5-2010

Long-Term Performance of Pavement Markings on Primary and Secondary Roads

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Recommended Citation

Johnson, Joshua, "Long-Term Performance of Pavement Markings on Primary and Secondary Roads" (2010). *All Theses*. 808.
https://tigerprints.clemson.edu/all_theses/808

LONG-TERM PERFORMANCE OF PAVEMENT MARKINGS ON PRIMARY AND SECONDARY ROADS

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Civil Engineering

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by
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May 2010

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ABSTRACT

This research analyzes waterbased and thermoplastic pavement markings on primary and secondary roads in South Carolina. The primary objective of this research was to develop retroreflectivity degradation models for these two pavement marking materials, as well as determine the expected useful life of the markings. Predicting retroreflectivity and marking life is important so that state DOTs may efficiently replace markings in order to reduce safety hazards as well as maintenance costs.

Data collection for this research lasted 21 months, where retroreflectivity of pavement markings was measured on over 100 primary and secondary roads in South Carolina. Variables such as marking type, date of application, traffic volume, among others were collected during this data collection period. Stepwise regression was performed to determine which variables were significant. Simple and multiple linear regression was completed to develop degradation models. These models were enhanced with the addition of buffer zones, which reduces the frequency of model over-prediction. Final degradation models were then created for waterbased and thermoplastic markings, along with estimated marking lives based on an assumed minimum retroreflectivity. The result of this research is a set of fully-functional models that state DOTs and other governing agencies may use in their pavement marking management systems.

DEDICATION

I dedicate this thesis to my parents, Bobby and Shama, for pushing me to excel even when I did not want to be pushed, to my quintessential and loving wife, Jenna, for her inexorable support and steadfastness, and to my Heavenly Father for His omniscient provisions along my journey to this occasion.

ACKNOWLEDGEMENTS

I would hereby like to acknowledge my advisor, Dr. Wayne Sarasua, who provided guidance on college’s tough questions, as well as valuable support on this research. I also thank Dr. W. Jeff Davis for his contributions to this research, as well as Dr. Jennifer Ogle for her assistance on this thesis. These three individuals truly made my graduate research a success.

I would also like to thank the entire Civil Engineering department of Clemson University for their help through both undergraduate and graduate degrees, and in particular, my professors for imparting priceless knowledge and life lessons to me.

Finally, I express my gratitude to the South Carolina Department of Transportation for identifying the need for this research and providing the necessary funding for this study.

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CHAPTER 1: INTRODUCTION

Pavement Markings

Pavement markings are a key component in ensuring driver safety in roadway transportation systems. Markings delineate the travel lanes as well as the edge of pavement, allowing the driver to clearly distinguish where he/she should drive. Marking characteristics, such as color and layout, also aid drivers in determining the safe travel direction and separation of traffic flow directions. Most pavement markings are retroreflective, which enhances the visibility of pavement markings at night.

Importance of Research

The purpose of this research is to create models for determining the degradation of pavement markings, specifically waterbased and thermoplastic markings. Upon the creation of these models, it will be possible to determine the frequency with which pavement markings of these materials should be replaced. Currently, many states replace pavement markings on a scheduled basis regardless of condition. This is not a very cost effective approach, and thus has led to this research to develop a more efficient replacement plan. The South Carolina Department of Transportation (SCDOT) has funded the research, which focuses on primary and secondary roads in South Carolina. Though similar research has been completed, these studies did not contain all of the same characteristics. Research of similar content can be found in *Chapter 2: Literature Review.*

The main purpose of retroreflective pavement markings is to increase roadway safety during nighttime conditions. Because of this, it is important that DOTs maintain pavement markings which remain within acceptable levels of retroreflectivity. The Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways (2003) does not currently stipulate minimum retroreflectivity values for pavement markings. The Federal Highway Administration (FHWA) has also not set minimum standards, though such standards are in the process of being created. In light of this, it will be extremely beneficial for the SCDOT to have policies in place which predict the degradation of pavement markings and allow for cost-effective management of these markings to comply with minimum retroreflectivity values.

Introduction of Research Project

In February 2008, the SCDOT funded the research project for the civil engineering department of Clemson University to complete. This project was set to last 30 months, and was separated into three phases. These phases consisted of a literature review (3 months), data collection (21 months), and analysis and composition of the final report (6 months). The objectives of the project, which are also the objectives of this thesis, are listed as follows:

- Develop a systematic and standardized methodology to quantitatively evaluate pavement marking materials used on South Carolina's primary and secondary roads to track the performance and lifecycle of pavement markings from when they are first installed to the time of their replacement

- Develop a method for determining the maximum service life for different types of markings
- Determine what type of material is best to use to provide a pavement marking program that is consistent throughout the state and based on best practices

To successfully meet the project objectives, the research team assigned to this project developed a secondary list of objectives, which are as follows:

- Conduct a literature review to determine similar research project methods and identify possible techniques, as well as determine variables that may influence degradation of retroreflectivity in pavement markings
- Develop procedures for collecting retroreflectivity data
- Establish sites on primary and secondary roads with newly placed waterbased and thermoplastic markings
- Collect data at each site every 3 months for a total of 6 data collection rounds
- Use regression to determine significant variables in pavement marking degradation and develop a prediction model with those variables

The following chapters contain excerpts from the completed literature review and discussions of research methodology, data collection, analysis, results, conclusions, and recommendations.

CHAPTER 2: LITERATURE REVIEW

Overview

A literature review was completed in order to gain knowledge on the subject of retroreflective pavement markings. The review was based off the literature of the earlier project, *Evaluation of Interstate Pavement Marking Retroreflectivity* (1), with additional research completed in order to include new developments. The additional research was completed mostly using Transportation Research Board (TRB) journals and Transportation Research Information Services (TRIS). Because the literature review was performed as a team, much of it can also be found in another thesis related to this research, *One Year Performance of Waterborne Pavement Markings Used on Primary and Secondary Roads of South Carolina* (2).

Definition of Retroreflectivity

According to McGee and Mace (3), retroreflection is an event that occurs when “light rays strike a surface and are redirected directly back to the source of light.” The MUTCD (4) defines retroreflectivity as “a property of a surface that allows a large portion of light coming from a point source to be returned directly back to a point near its origin.” Smadi et al. (5) define retroreflectivity as “an engineering measure of the efficiency of the marking optics to reflect headlamp illumination incident on the pavement marking back to the driver.”

A typical pavement marking material consists of binders, pigments, fillers, and glass beads. Binders are responsible for the thickness of marking material and adhere to the road surface, pigments distribute color throughout the mix, and fillers impart durability to the mix. The retroreflective effect of pavement markings is made possible with the help of small glass beads which are added by dropping them on the marking during the application of material in liquid form.

The retroreflection process in a glass bead occurs in three steps. As the light ray enters a bead, it gets refracted or bent. Once inside, it gets reflected in the material in which the bead is embedded, and then gets refracted a second time while leaving the bead surface (6). Figure 2.1 illustrates this event.

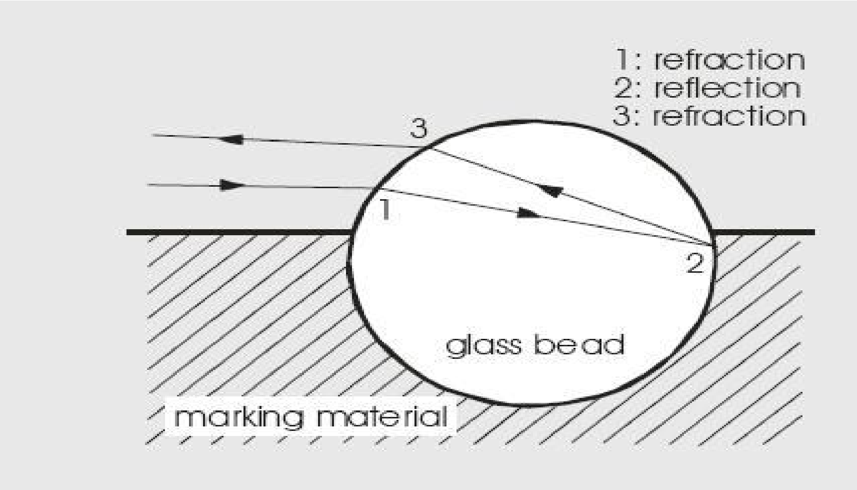


Figure 2.1: Three Step Process of Retroreflection in a Glass Bead (6)

The retroreflectivity of a pavement marking depends on several factors, such as bead size, bead type, quantity of beads, angle of bead embedment, and application method, among others. Retroreflectivity degrades over time as beads become dislodged from the marking or are worn down. This degradation can be due to weather, traffic, snowplowing, and other adverse conditions for the roadway.

Retroreflectivity Measurement

The most common measure of pavement marking retroreflectivity is the coefficient of retroreflected luminance (R_L). ASTM defines R_L as the ratio of luminance in the direction of observation to normal illuminance, at the surface on a plane normal to incident light, expressed in millicandelas per square meter per lux (mcd/m^2/lux) in the standard *E 808-01 (re-approved 2009) - Standard Practice for Describing Retroreflection* (7).

The current accepted standard for measurement of retroreflectivity of pavement marking materials using a portable retroreflectometer is *ASTM E 1710-05* (8). It is adapted from standards originally set by the European Committee for Normalization (CEN). The standard clearly defines the requirements of a portable retroreflectometer to simulate nighttime visibility for an average driver in a passenger car. The measurement geometry of the instrument should be based on a viewing distance of 30 meters (98.43 ft), a headlight mounting height of 0.65 meters (2.13 ft) directly above the stripe, and an eye height of 1.2 meters (3.94 ft) directly over the stripe. These measurements create a co-entrance angle between the headlamp beam and pavement surface of 1.24 degrees and an observation angle of 1.05 degrees. The key parameters of the standard are shown in Figure 2.2.

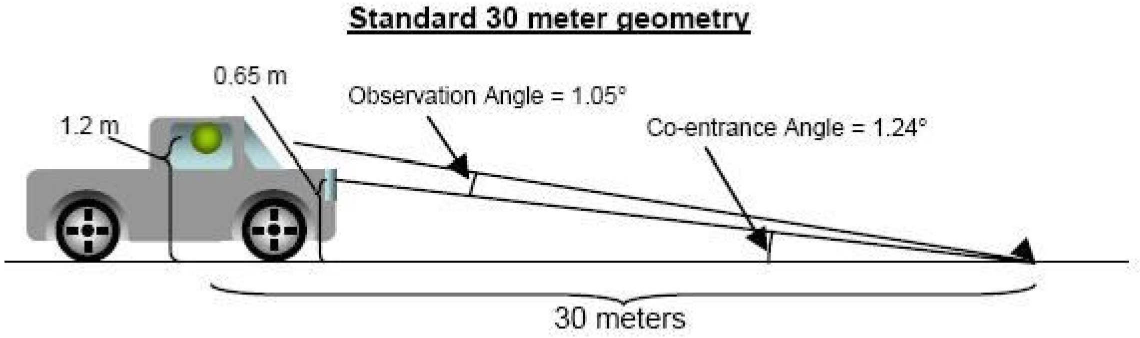


Figure 2.2: Standard 30-Meter Geometry Replicated by Retroreflectometers (9)

ASTM E 1710-05 also requires that the surface of marking be clean and dry, the reading direction of retroreflectometer be placed in the direction of traffic and the retroreflectometer be calibrated every hour.

Another ASTM Standard of relevance to the study is *ASTM E 2177-01,* which is the *Standard Test Method for Measuring Coefficient of Retroreflected Luminance of Pavement Markings in a Standard Condition of Wetness* (10). This test method is also referred to as the “recovery method” or “bucket method.” The procedure is for the intent of measuring retroreflectivity of pavement marking materials after rain has stopped and the marking is still wet. The test condition is created by liberally wetting the road marking and waiting a certain time period after wetting for water to runoff. Wetness can be achieved either with the help of a hand sprayer or a bucket of water. If a hand sprayer is used, the marking should be sprayed with water for 30 seconds. Otherwise, two to five liters of water in a bucket is poured slowly over the marking. The marking retroreflectivity is then measured after 45 ± 5 seconds after pouring is completed. Two to three readings are obtained by simply triggering the instrument a second or third time without any movement.

Minimum Acceptable Retroreflectivity Values

According to section 406(a) of the 1993 Department of Transportation Appropriations Act, the secretary of transportation is required to revise the MUTCD to include a standard for a minimum level of retroreflectivity to be maintained for pavement markings and signs which shall apply to all roads open to public travel (11). Accordingly, the FHWA did develop candidate MUTCD criteria, but it has not been approved and implemented as a policy yet (12).

Paniati and Schwab (1991) (13) discussed the development of a model to address the required reflectivity of traffic control devices to meet driver visibility requirements. Their paper recognized that determination of minimum retroreflectivity is a complex process involving the interaction of driver characteristics, vehicle headlight characteristics, roadway geometry, size and location of markings, and glare from oncoming vehicles.

A study in 1996 focusing specifically on retroreflectivity requirements for older drivers by Graham et al. (14) used retroreflectivity measurements of existing roadway markers and subjective evaluations of their adequacy to determine a threshold. The authors reported that 85 percent of subjects aged 60 years and older rated a marking retroreflectivity of 100 mcd/m^2/lux adequate or more than adequate for nighttime conditions.

In the fall of 1999, the FHWA sponsored three workshops to discuss their efforts to establish minimum levels of retroreflectivity for pavement markings (12). Representatives from 67 state, county, and city agencies gave their inputs at the workshop. Based on FHWA guidelines, state and local agencies made recommendations for pavement marking retroreflectivity for roads without Retroreflective Raised Pavement Markers (RRPMs) or roadway lighting. For white markings, they recommended a retroreflectivity of 100 mcd/m^2/lux on freeways and 80 mcd/m^2/lux on collector and arterial roads. For yellow centerlines they recommended 80 mcd/m^2/lux on freeways and 65 mcd/m^2/lux on collectors and arterials. Unfortunately, the participants of the workshop could not reach an agreement to have these minimum values adopted as standards without further research.

The Minnesota Department of Transportation (MnDOT) (15) undertook a research project in 2000 to determine a threshold for acceptable retroreflectivity values for the state. Members of general public were asked to drive state and county roads after dark and grade the visibility of edge lines and centerlines. The project results pointed to a threshold level between 80 and 120 mcd/m^2/lux. As a result of the project, MnDOT uses 120 mcd/m^2/lux as a minimum retroreflectivity threshold for its pavement marking management program.

Parker and Meja (16) performed a study in New Jersey in 2003 using a Laserlux retroreflectometer and a survey of the New Jersey driving public to determine visibility of markings on a 32-mile circuit. They concluded that the minimum acceptable level of retroreflectivity appeared to be between 80 and 130 mcd/m²/lux for drivers under 55 and between 120 and 165 mcd/m²/lux for drivers older than 55.

During the summer of 2007, the FHWA held two conferences with the primary goal of finalizing the wording and content of new minimum pavement marking and traffic sign retroreflectivity levels. The new traffic sign minimum levels were put into effect as of January 2008 (17), while pavement marking minimums are still pending.

An additional report by Debaillon, et al. in October 2007 (18) did recommend minimum values for retroreflectivity to the FHWA. This research took into account pavement type, vehicle type, RRPM presence, marking configuration, and speed. The recommendations made in this report are shown in Table 2.1.

Table 2.1: Recommended Minimum Retroreflectivity Values (18)

Roadway Marking Configuration	**Without RRPMs**			**With RRPMs**
	≤ 50 mph	55 – 65 mph	≥ 70 mph	-
Fully-Marked Roadway (centerline, lane lines and/or edge line)	40	60	90	40
Roadways with Centerlines Only	90	250	575	50

Retroreflectivity Degradation Predictive Models

In 1997, Perrin, Martin, and Hansen (19) evaluated marking materials on Utah highways using a Laserlux mobile unit. Three marking materials were compared: paint, epoxy, and tape. Pavements included both Portland Cement Concrete (PCC) and Asphalt

Concrete (AC) types. Researchers employed the resulting data to investigate relationships between material age, Average Annual Daily Traffic (AADT), and pavement type on marking retroreflectivity or useful lifetime. They found that each of these variables was significant, and that the general relationship between the independent and dependent variables was hyperbolic.

Also in 1997, Andrady et al. (20) developed the following equation which relates retroreflectivity of pavement marking materials to time.

$$T_{100} = 10^{(R_0 - 100)/b}$$

where

T_{100} = Duration in months for retroreflectivity to reach a value of 100 mcd/m^2/lux

R_0 = Estimate of initial retroreflectivity value

b = Gradient of semi-logarithmic plot of retroreflectivity

Using the equation, Andrady was able to predict the lifetime of epoxy markings as 18.8 months and the lifetime of thermoplastic markings in the range of 7.8 to 40.6 months.

In 1999, Migletz et al. (21) reported on the results of a study of pavement marking retroreflectivity performed on behalf of FHWA. This study was performed during the fall of 1994 and spring of 1995, where retroreflectivity of selected sections of pavement markings in 32 states were measured. Although based upon a limited amount of data, statistical procedures for evaluating replacement needs of markings were developed. These were developed not to predict the life of the markings, but to determine when, based upon collected data, markings should be replaced. Two basic approaches were evaluated. In one approach, markings were considered for replacement when the mean retroreflectivity for 15 sample points fell below some threshold value. The other approach recommended replacement when the median of 15 sample points fell below the threshold.

Jung-Taek, Maleck, and Taylor of Michigan State University completed a study in 1999 for the Michigan Department of Transportation to determine a degradation model for waterbased, polyester, and thermoplastic pavement markings (22). They reported results from their four-year project, which evaluated various pavement marking materials to develop guidelines for their most cost-effective use. The results of this study were based on data collected with a handheld retroreflectometer using 15-meter geometry. From this study, a number of interesting results were obtained. First, retroreflectivity degradation was found to average 0.14 percent per day, with service lives of 445, 439, and 427 days for waterbased, polyester, and thermoplastic markings, respectively. The research examined the relationships between retroreflectivity degradation and average daily traffic (ADT), speed limit, and commercial traffic on the measured sections. These factors were found to have no statistically significant correlation with retroreflectivity deterioration. Measured sections in colder locations where winter maintenance activities occurred were found to correlate with retroreflectivity loss. The linear regression models developed by Maleck and Taylor for waterbased and thermoplastic markings were as follows:

$$Y = -\ 0.4035\ X + 279.42,\ \ R^2 = 0.17\quad \text{(Waterbased Paints)}$$

$$Y = -\ 0.3622\ X + 254.82,\ \ R^2 = 0.14\ \text{(Thermoplastic Paints)}$$

where

Y=Retroreflectivity of pavement markings in mcd/m^2/lux

X=Age of markings in days

Many recent studies use Cumulative number of Traffic Passages (CTP) as a variable in their models, which is the product of ADT and time, measured as millions of vehicle passages per lane. It is the cumulative exposure of a marking to vehicles since it was first installed. In 2001, Migletz et al. (23) published a research paper in which they summarized the findings of their four-year study spread through 19 states to evaluate the durability of a variety of marking materials. They used CTP as the primary variable and quantified the relationship between the coefficient of retroreflectivity (R_L) and CTP using different model forms such as linear, quadratic, and exponential regressions. The general forms of the models are shown below, where a is initial retroreflectivity and b is the numerical coefficient of CTP:

Linear Model: Mean $R_L = a + (b*CTP)$

Quadratic Model: Mean $R_L = a + (b*CTP) + c * (CTP)^2$

Exponential Model: Mean $R_L = a * e^{(b*CTP)}$

In the study, the minimum threshold values were set to range between 85 – 150 mcd/m^2/lux for white lines and 55 – 100 mcd/m^2/lux for yellow lines. Using these thresholds, the study found the service life for white waterbased markings on freeways in the range of 4.1 – 18.4 months.

In 2002, Abboud and Bowman (24, 25, 26) conducted a study of the cost and longevity of waterbased and thermoplastic markings to determine a useful lifetime. The authors used a minimum retroreflectivity threshold of 150 mcd/m^2/lux, determined from their previous study of crash data and traffic exposure on Alabama state highways. The researchers developed a logarithmic model relating retroreflectivity to exposure of markings to vehicular traffic. The equations they developed are as follows:

$$R_L = -19.457 \text{ Ln (VE)} + 267, \quad R^2 = 0.31 \quad \text{(Waterbased)}$$

$$R_L = -70.806 \text{ Ln (VE)} + 640, \quad R^2 = 0.58 \quad \text{(Thermoplastic)}$$

where

R_L = Pavement Marking Retroreflectivity in mcd/m^2/lux

Ln = Natural Logarithm

VE = Vehicle Exposure in thousands of vehicles

Thamizharasan, A., Sarasua, W. A., Clarke, D., and Davis, W. J. (27) presented a research paper at the TRB Annual meeting in 2003 in which they developed two models to predict the pavement marking degradation. They first developed a nonlinear model based on time. They found out that when markings are newly applied the retroreflectivity initially increases until glass beads become exposed and then retroreflectivity decreases linearly to a minimum value due to various factors such as traffic exposure and environmental conditions. The other important variables considered while developing the model were marking color, surface type, marking material, and traffic volume or AADT. The study found that traffic volumes were not statistically significant for retroreflectivity degradation along straight sections of road.

Effect of Marking Placement Direction

Researchers Rasdorf, Zhang, and Hummer from North Carolina State University (28) performed a unique study in 2007-2008 addressing the impact of directionality of paint laying on pavement marking retroreflectivity for two-lane highway centerlines. Objectives of the study were to ascertain whether there is a relationship between retroreflectivity values and paint installation direction and whether retroreflectivity directionality would impact the minimum standards for retroreflectivity levels required by the FHWA, which are still pending.

The data collection effort mainly consisted of measuring the retroreflectivity of centerline pavement markings in both directions of traffic flow. The conclusions of the study were: (a) Retroreflectivity values measured along the direction of striping were always higher than those measured in the opposite direction for two-lane highways. (b) The study was able to establish a clear relationship between retroreflectivity and age. The study results were compared to a previous work done by Sitzabee, a fellow researcher from NCSU in 2008, which said that pavement marking retroreflectivity degrades at an average rate of about 50 mcd/m^2/lux annually for thermoplastic and waterbased markings. Results of the study were similar to the results reported in the previous work. (c) When comparing retroreflectivity values of yellow centerline paint pavement markings to pending FHWA minimum standards, the value taken in the opposite direction to the direction of striping should be used.

Effect of Wetness on Pavement Marking Retroreflectivity

In 2004, Aktan and Schnell (29) conducted a study to evaluate the performance of three different pavement marking materials under dry, wet, and rainy conditions in the field. The pavement marking materials used were paint with large glass beads, thermoplastic with high index beads, and patterned tape with mixed high index beads. Under dry conditions, all materials exhibited acceptable retroreflectivity, measured using an LTL-X handheld retroreflectometer and complying with the *ASTM E 1710* standard. Under wet conditions, the retroreflectivity values measured were much lower than the dry measurements. The test procedure employed was in compliance with the standard *ASTM E 2177*. Under simulated rain conditions, retroreflectivity was the lowest for all three materials.

In a 2005 study, Gibbons et al. (30) evaluated the visibility of six pavement marking materials under simulated rain conditions with a rainfall rate of 0.8 in/hr. The study indicated that visibility distance is highly correlated to luminance of the pavement marking material and moderately correlated to the measured retroreflectivity. Factors affecting visibility distance are wetness of pavement markings, material type, and vehicle type. The recovery time for visibility distance depends on the pavement marking material type. The average time of recovery was six minutes for visibility to reach normal conditions after rain.

Effect of Lane and Shoulder Width on Vehicle Lateral Placement

Though there are no studies which relate retroreflectivity degradation with lane or shoulder width, it can be concluded that these variables can potentially affect retroreflectivity. This is based on the concept of vehicular traffic driving over the markings causing glass beads to become dislodged and thus decreasing the retroreflectivity. Studies have been conducted that relate vehicle lateral placement to lane and shoulder width. With an increased probability of drivers driving closer to the edge lines or centerlines comes the possibility that drivers venture onto the lines themselves. Repeated occurrences of this results in faster marking degradation.

In 1969, the Missouri State Highway Department (31) undertook a project to study the effect of white edge lines on lateral position of vehicles on two-lane highways having a width in the range of 20 – 24 feet. The main finding of the study was that vehicles tend to move closer to the centerlines under free flow conditions. In 1971, Hassan (32) conducted a similar study in Maryland with two two-lane roads, one having a width of 18 feet and the other a width of 24 feet. The results of the study were similar to the Missouri State Highway Department project. More recent studies have also been conducted, including a 2006 study by Tsyganov et al. (33) in Texas where three two-lane roads with widths 9, 10, and 11 feet were selected to study the edge line effects on lateral placement of vehicles. The findings of the study were that as the width of the lane increases, drivers tend to be closer to the centerlines under all conditions of illumination.

In their research paper in 2003, Driel et al. (34) addressed the effect of shoulder width on the lateral placement of vehicles. The main findings of the study were that with wide shoulders vehicles tend to move more towards the edge of road.

Environmental Effect on Pavement Markings

The Pavement Marking Handbook (35) of the Texas Department of Transportation breaks down the effect of environment on performance of pavement markings into two broad categories:

- Weather conditions at the time of placement of markings
- Climate throughout the year

Quality control at the time of laying the markings is of utmost importance to ensure proper performance of pavement marking material. SCDOT specifications (36) require the air temperature to be at least 50º F before commencement of the laying operation for waterbased markings to ensure proper drying and curing. A relative humidity of less than 85 percent is also required. Wind velocity affects the drop-on beads dispersion. If beads are dropped on the newly laid paint with strong winds blowing, they may not uniformly reach the binder material. Climatic conditions can have adverse effects on long-term performance of pavement markings. Regions with heavy snowfall that are snowplowed frequently can cause pavement marking retroreflectivity degradation due to heavy abrasion. In hot and humid climates, exposure of the pavement to ultraviolet rays of sunlight results in fading of color and cracking of pavement markings.

Survey of States

As a part of the research project, the research team created a survey and sent it to the DOT of each state in the United States. The survey was created using SurveyMonkey.com and was available online for six months for the state DOTs to complete. In this time, 20 states responded with full or partial completion of the survey. The main purpose of the survey was to learn of the pavement marking management systems in place in other states, if any. The survey also gave insight to other information such as the most commonly used marking material, replacement frequencies, and what factors DOTs felt were most important in retroreflectivity degradation.

From the survey, it was found that waterbased markings are by far the most commonly used material on primary and secondary roads in other states, though many states did use at least some thermoplastic and/or other materials. Figures 2.3 and 2.4 show the breakdown of states that use one material for at least 50 percent of their markings on primary and secondary roads. Clearly, of the states that responded, waterbased markings are used the most, with a few states also using thermoplastic for the majority of their markings.

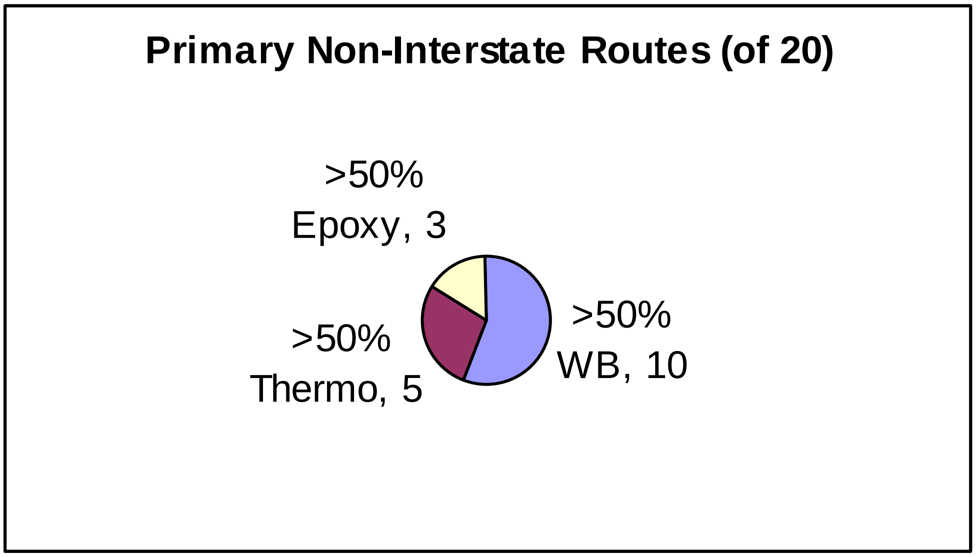


Figure 2.3: States Using One Material for 50% or More of Primary Routes

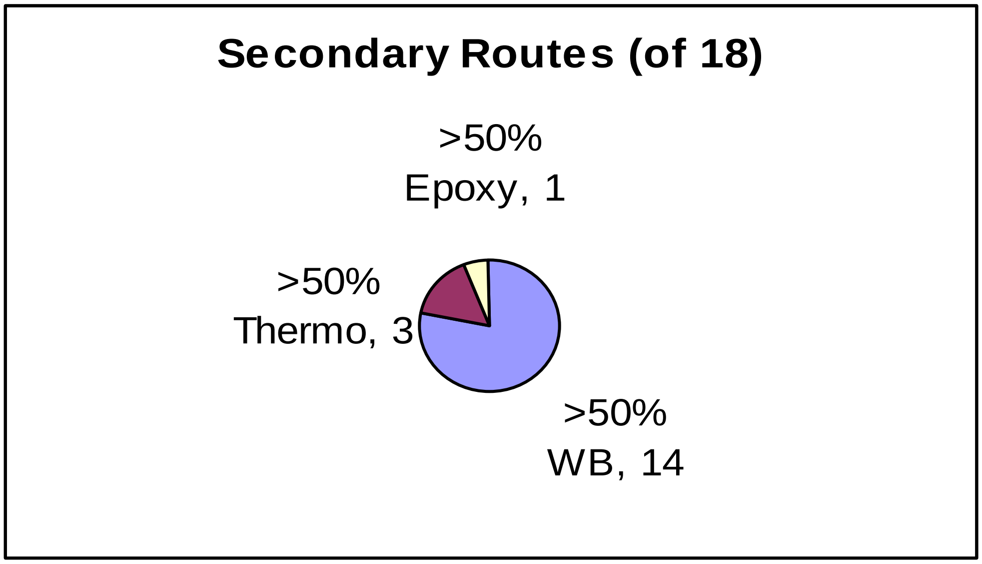


Figure 2.4: States Using One Material for 50% or More of Secondary Routes

Of the two materials, the states agree that waterbased markings should be replaced more frequently than thermoplastic markings. When ranking factors that contribute to marking deterioration, the states ranked all factors except history of road (marking material, application quality control, traffic volume, weather and climate, and road surface) as having similar importance. This is shown in Figure 2.5.

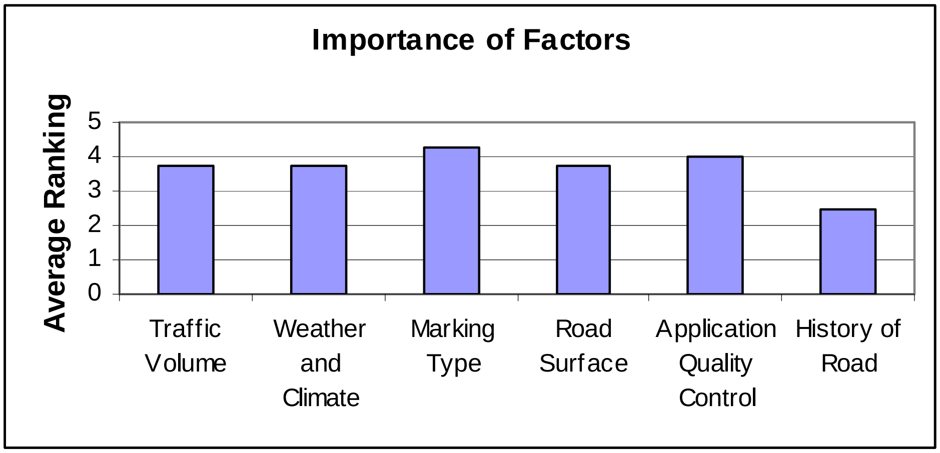


Figure 2.5: States' Ranking of Factors Contributing to Degradation

Of the states that responded, eight have developed a marking inventory system in which they inspect markings periodically. The inspections range from subjective nighttime inspections to retroreflectometer readings. A very important finding of the survey was that of the states that responded, no state's management system is able to predict pavement marking degradation.

Chapter Summary

There have been a large number of studies regarding pavement markings. These studies range from predicting degradation to determining minimum acceptable retroreflectivity values to analyzing other variables such as marking wetness and direction of application.

From the literature regarding these studies, several things can be concluded. The first and most important conclusion is that there currently is no standard for the minimum acceptable retroreflectivity threshold, though such standards are pending. The lack of a federal standard makes creating an estimate of marking life difficult. Until such standards are created, the widely used threshold of 100 mcd/m^2/lux will be used.

Another major conclusion derived from the literature is the lack of consistency in retroreflectivity degradation models. The significant variables determined by past research projects vary, though marking age and traffic volume seem to be the most common variables used. Some models deem only one of these variables significant, while others find both as major contributors to retroreflectivity degradation. Another major difference in predictive models is the initial retroreflectivity value. Most models assume a constant initial value for each material, but this presents a problem due to the variability in marking application. Accompanied with the variability in degradation models is variation in the predicted life spans of markings. Models from previous research give the life cycle of pavement markings as a very wide range, which is less than ideal when trying to create a pavement marking management system.

Though this research project does not aim to perform a definitive analysis of the effects of wetness or directionality on pavement marking retroreflectivity, it is an important aspect, and thus is noted in the literature review. These aspects were taken into account in the project, and additional data collection was performed to test that the findings of this project coincide with the literature.

An important characteristic of this research is the approach of "leaving no stone unturned." The research observes a large number of variables including marking age, varying initial value, traffic volume, lane width, shoulder width, climate, marking thickness, and application rate for both waterbased and thermoplastic pavement markings, while taking into account marking wetness and directionality.

CHAPTER 3: RESEARCH METHODOLOGY

Project Commencement

Through preliminary meetings with the SCDOT committee governing the project, it was determined that designated employees of each of the SCDOT districts would supply the research team with potential roadways to be included in the project. These roadways were to have had new markings laid up to 25 days prior to the research team being notified. The information included in the notification was road name, nearest crossing streets of new marking beginning and ending, marking material, pavement type, application rate, wet film thickness, bead type, and bead and paint manufacturers. These notifications were sent through e-mail, and often included multiple newly marked roadways.

From these lists of newly marked roadways, the research team selected certain roads for potential “sites.” The goal in selecting sites was to establish a distribution of at least 100 sites spread across South Carolina. For this reason, the research team became more selective in choosing potential sites as the site establishment period continued. By the end of the site establishment period, a sufficient distribution was formed; however, the ideal distribution was not achieved, as there were many counties in South Carolina where no sites were established. Figure 3.1 shows the distribution of sites established throughout South Carolina. Sites with waterbased markings are represented by Palmetto trees, while sites with thermoplastic markings are represented by maple leaves.

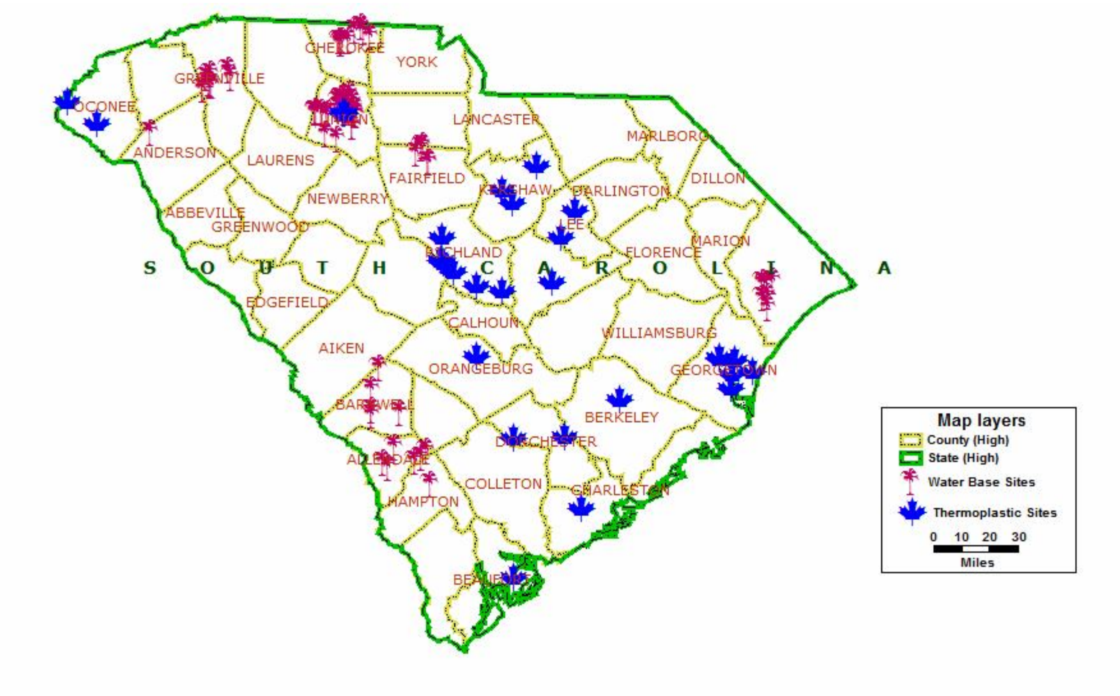


Figure 3.1: Sites Established in South Carolina

Throughout the project, the research team was forced to abandon some sites. In many cases, this was caused by repaving, remarking, or the addition of a chip seal to the roadway. Some other sites were abandoned due to budget and time constraints, under the basis that there were many similar sites within the area. This also allowed the research team to establish additional sites. Sites in Georgetown and Horry counties (the far right corner of the state) were added during the second year of the project. This was to help account for abandoned sites as well as improve the distribution of data collection locations.

Site Establishment

The site establishment period began in May 2008 and lasted through the beginning of August 2008. During this time, 92 sites were established in 18 counties across the state. Thirteen additional sites were added in two additional counties—Georgetown and Horry—after one year. Before roadways could be accepted as potential sites, it had to be verified that the new markings were placed within a 15-25 day window prior to site establishment. After determining roadways where potential sites would be placed and verifying the 15-25 day criteria, the research team traveled to the roadways to establish each individual research site. The first step of site establishment was to find a stretch of road where the team of two could safely operate with proper sight distance for oncoming traffic. This often meant finding a long, straight stretch of road with a large area (i.e. shoulder or parking lot) to park the vehicle. Once the road section was found on which to establish the site, additional safety measures were taken to protect the research team members. This included wearing safety vests and placing cones and a "road work ahead" sign along the shoulder of the road.

Next, a 100-ft. tape measure was laid along the edge of the roadway, and templates were painted using temporary marking paint every 25 feet along the white edge line, for a total of five templates. The templates corresponded to the shape of the bottom of the retroreflectometer to be used in data collection. In doing this, it ensured that the data would be collected at the precise locations on every visit to the site. This was repeated for the solid yellow centerline, if present, while using extreme caution in avoiding traffic. Finally, the site was given an identification number, which was painted beside the first template. A long line was also painted across part of the travel lane to help with recognition when traveling back to the site for future data collection. Examples of site establishment and numbering are shown in Figures 3.2 and 3.3.

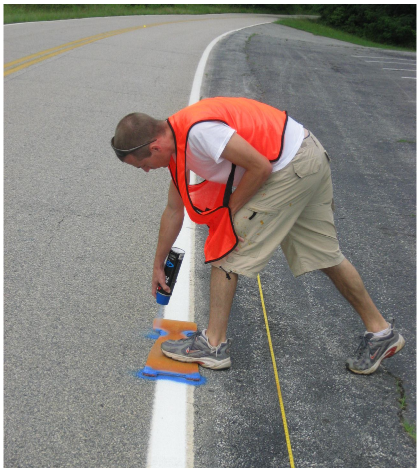


Figure 3.2: Site Establishment

Figure 3.3: Site Numbering

Data Collection

After site establishment, the first of six rounds of data was collected at the site. This was done using the retroreflectometer, following the retroreflectometer's procedures. This included calibration of the unit at the beginning of each day. An image of the retroreflectometer on a data collection point is shown in Figure 3.4.

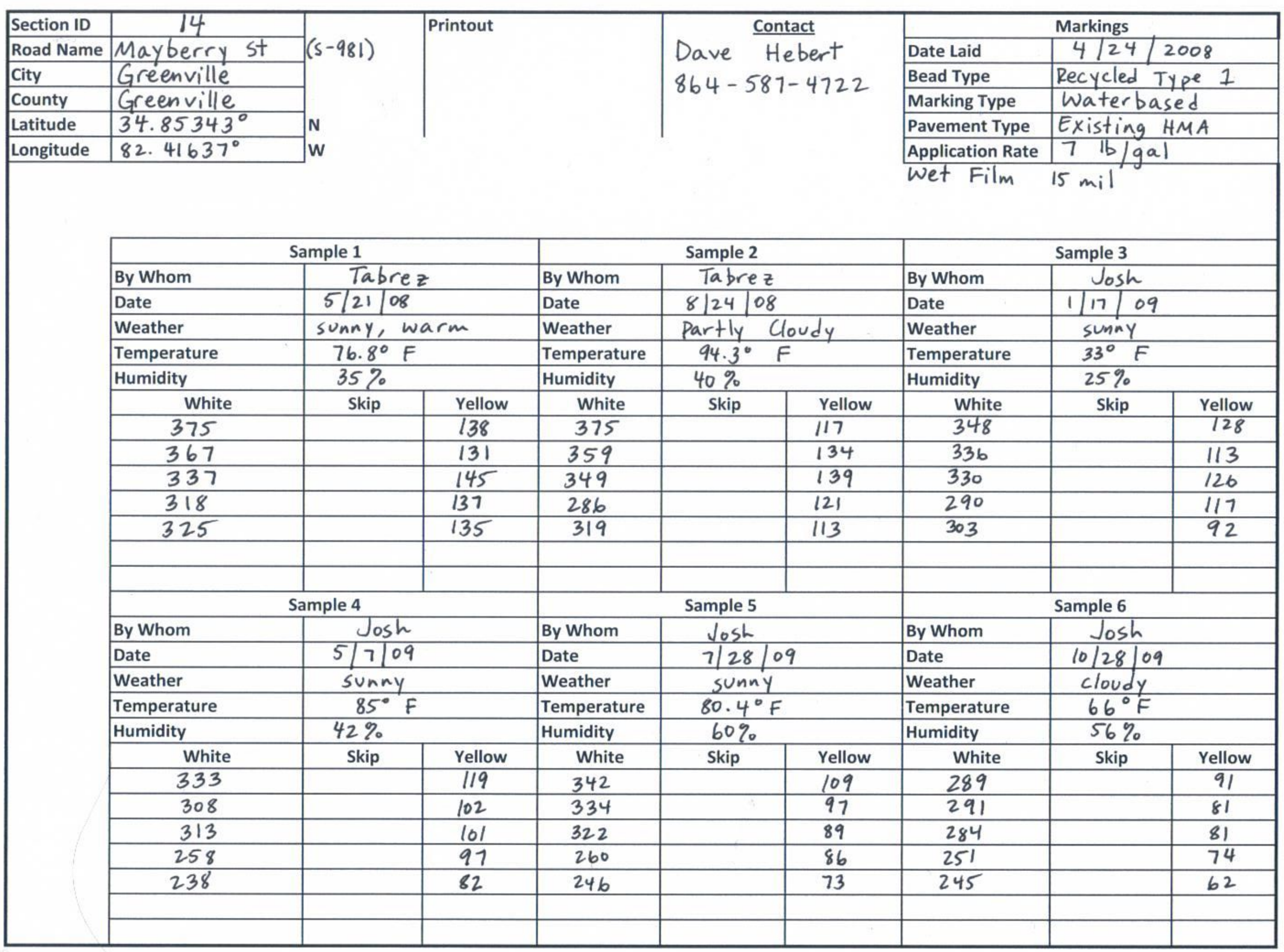
Figure 3.4: Retroreflectometer Collecting Data

At the first data collection point, a printout of the GPS coordinates was created to aid in finding the site for future data collection. For all of the data collection points, the retroreflectivity readings were recorded on a data sheet, which was kept in a notebook. In the instance of skip—or dashed—lines, readings were taken at the beginning, middle, and end of two of the markings. All of the information obtained from SCDOT about the site was also recorded on the data sheet, as well as the date, temperature, and humidity. An example of a data collection sheet is shown in Figure 3.5 at the end of this chapter. Upon completion of the first round of data collection, all of the safety equipment was gathered and the research team moved on to the next potential site. Data collection was performed at each site approximately every three months, for a total of six data collection rounds. The sixth and final data collection round was completed in February 2010.

Additional Data Collection

After a few rounds of data collection, it was determined that two additional variables needed to be included in the study. One of these is the effect of the paint-laying direction on retroreflectivity, and the other is the effect of wetness on retroreflectivity. In rounds four through six, additional steps were taken to study these effects. For the directional study, the retroreflectometer was faced backward on the fifth painted template on the yellow marking such that it would measure the retroreflectivity in the opposing direction of the site layout. From the literature, it is believed that the reading will always be less in the opposing direction of the paint laying. To attempt to verify this, these “backwards” readings were also taken on the white edge line for the sixth round. This was because the painting direction of the white edge line was known to be in the direction of travel, while the painting direction of the yellow centerline was unknown.

In the wetness study, the fifth painted template on the white edge line was first swept clean and then soaked with water. Readings were taken at 30 seconds, one minute, and two minutes after the wetting ceased. Since no set standards were used in this study nor the directional study, these can only be used as observational studies. Though conclusions can be drawn from these studies, they can not be ruled as definitive. Additional qualitative information was observed and recorded as well. An example of a data collection sheet containing the additional information collected is shown in Figure 3.6 at the end of this chapter.



Section ID	14	
Road Name	Mayberry St	(S-981)
City	Greenville	
County	Greenville	
Latitude	34.85343°	N
Longitude	82. 41637°	W

Printout

Contact

Dave Hebert
864-587-4722

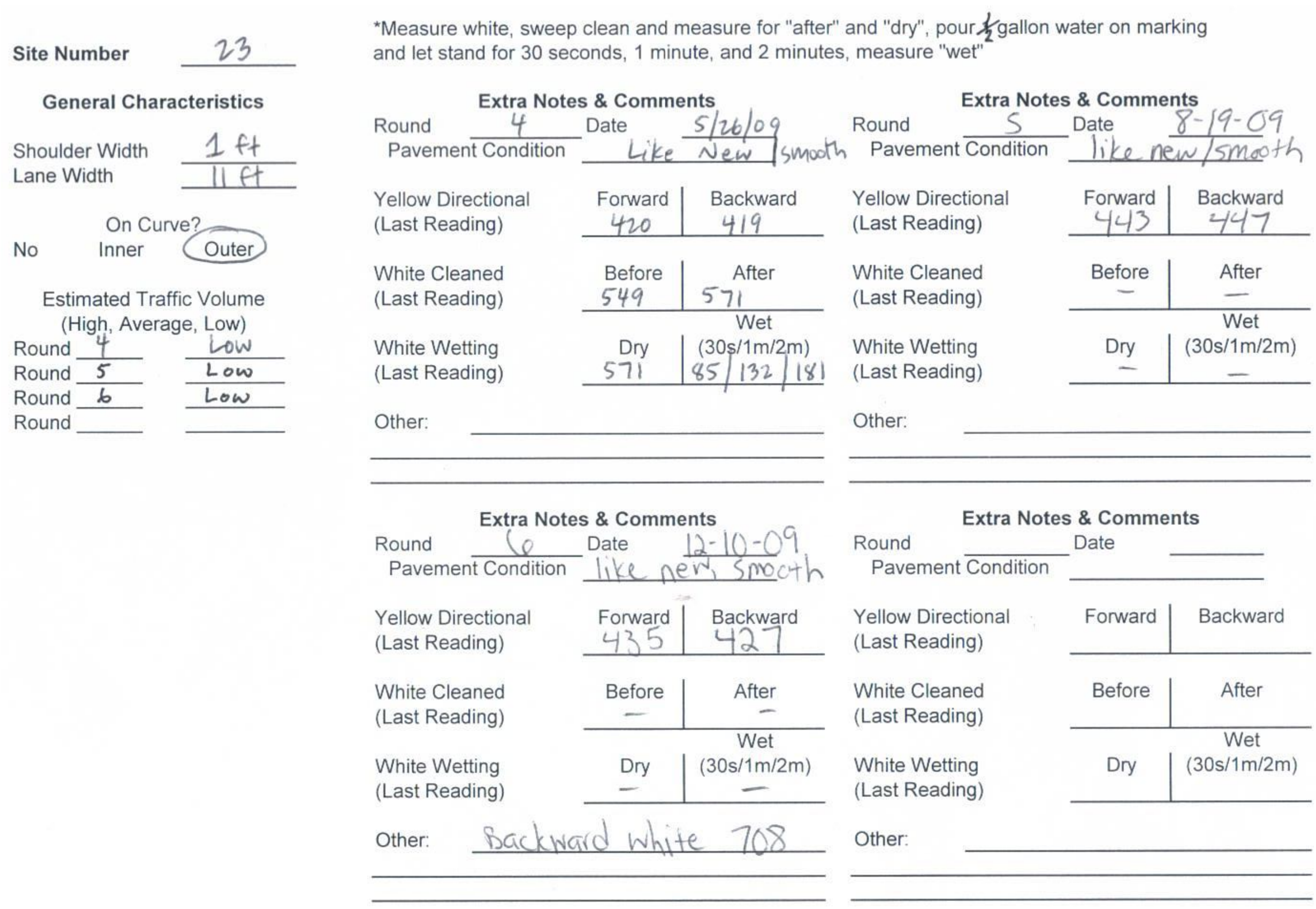
Markings	
Date Laid	4/24/2008
Bead Type	Recycled Type 1
Marking Type	Waterbased
Pavement Type	Existing HMA
Application Rate	7 lb/gal

Wet Film 15 mil

Sample 1			Sample 2			Sample 3		
By Whom	Tabrez		By Whom	Tabrez		By Whom	Josh	
Date	5/21/08		Date	8/24/08		Date	1/17/09	
Weather	sunny, warm		Weather	Partly Cloudy		Weather	sunny	
Temperature	76.8° F		Temperature	94.3° F		Temperature	33° F	
Humidity	35%		Humidity	40%		Humidity	25%	
White	Skip	Yellow	White	Skip	Yellow	White	Skip	Yellow
375		138	375		117	348		128
367		131	359		134	336		113
337		145	349		139	330		126
318		137	286		121	290		117
325		135	319		113	303		92

Sample 4			Sample 5			Sample 6		
By Whom	Josh		By Whom	Josh		By Whom	Josh	
Date	5/7/09		Date	7/28/09		Date	10/28/09	
Weather	sunny		Weather	sunny		Weather	cloudy	
Temperature	85° F		Temperature	80.4° F		Temperature	66° F	
Humidity	42%		Humidity	60%		Humidity	56%	
White	Skip	Yellow	White	Skip	Yellow	White	Skip	Yellow
333		119	342		109	289		91
308		102	334		97	291		81
313		101	322		89	284		81
258		97	260		86	251		74
238		82	246		73	245		62

Figure 3.5: Sample Data Collection Sheet



Site Number 23

General Characteristics

Shoulder Width 1 ft
Lane Width 11 ft

On Curve?
No Inner [✓ Outer]

Estimated Traffic Volume
(High, Average, Low)
Round 4 Low
Round 5 Low
Round 6 Low
Round

*Measure white, sweep clean and measure for "after" and "dry", pour ½ gallon water on marking and let stand for 30 seconds, 1 minute, and 2 minutes, measure "wet"

Extra Notes & Comments

Round 4 Date 5/26/09
Pavement Condition Like New / smooth

Yellow Directional (Last Reading)	Forward 420	Backward 419
White Cleaned (Last Reading)	Before 549	After 571
White Wetting (Last Reading)	Dry 571	Wet (30s/1m/2m) 85 / 132 / 181

Other:

Extra Notes & Comments

Round 5 Date 8-19-09
Pavement Condition like new/smooth

Yellow Directional (Last Reading)	Forward 443	Backward 447
White Cleaned (Last Reading)	Before –	After –
White Wetting (Last Reading)	Dry –	Wet (30s/1m/2m) –

Other:

Extra Notes & Comments

Round 6 Date 12-10-09
Pavement Condition like new, Smooth

Yellow Directional (Last Reading)	Forward 435	Backward 427
White Cleaned (Last Reading)	Before –	After –
White Wetting (Last Reading)	Dry –	Wet (30s/1m/2m) –

Other: Backward white 708

Extra Notes & Comments

Round Date
Pavement Condition

Yellow Directional (Last Reading)	Forward	Backward
White Cleaned (Last Reading)	Before	After
White Wetting (Last Reading)	Dry	Wet (30s/1m/2m)

Other:

Figure 3.6: Sample Supplemental Data Collection Sheet

CHAPTER 4: DATA ANALYSIS

Discussion of Variables

The primary objective of the research is to establish a degradation model for pavement marking retroreflectivity. The first step in accomplishing this is organizing the data to show the various data types that were collected, along with the sample size for each. A breakdown of the data collected is shown in Table 4.1.

Table 4.1: Summary of Sites

Variable	**Category**	**Established Sites**	**Sites with 6 Rounds Collected**
	Total	105	60
Marking Type	Waterbase (WB)	75	40
	Thermoplastic (T)	30	20
Marking Color by Material and Configuration	White Edge WB	53	23
	Yellow Solid WB	68	40
	White Skip WB	2	1
	Yellow Skip WB	13	4
	White Edge T	23	12
	Yellow Solid T	15	11
	White Skip T	2	1
	Yellow Skip T	18	11
Pavement Type	New HMA	22	11
	Existing HMA	74	41
	Chip Seal	9	8

From this table, it became possible to determine which models would be created. Only marking categories with adequate sample sizes were taken into account in the analysis. From Table 4.1, it was determined that white skip markings would not be analyzed due to the small sample size for both thermoplastic and waterbased markings. Though pavement type seemed to have an adequate sample size to be considered in analysis, upon further review, it was removed from consideration. This was because of the distribution of marking type on the various pavement surfaces. All chip seal pavements contained waterbased markings, while all new hot mix asphalt (HMA) pavements contained thermoplastic markings. Only 15 of 74 existing HMA pavements contained thermoplastic markings.

The rightmost column of Table 4.1 lists the number of sites for which all six rounds of data were collected. The three factors resulting in less rounds being collected are site obliteration (repaving, remarking, or adding a chip seal), voluntary abandonment, and late site establishment. The number of rounds collected on these sites varies from one to five, with the majority having four rounds collected. The sites established in the second year of research only had four rounds of data collected.

Additional variables were recorded that were not included in Table 4.1. These variables are marking application rate, bead type, and wet film thickness. These variables were not considered in analysis due to the reasons shown in Table 4.2.

Table 4.2: Variables Eliminated from Analysis

Variable	**Reason for Exclusion**
Bead Type	All waterbased markings use Type I recycled beads. Thermoplastic use recycled beads of various types, but sample size is minimal here.
Wet Film Thickness	With the exception of a few sites, standard numbers were reported. Without accurate measurements during application, this variable becomes useless.
Application Rate	Standard numbers were reported for all sites.

Considering Tables 4.1 and 4.2, a final list of analysis variables was determined. The variables were initial retroreflectivity, days after application, traffic volume, temperature, humidity, lane width, and shoulder width. These variables were used in stepwise regression analysis for white edge line, yellow centerline, and yellow skip line waterbased and thermoplastic markings.

Stepwise Regression Analysis

The purpose of stepwise regression analysis was to determine which variables were significant in predicting retroreflectivity of pavement markings. This was completed using the StatPro add-in for Microsoft Excel 2003. This program allows you to specify the dependent variable, independent variables, and maximum acceptable p-value for the variables to enter the model (thus making it significant). The produced output lists the significant variables, their coefficients and p-values, and r-squared values. The r-squared values given begin with the most significant variable and then show the increase in r-squared if other significant variables are added to the model.

Before the stepwise regression was completed, “bad” data points had to be removed. These outliers consisted of particular site visits where it was noted that excessive amounts of dirt, grass, or wetness of markings caused the retroreflectivity readings to be much lower. To preserve the sample sizes in the data, only this small amount of points were removed, and not the entire site itself. Appendix A contains tables showing all data points (minus the “bad” points) and their associated variables.

Median Retroreflectivity Stepwise Regression

The variables found significant in the stepwise regression analysis are shown in Table 4.3. This analysis was completed using the median retroreflectivity value of each round at each site as the dependent variable, and all other variables as independent.

Table 4.3: Stepwise Regression for Median Retroreflectivity

Material	**Initial Value**	**Days**	**Traffic Volume**	**Humidity**	**Temp**	**Lane Width**	**Shoulder Width**
White Edge WB	X	X					
Yellow Solid WB	X	X				X	
Yellow Skip WB	X						
White Edge T		X					X
Yellow Solid T	X	X					
Yellow Skip T	X	X					

From Table 4.3 and the r-squared values given in the output, a few conclusions were drawn. The first of these was that initial retroreflectivity and days after application were the most significant variables for all marking types and configurations. Only yellow skip lines with waterbased material did not return days as a significant variable, and only white thermoplastic edge lines did not return initial retroreflectivity values as significant. Though the r-squared values for these stepwise models were high (0.48-0.76 for waterbased, 0.11-0.38 for thermoplastic), from a practical standpoint, it was decided that initial values should be excluded from the model. This is because retroreflectivity measurements would have to be taken on every roadway at the time of application in order to predict marking life using this model.

Alternatives to producing models utilizing initial values include a) assuming an initial value for each marking material and configuration, b) producing a model for retroreflectivity differences from initial values, and c) producing a percent difference from initial values model for retroreflectivity. From viewing the first round of data collection for all sites, it was determined that assuming an initial value would be a mistake, due to the varying initial values in retroreflectivity. Retroreflectivity difference models would be most accurate if marking degradation was uniform and similar for all sites of each material, no matter the initial value. Percent difference models would be most accurate if markings with a higher initial retroreflectivity degraded at a faster uniform rate than those with lower initial values. Because this relationship was unknown, stepwise regression analysis was completed for both.

Since stepwise regression was completed for differences and percent differences, other conclusions about significant variables from Table 4.3 were ignored. They were re-evaluated in the difference and percent difference stepwise regression.

Retroreflectivity Difference Stepwise Regression

The procedure for completing stepwise regression using differences from the initial retroreflectivity as the dependent variable was the same as in the previous stepwise regression analysis. The variables found significant in this analysis are shown in Table 4.4.

Table 4.4: Stepwise Regression for Retroreflectivity Difference

Material	Days After Application	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
White Edge WB	X					
Yellow Solid WB	X				X	
Yellow Skip WB						
White Edge T	X					X
Yellow Solid T	X					
Yellow Skip T	X					

The results of this stepwise regression were similar to those using median retroreflectivity. Producing a model using these variables would be more useful than one using initial values as a variable. The r-squared values, however, were much lower using this type of analysis (0.18-0.29 for waterbased, 0.14-0.18 for thermoplastic). This is because initial values were the major cause for higher r-squared values. This essentially meant that if initial retroreflectivity values were known for all road markings, the model could predict the life of each individual marking. Since the goal of the research was to produce degradation models for markings as a whole, the sacrifice in r-squared values was necessary.

As Tables 4.3 and 4.4 show, lane width and shoulder width were reported as significant in the median stepwise regression, as well as this stepwise regression of differences. The decision on the use of these variables in the model is discussed in greater detail in the *Discussion of Possible Models* section of this chapter.

In this stepwise regression analysis, no significant variables were found for waterbased yellow skip lines. This is because of missing data for the limited number of sites with waterbased yellow skip lines. If any included variable is missing for a data point in stepwise regression, the entire data point is left out. In this case, many of the data points were missing temperature, humidity, lane width, or shoulder width, causing the entire data point to be left out.

Retroreflectivity Percent Difference Stepwise Regression

A new variable was created for percent difference from initial retroreflectivity using the formula $\%Difference = {}^{(Median - Initial)}\!\big/_{Initial} \times 100$. This percent difference then became the dependent variable in the stepwise regression analysis. The variables found to be significant in the analysis are shown in Table 4.5.

Table 4.5: Stepwise Regression for Retroreflectivity Percent Difference

Material	**Days After Application**	**Traffic Volume**	**Humidity**	**Temp**	**Lane Width**	**Shoulder Width**
White Edge WB	X	X			X	X
Yellow Solid WB	X				X	
Yellow Skip WB						
White Edge T	X					X
Yellow Solid T	X					
Yellow Skip T	X					

With the exception of waterbased white edge lines, the results of this stepwise regression were the same as the regression using retroreflectivity differences. The r-squared values were slightly higher for waterbased and slightly lower for thermoplastic in this stepwise regression (0.27-0.36 for waterbased, 0.12-0.13 for thermoplastic). The waterbased r-squared values most likely increased because of the additional variables found significant for white edge lines.

Lane width and shoulder width were also found significant in this stepwise regression, and traffic volume was also added as a significant variable. The decision to retain or disregard these variables is discussed in detail in the *Discussion of Possible Models* section of this chapter. No significant variables were found for waterbased yellow skip lines in this stepwise regression for the same reason as in the difference from initial retroreflectivity stepwise regression.

Discussion of Possible Models

Because of the need to eliminate initial retroreflectivity as an independent variable in the model, both difference and percent difference from initial values were modeled. In most cases, simple linear regression was completed using only days after application as the independent variable because this was the only variable found significant in stepwise regression analysis. However, in some cases, additional variables needed to be examined to determine their contribution to the model.

Waterbased White Edge Lines

The first marking configuration examined turned out to be the most complex because different variables were found to be significant in the difference and percent difference from initial value stepwise regression. The stepwise regression using difference from initial value as the dependent variable only found days after application to be significant, so the model was created using only that variable. However, the stepwise regression using percent difference from initial value as the dependent variable also found traffic volume, lane width, and shoulder width as significant variables. To determine whether these variables truly were significant and useful to the model, further investigation was required.

A variable was deemed useful if its contribution to the model outweighed the additional cost and complications created when adding the variable. Of the four significant independent variables, days after application is the easiest to use in a model, followed by lane width, traffic volume, and then shoulder width. Traffic volume and shoulder width are particularly difficult to include in a model because accurate data is not always available, and the values are constantly changing. To try and create a model that was most useful, multiple scenarios were examined using simple and multiple linear regression. A summary of these results is shown in Table 4.6.

Table 4.6: Waterbased White Edge Line Regression Scenarios

Regression Type	Variables Included	R-squared
Multiple	Days, Lane Width, Traffic Volume, Shoulder Width	0.31
Single	Days	0.21
Multiple	Lane Width, Traffic Volume, Shoulder Width	0.07
Multiple	Days, Lane Width	-
Multiple	Days, Lane Width, Traffic Volume	0.23
Multiple	Days, Lane Width, Shoulder Width	0.27

The first model was created using all significant variables. This produced the highest r-squared value, but raised the question of usefulness of the variables. To determine the impact of the additional variables, days after application was then modeled alone, followed by a model using all significant variables except days. The decrease in r-squared was observed to be 0.1 when removing lane width, traffic volume, and shoulder width. Because lane width was deemed the next easiest variable to model, an attempt was made at completing multiple linear regression using days after application and lane width as independent variables. In this model, lane width was found to be insignificant, so the r-squared value was omitted from Table 4.6. In completing the final two models, it was determined that lane width was only significant when traffic volume or shoulder width was included in the model. This created a predicament because of the difficulty of including traffic volume or shoulder width in the final model. Using all of this information, it was determined that two models would be created. The first model was formed for its usefulness to a governing organization such as the SCDOT and contained only days after application as the independent variable. The second model was created for its scientific value and contained days after application, lane width, traffic volume, and shoulder width as independent variables.

Waterbased Solid Yellow Centerlines

For both difference and percent difference stepwise regression, lane width was found to be significant for waterbased solid yellow centerlines. The coefficient associated with this variable was found to be negative in both cases, which was contrary to what would be expected. The negative correlation implies that retroreflectivity decreases with larger lane width. In reality, this is not the case because drivers travel over the markings less when the lanes are wider, resulting in less marking degradation. Upon further examination, it was found that some data points were omitted from the stepwise regression due to missing values of temperature, humidity, lane width, or shoulder width, as in the case of waterbased yellow skip lines. This smaller sample size was the probable cause of lane width being found as a significant variable. To confirm this, simple regression was completed using only days after application as the dependent variable, and this was compared to multiple regression using days after application and lane width as dependent variables. In the percent difference from initial value regression, the r-squared values were only slightly higher when lane width was added, while the r-squared values actually decreased in the difference from initial value regression. For these reasons, it was determined that lane width should be removed from the model for waterbased solid yellow centerlines, leaving only days after application as the independent variable.

Waterbased Yellow Skip Lines

The largest hindrance in creating a model for waterbased yellow skip lines was the small sample size. Only 13 sites were established with waterbased yellow skip lines, and only four of those 13 had data collected on them in rounds five and six. With such a small sample size, any variability in the data could have a detrimental effect on the model. However, before determining what this model would be, the significant variables had to be determined. Since the sample size was small and some data points were excluded in stepwise regression, no variables were found significant. It was concluded that the markings would perform most similarly to waterbased yellow solid centerlines, and thus days after application and lane width were analyzed as potential significant variables. In regression of both the difference and percent difference from initial value, adding lane width improved the model, and therefore, it was determined that it should be included.

Thermoplastic White Edge Line

Days after application and shoulder width were the two variables found significant in both the difference and percent difference from initial value stepwise regression for thermoplastic white edge lines. Examination of the coefficients associated with these variables revealed that there was a positive correlation between difference in retroreflectivity and days after application. This meant that over the six rounds of data collection, the retroreflectivity values had increased on average. Though this is desirable from a maintenance standpoint, this meant that creating a degradation model was not possible after six rounds (about 21 months). A “degradation” model created based on this data would imply that if thermoplastic markings were placed, they would never have to be replaced because retroreflectivity would continuously increase. For this reason, thermoplastic white edge markings degradation models were not created.

Observed data indicates that some thermoplastic white edge line markings have begun decreasing from their maximum value, while others are still increasing after six rounds of data collection. It is predicted that all sites will now begin decreasing, and the retroreflectivity modeled versus time will resemble Figure 4.1.

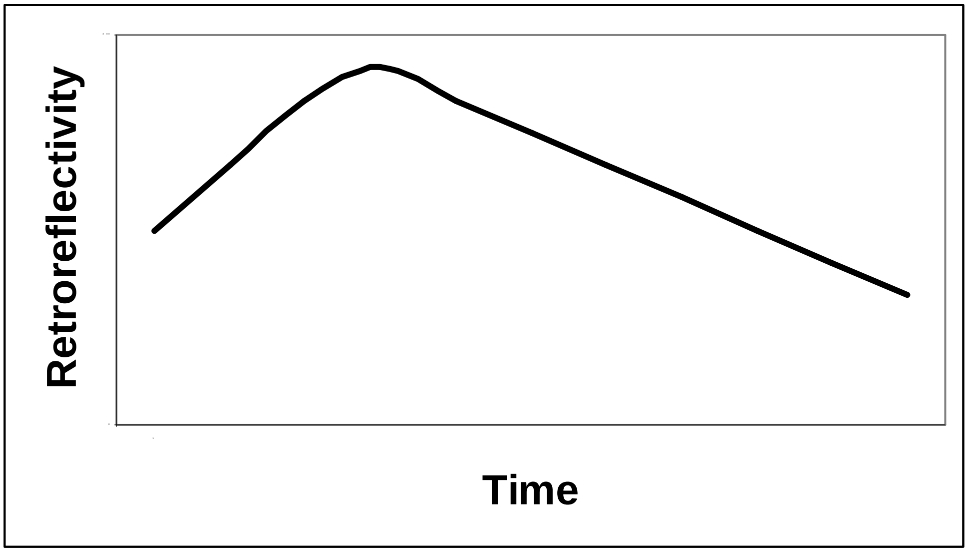


Figure 4.1: Predicted Thermoplastic White Edge Line Model

Thermoplastic Yellow Solid Centerlines and Skip Lines

Unlike thermoplastic white edge lines, yellow thermoplastic markings did begin to deteriorate during the six rounds of data collection. This enabled them to be modeled using days from application as the independent variable. This was the only variable that was found to be significant in both the difference and percent difference from initial value stepwise regression for thermoplastic yellow centerlines and skip lines. The first possible model analyzed was the linear model created from simple linear regression. The y-intercept for this model was relatively high. Because of this high intercept, the model degradation slope was very steep. Observation of the data led to the conclusion that the marking retroreflectivity performed similarly to the expected model for thermoplastic white edge lines, shown in Figure 4.1. This also explained the high intercept from the previous linear model. For these reasons, a model using a polynomial was explored. The increase in r-squared using a polynomial model was small (from 0.16 to 0.19 for solid centerlines difference model). Using a polynomial model would not require any extra effort, since the degradation prediction model would be used in computer software. Finally, a third model was explored. This model was linear with the y-intercept forced to be zero. Though this model produced the lowest r-squared value (0.13 for solid centerlines difference model), the slope of the degradation curve seemed to be the most realistic. Hence, both this model and the polynomial model were carried throughout the remainder of the analysis.

Summary of Possible Models

After careful analysis of each marking configuration, the variables used in the final models were determined. A summary of these results is shown in Table 4.7. The final models created using these variables are discussed in the *Final Degradation Models* section of this chapter.

Table 4.7: Summary of Modeled Variables

Material	**Variables Used**	**Notes**
White Edge WB	Days (Difference and Percent Difference Models)	Created for governing body usage
	Days, Lane Width, Traffic Volume, Shoulder Width (Percent Difference Model)	Created for scientific value only
Yellow Solid WB	Days	
Yellow Skip WB	Days, Lane Width	Beware of small sample size
White Edge T	-	Model not created
Yellow Solid T	Days	Two models created
Yellow Skip T	Days	Two models created

Final Degradation Models

Models were created for all marking configurations except thermoplastic white edge lines. All waterbased models created were linear, while the thermoplastic models created were both linear and nonlinear. These nonlinear models were second order equations. Models using only days as the dependent variable were also plotted on graphs of difference or percent difference versus days after application. For these cases, the model was created using the graph’s trendline. Using this trendline allowed the equation’s constant to be set to zero. This is because the retroreflectivity should be equal to the initial retroreflectivity value at zero days. Setting the constant to zero had a minute effect on the model itself because the constant was already very close to zero. Table 4.8 lists the models created and their r-squared values followed by a legend in Table 4.9. The additional scientific model created for waterbased white edge lines is shown, but is not discussed any further.

Table 4.8: Final Degradation Models

Material	Model	R-Squared
White Edge WB (DOT)	DIFF = -0.1615 (D)	0.21
	% DIFF = -0.0557 (D)	0.21
White Edge WB (Scientific)	% DIFF = -80.9647 – 0.054 (D) – 0.0019(T) + 8.6394 (L) – 2.1990 (S)	0.32
Yellow Solid WB	DIFF = -0.0731 (D)	0.27
	% DIFF = -0.0562 (D)	0.27
Yellow Skip WB	DIFF = -107.8255 – 0.0330 (D) + 10.8849 (L)	0.17
	% DIFF = -68.3431 – 0.0227 (D) + 6.9175 (L)	0.16
Yellow Solid T (Polynomial)	DIFF = -0.0005 (D^2) + 0.1128 (D)	0.19
	% DIFF = -0.0002 (D^2) + 0.0471 (D)	0.17
Yellow Solid T (Linear)	DIFF = -0.1176 (D)	0.13
	% DIFF =-0.0454 (D)	0.11
Yellow Skip T (Polynomial)	DIFF = -0.0006 (D^2) + 0.0471 (D)	0.27
	% DIFF = -0.0002 (D^2) + 0.0612 (D)	0.22
Yellow Skip T (Linear)	DIFF = -0.1484 (D)	0.19
	% DIFF = -0.0468 (D)	0.14

Table 4.9: Legend for Table 4.8

Variable	Stands For	Units
D	Days After Application	Days
T	Traffic Volume	AADT
L	Lane Width	Feet
S	Shoulder Width	Feet

Model Application

To use any of these models, the date of application, marking material, and marking color should be known. If the marking is a waterbased yellow skip line, the lane width also should be known. To apply these equations, initial retroreflectivity needs to be known as well. These equations can then be used to determine present retroreflectivity values or marking life, assuming a minimum threshold for retroreflectivity. As an illustrative example, suppose the marking type is a waterbased white edge line having been placed 400 days from the current date with an initial retroreflectivity value of 300 mcd/m^2/lux. The models can be used to determine current retroreflectivity as follows:

$$\text{DIFF} = -0.1615\ (D) = -0.1615\ (400) \approx -65$$

$$\text{Therefore, Retroreflectivity} = 300 - 65 = 235\ \text{mcd/m}^2\text{/lux}$$

$$\%\ \text{DIFF} = -0.0557\ (D) = -0.0557\ (400) \approx -22\%$$

$$\text{Therefore, Retroreflectivity} = 300 - (0.22)(300) = 234\ \text{mcd/m}^2\text{/lux}$$

Now suppose the minimum threshold for retroreflectivity of this marking is set to be 100 mcd/m^2/lux. In this case, the difference is known to be -200 mcd/m^2/lux, and the percent difference is known to be -67 percent. The number of days until the marking reaches the minimum threshold can be determined as follows:

$$\text{DIFF} = -200 = -0.1615\ (D)$$

Solving for Days, Marking Life ≈ 1238 days ≈ 3.39 years

$$\%\ \text{DIFF} = -67\% = -0.0557\ (D)$$

Solving for Days, Marking Life ≈ 1203 days ≈ 3.30 years

The model was applied to all sites for each round of data collected. An example of this is shown in Table 4.10. Appendix B shows tables of the model applied to all sites. Further discussion of model performance is contained in the next section of this chapter.

Table 4.10: Modeled Example Site 61 (Waterbased White Edge)

Days After Application	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)	% Error
17	334	331	-0.8	333	-0.3
110	297	316	6.5	328	10.4
246	282	294	4.4	320	13.6
332	264	280	6.2	316	19.5
436	253	264	4.2	310	22.4
558	264	244	-7.6	303	14.7

Model Performance

In order to determine the models' performance, they needed to be tested. Each site was modeled using its recorded initial value to obtain the predicted retroreflectivity at the actual time data was collected. The performance of the models is shown in Table 4.11. The percentages of sites within given ranges of error are shown. The far right column shows the percentage of sites with ± 20 percent error, which is equal to the sum of the first two error columns.

Table 4.11: Model Performance

<table>
<tr><th>Material</th><th>Model</th><th colspan="2"><±10% Error</th><th colspan="2">±10-20% Error</th><th colspan="2">>±20% Error</th><th colspan="2"><±20% Error</th></tr>
<tr><td rowspan="2">White Edge WB</td><td>DIFF</td><td colspan="2">58%</td><td colspan="2">16%</td><td colspan="2">26%</td><td colspan="2">74%</td></tr>
<tr><td>% DIFF</td><td colspan="2">52%</td><td colspan="2">17%</td><td colspan="2">31%</td><td colspan="2">69%</td></tr>
<tr><td rowspan="2">Yellow Solid WB</td><td>DIFF</td><td colspan="2">52%</td><td colspan="2">21%</td><td colspan="2">27%</td><td colspan="2">73%</td></tr>
<tr><td>% DIFF</td><td colspan="2">53%</td><td colspan="2">20%</td><td colspan="2">27%</td><td colspan="2">73%</td></tr>
<tr><td rowspan="2">Yellow Skip WB</td><td>DIFF</td><td colspan="2">57%</td><td colspan="2">32%</td><td colspan="2">11%</td><td colspan="2">89%</td></tr>
<tr><td>% DIFF</td><td colspan="2">61%</td><td colspan="2">30%</td><td colspan="2">9%</td><td colspan="2">91%</td></tr>
<tr><td rowspan="2">Yellow Solid T*</td><td>DIFF</td><td>35%</td><td>25%</td><td>12%</td><td>22%</td><td>53%</td><td>52%</td><td>47%</td><td>47%</td></tr>
<tr><td>% DIFF</td><td>32%</td><td>23%</td><td>9%</td><td>19%</td><td>59%</td><td>57%</td><td>41%</td><td>42%</td></tr>
<tr><td rowspan="2">Yellow Skip T*</td><td>DIFF</td><td>46%</td><td>44%</td><td>15%</td><td>15%</td><td>38%</td><td>41%</td><td>61%</td><td>59%</td></tr>
<tr><td>% DIFF</td><td>45%</td><td>44%</td><td>10%</td><td>12%</td><td>45%</td><td>45%</td><td>55%</td><td>56%</td></tr>
</table>

*Percentages labeled as | Polynomial | Linear |

From the left percent error columns in Table 4.11, it seems that the model only does a mediocre job of predicting retroreflectivity. Ideally, the models would predict all retroreflectivity values within 10 percent of the actual values. Because of the expected variability in the data, it is understood that this is not possible. Therefore, the larger percentages of sites predicted within 20 percent error (far right column) is much more encouraging. A discussion of how this variability should be accounted for is found in the *Creation of a Margin of Safety* section of this chapter.

There are two ways that the models can produce error. Models can either under-predict or over-predict the actual retroreflectivity. Under-prediction could lead to early marking replacement, but is not a safety issue. However, over-prediction is a safety issue because markings could reach low levels of retroreflectivity before the model predicts that they should be replaced. Table 4.12 shows the percentages of sites that over-predict by given ranges of error.

Table 4.12: Over-Prediction Frequency

Material	**Model**	**<10% Over**		**10-20% Over**		**>20% Over**		**<20% Over**	
White Edge WB	DIFF	18%		4%		17%		83%	
	% DIFF	14%		14%		27%		73%	
Yellow Solid WB	DIFF	14%		9%		13%		87%	
	% DIFF	14%		10%		19%		81%	
Yellow Skip WB	DIFF	14%		7%		4%		96%	
	% DIFF	15%		7%		4%		96%	
Yellow Solid T*	DIFF	23%	4%	7%	11%	33%	30%	67%	70%
	% DIFF	22%	4%	4%	5%	41%	40%	59%	60%
Yellow Skip T*	DIFF	32%	9%	8%	4%	24%	24%	76%	76%
	% DIFF	36%	10%	6%	4%	35%	35%	65%	65%

*Percentages labeled as | Polynomial | Linear |

The cause of the much higher percentages for over-prediction of less than 10 percent in the polynomial models was the first round of data collection. The polynomial models over-predicted all data points from round one by less than one percent. The far right column of Table 4.12 shows the percentage of sites that were predicted at less than 20 percent over the actual retroreflectivity value. This is equal to 100 percent minus the percentage of values over-predicted by more than 20 percent. Upon examining these numbers, it can be determined that the difference models were much better predictors of retroreflectivity. In all cases, the difference models produced a higher percentage of sites predicted at less than 20 percent over the actual retroreflectivity value. This supports the theory that all markings of a particular type deteriorate at the same rate, no matter the initial retroreflectivity value. For this reason, it is recommended that only difference models be used as means of predicting retroreflectivity.

Creation of a Margin of Safety

When using the models, there is a chance that the model will over-predict what the actual retroreflectivity of a marking is, as depicted in Table 4.12. To account for this, a margin of safety should be created to decrease the chance of this happening, particularly as the marking reaches the minimum threshold of retroreflectivity. To examine this, a trial and error process was completed to determine what additional amount of retroreflectivity should be subtracted from the model to result in 10 percent or less of the data points to be over-predicted by 20 percent or more. For example, the waterbased white edge line difference model would then read “DIFF = -0.1615(D) – X”, where X is the margin of safety. These results are shown in Table 4.13 for the difference model.

Table 4.13: Margins of Safety

Material	**Margin of Safety for Over-Prediction to Occur…**			
	≤10% of the Time		**≤5% of the Time**	
White Edge (WB)	24		59	
Yellow Solid (WB)	9		20	
Yellow Skip (WB)	0		0	
Yellow Solid (T)*	63	65	86	88
Yellow Skip (T)*	58	77	101	81

*Margin of safety values labeled as | Polynomial | Linear |

As expected, the models that had the least percentage of sites being over-predicted required the smallest margin of safety. Waterbased yellow skip lines required no margin of safety because 96 percent of the data points were either under-predicted or over-predicted by less than 20 percent. Observations were made about the data points that were still over-predicted by greater than 20 percent even after the margin of safety was applied. In many cases, these data points were for sites with extremely low measured retroreflectivity values, particularly in the later rounds. Following the degradation model, in this scenario, the marking would have been replaced before it reached these low levels of retroreflectivity. Other observed instances with high over-prediction include markings that deteriorated at a much faster rate than normal. There was no observed explanation in the field to explain the faster degradation of these outliers.

Using the difference models is an acceptable method of predicting retroreflectivity of pavement markings. Including a margin of safety in the model increases its usefulness because of the added conservatism that helps avoid a safety issue. It can therefore be concluded that these models are adequate for predicting pavement marking retroreflectivity.

Yellow Directional Study

One aspect of research not considered initially was the retroreflectivity difference depending on which direction the retroreflectometer was facing. Because of the tendency of the glass beads to roll or become embedded in the paint, it is possible that retroreflectivity is higher in one direction that the other. In particular, retroreflectivity could possibly be higher in the direction that the paint-laying truck traveled. To determine the accuracy of this, yellow centerline markings were measured in both directions during the fourth round of data collection. It was determined that on average, waterbased markings were 29.8 percent higher and thermoplastic markings were 9.6 percent higher in one direction than the other.

After realizing this, the question became whether or not this affected the degradation model for yellow markings. To determine this, the solid yellow markings for both waterbased and thermoplastic marking materials were split into high and low direction data sets. The data sets were modeled using the difference models to determine the percentage of times the retroreflectivity was over-predicted. The thermoplastic model used was the polynomial because of its higher r-squared value. These values were compared to the percentage from the total model that was previously calculated. The results are shown in Table 4.14.

Table 4.14: Directionality Effect on Degradation Models

Material	**Direction**	**Over-Predicted >20%**
Waterbased	High	10%
	Low	14%
	Total	13%
Thermoplastic	High	35%
	Low	29%
	Total	33%

The results from Table 4.14 were determined to be inconclusive. The difference in over-prediction was relatively small for both materials. The over-prediction was higher for the low direction for waterbased markings but lower for the low direction in thermoplastic markings. This could mean that the markings behave differently, but it is more likely that the differences are caused by another factor. It is believed that the factor that most affected the differences in over-prediction was sample size. After splitting the data sets into high- and low-direction groups, the sample size was reduced significantly in all cases. This could easily have caused the over-prediction percentages to be different.

Therefore, for the purpose of this study, it was concluded that directionality did not affect the marking degradation model.

One important piece of information that was concluded from this study was that direction of paint-laying should be taken into account when predicting marking degradation. This is because the initial retroreflectivity will be lower in one direction than the other. Following the theory that markings deteriorate at the same rate no matter the initial value means that the marking will reach the minimum retroreflectivity threshold in one direction before the other. If the retroreflectivity is not predicted properly, this could become a safety issue.

White Wetting Study

After several rounds of data collection, it was observed that marking wetness greatly affected retroreflectivity. Even minor amounts of water not obvious at first glance had an effect on the data. In one early morning instance, dew on the marking lowered the retroreflectivity significantly. These observations led to added data collection for the effect of water on white pavement markings. The procedures used in this study are outlined in *Chapter 3: Research Methodology*. A resulting graph of the study is shown in Figure 4.2.

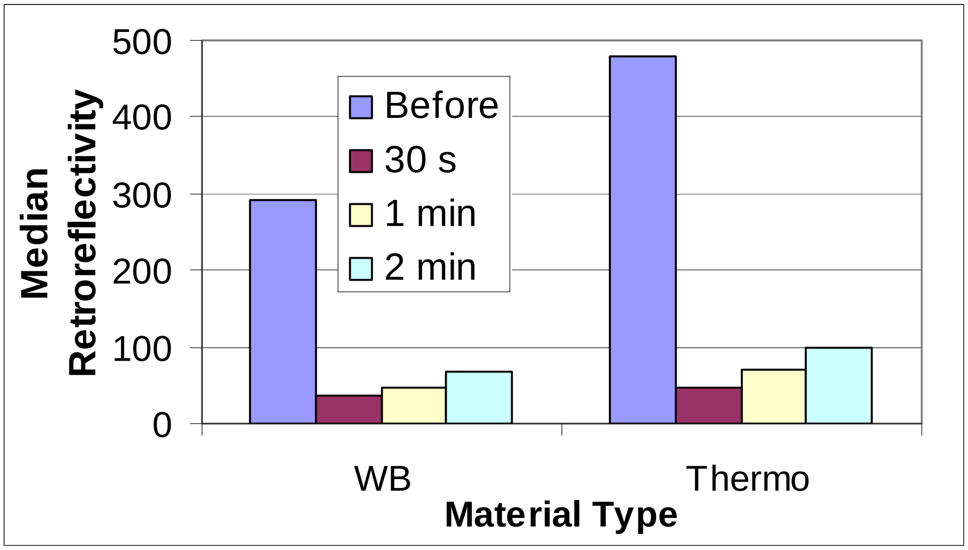


Figure 4.2: White Wetting Study by Material

Figure 4.2 shows the median retroreflectivity observed for waterbased and thermoplastic markings before wetting and 30 seconds, one minute, and two minutes after wetting. This shows the detrimental effect of water on the markings. Several observations were made about the ability of the markings to recover from the initial wetting. One observation pertained to the uniformity of the marking. In some instances, water would puddle on top of the marking, decreasing the recovery of the marking within the two-minute time frame. Another more obvious observation was that sunny weather enabled faster recovery due to the sun drying the water at a faster rate. Because this study was not the focal point of the research, only this minor work was completed. Though developing models to determine the time it takes markings of the two materials to recover from wetness would be beneficial, it was outside the scope of this research.

Pavement Marking Lifetime

The principal goal of this research was to develop degradation models of pavement markings in order to predict marking life. Because of high variability in initial retroreflectivity and the lack of set standards for minimum allowable retroreflectivity, predicting an all-encompassing marking life was not possible. However, it was possible to obtain an estimate of pavement marking life based on certain assumptions.

The first assumption is that the initial value of markings will meet a certain standard. Though these standards have not been set by SCDOT, it is possible that they will be included in future marking application contracts. For the purpose of predicting marking life, the maximum initial value found among all sites for each material were determined. Assuming the initial value is set to 90 percent of this maximum and that the minimum retroreflectivity is 100 mcd/m^2/lux, it becomes possible to predict marking life for all marking configurations using the difference models and their margins of safety. These results are shown in Table 4.15.

Table 4.15: Marking Life Predictions

Material	**Max Initial Value Observed**	**90% of Max Initial Value**	**Marking Life**			
			Days		**Years**	
White Edge (WB)	467	420	1833		5.02	
Yellow Solid (WB)	218	196	1193		3.27	
Yellow Skip (WB)	182	164	1970*		5.40*	
White Edge (T)	501	451	-		-	
Yellow Solid (T)**	320	288	625	1046	1.71	2.87
Yellow Skip (T)**	446	401	757	1509	2.07	4.14

*Based on 10 ft lane width

** Marking Life labeled as | Polynomial | Linear |

One unexpected result was produced from the data in Table 4.15. The marking life for yellow waterbased markings was calculated to be higher than the marking life of yellow thermoplastic markings. This was not expected because of the generally much-higher values of retroreflectivity in thermoplastic markings. Upon obtaining this result, the data was studied further. In the case of the polynomial models, the cause of the shorter marking life was determined to be the steep slope of the yellow thermoplastic polynomial degradation curve after approximately 500 days. However, even the shallower slope of the linear thermoplastic degradation curves resulted in shorter marking lives. This raises the question of whether yellow thermoplastic markings are actually better than yellow waterbased markings. It can be noted that the higher margins of safety applied to the thermoplastic markings had a greater effect on the marking life. Further study using additional rounds of data would be necessary in order to verify these results.

Until further data can be collected, it is recommended that the linear models with a y-intercept of zero be used as the predictive models.

Because the models created were based on 21 months of data collection, it is recommended that these models be used with caution for time periods greater than 21 months after marking placement. Additional data collection is necessary to verify these models for the remainder of pavement marking life.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

The objective of this research was to develop degradation models for waterbased and thermoplastic pavement markings. These models, once fully developed, may be used by the SCDOT to determine how often to replace the pavement markings on primary and secondary roads in South Carolina. The research and analysis included in this thesis fulfilled the objective of creating degradation models, and many important conclusions were drawn. However, there are still some areas where improvement is needed, which are discussed in the *Recommendations* section of this chapter.

Research Conclusions

The degradation models that were developed to predict pavement marking retroreflectivity are shown in Table 5.1. The margins of safety associated with these models are also shown, as they should be used in conjunction with the models as a means of conservativeness.

Table 5.1 Retroreflectivity Degradation Models

Material	**Model**	**R-Squared**	**Margin of Safety**
White Edge (WB)	DIFF = -0.1615 (D)	0.21	24
Yellow Solid (WB)	DIFF = -0.0731 (D)	0.27	9
Yellow Skip (WB)	DIFF = -107.8255 – 0.0330 (D) + 10.8849 (L)	0.17	0
Yellow Solid (T)	DIFF = -0.1176 (D)	0.13	65
Yellow Skip (T)	DIFF = -0.1484 (D)	0.19	77

- Days after application is the most significant variable in retroreflectivity degradation for waterbased and thermoplastic markings. Lane width was also found to be significant in waterbased yellow skip lines. Traffic volume and shoulder width were found to be marginally significant in waterbased white edge lines, but the improvement to the model was not enough to warrant adding the complexity to the model.
- White thermoplastic markings were unable to be modeled because the trend of degradation was positive, meaning that over six rounds of data collection, the markings had an increasing trend in retroreflectivity. Additional rounds of data collection will be required to develop a degradation model for white thermoplastic markings.
- Yellow thermoplastic markings were modeled using a polynomial trend and a linear trend. Though the polynomial trend produced a higher r-squared value, the slope of the trend was a cause for concern. Therefore, the linear trend was chosen

to be the final model. Extra rounds of data collection will be required to either confirm the linear trend or promote use of the polynomial trend.

- The initial retroreflectivity values of markings vary greatly. However, no matter the initial value, markings degrade at the same rate. Difference models were used because of this.
- The direction in which markings are placed is important, especially for waterbased markings. In most cases, the retroreflectivity is higher in the direction of marking placement. For this reason, the lower value should be used when determining marking life.
- Marking wetness greatly affects marking retroreflectivity. In this analysis, data points where wetness was observed were removed from the data set. Marking uniformity and drainage around markings is important in minimizing recovery time from wetness.

Recommendations

- Additional data collection is necessary to produce white thermoplastic models and to improve yellow thermoplastic models. If yellow thermoplastic models still lead to the conclusion that their marking life is less than that of yellow waterbased markings, it is recommended that additional research be done for only yellow markings with an increased sample size. If results are produced that are similar to those found in this research, it is recommended that yellow thermoplastic markings never be used in lieu of yellow waterbased markings.

- Minimum initial values should be set for contractors applying pavement markings. Using minimum initial values enable the models to predict the minimum life of markings. For more accurate results, the initial values should be measured so that the models may be applied. The recommended minimum values, which are 90 percent of the highest initial values observed in this research are shown in Table 5.2.

Table 5.2: Recommended Initial Retroreflectivity

Material	**90% of Max Initial Value**
White Edge (WB)	420
Yellow Solid (WB)	196
Yellow Skip (WB)	164
White Edge (T)	451
Yellow Solid (T)	288
Yellow Skip (T)	401

- If a minimum retroreflectivity threshold is established, it should be extremely low. Currently, a threshold value of 100 mcd/m^2/lux is commonly thought of as the minimum, but under dry conditions, this is still relatively high. Establishing a standard this high will likely result in an increase in litigation when careless drivers leave the travel lane and crash. Forcing DOTs to comply with high minimums will result in increased pavement marking maintenance expenses.

Instead, retroreflectivity goals should be established for guidance on minimum preferred retroreflectivity levels.

After these conclusions and recommendations were produced, the research project was proposed for extension to the SCDOT. This proposal resulted in a project extension of 18 months. This 18-month extension will enable the production of white thermoplastic models as well as improved yellow thermoplastic models. In addition, a third marking material type will be included. The new marking type is high build, which is similar to waterbased markings. High build markings used two glass bead drops, where the second drop contains larger glass beads. It is anticipated that these white high build markings will have a longer marking life than white waterbased markings, but a shorter marking life than white thermoplastic markings.

APPENDICES

Appendix A: Raw Data

Table A.1: Waterbased White Edge Line Raw Data

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
1	1	232	232	27	4,600	0.48	82.6	*	*
2	1	257	257	14	19,200	0.28	82.9	*	0.2
3	1	169	169	13	6,200	0.37	83.8	10	0.2
4	1	116	116	13	11,300	0.58	79.0	10	1.5
5	1	355	355	22	7,500	0.37	84.7	*	2.0
8	1	130	130	15	8,200	0.47	78.8	11	0.0
14	1	337	337	28	1,000	0.35	76.8	11	6.0
24	1	319	319	21	25	0.55	86.0	10	0.0
27	1	261	261	21	50	0.53	87.0	11	1.0
28	1	269	269	21	150	0.52	88.0	10	0.0
29	1	398	398	23	3,700	*	*	10	0.3
30	1	461	461	23	1,850	*	*	10	0.5
31	1	356	356	22	500	*	*	10	0.5
33	1	363	363	17	500	*	*	10	0.5
34	1	363	363	17	600	*	*	10	0.5
35	1	290	290	17	700	*	*	10	0.3
36	1	363	363	17	1,150	*	*	10	0.3
37	1	355	355	17	550	*	*	9	0.2
38	1	314	314	16	150	*	*	*	0.2
39	1	251	251	26	1,450	*	*	10	0.3
40	1	167	167	26	500	*	*	9	*
41	1	166	166	26	500	*	*	9	0.0
42	1	122	122	26	500	*	*	10	5.0
49	1	378	378	20	1,450	*	79.0	10	0.5
50	1	397	397	20	650	*	79.0	10	1.0
51	1	390	390	20	375	*	79.0	10	0.2
52	1	311	311	20	225	*	79.0	10	10.0
53	1	370	370	20	100	*	79.0	9	0.0
54	1	360	360	20	100	*	79.0	9	0.0
55	1	429	429	20	600	*	79.0	10	2.0
56	1	378	378	20	275	*	79.0	9	0.3
57	1	294	294	16	350	*	78.0	10	0.0
58	1	376	376	17	1,850	*	78.0	10	0.3
59	1	419	419	17	3,200	*	78.0	11	0.0
60	1	375	375	17	500	*	78.0	10	0.0
61	1	334	334	17	75	*	78.0	10	0.5
62	1	467	467	17	175	*	78.0	10	0.5
63	1	408	408	17	175	*	78.0	9	0.5
64	1	410	410	16	550	*	78.0	10	0.3

Table A.1: Waterbased White Edge Line (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
115	1	298	298	15	5,300	0.50	88.0	11	*
117	1	332	332	29	425	0.40	87.0	10	*
118	1	237	237	29	325	0.40	87.0	10	0.5
119	1	407	407	29	900	0.40	87.0	11	1.5
120	1	314	314	29	850	0.40	85.0	9	*
151	1	352	352	20	*	0.53	89.2	*	0.5
152	1	172	172	20	*	0.42	95.2	*	0.5
153	1	294	294	20	*	0.43	90.3	*	*
154	1	309	309	19	*	0.41	91.4	*	*
155	1	316	316	19	*	0.38	94.8	*	*
156	1	303	303	19	*	0.40	92.0	*	*
157	1	237	237	18	*	0.39	93.0	*	1.0
1	2	232	240	98	4600	0.32	95.9	*	*
2	2	257	262	98	19200	0.38	80.6	*	0.2
3	2	169	166	98	6200	0.33	89.8	10	0.2
4	2	116	93	98	11300	0.36	89.2	10	1.5
5	2	355	328	98	7500	0.31	90.5	*	2.0
8	2	130	98	93	8200	0.57	77.6	11	0.0
14	2	337	349	96	1000	0.40	94.3	11	6.0
24	2	319	328	110	25	0.47	81.3	10	0.0
27	2	261	294	110	50	0.40	86.0	11	1.0
28	2	269	244	110	150	0.40	86.0	10	0.0
29	2	398	284	131	3700	0.46	71.8	10	0.3
30	2	461	468	131	1850	0.46	71.8	10	0.5
31	2	356	380	116	500	0.30	74.0	10	0.5
33	2	363	261	116	500	0.30	74.0	10	0.5
34	2	363	331	116	600	0.30	74.0	10	0.5
35	2	290	281	116	700	0.30	74.0	10	0.3
36	2	363	339	116	1150	0.30	74.0	10	0.3
37	2	355	353	116	550	0.30	74.0	9	0.2
38	2	314	308	116	150	0.30	74.0	*	0.2
39	2	251	171	116	1450	0.30	80.0	10	0.3
40	2	167	133	116	500	0.35	80.0	9	*
41	2	166	139	116	500	0.31	84.0	9	0.0
42	2	122	99	116	500	0.33	83.0	10	5.0
49	2	378	411	116	1450	0.35	81.0	10	0.5
50	2	397	439	116	650	0.37	83.0	10	1.0
51	2	390	288	116	375	0.37	83.0	10	0.2
52	2	311	171	116	225	0.30	80.0	10	10.0
53	2	370	215	116	100	0.30	80.0	9	0.0
54	2	360	448	116	100	0.27	83.0	9	0.0

Table A.1: Waterbased White Edge Line Raw Data (Continued)

Site #	**Round**	**Initial Retro**	**Median Retro**	**Days After App**	**Traffic Volume**	**Humidity**	**Temp**	**Lane Width**	**Shoulder Width**
55	2	429	483	116	600	0.30	83.0	10	2.0
56	2	378	377	116	275	0.27	83.0	9	0.3
57	2	294	380	110	350	0.38	83.0	10	0.0
58	2	376	254	110	1850	0.38	74.0	10	0.3
59	2	419	390	110	3200	0.35	85.0	11	0.0
60	2	375	327	110	500	0.35	85.0	10	0.0
61	2	334	297	110	75	0.38	84.0	10	0.5
62	2	467	446	110	175	0.35	85.0	10	0.5
63	2	408	401	110	175	0.26	89.0	9	0.5
64	2	410	416	110	550	0.38	84.0	10	0.3
115	2	298	249	113	5300	0.54	88.0	11	*
117	2	332	311	80	425	0.54	75.0	10	*
118	2	237	241	80	325	0.52	75.0	10	0.5
119	2	407	367	80	900	0.52	76.0	11	1.5
120	2	314	298	80	850	0.50	76.0	9	*
152	2	172	139	123	*	0.55	88.3	*	0.5
155	2	316	251	122	*	0.42	81.3	*	*
156	2	303	302	122	*	0.36	80.1	*	*
157	2	237	285	121	*	0.51	85.6	*	1.0
1	3	232	205	256	4600	0.20	29.0	*	*
2	3	257	252	246	19200	0.33	59.0	*	0.2
3	3	169	94	231	6200	0.20	60.0	10	0.2
4	3	116	84	231	11300	0.20	60.0	10	1.5
5	3	355	267	231	7500	0.20	60.0	*	2.0
8	3	130	113	239	8200	0.33	59.0	11	0.0
14	3	337	330	242	1000	0.25	33.0	11	6.0
27	3	261	251	243	50	0.30	70.0	11	1.0
28	3	269	239	243	150	0.31	75.0	10	0.0
29	3	398	319	242	3700	0.27	60.0	10	0.3
30	3	461	419	242	1850	0.27	60.0	10	0.5
31	3	356	339	242	500	0.27	60.0	10	0.5
34	3	363	293	242	600	0.27	60.0	10	0.5
35	3	290	304	242	700	0.27	60.0	10	0.3
36	3	363	323	242	1150	0.27	60.0	10	0.3
37	3	355	355	242	550	0.27	60.0	9	0.2
38	3	314	285	242	150	0.27	60.0	*	0.2
40	3	167	56	256	500	0.30	76.6	9	*
41	3	166	46	256	500	0.30	80.2	9	0.0
42	3	122	83	256	500	0.30	85.3	10	5.0
49	3	378	357	249	1450	0.27	83.0	10	0.5
50	3	397	387	249	650	0.27	88.0	10	1.0

Table A.1: Waterbased White Edge Line Raw Data (Continued)

Site #	**Round**	**Initial Retro**	**Median Retro**	**Days After App**	**Traffic Volume**	**Humidity**	**Temp**	**Lane Width**	**Shoulder Width**
51	3	390	258	249	375	0.27	88.0	10	0.2
53	3	370	268	249	100	0.27	88.0	9	0.0
54	3	360	331	249	100	0.26	88.0	9	0.0
55	3	429	392	249	600	0.26	88.0	10	2.0
56	3	378	350	249	275	0.26	88.0	9	0.3
57	3	294	393	246	350	0.29	82.0	10	0.0
58	3	376	204	246	1850	0.29	82.0	10	0.3
59	3	419	377	246	3200	0.29	80.0	11	0.0
60	3	375	295	246	500	0.29	80.0	10	0.0
61	3	334	282	246	75	0.27	80.0	10	0.5
62	3	467	467	246	175	0.28	83.0	10	0.5
63	3	408	375	246	175	0.27	86.0	9	0.5
64	3	410	397	246	550	0.28	86.0	10	0.3
115	3	298	127	260	5300	0.54	82.0	11	*
117	3	332	313	227	425	0.53	84.0	10	*
118	3	237	196	227	325	0.52	85.0	10	0.5
119	3	407	357	227	900	0.52	85.0	11	1.5
120	3	314	310	227	850	0.50	85.0	9	*
152	3	172	133	202	*	0.35	46.0	*	0.5
155	3	316	247	201	*	0.35	47.0	*	*
156	3	303	257	201	*	0.35	47.0	*	*
157	3	237	229	200	*	0.35	48.0	*	1.0
2	4	257	214	334	19200	0.27	73.0	*	0.2
3	4	169	132	334	6200	0.27	73.0	10	0.2
4	4	116	69	334	11300	0.27	73.0	10	1.5
5	4	355	234	334	7500	0.25	90.0	*	2.0
8	4	130	112	359	8200	0.40	84.0	11	0.0
14	4	337	308	352	1000	0.42	85.0	11	6.0
27	4	261	245	357	50	0.53	80.6	11	1.0
28	4	269	269	357	150	0.50	86.7	10	0.0
29	4	398	337	360	3700	0.71	80.8	10	0.3
30	4	461	372	360	1850	0.62	85.5	10	0.5
31	4	356	373	360	500	0.56	87.6	10	0.5
33	4	363	250	360	500	0.50	93.0	10	0.5
34	4	363	232	360	600	0.48	92.1	10	0.5
35	4	290	338	360	700	0.44	95.0	10	0.3
36	4	363	351	360	1150	0.44	95.0	10	0.3
37	4	355	286	371	550	0.43	89.4	9	0.2
38	4	314	313	360	150	0.44	95.0	*	0.2
39	4	251	159	381	1450	0.48	82.9	10	0.3
40	4	167	76	381	500	0.45	87.4	9	*

Table A.1: Waterbased White Edge Line Raw Data (Continued)

Site #	**Round**	**Initial Retro**	**Median Retro**	**Days After App**	**Traffic Volume**	**Humidity**	**Temp**	**Lane Width**	**Shoulder Width**
41	4	166	80	381	500	0.47	85.5	9	0.0
42	4	122	56	381	500	0.44	87.3	10	5.0
49	4	378	315	356	1450	0.45	88.0	10	0.5
50	4	397	378	356	650	0.46	86.0	10	1.0
51	4	390	303	356	375	0.48	85.5	10	0.2
52	4	311	144	356	225	0.46	86.0	10	10.0
53	4	370	222	356	100	0.46	86.0	9	0.0
54	4	360	324	356	100	0.46	86.0	9	0.0
55	4	429	340	356	600	0.46	84.7	10	2.0
56	4	378	334	356	275	0.43	83.7	9	0.3
57	4	294	376	332	350	0.49	94.0	10	0.0
58	4	376	169	332	1850	0.50	95.0	10	0.3
59	4	419	355	343	3200	0.45	87.8	11	0.0
60	4	375	137	343	500	0.44	88.3	10	0.0
61	4	334	264	332	75	0.56	87.1	10	0.5
62	4	467	389	332	175	0.56	91.0	10	0.5
63	4	408	334	332	175	0.49	93.0	9	0.5
64	4	410	408	332	550	0.49	93.0	10	0.3
117	4	332	306	294	425	0.41	87.0	10	*
118	4	237	196	294	325	0.58	85.0	10	0.5
119	4	407	373	294	900	0.43	87.0	11	1.5
120	4	314	309	294	850	0.48	84.0	9	*
2	5	257	201	439	19200	0.62	79.3	*	0.2
3	5	169	115	438	6200	0.52	83.1	10	0.2
4	5	116	56	438	11300	0.52	84.6	10	1.5
5	5	355	100	447	7500	0.53	82.2	*	2.0
14	5	337	322	460	1000	0.60	80.4	11	6.0
24	5	319	118	464	25	0.44	86.0	10	0.0
27	5	261	238	464	50	0.46	85.0	11	1.0
28	5	269	282	464	150	0.46	85.0	10	0.0
29	5	398	250	470	3700	0.49	76.3	10	0.3
30	5	461	380	470	1850	0.49	76.8	10	0.5
39	5	251	140	487	1450	0.42	68.0	10	0.3
40	5	167	123	487	500	0.41	73.4	9	*
41	5	166	53	487	500	0.39	73.4	9	0.0
42	5	122	40	487	500	0.39	72.0	10	5.0
49	5	378	345	452	1450	0.42	84.6	10	0.5
51	5	390	245	452	375	0.39	84.0	10	0.2
53	5	370	210	452	100	0.39	84.2	9	0.0
55	5	429	353	452	600	0.39	84.4	10	2.0
59	5	419	343	436	3200	0.44	81.0	11	0.0

Table A.1: Waterbased White Edge Line Raw Data (Continued)

Site #	**Round**	**Initial Retro**	**Median Retro**	**Days After App**	**Traffic Volume**	**Humidity**	**Temp**	**Lane Width**	**Shoulder Width**
61	5	334	253	436	75	0.43	76.8	10	0.5
117	5	332	393	475	425	0.34	42.0	10	*
118	5	237	363	475	325	0.26	42.0	10	0.5
119	5	407	264	475	900	0.37	40.0	11	1.5
120	5	314	338	475	850	0.39	36.0	9	*
3	6	169	107	532	6200	0.53	73.4	10	0.2
5	6	355	182	541	7500	0.53	75.0	*	2.0
14	6	337	284	552	1000	0.56	66.0	11	6.0
24	6	319	125	573	25	0.26	52.0	10	0.0
27	6	261	202	573	50	0.26	52.0	11	1.0
28	6	269	222	573	150	0.26	52.0	10	0.0
29	6	398	197	592	3700	0.23	28.0	10	0.3
30	6	461	383	592	1850	0.23	28.0	10	0.5
39	6	251	116	595	1450	0.20	54.0	10	0.3
40	6	167	118	595	500	0.20	54.0	9	*
41	6	166	83	595	500	0.20	55.0	9	0.0
42	6	122	33	595	500	0.20	55.0	10	5.0
49	6	378	273	574	1450	0.21	33.0	10	0.5
51	6	390	300	574	375	0.23	32.0	10	0.2
53	6	370	220	574	100	0.24	32.0	9	0.0
55	6	429	310	574	600	0.24	31.0	10	2.0
59	6	419	265	558	3200	0.23	32.0	11	0.0
61	6	334	264	558	75	0.23	32.0	10	0.5
117	6	332	408	536	425	0.23	63.0	10	*
118	6	237	377	536	325	0.23	63.0	10	0.5
119	6	407	250	536	900	0.24	63.0	11	1.5
120	6	314	328	536	850	0.27	63.0	9	*

Table A.2: Waterbased Yellow Solid Centerline Raw Data

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
2	1	162	162	14	19,200	0.28	82.9	*	0.17
3	1	135	135	13	6,200	0.37	83.8	10	0.17
4	1	166	166	13	11,300	0.58	79	10	1.5
5	1	116	116	22	7,500	0.37	84.7	*	3
6	1	159	159	21	2,900	0.54	78.8	9	*
7	1	149	149	20	8,100	0.42	76.8	11	*
8	1	97	97	15	8,200	0.47	71.6	11	0
12	1	158	158	28	1,000	0.34	75.2	9	*
13	1	155	155	27	6,600	0.35	76.8	10	*
14	1	137	137	28	1,000	0.35	76.8	11	6
24	1	104	104	21	25	0.55	86	10	0
25	1	134	134	21	250	0.54	86	11	0
26	1	61	61	21	450	0.53	87	10	*
27	1	160	160	21	50	0.53	87	11	1
28	1	171	171	21	150	0.52	88	10	0
29	1	218	218	23	3,700	*	*	10	0.33
30	1	155	155	23	1,850	*	*	10	0.5
31	1	176	176	22	500	*	*	10	0.5
32	1	157	157	22	325	*	*	9	0.33
34	1	121	121	17	600	*	*	10	0.5
37	1	147	147	17	550	*	*	9	0.17
38	1	100	100	16	150	*	*	*	0.17
39	1	114	114	26	1,450	*	*	10	0.25
40	1	52	52	26	500	*	*	9	*
41	1	32	32	26	500	*	*	9	0
42	1	44	44	26	500	*	*	10	5
43	1	103	103	24	200	*	*	*	*
44	1	148	148	25	4,700	*	*	19	2
45	1	125	125	25	500	*	*	19	*
46	1	41	41	25	500	*	*	17	*
47	1	62	62	26	500	*	*	17	*
48	1	125	125	26	500	*	*	13	*
49	1	119	119	20	1,450	*	79	10	0.5
50	1	145	145	20	650	*	79	10	1
52	1	122	122	20	225	*	79	10	10
53	1	161	161	20	100	*	79	9	0
54	1	124	124	20	100	*	79	9	0
55	1	189	189	20	600	*	80	10	2
56	1	153	153	20	275	*	80	9	0.33
57	1	195	195	16	350	*	78	10	0

Table A.2: Waterbased Yellow Solid Centerline Raw Data (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
58	1	168	168	17	1,850	*	78	10	0.33
59	1	141	141	17	3,200	*	78	11	0
60	1	167	167	17	500	*	78	10	0
61	1	79	79	17	75	*	79	10	0.5
62	1	195	195	17	175	*	79	10	0.5
63	1	178	178	17	175	*	79	9	0.5
64	1	191	191	16	550	*	79	10	0.33
72	1	132	132	26	1,000	*	*	10	0
109	1	195	195	22	50	0.5	88	*	*
110	1	175	175	23	50	0.50	90	10	*
111	1	168	168	23	250	0.50	93	9.5	*
112	1	129	129	23	60	0.50	90	9.5	*
113	1	171	171	23	60	0.50	90	9	*
114	1	194	194	23	75	0.50	89	10	1
115	1	161	161	15	5,300	0.50	88	11	*
116	1	114	114	29	700	0.45	87	10	*
117	1	108	108	29	425	0.40	87	10	*
118	1	184	184	29	325	0.40	87	10	0.5
119	1	204	204	29	900	0.40	87	11	1.5
120	1	167	167	29	850	0.40	85	9	*
151	1	146	146	20	*	0.53	89.2	*	*
152	1	155	155	20	*	0.42	95.2	*	*
153	1	166	166	20	*	0.43	90.3	*	*
154	1	132	132	19	*	0.41	91.4	*	*
155	1	158	158	19	*	0.38	94.8	*	*
156	1	180	180	19	*	0.40	92	*	*
157	1	120	120	18	*	0.39	93	*	*
2	2	162	162	98	19200	0.38	80.6	*	0.17
3	2	135	124	98	6200	0.33	89.8	10	0.17
4	2	166	149	97	11300	0.36	89.2	10	1.5
5	2	116	114	97	7500	0.31	90.5	*	3
6	2	159	145	93	2900	0.57	77.1	9	*
7	2	149	145	93	8100	0.60	78.1	11	*
8	2	97	94	93	8200	0.57	77.6	11	0
12	2	158	145	96	1000	0.63	79.3	9	*
13	2	155	162	96	6600	0.52	83.8	10	*
14	2	137	121	96	1000	0.40	94.3	11	6
24	2	104	88	110	25	0.47	81.3	10	0
25	2	134	133	110	250	0.47	81.3	11	0
26	2	61	65	110	450	0.40	86	10	*
27	2	160	129	110	50	0.40	86	11	1

Table A.2: Waterbased Yellow Solid Centerline Raw Data (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
28	2	171	160	110	150	0.40	86	10	0
29	2	218	222	131	3700	0.46	71.8	10	0.33
30	2	155	194	131	1850	0.46	71.8	10	0.5
31	2	176	179	116	500	0.30	74	10	0.5
32	2	157	164	116	325	0.30	74	9	0.33
34	2	121	124	116	600	0.30	74	10	0.5
37	2	147	166	116	550	0.30	74	9	0.17
38	2	100	120	116	150	0.30	74	*	0.17
39	2	114	92	116	1450	0.30	80	10	0.25
40	2	52	45	116	500	0.35	80	9	*
41	2	32	31	116	500	0.31	84	9	0
42	2	44	40	116	500	0.33	83	10	5
43	2	103	112	139	200	0.31	82.6	*	*
44	2	148	153	116	4700	0.33	84.7	19	2
45	2	125	122	116	500	0.33	84.7	19	*
46	2	41	39	116	500	0.31	83.5	17	*
47	2	62	60	116	500	0.31	82.8	17	*
48	2	125	127	116	500	0.33	83	13	*
49	2	119	146	116	1450	0.35	81	10	0.5
50	2	145	167	116	650	0.37	83	10	1
52	2	122	135	116	225	0.30	80	10	10
53	2	161	181	116	100	0.30	80	9	0
54	2	124	153	116	100	0.27	80	9	0
55	2	189	215	116	600	0.30	83	10	2
56	2	153	183	116	275	0.27	83	9	0.33
57	2	195	192	110	350	0.38	74	10	0
58	2	168	150	110	1850	0.38	74	10	0.33
59	2	141	136	110	3200	0.35	85	11	0
60	2	167	133	110	500	0.35	85	10	0
61	2	79	69	110	75	0.38	84	10	0.5
62	2	195	187	110	175	0.35	85	10	0.5
63	2	178	170	110	175	0.26	89	9	0.5
64	2	191	186	110	550	0.38	84	10	0.33
72	2	132	130	96	1000	0.31	78	10	0
109	2	195	180	134	50	0.67	72	*	*
110	2	175	167	113	50	0.54	77	10	*
111	2	168	135	113	250	0.67	67	9.5	*
112	2	129	118	113	60	0.67	69	9.5	*
113	2	171	145	113	60	0.65	69	9	*
114	2	194	167	113	75	0.64	72	10	1
115	2	161	99	113	5300	0.54	78	11	*

Table A.2: Waterbased Yellow Solid Centerline Raw Data (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
116	2	114	112	80	700	0.54	75	10	*
117	2	108	105	80	425	0.54	75	10	*
118	2	184	175	80	325	0.52	75	10	0.5
119	2	204	189	80	900	0.52	76	11	1.5
120	2	167	142	80	850	0.50	76	9	*
152	2	155	130	123	*	0.55	83.3	*	*
155	2	158	149	122	*	0.42	81.3	*	*
156	2	180	187	122	*	0.46	80.1	*	*
157	2	120	89	121	*	0.51	85.6	*	*
2	3	162	143	246	19200	0.33	59	*	0.17
3	3	135	102	231	6200	0.20	60	10	0.17
4	3	166	150	230	11300	0.20	60	10	1.5
5	3	116	72	230	7500	0.20	60	*	3
6	3	159	99	239	2900	0.33	59	9	*
7	3	149	136	239	8100	0.33	59	11	*
8	3	97	100	239	8200	0.33	59	11	0
12	3	158	128	242	1000	0.25	33	9	*
13	3	155	149	242	6600	0.25	33	10	*
14	3	137	117	242	1000	0.25	33	11	6
24	3	104	93	243	25	0.31	68	10	0
25	3	134	132	243	250	0.31	68	11	0
26	3	61	71	243	450	0.32	70	10	*
27	3	160	128	243	50	0.30	70	11	1
28	3	171	144	243	150	0.31	75	10	0
29	3	218	155	242	3700	0.27	60	10	0.33
30	3	155	130	242	1850	0.27	60	10	0.5
31	3	176	158	242	500	0.27	60	10	0.5
32	3	157	149	242	325	0.27	60	9	0.33
34	3	121	108	242	600	0.27	60	10	0.5
37	3	147	149	242	550	0.27	60	9	0.17
38	3	100	112	242	150	0.27	60	*	0.17
40	3	52	28	256	500	0.30	76.6	9	*
41	3	32	26	256	500	0.30	82	9	0
42	3	44	33	256	500	0.30	85.3	10	5
43	3	103	54	279	200	0.29	83.7	*	*
44	3	148	56	256	4700	0.30	82.2	19	2
45	3	125	95	256	500	0.30	82.9	19	*
46	3	41	28	256	500	0.31	82	17	*
47	3	62	40	256	500	0.30	84.7	17	*
48	3	125	53	256	500	0.31	84.2	13	*
49	3	119	121	249	1450	0.27	83	10	0.5

Table A.2: Waterbased Yellow Solid Centerline Raw Data (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
50	3	145	142	249	650	0.27	88	10	1
52	3	122	82	249	225	0.27	88	10	10
53	3	161	111	249	100	0.27	88	9	0
54	3	124	120	249	100	0.26	88	9	0
55	3	189	156	249	600	0.26	88	10	2
56	3	153	149	249	275	0.26	88	9	0.33
57	3	195	169	246	350	0.29	82	10	0
58	3	168	106	246	1850	0.29	82	10	0.33
59	3	141	103	246	3200	0.29	80	11	0
60	3	167	112	246	500	0.29	80	10	0
61	3	79	60	246	75	0.27	80	10	0.5
62	3	195	182	246	175	0.28	83	10	0.5
63	3	178	149	246	175	0.27	86	9	0.5
64	3	191	177	246	550	0.28	86	10	0.33
72	3	132	123	227	1000	0.39	79	10	0
109	3	195	195	281	50	0.50	83	*	*
110	3	175	173	260	50	0.49	82	10	*
111	3	168	143	260	250	0.50	83	9.5	*
112	3	129	116	260	60	0.46	83	9.5	*
113	3	171	129	260	60	0.48	84	9	*
114	3	194	171	260	75	0.47	83	10	1
115	3	161	72	260	5300	0.54	82	11	*
116	3	114	101	227	700	0.48	82	10	*
117	3	108	101	227	425	0.53	84	10	*
118	3	184	184	227	325	0.52	85	10	0.5
119	3	204	184	227	900	0.52	85	11	1.5
120	3	167	139	227	850	0.50	85	9	*
152	3	155	102	202	*	0.35	46	*	*
155	3	158	128	201	*	0.35	47	*	*
156	3	180	169	201	*	0.35	47	*	*
157	3	120	67	200	*	0.35	48	*	*
2	4	162	161	334	19200	0.27	73	*	0.17
3	4	135	78	334	6200	0.27	73	10	0.17
4	4	166	145	333	11300	0.27	73	10	1.5
5	4	116	60	333	7500	0.25	90	*	3
6	4	159	88	327	2900	0.26	90	9	*
7	4	149	115	327	8100	0.26	90	11	*
8	4	97	99	359	8200	0.40	84	11	0
12	4	158	125	352	1000	0.40	84	9	*
13	4	155	129	352	6600	0.40	84	10	*
14	4	137	101	352	1000	0.42	85	11	6

Table A.2: Waterbased Yellow Solid Centerline Raw Data (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
24	4	104	63	357	25	0.53	81.7	10	0
25	4	134	125	357	250	0.41	91	11	0
26	4	61	58	357	450	0.48	83.5	10	*
27	4	160	126	357	50	0.53	80.6	11	1
28	4	171	146	357	150	0.50	86.7	10	0
29	4	218	162	360	3700	0.71	80.8	10	0.33
30	4	155	162	360	1850	0.62	85.5	10	0.5
31	4	176	168	360	500	0.56	87.6	10	0.5
32	4	157	150	360	325	0.55	89.4	9	0.33
34	4	121	99	360	600	0.48	92.1	10	0.5
37	4	147	150	371	550	0.43	89.4	9	0.17
38	4	100	101	360	150	0.44	95	*	0.17
39	4	114	65	381	1450	0.48	82.9	10	0.25
40	4	52	30	381	500	0.45	87.4	9	*
41	4	32	23	381	500	0.47	85.5	9	0
42	4	44	28	381	500	0.44	87.3	10	5
44	4	148	97	381	4700	0.47	87	19	2
45	4	125	99	381	500	0.40	87.8	19	*
46	4	41	23	381	500	0.40	87.8	17	*
47	4	62	36	381	500	0.40	87.8	17	*
48	4	125	66	381	500	0.40	87.8	13	*
49	4	119	117	356	1450	0.45	88	10	0.5
50	4	145	142	356	650	0.46	86	10	1
52	4	122	84	356	225	0.46	86	10	10
53	4	161	112	356	100	0.46	86	9	0
54	4	124	116	356	100	0.46	86	9	0
55	4	189	141	356	600	0.46	84.7	10	2
56	4	153	145	356	275	0.43	83.7	9	0.33
57	4	195	169	332	350	0.49	94	10	0
58	4	168	108	332	1850	0.50	95	10	0.33
59	4	141	98	343	3200	0.45	87.8	11	0
60	4	167	90	343	500	0.44	88.3	10	0
61	4	79	56	332	75	0.56	87.1	10	0.5
62	4	195	176	332	175	0.56	91	10	0.5
63	4	178	128	332	175	0.49	93	9	0.5
64	4	191	168	332	550	0.49	93	10	0.33
72	4	132	115	323	1000	0.42	89.6	10	0
110	4	175	157	327	50	0.59	84	10	*
111	4	168	180	327	250	0.66	86	9.5	*
112	4	129	119	327	60	0.63	87	9.5	*
113	4	171	131	327	60	0.57	86	9	*

Table A.2: Waterbased Yellow Solid Centerline Raw Data (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
114	4	194	227	327	75	0.57	86	10	1
115	4	161	167	327	5300	0.55	86	11	*
116	4	114	101	294	700	0.49	85	10	*
117	4	108	101	294	425	0.41	87	10	*
118	4	184	182	294	325	0.58	85	10	0.5
119	4	204	193	294	900	0.43	87	11	1.5
120	4	167	140	294	850	0.48	84	9	*
2	5	162	152	439	19200	0.62	79.3	*	0.17
3	5	135	79	438	6200	0.52	83.1	10	0.17
4	5	166	137	438	11300	0.52	84.6	10	1.5
5	5	116	41	447	7500	0.53	82.2	*	3
6	5	159	71	439	2900	0.60	78.3	9	*
7	5	149	82	438	8100	0.60	78.8	11	*
12	5	158	125	460	1000	0.58	76.8	9	*
13	5	155	130	459	6600	0.61	79.1	10	*
14	5	137	89	460	1000	0.6	80.4	11	6
24	5	104	62	464	25	0.44	86	10	0
25	5	134	119	464	250	0.44	86	11	0
26	5	61	47	464	450	0.44	86	10	*
27	5	160	124	464	50	0.46	85	11	1
28	5	171	149	464	150	0.46	85	10	0
29	5	218	156	470	3700	0.49	76.3	10	0.33
30	5	155	163	470	1850	0.49	76.8	10	0.5
39	5	114	72	487	1450	0.42	68	10	0.25
40	5	52	29	487	500	0.41	73.4	9	*
41	5	32	22	487	500	0.39	73.4	9	0
42	5	44	30	487	500	0.39	72	10	5
44	5	148	91	486	4700	0.37	75	19	2
45	5	125	94	486	500	0.37	76	19	*
46	5	41	23	486	500	0.37	76	17	*
47	5	62	62	487	500	0.35	76	17	*
48	5	125	38	487	500	0.35	76	13	*
49	5	119	119	452	1450	0.42	84.6	10	0.5
53	5	161	116	452	100	0.39	84.2	9	0
55	5	189	135	452	600	0.39	84.4	10	2
59	5	141	94	436	3200	0.44	81	11	0
61	5	79	58	436	75	0.43	76.8	10	0.5
72	5	132	111	425	1000	0.44	82.8	10	0
110	5	175	163	502	50	0.28	50	10	*
111	5	168	165	502	250	0.29	50	9.5	*
112	5	129	113	502	60	0.30	50	9.5	*

Table A.2: Waterbased Yellow Solid Centerline Raw Data (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
113	5	171	116	502	60	0.32	49	9	*
114	5	194	203	502	75	0.32	45	10	1
115	5	161	95	492	5300	0.23	53	11	*
116	5	114	73	475	700	0.27	43	10	*
117	5	108	150	475	425	0.34	42	10	*
118	5	184	168	475	325	0.26	42	10	0.5
119	5	204	57	475	900	0.37	40	11	1.5
120	5	167	160	475	850	0.39	36	9	*
3	6	135	65	532	6200	0.53	73.4	10	0.17
5	6	116	41	541	7500	0.53	75	*	3
6	6	159	58	533	2900	0.57	71	9	*
12	6	158	111	552	1000	0.40	72	9	*
14	6	137	81	552	1000	0.56	66	11	6
24	6	104	51	573	25	0.26	52	10	0
25	6	134	111	573	250	0.26	52	11	0
26	6	61	50	573	450	0.26	52	10	*
27	6	160	112	573	50	0.26	52	11	1
28	6	171	129	573	150	0.26	52	10	0
29	6	218	149	592	3700	0.23	28	10	0.33
30	6	155	160	592	1850	0.23	29	10	0.5
39	6	114	65	595	1450	0.20	54	10	0.25
40	6	52	30	595	500	0.20	54	9	*
41	6	32	24	595	500	0.20	55	9	0
42	6	44	27	595	500	0.20	55	10	5
44	6	148	84	594	4700	0.20	56	19	2
45	6	125	82	594	500	0.20	56	19	*
46	6	41	19	594	500	0.20	56	17	*
47	6	62	32	595	500	0.20	56	17	*
48	6	125	50	595	500	0.20	56	13	*
49	6	119	116	574	1450	0.21	33	10	0.5
53	6	161	88	574	100	0.24	32	9	0
55	6	189	130	574	600	0.24	31	10	2
59	6	141	99	558	3200	0.23	32	11	0
61	6	79	53	558	75	0.23	32	10	0.5
72	6	132	87	547	1000	0.22	33	10	0
110	6	175	152	563	50	0.24	60	10	*
111	6	168	135	563	250	0.23	63	9.5	*
112	6	129	111.5	563	60	0.23	63	9.5	*

Table A.2: Waterbased Yellow Solid Centerline Raw Data (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
113	6	171	105	563	60	0.22	63	9	*
114	6	194	199	563	75	0.22	64	10	1
115	6	161	81	545	5300	0.23	60	11	*
116	6	114	74	536	700	0.22	63	10	*
117	6	108	154	536	425	0.23	63	10	*
118	6	184	160	536	325	0.23	63	10	0.5
119	6	204	57	536	900	0.24	63	11	1.5
120	6	167	145	536	850	0.27	63	9	*

Table A.3: Waterbased Yellow Skip Line Raw Data

Site #	**Round**	**Initial Retro**	**Median Retro**	**Days After App**	**Traffic Volume**	**Humidity**	**Temp**	**Lane Width**	**Shoulder Width**
1	1	181.5	181.5	27	4600	0.48	82.6	*	*
25	1	130	130	21	250	0.54	86	11	0
28	1	142	142	21	150	0.52	88	10	0
30	1	145.5	145.5	23	1850	*	*	10	0.5
31	1	172.5	172.5	22	500	*	*	10	0.5
32	1	160	160	22	325	*	*	9	0.33
34	1	125	125	17	600	*	*	10	0.5
35	1	128	128	17	700	*	*	10	0.33
36	1	102	102	17	1150	*	*	10	0.33
51	1	173	173	20	375	*	79	10	0.17
151	1	168.5	168.5	20	*	0.53	89.2	*	*
153	1	156.5	156.5	20	*	0.43	90.3	*	*
156	1	169	169	19	*	0.40	92	*	*
1	2	181.5	173	98	4600	0.32	95.9	*	*
25	2	130	124	110	250	0.47	81.3	11	0
28	2	142	138	110	150	0.40	86	10	0
30	2	145.5	166.5	131	1850	0.46	71.8	10	0.5
31	2	172.5	170	116	500	0.30	74	10	0.5
32	2	160	139.5	116	325	0.30	74	9	0.33
34	2	125	120.5	116	600	0.30	74	10	0.5
35	2	128	140.5	116	700	0.30	74	10	0.33
36	2	102	103.5	116	1150	0.30	74	10	0.33
51	2	173	201.5	116	375	0.37	83	10	0.17
156	2	169	148.5	122	*	0.46	80.1	*	*
1	3	181.5	174.5	256	4600	0.20	29	*	*
25	3	130	140.5	243	250	0.31	68	11	0
28	3	142	116.5	243	150	0.31	75	10	0
30	3	145.5	104	242	1850	0.27	60	10	0.5
31	3	172.5	137.5	242	500	0.27	60	10	0.5
32	3	160	128	242	325	0.27	60	9	0.33
34	3	125	104.5	242	600	0.27	60	10	0.5
35	3	128	127	242	700	0.27	60	10	0.33
36	3	102	110.5	242	1150	0.27	60	10	0.33
51	3	173	171.5	249	375	0.27	88	10	0.17
156	3	169	144.5	201	*	0.35	47	*	*
1	4	182	154	366	4600	*	77	*	*
25	4	130	124.5	357	250	0.41	91	11	0
28	4	142	117	357	150	0.50	86.7	10	0
30	4	145.5	148.5	360	1850	0.62	85.5	10	0.5
31	4	172.5	138.5	360	500	0.56	87.6	10	0.5

Table A.3: Waterbased Yellow Skip Line Raw Data (Continued)

Site #	**Round**	**Initial Retro**	**Median Retro**	**Days After App**	**Traffic Volume**	**Humidity**	**Temp**	**Lane Width**	**Shoulder Width**
32	4	160	131.5	360	325	0.55	89.4	9	0.33
34	4	125	92.5	360	600	0.48	92.1	10	0.5
35	4	128	149.5	360	700	0.44	95	10	0.33
36	4	102	99	360	1150	0.44	95	10	0.33
51	4	173	179.5	356	375	0.48	85.5	10	0.17
25	5	130	135	464	250	0.44	86	11	0
28	5	142	115	464	150	0.46	85	10	0
30	5	145.5	147	470	1850	0.49	76.8	10	0.5
51	5	173	183	452	375	0.39	84	10	0.17
25	6	130	122	573	250	0.26	52	11	0
28	6	142	88.5	573	150	0.26	52	10	0
30	6	145.5	142.5	592	1850	0.23	29	10	0.5
51	6	173	168	574	375	0.23	32	10	0.17

Table A.4: Thermoplastic White Edge Line Raw Data

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
15	1	501	501	21	6300	0.42	84	11	12
16	1	449	449	21	4700	0.42	86	12	*
17	1	461	461	20	250	0.42	87	10	1
18	1	449	449	17	2600	0.55	88	11	0.5
19	1	446	446	9	4400	0.51	91	11	0.5
20	1	331	331	17	7000	0.51	91	11	0.5
21	1	455	455	25	8600	0.45	93	12	0.5
23	1	429	429	16	100	0.36	90	11	1
76	1	430	430	22	22000	*	*	*	*
80	1	446	446	23	4800	0.57	73.8	10	14
81	1	435	435	35	1000	0.55	76.5	10	0
82	1	460	460	36	1800	0.47	81.5	10	1
83	1	459	459	34	1500	0.41	90.9	9	2
84	1	418	418	33	1650	0.42	83.3	10	2
85	1	462	462	35	4800	0.46	79.3	10	0
100	1	435	435	15	15700	0.51	84	12	5
101	1	395	395	18	1750	0.35	103	12	2
102	1	458	458	25	7000	0.75	90	11	2
103	1	344	344	42	750	0.5	91	11	2
104	1	288	288	29	500	0.4	95	11	2
105	1	388	388	30	250	0.4	96	10	2
106	1	380	380	35	19300	0.66	95	12	2
107	1	400	400	35	3700	0.62	96	10.5	0.5
108	1	404	404	29	7600	0.72	86	11	*
15	2	501	505	116	6300	0.40	109	11	12
16	2	449	347	116	4700	0.35	104.7	12	*
17	2	461	528	115	250	0.28	104	10	1
18	2	449	597	119	2600	0.57	93.9	11	0.5
19	2	446	509	119	4400	0.57	93.9	11	0.5
20	2	331	387	119	7000	0.41	90	11	0.5
21	2	455	411	127	8600	0.48	90	12	0.5
23	2	429	469	123	100	0.47	74	11	1
76	2	430	381	134	22000	0.31	70	*	*
80	2	446	429	113	4800	0.43	94.1	10	14
81	2	435	485	125	1000	0.45	94.6	10	0
82	2	460	472	126	1800	0.47	94.1	10	1
83	2	459	437	124	1500	0.61	87.3	9	2
84	2	418	424	123	1650	0.66	83.5	10	2
85	2	462	482	125	4800	0.40	97.2	10	0
100	2	435	509	115	15700	0.60	87	12	5

Table A.4: Thermoplastic White Edge Line Raw Data (Continued)

Site #	**Round**	**Initial Retro**	**Median Retro**	**Days After App**	**Traffic Volume**	**Humidity**	**Temp**	**Lane Width**	**Shoulder Width**
101	2	395	509	123	1750	0.40	77	12	2
102	2	458	485	143	7000	0.40	73	11	2
103	2	344	393	143	750	0.40	77	11	2
104	2	288	505	130	500	0.40	77	11	2
105	2	388	452	131	250	0.40	76	10	2
106	2	380	421	148	19300	0.80	72	12	2
107	2	400	407	148	3700	0.81	75	10.5	0.5
108	2	404	337	142	7600	0.81	73	11	*
15	3	501	240	258	6300	0.25	34	11	12
16	3	449	396	258	4700	0.25	35	12	*
18	3	449	673	240	2600	0.20	70	11	0.5
19	3	446	522	240	4400	0.20	70	11	0.5
20	3	331	266	258	7000	0.20	65	11	0.5
21	3	455	516	266	8600	0.20	65	12	0.5
23	3	429	575	263	100	0.20	74.8	11	1
76	3	430	417	249	22000	0.20	90	*	*
80	3	446	488.5	222	4800	0.32	66	10	14
81	3	435	473	234	1000	0.39	57	10	0
82	3	460	511	235	1800	0.41	57	10	1
83	3	459	534	233	1500	0.40	61	9	2
84	3	418	479	232	1650	0.39	61	10	2
85	3	462	514	234	4800	0.39	59	10	0
100	3	435	533	227	15700	0.58	78	12	5
101	3	395	510	217	1750	*	48	12	2
102	3	458	349	281	7000	0.40	70	11	2
103	3	344	366	281	750	0.24	68	11	2
104	3	288	641	268	500	0.25	69	11	2
105	3	388	575	269	250	0.22	66	10	2
106	3	380	449	245	19300	0.62	50	12	2
107	3	400	443	245	3700	0.25	68	10.5	0.5
108	3	404	401	291	7600	0.65	77	11	*
15	4	501	319	370	6300	0.54	76.3	11	12
17	4	461	391	369	250	0.49	82.2	10	1
18	4	449	734	370	2600	0.52	85	11	0.5
19	4	446	617	370	4400	0.52	85	11	0.5
20	4	331	297	370	7000	0.53	85	11	0.5
21	4	455	443	378	8600	0.42	85	12	0.5
23	4	429	549	371	100	0.52	85	11	1
76	4	430	377	294	22000	0.42	85	*	*
80	4	446	365	300	4800	0.25	48	10	14

Table A.4: Thermoplastic White Edge Line Raw Data (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
82	4	460	504	313	1800	0.28	49	10	1
83	4	459	496	311	1500	0.25	49	9	2
84	4	418	280	310	1650	0.25	49	10	2
85	4	462	494	312	4800	0.28	48	10	0
100	4	435	578	374	15700	0.51	80	12	5
101	4	395	420	356	1750	0.49	76	12	2
102	4	458	509	399	7000	0.40	79	11	2
103	4	344	450	103	750	0.41	82.8	11	2
104	4	288	597	380	500	0.37	85.1	11	2
105	4	388	670	381	250	0.30	88	10	2
106	4	380	584	363	19300	0.63	73	12	2
107	4	400	536	363	3700	0.60	73	10.5	0.5
108	4	404	500	361	7600	0.61	79	11	*
15	5	501	338	461	6300	0.49	90.5	11	12
16	5	449	490	461	4700	0.57	87.3	12	*
17	5	461	418	460	250	0.39	92	10	1
18	5	449	658	456	2600	0.67	81.3	11	0.5
19	5	446	642	456	4400	0.55	87.4	11	0.5
20	5	331	291	456	7000	0.45	90.3	11	0.5
21	5	455	525	464	8600	0.48	92.7	12	0.5
23	5	429	625	456	100	0.44	82.6	11	1
76	5	430	277	409	22000	0.5	85.3	*	*
100	5	435	665	415	15700	0.68	86	12	5
101	5	395	584	416	1750	0.56	85	12	2
102	5	458	373	551	7000	0.27	44	11	2
103	5	344	466	492	750	0.38	71	11	2
104	5	288	599	479	500	0.38	71	11	2
105	5	388	651	480	250	0.34	71	10	2
107	5	400	555	515	3700	0.35	42	10.5	0.5
108	5	404	475	509	7600	0.24	52	11	*
15	6	501	239	569	6300	0.52	57	11	12
17	6	461	261	568	250	0.53	67	10	1
21	6	455	491	588	8600	0.30	42	12	0.5
23	6	429	689	569	100	0.30	46	11	1
100	6	435	660	593	15700	0.25	57	12	5
101	6	395	548	568	1750	0.33	43	12	2
102	6	458	335	612	7000	0.23	46	11	2

Table A.4: Thermoplastic White Edge Line Raw Data (Continued)

Site #	**Round**	**Initial Retro**	**Median Retro**	**Days After App**	**Traffic Volume**	**Humidity**	**Temp**	**Lane Width**	**Shoulder Width**
103	6	344	376	621	750	0.20	48	11	2
104	6	288	637	608	500	0.20	48	11	2
105	6	388	761	609	250	0.20	50	10	2
107	6	400	554	576	3700	0.29	52	10.5	0.5
108	6	404	450	573	7600	0.54	50	11	*

Table A.5: Thermoplastic Yellow Solid Centerline Raw Data

Site #	**Round**	**Initial Retro**	**Median Retro**	**Days After App**	**Traffic Volume**	**Humidity**	**Temp**	**Lane Width**	**Shoulder Width**
15	1	260	260	21	6300	0.42	84	11	12
18	1	272	272	17	2600	0.55	88	11	0.5
20	1	211	211	17	7000	0.51	91	11	0.5
21	1	266	266	25	8600	0.45	93	12	0.5
22	1	263	263	21	5200	0.40	93	*	*
23	1	302	302	16	100	0.36	90	11	1
70	1	285	285	25	200	*	*	10	0
71	1	301	301	25	275	*	*	13	0
73	1	320	320	25	600	*	*	10	0
74	1	193	193	21	25000	*	*	*	*
75	1	245	245	21	25000	*	*	*	*
76	1	262	262	22	22000	*	*	*	*
85	1	256	256	35	4800	0.46	79.3	10	0
100	1	224	224	15	15700	0.51	84	12	5
101	1	154	154	18	1750	0.35	103	12	2
102	1	307	307	25	7000	0.75	90	11	2
103	1	207	207	42	750	0.50	91	11	2
104	1	185	185	29	500	0.40	95	11	2
15	2	260	287	116	6300	0.40	109	11	12
18	2	272	359	119	2600	0.57	93.9	11	0.5
20	2	211	132	119	7000	0.41	90	11	0.5
21	2	266	293	127	8600	0.48	90	12	0.5
22	2	263	287	128	5200	0.47	74	*	*
23	2	302	409	123	100	0.47	74	11	1
70	2	285	318	120	200	0.32	74	10	0
71	2	301	265	120	275	0.30	78.3	13	0
73	2	320	309	120	600	0.32	76	10	0
74	2	193	159	133	25000	0.31	70	*	*
75	2	245	197	133	25000	0.31	70	*	*
76	2	262	231	134	22000	0.31	70	*	*
85	2	256	252	125	4800	0.40	97.2	10	0
100	2	224	317	115	15700	0.60	87	12	5
101	2	154	171	123	1750	0.40	77	12	2
102	2	307	345	143	7000	0.40	73	11	2
103	2	207	142	143	750	0.40	77	11	2
104	2	185	326	130	500	0.40	77	11	2
15	3	260	182	258	6300	0.25	34	11	12
18	3	272	316	240	2600	0.20	70	11	0.5
20	3	211	66	258	7000	0.20	65	11	0.5
21	3	266	195	266	8600	0.20	65	12	0.5
22	3	263	284	268	5200	0.20	74.8	*	*

Table A.5: Thermoplastic Yellow Solid Centerline Raw Data (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
23	3	302	384	263	100	0.20	74.8	11	1
70	3	285	310	251	200	0.22	87	10	0
71	3	301	251	251	275	0.39	79	13	0
73	3	320	302	251	600	0.21	87	10	0
74	3	193	140	248	25000	0.20	90	*	*
75	3	245	178	248	25000	0.20	90	*	*
76	3	262	188	249	22000	0.20	90	*	*
85	3	256	273	234	4800	0.39	59	10	0
100	3	224	321	227	15700	0.58	78	12	5
101	3	154	202	217	1750	*	48	12	2
102	3	307	313	281	7000	0.40	70	11	2
103	3	207	58	281	750	0.24	68	11	2
104	3	185	320	268	500	0.25	69	11	2
15	4	260	147	370	6300	0.54	76.3	11	12
18	4	272	311	370	2600	0.52	85	11	0.5
20	4	211	96	370	7000	0.53	85	11	0.5
21	4	266	131	378	8600	0.42	85	12	0.5
22	4	263	129	376	5200	*	*	*	*
23	4	302	420	371	100	0.52	85	11	1
70	4	285	352	347	200	0.44	88.9	10	0
71	4	301	332	347	275	0.42	89.6	13	0
73	4	320	345	347	600	0.21	87	10	0
74	4	193	117	293	25000	0.20	90	*	*
75	4	245	187	294	25000	0.20	90	*	*
76	4	262	194	294	22000	0.42	85	*	*
85	4	256	241	312	4800	0.28	48	10	0
100	4	224	321	374	15700	0.51	80	12	5
101	4	154	207	356	1750	0.49	76	12	2
102	4	307	255	399	7000	0.40	79	11	2
103	4	207	93	393	750	0.41	82.8	11	2
104	4	185	344	380	500	0.37	85.1	11	2
15	5	260	181	461	6300	0.49	90.5	11	12
18	5	272	188	456	2600	0.67	81.3	11	0.5
20	5	211	102	456	7000	0.45	90.3	11	0.5
21	5	266	158	464	8600	0.48	92.7	12	0.5
22	5	263	141	461	5200	0.63	79.5	*	*
23	5	302	443	456	100	0.44	82.6	11	1
70	5	285	421	425	200	0.41	79.2	10	0
71	5	301	134	425	275	0.44	82	13	0
73	5	320	174	425	600	0.44	83.5	10	0
74	5	193	56	408	25000	0.54	82.8	*	*

Table A.5: Thermoplastic Yellow Solid Centerline Raw Data (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
75	5	245	178	408	25000	0.52	84	*	*
76	5	262	180	409	22000	0.50	85.3	*	*
100	5	224	201	415	15700	0.68	86	12	5
101	5	154	241	416	1750	0.56	85	12	2
102	5	307	129	551	7000	0.27	44	11	2
103	5	207	101	492	750	0.38	71	11	2
104	5	185	188	479	500	0.38	71	11	2
15	6	260	139	569	6300	0.52	57	11	12
18	6	272	172	580	2600	0.30	52	11	0.5
21	6	266	104	588	8600	0.30	42	12	0.5
22	6	263	149	574	5200	0.30	42	*	*
23	6	302	435	569	100	0.30	46	11	1
70	6	285	353	547	200	0.23	32	10	0
71	6	301	106	547	275	0.22	32	13	0
73	6	320	118	547	600	0.22	33	10	0
75	6	245	119	520	25000	0.30	48	*	*
100	6	224	136	593	15700	0.25	57	12	5
101	6	154	158	568	1750	0.33	43	12	2
102	6	307	123	612	7000	0.23	46	11	2
103	6	207	56	621	750	0.20	48	11	2
104	6	185	84	608	500	0.20	48	11	2

Table A.6: Thermoplastic Yellow Skip Line Raw Data

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
15	1	270	270	21	6300	0.42	84	11	12
16	1	276.5	276.5	21	4700	0.42	86	12	*
17	1	281	281	20	250	0.42	87	10	1
19	1	257.5	257.5	17	4400	0.51	91	11	0.5
21	1	446	446	25	8600	0.45	93	12	0.5
81	1	264.5	264.5	35	1000	0.55	76.5	10	0
82	1	301	301	36	1800	0.47	81.5	10	1
83	1	290.5	290.5	34	1500	0.41	90.9	9	2
84	1	266.5	266.5	33	1650	0.42	83.3	10	2
100	1	207	207	15	15700	0.51	84	12	5
102	1	304.5	304.5	25	7000	0.75	90	11	2
105	1	212	212	30	250	0.4	96	10	2
106	1	437.5	437.5	35	19300	0.66	95	12	2
107	1	274.5	274.5	35	3700	0.62	96	10.5	0.5
108	1	266.5	266.5	29	7600	0.72	86	11	*
15	2	270	271	116	6300	0.40	109	11	12
16	2	276.5	270.5	116	4700	0.35	104.7	12	*
17	2	281	262	115	250	0.28	104	10	1
19	2	257.5	241.5	119	4400	0.57	93.9	11	0.5
21	2	446	498.5	127	8600	0.48	90	12	0.5
81	2	264.5	242	125	1000	0.45	94.6	10	0
82	2	301	303.5	126	1800	0.47	94.1	10	1
83	2	290.5	268	124	1500	0.61	87.3	9	2
84	2	266.5	274	123	1650	0.66	83.5	10	2
100	2	207	330	115	15700	0.60	87	12	5
102	2	304.5	336.5	143	7000	0.40	73	11	2
105	2	212	328.5	131	250	0.40	76	10	2
106	2	437.5	433	148	19300	0.80	72	12	2
107	2	274.5	230.5	148	3700	0.81	75	10.5	0.5
108	2	266.5	263.5	142	7600	0.81	73	11	*
15	3	270	205.5	258	6300	0.25	34	11	12
16	3	276.5	131.5	258	4700	0.25	35	12	*
19	3	257.5	121	240	4400	0.20	70	11	0.5
21	3	446	442.5	266	8600	0.20	65	12	0.5
81	3	264.5	248.5	234	1000	0.39	57	10	0
82	3	301	316.5	235	1800	0.41	57	10	1
83	3	290.5	298	233	1500	0.40	61	9	2
84	3	266.5	303	232	1650	0.39	61	10	2
100	3	207	336.5	227	15700	0.58	78	12	5
102	3	304.5	321	281	7000	0.40	70	11	2
105	3	212	285.5	269	250	0.22	66	10	2

Table A.6: Thermoplastic Yellow Skip Line Raw Data (Continued)

Site #	Round	Initial Retro	Median Retro	Days After App	Traffic Volume	Humidity	Temp	Lane Width	Shoulder Width
106	3	437.5	418	245	19300	0.62	50	12	2
107	3	274.5	214	245	3700	0.25	68	10.5	0.5
108	3	266.5	255.5	291	7600	0.65	77	11	*
15	4	270	178.5	370	6300	0.54	76.3	11	12
16	4	276.5	119.5	370	4700	0.53	76	12	*
17	4	281	215	369	250	0.49	82.2	10	1
19	4	257.5	95.5	370	4400	0.52	85	11	0.5
21	4	446	294	378	8600	0.42	85	12	0.5
82	4	301	229	313	1800	0.28	49	10	1
83	4	290.5	244	311	1500	0.25	49	9	2
84	4	266.5	294	310	1650	0.25	49	10	2
100	4	207	319.5	374	15700	0.51	80	12	5
102	4	304.5	382	399	7000	0.40	79	11	2
105	4	212	418	381	250	0.30	88	10	2
106	4	437.5	500.5	363	19300	0.63	73	12	2
107	4	274.5	209	363	3700	0.60	73	10.5	0.5
108	4	266.5	252.5	361	7600	0.61	79	11	*
15	5	270	163.5	461	6300	0.49	90.5	11	12
16	5	276.5	139	461	4700	0.57	87.3	12	*
17	5	281	255	460	250	0.39	92	10	1
19	5	257.5	137.5	456	4400	0.55	87.4	11	0.5
21	5	446	227.5	464	8600	0.48	92.7	12	0.5
100	5	207	222	415	15700	0.68	86	12	5
102	5	304.5	240	551	7000	0.27	44	11	2
105	5	212	450	480	250	0.34	71	10	2
107	5	274.5	98	515	3700	0.35	42	10.5	0.5
108	5	266.5	116.5	509	7600	0.24	52	11	*
15	6	270	140.5	569	6300	0.52	57	11	12
16	6	276.5	153.5	569	4700	0.57	61	12	*
17	6	281	200.5	568	250	0.53	67	10	1
19	6	257.5	135.5	580	4400	0.30	52	11	0.5
21	6	446	196.5	588	8600	0.30	42	12	0.5
100	6	207	135.5	593	15700	0.25	57	12	5
102	6	304.5	171.5	612	7000	0.23	46	11	2
105	6	212	152.5	609	250	0.20	50	10	2
107	6	274.5	78	576	3700	0.29	52	10.5	0.5
108	6	266.5	86	573	7600	0.54	50	11	*

Appendix B: Modeled Sites

Table B.1: Waterbased White Edge Line Modeled

* “Days” model only

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)*	% Error
1	1	27	232	228	-1.9	230	-0.6
2	1	14	257	255	-0.9	256	-0.3
3	1	13	169	167	-1.2	168	-0.4
4	1	13	116	114	-1.8	115	-0.6
5	1	22	355	351	-1.0	354	-0.3
8	1	15	130	128	-1.9	129	-0.6
14	1	28	337	332	-1.3	335	-0.5
24	1	21	319	316	-1.1	318	-0.4
27	1	21	261	258	-1.3	260	-0.4
28	1	21	269	266	-1.3	268	-0.4
29	1	23	398	394	-0.9	397	-0.3
30	1	23	461	457	-0.8	460	-0.3
31	1	22	356	352	-1.0	355	-0.3
33	1	17	363	360	-0.8	362	-0.3
34	1	17	363	360	-0.8	362	-0.3
35	1	17	290	287	-0.9	289	-0.3
36	1	17	363	360	-0.8	362	-0.3
37	1	17	355	352	-0.8	354	-0.3
38	1	16	314	311	-0.8	313	-0.3
39	1	26	251	247	-1.7	250	-0.6
40	1	26	167	163	-2.5	166	-0.9
41	1	26	166	162	-2.5	165	-0.9
42	1	26	122	118	-3.4	121	-1.2
49	1	20	378	375	-0.9	377	-0.3
50	1	20	397	394	-0.8	396	-0.3
51	1	20	390	387	-0.8	389	-0.3
52	1	20	311	308	-1.0	310	-0.4
53	1	20	370	367	-0.9	369	-0.3
54	1	20	360	357	-0.9	359	-0.3
55	1	20	429	426	-0.8	428	-0.3
56	1	20	378	375	-0.9	377	-0.3
57	1	16	294	291	-0.9	293	-0.3
58	1	17	376	373	-0.7	375	-0.3
59	1	17	419	416	-0.7	418	-0.2
60	1	17	375	372	-0.7	374	-0.3
61	1	17	334	331	-0.8	333	-0.3
62	1	17	467	464	-0.6	466	-0.2
63	1	17	408	405	-0.7	407	-0.2

Table B.1: Waterbased White Edge Line Modeled (Continued)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)*	% Error
64	1	16	410	407	-0.6	409	-0.2
115	1	15	298	296	-0.8	297	-0.3
117	1	29	332	327	-1.4	330	-0.5
118	1	29	237	232	-2.0	235	-0.7
119	1	29	407	402	-1.2	405	-0.4
120	1	29	314	309	-1.5	312	-0.5
151	1	20	352	349	-0.9	351	-0.3
152	1	20	172	169	-1.9	171	-0.6
153	1	20	294	291	-1.1	293	-0.4
154	1	19	309	306	-1.0	308	-0.3
155	1	19	316	313	-1.0	315	-0.3
156	1	19	303	300	-1.0	302	-0.3
157	1	18	237	234	-1.2	236	-0.4
1	2	98	240	216	-9.9	227	-5.6
2	2	98	262	241	-7.9	252	-4.0
3	2	98	166	153	-7.7	164	-1.5
4	2	98	93	100	7.7	111	18.9
5	2	98	328	339	3.4	350	6.6
8	2	93	98	115	17.3	125	27.4
14	2	96	349	321	-7.9	332	-5.0
24	2	110	328	301	-8.2	313	-4.6
27	2	110	294	243	-17.3	255	-13.3
28	2	110	244	251	3.0	263	7.7
29	2	131	284	377	32.7	391	37.6
30	2	131	468	440	-6.0	454	-3.1
31	2	116	380	337	-11.2	350	-8.0
33	2	116	261	344	31.9	357	36.6
34	2	116	331	344	4.0	357	7.7
35	2	116	281	271	-3.5	284	0.9
36	2	116	339	344	1.6	357	5.2
37	2	116	353	336	-4.7	349	-1.3
38	2	116	308	295	-4.1	308	-0.1
39	2	116	171	232	35.8	245	43.0
40	2	116	133	148	11.5	161	20.7
41	2	116	139	147	5.9	160	14.8
42	2	116	99	103	4.3	116	16.7
49	2	116	411	359	-12.6	372	-9.6
50	2	116	439	378	-13.8	391	-11.0
51	2	116	288	371	28.9	384	33.2
52	2	116	171	292	70.9	305	78.1
53	2	116	215	351	63.4	364	69.1

Table B.1: Waterbased White Edge Line Modeled (Continued)

Site #	**Round**	**Days After App**	**Measured**	**Predicted (DIFF)**	**% Error**	**Predicted (% DIFF)***	**% Error**
54	2	116	448	341	-23.8	354	-21.1
55	2	116	483	410	-15.1	423	-12.5
56	2	116	377	359	-4.7	372	-1.4
57	2	110	380	276	-27.3	288	-24.2
58	2	110	254	358	41.0	370	45.6
59	2	110	390	401	2.9	413	5.9
60	2	110	327	357	9.2	369	12.8
61	2	110	297	316	6.5	328	10.4
62	2	110	446	449	0.7	461	3.3
63	2	110	401	390	-2.7	402	0.2
64	2	110	416	392	-5.7	404	-2.9
115	2	113	249	280	12.3	292	17.2
117	2	80	311	319	2.6	328	5.3
118	2	80	241	224	-7.0	233	-3.5
119	2	80	367	394	7.4	403	9.7
120	2	80	298	301	1.0	310	3.9
152	2	123	139	152	9.5	165	18.8
155	2	122	251	296	18.0	309	23.2
156	2	122	302	283	-6.2	296	-1.9
157	2	121	285	217	-23.7	230	-19.2
1	3	256	205	191	-7.0	218	6.2
2	3	246	252	217	-13.8	243	-3.5
3	3	231	94	132	40.1	156	66.1
4	3	231	84	79	-6.3	103	22.8
5	3	231	267	318	19.0	342	28.1
8	3	239	113	91	-19.1	117	3.3
14	3	242	330	298	-9.7	324	-2.0
27	3	243	251	222	-11.7	247	-1.4
28	3	243	239	230	-3.9	255	6.9
29	3	242	319	359	12.5	385	20.5
30	3	242	419	422	0.7	448	6.8
31	3	242	339	317	-6.5	343	1.0
34	3	242	293	324	10.6	350	19.3
35	3	242	304	251	-17.5	277	-9.0
36	3	242	323	324	0.3	350	8.2
37	3	242	355	316	-11.0	342	-3.8
38	3	242	285	275	-3.5	301	5.4
40	3	256	56	126	124.4	153	172.8
41	3	256	46	125	171.0	152	229.9
42	3	256	83	81	-2.8	108	29.8
49	3	249	357	338	-5.4	364	2.0

Table B.1: Waterbased White Edge Line Modeled (Continued)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)*	% Error
50	3	249	387	357	-7.8	383	-1.0
51	3	249	258	350	35.6	376	45.8
53	3	249	268	330	23.1	356	32.9
54	3	249	331	320	-3.4	346	4.6
55	3	249	392	389	-0.8	415	5.9
56	3	249	350	338	-3.5	364	4.0
57	3	246	393	254	-35.3	280	-28.7
58	3	246	204	336	64.8	362	77.6
59	3	246	377	379	0.6	405	7.5
60	3	246	295	335	13.7	361	22.5
61	3	246	282	294	4.4	320	13.6
62	3	246	467	427	-8.5	453	-2.9
63	3	246	375	368	-1.8	394	5.1
64	3	246	397	370	-6.7	396	-0.2
115	3	260	127	256	101.6	284	123.2
117	3	227	313	295	-5.6	319	2.0
118	3	227	196	200	2.2	224	14.5
119	3	227	357	370	3.7	394	10.5
120	3	227	310	277	-10.5	301	-2.8
152	3	202	133	139	4.8	161	20.9
155	3	201	247	284	14.8	305	23.4
156	3	201	257	271	5.3	292	13.5
157	3	200	229	205	-10.6	226	-1.4
2	4	334	214	203	-5.1	238	11.4
3	4	334	132	115	-12.8	150	13.9
4	4	334	69	62	-10.1	97	41.2
5	4	334	234	301	28.7	336	43.8
8	4	359	112	72	-35.7	110	-1.8
14	4	352	308	280	-9.0	317	3.0
27	4	357	245	203	-17.0	241	-1.6
28	4	357	269	211	-21.4	249	-7.4
29	4	360	337	340	0.8	378	12.2
30	4	360	372	403	8.3	441	18.5
31	4	360	373	298	-20.1	336	-9.9
33	4	360	250	305	21.9	343	37.2
34	4	360	232	305	31.4	343	47.8
35	4	360	338	232	-31.4	270	-20.1
36	4	360	351	305	-13.1	343	-2.3
37	4	371	286	295	3.2	334	16.9
38	4	360	313	256	-18.3	294	-6.1
39	4	381	159	189	19.2	230	44.5

Table B.1: Waterbased White Edge Line Modeled (Continued)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)*	% Error
40	4	381	76	105	38.8	146	91.8
41	4	381	80	104	30.6	145	81.0
42	4	381	56	60	8.0	101	80.0
49	4	356	315	321	1.7	358	13.7
50	4	356	378	340	-10.2	377	-0.2
51	4	356	303	333	9.7	370	22.2
52	4	356	144	254	76.0	291	102.2
53	4	356	222	313	40.8	350	57.7
54	4	356	324	303	-6.6	340	5.0
55	4	356	340	372	9.3	409	20.3
56	4	356	334	321	-4.0	358	7.2
57	4	332	376	240	-36.1	276	-26.7
58	4	332	169	322	90.8	358	111.5
59	4	343	355	364	2.4	400	12.6
60	4	343	137	320	133.3	356	159.8
61	4	332	264	280	6.2	316	19.5
62	4	332	389	413	6.3	449	15.3
63	4	332	334	354	6.1	390	16.6
64	4	332	408	356	-12.7	392	-4.0
117	4	294	306	285	-7.0	316	3.1
118	4	294	196	190	-3.3	221	12.6
119	4	294	373	360	-3.6	391	4.7
120	4	294	309	267	-13.7	298	-3.7
2	5	439	201	186	-7.4	233	15.7
3	5	438	115	98	-14.6	145	25.7
4	5	438	56	45	-19.2	92	63.6
5	5	447	100	283	182.8	330	230.1
14	5	460	322	263	-18.4	311	-3.3
24	5	464	118	244	106.8	293	148.4
27	5	464	238	186	-21.8	235	-1.2
28	5	464	282	194	-31.2	243	-13.8
29	5	470	250	322	28.8	372	48.7
30	5	470	380	385	1.3	435	14.4
39	5	487	140	172	23.1	224	59.9
40	5	487	123	88	-28.2	140	13.7
41	5	487	53	87	64.8	139	162.0
42	5	487	40	43	8.4	95	137.2
49	5	452	345	305	-11.6	353	2.3
51	5	452	245	317	29.4	365	48.9
53	5	452	210	297	41.4	345	64.2
55	5	452	353	356	0.9	404	14.4

Table B.1: Waterbased White Edge Line Modeled (Continued)

Site #	**Round**	**Days After App**	**Measured**	**Predicted (DIFF)**	**% Error**	**Predicted (% DIFF)***	**% Error**
59	5	436	343	349	1.6	395	15.1
61	5	436	253	264	4.2	310	22.4
117	5	475	393	255	-35.0	306	-22.3
118	5	475	363	160	-55.8	211	-42.0
119	5	475	264	330	25.1	381	44.1
120	5	475	338	237	-29.8	288	-14.9
3	6	532	107	83	-22.4	139	30.3
5	6	541	182	268	47.0	325	78.5
14	6	552	284	248	-12.7	306	7.8
24	6	573	125	226	81.2	287	129.7
27	6	573	202	168	-16.6	229	13.4
28	6	573	222	176	-20.5	237	6.8
29	6	592	197	302	53.5	365	85.3
30	6	592	383	365	-4.6	428	11.8
39	6	595	116	155	33.5	218	87.8
40	6	595	118	71	-39.9	134	13.4
41	6	595	83	70	-15.8	133	60.1
42	6	595	33	26	-21.5	89	169.3
49	6	574	273	285	4.5	346	26.8
51	6	574	300	297	-0.9	358	19.3
53	6	574	220	277	26.0	338	53.6
55	6	574	310	336	8.5	397	28.1
59	6	558	265	329	24.1	388	46.4
61	6	558	264	244	-7.6	303	14.7
117	6	536	408	245	-39.8	302	-25.9
118	6	536	377	150	-60.1	207	-45.1
119	6	536	250	320	28.2	377	50.9
120	6	536	328	227	-30.7	284	-13.4

Table B.2: Waterbased Yellow Solid Centerline Modeled

Site #	**Round**	**Days After App**	**Measured**	**Predicted (DIFF)**	**% Error**	**Predicted (% DIFF)**	**% Error**
2	1	14	162	161	-0.6	161	-0.5
3	1	13	135	134	-0.7	134	-0.5
4	1	13	166	165	-0.6	165	-0.4
5	1	22	116	114	-1.4	115	-1.1
6	1	21	159	157	-1.0	158	-0.7
7	1	20	149	148	-1.0	148	-0.8
8	1	15	97	96	-1.1	96	-0.9
12	1	28	158	156	-1.3	156	-1.0
13	1	27	155	153	-1.3	153	-1.0
14	1	28	137	135	-1.5	135	-1.1
24	1	21	104	102	-1.5	103	-1.1
25	1	21	134	132	-1.1	133	-0.9
26	1	21	61	59	-2.5	60	-1.9
27	1	21	160	158	-1.0	159	-0.7
28	1	21	171	169	-0.9	170	-0.7
29	1	23	218	216	-0.8	217	-0.6
30	1	23	155	153	-1.1	154	-0.8
31	1	22	176	174	-0.9	175	-0.7
32	1	22	157	155	-1.0	156	-0.8
34	1	17	121	120	-1.0	120	-0.8
37	1	17	147	146	-0.8	146	-0.6
38	1	16	100	99	-1.2	99	-0.9
39	1	26	114	112	-1.7	113	-1.3
40	1	26	52	50	-3.7	51	-2.8
41	1	26	32	30	-5.9	31	-4.6
42	1	26	44	42	-4.3	43	-3.3
43	1	24	103	101	-1.7	102	-1.3
44	1	25	148	146	-1.2	147	-0.9
45	1	25	125	123	-1.5	124	-1.1
46	1	25	41	39	-4.5	40	-3.4
47	1	26	62	60	-3.1	61	-2.4
48	1	26	125	123	-1.5	124	-1.2
49	1	20	119	118	-1.2	118	-0.9
50	1	20	145	144	-1.0	144	-0.8
52	1	20	122	121	-1.2	121	-0.9
53	1	20	161	160	-0.9	160	-0.7
54	1	20	124	123	-1.2	123	-0.9
55	1	20	189	188	-0.8	188	-0.6
56	1	20	153	152	-1.0	152	-0.7
57	1	16	195	194	-0.6	194	-0.5
58	1	17	168	167	-0.7	167	-0.6

Table B.2: Waterbased Yellow Solid Centerline Modeled (Continued)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)	% Error
59	1	17	141	140	-0.9	140	-0.7
60	1	17	167	166	-0.7	166	-0.6
61	1	17	79	78	-1.6	78	-1.2
62	1	17	195	194	-0.6	194	-0.5
63	1	17	178	177	-0.7	177	-0.5
64	1	16	191	190	-0.6	190	-0.5
72	1	26	132	130	-1.4	131	-1.1
109	1	22	195	193	-0.8	194	-0.6
110	1	23	175	173	-1.0	174	-0.7
111	1	23	168	166	-1.0	167	-0.8
112	1	23	129	127	-1.3	128	-1.0
113	1	23	171	169	-1.0	170	-0.8
114	1	23	194	192	-0.9	193	-0.7
115	1	15	161	160	-0.7	160	-0.5
116	1	29	114	112	-1.9	112	-1.4
117	1	29	108	106	-2.0	106	-1.5
118	1	29	184	182	-1.2	182	-0.9
119	1	29	204	202	-1.0	202	-0.8
120	1	29	167	165	-1.3	165	-1.0
151	1	20	146	145	-1.0	145	-0.8
152	1	20	155	154	-0.9	154	-0.7
153	1	20	166	165	-0.9	165	-0.7
154	1	19	132	131	-1.1	131	-0.8
155	1	19	158	157	-0.9	157	-0.7
156	1	19	180	179	-0.8	179	-0.6
157	1	18	120	119	-1.1	119	-0.8
2	2	98	162	155	-4.4	156	-3.4
3	2	98	124	128	3.1	129	4.4
4	2	97	149	159	6.7	161	7.8
5	2	97	114	109	-4.5	111	-3.0
6	2	93	145	152	5.0	154	6.1
7	2	93	145	142	-1.9	144	-0.8
8	2	93	94	90	-4.0	92	-2.4
12	2	96	145	151	4.1	153	5.2
13	2	96	162	148	-8.7	150	-7.7
14	2	96	121	130	7.4	132	8.8
24	2	110	88	96	9.0	98	11.2
25	2	110	133	126	-5.3	128	-3.9
26	2	110	65	53	-18.5	55	-15.7
27	2	110	129	152	17.8	154	19.2
28	2	110	160	163	1.8	165	3.0

Table B.2: Waterbased Yellow Solid Centerline Modeled (Continued)

Site #	**Round**	**Days After App**	**Measured**	**Predicted (DIFF)**	**% Error**	**Predicted (% DIFF)**	**% Error**
29	2	131	222	208	-6.1	211	-5.1
30	2	131	194	145	-25.0	148	-23.9
31	2	116	179	168	-6.4	169	-5.3
32	2	116	164	149	-9.4	150	-8.2
34	2	116	124	113	-9.3	114	-7.7
37	2	116	166	139	-16.6	140	-15.4
38	2	116	120	92	-23.7	93	-22.1
39	2	116	92	106	14.7	107	16.8
40	2	116	45	44	-3.3	45	1.1
41	2	116	31	24	-24.1	25	-17.8
42	2	116	40	36	-11.2	37	-6.3
43	2	139	112	93	-17.1	95	-15.0
44	2	116	153	140	-8.8	141	-7.5
45	2	116	122	117	-4.5	118	-2.9
46	2	116	39	33	-16.6	34	-11.6
47	2	116	60	54	-10.8	55	-7.5
48	2	116	127	117	-8.3	118	-6.7
49	2	116	146	111	-24.3	112	-23.0
50	2	116	167	137	-18.3	138	-17.1
52	2	116	135	114	-15.9	115	-14.5
53	2	116	181	153	-15.7	154	-14.7
54	2	116	153	116	-24.5	117	-23.2
55	2	116	215	181	-16.0	182	-15.1
56	2	116	183	145	-21.0	146	-20.0
57	2	110	192	187	-2.6	189	-1.7
58	2	110	150	160	6.6	162	7.9
59	2	110	136	133	-2.2	135	-0.9
60	2	110	133	159	19.5	161	20.9
61	2	110	69	71	2.8	73	5.5
62	2	110	187	187	0.0	189	1.0
63	2	110	170	170	0.0	172	1.1
64	2	110	186	183	-1.6	185	-0.6
72	2	96	130	125	-3.9	127	-2.6
109	2	134	180	185	2.9	187	4.1
110	2	113	167	167	-0.2	169	1.0
111	2	113	135	160	18.3	162	19.7
112	2	113	118	121	2.3	123	3.9
113	2	113	145	163	12.2	165	13.6
114	2	113	167	186	11.2	188	12.4
115	2	113	99	153	54.3	155	56.2
116	2	80	112	108	-3.4	110	-2.2

Table B.2: Waterbased Yellow Solid Centerline Modeled (Continued)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)	% Error
117	2	80	105	102	-2.7	104	-1.4
118	2	80	175	178	1.8	180	2.6
119	2	80	189	198	4.8	200	5.6
120	2	80	142	161	13.5	163	14.4
152	2	123	130	146	12.3	148	13.9
155	2	122	149	149	0.1	151	1.4
156	2	122	187	171	-8.5	173	-7.4
157	2	121	89	111	24.9	113	27.2
2	3	246	143	144	0.7	148	3.6
3	3	231	102	118	15.8	122	19.6
4	3	230	150	149	-0.5	153	2.0
5	3	230	72	99	37.8	103	43.2
6	3	239	99	142	43.0	146	47.0
7	3	239	136	132	-3.3	136	-0.3
8	3	239	100	80	-20.5	84	-16.4
12	3	242	128	140	9.6	144	12.8
13	3	242	149	137	-7.8	141	-5.1
14	3	242	117	119	2.0	123	5.5
24	3	243	93	86	-7.3	90	-2.9
25	3	243	132	116	-11.9	120	-8.8
26	3	243	71	43	-39.1	47	-33.3
27	3	243	128	142	11.1	146	14.3
28	3	243	144	153	6.4	157	9.3
29	3	242	155	200	29.2	204	31.9
30	3	242	130	137	5.6	141	8.8
31	3	242	158	158	0.2	162	2.8
32	3	242	149	139	-6.5	143	-3.8
34	3	242	108	103	-4.3	107	-0.6
37	3	242	149	129	-13.2	133	-10.5
38	3	242	112	82	-26.5	86	-22.9
40	3	256	28	33	18.9	38	34.3
41	3	256	26	13	-48.9	18	-32.3
42	3	256	33	25	-23.4	30	-10.3
43	3	279	54	83	53.0	87	61.7
44	3	256	56	129	130.9	134	138.6
45	3	256	95	106	11.9	111	16.4
46	3	256	28	22	-20.4	27	-5.0
47	3	256	40	43	8.2	48	19.0
48	3	256	53	106	100.5	111	108.7
49	3	249	121	101	-16.7	105	-13.2
50	3	249	142	127	-10.7	131	-7.7

Table B.2: Waterbased Yellow Solid Centerline Modeled (Continued)

Site #	**Round**	**Days After App**	**Measured**	**Predicted (DIFF)**	**% Error**	**Predicted (% DIFF)**	**% Error**
52	3	249	82	104	26.6	108	31.7
53	3	249	111	143	28.6	147	32.4
54	3	249	120	106	-11.8	110	-8.3
55	3	249	156	171	9.5	175	12.2
56	3	249	149	135	-9.5	139	-6.7
57	3	246	169	177	4.7	181	7.2
58	3	246	106	150	41.5	154	45.4
59	3	246	103	123	19.4	127	23.5
60	3	246	112	149	33.1	153	36.8
61	3	246	60	61	1.7	65	8.6
62	3	246	182	177	-2.7	181	-0.5
63	3	246	149	160	7.4	164	10.2
64	3	246	177	173	-2.3	177	0.1
72	3	227	123	115	-6.2	119	-3.1
109	3	281	195	174	-10.5	179	-8.1
110	3	260	173	156	-9.8	160	-7.3
111	3	260	143	149	4.2	153	7.3
112	3	260	116	110	-5.2	114	-1.4
113	3	260	129	152	17.8	156	21.2
114	3	260	171	175	2.3	179	4.9
115	3	260	72	142	97.2	146	103.3
116	3	227	101	97	-3.6	101	0.2
117	3	227	101	91	-9.5	95	-5.7
118	3	227	184	167	-9.0	171	-6.9
119	3	227	184	187	1.9	191	3.9
120	3	227	139	150	8.2	154	11.0
152	3	202	102	140	37.5	144	40.8
155	3	201	128	143	12.0	147	14.6
156	3	201	169	165	-2.2	169	-0.2
157	3	200	67	105	57.3	109	62.3
2	4	334	161	138	-14.5	143	-11.0
3	4	334	78	111	41.8	116	49.0
4	4	333	145	142	-2.3	147	1.6
5	4	333	60	92	52.8	97	62.1
6	4	327	88	135	53.5	141	59.8
7	4	327	115	125	8.8	131	13.6
8	4	359	99	71	-28.5	77	-22.4
12	4	352	125	132	5.8	138	10.6
13	4	352	129	129	0.2	135	4.8
14	4	352	101	111	10.2	117	16.1
24	4	357	63	78	23.7	84	33.2

Table B.2: Waterbased Yellow Solid Centerline Modeled (Continued)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)	% Error
25	4	357	125	108	-13.7	114	-8.9
26	4	357	58	35	-39.8	41	-29.4
27	4	357	126	134	6.3	140	11.1
28	4	357	146	145	-0.8	151	3.4
29	4	360	162	192	18.3	198	22.1
30	4	360	162	129	-20.6	135	-16.8
31	4	360	168	150	-10.9	156	-7.3
32	4	360	150	131	-12.9	137	-8.8
34	4	360	99	95	-4.4	101	1.8
37	4	371	150	120	-20.1	126	-15.9
38	4	360	101	74	-27.0	80	-21.0
39	4	381	65	86	32.5	93	42.4
40	4	381	30	24	-19.5	31	2.0
41	4	381	23	4	-82.0	11	-54.0
42	4	381	28	16	-42.3	23	-19.3
44	4	381	97	120	23.9	127	30.5
45	4	381	99	97	-1.9	104	4.6
46	4	381	23	13	-42.8	20	-14.8
47	4	381	36	34	-5.1	41	12.7
48	4	381	66	97	47.2	104	57.0
49	4	356	117	93	-20.5	99	-15.4
50	4	356	142	119	-16.2	125	-12.0
52	4	356	84	96	14.3	102	21.4
53	4	356	112	135	20.5	141	25.9
54	4	356	116	98	-15.5	104	-10.4
55	4	356	141	163	15.6	169	19.9
56	4	356	145	127	-12.4	133	-8.3
57	4	332	169	171	1.0	176	4.3
58	4	332	108	144	33.1	149	38.3
59	4	343	98	116	18.3	122	24.2
60	4	343	90	142	57.7	148	64.1
61	4	332	56	55	-2.3	60	7.8
62	4	332	176	171	-3.0	176	0.2
63	4	332	128	154	20.1	159	24.5
64	4	332	168	167	-0.8	172	2.6
72	4	323	115	108	-5.7	114	-1.0
110	4	327	157	151	-3.8	157	-0.2
111	4	327	180	144	-19.9	150	-16.9
112	4	327	119	105	-11.7	111	-7.0
113	4	327	131	147	12.3	153	16.5
114	4	327	227	170	-25.1	176	-22.6

Table B.2: Waterbased Yellow Solid Centerline Modeled (Continued)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)	% Error
115	4	327	167	137	-17.9	143	-14.6
116	4	294	101	93	-8.4	97	-3.5
117	4	294	101	87	-14.3	91	-9.4
118	4	294	182	163	-10.7	167	-8.0
119	4	294	193	183	-5.4	187	-2.9
120	4	294	140	146	3.9	150	7.5
2	5	439	152	130	-14.5	137	-9.7
3	5	438	79	103	30.4	110	39.7
4	5	438	137	134	-2.2	141	3.2
5	5	447	41	83	103.2	91	121.7
6	5	439	71	127	78.7	134	89.2
7	5	438	82	117	42.7	124	51.7
12	5	460	125	124	-0.5	132	5.7
13	5	459	130	121	-6.6	129	-0.6
14	5	460	89	103	16.2	111	24.9
24	5	464	62	70	13.0	78	25.7
25	5	464	119	100	-15.9	108	-9.3
26	5	464	47	27	-42.4	35	-25.7
27	5	464	124	126	1.7	134	8.0
28	5	464	149	137	-8.0	145	-2.7
29	5	470	156	184	17.7	192	22.8
30	5	470	163	121	-26.0	129	-21.1
39	5	487	72	78	8.9	87	20.3
40	5	487	29	16	-43.4	25	-15.1
41	5	487	22	-4	-116.4	5	-79.0
42	5	487	30	8	-72.0	17	-44.6
44	5	486	91	112	23.6	121	32.6
45	5	486	94	89	-4.8	98	3.9
46	5	486	23	5	-76.2	14	-40.5
47	5	487	62	26	-57.4	35	-44.1
48	5	487	38	89	135.3	98	156.9
49	5	452	119	86	-27.8	94	-21.3
53	5	452	116	128	10.3	136	16.9
55	5	452	135	156	15.5	164	21.2
59	5	436	94	109	16.1	116	23.9
61	5	436	58	47	-18.7	54	-6.0
72	5	425	111	101	-9.1	108	-2.6
110	5	502	163	138	-15.2	147	-9.9
111	5	502	165	131	-20.4	140	-15.3
112	5	502	113	92	-18.3	101	-10.8
113	5	502	116	134	15.8	143	23.1

Table B.2: Waterbased Yellow Solid Centerline Modeled (Continued)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)	% Error
114	5	502	203	157	-22.5	166	-18.3
115	5	492	95	125	31.6	133	40.4
116	5	475	73	79	8.6	87	19.6
117	5	475	150	73	-51.1	81	-45.8
118	5	475	168	149	-11.1	157	-6.4
119	5	475	57	169	197.0	177	211.1
120	5	475	160	132	-17.3	140	-12.3
3	6	532	65	96	47.9	105	61.7
5	6	541	41	76	86.5	86	108.8
6	6	533	58	120	107.0	129	122.5
12	6	552	111	118	6.0	127	14.4
14	6	552	81	97	19.3	106	30.8
24	6	573	51	62	21.8	72	40.8
25	6	573	111	92	-17.0	102	-8.3
26	6	573	50	19	-61.8	29	-42.4
27	6	573	112	118	5.5	128	14.1
28	6	573	129	129	0.1	139	7.6
29	6	592	149	175	17.3	185	24.0
30	6	592	160	112	-30.2	122	-23.9
39	6	595	65	71	8.5	81	23.9
40	6	595	30	9	-71.6	19	-38.1
41	6	595	24	-11	-147.9	-1	-106.0
42	6	595	27	1	-98.1	11	-60.9
44	6	594	84	105	24.5	115	36.4
45	6	594	82	82	-0.5	92	11.7
46	6	594	19	-2	-112.7	8	-59.9
47	6	595	32	19	-42.2	29	-10.7
48	6	595	50	82	63.0	92	83.1
49	6	574	116	77	-33.6	87	-25.2
53	6	574	88	119	35.3	129	46.3
55	6	574	130	147	13.1	157	20.6
59	6	558	99	100	1.2	110	10.7
61	6	558	53	38	-27.9	48	-10.1
72	6	547	87	92	5.8	101	16.4
110	6	563	152	134	-11.9	143	-5.7
111	6	563	135	127	-6.0	136	1.0
112	6	563	111.5	88	-21.2	97	-12.7
113	6	563	105	130	23.7	139	32.7

Table B.2: Waterbased Yellow Solid Centerline Modeled (Continued)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)	% Error
114	6	563	199	153	-23.2	162	-18.4
115	6	545	81	121	49.6	130	61.0
116	6	536	74	75	1.1	84	13.3
117	6	536	154	69	-55.3	78	-49.4
118	6	536	160	145	-9.5	154	-3.8
119	6	536	57	165	189.2	174	205.0
120	6	536	145	128	-11.8	137	-5.6

Table B.3: Waterbased Yellow Skip Line Modeled

Site #	Round	Days After App	Lane Width	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)	% Error
1	1	27	-	181.5	-	-	-	-
25	1	21	11	130	141	8.6	137	5.6
28	1	21	10	142	142	0.2	142	0.3
30	1	23	10	145.5	146	0.2	146	0.2
31	1	22	10	172.5	173	0.2	173	0.2
32	1	22	9	160	149	-6.6	153	-4.1
34	1	17	10	125	125	0.4	125	0.4
35	1	17	10	128	128	0.4	128	0.3
36	1	17	10	102	102	0.5	102	0.4
51	1	20	10	173	173	0.2	173	0.2
151	1	20	-	168.5	-	-	-	-
153	1	20	-	156.5	-	-	-	-
156	1	19	-	169	-	-	-	-
1	2	98	-	173	-	-	-	-
25	2	110	11	124	138	11.5	135	9.1
28	2	110	10	138	139	1.0	140	1.7
30	2	131	10	166.5	142	-14.6	143	-13.9
31	2	116	10	170	170	-0.2	171	0.4
32	2	116	9	139.5	146	4.9	151	8.4
34	2	116	10	120.5	122	1.4	123	2.2
35	2	116	10	140.5	125	-10.9	126	-10.2
36	2	116	10	103.5	99	-4.2	100	-3.2
51	2	116	10	201.5	170	-15.5	171	-15.0
156	2	122	-	148.5	-	-	-	-
1	3	256	-	174.5	-	-	-	-
25	3	243	11	140.5	134	-4.7	132	-5.9
28	3	243	10	116.5	135	15.9	137	17.9
30	3	242	10	104	139	33.2	141	35.4
31	3	242	10	137.5	166	20.4	168	22.1
32	3	242	9	128	142	11.1	148	16.0
34	3	242	10	104.5	118	13.0	120	15.2
35	3	242	10	127	121	-4.7	123	-2.9
36	3	242	10	110.5	95	-14.0	97	-11.9
51	3	249	10	171.5	166	-3.3	168	-1.9
156	3	201	-	144.5	-	-	-	-
1	4	366	-	154	-	-	-	-
25	4	357	11	124.5	130	4.5	130	4.1
28	4	357	10	117	131	12.2	135	15.2
30	4	360	10	148.5	135	-9.3	138	-7.0
31	4	360	10	138.5	162	16.7	165	19.2
32	4	360	9	131.5	138	5.1	146	10.8

Table B.3: Waterbased Yellow Skip Line Modeled (Continued)

Site #	**Round**	**Days After App**	**Lane Width**	**Measured**	**Predicted (DIFF)**	**% Error**	**Predicted (% DIFF)**	**% Error**
34	4	360	10	92.5	114	23.4	118	27.2
35	4	360	10	149.5	117	-21.6	121	-19.3
36	4	360	10	99	91	-7.9	95	-4.4
51	4	356	10	179.5	162	-9.6	166	-7.7
25	5	464	11	135	127	-6.2	127	-5.8
28	5	464	10	115	128	11.1	132	15.0
30	5	470	10	147	131	-10.9	136	-7.7
51	5	452	10	183	159	-13.1	164	-10.6
25	6	573	11	122	123	0.8	125	2.2
28	6	573	10	88.5	124	40.2	130	46.7
30	6	592	10	142.5	127	-10.9	133	-6.7
51	6	574	10	168	155	-7.7	161	-4.3

Table B.4: Thermoplastic Yellow Solid Centerline Modeled (Linear)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)	% Error
15	1	21	260	258	-0.9	259	-0.4
18	1	17	272	270	-0.7	271	-0.3
20	1	17	211	209	-0.9	210	-0.4
21	1	25	266	263	-1.1	265	-0.4
22	1	21	263	261	-0.9	262	-0.4
23	1	16	302	300	-0.6	301	-0.2
70	1	25	285	282	-1.0	284	-0.4
71	1	25	301	298	-1.0	300	-0.4
73	1	25	320	317	-0.9	319	-0.4
74	1	21	193	191	-1.3	192	-0.5
75	1	21	245	243	-1.0	244	-0.4
76	1	22	262	259	-1.0	261	-0.4
85	1	35	256	252	-1.6	254	-0.6
100	1	15	224	222	-0.8	223	-0.3
101	1	18	154	152	-1.4	153	-0.5
102	1	25	307	304	-1.0	306	-0.4
103	1	42	207	202	-2.4	205	-0.9
104	1	29	185	182	-1.8	184	-0.7
15	2	116	287	246	-14.2	255	-11.2
18	2	119	359	258	-28.1	267	-25.7
20	2	119	132	197	49.2	206	55.8
21	2	127	293	251	-14.3	260	-11.2
22	2	128	287	248	-13.6	257	-10.4
23	2	123	409	288	-29.7	296	-27.5
70	2	120	318	271	-14.8	280	-12.1
71	2	120	265	287	8.3	296	11.5
73	2	120	309	306	-1.0	315	1.8
74	2	133	159	177	11.5	187	17.6
75	2	133	197	229	16.4	239	21.3
76	2	134	231	246	6.6	256	10.8
85	2	125	252	241	-4.2	250	-0.7
100	2	115	317	210	-33.6	219	-31.0
101	2	123	171	140	-18.4	148	-13.2
102	2	143	345	290	-15.9	301	-12.9
103	2	143	142	190	33.9	201	41.2
104	2	130	326	170	-47.9	179	-45.1
15	3	258	182	230	26.2	248	36.4
18	3	240	316	244	-22.9	261	-17.4
20	3	258	66	181	173.7	199	201.9
21	3	266	195	235	20.4	254	30.2
22	3	268	284	231	-18.5	251	-11.7

Table B.4: Thermoplastic Yellow Solid Centerline Modeled (Linear) (Continued)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)	% Error
23	3	263	384	271	-29.4	290	-24.5
70	3	251	310	255	-17.6	274	-11.7
71	3	251	251	271	8.2	290	15.4
73	3	251	302	290	-3.8	309	2.2
74	3	248	140	164	17.0	182	29.8
75	3	248	178	216	21.3	234	31.3
76	3	249	188	233	23.8	251	33.3
85	3	234	273	228	-16.3	245	-10.1
100	3	227	321	197	-38.5	214	-33.4
101	3	217	202	128	-36.4	144	-28.6
102	3	281	313	274	-12.5	294	-6.0
103	3	281	58	174	199.9	194	234.9
104	3	268	320	153	-52.0	173	-46.0
15	4	370	147	216	47.3	243	65.4
18	4	370	311	228	-26.5	255	-17.9
20	4	370	96	167	74.5	194	102.3
21	4	378	131	222	69.1	249	90.0
22	4	376	129	219	69.6	246	90.6
23	4	371	420	258	-38.5	285	-32.1
70	4	347	352	244	-30.6	269	-23.5
71	4	347	332	260	-21.6	285	-14.1
73	4	347	345	279	-19.1	304	-11.8
74	4	293	117	159	35.5	180	53.6
75	4	294	187	210	12.5	232	23.9
76	4	294	194	227	17.2	249	28.2
85	4	312	241	219	-9.0	242	0.3
100	4	374	321	180	-43.9	207	-35.5
101	4	356	207	112	-45.8	138	-33.4
102	4	399	255	260	2.0	289	13.3
103	4	393	93	161	72.9	189	103.4
104	4	380	344	140	-59.2	168	-51.2
15	5	461	181	206	13.7	239	32.1
18	5	456	188	218	16.2	251	33.7
20	5	456	102	157	54.3	190	86.6
21	5	464	158	211	33.8	245	55.0
22	5	461	141	209	48.1	242	71.7
23	5	456	443	248	-43.9	281	-36.5
70	5	425	421	235	-44.2	266	-36.9
71	5	425	134	251	87.3	282	110.2
73	5	425	174	270	55.2	301	72.8
74	5	408	56	145	159.0	174	211.6

Table B.4: Thermoplastic Yellow Solid Centerline Modeled (Linear) (Continued)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)	% Error
75	5	408	178	197	10.7	226	27.2
76	5	409	180	214	18.8	243	35.2
100	5	415	201	175	-12.8	205	2.1
101	5	416	241	105	-56.4	135	-43.9
102	5	551	129	242	87.8	282	118.6
103	5	492	101	149	47.7	185	82.8
104	5	479	188	129	-31.6	163	-13.2
15	6	569	139	193	38.9	234	68.5
18	6	580	172	204	18.5	246	42.8
21	6	588	104	197	89.3	239	130.1
22	6	574	149	195	31.2	237	59.0
23	6	569	435	235	-46.0	276	-36.5
70	6	547	353	221	-37.5	260	-26.3
71	6	547	106	237	123.3	276	160.5
73	6	547	118	256	116.7	295	150.1
75	6	520	119	184	54.5	221	86.0
100	6	593	136	154	13.4	197	44.9
101	6	568	158	87	-44.8	128	-18.9
102	6	612	123	235	91.1	279	127.0
103	6	621	56	134	139.2	179	219.3
104	6	608	84	113	35.1	157	87.4

Table B.5: Thermoplastic Yellow Skip Line Modeled (Linear)

Site #	Round	Days After App	Measured	Predicted (DIFF)	% Error	Predicted (% DIFF)	% Error
15	1	21	270	267	-1.2	269	-0.4
16	1	21	276.5	273	-1.1	276	-0.4
17	1	20	281	278	-1.1	280	-0.3
19	1	17	257.5	255	-1.0	257	-0.3
21	1	25	446	442	-0.8	445	-0.3
81	1	35	264.5	259	-2.0	263	-0.6
82	1	36	301	296	-1.8	299	-0.6
83	1	34	290.5	285	-1.7	289	-0.5
84	1	33	266.5	262	-1.8	265	-0.6
100	1	15	207	205	-1.1	206	-0.3
102	1	25	304.5	301	-1.2	303	-0.4
105	1	30	212	208	-2.1	211	-0.7
106	1	35	437.5	432	-1.2	436	-0.4
107	1	35	274.5	269	-1.9	273	-0.6
108	1	29	266.5	262	-1.6	265	-0.5
15	2	116	271	253	-6.7	265	-2.4
16	2	116	270.5	259	-4.1	271	0.2
17	2	115	262	264	0.7	276	5.2
19	2	119	241.5	240	-0.7	252	4.3
21	2	127	498.5	427	-14.3	440	-11.7
81	2	125	242	246	1.6	259	6.9
82	2	126	303.5	282	-7.0	295	-2.8
83	2	124	268	272	1.5	285	6.2
84	2	123	274	248	-9.4	261	-4.8
100	2	115	330	190	-42.4	202	-38.9
102	2	143	336.5	283	-15.8	298	-11.5
105	2	131	328.5	193	-41.4	206	-37.3
106	2	148	433	416	-4.0	431	-0.6
107	2	148	230.5	253	9.6	268	16.1
108	2	142	263.5	245	-6.9	260	-1.4
15	3	258	205.5	232	12.8	258	25.5
16	3	258	131.5	238	81.2	264	101.1
19	3	240	121	222	83.4	246	103.5
21	3	266	442.5	407	-8.1	434	-2.0
81	3	234	248.5	230	-7.5	254	2.0
82	3	235	316.5	266	-15.9	290	-8.4
83	3	233	298	256	-14.1	280	-6.2
84	3	232	303	232	-23.4	256	-15.6
100	3	227	336.5	173	-48.5	196	-41.6
102	3	281	321	263	-18.1	291	-9.2

Table B.5: Thermoplastic Yellow Skip Line Modeled (Linear) (Continued)

Site #	**Round**	**Days After App**	**Measured**	**Predicted (DIFF)**	**% Error**	**Predicted (% DIFF)**	**% Error**
105	3	269	285.5	172	-39.7	199	-30.2
106	3	245	418	401	-4.0	426	1.9
107	3	245	214	238	11.3	263	22.9
108	3	291	255.5	223	-12.6	253	-1.0
15	4	370	178.5	215	20.5	253	41.6
16	4	370	119.5	222	85.4	259	116.9
17	4	369	215	226	5.2	264	22.7
19	4	370	95.5	203	112.1	240	151.5
21	4	378	294	390	32.6	428	45.7
82	4	313	229	255	11.2	286	25.0
83	4	311	244	244	0.1	276	13.1
84	4	310	294	220	-25.0	252	-14.3
100	4	374	319.5	151	-52.6	189	-40.7
102	4	399	382	245	-35.8	286	-25.2
105	4	381	418	155	-62.8	194	-53.5
106	4	363	500.5	384	-23.4	421	-16.0
107	4	363	209	221	5.6	258	23.2
108	4	361	252.5	213	-15.7	250	-1.1
15	5	461	163.5	202	23.3	248	51.9
16	5	461	139	208	49.7	255	83.4
17	5	460	255	213	-16.6	259	1.8
19	5	456	137.5	190	38.1	236	71.8
21	5	464	227.5	377	65.8	424	86.5
100	5	415	222	145	-34.5	188	-15.5
102	5	551	240	223	-7.2	279	16.1
105	5	480	450	141	-68.7	190	-57.9
107	5	515	98	198	102.1	250	155.5
108	5	509	116.5	191	63.9	243	108.3
15	6	569	140.5	186	32.1	243	73.2
16	6	569	153.5	192	25.1	250	62.8
17	6	568	200.5	197	-1.9	254	26.9
19	6	580	135.5	171	26.5	230	70.0
21	6	588	196.5	359	82.6	418	113.0
100	6	593	135.5	119	-12.2	179	32.3
102	6	612	171.5	214	24.6	276	60.9
105	6	609	152.5	122	-20.2	183	20.3
107	6	576	78	189	142.3	248	217.4
108	6	573	86	181	111.0	240	178.7

Appendix C: Modeled Graphs

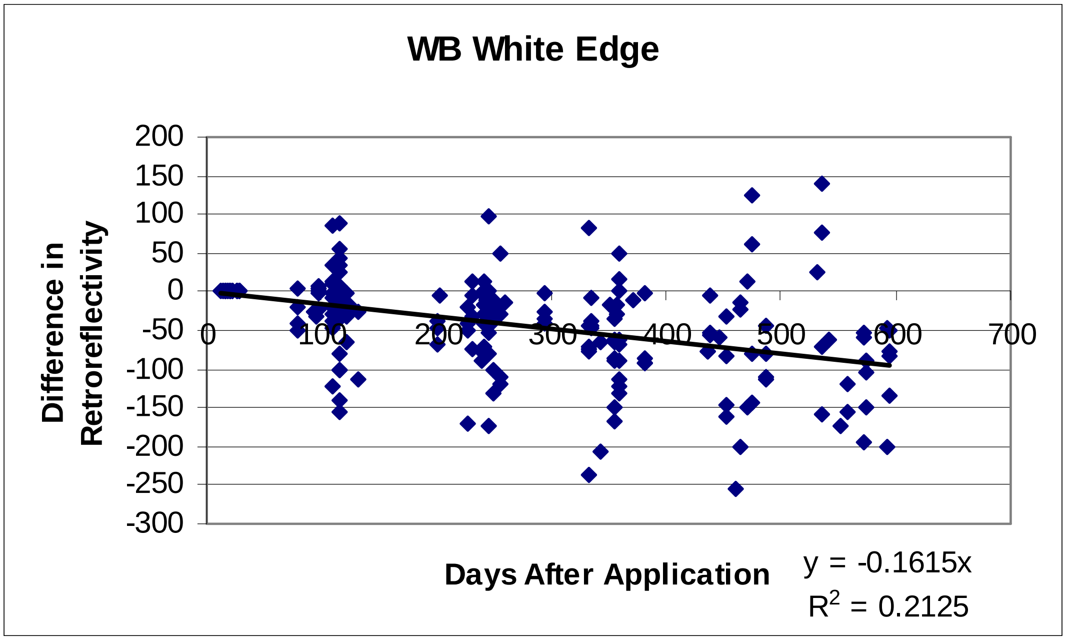


Figure C.1: Waterbased White Edge Line Difference Model

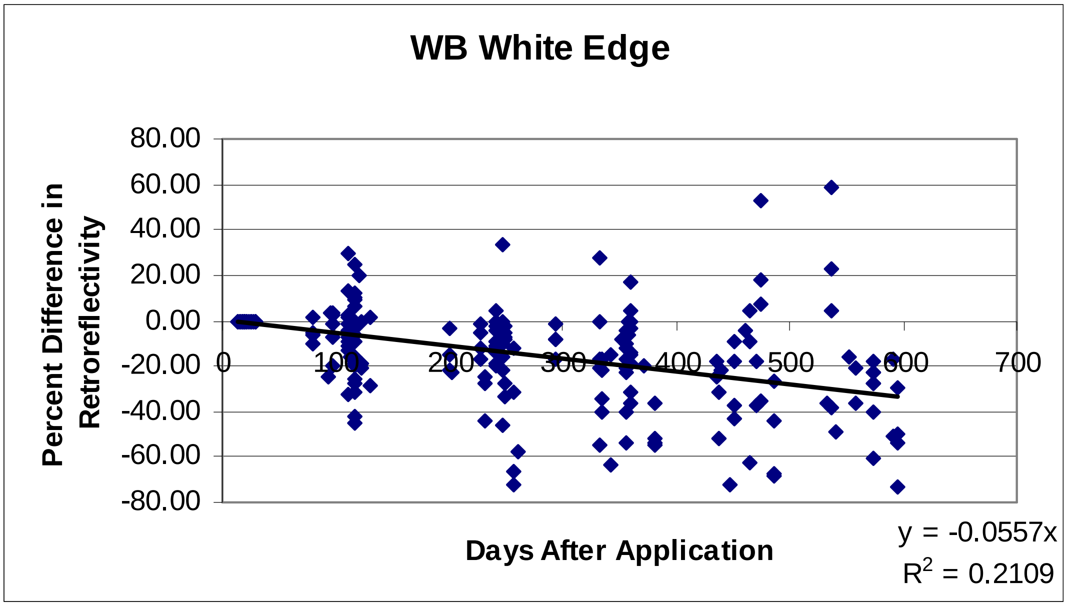


Figure C.2: Waterbased White Edge Line Percent Difference Model

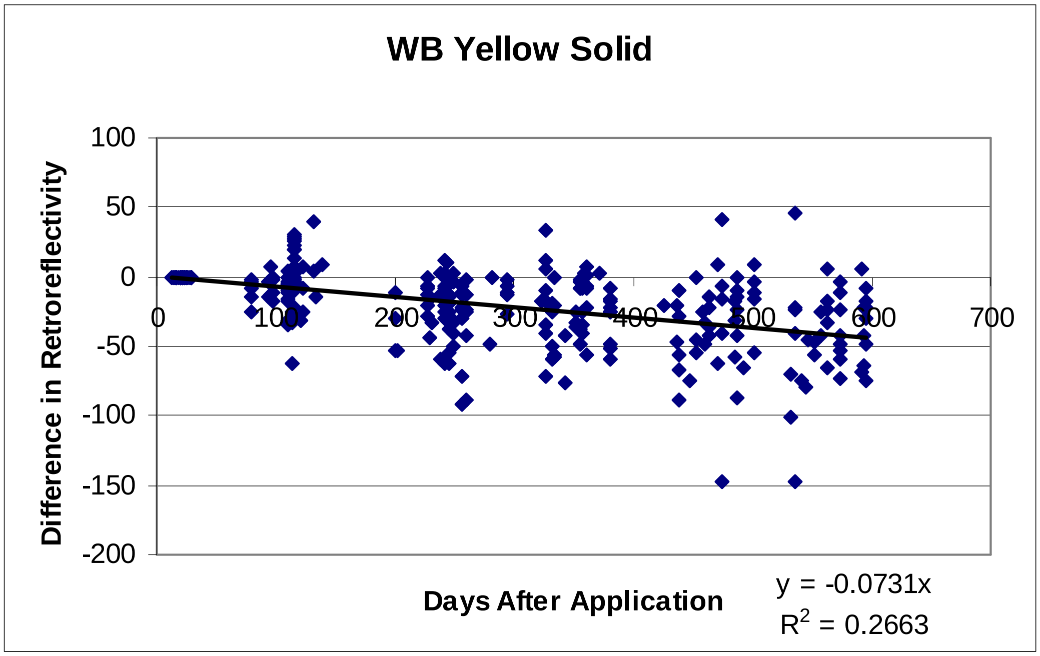


Figure C.3: Waterbased Yellow Solid Centerline Difference Model

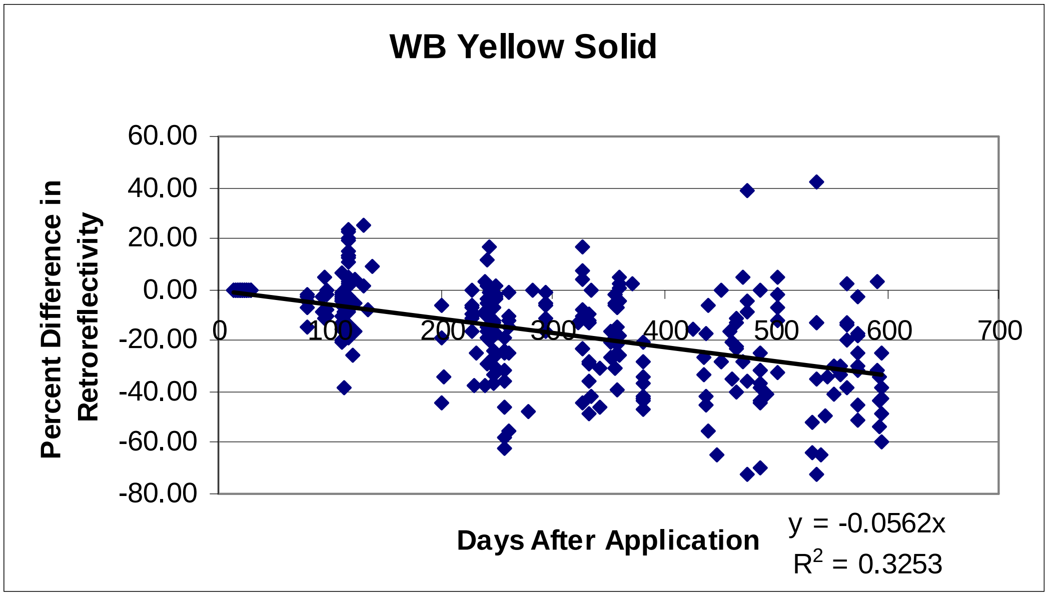


Figure C.4: Waterbased Yellow Solid Centerline Percent Difference Model

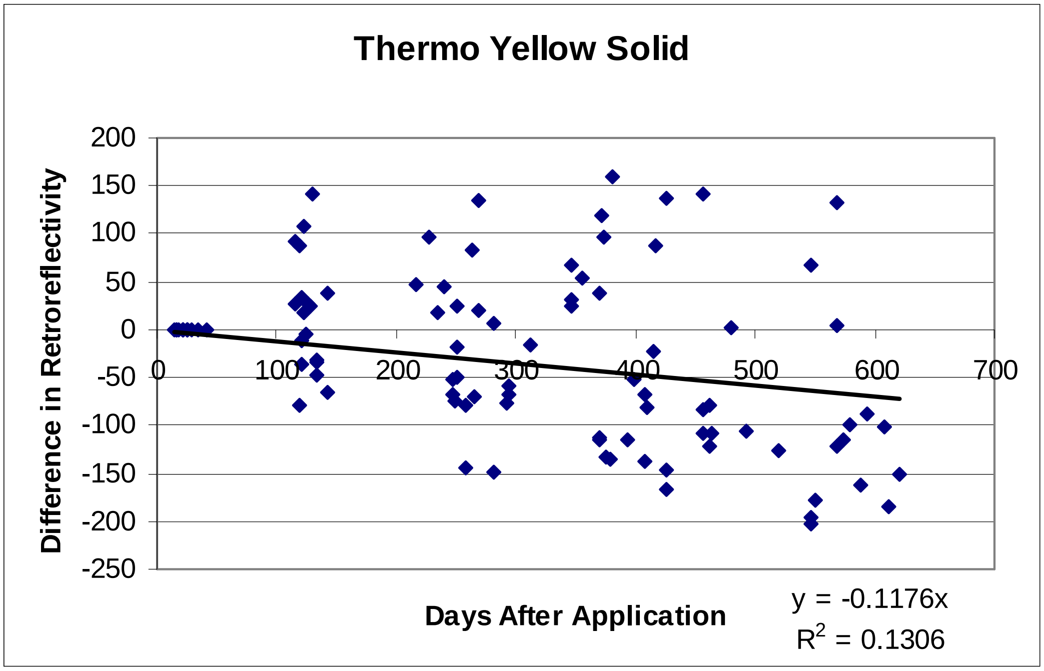


Figure C.5: Thermoplastic Yellow Solid Centerline Linear Difference Model

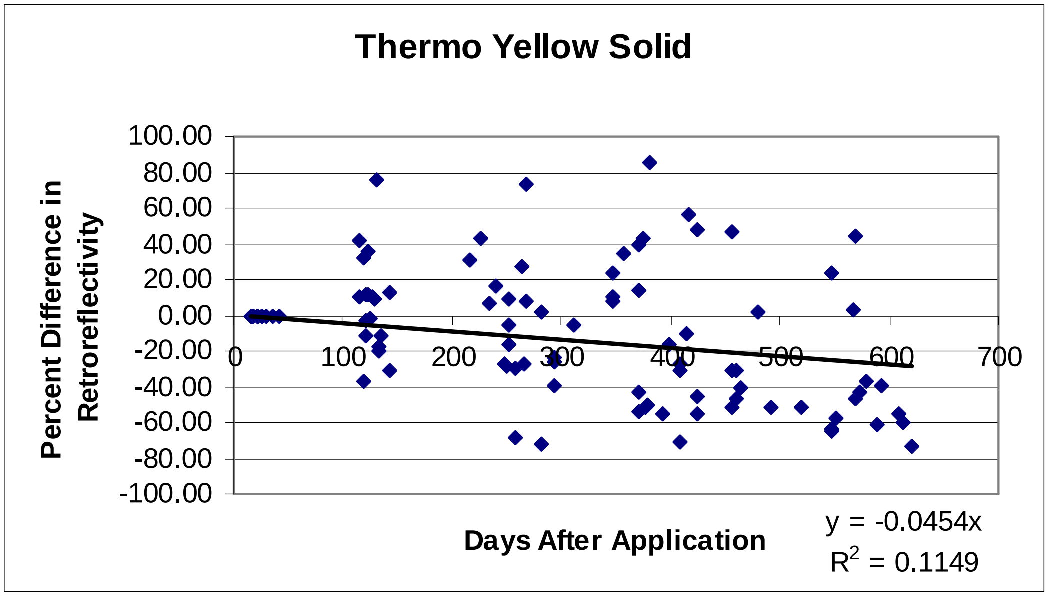


Figure C.6: Thermoplastic Yellow Solid Centerline Linear Percent Difference Model

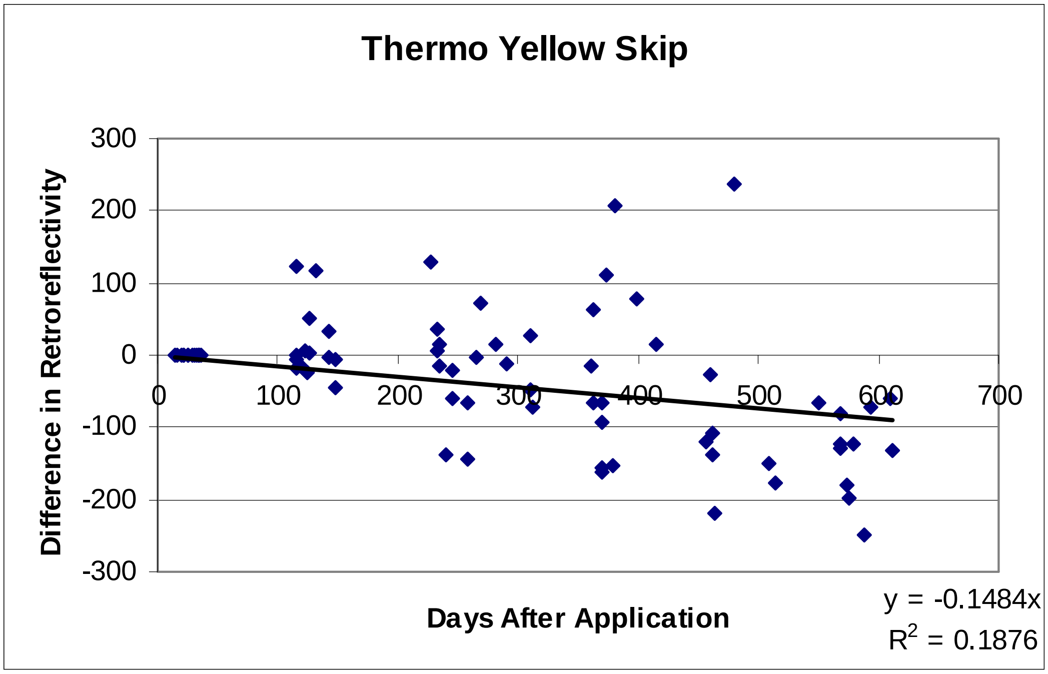


Figure C.7: Thermoplastic Yellow Skip Line Linear Difference Model

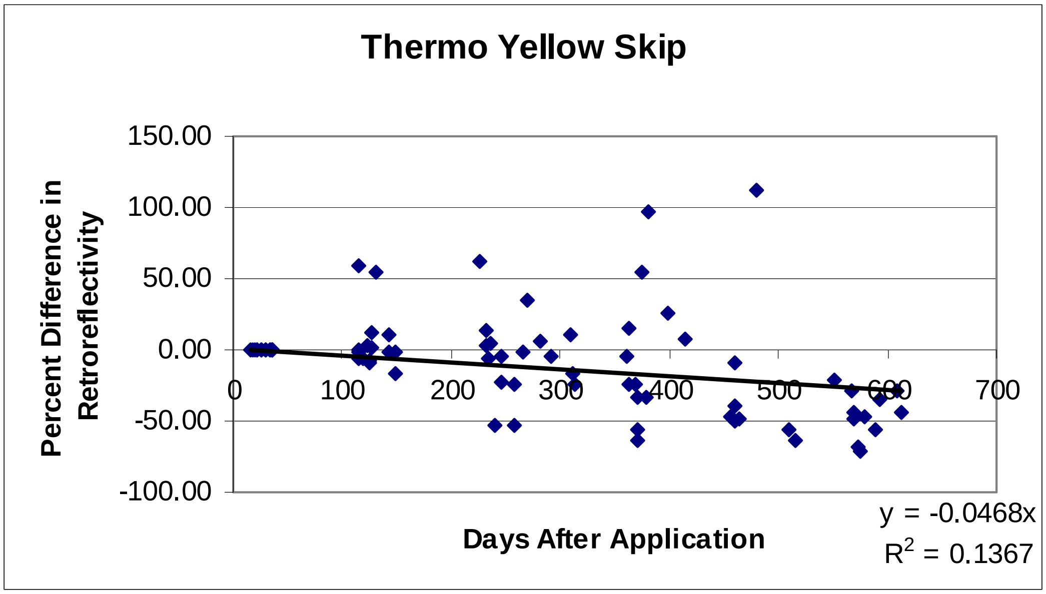


Figure C.8: Thermoplastic Yellow Skip Line Linear Percent Difference Model

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