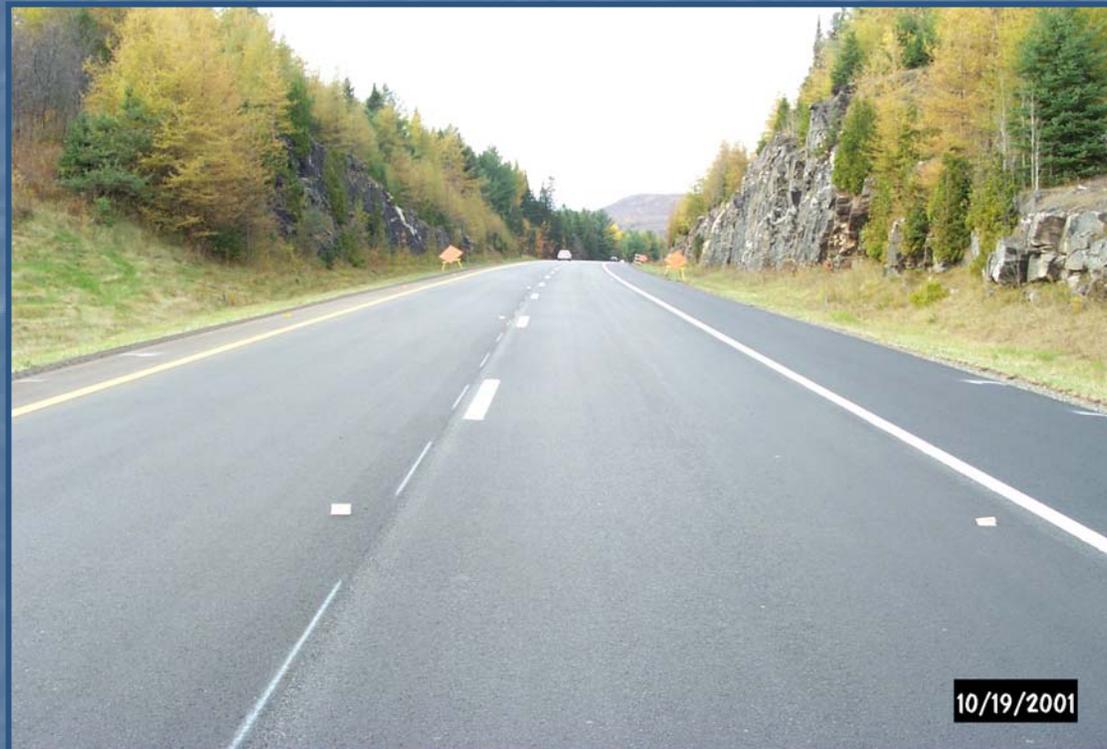


Pavement Marking Durability



Presented By: Jennifer Vosburgh, EI

Research Overview and Objectives

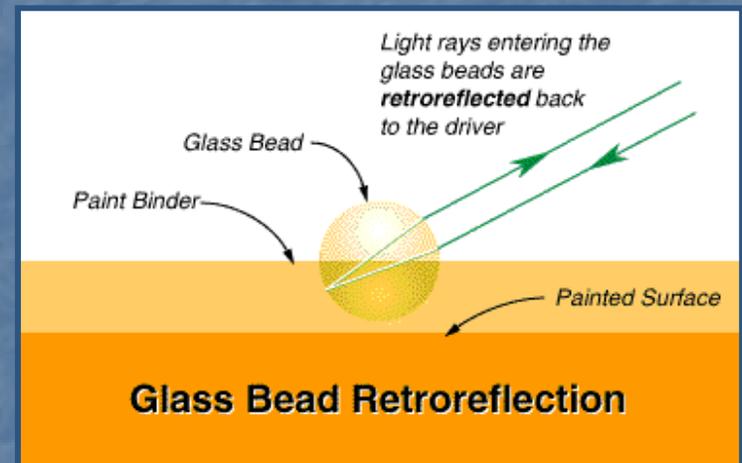
- Longitudinal pavement markings are the most widely implemented traffic control devices.
- Numerous types of materials are applied to roadways including thermoplastic, epoxy, and polyurea.
- Degradation is caused by environmental factors.
- Goals:
 - To determine service life and overall cost of various markings in terms of degradation with consideration to durability, retroreflectivity, and cost.
 - To develop recommendations for a pavement marking application and replacement strategy.

Background

- Pavement markings provide a visual reference that aid to position the car within the roadway.
- MUTCD 3A.02 – markings that must be visible at night, should be retroreflective unless ambient lighting assures that markings are adequately visible and consideration should be given to selecting pavement marking materials...
- Retroreflective materials are utilized during application to provide for nighttime visibility.

Background, Cont.

- “Retroreflectivity is the property to reflect light back towards its source.” - FHWA
- Spherical glass beads are embedded into the marking binder during installation.
- The binder contains pigments which scatter the light and allow more for light reflection.



Background, Cont.

- Over time, pavement markings degrade and become less reflective.
- Causes of degradation include:
 - Improper application.
 - Wear by vehicles.
 - Oxidation and ultraviolet sunlight.
 - Fading pigments.
 - Binder can become brittle creating holidays or bead release.
 - Damage from winter maintenance practices.
- Once markings no longer exhibit acceptable nighttime visibility, the markings should be replaced.

Project Scope

- Phase I: Literature Review.
- Phase II: Data compilation from existing projects.
- Phase III: Data Collection from new projects.
- Phase IV: Data Reduction/Interim Report
- Phase V: Economic Analysis of life cycle costs.
- Phase VI: An evaluation of the deterioration mechanisms of the performance factors.
- Phase VII: Final Report.

Phase I: Literature Review

- To gain knowledge of testing procedures, current research, current operation practices and innovative technologies regarding pavement markings.
 - Field Studies.
 - Laboratory Studies.
 - Sampling Procedures.
 - Pavement Management Marking Systems (PMMS).

Data Collection (Phase II and III)

- Marking Type:
 - Thermoplastic (76%)
 - Polyurea (20%)
 - Epoxy (4%)
 - Waterborne Paint
 - Permanent Tape
- Site Location Selection:
 - Roadway Classification
 - Geographic Location
 - AADT
 - Age



Data Collection (Phase II and III)

- Thermoplastic Markings (AASHTO M-249):
 - Homogenously composed of pigment, filler, resins (hydrocarbon or alkyd) and glass reflectorizing spheres.
 - Thermoplastic resin – linear macromolecular structure that will repeatedly soften when heated and harden when cooled.
 - Hydrocarbon – petroleum derived resins (most frequently specified).
 - Alkyd – naturally occurring resin that is resistant to petroleum products.
 - Subject to VTrans Standard Specifications 646.07(c) and 708.08.

Data Collection (Phase II and III)

- Polyurea Markings:
 - Two part component, polyurea coating material with glass beads and possibly additional reflective elements.
 - Chemical technology based on two component reacted materials:
 - Amine blend
 - Isocyanate mixture
 - Results in very rapid reactions which produce extended chain polymer structures generally in membranous form.
 - Subject to VTrans Specifications 646.07(modified) and 708.15.

Data Collection (Phase II and III)

- Epoxy Markings:
 - Two component (two parts resin to one part curing agent), epoxy materials with glass beads applied as it cures
 - Epoxy resin – polyether resin formed originally by the polymerization of bisphenol A and epichlorohydrin, having high strength and low shrinkage during curing.
 - Subject to VTrans Specifications 646.07(b) and 708.08(c).

Data Collection (Phase II and III)

■ Glass Beads:

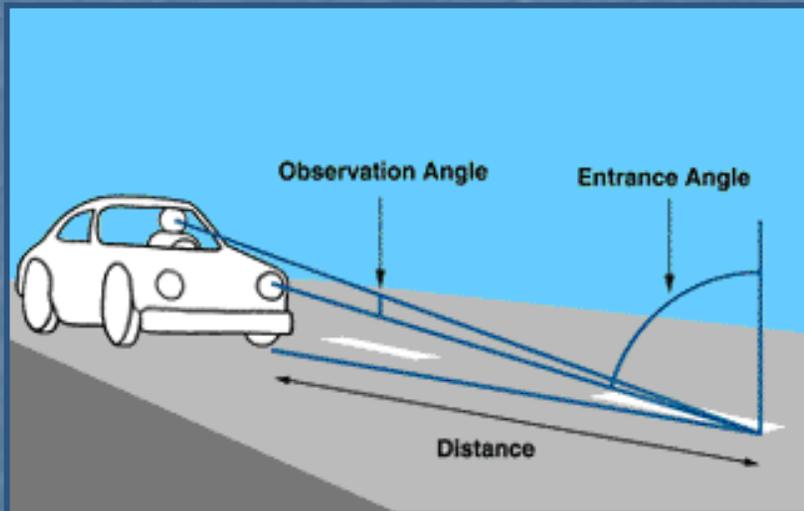
- Since 1997, crushed clear glass (max. size of 33 mils) has been added to thermoplastics at a rate of 9-10% of the total weight.
- Remainder comprised of 35% filler materials, 25% binder material, and 30% glass beads.
- Glass beads slightly smaller gradation than AASHTO Specification M 247-05 (Type I).

Data Collection (Phase II and III)

- Test Sites:
 - A minimum of 5 randomly selected sites as delineated by mile marker location.
 - Within each test site – 5 locations are assessed at intervals of 10' and includes: edge, center or skip lines.
 - Many sites were established at locations with markings up to two years old.
 - Evaluation criteria includes the following –
 - Retroreflectivity (ASTM E1710-97 modified)
 - Durability (ASTM D913-00)
 - Photographic Representation

Data Collection (Phase II and III)

- Retroreflectivity readings were collected with LTL 2000 Retrometer



- 30-meter geometry or "driver geometry" - (Adopted by ASTM)
- millicandelas/m²/lux
- Calibration
- Provides for reproducibility, accuracy, and repeatability
- Winter Data Collection

Data Collection (Phase II and III)

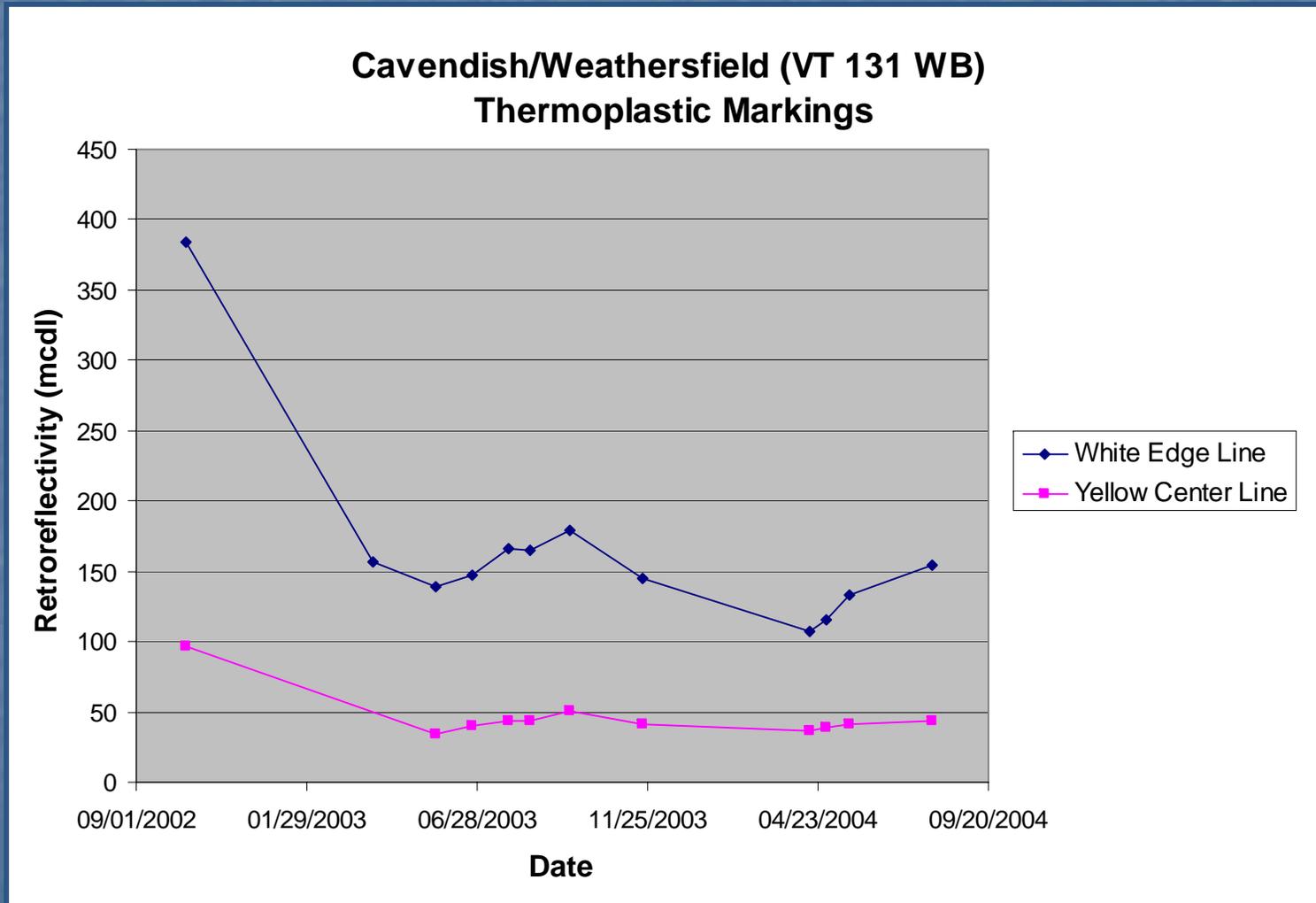


- When possible, initial retroreflectivity readings were collected within 14 days of application in order to comply with ASTM Standard D 6359-99.
 - Minimum retroreflectance requirements:
 - White – 250 mcdl
 - Yellow – 175 mcdl

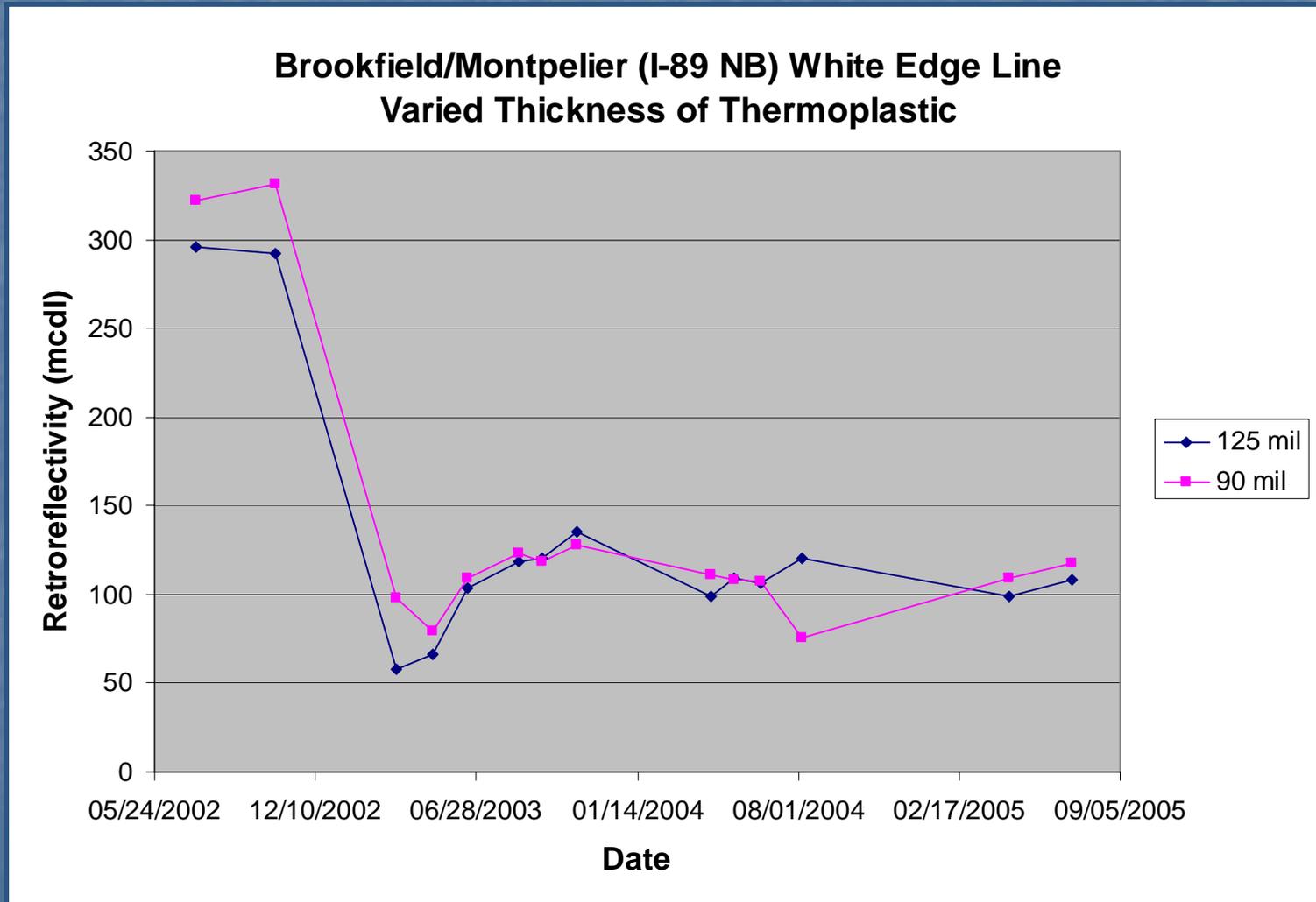
Phase IV: Data Reduction

- All raw field data was recorded.
- Data was transcribed into Excel spreadsheets.
- Data was processed to find anomalous readings.
- Plots of Retroreflectivity reading vs. time:
 - Readings displayed significant variability.
 - All markings displayed similar patterns.

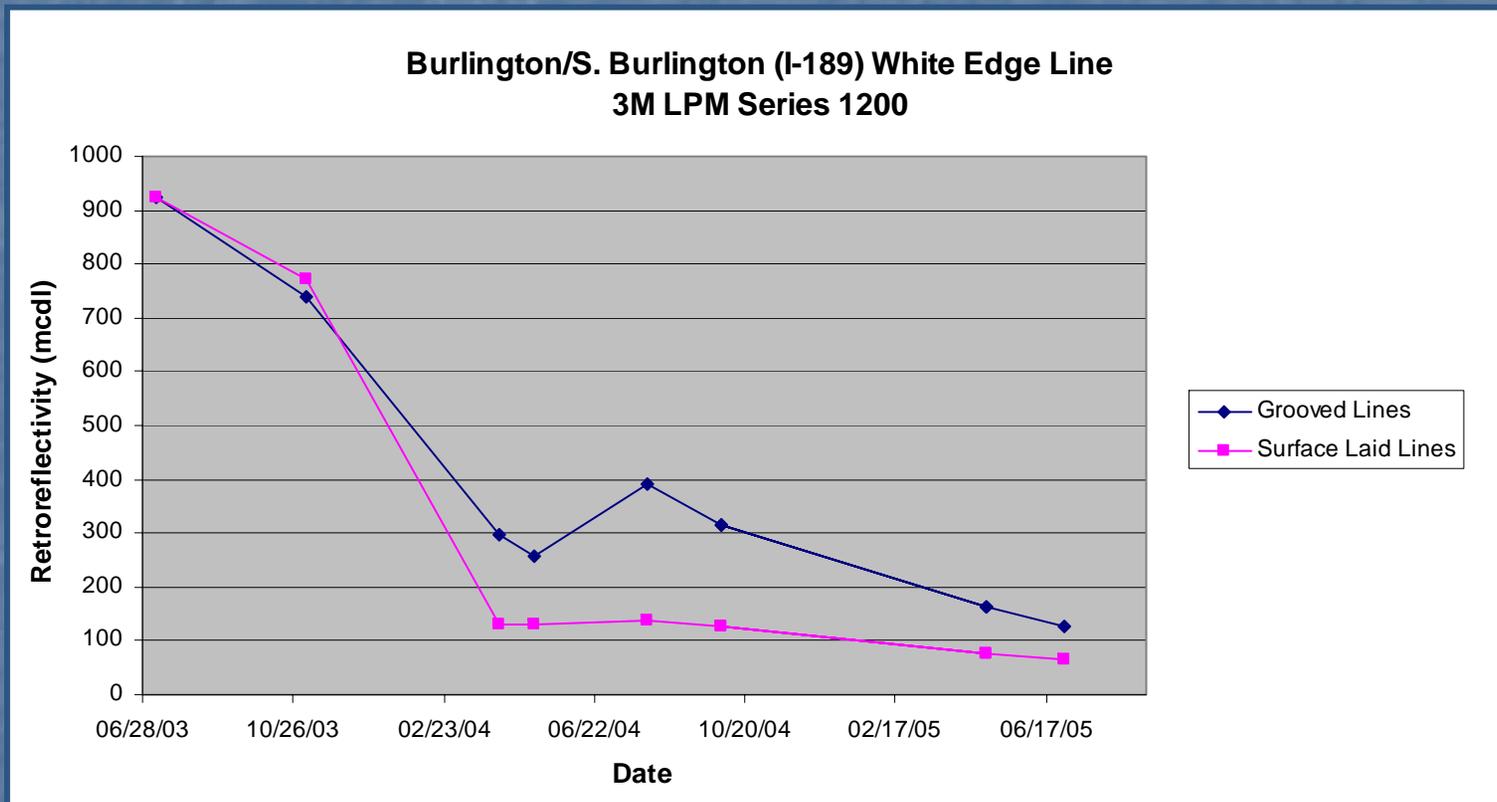
Phase IV: Data Reduction



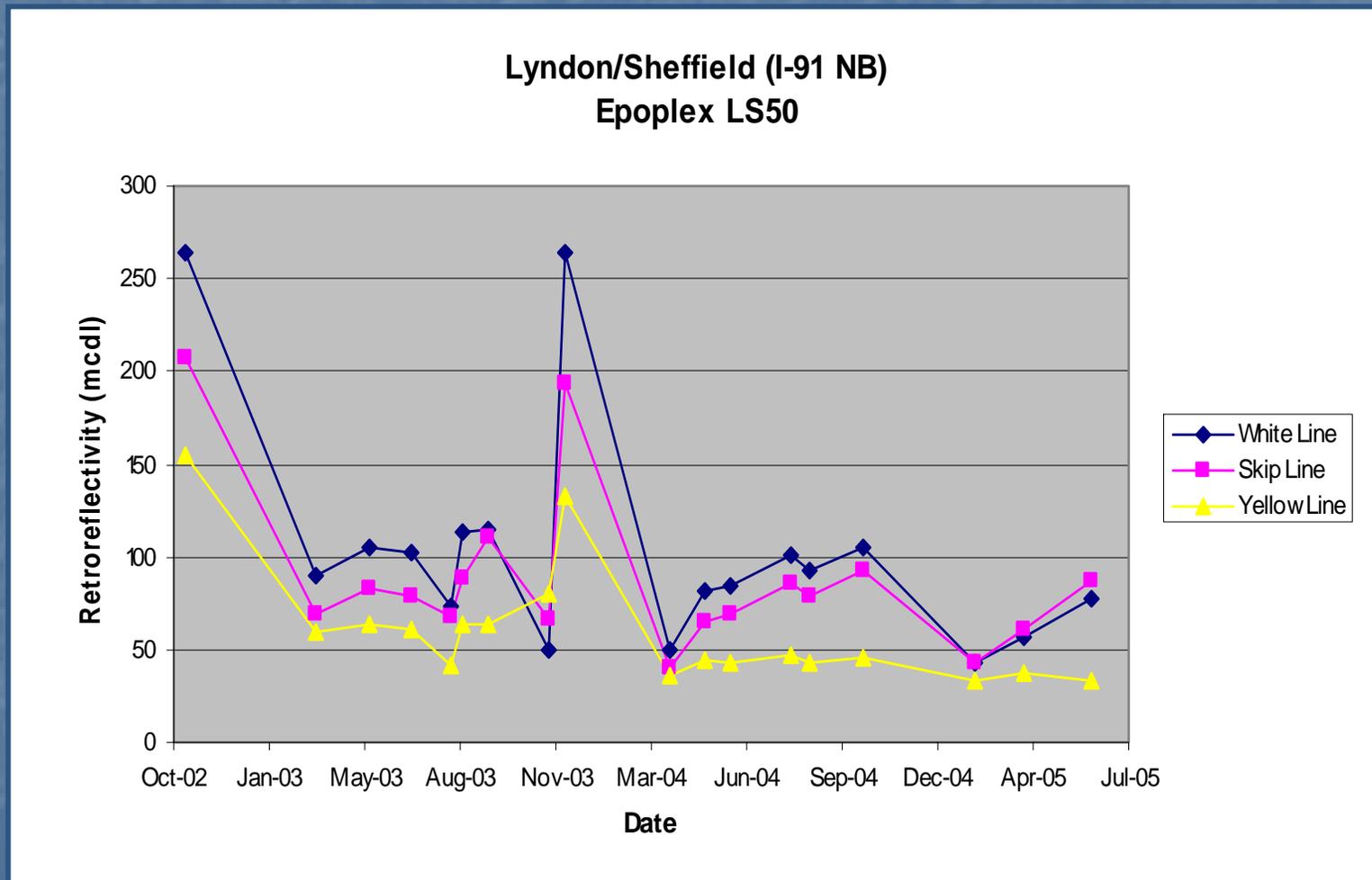
Phase IV: Data Reduction



Phase IV: Data Reduction



Phase IV: Data Reduction



Phase IV: Data Reduction

- Estimate for Service Life – Statistical Modeling of the degradation of retroreflectivity:
 - Roadway Characteristics
 - Traffic Characteristics
 - Other Attributes
- Evaluation Considerations:
 - Large Variability
 - Need for pre-defined benchmark

Phase IV: Data Reduction

Recommended Retroreflectivity Values

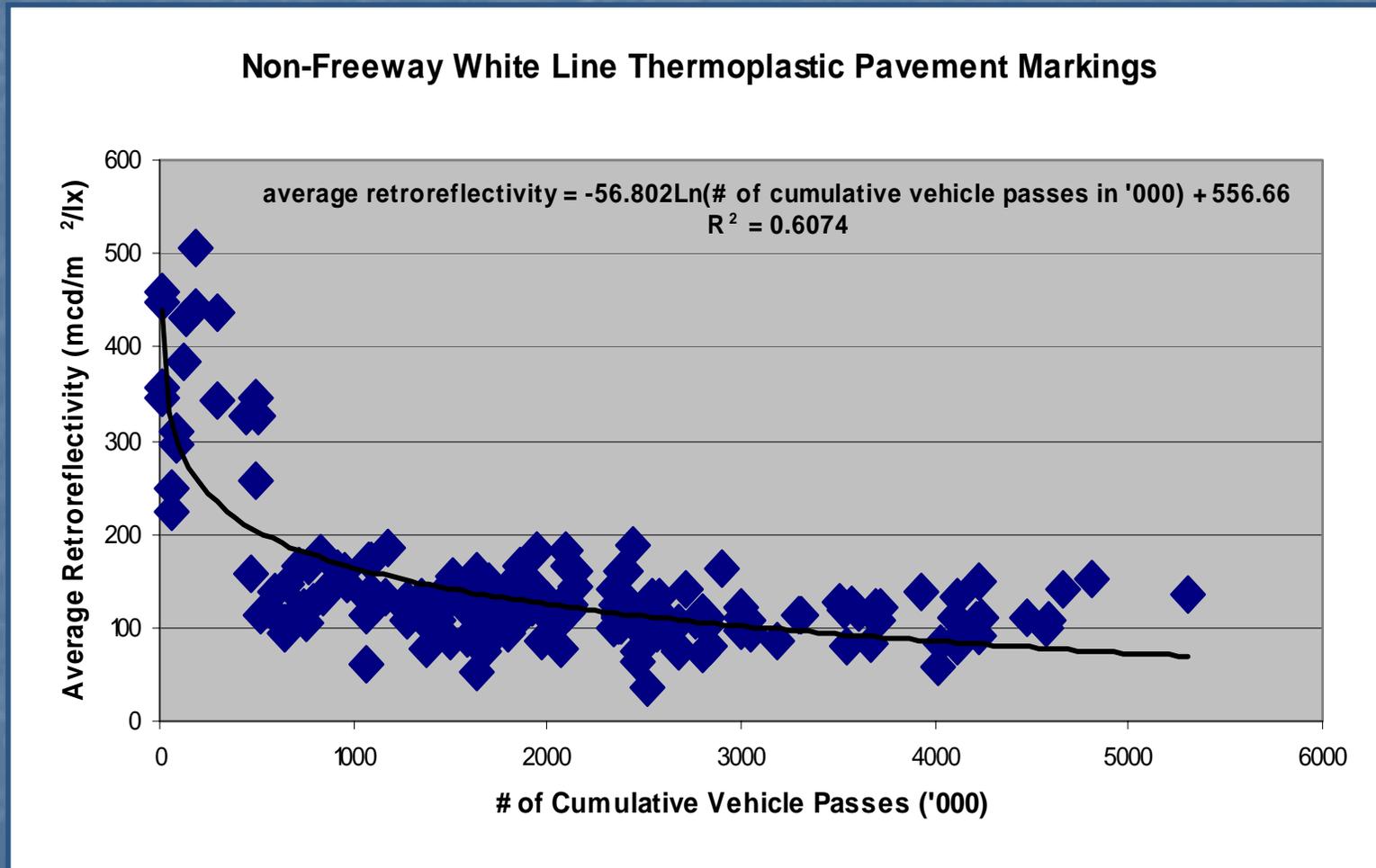
1998 FHWA Research-Recommended Pavement Marking Values			
Type	Non-Frwy	Non-Frwy	Freeway
Option 1	<= 40 mph	>= 45 mph	>= 55 mph
Option 2	<= 40 mph	>= 45 mph	>= 60 mph, >10K ADT
Option 3	<= 40 mph	45-55 mph	>= 60 mph
White	85	100	150
Yellow	55	65	100

Phase IV: Data Reduction

- Thermoplastic Markings:
 - Degradation analysis in terms of retroreflectivity, time since installation, and cumulative traffic passages.
 - 19 Roadway Sections.
 - 1,100 Individual Measurements.
 - 69 Longitudinal Lines.
 - Grouped by roadway, material, and color.

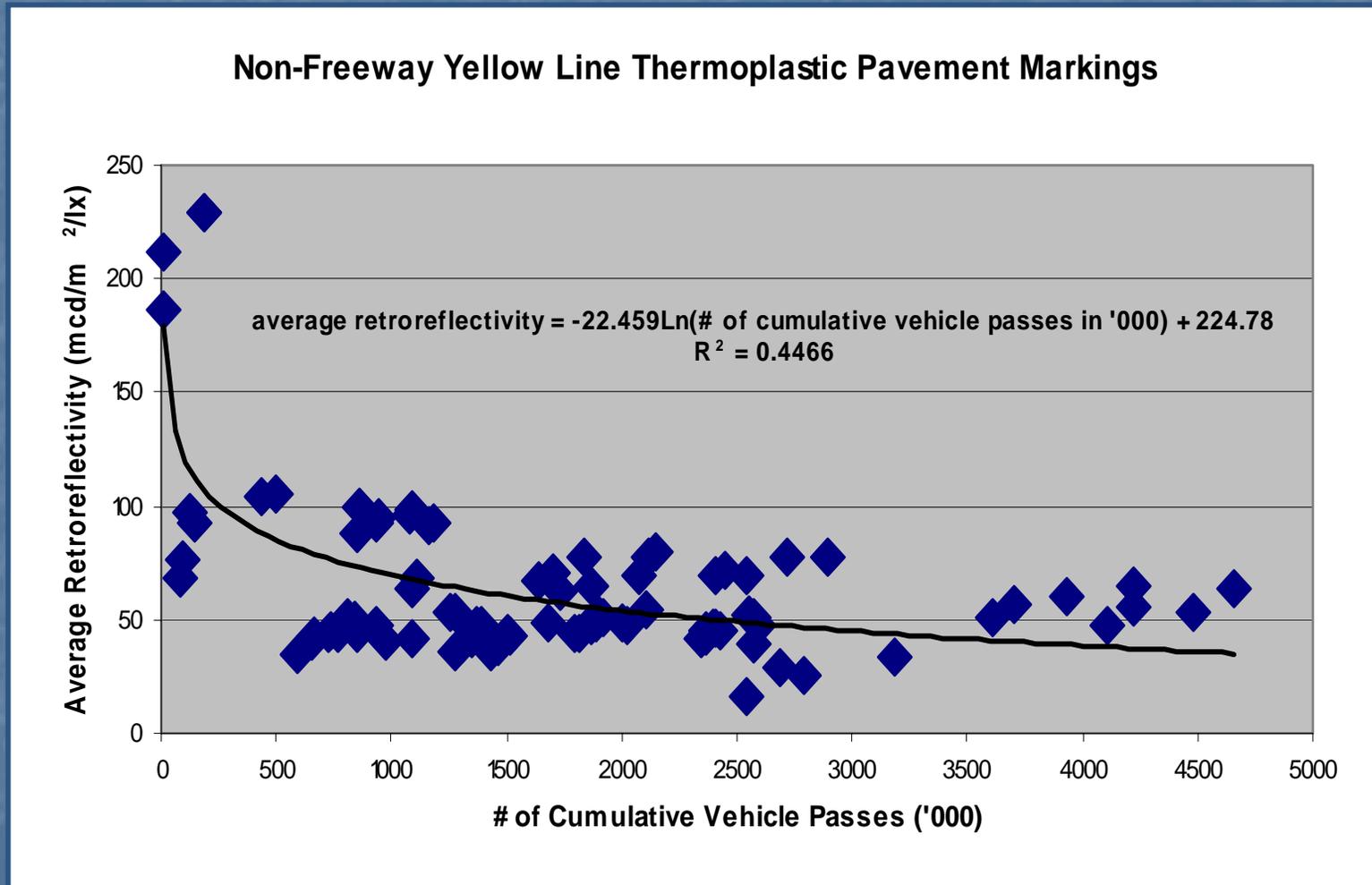
Phase IV: Data Reduction

White Edge Line Retroreflectivity



Phase IV: Data Reduction

Yellow Line Retroreflectivity



Phase IV: Data Reduction

■ Findings

- Large Data Sets – more accurate degradation models.
- Use of FHWA recommended minimum retroreflectivity values-
 - Non-Freeway White Line: $X=3100, R^2=.60$
 - Non-Freeway Yellow Line: $X=1230, R^2=.45$
 - Freeway White Line: $X=570, R^2=.35$
 - Freeway Yellow Line: $X=540, R^2=.05$
 - $X=\#$ of cumulative vehicle passes in 1000's of vehicles

Phase IV: Data Reduction

- Additional Analysis:
 - Additional readings required for analysis of degradation in polyurea and epoxy markings.
 - Examine data sets for anomalous readings.
 - To include other independent variables such as average snowfall amounts, pavement types, raw data, curved vs. straight sections.

Remaining Phases

- Phase V: Economic Analysis of life cycle costs.
- Phase VI: An evaluation of the deterioration mechanisms of the performance factors.
- Phase VII: Final Report.

Questions?



- For further information please contact the Materials and Research Section of the Vermont Agency of Transportation:
 - Jennifer Vosburgh, Research Engineer
 - (802) 828-2553
 - Kat Patterson, Research Technician
 - (802) 828-6945

