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Project Title: DESIGNING AN EXPERIMENTAL FACILITY FOR ROADWAY SIGN RETROREFLECTIVITY MEASUREMENT

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1.0 INTRODUCTION

Dr. Joseph Hummer and Dr. William Rasdorf have recently completed a two-year research project for the NCDOT Signing Section on sign retroreflectivity and sign inspector performance [Rasdorf, et. al. 2006]. The results of this research project have indicated a need to better understand how the retroreflectivity of sign sheeting degrades over many years in the field.

The research project found that there was a lack of signs in the field greater than 10 years old with Type III encapsulated lens sheeting, as specified by ASTM Standard D4956. Most Type III encapsulated lens sheeting in place in North Carolina is less than five years old, except for some older signs along interstate routes. Because of the paucity of older Type III signs, there was no clear point on the Type III sign deterioration curves where a sign would be expected to be below the FHWA proposed minimum retroreflectivity standards [Carlson and Hawkins, 2003]. The lack of quantitative deterioration information makes it difficult to predict when Type III encapsulated lens sheeting will deteriorate below the standard and need to be replaced. However, as the North Carolina Department of Transportation (NCDOT) moves towards using only Type III or greater sign sheeting, the long-term performance of these sheetings will need to be understood.

One way of achieving this understanding is to establish a sign farm. A sign farm is an arrangement of signs in a controlled area that have their retroreflectivity measured at regular intervals to determine how their retroreflectivity deteriorates as a function of time and other factors. While field measurement of in-place signs affords valuable data, as demonstrated in the research project by Hummer and Rasdorf, there are uncontrollable factors that are faced when using only in-place signs. Vandalism, such as gunshots and paintballs, can cause a sign to deteriorate prematurely. Natural deposits of tree sap and dust can also cause premature deterioration and damage. Because of these uncontrollable factors, there is a need to design and build a sign farm in which a wide range of variables of interest to the NCDOT can be controlled. The variables that have been incorporated into the sign farm design are sign color, sheeting type, and orientation.

2.0 OBJECTIVES

The objectives of the sign farm design are as follows:

- Measure sign retroreflectivity over time in order to better model sign deterioration.
- Determine when signs will be below the proposed FHWA minimum retroreflectivity standards.
- Evaluate sign sheeting types and colors most used by the NCDOT currently and in the future.
- Minimize the costs and space requirements associated with the sign farm.

The objectives of this report are:

- Present one template base sign farm design.
- Suggest implementation strategies to NCDOT regarding the sign farm base concept.

3.0 BENEFITS

A better understanding of sign sheeting performance will help NCDOT better manage their sign assets because NCDOT will be able to predict when signs will deteriorate to the point where they require replacement. Improved knowledge about the deterioration of certain sheetings will also inform NCDOT sign specification and purchasing decisions. The findings from the sign farm will also be helpful to other DOTs and researchers across the United States because currently there are no sign farms designed to evaluate the long-term performance of Type III and greater sign sheetings that we know of. The National Transportation Product Evaluation Program (NTPEP) does monitor the deterioration of retroreflectivity over time in a controlled setting. However, the NTPEP experiments only last for three years, yielding no data as to when signs are expected to deteriorate below the FHWA proposed minimum retroreflectivity standards.

4.0 DESIGN

The sign farm design process involves the following three steps:

- Sign Selection Process
- Layout and Installation
- Retroreflectivity Measurement

The sign selection process entails determining the sign sheeting types and colors to be studied and the required sample size. Signs are then selected based on their sheeting type, color(s), cost, and criticality to safety. Once the signs to be studied are selected, the necessary sign layout and installation parameters can be determined in order for the signs to all get exposure to the sun and weather. Once the sign farm has been installed, a data collection program can measure sign retroreflectivity and monitor its deterioration over time. The sign farm design outlined in this section can be viewed as a base configuration that can be modified based on the requirements of NCDOT.

4.1 Sign Selection Process

One of the objectives of the sign farm design is to evaluate sign sheeting types and colors most used by the NCDOT currently and in the future. The “most used” criterion motivated the selection of sign sheeting types and colors as well as the actual signs chosen for the sign farm.

4.1.1 Sheeting Type

Sign sheeting types were selected based on the sheeting types that NCDOT is currently installing or is planning to install in the near future. Currently, The NCDOT has a sign sheeting materials contract with 3M™. Other major manufacturers of sign sheeting materials are Avery Dennison®, Nippon Carbide, ATSM, Inc., Kiwalite®, and LG Lite [FHWA, 2005]. The sheetings selected for the sign farm are as follows:

- Type III encapsulated lens (glass bead), 3M™ High Intensity
- Type III prismatic, 3M™ High Intensity Prismatic
- Type IX prismatic, 3M™ Diamond Grade™ VIP

Type III encapsulated lens sheeting, or more specifically, 3M™ High Intensity sheeting, was selected because it is presently being used for all new sign installations on secondary and most primary roads. Type III prismatic sheeting, with the 3M™ brand name High Intensity Prismatic, is being considered for use by the NCDOT because it has the potential to maintain its retroreflectivity longer than a more easily damaged encapsulated lens sheeting. Type IX prismatic sheeting from 3M™ is currently being used by the NCDOT on interstate signage and important primary road guide signs. Type I sheeting was not selected for the sign farm because NCDOT has discontinued new installations of Type I sheeting.

4.1.2 Colors

Similar to sign sheeting types, sign colors for the sign farm were selected based on the sign colors most commonly used in permanent signage by the NCDOT. The requirement that the signs be permanent eliminates orange signs from consideration because they are used only on a temporary basis for work zone signage. Brown signs were also not included in the sign farm because they are primarily used to guide drivers to daytime attractions, and therefore do not need high visibility at night. The sign colors selected for the sign farm are:

- White
- Yellow
- Red
- Green

The selected sign colors are the colors most typically used for regulatory, warning, and guide signs across NC. Blue signs are not included in the basic design of the sign farm because the FHWA has not proposed minimum retroreflectivity values for blue signs, but they can be added by the NCDOT at their discretion. We propose that the NCDOT not include fluorescent colors in the sign farm, as these are very rarely used in the field.

4.1.3. Sample Size

In order to have a sample size that will provide for 95% confidence in the analysis results, each sheeting color should have the total sample size indicated in Table 1, column D. The total sample size (column D) is equal to four times the maximum needed sample size per orientation (column C) because the sign farm will be testing signs facing north, south, east, and west.

Table 1. Color and Size of Signs Selected for Sign Farm

Column	(A)	(B)	(C)	(D)
Sheeting Color	Standard Deviation from Field Study	Acceptable Difference in R_a Values	Sample Size per Orientation	Total Sample Size
White	15.6	24.4	4	16
Yellow	18.2	19.9	4	16
Red	7.2	5.2	8	32
Green	3.9	4.1	4	16

The sample size per orientation was derived from the standard deviation of R_a values (column A) with the same Type III sheeting color and age from the NCSU field study [Rasdorf, et. al. 2006],

and an acceptable difference in the sign farm R_a results (column B) equivalent to 10% of the average R_a value for the same Type III sheeting color and age. Column C was calculated from columns A and B by using the sample size formula $\{(1.96*\text{Column A})/\text{Column B}\}^2$ and then rounding to the nearest multiple of 4.

4.1.4 Sign Selection

Specific signs were selected for the sign farm based on a combination of their sheeting color(s), cost, and how critical they are in the field. Ideal signs would have one to two sheeting colors that could be measured for retroreflectivity, would be critical to driver safety, and would be a typical size that minimizes sign purchasing costs. Table 2 and Figure 1 show the signs selected as a result of these criteria for the basic sign farm design.

The Stop (R1-1) sign was selected because it is the most critical red color sign in the field, and the NCDOT places a high priority on maintaining stop sign retroreflectivity. The 30" Stop sign size is the size most used on secondary roads and is less expensive than the 36" version. The Stop Ahead (W3-1) sign was selected primarily because it has large areas of both yellow and red sheeting. It could be measured for both yellow and red retroreflectivity thereby reducing the number of red Stop signs needed in the farm. The Speed Limit (R2-1) sign was chosen for the sign farm because it is the most common white background sheeting sign in the field on all road types. The Destination Sign (D1-2) was chosen because it is a common green background sign on secondary and primary roads.

Table 2. Color and Size of Signs Selected for Sign Farm

Sign Message	Sign Color Background (legend)	Sign MUTCD Code	Sign Size	Number of Signs per Sheeting Type	Total Number of Signs
Stop	Red	R1-1	30"	16	48
Stop Ahead	Yellow (Red)	W3-1	36" x 36"	16	48
Speed Limit	White	R2-1	24" x 30"	16	48
Destination Sign	Green	D1-2	54" x 24"	16	48
TOTAL				64	192

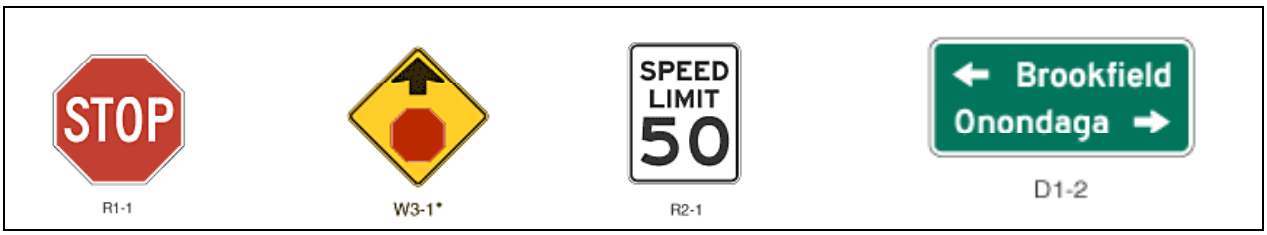

Figure 1. Signs Selected for Basic Sign Farm Design with MUTCD Code

4.2 Layout and Installation

All of the signs included in the basic sign farm design are intended to be installed at approximately the same time to ensure that all signs have the same installation date and therefore

can be easily compared. The signs will be installed at a height of five feet from the ground to the bottom of the sign, which is consistent with the MUTCD-specified height for rural roads as given in Figure 2A-1 of the MUTCD [FHWA, 2004].

The necessary spacing between the signs is based on the angle of the sun and the dimensions of the sign. This design requires that when the angle between the sun and the ground is 15° or greater, none of the signs, except those facing west when the sun is facing east, etc., will be covered by shadow. Since the height of the largest sign (Stop Ahead) is 4.25 ft, sign supports need to be spaced at least 16 feet from the nearest sign that could be casting a shadow.

In order to increase the sign support density in the sign farm, modules of 16 signs each were designed so that they minimize shadows cast from one sign to another and test four different sign orientations: north, south, east, and west. Figure 2 shows the design of a typical "module" of 16 signs. Each sign when it is installed will have a label on the front of its support with its assigned sign inventory number to aid in data collection. The signs will also be marked on their back face with their sign inventory number, the sign manufacturing date, and the sign installation date.

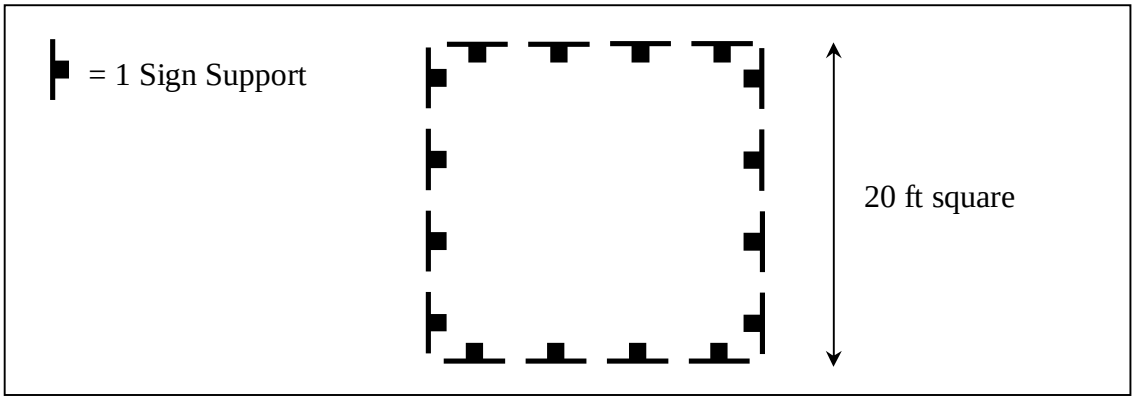

Figure 2. Layout of Sign Module

The basic sign layout, as shown in Figure 3, will consist of four modules per each of the three sheeting types, for a total of 12 modules. Per Table 2 the four modules per sheeting type consist of the following:

1. 16 Stop signs
2. 16 Stop Ahead signs
3. 16 Speed Limit signs
4. 16 Destination signs

A layout of the entire sign farm is shown in Figure 4. This layout includes an area for the basic, 12-module sign farm as well as 18 additional module locations for future sign farm expansion.

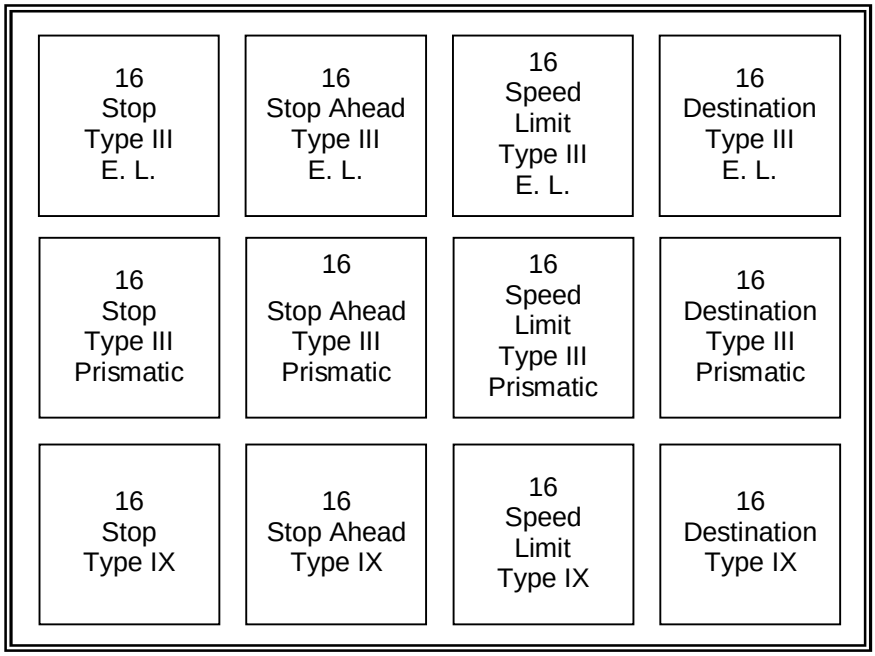

Figure 3. Basic 12 Module Sign Layout

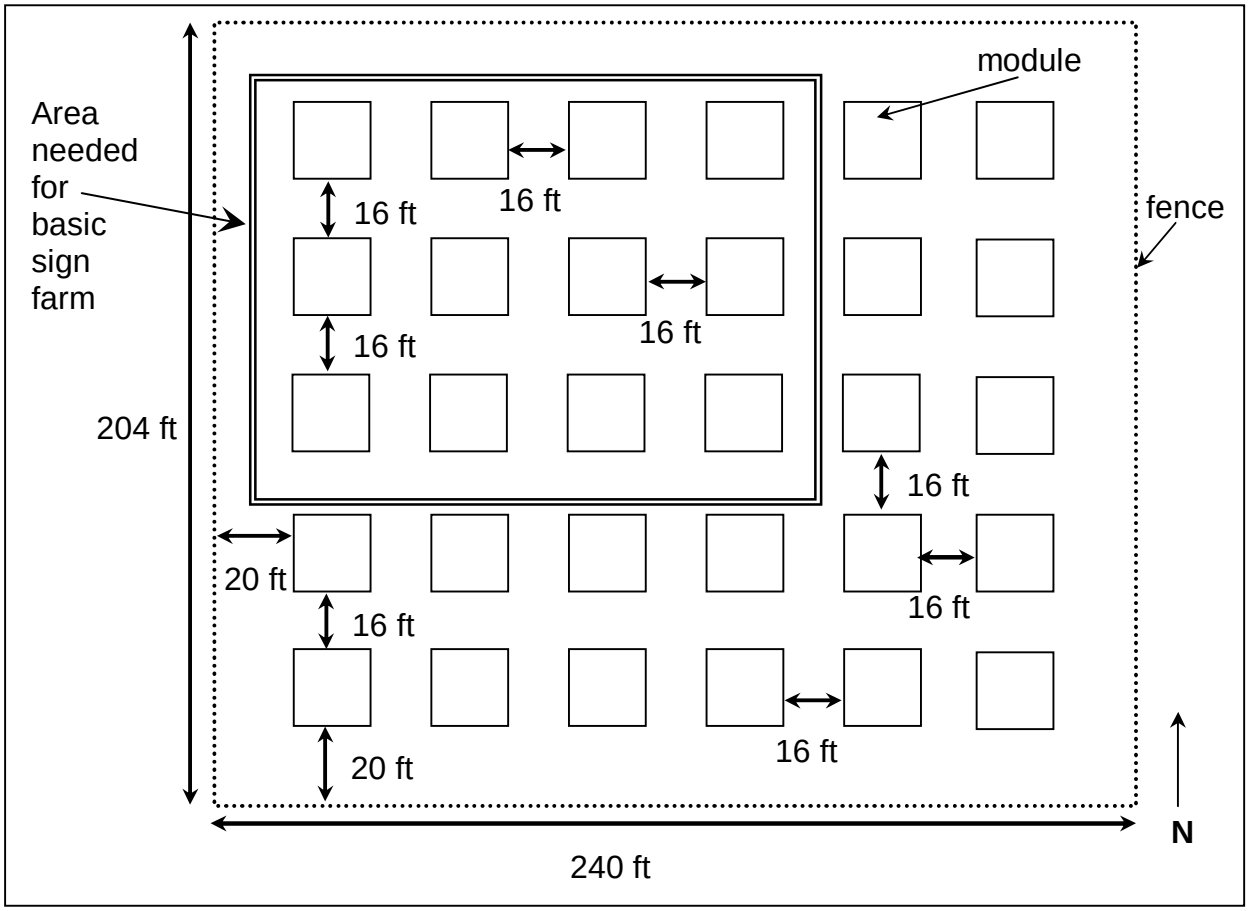

Figure 4. 30 Module Sign Farm Layout

Other layout arrangements of the modules, such as the checkerboard design shown in Figure 5, are also possible. The checkerboard design provides 15 module locations, which would include the basic 12-module sign farm as well as 3 additional module locations to test blue sheeting signs.

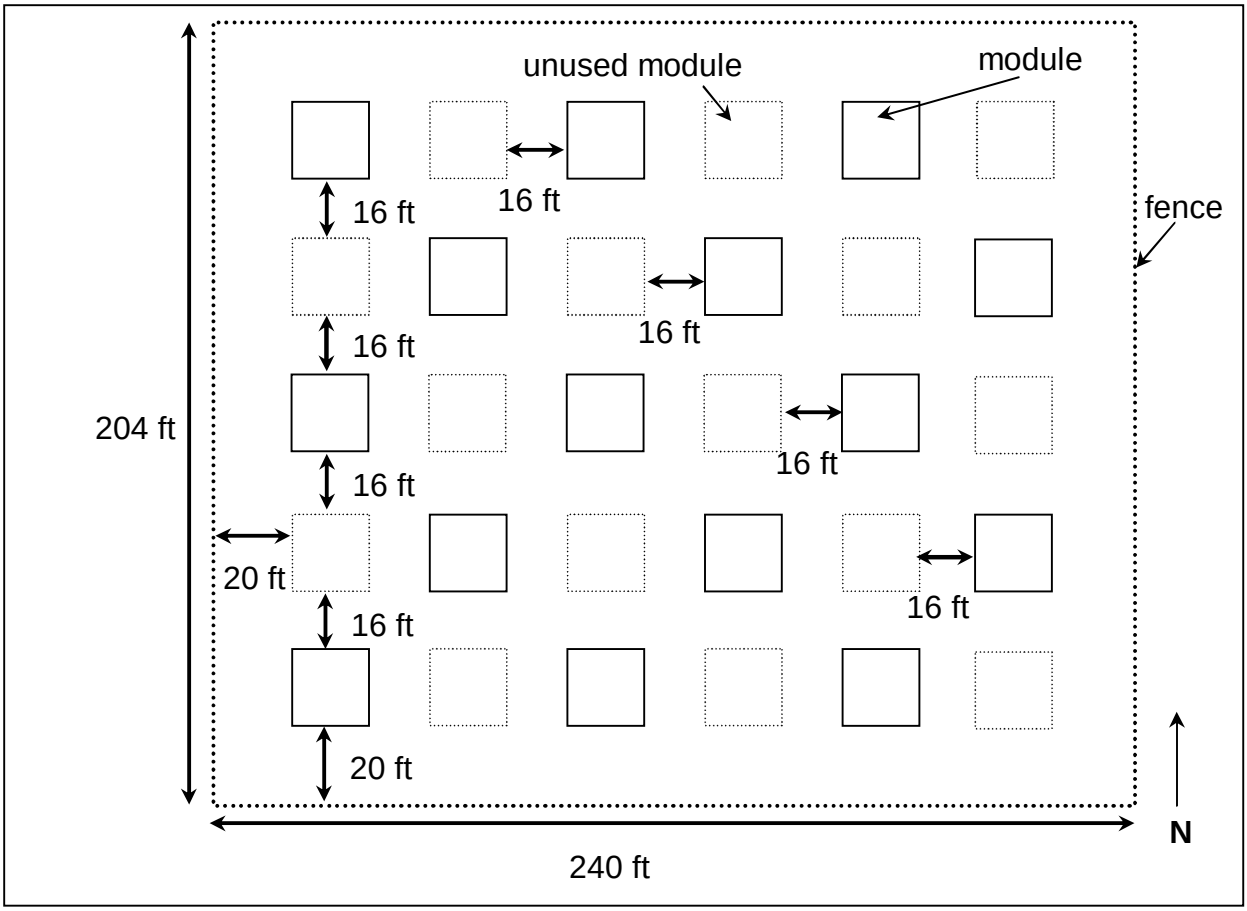

Figure 5. 15 Module Checkerboard Sign Farm Layout

The sign farm, with a module size of 20 ft square and a spacing of 16 ft between modules, will need a level area at least 204 ft by 240 ft, or 1.12 acres. This area should be as far as possible from surrounding trees and buildings and should have a gravel, bare dirt, or paved surface to limit vegetation (grass). This will reduce the cost to maintain the area and the chances of damage to the signs from maintenance operations.

A barbed-wire fence surrounds the sign farm in order to prevent vandalism to and theft of the signs. The fence should be no taller than 9 feet so that it does not cast any shadows on the signs and at least 7 feet high for protection. The sign farm should be in a secure area with limited access, such as inside of an NCDOT compound, and should not be easily visible to passersby in order to limit vandalism and theft. The fence should have a gate that is locked at all times. The gate can be located at any convenient location in the sign farm layout.

The sign farm layout can be implemented in one or more locations across NC. The first location should be in the greater Raleigh area because of this area's typical NC climate, ease of access, and likelihood of available space. If there are funds for additional sign farm locations, the second priority location would be near the coast, and the third priority location would be in the mountains. Near the coast there is greater exposure to salty air and the sun, while in the mountains the signs will be exposed to cold temperatures, snow, ice, and road salt. Wilmington and Asheville are likely locations for additional sign farms.

4.3 Selecting and Installing Signs

Signs to be installed in the sign farm should be selected from the usual sign supplier for NC, the Correction Enterprises Bunn Sign Shop. The signs selected should not be part of a special run, although the green guide signs and some of the Type III prismatic and Type IX prismatic sheeting signs may need to be specially manufactured because they are not manufactured on a regular basis by the sign shop. Additional signs can be ordered from the sign shop so there are replacements in case some signs are damaged during shipping or installation.

Once the signs arrive on site, they ought to be examined closely for any defects. The initial retroreflectivity of all signs is to be measured in four places and compared to the typical initial retroreflectivity value for the sheeting type and color. If the retroreflectivity at all four places is not within the typical initial range, then a replacement sign should be installed in place of the original sign. The replacement sign would need to meet the same initial retroreflectivity criterion. Four replacement signs should be ordered for every module in the sign farm (for a total of 16 + 4 = 20 signs for each sign/sheeting type combination). All of the signs selected for the sign farm should have a known manufacturing date, and both the manufacturing and installation dates for each sign should be recorded. A regular division sign crew using typical materials and tools should install the signs.

4.4 Retroreflectivity Measurement

Once the sign farm is installed, all signs should have their initial retroreflectivity measured in four locations using an observation angle of 0.2°, an entrance angle of -4.0°, and a rotational angle of 0°. The retroreflectivity values and the date they were measured should be recorded and entered into a database along with the sign inventory number, sign installation date, sign manufacture date, and sign attributes such as sign color, message, orientation, and sheeting type. Every year each sign should be measured in four locations for retroreflectivity using a calibrated retroreflectometer. The retroreflectivity values and the date should be entered into the database for each sign and color combination, since some signs are measured for two colors.

5.0 COST ESTIMATE

For the NCDOT sign farm design, the cost of Type III encapsulated lens, Type III prismatic, and Type IX prismatic sheeting signs has been obtained from the Bunn Sign Shop of Correction Enterprises. The cost of sign installation (materials and labor) was obtained from NCDOT Division 6. Table 3 lists the prices for each Type III encapsulated lens, Type III prismatic, and Type IX prismatic sheeting sign and its installation. Note that the cost of Type III encapsulated lens sheeting is the same as Type III prismatic.

Table 3. Cost of Signs and Installation (SI) for Sign Farm

Sign Message	Sign Color Background (legend)	SI Cost for Type III Encapsulated Lens Sheeting	SI Cost for Type III Prismatic Sheeting	SI Cost for Type IX Prismatic Sheeting	TOTAL
Stop	Red	$74.00	$74.00	$76.95	$4,499
Stop Ahead	Yellow (red)	$83.72	$83.72	$149.85	$6,418
Speed Limit	White	$76.81	$76.81	$96.78	$5,008
Destination Sign	Green	$139.05	$139.05	$194.83	$12,066
	TOTAL	$8,365	$8,365	$11,261	**$27,991**

The cost of the barbed-wire chain-link fence was estimated to be $20,000 using a fence cost estimating tool with a total fence length of 888 feet, one 12 ft gate, and a fence height of 8 feet. The installation cost, including the fence, gate, signs, and supports but excluding site preparation, is estimated to be $48,000. The NCDOT should not need to purchase an additional retroreflectometer for the sign farm. The NCDOT presently owns a RetroSign® 4500 retroreflectometer. The NCSU research team used this retroreflectometer. It was found to be in good working order. This instrument should be used for the sign farm measurements.

6.0 DESIGN VARIATIONS

Adding additional variables could change the basic sign farm design outlined in the previous sections. Blue signs could be incorporated into the design by adding one additional module per each of the three sign sheeting types. One blue sign that could be used because of its economical size is the Rest Area sign (MUTCD code D5-2a), shown in Figure 6. Adding the D5-2a sign to the basic three sheeting type sign farm design would cost an additional $8,850.

Figure 6. Rest Area, Yield, and Keep Right Signs

A greater variety of signs can be selected for each color, such as adding a module of yield signs (white and red color) or keep right signs (white) as shown in Figure 6. Additional sheeting types could be considered, such as the proposed Type XI sheeting (3M™ Diamond Grade™ DG3) and sheeting produced by other manufacturers, such as Avery Dennison®. The number of signs in each module as well as the number of modules can be modified to create a larger or smaller sample size. The layout of the modules can be modified to accommodate an unusually shaped

area or any other configuration. The sign farm design aims for flexibility in order to meet the research requirements of the NCDOT.

7.0 REFERENCES

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Federal Highway Administration (FHWA) (2004). "Manual on Uniform Traffic Control Devices 2003 Edition with Revision No. 1." FHWA, Washington, DC. Figure 2A-1.

Federal Highway Adminstration (FHWA) (2005). "FHWA Retroreflective Sheeting Identification Guide – September 2005." FHWA, Washington, DC. Accessed October 17, 2006 at http://safety.fhwa.dot.gov/roadway_dept/docs/retrore_sheet_id.pdf

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