CHAPTER 1
INTRODUCTION

1.1. BACKGROUND

The Metropolitan Government of Nashville-Davidson County is responsible for providing the Metro with a safe and efficient transportation system. Metro Public Works maintains all roadways within Metro Nashville Davidson County except roads that are private, state routes maintained by TDOT, and roads maintained by satellite cities.

The Department of Public Works delivers a wide range of services that help define the quality of life for residents of Nashville/Davidson County. Over 400 dedicated Public Works employees work day and night to help ensure a safe, clean and convenient transportation network of public streets and alleys, and to provide an efficient system for managing trash and other waste in Davidson County. These "unsung heroes" repair potholes and public sidewalks; mow grass and trim tree limbs near Metro roadways; change traffic signal bulbs; create and put up street signs; and clean up roadside dumping and litter.

In order to better manage the maintenance and rehabilitation of the 2320 miles of roadway pavement in Davidson County's roadway network, Metro Public Works implemented a comprehensive strategic plan in 2003. This document is an update of that plan that reflects changes implemented since the program started.

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, section 1034 of ISTEA amended title 23, called for the development of six (6) management systems by State Highway Agencies (SHA) beginning in Federal fiscal year 1995. Although Pavement Management Systems (PMS) have been around much longer than 1995, this was the first major legislation on the part of the Federal Government to mandate the use of PMS within State and local municipalities. It was anticipated in the beginning that PMS would be designed at various levels of technical complexity depending on the nature of the pavement network. It quickly became apparent to many government agencies that they had to learn what software features to evaluate when selecting a pavement management software program.

PMS programs come in varying levels of complexity. There are those that are extremely sophisticated with a steep learning curve and there are simple programs that are user friendly that require very little training. There are pavement management software programs that are so data intense that some government agencies cannot afford to collect the data on a regular basis to keep the system working.

The Metropolitan Government of Nashville and Davidson County, TN (Metro) implemented its first formal pavement management program in 1993 by retaining Infrastructure Management Services (IMS) to install and configure PavePro PMS software and perform a pavement evaluation survey of all Metro streets. The system used roughness, rutting, distress, and deflection data collected by a survey vehicle to calculate a pavement condition rating for each pavement segment. These data were used to develop paving lists and perform "what if" scenarios for budgeting and planning purposes.

While the system was well designed, the scope was not tailored to the needs of Metro. An audit by Maximus, Inc., revealed that the system had fallen into disuse by 2002 due to the cost of collecting data and maintaining the system. Deflection data were particularly costly, and therefore not collected, which resulted in pavement condition ratings that were not accurate. The system could not generate useful pavement condition data, and therefore pavement models and paving plans, without the required deflection data. Paving plans were generated from a mix of PMS condition data and Metro council member input.

The audit also faulted the program for focusing on overlays as the only treatment prescribed by the pavement management system. Pavement was left to deteriorate until its condition was poor enough to justify an overlay. Maximus auditors estimated that implementation of a pavement preservation program, which would treat pavement before it failed, would save Metro between 2.0 million and 4.7 million dollars annually.

Based on the recommendations of the Maximus audit, Metro has been improving its pavement management program since 2002. This project addressed two major recommendations of the Maximus audit report:

- "The Department should amend its method of identification of street segments for repaving" (p II-54)
- "The use by Metro Nashville of surface treatments, such as slurry seal, used for preventive maintenance of asphalt pavement needs to be expanded" (p IV-61).

A new PMS software package was selected to aid in identifying street segments for repaving. The new software was selected, installed, and customized to reflect Metro's needs in a PMS, particularly the amount and type of data required to maintain the PMS. Various surface treatments, including but not limited to slurry seals, were evaluated and the most appropriate treatments were incorporated into the pavement management program.

Based on field trials of various surface treatments and pavement rejuvenators, MPW began a preservation program that extends pavement life while reducing maintenance costs. A letter dated May 9, 2005 from Maximus discusses a review of the new preservation program and acknowledges that it should result in a cost savings of approximately $1.5 million per year over the previous paving program.

1.2. PROJECT SCOPE AND OBJECTIVES

MPW has maintenance responsibilities for over 2,320 centerline miles (5,600 lane miles) of roadway pavement network. This network consists of local streets, connector routes, and arterial routes and is comprised almost entirely of asphalt concrete (AC) pavement. To enhance its overall pavement management approach and develop a long-range strategic paving plan, MPW awarded a contract in 2003 to review the existing pavement management system and assist MPW with the implementation of an improved PMS program. The ultimate goal for the Metro’s pavement management system is an easy-to-use system that can:

- Compile past information (construction records, materials information, traffic data, and condition information) on a segment-by-segment basis.
- Conduct new distress surveys to define distress types, levels, and conditions.
- Project future pavement conditions based on realistic pavement deterioration models.

- Project future pavement rehabilitation needs (short- and long-term needs) based on pavement conditions and any other priorities and criteria specified by Metro Nashville and established through the new project.
- Provide detailed reports and graphical displays.
- Provide a logical basis for identifying and selecting roadway improvement projects.
- Incorporate new maintenance policies, repair techniques, and advanced surfacing materials and methods.
- Link with the existing geographical information system (GIS) to provide graphical summaries of data and analysis results.
- Prepare 5-year (and beyond) plans that include prioritized lists of projects to be conducted each year to maintain a specified level of service and estimated costs for each project.

To achieve the goal, Metro Nashville identified several major tasks to be included in the PMS contract:

- Evaluate the existing pavement management program, compare with state-of-the-art systems, and recommend the most effective system for Metro Nashville.
- Establish levels of service consistent with roadway usage, traffic levels, and other priorities.
- Evaluate and recommend new/improved paving systems.
- Conduct a cost analysis of in-house maintenance and rehabilitation (M&R) activities versus contract services.
- Develop an objective-paving program to aid Metro Nashville officials in making effective short- and long-term budgeting recommendations.
- Develop strategies to implement a three-tier program of reconstruction, rehabilitation, and preventive maintenance.
- Develop and implement an educational program aimed to reach out to citizens.
- Prepare recommendations for staff organization and workload equalization.
- Develop guidelines for selection of appropriate preventive maintenance treatments.
- Establish recommended annual budgets associated with the M&R program.

This strategic plan describes how these goals have been met and put into practice.

1.3. CURRENT PAVING PROGRAM

Metro Public Works is responsible for maintaining approximately 2300 centerline miles (5600 lane miles) of roadway pavements. In order to better manage the large road network, the paving program was divided into five groups, with each group having its own budget. Group boundaries are generally defined as I-40, I-65, and the downtown loop. Paving projects are let on a group basis, i.e., paving contracts consist of roads selected from a single paving group. The five groups and their associated statistics in 2007 are listed in Table 1.1. Group boundaries are shown in Figure 1.1.

Table 1.1. Paving group statistics.

	Group 1	Group 2	Group 3	Group 4	Group 5
Centerline miles	445	491	350	446	596

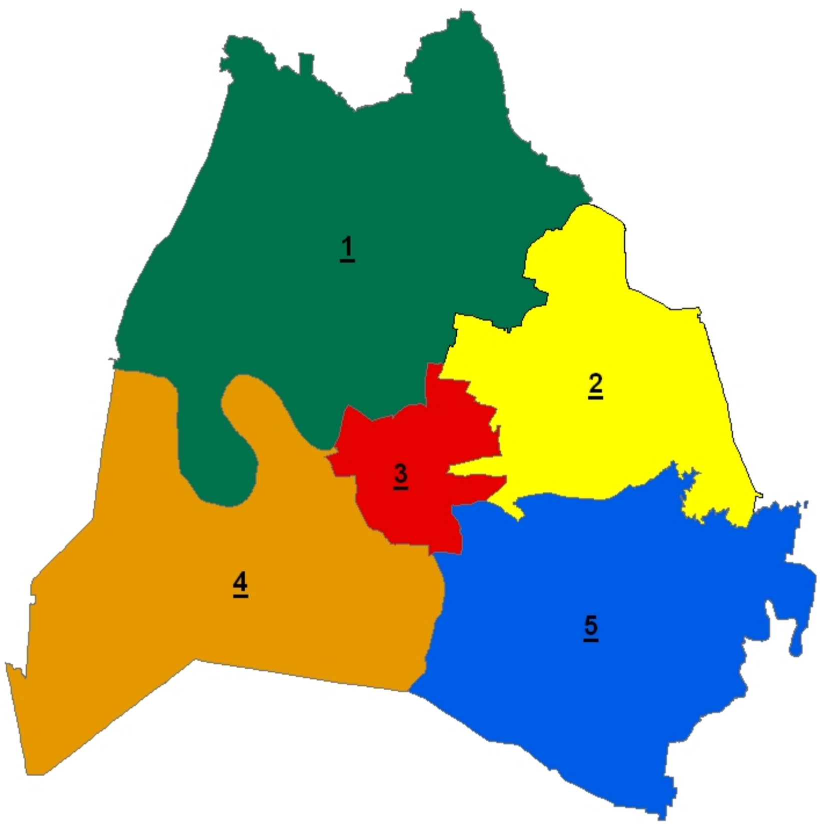


Figure 1-1. Metro paving groups.

CHAPTER 2

PAVEMENT MANAGEMENT SYSTEM

2.1. INTRODUCTION TO PAVEMENT MANAGEMENT

The ability of a pavement system to serve a society is largely a function of planning. Planning is the intersection between engineering and politics. Pavement managers respond to the needs of society by planning the growth of the pavement system within the constraints of financing, public policy, environment, and technology. The pavement manager's first responsibility is to make the best possible use of public funds. The manager must expand the pavement system to serve society's needs while maintaining the system in a safe and serviceable condition. This task would be easy if pavements did not deteriorate, but the serviceability of all pavements begins to decrease the day they are placed in service, if not sooner. Cracks and ruts form under traffic load, utility companies trench and patch across roadways, and asphalt binder becomes brittle and cracks from exposure to the environment. As the pavement deteriorates, action must be taken to restore or prevent the loss of pavement serviceability. When adequate funds are not available to meet demands, the manager must decide which needs are most important. Pavement management is an important tool in the decision process.

Pavement management is a systematic method to assess pavement condition, to identify M&R needs, and to plan pavement maintenance and rehabilitation (M&R) activities. A pavement management system (PMS) is a tool to track pavement inventory and condition, estimate future condition, determine M&R requirements and costs, and develop and prioritize M&R projects.

Figure 2.1 illustrates the typical deterioration relationship for most pavements, and highlights when different types of maintenance should be applied Preventive Maintenance includes such activities as crack sealing, rejuvenators, sealers, etc.

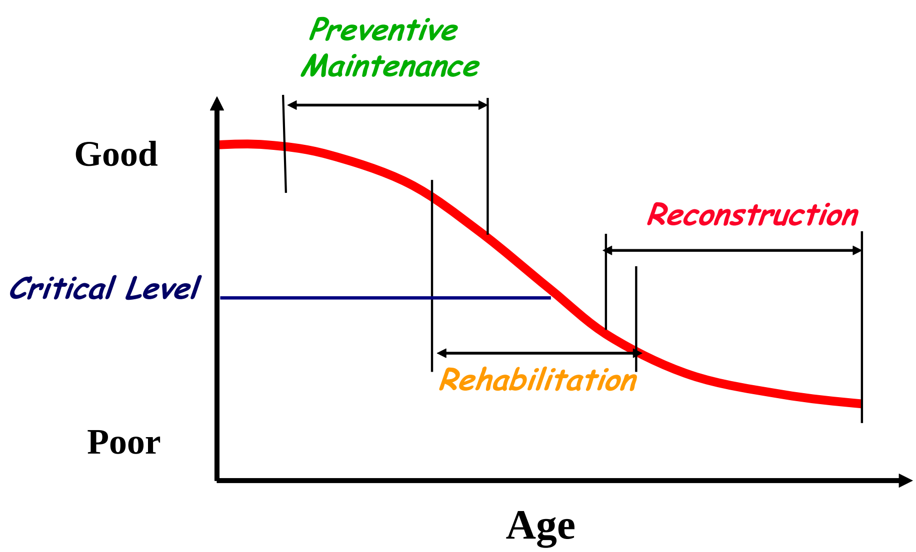


Figure 2.1. Illustration of pavement deterioration and M&R costs.

Resurfacing is selected for badly deteriorated pavements that can no longer provide service and must be replaced with a new pavement. Reconstruction typically entails the placement of large patches and/or asphalt concrete overlays. Unit costs are much lower for preventive maintenance if applied before major distress occurs as compared to rehabilitation costs for a badly deteriorated pavement.

The first step in pavement management is to determine the state of the pavement system. This is accomplished by a comprehensive inspection of all pavements in the road network. The network of pavements is first divided into logical components, such as a single street, called a *route*. Each route is then divided into pieces small enough to efficiently manage, known as *segments*. Each segment is evaluated for surface condition and assigned a level of importance. Condition evaluation requires at minimum a visual inspection (using automated digital imaging) with independent measurement of roughness, rutting, and raveling. The level of detail of the visual survey is selected to complement the other data collected during the evaluation process: a condition rating in accordance with ASTM D6433 Pavement Condition Index (PCI) survey with 38 distress types and multiple severity levels. The importance of a segment is determined by the pavement manager, and is typically a function of street use, location, traffic type, and traffic volume.

After the condition of the pavement network has been determined, the pavement manager must select treatment options that are appropriate to address the maintenance and rehabilitation (M&R) needs of the pavement system. The selection of treatment options is based on applicability, availability, and cost of treatments that have been proven effective in field tests along Nashville streets. Treatments should address or prevent deficiencies in the pavement without causing additional problems. A treatment that requires materials or skills not readily available should not be selected. The total cost of a treatment process throughout its life cycle should be considered, because often a treatment with a low initial cost will not have the greatest cost-to-benefit ratio. Once the treatment options have been selected, the guidelines for use and application of each option must be established. The combination of treatment options and guidelines for selecting the appropriate option for a project are collectively known as a *maintenance policy*.

By standardizing the available treatments and the treatment selection process, a maintenance policy allows reasonably accurate estimation of maintenance needs several years into the future based on current pavement conditions. The estimated M&R needs can be used to develop paving plans and M&R projects. Historical and bid cost data can be used to calculate the cost of the required M&R projects, which is then compared to anticipated budget levels to determine the most effective way to allocate funding. PMS cost data can also provide support for additional funding requests, and justify planned or previous expenditures.

2.2. PMS SOFTWARE SELECTION PROCESS

PMS software packages vary in scope, sophistication, ease-of-use, and capability, and no one package will satisfy the needs of the many different state and local PMS users. The proper software must be chosen, or the PMS will fall into disuse.

Metro Paving Department personnel evaluated several candidate software packages before selecting PMS software for use. Most of the software programs selected as candidates by Metro were listed in the Pavement Management Catalog produced by the U.S. Department of Transportation and Federal Highway Administration Office of Asset Management. Other software programs evaluated were chosen based on their presence in the pavement management industry.

The software selection approach taken by Metro was to define the major components of PMS software and then determine the needs of Metro with respect to each component. Rating forms and criteria were developed prior to reviewing the candidate software packages. Each component of each candidate package was then rated on a scale of 1 (low) to 10 (high) against Metro's needs. Each software package was scored in the following 24 areas based on the criteria listed below.

- **Segment Identification Scheme:** *Ease of use, flexibility, ability to fit in with other systems.*

  The method used to identify a particular pavement segment should be easy to understand. Data about the route name, roadway location from segment start to segment end, address, and block-to-block segments should be readily accessible.

- **Segmentation:** *Adequate segment descriptors, dynamic segmentation.*

  The method used by the software to divide the pavement network into manageable segments should be logical and easy to follow. The segmentation method should complement the segment identification scheme.

- **Pavement Data:** *Supports pavement data with ease and flexibility.*

  The program should store physical pavement inventory data from the field such as geometrics, construction date, layer thickness, layer properties, and subgrade.

- **Pavement Condition:** *Supports pavement condition data with ease and flexibility.*

  The software should provide tools to manage and report pavement condition data such as distress, roughness, and rutting, and to correlate the data into pavement condition indices for reporting the overall condition of the roadway.

- **History:** *Supports pavement construction and condition history.*

  The program should store, manage, and analyze a wide range of historical data needed to produce future rehabilitation and maintenance projects.

- **Other Inventory:** *Ability to support other roadway assets in the PMS.*

  The program should store, manage, and analyze other right-of-way assets (sidewalks, utilities, etc.) in conjunction with pavement data, or integrate with software for managing other assets.

- **Flexibility:** *Allows the user to make changes in screens, reports, fields, and indices.*

  The software allows the user to customize the input, analysis, output, and presentation systems. The more flexible a system is, the less training and the fewer changes in current pavement management procedures need to occur.

- **Distress Analysis:** *Process used to calculate surface distress index.*

  The software should have the ability to calculate the selected condition index from distress data.

- **Condition Modeling Tools:** *Mathematical model used to predict future road condition.*

  The system should allow the user to easily estimate future pavement condition based on historical pavement condition data.

- **Treatment Selection:** *The right treatment at the right place at the right time.*

  The software should select the right preventive maintenance or rehabilitation treatment based on the condition of the road is critical to a successful pavement management system. The treatment selection system must also be easy for Metro to understand and change.

- **Prioritization:** *Prioritize a maintenance & rehabilitation schedule.*

  The software requires the ability to take pavement condition data of the roadway network and generate an M&R list based on other variables within the pavement management system such as functional class, planned utility projects, etc.

- **Economics:** *Budget analysis.*

  The software must simulate various budget scenarios, estimating future pavement condition of the network based on current pavement condition and various funding levels. Like treatment selection, the budgets in the software must be easy to understand and change.

- **Reports:** *Software is flexible enough to generate various types of reports.*

  The software should allow the end user to easily generate custom reports using tools similar to existing products (MS Access, Crystal Reports, etc.)

- **Graphs:** *Software is flexible enough to generate various types of graphs.*

  The software should have the ability to produce various types of charts and graphs. The software should allow the end user to create or modify custom graphs.

- **GIS:** *Software supports a "live link" to update and view pavement data through a GIS.*

  The software should be designed to easily work with GIS software applications. Data from the system can be used to automatically update GIS maps at the agency. Two-way data sharing at the database level is the preferred method of GIS interaction.

- **Web:** *The ability to report data and access data through the web.*

  The software should be designed to allow data access and reporting through a Web based application.

- **Interaction with other software:** *The ability to interact with other software applications.*

  The software should use an open data standard to allow data sharing with current and future Metro applications.

- **Data:** *Supports the inclusion of various types of data in the system easily.*

The software supports and manages other data elements such as images, GPS, traffic and other data issues within the pavement management system.

- **Network:** *Operates on the network with ease and flexibility.*

  The software requires capability to operate in a network environment with ease and flexibility. The software should support multiple simultaneous users.

- **Security:** *Data must be safe from malicious or accidental corruption.*

  The software requires capability to serve several users and still provide data protection. The software should support user-, field-, and record-level locking to allow interaction with non Paving Department employees.

- **Ease of use:** *Software is easy to use.*

  Users should be able to update and query the system with a minimum of difficulty.

- **Ease of training:** *Software is easy to learn to use.*

  New users should be able to use the software after a minimal training period.

- **Cost:** *Software cost must be reasonably priced.*

  The software cost should be competitive, and allow for per-seat and expandable licenses.

2.3. REVIEW OF CANDIDATE PMS SOFTWARE

Interviews were conducted with PMS software providers to review and evaluate candidate pavement management systems for the Metro Nashville and Davidson County Long Range Strategic Paving Plan. Many candidate systems were rejected early in the process for reasons of cost or scope. Systems with a software cost of more than $50,000 were rejected. Other packages were rejected because the vendor required the client to purchase pavement management services in order to receive the (often proprietary) software. Still other packages were rejected as insufficient for the size and scope of the Metro road network. Once all of the candidate PMS providers were evaluated, CartêGraph's Pavement View Plus was selected for implementation at Nashville and Davidson County. Items such as ease of use, learning curve, and cost were key factors.

2.4. CARTÊGRAPH PAVEMENTVIEW PLUS

PAVEMENTview Plus is divided into two modules. The "Segments" module contains inventory data for the network, including current conditions and physical attribute data. The other module, "Segment Analysis Models", contains the analysis routines and information required to produce a paving plan for Metro's pavement network.

Both modules allow users to create custom forms, or data access screens. For example, the default inventory form has several fields (data items, such as pavement type or street name) but can be modified to omit fields that are not needed or to add new fields. This form has been modified to display only the information of interest to Metro Paving and added fields to the inventory database to store total route lengths and a flag (yes or no) for routes where state funds are used in maintenance. The network inventory forms have been modified to display the digital images used in distress data collection. Multiple forms may be open at the same time in the software.

The entire system was linked to Metro's Geographic Information System (GIS) using CartêGraph's MAPdirector for ArcGIS software. Because the data from the system is stored in the Microsoft SQL Server database operated by Metro's IT department, it is also possible to get information directly from the database for use in the GIS or other related applications. Using SQL Server to store the PMS data also improves the integrity of the system and insures that the data is backed up appropriately in the processes used by the IT department.

The process of customizing PAVEMENTview Plus for Metro Public works consisted of four parts:

- *Schema* modification (a schema is the definition of the fields in the database and how they are related to each other) – This process involves deciding which fields to add to the PAVEMENTview database.
- Form modification – the creation of appropriate forms that make the data easy to get to and read while still showing all the required information in a minimum of space.
- Data modification – adding the required data to the pick lists (drop-down menus) in the inventory and the parameters of the pavement management engine.
- Report modification – adding and editing the default reports provided with the software to retrieve the required information from the system in a printable format. This includes creating custom charts.

Each part of the process is described in more detail below.

2.4.1. Schema Modification

Only a few data fields were added to the software to accommodate the data that was either available in the systems currently maintained by Metro or collected as a part of this effort. Most data could be accommodated by existing fields in PAVEMENTview Plus. Fields and record-sets had to be added to store the links to the photographs collected during the survey. There are four additional record-sets, one for each camera on the digital survey vehicle (forward, sign, rear, and downward). Each record-set contains fields for the name of the file (digital picture) and station recorded by the survey vehicle's DMI. All of these record-sets were added under the root record-set for inventories: Segments.

Several fields were also added to the Segments record-set itself:

- Is State Aid – a yes or no field that marks a road as eligible for state assistance when improvements are performed. These streets are still maintained by Metro. This information was obtained from Metro's GIS system.
- Paving Group – A list of districts for each paving group was stored in the Zone field (a default PAVEMENTview field), and a new field was created to store the paving group data. The new field is a text field as opposed to a numerical field to allow expansion of the system.
- Sequence ID – A numeric field used to put the segments of a route in order when viewing pictures or browsing the database.

A length field was also added to the Route record-set that, like Segments, is a root record-set. This length field stores the total length of all the segments on a route as provided by the GIS. This field should not be confused with the length field under the Segments record-set. The latter is a measurement of the length of an individual segment.

2.4.2. Form Modifications

Default forms were used whenever possible. Figure 2.2 shows the modified Segment Information screen from the CartêGraph PMS software. This is the most commonly used form in the PMS. Segment identification elements including route name, segment start, segment end, start address, end address, route length, and pavement length and width are found here. Also displayed are the current condition and the latest survey image of the current segment. This form is also used to access other forms showing construction history, distress details, and other camera views.

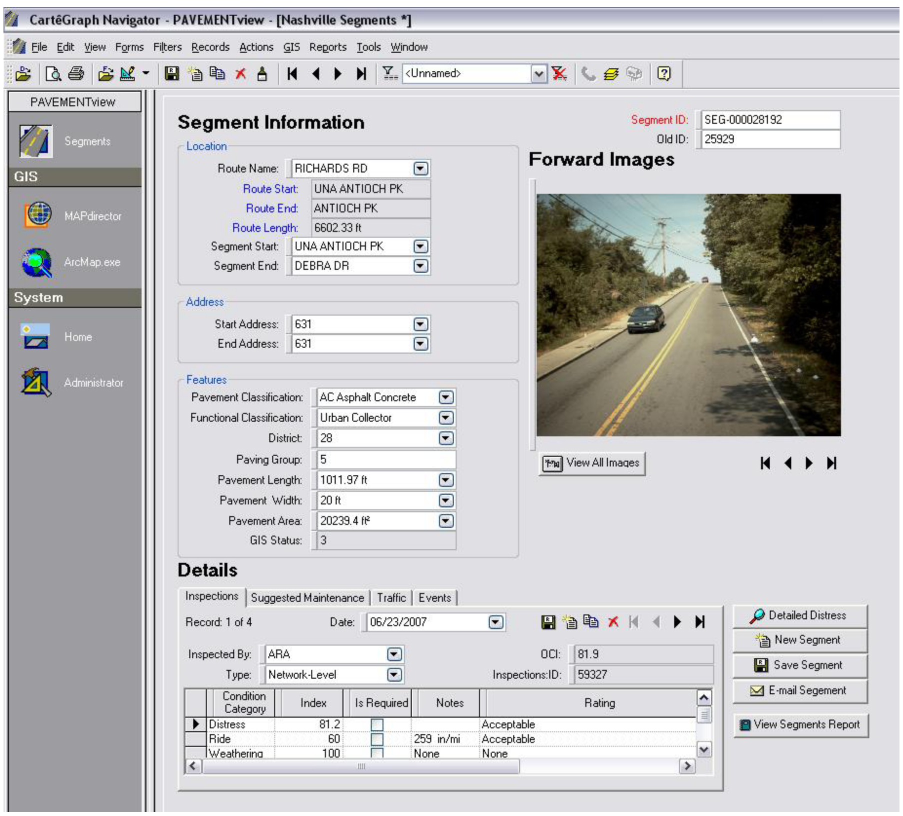


Figure 2.2. Example of pavement Segment data with forward view roadway image.

Figure 2.3 shows the distress detail form, accessed from the "Detailed Distresses" button of the main form. This form is used to review, modify, and update distress inspection data. These distresses are then used to calculate the distress condition index, discussed in Chapter 3. A reference area, showing a typical photo and standards for identifying each distress, is included on this form.

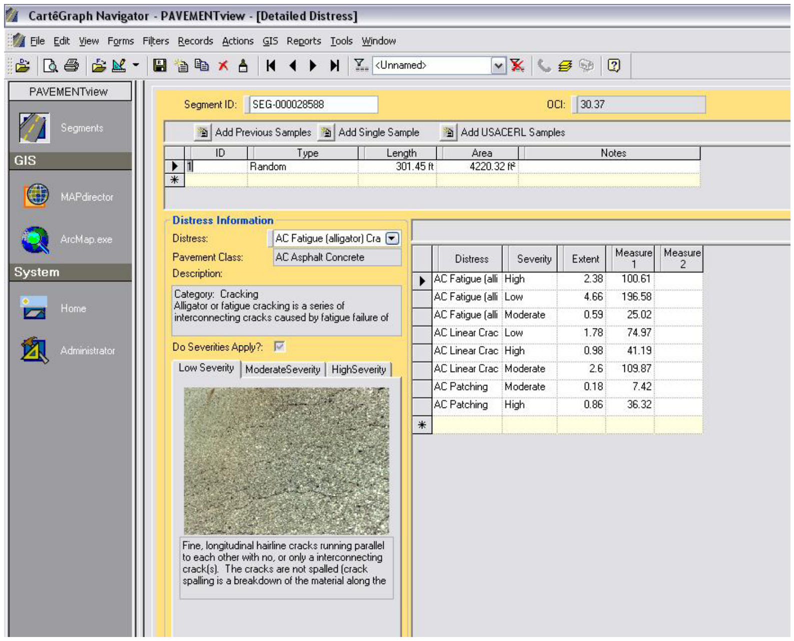


Figure 2.3. Example of distress data and associated digital images

Construction history information is accessed from the "Events" tab of the main form, as shown in Figure 2.4. Information about M&R performed on this segment of roadway is displayed in place of the condition information. The road shown in the figure received a mill and 1.5-inch asphalt overlay in June of 2005.

Figure 2.5 shows the analysis screen, where the parameters are combined to create a work plan. When analyzed together, the combination of parameters generate a specific work plan and future condition assessment of the network. This is the work engine of the pavement management system

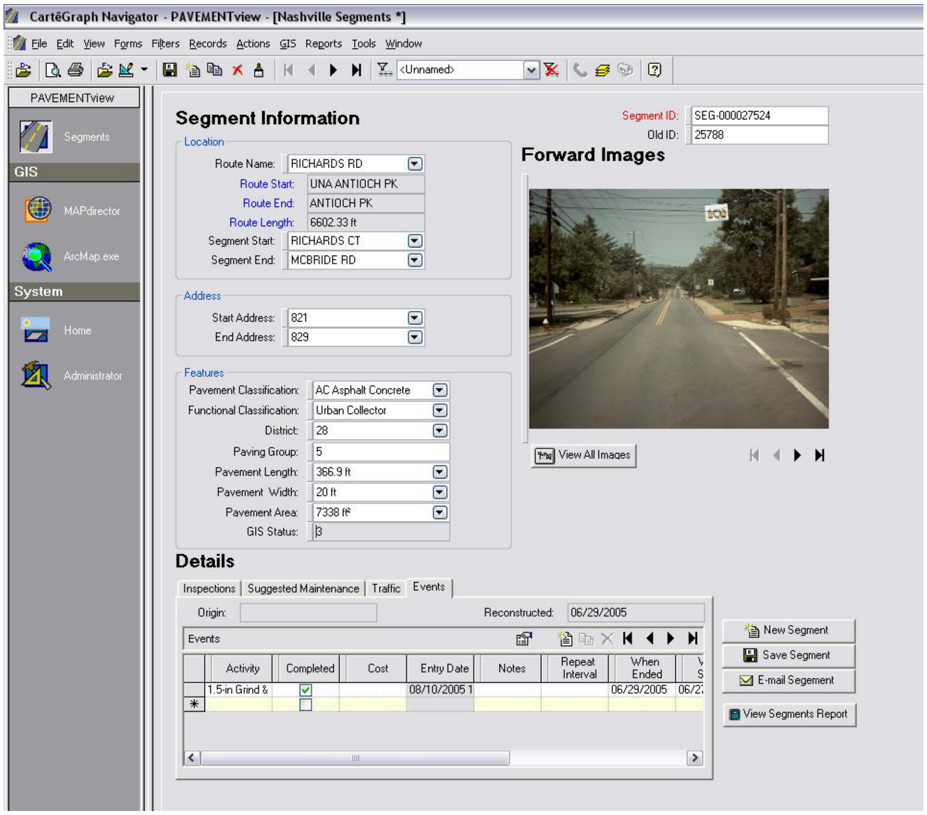


Figure 2.4. Example screen showing construction.

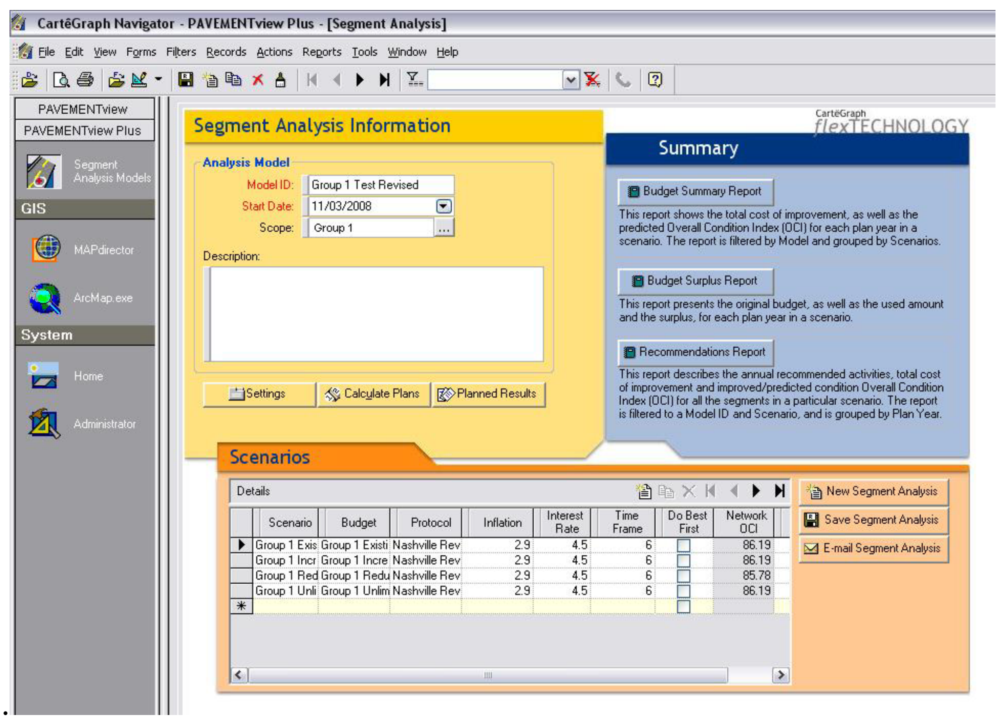


Figure 2.5. Segment Analysis screen used to generate work plans.

2.4.3. Data Modification

The data modification in the inventory module consisted primarily of modifying pick lists (drop-down menus) with the choices specified by Metro. For example, the pick list for "Jurisdiction" was modified to include "Metro Nashville", "Private", "State Highway", and "Unknown". Changes were also made to the condition calculation factors, discussed in Chapter 3.

The pavement management analysis module customizations were, by necessity, more complicated since they did not involve simply storing data. Due to the complexity, Chapters 3 and 4 are devoted to discussing the modifications to the pavement management analysis module. Chapter 3 discusses condition data and how the software stores and handles it. Chapter 4 is the decision making process used by the software to generate work plans. The "Settings" form shown in Figure 2.6 is where the various parameters required to generate these work plans are configured.

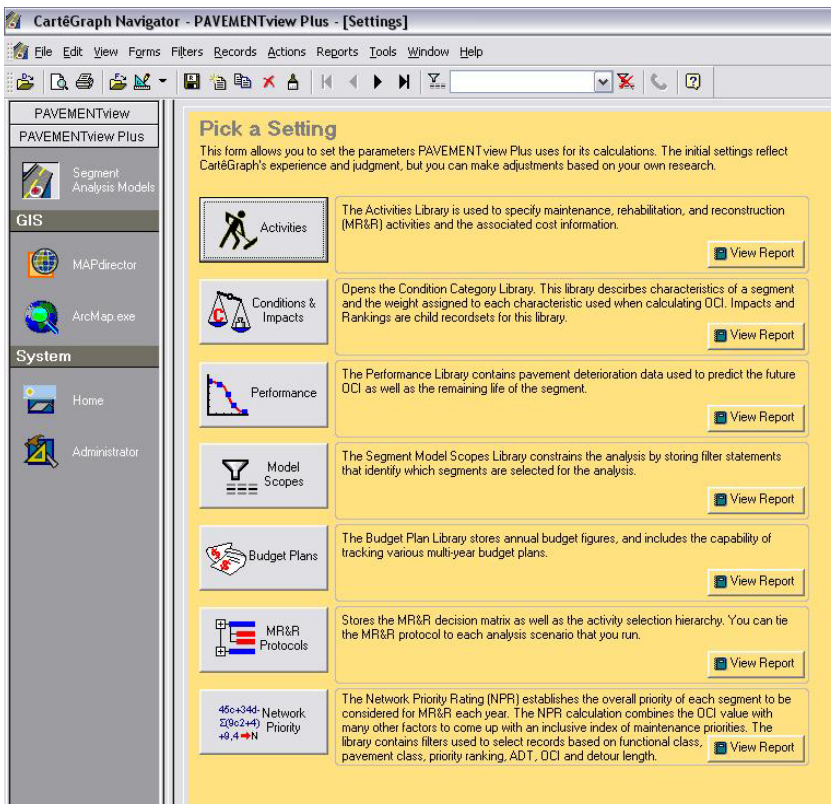


Figure 2.6. Pavement analysis settings form.

The parameters that can be customized from the "Settings" form are:

- Activities – A list of the maintenance, rehabilitation, and reconstruction (MR&R) activities used by Metro and the associated cost information as shown in Figure 2.7.
- MR&R Impact – The effects of performing an activity in a particular segment as shown in Figure 2.8. For example, reconstruction using HMA sets the PCI (Distress) rating to 100 and the Ride index to 100. On the other hand, a crack seal improves distress and ride by 10%. Also used to define the overall condition index (OCI).

- Model Scopes – Creates filters to limit the type of roadway for analysis. Roads may be included or excluded by any parameter found in the pavement inventory such as, state aid routes, routes maintained by other agencies, functional classifications, etc.
- Budget Plans – The list of different budgets that could be used for pavement rehabilitation as shown in Figure 2.9. Note that within each budget different money sources can exist. In Metro's case, there would be at least two different categories of funds: those used for state aid roads and others from the general fund.
- MR&R Protocol – The set of criteria that determines the treatment selection process as shown in Figure 2.10. This setting provides access to the MR&R decision matrix and the activity selection hierarchy.

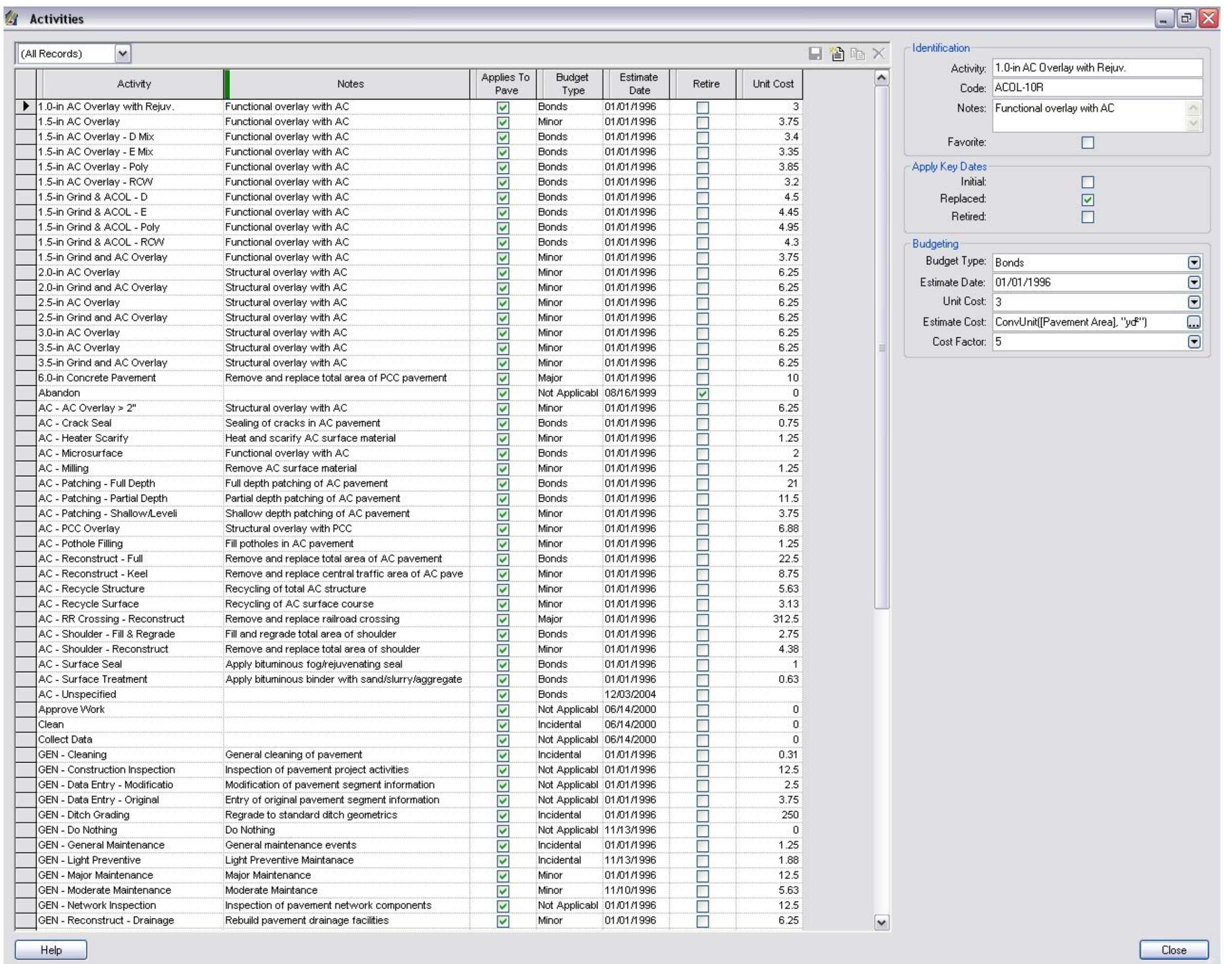


Figure 2.7. M&R activity set-up and costs.

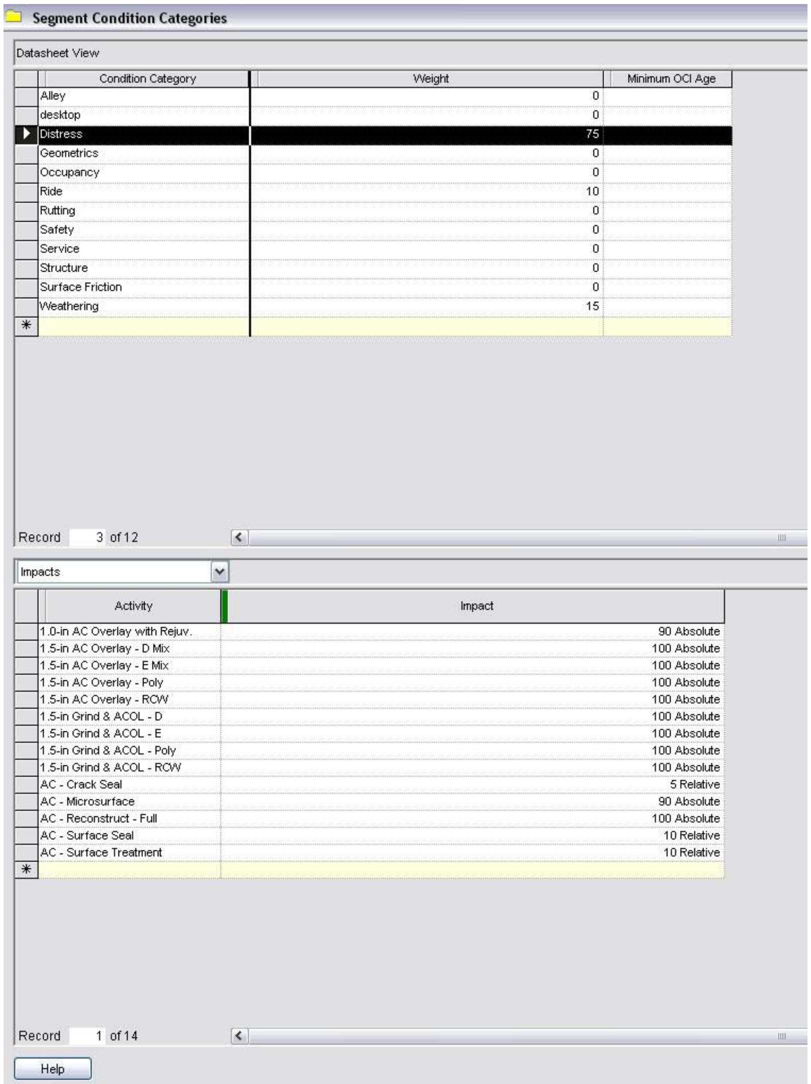


Figure 2.8. MR&R impact definition.

Figure 2.9. Typical budget setup.

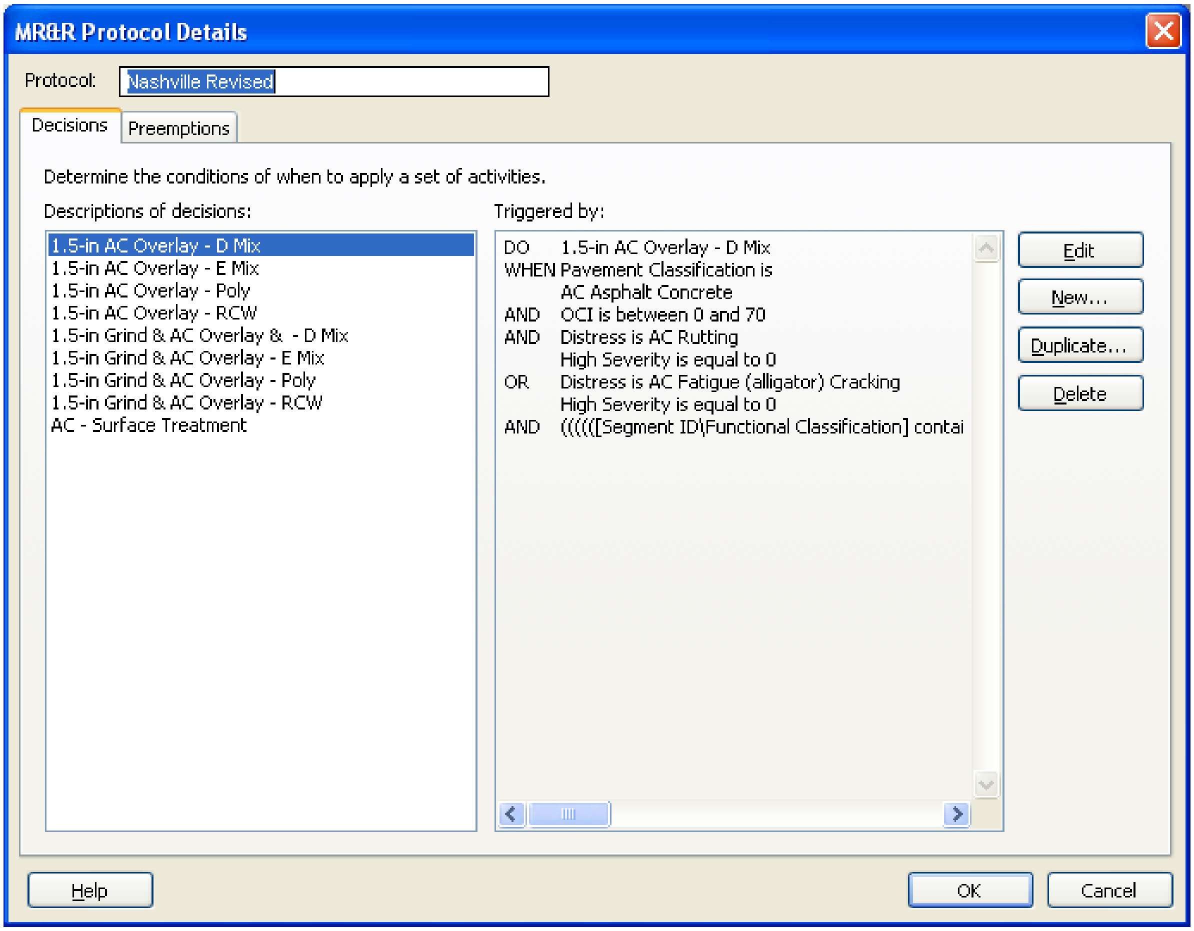


Figure 2.10. MR&R protocol definition.

- NPR Calculations – The equations used to rank streets in order of need using a prioritization analysis as shown in Figure 2.11. The Network Priority Rating (NPR) establishes the overall priority of each segment to be considered for MR&R each year. The NPR calculation combines the overall condition value with many other factors to come up with the inclusive index of maintenance priorities.

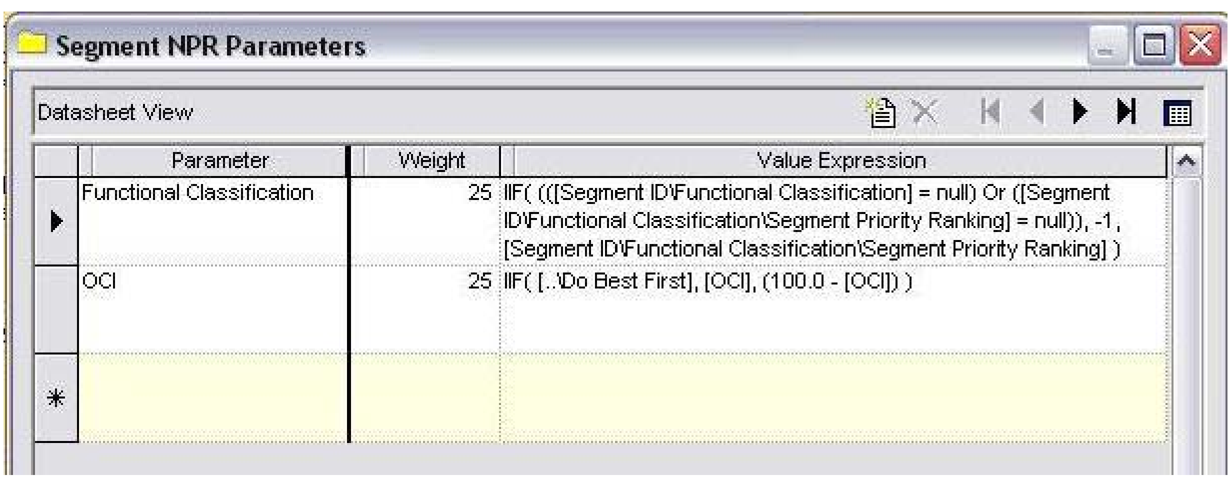


Figure 2.11. Typical NPR parameters in Metro PMS software.

- Performance – The age-versus-condition curves used to estimate the future condition of a pavement segment. Given a known current condition, the future condition can be determined by estimating the apparent age of the segment (note that this is different than the actual age) and then determining the condition for future years based on this. Performance curves can be accessed from either the inventory or management modules, but they are mainly used in the management module for the Metro Nashville implementation. Figure 2.12 shows a typical performance curve.

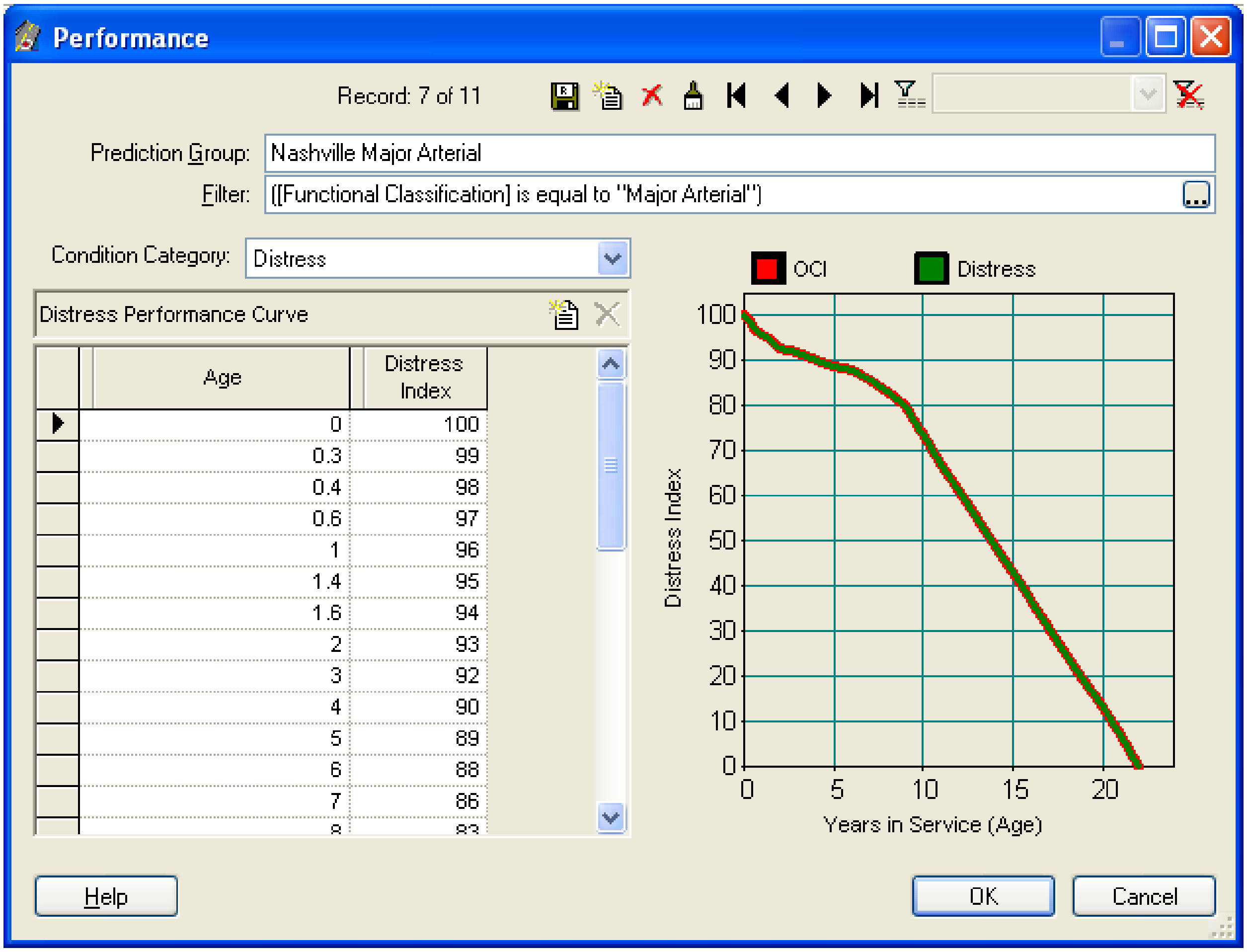


Figure 2.12. Typical CartêGraph deterioration curve.

2.4.4. Report Modification

The final part of the pavement management software that was customized was the report module. It was changed to match some of the existing reports in Metro's PavePro software and/or to address paving plan requirements. Two reports were created that list current condition (OCI) grouped into both district and paving group. ARA also modified a chart report to display the percentage of pavement (by area) within a certain condition category (excellent, good, fair, or poor). These data are displayed as a pie chart.

CHAPTER 3

PAVEMENT MANAGEMENT DATA

3.1. PMS DATA REQUIREMENTS

The key component to a quality PMS is quality data collection during the pavement evaluation process. It is important that the data collected during each inspection can be compared with previous pavement inspections. Several methods for data collection are available. The methods selected should reflect the capabilities and goals of the pavement management program.

All pavement management programs should include a visual inspection of some type. A properly executed visual evaluation is one of the most reliable and efficient forms of pavement evaluation available. It is simple, inexpensive, and provides a great deal of valuable information about pavement condition. Visual inspection techniques range from informal drive-overs to formal methods such as the PCI or Long Term Pavement Performance methods. Larger transportation networks, like Metro's, tend to use the more formal systems. These systems, particularly PCI, provide a comprehensive record of pavement distresses at the time of the evaluation and are highly repeatable. Larger systems also tend to use image-based survey methods, which use a vehicle to collect film, video, or digital images of the pavement system. These images are then analyzed for the required distress data. An image-based assessment has the advantages in safety and speed of a drive-over survey without sacrificing the quality of a walking survey. The survey vehicles may also be used to collect additional data, such as roughness or right-of-way images, concurrently with the images.

Additional data are often collected to detect conditions not identifiable by visual inspection. The tests to collect these data are categorized into destructive, semi-destructive, and nondestructive testing.

Destructive testing is the traditional test method to determine physical pavement properties. Tests are conducted in test pits, samples are obtained from core borings, and laboratory tests are conducted on the samples. These tests have the advantage of examining actual in-service materials, however, they also have several disadvantages. Destructive tests are expensive, particularly considering the amount of testing necessary for a network-level survey and the fact that most properties determined by destructive testing change very little between surveys. Destructive testing can also have a significant impact on traffic.

Semi-destructive tests are tests that deploy a penetration device through a small-diameter hole. Common semi-destructive tests include the cone penetrometer and dynamic cone penetrometer. Semi-destructive tests typically characterize pavement layer and subgrade strength and moisture level. Although semi-destructive tests are typically faster and cheaper than destructive testing, they still require a small core or drill hole, and still affect traffic flow.

Several nondestructive alternative testing techniques are frequently used to allow examination of a considerably broader expanse of pavement than is practical with physical sampling. Among nondestructive testing techniques are ground penetration radar (GPR), seismic methods, impact and dynamic loading devices, friction measuring equipment, and roughness measuring devices. Each can provide valuable information of conditions, and each has certain limitations. In practice, it is appropriate to select from available nondestructive techniques to fulfill specific investigative requirements.

A PMS also requires financial data to provide accurate results. The most import data of this type are the treatment costs. The best sources for cost data are the financial records of previous projects. If these are not available, bid tabs, quotes, and estimates can be used to determine the cost data. Financial data should be updated periodically, either by a simple inflation factor, or by recomputing unit costs based on projects completed since the last cost data update.

3.2. PAVEMENT DATA SELECTED FOR THE METRO PMS

The Cartêgraph PAVEMENT *view* Plus software is capable of storing and analyzing nearly any type of pavement data. Discussions with MPW personnel indicated that Metro is most interested in the surface condition, rutting, raveling, and ride quality of Metro pavements. A modified ASTM D6433 PCI survey was selected as the network level surface condition assessment procedure. The PCI method is well defined and is universally accepted and used. The PCI method also includes provisions to include rutting in the visual assessment. The International Roughness Index (IRI) was selected as the network-level ride quality measurement. IRI is determined by the absolute vertical travel of a standard wheel-and-spring system traveling at a standard speed over a pavement. IRI is typically calculated from non-contact profile measuring devices such as laser or acoustic profilometers.

Due to the various stresses applied and the dynamic properties of paved surfaces, pavement condition data have a limited life span, i.e., data collected quickly become out of date. Surface condition data are typically valid for two to three years. Profile data are valid for approximately one to two years. ARA recommends that each pavement segment in the Metro pavement system be surveyed for surface condition and ride quality every two years. Some high-traffic or high-profile areas may warrant annual inspection.

Data is generally of higher quality if a portion of the network is surveyed every year rather than waiting several years and surveying the entire network. Using this process keeps the data more up-to-date, and therefore more representative of the actual network conditions. It also allows Metro to flag problem areas that should be surveyed in sequential years due to rapid deterioration or other issues.

3.3. BENEFITS OF DIGITAL IMAGE-BASED DATA COLLECTION

Pavement condition data were collected using image-based survey procedures. In the past, manual surveys have been used by most agencies to collect pavement distress data. Manual surveys are labor and time intensive, and data reliability depends on training and rater performance. A number of studies have shown that manual ratings have high levels of variability with respect to rater repeatability as well as high rater-to-rater variability.

Image-based data collection systems produce permanent pavement surface images, offering the advantage of correlating rater analysis results for accuracy and repeatability. An additional advantage to using fixed images is the ability to re-calibrate raters who tend to drift from desired interpretations with time. Fixed images also provide a consistent calibration for new raters. The combination of establishing rater performance requirements and performing QC monitoring enables the production of the desired quality of data.

Image based data collection also provides a record of non-pavement assets, including but not limited to sidewalks, markings, and signs. These images can be made available to other areas of the Public Works Department to aid in planning and maintenance.

3.4. GIS UPDATES

Metro Nashville uses GIS-centric processes to plan, communicate, and manage the maintenance of its assets, including the publication of hardcopy and web-based maps to foster communication within Public Works and across the Metropolitan Government of Nashville - Davidson County, with consultants and other third-party organizations, and with the public at large. Aspects of the PMS process and the distress data that is collected as part of each year's roadway survey are reflected onto Metro's GIS-based roadway centerline data assets, where they are made available for use with other projects and programs within the government.

Specifically, each segment's last-paved date and overall condition data (see discussion of OCI found later in this document) are made available to the GIS roadway centerline dataset. By virtue of the GIS updates, the last-paved date is made available to the greater Metro Nashville permitting suite, where it affects a fee that is levied at the time of permit request to help discourage and pay for the repair of cuts made into recently-paved sections of roadway. Another aspect of the GIS updates is the availability of the OCI and planned project type and IDs for each centerline segment — as well as the full extents of planned projects. This level of information is useful in coordinating projects across different departments (Water Services, ROW Maintenance) and related organizations (NES, TDOT), as well as in a variety of customer service and public relations situations.

The process for reflecting the pavement distress data (and other data stored within the PMS) onto the GIS resources is currently a database-intensive exercise that requires access to both "before" and "after" datasets from the PMS and the GIS. Since it is possible for the GIS data assets to change (e.g., through the splitting/intersection of a maintained segment to accommodate the recent addition of a new subdivision) between the time the data collection process begins and the time the updated PMS data is exported for use inside GIS, the distress data is always mapped to the "before" GIS resource as it stood when the data collection process began. Once that "before" copy of the GIS data is updated (thereby maintaining a 1:1 relationship between segment IDs in the GIS data and the PMS data), GIS technicians use logical and spatial joins to isolate any affected records (e.g., "children" of the split "parent" segments from the example above) in the more current "after" centerline dataset and update those individually. The resulting dataset is the most recent version of the Metro enterprise roadway centerline dataset with current OCI values and pavement management project data for each segment that is accepted for maintenance.

The result of this GIS update process is that the Metro roadway distress data and the proposed project plans from the PMS can be displayed in a manner that helps stakeholders to visualize problems and their proposed solutions, as well as the "what-if" effects of applying various alternative treatments under varying levels of fiscal resources. While the GIS update process is detailed and time-consuming work in its current form, this process will become easier and faster as new server-based tools are developed and implemented. Considering the status of Metro's movement toward the further deployment of server-based GIS tools, plans include the automation of the GIS update process through the eventual deployment of CartêGraph's GEODATA*connect* product and/or through the use of custom ESRI ArcGIS Server processes.

3.5. DATA COLLECTION PROCESS

3.5.1. Network Definition

Before beginning the pavement evaluation survey, the Metro pavement network was defined. Roads that Metro is not responsible for maintaining, including state, federal, and private roads, were removed from the network. The network was divided into routes based on street names. Routes were divided into segments based on four criteria:

- **Block-to-block:** Segments change at each intersection,
- **Pavement change:** Segments change at changes in pavement construction history,
- **½-mile:** Segments are no longer than ½-mile in length,
- **Paving groups:** Segments must be entirely within one paving group.

These criteria resulted in a network containing 25,184 segments. Each segment was assigned to one of the five paving groups defined in Chapter 1.

3.5.2. Data Collection Vehicle

A survey vehicle equipped with digital cameras was used to collect survey images, which were analyzed for distress at specialized workstations. A laser profilometer mounted on the survey vehicle was used to collect pavement roughness (profile) data. The distress and profile data were then loaded into the pavement management software, and the images linked to pavement management segments. The van-mounted camera and profiler system is manufactured by International Cybernetics Corporation (ICC). This equipment simultaneously collects digital images of the pavement surface and right-of-way, longitudinal profile data (pavement roughness), and transverse profile data (rutting). Additionally, the vehicle is equipped with a differential global positioning system (GPS) receiver and an inertial navigation system capable of measuring the location of the vehicle and the images with sub-meter accuracy. The ARA digital survey vehicle (DSV) is shown in Figure 3.1. The survey system characteristics are summarized in Table 3.1.

Pavement images were collected using the vehicle-based digital imaging system consisting of Bassler 2,000-pixel digital line-scan camera, a computerized controller, and pavement illumination mounted on a van. The digital line scan camera is mounted on the rear of the vehicle and records continuous images with a width of survey of 14.5 feet (4.4 meters). Both wheel paths are included in the image. The computerized controller synchronizes the digital camera speed to the speed of the vehicle to record distresses as small as 1-mm in width at speeds of up to 50 MPH with controlled illumination. The pavement image is divided into 20-foot segments and stored in JPEG format on 40 GB removable hard drives. Each drive can hold enough images to cover over 150 lane-miles of survey.

Figure 3.1. Digital survey vehicle.

The pavement illumination system consists of ten 150W metal halide stage lights mounted on a custom framework on the rear of the DSV. The lights are fitted with specialized lenses that focus the light into a narrow band of intense illumination directly under the digital line scan camera. The illumination system ensures consistent lighting during the survey process, and mitigates the effects of cloudy days and shadows.

A Class I, 3-sensor, South Dakota-type Road Profiler, conforming to ASTM E950, was used for road roughness data collection. The profiler was mounted on the DSV used for digital image data collection, as shown in Figure 3.2. It uses three16-kHz Selcom lasers, accelerometers, and a DMI to collect pavement profile data.

Figure 3.2. Profiler on Digital Survey Vehicle.

Table 3.1. Survey system characteristics.

Survey System	Manufacturer	Camera or Sensor Type	No. of Sensors	Resolution or Accuracy	Survey Speed, Max
Digital Pavement Imaging System	International Cybernetics Corporation	Bassler Line-Scan Monochrome	1	2,000 pixels per scan line	50 MPH @ 20-ft image Intervals
Road Profiler	ICC	Selcom, 16 kHz, Laser	3	0.002 inches	60 + MPH
GPS Receiver	Trimble	AG 132	1	10 meter, uncorrected	60 + MPH
Differential GPS	Applanix	DGPS	2	Sub-meter	60 + MPH
POS LV – X, Y Position	Applanix	N/A	1	0.50 m	15 sec signal outage
POS LV – Z Vert. Pos.	Applanix	N/A	1	0.50 m	15 sec signal outage
Roll & Pitch	Applanix	N/A	1	0.07 degrees	15 sec signal outage
True Heading	Applanix	N/A	1	0.07 degrees	15 sec signal outage
Windshield & Shoulder Images	ICC	Color, Digital Video Camera	3	1300 by 1024 pixels, each	60 + MPH @ 25-ft intervals
Distance Measuring Instrument	ICC	N/A	1	1-ft per mile	60 + MPH

3.5.3. Pavement Distress Data

Distress data were obtained by analyzing digital images of the pavement segments for distresses. The DSV was used to collect images of all Metro street segments. Figure 3.3 is a typical pavement image. A test section of roadway located in Nashville was used for verification and quality control of pavement distress analysis. Detailed distress data were collected for this section prior to starting data collection. Thereafter, the site was surveyed every week or every 500 miles.

Periodically, the digital images from the DSV were shipped to the data processing center in Harrisburg, PA. The images were merged into the master project database for data reduction. The data were reviewed to ensure that the images were complete and of good quality, and that the segment limits were marked properly. Any necessary revisions were made and the images were made available for pavement distress data reduction. If necessary, the pavement images were re-collected.

Pavement distress data reduction was performed at specialized workstations. Each workstation has three monitors. One monitor displays a scale pavement image; the second displays two ROW images, while the third displays the program controls and data entry screen. The images for each segment were viewed and the data entered into the project database. Trained pavement distress raters performed the distress data reduction using ASTM Standard D6433-99 (PCI for Roads and Parking Lots). Fifty percent of the pavement images were analyzed. The data collected was summarized in a format that could be loaded into the Cartêgraph PAVEMENT*view* Plus pavement management software.

3.5.4. Right-Of-Way Images

ROW images were collected at 20-foot intervals using 1300 pixel by 1024 pixel digital color cameras. The primary ROW camera was pointed straight ahead of the survey vehicle. The secondary ROW camera was pointed towards the right shoulder for a view of assets not located on or directly above the pavement, such as roadside signs. ROW images are linked to pavement images and other data collected by the DSV using GPS or distance-measuring instrument data. Figure 3.3 is a sample image from downward camera while Figures 3.4 through 3.6 are sample ROW images.

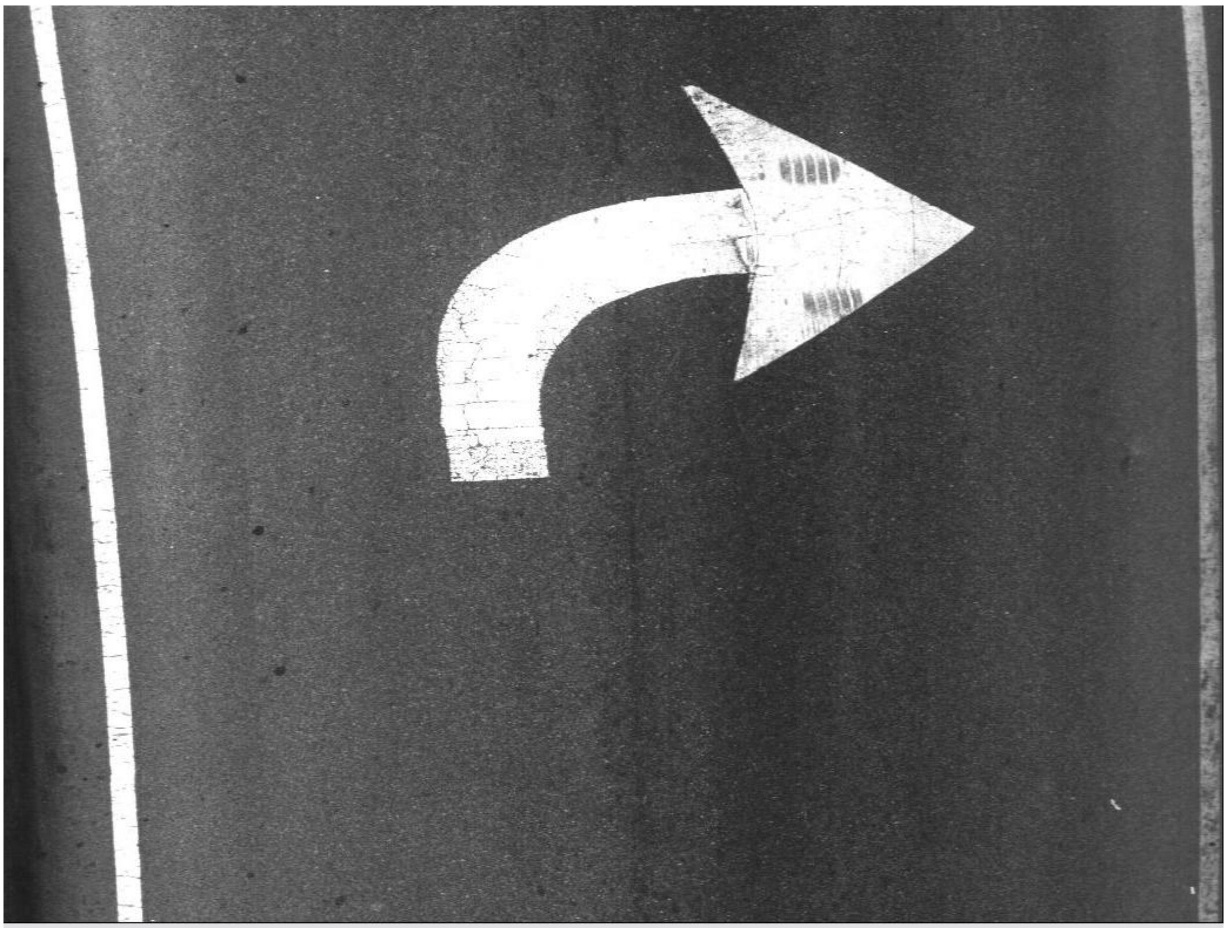


Figure 3.3. Sample image from downward camera.

Figure 3.4. Primary ROW image.

Figure 3.5. Secondary ROW image.

Figure 3.6. Reverse ROW view image.

3.5.5. Road Roughness Data

The International Roughness Index was calculated from the profile data. Rut depth was also calculated by comparing profile data from each wheel path to the center sensor. Software simulates placing a straightedge across the wheel paths and measuring the rutting from this reference.

Profile measurements at were collected at intervals of approximately 3 inches. The laser sensors have a height resolution of 0.002 inches. The system uses the continuous 16-khz output of the lasers to determine the height points, a process that eliminates narrow cracks and openings from roughness calculations.

Industry standard reporting software, developed by ICC and UMTRI, were used to convert the sensor and accelerometer readings into longitudinal profiles and calculate IRI in accordance with ASTM E1926-98.

ARA data collection equipment is periodically calibrated at profiler validation sites in Harrisburg, PA. These sites are chosen and maintained by the Pennsylvania Department of Transportation. The sites have been selected by PennDOT to cover the range of roughness applicable to most highway systems. The profiler equipment traverses each site three times. The IRI for each run at each site is determined by using the software developed by ICC. These IRI values were averaged. The average IRI for each site was compared with the reference IRI for that site to verify accuracy. In addition, the IRI value for the individual runs of each site were compared with the average IRI of that site to verify repeatability. The internal QA accuracy requirement is +/- 5%.

A test site for roughness verification was also established in Nashville for quality control. The site was surveyed every week or every 500 miles. The results of each survey were compared with the initial reference values to verify accuracy and repeatability.

3.6. OVERALL CONDITION INDEX

PMS software stores, sorts, and analyzes large amounts of many different types of data. This data must be represented in a manner to allow human pavement managers compare the relative quality of pavement sections to make a decision about M&R and funding priorities. The overall condition index (OCI) is a single number representing the condition of a pavement section based on all the data available for that section. The Metro PMS is set up such that the OCI ranges from 0 to 100, with a 0 OCI indicating failed pavement and a 100 OCI indicating perfect pavement.

CartêGraph allows the user to combine several condition indices (cracking, rutting, surface distress, roughness, etc.) to calculate the OCI. Originally, the OCI defined for Metro was a combination of a surface distress rating and rideability. Surface distress was measured using the PCI methodology, which reflects surface condition, rutting, and structural cracking. Rideability was measured using the International Roughness Index (IRI), which reflects ride quality. Since IRI is measured in in/mi with smaller numbers representing a smoother ride and PCI is measured on a 0 to 100 scale with 100 representing a pavement with no distress, one of these measures had to be altered. Since OCI corresponded to a 0 (bad) to 100 (good) scale, IRI was normalized to the same scale. While the CartêGraph database used this normalized 0 to 100 rating for IRI in these calculations, the original value is also stored for later analysis, if necessary

OCI was calculated using a simple weighted average:

$$OCI=(0.80PCI)+(0.20IRI_n)$$

where:

PCI is the segment PCI

IRI_n is the normalized IRI (see Section 3.6.3)

This equation applies weighting factors to the PCI (80%) and IRI (20%) so that the OCI properly represents the impact of both indices on pavement performance and serviceability.

As it was implemented, Metro noted that there was a factor that was not accounted for in the OCI: the raveling on the road. This value is important because a raveled segment of pavement with limited amounts of other surface distresses can be treated inexpensively while significantly increasing the segment’s remaining life. Typically, raveling is considered a distress in the PCI methodology with a very high deduct value. In other words, in the professional opinion of Metro staff, entering raveling as a PCI distress would reduce the PCI and OCI by too much. It was determined that the best way to generate an OCI was to include raveling/weathering as a third term in the OCI calculation equation. More information regarding the measurement of raveling can be found in section 3.6.2.

A final modification to the OCI was made due to the method used to evaluate raveling: segments less than five years old may have incorrect raveling values if an open-graded asphalt mix was used to pave the segment. Based on this, the current equation for OCI is:

If Age < 5 or R_n is null:

$$OCI=(0.88PCI)+(0.12IRI_n)$$

Otherwise:

$$OCI=(0.75PCI)+(0.10IRI_n)+(0.15R_n)$$

where:

Age is the time since the last major rehabilitation

PCI is the segment PCI

IRI_n is the normalized IRI according to Table 3.7

R_n is the normalized raveling according to Table 3.6

Deflection data has been used by the Metro to determine the structural integrity of the pavements, but this is very costly at the network level. Roads that carry heavy tractor-trailer vehicles may need periodic evaluation using deflection data. For most roads in the Metro network, deflection data is not warranted on a network level basis. Deflection data can be collected more cost effectively on a project level basis when the distress data indicates a possible structural deficiency.

3.6.1. Pavement Condition Index

The PCI method is a distress based condition index, i.e., specific distresses in the pavement are identified and tallied, and the type, severity, and extent of each distress is used to calculate a single number representing the pavement condition. This number is a composite value representing both structural integrity and serviceability, with higher numbers reflecting better pavement. A distress is any pavement condition that causes a loss of serviceability. Typical distresses include cracks, ruts, and bumps. ASTM D6433 defines 38 distinct distresses; 18 for AC pavements and 18 for PCC pavements as listed in Table 3.2. Most distresses have three severity levels defined by the standard: high, medium, and low.

3.6.1.1. Development of PCI Procedure

The pavement condition index (PCI) method of rating the condition of both asphalt surfaced and concrete surfaced pavements originated with the U.S. Army Corps of Engineers. It has found widespread acceptance and implementation throughout the U.S. for roadway pavements at the state, county, and municipal levels. The procedure has been standardized in ASTM D6433.

The first step in calculating the pavement condition index (PCI) of a sample unit is to determine the distress density, which is the percent coverage of a distress. Density is determined by dividing the quantity of a distress by the size of the sample unit. The densities for each distress type are then used to obtain a deduct value for each distress. A deduct value is a number that reflects how much a distress degrades pavement performance. Charts for determining deduct values for each distress, as a function of distress type, severity level, and density, is located in the appendix of ASTM D6433.   Table 3.2 gives a list of the distress types that re defined in ASTM 6433 for both asphalt and concrete surfaced roads.

Table 3.2. Distresses in AC and PCC pavements as defined by ASTM D6433.

AC Distresses	PCC Distresses
Alligator cracking	Blow-up
Bleeding	Corner break
Block cracking	Divided slab
Bumps and sags	Durability cracking
Corrugation	Faulting
Depressions	Joint seal damage
Edge cracking	Lane/shoulder drop-off
Joint reflection cracking	Linear cracking
Lane/shoulder drop-off	Large patches
Longitudinal and transverse (L&T) cracking	Small patches
Patching and utility cuts	Polished aggregate
Polished aggregate	Popouts
Potholes	Pumping
Railroad crossing	Punchout
Rutting	Railroad crossing
Shoving	Scaling
Slippage cracking	Shrinkage cracking
Swelling	Corner spalling
Weathering/raveling	Joint spalling

The early form of the PCI calculation was to simply sum all deducts and subtract this total from 100 as:

$$PCI = 100 - \sum AllDeducts$$

This simple computation of the PCI was initially incorporated into most PMS software including the CartêGraph software that was installed for the Metro.

But implementation of the PCI process by the Corps of Engineers (and other agencies) on both roads and airfields showed that when there were multiple distresses in a sample unit, the simple calculation above resulted in PCI values lower than the ratings of field experts. Therefore, an adjustment procedure was developed to bring the PCI into agreement with the performance rated values. A corrected deduct value (CDV) concept was first added to the calculation process, and then a limit on the number of distress types that could be included was added. These corrections were made over a number of years as experience was gained with the PCI procedure.

The equation below limits how many deducts can be applied to a sample unit during calculation of the PCI:

$$m = 1 + \frac{9}{98}(100 - HDV)$$

where:

m = number of allowable deduct values

HDV = highest individual deduct value

No more than ten deduct values may be applied to any given sample unit.

The deduct values are summed to determine the total deduct value, and the number of deduct values greater than two is counted and termed *q*. The total deduct value (TDV) and *q* are used to find the CDV from a chart. Then the lowest deduct value greater than two is changed to five and the process is repeated. This cycle continues until *q* = 1, that is, there is only one deduct value greater than two. The largest corrected deduct value is then subtracted from 100 to determine the PCI of the sample unit. The modified PCI procedure is illustrated in Figure 3.7.

The adjustments to the procedure result in a somewhat higher PCI value because some distresses are dropped from the calculation when there are multiple distresses present and the TDV is reduced to the CDV. The CDV correction had already been added to the CartêGraph software delivered to the Metro Nashville in 2004, and the limits on the number of deducts was added in early 2006.

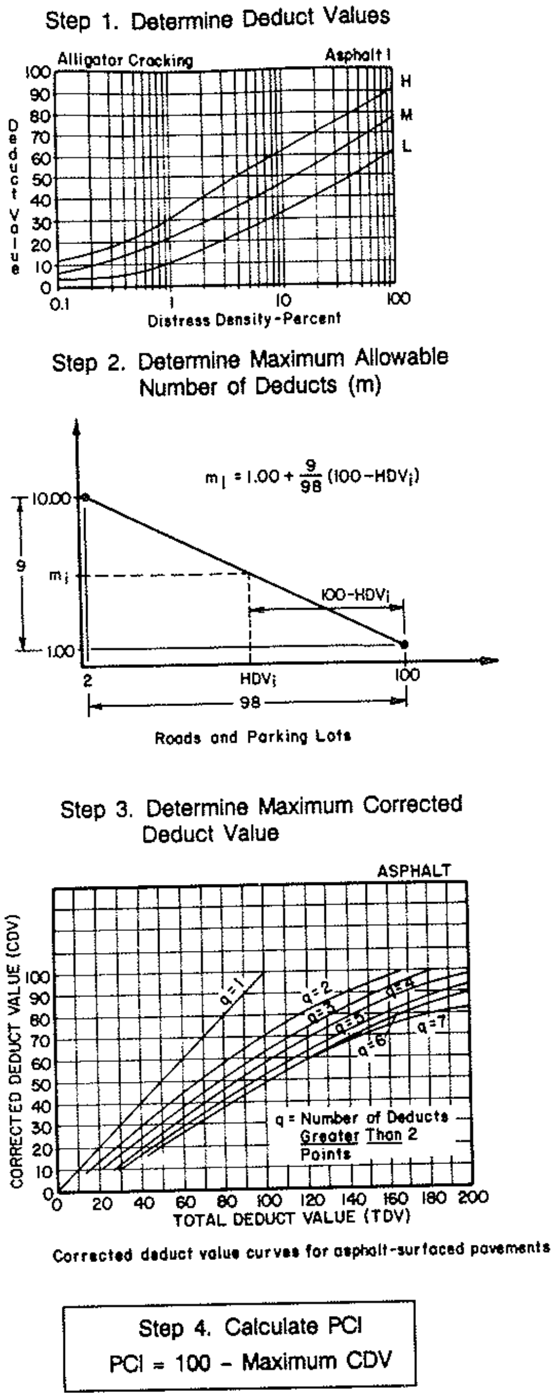
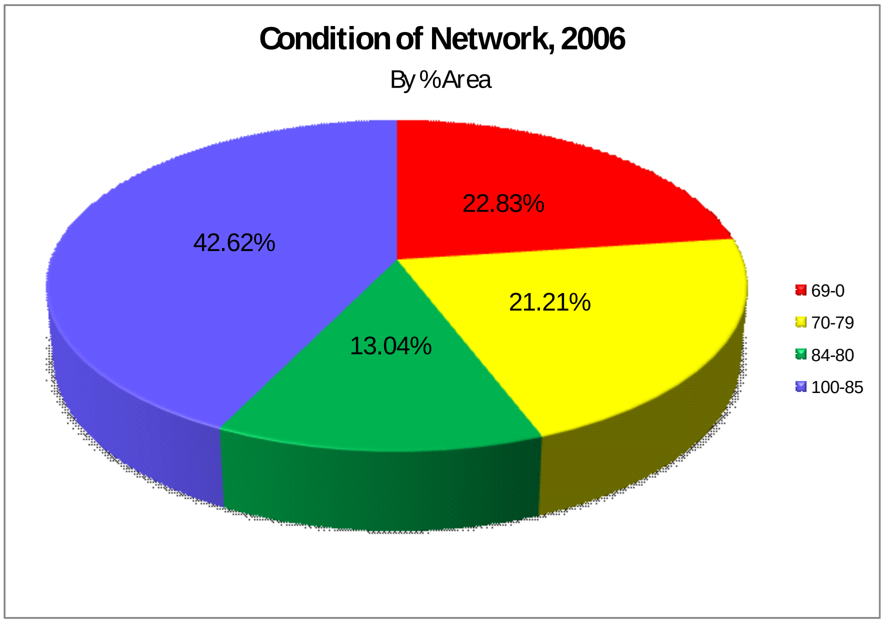


Figure 3.7. Illustration of PCI procedure.

The pie charts in Figure 3.8 show an increase in the overall condition of the Metro Nashville pavements from 2006 to 2007; i.e., the percent of roads in the 85 – 100 range increased from 42.62 percent to 45.53 percent. Both year's conditions are based on identical evaluation procedures. The improvement in condition is likely due to an aggressive, state-of-the-practice paving program and the implementation of a pavement rejuvenation program.



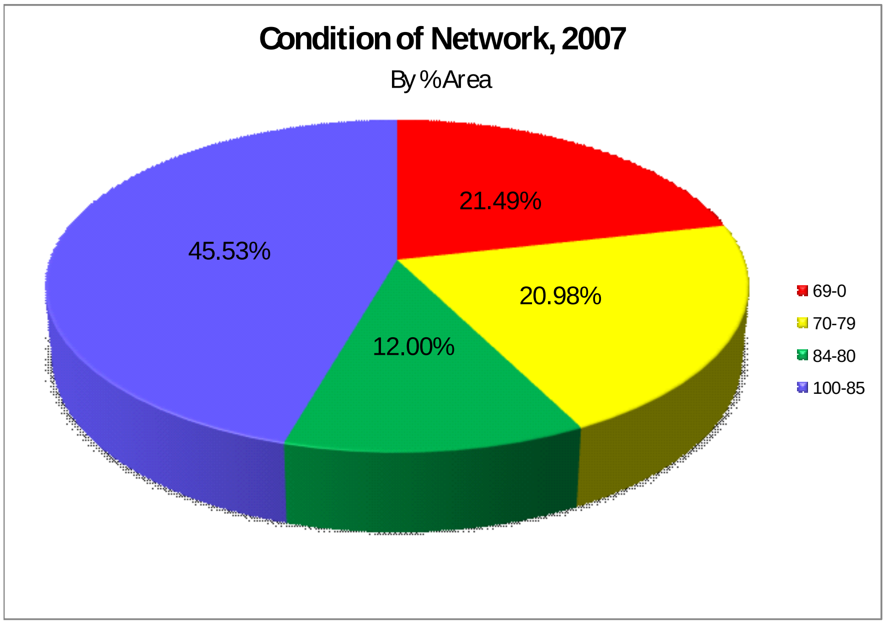


Figure 3.8. Latest condition results for Metro Nashville.

3.6.1.2. Implementation of PCI Procedure

A modified ASTM D6433 standard was used to determine the PCI for Metro roads. ASTM D6433 was developed using manual survey methods. This survey used automated methods, which detect certain distresses, particularly rutting, better than manual methods. To account for this, the deduct values, which reflect the loss of serviceability caused by a distress, were adjusted to account for the increased volumes of rutting detected. The adjustment factors shown in Table 3.3 were applied to the rutting deduct value tables to reduce the impact of rutting on the PCI.

Table 3.3. Rutting deduct value adjustment factors.

Rutting Severity	Adjustment Factor
Low	.100
Moderate	.143
High	.222

The process of determining the PCI of a pavement is highly repeatable. Distresses are objective and quantifiable; calculations for determining the PCI of a pavement are standardized. There is no room for differing “expert opinions” of the impact of a given distress on serviceability. A given set of distresses will always result in the same PCI. It is possible to achieve a 95% confidence interval of less than five PCI points even when less than 15% of the pavement has been examined.

The PCI value of a pavement is determined by visually inspecting a segment of pavement and recording distress types and severities present. Each distress type, severity, and amount has an associated deduct value, reflecting the decrease in serviceability caused by that distress. The deduct values are totaled and adjusted for the amounts and types of distresses. The resulting number is the PCI for that pavement segment.

Each pavement segment must either be surveyed in its entirety, or broken into sample units for statistical sampling. A sample unit is a portion of a segment that is a convenient size for counting distresses. Sample units, in accordance with the ASTM standard, should be between 1500 ft^2 and 3500 ft^2 in size. If an image-based survey method is used, images frames should be combined to form appropriate size sample units. This survey analyzed 50% of the image frames for distresses.

Statistical sampling allows calculation of the PCI of a pavement without measuring every single distress located on that pavement. Statistical sampling is often used for network-level surveys. A network-level survey is a "snapshot" of the condition of the entire network, used to determine pavement rehabilitation needs and priorities. Network-level surveys differ in scope and detail from project-level surveys, which are used to determine project extents and rehabilitation activities. Project-level surveys are typically performed on segments identified as candidates for rehabilitation by a network-level survey.

3.6.2. Determination of Raveling

Raveling on the streets and roads of Nashville has presented a challenge to the extent that more than half of the network is affected, but it is very difficult to quantify from the digital images. A separate manual survey for raveling is very expensive. A special study was made using on-board lasers to measure surface texture and then the measurements were correlated to raveling determinations made by manually surveying selected street segments.

According to ASTM D6433 , the definition of raveling and rating of severity levels is:

Weathering and raveling are the wearing away of the pavement surface due to a loss of asphalt or tar binder and dislodged aggregate particles. These distresses indicate that either the asphalt binder has hardened appreciably or that a poor-quality mixture is present. In addition, *raveling may be caused by certain types of traffic, for example, tracked vehicles. Softening of the surface and dislodging of the aggregates due to oil spillage also are included under raveling. Severity levels are defined as:*

- *Low - Aggregate or binder has started to wear away. In some areas, the surface is starting to pit. In the case of oil spillage, the oil stain can be seen, but the surface is hard and cannot be penetrated with a coin.*
- *Medium - Aggregate or binder has worn away. The surface texture is moderately rough and pitted. In the case of oil spillage, the surface is soft and can be penetrated with a coin.*
- *High - Aggregate or binder has been worn away considerably. The surface texture is very rough and severely pitted. The pitted areas are less than 10 mm (4 in.) in diameter and less than 13 mm (1⁄2 in.) deep; pitted areas larger than this are counted as potholes. In the case of oil spillage, the asphalt binder has lost its binding effect and the aggregate has become loose.*

Identification of raveling from video images or by the data collection operator proved to be an inadequate procedure. Manual distress data collection using inspectors walking the roadway sections is time-consuming, costly, and unsafe.

The initial survey of the Metro network was made in 2004, with resurveys of parts of the network made in 2005 and 2006. The collection of raveling data with the automated survey method has not been satisfactory. Measurement of pavement texture using automated laser techniques was correlated to raveling.

The study to develop a correlation between texture and raveling was as follows:

1. Nashville personnel identified thirty-one (31) pavement sections that represent the full range of raveling expected. Consistent raveling within each section was also a criterion.
2. Nashville personnel quantified the severity and extent of raveling in each section. Two different personnel conducted independent manual “Foot on the Ground” evaluations at different times. The rating range for each section was none, low, or high. These values were considered ground truth.
3. The 31 sections were then evaluated with a 32-kHz laser sensor in the left wheel path to collect the macrotexture data. The data was summarized in 5-ft. intervals.
4. The method of analysis chosen was to determine the frequency distribution of the mean texture depth (MTD) values within each section and performed a correlation of MTD values at various percentiles with ground truth raveling values. Limiting MTD values for a determined percentile will be determined to identify the severity of raveling for each pavement section in Nashville’s highway network.

Criteria for determining the severity level of raveling in each pavement section was developed as follows:

1. The frequency distribution of the mean texture depth (MTD) values within each section was determined.

2. The MTD values at various percentiles were chosen for comparison to the ground truth raveling values for each test section.
3. Several limiting values of MTD for each percentile were chosen by inspection to determine none, low, and high severity raveling for each section.
4. Trial and error testing against the ground truth raveling values was performed to achieve the best percentile of MTD and the best Limiting Values.
5. The final step was to test the predicting MTD criteria against several hundred randomly selected pavement sections.

The manual survey of the 31 initial test sections had an exact agreement between the two raters on 21 of the sections (68%). This accuracy was expected due to the subjective nature of the evaluation. The severity levels used by Nashville are none, low, and high. Initially, the mean texture depth (MTD) was compared to each individual rater. The comparison was not favorable in either case. It was decided from a visual inspection of the analysis that a comparison would be more favorable if a medium level of severity for raveling was introduced. A severity level of medium was then assigned to any section where the level of severity was called low by one rater and high by the other. This modification resulted in an agreement of 28 of the initial test sections (90%). Table 3.4 shows the manual rating from the two individual raters and the combined rating with medium level of severity assigned, as defined above. The combined rating was taken as ground truth for further analysis.

Table 3.4. Raveling data.

Test Section	Rater 1	Rater 2	Combination of Rater 1 & Rater 2	MTD Frequency Distribution Percentages									
				95	90	85	80	75	70	65	60	55	50
52405	High	High	High	1.313	1.272	1.209	1.162	1.126	1.098	1.062	1.035	1.015	0.995
52510	None	Low	Low	1.065	0.925	0.877	0.843	0.809	0.795	0.775	0.762	0.748	0.737
52668	None	Low	Low	0.953	0.882	0.851	0.839	0.807	0.791	0.781	0.762	0.742	0.73
52845	None	Low	Low	1.02	0.965	0.915	0.869	0.853	0.835	0.811	0.793	0.779	0.764
53009	Low	Low	Low	0.807	0.766	0.733	0.724	0.704	0.692	0.676	0.654	0.63	0.62
53118	Low	High	Med	1.019	0.961	0.92	0.898	0.879	0.844	0.826	0.81	0.791	0.762
53347	Low	High	Med	1.339	1.077	1.003	0.966	0.885	0.86	0.85	0.829	0.809	0.795
53362	Low	High	Med	1.007	0.967	0.909	0.855	0.834	0.821	0.801	0.787	0.776	0.764
53467	Low	High	Med	1.169	1.006	0.975	0.919	0.914	0.908	0.866	0.855	0.834	0.818
53643	Low	High	Med	1.199	1.143	1.093	1.067	1.023	0.981	0.952	0.93	0.894	0.867
53794	Low	High	Med	1.131	1.046	0.997	0.958	0.931	0.904	0.891	0.868	0.839	0.808
53947	None	None	None	0.862	0.823	0.807	0.787	0.763	0.739	0.724	0.711	0.7	0.686
54044	Low	Low	Low	1.214	1.153	1.1	1.043	1.008	0.982	0.949	0.911	0.88	0.846
54087	None	None	None	1.01	0.949	0.903	0.876	0.839	0.809	0.792	0.776	0.756	0.743
54183	Low	Low	Low	1.119	0.955	0.913	0.869	0.847	0.825	0.76	0.741	0.719	0.708
54297	High	High	High	1.27	1.195	1.122	1.088	1.044	1.019	0.991	0.981	0.953	0.932
54298	High	High	High	1.215	1.07	0.999	0.967	0.92	0.904	0.892	0.875	0.863	0.85
54319	High	High	High	1.295	1.201	1.158	1.129	1.086	1.048	1.028	0.988	0.941	0.921
54351	None	None	None	0.838	0.788	0.744	0.719	0.703	0.69	0.678	0.663	0.653	0.646
57690	Low	Low	Low	0.879	0.855	0.839	0.809	0.794	0.769	0.757	0.737	0.716	0.706
57767	None	None	None	0.706	0.684	0.671	0.66	0.639	0.632	0.617	0.608	0.599	0.592
57835	None	None	None	0.836	0.796	0.755	0.716	0.708	0.697	0.685	0.673	0.662	0.648
57964	None	None	None	0.968	0.774	0.735	0.723	0.709	0.698	0.68	0.668	0.657	0.636
57965	None	None	None	0.786	0.758	0.725	0.715	0.703	0.695	0.671	0.66	0.652	0.635
57997	Low	Low	Low	0.881	0.815	0.799	0.774	0.756	0.744	0.732	0.721	0.708	0.691
58066	None	None	None	0.891	0.866	0.817	0.799	0.778	0.759	0.751	0.736	0.728	0.716
58067	None	None	None	0.833	0.805	0.774	0.744	0.735	0.707	0.696	0.681	0.665	0.658
58100	None	None	None	0.838	0.8	0.769	0.748	0.733	0.718	0.69	0.681	0.66	0.649
58835	Low	Low	Low	1.061	0.955	0.895	0.876	0.861	0.838	0.819	0.801	0.787	0.777
61466	Low	Low	Low	0.884	0.851	0.823	0.801	0.77	0.758	0.738	0.725	0.717	0.708
63652	Low	High	Med	1.668	1.5	1.387	1.282	1.231	1.193	1.15	1.1	1.062	1.023

The MTD values at the 50, 55, 60, 65, 70, 75, 80, 85, 90 and 95th percentile for each test section versus the ground truth raveling values are also shown in Table 1. The average MTD values were calculated for None, Low, Med, and High severity levels for each of the percentile groups. These average MTD values were used to make the initial range of MTD values for each level of severity. This analysis showed the 75th percentile of MTD values to be the best predictor of the level of raveling severity.

The next step was to use the 75th percentile MTD values and refine the ranges to increase the prediction accuracy. This was accomplished through trial and error variations of the ranges of MTD values for each level of raveling severity. The accuracy of the prediction of the severity level to the ground truth raveling values was increased to 61%.

ARA and Nashville personnel judged this procedure to be very promising for identifying and quantifying raveling.

The MTD criteria chosen are:

1. *The MTD value at the 75th Percentile Level*
2. *MTD values for various severity levels of raveling*
    a. *None - <0.75*
    b. *Low - =0.75 & <0.85*
    c. *Medium – =0.85 & <0.89*
    d. *High -- = or >0.89*

As a further test of the acceptability of this procedure, 517 randomly selected pavement sections were chosen for evaluation. The MTD criteria were applied to the 517 test sections and the level of raveling determined. The comparison was made to an experienced rater who manually surveyed the sections with the following instructions:

a. If you can reasonably agree with the rating as generated from the MTD criteria, rate the section the same.

b. If you ***cannot*** reasonably rate the section the same, provide a new rated value for raveling on that section.

The results of the comparison of the MTD criteria to ground truth on the 517 randomly selected sections are shown in Table 3.5.

Table 3.5. Field test results on 517 Metro pavement sections.

Section Analysis Summary	No. of Sections
Texture Criteria 2-severity levels > Manual Survey	6
Texture Criteria 2-severity levels < Manual Survey	4
Texture Criteria 1-severity level > Manual Survey	39
Texture Criteria 1-severity level < Manual Survey	37
Texture Criteria Exact Match to Manual Survey	431

As can be seen from Table 3.5, 431 out of the 517 pavement sections had exact matches between the MTD criteria and the manual survey. This provided an accuracy level of 83%. Based upon the analysis and the subjective nature of determining the severity levels of raveling, the MTD criteria were judged to be an excellent indicator of the severity of raveling and are currently implemented in Nashville. Also, Table 3.5 shows that only 10 pavement sections had 2-severity levels difference between the two methods.

To calculate OCI, a raveling severity must be normalized to a 0 to 100 scale similar to the normalization performed for IRI (see Sections 3.6 and 3.6.2). Normalized deduct values for raveling are shown in Table 3.6.

Table 3.6. Raveling deduct value adjustment factors.

Raveling Severity	**Normalized Deduct Value, R_n**
None	100
Low	67
Moderate	33
High	0

3.6.3. International Roughness Index

IRI is a measurement of ride quality, expressed as the amount of vertical travel a given road will create in a standard suspension assembly. Results are typically expressed in terms of inches per mile. Higher values indicate more suspension travel, and therefore a lower ride quality. New pavement typically has an IRI of approximately 75 in/mile to 100 in/mile. IRI values above 300 are normally considered rough. The most accurate method to determine IRI is to calculate it using profile information collected from the rutting sensors on the survey vehicle.

IRI data were normalized to a 100-point scale so that it could be included in the OCI. To normalize the data, the data were plotted on a histogram to determine the range and distribution of IRI within the network. Normalized IRI values were then assigned to IRI ranges based on the scale in Table 3.7.

Table 3.7. Normalized IRI values.

IRI	**IRI_n**
0	100
100	90
150	80
200	70
250	60
300	50
350	40
400	30
500	20
600	10
800	0

3.7. FINANCIAL DATA

3.7.1. Budgets

Budgets are defined by three factors: the year of the plan, the type of budget, and the amount available for that type of budget and year. Some agencies only have one type of budget for their networks; in Metro Nashville's case there are two. The first budget is for state-aid roads: roads where Tennessee pays for part of the pavement repair. The second budget is for the remaining roads in the network where repairs are fully funded by Metro. Budget data are typically determined from previous years funding levels and adjusted for any anticipated changes. A budget must be defined for each year the software is developing a plan.

3.7.2. Costs

The CartêGraph software can accommodate an array of pavement preservation, maintenance, and rehabilitation activities. Unit costs are associated with each activity, and the unit costs are multiplied by the area of the street selected for repair to calculate the total cost of M&R. In addition to unit cost, the type of budget that this activity draws its money from must be specified. If multiple budget types can be used, copies of the same activity must be specified. Table 3.8 lists the unit costs used for the M&R treatments selected by Metro. These costs were developed by reviewing bid tabs and work order histories for projects completed by Metro in the past two years.

Table 3.8. Unit costs for maintenance activities.

Maintenance Activity	Unit Cost
Milling of AC surfaces	$19 ton
1.5-in AC Overlay - D Mix (PG64-22)	$3.04 sy
1.5-in AC Overlay - E Mix (PG64-22)	$2.81 sy
1.5-in AC Overlay – E Warm Mix	$4.22 sy
1.5-in AC Overlay – A (PG64-22)	$2.36 sy
1.5-in Overlay – D Mix (PG76-22)	$3.57sy
Aggregate base, Grading D	$40 ton
Bituminous Tack Coat	$350 ton
AC - Crack Seal with routing	$2.00 lf
AC - Patching - Full Depth	$19.00 sy
AC - Patching - Partial Depth	$10.50 sy
Infrared Patching	$600.00 sf
AC - Reconstruct - Full	$20.50 sy
AC - Shoulder - Fill & Regrade	$2.50 sy
AC – Single Surface Treatment	$1.00 sy
AC – Double Surface Treatment	$2.00 sy
Rejuvenator Application	$0.64 sy
Soy based Asphalt Rejuvenator	$0.97 sy
Polymer Asphalt Rejuvenating Seal	$0.97 sy

3.8. GASB 34 REQUIREMENTS

GASB 34 stands for Governmental Accounting Standards Board Statement 34. GASB is the organization that provides guidelines for financial reporting by government entities. GASB 34 is a policy statement issued in 1999 recommending significant changes in the structure of financial reporting methods. One area greatly affected by GASB 34 is valuation of long-term assets, such as bridges, roads, and other infrastructure items.

Prior to 1999, all governmental assets were valued at their purchase (construction) price and depreciated a set amount each year. Annual depreciation on all assets was listed as an expense in financial report. Repairs to the asset were considered expenses, but any preservation or rehabilitation treatments, e.g., rejuvenators or microsurfacing, were considered capital expenditures that must also be depreciated. Under this system, a government had little financial incentive to preserve infrastructure items, as financial reports would show large capital expenditures with little or no improvement in serviceability observed by the average citizen.

GASB 34 introduced the concept of "perpetual assets" into accounting, i.e., assets that depreciate with serviceability, not time. The perpetual asset concept recognizes the reality that a 20-year-old road in satisfactory condition is just as valuable as a 2-year-old road in satisfactory condition. The road should not be depreciated and the depreciation listed as an expense simply because it is old. Instead, any preservation or rehabilitation maintenance to keep the road in satisfactory condition should be listed as an expense. This is known as the modified approach to reporting.

To be allowed to use the modified approach, an agency must have in place a system to evaluate and track asset condition, and assets must be maintained at a target serviceability level. The PMS system implemented by Metro exceeds the GASB requirements for tracking pavement condition, and the Metro pavement management program specifies inspecting 50% of the pavement network annually. Metro has selected a target serviceability level for the network of 70% of all pavements having an OCI greater than 70.

3.9. CURRENT NETWORK CONDITION

The Metro street network consists of 25,577segments defined out of 2,320 centerline miles. The area-weighted average OCI of all streets in the network is 81.26. All paving groups exceed the GASB target serviceability level, as shown in Table 3.1 and Figure 3.9. The most common distress is low severity rutting, followed by linear cracking, patching, and medium severity rutting.

Figure 3.10 is a map of the Metro highlighting the current conditions of Metro roads. Green indicates the roadway is in satisfactory condition (OCI of 70 or above) and red indicates unsatisfactory condition (OCI below 70). Non-metro roads are shown in gray.

Table 3.9. Network Condition Summary.

Paving Group	**% of Network with OCI > 70**		
	By Segment	**By Area**	**By Lane Mile**
Group 1	74.1%	73.2%	72.9%
Group 2	84.2%	81.3%	81.6%
Group 3	72.1%	71.8%	70.0%
Group 4	82.3%	82.6%	83.5%
Group 5	84.4%	82.5%	82.4%
All Groups	79.4%	78.5%	78.6%

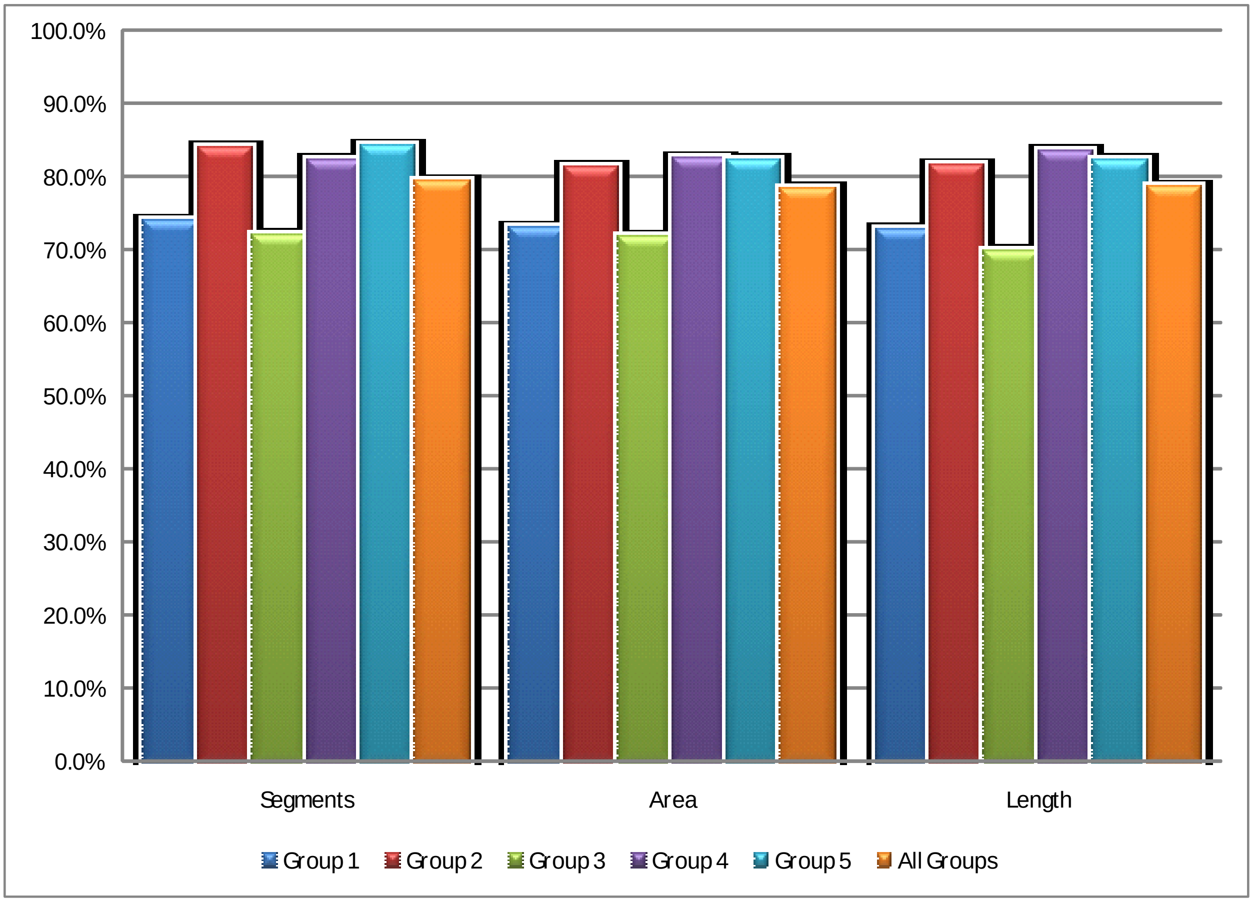


Figure 3.9. Percentage of network with OCI > 70.

3.10. DETERIORATION MODELS

Deterioration models are used to estimate pavement condition in future years. This allows the software to determine the likely M&R needs for pavement segments several years into the future. Deterioration models, often referred to as "family curves" are developed by regression analysis of age-vs.-condition data for a group of similar pavements. Deterioration models for individual condition categories can be specified in the table shown. The OCI deterioration model is then calculated by the program using the weights of individual condition categories. The family curve can then be used estimate the future condition of pavements similar to the ones used to build the family curve, as illustrated in Figure 3.11.

Four deterioration curves were developed for Metro based on functional class: major arterial, minor arterial, collector, and local. Functional class data were provided by the zoning commission. Zoning commission data were used to increase the level of integration among the data in the Metro GIS. Curves were developed using non-linear regression techniques on approximately 11,000 age-condition data points. Figure 3.12 shows the four Metro pavement deterioration curves.

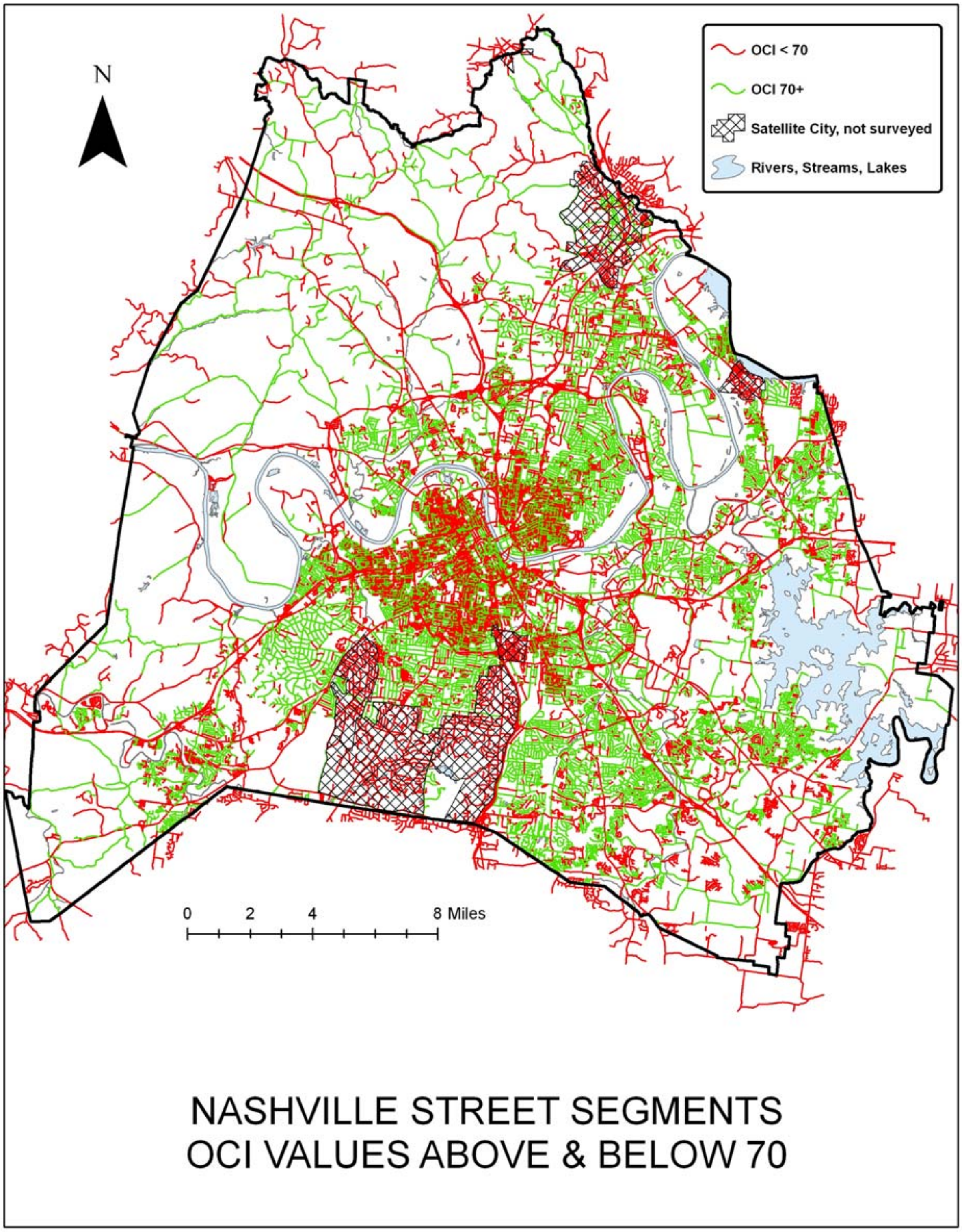


Figure 3.10. Color-coded map of Davison County showing OCI ranges of roadways.

All pavements tend to deteriorate at approximately the same rate until about 8 years of age, after which point arterial pavements tend to deteriorate faster than local and collector pavements. The prediction curves indicate that major arterial streets deteriorate below an OCI of 70 (unacceptable condition) in slightly more than 10 years. Minor arterial streets fall to an OCI of 70 in approximately 12 years. Local and collector streets remain above an OCI of 70 for more than 15 years.

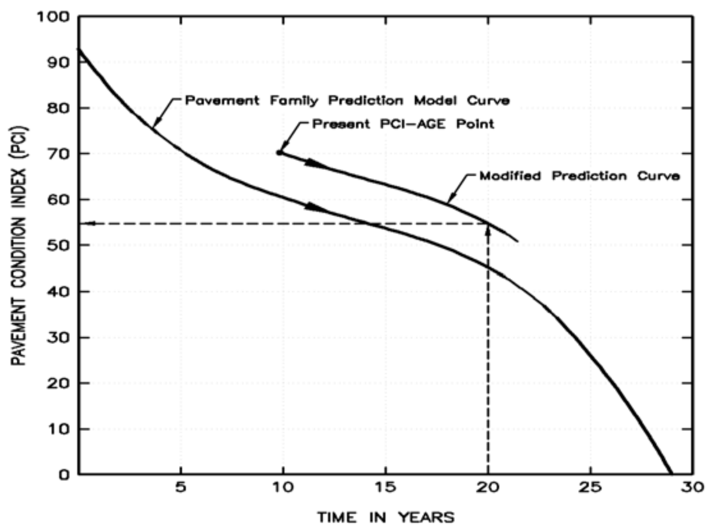


Figure 3.11. Predicting pavement condition.

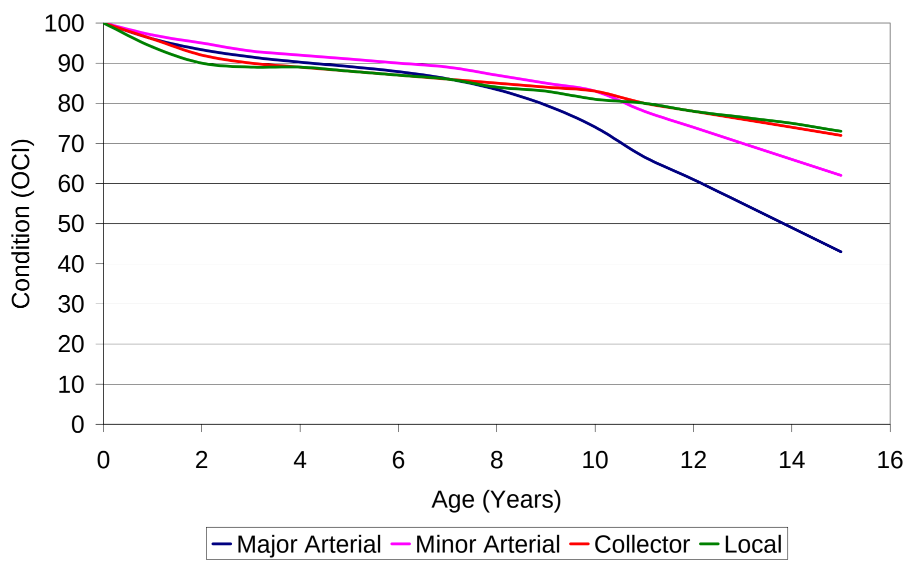


Figure 3.12. Metro Nashville deterioration curves.

This page intentionally blank.

CHAPTER 4

PAVEMENT MANAGEMENT PROCESS

4.1 ROLE OF THE PMS SOFTWARE AND PAVEMENT MANAGER

The Pavement Manager will ensure the PMS software is properly maintained and that pavement condition data will be collected on a regular basis. Construction history data must be updated as projects are completed. Utility holds and other stops must be entered into the system. Other data, such as bike lanes, bus routes, and any other data affecting paving schedule decisions must be updated in the PMS.

Once the required data has been gathered, the PMS software develops an M&R plan based on pavement condition, M&R policy, and available budget. CartêGraph PAVEMENTview Plus PMS software uses a two-step treatment selection process. The first step is to determine all technically appropriate M&R treatments available to maintain or improve a segment. Some segments may have multiple technically appropriate treatments. CartêGraph PAVEMENTview Plus uses a treatment selection matrix for this process. The next step is to determine which segments (and in the case of multiple possible treatments for a segment, which treatments) are actually recommended for treatment based on the available budget and the network priority rating calculations. These segments and their associated recommended treatments make up the work plan. Figure 4.1 is a schematic showing the process used by the software to develop a work plan. The plan estimates both the type of work required on each segment, and the required budget. The list of projects generated typically covers multiple years and is prioritized by segment to provide the maximum benefit to the pavement network.

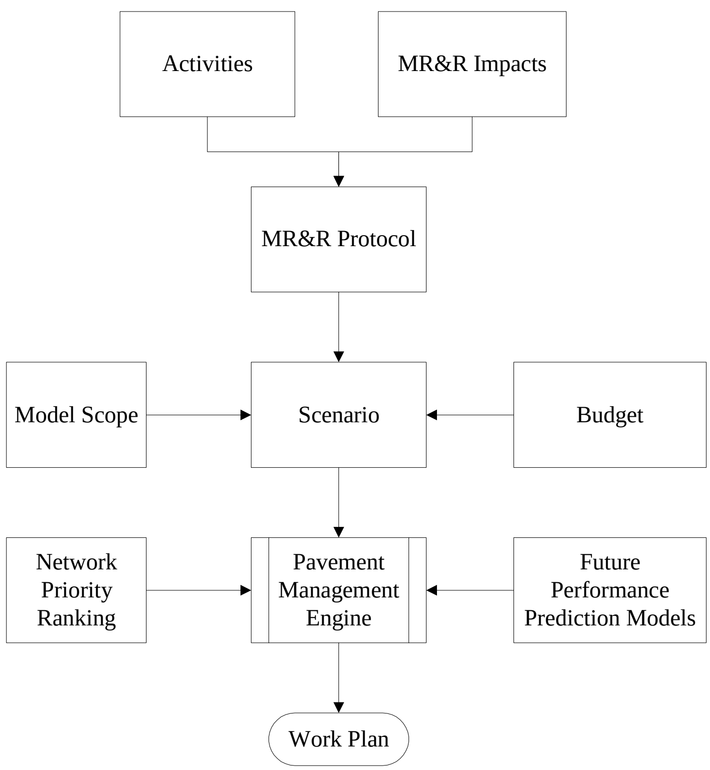


Figure 4.1. Flow chart illustrating PMS process.

The Pavement Manager then takes the M&R work plan recommendations from the PMS software and determines the best way to implement them. This typically involves combining adjacent segments into projects for bidding. Oftentimes M&R on a segment will be promoted from an out-year project to a current year project based on factors too complex for the PMS, such as an adjacent construction project or contingency funding. Paving projects are subject to the limitation that the area-weighted average condition of all segments in a project should be less than 70. While the paving manager has discretion as to when and how to apply the software recommendations, the software ensures that a street or neighborhood is not "forgotten."

4.2 DATA PROCESSING

Figure 4.2 shows the combination of processes used to take existing Metro data, collect and process new data, and combine it into a final deliverable that can replace or augment the existing pavement management data store. The following sections describe each process and provide additional information where needed. Details regarding the major work activities (as identified in Figure 4.2) are covered in other sections of this report.

4.2.1 Existing Data

The pavement management store consists of three distinct parts:

- Database – A database in Microsoft SQL Server 2000 format that can be used along with the CartêGraph PAVEMENTview and PAVEMENTview Plus application. This database stores all the required attributes (route, from, to, pavement type, etc.) for each pavement management segment in the Metro network. It also stores current and historic condition measurements and a construction history for the pavement segment.
- GIS – The GIS, based on the street centerline maintained by the planning department, contains general attribute data and specific locations for each pavement segment in the Metro network. .
- Images – Each time a pavement segment is surveyed, digital images are collected according to the protocols established in this report. Historic images (images from surveys not related to the most recent inspection) are kept in the system for comparative purposes.

4.2.2 Routing and Existing Data Evaluation

This step consists of the pavement management consultant examining the existing data for changes since the last survey was completed. These changes can be due to changes in ownership of particular segments, new segments accepted for maintenance, new attributes provided by planning or collected by Metro, and changes to the data due to changes in Metro's business processes.

Once the data have been checked and any changes addressed, a routing plan for the surveyors is created based on the previous year's actual survey routes, changes to the data, and known issues caused by things such as construction.

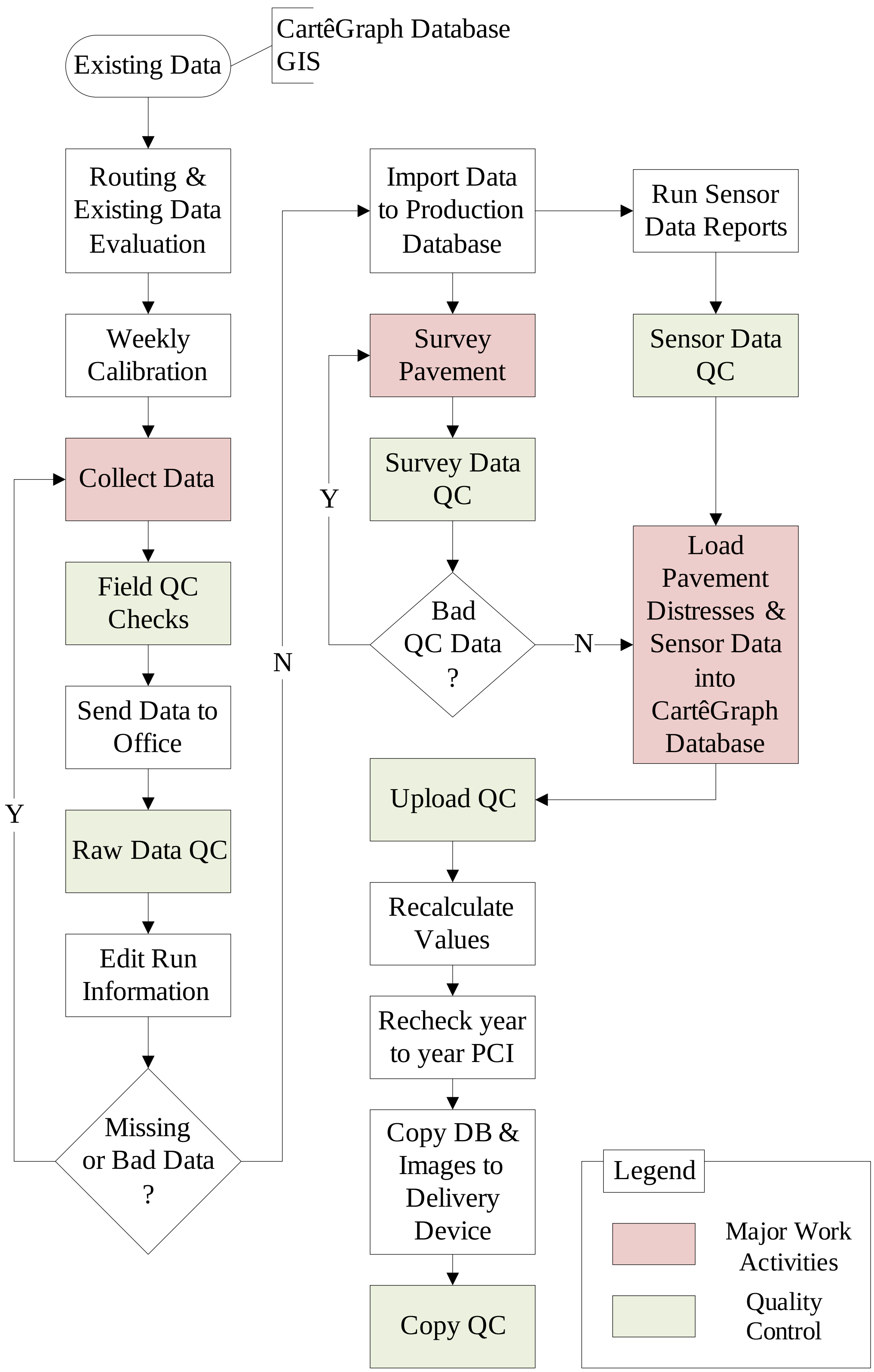


Figure 4.2. Flow chart illustrating data processing.

4.2.3 Calibration

Upon arriving with a survey vehicle in Nashville, our survey crew establishes an on-site calibration course to check the camera systems and vehicle sensors. The field crew performs these calibration tests themselves and checks the data for consistency in the field. If the calibration data passes the field QC data checks, it is sent to the consultant's offices for another QC check and archiving. This test checks for consistency; data accuracy is checked on the consultant's established course before the survey crew leaves their office.

4.2.4 Field QC Checks

Several checks are preformed in the field both during a survey *run* (a route of contiguous pavement segments that can be driven in less than half a day) and after the run has been completed. These checks include:

- Small images – If images (especially from the pavement camera) are far smaller than average, the field crew will check them in the on-board computer. This kind of error may occur when a piece of equipment is not working properly. It can also occur in poor lighting conditions.
- Preliminary image QC – As the vehicle is moving, the operator (the crew member sitting in the passenger seat) can view the images as they are taken by the various cameras on the survey vehicle. The operator will quickly evaluate if the images can be used for pavement surveys, virtual drives, signage surveys, and any other known purpose.
- Preliminary sensor data QC – Along with the images, the operator can also view the sensor data (georeference, rutting, ride, and texture) and check for inconsistent values (e.g. a low IRI value on rough pavement).

4.2.5 Data Transmittal

Data are sent to the consultant's offices at least twice a week for concurrent review on removable hard drives. A reliable vendor and special containers are used to assure minimum data corruption from poor handling of the hard drives.

4.2.6 Raw Data QC

While the field checks make data collection far easier, the survey vehicle moves at prevailing traffic speeds and collects images from four different cameras every 20 feet. Obviously, the operator cannot safely and effectively monitor all the data collected by the vehicle during or immediately after a run is completed. The raw data QC is meant to supplement the field QC. The following checks are performed on the data once it reaches our offices:

- All entries from the vehicle database are checked. This includes the georeference for each photo and each 528 foot (or less) entry for sensor data.
- Consistency between the vehicle database and the delivered images is confirmed. In other words, the consultant's personnel make sure there is a real photo for each photo entry in the vehicle database.
- 10% of the images collected in each run by each camera are checked for quality.
- Georeference data are compared to Metro's basemap.

- The distance between images is checked. Distances less than 19.5 feet or greater than 20.5 feet can indicate problems or small missed pavement areas.

Backup copies of the vehicle database and the associated images are also made during this step. Runs that fail these checks are sent back to the field crews to complete. These checks are preformed while the field crews continue their work on site.

4.2.7 Edit Run Information

To expedite the collection of data in the field, our operators will make annotations in vehicle database regarding small changes that need to be made. For example, if an operator started a run too early or misidentified a segment a note will be made. During this step, our office personnel make any changes noted by the operator or observed during the raw data QC. Any data that cannot be resolved using in-office editing is sent back to the field crews for recollection.

4.2.8 Sensor Data QC

Between pre-survey calibration, weekly calibrations, and field QC not much needs to be done in the sensor QC checks. Reports for each run are created based on the vehicle database and checked for values that are outside of a given range. In addition, the weekly calibration data is checked in the consultant's offices and comparisons are made between data collected in the current year and data collected in the previous year. These comparisons do require the consultant to collect a limited amount of data on random segments that are not scheduled to be surveyed in the current year.

4.2.9 Survey Data QC

Because there are several rounds of data collection in the database, the main method of quality control for surveyed pavement is comparison with prior year data. All data (100%) are checked against the last survey of the segment. An increase of more than 6 PCI or a decrease of more than 10 PCI flags a segment for review. A QC technician will review the current survey images and compare them to the previous survey. If the large difference is justified (e.g. the road was repaved) then the segment is marked as passing QC. Segments that fail this check are reanalyzed and reprocessed.

In addition to a comparison check, a 10% resurvey is performed for the entire surveyed network. If the PCI between the two surveys is not within 9 PCI, the segment is flagged for additional attention by the survey supervisor. The supervisor will determine the cause of the difference and address any issues as required. The resurveyed segment selection takes into account the run in which the data was collected, the surveyor, and the day it was surveyed.

4.2.10 Upload QC

Once the data has been uploaded into the existing database, a few checks are preformed to make sure there were no issues with the data transfer. Because of the large number of segments in the Metro database, this is a required step. The checks include:

- All expected data uploaded
- Distress extents within acceptable ranges (usually between 0 and 100)
- No duplicate distress-severity combinations

- No PCI values less than 0

4.2.11 Copy QC

Because there are so many individual files (over 1,300,000 in the 2007 deliverable) the final QC check is to make sure every single file has been transferred to the delivery media (usually an external USB drive). This is done using both number of files and total file size counts.

4.2.12 Tracking

The status of each pavement management segment is tracked as it progresses through data collection, analysis, QC and processing. This allows us to quickly determine the status of the field and office work.

4.3 ROLE OF THE OCI

OCI is the primary factor in treatment selection for MPW. Pavements with an OCI below 70 are flagged as candidates for an overlay or reconstruction. Pavements with a condition above 70 are flagged as candidates for crack sealing, surface treatment, or thin overlay depending on age and functional classification. Photos 4.1 through 4.8 show typical OCI 70pavements.

Photo 4.1. Forrest Avenue, segment 3747, block cracking, patching, and linear cracking.

Photo 4.2. Spence Lane, segment 27319, linear cracking, rutting, and roughness.

Photo 4.3. Tanglewood Trail, segment 8108, fatigue cracking, roughness, and patching.

Photo 4.4. Ordway Place, segment 5870, patching, rutting, linear cracking, and block cracking.

Photo 4.5. Piedmont Avenue, segment 34172, linear cracking, patching, and roughness.

Photo 4.6. Burkitt Road, segment 40524, rutting, weathering, edge cracking, patching, and fatigue cracking.

Photo 4.7. Lellyett Street, segment 5, rutting, block cracking, weathering, and linear cracking.

Photo 4.8. North DuPont Avenue, segment 13, rutting, patching, and linear cracking.

4.4 TREATMENT SELECTION MATRIX

Table 4.l shows the treatment selection matrix implemented by MPW. The treatment selection matrix is based on the guidelines used by the MPW paving office when selecting paving projects. The rules are summarized as follows:

- Pavements must have an OCI<70 to be a candidate for repaving.
- Pavements must have a curb to be recommended for milling prior to an overlay.
- Pavements must have an OCI<40 and structural distresses, or have an OCI<60 and high severity structural distresses to be a candidate for reconstruction.
- The grade of hot mix (HMA) used in an overlay is based on the functional class of the segment as follows:
    - RCW: Local streets
    - E-Mix: Collectors
    - D-Mix: Arterial
    - Polymer: Industrial
- Pavements must have an OCI<70 and be less than 10 years old to be eligible for crack sealing. Only residential and collector streets are eligible for crack sealing.

- Pavements must have an OCI<70 and be less than 7 years old to be eligible for surface seals (fog seals, chip seals, slurry seals). Surface treatments are not recommended for arterial pavements.
- Pavements must have an OCI<70 and be less than 5 years old to be eligible for surface treatments (penetrants and sealants). Only residential streets are eligible for surface treatments.

Table 4.1. Treatment selection matrix.

Condition	Treatment	Age (years)	Functional Class	Distresses	Other
OCI<critical	Crack Seal	<10	Residential Collector	L&T Block Edge Joint Reflection	N/A
OCI<critical	Surface Treatment (Penetrants and rejuvenators)	<5	Residential	N/A	N/A
OCI<critical	Surface Seals (chip seals and slurry seals)	<7	Residential Collector Commercial	N/A	N/A
OCI<critical	RCW Overlay (recycled mix)	N/A	Residential	N/A	No curb
OCI<critical	Mill/RCW Overlay	N/A	Residential	N/A	N/A
OCI<critical	E-mix Overlay	N/A	Collector Commercial	N/A	No curb
OCI<critical	Mill/E-mix Overlay	N/A	Collector Commercial	N/A	N/A
OCI<critical	D-mix Overlay	N/A	Arterial	N/A	No curb
OCI<critical	Mill/D-mix Overlay	N/A	Arterial	N/A	N/A
OCI<critical	Polymer Overlay	N/A	Industrial	N/A	No curb
OCI<critical	Mill/Polymer Overlay	N/A	Industrial	N/A	N/A
OCI<40	Reconstruction	N/A	N/A	Alligator Rutting Corrugation High Bleeding	N/A
40<OCI<critical	Reconstruction	N/A	N/A	High Alligator High Rutting High Corrugation High Bleeding	N/A

4.5 NETWORK PRIORITIZATION RATING CALCULATION

After CartêGraph PAVEMENTview Plus has developed a list of technically applicable treatments, the segments and associated treatments are prioritized according to the network prioritization rating (NPR) calculation. The NPR is a numerical index ranging from 0 for a low priority road segment to 100 for a high priority road segment. The NPR rating is computed by assigning weights, or importance factors, to various street parameters. MPW prioritizes segments according to functional class, OCI, and the paving hold list. The paving hold list can be used to delay a project or move the project timetable forward. Table 4.2 shows NPR component values for the three factors used by MPW.

Table 4.2. NPR component values.

Factor	Weighting Factor	Factor Value	NPR Value
OCI	25	Any	OCI
Functional Class	25	Arterial	100
		Collector	50
		Local/Other	25
Capital Project List (Hold List)	50	Delay	0
		None	50
		Move Up	100

Using an arterial segment with an OCI of 65 and no paving holds, the NPR for the segment is calculated as follows:

$$NPR = \frac{25 * OCI + 25 * FC + 50 * Hold}{100} = \frac{25*65+25*100+50*50}{100} = 66.25$$

A residential street with an OCI of 40 and paving hold would end up with an NPR of 16.25. In this case, the arterial would be worked on first even though its OCI is much higher.

This NPR selection method avoids a "worst-first" M&R plan. Worst-first plans focus on the very worst pavements, spending money on costly fixes for a few pavements while the remaining pavements are neglected, eventually requiring costly repairs. Under the method used in the Cartêgraph Pavementview Plus system, precedence is given to preventive M&R first. Pavements that are below the critical OCI but have not completely failed are recommended next, with completely failed pavements rehabilitated last. This results in money being spent to rehabilitate pavements before rehabilitation becomes prohibitively expensive. While the repairs of the very worst pavements are delayed, the delay does not significantly affect the cost of repairs.

This prioritization method results in more efficient use of resources by allocating money where it has the most impact and considering pavement deterioration in segments not immediately repaired. This method also considers the fact that pavements in better condition are often less costly to repair.

4.6 WORK PLAN GENERATION

Work plans are generated by listing segments in NPR order (from 100 to 0) and applying treatments until the budget for that plan year reaches zero. When the budget reaches 0, the software repeats the entire process for the next plan year.

The software does not stop generating projects at the first segment that cannot be rehabilitated because of lack of funding. For example, the unit cost to overlay a segment might be $\$3.75/ft^2$, the NPR is 75, and it has an area of 20,000 ft^2. At the point where this segment is considered for an overlay, there may be \$70,000 left to spend from the budget. Since the cost of the overlay is \$75,000, it is not programmed for this year. However, the next segment in the list might have an area of 10,000 ft^2 and an NPR of 74.6. While the first segment is not programmed, the second, smaller segment is programmed with a cost of $37,500. The program would continue going down the list looking for other segments that can be rehabilitated for less than $32,500 (what remains in the budget).

There are some other factors involved in the work plan generation. First, it is possible to have more than one budget. As in the example above, the program will keep trying to determine if there is money available to perform feasible treatments even after it finds segments that do not qualify because of budget limits. For example, Paving may run out of money in its "MPW Only" budget (where road rehabilitation is fully funded by MPW) but there still might be money in the "State-Aid" budget. In this case, Cartêgraph Pavementview Plus will continue looking for segments that are on State Aid routes that require rehabilitation. It is possible to end a year with surplus funds in the budget. This means that all the feasible rehabilitations have been performed for that year based on the decision matrix.

At this point, the software has generated its best estimate of M&R requirements and how to address them. The Pavement Manager takes this list and uses engineering judgment to develop the final M&R list. When developing paving group project limits, projects are subject to the condition that the area-weighted average OCI of all segments in a paving project should be less than 70. Surface treatment, crack sealing, and thin overlay projects are not subject to this limitation. The three most common adjustments to the M&R list are:

- Combining projects
- Delaying projects
- Advancing projects

The most common of these is to combine projects. For example, the software may recommend repaving Church Street from 1st to 2nd, 2nd to 3rd, and 3rd to 4th. When the paving list is published, it would simply state "Church Street from 1st to 4th."

Projects are typically delayed to accommodate some sort of construction that would affect the condition of the street. Typically, this is some sort of planned utility work, such as replacing storm sewers along a road. It could be a construction project that would result in a temporary increase of heavy truck traffic along a route; in this case it would be better to delay repaving until after the construction project so that the old pavement is damaged, not the newly repaved surface.

Project schedules are typically moved forward due to proximity to other projects. For example, Cartêgraph Pavementview Plus may recommend repaving Church Street from 1st to 4th and 6th to 10th in year 1 of the plan, and from 4th to 6th in year 3 of the plan. To minimize mobilization costs and traffic disruption, the Pavement Manager may decide to pave the entire street from 1st to 10th in year 1 of the plan.

4.7 MODEL SCOPE

It is possible to eliminate certain segments from any consideration in the work plan through model scopes. A model scope is a filter that specifies which segments should be eligible for the work plan. They are setup in the Model Scope screen in Cartêgraph Pavementview Plus. For example, MPW may want to consider a plan that does not include the State Aid roads. By defining a model scope that excludes State Aid roads, the segments that are defined as State Aid are removed from the NPR list.

4.8 GIS MAPPING OF PAVING PROJECTS

The PMS data is linked to MPW's enterprise GIS. This link allows any of the data maintained in the PMS to be displayed as an attribute in the GIS. For instance, all pavement segments with OCI of 70 or higher can be displayed graphically in the GIS as green segments on a map, while segments with an OCI less than 70 can be displayed in red. Subsequently, as paving projects are identified, the scope of these projects will include specific pavement segments that correlate to records in the PMS. These segments can be highlighted on a map generated by the GIS. The data may also be viewed, printed or published to the web as an Internet map service or static map.

CHAPTER 5

IN-HOUSE PAVING AND CONTRACTOR PAVING PROGRAMS

5.1 CONTRAST BETWEEN IN-HOUSE PAVING AND CONTRACTOR SERVICES

MPW has the flexibility to choose between in-house forces and outside contractors when implementing a pavement restoration project. Such flexibility is key to the timely and efficient programming of projects in the pavement management system. Choosing between in-house and contractual services requires an understanding of the unique characteristics of each choice.

Specific work skills such as paving operations must be utilized regularly or they will be lost. Paving contractors pave continuously; their crews and equipment are skilled and well maintained. Public Works employees often perform many duties, only one of which is paving. Employees with several years experience but without recent experience are better than employees with no experience at all, but such crews will rarely be efficient when pressed into service on paving projects. The equipment is likely to need repairs, crews will need more time to mobilize, and safety issues may be more likely to arise due to lack of practice of those paving skills. Newer employees will have few opportunities to work with veteran employees.

When choosing between in-house and outside crew assignments, managers should consider the amount of interaction needed with the public, the potential for change orders, and the discretionary judgment likely needed in the field. Typically, in-house crews interact more effectively with the public than do contractual crews. Change orders can be handled more efficiently with in-house crews, and policy decisions can be made and communicated easier with in-house crews.

By contrast, projects that require longer hours during the day or work on weekends should typically be assigned to outside contractors. Likewise, projects requiring longer commitment of personnel and more coordination among crews may be accomplished more efficiently by outside crews. Finally, a large number of similar jobs may be completed faster by contract.

In general, contractor crews are best used when a high degree of labor coordination or time commitment is involved. In-house crews are best used for complex projects involving citizen interaction, potential change orders, and policy decisions in the field. Wise choices among in-house and contractor crews will stretch pavement dollars further.

If a public works department has the appropriate equipment and skilled employees, that department should be undertaking significant paving projects each year. The annual volume of work ideally should approach the department's historic annual capacity of work. Younger employees should have mentors within the work force who will pass along the skills necessary to accomplish significant paving projects.

5.2 IN-HOUSE PAVING

The availability of an in-house paving crew is essential to any public works department that maintains public roads. In-house crews can respond on an emergency basis and significantly reduce downtime of critical roadways. In-house crews also have the flexibility to handle smaller projects, stretching resources by utilizing public staff and equipment that otherwise would not be engaged.

MPW has established paving crews that have engaged in complex paving operations for years. MPW crews have years of project experience, available and well-maintained equipment, and sufficient tools, signs, and transportation to accomplish paving tasks with no outside resources. HMAC is obtained from the batch plant using city trucks rather than relying on delivery by an outside contractor. A summary of MPW paving capabilities is located in Appendix A.

In-house crews provide tangible value that cannot be duplicated by outsourcing, and does not appear in a direct comparison of costs on a per-unit basis. When assessing the role of public works departments in paving, these additional benefits need to be considered. The ability of public works crews to respond to these circumstances, though, is directly related to those crews having a significant portion of ongoing paving projects. Keeping skills fresh and passing those skills on to new employees is vital to maintaining paving capacity in the department.

5.2.1 Emergency and Safety Projects

Most paving needs develop slowly, providing time for repair or pavement preservation methods to be programmed, often years in advance. However, some repair needs are immediate and constitute an emergency condition or a significant safety need that cannot be delayed, e.g., a sinkhole or burst water main.

In theory, emergency repairs could be outsourced, using a standard hourly rate for repair. In practice, outsourcing for such work presents significant problems in terms of response time, cost, and oversight of the work. Frequent use of outsourcing for emergency and safety repairs can be expensive, even when contractors are responsive and attentive to needs.

While small cities often have no choice but to use outsourced paving crews, larger cities have too many emergency conditions to make outsourcing feasible in all circumstances. The city may have to pay a considerable penalty to get the crew to the city project. If the city demands priority at the time of bidding without penalty, contractors may bid a high unit price in order to cover unknown conditions. Either way, the city will likely pay a premium for prompt service in emergency conditions.

In-house paving crews can be diverted from another task immediately, committing as much staff and equipment as may be necessary without having to negotiate with an outside contractor. A paving crew already in the field making routine repairs on other sites can often make an emergency repair in the course of the day’s work with limited disruption. A safety project can be scheduled within days, sometimes hours, of the initial repair decision being made.

5.2.2 Budget Constraints

An in-house paving crew also gives an agency an opportunity to respond to critical projects during times of budget restrictions. Typically, members of a paving crew perform other tasks during the year, including right-of-way mowing and maintenance, storm drain repairs, snow removal, trash pickup along roadways, and sign placement. Such crew members can be shifted from those tasks to a paving project; in such a case, the only direct cost would be the materials and any equipment rental. Obviously, excessive diversion from other work will simply cause a backlog in those work areas, but the availability of in-house crews for paving can make a significant difference in project completion during times of budget restrictions.

The flexibility to shift resources during constrained budget periods is very helpful to public works management. When municipal budgets are restricted, funding for outsourced capital work, including paving projects, is frequently cut or placed on hold. In contrast, the layoff of public employees is among the least used methods of budget reduction. If public works employees have multiple skills, including paving, and the appropriate equipment is available, many projects can still be completed in-house. Public works management then has the simpler task of obtaining material to get the public employees and public equipment engaged in construction work.

By contrast, a public works department with few or no employees with paving skills and aging, unreliable equipment cannot provide a significant response to paving needs during a budget crisis. Fewer projects get completed, since such work must be accomplished using contractual services. The less skilled employees are then assigned low-profile tasks, e.g., right-of-way maintenance. While such work is always needed, the department is not able to respond to the more critical paving needs of the community. Over time, the public perception of the department's value to the community will be diminished.

5.2.3 Time Constraints

Some projects that do not necessarily qualify as emergency or essential safety projects may nonetheless have a tight time schedule that does not permit the normal contractual bidding schedule to be met. An accelerated utility project, work related to a major but unanticipated event, or a deadline for a grant application all may create projects that cannot wait for the next bidding schedule but would not appropriately be considered emergencies or urgent safety needs.

Such projects are well suited for public works departments to handle in-house. These projects are often complex and require on-going policy decisions. Engineering design can be accomplished quickly and given directly to public works crews, saving valuable time. Assuming timely completion has a value, the use of in-house paving crews has considerable potential to save money in such circumstances.

5.2.4 Citizen Interaction

Most paving projects, especially those involving standard overlays, are accomplished with limited public involvement. Provided notification of on-street parking restrictions is made in advance and traffic control follows recognized standards, the public relations element of most paving projects can be effectively handled by the private sector.

However, some paving projects do involve a heightened level of public involvement. Typically, such projects involve cases where on-street parking is critical (for access to small businesses or high density residential areas), locations where driveway abutments require extensive adjustments, streets with critical slopes for drainage, sites at which particular pavement markings or traffic calming devices have been installed, or communities which have experienced poorly implemented projects in the past. In cases where the neighborhood sensitivity to the paving project is high, the required attention to details outside the normal scope of paving and interaction with the public is more than routinely encountered.

In such cases, the ability of the paving crew to make effective decisions consistent with department policy is very important. A paving crew not familiar with specific neighborhood needs can make mistakes that can harm the department's image as well as incur additional expense. Giving 24-hour notice for on-street parking may not be sufficient if the drivers are out of town (college students during spring break) or rarely drive (elderly residents). Restricting parking from both sides of a neighborhood business area without off-street parking on the same day may give shoppers no parking opportunities and harm the businesses for the entire day. A paving crew that is not aware of a local drainage problem may unintentionally alter the storm water flow and create or aggravate a drainage problem. Special attention may be needed in areas with bikeways, pedestrian crossings, traffic calming devices, or other devices and markings in the pavement.

In all these cases, field decisions consistent with department policy must be made quickly. When a senior manager needs to be consulted for a policy decision, a department employee will likely be able to reach the right person faster than someone not involved in local government. If field changes or additional work are needed, the public works crew can complete the work without having to negotiate a change order. If discussions involve a citizen, the correct information is more likely to be conveyed from within the department rather than through an outside party.

Finally, the value of citizens seeing MPW staff, vehicles, and equipment at work on their street cannot be dismissed. While citizens may be appreciative in seeing a private contractor maintaining a street, those citizens may not know who is paying for the work. Giving citizens the opportunity to see their own local government employees providing services effectively has long-term public relations value for the department.

5.3 CONTRACTOR PAVING

Public agencies contract for those services that are not efficient or practical to be provided in-house or which do not fit within the agency's mission. MPW is fortunate to have multiple contractors that bid on each paving project, which results in competitive paving project costs. Maintaining qualified staff and equipment to provide all of the city's paving needs would not be economical, since insufficient work would be available for the crews during portions of the year.

Municipalities in northern climates can support a larger public works staff than southern municipalities. During construction season, more people can be hired and assigned to paving crews. During winter months, the extra personnel are allocated to snow removal and winter maintenance operations. In Nashville's climate, winter work opportunities are limited, making it uneconomical to hire large numbers of people for construction season work.

Contractual operations can take two forms, a general contractor or a construction manager. A general contractor obtains quotations from several specialized subcontractors and then submits a single bid; the general contractor signs the contract, provides all bonds and insurance, and pays the subcontractors after receiving payment from MPW. A construction manager is an agent for the governmental department who administers a series of contracts with a group of specialized contractors working under the coordination of the construction manager. (The construction manager may be a government employee, an independent manager, or one of the contractors bidding on the work).

Most bids handled by MPW involve a single general contractor rather than a group of individual contractors working under a construction manager's direction. Typically, contractual operations by general contractors provide five broad advantages over in-house operations:

5.3.1 Sole Responsibility

Having a general contractor handling a pavement project provides a single point of contact for MPW. The general contractor for paving operations typically owns and operates the hot-mix plant and owns or leases necessary equipment. The general contractor may have subcontractors for functions such as traffic control, truck transport, concrete work, utility work, paving markings, testing, and traffic loop maintenance. Because the general contractor has sole responsibility for the project, MPW officials have no need to contact subcontractors directly. Additionally, the general contractor takes responsibility for problems and addresses the issue of specific responsibility within the construction team without MPW having to be involved.

The cost savings of a general contractor are significant, since considerable MPW staff time could be involved in trying to determine which of several subcontractors was responsible for an error or delay. The general contractor builds the cost of this part of project management into the contract price, so MPW ultimately pays for the service. However, MPW personnel can then direct their time and attention to other areas rather than being involved with the details of the project operation.

Should the general contractor fail to pay a subcontractor or supplier, declare bankruptcy, or simply abandon the job, the project's payment bond is available to resolve any claims without MPW being directly liable. Should a warranty item arise which the contractor is not able or willing to resolve, the performance bond is available for use in resolving MPW's claim. An outside bonding company normally issues both the payment bond and performance bond for 100 percent of the contract value. The cost of the bonds is paid by the contractor as a condition of the contract and is built into the contract price as part of the original bid.

5.3.2 Productivity and Flexibility

Private contractors typically have fewer labor regulations than public agencies. A government agency must operate under rules of civil service protection, meaning the ability to hire and fire employees is restricted and cumbersome. A private contractor can lay off employees when insufficient work is available or when the construction season ends, then rehire the desired available employees when work is available, actions that public agencies cannot consider. The retirement programs of private employers, if provided, are typically transportable 401k individual accounts, not the defined pension programs of the public sector that anticipate and reward many years of uninterrupted service with a single public agency.

Private paving contractors provide services for state, municipal, and private clients and normally have high tonnage jobs that make the use of large-scale, efficient equipment economically feasible. By contrast, a municipal public works department could not justify the cost of such equipment, even though the equipment makes a paving crew more productive.

5.3.3 Extended Work Hours

As a consequence of having a different set of hiring rules, private employees can demand longer work hours during the construction season, since employees know they may be laid off in winter. That flexibility means that private contractors can operate late in the day during summer months and on weekends. When paving locations require night operations, private contractors can provide that service as well, keeping their batch plants operating as late as needed. A public works department could request but could not demand that a batch plant stay open for the convenience of MPW crews. This flexibility increases productivity on a daily and weekly basis. Contractors can pay overtime to production workers and managers as needed to keep sufficient workers on the job.

Public works employees work nights and weekends, too, but such work is normally on an emergency basis. Government agencies rarely have excess funds to pay production workers the required overtime, and government managers on fixed salaries typically must take either compensation time or simply work the hours as part of a set annual salary. Given the number of emergency circumstances that arise in the course of a year, government agencies are usually reluctant to involve public employees in extensive night and weekend work for routine projects.

5.3.4 Large Project Responsiveness

Contractors specialize in labor management and have the flexibility to optimize work production through temporary hiring, overtime work, and subcontracts with other contractors. The result of this management is fast turnaround time, often faster than the public sector, constrained by rules and policy, can provide. If a large project needs to be completed as quickly as possible, the private contractor can typically respond more quickly and efficiently than the public sector. Additionally, the work deferred by the private contractor will usually have less public consequence than that deferred by the public sector.

A quicker response time may come at a higher cost, however. Hiring and training temporary or seasonal workers is expensive. Contracts with other contractors involve overhead that will be passed on to the public sector. Increased management effort on the part of the contractor and the assumption of more cost and liability by using temporary workers, working overtime, or retaining subcontractors will result in a premium price for the work.

5.3.5 Streamlined Procurement Practices

Public agencies must follow strict procurement practices, including public biddings, detailed specifications, contract documents, and utilization of small and disadvantaged businesses. The result is an extended, complicated purchasing process that is rigid and time-consuming.

Private contractors are not required to follow the strict and complex procurement practices used by government entities. They can take advantage of bulk or repeated purchases from a long-time business associate and demand priority service as a result. They need to meet the specifications of the public contract, but their own purchasing can be done with less detailed contractual language. As a result, the private purchasing process is less time-consuming and more responsive.

5.4 CONTRACTOR PAVING CAPABILITIES

Just as the capacity and skill level of MPW is vital in determining the role of the department in providing paving and milling services, the ability of private contractors to provide both routine and specialized pavement preservation services is equally important. MPW is fortunate to have several contractors available to provide most pavment preservation service. Services available include:

- Milling and overlay
- New construction
- Reconstruction
- Surface seals and rejuvenators

- Crack sealing
- Pothole patching
- Spot removal and patching
- Shoulder maintenance
- Emergency road maintenance.

At least one contractor has indicated interest in bidding on each of the above categories on a group project basis. Currently, none of the local contractors have equipment for cold in-place recycling, but would likely acquire such capability if quantities were extensive and commitment to such work was on-going.

The current contractors have at least one asphalt plant in Davidson County and more in surrounding counties. Stockpiles of aggregates are maintained, and contractors can develop a range of specific mixes. The contractors prefer using their own batch plants and are not interested in having a designated material source. Given the narrow differences in unit costs by plant, little savings would appear to be achieved by using a single source. The contractors are not interested in laying asphalt produced by government agencies or other contractors.

5.5 VALIDITY OF COST COMPARISONS BETWEEN IN-HOUSE AND CONTRACTOR PAVING

A common policy question arises when comparing in-house versus contractual paving. A natural curiosity exists with respect to comparative costs. Does a private contractor pave streets at a lower cost than a public works department? If so, should private contractors always be used?

In practice, the question is not that simple. First, the full costs of paving must be determined. Second, costs savings that are passed to the public agency and which are absorbed in internal operations of the public or private sector must be identified. Finally, the non-monetary costs, or costs that impact parties beyond the public agency and the contractor, must be quantified.

For the public agency, the true cost of paving is more than the material costs of asphalt concrete, tack coat, and stone. The cost of purchasing and maintaining equipment must be identified, even though the public sector does not track depreciation costs. An annualized cost that includes salvage value is typically used in place of depreciation. The cost of transporting material from a batch plant or quarry to a job site must be included if performed by the public sector, which includes both labor and equipment. The incremental cost of providing insurance for equipment and personnel involved in paving operations should be included. Finally, the lost opportunity cost of crews not performing other work must be evaluated when assigning public crews to paving operations.

The private contractor has a similar set of costs for materials and transport, including purchase or rental of equipment. However, the private contractor is able to take advantage of certain tax laws with respect to depreciation and other costs. Having flexibility in renting or leasing equipment means that the contractor is less likely to purchase equipment in one initial lump sum payment as do public agencies. Because the equipment is often on a lease or other contract, the private contractor has an incentive to keep such equipment productive and to trade it before high maintenance or downtime costs occur. Public agencies have to compete for capital monies within tight multi-department budgets and often have to keep equipment well beyond optimum trade times.

Performing work at a lower cost is only meaningful if the savings can be realized by the public agency. A contractor who achieves savings on a job does not normally lower the price via a change order unless the savings has been expressly identified as part of a negotiation process. A public agency that completes a job ahead of schedule benefits only if the crew can proceed to another assignment, and the realization of the savings may never be quantified and reported.

Care must be taken to ensure the scope of projects is comparable. A public works department that has to complete many small projects scattered throughout an urban area cannot be expected to meet the same unit price as a contractor with a few large projects in one area of the county. Likewise, a private contractor who must complete work in a short time period will incur higher cost than a public agency or another contractor who is given much longer to complete the same scope of work.

CHAPTER 6
COMMUNITY OUTREACH

6.1 OBJECTIVES OF OUTREACH PROGRAM

One goal of MPW, as an organization of public servants, is to "build a great city" around core community values: seek consensus, avoid divisions, build-preserve-protect, improve the quality of life, and encourage informed, active, involved citizens. These values are reflected in broad community goals that relate to pavement restoration and preservation. One obvious goal would be to build, preserve, and protect the investment in the community's road and street system. Improving the quality of life in the community is a goal partially achieved through the pavement management program. However, the program must avoid decisions that create divisions in the community and must respond to community needs in all parts of the county.

To adhere to these values, certain specific objectives must be achieved in community outreach. MPW must first inform citizens that a pavement management program exists and explain what the program does. MPW then should provide a general understanding of the challenges of pavement maintenance and emphasize the strategic nature of the management process. Finally, the department needs to highlight the efficient use of tax dollars in the pavement management system in contrast to traditional paving programs. Communicating this information and effectively involving citizens in the process is best done through web-based means.

Appropriately, the approach the MPW has chosen for the adoption and deployment of a pavement management system fits well with the department's goals and values, as the proper implementation of a pavement management system both *requires* and *provides*:

- Objective, quantifiable data about the current conditions of the roadway network itself and of the component street segments, and the effects of varying approaches and budgetary levels on the ability to adequately maintain the network as a whole.
- Opportunities for discussion with council members, Mayoral committees, local businesses, and private citizens about the pavement management methodology that has been adopted.
- A means for MPW to proactively notify the public, utilities, and other governmental and regulatory bodies about planned work well in advance of its effect on transportation, traffic, business, etc.
- A means for feedback to be incorporated into the roadway rehabilitation process, and for stakeholders to make objective decisions and justify them to all parties.

6.2 INFORMATION TO BE MADE AVAILABLE

Citizens need to know that a pavement management program exists. The concept of a comprehensive analysis of street conditions using scientific and objective measures is a novel one for most citizens, regardless of background and experience. The knowledge that the program is in place and that it provides a process that is objective and non-political in nature is significant. That knowledge provides citizens with a basic assurance that a rational and equitable approach to street maintenance is on-going.

The pavement management program should provide answers to basic questions as part of its public information process. For MPW, ten key questions have been identified. The ten questions and answers shown below will provide a basic introduction to the pavement management program.

Question 1: What is a pavement management system?

A pavement management system is a computer-assisted process that examines all public roads and determines the best means to preserve and repair each road individually and the road system as a whole. Decisions are based on pavement condition, ride quality, costs of treatment, benefits to the individual roadway segment, and benefits to the entire road system. Because maintenance funds are always limited, the management system recommends the optimum sequence of repairs to make the best use of taxpayer dollars. The system provides a fair and equitable way to compare repair needs in all the city's neighborhoods to ensure the decisions are in the community's overall best interests.

Question 2: We have so many streets. How is the information collected and evaluated?

Covering half the county's roadways per year, MPW uses specially-designed digital survey vehicles to photograph and collect roadway distress data on every street that is accepted for maintenance by the Metropolitan Government of Nashville - Davidson County. Trained technicians then view sections of a road to determine the amount of pavement damage, using a uniform scoring method. Finely-calibrated measuring devices mounted on the vehicle evaluate the ride quality and record the amount of rutting in the pavement. All this information is stored on a computer for processing using specialized pavement management software configured for Nashville's needs. This process results in the full analysis of the entire county's accepted roadways on a revolving 2-year cycle, with each half of the county's roadway data being updated for distress every other year.

Question 3: How does all of the data help make repair decisions?

MPW scores the streets in two categories – *pavement stress* and *ride quality* – to obtain an overall score for the street. Pavement distresses include cracks, potholes, and ruts. Ride quality is the measure of how "bumpy" a road is. The scores help public works officials determine the best strategy for each street. One location may need a complete overlay while another street may only need some cracks repaired and potholes filled. By tailoring the repair decision to the needs for each street, based on the data collected, MPW can stretch tax dollars further while making the best repair decision for each street. For further information on this topic, see Chapter 3, page 3-8 of the Long Range Strategic Paving Plan.

Question 4: MPW never has enough money for street repair. What difference can a pavement management decision make?

This is where a pavement management program makes a big difference. First, the right decision is made for each street using the field data and the strategy recommended for the particular condition of the street, saving MPW from wasting funds on repair strategies that may be excessive or unproductive at a particular location. Second, the scoring system helps set priorities for repairs based on objective data. Third, the computerized system ensures that a particular street or neighborhood is not “forgotten” in the decision-making process.

Question 5: What is wrong with just filling the potholes and overlaying the street every few years?

Filling potholes and overlaying streets with a new asphalt surface will continue to be important and major parts of Metro’s maintenance program. Sometimes, though, other methods can renew the roadway surface quicker and cheaper than traditional resurfacing techniques. For instance, filling cracks with liquid asphalt can seal the roadway from the damage of water during the freezing and thawing of winter conditions that otherwise would severely damage the pavement. Not only is the cost of pavement replacement saved, the expense of raising gutter lines or milling the street down to make room for the new surface is also avoided. In the case of potholes, the damage may result from a weak base underneath the pavement, and that base material may be weak due to trapped water from a drainage problem or a leaking water line. Correcting these types of problems using base repair techniques can eliminate future pothole problems at that location., but just filling the pothole and overlaying the street will not.

Question 6: If a street gets a very poor condition score, will it always be a priority for repair?

Not necessarily, and this is where pavement management strategy gets tough. Sometimes a street is in such poor condition that only a complete reconstruction will make a difference. In that case, the best decision may be to use the limited maintenance funds to repair other roads that are in better condition by using less costly methods. If those roads can be fixed early (before they are in very poor condition), they will last longer and never reach the very poor condition of some roads. This approach stretches the repair dollars and gets more roads repaired faster. The roads in the poorest condition cannot benefit from the other pavement strategies, and will be scheduled for full reconstruction when they reach the end of their usable life.

Question 7: That sounds like MPW will be fixing roads that are still in fair condition while letting the worst roads fall apart. How can that make sense?

The secret to good pavement management is repairing roads that are still in “fair” condition but experiencing the early stages of pavement distress, reduced ride quality, and rutting. By keeping those roads in good condition with lower cost repairs, MPW will still have money for reconstructing a few roads each year that are in the worst condition. Industry studies have shown that a dollar spent early in road repair and rejuvenation can give the same improvement as four dollars spent later in the road’s life when repairs are more expensive because reconstruction is necessary. If funds are spent only on the worst roads, our community will stay in a cycle where we can afford only to reconstruct a few roads in very poor condition each year while neglecting simple, lower cost repairs on other roads. If we concentrate on the worst roads, we will never catch up. By spending wisely and strategically, we can continually improve the overall condition of MPW streets with the same amount of funds.

Question 8: Then will we always have roads in very poor condition that we have to let go until they can be fully reconstructed?

In the first years of a pavement management system, some roads in very poor condition have to be neglected until the very expensive repairs can be scheduled. Remember that the other roads in the system are receiving repairs earlier, and they never reach that very poor condition. As pavement management strategy is implemented over several years, the number of very poor roads drops to only a small portion of the road system.

Question 9: Once the pavement management system has been in place for a few years, what can we expect to see?

As funds are redirected to new maintenance and repair strategies, the community will see different methods used to improve roadway conditions. The performance of those methods will be monitored, since data on every road will be collected every 2 years. That fresh data will allow public works officials to see the results of improvements so that processes can be "fine-tuned" to be more effective. Receiving updated roadway distress condition data every 2 years also means that problem locations can be identified earlier. Just like a medical check up helps someone identify a health problem at an early stage, road distress data helps engineers identify and categorize repair needs early. Those repairs can be scheduled years in advance, with each year's maintenance schedule constrained by the total funds available. The pavement management system can quantify and illustrate the impact of delaying repairs to future years will be reflected in those future budgets, giving policy makers an objective feedback to budget proposals.

Question 10: If MPW can anticipate repair costs and strategy several years in advance, what other benefits can that knowledge offer?

The pavement information that MPW will collect on every street every other year will be useful in many ways.

First, MPW can determine if policies and inspection services relating to acceptance of new streets from developers, repair procedures for utility cuts, and even the new maintenance strategies themselves are effective. The new pavement data will produce a regular "score card" of pavement conditions and a progress report on the effectiveness of the pavement rejuvenation and restoration treatments in use as part of the program.

Second, MPW and local utilities can coordinate future road work more efficiently, since the planned schedule and method of a future road repair will be more accurate and consistent. If the repair strategy is crack-filling rather than an overlay, a utility can proceed with a scheduled cut without having a major impact on Metro's repair program. Likewise, MPW can determine the cost of delaying road improvements until a future utility project can be completed to be sure the delay will not result in more expensive and extensive repair.

Third, MPW officials can keep track of our many miles of streets more effectively, since a recent photograph of every section of roadway, along with all the pavement data for that location, is always available by computer. A public works official can "drive" a street from the computer screen, with each section of road appearing in sequence. That saves long drive times between sites in the field and enables MPW officials to examine more roads effectively.

Fourth, the pavement management system provides an accurate means for policy makers to measure how wisely tax dollars are being used, since the program can provide a road condition score by street, by area, or countywide. Policy makers and legislators will be able to monitor progress by location or by year, and have a means to anticipate future budget demands.

Finally, questions about planned work on MPW roads can be answered objectively and fairly. Want to know how much money MPW would need to bring all roadways to a certain standard within 5, 10, or more years? Interested in the impact on roadways of a budget cut in repair funds? Just want to find out the condition of the road you drive the most? With an effective pavement management system everyone can "know the score."

6.3 ORGANIZATION OF THE WEB SITE

A web-based public information campaign is fundamentally different than other publishing or knowledge-based systems. The differences are key to understanding how to present public information on the web in contrast to information via print, television, or radio.

Historically, public information programs use a linear, controlled approach. A brochure or television program is organized on a step-by-step basis as determined by the operating agency providing the information; readers can skip a page or turn back, but the text follows a single outline. The television program provides no choice at all; the viewer is fully captive to the broadcast format. Newspaper articles or radio talk shows may concentrate on a topic of interest, but the information is not organized and may not be easily retrievable later.

In contrast, a well designed website enables the reader to explore the accumulated information at his or her own pace. The reader can investigate a topic in more detail, or skip over to something else. Hyperlinks permit the reader to quickly divert to a reference, then return. Alternatively, the reader can continue to explore the new topic. Because the reader controls the exploration, he or she is more likely to keep reading. Comprehension is improved because explanations are embedded in a hyperlink, and the reader can move at his or her own pace.

To be effective, the web site must present information in a manner that anticipates the reader's reaction. The "home page" will introduce the topic and provide the broad areas of information as well as a means to search the site. Each broad area of information will provide access to more specialized areas. Links back to the home page and other central pages should be provided on every page. Short-cuts should be provided for experienced users.

A mix of text, graphics, and video should be presented. Consideration should to given to the different means of learning: reading, visual, etc., so that the site can be useful to a range of readers and viewers.

6.4 USE OF THE WEB BROWSER

All information on the web site will be produced in Hypertext Markup Language (HTML), a method of producing text and links on the web, and will be accompanied by images rendered in cross-platform file formats (eg. JPEG, and GIF). In the web design, consideration should be given to maintaining a balance between speed and accessibility. More advanced web browsers and faster access speeds can permit specialized presentations, but such programming may limit access to the site for other users. The need for non-standard plug-ins should be avoided, but it should also be noted the Davidson County web design standards do permit the use of Macromedia Flash and Adobe Acrobat . While personal digital assistants (PDA's) are now being used to access the web, the web site will not be designed to accommodate PDA browsers at this time.

6.5 DESCRIPTION OF WEB SITE

The entry point to the pavement management website will be through the Metro Nashville Department of Public Works: http://www.nashville.gov/pw/index.htm. However, a more direct link from the Metro government home page would be desirable. Citizens do not necessarily associate "paving" with "public works" and are not likely to go through a list of Metro departments. Additionally, the Transportation on the government home page would likely lead citizens to look there first.

The department home page will provide a link to three transportation-related public works program categories: bikeways, sidewalks, and paving. Clicking on the paving icon will link the viewer to the paving home page. The paving section will follow the general format of the successful sidewalk program website.

The paving homepage should have some appealing photos, including a video link, and some general information. The pull down menu will offer links on how to use the web site, access to the full Paving Master Plan, frequently asked questions, project types, pavement cuts, a project search/road viewer option, and a list of paving program contacts. Return links to public works programs and the public works home page will be provided as well.

The page offering guidance on using the web site should provide users simple instructions on accessing information, especially use of the project search/road viewer module. This page should assume the user has very limited knowledge of pavement management or public works functions.

The Paving Master Plan page will provide an electronic version of this report. The page presents an outline of the report, and each chapter can be downloaded independently. A separate link that offers the option of a single download should also be provided. The report will be offered only in Adobe™ PDF™ format so that any it retains the appearance and content originally defined by its authors once downloaded and in the hands of the general public.

The frequently asked questions (FAQ) list will be the questions and answers described in Section 6.2. This page should be updated in the future as new questions are asked that merit inclusion in the list.

The description of project types will focus on asphalt resurfacing, crack sealing, and pavement preservation programs. Links to information on details of each process will be offered. Those links could include photos, videos, sketches, and more detail on each process.

The page on pavement cuts will provide detailed information for private contractors who need to know specific procedures for applying for street cut permits and a description of the street cut policy. Graphics from Chapter 8 of this report should be provided so that contractors and citizens can understand how repairs to new cuts and the effect of nearby old cuts will be made.

The project search/road viewer module will be the most ambitious portion of the pavement management website. Users will have a choice of using the project search function to look for specific pavement projects by keying in attributes such as Street Name, Project Type, Project ID, Paving Group, Council District, Status, etc., or to use the point-and-click map viewer to visually "drill down" to the segment level using pan and zoom tools. Either approach will allow the user to select the segments of their choice, to view project-related data for the selected segments, to and use the roadway viewer to access the video of that segment to virtually "drive" a street and see the amount of visual damage, if any. (Bear in mind that, since only the segments that are accepted for maintenance by MPW are analyzed and photographed, it is only these segments that can be viewed by the roadway viewer.)

This page intentionally blank.

CHAPTER 7

STAFF ORGANIZATION AND WORKLOAD DISTRIBUTION

7.1 PAVING OFFICE'S ROLE WITHIN ENGINEERING

The pavement management office is one of six sections within the Engineering Division of MPW. The other sections within Engineering are:

- Street and Road Design
- Construction Compliance
- Traffic Engineering
- Traffic and Parking
- Permitting

Engineering is one of four divisions within Metro Public Works. Administration and Finance, Waste Management, and Streets and Roads form the other divisions. The Pavement Management office has regular contact with the Administration and Finance Division and the Streets and Roads Division. Each division requires specific communications styles and substance. Additionally, Pavement Management needs to communicate projects and policies through the department's Public Information Coordinator.

The amount of funding associated with the existing pavement management program and the large number of individual projects requires very specific accounting procedures and strong management accountability in terms of policy. The paving office itself is primarily responsible for entering and maintaining material quantity data in spreadsheet form for all contracts. GASB Statement 34 requirements, which require that the value of infrastructure be shown on Metro's balance sheets, provides the option of an asset-management system such as the pavement management program, and that information is essential for both the department financial management and the auditors for Metro itself.

Several items require routine communication between Pavement Management and Streets and Roads. The specific paving projects assigned to in-house forces require specific, clear information regarding location, type of repair, schedule, priority, quantities, utility coordination, etc. Spot repairs such as potholes also require clear, unambiguous directives to avoid crew inefficiencies in locating specific potholes. Projects involving old street cuts may require information from the utility itself.

Streets and Roads provides communication back to the Pavement Management office on several issues. Information on completed work orders need to include actual quantities, crew hours, time to complete, and similar data that would be logged on the pavement management spreadsheets in the same manner as an outside contract project would be. Unresolved issues, significant scheduling delays, and other managerial matters need to be addressed in a clear manner to ensure accuracy. Unrelated problems observed by Streets and Road crews that are relevant to Pavement Management also need to be routinely communicated.

The primary purpose of the metro paving office is pavement management. Within the Pavement Management office itself, the interaction among staff members and outside agencies representing Pavement Management is a critical element in the existing pavement management process. The paving manager has six areas of supervision: service requests, paving projects, pavement preservation, coordination with utilities, contractual bid administration, and data collection. In addition, there are also administrative responsibilities, including reconciliation of bid quantities with field tabulation of the actual quantities in place and close interactions with the Special Operations section of Public Works to facilitate the in-house paving operations.

7.2. CURRENT STAFF ORGANIZATIONAL STRUCTURE AND WORKLOAD

7.2.1 Pavement Management

Pavement Management is not a single activity, but rather a group of activities dealing with selection of M&R projects. It involves interpreting PMS software output, generating paving lists, and estimating M&R and budget requirements. This function is currently performed by the paving program manager with support from IT Technician, two engineering technicians, and an administrative assistant. A technician generates a list of candidate projects using the PMS software, and a consultant inspects the segments on the candidate list to develop a paving list. The paving manager, with input from staff engineers and technicians, prioritizes and finalizes the paving list based on the consultant's recommendations.

7.2.2 Service Requests

This function involves fielding all requests from citizens, public officials, and other agencies, as well as producing intra-office reports. Service requests are coordinated with the customer service department. Follow-up by an engineering technician is required to ensure satisfactory completion (by field evaluation, work order report, field engineer’s verification, or other method). The paving program manager ensures the proper M&R is considered, that the project or task is scheduled in an efficient manner (by combining with a larger project or completed as an individual project), and that the priority of the project is consistent with the pavement management program.

7.2.3 Utility Coordination

This function provides coordination with affected utilities, primarily Metro Water, Nashville Gas, Nashville Electric Service, and occasionally telecommunication providers such as Bell South and Comcast. There are three key areas of coordination that must be accomplished

- Excavation of existing streets by utilities on an emergency or routine basis
- Excavation of existing streets by Metro Public Works for street restoration or improvement projects
- Scheduling of joint improvement projects that provide “win-win” conditions for both the utilities and Public Works.

Utility coordination is performed by an engineering technician, who is responsible for administration, compliance with Metro patch design standards, and field inspection.

7.2.4 Contract Design, Administration and Paving Construction Inspection

The design and administration of pavement restoration contracts for outside services is handled by Collier Engineering, a local engineering firm which has a five year contract with

Metro Public Works. Collier provides the engineering design for the various projects, prepares bid documents, administers the contract, provides construction observation, and issues routine reports to Public Works. Additionally, Collier inspects paving projects completed in-house. The information that Collier provides regarding time of completion and actual quantities is an input to the spreadsheets and service reports maintained and administered by the paving office. Information on a project's completion is also significant when close communication with a utility is needed. A staff engineer oversees and administers the contractor, and is responsible for ensuring the project designs adhere to Metro standards.

7.2.5 Data Collection

Data collection is the process of gathering information required to make informed decisions about the paving schedule and making it available to the decision makers. The most visible type of data collection is the pavement condition survey. Historically, Metro has used contractors to perform distress data collection. Staff engineers and technicians oversee data collection and perform quality control checks of the data collection process.

7.3 STAFF ORGANIZATIONAL STRUCTURE AND WORKLOAD

Due to the pavement management program , new skills and new lines of communication have developed among functional units within Metro Public Works and among Metro departments. Managers now to consider pavement strategies as well as project scope, location, and priority. Project priorities under a comprehensive pavement management program are different from previous procedures. Managers are now able to articulate the reasons a road repair is being delayed or accelerated, how one location was chosen over another, why one treatment strategy is more appropriate than another, and how the entire process actually saves money while improving the quality of pavement throughout the community. Workloads among staff have shifted because of the pavement management program implementation, and adjustments to individual tasks and responsibilities. The recommended organization chart for the Metro Pavement Management Office is shown in Figure 7.1.

Understanding the impact of the pavement management program on current workloads, the new skills required, the nature and character of the communication needed, the changing objectives, and the adjustment of workloads in the future are all key to successful implementation of the pavement management program within Metro government. The pavement management system has had a positive impact on each function.

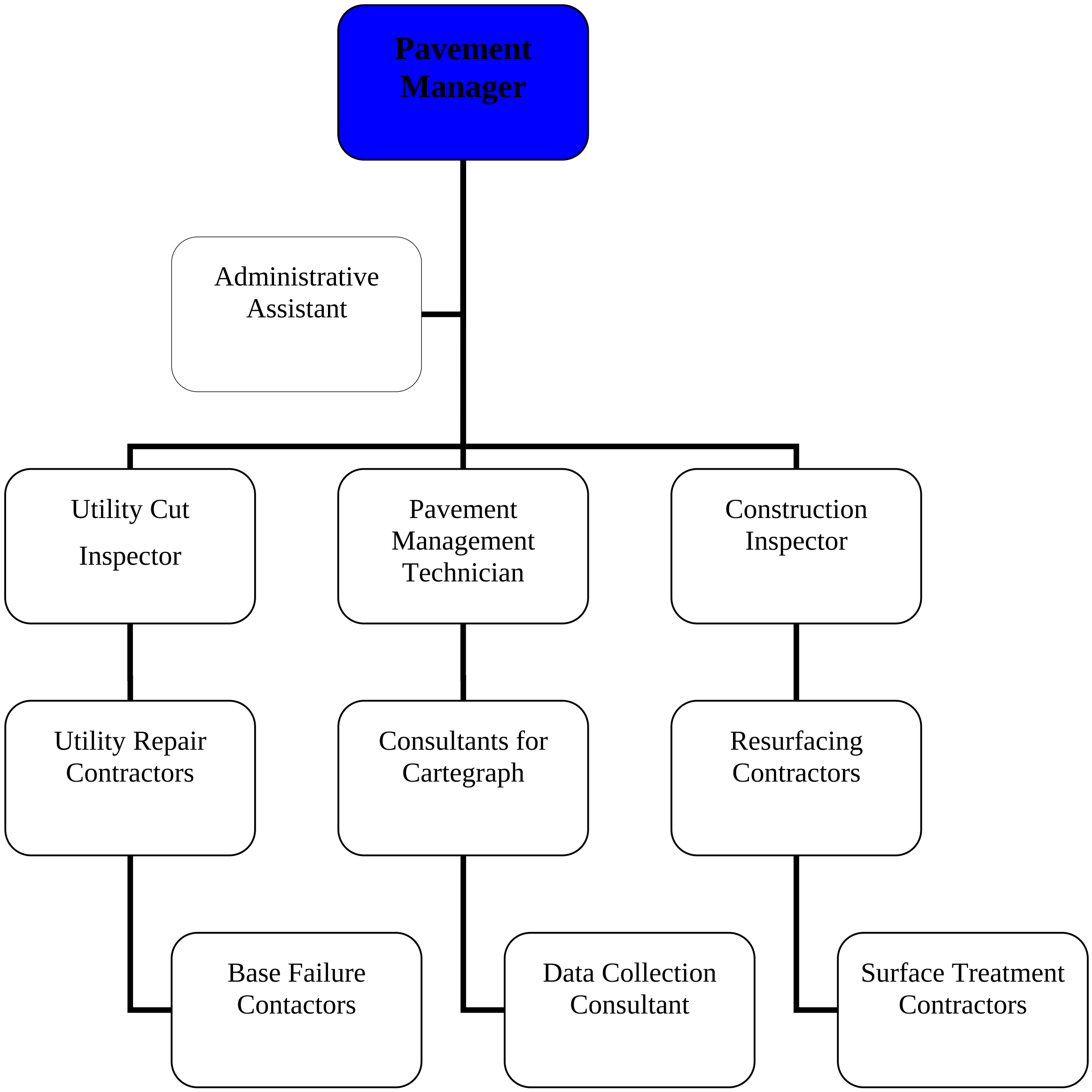


Figure 7.1. Recommended organization chart for Pavement Management Office.

7.4 FUTURE OBJECTIVES

Responsibilities within the Paving Office will continue to evolve. The new tools provided by the pavement management system will provide opportunities to modify existing job objectives or define new objectives. The most likely job objective change is anticipated to be the area of utility coordination.

Excavation of existing streets by utilities is handled by permit, but ensuring such permits are actually obtained on a timely basis is difficult, especially in an emergency. The location of the cut must be accurately recorded, and an acceptable area and method of repair must be determined. Follow-up is essential to confirm that the cut was in the location as recorded, that the scope was consistent with the permit, and that the repairs meet Metro Public Works policy. Results of the final inspection should be recorded in the pavement management system.

Street restoration or improvement by Metro Public Works may impact utilities. Valve and manhole lids must be raised for overlay projects or marked and protected during milling operations. Deeper excavations for storm water systems, crown or super-elevation adjustments, or curb and gutter replacement also require utility notification and coordination.

Pavement management systems offer the potential for improving the third type of utility coordination: joint scheduling of major capital improvements by Metro Public Works and utilities. Because the pavement management system can project repairs several years in advance within a financially constrained model, Metro Public Works can commit to restoration and other maintenance projects with reasonable assurance of its ability to honor those commitments. Utilities already program major improvements years in advance, and they can achieve cost savings by making those improvements at the same time that the road project is under construction. Such coordination can provide cost savings or both Public Works and the utilities as well as reduce delays and inconvenience for the public.

Other future job objectives are likely to involve the following areas: pavement marking coordination, intelligent transportation system loop detection system coordination, pedestrian controls and bicycle lane assignments, traffic calming systems, pavement coloration techniques, and pavement texture systems.

This page intentionally blank.

CHAPTER 8

GUIDELINES FOR PERFORMING RESURFACING AND PAVEMENT PRESERVATION TREATMENTS

8.1 PAVEMENT PRESERVATION AND RESURFACING METHODS

Preventive maintenance has been defined by AASHTO as a planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without substantially increasing structural capacity). In simplistic language, it is applying the right treatment to the right pavement at the right time.

The key to successful pavement preservation is to have a "toolbox" that includes various pavement surfacings and treatments that can achieve the most cost effective solution for a particular condition and time. The most common types of preservation treatments for asphalt concrete pavements are thin asphalt concrete overlay, surface seals, crack sealing, and rejuvenators. These treatments retard pavement deterioration, renew usefulness of the existing surface, and seal cracks to prevent surface water infiltration and retard crack deterioration. These treatments do not significantly increase the strength of the pavement, but benefit pavements by protecting the pavement structure from premature deterioration and by improving or restoring pavement surface condition including texture and ride quality. The net effect of such maintenance actions is to extend the pavement life while maintaining the desired level of service, including safety requirements, at minimum cost.

8.2 PURPOSE OF PAVEMENT PRESERVATION METHODS

The interest in pavement preservation has increased with the need for less expensive treatments, the growing importance of preventive maintenance, and the ongoing improvements in the technology and cost-effectiveness of thin surfacings, sealers, and rejuvenators. In addition, these treatments are more sustainable than traditional overlays because they use less material and less energy (e.g., surface seals and rejuvenators do not require heating), and their impact on other features of the roadway is minimal (e.g., reduction in curb height, and the need to increase thickness of shoulders and adjust height of guide rails). Rejuvenators and surface sealers have the potential to improve pavement surface condition, protect the pavement structure from moisture infiltration, and extend the service life on a cost-effective basis.

Pavement preservation treatments seal the pavement surface, improve the pavement profile (by reducing roughness and rutting), and improve pavement friction. Thin pavement surfacings do not substantially increase pavement structural strength and cannot effectively correct large surface distortions. Notable benefits of thin surfacings, rejuvenators, and sealers and the reasons for their selection as a pavement preservation decision are:

- **Protecting pavement structure.** Thin pavement surfacings, rejuvenators, and sealers can be used as preventive maintenance treatments to prevent premature deterioration of the pavement or to retard the progress of pavement defects. Rejuvenators add back oils lost from the AC surface to renew the flexibility of the weathered surface. Sealers apply a protective coating that will retard further oxidation and weathering. The objective is to slow down the rate of pavement deterioration and cost-effectively increase the useful life of the pavement. As a preventive maintenance treatment, thin pavement surfacings and sealers are typically applied to a pavement that is in reasonably good condition.

- **Restoring or improving pavement surface.** Thin pavement surfacings, rejuvenators, and sealers are inexpensive methods to restore pavement serviceability to an acceptable level. Micro-milling can be used to restore pavement friction, eliminate wheel track rutting, and improve overall surface smoothness.
- **Improve riding surface.** Thin pavement surfacings can be used as a riding surface for new or rehabilitated pavements. Thin overlays can significantly improve road smoothness, increase friction, and reduce noise.
- **Holding pavement until a permanent treatment is applied.** Thin pavement surfacings, rejuvenators, and sealers can serve as temporary treatments, keeping the pavement at or above an acceptable condition, until a permanent treatment can be implemented. This situation may arise, for example, because of lack of funding, unexpected rapid deterioration of the pavement surface, or the need to extend pavement life-span by a few years.

8.3 PAVEMENT PRESERVATION AND PAVEMENT MANAGEMENT

This section explains how to incorporate the use of maintenance treatments into the pavement preservation planning and budgeting process, and provides guidelines for the selection of appropriate maintenance and repair.

8.3.1 MPW Preservation Program

MPW underwent a performance audit by Maximus in May 2002 that recommended MPW consider a new approach to pavement maintenance. Based on this review, MPW contracted for a pavement management study that surveyed the surface condition of the Metro roads, implemented a pavement management software, set criteria for prioritization of maintenance activities, established a series of test sections to evaluate potential surfacing and restoration materials, and consequently developed and implemented a pavement preservation and restoration program.

After the evaluation of a number of proprietary products in test sections on Metro streets, a product called Reclamite was selected to rejuvenate and protect pavements that are 2 to 3 years old (when OCI is greater than 80). An application of Reclamite is shown in Figure 8.1; note that the material is initially pink in color but cures to black within 24 hours.

Another product, PASS, emerged in the test sections as a good material to minimize raveling and extend lifetime of roadways that were last paved 8 to 9 years back. PASS is polymer modified asphalt surface sealer applied as a fog seal. Figure 8.2 shows the application of PASS on Metro roadways. PASS costs about $0.60 per sq yard as compared to traditional mill and overlay at about $6.00 per sq yard (1.5” overlay). PASS lets Metro Nashville extend a roadway’s lifetime by about 5 years before resurfacing is needed.

Figure 8.1. Application of Reclamite to Metro street.

Figure 8.2. Application of PASS surface sealer on Metro street.

MPW has also adopted a crack sealing program. Over time, sunlight oxidizes the oils in the asphalt causing it to become brittle and crack. Also, construction joints between paving lanes tend to develop cracks. Cracks in asphalt roadways provide an entrance for water into the pavement which ultimately leads to more deterioration. Figure 8.3 shows crack sealing of Metro streets.

Figure 8.3. Crack sealing of Metro streets.

Other treatment techniques are under evaluation by MPW. These include such materials as Joint Bond, NovaChip, and Warm Mix Asphalt. Other techniques and materials will be included in field trials as new candidates with potential for extending pavement life are identified. As new products and treatments are found to be beneficial and cost effective, they will be integrated into the MPW pavement management program.

8.3.2 Integrating Pavement Preservation Treatments into a PMS

The use of thin pavement surfacings, sealers, and rejuvenators should follow the principle of applying the Right Treatment on the Right Road at the Right Time. Consequently, the selection of the Right Treatment is not the task of choosing between different types of pavement surfacings; it is the task of choosing between all feasible pavement preservation treatments (including regular overlays, thin overlays, surface sealers, rejuvenators, sealing of cracks, cold-in-place recycling, etc). Similarly, the selection of the Right Road should consider not just one section of the network that may be suitable for maintenance treatment, but also the needs of the entire network. The Right Road involves distributing limited resources among the entire system. Finally, the Right Time must consider the consequences, including cost, of implementing the treatments in different years. Consequently, the selection of the correct maintenance treatment should be part of pavement management process.

The process of preparing prioritized pavement preservation budgets is illustrated in Figure 8.4. The process consists of a yearly pavement management cycle of eight basic planning, budgeting, engineering and implementation activities. To be effective as preventive maintenance treatments, thin pavement surfacings, sealers, and rejuvenators must be applied during early stages of distress development. Crack sealing should be a continuous program that is conducted as a systematic process.

Currently, the only treatment approved for arterial roadways is resurfacing due to the safety aspects of sealers and rejuvenators. Most of these treatments reduce, at least temporarily, the surface friction.

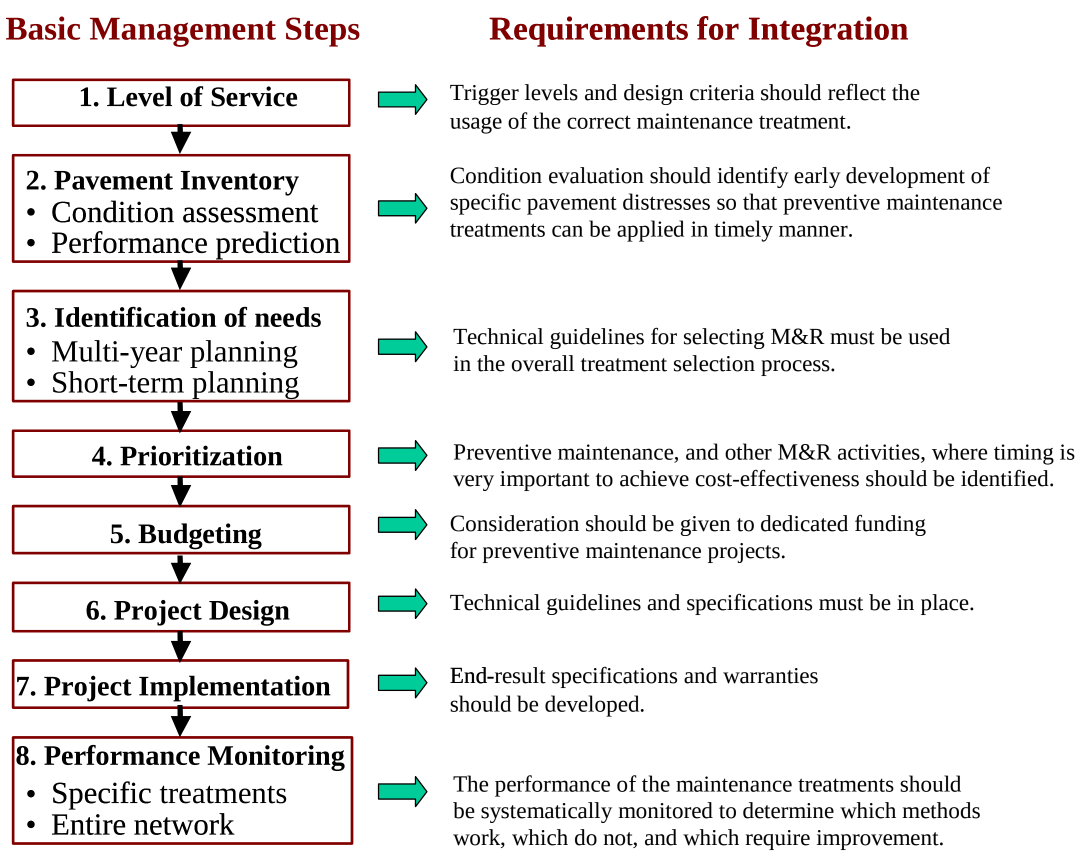


Figure 8.4. Integrating preventive maintenance into the management process.

8.3.3 Treatment Selection

Thin pavement surfacings, surface seals, and rejuvenators can play an important role in pavement preservation, particularly in the area of preventive maintenance. Guidance for the selection of these surfacings and treatments is summarized in Tables 8.1, 8.2, and 8.3.

Table 8.1. Preservation treatments to protect the pavement structure.

Type of Treatment	Protect AC Surfaces Against Factors Indicated							
	Penetration of water (*cracking and segregation*)		Loss of aggregate (*raveling)*		Hardening of Asphalt Binder		Overall Low Durability	
	Type of street							
	Local	Arterial	Local	Arterial	Local	Arterial	Local	Arterial
HMA Resurfacing	○	○	○	○	○	○	○	○
Thin overlay	○	●	○	●	○	○	✶	✶
HIP recycling			○	○			●	○
Surface treatment	○	○	○	○	○	○		●
Micro-surfacing	●	✶	●	✶	●	✶	✶	●
Slurry seal	✶	○	✶		✶	○	●	●
Surface seal	○		○	○	●	○	○	○
Rejuvenator	○	○	✶	✶	●	●	●	●
Surface abrasion							○	●
Crack Sealing	●	✶					●	✶
Fog Seal	○		○				○	

○ Can be used ● Should be considered ✶ Typical application

Table 8.2. Preservation treatments to restore or improve pavement surface.

Type of Treatment	Improve Pavement Surface Because of Factors Indicated									
	Roughness		Friction		Cross section		Pavement-Tire Noise		Aesthetics/ Delineation	
	Type of street									
	Local	Arterial	Local	Arterial	Local	Arterial	Local	Arterial	Local	Arterial
Thin overlay	●	●	○	●	●	●		✶		○
HIP recycling		●		○		●				
Surface treatment			○	○	○					
Micro-surfacing	○	○	○	●	●	○		○	●	●
Slurry seal			●	○	○			○	●	○
Surface seal									○	○
Surface abrasion	○	●	○	○	●	●				✶
Crack Sealing		○						○		

○ Can be used ● Should be considered ✶ Typical application

Table 8.3. Preservation treatments to provide riding surface.

Thin Pavement Surfacing	Addition of Wearing Surface Over Materials Indicated							
	Granular base		Surface treatment		Cold-in-place recycled mix		Hot-in-place recycled mix	
	Type of street							
	Local	Arterial	Local	Arterial	Local	Arterial	Local	Arterial
Thin overlay	●	○			●	●	●	●
HIP recycling								
Surface treatment	✶	✶	✶	✶	●	●	●	○
Micro-surfacing			○	●	○	○	●	●
Slurry seal			●	○	○		○	○
Surface seal						●		●

○ Can be used ● Should be considered ✶ Typical application

The treatments listed in Tables 8.1, 8.2, and 8.3 are described in Appendix D. Information on treatment selection in Tables 8.1 to 8.3 is general. For example, according to Table 8.1, pavement friction on arterial streets can be improved by using a thin overlay, surface treatment, micro-surfacing, slurry seal, or surface abrasion. The final selection of a specific treatment should be done by experienced personnel familiar with local conditions.

Typically, the selection of the preferred treatment is a two-step process. This process is mirrored by the treatment selection algorithms used in the PMS software. Specific treatment selection rules used by the software are discussed in Section 4.3. The first step is the selection of candidate treatments or alternatives, or the selection of generic treatments. The second step is a detailed evaluation of alternatives in terms of costs and benefits. The first step can be viewed as a network-level selection and the second step as a project-level selection. The steps are summarized below.

The selection of candidate treatments can be facilitated by using decision trees or tables. Candidate treatments can also be generated by a pavement management process as generic treatments. Considerations used to select alternatives include:

- Pavement type and pavement structure
- Roadway classification
- The type, extent, and severity of distresses
- Traffic volume, composition, and speed
- Policy of MPW regarding pavement preservation (e.g., preventive maintenance and type and timing of pavement preservation treatments)

Modern PMS software, such as Cartêgraph Pavementview Plus, is sophisticated enough to determine treatment alternatives for pavement preservation using a treatment selection matrix.

Determining the optimum treatment for a candidate project is more complex than suggesting technically appropriate treatments. Cartêgraph Pavementview Plus attempts to determine the optimum treatment based on economics and general engineering principles, but to select what is truly the right treatment at the right time requires specific local knowledge of conditions. The final say on pavement preservation treatment selection should be left to paving program engineers, not computer software. The evaluation of alternatives includes factors such as:

- Economic analysis of alternatives
- Initial construction costs
- Minimum desirable life-span of the treatment
- Future maintenance requirements; impact on future rehabilitation options
- Local experience of MPW or Tennessee Department of Transportation (TDOT) with long-term performance of the treatment
- Preferences of users and local residents
- Specific pavement surface properties such as pavement friction and pavement-tire noise
- Traffic restrictions during construction; duration of construction; delays during construction
- Weather requirements during construction
- Conservation of materials and energy
- Availability of local materials; availability of experienced contractors

8.3.4 Utility Cut Repairs

Utility cuts can have a significant impact on the life of a pavement. Recommendations regarding utility cut repair guidelines and specifications for the utility cut permitting are located in Appendix E.

8.4 COSTS AND BENEFITS

Typical costs and benefits of thin pavement surfacings, rejuvenators, and sealers are summarized in Table 8.4. These are average costs, and actual project costs may vary. Expected benefits of thin pavement surfacings are provided as a range of life-spans in years. Longer life-spans are typically associated with thicker or multiple treatments, higher-quality materials, improved construction quality, lower traffic volumes, and the application of treatments to pavements in better condition.

When a treatment is *applied to restore pavement surface* and is initiated as a remedy for a specific distress its benefit is expressed in terms of the life span of the treatment itself. For example, if slurry seal is used to restore pavement friction, its benefit is expressed as the time-span of the slurry seal.

Table 8.4. Expected benefits and typical cost of thin pavement surfacings.

Treatment	Expected Life (years)	Application/Benefits	Unit cost ($/yd² or $/ft)
Thin hot mix overlay (<1-1/2 in)	8 to 10	Adds new surface; levels rough pavements, improves friction	2.50 to 3.50
Hot-in-place recycling (<1-1/2 in)	5 to 7	Rework existing surfaces; recompacts mix; gives new riding surface	4.50 to 6.50
Micro-surfacing (1/2 to ¾ in)	5 to 9	Polymer-modified slurry seal; improves friction, seals surface against raveling and oxidation, fills ruts	3.00
Thin-bonded overlay (NovaChip)	6 to 8	Alternate to hot-mix overlay; open-graded	2.50 to 4.50
Slurry seal	3 to 7	Thin surface of asphalt emulsion, fine aggregate, and water; improves friction, seals and protects	1.50
Surface treatment (chip seal)	5 to 8	Seals existing surface, improves friction	2.00 to 2.50
Surface seal (Rejuvaseal, GSB-88)	1 to 3	Seals existing surface; applied to structurally sound pavements	0.75
Rejuvenator (Reclamite)	1 to 5	Penetrates into surface of existing AC; replenishes lighter oils; adds new life to weathered surfaces	0.65 to .85
Surface abrasion	1 to 5	Removes uneven surfaces; improves friction	1.00 to 2.00
Crack Sealing	3 to 5	Seals cracks to prevent water infiltration	1.50 to 3.00

8.5 IDENTIFICATION OF NEEDS AND PRIORITIZATION

The identification and prioritization of needs for larger municipalities such as Metro Nashville cannot effectively be accomplished without the aid of specialized computer software. MPW has purchased and installed a software package to implement the pavement management program and help the Public Works Department identify those pavements to be treated and the most cost effective and timely method of treatment.

There are two types of identification of needs:

- Short-term needs during the first year
- Multi-year needs
    - 1 - 5 years
    - 6 - 12 years

8.6 SHORT-TERM IDENTIFICATION OF NEEDS AND PRIORITIZATION

Because of the complexity of multi-year planning procedures, it is normally easier to implement a pavement management system based on short-term planning and prioritization. Figure 8.2 shows the connection between the levels of service, identification of needs, prioritization, and budgeting for short-term planning and prioritization.

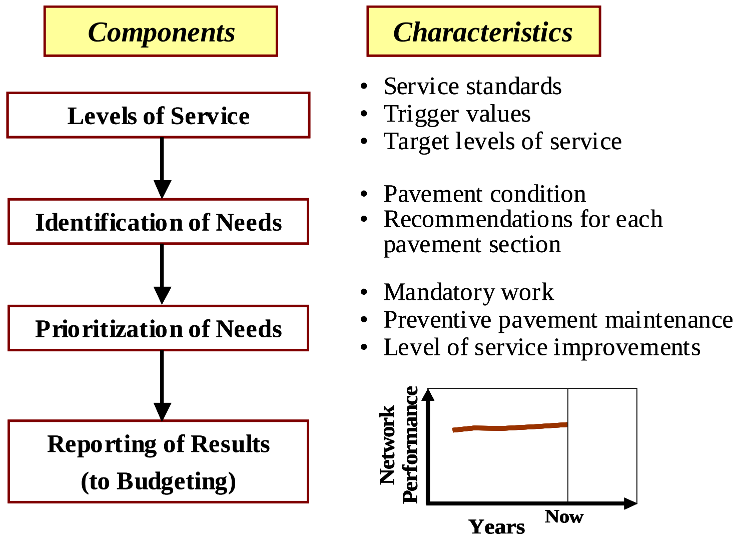


Figure 8.2. Short-term planning and prioritization.

8.6.1 Short-Term Identification of Needs

The process for identifying maintenance and rehabilitation actions combines all pavement preservation and resurfacing needs (maintenance as well as rehabilitation treatments). Some municipalities prepare separate budgets for maintenance (operating) and rehabilitation (capital) work. While this may be necessary for administrative reasons, it is preferable to have only one integrated process for the identification and prioritization of pavement preservation needs. The process of identifying the short-term needs includes the following:

1. The pavement inventory, including pavement condition, is updated; this has been accomplished for MPW.
2. A decision must be made as to what types of treatment should be included in the needs. In general, all roadway maintenance and rehabilitation activities that can be planned at least a year in advance should be included. Such activities may include, for example, ditching, repair or replacement of culverts, sealing cracks and joints, patching, asphalt concrete overlays, and full-depth repairs, utility cut repairs and other repairs. The treatments selected by MPW have been input into the PMS.
3. Each roadway section in the inventory is reviewed to determine if the section requires a pavement preservation treatment in the next few years. Many sections may not require any treatment, some sections may require a preventive maintenance treatment (e.g., crack sealing, rejuvenators, etc.), and some may require other types of maintenance or rehabilitation. MPW identifies the candidate treatments using PMS software programmed with agency-specific guidelines, impacts to other infrastructure issues, budget constraints, and legal and safety requirements.
4. The best treatment for the given section is selected. Typically, the selected treatments are generic (e.g., one-lift overlay or a multi-lift overlay), particularly if the software selects the treatments. The Pavement Manager selects the specific treatment for a given section. The selection of the treatments must be realistic and must consider the appropriate levels of service. It is important to realize that the identification of needs

is not a creation of a wish list, but a documentation of the needs that are necessary on the basis of approved and mandated standards and levels of service.

8.6.2 Prioritization of Short-Term Needs

If it is expected that some projects may not be funded because of limited funding, the list needs to be prioritized. Projects that address minimum safety-related levels of service are typically considered mandatory and are given the highest priority. Incomplete projects from previous years are also given high priority.

There are many ways to prioritize projects. The priority levels, together with roadway classes, already convey basic priorities. It is easier and preferable to prioritize projects that belong to the same priority level and roadway class than to prioritize projects across priority levels and roadway classes. Typical prioritization criteria include the following considerations that can be applied individually or in combination:

- pavement condition (in relation to the level of service)
- roadway class
- traffic volume and percentage of commercial vehicles
- cost effectiveness (benefit-cost ratio)

To be credible, the process of identification of needs and prioritization must be consistent, transparent, and logical. Each pavement section, and its recommended treatment, is described in terms of location (and road class), treatment type, recommended construction year, estimated cost and, very importantly, priority level. The priority level shows the main reason why the treatment is recommended for implementation. Priority levels assigned to each recommended pavement preservation treatments are:

1. Minimum safety-related levels of service need to be met.
2. Minimum acceptable levels of service need be met.
3. Cost effectiveness concerns (includes projects where timing is very important to achieve cost effectiveness).
4. Projects to achieve a target level of service.

The individual treatments are sorted by the overall condition rating, priority levels, and roadway classes. The resulting list represents the total documented needs for the preservation of the road system. The specific method used by MPW PMS software to prioritize pavement projects is discussed in Section 4.4.

8.7 MULTI-YEAR IDENTIFICATION OF NEEDS AND PRIORITIZATION

Multi-year identification of needs and prioritization can answer the following:

- What funding is required in future years to achieve target levels of service?
- What will be the future condition of the network given projected funding levels?
- How much additional funding will be required in the future to compensate for a budget cut now?

- How will the condition of the pavement network change if funds are diverted to preventive maintenance?

Multi-year planning also improves engineering and economic decision making because it considers the long-term impacts of accelerating or postponing projects from one year to another. Impacts considered include trade-offs between lower-cost treatments that have to be paid for now versus more expensive treatments that will need to be paid for later, or the impact of diverting funds to preventive maintenance. The basic components and characteristics of multi-year planning are shown in Figure 8.3 and are outlined in the following sections.

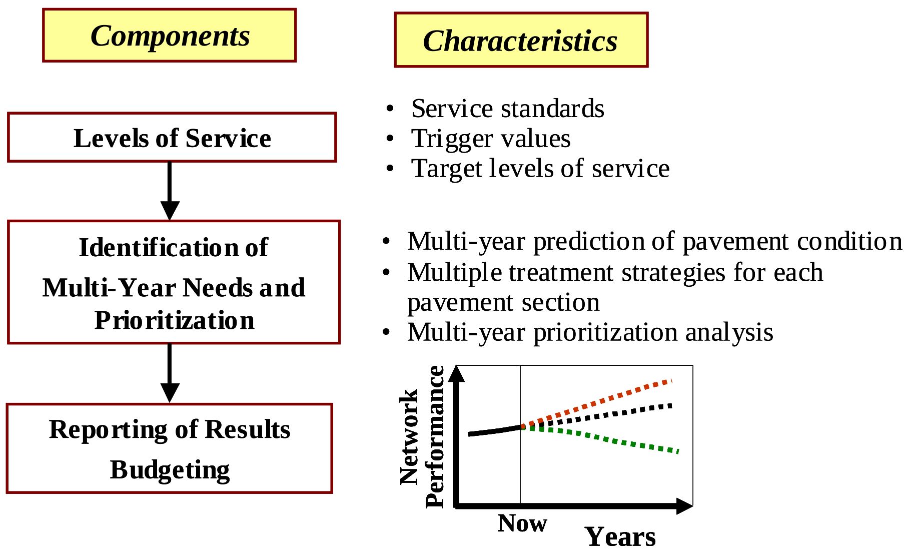


Figure 8.3. Multi-year planning and prioritization.

8.7.1 Generation of Feasible Alternatives

The success of multi-year planning and the accuracy of future funding requirements depend on multi-year predictions of pavement performance.

The prioritization analysis can consider several treatment options in each analysis year. The concept is illustrated in Figure 8.4 for one pavement section. For illustrative purposes, of the many options that can be generated for different years, only two alternatives are shown here. The first is a single lift resurfacing 3 years from now; the second is a two-lift resurfacing 9 years from now. With multi-year prioritization analysis, these two alternatives (pay now or pay later) can be evaluated on an equal footing, while still considering other projects.

8.7.2 Multi-Year Prioritization

An important feature of multi-year prioritization analysis is its ability to prioritize (or optimize) competing treatments using the cost effectiveness of individual treatments. To do this, each treatment is characterized by its cost and benefit. The cost aspect of the treatment should be based on its life cycle cost as much as possible. However, in practice, only the initial treatment costs, and perhaps routine maintenance costs, are used because the exact nature of the treatments is not known in the planning stage (at the network level).

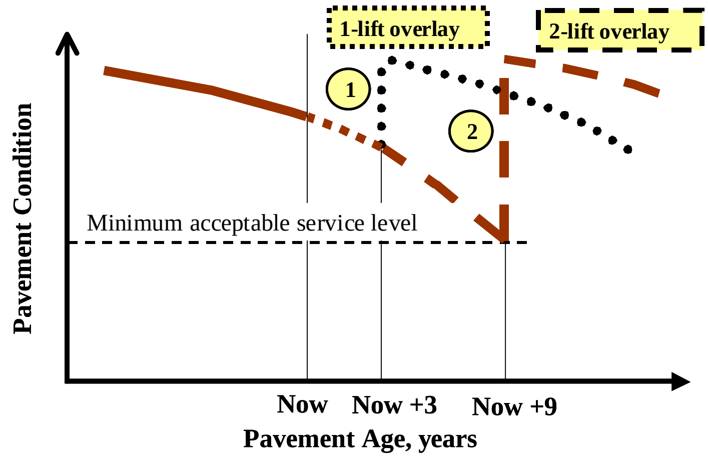


Figure 8.4. Alternative treatments and alternative timing of treatments.

Benefits, or effectiveness of the treatment, are based on the additional pavement life the treatment is expected to provide and may include the reduction in user costs. For example, if two projects provide the same benefit in terms of additional pavement life, the project on the roadway serving a higher traffic volume may be chosen first.

8.7.3 Integrating Preventive Maintenance with Multi-Year Prioritization

The candidate projects included in multi-year analysis should also include preventive and other maintenance activities. These activities have been incorporated into the analyses made by the PMS software implemented for Metro Nashville. The cost effectiveness of these activities can be compared with the cost effectiveness of activities recommended for other priority levels. Consequently, the distinction between funding for preventive maintenance and funding for target levels of service can be made directly through cost-effectiveness analysis.

8.7.4 Reporting Results and Consequences of Different Funding Levels

Depending on available funding, the projects not funded one year are considered for funding in the subsequent year (or years). By changing the amount of funding, the amount of work will change, and so will the condition of the pavement network. However, regardless of the funding, the list of prioritized projects still represents the best value for the money. The Cartêgraph Pavementview Plus software will produce the list of prioritized projects, expected costs, and consequences in terms of future condition.

The results of multi-year prioritization can show the relationship between the pavement investment and the resulting level of service provided to the community. An example of this type of analysis is illustrated in Figure 8.5, which shows the consequences of changes in proposed funding levels. In this example, a 10 percent growth in funding, sustained for several years, will result in achieving the desirable target level of service in some future year. Likewise, a decrease in funding can result in a more rapid reduction of overall pavement condition.

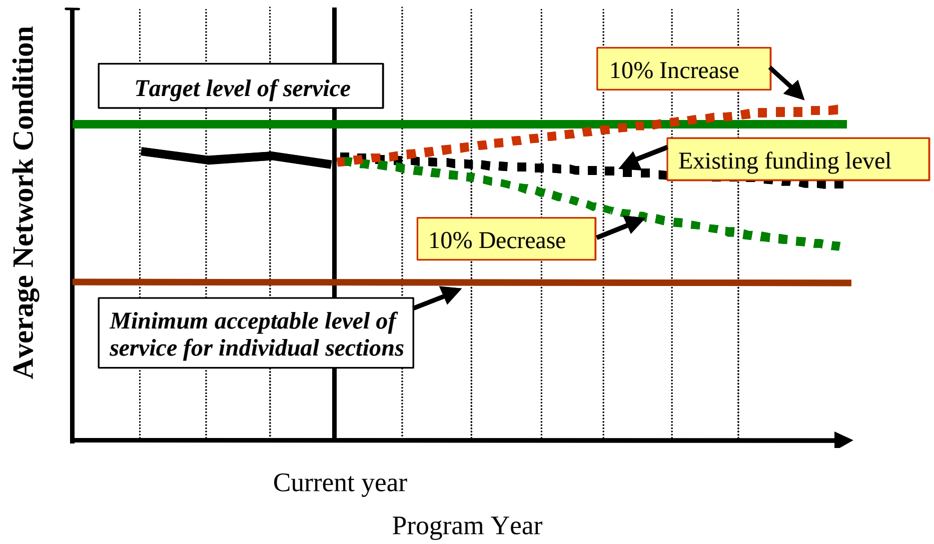


Figure 8.5. Consequences of different funding levels.

Prioritized pavement preservation needs provide important input for the preparation of annual and multi-year budgets. However, budgets must also consider many other funding needs and programming considerations.

Multi-year prioritization analysis is a powerful and useful decision support tool for managing pavement infrastructure. It requires a long-term commitment to succeed and must be supported by a computerized pavement management system, such as Cartêgraph Pavementview Plus.

Increases in the unit cost for hot-mix asphalt have caused significant increases in the cost of paving in the Metro. Table 8.5 shows this cost increase over the 5-year period since 2003; note that costs for 2007 and 2008 are projected costs.

Table 8.5. Metro paving budget increase due to asphalt prices.

Year	Budget	Paving Lane Miles	Cost of HMA per ton
2003	$9.2 M	283	$35.00
2004	$9.2 M	256	$38.00
2005	$9.2 M	196	$40.00
2006	$10.7 M	207	$60.00
2007	$13.9 M	225	$61.50

8.8 PRIORITIZED BUDGETING

Budgeting builds on the results of planning and prioritization activities and produces a financial document that determines how the money will be invested in the infrastructure. Budgeting combines technical and financial decision making as illustrated in Figure 8.6.

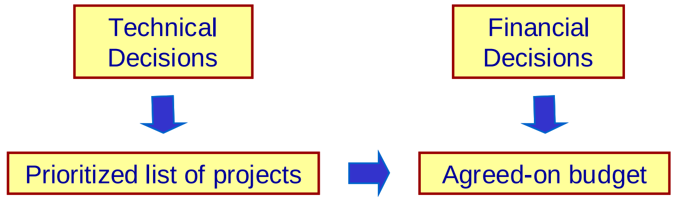


Figure 8.6. Budgeting as a combination of technical and financial decision making.

The annual MPW budget consists of many line items. Budgeting activities are schematically illustrated in Figure 8.7, where pavement preservation activities are a line-item input in the planning and budgeting operation. Programming and packaging of projects must take into account a number of needs and considerations.

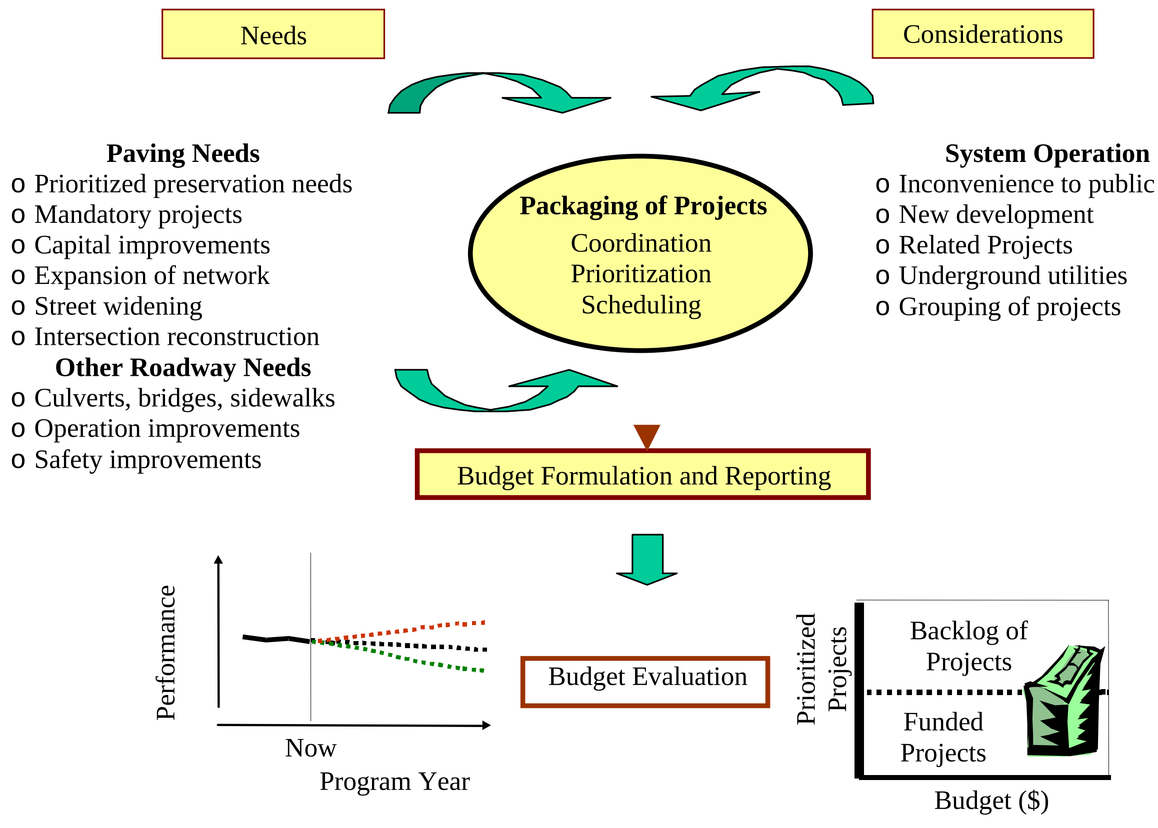


Figure 8.7. Key budgeting activities.

The <u>needs</u> include:

- *Prioritized pavement preservation and resurfacing* which are comprised of the preventative maintenance activities identified for each road segment.
- *Capital improvements* include expansion of the road network and major improvements such as street widening, intersection reconstruction, etc.

- *Other roadway needs* that include other roadway components (e.g., culverts, bridges, and sidewalks), operational improvements (e.g., widening at an intersection and system expansion), and safety improvements.

The considerations include:

- *System operation* which includes staging projects to minimize inconvenience to the traveling public and advancing projects because of new residential and industrial development.
- *Related projects*, such as work on underground utilities that should be coordinated to minimize disruption to the public.

The results of the budget allocation can be quantified and reported using the following means:

- Show the consequences of different budgets in terms of pavement condition.
- List the specific projects that will not be done because of funding limitations.
- Track the quantity of unfunded needs and the changes in unfunded needs from year to year.
- Monitor network performance trends.

8.9 PROJECT DESIGN AND IMPLEMENTATION

The priority planning and budgeting process recommends which sections should receive pavement preservation treatments and resurfacing during which year. These recommendations include the general treatment type (e.g., a thin overlay) and the estimated cost of the treatment. Project design determines the actual treatment type and provides additional details required for the construction of the project (such as the layer thickness, type of material, and construction methods). It often uses the results of physical tests of the existing pavement materials.

Two main concerns during the implementation of projects are whether to use in-house forces or contractors and what inspection and quality control procedures will be used during construction to ensure quality work. Many of the preservation applications use specialized equipment and products that may be more cost effective to rely on contractor equipment and forces.

In addition to quality control and quality assurance procedures, warranties can be used to ensure basic construction quality. Warranties are important for pavement preservation treatments where the construction procedures and the selection of materials are difficult to specify and enforce (e.g., for sealing cracks in asphalt concrete pavements and for micro-surfacing). The typical warranty period for “thin” paving jobs, rehabilitation, and reconstruction work is for one year.

Periodic pavement performance monitoring is important for both individual projects and for the entire pavement network. Performance monitoring can guide the Public Works Department in decisions to expand, change, or discontinue the use of a particular treatment based on the cost effectiveness of the treatment. Regular condition evaluation of all the pavement sections in the network can provide a clear indication of the long-term trend in the health of the network. This does not mean that the entire road network needs to be surveyed during a given year; only a portion of the network can be surveyed each year of every few years

Metro Public Works surveys one-half of the network each year so that each pavement section is evaluated every 2 years as to its distress condition.

8.10 SHORT TERM PLAN FOR PAVEMENT RESURFACING AND PRESERVATION

The ultimate product from the PMS program is the plan for pavement preservation and resurfacing. The Cartêgraph Pavementview Plus software can provide a prioritized list of pavement sections with identified maintenance needs for each year of a multi-year plan. The plan is based on the decision matrix as described in Chapter 4 that provides the guidelines for selection of projects.

In order to create a practical paving plan for MPW, the recommended sections from Cartêgraph Pavementview Plus are combined into a logical paving and treatment sequence.

The short-term plan is based on the immediate needs as defined by the OCI. Projects are identified by street segments, costs are estimated and work packages are developed so that the maintenance and paving can be accomplished with in-house forces or handled through contracts.

The short-tem plan is available to the citizens of Nashville and Davidson County on the Metro web site, and this list of projects is kept current by the MPW PMO.

8.11 MULTI-YEAR PLAN FOR PAVEMENT RESURFACING AND PRESERVATION

The Cartêgraph Pavementview Plus software will be used to project future pavement condition and identify at what point in time a given street segment will meet the criteria for pavement preservation, maintenance, or resurfacing. The software will aid the Pavement Management Office in the preparation of the 5-year and 12-year plans described below.

8.11.1 Five-year Plan

Streets that fall below the target OCI value of 70 during the next 5 years and meet other requirements for resurfacing will be put in the 5-year plan.

8.11.2 Twelve-year Plan

Projects that go in the 12-year plan are those streets that currently are above the critical OCI of 70 but, based on the deterioration rate developed by the software, will become candidates for paving in the next 5 to 12 years. Factors that are considered in the selection and prioritization of the candidates streets are age, activity, and condition.

This plan gives the lane miles that will be resurfaced during each of the years but does not identify specific streets by name. The plan does describe the preservation and resurfacing that is recommended in terms of quantities and projected cost for each year.

This page intentionally blank.

CHAPTER 9

SUMMARY AND RECOMMENDTIONS

9.1. IMPLEMENTATION OF PMS IN NASHVILLE AND DAVIDSON COUNTY

MPW has, through contract with the ERES Division of Applied Research Associates, Inc., implemented a pavement management program for the entire MPW road network. Pavement condition data, including digital images of pavement distresses, pavement roughness, and rutting, were collected with state-of-the-art automated equipment. A software package, called Cartegraph PAVEMENT*view* Plus, was selected and installed in the Office of Pavement Management to accommodate the pavement condition database and interact with Metro's GIS databases.

The PMS software will allow the Office of Pavement Management to develop short-term and long-term (5-year and 12-year) plans for maintaining and resurfacing the roads and streets throughout the city and county. New pavement preservation treatments have been included in the maintenance options and these will be applied to extend pavement life while optimizing the paving budget – i.e., allow more miles of roads to be maintained and improved each budget year.

The current MPW street network consists of 25,577 segments that were defined from 2,320 centerline miles. The area-weighted average OCI of all streets in the network is 81.26. All five paving groups meet the GASB 34 target set by Metro, with 78.58% of all centerline miles having an OCI greater than 70.

The selection of pavement sections to be serviced in a given budget year is based on criteria that considers the importance of the roadway in terms of traffic and usage, the current and projected condition of the pavement, age of the existing surface, and other factors that impact pavement performance.

The PMS program is being coordinated with the requirements for utility intrusions into the streets of Nashville. Improved guidelines for repair of utility cuts were developed under the research contract along with recommendations for quality assurance measures to ensure acceptable repairs.

Methods of accomplishing the paving program were investigated with consideration to in-house forces and contract services, and recommendations were made as to the best arrangement for future paving operations. A combination of both in-house and contracted approaches gives Metro the most cost effective and overall responsive services. The in-house forces will be assigned one of the five paving groups within MPW, but will continue to be available for on-call support in other areas if needed.

A web-based community outreach program was developed. From the internet, each citizen of Metro can learn about the PMS program and review the paving schedule that has been developed for the current year as well as future years.

9.2. RECOMMENDATIONS FOR CONSIDERATION

Some considerations for MPW and the Pavement Management Office that are proposed by the research team are:

- Test sections should be used by MPW to evaluate new products and pavement surfacings that have potential to improve pavement performance and save maintenance dollars.
- The guidelines for utility cut repairs, provided in Chapter 8 of this report, should be adopted and implemented.
- The street network should be periodically resurveyed in order to keep the database current. General recommendation is to resurvey every 2 to 3 years; resurveying one-half of the next work each year appears to be a reasonable approach.
- A full-time database manager should be identified, trained on the Cartêgraph PAVEMENT*view* Plus software, and be assigned responsibility of maintaining the database and operating the software applications as required.

Specific recommendations regarding implementation of the PMS program to ensure that the overall condition of the Metro Nashville roads is maintained at the desired level are:

- Implement an annual Pavement Preservation Plan starting with local roads less than 5 years old utilizing various types of surface treatments to extend the life cycle of these roads to a minimum of 15 years. This will require application of surface treatment to approximately 250 lane miles every year.
- Implement an annual Resurfacing Plan based on 15-year life cycle for each road. Based on the 5600 lane miles in Metro Nashville, this would require resurfacing approximately 373 lane miles per year. Currently, the Metro resurfaces approximately 225 lane miles with the current budget. This means Metro is 148 lane miles short each year in order to meet a 15-year cycle. An annual budget of approximately $16,000,000 would be required.
- Implement an annual Crack Sealing Plan for roads less than 10 years old. Sealing of the construction joints and other longitudinal cracks will increase the life cycle of their roads to a minimum of 15 years. Based on the condition of Metro's roads, approximately 65 miles of crack sealing should be done each year.
- Implement an Annual Fog Seal Program for roads 10 years or older that are severely raveled with very little cracking

APPENDIX A
MPW PAVING CAPACITY

Relevant equipment available to MPW ranges in age, with most having been acquired from 1979 to 2003. Overall, about 84 major pieces of equipment and 18 units of hand-operated equipment are in inventory.

A.1 PAVING EQUIPMENT

- **Pavers:** Both a 2003 paver and a 1987 paver are available.
- **Rollers:** A 1986 vibratory roller, a 1988 roller, a 1994 vibratory roller, a 1995 tandem roller, and a 2000 roller are all in service.
- **Oil Distributors:** Two oil distributor trucks, a 1994 model and a 1993 model, are in inventory.

A.2 MILLING EQUIPMENT

The equipment available for milling operations are:

- **Milling Machines:** Both a 1990 milling machine and a 1998 milling machine are in the equipment fleet.
- **Road Graders:** Five graders are in the fleet, with model years of 1979, 1980, 1984, 1988, and 1990. (Public Works departments typically keep road graders for many years for snow removal, since municipal governments rarely use the graders in high volume work.)

A.3 GENERAL EQUIPMENT

- **Tri-Axle Dump Trucks:** A total of 19 tri-axle dump trucks are in the MPW fleet, ranging in age from 1989 to 2001. Ten of these would routinely be available for a paving project.
- **Skid Loaders:** Two new (2003) skid loaders are in the fleet. (This is the same equipment as referenced in the paving equipment.) Both a 1999 and a 2000 dirt loader are also available.
- **Power Broom:** Both a 1999 power broom and a 2000 power broom are in the fleet.

Hand equipment available to milling crews include one pavement breaker in good condition and five in fair condition, along with three jackhammers in poor condition and a vibratory compactor in fair condition. The department has one mason saw in good condition and two in fair condition.

The department also has two shoulder machines and various other trucks and loaders that could substitute for a short time period on a job site.

A.4 MPW PAVING CAPACITY INTERVIEW RESULTS

On December 17, 2003, MPW officials met with the consulting team representative to discuss current and future paving capacity of the department. The following information is a summary of that meeting.

Currently, no plans exist to purchase new equipment for the paving operation. A paver was replaced last year.

Aggregates and other materials for temporary repairs are stockpiled, but permanent materials (asphalt concrete) are purchased as needed under on-going contracts. All materials purchased meet state specifications.

MPW does not anticipate performing slurry seal operations in-house. The possibility of crack sealing operations in-house is still under review. New staff would not likely be required for crack sealing.

Given the current staff composition, MPW can place on a given day a full milling crew, a full paving crew, and 26 maintenance crews. The milling and paving crews normally have seven or more members. Truck drivers to support these crews are not included in the numbers. Certain locations may require more staff to support traffic control or other functions. The sizes of maintenance crews vary by project type and location.

The typical MPW paving project is about 500 tons and requires three quarters of a day to complete. If 6 hours (three quarters of a work day) is spent in actual paving, then the typical paving production would be 83 tons per hour, very close to the 80 tons per hour needed to match the unit cost of private sector paving crews.

The annual amount of patching performed is about 66,000 square yards. MPW provides traffic control. Materials are purchased at the batch plants by MPW using contractual unit prices and transported by MPW employees to the job site in MPW trucks.

MPW has established rental rates that include maintenance, overhead, and fuel as well as amortized costs. These rates were used in computing the unit cost for MPW to perform paving and milling operations as discussed previously.

Metro government is self-insured. Since MPW is paying for all materials and labor, it does not need performance or payment bonds.

MPW officials envision the department participating in the group paving program, paving a complete group, as well as continuing the special projects paving program.

MPW Engineering or Street Service staffs provide in-house maintenance and repair projects that require design or detailed instruction.

A major work order must be approved by the department’s Work Order Committee.

Two paving machines and two milling machines are listed in the equipment inventory. Both machine types can be used simultaneously, or the older machine of each type can serve as backup. While MPW can field two milling crews or two paving crews simultaneously on a temporary basis by reassigning existing personnel, it cannot support a second crew of either type permanently without hiring new staff.

Public Works has a “Grade Crew” that supports reconstruction and base failure repairs as well as other maintenance functions.

In-house personnel provide quality assurance for in-house paving and repair operations. The testing is provided by an outside vendor who is state-certified.

The typical experience level of a project manager is 30 years, while the typical paving crew foreman has 12 years experience. A typical equipment operator has 20 years experience and formal training.

The typical work shift of the paving crew is 10 hours; under emergency conditions, the work shift may be extended to 12 or 14 hours.

The typical backlog of work orders is about 2 weeks.

Work orders are written and issued by a compliance inspector, a supervisor, and staff engineer in the Engineering Division. A supervisor selects the repair technique; the decision can be overridden by the Director. Field inspections are made in advance by a compliance inspector, a foreman, or a supervisor.

MPW has equipment to heat asphalt in advance of pothole repair in winter, as well as materials appropriate for both hot patch and cold patch repairs in cold weather conditions. MPW uses cold mix as a material source for asphalt repairs when batch plants close for winter.

The existing equipment fleet can enter alleys safely and efficiently for repairs. However, there is a desire to create a separate maintenance policy for alleys in the downtown area and in other key commercial locations.

Concrete and flowable-fill material are sometimes used for utility cut repairs in winter conditions. A supervisor schedules and inspects temporary repairs. Foremen and managers do not frequently need to make policy decisions regarding pavement repair. Work orders are organized by location, type, and priority. Work orders assigned are grouped by the area of the city and by the type of repair. Crews have discretion in the order of the repair in a group of standard work orders.

MPW staff have regular crew meetings in which the projects for the next week or month are discussed in advance. Foremen and managers routinely plan 2 to 3 months in advance. Supervisors place orders for materials based on need. Excess materials at the end of the day are stored for future use.

Supervisors make routine inspections of equipment and tools. Drivers or operators have a checklist to examine prior to the start of the workday, and one crew member checks to be sure all material, tools, safety gear, and signs are on the trucks before leaving the shop. The foreman is responsible for ensuring that MPW, state, and federal safety standards are routinely followed in the field. Crews are familiar with Chapter 6 (Temporary Traffic Control) of the *Manual on Uniform Traffic Control Devices (MUTCD).*

This page intentionally blank.

APPENDIX B

GLOSSARY

One of the objectives of the glossary is to promote common terminology for thin pavement surfacings. This is necessary because many terms describing types of thin pavement surfacings, and even the term *thin pavement surfacing*, do not have generally accepted definitions. To facilitate the introduction of a common terminology, the glossary also includes definition of terms that are not recommended as part of common terminology promoted by this best practice.

Asphalt binder – Asphalt material (such as asphalt cement, asphalt emulsion, or liquid asphalt) used to bind together aggregate particles or to bind them to the pavement surface.

Asphalt emulsion – An homogeneous mixture of asphalt cement (AC), water and emulsifier where microscopic droplets of asphalt are dispersed and suspended in water. Typically, asphalt cement makes up to 70 percent of the emulsion. Emulsions are used for many thin pavement surfaces such as surface treatment, micro-surfacing, slurry seal, and restorative seal. Different types of asphalt emulsions are defined in Table B.1.

Table B.1. Types of asphalt emulsion

<table>
<tr><th colspan="2"></th><th colspan="2">Type of asphalt emulsion</th></tr>
<tr><th colspan="2">Characteristic</th><th>Type</th><th>Abbreviation</th></tr>
<tr><td colspan="2">Electrical charge of the emulsion</td><td>Cationic (C, or positive charge); Anionic (or negative charge); Nonionic (or neutral charge)</td><td>C[1]</td></tr>
<tr><td colspan="2">Setting time (time to revert to asphalt cement)</td><td>Rapid Setting (RS); Medium Setting (MS), Slow Setting (SS)</td><td>RS, MS, SS</td></tr>
<tr><td colspan="2">Viscosity of emulsion[2]</td><td>Low viscosity, High viscosity</td><td>1, 2</td></tr>
<tr><td colspan="2">Hardness of AC in emulsion[3]</td><td>Hard</td><td>h</td></tr>
<tr><td colspan="2">Passing the flow test[4]</td><td>High Float</td><td>HF</td></tr>
<tr><td colspan="2">Penetration in HF emulsion</td><td>Low, Medium, or High Penetration</td><td>100, 150, 250</td></tr>
<tr><td rowspan="2">Addition to AC in the emulsion</td><td>Polymers</td><td>Polymer modified</td><td>P</td></tr>
<tr><td>Rubber (ground rubber tires)</td><td>Rubberized</td><td>No commonly used abbreviation</td></tr>
</table>

[1] For anionic emulsions, the C designation is simply omitted. Nonionic emulsions are seldom used.

[2] Viscosity is a measure of the fluidity of an emulsion at specified temperatures. Applies only to RS, MS and SS emulsions. Performance-grading of the asphalt cement used for emulsion is not yet available.

[3] As measured by penetration test.

[4] ASTM D-139. Unless otherwise specified (by the HF designation), the emulsion is not high float.

Example: CRS-2P means *cationic rapid setting high viscosity polymerized asphalt emulsion*.

Cape seal – Application of slurry seal to a newly constructed surface treatment.

Crack Sealing – A maintenance procedure that involves placement of specialized materials into working cracks using unique configurations to reduce the intrusion of incompressible materials into the crack and to prevent infiltration of water into the underlying pavement layers.

Dense-graded – Dense-graded (*or graded*) refers to the property of aggregate or to the property of materials utilizing such aggregate, e.g., dense-graded asphalt concrete. Dense-graded aggregate has aggregate particles that are fairly uniformly distributed throughout a full range of applicable sieve sizes. Refer also to the definition for open-graded.

Diamond grinding – Removing the surface of an asphalt pavement (or Portland concrete pavement) using a machine equipped with closely-spaced parallel diamond-tipped saw blades. The ridges left between the blades break off readily resulting in a texture depth[1] that is similar to that of new asphalt concrete. Some agencies accept the use of diamond grinding as a finished surface if it if used to improve smoothness of newly constructed asphalt concrete pavements.

Emulsified Asphalt – A liquid mixture of asphalt binder, water, and an emulsifying agent. Minute globules of asphalt are suspended in water by using an emulsifying agent. These asphalt globules are either anionic (negatively charged) or cationic (positively charged).

Fog Seal – A light application of slow setting asphalt emulsion diluted with water and without the addition of any aggregate applied to the surface of a bituminous pavement. Fog seals are used to renew aged asphalt surfaces, seal small cracks and surface voids, or adjust the quality of binder in newly applied chip seals.

Full-Depth Patching – Removal and replacement of a segment of pavement to the level of the subgrade in order to restore areas of deterioration. May be either flexible (asphalt) or rigid (concrete) pavement.

Hot-in-place recycling – A paving process that involves softening of the existing asphalt surface with heat, mechanically removing the surface material and mixing it on the road (in-place) with a recycling agent and, if required, with aggregate or beneficiating hot mix, at temperatures normally associated with hot-mix paving. Hot-in-place recycling qualifies, as a thin pavement surfacing if the total depth of the recycled layer and the additional layer used to protect the recycled layer is less than 40 mm.

Hot-in-place recycling with an integral overlay – Hot-in-place recycling with the addition of a thin layer of hot mix (on the top of the recycled layer) during the recycling operation. Hot-in-place recycling with an integral overlay qualifies as a thin pavement surfacing if the total depth of the recycled and new layers is less than 40 mm.

Hot Mix Asphalt Concrete (HMAC or HMA) – A thoroughly controlled mixture of asphalt

[1] Texture depth of the pavement surface is typically measured by the sand patch test (ASTM E965). The test involves taking a known volume of artificial sand (glass beads) and spreading it over the pavement surface until all depressions are filled to the peaks. The ratio of volume of sand to the area covered by the sand is the surface texture depth. Typical hot mix AC has a texture depth of about .4 mm or less.

binder and well-graded, high quality aggregate thoroughly compacted into a uniform dense mass. HMAC pavements may also contain additives such as anti-stripping agents and polymers.

Infrared Patching – A technique where infrared heating systems apply heat to pavement surfaces and aid in the removal of existing material and replacement with new asphalt mixture. Infrared thermal bond bituminous pavement patching is a method of blending new asphalt mix with infrared heated existing blacktop pavement to create a joint-free integral patch. A special machine is used to heat the existing blacktop to a depth of approximately two inches without oxidation or burning. There is no flame in direct contact with the existing blacktop surface. The unit is also equipped with chambers which are capable of storing up to four tons of fresh bituminous materials at a consistent temperature.

Liquid asphalt – Asphalt cement which has been modified by blending it with petroleum solvents (kerosene, diesel fuel) to be liquid at room temperature. Liquid asphalt is also called *cut-back*. The use of liquid asphalts is minor due to environmental concerns and the high cost of solvents.

Micro-milling – Removal of the surface of an asphalt concrete pavement (or Portland cement concrete pavement) by a self-propelled guided unit equipped with a helical cutting drum with carbide-tipped tools. Typically, the depth of micro-milling is up to 15 mm and results in a surface texture depth of about 1 mm.

Micro-surfacing – An unheated mixture of polymer-modified asphalt emulsion, high-quality frictional aggregate, mineral filler, water, and other additives, mixed and uniformly spread over the pavement surface as a slurry. The fundamental difference between micro-surfacing and a slurry seal is in the aggregate used to produce the slurry. Aggregate used for micro-surfacing has typically larger particles than the aggregate used for a slurry seal. The particles are 100 percent crushed, interlock, and produce a strong stone skeleton.

Milling – Removal of asphalt or Portland cement materials from pavements by a self-propelled unit having a cutting drum equipped with carbide-tipped tools.

Open-graded – Refers to the property of aggregate or to the property of materials utilizing such aggregate, e.g., open-graded friction course. Open-graded aggregate has similar-size aggregate particles and thus a large amount of voids between the particles. Refer also to the definition for dense-graded.

Preventive maintenance – A planned strategy of cost-effective treatments. There is a difference between preventive maintenance (a strategy) and preventive maintenance treatment (an action).

Preventive maintenance treatment – A treatment performed to prevent premature deterioration of the pavement, or to retard the progress of pavement defects. The objective is to slow down the rate of pavement deterioration and cost effectively increase the useful life of the pavement.

Precision milling – Removal of the surface of an asphalt concrete (or Portland cement concrete) pavement by a self-propelled unit having a cutting drum equipped with closely spaced carbide-tipped tools. Typically, the depth of precision milling is up to 25 mm and results in a surface texture depth of about 5 mm.

Recycling agent – Bituminous material added to reclaimed asphalt concrete material to improve binder deficiencies and to restore aged binder to desired specifications. Also called *rejuvenating agent* or *rejuvenator*.

Rejuvenator - A type of fog seal product meant to soften or "rejuvenate" the aged asphalt. These generally are emulsions of oils meant to replace the oxidized "maltene" fractions in the asphalt, and may include polymers, asphalt and other additives.

Rejuvenating Agent – Similar to recycling agents in material composition, these products are added to existing aged or oxidized HMA pavements in order to restore pavement surface flexibility and to retard block cracking.

Surface or Restorative seal – An application of a bituminous material to the surface of asphalt concrete pavement. Restorative seals are also referred to as rejuvenators or fog seals. Some agencies or suppliers recommend light sanding after the application of restorative seals (about one kg of sand per square meter).

Scrub seal – Application of asphalt binder to the pavement surface followed by the broom scrubbing of the binder into cracks and voids, and sanding. See also the definition of surface treatment..

Slurry seal – An unheated mixture of emulsion, graded fine aggregate, mineral filler, water, and other additives, mixed and uniformly spread over the pavement surface as a slurry. Slurry seal is also referred to as quickset slurry seal or polymer-modified quickset slurry seal, emulsified asphalt slurry seal, and thin cold-mix seal. Slurry seal is similar to micro-surfacing, but lacks the interlocking aggregate skeleton formed by crushed aggregate particles. Also, slurry seal emulsion may not be polymer-modified.

Street types - Functional classification is the process by which streets and highways are grouped into classes, or systems, according to the character of service they are intended to provide. Basic to this process is the recognition that individual roads and streets do not serve travel independently in any major way. Rather, most travel involves movement through a network of roads. It becomes necessary then to determine how this travel can be channelized within the network in a logical and efficient manner. Functional classification defines the nature of this channelization process by defining the part that any particular road or street should play in serving the flow of trips through a highway network. Some street definitions are:

Arterial - A major street or roadway with high volumes of traffic and high speeds, usually with limited or no street side parking; arterials are used primarily for through traffic.

Collector – Streets that collect traffic from local roads and bring all developed areas within a reasonable distance of an arterial road; (2) provide service to smaller communities; and (3) link the locally important traffic generators with their rural hinterland. The collector routes generally serve travel of primarily intra-county rather than statewide importance and constitute those routes on which (regardless of traffic volume) predominant travel distances are shorter than on arterial routes.

Expressways - Streets or highways intended for fast and heavy traffic traveling a considerable distance on which points of ingress or egress and crossings are controlled, limited or separated.

Local – (Residential) - The lowest level street; it's primary functions are to provide access to individual residential properties predominantly from the front, carry traffic that has its destination or origin on that street or from within the local neighborhood, and provide backbone to pedestrian and bicycle networks. Local streets carry only traffic that originates or has its destination on that street.

Alley- A narrow passage or way in a city between or behind buildings, as distinct from a public street. Alleys are narrow, without sidewalks, curb & gutter. Alley names are not used
for address assignment.

Avenue - A wide street or thoroughfare, often lined with trees. It is predominantly straight, normally with sidewalks, leads through residential or commercial development,

Boulevard - A broad street often tree-lined and landscaped. Usually used for arterials or collectors.

Circle - Normally residential, terminates on the same street where it originates.

Court - A short street with outlet at one end only (dead-end street), constructed with turn-a-round at the other end. Also referred to as a 'Cul de Sac'.

Bicycle Lane - A portion of the roadway which has been designated by striping, signing, and pavement marking for the preferential or exclusive use of bicyclists.

Surface abrasion – A process of abrading pavement surface to reduce roughness or improve pavement friction, resulting in the surface that can be used as a driving surface. Surface abrasion includes diamond grinding, micro-milling, precision milling, and other techniques.

Surface Treatment – An application of asphalt binder, immediately followed by an application of cover aggregate, to any type of pavement surface. Surface treatment is also called *bituminous surface treatment* or *asphalt surface treatment* or a chip seal. There are different types of surface treatments depending on the type of cover aggregate and the number of applications. One application of binder and one application of cover aggregate is termed a single surface treatment while two applications of binder and two application of cover aggregate is termed double bituminous surface treatment (DBST).

Stone Matrix Asphalt (SMA) – A mixture of asphalt binder, stabilizer material, mineral filler, and gap-graded aggregate. SMAs are used as a rut resistant wearing course.

Tack coat – Application of bituminous material, typically asphalt emulsion diluted by water, to the surface of asphalt concrete (or Portland concrete) layer. It is used to improve a bond between the existing surface and the overlying course. A tack coat applied on a granular surface is called *prime coat.*

Thin (asphalt concrete) overlays – Asphalt concrete overlays less than 40 mm thick. Overlays that are less than 20 mm thick are commonly called **ultra-thin (asphalt concrete) overlays**.

Thin pavement surfacing – A pavement surface layer or treatment that is less than 40 mm thick.

Warm Asphalt - A hot asphalt mix produced at 50 to 75^0 F lower than conventional hot-mix asphalt; warm mix is trucked to the site, paved and compacted, and meets density, smoothness, and rut resistance. Some advantages include lower plant emissions, lower energy consumption, and may cause less cracking because the binder did not age as much during construction.

APPENDIX C

RESURFACING AND PAVEMENT PRESERVATION TREATMENTS

This Appendix contains brief descriptions of some preservation methods, and discusses those that have been evaluated by the Metro Nashville. Metro has conducted field evaluations of a number of maintenance and pavement preservation treatments under real conditions with 500-ft test sections on selected streets maintained by Public Works. Some products that have been evaluated include:

- Reclamite
- GSB 88
- Rejuvaseal
- PASS
- Re-Play (Soy)
- Crack Seal
- GSB-Restore
- Slurry/Micro
- Joint Bond
- Infrared Patching

The field evaluations will continue as new products are identified with promise to improve the Metro maintenance and pavement preservation program in a cost-effective manner.

The discussions below provide brief descriptions of various pavement preservation methods, selection criteria, materials and construction, and surface preparation, along with sources for more information.

C.1 THIN HOT MIX OVERLAYS

C.1.1 Definition

The thickness of thin hot mix asphalt concrete (AC) overlays is generally less than 2 inches (50 mm). This distinction is made because overlays that are more than 2 inches thick are usually associated with routine paving operations, whereas overlays that are less than 40 mm thick typically require special specifications. Also, such thin overlays provide a similar function, as do other thin pavement surfacings. Figure C.1 illustrates the processes involved in construction of thin overlays. Mill and overlay has been used by the Metro for many years; although this method of maintenance provides a good riding surface, it is not always the most cost-effective treatment.

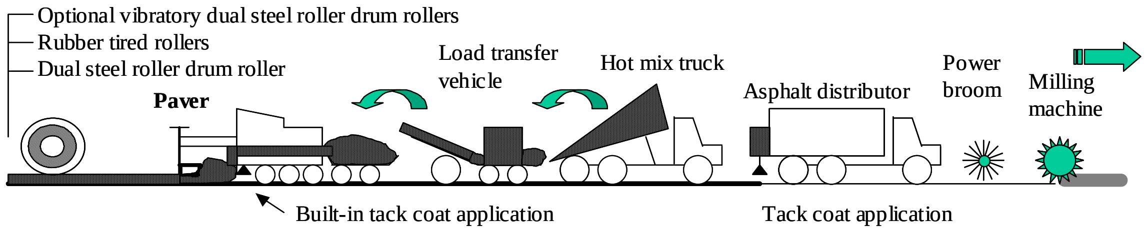


Figure C.1. Construction sequence for hot mix overlays with prior milling.

C.1.2 Selection Criteria

Thin AC overlays are typically used on structurally sound pavements to provide a new waterproof surface, to improve ride quality, to increase pavement friction and reduce noise. They can be also used as a preventive maintenance treatment to slow surface raveling, seal small cracks, and provide a waterproof surface. If thin AC overlays are applied to badly cracked AC pavement, the cracks will likely reflect through the new surface in a short time. Areas with significant load associated distresses, i.e., medium to high severity alligator cracking or rutting, are not candidates for thin overlays.

C.1.3 Materials and Construction

The two main types of hot mix used for thin overlays are dense-graded and open-graded mixes. Dense-graded mixes typically use sandy mixes with the largest aggregate particle passing ½-inch sieve. Open-graded mixes contain a large percentage of one-size coarse aggregate resulting in a mix with interconnected voids and high permeability. The existence of distresses such as segregation, raveling and block cracking, or conditions that do not permit raising of the pavement surface, may dictate a partial removal of the existing asphalt concrete by milling or precision milling prior to overlay.

C.1.4 Surface Preparation

Thin AC overlays should be constructed on an existing surface that is uniform and allows good bond with the overlay. Improvements to the existing surface before applying the overlay may include precision milling to improve ride quality and cross-section, application of a leveling course or a scratch course, patching, full-depth repairs, and application of a tack coat.

A tack coat is generally applied prior to placing a thin overlay in order to improve the bond between the existing surface and the overlay. The bond increases the strength of the pavement structure (by limiting slippage between layers) and the durability of the overlay (by reducing the possibility of delamination). Too much tack coat can be detrimental, particularly with conventional overlays causing bleeding in the overlay. A tack coat is also necessary to seal the pavement when open-graded overlays are used. Tack coats are typically 0.03 to 0.07 gal/yd^2 of asphalt emulsion SS-1 or SS-1h, CSS-1, CSS-1h, or RG 250.

C.1.5 Application

The thin AC overlay is constructed in two steps as a leveling or scratch course and a surface course. Both courses use the same material consisting of high quality crushed aggregate passing the 3/8-inch sieve and containing 6.0 percent of asphalt cement. The product can be constructed by most typical paving contractors using the following steps:

- A scratch (leveling) course is applied with a paving machine or a grader using a box-like attachment shown in Figure C.2. The scratch course is used to fill in depressions and ruts. The scratch coat is compacted by rubber-tired and steel wheel rollers.
- A 1-½-inch thick surface coat is then applied by a paver and compacted by rubber-tired or steel wheel rollers operating in a static mode.

Figure C.2. Application of a scratch coat of a densely graded hot mix by a grader with box-like attachment.

NovaChip, a proprietary ultra-thin hot mix overlay product, is typically 15 to 20 mm thick and contains an open-graded high quality aggregate passing the ½-inch sieve. A specialized paving machine with built-in application of a tack coat applies the mix. The application of a heavy tack coat applied just prior to the NovaChip mix is one of the strong advantages of this treatment. Special attention must be paid to handling the open-graded mix around pavement utility openings. NovaChip can improve pavement friction and provides a quiet pavement surface because of its porosity and surface texture (Figure C.3). It also reduces splash/spray during heavy rainfall. The thick emulsion tack coat of 0.2 gal per square yard achieves the impermeability of the surface. Figure C.4 compares the surface texture of NovaChip to a fine sand mix. NovaChip will be evaluated on a case-by-case basis dependent upon the type of facility and its condition.

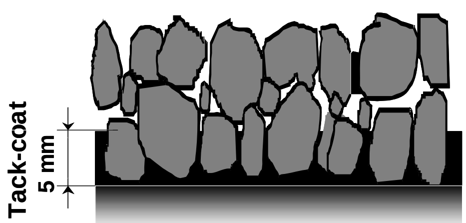


Figure C.3: Aggregate skeleton of Nova Chip surface.

Figure C.4. NovaChip surface on the left; sand mix surface on the right.

C.1.6 Resources

The publication *Thin Hot-Mix Asphalt Surfacings* by the National Asphalt Pavement Association (2001) contains description of several proprietary thin hot mix overlay products.

C.2 HOT-IN-PLACE RECYCLING

Hot-in-place (HIP) recycling (with or without integral overlay) is sometimes done to the depth of only 1 inch. Thus, even after sealing the recycled layer with a slurry seal, surface treatment, or with an integral hot mix overlay, the resulting thickness of the new and re-processed layers can still be considered a thin surfacing. The construction of HIP recycling with an integral overlay is schematically illustrated in Figure C.5.

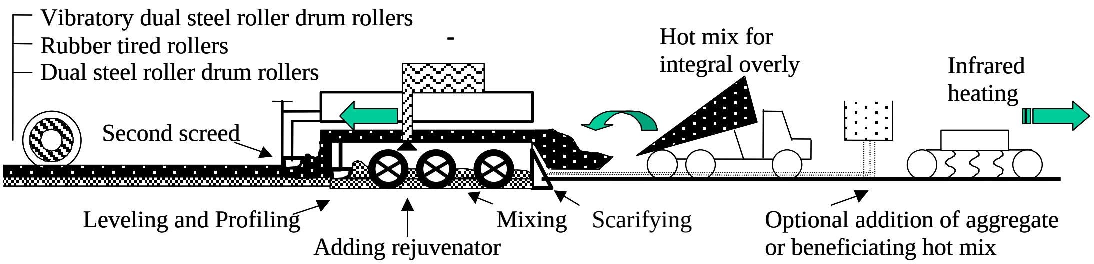


Figure C.5. Construction sequence for hot-in-place recycling with an integral overlay.

C.2.1 Materials and Construction

The recycled AC is typically mixed with a recycling agent, and can be further supplemented with pre-heated aggregate. The resulting recycled layer can be used as a driving surface or can be protected by a slurry seal, surface treatment or a thin overlay. If an integral overlay is used, the overlay serves as the new riding surface. The depth of the recycling layer ranges from 1 inch to 2 inches. The actual recycling depth may vary considerably depending on existing road conditions.

C.2.2 Selection Criteria

HIP recycling is suitable for structurally sound pavements with surface defects that affect mainly the top pavement layer, such as raveling and segregation, cracking, and rutting. The existing AC surface layer should be suitable for recycling. The layer should have a uniform composition (gradation, asphalt content, thickness) and materials of good quality (aggregate and asphalt binder). Material properties of pavements considered for HIP recycling should be thoroughly evaluated. Because of the size of a recycling train, HIP recycling is suitable for large projects with room to maneuver (e.g., on rural highways or on multilane arterial roads or streets).

C.2.3 Resources

The FHWA publication *Pavement Recycling Guidelines for State and Local Governments* (1997) describes all aspects of recycling of asphalt pavement materials to produce new pavement materials.

C.3 MICRO-SURFACING

Micro-surfacing is a mixture of polymer-modified asphalt emulsion, high-quality frictional aggregate, mineral filler, water, and other additives, mixed and uniformly spread over the pavement surface as a slurry. The construction of micro-surfacing using a self-propelled continuous feed mixing machine is schematically illustrated in Figure C.6 and shown on a photograph in Figure C.7.

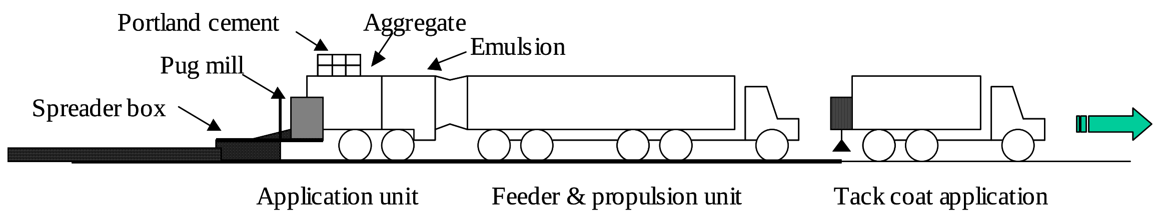


Figure C.6. Construction sequence for micro-surfacing.

Figure C.7. Truck-mounted self-propelled micro-surfacing machine (left) and finished surface using Type II aggregate (right).

C.3.1 Materials and Construction

Micro-surfacing mix is always designed by a contractor and consists of the following three main ingredients:

- Polymer-modified asphalt emulsion contains about 60 to 65 percent of asphalt cement. Polymers, typically latex, represent about 3 to 5 percent of the weight of asphalt cement. Altogether, micro-surfacing contains about 8 to 9 percent of residual asphalt binder. The addition of polymers improves bonding properties of asphalt cement and reduces its temperature susceptibility.

- Aggregate used for micro-surfacing is manufactured high-quality crushed stone, typically dense-graded. The International Slurry Surfacing Association recommends two types of gradations, one passing 0.25-inch (6.3-mm) sieve size called Type II, and another passing 0.375-inch (9.5-mm) sieve size called Type III. The Type III gradation is typically used on high traffic volume facilities and results in a minimum thickness of about 3/8-inch for a single course. The appearance of Type II micro-surfacing texture is shown in Figure C.7. The surface shows stony character of the texture typical for micro-surfacing.
- Mineral filler (Portland cement or hydrated lime) is used to control curing time of the mix. The amount of mineral filler is typically less than 1 percent of the total dry mix weight.
- Tack coat of RS-2P polymer modified emulsion applied prior to application of the Micro-surfacing.

C.3.2 Surface Preparation

Micro-surfacing is used to correct superficial distresses such as cracking, raveling and segregation, flushing, and loss of friction. Because micro-surfacing contains high-quality crushed aggregate, it is also used to fill in ruts and surface deformation to the depth of up to 1-½-inches. As a preventive maintenance treatment, it can be used to seal the surface from water infiltration when minor cracking or moderate raveling appears. Micro-surfacing has excellent frictional properties and is used on high-speed roads.

The surface on which micro-surfacing is applied should have uniform characteristics and provide a good bond. Areas that exhibit considerably more severe defects (raveling, cracking, or rutting) than the remainder of the section should be treated with an additional course of micro-surfacing (Figure C.8) or repaired by other means. When the surface of the pavement has minor distortions or has ruts exceeding about ¼-inch, two courses of micro-surfacing are recommended. The first (scratch) course is designed to improve the profile of the pavement, and the second course provides the wearing surface.

Figure C.8. Pre-treating of a severely raveled centerline joint with a light application of micro-surfacing prior to applying a regular course of micro-surfacing on the entire surface.

Many agencies rout and seal working cracks (e.g., transverse cracks) shortly before micro-surfacing is applied. However, micro-surfacing may not bond to the new crack sealant resulting in the loss of material. Some agencies require that routing and sealing of cracks is done a year before micro-surfacing. Other agencies carry out routing and sealing several months after micro-surfacing. This sequence is recommended because it eliminates the possibility of de-bonding and ensures that only cracks that are not sealed by micro-surfacing are routed and sealed.

C.3.3 Resources

The International Slurry Surfacing Association website www.slurry.org contains specifications and useful guidance (2003).

C.4 SLURRY SEAL

Slurry seal is a mixture of asphalt emulsion, graded fine aggregate, mineral filler, water, and other additives, mixed and uniformly spread over the pavement surface as slurry. Slurry seal is similar to micro-surfacing, but lacks the interlocking aggregate skeleton formed by crushed aggregate particles. Also, slurry seal emulsion may not be polymer-modified. The construction of slurry seal using a self-propelled truck-mounted mixing machine is schematically illustrated in Figure C.9.

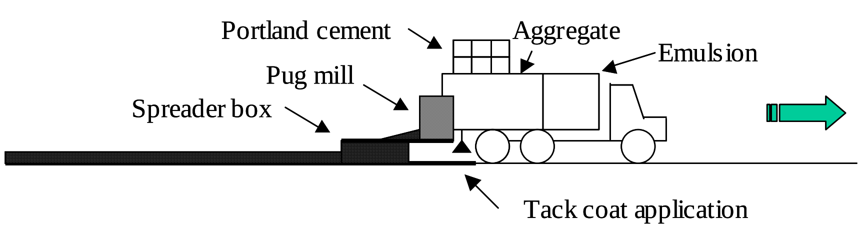


Figure C.9. Construction sequence for slurry seal.

C.4.1 Materials and Construction

Asphalt emulsion used for slurry seal work is typically cationic and contains about 60 to 65 percent of residual asphalt cement. The finished product contains 9 to 10 percent of asphalt cement. Aggregate used for slurry seals should be crushed high quality dense graded aggregate. Its gradation generally follows one of the three gradation types recommended by the International Slurry Surfacing Association. The Type I is used for residential streets; Type III for primarily roads and expressways. The thickness of a single application of Type I slurry seal is typically less than ¼-inch.

Mineral filler (Portland cement or hydrated lime) is used to control curing time of the mix (break time of the emulsion). The amount of mineral filler is typically less than 1 percent of the total dry mix weight.

C.4.2 Surface Preparation

Slurry seals are used to correct superficial distresses such as raveling and coarse aggregate loss, seal small cracks, and improve pavement friction. They are also used as a preventive maintenance treatment to seal pavement surfaces from intrusion of water and slow surface oxidation and raveling. Slurry seals are effective where the primary problem is hardening of asphalt binder resulting in minor cracking and raveling. Slurry seals will not perform well if the pavement has moderate or severe cracks, or progressive rutting.

The surface on which a slurry seal is applied should have uniform characteristics and provide a good bond. If defects such as moderate or severe raveling, cracking, or rutting occur intermittently or frequently, the section is probably not a good candidate for slurry sealing. Working cracks, such as transverse cracks, should be sealed, preferably after slurry sealing.

C.4.3 Resources

The International Slurry Surfacing Association website www.slurry.org contains specification for slurry seal and useful technology tips (2003).

C.5 SURFACE TREATMENT

Surface treatment (also called chip seal) is the application of asphalt binder immediately followed by an application of cover aggregate, to any type of pavement surface. Typically, surface treatments are applied on top of a granular base producing surface-treated pavement. Surface treatments can be also applied to new or existing AC pavements as a preventive or corrective maintenance treatment. An illustration of a surface treatment operation is shown in Figure C.10.

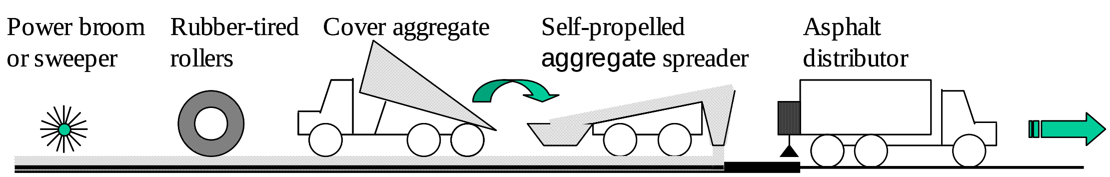


Figure C.10. Construction sequence for surface treatment.

C.5.1 Materials and Construction

Typically, the asphalt binder is asphalt emulsion applied at an elevated temperature using an asphalt distributor as shown in Figure C.11. The selection of the type of asphalt emulsion depends, in addition to the availability of the emulsion, on several factors:

- Cationic emulsions work best with sandstones and granites (negatively charged aggregates); anionic emulsions are most suited for limestone and dolomite aggregates.
- Polymer-modified emulsions are typically specified for applications on asphalt concrete surfaces.
- Rapid setting emulsions are generally recommended because of their less stringent weather restrictions.

The emulsion typically has a brown color that changes into black as the emulsion cures. Nozzles on the spray bar provide desired coverage of the surface.

Figure C.11. Asphalt distributor applying emulsion.

The cover aggregate can be either one size, (open-graded) as shown in Figure C.12, or multiple sizes (dense-graded) as shown in Figure C.13. Surface treatment using open-graded aggregate (or chips) is called chip seal. The selection of aggregates depends, on several factors:

- Open-graded aggregate should be of high quality and washed (dust free). Such aggregate is typically available only from large commercial producers.
- Graded aggregate is less expensive and requires less emulsion.
- Rural or urban setting. Initial traffic on graded aggregate may produce excessive dust; a one-size uniform aggregate free of dust and fines is recommended.
- The use of one-size aggregate reduces the amount of excess aggregate and is preferred for high traffic volume roads.

The design of aggregate surface treatments calls for about 70 to 80 percent of the aggregate imbedded by the binder. This requires a proper balance between the amount of emulsion applied to the surface and the amount and type cover aggregate. Design procedures are available to determine application rates and take into account the type and porosity of the surface, size, type and shape of the cover aggregate, and traffic volumes.

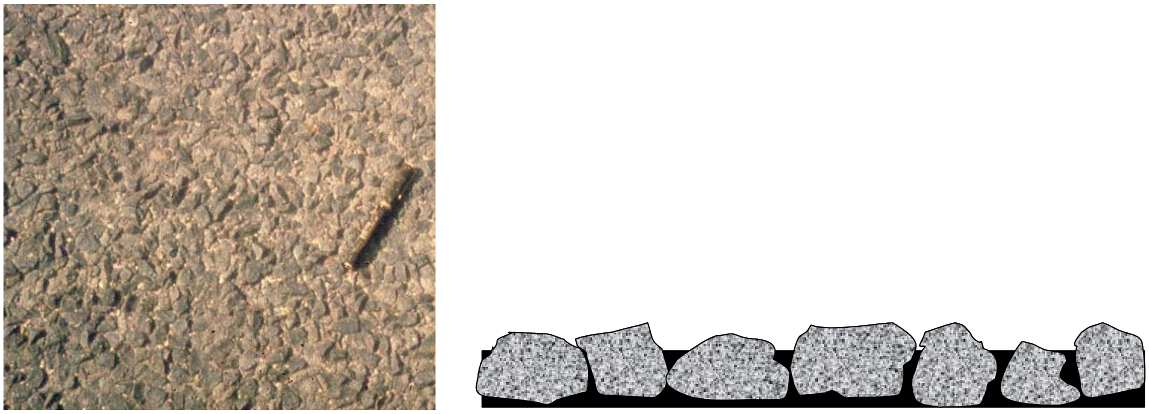


Figure C.12. Surface of a newly constructed surface treatment using uniform size aggregate.

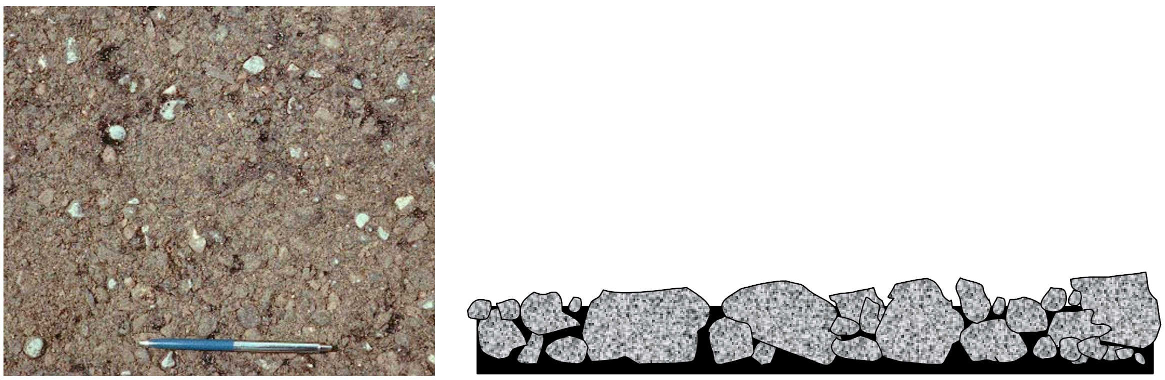


Figure C.13. Surface of a newly constructed surface treatment using graded aggregate with fine particles.

Figure C.14 shows an example of emulsion application rates for chip seals applied to an asphalt concrete surface. It should be noted that the application rate of the emulsion is decreasing with the increasing traffic volumes.

Modern asphalt distributors that can automatically maintain selected application rates regardless of the distributor to speed facilitate the need for accurate application of the binder and aggregate cover. Newly constructed surface treatments need to be protected from high-speed traffic for several hours after construction, and the public needs to be protected from loose chips and dust.

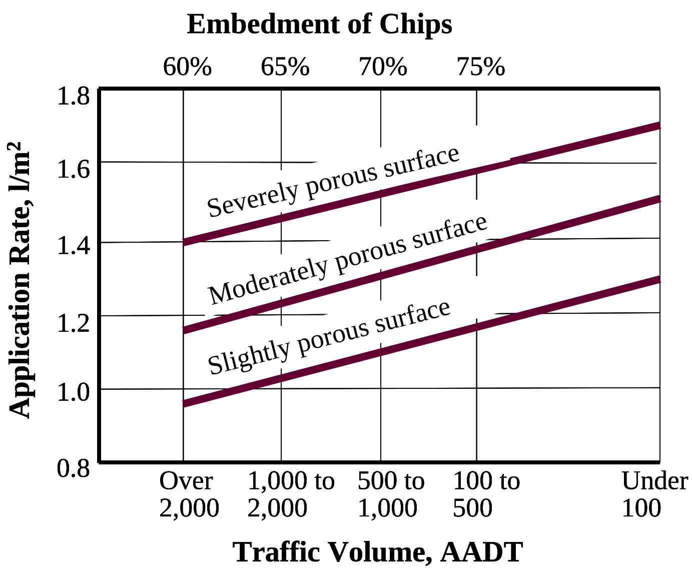


Figure C.14. Example of application rates for asphalt emulsion. Higher traffic volumes require lower application rates.

Rolling of the cover aggregate with a pneumatic roller is critical to success. The rolling embeds the chips into the asphalt and rolls them so that the least dimension is vertical. Pneumatic rollers conform to the shape of the roadway and therefore provide equal pressure to uneven spots. This also minimizes the amount of loose aggregate. Figure C.15 illustrates the effects of rolling.

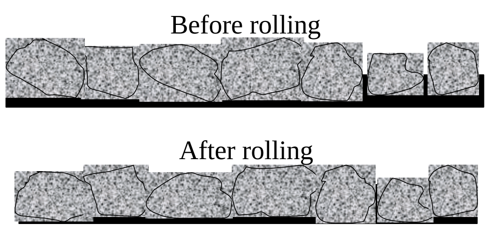


Figure C.15. Effects of rolling.

Some agencies remove excess aggregate aggressively, other agencies prefer to leave excess aggregate on the road and “live with it”, waiting until the access aggregate is dispersed by traffic. On roads with high traffic volume, the removal of excess aggregate is required for safety reasons. For the surface treatment itself, it is preferable to leave some “excess” aggregate on because it can be imbedded by traffic as aggregate particles rotate, imbed, and create additional openings in the mat.

Surface treatments applied to existing AC pavements can be used as preventive or corrective treatments. As a preventive treatment the surface treatment is primarily used to seal the surface with non-load associated cracks and raveling. As a corrective measure, surface treatments are used to restore skid resistance and to maintain wearing surface on thin AC pavements.

The surface on which a surface treatment is applied should have uniform capacity to absorb emulsion. If the pavement has, for example, areas of raveling or segregation, the raveled and segregated areas should be pre-treated (e.g., by priming or spray patching). If left untreated, these areas will absorb emulsion and will fail to have enough binder to seal the surface and retain cover aggregate -- precisely in the areas where the pavement needs the protection most. On the other hand, an increase in the emulsion application rate to match raveled and segregated areas may result in flushing elsewhere. Working cracks, such as transverse cracks, should be sealed, preferably after the surface treatment application.

C.5.2 Resources

Several agencies have published recommendations for the design construction of surface treatments including Ontario Ministry of Transportation (Cooper and Aquin, 1983) and Minnesota Department of Transportation (Janish and Gaillard, 1998). Practical handbooks were also published by The Asphalt Institute (1969) and by Asphalt Emulsion Manufacturers Association (no date).

C.6 SURFACE SEALS

Surface seals consist of a sprayed application of a bituminous material or specialty product, to the surface of existing AC pavements. Surface seals that apply diluted asphalt emulsion are also called fog seals. Some agencies or suppliers recommend light sanding of restorative seals (about 1-3/4 pound of sand per square yard). The application process is illustrated in Figure C.16.

Figure C.16. Construction sequence for restorative seal.

Surface seals are used on asphalt pavements within the first few years of their existence as a preservative for retarding the natural oxidation process and giving effective treatment for solving specific pavement problems such as raveling and oxidation.

The Metro has evaluated some surface seals and found PASS to provide satisfactory results; the Metro has adopted PASS into its preservation program. PASS is a polymer-modified asphalt surface sealer, a type of fog sealer. Rejuvenates and seals worn asphalt. It fills cracks and provides a durable membrane to resist reflective cracking

GSB 88, introduced in 1988, is a specialty product currently under evaluation by the Tennessee DOT. It is used on pavements that are less than 5 years old in order to seal the surface and prevent weathering and oxidation. Metro experience with GSB 88 is that it takes too long to cure, stays tacky too long, and does not provide enough material composition – too thin.

GSB Restore was found to be better than GSB 88 for penetration into the pavement surface with greater material composition. It is still under evaluation by the Metro.

Another product, RejuvaSeal, is proclaimed to seal, protect, and revitalize asphalt pavement surfaces. It penetrates the surface of asphalt; reduces viscosity and brittleness in the top 3/8 inch of asphalt while significantly increasing ductility and flexibility. Asphalt surfaces treated with RejuvaSeal are fuel, water, and chemical resistant. The Metro experience with this product indicated a strong coal-tar smell with unfavorable public perception; the smell is too strong for application on residential streets.

A product called Re-Play is also under evaluation. This sealant is made for soy oil. It has a slight but not unpleasant odor.

C.6.1 Selection Criteria and Surface Preparation

Surface seals are used to prevent oxidation and hardening of asphalt cement and to seal minor cracks. These seals can also slow the progression of raveling and aggregate loss. The pavement should be in good condition and should be broomed before the emulsion is applied.

C.6.2 Materials and Construction

Application rates for GSB 88 is .10 to .15 gallons per square yard. There is some concern that this product could cause a reduction in pavement friction.

PASS is 67% asphalt; 20% rejuvenator; 2% polymer. PASS applications cost only about 1/8 of the cost of traditional resurfacing using milling with 1.5 inch AC overlay.

C.6.3 Resources

A handbook by Emulsion Manufacturers Association provides guidelines for the use of restorative seals using asphalt emulsions.

C.7 SURFACE ABRASION

Surface abrasion includes diamond grinding, micro-milling, precision milling and other techniques that remove unevenness from the pavement surface, or improve its texture, and leave an abraded surface that is used as a driving surface. The operation is illustrated in Figure C.17.

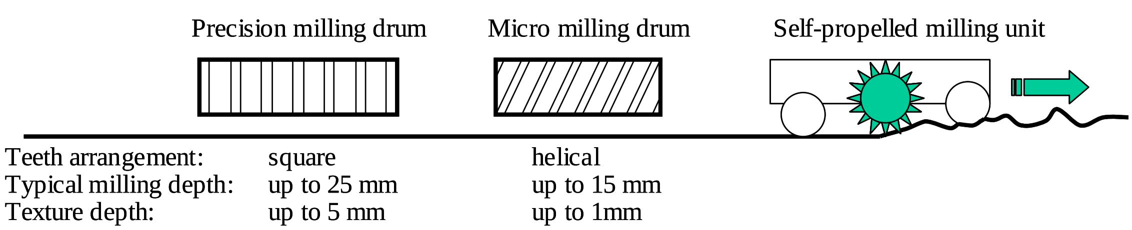


Figure C.17. Construction sequence for micro-milling or precision milling.

C.7.1 Selection Criteria

Surface abrasion techniques can smooth out stepping at transverse cracks, wheel track rutting and improve pavement friction. The pavement should have sufficient structural capacity so that the reduction in thickness is not of concern. Figure C.18 shows an example of pavement surface where micro-milling was used to reduce rutting and improve smoothness; the milled surface on the right has darker color and has groves with peak-to-peak distance of about 5/8 inch.

Figure C.18. Micro-milling application to reduce rutting and increase smoothness.

C.8 REJUVENATORS

Rejuvenators consist of a sprayed application of a bituminous material or specialty product, to the surface of existing AC pavements for the purpose of replenishing the lighter oils and softening a weathered surface. The Metro field trials found Reclamite to do a good job of rejuvenation, and Metro has adopted it to rejuvenate and protect pavements that are 2 to 3 years old with an OCI>80.

C.8.1 Selection Criteria

Rejuvenators are used on AC pavements that have oxidized and hardened; it is not suited for sealing cracks or for use on rutted pavement. It will seal minor cracks and soften the asphalt cement in the AC mix. These seals can also slow the progression of raveling and aggregate loss. The pavement should be in good condition and should be broomed before the emulsion is applied.

C.8.2 Materials and Construction

Reclamite is a widely recognized rejuvenator with many years of experience. It has been evaluated by many agencies including the U.S. Army Corps of Engineers. Studies have documented the ability of Reclamite to lower the viscosity of the asphalt binder in an AC pavement, to reduce the incidence of small cracks, and to reduce fines loss over a period of at least 3 years. Another rejuvenator that has some experience in Tennessee is RejuvaSeal. RejuvaSeal penetrates from 1/8 inch to ½ inch into the AC surface. Figure C.19 shows the application process.

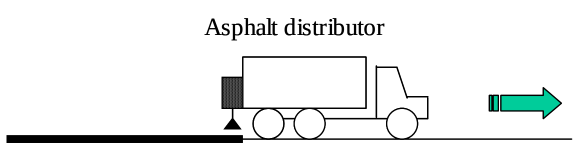


Figure C.19. Construction sequence for rejuvenators (note that light sanding is sometimes used).

Reclamite has been used extensively throughout the State of Tennessee with reported good success; examples are in cities of Oak Ridge, Athens, Clarksville, Lebanon, Spring Hill, Columbia, Kingston, and others. Oak Ridge currently treats about 5 percent of its streets with Reclamite each year.

The recommended procedure for using Reclamite is to:

1. Sweep street
2. Apply rejuvenator with asphalt distributor
3. Hand spray corners and hard to reach areas
4. Cover with sand or screenings after penetration has occurred (after about 1 hour)
5. Sweep up sand after 24 hours
6. Dark color fades in about 45 days

These products cost about $0.65 to $0.85 per square yard in place.

Figure C.20 shows the application and results of the Reclamite field trials in Nashville.

Figure C.20. Reclamite application on field section in Nashville.

C.8.3 Resources

"Evaluation of Rejuvenators for Bituminous Pavements," U.S. Amy Engineer Waterways Experiment Station, Report Number AFCEC-TR-76-3, February 1976.

C.9 CRACK SEALING

The purpose of sealing cracks in asphalt concrete pavement is to protect the pavement structure from premature failure; it is the most common maintenance option to help protect the pavement structure. The sealant protects the pavement by minimizing moisture infiltration through the crack opening and preventing the retention of debris in the crack, as shown in Figure C.21. When sealing is performed at the proper time, using the appropriate materials and procedures, the life-cycle performance of the pavement can be increased and maintenance costs reduced. Crack sealing has been implemented in the Metro.

The objectives of crack sealing are to:

- Reduce moisture infiltration
- Reduce incompressible material in cracks

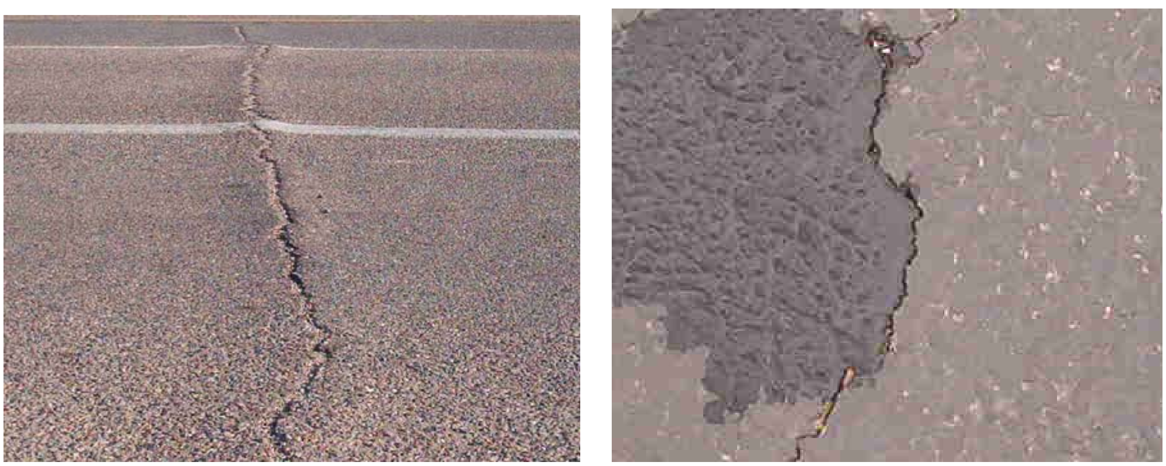


Figure C.21. Both water and incompressibles enter cracks that are not properly sealed.

C.9.1 Selection Criteria

Crack sealing works best when applied to:

- Relatively new pavement surfaces
- Pavements with good structural support
- Little or no secondary cracking
- Little or no raveling at crack face
- Cool weather (fall or spring)
- Proper preparation (clean and dry)

C.9.2 Materials and Construction

Routing adds up to 50% to the sealant life at 10% added cost. Figure C.22 shows the routing and cleaning operation. Figures C.22 and C.23 show the proper application of the sealant to achieve the overband. Equipment to prepare and apply cracking sealant costs about $50,000.

First, the cracks are cleaned and dried using a hot compressed air heat lance. Then, the cracks are filled with hot poured rubberized joint and crack sealant. It is often placed in advance of overlays and surface treatments to improve performance.

Figure C.22. Routing and cleaning are important to good seal performance.

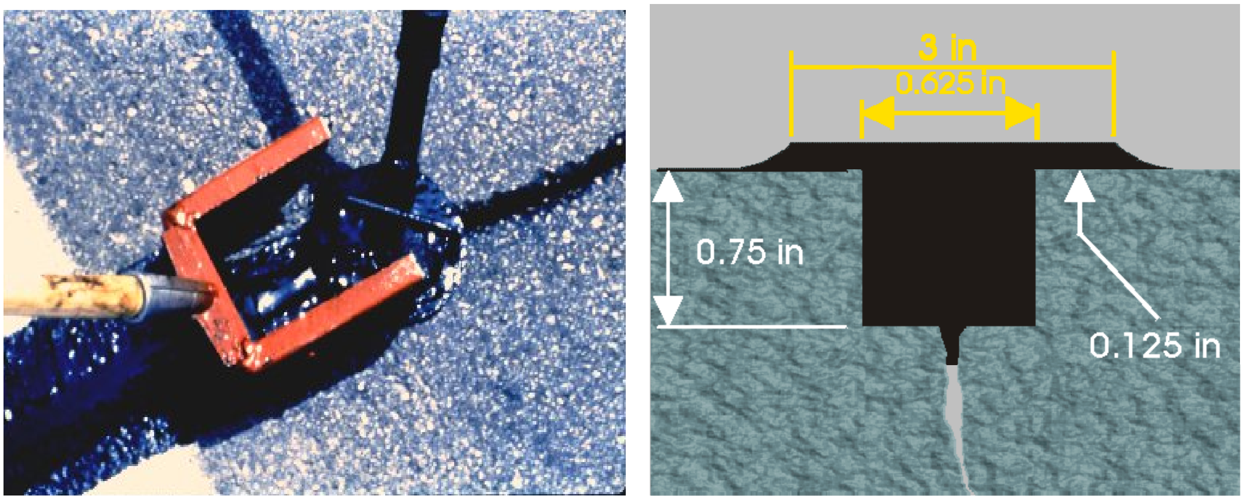


Figure C.23. Application of sealant to achieve overband.

C.9.3 Resources

Manual of Practice- FHWA-RD-99-147, “Materials and Procedures for Sealing and Filling Cracks in Asphalt-Surfaced Pavements” (February 2001)

Available through Turner-Fairbanks Highway Research Center, 6300 Georgetown Pike, McLean, VA 22101-2296; www.tfhrc.gov

U.S. Departments of the Army and Air Force, TM 5-822-11/AFM 88-6, Chapter 7 "Standard Practice for Sealing Joints and Cracks in Rigid and Flexible Pavements," Washington, D.C.

C.10 INFRARED PATCHING

This technology uses infrared to heat existing AC surfaces and blends in new AC mix to create a joint-free integral patch. The machine is capable of heating the existing AC to a depth of approximately two inches without oxidation or burning. No flame is in direct contact with the existing surface. Infrared asphalt recycling equipment uses "invisible heat" to emplace recycled asphalt. The equipment produces intense infrared wavelengths that reach temperatures near 1200 degrees Fahrenheit and directs them onto the bituminous surface that absorbs the wavelength and creates energy in the asphalt. The energy is heat and this heat conducts through the asphalt to the depth necessary for the scarification and repair of the damaged asphalted area.

C.10.1 Selection Criteria

Infrared asphalt recyclers are a cost-effective method of asphalt repair. Infrared repair techniques are faster than cutting out and replacing asphalt, and the resulting sealed joint is much more difficult for water to seep into. Infrared asphalt recyclers warm the existing asphalt in and around the repair area to over 300 degrees Fahrenheit - the same temperature that new asphalt is when manufactured at the plant. The softened asphalt can be scarified to mix in hot liquid binder and fresh asphalt, if needed, before compaction

Infrared patching seems to work very well but there it is new enough that there is limited competition for bidding. Experienced contractors are needed to level the playing field. The Metro has implemented infrared patching on some city streets.

C.10.2 Materials and Construction

Infrared heaters offer reliable operation in all weather conditions. High-pressure LP gas fired systems stay lit despite high-winds. Heat output is adjustable to allow infrared penetration for varying asphalt depths. Multi-heat zones allow heating of smaller areas. A self-propelled system allows the unit to easily be moved from patch to patch.

Metro Nashville has evaluated the infrared technique for patching and found it to be very satisfactory. Figures C.24 and C.25 highlight the patching procedure as used in the Metro.

C.10.3 Resources

Manufacturer literature.

Figure C.24. Heating area to be patched with Infrared machine.

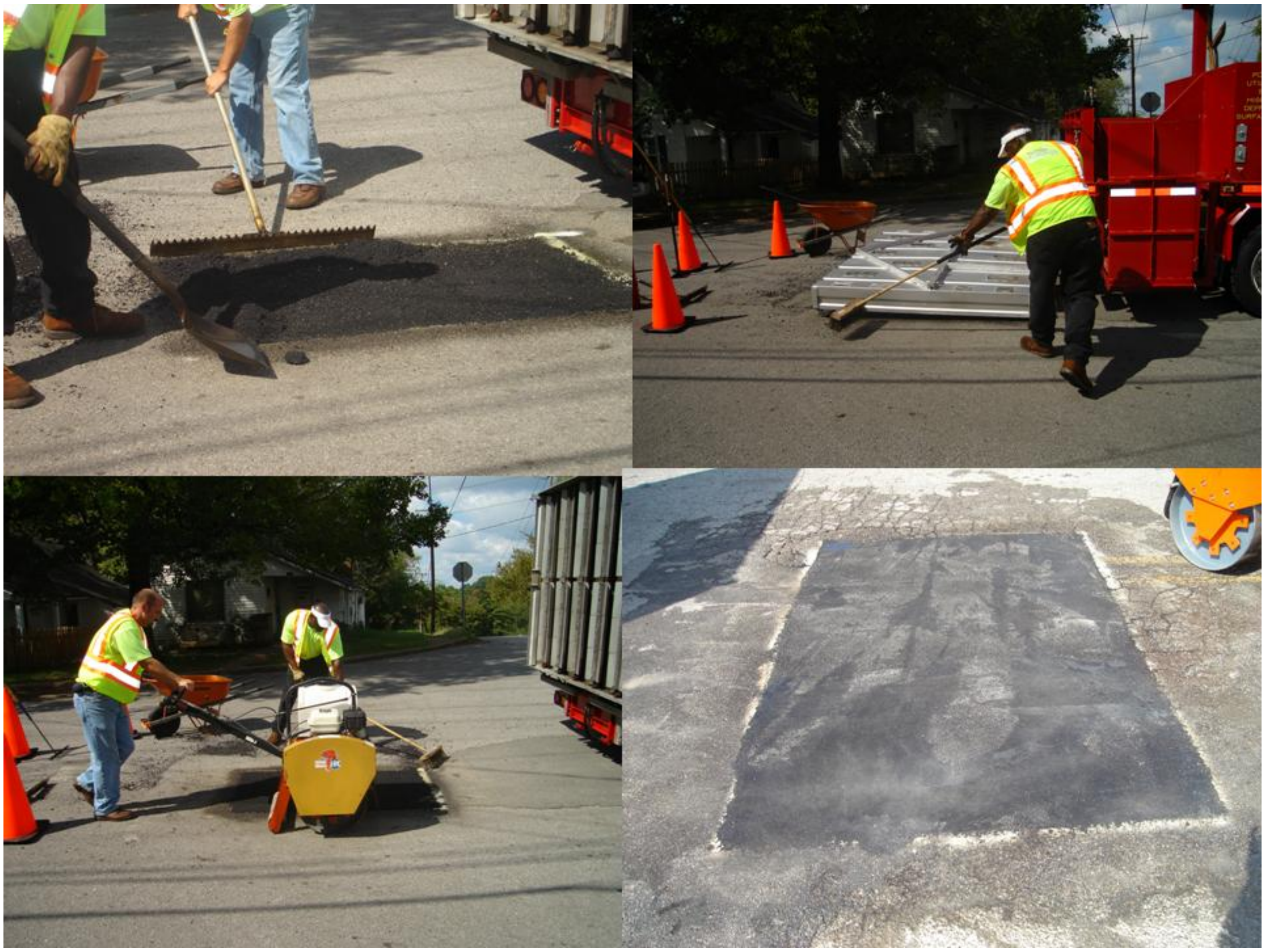


Figure C.25. Adding new mix heating, and compaction.

C.11 WARM MIX ASPHALT

European countries are using technologies that appear to allow a reduction in the temperatures at which asphalt mixes are produced and placed. These technologies have been labeled Warm Mix Asphalt (WMA). The immediate benefit to producing WMA is the reduction in energy consumption required by burning fuels to heat traditional hot mix asphalt (HMA) to temperatures in excess of 300° F at the production plant. These high production temperatures are needed to allow the asphalt binder to become viscous enough to completely coat the aggregate in the HMA, have good workability during laying and compaction, and durability during traffic exposure. With the decreased production temperature comes the additional benefit of reduced emissions from burning fuels, fumes, and odors generated at the plant and the paving site.

There are three technologies that have been developed and used in European countries to produce WMA:

1. The addition of a synthetic zeolite called Aspha-Min® during mixing at the plant to create a foaming effect in the binder.

2. A two-component binder system called WAM-Foam® (Warm Asphalt Mix Foam), which introduces a soft binder and hard foamed binder at different stages during plant production.
3. The use of organic additives such as Sasobit®, a Fischer-Tropsch paraffin wax and Asphaltan B®, a low molecular weight esterified wax.

The Aspha-Min and Sasobit products have been used in the United States. A fourth technology has been developed and used in the United States to produce WMA; this fourth process is plant production with an asphalt emulsion product called Evotherm™, which uses a chemical additive technology and a "dispersed asphalt technology" delivery system.

All four technologies appear to allow the production of WMA by reducing the viscosity of the asphalt binder at a given temperature. This reduced viscosity allows the aggregate to be fully coated at a lower temperature than what is traditionally required in HMA production. However, some of these technologies require significant equipment modifications.

This technology could have a significant impact on transportation construction projects in and around non-attainment areas such as large metropolitan areas that have air quality restrictions. The reduction in fuel usage to produce the mix would also have a significant impact on the cost of transportation construction projects.

C.11.1 Selection Criteria

The Metro plans to conduct evaluation of WMA and determined if it has a place in the maintenance and preservation program.

This page intentionally blank.

APPENDIX D

UTILITY CUT REPAIR GUIDELINES AND SPECIFICATIONS FOR THE PERMITTING PROCESS

D.1 OVERVIEW OF UTILITY CUT ISSUES

In recent years, utility owners have increasingly chosen to take their distribution networks underground. According to a 1997 report published by APWA, "Managing Utility Cuts",

> "The issues surrounding the management of utility cuts are as varied as the cuts are numerous. As the demand for greater access to the right of way increases, so will the need for better coordination of multi-agency schedules and a higher level of accountability for employing less intrusive, more durable and cost efficient methods for making utility cuts."

This has certainly been the experience of Nashville.

As a result, several cities across the nation have undertaken projects to make fair and uniform assessment of the damage due to utility cuts, and to assess an appropriate fee schedule to recover the damages. Additionally, research has been conducted to establish a more "engineered" approach to repairing the cuts. In other words, agencies are adopting a "do it right the first time" specification.

This study researched current practices and reviewed other agency specifications, then used these findings to develop a guide to utility cut management. The findings and recommendations are presented in three parts:

- Current Practices within MPW
- Process Used to Identify Level of Utility Degradation
- Specifications and Construction Guidelines for Trench Repair

D.2 CURRENT PRACTICES IN MPW

In 1997, MPW amended Chapter 13.20, Excavations and Obstructions, of the Metropolitan Code of Laws in an attempt to increase the service life of the MPW's pavement network. This amendment, enacted through Ordinance 97-785, Excavations and Obstructions, now requires that any pavement surface removed or damaged as a result of an excavation must be replaced by, and at the expense of, the person or organization responsible for making the excavation. In addition, a reputable paving contractor must perform the repair in accordance with the requirements and specifications of the Department, and the repair can only be performed in the presence of a Department inspector.

The applicable specification for pavement repair on MPW roads and streets is contained in Section 02575, Pavement Repair, of the MPW Standards. Specifically, Paragraph 3.9 stipulates that full lane or roadway width milling and/or paving is required where successive or continuous excavations are planned so as not to "checkerboard" the repair and to provide a smooth riding surface. The length of full width milling and/or paving is to be from manhole to manhole centerline from the first excavation point to the last. In addition, if the excavation is within 300 feet of an intersection, the repair limits are to be extended to the radius point of the intersection.

According to Section 13.20.030.D.1 of the Metro Code, an excavation permit is required for each separate excavation. A single excavation is defined as having a maximum area of 6 square yards or a maximum length of 33 ft. Excavations having an area or length greater than these limits must be separated into two or more excavations, each requiring its own permit. In addition to the permit fee, an excavation made in a pavement surface less than 5 years old is assessed a fee of $500 plus 20% of the average cost to repair the excavation according to MPW specifications

In 2001, the Department issued a contract to IMS/Terracon, a pavement management consultant, to study the impact of utility cuts on the service life of MPW pavements and to develop a fee schedule for excavation permits that would prorate the cost of repairing excavations among the permit holders who damaged the surface (Development of a Street Damage Restoration Fee Schedule for the Metropolitan Government of Nashville and Davidson County, Terracon, February 2001). The fee schedule was designed to recoup the cost of milling and paving an entire block once the surface condition deteriorated to a specified level. The fee schedule was also weighted based on the age of the surface, with higher fees charged for excavations in newer pavements. This fee schedule, however, was never implemented.

D.2.1 Specification Issues

The current specification for pavement repair, Section 02575, specifies high-quality materials and procedures. The IMS/Terracon study concluded that repairs made in accordance with this specification were actually stronger than the surrounding pavement. The major concern expressed by the Department staff with this specification lies in the lack of enforcement of Paragraph 3.9. Utility companies are not being required to mill and pave full width between successive cuts or along continuous cuts or between cuts and to intersections 300 feet or less in proximity.

Part of the problem lies in the wording of this provision. Rarely does a utility plan for and request permits for multiple cuts within the same block. The most common scenario involves a request for a single cut within a block that already contains one or more cuts; there is no provision to have the utilities mill and/or pave full width between the proposed cut and an existing cut. Two options were presented in the Terracon report to MPW to address the ride quality and aesthetics issues posed by utility cuts.

Option 1 is to amend Paragraph 3.9 of the Pavement Repair specification to require full width milling and paving between the proposed cut and any existing cut within 10 feet. The suggested 10-foot length will prevent numerous adjacent small repairs that deteriorate ride quality, appearance and overall performance. Of course, this option is viable only if it is enforced, but nearly 100 percent compliance should be achievable if the issuance of future permits to a given utility is tied to their past compliance with the specification.

Option 2 is to implement the fee schedule proposed in the IMS/Terracon report. On the average, this option would generate sufficient funds to repave an entire block once 15 percent of the block's surface area is affected by a utility cut repair. The proposed fees are easily calculated from the information contained in the permit application and the pavement management system database, and the fees should be easy to collect if issuance of the permit is tied to payment of the fees. The higher fees will be cheaper for the utilities than the extensive paving required by Option 1. The significantly higher permit fees will likely be strongly opposed by the utilities.

Option 1 is recommended because it offers the path of least resistance in meeting the goal of smoother riding pavement surfaces. The specification is already in place, so a small amendment should not be too difficult to accomplish. The amendment should be accomplished prior to the start of enforcement. The utilities likely would voice opposition to the sudden enforcement of the current specification, so opposition to enforcement of the amended specification can certainly be expected.

D.2.2 Performance of Utility Cut Repairs

Utility cuts, like other patches, cause damage that reduces the level of service of the street. This is not a new concept, but one that pavement engineers have dealt with since cuts in the pavement right-of-way to bury utilities have been allowed. The surface condition rating method selected by MPW, ASTM D6433, includes a serviceability deduct value for the presence of a utility cut. This deduct value is comparable in severity to the deduct values assigned for longitudinal and transverse cracking. The problem is not one of "does the cut damage the pavement," but rather, "how can the impacts be quantified as to costs and how do these translate into reasonable and defensible fees?"

In 2002, the Construction Practices Subcommittee of the APWA was assigned to research available documents related to pavement degradation caused by utility cuts. A summary of the major findings of their literature review follows:

- Factors influencing the performance of a patch include the pavement material, soil conditions, climate, traffic and repair techniques. These roughly correlate with the same factors influencing the life of a new pavement.
- Poor construction techniques, such as rocking the jackhammer while cutting the boundary of the patch, can damage the area adjacent to the cut and further degrade the patch and surrounding pavement. Studies showed this zone of influence to be 1.5 to 6 feet beyond the patch.
- Pavement cut repairs made using quality materials and sound engineering and construction techniques tend to perform as well as the surrounding pavement.
- Poor performance of the patch tends to be a result of inadequate compaction of the materials, insufficient thickness of materials, poor quality of materials, and damage to the side of the cut.
- Most of the reports included a cost analysis associated with the cuts ranging from $2 per square yard to $540 per square yard.
- The estimated reduction in pavement life due to a utility cut was found to be from 20 to 56% of the original life of the pavement.

These observations are consistent with the findings of the Terracon report and with other studies such as the Salt Lake City report (*Public Works*, April 2002) where structural testing was used to quantify the degradation caused by a utility cut. The Terracon report suggested the unit rate for pavement overlay was $21.67 per square yard. Further it was determined that the fees for recovery should be prorated due to the age of the pavement, and that new pavements should have the highest rate of recovery. A full table of fees is found in the Terracon report.

The Salt Lake City report used deflection tests with an FWD (Falling Weight Deflectometer) to prove that the zone of influence or damage beyond the visual limit of the trench was at least 2 feet. It was suggested that a "T" patch (replaces surface course at least 2 feet beyond trench boundaries) be used to compensate for this damage. Additional suggestions were made for selecting the cut boundaries. Other somewhat intangible costs were discussed, but no consensus seemed to exist for recovery of these costs. They include traffic disruption, safety of repair personnel, emergency vehicle response times due to rough patches and others.

The findings of the report prepared by Terracon are consistent with those of other agencies, and it is recommended that these findings be used in developing MPW's specification and permit fee policy.

D.3 CONSTRUCTION GUIDELINES FOR TRENCH REPAIR

Chapter 13.20 of the Metro Code has been cited as a model by the APWA and referenced in many of the articles studied for this report. Therefore, it is recommended that the current code be modified to include recent improvements in practice being used by other municipalities. The requirement for patch awareness and repair training and a specification for the "T" patch are also submitted for adoption. The recommended modifications are summarized as follows:

D.3.1 Requirements for Training

Recognizing that education and awareness by the utility companies as to the impact of their cuts on pavement life and the quality of the community is needed, it is suggested that representatives from utility companies and contractors be required to attend a ½-day workshop on patching utility cuts. This workshop would cover the impacts of cuts on street performance and the associated economic burden on the community as well as proper utility cut procedures. The workshop should be based on the Strategic Highway Research Program manuals of practice and include the rating tree procedure. The presence of a workshop graduate would be required to perform a utility cut or utility cut repair.

D.3.2 T-Patches

T-Patches are pavement cuts made outside the trench boundaries so there is not a continuous vertical shear plane from the edge of the trench to the pavement surface. Research shows that the zone of influence is at least 2 feet from the edge of the trench. To take advantage of the layering effects of a flexible pavement, the compacted base and the surface course should be extended at least 2 feet from the edge of the trench. This design minimizes the reflective cracking due to excessive strains at the bottom of each layer at the edge of the trench and allows better compaction of the base material and new HMAC. Diagrams for typical T-patches are shown below as Figure D.1 shows the details or trench repairs in both the crossing (transverse) direction and parallel (longitudinal) direction. Figures D.2 and D.3 are notes that comprise part of the specifications for the flush trench repairs and support the details in Figure D.1. Figures D.5 and D.6 are notes that comprise part of the specifications for the recessed trench repairs and support the details in Figure D.4. Figure D.7 provides details for trench repairs outside the roadway. Figure D.8 provides details for temporary patch.

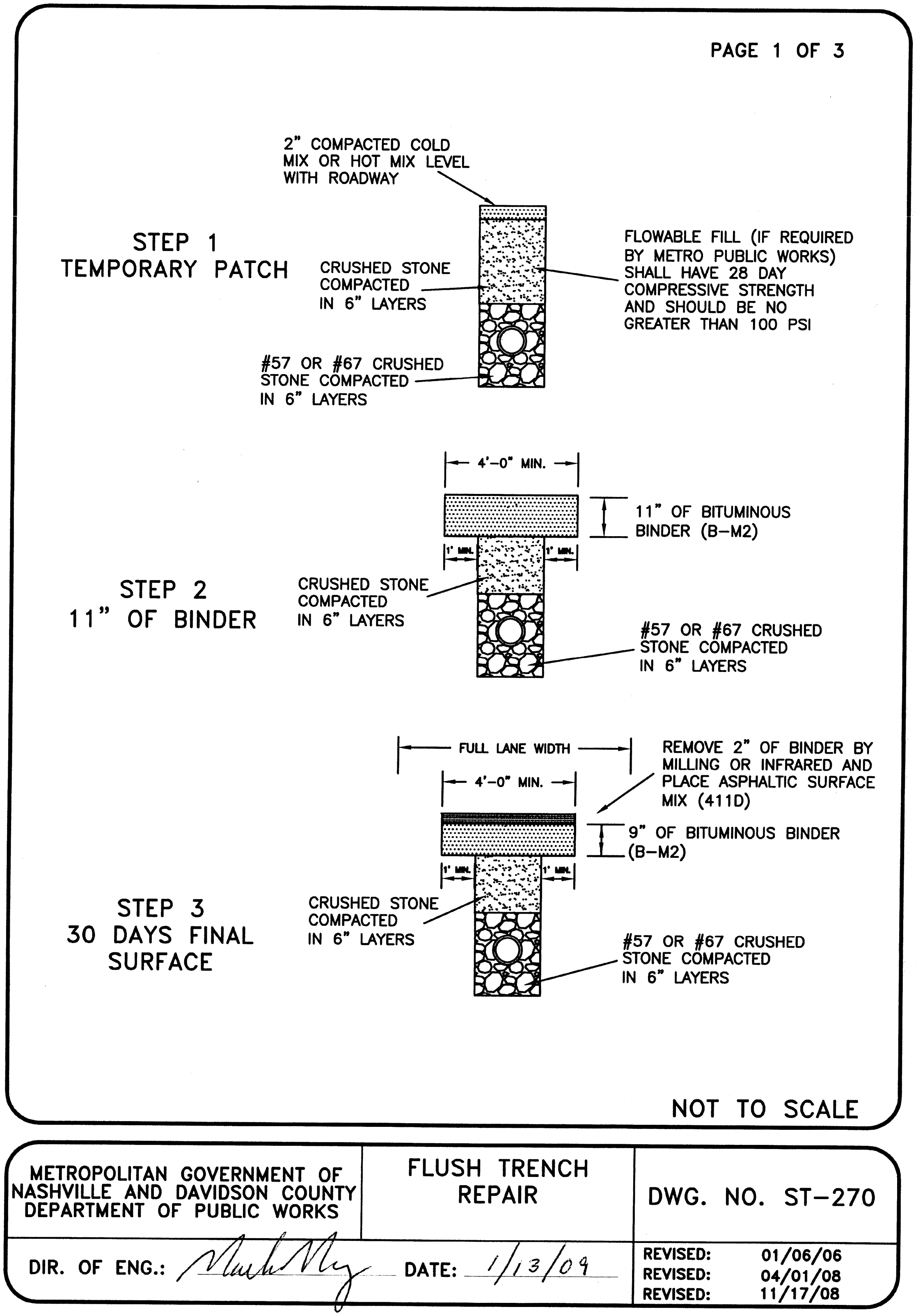


Figure D.1 Details of a flush trench repair.

GENERAL NOTES

PAGE 2 OF 3

1. PRIOR TO PLACEMENT OF CRUSHED STONE OR FLOWABLE FILL THE DEPARTMENT OF PUBLIC WORKS PERMITS OFFICE WILL BE NOTIFIED AND AN INSPECTION OF THE TRENCH WILL BE MADE BY A REPRESENTATIVE OF THE DEPARTMENT OF PUBLIC WORKS PERMITS OFFICE. AT THE COMPLETION OF THE INSTALLATION OF THE CRUSHED STONE OR FLOWABLE FILL, THE DEPARTMENT OF PUBLIC WORKS PERMITS OFFICE WILL BE NOTIFIED AND AN INSPECTION OF THE BACKFILL WILL BE MADE BY A REPRESENTATIVE OF THE DEPARTMENT OF PUBLIC WORKS. AFTER ACCEPTANCE OF THE BACKFILL BY THE REPRESENTATIVE OF THE DEPARTMENT OF PUBLIC WORKS PERMITS OFFICE, THE ASPHALT PAVEMENT CAN BE APPLIED.

2. INSPECTION PERSONNEL OF THE DEPARTMENT OF PUBLIC WORKS SHALL BE NOTIFIED BY CONTRACTOR/PERMITEE AT LEAST TWO (2) DAYS PRIOR TO REQUEST FOR INSPECTION.

3. THE WORK PERFORMED SHALL BE FREE FROM WORKMANSHIP DEFECTS FOR A PERIOD OF ONE (1) YEAR AFTER THE DATE OF ACCEPTANCE BY THE DEPARTMENT OF PUBLIC WORKS PERMIT OFFICE.

4. EXISTING PAVEMENTS, BASES, CURBS & GUTTERS AND SIDEWALKS SHALL BE CUT AND BROUGHT TO A NEAT LINE BY USE OF AN AIR HAMMER, SAW OR OTHER SUITABLE EQUIPMENT. EXPANSION JOINTS REMOVED SHALL BE REPLACED

5. THE MINIMUM WIDTH TO BE TRIMMED ON EACH SIDE OF THE TRENCH LINE, AS SEEN IN THE SECTION MAY BE WAIVED OR AMENDED UPON APPROVAL OF THE METRO INSPECTOR, HOWEVER, A MINIMUM WIDTH OF REPLACEMENT SHALL BE 4'–0" TO ALLOW FOR A ROLLER.

6. IF PERMANENT PAVEMENT REPAIRS CANNOT BE MADE WITHIN THREE (3) DAYS, THEN TEMPORARY REPLACEMENT SHALL BE MADE WITH 2" COLD MIX OR HOT BITUMINOUS SEAL COAT OVER COMPACTED CRUSHED STONE. PERMANENT PAVEMENT REPAIR TO BE COMPLETED WITHIN THE TIME PERIOD AS PER METRO CODE 13.20.

7. ALL EXCAVATIONS MADE WITHIN PUBLIC RIGHT–OF–WAY REQUIRE EXCAVATIONS AND STREET CLOSURE PERMITS FROM THE DEPARTMENT OF PUBLIC WORKS PRIOR TO COMMENCING WORK AS PER METRO CODE 13.20.

8. FLOWABLE FILL WILL BE REQUIRED ON ALL ARTERIALS, COLLECTORS AND DOWNTOWN STREETS. FLOWABLE FILL SHALL MEET THE REQUIREMENTS IN TENNESSEE DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS SECTION 204, EXCEPT AS MODIFIED BY PUBLIC WORKS TECHNICAL SPECIFICATIONS 02225, LATEST REVISION.

9. IN THE EVENT OF ANY CONFLICT, DISCREPANCY, OR INCONSISTENCY AMONG THE PLANS AND THESE STANDARD DETAILS, THE REQUIREMENTS OF THE STANDARD DETAILS SHALL GOVERN.

10. ALL REPAIRS SHALL INCLUDE FULL LANE WIDTH RESURFACING EXCEPT WHEN UTILIZING INFRARED TECHNOLOGY. SEE INFRARED SPECIFICATIONS ATTACHED. THERE WILL BE A MAXIMUM OF 40 FT LONGITUDINAL REPAIR WHEN USING INFRARED TECHNOLOGY ON AN EXCAVATED PATCH.

11. ALL REPAIRS SHALL UTILIZE A 1–FOOT CUTBACK ON ALL SIDES EXCEPT THE EDGE OF PAVEMENT.

NOT TO SCALE

METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY DEPARTMENT OF PUBLIC WORKS	FLUSH TRENCH REPAIR NOTES	DWG. NO. ST–270a
DIR. OF ENG.:	DATE: 12/8/08	REVISED: 07/31/02 REVISED: 09/10/04 REVISED: 11/17/08

Figure D.2. Page 1 of notes pertaining to a flush trench repair.

GENERAL NOTES CONTINUED:

12. NEW UTILITY CUTS WILL BE MILLED AND PAVED TO ANY EXISTING UTILITY CUT OR DAMAGED PAVEMENT WITHIN 10–FEET. IF EXISTING CUT OR DAMAGED PAVEMENT IS LESS THAN 10–FEET IN LENGTH, THE EXISTING CUT OR DAMAGED PAVEMENT SHALL ALSO BE MILLED AND PAVED.

13. ASPHALT REPAIR ADJACENT TO CURB AND GUTTER ALONG A ROADWAY GREATER THAN 24–INCHES SHALL HAVE FULL LANE WIDTH PAVING.

14. WHEN GRADED STONE (I.E. #57, #67, #78 STONE) IS USED THERE IS GENERALLY NO COMPACTION EQUIPMENT REQUIRED. THE MATERIAL DOES, HOWEVER, NEED TO BE PUT IN THE TRENCH IN APPROXIMATELY 12–INCH LIFTS.

15. GRADED STONE PLACED IN TRENCH SHOULD BE CAPPED WITH 8 TO 12–INCHES OF PUG MIX (MIX IS ESSENTIALLY TYPE A BASE, GRADE D, OR MORE COMMONLY KNOWN AS "CRUSHER RUN"). SEE TDOT STANDARD SPECIFICATION 303.07.

16. TYPE "A" BASE, GRADE "D" CAN BE USED FOR THE ENTIRE BACKFILL AND COMPACTED BY MECHANICAL METHODS IN NO MORE THAN 6–INCH LIFTS AS PROVIDED IN SECTION 204.11 OF TDOT STANDARD SPECIFICATIONS.

17. THE PUG MIX SHOULD BE COMPACTED IN 6–INCH LIFTS WITH A STEEL SHELL ROLLER OR OTHER MECHANICAL VIBRATORY COMPACTION EQUIPMENT. SEE TDOT STANDARD SPECIFICATIONS 303.08 AND 303.09. MATERIAL SHOULD BE ALLOWED TO CURE UNTIL ALL THE MOISTURE IS GONE FROM STONE (USUALLY 24–48 HOURS).

18. THE TRENCH SHOULD THEN HAVE 11–INCHES OF BINDER PLACED LEVEL WITH THE ROADWAY IN A MINIMUM OF TWO (2) LIFTS AND COMPACTED WITH MECHANICAL COMPACTION EQUIPMENT.

19. THE BINDER SURFACE SHALL BE MILLED OR HEATED USING INFRARED TECHNOLOGY TWO 2–INCHES IN DEPTH AND REPLACED WITH TWO (2) INCHES OF SURFACE MIX AND COMPACTED WITH MECHANICAL COMPACTION EQUIPMENT.

20. INTERSECTION REPAIRS WILL ONLY REQUIRE FULL LANE WIDTH PAVING.

22. ANY DISTURBED PAVEMENT MARKINGS MUST BE RESTORED TO CURRENT METRO STANDARDS.

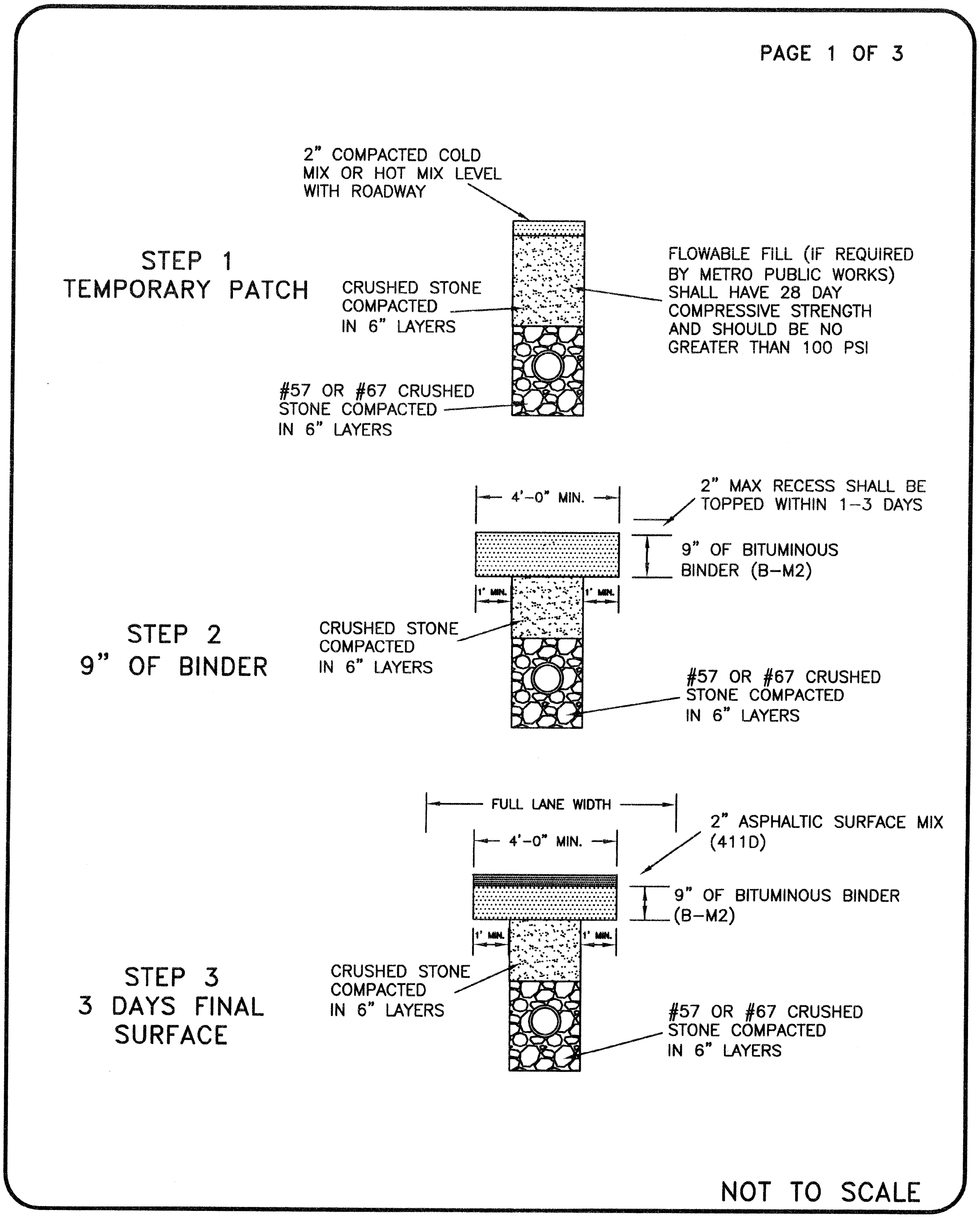
23. DIAGONAL REPAIRS WILL BE REQUIRED TO BE SQUARED OFF AND MILLED AND PAVED. NO INFRARED TECHNOLOGY ALLOWED ON THIS TYPE OF REPAIR.

24. ALL LONGITUDINAL REPAIRS MORE THAN 40 FT IN LENGTH WILL BE REQUIRED TO BE MILLED AND PAVED.

NOT TO SCALE

METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY DEPARTMENT OF PUBLIC WORKS	FLUSH TRENCH REPAIR NOTES	DWG. NO. ST–270b
DIR. OF ENG.: Mark Macy	DATE: 12/2/08	REVISED: 03/31/06 REVISED: 11/17/08 REVISED:

Figure D.3. Page 2 of notes pertaining to a flush trench repair.



METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY DEPARTMENT OF PUBLIC WORKS	RECESSED TRENCH REPAIR	DWG. NO. ST-271
DIR. OF ENG.:	DATE: 12/2/08	REVISED: 01/06/06 REVISED: 04/01/08 REVISED: 11/17/08

Figure D.4. Details of a recessed trench repair.

GENERAL NOTES

PAGE 2 OF 3

1. PRIOR TO PLACEMENT OF CRUSHED STONE OR FLOWABLE FILL THE DEPARTMENT OF PUBLIC WORKS PERMITS OFFICE WILL BE NOTIFIED AND AN INSPECTION OF THE TRENCH WILL BE MADE BY A REPRESENTATIVE OF THE DEPARTMENT OF PUBLIC WORKS PERMITS OFFICE. AT THE COMPLETION OF THE INSTALLATION OF THE CRUSHED STONE OR FLOWABLE FILL, THE DEPARTMENT OF PUBLIC WORKS PERMITS OFFICE WILL BE NOTIFIED AND AN INSPECTION OF THE BACKFILL WILL BE MADE BY A REPRESENTATIVE OF THE DEPARTMENT OF PUBLIC WORKS. AFTER ACCEPTANCE OF THE BACKFILL BY THE REPRESENTATIVE OF THE DEPARTMENT OF PUBLIC WORKS PERMITS OFFICE, THE ASPHALT PAVEMENT CAN BE APPLIED.

2. INSPECTION PERSONNEL OF THE DEPARTMENT OF PUBLIC WORKS SHALL BE NOTIFIED BY CONTRACTOR/PERMITEE AT LEAST TWO (2) DAYS PRIOR TO REQUEST FOR INSPECTION.

3. THE WORK PERFORMED SHALL BE FREE FROM WORKMANSHIP DEFECTS FOR A PERIOD OF ONE (1) YEAR AFTER THE DATE OF ACCEPTANCE BY THE DEPARTMENT OF PUBLIC WORKS PERMIT OFFICE.

4. EXISTING PAVEMENTS, BASES, CURBS & GUTTERS AND SIDEWALKS SHALL BE CUT AND BROUGHT TO A NEAT LINE BY USE OF AN AIR HAMMER, SAW OR OTHER SUITABLE EQUIPMENT. EXPANSION JOINTS REMOVED SHALL BE REPLACED.

5. THE MINIMUM WIDTH TO BE TRIMMED ON EACH SIDE OF THE TRENCH LINE, AS SEEN IN THE SECTION MAY BE WAIVED OR AMENDED UPON APPROVAL OF THE METRO INSPECTOR, HOWEVER, A MINIMUM WIDTH OF REPLACEMENT SHALL BE 4'–0" TO ALLOW FOR A ROLLER.

6. IF PERMANENT PAVEMENT REPAIRS CANNOT BE MADE WITHIN THREE (3) DAYS, THEN TEMPORARY REPLACEMENT SHALL BE MADE WITH 2" COLD MIX OR HOT BITUMINOUS SEAL COAT OVER COMPACTED CRUSHED STONE. PERMANENT PAVEMENT REPAIR TO BE COMPLETED WITHIN THE TIME PERIOD AS PER METRO CODE 13.20.

7. ALL EXCAVATIONS MADE WITHIN PUBLIC RIGHT–OF–WAY REQUIRE EXCAVATIONS AND STREET CLOSURE PERMITS FROM THE DEPARTMENT OF PUBLIC WORKS PRIOR TO COMMENCING WORK AS PER METRO CODE 13.20.

8. FLOWABLE FILL WILL BE REQUIRED ON ALL ARTERIALS, COLLECTORS AND DOWNTOWN STREETS. FLOWABLE FILL SHALL MEET THE REQUIREMENTS IN TENNESSEE DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS SECTION 204, EXCEPT AS MODIFIED BY PUBLIC WORKS TECHNICAL SPECIFICATIONS 02225, LATEST REVISION.

9. IN THE EVENT OF ANY CONFLICT, DISCREPANCY, OR INCONSISTENCY AMONG THE PLANS AND THESE STANDARD DETAILS, THE REQUIREMENTS OF THE STANDARD DETAILS SHALL GOVERN.

10. ALL REPAIRS SHALL INCLUDE FULL LANE WIDTH RESURFACING EXCEPT WHEN UTILIZING INFRARED TECHNOLOGY. SEE INFRARED SPECIFICATIONS ATTACHED. THERE WILL BE A MAXIMUM OF 40 FT LONGITUDINAL REPAIR WHEN USING INFRARED TECHNOLOGY ON AN EXCAVATED PATCH.

11. ALL REPAIRS SHALL UTILIZE A 1–FOOT CUTBACK ON ALL SIDES EXCEPT THE EDGE OF PAVEMENT.

NOT TO SCALE

METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY DEPARTMENT OF PUBLIC WORKS	RECESSED TRENCH REPAIR NOTES	DWG. NO. ST–271a
DIR. OF ENG.: Mark Macy	DATE: 12/8/08	REVISED: 07/31/02 REVISED: 09/10/04 REVISED: 11/17/08

Figure D.5. Page 1 of notes pertaining to a recessed trench repair.

GENERAL NOTES CONTINUED:

12. NEW UTILITY CUTS WILL BE MILLED AND PAVED TO ANY EXISTING UTILITY CUT OR DAMAGED PAVEMENT WITHIN 10-FEET. IF EXISTING CUT OR DAMAGED PAVEMENT IS LESS THAN 10-FEET IN LENGTH, THE EXISTING CUT OR DAMAGED PAVEMENT SHALL ALSO BE MILLED AND PAVED.

13. ASPHALT REPAIR ADJACENT TO CURB AND GUTTER ALONG A ROADWAY GREATER THAN 24-INCHES SHALL HAVE FULL LANE WIDTH PAVING.

14. WHEN GRADED STONE (I.E. #57, #67, #78 STONE) IS USED THERE IS GENERALLY NO COMPACTION EQUIPMENT REQUIRED. THE MATERIAL DOES, HOWEVER, NEED TO BE PUT IN THE TRENCH IN APPROXIMATELY 12-INCH LIFTS.

15. GRADED STONE PLACED IN TRENCH SHOULD BE CAPPED WITH 8 TO 12-INCHES OF PUG MIX (MIX IS ESSENTIALLY TYPE A BASE, GRADE D, OR MORE COMMONLY KNOWN AS "CRUSHER RUN"). SEE TDOT STANDARD SPECIFICATION 303.07.

16. TYPE "A" BASE, GRADE "D" CAN BE USED FOR THE ENTIRE BACKFILL AND COMPACTED BY MECHANICAL METHODS IN NO MORE THAN 6-INCH LIFTS AS PROVIDED IN SECTION 204.11 OF TDOT STANDARD SPECIFICATIONS.

17. THE PUG MIX SHOULD BE COMPACTED IN 6-INCH LIFTS WITH A STEEL SHELL ROLLER OR OTHER MECHANICAL VIBRATORY COMPACTION EQUIPMENT. SEE TDOT STANDARD SPECIFICATIONS 303.08 AND 303.09. MATERIAL SHOULD BE ALLOWED TO CURE UNTIL ALL THE MOISTURE IS GONE FROM STONE (USUALLY 24-48 HOURS).

18. THE TRENCH SHOULD THEN HAVE 11-INCHES OF BINDER PLACED LEVEL WITH THE ROADWAY IN A MINIMUM OF TWO (2) LIFTS AND COMPACTED WITH MECHANICAL COMPACTION EQUIPMENT.

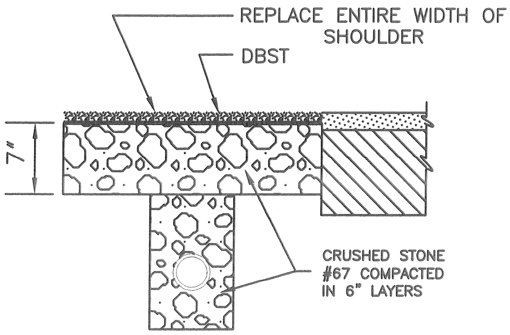
19. ASPHALT SURFACE MATERIAL SHOULD BE PLACED AT 2-INCH THICKNESS AND COMPACTED WITHIN 1-3 DAYS AFTER THE BINDER IS PLACED.

20. INTERSECTION REPAIRS WILL ONLY REQUIRE FULL LANE WIDTH PAVING.

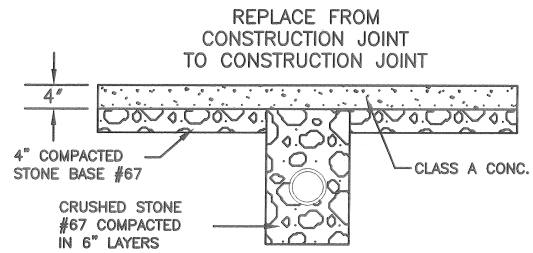
NOT TO SCALE

METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY DEPARTMENT OF PUBLIC WORKS	RECESSED TRENCH REPAIR NOTES	DWG. NO. ST-271b
DIR. OF ENG.: Mark Macy	DATE: 12/2/08	REVISED: 03/31/06 REVISED: 11/17/08 REVISED:

Figure D.6. Page 2 of notes pertaining to a recessed trench repair



SHOULDER REPLACEMENT



SIDEWALK REPLACEMENT

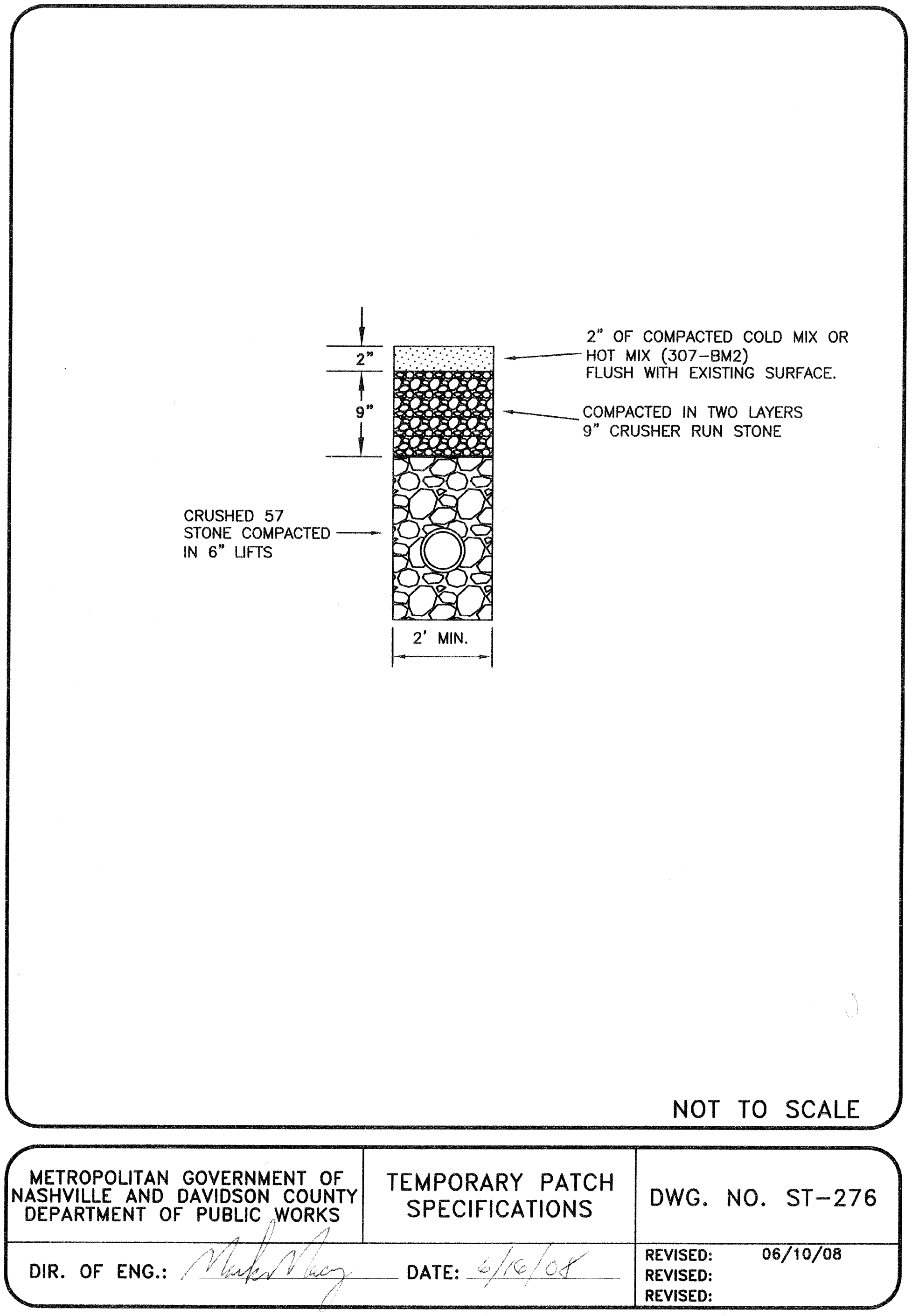
GENERAL NOTES:

1. ALL WORK SHALL BE FIELD CHECKED AND APPROVED BY THE METROPOLITAN PUBLIC WORKS DEPARTMENT PRIOR TO ITS BEGINNING AND AFTER COMPLETION THEREOF.
2. INSPECTION PERSONNEL OF THE DEPARTMENT SHALL BE NOTIFIED AT LEAST TWO (2) DAYS PRIOR TO COMMENCING WORK.
3. THE WORK PERFORMED SHALL BE FREE FROM WORKMANSHIP DEFECTS FOR A PERIOD OF ONE (1) YEAR AFTER COMPLETION.
4. EXISTING PAVEMENTS, BASES, CURBS & GUTTERS AND SIDEWALKS SHALL BE CUT AND BROUGHT TO A NEAT LINE BY USE OF AN AIR HAMMER, SAW OR OTHER SUITABLE EQUIPMENT. EXPANSION JOINTS REMOVED SHALL BE REPLACED.
5. THE MINIMUM WIDTH TO BE TRIMMED ON EACH SIDE OF THE TRENCH LINE, AS SEEN IN THE SECTION MAY BE WAIVED OR AMENDED UPON APPROVAL OF THE METRO INSPECTOR, HOWEVER, A MINIMUM WIDTH OF REPLACEMENT SHALL BE 4'–0" TO ALLOW FOR A ROLLER.
6. IF PERMANENT PAVEMENT REPAIRS CANNOT BE MADE WITHIN THREE (3) DAYS, THEN TEMPORARY REPLACEMENT SHALL BE MADE WITH 2" COLD MIX OR HOT BITUMINOUS SEAL COAT OVER COMPACTED CRUSHED STONE.
7. ALL EXCAVATIONS MADE WITHIN PUBLIC RIGHT–OF–WAY REQUIRE EXCAVATIONS AND STREET CLOSURE PERMITS FROM THE PUBLIC WORKS DEPARTMENT PRIOR TO COMMENCING WORK.
8. IN THE EVENT OF ANY CONFLICT, DISCREPENCY, OR INCONSISTENCY AMONG THE PLANS AND THESE STANDARD DETAILS, THE REQUIREMENTS OF THE STANDARD DETAILS SHALL GOVERN.

NOT TO SCALE

METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY DEPARTMENT OF PUBLIC WORKS	TRENCH REPAIR OUTSIDE ROADWAY	DWG. NO. ST–272
DIR. OF ENG.:	DATE: 9/10/04	REVISED: 12/01/00 REVISED: 06/23/04 REVISED: 09/10/04

Figure D.7. Details for trench repair outside of roadway.



- Figure D.8. Details for a temporary patch

D.4 UTILITY CUT GUIDELINES

Guidelines for consideration when updating the existing specification are presented in this section. The recommended practices can be easily converted to specifications and incorporated into the appropriate sections of Chapter 13.20 of the Metro Code.

D.4.1 General Requirements

All contractors and public utility agencies must obtain a ROW Permit for any work performed within the public rights-of-way of Metropolitan Nashville and Davidson County. The storage of materials and equipment within the public rights-of-way also requires a permit.

To preserve the original investment of the street and roadway systems, minimize the disruption and maximize the safety to the traveling public caused by construction, and reduce future maintenance problems, it is the policy of some agencies to require the installation of new utilities across existing streets be done by boring or tunneling. Open cutting of existing streets for the installation of new utilities will be permitted only when it can be proven it is not possible to use boring or tunneling techniques.

Applicants for Right-of-Way Permits must plan for adequate time for review and approval by the MPW and any other involved agencies. Generally, the greater the scope of work, the longer the permit review and approval process will take. Definitions and Abbreviations are found in the Glossary in Appendix C.

Upon obtaining a permit and after making the cut, the applicants are required to repair the streets using a quality approach to preserve the value of the street.

D.4.2 Quality Requirements

Every street and street repair situation is unique. Design criteria and construction standards cannot address every situation but, in order to maintain some form of consistency, these standards have been developed. In most cases, they provide the minimum acceptable standards for construction or repair. Consequently, when strictly applied, they will provide the minimally acceptable product. Therefore, this criteria has been developed to maintain the same integrity of the street pavement and subsurface condition prior to its being cut for utility installations.

The proposed criteria are guidelines to achieve the goal of "Quality" in street repairs. When used in conjunction with good planning and judgment, the repair methods will maintain the street at an acceptable condition with minimal patching failures.

Quality assurance measures, recommended further in this chapter, should be enforced to ensure the desired quality level.

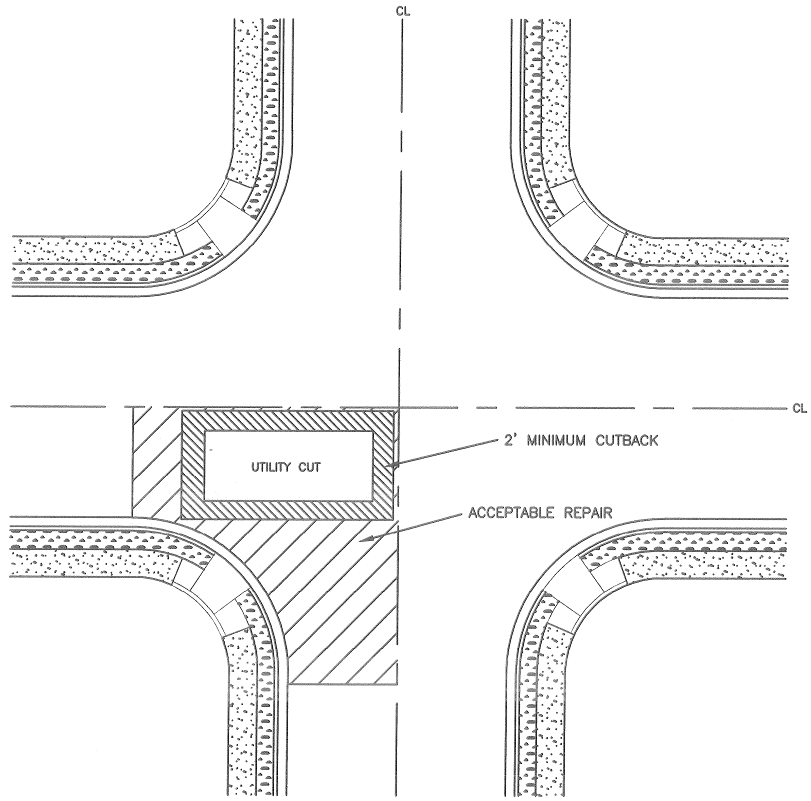
D.4.3 Appearance of Utility Cut Repairs

The final appearance of the street after the repairs are made should be acceptable with an engineered appearance. Street repairs that are satisfactory from a functional point of view may produce a negative reaction from the public if they give the appearance of being poorly planned or executed. The public's perception of street repairs is based primarily on shape, size, and orientation--the geometry of a patch. Following are guidelines for the geometry of a quality patch:

- Street repairs should leave a pavement in a condition at least as good as, if not better than, the condition prior to the repairs. In most cases, and particularly in the cases of extensive excavation and repairs, it is desirable to survey the existing pavement condition with a representative of MPW prior to the work. After completion of the work, survey the pavement condition again to verify that the pavement condition has been maintained or improved. In the case of minor repairs, these pavement surveys can be made by visual observation.
- In the case of major projects that involve excessive haul of materials or unusually heavy construction equipment or activity, non-destructive testing of the pavement condition before and after construction may be required.
- Excavations and street repairs, even well constructed street repairs, shorten a pavement's life. Several types of street distress, settlement, alligator cracking, and potholes, often show up around patches. Quality street repairs should attempt to reduce the occurrence of these types of distress.
- Avoid weakening or destroying the existing pavement around an excavation with heavy construction equipment, stockpiling, or delivery of materials, etc. When damage does occur, remove the damaged pavement, extending the limits of the street repair, before replacing the pavement. No stockpiling of backfill or road building materials is permitted on the pavement.

D.4.4 Utility Cut Repair Details

Figures D.9 through D.11 show the acceptable methods for making utility cut repairs in intersections. Figure D.9 is the case where the utility cut is contained in only one quarter of the intersection; Figure D.10 is the case where the utility cut encompasses more than one quarter but is contained in one half of the intersection. Figure D.11 is for the case where the utility cut encompasses more than one half of the intersection.



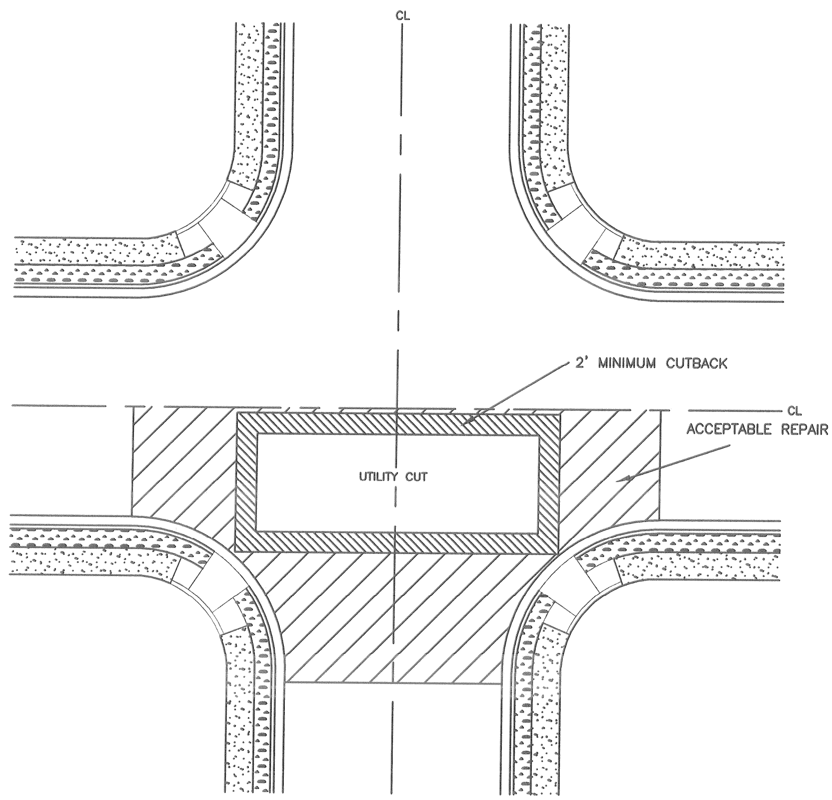
GENERAL NOTES

1. SEE ST–270 FOR TRENCH REPAIRS WITHIN AND OUTSIDE ROADWAY.
2. SEE ST–271 AND ST–271a FOR TRENCH REPAIR NOTES.

NOT TO SCALE

METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY DEPARTMENT OF PUBLIC WORKS	UTILITY CUT LOCATIONS AT INTERSECTIONS EXAMPLE 1	DWG. NO. ST–273
DIR. OF ENG.:	DATE: 3/29/06	REVISED: 03/16/06 REVISED: REVISED:

Figure D.9. Utility cut contained in one quarter of intersection.



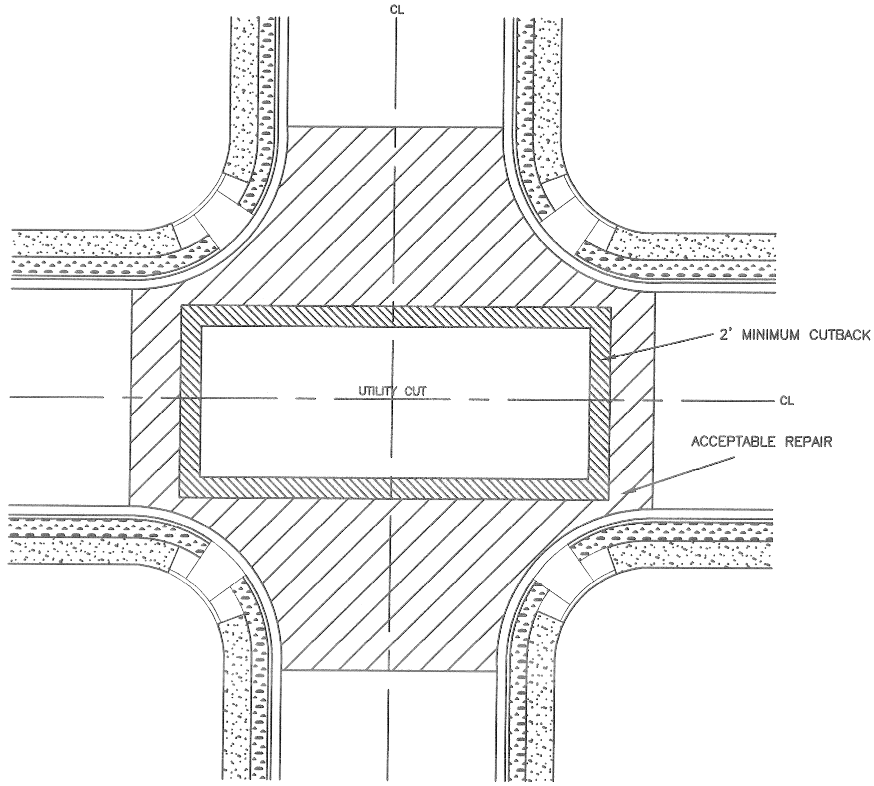
GENERAL NOTES

1. SEE ST–270 FOR TRENCH REPAIRS WITHIN AND OUTSIDE ROADWAY.
2. SEE ST–271 AND ST–271a FOR TRENCH REPAIR NOTES.

NOT TO SCALE

METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY DEPARTMENT OF PUBLIC WORKS	UTILITY CUT LOCATIONS AT INTERSECTIONS EXAMPLE 1	DWG. NO. ST–274
DIR. OF ENG.: [signature]	DATE: 3/29/06	REVISED: 03/16/06 REVISED: REVISED:

Figure D.10. Utility cut contained in one half of intersection.



GENERAL NOTES

1. SEE ST–270 FOR TRENCH REPAIRS WITHIN AND OUTSIDE ROADWAY.
2. SEE ST–271 AND ST–271a FOR TRENCH REPAIR NOTES.

NOT TO SCALE

METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY DEPARTMENT OF PUBLIC WORKS	UTILITY CUT LOCATIONS AT INTERSECTIONS EXAMPLE 3	DWG. NO. ST–275
DIR. OF ENG.:	DATE: 3/29/06	REVISED: 03/16/06 REVISED: REVISED:

Figure D.11. Utility cut contained encompasses more than one-half of intersection.

Some examples of repair methods that are not acceptable and the corresponding acceptable method are provided in the following Figures D.12 through D.24.

Example 1

Existing pavements should be removed to clean, straight lines parallel and perpendicular to the flow of traffic. Do not construct patches with angled sides and irregular shapes. All repairs should be full lane width.

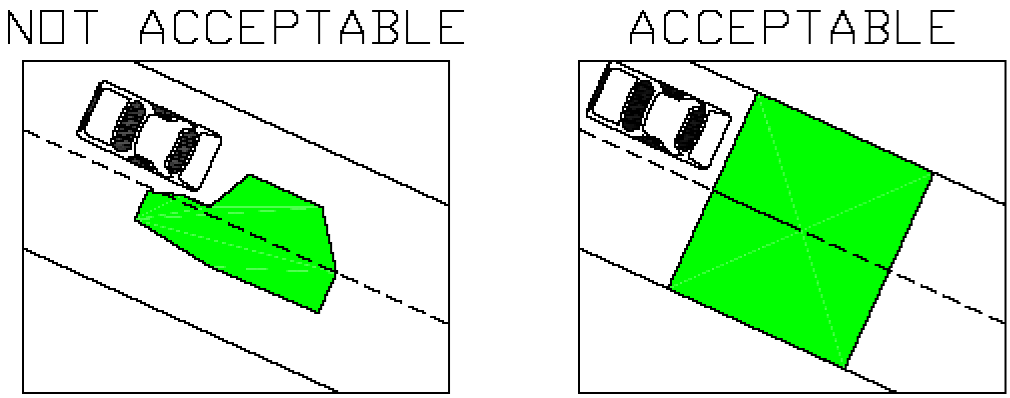


Figure D.12. Example 1: Do not construct patches with angled sides and irregular shapes.

Example 2

Avoid patches within existing patches. If this cannot be avoided, make the boundaries of the patches coincide. All repairs should be full lane width.

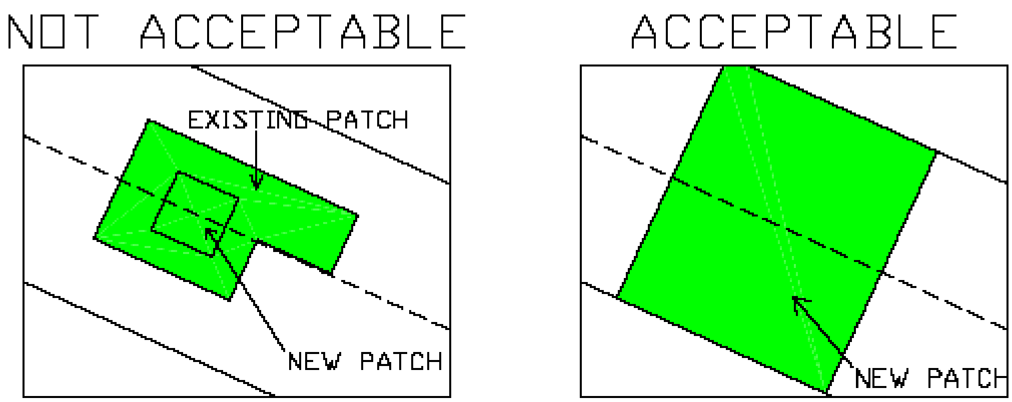


Figure D.13. Example 2: Avoid patches within existing patches.

Example 3

Do not leave strips of pavement less than one-half lane in width from the edge of the new patch to the edge of an existing patch or the lip of the gutter.

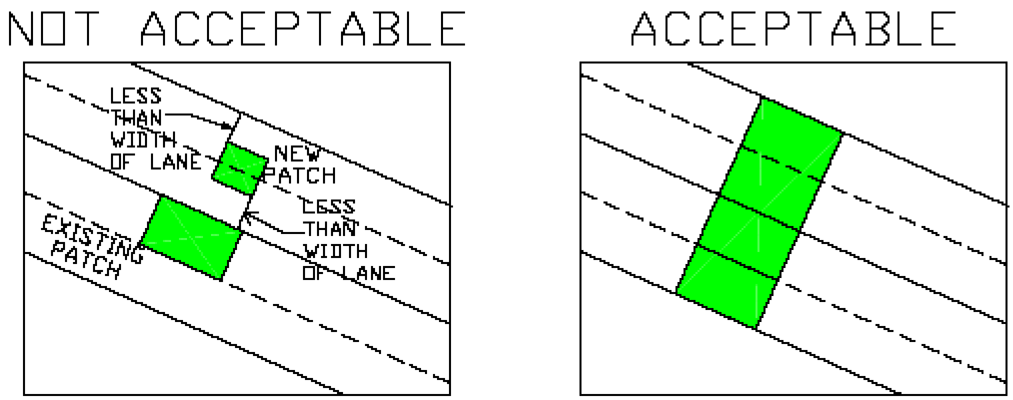


Figure D.14. Example 3: Do not leave strips of pavement less than one-half lane in width.

Example 4

In concrete pavements, remove sections to existing joints, or new saw cut joints at mid-slab, that are in good repair. In damaged concrete, the limits of removal should be determined in the field by a representative of MPW.

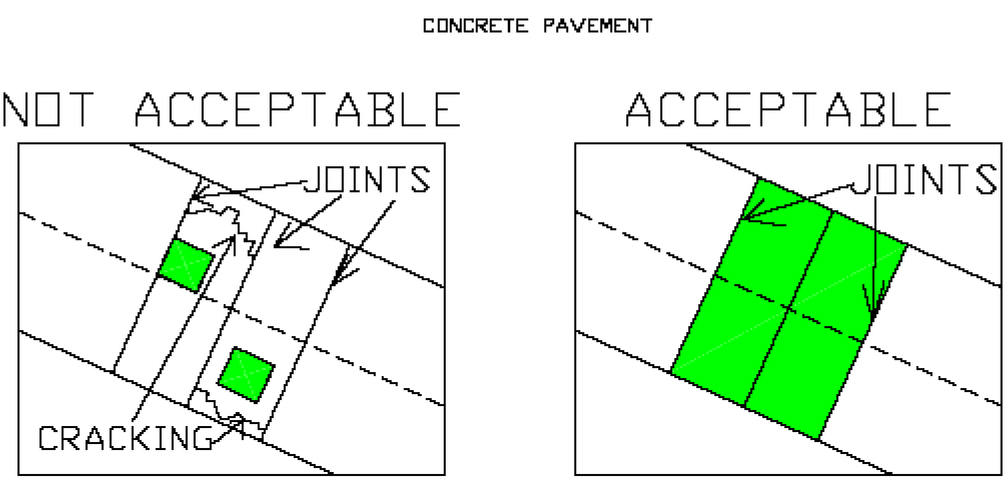


Figure D.15. Example 4: In concrete pavements, remove sections to existing joints.

Example 5

Asphalt and concrete pavements should be removed by saw cutting or grinding. Avoid breaking away the edges of the existing pavement or damaging the remaining pavement with heavy construction equipment.

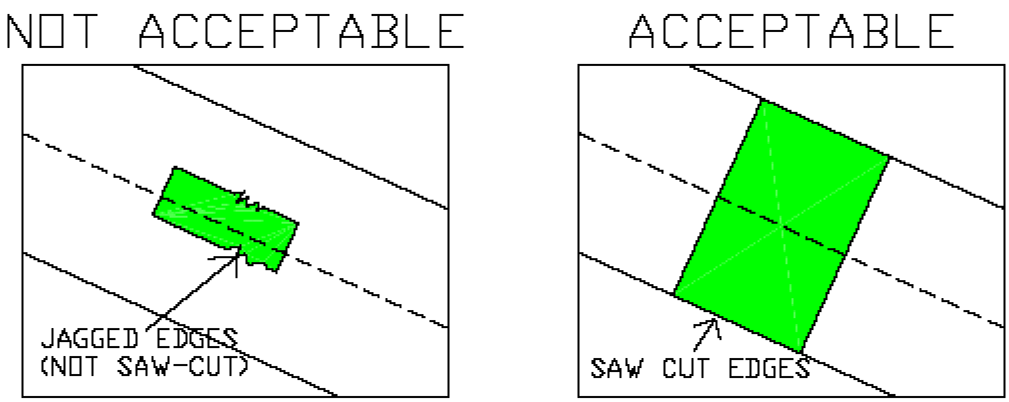


Figure D.16. Example 5: All edges shall be saw cut.

Example 6

In the case of a series of patches or patches for service lines off a main trench, repair the pavement over the patches by grinding and overlay when the spacing between the patches is less than 10 feet. In cases where the existing pavement is in poor condition (in the Strategic Paving Plan) and may require overlay within the next few years, this requirement may be modified or waived by the MPW Pavement Manager.

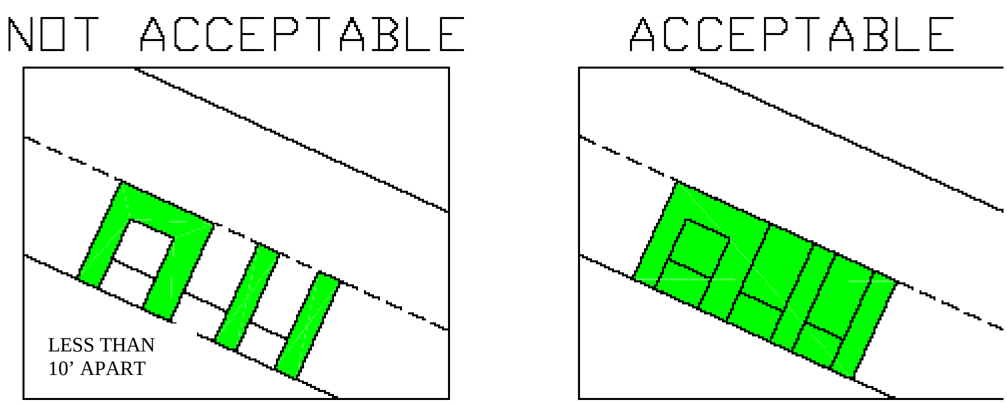


Figure D.17. Example 6: The patched area must include any existing patches within 10 feet.

Example 7

Completed street repairs should have rideability at least as good as, if not better than, the pavement prior to the repairs. A driver may be able to see a street repair, but in the case of a quality repair, should not be able to "feel" it in normal driving. A patch should provide a smooth ride with smooth transitions on and off the repair and all joints should be located outside the wheel path. Overlays should be placed by first removing the existing pavement to the desired depth by grinding or milling, and then placing the pavement flush with the adjacent surfaces. Overlays with feathered edges are not acceptable.

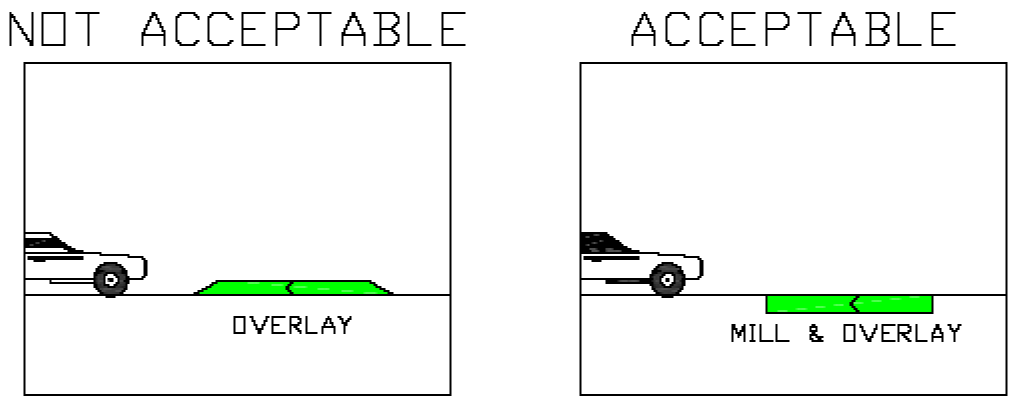


Figure D.18. Example 7: Patches may not decrease rideability.

Example 8

Surface tolerances for street repairs should meet the standard for new construction. That is, the finished surface of the street repair should be tested with a ten- (10-) foot straightedge parallel to the centerline or perpendicular across joints. Variations measured from the testing face of the straightedge to the surface of the street repair should not exceed one-quarter- (¼-) inch.

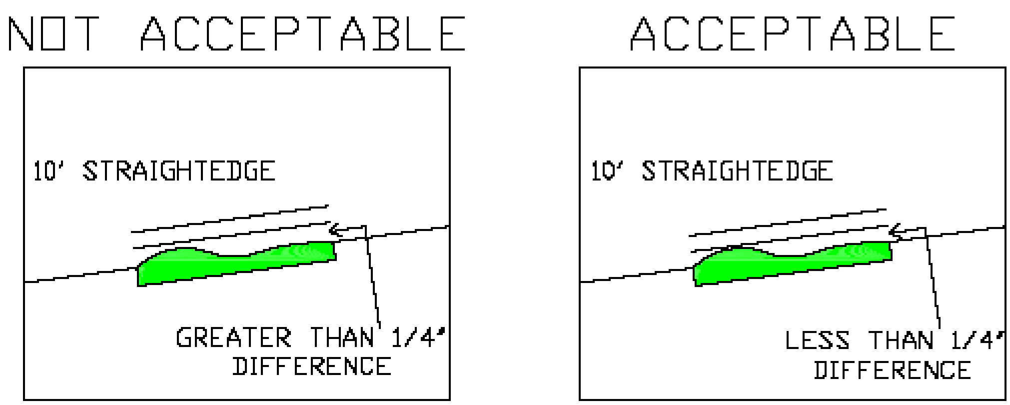


Figure D.19. Example 8: Surface tolerances for street repairs should meet the standard for new construction.

Example 9

Transverse patches on arterial and collector streets shall be overlaid across the entire street width for a distance of two- (2-) feet minimum on all sides of the trench using a T-Patch.

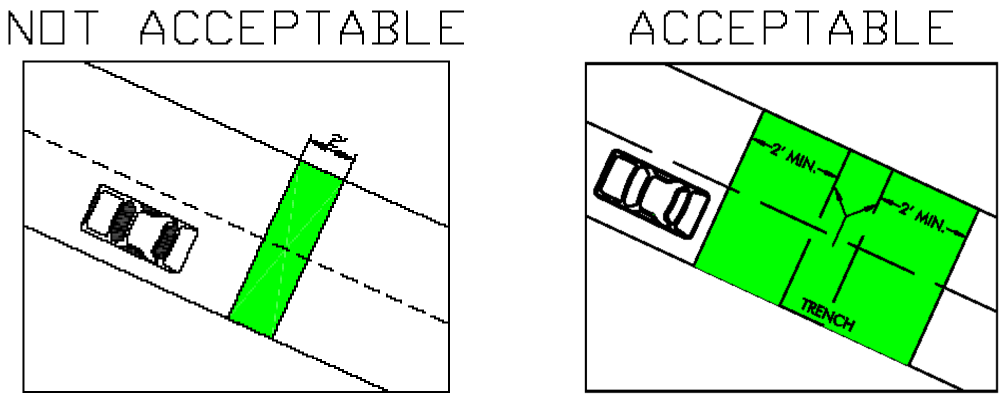


Figure D.20. Example 9: Trenches must be patched using a T-Patch.

Example 10

Do not allow the edges of patches to fall in existing wheel paths. The edges of patches parallel to the direction of traffic shall be limited to the boundaries of lanes or to the centerline of travel lanes.

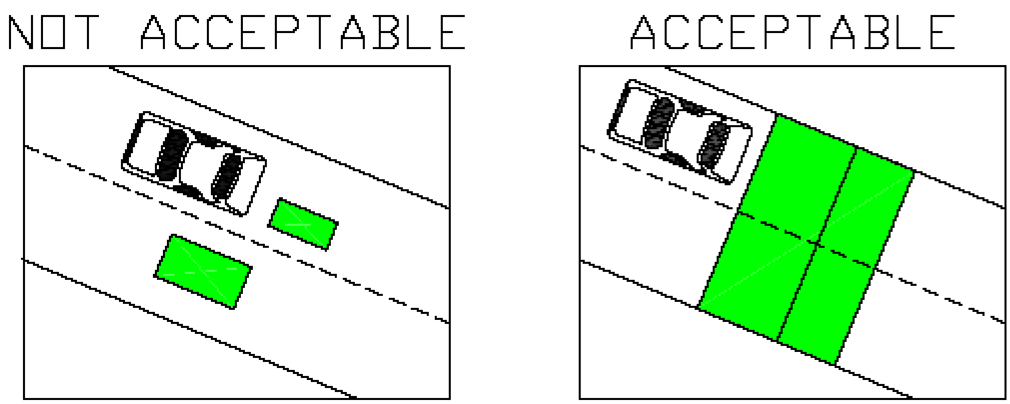


Figure D.21. Example 10: Do not allow the edges of patches to fall in wheel paths.

Example 11

Patches should have a smooth longitudinal grade consistent with the existing roadway. Patches should also have a cross slope or cross section consistent with the design of the existing roadway.

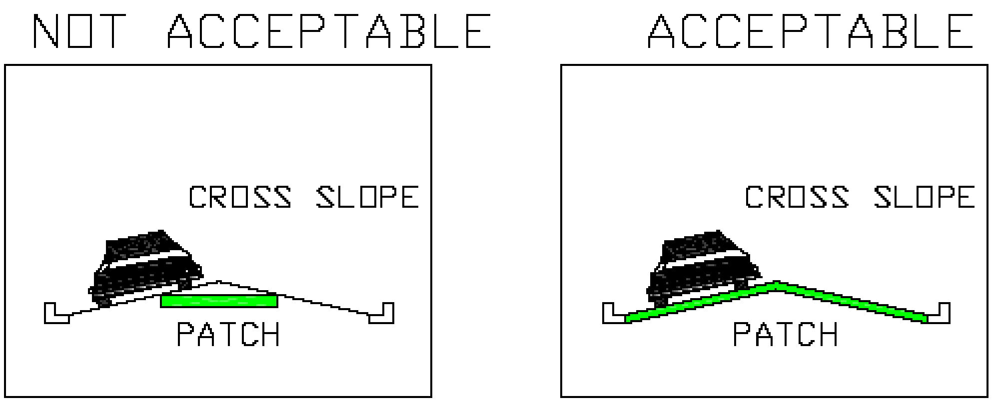


Figure D.22. Example 11. Patch slope and grade must match existing pavement.

Example 12

When the proposed excavation falls within 10 feet of a section of pavement damaged during the utility repair, the failed area shall be removed to sound pavement and patched. Scarring, gouging, or other damaged pavement adjacent to a patch shall be removed and the pavement repaired to the satisfaction of the MPW.

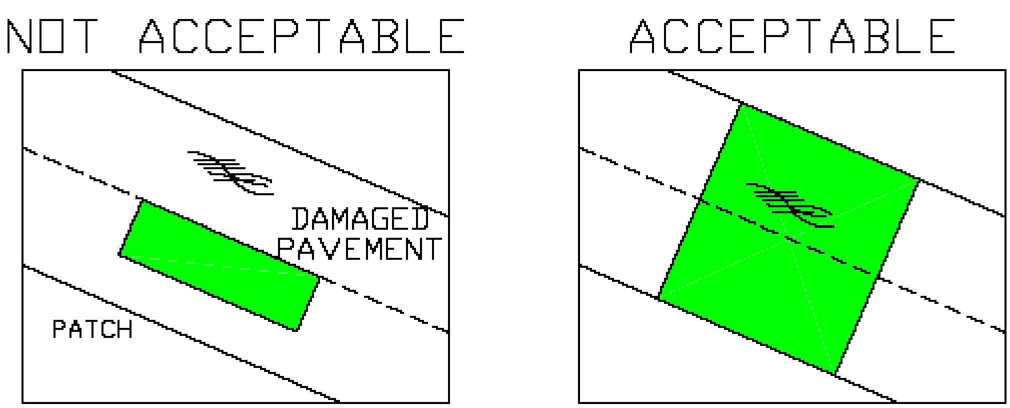


Figure D.23. Example 12: Damaged pavement within 10 feet of a patch must also be patched.

Example 13

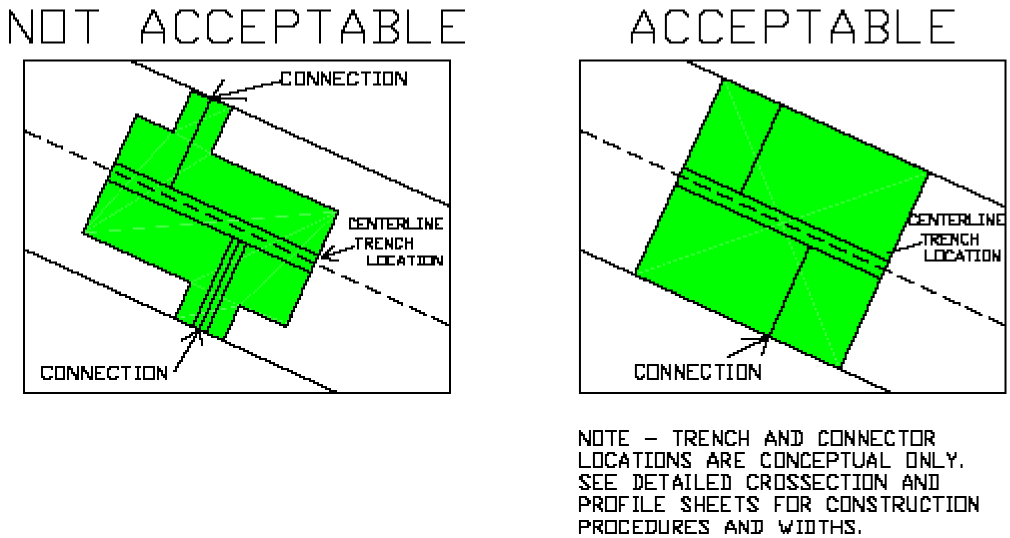


Figure D.24. Example 13: Patches must avoid frequent width changes.

D.5 TESTING AND INSPECTION

The contractor is required to provide material testing for each phase of the work and at no cost to MPW. The testing firm chosen to perform this work for the Contractor must be qualified and identified on the Permit application.

D.5.1 Testing Requirements

Density and thickness tests may be required to ensure compaction requirements are met and the appropriate compacted thickness of repair material has been placed. The number of tests required will be as directed by MPW. The costs of any testing, as required, shall be borne by the contractor. If sections with deficient thickness or density are found, the full section for a reasonable distance on each side of the deficiency shall be refused. All such sections shall be removed and reinstalled to these Guidelines.

D.5.2 Inspection Requirements

All construction work within the public rights-of-way shall be subject to inspection by MPW and certain types of work may have continuous inspection. It shall be the responsibility of the contractor to provide safe access for the inspector to perform the required inspections.

It shall be the responsibility of the person performing the work authorized by the Permit to notify MPW or an authorized representative that such work is ready for inspection. Every request for inspection is to be received at least twenty-four (24) hours before such inspection is desired. Such requests may be in writing or by telephoning or faxing MPW.

MPW may make or require other inspections of any work as deemed necessary to ascertain compliance with the provisions of these guidelines. Any work performed without the required inspections shall be subject to removal and replacement at the contractor's expense, regardless of the quality of the work.

Where large scale projects exceed the ability of the MPW to provide inspection, the contractor or utility company will incur the cost of a private inspection firm. This inspection firm will be mutually agreed upon by the Permit applicant and MPW prior to issuance of the Permit.

D.6 CONSTRUCTION DETAILS

The conditions described below apply to all work done within the public rights-of-way such as utility line installation or repairs performed by any contractor or utility department, public or private.

D.6.1 Protection of Existing Improvements

The contractor shall at all times take proper precautions and be responsible for the protection of existing street and alley surfaces, driveway culverts, street intersection culverts or aprons, irrigation systems, mail boxes, driveway approaches, curb, gutter and sidewalks and all other identifiable installations that may be encountered during construction.

The contractor shall, at all times, take proper precautions for the protection of existing utilities, the presence of which are known or can be determined by field locations of the utility companies. The contractor shall contact the local One Call for utility locations a minimum of two (2) working days prior to the proposed start of work.

Existing improvements to adjacent property such as landscaping, fencing, utility services, driveway surfaces, etc., which are not to be removed shall be protected from injury or damage resulting from the contractor's operations.

The contractor shall at all times take proper precautions for the protection of property pins/corners and survey control monuments encountered during construction. Any damaged or disturbed survey markers shall be replaced by a registered land surveyor at the contractor's expense.

The repair of any damaged improvements as described above shall be the responsibility of the permit holder.

The contractor shall make adequate provisions to assure that traffic and adjacent property owners experience a minimum of inconvenience

All work shall be done in an expedient manner. Repairs shall be made as rapidly as is consistent with high-quality workmanship and materials. Use of fast-setting concrete and similar techniques is encouraged whenever possible without sacrificing the quality of repair. For repairs 12 feet or less in length, completion of the work including replacement of pavement and cleanup shall normally be accomplished within two (2) weeks after the repair work or activity involving the cut is done. For repairs greater than 12 feet in length, the final surface shall not be placed for a minimum of 42 days from the placement of the binder material. Extension of time for completion, including winter and other weather delays, shall be with the written approval of MPW. If the repairs are not completed in the allotted time, MPW has the right to repair the street at the contractor's expense.

D.6.2 Temporary Surfaces Required

When the final surface is not immediately installed, it shall be necessary to place a temporary asphalt surface on any street cut opening. The temporary surface installation and maintenance shall be the responsibility of the Permittee until the permanent surface is completed and accepted. It shall be either a hot mix or cold mix asphalt paving material. Temporary surfaces shall be compacted, rolled smooth, and sealed to prevent degradation of the repair and existing structures during the temporary period. Permanent patching shall occur within two (2) weeks except as outlined by the MPW in the Permit.

D.6.3 Pavement Patches

All permanent pavement patches and repairs shall be made with "in kind" materials. For example, concrete patches in concrete surfaces, full depth asphalt patches with full depth asphalt, concrete pavement with asphalt overlay patches will be expected in permanent "overlaid" concrete streets, etc. In no case is there to be an asphalt patch in concrete streets or concrete patch in asphalt streets. Any repair not meeting these requirements will be removed and replaced by the contractor at no expense to MPW.

D.6.4 Removal and Replacement of Unsatisfactory Work

Removal and replacement of unsatisfactory work shall be completed within fifteen (15) days of written notification of the deficiency unless deemed an emergency requiring immediate action. In the event the replacement work has not been completed, MPW will take action upon the contractor's bond to cover all related costs.

D.6.5 Warranty for Satisfactory Work

The utility company will be held responsible for a 24-month period for any defects in the patch that may result in a PCI of 85 or less as defined by ASTM D6433 as modified for this study.

D.7 REMOVALS

D.7.1 Paved Streets

Bituminous pavement removal areas shall be saw cut to clean, straight lines that are perpendicular or parallel to the flow of traffic.

In existing pavement, all excavations within 36 inches of the edge of the asphalt shall require removal and replacement from the edge of asphalt to the excavation edge.

Concrete pavement, driveways, streets, and alleys shall be removed to neatly sawed edges cut to full depth.

D.7.2 Gravel Streets

When trenches are excavated in streets or alleys that have only a gravel surface, the contractor shall replace such surfacing on a satisfactory compacted backfill with gravel conforming to MPW specification aggregate base course. Gravel replacement shall be one (1) inch greater in depth to that which originally existed, but not less than four (4) inches. The surface shall conform to the original street grade. Where the completed surface settles, additional gravel base shall be placed and compacted by the Contractor within fourteen (14) days after being notified by MPW, to restore the roadbed surface to finished grade.

Some streets may have been treated with a special surface treatment to control dust and/or bind the aggregates together. In these cases, the Contractor is responsible for installing the gravel surface in the same manner as what was existing. Such surface treatments shall be of the same chemical composition as what existed prior to the excavation work. MPW shall note on the permit the surface treatment that will be required.

D.7.3 Concrete Curb, Gutter and Sidewalk

Concrete shall be removed to neatly sawed edges to full depth for sidewalks and curb and gutter and shall be saw-cut in straight lines either parallel to the curb or perpendicular to the alignment of the sidewalk or curb. Any removal shall be done to the nearest joint. Replaced sections may require doweling connections if required by MPW.

D.8 BACKFILL

D.8.1 Flowable-Fill

Flowable-fill may be used as utility trench backfill for all trenches unless otherwise specified by MPW. This requirement applies to all pavement and gravel locations. Compaction will be as specified by MPW.

The recommended mix for flowable-fill is shown below. Concrete backfill will not be allowed within the public right-of-way. Flash-fill may be used if approved by MPW. Refer to the appropriate MPW specification.

Table D.1. Recommended flowable-fill mix design.

INGREDIENTS	POUNDS/CUBIC YARD
Cement	42 (0.47 sack)
Water	235 (39 gallons or as needed)
Coarse Aggregate (Size No. 57)	1700
Sand (ASTM C-33)	1845

The maximum desired 28-day strength is 60 psi. The above combination of material, or an equivalent, may be used to obtain the desired "flowable-fill".

Flowable-fill or flash-fill shall be prohibited as a temporary or permanent street surface. Trenches shall initially be backfilled to the level of the original surface. After the flowable-fill has cured, the top surface of the flowable-fill shall be removed and the temporary or permanent surface shall be placed.

Bridging and cutback requirements as described in these standards may still be required if the street failures indicate a clear need.

Repair of failed trenches will be the responsibility of the party requiring the trench.

D.8.2 Conventional Backfill (Other Than Flowable-Fill)

When "non flowable-fill" backfill material has been pre-approved by MPW, backfill in existing or proposed streets, curbs, gutters, sidewalks and alleys is divided into three (3) categories: initial, intermediate and final lifts as defined below:

- The INITIAL LIFT, comprised of washed, clean gravel material**,** consists of the section from the bottom of the excavation to a point six to twelve (6 - 12) inches above the top of the installation. Placement and compaction of the initial layer shall be as specified by the utility company to protect their installation.

- The INTERMEDIATE LIFT, generally comprised of #67 crushed stone, consists of the section above the initial layer to a point within six (6) inches of the ground level or the bottom of the pavement section, whichever is greater.
- The FINAL LIFT includes both road base and asphalt surfacing. Road base material shall meet MPW specification for aggregate base course or as specified by MPW. Maximum dry density of all soil types used will be determined in accordance with AASHTO T 99 or AASHTO T 180. These densities will be determined prior to placement of backfill.

D.9 RESTORATION

D.9.1 Bore Holes - Vertical and Horizontal

For openings less than or equal to 6 inches in diameter, bore holes shall be filled with patching material (cold mix is not acceptable) to prevent entry of moisture. Patching material used shall be in all cases compatible with the existing surface. Subgrade shall be replaced with flowable fill to provide necessary support to the surface. The sealing of bore holes is the responsibility of the contractor or persons making the bore. For openings greater than 6 inches in diameter, the limits of repair shall be identified in the permit. The completed job shall be flush with the surrounding pavement and have no indentations, pockets, or recesses that may trap and hold water.

D.9.2 Subgrade

The subgrade for the pavement structure shall be graded to conform to the cross sections and profile required by the construction plans. Prior to the placement of aggregate base course or sub-course, the subgrade should be properly prepared. The subgrade should be scarified to a minimum depth of six (6) inches, moisture adjusted as necessary, and recompacted.

Prior to approval to place the base or sub-base course, all utility main and service trenches shall be compacted. The density requirement also applies to all utility trenches within the public rights-of-way from a point four (4) feet beyond the edge of asphalt and descending at 1:1 outward.

D.9.3 Asphalt Surfacing

Any damage, even superficial, to the existing asphalt surface in the vicinity of the work shall be repaired at the expense of the Contractor, including but not limited to gouges, scrapes, outrigger marks, backhoe bucket marks, etc. A slurry seal type covering will be considered the minimum repair. Patching may be required, at the discretion of MPW.

The depth of asphalt patches in asphalt streets shall typically be the depth of the existing asphalt surface plus 1 inch or as specified by the Engineer.

The asphalt patch area for street excavations that fall within the wheel path of the vehicular travel lane shall be increased in size to the center of the lane or adjacent lane. In no circumstance will the edge of a patch area be allowed to fall within the wheel path.

In streets that are less than five (5) years old or have a PCI greater than 85, the MPW reserves the right to deny any street excavation or require repairs that are over and above these specifications.

D.9.4 Concrete Surfacing and Patching

The concrete pavement shall be replaced with 4,000 psi concrete to match the finish and thickness of the existing pavement, but not less than eight (8) inches thick. All concrete construction shall be protected from vehicular traffic, including contractor vehicles, until the concrete has achieved eighty (80) percent of its ultimate strength. Concrete shall be coated and sealed with a uniform application of membrane curing compound applied in accordance with manufacturer's recommendations.

The use of quick-curing concrete (3000 psi strength within 48 hours) shall be used on all arterial and collector streets when repair areas are less than 500 square feet or when temperatures are below 40° F. Quick-curing concrete repairs may be opened to traffic within two (2) days or when the concrete has achieved eighty (80) percent of its ultimate strength.

Where existing cracks or damage is adjacent to the area being repaired, the repair area shall include the cracked or damaged concrete. Pavement repairs shall include all areas of damage, including leak test holes, pot holes, equipment, and/or material scarring of the exiting surface.

When repairing concrete, removal perimeter shall be saw-cut, and replacement concrete shall be doweled into the old concrete as directed by MPW.

D.10 IMPLEMENTATION

The community investment in streets and roads is a major component of the community assets. As custodians of these facilities, MPW has the obligation and responsibility to protect the public interest.

Presented herein have been concepts and examples that can easily be incorporated into MPW specifications. These examples provide a cost-effective approach to achieve quality repairs of utility cuts that will satisfy the public motorists and achieve levels of service meeting the expectations of MPW.

APPENDIX E

UTILITY CUT REPAIR GUIDELINES AND SPECIFICATIONS FOR THE PERMITTING PROCESS

E.1 OVERVIEW OF UTILITY CUT ISSUES

In recent years, utility owners have increasingly chosen to take their distribution networks underground. According to a 1997 report published by APWA, "Managing Utility Cuts", "The issues surrounding the management of utility cuts are as varied as the cuts are numerous. As the demand for greater access to the right of way increases, so will the need for better coordination of multi-agency schedules and a higher level of accountability for employing less intrusive, more durable and cost efficient methods for making utility cuts." This has certainly been the experience of Nashville.

As a result, several cities across the nation have undertaken projects to make fair and uniform assessment of the damage due to utility cuts and to assess an appropriate fee schedule to recover the damages. Additionally, research has been conducted to establish a more "engineered" approach to repairing the cuts. In other words, agencies are adopting a "do it right the first time" specification.

This study researched current practices and reviewed other agency specifications, then used these findings to develop a guide to utility cut management. The findings and recommendations are presented in three parts:

- Current Practices within MPW
- Process Used to Identify Level of Utility Degradation
- Specifications and Construction Guidelines for Trench Repair

E.2 CURRENT PRACTICES IN MPW

In 1997, MPW amended Chapter 13.20, Excavations and Obstructions, of the Metropolitan Code of Laws in an attempt to increase the service life of the MPW's pavement network. This amendment, enacted through Ordinance 97-785, Excavations and Obstructions, now requires that any pavement surface removed or damaged as a result of an excavation must be replaced by, and at the expense of, the person making the excavation. In addition, a reputable paving contractor must perform the repair in accordance with the requirements and specifications of the Department, and the repair can only be performed in the presence of a Department inspector.

The applicable specification for pavement repair on MPW roads and streets is contained in Section 02575, Pavement Repair, of the MPW Standards. Specifically, Paragraph 3.9 stipulates that full lane or roadway width milling and/or paving is required where successive or continuous excavations are planned so as not to "checkerboard" the repair and to provide a smooth riding surface. The length of full width milling and/or paving is to be from manhole to manhole centerline from the first excavation point to the last. In addition, if the excavation is within 300 feet of an intersection, the repair limits are to be extended to the radius point of the intersection.

According to Section 13.20.030.D.1 of the Metro Code, an excavation permit is required for each separate excavation at a cost of $30 per permit. A single excavation is defined as having a maximum area of 6 square yards or a maximum length of 33 ft. Excavations having an area or length greater than these limits must be separated into 2 or more excavations, each requiring its own permit. In addition to the permit fee, an excavation made in a pavement surface less than 5 years old is assessed a fee of $500 plus 20% of the average cost to repair the excavation according to MPW specifications

In 2001, the Department retained IMS/Terracon, a pavement management consultant, to study the impact of utility cuts on the service life of MPW pavements and to develop a fee schedule for excavation permits that would prorate the cost of repairing excavations among the permit holders who damaged the surface (Development of a Street Damage Restoration Fee Schedule for the Metropolitan Government of Nashville and Davidson County, Terracon, February 2001). The fee schedule was designed to recoup the cost of milling and paving an entire block once the surface condition deteriorated to a specified level. The fee schedule was also weighted based on the age of the surface, with higher fees charged for excavations in newer pavements. This fee schedule, however, was never implemented.

E.2.1 Specification Issues

The current specification for pavement repair, Section 02575, specifies high-quality materials and procedures. The IMS/Terracon study concluded that repairs made in accordance with this specification were actually stronger than the surrounding pavement. The major concern expressed by the Department staff with this specification lies in the lack of enforcement of Paragraph 3.9. Utility companies are not being required to mill and pave full width between successive cuts or along continuous cuts or between cuts and to intersections 300 feet or less in proximity.

Part of the problem lies in the wording of this provision. Rarely does a utility plan for and request permits for multiple cuts within the same block. The most common scenario involves a request for a single cut within a block that already contains one or more cuts; there is no provision to have the utilities mill and/or pave full width between the proposed cut and an existing cut. Two options were presented in the Terracon report to MPW to address the ride quality and aesthetics issues posed by utility cuts.

Option 1 is to amend Paragraph 3.9 of the Pavement Repair specification to require full width milling and paving between the proposed cut and any existing cut within 10 feet. The suggested 10-foot length will prevent numerous adjacent small repairs that deteriorate ride quality, appearance and overall performance. Of course, this option is viable only if it is enforced, but nearly 100 percent compliance should be achievable if the issuance of future permits to a given utility is tied to their past compliance with the specification.

Option 2 is to implement the fee schedule proposed in the IMS/Terracon report. On the average, this option would generate sufficient funds to repave an entire block once 15 percent of the block's surface area is affected by a utility cut repair. The proposed fees are easily calculated from the information contained in the permit application and the pavement management system database, and the fees should be easy to collect if issuance of the permit is tied to payment of the fees. The higher fees will be cheaper for the utilities than the extensive paving required by Option 1. The significantly higher permit fees will likely be strongly opposed by the utilities.

Option 1 is recommended because it offers the path of least resistance in meeting the goal of smoother riding pavement surfaces. The specification is already in place, so a small amendment should not be too difficult to accomplish. The amendment should be accomplished prior to the start of enforcement. The utilities likely would voice opposition to the sudden enforcement of the current specification, so opposition to enforcement of the amended specification can certainly be expected.

E.2.2 Performance of Utility Cut Repairs

Utility cuts, like other patches, cause damage that reduces the level of service of the street on which they are made. This is not a new concept, but one that pavement engineers have dealt with since cuts in the pavement right-of-way to bury utilities have been allowed. The surface condition rating method selected by MPW, ASTM D6433, includes a serviceability deduct value for the presence of a utility cut. This deduct value is comparable in severity to the deduct values assigned for longitudinal and transverse cracking. The problem is not one of "does the cut damage the pavement," but rather, "how can the impacts be quantified as to costs and how do these translate into reasonable and defensible fees?"

In 2002, the Construction Practices Subcommittee of the APWA was assigned to research available documents related to pavement degradation caused by utility cuts. A summary of the major findings of their literature review is:

- Factors influencing the performance of a patch include the pavement material, soil conditions, climate, traffic and repair techniques. These roughly correlate with the same factors influencing the life of a new pavement.
- Poor construction techniques, such as rocking the jackhammer while cutting the boundary of the patch, can damage the area adjacent to the cut and further degrade the patch and surrounding pavement. Studies showed this zone of influence to be 1.5 to 6 feet beyond the patch.
- Pavement cut repairs made using quality materials and sound engineering and construction techniques tend to perform as well as the surrounding pavement.
- Poor performance of the patch tends to be a result of inadequate compaction of the materials, insufficient thickness of materials, poor quality of materials, and damage to the side of the cut.
- Most of the reports included a cost analysis associated with the cuts ranging from $2 per square yard to $540 per square yard.
- The estimated reduction in pavement life due to a utility cut was found to be from 20 to 56% of the original life of the pavement.

These observations are consistent with the findings of the Terracon report and with other studies such as the Salt Lake City report (*Public Works*, April 2002) where structural testing was used to quantify the degradation caused by a utility cut. The Terracon report suggested the unit rate for pavement overlay was $21.67 per square yard. Further it was determined that the fees for recovery should be prorated due to the age of the pavement and that new pavements should have the highest rate of recovery. A full table of fees is found in the Terracon report.

The Salt Lake City report used deflection tests with an FWD (Falling Weight Deflectometer) to prove that the zone of influence or damage beyond the visual limit of the trench was at least 2 feet. It was suggested that a “T” patch (replaces surface course at least 2 feet beyond trench boundaries) be used to compensate for this damage. Additional suggestions were made for selecting the cut boundaries. Other somewhat intangible costs were discussed but no consensus seemed to exist for recovery of these costs. They include traffic disruption, safety of repair personnel, emergency vehicle response times due to rough patches and others.

The findings of the report prepared by Terracon are consistent with those of other agencies and it is recommended that these findings be used in developing MPW's specification and permit fee policy.

E.3 CONSTRUCTION GUIDELINES FOR TRENCH REPAIR

Chapter 13.20 of the Metro Code has been cited as a model by the APWA and referenced in many of the articles studied for this report. Therefore, it is recommended that the current code be modified to include recent improvements in practice being used by other municipalities. The requirement for patch awareness and repair training and a specification for the “T” patch are also submitted for adoption. The recommended modifications are summarized as follows:

E.3.1 Requirements for Training

Recognizing that education and awareness by the utility companies as to the impact of their cuts on pavement life and the quality of the community is needed, it is suggested that representatives from utility companies and contractors be required to attend a ½-day workshop on patching utility cuts. This workshop would cover the impacts of cuts on street performance and the associated economic burden on the community as well as proper utility cut procedures. The workshop should be based on the Strategic Highway Research Program manuals of practice and include the rating tree procedure. The presence of a workshop graduate would be required to perform a utility cut or utility cut repair.

E.3.2 T-Patches

T-Patches are pavement cuts made outside the trench boundaries so there is not a continuous vertical shear plane from the edge of the trench to the pavement surface. Research shows that the zone of influence is at least 2 feet from the edge of the trench. To take advantage of the layering effects of a flexible pavement, the compacted base and the surface course should be extended at least 2 feet from the edge of the trench. This design minimizes the reflective cracking due to excessive strains at the bottom of each layer at the edge of the trench and allows better compaction of the base material and new HMAC. Diagrams for typical T-patches are shown below as Figures E.1 through E.4.

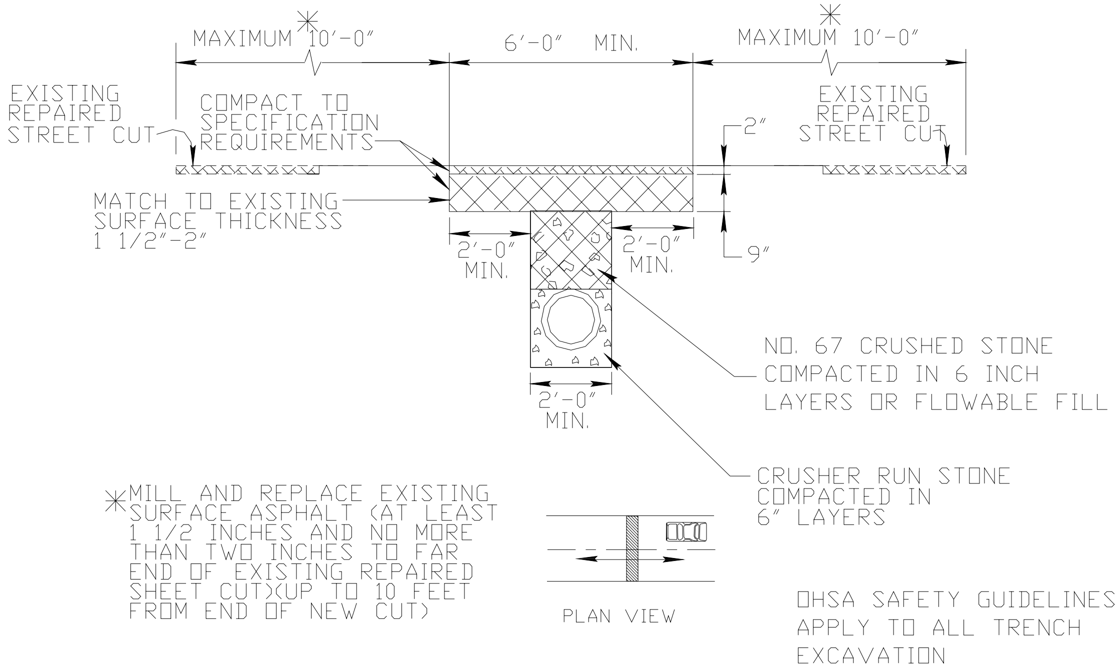


Figure E.1 Transverse section view of a transverse utility cut repair.

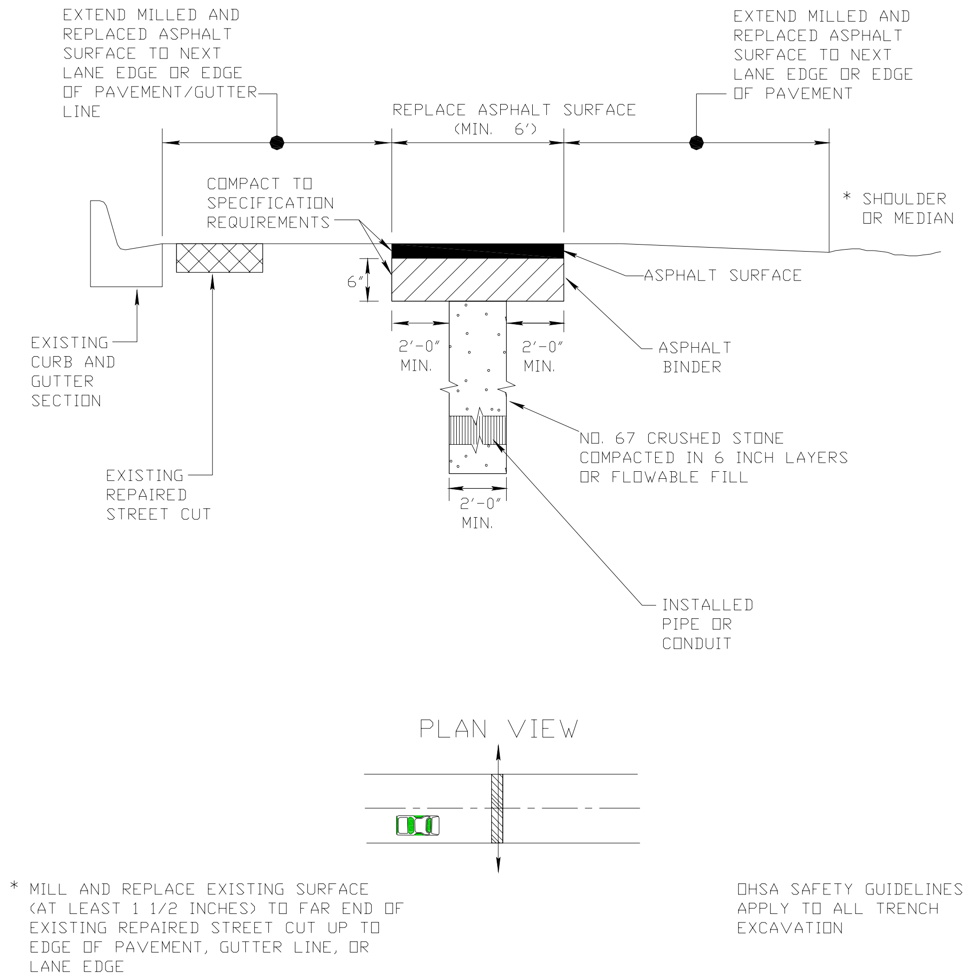


Figure E.2. Longitudinal section view of a transverse utility cut repair.

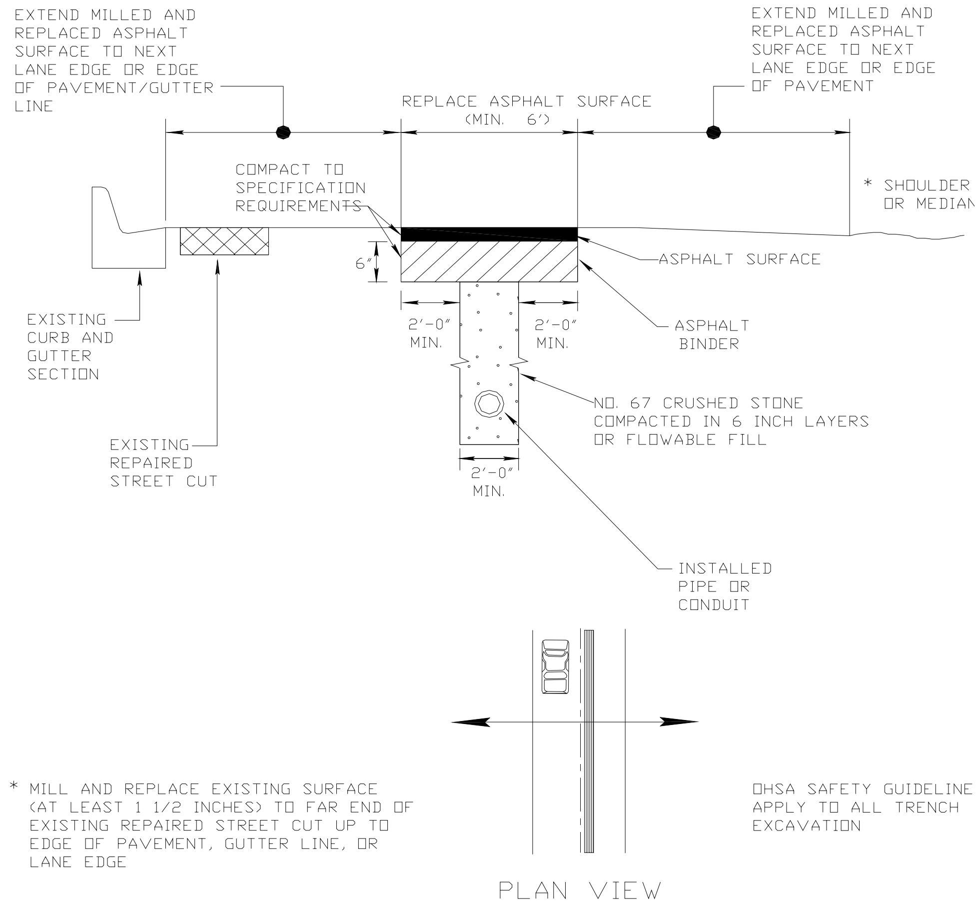


Figure E.3. Transverse section view of parallel utility cut repair.

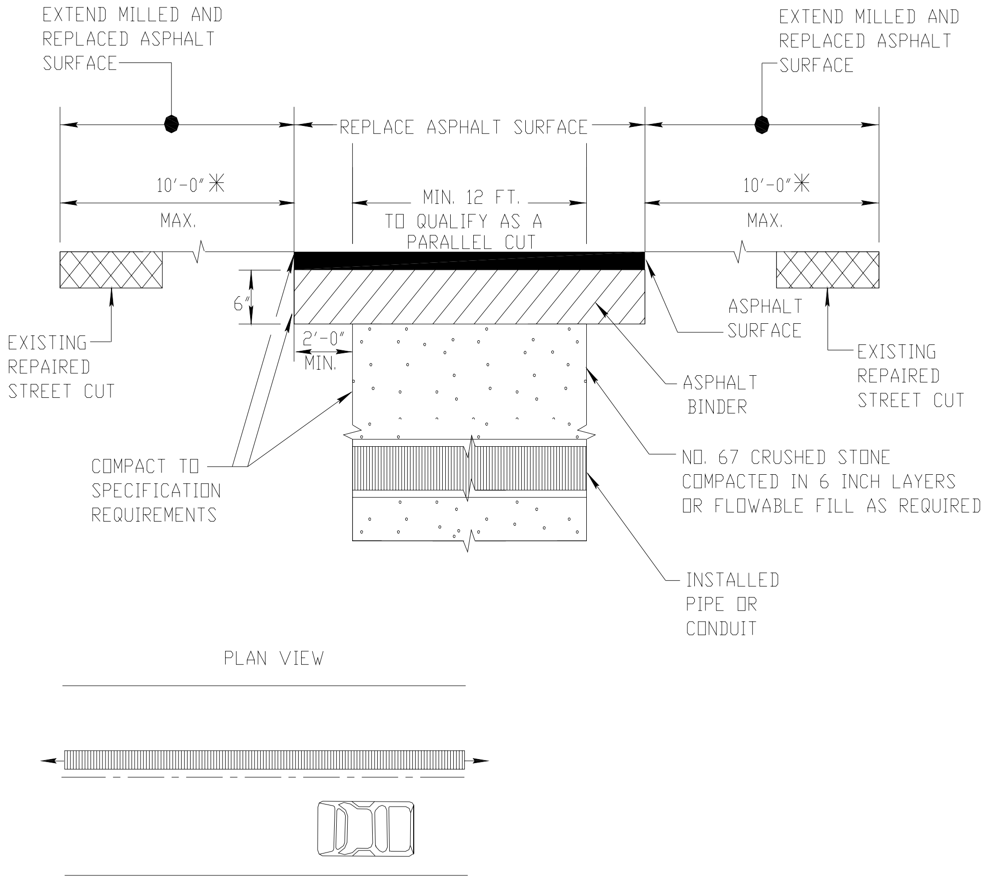


Figure E.4. Longitudinal section view of a parallel utility cut repair.

Some construction requirements related to Figures E.1 through E.4 are:

- Remove additional material using a diamond blade saw to cut a vertical face to edge of pavement, a lane stripe (other than outside edge of pavement), or existing patch if such a feature is within 2 feet of the patch.
- Base course material shall be crushed aggregate conforming to TDOT specifications in lifts not exceeding 8 inches after compaction. Compact per APWA Section 02324 or equivalent TDOT specifications.
- Provide 28-day 60-psi controlled low strength material (commonly known as flowable fill) as specified in APWA Section 02062 or TDOT equivalent. Use fill that does not require vibration. Cure to initial set before placing new untreated base or HMA.
- Tack coat to be applied to all vertical surfaces, but do not over tack the surfaces. Prime the top of the base course with a light spray of emulsion. The base material should be visible through the prime coat. Do not allow emulsion to "pond" on the base.

- HMA materials as specified in APWA Section 02985 or TDOT equivalent shall be placed in 3-inch lifts compacted to 96 percent of laboratory density.
- The compacted base shall be a minimum of 9 inches thick for patches crossing the pavement and 6 inches thick for patches parallel to the street.

E.4 UTILITY CUT GUIDELINES

Guidelines for consideration when updating the existing specification are presented in this section. The recommended practices can be easily converted to specifications and incorporated into the appropriate sections of Chapter 13.20 of the Metro Code.

E.4.1 General Requirements

All contractors and public utility agencies must obtain a ROW Permit for any work performed within the public rights-of-way of Metropolitan Nashville and Davidson County. The storage of materials and equipment within the public rights-of-way also requires a permit.

To preserve the original investment of the street and roadway systems, minimize the disruption and maximize the safety to the traveling public caused by construction, and reduce future maintenance problems, it is the policy of some agencies to require the installation of new utilities across existing streets be done by boring or tunneling. Open cutting of existing streets for the installation of new utilities will be permitted only when it can be proven it is not possible to use boring or tunneling techniques.

Applicants for Right-of-Way Permits must plan for adequate time for review and approval by the MPW and any other involved agencies. Generally, the greater the scope of work, the longer the permit review and approval process will take. Definitions and Abbreviations are found in the Glossary in Appendix C.

Upon obtaining a permit and after making the cut, the applicants are required to repair the streets using a quality approach to preserve the value of the street.

E.4.2 Quality Requirements

Every street and street repair situation is unique. Design criteria and construction standards cannot address every situation but, in order to maintain some form of consistency, these standards have been developed. In most cases, they provide the minimum acceptable standards for construction or repair. Consequently, when strictly applied, they will provide the minimally acceptable product. Therefore, this criteria has been developed to maintain the same integrity of the street pavement and subsurface condition prior to its being cut for utility installations.

The proposed criteria are guidelines to achieve the goal of "Quality" in street repairs. When used in conjunction with good planning and judgment, the repair methods will maintain the street at an acceptable condition with minimal patching failures.

Quality assurance measures, recommended further in this chapter, should be enforced to ensure the desired quality level.

E.4.3 Appearance of Utility Cut Repairs

The final appearance of the street after the repairs are made should be acceptable with an engineered appearance. Street repairs that are satisfactory from a functional point of view may produce a negative reaction from the public if they give the appearance of being poorly planned or executed. The public's perception of street repairs is based primarily on shape, size, and orientation--the geometry of a patch. Following are guidelines for the geometry of a quality patch:

- Street repairs should leave a pavement in a condition at least as good as, if not better than, the condition prior to the repairs. In most cases, and particularly in the cases of extensive excavation and repairs, it is desirable to survey the existing pavement condition with a representative of MPW prior to the work. After completion of the work, survey the pavement condition again to verify that the pavement condition has been maintained or improved. In the case of minor repairs, these pavement surveys can be made by visual observation.
- In the case of major projects that involve excessive haul of materials or unusually heavy construction equipment or activity, non-destructive testing of the pavement condition before and after construction may be required.
- Excavations and street repairs, even well constructed street repairs, shorten a pavement's life. Several types of street distress, settlement, alligator cracking, and potholes, often show up around patches. Quality street repairs should attempt to reduce the occurrence of these types of distress.
- Avoid weakening or destroying the existing pavement around an excavation with heavy construction equipment, stockpiling, or delivery of materials, etc. When damage does occur, remove the damaged pavement, extending the limits of the street repair, before replacing the pavement. No stockpiling of backfill or road building materials is permitted on the pavement.

E.4.4 Utility Cut Repair Details

Some examples of repair methods that are not acceptable and the corresponding acceptable method are provided in the following examples. These examples must also apply the requirements given in Figures E.1 through E.4.

Example 1

Existing pavements should be removed to clean, straight lines parallel and perpendicular to the flow of traffic. Do not construct patches with angled sides and irregular shapes. All repairs should be full lane width.

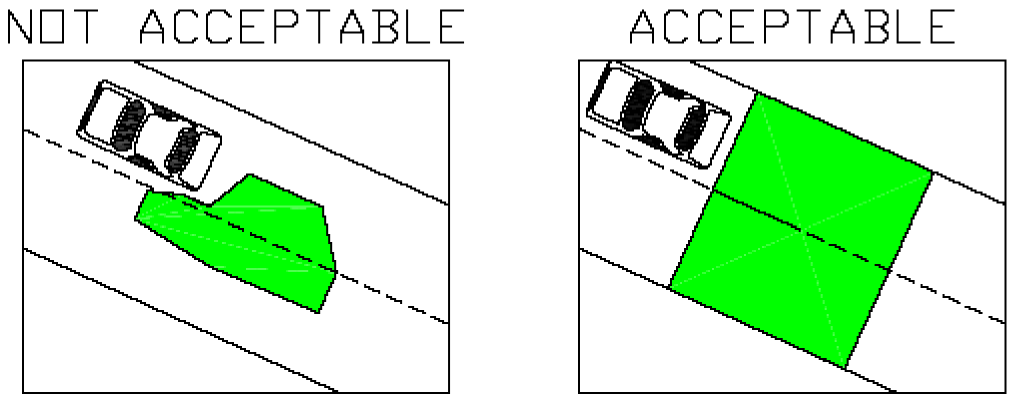


Figure E.5. Example 1: Do not construct patches with angled sides and irregular shapes.

Example 2

Avoid patches within existing patches. If this cannot be avoided, make the boundaries of the patches coincide. All repairs should be full lane width.

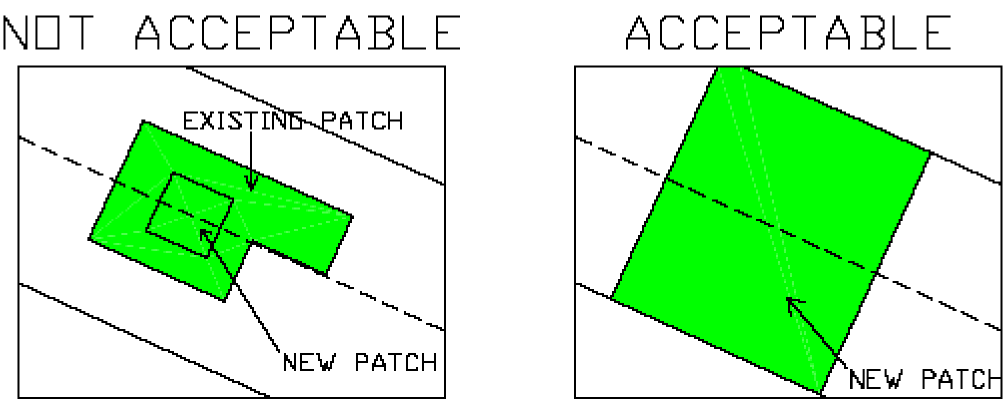


Figure E.6. Example 2: Avoid patches within existing patches.

Example 3

Do not leave strips of pavement less than one-half lane in width from the edge of the new patch to the edge of an existing patch or the lip of the gutter.

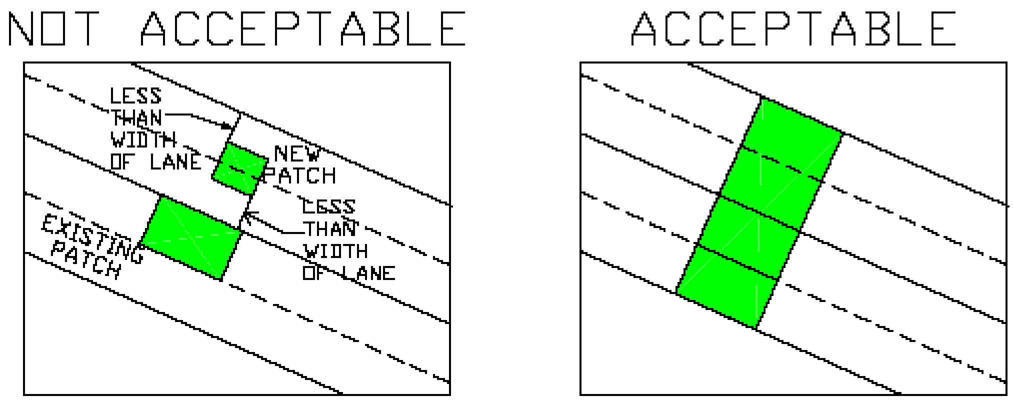


Figure E.7. Example 3: Do not leave strips of pavement less than one-half lane in width.

Example 4

In concrete pavements, remove sections to existing joints, or new saw cut joints at mid-slab, that are in good repair. In damaged concrete, the limits of removal should be determined in the field by a representative of MPW.

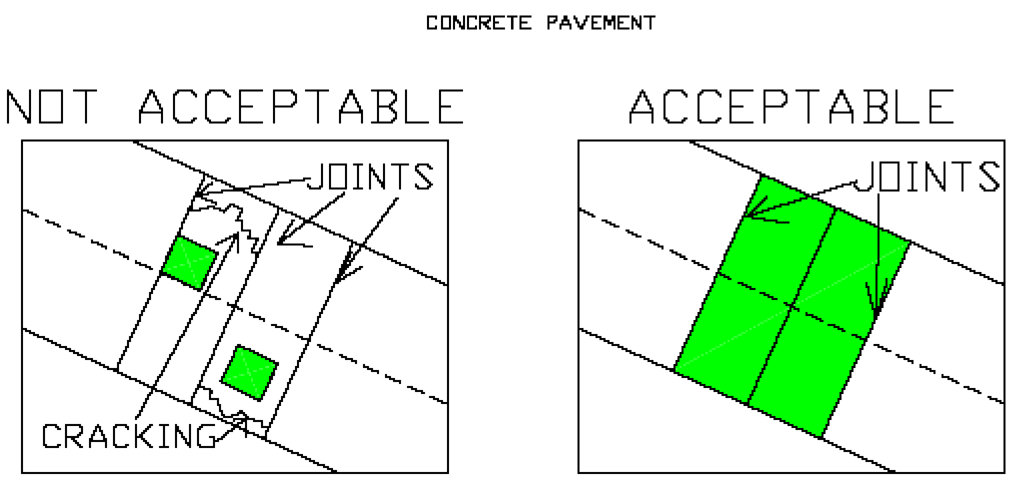


Figure E.8. Example 4: In concrete pavements, remove sections to existing joints.

Example 5

Asphalt and concrete pavements should be removed by saw cutting or grinding. Avoid breaking away the edges of the existing pavement or damaging the remaining pavement with heavy construction equipment.

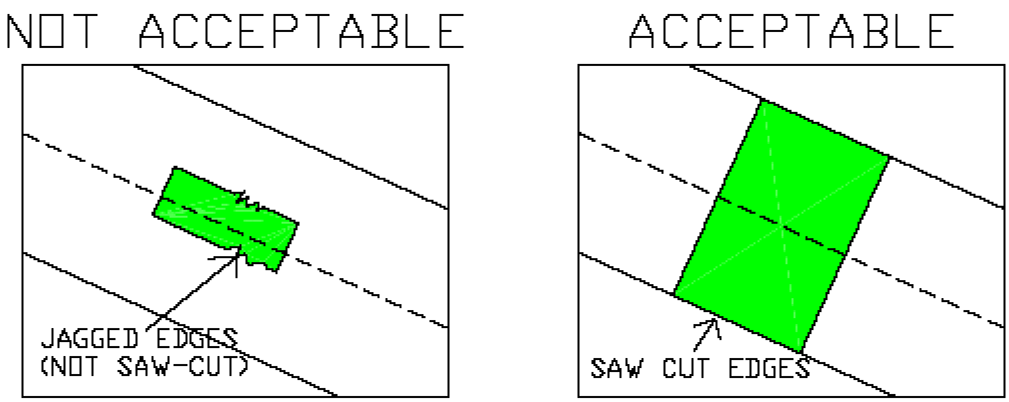


Figure E.9. Example 5: All edges shall be saw cut.

Example 6

In the case of a series of patches or patches for service lines off a main trench, repair the pavement over the patches by grinding and overlay when the spacing between the patches is less than 10 feet. In cases where the existing pavement is in poor condition (in the Strategic Paving Plan) and may require overlay within the next few years, this requirement may be modified or waived by the MPW Pavement Manager.

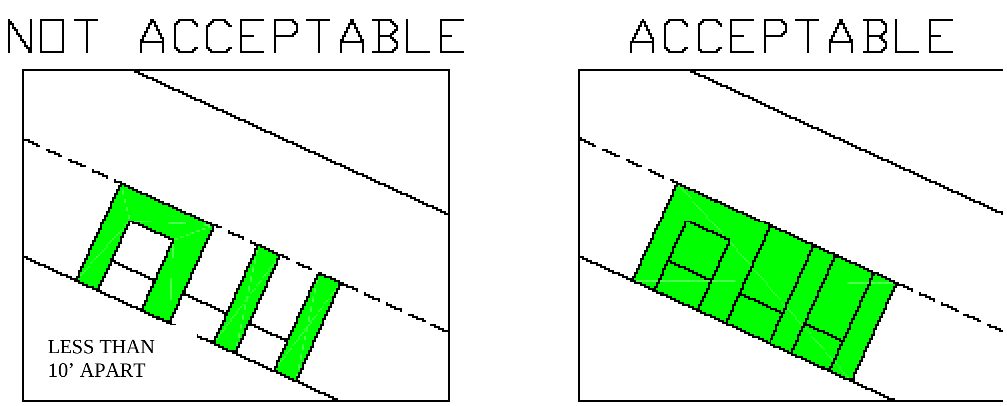


Figure E.10. Example 6: The patched area must include any existing patches within 10 feet.

Example 7

Completed street repairs should have rideability at least as good as, if not better than, the pavement prior to the repairs. A driver may be able to see a street repair, but in the case of a quality repair, should not be able to "feel" it in normal driving. A patch should provide a smooth ride with smooth transitions on and off the repair and all joints should be located outside the wheel path. Overlays should be placed by first removing the existing pavement to the desired depth by grinding or milling, and then placing the pavement flush with the adjacent surfaces. Overlays with feathered edges are not acceptable.

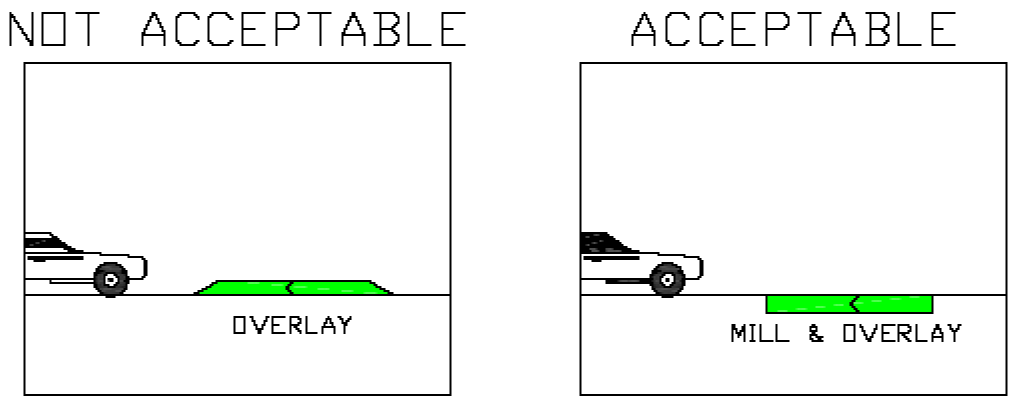


Figure E.11. Example 7: Patches may not decrease rideability.

Example 8

Surface tolerances for street repairs should meet the standard for new construction. That is, the finished surface of the street repair should be tested with a ten- (10-) foot straightedge parallel to the centerline or perpendicular across joints. Variations measured from the testing face of the straightedge to the surface of the street repair should not exceed one-quarter- (¼-) inch.

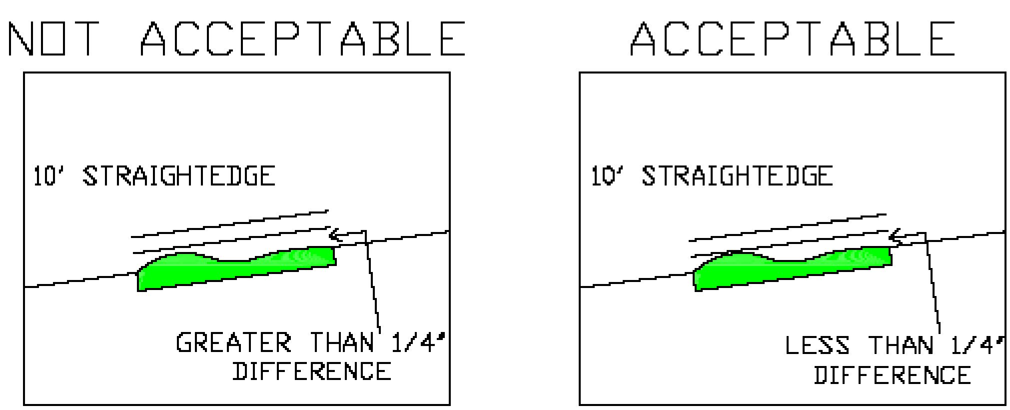


Figure E.12. Example 8: Surface tolerances for street repairs should meet the standard for new construction.

Example 9

Transverse patches on arterial and collector streets shall be overlaid across the entire street width for a distance of two- (2-) feet minimum on all sides of the trench using a T-Patch.

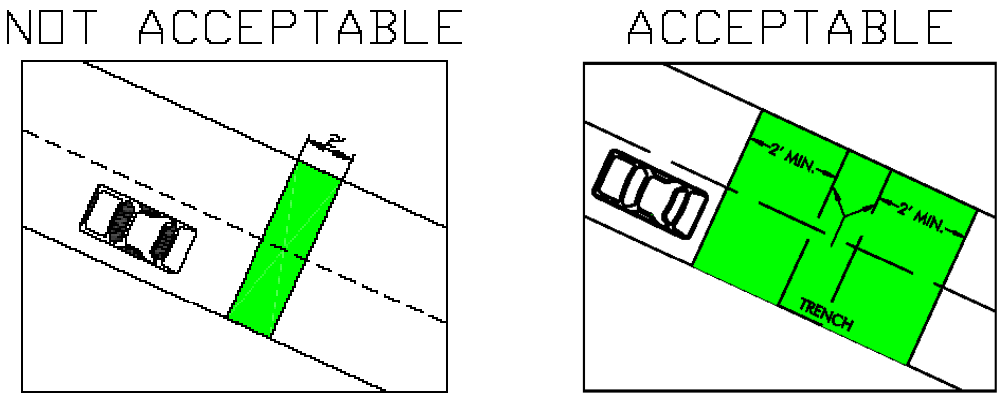


Figure E.13. Example 9: Trenches must be patched using a T-Patch.

Example 10

Do not allow the edges of patches to fall in existing wheel paths. The edges of patches parallel to the direction of traffic shall be limited to the boundaries of lanes or to the centerline of travel lanes.

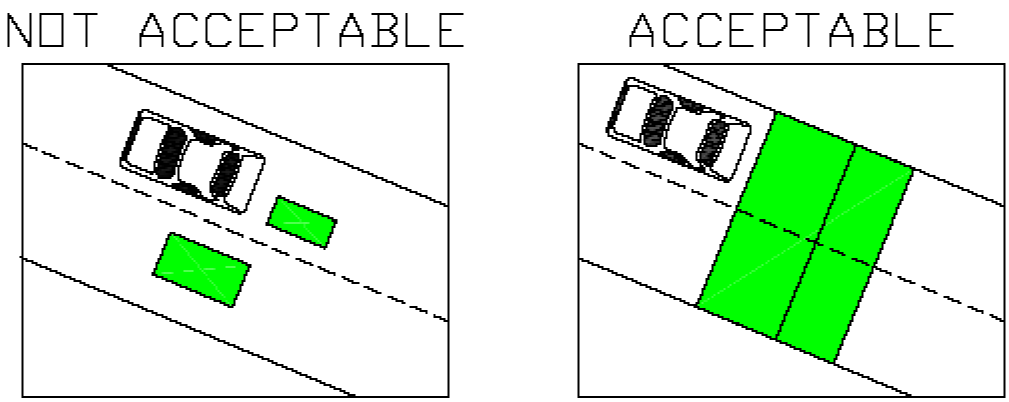


Figure E.14. Example 10: Do not allow the edges of patches to fall in wheel paths.

Example 11

Patches should have a smooth longitudinal grade consistent with the existing roadway. Patches should also have a cross slope or cross section consistent with the design of the existing roadway.

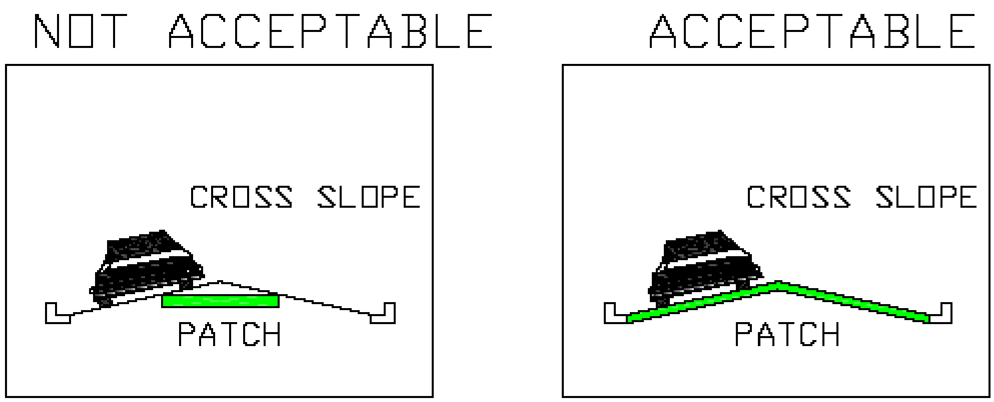


Figure E.15. Example 11. Patch slope and grade must match existing pavement.

Example 12

When the proposed excavation falls within 10 feet of a section of pavement damaged during the utility repair, the failed area shall be removed to sound pavement and patched. Scarring, gouging, or other damaged pavement adjacent to a patch shall be removed and the pavement repaired to the satisfaction of the MPW.

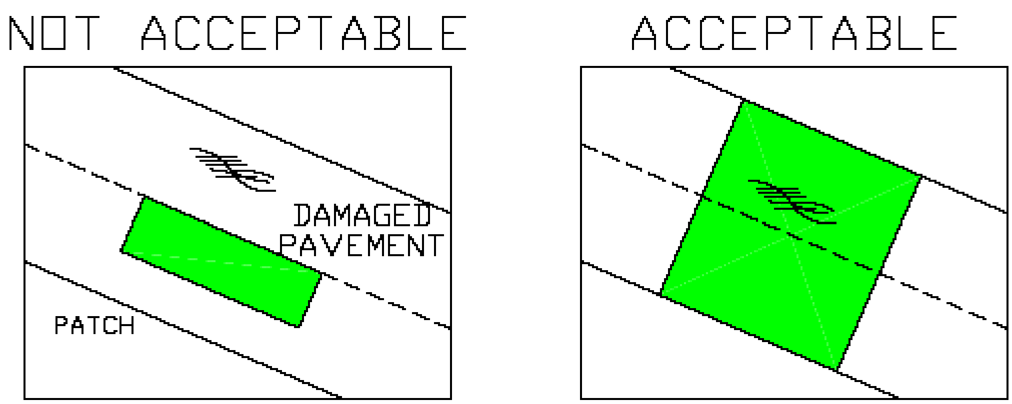


Figure E.16. Example 12: Damaged pavement within 10 feet of a patch must also be patched.

Example 13

For patches in asphalt, a tack coat shall be applied to all edges of the existing asphalt before placing the new pavement. After placing the new asphalt, all seams (joints) between the new and existing pavements shall be sealed with an asphalt tack coat or rubberized crack seal material. Avoid frequent changes in width of patches. For future maintenance, this simplifies removal of adjacent pavement failures.

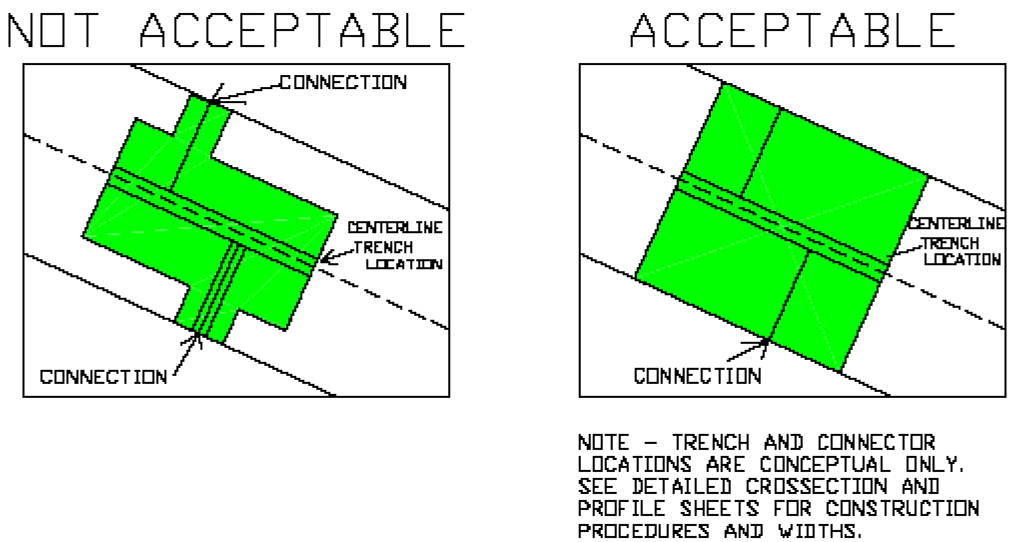


Figure E.17. Example 13: Patches must avoid frequent width changes.

E.5 TESTING AND INSPECTION

The contractor is required to provide material testing for each phase of the work and at no cost to MPW. The testing firm chosen to perform this work for the Contractor must be qualified and identified on the Permit application.

E.5.1 Testing Requirements

Density and thickness tests may be required to ensure compaction requirements are met and the appropriate compacted thickness of repair material has been placed. The number of tests required will be as directed by MPW. The costs of any testing, as required, shall be borne by the contractor. If sections with deficient thickness or density are found, the full section for a reasonable distance on each side of the deficiency shall be refused. All such sections shall be removed and reinstalled to these Guidelines.

E.5.2 Inspection Requirements

All construction work within the public rights-of-way shall be subject to inspection by MPW and certain types of work may have continuous inspection. It shall be the responsibility of the contractor to provide safe access for the inspector to perform the required inspections.

It shall be the responsibility of the person performing the work authorized by the Permit to notify MPW or an authorized representative that such work is ready for inspection. Every request for inspection is to be received at least twenty-four (24) hours before such inspection is desired. Such requests may be in writing or by telephoning or faxing MPW.

MPW may make or require other inspections of any work as deemed necessary to ascertain compliance with the provisions of these guidelines. Any work performed without the required inspections shall be subject to removal and replacement at the contractor's expense, regardless of the quality of the work.

Where large scale projects exceed the ability of the MPW to provide inspection, the contractor or utility company will incur the cost of a private inspection firm. This inspection firm will be mutually agreed upon by the Permit applicant and MPW prior to issuance of the Permit.

E.6 CONSTRUCTION DETAILS

The conditions described below apply to all work done within the public rights-of-way such as utility line installation or repairs performed by any contractor or utility department, public or private.

E.6.1 Protection of Existing Improvements

The contractor shall at all times take proper precautions and be responsible for the protection of existing street and alley surfaces, driveway culverts, street intersection culverts or aprons, irrigation systems, mail boxes, driveway approaches, curb, gutter and sidewalks and all other identifiable installations that may be encountered during construction.

The contractor shall, at all times, take proper precautions for the protection of existing utilities, the presence of which are known or can be determined by field locations of the utility companies. The contractor shall contact the local One Call for utility locations a minimum of two (2) working days prior to the proposed start of work.

Existing improvements to adjacent property such as landscaping, fencing, utility services, driveway surfaces, etc., that are not to be removed shall be protected from injury or damage resulting from the contractor's operations.

The contractor shall at all times take proper precautions for the protection of property pins/corners and survey control monuments encountered during construction. Any damaged or disturbed survey markers shall be replaced by a registered land surveyor at the contractor's expense.

The repair of any damaged improvements as described above shall be the responsibility of the permit holder.

The contractor shall make adequate provisions to assure that traffic and adjacent property owners experience a minimum of inconvenience

All work shall be done in an expedient manner. Repairs shall be made as rapidly as is consistent with high quality workmanship and materials. Use of fast setting concrete and similar techniques are encouraged whenever possible without sacrificing the quality of repair. For repairs 12 feet or less in length, completion of the work including replacement of pavement and cleanup shall normally be accomplished within two (2) weeks after the repair work or activity involving the cut is done. For repairs greater than 12 feet in length, the final surface shall not be placed for a minimum of 42 days from the placement of the binder material. Extension of time for completion, including winter and other weather delays, shall be with the written approval of MPW. If the repairs are not completed in the allotted time, MPW has the right to repair the street at the contractor's expense.

E.6.2 Temporary Surfaces Required

When the final surface is not immediately installed, it shall be necessary to place a temporary asphalt surface on any street cut opening. The temporary surface installation and maintenance shall be the responsibility of the Permittee until the permanent surface is completed and accepted. It shall be either a hot mix or cold mix asphalt paving material. Temporary surfaces shall be compacted, rolled smooth and sealed to prevent degradation of the repair and existing structures during the temporary period. Permanent patching shall occur within two (2) weeks except as outlined by the MPW in the Permit.

E.6.3 Pavement Patches

All permanent pavement patches and repairs shall be made with "in kind" materials. For example, concrete patches in concrete surfaces, full depth asphalt patches with full depth asphalt, concrete pavement with asphalt overlay patches will be expected in permanent "overlaid" concrete streets, etc. In no case is there to be an asphalt patch in concrete streets or concrete patch in asphalt streets. Any repair not meeting these requirements will be removed and replaced by the contractor at no expense to MPW.

E.6.4 Removal and Replacement of Unsatisfactory Work

Removal and replacement of unsatisfactory work shall be completed within fifteen (15) days of written notification of the deficiency unless deemed an emergency requiring immediate action. In the event the replacement work has not been completed, MPW will take action upon the contractor's bond to cover all related costs.

E.6.5 Warranty for Satisfactory Work

The utility company will be held responsible for a 24-month period for any defects in the patch that may result in a PCI of 85 or less as defined by ASTM D6433 as modified for this study.

E.7 REMOVALS

E.7.1 Paved Streets

Bituminous pavement removal areas shall be saw cut to clean, straight lines that are perpendicular or parallel to the flow of traffic.

In existing pavement, all excavations within 36 inches of the edge of the asphalt shall require removal and replacement from the edge of asphalt to the excavation edge.

Concrete pavement, driveways, streets, and alleys shall be removed to neatly sawed edges cut to full depth.

E.7.2 Gravel Streets

When trenches are excavated in streets or alleys that have only a gravel surface, the contractor shall replace such surfacing on a satisfactory compacted backfill with gravel conforming to MPW specification aggregate base course. Gravel replacement shall be one (1) inch greater in depth to that which originally existed, but not less than four (4) inches. The surface shall conform to the original street grade. Where the completed surface settles, additional gravel base shall be placed and compacted by the Contractor within fourteen (14) days after being notified by MPW, to restore the roadbed surface to finished grade.

Some streets may have been treated with a special surface treatment to control dust and/or bind the aggregates together. In these cases, the Contractor is responsible for installing the gravel surface in the same manner as what was existing. Such surface treatments shall be of the same chemical composition as what existed prior to the excavation work. MPW shall note on the permit the surface treatment that will be required.

E.7.3 Concrete Curb, Gutter and Sidewalk

Concrete shall be removed to neatly sawed edges to full depth for sidewalks and curb and gutter and shall be saw cut in straight lines either parallel to the curb or perpendicular to the alignment of the sidewalk or curb. Any removal shall be done to the nearest joint. Replaced sections may require doweling connections if required by MPW.

E.8 BACKFILL

E.8.1 Flowable-Fill

Flowable-fill may be used as utility trench backfill for all trenches unless otherwise specified by MPW. This requirement applies to all pavement and gravel locations. Compaction will be as specified by MPW.

The recommended mix for flowable-fill is shown below. Concrete backfill will not be allowed within the public right-of-way. Flash-fill may be used if approved by MPW. Refer to the appropriate MPW specification.

Table E.1. Recommended flowable-fill mix design.

INGREDIENTS	POUNDS/CUBIC YARD
Cement	42 (0.47 sack)
Water	235 (39 gallons or as needed)
Coarse Aggregate (Size No. 57)	1700
Sand (ASTM C-33)	1845

The maximum desired 28-day strength is 60 psi. The above combination of material, or an equivalent, may be used to obtain the desired "flowable-fill".

Flowable-fill or flash-fill shall be prohibited as a temporary or permanent street surface. Trenches shall initially be backfilled to the level of the original surface. After the flowable-fill has cured, the top surface of the flowable-fill shall be removed and the temporary or permanent surface shall be placed.

Bridging and cutback requirements as described in these standards may still be required if the street failures indicate a clear need.

Repair of failed trenches will be the responsibility of the party requiring the trench.

E.8.2 Conventional Backfill (Other Than Flowable-Fill)

When "non flowable-fill" backfill material has been pre-approved by MPW, backfill in existing or proposed streets, curbs, gutters, sidewalks and alleys is divided into three (3) categories: initial, intermediate and final lifts as defined below:

- The INITIAL LIFT, comprised of washed, clean gravel material**,** consists of the section from the bottom of the excavation to a point six to twelve (6 - 12) inches above the top of the installation. Placement and compaction of the initial layer shall be as specified by the utility company to protect their installation.

- The INTERMEDIATE LIFT, generally comprised of #67 crushed stone, consists of the section above the initial layer to a point within six (6) inches of the ground level or the bottom of the pavement section, whichever is greater.
- The FINAL LIFT includes both road base and asphalt surfacing. Road base material shall meet MPW specification for aggregate base course or as specified by MPW. Maximum dry density of all soil types used will be determined in accordance with AASHTO T 99 or AASHTO T 180. These densities will be determined prior to placement of backfill.

E.9 RESTORATION

E.9.1 Bore Holes - Vertical and Horizontal

For openings less than or equal to 6 inches in diameter, bore holes shall be filled with patching material (cold mix is not acceptable) to prevent entry of moisture. Patching material used shall be in all cases compatible with the existing surface. Subgrade shall be replaced with flowable fill to provide necessary support to the surface. The sealing of bore holes is the responsibility of the contractor or persons making the bore. For openings greater than 6 inches in diameter, the limits of repair shall be identified in the permit. The completed job shall be flush with the surrounding pavement and have no indentations, pockets, or recesses that may trap and hold water.

E.9.2 Subgrade

The subgrade for the pavement structure shall be graded to conform to the cross sections and profile required by the construction plans. Prior to the placement of aggregate base course or sub-course, the subgrade should be properly prepared. The subgrade should be scarified to a minimum depth of six (6) inches, moisture adjusted as necessary, and recompacted.

Prior to approval to place the base or sub-base course, all utility main and service trenches shall be compacted. The density requirement also applies to all utility trenches within the public rights-of-way from a point four (4) feet beyond the edge of asphalt and descending at 1:1 outward.

E.9.3 Asphalt Surfacing

Any damage, even superficial, to the existing asphalt surface in the vicinity of the work shall be repaired at the expense of the Contractor, including but not limited to gouges, scrapes, outrigger marks, backhoe bucket marks, etc. A slurry seal type covering will be considered the minimum repair. Patching may be required, at the discretion of MPW.

The depth of asphalt patches in asphalt streets shall typically be the depth of the existing asphalt surface plus 1 inch or as specified by the Engineer.

The asphalt patch area for street excavations that fall within the wheel path of the vehicular travel lane shall be increased in size to the center of the lane or adjacent lane. In no circumstance will the edge of a patch area be allowed to fall within the wheel path.

In streets that are less than five (5) years old or have a PCI greater than 85, the MPW reserves the right to deny any street excavation or require repairs that are over and above these specifications.

E.9.4 Concrete Surfacing and Patching

The concrete pavement shall be replaced with 4,000 psi concrete to match the finish and thickness of the existing pavement, but not less than eight (8) inches thick. All concrete construction shall be protected from vehicular traffic, including contractor vehicles, until the concrete has achieved eighty (80) percent of its ultimate strength. Concrete shall be coated and sealed with a uniform application of membrane curing compound applied in accordance with manufacturer's recommendations.

The use of quick curing concrete (3000 psi strength within 48 hours) shall be used on all arterial and collector streets when repair areas are less than 500 square feet or when temperatures are below 40° F. Quick curing concrete repairs may be opened to traffic within two (2) days or when the concrete has achieved eighty (80) percent of its ultimate strength.

Where existing cracks or damage is adjacent to the area being repaired, the repair area shall include the cracked or damaged concrete. Pavement repairs shall include all areas of damage, including leak test holes, pot holes, equipment, and/or material scarring of the exiting surface.

When repairing concrete, removal perimeter shall be saw cut and replacement concrete shall be doweled into the old concrete as directed by MPW.

E.10 IMPLEMENTATION

The community investment in streets and roads is a major component of the community assets. As custodians of these facilities, MPW has the obligation and responsibility to protect the public interest.

Presented herein have been concepts and examples that can easily be incorporated into MPW specifications. These examples provide a cost-effective approach to achieve quality repairs of utility cuts that will satisfy the public motorists and achieve levels of service meeting the expectations of MPW.