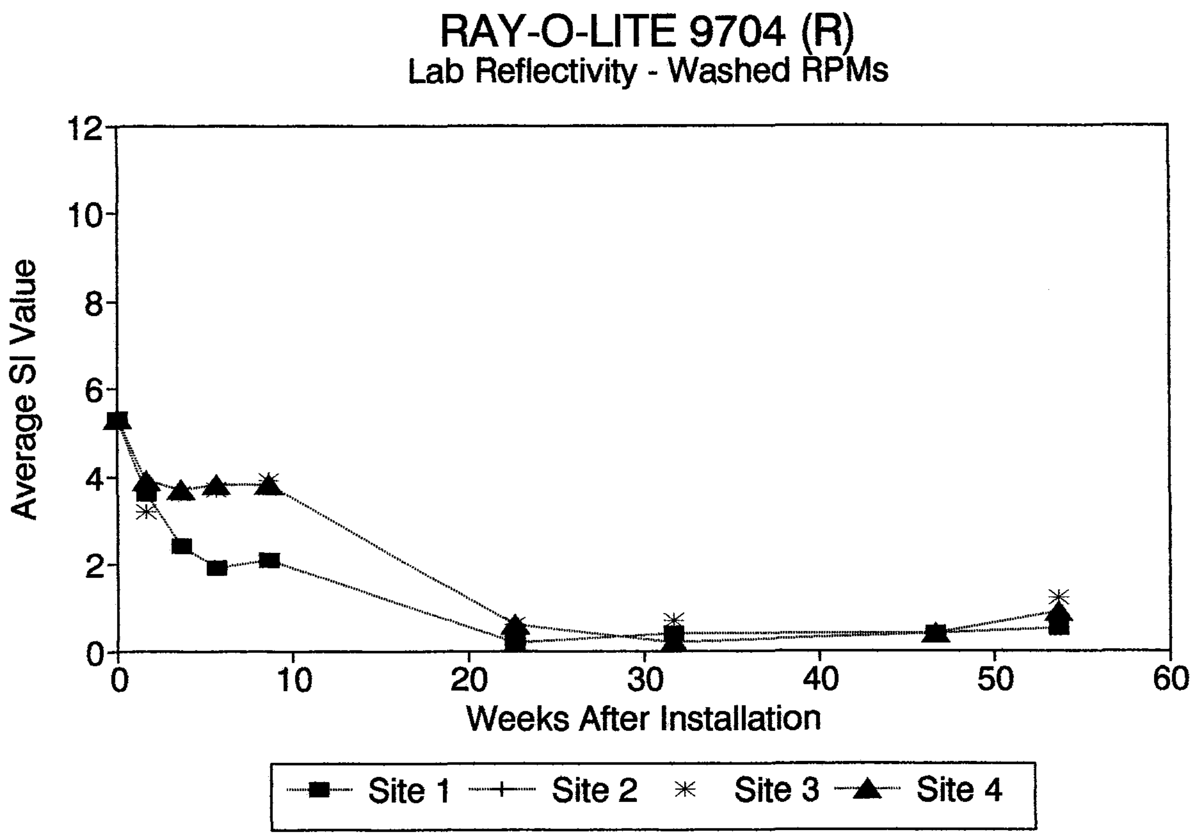
--- No standard deviation (only one data point obtained)



Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	5.3	5.3	5.3	5.3
2	1.5	N.A	1.8	3.0
4	2.2	N.A	1.8	2.7
6	0.6	N.A	2.2	3.3
9	0.9	N.A	2.5	2.9
23	0.1	N.A	0.3	0.5
32	0.4	N.A	0.4	0.2
48	0.4	N.A	N.A	0.4
54	0.4	N.A	0.3	0.5

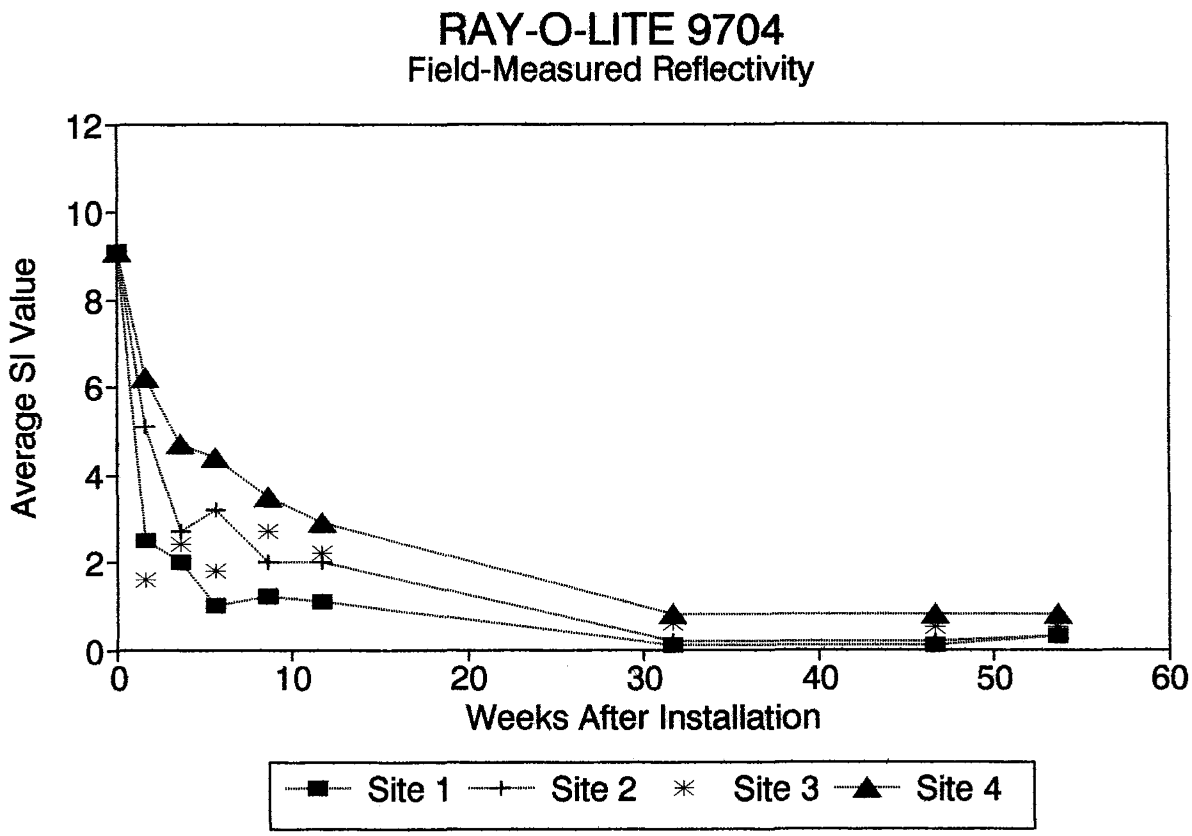
N.A. Data not available



Laboratory SI Values
Washed Markers

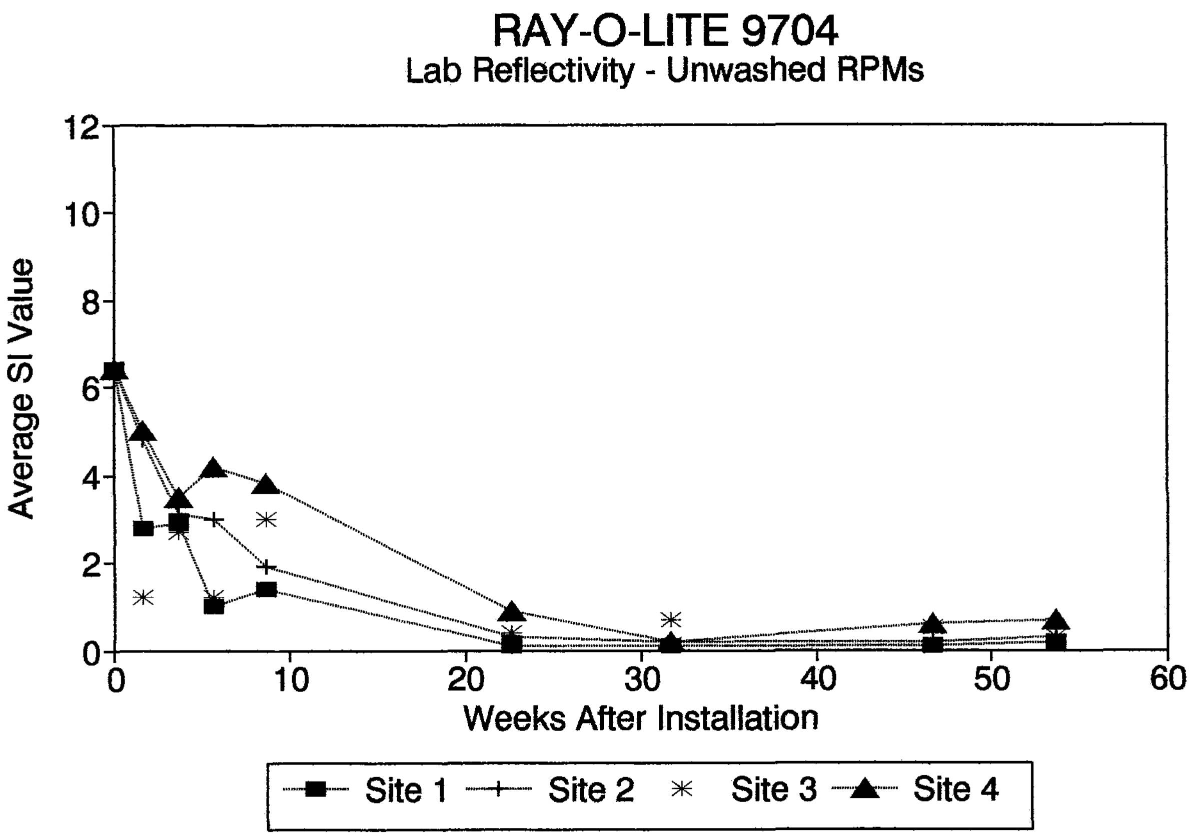
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	5.3	5.3	5.3	5.3
2	3.6	NA	3.2	3.9
4	2.4	NA	3.6	3.7
6	1.9	NA	3.7	3.8
9	2.1	NA	3.9	3.8
23	0.2	NA	0.6	0.6
32	0.4	NA	0.7	0.2
48	0.4	NA	NA	0.4
54	0.5	NA	1.2	0.9

N.A. Data not available



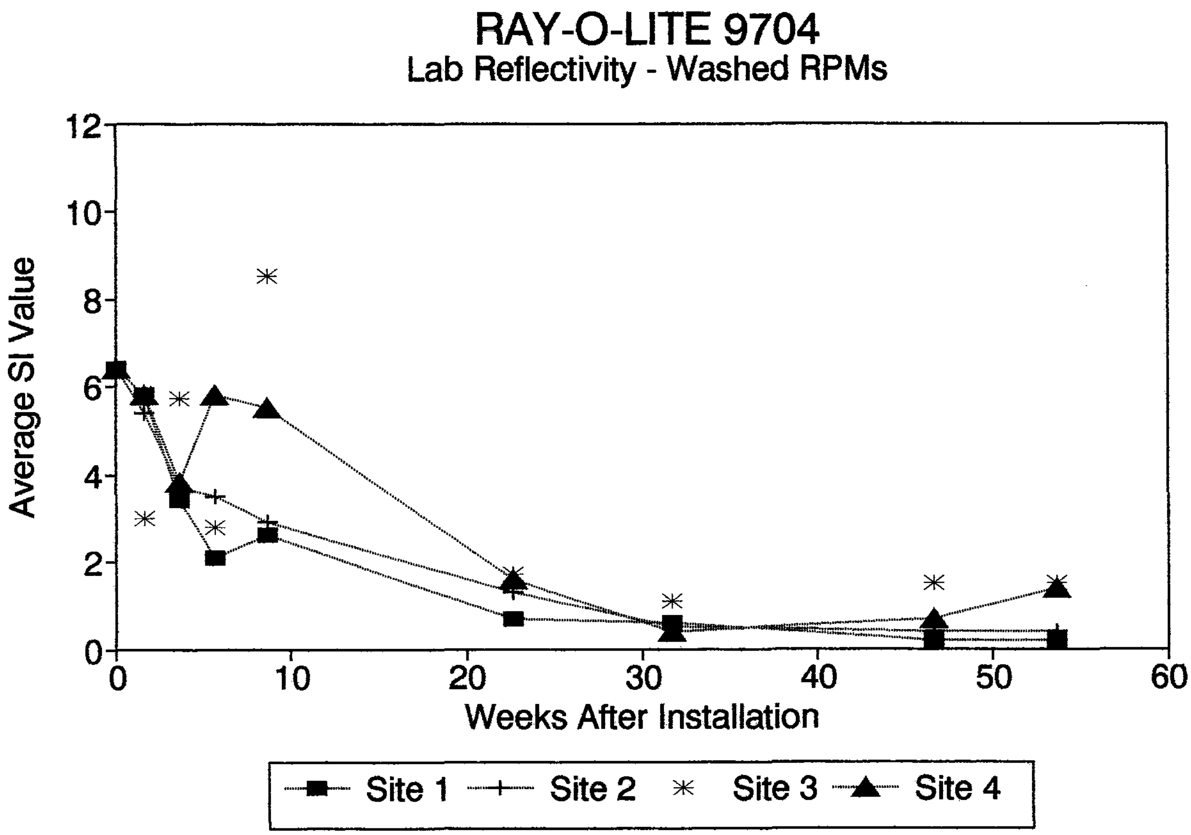
Average Reflectometer SI Values
(Standard Deviation of SI Values)

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	9.1 (2.2)	9.1 (2.2)	9.1 (2.2)	9.1 (2.2)
2	2.5 (0.8)	5.1 (0.8)	1.6 (0.6)	6.2 (0.3)
4	2.0 (0.4)	2.7 (1.1)	2.4 (0.5)	4.7 (0.8)
6	1.0 (0.3)	3.2 (0.8)	1.8 (0.7)	4.4 (0.8)
9	1.2 (0.2)	2.0 (0.4)	2.7 (0.7)	3.5 (0.6)
12	1.1 (0.4)	2.0 (0.4)	2.2 (0.3)	2.9 (0.4)
32	0.1 (0.1)	0.2 (0.0)	0.6 (0.2)	0.8 (0.4)
48	0.1 (0.0)	0.2 (0.0)	0.5 (0.1)	0.8 (0.2)
54	0.3 (0.1)	0.3 (0.2)	0.5 (0.2)	0.8 (0.1)



Laboratory SI Values
Unwashed Markers

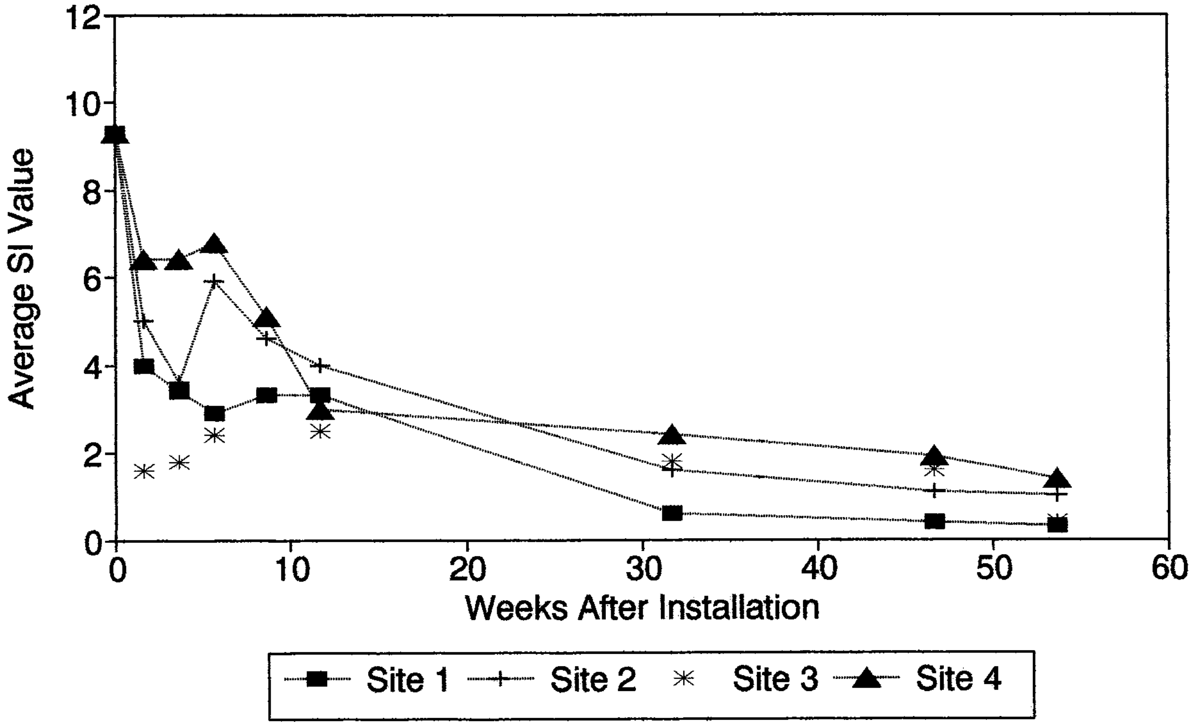
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	6.4	6.4	6.4	6.4
2	2.8	4.8	1.2	5.0
4	2.9	3.1	2.7	3.5
6	1.0	3.0	1.2	4.2
9	1.4	1.9	3.0	3.8
12	0.1	0.3	0.4	0.9
32	0.1	0.2	0.7	0.2
48	0.1	0.2	0.5	0.6
54	0.2	0.3	0.3	0.7



Laboratory SI Values
Washed Markers

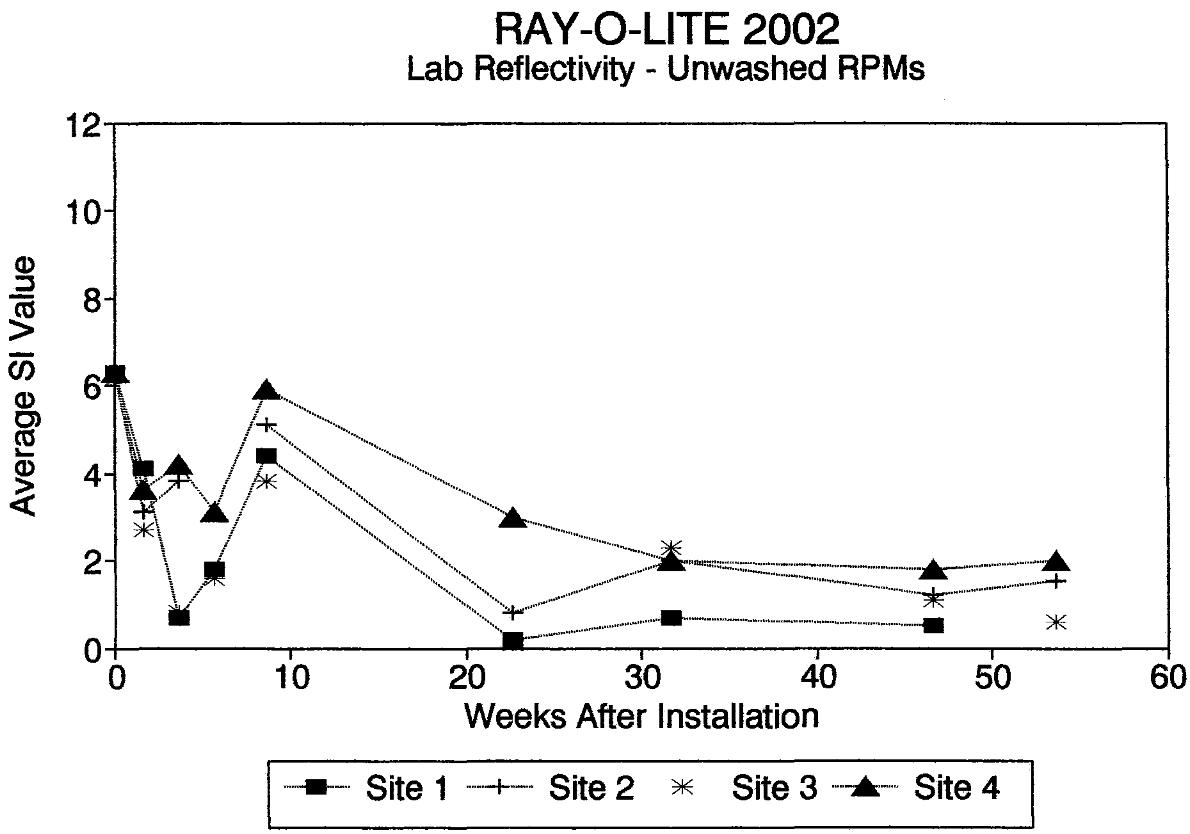
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	6.4	6.4	6.4	6.4
2	5.8	5.4	3.0	5.8
4	3.4	3.7	5.7	3.8
6	2.1	3.5	2.8	5.8
9	2.6	2.9	8.5	5.5
23	0.7	1.3	1.7	1.6
32	0.6	0.5	1.1	0.4
48	0.2	0.4	1.5	0.7
54	0.2	0.4	1.5	1.4

RAY-O-LITE 2002
Field-Measured Reflectivity



Average Reflectometer SI Values
(Standard Deviation of SI Values)

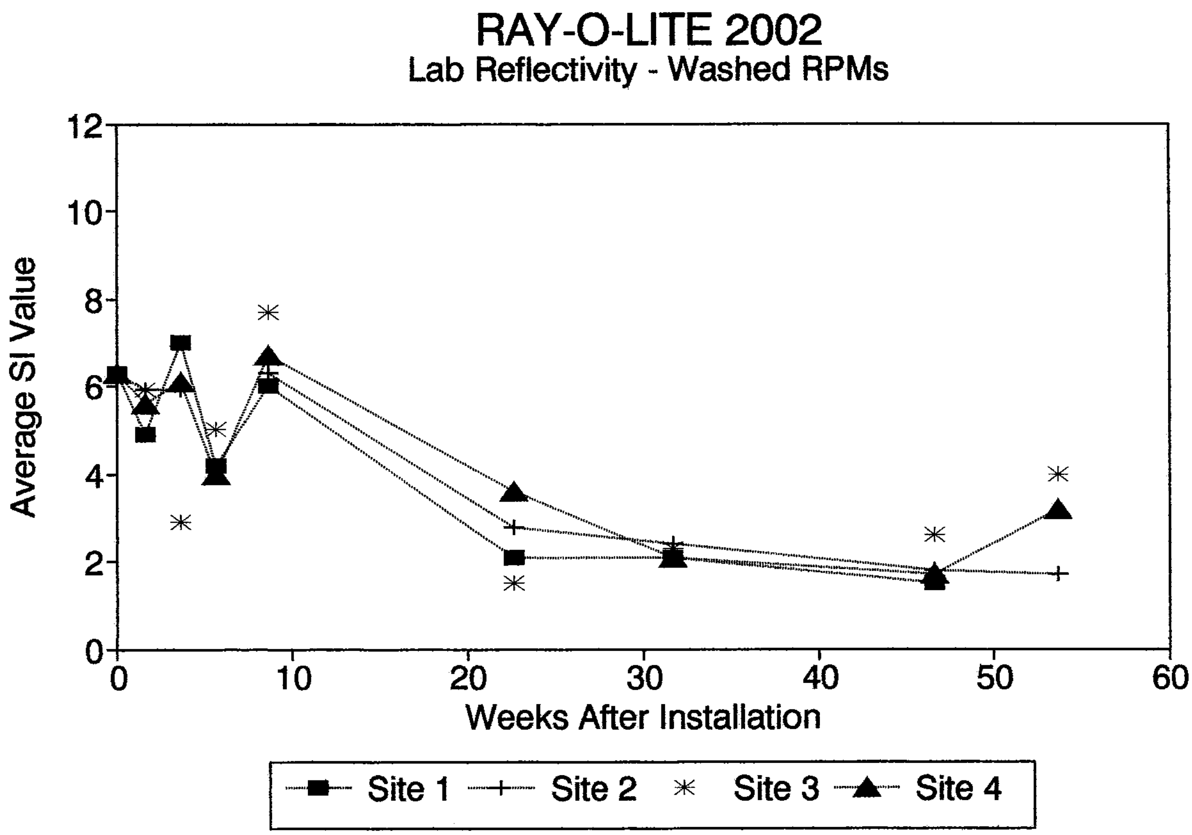
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	9.3 (1.8)	9.3 (1.8)	9.3 (1.8)	9.3 (1.8)
2	4.0 (0.6)	5.0 (1.0)	1.6 (1.1)	6.4 (1.4)
4	3.4 (1.6)	3.6 (0.3)	1.8 (0.6)	6.4 (3.3)
6	2.9 (0.6)	5.9 (0.1)	2.4 (0.2)	6.8 (2.1)
9	3.3 (0.5)	4.6 (0.5)	3.3 (0.5)	5.1 (0.7)
12	3.3 (0.6)	4.0 (0.8)	2.5 (0.9)	3.0 (0.7)
32	0.6 (0.4)	1.6 (1.4)	1.8 (0.5)	2.4 (0.6)
48	0.4 (0.2)	1.1 (0.8)	1.6 (0.5)	1.9 (0.5)
54	0.3 (0.2)	1.0 (0.5)	1.4 (0.2)	1.4 (1.0)



Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	6.3	6.3	6.3	6.3
2	4.1	3.1	2.7	3.6
4	0.7	3.8	0.8	4.2
6	1.8	N.A	1.6	3.1
9	4.4	5.1	3.8	5.9
23	0.2	0.8	0.1	3.0
32	0.7	2.0	2.3	2.0
48	0.5	1.2	1.1	1.8
54	N.A	1.5	0.6	2.0

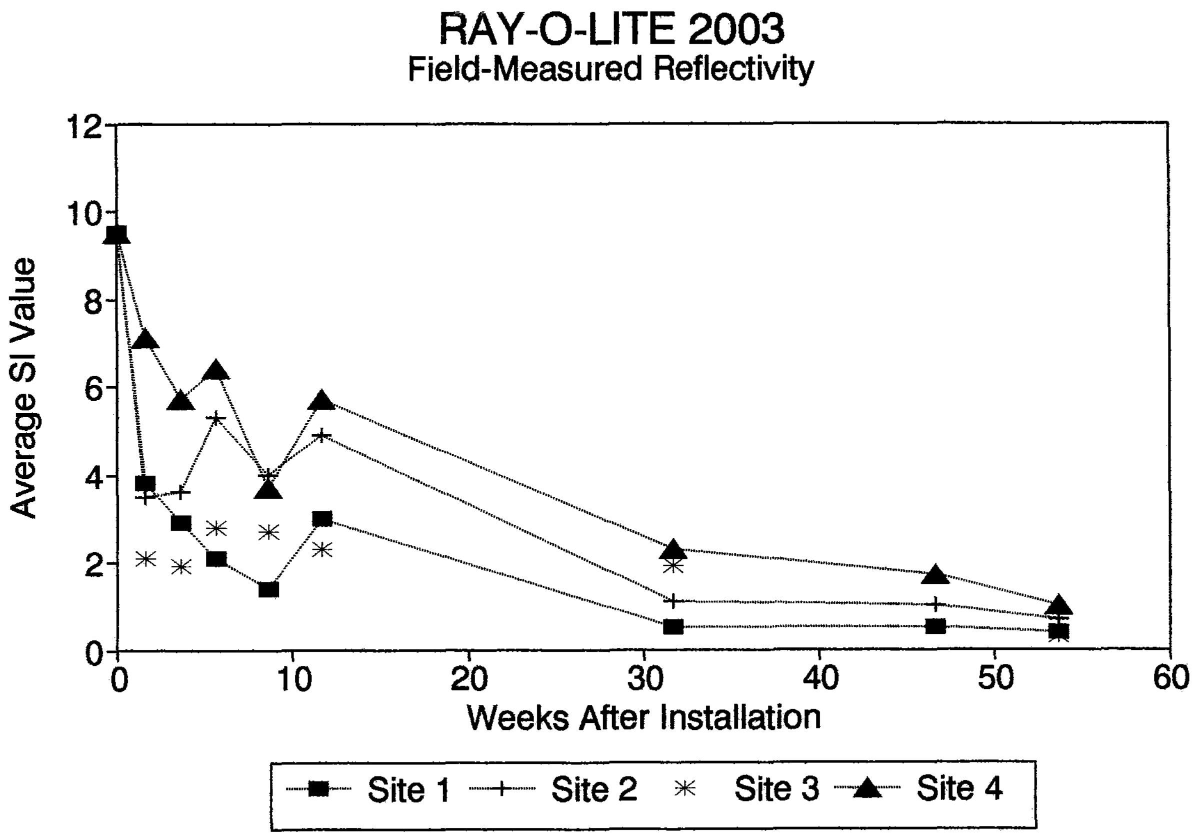
N.A. Data not available



Laboratory SI Values
Washed Markers

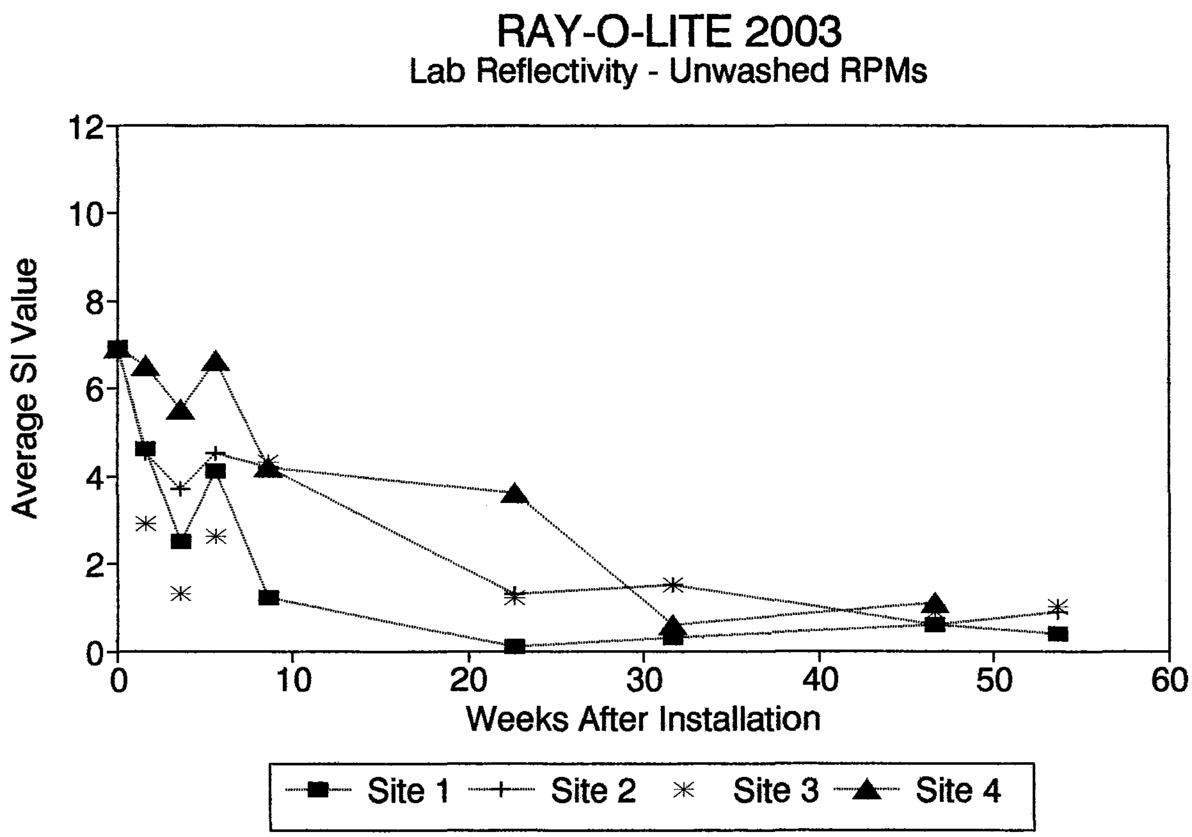
Weeks after Installation	Site 1	Site 2	Site 3	Site 4
0	6.3	6.3	6.3	6.3
2	4.9	5.9	5.9	5.6
4	7.0	5.9	2.9	6.1
6	4.2	N.A	5.0	4.0
9	6.0	6.3	7.7	6.7
23	2.1	2.8	1.5	3.6
32	2.1	2.4	2.3	2.1
48	1.5	1.8	2.6	1.7
54	N.A	1.7	4.0	3.2

N.A. Data not available



Average Reflectometer SI Values
(Standard Deviation of SI Values)

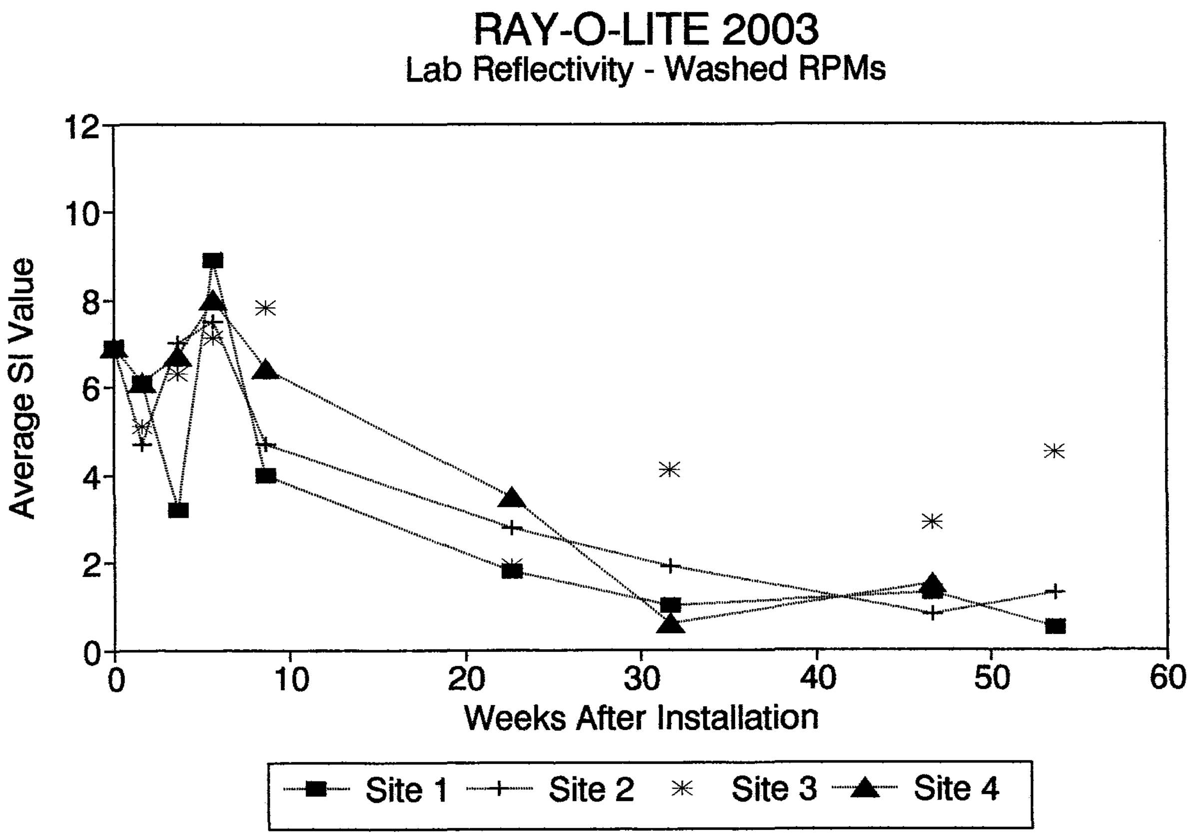
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	9.5 (3.3)	9.5 (3.3)	9.5 (3.3)	9.5 (3.3)
2	3.8 (3.4)	3.5 (1.6)	2.1 (0.9)	7.1 (0.9)
4	2.9 (1.8)	3.6 (0.4)	1.9 (0.4)	5.7 (0.4)
6	2.1 (1.5)	5.3 (1.2)	2.8 (0.2)	6.4 (1.0)
9	1.4 (0.2)	4.0 (0.3)	2.7 (0.7)	3.7 (0.7)
12	3.0 (1.3)	4.9 (0.9)	2.3 (0.6)	5.7 (1.2)
32	0.5 (0.3)	1.1 (0.4)	1.9 (0.5)	2.3 (1.0)
48	0.5 (0.2)	1.0 (0.3)	0.5 (0.4)	1.7 (0.5)
54	0.4 (0.2)	0.7 (0.3)	0.3 (0.2)	1.0 (0.3)



Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	6.9	6.9	6.9	6.9
2	4.6	4.5	2.9	6.5
4	2.5	3.7	1.3	5.5
6	4.1	4.5	2.6	6.6
9	1.2	4.2	4.3	4.2
23	0.1	1.3	1.2	3.6
32	0.3	1.5	1.5	0.6
48	0.6	0.6	0.9	1.1
54	0.4	0.9	.9	N.A

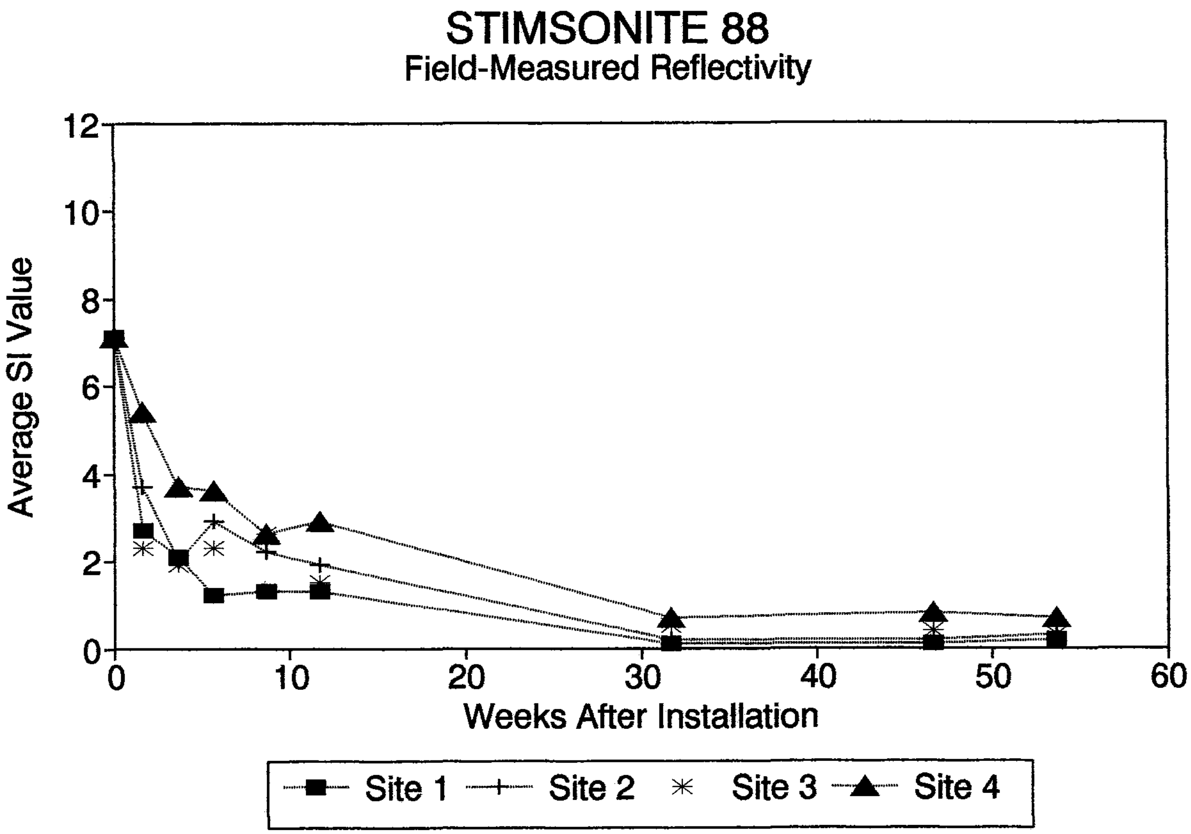
N.A. Data not available



Laboratory SI Values
Washed Markers

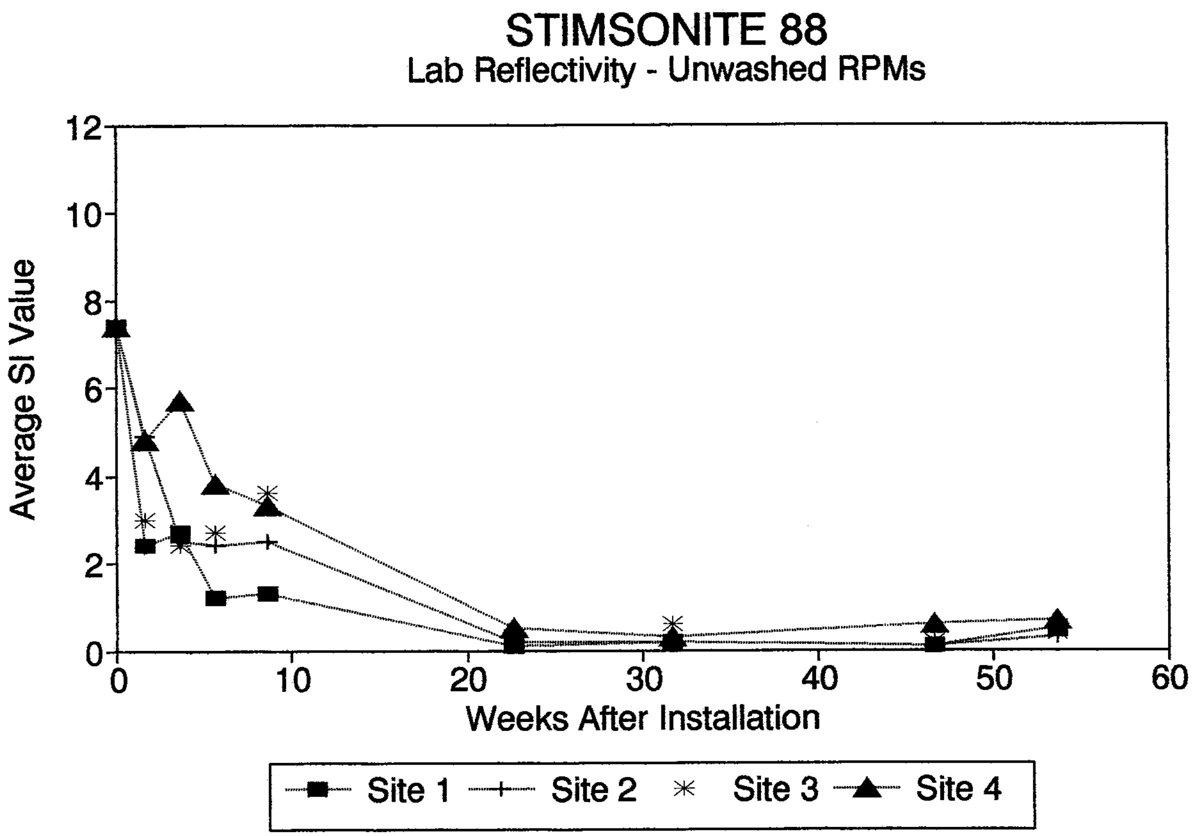
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	6.9	6.9	6.9	6.9
2	6.1	4.7	5.1	6.1
4	3.2	7.0	6.3	6.7
6	8.9	7.5	7.1	8.0
9	4.0	4.7	7.8	6.4
23	1.8	2.8	1.9	3.5
32	1.0	1.9	4.1	0.6
48	1.3	0.8	2.9	1.5
54	0.5	1.3	4.5	N.A

N.A. Data not available



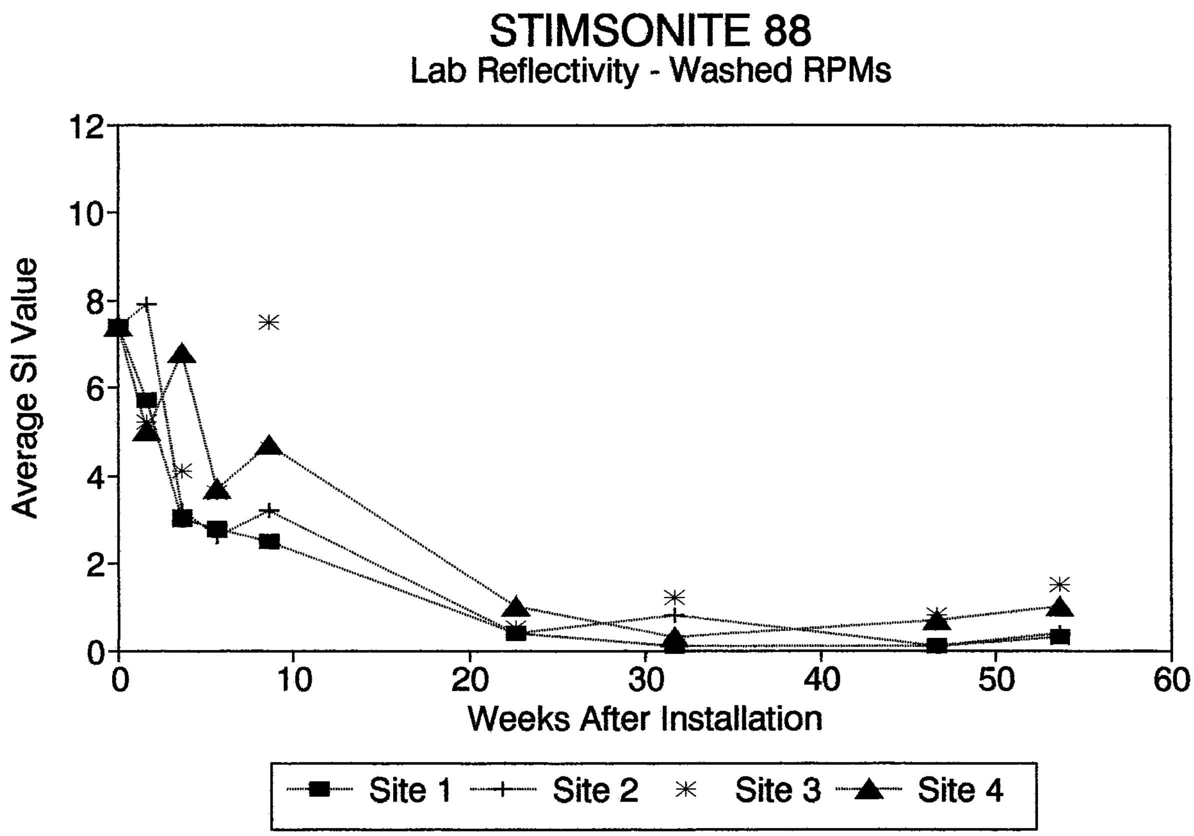
Average Reflectometer SI Values
(Standard Deviation of SI Values)

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	7.1 (2.1)	7.1 (2.1)	7.1 (2.1)	7.1 (2.1)
2	2.7 (0.6)	3.7 (1.0)	2.3 (1.3)	5.4 (2.2)
4	2.1 (0.7)	2.0 (0.6)	1.9 (0.8)	3.7 (1.9)
6	1.2 (0.2)	2.9 (0.2)	2.3 (0.8)	3.6 (0.7)
9	1.3 (0.4)	2.2 (0.3)	2.6 (0.8)	2.6 (0.6)
12	1.3 (0.3)	1.9 (0.4)	1.5 (0.6)	2.9 (0.6)
32	0.1 (0.1)	0.2 (0.1)	0.5 (0.1)	0.7 (0.4)
48	0.1 (0.0)	0.2 (0.0)	0.4 (0.1)	0.8 (0.2)
54	0.2 (0.0)	0.3 (0.1)	0.3 (0.1)	0.7 (0.2)



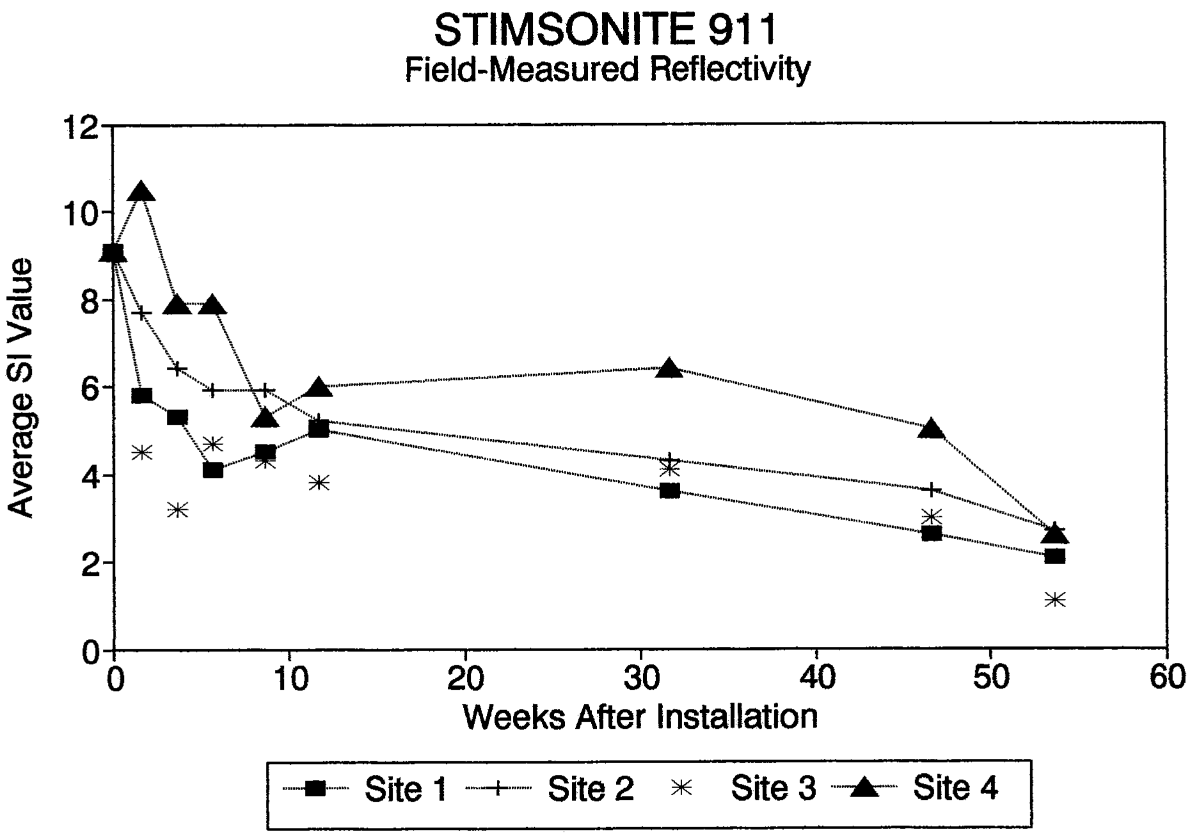
Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	7.4	7.4	7.4	7.4
2	2.4	4.9	3.0	4.8
4	2.7	2.5	2.4	5.7
6	1.2	2.4	2.7	3.8
9	1.3	2.5	3.6	3.3
23	0.1	0.2	0.3	0.5
32	0.2	0.2	0.6	0.3
48	0.1	0.1	0.2	0.6
54	0.5	0.3	0.4	0.7



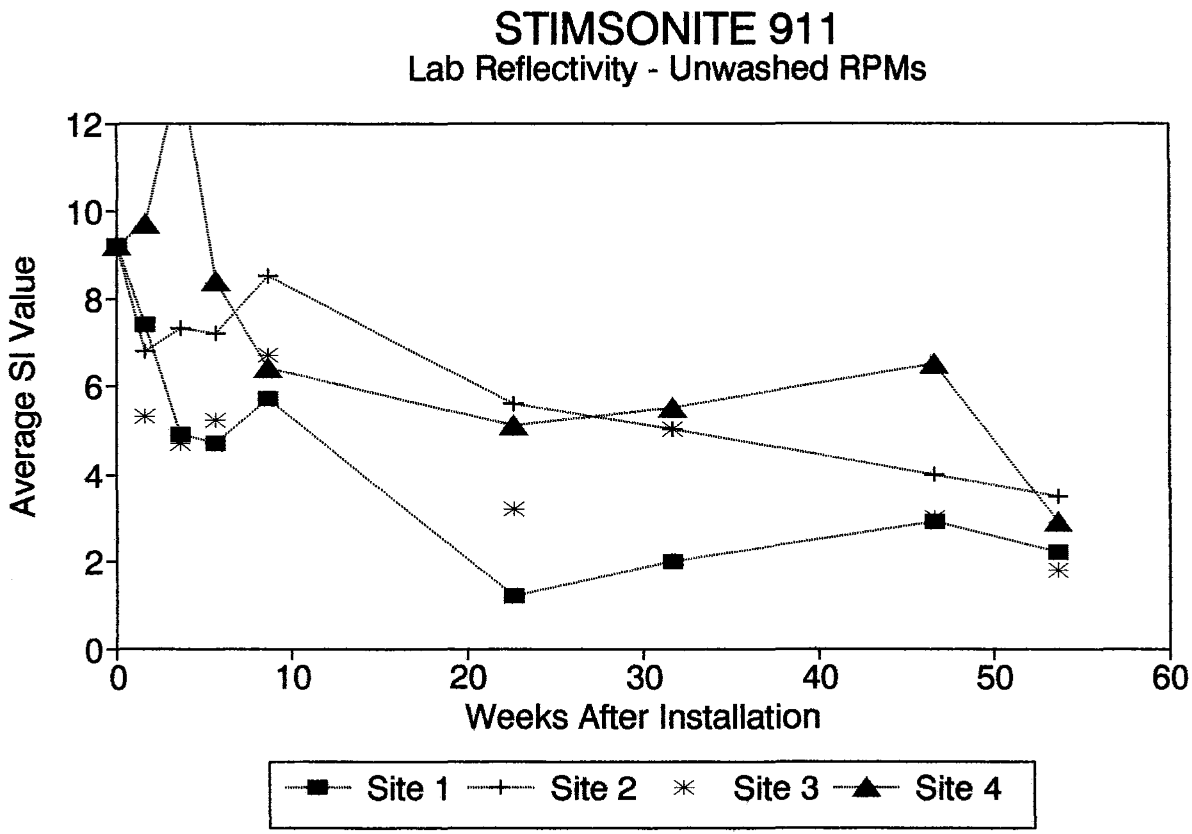
Laboratory SI Values
Washed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	7.4	7.4	7.4	7.4
2	5.7	7.9	5.2	5.0
4	3.0	3.2	4.1	6.8
6	2.8	2.6	3.6	3.7
9	2.5	3.2	7.5	4.7
23	0.4	0.4	0.5	1.0
32	0.1	0.8	1.2	0.3
48	0.1	0.1	0.8	0.7
54	0.3	0.4	1.5	1.0



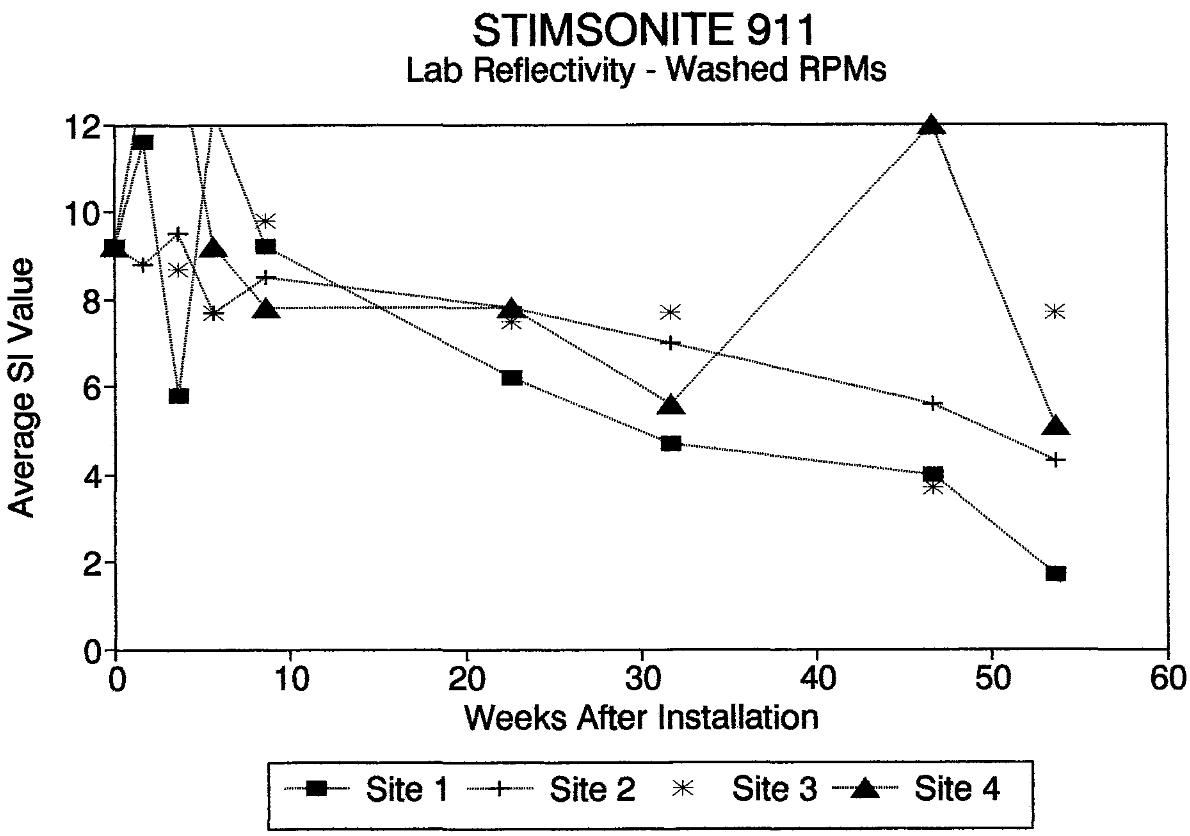
Average Reflectometer SI Values
(Standard Deviation of SI Values)

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	9.1 (2.5)	9.1 (2.5)	9.1 (2.5)	9.1 (2.5)
2	5.8 (0.4)	7.7 (2.0)	4.5 (1.8)	10.5 (1.8)
4	5.3 (1.0)	6.4 (2.3)	3.2 (1.1)	7.9 (2.2)
6	4.1 (1.2)	5.9 (1.2)	4.7 (1.3)	7.9 (1.9)
9	4.5 (0.8)	5.9 (1.3)	4.3 (1.1)	5.3 (1.4)
12	5.0 (1.2)	5.2 (0.9)	3.8 (1.7)	6.0 (1.6)
32	3.6 (1.1)	4.3 (0.8)	4.1 (1.1)	6.4 (1.5)
48	2.6 (0.5)	3.6 (0.7)	3.0 (0.7)	5.0 (1.3)
54	2.1 (0.4)	2.7 (0.6)	1.1 (0.5)	2.6 (0.7)



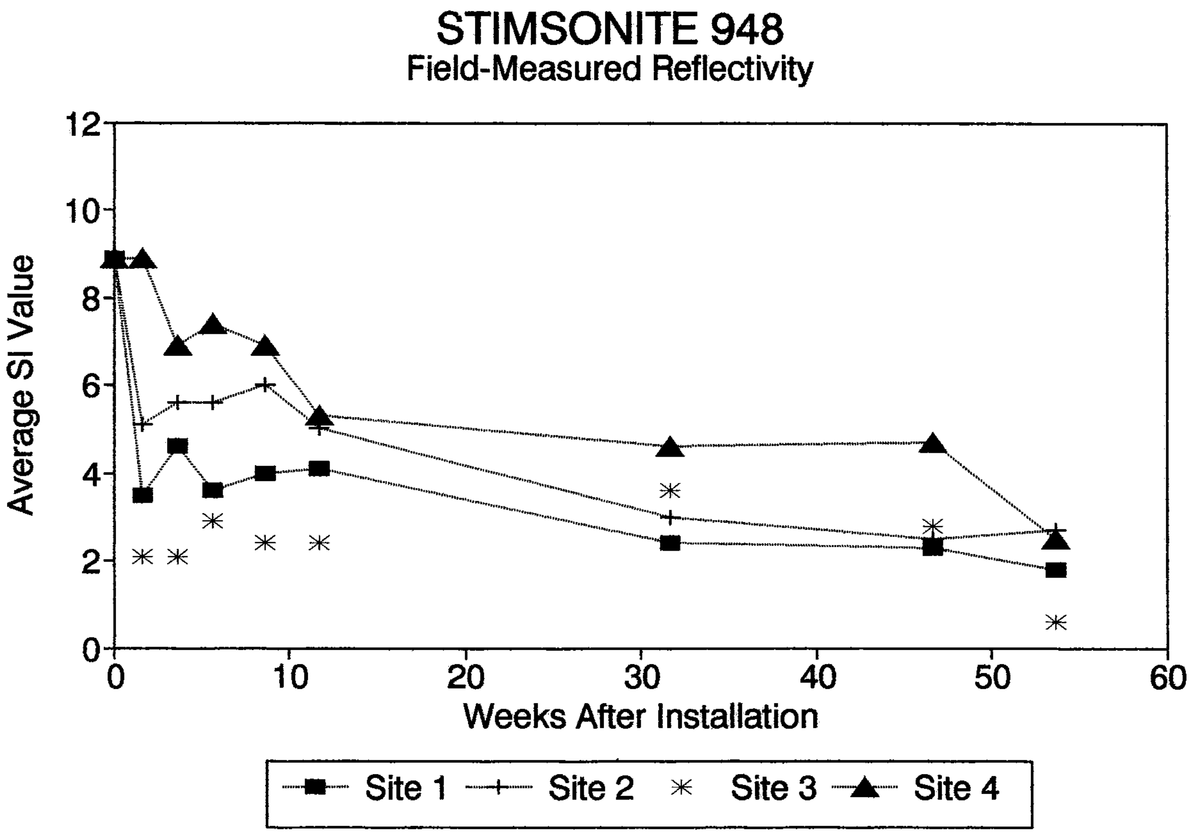
Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	9.2	9.2	9.2	9.2
2	7.4	6.8	5.3	9.7
4	4.9	7.3	4.7	13.4
6	4.7	7.2	5.2	8.4
9	5.7	8.5	6.7	6.4
23	1.2	5.6	3.2	5.1
32	2.0	5.0	5.0	5.5
48	2.9	4.0	3.0	6.5
54	2.2	3.5	1.8	2.9



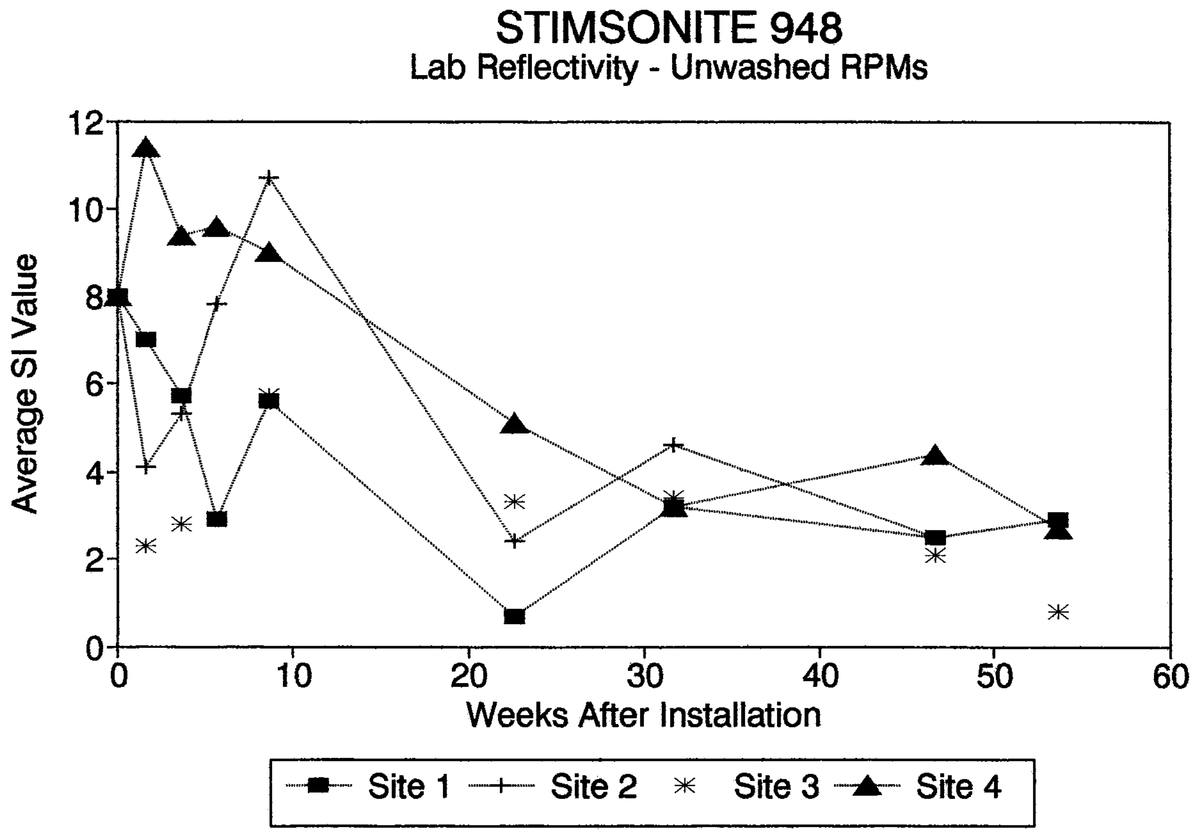
Laboratory SI Values
Washed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	9.2	9.2	9.2	9.2
2	11.6	8.8	12.4	13.3
4	5.8	9.5	8.7	13.9
6	12.3	7.7	7.7	9.2
9	9.2	8.5	9.8	7.8
23	6.2	7.8	7.5	7.8
32	4.7	7.0	7.7	5.6
48	4.0	5.6	3.7	12.0
54	1.7	4.3	7.7	5.1



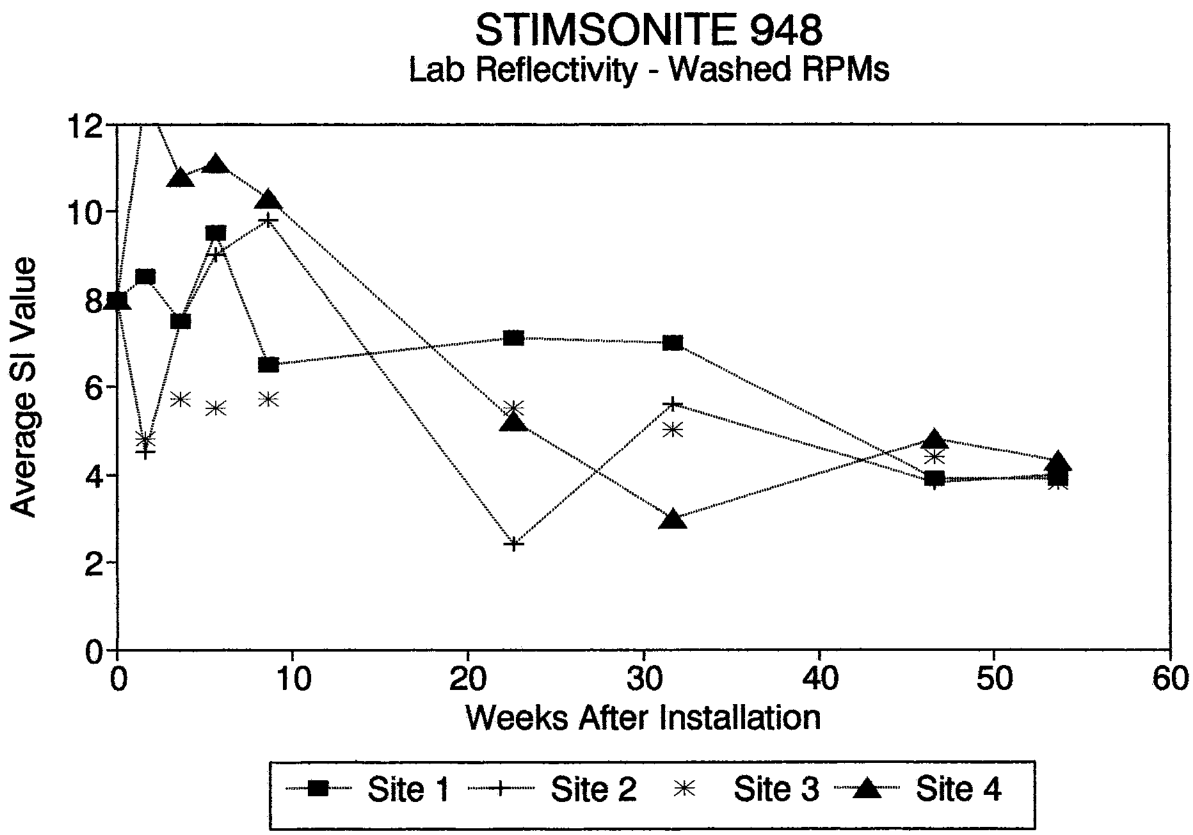
Average Reflectometer SI Values
(Standard Deviation of SI Values)

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	8.9 (2.4)	8.9 (2.4)	8.9 (2.4)	8.9 (2.4)
2	3.5 (1.0)	5.1 (2.7)	2.1 (0.7)	8.9 (2.5)
4	4.6 (1.0)	5.6 (1.8)	2.1 (0.5)	6.9 (1.3)
6	3.6 (1.9)	5.6 (1.4)	2.9 (1.2)	7.4 (2.1)
9	4.0 (1.6)	6.0 (1.7)	2.4 (0.8)	6.9 (0.8)
12	4.1 (1.3)	5.0 (1.3)	2.4 (0.8)	5.3 (1.3)
32	2.4 (0.8)	3.0 (0.8)	3.6 (1.4)	4.6 (1.3)
48	2.3 (0.6)	2.5 (1.1)	2.8 (0.6)	4.7 (1.5)
54	1.8 (0.5)	2.7 (1.0)	0.6 (0.3)	2.5 (1.0)



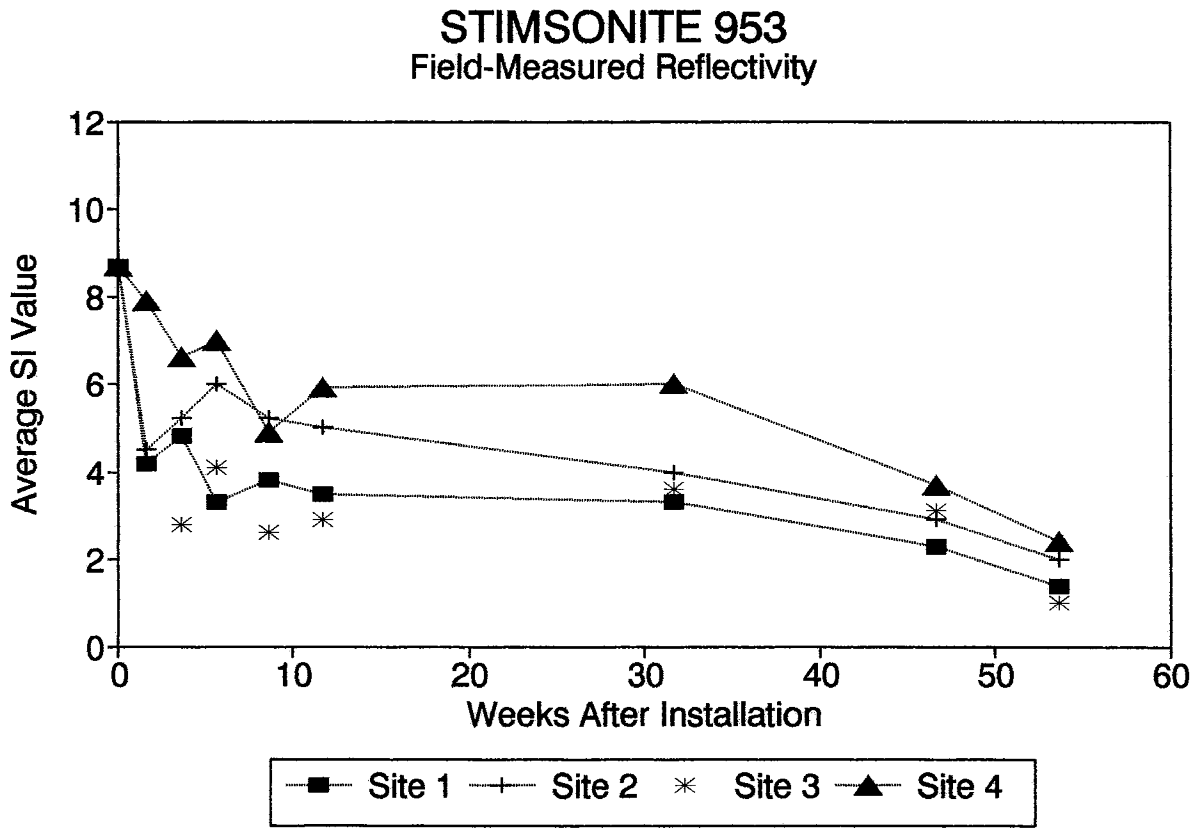
Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	8.0	8.0	8.0	8.0
2	7.0	4.1	2.3	11.4
4	5.7	5.3	2.8	9.4
6	2.9	7.8	2.9	9.6
9	5.6	10.7	5.7	9.0
23	0.7	2.4	3.3	5.1
32	3.2	4.6	3.4	3.2
48	2.5	2.5	2.1	4.4
54	2.9	2.9	0.8	2.9



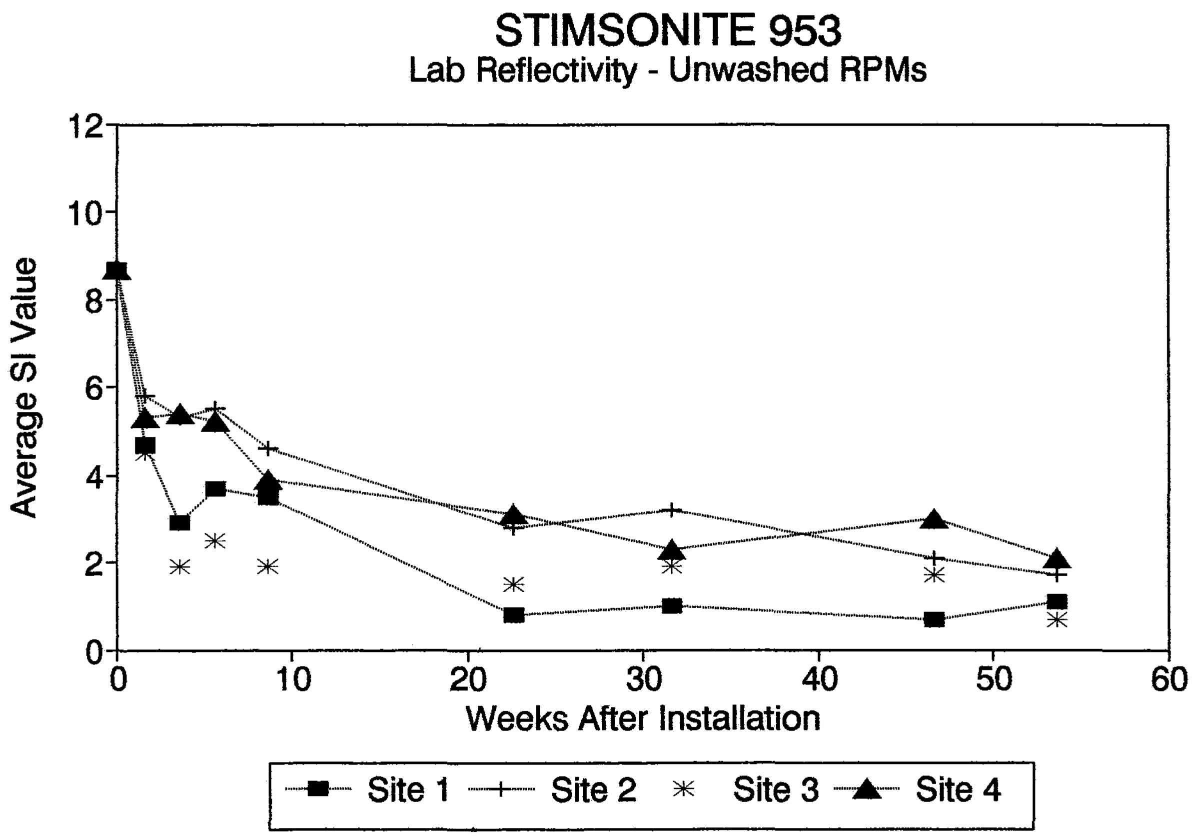
Laboratory SI Values
Washed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	8.0	8.0	8.0	8.0
2	8.5	4.5	4.8	12.7
4	7.5	7.5	5.7	10.8
6	9.5	9.0	5.5	11.1
9	6.5	9.8	5.7	10.3
23	7.1	2.4	5.5	5.2
32	7.0	5.6	5.0	3.0
48	3.9	3.8	4.4	4.8
54	3.9	4.0	3.8	4.3



Average Reflectometer SI Values
(Standard Deviation of SI Values)

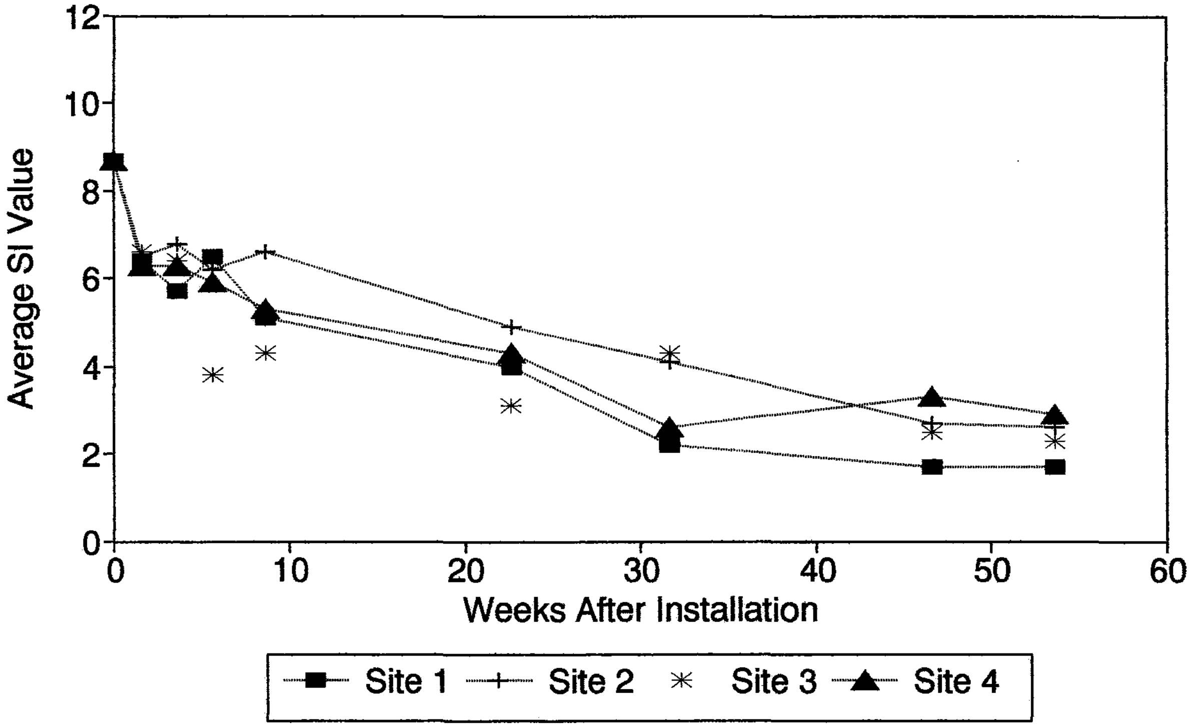
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	7.3 (1.4)	7.3 (1.4)	7.3 (1.4)	7.3 (1.4)
2	4.2 (1.4)	4.5 (2.4)	4.2 (2.1)	7.9 (0.3)
4	4.8 (0.2)	5.2 (1.6)	2.8 (0.7)	6.6 (0.8)
6	3.3 (1.0)	6.0 (0.4)	4.1 (0.9)	7.0 (0.4)
9	3.8 (0.9)	5.2 (0.5)	2.6 (0.3)	4.9 (1.1)
12	3.5 (1.2)	5.0 (0.9)	2.9 (0.4)	5.9 (1.3)
32	3.3 (1.2)	4.0 (1.0)	3.6 (0.7)	6.0 (1.4)
48	2.3 (0.6)	2.9 (0.8)	3.1 (0.6)	3.7 (1.6)
54	1.4 (0.4)	2.0 (0.6)	1.0 (0.3)	2.4 (0.9)



Laboratory SI Values
Unwashed Markers

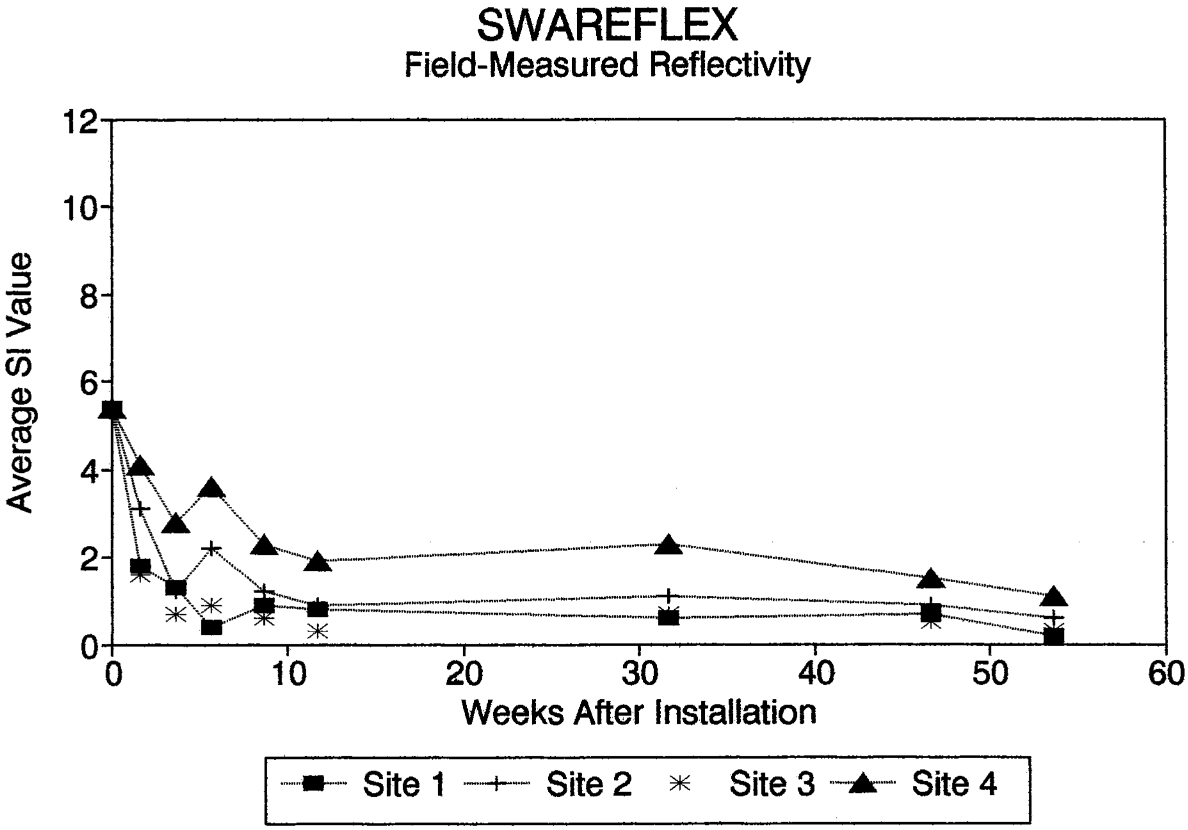
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	8.7	8.7	8.7	8.7
2	4.7	5.8	4.5	5.3
4	2.9	5.3	1.9	5.4
6	3.7	5.5	2.5	5.2
9	3.5	4.6	1.9	3.9
23	0.8	2.8	1.5	3.1
32	1.0	3.2	1.9	2.3
48	0.7	2.1	1.7	3.0
54	1.1	1.7	0.7	2.1

STIMSONITE 953
Lab Reflectivity - Washed RPMs



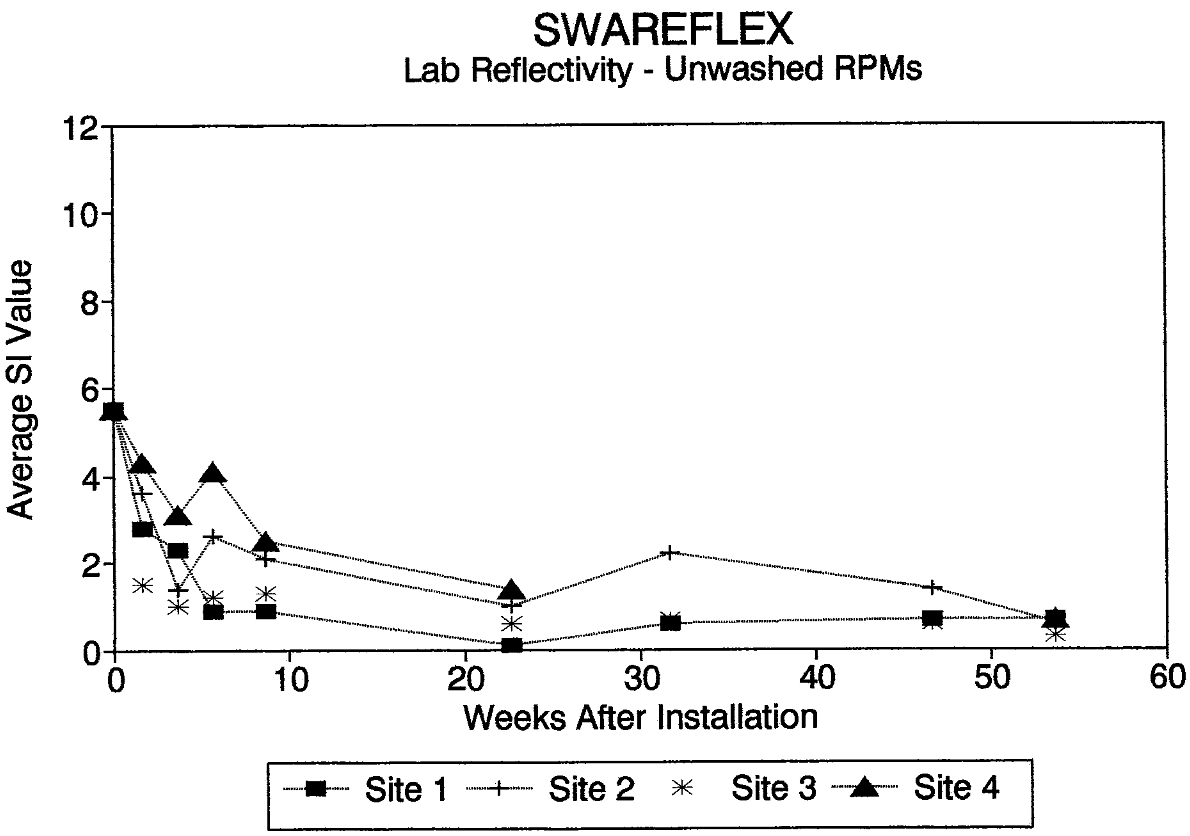
Laboratory SI Values
Washed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	8.0	8.0	8.0	8.0
2	8.5	4.5	4.8	12.7
4	7.5	7.5	5.7	10.8
6	9.5	9.0	5.5	11.1
9	6.5	9.8	5.7	10.3
23	7.1	2.4	5.5	5.2
32	7.0	5.6	5.0	3.0
48	3.9	3.8	4.4	4.8
54	3.9	4.0	3.8	4.3



Average Reflectometer SI Values
(Standard Deviation of SI Values)

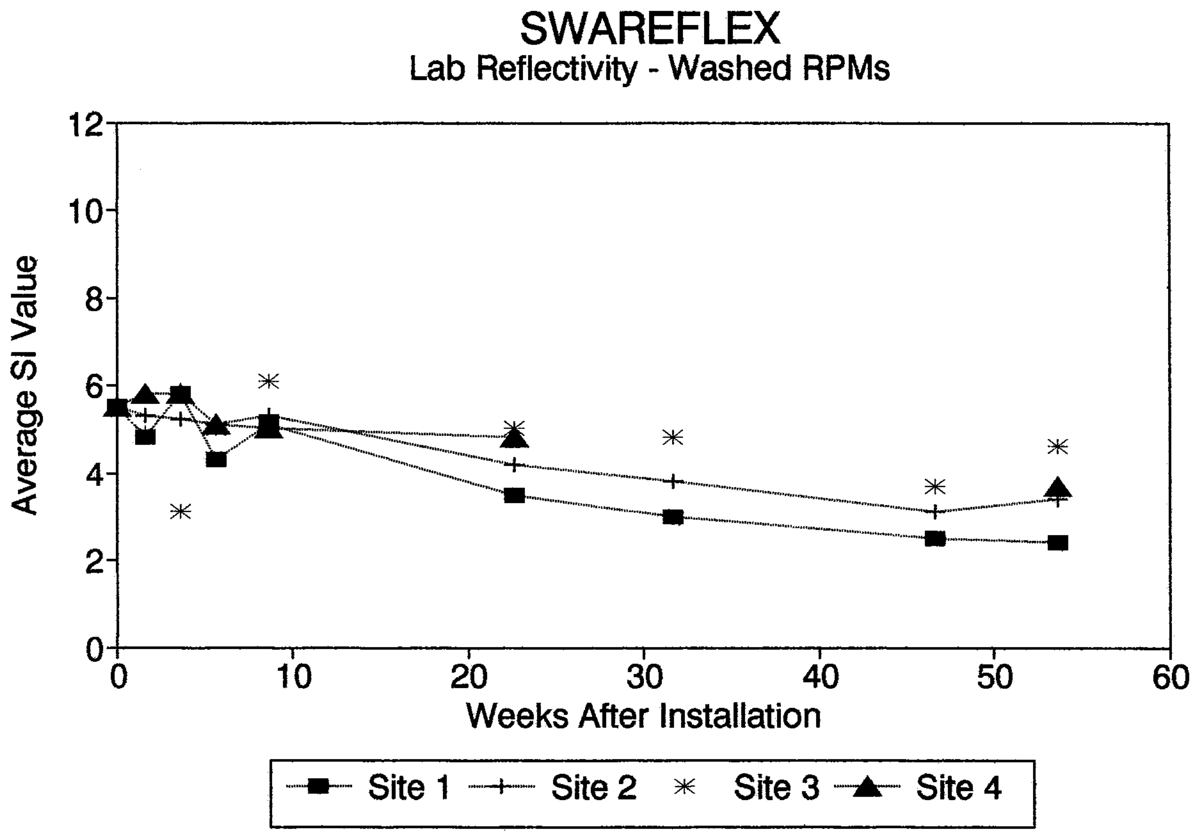
Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	5.4 (1.0)	5.4 (1.0)	5.4 (1.0)	5.4 (1.0)
2	1.8 (0.7)	3.1 (0.8)	1.6 (0.7)	4.1 (1.8)
4	1.3 (0.2)	1.2 (0.3)	0.7 (0.2)	2.8 (0.6)
6	0.4 (0.1)	2.2 (0.1)	0.9 (0.3)	3.6 (0.5)
9	0.9 (0.1)	1.2 (0.6)	0.6 (0.2)	2.3 (0.6)
12	0.8 (0.3)	0.9 (0.2)	0.3 (0.2)	1.9 (0.4)
32	0.6 (0.1)	1.1 (0.4)	0.7 (0.2)	2.3 (0.6)
48	0.7 (0.1)	0.9 (0.3)	0.5 (0.1)	1.5 (0.6)
54	0.2 (0.1)	0.6 (0.2)	0.3 (0.1)	1.1 (0.6)



Laboratory SI Values
Unwashed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	5.5	5.5	5.5	5.5
2	2.8	3.6	1.5	4.3
4	2.3	1.4	1.0	3.1
6	0.9	2.6	1.2	4.1
9	0.9	2.1	1.3	2.5
23	0.1	1.0	0.6	1.4
32	0.6	2.2	0.7	N.A
48	0.7	1.4	0.6	N.A
54	0.7	0.6	0.3	0.7

N.A. Data not available



Laboratory SI Values
Washed Markers

Weeks After Installation	Site 1	Site 2	Site 3	Site 4
0	5.5	5.5	5.5	5.5
2	4.8	5.3	4.9	5.8
4	5.8	5.2	3.1	5.8
6	4.3	5.1	5.0	5.1
9	5.1	5.3	6.1	5.0
23	3.5	4.2	5.0	4.8
32	3.0	3.8	4.8	N.A.
48	2.5	3.1	3.7	N.A.
54	2.4	3.4	4.6	3.7

N.A. Data not available

APPENDIX C - EFFECT OF DIRT ACCUMULATION UPON RRPM REFLECTIVITY LOSS

Apex 921

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	22	-14	77	45	33
4	22	15	39	60	34
6	26	8	17	29	20
9	17	28	41	48	34
23	0	3	15	3	5
32	6	3	6	0	4
48	6	0	-3	-3	0
54	3	0	16	3	5

Apex 918

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	23	21	72	23	35
4	17	23	21	26	22
6	14	0	22	-4	8
9	9	5	27	10	13
23	-	2	5	5	4
32	0	0	5	0	1
48	0	0	4	-3	0
54	3	5	10	5	6

Apex 928

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	43	0	23	41	27
4	11	21	100	18	37
6	23	5	82	7	29
9	33	44	4	100	45
23	4	0	4	0	2
32	0	0	17	0	4
48	4	4	0	4	3
54	0	0	12	5	4

Apex 807

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	18	36	15	14	21
4	5	0	29	0	8
6	0	-6	-25	0	-8
9	0	0	13	13	6
23	0	0	0	0	0
32	0	0	-5	0	-1
48	0	4	0	4	2
54	0	-5	0	0	-1

Apex 817

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	-	100	67	14	83
4	-	29	67	0	48
6	50	-	0	0	17
9	33	-	-	13	42
23	0	0	-13	0	-3
32	-13	0	-67	0	-20
48	10	0	40	4	13
54	17	13	0	0	10

Batterson

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	81	60	97	53	73
4	46	36	69	86	59
6	31	51	72	75	57
9	16	45	92	63	54
23	26	22	63	17	32
32	17	22	51	14	26
48	12	6	33	12	16
54	0	6	6	20	8

Empco

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	17	0	100	0	29
4	21	23	-	-13	11
6	27	43	29	13	28
9	38	18	63	43	40
23	6	18	7	0	8
32	0	6	6	0	3
48	6	0	6	-6	1
54	-	6	12	7	8

Ray-O-Lite 8704 (S)

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	63	100	-	-	81
4	20	23	-	-	22
6	6	27	-	-	17
9	26	100	-	-	76
23	6	8	-	-	7
32	6	6	-	-	6
48	2	0	0	-	1
54	0	2	15	-	6

Ray-O-Lite 8704 (R)

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	55	-	40	39	45
4	7	-	51	39	32
6	28	-	48	25	34
9	27	-	50	38	38
23	2	-	6	2	3
32	6	-	6	0	4
48	0	-	-	0	0
54	2	-	18	8	9

Ray-O-Lite 9704

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	83	38	35	44	50
4	14	18	81	10	31
6	20	15	38	73	36
9	24	22	100	65	53
23	10	16	22	13	15
32	8	5	7	3	6
48	2	3	17	2	6
54	0	2	20	12	8

Ray-O-Lite 2002

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	36	88	89	74	72
4	100	84	58	91	83
6	53	-	72	28	51
9	84	100	100	100	96
23	31	36	23	18	27
32	25	9	0	2	9
48	19	12	29	-2	14
54	-	13	60	28	34

Ray-O-Lite 2003

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	65	8	53	-	42
4	16	100	89	86	73
6	100	100	100	100	100
9	49	19	100	89	64
23	25	27	12	-7	14
32	11	7	48	0	17
48	11	3	33	7	14
54	2	7	59	0	23

Stimsonite 88

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	68	100	50	8	56
4	6	14	34	65	30
6	26	4	17	-3	11
9	20	14	100	34	42
23	4	3	3	7	4
32	3	8	9	0	5
48	0	0	8	2	2
54	-3	1	16	5	5

Stimsonite 911

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	100	83	100	100	96
4	21	100	89	-	70
6	100	26	60	100	71
9	100	0	100	50	63
23	63	61	72	66	65
32	38	48	61	3	37
48	18	31	11	100	40
54	-7	14	80	33	30

Stimsonite 948

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	100	10	44	-	51
4	78	92	56	-	75
6	100	100	51	-	84
9	38	-	60	-	49
23	88	-4	47	4	34
32	79	29	35	-4	35
48	26	24	39	11	25
54	20	22	42	30	28

Stimsonite 953

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	43	24	50	29	37
4	48	44	66	27	46
6	56	22	21	20	30
9	31	49	35	29	36
23	41	36	22	21	30
32	16	16	35	5	18
48	13	9	11	5	10
54	8	13	21	12	14

Swareflex

Weeks After Installation	Percent of Reflectivity Loss Due to Dirt Accumulation				
	Site 1	Site 2	Site 3	Site 4	Average
2	74	90	85	100	87
4	100	93	47	100	85
6	74	86	88	71	80
9	91	94	100	83	92
23	63	71	90	83	77
32	49	49	85	-	61
48	38	42	63	-	47
54	35	57	83	63	59