Local Agency Pavement Marking Plan

Final Report
July 2010

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Institute for Transportation

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16. Abstract

The proposed Federal Highway Administration (FHWA) amendments to the Manual on Uniform Traffic Control Devices (MUTCD) will change the way local agencies manage their pavement markings and place a focus on pavement marking quality and management methods. The research effort covered in this report demonstrates how a pavement marking maintenance method can be developed and used at the local agency level.

The report addresses the common problems faced by agencies in achieving good pavement marking quality and provides recommendations specific to the problems, in terms of assessing pavement marking needs, selecting pavement marking materials, contracting out pavement marking services, measuring and monitoring performance, and developing management tools to visualize pavement marking needs in a geographical information system (GIS) format.

The research includes five case studies, for three counties and two cities, where retroreflectivity was measured over a spring and fall season and then mapped to evaluate pavement marking performance and needs. The research also includes more than 35 field demonstrations (installation and monitoring) of both longitudinal and transverse durable markings in a variety of local agency settings, all within an intense snow plow state.

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LOCAL AGENCY PAVEMENT MARKING PLAN

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EXECUTIVE SUMMARY

This project is focused on assisting local agencies in providing effective and consistent pavement markings on Iowa's public roadways to improve both the safety and quality of travel for the public. The research demonstrates a reliable and practical process for viewing, understanding, and making decisions about pavement marking needs, durability, and quality.

Background

On April 22, 2010, the Federal Highway Administration (FWHA) published a notice of proposed amendments (NPA) for the Manual on Uniform Traffic Control Devices (MUTCD) regarding pavement marking retroreflectivity. The proposed revisions would establish a uniform minimum level of nighttime pavement marking performance, based on the visibility needs of nighttime drivers. The proposed revisions will promote safety, enhance traffic operations, and facilitate comfort and convenience for all drivers, including older drivers.

Given the relatively short life that pavement markings have, in terms of an agency asset, and the lack of performance benchmarks, it has been convenient, up to this point, for many agencies to simply refresh all markings on a cyclical basis. However, with the anticipated amendments to the MUTCD, agencies will need to have a maintenance method in place to manage pavement marking performance at a given benchmark. To do this, agencies will need to understand the performance of their markings, be able to set goals to achieve compliance, and develop the ability to trigger corrective action when performance fails to meet expectations. As the adage goes, "What gets watched…gets done."

Research Approach

The research team, in conjunction with the project technical advisory committee, completed the following tasks:

- Surveyed current pavement marking practices for local Iowa agencies
- Demonstrated new tools to manage pavement marking retroreflectivity through five demonstration studies
- Demonstrated the performance of different pavement marking products of interest to local agencies

A summary of findings for each task follows:

Survey of Current Practice - Local agencies will continue to rely on both in-house crews and private contractors for pavement marking maintenance. Decisions regarding pavement marking materials, and the frequency of application, will be more of a challenge following the final FHWA rulemaking on minimum thresholds. This report provides local agencies with information specific to monitoring quality, improved material selection and cost effectiveness, contracting, and conducting annual condition assessments.

Pavement Marking Management Tool - Case studies were completed for two cities and three counties, representing different pavement marking installation practices. Maps were produced in a geographical information system (GIS) environment to show the pavement marking retroreflectivity conditions by line type and time period. A discussion is provided in terms of map formatting, marking performance thresholds, and the overall utility provided.

Pavement Marking Field Demonstrations - In an effort to support agency decision making, the research team identified reasonable pavement marking alternatives to field demonstrate under local agency conditions. These demonstrations were divided into two categories: longitudinal and transverse markings.

Longitudinal Marking Demonstrations - These two demonstrations provide local agencies with high-build waterborne paint performance examples under two very different conditions, urban and rural. Each setting included both grooved and surface-applied marking segments, so performance could be compared. Under urban conditions, the white skip lines performed for 2 years. The left-turn channelizing lines were still acceptable beyond 2.5 years. In the rural two-lane roadway setting, the grooved edge-line pavement markings performed beyond 2.5 years, in contrast to the surface-applied edge-line and center-line markings, which did not perform beyond 1 year. These demonstrations highlight the need to monitor pavement marking performance by line type, given the variation in performance. These examples are a beginning point for agencies in considering their material selection options over the wide variety of pavement marking materials and installation techniques that are available.

Transverse Marking Demonstrations - The heat-in-place, precut, thermoplastic markings were installed across central Iowa and in a variety of settings, beginning in 2007 and ending in 2009. With a few exceptions, this type of durable marking provided agencies with more than 2 years of effective performance, in contrast to annual painting with waterborne paint. After 2 winters, some left-turn-arrow markings had retroreflectivity readings of more than 300 millicandelas (mcd), regardless of surface type. The life of these markings can be further extended through patching the damaged areas. Concrete surfaces require the use of a primer, which can slow the installation process, and more failures occurred on concrete surfaces than on asphalt. The cooling time for these markings can be accelerated, versus waiting for paint to dry, in humid and cloudy conditions.

Recommendations

The following recommendations are presented to assist local agencies in developing a pavement marking plan that meets the visibility needs of both daytime and nighttime drivers on the local roadway network. With a national pavement marking minimum performance threshold and tools for local agencies to manage marking thresholds, the goal of promoting safety, enhancing traffic operations, and facilitating the comfort and convenience for all drivers is attainable and will appropriately begin at the local level.

Recommendations for local agencies in developing a pavement marking plan follow.

Get Organized

- A clear strategy serves as an organizational magnifying glass, from the ground up. Develop a maintenance method that clearly, and as simply as possible, shows pavement marking conditions, compliance to a benchmark, improvement actions selected, and costs. Selecting a champion to see this initiative through is critical.

Measure and Monitor

- Understand pavement marking performance and annual needs. Begin conducting an annual nighttime survey for pavement marking retroreflectivity and a daytime survey for presence. If a pavement marking retroreflectometer is available, measure marking performance on a consistent basis. Storing this information within a GIS database allows for easier review and decision making and serves as a tool to communicate striping needs.

Develop a Strategy

- To support funding, develop an agency guideline for pavement marking performance and material selection, specific to local conditions.
- For roadways having a remaining service life of at least 5 years, higher traffic volumes, and a history of not keeping a pavement marking line for 12 months, consider more durable pavement marking materials, such as high-build waterborne paint, epoxy, polyurea, or tape, and consider grooving these markings in, to extend their performance.

Consider your Options

- Multi-agency agreements provide agencies of all sizes the advantages of larger quantity pricing and consistent material and installation specifications, and ease the burden of the contracting and/or dispute-resolution process. These agreements can be with a private contractor or another local agency.

Communicate Effectively

- As part of an annual pavement marking contract, agencies can rank pavement marking placement by developing installation maps that are given priority throughout the paint season.
- Have agency staff monitor the quality and quantity of contractor-applied markings.
- Track material installation by date, line, and quantity, and record these in a tabular format, so the information can be used to make more effective decisions each year.

INTRODUCTION

This project is focused on assisting local agencies in providing effective and consistent pavement markings on Iowa's public roadways to improve both the safety and the quality of travel for the public. The research demonstrates a reliable and practical process for viewing, understanding, and making decisions about pavement marking needs, durability, and quality. This project provides important pavement marking support for cities and counties, specifically through these contributions:

- Survey of existing pavement marking practices for local agencies
- Demonstration on tools to manage pavement markings with five case studies (two cities and three counties), which includes a survey of existing marking retroreflectivity, along with the demonstration of visual tools in mapping and tracking marking performance
- Pavement marking field demonstrations, which include the multi-year evaluation of durable pavement marking products under a variety of local agency conditions and roadway settings

These findings are documented within the Research Approach section of this report. A discussion on relevant pavement marking related topics follows.

Background

Providing good pavement markings is an essential component toward safe and efficient travel on Iowa's public roadways. According to Tom Welch, state safety engineer for the Iowa DOT, "every older driver forum has included a consistent demand for brighter and more durable pavement markings."

Based on a recent Iowa DOT project that focused on pavement marking performance, agencies are cautioned in choosing marking materials without field verification of performance in terms of durability and retroreflectivity (which provides an estimate of the nighttime guidance provided to motorists). The study notes that an agency's ability to select materials that will perform well is a significant challenge, given the variety and cost of products, differences in application methods, and continuous changes in roadway, operations, and environmental conditions.

Local agencies in Iowa, rely heavily on contractors to apply pavement markings and, in some cases, lack the tools to clearly identify marking conditions system wide, select the appropriate combinations of markings to apply based on needs, and then track performance and budget for annual or bi-annual marking needs.

Pavement markings convey important information about the roadway to drivers. Pavement markings exist as longitudinal, transverse, text, and symbol markings, with the major focus of the Iowa DOT and local agencies being on longitudinal markings. The Manual on Uniform Traffic Control Devices (MUTCD) places standards and specifications on pavement markings. The manual includes specifications for roadways, explaining appropriate colors and marking layouts for different traffic configurations and conditions. Before any new highway, paved detour, or temporary route is opened to traffic, all necessary markings should be in place *(1)*. MUTCD also specifies, markings that must be visible at night shall be retroreflective, unless ambient illumination assures that the markings are adequately visible. Longitudinal pavement markings provide delineation of the roadway surface during daylight and non-daylight conditions. Agencies today have a wide variety of pavement marking materials to choose from. The materials can vary widely in cost and performance. Agencies face a significant challenge in maintaining these markings to appropriate levels. Pavement marking performance is typically characterized in terms of daytime presence and nighttime retroreflectivity.

The Federal Highway Administration (FHWA) has recently published a request for rulemaking on pavement marking minimum retroreflectivity standards with a proposed implementation phase-in of 4 years after approval (expected in the fall of 2014). In 1992, Congress mandated that minimum retroreflectivity requirements for signs and pavement markings be developed *(2)*. The FHWA continues to conduct research to develop minimum retroreflectivity standards. Requirements will be initiated once research has concluded and the results are analyzed and considered. Previous research is being updated due to changes in roadway user characteristics, vehicle preferences, headlamp performance, and available research tools *(2)*. These requirements may require agencies to maintain markings by implementing a strict paint schedule or developing a pavement marking management system.

Pavement Marking Materials

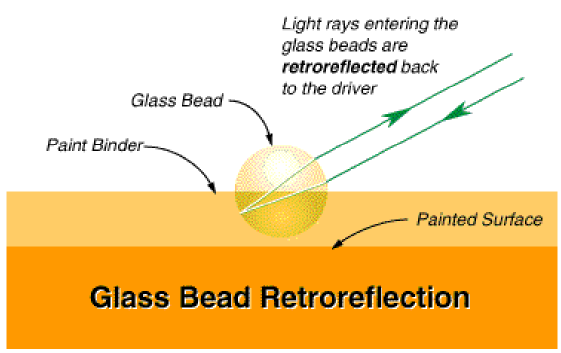
The MUTCD provides specifications for the placement of road markings. Longitudinal pavement markings provide delineation of the traveled way, as well as communicate messages to drivers, such as lines indicating passing or no passing zones. However, MUTCD does not specify the material to be used for the markings.

Materials are chosen based on an agency's pavement marking specifications *(3)*. Roughly 20 different materials are currently used for longitudinal pavement markings *(4)*. Although material selection specifications are based on several factors, the two most common materials are waterborne and thermoplastic paint. The National Cooperative Highway Research Program (NCHRP) survey indicated that waterborne paint is used by 78% of agencies and comprises 60% of total centerline mileage. However, because of its low price, waterborne paint accounts for only 17% of total expenditures on pavement markings. The more expensive and durable thermoplastic material is used by 69% of the agencies surveyed and comprises 23% of the total mileage. Because of its higher price, 35% of total expenditures on pavement markings is attributed to thermoplastic material.

The University of Hampshire performed a research project for the New Hampshire DOT (NHDOT) to analyze possibilities of improving acrylic waterborne paints *(5)*. The report mainly focused on paint formulations and application techniques to improve the durability of the marking. The research recommended a revision of the pavement marking specifications and the development of a test deck to introduce new retroreflective bead and paint combinations. Waterborne paint became more popular after the Environmental Protection Agency (EPA) established standards on volatile organic compounds (VOC) in 1995 *(5)*. Conventional solvent-based paints had VOC concentrations greater than 450 g/l. The EPA regulation set the upper VOC concentration of 150 g/l. Agencies were forced to find marking materials under the set regulation, thus waterborne materials were quickly adopted. The most common material being used is 100% acrylic waterborne paint that has VOC concentrations between 98 and 120 g/l.

Retroreflective Materials

Previous research of retroreflective elements show the characteristics evaluated in this study are important for maximizing pavement marking performance. Pavement markings guide drivers on the roadway, whether it is during daylight or non-daylight conditions. Pavement markings perform effectively during non-daylight hours by providing retroreflectivity. This characteristic is either provided as a matrix or a glass bead, which is applied to the surface of the marking during application. Retroreflectivity represents the amount of light that is reflected back to the source (See Figure 1).



Source: HIGHWAY TECHNET

Figure 1. Illustration of Retroreflectivity

Reflection gives drivers appropriate information at a safe distance so they have sufficient reaction time. Light from the headlamp enters the glass bead and is retroreflected back to the driver's eye. If the glass bead is not properly embedded, the light will not be retroreflected at the appropriate angle, and the light will scatter and the driver will not be able to see the marking. Bead roll also causes a loss in retroreflectivity, because paint covering the glass bead prevents light from entering the sphere. These attributes contribute to the delineation of pavement markings during nighttime conditions.

Glass beads are the most commonly used retroreflective element with waterborne paint. Several different types of beads are available on the market. More important than type, is the size of the bead used in the marking. Bead types I and II are specified by the American Association of State Highway Transportation Officials (AASHTO), whereas the FHWA specifies gradations for types 3, 4, and 5. Type I beads are the smallest bead on the market and are commonly used in thermoplastic markings. The most common drop-on glass bead used with paint is the Type I glass bead.

Large beads (Types 3, 4, and 5) are known for their ability to improve wet-night visibility. The large bead higher profile allows the surface to protrude through a film of water, unlike small beads (Type I and II) *(6)*. Wet markings with small beads become invisible in wet-night conditions, because a film of water over the beads refracts the light before it can reach the glass bead.

In 2005, the NHDOT analyzed the potential of using polymethymethacrylate (PMMA) beads in place of glass beads *(7)*. The overall goal of the research was to improve the durability of pavement markings that sustain retroreflectivity. Field and lab tests revealed that the PMMA technology resulted in significantly higher wear resistance over conventional beads.

The Texas DOT (TxDOT) developed a pavement marking handbook to assist pavement marking personnel with marking material selection, installation, and inspection (6). The handbook discusses installation and inspection that includes bead application properties.

The two most important field-controlled properties are the amount and dispersion of exposed beads across a line and the depth of bead embedment. These properties are controlled by bead drop rate, speed of the striping truck, temperature, and viscosity of the paint. The number of glass beads being applied and the dispersion is difficult to observe and inspect. Pavement marking crews often observe embedment and dispersion by close-up visual examination and the sun-over-shoulder method. Other crews make adjustments based on retroreflectivity readings taken on fresh markings.

The handbook recommends beads are embedded at 60% of the bead diameter. Bead embedment beneath the recommended depth results in loss of light in different directions and beads that can be easily worn away by traffic and maintenance activities. Beads that are located at depths greater than 60% of the bead diameter still reflect light; however, the retroreflectance is not as high as a properly-embedded bead. Proper bead dispersion and embedment are important properties in maximizing the retroreflectivity of longitudinal pavement markings.

One of the most common and cost-effective materials being used in many states is the combination of waterborne paint and VisiBeads™. The Oregon DOT (ODOT) evaluated waterborne paint and VisiBeads™ application techniques and performance to determine its future use of the material *(8)*.

The study considered cost, environmental concerns, and operational issues of both materials. Results concluded that waterborne paint is an acceptable alternative to conventional paints. However, some issues were found with the application techniques and bead rate of the VisiBeads™. Potters Industries representatives recommended a bead application rate of 15 pounds per gallon, which was unrealistic to ODOT personnel, because of increased cost and the lack of wet paint film thickness. ODOT also had issues with gun modifications to accommodate the VisiBeads™, which since have been resolved.

Pavement Marking Performance

Several research studies have been conducted on the service life of pavement markings and projecting the life cycle of markings. These studies attempted to quantify the performance of pavement markings by retroreflectivity. This is accomplished by maintaining minimum levels. However, minimal research has looked at the application process to increase the performance of pavement markings. The FHWA continues to research the effect of implementing a minimum retroreflectivity level for pavement markings. Maintaining a minimum retroreflectivity level may require a monitoring program or the implementation of a pavement marking management tool. Research continues to develop in the area of performance to predict the service life of pavement marking materials.

Driver preference is for pavement markings to exhibit retroreflectivity readings greater than 100 millicandelas per square meter per lux (mcd/m2/lux) *(9)*. Several studies have set the minimum threshold retroreflectivity at 100 or 150 mcd/m2/lux. Research findings and expert opinions continue to be assessed and transportation agencies may struggle to maintain minimum acceptable retroreflectivity. Pavement marking management systems may help agencies maintain requirements by providing striping schedules.

The implementation of the VOC concentration regulations by the EPA brought on several studies of waterborne pavement markings. The Missouri DOT (MoDOT) conducted a study in 2005 that analyzed the properties and durability of different bead and waterborne paint combinations *(10)*. Test sections throughout MoDOT district roadways were evaluated to find results of different combinations. The project presented the need for a minimum initial retroreflectivity of 350 mcd/m2/lux for white lines and 225 mcd/m2/lux for yellow lines, to obtain a service life of 2 years. The study also recommended restriping of white lines at 200 mcd/m2/lux and 175 mcd/m2/lux for yellow longitudinal pavement markings.

The Utah DOT (UDOT) performed a study on waterborne traffic paint to provide more information about the effects of traffic and other road activities on the markings *(11)*. The study reported that waterborne paint retroreflectivity failure (100 mcd/m2/lux) occurs between 8 and 17 months after painting, depending on the annual average daily traffic (AADT) of the roadway. The primary factors affecting the life of a pavement marking include snowplowing, curvature of a roadway, pavement type, and condition. The research report resulted in the development of a pavement marking decision matrix to be used by UDOT decision makers.

Clemson University looked at analyzing retroreflectivity levels in the process of developing degradation models of pavement markings *(12)*. They concluded that several factors, including pavement surface, marking material and color, and maintenance activities, affected the performance and retroreflectivity of pavement markings.

A service life study that included 19 states evaluated the service life of pavement markings over a period of 4 years and found that regression models best fit the data *(13)*. The evaluation was done on several marking materials and variations that can be attributed to roadway type, regional location, marking specifications, contractor installation procedures and quality control, and winter maintenance activities.

The Washington State Transportation Center (TRAC) conducted a study with the intent of developing retroreflectivity degradation curves for pavement markings *(14)*. They found a high variability in data, concluding that striping performance predictions cannot be determined with a high level of statistical confidence.

Different materials have been evaluated extensively in an attempt to help decision makers choose cost-effective materials. At Iowa State University, Thomas and Schloz completed a research project for the Iowa DOT to develop a program that evaluated various products used as pavement markings *(15)*. This program would assist state and local agencies with decision making by providing a database of performance and cost information of different materials.

The study recommended that the Iowa DOT should not conduct a test deck, but rather follow pavement marking evaluation done by the National Transportation Product Evaluation Program (NTPEP). NTPEP was established in 1994 by AASHTO and member states. The program evaluates several different marking materials in different states across the country to assist state and local agency decision making.

Michigan State University was contracted by the Michigan DOT (MDOT) to investigate the use of different pavement marking materials *(16)*. MDOT wanted to develop guidelines governing the cost-effective use of pavement marking materials. Results of the study showed that retroreflectivity did not vary much between different materials, and that winter maintenance appeared to be the main factor affecting the decay of retroreflectivity.

Additional research of pavement marking performance has led to the development of pavement marking management systems. Transportation Research Record 1794, 2002, contained two research papers on the development of pavement marking management systems. Abboud and Bowman *(17)* established a way to set striping schedules that account for factors affecting scheduling, application cost, service life, and user cost relative to crashes during the stripes lifetime.

Rich et al. studied the performance and durability of longitudinal pavement markings in Michigan to develop a practical marking management system *(18)*. Their efforts included evaluation of the glass sphere content. Two techniques were used to quantify the glass sphere content in the paint.

With the first method, aluminum plates were fastened to the roadway and painted by the striping operation. The plates were pyrolyzed at elevated temperatures, from which a mass fraction of glass spheres before and after the pyrolyation can be calculated.

The second method dealt with photographs of the plates at low magnifications. The images were converted to binary images that were evaluated using image analysis software. The software was able to determine the number of spheres per area, average size, and aerial percent. The research concluded that retroreflectivity is directly related to glass sphere content and the decay of retroreflectivity is related to seasonal maintenance activities.

The Minnesota DOT (Mn/DOT) used the general public to evaluate markings to establish a threshold value of retroreflectivity to be used in a pavement marking management program *(19)*. Minnesota citizens drove vehicles on several different facilities with an interviewer that asked questions pertaining to detection distance of the pavement markings along the route. As a result the Mn/DOT has established a minimum retroreflectivity threshold of 120 mcd/m2/lux.

Relationship between Pavement Marking Retroreflectivity and Safety

Highway safety has been linked to several attributes of the roadway. Several transportation officials and researchers have attempted to relate visibility and retroreflectivity to safety. Transportation agencies continue to look for ways to accommodate the rise in the average age of drivers on the roadway.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) contains provisions that include improving pavement markings in all states, specifically targeted at older drivers *(20)*. The article supports bigger and brighter signs, more conspicuous signals, and wider pavement marking, in an attempt to make highways safer for older drivers.

The University of Iowa completed a study in 2003, Enhancing Pavement Markings Visibility for Older Drivers, to determine the effects of increasing the width and retroreflectivity of pavement markings *(21)*. The study was trying to determine an effective method to increase the detection distance. It found that distances are driven by retroreflectivity rather than width.

NCHRP Project 17-28 attempted to quantify the relationship between retroreflectivity and safety over time *(22)*. The research concluded that there is no safety benefit of higher retroreflectivity for longitudinal markings; however, it is important that the markings are present and visible to drivers.

Cottrell Jr. and Hanson conducted a research project to determine the safety, motorist opinion, and cost-effectiveness of pavement marking materials used by the Virginia DOT (VDOT) *(23)*. Motorists indicated in surveys that people prefer pavement markings with higher retroreflectivity. They also concluded that more data was needed to determine if the type of pavement marking affects the safety of the facility. Recent research has not proven the significance of higher retroreflectivity, but drivers indicated that they feel more comfortable with brighter pavement markings.

Run-off-the-road crashes are one of the most common types of crashes on rural facilities. One study attempted to find a relationship between retroreflectivity and crashes on rural facilities *(24)*. The research proposed that lower retroreflectivity values were a contributing factor in crashes. Previous research has been done in this area; however, no other study has determined a statistically significant relationship. The study managed to identify a statistically significant relationship between low pavement marking retroreflectivity and safety performance.

Agencies should look to reduce the number of crashes by making more informed decisions about their pavement marking management programs in the areas that low retroreflectivity values exist.

RESEARCH APPROACH

The research team, in conjunction with the project technical advisory committee, developed a research approach that included a number of key tasks to be completed to achieve the project objectives. These were the key tasks:

- Survey of pavement marking current practices for Iowa local agencies
- Tools to manage pavement markings (five case studies)
- Pavement marking field demonstrations (36 demos)

Survey of Pavement Marking Practices

The research team developed and conducted a survey of city and county pavement marking practices, which included their existing budgets, needs, concerns, and material evaluations (See Figure 2). The survey was used to establish typical application methods, how often markings are being rated or replaced, and what types of materials are being used. The survey effort included follow-up interviews, where necessary, and was solicited via the County Service Bureau to all counties, using the Iowa DOT mail list to distribute to cities above 5,000 in population.

Survey responses were received from 11 cities and 33 counties, with the results provided in Tables 1 and 2, respectively.

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IOWA STATE UNIVERSITY

Local Agency Pavement Marking Plan
Statewide Survey

BUDGET

1. What is your annual budget for pavement markings (material plus installation)?

$ ______________________

INSTALLATION

Who installs your pavement markings (Staff, Contractor, Other)?

____

____

____

MATERIALS

Please list the pavement marking material types used by your agency from most commonly used to least commonly used:

1. ______________
2. ______________
3. ______________
4. ______________
5. ______________
6. ______________
7. ______________
8. ______________

COMMON MATERIALS:

- Waterborne
- Durable Waterborne
- Thermoplastic
- Tape
- Epoxy
- Polyurea

OTHER

How do you select which roadways to paint (Cycle, Annual Rotation, Visual Inspection, Measured Retroreflectivity, Other)?

____

____

____

Iowa State University's Center for Transportation Research and Education (CTRE) administers the following programs: Bridge Engineering Center • Center for Weather Impacts on Mobility and Safety • Construction Management & Technology • Iowa Local Technical Assistance Program • Iowa Statewide Urban Design and Specifications • Iowa Traffic Safety Data Service • Midwest Transportation Consortium • National Concrete Pavement Technology Center • Partnership for Geotechnical Advancement • Roadway Infrastructure Management Systems • Traffic Safety and Operations

Do you paint by line type (For example: Yellow centerline is painted one year and edge line the next)?

____

____

____

Do you inspect new pavement markings for quality? If so, please describe the inspection process. Is the inspection done by agency staff or others?

____

____

____

____

____

____

For existing markings, do you have an established pavement marking evaluation process? If so, please describe.

____

____

____

If you use your own crews to place pavement markings, what equipment is used?

____

____

____

CONTACT INFORMATION:

Name: ______________________

Organization: ______________________

Phone: ______________________

Email: ______________________

Please send responses via email, fax, or mail to:

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2

Figure 2. Local agency survey form

Table 1. Survey responses from cities

AGENCY	INSTALLATION	PAVEMENT MARKING MATERIALS USED			PROJECT SELECTION	BUDGET
		1	2	3		
Cedar Rapids	Staff / Contractor	Waterborne	Tape	Polyurea / Epoxy	Cycle / Visual Inspection	$400,000
Charles City	Staff	Waterborne			Cycle	$9,435
Clarinda	Contractor				Annual Rotation	$5,345
Clinton	Staff	Waterborne			Visual Inspection	$15,000
Council Bluffs	Staff	Waterborne	Tape		Cycle	$30,000
Harlan	Staff	Waterborne			Visual Inspection	$2,000
Sioux Center	Staff / Contractor				Annual Rotation	$12,000
Sioux City	Contractor	Waterborne	Epoxy	Tape	Visual / Complaint Basis	$125,000
Springville	Staff	Durable Waterborne			Visual Inspection	$15,000
Urbandale	Staff	Waterborne	Tape		Cycle	$47,500
West Des Moines	Staff / Contractor	Waterborne	Polyurea	Tape	Biannual Rotation	$80,000

Table 2. Survey responses from counties

AGENCY	INSTALLATION	PAVEMENT MARKING MATERIALS USED			PROJECT SELECTION	BUDGET
		1	2	3		
Allamakee County	Contractor	Waterborne	Durable Waterborne	Epoxy	Visual Inspection	$25,000
Appanoose County	Contractor	Waterborne			Visual Inspection	$30,000
Black Hawk County	Contractor	Waterborne	Epoxy		Cycle, Visual Inspection	$50,000
Boone County	Contractor	Waterborne			Cycle, Visual Inspection	$45,000
Bremer County	Contractor	Waterborne	Tape		Cycle, Visual Inspection	$30,000
Buchanan County	Contractor	Waterborne			Visual Inspection	$45,000
Cedar County	Contractor	Waterborne	Epoxy			$60,000
Cerro Gordo County	Contractor	Waterborne	Polyurea		Visual Inspection	$60,000
Clinton County	Contractor	Waterborne	Epoxy	Durable Waterborne	Cycle	$85,000
Crawford County	Contractor	Waterborne			Visual Inspection	$35,000
Dallas County	Contractor	Durable Waterborne	Waterborne	Polyurea	Visual, Measured Retroreflectivity	$50,000
Delaware County	Contractor	Waterborne	Durable Waterborne	Epoxy	Cycle, Visual Inspection	$50,000
Franklin County	Contractor	Waterborne			Cycle, Annual Rotation	$60,000
Fremont County	Contractor	Waterborne	Durable Waterborne	Epoxy	Cycle	$32,500
Grundy County	Contractor	Waterborne	Epoxy		Annual Rotation, Visual Inspection	$50,000
Hancock County	Contractor	Waterborne			Cycle, Visual Inspection	$75,000
Henry County	Staff	Waterborne			Annual Rotation, Visual Inspection	$47,000
Jefferson County	Staff	Durable Waterborne			Annual Rotation, Visual Inspection	$25,000
Jones County	Contractor	Waterborne			Cycle, Visual Inspection	$50,000
Keokuk County	Contractor	Waterborne	Epoxy	Durable Waterborne	Cycle, Visual Inspection	$25,000
Lee County	Contractor	Waterborne			Cycle, Visual Inspection	$35,000
Linn County	Staff	Waterborne	Epoxy		Visual Inspection	$19,000
Marion County	Contractor, Staff	Waterborne			Visual Inspection, Cycle	$40,000
Monona County	Contractor	Waterborne			Visual Inspection	$48,000
Muscatine County	Contractor	Waterborne	Epoxy			$75,000
Osceola County	Contractor	Waterborne			Visual Inspection	$25,000
Palo Alto County	Contractor	Waterborne	Durable Waterborne		Cycle	$26,000
Polk County	Contractor	Waterborne			Cycle	$160,000
Story County	Contractor	Waterborne			Cycle	$55,000
Warren County	Contractor	Waterborne	Durable Waterborne	Epoxy	Visual Inspection	$62,000
Washington County	Contractor	Waterborne			Annual Rotation	$30,000
Webster County	Contractor	Waterborne			Cycle	$87,500
Wright County	Contractor	Waterborne			Cycle, Annual Rotation	$30,000

Local Agency Pavement Marking Practices in Minnesota

The research team recently completed a related survey of local agencies in Minnesota (9 counties and 6 cities) *(25)*. Here is a summary of the findings:

1. What determines your annual paint program?
    - 7 agencies—no assessment (paint all lines each year)
    - 3 agencies—subjective assessment of durable markings only
    - 4 agencies—subjective assessment (daytime only) of all markings
    - 1 agency—subjective assessment (nighttime) of all markings

2. How is this work performed?
    - 4 agencies use their in-house crews for latex markings
    - 7 agencies contract out all pavement marking work
    - 1 agency contracts directly with Mn/DOT
    - 3 agencies participate in a multi-agency agreement contract

3. What specifications do you use (beads and paint)?
    - 4 agencies use their own (agency specific) specifications
    - 11 agencies use Mn/DOT standard specifications for materials and application

4. What are your quality control practices?
    - 4 agencies—none (agency uses in-house crews)
    - 1 agency—none (agency uses Mn/DOT)
    - 3 agencies—none (agency uses private Contractors)
    - 1 agency—minimal (agency only monitors quantities)
    - 5 agencies—moderate (agency employee monitors marking operations)
    - 1 agency—enhanced (agency employee monitors marking operations, quantity, and quality)

Tools to Manage Pavement Markings

Pavement marking performance is described in terms of the marking's daytime presence and nighttime retroreflectivity. As shown in Tables 1 and 2, no Iowa city or county agencies were using pavement marking retroreflectivity measurements as part of their annual assessment process.

As a result, the research team chose to demonstrate how an agency could conduct a system-wide retroreflectivity assessment to be used as part of their pavement marking needs and annual striping plans. Over time, this information can be used to assess the durability and performance of different pavement marking products and installation methods.

Case studies were conducted for two cities and three counties, representing different pavement marking installation practices (See Table 3). The demonstration included the following steps for each agency:

- Work with the agency to identify the roadways to be included
- Develop a data collection protocol
- Conduct field measurements using a handheld retroreflectometer (Delta LTL-X 30-Meter Retroreflectometer), which reports retroreflectivity in units of millicandella per meter squared per lux (mcd).
- Summarize and report the data in a geographical information system (GIS) environment
- Provide retroreflectivity GIS maps back to each agency for comments and feedback

Table 3. Case study locations and installation methods currently used

	Pavement Marking Applied Using:	
Agency	**Contractor**	**Agency Staff**
Dallas County	☒	
Marion County	☒	
Henry County		☒
City of West Des Moines	☒	☒
City of Ames		☒

Field measurements of pavement marking retroreflectivity were collected at two different times covering a spring and fall time period. This was to demonstrate the pavement marking retroreflectivity degradation due to normal traffic operations (spring to fall) and damage due to winter maintenance operations (fall to spring). Table 4 shows the dates for collection by agency.

Table 4. Case study locations and measurement time periods

	Retroreflectivity Measurements		
Agency	**Fall 2006**	**Spring 2007**	**Fall 2007**
Dallas County	☒	☒	
Marion County	☒	☒	
Henry County		☒	☒
City of West Des Moines		☒	☒
City of Ames	☒	☒	

The objective for each case study was to produce a map that visually showed the pavement marking retroreflectivity conditions by line type and time period. The maps can benefit each agency in the following tasks:

- Visualize pavement marking needs and communicate these needs at multiple levels (such as maintenance, engineer, and elected official).
- Support agency decision making in terms of determining their annual striping plans (as in what to paint each paint season).
- Manage pavement marking performance over time through monitoring changes in retroreflectivity, quality control procedures, material selection, and installation methods.

Figure 3 shows a sample map that illustrates a number of key features:

- Each dot on the map represents an average retroreflectivity reading (five readings were obtained and averaged every half mile) for each line type (edge line and centerline).
- The legend identifies each retroreflectivity threshold level by color. The thresholds are different depending on the marking color and line type. For example, red dots on the map represent a value of 150 mcd or lower for white edge lines and of 100 mcd or lower for the centerline.
- For each county, the dots are offset from the roadway centerline to show each line separately. For cities, separate maps were developed by line type to reduce clutter, given the urban street network.

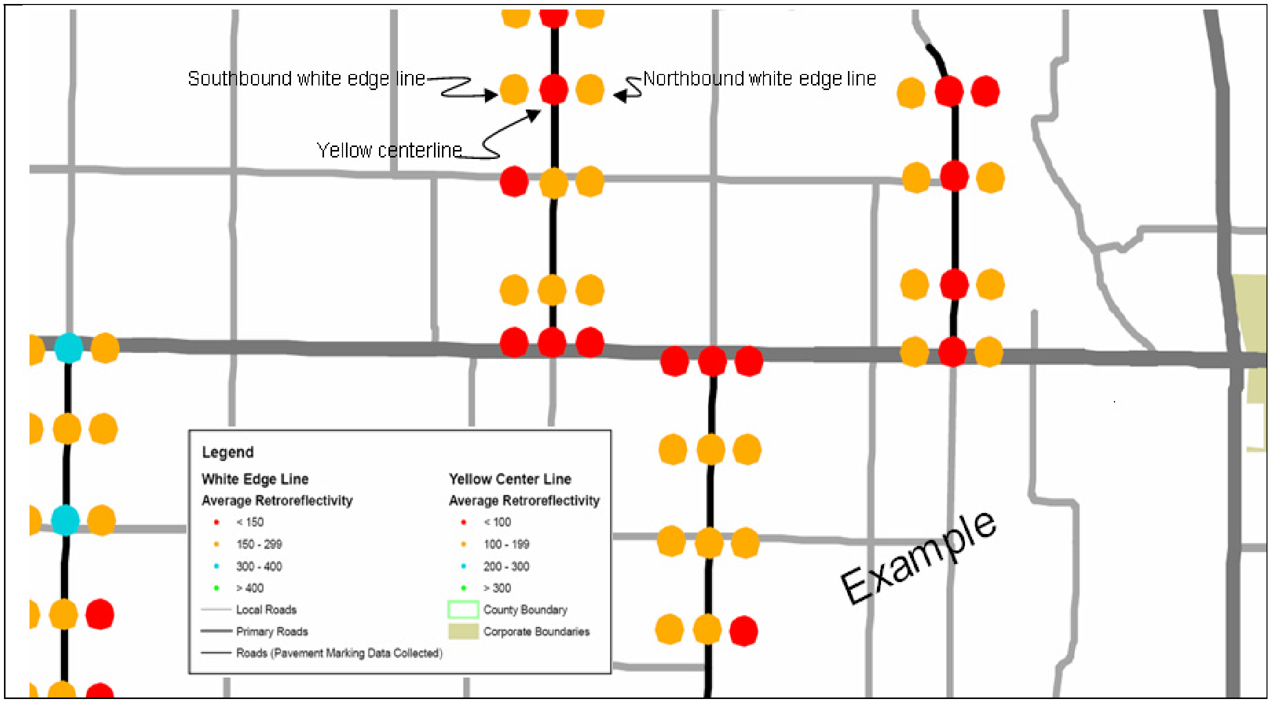


Figure 3. Sample case study map showing pavement marking retroreflectivity

Case study maps for each agency are shown in Figures 4 through 22. Each map represents either a spring or fall time period. The same legend is used for each map, along with the agency name and collection period.

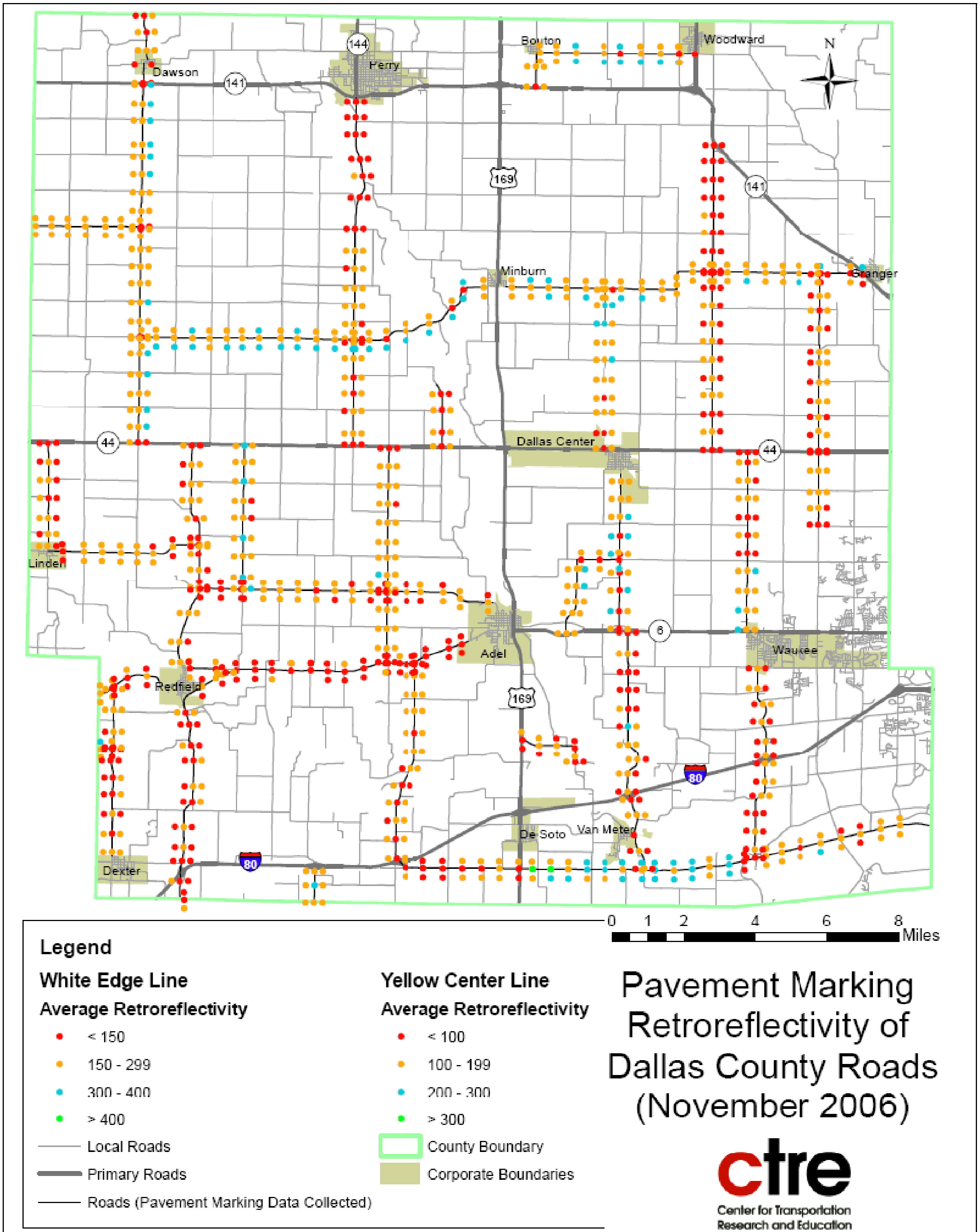


Figure 4. Dallas County retroreflectivity map – November 2006

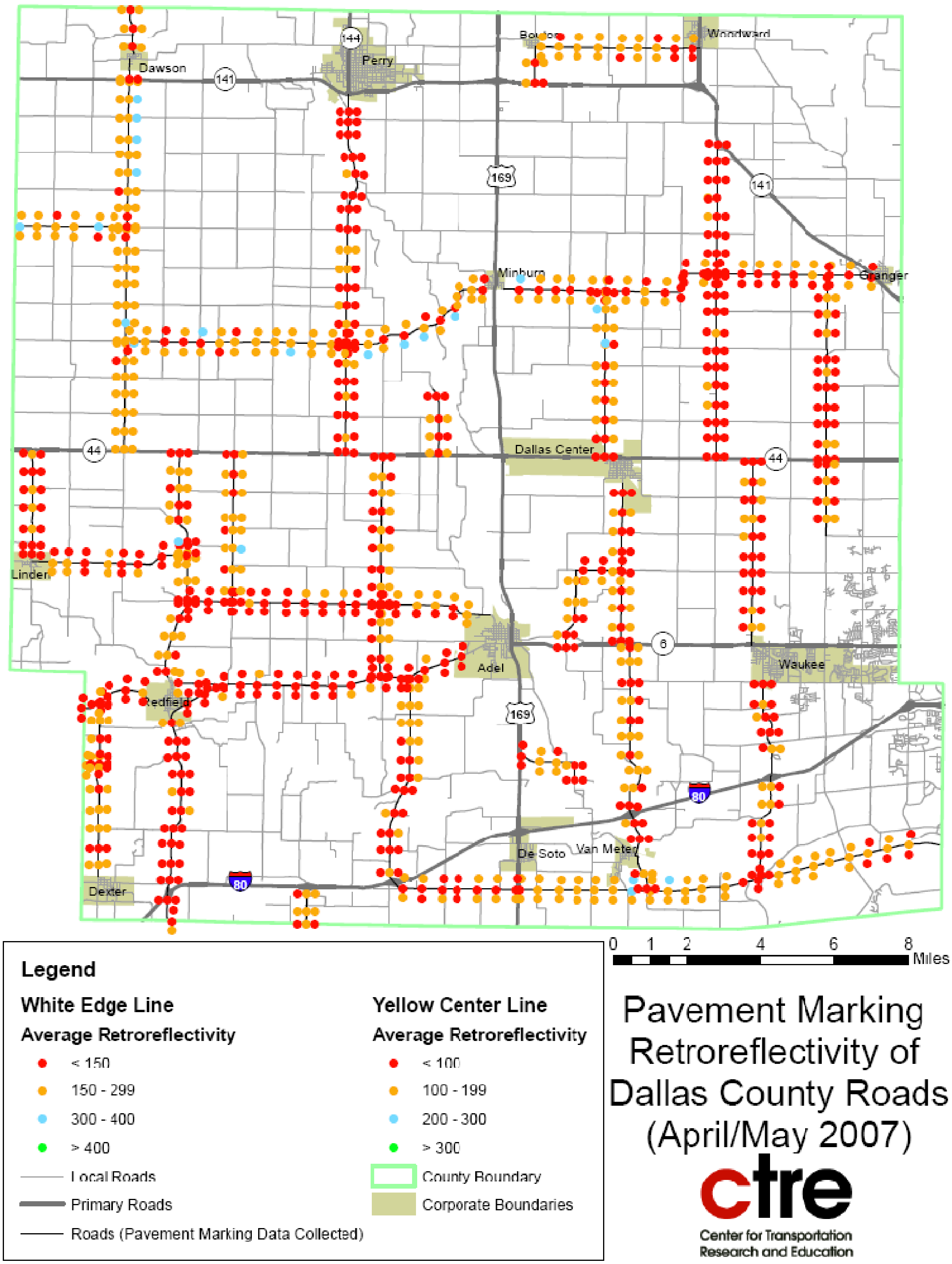


Figure 5. Dallas County retroreflectivity map – May 2007

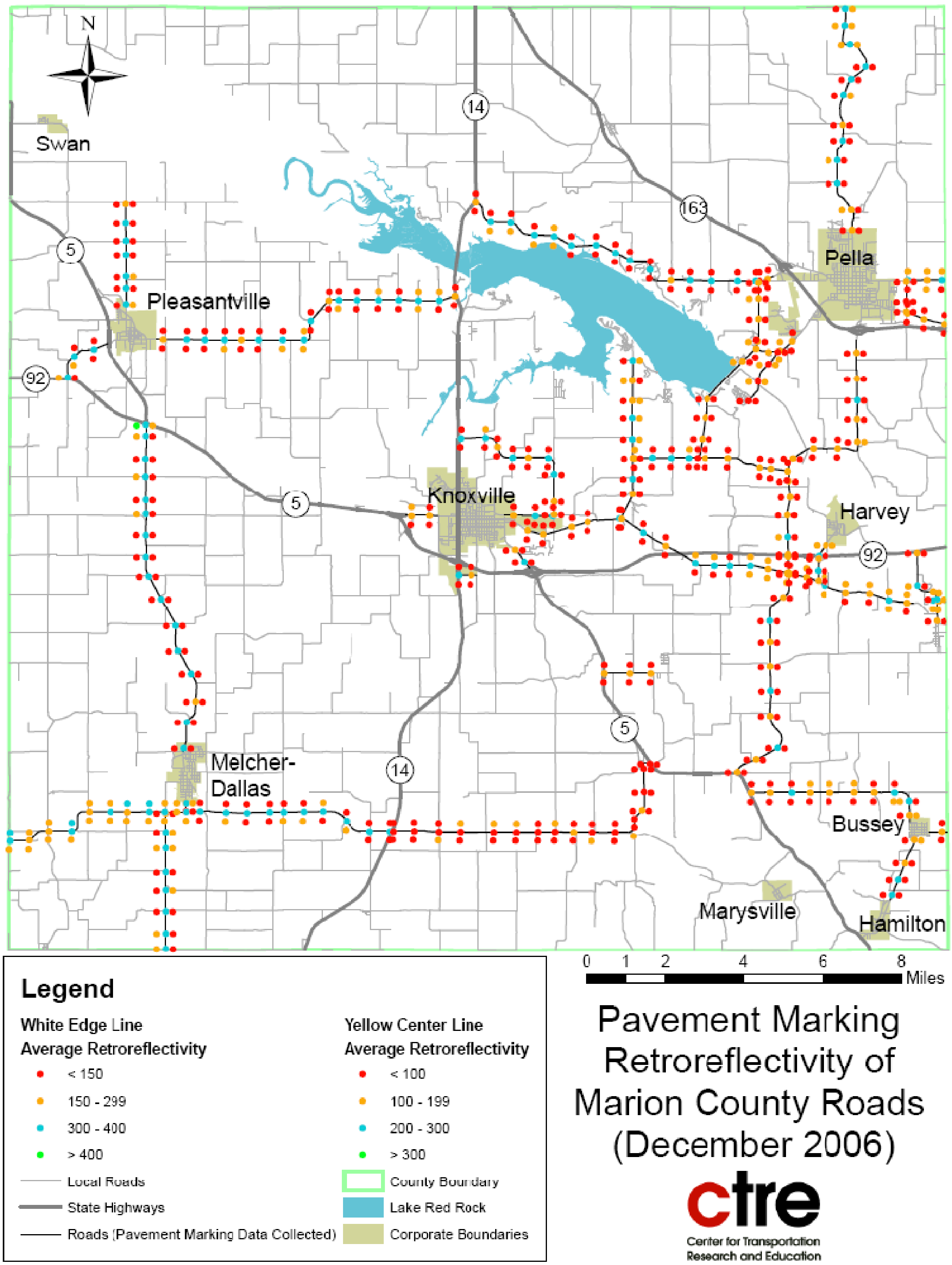


Figure 6. Marion County retroreflectivity map – December 2006

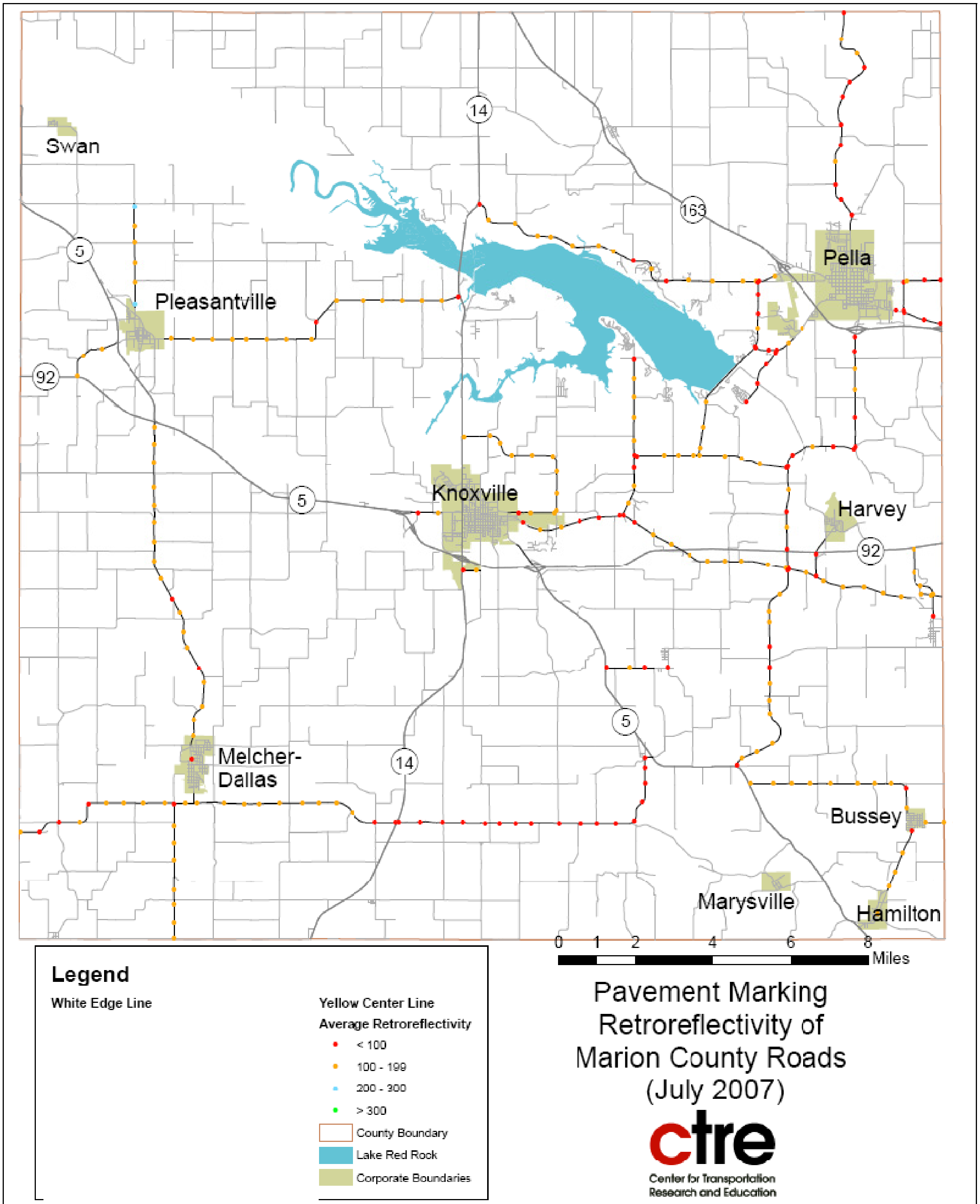


Figure 7. Marion County retroreflectivity map (yellow centerline) – July 2007

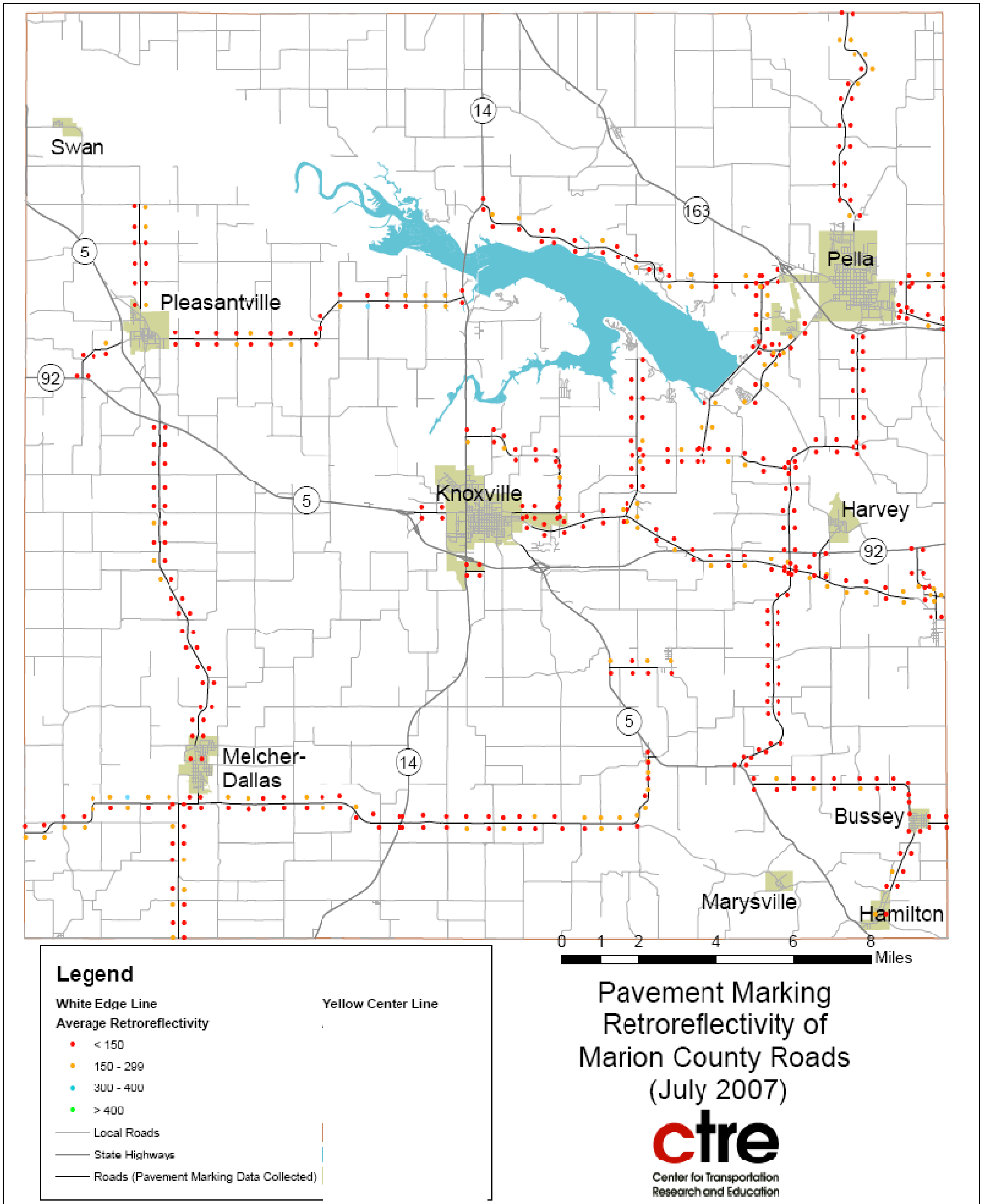


Figure 8. Marion County retroreflectivity map (white edge line) – July 2007

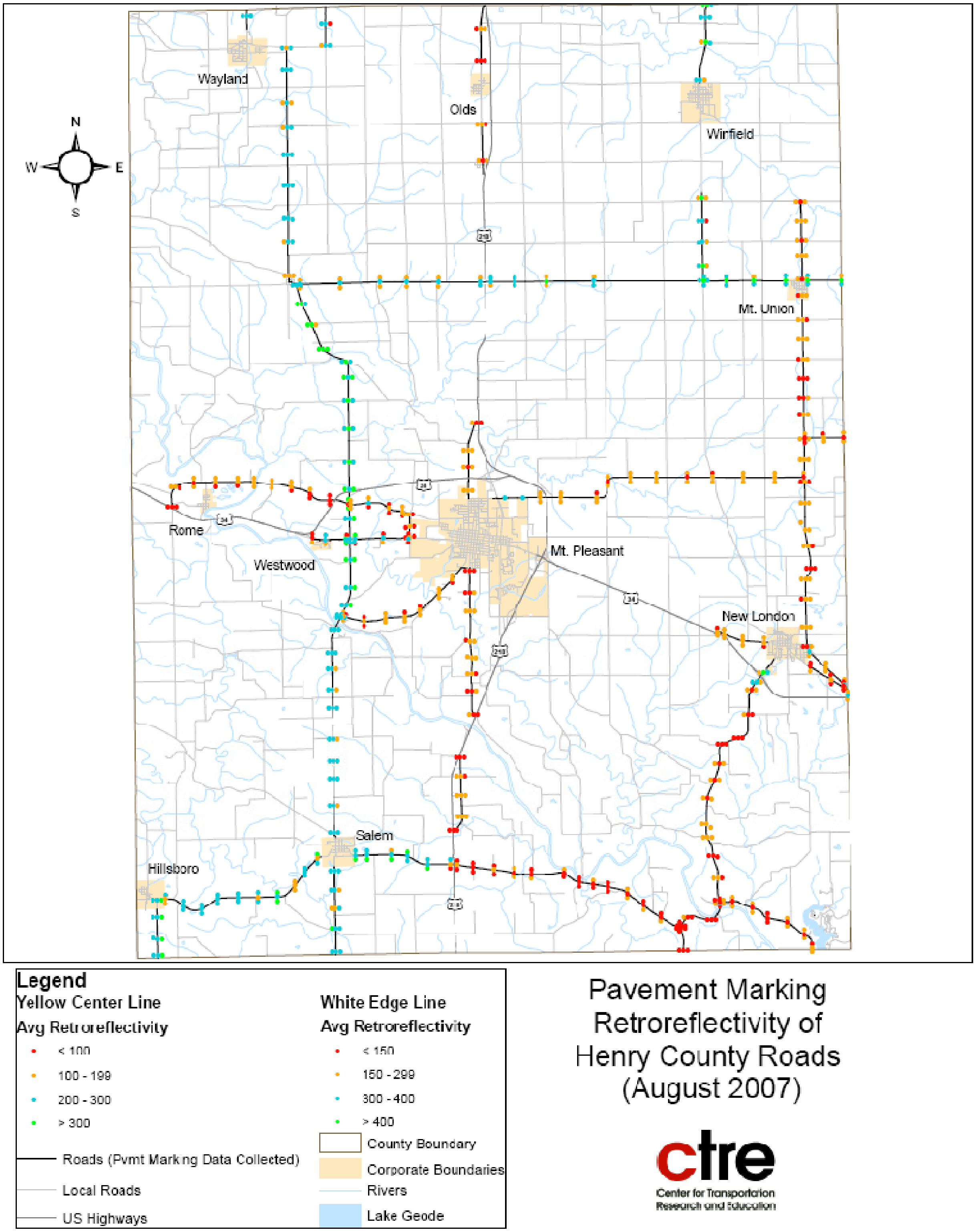


Figure 9. Henry County retroreflectivity map – August 2007

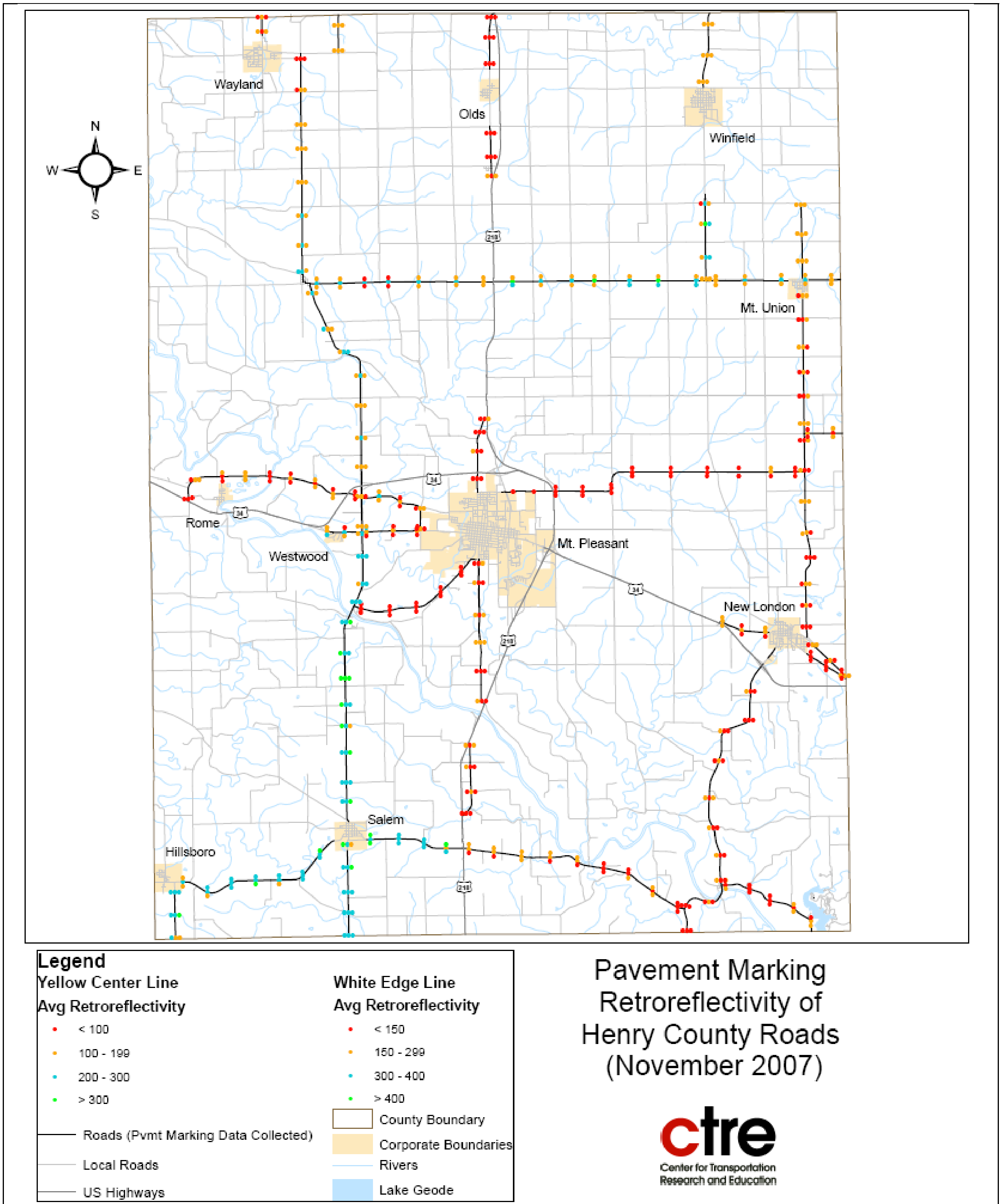


Figure 10. Henry County retroreflectivity map – November 2007

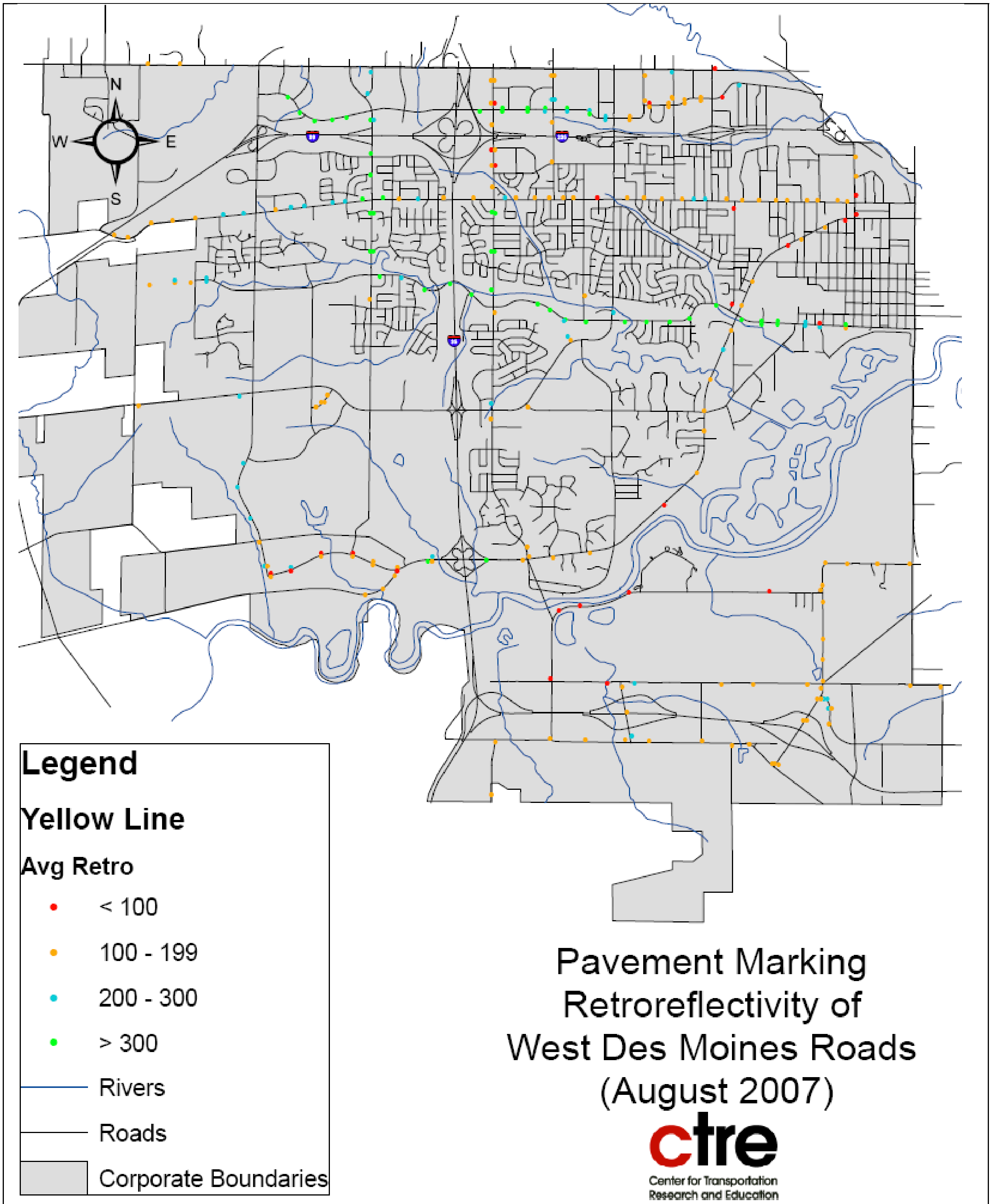


Figure 11. West Des Moines retroreflectivity map (yellow line) – August 2007

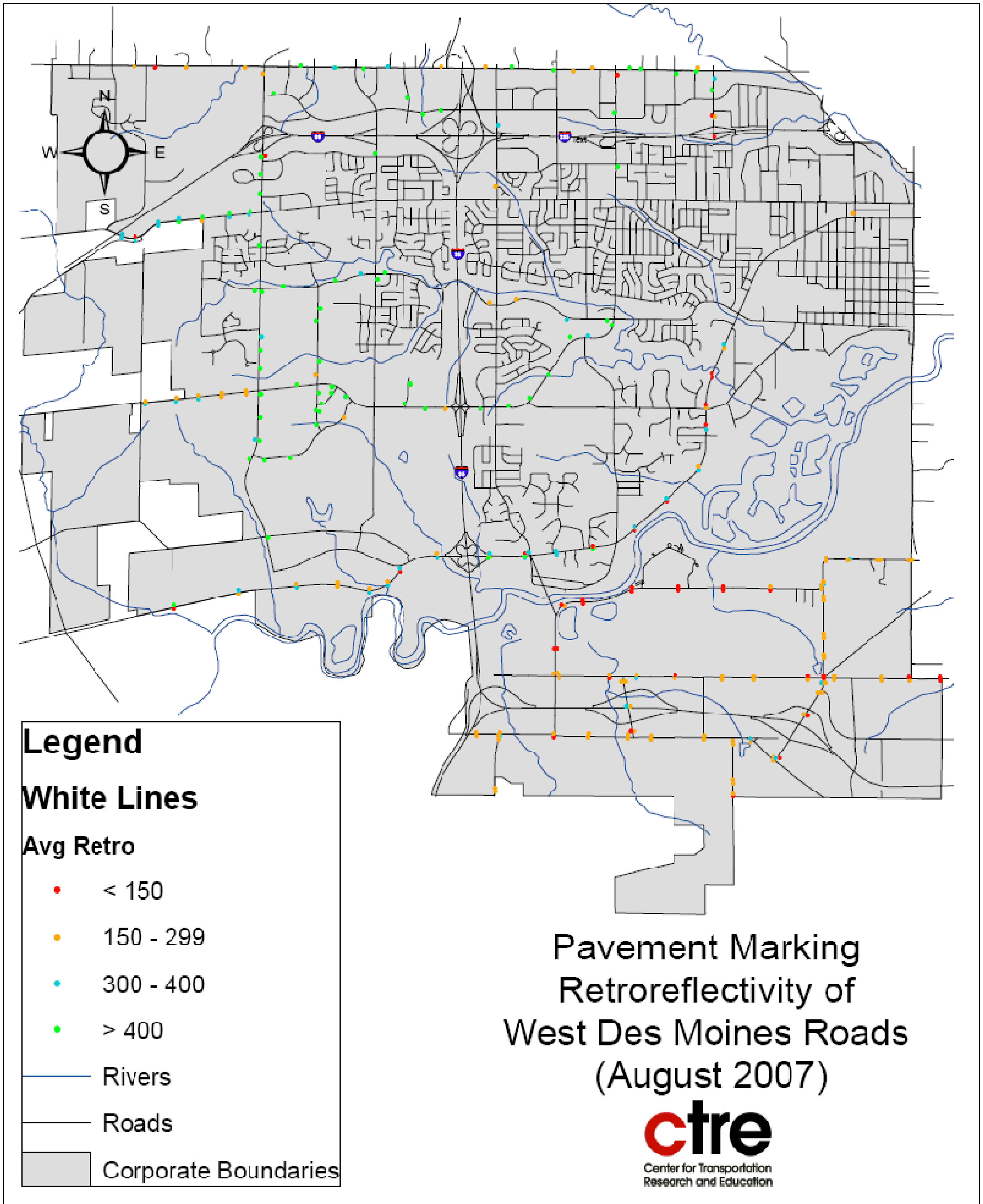


Figure 12. West Des Moines retroreflectivity map (white edge line) – August 2007

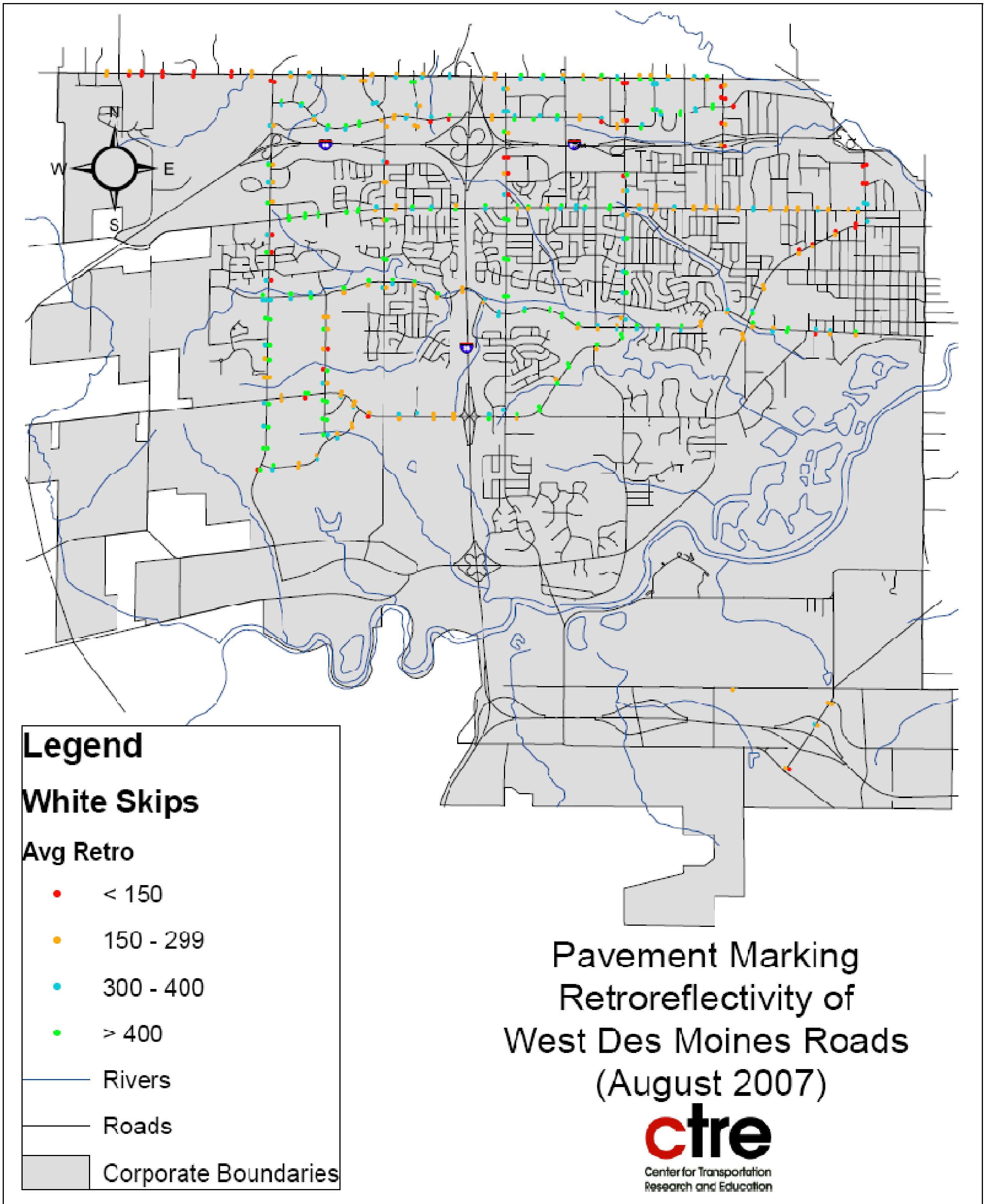


Figure 13. West Des Moines retroreflectivity map (white skip line) – August 2007

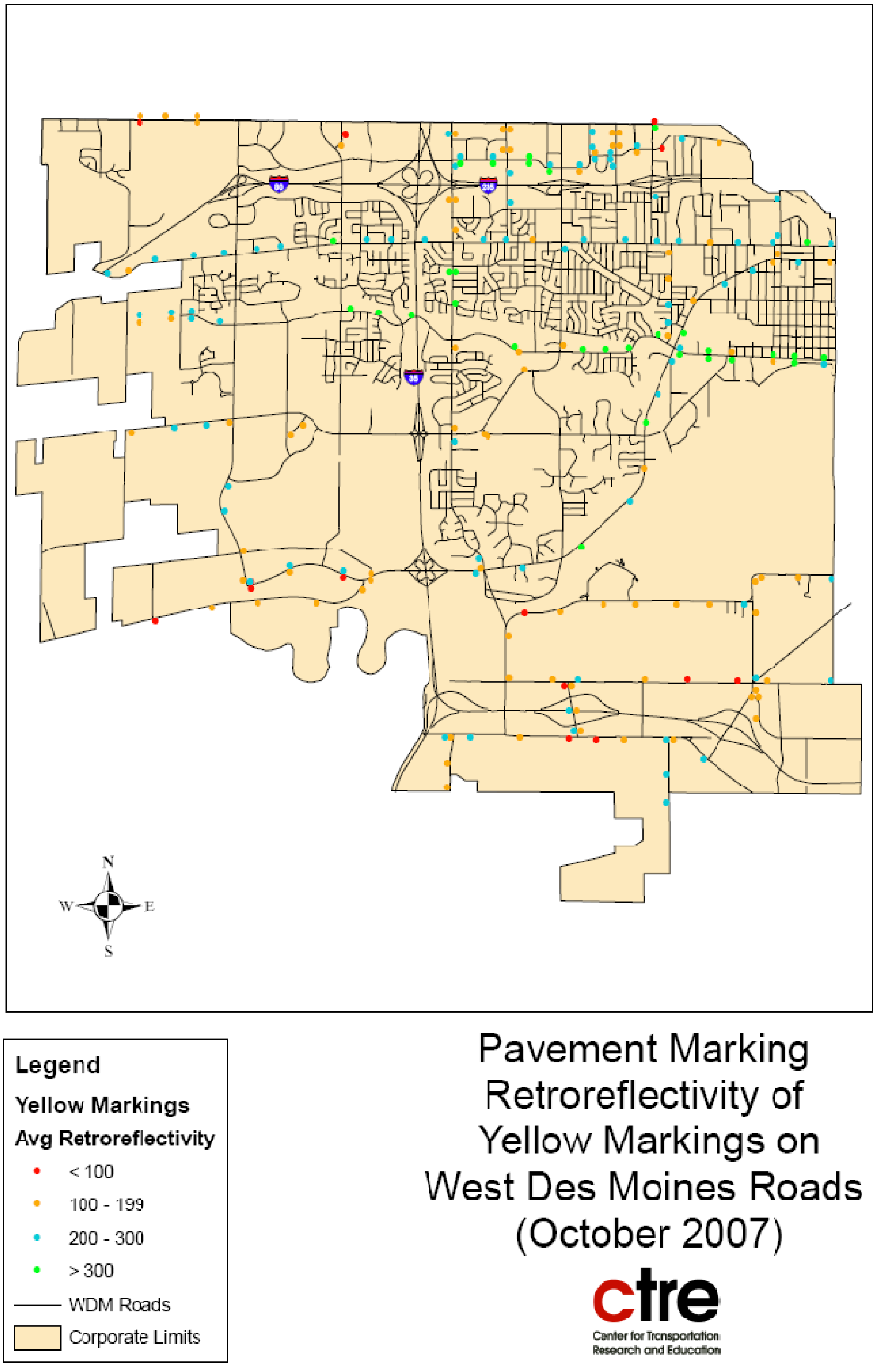


Figure 14. West Des Moines retroreflectivity map (yellow markings) – October 2007

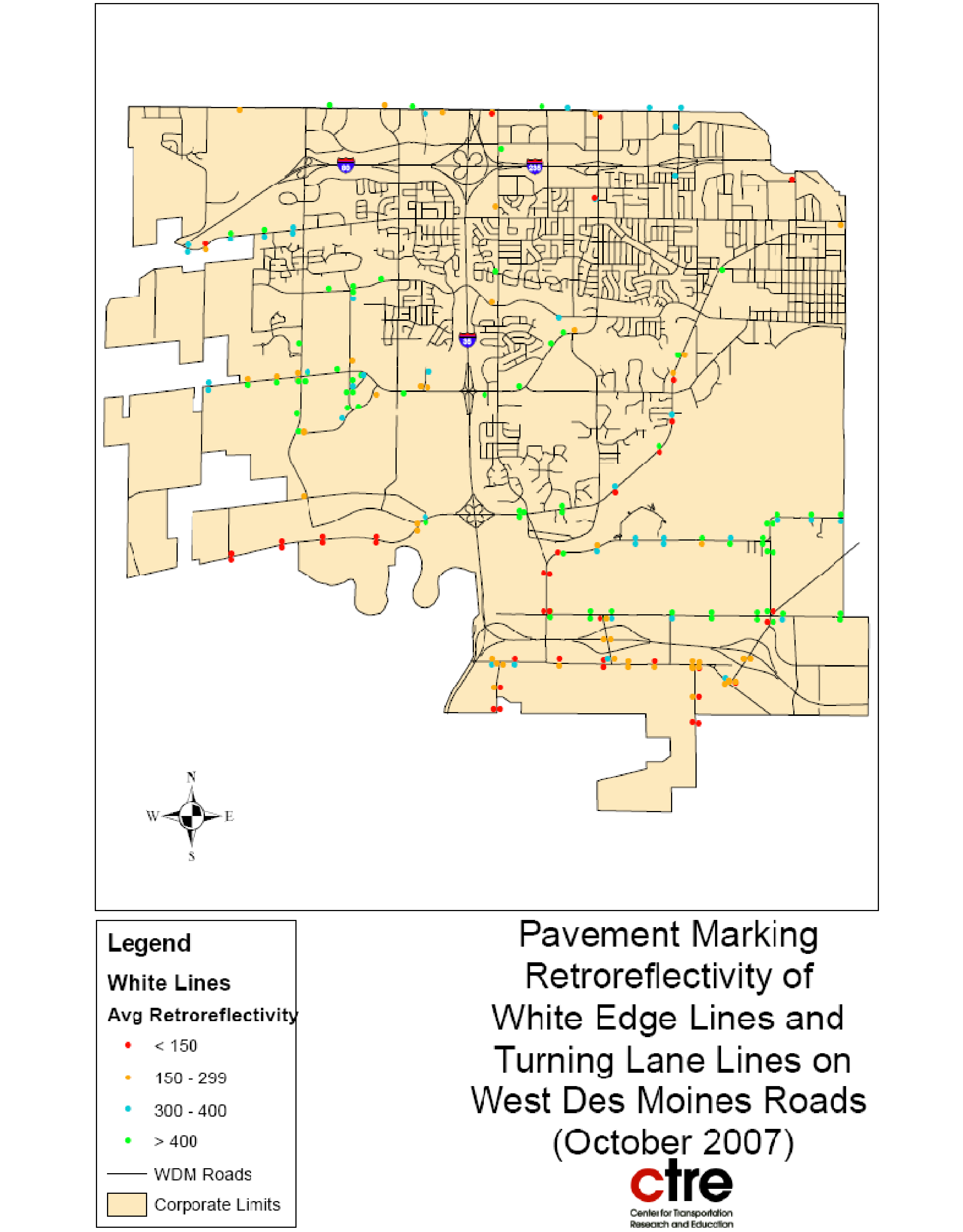


Figure 15. West Des Moines retroreflectivity map (white edge line) – October 2007

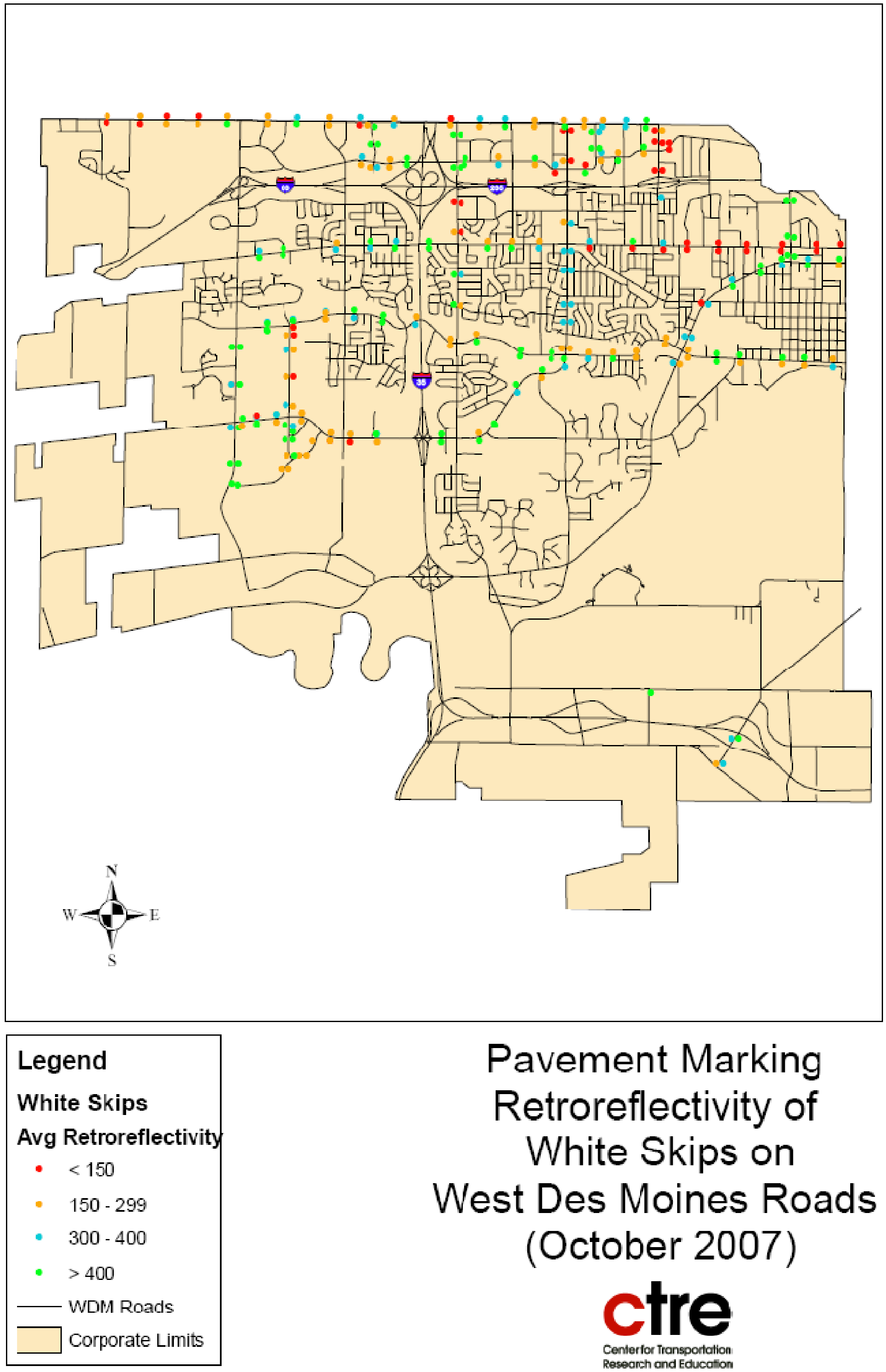


Figure 16. West Des Moines retroreflectivity map (white skip line) – October 2007

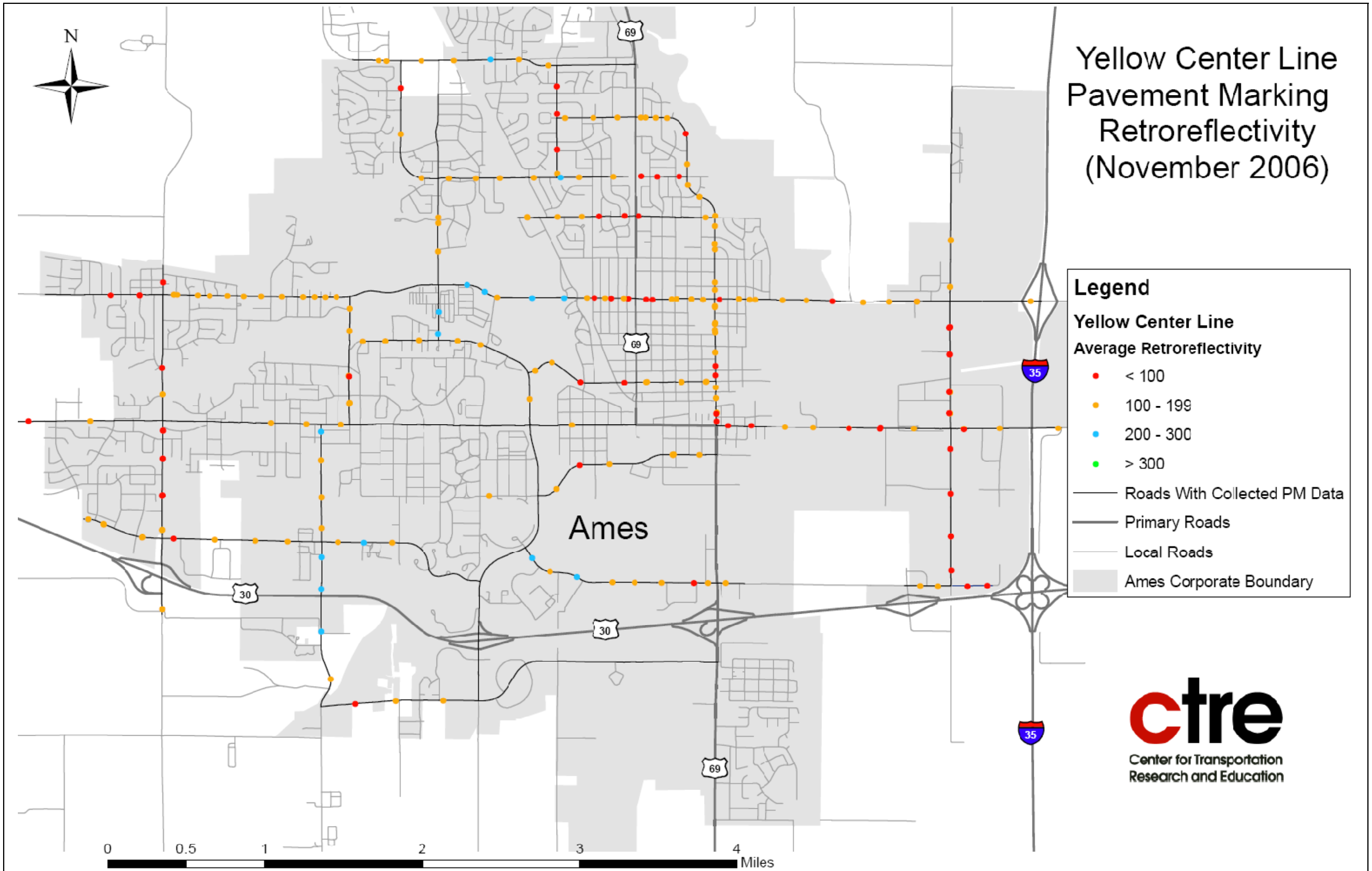


Figure 17. Ames retroreflectivity map (yellow center line) – November 2006

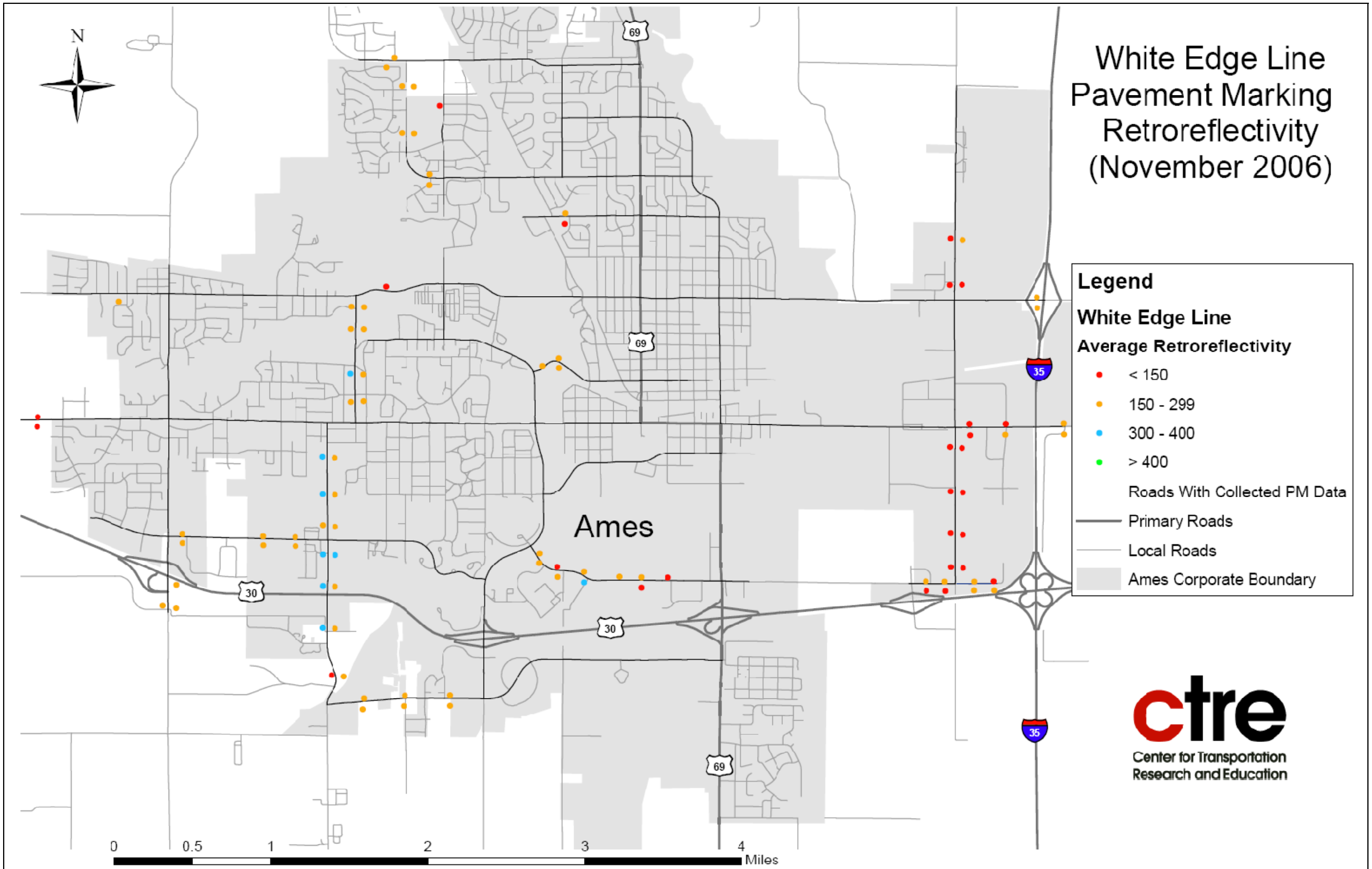


Figure 18. Ames retroreflectivity map (white edge line) – November 2006

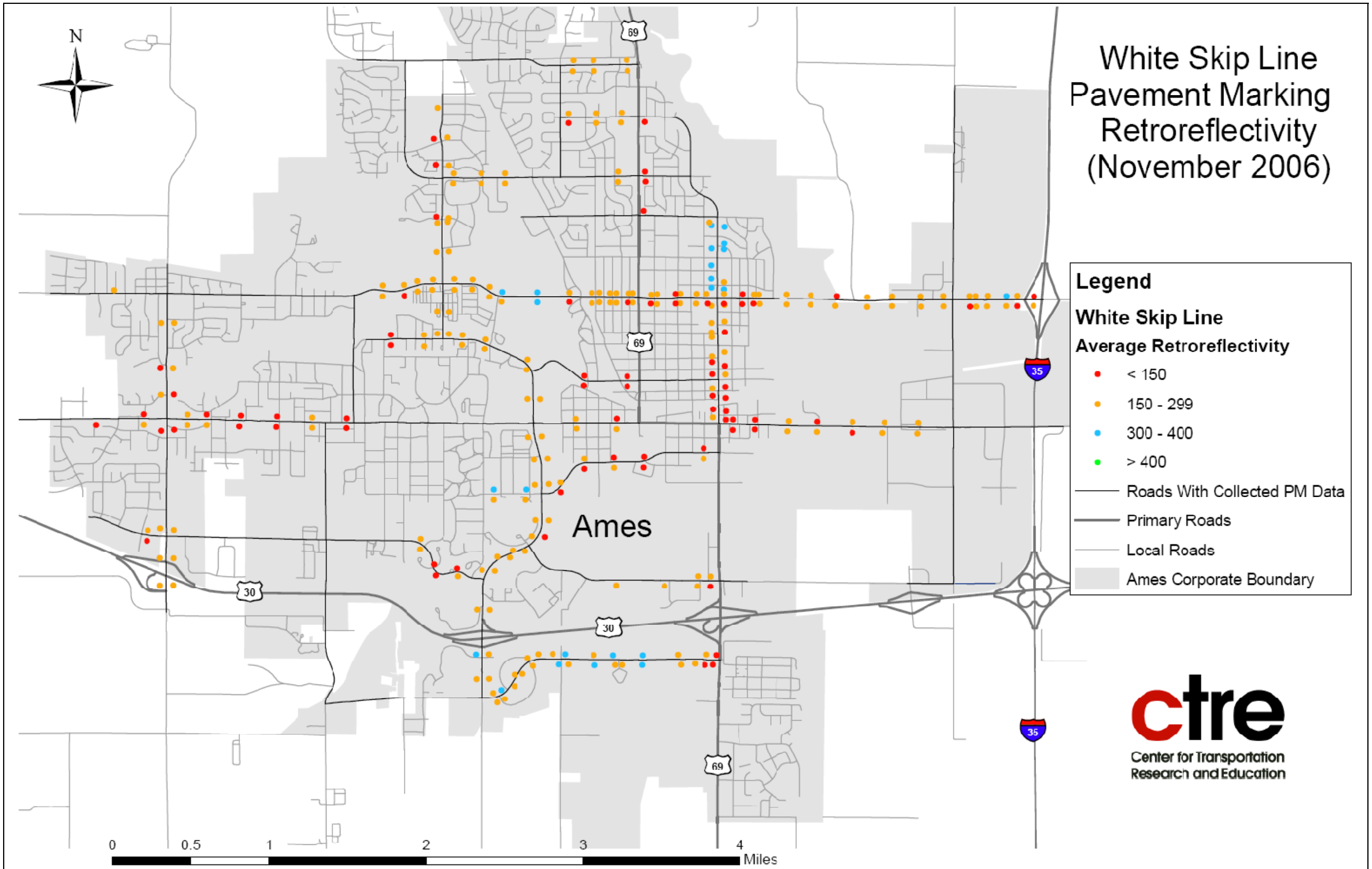


Figure 19. Ames retroreflectivity map (white skip line) – November 2006

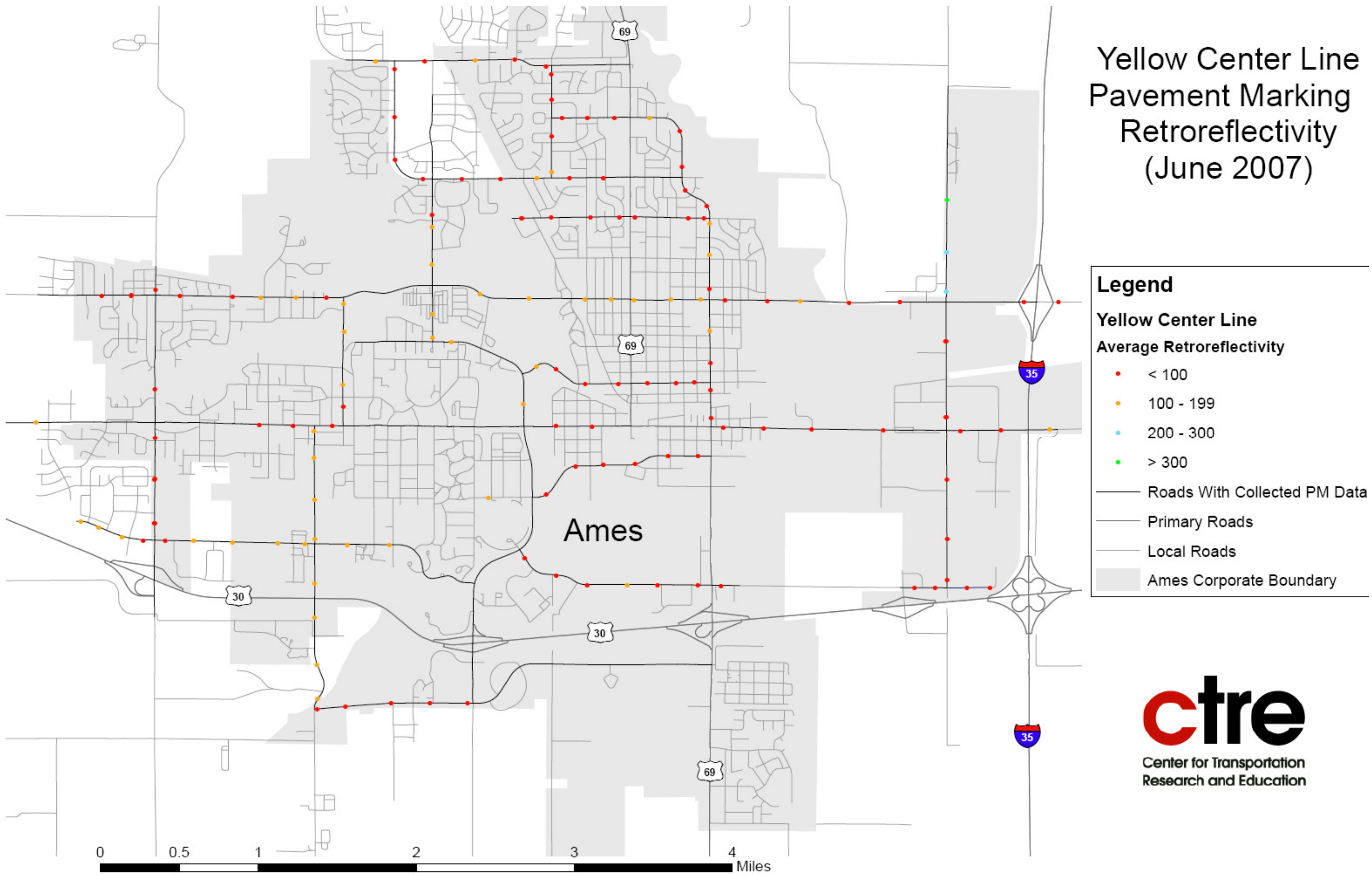


Figure 20. Ames retroreflectivity map (yellow center line) – June 2007

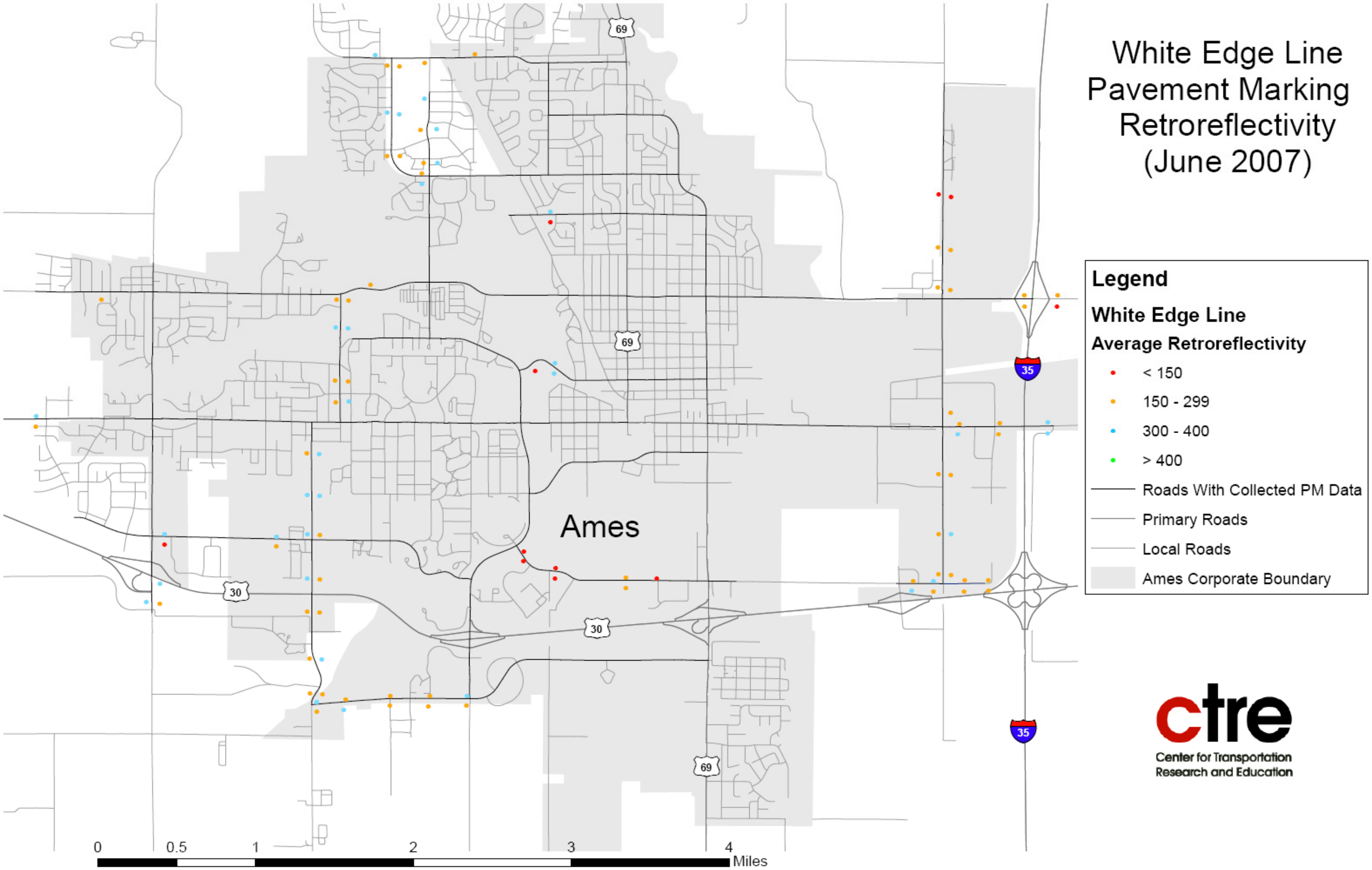


Figure 21. Ames retroreflectivity map (white edge line) – June 2007

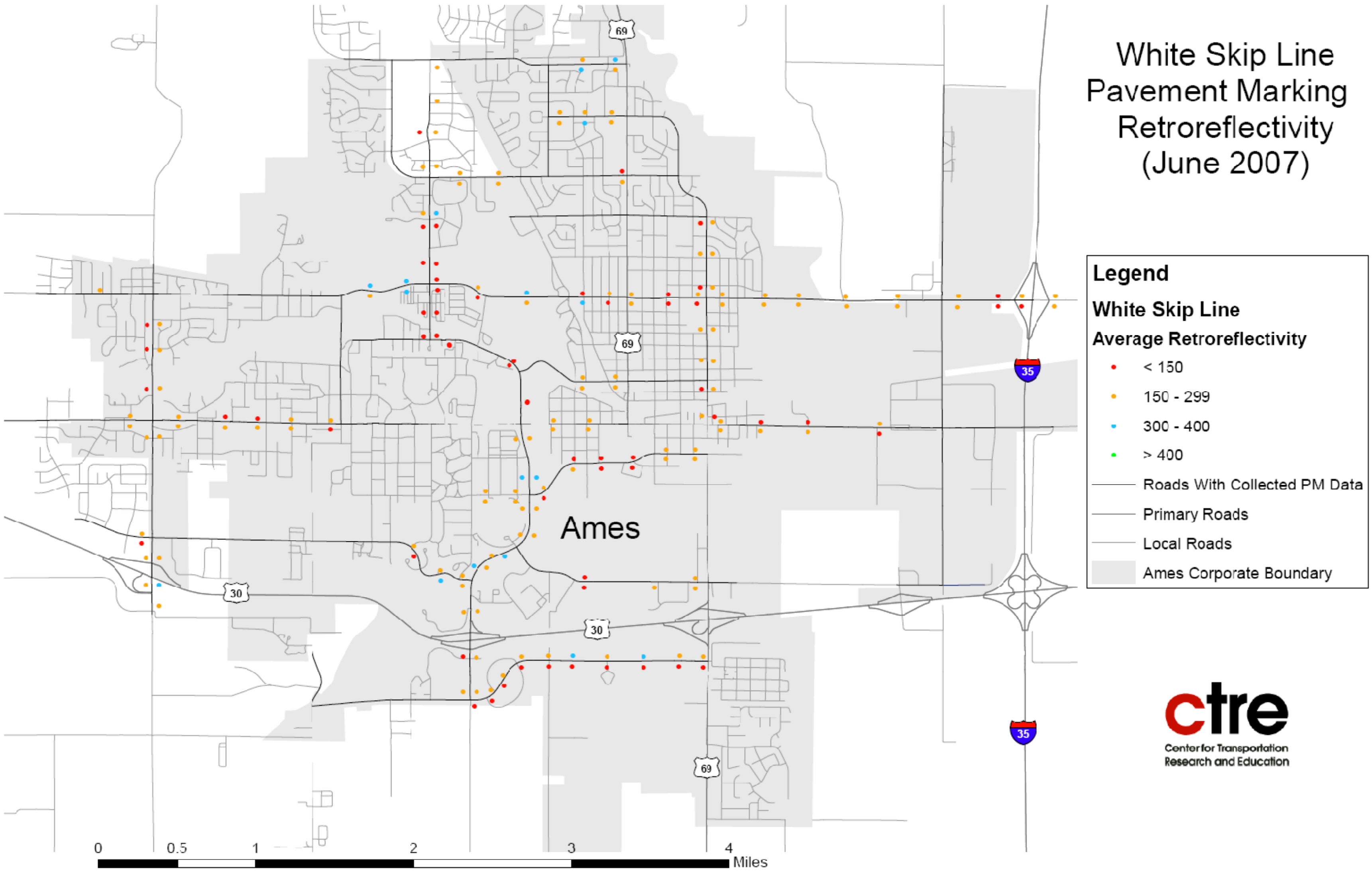


Figure 22. Ames retroreflectivity map (white skip line) – June 2007

Pavement Marking Field Demonstrations

Based on the results of the survey, the majority of local agencies are using waterborne paint as their primary marking material for longitudinal (long-line) and transverse (stop bar, crosswalk, and legend) markings. Waterborne paint is typically the least expensive pavement marking option for agencies; however, it has a limited service life (requiring at least annual replacement), especially for higher traffic roadways and transverse markings within the wheel-paths.

In an effort to support agency decision making, the research team worked with the technical advisory committee (TAC), industry, and the Iowa DOT to identify reasonable pavement marking alternatives to field demonstrate under local agency conditions. The following list illustrates the demonstration sites and the products used. This section contains the details for each product demonstration and material evaluation.

- Longitudinal markings using high-build waterborne paint with Type IV beads:
  - City of West Des Moines (West Lakes Parkway)
  - Dallas County (County Road R22)

- Transverse markings using preformed thermoplastic (from Flint Trading Company and Ennis Paint/Traffic Safety Solutions):
  - Marion County
  - Polk County
  - Story County
  - City of Ames
  - City of Ankeny
  - City of Des Moines*
  - City of Knoxville*
  - City of Pella
  - City of Polk City
  - Iowa DOT
  - Iowa State University

* While the research team was installing the thermoplastic markings, both Knoxville and Des Moines installed other markings at the same time and intersection (waterborne and epoxy paint, respectively). These additional products were included in the 12-month review of material performance and the information is included within this report. The waterborne paint used in Knoxville is to Iowa DOT specifications and the epoxy used in Des Moines is POLY-CARB MARK-55.3.

Longitudinal Marking Demonstrations

The research team worked with a local contractor to install pavement markings in both an urban and a rural setting. In an effort to represent the damage that occurs to the markings during winter snow removal operations, roughly half of the markings on each test deck were placed within a groove (80 mil depth), with the remaining being surface applied.

The marking materials used for each site were the same and consisted of a “thicker” waterborne paint (referred to as high-build, which tends to have a longer life, given the extra thickness), along with a Type IV glass bead (larger size bead compared to a typical Type I bead used with regular waterborne paint). The urban test deck was on West Lakes Parkway in West Des Moines (between University Avenue and Westown Parkway) and the rural test deck was on County Road R 22 in Dallas County (from Ashworth Road north, roughly 2,000 feet).

West Lakes Parkway – This demonstration included painting the white skip lines and the left turn lane channelization lines from University Avenue to Westown Parkway. The southbound direction included white skip lines placed within an 80 mil groove. The northbound direction included white skip lines that were surface applied (not placed in a groove). The left turn lane channelization markings for both directions were all surface applied. Figure 23 provides a photo and summary of the West Lakes Parkway test deck.

Figure 23. West Lakes Parkway test deck information

Figures 24 through 27 show the pavement marking performance maps developed after four measurements from 2007 through 2009.

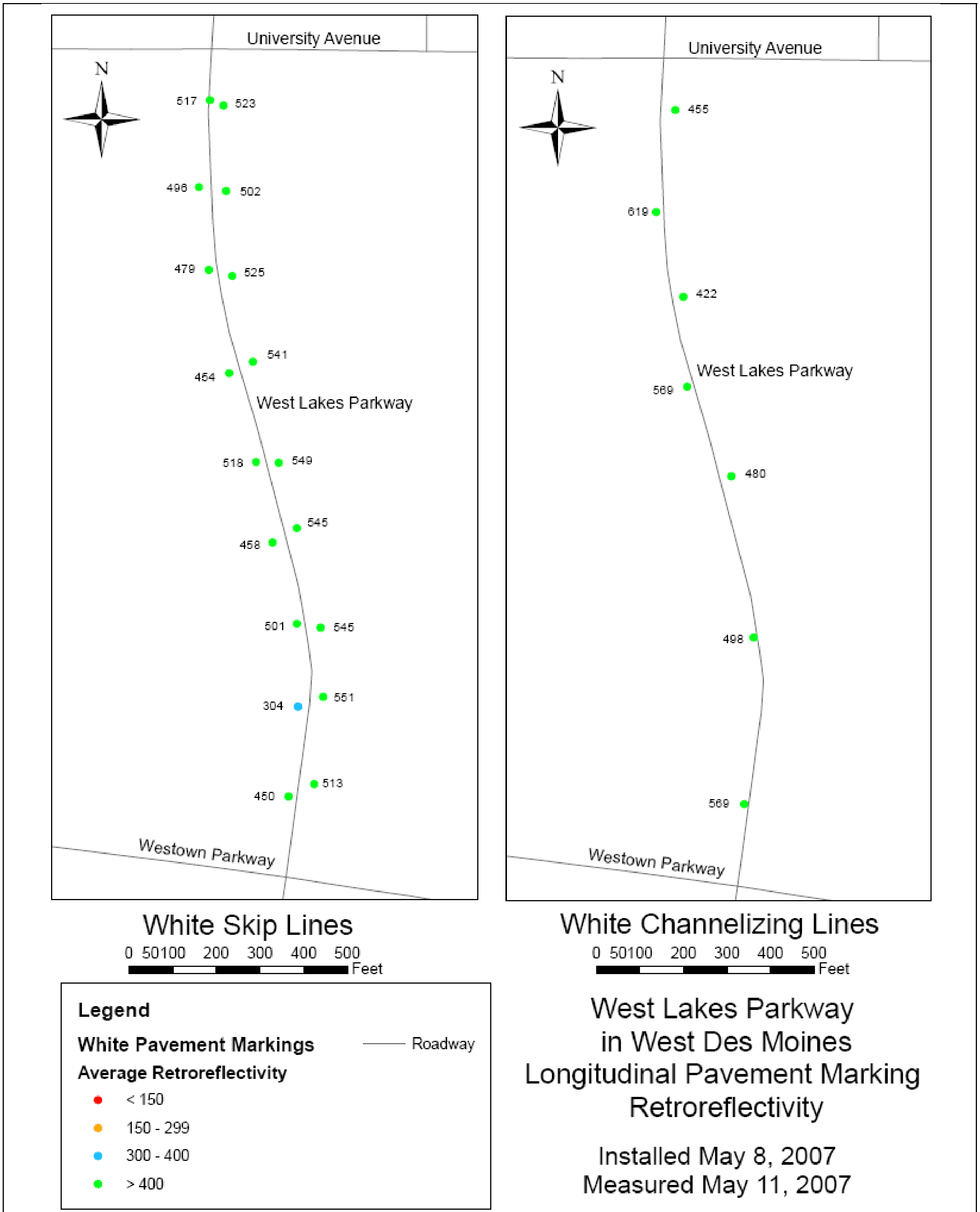


Figure 24. West Lakes Parkway retroreflectivity data – May 2007

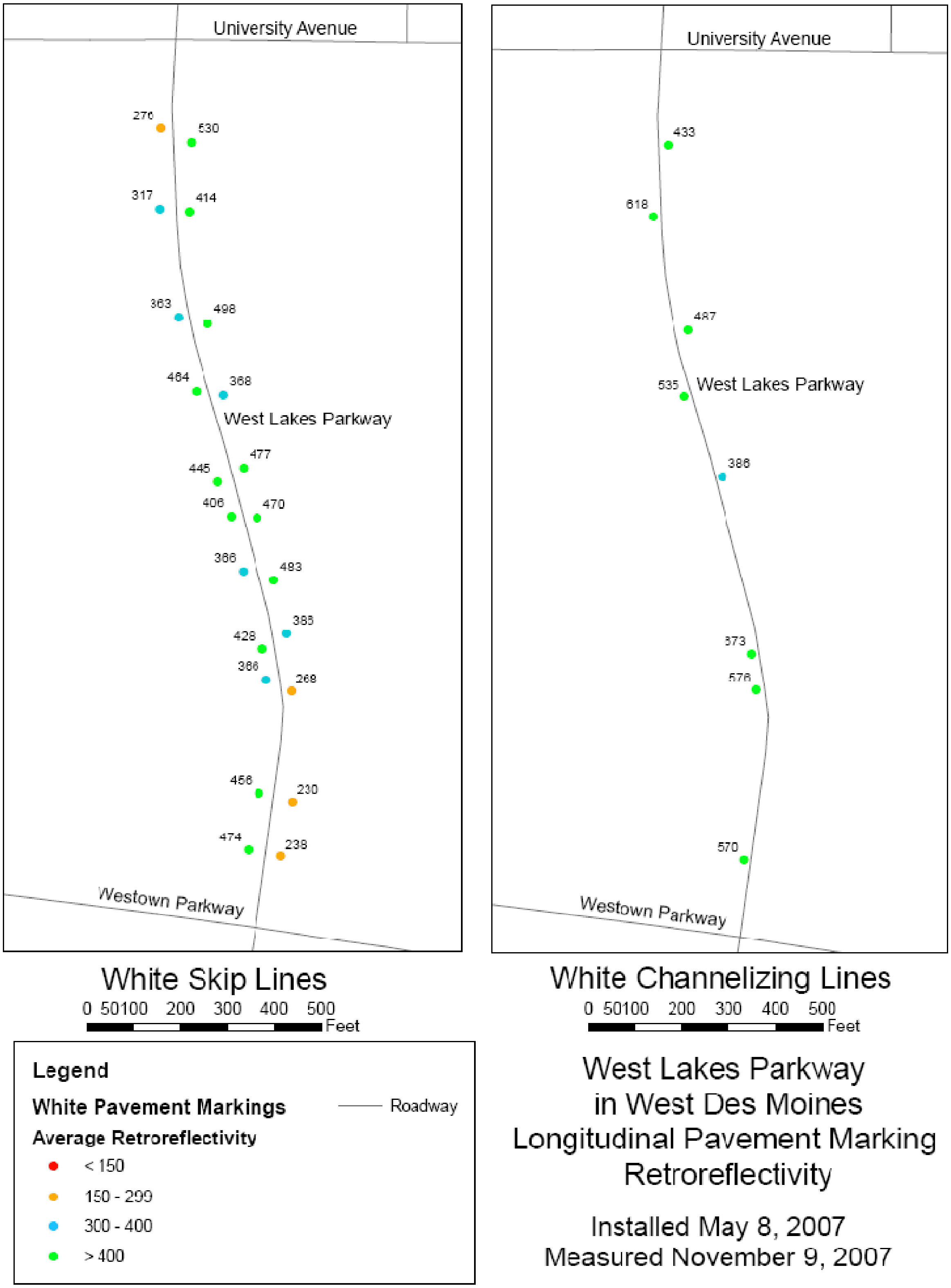


Figure 25. West Lakes Parkway retroreflectivity data – November 2007

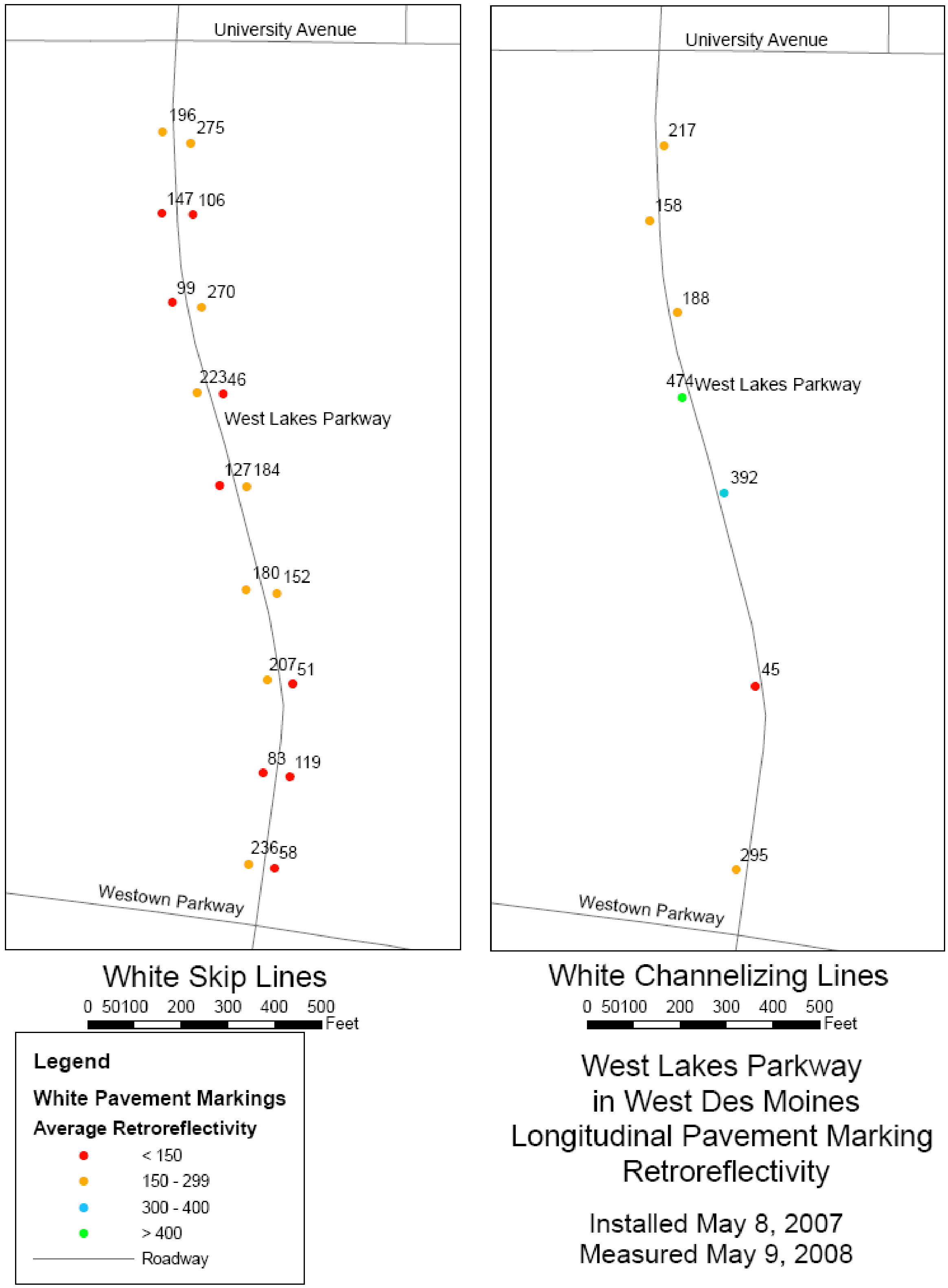


Figure 26. West Lakes Parkway retroreflectivity data – May 2008

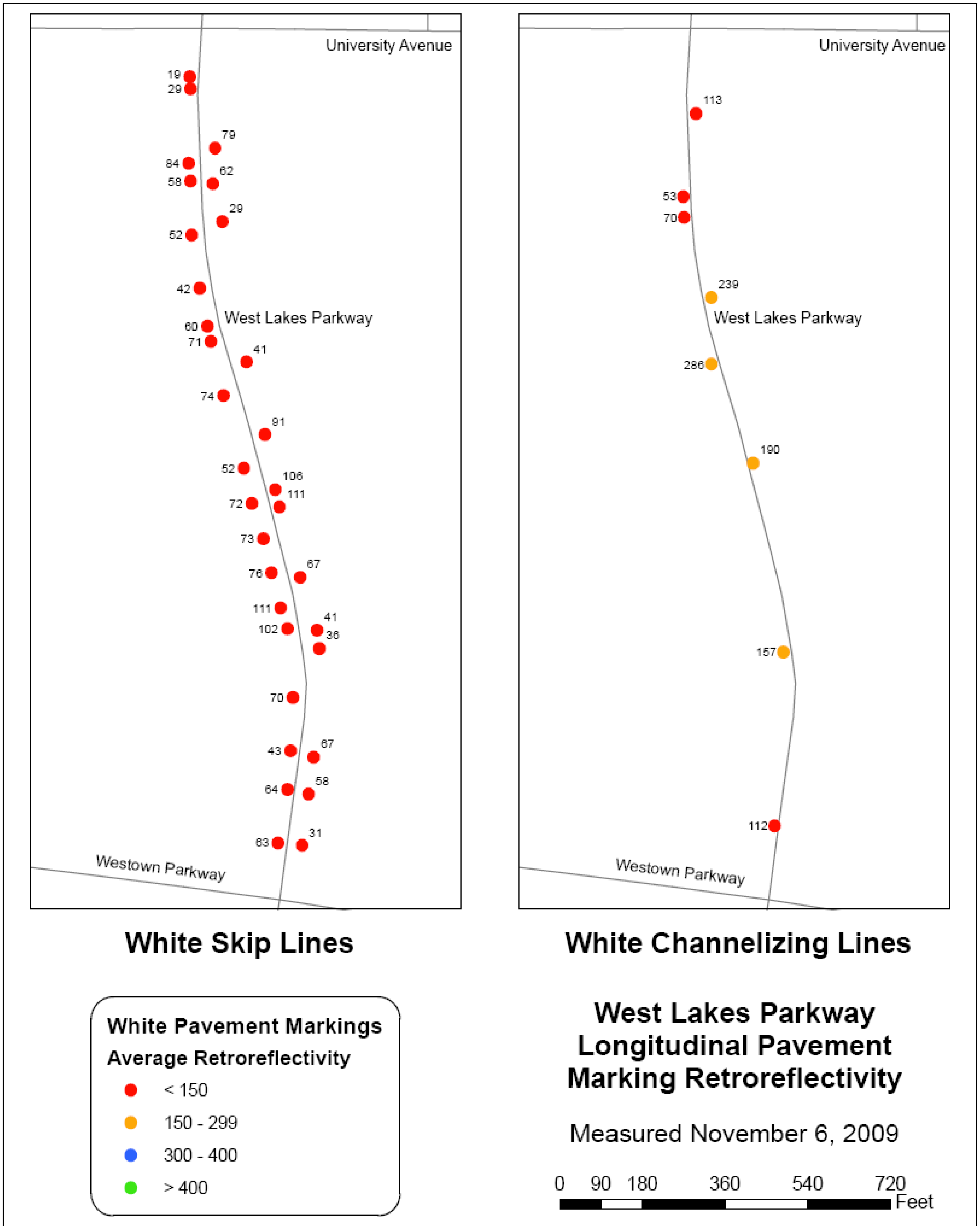


Figure 27. West Lakes Parkway retroreflectivity data – November 2009

R22 – This test deck included painting both white edge lines and the double yellow centerline from CR-F64 or Ashworth Road north, roughly 2,000 feet. Markings within the first 1,000 were placed within an 80 mil groove. Markings for the remaining 1,000 feet were surface applied. Figure 28 provides a photo and summary of the R22 test deck. The non-grooved section was painted over in 2009, so no data are shown for this section on the November 2009 map.

Figure 28. R22 test deck information

Figures 29 through 32 show the pavement marking performance maps developed after four measurements from 2007 through 2009.

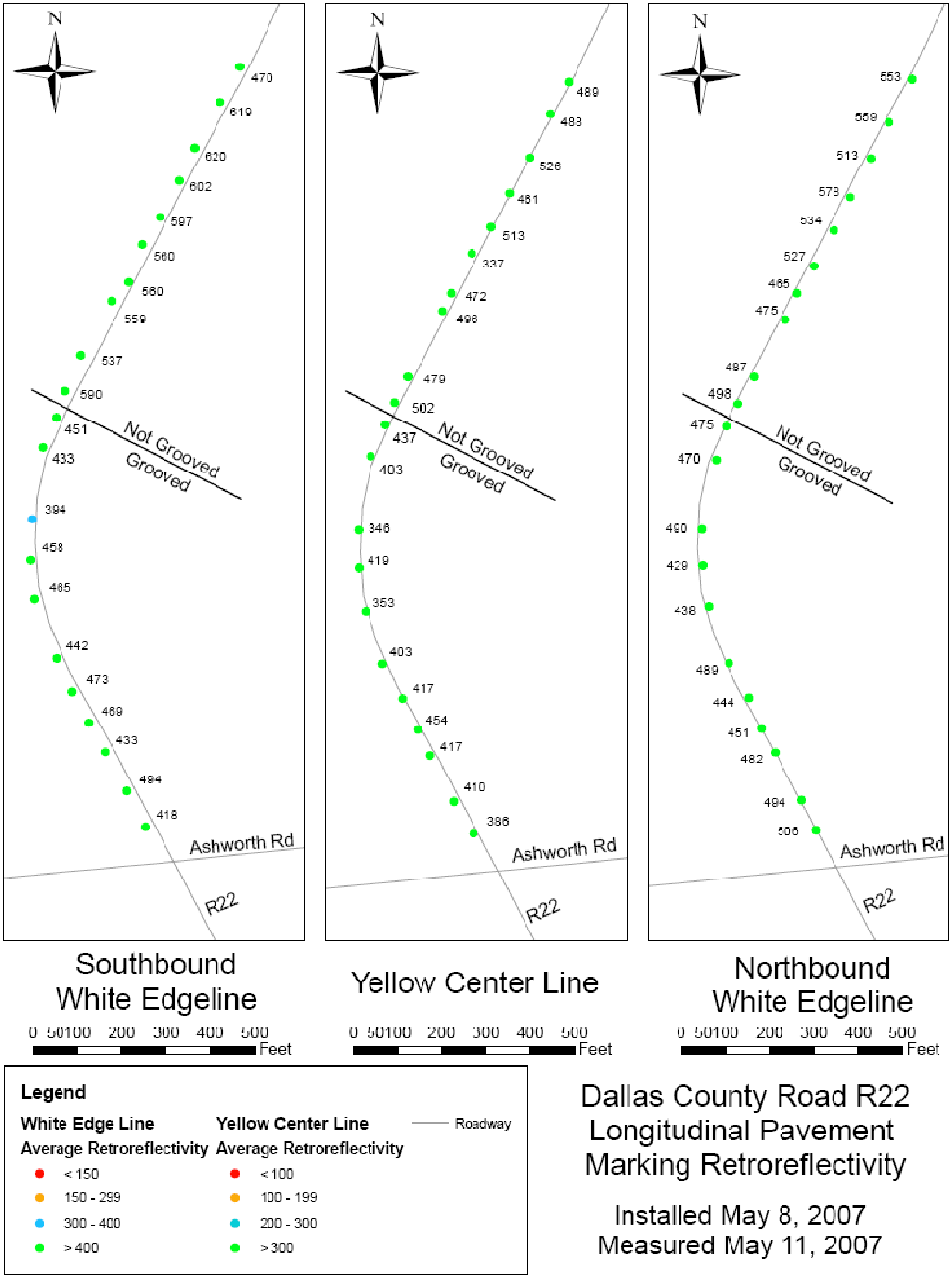


Figure 29. R22 retroreflectivity data – May 2007

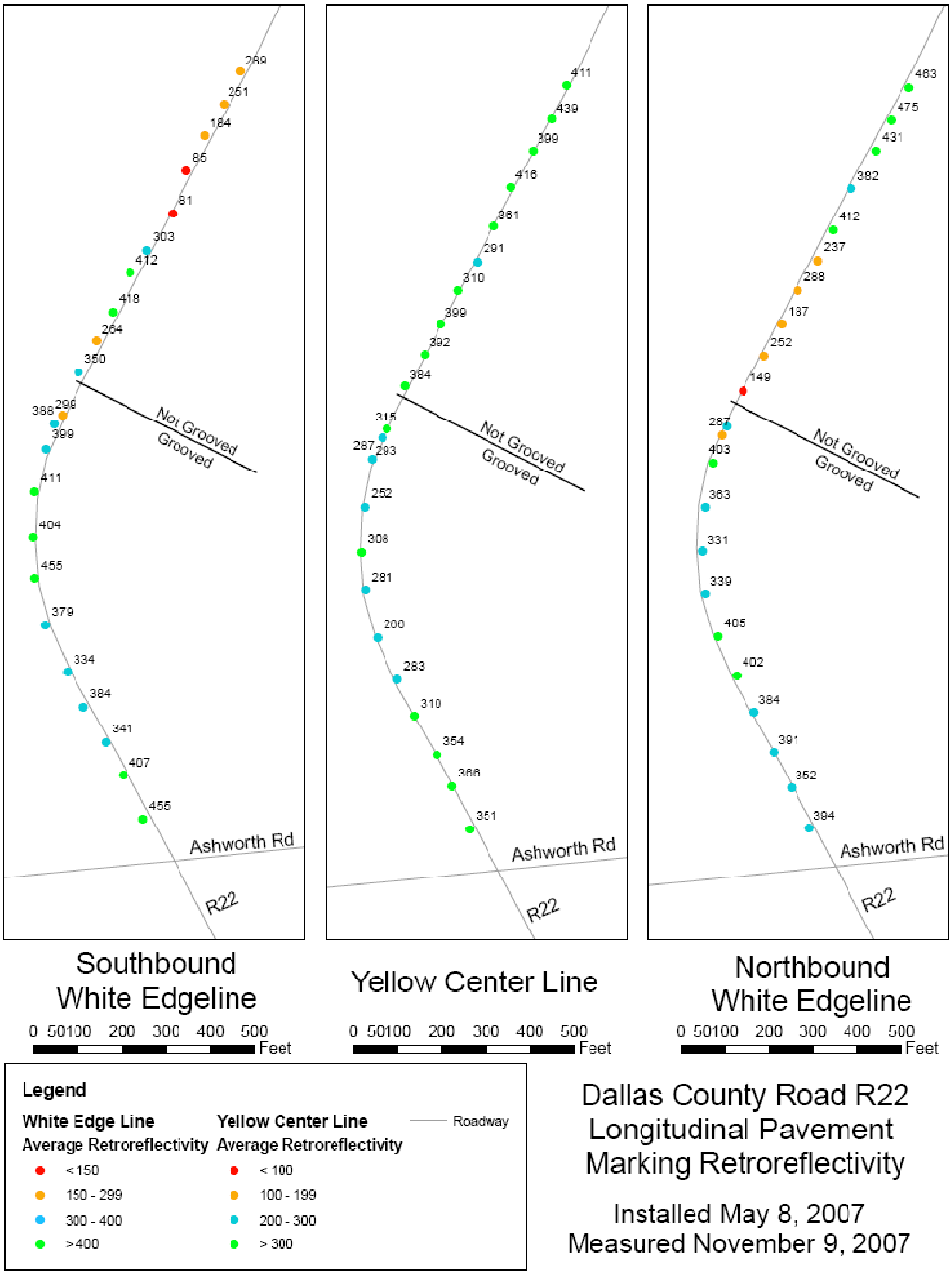


Figure 30. R22 retroreflectivity data – November 2007

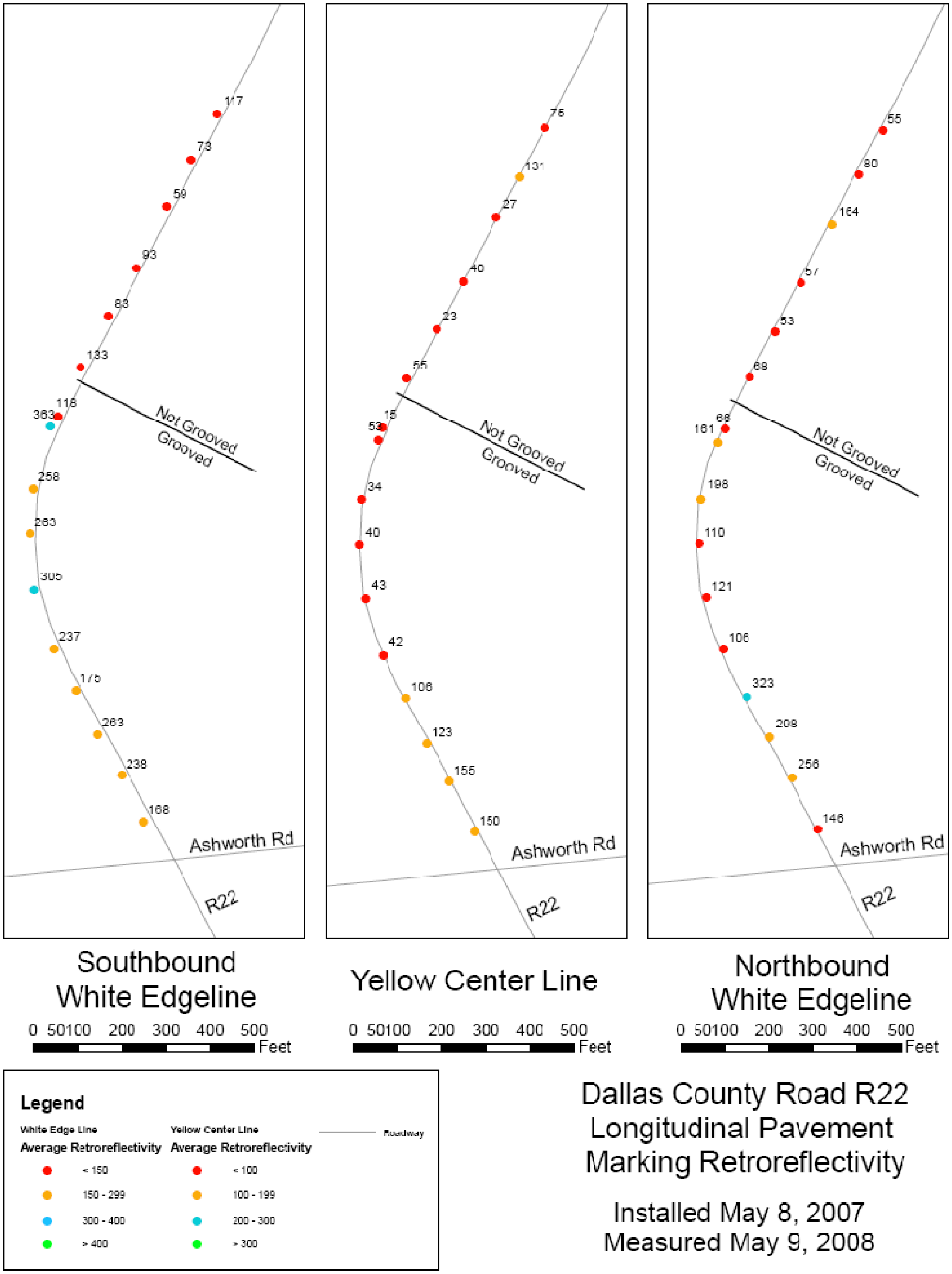


Figure 31. R22 retroreflectivity data – May 2008

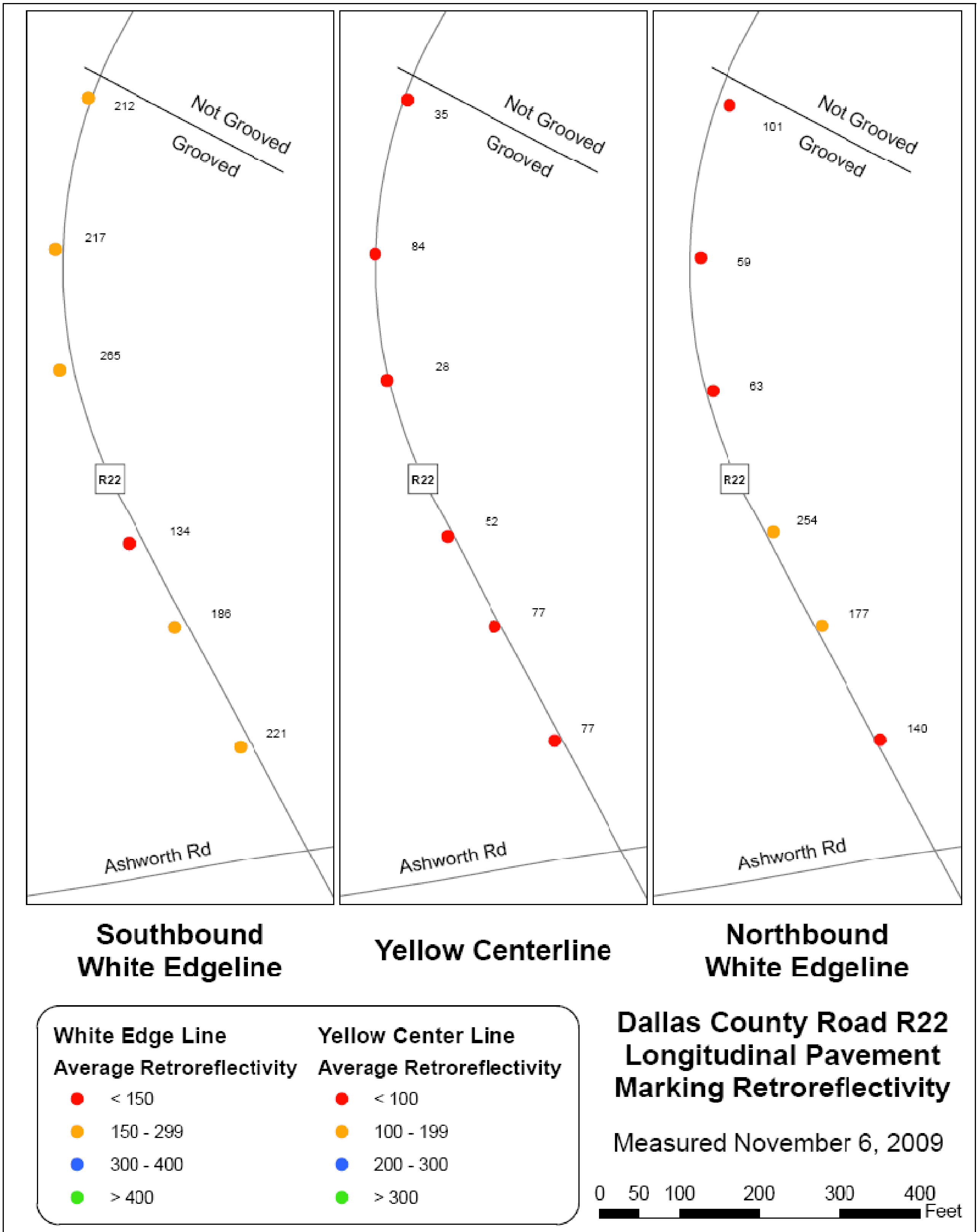


Figure 32. R22 retroreflectivity data – November 2009

Transverse Marking Demonstrations

The research team worked with a variety of agencies to select transverse marking demonstration locations and marking types. Figure 33 shows the site locations, which are all within central Iowa. Blue markers represent either a stop bar or crosswalk and green markers represent legend markings, such as arrows and ONLYs.

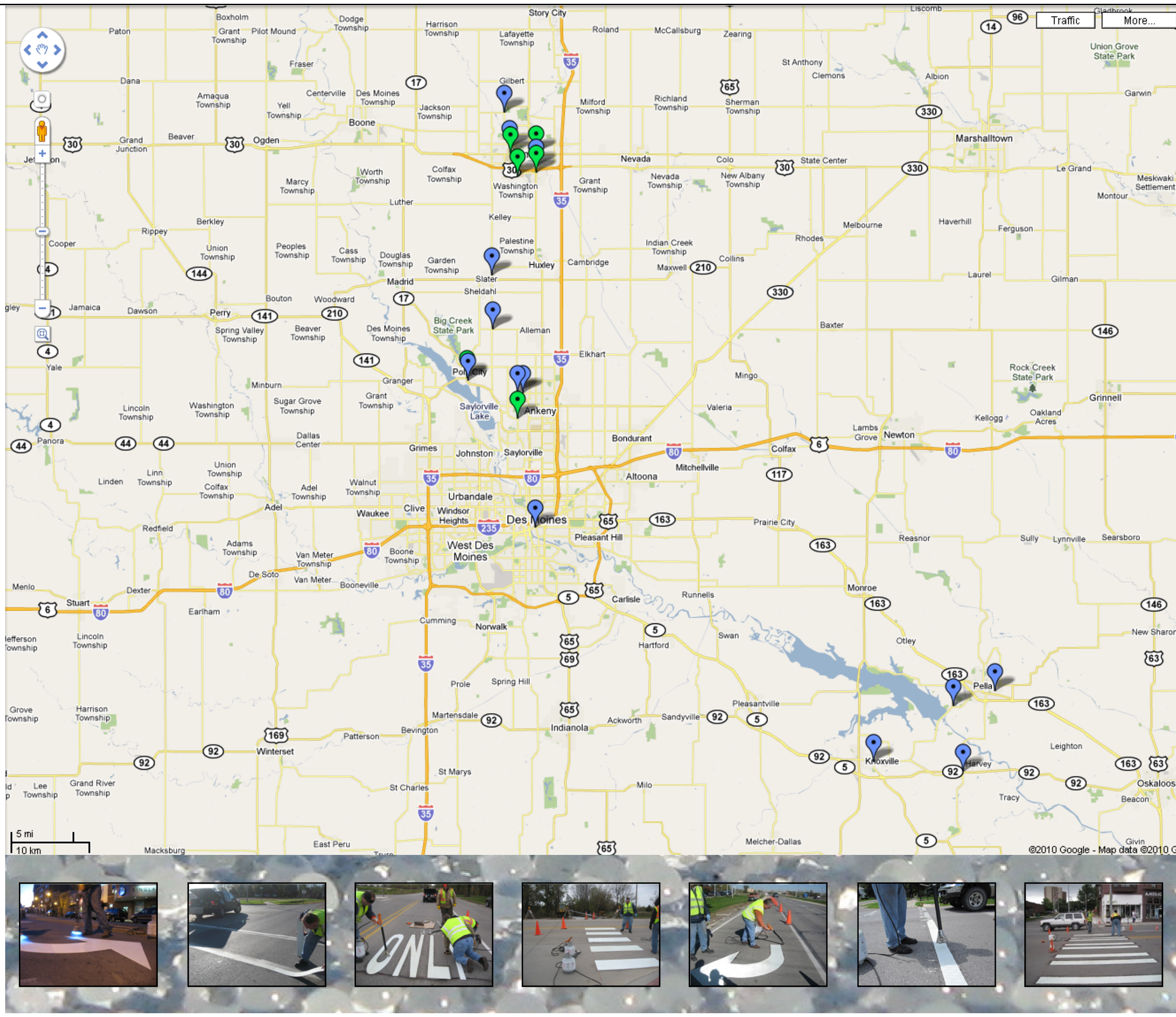


Figure 33. Transverse marking demonstration locations

The research team worked with two pavement marking industry suppliers to purchase and assist with product installation. These heated-in-place materials were installed:

- Flint Trading Company Pre-Mark 125 mil preform thermoplastic
- Flint Trading Company ViziGRIP Pre-Mark 125 mil preform thermoplastic
- Ennis Paint/Traffic Safety Solutions preform thermoplastic

The installation consisted of using a heating torch to remove moisture from the pavement and using a sealant prior to placement on concrete surfaces. Once the surface was prepared, the pre-cut marking material was laid in place and heated with a torch to create a sufficient bond. This process is shown in Figure 34.

Figure 34. Installing preformed thermoplastic pavement markings

Table 5 identifies the locations, dates of installation, and other features for the demonstration sites. These sites are all within central Iowa and include a variety of agencies and roadway settings. Marking installations began in September of 2007 and continued through August of 2009.

Table 5. Transverse pavement marking information by year of installation

Agency	Location	Marking Type	Mtl / Surface	Mfg.	Year
Ames	Duff at RR-Xing	RRXing	Thermo/ACC	Flint	2007
Ames	Lincoln Way at Welch	LT Arrow	Thermo/ACC	Flint	2007
Ames	Lincoln Way at Welch	LT Arrow	Thermo/ACC	Flint	2007
Ames	Airport Rd at Univ Blvd	RT Arrow and ONLY	Thermo/PCC	Ennis	2007
Iowa DOT	Duff at Airport Rd	RT Arrow	Thermo/PCC	Ennis	2007
Slater	R38 at Main St	6" X-Walk	Thermo/ACC	Ennis	2007
Slater	R38 at Main St	Stop Bar	Thermo/ACC	Flint	2007
Polk Co	R38 at NW142nd	Stop Bar	Thermo/ACC	Flint	2007
Polk Co	R38 at NW142nd	Stop Bar	Thermo/ACC	Flint	2007
Polk City	Hwy 415 at Southside Dr	24" X-Walk	Thermo/PCC	Flint	2007
Polk City	Hwy 415 at W. Bridge	LT Arrows/ONLY	Thermo/PCC	Flint	2007
Ankeny	NW 18 at NW Irvindale	6" X-Walk	Thermo/ACC	Flint	2007
Ankeny	NW 18 at NW Irvindale	Stop Bar	Thermo/PCC	Flint	2007
Ankeny	NW 18 at NW Irvindale	LT Arrow	Thermo/PCC	Flint	2007
Ankeny	Irvindale at Plk City Dr	LT Arrow	Thermo/ACC	Flint	2007
Ankeny	Bike Xing NW18/Irvindale	8" X-Walk	Thermo/PCC	Flint	2007
Ames	Duff at RR-Xing	RRXing	Thermo/ACC	Flint	2008
Ames	Lincoln Way at Welch	LT Arrow	Thermo/ACC	Flint	2008
Ames	Lincoln Way at Welch	LT Arrow	Thermo/ACC	Flint	2008
Ames	Airport Rd at Univ Blvd	RT Arrow and ONLY	Thermo/PCC	Flint	2008
Iowa DOT	Duff at Airport Rd	RT Arrow	Thermo/PCC	Flint	2008
Slater	R38 at Main St	6" X-Walk	Thermo/ACC	Flint	2008
Slater	R38 at Main St	Stop Bar	Thermo/ACC	Flint	2008
Polk Co	R38 at NW142nd	Stop Bar	Thermo/ACC	Flint	2008
Polk Co	R38 at NW142nd	Stop Bar	Thermo/ACC	Flint	2008
Polk City	Hwy 415 at Southside Dr	24" X-Walk	Thermo/PCC	Flint	2008
Polk City	Hwy 415 at W. Bridge	LT Arrows/ONLY	Thermo/PCC	Flint	2008
Ankeny	NW 18 at NW Irvindale	6" X-Walk	Thermo/ACC	Flint	2008
Ankeny	NW 18 at NW Irvindale	Stop Bar	Thermo/PCC	Flint	2008
Ankeny	NW 18 at NW Irvindale	LT Arrow	Thermo/PCC	Flint	2008
Ankeny	Irvindale at Plk City Dr	LT Arrow	Thermo/ACC	Flint	2008
Ankeny	Bike Xing NW18/Irvindale	8" X-Walk	Thermo/PCC	Flint	2008
Des Moines	E. 5th at Grand Ave	24" X-Walk	Thermo/ACC	Flint	2009
Des Moines	E. 5th at Grand Ave	Stop Bar/6" X-Walk	Epoxy/ACC	PolyCarb	2009
Knoxville	Robinson St at Attica Rd	Stop Bar	Thermo/ACC	Flint	2009
Knoxville	Robinson St at Attica Rd	24" X-Walk	Thermo/ACC	Flint	2009
Knoxville	Robinson St at Attica Rd	Stop Bar/6" X-Walk	Waterborne/ACC	NA	2009
Marion Co	Hwy T17 at Hwy 92	Stop Bar	Thermo/ACC	Flint	2009
Marion Co	202nd Ave at T15	Stop Bar	Thermo/PCC	Flint	2009
Marion Co	Idaho Dr at T15	Stop Bar	Thermo/ACC	Flint	2009
Pella	E Univ at E 13th	Stop Bar	Thermo/PCC	Flint	2009
Pella	E Univ at E 13th	24" X-Walk	Thermo/PCC	Flint	2009
Pella	E 13th at E Univ	Stop Bar	Thermo/PCC	Flint	2009
Pella	E 13th at E Univ	24" X-Walk	Thermo/PCC	Flint	2009

The performance of each marking was monitored, qualitatively and quantitatively, using two factors: presence and retroreflectivity. Presence is indicated in terms of a pass or fail rating, where Fail indicates that the amount of material remaining on the roadway surface is not sufficient to define the marking for motorists. Retroreflectivity, denoted by (R_L), is measured for this study using a handheld device (Delta LTL-X 30-Meter Retroreflectometer), which reports retroreflectivity in units of millicandella per meter squared per lux (mcd). This information is presented in Tables 6, 7, and 8.

Table 6. Transverse pavement marking performance (installed in 2007)

Agency	Location	Marking Type	Mtl / Surface	2007 R_L	2007 Presence	2008 R_L	2008 Presence	2009 R_L	2009 Presence	2010 R_L	2010 Presence
Ames	S. 16th at Duff	Stop Bar	Thermo/PCC	231	Pass	57	Pass		Pass		Fail
ISU Campus	Pammel Dr at Bissell Rd	Stop Bar	Thermo/ACC	394	Pass	65	Pass		Pass	49	Pass
Story County	Cameron Rd at GW Carver	Stop Bar	Thermo/PCC	634	Pass	NA*	Pass		Fail		Fail
Ames	S. 16th at Duff	Stop Bar	Thermo/PCC		Pass	126	Pass		Pass		Fail
ISU Campus	Pammel Dr at Bissell Rd	Stop Bar	Thermo/ACC		Pass	62	Pass		Pass	38	Pass**
Story County	Cameron Rd at GW Carver	Stop Bar	Thermo/PCC		Pass	NA*	Pass		Fail		Fail

**Inadvertently painted over (retro value not available). **Significant material loss within the wheel path (marginal pass)*

Table 7. Transverse pavement marking performance (installed in 2008)

				2008		2009		2010	
Agency	Location	Marking Type	Mtl / Surface	R_L	Presence	R_L	Presence	R_L	Presence
Ames	Duff at RR-Xing	RRXing	Thermo/ACC	519	Pass		Pass	121	Pass
Ames	Lincoln Way at Welch	LT Arrow	Thermo/ACC	457	Pass		Pass	277	Pass
Ames	Lincoln Way at Welch	LT Arrow	Thermo/ACC	638	Pass		Pass	201	Pass
Ames	Airport Rd at Univ Blvd	RT Arrows/ONLY	Thermo/PCC		Pass		Pass	202	Pass
Iowa DOT	Duff at Airport Rd	RT Arrow	Thermo/PCC	433	Pass		Pass	140	Pass
Slater	R38 at Main St	6" X-Walk	Thermo/ACC	402	Pass		Fail*	71	Pass
Slater	R38 at Main St	Stop Bar	Thermo/ACC	526	Pass		Pass	63	Pass
Polk Co	R38 at NW142nd	Stop Bar	Thermo/ACC	513	Pass		Pass	132	Pass
Polk Co	R38 at NW142nd	Stop Bar	Thermo/ACC	508	Pass		Pass	147	Pass
Polk City	Hwy 415 at Southside Dr	24" X-Walk	Thermo/PCC	494	Pass		Fail*	110	Fail**
Polk City	Hwy 415 at W. Bridge	LT Arrows/ONLY	Thermo/PCC	543	Pass		Pass	136	Pass
Ankeny	NW 18 at NW Irvindale	6" X-Walk	Thermo/ACC	487	Pass		Pass	112	Pass
Ankeny	NW 18 at NW Irvindale	Stop Bar	Thermo/PCC	530	Pass		Pass	209	Pass
Ankeny	NW 18 at NW Irvindale	LT Arrow	Thermo/PCC	429	Pass		Pass	313	Pass
Ankeny	Irvindale at Plk City Dr	LT Arrow	Thermo/ACC	404	Pass		Pass	317	Pass
Ankeny	Bike Xing NW18/Irvindale	8" X-Walk	Thermo/PCC	408	Pass		Pass	242	Pass

**Significant material loss, re-applied material June 2009. **Significant material loss.*

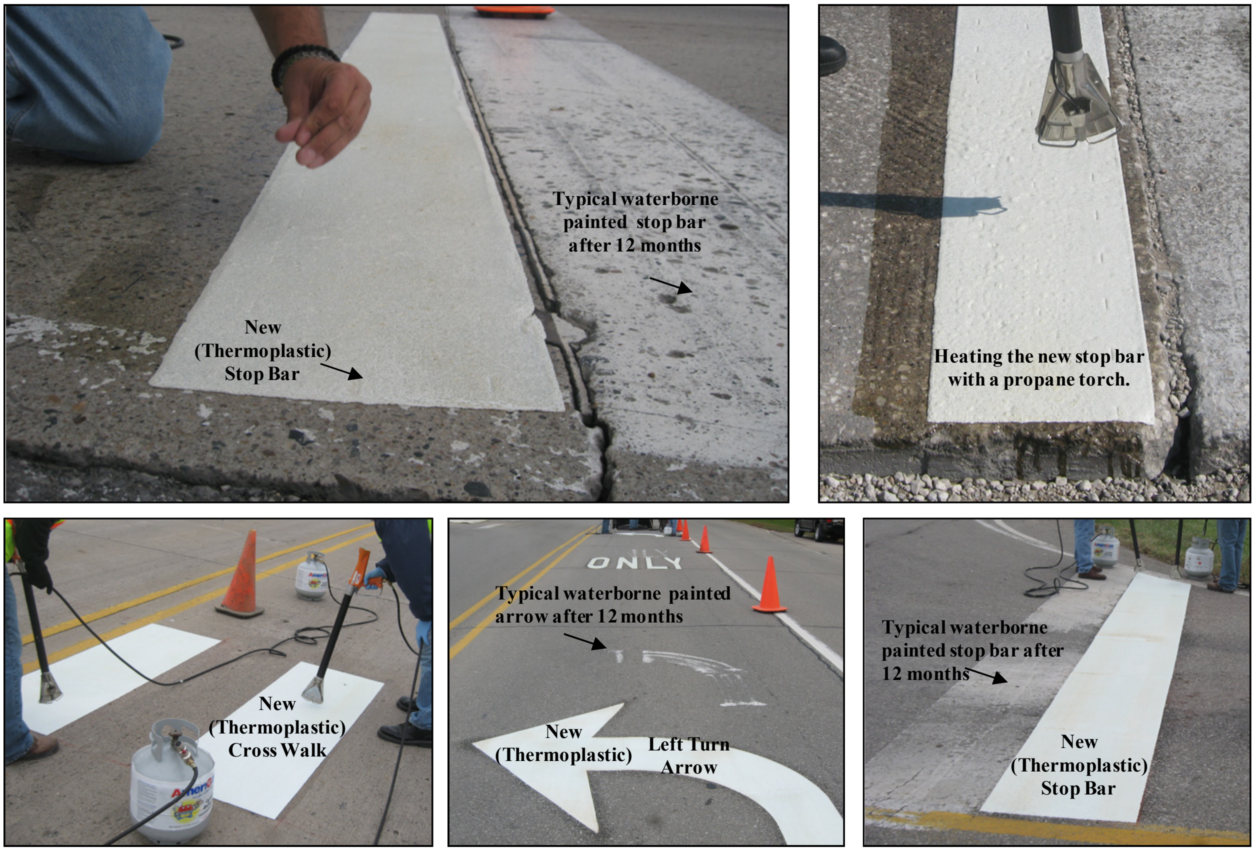
Table 8. Transverse pavement marking performance (installed in 2009)

				2009		2010	
Agency	Location	Marking Type	Mtl / Surface	R_L	Presence	R_L	Presence
Des Moines	E. 5th at Grand Ave	24" X-Walk	Thermo/ACC		Pass	102	Pass
Des Moines	E. 5th at Grand Ave	Stop Bar/6" X-Walk	Epoxy/ACC		Pass	69	Pass
Knoxville	Robinson St at Attica Rd	Stop Bar	Thermo/ACC		Pass	127	Pass
Knoxville	Robinson St at Attica Rd	24" X-Walk	Thermo/ACC		Pass	116	Pass
Knoxville	Robinson St at Attica Rd	Stop Bar/6" X-Walk	Waterborne/ACC		Pass	NA*	Fail
Marion Co	Hwy T17 at Hwy 92	Stop Bar	Thermo/ACC		Pass	93	Pass
Marion Co	202nd Ave at T15	Stop Bar	Thermo/PCC		Pass	101	Pass
Marion Co	Idaho Dr at T15	Stop Bar	Thermo/ACC		Pass	96	Pass
Pella	E Univ at E 13th	Stop Bar	Thermo/PCC		Pass	124	Pass
Pella	E Univ at E 13th	24" X-Walk	Thermo/PCC		Pass	58	Pass
Pella	E 13th at E Univ	Stop Bar	Thermo/PCC		Pass	138	Pass
Pella	E 13th at E Univ	24" X-Walk	Thermo/PCC		Pass	138	Pass

**Significant material loss (retro value not available).*

Figures 35 through 48 show the performance between paint, thermoplastic, and epoxy, as well as typical damage due to winter operations and traffic.

Installation:



Wear and snow plow damage:

Figure 35. Transverse marking installation and performance

October 2008 – Urban Right Turn Arrow Installation (R_L=433), on concrete.

June 2010 – Same location as above, after 20 months. (R_L=140, Presence=Pass).

Figure 36. Urban right turn arrow example

[Ankeny – Irvindale at Polk City Dr]

October 2008 – Rural Left Turn Arrow Installation (R_L=404), on asphalt.

June 2010 – Same location as above, after 20 months. (R_L=317, Presence=Pass).

Figure 37. Rural left turn arrow example

October 2008 – Urban Left Turn Arrow Installation (R_L=429), on concrete.

June 2010 – Same location as above, after 20 months. (R_L=313, Presence=Pass).

Figure 38. Urban left turn arrow example

October 2008 – Rural Stop Bar Installation (R_L=513), on asphalt. Paint (left) was installed Summer 2008.

June 2010 – Same location as above, after 20 months. (R_L=132, Presence=Pass).

Figure 39. Rural stop bar example

October 2008 – Urban Stop Bar Installation (R_L=530), on concrete and within a groove of variable depth.

June 2010 – Same location as above, after 20 months. (R_L=209, Presence=Pass).

Figure 40. Urban stop bar example

October 2008 – Urban Stop Bar Installation (R_L=526), on asphalt which is rutted within the wheel paths.

June 2010 – Same location as above, after 20 months. (R_L=63, Presence=Pass).

Figure 41. Urban stop bar example

October 2008 – Urban 6” Crosswalk Installation (R_L=487), on asphalt.

June 2010 – Same location as above, after 20 months. (R_L=112, Presence=Pass).

Figure 42. Urban 6" crosswalk example

[Ankeny– Trail Crossing for NW 18th East of NW Irvindale]

October 2008 – Urban 8” Crosswalk Installation (R_L=408), on asphalt.

June 2010 – Same location as above, after 20 months. (R_L=242, Presence=Pass).

Figure 43. Urban 8" crosswalk example

July 2009 – Urban 24” Stop Bar and Crosswalk on asphalt.

July 2010 – Same location as above, after 12 months. (R_L=122, Presence=Pass).

Figure 44. Urban 24" crosswalk example

June 2009 – Urban Crosswalk Installation on asphalt.

July 2010 – Same location as above, after 12 months. (R_L=102, Presence=Pass). The dark line is pavement joint sealant.

Figure 45. Urban (Des Moines) crosswalk example

June 2009 – Urban Crosswalk Installation on asphalt.

November 2009 – Same location as above, after 5 months (dark conditions). A high friction material was used for this crosswalk (pattern shows up in this photo).

Figure 46. Urban (Des Moines) crosswalk example (night view)

July 2010 – Thermoplastic after 12 months (Stop bar and Crosswalk placed on the south leg of the intersection. Presence=Pass.

July 2010 – Waterborne Paint after 12 months (Stop bar and Crosswalk placed on the north leg of the same intersection as above. Presence=Fail.

Figure 47. Performance contrast at 12 months (waterborne and thermoplastic)

June 2009 – Epoxy Urban Stop Bar and Crosswalk on asphalt. Marking material is Poly Carb M-55.3

July 2010 – Same location as above, after 12 months. (R_L=69, Presence=Pass).

Figure 48. Performance contrast at 12 months (epoxy)

RESULTS AND ANALYSIS

The research team, in conjunction with the project TAC, completed the following tasks:

- Surveyed current pavement marking practices for local Iowa agencies.
- Demonstrated new tools to manage pavement marking retroreflectivity through five demonstration studies.
- Demonstrated the performance of different pavement marking products of interest to local agencies.

This section presents an analysis and summary of results for each of the completed tasks.

Survey of Current Practice

The responses from 11 cities show that the majority of pavement marking is installed using in-house staff (81%) and that waterborne paint is the most common marking material (9 out of 11 agencies). 5 of the 11 agencies are using some durable marking materials (tape, epoxy, and polyurea). Annual budgets for pavement marking materials and installation range between $2,000 (Harlan) and $400,000 (Cedar Rapids).

Counties typically identify roadways for restriping through cyclical painting schedules, with some reporting of visual inspections that they use, as well. The 33 county responses show the majority of pavement marking is installed using contractors (91%) and that waterborne paint is the most common marking material (100%). Several counties use durable materials including epoxy and high-build waterborne paint, and one agency reported using tape. Restriping is typically identified using a combination of cycle and visual inspection. Annual budgets for pavement marking materials and installation range between $19,000 (Linn County) and $160,000 (Polk County).

Local agencies within Iowa, and especially counties, rely on private contractors for pavement marking installations and typically use waterborne paint applied on an annual or cyclical basis. To extend marking life, some agencies (mostly cities) use durable markings, such as epoxy and high-build waterborne paint.

Decisions about pavement marking materials and the frequency of application can be a difficult challenge for agencies, particularly given the FHWA proposed minimum thresholds and the emphasis on managing retroreflectivity. Given a renewed national focus on the safety of local roadways and the established link between retroreflectivity and safety, agencies are under more pressure to select marking products and installation schedules to achieve a minimum threshold of marking performance all year long. Iowa’s challenging winter conditions and limited season for painting add additional complexities when determining annual paint programs.

Based on the survey findings, considerations for local agencies follow under these categories:

- Monitoring
- Material costs
- Material selection
- Contracting
- Annual condition assessment

Monitoring

- Have agency staff monitor the quality and quantity of contractor-applied markings.
- Track material installation by date, line, quantity, and type in a graphical format, so the information can be used to make more effective decisions each year.

Material Costs

- For roadways having a remaining service life of at least 5 years, higher traffic volumes, and a history of not keeping a pavement marking line for 12 months, consider more durable pavement marking materials, such as high-build waterborne paint, epoxy, polyurea, or tape, and consider grooving these markings in to extend their performance. Typical pricing for these materials is shown in Table 9.

Table 9. Typical pavement marking material costs in Iowa

	Range of Costs Per Station	
Material	From	To
Waterborne	$ 9	$ 12
Epoxy	$ 25	$ 35
Polyurea	$ 60	$ 80
Tape	$ 300	$ 400

Prices do not reflect installation costs which can range between 25% to 50% of the material costs.

Material Selection

- To support funding, develop an agency guideline for material selection and performance. Three sample guidelines are provided in Figures 49, 50, and 51.

Remaining Pavement Service Life	Primary 2 & 3 - Lane RURAL + URBAN ≤ 55 mph	Primary 4+ - Lane RURAL	 URBAN
≤ 2 yrs	**Waterborne**	**Waterbourne**	**HB Waterborne** Waterborne
3 - 5 yrs	**HB Waterborne** Waterborne	**HB Waterborne** Waterborne	**HB Waterborne** Waterborne Thermoplastic (ACC Only)
5+ yrs	**HB Waterborne** Recess Dashlines	**HB Waterborne** Recess Dashlines	**HB Waterborne** Recess Dashlines Thermoplastic (ACC Only) Tape

Figure 49. Iowa DOT pavement marking application matrix (partial view) *(26)*

TWO LANE TWO WAY HIGHWAYS

Remaining Pavement Surface Life[1] (years)	ADT			
	<1,500		>1,500	
	Edgeline	Centerline	Edgeline	Centerline
0-2	Paint	Paint	Paint	Paint
2+	Paint	Paint	Epoxy	Epoxy

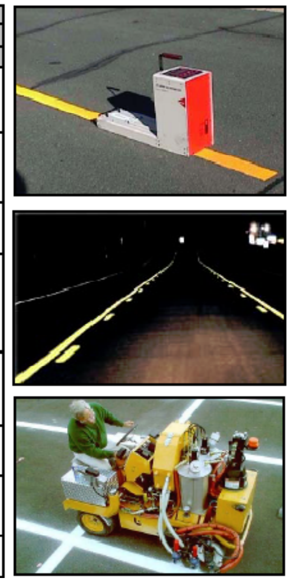
Anticipated life of existing pavement is based on planned projects and anticipated life of surface is based on preventive maintenance plans. For the purpose of this tech memo the expected life of a seal coat is greater than 6 years. All marking materials used shall be on Min/DOT's Qualified Products list.

Figure 50. Minnesota DOT pavement marking technical memorandum *(27)*

PAVEMENT MARKING DECISION MATRIX[A,B]

9/18/2008

SURFACE TYPE	SURFACE CONDITION	AADT per Lane: Low <15,000	AADT per Lane: Medium 15,000-50,000	AADT per Lane: High[1] >50,000
Asphalt/Open-Graded Surface Course	New (Pavement Life>5yrs)	waterborne	tape[3] waterborne epoxy[2]	tape[3] epoxy[2]
	Fair (2<Pavement Life<5 yrs)	waterborne	waterborne epoxy[2]	tape[5] waterborne epoxy[2]
	Poor (Pavement Life<2 yrs)	waterborne	waterborne	waterborne
Concrete	New[1] (Pavement Life>5yrs)	waterborne	tape[3] polyurea waterborne epoxy[2]	grooved tape[3] grooved polyurea grooved epoxy[2] grooved waterborne
	Fair (2 yrs<Pavement Life<5 yrs)	waterborne	waterborne epoxy[2]	polyurea waterborne epoxy[2]
	Poor (Pavement Life<2 yrs)	waterborne	waterborne	waterborne
Chip Seal/Thin Overlay < 1.5"	More than 1 year	waterborne	waterborne epoxy[2]	waterborne epoxy[2]
	Less than 1 year	waterborne	waterborne	waterborne



General Notes:

A. Intended for use as a general guide and is based on performance history in Utah. Projects with special conditions may require independent decisions based on sound engineering judgement.
B. All pavement marking type options are listed in the order of priority/recommended installations See Material Information sheet for relative costs.

Specific Notes:

1. For all AADT > 50,000 and for new concrete interstate, grooving is recommended for all pavement marking types in ultimate build out conditions (full width) with no anticipated long term lane line changes
2. All epoxy permitted by Special Provision only. Manufacturer's warranty should be required.
3. Roadway lighting increases the visibility of tape installed in urban areas.

Figure 51. Utah DOT pavement marking decision matrix *(28)*

Contracting

- Agencies can consider using in-house crews as a best practice because of the benefits of flexibility in scheduling, lack of need for contracting/monitoring, and minimized concerns for quality control. However, these benefits can be highly dependent on the size, budget, and operational conditions of each local agency.
- Multi-agency agreements provide agencies of all sizes the advantages of larger quantity pricing, consistent material and installation specifications, and ease of contracting and/or dispute resolution.
- As part of an annual pavement marking contract, agencies can rank pavement marking placement by developing installation maps that are given priority throughout the paint season. Figure 52 shows a sample map from Wright County Minnesota *(25)*.

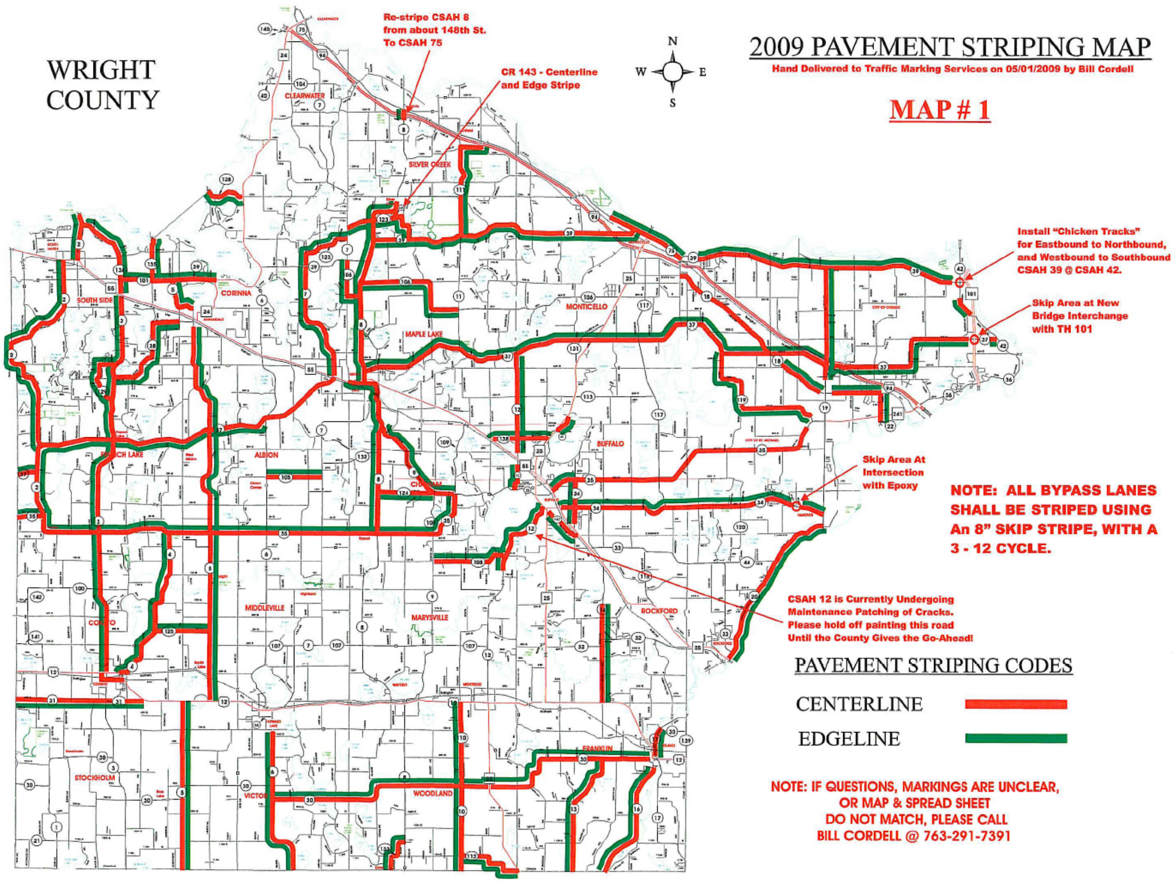


Figure 52. Wright County Minnesota map used to identify annual pavement marking plan

Annual Condition Assessment

- Begin conducting an annual nighttime survey for pavement marking retroreflectivity and a daytime survey for presence. Storing this information within a GIS database allows for easier review and decision making and serves as a tool to communicate striping needs.

Pavement Marking Management Tools

The research team and TAC chose to demonstrate how an agency could conduct a system-wide retroreflectivity assessment—to serve as a tool in determining annual pavement marking needs and developing an annual striping plan. The assessment maps also serve as a communication tool at all staff levels, given that pavement marking performance levels can be assessed at a glance. In simple terms, red is bad and green is good. And, finally, over time, this information can be used to assess the durability and performance of different pavement marking products and installation methods.

Case studies were completed for two cities and three counties, representing different pavement marking installation practice. Maps were produced to show the pavement marking retroreflectivity conditions by line type and time period. A discussion on the demonstration maps follows.

Map Formatting

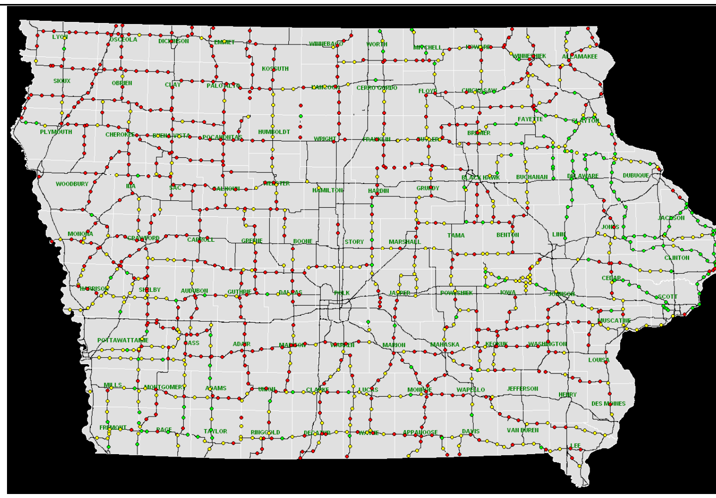
- Map formatting varies slightly, given a desire to consider different styles. For example, some maps combine the white edge and yellow centerline measurements (See Figure 6), while others separate these into two different maps (See Figures 7 and 8). Another map was produced for each city to show the white skip lines (See Figure 13).
- Map appearance also varies, given the scale of the roadway network, available base mapping, and size of thematic dots used for each map.

Retroreflectivity Performance

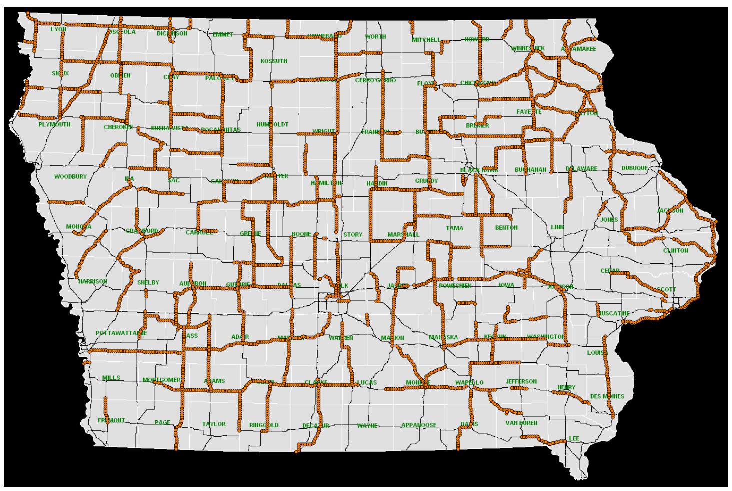
- The maps were produced to demonstrate the capabilities and power of mapping retroreflectivity using GIS. In an ideal situation, the data would be collected in the spring, prior to the painting season, and then again in the fall, to reflect what was painted and improved that season. However, due to staffing limitations, the data did not always include a paint season between time periods. For example, Dallas County data were collected in November of 2006 (Figure 4) and May of 2007 (Figure 5), with no painting being completed between these time periods. As a result, the maps do not show the "improved" condition, which could result from painting. The maps do, however, show the continued degradation of retroreflectivity for some markings (where the later measurement was different enough to change the color of the dot).

Utility

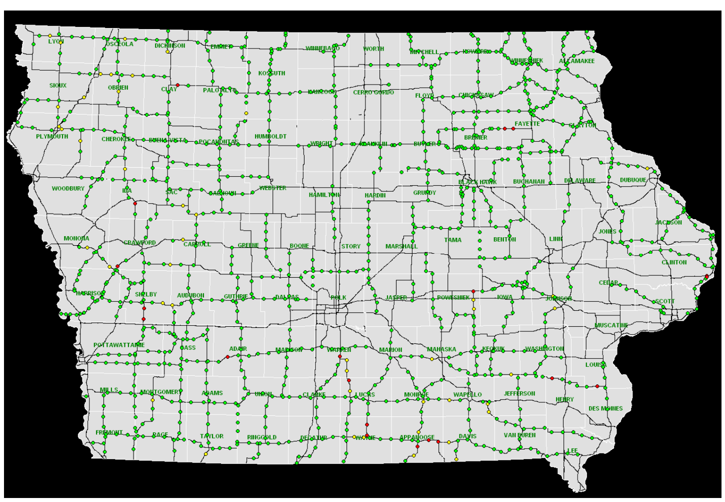
- The Iowa DOT has used pavement marking retroreflectivity maps to manage markings statewide since 2004. This system includes both retroreflectivity and which roadways were painted by line type and year (see Figure 53). These maps (and the Iowa DOT example) can serve as a starting point for local agencies beginning to build tools to help visualize and manage pavement marking retroreflectivity.



Spring 2004 – Iowa DOT Pavement Marking Condition (Yellow Centerline)



Summer 2004 – Iowa DOT Pavement Marking (Painted Yellow Centerline)



Fall 2004 – Iowa DOT Pavement Marking Condition (Yellow Centerline)

Figure 53. Mapping retroreflectivity (Iowa DOT)

Pavement Marking Field Demonstrations

In an effort to support agency decision making, the research team worked with the TAC, industry, and the Iowa DOT to identify reasonable pavement marking alternatives to field demonstrate under local agency conditions. The demonstrations were divided into two categories: longitudinal markings and transverse markings. A discussion on the findings for each follows.

Longitudinal Marking Demonstrations

The research team worked with a local contractor to install pavement markings in both an urban and a rural setting. Roughly half of the markings were placed within a groove (80 mil depth), with the other half being surface applied. The marking materials used for each site were the same and consisted of a high-build waterborne paint and a Type IV glass bead. The urban test deck, a concrete roadway. was on West Lakes Parkway in West Des Moines (between University Avenue and Westown Parkway). The rural test deck, an asphalt roadway, was on County Road R22 in Dallas County (from Ashworth Road north, roughly 2,000 feet). Each test deck installation and evaluation included the following:

- Installation by the same contractor using the same crew, paint, beads, long-line striper, and grooving equipment, on the same day (May 8, 2007) (See Figures 23 and 28).
- On-site installation observation by the research team and agency staff.
- Sufficient traffic control to allow the paint to dry prior to opening up the roadway to traffic.
- Retroreflectivity measurements at set intervals (initial, 6 months, 1 year, and 2.5 years) after installation using a Delta LTL-X 30-Meter Retroreflectometer
- Thematic maps showing the retroreflectivity measurements over time using GIS (See Figures 24-27 and 29-32).

Table 10 shows the change in retroreflectivity for each site over time. The following observations were made.

West Lakes Parkway/Urban setting:

- Retroreflectivity – Initial averages ranged from 464 to 533 mcd. After 1 year, both the grooved and surface-applied white skip markings measured the same (367 mcd) and had lost 64% and 74% of their initial values, respectively. At 2.5 years, these skip lines had lost nearly 90% of their initial value and were in need of replacement. The surface-applied white channelizing lines, which have much less travel over them, still measured 153 mcd at 2.5 years and could last another season.

- Grooving – At 1 year, the grooved white skip markings measured higher than the surface-applied skips, even though the initial average was 59 mcd lower. It appears that the groove did extend the life of these markings; however, at 2.5 years, no significant differences were measured. The groove will provide protection for the new southbound white skip markings, once painted.

R22/Rural setting:

- Retroreflectivity – Initial averages ranged from 404 to 571 mcd. After 6 months, the worst performance was observed for the surface-applied southbound white edge line, which had lost 54% of its initial value. In contrast, the grooved portion of the same line had the best performance, losing only 13% of its initial value. The remaining lines ranged from 20% to 33% loss. After 1 year, the southbound and northbound grooved edge lines measured 239 and 191 mcd, respectively. All other markings were less than 100 mcd and had lost from 79% to 89% of their initial value. At 2.5 years, the southbound and northbound grooved edge lines measured an impressive 206 and 132 mcd, respectively, and were expected to perform over another season. The only other remaining marking (not painted over) was the yellow grooved centerline, which measured 59 mcd.

- Grooving – At 1 year, the grooved versus surface-applied marking performance was noticeable. The southbound edge line measured 239 mcd in the grooved section and 93 mcd in the surface-applied section. The northbound edge line measured 191 mcd where grooved and 78 mcd where surface-applied. The yellow centerline did not show a similar trend, as the difference between grooved and surface applied was only 31 mcd. At 2.5 years, the grooved edge lines were the only functional markings remaining, and they appeared acceptable for one more season.

Table 10. Longitudinal test site retroreflectivity measurements over time

	Average Retroreflectivity (mcd)			
	Initial	6 Months	1 Year	2.5 Years
West Lakes Parkway (Urban)				
Southbound White Skips (G)	464	397	166	64
Northbound White Skips (S)	533	397	140	57
White Channelizing Lines (S)	516	549	253	153
County Road R22 (Rural)				
Southbound White Edge (S)	571	264	93	*
Southbound White Edge (G)	448	388	239	206
Yellow Centerline (S)	475	380	52	*
Yellow Centerline (G)	404	306	83	59
Northbound White Edge (S)	490	328	78	*
Northbound White Edge (G)	470	368	191	132

"(G)" = markings installed within a groove; "(S)" = markings installed on the roadway surface.

**Painted over (no measurement)*

	% Change in Avg Retroreflectivity (mcd)			
	Initial	6 Months	1 Year	2.5 Years
West Lakes Parkway (Urban)				
Southbound White Skips (G)	464	-14%	-64%	-86%
Northbound White Skips (S)	533	-26%	-74%	-89%
White Channelizing Lines (S)	516	6%	-51%	-70%
County Road R22 (Rural)				
Southbound White Edge (S)	571	-54%	-84%	*
Southbound White Edge (G)	448	-13%	-47%	-54%
Yellow Centerline (S)	475	-20%	-89%	*
Yellow Centerline (G)	404	-24%	-79%	-85%
Northbound White Edge (S)	490	-33%	-84%	*
Northbound White Edge (G)	470	-22%	-59%	-72%

Transverse Marking Demonstrations

The research team worked with two pavement marking vendors (Flint and Ennis) to install the thermoplastic markings. Installations began for both the Flint and Ennis products in 2007. Additional (Flint) products were installed in both 2008 and 2009. The research team worked with a range of agencies, including city, county, and state agencies, and Iowa State University (ISU). Each site installation and evaluation included:

- Installation by the material vendor using the same products and equipment (See Figures 35-48);
- On-site installation observation by the research team and agency staff,
- Sufficient traffic control to allow the materials to cool prior to opening up the roadway to traffic;
- Presence observations, annually;
- Retroreflectivity measurements at periodic intervals using a Delta LTL-X 30-Meter Retroreflectometer.

Tables 6 through 8 show the changes in observed presence and measured retroreflectivity over time. A discussion for each table (which represents an installation year) follows.

Table 6/Installed in 2007:

- Presence – Of the six stop bars installed in 2007, two (both on the ISU campus and on asphalt) made it through 3 winters and appear acceptable for another season (in terms of presence) (See Figure 54). Of the remaining four stop bars, which were all on concrete, two failed after the second winter (both on Cameron Road at George Washington Carver in Ames), and the other two failed after the third winter (on South 16th Street at Duff Avenue in Ames).

- Retroreflectivity – Initial retroreflectivity measurements varied significantly from 231 to 634 mcd. After the first winter, all markings measured roughly 60 mcd, with a variance of only 8 mcd between markings. After 3 winters, the remaining two stop bars measured less than 50 mcd.

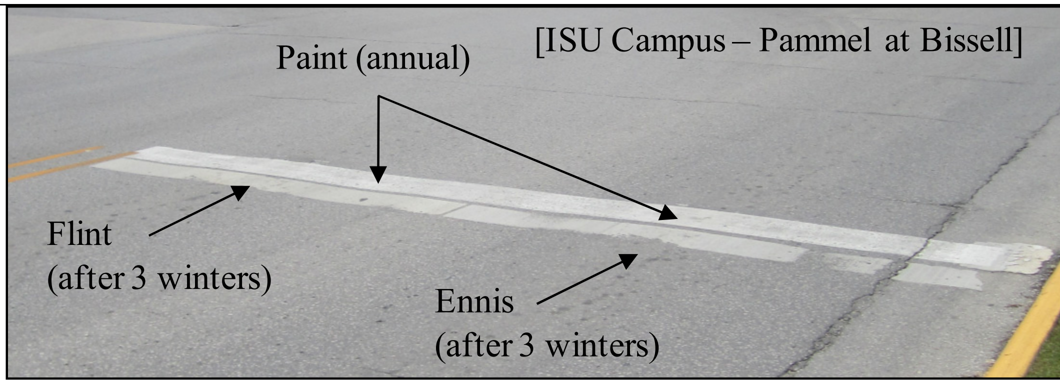


Figure 54. Stop bar performance (after 3 winters)

Table 7/Installed in 2008:

- Presence – The 2008 installations included 9 arrows, 4 stop bars, a rail-road crossing, and 4 crosswalks of varying widths (6-, 8-, and 24-inch bars). Overall, the majority of markings (with 2 exceptions) performed very well after two winters. The performance held across a range of marking types and roadway conditions, which included different surface types, varying traffic loads and patterns, and different agency winter maintenance policies and equipment. (Figure 35 shows some of the typical marking damage experienced and Figures 36-45 show photos of a number of these markings after one or two winters.)

  The 6 in. crosswalk in Slater and 24 in. crosswalk in Polk City were replaced after the first winter due to excessive loss, which appeared to be a result of snow plow damage. Once replaced, the Slater crosswalk retained acceptable presence over the following winter. Figure 55 shows the Polk City crosswalk, which is on a concrete roadway, which was once again heavily damaged due to winter plowing operations. (This route is plowed by the Iowa DOT.)

Figure 55. Polk City crosswalk (snow plow damage)

- Retroreflectivity – For the markings as a group, the average initial retroreflectivity was 486 mcd and after 2 years was 173 mcd (-63%). The 2009 retroreflectivity measurements were lost when a field computer crashed. Among marking types, Table 11 shows that arrows had the least amount of loss (50%) followed by crosswalks, then stop bars. Two arrows, installed at different locations within Ankeny, retained more than 70% of their initial value after 2 winters (See Figures 37 and 38). The stop bar that had lost 88% of its initial value still passed in terms of presence (See Figure 41).

Table 11. Transverse markings - change in retroreflectivity by marking type

	% Change in Avg Retroreflectivity		
	Arrows	Stop Bar	Crosswalk
Average	-50%	-73%	-59%
Best Performing	-22%	-61%	-41%
Worst Performing	-75%	-88%	-77%

Note: % Change from intitial retroreflectivity after two winters.

Based on limited data (not statistically significant).

Themoplastic markings only.

Table 8/Installed in 2009:

- Presence – The 2009 installations included six stop bars and four 24-in. crosswalks. All of the markings have retained enough presence after 1 winter to remain in place for another season. Figures 44 and 45 show two different locations after 12 months. In Knoxville, the city used waterborne paint for the stop bar and crosswalk on the north side of the intersection and the research team used the thermoplastic markings for the stop bar and crosswalk on the south side (See Figure 47). As shown, the waterborne-painted markings are very faint after 12 months and are in need of being repainted. In another comparison, at East 5th Street and Grand Avenue in Des Moines, the south stop bar and crosswalk were installed using epoxy and the east crosswalk was installed using thermoplastic markings. Both markings have excellent presence after 12 months, but are not directly comparable to each other, given that Grand Avenue is a four-lane roadway that carries a significantly higher traffic volume than East 5th Street, which is a two-lane roadway (See Figure 45).

- Retroreflectivity – Initial retroreflectivity measurements were lost when a field computer crashed; however, for the thermoplastic markings as a group, the average retroreflectivity after 1 year was 106 mcd. When considered by marking type, the stop bars averaged 113 mcd, with a range from 93 to 138 mcd. The crosswalks averaged 103 mcd, with a range from 58 to 138 mcd. Given the barely-visible condition of the waterborne-painted crosswalk in Knoxville, 1-year retroreflectivity measurements were not obtained. The epoxy stop bar and 6 in. crosswalk in Des Moines, however, measured 69 mcd after 1 year, which is below the range (93 to 138 mcd) found for the thermoplastic stop bar markings.

CONCLUSIONS AND RECOMMENDATIONS

This section provides conclusions for the research effort, along with recommendations for local agencies to improve pavement marking performance.

Conclusions

On April 22, 2010, the FHWA published a notice of proposed amendments (NPA) for the MUTCD regarding pavement marking retroreflectivity. The proposed revisions would establish a uniform minimum level of nighttime pavement marking performance based on the visibility needs of nighttime drivers. The proposed revisions will promote safety, enhance traffic operations, and facilitate comfort and convenience for all drivers, including older drivers. The proposed rulemaking can be found online at http://edocket.access.gpo.gov/2010/2010-9294.htm. Comments on the proposed document are due on or before August 20, 2010.

The goal of the NPA is to amend the MUTCD to include methods to maintain minimum pavement marking retroreflectivity and associated minimum maintained values for longitudinal marking retroreflectivity. The FHWA proposes a phase-in compliance period of 4 years (from the date of the Final Rule) for implementation and continued use of a maintenance method that is designed to maintain pavement marking retroreflectivity at or above the established minimum levels and 6 years for replacement of pavement markings that are identified using the maintenance method as failing to meet the established minimum levels *(29)*.

Once the rulemaking process is completed, each local agency will be responsible as follows.

- Implement a maintenance method that will maintain marking retroreflectivity levels
- Take actions to assure that all pavement markings meet the established minimum levels

The proposed FHWA amendments to the MUTCD will change the way local agencies manage their pavement markings and place a focus on pavement marking quality and management methods. This research effort demonstrates how a pavement marking maintenance method can be developed and used at the local agency level. The report addresses the common problems faced by agencies in achieving good pavement marking quality and provides recommendations specific to the problems—in terms of assessing pavement marking needs, selecting pavement marking materials, contracting out pavement marking services, measuring and monitoring performance, and developing management tools to visualize pavement marking needs in a GIS format. The research includes five case studies, for three counties and two cities, where retroreflectivity was measured over a spring and fall season and then mapped to evaluate pavement marking performance and needs. The research also includes more than 35 field demonstrations (installation and monitoring) of both longitudinal and transverse durable markings, in a variety of local agency settings, all within an intense snow plow state.

Survey of Current Practice - Local agencies will continue to rely on both in-house crews and private contractors for pavement marking maintenance. Decisions regarding pavement marking materials, and the frequency of application, will be more of a challenge following FHWA's final rulemaking on minimum thresholds. This report provides local agencies with specific information to monitor quality, improve material selection and cost effectiveness, contract for services, and conduct annual condition assessments.

Pavement Marking Management Tool - Case studies were completed for two cities and three counties, representing different pavement marking installation practices. Maps were produced in a GIS environment to show the pavement marking retroreflectivity conditions by line type and time period. A discussion is provided in terms of map formatting, marking performance thresholds, and the overall utility provided.

Pavement Marking Field Demonstrations - In an effort to support agency decision making, the research team identified reasonable pavement marking alternatives to field demonstrate under local agency conditions. The demonstrations were divided into two categories: longitudinal markings and transverse markings.

Longitudinal Marking Demonstrations - These two demonstrations provide local agencies with high-build waterborne paint performance examples under two very different conditions, urban and rural. Each setting included both grooved and surface-applied marking segments, so performance could be compared. Under urban conditions, the white skip lines performed for 2 years. The left-turn channelizing lines were still acceptable beyond 2.5 years. In the rural two-lane roadway setting, the grooved edge line pavement markings performed beyond 2.5 years, in contrast to the surface-applied edge line and center line markings, which did not perform beyond 1 year. These demonstrations highlight the need to monitor pavement marking performance by line type, given the variation in performance. These examples are a starting point for agencies in considering their material selection options over the wide variety of pavement marking materials and installation techniques that are available.

Transverse Marking Demonstrations – The heat-in-place, precut, thermoplastic markings were installed across central Iowa and in a variety of settings, beginning in 2007 and ending in 2009. With a few exceptions, this type of durable marking provided agencies with more than 2 years of effective performance, in contrast to annual painting with waterborne paint. After 2 winters, some left turn arrow markings had retroreflectivity readings of above 300 mcd, regardless of surface type. The life of these markings can be further extended through patching the damaged areas. Concrete surfaces require the use of a primer, which can slow the installation process, and more failures occurred on concrete surfaces than on asphalt. The cooling time for these markings can be accelerated, versus waiting for paint to dry, in humid and cloudy conditions.

Recommendations

Given the relatively short life that pavement markings have, in terms of an agency asset, and the lack of performance benchmarks, it has been convenient, up to this point, for many agencies to simply refresh all markings on a cyclical basis. However, with the anticipated amendments to the MUTCD, agencies will need to have a maintenance method in place to manage pavement marking performance at a given benchmark. To do this, agencies need to understand the performance of their markings, be able to set goals to achieve compliance, and develop the ability to trigger corrective action when performance fails to meet expectations. As the adage goes, "What gets watched…gets done."

The following recommendations are presented to assist local agencies in developing a pavement marking plan to meet the visibility needs of both daytime and nighttime drivers on the local roadway network. With a national pavement marking minimum performance threshold, and tools for local agencies to manage marking thresholds, the goals of promoting safety, enhancing traffic operations, and facilitating the comfort and convenience for all drivers are attainable and will appropriately begin at the local level.

Get Organized

- A clear strategy serves as an organizational magnifying glass, from the ground up. Develop a maintenance method that clearly, and as simply as possible, shows pavement marking conditions, compliance to a benchmark, improvement actions selected, and costs. Selecting a champion to see this initiative through is critical.

Measure and Monitor

- Understand pavement marking performance and annual needs. Begin conducting an annual nighttime survey for pavement marking retroreflectivity and a daytime survey for presence. If a pavement marking retroreflectometer is available, measure marking performance on a consistent basis. Storing this information within a GIS database allows for easier review and decision making and serves as a tool to communicate striping needs.

Develop a Strategy

- To support funding, develop an agency guideline for pavement marking performance and material selection, specific to local conditions.
- For roadways having a remaining service life of at least 5 years, higher traffic volumes, and a history of not keeping a pavement marking line for 12 months, consider more durable pavement marking materials, such as high-build waterborne paint, epoxy, polyurea, or tape, and consider grooving these markings in, to extend their performance.

Consider your Options

- Multi-agency agreements provide agencies of all sizes the advantages of larger quantity pricing and consistent material and installation specifications, and ease the burden of the contracting and/or dispute-resolution process. These agreements can be with a private contractor or another local agency.

Communicate Effectively

- As part of an annual pavement marking contract, agencies can rank pavement marking placement by developing installation maps that are given priority throughout the paint season.
- Have agency staff monitor the quality and quantity of contractor-applied markings.
- Track material installation by date, line, and quantity, and record these in a tabular format, so the information can be used to make more effective decisions each year.

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