Implementing North Carolina Department of Transportation Program for Maintenance Assessment and Funding Needs

Lacy D. Love and Timothy B. Baughman

The North Carolina Department of Transportation has developed and implemented a state highway maintenance assessment program. Without a method with which to assess the maintenance condition of the total system, the department's request for increased maintenance funding was based on the previous year's expenditures and an estimate of unmet needs. The unmet needs estimate was based on the professional opinion of field managers and engineers and not on actual measured quantities. A maintenance assessment program will provide a tool for tying funding levels to actual field conditions, identify inadequately maintained roadway features, and determine the funding levels needed to achieve a specific maintenance condition. A literature review was conducted, then a program framework was devised to collect roadway feature data, summarize the data collected, evaluate and interpret the results, and present the results. Then, a plan was established to determine the roadway features to be evaluated, determine survey methodology and data collection methods, determine how the condition of the features relates to department expenditures, and calculate a realistic budget to achieve an acceptable maintenance condition. By implementing a maintenance assessment program, the North Carolina Department of Transportation is taking the first step toward shifting from a reactive "fixing" mode to a proactive prevention mode. This should lead the way to greater customer satisfaction, effective use of resources, higher quality products and services, avoidance of rework, and empowerment of local managers and supervisors.

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For many years, the North Carolina Department of Transportation (NCDOT) has conducted surveys to assess the condition of pavements and bridges in the state. With information from the pavement condition survey and the bridge condition rating program, NCDOT identifies deficiencies in these assets and develops priorities and work plans to address maintenance needs. However, there was no system in place to evaluate the condition of roadside features, such as shoulders and ditches, drainage, brush and tree control, guardrails, traffic control devices, and turf condition.

Without a methodology for evaluating these features, the annual maintenance plan was based more on historical accomplishments than on actual needs of the highway system. A valid assessment of the condition of the roadside features could not be made. Maintenance work tended to be more reactive rather than proactive. Maintenance operations priorities were not based on objective data but were subject to historical accomplishments.

History of Maintenance Funding

North Carolina's highway system consists of 125 494 km (77,978 mi) of roadway. Since 1988, the number of lane kilometers has grown by 15 percent and the vehicle kilometers traveled has jumped by more than 47 percent. However, although the system and its use continue to grow, the funds necessary to maintain the system have not kept pace, as illustrated in Figure 1.

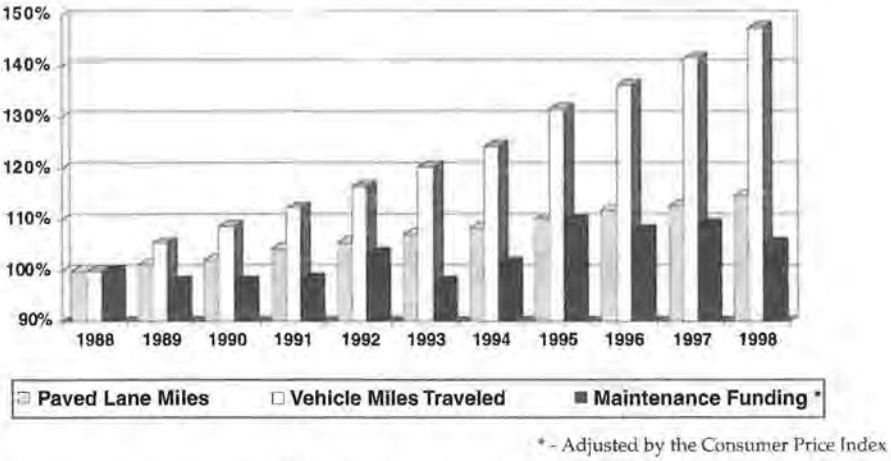


FIGURE 1 Growth of NCDOT highway system versus maintenance funding.

This growth has resulted in an increase in workload without a concurrent increase in funding. Although improving technology and more efficient operations have helped meet this greater demand, there continues to be a shortfall of maintenance funding. This shortfall has caused a backlog of work and a further deterioration in the condition of the highway system.

Obviously, insufficient funding of maintenance over time will lead to a highway system in poor condition. Previous funding increase requests have been unable to document the maintenance condition of the highway system or, if it is in poor condition, how severe the problem is. A methodology was needed to determine the condition of the state's bridge and roadway features and to estimate the cost for achieving a specific level of service.

Equally important to the determination of the system condition is the presentation of the information. The results of the maintenance assessment program must be communicated in a commonsense format that can be easily understood.

Maintenance Evaluation Strategy

In 1997, the North Carolina General Assembly passed legislation requiring NCDOT to survey the state highway system, determine the condition of the system, and develop funding needs for annual routine maintenance and the annual resurfacing program and for eliminating the maintenance backlog and the resurfacing backlog. This legislation requires the department to submit a report to the general assembly each even-numbered calendar year. The first report to the legislature was submitted in 1998, and although the next report was not due until November 2000, a second condition assessment was conducted in 1999.

NCDOT's intent goes beyond just satisfying a legislative requirement. The study also will relate funding levels to actual field conditions by providing clear links among maintenance objectives, maintenance activities, different levels of maintenance service, the maintenance budget, and actual maintenance conditions.

From this evaluation, it was expected that several objectives would be satisfied. First, the condition of the state highway system could be determined. Second, the maintenance condition is directly related to the level of funding. Third, based on the results of the survey, current funding levels were anticipated to be inadequate. Last, a strategy can be developed to calculate the amount of maintenance funding needed to achieve a predetermined level of service throughout the state.

This paper documents the procedures NCDOT used to develop a maintenance condition assessment program and how it conducted the maintenance survey program for determining the condition of roadside features. Illustrated is how this information is used, along with the pavement and bridge condition surveys, to document the overall condition of the state highway system and to estimate the cost to maintain it at an acceptable level. These results will enable NCDOT to identify features that have a low condition rating and to target funds to improve their condition. One of the goals of this effort is to shift to a proactive maintenance mode, allocating resources where needed, to provide uniform levels of service and greater customer satisfaction.

Maintenance Condition Assessment Program

As more emphasis is placed on the condition of the highway infrastructure, there is an increase in the focus of maintenance, resulting in increased workloads and greater maintenance demands. However, limited maintenance

funds and even public perceptions of maintenance departments have created the need for developing quality assurance programs in the maintenance of highways. Quality assurance in highway maintenance has been described as the planned and systematic actions needed to meet the needs and expectations of the user. Building off the successes of current quality assurance programs in other states (such as Washington, Florida, and Virginia) and NCHRP Project 14-12 (*1–4*), a program was developed to implement similar management practices for NCDOT. The program is expected to accomplish the following objectives:

- Predict the funding level needed to achieve an acceptable level of maintenance;
- Relate additional funding to improved maintenance conditions;
- Develop a priority strategy to direct maintenance operations when funding levels are less than the calculated needs;
- Achieve a uniform level of service throughout the state;
- Identify areas requiring additional employee skills and equipment to accomplish tasks or the shifting of employees from one feature responsibility to another; and
- Validate that the condition of the highway system is directly related to the finding level, and demonstrate that when funding levels are inadequate, the highway system's condition will suffer.

Meeting these objectives will enable NCDOT to shift from a "fixing" reactive mode to a proactive mode of prevention, thereby incurring the benefits associated with repairs that have a lower unit cost and that do not have to be repeated. Eventually, this should lead to better-maintained highways and greater levels of customer satisfaction.

The following sections describe the method used for collecting roadway maintenance information in order to determine the overall condition of highways in the state. With these data, funding levels can be generated to address maintenance needs and a strategy can be developed for prioritizing maintenance operations.

However, a quality assessment and assurance program must be based on good data. The first step in developing a maintenance assessment survey was to identify which features would be measured and how these relate to maintenance activities.

Maintenance Activity Expenditures and Functions

Highway maintenance is those work activities associated with the maintenance and upkeep of the roadway and bridge infrastructure. Work activities can be divided into two categories: recurring programs and performance-based activities. (Although the department's effort includes all bridge and roadway maintenance work activities, for the purpose of this paper only the roadway work activities will be covered.) For NCDOT, the roadway recurring programs consist of fixed-cost programs such as incident management, rest area and welcome center maintenance, traffic signal maintenance, roadway lighting maintenance, sign lighting costs, municipal agreements, plant bed maintenance, and unpaved road maintenance. Because of the importance of these activities, allocations are largely ensured and the funding needs for these programs are very predictable.

However, expenditures for performance-based activities are more variable and depend on historical expenditures and budget constraints. These activities include routine pavement maintenance, maintenance of shoulders and ditches, drainage, mowing, litter pickup, guardrail repair, signs, pavement markings, and vegetation control. The maintenance assessment program was developed to assess these performance-based activities.

Element Features and Conditions

To ensure meaningful results, performance-based activities accounting for 80 percent of the maintenance expenditures were identified. Although it was found that ditch and shoulder maintenance activities should be a component of the assessment program, because this work accounts for nearly 11 percent of highway maintenance expenditures, there was no need to include the maintenance of pipe underdrains, which amounts to less than 0.01 percent of expenditures.

After the significant performance-based activities were identified, an analysis was made to see if they could be linked to measurable roadway features. Those that could were grouped into similar categories of elements. For example, under the element *unpaved shoulders and ditches,* a significant amount of funds was expended on rebuilding low shoulders, cutting high shoulders, cleaning ditches, and repairing ditch erosion. Therefore, it was decided that for this element, the features that the maintenance assessment survey should detect and measure were low shoulders, high shoulders, blocked ditches, and eroded ditches.

Six major maintenance elements were identified for evaluation under the maintenance assessment survey: roadway pavement, unpaved shoulders and ditches, drainage, roadside, traffic control devices, and environmental. Except for roadway pavements, each of these elements has several features and characteristics that would be evaluated against certain threshold conditions.

Following identification of the features and elements to be surveyed, the next task was to determine the threshold level at which a condition would be noted and measured. It was decided that this threshold value would be related to the point at which work ordinarily would be directed to correct the condition. For example, although a 2.5-cm (1-in.) drop-off adjacent to the pavement is a low shoulder, a maintenance crew would not be scheduled to repair the shoulder. However, a 5-cm (2-in.) drop-off would trigger corrective action and would be noted and measured. A threshold level was established for each element's feature to be identified during the maintenance assessment survey. The maintenance features and their threshold conditions are shown in Table 1. Pavements were evaluated by using NCDOT pavement rating systems already in place.

For each element feature to be surveyed, detailed descriptions of the threshold condition were developed. These are provided in Figures 2 through 6.

Conducting Survey

Because surveying the entire highway network would be an overwhelming task, a statistical sampling was made to determine the number of sites to be surveyed. With a confidence level of 95 percent and an accuracy of ±6 percent, a target sample size was calculated that would be indicative of the state's highways. Calculations were made for each of the four highway systems (Interstate, primary, urban, and secondary), and approximately 1,000 sites were randomly selected statewide for inspection, as shown in Table 2. To further expedite the survey, a team from each of NCDOT's 14 divisions was assigned the duty of collecting the field data for the primary, urban, and secondary sites. Teams from the State Pavement Management Office were given responsibility for surveying all Interstate sites.

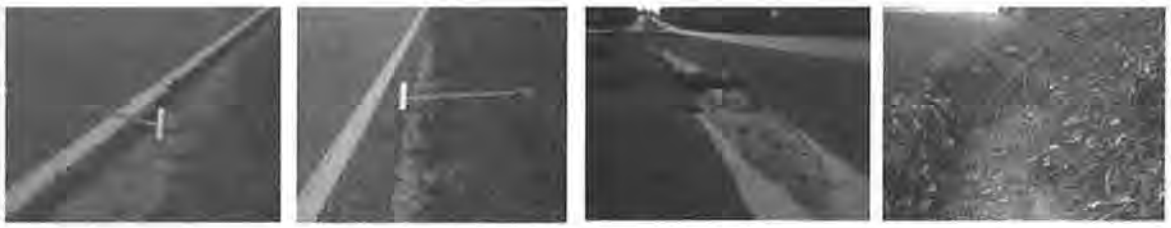
Each site consisted of a 0.3-km (0.2-mi) section. The surveys were done on foot, and the teams made several passes to adequately assess all the features. Because the information collected must be uniform and consistent, training sessions were held for the inspection teams. During training, the process and procedures were described, the elements and features were reviewed, and safety issues were discussed. Then, to ensure consistency, the teams evaluated test sections and compared their findings.

Before beginning the survey at each site, the teams marked on the pavement the beginning and ending points of the survey and the site number. Thus, the segment could

TABLE 1 Maintenance Element Features and Threshold Conditions

Element	Feature	Threshold Condition
Roadway Pavement	Flexible Pavement	*NCDOT Pavement Condition Survey*
	Rigid Pavement	*NCDOT Rigid Pavement Rating System*
Unpaved Shoulders and Ditches	Low Shoulder	Low ≥ 2 inches
	High Shoulder	High ≥ 1 inch
	Lateral Ditches	Blocked ≥ 50% and Not Functioning as designed
	Lateral Ditch Erosion	Eroded ≥ 1 ft
Drainage	Crossline Pipe	Blocked ≥ 50%, or Damaged
	Driveway Pipe	Blocked > 50%, or Damaged
	Curb & Gutter	Blocked ≥ 2 in x 2 ft, or Damaged
	Catch Basin & Drop Inlet	Blocked ≥ 25%, Damaged, or Grate Problem
	Other Drainage Features	Not Functioning as designed
Roadside	Mowing	Average Grass Height
	Brush and Tree Control	Within 15' above, 10' back of ditch/shoulder
	Litter & Debris	Number of Pieces ≥ Fist-Sized
	Slope	Failures ≥ 1ft wide
	Guardrail	Damaged, or Not Functioning as designed
Traffic Control Devices	Traffic Signs	Illegible, Missing, or Obliterated
	Pavement Striping	Worn, Missing, or Obliterated
	Words and Symbols	Damaged or Missing
	Pavement Markers	Worn, Missing, or Obliterated
Environmental	Turf Condition	Bare, Dead, Diseased, Distressed, or Weedy
	Misc. Vegetation Management	Uncontrolled Growth at Signs or Guardrail

1 ft = 0.305 m; 1 in. = 25.4 mm.



Low Shoulders	High Shoulders	Lateral Ditches	Lateral Ditch Erosion
Threshold Condition Low ≥ 2 inches.	*Threshold Condition* High ≥ 1 inch.	*Threshold Condition* Blocked ≥ 50% and not functioning properly.	*Threshold Condition* Eroded ≥ 1 ft.
Total Segment Inventory Total shoulder length in the segment.	*Total Segment Inventory* Same as Low Shoulder inventory.	*Total Segment Inventory* Total ditch length in the segment.	*Total Segment Inventory* Same as Lateral Ditches inventory
Measured Amount Sum of longitudinal lengths of low shoulder.	*Measured Amount* Sum of longitudinal lengths of low shoulder.	*Measured Amount* Sum of longitudinal lengths of blocked ditch that are not functioning properly.	*Measured Amount* Sum of longitudinal lengths of eroded ditch.
Special Instructions Adjust shoulder inventory where unpaved shoulder does not exist (due to curb and gutter, median barrier, etc.).	*Special Instructions* See special instructions for Low Shoulders	*Special Instructions* Outfall ditches will not be rated. Do not deduct ordinary driveway pipe from inventory. Deduct closed systems and side-road crossline pipe from inventory.	*Special Instructions* See special instructions for Lateral Ditches.

FIGURE 2 Unpaved shoulders and ditches (1 in. = 25.4 mm; 1 ft = 0.305 m).

be revisited if there were problems or concerns with the data that had been collected.

Some randomly selected sites were not surveyed. Sites that fell within a road project under construction or were in an interchange area and sites where a portion of the road segment included a long bridge structure were not surveyed.

Reporting Survey Data

As the inspection teams walked each site, they recorded the field conditions on a form created for the purpose (Figure 7). The completed forms were faxed to the State Roadway Maintenance Unit, where the information was entered into a database.

Crossline Pipe	Driveway Pipe	Curb & Gutter	Catch Basins & Drop Inlets	Other Drainage Features
Threshold Condition Blocked ≥ 50%, or damaged.	*Threshold Condition* Blocked ≥ 50%, or damaged.	*Threshold Condition* Blocked 2 in. x 2 ft., or damaged.	*Threshold Condition* Blocked ≥ 25%, structure damage, or missing or damaged grates.	*Threshold Condition* Not functioning as designed.
Total Segment Inventory Number of crossline pipes in the segment.	*Total Segment Inventory* Number of driveway pipes in the segment.	*Total Segment Inventory* Total length of curb and gutter in the segment.	*Total Segment Inventory* Number of catch basins and drop inlets in the segment.	*Total Segment Inventory* Number of other drainage features in the segment.
Measured Amount Number of blocked or damaged crossline pipes.	*Measured Amount* Number of blocked or damaged driveway pipes.	*Measured Amount* Sum of longitudinal lengths of blocked or damaged curb and gutter.	*Measured Amount* Number of catch basins or drop inlets that are blocked, damaged, or have missing or damaged grates.	*Measured Amount* Number of other drainage features not functioning as designed.
Special Instructions Only pipes 48 inches or less will be evaluated. Lateral pipes that are side-road crossline pipes will be evaluated as a crossline pipe.	*Special Instructions* See Special Instructions for Crossline Pipe.	*Special Instructions* Only blockage that creates a diversion of water flow is to be recorded.	*Special Instructions* None	*Special Instructions* Where two drainage features are working together as a system, count them a single occurrence.

FIGURE 3 Drainage (1 in. = 25.4 mm; 1 ft = 0.305 m).

Mowing	Brush and Tree Control	Litter & Debris	Slope	Guardrail
Threshold Condition Determine the average height of the grass in the area.	*Threshold Condition* Brush and trees within 15 feet above the road, and 10 feet back of ditch or shoulder point.	*Threshold Condition* Note litter or debris that is fist-sized or larger.	*Threshold Condition* Slope failures should be noted whenever a washout or ruts ≥ 1 ft.	*Threshold Condition* Not functioning as designed, or damaged.
Total Segment Inventory There will be no inventory of mowing.	*Total Segment Inventory* The total length of forested area in the segment.	*Total Segment Inventory* There will be no inventory of litter and debris.	*Total Segment Inventory* The total length of outside slope in the segment.	*Total Segment Inventory* The total length of guardrail in the segment.
Measured Amount Record the average height on the survey form.	*Measured Amount* Sum of longitudinal distances where the brush and tree control zone is not clear.	*Measured Amount* Record the number of pieces of litter that are fist-sized or larger.	*Measured Amount* Sum of longitudinal lengths of eroded slope.	*Measured Amount* Sum of longitudinal length of guardrail that is not functioning as designed or has been damaged.
Special Instructions Ignore any residential mowing.	*Special Instructions* Note brush and trees that a tractor mower cannot mow, and trees beyond the control zone but still a safety concern. An exception is brush and trees that will not be removed due to public sensitivity.	*Special Instructions* If the test section has more than 200 pieces of litter, stop the count.	*Special Instructions* Measure the greatest longitudinal width of the failure during the survey.	*Special Instructions* Do not record barrier that is an old design, is only slightly damaged and still functions as designed, or is just aesthetically unpleasing.

FIGURE 4 Roadside (1 ft = 0.305 m).

Traffic Signs	Pavement Striping	Words and Symbols	Pavement Markers
Threshold Condition Note signs that are illegible, missing, or obliterated.	*Threshold Condition* Note pavement striping that is worn, missing, or obliterated.	*Threshold Condition* Note words or symbols that are worn, missing, or obliterated.	*Threshold Condition* Note pavement markers that are damaged or missing.
Total Segment Inventory The total number of traffic signs in the segment.	*Total Segment Inventory* The total length of pavement striping in the segment.	*Total Segment Inventory* The total number of word and symbol markings in the segment.	*Total Segment Inventory* The total number of pavement markers that should be in the segment.
Measured Amount Number of illegible, missing, or obliterated signs	*Measured Amount* Sum of longitudinal lengths of worn, missing or obliterated center lines, edge lines, or lane lines.	*Measured Amount* Number of words or symbols worn, missing, or obliterated.	*Measured Amount* Number of pavement markers damaged or missing.
Special Instructions Do not rate overhead signs on structures, street name signs, historic marker signs, and non-DOT signs.	*Special Instructions* Only the marking is to be measured, not the unpainted gap.	*Special Instructions* None	*Special Instructions* If pavement markers have not been installed in the segment both the Inventory and the Measured Amount will be zero.

FIGURE 5 Traffic control devices.

Turf Condition	Misc. Vegetation Management
Threshold Condition Note areas of bare, dead, diseased, distressed, or weedy turf.	*Threshold Condition* Note areas of uncontrolled vegetation growth around guardrail and signs.
Total Segment Inventory Total roadside length in the segment.	*Total Segment Inventory* The longitudinal length of all guardrail and traffic sign installations.
Measured Amount Sum of longitudinal lengths (parallel to the roadway) of poor turf growth.	*Measured Amount* Sum of longitudinal lengths of uncontrolled vegetation growth around the guardrail or signs.
Special Instructions Only the condition of turf within the normal mowing limits will be evaluated.	*Special Instructions* Use a length of 2 feet for each sign installation.

FIGURE 6 Environmental (1 ft = 0.305 m).

Besides recording the amount of each feature that exceeded the threshold condition, the teams measured the inventory of certain features existing in the section. This was necessary because a complete statewide inventory does not exist for all the features that were being surveyed. The findings from the inventory made during the maintenance survey help to estimate the statewide quantity of the various features. For example, the number of driveway pipes found within the various surveyed sites was used to estimate the total number of driveway pipes in the statewide system.

From the survey data a number could be calculated that represented the percent of each feature that exceeded the threshold condition listed in Table 1. This was done for all sites surveyed for each of the four highway systems. On the basis of the predetermined target sample size and an analysis of the results, the department was confident that the aggregate of all the sample sites represented the condition of the statewide system.

Maintenance Funding Needs

A detailed survey was conducted through the Maintenance Condition Assessment Program and the pavement condition survey to assess the condition of roadway features. These features were categorized into the previously identified six major elements. The photographs in Figure 8 illustrate some of the features recorded during the survey. For each of the four highway systems, the deficient conditions were recorded and summarized.

Level of Service

To effectively evaluate the condition of the state highway system, it was necessary to establish commonsense definitions for different levels of services, ones that could be easily understood and clearly linked to outcome performance measures. A five-level grading system was used, similar to those used in the Washington State Department of Transportation's Maintenance Accountability Process (*1*).

Level of Service A (Best)

In Level A, the roadway, bridges, and associated features are in excellent condition. Very few deficiencies are present, all systems are operational, and the overall appearance is pleasing. Preventive maintenance is a high priority in all maintenance activities.

Level of Service B (Good)

Level B is a high level of service in which the roadway, bridges, and associated features are in good condition. Very few deficiencies are present in safety and investment protection, but moderate deficiencies exist in other areas. All systems are operational. Preventive maintenance is a high priority for safety-related activities but is deferred for other areas, resulting in additional corrective maintenance activities.

Level of Service C (Fair)

In Level C, the roadway, bridges, and associated features are in fair condition. Very few deficiencies are present in safety-related activities, but moderate deficiencies exist for investment protection, and there are significant aesthetics-related deficiencies. Preventive maintenance

TABLE 2 Sample Size Requirements

	Mileage	Population Units	Number of Samples
Interstate	816	4,080	250
Primary	11,110	55,550	266
Urban	6,127	30,635	264
Secondary	48,534	242,670	267
		Total Sample Size	**1,047**

1 mi = 1.6 km.

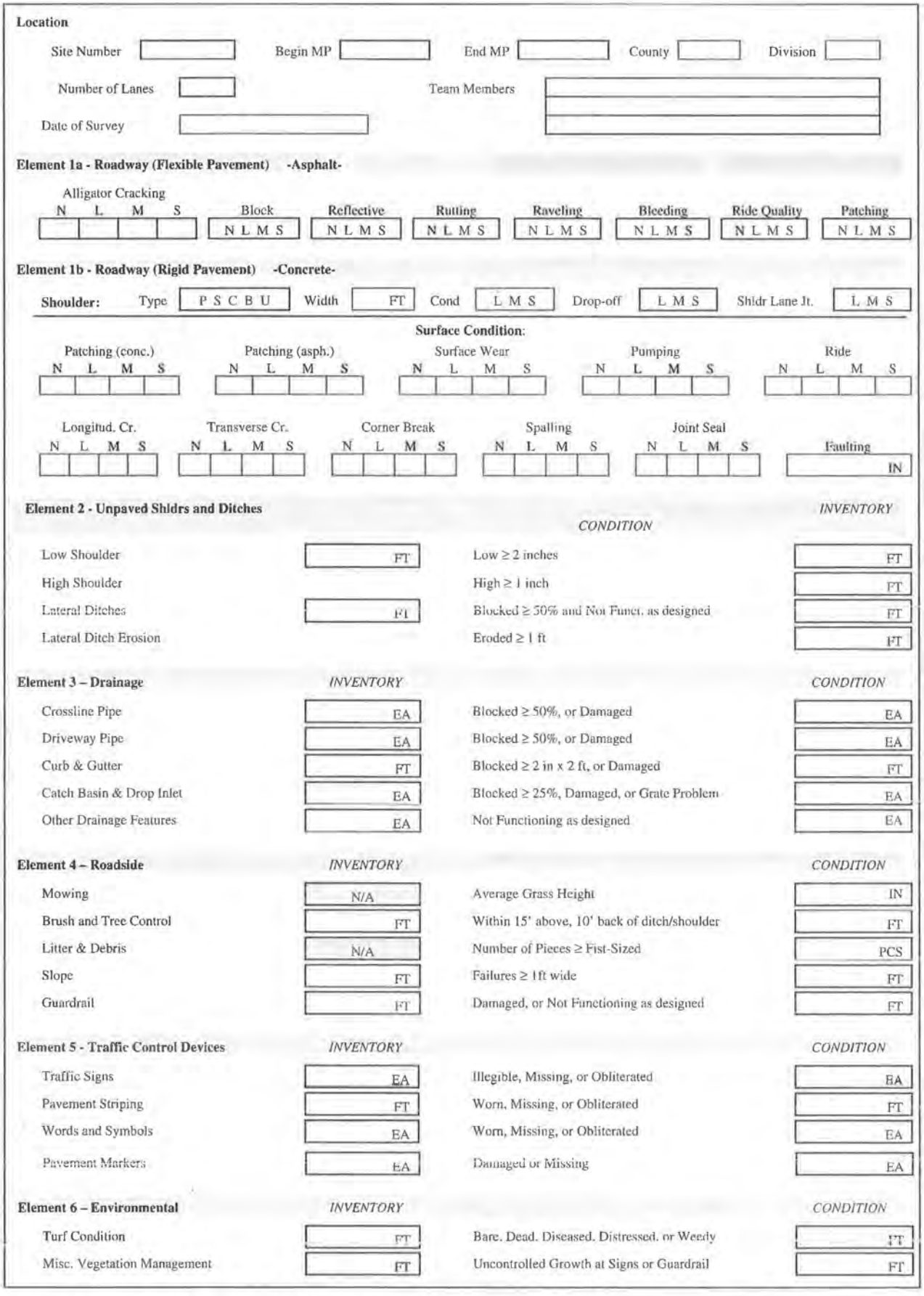


FIGURE 7 Inventory form (1 in. = 25.4 mm; 1 ft = 0.305 m).

FIGURE 8 Examples of recorded features.

is deferred for many activities except safety-related work. Corrective maintenance is routinely practiced for all activities. A backlog of deficiencies is building and will have to be dealt with eventually, at a higher cost. Some roadway structural problems begin to appear because of long-term deterioration of the system. There is a noticeable decrease in appearance, and systems may occasionally be inoperable.

Level of Service D (Poor)

Level D is a low-maintenance service level in which the roadway, bridges, and associated features are kept in generally poor condition. Moderate deficiencies are present in safety-related activities, and there are significant deficiencies for all other activities. Very little preventive maintenance is accomplished; maintenance is reactive and places emphasis on correcting problems as they occur. A significant backlog of deficiencies will build up. Safety problems begin to appear that increase risk and liability, and significant structural deficiencies exist that accelerate the long-term deterioration of the system. The overall appearance of the system is very poor. System failures occur regularly because it is impossible to react in a timely manner to all problems.

Level of Service F (Worst)

Level F is a very low service level in which the roadway, bridges, and associated features are kept in poor and failing condition. Significant deficiencies are present in all maintenance activities. The overall appearance is not aesthetically pleasing. Preventive maintenance is not practiced for any maintenance activities. Maintenance is totally reactive and places emphasis on correcting problems as they occur. Significant backlogs of maintenance deficiencies exist. Excessive safety problems occur. A backlog of system failures occurs because it is impossible to react in a timely manner to all problems.

Acceptable Levels of Service

Obviously, it would be desirable for the entire highway system to be maintained at Level A. However, it would be impractical, if not impossible, to achieve this level of service for all highways. On the other hand, there are valid reasons for some of the features to be maintained at a high level of service, especially those features associated with safety, such as guardrails. Other features, such as pavement striping, low shoulders, raised pavement markers, and pavements, are safety items as well and should be maintained at a high level. The lower the level of service of these features, the poorer the condition and the greater the potential for accidents.

To relate the five levels of service to performance standards and condition ratings, extensive research was conducted of the procedures used in other state departments of transportation. A work session was held with field representatives from each of NCDOT's 14 divisions to provide input based on their knowledge of the highway system and its maintenance condition. Baselining what other agencies have done and using input from the professional staff, various levels of service were established for each maintenance feature. An example of the performance measure for the primary highway system is provided in Figure 9.

ELEMENT 1 Roadway Pavement			Service Level					Acceptable Level of Service
			A	B	C	D	F	
Activities	Condition Indicators	Performance Measures	Threshold	Threshold	Threshold	Threshold	Threshold	
Pavement Maintenance	Pavement Condition Rating	PCR	98	93	86	70	<70	C

ELEMENT 2 Unpaved Shoulders and Ditches			Service Level					Acceptable Level of Service
			A	B	C	D	F	
Activities	Condition Indicators	Performance Measures	Threshold	Threshold	Threshold	Threshold	Threshold	
Low Shoulder	Low ≥ 2 inches	FT	1%	5%	8%	11%	>11%	C
High Shoulder	High ≥ 2 inches	FT	1%	4%	6%	10%	>10%	C
Lateral Ditches	Blocked ≥ 50% & not funct. as designed	FT	2%	6%	9%	12%	>12%	C
Lateral Ditch Erosion	Eroded ≥ 1 ft	FT	1%	2%	3%	4%	> 4%	A

ELEMENT 3 Drainage			Service Level					Acceptable Level of Service
			A	B	C	D	F	
Activities	Condition Indicators	Performance Measures	Threshold	Threshold	Threshold	Threshold	Threshold	
Crossline Pipe	Blocked ≥ 50% , or Damaged	EA	2%	7%	11%	15%	> 15%	C
Driveway Pipe	Blocked ≥ 50% , or Damaged	EA	10%	15%	25%	35%	> 35%	C
Curb & Gutter	Blocked ≥ 2 in x 2 ft, or Damaged	FT	2%	5%	7%	11%	> 11%	C
Catch Basin & Drop Inlet	Blocked ≥ 25% , Damaged, or Grate Problem	EA	2%	5%	8%	12%	> 12%	C
Other Drainage Features	Not Functioning as designed	EA	2%	6%	9%	12%	>12%	C

ELEMENT 4 Roadside			Service Level					Acceptable Level of Service
			A	B	C	D	F	
Activities	Condition Indicators	Performance Measures	Threshold	Threshold	Threshold	Threshold	Threshold	
Mowing	Average Grass Height	IN	6	8	10	14	> 14	C
Brush & Tree Control	Within 15' above, 10' back of ditch/shoulder	FT	5%	10%	15%	25%	> 25%	C
Litter & Debris	Number of Pieces ≥ Fist-Sized	PCS	30	60	120	200	> 200	C
Slope	Failures ≥ 1 ft wide	FT	1%	3%	5%	7%	> 7%	B
Guardrail	Damaged, or Not Functioning as designed	FT	1%	3%	5%	7%	> 7%	A

ELEMENT 5 Traffic Control Devices			Service Level					Acceptable Level of Service
			A	B	C	D	F	
Activities	Condition Indicators	Performance Measures	Threshold	Threshold	Threshold	Threshold	Threshold	
Traffic Signs	Illegible, Missing, or Obliterated	EA	1%	3%	6%	8%	> 8%	C
Pavement Striping	Worn, Missing, or Obliterated	FT	2%	5%	8%	11%	>11%	C
Words & Symbols	Worn, Missing, or Obliterated	EA	1%	4%	8%	11%	>11%	C
Pavement Markers	Damaged or Missing	EA	5%	10%	15%	20%	>20%	B

ELEMENT 6 Environmental			Service Level					Acceptable Level of Service
			A	B	C	D	F	
Activities	Condition Indicators	Performance Measures	Threshold	Threshold	Threshold	Threshold	Threshold	
Turf Condition	Bare, Dead, Diseased, Distressed, or Weedy	FT	3%	7%	11%	15%	> 15%	C
Misc. Vegetation Mgmt.	Uncontrolled Growth at Signs or Guardrail	FT	5%	10%	15%	25%	> 25%	C

FIGURE 9 Primary highway system maintenance performance measures (1 in. = 25.4 mm; 1 ft = 0.305 m).

Survey Findings

The results of the 1998 survey were compared with minimum acceptable levels. One level of analysis determined the extent to which each feature exceeded the previous defined threshold values from Table 1. Figure 10 provides a graphical representation of the results of the primary highway system. Another assessment compared the survey findings with the previously identified levels of service (Figure 9) to determine the average service level for each feature. An example of this comparison is shown in Figure 11, which illustrates the average statewide level of service by maintenance activity on the primary highway system.

The level of service figures generated from the statewide 1998 maintenance assessment survey illustrated that a few activities were being maintained at an acceptable level. However, many activities were being maintained at a poor D or unacceptable F level of service because of a lack of funds. Also, as was mentioned, some features must be

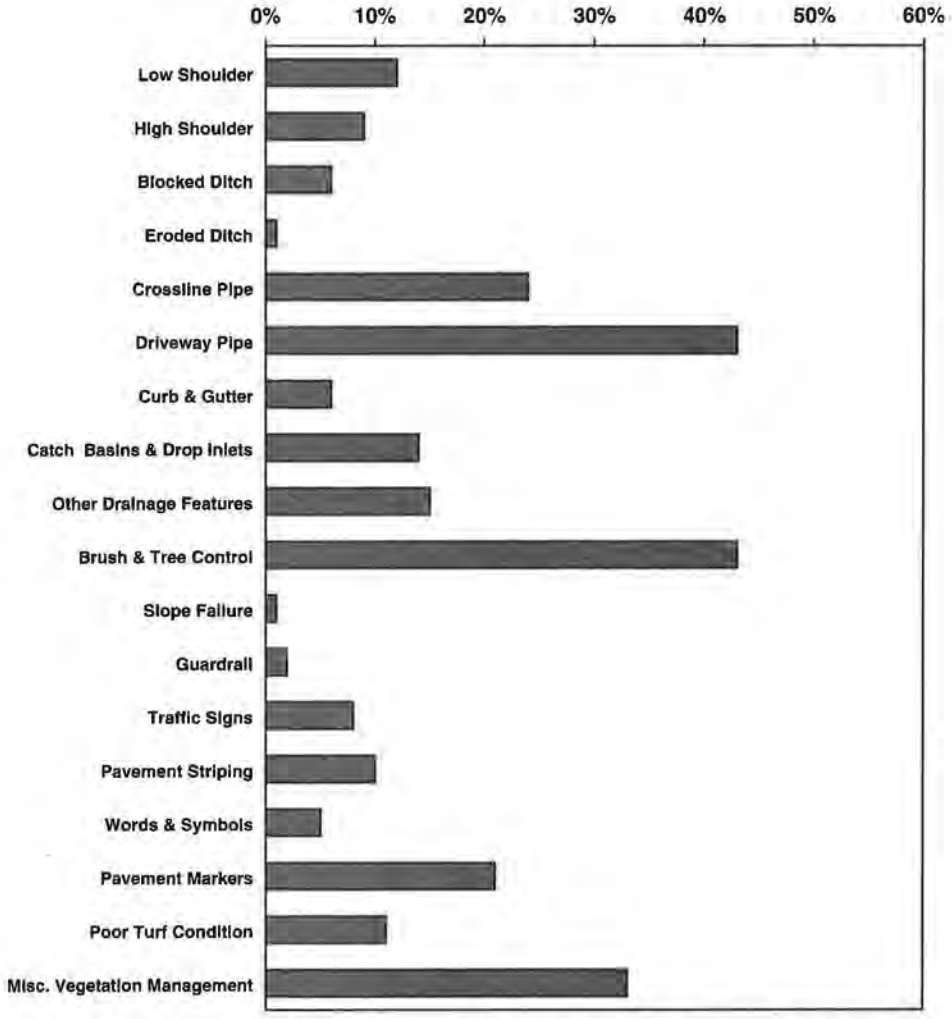


FIGURE 10 Percentage of features exceeding threshold value for primary highway system, 1998 survey.

maintained at a high level of service because of safety concerns and considerations.

A main objective of the study was to estimate the funding required to maintain the state system of highways at an acceptable level. For each highway system (Interstate, primary, urban, secondary), funding levels were estimated to achieve the various levels of service. An example is shown in Figure 12, where the required maintenance funding is given (for all features of the primary system) to meet the various service levels. These costs were generated for all features in each highway system. After comparing the actual feature service level with the acceptable level of service, the cost to meet the acceptable level could be determined. Table 3 is a summary of the costs estimated to achieve a statewide acceptable level of service for all four highway systems.

With data from the 1998 survey, it was estimated that it would cost $316.8 million to fund the performance-based activities in order to provide an acceptable level of service. It should be noted that the survey was conducted statewide and the results cannot be applied specifically to a county, district, or division area.

RECOMMENDATIONS

An analysis of the condition of the highway system was made by using the maintenance condition assessment program. From this, the maintenance activities necessary to achieve the various levels of service were determined, along with their estimated costs. To provide the citizens of North Carolina with a safe and uniformly maintained highway system, cost estimates were itemized, reflecting

Maintenance Activity	LOS A	LOS B	LOS C	LOS D	LOS F
Roadway Pavement					
Pavement			✪	❐	
Unpaved Shoulders and Ditches					
Low Shoulder			✪		❐
High Shoulder			✪	❐	
Lateral Ditches			❐ ✪		
Lateral Ditch Erosion	✪ ❐				
Drainage					
Crossline Pipe			✪		❐
Driveway Pipe			✪		❐
Curb & Gutter			❐ ✪		
Catch Basin & Drop Inlet			✪		❐
Other Drainage Features			✪		❐
Roadside					
Mowing			✪❐		
Brush and Tree Control			✪		❐
Litter & Debris			✪	❐	
Slope		❐ ✪			
Guardrail	✪	❐			
Traffic Control Devices					
Traffic Signs			✪	❐	
Pavement Striping			✪	❐	
Words and Symbols			❐ ✪		
Pavement Markers		✪			❐
Environmental					
Turf Condition			✪	❐	
Misc. Vegetation Management			✪		❐

✪ - Acceptable Service Level ❐ - Average Feature Service Level

FIGURE 11 Maintenance levels of service for primary highway system.

a need to achieve at least a C level of service. However, some of the cost estimates reflected a higher level of service because of safety concerns and considerations.

On the basis of these service levels, NCDOT developed a statewide annual maintenance funding plan, shown in Table 4. This plan not only would allow the establishment of a sound maintenance program that would provide an acceptable level of service but also address the backlog of maintenance needs that has been building over the years.

By adding all the other maintenance programs and obligations, such as statewide programs, disasters and emergencies, routine bridge maintenance programs, contract resurfacing, and contract resurfacing backlog costs, to the $316.8 million shown in Table 3, NCDOT estimated that its total highway maintenance budget should be approximately $705 million for the 1999–2000 fiscal year. In contrast, the department's budget for the previous year was $462 million, some $243 million shy of the mark.

Summary and Conclusions

To evaluate the condition of the state highway system in North Carolina, a maintenance assessment program has been developed and implemented by NCDOT. Several objectives were satisfied, including the following:

- The condition of the state highway system has been measured and assessed.
- A framework that links work activity expenditures to actual highway feature condition has been developed.
- The funds necessary to maintain the system at various service levels has been calculated.
- The funds necessary to maintain the system at an acceptable level has been computed.
- Highway features that failed to meet the acceptable maintenance condition have been identified.
- A methodology has been established to validate that the condition of the highway system is directly related to the funding level and to demonstrate that when funding levels are inadequate, the highway system's condition will suffer.
- Attention has been brought to the condition of the highway system and the need to adequately fund maintenance activities.
- A mechanism by which to communicate clearly to the state legislature the condition and funding needs of the highway system has been developed.

Primary Highway System				
Maintenance Activity	**Total Cost Level of Service A**	**Total Cost Level of Service B**	**Total Cost Level of Service C**	**Total Cost Level of Service D**
Pavements				
Subtotal	$ 25,893,549	$ 22,436,529	$ 18,020,129	$ 13,543,829
Shoulders & Ditches				
Low Shoulder	$ 8,587,321	$ 7,639,441	$ 6,928,531	$ 6,217,621
High Shoulder	$ 7,638,892	$ 6,927,982	$ 6,454,042	$ 5,506,162
Lateral Ditches	$ 4,777,563	$ 3,066,043	$ 1,782,403	$ 498,763
Lateral Ditch Erosion	$ 99,491	$ 60,340	$ 35,373	$ 16,825
Subtotal	$ 21,103,268	$ 17,693,807	$ 15,200,350	$ 12,239,371
Drainage				
Crossline Pipe	$ 6,244,931	$ 5,801,025	$ 5,445,900	$ 5,090,775
Driveway Pipe	$ 3,685,529	$ 3,309,449	$ 2,557,289	$ 1,805,129
Curb & Gutter	$ 178,125	$ 149,505	$ 130,425	$ 92,265
Catch Basins & Drop Inlets	$ 1,388,319	$ 1,267,884	$ 1,147,449	$ 986,869
Other Drainage Features	$ 2,704,330	$ 2,130,830	$ 1,700,705	$ 1,270,580
Subtotal	$ 14,201,234	$ 12,658,692	$ 10,981,767	$ 9,245,617
Roadside				
Mowing	$ 12,253,786	$ 10,252,726	$ 6,250,606	$ 4,249,546
Brush & Tree Control	$ 4,433,780	$ 4,324,625	$ 4,215,470	$ 3,997,160
Litter & Debris	$ 6,546,137	$ 4,364,091	$ 2,909,394	$ 1,454,697
Slope Failure	$ 409,897	$ 343,285	$ 295,875	$ 262,475
Guardrail	$ 1,676,807	$ 680,449	$ 515,489	$ 390,779
Subtotal	$ 25,320,406	$ 19,965,176	$ 14,186,834	$ 11,960,139
Traffic Control Devices				
Traffic Signs	$ 9,792,386	$ 8,692,386	$ 7,042,386	$ 5,942,386
Pavement Striping	$ 5,262,479	$ 4,311,671	$ 3,360,863	$ 2,410,055
Words & Symbols	$ 935,804	$ 709,495	$ 407,749	$ 181,439
Pavement Markers	$ 1,316,865	$ 1,154,378	$ 991,891	$ 829,404
Subtotal	$ 17,307,534	$ 14,867,930	$ 11,802,889	$ 9,363,285
Environmental				
Turf Condition	$ 5,613,590	$ 3,701,430	$ 1,789,270	$ 1,469,270
Misc. Vegetation Management	$ 1,188,344	$ 1,114,744	$ 1,041,144	$ 893,944
Subtotal	$ 6,801,934	$ 4,816,174	$ 2,830,414	$ 2,363,214
Total Funding to Achieve LOS	**$ 110,627,924**	**$ 92,438,308**	**$ 73,022,383**	**$ 58,715,455**

FIGURE 12 Primary highway system road maintenance funding matrix table.

By implementing a maintenance condition program and obtaining the desired level of funding, NCDOT will be able to shift from a reactive mode of fixing problems to a proactive mode of preventing them. Eventually, this will lead to greater customer satisfaction at unit costs below those currently experienced by the agency, permit the department to target funds to address highway features that are in poor condition, identify areas requiring additional employee skills or areas where employees can be shifted, and redirect funding to achieve a uniform level of service throughout the state.

Future Work and Objectives

The 1998 maintenance assessment study laid the groundwork for an overall total quality assessment and assurance program for NCDOT. Beyond providing information for funding requests and identifying features in poor maintenance condition, it is anticipated that the system may be expanded to provide results on a division level for allocation of resources. In 1999, the study was repeated to validate the first study's results and to also conduct an evaluation of one of the 14 divisions. The results of the 1999 survey for the primary highway

TABLE 3 Estimated Cost to Achieve Acceptable Statewide Level of Service

Maintenance Activity	Actual Expenditures	Funds Needed
Pavement Maintenance		
Pavement	$56,096,877	$123,246,298
Subtotal	$56,096,877	$123,246,298
Shoulders & Ditches		
Low Shoulder	$14,482,939	$20,021,709
High Shoulder	$14,200,311	$18,598,583
Lateral Ditches	$7,440,081	$7,808,887
Lateral Ditch Erosion	$601,842	$356,864
Subtotal	$36,725,173	$46,786,043
Drainage		
Crossline Pipe	$11,938,509	$21,506,565
Driveway Pipe	$4,737,222	$15,146,686
Curb & Gutter	$1,141,374	$1,076,484
Catch Basins & Drop Inlets	$2,257,001	$4,301,579
Other Drainage Features	$2,257,001	$5,304,325
Subtotal	$22,331,107	$47,335,639
Roadside		
Mowing	$20,159,558	$21,016,878
Brush & Tree Control	$11,053,151	$15,710,234
Litter & Debris	$4,543,160	$5,382,087
Slope Failures	$1,433,069	$1,057,931
Guardrail	$2,700,633	$4,062,950
Subtotal	$39,889,571	$47,230,079
Traffic Control Devices		
Traffic Signs	$16,224,996	$16,281,988
Pavement Striping	$9,832,715	$21,576,477
Words & Symbols	$1,985,337	$4,945,665
Pavement Markers	$314,569	$3,094,008
Subtotal	$28,357,617	$45,898,138
Environmental		
Turf Condition	$2,364,827	$3,403,605
Misc. Vegetation Management	$3,035,977	$2,869,543
Subtotal	$5,400,804	$6,273,148
Total Routine Maintenance Funding	**$188,801,149**	**$316,769,344**

TABLE 4 Statewide Annual Maintenance Funding Plan, Fiscal Year 1999–2000

MAINTENANCE PROGRAMS	FY 1999-2000 Funding (millions)
Statewide Programs	$10.33
Disasters/Emergencies	$32.00
Routine Road Maintenance	
a. Reoccurring Programs	$72.08
b. Performance Based Programs	$316.78
Routine Bridge Maintenance	
a. Reoccurring Programs	$24.64
b. Performance Based Programs	$19.74
Routine Maintenance Backlog	$22.50
Contract Resurfacing	$200.00
Contract Resurfacing Backlog	$7.00
GRAND TOTAL	**$705.07**

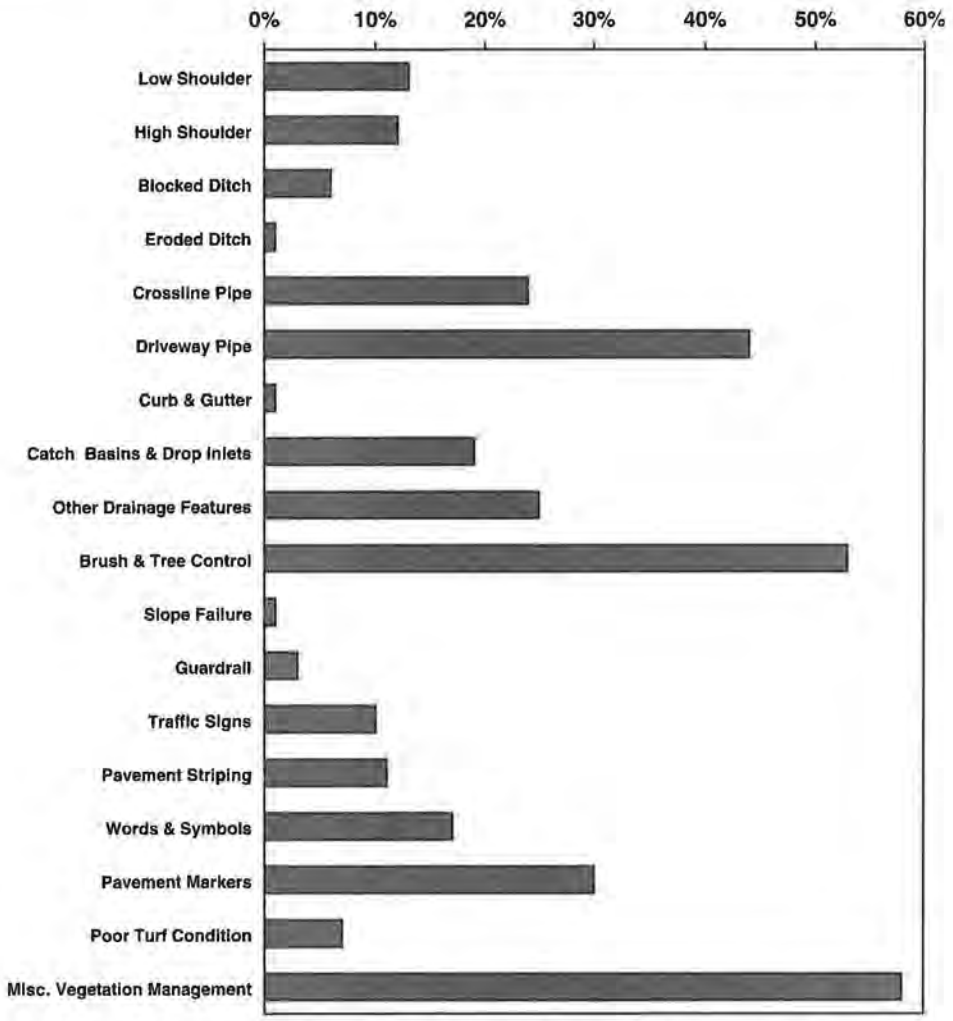


FIGURE 13 Percentage of features exceeding threshold value for primary highway system, 1999 survey.

system, shown in Figure 13, were very similar to the 1998 findings.

The 1999 North Carolina General Assembly established a task force consisting of legislative and community leaders to investigate current funding deficiencies and recommend potential avenues to address the shortfall in transportation funding. The task force will complete its work in time for the 2001 legislative session. Although this will not benefit the 2000–2001 fiscal budget year, the department will continue to evaluate the condition of the state highway system and seek additional sources of funds to address deficiencies identified in the study.

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